7. Astronomical Chronology of Vedic Literature : Some New Arguments

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Abstract

Since the 1780s, Western researchers (Playfair, Bailly, Jacobi) have noticed data in Indian astronomy, both astronomical tables and stray astronomical references in religious and epic texts, which, through the millennial clock of the precession, indicate a surprisingly high chronology for Vedic civilization. The idea that the composition of Vedic hymns started before 4000 BC was perfectly compatible with early Romantic notions of India as the homeland of pre-Christian European civilization (Voltaire, Schlegel), but came in conflict with Max Müller's far lower chronology, with the Rg-Veda composed only ca. 1500 BC, which became normative from ca. 1870 onwards. The astronomy-based high chronology was picked up by Indians only in 1893 (B.G. Tilak's *Orion*) and entered the politically tainted Aryan Invasion debate only in the 1990s,-- so it cannot be dismissed as merely a "Hindu-chauvinist fantasy". But dismissed it is, mostly in very cavalier rhetoric which betrays the philologists' unfamiliarity with the cogency of scientific reasoning. We will now look into the recent crop of arguments mustered to neutralize this inconvenient body of astronomical evidence, apparently so in contradiction with the chronologies based on archaeological findings (horse, spoked wheel, bronze, iron) and on comparative-historical linguistics. This will implicitly necessitate a second look at the arguments in favour of a high chronology as well. Finally, we add a little meditation on what to do in scientific research when different bodies of evidence point to opposite conclusions.

7.1. Introduction

The question of the chronology of Vedic literature nowadays comes up mostly in discussions of the Aryan Invasion Theory (AIT) and its alternatives, particularly the so-called Out-of-India Theory (OIT). Thus, in a recent exchange on the Indo-Eurasian Research list, someone mentioned the claim she had heard about astronomical data supporting a high chronology for the Rg-Veda, pushing it farther back than the commonly accepted date of 1500-1200 BC, even as far as 4000 BC. And she asked if anyone could explain to her "why this argumentation is incorrect (apart from that we know that it can't be correct)". (#2205)

Though the list reunites practically all leading scholars working on matters closely or remotely related to the Aryan Invasion debate, and is strongly committed to upholding the AIT orthodoxy and the concomitant conservative Vedic chronology, not a single member offered any attempt to point out factual or logical mistakes in the astronomical evidence mustered so far for a high chronology. The only answers concerned non-astronomical evidence for a lower chronology. Thus, a famous Harvard professor (and IER list moderator) replied: "For example, because a hoary Rgveda in 3000 or 4000 BCE would have chariots before their invention, and horses in the Panjab before they were first imported around 1800 BCE. (Revisionists, Hindutva people, etc., want to get around these stubborn, disturbing facts by secondary and tertiary elaborations, rewriting the several sciences involved; Occam's razor applies.)" (#2213)

In my reply (#2229, 6-11-2005), I pointed out that astronomers from Playfair and Bailly through Jacobi down to Narahari Achar have developed a *consistent* narrative where astronomical elements of an absolute chronology neatly match the commonly-agreed relative

chronology of the text passages in which they appear. These astronomy-based chronologies consistently point to a much higher Vedic chronology than usually accepted in the predominant (version of the) AIT. In summarizing the astronomical evidence, I would, like in an earlier publication (Elst 1999:117), still add the phrase, "for what it is worth", because I am quite aware that it is in conflict with the conclusions from other types of evidence.

Thus, we do seem to have conflicting testimonies here between the accepted dates for horses and chariots, as indicated by archaeological findings, and the astronomical data. But the solution is not to "get around these stubborn, disturbing facts" of astronomy by smugly dismissing them as *testimonia non grata*. Nor to declare dogmatically that "we know that it can't be correct". Until we manage to reconcile the conflicting types of evidence (by revising them, by some new meta-perspective, who knows?), we simply have to live with uncertainty. This seems to panic some of the academics involved, but in the process of scientific discovery and theory-formation, it is a perfectly normal phase. Alright, we have a problem here, one that forces us into some rethinking, but sincere researchers would rather welcome that as "just the right sort of problem to have".

Against the consistent and straightforward high-chronology interpretation of the astronomical evidence, the AIT has never offered a consistent interpretation of these data supporting its own low chronology. All we have is piecemeal attempts to deconstruct one datum or another, weakening its logical impact or dismissing it as imprecise. A typical example is Witzel's 1999 reply to Achar 1999, another is Kim Plofker 2000, yet another is S. Zimmer 2003:404 (in fact only a single page of generalities, without any argumentative impact). In spite of this poverty in alternative explanations, nobody seems to be bothered by this inability to refute the stubborn astronomical evidence or to domesticate it somehow into the prevalent paradigm.

This refusal to take the astronomical evidence seriously can go quite far in its special pleading. I recall an internet discussion on Dominic Wujastyk's old Liverpool Indology discussion list about the astronomical self-dating of the *Vedânga Jyotiṣa* to 1350 BC (by locating the winter solstice in the asterism of Dhanishtha and the spring equinox in Bharani, *cfr. infra*), in the middle of the Rig-Vedic composition period under the standard chronology, but more likely implying an older date for the RV. Someone argued that for reasons of language and literary genre, this text must really date to ca. 200 BC, and that we must put the chronological anomaly down to an inaccuracy on the part of the author-astronomer.

Note first of all that if this "correction by inaccuracy" to 1150 years later is acceptable, then so is a similar correction in the opposite direction: the VJ written in 2500 BC. If the latter is far-fetched and ridiculous, then the conventional dating of the VJ to 200 BC is equally far-fetched and ridiculous. In reality, either deviation is extremely unlikely. A time-span of 1150 years corresponds to more than 16 degrees of arc in the precession (*cfr. infra*), or more than a whole lunar asterism of 13°20'. This implies that the author described an astronomical phenomenon as taking place in asterism X, when in fact his very own eyes had seen it taking place in asterism (X+1) or even asterism (X+2). As if he datelined his letter from "New York, Canada", or even from "Ottawa, Mexico". Of all things, an astronomical manual would seem to be the very last place where to expect such wild inaccuracies. But because this blatant special pleading was in the service of the established theory and not of some "far-fetched" alternative, nobody objected. Well, I'd say: Occam's Razor applies.

Those who propose a date of 200 BC should also explain the absence of Hellenistic influence in the Vedanga Jyotisha, otherwise so plentiful in Indian astronomical and astrological works of the Hellenistic age. Someone more prudent claimed David Pingree, who was said to have ascribed to the Vedanga Jyotisha a date of ca. 400 BC and an undeniable Babylonian influence. But the book doesn't even mention the twelve-part Zodiac, which was all the rage in the Babylonian sphere of influence in those days, vide e.g. the fast-

spreading practice of Zodiac-based horoscopy from at least the 5th century BC and the Biblical descriptions (securely dated to the 6th century BC at the latest) of Jacob's twelve sons and their tribes, clearly displaying the imprint of the Zodiacal symbols. Pingree's assertions would all be convenient, but the disappointing fact is that the VJ is clumsy in parts where new Babylonian insights could have greatly helped, and that it focuses on systematizing precisely those astronomical and calendrical concepts that were in evidence in the older Vedic literature. Meanwhile, its chronological self-testimony remains unassailable.

The only hypothesis so far that could take care of all the disturbing astronomical data is that there was a *vast right-wing conspiracy*, with all those Vedic seers antedating their observations just to fool posterity,-- and being consistent in their antedating, coordinating with one another across regions and centuries. But here again, I would say: Occam's Razor applies.

