The Great Year in Greek, Persian and Hindu Astronomy

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1. Introduction

PLATO defines (Timaios 39 C–D) the *Perfect Year* as a period at the end of which the fixed stars and planets return to the point from which they started their revolutions. ARISTOTLE[1] calls the same period *Greatest Year*, and says that in the winter of this year a flood (kataklysmos) takes place, in the summer a conflagration (ekpyrosis). In later Greek and Latin texts this cosmic period is called the *Great Year*.

In a series of papers[2,3,4,5,6] and in a joint paper with E. S. KENNEDY[7] I have investigated the history of the doctrine of the "Great Year", and the application of this doctrine in Persian and Hindu Astronomy.

My papers on this subject have been vigorously criticized by D. PINGREE[8,9,10]. In his papers, many of my arguments are distorted and many are left out altogether. Moreover, some of my papers are not easily accessible, and recently I have found new connections between Hellenistic and Persian astronomy. For these reasons, it seems desirable to present a new exposition of the whole subject. All my arguments will be explained anew, and PINGREE's criticism will be refuted.

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[1] CENSORINUS: De die natali, Chapter 18.

[2] B. L. VAN DER WAERDEN: Das Grosse Jahr und die Ewige Wiederkehr. Hermes **80** (1952) p. 129–155.

[3] B. L. VAN DER WAERDEN: Das Grosse Jahr des Orpheus. Hermes **81** (1953) p. 481–484.

[4] B. L. VAN DER WAERDEN: Diophantische Gleichungen und Planetenperioden in der indischen Astronomie. Vierteljahrsschrift naturf. Ges. Zürich **100** (1955) p. 153–170.

[5] B. L. VAN DER WAERDEN: Ausgleichspunkt, Methode der Perser und indische Planetenrechnung. Archive Hist. Exact Sci. **1** (1961) p. 107–121.

[6] B. L. VAN DER WAERDEN: Das heliozentrische System in der griechischen, persischen und indischen Astronomie. Neujahrsblatt naturf. Ges. Zürich 55 (1970)

[7] E. S. KENNEDY & B. L. VAN DER WAERDEN: The World-Year of the Persians. J. Amer. Oriental Soc. **83** (1963) p. 315–327.

[8] D. PINGREE: Astronomy and Astrology in India and Iran. Isis **54** (1963) p. 229–245.

[9] D. PINGREE: The Persian "Observation" of the Solar Apogee in Ca. A.D. 450. J. of Near Eastern Studies **24** (1965) p. 334–336.

[10] D. PINGREE: Review of [6]. Centaurus **20** (1976) p. 258–260.

In my expository paper[6], I have presented some arguments in favour of the hypothesis that the astronomy of the Persians and of ÂRYABHAṬA was influenced by the heliocentric system of ARISTARCHOS of Samos. In the present paper I shall leave this subject aside. I hope to return to it on another occasion.

2. The "Great Year" and the Doctrine of Eternal Return in Greek Sources

From a fragment of EUDEMOS quoted by SIMPLIKIOS[11] we know that the PYTHAGOREANS believed in the eternal return of all things "according to numbers". If one believes the PYTHAGOREANS, says EUDEMOS, I too shall stand here again in future, holding this little stick in my hand and telling you myths, and you will sit here before me just as you are sitting now.

According to NEMESIOS[12] and other sources, the Stoic philosophers held the same opinion as the PYTHAGOREANS. There will be a conflagration caused by the planets, so they taught, and afterwards the world will be recreated and everything will be as before: there will be a PLATO and a SOCRATES, and an exact repetition of all motions in the sky and on earth.

The same doctrine of annihilation followed by a new creation and an exact repetition of everything in the world can be found in Hindu sources, notably in the Mahâbhârata and the Laws of MANU[13], as we shall see presently.

The idea of a Great Year with Flood and Ekpyrosis seems to be of Babylonian origin. BEROSSOS, a priest of the Babylonian god BÊL, who came to Greece about 300 B.C. and founded a school of astrology on the island Kos, tells us that a conflagration will take place when all planets come together in Cancer, and a deluge when they come together in Capricorn[14]. In another fragment[15], BEROSSOS gives the figure of 120 saroi as the sum of the regnal years of mythical kings before the Flood, 1 sar being 3600 years. Hence, a certain part of the Great Year was, according to the chronology of BEROSSOS,

$$120 \times 3600 = 432000 \text{ years.}$$

Several figures for the duration of the Great Year are given in later Greek texts. Of these figures I shall mention only those that are composed of factors 2, 3 and 5. According to CENSORINUS (De die natali, Ch. 18) the following Greatest Years were proposed:

HERACLITUS and LINUS	10800 years,
ORPHEUS	120000 years,
CASSANDRUS	3600000 years.

[11] SIMPLIKIOS: Commentary to Aristotle's Physics, p. 732 (ed. DIELS).

[12] NEMESIOS: Anthropology **38**, p. 309 (ed. MATTHAEI).

[13] G. BÜHLER: The Law of Manu. Sacred Books of the East 25 (Oxford, Clarendon Press 1886).

[14] SENECA: Quaest. nat. III 29.

[15] P. SCHNABEL: Berossos (Leipzig 1923) p. 261–263.

On the other hand, AETIOS tells us: "According to Herakleitos the Great Year contains 18000 years, but according to Diogenes the Stoic 360 such years as that of Herakleitos". (AETIOS II 32; see [2], p. 134).

I shall leave aside the Great Year of HERACLITUS and LINUS, because its connections with Babylonian, Persian or Indian cosmic periods are not clear. More important for us is the "Great Year of Orpheus".

There are three periods formed from the factor 12 multiplied by powers of 10, *viz*:

a) the "Chaldaean Dodekaeteris" of 12 years, mentioned by CENSORINUS, also called Dodekaeteris of Zeus (*i.e.* of the planet Jupiter) and ascribed to ORPHEUS or to ZOROASTER [16],

b) a Persian period of 12000 years, consisting of 12 millennia, each governed by a zodiacal sign [17],

c) the Great Year of ORPHEUS of 120000 years [3].

Periods a) and c) were both ascribed to ORPHEUS; this probably means that they were mentioned in the "Books of Orpheus". Periods a) and b) are connected with the 12 zodiacal signs.

The Great Year of BEROSSOS was composed of the factors 120 and 3600. Just so, the Great Year of DIOGENES was composed of the factors 360 and 18000, and the Persian period b) of 12 and 1000. The Great Years of ORPHEUS and CASSANDRUS may be obtained from the same factors:

$$120 \times 1000 = 120000$$
$$3600 \times 1000 = 3600000$$

3. The Indian Yuga System

The Laws of MANU and the MAHÂBHÂRATA both contain a passage on Yugas, *i.e.* cosmic periods. The two passages clearly come from a common source which, according to BÜHLER [13], existed already in the second century A.D. BÜHLER has translated the two passages and printed them in parallel columns ([13], p. lxxxiii). The MAHÂBHÂRATA passage begins thus:

> In the commencement exists the Brahman without beginning or end, unborn, luminous, free from decay, immutable, eternal, unfathomable by reasoning, not to be fully known.

Next the author proceeds to an explanation of the divisions of time, starting with nimeshas (twinklings of the eye) and then passing to days, months and years. A year is called "a day and night of the gods". The next larger unit is the "year of the gods", consisting of 360 ordinary years.

Our passage describes the duration of a "night and day of Brahman" and the four successive Yugas or World-Ages as follows:

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[16] J. BIDEZ & F. CUMONT: Les mages hellénisés (Paris 1938, Les belles lettres). I, p. 120–127, and II, p. 138–187. See also the article Dodekaeteris by F. BOLL in Pauly-Wissowa's Realencyclopaedie.

[17] E. S. KENNEDY: Ramifications of the World Year Concept in Islamic Astrology. Ithaca 26 VIII–2 IX 1962 (Hermann, Paris), p. 23–45, especially Chapter IV.

They declare that the Krita age consists of four thousand years of the gods; the twilight preceding it consists of as many hundreds, and the twilight following it of the same number.

This means that the Kritayuaga is a period of

$$400 + 4000 + 400 = 4800$$

years of the gods.

In the (other) three ages, with their twilights preceding and following, the thousands and hundreds are diminished by one (in each).

Thus, the Tretâyuga has

$$300 + 3000 + 300 = 3600$$

years of the gods, the Dvâparayuga

$$200 + 2000 + 200 = 2400$$

and the Kaliyuga

$$100 + 1000 + 100 = 1200$$

years of the gods, *i.e.*

$$1200 \times 360 = 432000 \text{ years.}$$

The reader will remember that in the Great Year of BEROSSOS the sum of the regnal years of the kings before the Flood, was also 432000 years. This period was a well-defined part of the "Great Year" of BEROSSOS, and the Kaliyuga is a well-defined part of the Indian Mahâyuga.

