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Records of *Vyatīpāta* in Stone Inscriptions

B S Shylaja* and Geetha Kydala*

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Abstract

In Indian astronomical texts we come across the term *Vyatīpāta* whose equivalent does not exist in European texts. The term implies the instant at which the magnitude of the declination of the Sun and Moon are equal. *Siddānta Śiromaṇi* and many other texts give an elaborate description of the method of determining *Vyatīpāta*. Here we describe their records in stone inscriptions and show that they can be treated as the best records of observations. The discovery of a possible record of observation of *Vyatīpāta* in an old calendar also is discussed.

Key words: Fixing the nodes, Indian astronomical records, Observational techniques, Prediction of eclipses, Stone inscriptions, *Vyatīpāta*

1. Introduction

In the astronomical texts the terms *Vyatīpāta* and *Vaidhṛti* are explained.

The instant, *Vyatīpāta,* when the declinations of the moon and sun are of equal magnitude, was considered extremely important by astronomers. This term appears very often in stone inscriptions, which record eclipses all over India covering a span of about 1000 years (Shylaja and Geetha, 2013). The context of the inscriptions may be grants, donations to temples or records of death of war heroes, self-immolation of saints or women committing sati. This only implies that they were special occasions.

A detailed study of these inscriptions has yielded valuable information on not only eclipses but other celestial events like planetary conjunctions. We have been able to compile *Vyatīpāta* records of almost every year upto the 13th century and later some specific years. This raises two questions.

Why were *Vyatīpātas* observed and documented?

Why there is a sudden disappearance of the term in the stone inscriptions found later than about 16th century?

2. Basic definition

To find an answer for these questions let us begin with the definition of the word *Vyatīpāta* itself. This is not to be mistaken with the *yoga* (one of the five elements of calendar, *pañcāṅga*) with an identical name. As given in the chapter on *pātādhyāya* of *Siddhānta Śekhara* of Śṛīpati, it reads:-

When the sum of the longitudes of the sun and the moon is six *rāsis* (180^{o}), they are in opposite *ayana,* but in the same *gola* and their *krāntis* (declinations) are equal, the moment is *Vyatīpāta pāta.* When the sum of the longitudes of the sun and of the moon is equal to 180^{0}, it is quite natural that both are being in the opposite *ayana*s. But why Śṛīpati here mentioned both conditions is not clear (Bhat, 2013). Only when the inclination of the moon's orbit is ignored, does the *vyātipāta* occur when the sum of the longitudes

*Jawaharlal Nehru Planetarium, High Grounds, Bangalore 560001

of the sun and moon is equal to 180^0. Hence, the definition given in *Siddhānta Śekhara* of Śrīpati is only approximate.

There is another conjunction defined as *Vaidhṛti*, when the sum of longitudes of the sun and moon is 12 *rāsis* (360^o), they are in the same *ayana* but opposite *gola* and the *krāntis* are equal.

In the stone inscriptions we found no record of *Vaidhṛti*.

The astronomy texts like *Siddhāta Śekhara, Tantra Saṃgraha* and even *Siddhānta Śiromaṇi* describe the method of calculation of eclipses in one chapter and the *Vyatīpāta* in another chapter, although the two are inter-related. For the eclipse calculation, it is important to know the time of conjunction and the longitudinal difference from sunrise or to sunset. It is also very important to know the maximum latitude of the moon, which in turn decides the visibility of eclipses.

Vyatīpāta calculation deals with the *krānti* or declination. It is easy to measure the declination of the moon on days near to full moon rather than the days near the new moon. *Vyatīpāta* provides the position of *Rāhu*, which in turn will decide the maximum declination and the latitude of the moon at conjunctions.

The basic observational tool that was available for the astronomers was a gnomon and they measured only two quantities angle and time quite precisely. The rest of the quantities were estimated by calculations.

3. *Vyatīpāta* and the Ascending node *Rāhu*

One of the important objectives in understanding the motion of celestial bodies was the prediction of eclipses. The condition for eclipses had been laid done by the 5^{th} century or even prior to that. We try to understand this now in modern version of coordinates.

The movement of the sun and the moon across the zodiacal constellations are represented by the continuous change in the coordinates. The terms longitude and latitude or Right Ascension and Declination are frequently used to represent this motion.

