History of the Calendar

in Different Countries Through the Ages

M.N. Saha
and
N.C. Lahiri

COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
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FOREWORD

The Council of Scientific & Industrial Research (CSIR) of the Government of India appointed a Calendar Reform Committee under the chairmanship of Prof. Meghnad Saha in November 1952. The Committee was entrusted with the task of 'examining all the existing calendars which are being followed in the country at present and after a scientific study of the subject, submit proposals for an accurate and uniform calendar for the whole of India'. The following were the members of the Committee:

Prof. M.N. Saha, D.Sc., F.R.S., M.P. (Chairman)
Prof. A.C. Banerji, Vice-Chancellor, Allahabad University
Dr. K.L. Daftari, Nagpur
Shri J.S. Karandikar, Ex-Editor, The Kesari, Poona
Dr. Gorakh Prasad, D.Sc., Allahabad University
Prof. R.V. Vaidya, Madhav College, Ujjain
Shri N.C. Lahiri, Calcutta (Secretary)

Dr. Gorakh Prasad and Shri N.C. Lahiri came in place of Prof. S.N. Bose and Dr. Akbar Ali who were originally appointed but were unable to serve.

The Committee's Report was submitted to CSIR in 1955 and the Government, in accepting the recommendations of the Committee, decided that 'a unified National Calendar' (the Saka Calendar) be adopted for use with effect from 21 March 1956 A.D., i.e., 1 Chaitra 1878 Saka. The Report of the Calendar Reform Committee was published by CSIR in 1955. Part C of the Report consisting of a review of 'History of the calendar in different countries through the ages' by Prof. M.N. Saha and Shri N.C. Lahiri was also published separately. This useful publication has been out of print for some time and scientists in general, and astronomers in particular, have been conscious of the non-availability of this valuable review. Therefore, the CSIR has decided to reprint it. No changes have been made from the original except that 'Corrigenda and Addenda' have been incorporated into the text, and consequently the bibliography and the index (which pertain to the whole report) have been repaginated. The title page of the Report, Jawaharlal Nehru's message, and Saha & Lahiri's preface have also been included in the present volume.

I hope that this reprinted volume will be found useful and informative by calendaric astronomers, science historians and scientists in general.

New Delhi
15 August 1992.

S.K. Joshi
Director-General
Council of Scientific & Industrial Research
and Secretary,
Department of Scientific & Industrial Research

FACSIMILE OF ORIGINAL COVER

REPORT

OF THE

CALENDAR REFORM COMMITTEE

GOVERNMENT OF INDIA

सत्यमेव जयते

Council of Scientific and Industrial Research,
Old Mill Road,
New Delhi.
1955

सत्यमेव जयते

MESSAGE.

I am glad that the Calendar Reform Committee has started its labours. The Government of India has entrusted to it the work of examining the different calendars followed in this country and to submit proposals to the Government for an accurate and uniform calendar based on a scientific study for the whole of India. I am told that we have at present thirty different calendars, differing from each other in various ways, including the methods of time reckoning. These calendars are the natural result of our past political and cultural history and partly represent past political divisions in the country. Now that we have attained independence, it is obviously desirable that there should be a certain uniformity in the calendar for our civic, social and other purposes and that this should be based on a scientific approach to this problem.

It is true that for governmental and many other public purposes we follow the Gregorian calendar, which is used in the greater part of the world. The mere fact that it is largely used, makes it important. It has many virtues, but even this has certain defects which make it unsatisfactory for universal use.

It is always difficult to change a calendar to which people are used, because it affects social practices. But the attempt has to be made even though it may not be as complete as desired. In any event, the present confusion in our own calendars in India ought to be removed.

I hope that our Scientists will give a lead in this matter.

Jawaharlal Nehru

New Delhi,
February 18, 1953.

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Shri N. C. Lahiri acted as the Secretary of the Committee.

TRANSLITERATION

The scheme of transliteration of Sanskrit alphabets into Roman script adopted in this publication is the same as generally followed. The corresponding scripts are given below :—

VOWELS

अ	...	a
आ	...	ā
इ	...	i
ई	...	ī
उ	...	u
ऊ	...	ū
ऋ	...	ṛ
ऌ	...	ḷ
ए	...	e
ऐ	...	ai
ओ	...	o
औ	...	au

CONSONANTS

क्	...	k	प्	...	p
ख्	...	kh	फ्	...	ph
ग्	...	g	ब्	...	b
घ्	...	gh	भ्	...	bh
ङ्	...	ṅ	म्	...	m
च्	...	c	य्	...	y
छ्	...	ch	र्	...	r
ज्	...	j	ल्	...	l
झ्	...	jh	व्	...	v
ञ्	...	ñ			
ट्	...	ṭ	श्	...	ś
ठ्	...	ṭh	ष्	...	ṣ
ड्	...	ḍ	स्	...	s
ढ्	...	ḍh	ह्	...	h
ण्	...	ṇ			
त्	...	t	ं	...	ṁ
थ्	...	th	:	...	ḥ
द्	...	d	ऽ	...	'
ध्	...	dh			
न्	...	n			

N. B. Diacritical marks have not generally been used in names of persons belonging to recent times as well as in well-known geographical names.

PREFACE

The Calendar Reform Committee was appointed in November, 1952, by the Council of Scientific and Industrial Research (of the Government of India) with the following terms of reference :

"To examine all the existing calendars which are being followed in the country at present and after a scientific study of the subject, submit proposals for an accurate and uniform calendar for the whole of India".

In accordance with its terms of reference, the Committee (for personnel, see p. 4) has scientifically examined all the calendars prevalent in India (*vide* Part C, Chap. V), *viz.*,—

Gregorian Calendar...which is used for civil and administrative purposes (*vide* p. 170) all over the world.

Islamic Calendar......used for fixing up the dates of Islamic festivals (*vide* p. 179).

Indian Calendars or Pañcāṅgas......used for fixing up dates and moments of Hindu, Bauddha and Jaina festivals in different States of India, and in many cases for civil purposes also. They are about 30 in number. (*vide* Chap. V, p. 258).

It has been pointed out (p. 171) that the Gregorian calendar, which is used all over the world for civil and administrative purposes, is a very unscientific and inconvenient one. The World Calendar (p. 173), proposed by the World Calendar Association of New York, has been examined and found suitable for modern life. The proposal for its adoption by all the countries of the world for civil and administrative purposes was sponsored by the Indian Government before the U. N. O. and debated before the ECOSOC (Economic and Social Council) at Geneva in June, 1954 (p. 173) and its recommendations have been transmitted to the Governments of the World for their opinion. It is hoped that the World Calendar will be ultimately adopted. It will lead to a great simplification of modern life.

The introduction of the World Calendar in place of the Gregorian is a matter for the whole world, which has now to look for decision by the U. N. O.

The Islamic (Hejira) calendar has been discussed on p. 179, along with some proposals for reform suggested by Dr. Hashim Amir Ali of the Osmania University, and Janab Mohammed Ajmal Khan of the Ministry of Education. It is for the Islamic world to give its verdict on these suggestions. If these suggestions are accepted, the Islamic calendar would fall in line with other luni-solar calendars.

As these two important systems of calendars had to be left out, the Committee's labours were confined to an examination of the different systems of calendars used by Hindus, Bauddhas and Jainas in the different states of India, chiefly for the fixing up of the dates and moments of their religious festivals, and for certain civil purposes as well.

For the purpose of examining all the existing calendars of India, as per terms of reference, an appeal was issued to the Pañcāṅga (Almanac) makers for furnishing the Committee with three copies of their Pañcāṅgas. In reply to our request 60 Pañcāṅgas (Almanacs) were received from different parts of the country and were examined (p. 21). To facilitate examination of the calendars, a questionnaire was issued to which 51 replies were received (pp. 23-31). In addition to the above, 48 persons offered their suggestions (pp. 32-38) for reform of the Indian calendar. These views were very divergent in character. Some quoted ancient scriptures to prove that the earth is flat, with a golden mountain in the centre round which move the sun and the planets, others tried to refute the precession of equinoxes. All opinions were taken into consideration in arriving at the decisions of the Committee.

Principles followed in fixing up the Calendar :—The calendar has got two distinct uses—civil and religious. The Indian calendars are used not only for fixing up the dates and moments of religious observances but also for the purpose of dating of documents and for certain civil purposes not only by the rural, but also by a large section of the urban population. There is great divergence in practice in different parts of the country in this respect. Therefore a unified solar calendar has been proposed for all-India use for civil purposes. This has been based on the correct length of the year (*viz.* the tropical year) and the popular month-names, *viz.*, Caitra, Vaiśākha, etc. have been retained (see p. 6).

Calendars are based partly on SCIENCE which nobody is permitted to violate and partly on CONVENTIONS which are man-made and vary from place to place. The Indian calendars put up by almanac-makers commit the violation of the following principles of science :—

They take the length of the year to be 365.258756 days (p. 240, Part C of Report) as given by the *Sūrya-Siddhānta* about 500 A. D. ; while the correct length of the tropical year, which alone can be used according to the *Sūrya-Siddhānta* and modern astronomy for calendarical use, is 365.242196 days. The difference of .01656 days is partly due to errors of observation, not infrequent in those days, and to their failure to recognize the precession of equinoxes. As the Sūrya-Siddhānta value of the year-length is still used in almanac-making, the year-beginning is advancing by .01656 days per year, so that in the course of nearly 1400 years, the year-beginning has advanced by 23.2 days, with the result that the Indian solar year, instead of starting on the day following the vernal equinox, i.e., on March 22, as prescribed in the Sūrya-Siddhānta (see Chap. V, p. 239), starts on April 13 or 14. The situation is the same as happened in Europe due to the acceptance of 365.25 days as the length of the year at the time of Julius Caesar ; the Christmas originally linked to the winter solstice preceded it by 10 days by 1582 A.D., when the error was rectified by the promulgation of a bull by Pope Gregory XIII. By this, Friday, October 5 was proclaimed as Friday, October 15, and new leap-year rules were introduced.

Unlike Europe, where the Pope in the medieval times possessed an authority which every one in Catholic Europe respected, India had a multiplicity of eras and year-beginnings due to her history during the years 500-1200 A. D. But for calendaric calculations, our astronomers all over India have been using only the Śaka era since Āryabhaṭa (500 A.D.) certainly and probably from much earlier times, and in local almanacs other eras are simply imposed on it. The Calendar Committee has therefore recommended :—

That for all official purposes, the Central as well as State Governments should use the Śaka era along with the civil calendar proposed by the Committee (p.6). It is suggested that the change-over may take place from the Śaka year 1878, Caitra 1 (1956, March 21). If this is accepted, the last month of the year, *viz.*, 1877 Śaka, the solar Phālguna, which has a normal length of 30 days, will have an extra number of 6 or 7 days.

The pre-eminence of the Śaka era is due, as historical evidences cited on pp. 228-238 and 255-257 show, that it was the earliest era introduced in India, by Śaka ruling powers, and have been used exclusively by the Śākadvīpi Brahmins (forming the astrologer caste) for calendar-making on the basis of Siddhāntic (scientific) astronomy evolved by Indian astronomers on the basis of old Indian calendaric conceptions, which were put on scientific basis by blending with them astronomical conceptions prevalent in the West, from the third century B.C.

The era is also used exclusively for horoscope making, a practice introduced into India since the first century A.D. by the Śākadvīpi Brāhmaṇas.

The Calendar Committee has devised a solar calendar with fixed lengths of months for all-India use, in which it has been proposed to give up the calculations of the Sūrya-Siddhānta in which the solar months vary from 29 to 32 days.

Religious Calendar—The Committee's task resolved itself into a critical examination of the different Indian local calendars, about 30 in number, which use different methods of calculation. This produces great confusion.

As already stated the Sūrya-Siddhānta year being longer than the tropical year by about 24 mins., the Hindu calendar months have gone out of the seasons to which they conformed when the Siddhāntic rules were framed ; as a result, the religious festivals are being observed not in the seasons for which they were intended but in wrong seasons. The Committee felt that the error should be corrected once for all and the months brought back to their original seasons. But with a view to avoiding any violent break in the present day practices, the desired shifting has not been effected, but any further increase of the error has been stopped by adopting the tropical year for our religious calendar also (see p. 7).

Before the rise of Siddhānta Jyotiṣa (400 A.D.), India used only the lunar calendar calculated according to the Vedāṅga Jyotiṣa rules and most religious festivals (e.g. the Janmāṣṭamī, the birthday of Śrī Kṛṣṇa) used to be fixed up by the lunar calendar which used only tithi and nakṣatra. The Calendar Committee could not find out any way of breaking off with the lunar affiliation short of a religious revolution and has, therefore, decided to keep them. For this purpose, the lunar year is to be pegged on to the solar year by a number of conventions. The Committee has adhered to the ancient conventions as far as possible. But the erroneous calculations of tithis and nakṣatras have been replaced by modern calculations given in the nautical almanacs and modern ephemerides, and the religious holidays have been fixed for a central station of India (*vide* page 40).

The present practice is to calculate the tithi for each locality and the result is that the same tithi may not occur on the same day at all places. The Calendar Committee has found that the continuance of different lunar calendars for different places is a relic of medieval practice when communication was difficult, the printing press did not exist and astrologers of each locality used to calculate the calendar for that locality based on Siddhāntic rules and used to proclaim it on the first day of the year to their clients. In these days of improved communication, free press, and radio, there is not the slightest justification for continuance of this practice and the Committee has fixed up the holidays for the central station (82° 30′ E, 23° 11′ N, see Report p. 40); and recommended that these holidays may be used for the whole of India. The dates of festivals of the Hindus, Jainas and Bauddhas have been determined on the above basis. This will put an end to the calendar confusion.

The confusion is symbolic of India's history. While all Christendom comprising people of Europe, Asia and America, follows the Gregorian calendar, and the whole of the Islamic world follows the Hejira calendar for civil and religious purposes, India uses 30 different systems for fixing up the same holidays in different parts of the country and frequently, two rival schools of pañcāṅga-makers in the same city fix up different dates for the same festival. This is a state of affairs which Independent India cannot tolerate. A revised national calendar, as proposed by us, should usher a new element of unity in India.

The Committee has therefore gone deeply into the history of calendar making in all countries from the earliest times particularly into the history of calendar-making in India (*vide* Chap. V) and has arrived at their conclusions. Its recommendations are entirely in agreement with the precepts laid down by the Siddhāntic astronomers, as given in the Sūrya-Siddhānta and other standard treatises (see p. 238 *et seq.*).

The Committee has also compiled a list of all religious festivals observed in diffirent parts of India and listed them under the headings (i) Lunar, and (ii) Solar, with their criteria for fixing the dates of their observances (pp. 102-106).

Where does the Government come in : Though India is a secular state, the Central Government and the State Governments have to declare a number of holidays in advance, a list of which will be found on pages 117-154 for the Central Government as well as for the States. These holidays are of four different kinds, viz. :—

(i) Holidays given according to the Gregorian calendar, e.g., Mahatma Gandhi's birthday, which falls on Oct. 2. These present no problem to any government.

(ii) But there are other holidays, which are given according to the position of the Sun (*vide* pp. 117-118).

(iii) Others which are given according to the luni-solar calendar (pp. 119-124).

(iv) Holidays for Moslems and Christians (pp. 125 and 126).

It is a task for the Central as well as State Governments to calculate in advance dates for the holidays it gives. This is done on the advice of Pañcāṅga-makers attached to each Government. In addition, numerous indigenous pañcāṅgas are prepared on the Siddhāntic system of calculations, the elements of which are now found to be completely erroneous. There is a wide movement in the country first sponsored by the great savant, patriot and political leader, the late Lokamanya B. G. Tilak, for making the pañcāṅga calculations on the basis of the correct and up-to date astronomical elements. As a result, there are almost in every State different schools of pañcāṅga calculations, differing in the durations of tithis, nakṣatras, etc., and consequently in the dates of religious festivals. The problem before the Government is : which one of the divergent systems is to be adopted. The Committee has suggested a system of calculations for the religious calendar also, based on most up-to-date elements of the motion of the sun and the moon. Calendars for five years from 1954-55 to 1958-59 have been prepared on this basis showing therein *inter alia* the dates of important festivals of different States (*vide* pp. 41-100). The lists of holidays for the Government of India and of each separate State for the five years have also been prepared from this calendar for the use of the Governments. The Committee hopes that the Government of India as well as the State Governments would adopt these lists in declaring their holidays in future. The Ephemerides Committee which has been formed by the Government of India, consisting of astronomers versed in the principles of calendar-making would act as advisers to the Central as well as State Governments. It may be assisted by an advisory committee to help it in its deliberations.

The responsibility of preparation of the five-yearly calendar and the list of holidays on the basis of recommendations adopted by the Committee has been shared by Sri N. C. Lahiri and Sri R. V. Vaidya, aided by some assistants and several pandits of note, amongst whom the following may be mentioned : Sri A. K. Lahiri, Sri N. R. Choudhury, Pandit Narendranath Jyotiratna, and Joytish Siddhanta Kesari Venkata Subba Sastry of Madras.

We have received great help from C. G. Rajan, B.A., Sowcarpet, Madras. He has kindly furnished us with valuable suggestions regarding 'Rules for fixing the dates of festivals for South India'.

We are indebted to the Astronomer Royal of Great Britain, Sir Harold Spencer Jones, and to Mr. Sadler, head of the Ephemerides divison of the Royal Observatory of U. K. for having very kindly supplied us with certain advance data relating to the sun and the moon which have facilitated our calculations. We have to thank the great oriental scholar, Otto Neugebauer for having helped us in clearing many obscure points in ancient calendaric astronomy. We wish to express our thanks to Prof. P. C. Sengupta for helping us in clearing many points of ancient and medieval Indian astronomy.

We have reproduced figures from certain books and our acknowledgement is due to the publishers. It was however not possible to obtain previous permission from them, but the sources have been mentioned at the relevant places.

It is a great pleasure and privilege to express our gratitude to our colleagues of the Calendar Committee for their active co-operation in the deliberations of the Committee, and ungrudging help whenever it was sought for.

M. N. Saha
Chairman

Calcutta,
The 10th Nov., 1955.

N. C. Lahiri
Secretary

REPORT

OF THE

CALENDAR REFORM COMMITTEE

PART C

History of the Calendar in different Countries through the Ages

BY

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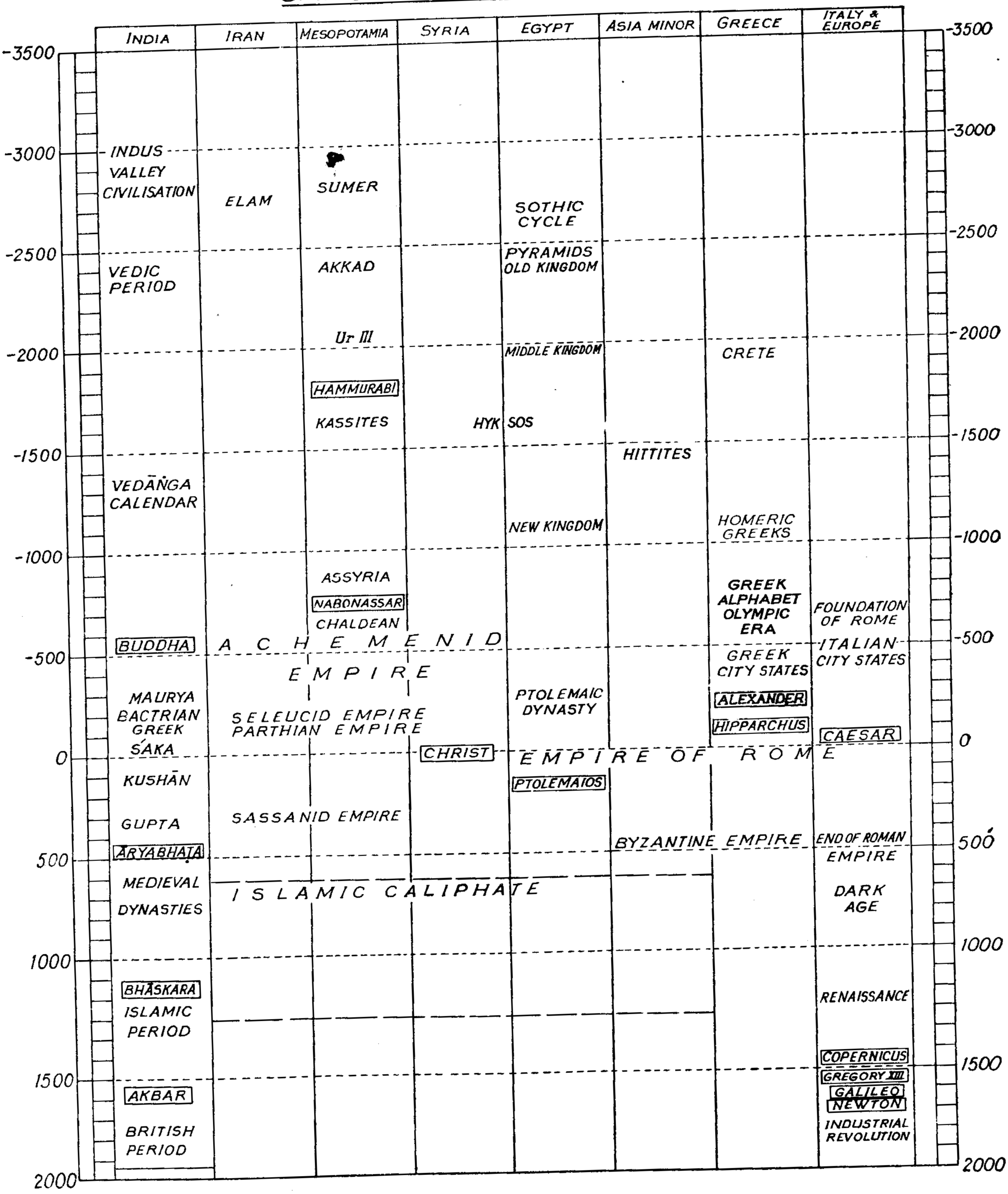
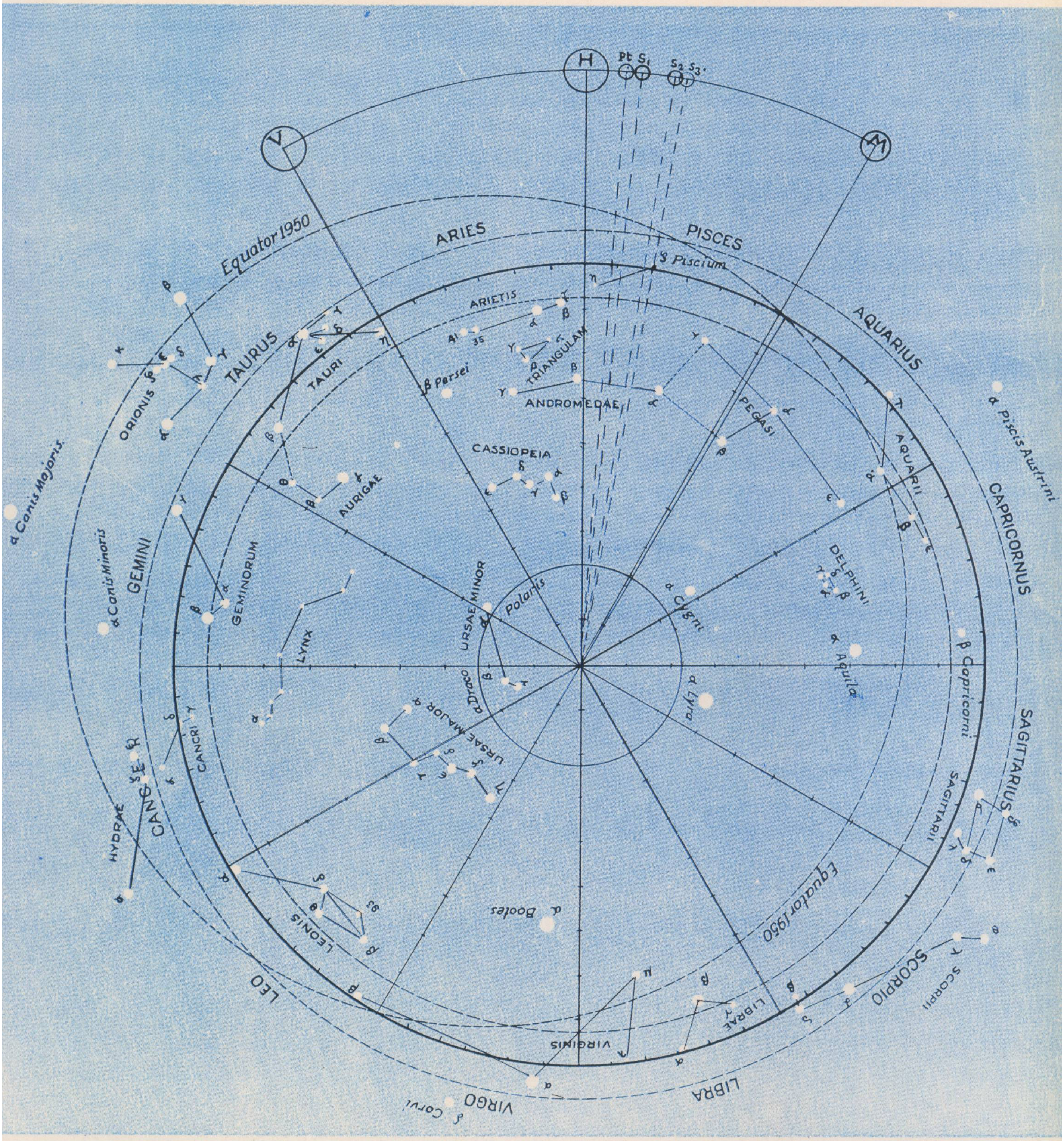
CHRONOLOGICAL TABLE



THE ZODIAC THROUGH THE AGES



MAGNITUDES.

- FIRST ●
- SECOND ●
- THIRD •
- FOURTH ·
- FIFTH ·

POSITIONS OF THE FIRST POINT OF ARIES (♈) IN DIFFERENT TIMES.

V = Vedic Times about	2300 B.C.
H = Hipparchos	140 B.C.
Pt. = Ptolemy	150 A.D.
S_1 = Sūrya Siddhānta	285 A.D.
S_2 = "	500 A.D.
S_3 = "	570 A.D.
M = Modern	1950 A.D.

CHAPTER I

General Principles of Calendar Making

1.1 INTRODUCTION

The Flux of Time, of which we are all conscious, is apparently without beginning or end, but it is cut up periodically by several natural phenomena, *viz.* :—

(1) by the ever-recurring alternation of daylight and night,

(2) by the recurrence of the moon's phases,

(3) by the recurrence of seasons.

It is these recurring phenomena which are used to measure time.

These phenomena have the greatest importance for man, for they determine all human and animal life. Even prehistoric men could not help noticing these time-periods, and their effect on life.

When human communities started organized social life in the valleys of the Indus and the Ganges (India), the Nile (Egypt), the Tigris and the Euphrates (Mesopotamia) and the Hoang Ho (China), several millenia before Christ (*vide* Chronological Table), these phenomena acquired new importance. For these early societies were founded on agriculture ; and agricultural practices depend on seasonal weather conditions. With these practices, therefore, grew national and religious festivals, necessary for the growth of social life, and of civilization. People wanted to know *in advance* when to expect the new moon or the full moon, when most of the ancient festivals were celebrated ; when to expect the onset of the winter or the monsoon ; when to prepare the ground for sowing ; the proper time for sowing and for harvesting. Calendars are nothing but predictions of these events, and were early framed on the basis of past experiences.

1.2 THE NATURAL PERIODS OF TIME

The three events mentioned in (1), (2) and (3) above define the natural divisions of time. They are :

The Day : defined by the alternation of daylight and night.

The Month : the complete cycle of moon's changes of phase, from end of new-moon to next end of new-moon (*amānta* months), or end of full-moon to end of next full-moon (*pūrṇimānta* months).

The Year : and its smaller subdivisions, *viz.*, the seasons.

The Day* :

The day, being the smallest unit, has been taken as ***the fundamental unit of time*** and the lengths of months, the year and the seasons are expressed in terms of the day as the unit.

But the day is to be defined. Many early nations defined the day as the time-period between sunrise to sunrise (*sāvana* day in India) or sunset to sunset (Babylonians and Jews). But the length of the day, so defined, when measured with even the rough chronometers of early days, was found to be variable. This is due to the fact that except at the equator, the sun does not rise or set at the same time in different seasons of the year. So gradually the practice arose of defining the day as the period from midnight to midnight, *i. e.*, when the sun is at the nadir to its next passage through the nadir. Even then the length of the day is found to be variable when measured by an accurate chronometer. The reasons are set forth in all astronomical text books. Then came the idea of the mean solar day, and it is now taken as the fundamental unit of time. The mean solar day is the average interval between the two successive passages of the sun over the meridian of a place derived from a very large number of observations of such meridian passages. The time between two passages is measured by an accurate chronometer.

In addition to the solar day, the astronomers define also a sidereal day, which is the time period between two successive transits of a fixed star. It measures the time of rotation of the earth round its axis.†

The solar day is larger than the sidereal day, because by the time the earth completes a rotation about its axis, the sun slips nearly a degree to the east, due to the motion of the earth in its orbit, and it takes a little more time for the sun to come to the

* Day here means 'Day and Night'. In ancient times, the duration of day-light from sunrise to sunset, and of the night from sunset to sunrise, were measured separately with the aid of water-clocks. It was comparatively late that the length of the Day, meaning day-light and night, was measured. It was distinguished by the term *ahorātra* in Sanskrit, *ahna* meaning daylight time, and *rātri* meaning night time. In Greece, this was known as Nychthemeron.

† Actually speaking, the sidereal day is defined in astronomy as the period between two successive meridian passages of the First point of Aries. As this point has a slow westward motion among the fixed stars, the duration of the so called sidereal day is very slightly less than the actual sidereal day or the period of rotation of the earth.

meridian of the place. We have the relation :

$365\frac{1}{4}$ mean solar days = $366\frac{1}{4}$ sidereal days.

Rotation of the earth = $23^h\ 56^m\ 4^s.100$ mean solar time.

Sidereal day = 23 56 4. 091 " " "

Mean solar day = 24 3 56. 555 sidereal time

The actual sidereal day, which measures the period of rotation of the earth is generally taken to be constant. The variable part of the solar day comes from two factors :

(1) Obliquity of the sun's path to the equator, and

(2) Unequal motion of the sun in different parts of the year.

(See H. Spencer Jones, *General Astronomy* p. 45). It has however been recently found that even the period of rotation of the earth is not constant but fluctuates both regularly and irregularly by amounts of the order of 10^{-8} seconds.

The Month :

The month is essentially a lunar phenomenon, and is the time-period from completion of new moon (conjunction of moon with the sun) to the next new moon. But the length of the month so defined varies from 29.246 to 29.817 days, owing to the eccentricity of the moon's orbit and other causes. The month or lunation used in astronomy is the mean synodic period, which is the number of days comprised within a large number of lunations divided by the number of lunations. Its value is given by

$$1 \text{ lunation} = 29.^d5305882 - 0.^d0000002\ T$$

where T = no. of centuries after 1900 A.D.

The present duration of a lunation = 29·5305881 days or $29^d\ 12^h\ 44^m\ 2.^s8$. There are other kinds of months derived from the moon and the sun which will be discussed later.

The Year and the Seasons :

The year is the period taken by the seasonal characteristics to recur. The early people had but a vague notion of the length of the year in terms of the day. In the earliest mythology of most nations, the year was taken to have comprised 360 days, consisting of 12 months each of 30 days. They apparently thought that the moon's phases recur at intervals of 30 days.

But experience soon showed that these measures of the month and the year were wrong, but they have left their stamp on history. The sexagesimal measure used in astronomy and trigonometry, as well as fanciful cycles of life of the Universe, invented by ancient nations, appear to have been inspired by these numbers.

It appears that the Egyptians found very early (as related in the next section) from the recurrence of the Nile floods that the year had a length of 365 days. Later they found the true length to be nearer 365.25 days.

The ancient Babylonians, or Chaldeans as they were called from about 600 B.C., appear to have been the earliest people who tried to obtain correct measures of the time-periods : the month, the year, and the seasons in terms of the day, and its subdivisions. Their determinations were transmitted to the Greeks who refined both the notions and measurements very greatly. This story will be told in Chapter II.

At present it is known that the length of the seasonal year (tropical year) is given by :—

Tropical year = 365·24219879—·0⁷614 (t—1900) days, where t = Gregorian year.

The present duration of a tropical year is 365·2421955 days or $365^d\ 5^h\ 48^m\ 45^s.7$.

The Sidereal Year :

In some countries, the ancients took the year to be the period when the sun returned to the same point in its path (the ecliptic). This is the time of revolution of the earth in its orbit round the sun. The tropical year, or the year of seasons, is the time of passage of the sun from one vernal equinox to the next vernal equinox. The two years would have been the same, if the vernal equinoctial point (hereafter called the vernal point) were fixed. But as narrated in Chapter IV, it recedes to the west at the rate of 50″ per year. The tropical year is therefore less than the sidereal year by the time taken by the sun to traverse 50″, i.e., by .014167 days or $20^m\ 24^s$.

For calendarical purpose, it is unmeaning to use the sidereal year ($365^d.256362$), as then the dates would not correspond to seasons. The use of the tropical year is enjoined by the Hindu astronomical treatises like the *Sūrya Siddhānta* and the *Pañca Siddhāntikā*. But these passages have been misunderstood, and Indian calendar makers have been using the sidereal year with a somewhat wrong length since the fifth century A.D.

1.3 THE PROBLEMS OF THE CALENDAR

Whatever may be the correct lengths of the astronomical month and the year, for application to human life, the following points have to be observed in framing a civil calendar.

(a) The civil year and the month must have an *integral number of days.*

(b) The starting day of the year, and of the month should be suitably defined. The dates must correspond strictly to seasons.

(c) For purposes of continuous dating, an era should be used, and it should be properly defined.

(d) The civil day, as distinguished from the astronomical day, should be defined for use in the calendar.

(e) If the lunar months have to be kept, there should be convenient devices for luni-solar adjustment.

A correct and satisfactory solution of these problems has not yet been obtained, though in the form of hundreds of calendars which have been used by different people of the world during historical times, we have so many attempted solutions. The early calendars were based on insufficient knowledge of the duration of the natural time cycles—day, month and year—and led to gross deviations from actual facts, which had to be rectified from time to time by the intervention of dictators like Julius Caesar, Pope Gregory XIII, or a founder of religion like Mohammed, or by great monarchs like Melik Shah the Seljuk, or Akber, the great Indian emperor.

Owing to the historical order of development, calendars have been used for the double purpose :

(i) of the adjustment of the civic and administrative life of the nation,

(ii) of the regulation of socio-religious life of the people.

In ancient and medieval times, society, state and church were intermingled, and the same calendar served all purposes. The modern tendency is to dissociate civic life and administration from socio-religious life. Also due to the enormous growth of intercourse amongst all nations of the world, the need has been felt for a World Calendar dissociated from all religious and social bias. Owing to historical reasons, the Gregorian calendar is now used internationally for civic and administrative purposes, but it is very inconvenient, and proposals have been made to the U. N. O. for the adoption of a simple World Calendar (*vide* § 2.7).

1.4 SUBDIVISIONS OF THE DAY

For pactical prurposes, the day is divided into 24 hours, an hour into sixty minutes and a minute into sixty seconds.

$\therefore$ 1 mean solar day $= 24 \times 60 \times 60 = 86{,}400$ seconds.

The subdivisions of time are measured by highly developed mechanical contrivances (clocks, watches and chronometers), but they have come into use only during comparatively recent times. The ancient people used very primitive devices.

The time-keeping apparatus of the ancients were the gnomon, the sundial, and the water-clock or the clepsydra. The first two depend on the motion of the sun, and require correction. The water-clock which probably was first invented in Egypt, appears to have been used down to the time of Galileo, when the discovery of pendulum motion led to the invention of clocks based on pendulum motion or use of the balance wheel.

Subdivisions of time can be measured by the motion of any substance, which repeats itself regularly ; at the present time in addition to pendulum clocks, quartz-clocks, and ammonia clocks have been used. The latter depend upon harmonic motions within the ammonium molecule, giving rise to spectral lines whose frequency can be accurately measured.

The present divisions of the solar day have interesting history.

It is stated by Sarton that the ancient Sumerians (original dwellers of Babylon) divided the day-time and night-time into three watches each. The watches were naturally of unequal lengths and varied throughout the year. It was only during equinoxes that the watches were of equal length, each of our 4 hours.

These unequal watches continued down to medieval times. The life of a medieval monk was watch-wise as follows.

(1) Matins—last watch of the night. The monk got up nearly two hours before sunrise and started his work,

(2) Prima—at sunrise,

(3) Tertia—half-way between sunrise and noon—time of saying Mass,

(4) Sexta—at noon (hence the word, Siesta—midday rest),

(5) Nona—mid-afternoon, whence our word Noon,

(6) Vespers—an hour before sunset,

(7) Compline—at sunset.

The watches were variable in duration and in their starting moments. Sarton remaks :

> A clock regularly running and dividing the day into periods of equal duration would have been, at first, more disturbing than useful. For monastic purposes, a human variable clock (*e. g.* a bell rung by a monk or lay brother at the needed irregular intervals) was more practical than an automatic one.*

But even in ancient times, the need for measurement of equal intervals of time was felt. The ancient Babylonians used the Nychthemeron (Day and Night

*Sarton, *Introduction to the History of Science*, Vol. III, Part I, p. 716.

combined = *Ahorātra*) into 12 hours of 30 *Gesh* each, *Gesh* being = 4 minutes. The Egyptians divided the day-light time into 12 hours, and the night into 12 hours. Later in medieval times, the 24-hour division for the whole day (day and night) has been adopted. The division into A.M. and P.M. were for the sake of convenience, so that the maximum number of times a bell has to be rung, on the completion of an hour, would not exceed 12, for apparently ringing a bell 24 times would be a torture of the flesh.

The broad divisions of the day were secured by the Hindus in two ways. They divided the day-time (from sunrise to sunset) into 4 equal parts each called a *prahara* or *yāma*. The night time was also similarly divided into 4 equal *praharas*. The *prahara* is so popular a unit in Indian time measurement that even the lay man expresses time in terms of *praharas* and half *praharas*. An alternative system of division of the time is the '*muhūrta*' obtained by dividing the daytime into 15 *muhūrtas* determined by gnomon shadow lengths. The day *muhūrtas* were measured from lengths of shadows of the gnomon. The night *muhūrtas* are similarly the fifteenth part of the night time.

As the durations of day and night are not equal except on the vernal and autumnal equinox days, the *prahara* and *muhūrta* of the day-time have not the same durations as those of their nocturnal counterparts. On equinox days, they are however equal, when

1 *Prahara* $= 3^h \ 0^m = 7^{gh} \ 30^v$
1 *Muhūrta* $= 0 \ \ 48 = 2 \ \ 0$

The Hindu astronomers appear to have switched on to the *ahorātra* during *Vedāṅga Jyotiṣa* times. As it is rather complicated, we do not give an account of it. The reader may consult Dixit's *Bhāratīya Jyotiśāstra*. But in *Siddhānta Jyotiṣa*, they had a full fledged scientific system.

The scientific divisions of time followed by the Siddhāntas are the *ghaṭikā* (*daṇḍa* or *nāḍī*), *prahara* or *yāma*, and *muhūrta* etc. The day is measured from sunrise and the period from sunrise to next sunrise is divided into 60 equal '*ghaṭikās*' or *daṇḍas* ; each *ghaṭī* is subdivided into 60 *vighaṭīs* or *palas*, and each *vighaṭī* or *pala* into 60 *vipalas*. So a day consists of 60 *ghaṭīs* or 3600 *palas* or 216000 *vipalas*. Thus

1 *ghaṭikā* $= 24^m \ 0^s.0$
1 *pala* $= 0 \ \ 24.0$
1 *vipala* $= 0 \ \ 0.4$

The *pala* or *vighaṭī* is sometimes subdivided into 6 divisions called a '*prāṇa*'. A *prāṇa* is therefore equivalent to 4 secs. of time. There are 360 *prāṇas* in a *ghaṭikā* and the day contains 360 × 60 or 21600 *prāṇas*, the same as the number of minutes (*kalā* or *liptikā*) in a circle. In *Siddhāntas* (astronomical treatises of the Hindus) there are conceptions with nomenclatures of still smaller divisions of time, but they had no practical utility.

None of the time-periods of the sun, and the moon, *viz*., the year and the season, and the lunations and half-lunations are integral multiples of the day ; on the other hand, the figures run to several places of decimals. How did the ancients, who quickly discovered that the time-periods were not integral multiples of the day, express their findings ?

It will take us a long dive into the history of mathematical notation to elucidate this story. The curious reader may consult Neugebauer's ***Exact Sciences in Antiquity*** or van der Waerden's *Science Awakening* (pp.51-61). In fact, the symbolism was very cumbrous before the discovery of the decimal notation about 600 A.D. in India, where it quickly replaced the old cumbrous notation. The discovery was quickly adopted by the Arabs for certain purposes, but was first made known to Europe by Leonardo of Pisa in a treatise on Arithmetic published in 1202 A.D., but a few more centuries passed before it was universally adopted.

The practice of expressing fractions by means of decimals came later, both in India and Europe. In India, an astronomer who wrote an astronomical treatise called '*Bhāsvatī*' in 1099 A. D. was called Śatānanda, (*i.e*., revelling in hundreds) because he used to write fractions in hundredths i.e. $\frac{1}{4}$ as 25 hundredths, $\frac{3}{4}$ as 75 hundredths. In Europe, the expression of fractions by decimals came into vogue about the seventeenth century.

The Hindu astronomer of the Siddhāntic age expressed the periods of the sun, the moon and the planets by the number of their periods in a *Mahāyuga* (4.32×10^6 years). The number is usually integral.

But how did this cumbrous system originate ?

Probably many of these values were obtained by counting the number of days between a large number of periods and dividing them by the number of periods. For example, take the case of the length of the mean lunation (lunar month). All ancient nations give this length correct to a large number of decimals. This must have been obtained by counting the number of days between two new moons, separated by a large number of years, and dividing it by the number of lunations contained in the interval. Of course, the utmost they could have done was to keep records for at most a hundred years, but the rule of three was always available.

In the following sections, the different ways of tackling the calendar problem in different centres of civilization have been described. We have described in Chap. II, the purely solar calendars, in which the moon is altogether discarded as a time-marker. This practice originated in Egypt about 3000 B.C. These calendars require only a correct knowledge of the length of year, and are therefore comparatively simpler. They required very little or almost no knowledge of astronomy.

We have described in Chap. III, the luni-solar calendars, prevalent in ancient Mesopotamia, India, China and most other countries. In these calendars, both the sun and the moon are used as time-markers, and therefore precise knowledge of their motion in the heavens was essential for the formulation of a correct calendar. We mark two stages : first the formulation of a calendar from a knowledge of only the length of the year, and of the mean lunar month. This was an older phase. It did not work satisfactorily, because it depended on the mean motion of the two luminaries. Actually, the time-predictions have to be verified by actual comparison of the predicted happenings (say of the vernal equinox day in the case of the sun, or the first appearance of the crescent of the moon after new moon on the western horizon) with the time of actual happenings. This gave rise to the need for watching the daily motion of the two luminaries, and invention of methods for recording and storing these observations ; in other words, this led to the science of astronomy. Early astronomy is almost completely calendarical. At a later stage, the five planets attracted attention, on account of their association with astrology.

We have therefore devoted Chap. IV to calendaric astronomy, which was evolved by the Chaldeans and taken over from them by the Greeks, and in time diffused to other countries.

In Chap. V, we have described the various stages of the development of the Indian calendar :—the empirical stage (Ṛg-Vedic), the mean motion stage (*Vedāṅga Jyotiṣa*), and the scientific stage (*Siddhānta Jyotiṣa*). From 1200 A.D., astronomical studies became decadent in India, and we have analysed the cause of decadence. We have given a full account of precession, as most Indian calendar makers still believe in the false theory of Trepidation which disappeared from Europe after 1687 A. D.

1.5 AHARGANA OR HEAP OF DAYS : JULIAN DAYS

Though the Flux of Time is a continuous process, it is divided for the sake of convenience and for natural reasons too, into years, months and days. The years are mostly counted from the beginning of an era, so that if we wish to date a memorable event, say the birth-day of George Washington, it can be seen from an inspection of his birth register that it took place on Feb.11, of the year 1732. But this practice by itself does not enable a scientific chronologist to fix up the event unambiguously on the absolute Scale of Time, unless the whole history of the particular method of date-recording is completely and accurately known. One must know the lengths of the individual months, the leap-year rules, and the history of calendar reform. In the particular case mentioned, though George Washington according to his birth register is stated to have been born on Feb. 11, 1732, his birth-day is celebrated on Feb. 22. Why ? Because Feb. 11 was the date according to the Julian calendar. But in 1752, England (America was then a colony of England) adopted the reformed Gregorian calendar, and by an Act of Parliament, declared Sept. 3 to be Sept.14, a difference of 11 days. Following the Gregorian calendar, Washington's birth-day had to be shifted to Feb. 22. A scientific chronologist, say of China, would find it difficult to locate Washington's birth-day unless he knew the whole history of the Gregorian calendar.

This difficulty is more pronounced when we have to deal a luni-solar calendar, say that of Babylon. Many records of lunar eclipses occuring in Babylon were known to the Alexandrian astronomer, Claudius Ptolemy, but they were dated in Seleucidean era, and Babylonian months, say year 179, 10th of Nisan. Now the Babylonian months were lunar, had lengths of 29 or 30 days, but the year could have lengths of 353, 354 383, 384 (*vide* § 3·3). Therefore when two eclipse datings were compared, it was impossible to calculate the number of days between them, unless the investigator had before him a record showing the lengths of years and months between the two events. Ptolemy expressed his datings according to the Egyptian calendar, which enables one to calculate the interval far more easily. He must have taken lot of pains to carry out the conversion from the Babylonian to Egyptian dates.

How much better it would have been if a great genius at the beginning of civilization, say near about 3000 B.C., started with a zero day, and started the practice of dating events by the number of days elapsed since this zero date, to the date when this particular event took place. Such a great genius did not appear and a confusing number of calendars came into existence. The scientific chronologist is now faced with the reverse problem : Suppose two ancient or medieval events are found dated according to two different calendars. How to reduce these dates to an absolute chronological scale ?

For this purpose, a medieval French scholar, Joseph Scaliger introduced in 1582 A.D., a system known as

'Julian Days' after his father, Julius Scaliger. The Julian period in years is

$$7980 \text{ years} = 19 \times 28 \times 15$$

19 being the length in years of the Metonic Cycle,
15 „ „ „ „ „ of the Cycle of Indiction,
and 28 „ „ „ „ „ of the Solar Cycle.

It was found by calculation that these three cycles started together on Jan. 1, 4713 B.C. So the Julian period as well as the Julian day numbers started from that date. The Julian period is intended to include all dates both in the past and in the future to which reference is likely to be made and to that extent it has an advantage over an era whose epoch lies within the limits of historical time. The years of the Julian period are seldom employed now, but the day of the Julian period is frequently used in astronomy and calendaric tables. Unlike the civil day, the Julian day number is completed at noon.

Let us give the Julian days for a number of world-events, as given by Ginzel, in his *Handbuch der Mathematischen und Technischen Chronologie.*

Table 1—Julian day numbers.

	Date		*Julian day*
Kaliyuga	... 17 February,	3102 B.C. ...	588,465
Nabonassar	... 26 February,	747 B.C.	1,448,638
Philippi	... 12 November,	324 B.C.	1,603,398
Śaka era	... 15 March,	78 A.D.	1,749,621
Diocletian	... 29 August,	284 A.D.	1,825,030
Hejira	... 16 July,	622 A.D.	1,948,440
Jezdegerd (Persian)	... 16 June,	632 A.D.	1,952,063
Burmese era	... 21 March,	638 A.D.	1,954,167
Newar era	... 20 October,	879 A.D.	2,042,405
Jelali era (Iran)	... 15 March,	1079 A.D.	2,115,236

It may be mentioned here that the ideas underlying continuous reckoning of days occurred much earlier to the celebrated Indian astronomer, Āryabhaṭa I (476–525 A.D.), who introduced it under the designation "*Ahargaṇa*" or heap of days in his celebrated *Āryabhaṭīya*. The idea of counting *ahargaṇa* or heaps of days elapsed from a specified epoch upto the given date dawned upon the Hindu astronomers as a necessity for calculating the position of planets for that date. They followed the cumbrous luni-solar calendar for dating purposes, which was not based upon any simple rules. It contains months of 29 or 30 days, and occasionally a thirteenth month, the recurrence of which was determined by elaborate methods. The dates of the months are not numbered serially, but designated by the *tithi* current at sunrise. It was accordingly found almost impossible to work out the mean positions of planets on the basis of the luni-solar calendar alone. For this purpose a continuous and uniform time scale was necessary, and this was served by the *ahargaṇa*.

Āryabhaṭa had somehow the idea that the planets, and the two nodes (which were treated as planets in Hindu astronomy) return to the first point of Aries after every 4.32×10^6 years, and there was a unique assemblage of planets at the first point of the Hindu sphere at some past date which he called the beginning of *Kali Yuga*. The date assigned to the *Kali* beginning is now known to be 3102 B.C., February 17-18. The common period of revolution of planets of 4.32×10^6 years constitute a *Mahāyuga* consiting of

Satya yuga of	1.728×10^6	years
Tretā yuga of	1.296×10^6	„
Dvāpara yuga of	0.864×10^6	„
Kali yuga of	0.432×10^6	„
Total	4.32×10^6	years

It may be noticed that

$$4.32 \times 10^6 = 12000 \times 360$$

Āryabhaṭa gave tables showing the number of sidereal revolutions of planets in the period of 4.32×10^6 years. The total number of days in a *Mahāyuga* = 1,577,917,800 which gives the length of a year = 365.25875 days.

Brahmagupta was evidently not satisfied that Āryabhaṭa's figures for the periods of planets were correct. He introduced a *Kalpa* = 1000 *Mahāyugas* = 4.32×10^9 years. The '*Kalpa*' was supposed to constitute a 'Day' of the Creator, Grand-father Brahmā. He gave the number of sidereal revolutions of the planets in a *Kalpa*, and thought he had improved Āryabhaṭa's figure for the year.

Brahmagupta's year = 365.25844 days.

Āryabhaṭa calculated '*Ahargaṇa*' or heap of days, from the beginning of the *Mahāyuga* as the zero-day.

But evidently this practice involves very large numbers, and is inconvenient to use. Therefore the later astronomers used modifications of the system by counting *Ahargaṇa* from other convenient epochs, within historical reach. The different epochs which have been used are :—

(1) The beginning of the Kali era or 3102 B.C.

(2) 427 Śaka era or 505 A.D. as is found in *Pañcasiddhāntikā* of Varāhamihira.

(3) 587 Śaka era or 665 A.D. as is found in the *Khaṇḍakhādyaka* of Brahmagupta.

(4) 854 Śaka era or 932 A.D, as is found in the *Laghumānasa* of Muñjāla.

(5) 961 Śaka era or 1039 A.D. in the *Siddhānta Śekhara* of Śrīpati.

The astronomical treatises of the Hindus have been divided into three categories according to the initial epoch employed for calculation. In which the calculations of *ahargaṇa* as well as the planetary mean places are made from the *Kalpa*, is called a *Siddhānta* ; when the calculations start from a *Mahāyuga* or *Kali*-beginning it is called a *Tantra*, and when it is done from a recent epoch it is called a *Karaṇa*. In any case, the mean places of the planets with their nodes and apsides are given for the epoch of the treatise from which calculations are to be started, with rules for finding the *ahargaṇa* for any later date. This *ahargaṇa* is then made use of in finding for that later date the positions of planets from their given initial positions and their daily motions, for,

The mean position at any epoch
= the mean position at the initial epoch
+ daily motion × ahargaṇa.

Due to the complexity of the Hindu luni-solar calendar, one has to go through complicated rules in determining the *ahargaṇa* for any particular day. Dr. Olaf Schmidt of the Brown University and the Institute of Advanced Study, in discussing the method of computation of the *Ahargaṇa* at length, has pointed out that the present Hindu method suffers from a disturbing discontinuity. The curious reader may go through his article published in the *Centaurus*.

We, however, give below the corresponding Julian day numbers and *Kali ahargaṇa* for certain modern dates.

	Julian days (elapsed at mean noon)	*Kali ahargaṇa* (elapsed at following midnight)
1900, Jan. 1	2,415,021	1,826,556
1947, Aug. 15	2,432,413	1,843,948
1956, Mar. 21	2,435,554	1,847,089

The difference between the two numbers 588,465 represents the Julian day number on the *Kali* epoch, as already stated.

The use of *ahargaṇa* plays a very important part in modern epigraphical researches when the date recorded in an inscription is required to be converted into the corresponding date of the Julian calendar. If the *Kali ahargaṇa* for the recorded date can be determined, then the problem of ascertaining the corresponding Julian or Gregorian date becomes a very easy task.

CHAPTER II

The Solar Calendar

2.1 TIME-RECKONINGS IN ANCIENT EGYPT

Like other nations of antiquity the early Egyptians had a year of 360 days divided into 12 months, each of 30 days ; but they found very early from the recurrence of the Nile flood, that the seasonal year consisted approximately of 365 days, and that a month or lunation (period from one new-moon to another) was nearly $29\frac{1}{2}$ days (real length 29.531 days). But they had already framed a calendar on the 30-day month, and 360-day year, which had received religious sanction. Hence arose the first necessity for calendar-reform recorded in ancient history. To persuade the people to agree to this reform their priests invented the following myth :

"The Earth god *Seb* and the sky goddess *Nut* had once illicit union. The supreme god *Ra*, the Sun, thereupon cursed the sky goddess *Nut* that the children of the union would be born neither *in any year* nor *in any month*. *Nut* turned to the god of wisdom, *Thoth*, for counsel. *Thoth* played a game of dice with the Moon-goddess, and won from her $\frac{1}{72}$th part of of her light out of which he made five extra days. To appease *Ra* the Sun-god, these five days were given to him, and his year gained by five days while the Moon-goddess's year lost five days. The extra five days in the solar year were not attached to any month, which continued to have 30 days as before ; but these days came at the end of the year, and were celebrated as the birthdays of the gods born of the union of *Seb* and *Nut*, *viz.*, Osiris, Isis, Nephthys, Set and Anubis, five chief gods of the Egyptian pantheon." *

Let us scrutinize the implications of this myth. ***This is tantamount to discarding the moon altogether as a time-maker, and basing the calendar entirely on the sun.*** This was a very wise step, for as has been found from ancient times, the moon is a very inconvenient time-marker. The Egyptians maintained the old custom of keeping months of 30 days' duration, and 12 months made a year. But five days (*Epagomenai* in Greek) were added to the year at the end, which were not attached to any month. They were celebrated as national holidays. Each month of the Egyptian calendar was divided into 3 weeks, each of 10 days (Decads).

The names of the Egyptian months together with the dates of beginning of each month as they stood in 22 B.C., are as follows :

* Zinner—*Geschichte der Sternkunde*, p. 3.

Egyptian Calendar			*Julian Calendar*
1 Thoth	(30)	...	29 August
1 Phaophi	(30)	...	28 September
1 Athyr	(30)	...	28 October
1 Choiak	(30)	...	27 November
1 Tybi	(30)	...	27 December
1 Mechir	(30)	...	26 January
1 Phamenoth	(30)	...	25 February
1 Pharmuthi	(30)	...	27 March
1 Pachon	(30)	...	26 April
1 Payni	(30)	...	26 May
1 Epiphi	(30)	...	25 June
1 Mesori	(30)	...	25 July
(1 Epagomenai	5)	...	24 August

The year was divided into three seasons, each of four months : Flood time, Seed time and Harvest time.

But the Egyptians soon found that even a year of 365 days did not represent the correct length of the year, which, as we now know, is nearly $365\frac{1}{4}$ days. This fact they appear to have discovered in two different ways :

(1) from their measurement of the length of the year from heliacal risings of Sirius, and

(2) from their long record of floods extending over centuries.

The fixed star Sirius, which is the most brilliant star in the heavens, was early associated with the chief goddess of the Egyptian pantheon, Isis, and was the subject of observation by her priests. The day of its first appearance on the eastern horizon at day-break (heliacal rising) appeared to have been carefully observed, and then on every subsequent day, its position in the sky at sunrise used to be noted. It was found that gradually it got ahead of the sun, so its appearance on the horizon would be observed sometime before sunrise, and on every successive sunrise, it would be found higher up in the heaven. After about a year it would be seen in the western horizon at sunset for a few days till it could no longer be traced. The Egyptians found as a result of long periods of observation, that it came again to the horizon at day break at the end of $365\frac{1}{4}$ days, not 365 days. If on one year, the heliacal rising of Sirius took place on Thoth 1, (Thoth was the name of the first month of the year) four years later it would take place on Thoth 2, and forty years later on Thoth 11. As the mean interval of heliacal rising of Sirius at the latitude of Memphis was 365.25 days, the Egyptians concluded that the heliacal rising of Sirius would continue to move round the year in a complete cycle of *ca.* 1460 years ; called the Sothic cycle, after Sothis (Isis). They also appear to have found from observations over long periods of years that the Nile flood occurred not at intervals of 365 days, but of 365¼ days.

On account of the deficiency of ¼ day in the year, the year-beginning lost touch with the arrival of the Nile flood, though the temple priests had devised a method of finding out the interval between Thoth 1, and arrival of the Nile flood by observations of the heliacal rising of the bright star Sirius, identified with their chief goddess Isis. But they kept the knowledge to themselves.

If the Egyptians carried out a reform of their calendar incorporating this fact, that the tropical year had a length of 365¼ days, their calendar could have been *almost* perfect. *All that they had to do was to take 6 extra days instead of 5 every fourth year*. But the 365-day year had so much soaked into the Egyptian mind, that this move for calendar reform was never adopted inspite of serious attempts by earlier Pharoahs, and later, a more serious one by the Graeco-Egyptian ruler Ptolemy Euergetes (238 B.C.). But it became generally known that the correct length of the year was 365¼ days. Fotheringham in his article on "The Calendar" observes :

An additional day was inserted at the close of the Egyptian year 23-22 B.C. on August 29 of what we call the Julian calendar, and at the close of every fourth year afterwards, so that the reformed or Alexandrian year began on August 30 of the Julian calendar in the year preceding a Julian leap year and on August 29 in all other years. The effect of this reform was to keep each Egyptian month fixed to the place in the natural year which it happened to occupy under the old calendar in the years 26-22 B.C. But the old calendar was not easily suppressed, and we find the two used side by side till A.D. 238 at least. The old calendar was probably the more popular, and was preferred by astronomers and astrologers. Ptolemy (150 A.D.) always used it, except in his treatise on annual phenomena, for which the new calendar was obviously more convenient. Theon in the fourth century A.D., though mentioning the old calendar, habitually used the new.

Though not quite perfect, the Egyptian calendar was greatly admired in antiquity on account of its simplicity, for the length of the year and the months were fixed by definite rules and not by officials or *pandits*. The religious observances fell on fixed days of the month and at stated hours, which were fixed about 1200 B.C.

On account of its simplicity, the Egyptian calendar was adopted by many nations of antiquity, and even sometimes by the learned Chaldeans and Greeks. Fotheringham observes :

"The Egyptian calendar was, upto the time of Julius Caesar's reform of the Roman calendar in 46 B.C., the only civil calendar in which the length of each month and of each year was fixed by rule instead of being determined by the discretion of officials or by direct observation. If the number of years between two astronomical observations, dated by the Egyptian calendar, was known, the exact number of days could be determined by a simple calculation. No such comparison could be made between dates referred to any other civil calendar unless the computer had access to a record showing the number of days that had actually been assigned to each month and the number of months that had actually been assigned to each year. It is true that the Egyptians did not use a continuous era, but were content to number the years of each reign separately, so that there was a difficulty in identifying a particular year, but the astronomers of the Ptolemaic age rectified this by the introduction of eras.* The simplicity and regularity of the Egyptian calendar commended it to astronomers, who found it excellently adapted to the construction of tables that could be readily applied and used even for a remote past or for a distant future without any fear that the system by which time was reckoned in the tables might not coincide with the system in actual use. In the second century B.C. we find Chaldean observations, sometimes nearly six centuries old, reduced to the Egyptian calendar in the works of Hipparchus (126 B.C.), who observed not in Egypt but at Rhodes, and cited from him by the Egyptian Ptolemy in the second century of our era ; we also find in the second century B.C., an Athenian observation of 432 B.C. reduced to the Egyptian calendar on an inscription found at Miletus, which appears to represent the work of the astronomer Epigenes". †

This calendar survives in a slightly modified form in the Armenian calendar, the three first months of the old Egyptian year corresponding exactly with the three last months of the Armenian year. The Alexandrian calendar is still the calendar of Abyssinia and of the Coptic Church, and is used for agricultural purposes in Egypt and other parts of northern Africa.

2.2. SOLAR CALENDARS OF OTHER ANCIENT NATIONS

The story of the calendar in Egypt has been given in full, because the ancient Egyptians evolved a very simple and convenient calendar which, as mentioned before, would have been almost perfect (provided the year was taken to consist of 365¼ days instead of 365 days). This was rendered possible by their bold initia-

* The Nabonassar Era—*vide* § 3.4.

† Article on 'The Calendar', *Nautical Almanac*, 1935.

tive of discarding the moon as a time-marker. But people in the remaining parts of the civilized world (*e.g.*, in Babylon, Greece, India and China) in ancient and moderm times, retained the moon and preferred the more complex luni-solar calendars described in Chap. III. This was rather fortunate, for if their rulers had adopted the Egyptian calendar, the priest-astronomers of ancient nations, particularly of Babylon, would never have taken to observation of the sun, the moon, and the planets, and tried to evolve mathematical formulae for predicting their positions amongst stars in advance (the Ephemerides), which form the basis on which our astronomical knowledge has been built up; for the Egyptian calendar was evolved simply from results of experiences extending over centuries, and required almost no astronomical sense, or observations either of the sun, the moon and stars, except the heliacal rising of Sirius. *It was simple and convenient, but like many perfect things, it killed intellectual curiosity.*

But as will be described in Chap. III, the luni-solar calendar is a very complex thing, and has taken infinite variations in different regions. Hence the simple Egyptian calendar appealed to many nations of antiquity as well as of modern times. We have related the case of the Greek astronomers Hipparchos and Ptolemy who preferred the Egyptian method of date-recording to the Greek methods. This was, however, not the solitary instance.

2.3 THE IRANIAN CALENDAR

The great Iranian conqueror Darius (520 B. C.), whose empire comprised Egypt, Mesopotamia, Syria and Asia Minor, besides his native country of Iran, certainly came into contact with the diverse calendars of older civilizations, but he appears to have preferred the Egyptian calendar to the more complex Babylonian calendar, and introduced it in his vast empire.

But the astronomers of Darius made correction of the deficit of ¼ day of the year in another way. They had all years of 365 days, but used an interacalary month of 30 days in a cycle of 120 years.

All the names of the old Iranian months and details of their calendar are not available now. The month-names as far as could be traced are stated below :—

1. Thuravāhara
2. Thaigraci
3. Adukani
4. ....
5. Garmapada
6. ....
7. Bāgayādi
8. ....
9. Atriyādija
10. Anāmaka
11. Margazana
12. Viyachna

The Persians did not have weeks or decads, but named the successive days of the month serially according to their gods or religious principles, as below :—

Zend	*Pehlewi*	*Nearest Vedic*
1. Ahurahē mazdāo	Aūharmazd	
2. Vanheus mananhō	Vohūman	
3. Ashahē vahistahē	Ardavahisht	
4. Kshathrahē vairjēhē	Shatvairō	
5. Spentajāo ārmatōis	Spendarmad	
6. Haurvatātō	Horvadad	
7. Ameretātō	Amerōdad	Amrtatva
8. Dathushō	Dīn-i-pavan Ātarō	
9. Āthrō	Ātarō	Atharvan
10. Apām	Āvān	Apāṁ
11. Hvarekshaētahē	Khūrshēd	
12. Māonhō	Māh	
13. Tistrjēhē	Tīr	
14. Geus	Gōsh	
15. Dathushō	Dīn-i-pavan Mitrō	
16. Mithrahē	Mitrō	Mitrāha
17. Sraoshahē	Srōsh	
18. Rashnaos	Rashnū	
19. Fravashinām	Fravardīn	
20. Verethraghnahē	Vāhrām	Vṛtraghnāha
21. Rāmanō	Rām	
22. Vātahē	Vād	
23. Dathushō	Dīn-i-pavan Dīnō	
24. Daēnajāo	Dīnō	
25. Ashōis	Ard	
26. Arstātō	Āshtād	
27. Asmanō	Āsmān	
28. Zemō	Zamjād	
29. Mathrahēspentahē	Mārspend	
30. Anaghranām	Anīrān	

After the Islamic conquest of Persia in 648 A.D., the purely lunar calendar of Islam (Hejira) was imposed on Persia, but it does not appear to have been liked by the native Iranians.