One might argue that this agreement of numerical values might have been accidental. But now look how the numbers 432000 are obtained in both cases! The units in the chronological system of BEROSSOS are

$$\begin{aligned} \text{saros} &= 3600 \text{ years,} \\ \text{neros} &= \ 360 \text{ years,} \\ \text{sossos} &= \ \ 60 \text{ years.} \end{aligned}$$

This system of counting is typically Babylonian: The Sumerians already had special signs for the numbers 60, 360 and 3600. Now the sum 432000 is obtained as

$$120 \text{ saroi} = 432000 \text{ years.}$$

Since the saros contains 10 neroi, one can also write this equation as

$$1200 \text{ neroi} = 432000 \text{ years.}$$

On the other hand, the Hindu "Year of the Gods" is just the Babylonian neros of 360 years, and the duration of the Kaliyuga is calculated as

$$1200 \text{ years of the Gods} = 432000 \text{ years.}$$

This is a strong argument in favour of a Babylonian origin of the Indian calculation.

The description of the four ages in the Indian text is very similar to that of HESIODOS. I shall quote the version of MANU:

In the Krita age Dharma is four-footed and entire, and (so is) Truth; nor does any gain accrue to men by unrighteousness. In the other (three ages), by reason of (unjust) gains, Dharma is deprived successively of one foot, and through (the prevalence of) theft, falsehood and fraud the merit is diminished by one-fourth (in each). (Men are) free from disease, accomplish all their aims, and live four hundred years in the Krita (age), but in the Treta and the succeeding (ages) their life is lessened by one quarter.

Next the sum total of the four ages is calculated as 12000 years of the gods, *i.e.* 4320000 years. This period is called *one age of the gods*. In later astronomical texts the same period is called *Caturyuga* (=fourfold Yuga) or *Mahâyuga* (=Great Yuga).

MANU proceeds:

But know that the sum of one thousand ages of the gods (makes) one day of Brahman, and that his night has the same length.

This "day of Brahman" is called in later texts *kalpa*:

$$1 \text{ kalpa} = 1000 \text{ Mahâyugas} = 4320000000 \text{ years.}$$

The MAHÂBHÂRATA passage adds:

When imperishable Brahman awakes at the end of this night, he modifies himself and creates the element (called) the Great One (and) from that the mind which is discrete.

The idea of a repeated creation of the world by the Supreme God also underlies a Hymn of the Magi summarized by DION CHRYSOSTOMOS[18].

The MANU passage ends thus:

To whatever course of action the Lord at first appointed each (kind of beings), that alone it has spontaneously adopted in each successive creation. Whatever he assigned to each at the (first) creation, noxiousness or harmlessness, gentleness or ferocity, virtue or sin, truth or falsehood, that clung (afterwards) spontaneously to it.

This is just the same doctrine of endless repetition as EUDEMOS ascribes to the PYTHAGOREANS, and NEMESIOS to the Stoics.

All in all, we have found a whole network of interrelations between Babylonian, Greek and Hindu doctrines.

Note on Pingree's Criticism

In his review[10] of my paper[6], PINGREE writes:

Another of the author's flaws is his failure to look at his sources critically: any text that can be interpreted to fit his hypotheses is accepted, and all others ignored. Thus

[18] See BIDEZ-CUMONT[16], I, p. 91 and II, p. 142–143.

Seneca's citation of Berossus is taken to represent a truly Babylonian source (pp. 21–22) though none of our hundreds of thousands of extant cuneiform texts would justify van der Waerden's interpretation of it.

This statement of PINGREE is wrong in several respects:

1) SENECA was not my only source. On page 141–143 of my paper[2]. I have presented several arguments, all pointing towards a Babylonian origin of the doctrine of the Great Year. One of these arguments was used by PINGREE himself on page 238 of his paper[8]. PINGREE writes:

> The last yuga, then, the kaliyuga, is 1/10 mahâyuga, or 432,000 years. This is a Babylonian number: sexagesimally it would be written 2,0,0,0. It is the span of time given to the Babylonian kingdom before the Flood in the histories of Berossos and Abydenos. It seems likely that it should have become a significant number in India at a time when other Babylonian influences were being felt ...

2) In my expository paper[6], written for a "Neujahrsblatt", I had to restrict myself to a few testimonies supporting my hypotheses, but in my more fundamental papers[2,3,4,5] and in the joint papers[7,22] I have always quoted *all* texts available to me. So PINGREE's assertion that I selected texts favourable to my hypotheses with the exclusion of others is not justified. It would be nice if he would think it over and withdraw his unjust accusation.

4. Al-Bîrûnî and Abû Ma'shar

If, as BEROSSOS says, the Deluge took place when all planets came together in Capricorn, then it must be possible to date the Deluge by means of astronomical calculations of conjunctions of planets in the past. According to AL-BÎRÛNÎ, several astrologers tried to date the Deluge by this method. In his "Chronology", BÎRÛNÎ[19] writes:

> Era of the Deluge. – The next following era is the era of the great Deluge, in which everything perished at the time of Noah. Here, too, there is such a difference of opinions, and such a confusion, that you have no chance of deciding as to the correctness of the matter, and you do not even feel inclined to investigate thoroughly its historical truth. The reason is, in the first instance, the difference regarding the period between the Era Adami and the Deluge, which we have mentioned already; and secondly, that difference, which we shall have to mention, regarding the period between the Deluge and the Era Alexandri. For the Jews derive from the Thora, and the following books, for this latter period 1,792 years, whilst the Christians derive from their Thora for the same period 2,938 years ...
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> The astrologers have tried to correct these years, beginning from the first of the conjunction of Saturn and Jupiter, for which the sages among the inhabitants of Babel, and the Chaldaens have constructed astronomical tables, the Deluge having originated in their country. For people say, that Noah built the ark in Kûfa, and that it was there that "the well poured forth its waters" (Sûra xi.42; xxiii.27); that the ark rested upon the mountain of Aljûdî, which is not very far from those regions. Now this conjunction occurred 229 years 108 days before the Deluge. This date they studied carefully, and tried

[19] ALBÎRÛNÎ: Chromology, translated by C. E. SACHAU (London 1879), p. 27–29.

by that to correct the subsequent times. So they found as the interval between the Deluge and the beginning of the reign of the first Nebukadnezar (*Nabonassar*), 2,604 years, and as the interval between Nebukadnezar and Alexander 436 years, a result which comes pretty near to that one, which is derived from the Thora of the Christians.

This was the era which 'Abû-Ma'shar Albalkhî wanted, upon which to base his statements regarding the mean places of the stars in his Canon. Now he supposed that the Deluge had taken place at the conjunction of the stars in the last part of Pisces, and the first part of Aries, and he tried to compute their places for that time. Then he found, that they – all of them – stood in conjunction in the space between the twenty-seventh degree of Pisces, and the end of the first degree of Aries. Further, he supposed that between that time and the epoch of the Era Alexandri, there is an interval of 2,790 intercalated years 7 months and 26 days. This computation comes near to that of the Christians, being 249 years and 3 months less than the estimate of the astronomers. Now, when he thought that he had well established the computation of this sum according to the method, which he has explained, and when he had arrived at the result, that the duration of those periods, which astronomers call "star-cycles", was 360,000 years, the beginning of which was to precede the time of the Deluge by 180,000 years, he drew the inconsiderate conclusion, that the Deluge had occurred once in every 180,000 years, and that it would again occur in future at similar intervals.

This man, who is so proud of his ingenuity, had computed these starcycles only from the motions of the stars, as they had been fixed by the observations of the Persians ...

What does BÎRÛNÎ mean by "the Persians"? I claim that his "Persians" are the authors of the "Tables of the Shâh", which were composed in Sassanid Persia under KHOSRO ANÛSHÎRVÂN about 560 and revised under YAZDIGERD III about 640 (see [20, 21, 22]). This claim is supported by several testimonies:

1) BÎRÛNÎ says in his Chronology ([19], p. 121) that the solar year has

$$365;\ 15, 32, 30$$

days according to "the Persians". If one leaves out of account the 365 days and multiplies the fractional part by 360, one obtains the so-called *excess of revolution* of the fixed stars in a solar year:

$$93;15 \text{ degrees.}$$

This same value is also attributed to "the Persians" by AL-HÂSHIMÎ (see [20], p. 147). On the other hand, the Escorial manuscript of the MUMTAHAN ZÎJ ascribes the value 93; 15 to the "Tables of the Shâh" (see again [20], p. 147). Hence, if we identify the "Persians" of BÎRÛNÎ and HÂSHIMÎ with the authors of the "Tables of the Shâh", the statements of the three authors are in perfect accordance.

