Date of the *Mahābhārata* War based on Simulations using Planetarium Software

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ABSTRACT

A compelling demonstration of the consistency of the astronomical references in the epic *Mahābhārata* is made on the basis of simulations using planetarium software. Planetary positions such as *śani* at *rohiṇi*, occurrences of eclipses, a lunar eclipse on the *kārtika* full moon followed by a solar eclipse on *jyeṣṭha amāvasya*, two eclipses separated by only thirteen days, a comet at *puṣya*, meteor showers, and a host of other events are shown to occur exactly as depicted in the epic. The events can not be dismissed as fiction in view of the simulations using modern planetarium software. The complexity and the totality of the events are such that nobody could have back calculated them and interpolated into the text at a later date, such as the 4th century CE. The date of 3067 BCE is proposed on the basis that the equinox occurred near *jyeṣṭha*; and there occurred a solar eclipse at *jyeṣṭha* in the middle of an eclipse season, the solar eclipse being bordered by two lunar eclipses. The earlier lunar eclipse occurred on *kārtika* full moon. The second lunar eclipse followed the solar eclipse in less than fourteen days. It is demonstrated that the simulations of the events described in the epic satisfy the stringent astronomical conditions surprisingly well. The simulations persuasively point to a date ~3000 BCE for the events and hence for the Mahābhārata war. The accuracy and the limitations of the simulations are also discussed.

I. Introduction

The *Mahābhārata* war is an important milestone event in the chronology of *Bhārata*. The great epic tells us that the war was fought[1] at the junction of the *dvāpara* and *kali* yugas. There is an age-old tradition of celebrating certain events connected to the epic such as the *Gītā jayanti* or *Bhīṣmāṣṭami*. No Bhāratīya ever doubted the historicity of the event. In spite of such long-standing traditions, the situation changed when Western (and some Indian too) scholars began to study the epic seriously from the 'rationalist historic' point of view. Doubts were expressed about the war having been a historical event. Even if the historicity of the war was conceded, the date of the event was deemed to be in doubt. The importance of determining the date of the *Mahābhārata* war for ancient Indian chronology can hardly be overstated[2]. A plethora of dates, derived on the basis of a number of diverse methodologies have been proposed and no consensus has been reached. Figure 1 displays a distribution of the dates attributed to the war based on the works of more than a hundred scholars[3]. The various methodologies used are indicated in figure 1a. A number of authors have concentrated only on the references to astronomical events such as eclipses[4] found in the epic as a basis for determining the date of the war. Figure 2 shows the distribution of dates from about forty scholars who have concentrated on the astronomical references in the epic. However, it has not been possible to arrive at a definite date on the

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[1] *antare caiva saṃprāpte kalidvāparayorabhūt/*
samantapañcake yuddhaṃ kurupāṇḍavasenayoḥ// MBh. 1.2.9

[2] Pusalker, A. D., "Traditional History from the earliest Time to the Accession of Parikshit", in *The Vedic Age*, Majumdar, R. C., Pusalker, A. D., and Majumdar, A. K. (ed.) Bharatiya Vidya Bhavan, (Mumbai, 1996)

[3] Sathe, S. *Search for the Year of the Bharata War*, Navabharati Publications, (Hyderabad, 1983)

[4] Ibid

basis of astronomical references either[5,6]. A new tool in the form of Planetarium Software[7] has recently become available for examining the astronomical references. It is the purpose of this paper to report the results of using the Planetarium software to simulate the astronomical events in the epic. These simulations compel one to agree that the astronomical references in the epic *Mahābhārata* form a consistent set, the events must have been observed and not put into the text by some later clever astronomer. These simulations also provide a basis for determining the date of the *Mahābhārata* war. The date of the events, 3067 BCE, is proposed on the basis of very stringent astronomical conditions that must be satisfied for the occurrence of the events described in the epic. It is based on the following facts: there was an equinox near *jyeṣṭha*; a solar eclipse occurred at *jyeṣṭha* in an eclipse season with two lunar eclipses on either side; the final lunar eclipse occurred in less than fourteen days after the solar eclipse. It is demonstrated conclusively by the simulations that the proposed date, which is identical to the one proposed earlier by Raghavan, provides the best agreement with the events described in the epic.