The Sun's Right Ascension (RA) is zero on March 21^{st} and increases to 6^h by June 22^{nd}, to 12^h by September 22^{nd} and to 18^h by December 22. The moon covers the same circle within a month. Thus, if the conjunction of sun and moon is taken as the starting point, the daily change in RA of both bodies needs to be monitored to calculate the next instant of conjunction. This is easier said than done. The conjunction is the instant of new moon which is very difficult to observe. It is easy to observe the full moon instead. The movement of moon can be noted very precisely which is again possible only up to the 13^{th} day. Again (the old moon of) 14^{th} day after full moon is quite difficult to observe. This became a very ritualistic exercise associated with the name "*Śivarātri"* (Abhyankar, 1997). This observation, however, records the east-west motion, namely the longitude. It is also known that the movements of both sun and moon have a north-south component defined by declination δ. The orbit of sun is inclined to the celestial equator by 23.5 degree while that of the moon is further inclined by 5 degrees. It is also known that this is the reason for not having eclipses every month.

The prediction of eclipses begins with the calculation of instants of new moon which is not directly observable. The center of the discs of sun and moon need to coincide or lie within half a degree for the eclipses to occur. For calculating this, the north-south coordinate namely declination is very vital. The daily observational record of the motions of sun and moon become very important. For example let us say *Vyatīpāta* or the magnitude of declinations of sun and moon match on the 7^{th} day after new moon. If the month happens to be March, the declination of the sun is $0^0 \pm 2^0$. Thus on the 7^{th} day moon also has a declination of $+2^0$ or -2^0. It passes through the cycle of maximum declination (this value can range from 28.5^0 to 18.5^0, as explained later) to minimum through the month and thus it is unlikely to have the same declination as the sun is either on the new moon day or the full moon day. Thus there is no possibility of eclipse during the month. However in the next month if the instant of *Vyatīpāta* moves closer to new moon, one needs to again calculate the possibility of eclipses.

Now let us address the question of the definition which involves magnitude of δ. This helps the prediction of lunar eclipses. For this purpose the shadow of the earth is relevant. For mathematical purposes the shadow itself is considered as a celestial body and the moon's motion along the shadow is calculated. The sun earth shadow geometry provides an easy tool for fixing the coordinates of the shadow which is exactly 180^0 away from the sun, in the Earth centered coordinate systems. The declination of the shadow, as can be easily understood, is exactly on the other side of the equator. Thus is the sun's declination is 7^0, the declination of the shadow is -7^0. Therefore if we find that the moon's declination is same as that sun in magnitude but is on the other side of the equator there is a possibility of lunar eclipse.

There is another complication introduced by the retrograde motion of the line of nodes. For all other planets the coordinates are calculated using the idea that generally they are in direct motion (longitude / RA increasing) and the duration when they are retrograde also is calculated. However for the nodes the longitude is always decreasing.

Month after month the position of node shifts, which can be noted only by meticulous observation of the declination of the sun and the moon. The shift is quite small about 20^O per year (retrograde – it moves to the west); 360^O in about 18 years. With about 3.3′ per day in about six months the node will coincide with the First Point of Aries. Thus after another 18 years (and 11 days) the node is back in the same position. In the meanwhile after 9 years (and 5 days) the nodes would have interchanged their positions. This is apparent from the fact that lunar and solar eclipses alternate around the same date after 9 years. For example there was a solar eclipse on 2013 November 3; exactly 9 years and 5 days earlier on 2004 October 28 there was a lunar eclipse.

This gives us the clue on the possible reason for noting down the instants of *Vyatīpāta* of which we find a wealth of records in the stone inscriptions.

The maximum declination for the moon can be 18.5^O or 28.5^O and this is fixed by the position of the Ascending node (*Rāhu)* with respect the First point of Aries. Let us consider two extreme cases when the Ascending node coincides with the First Point of Aries. The maximum declination of the moon can be 28.5^O. The other extreme when it coincides with the solstice will result in the maximum value of declination as 18.5^O. During the 18 years cycle the maximum declination ranges between the extremes and can have any value in between.

This value has been called *vikṣepayanānta* and is directly related to the longitude of Ascending node (*Rāhu)*.

In general all astronomical texts provide a chapter on calculations of the possibilities of eclipses, which is based on the longitude and latitude. The chapter on *Vyatīpāta* describes the method to get the maximum value of the declination of the moon.

These two quantities namely maximum declination, L and the longitude of the node, λ, are inter-related. (Ramasubramanian and Sriram, 2011).

$$\sin^2 L = \{\sin\lambda \sin i\}^2 + \{\sin i \cos\lambda \cos\varepsilon + \cos i \sin\varepsilon\}^2 \quad \ldots(1)$$

where i = the inclination of moon's orbit is 5°, λ is the longitude of the node and ε the obliquity of the ecliptic.