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[20] E. S. KENNEDY: A Survey of Islamic Astronomical Tables. Trans. Amer. Philos. Soc. **46**, p. 129–130, No. 30.

[21] E. S. KENNEDY: The Sassanian Astronomical Handbook Zîj-i Shâh. J. Amer. Oriental Soc. **78**, p. 246–262.

[22] J. J. BURCKHARDT & B. L. VAN DER WAERDEN: Das astronomische System der Persischen Tafeln I. Centaurus **13** (1968) p. 1–28.

2) BÎRÛNÎ states in his treatise on Transits[23] that the maximal equations of the sun and the moon according to the "Tables of the Shâh" agree exactly with the Hindu values 2°14′ and 4°56′ "because these values had passed from the Hindus to the Persians". In the first half of this sentence BÎRÛNÎ speaks of the "Tables of the Shâh" and in the second half of "the Persians". Obviously, BÎRÛNÎ is referring to the same set of tables in both parts of his sentence.

3) In the same treatise[23], BÎRÛNÎ says (30:10) about the equations of the five planets:

> The Hindus and Persians have a common opinion, so the zîjes of the Shâh, and Abû Ma'shar, and Ya'qûb ibn Târiq contain nothing on which they differ except only one thing, the difference of which does not exceed one minute. They have for

Saturn	Jupiter	Mars	Venus	Mercury
8°37′	5°6′	11°12′	2°13′	4°

In this statement, BÎRÛNÎ speaks first of "the Persians" and next, in the same context, of the Zîj of the Shâh. Once more, the statement makes sense only if "the Persians" are regarded as the authors of that Zîj. – The third author mentioned by BÎRÛNÎ, namely YA'QÛB IBN TÂRIQ, is the author of a zîj called "Sindhind Zîj", which is based on Hindu astronomy (see [20], p. 134).

4) So for BÎRUNÎ and AL-HÂSHIMÎ the situation is clear. Next we shall show that IBN AL QIFTI also uses the expression "the Persians" in the same sense. In his commentary to the tables of AL-KHWÂRIZMÎ (see [24]) IBN AL QIFTI states that in these tables the equations of the planets were calculated according to the "Method of the Persians". For an explanation of this method see [5] or [22] or [24]. In the paper of BURCKHARDT & VAN DER WAERDEN[22] it was shown that the "Method of the Persians" was actually used in the "Tables of the Shâh".

We now see that in BÎRÛNÎ's statement about the source of ABÛ MA'SHAR's cycle of 360000 years the expression "cycles which have been based upon the observations of the Persians" may safely be interpreted as "cycles mentioned in the Tables of the Shâh".

In the next section we shall see that ABÛ MA'SHAR himself claimed that the world-year of 360000 years is due to "the Persians and some of the Babylonians". As far as the Persians are concerned, his claim is in full agreement with the statement of AL-BÎRÛNÎ. This agreement implies that ABÛ MA'SHAR and AL-BÎRÛNÎ use the expression "the Persians" in the same sense. The meaning of "the Babylonians" will be discussed in a later section.

In his "Elements of Astrology"[25], BÎRÛNÎ gives a list of numbers of revolution of the planets in 360000 years according to "the thousands" of

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[23] AL-BÎRÛNÎ: On Transits, translated by E. S. KENNEDY. American University of Beirut Oriental Series No. 32, section 24: 7–11.

[24] O. NEUGEBAUER: The Astronomical Tables of al-Khwârizmî. Hist.-filos. Skrifter Danske Vid.-Selsk. **4**, no. 2 (1962). See also the earlier commentary of H. SUTER in the same Skrifter, 7th series **3** (1914), especially p. 33.

[25] AL-BÎRÛNÎ: The Book of Instruction in the Elements of the Art of Astrology, transl. by R. R. WRIGHT (London, Luzac 1934), Section 204, p. 113–114.

ABÛ MA'SHAR[26]. He states that ABÛ MA'SHAR has recorded these numbers "from Persian sources". As we have seen, these sources include the "Tables of the Shâh". So the "Tables of the Shâh" were certainly one of the main sources of ABÛ MA'SHAR's astronomical system. BÎRÛNÎ's figures are confirmed by AL-HÂSHIMÎ and AL-TANÛKHI (see PINGREE[26], p. 30).

Note on Pingree's Criticism

In his review[10], PINGREE writes:

In order to lend weight to his doctrine Abû Ma'shar, following the lead of a number of early 'Abbâsid scholars of Iranian origin (e.g., Ibn Nawbakht and Miskawayh), sought to ascribe its discovery to ante-Diluvian times, and eventually to God Himself. To this end he invented a mythological history according to which the first of three "Hermes", who is at once the Iranian Abanjhan (Hûshank), the Hebrew Khanûkh (Enoch), and the Arabian Idrîs received knowledge from God at Akhmîm (Panopolis) in Egypt. This knowledge included the astronomical "System of the Persians", of which Tahmûrath buried a description in the Sârawîya at Jay in Isfahân before the Flood, but not before Bûdhâsaf (the Bodhisattva) had carried the system to India. This manuscript was excavated not long before Abû Ma'shar's time, and he claims that his doctrine is directly derived from this ante-Diluvian source. His theories and the many fragments of his two books have been thoroughly discussed by the present reviewer in The Thousands of Abû Ma'shar, London 1968.

A little more than a millenium after Abû Ma'shar published his fiction Professor van der Waerden has resurrected this mythology. However, he has been misled into thinking that by "the Persians" Abû Ma'shar intended to refer to the Sasanians rather than to Hûsank and Tahmûrath of legendary fame. He thus conceives of Abû Ma'shar's system as representing an early Sasanian zij – on p. 48 he even tries to push it back to the period between −200 and −250 because al-Sijzî, quoting Abû Ma'shar, states that the Babylonians used it. In Abû Ma'shar's history the Babylonians do indeed derive their imperfect knowledge of astronomy from the second "Hermes", who, in the time of Nabrîz Bâni (whoever he is supposed to be), was the first to revive science after the Flood. To see this source quoted as serious history in 1970 is astonishing indeed.

All this is completely wrong. I never tried to resurrect ABÛ MA'SHAR's mythology. My main source was not ABÛ MA'SHAR but AL-BÎRÛNÎ, who said quite clearly that ABÛ MA'SHAR's "Great Year" and his numbers of revolution were derived from Persian sources. The "Persians" of AL-BÎRÛNÎ were definitely not the legendary Hûsank and Tamûrath, but real Sassanid Persians. Also, I never tried to push back ABÛ MA'SHAR's system to the period between −200 and −250. These time limits are invented by PINGREE. My own opinion about the time of invention of ABÛ MA'SHAR's system will be explained in section 11 of the present paper.

5. Three World-Years Compared

In an excerpt from ABÛ MA'SHAR's "Book of the Thousands", written by AL-SIJZÎ (about A.D. 1000), the World-Year of 360000 years is compared with

[26] D. PINGREE: The Thousands of Abû Ma'shar (London, Warburg Institute 1968).

two other, longer World-Years. The excerpt is preserved in two versions, which were translated by E. S. KENNEDY and discussed in our joint paper[7]. Both versions are said to come from the treatise *Al-Jâmi al-Shâhî* of AL-SIJZÎ. The first version A begins thus:

A world-year, according to the generality of the astrologers, is from the time of arrival of the planets at the first of Aries until the time of their return to the end of Pisces, without there being a difference in their amounts (i.e., longitudes). As for those in a region of India and their adherents, they say that the seven planets and their apogees and nodes begin the motion from the first of Aries, and they conjoin at the end of Pisces in 4,320,000,000 years. As for the partisans of the year of Arjabhaz (Aryabhata), they differ from them and make the world-year 4,320,000 years. The partisans of the years of the Arkand said differently from this. The Persians (ahl Fars) and some of the Babylonians said that the world-years are 36[0],000 solar years, of which there are 365 days, 15 minutes, 3[2] seconds, (and) 24 thirds, without requiring their apogees and nodes (to be at Aries 0°). If we divide the years of the Sindhind by a thousand there come out the Arjabhaz years. If we divide by twelve thousand there comes out the year of the Persians.

Version B gives essentially the same information, but adds a few words about ABÛ MA'SHAR, the author of the "Book of the Thousands":

As for those of one of the regions of India, they claim that the years of the world are 4,320,000,000, they being the partisans (*aṣḥāb*) of the Sindhind. However, the other group of them, they being the partisans of the years of Arjabhaz, they claim that the years of the world are 4,32[0],000. But the author (*ṣāḥib*) of the "Book of the Thousands" used the years of the Persians for the cycles and *tasyīrāt*. However, some of the moderns used the world-years according to the way the partisans of the Sindhind explained them, but we now, in this book, will utilize what the author of the "Book of the Thousands" used.

In these texts, three variants of the "World-Year" are compared, namely:

1) a World-Year of 4320000000 years, ascribed to "those in a region of India".