Now, at the end of the day, I am not sure about the astronomical evidence. Unlike the impregnable self-assuredness which Michael Witzel, Steve Farmer, Lars Martin Fosse and many other votaries of the AIT (mirroring some of their anti-AIT counterparts) bring to this debate, I must confess that my opinions in the matter are very wobbly, and I would be easy to convince of an alternative explanation of the astronomical data,-- if one had been offered. But so far, the contest is between (1) a consistent astronomy-based hypothesis with a high chronology and (2) a few disparate critiques of *some* of the astronomical data that, even if persuasive, would merely open up the *possibility* of a low chronology. The latter alternative is just not good enough to convince me.

7.2. The competence gap between philology and astronomy

One problem in discussing the astronomical evidence with philologists of the dominant schools of Indo-European linguistics and of ancient Indian history is that by and large, they haven't mastered the basic concepts of astronomy needed to understand the arguments. An instance of a consequential misunderstanding of astronomy is the paper by Michael Witzel (1999) on the Pleiades/*Kṛttikâ* and the Bears. He mentions correctly that the Great Bear was always visible (i.e. with its lowest point still above the horizon) at the Delhi latitude during the Vedic period, but that larger and larger parts of it would rise above and set below the horizon as the observer moves south from Delhi. So far, so good.

But further down, he incorrectly asserts just the opposite: "During the Indo-Iranian period, the 'bears' (*ṛkṣâḥ*) were not, of course, always visible in the night sky and rise from a partial position below the horizon, especially if we think of a BMAC [Bactria-Margiana Archaeological Complex] or of a still more northern location. That would not be possible even for most of the Panjab, and is only possible south of Delhi, below ca. 30° N."

The whole discussion is an erroneous one, as the position of the Great Bear is essentially the same for the Delhi area ca. 2900 BC and the Bactria-to-Panjab area in the 2nd millennium BC, the competing locations for the composition of the Vedas in this debate, viz. it is in each case circumpolar, with its whole daily cycle visible above the horizon (in Delhi, the constellation started to disappear partly under the horizon only in the 1st millennium BC, as shown by Achar 2000/1). So references to the Bear stars that "rise" (*udyanti*) in the north must in any case be interpreted in a sense compatible with this fact, without consequence whatsoever for the choice of time and place of the Vedic passages in question.

Moreover, Witzel's statement seems garbled, perhaps the result of careless writing and then failing to notice during the editing. The first sentence would have been right if we move the words around a bit: "During the Indo-Iranian period, the 'bears' (*ṛkṣâḥ*) *were*, of course, always visible in the night sky and [did] *not* rise from a partial position below the horizon,

especially if we think of a BMAC or of a still more northern location." Unfortunately, that is incompatible with the second sentence: "That would not be possible even for most of the Panjab, and is only possible south of Delhi, below ca. 30° N." What is possible down south is precisely that the Great Bear *does* rise and set, hiding below the horizon part of the time, partly or wholly.

So, back to his original first sentence: "During the Indo-Iranian period, the 'bears' (*ṛkṣâḥ*) were not, of course, always visible in the night sky and [*they did* (?)] rise from a partial position below the horizon, especially if we think of a BMAC or of a still more northern location." But that statement is simply untrue. Witzel usually locates the Indo-Iranian ancestors of the Vedic people in Bactria, 37°N, or even more north (coming from Russia, remember). At those latitudes, the Great Bear was above the horizon at *all* times under consideration as dates of the Vedas, contrary to what Witzel claims here. By contrast, the phrase "always visible in the night sky" does *not* apply to more southerly regions, such as those south of Delhi, again contrary to what he says. The closer you get to the equator, the more stars rise and set. At the equator, all stars rise and set and are above the horizon exactly half the time, with the Pole Star staying near the horizon. At the poles, no stars ever rise or set (except due to their own movement, unrelated to the earth's motions, over months or years in the case of planets, and over thousands or millions of years in the case of fixed stars), with the equatorial stars all remaining at the horizon.

The argument about the dependence of the Great Bear's seeming motion on the observer's latitude is important within the invasionist hypothesis that the Vedic poets (and likewise later even the astronomer Lagadha who wrote the Vedanga Jyotisha) retained descriptions of astronomical sightings from their ancestors, in this case about the rising and setting of the Great Bear. This means that on the one hand, they declaimed ancestral observations which they themselves had never seen; and on the other, they refrained from describing the actual observations of their own eyes. This reasoning, used by the AIT school at different points in this debate, looks like just the kind of special pleading against which Occam's Razor must be applied.

Witzel also leans heavily on David Pingree (1978), whose argument against the astronomical chronology, at least the way Witzel presents it, turns out to be surprisingly weak. Thus, on *Kṛttikâ*'s "never swerving from the east" (*Shatapatha Brâhmaṇa* 2:1:2:3), he is cited as stating that except for *Kṛttikâ*, there were also other constellations on the equator, likewise rising due east. Yes, but of those, only two were also on the ecliptic, one at the vernal and the other at the autumnal end. And of course, it doesn't invalidate that the Pleiades asterism, too, was on the equator, and this was the case around 2400 BC, not in 800 BC when conventional scholarship assumes the Shatapatha Brahmana was written. It also so happens that Krttika stood out as a favourite marker of the new year cycle in other cultures such as the Chinese, whose calendar correspondingly opens in 2697 BC. The fact that the Maori have reportedly also preserved it as the beginning of their year cycle may be a case of anachronism, but only in the sense that they stuck to this starting asterism after it moved away from the equator. There is no Maori text where the Pleiades are located due east at a time when this didn't correspond with reality anymore, as is here alleged of the Shatapatha Brahmana authors.

In this connection, Witzel proposes an unsuspected implication (every opponent should admit that he uses his erudite brain very resourcefully and creatively) of the Shatapatha Brahmana's interest in the positions of both Krttika and the Great Bear. About the latter, then commonly called *Saptarṣi*, "the Seven Seers", the book (2.1.2.4, and reportedly also the Taittiriya Aranyaka 1.11.2) says that it was "formerly called *Ṛkṣâḥ*", "the Bears", an imagery preserved in Greek, Latin and Germanic names of the constellation and clearly dating back to Proto-Indo-European times. "So, why can the Shatapatha Brahmana authors not have

transmitted another piece of traditional knowledge, that about the exact rising point of the *Kṛttikâ*-s,-- astronomical lore that dates back to the third millennium BCE?"

This is intended as a rhetorical poser, but in fact there is a straight answer to it: because the snippet of knowledge about the old name of the Bear is a lexicographical anecdote, the kind used by schoolmasters to enliven their dry lessons a bit, whereas that about the position of the Pleiades forms part of a specific astronomical instruction for practical use, viz. where the priest should orient his ritual paraphernalia before starting the sacrifice. The first type can be repeated verbatim after having collected dust for centuries, but the second has to be checked against actually observed reality.

Another instance of failing comprehension of astronomy is that Witzel misunderstands the term *heliacal rising*: "That means the Pleiades were rising in the east at nightfall at fall equinox, while the sun rises against their background at the spring equinox (heliacal rising at vernal equinox)."

When "the Pleiades were rising in the east at nightfall at fall equinox", i.e. in opposition to the setting sun, it means the sun was at 0° Libra (autumnal equinox) and the Pleiades at 0° Aries (the spring equinox point), and the Pleiades were visible all night long, setting again when the sun rose at the next daybreak. It does indeed follow that six months later, at spring equinox, "the sun rises against their background", or as they say: the sun is in conjunction with the Pleiades, making them invisible. However, that is not the meaning of "heliacal rising". This term refers to the moment when a star becomes visible again after having been in conjunction with the sun and hence invisible. In practice, this means you can see the star rise in the east just before dawn and just before the stars become invisible under the powerful daylight. Exactly how many days after the conjunction with the sun this will happen, depends on several factors including the latitude of the observer, but it should be at least two weeks or about 15°. This means that the Pleiades at 0° Aries were conjunct the sun on 21 March but didn't have their heliacal rising before ca. 5 April at the earliest, with the sun at ca. 15° Aries, more than two weeks *after* the vernal equinox.