Thus one needs to *measure* the maximum declination of the moon and note down the instants of *Vyatīpāta*; both of these can be achieved with a simple gnomon. Observations for the moon near full moon will fetch fairly accurate readings while those in the quarter phase may need a sighting tube as was used in the instruments of Jaisingh. When the declinations are equal we get an expression for η the angle between the node and the moon as

$$\sin \eta = \sin \varepsilon \ \sin \lambda_{sun} / \sin \ L \qquad \ldots(2)$$

The term η is the difference between the longitudes of the moon and ascending node. Since the former is known we can calculate the longitude of the node and hence the possibility of eclipse for the forthcoming full moon and new moon.

In simpler terms this means that the maximum declination of the moon within a range between 18.5° and 28.5°, will be decided by the location of the node - how far it is from the First Point of Aries. For example if the *Vyatīpāta* occurred, say, on March 31st its location is about 10° degrees east of the First Point of Aries. (On March 22nd the longitude / RA / declination of the sun are all zero). On March 31st the longitude of sun is about 10°. The declination of the sun will be about +4° and therefore the declination of moon may be +/- 4°. Using the equation (2) above we find that for both the extreme values of I, the difference in the longitudes of moon and the node will have a range of 10-12°. Thus if the new moon or full moon occurred during this period from 21st March to 31st March or so, there is a possibility of eclipse.

We discuss some examples as derived from stone inscription records in Section 5.

4. A CALENDAR INDICATING *VYATĪPĀTA*

A study of an old calendar of 19th century from the collection of Indian manuscripts by F Kielhorn in Gottingen has the tabular form giving the details essential for Hindu *pañcāṅga* makers. It is a long strip referred to as *Phalapatrikā*, as mentioned in the cover page of the document.

Kielhorn has written an introductory note attributing the source to a Joshi from Gujarat or Rajastan. He has mentioned in the note about many numbers in the calendar which are not clear to him. The Kali era is given as 255884963; the Śaka year number is 1784; *Vikrama Samvat* as 1919. This corresponds to March 1862 AD to March 1863 AD.

The table lists *tithi* (lunar phase), *karaṇa* (the half division of the *tithi*) and the names of the *karaṇa*. The names of the weekdays also are written down. The remarks column gives additional interesting information on the celestial events (Fig. 1).

The year of the calendar as judged by Kielhorn agrees well with the two *Śaka* scales. However, the name of the *Samvatsara* does not match. It is given as *Bhāva*. This is 8th in the list of *Samvatsaras* which is a cycle of 60 years. This scheme of naming the years has been very useful

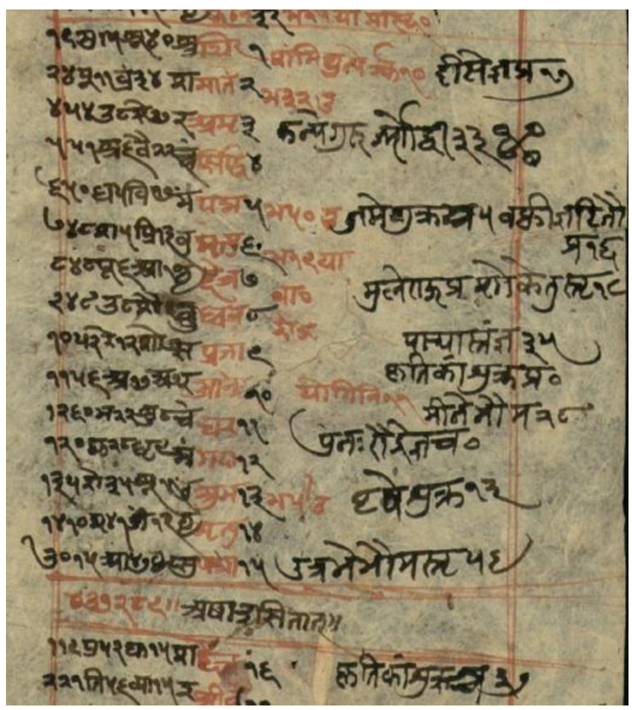

Fig. 1. Sample of the tabular calendar

in fixing the dates of stone inscriptions. (Shylaja, 1997, Shylaja and Geetha, 2012). For example, 1st June 1817 is recorded on a stone inscription with Śaka year marked as 1739 and the name of *Samvatsara as Eśvara* which is the 11th in the list. Therefore, this name *Bhāva* being allocated to 1862 appears to be an error in the calendar. The monograph on the transit of Venus of 1874 by Ragoonatha Chary mentions the name *Bhāva* for the *Samvatsara* (Shylaja, 2012). 1814 will be *Bhāva* as also 1874; the name for 1862 cannot be *Bhāva*.