In 1074-75 the Seljuq Sultan Jelal Uddiṇ Melik Shah called upon the celebrated Omar Khayyam and seven others to reform the old Persian calendar. The calendar as reformed by them was called Tarikh-i-Jelali, its era was the 10th Ramadan of Hejira

471=16th March, 1079 A.D. There are many interpretations of the Jelali reform, the modern interpretation being 8 intercalary days in 33 years, giving the length of the year as 365.24242 days. The year started from the day of or next to vernal equinox.

The Parsees in India, the followers of the Prophet Zarathustra are the descendants of Iranians who took shelter in India on the conquest of Persia by the Arabs. The following details about their calendar is reproduced from *Encyclopaedia Britannica* (14th edition), Parsees :—

The Parsees of India are divided into two sects, the Shahanshahis and the Kadmis. They differ as to the correct chronological date for the computation of the era of Yazdegerd, the last king of Sassanian dynasty, who was dethroned by the caliph Omar about A.D. 640. This led to the variation of a month in the celebration of the festivals. The Parsees compute time from the fall of Yazdegerd. Their calendar is divided into twelve months of thirty days each ; the other five days, being added for holy days, are not counted. Each day is named after some particular angel of bliss, under whose special protection it is passed. On feast days a division of five watches is made under the protection of five different divinities. In midwinter a feast of six days is held in commemoration of the six periods of creation. About March 21, the vernal equinox, a festival is held in honour of agriculture, when planting begins. In the middle of April a feast is held to celebrate the creation of trees, shrubs and flowers. On the fourth day of the sixth month a feast is held in honour of Sahrevar, the deity presiding over mountains and mines. On the sixteenth day of the seventh month a feast is held in honour of Mithra, the deity presiding over and directing the course of the sun, and also a festival to celebrate truth and friendship. On the tenth day of the eighth month a festival is held in honour of Farvardin, the deity who presides over the departed souls of men. This day is especially set apart for the performance of ceremonies for the dead. The people attend on the hills where the "towers of silence" are situated, and in the *sagris* pray for the departed souls. The Parsee scriptures require the last ten days of the year to be spent in doing deeds of charity.

In modern Iran when Riza Shah Pahlavi came to power in 1920, he instituted a reform of the existing Muslim calendar abandoning the strictly lunar reckoning and introducing purely solar year restoring the early Persian names which had never fallen entirely out of use.

The names of the months, and their lengths are as follows :

Farvardin-mah (31)	begins	21 or 22 March
Ardibahisht-mah (31)	,,	21 or 22 April
Khordad-mah (31)	,,	22 or 23 May
Tir-mah (31)	,,	22 or 23 June
Mordan-mah (31)	begins	23 or 24 July
Shartvar-mah (31)	,,	23 or 24 August
Mehr-mah (30)	,,	23 or 24 September
Aban-mah (30)	,,	23 or 24 October
Azar-mah (30)	,,	22 or 23 November
Dai-mah (30)	,,	22 or 23 December
Bahman-mah (30)	,,	21 or 22 January
Esfand-mah (29, 30)	,,	20 or 21 February

2.4 THE FRENCH REVOLUTION CALENDAR

The Egyptian calendar attracted the notice of the calendar committee of the French Revolutionary Government (1789-1795) who wanted *to replace Religion by Reason.* The committee consisted, amongst others, the great mathematicians Laplace and Lagrange and the poet d'Eglantine. *Laplace proposed that the year 1250 A.D., when according to his calculations the equinoctial line was perpendicular to the apse line of the Earth's orbit should be taken the starting point of the French Revolution Era in place of a hypothetical year of Christ's birth.* But the calendar committee did not agree with him but started the era of the glorious French revolution, with the autumnal equinox day of 1792 A.D., as this was nearest in date to the outbreak of the revolution. Sentiment proved stronger than cold scientific reasoning.

French Revolution Calendar

(1792 Sept. 22 to 1806)

(The Months consist of 30 days each)

	Month	*Season*	*Month beginning*
		AUTUMN	
1.	Vendemiaire :	Grape gathering	Sept. 22
2.	Brumaire :	Fog	Oct. 22
3.	Frimaire :	Frost	Nov. 21
		WINTER	
4.	Nivose :	Snow	Dec. 21
5.	Pluviose :	Rain	Jan. 20
6.	Ventose :	Wind	Feb. 19
		SPRING	
7.	Germinal :	Seed	March 21
8.	Floreal :	Blossom	April 20
9.	Prairial :	Pasture	May 20
		SUMMER	
10.	Messidor :	Harvest	June 19
11.	Thermidor :	Heat	July 19
12.	Fructidor :	Fruit	Aug. 18
	Day of Virtue	... ...	Sept. 17
	„ Genius	... ...	„ 18
	„ Labour	... ...	„ 19
	„ Opinion	... ...	„ 20
	„ Rewards	... ...	„ 21

The seven-day week was abandoned for a week of 10 days. The month names were invented by the poet member of the committe. The last five days were dedicated to the service of the poor (*Sans-Culottides*) and did not form part of any month.

After 13 years of service, the French Revolution calendar was abolished by Napoleon Bonaparte, then emperor of France, as part of his bargain with the Roman Catholic Church for his coronation by the Pope.

2.5 THE ROMAN CALENDAR

(The Christian Calendar)

What is now known as the Christian calendar, and used all over the world for civil purposes, had originally nothing to do with Christianity. It was, according to one view, originally the calendar of semi-savage tribes of Northern Europe, who started their year sometime before the beginning of Spring (March 1 to 25) and had only ten months of 304 days ending about the time of winter solstice (December 25), the remaining 61 days forming a period of hybernation when no work could be done due to the onset of winter, and were not counted at all. The city state of Rome also had originally this calendar, but several corrections were made by the Roman Governments [illegible] epochs and the final shape was given to it by Julius Caesar in 46 B.C. ; the calendar so revised is known as the Julian calendar.

As already stated, this calendar originally had contained ten months from March to December comprising 304 days. It may be regarded as certain that the months were lunar. The second Roman king of the legendary period, Numa Pompilius, is supposed to have added two months (51 days) to the year in about 673 B.C., making a total of 355 days ; January (named from the god Janus, who faced both ways) now began the year, and February preceded March, which became the third month. The number of days of the months were 29, 28, 31, 29, 31, 29, 31, 29, 29, 31, 29, 29. Adjustment of the year to the proper seasons was obtained by intercalation of a thirteenth month of actually 22 or 23 days' length (called Mercedonius) after two years or three years as was considered necessary, and was inserted between February and March.* Had the intercalation been applied regularly at alternate years the additional days in four years would have been 45 (22+23) or 11¼ days per year on average, and so the year-length would have been 366¼ days, only one day in excess of the correct length. But as the intercalation was applied rather arbitrarily sometimes after two years and sometimes after three years, the year-beginning gradually shifted and the year started before the arrival of the proper seasons.

The days of the month in the Roman calendar were enumerated backwards from the next following Kalends (1st of month), Nones (5th of month, except in the 31-day months, when the 7th of month), or Ides (13th of month, except in the 31-day months, when the 15th of month). The day after the Ides of March, for instance, would be expressed as 17 days before the Kalends of April.

The Romans upto 45 B.C. apparently had rather a vague idea of the correct length of the year. Julius Caesar after his conquest of Egypt in 44 B. C. introduced the leap-year system on the advice of Egyptian astronomer Sosigenes, who suggested that the mean length of the year should be fixed at 365¼ days, by making the normal length of the year 365 days and inserting an additional day every fourth year. At the same time the lengths of the months were fixed at their present durations. The extra day in leap years was obtained by repeating the sixth day before the Kalends of March. The name Quintilis, the 5th month from March, was changed to July (Julius) in 44 B.C. in honour of Julius Caesar, and the name Sextilis was changed to August in 8 B.C. during the reign of his successor, Augustus, and in honour of him. There is a very widespread idea that the durations of July and August were fixed at 31 days each in order to please the two Roman dictators Julius Caesar, and Octavious Caesar, also called Augustus, and for this purpose the two extra days were cut off from February, thus reducing its duration to 28 days. It is a nice story, but does not appear to have been critically probed.

Owing to the drifting of the year-beginning, the year 46 B.C. started about 90 days before the proper seasons. The months were first brought back to their correct seasons by giving the year corresponding to 46 B.C., a normal intercalation of 23 days after February and then inserting 67 additional days between November and December. This year therefore contained 445 days in all and is known as the *'year of confusion'*.

But the perfect calendar was still a long way off. Caesar wanted to start the new year on the 25th December, the winter solstice day. But people resisted that choice because a new-moon was due on January 1, 45 B.C. and some people considered that the new-moon was lucky. Caesar had to go along with them in their desire to start the new reckoning on a traditional lunar landmark.

* In fact, the intercalary month consisted sometimes of 27 days and sometimes of 28 days and was inserted after February 23. The last five days of February, which were due to be repeated after the close of the intercalary month, were not actually repeated, resulting in the intercalation of 22 or 23 days only.

The Julian calendar spread throughout the Roman empire and survived the introduction of Christianity. But the Christians introduced their own holidays which were partly Jewish in origin and for this, luni-solar and week-day reckonings had to be adopted.

Origin of the Seven-day Week

Historical scholarship has shown that unlike the year and the month, the seven-day week is an artificial man-made cycle. The need for having this short cycle arose out of the psychological need of mankind for having a day of rest and religious service after protracted labour extending over days. The seven-day week with a sabbatical day at the end, or something similar to it, is needed not only by God Almighty, but also by humbler toiling men. But there has been no unanimity of practice.

As already stated, the ancient Egyptians had a ten-day week. The Vedic Indians had a six-day week The ancient Babylonians who started the month on the day after new-moon, had the first, eighth, fifteenth, and the twenty-second day marked out for religious services. This was a kind of seven-day week with sabbaths, but the last week might be of eight or nine days' duration, according as the month which was lunar had a length of 29 or 30 days. The ancient Iranians had a separate name for each day of the month, but some days, at intervals of approximately seven, were marked out as Din-i-Parvan, for religious practices. The pattern followed appears to have been similar to the Babylonian practice. The continuous seven-day week came into general use sometime after the first century A.D. It was unknown to the writers of the New Testament who do not mention anything about the week day on which Christ was crucified or the week day on which he is alleged to have ascended to Heaven. The fixing of Friday and Sunday for these incidents is a later concoction, dating from the fifth century after Christ. All that the New Testament books say is that He was crucified on the day before the Hebrew festival of Passover which used to be celebrated and is still celebrated on the full-moon day of the month of Nisan.

The continuous seven-day week was evolved on astrological grounds by unnamed astronomers who may have been Chaldean or Greek at an unknown epoch, but before the first century A.D. The Jews adopted it as a cardinal part of their faith during days of their contact with the Chaldeans. It is not their invention. We give a short story of this invention, as it is generally believed. But it may not be quite accurate in all details.

Invention of the Seven-day Week

Much of ancient astronomical knowledge is due to Chaldean astronomers who flourished between the seventh century B.C. and the third century A.D., as related in §4·7. They gave particular attention to the study of the movement of the sun, the moon and the planets, which they identified with their gods, because they thought that destiny of kings and states were controlled by the gods, *i.e.*, by the planets, and attached the greatest importance to the observation of the position and movement of planets. They attached magical value to the number 'Seven' which was the number of planets or gods controlling human destiny.

In 'Planetary Astrology', the sun, the moon and the five planets, were identified with the chief gods of the Babylonian pantheon as given below :

	Planets	*Babylonian God-names*	*Their function*
(1)	Saturn	Ninib	God of Pestilence and Misery.
(2)	Jupiter	Marduk	King of Gods.
(3)	Mars	Nergal	God of War.
(4)	Sun	Shamash	God of Law & Order or Justice.
(5)	Venus	Ishtar	Goddess of Fertility.
(6)	Mercury	Nabu	God of Writing.
(7)	Moon	Sin	God of Agriculture.

These seven gods, sitting in solemn conclave, were supposed to control the destinies of kings and countries, and it was believed that their will and judgement with respect to a particular country or its ruler could be obtained from an interpretation of the position of the seven planets in the heavens, and the nature of motion of the planets (direct or retrograde).

The Chaldean god-names are given in the second column, and the functions they control in the third column. Their identification with the Roman gods is given in the first column. The planets* were put in the order of their supposed distances from the earth.

Further, the day was divided into 24 hours, and each of the seven gods was supposed to keep watch on the world over each hour of the day in rotation. The particular day was named after the god who kept watch at the first hour. Thus on Saturday, the watching god on the first hour was Saturn, and the day was named after him. The succeeding

*Planets used not in modern sense but in the old sense of a *wandering* heavenly body.

hours of Saturday were watched by the seven gods in rotation as follows :-

	Saturday
Hours	1 2 3 4 5 6 7 8...14 15 22 23 24 25
God Watching	1 2 3 4 5 6 7 1... 7 1 1 2 3 4 (Sun)

The table shows the picture for Saturday. On this day, Saturn keeps watch at the first hour, so the day is named after him. The second hour is watched over by (2) Jupiter, third by (3) Mars and so on. Saturn is thus seen to preside at the 8th, 15th and 22nd hours of Saturday. Then for the 23rd, 24th and 25th hours come in succession (2) Jupiter, (3) Mars and (4) Sun. The 25th hour is the first hour of the next day, which was accordingly named after the presiding planet of the hour, *viz.*, No. 4 which is Sun. We thus get Sunday following Saturday. If we now repeat the process, we get the names of the week days following each other, as follows .

Saturday, Sunday, Monday, Tuesday,
Wednesday, Thursday, and Friday.

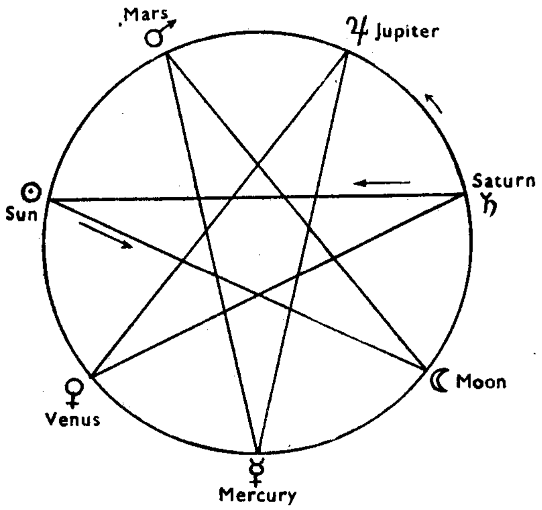


Fig. 1—The order of week-days derived from the order of planets. Saturday followed by Sunday, then Monday and so on.

The Jews, it may be mentioned, reckon the days by ordinal numbers—the first, second......seventh day. The first day is Saturday.

The seven-day week, from the account of its origin is clearly based on astrological ideology. The continuous seven-day week was unknown to the classical Greeks, the Romans, the Hindus, and early Christians. It was introduced into the Christian world by an edict of the Roman emperor Constantine, about 323 A.D., who changed the Sabbath to the Lord's Day (Sunday), the week-day next to the Jewish Sabbath. Its introduction into India is about the same time and from the same sources. The week-days are not found in earlier Hindu scriptures like the Vedas or the classics like the great epic *Mahābhārata.* They occur in inscriptions only from 484 A.D., but not in inscriptions of 300 A.D. Even now, they form but an unimportant part in the religious observances of the Hindus which are determined by the moon's phases.

It can therefore be said that the unbroken seven-day week was not a part of the religious life of any ancient nation, and it is not, even now, part of the religious life of many modern nations. It is a man-made institution introduced on psychological grounds, and therefore can be or should be modified if that leads to improvement and simplification of human life.

The Christian Era

The present Christian era came into vogue much later. About 530 A.D., the era-beginning was fixed from the birth year of Christ which was fixed after a certain amount of research by the Scythian Bishop Dionysius Exiguus and Christ's birth day (Christmas) was fixed on December 25 which was the Julian date for the winter solstice day and the ceremonial birth day of the Persian god Mithra in the first century B.C. The discovery of a Roman inscription at Ankara shows that King Herod of the Bible who is said to have ordered the massacre of innocents was dead for four years at 1 A.D., and therefore Christ must have been born on 4 B.C., or somewhat earlier.

2.6 THE GREGORIAN CALENDAR

The Julian year of 365.25 days was longer than the true year of 365.2422 by .0078 days, so the winter solstice day which fell on December 21 in 323 A.D., fell back by 10 days in 1582 A.D. and the Christmas day appeared to be losing all connections with the winter solstice. Similar discrepancy was also noticed in connection with the observance of the Easter.* Various proposals were made for correcting the error and the Council of Trent which assembled in 1545 authorised the Pope to deal with the matter. When in 1572, Gregory XIII became Pope, these schemes were considered and the plan that was most

* Easter, the most joyous of the Christian festivals, is observed annually throughout Christendom in commemoration of the resurrection of Jesus Christ, on the first Sunday after the full-moon following the vernal equinox day. The last days of Christ coincided with the Passover fast of the Jews and his death fell upon the day of the feast of the Passover, on the 14th day of the month of Nisan. As the date of Easter is associated with the moon's phases, as well as the vernal equinox day, it is a movable festival, falling anywhere between March 22 and April 25. A movement is going on for narrowing down the range of variation of the Easter day ; in 1928 the British Parliament passed the Easter Act, which contingent upon its acceptance internationally, fixed Easter day as the first Sunday after the second Saturday in April, falling between April 9 and 15. (*Vide Encyclopaedia Britannica*, Easter).

favoured was the one that had been proposed by Aloysius Lilius, a Neapolitan physician. In 1582, Pope Gregory XIII published a bull instituting the revised calendar and ordained that Friday, October 5 of that year was to be counted as Friday, October 15. For the future, centurial years that were not divisible by 400 were not to count as leap-years ; in consequence the number of leap-years in 400 years was reduced from 100 to 97 and the year-length of the calendar thus became 365·2425 days, the error being only one day in 3300 years.

The Gregorian reformation of the calendar was at once adopted by the Catholic states of Europe, but other Christian states took longer time to accept it. In Great Britain it was officially introduced in 1752. As the error had by that time amounted to 11 days, the September of 1752 was deprived of these days and 3rd September was designated as the 14th September. In some countries the Gregorian calendar was not adopted until the present century. China and Albania adopted it in 1912, Bulgaria in 1916, Soviet Russia in 1918, Roumania and Greece in 1924, and Turkey in 1927. The rules for Easter which were revised on the basis of the Gregorian calendar have not been adopted by the Greek orthodox Church.

Inspite of its wide use, the Christian or Gregorian calendar is a clumsy and inconvenient system of time-reckoning on account of the arbitrary length of its months ranging from 28 to 31. With a view to reforming it many schemes have been proposed, but the one deserving of serious consideration is the new World Calendar advocated originally by the Italian astronomer Armellini in 1887 and adopted by the World Calendar Association, Inc., which has its head-quarters in New York (630, Fifth Avenue, New York 20, N. Y), under the able presidentship of Miss Elisabeth Achelis *

In the ecclesiastical calendar some holy days are observed on fixed days of the year, others known as movable festivals are observed on fixed days of the week. Most of these are at fixed intervals before or after Easter day. When the Easter day of any year is fixed, the dates of other movable festivals can accordingly be ascertained. The Council of Nice convened in 325 A.D. adopted the rule for fixing the date of Easter—it was to fall on the first Sunday after the 14th day of the moon (nearly full moon) which occurs on or immediately after March 21. In fact there are certain special tables for determining the Easter day, based on the mean length of the lunar month, and the determination does not require any advance calculation of moon's position. The following are the principal holidays dependent on the date of Easter.

Days before Easter		*Days after Easter*	
Septuagesima Sunday	63	Low Sunday	7
Quinquagesima ,,	49	Rogation Sunday	35
Ash Wednesday	46	Ascension Day	39
Quadragesima Sunday	42	Whit Sunday	49
Palm Sunday	7	Trinity Sunday	56
Good Friday	2	Corpus Christi	60

2.7 THE WORLD CALENDAR

As already stated the Gregorian calendar is a most inconvenient system of time-reckoning. The days of the months vary from 28 to 31 ; quarters consist of 90 to 92 days ; and the two half-years contain 181 and 184 days. The week-days wander about the month from year to year, so the year and month beginnings may fall on any week-day, and this causes serious inconvenience to civic and economic activities. The number of working days per month varies from 24 to 27, which creates considerable confusion and uncertainty in economic dealings and in the preparation and analysis of statistics and accounts. The present Gregorian calendar is therefore in dire need of reform.

The question of resolving these difficulties had been under consideration for more than the last 100 years. In 1834, the Italian Padre Abbe' Mastrofini proposed the Thirteen-Month Calendar, which was strongly advocated by the positivist philosopher August Comte. But this calendar could not attract much attention and consequently it was abandoned. The plan of reform which has received the most favourable comments is, as mentioned earlier, that of the World Calendar Association.

Let us explain the ideas behind this movement :

Calendars are used for regulating two essentially distinct types of human activities, *viz.*,

(a) Civic and administrative,
(b) Social and religious.

In ancient and medieval times, different countries and religions had developed their characteristic calendars to serve both purposes, but in the modern age, due to historic reasons, almost all countries use :

(a) the Gregorian calendar for regulation of civic and administrative life,
(b) their own characteristic calendars for regulation of social and religious observances.

* She had been devoting her services ungrudgingly for the cause of calendar reform for the last twenty-five years, and also been publishing a '*Journal of Calendar Reform*' since then.

For example, India uses the Gregorian calendar for civic and administrative purposes, but various luni-solar calendars for fixing up dates for religious festivals of Hindus in different states. The Islamic countries also follow the same practice—Gregorian calendar for civic and administrative purposes, but the lunar calendar for religious purposes.

Even in Christian countries, which apparently use the Gregorian calendar for both purposes, in actual practice, some additional time-reckonings have to be done for fixing the date of Easter and other holidays which move with it. These reckonings constitute the ecclesiastic calendar, and are survival of earlier luni-solar calendars.

The disadvantages of the Gregorian calendar as used for civic and administrative purposes are :

(a) that the years and months begin on different week days,

(b) that months are of unequal length—from 28 to 31 days—and they start on week-days which are most changeable.

This happens because a normal year of 365 days consists of 52 weeks *plus* one day ; and a leap-year coming every fourth year, has 366 days, and consists of 52 weeks *plus* 2 days. If a normal year begins on a Sunday, the next year will start on Monday, and the year after a leap-year will jump two week-days.

This causes a most undesirable wandering of the week-day on which the year begins, as is seen for the next few years. This year 1954, has started on a Friday. We shall have

1955	starting	on	Saturday
1956	,,	,,	Sunday
1957	,,	,,	Tuesday
1958	,,	,,	Wednesday
1959	,,	,,	Thursday
1960	,,	,,	Friday
1961	,,	,,	Sunday

How much better it would be for civic and administrative life if a system could be devised that every year should start on a Sunday ?

The World Calendar Plan

This is how the World Calendar Plan proposes to prevent this wandering of the starting-day of the year. It is a very simple device.

If from 1961, which starts on a Sunday, the last day of the year (*i.e.* Dec. 31) which would be under the present system a Sunday, is called the *Worldsday*, that is, no week-day denomination is attached to it, then 1962 also will start on a Sunday, and so will every year till the next leap-year 1964. On that year another additional day, the *Leap-Year Day*, is inserted at the end of June, and have the usual Worldsday at the end of the year ; then 1965 will also start on a Sunday.

So, by this simple device of having a Worlds-day at the end of every year and a Leap-Year Day at the end of June every fourth year, both without any week-day denomination, every year can be made to start on a Sunday. This will prove to be an inestimable advantage for the civic life of mankind.

It is needless to add illustrations of the chaotic way in which the starting week-days of months vary. They are chaotic, because lengths of months vary from 28 to 31. There is not the slightest scientific justification for these varying lengths. They are said to have been due to the caprice of two Roman dictators, or some other historical cause not yet clear. How much better it would be for civic purposes, if each month could start on a fixed day of the week ?

The World Calendar plan proposes to put this right by dividing the year into four quarters, each of three months of 31, 30, 30 days' duration. According to this plan,

January, April, July, October would have each 31 days, and start on Sunday,

February, May, August, November would have each 30 days, and start on Wednesday,

March, June, September, December would have each 30 days, and start on Friday.

If this plan be adopted, the calendar will be perpetual and fool-proof. What a welcome change it would prove when compared to the present chaotic and wandering calendar ?

The year has to conform to the period of the sun, and this is covered by the leap-year rules, amended by Pope Gregory XIII in 1582. The leap-year rules introduced by the Iranian poet-astronomer Omar Khayyam in 1079, were more accurate, but less convenient. The Gregorian leap-year rules will cause a mistake of only one day in 3,300 years, which is trivial.

As regards the duration of months, the World Calendar plan is a marked improvement on the chaotic lengths and starting days of months, inherited from the Julian calendar, which has been tolerated too long. The months of all the quarters are identical and have got 31, 30 & 30 days, commencing on Sundays, Wednesdays and Fridays respectively. Each month has thus got exactly 26 working days. It has retained the present 12 months, thus the four quarters are always equal, each quarter has 3 months or 13 weeks or 91 days beginning on Sunday and ending with Saturday.

The objections to the World Calendar plan come from several Jewish organizations, on the ground that the World Calendar plan interferes with the unbroken seven-day week, by introducing Worldsday and Leap-year Day without any week-day denomination. This, they say, will interfere with *their* religious life.

As already shown, the religious sanction for the seven-day cycle is either non-existent, or slight, amongst communities other than the Jews, and even amongst them, it dates only from the first century A. D. The claims of certain Jewish Rabbis to prove that the seven-day week cycle has been ordained by God Almighty from the moment of creation which event, according to these Jewish Rabbis, took place on the day of the autumnal equinox, also a new moon day, is a fantastic conception of medieval scholars, which no sane man can entertain in these days of Darwin and Einstein.

The World Calendar plan has no intention of interfering with the characteristic calendars of communities or nations. They can exist side by side with the World Calendar. For such communities as intend to maintain the continuous seven-day week, their religious week-days, including Sundays, would no doubt wander through the World Calendar week-days, and cause some inconvenience to the very small fraction of people who would want to observe their religious rites according to established usage.

But these inconveniences can be adjusted by agreement, and it would be egoistical on the part of a particular community or communities to try to impede the passage of a measure of such great usefulness to the whole of mankind on the plea that the World Calendar plan interferes with the continuous seven-day week. Calendars are based on Science, which everybody must bow to ; and on Convention, which may be altered by mutual consent. The unbroken seven-day week is a *Convention*, but the World Calendar plan has proposed a far better *Convention*, which should be examined on its own merits.*

As a result of a request from the Government of India, the proposal of the World Calendar Reform had become the subject of discussion at the eighteenth session of the Economic and Social Council of the United Nations held at Geneva during June-July, 1954. Professor M. N. Saha, F. R. S., Chairman, Calendar Reform Committee, attended the ECOSOC meeting at Geneva to explain the desirability of the proposed reform.

* Being the full text of the address in support of the Indian proposal for World Calendar reform, by Prof. M. N. Saha, F.R.S. at the 18th Session of the Economic and Social Council of the United Nations, held at Geneva in June-July, 1954.

THE WORLD CALENDAR

1st QUARTER

JANUARY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

FEBRUARY

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

MARCH

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

2nd QUARTER

APRIL

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

MAY

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

JUNE

S	M	T	W	T	F	S	
					1	2	
3	4	5	6	7	8	9	
10	11	12	13	14	15	16	
17	18	19	20	21	22	23	
24	25	26	27	28	29	30	W

3rd QUARTER

JULY

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

AUGUST

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

SEPTEMBER

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

4th QUARTER

OCTOBER

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

NOVEMBER

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

DECEMBER

S	M	T	W	T	F	S	
					1	2	
3	4	5	6	7	8	9	
10	11	12	13	14	15	16	
17	18	19	20	21	22	23	
24	25	26	27	28	29	30	W

W (Worldsday, a World Holiday) equals 31 December (365th day) and follows 30 December every year.
W (Leapyear Day, another World Holiday) equals 31 June and follows 30 June in leap years.

In this Improved Calendar :

* Every year is the same.
* The quarters are equal : each quarter has exactly 91 days, 13 weeks or 3 months ; the four quarters are identical in form.
* Each month has 26 weekdays, plus Sundays.
* Each year begins on Sunday, 1 January ; each working year begins on Monday, 2 January.
* Each quarter begins on Sunday, ends on Saturday.
* The calendar is stabilized and perpetual, by ending the year with a 365th day that follows 30 December each year, called Worldsday dated "W" or 31 December, a year-end world holiday. Leap-year day is similarly added at the end of the second quarter, called Leapyear Day dated "W" or 31 June, another world holiday in leap years.

CHAPTER III

The Luni-Solar and Lunar Calendars

3.1 PRINCIPLES OF LUNI-SOLAR CALENDARS

The Egyptians appear to have been the only cultural nation of antiquity who discarded the moon entirely as a time-marker. Other contemporaneous cultural nations, *e.g.*, the Sumero-Akkadians of Babylon, and the Vedic Indians retained both the sun and the moon as time-markers, the sun for the year, the moon for the month.

The Indian astronomers called the moon ***māsakṛt***, (month-maker) and before the ***Siddhānta Jyotiṣa*** time, the moon was considered more important as a time-marker than the sun (***vide*** §5). It was the same with other nations too, for as Pannekoek remarks, we find the opinion written in the sacred books of many nations "For regulating time, the moon has been created".

The retention of both the sun and the moon, however, gives rise to a multitude of problems, of which a fair summary is given by Pannekoek as follows.*

"With all peoples of antiquity, the Indians, Babylonians, Jews, Greeks, we find the moon-calendar used ; the period of the moon, the regular sequence of the first appearance of the fine crescent moon in the evening sky, its growth to first quarter, to full moon, at the same time coming up later and filling the whole night, then the decrease to last quarter till its disappearance after the last thin crescent before sunrise was seen,—this regular cycle of the moon's phases in the period of 29½ days was everywhere the first basis of chronology".

"But the calendar could not be satisfactorily fixed with the establishment of the moon-cycle. In these ancient times, the people, the tribe, and the state was a political, spiritual and religious unity. Important events of society, the great agricultural performances, the beginning of the ploughing, the sowing or the harvesting were great popular festivals and at the same time chief religious ceremonies, when offerings were presented to the gods. The moon calendar had to adapt itself to the economic life of the people, which was governed *by the cycle of seasons*. Thus arose the practical problem of adapting the moon-period of 29½ days to the solar year of 365 days. *This chief problem of ancient chronology has been a mighty impulse to the study of astronomy, because it necessitated continuous observation of the sky.*"

* Article on '*Astrology and its influence upon the development of Astronomy*' by Anton Pannekoek, published in the *Journal of the Royal Astronomical Society of Canada*, April, 1930.

Twelve lunar months of 29½ days each, making a total of 354 days, fall nearly 11 days short of the solar year. In the next year, the beginning of each month occurs 11 days earlier, in three years 33 days will be lost.* To fix the same month to the same season always, there are no other means than after two or three years to intercalate a Thirteenth Month, number 13, by repeating the last month of the year.

The luni-solar adjustment which is next taken up is the first step to the solution of problems stated by Pannekoek, but it is not however the whole solution, for it leaves untouched the problem of correct prediction of the day when the crescent of the moon first appears after new moon in the western horizon. This will be taken up later (***vide*** §4).

Luni-solar adjustment can be satisfactorily made if we have accurate knowledge of the length of the tropical year, and of the mean length of the lunation. Let us see how these fundamental periods were determined in ancient times.

Length of Seasons and the Year

The length of the year was obtained in Egypt, as we have already seen, from the recurrence of the Nile flood. In Babylonia, no such striking natural phenomena were available. It is very probable that the Babylonians early learnt the use of the gnomon, with the aid of which they could determine the cardinal days of the year : ***viz.***, the summer and winter solstices, and the two equinoxes coming in between.

The lengths of the seasons were found by counting the number of days from one cardinal day to the next. The number may vary by one day from year to year, and astronomers must have realized that the correct length of a season was not a whole number but was fractional. Probably the correct length was found by taking a large number of observations, and taking the mean. The following table shows the length of the seasons and of the year as found by ancient astronomers.

* The mean duration of a lunar month consists of 29·530588 days and twelve such lunations amount to 354·36706 days, while the length of a tropical solar year is 365·24220 days. The length of a lunar year thus falls short of the solar year by 10.87514 days, and instead of there being exactly twelve lunar months in a year, there are 12.36827 months.

Table 2.—Showing the length of seasons.

	Euctemon (432 B.C.)	Calippos (370 B.C.)	Chaldean (200 B.C.)	Correct values for 1384 B.C.
	days	days	days	days
Spring	93	94	94.50	94.09
Summer	90	92	92·73	91·29
Autumn	90	89	88·59	88.58
Winter	92	90	89·44	91·29
Total ···	365	365	365.26	365.25

The length of the year was also found by the same method. The solar year is the period between successive transitions of the sun through the same cardinal point. Neugebauer thinks that summer solstice was first used for this purpose in ancient times. But subsequently evidences are found of the use of other cardinal points.

Thus we find that during the classical period in Babylon, the solar year started with the vernal equinox. But the Macedonian Greeks and the Jews started with the autumnal equinox. The west European countries appear to have started the solar year with the winter solstice.

The number of days in a solar year would vary between 365 and 366. Probably the exact length was determined by counting the number of days between the year-beginnings separated by a large number of years and taking the mean. The Indian practice, followed in the *Siddhāntas*, is to give the number of days in a *Kalpa* (a period of 4.32×10^9 years) from which one can find out the number of days in a year by simple division. This appears in modern times to be a rather cumbrous practice, but is probably reminiscent of taking the mean for a large number of years.

In ancient times, people had not learnt to follow the motion of the sun in the starry heavens, so they were unaware of the difference between the sidereal year and the tropical year. But from their method of measurement, they unconsciously chose the correct, or the tropical year.

Modern measurements show that the length of the tropical year is not constant, but is slowly varying. It is becoming shorter at the rate of ·0001 days or 8·6 secs. in 1600 years.

So that in Sumerian times, the tropical year had a length of 365.2425 days. The present length is 365·2422 days.

3.2 MOON'S SYNODIC PERIOD OR LUNATION : EMPIRICAL RELATION BETWEEN THE YEAR AND THE MONTH

The solar year has thus a pretty nearly constant value, but even the earliest astronomers appear to have observed, that the lunation, or the synodic period of the moon is not a constant, but is variable. As a matter of fact, the period varies from 29·246 to 29.817 days—nearly fourteen hours. The observation of the actual motion of the moon formed the most formidable problem in ancient astronomy (*vide* §4).

But all ancient nations show knowledge of an astonishingly correct value of the *mean synodic period*, which is known to be 29.530588 days. This is probably because they could count the number of days with fractions comprising a very large number of lunations, and therefore the mean value came out to be very correct.

With the aid of the knowledge of correct values of the length of the tropical year, and of the *mean* synodic period of the moon, it is possible to find out correct rules for luni-solar adjustment, as narrated below. But this could happen only at a later stage. The first stage was certainly empirical as is clearly indicated from a record of the great Babylonian king and law-giver Hammurabi (1800 B. C.), which says that the thirteenth month was proclaimed by royal order throughout the empire on the advice of priests. All religious observances were forbidden during this period.*

It is not known however, what principles, if any, guided the king or rather his advisers in their selection of the thirteenth month, but most probably the adjustment was empirical, *i.e.*, the month was discarded when the priests found from actual experience that the festival was going out of season. Many ancient nations who used the luni-solar calendar, do not appear to have gone beyond the empirical stage.

Empirical Relations between the Solar and Lunar Periods : The Intercalary Months.

The Chaldean astronomers (as the Babylonians were called after 600 B.C.) appear to have striven incessantly to obtain very accurate values for the mean lunation and the length of the solar year, and

* It is said that in ancient Palestine, the custom was that the Rabbis went to the fields and watched the time by their calendar for the ripening of wheat. If the lunar month of Addaru (last month of the year) fell back too much towards winter, they would proclaim a second Addaru in that year, so that the first of Nisan would coincide roughly with the ripening of wheat.

work out at the discovery of mathematical relationships between these two periods having the form—

$$m \text{ lunar months} = n \text{ solar years}$$

where both m and n are integers.

Let us describe some of these relations.

The *Octaeteris* : This depends on the relation :

8 tropical years = 2921.94 days
99 lunar months = 2923.53 days.

The difference is only 1.59 days in 8 years. We have used here the correct lengths of the two periods. The Babylonian values were slightly different.

According to this relation, there were to be three extra or intercalary months in a period of 8 years, and festivals would fall approximately in the right seasons, if these three months were suitably excluded for religious observances. But the rule was only approximate. In a few cycles, the discrepancy would be too large to be disregarded.

According to the celebrated exponent of Babylonian astronomy, Father Kugler, this system was in vogue from 528 B.C. to 505 B.C., then there was an interval when they used to have 10 intercalary months in a period of 27 years. From 383 B.C., the Chaldeans used the 19-year cycle, based on the relation :

19 solar years = 6939.60 days
235 lunar months = 6939.69 days.

There is a discrepancy of .09 days in 19 years, or a mistake of 1 day in 210 years.

The 19-year cycle, with 7 intercalary months was used throughout the whole Seleucid times (313 B.C.–75 B.C.), as shown by Pannekoek. This system has not been superseded inspite of various attempts.

These rules came into vogue at a time (383 B.C.), when Babylon had lost her independence and became a vassal state of the Persian empire of the Acheminids. We do not know what was the original calendar of pre-Acheminid Persia, but the great Acheminid emperor Darius preferred the simpler Egyptian solar calendar to the complex luni-solar calendar of Babylon. The population of Babylon could no longer depend upon the king to adjust the dates of their religious observances by royal decree, as happened in the time of Hammurabi (1800 B.C.). Probably therefore the priest-astronomers felt the need of mathematical rules which should take the place of royal decrees.

Table 3.—The 19-year cycle.

Cycle of 19 years showing Intercalary Months

(Compiled from Pannekoek's calculation of dates in Babylonian Tables of planets)

Year in the 19-year cycle	*Total no. of days*	*Years of the Seleucidean Era*					
1*	384	134	153	172	191	210	229
2	354	135	154	173	192	211	230
3	355	136	155	174	193	212	231
4*	384	137	156	175	194	213	232
5	355	138	157	176	195	214	233
6	354	139	158	177	196	215	234
7*	384	140	159	178	197	216	235
8	354	141	160	179	198	217	236
9*	384	142	161	180	199	218	237
10	355	143	162	181	200	219	238
11	354	144	163	182	201	220	239
12*	384	145	164	183	202	221	240
13	355	146	165	184	203	222	241
14	354	147	166	185	204	223	242
15*	384	148	167	186	205	224	243
16	354	149	168	187	206	225	244
17	355	150	169	188	207	226	245
18†	383	151	170	189	208	227	246
19	354	152	171	190	209	228	247
Total	6940						

N. B. Years marked * have a second Addaru, and years marked † have a second Ululu.

312 – Seleucidean era = Christian era B.C.
(Jan. to Sept.)

Seleucidean era – 311 = Christian era A.D.
(Jan. to Sept.)

The 'Nineteen-year cycle' is generally known as the 'Metonic Cycle' after Meton, an Athenian astronomer who unsuccessfully tried to introduce it at Athens in 432 B.C. But there is no proof that it was used at Athens before 343 B.C. The question of 'priority' of this discovery is therefore a disputed one.

3.3 THE LUNI-SOLAR CALENDARS OF THE BABYLONIANS, THE MACEDONIANS, THE ROMANS, AND THE JEWS

In addition to the Chaldeans, many other nations of antiquity, *viz.*, the Vedic Indians, the Greeks, the Romans and the Jews and others used the luni-solar calendar, and had to make luni-solar adjustments. It will be tedious to relate how they did it, except in the case of the Vedic Indians (*vide* § 5). But the knowledge of the nineteen-year rule appears to have diffused to all countries by the first century of the Christian era. From this time onwards, the lunar months of different nations appear to be interchangeable. This is shown in the following Table No. 4.

We have almost complete knowledge of the luni-solar calendars of the Babylonians during Seleucid times. The names of months with their normal lengths are shown in column (2) of the table.

Table 4.—Corresponding Lunar months.

Lunar Month-Names

(1) *Indian*	(2) *Chaldean*		(3) *Macedonian*	(4) *Jewish*
CAITRA	Addaru		Xanthicos	
Vaiśākha	NISANNU	(30)	Artemesios	Nissan
Jyaiṣṭha	Airu	(29)	Daisios	Iyyar
Āṣāḍha	Sivannu	(30)	Panemos	Sivan
Śrāvaṇa	Duzu	(29)	Loios	Tammuz
Bhādra	Abu	(30)	Gorpiaios	Ab
Āśvina	Ululu	(29)	Hyperberetrios	Ellul
Kārtika	Tasritu	(30)	DIOS	TISHRI
Mārgaśīrṣa	Arah Samnah	(29)	Appelaios	Marheshvan
Pauṣa	Kisilibu	(30)	Audynaios	Kislev
Māgha	Dhabitu	(29)	Peritios	Tebeth
Phālguna	Shabat	(30)	Dystros	Shebat
Caitra	Addaru	(29)	Xanthicos	Adar and Veadar

The first Babylonian month Nisannu, started with 30 days, and other months were alternately 29 and 30 days. A normal year thus consisted of 354 days, but occasionally an extra day was added to the last month, and it became a year of 355 days.

The effect of these intercalations was that the first month, *viz.*, the month of Nisannu, never strayed for more than 30 days beyond the day of vernal equinox.

As the table shows, the Babylonian year might be of 354, 355, 383, or 384 days' duration, and occasionally it is said that they extended to 385 days. It was therefore impossible to calculate the number of days between two incidents, dated according to the Chaldean calendar, unless the investigator had a table of past years showing the lengths of each individual year. Herein comes the superiority of the Egyptian system, where the number of days between two incidents, dated according to the Egyptian system, could be easily calculated. The two greatest astronomers of ancient times, Hipparchos and Ptolemy, therefore, preferred the Egyptian system of dating to the Chaldean or the Macedonian.

The Macedonian Greeks used the months given in column (3) in their home land. When they settled in Babylon as rulers (313 B.C.), they continued to use the same months, but got them linked to Chaldean months. Their first month was Dios, which was the seventh month of Chaldeans. This was probably linked to the autumnal equinox in the same way as Nisannu was to the vernal equinox. The Macedonian year started six months earlier than the Chaldean year.

The Macedonian months were used by the Parthians, the early Śakas, and the Kushans in India wihout change of name (*vide* § 5·5), and probably the month-lengths were also the same as in the Chaldean 19-year system. When the Śakas and Kushans began to rule in India, from first century B.C., they used the Macedonian months alternatively with the Indian months which are shown in the first column. The first Indian season, Spring, however according to immemorial Indian custom, has been on both sides of the vernal equinox (—30° to 30°), while in the Graeco-Chaldean system, the Spring started with vernal equinox (0°). The first Indian month is *Caitra,* the first of the spring months, and according to rules prevalent in Siddhāntic times (300 A.D.), the month was to be always on the lower side of the vernal equinox, *i.e.*, the beginning of lunar *Caitra* was to be on a date before the vernal equinox. It may be added that the Indian lunar months mentioned here are ***amānta*** or new moon ending.

3.4 THE INTRODUCTION OF THE ERA

For accurate date-recording, we require besides the month and the day, also a continuously running era. But the era came rather late in human history. We find dated records of kings in Babylon from about 1700 B.C. (Kassite kings). They used regnal years, lunar months, and the day of the lunar month. The ancient Egyptian records do not use any era, but sometimes the regnal years. But the use of regnal years is very inconvenient for purposes of exact chronology, because one has to locate the beginning of the reign of the king on the time-scale which often proves to be an extremely difficult problem, *e.g.*, in India, Emperor Asoke used regnal years, but it is a problem of nearly hundred years for archaeologists to find out the exact date of the commencement of his reign. This varies from 273 B.C. to 264 B.C.

In the writings of the Greek astronomers Hipparchos (140 B.C.) and Ptolemy (150 A.D.), we come across an era purporting to date from the time of one king Nabu Nazir of Babylon (747 B.C.), who is known to history, though this era is not used in records of the Babylonian kings themselves.

The inference has been made, though without clear proof, that the Babylonian or rather Chaldean astronomers who were the earliest systematic observers of the heavenly bodies, got tired of the use of the regnal years, and felt the need of a continuously running era for precision in time-reckoning. They took advantage of a unique gathering of planets about Feb. 26, 747 B.C. when Nabu Nazir was reigning in Babylon to proclaim that the gods have ordained the 'introduction of a continuously running era' (*Sky and Telescope*, Vol. I, p. 9, April, 1942).

But the use of the Nabonassar era appears to have been confined to astronomers. The kings continued to record events in their regnal years as this had a great propaganda value for the royal family which they were unwilling to forego.

It is now known that the other ancient eras, like that of the *Greek Olympiads* (776 B.C.) or the era of *Foundation of Rome* (753 B.C.) are extrapolated eras. The ancient Greek method of dating by Olympiads is of uncertain origin, but the system was critically examined by the Alexandrian chronologists, particularly Eratosthenes (3rd century B.C.), the founder of scientific chronology. According to the *Encyclopaedia Britannica*, 14th edition, Greek chronology is not reliable till the 50th Olympiad (*i.e.* 576 B.C.). The era was therefore invented a long time after its alleged year of starting. The era of the Foundation of Rome had a similar history (see *Encyclopaedia Britannica*, 14th edition, Chronology). The starting years of these eras are suspiciously close to that of the Nabonassar era (747 B.C.). Probably both these eras were plagiarized from the era of Nabonassar after the savants of ancient Greece and Rome acquired the time-sense.

It is noteworthy that Hipparchos and Ptolemy used neither the era of Olympiads nor the era of Foundation of Rome, nor Greek or Chaldean months which were lunar, but the Nabonassar era and the more convenient Egyptian solar months. They preferred science to nationalistic chauvinism.

The Seleucidean and other derived Eras

The Seleucidean Era (*the S. E. era*) : The first continuously running era which ran into general circulation is that introduced to commemorate the foundation of Seleucus's dynasty and dates from the year when Seleucus occupied the city of Babylon after defeating his rivals. There were two methods of counting, differing in the initial year and the first day of the year.

According to the official (Macedonian) reckoning, the era started from the lunar month of Dios (near autumnal equinox) in the year (—311) A.D. or 312 B.C. The months had Macedonian names.

According to the native Babylonian reckoning, the era started from the lunar month of Nisan (near vernal equinox) six months later than the starting of the Macedonian year. The months had Chaldean names, as given in Table No. 4.

The Seleucid monarchs ruled over a vast empire from Syria to the borders of Afghanistan from 311 B.C. to 65 B.C. *i.e.*, nearly for 250 years and under their rule, the knowledge of Graeco-Chaldean astronomy and time-calculations spread far and wide, ultimately reaching India, and profoundly modifying the indigenous system in India. The use of Macedonian months spread over all these countries, as is apparent from contemporary inscriptions and coin-datings mentioned in § 5·5. The months were *amānta, i.e.*, started after the new-moon was completed and were pegged on to the solar year which started on the day of the vernal equinox. The Nisan was the first lunar month after the vernal equinox. There were 7 intercalary months in a period of 19 years. The correspondence between Chaldean and Greek months and the position of the intercalary months have been worked out by Prof. Pannekoek between the years 134-247 of the Seleucidean era, as already given (*vide* § 3·2 and 3·3) along with their Indian equivalent lunar months.

The Parthian Era

Since the introduction of the Seleucidean era, the practice arose for a nation or a dynasty to start eras commemorating some great event in their national or dynastic life. The first in record is the Parthian era, and the story of its starting is well-known. The Seleucid emperors ruled the Near East from 312 B.C. imposing on the countries under their domination Greek culture, the Seleucidean era, and the Graeco-Chaldean system of time-reckoning. About 250 B.C., there were wide-spread revolts against Seleucid rule in Bactria, in Parthia (Eastern Persia), and other parts of the Near East. The revolt in Parthia was led by one Arsaces and his brother Tiridates who belonged to an Iranian tribe, which had adopted Greek culture. To commemorate their liberation from Seleucidean rule, the Parthians introduced an era, beginning 64 years after the Seleucid era (*i.e.* 248 B.C.). But at first this era (Arsacid era) was only rarely used. The early Parthian emperors preferred to use on their coins the Seleucidean era, the Macedonian months, and the Graeco-Chaldean system of time-reckoning inscribed in Greek letters. In the first century A.D., there was a Zoroastrian revival, the S.E. was dropped in favour of the Parthian era and Pehlevi began to be used in place of Greek, though Macedonian month-names were still kept.

Though kings bearing Parthian names ruled at Taxila about the first century B.C. to first century A.D., *e.g.*, king Gondophernes, no clear evidence of the use of the Parthian era on Indian soil has yet been found.

It is very likely that the Śaka era, with its methods of calendar-reckoning, which came into vogue in India during the *Siddhānta Jyotiṣa* times, was started by the Śaka tribes when they attained prominence, and started an era of their own, in imitation of the Parthians. They, however, retained the Graeco-Chaldean method of lunar month-reckoning and probably the same system of intercalary months.

3.5 THE JEWISH CALENDAR

The ancient Jewish calendar was lunar, the beginning of the month being determined by the first visibility of the lunar crescent. As the month-names show (col. 4 of the table No. 4), they were evidently derived from the Babylonian month-names excepting one or two, *viz.*, Marheshvan and Tammuz. The day began in the evening and probably at sunset. The year used to begin with the spring month Abib or Nisan, the latter being the Babylonian name of the month which was adopted by the Jews in the post-exilic times. Intercalation was performed, when necessary, repeating the twelfth month 'Adar' which was then known as 'Veadar' followed by Adar. The year-beginning was subsequently changed and in the last century before Christ, it became the month of Tishri, corresponding to the Macedonian month of *Dios*. This must have been due to the desire or need to follow the practice of the ruling race.

Originally there were no definite rules for intercalation and for fixing up the beginning of the months. Because various religious festivals and sacrifices were fixed with reference to the beginning of the month, information about it was spread throughout the country by messengers and by signal fires on hilltops.

About the 4th century A.D., fixed rules were introduced in the calendar and nothing was left to observation or discretion. Intercalation is governed by a 19-year cycle in which the 3rd, 6th, 8th, 11th, 14th, 17th and 19th years have got an extra month. The actual beginning of the initial month of the year, *viz.*, Tishri is obtained from the mean new-moon by complicated rules which are designed to prevent certain solemn days from falling on inconvenient days of the week. As a result, a common year may consist of 353, 354 or 355 days and an embolismic or leap-year of 383, 384 or 385 days. Ten of the months have got fixed durations of 29 or 30 days, as well as the intercalary month which contains 30 days, the other two varying according to the requisite length of the year.

The Jewish Era of Creation

The Jews use an Era (*Anno Mundi, libriath olum*) or 'Era of Creation' which is supposed to have been started from the day of creation of the world. We quote the following passages from *Encyclopaedia Britannica;* 14th edition, 'Chronology, *Jewish*'.

(1) The era is supposed to begin, according to the mnemonic *Beharad*, at the beginning of the lunar cycle on the night between Sunday and Monday, Oct. 7, 3761 B.C., at 11 hours 11⅓ minutes P.M. This is indicated by *be* (*beth*, two, *i.e.*, 2nd day of week), *ha* (*he*, five, *i.e.*, fifth hour after sunset) and *Rad* (*Resh, dalet*, 204 minims after the hour).

(2) In the Bible various eras occur, *e.g.*, the Flood, the Exodus, the Earthquake in the days of King Uzziah, the regnal years of monarchs and the Babylonian exile. During the exile and after, Jews reckoned by the years of the Persian kings. Such reckonings occur not only in the Bible (*e.g.*, Daniel viii, I) but also in the Assouan papyri. After Alexander, the Jews employed the Seleucid era (called *Minyan Shetaroth*, or era of deeds, since legal deeds were dated by this era). So great was the influence exerted by Alexander, that this era persisted in the East till the 16th century, and is still not extinct in south Arabia. This is the only era of antiquity that has survived. Others, which fell into disuse, were the Maccabaean eras, dating from the accession of each prince, and the national era (143-142 B.C.), when Judæa became free under Simon. That the era described in Jubilees was other than hypothetical, is probable. Dates have also been reckoned from the fall of the second Temple (*Le-Horban hab-bayyith*). The equation of the eras is as follows:

Year 1 after destruction = A.M. 3831
= 383 Seleucid
= A.D. 71

The 'Era of Creation' is supposed to have started from the day of autumnal equinox of the year 3761 B.C. So the sun and the moon must have existed before the day of creation !!

3.6 THE ISLAMIC CALENDAR

The Mohammedan calendar is purely lunar and has no connection with the solar year. The year consists of 12 lunar months, the beginning of each month being determined by the first observation of the crescent moon in the evening sky. The months have accordingly got 29 or 30 days and the year 354 or 355 days. The new-year day of the Mohammedan calendar thus retrogrades through the seasons and completes the cycle in a period of about 32½ solar years.

The era of the Mohammedan calendar, *viz.*, the Hejira (A.H.), which was probably introduced by the Caliph Umar about 638-639 A.D., started from the evening of 622 A.D., July 15, Thursday*, when the crescent moon of the first month Muharram of the Mohammedan calendar was first visible. This was the new-year day preceding the emigration of Muhammad from Mecca which took place about Sept. 20 (8 Rabi I), 622 A.D.

*As the day of the Islamic calendar commences from sunset, Friday started from the evening of that day.

For astronomical and chronological purposes the lengths of the months are however fixed by rule and not by observation. The lengths of the months in days for this purpose are as follows :

Muharram	30
Safar	29
Rabi-ul awwal	30
Rabi-us sani	29
Jamada'l awwal	30
Jamada-s sani	29
Rajab	30
Shaban	29
Ramadan	30
Shawal	29
Zilkada	30
Zilhijja	......29 (or 30)

The leap-year, in which Zilhijja has one day more, contains 355 days and is known as *Kabishah*. In a cycle of 30 years, there are 19 common years of 354 days and 11 leap-years of 355 days. Thus 360 lunations are made equivalent to 10,631 days or only ·012 days less than its actual duration. The rule for determining the leap-year of this fixed calendar is that, if after dividing the Hejira year by 30, the remainder is 2, 5, 7, 10, 13, 16, 18, 21, 24, 26 or 29, then it is a leap-year.

The only purely lunar calendar is the 'Islamic calendar', which has been in vogue amongst the followers of Islam since the death of the Prophet Muhammad (632 A.D.). But it is well-known that before this period Mecca observed some kind of luni-solar calendar in common with all countries of the Near East. The common story is that when pilgrims from distant countries and other parts of Arabia came to perform Hajj at Mecca (Hajj is a pre-Islamic practice), they often found that it was an *intercalary month* according to Meccan calculation, when no religious festival could be performed, and had to wait for a month before they were allowed to perform the rites. This meant great hardships for distant visitors and to prevent recurrence of such incidents the Prophet forbade the use of intercalary or 13th month and decreed that the calendar should henceforth be purely lunar.

It has now been shown by Dr. Hashim Amir Ali of the Osmania University, Hyderabad, that the Mohammedan calendar was originally luni-solar in which intercalation was made when necessary, and not purely lunar. This view-point has now been strongly supported by Mohammed Ajmal Khan of the Ministry of Education, Govt. of India. They emphasize that upto the last year of the life of Mohammed, *i.e.*, upto A.H. 10 or A.D. 632, a thirteenth month was intercalated when necessary. The Arabs, among whom there were relatively few men conversant with astronomical calculations, had a system in which a family of astronomers, known as Qalammas was responsible for proclaiming at the Hajj (falling in the last month of the year : Zilhijja) that a thirteenth month would or would not be added. Astronomically such intercalation should be made 3 times in 8 years or 7 times in 19 years. The elder of the Qalamma had a certain amount of discretion in determining when this intercalation was to be practised, and this very practice afterwards caused great confusion.

According to this view, proper intercalation was applied in all the years where necessary upto A.H. 10 and consequently the year A.H. 11 (coming next to the Hajj of A.H. 10) which started on March 29, 632 A.D. (*i.e.*, after the vernal equinox day) seems to have been a rather normal year, and as such all the previous new-year days appear to have been celebrated on the visibility of the crescent moon after the vernal equinox day. The Muslim months should accordingly occupy permanent places in the seasons as follows* :—

Muharram...	Mar.—April	Rajab	...Sept.—Oct.
Safar...	... April—May	Shaban	...Oct.—Nov.
Rabi I	... May —June	Ramadan	...Nov.—Dec.
Rabi II	... June —July	Shawal	...Dec.—Jan.
Jamadi I	... July —Aug.	Zilkada	...Jan. —Feb.
Jamadi II	... Aug. —Sept.	Zilhijja	...Feb. —Mar.

* If this view is accepted, it would then be necessary to shift the starting epoch of the Hejira era, which is commonly accepted as July 16, 622 A.D., to an earlier date, as 4 intercalary months or 118 days will then have to be inserted between the new-year days of A.H. 1 and of A.H. 11, which is March 29, 632 A.D. The initial epoch of the Hejira era thus arrived at is the evening of March 19, 622 A.D., Friday, the day following the vernal equinox.

CHAPTER IV

Calendaric Astronomy

4.1 THE MOON'S MOVEMENT IN THE SKY

The scheme of lunar months given in Table No. 4 in a nineteen-year period, which came into vogue in Babylon about 383 B.C. did not, however, completely satisfy the needs of the Babylonian calendar, because for religious purposes, the month was to start on the day the crescent moon was first visible in the western horizon after conjunction with the sun (the new-moon), a custom which is still followed in the Islamic countries. But the first visibility may not occur on the predicted day for manifold reasons.

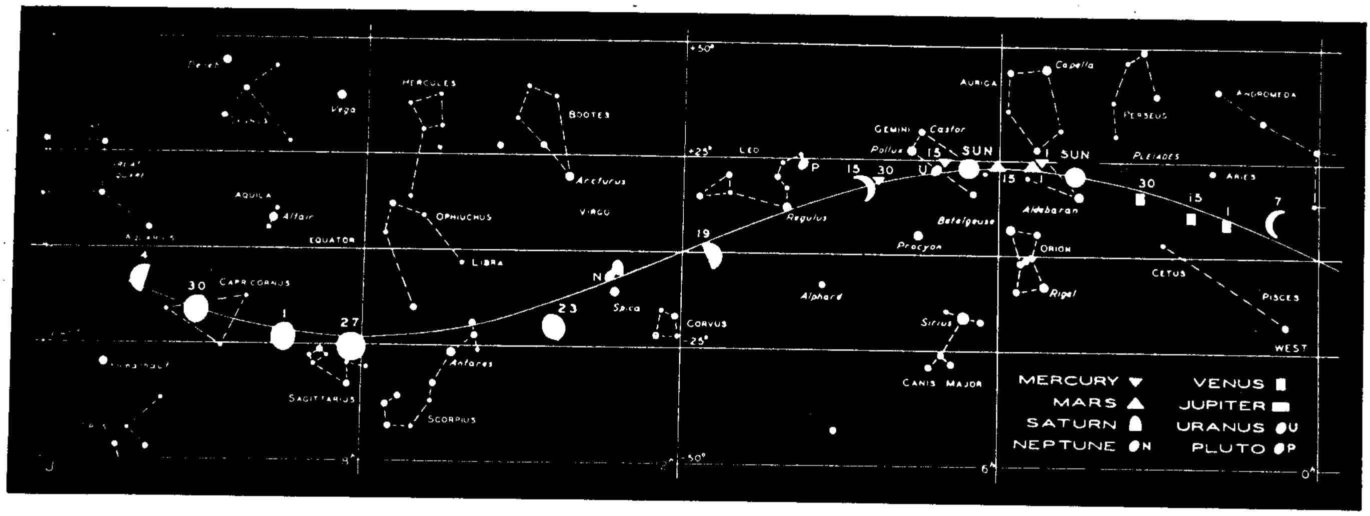


Fig. 2—Showing the positions of the sun, moon and planets among the stars in June, 1953.

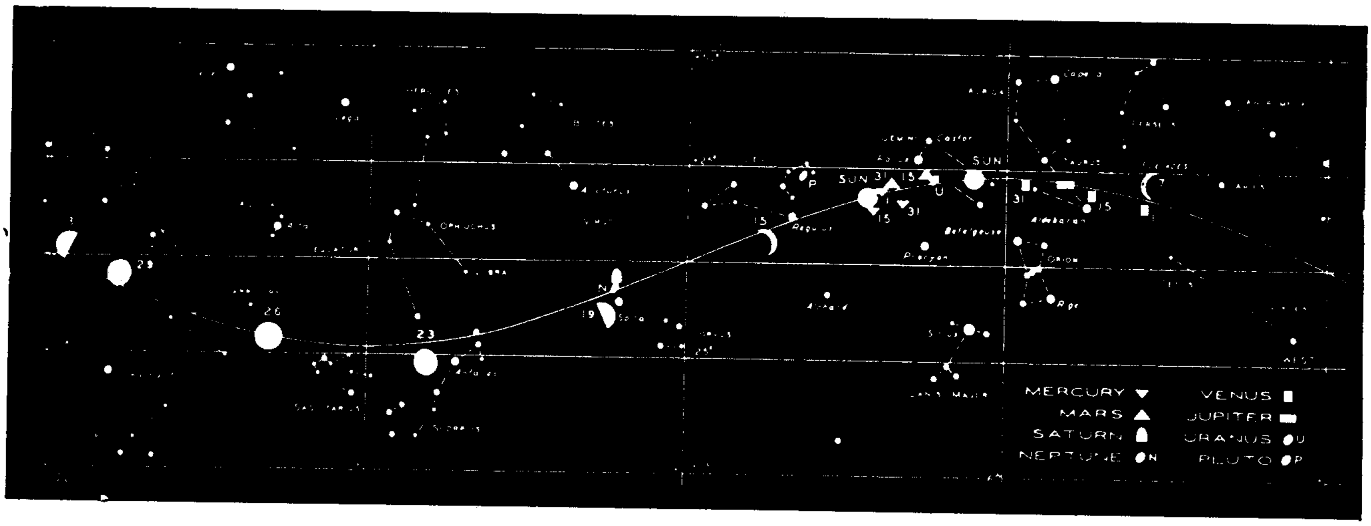


Fig. 3—Showing the positions of the sun, moon and planets among the stars in July, 1953.

The table given on p. 176 is based on mean values of the lengths of the year and the synodic month, which is equivalent to the assumption that the sun and the moon move uniformly in the same great circle in the heavens. But even the most primitive observers could not fail to notice that neither do the two luminaries move in the same path, nor do they move uniformly, each in its own path.

The motion of the moon amongst the stars is the easiest to observe. This is illustrated in the two figures reproduced from the *Sky and Telescope*, giving positions of the moon, the sun, and the planets in the field of fixed stars in the months of June and July, 1953.

The central horizontal line is the line of the celestial equator (§ 4.4), and the sinuous line represents the ecliptic or the sun's path (§ 4.5), but we may ignore these now, and simply concentrate on the moon and the stars or star-clusters near which it passes.

The moon begins as a thin crescent on the western horizon on the evening of June 12, the day of the first visibility after the new-moon, at an angle of 11°, from the sun which has just set, below the bright stars Castor and Pollux (*Punarvasu*). Then we notice the position of the moon on successive evenings at *sunset*. We find she is moving eastward at the rate of about 13° and becoming fuller (increasing in phase). She passes the bright star Regulus (*Maghā*) on the 17th, on the 19th, she is half and passes *β Leonis* (*Uttara Phalguni*) leaving it a good deal to the north. Then she passes the bright star Spica (*α Virginis* or *Citrā*) on the 21st, and is then gibbous on the 23rd near the star *α-Libra* (*Viśākhā*). Then she passes the well known Scorpion-cluster and becomes full on the 27th, near a star-cluster which cannot be seen on the night of full-moon, but can be detected later as the star cluster Sagittarius. On the full moon day, she rises nearly at sunset, at 180° from the sun (opposition). On each successive night after full moon she rises later and later, and passes the phases in the reverse order, *i.e.*, becomes gibbous on June 30, when she has the bright star Altair (*Śravaṇa*) far to the north and is half on July 4, and becomes a crescent on July 7 on the eastern sky, and then fails to appear for three days, and must have passed the sun on the 11th July which is the new moon day, when she is with the sun (*Amāvasyā* or conjunction, *lit.* the sun and the moon living together). On the 12th July, she reappears on the western horizon as a thin crescent, near the star *δ-Cancri* (*Puṣya*), and the cycle again starts.

The crescent of the moon, either in the western or the eastern sky, is always turned away from the sun.

The ancients must have observed the motion of the moon day after day, from new-moon to new-moon (a full lunation or lunar month) and become familiar with the stars or star-clusters which she passes. It is always easy to observe them when the moon is a crescent ; when the moon becomes fuller, the stars are lost in the moon's glare particularly if they are faint. But if observations be carried on for a number of years, the observers would become familiar with all the stars or star-clusters which the moon passes.

By observations like this, the ancients must have found that both the moon and the sun are moving to the east, the moon very fast, the sun more slowly. By the time the moon, after making a whole round, comes back to the sun, the latter has moved further to the east by about 30°. For example in the above figures Nos. 2 and 3, the sun was somewhat to the west of the bright star-group *Orionis* (*Mṛgaśiras*) to the west of Castor and Pollux on June 11th, the day of the new-moon. But on the next new-moon day, July 11th, she has moved near Castor and Pollux (*Punarvasu*) about 30° to the east.