Witzel also believes that chronological and geographical conclusions can be drawn from the fact that some of the names of the Krttika stars "are connected with rain, e.g. Abharayanti, Meghayanti, Varshayanti,-- which fits very well the location" of Vedic but post-Rg-Vedic literature in Haryana-Delhi-UP, "where the rainy season only starts in mid-July (…) ca. 1000 BCE", but would make no sense for Harappa in 2900 BC. He seems to see a connection between the Pleiades and the onset of the Monsoon, similar to that between Sirius and the flooding of the Nile in Pharaonic (but no longer in today's) Egypt, which can be used as a chronological marker in precessional terms, *cfr. infra*. Yet, this is not the case for any time of Vedic composition seriously proposed by any party to the debate. I have as yet no explanation why these stars have rain-connected names, but it cannot be due to any of the various possible positions where the Pleiades could have "marked" the time of the year just before or at the start of the Delhi Monsoon, i.e. when the sun is in tropical Cancer. They would rise in opposition to the sun (i.e. at sunset) in Capricorn, i.e. some 8000 BC. They would be in heliacal rising (end of Gemini) ca. 3500 AD. And they would rise in conjunction with the sun (at sunrise, invisible) in Cancer, i.e. towards 5000 AD. So, none of these are relevant to the present debate, and Witzel doesn't seem to realize it. No big deal, he's a great philologist, but he should understand that his astronomical reasoning isn't helping his cause.

For another example of an astronomical misunderstanding in the orthodox school, in a reply to my intervention on the Indo-Eurasian Research list (#2229), someone wrote (#2234):

"One of the issues that most Vedic astronomy-based chronologies as well as the opponents have ignored so far, is they have based their calculations from India. This is true that the locations that are mentioned in RV are of greater Panjab and Eastern Afghanistan. The location of Delhi, used by most of the chronologists, is roughly on the south-eastern side

of the geography of the Rg-Veda (...). Though I have not analyzed the dates on Panchanga (Hindu calendar) software like Dr. N. Achar etc. have done, I would like to point out a plain fact: as we would move north the chronology would become lower. The revised astronomical chronology based on the higher northern latitudes, when combined with the evidence of horse domestication etc., could perhaps give a better date for the RV without violating the astronomical data of the RV and the Brahmanas. As the movement of the Aryans has a general direction from northwest to southeast, many chronological gaps could be shrunk (due to the movement south from northern locales) based on the astronomical data in later texts. (...) What if the observations were made, say, from Kabul or Srinagar or a location in Sogdia?"

This assertion was welcomed and approved by Michael Witzel, but it is simply incorrect. While some astronomical observations do indeed change with latitude (e.g. whether a star remains above the horizon 24 hours rather than rising and setting, or how long day and night are at summer solstice), the precession puts the same zodiacal degree against the same star regardless of the observer's position on earth. And it is the precession on which the entire astronomical chronology is based.

All this confirms my view that the attempt to reconcile the astronomical data with a low chronology for Vedic literature is so far clumsy and unconvincing. However, we should not leave it at that and cry victory for the high chronology, as too many Hindu chauvinists tend to do. What we need now is to write a complete survey of *all* the astronomical evidence, and see if it remains consistent. In this paper, I can only make a beginning with that job.

7.3. Astronomical tables

The question of the date of the Rg-Veda was decided for a long time by Friedrich Max Müller's shoddily argued choice for about 1200 BC. He simply assumed a period of 200 years for successive layers of Vedic literature: Upanishads in the two centuries before the Buddha, Brahmanas in the two centuries before that, then two centuries for Sama-, Yajur- and Atharva-Veda, and then the Rg-Veda, receiving its final editing ca. 1200. Though he later retracted it and accepted that we may never know the Vedic date for sure, this arbitrary guess by the editor of the *Sacred Books of the East* series has become the orthodoxy. More recent generations of scholars don't swear by his authority anymore but settle for the comforting notion that on this count, he had been right by sheer luck because newer methods unknown to him have confirmed his chronology.

It is too often forgotten that in his own day, other scholars rejected this extremely late date on a variety of grounds. Maurice Winternitz (1907:vol.1:288) based his estimate on purely philological considerations: "We cannot explain the development of the whole of this great literature if we assume as late a date as round about 1200 BC or 1500 BC as its starting-point." While sounding plausible, this objection, similarly based on a mere feeling of how long a phase in literary and philosophical development should take, is of course not decisive.

We need a firmer basis to decide this chronological question, and the most explicit chronology is provided by astronomical markers of time. They are less corruptible than archaeological samples subjected to C-14 dating, except that conservative philologists will object that we don't have the actual astronomical observations but only literary reports of or references to them,-- and these literary items are fallible again, in a number of ways. They may be anachronistic reminiscences falsely looking like immediate observations, they may have been deliberately antedated, or sometimes in manuscripts they may simply be a misreading of a lost original stupidly mistranscribed by an unattentive medieval copyist.

However, it is unique to the astronomical evidence that in some cases, such wrong dating is practically impossible. This unique property was already addressed in one of the earliest non-philological estimates of the date of the Vedas, at once among the most scientific. In 1790, the Scottish mathematician John Playfair demonstrated that the starting-date of the astronomical observations recorded in the ephemeris tables still in use among Hindu astrologers (of which three copies had reached Europe between 1687 and 1787) had to be 4300 BC. His proposal was dismissed as absurd or as blasphemous by some, but it has so far not been refuted by any scientist.

Playfair's judicious use of astronomy was countered by John Bentley with a scriptural argument which will not convince many people today. Bentley (1825/1990:xxvii) objected: "By his [= Playfair's] attempt to uphold the antiquity of Hindu books against absolute facts, he thereby supports all those horrid abuses and impositions found in them, under the pretended sanction of antiquity. Nay, his aim goes still deeper, for by the same means he endeavours to overturn the Mosaic account, and sap the very foundation of our religion: for if we are to believe in the antiquity of Hindu books, as he would wish us, then the Mosaic account is all a fable, or a fiction."

Bentley (1825/1990:111), whom we would now call a "creationist" upholding Biblical chronology literally, also extrapolated his chronology (thus providing the public with a first test of its plausibility) to "prove" that Krishna was born on 7 August in AD 600, while the most conservative estimate elsewhere is the 9th century BC. Likewise he "proved" (1825/1990:158 ff.) that Varaha Mihira (AD 510-587) was a contemporary of the Moghul emperor Akbar (r.1556-1605).

Bentley did not object to astronomy per se, in so far as it could be helpful in showing up the falsehood of Brahminical scriptures. However, it did precisely the reverse. Falsehood in this context could have meant that the Brahmins falsely claimed high antiquity for their texts by presenting as ancient astronomical observations recorded in Scripture what were in fact back-calculations from a much later age. But Playfair showed that this was impossible. Back-calculation of planetary positions is a highly complex affair requiring knowledge of a number of physical laws, universal constants and actual measurements of densities, diameters and distances. Though Brahminical astronomy was sophisticated for its time, it could only back-calculate planetary position of the presumed Vedic age with an inaccuracy margin quickly rising to at least several degrees of arc.