The remarks column contains many conjunctions and entry of moon and sun into constellations. For example, it records "*Śrāvaṇe Bhaumaśca*" implying that Mars was near to *Śrāvaṇa*, Altair (Aquila). We also find entries like "*Mīne Bhauma*" – implying the entry of Mars in to Pisces. The first month i.e. the calendar itself begins with the first day after new moon. This convention is being followed even today by the followers of lunar calendars. In the year 1862, new moon occurred on 30th March. Therefore, this calendar begins on the 1st April 1862. Exactly after 12 days appears the entry "*Meṣe Arkaḥ*" – the sun enters Aries. Further, the conjunctions of Saturn and Venus, entry of Venus into Aries (9 June1862) are given. Venus near Kṛttikā (Pleiades) is indicated on (24 July 1862). The further passage is marked by Venus in Gemini (28 July 1862).

Another interesting aspect is the notation with symbols. One particular symbol looks like 'X' and appears on four dates. It coincides with the dates of lunar and solar eclipses, in 1862, both of which were not visible from India. Therefore, we conclude that 'X' symbol stands for conjunctions or oppositions. The events are off by a few days which may be because of observational errors. On one occasion it has a remark associated as "*gurodaya*" referring to the heliacal rising of Jupiter.

The table is full of numerical entries - a good tool to find the mechanism that was used for calculation.

The calendar is a long table with entries made in two different colours - dull orange coloured entries and black coloured entries. The lunar calendar months are separated by horizontal lives. The details of the day like the phase (*tithi*), *yoga, karaṇa* are all entered as numbers in a specific sequence. The numbers of the tropical months are inserted later.

It appears that the orange coloured numerals are calculated earlier. The black ones are added later on perhaps after making observations. For example, "*Meṣe Arkaḥ*" – the entry of the sun in to Aries is marked in orange. Next to it in black colour is the work "*Śate Śukraśa*" meaning Venus was in "*Śatabhiṣa*"; which was perhaps based on actual observation. This way, it is possible to identify marking corresponding to the positions of all planets mostly based on observations. Quite interestingly the positions of *Rāhu* and *Ketu* also are indicated. Although, it remains to be verified as to how they did it, the clue is provided by the month of September. The new moon entry has a long remark added later on (Fig. 2) clearly indicating the positions of *Rāhu* and *Ketu*. This assumes importance since the following new moon also has similar entries and the one later had an eclipse (21st December 1862), which was visible as a partial eclipse only from north India. (NASA eclipse Home page). Here the X like mark perhaps refers to *Vyatīpāta*. (This is different from the *yoga* which bears the same name). This is a condition demanding that the declination of the sun and moon are equal in magnitude. The implication is straight forward - if the magnitudes are equal and it is a new moon, it is an eclipse. 15 days later the magnitudes are again equal but opposite in sign – this implies possibility of lunar eclipse.

The only error in the table is the name of *Samvatsara* which is written as '*Bhāva*' very clearly. It should have been *Rudhirodgāri*.

It is quite possible that the observational remarks (for the calendar of 1862) were added in