2) a World-Year of 4320000 years, ascribed to *Arjabhaz*,

3) a World-Year of 360000 years, ascribed in version A to "the Persians and some of the Babylonians", and in version B to "the Persians". This World-Year was used by ABÛ MA'SHAR in his "Book of the Thousands".

The period 1), of 4320 millions of years, is the *Kalpa* used by BRAHMAGUPTA in his Brâhmasphutasiddhânta[27], written A.D. 628.

The period 2) is the *Mahâyuga* or *Catoryuga* used by ÂRYABHAṬA (called *Arjabhaz* by Arab authors) in his treatise Âryabhatîya[28]. Right at the beginning of this treatise, the author says that he was just 23 years old in A.D. 499, when 3600 years of the Kaliyuga had passed. So the treatise was written in A.D. 499 or later.

The period 3) is the "Great Year" of ABÛ MA'SHAR AL-BALKHÎ. According to AL-BÎRÛNÎ, this Great Year was derived from "the cycles of the Persians".

ABÛ MA'SHAR too ascribes the period 3) to "the Persians", just as he ascribes 1) to "the Indians" and 2) to "Arjabhaz". The ascriptions of 1) and 2)

[27] Brâhmasphuṭasiddhânta, by BRAHMAGUPTA, edited with his own commentary by M. S. DVIVEDI (Benares, Medical Hall Press 1900), reprinted from Pandit, Vol. 24.

[28] W. E. CLARK: The Âryabhaṭîya of Âryabhaṭa (Chicago 1930).

are correct, so I see no reason to doubt the ascription of 3) to "the Persians". Moreover this ascription is confirmed by AL-BÎRÛNÎ.

The period 1) is 1000 times the period 2), and 2) is 12 times 3), as Version A correctly states.

The three astronomical systems mentioned under 1) 2) 3) are similar in many details. They are all based upon the assumption of an approximate conjunction of all planets near the point 0° Aries in February, 3102 B.C. In the systems 1) and 2), this conjunction marks the beginning of the Kaliyuga. In the system 3) adopted by ABÛ MA'SHAR, the conjunction of 3102 B.C. was connected with a Flood, and it took place, according to the calculations of KENNEDY & VAN DER WAERDEN[7], in the night just before Thursday, February 17. The duration of ABÛ MA'SHAR's World-Year was 131493240 days, and it began on a Tuesday and ended with a Friday, as AL-HÂSHIMÎ states (see PINGREE[26], p. 35).

The most natural interpretation of AL-HÂSHIMÎ's words seems to be that the first day of the World-Year was a Tuesday and the last day a Friday. This interpretation is in full accord with the calculations of KENNEDY & VAN DER WAERDEN.

In PINGREE's opinion ([26], p. 35–36) the first day of ABÛ MA'SHAR's Great Year would be a Wednesday and the last day a Saturday, but this is in contradiction with the very words of AL-HÂSHIMÎ as well as with our calculations.

I shall now compare the numbers of revolutions in 360000 years according to ABÛ MA'SHAR and ÂRYABHAṬA. The latter composed (about A.D. 500) two astronomical systems. In the first, the "midnight system", which is known from VARÂHA MIHIRA's account of the old Sûryasiddhânta[29] and also from the treatise Khaṇḍakhâdyaka of BRAHMAGUPTA[30], the conjunction which marks the beginning Kaliyuga is assumed to take place at midnight between Thursday, February 17 and Friday, February 18, 3102 B.C. In the "morning system", which is the system of the Âryabhaṭîya, the conjunction takes place at sunrise on Friday, 18 February. The two systems differ only in details. The numbers for ABÛ MA'SHAR are taken from PINGREE's book[26], the figures for ÂRYABHAṬA from my paper[4].

Numbers of Revolutions in 360000 years

Planet	Abû Ma'shar	Midnight System	Sunrise System
Saturn	12214	$12214-\frac{1}{3}$	$12214-\frac{1}{3}$
Jupiter	30352	$30352-\frac{1}{3}$	30352
Mars	191402	191402	191402
Sun	360000	360000	360000
Venus	585199	585199	585199
Mercury	1494751	1494750	$1494751+\frac{2}{3}$
Moon	4812778	4812778	4812778

[29] VARÂHAMIHIRA: Pañcasiddhântikâ, ed. THIBAUT & DVIVEDIN (Benares 1889, reprinted Lahore 1930). New translation by NEUGEBAUER & PINGREE, Danske Vidensk. Selskab. Hist.-Fil. Skrifter 6 (1970–71).

[30] BRAHMAGUPTA: Khaṇḍakhâdyaka, translated by P. SENGUPTA (Calcutta 1934).

In my paper[4] I have shown that the mean longitudes computed from ÂRYABHAṬA's theory are very good for the lifetime of ÂRYABHAṬA (A.D. 500), but less good for dates one or two centuries earlier or later. The "sunrise system" is even better than the "midnight system". My explanation is that ÂRYABHAṬA adjusted his numbers of revolutions to observations made in his own time. In his theory, the mean longitudes of all planets are supposed to be *exactly* zero at the time of the conjunction of 3102 B.C. If this is assumed, the only possible way of adjusting the mean longitudes is, to change the numbers of revolutions in a Mahâyuga. In ÂRYABHAṬA's system all numbers of revolutions must be divisible by 4. If one of the numbers is increased by 4 units, the mean longitudes for A.D. 499 are increased by 1°12′ (see [4], p. 157). In this way, a good adaptation to observations is always possible.

In ABÛ MA'SHAR's system, the situation is different. Because there is a conjunction in the middle of his "Great Year", his numbers of revolutions for Saturn, Jupiter, Mars and the moon must be even. If one of the numbers is increased by 2, the mean longitude for A.D. 799 is increased by 7°48′, so that a good adaptation to observations is not always possible. The only way to overcome this difficulty is to add constant correction terms to the longitudes. It seems that ABÛ MA'SHAR did just that, for BÎRÛNÎ[19] says that according to ABÛ MA'SHAR's calculation for the time of the Deluge the planets "stood in conjunction in the space between the twenty-seventh degree of Pisces and the end of the first degree of Aries".

PINGREE ([8], p. 245) made the important remark that in the kalpa system of BRAHMAGUPTA the mean planets are precisely between the limits set by ABÛ MA'SHAR at the beginning of Kaliyuga. It is quite possible that ABÛ MA'SHAR used this kalpa system in order to obtain suitable correction terms to the planetary longitudes. He may well have taken his period of 360000 years from Persian sources (as BÎRÛNÎ says), but his correction terms from BRAHMAGUPTA.

The three astronomical systems 1), 2), 3) agree in so many points that they must have a common origin. On this point I agree with PINGREE, but I do not share his opinion that this origin was Indian. In order to state my arguments clearly, I must first discuss the history of the "Tables of the Shâh".

6. The Tables of the Shâh

The Arabic name of this table set is, according to KENNEDY[20], *Zîj ash-Shâh*. It is a translation of a Pahlavi original, which was probably called *Zîk-i Shatro-ayâr*. The history of this Persian table set is told by AL-HÂSHIMÎ as follows (see [22], p. 4):

> Khusro Anûshîrvân, when he beheld the difference between the Arkand and what Ptolemy asserted, he gathered together the people learned in computation and in (astrological) judgments, and he looked over these two books. He found the Arkand to be the most accurate by observation and eyesight, and judgments based upon its planets more accurate. So he worked out a zîj called "The Shâh" and he made it in kardajas with four kardajas.

They were using it until the reign of Yazdigerd ibn Shahriyar ibn Khusro. He brought out a zîj and he named it after the example of the Shah. He made it in three kardajas and called it "The Triple". Its explanatory text and apogees and nodes and mean (motions) and equations correspond to those of the Arkand as to midnight (epoch). People still work with it.

The work Arkand, which occurs three times in this text, is probably derived from Sanskrit Khaṇḍakhâdyaka. This is the name of an extant treatise of BRAHMAGUPTA[30], in which the calculation of planetary positions according to the Midnight System of Âryabhata is taught. Now KHUSRO ANÛSHÎRVÂN reigned in Persia from 531 to 579, and the Khandakhâdyaka was written in 665, so the astronomers of KHUSRO could not use this treatise, but they could use the underlying Midnight System, which was composed about A.D. 500. In fact, the calculations of KENNEDY[21] and of BURCKHARDT & VAN DER WAERDEN[22] have shown that the Tables of the Shâh agree with the Khaṇḍakhâdyaka and hence with the Midnight System in many points, including mean motions, apogees and maximal equations.