With our modern knowledge, it is easy to determine what the actual positions were, and what the results of back-calculations with the Brahminical formulae would have been, e.g.: "Aldebaran was therefore 40' before the point of the vernal equinox, according to the Indian astronomy, in the year 3102 before Christ. (...) [Modern astronomy] gives the longitude of that star 13' from the vernal equinox, at the time of the Calyougham, agreeing, within 53', with the determination of the Indian astronomy. This agreement is the more remarkable, that the Brahmins, by their own rules for computing the motion of the fixed stars, could not have assigned this place to Aldebaran for the beginning of Calyougham, had they calculated it from a modern observation. For as they make the motion of the fixed stars too great by more than 3" annually, if they had calculated backward from 1491, they would have placed the fixed stars less advanced by 4° or 5°, at their ancient epoch, than they have actually done." (Playfair 1790/1983:87)

So, it turns out that the data given by the Brahmins corresponded not with the results deduced from their formulae, but with the actual positions, and this, according to Playfair, for nine different astronomical parameters. This is a bit much to explain away as coincidence or sheer luck.

That Hindu astronomical lore about ancient times cannot be based on later back-calculation, was also argued by Playfair's contemporary, the French astronomer (and first

Revolutionary mayor of Paris, 1789-91, beheaded in 1793) Jean-Sylvain Bailly: “the motions of the stars calculated by the Hindus before some 4500 years vary not even a single minute from the [modern] tables of Cassini and Meyer. The Indian tables give the same annual variation of the moon as that discovered by Tycho Brahe -- a variation unknown to the school of Alexandria and also to the Arabs”. (1787, quoted in Sathe 1982:32)

Fabricating astronomical data going back thousands of years requires knowledge of Kepler’s and Newton’s laws describing the mechanics of the solar system and a mastery of differential equations. Failing this advanced knowledge, the data in the Brahminical tables must be based on actual observation. Ergo, the Vedic seers were present in person to record astronomical observations and preserve them for thousands of years: “The observations on which the astronomy of India is founded, were made more than three thousand years before the Christian era. (...) Two other elements of this astronomy, the equation of the sun's centre and the obliquity of the ecliptic (...) seem to point to a period still more remote, and to fix the origin of this astronomy 1000 or 1200 years earlier, that is, 4300 years before the Christian era”. (Playfair 1790/1971:118)

Disputants may start by trying to prove Playfair and Bailly factually wrong. Indeed, I think it is high time to recheck their argumentation on the basis of all their original data. Meanwhile , it remains something of a scandal that Playfair's and Bailly's findings have been lying around for two hundred years while linguists and Indologists were publishing speculations on Vedic chronology in stark disregard for the contribution of astronomy.

7.4. The start of Kali-Yuga

Hindu tradition makes mention of the conjunction of the “seven planets” (Saturn, Jupiter, Mars, Venus, Mercury, sun and moon) and Ketu (southern lunar node, the northern node/Rahu being by definition in the opposite location) near the fixed star Revati (*Zeta Piscium*) on 18 February 3102 BC. This date, at which Krishna is supposed to have breathed his last, is conventionally the start of the so-called Kali-Yuga, the "age of strife", the low point in a declining sequence of four ages. However, modern scholars have claimed that the Kali-Yuga system of time-reckoning was a much younger invention, not attested before the 6th century AD.

Against this modernist opinion, Bailly and Playfair had already shown that the position of the moon (the fastest-moving “planet”, hence the hardest to back-calculate with precision) at the putative beginning of Kali-Yuga, 18 February 3102, as given by Hindu tradition, was accurate to 37’. (Playfair 1790/1971:88-89) Either the Brahmins had made an incredibly lucky guess, or they had recorded an actual observation on Kali Yuga day itself. Richard L. Thompson (1989:19-24) argues that the *Jyotiṣa-shâstra*-s (treatises on astronomy and, increasingly, astrology, mostly from the first millennium AD) are correct in mentioning this remarkable conjunction on that exact day, for there was indeed a conjunction of Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn, Ketu and the fixed star Revati.

True, the conjunction was not spectacularly exact, having an orb of 40° between the two most extreme planetary positions. But that exactly gives additional support to the hypothesis of an actual observation as opposed to a back-calculation. Indeed, if the Hindu astronomers were able to calculate this position after a lapse of many centuries (when the *Jyotiṣa-Shâstra*s were written), it is unclear what reason they would have had for picking out that particular conjunction. Surely, such conjunctions are spectacular to those who witness one, and hence worth recording if observed. But they are not that exceptional when

considered over millennia: even closer conjunctions of all visible planets do occur, most recently on 5 February 1962. Thompson (1989:21 and 2000:212-223) reports that his computer found three such conjunctions occurring between the Kali Yuga date and the modern age. If the Hindu astronomers had simply been going over their astronomical tables looking for an exceptional conjunction, they could have found more spectacular ones than the one on 18 February 3102 BC.

Incidentally, Thompson (2000:216) has discovered an even stranger fact about the Kali Yuga alignment: apart from the visible planets, it also included Pluto and, within an orb of altogether 90° stretching left and right, Uranus, Neptune and the biggest asteroid, Ceres. The complete list of planetary longitudes at the Greenwich midnight hour (when it is dawn in India) beginning the back-calculated Gregorian date of 18 February 3102 BC, i.e. Julian day 588465.5 (with count starting at noon on 1 January 4713 BC) and counted in tropical degrees, i.e. from the vernal equinox point, is given as follows: Sun 303.84°; Moon 304.44°; Mercury 288.36°; Venus 316.37°; Mars 300.61°; Jupiter 317.43°; Saturn 276.51°; Uranus 340.73°; Neptune 250.31°; Pluto 308.60°; Ketu 327.21°; Ceres 328.56°.

On the other hand, the Kali Yuga alignment clustered around the fixed star *Revatî* (*Zeta Piscium*). There was nothing particularly important about this star at that time, neither by location nor by intrinsic properties such as magnitude (many tables of fixed stars used by Western astrologers don't even bother to list it). By contrast, it became very important at the time of the incorporation of Hellenistic astronomy into *Siddhântika* astronomy: it marked the end of the sidereal Zodiac, with sidereal 0° of Aries taken to fall immediately after Revati (though schools of astrologers differ on just how "immediately"). It has retained that status throughout the nearly two millennia of Hindu sidereal astrology. Of course, the planets cannot help it that they were conjunct this star in 3102 BC, it just happened to be the case. Still, those who want to uphold the hypothesis of back-projection by Siddhantic-age astronomers might feel encouraged by this coincidence, because of the element of non-coincidence, viz. the selection of *this* rather than another mega-conjunction.

While the authentication of the stellar observation for the so-called Kali Yuga date is certainly remarkable, we should not read more into it than what it actually proves. Yes, this finding supports the existence of a continuous tradition of astronomical observations spanning more than five thousand years. Among other things, this adds to the seriousness of all other stellar observations mentioned in the Vedic corpus, by *Dîrghatamas* and other astro-attuned seers, showing that they deserve better than the cavalier treatment they have been getting from the philologists. But it need not be accepted as proof that the notion of Kali Yuga itself is that old. Nor does it prove by itself that the events related in the Mahabharata date back to that time.

Conflation of different historical memories into a single epic event is not uncommon in ancient literature. In this case, the combined literary and archaeological evidence seems to militate against the high astronomically derived date for the Bharata war. A higher date than the 900 BC pushed in some textbooks, yes, but the 32nd century BC, unlikely. Thus, whereas the *Râmâyaṇa* heroes Rama and Hanuman are armed with bow and arrow c.q. with a mace, the core story of the *Mahâbhârata* (not just the many sideshows added later, with generally acknowledged anachronisms) is full of "modern" weaponry: metal armour, helmets and swords, which presuppose bronze if not iron technology; and horse-drawn chariots, with unarmed Krishna gaining access to the battlefield by serving as charioteer. These technologies are not in evidence in the archaeological record at all for this early date. This

could be a back-projection by the later editors of technology common in their own time, but given the centrality of precisely these items of material culture in the epic's core narrative, that would sound like special pleading.