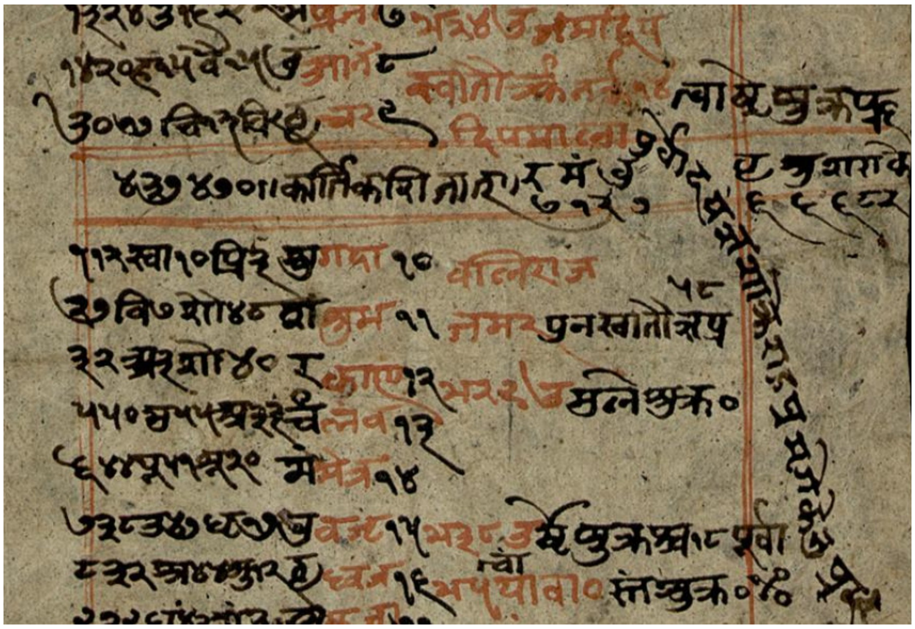

Fig. 2. The entry corresponding to the positions of *Rāhu* and *Ketu*

the year 1874, which was called *Bhāva*. However, this cannot be proved.

The last entries are pictorial. The shape of a bird and other geometrical patterns with some numbers are seen. The meanings are immediately not apparent (Fig. 3).

There are many other notations and abbreviations which need to be studied very carefully in order to understand the technique that was used for observations and subsequent calculations.

5. Discussion

We may now take some examples of records of *Vyatīpāta* from stone inscriptions.

A record from 1228 AD verified from the name of *Samvatsara* as *Sarvadhāri*, gives *vyatīpāta* on October 14th. On that day the sun's declination was about -11^0 and decreasing. The moon on 13th had a declination of $+8^0$ and on the 14th, $+19^0$. Thus during this period *the Vyatīpāta* had occurred.

In the year October 25th, 1128 AD, a partial eclipse occurred. However it was not visible from India – the inscription No. 411 of EKU Vol V from Sanigaram in AP mentions this as *Vyatīpāta*.

There are 3 records for 1018AD as *Puṣyaśu* 13, *vyatīpāta of Śaka* 940 *Kā7ayukthi*. The epigraphists have declared that this is irregular. However we find that this exactly fits into the definition of *Vyatīpāta*. The next day moon was farthest north with a declination of 28.3^0.

On December 25th, 1117AD there was a possible partial eclipse which was not visible from India. This is recorded as *Vyatīpāta* in the inscription no. 439 at Hanumakonda in AP (EKU vol V part II).

EC VIII no 161, Shanthigrama records *Dakṣiṇāyana Sankrānti* of 1227 AD, June 27th and *Vyatīpāta*. The declination of the moon was about -26^0 in the evening. The *Vyatīpāta* must have occurred sometime during the day. The following month there was a lunar and a solar eclipse.

During July 19th to 21st, 1214 AD, the moon's declination changed from -11° to -21°. The