The ancients must have found that the moon takes a little over 27.3 days (sidereal period of the moon), to return to the same star, but to overtake the sun, it takes a little longer, a little over 29.5 days (the synodic period of the moon). Exactly,

the mean sidereal period = 27.321661 days
= $27^d\ 7^h\ 43^m\ 11^s.5$
with a variation of ± $3\frac{1}{2}$ hours
and the mean synodic period = 29.530588 days
= $29^d\ 12^h\ 44^m\ 2^s$.
with a variation of ±7 hours.

The Lunar Mansions :

Many ancient nations developed the habit of designating the day-to-day (or night-to-night) position of the moon by the stars or star-clusters it passed on successive nights. The number of such stars or star-clusters was either 27 or 28 ; the ambiguity was due to the fact that the mean sidereal period of the moon is about $27\frac{1}{3}$ days, the actual period having a variation of seven hours, and the ancients who did not know how to deal with fractions, oscillated between 27 and 28. In India, originally there were 28 *nakṣatras*, but ultimately 27 was accepted as the number of lunar *nakṣatras* (or asterisms).

The lunar zodiac is also found amongst the Chinese who designate them by the term *Hsiu* ; and amongst the Arabs, who call them *Manzil*, both terms denoting mansions. Both the Chinese and the Arabs had 28 mansions. The Indian term '*nakṣatra*' is of uncertain etymological origin. Some hold that the term *nakṣatra* carried the sense that 'it does not move' and meant a star.

Names of certain '*nakṣatras*' are found in the oldest scriptures of India, *viz*., the Rg-Vedas, but a full list is first found in the Yajurveda (*vide* § 5·3). In the older classics of India (the Yajurveda, the *Mahābhārata*), the *nakṣatras* invariably start with *Kṛttikā*, the Pleiades ; the supposition has been made that the *Kṛttikās* were near the vernal point, when this enumeration was started. This is apparent from the couplet found in the *Taittirīya Brāhmaṇa* which runs thus :

Taittirīya Brāhmaṇa, i, 1, 2, 1.

Kṛttikā svagnimādadhita
Mukhaṁ vā etannakṣatrānāṁ, Yatkṛttikā.

Translation : One should consecrate the (sacred) fire in the *Kṛttikās* ; the *Kṛttikās* are the mouth of the *nakṣatras*.

Later during *Siddhānta Jyotiṣa* times the enumeration started with *Aśvinī* (α, β *Arietis*), and this is still reckoned to be the first of the *naksatras*, although the vernal point has now receded to the *Uttarabhādrapadā* group which should accordingly be taken as the first *naksatra*. But the change has not been done because the Indian astrologers have failed to correct the calendar for the precession of equinoxes.

The Chinese start their *Hsius* with *Citrā* or α *Virginis*. This refers probably to the time when α *Virginis* was near the autumnal equinoctial point (285 A.D.). The Arabs start their *Manzils* with β *Arietis* (Ash-Sharaṭāni).

There has been a good deal of controversy regarding the place of origin of the lunar zodiac. Many savants were inclined to ascribe the origin of the 27 *nakṣatra* system to ancient Babylon, like all other early astronomical discoveries. But as far as the authors of this book are aware, there is no positive evidence in favour of this view. Thousands of clay tablets containing astronomical data going back to 2000 B.C., and extending up to the first century A.D. have been obtained, but none of them are known to have any reference to 27 or 28 lunar mansions.

On the other hand (as mentioned before) some of the *nakṣatra* names are found in the oldest strata of the Rg-Vedas (*vide* § 5·2), which must be dated before 1200 B.C., and a full list with some difference in names is found in the Yajur-Veda, which must be dated before 600 B.C. Nobody has yet been able, to refute yet Max Muller's arguments in favour of the indigenous origin of the Indian *nakṣatra* system given in his preface to the Rg-Veda Saṁhitā, page xxxv.

It should be admitted that the lunar zodiac was pre-scientific, i.e., it originated before astronomers became conscious of the celestial equator and the ecliptic, and began to give positions of steller bodies with these as reference planes. The *nakṣatras* give very roughly the night-to-night position of the moon, by indicating its proximity to stars and star-groups. Many of the Indian stars identified as *nakṣatras* are not at all near the ecliptic or the moon's path which, on account of its obliquity, is contained in a belt within ±5° of the ecliptic. Such are for example :

(15) *Svātī*, which is identified with Arcturus (α *Bootis*), which has a latitude of 31° N.

(22) *Śravaṇa*, identified with α, β, γ *Aquilae*, having the latitude of 29° N.

(23) *Śraviṣṭhā*, identified with α, β, γ, δ *Delphini*, a having the latitude of 33° N.

(25) *Pūrva Bhādrapadā* identified with α *Pegasi* and some other adjacent stars, α *Pegasi* having latitude of 19° N.

At one time the brilliant star Vega (α *Lyrae*) was also included making 28 *naksatras*. But this has a latitude of 62° N and was later discarded.

No satisfactory argument has been given for the inclusion of such distant stars in the lunar zodiac. The Arabs and the Chinese do not include these distant stars in their lunar zodiac, but fainter ones near the ecliptic. Prof. P. C. Sengupta is of the opinion that Indians generally preferred bright stars, but when such were not available near the ecliptic, they chose brighter ones away from the ecliptic, which could be obtained on the line joining the moon's cusps.

The *nakṣatras* were used to name the 'days' in the earliest strata of Indian literature. Thus when the moon is expected to be found in the *Maghā nakṣatra* (α *Leonis*), the day would be called the Maghā day. This is the oldest method of designating the day, for it is found in the Ṛg-Vedas. Other methods of designating the day by *tithis* or lunar days, or by the seven week-days, came later. The system has continued to the present times. In old times, astrology was based almost entirely on the *nakṣatras*, *e.g.*, in Asoke's records, the *Puṣya nakṣatra* day was regarded as auspicious when *Brāhmaṇas* and *Śramaṇas* were fed, in order to enhance the king's *puṇya* (religious merits). In the *Mahābhārata* also we find that the days are designated by *nakṣatras* which apparently mean the star or star-cluster near which the moon is expected to be seen during the night.

As is apparent from Table No. 5, the *naksatras* are at rather unequal distances, i.e., they rarely follow the ideal distance of 13⅓°. This is rather inconvenient for precision time-reckoning. We find in the *Vedāṅga Jyotiṣa* times an attempt at a precise definition of the two limits of a *nakṣatra*, which was defined as 800′ (=13° 20′) of the ecliptic. The *nakṣatra* was named according to the most prominent star (*Yogatārā*) contained within these limits. These are given in column (2) of Table 5.

We do not, however, have any idea as to how the beginnings and endings of the *nakṣatra* divisions were fixed in India. The prominent ecliptic stars which were used as *Yogatārās* (junction-stars) in pre-Siddhāntic period, are not distributed at regular intervals along the ecliptic ; and so it was found very difficult to include the stars in their respective equal divisions. This will be clear from table (No. 5) where the junction stars of the *nakṣatras* according to the *Sūrya-Siddhānta* are given in col. (2). The celestial longitudes of the stars for 1956 A.D. are given in col. (4) and the beginnings of each division for the same year are given in col. (5), taking the star α *Virginis* to occupy the middle position of the *nakṣatra Citrā*, which marked

Table 5.—Stars of the Nakṣatra divisions.

Positions of the Junction Stars of Naksatra Divisions of the Siddhantas

	Name of nakṣatras (1)	Junction star (*Yogatārā*) of nakṣatras (2)	Latitude (3)	Longitude *Sāyana* (1956) (4)	Beginning point of the nakṣatra division (1956) (5)	Position of the star in the nakṣatra division. (6)
1.	Aśvinī	β Arietis	+ 8° 29′	33° 22′	28° 15′	10° 7′
2.	Bharaṇī	41 Arietis	+10 27	47 36	36 35	11 1
3.	Kṛttikā	η Tauri	+ 4 3	59 23	49 55	9 28
4.	Rohiṇī	α Tauri	− 5 28	69 11	63 15	5 56
5.	Mṛgaśiras	λ Orionis	−13 23	83 6	76 35	6 31
6.	Ārdrā	α Orionis	−16 2	88 9	89 55	(−)1 46
7.	Punarvasu	β Geminorum	+ 6 41	112 37	103 15	9 22
8.	Puṣya	δ Cancri	+ 0 5	128 7	116 35	11 32
9.	Āśleṣā	α Cancri	− 5 5	133 2	129 55	3 7
10.	Maghā	α Leonis	+ 0 28	149 13	143 15	5 58
11.	Pūrva Phalgunī	δ Leonis	+14 20	160 42	156 35	4 7
12.	Uttara Phalgunī	β Leonis	+12 16	171 1	169 55	1 6
13.	Hasta	δ Corvi	−12 12	192 51	183 15	9 36
14.	Citrā	α Virginis	− 2 3	203 14	196 35	6 39
15.	Svātī	α Bootis	+30 46	203 38	209 55	(−)6 17
16.	Viśākhā	α Libra	+ 0 20	224 28	223 15	1 13
17.	Anurādhā	δ Scorpii	− 1 59	241 58	236 35	5 23
18.	Jyeṣṭhā	α Scorpii	− 4 34	249. 9	249 55	(−)0 46
19.	Mūla	λ Scorpii	−13 47	263 59	263 15	0 44
20.	Pūrvāṣāḍhā	δ Sagittarii	− 6 28	273 58	276 35	(−)2 37
21.	Uttarāṣāḍhā	σ Sagittarii	− 3 27	281 47	289 55	(−)8 8
22.	Śravaṇa	α Aquilae	+29 18	301 10	303 15	(−)2 5
23.	Dhaniṣṭhā	β Delphini	+31 55	315 44	316 35	(−)0 51
24.	Śatabhiṣaj	λ Aquarii	− 0 23	340 58	329 55	11 3
25.	Pūrva Bhādrapadā	α Pegasi	+19 24	352 53	343 15	9 38
26.	Uttara Bhādrapadā	γ Pegasi	+12 36	8 33	356 35	11 58
27.	Revatī	ζ Piscium	− 0 13	19 16	9 55	9 21

the position of the autumnal equinox at the time when the table was compiled. The figures in the last column represent the position of the star in the *nakṣatra* division of that name. It seems that a few of the *Yogatārās*, *viz*., No. 6 *Ārdrā*, No. 15 *Svāti*, No. 18 *Jyeṣṭhā*, No. 20 *Pūrvāṣāḍhā*, No. 21 *Uttarāṣāḍhā*, No. 22 *Śravaṇa*, and No. 23 *Dhaniṣṭhā* fall outside the *nakṣatra* division of which they are supposed to form the *Yogatārā*. Matters do not improve much, if we shift the beginning of each division so as to place ζ *Piscium* (*Revatī*) at the end of the Revatī division or in other words at the beginning of the *Aśvinī* division. This will mean that the figures in col. (6) will then have to be increased by 3° 59′, which will push up the *Yogatārās* of 1 *Aśvinī*, 2 *Bharaṇī*, 3 *Kṛttikā*, 8 *Puṣya*, 13 *Hasta*, 25 *P. Bhādrapadā*, and 26 *U. Bhādrapadā*, so as to go outside the *nakṣatra* division of which they form the *Yogatārā*. In fact no arrangement at any time appears to have been satisfactory enough for all the *Yogatārās* to fall within their respective *nakṣatra* divisions.

The divisions of *nakṣatras* shown in the table, as already stated, has been based on the assumption that the star Spica occupies the 180th degree of the lunar zodiac. This arrangement agrees with the statement of the *Vedāṅga Jyotiṣa* that the *Dhaniṣṭhā* star (α or β *Delphini*) marked the beginning of the *Dhaniṣṭhā* division, and also of the Varāha's *Sūrya Siddhānta* that Regulus (α *Leonis*) is situated at the 6th degree of the *Maghā* division.

4.2 LONG PERIOD OBSERVATIONS OF THE MOON : THE CHALDEAN SAROS

The moon gains on the sun at the average rate of $12\frac{1}{5}^{\circ}$ per day, but it did not take the ancients long to discover that the daily gain of the moon on the sun is far from uniform ; in fact as we know now, it varies from approximately $10\frac{3}{4}^{\circ}$ to $14\frac{1}{2}^{\circ}$ per day. It was therefore not possible to say beforehand whether the crescent moon would appear on the 29th or on the 30th day after the beginning of the previous month.

But the exact prediction of the day was a necessity from the socio-religious point of view. In India, the month was measured from full-moon to full-moon, and in the *Mahābhārata*, the great epic which was compiled from older materials about 400 B. C., it is recorded that sometimes the full moon occurred on the thirteenth day after the new-moon, This was taken to forebode great calamities for mankind. There were similar ideas in Babylon of which Pannekoek says :

"When the Moon is full on the night of the 14th, the normal time, it was a lucky omen ; when full-moon happened on the night of the 13th, 15th or 16th, it was abnormal, hence a bad omen. Here astrology and calendar were merged ; deviation in the calendar was considered an unlucky sign and had to be restored at the end of the month."*

Neugebauer says :

"The months of the Babylonian calendar are always real lunar months, the first day of which begins with the first visibility of the new crescent. The exact prediction of this phenomenon is the main problem of the lunar theory as known to us from about 250 B. C. onwards."†

This is rather comparatively late date. The reason is that the accomplishment of this objective depends on the evolution of methods of exact astronomical observations, and of a method of recording them in precise mathematical language. Some ancient people never reached this stage. As far as we are aware, the ancient Babylonians were the first to evolve methods of observational astronomy. They also arrived at the principles of angular measurements, found the apparent paths of the moon, the sun, and the planets in the heavens, and discovered that it was only the sun's path (the ecliptic) which was fixed, and the paths of the moon, and the planets deviated somewhat from it. How this was done will be related later.

But even before these accurate methods had been discovered, the Babylonian astronomers had learnt a lot more about the moon from long period observations. The most remarkable of these discoveries is that of the Chaldean Saros, or a period of 18 years 10⅓ days, in which the eclipses of the sun and the moon recur.

The occurrence of solar or lunar eclipses, when the two great luminaries disappear suddenly, either partially or wholly, were very striking phenomena for the ancient and medieval people, and gave rise to gloomy forebodings. There were all kinds of speculations about the cause of the eclipses, *e.g.*, that the sun and the moon were periodically devoured by demons or dragons. The ancient astronomers, however, found that a solar eclipse takes place only near conjunction (new-moon), but every conjunction of the sun and the moon is not the occasion for a solar eclipse. A lunar eclipse takes place only near opposition (full-moon), but every opposition of the sun and the moon is not the occasion for a lunar eclipse.

In many ancient countries, China and Babylon for example, records of occurrence of eclipses had been kept. The celebrated Greek astronomer, Ptolemy of Alexandria (*ca*. 150 A. D.) had before him a record of eclipses kept at the Babylonian archives dating from 747 B. C. They gave date of occurrence, time. and features of the eclipse, whether they were partial or total. From an analysis of these records, the Chaldean astronomers tried to discover the laws of periodicity of eclipses, which ultimately resulted in the discovery of the Saros cycle of 18 years and 10 or 11 days. The basis of the Saros cycle is as follows :

We do not exactly know when the ancient astronomers outgrew the myth of demons periodically devouring the sun and the moon during eclipse times, and arrived at the physical explanations now known to every student of astronomy, and reproduced in the diagrams given below.

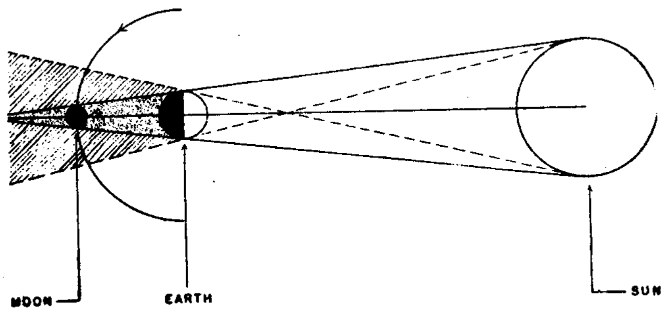


Fig. 4—Showing an eclipse of the moon.

But when they arrived at physical explanation of eclipses, they had an understanding as to why there are no eclipses during every full moon and new moon. The paths of the two luminaries must be in different planes. This we take up in a subsequent section more fully, when we describe how the sun's path or ecliptic was discovered.

Suffice it to say that at some ancient epoch, some Chaldean astronomer discovered that the moon's path was different from the sun's, and therefore cuts the sun's path at two points, now called *Nodes*. The condition for an eclipse to happen is that the full-moon and new-moon must take place sufficiently close to the Nodes, otherwise the luminaries would be too far apart, for an eclipse to take place.

The 'Nodes' now take the place of the mythical dragons which were supposed to waylay the sun and the moon, periodically, and swallow and disgorge them. In Hindu astronomy, the ascending node is called

* A. Pannekoek : *The Origin of Astronomy.*

† O. Neugebauer : *Babylonian Planetary Theory.*

Rahu with the symbol ☊, and the descending node is called *Ketu* with the symbol ☋, the names of the two

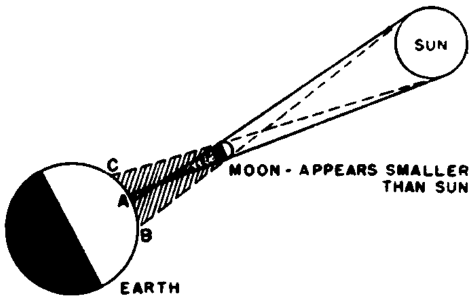


Fig. 5—Showing an annular eclipse of the sun.

halves of the demon, who was cut in two by gods, so that the sun and the moon could get out.

In very ancient times, it was found that the two 'Nodes' were not fixed, but moved steadily to the west, so that the sun took less than a year to return to the same node. This time is known as the '*Draconitic year*' or year of the Dragons, and its length is 346.62005 days. The time in which the moon returns to the same node is known as the draconitic month or the month of dragons. It is slightly less than the sidereal month, because the nodes regress to the west. Its value is 27.21222 days.

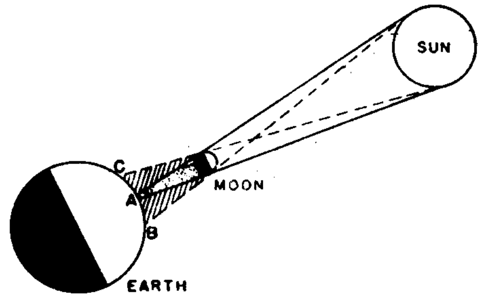


Fig. 6—Showing a total eclipse of the sun.

The Chaldeans appear to have found, about 400 B. C., that 223 synodic months = 242 draconitic months.

The reader can verify

223 synodic month = 6585.321 days
242 draconitic months = 6585.357 days

From their long observations of eclipses, the Chaldean astronomers must have found that eclipses recur after an interval of $6585\frac{1}{3}$ days or 18 years $11\frac{1}{3}$ days (or 18 years $10\frac{1}{3}$ days if 5 leap-years intervene). This cycle has been known as the *Chaldean Saros*. The extent to which a knowledge of the cycle is useful is given in the following modern table.

Table 6.—List of Lunar Eclipses of the Saros cycle.

Lunar Eclipses

1914, Mar. 12	1932, Mar. 22	1950, Apr. 2	Asc.	Part.-Total
Sept. 4	Sept. 14	Sept. 26	Des.	Part.-Total
1916, Jan. 20	1934, Jan. 30	1952, Feb. 11	Asc.	Partial
July 15	July 26	Aug. 5	Des.	Partial
1917, Jan. 8	1935, Jan. 19	1953, Jan. 29	Asc.	Total
July 4	July 16	July 26	Des.	Total
Dec. 28	1936, Jan. 8	1954, Jan. 19	Asc.	Total
1918, June 24	July 4	July 16	Des.	Partial
1919, Nov. 7	1937, Nov. 18	1955, Nov. 29	Asc.	Partial
1920, May 3	1938, May 14	1956, May 24	Des.	Total-Part.
Oct. 27	Nov. 7	Nov. 18	Asc.	Total
1921, Apr. 22	1939, May 3	1957, May 13	Des.	Total
Oct. 16	Oct. 28	Nov. 7	Asc.	Part.-Total
1923, Mar. 3	1941, Mar. 13	1959, Mar. 24	Des.	Partial
Aug. 26	Sept. 5	---	Asc.	Partial
1924, Feb. 20	1942, Mar. 3	1960, Mar. 13	Des.	Total
Aug. 14	Aug. 26	Sept. 5	Asc.	Total
1925, Feb. 8	1943, Feb. 20	1961, Mar. 2	Des.	Partial
Aug. 4	Aug. 15	Aug. 26	Asc.	Part.-Total
1927, June 15	1945, June 25	1963, July 6	Asc.	Total-Part.
Dec. 8	Dec. 19	Dec. 30	Des.	Total
1928, June 3	1946, June 14	1964, June 25	Asc.	Total
Nov. 27	Dec. 8	Dec. 19	Des.	Total
—	1947, June 3	1965, June 14	Asc.	Partial
1930, Apr. 13	1948, Apr. 23	—	Asc.	Partial
Oct. 7	—	—	Des.	Partial
1931, Apr. 2	1949, Apr. 13	1967, Apr. 24	Asc.	Total
Sept. 26	Oct. 7	Oct. 18	Des.	Total

Table 7.—List of Solar Eclipses.

Eclipses of the Saros cycle

Solar Eclipses

The dates of recurrence of the corresponding eclipses in three cycles from 1914 to 1967, the node at which the eclipse occurs, and the nature of the eclipse are shown below.

1914, Feb. 25	1932, Mar. 7	1950, Mar. 18	Asc.	Annular
Aug. 21	Aug. 31	Sept. 12	Des.	Total
1915, Feb. 14	1933, Feb. 24	1951, Mar. 7	Asc.	Annular
Aug. 10	Aug. 21	Sept. 1	Des.	Annular
1916, Feb. 3	1934, Feb. 14	1952, Feb. 25	Asc.	Total
July 30	Aug. 10	Aug. 20	Des.	Annular
Dec. 24	1935, Jan. 5	1953, —	Asc.	Partial
1917, Jan. 23	Feb. 3	Feb. 14	Asc.	Partial
June 19	June 30	July 11	Des.	Partial
July 19	July 30	Aug. 9	Des.	Partial
Dec. 14	Dec. 25	1954, Jan. 5	Asc.	Annular
1918, June 8	1936, June 19	June 30	Des.	Total
Dec. 3	Dec. 13	Dec. 25	Asc.	Annular
1919, May 29	1937, June 8	1955, June 20	Des.	Total
Nov. 22	Dec. 2	Dec. 14	Asc.	Annular
1920, May 18	1938, May 29	1956, June 8	Des.	Part.-Total
Nov. 10	Nov. 22	Dec. 2	Asc.	Partial
1921, Apr. 8	1939, Apr. 19	1957, Apr. 29	Des.	Annular
Oct. 1	Oct. 12	Oct. 23	Asc.	Total-Part.
1922, Mar. 28	1940, Apr. 7	1958, Apr. 19	Des.	Annular
Sept. 21	Oct. 1	Oct. 12	Asc.	Total
1923, Mar. 17	1941, Mar. 27	1959, Apr. 8	Des.	Annular
Sept. 10	Sept. 21	Oct. 2	Asc.	Total
1924, Mar. 5	1942, Mar. 16	1960, Mar. 27	Des.	Partial
July 31	Aug. 12	—	Asc.	Partial
Aug. 30	Sept. 10	Sept. 20	Asc.	Partial
1925, Jan. 24	1943, Feb. 4	1961, Feb. 15	Des.	Total
July 20	Aug. 1	Aug. 11	Asc.	Annular
1926, Jan. 14	1944, Jan. 25	1962, Feb. 5	Des.	Total
July 9	July 20	July 31	Asc.	Annular
1927, Jan. 3	1945, Jan. 14	1963, Jan. 25	Des.	Ann.-Total
June 29	July 9	July 20	Asc.	Total
Dec. 24	1946, Jan. 3	1964, Jan. 14	Des.	Partial
1928, May 19	May 30	June 10	Asc.	Total-Part.
June 17	June 29	July 9	Asc.	Partial
Nov. 12	Nov. 23	Dec. 4	Des.	Partial
1929, May 9	1947, May 20	1965, May 30	Asc.	Total
Nov. 1	Nov. 12	Nov. 23	Des.	Annular
1930, Apr. 28	1948, May 9	1966, May 20	Asc.	Ann.-Total
Oct. 21	Nov. 1	Nov. 12	Des.	Total
1931, Apr. 18	1949, Apr. 28	1967, May 9	Asc.	Partial
Sept. 12	—	—	Des.	Partial
Oct. 11	Oct. 21	Nov. 2	Des.	Part.-Total

The problem of first visibility of the moon with which we started cannot therefore be taken up unless we describe how the path of the sun and the moon in the sky were discovered in ancient times. This is taken up in the succeeding sections.

4.3 THE GNOMON

Observations of the positions of the sun, the moon, planets and stars are now made very accurately with elaborate instruments installed in observatories. But these instruments have been evolved after thousands of years of experience and application of human ingenuity, and have undergone radical changes in design and set-up with every great technological discovery. But let us see how the early astronomers who had no instruments or very primitive ones made observations, collected the fundamental data, and evolved the basic astronomical ideas.

The earliest instrument used by primitive astronomers appears to have been the gnomon, which we now describe.

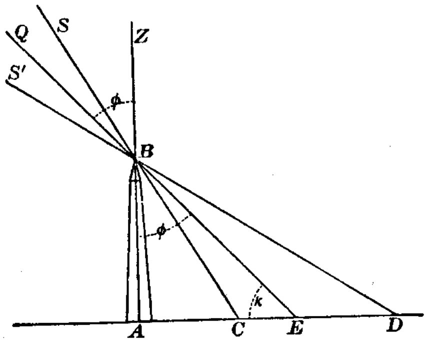


Fig. 7—The gnomon

The ancients determined the latitude of the place, obliquity of the ecliptic, the length of the year and the time of day by measuring the length and direction of shadow of the gnomon. The figure shows the noon-shadow of the gnomon AB, AE being the equinoctial shadow and AC and AD the shadow on two solstice-days, at a place on latitude = ϕ.

Nobody can fail to see the change in direction and length of shadows of vertical objects throughout the day-time, and throughout the year. When these observations are carefully made, by means of the gnomon (*Śaṅku* in Sanskrit), which is simply a vertical stick planted into the ground, and standing on fairly level ground of large area, without obstructions from any direction, a good deal of astronomical knowledge can be easily deduced. These observations appear to have been made in all ancient countries.

We have the following description, by George Sarton, of observations made in ancient times in Greece with the aid of the gnomon.*

"It (the gnomon) is simply a stick or a pole planted vertically in the ground, or one might use a column built for that purpose or for any other ; the Egyptian obelisks would have been perfect gnomons if sufficiently isolated from other buildings. Any intelligent person, having driven his spear into the sand, might have noticed that its shadow turned around during the day and that it varied in length as it turned. The gnomon in its simplest form was the systematization of that casual experiment. Instead of a spear, a measured stick was established solidly in a vertical position in the middle of a horizontal plane, well smoothed out and unobstructed all around in order that the shadow could be seen clearly from sunup to sundown. The astronomer (the systematic user of the gnomon deserves that name) observing the shadow throughout the year would see that it reached a minimum every day (real noon), and that minimum varied from day to day, being shortest at one time of the year (*summer solstice*) and longest six months later (*winter solstice*). Moreover, the direction of the shadow turned around from West to East during each day, describing a fan the amplitude of which varied througout the year".*

From the observation of the shadows cast by the gnomon, many useful deductions could be made. These are :—

(1) Mark the points in the morning and in the evening when the shadows are equal in length and draw the lines showing the shadows. Then bisect the angle between the two shadow lines. This gives us the *meridian* or the north-south direction of the place.

The process of bisection was done by taking a rope attaching extreme points to the end points of the equal shadows ; then take the mid-point of the rope, and stretch the rope, and mark the position of the mid-point. This connected to the pole gives us the meridian line. If we draw a circle, with the pole as centre, and draw the meridian, the point where it strikes the northern semi-circle is the North point, opposite is the South point. The East and West points are found by drawing a line at right angles to the north-south direction.

So the cardinal directions are found.

(2) Observe the position of the sunrise from day to day. If observations are carried on throughout the year, there will be found two days in the year when the sun will arise exactly on the east point. Then it is found that the day and night are equal in length. These days are called the *Equinoctial days*. Let us start from the equinoctial day in Spring (vernal equinox). This happens on March 21st. Then we observe that the sun at sunrise is steadily moving to the north, at first rapidly, then more slowly. Near the extreme north, the sun's movement is very slow, so this point is called the '*Solstice*' which means the sun standing still. Actually the sun reaches its northern-most point on June 22 (summer solstice).

* Sarton mentions Anaximander (*c.* 610-545 B.C.) of Miletus as the earliest Ionian philosopher who used the gnomon in Greater Greece.

* George Sarton : *A History of Science*, p. 174.

The day is longest on this date. Then the sun begins to move south till it crosses the east point on September 23, when day and night again become equal (the autumnal equinox day). It continues to move south, till the extreme south is reached on December 22, (the winter solstice day), when daylight is shortest for places on the northern hemisphere. Then the sun turns back towards the east point reaching it on March 21, and the year-cycle is complete.

The gnomon thus enabled the ancient astronomers (in Babylon, India, Greece, and China) to determine :

(a) *The Cardinal points :* East, North, West, and South ; the north-south line is the meridian line (the *Yāmyottara-rekhā* in Indian astronomy).

(b) *The Cardinal days of the Year : viz.,*

The Vernal Equinox (V.E.) day, when day and night are equal.

The Summer Solstice (S.S.) day, when the day is the longest for observers on the northern hemisphere.

The Autumnal Equinox (A.E.) day, when day and night are again equal.

The Winter Solstice (W.S.) day, when the day is the shortest for observers on the northern hemisphere.

All early astronomical work was done in the northern hemisphere.

These methods are fully described in the *Sūrya-Siddhānta*, Chap. III, but they appear to have been practised from far more ancient times. In the appendix (5-C), we have quoted passages from the *Aitareya Brāhmaṇa* which shows that the gnomon was used to determine the cardinal days of the year at the time when this ritualistic book was compiled. The date is at least 600 B.C., i.e., before India had the Greek contact. It may be considerably older even.

(c) *To mark out the Seasons :* We have mentioned earlier that in countries other than Egypt, there were no impressive physical phenomenon like the arrival of the annual flood of the Nile to mark the beginning of the solar year, or of the seasons. The seasons pass imperceptibly from the one to the other.

The gnomon observations probably enabled the early astronomers of Babylon and Greece to define the onset of the seasons, and the length of the year with greater precision.

In Graeco-Chaldean astronomy, we have four seasons :

Spring ···	from	V.E.	to	S.S.
Summer··· ···	„	S.S.	to	A.E.
Autumn······	„	A.E.	to	W.S.
Winter··· ···	„	W.S.	to	V.E.

Thus every season starts immediately after a cardinal day of the year and ends on the next cardinal day.

According to Neugebauer :

"Babylonian astronomy (during Seleucid periods, 300 B.C.-75 A.D.) was satisfied with an exact four-division of the seasons as far as solstices and equinoxes are concerned, with the summer solstice (and *not* the vernal point) as the fixed point."*

At a later stage, they however found that the four seasons had unequal lengths (*vide* § 3·1).

The above definition of 'seasons' has come down to modern astronomy. The Hindu definition of seasons was different (*vide* § 5·6 and 5-A)

The observation of the *Cardinal days* of the year appear to have been carried out all over the ancient world by other methods, and often in a far more elaborate manner. People would observe the day-to-day rise of the sun on the eastern horizon, and mark out the days when the sun was farthest north (summer solstice day), or farthest south (winter solstice day). The time period taken by the sun to pass from the southern solstitial point to the northern solstitial point was known in the Vedas as the *Uttarāyaṇa* (northern passage), and that taken by the sun to pass from the northern solstitial point to the southern solstitial point was known as the *Dakṣiṇāyana* (southern passage). Exactly midway between these points the sun rises on the vernal and autumnal equinoctial days. From the passage in the *Śatapatha Brāhmaṇa*, quoted later (*vide* § 5·3), we see clearly that the point on the eastern horizon, where the sun rose on these days, was recognized to be the true east.

Doubt has been expressed about the ability of Vedic Aryans to make these observations, but to these objections, B. G. Tilak replied in his *Orion*, pp. 16-17.

"Prof. Weber and Dr. Schrader appear to doubt the conclusion on the sole ground that we cannot suppose the primitive Aryans to have so far advanced in civilization as to correctly comprehend such problems. This means that we must refuse to draw legitimate inferences from plain facts when such inferences conflict with our preconceived notions about the primitive Aryan civilization. I am not disposed to follow this method, nor do I think that people, who knew and worked in metals, made clothing of wool, constructed boats, built houses and chariots, performed sacrifices, and had made some advance in agriculture, were incapable of ascertaining the solar and the lunar years. They could not have determined it correct to a fraction of a second as modern astronomers have done ; but a rough practical estimate was, certainly, not beyond their powers of comprehension."

The best example of the ability of the ancient people to observe the cardinal points of the sun's motion is afforded by the Stonehenge in the Salisbury plains of England, of which detailed accounts

* Neugebauer : *Babylonian Planetary Theory*, Proc. Amer. Philos. Soc. Vol. 98 : 1, 1954, p. 64.

have recently appeared in *Scientific American* (188, 6-25, 1953) and *Discovery* (1953, Vol. XIV, p.276).

It is related in these two publications, that not a long time subsequent to 1800 B.C., say about 1500-1200 B.C., the then inhabitants of Britain, who had not even learnt the use of any metal, but used only stone implements, could construct a huge circular area enclosed by large upright monoliths forming lintels and with a horse-shoe shaped central area having its axis in the direction of sunrise on the summer solstice day. It has been proved, almost beyond any doubt, that the Stonehenge was used for the ceremonial observation of sunrise on this day. Sir Norman Lockyer in 1900 found that the direction of the axis of the horse-shoe actually makes an angle of about $1\frac{1}{2}°$ with the present direction of sunrise on the summer solstice day. He did not think that it was a mistake on the part of the original builders ; but that on account of the change in obliquity (angle between equator and ecliptic), the present direction of sunrise had changed to the extent of $1\frac{1}{2}°$ and using the rate of change of obliquity, he could fix up the time of construction at 1800 ± 200 B.C. This estimate has been brilliantly confirmed by C^{14}-analysis of some wood charcoal found in the local burial pits which are presumed to be contemporary with the erection of the Stonehenge.

After this brilliant confirmation of Lockyer's hypothesis, it is hoped that there will be less hesitation on the part of scholars to admit that it was possible for the Vedic Aryans who knew the use of metal and were far more advanced than the stone-age people of Britain, to devise methods for the observation of the cardinal points of the year.

How did they observe these points ? Probably in the same way as the Britishers of 1500 B.C., by observing from a central place, the directions of sunrise on the eastern horizon throughout the year. The directions of the solstitial rises could be easily marked. Probably the equinoctial points were found by bisecting the angle between these two directions by means of ropes as described in the *Sulva-Sūtras*.

4.4 NIGHT OBSERVATIONS : THE CELESTIAL POLE AND THE EQUATOR

Almost all ancient nations were familiar with the night-sky either as shepherds, travellers or navigators, and were acquainted with more detailed knowledge of the revolving blue firmament studded with stars than the modern city dweller. The striking constell-tions like the Great.Bear, the Pleiades, the Orion could not but catch their fancy and references to these star-groups are found in ancient literature, in the Vedas, in the book of Job (the Bible) and in Homer. In the last, the star-groups are used by sailors to find out their orientation. Representations of star-groups are found in ancient Babylonian boundary stones of about 1300 B.C. (*see* Fig. 15).

Let us now see how these observations were made.

Suppose, on a clear moonless evening in early Spring (say March) and at about 8-30 P.M., we take our stand in a wide field undisturbed by city lights,

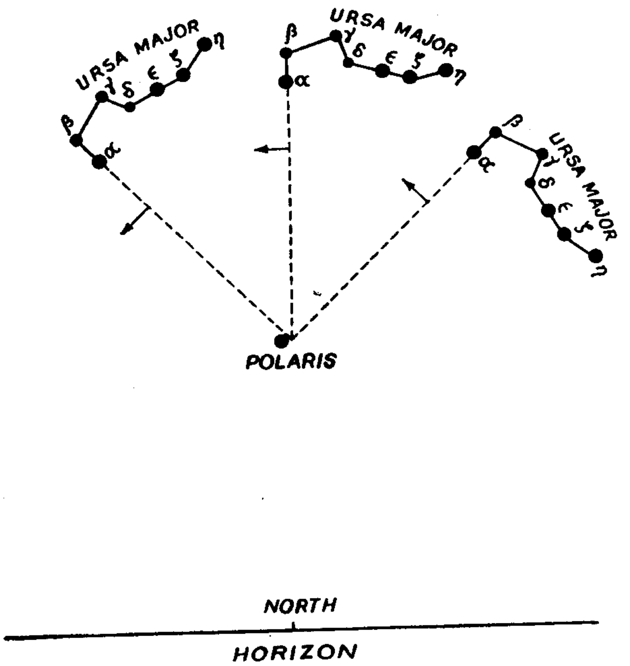


Fig. 8—Showing the positions of Ursa Major (*Saptarṣi*) at interval of 3 hours.

and our vision is unobstructed in all directions. We now face the north. We shall find the appearance of the heavens as shown in Fig. (8) :

In the north, a little high up to our right hand side we cannot fail to observe the conspicuous constellation of seven stars, called in Europe the Great Bear, but in India, the *Saptarṣi* or seven seers. If we observe the heavens 3 hours later, we shall observe that the group has changed its position as shown in Fig. (8). Let us fix our attention on the two front stars (the pointers) of the Great Bear and join a line through them. The line joining these two stars appear to behave like the hands of a watch, for if produced they pass through a star half as bright at some distance, and appear to have revolved about it as centre. This star is called the Pole Star or *Polaris*, or *Dhruva* in Sanskrit which means fixed. If we observe throughout the night, we shall find that the Polaris remains approximately fixed, and the line of pointers continues to go round it. The next day, at

8-26 P.M., nearly 24 hours later they are again almost exactly at the same position.

We naturally come to the conclusion that the whole starry heavens have been rotating round an axis passing through the observer and the Pole Star from *east to west*, and the rotation is completed in nearly 24 hours (exactly $23^h\ 56^m\ 4^s$ of mean solar time).

Definition of the Poles

The celestial poles, or the poles round which the rotation of the celestial sphere takes place may therefore be defined as those two points in the sky where a star would have no diurnal motion. The exact position of either pole may be determined with proper instruments by finding the centre of the small diurnal circle described by some star near it, as for instance, the stars belonging to the Ursa Minor group. Actually the so-called pole star is at present 57 minutes away from the correct position of the pole which is not actually occupied by any star.

Since the two poles are diametrically opposite in the sky; only one of them is usually visible from a given place : observers north of the equator see only the north pole, and *vice versa* in the southern hemisphere. The south pole is not marked by any prominent star.

Knowing as we now do, that the apparent revolution of the celestial sphere is due to the rotation of the earth on its axis, we may also define the poles as the two points where the earth's axis of rotation (or any set of lines parallel to it), produced indefinitely, would pierce the celestial sphere.

The Celestial Equator and Hour Circles

The celestial equator is the great circle of the celestial sphere, drawn halfway between the poles

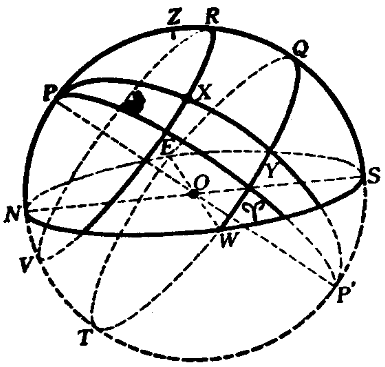


Fig. 9—The celestial sphere.

(and therefore everywhere 90° from each of them), and is the great circle in which the plane of the earth's equator cuts the celestial sphere, as illustrated in Fig. (9). Small circles drawn parallel to the celestial equator, like the parallels of latitude on the earth, are called parallels of declination. A star's parallel of declination is identical with its diurnal circle.

The great circles of the celestial sphere, which pass through the poles in the same way as the meridians on the earth, and which are therefore perpendicular to the celestial equator, are called hour-circles. Each star has its own hour-circle, which at the moment when the star passes the north-south line through the zenith of the observer, coincides with the celestial meridian of the place.

4.5 THE APPARENT PATH OF THE SUN IN THE SKY : THE ECLIPTIC

The apparent path of the sun in the sky is known in astronomical language as the ecliptic. It is a great circle cutting the celestial equator at an angle of *ca* $23\frac{1}{2}°$ (exactly 23° 26′ 43″ in 1955, but the angle varies from 22° 35' to 24° 13'). This is known as the *obliquity* of the ecliptic.

The ecliptic is the most important reference circle in the heavens, and let us see how a knowledge of it was obtained in ancient times.

It is obvious that a knowledge of the stars marking the sun's path could not be obtained directly as in the case of the moon ; for when the sun is up, not even the brightest stars are visible. The knowledge must have been obtained indirectly. Early observers were accustomed to observe the heliacal rising of stars, i.e., observe the brilliant stars lying close to the sun which are on the horizon just before sunrise. This must have given them a rough idea of the stars lying close to the sun's path. From these observations, as well as from successive appearances of the moon on the first days of the month as narrated in § 4·1, they must have also deduced that the sun was slipping from the west to the east with reference to the fixed stars, and completing a revolution in one year. *But how was this path rigorously fixed* ?

It appears that a knowledge of the stars lying on, or close to the moon's path was obtained from observations made during lunar, rarely of solar eclipses.

They must have realized, as narrated in § 4.2, that during a total lunar eclipse, the moon occupies a position in the heavens opposite the sun, and the stars close to the moon, which become visible during totality, approximately mark out points on the sun's path. So the word '*Ecliptic*' which means the locus of eclipses, came to denote the sun's path.

The two points of intersection of the ecliptic with the celestial equator are called respectively the

First point of Aries, and the *First point of Libra*. The first point of Aries is the ascending node, when the sun passes from the south to the north ; the first point of Libra is the descending node, when the sun passes from the north to the south. We have vernal equinox when the sun is at the first point of Aries, summer solstice when the sun is at the first point of Cancer, autumnal equinox when the sun is at the first point of Libra, and winter solstice when the sun is at the first point of Capricorn. To the origin of nomenclature, we return later.

The celestial equator and the ecliptic are the most important reference planes in astronomy. The positions of all heavenly bodies are given in terms of these planes, taking the first point of Aries as the initial point. We explain below the scientific definitions of spherical co-ordinates used to denote the position of a body on the celestial globe.

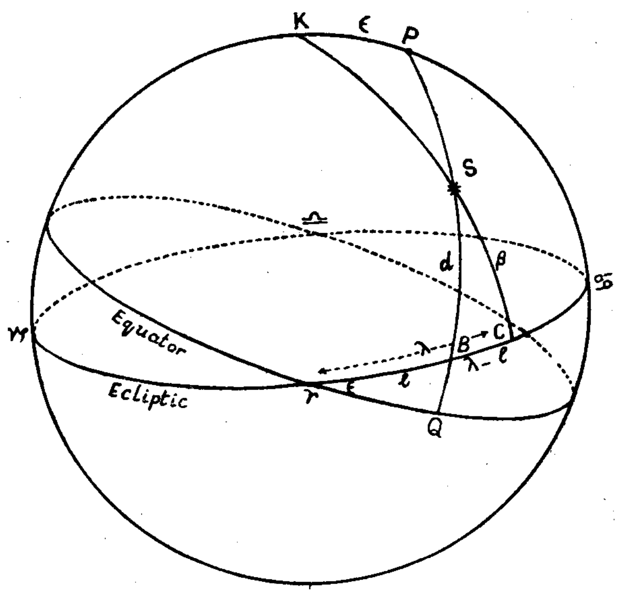


Fig. 10.—Showing the spherical co-ordinates of a star.

In this figure :

P = Celestial pole (*dhruva*).
♈Q♎ = Celestial equator.
K = Pole of the ecliptic (*kadamba*).
♈♋ = Plane of the ecliptic.
♈ = First point of Aries (vernal equinox).
♋ = First point of Cancer (summer solstice).
♎ = First point of Libra (autumnal equinox).
♑ = First point of Capricorn (winter solstice).
S = A heavenly body.
PS = Great circle thro'P,S cutting equator at Q.
♈Q = Right ascension = α
QS = Declination = δ
KS = Great circle through K, S cutting ecliptic at C.
♈C = Celestial longitude = λ
CS = Celestial latitude = β

Let PS cut the ecliptic at B. Then

♈B = Polar longitude or *dhruvaka* = l
BS = Polar latitude or *vikṣepa* = d

These last two peculiar co-ordinates, now no longer used, were used by the *Sūrya Siddhānta* to denote star positions. They have been traced by Neugebauer to Hipparchos five centuries earlier.

The position of a stellar body may be defined by either its right ascension (α) and declination (δ), or its celestial longitude(λ) and latitude(β).

The positions of stars in these co-ordinates began to be given from the time of Claudius Ptolemy (150 A.D.) who used them in his *Syntaxis*.

4.6 THE ZODIAC AND THE SIGNS

The early astronomers must have found that the sun's path in the heavens was almost fixed, while that of the moon, and of the planets, which acquired for astrological reasons great importance from about 1200 B.C., strayed some degrees to the north and south of the ecliptic.

In case of the moon the deviation from the ecliptic was found to be not much greater than 5°, but some of the planets strayed much more ; in the case of Venus, her perpendicular distance from the ecliptic rises sometimes as high as 8° degrees. So a belt was imagined straying about 9° north and 9° south of the ecliptic, in which the planets would always remain in course of their movement. This belt came to be known as the 'Zodiac.'

The complete cycle of this belt was divided into 12 equal sectors each of 30°, and each sector called a 'Sign'. The signs started with one of the points of intersection of the ecliptic and the equator, and the first sign was called 'Aries' after the constellation of stars within it. The names of the succeeding signs are given in Table No. 8 on the next page, in which :

The first column gives the beginning and ending of the signs, the vernal equinoctial point being taken as the origin.

The second column gives the international names which are in Latin with the symbols used to denote the signs.

The third column gives their English equivalent.

The fourth column gives the Greek names. They are synonimous with the international names.

The fifth column gives a set of alternative names for the signs given by Varāhamihira.

Table 8.—Zodiacal Signs.

Different Names of Zodiacal Signs

Beginning and ending of the Signs (1)	Name of the Signs & Symbol (2)	English equivalent (3)	Greek names (4)	Varāha Mihira (5)	Indian names (6)	Babylonian names (7)
0°- 30°	♈ Aries	Ram	Krios	Kriya	Meṣa	Ku or Iku (Ram)
30 - 60	♉ Taurus	Bull	Tauros	Tāburi	Vṛṣabha	Te-te (Bull)
60 - 90	♊ Gemini	Twins	Didumoi	Jituma	Mithuna	Masmasu (Twins)
90 -120	♋ Cancer	Crab	Karxinos	Kulīra	Karka or Karkaṭa	Nangaru (Crab)
120 -150	♌ Leo	Lion	Leon	Leya	Siṁha	Aru (Lion)
150 -180	♍ Virgo	Virgin	Parthenos	Pāthona	Kanyā	Ki (Virgin)
180 -210	♎ Libra	Balance	Zugos	Jūka	Tulā	Nuru (Scales)
210 -240	♏ Scorpio	Scorpion	Scorpios	Kaurpa	Vṛścika	Akrabu (Scorpion)
240 -270	♐ Sagittarius	Archer	Tozeutes	Taukṣika	Dhanuḥ	Pa (Archer)
270 -300	♑ Capricornus	Goat	Ligoxeros	Ākokera	Makara	Sahu (Goat)
300 -330	♒ Aquarius	Water Bearer	Gdroxoos	Hṛdroga	Kumbha	Gu (Water carrier)
330 -360	♓ Pisces	Fish	Ichthues	Antyabha	Mīna	Zib (Fish)

The sixth column gives the Indian names.

The seventh column gives the Babylonian names.

It can be easily inferred from the table that the names are of Babylonian origin, but their exact significance is not always known. It has been assumed that the symbols used to denote the signs have been devised from a representation of the figure of the animal or object after which the sign has been named, for example, the mouth and horns of the Ram, the same of the Bull, and so on.

It is seen that Varāhamihira's alternative names given in column (5) are simply the Greek names corrupted in course of transmission and as adopted for Sanskrit; with the exception of the name for Scorpion, which is given as 'Kaurpa'. This has phonetic analogy with the corresponding Babylonian sign name Akrabu for Scorpion. The purely Sanskrit names given in column (6) are all translations of Greek names with the exceptions of :

(3) Twins, which become *Mithuna* or Amorous couple',

(9) the Archer, which becomes the 'Bow',

(10) the Goat, which becomes the 'Crocodile',

(11) Water bearer, which becomes the 'Waterpot'.

Some of them appear to have been translations of Babylonian names.

The Babylonian names, as interpreted by Ginzel* are given in the seventh column, with their meanings.

It is thus seen that the names of the zodiacal signs are originally of Babylonian origin. They were taken over almost without change by the Greeks, and subsequently by the Romans, and the Hindus, from Graeco-Chaldean astrology.

* Ginzel, *Handbuch der Mathematischen und Technischen Chronologie*, Vol. I, p. 84.

But why was such an odd assortment of animal names chosen for the 'Signs'? There have been interesting speculations. The reader may consult Brown's *Researches into the Origin of the Primitive Constellations of the Greeks, Phoenicians and Babylonians*, London, 1900.

These signs were taken up by almost all nations in the centuries before the Christian era on account of the significance attached to them by astrologers. In Greece, they were first supposed to have been introduced by the early Greek astronomer Cleostratos, an astronomer who observed about 532 B.C. in the island of Tenedos off the Hellespont who introduced the designation 'Zodiac' to describe the belt of stars about the ecliptic. The twelve 'Zodical Signs' are not known in older ritualistic Indian literature like the *Brāhmaṇas*. They appear to have come to India in the wake of the Macedonian Greeks or of nations like the Śakas who were intermediaries for transmission of Greek culture to India.

Confusion in the starting point of the Zodiac

The 'Initial Point' of the zodiac should be the *Vernal Point* or the point of intersection of the ecliptic and the equator, but as will be shown in the next section, this point is not fixed, but moves west-ward along the ecliptic at the rate of approximately 50″ per year (precession of the equinoxes). This motion is unidirectional, but before Newton proved it to be so in 1687 from dynamics and the law of gravitation, there was no unanimity even amongst genuine astronomers about the uni-directional nature of precessional motion, inspite of overwhelming observational evidences.

The hesitation of the medieval astronomers in accepting precession can be easily understood. Most of them earned their livelihood by practising the 'Astrological Cult' which was reared on the basis that the signs of the zodiac are fixed, and coincident with certain star-groups ; but this assumption crumbles to the ground if precession is accepted. But as historical records now show, though astronomers had clearly recognized that the initial point should be the point of intersection of the equator and the ecliptic, there was no unanimity even amongst ancient astronomers of different ages regarding the location of this point in the heavens, because it was not occupied by any prominent star at any epoch and the ancients were unaware of the importance of its motion (*vide* § 4·9).

4.7 CHALDEAN CONTRIBUTIONS TO ASTRONOMY : RISE OF PLANETARY AND HOROSCOPIC ASTROLOGY

We have seen that it was the needs of the calendar which gave rise to scientific astronomy—which in the earliest times covered :

(a) Systematic observation of the movements of the moon, and the sun,

(b) Recording of the observations in some convenient form on permanent materials,

(c) Invention of mathematical methods to deal with the observations, with a view to predict astronomical events.

It is not, however, correct to say that it was the calendar based on the sun and the moon which provided the sole stimulus for astronomical studies. At one time, *"the planets strongly captured the attention of man"*.*

The attention of mankind was drawn in remote antiquity to the five star-like bodies :

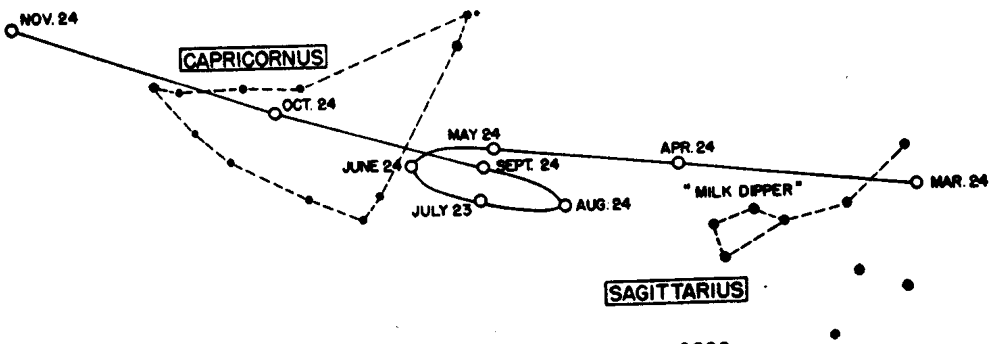
Venus, Jupiter, Mars, Saturn and Mercury.

Venus and Jupiter and occasionally Mars are more brilliant than ordinary stars. Sooner or later it was found that while the ordinary stars remain fixed on the revolving heavens these five stars creep along them, as a modern author puts it, *'like glow-worms on a whirling globe'*, each in its own way. Venus appears as a morning and evening star, the maximum elongation being 47°. It early drew the attention of sea-faring people, its appearance on the eastern horizon indicating early sunrise to persons on lonely seas. But it took mankind some time to discover that it was the same luminary which appeared for some period as a morning star, then as an evening star. Its brilliance could not but strike the imagination of mankind. Mercury also appears regularly as morning and evening star, and it must have been discovered later than Venus, but still at such a remote age in antiquity that all traces of its discovery are lost.

The motion of the brilliant luminary, Jupiter across the sky attracted early attention ; Mars occasionally bursts into brilliance with fierce, red light, which could not but attract notice. The three planets, Mars, Jupiter, and Saturn though generally moving to the east, from time to time reverse their direction of motion (retrograde motion), as shown in Fig. 11.

From very early times and amongst widely separated communities, mystical importance was ascribed to the wandering of the planets.

These mystical ideas took a very definite form in the shape of *'Planetary Astrology'* which grew in Mesopotamia during the period 1800 B.C. to 800 B.C. This Planetary Astrology is to be distinguished from



The Path of Mars Among the Stars in 1939.

Fig. 11—Showing the retrograde motion of Mars.

Although the planets always move in the same direction round the sun, their apparent motion among the fixed stars as seen from the earth, is not always in the same forward direction. They sometimes appear to move also in the backward direction among the stars, and this is known as the retrograde motion of a planet. The above figure reproduced from *Pictorial Astronomy* by Alter and Cleminshaw illustrates how Mars was seen to retrograde during June 24 to August 24.

* A. Pannekoek : *The Origin of Astronomy*, p. 351.

an older form of Astrology widely found in Vedic India, which centred mainly round the moon, and the lunar mansions, and to a lesser extent on the sun. The conjunction of the moon with certain *nakṣatras* was considered lucky, others unlucky (*vide* § 4·1).

Planetary Astrology took the world by the storm after 300 B.C. and its influence was strongest during middle ages in Europe, till the rise of rationalism and modern science almost completely undermined this influence. But it still survives amongst the credulous in the West, but to a far greater extent than amongst the eastern nations.

emerged in Babylonian history from the time of Assyrian supremacy (*ca.* 1300 B.C.), for these appeared to be linked up with the mysteries of Heaven itself, and the astrologer enjoyed very great prestige amongst the public, for did he not possess the mysterious power of foretelling correctly the dates of eclipses !

Here are some of the samples of astronomical omina during the last centuries of Assyrian power (900 B.C.-600 B.C.).

"Mercury went back as far as the Pleiades" ; "Jupiter enters Cancer" ; "Venus appears in the East" ; "Mars is very bright" ; "Jupiter appears in the region of Orion" ;

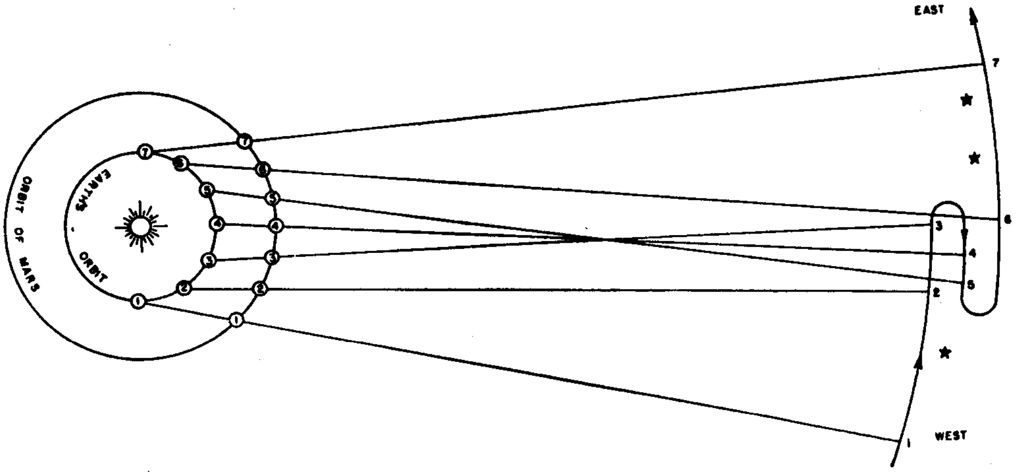


Fig. 12—Showing the motion of Mars relative to the earth.

By placing the sun at the centre and having the earth and the other planets revolve in circles around it, Copernicus (1473-1543) was able to explain the backward motion of the planets among the stars much more simply than in the Ptolemaic system. This is illustrated in the above figure, taken from *Pictorial Astronomy*, in the case of Mars as seen from the earth. The earth's speed is 18½ miles a second while that of Mars is only 15 miles a second. As the earth overtakes Mars, the latter seems to move backward. The direct motion of Mars to the east is shown at positions 1, 2 and 3, backward or retrograde motion to the west at 4 and 5, and direct motion to the east again at 6 and 7.

What was the reason for the strong fascination which man has for astrology ?

Mankind has always a psychological weakness for omina, *i.e.*, some signs which can predict future events, good or bad. The older form of omina were rather crude, *viz.*, flight of certain birds like the crow, or movements of animals like the jackal or the snake, howlings of certain birds and animals. In many countries, sheep and goats were sacrificed to gods on the eve of great enterprises, and Augurs claimed to be able to interpret the intentions of the gods from an examination of lines and convolutions on the liver of the sacrificial animal (Hepatoscopy). Meteorological phenomena such as a lightning discharge, haloes round the moon, aurora were also regarded as 'omens'.

The older forms of omina were all apparently very crude compared to planetary omina which gradually

"Mars stands in Scorpio, turns and goes forth with diminished brilliancy" ; "Saturn has appeared in the Lion" ; "Mars approached Jupiter" ; and so on.

There is not a trace of scientific interest in these texts ; the mind of the reporters is entirely occupied by the omens : When such or such happens,

"it is lucky for the king, my lord" ;
or, "copious floods will come" ;
"there will be devastation" ;
"the crops will be diminished" ;
"the king will be besieged" ;
"the enemy will be slain" ;
"there will be raging of lions and wolves" ;
"the gods intend Akkad for happiness" ;
and so on.

Yet, with all those observations, these reports represent a considerable astronomical activity. For the first time in history a large number of data on the planets had been collected ; it implies a detailed knowledge of facts about their motion."*

The huge temples, called Ziggurats, ruins of which have been found in Mesopotamia, are supposed to have been dedicated to the planetary gods, each storey being assigned to a particular god. It was the duty of temple priests to keep the planets under observation, and record their positions on the only writing material available then *viz.*, clay-tablets. Hundreds of thousands such clay tablets have been discovered in the ruins of Ziggurats, royal palaces and libraries, and patiently interpreted by western scholars like Kugler.

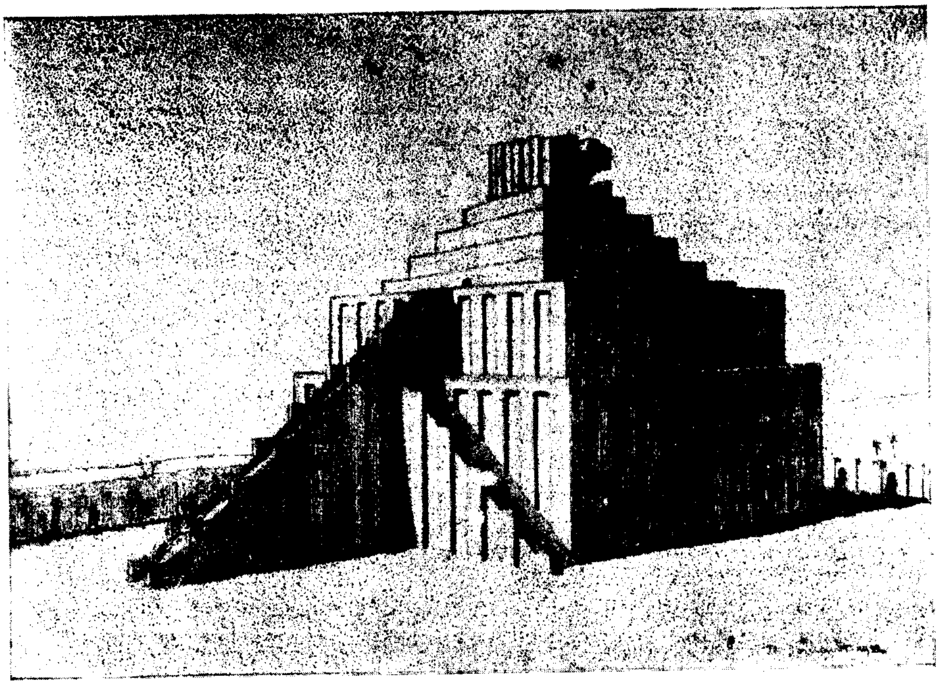


Fig. 13—Ziggurat.
(Reproduced from Zinner's *Geschichte der Sternkunde*)

At first, planetary astrology appear to have been confined to states, and kings or powerful officials representing the state. But after the conquest of Babylon by the Persian conqueror Cyrus (538 B.C.), they appear to have been extended to private individuals. Thus came into existence 'Horoscopic Astrology', in which a chart is made of the 12 signs of the zodiac with the position of the planets shown therein, for the time of his birth, from which are foretold the events of his life and career. We are not interested in 'Horoscopic Astrology' at all, but wish only to remark that but for the stimulus provided by astrology, there would not have been that intense activity during ancient and (from about 500 B.C.) medieval times, for large scale observations of the sun, the moon, and the planets, and compilation of tables of positions, which afforded the basis on which modern astronomy has been built up. In the large number of ancient horoscopes which have been studied by scholars, and in the astronomical tables compiled by ancient and medieval scholars, we have a huge amount of data on planets.

Pannekoek observes :

"The circumstance that made this possible for astronomy was the occurrence of extremely simple and striking periodicities in the celestial phenomena. What looked irregular on occasional and superficial observing revealed its regularity in a continuous abundance of data.

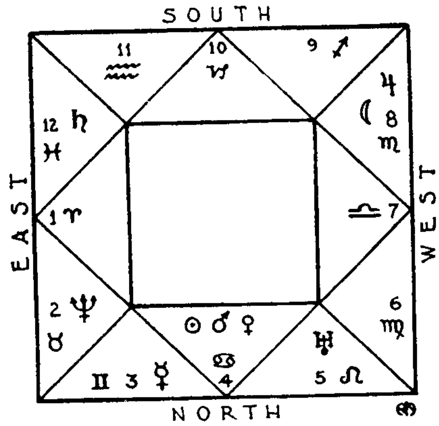


Fig. 14—Showing a horoscope cast in the European method. The sign Aries, the first house or ascendant, is in the east. The sign Capricornus, the 10th house, is on the meridian at the time of birth and so is in the south. The planets occupying the different signs are shown by the respective symbols.

* Pannekoek : *The Origin of Astronomy*—reprinted from the Monthly Notices of the Royal Astronomical Society, Vol III, No. 4, 1951, pp. 351-52.

Regularities were not sought for ; but regularities imposed themselves, without giving surprise. They aroused certain expectations. Expectation is the first unconscious form of generalized knowledge, like all technical knowledge in daily life growing out of practical experience. Then gradually the expectation develops into prediction, an indication that the rule, the regularity, has entered consciousness. In the celestial phenomena the regularities appear as fixed periods, after which the same aspects return. Knowledge of the periods was the first form of astronomical theory".*

The astronomical knowledge which the Chaldean astronomers bequeathed to the world are :—

(1) Conception of the celestial equator and racognition of the ecliptic as the sun's path.

(2) A number of relations between the synodic and other periods of the moon and planets, *viz.*,

1 year = 12.36914 lunar months ;
modern value = 12.36827 lunar months.

Mean daily motion of the sun = 59′ 9″ ;
modern value = 59′ 8″.3.

Mean daily motion of the moon = 13° 10′ 35″ ;
modern value = 13° 10′ 35″.0

Extreme values of the true motion of the moon :
15° 14′ 35″ to 11° 6′ 35 .

According to modern determination these limits are about 15° 23′ to 11° 46′.

Length of the anomalistic month = 27.55555 days ;
modern value = 27.55455 days.