AL-HÂSHIMÎ states that KHUSRO compared the Arkand with a book of PTOLEMY. It follows that a book of PTOLEMY existed at the Sassanian court. This is confirmed by a statement in the fourth book of the Dênkart to the effect that Shapur I added a copy (or a translation) of Al-majistî (*i.e.* the Almagest) to the books in his Royal Treasury[31]. However, the astronomers of KHUSRO did not use the Almagest. According to AL-HÂSHIMÎ, they preferred to use the Arkand, *i.e.* the Midnight System of ÂRYABHAṬA.

In the Tables of the Shâh, the year was supposed to contain (in sexagesimal fractions)

$$365;15,32,30 \text{ days (see } [20], \text{ p. } 147).$$

On the other hand, in the Midnight System, the duration of the year is only

$$365;15,31,30 \text{ days}^{32}.$$

From these figures one sees that 3600 years (the time from the conjunction of 3102 B.C. to the lifetime of Âryabhata) contain one more day according to the Tables of the Shâh than according to the Midnight System. In the latter system, the conjunction took place between February 17 and 18, 3102 B.C., at midnight local time Ujjain. Hence the Tables of the Shâh must have placed the conjunction at about midnight just before February 17. This result agrees well with BÎRÛNÎ's statement that the Zîj-i Shâh used midnight epoch in contrast to the general practice of using noon. See KENNEDY's Survey[20], p. 130.

Let us recall that the Epoch of the Flood according to BÎRÛNÎ's Chronological Table ([19], p. 133) is the same midnight before Thursday, February 17, and that this midnight was also the middle of the Great Year of ABÛ MA'SHAR. Once more, ABÛ MA'SHAR agrees with "the Persians".

[31] See R. C. ZAEHNER: Zurvan, a Zoroastrian Dilemma (Oxford 1955), p. 139.

[32] This duration was found by dividing the number of days in a Mahâyuga by the number of years.

In ÂRYABHAṬA's Midnight System, the conjunction of 3102 B.C. took place at midnight between Thursday and Friday. In his Sunrise System, the system of the treatise Âryabhaṭîya, the conjunction took place at sunrise on Friday, February 18. So the Thursday date of the Tables of the Shâh was certainly not derived from any of the two systems of ÂRYABHAṬA.

On the other hand, it seems that ÂRYABHAṬA knew about the Thursday tradition. In the treatise Âryabhaṭîya he writes:

> I.3. There are 14 Manus in a day of Brahman (a kalpa), and 72 yugas constitute the period of a Manu. Since the beginning of this kalpa up to the Thursday of the Bhârata battle 6 Manus, 27 yugas and 3 yugapadas have elapsed (translation of W. E. CLARK [28], p. 12).

This calls for some explanation. What ÂRYABHAṬA calls a *yuga* is the mahâyuga of 4320000 years. It is divided into 4 yugapadas or quarter-yugas of 1080000 years each. The kaliyuga in which we now live is the last quarteryuga of the current yuga. Hence the beginning of the kaliyuga is the moment when three yugapadas of the current yuga have elapsed. ÂRYABHAṬA identifies this beginning of the kaliyuga with "the Thursday of the Bhârata battle". On this point, ÂRYABHAṬA is in accordance with an earlier tradition, for in the Mahâbhârata it is said that the great battle of Bhârata began at the beginning of the kaliyuga. If Thursday was the first day of the battle, the kaliyuga must have begun in the night before Thursday. This is in contradiction with ÂRYABHAṬA's own system, in which the kaliyuga began at sunrise on Friday morning.

How can we explain this contradiction? The most natural explanation seems to be that ÂRYABHAṬA found the Thursday date in an earlier tradition. This earlier tradition was perhaps connected with the Persian doctrine of a Great Year consisting of two halves of 180000 years each, separated by a Great Conjunction in the night before Thursday, February 17, 3102 B.C. Because ÂRYABHAṬA's year was shorter, he was forced to shift this conjunction to Friday morning, but when he mentioned the Bhârata battle he kept the traditional Thursday date.

Another fact points into the same direction. In the old Sûrya-Siddhânta, which is based on the Midnight System of ÂRYABHAṬA, a lunar period of 180000 years is used[33]. The number of revolutions of the moon during this period according to the old Sûrya-Siddhânta is exactly the same as in the Persian System, namely 2406389. It seems possible that ÂRYABHAṬA took this period of 180000 years from an earlier tradition, which was somehow connected with the Persian Great Year.

We thus are led to the conjecture that the "Persian System" with its Thursday conjunction and its Great Year of 360000 years existed even before the time of ÂRYABHAṬA, *i.e.* before A.D. 500.

In the next section we shall see that an earlier version of the Tables of the Shâh actually existed before A.D. 500.

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[33] VARÂHAMIHIRA: Pañcasiddhântikâ I 14: "According to the Saura (= Sûryasiddhânta) there are in 180000 years 66389 intercalary months and 1045092 lunar days."

7. Persian predecessors of the Tables of the Shâh

AL-BÎRÛNÎ informs us in his Masudic Canon[34] that KHUSRO ANÛSHÎRVÂN convoked, in the year A.D. 556, an assemblage of astronomers for the purpose of *correcting* the Zîj ash-Shahriyâr *i.e.* the Tables of the Shâh. From this testimony, TAQÎZÂDEH & KENNEDY ([20], p. 130) concluded that a Persian set of tables existed already at that date.

Another very valuable information is given by IBN YÛNIS in the Leiden fragment of his Hâkimî Zîj[35]. IBN YÛNIS states that the Persians observed the apogee of the sun at 77°55′ about A.D. 450 and again at 80° about A.D. 610 (see [7], p. 325). Now what does IBN YÛNIS mean by the expression "observing the sun's apogee"? The solar apogee is not an object one can see in the sky. One has to determine it from three observations of the sun's position, *e.g.* from two equinoxes and one solstice (method of HIPPARCHOS and PTOLEMY) or from three lunar eclipses. IBN YÛNIS knew this: he was a competent astronomer, who collected many ancient observations and made observations himself. So we may safely interpret his statement as follows: The Persian astronomers determined the apogee of the sun by observations made about A.D. 450 and again by observations made about A.D. 610. What was the situation of the Persian astronomers about 610? They had the choice between several values of the solar apogee. They may have known PTOLEMY's value 65°30′. The value 77°55′ was known already about 450, as we know from IBN YÛNIS, and the value 80° was known from the "Arkand" system, *i.e.* from the midnight system of ÂRYABHAṬA. The Persians made observations and decided to adopt the value 80°, for AL-BÎRÛNÎ informs us that the value 80° was used in the Tables of the Shâh. BÎRÛNÎ probably had in mind the Yazdigerd edition of the Tables, which was composed between 632 and 642. Hence the statement of IBN YÛNIS concerning the observations of the apogee about 610 is in accordance with what we know from other sources.

I feel we should interpret the other statement of IBN YÛNIS in the same way. About 450, a hundred years before KHUSRO, the Persian astronomers were in doubt about the value of the solar apogee. They made observations and adopted the value 77°55′. The same value was also used in the tables of AL-KHWÂRIZMÎ[24].

Why did the Persians observe the apogee? The most natural answer to this question is: because they wanted to compute a table for the motion of the sun. So we may conjecture that about 450 the Persians actually computed astronomical tables. This conjecture is confirmed by BÎRÛNÎ's testimony quoted right at the beginning of the present section. Combining the statements of BÎRÛNÎ and IBN YÛNIS, we may conclude that *a set of astronomical tables was composed about 450 or a little later, and revised under Khusro Anŭshîrvân about 560.*

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[34] AL-BÎRÛNÎ: Al Qânûn al-Mas'ûdî. Osmania Oriental Publications Bureau, Hyderabat-Deccan (1954–56), p. 1423.

[35] IBN YÛNIS: Az-Zîj al-Kabîr al-Hâkimî. Leiden Cod. Or. 143, p. 124.

Note on Pingree's Criticism

In his paper[9] and again in [10] PINGREE claims to have demonstrated that the value 77°55′ of the longitude of the apogee of the sun, reported by IBN YÛNIS as observed by the Persians about A.D. 450, was "in fact computed by means of the parameters of an Indian text, the *Paitâmahasiddhânta* of the *Viṣṇudharmottarapurâṇa* – and computed from the beginning of the Kalpa!" Now let us have a look at this "demonstration".

In the Appendix to his paper[9], PINGREE compares two texts which he calls (B) and (P):

(B), the Brâhmasphuṭasiddhanta of BRAHMAGUPTA,

(P), the Paitâmahasiddhânta, incorporated in the Višnudharmottarapurâna.

PINGREE shows that many parameters, including the motion of the solar apogee from the beginning of the kalpa, are just the same in both texts. He also calculates the longitude of the apogee of the sun according to the texts (B) and (P), and he finds 77;54,7,17 degrees, which may be rounded off to 77°55′.