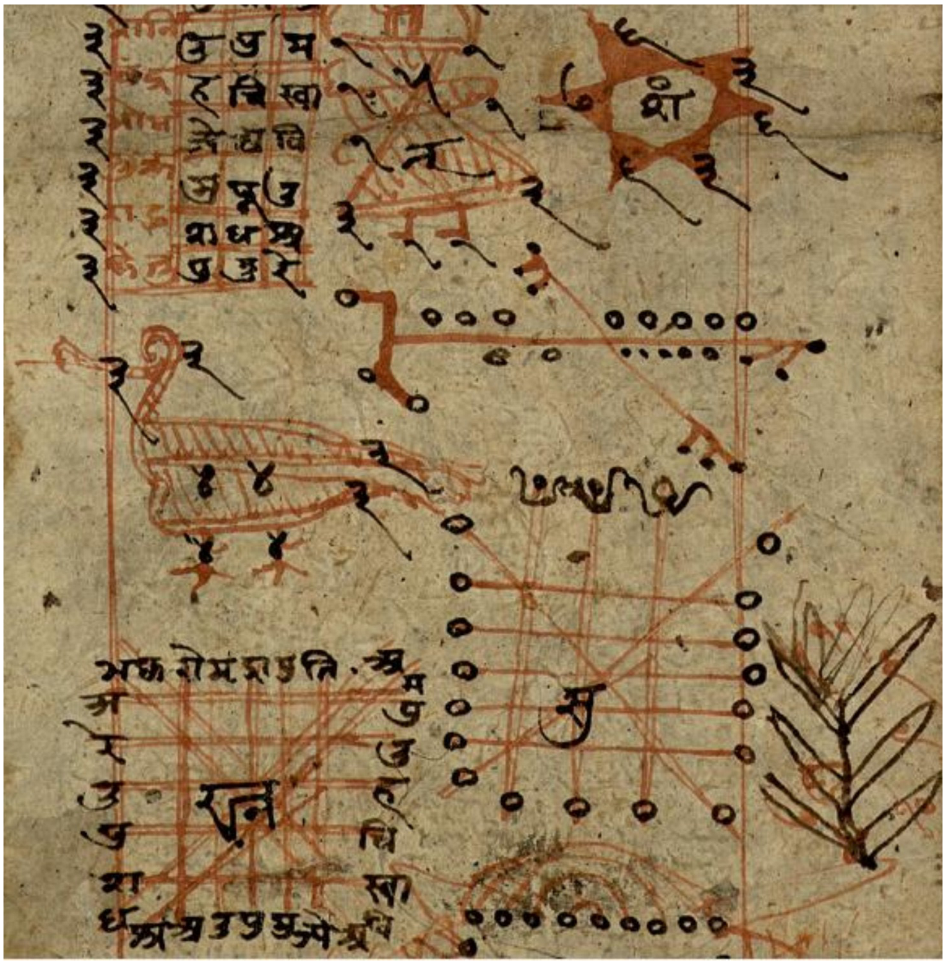

Fig. 3. The geometrical patterns at the end of the Table

sun's declination was +20°. Thus it was a case for *Vyatīpāta* on July 20th and it is recorded in EC vol XII no. 48, Dabbeghatta. A copper plate from the same village gives the position of sun in *Revati* which corresponds to March (Māgha); the moon on the 11th day after new moon. It says "*pātayuta"* which implies *Vyatīpāta*. Between 5th and 6th the declination of moon changed from $+11^0$ to $+7^0$. The sun had declination of -7^0 on the same day. The name of *Samvatsara* is *Siddhārthi* which puts it to 1080AD.

The year 1148 AD had a maximum value of declination of the moon as 28.2^0. There was an eclipse in April indicating that the node was not far from the First Point of Aries. Later in December *Vyatīpāta* occurred on 25th as recorded by two inscriptions at different locations (EC vol XII, no. 20 Elugere and EKU no. 80 Hada). The node coincided with the first point of Aries on March 21st, in the next year as indicated by an eclipse record – the eclipse was not visible from India but the date is recorded as *Vyatīpāta*.

The record of June 13th, 1238 AD (EC vol XII, no. 31 Kalluru) mentions *Vyatīpāta*; the solar eclipse was not visible to India. Same is the case with April 9th, 1149 AD (EKU vol I no. 199).

The record of solar eclipse of July 14th, 1162 AD (EC vol XII no. 12, Gubbi) includes the word *Vyatīpāta*. The moon was moving northwards and the sun southwards. The eclipse

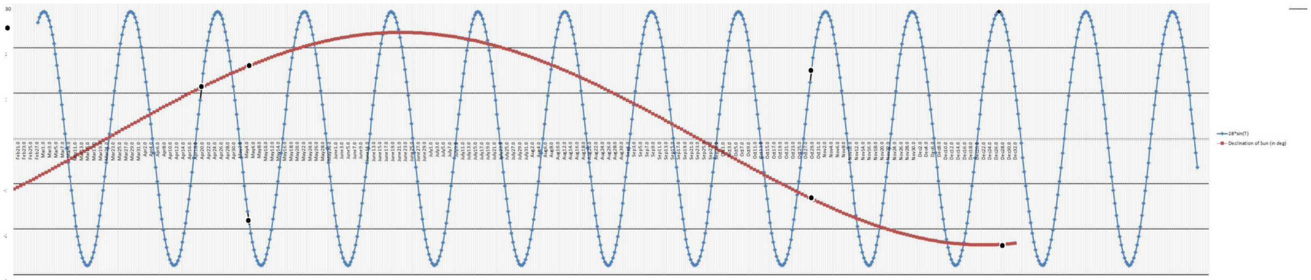

Fig. 4. The variation of the moon's declination in AD1148; the sun's declination and the points noted from stone inscriptions as *Vyatīpāta* are indicated

was not visible from India and therefore this is a record of *Vyatīpāta*.