Additional impetus for this work derives from the fact that two astrophysicists have recently published on the date of the *Mahābhārata* war, and they have proposed two different dates. It will be shown that these dates have to be rejected as unacceptable on the basis of these simulations, as the implied planetary positions are incompatible with the positions described in the epic.

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[5] Dikshit, S. B., *Bhāratīya Jyotiṣśāstra* , Government of India Press, (Calcutta, 1969) Part I, pp 107-127.

[6] Kane, P. V., *History of Dharmasastra*, BORI, (Poona, 1958) Vol. III pp 902-923.

[7]Other Resources for Amateur Astronomers, Sky and Telescope Magazine, vol 101, Sky publishing Co., 2001. (further references to STM)

The problem was first suggested to the author by Dr. Kalyanaraman and the author started the project with an uncharacteristic naivete overflowing with confidence about applying the new tool to determine the date of the war. However, soon he realized both the enormity and the complexity of the problem and that while he was among the first to use the Planetarium software, he was not the only one[8]. He was amazed by the number of people, who have attempted to determine the date of the *Mahābhārata* war[9]. He can echo the sentiments expressed by the fourteenth century Kannada poet, who under the penname *kumāra vyāsa* composed in verse form the epic *Mahābhārata* in Kannada. *Kumāra vyāsa* in explaining as to why he chose to compose the *Mahābhārata*, instead of the *Rāmāyaṇa*, says " *tiṇukidanu phaṇirāya rāmāyaṇada kavigaḷa bhāradali*". " even the great serpent, *ādiśeṣa* groaned under the weight of the number of people who have composed *Rāmāyaṇa*". The present author can say "*tiṇukuvanu phaṇirāya bhāratada kālavaḷeva jāṇara bhāradali*" " the great serpent groans under the weight of the pandits who have tried to determine the date of the *Bhārata* war".

The plan of the paper is as follows. A brief description of the salient features of the software and the products that are commercially available will be given first. For purposes of the simulations, a core set of the astronomical references in the epic (such as those in *udyogaparva*) before the beginning of

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[8] Simson, Georg Von, "Narrated Time and its Relation to the Supposed Year Myth in the Mahabharata" in *Composing a Tradition, Proceedings of the First Dalbrovnik International Conference on Sanskrit Epics and Puranas*, (Zagreb, 1999) pp 49-66. Simson, who thinks about the whole epic as a metaphor for the Year, uses the software Redshift trivially to demonstrate the Saros cycle of eclipses and nothing more. Dr. Balakrishna has used the Planetarium software, Lodestar, to study the occurrence of eclipse pairs separated by less than fourteen days from among thousands of eclipses

[9] Sathe, S. *Search for the Year of the Bharata War*, Navabharati Publications, (Hyderabad, 1983)

the war till the death of *Bhīṣhma* is selected. The acceptability of any given date as a possible date of the war will be judged on the basis of how faithfully this basic set of references is simulated. A review of the works of two astrophysicists, Kochhar[10] and Sidharth[11] and two astronomers, Sengupta[12] and Srinivasa Raghavan[13] will be given. The limitations and reliability of the simulations are then discussed. The remaining astronomical references in the epic and their simulation are critically examined in the context of readings variant from the critical edition.