By its own account, the Mahabharata closes off the Vedic period, and it credits one of its cast's patriarchs, *Vyâsa*, with the final edition of the Vedic corpus. This tallies with the fact that the epic's earliest characters are mentioned in the very youngest parts of the Yajur and Atharva Veda. In the chronology which we will see emerging from the Vedic astronomical data, the composition of at least these two younger Vedas was certainly not completed by 3102 BC. So today I will merely mark the question of the Mahabharata's timing as a topic for further inquiry.

7.5. The precession of the equinox

The decisive evidence for a high chronology of the Vedas is the Vedic information about the position of the equinox against the stellar background. The equinox, or the sun's position yielding equality of day and night, occurs when the sun crosses the equatorial plane on its apparent annual march along the ecliptic, i.e. the plane in which the earth revolves around the sun. This plane is called "ecliptic" because when the moon crosses it, this may produce solar or lunar eclipses. When the sun crosses the equatorial plane in northward direction (*uttarâyaṇa*), this is called the vernal or spring equinox; when it crosses it in southward direction (*dakṣinâyana*), it is called the autumnal equinox. The phenomenon of the "precession of the equinoxes" takes the ecliptical constellations (also known as the sidereal Zodiac, i.e. those constellations through which the sun passes) slowly past the vernal equinox point, at a pace of 1° in nearly 71 years, or a full cycle of 360° in ca. 25,791 years.

The sidereal Zodiac, used in astrology by most Hindu and some Western astrologers, consists of the actually visible constellations on the ecliptic. It is contrasted with the tropical Zodiac, an abstract division of the ecliptic in twelve equal sectors of which the first one starts by definition at the spring end of the equinox axis, the intersection of the equatorial plane and the ecliptic, which are tilted more than 23° from each other. This tropical Zodiac, used by most Western and some Hindu astrologers, is unrelated to the background of constellations: it could be constructed even if the universe consisted only of the sun and the earth.

The Vedic cosmography and calendar were not sidereal like the Hindu astrology of the last one and a half millennium, nor were they used as a basis for a system of fortune-telling. Both the use of the sidereal Zodiac and its application to predictive horoscopy were innovations developed after the import of Hellenistic ideas in the wake of Alexander's conquest. Though nowadays they are sold as "Vedic astrology", they are quite foreign to Vedic *jyotiṣa* (a prakritism reconstructible as Sanskrit **dyautiṣa*, the science of *Dyaus*/heaven), a term which meant "astronomy" for millennia before acquiring its present meaning of "astrology". The Vedic ordering of the year cycle was essentially tropical, i.e. tied to the tropics, the points where the sun changes course from southward to northward (at the southernmost point, tropic of Capricorn) or from northward to southward (at the northernmost point, tropic of Cancer). The tropical year, or more recently the tropical Zodiac, is tied to the actual seasons determined by the earth/sun cycle, and not to the constellations.

So, the Vedic year was primarily divided into the six seasons typical of the Indian climate, theologically corresponding to the original six *âditya*'s, a category (later expanded to twelve) of cosmic gods given in RV 2.27.1. They are, with their presiding *âditya*: firstly *Shishira*, moist winter (Mitra); secondly *Vasanta*, spring (Aryaman); thirdly *Grîshma*, summer (Bhaga); fourthly *Varṣâ*, rainy season (Varuna); fifthly *Sharada*, autumn (Daksha); sixthly *Hemanta*, dry winter (Amsha). Given the association of gods with the heavens, such theo-correspondences (given in Holay 1992:102) were echoed in similar correspondence systems for other divisions of the heavens, e.g. between the 27 or 28 lunar asterisms and that many gods. In their turn, these six seasons were each divided in two tropical months, the first strict 12-month calendar, constructed without regard to the moon's motions. In this system, the months practically coincided with the tropical Zodiac signs (as they still do in the Iranian calendar, which starts at spring equinox or *Newroz*). A similar purely tropical or season-based calendar existed in China, dividing the solar year not in 12 but in 24 terms.

The Rg-Veda also had a soli-lunar calendar, using the motions of sun and moon but constraining them in the tropical framework of the seasons and solstices. This means that the month was defined as a lunar cycle from new moon to new moon. However, if you try to fit a number of lunar months into the solar year, you either fall short by about eleven days in case you reckon only twelve of them (as happens year after year in the Islamic calendar), or you exceed the solar year by some eighteen days in case you count thirteen lunar cycles. So, to keep the solar and lunar counts in sync, an extra month had to be intercalated every time the lunar system fell that much behind. Verse RV 1:25:8 refers to this mechanism, where Varuna is described as He who "knows the twelve months and their productions, and *that which is supplementarily engendered*". What was supplemented to the twelve months was a thirteenth intercalary month, and this seven times in nineteen years. This system successfully overcame the incommensurability of lunar months and solar years. By combining them in a ratio of seven "long" and twelve "short" years in every period of nineteen solar years, you can keep the lunar and solar cycles in harmony for centuries without further corrections, for (12 x 12 + 7 x 13) lunar months = 19 solar years.

Unfortunately, a formula, recorded but not invented by Lagadha in his Vedanga Jyotisha, was used imposing a rhythm of eight intercalary months per twenty years, or two in a *yuga* of five years. (Achar 1997) Seven months in nineteen years does not equal eight in twenty, so after a few decades the year thus conceived would diverge seriously from the solar year. But fortunately again, this theoretical formula was corrected in practice, for you don't even need to know any formula in order to implement the principle of intercalation successfully. Year after year, you can simply count the actual lunations (new moons), and if there's thirteen between two successive winter solstices, or four between two successive solstice and equinox points, one of the months will be counted as intercalary. Another way to do it is to pick the first lunar month that does not contain a *sankranti*, a starting point of one of the twelve tropical sectors of the ecliptic, or in other words, a lunar months that falls entirely within a single Zodiac sector. Coming after month X, the intercalary month can simply be named "X-bis", a practice still followed in the Chinese and Jewish (originally Babylonian) soli-lunar calendars.

In the Hindu calendar, the practice is as follows: "The mean duration between two solar *râshi sankranti*s (beginnings of a sector of the twelve-sign Zodiac) is greater than the mean duration of the synodic lunar month by about one day. Further, due to the non-uniform motions of the moon and earth in their respective orbits, the lengths of the lunar and solar months vary. Therefore, on an average of about once in 32 months there is no *râshi sankranti*

during a particular lunar month. Such a month is then called *adhikamâsa* and given the same name as that of the following ordinary (*shuddha*) month." (Abhayankar 1993:61)

The point to be emphasized once more is that the system of six seasons and the soli-lunar calendar were purely conceived in terms of the year cycle, astronomically tied only to the abstract solstice axis (tropical Cancer/Capricorn), and in the second case also to the moon, but not to the constellations. It could all work and remain unchanged even if all the other celestial bodies, stars and planets and constellations alike, were suddenly to disappear. This contrasts with the later system of 27 or 28 moon-stations or asterisms (*nakṣatra*-s), where twelve "months" were tied to a set of two or three asterisms each. But even there, the ancients generally used the stars only as markers for the earthly seasons, e.g. the Egyptians used the heliacal rising of Sirius as a marker of the yearly overflowing of the Nile, as long as it applied. They subordinated the sidereal data to the seasonal/tropical framework, either not realizing that the one set slowly shifted vis-à-vis the other through the precession, or accepting this shift as only a long-term inconvenience that had little immediate consequence.