So far I agree, but the next step in the argument seems very doubtful:

"As the latter work (the Viṣṇudharmottarapurâṇa) was compiled between ca. A.D. 450 and 650, the Paitâmahasiddhânta must be even older; and as it is referred to by Âryabhaṭa under the name Svayambhû (Âryabhaṭîya, Golâdhyâya, 50), it must be dated at least A.D. 450."

To this conclusion I have two objections. First, it is not at all certain that the work referred to by ÂRYABHATA under the name SVAYAMBHÛ (which means Brâhma or Paitâmaha) is the same as text (B). There were several astronomical treatises going under the name Brahmasiddhânta or Paitâmahasiddhânta; PINGREE ([36], p. 178–179) mentions four of them. ÂRYABHAṬA mentions "the universally true science of astronomy, which was formerly revealed by Svayambhû", but I do not know what revelation he refers to, and I think that PINGREE does not know it either. He only guesses, and he presents his guess as if it were a certain truth.

My second objection is: Even if one admits that ÂRYABHAṬA refers to the text (B), then it would follow only that this text existed by A.D. 499, but not that it existed A.D. 450, as PINGREE claims.

So why not accept IBN YÛNIS definite statement that the Persians observed the apogee about 450 and again about 610? The author of the astronomical system exposed in the texts (B) and (P) may well have known a Persian table set in which the apogee was located at 77°55′.

In PINGREE's opinion ABÛ MA'SHAR got the idea of a Great Year connected with the conjunction of 3102 B.C. from India. He rounded off the numbers of revolutions in a Mahâyuga so as to make them divisible by 12, and thus he obtained his period of 360000 years. As far as I can see, PINGREE has no good arguments in favour of his thesis: he just speaks of "Abû Ma'shar's rounding off of the *Sindhind* parameters" as if it were a fact ([26], p. 33).

In my opinion, it is much more probable that the Hindu astronomers learnt about the conjunction of 3102 B.C. from the Persians. I suppose ÂRYABHAṬA

[36] D. PINGREE: The Later Paulisasiddhânta, Centaurus **14**, p. 172–241.

and BRAHMAGUPTA replaced, for good reasons, the Persian "Great Year" of 360000 years by the Mahâyuga and Kalpa they knew from earlier traditions. The larger periods enabled the Hindu astronomers to construct better and more flexible astronomical systems. This hypothesis seems reasonable from the astronomical point of view, and it agrees with the testimonies of IBN YÛNIS and AL-BÎRÛNÎ, for the latter asserts that ABÛ MA'SHAR's system was exclusively based on "the motions of the stars, as they had been fixed by the observations of the Persians".

It is true that in AL-BÎRÛNÎ's India a different opinion on ABÛ MA'SHAR's source seems to be expressed. BÎRÛNÎ writes[37]:

> "The context of these passages makes it clear that this destruction of the world takes place at the end of a kalpa, and hence is derived the theory of Abû-Ma'shar that a deluge takes place at the conjunction of the planets, because, in fact, they stand in conjunction at the end of each caturyuga and at the beginning of each kaliyuga."

In this passage, BÎRÛNÎ seems to say that ABÛ MA'SHAR's theory of returning deluges was derived from Hindu sources. However, his statement in "India" is rather vague, and the reason he gives for it is not very convincing, whereas his statement concerning ABÛ MA'SHAR's Persian sources in the "Chronology" is clear and definite. When writing the "Chronology", BÎRÛNÎ had the Persian tables and the text of ABÛ MA'SHAR before his eyes, and he could compare the Persian cycles with those of ABÛ MA'SHAR.

One more argument in favour of my hypothesis was presented in my joint paper with KENNEDY[7] on p. 323:

> In classical Greek and Hellenistic literature, the doctrine of the "Great Year" was already connected with the myths of the Deluge and Ekpyrosis. These catastrophes were supposed to return periodically when the planets came together in certain signs of the zodiac. In the Persian system, we still find the Deluge connected with a conjuction of the planets. Âryabhaṭa does not mention the Deluge: he only alludes to the "battle of Bhârata" on Thursday, February 17, −3101. The idea of a Deluge in the middle of a cycle of 360,000 years cannot be derived from India; it must have come to Persia from the West.

I admit that the opinions expressed in this "Note on Pingree's Criticism" are not certain, but in any case they rest on a better foundation than PINGREE's firm assertions.

8. Persian Astronomy before Khusro

According to the middle-Persian treatise Dênkart, the Sassanian king SHÂPÛR I (240–270) collected writings from India, the Byzantine Empire, and other lands, and which treated of medicine, astronomy, movement, time, space, substance, creation, becoming, passing away, *etc.* (see [31], p. 8). Among the books collected was PTOLEMY's Almagest (see [31], p. 139). The hexameters of the first-century astrologer DOROTHEOS of Sidon were translated into Pahlavi under

[37] AL-BÎRÛNÎ, India I, translated by E. C. SACHAU, p. 325.

SHÂPÛR (see PINGREE[8], p. 241). Also translated during the Sassanid Period were the "Anthologies" of VETTIUS VALENS (see again[8], p. 241–242). From these facts, NEUGEBAUER[39] rightly concluded that "serious astronomical activity was taking place in Persia in the third century". Later on, under KHUSRO ANÛSHÎRVÂN, the "Paranatellonta" of TEUKROS the Babylonian were also translated into Pahlavi[38]. The contents of the Paranatellonta will be discussed in Section 11.

Without astronomical tables it is impossible to cast horoscopes. Therefore we may safely assume that the Persians had astronomical tables from the very beginning under SHÂPÛR I. The observation of the apogee of the sun about A.D. 450 was probably made in order to correct existing tables.

In KENNEDY's paper[17], Persian methods for computing mean conjunctions of Jupiter and Saturn are discussed. These methods are found in several Persian sources, but not in Hindu treatises. Both PINGREE and KENNEDY assume the conjunction astronomy and its astrological applications to have been invented in Sassanid Persia ([17], p. 41).

The lapse of time between two successive conjunctions of Jupiter and Saturn is nearly 20 years. The motion of Saturn during this time is given by ABÛ MA'SHAR as

$$242°25'17''.$$

Other authors give slightly different values ([17], p. 31). ABÛ MA'SHAR's value is in full accordance with his cycle of 360000 years, in which period the numbers of revolutions of Jupiter and Saturn are 30352 and 12214. The difference between these numbers is 18138; hence there are 18138 conjunctions in 360000 years, and the motion of Saturn from one mean conjunction to the next is

$$\frac{12214}{18138} \cdot 360° = 242°25'17'' \ldots$$

Starting with the assumed conjunction of 3102 B.C., the times of the successive mean conjunctions can be calculated. If the mean motions of the Persian system based upon the cycle of 360000 years were correct, the differences of the mean longitudes of Jupiter and Saturn ought to be zero at the times of the calculated mean conjunctions. Actually, they are not zero. According to the calculations of KENNEDY & VAN DER WAERDEN[7] the error is approximately

5° in the 3rd century,
4° in the 4th century,
2° in the 5th century,
1° in the 6th century.

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[38] F. BOLL: Sphaera. Teubner, Leipzig 1903. See also C. A. NALLINO: Tracce di opere greche giunte agli arabi per trafila pehlevica, Raccolta di scritti **6** (1948), p. 285–303.

[39] O. NEUGEBAUER: Review of L'Inde classique by L. Renou and J. Filliozat, Archives Internationales d'Histoire des Sciences **8**, p. 172.

From these errors KENNEDY & VAN DER WAERDEN[7] concluded that the Persian system in the form in which we know it, with 18138 mean conjunctions in 360000 years, cannot have originated before the 5th century. Now we know that in 556 KHUSRO's astronomers decided to replace the old "Tables of the Shâh" by better tables based on the "Midnight System" of ÂRYABHAṬA. Therefore the most probable time of invention of the "Persian System" with its numbers of revolutions 30352 and 12214 for Jupiter and Saturn seems to be the fifth century A.D.

This conclusion is well in accordance with the testimony of IBN YÛNIS concerning the observation of the solar apogee about A.D. 450. So we may conjecture that about this time the Persians composed tables of the same kind as the later "Tables of the Shâh", but based upon the cycle of 360000 years.

9. The Hellenistic Origin of the "Persian System"

My next hypothesis is that the "Persian System" with its conjunction of 3102 B.C. in the middle of a cycle of 360000 years was ultimately derived from Hellenistic sources.

Let me first note that the conjunction of 3102 B.C. was not observed, but calculated. In that year, no matter whether the calculation is made for February 17 or 18 or any other date in that neighbourhood, no conjunction of the planets took place. On February 17 the mean longitudes of Jupiter and Saturn differed by more than 40°. The main reason for this deviation is that the real Saturn moves much faster than it was supposed to move in the Persian system[40]. The difference amounts to 26" a year, or 26° in the 3600 years from 3102 B.C. to the time of ÂRYABHAṬA.