The problem of eclipse pairs occurring within an interval of thirteen days is addressed next. It is shown that one must really consider an eclipse season with three eclipses, with two lunar eclipses bordering a solar eclipse. The fact that there was an equinox at *jyeṣṭha* renders the conditions to be very stringent and leads to the proposed date of the event. This also turns out to be identical to the date, which had been proposed by Raghavan. The simulations show that the astronomical events must have occurred around 3000 BCE, thus establishing the date of the war also as ~3000 BCE. Preliminary reports of this study have been presented[14] at the International Conference on *Mahābhārata* in Montreal, and at the WAVES conference in Dartmouth. The

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[10] Kochhar, R., *The Vedic People,* Orient Longman, (Hyderabad, 1997). (further references to KR)

[11] Sidharth, B. G., *The Celestial Key to the Vedas,* Inner Traditions, (Rochester, 1999) (further references to SBG)

[12] Sengupta, P. C., *Ancient Indian Chronology,* University of Calcutta, (Calcutta, 1947) (further references to SPC)

[13] Raghavan, K. S., *The Date of the Mahabharata War*, Srirangam Printers, (Srinivasanagar, 1969) (further references to RKS)

[14] To be published

earlier presentations had concentrated only on planetary positions and had not considered the eclipse season of three eclipses and the equinox at *jyeṣṭha.* This is the first time a full report is being presented.

II. The Planetarium Software

The term Planetarium software refers to a collection of computer programs, which can generate and display on the screen of a computer monitor thousands of stars and other heavenly objects as seen in the sky at any given location on earth and at any given date and time (between 4000 BCE and 8000 CE), all at the touch of a mouse. These software products draw from the most up to date star catalogues and are based on the current theories of planetary and stellar phenomena. They are routinely used for telescopic applications both in manual and computer controlled modes of operation, for they can project at which part of the sky and at what time a desired object becomes visible in the sky and direct the telescope accordingly. These can also be used as tools of research in exploring ancient astronomy as has been shown by the author in some recent publications[15].

There are several such products commercially available[16]: The Sky, SkyMap Pro, Red Shift, Cybersky, etc., for PC applications and Voyager for McIntash applications. The author has found SkyMap Pro to be the best suited for current applications, but he has also used Red Shift, Cybersky and occasionally, The Sky as supplementary tools. In addition, the author has found another computer program, Pancang2, developed by Professor Yano[17] and his associates, to be very useful. This latter program can calculate the *tithi* and *nakṣatra* for any day on the Gregorian calendar

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[15] Achar, B. N. N., On Exploring the Vedic sky with Modern Computer Software, EJVS, 5-2, 1999

[16] STM

[17] Yano, M., and Fushimi, M., Pancang2, a program based on sūrya siddhānta, available by ftp://ccftp.kyoto-su.ac.jp/pub/doc/sanskrit/

III. Basic set of Astronomical References

There are a large number of references to astronomical events, which are scattered throughout the text of the epic and have been catalogued[18]. Figure 3 gives the distribution among the *parva*s of the *slokas,* about one hundred and fifty in number, and referring to astronomical events. Admittedly many of the references are astrological in nature and the possibility that of some these may be later interpolations can not be overruled. However, there must be a few genuine events that were observed and noted in view of the importance of the war. In fact, a majority of the astronomical references appear in *udyoga* and *Bhīṣma parva*s referring to events just before or at the start of the war. A set of about forty references has been selected out of more than one hundred fifty for simulation by the planetarium software. The hundred and odd references not included in the basic set contain: (a) repeated references to the events already selected, (b) references of a very general nature such as time and its division into *kalā, muhurta, pakṣa, māsa* etc., (c) references that are not directly connected with the war, and finally, (d) those that are purely astrological in nature. A further subset of the selected list of about a dozen astronomical references gives a more or less coherent chronology of astronomical events starting with *Kṛṣṇa*'s departure for his diplomatic mission to *Hastināpura* before the war and ending with *Bhīṣhma*'s death after the war at the beginning of *uttarāyaṇa*.:

(i) *Kṛṣṇa* leaves for *Hastināpura* on the diplomatic mission for peace in the *maitrī muhūrta* in the month of *kārtīka* on the day of *revatī nakṣatra:*

tato vyapete tamasi sūrye vimala udgate
maitre muhūrte saṃprāpte mṛdvarciṣe divākare //
kaumude māsi revatyāṃ śaradante himāgame
sphītasayasukhe kāle kalyaḥ sattvavantāṃ varaḥ // (V 81.6-7)

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[18] Sathe, S., Deshmukh, V., and Joshi, P., *Bharatiya Yuddha: Astronomical References*, Shri Babasaheb Apte Smarak Samiti, (Pune, 1985).