In the year 1142 AD we have a record dated May 27th with *Vyatīpāta* (EKU Vol I no. 36 hada); there is another record indicating lunar eclipse on August 8th. Thus *Vyatīpāta* is justified. In the year 1143 AD the full moon occurred on December 23rd; the declination of moon was $+22^0$. The declination of the sun reached -23.5^0 on December 26th and therefore this date of December 23rd recorded as *Puṣya* full moon is a *Vyatīpāta*.

The record of Arasikere on *Vyatīpāta* dated April 21st, 1190 AD clearly shows that the *Vyatīpāta* occurred after the full moon instant; the declination changed from -11^0 to -16^0 on the full moon day when the sun had a declination of $+12^0$ (EC vol X no. 36). Such observations helped in predicting the eclipse for the coming months – in this case it occurred after 2 months in July. In the same year in August, *Vyatīpāta* has been recorded (EC vol X 157, Kellangere). The declination of the moon was -17^0 and changed to about -12^0 while that of sun was $+14^0$. Interestingly on this day Jupiter was in conjunction with the moon.

The year 1148 AD has six records; these were used as test cases for the theoretical aspects outlined in Section 3. To get the value of the maximum declination of the moon, graphical templates depicting the variation of the lunar declination were prepared and matched with the solar values by shifting each one along the time (longitude) axis. The values agreed well for a value of 28^o. Out of the six records two from different places record the solar eclipse of 30th of April. Two lunar eclipses of May 5th and October 29th are also recorded. It is interesting to note that both are penumbral eclipses, which are very difficult to observe and record. The other record is confusing. It mentions *Uttarāyaṇa* and *Vyatīpāta* on *śrāvaṇa Śuddha 5* which corresponds to June 23rd. It may be a reference to the summer solstice, *Dakṣiṇāyaṇa*. But the moon had a declination of $+8^0$ and therefore it was not *Vyatīpāta*. The other two records of *Uttarāyaṇa* also are not clear. One states that it is on *Pushya śu14* corresponding to 27th of December. The moon had northern most declination on 26th and therefore on 24th its value was equal to that of sun. The word *Vyatīpāta* is justified. The second record puts *Uttarāyaṇa* as *Puṣya śu 10* – three days earlier. This can be attributed to observational errors as seen from the Fig. 4.

There are two inscriptions in the same village Heralagatte mentioning lunar eclipse of February 15th, 1272 AD (EC Vol XII no 247 and 248). One of them mentions about *Vyatīpāta* which must have happened during the day since the moon's declination changed from 12^0 to 9^0 and the sun's declination was -12^0 and increasing to north.

The *Vyatīpāta* having occurred on the day after new moon is recorded on September 28th, 1383 AD, (EC Vol VIII no 48 Ramanathapura). This is a very important record to fix the position of the node since an eclipse had occurred on August 29th. Similarly the *Vyatīpāta* on the full moon day of September 25th, 1219 AD is recorded in EC Vol VIII no 28 Doddageddavalli. The previous month had an eclipse. In the same village exists a record (No 41) of October 23rd, 1201 AD, again indicating only *Vyatīpāta* on a full moon day. Quite interestingly another record of the same year mentions about *Vyatīpāta* two days after the new moon on January 6th (EKU vol I no 41 hada). Occult program puts it as possible partial eclipse visible only from Antarctica.

Let us consider the example from 12th Century (EC Vol VI no.74, Tonnuru) on a stone near a temple. It cites *Vyatīpāta* and the details of the date correspond to *Saumya, śrāvaṇa śuddha* 15; this implies the full moon and the epigraphists have given the date as July 29th, 1189 AD. There was no eclipse on that day. However the name of the year *Saumya* appears in another stone inscription (EC Vol VIII, No 60, Soraba) with the record of solar eclipse in the month *Māgha*. It exactly matches with the event of annular eclipse of February 17th, 1189 AD, which was visible from South India. Since the reckoning of the year is from the first day after new moon during March – April, we have to take a relook at the Tonnuru inscription. The year should be 1188 AD since *Saumya* commenced in March – April 1188 AD. We find a lunar eclipse in *śrāvaṇa* on August 8th, 1188 AD recorded *Vyatīpāta*. It is interesting to note that this was a penumbral eclipse not visible from India. The center of the earth's shadow and the moon were separated by a value marginally more than the shadow diameter of about 50′. The moon would have moved by about a degree in about 12 hours to attain the exact value of the declination of the shadow (negative but equal in magnitude to the declination of the sun). Thus the astronomers in India recorded the event as a *Vyatīpāta*.