In the astrologers' debate between siderealists and tropicalists, the former argue that sidereal time-reckoning based on star-gazing must have preceded (and therefore be preferable to) the tropical system based on abstract mathematical determinations and divisions of the equator and the ecliptic, because looking at the visible constellations is easier and more natural. In my judgment, this argument is trumped by the pro-tropicalist argument that the tropical division of the year only formalizes an even more immediate experience than the observations of the stars, viz. the all-important seasonal cycle affecting human life in so many ways. The celestial observation that yields the tropical Zodiac is also simpler than the observation of the unequal and irregular constellations of the sidereal Zodiac, viz. the location of sunrise at the eastern horizon, which shifts through the year from northeast (farthest in June) to due east (September) to southeast (farthest in December) and back to due east (March).

Therefore, in the Vedic calendar, the winter solstice was celebrated purely on the winter solstice day (or the nearest full moon), chastely defined as the moment when the *uttarâyaṇa* starts, the sun's northward course, regardless of the sidereal background. It always falls on ca. 21 December of the Gregorian calendar, which in the tropical Zodiac coincides with the entry of the sun into the abstract tropical sector of Capricorn. This contrasts with the situation of the last sixteen centuries, when the Hindu calendar has sidelined the actual winter solstice in favour of *Makara Sankranti*, the entry of the sun into the sidereal constellation of *Makara*/Capricorn, nowadays on the Gregorian date of 14 or 15 January and moving on at the rate of a day in nearly 70 years, regardless of that date's irrelevance to the seasonal cycle. Likewise, the New Year's day is defined as the entry in sidereal Aries and moves at that same rate, now falling in mid-April instead of on 21 March, and ultimately making the round of the whole year over a cycle of 25,791 years. (Some "rationalists" among Hindu calendar-makers now argue for a return to the real winter solstice and spring equinox.)

So, to sum up, the shifting of the sidereal Capricorn constellation away from the tropical Capricorn point of the Winter Solstice is an instance of a giant cyclical motion known as the precession. The whole tour is made in about 25,791 years, during which Capricorn will pass through all tropical sectors marking the seasons, or conversely: during which the vernal equinox point will pass through all the ecliptical constellations in reverse order. The equinox point was in sidereal Taurus for the Harappans and in Aries for the Buddha, it has been in

Pisces during the Christian age and still is today, and will be in Aquarius from the 23rd century onwards. If data about the precession are properly recorded, they provide the best and often the only clue to an absolute chronology for ancient events.

The borderline between the sidereal constellations are hazy and arbitrary, so it is hard to decide when exactly the sidereal and tropical Zodiacs coincided. Hindu astrologers and calendar-makers accept the star Revati as the determinator, not of the beginning but of the end of the sidereal year cycle; but do not all agree on the exact number of degrees between the star and the actual start of the Aries constellation. However, even admitting an uncertainty of several degrees of arc, the coinciding did at any rate take place sometime in the early centuries of the Christian Era. This is the time when editors gave the main Purana (historical-cum-mythological) books their final form, so the Vishnu Purana 2:8:63 records that day and night are equal when the sun reaches Aries or Libra; that the sun's reaching Capricorn starts its northern course, and Cancer its southern course. This would always be true by definition for the tropical Zodiac, but only accidentally and in precisely those few centuries for the sidereal Zodiac, which India was then adopting.

7.6. The precession in practice

The shift in the vernal equinox vis-à-vis the constellations can be gleaned from a number of Vedic and post-Vedic indications. They mention constellations on the equinox points which were there from 4,000 BC for the Rg-Veda. The first one is *Mṛgashîrṣa* or "head of the deer/beast", that beast being Orion (*Lambda Orionis*), who (or whose head star) is otherwise also known as *Prajâpati*, "the lord of the creatures" or "leader of the pack"; as already pointed out by B.G. Tilak (1893). Then follow the star *Rohiṇî* or Aldebaran corresponding to 3000 BC; then *Kṛttikâ* or the Pleiades corresponding to ca. 2300 BC; and finally the asterism *Bharaṇî* corresponding to ca. 1350. (To be sure, the equinox axis never points exactly towards the constellation Orion, which lies south of the ecliptic; but the relatively starless area between the constellations of Gemini and Taurus was named after the conspicuous constellation Orion which lies nearby to the south on the same longitude.)

It has been argued, most famously in the classic study by de Santillana & von Dechend 1969, and further developed by Davidson 1985 and Worthen 1991, that some ancient myths in various cultures are figurative descriptions of the shift of the equinox from one asterism to the next. One such "myth of replacement" is found in Rg-Veda 10:61:5-8. Abhayankar 1993:7 explains: "Due to precession, the first point of Aries or the vernal equinox moved and this fact has been stated in the Rig Veda (tenth mandala) in the form of a story. Prajapati fell in love with Rohini (Aldebaran) and chased her, but the gods dissuaded him with their arrows. Ultimately, the sun gave shelter to this beautiful lady. Analysing this story we can recognize the knowledge Vedic seers had about precession. Prajapati is a star at the apex of the constellation Orion which is known as Kalpurush, the mighty personality who calculates time. The calculation of time was introduced when Prajapati was at the vernal equinox which due to precession shifted to the bright star Rohini, the beautiful lady described in that story. The appearance of the sun and the shelter given to Rohini clearly indicate its association with the vernal equinox."

Even regardless of this celestial romance, the very use of the term *Kâlapuruṣa*, "time-man", for the head star of Orion, as well as its alternative name *Prajâpati*, "lord of the

crowd", "shepherd of the flock", the acknowledged god of the year cycle, seem to be unmistakable reminiscences of the time when this star opened the year cycle, i.e. when it marked the equinox ca. 4000 BC. And yet, before we follow Tilak in concluding that the Rg-Veda, and then moreover its youngest 10th book, must have been composed in ca. 4000 BC, we must differentiate between different types of chronological testimony. When actual astronomical observations are given, it stands to reason that the author is describing what his own eyes have seen. However, when a celestial phenomenon is translated into a mythical story, and that story is repeated without an explicit reference to observational astronomy, it is perfectly possible that the story had taken on a life of its own and was being renarrated generations after the initial observation. Therefore, Tilak's dating of this hymn is only a possibility, without compelling proof. It is only a *terminus post quem*: it would be unreasonable to assume that the Vedic seer related a story based on an astronomical phenomenon that was yet to take place, but it is entirely possible that his story referred to a phenomenon that had already taken place, whether ten minutes earlier, ten years earlier, or even ten centuries earlier.

I am aware that enthusiasts of a high chronology for the Vedas might deplore the point I just made as a concession to the evasive strategy of their low-chronology opponents. Apart from simply ignoring the astronomical evidence, defenders of the AIT and therefore of a low Vedic chronology have indeed argued that astronomical references in the Vedas were but fossilized references to far older observations. Thus, Romila Thapar (1992) affirms her belief in "the generally accepted chronology that the Rig-Vedic hymns were composed over a period extending from about 1500 to 1000 BC", and opines that when "references to what have been interpreted as configurations of stars have been used to suggest dates of about 4000 BC for these hymns, (…) planetary positions could have been observed in earlier times and such observations been handed down as part of an oral tradition", so that they "do not constitute proof of the chronology of the Vedic hymns". But I concede that argument only for those instances when astronomical references have gotten far removed from their observational origin. It becomes unacceptable special pleading when it concerns testimonies of actual observations, unless Prof. Thapar wants us to believe that the Vedic seers cared to inform us of observations made by their distant ancestors yet withheld from us any observations made with their own eyes.

The other textual references susceptible to precessional dating are fortunately closer to their observational basis than the Rohini story. In the 3rd millennium BC, Krttika was on or very near the vernal equinox, a natural starting point. It stands to reason that lists of ecliptical asterisms opening with Krttika date from that period. Such is the case with Atharva-Veda 19:7, Taittiriya Samhitâ 4:4:10, Maitrâyanî Samhitâ 2:13:20, Kâthaka Samhitâ 39:13 (as listed in Kansara 1992:282).