Or 9 anomalistic months = 248 days ;
modern value = 247.991 days.

Length of the synodic month = 29.530594 days ;
modern value = 29.530588 days.

223 synodic months = 242 draconitic months.
This gave rise to the Chaldean Saros cycle of eclipses.

269 anomalistic months = 251 synodic months.
The length of the anomalistic month deduced from this relation = 27.554569 days, the modern value being 27.554550 days.

The Greek papyri gives longitudes of the moon for dates 248 days apart. This period is based on the Babylonian relation : 9 anomalistic months = 248 days. After eleven such steps of 248 days, there is a big step of 303 days in the ephemeris. The length of the anomalistic month derived from these steps are as follows.

	No. of anomalistic months	*No. of days*	*Length of the anomalistic month derived*	
D	9	248	27.555,556	days
△	11	303	27.545,455	„
C = 11D + △ ...	110	3031	27.554,545	„
		Actual value =	27.554,550	„

It is not sure whether these figures were arrived at by the Babylonians or by astronomers of other places. But these and the more accurate approximation of the moon's motion is found in the *Pañca Siddhāntikā* of Varāhamihira and is found used by Tamil astronomers.

In the *Pañca Siddhāntikā* the synodic revolutions of planets are given, but they apparently differ much from the actual figures. The figures are quoted in col. (2) of the table No. 9 below. The actual periods of the synodic revolutions in days are given in col. (3).

Table 9.—Synodic revolutions of planets from Pañca-Siddhāntikā.

Planet	*As given in P.S.*	*Actual (days)*	*Converted from Col. (2) (days)*
(1)	(2)	(3)	(4)
Mars	$768\frac{3}{4}$	779.936	779.944
Mercury	$114\frac{6}{29}$	115.878	115.870
Jupiter	$393\frac{1}{7}$	398.884	398.868
Venus	$575\frac{1}{2}$	583.921	583.880
Saturn	$372\frac{2}{3}$	378.092	378.093

Dr. Thibaut in his *Pañca Siddhāntikā* could not explain the figures in col. (2). It can be verified that we can obtain the figures in col. (3) if we multiply the corresponding figures in col. (2) by

$$\frac{365.2422}{360} \text{ or by } \left(1+\frac{5.2422}{360}\right)$$

The figures obtained by such multiplication are shown in col. (4), which are found to be very close to the fgures in col. (3). The figures in col. (2) can be explained in another way, *viz.*, they are in degrees representing the arc through which the sun moves between two conjunctions. In other words, the figures in col. (2), not being ordinary mean solar days, are '*saura days*' of Indian astronomy, a *saura* day being the time taken by the sun to move through one degree by mean motion, or 360 *saura* days = 365.2422 mean solar days. This explanation has been found by O. Neugebauer (*vide* his *Exact Sciences in Antiquity*). Most of these data were known to Hipparchos and also to Geminus, a Greek astronomer, who flourished about 70 B.C.

The "astronomical science" as evolved by the Chaldean astronomers, is seen to be in reality the by-

*Pannekoek : *The Origin of Astronomy*, p. 352.

product of the huge amount of astrological nonsense, a few pearls in a huge mass of dung, as Alberuni observed nearly ten centuries ago. Let us see when these "pearls" gradually crystallized out of the dung-heap.

Two texts called *'Mul Apin'* dated round about 700 B.C. have been discovered which contain summary of the astronomical knowledge of the time. Here is one of the pertinent passages from Neugebauer's *Exact Sciences in Antiquity* (p. 96).

"They are undoubtedly based on older material. They contain a summary of the astronomical knowledge of their time. The first tablet is mostly concerned with the fixed stars which are arranged in three "roads", the middle one being an equatorial belt of about 30° width. The second tablet concerns the planets, the moon, the seasons, lengths of shadow, and related problems. These texts are incompletely published and even the published parts are full of difficulties in detail. So much, however, is clear: we find here a discussion of elementary astronomical concepts, still quite descriptive in character but on a purely rational basis. The data on risings and settings, though still in a rather schematic form, are our main basis for the identification of the Babylonian constellations."

The passage indicates that the Chaldean astronomers of this period could locate the north pole, and had come to an idea of the celestial equator, and could trace it in the heavens. We do not know when they came to the knowledge that the celestial equator cuts the horizon at the east and west points as determined by the gnomon.

The Ecliptic :—From archæological records, it is generally held that a knowledge of the star-groups lying close to the ecliptic was obtained in Babylon as early as 1300 B.C., for some of the ecliptic star-groups like the Cancer, or Scorpion are found portrayed on boundary

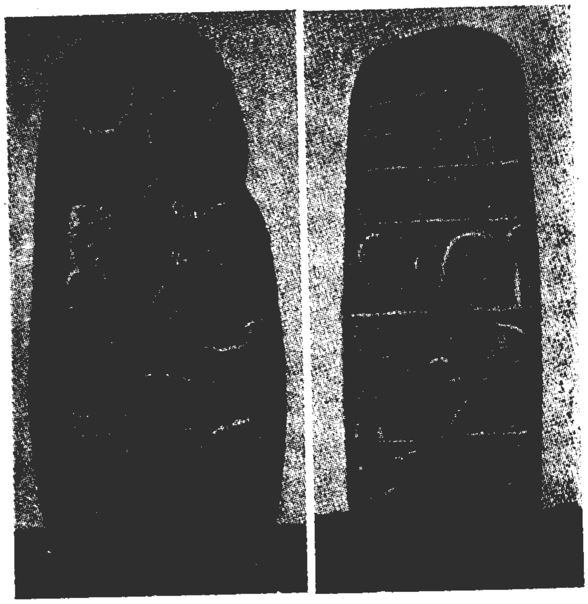


Fig. 15—Two sculptured stones of ancient Babylon displaying the Sun, the Moon, Venus and Scorpion—symbols of a primitive astrological science which fathered the modern conception of astronomy.

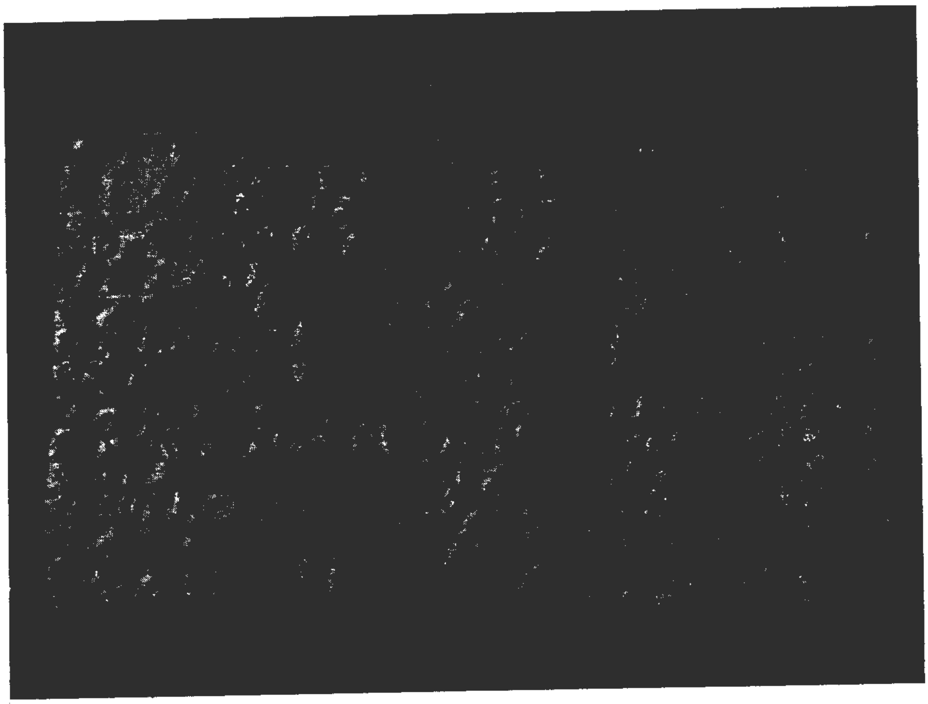


Fig. 16—Babylonian Boundary Stone showing Pythagorian numbers (Plimpton 322).
(Reproduced from Neugebauer's *Exact Sciences in Antiquity*)

stones which can be dated 1300 B.C. Neugebauer and Sachs maintain that the ecliptic is first found mentioned in a Babylonian text of 419 B.C., but its use as a reference plane must have started *much* earlier, probably before 550 B.C. But the steps by which the knowledge of stars marking the ecliptic

Fig. 17—Babylonian Boundary stone showing lunar ephemeris engraved on it (A. 3412 Rev.) (*Exact Sciences in Antiquity*)

was obtained, are not yet known with precision. Only some guesses can be made.

The early astronomers probably observed that the bright stars Regulus (α *Leonis*), Spica (α *Virginis*), the conspicuous group Pleiades, and certain fainter stars α *Librae*, α *Scorpii* were almost on the sun's path. The ecliptic could be roughly constructed by joining these stars.

'Regulus' or α *Leonis* was the 'Royal Star' in Babylonian mythology. In Indian classics, it is known as *Maghā* (or the Great) and the presiding deity is *Indra*, the most powerful Vedic god. It is almost exactly on the ecliptic. *Citrā* (or α *Virginis*) is 2° to the south.

The First Point of Aries :—The first point of Aries is the fiducial point from which all astronomical measurements are made. But how was this point, or any other cardinal point, say the first point of Cancer (summer solstice), the first point of Capricornus (winter solstice) and the first point of Libra, were located on the circle of the ecliptic in early times ?

For rarely have the first point of Aries nor any other of the cardinal points been occupied by prominent stars during historical times. Even if for measurement, the ancient astronomers used some kind of astronomical instrument, say the armillary sphere, it would be difficult for them to locate the first point of Aries correct within a degree.

Probably the first stage was to determine the angular distance of heavenly bodies from some 'Normal Stars' as indicated by Sachs.* These normal stars were stars either on the ecliptic, like Regulus, Spica, or α *Librae* or some other stars close to it. Sachs gives *a list of 34* such normal stars. Probably the ecliptic positions of these normal stars were determined after some effort by some method not yet known, and then the positions of other heavenly

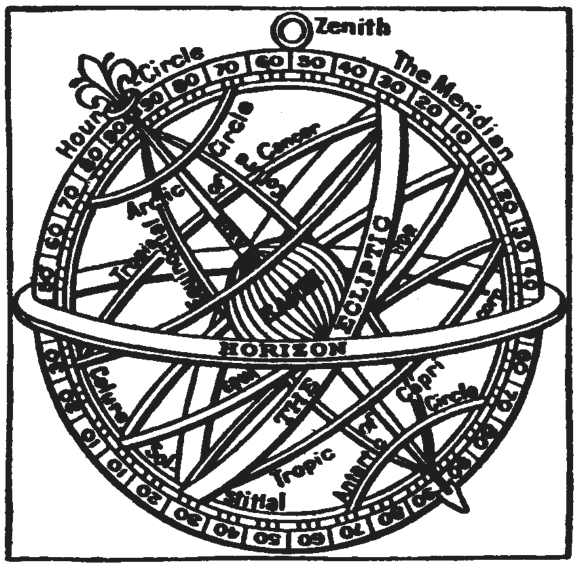


Fig. 18—Armillary sphere.
(Reproduced from *Encyclopaedia Britannica*).

bodies referred to the first point of Aries or the beginning of a sign could be found. The early observations are rough and no accuracy of less than a degree is claimed by any classical scholar for them.

* A. Sachs, Babylonian Horoscopes, p. 53, *Journal of Cuneiform Studies*, Vol. VI. No. 2.

Precession of Equinoxes :—But the first point of Aries is not a fixed point on the ecliptic, though all ancient astronomers belived it to be *fixed* once for all. It moves steadily to the west at the rate of 50″ per

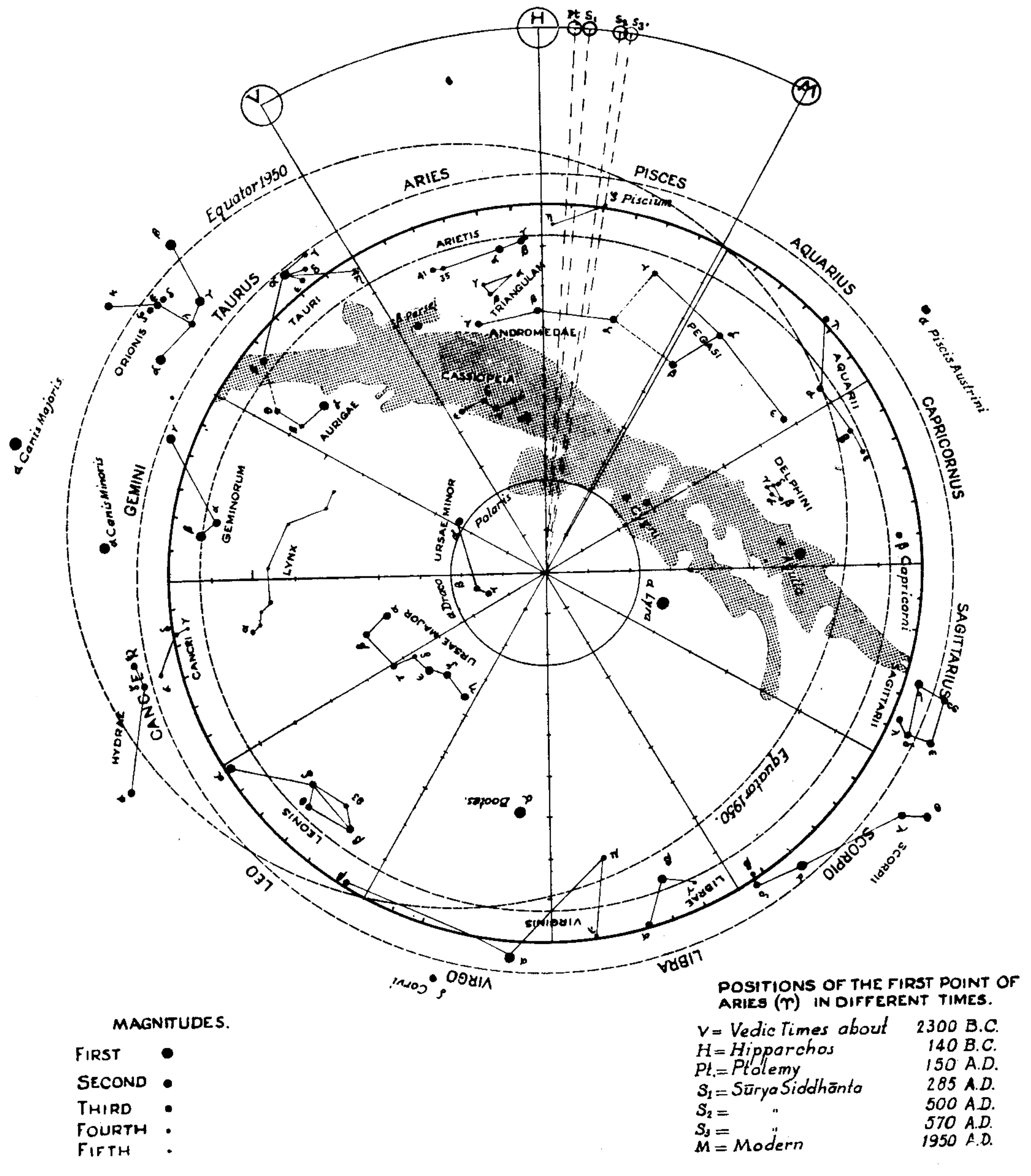


Fig. 19—The Zodiac through ages.

year. Astronomers of different ages must have given measurements of stellar positions from observations made either during their own times, or from observations made by their predecessors, quite unconscious of the fact that the reference point had shifted. The result is that the positions of stars given by different astronomers of antiquity do not tally, and the positions given by the *same astronomer are not always consistent*. This is illustrated in Fig. 19 of the Zodiac.

Let us take Hipparchos's First point of Aries ♈ as our standard point.

Ptolemy's first point of Aries ♈ is 4° to the west of Hipparchos's.

Clay tablet records have been obtained in Mesopotamia which have been interpreted as representing two systems of Ephemeris known as Systems A and B. System B indicates that the vernal point is Aries 8°. This indicates that the observations were taken about 550 years before Ptolemy. This coincides approximately with the time of the Chaldean astronomer Kidinnu, who observed at Borsippa near Babylon, and is taken to be the author of the nineteen-year cycle. System A uses Aries 10° as the vernal point ; the author of this system might have flourished 120-150 years before Kidinnu, and may be identified with Naburiannu, son of Balatu, who flourished about 490

B.C. Older still is the use of Aries 15° by Eudoxus of Cnidus, the first Greek astronomer to start a geometrical theory of planetary motion. This refers to observations dating from about 810 B.C. These dates, before they are accepted, should receive independent verification.

The Use of Spherical Co-ordinates

The ancient astronomers were interested primarily in the moon and the planets but later about 150 B.C., Hipparchos gives lists of fixed stars as well with their positions.

It was clearly observed that though these planets keep near the ecliptic, they deviate by small amounts sometimes to the north, sometimes to the south. In the case of the moon, the maximum deviation amounts to nearly 5° (inclination of the moon's orbit to the ecliptic). In the case of planets, excepting in the case of Mercury and Venus, the deviation was not large.

In the case of the moon, a knowledge of the moon's celestial latitude was necessary for prediction of eclipses and therefore both the celestial longitude and latitude used to be recorded by the Chaldean astronomers of the Seleucidean period. In the case of planets, only the celestial longitude appear to have been used.

The Chaldean astronomers were the first to frame lunar and planetary ephemerides (*i.e.* calculation in advance of lunar and planetary positions—the precursor of modern Nautical Almanacs and Ephemerides) from about 500 B.C. But during these times, neither the knowledge of the sphere nor of spherical or plane trigonometry had developed. The Chaldeans had only developed the ideas of angular measurement which they expressed in degrees, minutes and seconds, the whole circle being divided into 360° degrees. Their methods, which have been elucidated by Neugebauer, Sachs and others were arithemetical. They took maximum and minimum values of astronomical quantities, and interpolated for an intermediate period, assuming the change to be linear (zigzag function, *vide* Neugebauer, *Exact Sciences in Antiquity*, Chap. V, Babylonian Astronomy).

It was the Greeks who introduced geometrical methods to deal with positions of heavenly bodies, and made the next great advance in astronomy. But they developed trigonometry only to a rudimentary stage (*vide* § 4·8). But they also used Babylonian arithmetical methods alternately. Thus while Ptolemy uses the trigonometric chord functions in his *Syntaxis*, in the astrological text, called *Tetrabiblos*, he uses the Babylonian arithmetical methods.

Though the calendar, as we have seen, gave the first stimulus for the cultivation of the astronomical science, the use of astronomy for perfecting the calender appears in the West to have come to a stop after the Seleucidean era. For Rome conquered the whole western Asia up to the Euphrates by about 80 A. D., and the Julian calendar replaced the Babylonian luni-solar calendar, which have, however, continued to currency probably in limited regions like Syria, Arabia and Iraq amongst certain communities. The Sassanid Persians also followed their own solar calendars inherited from Acheminid times. But the elements of the Chaldean luni-solar calendar have been used in a limited way, for the Christian ecclesiastic calendar for Christianity arose in Palestine and Syria, and the most important event in Christ's life, His crucifixion, is recorded in terms of the luni-solar calendar prevalent in Palestine about the first century A.D.

4.8 GREEK CONTRIBUTION TO ASTRONOMY

It has been considered necessary to give a short account of Greek contributions to astronomy, because there is a widespread view that it was Greek astronomy which formed the basis of calendar reform in India which took place about 400 A.D. (*Siddhānta Jyotiṣa* calendar). Let us see how far this view is correct. The Greeks themselves appear to have made no use of astronomy for the reform of their own calendars, as was done later in India. They cultivated astronomy partly as pure science, partly as an indispensable adjunct to astrology.

It is now well-known that Greek civilization had a long past going back to at least 1500 B.C. The remains of this civilization have been found in Crete (Minoan), and on the Greek mainland itself (Mycenean). Inscriptions have been found in strange scripts (Linear A, and B) which defied decipherment till 1952. We have therefore as yet no knowledge of the calendar in the Mycenean age of Greece (1400 B.C.—1000 B.C.), but probably they will now be forthcoming.

The Homeric poems '*Iliad*' and '*Odyssey*' written about 900 B.C., as well as Hesiod writing about 700 B.C. show considerable acquaintance of stars and constellations needed for sea-faring people, to find out their orientation when out at sea.

From about 750 B.C., the Greek city-states began to emerge ; they were engaged in maritime trade over the whole Mediterranean basin. These activities brought them into contact with many older nations who had attained a high standard of civilization, e.g., the Egyptians, the nations of the Near East, *viz*., the Lydians, the Phoenicians, and the Assyrians and imbibed many elements of their civilization. The older Greek scholars themselves admit that the Greeks borrowed their script* from the Phoenicians, their coinage from the Lydians, their preliminary ideas of geometry from the Egyptians and of astronomy from the Chaldeans. But they enriched all these sciences beyond measure by their own original thoughts and contributions. As Plato (428-348 B.C.) proudly remarks : "...*whatever the Greeks acquire from foreigners, is turned by them into something nobler.*"

Greek science goes no further back than Thales of Miletus (624-548 B.C.), who is reckoned to be the first of the seven sages of Greece. Considerable knowledge of astronomy and physics was ascribed to him by later writers. He is supposed to have predicted the occurrence of an almost total solar eclipse, which occurred on May 28, 585 B.C., on the basis of his knowledge of the Chaldean Saros. These stories are now disbelieved by scholars well versed in Assyriology, for according to their finding, the Chaldeans themselves before 400 B.C., had no knowledge of the Saros of 18 years $10\frac{1}{3}$ days used later to predict the eclipses, but they used other methods with only partial success. Thales might have used one of these methods, but not certainly the Chaldean Saros. Considering the crude state of Greek civilization in Thales' times, these scholars think that it is a fairytale of modern times that Thales knew anything about the Saros. Thales lived in a coastal city of Asia Minor which had active contact with the great civilizations of the Near East, and probably much of the knowledge ascribed to him were picked up from Babylon and Egypt.

The next figure in Greek astronomy is Anaximander, (610-545 B.C.), likewise of Miletus a junior contemporary of Thales, who is said to have introduced the use of the gnomon (*vide* § 4·3). This may be conceded, but this practice was derived most probably from the Chaldeans, who used the gnomon from much earlier times. Cleostratos (530 B.C.) of Tenedos was cited by later authors to have introduced the knowledge of the zodiac, of the eight-year cycle of intercalations in Greece, but probably he merely transmitted the Babylonian knowledge and practice. Meton of Athens is said to have introduced the nineteen-year cycle of 7 intercalary months in Athens in 432 B.C., but as remarked earlier, its use in Greek calendars cannot be dated before 342 B.C., though it was known in Babylon from at least 383 B.C. The question of priority of this discovery is still to be decided, probably by fresh finds and interpretation of ancient astronomical records.

We have besides philosophers of the Pythagorian school (500-300 B. C.), a religious brotherhood which cultivated geometry, astronomy, physics and mathematics. They are cited by later writers to have propagated the view that the earth was a sphere, and the planets were also spherical bodies like the earth, but it is difficult to state when, and on what grounds these theories were first propounded.

These were the periods of tutelage. Greek genius in astronomy began to flower only after 400 B.C., and was aided by a number of causes.

The first was the development of geometry as a science by philosophers of the Pythagorean school (500-300 B. C.), and other scholars, notably Hippocrates of Chios (450-430 B.C.), and Democritos of Abdera (460-370 B.C.). A great impetus to both plane and solid geometry was given by Plato (428-348 B.C.), famous philosopher and founder of a school of studies and research known to the world as the '*Academy*'. Plato counted amongst his contemporaries and juniors several geometers of distinction, *viz*., Archytas of Tarentum (first half of fourth century B.C.), Theaitetus of Athens (*c.* 380 B.C.), Eudoxus of Cnidos (d. 355 B.C.), and several others. All the geometrical knowledge developed by these and other scholars was compiled, and rewritten into a logical system with rich contributions of his own by Euclid, who lived in the Museum of Alexandria (280 B.C.), and was bequeathed to the world in thirteen (or fifteen) books known as the ***Elements of Euclid***, which have remained to this day the basis of the teaching of elementary geometry. There is no other book of science which have remained current and authoritative for such a long stretch of time, now extending over two thousand years.

The second factor was political. During the sixth and fifth centuries before Christ, the Greek savants and scholars had indeed undertaken educational journeys to the Near East in search of knowledge —journeys which were made possible and safe under the orderly regime of the Acheminid empire (Persian). But it was the conquest of the Persian empire by Alexander of Macedon in 330 B.C., which rendered these contacts easier and more fruitful. The Greek successor dynasties, *viz.*, the Ptolemaic dynasty in Egypt, and the Seleucid dynasty in Babylon and other dynasties in Asia Minor were all great patrons of learning and encouraged and maintained scholars ; the former set up the famous Museum at Alexandria, which was a research institution with a great library, an observatory and other necessary equipment. It attracted scholars from all parts of Greater Greece and provided them with free board, lodge and a salary. This place nurtured a number of great Greek geniuses :

* It appears that the Greeks of Homeric poems used linear A and B, but about 900 B.C., they borrowed the simpler Phoenician script and adopted it to their use by the addition of vowels. Thereby they forgot their old script and history, which became myth and legend. The decipherment of Minoan Linear B has been achieved in 1952 by Ventris and Chadwick.

Euclid, already mentioned; Eratosthenes who first measured correctly the diameter of the earth and was the founder of scientific chronology; and others whom we shall meet presently.

On the Asiatic side, under the centralized rule of the Seleucids, the later Chaldean and Greek astronomical efforts became very much intermingled. A Chaldean priest, Berossus, who lived during the reign of the second Seleucidean king Antiochos Soter (282-261 B.C.), translated into Greek the standard Chaldean works on astronomy and astrology. The period from 340 B.C. to 150 A.D. may be called the most flourishing period of astronomical studies in antiquity. The Chaldeans figured prominently during the earlier part of this period but their methods were based on a primitive form of algebra and arithmetic. According to Neugebauer, their contributions in mathematics and astronomy were as good as those of the contemporary Greeks who used geometry, but they gradually faded into obscurity on account of their infatuation with astrology; and the Greeks, though they were great believers in astrology, freed themselves at least from astrolatry, and cultivated astronomy as part of astrology, and emerged as leaders in astronomical science.

The earliest Greek astronomer to use geometrical ideas in astronomy is, if we leave aside the Pythagoreans, probably Eudoxus of Cnidos (d. 355 B.C.), a junior contemporary, friend and pupil of Plato. He made great original discoveries in geometry, and Books V and VI of Euclid are ascribed to him. It was probably his knowledge of geometry which led him to make the first scientific attempt to give a geometrical explanation for the irregular motions of the sun, the moon, and the planets. Twenty-seven spheres, all concentric to the earth were needed to account for these motions. This theory had but a short life, but it is remarkable as the first instance, when heavenly bodies, connected with great gods, were treated on a human level.

Eudoxus is supposed to be the inventor of geometrical methods for determining the sizes and distances of the sun and the moon, usually ascribed to Aristarchus of Samos (*fl.* 280 B.C.), who is known to have taught that the daily revolution of the celestial sphere was due to the rotation of the earth round its axis. He is also said to have first put forward the heliocentric theory of the universe. Neither of these theories was accepted by contemporary astronomers. The world had to wait for the appearance of a Copernicus (1473-1543), for the acceptance of these views.

Apollonius of Perga (born about 262 B.C.) known more for his treatise on Conics, originated the theory of epicycles, and eccentrics to account for planetary motion. He was a junior contemporary of two great figures: Eratosthenes already mentioned and Archimedes of Syracuse (287-212 B.C.), a great figure in mechanics, hydrostatics and other sciences, but to astronomy, he is remembered as originator of the idea of Planetarium—a revolving open sphere with internal mechanisms with which he could imitate the motions of the sun, the moon, and the five planets.

Archimedes is also credited with attempts for finding out the actual distances of the planets from the earth. We do not know whether this is correct or not, but about this time, we find the planets arranged according to the order of their distances from the earth:

Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn

or if we take the reverse order:

Saturn, Jupiter, Mars, Sun, Venus, Mercury, Moon.

This last order was taken up by astrology and formed the basis of the seven-day week, which came into vogue about the first century A.D.

The greatest name in Greek astronomy is Hipparchos of Nicaea, in Bithynia who settled in the island of Rhodes and had an observatory there (*fl.* 161-127 B.C.). He probably corresponded with the savants at the Museum of Alexandria. Not much of his writings have come down to us, except through quotations and remarks by Claudius Ptolemy, the famous Alexandrian astronomer who flourished three centuries later. Sarton writes about Hipparchos:

> "It is possible that all the Ptolemaic instruments, except the mural quadant, had already been invented by him (e.g. diopter, parallactic and meridian instruments). He was the first Greek observer who divided the circles of his instruments into 360 degrees. He constructed the first celestial globe on record.
>
> He used and probably invented the stereographic projection. He made an immense number of astronomical observations with amazing accuracy".

The principle of measurement of angles was certainly derived from the Chaldeans. Hipparchos gave a catalogue of 850 stars with their positions which is reproduced in Ptolemy's *Syntaxis*. Vogt found that of the 471 preserved numbers giving position, 64 are declinations, 67 are right ascensions, 340 are in polar longitudes and latitudes, which reappear in the *Sūrya Siddhānta*, six hundred years later.

It is suggested that after his discovery of precession (*vide* § 4.9), Hipparchos probably used celestial longitudes and latitudes. But these co-ordinates had been already used by the Chaldeans at least a century earlier.

Hipparchos had probably some knowledge of plane and spherical trigonometry necessary for the solution of astronomical problems, *e. g.*, finding out the time of rise of zodiacal signs during the year, a problem of great importance to horoscopic astrology. It is the current opinion that he used the double chord, illustrated below :

$$\text{Chord } (2\,\alpha) = 2\text{ R Sin }\alpha$$

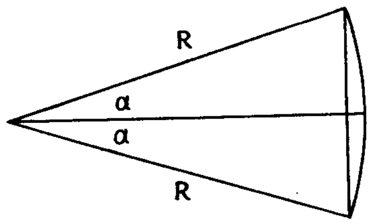


Fig. 20

and gave a table of double-chords from 0° to 90°, which was later improved by Ptolemy in his *Syntaxis*. It is suggested by Neugebauer, that the 'Sine function' (*Jyā* in Hindu astronomy) was introduced 600 years later by Āryabhaṭa, and replaced the double chord. The Hindu astronomers used *Utkramajyā* which is the ver sine function, 1—cos α, but do not appear to have used the cosine function as such. Neither the Greeks nor the Hindus used the tangent, and the cotangent, which were introduced by Arab astronomers about the ninth century (al-Battānī, 858-929 A.D.), and were known in Latin in early days as *Umbra Versa*, and *Umbra Extensa* (extent of shadow) respectively. These are reminiscent of the practice of designating the zenith distance Z of the sun by the length l of the shadow of the gnomon, $l = p \tan Z$, p being the height of the gnomon.

Between Hipparchos and Claudius Ptolemy (150 A.D.), who lived at the Alexandrian Museum from 128 A.D. to 151 A.D., there is a gap of 300 years, which saw the phenomenal rise of horoscopic astrology. There are, however, very few great names in astronomy. Menelaos, a Greek astronomer who lived in Rome about 98 A.D., laid the foundation of spherical trigonometry, but it was confined to a transversal proposition from which Ptolemy deduced solutions for only right angled spherical triangles, of which either two sides or an angle and one side are given. The Hindu astronomers likewise used only solutions of right angled spherical triangles. The discovery of general relations in spherical triogonometry was the work of Arabic astronomers (al-Battānī).

Claudius Ptolemy who worked at Alexandria between 128-151 A.D., was, as Sarton says, a man of the Euclidean type. Great equally as an astronomer, mathematician, geographer, physicist, and chronologist, his main work is the great mathematical and astronomical treatise known in Greek as '*Syntaxis*', and in Arabic translation as the *Almagest*. It has been long supposed that it rendered all previous treatises in astronomy obsolete, and remained a standard text, which fertilized the brains of all ancient and medieval astronomers, Greek, Jew, Arab, and European, till the rise of the heliocentric theory of the universe rendered it obsolete. This opinion appears to have been rather exaggerated. Strangely enough, the *Syntaxis* appears to have been quite unknown to Hindu astronomers of the 5th century A.D.

Ptolemy's chief contribution to astronomy was his elaborate theory of planetary motion and discovery of a second inequality in the motion of the moon, now called *Evection*. He gave a catalogue of 1028 stars with their positions, most of which have been shown to have been taken from Hipparchos by adding 3° to the longitudes given by him. This represents the shift of the first point of Aries since Hipparchos's time according to Ptolemy's calculation. The actual value is 4°.

Ptolemy wrote a treatise on astrology known as the "*Tetrabiblos*" which long remained the Bible of the astrologers.

After Ptolemy, there were no great figure in astronomy except few commentators and workers of mediocre ability like Theon of Alexandria (about 370 A.D.), who initiated the false theory of trepidation of the equinoxes, and Paulus of Alexandria (fl. 378 A.D.) who wrote an astrological introduction. He is supposed to have been the inspirer of the Indian Siddhānta known as '*Pauliśa*' *Siddhānta*' (*vide* § 5·6), but this hypothesis started by Alberuni has never been proved. With the advent of Christianity, and after murder of the learned Hypatia (415 A.D.), the 'light' goes out of Greece.

The Greek contributions to astronomy are :

A geocentric theory of the universe, with the planets in the order given on page 203.

The treatment of planets as spherical bodies similar to the earth.

Geometrization of astronomy, development of the concepts of the equator, the ecliptic and of spherical co-ordinates (right ascension and declination, celestial latitude and longitude), some elementary knowledge of plane and spherical trigometry to deal with astronomical problems.

Knowledge of planetary orbits, and attempts to explain them with the aid of epicyclic theories.

4.9 DISCOVERY OF THE PRECESSION OF THE EQUINOXES

In the previous sections, we have stated how the Chaldean and Greek astronomers started giving positions of planets, and stars, with the point of intersection of the ecliptic and the equator—the first point of Aries—as the fiducial point. We shall now relate how the discovery was made that this point is not fixed in the heavens, but has a slow motion along the ecliptic to the west at the rate of *ca.* 50″ per year. The rate is very small, but as it is unidirectional and cumulative, it is of immense importance to astronomy, and incidentally is very damaging to astrology.

When the sun, in course of its yearly journey arrives at the first point of Aries, we have the vernal equinox. The first point of Aries is therefore also called the *vernal point.*

The position of the vernal point has rarely in the course of history, been occupied by a prominent star, but in India, as narrated in § 5·4, its nearness to star-groups as well as the nearness of other cardinal points to star-groups have been noted from very early times. Traditions of different epochs record different stars as being near to the cardinal points. But nobody appeard to have drawn any conclusion from these records (*vide* for details § 5·4).

In Babylon also, different sets of positions of stars and planets record Aries 15°, Aries 10°, and Aries 8° (the zero is of Ptolemy's) as being the vernal point. But no Chaldean astronomer to our knowledge appears to have drawn any conclusion from these data.

The first astronomer known to have drawn attention to the precession of the equinoxes was Hipparchos. He particularly mentions that the distance of the bright star Spica (*α Virginis* or *Citrā*) has shifted by 2° from the autumnal equinoctial point since the time of his predecessor Timocharis who observed at Alexandria about 280 B.C. He concluded that the autumnal point, and therefore also the vernal point, was moving westward at the rate of $51\frac{1}{2}$ seconds per year.

It is not known whether Hipparchos considered the motion as unidirectional. It was impossible for him to say anything definite on this point, as obeservations extending over centuries are required to enable one to make a definite statement on this point.

Though Hipparchos made, as time showed, one of the greatest astronomical discoveries of all times, which is all-important for the calendar, as well as for astronomy, its great importance does not appear to have been realized by either his contemporaries or followers for thousands of years.

Let us, therefore, dwell a little on the consequences of this discovery. Later and more accurate observations have shown that the rate is nearly 50″ per year, but is subject to variations which we may disregard at this stage. The shift is accumulative and in 100 years would amount to 1° 24′, and in about 26000 years the first point will go completely round the ecliptic. The period depends upon certain factors and is not constant.

The tropical year, or the year which decides the recurrence of seasons, is the time-interval for the return of the sun in its orbit, starting from the year's vernal equinoctial point to the next vernal equinoctial point. If these points were fixed on the ecliptic, the tropical year would be the same as the sidereal year, which is the same as the time of revolution of the earth in its orbit. But since the vernal equinoctial point slips to the west, the sun has to travel $360° 0' 0'' - 50'' = 359° 59' 10''$ to arrive at the new vernal equinoctial point, hence the duration of the tropical year is less than that of the sidereal year by about 20 minutes. In exact terms :

duration of the sidereal year = 365.25636 mean solar days
" " " tropical " = 365.24220 "
at the present time.

Further Consequences of the Precession of the Equinoxes

We may now consider some consequences of the precession of the equinoxes.

Hipparchos appears first to have marked out the beginning of the astronomical first point of Aries. It started 8° west of the star *α Arietis.* Ptolemy had found that it had shifted by his time by about 3°, and gave the rate of precession as 36″ per year. In this, he was wrong, the true shift being about 4°. Ptolemy in his '*Uranometry*' gives the starting point of the sign of Aries as 6° to the west of *β Arietis,* and the other constellations marked at intervals of 30° may be marked out on the zodiac. The picture (Fig. 19) gives the boundaries of the different signs according to Hipparchos. The boundaries of the signs of Ptolemy would be 4° to the west of those of Hipparchos.

By the time of Ptolemy, (and probably much earlier), a complex system of *astrology* had developed which connected men's destiny in life with the position of planets in the different signs at the time of his birth (horoscopy). It was claimed that even the fortunes of nations and countries could be calculated in advance from planetary positions in the signs. Though a few rational men like Seneca and Cicero were as much sceptical about the claims of astrology as the modern man, the general mass became converted to its claims, even astronomers not excepted. Even the great Ptolemy wrote a treatise '*The Tetrabiblos*' exposing the principles of Astrology.

In fact, belief in astrology was one of the main incentives for the observation of the positions of heavenly bodies in ancient and medieval times which were carried out by medieval astronomers with so much zeal under the willing patronage of influential persons.

The discovery of precession is very disconcerting to astrologers, for in the astrological lore, the signs are identified with certain fixed star-clusters ; whereas precession tends to take them entirely out of these star-clusters. Thus since Hipparchos's time, the shift has been nearly 30 degrees, and what was the sign of Pisces in Hipparchos's time has now become the sign of Aries, and the astronomical sign of Aries has now nothing to do with the Aries constellation.

This consequence must have been foreseen by the followers of Ptolemy, and they probably started, more on psychological than on scientific grounds, to find out theories to mitigate the devastating influence of precession on astrology. Astronomers immediately following Ptolemy barely mentioned precession. It was first referred to by Theon of Alexandria (*ca.* 370 A.D.) who invented the theory of *Trepidation, i.e.,* he said that the precessional motion was not unidirectional, but oscillatory. He gave the amplitude of oscillation as 8°. Probably this figure was suggested by the fact that at Theon's time the first point of Aries had shifted by a little less than 8° from Hipparchos's position, and Theon thought that it would go back and save astrology.

Proclos the successor (410-485 A.D.), head of the Platonic Academy at Athens, a very learned man and one of the founders of Neoplatonism, denied the existence of precession !

After the sixth century A.D., the dark age set in Europe and the mantle of scientific investigation fell on the Hindus and the Arabs. Let us see how the Arab astronomers regarded the precession.

Thabit ibn Qurra (826-901 A.D.), who flourished at Baghdad under the early Abbasides, translated Ptolemy's *Almagest* into Arabic ; he noted precession, but upheld the theory of trepidation. But the other great Arabic astronomers like al-Farghānī (861-Baghdad), al-Battānī (858-Syria), Abd al-Rahamān al-Ṣūfī (903-986-Teheran) and Ibn Yūnus (d. 1009—Cairo), all noted precession and rejected the theory of trepidation. In fact al-Battānī gave the rate of precession as 54″ per year, which is far more correct than the rate given by Ptolemy, *viz.*, 36″ per year.

But unfortunately, Europe recovering from the slumbers of dark ages were more influenced by the Spanish-Muslim astronomers al-Zarquali (1029-1087 of Cordova). and al-Bitruji (*ca* 1150, living at Seville), who upheld the theory of trepidation. As their influence was considerable. they were largely responsible for its diffusion among the Muslim, Jewish and Christian astronomers, so much so that Johann Werner (1522) and Copernicus himself (1543) were still accepting it ; Tycho Brahe and Kepler had doubts concerning the continuity and regularity of the precession, but they finally rejected the trepidation. The theory of trepidation was completely given up in Europe after 1687, when Newton gave a physical explanation of it from dynamics and the law of gravitation. This is given in appendix (4-A), for the benefit of Indian astrologers and almanac-makers who still believe in the theory of trepidation and oppose reform of the wrong calendar they are using for centuries.

Sarton from whose writings much of this account has been compiled, writes* :

"The persistence of the false theory of trepidation is difficult to understand. At the very beginning of our era, the time span of the observations was still too small to measure the precession with precision and without ambiguity, but as the centuries passed there could not remain any ambiguity. Between the stellar observations registered in the *Almagest* and those that could be made by Copernicus, almost fifteen centuries had elapsed, and the difference of longitudes would amount to 21°."

* Sarton, *A History of Science*, p. 446.

APPENDIX 4-A

Newton's Explanation of the Precession of the Equinoxes

In view of the prevailing confusion in the minds of Indian almanac makers regarding precession of the equinoxes, a short sketch of the physical explanation of the phenomenon originally given first by Newton is given here in the hope that those amongst Indian calendar makers who believe in science, may be persuaded to give up their belief in the theory of trepidation and be converted to the *sāyana* reckoning advocated in these pages. This explanation will be found in any standard book on Dynamics or Dynamical Astronomy, *e.g.*, in Webster's *Dynamics*.

We have now to regard the earth as a material sphere, spinning rapidly round its axes, which is inclined at an angle of $\frac{\pi}{2}-\omega$ to the plane of the ecliptic, where ω=obliquity of the ecliptic to the equator.

The earth is kept in its orbit by the gravitational pull of the sun, which is situated at one of the foci of the earth's orbit which is an ellipse. Dynamics shows that the plane of the ecliptic is almost invariant, *i.e.*, does not change with time, except a very small oscillation due to attraction of other planets on the earth. What is then precession due to ?

This is explained by means of the following figure.

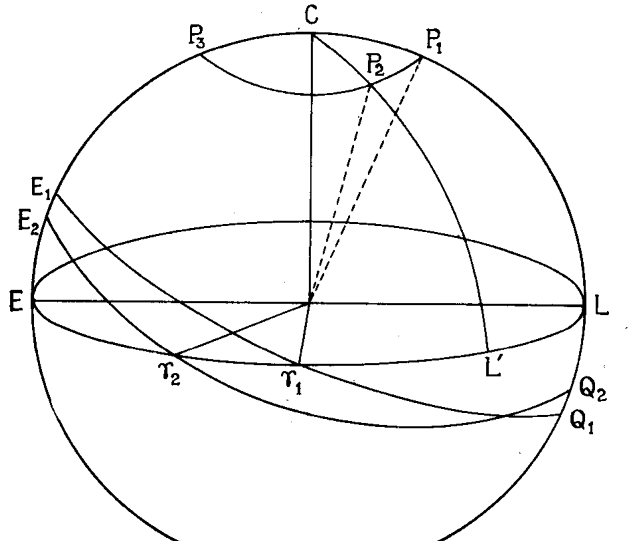


Fig. 21—Showing the precession of the equinoxes.

In the above figure (No. 21), C is the pole of the ecliptic $EL'L$. Let Υ_1 midway between E and L be the first point of Aries for year 1. Then the celestial pole is P_1, and the celestial equator is $E_1\Upsilon_1 Q_1$. Due to precession of the equinoxes, the first point of Aries is slowly moving in the backward direction $L\ \Upsilon_1\ E$ along the ecliptic. If Υ_1 shifts to Υ_2 in year 2, the celestial pole shifts to P_2 along the small circle $P_1\ P_2\ P_3$...,where CP=obliquity of the ecliptic. The celestial equator assumes a new position $E_2\ \Upsilon_2\ Q_2$ in year 2.

The celestial pole P therefore goes round the pole of the ecliptic C, and it makes a complete cycle in a period of about 26000 years as shown in fig. 22.

At present (1950 A. D.), the celestial pole is 58′ from Polaris (*α Ursæ Minoris*) which is a star of the second magnitude. CP, *i.e.*, the line joining the pole of the ecliptic C to the celestial pole P continues to approach the Polaris up to 2105 A. D., when the pole would be only 30′ away from the star and will then begin to recede from it.

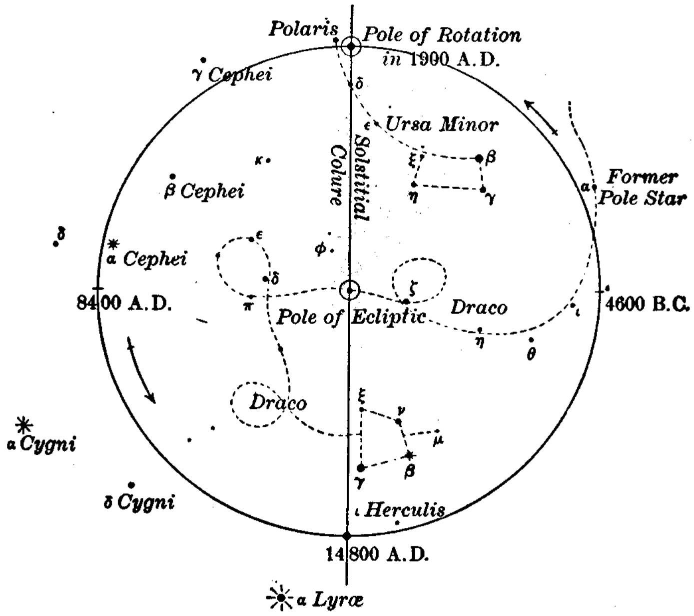


Fig. 22—Showing the precessional path of the celestial pole among the stars.
(Taken from *Astronomy* by Russell & others)

It will be seen that the celestial pole has not been marked with a prominent star for most part of this period of 26000 years. About 2700 B. C., the second magnitude star *α Draconis* was the pole-star, as was probably known to the ancient Egyptians, the Chinese and the Ṛg-Vedic Hindus. Conscious human history hardly goes beyond this period. The prominent stars which will become pole stars in future are :

γ Cephei............4500 A.D.
α Cephei............7500 A.D.
δ Cygni ....11200 A.D.
α Lyræ (Vega)...13600 A.D.

The last is a first magnitude star, the brightest in the northern heavens and can be easily picked up with the naked eye.

The phenomenon of precession of the equinoxes tells us that in addition to rotation, the earth has another motion, *viz.*, a slow conical motion of its axis round the pole of the ecliptic which causes the equinoxes to move bakward. The phenomenon can be visualized by reference to the motion of tops played by boys (Fig. 23).

It is a matter of common experience with those who have played with tops that when the top is thrown spinning on the earth, the axis round which the top is spinning very often is not vertical, but is oblique ; and it is also having a slow motion in a circle round the vertical as shown in fig. 23. This last motion is *precessional motion.* The top may be likened to the earth, and the vertical direction of gravity, corresponds to the pole of the ecliptic. The

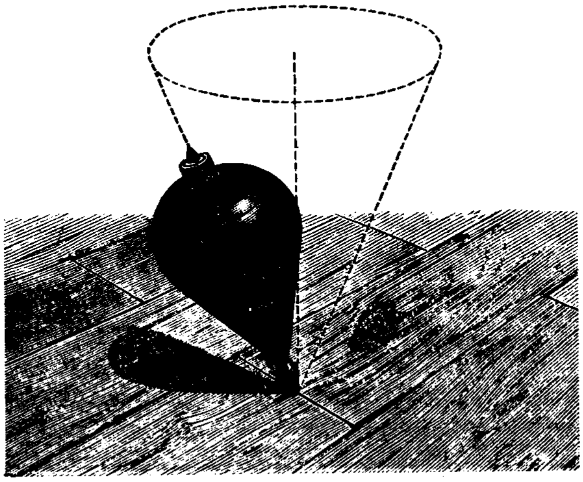


Fig. 23—Motion of a top.
The spinning top, which is likened to the earth, causes precessional motion of its axis.

top would have fallen but for its spin. When it slows down, the top falls down ; the precessional motion of the top is due to the pull exerted by the gravity.

Now turning to the earth, we see that as a first approximation, we may take it as a point of mass concentrated at the centre, and then deduce its orbit as is done in classical planetary theory. This would have been all right, if the earth were a *homogeneous sphere*. But the earth is not a sphere, but a spheroid, having its polar axis shorter than the equatorial axis by 43 kms. (=27 miles). There is an equatorial bulge of matter. The pull due to the sun, is now equivalent to a force in the ecliptic passing through the centre of the earth defining the orbital motion, plus a couple, which tends to turn the equator of the earth into the plane of the ecliptic. It is this couple which produces *precessional motion.*

For details of calculation the reader may refer to a book on Rigid Dynamics, say A.G. Webster, *Dynamics*, pp. 298-302. We mention only the results here :

If ψ be the angle of precession, *i.e.*, the angle P_1CP_2 in fig. 21. we have due to the sun's attraction

$$\psi=\frac{3\gamma m}{2\Omega r^3}\times\frac{C-A}{C}\cos\ \omega\ \left(t-\frac{\sin\ 2l}{2n}\right)$$

where :

γ = gravitational constant = 6.67×10^{-8} c. g. s. units ;
C = moment of inertia of the earth round the polar axis ;
A = moment of inertia of the earth round an equatorial axis ;
ω = obliquity of the ecliptic = 23° 26′ 45″ ;
m = mass of the sun = 1.99×10^{33} gms ;
r = distance of the earth from the sun = 1.497×10^{13} cms ;
$\frac{\gamma m}{r^3}$ = tide-raising term ;
l = longitude of the sun ;
n = angular velocity of the earth ;
Ω = angular rotational speed of the earth in radians.

If the earth were a homogeneous sphere, C would be $=A$, and $\psi=0$. But taking the polar radius $c=a\,(1-\epsilon)$, where ϵ = ellipticity of the earth, it can be shown that for the earth, in which concentric layers are taken to be homogeneous

$$\frac{(C-A)}{C}=\epsilon=\frac{1}{297}\ \text{(nearly)}.$$

But actually $\frac{C-A}{C}$ is the mechanical ellipticity of the earth, the value of which has been found by observation as $\frac{1}{304}$.

Substituting the values as given above in the expression

$$\frac{d\psi_s}{dt}=\frac{3\gamma m}{2\Omega r^3}\cdot\frac{C-A}{C}\ \cos\,\omega\ (1-\cos\,2l)$$

we get the progressive part of the solar precession $=2{\cdot}46\times10^{-12}$.

This is in radians per second of time. To convert it to seconds of arc per year, we have to multiply the expression by $2.063\times10^5\ \times3.156\times10^7$.

2.063×10^5 being the number of seconds of angle in a radian, and 3.156×10^7 the number of seconds of time in the year.

We have therefore the rate of solar precession $=16.''0$ per year.

We have now to calculate the action of the moon which, in spite of its much smaller mass, exerts a far larger perturbing force as the lunar distance is much smaller. In fact the tide raising force $\left(\frac{\gamma m}{r^3}\right)$ for the moon is more than double that of the sun. This makes the rate of lunar precession = 34″.4 per year.

But there is another complication. The moon's orbit is not coincident with he sun's path (ecliptic) but is inclined at an average angle of 5° 9′, the extreme values being 5° 19′ and 4° 59′. Further the points of intersection of the moon's orbit with the ecliptic travel round the ecliptic in a period of 18.6 years. The pole of the moon's orbit M therefore moves round the pole of the ecliptic C as shown in fig. 24 in a period of 18.6 years. The lunar precessional angle ψ_m has therefore to be defined from the instantaneous position of M.

Combination of the two precessional motions.

The two precessions can be combined as in fig. 24. Here C, M are the poles of the ecliptic and of the moon's orbit. P is the celestial pole. The solar precession can be represented by the vector ψ_s along the line PS perpendicular to CP, but the lunar precession is represented by the vector PR, which goes up and down as M goes round C in a

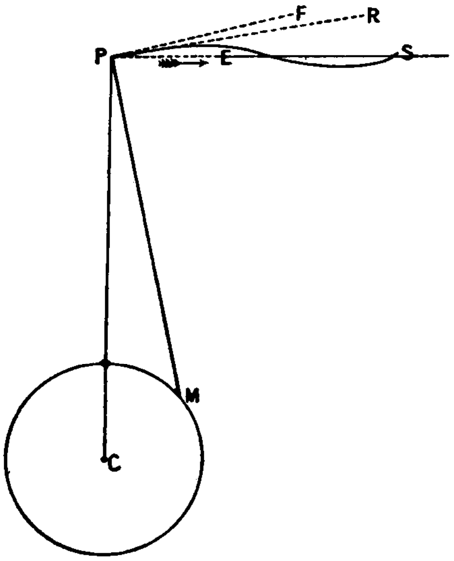


Fig. 24—Combination of two precessional motions.

complete cycle of 18.6 years (period of moon's node). Therefore the motion is equivalent to

$$\psi_{ms} = \psi_s + \psi_m \text{ Cos } MPC \ldots \text{parallel to } PS.$$
$$\psi_n = \psi_m \text{ Sin } MPC \ldots \text{perpendicular to } PS.$$

This causes certain irregularities in the precessional motion and also in the annual variation of the obliquity of the ecliptic, which would otherwise have been uniform. These periodic (period=18·6 years) variations are known as *Nutation*.

Annual Rate of Precessional Motion

The solar and lunar precessions amount to 50."37 per tropical year, with a very small centurial variation. After making necessary corrections for the slight motion of the plane of the ecliptic due to attraction of planets, the annual rate of general precession in longitude is obtained as follows :—

Rate of precession = 50."2564 + 0."0222 T per trop. year, where T = Tropical centuries after 1900 A.D.

The nutation in longitude may amount to ±17."2 according to different positions of the lunar node, but its effect on the annual *rate of precession* does not exceed ±5."8, so that the actual precession rate per year may vary between 44."5 to 56."0.

The average rate of annual precession is not constant, it is very slowly increasing. The annual rate for certain epochs along with the period taken by the equinoxes to move through 1°, are however stated below :—

	Rate of precession	*No. of years per degree*
2000 B.C.	49."391	72.89
0	49.835	72.24
1900 A.D.	50.256	71.63
2000 A.D.	50.279	71.60

APPENDIX 4-B

Stars of the Lunar Mansions

Comparative statement showing the Indian *Nakṣatras*, Chinese *Hsius*, and Arabic *Manzils*, together with the names of stars comprising the mansions.

Indian *Nakṣatra*				Chinese *Hsiu*		Arabic *Manzil*		Junction star (*Yogatārā*) of the Nakṣatra	Magnitude	Celestial Latitude	Celestial Longitude (1956)
No. (1)	No. (2)	Name	Meaning	No.	Name	No.	Name				
1	27	Aśvinī (β, γ Arietis)	Equestrian	16	Lou (α, β, γ Arietis)	1	ash-Sharaṭāni (β, γ Arietis)	β Arietis	2.72	+ 8° 29′	33° 22′
2	28	Bharaṇī (35, 39, 41 Arietis)	Bearer	17	Wei (35, 39, 41 Arietis)	2	al-Buṭain (35, 39, 41 Arietis)	41 Arietis	3.68	+ 10 27	47 36
3	1	Kṛttikā (Pleiades)	Interlaced	18	Mao (Pleiades)	3	at-Turaijā (Pleiades)	η Tauri	2.96	+ 4 3	59 23
4	2	Rohiṇī ($\alpha, \theta, \gamma, \delta, \epsilon$ Tauri)	Ruddy	19	Pi ($\alpha, \theta, \gamma, \delta, \epsilon$ Tauri)	4	al-Dabarān ($\alpha, \theta, \gamma, \delta, \epsilon$ Tauri)	α Tauri	1.06	− 5 28	69 11
5	3	Mṛgaśiras ($\lambda, \theta_1, \theta_2$ Orionis)	Stag's head	20	Tzu ($\lambda, \theta_1, \theta_2$ Orionis)	5	al-Haq'ah ($\lambda, \theta_1, \theta_2$ Orionis)	λ Orionis	3.7	− 13 23	83 6
6	4	Ārdrā (α Orionis)	Moist	21	Ts'an ($\alpha, \beta, \gamma, \delta, \epsilon, \xi, \eta, \kappa$ Orionis)	6	al-Han'ah ($\eta, \mu, \nu, \gamma, \xi$ Geminorum)	α Orionis	0.6 v	− 16 2	88 9
7	5	Punarvasu (α, β Geminorum)	The good again	22	Ching ($\mu, \nu, \gamma, \xi, \lambda, \zeta, \epsilon$ Gemin.)	7	adh-Dhirā'u (α, β Geminorum)	β Geminorum	1.21	+ 6 41	112 37
8	6	Puṣya (γ, δ, θ Cancri)	Flower	23	Kuei ($\gamma, \delta, \theta, \eta$ Cancri)	8	an-Naṭrah (γ, δ, ϵ Cancri)	δ Cancri	4.17	+ 0 5	128 7
9	7	Āśleṣā ($\eta\ \sigma, \delta, \epsilon, \rho, \zeta$ Hydrae)	Embracer	24	Liu ($\eta, \sigma, \delta, \epsilon, \rho, \zeta, \omega, \theta$ Hydrae)	9	aṭ-Ṭarf (ξ Cancri, λ Leonis)	ϵ Hydrae (α Cancri)	3.48 (4.27)	− 11 6 (− 5 5)	131 44 (133 2)
10	8	Maghā ($\alpha, \eta, \gamma, \zeta, \mu, \epsilon$ Leonis)	Generous	25	Hsing (α, ι Hydrae)	10	al-Jabhah (α Leonis and 3 more)	α Leonis	1.34	+ 0 28	149 13
11	9	Pūrva Phalgunī (δ, θ Leonis)	The first Phalgunī	26	Chang ($\kappa, \lambda, \mu, \theta, \nu, \upsilon$, Hydrae)	11	az-Zubrah (δ, θ Leonis)	δ Leonis	2.58	+ 14 20	160 42
12	10	Uttara Phalgunī (β, 93 Leonis)	The second Phalgunī	27	I (α Crateris)	12	as-Sarfah (β Leonis)	β Leonis	2.23	+ 12 16	171 1
13	11	Hasta ($\delta, \gamma, \epsilon, \alpha, \beta$ Corvi)	Hand	28	Chen ($\gamma, \epsilon, \delta, \beta, \eta$ Corvi)	13	al-'awwā ($\beta, \eta, \gamma, \delta, \epsilon$ Virginis)	δ Corvi	3.11	− 12 12	192 51
14	12	Citrā (α Virginis)	Bright	1	Chio (α Virginis)	14	aṣ-Ṣimāk (α Virginis)	α Virginis	1.21	− 2 3	203 14

Stars of the Lunar Mansions—*contd.*

Indian *Nakṣatra* No. (1)	No. (2)	Name	Meaning	Chinese *Hsiu* No.	Name	Arabic *Manzil* No.	Name	Junction Star (*Yogatārā*) of the Nakṣatra	Magnitude	Celestial Latitude	Celestial Longitude (1956)
15	13	Svāti (α Bootis)	Sword	2	K,ang (ι, κ, λ, μ Virginis)	15	al-Ghafr (ι, κ, λ Virginis)	α Bootis	0.24	+ 30° 46′	203° 38′
16	14	Viśākhā (α, β, ι, γ Librae)	Branched	3	Ti (α, β, ι, γ Librae)	16	az-Zubānay (α, β Librae)	α Librae (ι Librae)	2.90 (4.66)	+ 0 20 (− 1 51)	224 28 (230 23)
17	15	Anurādhā (β, δ, π Scorpii)	Propitious	4	Fang (β, δ, π, ρ Scorpii)	17	al-Iklīl (β, δ, π Scorpii)	δ Scorpii	2.54	− 1 59	241 58
18	16	Jyeṣṭhā (α, σ, τ Scorpii)	First born	5	Hsin (α, σ, τ Scorpii)	18	al-Qalb (α Scorpii)	α Scorpii	1.22	− 4 34	249 9
19	17	Mūla (λ, υ Scorpii)	Root	6	Wei (All the stars in the tail of Scorpion)	19	ash-Shaulah (λ, υ Scorpii)	λ Scorpii	1.71	− 13 47	263 59
20	18	Pūrvāṣāḍhā (δ, ε Sagittarii)	Former Unconquered	7	Chi (γ, δ, ε Sagittarii and β Telescopii)	20	an-Na'ājim (γ, δ, ε, η, θ, σ, τ, ζ Sagittarii)	δ Sagittarii	2.84	− 6 28	273 58
21	19	Uttarāṣāḍhā (θ, τ, σ, γ Sagittarii)	Latter Unconquered	8	Tou (θ, τ, σ, γ, λ, μ Sagittarii)	21	al-Baldah (Space vacant of stars above the head of Sagittarius)	σ Sagittarii	2.14	− 3 27	281 47
—	20	*Abhijit* (α, ε, ξ Lyrae)	Victorious	9	Niu (α, β Capricorni)	22	Sa'd adh-dhābiḥ (α, β Capricorni)	α Lyrae	0.14	+ 61 44	284 42
22	21	Śravaṇa (Śroṇā) (α, β, γ Aquilae)	Ear (lame)	10	Nü (ε, μ, υ Aquarii)	23	S'ad-bula' (ε, μ, υ Aquarii)	α Aquilae	0.89	+ 29 18	301 10
23	22	Dhaniṣṭhā (Śraviṣṭhā) (α, β, δ, γ Delphini)	Wealthy (most famous)	11	Hsü (β, ξ Aquarii)	24	Sa'd-as-Su'ūd (β, ξ Aquarii)	β Delphini	3.72	+ 31 55	315 44
24	23	Śatabhiṣaj (Śatatārakā) (λ Aquarii and 100 adjacent stars)	Hundred physicians (hundred stars)	12	Wei (α Aquarii ; θ, ε Pegasi)	25	Sa'd al-ahbija (α, γ, ζ, η Aquarii)	λ Aquarii	3.84	− 0 23	340 58
25	24	Pūrva Bhādrapadā (α, β Pegasi)	Former auspicious feet	13	Shih (α, β Pegasi)	26	al-Fargh al-awwal (α, β Pegasi)	α Pegasi	2.57	+ 19 24	352 53
26	25	Uttara Bhādrapadā (γ Pegasi, α Andromedæ)	Latter auspicious feet	14	Pi (γ Pegasi, α Andromedæ)	27	al-Fargh al-tāni (γ Pegasi, α Andromedæ)	γ Pegasi	2.87	+ 12 36	8 33
27	26	Revatī (32 Stars of which southernmost is ζ Piscium)	Wealthy	15	K'uei (16 Stars from ψ Piscium to γ Andromedæ)	28	baṭn-al-Ḥūt (β Andromedæ & other stars)	ζ Piscium	5.57	− 0 13	19 16

Note :—The first series of numbers under the column 'Indian *Nakṣatra*' starts from Aśvinī as 1 following the Siddhāntic system, and the second series starts from Kṛttikā according to the older system which includes Abhijit.

CHAPTER V

Indian Calendar

5.1 THE PERIODS IN INDIAN HISTORY

The time-periods in Indian history necessary for our purpose are shown in the Chronological Table.

The earliest civilization so far discovered in India is the Harappā-Mohenjo-Daro civilization (sometimes also called the Indus-Valley civilization) named after the two ancient buried cities of Harappā in the Punjab and Mohenjo-Daro in Sind. They were first brought to light by the late R.D. Banerjee, Superintendent of the Western Circle of Archaeology of India in 1924. It has now been ascertained that this civilization extended right upto Rupar on the Sutlej in the east and to the Narmadā valley in the south. This civilization was certainly contemporaneous with the Mesopotamian civilizations of about 2500 B.C., nearly 500 years before the city of Babylon had risen to supremacy amongst the cities of Sumer and Akkad; and with the first dynastic civilization of Egypt. How far back it projected into the time-scale is not yet known, but certainly many thousand years back.

From the material records of the Indus-valley civilization, it is obvious that the Harappā-Mohenjo-Daro people had attained to as high a standard of civilization, if not higher, as the contemporary people of Iraq and Egypt. But the script has not yet been deciphered; it is therefore difficult to give a chronological history, but it is not so difficult to make a study of the attainments of this civilization in arts and sciences; they could build well planned cities, used a drainage system superior to that of contemporary Egypt or Iraq, used copper and bronze, and had evidently evloved a highly complex social organization.

All civilized communities have been found to have evolved accurate systems of weights and measures and some kind of calendar for the regulation of social life. We have some evidences of the use of standard weights and measures in the Indus valley.

But had they evolved a calendar? The presumption is that they must have, but nothing has yet been discoverd amongst the artefacts left by these people so far recovered by the Archaeological Survey which throws light on the calendar, or the system of time-measurement they used.