So the conjunction of 3102 B.C. was found by a backward calculation, perhaps by one of those astrologers who, according to BÎRÛNÎ, tried to date the flood by computing conjunctions of Jupiter and Saturn. Now for such an extrapolation one needs methods to calculate mean longitudes of planets. The Babylonians of the Seleucid era had no such methods: the notion "mean longitude" does not occur in their theories. The Greeks of the hellenistic age were the first to calculate planetary longitudes by first computing mean longitudes and next adding correction terms. This is the main reason why I suppose that the conjunction of 3102 B.C. was a Greek invention.

Another reason is a passage from ABÛ MA'SHAR's "Book of Conjunctions"[41]. The first part of this passage was quoted in KENNEDY's paper[17], p. 25. This quotation ends with the words:

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[40] See B. L. VAN DER WAERDEN: Vergleich der mittleren Bewegungen in der griechischen und indischen Astronomie. Centaurus **11** (1965) p. 16.

[41] Kitâb al-qirânat, Escorial MS arabe 937, fol. 5r. See also footnote [42].

[42] According to KENNEDY[7], note [32], another copy of the "Book of Conjunctions", *Kitâb al-Qirânât*, is in the library of the Near East School of Theology, Beirut, MS PB 20. A Latin translation, *Albumasar de magnis coniunctionibus annorum revolutionibus ac eorum profectionibus*, was published in Venice 1515.

And there is between the first day of the year of the Flood and the first day of the year in which was the conjunction indicating the Arab people, three thousand and six hundred and seventyone years, 3761.

According to KENNEDY, the "conjunction of the Arabs" was A.D. 571. If one counts back from this year 3671 solar years, one arrives at the year 3101 B.C., the year just after the conjunction of 3102 B.C.

The continuation of this passage in the Escorial MS Arabe 937, fol. 5r reads:

And verily ANYNÛS and others mentioned that between the beginning of the birth of Adam, the prayers of God upon him, and the Friday night on which was the Deluge was two thousand and two hundred and twenty-six years and one month and twenty-three days and four hours ...[43].

The name ANYNÛS mentioned here is almost certainly a Greek name; it may be read as ANIANOS. If some dots are changed, the name can be read as ABTNÛS. As suggested by A. SACHS[44], it is possible that the Greek historian ABYDENOS is meant, who wrote a book on Babylonian history and chronology, partly based on the "Babyloniaka" of BEROSSOS. Since BEROSSOS wrote on the Deluge and on the Great Year, the name ABYDENOS would fit extremely well. However, since the identification of ANYNÛS with ABYDENOS is far from certain, I shall restrict myself to stating that ABÛ MA'SHAR connected his date of the Deluge with the name of a Greek author who had computed the time from the creation to the Deluge.

A similar statement about the date of the deluge according to a Greek author, probably drawn from the same source, is found in BÎRÛNÎ's "Chronology". I quote from SACHAU's translation, page 25:

According to one of the historians, Anianus, the interval between the creation and the night of the Friday when the deluge commenced, is 2226 years 23 days and 4 hours. This statement by Anianus is reported by Ibn-Albâzyâr in his Kitâb-alkirânât (Book of the Conjunctions) ...

In this translation the name ANIANUS is based on a conjecture due to the translator SACHAU. On page 374 SACHAU notes that in the manuscripts the name is written as 'THNYWS, which might mean ATHENAIOS. In his opinion, the author ATHENAIOS is out of the question; therefore he prefers the reading ANIANUS. This ANIANUS was an Egyptian monk, a contemporary of PANODORUS, who was known as a chronographer. The two readings ANYNÛS and ATHNYWS differ only in the diacritical dots.

Note that a historian ATHENAIOS, who wrote about Assyrian history, is mentioned by DIODOROS II 20. I shall quote the translation of OLDWATER in Loeb's Classical Library:

Such, then, is the account that Ctesias of Cnidus has given about Semiramis; but Athenaeus and certain other historians say that she was a comely courtesan and because of her beauty was loved by the king of the Assyrians. Now at first she was accorded only a moderate acceptance in the plalace, but later, when she had been proclaimed a lawful

[43] This translation was made by Dr. ANWAR SINNU and kindly communicated to me by E. S. KENNEDY.

[44] See[8], p. 243, footnote [114].

wife, she persuaded the king to yield the royal prerogatives to her for a period of five days. And Semiramis, upon receiving the sceptre and the regal garb, on the first day held high festival and gave a magnificent banquet, at which she persuaded the commanders of the military forces and all the greatest dignitaries to co-operate with her; and on the second day, while the people and the most notable citizens were paying her their respects as queen, she arrested her husband and put him in prison; and since she was by nature a woman of great designs and bold as well, she seized the throne and remaining queen until old age accomplished many great things. Such, then, are the conflicting accounts which may be found in the historians regarding the career of Semiramis.

10. The "Chaldaeans" and the "Babylonians"

We have seen that AL-BÎRÛNÎ, in his account of the attempts of the astrologers to date the Deluge by means of conjunctions of Saturn and Jupiter, mentions "the inhabitants of Babel and the Chaldaeans".

We also have seen that ABŪ MA'SHAR ascribes the cycle of 360000 years to "the Persians and some of the Babylonians".

Who were the "Babylonians" mentioned by BÎRÛNÎ as well as by ABŪ MA'SHAR?

In ancient astronomical and astrological texts one finds many references to collectivities such as

"the Chaldaeans",
"the Egyptians",
"the Babylonians",
"the Persians",
"the Indians".

In a recent paper[45] I have collected many quotations from the "Chaldaeans" and the "Egyptians", and I have shown that these can all be understood as quotations from specific treatises written by or ascribed to Chaldaean and Egyptian authors. Concerning the origin of these treatises I have reached the following conclusions:

1) All testimonies referring to the "Chaldaeans" come from one treatise (or group of related treatises) written in Greek between 330 and 170 B.C., in which Babylonian astronomy and astrology were summarized. This treatise, from which we have extensive excerpts (*e.g.* in the "Isagoge" of GEMINOS), was based on cuneiform texts.

2) All testimonies referring to the "Egyptians" come from one astrological treatise written in Greek in Hellenistic Egypt before 150 B.C. The authors of this treatise are sometimes quoted as "NECHEPSO and PETOSIRIS", sometimes as "the Egyptians around PETOSIRIS", and very often just as "the Egyptians" or "the ancient Egyptians".

I shall illustrate the consequences of these conclusions by an example. In LYDUS, De Mensibus II 12 we read:

[45] B. L. VAN DER WAERDEN: Die "Aegypter" und die "Chaldäer". Sitzungsber. Heidelberger Akad. (Math.-nat.) 1972, Abhandlung 5.

The Egyptians and Chaldaeans call the seventh day of the week and also the corresponding star *Phainon.*

If this statement is interpreted as a testimony about the inhabitants of Egypt and southern Babylonia, it is just nonsense, for the Egyptians called the planet Saturn "Horus the Bull", and the Babylonians called it *kaimanu.* However, as a statement about books written in Greek it is perfectly reasonable. In both books the Greek word *Phainon* was used to denote Saturday as well as Saturn. This is a meaningful and interesting statement. It implies that the planetary week, in which each weekday is put under the supremacy of a planet, was used in the book of the "Chaldaeans" as well as in that of the "Egyptians".

Regarding "the Persians", the situation is similar, as we have seen in section 4. The "Persians" are authors of treatises written in Middle Persian (Pahlavi), or more specifically the authors of "Tables of the Shâh".

The same thing holds for "the Indians". When BÎRÛNÎ speaks of "the Hindus and Persians" (see section 4), he is comparing astronomical parameters used by Persian and Hindu authors. When ABÛ MA'SHAR speaks of "those in a region of India" who use the kalpa of 4320 millions of years (see section 5), he just means BRAHMAGUPTA.

Now consider the "Babylonians". They are mentioned twice in the "Anthologies" of VETTIUS VALENS[46].

1) In VI 3, on page 249 of KROLL's edition, VETTIUS speaks of Saturn and says: "The Babylonians call the planet Phainon". This statement makes sense only if VETTIUS had before his eyes an exposition of the doctrines of the Babylonians written in Greek.

2) In IX 11, on page 353, VETTIUS makes a distinctions between "Chaldaeans" and "Babylonians". He ascribes to the Chaldaeans a certain duration of the year, and to the Babylonians another, namely

$$365+\frac{1}{4}+\frac{1}{144}\ \text{days}.$$

If the word "Chaldaeans" is taken in its usual sense as Babylonian astronomers, a distinction between Chaldaeans and Babylonians makes no sense. It does make sense if we assume that his figures were taken from two different sources. In the first source certain doctrines were ascribed to the Chaldaeans, and in the other source doctrines were ascribed to the Babylonians. The duration of the year was different according to his two sources.