Remark that the second half of the 3rd millennium BC, the high tide of the Harappan cities, is also identified by K.D. Sethna (1981) as the period of the Sutras, the Vedas being assigned to the proto-Harappan period, all on the basis of the evidence of material culture (with special focus on cotton/*karpâsa*) as attested in the literary and archaeological records. According to Asko Parpola, Indus-Saraswati seal 430, reasonably datable to that period and depicting seven girls in a row, may refer to the observation of the Pleiades, known even today as the "Seven Sisters".

Another observable shift due to the precession pertains to the Pole Star, a position of honour rotated between a few northerly stars by virtue of the precession of the polar axis, and

frequently left unoccupied for thousands of years. The star *Yama*, also known as Thuban or *Alpha Draconis*, was very close to the North Pole in the early 3rd millennium BC, and passably close in the preceding and subsequent centuries, but certainly not in 1200 BC where the dominant school wants to place the Rg-Veda. This was one of the arguments introduced by Hermann Jacobi (1894) in favour of a high chronology. Abhayankar (1993:7) sums up: "Taking Alpha Draconis as the pole star, Jacobi calculated that these verses were composed in 2780 BC +/- 500 years." Yama identifiable as the star Thuban is mentioned in the youngest book of the Rg-Veda (10:82:2, 10:135:1), but otherwise the notion of Pole Star is not in evidence in the Rg-Veda. It makes its appearance in later Vedic literature (as in the wedding ritual where the Pole Star is pointed out as a symbol of faithful steadfastness), then disappears again except as a literary reference to precisely that Vedic literature.

Other data revealing the precessional phases include the constellational positions of the solstices or of solar and lunar positions at the beginning of the monsoon and at solstitial and other datable festivals, and these too confirm the high chronology. Thus, the Kaushîtakî Brâhmana 19:2-3 puts the winter solstice at the new moon of the sidereal month of Mâgha (i.e. the *Mahâshivarâtri* festival), which now falls 70 days later. This points to a date in the first half of the 3rd millennium BC. Admittedly, the indication is not mathematically precise and allows for a variation of up to 15° in either direction, as correctly objected by Hock 2005:298. But even in the improbable case of the maximum deviation in the most favoured direction, this would still be in the first half of the 2nd millennium BC, before the conventional date of the Rg-Veda and nearly a millennium before the conventional date of the Kaushîtakî Brâhmana itself.

Further, Hock 2005:298 mentions intercalation and the varied use of both full and new moon as the beginning of a month, *paurnimânta* or *krsnâdi* c.q. *amânta* or *shuklâdi*, as factors of uncertainty. As Abhyankar 1993:58 points out, the *amânta* system has prevailed from at least the Vedânga Jyotisha down to the present, and there is no reason to think otherwise for the pre-VJ literature with which we are concerned here. He allows for the possibility that "it appears that in the ancient Vedic period the months might have been *paurnimânta*", but this on no better ground than that "the Indian name for full moon is *pûrnamâsi* or *paurnima*, which means both the full moon and the complete month". Since this terminology has been used for at least 3300 years under the *amânta* system, there is no reason to see it as an argument against the use of that same system at its time of coining.

The precession-based estimates of the chronology of ancient Indian literature neatly correspond with its undisputed relative chronology. If the Vedic seers hadn't meant what they wrote, or had been too incompetent to record astronomical observations, we would expect a garbled chronology resulting therefrom. But that is not the case at all. When text A is known among philologists to precede text B which in turn precedes text C, and the three contain astronomical dating, it is found that the latter chronology corresponds to the philological one.

For instance, Abhayankar (193:62) shows: "From Vedic literature, we learn that there was an epoch when the yearly sacrifice (*samavatsara satra*) was begun in the lunar month of Phalguna (*amânta Phâlguna* day K8 [i.e. the 8th day of the *krsna*/"black" or waning half] on an average). At that time, Phalguna, Jyeshta, Bhadrapada and Margashirsha represented the months of winter solstice, spring equinox, summer solstice and autumnal equinox, respectively." This means e.g. that a full moon around spring equinox fell near the star Jyeshta (Antares or *Alpha Scorpionis*), the dominant star of the constellation named after it. Given that Antares now is 69° past the equinoctial axis, this points to around 69 x 71 years

ago, give or take a century, or ca. 2900 BC. At the time of the Vedanga Jyotisha, "the position of the sun at the four cardinal instants were Dhanishtha at winter solstice, Bharani at spring equinox", etc., or ca. 1350 BC. "The *Kṛttikâdi nakṣatra* list [i.e. the 27-part lunar Zodiac starting with the Pleiades/*Kṛttikâ*] of Yajurveda (…) does indicate that the spring equinox occurred when the sun was in Krttika nakshatra", as was the case ca. 2300 BC. "This means the Yajur Veda period lies between the Rigvedic and Vedânga Jyotisha periods, a proposition accepted by all."

It may be mentioned here in passing that the Vedânga Jyotisha has been dated even earlier than the usual 1350 BC, though still supportive of the relative chronology just outlined. Achar (2000/2) explains that the identification of Dhanishtha as *Bèta Delphini*, which lies at ca. 30° from the ecliptic, is from Siddhântic astronomy, well into the Christian age, whereas Vedic astronomy only used stars close to the ecliptic as markers of the 27 lunar zones. He therefore proposes to identify it with *Delta Capricorni*, which satisfies this condition, but it lies several degrees ahead in longitude, corresponding to a date of ca. 1800 BC. Obviously, this would provide an even more compelling pointer to a synchronicity of the Harappan cities and much of Vedic literature. But our argumentation is not dependent on this unorthodox identification.

7.7. The disputed age of Baudhâyana

In the *Shulba* appended to Baudhâyana's *Shrauta Sûtra*, mathematical instructions are given for the construction of Vedic altars. One of its remarkable contributions is the theorem usually ascribed to Pythagoras, first for the special case of a square (the form in which it must have been discovered), then for the general case of the rectangle: "The diagonal of the rectangle produces the combined surface which the length and the breadth produce separately." This and other instances of advanced mathematics presented by Baudhâyana have been shown by the American mathematician A. Seidenberg to be the origin of similar mathematical techniques and "discoveries" in Greece and Babylonia, some of which have been securely dated to 1700 BC. So, 1700 BC was a *terminus ante quem* for Baudhâyana's mathematics, which would reasonably be dated to the later part of the Harappan period ending ca. 1900 BC.

However, Seidenberg was told by the Indologists that these Sutras, or any Vedic text for that matter, were definitely written later than 1700 BC. But mathematical data cannot be manipulated just like that, and Seidenberg (1962:515, quoted by Rajaram & Frawley 1995:85) remained convinced of his case: "Whatever the difficulty there may be [concerning chronology], it is small in comparison with the difficulty of deriving the Vedic ritual application of the theorem from Babylonia. (The reverse derivation is easy) ... the application involves geometric algebra, and there is no evidence of geometric algebra from Babylonia. And the geometry of Babylonia is already secondary whereas in India it is primary." To satisfy the Indologists, he said that the *Shulba Sûtra* had conserved an older tradition, and that it is from this one that the Babylonians had learned their mathematics: "Hence we do not hesitate to place the Vedic (...) rituals, or more exactly, rituals exactly like them, far back of

1700 BC. (...) elements of geometry found in Egypt and Babylonia stem from a ritual system of the kind described in the Sulvasutras". (Seidenberg 1962:515, quoted by Rajaram & Frawley 1995:85)

This is then one of those "entities multiplied beyond necessity" that Occam's razor warns against: a ritual, annex altar, annex geometry, which is exactly like the Vedic ritual, annex altar, annex geometry, only it is not the Vedic ritual but a thousand or so years older. Let us simplify matters and assume that it was Baudhâyana himself who devised his mathematical theories "far back of 1700 BC". Is there a way to find independent confirmation of this suspicion? Yes, there is: the precession of the equinoxes.