It is held on quite sound grounds that the Harappā-Mohenjodāro people were succeeded in the Punjab and in the valley of the now lost Sarasvatī river by the Aryan people who were either autochthonous or more probably came through Afghanistan in single or successive streams between 2500 B.C. and 1500 B.C. Others would go further back in time-scale from certain astronomical evidences.

Few, almost none of the material records or artefacts of the early Aryans except some potteries tentatively ascribed to them, have so far been discovered. Almost the whole of our knowledge about them are derived from the hymns of the Ṛg-Vedas which were composed by priestly families amongst them in an archaic form of Sanskrit (Vedic Sanskrit), in honour of the gods they worshipped; in these hymns are found occasional references to the sun, the moon, certain stars, and to months and seasons. Some think that there are also references to planets, *i.e.*, the Vedic Aryans could distinguish between fixed stars and planets, but this is doubtful. From certain references which we discuss in § 5.2, we may conclude that they used an empirical luni-solar calendar. Probably this was used till 1300 B.C. We do not come across sufficient material records until we come to the time of Aśoka about 270 B.C.

What was the calendar during the period 1300 B.C.—250 B.C.? The *Yajur-Veda*, the *Brāhmaṇas*, the *Upaniṣads* and other post Ṛg-Vedic literature, and the early Buddhistic literature contain occasional astronomical references, from which the nature of the calender used for ceremonical and other purposes can be inferred. The interpretation of the texts is neither easy, nor unambiguous. The latter part of this period has been called by S. B. Dīkṣit, our pioneer in calendar research, as the *Vedāṅga Jyotiṣa period*. This is discussed in § 5.4.

The Vedāṅga Jyotiṣa calendar appears to have been almost completely free from foreign influence, though this point of view has been contested. The Persian conqueror Darius conquered Afghanistan, and Gāndhār, about 518 B.C.; this region appears to have continued under the Achemenids for nearly two centuries. The Achemenids used a solar calendar probably adopted from Egypt in contrast to the luni-solar calendar of India, but this does not appear to have disturbed the indigenous luni-solar calendarical system.

The Vedāṅga Jyotiṣa period, which as we shall show, was continued by Indian dynasts up to the time of the Sātavāhanas (200 A.D.), was succeeded by the *Siddhānta Jyotiṣa* period, but the first record of this period is available only about 400 A.D. The transitional period from 100 A.D. to 400 A.D. is one of the darkest periods in Indian chronology. Due to successive invasions by Macedonian and Bactrian Greeks (*Yavanas*), Parthians (*Pallavas*), Śakas and Kuṣāṇas, the period from 300 B.C. to 200 A.D. is one of large foreign contacts which profoundly modified Indian life in arts, sciences, sculpture and state-craft. But the history of this period was entirely forgotten and is being recovered bit by bit from inscriptions, foreign references, and from artefacts recovered in excavations of the sites occupied by invaders of this period. Let us give a bird's eye view of the history of this period, imperfect as it is, so that the reader may follow without strain our account of the transition of the *Vedāṅga Jyotiṣa* calendar to *Siddhāntic* calendar.

In 323 B.C., Alexander of Macedon raided the Punjab, but this incident by itself had no such profound influence on Indian life as is generally made out. Its influence was rather indirect. In India, it gave rise to a great national movement of unification under Candragupta and Cāṇakya. In the former empire of Darius, it gave rise to a number of Greek states which became the focus of radiation of Greek culture throughout the East. The most important were Egypt under the rule of the Ptolemies, with capital at Alexandria, and the Near East under the Seleucids with capital at Babylon, which was succeeded a few years later by Seleucia a few miles distant from later Baghdad. In 306 B.C., Candragupta and Seleucus faced each other, but the Greek army was rolled back to the borders of modern Iran, and almost the whole of modern Afghanistan except Bactria (modern Balkh) constituting the four satrapies of the old Persian empire were ceded to India. They continued to be politically and culturally parts of India till the tenth century A.D.

The Mauryas kept out the Greeks till 186 B.C., when on the break-up of their empire, the Greek settlers in Bactria who had revolted from their overlords, the Seleucids, began to make inroads into India. There were two rival Greek houses, the earlier, the Euthydemids who under Demetrius and Menander (175 B.C.) took possession of the Punjab and Sind between 180 B.C. to 150 B.C. and threatened even Pātaliputra but were rolled back beyond the Jamunā by the Śuṅgas ; the line of Eukratidas who ousted Demetrius and his line from Bactria and Afghanistan proper about 160 B.C., reigned in Afghanistan up to 50 B.C. But there rose about 226 B.C., a great barrier between the Eastern Greeks (Bactrians and Indian Greeks) and the Western Greeks in the shape of the Parthian empire (248 B.C.), which became very powerful under Mithradates I (175—150 B.C.), who controlled the whole of Iran and wrested Bactria from the line of Eukratidas in 138 B.C.

But inspite of these political happenings, Greek remained the language of culture throughout the whole Near East, from Asia Minor to North-Western India. The Parthians since 128 B.C. called themselves 'Philhellens' or lover of Greek culture and used Greek on their coins, and the Graeco-Chaldean method of date-recording on their inscriptions. But about 140 B.C., a new power was on the move, *viz.*, the Śakas from Central Asia ; they began to emerge as a ruling race from about 138 B.C. In 129 B.C. they attacked Bactria, and by 123 B.C. they wrested it completely out of the Parthian empire, after defeating and killing on the battlefield two successive Parthian emperors, *viz.*, Phraates II (128 B.C.) and Artabanus I (123 B.C.).

The early Śakas appear from their coins to have been under the spell of Greek civilization, and used Greek as a language of culture and put motifs taken from Greek mythology on their coins. Pressed by the next Parthian emperor, Mithradates II (123—90 B.C.), they poured by 80 B.C., into the whole of what is modern Afghanistan, except the Kabul valley, which the Greeks held for sometime. Their new territory became known as 'Śakasthān' comprising modern Afghanistan and parts of N.W. India. From Afghanistan, they poured in successive streams to Mālwa, Guzrāt, Taxilā about 70 B.C., and to Mathurā, somewhat later and had put an end to the numerous Greek principalities in the Punjab. Their further progress was barred by the Sātavāhanas in the South, and numerous small kingdoms which arose in the Gangetic valley on the break-up of the Śuṅga and Kāṇva empires (45 A.D.). After 50 A.D., the Śakas of the North were supplanted by the Kuṣāṇas belonging to a kindred race, and speaking the Śaka language ; they ruled Northern India from their capitals at Peshawar and Mathurā up to at least 170 A.D. Contemporaneously with them, were the Śaka Satrap houses of Ujjain, who started ruling from about first century of the Christian era.

A chart of these historical incidents is attached for the sake of elucidation as they are necessary for the comprehension of the extent and amount of Greek culture, which was propagated into India, *not so much through the Greeks directly*, but as it appears now, indirectly through the early Śakas and their successors, the Kuṣāṇas.

It now appears very probable that it was during the regime of the Śaka and Kuṣāṇa rulers (100 B.C.-200 A.D.) that a knowledge of the Graeco-Chaldean astronomy, which had developed in the Grecian world after 300 B.C., and ended with the astronomer

Ptolemy (150 A.D.), and in the Near East under the Seleucids (300 B.C. to 100 A.D.), penetrated into India, being brought by astronomers belonging to the Śaka countries, who later were absorbed into Indian society as *Śākadvīpī* or Scythian Brahmins. The borrowings appear to be more from Seleucid Babylon than from the west. The knowledge of Graeco-Chaldean astronomy was the basis on which the calendar prescribed by the *Sūrya Siddhānta* and other *Siddhāntas* were built up. It completely replaced the former *Vedāṅga Jyotiṣa* calendar and by about 400 A.D. when the *Vedāṅga Jyotiṣa* calendar had completely disappeared from all parts of India.

From 400 A.D. to 1200 A.D., almost the whole of India used calendars based on *Siddhānta Jyotiṣa* for date-recording. All Indian astronomers used the Śaka era for purposes of accurate calculations, but its use for date-recording by kings and writers was generally confined to parts of the South. In general, the Indian dynasties used eras of their own, or regnal years, though the annual calendar was compiled according to rules laid down either in the *Sūrya Siddhānta*, the *Ārya Siddhānta* or the *Brahma Siddhānta*. These did not much differ in essentials.

When India since 1200 A.D. fell under Islamic domination, the rulers introduced the lunar Hejira calendar for civil and administrative purposes as well. Indian calendars were retained only in isolated localities where Hindus happened to maintain their ndependence, or used only for religious purposes. The emperor Akber in 1584 tried to suppress the Hejira calendar for administrative purposes by the *Tārikh-Ilāhi*, a modified version of the solar calendar of Iran, but this fell in disuse from about 1630. Since the advent of British rule in 1757, the Gregorian calendar has been used for civil and administrative purposes, which is still being continued.

We have attempted to give below short accounts of calendars in use in different epochs of history.

5.2 CALENDAR IN THE RIG-VEDIC AGE (—1200 B.C.)

The Vedic Literature : The knowledge of the calendar in this age can be obtained only from the Vedic literature which consists however of different strata, greatly differing in age. According to the great orientalist Max Müller four periods each presupposing the preceding can be distinguished. They are :—

(a) *The Chandas and Mantras* composing the *Saṁhitās* or collections of hymns, prayers, incantations, benedictions, sacrificial formulas, and litanies comprising the four Vedas : The Ṛk, Sāma, Yajus and Atharva.

(b) *The Brāhmaṇas* which are prose texts containing theological matter, particularly observations on sacrifices and their mystical significances ; attached to the *Brāhmaṇas*, but reckoned also as independent works are the *Āraṇyakas* or *Upaniṣads* containing meditations of forest hermits and ascetics on God, the world, and mankind. These treatises are attached to each of the individual Vedas.

(c) The *Sūtras* or Aphorisms, or *Vedāṅgas.*

'*Vedāṅgas*', *lit.* limbs of Vedas, are post-Vedic *Sūtra* or aphorism literature which grew as results of attempts to understand the Vedas in their various aspects, and sometimes to develop the ideas contained in the Vedas. According to the orthodox view, there are six *Vedāṅgas* as follows :

(1) *Śikṣā :* or phonetics ; texts explaining how the Vedic literature proper is to be pronounced, and memorized.

(2) *Kalpa* : or ritualistic literature, of which four types are known : *Śrauta Sūtras* dealing with sacrifices ; *Gṛhya Sūtras* dealing with domestic duties of a householder ; *Dharma Sūtras* dealing with religious and social laws ; *Sūlva Sūtras* dealing with the construction of sacrificial altars.

(3) *Vyākaraṇa :* or Grammar, *e. g.*, Pāṇini's famous *Aṣṭādhyāyī*, which once for all fixed up the Sanskrit language. The *Aṣṭādhyāyī* is however the culmination of attempts by large number of older authors, whose works were rendered obsolete by Pāṇini' masterpiece.

(4) *Nirukta* or Etymology: explanation of the Vedic words ascribed to one Yāska, who lived before Pāṇini.

(5) *Chandas*—Metrics ascribed to Piṅgala.

(6) *Jyotiṣa*—Astronomy: the Ṛg-Jyotiṣa is ascribed to one Lagadha, of whom nothing is known.

Only the sixth Vedāṅga or Jyotiṣa interests us, though there are occasional references to the calendar in all Sūtra literatures.

Age of the Vedic Literature *

The above gives the 'Philologists' stratification of the age of the Vedic literature. About the actual age of each strata, there is great divergence of opinion, though it is admitted that the oldest in point of age are the *Saṁhitās*, then come the *Brāhmaṇas* and

* Much of the substance-matter of this section is taken from Winternitz's *A History of Indian Literature* Vol. I, published by the University of Calcutta. Chap. I, on Vedic Literature.

Upaniṣads, next the *Sūtras* or the *Vedāṅgas.* Of the four Vedas, the Rg-Vedas are by common consent taken to be the earliest in age and as Winternitz remarks, though all subsequent Indian literature refers to the Ṛg-Vedas, they presuppose nothing extant.

Max Müller made a rough assignment of age to the different strata as follows on the assumption that the Brāhmaṇic and Upaniṣadic literature predated the rise of Buddhism, and that the *Sūtra* literature which may be synchronous with the Buddhistic literature may be dated 600 B.C. to 200 B.C. Working backwards he assigned the Brāhmaṇic literature to 600 B.C. to 800 B.C., the interval 800 B.C. to 1000 B.C. as the period in which the collections of hymns were arranged, and 1000 B,C. to 1200 B.C, as the period of the beginning of Vedic poetry. He always regarded these periods as *terminus ad quem,* and in his Gifford Lectures on Physical Religion in 1889, he expressly states "*that we connot hope to fix a terminus a quo. Whether the Vedic hymns were composed 1000, 1200, 2000* or *3000 years B.C., no power on earth will ever determine.* *

It is not correct therefore to say, as some people say, that Max Müller had proved that 1200-1000 B.C. is the date of the Ṛg-Vedas. †

Other authorities, Schrader, Tilak, Jacobi, and P. C. Sengupta have found much older age for Rg-Vedic Indians : in fact, even as early as 4000 B.C., for some incidents described in the Ṛg-Vedas.* But their arguments, being based on interpretations of vague passages assumed to refer to astronomical phenomena have not commanded general recognition.

Let us first look at the strata within the Ṛg-Veda itself. The Ṛg-Vedas are divided into 10 *Maṇḍalas* (*lit.* circles) or books. Of these, the 2nd to the 8th books are ascribed to certain priestly families, *e.g,* the 2nd book is ascribed to *Gritsamadas,* the 3rd to the *Viśvāmitras,* etc. These are agreed to be the oldest parts of the Vedas.

The ninth book is devoted to *Soma* which is an intoxicating drink pressed out of a plant. The drink was dear to the Aryans and is also mystically identified with the Moon.

* For details about Vedic antiquity, see *Ancient Indian Chronology* by P. C. Sengupta.

† It appears that Max Müller has been a bit dogmatic in his opinion. Shortly after his death the names of the Vedic gods, *Indra, Varuṇa, Mitra* and the *Nāsatyas* in their Ṛg-Vedic forms were discovered in the Hittite clay tablets discovered at Boghaz Kuei in Asia Minor. They have been assigned to about 1450 B.C. More evidences about the Vedic Aryans were discovered in the excavations in the Sarasvatī valley now being undertaken by the Archaelogical Dept. of the Govt. of India. Further, fresh evidences are expected also in the archaeological work undertaken in Afghanistan, Iran and Central Asia.

The first and the tenth books are miscellaneous collections ascribed to different authors. They are taken to be the latest in age.

The Ṛg-Vedas consist of 1028 hymns, containing over 40,000 lines of verses.

The Vedas are regarded as '*Śrutis*' or "revealed knowledge preserved by hearing." According to savants, they were the *outpourings of the heart and mind,* of ancient priestly leaders, to their gods which were mostly forces of nature, intermingled very often with secular matter. Priestly families were trained to memorize the texts and pass them on to succeding generations in ways which guaranteed their transmission without error or alteration of the text. Savants are almost unanimous in their opinion that the Ṛg-Vedic texts which were composed in an archaic form of Sanskrit, which was not completly understood even in 500 B.C,, have come to us without change. The orthodox Indian view that they are revealed knowledge is of course not shared by scholars, both eastern and western, who point out that very often in the text of the Vedas themselves and in *Anukramaṇis* or introductions to texts, the authors of each hymn are mentioned by name and family.

To which locality are the Vedas to be ascribed ?

As regards locality, they are certainly to be ascribed to parts of Afghanistan, east of the Hindukush and the Punjab. The rivers of the Punjab, the Indus and its tributaries on both sides and the now lost Sarasvatī are frequently mentioned, the Ganges only once in a later text. The authors call themselves *Āryas* or Aryans, in contrast to the *Dāsas* or *Dasyus* who were alien to them, and with whom they came in frequent clash. The Dasyus are now taken to be partly Indus valley people, partly aboriginals.

The Rg-Vedas describe a highly complex society of priests, warriors, merchants and artisans, and slaves but the rigid caste system had not yet developed. There are also references to cities, but no artefacts except some pottery, have yet been discovered which can be referred to the Rg-Vedic Aryans.

The Ṛg-Vedic Aryans, it appears, were contemporaneous (if not older) with the great civilizations of Mesopotamia, both Sumerian, and later Accadian, and according to one view, some of the royal families of Asia Minor, were probably '*Vedic Aryans*'. It is therefore quite probable that they had attained as high a stage of civilization as that of Egypt of the Pyramid builders (2700 BC.), or of Sumer and Accad under Sargon I.

Let us see what information we can gather about the calendar which they must have used, for no civilized community can be without a calendar.

Further, the whole life of Vedic Aryans was centred round sacrifices to their great gods ; and sacrifices had to be carefully timed with respect to seasons, and moon's phases. In fact, some sacrifices were year-long, as Dr. Martin Haug, the great Vedic scholar remarks in his introduction (p. 46) to *Aitareya Brāhmaṇa* (affiliated to the Ṛg-Veda).

"The Sattras [or sacrifices] which lasted for one year, were nothing but an imitation of the sun's yearly course. They were divided into two distinct parts, each of six months of thirty days each ; in the midst of both was the *Viṣuvān*, *i.e.*, equator, or central day, cutting the whole Sattra into two halves".

This refers to somewhat later times than the Ṛg-Veda, but even during these early times, the sacrificial cult was fully developed. Let us see what references we get about the calendar from the Ṛg-Vedic times.

Calendaric and Astronomical References in the Rig-Vedas

These are few, and interspersed along with other matter. This is not to be wondered at, for the hymns are addressed chiefly to the gods, *Agni* (sacrificial fire), *Indra* (the national warrior god), etc., and other references are only incidental. The direct references are found only in Books 1 and 10 which are later in age than the family books.

Let us give the texts of a few hymns and their translations in English.

Ṛg-Veda, 1.164.11

Dvādaśāraṁ nahi tajjarāya varvarti cakraṁ
paridyāmṛtasya
Ā putrā agne mithunāso atra sapta śatāni
viṁśatisca tasthuḥ.

Translation : The wheel (or time) having twelve spokes revolve round the heavens, but it does not wear out. Oh Agni ! 720 pairs of sons ride this (wheel).

Here the year is likened to a wheel, having 12 spokes (or months) ; the 720 pairs of sons are 360 days and nights.

The interpretation commonly accepted is that the year was taken to consist of 360 days divided into 12 months, and the night and the day (following or preceding) constituted a couple.

Ṛg-Veda, 1.164.48.

Dvādaśa pradhayaścakramekaṁ trīṇi nabhyāni
ka u tacciketa
Tasmin tsākaṁ triśatā na śaṇkavo'rpitāḥ
ṣaṣṭirna calācalāsaḥ.

Translation : Twelve spoke-boards : One wheel : three navels. Who understands these ? In these there are 360 śaṅkus (rods) put in like pegs which do not get loosened".

The year is compared to a revolving wheel, whose circumference is divided into 12 parts (twelve months). They are grouped into three navels (seasons).

Here also we have a year of 360 days, divided into 12 months, four months constituting a season, as we find in the oldest inscriptions.

If the interpretation of the last passage is correct, we have the earliest reference to the later *cāturmāsya* system, or division of the year into three seasons each of four months.

It appears from these passages that Vedic Aryans had once a year of 360 days as ancient Egyptians also had, but they discovered later that this was not the correct value either for 12 lunar months, or for a seasonal year. For the following reference shows that they used also a ***thirteenth month.***

Ṛg-Veda, 1. 25. 8

Veda māso dhṛtavrato dvādaśa prajāvataḥ
vedāya upajāyate.

Translation : ***Dhṛtavrata*** (***Varuṇa***) knows the twelve months : (and) the animals created during that period ; (and) he knows (the intercalary month) which is created (near the twelve months).

This passage makes it clear that the calendar was luni-solar. But how was the adjustment made ?

A hymn in the *Ṛg-Veda* first noted by Tilak comes to our help.

Ṛg-Veda, 4. 33. 7

Dvādaśa dyūn yadagohyasyā tithye raṇannṛbhabaḥ
sasantaḥ.
Sukṣetrākṛnvannanayaṁ ta sindhūn dhanvātiṣṭha
nnoṣadhīr nimnamāpaḥ.

Translation : When the *Ṛbhus* sleeping for twelve days have made themselves comfortable as guests of the unconcealable (sun), they bring the fields in good order and direct the rivers. The plants grow in wildernesses, and lowland is spread with water".

According to Tilak, the *Ṛbhus* are the genii of seasons. They are said to enjoy the hospitality of the sun for twelve days in the above verse. This passage, according to Tilak means the adjustment of the solar year with the lunar (*i.e.*, 366—354=12 days).*

* *cf. Ancient Indian Chronology*, Chapter VI.

Another hymn from Atharva Veda (4.11.11) states that: 'Prajāpati, the lord of yearly sacrifices after finishing one year's sacrifice, prepared himself for the next year's sacrifice'.

The sacrificial literature of India still preserves the memory of these days by ordaining that a person wishing to perform a yearly sacrifice should devote 12 days (*dvādaśāha*) before its commencement to the preparatory rites.

Did the Ṛg-Vedic Aryans have any knowledge of the lunar zodiac, or designate the days by the lunar mansions, as we find widely prevalent during later times ?

There is no explicit reference to this point, but words which are now used to denote the lunar mansions are found in several verses of the Ṛg-Vedas, e.g.,

Citrā (α *Virginis*) is mentioned in RV. 4-51-2
Maghā (α *Leonis*) is mentioned in RV. 10-85-13
but in these passages the meaning of these words is not very clear.

The following references are more explicit.

Ṛg-Veda, 5. 54. 13

Yuṣmā dattrasya Maruto vicetaso rāyaḥ syāma
rathyo vayasvataḥ na yo yucchati tiṣyo yathā
divo'sme rāranta Marutaḥ sahasriṇaṁ.

Translation : You wise *Maruts,* we would like to be disposer of the wealth conferred by you on us ; it should not deviate (from us) as *Tiṣya* does not deviate from the heavens.

Here one is tempted to identify the word '*Tiṣya*' with the lunar asterism of that name, *viz.*, *Puṣya* (δ *Cancri*).

The following reference is more explicit.

Ṛg- Veda, 10. 85. 13

Sūryāyā vahatuḥ prāgāt savitā yamavāsṛjat
Aghāsu hanyante gāvo'rjunyoḥ paryuhyate.

Translation : The (dowry) of cows which was given by *Savitā* (Sun) had already gone ahead of *Suryā.* On the *Aghā*-day, the cattle were slain (acc. to Sāyaṇa had departed), on the two *Arjunī*-days, she was led to the bridegroom's house.

This passage occurs in the famous bridal hymn, where the Sun god (*Savitṛ*) gives away his daughter *Suryā* to *Soma* (Moon) in marriage. It says that on the *Aghā*-day the cows, given as bridal dowry are, driven away ; on the two *Arjunī*-days, the bride goes to the bridegroom's house.

This hymn is repeated in the *Atharva Saṁhitā* as follows :

Atharva Saṁhitā, 14.1.13

Sūryāyā vahatuḥ prāgāt savitā yam avāsṛjat
Maghāsu hanyante gāvaḥ phalgunīṣu vyuhyate.

Translation : The first line is identical. In the second line, the only change is *Maghā* for *Aghā,* and *Phalgunī* for *Arjunī*. In the lunar zodiac, *Maghā* stands for lunar asterism No. 10, of which the chief star is α *Leonis*. The two *Phalgunī* stars, *Uttara Phalgunī* (No.12) and *Purva Phalgunī* (No. 11) stand for β *Leonis* and δ *Leonis*.

This verse shows that the custom of designating the day (it means day and night) by the lunar asterism in which the moon is found in the night, which is found widely in vogue in later times, and is used even to-day for religious purposes, was in use at the time when this hymn was written. The practice therefore dates earlier than 1200 B.C. at least.

Longer periods of Time : The Yuga

'*Yuga*' is a very common word used in Indian literature of all times to denote an integral number of years when certain astronomical events recur. It exactly corresponds to the Chaldean word 'Saros' which has gone into international vocabulary. In later Indian literature we have Yugas of all kinds : the five yearly yuga, sixty yearly yuga, and Mahāyugas of $4{\cdot}32 \times 10^6$ years. Was any Yuga, known in Ṛg-Vedic times ?

There is evidence that some kind of a short period yuga, probably the five yearly yuga of later times, in which the moon's phases roughly recur, and which was the chief theme of the *Vedāṅga Jyotiṣa* was known in Ṛg-Vedic times as the following quotation shows :

Ṛg-Saṁhitā, 1.158.6

Dīrghatamā māmateyo jujurvān daśame yuge
apāmarthaṁ yatīnāṁ Brahmā bhavati sārathiḥ.

Translation : *Dirghatamā* the son of *Mamatā* having grown old in the tenth yuga became the charioter of the *karma* which leads to semi-result.

The most rational explanation of the word yuga here is probably the five yearly yuga of *Vedāṅga Jyotiṣa* for it is rational to expect that a man becomes old after he attains the 50th year. But there have been other explanations.

The Seasons and the Year

The most commonly used word for year in the Indian literature is *Varṣa* or *Vatsara.* The word '*Versa*' is very similar to *Varṣā,* the rainy season, and is probably derived from it. But curiously enough, this word is not found in Ṛg-Vedas. But the words *Śarad* (Autumn), *Hemanta* (early Winter) etc., are very often found to denote 'seasons' and sometimes years, just as in English we very often say 'A young lady of eighteen summers'.

Summary : The above passages show that the Ṛg-Vedic Aryans, who must be placed at least before 1200 B.C., had a luni-solar calendar, and used intercalary months. We do not have, however, their names for the 12 months, and there is no clue to find out how the intercalary month which is mentioned at one place was introduced. It appears that they denoted individual days by the *nakṣatra* i.e., by the lunar asterism in which the moon is found at the night, and hence it is permissible to deduce that they used the lunar zodiac for describing the motion of the moon. There is no mention of the *tithi* (or the lunar day) widely used in Indian calendars, in the Ṛg-Vedas. The solar year was probably taken to consist of 366 days, of which 12 were dropped for luni-solar adjustment.

5.3 CALENDARIC REFERENCES IN THE YAJUR VEDIC LITERATURE

The Atharva Veda consisting mostly of magic incantations also contain calendaric references, but we shall make only occasional use of them, as the text of this Veda has not probably come to us in unadulterated form, for the Atharva Veda was not regarded as holy as the Ṛg-Veda.

Of the two other Vedas, the Sāma-Vedas contain no new matter than what is contained in the Ṛg-Veda. But there are copious calendaric reference in the Yajurveda for obvious reasons, which are clearly brought out in the following extracts from Winternitz's introductry remarks to Yajurvedic studies (p. 158-159) :

"The two Saṁhitās [Ṛk and Atharva] which have so far been discussed have in common the fact that they were not compiled for special liturgical purposes. Although most of the hymns of the Ṛg-Veda could be, and actually were used for sacrificial purposes, and although the songs and spells of the Atharvaveda were almost throughout employed for ritualistic and magic purposes, yet the collection and agrrangement of the hymns in these Saṁhitās have nothing to do with the various liturgical and ritualistic purposes. The hymns were collected for their own sake and arranged and placed, in both these collections, with regard to their supposed authors or the singer-schools to which they belonged, partly also according to their contents and still more their external form-number of verses and such like. They are as we may say, collections of songs which pursue a *literary* object.

It is quite different with the Saṁhitās of the two other Vedas, the Sāmaveda and the Yajurveda. In these collections we find the songs, verses, and benedictions arranged according to their practical purposes, in exactly the order in which they were used at the sacrifice. These are, in fact, nothing more than *prayer-books and song-books* for the practical use of certain sacrificial priests—not indeed written books, but texts, which existed only in the heads of teachers and priests and were preserved by means of oral teaching and learning in the priests' schools.*

The Yajurvedas were compiled for the use of the Adhvaryu priest "*Executor of the Sacrifice*" who performs all the sacrificial acts, and at the same time uttering prose prayers and sacrificial formulae (Yajus). They are the liturgical Saṁhitās, and prayer books of the priests.

Winternitz gives reasons to believe that the Saṁhitās of the Black Yajurveda school are older than those of the White school.

Even such a conservative thinker as Berriedale Keith gives 600 B.C. as the *terminus ad quem* for the verses of the Yajurveda Saṁhitā. As we shall see, there are references which point to a much earlier origin.

The Yajur-Veda gives the names of twelve months, and the names of the lunar mansions with their presiding deities, and talks of the sun's northernly and southernly motion. We do not give the texts here, but only Dr. Berriedale Keith's translation.

Taittirīya Saṁhitā, 4.4.11

(a) (Ye are) Madhu and Mādhava, the months of Spring.

(b) (Ye are) Śukra and Śuci, the months of Summer.

(c) (Ye are) Nabha and Nabhasya, the months of Rain.

(d) (Ye are) Iṣa and Ūrja, the months of Autumn.

(e) (Ye are) Sahas and Sahasya, the months of (Early) Winter (*Hemanta*).

(f) (Ye are) Tapas and Tapasya, the months of cool season.

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* There are two schools of the Yajurveda Saṁhitā each with a number of recensions as shown below :

1. The Black Yajurveda School, with the following recensions :
   (a) The Kaṭhaka
   (b) The Kapiṣṭhala-Kaṭha-Saṁhitā, which is preserved only in a few fragments of manuscript.
   (c) The Maitrāyaṇī-Saṁhitā—shortly called M. S.
   (d) The Taittirīya-Saṁhitā, also called "Āpastamba-Saṁhitā" after the Apastamba-School, one of the chief schools in which this text was taught—shortly called T. S.

These four recensions are closely inter-related, and are designated as belonging to the "Black Yajurveda". Differing from them is the White Yajurveda which is known as Śukla Yajurveda.

2. The Vājasaneyi-Saṁhitā shortly called V. S. which takes its name from Yājñavalkya Vājasaneya, the chief teacher of this Veda. Of this Vājasaneyi-Saṁhitā there are two recensions, that of the Kāṇva and that of the Mādhyandina-school, which however differ very little from each other.

The month-names which are given here and repeated in many other verses of the Yajur-Veda have been interpreted by all authorities to be tropical. Further this is probably the earliest mention of month-names in Indian literature ; these names are no longer in use, and have been replaced by lunar month-names (*Caitra*, *Vaiśākha*, etc.) which are, however, found at a later stage.

Madhu and *Mādhava* have been taken in later literature to correspond to the time-period when the sun moves from -30° to 30° along the ecliptic, and so on for the other months. But we have no reason to believe that the Yajurvedic priests had developed such a fine mathematical sense of seasonal definition. But it is almost certain that they must have developed some method of observing the cardinal points of the sun's yearly course, *viz*., the two solstices and the equinoxes. From these observations, they must have counted that the number of days in a year was 366 in round numbers.

The Yajur-Veda speaks in many places of the *Uttarāyaṇa*, the northernly course of the sun from winter solstice to summer solstice and the *Dakṣiṇāyana* or the southernly course from summer solstice to winter solstice and the *Viṣuvān*, or the equinoctial point. The *ayanas* or courses must have received their designation from daily notings of sunrise on the eastern horizon. The year-long observation of shadows cast by a gnomon, of which we have evidences, may have formed an alternative method for fixing up the solstitial days, and the cardinal points on the horizon, (*vide* Appendix 5-C), where some passages from the *Aitareya Brāhmaṇa* attached to the Ṛg-Veda are stated in favour of the view that the cardinal points were observed by means of the gnomon.

Once they learnt to anticipate the cardinal days, determination of the month-beginnings marking seasons would not be difficult. The *Madhu*-month (the first month of spring) would begin 30 or 31 days before the vernal equinox day or 61 days after the winter solstice day, and the *Mādhava* month on the day after the equinoctial day and so on. Average length of $30\frac{1}{2}$ days ($=\frac{366}{12}$) would be given to each month, or 30 and 31 days to the two months forming a season.

The Nakshatras

One of the peculiar features of the Indian calendars is the use of the *Nakṣatras* as explained in § 4·1. Evidences have been given that the custom started from Rg-Vedic times. But we come across a full list of *Nakṣatras* only in the Yajurveda with names of presiding deities as given in Table No. 10 (p. 220), taken from Dīkṣit's *Bhāratiya Jyotiśāstra*.

There are several points to be noticed in this list, which may be compared with the list given on p. 210.

First, the *nakṣatras* start with *Kṛttikās* which all authorities identify with the conspicuous group Pleiades. What is the significance of this ?

At the present times, the *nakṣatras* start with *Aśvinī*, of which the junction star is α or β *Arietis*. This custom, *Aśvinyādi*, was introduced in Siddhānta Jyotiṣa time (500 A.D.), when the astronomical first point of Aries was near the end of the *Revatī nakṣatra* (ζ *Piscium*), or the beginning of *Aśvinī*. We do not enter into the controversy about the exact location of this point by the Siddhānta astronomers, which is fully discussed in Appendix 5-B. At present, the astronomical first point had shifted by as much as 19° from ζ *Piscium*, but the orthodox Indian calendar makers do not admit in the continued precession of the equinoxes, and still count the *nakṣatras* from *Aśvinī*.

In all older literatures, on the other hand, including the great epic *Mahābhārata*, whose composition or compilation may be dated about 400 B.C., the first *nakṣatra* is *Kṛttikā*. It therefore stands to reason to assume that at one time, when the *nakṣatra* enumeration started, the Pleiades were close to the astronomical first point of Aries, or rose near the true east. This is implied in the following verse which S. B. Dīkṣit picked out of the *Śatapatha Brāhmaṇa* :

Śatapatha Brāhmaṇa, 2.1.2.

> Ekaṁ dve trīṇi catvāriti vā anyāni
> nakṣatrānyathaitā eva bhūyiṣṭhā yat kṛttikā....
> Etā ha vai prācyai diśo na cyavante
> sarvāṇi ha vā anyāni nakṣatrāṇi
> prācyai diśaścyavante.

Translation :—Other *nakṣatras* have one, two, three or four (stars) only ; these *Kṛttikās* have many (stars)...They do not deviate from the east ; all other *nakṣatras* deviate from the east.

The names as given in this list are somewhat different from those now adopted, which have come into vogue since 500 A.D.; for example, we have :

No. 6 Tiṣya for Puṣya
No. 16 Rohiṇī for Jyeṣṭhā
(There are thus two Rohiṇīs, No. 2, and No. 16).
No. 17 Vicṛtau for Mūla
No. 20 Śroṇā for Śravaṇa
No. 21 Śraviṣṭhā for Dhaniṣṭhā
No. 23 Proṣṭhapada for Bhādrapadā
No. 26 Aśvajuya for Aśvinī
No. 27 Apabharaṇī for Bharaṇī

The more important question is whether the lunar mansions denote definite clusters of stars, or the nakṣatra-divisions of later times, amounting to $13^\circ\ 20'$ or $800'$ minutes ? This point has been discussed in § 4·1.

Table 10.

Names of Nakshatras in the Yajurveda with their Presiding Deities

No.	*Name of Nakṣatra*	*Presiding Deity*	*Number** *(Grammatical)*	*Principal Star*	*Longitude (1950·0)*			*Latitude*		
1.	Kṛttikā	Agni	P	η Tauri	59°	17′	39″	+ 4°	2′	46″
2.	Rohiṇī	Prajāpati	S	α Tauri	69	5	25	− 5	28	14
3.	Mṛgaśīrṣa	Soma	S	λ Orionis	83	0	31	− 13	22	32
	Invakā	"	P							
4.	Ārdrā	Rudra	S	α Orionis	88	3	22	− 16	1	59
	Bāhū	"	D							
5.	Punarvasu	Aditi	D	β Geminorum	112	31	29	+ 6	40	51
6.	Tiṣya	Bṛhaspati	S	δ Cancri	128	1	23	+ 0	4	32
7.	Āśreṣā	Sarpa	P	ε Hydrae	131	38	59	− 11	6	25
8.	Maghā	Pitṛ	P	α Leonis	149	8	1	+ 0	27	48
9.	Phalgunī	Aryamā	D	δ Leonis	160	36	52	+ 14	19	58
	Pūrva Phalgunī									
10.	Phalgunī	Bhaga	D	β Leonis	170	55	23	+ 12	16	13
	Uttara Phalgunī									
11.	Hasta	Savitā	S	δ Corvi	192	45	23	− 12	11	31
12.	Citrā	Indra, Tvaṣṭā	S	α Virginis	203	8	37	− 2	3	4
13.	Svātī	Vāyu	S	α Bootis	203	32	8	+ 30	46	3
	Niṣṭyā									
14.	Viśākhā	Indrāgni	D	α Libræ	224	23	7	+ 0	20	19
15.	Anurādhā	Mitra	P	δ Scorpii	241	52	23	− 1	58	49
16.	Rohiṇī	Indra	S	α Scorpii	249	3	51	− 4	33	50
	Jyeṣṭhā									
17.	Vicṛtau	Pitṛ	D	λ Scorpii	263	53	14	− 13	46	56
	Mūlabarhaṇī, Mūla	Nirṛti, Prajāpati	S							
18.	Aṣāḍhā	Āpaḥ	P	δ Sagittarii	273	52	55	− 6	27	58
	Pūrvāṣāḍhā									
19.	Aṣāḍhā	Viśvedeva	P	σ Sagittarii	281	41	11	− 3	26	36
	Uttarāṣāḍhā									
—	Abhijit	Brahma	S	α Lyrae	284	36	54	+ 61	44	7
20.	Śroṇā	Viṣṇu	S	α Aquilae	301	4	16	+ 29	18	18
21.	Śraviṣṭhā	Vasu	P	β Delphini	315	38	38	+ 31	55	21
22.	Śatabhiṣak	Indra, Varuṇa	S	λ Aquarii	340	52	38	− 0	23	8
23.	Proṣṭhapada	Ajaekapād	P	α Pegasi	352	47	19	+ 19	24	25
	Pūrva Proṣṭhapada									
24.	Proṣṭhapada	Ahirbudhniya	P	γ Pegasi	8	27	32	+ 12	35	55
	Uttara Proṣṭhapada									
25.	Revatī	Pūṣā	S	ζ Piscium	19	10	40	− 0	12	52
26.	Aśvayuja	Aśvin	D	β Arietis	33	16	18	+ 8	29	7
27.	Apabharaṇī	Yama	P	41 Arietis	47	30	19	+ 10	26	48

* S = Singular ; D = Dual ; P = Plural.

The Lunar Month-Names

The solar month-names given earlier have not gone into general currency. The month-names generally used are of lunar origin as given in § 5·7. These names are first found in the *Taittirīya Saṁhitā* 7.4.8, and in many other places of the Yajur-Veda literature; but in a somewhat different form. We quote parts of the passage.

Taittirīya Saṁhitā, 7.4.8.

Saṁvatsarasya yat phalgunī pūrṇamāso mukhata eva saṁvatsaramārabhya dīkṣante tasyai kaiva niryā-yat sāmmedhye viṣuvānt saṁpadyate Citrā pūrṇamāse dikṣeran mukhaṁ vā etat saṁvatsarasya yat citrā pūrṇamāso mukhata eva...

Translation :—One should get consecrated on the *Phalgunī* full-moon day because *Phālguna* full moon is the "*mouth*" of the year. Hence, (such people) are taken as consecrated from the very beginning of the year. But such people have to accept one *'niryā'* (draw back), viz., that the *'Viṣuvān'* occurs in the cloudly season (*sammedhya*). Hence, one should consecrate on the *Citrā* full-moon day. The *Citrā* full moon month is the 'mouth' of the year.

From these passages, we learn that the lunar month came gradually. The ancient Indians reckoned by the *pakṣa* or the fortnight, and distinguished the closing full moon day of the *pakṣa* by the *nakṣatra* where the moon was full. Thus *Phālgunī Paurṇamāsī* is that full moon when the moon gets full near the *Uttara Phalgunī* star (*β Leonis*), one of the lunar mansions. *Caitrī Paurṇamāsī* is that full moon, when the moon gets full near the *Citrā* star (*α Virginis*), which is the 14th lunar mansion. Later, as the months were always full-moon ending, the word *paurṇamāsī* was dropped, and, e.g., the first part of *Caitra-Paurṇamāsī*, i.e., *Caitra* became the lunar month-name. The above passage says that the *Phālguna Paurṇamāsī* was regarded as the last day of the year and less frequently the *Caitra Paurṇamāsī*. This system still continues, and the first lunar month *Caitra* of the lunar year begins on the day after *Phālgunī Paurṇamāsī*.

There are twenty-seven *nakṣatras* and so only 12 can be selected for lunar month-names.

The twelve names which we have got are :

Caitra	from	Citrā	(No. 14)
Vaiśākha	„	Viśākha	(„ 16)
Jyaiṣṭha	„	Jyeṣṭhā	(„ 18)
Āṣāḍha	„	Āṣāḍhā	(„ 20 & 21)
Śrāvaṇa	„	Śravaṇa	(„ 22)
Bhādra	„	Bhādrapadā	(„ 25 & 26)
Āśvina	„	Aśvinī	(„ 1)
Kārtika	„	Kṛttikā	(„ 3)
Mārgaśīrṣa	„	Mṛgaśiras	(„ 5)
Pauṣa	„	Puṣya	(„ 8)
Māgha	„	Maghā	(„ 10)
Phālguna	„	Phalgunī	(„ 11 & 12)

Of course, full moon takes place by turn in all the *nakṣatras*. But only 12 at approximately equal intervals could be selected. But we have too *Rauhiṇya paurṇamāsī* etc. the *pakṣa* when the moon becomes full near *Rohiṇī*, or Aldebaran (lunar mansion No. 4). But *Rauhiṇya* was not selected for the name of a lunar month, because it was too near *Kṛttikā-Paurṇamāsī*.

Tithi

'Tithi' or 'Lunar Day' is a very important conception in Hindu astronomy, for holidays are always dated by the *tithi*. According to Siddhāntic definition, a *tithi* is completed when the moon is ahead of the sun by 12°, or integral multiples of 12° (*vide* § 5·7).

Thus the first *tithi* (*Pratipada, lit.* when the moon is regenerated) in the waxing half starts when the moon is in conjunction with the sun, and ends when she has gone ahead of the sun by 12°, when the second *tithi* of the waxing moon begins. The *tithis* are numbered ordinally from 1 to 15, the end of the fifteenth *tithi* being full-moon. Then begins the *tithis* of the waning moon, numbered from 1 to 15, the end of the 15th *tithi* being the new-moon. There are thirty *tithis* in a lunar month, and though the average duration is less than a solar day, being 23.62 hours, the length of individual *tithis* may vary from 26.8 to 20.0 hours., on account of irregularity in the moon's motion.

This is the definition of the *tithi* given in *Siddhāntas* or scientific astronomy which started about 400 A.D. But this presupposes knowledge of measurement of angles, and precise scientific observation, of which we find no trace in the Vedic literature. What was then the origin of this system ?

We have no reference to *tithi* in the Ṛg-Veda. The first reference is found in Yajurvedic literature, and the *Brāhmaṇas*. The *Taittirīya Saṁhitā* talks of the *pañcadaśī tithi*, which shows that the lunar *pakṣa* was divided into 15 *tithis*, counted by ordinal numbers from 1 to 15 for each *pakṣa*. But what was the time-period meant by a *tithi* ? The *Aitareya Brāhmaṇa* attached to the Ṛg-Veda gives the following definition of the *tithi*.

Aitareya Brāhmaṇa, 32.10

Yāṁ paryastamiyād abhyudiyāditi sā tithiḥ.

The *tithi* is that time-period about which the moon sets or rises.

This has been interpreted by Prof. P. C. Sengupta as follows :

During the waxing moon (*śukla pakṣa*), the *tithi* was reckoned from moon-set to moon-set ; and during the waning moon (*kṛṣṇa pakṣa*), the *tithi* was reckoned from moon-rise to moon-rise. The *tithis* were thus of unequal length, as shown by Prof. P. C. Sengupta in Table No. 11 on page 222.

5.4 THE VEDANGA JYOTISHA CALENDAR

The history of the Indian calendar from the end of the Yajurveda period to the beginning of the *Siddhānta Jyotiṣa* period is very imperfectly known though there are plenty of calendaric references in the *Brāhmaṇas*, *Sūtras*, and the epic *Mahābhārata* and various literature. On time-scale, it extends from

Table 11.

Duration of Vedic Tithi

English Date	Modern Tithi	Ending of Vedic Tithi: Event	Ending of Vedic Tithi: Time of Event (L. M. T.-Cal.)	Duration of Vedic Tithi	Vedic Elapsed Tithi No.
(1936 A.D.)			h m	h m	
Oct. 15	Amāvasyā	Moonset or Sunset	17 34	—	—
16	Pratipad	"	17 33	—	—
17	Dvitiyā	Moonset	18 36	25 3	1
18	Tṛtīya	"	19 16	24 40	2
19	Caturthi	"	20 3	24 45	3
20	Pañcamī	"	20 53	24 50	4
21	Ṣaṣṭhī	"	21 46	24 53	5
22	Saptamī	"	22 41	24 55	6
23	Aṣṭam ī	"	23 38	24 57	7
24	Navamī	"	24 36	24 58	8
25	Daśamī	"	25 35	24 59	9
26	Ekādaśī	"	26 35	25 0	10
27	Dvādaśī	"	27 37	25 2	11
28	Trayodaśī	"	28 42	25 5	12
29	Caturdaśī	Moonset	29 49	25 7	13
30	Pūrṇimā	Moonrise or Sunset	17 22	11 33	14
31	Pratipad & Dvītiyā	Moonrise	18 18	24 56	15
Nov. 1	Tṛtiyā	"	19 18	25 0	16
2	Caturthī	"	20 20	25 2	17
3	Pañcamī	"	21 23	25 3	18
4	Ṣaṣṭhī	"	22 23	25 0	19
5	Saptamī	"	23 21	24 58	20
6	Aṣṭamī	"	24 14	24 53	21
7	Navamī	"	25 7	24 53	22
8	Daśamī	"	25 58	24 51	23
9	Ekādaśī	"	26 47	24 49	24
10	Dvādaśī	"	27 37	24 50	25
11	Trayodaśī	"	28 27	24 50	26
12	Caturdaśī	Moonrise	29 17	24 50	27
13	"	Sunrise	30 14	24 57	28
14	Amāvasyā	Sunset	17 15	11 1	29
Nov. 15	Pratipad	Moonset	18 0	24 45	1

Note :—The Vedic tithi ends at moonset in the light half and at moonrise in the dark half. Near *amāvasyā* when the moon remains invisible, the ending is at sunset. There are 29 or 30 such tithis in a lunar month, and all tithis are of more than 24 hours' duration except *amāvasyā* and *pūrṇimā* which are of about 12 hours' duration.

an unknown antiquity, which is set by some at 1300 B.C. to 300 A.D.

The *Vedāṅga Jyotiṣa* is generally assigned to this period. It may be said to be a sort of collection of short aphorisms giving mathematical rules for fixing the calendar in advance, and is known in three versions: the Rg-Jyotiṣa consisting of 36 verses, attached to the Rg-Veda and ascribed to one Lagadha as mentioned earlier, the Yājuṣ Jyotiṣa attached to the Yajurveda and consisting of 43 verses, and there is a text ascribed to one Somākara, a commentator of unknown age of the Vedas. The dfffferent texts contain about the same matter, but the verses are haphazardly arranged showing that the original texts have not come down to us in an unadulterated form. The number of independent verses in all the versions is not more than 49, and some of the verses have not been interpreted.

There are several other calendarical treatises which can be assigned to this period. The *Sūrya Prajñapti*, a Jaina astronomical work, the *Jyotiṣakaraṇḍa*, and the *Kālālokaprakāśa*.

A short account of the calendaric rules followed in these treatises is given in Varāhamihira's *Pañca Siddhāntikā*, Chap. XII, where the rules are collected as "*Paitāmaha Siddhānta*" or Astronomical Calendar according to Grandfather Brahmā, the Creator, in Hindu mythology. That shows the high antiquity of the rules. Varāhamihira, as well as Brahmagupta describe the rules as very "inaccurate" (*Dūravibhraṣṭau*, furthest from truth in Varāhamihira's language) though they pay a formal courtesy to the supposed authors. But such has been the case with calendars of all ancient nations, including the Babylonians at this period and a critical account of the *Vedāṅga Jyotiṣa* is important from the historical point of view.

It may be remarked here that there are minor differences between *Vedāṅga Jyotiṣa*, the Jain systems, and the *Paitāmaha Siddhānta*, which appear to be the latest of this group. The older treatises have a year of 366 days, while the *Paitāmaha Siddhānta* has a year of 365·3569 days (Dīkṣit).

There is an extensive literature on *Vedāṅga Jyotiṣa* which has been studied by Dr. G. Thibaut, S. B. Dīkṣit, S. K. Pillai, and Dr. R. Shama Sastry, amongst others. We here give an account of the calendar according to the *Paitāmaha Siddhānta*.

Summary of the Contents

"Five years constitute a *Yuga* or Saros of the sun and the moon.

The *yuga* comprises 1830 *sāvana* days (civil days) and 1860 *tithis* (lunar days).

In the *yuga*, there are 62 lunar months and 60 solar months. So two months are omitted as intercalary months, in a period of 5 years.

The number of omitted *tithis* in the period is 30.

There are 67 *nakṣatra*-months (sidereal months) in the *yuga*. The moon passes through $67 \times 27 = 1809$ *nakṣatras* within this period.

The *yuga* begins at winter solstice with the sun, and the moon together at the *Dhaniṣṭhā* asterism (α or β *Delphini*)."

These are the main points from which the five yearly calendar can be constructed.

The *Vedāṅga Jyotiṣa* further describes measurements of the subdivisions of the day by means of the clepsydra, as well as by gnomon-shadows.

One particular feature is the assumption that the ratio of the length of the day to that of the night on the summer solstice day is as 3 : 2.

Let us now examine these points critically.

We observe that all the mathematical rules point out only to mean motions of the sun and the moon, *i.e*, the periods of the sun and the moon were obtained by counting the number of *sāvana* days in a large number of years and months, and dividing the number by the number of periods (year or month). No evidence is found of the systematic day to day observations of the sun and the moon. Only the lunar zodiac was used for describing the positions of the sun and the moon, which appears to have been divided into 27 equal parts or *nakṣatras*; in other words the *nakṣatras* no longer denoted star-clusters but equal divisions of the lunar belt.

There is no mention of the zodiac or twelve signs of the zodiac, or of week days, or of planetary motion.

Let us now look critically into the rules.

5 solar years $= 365.2422 \times 5 = 1826.2110$ days;
62 synodic months $= 29.53059 \times 62 = 1830.8965$ days;
67 sidereal months $= 27.32166 \times 67 = 1830.5512$ days.

Therefore, regarded as a measure for luni-solar adjustment, the error is 4.685 days in a period of 5 years, i.e., if we started a *yuga* with the sun and the moon together on the winter solstice day, the beginning of the next *yuga* (6th year) would occur 4.685 days later than the winter solstice and in 5 to 6 yugas the discrepancy would amount to a month or half season. This cannot escape notice, and therefore there must have been some way of bringing back the *yuga* to the winter solstice day. Otherwise the calendar becomes useless. But how could it have been done?

This is a matter for conjecture and several hypotheses have been proposed. According to S. B. Dīkṣit, we should have in 95 years:

according to the *V. J.*, $\frac{2}{5} \times 95 = 38$ intercalary months, while actually we have, $\frac{7}{19} \times 95 = 35$ intercalary months.

So the *Vedāṅga Jyotiṣa* rules introduce 3 more intercalary months than necessary in 95 years, and if these are dropped, we can have good adjustment. This could have been done as follows:

In the first period of 30 years = 6 *yugas*, suppose they had 11 intercalary months instead of 12.

The beginning of the *yuga* would go ahead of the winter solstice in 30 years by $4{\cdot}685 \times 6 = 28.110$ days.

But if we do not have the intercalary month on the 30th year, the *yuga*-beginning is brought back to $29.53 - 28.110 = 1.421$ days before the W.S. day. The same process is repeated for the next period of 30 years. The *yuga*-beginning is thus brought back to 2.842 days before the W.S. day.

The next period may be taken to consist of 35 years, i.e., 7 *yugas* each of five years, in which the *yuga*-beginning goes ahead by 3.264 days. The combined result of the three periods of 30, 30, and 35 years is to put the *yuga* beginning ahead of the W.S. day by 0.422 days only. Other conjectural cycles are described by Dr. Shama Sastry.

But was any such practice really followed? We have no evidence from the verses; but S. B. Dīkṣit mentions that intercalary months were inserted only when needed, and hence probably they were 'dropped when not needed.'

Tithis

The main object of the *Vedāṅga Jyotiṣa* calendar appears to have been the correct prediction of the *tithi* and *nakṣatra* on any *sāvana* (civil) day within the *yuga*. In this respect, the rules were more accurate. A *tithi* is defined as $\frac{1}{30}$th of the lunar month. The correct measure is

$$1\ tithi = \frac{29.530588}{30} = .984353 \text{ days,}$$

while the measure taken $= \frac{61}{62} = .983871$ days. The mistake is .000482 days on the lower side or one *tithi* in 2075 days or in $5\frac{2}{3}$ years.

The five yearly period consists of 1830 civil days in which there are 62 synodical months.

We know $62 \times 29.53059 = 1830.8965$ days. Hence in order to make the *tithi* calculations correct, one day (exactly 0.8965 days) had to be added to the total number of civil days in the period.

Nakshatras

The days were named according to the *nakṣatras* or lunar asterisms in which the moon was found, and a lot of crude astrology* had grown up round this system. So it was necessary to predict the *nakṣatra* in advance. The *Vedāṅga Jyotiṣa* calendar prescribed some methods for such predictions.

In a five yearly period of 1830 days, the sidereal revolutions of the moon amounted to 67 in which there are 1809 *nakṣatras*.

$$\text{Actually 1 } nakṣatra \text{ day} = \frac{27.32166}{27} = 1.011913 \text{ days,}$$

$$\text{while the measure taken} = \frac{1830}{1809} = 1.011608 \text{ days.}$$

*Astrology based only on the sun and the moon. Later post-Siddhāntic astrology in India is largely Graeco-Chaldean, and makes use of the signs of the zodiac, and of planetary position and motion.

The mistake was .000305 days on the lower side or 1 *nakṣatra* in 3279 days or about 9 years.

The Time of the Vedanga Jyotisha

All recensions of the Vedāṅga Jyotiṣa contain the following verses:

Svarākramete somārkau yadā sākaṁ savāsavau
Syāttadādiyugaṁ māghastapaḥ śuklo'yanaṁ hyudak. (6)
Prapadyete śraviṣṭhādau sūryācandramasāvudak
Sārpārdhe dakṣiṇārkastu māghaśrāvaṇayoḥ sadā. (7)

These two verses taken together yield the following:

The winter solstice took place at the lunar asterism *Śraviṣṭhā*, which is later called *Dhaniṣṭhā*.

This is the 21st *nakṣatra* in the *Kṛttikādi* system and 23rd in the *Aśvinyādi* system and its component stars are α, β, γ and δ *Delphini*.* These stars are far away from the ecliptic. We have for 1950:

α Delphini,	Long. = 316° 41′	Lat.	= +33° 2′
β ,,	,, = 315 39	,,	= +31 55
γ ,,	,, = 318 40	,,	= +32 41
δ ,,	,, = 318 35	,,	= +31 57

The Arabs have β and ξ *Aquarii* which also represent the Chinese *Hsiu*.

It has been stated in the *Vedāṅga Jyotiṣa* that the junction star of the asterism was placed at the beginning of the division and it marked the beginning of *Uttarāyaṇa* or the W.S. day. Thus the star representing the *Dhaniṣṭhā* division had 270° as the longitude at the time when the tradition of the *Vedāṅga Jyotiṣa* calendar was formulated. If α *Delphini* is taken as the principal star of the asterism, then its longitude was 270° at the time of the *Vedāṅga Jyotiṣa* and in 1950, its longitude is 316° 41′. As the solstices take about 72 years to retrograde through one degree, the time of *Vedāṅga Jyotiṣa* is found to be $(316° 41' - 270°) \times 72 = 46.°7 \times 72 = 3362$ years before 1950 A.D. or 1413 B.C. The star β *Delphini*, however, yields a somewhat lower period, i.e., about 1338 B.C.

The Plan of the Calendar

In a period of 5 years, there are :—
1830 civil days,
62 lunar months, and so 1860 *tithis*,
67 sidereal months and so 1809 *nakṣatras*.

As the period contains 60 solar months, there are 2 intercalary months which are placed after every

* On a Dhaniṣṭhā day the moon got conjoined with both the β and α Delphinis at interval of 2 hours.

30 lunar months. Thus in the third year, the month *Śrāvaṇa* is *adhika* which is followed by *śuddha Śrāvaṇa* ; and in the fifth year the last month is also *adhika* which is *adhika Māgha*.

There are 1860 *tithis* while the number of civil days is 1830 ; so there are 30 omitted *tithis* (*tithi kṣaya*). Each period of 61 days contains 62 *tithis*, so one *tithi* is omitted after 61 civil days. From this consideration the number of civil days per month can be obtained and will be shown in the table below. The *Vedāṅga Jyotiṣa* people regularly counted a *tithi* to a day, but after 61 days one *tithi* was omitted.

As regards *nakṣatras*, their number is 1809 in 1830 civil days, the difference being 21. So 87$\frac{1}{7}$ days were equivalent to 86$\frac{1}{7}$ *nakṣatras*. They counted a *nakṣatra* to a day successively, but after every 87 days (actually 87$\frac{1}{7}$ days), one *nakṣatra* was repeated for two days.

The five different years of the period had distinctive names, *viz.*, (1) Saṁvatsara, (2) Parivatsara, (3) Idāvatsara, (4) Anuvatsara, and (5) Idvatsara.

The plan of the five yearly calendar is shown below :

Table 12.

Number of days in each month of the Vedanga Jyotisa Calendar

	Saṁvat-sara	*Parivat-sara*	*Idāvat-sara*	*Anuvat-sara*	*Idvat-sara*
Māgha	30	29	29	29	29
Phālguna	30	30	30	30	30
Caitra	29	29	29	29	29
Vaiśākha	30	30	30	30	30
Jyaiṣṭha	29	29	29	29	29
Āṣāḍha	30	30	30	30	30
Śrāvaṇa (*adhika*)	—	—	29	—	—
Śrāvaṇa	29	29	30	29	29
Bhādrapada	30	30	30	30	30
Āśvina	29	29	29	29	29
Kārtika	30	30	30	30	30
Mārgaśirṣa	29	29	29	29	29
Pauṣa	30	30	30	30	30
Māgha (*adhika*)	—	—	—	—	29 or 30
Total No. of days in the year	355	354	384	354	383 or 384

As already shown, the actual length of 62 lunar months is 1830.8965 days, while there are 1830 civil days in the five yearly period. It is therefore very likely that one civil day was added to the period when necessary to make it conform to the phases of the moon which were regularly observed. This additional day was no doubt placed at the end of the period, and when it was added the last month *adhika Māgha* contained 30 days instead of 29 days which was otherwise its due.

The ratio $\frac{3}{2}$ for the duration of the longest day to that of the shortest night given in the *Vedāṅga Jyotiṣa* was first noted by Dr. Thibaut. Later the same ratio was found by Father Kugler from Babylonian cuneiform records of the Seleucidean period. The ratio is characteristic of a latitude of 35° N, which is nearly that of Babylon (for Babylon $\phi = 32°\ 40'$N). Hence it has been inferred that the *Vedāṅga Jyotiṣa*-astronomers got this ratio from Seleucidean Babylon. But it may be pointed out that the Vedic life centred round North-Western India, from the Sarasvatī valley (Kurukṣetra $\phi = 29°\ 58'$) to Gāndhār ($\phi = 31°\ 32'$N). The ratios of the duration of daylight to night on the summer-solstice day for different latitudes are as follows :

Table 13.

Longest day and shortest night

(Calculated with obliquity of ecliptic as 23° 51′ which is for 1300 B. C. The results for 500 B. C. are also almost the same.)

Latitude	*Longest day*	*Shortest night*	*Ratio*
30° N	$13^h\ 58^m$	$10^h\ 2^m$	1.39
31° N	14 3	9 57	1.41
31° 32′ N	14 6	9 54	1.42
32° N	14 8	9 52	1.43
32°40′ N	14 12	9 48	1.45
33° N	14 14	9 46	1.46
34° N	14 19	9 41	1.48
35° N	14 24	9 36	1.50

It is seen from the above table, that even at the latitude of Babylon, the ratio is not 1.50 but 1.45. At Gāndhār, it is 1.42. The difference is not very large. But there is another factor to which attention must be drawn.

Both Babylonians and Indians measured subdivisions of the day by means of some kind of Clepsydra. A description of the Clepsydra used by Indians during the *Vedāṅga Jyotiṣa*-period will be found in S.B. Dīkṣit's *Bhāratīya Jyotiśāstra* (Sec. II, Chap. I). But the day-length must have been measured from the observed time of sunrise to the observed time of sunset. This is somewhat larger than the astronomical time of sunrise on account of refraction. Assuming that the effect of refraction is to elevate a celestial body near the horizon by about 35′, and the sun's semi-diameter is about 16′, the sun's upper limb appears on the horizon at a place on 32° latitude, about 4$\frac{1}{2}$ minutes before the centre of the sun is due on the horizon. For the same reason, the sunset takes place 4$\frac{1}{2}$ minutes after the astronomical calculated sunset. So the apparent length of the day is increased by $2 \times 4\frac{1}{2}$ min. or by 9 minutes. Therefore for the latitude of Babylon we have the length of maximum day-light $14^h\ 12^m + 9^m = 14^h\ 21^m$, and the night is $9^h\ 39^m$. The ratio is now 1.49. Taking the effect of refraction into consideration the ratio for Gāndhār also becomes 1.46, which is not much different from 1.50 as for Babylon. So it is not necessary to assume that the ratio was obtained from Babylonian sources.

Effect of Precession

The *Vedāṅga Jyotiṣa* was prevalent for a long time over India, for over 1300 years (1000 B.C. to 300 A.D.). Hence it is likely that the subsequent astronomers noticed the gradual shift of the solstitial colure in the lunar zodiac. In fact, several references are found to this effect. Garga, an astronomer whose name is found in the *Mahābhārata*, where he is described as having an astronomical school at a place called Gargasrota in the Sarasvatī basin, is the reputed author of a pre-Siddhāntic calendaric treatise called *Garga Saṁhitā*. He notes :

Yadā nivartate'prāptaḥ śraviṣṭhāmuttarāyaṇe
Aśleṣāṁ dakṣiṇe'prāptaḥ tadā vindyānmahad bhayam.

Translation : When at the time of *Uttarāyaṇa* the sun is found turning (north) without reaching the *Śraviṣṭhās*, and (at the time of *Dakṣiṇāyana*) turning (south) without reaching the *Āśleṣā*, it should be taken to indicate a period of calamity.

It shows that at the time of Garga the W.S. did no longer occur in *Śraviṣṭhā*, neither the S.S. occurred in the *Āśleṣā* division. At the time of *Vedāṅga Jyotiṣa* the two solstices were marked by the starting point of *Śraviṣṭhā* and the middle point of *Āśleṣā* respectively. Garga therefore observed that the solstices were receding back over the lunar calendar, and had shifted at least by half a *nakṣatra*-division from the middle of *Āśleṣā*. His observations are therefore at least 480 years later than those of the *Vedāṅga Jyotiṣa*.

In the *Mahābhārata* we get the following verse :

Aśvamedha, Chap. 44,2

Ahaḥ pūrvaṁ tatorātrirmāsāḥ śukladayaḥ smṛtāḥ
Śravaṇādīni ṛkṣāni ṛtavaḥ śiśirādayaḥ

Translation : Day comes first and then the night ; months are known to commence with the bright half, the *nakṣatras* with *Śravaṇa*, and the seasons with *Śiśira*.

Here the asterism *Śravaṇa* is described as the one where the winter solstice takes place. *Śravaṇa* is just preceding *Śraviṣṭhā* and the solstices take about 960 years to retrograde through one *nakṣatra* division. We get from this the time of composition of the *Mahābhārata* as about 450 B.C. or sometime earlier.

Varāhamihira also notes that the winter solstice no longer took place at *Dhaniṣṭhā*.

Pañca Siddhāntikā, III, 21

Āśleṣārdhādāsīt yadā nivṛttiḥ kiloṣṇakiraṇasya
Yuktamayanaṁ tadāsīt sāmpratamayanaṁ punarvasutaḥ.

Translation : When the return of the sun towards the south (*i.e.*, the summer solstice) took place from the middle of *Āśleṣā*, the *ayana* was right : at the present time *ayana* begins from *Punarvasu*.

In his *Bṛhat Saṁhitā*, an astrological treatise, he records :

Bṛhat Saṁhitā, III, 1

Āśleṣārdhātdakṣiṇaṁ uttaramayaṇaṁ raverdhaniṣṭhādyam
Nūnaṁ kadācidāsīt yenoktaṁ pūrvaśāstreṣu.

Translation : The beginning of the southern motion when the sun has passed half of *Āśleṣā* and the beginning of the northern motion when the sun has passed the beginning of *Dhaniṣṭhā*, must have taken place at some epoch ; for these are recorded in old treatises.

From the time of *Vedāṅga Jyotiṣa* to Varāhamihira's time the summer solstice moved through more than $1\frac{1}{2}$ *nakṣatras* ($\frac{1}{2}$ of *Āśleṣā* + *Puṣya*) which indicated a lapse of more than 1500 years from the time of *Vedāṅga Jyotiṣa*.