3) Three chapters of an anonymous author, known as "The Astrologer of 379", were copied by PALCHOS[47]. At the end of the first chapter a list of authors is given who have written about the phenomena of the fixed stars. The first

[46] VETTIUS VALENS: Anthologiae, ed. W. KROLL (Berlin 1908). See also O. NEUGEBAUER: The Chronology of Vettius Valens, Harvard Theological Review **47** (1954), p. 65–67.

[47] The text of the "Astrologer of 379" was published by F. CUMONT in Catalogus codicum astrologorum Graecorum V 1, p. 194–211.

authors listed are "The Babylonians and the Chaldaeans". Just as in the text of VETTIUS VALENS, a clear distinction is made between the two sources.

The subject matter in this chapter of the Anonymous is just the same as in the Paranatellonta of "TEUKROS the Babylonian"[38]. Hence we may conjecture that the "Babylonian" source of the Anonymous was just TEUKROS.

4) ALEXANDER of Aphrodisias[48], speaking of the number seven of the Pleiads, first mentions the Chaldaeans, next the Greeks, again the Chaldaeans and finally the Babylonians. By the "Babylonians" he may well mean TEUKROS, who mentions the Pleiads several times in his Paranatellonta (see BOLL[38], p. 122 and 280).

Let us now pass to Islamic sources. ABÛ MA'SHAR and AL-BATTÂNÎ and AL-BÎRÛNÎ ascribe certain astronomical theories and numerical values to "the Babylonians" or to "the people of Babylon". I shall mention four cases.

According to AL-BATTÂNÎ[49] the "Egyptians" and the "Babylonians" assumed the duration of the year to be

$$365;15,30 \text{ days.}$$

VARÂHA MIHIRA ascribes the same value to the Paulisa-Siddhânta. Nobody doubts that this Siddhânta was based on a Greek treatise from the Hellenistic period.

5) A very interesting testimony concerning "the people of Babylon" (*ahl Bâbil*) comes from AL-BÎRÛNÎ, who in his book Risâ'il IV describes several methods for calculating the rising times of the twelve zodiacal signs[50]. Most methods make use of trigonometry, but the last three methods are purely arithmetical. I shall call these methods A, B, and C:

A: Risâ'il IV, 137: 2–12
B: Risâ'il IV, 137: 13–138:2
C: Risâ'il IV, 138: 3–13.

As LESLEY has shown[50], methods A and C are based on the same arithmetical methods as were used in cuneiform texts belonging to the ancient Babylonian System A. However, these methods were adapted to different latitudes by using multiples of the equinoctial shadow length. This adaptation is not made in cuneiform texts; hence LESLEY concludes that the adaptation to other climata than that of Babylon was made in the Hellenistic age.

BÎRÛNÎ ascribes Method B to "some of the books of the Persians", and Method C to "the people of Babylon". It seems that he found both methods in one and the same Persian source, for after having described Method B, he writes:

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[48] ALEXANDER APHRODISIENSIS: In Aristotelis Metaphysica commentaria, ed. HAYDUK (Berlin 1891) p. 832. See also BOLL[38], p. 366.

[49] AL-BATTÂNÎ: Opus astronomicum I, edited by C. A. NALLINO (Milano 1903), p. 40.

[50] M. LESLEY: Bîrûnî on Rising Times and Daylight Lengths. Centaurus **5** (1957) p. 121–141. More material is in AL-BÎRÛNÎ's "Exhaustive Treatise on Shadows", Translation and Commentary by E. S. KENNEDY (Institute for History of Arabic Science, University of Aleppo 1976, Chapter 22).

The (Persian) author of the operation said. "As for the people of Babylon, they multiplied the equatorial shadow by twenty-five and divided the result by eighteen, and subtracted what results from thirty. There remained the ascension for Aries. Then they subtracted twice the ascension for Aries from sixty, and divided the remainder by five. There resulted the base of increase for each sign, and they did it to the ascension for Aries to obtain Taurus, and to the ascension for Taurus to obtain Gemini, and so on to obtain Virgo"[51].

The last sentence implies that the ascension times of the signs from Aries to Virgo form an arithmetical sequence, just as in the Anaphorikos of HYPSIKLES and in the Anthologies of VETTIUS VALENS[52].

The conclusion is the same as before: The "Babylonians" were Hellenistic authors.

6) Another testimony of AL-BÎRÛNÎ has already been quoted in Section 4:

The astrologers have tried to correct these years, beginning from the first of the conjunctions of Saturn and Jupiter, for which the sages among the inhabitants of Babel, and the Chaldaeans have constructed astronomical tables, the Deluge having originated in their country.

Once more, as in the testimonies of VETTIUS VALENS and PALCHOS, the Chaldaeans are distinguished from the Babylonians. This is correct, for according to our results the "Chaldaeans" were early Hellenistic authors, whereas the "Babylonians" were late Hellenistic authors. I guess the "Chaldaean" books were written in the third century B.C., and the "Babylonian" books in the first century A.D.

7) In Section 5 I have already quoted the testimony of ABÛ MA'SHAR (Version A):

The Persians and some of the Babylonians said that the world-years are 360000 solar years, of which there are 365 days, 15 minutes, 32 seconds, and 24 thirds, without requiring the apogees and nodes (to be at Aries 0°).

I suppose the quotation "The Persians and some of the Babylonians" means that ABÛ MA'SHAR found the description of the World-Year in a Persian source, in which a Babylonian source was quoted, as in testimony 5).

Can we make a reasonable guess about this source? I think we can.

11. Teukros the Babylonian

In my opinion it is extremely probable that the common source of all quotations from "the Babylonians" was "TEUKROS the Babylonian". Several arguments in favour of this identification were presented in my paper[53] in the

[51] This translation was kindly communicated to me by E. S. KENNEDY.

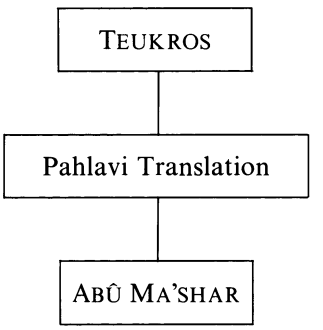
[52] O. NEUGEBAUER: On Some Astronomical Papyri and Related Problems of Ancient Geography. Transactions of the American Philos. Soc. **32** (1942), p. 251–263.

[53] B. L. VAN DER WAERDEN: The "Babylonians" and the "Persians". Prismata, Festschrift für Willy Hartner (Steiner, Wiesbaden 1977), p. 431–440.

Festschrift for WILLY HARTNER. As we have seen, "the Babylonians" were quoted by VETTIUS VALENS as well as by ABÛ MA'SHAR and AL-BÎRÛNÎ, and we also know that these three authors have known and used the work of TEUKROS. This seems to be a strong argument in favour of the identification.

About the lifetime of TEUKROS not much is known. BOLL showed ([38]. p. 8) that he must have lived before circa A.D. 100. On the other hand, GUNDEL[54] concludes from the longitudes in the "Paranatellonta" of TEUKROS that he lived "not long after Hipparchos". We may conclude that TEUKROS lived, most probably, between HIPPARCHOS (130 B.C.) and VETTIUS VALENS (A.D. 140).

In Islamic sources TEUKROS was known as TÎNQALÛS or TÎNQARÛS or TANKALÛSHÂ. His "Paranatellonta" were translated into Pahlavi under KHUSRO ANÔSHÎRVÂN, and this translation was used by ABÛ MA'SHAR in his "Great Introduction". In fact, book 6, Chapter 1 of this work contains three variants of the list of "Paranatellonta" or simultaneously rising (or culminating or setting) stars[55]. One of the variants is ascribed to the "Persians", one to the Indians and one to PTOLEMY. The "Persian" list was derived from the Pahlavi version of the work of TEUKROS. So the road of transmittance was



I suppose that ABÛ MA'SHAR's knowledge about the Great Year of 360000 years and the Conjunction of 3102 B.C. was transmitted by the same road.

I don't believe that TEUKROS the Babylonian invented the "Persian System". According to BOLL[38], TEUKROS was not an original astronomer, but rather a compilator. The man who discovered the conjunction of 3102 B.C. must have been an astronomer who calculated conjunctions in the past and found an approximate conjunction of all planets near 0° Aries in the year 3102. Only after this discovery was it possible to set up an astronomical theory based upon the assumption that this conjunction took place in the middle of a "Great Year" of 360000 years.

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[54] W. GUNDEL & H. G. GUNDEL: Astrologumena (F. Steiner, Wiesbaden 1966), p. 112 and 379

[55] A German translation of this part of the Great Introduction by K. DYROFF was printed together with the Arab text. in BOLL's Sphaera [38], p. 490–539.