When the eclipse was not visible in spite of the equality in declination only *Vyatīpāta* is mentioned.

EC vol XII no 47 Kunakanadu mentiones *Vyatīpāta* of February 18th, 1197AD. The epigraphists have not given any weightage to the word *Vyatīpāta* mentioned in the text and give the date erroneously as February 24th.

The record of the pair of eclipses in Feb – March 1197 AD are available; interestingly the February 17th solar eclipse is not recorded but cited as *Vyatīpāta* only.

For the year 1123 AD we have 3 records during August – September. One cites the death of a saint and compares it to the darkness created by *Rāhu* upon engulfing the full moon. Although this may be treated as a poetic rendering the other two give the dates of *Vyatīpāta*; one identifies it as *Vyatīpāta Viṣuva* implying the record just before the autumnal equinox. The following month there was an eclipse but not visible from India. This shows that a meticulous record of *Vyatīpātas* were maintained for prediction of eclipses.

The record from Laalanakere in Nagamangala (EC vol VII no 62) gives *Vyatīpāta* on January 30th, 1219 AD, which is verifiable from *Bahudhānya* and *Māgha śu* 13. On that the moon reached farthest north position and was moving south. The sun was moving northwards from -22^0 and hence this is a *Vyatīpāta*. Another record in the same temple indicates the *Vyatīpāta* on April 26th, 1165 AD with verifiable details (*Pārthiva, Vaiśākha śu* 13). Moon attained maximum declination on 18th ($+25^0$) and was moving southwards (13^0 on 21st) and the sun was moving northwards. The inscription EKU Vol I no. 15 of Hadagali mentions about *Vyatīpāta* on January 8th, 1201 AD. Occult predicts a penumbral eclipse on the same day.

Chronologically the last *Vyatīpāta* we see is dated September 6th, 1587 AD. (EC Vol XI no.

183, Khandya). The lunar eclipse also is mentioned. It was almost a total lunar eclipse with the node just about a degree away from the conjunction.

Now we need to answer the second question, why the records cease after about 15th century. Our study covers more than 1000 documentations spread all over South India, more specifically in and around Karnataka. The earliest record is from the 9th century and the most recent is 19th century. The number of records is predominantly large during the 10th to14th centuries. It is unlikely that there may be any selection effect to be responsible for missing records on *Vyatīpāta* beyond 15th century.

We have found about 340 *Vyatīpāta* records upto 13th century and none thereafter. The reason for this may reflect a great advancement in the mathematical tools available for calculation of eclipses. By 15th century, great mathematicians had developed complicated procedures which proved to be quite accurate and had taken care of the small corrections like precession. The precise corrections for parallax by Nīlakaṇṭha Somāyaji and the trigonometric solutions simplified to series expansion by Gaṇeśa Daivajña are some examples. Only at the last level of calculations, the series were terminated to the second term providing prediction timings within the observable errors. Therefore it is possible that monitoring of *Vyatīpāta* was no more needed.

This argument cannot be turned down as speculation since the techniques adopted for eclipse calculations later did not need observations at all. The best testimony for this is the case of a text "*grahaṇamālā*" of 16th century – it is a canon of eclipses from 15th century to 21st century prepared without ever looking up. The author could not, for the simple reason that he was kept in the prison when he prepared these tables. The preface also mentions that Emperor Akbar released him from the prison admiring his mathematical skills.

Another similar canon of eclipses is available for the 19th century in Oriental Research Institute, Mysuru (Mysore). The language is Sanskrit but the script is Kannada.

From the several interesting examples of *Vyatīpāta* of the 12th and 13th century, contrary to the accusation that the entries appear to have been made without actual observations, we notice that *Vyatīpātas* do not even hint at eclipses although the events occurred on full moon or new moon day. The reason appears to be that they observed the *Vyatīpāta*, of which eclipse is only a special case. As they did not observe the eclipse, the records state it as only *Vyatīpāta*.

We find a couple of very interesting examples when *Vyatīpāta* is recorded for full moon nights. Modern softwares like the Occult records these dates as, "possible penumbral eclipse". As is well known penumbral eclipses are very difficult to observe since the change in the brightness of the moon in the penumbral shadow is hardly noticeable. Today looking back at the records, we notice that the eclipses did occur and were visible on the other side of the globe or at the Polar Regions.

The records of *Vyatīpāta* are therefore, honest reports of meticulous observations and provided a practical tool for prediction of eclipses.

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