It is thus seen that the Hindu astronomers observed the shifting of the cardinal points due to precession of the equinoxes ; but as they had not developed the sense of era, they were unable to find out the time-interval between different records, and obtain a rate for precession, as was done by Hipparchos. Their observations were also crude, as they used only the lunar zodiac. The shifting of the solstitial colures remained to them an unsolved mystery.

5.5 CRITICAL REVIEW OF THE INSCRIPTIONAL RECORDS ABOUT CALENDAR

In this chapter, we are undertaking a critical review of the references to the calendar in ancient inscriptions, because, from the point of view of accurate history, inscriptional records are far more valuable than any references in ancient scriptures or classics, as they are contemporary documents, which have remained unaltered since the framers left them*.

* Sometimes inscriptions and copper plate records have been found to have been forged at a latter date but such instances are rare and can not escape detection by an experienced archaeologist.

References in ancient scriptures, poems, epics and other literatures are, on the other hand, very often liable to alterations, interpolations and errors in the hands of *latter-day copyists* and are, therefore, less trust-worthy.

The oldest inscriptional records bearing a date (barring those belonging to the Indus-valley period which have not been deciphered) belong to the reign of the Emperor Aśoka (273-236 B.C.). From these, we can make fairly accurate deductions regarding the calendar then in use.

We take the Fifth Pillar Edict, Rāmpurvā version found at the Champāraṇ district, Bihar. The language is Aśokan Prākrt, the script is the oldest form of Brāhmī. (Sircar pp. 62-63)

Fifth Pillar Edict—Rāmpurvā Version

(1) *Saḍuvīsati[va]sābhisitena* (*Ṣaḍviṁśati-varṣābhiṣiktena*)—'After twenty-six years had elapsed since coronation'.

(2) *Tīsu cātuṁmā[sī]su tisyaṁ puṁnamāsiyaṁ tini-divasāni cāvudasaṁ paṁnaḍasaṁ paṭipadaṁ*······ (*Tisṛṣu cāturmāsīṣu tiṣyāyāṁ pūrṇamāsyāṁ, triṣu divaseṣu-caturdaśe pañcadaśe pratipadi*······

'On the three *cāturmāsī* days, on the *tiṣya* full moon day, on the 14th, 15th and the first day···············'

(On these and some other days, sale of fish is forbidden).

Again, in the same :

(3) *Aṭhami-pakhāye cāvudasāye paṁnaḍasāye tisāye punāvasune*······(*Aṣṭamī-pakṣe, catur-daśyāṁ, pañcadaśyāṁ, tiṣyāyāṁ, punarvasau*···········) ;

'On the eighth *pakṣa*, on the 14th, and the 15th (new moon) on the *Tiṣya* and *Punarvasu Nakṣatra* days········,

(On these days, he forbids the castration of bulls).

From these passages, we conclude that :

1. No era was used, but regnal years (number of years elapsed since the king's coronation) were used for dating.
2. The time-reckoning was by seasons, each of 8 *pakṣas*. The seasons are :

   Grīsma (Summer) : Comprising *Caitra, Vaiśākha, Jyaiṣṭha, Āṣāḍha.*

   Varṣā (Rains) : Comprising *Śrāvaṇa, Bhādra, Āśvina, Kārtika.*

   Hemanta (Winter) : Comprising *Agrahāyaṇa, Pauṣa, Māgha, Phālguna.*
3. The months are not mentioned by name, except in one case where the month of *Māgha* is mentioned. They are *pūrṇimānta*, i.e., they started after full moon and ended in full moon. This is not expressly mentioned but can be inferred from the fact that the 14th, the 15th (*Pañcadaśī*) and the *Pratipada*, i.e., the first *tithi* are enjoined to be the days on which certain actions are forbidden. These must be the three days of invisibility of the moon, the 14th being before new moon, the 15th the new moon, and the first, the day after new moon, which were observed as unsuitable for many particular performances.
4. The day reckoning was by the *tithi* (lunar day), but the word *tithi* is probably not to be taken in the sense of the present Siddhāntic *tithi*, but in the sense of the Vedāṅga Jyotiṣa *tithi* or the old Brāhmaṇic *tithi*. In the latter system, a *tithi* was counted from moon-set to moon-set during the bright half, and from moon-rise to moon-rise during the dark-half. There was the same *tithi* for the whole day. Prof. P. C. Sen Gupta has discussed this method of *tithi* reckoning (see p. 222).
5. Two days are mentioned by the lunar asterisms *Tiṣya* (*δ Cancri*), and *Punarvasu* (*β Geminorum*). As suggested one was probably his birth *nakṣatra*, the other his coronation *nakṣatra*. The days were therefore also named after the *nakṣatra*. This system is found in vogue in the epic *Mahābhārata*, e.g., in the following passage :

Balarāma, the elder brother of Kṛṣṇa, after returning from pilgrimage on the eighteenth day of the battle states :

M. Bh., Śalya Parva, Ch. 34, 6

Catvāriṁśadahānyadya dve ca me niḥsṛtasya vai
Puṣyeṇa saṁprayāto'smi Śravaṇe punarāgataḥ.

Translation : It is forty-two days since I left the house. I started on the *Puṣya* (day) and have returned on the *Śravaṇa*.

6. There is no mention of the year-beginning. The *Tiṣya Pūrṇamāsī*, i.e., the full-moon day ending the lunar month of *Pauṣa* is marked out particularly.

It appears from the records that in Aśoka's time, the principles followed in framing the calendar were those given in the *Vedāṅga Jyotiṣa*. No era was used. From the inscriptions, we can make no inference about the luni-solar adjustment, but there is no doubt that the year was seasonal as given in the inscription of the Sātavāhanas (see next page).

No records bearing a date of the imperial dynasties following the Mauryas, *viz.*, the Śuṅgas, and Kāṇvas (186 B.C.-45 A.D.) are known. But the next imperial dynasty, the Sātavāhanas have left plenty of dated records. In these, the same system of date-recording by regnal years, the seasons, the *pakṣas*, and *tithis* are found. There are 8 *pakṣas* in a season of four months, and they were serially numbered from 1 to 8. The odd ones were *Kṛṣṇa pakṣas*, the even ones *Śukla pakṣas*.

Some examples are given below :

(1) Nāsik Inscription of the Sātavāhana Emperor, Gautamīputra Śrī Sātakarṇi (Sircar, pp. 192-93).

Datā paṭikā Savachare 10+8 *vāsapakhe* 2 *divase* 1 (*dattā paṭṭikā Saṁvatsare aṣṭādaśe* 18 *Varṣāpakṣe divtīye* 2 *divase prathame* 1).

i.e. the inscription was recorded in the eighteenth year elapsed since the coronation on the first day of the second *Pakṣa* of the *Varṣā* season, i.e., in the lunar month of *Śrāvaṇa*, on the first day after new moon (*Śukla pakṣa*).

There are other Sātavāhana inscriptions similarly dated as summarized in the table below :

Table 14.

Table of Inscriptions of Sātavāhana Kings, showing date-recording.

Lüders			
1024	Raño Gotamiputasa Sāmi-Siriyaña-Sātakaṇisa	16-G	1-5
1100	Raño Vāsiṭhiputasa Sāmi-Siri-Pulumāvisa	7-G	5-1
1106	R. V. Siri-Pulumāvisa ...	24-H	3-2
1122	R. V. Siri-Pulumayisa ...	6-G	5-6
1123	R. V. Siri-Pulumayisa ...	19-G	2-13
1124	R. V. Siri-Pulumavisa ...	19-G	2-13
		22-G	1-7
1126	R. G. Sātakaṇisa ...	24-V	4-5
1146	R. G. Sāmi Siriyaña Sātakaṇisa ...	7-H	1
1147	R. V. Sāmi Siri-Pulumāisa ...	2-H	8
90	(Sircar)-Sīri-Pulumāvisa ...	8-H	2-1

R means raño, V-Vāsiṭhiputasa, G-Gotamiputasa.

The number in the first column indicates the serial number of the inscription in Lüders' list. The last column contains dates, in an abridged form ; e.g., in 1123, we have 19, G 2-13. Here '19' is the regnal year, G denotes *Grīṣma* or summer season, '2' following G denotes the second *pakṣa*, i.e., the second half of the month of Caitra, constituting the *Śukla pakṣa*, and the last numeral '13' denotes the day. But it is not clear whether the day is the lunar day, i.e., the *tithi* or the solar day. Even if it be the tithi, it is probably not the Siddhāntic *tithi*, but the old Brāhmaṇic or Vedāṅga *tithi*.

According to our calculations, the date of Gautamīputra Śātakarṇi would be about the first century A.D. We take some still later records.

(2) Rājā Vīrapuruṣadatta of Nāgārjunīkoṇḍa (Sircar, pp. 220-221)

Raṁño Siri Vīrapurisadatasa Sava 6 vā pa 6 di 10 (Rājñaḥ Śrī Vīrapuruṣadattasya saṁvatsare ṣaṣṭhe 6 varṣāpakṣe ṣaṣṭhe 6 divase daśame 10.

On the sixth year of King Śrī Vīrapuruṣadatta on the 6th *pakṣa* of the *varṣā* season, on the tenth day. The sixth of *varṣā pakṣa* is month of Āśvina, second or light half (*Śukla pakṣa*).

It is obvious from the above inscriptional evidences, that continuous era-recording was not used by Indian dynasts up to the time of the Sātavāhanas, and no ancient books, not even the *Mahābhārata* mentions an era.

As no era is mentioned, it has been difficult to work out a chronology of the early Indian dynasts including the Sātavāhanas.

The Coming of the Era to India

As we have seen in § 3.5, the era reckoning had been in use in Babylon since 747 B.C., and the Seleucidean era which marked the accession to power of Seleucus at Babylon in 312 B.C., was widely current in the whole of the Middle East, both by the royalty and the public.

But though as Aśoka's Girnar inscription says that he was in diplomatic correspondence with five Greek kings of the West, including Antiochus I and II of Babylon, and the Ptolemy of Egypt, and sent Buddhist missionaries to these countries, it is clear from his records that he continued to use the purely Indian methods of date-recording based on the *Vedāṅga-Jyotiṣa*. There is not the slightest indication that any of the Indian imperial dynasties which followed the Mauryas, *viz.*, the Suṅgas and Kāṇvas (186 B.C.-45 A.D.), the Śatavāhanas (100 A.D.) allowed themselves to be influenced by the Graeco-Chaldean luni-solar calendar which was then in vogue in the Near East.

From about 180 B.C., North-Western India having Taxila as capital passed under the Bactrian Greeks.

It is rather strange that though we have plenty of coins of the Bactrian Greeks who ruled in Afghanistan and N.W. India between 160 B.C., and 50 B.C., from which their names have been recovered, and some kind of chronology has been worked out, not a single record has *yet* been discovered which bears a date, except two doubtful ones. One is the coin of a certain Plato, found in the Kabul valley, which bears certain symbols which have been interpreted as 147 of the Seleucidean era, i.e., 165 B.C., Plato has been identified by Tarn to be a brother of Eucratidas, founder of the second Greek ruling house (175 B.C.-139 B.C.) in Bactria. But the interpretation is doubtful.

The second one is an inscription of the time of king Menander, the great king of the Euthydemid house who ruled over the Punjab, Sind and Rajputana about 150 B.C., on the Shinkot Steatite Casket, the only one of the Greek kings who has found a permanent place in Indian literature in the celebrated *Milinda Pañho*, a philosophical treatise meaning questions of king Menander. The inscription referred to mentions regnal year 5, the Indian month of *Vaiśākha*, and the twenty-fifth day. Thus the date-recording is Indian, but slightly different from the system used in Aśokan or Śatavāhana inscriptions because the *pakṣa* is omitted.

Our studies given in § 3·3, shows that a mathematically accurate luni-solar calendar, based on astronomical knowledge, was first evolved in Seleucid Babylon between 300 B.C. to 200 B.C. by Chaldean astronomers. The features of this calendar were :

(a) The use of the Seleucidean era for numbering years in place of the regnal years.

(b) The beginning of the year with the lunar month of Nisan which was to start on a date not later than a month of the vernal eqxinox.

(This corresponds to the Indian month of *Vaiśākha* later defined in Siddhāntic calendars).

(c) There was an alternative method of starting with the Greek month of *Dios* which was to begin on a date not later than a month of the autumnal equinox.

(This corresponds to the Indian month of *Kārtika*, as later defined in Siddhāntic calendars).

(d) Luni-solar adjustment was done by the nineteen-year cycle (*vide* § 3·2 – 3·4).

This system of date-recording spread far and wide in the Near East and was adopted by other ruling dynasties, viz., the Parthians, who however used an era starting from 248 B.C. They used Macedonian months without alteration.

It can now be shown that this system penetrated gradually into India.

Era or eras of unknown origin began to be mentioned in certain inscriptions found in the North-Western Punjab and the Kabul valley about the first century B.C. Some of them mention kings belonging to the Śaka tribes who ruled Ariana (west and southern Afghanistan comprising the Herat regions-Area), the Kāndāhār regions (Arachosia), and Gāndhāra (N.W. Punjab) between the second century B.C. and the first century A.D. The inscriptions are mostly in Kharoṣṭhī and later ones found on Indian soil are in Brāhmī. The Kharosthī inscriptions are collected by Dr.Sten Konow in his monumental work *Corpus Inscriptionum Indicarum*, Vol. II., Part I., and are reproduced below in Groups A and B.

Group A is identical with Konow's A (with the omission of Nos. 20-23) and contains dates from year 58 to 200. Group B, identica with Konow's B-Group, contains the inscriptions of Kuṣāṇa period bearing dates of years between 3C0 and 400.

GROUP A

1. Maira : [*saṁ 58*].
2. Ṣahdaur A : *ra* [*ja*] *no Damijadasa saka-sa....* [*ṣaṣṭi...60*].
   (Reading uncertain.)
3. Ṣahdaur B : [*maharayasa ?*] *Ayasa saṁ....*
4. Mānsehrā : *...aḍhaṣaṭhi....*
5. Fatehjang : *saṁ 68 Proṭharatasa masasa divase ṣodaśe 16.*
6. Taxila copper-plate : *saṁvatśaraye aṭhasatatimae 78 maharayasa mahaṁtasa Mogasa Panemasa masasa divase paṁcame 5 etaye purvaye.*
7. Mucai : *vaṣe ekaśitimaye 81.*
8. Kala Sang : [*saṁ 100*]. Reading uncertain.
9. Mount Banj : *saṁvatśaraye 102.*
10. Takht-i-Bāhī : *maharayasa Guduvharasa vaṣa 26 saṁvatśarae tiśatimae 103 Veśakhasa masasa divase* [*praṭha*] *me* [*di 1 atra puña*] *pakṣe.*
11. Pājā : *saṁvatśaraye ekadaśa* [*śa**] *timaye 111 Śravaṇasa masasa di* [*va**] *se paṁ*[*cada*]*śe 15.*
12. Kāldarra : *vaṣa 113 Śravaṇasa 20.*
13. Mārguz : [*vaṣe 1**]*17.*
14. Panjtār : *saṁ 122 Śravaṇasa masasa di praḍhame 1 maharayasa Guṣaṇasa rajami.*
15. Taxila silver scroll : *sa 136 ayasa Aṣaḍasa masasa divase 15 iśa divase...maharajasa rajatirajasa devaputrasa Khuṣaṇasa aroga; dakṣiṇae.*
16. Peṣāwar Museum, No. 20 : *saṁ 168 Jeṭhamase divase paṁcadaśe.*
17. Khalatse : *saṁ 187 maharajasa Uvimaka* [*vthi*] *sasa.*
18. Taxila silver vase : *ka 191 maharaja* [*bhrata Maṇigulasa putrasa**]*Jihoṇikasa Cukhsasa kṣatrapasa.*
19. Dewai : *saṁ 200 Veśakhasa masasa divase aṭhame 8 itra khaṇasa.*

The Method of Date Recording

A record fully dated in Group A gives :

The year of the era in figures and words ; though it does not give any particular designation to the era.

The month, mostly in Sanskrit ; the day, by its ordinal number, e.g., No. 11, which means in the year 111 on the 15th day of the month of *Śrāvaṇa*.

The months are all in Sanskrit, except in No. 6, in which the month is in Greek (*Panemos* = *Āṣāḍha*). No. 6 alone of this group contains the rather mysterious phrase '*Etaye purvaye*' which means, 'before these'. This phrase, the meaning of which is not clear, occurs in Kuṣāṇa (Group B) and even in Gupta inscriptions.

This method of dating is quite different from that of the contemporary Indian dynasts, *viz.*, the Sātavāhanas, which mentioned regnal years, the season, the *pakṣa*, and then probably the old *tithi* or the lunar day. But it agrees with the method followed in contemporary Parthia, which mentions the year usually in the Seleucidean era, rarely in the Arsacid era, the name of the month in Greek, and the ordinal number of the day, which ranges from 1 to 30 (see Debevoise, 1938). From No. 10, it appears that whenever Indian months were used they were *Pūrṇimānta*, following the classical Indian custom.

Date of records of Group A

None of the inscriptions of Group A appear to be 'Royal Records' but some contain names of kings, e.g., No. 6, which mentions a *Mahārājā Mahaṁta* Moga, who is taken to be identical with a king whose coins have been found in large numbers in Gāndhāra. He calls himself '*Maues*' in the Greek inscription on the obverse, and *Moasa* (i.e. of Moa) in Kharoṣṭhī on the reverse. The title given there usually is *Maharajasa Rajatirajasa Mahaṁtasa.* It is held that King Moga was Saka leader who starting from a base in Seistan or Arachosia, invaded Gāndhāra through the southern route, sailed up the Indus, and ousted the Greek rulers Archebius from Taxila, Artemidorus from Puṣkalāvatī and Telephos from Kapśā (Bachhofer, 1936) and founded a large empire comprising parts of Afghanistan, Gāndhāra and the Punjab.

He is generally held to have been a Śaka, but some hold without sufficient reason that he was a Parthian. He is the first of Indo-Scythian kings known to numismatics. He was followed by other Indo-Scythian kings in Gāndhāra, who are known from wide variety of coins issued, viz., Azes I, Azilises and Azes II. But there is no clear reference to them in these inscriptions except the word '*Ayasa*' in Nos. 10 and 15, which is supposed to stand for Azes. But this has been disputed.

This series starts with the year 58, if Cunningham's reading of (1) with the additional reading of the king's name 'Moasa' is accepted. But even if we reject it, the series certainly starts with the year 68 in No. 5, and goes up to 136 at fairly small intervals, then to 168, 187, 191, 200 containing names of rulers known from coins, viz., besides Maues above mentioned, Gondophernes (103 = 20 B.C.), some Kuṣāṇa king (122 = 1 B.C.), Devaputra Kuṣāṇa (136 = 14 A.D.), Mahārāj-bhrātā Jehonika (191 = 69 A.D.). They are held to be dated in the same era, which is usually called the Old Śaka Era, shortly called O.S.E. But up to this time, there has been no unanimity amongst scholars about the starting date of the era used in inscriptions grouped under A.

We now take the second group of inscriptions which are those of the Kuṣāṇas, who ruled in North India in the second century A.D.

GROUP B

The Kuṣāṇa Inscriptions after Kaniṣka :

24. Kaniṣka casket : *saṁ 1 ma[harayasa] Kaniṣkasa.*
25. Sui Vihār : *maharajasya rajatirajasya devaputrasya Kaniṣkasya saṁvatśare ekadaśe saṁ 11 Daisi(ṁ)kasya masas[y]a divase(ṁ) aṭhaviśe 28 [aya] tra divase.*
26. Zeda : *saṁ 11 Aṣaḍasa masasa di 20 Utaraphaguṇe iśa kṣuṇami............muroḍasa marjhakasa Kaṇiṣkasa rajami.*
27. Māṇikiāla : *saṁ 18 Kartiyasa majh [e] divase 20 etra purvae maharajasa Kaṇeṣkasa.*
28. Box lid : *saṁ 18 masye Arthamisiya sastehi 10 iś [e] kṣunaṁmri.*
29. Kurram : *saṁ 20 masasa Avadunakasa di 20 iś [e] kṣunaṁmi.*
30. Peṣāwar Museum, No. 21 : *maharajasa [Vajuṣ] kasa saṁ [24 Jeṭhasa ?] masasadi······iśe kṣunaṁmi.*
31. Hidda : *saṁvatśarae aṭhaviṁśatihi 28 masye Apelae sastehi daśahi 10 iś [e] kṣunaṁmi.*
32. Ṣakardarra : *saṁ 40 P [r]oṭhavadasa masasa divas[ami] viśami di 20 atra divasakāle.*
33. Ārā : *maharajasa rajatirajasa devaputrasa kaisarasa Vajheṣkaputrasa Kaniṣkasa saṁvatśarae ekacapar[i]śa[i] saṁ 41 Jeṭhasa masasa di 25 iś [e] divasakṣuṇami.*
34. Wardak : *saṁ 51 masy[e] Arthamisiya sastehi 15 imeṇa gaḍrigreṇa······maharaja rajatiraja Hoveṣkasra agrabhagrae.*

35. Uṇḍ : *saṁ 61 Cetrasa mahasa divase aṭhami di 8 iśa kṣunami*·········*Purvaṣaḍe.*

36. Mamāne Ḍherī : *śaṁ 89 Margaśirasra masi 5 iśe kṣunami.*

An incomplete date, *maśasa di 25*, is further found in the Kāniza Ḍherī inscription.

The second group Nos. 24-36 contains Kharoṣṭhī inscriptions of the Kuṣāṇa kings after the first Kaniṣka. These and Kuṣāṇa Brāhmī inscriptions mention :

Years from 1 to 98, the kings Kaniṣka I from 1 to 24,
Vajheska from 24-28, Kaniṣka II of the year 41,
Huviṣka from 33-60,
Vāsudeva from 62-98.

The King's name and the titles are given in full, and in the genitive. The era is generally ascribed to the famous Kaniṣka as we have a record of his first year.

Their method of date-recording is the same as in Group A, viz., (see No. 25) the year of the era, the month name in Greek or Sanskrit, the ordinal number of the day, then the phrase equivalent to *asyāṁ pūrvāyāṁ* (before these), but in these inscriptions, it is expressed in the form *iśe kṣunami* or its variant, which has been interpreted by Konow as equivalent of *asyāṁ* or *etasyāṁ pūrvāyāṁ* in the Khotanī Śaka language which Konow thinks was the mother tongue of kings of the Kaniṣka group and which they use in their inscriptions. In fact kings of this group use a number of Khotanī Śaka words, and from their wide range of coins are known to have put in a medley of Greek, Iranian, and Indian gods including Buddha on their coins, but the names of the gods are not in their original Indian, Iranian or Greek form but invariably in the form used in the Khotanī Śaka language.

The method of date-recording followed by the Kuṣāṇas, in spite of its identity with that of Group A shows some interesting variations. In the Kharoṣṭhī inscriptions of the Kuṣāṇas, the months are mostly Greek, less so in Sanskrit (*Caitra, Vaiśākha,* etc.). The days run from 1 to 30 and clearly they are not *tithis* but solar days. When we turn to Brāhmī inscriptions, we find that the month names are mostly seasonal : *Grīṣma, Varṣā,* or *Hemanta* as in the Sātavāhana records. But since 4 is the maximum number attached to these, and the day numbers run from 1 to 30, the number after the season denotes a month, not a *pakṣa* and the days are solar. Thus G 4 denotes the fourth month of the *Grīṣma* season, viz, *Āṣāḍha*, and not the fourth *pakṣa* as was the case with the Sātavāhanas which would be the second half of *Vaiśākha*. The *pakṣa* is given up.

This is a deviation from Sātavāhana method of date-recording and follows closely the Graeco-Chaldean method. Some inscriptions mention Greek months (e. g. *Gorpiaios* which is *Āśvina* or *Bhādra* in Sircar's No. 49, p. 146) others Indian lunar months (e. g. *Śrāvaṇa* in No. 51), but their number is small compared with the seasonal mode of recording months. These inscriptions give no indication as to whether the month is *Pūrṇimānta* or *Amānta*. The Indian months are *Pūrṇimānta*.

But the Zeda inscription of year 11 (No. 26 of Group B) mentions that the *nakṣatra* was *Uttaraphalgunī* on the 20th of *Āṣāḍha*, and (35) mentions that in the year 61, the *nakṣatra* on the 8th day of *Caitra* was *Pūrvāṣāḍhā*. A comparison with tables of *nakṣatras* shows that the months ended in full moon (*Pūrṇimānta*). As *pūrṇimānta* months were unknown outside India, the Kuṣāṇas must have yielded to Indian influence and adapted their original time-reckonings to the Indian custom; at least in their use of Indian months.

Historians and chronologists now almost unanimously hold that all these inscriptions of Group B are dated in the same era which is sometimes called the Kuṣāṇa era, which was founded by King Kaniṣka. This is said to be proved by the fact that the inscriptions range from year 1, and we have phrases as in No. 25 'of the *Mahārāja Rājādhirāja Devaputra Kaniṣka*, in the year 11. But a little more scrutiny shows that it is only a conventional phraseology, used in almost all Kuṣāṇa inscriptions, for even in as late as an inscription of year 98 of this group, we read 'of the Mahārājā Vāsudeva in the year 98'. It is therefore by no means clear that such phrases can be interpreted to mean that Kaniṣka started an entirely new era. In fact, from Kaniṣka's profuse use of Greek months and Greek gods, in his inscriptions and coins, Cunningham was led to the belief that Kaniṣka dated his inscriptions in the Seleucidean era, with hundreds omitted, so that year 1 of Kaniṣka, is the year 401 of S. E. and year 90 of the Christian era.

But it has been known for some time that the Kuṣāṇa empire did not stop with that Vāsudeva who comes after Huviṣka. Dr. L. Bachhofer (1936) has proved from numismatics the existence of :

Kaniṣka III, reigning apparently after Vāsudeva I,
Vāsudeva II, reigning after Kaniṣka III.

The kings appear to have retained full control of the whole of modern Afghanistan including Bactria which appears to have been the home land of the Kuṣāṇas and some parts of the Punjab, right up to Mathurā.

There is yet no proof for or against the point that they retained the eastern parts, after year 98 of Kuṣāṇa era. Herzfeld had established that Vāsudeva II, who appears to have come after Kaniṣka III about 210 A.D., was deprived of Bactria by Ardeshir I, the founder of the Sasanid dynasty of Persia. The Sasanids converted Bactria into a royal province under the charge of the crown prince, who struck coins closely imitating those of the Kuṣāṇas. Vāsudeva II is also mentioned in the Armenian records of Moise of Khorene, a Jewish scholar, under the name Vehsadjan, as an Indian king who tried to form a league with Armenia and other older powers against the rising imperialism of Ardeshir. Vasudeva II is also thought to have sent an embassy to China about 230 A.D *.

The second Sassanian king Shapur I, claims to have conquered sometime after 240 A.D. 'PSKVR', which has been identified with Puruṣapura or Peshawar, the capital of the Kuṣāṇas. This has also been confirmed by the French excavations at Begram (Kāpiśī) in Afghanistan, which was destroyed by Shapur between 242 and 250 A.D. But this probably was not a permanent occupation but a raid, as a Kuṣāṇa king or Shah is mentioned in the Paikuli inscription of the Sasanid king Narseh (293-302 A.D.).

Kushana Method of Date-recording In India :

It appears rather strange that the Kuṣāṇa way of date-recording should suddenly come to a dead stop on Indian soil with the year 98 of Vāsudeva I, and no records containing a year number exceeding 100 should be found on Indian soil.

The mystery appears now to have been successfully solved by Mrs. Van Lohuizen de Leeuw in her book *The Scythian Period* (pub. 1949). She has proved that several Brāhmī inscriptions in the Mathurā region bear dates from years 5 to 57 in which, following an old Indian practice, the figure for hundred has been omitted. Thus '5' stands for 105, '14' stands for 114 of the Kuṣāṇa era. The following example will suffice (*vide* pp. 242-43 of *The Scythian Period*).

One and the same person Āryā Vasulā, female pupil of Āryā Saṅgamikā, holding the important position of a religious preacher in the Jaina community, is mentioned in two Brāhmī inscriptions (No. 24 and No. 70 of Lüders) bearing the year designations of 15 and 86 respectively, the date-recording being in the typical Kuṣāṇa style. The palaeographical evidence also shows that the inscriptions were recorded in the Kuṣāṇa age, though the name of the reigning monarch is not mentioned. Now it is clearly impossible that the same person would occupy such an important position from the year 15 to 86, a period of 71 years. L. de Leeuw therefore suggests that while 86 is the usual Kuṣāṇa year (reckoning from year 1 of Kaniṣka), '15' is really with hundred omitted and represents actually the year 115 of Kaniṣka, i.e., dates of the two inscriptions differ by 115 − 86 = 29 years, which is much more plausible. In other words, after the year 100 of the Kaniṣka era was passed, hundreds were dropped in inscriptions found near about Mathurā.

The author has sustained her ground by numerous other illustrations, and there seems to be no doubt that this is a brilliant suggestion and it can be taken as proved that in numbering years of an era, hundreds were omitted *in certain parts* of the Kuṣāṇa dominion in the second century of the Kaniṣka era. L. de Leeuw has found such dates in no less than 7 instances bearing years 5, 12, 15, 22, 35, 50, 57 in which apparently 100 has been omitted, so that 57 really stands for 157, and if we take the Kaniṣka era to have started from 78 A.D., the date of the last one is A.D. 235 = (157 + 78). Probably the name of the reigning king was not mentioned, as he had either lost control over these regions, or as the inscriptions were religious, it was not considered necessary. The second alternative appears to be more correct.

This is supported by the inscription on an image discovered by Dayaram Sahni in Mathurā in 1927. It mentions *Mahārāja Devaputra* Kaniṣka. But on palaeographic grounds, he can neither be Kaniṣka I (1-24) nor Kaniṣka II (41), but a later Kaniṣka, coming after Vāsudeva I, and 14 is really year 114 of the Kaniṣka era. We may identify him with Kaniṣka III of Bachhofer.

So we come to this conclusion :

The records of Kuṣaṇa kings, after Kaniṣka I range from year 1 to 98. In the second century of the Kaniṣka era, hundreds are omitted and such records have been found up to year 157, i.e., year 235 of the Christian era.

This raises a strong presumption that Kaniṣka was not the founder of the era, but he used one already in vogue, but omitted the hundreds. Thus year 1 of Kaniṣka is really year 1 plus some hundred, may be 1, 2, or 3. L. de Leeuw does not expressly suggest this, though it is apparent from her reasoning *that year 1 of King Kaniṣka is year 201 of the Old Śaka era**. If this suggestion be correct, since the old Śaka era is taken to have started in 123 B.C. (−122 A.D.) instead of in 129 B.C., as postulated by L. de Leeuw, Kaniṣka started reigning in (201 − 123) = 78 A.D.

* Ghirshman thought that the Vāsudeva Kuṣāṇa of these references is Vāsudeva I, whose last reference is year 98. He equated year 98 of Kaniṣka's era to year 242-250 A.D., and arrived at the date 144 to 152 A.D. for the initial year of the Kaniṣka era. But the equation of this Vāsudeva with Vāsudeva I is certainly wrong. This must be Vāsudeva II, or may be a still later Vāsudeva.

* The suggestion is of Prof. M. N. Saha.

From the above review of inscriptional records and contemporary history, the following story has been reconstructed.

(1) The Śaka era was first started in 123 B.C. when the Sakas coming from Central Asia due to the pressure of Hūṇas wrested Bactria from the Parthian emperors after a seven years' war. The leader was probably one 'Azes', and therefore the era was also alternately called the 'Azes' era. This Azes is not to be confounded with the two later Azes who succeeded Maues and reigned between 45 B. C. to 20 B. C. Earlier Sakas used Macedonian months and Graeco-Chaldean method of date recording, prevalent throughout the whole of Near East. In Indian dominions, Indian months which were equated to Greek months were used. As their coins show, the ruling class had adopted Greek culture.

(2) When the Sakas spread from 'Śakasthān', i.e., modern Afghanistan into contiguous parts of India, they began to be influenced by Indian culture. During the first stage, they exclusively used Greek in their coins, but later they began to use Kharoṣṭhī and Brāhmī as well. The coins of Maues (80 B.C.—45 B.C.), Azes I, Azilises, Azes II show increasing influence of Indian culture. The southern Sakas who penetrated into Saurashtra and Malwa show Indian influence to a greater degree.

(3) In the first three centuries, they (Maues group, Nahapāna group and Kuṣāṇas) used the old Śaka era omitting hundreds, and using a method of date-recording which was an exact copy of the contemporary Graeco-Chaldean system prevalent throughout the Parthian empire (Macedonian months, and ordinal number of days). But they also began to use Indian months. Whenever they did it, the month was *Pūrṇimānta*, as was the custom with old Hindu dynasts (Mauryas and Sātavāhanas).

(4) The classical Śaka era starting from 78 A.D. is nothing but the old Śaka era, starting from 123 B.C. with 200 omitted, so that the year 1 of Kaniṣka is year 201 of the Old Śaka era.

Śaka Era in the South-West.

Besides the earlier Śakas belonging to the Maues group, and the Kuṣāṇas, there was another group of Śaka kings, who penetrated into the south-western part of India. The earliest representative of this group was Nahapāna and his son-in-law Uṣavadāta. Their records are dated in years 41 to 46 of an unknown era. They use Indian lunar months and days (probably *tithis*). These Śakas ruled in Rajputana, Malwa, and northern Maharastra and were engaged in continuous warfare with the Sātavāhana ruler Gautamīputra Śātakarṇi who claim to have destroyed them root and branch.

The senior author has shown that Nahapāna used the old Śaka era with one hundred omitted, so that the year 46 of Nahapāna was the year 146 of the old Śaka era or about 24 A.D.

The Sātavāhana kings Gautamīputra Śātakarṇi and his son Vāsiṣṭhīputra Pulumavi, whose records are found dated in the typical Indian fashion, reigned according to his hypothesis from about 40 A.D. to 80 A.D. From epigraphical record, Nahapāna is at least separated by about 100 years from the next group of Śaka rulers, *viz.*, the Śakas of Ujjain belonging to the house of Caṣṭana.

The Śaka satraps of Ujjain.

We come across the records of another Śaka ruling family, reigning in Ujjain.

[Andau (Cutch) stone inscriptions of the time of Caṣṭana and Rudradāman, Sircar, p. 167].

Rājñaḥ Caṣṭanasya Jāmotika-putrasya rājñaḥ Rudradāmnaḥ Jayadāma-putrasya [ca] varṣe dvipañcāśe 52 Phālguna-bahulasya (=kṛṣṇa-pakṣasya) dvitīya vāre (=divase) 2 madanena Siṁhila-putreṇa bhaginyāḥ Jyeṣṭhavīrāyāḥ Siṁhila-duhituḥ aupaśati sagotrāyāḥ yaṣṭiḥ utthāpitā····.

Translation : Of king Caṣṭana, son of Jāmotika and of king Rudradāman son of Jayadāman, in the year 52, on the dark half of the month of Phālguna and on the 2nd day····

This inscription mentions the year 52, the second day of the *Kṛṣṇa pakṣa* of the month of *Phālguna*.

There is no doubt that the year mentioned is that of the *Śaka era as now known*. For this satrapal house reigned continuosly for nearly 300 years and has left a wealth of dated records. But the name of the era is not mentioned in the earlier records. They are mentioned merely as years so and so.

The earliest authentic instance of the use of Śaka era by name is supplied by the Bādāmi inscription of Calikya Vallabhesvara (Pulakesin I of the Cālukya dynasty), dated 465 of the Śaka era (*Śaka-Varṣeṣu Catuś-śateṣu pañca-ṣasṭhi-yuteṣu* : *Epigraphia Indica* XXVII, p. 8). In literature the use of the era by name appears still earlier. The *Lokavibhāga* of Siṁhasūri, a Digambara Jaina work in Sanskrit is stated in a manuscript to have been completed in 80 beyond 300 (i.e. 380) of the Śaka years (*Ep. Ind.*, XXVII, p. 5). There is no doubt that the era used in the records of the western satrapal house beginning with Caṣṭana and Rudradāman have come down to the present times as the Śaka Era, which is the 'Era' par excellence used by Indian astronomers for purposes of calculation. There ere 30 or more 'Eras' which have been in use in India (*vide* § 5·8), but none of them have been used for calendarical calculation by the Indian astronomers.

Yet it is difficult to assign the origin of the Śaka era to the western satraps. An era can be founded only by an imperial dynasty like the Seleucids, the Parthians or the Guptas. The western satraps never claim, in their numerous records, any imperial position. They are always satisfied with the subordinate titles like *Kṣatrapa* (*Satrap*) or *Mahā Kṣatrapa* (Great *Satrap*) while the imperial position is claimed by their northern contemporaries, the Kuṣāṇas.

The conclusion is that the western Kṣatrapas used the old Śaka era, with 200 omitted ; so that year 1 of the present Śaka era is year 201 of the old Śaka era, i.e., (201—122) = 79 A.D.

The gradual adoption of characteristic Indian ideas by the Śakas is shown in a record of Satrap Rudrasiṁha dated 103 S.E. or 181 A.D.

[Gundā Stone Inscription of the time of Rudrasiṁha I, Sircar, p. 176]

Siddham. Rājñaḥ mahākṣatrapasya svāmi-Caṣṭana-prapautrasya rājñaḥ kṣatrapasya svāmī Jayadāmapautrasya rājñaḥ mahākṣatrapasya svāmi-Rudradāma-putrasya rājñaḥ kṣatrapasya svāmi-Rudrasiṁhasya varṣe tryutta-raśata (*tame*) (= *adhika*) *103 Vaiśākha śuddhe* (= *śuklapakṣe*) *pañcama-dhanya tithau Rohiṇī nakṣatra-muhūrte ābhireṇa senāpati Bappakasya putreṇa senāpati Rudrabhūtinā grāme rasāpadrake vāpī* (= *kūpaḥ*) *khānitā, bandhitā* [*śilādibhiḥ*] *ca sarva sattvānāṁ hita-sukhārtham iti.*

Translation : Of king Mahākṣatrapa······of Svāmī Rudrasiṁha in the year 103 in the light half of the month of Vaiśākha on the 5th tithi and in the Rohiṇī nakṣatra muhūrta,......

The Śaka satrap Rudrasiṁha, reigning in 181 A.D. thus dates his inscriptions using an era (the Śaka era), purely Indian months, *tithis* and *nakṣatras*. This is in full Siddhāntic style, because the characteristic features of Siddhāntic method of date recording which mention *tithi* and *nakṣatra* are first found in this inscription. The 'week day' is however not mentioned. This is first mentioned in an inscription of the emperor Budhagupta (484 A. D.).

Śate pañcaṣaṣṭyādhike varṣāṇāṁ bhūpatau ca
Budhagupte Āṣāḍha māsa [*śukla*]—[*drā*] *dasyāṁ suraguror divase······*

(*Iran Stone Pillar Inscription of Budha Gupta*— Gupta year 165 = 484 A.D.).

Translation : In the year 165 of the Gupta era during the reign of emperor Budhagupta in the month of Āṣāḍha and on the 12th tithi of the light half which was a Thursday (i.e. day dedicated to the preceptor of Gods).

5.6 SOLAR CALENDAR IN THE SIDDHANTA JYOTISHA PERIOD

Rise of Siddhantas or Scientific Astronomy

The *Vedāṅga Jyotiṣa* calendarical rules appear, from inscriptional records, to have been used right up to the end of the reign of the Sātavāhanas (200 A.D.). The analysis of inscriptional data on methods of date-recording given in § 5·5 shows that it was the Śaka and Kuṣāṇa rulers (50 B.C. – 100 A.D.), who introduced the Graeco-Chaldean methods of date-recording, prevalent in the Near East into India. These methods require a knowledge of the fundamentals of astronomy, which must have been available to the Śaka and Kuṣāṇa rulers. In India, as the inscriptional records show, some purely Indian dynasts probably accepted the system in full from about 248 A.D. (date of foundation of the Kalachuri era, the earliest era founded by Indian kings, leaving aside the Saka era which is admittedly of foreign origin and the Vikrama era whose origin is still shrouded in mystery). During the time of the Guptas who founded an era commemorating their accession to power in 319 A.D. the integration of the western system with the Indian appears to have been complete.

Indian astronomical treatises, explaining the rules of calendaric astronomy, are known as ***Siddhāntas***, but it is difficult to find out their dates. The earliest Indian astronomer who gave a date for himself was the celebrated Āryabhaṭa who flourished in the ancient city of Pātaliputra and was born in 476 A.D.

It is necessary to reply to a question which has very often been asked, but never satisfactorily answered, *viz.*,

Why did the Indian savants who were in touch with the Greeks, and probably with Greek science since the time of Alexander's raid (*323 B.C.*), *take about 500-600 years to assimilate Greek astronomy, and use it for their own calendar-framing* ?

The Indians of 300 B.C. to 400 A.D., were quite vigorous in body as well as in intellect as is shown by their capacity to resist successive hordes of foreign invaders, and their remarkable contributions to religion, art, literature and certain sciences. Why did they not accept the fundamentals of Greek astronomy for calendarical calculations earlier ?

The reply to this query appears to be as follows :

The Greeks of Alexander's time had almost nothing to give to the Indians in calendaric astronomy, for their own knowledge of astronomy at this period was extremely crude and far inferior to that of the contemporary Chaldeans. The remarkable achievements of the Greeks in astronomy, and geometry, though they started from the time of Alexander (Plato's Academy), really flowered in full bloom in the century following Alexander (330 B.C. – 200 B.C.). The culmination is found in Hipparchos of Rhodes who flourished from 160—120 B.C. ; he wrote treatises on astronomy. Simultaneously in Seleucid Babylon, Chaldean and Greek astronomers made scientific contributions of the highest order to astronomy (*vide* § 4.7 & 4.8), but none of their works have survived, but are now being found by archaeological explorations.

It is therefore obvious that the Indians of the age of Aśoka (273 B.C.—200 B.C.), who were in touch with the Greek kingdoms of Babylon and Egypt, had not much to learn from the Greeks in astronomy.

The Mauryas were succeeded by the Suṅgas (186 B.C.—75 B.C.), but Indians during this age were in touch only with the Bactrian Greeks. But by this time, the Parthian empire had arisen (250 B.C.), producing a wedge between western and eastern Greeks. The only dated record of the Indo-Bactrian king, Menander (150 B.C.), is purely Indian in style.

By about 150 B.C., direct contact between India and Greater Greece which included Babylon had almost ceased, due to the growth of the Parthian empire. Whatever ideas came, was through the Śaka-Kuṣāṇa kingdoms which came into existence after 90 B. C. By that time, astronomy was regarded as only secondary to planetary and horoscopic astrology, which had grown to mighty proportions in the West. This may have been probably one of the main reasons for late acceptance of Graeco-Chaldean astronomy in India, *for Indian thought during these years was definitely hostile to astrology.*

It will surprise many of our readers to be told that astrology was not liked by Indian leaders of thought, which dominated Indian life during the period 500 B.C. – 1 A.D. Nevertheless, it is a very correct view.

The Great Buddha, Whose thoughts and ideas dominated India from 500 B.C. to the early centuries of the Christian era, was a determined foe of astrology. In Buddha's time, and for hundreds of years after Buddha, there was in India no elaborate planetary or horoscopic astrology, but a crude kind of astrology based on conjunctions of the moon with stars and on various kinds of omina such as appearance of comets, eclipses, etc. But Buddha appears to have held even such astrological forecasts in great contempt, as is evident from the following passage ascribed to him :

> Yathā vā pan'eke bhonto. Samaṇa-brāhmaṇā saddhā-deyyāni bhojanāni bhuñjitva te evarūpāya tiracchāna-vijjāya micchājīvena-jībikaṁ kappenti-seyyathidaṁ "canda-ggāho bhavissati, suriyaggāho bhavissati, nakkhatta-ggāho bhavissati. Candima suriyānaṁ pathagamanaṁ bhavissati, candima suriyānaṁ uppathagamanaṁ, bhavissati, nakkhattānaṁ pathagamanaṁ bhavissati, nakkhattānaṁ uppathagamanaṁ bhavissati. Ukkāpāto bhavissati. Disā-ḍāho bhavissati. Bhūmicālo bhavissati. Devadundubhi bhavissati. Candima suriya nakkhattanaṁ uggamanaṁ ogamaṇaṁ saṁkilesaṁ vodānaṁ bhavissati."*

(*Dīgha Nikāya*, Vol. 1, p. 68, Pali Text Book Society)

Translation : Some *brāhmaṇas* and *śramaṇas* earn their livelihood by taking to beastly professions and eating food brought to them out of fear ; they say : "there will be a solar eclipse, a lunar eclipse, occultation of the stars, the sun and the moon will move in the correct direction, in the incorrect direction, the nakṣatras will move in the correct path, in the incorrect path, there will be precipitation of meteors, burning of the cardinal directions (?), earthquakes, roar of heavenly war drums, the sun, the moon, and the stars will rise and set wrongly producing wide distress amongst all beings, etc."

This attitude to astrology and astrolatry on the part of Indian leaders of thought during the period of 500 B.C. to 100 A.D., was undoubtedly a correct one, and would be welcomed by rationalists of all ages and countries. But such ideas had apparently a very deterrent effect on the study of astronomy in India. Pursuit of astronomical knowledge was confused with astrology, and its cultivation was definitely forbidden in the thousands of monasteries which sprang all over the country within few hundred years of the Nirvāṇa (544 B.C./ 483 B.C). Yet monasteries were exactly the places where astronomical studies could be quietly pursued and monks were, on account of their leisure and temparament, eminently fitted for taking up such studies, as had happened later in Europe, where some of the most eminent astronomers came from the monkist ranks, e.g., Copernicus and Fabricius.

Neither did Hindu leaders, opposed to Buddhism, encourage astrology and astrolatry. The practical politician thought that the practice of astrology was not conducive to the exercise of personal initiative and condemned it in no uncertain terms. In the *Arthaśāstra* of Kauṭilya, a treatise on statecraft, which took shape between 300 B.C. and 100 A.D., and is ascribed to Cānakya, the following passage is found :

* Acknowledgement is due to Prof. Mm. Bidhusekhar Sastri, who supplied these passages.

Kauṭilīya Arthaśāstra

Nakṣatraṁ atipṛcchantaṁ bālaṁ artho'tivartate
Artho hyarthasya nakṣatraṁ kiṁ kariṣyanti tārakāḥ.

Translation: The objective (*artha*) eludes the foolish man (*bālam*) who enquires too much from the stars. The objective should be the *nakṣatra* of the objective, of what avail are the stars ?

This may be taken to represent the views of the practical politician about astrology and astrolatry, during the period 500 B.C. to 100 B.C.

Cānakya was the great minister of Candragupta, and history says that these two great leaders rolled back the hordes of the Macedonians, who had conquered the Acheminid Empire of Iran comprising the whole of the Near East to the borders of Iran, and thereafter laid the foundation of the greatest empire India has ever seen. They clearly *not only did not believe in astrology, but openly, and without reserve, ridiculed its pretensions.*

But the influence of original Buddhism waned after the rise of Mahāyānist Buddhism, which received great encouragement during the reign of Kaniṣka (78 A.D. to 102 A.D.) and other Kuṣāṇa and Saka kings. Then came Buddhist iconography, coins, and knowledge of the methods of western date-recording which the Śakas and Kuṣāṇas used. They blended with the indigenous Indian system slowly.

The focus of diffusion of western astronomical knowledge appears to have been the city of Ujjayinī, capital of the western Satraps who were apparently the first to use a continuous era (the Śaka era), and a method of date-recording which was at first purely Graeco-Chaldean as prevalent in Seleucid Babylon, but gradually Indian elements like the *tithi* and the *nakṣatra* were blended, as we find for the first time in the inscription of Satrap Rudrasiṁha, dated 181 A.D. (*vide* § 5·5).

This city of Ujjayinī was later adopted as the Indian Greenwich, for the measurement of longitudes of places. The borrowal of astronomical knowledge was not therefore from Greece direct, but as now becomes increasingly clearer, from the West, which included Seleucid Babylon, and probably through Arsacid Persia. The language of culture in these regions was Greek, and we therefore find Greek words like *kendra* (centre), *liptikā* (lepton), *horā* (hour) in use by Indian astronomers.

This view is supported by the Indian myth that astrolatry and astrology were brought to India by a party of *Śākadvīpi Brāhmaṇas* (Scythian Brahmins), who were invited to come to India for curing Śāmba, the son of Kṛṣṇa, of leprosy by means of incantations to the Sungod. Professional astrologers, in many parts of India, admit to being descendants of these *Śākadvīpi Brāhmaṇas* and probably many of the eminent astronomers like Āryabhaṭa and Varāhamihira who made great scientfic contributions to astronomy belonged to this race. The planetary Sungod is always shown with high boots on, as in the case of Central Asian kings (e.g., Kaniṣka).

It is a task for the historian to trace how the steps in which the importation of western astronomical knowledge took place for the *Siddhāntas*, which incorporate this knowledge and are all a few centuries later, and many of them bear no date.

A good *point d'appui* for discussion is Varāhamihira's *Pañca Siddhāntikā* ; for Varahamihira's date is known. He died in 587 A.D., in ripe old age so he must have written his book about 550 A.D. This is a compendium reviewing the knowledge contained in the five *Siddhāntas* which were current at his time. These were regarded as '*Apauruṣeya*' or "knowledge revealed by gods or mythical persons".

The five Siddhāntas are :

- *Paitāmaha* ···Ascribed to Grandfather Brahmā.
- *Vāsiṣṭha* ···Ascribed to the mythical sage Vasiṣṭha, a Vedic patriarch, and revealed by him to one Māṇḍavya.
- *Romaka* ···Revealed by god Viṣṇu to Ṛṣi Romaśa or Romaka.
- *Pauliśa* ···Ascribed sometimes to the sage Pulastya, one of the seven seers or patriarchs forming the Great Bear constellation of stars (but see later).
- *Sūrya* ···Revealed by the Sungod to Asura Maya, architect of gods, who propounds them to the Ṛṣis.

The five Siddhāntas are given in the increasing order of their accuracy according to Varāhamihira. Thus Varāhamihira considers the *Sūrya Siddhānta* as the most accurate, and next in order are the *Pauliśa*, and the *Romaka*. The *Vāsiṣṭha* and *Paitāmaha* are, according to Varāhamihira, not accurate.

Why were those *Siddhāntas* regarded as "*Apauruṣeya*" (i.e. not due to any mortal man) ? Dīkṣit says (*Bhāratīya Jyotiśāstra*, Part II, Chap. 1) :

"The knowledge of astronomy as seen developed during the Vedic and Vedāṅga Jyotiṣa periods and described in Part I, was *wide* as compared with the length of the period ; but *it is very meagre, when compared with the present position****. The oldest of astronomical knowledge (given in the oldest Siddhāntas) reveal a sudden rise in the *standard* of astronomical knowledge. Those who raised the standard as given in these works, were naturally regarded as superhuman and hence the available ancient works on astronomy are regarded as '*apauruṣeya*' (i.e. not compiled by mortal men) and it is clear that the belief has been formed later".

This statement, made by Dīkṣit nearly sixty years ago, really singles out only one phase of the issue, viz., the wide gulf in the level of astronomical knowledge of the Siddhāntas and that in the *Vedāṅga Jyotiṣa*; but leaves the question of actual authorship open. In our opinion the *Siddhāntas* were regarded as *Apauruṣeya* because they appear to have been compilations by different schools of the knowledge of calendaric astronomy, as they diffused from the West during the period 100 B.C.—400 A.D. But let us look into them a little more closely.

The Paitamaha Siddhanta: described in five stanzas in Chap. XII. of the *Pañca Siddhāntikā*.

As already discussed it is a revised edition of the *Vedāṅga Jyotiṣa*, but later authors say that it contained rules for the calculation of motions of the sun, the moon and also the planets which were not given by the *Vedāṅga Jyotiṣa*. As the full text of the original Siddhānta has not been recovered, it is difficult to say how the borrowal took place.

The Vasistha Siddhanta: as known to Varāhamihira is described in 13 couplets in Chap. II of *the Pañca Siddhāntikā*. It describes methods of calculating *tithi* and *nakṣatra*, which are inaccurate. Besides it mentions *Rāśi* (zodiacal signs), angular measurements, discusses length of the day, and the *lagna* (ascendant part of the zodiac). Apparently this represents one attempt by a school to propagate western astronomical knowledge. The school persisted and we have *Vāsiṣṭha Siddhāntas* later than Varāhamihira. One of the most famous was Viṣṇucandra (who was somewhat later than Āryabhaṭa) who was conscious of the phenomenon of precession of the equinoxes. No text of the Siddhānta is available, except some quotations.

Varāhamihira pays a formal courtesy to *Paitāmaha* and *Vāśiṣṭha*; this does not prevent him from describing these two as '*dūravibhraṣṭau*', i.e., furthest from truth.

The Romaka Siddhanta:

The *Romaka Siddhānta* as reviewed by Varāhamihira uses:

$$\text{A Yuga of 2850 years} = 19 \times 5 \times 30 \text{ years};$$
$$150 \text{ years} = 54787 \text{ days};$$
$$1 \text{ year} = 365.2467 \text{ days}.$$

The number of intercalary months in the *yuga* is given as 1050, i.e., there are 7 intercalary months in 19 years.

We need not go any further into the contents of this Siddhānta. As the name indicates, the knowledge was borrowed from the West, which was vaguely known as 'Romaka' after the first century A.D. The *yuga* taken is quite un-Indian, but appears to be a blending of the nineteen-year cycle of Babylon, the five-yearly yuga of *Vedāṅga Jyotiṣa*, and the number 30 which is the number of *tithis* in a month. The length of the year is identical with Hipparchos's (365.2467), and this alone of the Siddhāntas gives a length of the year which is unmistakeably tropical.

The *Romaka Siddhānta* appears to represent a distinct school who tried to propagate western astronomical knowledge on the lines of Hipparchos. One of the later propounders was Śrīṣeṇa, who flourished between Āryabhaṭa and Brahmagupta; the latter ridicules him roundly for having made a "*kānthā*", i.e. a wrapper made out of discarded rags of all types—meaning probably Śrīṣeṇa's attempt to blend two incongruous systems of knowledge, western and eastern.

The Paulisa Siddhanta:

This Siddhānta was at one time regarded as the rival of the *Sūrya Siddhānta*, but no text is available now. But it continued to be current up to the time of Bhaṭṭotpala (966 A.D.), who quotes from it.

Alberuni (1030-44 A.D.) who was acquainted with it, said that it was an adaptation from an astronomical treatise of Paulus of Sainthra, i.e., of Alexandria. But it is not clear whether he had actually seen Paulus's treatise, and compared it with the *Pauliśa Siddhānta* or simply made a guess on the analogy of names merely. The name of one Paulus is found in the Alexandrian list of savants (378 A.D.) but his only known work is one on astrology, and it has nothing in common with *Pauliśa Siddhāntā*, which appears to have been purely an astronomical treatise as we can reconstruct it from the *Pañca Siddhāntikā* (*vide infra*). The ascription to Paulus of Alexandria is not therefore proved. There is, however, reference in the *Pauliśa Siddhānta* to Alexandria, or Yavanapura, as it was known to Hindu savants. The longitudes of Ujjainī and Banaras are given with reference to Alexandria (P. S., Chap. III).

The *Pañca Siddhāntikā* devotes a few stanzas of Chaps. I, III, VI, VII, and VIII to this exposition of the *Pauliśa Siddhānta*. Nobody seems to have gone critically into the contents of these chapters after Dr. Thibaut who tried to explain these in his introduction to the *Pañca Siddhāntikā*, but left most of them unexplained owing to their obscurity.

In Chap. I, (verses 24—25), 30 Lords of the days of the month are mentioned. This is quite un-Indian and reminds one of the Iranian calendar in which each one of thirty days of the month is named after a god or principle (*see* § 2.3). The names of the lords of the days as given in the *Pauliśa Siddhānta* are of course all Indian.

The Surya Siddhanta

Of all the Siddhāntas mentioned by Varāhamihira this alone has survived and is still regarded with veneration by Indian astrologers. This Siddhānta was published with annotations by Rev. E. Burgess, in 1860, and has been republished by the Calcutta University under the editorship of P. L. Gangooly, with an introduction by Prof. P. C. Sengupta.

This is supposed to have been described by the Sungod to *Asura Maya*, the architect of the gods, who revealed it to the Indian Ṛṣis. These legends certainly represent some sort of borrowing from the West, but it would be fruitless to define its exact nature unless the text is more critically examined. Varāhamihira describes in Chapters IX, X, XI, XVI, XVII of the *Pañca Siddhāntikā* the contents of the *Sūrya Siddhānta* as known to him ; they are somewhat different from those as found in the modern text. It appears that this Siddhānta was constantly revised with respect to the astronomical constants contained in it as all astronomical treatises should be. The text as we have now was fixed up by Raṅganātha in 1603 after which there have been no changes. Burgess, from a study of the astronomical constants, thought that the final text referred to the year 1091 A.D. Prof. P. C. Sengupta shows that the S.S. as reported by Varāhamihira borrowed elements of astronomical data from Āryabhaṭa, and the S.S. as current now has borrowed elements from Brahmagupta (628 A.D.).

The modern *Sūrya Siddhānta* is a book of 500 verses divided into 14 chapters, contents of which are described briefly below :

Chap. I—Mean motions of the Planets.
" II—True places of the Planets.
" III—Direction, Place, and Time.
" IV—Eclipses, and especially Lunar Eclipses.
" V—Parallax in a Solar Eclipse.
" VI—Projection of Eclipses.
" VII—Planetary Conjunctions.
" VIII—The Asterisms.
" IX—Heliacal Risings and Settings.
" X—Moon's Risings and Settings, and the Elevation of her Cusps.
" XI—Certain malignant Aspects of the Sun and the Moon.
Chap. XII—Cosmogony, Geography, Dimension of the Creation.
" XIII—Armillary Sphere, and other Instruments.
" XIV—Different modes of reckoning Time.

A scrutiny of the text shows that it is, with the exception of a few elements, almost completely astronomical. A few verses in Chap. III, *viz.*, Nos. 9-12 deal with the trepidation theory of the precession of equinoxes. These are regarded by all critics of the *Sūrya Siddhānta* to be interpolations made after the 12th century.

It will take us too much away from our main theme to give a critical account of this treatise, but every critic has admitted that the text does not show any influence of Ptolemy's *Almagest*. Prof. P. C. Sengupta's introduction is particularly valuable. This Siddhānta indicates that longitudes should be calculated from Ujjain and makes no mention of Alexandria. Prof. Sengupta thinks that it dated from about 400 A.D., but a scrutiny of the co-ordinates of certain stars marking the ecliptic, which we have discussed in Appendix 5-B, shows that it might have utilized data collected about 280 A.D., when the star *Citrā* (*α Virginis*), was close to the autumnal equinoctial point, and is therefore subsequent to 280 A.D.

The rules of framing the calendar are found in Chapter XII of which we give an account in the next section.

After about 500 A.D., the Indian astronomers gave up the pretext of ascribing astronomical treatises to gods or mythical sages and began to claim authorship of the treatises they had written ; the earliest that has survived is that of Āryabhaṭa (476—523 A.D.). The objects of their treatises were to frame rules for calendaric calculations, knowledge of astronomy forming the basis on which these rules were framed.

In addition to the *Sūrya Siddhānta* only two other systems have survived, *viz.*,

The Ārya Siddhānta—due to Āryabhaṭa II, an astronomer of the 10th century, and supposed to be related to the *Āryabhaṭīya* of Āryabhaṭa, who claims to have derived it from *Brahmā*, the Creator.

The Brahma Siddhānta—vaguely related to the *Paitāmaha Siddhānta*, but the human authorship is ascribed to the celebrated astronomer Brahmagupta (628 A.D.).

But a number of astronomical treatises like that of *Siddhānta Śiromaṇi* by Bhāskarācārya and many others, have survived either on account of their own merit or their connection with astrology.

The Solar Calendar according to the Surya Siddhanta

The first few verses of Chap. XII deal with the creation of the world according to Hindu conception, and the creation of the elements ; of the sun, the moon, and the planets. The universe is taken to be geocentric, and the planets in order of their decreasing distances from the earth are given as (*vide* verse 31,) :

Saturn, Jupiter, Mars, the Sun, Venus, Mercury and the Moon.

The fixed stars are placed beyond the orbit of Saturn.

Sūrya Siddhānta, XII, *Verse* 32

Madhye samantāt daṇḍasya bhūgolo byomni tiṣṭhati
Bibhrāṇaḥ paramāṁ śaktiṁ brahmaṇo dhāraṇātmikāṁ.

Translation : Quite in the middle of the celestial egg (*Brahmāṇḍa*), the earth sphere (*Bhūgola*) stands in the ether, bearing the supreme might of *Brahmā* which has the nature of a self supporting force.

The astronomers are thus conscious that the earth is a spherical body suspended in ether (*byomni*)

Verse 34 : Describes the earth's polar axis, which passing through the earth's centre emerges as mountains of gold on either side.

Verse 35 : Gods and Ṛṣis are supposed to dwell on the upper (northern) pole, and the demons are supposed to dwell on the nether (south) pole.

Verse 43 : Describes two pole-stars (*Dhruva-tārās*) which are fixed in the sky.

The author could have been aware only of the Polaris. By analogy he inferred the existence of a southern pole-star which, as is well-known, does not exist. He had apparently no knowledge of the sky far south of the equator.

The remaining verses describe the equator : As in modern astronomy, it says that the polar star is on the horizon of a person on the equator and the co-latitude (*Lambaka*) of the equator is 90°.

The Siddhāntic astronomers thus completely accepted the geocentric theory of the solar system. It was a great improvement on the ideas of the world prevalent in India at the time of the great epic *Mahābhārata* (date about 300 B.C.), in which the earth is described to be a flat disc, with the *Sumeru* mountain as a protruding peg in the centre, round which the diurnal motion of the celestial globe carrying the stars, planets, the sun and the moon takes place. This idea of the world is also found in the *Jātakas* and other Buddhist scriptures.

In the subsequent verses four cardinal points on the equator are recognized, these are :

Laṅkā, which is technically the name of a locality on the equator lying in the meridian of Ujjayinī, which was the Greenwich of ancient India. This Laṅkā had nothing to do with Ceylon, but is a fictitious name ;

90° west of Lankā the city called Romaka, and 90° east of Laṅkā the city known as Yamakoṭi.

The name Romaka vaguely refers to the capital of the Roman Empire. 'Yamakoṭi' is quite fanciful.

The *Sūrya Siddhānta* takes it for granted that the sun's yearly motion through the ecliptic is known to the reader and now proceeds to explain the Signs of the Zodiac.

Sūrya Siddhānta XII, 45

Meṣādau devabhāgasthe devānāṁ yāti darśanaṁ
Asurāṇāṁ tulādau tu sūryastadbhāga sañcaraḥ.

Translation : In the half revolution beginning with *Meṣādi* (*lit.* the initial point of Aries), the sun being in the hemisphere of gods, is visible to the gods, ; but while in that beginning with *Tulādi* (*lit.* the initial point of Libra) he is visible to the demons moving in their hemesphere.

This means that when the sun reaches *Meṣādi,* the initial point of the sign of Aries, the gods who are supposed to be in the north pole just witness the rising of the sun and has the sun over the horizon for six months. All these six months, the demons who are supposed to be at the south pole are in the dark. It is *vice versa* for their enemies the *Asuras* for whom, dwelling in the south pole, the sun rises for them when it is at *Tulādi* (beginning of the Tulā sign i.e., first point of Libra) and remains above the horizon for six months.

According to the S.S., therefore, *the first point of Aries is coincident with the vernal equinoctial point, and the first point of Libra with the autumnal equinoctial point.*

Sūrya Siddhāntā, XIV, 9 and 10

Bhānormakarasaṁkrānteḥ ṣaṇmāsā uttarāyaṇaṁ
Karkādestu tathaiva syāt ṣaṇmāsā dakṣiṇāyanaṁ. 9
Dvirāśināthā ṛtava stato'pi śiśirādayaḥ
Meṣādayo dvādaśaite māsāstaireva vatsaraḥ. 10.

Translation: From the moment of the sun's entrance (*saṁkrānti*) into *Makara*, the sign of Capricorn, six months make up his northward progress (*uttarāyaṇa*) ; so likewise from the moment of entrance into *Karkaṭa*, the sign of Cancer, six months are his southward progress (*dakṣiṇāyana*). (9)

Thence also are reckoned the seasons (*ṛtu*), the cool season (*śiśira*) and the rest, each prevailing through two signs. These twelve, commencing with

Aries, are the months ; of them is made up the year (10).

These quotations leave not the slightest doubt that according to the compilers of the S.S., the first point of the zodiac is the point of intersection of the ecliptic and the equator, and the signs of the zodiac cover 30° each of the ecliptic.