A.A. MacDonell and A.B. Keith (1912:vol.1:423-424, entry *Nakṣatra*) cite the opinion of several philologists about a reference to a solstice in Magha in the *Baudhâyana Shrauta Sûtra* (like in the Kaushitaki Brahmana 19:3), to which the Shulba is an appendix. *Maghâ* is the asterism around the star Regulus, but the derived name *Mâgha* is used for an entire month (names of months are typically the name of the most prominent one of the two or three asterisms/*nakṣatra*s which make up that one-twelfth of the ecliptic), spatially equivalent to a zone of about 30° around that star, so any deduction here must take a fair degree of imprecision into account. The 18th- and 19th-century philologists cited disagree about whether a *Mâgha* solstice was in 1181 BC or in 1391 BC. The authors themselves consider it "only fair to allow a thousand years for possible errors", demonstrating the typical cavalier attitude of philologists to data from hard science. They settle for a date between 800 BC and 600 BC, "quite in harmony with the probable date of the Brahmana literature". After moving the date around over a whole millennium, it is no surprise that this "harmony" with the established hypothesis emerges. Understandably self-confident, they find the Easter egg that they themselves have concealed.

However, it is very easy to calculate that Regulus, currently at almost exactly 60° from the solstitial axis, was on that axis about 60 x 71 years ago, i.e. in the 23rd century BC. Though we must indeed allow for an inexactitude of up to 15°, equivalent to about 1075 years on either side, the Mâgha solstice described is much more likely to have been in 2200 BC than in 1100 BC, while Keith's and MacDonell's 600 BC is totally beyond the pale. It may have taken place even before the 23rd century BC: maybe only the asterism around Regulus had reached the solstitial axis but not yet the star itself. Most likely, then, this reference to a Mâgha solstice confirms that the Brahmana and Sutra literature including the Baudhayana Shrauta Sutra (annex Shulba) dates to the later 3rd millennium BC. In that case, Seidenberg's reconstruction of the development and transmission of mathematical knowledge and the astronomical references in the literature confirm each other in placing Baudhayana's late-Vedic work in the later part of the Harappan period.

7.8. The objection of vagueness

A factor of uncertainty in precessional chronology is that the equinox moves very slowly (1° in nearly 71 years), so that any inexactness in the Vedic indications and any

ambiguity in the constellations' boundaries makes a difference of centuries. This occasional inexactness might, for example, be enough to neutralize the shift of ca. five centuries in Kalidâsa's date, who could be dated to ca. 100 BC on narrowly interpreted astronomical grounds, rather than the conventional date of ca. AD 400.

The great playwright and poet wrote that the monsoon rains started at the beginning of the sidereal month of Aṣâḍha, which was most accurate in the last centuries BC: "We can, therefore, say that about 2000 years have elapsed since the period of Kâlidâsa", according to P.V. Holay (1992:109). This implicit astronomy-based chronology of Kalidasa could be enlisted as evidence for a higher chronology of the imperial Guptas, at whose court he supposedly worked. That unconventional chronology has been proposed by K.D. Sethna 1989, with the Gupta king Candragupta taking the place of the *Sandrokottos*/Chandragupta whom Greek ambassador Megasthenes met ca. 300 BC, pushing his namesake Chandragupta Maurya six centuries deeper into the past. The Maurya-Megasthenes synchronism is known as the "sheet-anchor of Indian chronology", so amending it would have far-reaching (but as it turns out, also far-fetched) implications for Indian chronology in the Buddhist and pre-Muslim ages. If an astronomical re-dating of the playwright is taken as evidence in support of such a drastic chronological revisionism, one can expect that the ever-conservative academic world will want to invoke the vagueness of precessional dating to downplay or nullify it. However, shifting Kâlidâsa to ca. 100 BC would not necessarily have such drastic implications, as philologists had already questioned his synchronism with the Guptas on other grounds, arguing that he fits better in the Shunga or immediately post-Shunga age, which happens to be just around 100 BC. So, either way, the playwright's birth date can be accommodated into the prevailing chronological paradigm.

At any rate, if need be, the inexactitude of precessional dating can passably be invoked to ignore a shift of five centuries, or rather to impose a shift of five centuries from the astronomically most likely date to the date so far accepted on (no less hazy) literary grounds. But it can never account for a shift of millennia (with each millennium corresponding to about 14 degrees of arc) needed to move the incipient Rg-Veda from the pre-Harappan to the post-Harappan period, from beyond 3000 BC as calculated by the astronomers to 1200 BC as surmised by Friedrich Max Müller.

7.9. Coordinating Harappa and the Vedas

If precessional dating does offer a valid clue to ancient Indian chronology, we will have to place the Rg-Veda in the early Harappan period and much of the later Vedic literature in the mature Harappan and immediately post-Harappan period. Of course, we will need to take into account many complicating factors, such as the incurable tendency of ancient traditionists to add chapters and interpolations to the texts entrusted to them, too evident (and even explicitly acknowledged) in the Mahabharata but sneakingly present in many other text corpora too. After the truly Harappan-age materials in the literary record have been identified, we would have to open a whole can of initially uncomfortable questions,

particularly of how to match different types of data, principally literary and archaeological. One obvious job would be to match Vedic and Harappan astronomy.

So far, we do not dispose of anything like astro-observational data from the Harappan ruins. Asko Parpola (1994) identifies plenty of stellar motifs in the Harappan seals, showing at least that stellar lore was central to their worldview. He often tries to make sense of Harappan data by referring to Vedic data (e.g. Parpola 1983, 1985), on the AIT-based assumption that the Aryan invaders integrated Harappan astronomy and religion. This may be a case of multiplying entities without necessity: instead of saying that there are two cultures which happen to share some astro-religious lore, we could equally assume that these two cultures are one, until proof of the contrary. Arguments developed by Parpola (1989-90) for a Harappan origin of Vedic and Hindu cultural items, e.g. of astronomy-based nomenclature (names like *Kârttika*, "of the Pleiades"), are just as much arguments for an identity of Vedic and Harappan. The point to remember is that even Parpola, often cited as an argument of authority by Indian defenders of the AIT, fully acknowledges the continuity between Vedic and Harappan culture, at least regarding the relatively "hard" evidence of astronomy and stellar symbolism.

7.10. Conclusion

The astronomical lore in Vedic literature provides elements of an absolute chronology in a consistent way. Moreover, it is encouraging to note that the astronomical evidence is free of contradictions. There would be a real problem if the astronomical indications had put the Upanishads earlier than the Rg-Veda, or Kalidasa earlier than the Brahmanas, but that is not the case: the astronomical evidence is consistent. Inconsistency would give support to the predictable objection that these astronomical references are but poetical fabulation without any scientific contents. However, the facts are just the opposite. To the extent that there are astronomical indications in the Vedas, these form a consistent set of data detailing an absolute chronology for Vedic literature in full agreement with the known relative chronology of the different texts of this literature. They contradict the hypothesis that the Vedas were composed after an invasion in ca. 1500 BC. Not one of the astronomical data in Vedic literature confirms the AIT-based low Vedic chronology.

Indeed, the whole corpus of astronomical evidence is hard to reconcile with the AIT, and has been standing as a growing challenge to the AIT for two centuries, i.e. from before the AIT had even been thought up. A convincing refutation would require an alternative but consistent (philogically as well as astronomically sound) interpretation of the existing astronomical indications that brings Vedic literature down to a much later age. But so far, such a reading of those text passages has not been offered. There is as yet no astronomical information which puts the Vedas at an AIT-compatible date.

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