It is supposed on good grounds that much of the astronomical knowledge found in the *Sūrya Siddhānta* is derived from Graeco-Chaldean sources. But it is clear from the text that the compilers of the S.S. had no knowledge of the precession of equinoxes, but they took the first point of Aries to be fixed. This is not to be wondered at, for as shown in § 4.9, inspite of the works of Hipparchos and Ptolemy, precession was either not accepted or no importance was attached to it by the astronomers of the Roman empire. It may be added that the compilers of the S.S. were not aware of the theory of trepidation of equinoxes which appears to have been first formulated in the West by Theon of Alexandria (*ca.* 370 A.D.). It is also important to note that the Indian astronomers did not take the first point of Aries to be identical with that given either by Hipparchos, Ptolemy or any other western authority as would have been the case if there was blind-folded borrowing. They assimilated the astronomical knowledge intelligently and took the first point of Aries as the point of intersection of the equator and the ecliptic, and made successive attempts to determine it by some kind of actual observations, as shown in appendix 5-B. These observations appear first to have been made about 280 A.D.

Length of the Year

The length of the year, according to the different authorities are as follows.

					days
Sūrya Siddhānta of Varāhamihira ...	365^d	6^h	12^m	36^s	=365.25875
Current S.S. ...	365	6	12	36.56	=365.258756
Ptolemy (sidereal)	365	6	9	48.6	=365.256813
Correct length of the sidereal year....	365	6	9	9.7	=365.256362
Correct length of the tropical year···	365	5	48	45.7	=365.242196

N. B. Varāhamihira's length of the year is also found in Āryabhaṭa's *ārdharātrika*, or midnight system, and in Brahmagupta's *Khaṇḍa Khādyaka.*

How did the Indian savants manage to have such a wrong value for the length of the year ?

The year, according to the *Sūrya Siddhānta*, is meant to be clearly tropical, but as the Indian savants compiling the S.S. were ignorant of the phenomenon of precession of the equinoxes, they were unaware of the distinction between the sidereal year and the tropical year. They had to obtain the year-length either from observation or from outside sources. If they obtained it from observations, they must have counted the number of days passed between the return of the sun to the same point in the sky over a number of years. Such observations would show that the year had not the traditional value of 366 days given in *Vedāṅga Jyotiṣa,* but somewhat less. In fact, the *Paitāmaha* length is 365.3569 days and there is no reason to believe that it was derived from foreign sources. Successive observations must have enabled the Indian savants to push the accuracy still higher.

Or alternatively they might have borrowed the value from Graeco-Chaldean astronomy, but we cannot then explain why their value is larger than Ptolemy's. We have seen that the *Romaka Siddhānta* gives a value which is Hipparchos's, and tropical, but the three more correct Siddhāntas reject it, as being too small. This however indicates that they probably tried to derive the length from observations as stated in the previous paragraph and found the *Romaka Siddhānta*-length too small. If they had taken it from some other source, we have still to discover that source. It is certainly not Ptolemy's *Almagest.*

The ex-cathedra style of writing adopted by the Siddhāntic astronomers, e.g., the number of days in a *Kalpa* (a period of 4.32×10^9 years) is 1,577,917,828,000 according to Grandfather *Brahmā*, or the Sungod, does not enable one to trace the steps by which these conclusions were reached.

The two problems of (i) distinguishing between the tropical year, and the sidereal year and of (ii) determining the correct length of the year in terms of the mean solar days are very exacting ones.

We have seen how it took the West the whole time-period between 3000 B.C. to 1582 A.D. to arrive at the idea that the true length of the tropical year was close to 365.2425 days. Probably Iranian astronomers of Omar Khayam's time (1072 A.D.), who had the advantage of the great Arabian observations by al-Baṭṭānī and others had a more correct knowledge of this length. The final acceptance of the distinction between the tropical and the sidereal year dates only from 1687 A.D., when Newton proved the theory of trepidation to be wrong.

The Siddhāntic astronomers of 500-900 A.D. cannot therefore be blamed for their failure to grasp the two problems. But what to say of their blind followers who, in the twentieth century, would continue to proclaim their belief in the theory of trepidation ?

Effect of continuance of the mistake

The *Sūrya Siddhānta* value, *viz.*, 365.258756 days is larger than the correct sidereal value by ·002394 days and larger than the tropical length by .016560 days.

As the S.S. value is still used in almanac-framing, the effect has been that the year-beginning is advancing by .01656 days per year, so that in course of nearly 1400 years, the year-beginning has advanced by 23.2 days, so that the Indian solar year, instead of starting on the day after the vernal equinox (March 22) now starts on April 13th or 14th. The situation is the same as happened in Europe, where owing to the use of a year-length of 365.25 days, since the time of Julius Cæsar, the Christmas preceded the winter solstice by 10 days, when the error was rectified by a Bull of Gregory XIII, and the calendar was stabilized by introducing revised leap-year rules.

The Calendar Reform Committee has proposed that the Indian New Year should start on the day after the vernal equinox day. Most of the Indian calendar makers belong to the no-changer school, or the *nirayana* school (i.e., school not believing in the precession of the equinoxes). But this school does not realize that even if the sidereal length of the year be acceped, the Indian year-length used by them is larger by nearly ·0024 days, which cannot be tolerated. So if a change has to be made, it is better to do it whole-hog, i.e., take the year-length to be tropical, and start the year on the day after the vernal equinox.

This is the proposal of the Indian Calendar Reform Committee, and it is in full agreement with the canons laid down in the *Sūrya Siddhānta*.

Historical Note on the Year-beginning

The Indian year, throughout ages, has been of two kinds, the solar and the lunar, each having its own starting day. The year-beginning for the two kinds of years, for different eras, is shown in Table No. 27.

The Starting Day of the Solar Year

In the Vedic age, the year-beginning was related probably to one of the cardinal days of the year, but we do not know which cardinal day it was. The *Vedāṅga Jyotiṣa* started the year from the winter solstice day, *Brāhmanas* started the year from the Indian Spring (*Vasanta*) when the tropical (*Sāyana*) longitude of the sun amounted to 330°.

The Siddhāntic astronomers must have found a confusion, and so fixed up a rule for fixing the year-beginning, which we have just now dicussed. These rules amount to :

(a) Starting the astronomical year from the moment the sun crosses the vernal equinoctial point.

(b) Starting the civil year on the day following.

The Siddhāntic astronomers thus brought the Indian calendar on a line with the Graeco-Chaldean calendar prevalent in the Near East during the Seleucid times.

In a few cases, e.g., in the case of the Vikrama era reckoning as followed in parts of Guzrat, the year-beginning is in *Kārtika*. This seems to be reminiscent of the custom amongst the Macedonian Greek rulers of Babylon to start the year on the autumnal equinox day.

The First Month of the Year :

This has to be defined with respect to the definition of the seasons.

According to modern convention, which is derived from Graeco-Chaldean sources, the first season of the year is spring ; it begins on the day of vernal equinox, as shown in fig. 25 which shows also the other seasons. The Indian classification of seasons is, however, different as the following table shows.

Table 15—Indian Seasons.

—30° to 30°	...Spring (Vasanta)	Caitra & Vaiśākha
30 to 90	...Summer (Grīṣma)	Jyaiṣṭha & Āṣāḍha
90 to 150	...Rains (Varṣā)	Śrāvaṇa & Bhādra
150 to 210	...Early Autumn (Śarat)	Āśvina & Kārtika
210 to 270	...Late Autumn (Hemanta)	Agrahāyaṇa & Pauṣa
270 to 330	...Winter (Śiśira)	Māgha & Phālguna

The Siddhāntic astronomers, therefore, found themselves in a difficulty. If they were to follow the Indian convention, *Caitra* would be the first month of the solar year. If they were to follow the Graeco-Chaldean covention, they had to take *Vaiśākha* as the first month of the solar year.

They struck a compromise. For defining the solar year, they took *Vaiśākha* as the first month and for defining the lunar year they took *Caitra* as the first month (*see* § 5·7).

But this rule has been followed only in North India. In South India, they had different practices, as shown in the list of solar month-names (Table No. 16).

In North India the first month is Vaiśākha as laid down in the S.S. which starts just after sun's passage through the V.E. point.

It is interesting to see that in Tamil Nad, some of the names are of Sanskritic origin, others are of Tamil origin. *But the most striking fact is that the first month, starting after vernal equinox is not Vaiśākha as in the*

Table 16.

Corresponding Names of Solar Months.

Indian Names of Signs	*Bengal Orissa*	*Assam*	*Tamil*	*Tinnevelly or S. Malayalam (Orissa)*	*N. Malayalam*
MEṢA	VAIŚĀKHA	BAHĀG	CITTIRAI	MEṢA	MEDAM
Vṛṣava	Jyaiṣṭha	Jeṭh	Vaikāśi	Vṛṣava	Edavam
Mithuna	Āṣāḍha	Āhār	Āṇi	Mithuna	Midhunam
Karkaṭa	Śrāvaṇa	Śāon	Āḍi	Karkiṭaka	Karkiṭaka
Siṁha	Bhādra	Bhād	Āvaṇi	*SIMHA*	Ciṅgam
Kanyā	Āśvina	Āhin	Puraṭṭāśi	Kanyā	KANNI
Tulā	Kārtika	Kāti	Arppiśi (Aippaśi)	Thulā	Thulam
Vṛścika	Agrahāyaṇa	Aghoṇ	Kārthigai	Vṛścika	Vṛścikam
Dhanuḥ	Pauṣa	Puha	Mārgali	Dhanus	Dhanu
Makara	Māgha	Māgh	Thai	Makara	Makaram
Kumbha	Phālguna	Phāgun	Māśi	Kumbha	Kumbham
Mīna	Caitra	Ca't	Paṅguni	Mīna	Mīnam

(The first month of the year has been distinguished by capitals).

N.B. The Bengali or Oriya names of solar months are taken without change from Sanskrit. The Assamese names are the same, but have local pronunciations.

rest of India but Chittirai or Caitra, and so on. We do not know why Tamil astronomers adopted a different convention. We can onlv guess : probably they wanted to continue the old Indian usage that *Caitra* is to remain the first month of the year.

In Tinnevelley and Malayalam districts the solar months are named after the signs of the zodiac.

There is, therefore, no uniformity of practice in the nomenclature of the solar months, and in fixing up the name of the first month of the solar year.

Solar Months : Definition

After having defined the solar year, and the year beginning, the *Sūrya Siddhānta* proceeds to define the "Solar Month."

Sūrya Siddhānta, Chap. 1,13

Aindavastithibhi-stadvat saṁkrāntyā saura ucyate
Māsairdvādaśabhirvarṣaṁ divyaṁ tadaharucyate.

Translation : A lunar month, of as many lunar days (*tithi*) ; a solar (*saura*) month is determined by the entrance of the sun into a sign of the zodiac, *i.e.* the length of the month is the time taken by the sun in passing 30° of its orbit, beginning from the initial point of a sign ; twelve months make a year, this is called a day of the gods.

This definiton is accepted by the *Ārya*, and *Brahma Siddhāntas* as well.

The working of this rule gives rise to plenty of difficulties, which are described below :

The mean length of a solar month
=30.43823 according to S.S.
=30.43685 according to modern data.

The actual lengths of the different solar months, however, differ widely from the above mean values. This is due to the fact that the earth does not move with uniform motion in a circular orbit round the sun, but moves in an elliptic orbit, one focus of which is occupied by the sun, and according to Kepler's second law, it sweeps over equal areas round the sun in equal intervals of time. When the earth is farthest from the sun, i.e. at aphelion (sun at apogee) of the elliptic orbit, the actual velocity of the earth becomes slowest, and the apparent angular velocity of the sun becomes minimum, and consequently the length of the solar month is greatest. This happens about 3rd or 4th July, *i.e.*, about the middle of the solar month of Āṣāḍha (*Mithuna*), and consequently this month has got the greatest length. The circumstances become reversed six months later on about 2nd or 3rd January, when the earth is nearest to the sun, *i.e.*, at perihelion (sun at perigee), the angular velocity of the sun at that time becomes maximum, and consequently the solar month of Pauṣa (*Dhanuḥ*) which is opposite to Āṣāḍha, has got the minimum length. The following two figures (Nos. 25 & 26) will explain the position.

The durations of the different months, which are different from each other due to the above reason, are also not *fixed for all time.* The durations of the solar months undergo gradual variations on account of two reasons; *viz.*,

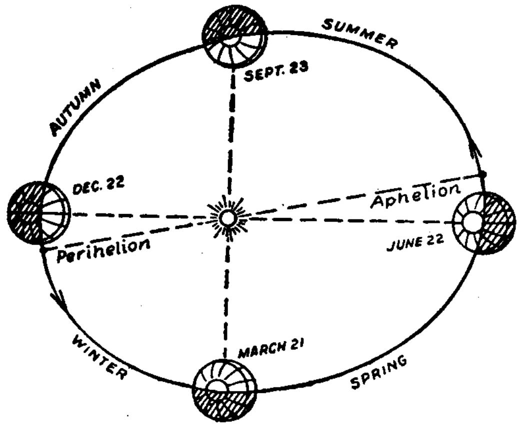

Fig. 25

(i) the line of apsides of the earth's elliptic orbit (i.e., the aphelion and perihelion points) is not fixed

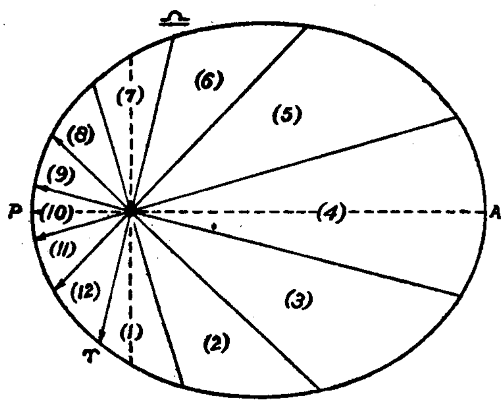

Fig. 26

in space but is advancing along the ecliptic at the rate of 61″.89 per year or 1.°72 per century. This is made up of the precessional velocity of 50.″27 per year in the retrograde direction and the perihelion velocity of 11.″62 per year in the direct direction due to planetary attraction. This movement of the apse line with respect to the V.E. point causes variation in the lengths of the different months.

(ii) The second reason is that the ellipticity of the earth's orbit is not constant; it is gradually changing. At present the eccentricity of the orbit is diminishing and the elliptic orbit is tending to become circular. As a result, the greatest duration of the month is diminishing in length and the least one increasing. Similarly the lengths of other months are also undergoing variation.

The modern elliptic theory of planetary orbits was not known to the makers of Indian Siddhāntas, but they knew that the sun's true motion was far from uniform. They conceived that the sun has uniform motion in a circle, with the earth not exactly at the centre of that circle, but at a small distance from it. The orbit therefore becomes an eccentric circle or an epicycle. Here also the angular motion of the sun becomes minimum when at apogee or farthest from the earth, and maximum when nearest to the eartn or at perigee. In this case the size and eccentricity of the circle are invariable quantities, and consequently the maximum and minimum limits of the months are constant. The apse line advances in this case also, but with a very slow motion, which according to the *Sūrya Siddhānta* amounts to a degree of arc in 31,008 years, or 11″ in a century. The variations of the durations of months due to this slow motion of the apse line is quite negligible and the lengths of the months according to the *Sūrya Siddhānta* are practically constant over ages.

Table 17—Lengths of different solar months reckoned from the vernal equinox.

		Lengths of Solar months.						
		According to Sūrya Siddhānta			*Modern value (1950 A.D.)*			*Names of Months (as proposed)*
(1)	(2)	(3)			(4)			(5)
		d	h	m	d	h	m	
Vaiśākha (Meṣa)	(0°–30°)	30	22	26.8	30	11	25.2	Caitra
Jyaiṣṭha (Vṛṣa)	(30 –60)	31	10	5.2	30	23	29.6	Vaiśākha
Āṣāḍha (Mithuna)	(60 –90)	31	15	28.4	31	8	10.1	Jyaiṣṭha
Śrāvaṇa (Karkaṭa)	(90 –120)	31	11	24.4	31	10	54.6	Āṣāḍha
Bhādra (Siṁha)	(120 –150)	31	0	26.8	31	6	53.1	Śrāvaṇa
Āśvina (Kanyā)	(150 –180)	30	10	35.6	30	21	18.7	Bhādra
Kārtika (Tulā)	(180 –210)	29	21	26.4	30	8	58.2	Āśvina
Agrahāyaṇa (Vṛścika)	(210 –240)	29	11	46.0	29	21	14.6	Kārtika
Pauṣa (Dhanuḥ)	(240 –270)	29	7	37.6	29	13	8.7	Agrahāyana
Māgha (Makara)	(270 –300)	29	10	45.2	29	10	38.6	Pauṣa
Phālguna (Kumbha)	(300 –330)	29	19	41.2	29	14	18.5	Māgha
Caitra (Mīna)	(330 –360)	30	8	29.0	29	23	18.9	Phālguna
		365	6	12·6	365	5	48·8	

In the *Sūrya Siddhānta*, a formula is given for finding the true longitude of the sun from its mean longitude. As the length of a month is the time taken by the sun to traverse arcs of 30° each along the ecliptic by its true motion, the lengths of the different months can be worked out when its true longitudes on different dates of the year are known. The true longitude is obtained by the *Sūrya Siddhānta* with the help of the following formula :

$$\text{True Long.} = \text{Mean Long.} - 133.'68 \sin K + 3.'18 \sin^2 K$$

where K = Mandakendra of the sun,
i.e., = mean sun − sun's apogee.

At the approximate time of each *saṁkrānti*, the true longitude of the sun is calculated by the above formula for two successive days, one before the attainment of the desired multiple of 30° of longitude and the other after it, and then the actual time of crossing the exact multiple of 30th degree is obtained by the rule of simple proportion. This is called the time of *saṁkrānti* or solar transit. The time interval between the two successive *saṁkrāntis* is the actual length of the month, The lengths of the months thus derived from the *Sūrya Siddhānta* compared with the modern values, *i.e.*, the values which we get after taking the elliptic motion of the sun, and the shift of the first point of Aries are shown in Table No. 17, on p. 243, in which :—

Column (1) gives the names of months.
,, (2) gives the arc measured from the first point of Aries (the V.E. point) covered by the true longitude of the sun.
,, (3) gives the lengths of the months derived from the *Sūrya-Siddhānta* rules.
,, (4) gives the correct lengths of the months as in 1950 A.D.
,, (5) gives the corresponding names of the months as proposed by the Committee.

It would appear from table No. 17 that the lengths of the months of the *Sūrya Siddhānta* are no longer correct ; they greatly differ from their corresponding modern values, sometimes by as much as $11\frac{1}{2}$ hours. The *Sūrya Siddhānta* values, which the almanac makers still use, are therefore grossly incorrect. Moreover, the lengths of the months are undergoing gradual variation with times due to reasons already explained.

Different conventions for fixing up the beginning of the solar month

The *saṁkrānti* or ingress of the sun into the different signs may take place at any hour of the day. Astronomically speaking the month starts from that moment. But for civil purposes, the month should start from a sunrise ; it should therefore start either on the day of the *saṁkrānti* or the next following day according to the convention adopted for the locality. There are four different conventions in different States of India for determining the beginning of the civil month.

Rules of Samkranti

The Bengal rule : In Bengal, when a *saṁkrānti* takes place between sunrise and midnight of a civil day, the solar month begins on the following day ; and when it occurs after midnight, the month begins on the next following day, i.e., on the third day. This is the general rule ; but if the *saṁkrānti* occurs in the period between 24 minutes before midnight to 24 minutes after midnight, then the duration of *tithi* current at sunrise will have to be examined. If the *tithi* at sunrise extends up to the moment of *saṁkrānti*, the month begins on the next day : if the *tithi* ends before *saṁkrānti*, the month begins on the next following or the third day. But in case of *Karkata* and *Makara saṁkrāntis*, the criterion of *tithi* is not to be considered. If the *Karkaṭa saṁkrānti* falls in the above period of 48 minutes about the midnight, the month begins on the next day, and if the *Makara saṁkrānti* falls in that period, the month begins on the third day.

The Orissa rule : In Orissa the solar months of the Āmli and Vilāyati eras begin civilly on the same day (sunrise to next sunrise) as the *saṁkrānti*, irrespective of whether this takes place before or after midnight.

The Tamil rule : In the Tamil districts the rule is that when a *saṁkrānti* takes place before sunset, the month begins on the same day, while if it takes place after sunset the month begins on the following day.

The Malabar rule : The rule observed in the North and South Malayalam country is that, if the *samkrānti* takes place between sunrise and 18 *ghaṭikās* ($7^h\ 12^m$) or more correctly $\frac{3}{5}$th of the duration of day from sunrise (about 1-12 P.M.) the month begins on the same day, otherwise it begins on the following day.

It will be observed that as a result of the different conventions combined with the incorrect month-lengths of the *Sūrya Siddhānta* we are faced with the following problems

(1) the civil day of the solar month-beginning may differ by 1 to 2 days in different parts of India.

(2) The integral number of days of the different solar months also vary from 29 to 32.

The months of *Kārtika*, *Agrahāyaṇa*, *Pauṣa*, *Māgha* and *Phālguna* contain 29 or 30 days each, of which two months must be of 29 days, and others of 30 days. The months *Caitra*, *Vaiśākha* and *Āśvina* contain 30 or 31 days.

The ' rest, *viz.*, *Jyaiṣṭha*, *Āṣāḍha*, *Śrāvaṇa* and *Bhādra* have got 31 to 32 days each, of which one or two months will contain 32 days every year.

(3) The length of the month by integral number of civil days is not fixed, it varies from year to year.

Justification of the Solar Calendar as proposed by the Committee

It has been shown that the intention of the maker of *Sūrya Siddhānta* and of other *Siddhāntas* was to start the year from the moment of sun's crossing the vernal equinoctial point and to start the civil year from the day following. The Committee has also adopted this view and proposed that the civil year for all-India use should start from the day following the V. E. day, *i.e.*, from March 22. In the Vedic literature also it is found that the starting of the year was related with one or other of the cardinal days of the year. The *Vedāṅga Jyotiṣa* started the year from the winter solstice day, the *Brāhmaṇas* started the year from the Indian spring (*Vasanta*) when the tropical (*Sāyana*) longitude of the sun amounted to 330°, but in the Siddhāntic period the year-beginning coincided with the V. E. day. So in adopting the *Sāyana* system in our calendar calculations, the Indian tradition, from the Vedic times up to the Siddhāntic times, has been very faithfully observed. This has ensured that the Indian seasons would occupy permanent places in the calendar.

As regards the number of days per month, although the *Sūrya Siddhānta* defines only the astronomical solar month as the time taken by the sun to traverse 30° of arc of the ecliptic, four different conventions have been evolved in different States of India for determining the first day of the civil month from the actual time of transit as narrated earlier. None of the conventions is perfect. Such rules do not yield fixed number of days for a month, as a result of which it becomes extremely difficult for a chronologist to locate any given date of this calendar, unambiguously, in the Gregorian calendar, without going through lengthy and laborious calculations. Moreover, the number of days of months obtained from such rules vary from 29 to 32, which is very inconvenient from various aspects of civil life.

The Committee has therefore felt that there is no need for keeping the solar months as astronomically defined. The length of 30 and 31 days are quite enough for civil purposes. Moreover, fixed durations of months by integral number of days is the most convenient system in calendar making. The five months from the second to the sixth have the lengths of over 30½ days, and so their lengths have been rounded to 31 days each ; and to the remaining months 30 days have been allotted.

5.7 THE LUNAR CALENDAR IN THE SIDDHANTA JYOTISHA PERIOD

The broad divisions of the year into seasons or months are obtained by the solar calendar, but since for religious and social puposes the lunar calendar had been used in India from the Vedic times, it becomes incumbent to devise methods for pegging on the lunar calendar to the solar.

The extent to which the lunar calendar affects Indian socio-religious life will be apparent from the tables of holidays we have given on pp. 117-154. There the religious and social ceremonies and observances and holidays of all states and communities are classified under the headings :

(1) Regulated by the solar calendar of the Siddhāntas ;

(2) Regulated by Gregorian dates ;

(3) Regulated by the lunar calendar.

The tables show that by far the largest number of religious holidays and other important social ceremonies are regulated by the lunar calendar. It is difficult to see how the lunar affiliation, inconvenient as it is, can be replaced altogether, short of a revolution in which we break entirely with our past. The lunar calendar will therefore continue to play a very important part as we continue to keep our connection with the past, and with our cherished traditions.

Let us now restate the problems which arise when, with reference to India, we want to peg the lunar calendar to the solar, how it was tackled in the past, and how the Calendar Reform Committee wants to tackle it.

The lunar month consists of 29.5306 days and 12 such lunar months fall short of the solar year by 10.88 days. After about 2 or 3 years one additional or intercalary lunar month is therefore necessary to make up the year ; and in 19 years there are 7 such intercalary months. In Babylon and Greece there were fixed rules for intercalation ; the intercalary months appeared at stated intervals and were placed at fixed positions in the calendar (*vide* § 3.2). It appears that some kind of rough rules of intercalation of lunar months were followed in India up to the first or second century A.D. when the calendar was framed according to the rules of *Vedāṅga Jyotiṣa* (*vide* § 5.4). Thereafter the Siddhāntic system of calendar-making began to develop, replacing the old *Vedāṅga* calendar.

The *Vedāṅga* calendar as we have seen was crude and was based on approximate values of the lunar and solar periods, the calendar was framed on the mean motions of the luminaries, and as such an intercalary month was inserted regularly after every period of 30 months.

The *Siddhānta Jyotiṣa* introduced the idea of true positions of the luminaries as distinct from their mean positions, and devised rules for framing the calendar on the basis of the true positions, and adopted more correct values for the periods of the moon and the sun. But some time elapsed before new rules were adopted, and intercalary months continued to be calculated on the basis of the mean motions of the sun and the moon, employing however more correct values of their periods as given by the *Siddhāntas*. In this connection the following remarks by Sewell and Dīkṣit, in the *Indian Calendar* (p. 27) are worth noting.

"It must be noted with regard to the intercalation and suppression of months, that whereas at present these are regulated by the sun's and moon's apparent motion,—in other words, by the apparent length of the solar and lunar months —and though this practice has been in use at least from 1100 A.D. and was followed by Bhāskarācārya, there is evidence to show that in earlier times they were regulated by the mean length of months. It was at the time of the celebrated astronomer Śrīpati (1039 A.D.) that the change of practice took place".

Intercalary months or Malamasas.

The length of the *Sūrya Siddhānta* year is 365.258756 days and of a lunar month according to the S. S. is 29.5305879 days. Twelve such lunar months fall short of the S. S. year by 10.891701 days. The lunar year therefore slides back on the solar scale each year by about 11 days. If the months were allowed to slide back continuously it would have completed the cycle in 33.5355 years, and the festivals attached to the lunar calendar would have moved through all the seasons of the year within this period, as now happens with the Islamic calendar.

To prevent the occurrence of this undesirable feature, the system of intercalary months or *mala māsas* have been introduced. Taking the mean vaules of the lunation-period and of the length of the solar year, the time when one extra month (*i.e.*, intercalary month) will have to be introduced can easily be determined. But the luminaries do not move with uniform angular motions throughout their period of revolution and so the determination af the intercalary month on the basis of the actual movement of the sun and the moon is a very difficult problem. The calculations according to the mean motions are however shown below.

Table 18—Calculation of intercalary months in a 19-year cycle.

	Sūrya Siddhānta days	*Modern-Sidereal* days	*Modern-Tropical* days
Length of year	365.258756	365.256361	365.242195
Solar month	30.438230	30.438030	30.436850
Lunation	29.530588	29.530588	29 530588
No. of solar months after which a lunar month is added	32.5355	32.5427	32.5850
19 years=	6939.91636	6939.86896	6939.60171
235 lunations (=19×12+7)=	6939.68818	6939.68818	6939.68818
Error in the 19-year cycle	−0.22818	−0.18078	+0.08647

It would appear from the above figures that the 19-year cycle with 7 *mala māsas* is a better approximation if we adopt the tropical year, and the error gradually increases with the sidereal year and the Sūrya Siddhānta year. In 11½ cycles, *i.e.*, in 220 years, the discrepancy would amount to only a day in the case of the tropical year.

It is also seen that one intercalary month is to be added at intervals of 32½ solar months, or in other words an intercalary month recurs alternately after 32 and 33 solar months. According to this scheme the intercalary months in a period of 19 years would be as follows :—

Year	*Intercalary month*	*Year*	*Intercalary month*
1	—	11	10 Pauṣa
2	—	12	—
3	9 Mārgaśīrṣa	13	—
4	—	14	7 Āśvina
5	—	15	—
6	5 Śrāvaṇa	16	—
7	—	17	3 Jyestha
8	—	18	—
9	2 Vaiśākha	19	12 Phālguna
10	—		

But the makers of Indian calendars have not followed any scheme for intercalation based on mean motions. They evolved a plan for distinguishing an intercalary month from a normal month based on the true motions of the sun and the moon. This plan is also followed in giving the name to a lunar month, as explained below :

Siddhantic rules for the Lunar Calendar

There are two kinds of lunar months used in India, the new-moon ending and the full-moon ending. In calendarical calculations only the new-moon ending months are used.

(i) The new-moon ending lunar month covers the period from one new-moon to the next. This is known as *amānta* or *mukhya cāndra māsa*. It gets the same name as the solar month in which the moment of initial new-moon of the month falls. For this purpose the solar month is to be reckoned from the exact moment of one *saṁkrānti* of the sun to the moment of the next *saṁkrānti*. When a solar month completely covers a lunar month, *i.e.*, when there are two moments of new-moon (*amānta*), one at the beginning and the other at the end of a solar month, then the lunar month beginning from the first new-moon is the intercalary month, which is then called an *adhika* or *mala māsa*, and the lunar month beginning from the second new-moon is the normal month which is termed as *śuddha* or *nija* in the Siddhāntic system. Both the months bear the name of the same solar month but are prefixed by *adhika* or *śuddha* as the case may be. In an *adhika* month religious observances are not generally allowed.

If on the other hand, a lunar month completely covers a solar month, no new-moon having occurred in that solar month, the particular lunar month is then called a *kṣaya* or decayed month.

As the *mukhya* or new-moon ending lunar month begins from the *Amāvasyā* or the new-moon occurring in the solar month bearing the same name, the lunar month may begin on any day during that solar month —it may begin on the first or even on the last day of that solar month.

(ii) The full-moon ending lunar month known as *pūrṇimānta* or *gauna cāndra māsa*, covers the period from one full-moon to the next, and is determined on the basis of the corresponding new-moon ending month as defined above. It begins from the moment of full-moon just a fort-night before the initial new-moon of an *amānta* month, and it also takes the name of that month.

But in the *gauṇamāna* (*i.e.*, full-moon ending lunar month), as the month starts 15 days earlier than the new-moon ending month, it may begin on any day during the last half of the preceding solar month and the first half of the solar month in question. It will therefore be seen that while the new-moon ending or *mukhya* month sometimes falls almost entirely outside (*i.e.*, after) the relative solar month, the full-moon ending or a *gauna* month always covers at least half of the solar month of that name.

The months used for civil purposes in the Hindi calendar are the full-moon ending lunar months, and are sub-divided into two halves—*kṛṣṇa pakṣa* covering the period from full-moon to new-moon and termed as *vadi*, and *śukla paksa* covering the period from new-moon to full-moon and termed as *śudi*. As these months are on the *gauna māna*, the *vadi* half of a month comes first followed by the *śudi* half. The last day of the year is therefore a full-moon day, the *Phālgunī* (or *Holi*) *Pūrṇimā*, in keeping with the ancient Indian custom.

The Saṁvat and Śaka years in the Hindi calendar begins with *Caitra Śukla Pratipad*. For astronomical purposes, however, the year begins a few days later with the entrance of the sun into Meṣa.

The calendars of *Āṣāḍhī Saṁvat* and *Kārtikī Saṁvat* are, on the other hand, based on the new-moon ending months, and consequently the months begin 15 days later than the months of the *Caitrādi* full-moon ending calendar. The *Āṣāḍhī* calendar begins with *Āṣāḍha Śukla* 1, and the *Kārtikī* calendar with *Kārtika Śukla* 1.

The table (No. 20 on p. 249) shows the scheme of the different calendars for the year Śaka 1875 (1953-54). The year contains a *mala* or *adhika* month.

It may be seen from the above mentioned table that in case of the light half of the month (*śudi* half) the month has the same name for the two systems of month-reckonings, but in the dark half of the month (*vadi* half) the names of the months in the two systems are different.

The year-beginnings of the Saṁvat era in the three systems of luni-solar calendar are also different, as may be seen from the following table.

Table 19—Showing the year-beginnings of the different systems of Saṁvat era.

Calendar	Caitrādi system	Āṣāḍhādi system	Kārtikādi system
Saṁvat era	2010	2010	2010
Beginning of year	Caitra S 1 (16 Mar., 1953)	Āṣāḍha S 1 (12 July, 1953)	Kārtika S 1 (7 Nov., 1953)

Counting of the Succession of Days

In all the calendars used in India, days are counted according to the solar reckoning, as well as according to the lunar reckoning (*i.e.*, by *tithi* or lunar day). But there is a difference in emphasis.

In the eastern regions (Bengal, Orissa and Assam), and in Tamil Nād and Malabar, the solar reckoning is given more prominence. The almanacs give solar months and count the days serially from 1 to 29, 30, 31 or 32 as the case may be. The *tithi* endings are given for every day, and the *tithi* may start at any moment of the day.

In other parts of India (except Bengal, Orissa, Assam and Tamil Nād), the counting of days is based on the lunar reckoning, and the number of the *tithi* current at sunrise is used as the ordinal number of the date necessary in civil affairs. So there are 29 or 30 days in a month, but the days are not always counted serially from 1 to 29 or 30.

The month in the lunar calendar is divided into two half-months, the *śudi* and *vadi* halves in the new-moon ending system, and the *vadi* and *śudi* halves in the full-moon ending system. In fact the year is divided into 24 half-months instead of 12 months. So there are 14 to 15 days in a half-month (*vide* Table 20).

The *tithi* or lunar day is measured by the positions of the moon and the sun. When they are in conjunction, *i.e.*, at new-moon the 30th *tithi* or *amāvasyā* ends and the first *tithi* starts which continues upto the moment when the moon gains on the sun by 12° in longitude. Similarly when the difference between the moon and the sun is 24° the second *tithi* ends, and so on. The average duration of a *tithi* is $23^h\ 37.^m5$, but the actual duration of a particular *tithi* undergoes wide variations from the above average according to the different positions of the sun, the moon and the lines of their apsides. It may become as great as $26^h\ 47^m$ and as small as $19^h\ 59^m$. So generally to every day there is a *tithi*. But sometimes a *tithi* begins and ends on the same civil day, and such a *tithi* is dropped ; and some religious ceremonies of auspicious character are not allowed to take place on such a *tithi*, and the following day begins with the next following *tithi*. For example, if the third *tithi* is dropped, the sequence of days of the half-month is 1, 2, 4, 5 etc., thus the seriality is broken here.

As opposed to the above-mentioned case, the *tithi* sometimes extends over two days, there being no *tithi* ending in a day (from sunrise to next sunrise). As the same *tithi* remains current on two successive sunrises, the same *tithi*-number is allotted to both the days ; in the second day, however, it is suffixed by the term '*adhika*'. For example if the third *tithi* is repeated, then the sequence of days of the half-month would be 1, 2, 3, 3 *adhika*, 4, etc.

Some improvement in the use of *tithi* for dating purposes is, however, observed in the Fusli calendar in vogue in some parts of Northern India. In this calendar the month begins from the day following the full-moon and dates are counted consecutively from 1 to 29 or 30 without any break at new-moon, or any gapping or over-lapping of dates with *kṣaya tithi* or *adhika tithi*. In fact the dates of this calendar have no connection with *tithis* after the starting of the month has been determined. The year of Fusli begins after the full-moon day of lunar *Bhādra*

Mala Masa and Kshaya Masa

It has been stated before that even at the beginning of the Siddhānta Jyotiṣa period, the intercalary months (*mala* or *adhika*) were determined on the basis of the mean motions of the sun and the moon, and as such there was no possibility of the occurrence of any so called *kṣaya* or decayed month. But as already mentioned, from about 1100 A.D., the intercalary months are being determined on the basis of the true motions of the luminaries, *i.e.*, on the actual lengths of the new-moon-ending lunar month and of the different solar months as obtained from Siddhāntic rules. This gave rise to the occurrence of *kṣaya* months, and the intercalary months were also placed at very irregular intervals.

The period from new-moon to new-moon (the lunar month) is not a period of fixed duration ; it varies within certain limits according to the different positions of the apse line of the lunar and solar orbits, as follows :—

LENGTH OF THE LUNATION

By mean motion	*According to S.S.*	*Modern*
d h	d h	d h
	29 6.3	29 5.9
29 12.73	to	to
	29 19.1	29 19.6

Comparing these values with the actual lengths of solar months given in Table 24, it is observed that the *minimum* length of the lunar month falls short of all the solar months, even of the shortest month of *Pauṣa*. But as a *mala māsa* is not possible in that month, the maximum and minimum limits of the lunar months are recalculated for each of the solar months from *Kārtika* to *Phālguna* separately.

Table 20.

Scheme of the Luni-Solar Calendar

(Śaka 1875=1953-54 A.D.)

Religious Calendar		Civil Luni-Solar Calendar		Initial date reckoned on the Solar Calendar as is now in use.	
Mukhya or new-moon ending	*Gauṇa or full-moon ending*	*Full-moon ending*	*New-moom ending*	*Indian Solar Calendar date*	*Gregorian date*
Caitra S	Caitra S	Caitra S	Caitra S	2 Caitra	16 Mar.
Caitra K	Vaiśākha K	Vaiśākha V	Caitra V	17 Caitra	31 Mar.
Vaiśākha S (*mala*)	*Vaiśākha* S (*mala*)	*Vaiśākha* S (*adhika*)	*Vaiśākha* S (*adhika*)	1 Vaiśākha	14 Apr.
Vaiśākha K (*mala*)	*Vaiśākha* K (*mala*)	*Vaiśākha* V (*adhika*)	*Vaiśākha* V (*adhika*)	17 Vaiśākha	30 Apr.
Vaiśākha S (śuddha)	Vaiśākha S (śuddha)	Vaiśākha S	Vaiśākha S	31 Vaiśākha	14 May
Vaiśākha K (śuddha)	Jyeṣṭha K	Jyeṣṭha V	Vaiśākha V	15 Jyeṣṭha	29 May
Jyeṣṭha S	Jyeṣṭha S	Jyeṣṭha S	Jyeṣṭha S	29 Jyeṣṭha	12 June
Jyeṣṭha K	Āṣāḍha K	Āṣāḍha V	Jyeṣṭha V	14 Āṣāḍha	28 June
Āṣāḍha S	Āṣāḍha S	Āṣāḍha S	Āṣāḍha S	28 Āṣāḍha	12 July
Āṣāḍha K	Śrāvaṇa K	Śrāvaṇa V	Āṣāḍha V	11 Śrāvaṇa	27 July
Śrāvaṇa S	Śrāvaṇa S	Śrāvaṇa S	Śrāvaṇa S	25 Śrāvaṇa	10 Aug.
Śrāvaṇa K	Bhādra K	Bhādra V	Śrāvaṇa V	9 Bhādra	25 Aug.
Bhādra S	Bhādra S	Bhādra S	Bhādra S	24 Bhādra	9 Sep.
Bhādra K	Āśvina K	Āśvina V	Bhādra V	8 Āśvina	24 Sep.
Āśvina S	Āśvina S	Āśvina S	Āśvina S	23 Āśvina	9 Oct.
Āśvina K	Kārtika K	Kārtika V	Āśvina V	6 Kārtika	23 Oct.
Kārtika S	Kārtika S	Kārtika S	Kārtika S	21 Kārtika	7 Nov.
Kārtika K	Mārga. K	Mārga. V	Kārtika V	5 Agrah.	21 Nov.
Mārga. S	Mārga. S	Mārga. S	Mārga. S	21 Agrah.	7 Dec.
Mārga. K	Pauṣa K	Pauṣa V	Mārga. V	6 Pauṣa	21 Dec.
Pauṣa S	Pauṣa S	Pauṣa S	Pauṣa S	22 Pauṣa	6 Jan, 1954
Pauṣa K	Māgha K	Māgha V	Pauṣa V	6 Māgha	20 Jan.
Māgha S	Māgha S	Māgha S	Māgha S	21 Māgha	4 Feb.
Māgha K	Phālguna K	Phālguna V	Māgha V	6 Phālguna	18 Feb.
Phālguna S	Phālguna S	Phālguna S	Phālguna S	22 Phālguna	6 Mar.
Phālguna K	Caitra K	Caitra V	Phālguna V	6 Caitra	20 Mar.

S = Śukla pakṣa or Sudi.
K = Kṛṣṇa pakṣa.
V = „ „ or Vadi.

When the lunar month nearly covers the Solar month of	*Length of the lunar month.* *Minimum* d h	*Maximum* d h
Kārtika or Phālguna	29 9.7	29 18.0
Agrahāyaṇa or Māgha	29 10.5	29 18.8
Pauṣa	29 10.8	29 19.1

Comparing the above limits with the actual lengths of months stated before, it is found that the minimum length of the lunar month falls short of all the solar months except *Pauṣa*. So a *malamāsa* or intercalary month is possible in all the months except the month of *Pauṣa* only.

The maximum duration of a lunar month, on the other hand, exceeds the lengths of the solar months only in case of solar *Agrahāyaṇa*, *Pauṣa* and *Māgha*. So a *kṣaya* month is possible only in these three months.

A list is given below showing the actual intercalary months occurring during the period Śaka 1823 (1901-2 A. D.) to Śaka 1918 (1996-97 A. D.) on the basis of *Sūrya Siddhānta* calculations.

Table 21.

Intercalary months in the present century

Śaka		Śaka	
1823	Śrāvaṇa	1872	Āṣāḍha
1826	Jyaiṣṭha	1875	Vaiśākha
1828	Caitra	1877	Bhādra
1831	Śrāvaṇa	1880	Śrāvaṇa
1834	Āṣāḍha	1883	Jyaiṣṭha
1837	Vaiśākha	1885*	Āśvina, Caitra
1839	Bhādra	1888	Śrāvaṇa
1842	Śrāvaṇa	1891	Āṣāḍha
1845	Jyaiṣṭha	1894	Vaiśākha
1847	Caitra	1896	Bhādra
1850	Śrāvaṇa	1899	Āṣāḍha
1853	Āṣāḍha	1902	Jyaiṣṭha
1856	Vaiśākha	1904**	Āśvina-Phāl.
1858	Bhādra	1907	Śrāvaṇa
1861	Śrāvaṇa	1910	Jyaiṣṭha
1864	Jyaiṣṭha	1913	Vaiśākha
1866	Caitra	1915	Bhādra
1869	Śrāvaṇa	1918	Āṣāḍha

* Pauṣa is *Kṣaya*, ** Māgha is *Kṣaya*.

As regards the *kṣaya* months that occurred and will be occurring during the period from 421 Śaka (499-500 A.D.) to 1885 Śaka (1963-64 A.D.) a statement is given below showing all such years mentioning the month which is *kṣaya* and also the months which are *adhika* in these years. The calculations are based on *Sūrya Siddhānta* without *bīja* corrections upto 1500 A. D. and with these corrections after that year.

Table 22—Kṣaya or decayed months

Śaka	*A.D.*	*Kṣaya month*	*Adhika months before and after the Kṣaya month*
448	526-27	Pauṣa	Kārtika, Phālguna
467	545-46	Pauṣa	Kārtika, Phālguna
486	564-65	Pauṣa	Āśvina, Phālguna
532	610-11	Mārgaśirṣa	Kārtika, Vaiśākha
551	629-30	Pauṣa	Āśvina, Caitra
692	770-71	Pauṣa	Āśvina, Caitra
814	892-93	Mārgaśirṣa	Kārtika, Caitra
833	911-12	Pauṣa	Āśvina, Caitra
974	1052-53	Pauṣa	Āśvina, Caitra
1115	1193-94	Pauṣa	Āśvina, Caitra
1180	1258-59	Pauṣa	Kārtika, Caitra
1199	1277-78	Pauṣa	Kārtika, Phālguna
1218	1296-97	Pauṣa	Mārga., Phālguna
1237	1315-16	Mārgaśirṣa	Kārtika, Phālguna
1256	1334-35	Pauṣa	Āśvina, Phālguna
1302	1380-81	Mārgaśirṣa	Kārtika, Vaiśākha
1321	1399-1400	Pauṣa	Kārtika, Caitra
1397	1475-76	Māgha	Āśvina, Phālguna
1443	1521-22	Mārgaśirṣa	Kārtika, Vaiśākha
1462	1540-41	Pauṣa	Āśvina, Caitra
1603	1681-82	Pauṣa	Āśvina, Caitra
1744	1822-23	Pauṣa	Āśvina, Caitra
1885	1963-64	Pauṣa	Āśvina, Caitra

It will be observed from the above table that according to *Sūrya Siddhānta* calculations one *kṣaya* month occurs on average after 63 years. But one may repeat as soon as after 19 years and as late as after 141 years. In rare cases they recur after 46, 65, 76 and 122 years.

Intercalary months according to modern calculations

The lunar calendar proposed by the Committee for religious purposes is based on the most up-to-date value of the tropical year and the correct timings of new-moon. As such the intercalary months according to these calculations would not always be the same as determined from *Sūrya Siddhānta*-calculations and shown above. The intercalary (*mala* or *adhika*) and decayed (*kṣaya*) months according to these calculations are shown below for Śaka years 1877 to 1902.

Table 23—Intercalary month according to modern calculations.

Śaka	A.D	Intercalary Month	Śaka	A.D.	Intercalary Month
1877	1955-56	Bhādra	1896	1974-75	Bhādra
1880	1958-59	Śrāvaṇa	1899	1977-78	Śrāvaṇa
1883	1961-62	Jyaiṣṭha	1902	1980-81	Jyaiṣṭha
1885	1963-64	*Kārtika* & Caitra (Agrahāyaṇa *kṣaya*)			
1888	1966-67	Śrāvaṇa			
1891	1969-70	Āṣāḍha			
1894	1972-73	Vaiśākha			

Proposal of the Committee about the Lunar Calendar

According to the Siddhāntic rules, the lunar calendar is pegged on to the solar calendar, and so it is the luni-solar calendar with which we are at present concerned. It has already been shown that the length of the *Sūrya Siddhānta* year is greater than the year of the seasons (*i.e.*, the tropical year) by about 24 minutes. As a result of this the seasons have fallen back by about 23 days in our solar calendar. The lunar calendar, being pegged on to the Siddhāntic solar calendar, has also gone out of seasons by about the same period, and consequently religious festivals are not being observed in the seasons originally intended.

The solar (saura) month for the religious calendar

Although the Committee considers that the solar year to which the religious lunar calendar is to be pegged on should also start from the V. E. day, it felt that the change would be too violent ; with a view to avoiding any such great changes in the present day religious observances, it has been considered expedient not to introduce for sometime to come any discontinuity in this system, but only to stop further increase of the present error. The solar year for the religious calendar with *Vaiśākha* as its first saura month should now commence when the tropical longitude of the sun amounts to 23° 15'. This saura month will determine the corresponding lunar months required for fixing the dates of religious festivals. The lengths of such months, which are also fractional, are stated below, giving the lengths according to the *Sūrya Siddhānta* calculations compared with the corresponding modern values.

Table 24—Lengths of Solar months of the Religious Calendar.

Saura Māsa	*Long. of Sun*		*Lengths of Months According to Sūrya Siddhānta*			*Modern Value (1950 A.D.)*		
Vaiśākha	23°	15'—	30^d	22^h	27^m	30^d	20^h	55^m
Jyaiṣṭha	53	15—	31	10	5	31	6	39
Āṣāḍha	83	15—	31	15	28	31	10	53
Śrāvaṇa	113	15—	31	11	24	31	8	22
Bhādrapada	143	15—	31	0	27	30	23	51
Āśvina	173	15—	30	10	36	30	11	51
Kārtika	203	15—	29	21	27	29	23	41
Mārgaśirṣa	233	15—	29	11	46	29	14	33
Pauṣa	263	15—	29	7	38	29	10	40
Māgha	293	15—	29	10	45	29	12	57
Phālguna	323	15—	29	19	41	29	20	54
Caitra	353	15—	30	8	29	30	8	33
			365	6	13	365	5	49

The lengths of the months according to the *Sūrya Siddhānta* are the same as shown earlier, as the same month was used by the S. S. for both the purposes. But the modern value is different from that shown before, due to the fact that a different point is taken here for the beginning of months. The modern value is, however, not fixed for all times, but it undergoes slight variation as explained previously.

The luni-solar calendar by which the religious festivals are determined has been pegged on to the religious solar calendar starting from a point 23° 15' ahead of the V. E. point. As this religious solar calendar is based on the tropical year, the luni-solar calendar pegged on to it would not go out of the seasons to which they at present conform, and so the religious festivals would continue to be observed in the present seasons and there would be no further shifting.

The Committee has proposed that the luni-solar calendar should no longer be used for civil purposes in any part of India. In its place the unified solar calendar proposed by the Committee should be used uniformly in all parts of India irrespective of whether the luni-solar or solar calendar is in vogue in any particular part of the country.

5.8 INDIAN ERAS

Whenever we wish to define a date precisely we have to mention the year, generally current of an era, besides the month and the particular day of the month, and the week-day. This enables an astronomer, well-versed in technical chronology, to place the event correctly on the time-scale. In international practice the Christian era is used, which is supposed to have started from the birth-year of Jesus Christ. But as mentioned in Chapter II, it is an *extrapolated era* which came in use five hundred years after the birth of the Founder of Christianity, and its day of starting may be widely different from the actual birthday of Christ, about which there exists no precise knowledge.

In India, nearly 30 different eras were or are used which can be classified as follows :—

(1) Eras of foreign origin, e.g., the Christian era, the Hejira era, and the Tārikh Ilāhi of Akber.

(2) Eras of purely Indian origin, list given.

(3) Hybrid eras which came into existence in the wake of Akber's introduction of Tārikh Ilāhi.

Table 27 shows purely Indian eras, with their starting years in terms of the Christian era, the elapsed year of the era*, the year-beginning, solar, lunar or both solar and the lunar as the case may be, the particular regions of India where it is current. Inspite of the apparent diversity in the ages of the eras, the methods of calendarical calculations associated with each era are almost identical ; to be more accurate only slightly different and follow the rules given in either of the three Siddhāntas, *Sūrya*, *Ārya* and *Brahma*. The three methods differ but slightly.

* Generally, but not always the Indian eras have "elapsed years". Thus year 1876 of Śaka era would be, if we followed the western convention, year 1877 Śaka (current).

The apparent antiquity of certain eras, e.g., the *Kaliyuga* or the *Saptarṣi*, are however rather deceptive, for these eras are not mentioned either in the Vedic literature or even in the *Mahābhārata* (a work of the 4th to 2nd century B.C.). The best proof, however, that no *eras* were used in date-recording in ancient India is obtained from "Inscriptions" which give 'contemporary evidence' of the method of date-recording in use at the time when the inscription was composed.

In India, the oldest inscriptions so far discovered and deciphered satisfactorily are those of the Emperor Aśoka (273 to 227 B.C.); for the earlier Indus valley seal recordings have not yet been deciphered and no inscriptions or seals which can be referred to the time-period between 2500 B.C. (time of Indus valley civilization) and 250 B.C. (time of Aśoka) have yet been brought to light. Aśoka mentions in his inscriptions only the number of years elapsed since his coronation. No month, week-day or the serial number of the day in the month is mentioned. A typical Aśokan inscription giving time references is given in § 5. 5.

Continuous eras first began to be used in the records of the Indo-Scythian kings who reigned in modern Afghanistan and North-Western India between 100 B.C. to 100 A.D.

What is then the origin of the *Kaliyuga* or *Saptarṣi* era given in Table 27 which go back to thousands of years before Christ ? We are going to show presently that they are extrapolated eras invented much later than the alleged starting year.

It is clear from historical records that date-recording by an era in India started from the time of the Kuṣāṇa emperors and Śaka satraps of Ujjain. But India cannot be singled out in this respect, for none of the great nations of antiquity, *viz.*, Egypt, Babylon, Assyria or later Greece and Rome, used a continuously running era till rather late in their history. The introduction of the era is connected with the development of the sense of 'History' which came rather late to all civilized nations.

Critical Examination of Indian Eras

Here we are examining critically the claims of a few eras, which are supposed to date much earlier, e.g., the *Kaliyuga* era which is commonly believed to have been introduced in 3102 B.C., the *Saptarṣi* era, and the *Pāṇḍara-Kāla* mentioned by Kalhaṇa, the historian of Kashmir, who wrote in 1150 A.D., and supposed to be dating from 2449 B.C., and others.

The Saptarṣi era commoly known as Lokakāla or Laukika Kāla is measured by centuries and has 27 such centuries in the total period of the cycle. Each century is named after a *nakṣatra*, viz., *Aśvinī*, *Bharaṇī*, etc ; and the number of years within the century is generally mentioned, so that the number of year of the era never exceeds 100. This era was in use in Kashmir and neighbouring places. In fact this era has no relation with the seven *Ṛsis* (the Great Bear) in the sky or with any actual *nakṣatra* division. There is difference of opinion as to the beginning of the era. According to Vṛddha Garga and the Purāṇas the starting year of the tenth century named after Maghā are 3177 B.C., 477 B.C. and 2224 A.D. of the different cycles, when according to Varāhamihira the third century named Kṛttikā begins. The beginning years of Varāhamihira's Maghā century of the different cycles are however 2477 B. C., 224 A. D. and 2924 A.D.

The Pāṇḍava Kāla or the Yudhiṣṭhira era started from 2449 B.C. according to Varāhamihira.

The so-called Yudhiṣṭhira era (2449 B.C.) is given by Kalhaṇa, chronicler of Kashmir (1150 A.D.), who quotes the date from Vṛddha Garga, an astronomer whose time is unknown. This era also does not occur in any inscription or any ancient treatise prior to Kalhaṇa (1150 A.D.). Prof. M. N. Saha has shown that in the *Mahābhārata* the Kṛttikās are in many places taken as the first of the nakṣatras and are very nearly coincident with the vernal equinox. If we calculate the date of the M.Bh. incidents on this basis, the date comes out to be very nearly 2449 B.C.

It, however, niether proves that the incidents mentioned in the M.Bh., if they were actual occurrences, took place in 2449 B.C., for the epic was not certainly put to writing before 400 B.C. as we know from a verse already mentioned on p. 226. It is inconceiveable to think that the dates could be remembered correctly for over 2000 years, when writing was in a very primitive state. The astronomical references in the battle scenes, from which certain writers very laboriously deduce the date of these occurrences, are most probably later interpolations, on the supposition that the incidents occurred about 2449 B.C. There is no inscriptional record regarding the use of Yudhiṣṭhira era or Pāṇḍavakāla.

(a) The Kaliyuga Era

It is easy to show that the Kaliyuga era which purports to date from 3102 B.C. is really an extrapolated era just like the Christian era, introduced long long after the supposed year of its beginning.

It is first mentioned by Āryabhaṭa, the great astronomer of ancient Pātaliputra, who says that 3600 years of the Kaliyuga had passed when he was 23 years old which is Śaka year 421 (499 A. D.). It is not mentioned earlier either in books or in inscriptions. The first mention of this era in an inscription is found in the year 634-35 A.D., the inscription being that of king Pulakeśin II of the Cālukya dynasty of Bādāmī, or somewhat earlier in a Jain treatise. It was most probably an era invented on astrological grounds just like the era of Nabonassar, by Āryabhaṭa or some other astronomer, who felt that the great antiquity of Indian civilization could not be described by the eras then in use (Śaka, Chedi or Gupta era), as they were too recent.

What were these astrological grounds ?

The astrological grounds were that at the beginning of the Kaliyuga, the sun, the moon and the planets were in one zodiacal sign near the fixed Siddhāntic Meṣādi which according to some authorities is ζ *Piscium*, but according to others is 180° from *Citrā* or α *Virginis*. This was probably a back calculation based on the then prevailing knowledge of planetary motion, but has now been found to be totally wrong, when recalculated with the aid of more accurate modern data on planetary motion. We quote from *Ancient Indian Chronology*, pp. 35-39 by Prof. P. C. Sengupta, who has given a full exposition of Burgess's views on this point, with recalculations of his own.

should also be a total eclipse of the Sun ; but no such things happened at that time. The beginning of the *Kaliyuga* was the midnight at Ujjayinī terminating the 17th February of 3102 B.C., according to *Sūrya Siddhānta* and the *ārdharātrika* system of Āryabhaṭa's astronomy as described in the *Khaṇḍakhādyaka* of Brahmagupta. Again this *Kaliyuga* is said to have begun, according to the *Āryabhaṭīya* from the sunrise at Laṅkā (supposed to be on the equator and on the same meridian with Ujjain)—from the mean sunrise on the 18th Feb., 3102 B.C.

Now astronomical events of the type described above and more specially the conjunction of the sun and the moon cannot happen both at midnight and at the next mean sunrise. This shows that this Kaliyuga had an unreal beginning.

The researches of Bailey, Bentley and Burgess have shown that a conjunction of all the 'planets' did not happen at the beginning of this Kaliyuga. Burgess rightly observes : '*It seems hardly to admit of a doubt that the epoch* (the beginning of the astronomical Kaliyuga) *was arrived at by astronomical calculation carried backward.*

We also can corroborate the findings of above researchers in the following way and by using the most up-to-date equations for the planetary mean elements.

Now the precession of the equinoxes from 3102 B. C. to 499 A.D. or Āryabhaṭa's time works out to have been =49° 32′ 39″. The mean planetary elements at the beginning of the Kaliyuga, i.e., 17th Feb., 3102 B.C., Ujjayinī mean time 24 hours, are worked out and shown below. We have

Table 25—Longitudes of Planets at Kali-beginning.

Planet	Mean Tropical longitudes on Feb. 17, U.M.T. 24 hrs., 3102 B.C. (Moderns.)			Longitude at the same time measured from the Vernal Equinox of 499 A.D., i.e., Āryabhata's time.			The same as assumed in the *Ārdharātrika* system at the same time as before and also at next mean sunrise.			Error in the assumption of Āryabhaṭa and also of the modern *Sūrya-Siddhānta* and the *Khaṇḍakhādyaka*.		
Sun	301°	40′	9.22″	351°	12′	48″	0°	0′	0″	+ 8°	47′	12″
Moon	305	38	13.81	355	10	53	0	0	0	+ 4	49	7
Moon's Apogee	44	25	27.66	93	58	7	90	0	0	− 3	58	7
Moon's Node	147	20	15.05	196	52	54	180	0	0	−16	52	54
Mercury	268	24	1.65	317	56	41	0	0	0	+42	3	19
Venus	334	44	50.25	24	17	29	0	0	0	−24	17	29
Mars	290	2	54.67	339	35	34	0	0	0	+20	24	26
Jupiter	318	39	45.74	8	12	25	0	0	0	− 8	12	25
Saturn	282	24	15.07	331	56	54	0	0	0	+28	3	6

"Astronomical Kaliyuga an Astronomical Fiction"

At the beginning of the astronomical Kaliyuga, all the mean places of the planets, viz., the Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn, are taken to have been in conjunction at the beginning of the Hindu sphere, the moon's apogee and her ascending node at respectively a quarter circle and a half circle ahead of the same intial point. Under such a conjunction of all the planets, there

added 49° 32′ 39″ to these mean tropical longitudes arrived at from the rules used, so as to get the longitudes measured from the vernal equinox of Āryabhaṭa's time.

Hence we see that the assumed positions of the mean planets at the beginning of the astronomical Kaliyuga were really incorrect and the assumption was not a reality. But of what use this assumption was in Āryabhaṭa's time, i.e., 499 A.D., is now set forth below.

Āryabhaṭa says that when he was 23 years old, 3600 years of Kali had elapsed. According to his *Ārdharātrika* system :

3600 years = 1/1200 of a Mahāyuga = 1314931.5 days.

Again according to his *Audayika* system :

3600 years = 1/1200 of a Mahāyuga = 1314931.25 days.

Hence according to both these systems of astronomy of Āryabhaṭa, by counting 3600 years from the beginning of the astronomical *Kali* epoch, we arrive at the date March 21, 499 A.D., Ujjayinī mean time, 12 noon. The unreality of the *Kali* epoch is also evident from this finding. However, the position of mean planets at this time work out an given in table 26 below.

Table 26—Longitudes of Planets at 3600 Kaliyuga era.
Date : March 21, 499 A.D.—Ujjayinī Mean Midday.

Planet	Mean Long. *Ārdharātrika* system.	Mean Long. *Audayika* system.	Mean Long. Moderns.	Error in the *Audayika* system.
Sun	0° 0′ 0″	0° 0′ 0″	359° 42′ 5″	+17′ 55″
Moon	280 48 0	280 48 0	280 24 52	+23 8
Moon's Apogee	35 42 0	35 42 0	35 24 38	+17 22
Moon's Node	352 12 0	352 12 0	352 2 26	+ 9 34
Mercury	180 0 0	186 0 0	183 9 51	+2° 50′ 9″
Venus	356 24 0	356 24 0	356 7 51	+16 9
Mars	7 12 0	7 12 0	6 52 45	+19 15
Jupiter	186 0 0	187 12 0	187 10 47	+ 1 13
Saturn	49 12 0	49 12 0	48 21 13	+50 47

It is thus clear that the beginning of the Hindu astronomical *Kaliyuga* was the result of a back calculation wrong in its data, and was thus started wrongly.

It is also established that the astronomical Kaliyuga-reckoning is a pure astronomical fiction created for facilitating the Hindu astronomical calculations and was designed to be correct only for 499 A.D. This Kali-reckoning cannot be earlier than the date when the Hindu scientific *Siddhāntas* really came into being. As this conclusion cannot but be true, no Sanskrit work or epigraphic evidences would be forthcoming as to the use of this astronomical Kali-reckoning prior to the date 499 A.D".

(b) The Vikrama Era

The Vikrama Era is widely prevalent in Northern India, excepting Bengal, and used in inscriptions from the ninth century A.D. Let us probe into its origin.

In popular belief, the Vikrama era was started by king Vikramāditya of Ujjain who is claimed to have repelled an attack on this famous city by Śaka or Scythian hordes about 57 B. C. and founded an era to commemorate his great victory.

Unfortunately no historical documents or inscriptions have yet been discovered showing clearly the existence of a king Vikramāditya reigning at Ujjain about 57 B. C. Moreover a critical examination of inscriptions show the following details about this era.

The earliest mention of this era, where it is definitely connected with the name of king Vikramāditya is found in an inscription of one king Jaikadeva who ruled near Okhamandal in the Kathiawar State. The year mentioned is 794 of Vikrama era, i.e., 737 A.D. In a subsequent inscription, dated 795 V.E. it is also called the era of the lords of Mālava. So the Vikrama era and the era of Mālava lords are one and the same. Tracing back, we find the Mālavagaṇa era in use by a family of kings reigning at Mandasor, Rajputana between the years 461-589 V.E., as feudatories to the Imperial Guptas (319-550 A.D.). They call it not only the era of the Mālava tribe, but also alternatively as the Kṛta era. A number of inscriptions bearing dates in the Krta era have been found in Rajasthan, and the earliest of them goes back to the year 282 of the Kṛta era (The Nandsa Yupa inscription described by Prof. Altekar, *Epigraphia Indica*, Vol. XXVII, p. 225).

From these evidences, it has been concluded by historians that the earliest name so far found of this era was Kṛta. What this means is not clear. Then between 405-542 A.D., it came to be known as the era of the Mālava tribe and was used by the Verma kings of Mandasor, Rajputana, though they were feudatories of the Gupta emperors (319-550 A.D.). Its association with king Vikrama is first found in the year 737 A.D., nearly 800 years after the supposed date of king Vikrama. Its use appears to have been at first confined to Kathiawar and Rajasthan, for the whole of Northern India used between 320 A.D. to 600 A.D., the Gupta era, which fell into disuse with the disappearance of the Gupta rule in 550 A.D. For a time, Northern India used the Harṣa era introduced by the emperor Harṣa Vardhana (606 A.D.), but when the Gurjāra-Pratihārs, who came from

Rajasthan, conquered the city of Kanauj about 824 A.D., they brought the Vikrama era from their original home, and it became the current era all over northern India except the eastern region, and was used by all Rajput dynasties of medieval times.

The months of the Vikrama era are all lunar, and the first month is *Caitra*. The months begin after the full-moon but the year begins 15 days after the full-moon of Phālguna, i.e. after the new-moon of Caitra. But for astronomical calculations, it is pegged on to a solar year, which starts on the first of solar Vaiśākha, theoretically the day after the vernal equinox. The Vikrama era is current also in parts of Gujrat, but there the year begins in *Kārtika* and the months are *amanta*, which corresponds to the Macedonian month of Dios, and the epoch is just six months later. Thus the western and northern varieties of the Vikrama era follow respectively the Macedonian and Babylonian reckonings (see § 3.3), the year of starting is 255 years later than that of the Seleucidean era.

The conclusion is that the champions of the Vikrama era have still to prove the existence of king Vikrama of Ujjain. Early inscriptions show that the method of date-recording is not typically Indian as in the Sātavāhana inscriptions but follow the Saka-Kuṣāṇa method, which follows the contemporary Graeco-Chaldean method. It was therefore a foreign reckoning introduced either by the Greeks or Sakas, or an Indian prince or tribe who had imbibed some Graeco-Chaldean culture, but was adopted by the Mālava tribes who migrated from the Punjab to Rajasthan about the first century B.C. The association with a king Vikrama occured 800 years later, and is probably due to lapse of historical memory, for the only historical king Vikramāditya who is known to have crushed the Saka power in Ujjain, was king Candragupta II of the Gupta dynasty (about 395 A.D.). Before this, the Śaka dynasty in Ujjain had reigned almost in unbroken sequence from about 100 A.D. to 395 A.D., and had used an era of their own, later known as the 'Śaka' era. All the Gupta emperors from Samudragupta, had an "Āditya" title, and many of them had the title "Vikramāditya" so that the Gupta age was par excellence the age of Vikramādityas. But all the Gupta emperors use in their inscriptions the family era called the Guptakāla which commemorated the foundation of Gupta empire (319 A.D.). The association of the Mālava era with king Vikramāditya, and assignment of king Vikramāditya to Ujjain, was due to confusion of historical memory not infrequent in Indian history. It may be mentioned that the Vikrama era is never used by Indian astronomers for their calendaric calculations, for which puapose the Saka era is exclusively used.

(c) The Saka Era

The Saka Era is the era par excellence which has been used by Indian astronomers all over India in their calculations since the time of the astronomer Varāhamihira (died 587 A.D.) and probably earlier. The Indian almanac-makers, even now, use the Saka era for calculations, and then convert the calculations to their own systems.

This era is extensively used over the whole of India except in Tinnevelly and part of Malabar, and is more widely used than any other era. It is also called Śaka Kāla, Śaka Bhūpa Kāla, Śakendra Kāla, and Sālivāhana Saka and also Saka Saṁvat. Its years are *Caitrādi* for luni-solar reckoning and *Meṣādi* for solar reckoning. In the luni-solar reckoning the months are *pūrṇimāntā* in the North and *amāntā* in Southern India. The reckoning of the Śaka era begins with the vernal equinox of 78 A.D., and is measured by expired years, so the year between the vernal equinox of 78 A.D. to that of 79 A.D. is *zero* of Śaka era. In some pancāṅgas of Southern India the current year is however seen to be used instead of the elapsed year, where the number of year of the era is one more than the era in general use

But we are not yet sure about the origin of this era. It has been traced back to the Śaka satraps of Ujjain, from the year 52 (130 A.D.) to the end of the dynasty about 395 A.D. But in their own records, they merely record it as year so and so, but there is not the slightest doubt that the era used by them subsequently became known as the Śaka era (*vide* § 5.5).

The Old and the New Śaka era.

The dates given by different authorities about the starting year of the old Śaka era mentioned in § 5.5 vary from 155 B.C. to 88 B.C. as given below :

Konow : 88 B.C. (date of death of Mithradates II, the powerful Parthian emperor who is said to have subjugated the Sakas).

Konow has proposed a number of other dates.

Jayaswal : 120 B.C. :

Herzfeld : 110 B.C. : Settlement of the Śakas in Seistan by Mithradates II.

Rapson : 150 B.C. : Establishment of the Śaka kingdom of Seistan.

Tarn : 155 B.C. : Date of settlement of the Śaka immigrants in Seistan by Mithradates I.

Recently Dr. Van Lohuizen de Leeuw has discussed the starting point of this era in her thought-provoking book '*The Scythian Period of Indian History*'. She has rejected all the above dates, and fixed up 129 B.C. as the starting date of the old Saka era. She identifies this year as the one in which the Sakas, descending from the Trans-Oxus region, attacked the Parthian empire in which the Parthian emperor Phraates II was defeated and killed, and the rich province of Bactria was occupied by the Śakas. They founded an era to commemorate their victory over the Parthians which their successors took to India, as they expanded and put an end to the Bactrian Greek principalities in Afghanistan and north-west Punjab. She suggests that the old Śaka era was also used by the Kuṣaṇas, who were after all a Sakish ruling tribe, but from the time of Kaniṣka with hundreds omitted.

Dr. M. N. Saha has supported this theory in its main features, but he thinks that the era was founded in 123 B.C., for he shows from historical records that the Śakas assailed Bactria first in 129 B.C. and entered into a seven year conflict with the Parthians, and finally conquered Bactria in 123 B.C., when the Parthian emperor Artabanus II, was defeated and killed. Probably the Śakas then founded their era. This was also called the era of Azes. Dr. Van Lohuizen de Leeuw has accepted Saha's suggestion.

This hypothesis, though not finally settled appears to have, a good deal of probability, for the following reasons :

Dr. Saha points to the fact that Indian classics, which can be dated from the third century B.C. to the second century A.D., mentions three races in what is modern Afghanistan and N. W. India, *viz.*, the Śakas, the Yavanas, and the Pallavas, who attained to the status of ruling races. The order in which they are mentioned denotes correct chronological sequence, for they are arranged in the order of their chronological appearance in history, the Śakas being mentioned as a subject race in Darius's inscription (518 B.C.). But the Yavanas (Greeks) were the first to attain the status of a ruling race, from 312 B.C., the date of foundation of the Seleucid empire, whose power in the west was overthrown by the Parthians, or Pehlevis (Pallavas of Indian classics) in 248 B.C.

Both these ruling races of Yavanas and Pallavas used eras of their own, *viz.*, the Seleucidean era from 312 B.C., and the Parthian era from 248 B.C. Did the third race, *viz.*, the Śakas who were the last to attain status of a ruling race *ever use an era of their own* ? It would be surprising if they did not, for it became the fashion for all races, who attained the status of ruling people, to have eras of their own. The early Śakas, as their records show, were deeply influenced by their neighbours to the west, *viz.*, the Parthians who adopted Greek culture, and their coin-records show that they also adopted Greek culture, and therefore most probably, the Graeco-Chaldean method of date recording.

The points given in § 5.5 and above may be summarized as follows :—

(a) The Śakas starting from Central Asia attacked the Parthian empire in 129 B.C., and overcame Parthian resistance by 123 B.C. It is very probable that they started an era to commemorate their accession to power in Bactria from 123 B.C. They used Macedonian months and Graeco-Chaldean methods of calendaric calculations as prevalent in the Seleucid and Parthian dominions. Probably the era was sometimes named after Azes, who was probably their leader. But this Azes is not to be confounded with later Azes I or Azes II, who reigned in Taxila between 40 B.C. and 20 B.C. Within the first 200 years of its starting, the era was alternatively called the Azes era.

(b) This Śaka era (known to archaeologists as the old Śaka era) was used by the Śaka emperors and Śaka satraps in their Indian territories, but the time-reckoning began to be gradually influenced by Indian customs. They began to use Indian months alternatively with Macedonian months and *Pūrṇimānta* months in place of *Amānta* months. During the first 200 years, the hundreds were sometimes omitted, in the use of the era.

(c) The so-called Kaniṣka era is nothing but the old Śaka era with 200 omitted.

(d) The Śaka era was used by the house of Castana of Ujjain with 200 omitted, but gradually they forgot the origin of the era and continued their own reckoning without further omission of hundreds upto the end of the Śaka satrapal rule over Ujjainī about 395 A.D. As the early Indian astronomers were mostly of foreign origin (*viz.* Śākadvīpi Brāhmaṇa) the astronomical reckonings necessary for compiling the calendar were carried out using the Śaka era and Graeco-Chaldean astronomy. The blending of Graeco-Chaldean astronomy as known about the early years of the Christian era with older Indian calendarical features formed the basis of Siddhānta Jyotiṣa. The Śākadvīpi Brahmins also brought to India horoscopic astrology using the Śaka era exclusively in horoscopes, a custom which has persisted to this day. These facts explain the pre-eminence of the Śaka era.

(d) Other Eras

Buddha Nirvāṇa Era :—The Buddhists of Ceylon have been using since the first century B.C. the Buddhist Nirvāṇa era, having its era-beginning in 544 B.C. This era has not however been found in use on the Indian soil, except for a solitary instance in an inscription of Aśokachalla Dev found at Gaya dated in the year 1813 of the Buddhist Nirvāṇa era = 1270 A.D. Most of the antiquarians however put the date of Nirvāṇa in 483 B.C. The origin of the Buddha Nirvāṇa era used in Ceylon has not yet been satisfactorly explained.

The Gupta Era :—This era was clearly established by the founder of the Gupta dynasty (Candragupta I) to commemorate the accession to imperial power of his family, about 319 A.D., and was in vogue over the whole of Northern India from Saurashtra to Bengal during the days of their hegemony (319 A.D.-550 A.D.). After the decay of their empire, the era was continued by their former vassals, the Maitrakas of Vallabhi and was in use in parts of Guzrat and Rajputana up to the thirteenth century. Its use in Bengal was discontinued from about 510 A.D. with the disappearance of Gupta rule first in South Bengal, then over the whole of Eastern India. In the Uttar Pradesh (ancient Madhyadeśa), it was driven out by the Harṣa era, which had a short period of existence, 606-824 A.D., when the city of Kanauj was occupied by king Nāgabhata of the Pratihār dynasty, who hailed from Rajasthan. The Pratihārs brought with them the Vikrama era, which had been current in Rajasthan, and this became the great era of the north, used by all medieval Rajput dynasties, except those belonging to the eastern region.

Eras in Eastern India

Most parts of Bengal were under the Gupta emperors, and used the Gupta era during their hegemony (319-510 A.D.). But Gupta rule disappeared as mentioned above from major parts of Bengal from *ca.* 510 A.D., and the subsequent dynasties including the Pāla emperors (750 A.D.—1150 A.D.) used regnal years in their inscriptions for four hundred years of their rule. The Śaka era in Bengal appear to have been introduced by the Sena dynasty which replaced the Pālas ; the Senas were migrants from the south (Karṇāṭa-Kṣatriyas), where they were familiar with the Śaka era, but it was not used in royal records which continued to use regnal years. The Vikrama Saṁvat never became popular in Bengal, or Eastern India. After Mohamedan conquest, Bengal was left without an era. For official purposes, Hejira was used, but the learned men used the Śaka era, and the common people in certain parts used a rough reckoning, called *Parganati-Abda*, reckoned from the time of disappearance of Hindu rule.

After the introduction of *Tārikh Ilāhi*, the people of Bengal began to use the Sūrya Siddhānta reckoning, and the solar year. The Bengali San had thus a hybrid origin ; to find the current year of the Bengali San, we take Hejira year elasped in 1556, i.e., 963 and add to it the number of solar years. Thus 1954 A. D. is 963 A.D. + (1954 − 1556) = 1361 of Bengali San.

Other hybri.. eras

A number of other hybrid eras formed in a similar way to Bengali San is mentioned in the table (No. 27) : Āmli and Vilāyati in Bengal and Orissa, the various Fasli or harvest years in Bengal, Deccan, and Bombay.

All the other eras mentioned as hybrid in the chart were formed in a similar way, and the slight differences are due to mistakes in calculation, or differences in the time of introduction. While the Bengali San has Meṣādi as year-beginning, others have taken the year-beginning to be coincident with some important mythical event of local provenance, e.g., the year-beginning of the Āmli era used in Orissa, *viz.*, the 12th lunar day of the light half of the month of *Bhādra* is said to represent the birth date of king Indradyumna, the mythical king who is said to have discovered the site of modern Puri. The great temple of Puri was actually built by king Anyanka Bhīm Dev of the Gaṅgā dynasty about 1119 A.D., and kings of this dynasty who held sway in Orissa from 1035-1400 A. D. used the Gaṅgā era.

The Kollam era prevalent in the Malayalam countries is of obscure origin. The year of this era is known as the Kollam Āṇḍu. The era is also called the Era of Paraśurāma, and is said to have omitted thousands from their previous reckonings. In South Malabar it begins with the solar month Siṁha and in North Malabar with the solar month Kanyā. The era started from 825 A.D.

The Jovian cycle : In Southern India the years are named after the name of the Jovian year and so it also serves the purpose of an era of a short period, *viz.*, 60 years, after which the years recur. Details about Jovian years will be found in Appendix 5-E.

Table 27.

Indian Eras

ERA	Zero-year of Era	Year of era current in 1954 A. D. (latter part)	Date of commencement in 1954 A. D.	Year-beginning: Solar	Year-beginning: Luni-Solar	Pūrṇimānta or Amānta (Lunar months)	Provenance	Remarks
	A. D.							
Kali Yuga	−3101	5055	April	Meṣādi(Ver.equi.)	Caitra S 1	—	—	Extrapolated
Saptarṣi	−3176	—	—	—	Caitra S 1	Pūrṇimānta	Kashmir	—
Yudhiṣṭhira	−2448	—	—	—	—	—	—	—
Laukika	724 (?)	—	—	—	—	—	Multan & Kashmir	Adopted by Kalhaṇa
Buddha Nirvāṇa	− 544	2498	May 17	—	Vaiśākha S 15	—	Ceylon	—
Mahāvīra Nirvāṇa	− 527	2481	—	—	Kārtika S 1	—	—	—
Vikrama (I)	− 57	2011	April 4	Vernal equinox	Caitra S 1	Pūrṇimānta	N. India except Bengal	Earlier known as Kṛta or Mālavagaṇa.
" (II)	− 57	2011	Oct. 27	—	Kārtika S 1	Amānta	Gujerat	
" (III)	− 57	2011	July 1	—	Āṣāḍha S 1	Amānta	Kathiawar	
Christian	0	1954	Jan. 1	Jan. 1	—	—	World	—
Saka	**78**	**1876**	**April**	**Meṣādi** (Vernal equinox)	**Caitra S 1**	**P (N. India) A (S. India)**	**All India**	**Astronomer's era**
Chedi (Kālācuri)	248	—	—	—	Āśvina S 1	Pūrṇimānta	Western & Central India	—
Vallabhi	318	—	—	—	Kārtika S 1	Both P. & A.	Kathiawar & Saurashtra	From Gupta era
Gupta	319	—	—	—	Caitra S 1	Pūrṇimānta	Gupta empire (Cen. I. & Nep.)	—
Harṣa	606	—	—	—	—	—	Mathura & Kanauj	—
Hejirā	622	1374	Aug. 31	—	Muharram (Lun.)	—	—	Lunar reckoning
Bengali San	—	1361	April 14	Meṣādi	—	—	Bengal	963+ Solar years since 1556
Vilāyati	—	1362	Sept. 16	Kanyādi	—	—	Bengal & Orissa	—
Āmli	—	1362	Sept. 10	—	Bhādra S 12	—	Orissa	—
Fasli (I)	—	1362	Sept. 13	—	Bhādra K 1	Pūrṇimānta	Bengal	992+ Solar years since 1584
" (II)	—	1364	July 1	July 1	—	—	Deccan	—
" (III)	—	1364	June 8	Sun enters Mṛga. nakṣ.	—	—	Bombay	—
Magi	638	—	—	Meṣādi	—	—	Arakan, Chittagong	Similar to Bengali San
Gaṅgā	—	—	—	—	—	—	Eastern Deccan	—
Kollam (I)	824	1130	Sept. 17	Kanyādi	—	—	North Malabar	—
" (II)	824	1130	Aug. 17	Siṁhādi	—	—	South Malabar	—
Newar	879	—	—	—	Kārtika S 1	Amānta	Nepal	In vogue till 1768 A. D., suppressed by Gurkhas.
Cālukya Vikrama	1075	—	—	—	—	—	Western Deccan	Current only for 100 years.
Lakṣmaṇa Sena	1104-1118	—	—	—	Kārtika S 1	—	Mithilā	—
Siṁha	1113	—	—	—	Āṣāḍha S 1	Amānta	Gujerat	Started by Siddharāja Jayasiṁha
Tārīkh Ilāhi	1555	—	—	Vernal equinox	—	—	Akber's empire	Introduced by Akber (963 Hejirā)
Rāja Śaka	1673	—	—	—	Jyeṣṭha S 13	Amānta	Maharashtra	From the coronation of Śivāji

APPENDIX 5-A

The Seasons

We have seasons because the celestial equator is oblique to the sun's path (or the ecliptic), or in modern parlance, the axis of rotation of the earth is not perpendicular to its orbit, but inclined at an angle of $66\frac{1}{2}°$. This causes varying amounts of sunlight to fall on a particular locality throughout the year. If the earth's axis were perpendicular to the ecliptic, in other words the obliquity were zero, every portion of the earth from the equator to the pole would have had 12 hours of sunlight, and 12 hours of shade. There would have been no seasons on any part of the earth, just as we have now for places on the earth's equator, where we have no variation of season throughout the year, because the day and night are equal for all days of the year.

It can be proved from spherical trigonometry that the duration of sunlight for a place having the latitude ϕ is given by

$$12+\tfrac{2}{15}\ \mathrm{Sin}^{-1}\ (\ \tan\phi\ \tan\delta\ )\ \text{hours},$$

where δ=declination of the sun on that day ; δ being counted positive when it is north of the equator, and negative when south.

If δ is negative, i.e., when the sun is south of the equator, the second term of the above equation is negative, and daylight will be of less than 12 hours' duration.

This holds up to the latitude of $\frac{\pi}{2}-\epsilon=66\frac{1}{2}°$, i.e., the beginning of the arctic zone. Between the arctic circle and the north pole, the sun will remain constantly above the horizon more than twenty-four hours for several days together during the year. Thus at a place on 70° north latitude, the continuous day is observed for 64 days from 21st May to 24th July, at 80° north latitude it is for 133 days from 17th April to 28th August, at the north pole it is for six months from 21st March to 23rd September.

For a person on the north pole, the sun will appear on the horizon on the vernal equinox day, and will go on circling round the sky parallel to the horizon and rising every day a little up, till on the solstitial day, he attains the maximum altitude, *viz.*, 23° 27′. After that the sun will begin to move down and on the day of autumnal equinox, will pass below the horizon. Thus for six months, from 21st March (V.E.) there will be continuous day for a person on the north pole, and from the 23rd Sept. (A.E.) to the next 21st March (V.E.), there will be a continuous night for six months.

The position described above is for the northern hemisphere, *viz.*, for those dwelling north of the equator. In the southern hemisphere the position is just reversed ; when the day is longer in the northern hemisphere, it is shorter in the southern hemisphere.

The amount of daylight received at any place determines the season. When we have maximum sunlight, we have the hot season. When we have minimum sunlight, we shall have winter. The other seasons come in-between. Rain, frost, etc., are secondary effects produced by varying amounts of sunlight, and of the atmospheric conditions stimulated by the sunlight received. The sun is the sole arbiter of the seasons.

Hence the definitions of seasons as given by the ancient astronomers, whether Western and Indian, which base them on the cardinal days of the year, are the only *correct definitions*. A system which deviates from this practice is wrong.

The majority of the Indian calendar makers have not, however, followed this definition. The reason is more psychological than scientific. For along with astronomy, there has been also a growth of astrology which has fixed up its canons on the basis of a fixed zodiac commonly known as the *Nirayaṇa* system. The effect of this will be clear from the following example.

The winter season (*śiśira*) begins on the winter solstice day which date is also marked *in all the Siddhāntas* by sun's entry (*saṁkrānti*) into *Makara*. This event occurs on the 22nd December. But the Indian calendar makers, following the nirayaṇa system, state that the *Makara Saṁkrānti* happens not on the 22nd December but on the 14th January and the winter season also begins on that date. Similar is the case with other seasons also. The result is that there is a clear difference of 23 days in the reckoning of seasons. The later Hindu savants tried to reconcile the two points of view by adopting a theory of trepidation, which after Newton's explanation of precession, has been definitely shown to be false. It is therefore absolutely wrong to stick to the *nirayaṇa* system.

It is however refreshing to find that a few Indian savants have definitely stood against the false *nirayaṇa* system. The earliest were Muñjāla Bhaṭa (932 A.D.), a South Indian astronomer and Pṛthūdaka Svāmī (950 A.D.), who observed at Kurukṣetra. One of the latest was Mm. Bapudev Sastri, C. I. E., Professor in the Sanskrit College, Banaras, who wrote in 1862, as follows :

"Since the *nirayaṇa saṁkrāntis* cannot be determined with precision and without doubt and since the *nirayaṇa rāśis* have no bearing on the ecliptic and its northern and southern halves, we must not hanker after *nirayaṇa* system for the purposes of our religious and other rites. We must accept *sāyana* and our religious and other rites should be performed in accordance with the *sāyana* system".

It is not generally known that another great man who probably felt that the *nirayaṇa* system gave us wrong seasons, was Pandit Ishwar Chandra Vidyasagar. We learn from his biography that he had a course in Indian astronomy while he was a student of the Sanskrit College, Calcutta about 1840. Before him, the *Vasanta* r Spring consisted of the months *Madhu* and *Mādhava, i.e., Caitra* and *Vaiśākha*, as in other parts of India. But from 1850, Vidyasagar began to bring out text books in Bengali in which he retarded the seasons by a month, *e.g.*, he said that the spring consists of *Phālguna* and *Caitra*, and no one questioned it. So in Bengal, as far as popular notion goes, *Vasanta* season starts on Feb. 12, while in other parts it starts on March 14, a month later, while the correct astronomical date according to Hindu Siddhāntas is Feb. 19. Bengal thus commits a negative mistake of 7 days while other parts of India has a positive mistake of 23 days.

The position in respect of all the seasons is stated below :

	Sun's longitude	*Correct date*	*Present date*
Vasanta (Spring)	(–) 30° to 30°	Feb. 19 to Apr. 19	Mar. 14 to May 13
Grīṣma (Summer)	30° to 90°	Apr. 20 to June 20	May 14 to July 15
Varṣā (Rains)	90° to 150°	June 21 to Aug. 22	July 16 to Sep. 15
Śarat (Autumn)	150° to 210°	Aug. 23 to Oct. 22	Sep. 16 to Nov. 15
Hemanta (Late Autumn)	210° to 270°	Oct. 23 to Dec. 21	Nov. 16 to Jan. 12
Śiśira (Winter)	270° to 330°	Dec. 22 to Feb. 18	Jan. 13 to Mar. 14

In continuing to follow the *nirayaṇa* system, the Hindu calendar makers are under delusion that they are following the path of *Dharma*. They are act ually committing the whole Hindu society to *Adharma*.

The period covering the north-ward journey of the sun was known in Indian astronomy as the *Uttarāyaṇa i.e.*, north-ward passage and it consisted of the Winter, Spring and Summer. It is the period from winter solstice to summer solstice, and *vice-versa*, the period from summer solstice to winter solstice was known as the *Dakṣiṇāyana*, i.e., southward passage and it consisted of Rains, Autumn and *Hemanta*.

The names of months given in the second column of Table No. 28 are found first in *Taittirīya Saṁhitā*, and they are *tropical*, because they attempt to define the physical characteristics of the months.

Madhu......means 'Honey' and the name indicates that the month was pleasant like honey.

Mādhava...means 'Honeylike' or 'Sweet one'.

The names are thus expressive of the pleasantness of the spring season.

The figures in the third column of the table below denote the angular distance of the sun from the astronomical first point of Aries (the V.E. point) indicating the beginning of the month.

The two months constituting the 'Spring Season' would thus include the day from Feb. 19 or 20 to April 19 or 20. The Vernal Equinox day (March 21) would be just in the middle. The same is the case with other seasons each of two months.

Table 28.

Spring	Madhu	–30°	Honey or sweet spring
	Mādhava	0	The sweet one
Summer	Śukra	30	Illuminating
	Śuci	60	Burning
Rains	Nabhas	90	Cloud
	Nabhasya	120	Cloudy
Autumn	Isa	150	Moisture
	Ūrja	180	Force
Late Autumn	Sahas	210	Power
	Sahasya	240	Powerful
Winter	Tapas	270	Penance, mortification, fire
	Tapasya	300	Pain (produced by heat)

These names were seldom used by the common people, but they were very popular with poets.

The figures in the second column of table No. 29 denote the angular distance of the sun on the ecliptic, the origin being the first point of Aries. We have described in § 4.5 how an idea of the ecliptic was derived from night observations of the sky and observation of eclipses, and how it came to be used as a reference plane from very ancient times.

The Indian definition of the seasons, though was based on the cardinal days, was different from the definition of the westerners who divided the year into four seasons each of three months Winter, Spring, Summer and Autumn, starting from the four cardinal days. The ancient Indians divided the year into six seasons each of two months as given in the table below. The spring season did not start with the vernal equinox, as already stated but a month earlier and it was extended a month later, and so for every season.

Table 29.

Indian Seasons		*Tropical Month-names*	*Lunar Month-names*
Spring	(-30° to 30°)	Madhu & Mādhava	Caitra-Vaiśākha
Summer	(30° to 90°)	Śukra & Śuci	Jyaiṣṭha-Āṣāḍha
Rains	(90° to 150°)	Nabhas & Nabhasya	Śrāvaṇa-Bhādra
Autumn	(150° to 210°)	Iṣa & Ūrja	Aśvina-Kārtika
Late Autumn	(210° to 270°)	Sahas & Sahasya	Agrahāyaṇa-Pauṣa
Winter	(270° to 330°)	Tapas & Tapasya	Māgha-Phālguna

The early Greek astronomers have left records about their successive attempts to measure the length of the year correctly. It is now known that they all used the gnomon. Measures of the length of the different seasons and of the year by some of their eminent astronomers are given in the table (No. 30) below.

The Chaldeans must have also measured the length of the year by the same method, either somewhat earlier or simultaneously with the early Greeks, but their names, excepting those of a few have not survived. But if in reality, the nineteen-year cycle was of as early as 747 B.C., they must have arrived at a correct length of the year much earlier than any other nation.

The Length of the Seasons : The lengths of seasons were found exactly in the same way as in the case of the year, e.g., in the case of Spring, by counting the number of days from the day next to the vernal equinox day to the summer solstice day. The number would be variable from year to year, but a correct value was found by taking the observations for a number of years and taking the mean. The lengths obtained by early astronomers are :

Table 30.

	Spring days	Summer days	Autumn days	Winter days	Total days
Chaldean ...	94.50	92.73	88.59	89.44	365.26
Euctemon (432 B.C.)	93	90	90	92	365
Calippos (370 B.C.)	94	92	89	90	365
Correct values for 1384 B.C. ...	94.09	91.29	88.58	91.29	365.25

The ancients early discovered that the seasons were of unequal length, but they were ignorant of the physical reasons. These exact definitions of seasons, both in India and in the West, were arrived at very early, and are very important for accurate calendar-making ; but the true meaning of these definitions were forgotten in the succeeding periods in India.

In European astronomy, which is derived from Graeco-Chaldean astronomy, we have :

Spring	0°— 90°	from V.E. to S.S.
Summer	90°—180°	" S.S. to A.E.
Autumn	180°—270°	" A.E. to W.S.
Winter	270°—360°	" W.S. to V.E.

According to this scheme, the Rainy season consisting of months of *Nabhas* and *Nabhasya* formally set in when the sun crossed the summer solstice (June 22), as is evident from the lines in Kālidāsa's *Meghadūta* or Cloud-Messenger.

Pratyāsanne *Nabhasi* dayitājīvitā lambanārthī
Jīmūtena svakuśalamayīm hārayiṣyan pravṛttim.

Translation : When the month of *Nabhas* was imminent, (just marking the onset of monsoon), etc."

Or in the *Rāmāyaṇa, Ayodhyākāṇḍa*
Udaggatvā-abhyupābṛtte paretācaritām diśam
Ābṛnvānā diśaḥ sarvāḥ snigdhā dadṛśire ghanāḥ.

Translation : When the sun just reversed its motion after going (continuously) to the north, and began to proceed in the direction inhabited by departed souls (dakṣiṇāyana), the whole sky was overcast with clouds (i.e., the monsoon set in) ;..........

Winter solstice set in with the month of *Tapas*, which means penance. The winter solstice as mentioned above was the time from which the yearly sacrifices started.

The month names in the last column of table (No. 29) are 'lunar', but they were linked to the solar months. They are now in universal use all over India to denote solar as well as lunar months ; but the two varieties are distinguished by the adjectives 'Solar' or 'Lunar'.

Both the European and Indian definitions of seasons are scientific as they are based on the cardinal days. The difference in nomenclature is trivial.

The Length of the Year : The length of the year, as mentioned earlier, must have been found by counting the number of days from one equinox to another, or one solstice to another.

In actual practice, the number of days of the year, counted in this way would vary between 365 and 366. In the early stages, the length of the year was whole-numbered, but Indians of Vedāṅga Jyotiṣa period had a year of 366 days. Later when they came to a rigorous definition of the year, they realized that the number of days was not whole, but involved fractions. Probably the attempt at determining the exact length of the year involving fractional numbers was obtained by adding up the lengths for a number of years, and taking the mean.

APPENDIX 5-B

The Zero-point of the Hindu Zodiac

The Zero-point of the Hindu Zodiac : By this is meant the Vernal Equinoctial Point (first point of Aries) at the time when the Hindu savants switched on from the old *Vedāṅga-Jyotiṣa* calendar to the Siddhāntic calendar (let us ca'l this the epoch of the Siddhānta-Jyotiṣa or S. J.). There is a wide spread belief that a definite location can be found for this point from the data given in the Sūrya-Siddhānta and other standard treatises. This impression is however wrong.

Its location has to be inferred from the co-ordinates given for known stars in Chap. VIII of the *Sūrya Siddhānta.* From these data Dīkṣit thought that he had proved that it was very close to *Revatī* (ζ *Piscium*); but another school thinks that the autumnal equinoctial point (first point of Libra) at this epoch was very close to the star *Citrā* (Spica, α *Virginis*), and therefore the first point of Aries at the epoch of S.J was 180° behind this point. The celestial longitude in 1950 of ζ *Piscium* was 19° 10′ 39″ and of α *Virginis* was 203° 8′ 36″. The longitudes of the first point of Aries, according to the two schools therefore differ by 23° 9′(−)19° 11′=3° 58′ and they cannot be identical. *Revatī* or ζ *Piscium* was closest to ♈₀ (the V.E. point) about 575 A.D., and *Citrā* or α *Virginis* was closest to ♎ (the A.E. point) about 285 A.D., a clear difference of 290 years.

Thus even those who uphold the *nirayaṇa* school are not agreed amongst themselves regarding the exact location of the vernal point in the age of the *Sūrya-Siddhānta* and though they talk of the Hindu zero-point, they do not know where it is. Still such is the intoxication for partisanship that for 50 years, a wordy warfare regarding the adoption of either of these two points as the zero-point of the Hindu zodiac has gone on between the two rival factions known respectively as the *Revatī-Pakṣa* and *Citrā-Pakṣa,* but as we shall show the different parties are simply beating about the bush for nothing.

Chapter VIII of the S.S gives a table of the celestial co-ordinates (*Dhruvaka* and *Vikṣepa*) of the junction-stars (identifying stars) of 27 asterisms forming the Hindu lunar zodiac. It is agreed by all that these co-ordinates must have been given taking the position of the V.E. point at the observer's time as the fiducial point. It is possible to locate it, as Burgess had shown in his edition of the S.S., if with the aid of the data given, λ, i.e., celestial longitude of the junction-stars in the epoch of S.J. is calculated, and compare it with the λ of the same stars for 1950. Let the two values of λ be denoted by λ_1 and λ_2, λ_1 being the value at the epoch of S. J., λ_2 for the year 1950. Then $\lambda_2-\lambda_1$ should have a constant value, which is the celestial longitude of the V.E. point at the epoch of the S.J. on the assumption that they refer to observations at a definite point of time. The following is a short exposition of Burgess's calculations.

The S.S. gives the position of the junction-stars in terms of *Dhruvaka* and *Vikṣepa,* two co-ordinates peculiar to *Sūrya-Siddhānta.* Their meaning and relation to the usually adopted co-ordinates is illustrated by means of fig. 27 and for convenience of the reader, the standard designations, symbolisms used for the different systems of celestial co-ordinates along with their Hindu equivalents are shown in the table below :

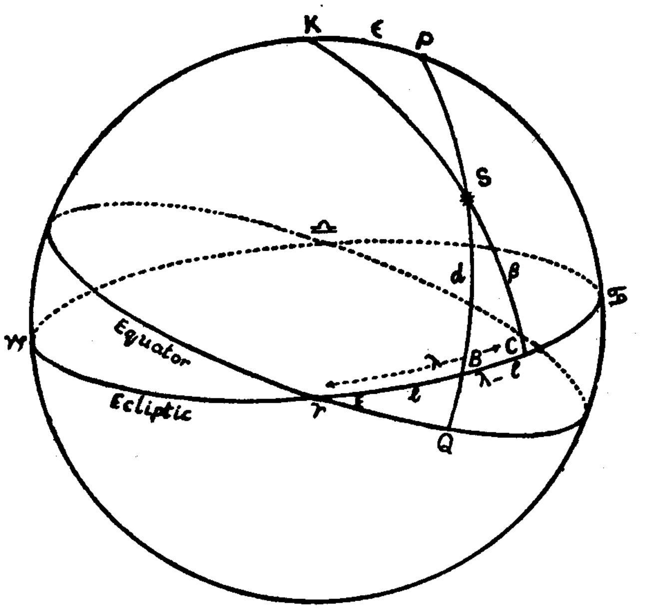

Fig. 27

Table 31—Siddhāntic designation of celestial co-ordinates.

Co-ordinate	*Hindu Designation*	*Symbol*	*Figure*	*Remarks*
Celestial longitude	Bhoga	λ	♈C	As in Sūrya Siddhānta
Celestial latitude	Śara	β	CS	Used by Bhāskara
Right Ascension	Viṣuvāṁśa	α	♈Q	Modern
Declination	Krānti	δ	QS	As in Sūrya Siddhānta
Polar longitude	Dhruvaka	l	♈B	"
Polar latitude	Vikṣepa	d	BS	"

With the aid of spherical trigonometry, the following relations may be deduced :—

$$\sin\beta = \sin d \sin B \quad \ldots\ldots(1)$$
$$\left.\begin{array}{l}\sin(\lambda-l)=\tan\beta\ \cot B\\ \text{or}\quad \tan(\lambda-l)=\tan d\ \cos B\end{array}\right\}\quad\ldots\ldots(2)$$
$$\text{where,}\quad \cot B=\cos l\ \tan\epsilon \quad\ldots\ldots(3)$$

The objective is to deduce the values of λ and β of a star whose l, d are to be found from Chap. VIII of S.S. As the formulae show, the key angle is B, which is determined with the aid of relation (3). Then (1) gives us β and (2) gives us $\lambda-l$. So λ and β for the star are found.

Proceeding in this way, Burgess calculated the values of λ and β of the junction-stars given in the S.S. We have checked these calculations. These are reproduced in table No. 32 on pp. 264-65 in which :

Column	1	gives us the serial no. of the nakṣatra.
"	2	" " their names.
"	3	" " the name of the junction star as accepted (see however later remarks).
"	4	" " the magnitude of the star.
"	5	" " the celestial longitude of the star in 1950 from data given in a modern Ephemeris.
"	6	" " the celestial latitude of the star.
"	7	" " the dhruvaka or polar longitude as given in S.S.
"	8	" " vikṣepa or polar latitude as given in S.S.
"	9	" " the celestial longitude of junction star from the data given in the S.S. converted with the aid of the formula mentioned above.
"	10	" " celestial latitude similarly converted from data given in S.S.
"	11	" " the difference in celestial longitude of the star for 1950 over that for the time of SS.
"	12	" " the difference between the latitudes.

It is evident that $\beta-\beta'$ ought to be zero for all stars, which is however not the fact as may be seen from the table. In the time of the S.S., the observations cannot be expected to have been very precise. But yet we cannot probably hold that an identification is correct when the difference is too large. We are therefore rejecting all identifications where $\beta-\beta'$ exceeds 2°. Probably these stars have not been correctly identified from the description given for them, or the co-ordinates given in the *Sūrya-Siddhānta* were erroneously determined or wrongly handed down to us. In the case of other stars, we find that $\lambda_2-\lambda_1$ is 16° 47′ (or 10° 52′), 16° 58′ and 26° 18′ for three stars. We are also rejecting these three identifications. This leaves us with the identification of 16 stars as somewhat certain. The values of $\lambda_2-\lambda_1$ are in three groups as follows :

	No	$\lambda_2-\lambda_1$	Average
Group 1	2	22° 53′	22° 33′
	8	22 1	
	9	22 57	
	14	**22 21**	
Group 2	1	21 16	20° 48′
	3	20 10	
	4	20 57	
	10	**20 8**	
	12	20 47	
	21	21 18	
	24	21 2	
Group 3	7	19 40	19° 9′
	18	18 58	
	20	19 14	
	22	18 34	
	27	**19 21**	

(*N.B.* In giving the *Dhruvaka* and *Vikṣepa*, the S.S. uses a unit called *Liptikā*, which means a minute of arc. This is traced to Greek "Lepton". Prof. R. V. Vaidya thinks that some of the figures for asterisms, as they are given by cryptic Sanskrit words, have not been properly interpreted).

We are not aware how the Hindu savants determined the *dhruvakas* and *vikṣepas*. It appears that they had a kind of armillary sphere with an ecliptic circle which they used to set to the ecliptic with the aid of standard stars like Puṣya (δ *Cancri*), Maghā (α *Leonis*) Citrā (α *Virginis*), Viśākhā (α *Libræ*) and Śatabhiṣaj (λ *Aquarii*) and Revatī (ζ *Piscium*). They could also calculate the *dhruvaka* and *vikṣepa* of a star during the moment of its transit over the meridian of the place of observation. They calculated the *daśama lagna* (known as the tenth house in astrological parlour) for the moment of transit from tables already constructed for the latitude of the observer, and this *daśama lagna* was the required *dhruvaka* of the star. By using two big vertical poles (i.e., gnomons) situated in the north-south line, the zenith distance of the star at transit could be determined from which the declination of the star was deduced, from the relation :

Declination = latitude of place *minus* zenith distance.

Since *Vikṣepa* $(BS)=QS-QB$ i.e., declination of the star *minus* declination of a point B on the ecliptic [which is $\sin^{-1}(\sin l \sin \epsilon)$], the polar longitude (dhruvaka) and the declination give the *vikṣepa* which is thus :

$$\delta-\sin^{-1}(\sin l\ \sin\epsilon)$$

Anyhow the above analysis seems to show that the co-ordinates of stars were determined at different epochs. Firstly when ♈ was respectively 22° 21′ ahead of the present ♈, secondly when it was 20° 8′ ahead, and thirdly when it was 19° 21′ ahead. The epochs come out to be 340 A.D., 500 A.D., and 560 A.D., respectively. The first epoch is nearly 200 years from the time of Ptolemy, and if it is assumed that Hindu astronomers assumed *Citrā* (Spica or α *Virginis*) to occupy the first point

Table 32.

Star-Positions of the Surya-Siddhanta

No.	Name of Nakṣatra	Junction-Star	Magnitude	Celestial Longitude in 1950 λ_2	Celestial Latitude in 1950 β	Dhruvaka as in S.S. l	Vikṣepa as in S.S. d	Celestial Longitude calculated from (l,d) λ_1	Celestial Latitude calculated from (l,d) β'	$\lambda_2 - \lambda_1$	$\beta - \beta'$	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
1	Aśvinī	β Arietis	2.72	33° 16′	+ 8° 29′	8° 0′	+ 10° 0′	12° 0′	+ 9° 10′	+ 21° 16′	− 0° 41′	
2	Bharaṇī	41 Arietis	3.68	47 30	+ 10 27	20 0	+ 12 0	24 37	+ 11 5	22 53	− 0 38	
	"	35 Arietis	4.58	46 14	+ 11 19	20 0	+ 12 0	24 37	+ 11 5	21 37	+ 0 14	
3	Kṛttikā	η Tauri	2.96	59 18	+ 4 3	37 30	+ 5 0	39 8	+ 4 43	20 10	− 0 40	
4	Rohiṇī	α Tauri	1.06	69 5	− 5 28	49 30	− 5 0	48 8	− 4 49	20 57	− 0 39	
5	Mṛgaśiras	λ Orionis	3.70	83 1	− 13 23	63 0	− 10 0	61 2	− 9 49	21 59	− 3 34	Latitudes differ much
6	Ārdrā	α Orionis	0.6 v	88 3	− 16 2	67 20	− 9 0	65 49	− 8 52	22 14	− 7 10	
7	Punarvasu	β Geminorum	1.21	112 32	+ 6 41	93 0	+ 6 0	92 52	+ 6 0	19 40	+ 0 41	
8	Puṣya	δ Cancri	4.17	128 1	+ 0 5	106 0	0 0	106 0	0 0	22 1	+ 0 5	
9	Āśleṣā	α Cancri	4.27	132 57	− 5 5	109 0	− 7 0	110 0	− 6 56	22 57	+ 1 51	
	"	ϵ Hydræ	3.48	131 39	− 11 6	109 0	− 7 0	110 0	− 6 56	21 39	− 4 10	Latitudes differ much
10	Maghā	α Leonis	1.34	149 8	+ 0 28	129 0	0 0	129 0	0 0	20 8	+ 0 28	
11	Pūrva Phalgunī	δ Leonis	2.58	160 37	+ 14 20	144 0	+ 12 0	139 56	+ 11 18	20 41	+ 3 2	Latitudes differ much
12	Uttara Phalgunī	β Leonis	2.23	170 55	+ 12 16	155 0	+ 13 0	150 8	+ 12 4	+ 20 47	+ 0 12	

Star-Positions of the Surya-Siddhanta—*contd.*

No.	Name of Nakṣatra	Junction-Star	Magni-tude	Celestial Longitude in 1950 λ_2	Celestial Latitude in 1950 β	Dhruvaka as in S.S. l	Vikṣepa as in S.S. d	Celestial Longitude calculated from (l,d) λ_1	Celestial Latitude calculated form (l,d) β'	$\lambda_2-\lambda_1$	$\beta-\beta'$	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
13	Hasta	δ Corvi	3.11	192° 45′	− 12° 11′	170° 0′	− 11° 0′	174° 24′	− 10° 6′	+18° 21′	− 2° 5′	Latitudes differ much
14	Citrā	α Virginis	1.21	203 9	− 2 3	180 0	− 2 0	180 48	− 1 50	22 21	− 0 13	
15	Svātī	α Bootis	0.24	203 32	+ 30 46	199 0	+ 37 0	182 56	+ 33 47	20 36	− 3 1	Latitudes differ much
16	Viśākhā	α Libræ	2.90	224 23	+ 0 20	213 0	− 1 30	213 31	− 1 24	10 52	+ 1 44	Identification doubtful
	"	ι Libræ	4.66	230 18	− 1 51	213 0	− 1 30	213 31	− 1 24	16 47	− 0 27	"
17	Anurādhā	δ Scorpii	2.54	241 52	− 1 59	224 0	− 3 0	224 54	− 2 52	16 58	+ 0 53	"
18	Jyeṣṭhā	α Scorpii	1.22	249 4	− 4 34	229 0	− 4 0	230 6	− 3 51	18 58	− 0 43	
19	Mūla	λ Scorpii	1.71	263 53	− 13 47	241 0	− 9 0	242 53	− 8 48	21 0	− 4 59	Latitudes differ much
20	Pūrvāṣāḍhā	δ Sagittarii	2.84	273 53	− 6 28	254 0	− 5 30	254 39	− 5 28	19 14	− 1 0	
21	Uttarāṣāḍhā	σ Sagittarii	2.14	281 41	− 3 27	260 0	− 5 0	260 23	− 4 59	21 18	+ 1 32	
22	Śravaṇa	α Aquilæ	0.89	301 4	+ 29 18	280 0	+ 30 0	282 30	+ 29 54	18 34	− 0 36	
23	Dhaniṣṭhā	β Delphini	3.72	315 39	+ 31 55	290 0	+ 36 0	296 8	+ 35 33	19 31	− 3 38	Latitudes differ much
24	Śatabhiṣaj	λ Aquarii	3.84	340 53	− 0 23	320 0	− 0 30	319 51	− 0 28	21 2	+ 0 5	
25	Pūrva Bhādrapadā	α Pegasi	2.57	352 47	+ 19 24	326 0	+ 24 0	334 38	+ 22 29	18 9	− 3 5	Latitudes differ much
26	Uttara Bhādrapadā	γ Pegasi	2.87	8 28	+ 12 36	337 0	+ 26 0	347 19	+ 24 0	21 9	− 11 24	"
	"	α Andromedæ	2.15	13 37	+ 25 41	337 0	+ 26 0	347 19	+ 24 0	26 18	+ 1 41	Identification doubtful
27	Revatī	ζ Piscium	5.57	19 11	− 0 13	359 50	0 0	359 50	0 0	+19 21	− 0 13	

of Libra, the epoch comes out to be 285 A.D., and the corresponding Vernal point 2° to the west of Ptolemy's.

This analysis shows that the Indian astronomers had arrived at the idea that the equinoctial point should be properly located with reference to some standard stars and there were probably three attempts, one about 285 A.D., the next about 500 A.D., and the last one about 570 A.D. They had not accepted the first point given by Ptolemy or any western astronomer.

The compiler (or compilers) of the S.S. was clearly unconscious of the precession of equinoxes, and while in his report, he made a selection of these data, he did not perceive that they were inconsistent with the idea of a fixed V.E. point.

But he did not err on the fundamental point. He had clearly laid down that Meṣādi, i.e., the first point of Aries from which the year was to be started was to be identified with the vernal equinoctial point.

It is to be noticed that though the maker of the S.S. has absorbed many of the ideas from Greek astronomy including the use of technical terms like *horā*, *liptikā*, *kendra*, etc., he did not either blindly copy the Graeco-Chaldean data. From whichever source he might have got the ideas, he absorbed it correctly and made an attempt to fix up the actual V.E. point, as required in Chaldean astronomy, otherwise his zero-point would have been coincident with Ptolemy's. We have shown that whatever the Hindu zero-point of the zodiac might be, it is not coincident with that of Ptolemy.

APPENDIX 5-C

Gnomon Measurements in the Aitareya Brahmana

References to the observation of the solstice are found in very early literature as the following passage from the *Aitareya Brāhmaṇa* shows :

'They perform the *Ekaviṁśa* day, the *Viṣuvān*, in the middle of the year : by this *Ekaviṁśa* day the gods raised up the sun towards the world of heaven (the highest region of the heavens, *viz.*, the zenith). For this reason this sun (as raised up) is (called) Ekaviṁśa, of this Ekaviṁśa sun (or the day), the ten days before are ordained for the hymns to be chanted during the day ; the ten days after are also ordained in the same way ; in the middle lies the Ekaviṁśa established on both sides in the *Virāj* (a period of ten days). It is certainly established in the *Virāj*. Therefore he going between (the two periods of 10 days) over these worlds, does not waver.'

'The gods were afraid of this *Āditya* (the sun) falling from this world of heaven (the highest place in the heavens) ; him with three worlds (diurnal circles) of heaven (in the heavens) from below they propped up ; the *Stomas* are the three worlds of heaven (diurnal circles in the heavens). They were also afraid of his falling away upward ; him with three worlds of heaven (diurnal circles in the heavens) from above they propped up ; the *Stomas* are the three worlds of heaven (diurnal circles in the heavens) indeed. Thus three below are the *Saptadaśas* (seventeen), three above ; in the middle is the *Ekaviṁśa* on both sides supported by *Svarasamans*. Therefore he going between these *Svarasamans* over these worlds does not waver'.

This obscure passage has been interpreted as follows by Prof. P.C. Sengupta in his *Ancient Indian Chronology*.

The Vedic year-long sacrifices were begun in the earliest times on the day following the winter solstice. Hence the Viṣuvān which means the middle day of the year was the summer solstice day. The above passage shows that the sun was observed by the Vedic Hindus to remain stationary i. e., without any change in the merdian zenith distance for 21 days near the summer solstice. The argument was this that if the sun remained stationary for 21 days, he must have had 10 days of northerly motion, 10 days of southerly motion, and the middle (eleventh) day was certainly the day of the summer solstice ; hence the sun going over these worlds, in the interval between the two periods of 10 days on either side, did not 'waver'. Thus from a rough observation, the Vedic Hindus could find the real day of the summer or winter solstice.

The next passage from the *Aitareya Brāhmaṇa* (not quoted) divides the Virāj of 10 days thus : $10=6+1+3$; the first 6 days were set apart for a Ṣaḍaha (six day-) period, followed by an *atirātra* or extra day and then came the three days of the three *Stomas* or *Svarasamans*. The atirātra days before and after the solstice day were respectively styled *Abhijit* and *Viśvajit* days. It may thus be inferred that the Vedic Hindus by more accurate observation found later on that the sun remained stationary at the summer solstice for 7 and not 21 days.

Question may now be asked how could they observe that the sun remained stationary for 21 days and not for 23, 27, 29, or 31 days. This depended on the degree of accuracy of observation possible for the Vedic Hindus by their methods of measurement. They probably observed the noon-shadow of a vertical pole.

APPENDIX 5-D

Precession of the Equinoxes amongst Indian Astronomers

On p. 226, we have given references to pre-Siddhāntic notices of the location of the vernal point in the sky. We saw that ancient Indian savants noticed its gradual shift (due to precession), but were only puzzled by the phenomenon. Let us see what was the experience of the Siddhāntic astronomers in this respect.

Dīkṣit, in his *Bhāratīya Jyotiśāstra*, has summarized the adventures of the idea of Precession of the Equinoxes amongst Indian astronomers of the Siddhānta period. The following account draws heavily on his Chap. 3 (p. 326) on *Ayana-Calana*, which literally means 'the movement of the solstitial points'. *

The 'Solstitial points' were known amongst Indians as '*Ayanas*' and Siddhāntic astronomers regarded them as 'imaginary planets' as they used to do in the case of the nodes of the lunar orbit. Though the nomenclature is cumbrous, the chapter actually deals with the precession of the equinoxes, as this point is 90° behind the summer solstitial point.

Before the Siddhāntic period, the lunar calendar was of primary importance, hence the exact fixation of the vernal equinoctial point (Υ_0) was not very important. It became important from the time the Indian astronomers of the Siddhānta period first realized that Υ_0 should form the zero-point of the zodiac ; and made attempts at different epochs (285 A.D.-600 A.D.) to give co-ordinates of stars (*Dhruvaka* and *Vikṣepa*) with respect to this as the initial point. Chapter VIII of modern *Sūrya-Siddhānta* gives a resume' of these co-ordinates for the junction-stars of the lunar asterisms. Our analysis of these data as given in Appendix 5-B shows that these co-ordinates must have been obtained by actual observations at different epochs, and as the compiler of the *Sūrya-Siddhānta* was ignorant of the phenomenon of precession of the equinoxes, he made an uncritical selection of these data compiled at different times and included them in his Chap. VIII.

From these data, it is impossible to determine the exact location of Υ_0 at the time when the *Sūrya-Siddhānta* was complied. So the wordy warfare between the upholders of the *Citrā-pakṣa* and the *Revatī-pakṣa* becomes meaningless as pointed out on p. 262.

The surmise that the early Siddhāntic astronomers were ignorant of the movement of the equinoxes is supported by the fact that neither of the early eminent astronomers Āryabhaṭa I (476—523 A.D.) nor Lalla (748 A.D.) whose dates are known, mention anything about precession of the equinoxes in their writings which have come down to us. If they derived their knowledge of astronomy from the West, they followed the current western practice of ignoring the precession. The astronomer Varāhamihira, who wrote about 550 A.D., and has left us a compendium of the five Siddhāntas, makes no mention of the phenomenon. This proves that the original *Sūrya Siddhānta* as known to Varāhamihira contained no reference to the movement of the equinoctial points. In his *Bṛhat Saṁhitā* as mentioned on p. 226, Varāhamihira, however, noted that the solstices were receding back, but he could not say anything about the actual nature of the precession or assign any rate to it.

But it is obvious that once the Indian astronomers recognized Υ_0 as the starting point of the zodiac, and started giving co-ordinates of stars in terms of Υ_0 as the starting point, they could not avoid noticing the movement of the equinoxes, just as it happened with Hipparchos in Greece. According to Brahmagupta (628 A.D.), the first astronomer who made a pointed reference to it was one Viṣṇu Candra, author of the *Vāsiṣṭha Siddhānta* whose date is given as *ca.* 578 A.D. He was supported by one Śrīṣeṇa of whom only the name survives. For holding these views these astronomers were roundly abused by Brahmagupta whose views on these points appear to have been confused. But undeterred by the great prestige of Brahmagupta, later astronomers continued to make references to the movement of the equinoctial points.

We cite some examples.

Muñjāla Bhaṭa, a south Indian astronomer, wrote a treatise called *Laghumānasa* in 854 Śaka or 932 A.D. A later commentator, Munīśvara, ascribes the following verses to him.

Uttarato yāmyadiśaṁ yāmyāntāttadanu
saumyadigbhāgaṁ
parisaratāṁ gaganasadāṁ calanaṁ kiñcid bhave-
dapame. 1.
Viṣuvadapakramamaṇḍala-saṁpāte prāci meṣādiḥ
paścāttulādiraṇayo-rapakramāsaṁbhavaḥ. proktaḥ. 2.
Rāśitrayāntaresmāt karkādiranukramānmṛgādiśca
tatra ca paramā krāntirjinabhāgamitātha tatraiva. 3.
Nirdiṣṭo-yanasandhiścalanaṁ tatraiva saṁbhavati
tadbhagaṇāḥ kalpe syu-go-rasa-rasago-'ṅka-candra
mitāḥ. 4.

* The word '*Ayana Calana*' strictly means the movement of the "Solstitial Points". Bhāskarācārya uses the word '*Sampāt-Calana*' for movement of the equinoctial points (♈ and ♎). Mathematically the two denominations are equivalent, but it has become the practice in Hindu astronomy to render the term 'Precession of the Equinoxes' by the words '*Ayana Calana*'. We shall follow this practice throughout.

Translation

1. While the celestial bodies move in the sky from north to south and again from south to north, a very small variation takes place in their declination.

2. The (ascending) node in which the celestial equator and the ecliptic intersect is the first point of Aries (*Meṣādi*), and it gives the 'East'. The second node is the first point of Libra (*Tulādi*), and these two points never change their declination value (which is zero).

3. The first point of Cancer (*Karkādi*) is at a distance of three signs (i.e. 90°) from it, and at a distance of three signs in the reverse order is the position of the first point of Capricorn (*Makarādi*). These give the positions of maximum declination which is 24 degrees.

4. The solstitial points (which mark the *ayanas*) show a movement, and the number of their revolutions in a *Kalpa* is counted as 199669.

The last passage recognizes precessional motion, says that it is continuous, and gives the rate as 59".9 per year. Muñjāla Bhaṭa makes no mention of trepidation. He noticed that the *Ayanas* had precessed by about 6° from the position given in the *Sūrya-Siddhānta*.

Pṛthūdaka Svāmī (born 928 A.D.), an astronomer who observed at Peihowa, near Kurukṣetra, commenting on a passage of Brahmagupta says :

"The revolution of *Ayana* in one *Kalpa* is 189411.
This is called the *Ayana Yuga*".

This passage recognizes the continuous nature of precessional motion, and gives the rate of precessional motion as 56".82 seconds per year.

So far we have no mention of the '*Theory of Trepidation.*' This is first mentioned in the *Ārya Siddhānta*, ascribed to Āryabhaṭa II, whose date is 1028 A.D. It says :

Ayanagrahadoḥ krāntijyācāpaṁ kendravat dhanarṇaṁ syāt
Ayanalavāstat saṁskṛta kheṭādayana carāpamalagnāni. 12.

Translation :—Find the sine declination (*krāntijyā*) of the *ayanagraha* (in a way similar to that of the sun's declination) ; from it deduce the amount of declination, plus (north) or minus (south), which is the amount of *ayanāṁśa*.* After applying this *ayanāṁśa*-correction to the planet, the values of *cara* (half the difference between the lengths of day and night), declination of planets, *lagna* (the orient ecliptic point), etc., are to be calculated.

This has been interpreted as follows (Dīkṣit, p.330).

The equinox oscillates between ±24°, and the number of revolutions of the *Ayana*-planet in a *Kalpa* is 578159, which gives the period of revolution as 7472 years and the annual rate of motion as 173".4. During a quarter period *viz.*, 1868 years, the *ayanāṁśa* increases from 0° to 24°, at first, rapidly, then gradually more slowly like the increase of declination of the sun. Thereafter it diminishes in like manner and after the lapse of 3736 years, i.e. the half period, it again becomes zero and goes on the other side. The annual rate of motion, which on the average amounts to 46".3 seconds, varies from ± 70".5 to 0"

We now come to a very controversial passage in the modern *Sūrya Siddhānta*, Chap. III, verses 9 to 12. These are :

Triṁśat kṛtyo yuge bhānāṁ cakraṁ prāk parilamvate
tadgunād bhūdinairbhaktāt dyugaṇāt yadabāpyate. 9
Taddostrighnā daśāptāṁśā vijñeyā ayanābhidhāḥ
tatsaṁskṛtādgrahāt krānticchāyā caradalādikaṁ
sphutaṁ dṛktulyatāṁ gacchedayane viṣuvadvaye. 10
Prāk cakraṁ calitaṁ hīne chāyārkāt karaṇāgate
antarāṁśai rathāvṛtya paścācchesaistathādhike. 11
Evaṁ viṣuvaticchāyā svadeśe yā dinārdhajā
dakṣinottara rekhāyāṁ sā tatra viṣuvat prabhā. 12

Translation

9. In an Age (*yuga*), the circle of the asterisms (*bha*) falls back eastward thirty score of revolutions. Of the result obtained after multiplying the sum of days (*dyugaṇa*) by this number, and dividing by the number of natural days in an Age,

10. Take the part which determines the sine, multiply it by three, and divide by ten ; thus are found the degrees called those of the precession (*ayana*). From the longitude of a planet as corrected by these are to be calculated the declination, shadow, ascensional difference (*caradala*) etc.

11. The circle, as thus corrected, accords with its observed place at the solstice (*ayana*) and at either equinox ; it has moved eastward, when the longitude of the sun, as obtained by calculation, is less than that derived from the shadow.

12. By the number of degrees of the difference ; then, turning back, it has moved westward by the amount of difference, when calculated longitude is greater.

These verses occur in the chapter on astronomical measurements by the gnomon, and are misfits there ; according to all authorities, these verses did not exist in the original *Sūrya-Siddhānta*, but have been extrapolated there, and have no reference to the context of the chapter. The extrapolation must, however, have taken place before the time of Bhāskarācārya II (1114-1178 A.D.), because he comments on this passage.

The passage supports the theory of trepidation and says that the amplitude of precessional oscillation is 27° and the period of one complete oscillation is stated to be 7200 years. The rate of precession is given as 54" per year, which is uniform and the same throughout the oscillation. These stanzas are quoted by Indian astrologers who are advocates of the *nirayana* system, in support of their arguments for sticking to the sidereal year. They say that the present *ayanāṁśa* is about 22°, and ♈ will go on processing for another 350 years till *ayanāṁśa* becomes 27° and will then turn back on its return journey.

* This is a technical term used by Indian astronomers to denote the distance of the vernal point from the fixed Hindu Zodiac.

This is sufficient argument to them to turn down all proposals for *Sāyana* reckoning taking the length of the year to be tropical.

We now take the opinion of the last great Indian astronomer Bhāskarācārya II (1150 A.D.).

He uses the term '*Sampāt-Calana*' *i.e.*, movement of the intersection of the ecliptic and the equator, instead of the classical term *Ayana*. He says :

Siddhānta Śiromani, Goladhyāya, Golabandhādhikāra

Tasya [viṣuvatkrāntivalayapātasya] apī calanamasti.
Ye'ayanacalana bhāgāḥ prasiddhāsta eva vilomagasya krāntipātasya bhāgāḥ

Translation :—It (the equinox) has also movement. What is commonly known as the amount of precession (*ayanāṁśa*) is the same as the longitude of the equinoctial point measured backwards.

This evidently shows that he regarded the change as due to the retrograde motion of the *node* (i.e. equinoctial point) like modern European astronomers.

He criticises Brahmagupta for his views on *Ayana Calana* and says : "One can observe that at the time of Brahmagupta, the *ayanāṁśa* value was very small and hence it is likely that it could not have come to his notice ; yet how is it that he did not take the rate of revolution of equinoxes as given by the *Sūrya-Siddhānta*, just as he has taken figures for rates in some other cases on the basis (or authority) of already proved and accepted rates".

He further says :

Ayanacalanaṁ yaduktaṁ Muñjālādyaiḥ sa evāyaṁ (krāntipātaḥ)
tatpakṣe tadbhaganāḥ kalpe go'ṅgartu-nanda-go-candrāḥ (199669).

Atha ca ye vā te vā bhaganāḥ bhavantu yadā ye'ṁśā nipuṇairupa labhyante tadā sa eva krāntipātaḥ.

Translation :—"What Muñjāla and others have mentioned as *Ayana Calana*', is nothing but the motion of this equinoctial point. According to their view the number of revolution in a *Kalpa* is 199669 (yielding annul rate of 59".9). Let whatsoever be the number of revolutions, whatever amount is obtained by expert observers is the angle of precession for that time."

From this it is clear that he recommends one to accept the *ayanāṁśa* which one would actually get by observation of sun's place at any particular time. Dīkṣit says :

I have not come across single statement in which Bhāskarācārya has clearly said that equinoctial point makes a complete "circular revolution", nor does he say that "it does not make it".

He has taken 1 minute per year as the ayana-motion and has supposed 11° as the *ayanāṁśa* in Śaka 1105. He thus means to take Śaka 445 as the zero-precession year.

We thus perceive that Indian astronomers up to the time of Bhāskarācārya were as much divided in their ideas about precesssion of the equinoxes as the contemporary Arab astronomers of the West (Hispano-Muslim), and the East. It is only after 1024 A.D. that they adopted a theory of trepidation. The earlier-astronomers like Muñjāla and Pṛthūdaka merely *noticed precession* and gave their own rates for it. Bhāskarācārya is non-committal about trepidation. The Indian astronomers do not appear to have been influenced by the views of the western astronomers, the earlier Greeks or later Arabs.

It will be *sheer stupidity* to hold to the theory of trepidation of equinoxes 270 years after it has been definitely proved to be wrong. The law of universal gravitation will not be changed by God Almighty to oblige astrologers.

APPENDIX 5-E

The Jovian Years

(*Barhaspatya Varṣa*)

The sidereal period of Jupiter, according to the *Sūrya Siddhānta* is 4332.32 days which is nearly 11.86 sidereal years. Therefore Jupiter roughly stays for one year in one zodiacal sign, if we calculate by mean motion.

This was taken advantage of to devise a cycle of 12 *Jovian* years. If we divide the *Sūrya-Siddhānta* period by 12, we get 361.026721 days which is taken as the length of a Jovian year. This is 4.232 days less than the *Sūrya Siddhānta* solar year. So if a Jovian year and an ordinary solar year begin on the same day, the Jovian year will begin to fall back, completing a complete retrogression in $85\frac{65}{211}$ solar years, according to the *Sūrya-Siddhānta.* So $85\frac{65}{211}$ solar years $=86\frac{65}{211}$ Jovian years, and one Jovian year is expunged in every $85\frac{65}{211}$ years. The expunged year is called the *Kṣaya* year. In actual practice, the interval between two expunctions is sometimes 85 and sometimes 86 years.

There was indeed at one time a period of 12 Jovian years, but at some past epoch, a fivefold multiple, a cycle of 60 Jovian years, each with a special name suffixed by the word 'Saṁvatsara', came into use.

The beginning of the Jovian years is determined by the entry of Jupiter into an Indian sign by mean motion, the 1st, 13th, 25th, 37th and 49th years being marked by the entry of Jupiter into the sign *Kumbha,* and not *Meṣa* which is otherwise the first of the signs of the Siddhāntas. It thus appears that the system of counting Jovian years is a pre-Siddhāntic practice

The sixty-year cycle is at present in daily use in Southern India (south of Narmada) where each year (the solar year or the luni-solar year) is named after that of the corresponding Jovian year. The years are counted there in regular succession and no *saṁvatsara* is expunged. This practice is being followed since about 905-06 A.D. (827 Śaka), as a result of which the number of North-Indian *Saṁvatsara* has been gradually gaining over that of the South from that time. The Śaka year 1876 (1954-55 A.D.) is named 41 Plavaṅga in the North while in the South it is 28 Jaya.

The following are the names of the different years :

(1) Prabhava	(21) Sarvajit	(41) Plavaṅga
(2) Vibhava	(22) Sarvadhārin	(42) Kīlaka
(3) Śukla	(23) Virodhin	(43) Saumya
(4) Pramoda	(24) Vikṛta	(44) Sādhāraṇa
(5) Prajāpati	(25) Khara	(45) Virodhakṛt
(6) Aṅgiras	(26) Nandana	(46) Paridhāvin
(7) Śrīmukha	(27) Vijaya	(47) Pramādin
(8) Bhāva	(28) Jaya	(48) Ānanda
(9) Yuvan	(29) Manmatha	(49) Rākṣasa
(10) Dhātri	(30) Durmukha	(50) Anala (Nala)
(11) Īśvara	(31) Hemalamba	(51) Piṅgala
(12) Bahudhānya	(32) Vilamba	(52) Kālayukta
(13) Pramāthin	(33) Vikārin	(53) Siddhārthin
(14) Vikrama	(34) Śarvarī	(54) Raudra
(15) Vṛṣa	(35) Plava	(55) Durmati
(16) Chitrabhānu	(36) Subhakṛt	(56) Dundubhi
(17) Subhānu	(37) Śobhana	(57) Rudhirodgārin
(18) Tārana	(38) Krodhin	(58) Raktākṣa
(19) Pārthiva	(39) Viśvāvasu	(59) Krodhana
(20) Vyaya	(40) Parābhava	(60) Kṣaya (Akṣaya)

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