(ii) On the way he halts at a place called *Vṛkasthala* and reaches *Hastināpura* on the day of *Bharaṇī*

(iii) He meets with various people to discuss the conditions of averting the war. The meetings go on until the day of *Puṣya*, on which *Duryodhana* rejects all offers of peace.

(iv) *Kṛṣṇa* leaves *Hastināpura* on the day of *uttara phālguni*. *Karṇa* accompanies him in his chariot and has a lengthy conversation with him. At the end of the conversation *Kṛṣṇa* sends a message to Bhīṣma and Droṇa through *Karṇa* that the *amāvāsyā* falls on the seventh day and war rituals be done on that day:

saptamāccāpi divasād amāvāsyā bhaviṣyati
sangrāmo yujyatāṃ tasyāṃ tāmāhuḥ śakradevatāṃ// (V 140.18)

(v) During this conversation *Karṇa* describes positions of the planets at that time in the following verses; but these verses are assumed to be of an astrological nature by everyone, except Raghavan:

prājāpatyaṃ hi nakṣatraṃ grahas tīkṣṇo mahādyutiḥ
śanaiścaraḥ pīḍayati pīḍayan prāṇinodhikaṃ//
kṛtvā cāṇgārako vakraṃ jyeṣṭhāyāṃ madhusūdana
anūrādhāṃ prārthayate maitraṃ saṃśmayanniva//
nūnaṃ mahadbhayaṃ kṛṣṇa karuṇāṃ samupasthitaṃ
viśeṣeṇa hi vārṣṇeya citrāṃ pīḍayate grahaḥ//
somasya lakṣma vyāvṛttaṃ rāhurarka mupeṣyati
divaścolkāḥ patanyetāḥ sanirghātāḥ sakampanāḥ// (V. 141. 7-10)

(vi)A lunar eclipse took place on the full moon day of *kartīka* together with a solar eclipse on the following new moon. There occurred two eclipses being separated by only thirteen days.

candrasūryavubhau grastāvekamāsīṃ trayodaśīṃ / (III. 6.32)

(vii) *Bhīṣma* expires soon after the sun turns northward

māgho'yaṃ samanuprāpto māsaḥ puṇyo Yudhiṣṭhira
tribhāga śeṣaḥ pakṣo'yaṃ śuklo bhavitum arhati // (XIII. 153.28)

Tradition has it that *Bhīṣma* passed away on *māgha śukla aṣṭami* and the anniversary is celebrated as such even today.

These constitute the basic set of astronomical facts: Before the war broke out there was a new moon at *jyeṣṭhā*. There was a lunar eclipse on the *kārtika* full moon, followed by a solar eclipse. There were two eclipses separated by

only thirteen days. The war broke out in the month of *mā*rgaśira and lasted for eighteen days. Bhīṣma passed away soon after the winter solstice in *māgha* and he had not slept for fifty-eight days before expiring. *Karṇa* described the then existing planetary positions, during a lengthy conversation that he had with *Kṛṣṇa* before the war broke out. Saturn was at *rohiṇi,* Mars had exhibited a retrograde motion earlier, but had become pro-grade again. *citrā* is being harassed by a *graha.* Any work, which professes to determine the date of the war on the basis of astronomy, must account for these events. If the events as projected in a given work fall outside the framework of this time interval, the date proposed by that work could be rejected. If, however, events fall within the framework of the time interval, the date may be considered to be an acceptable date, but there is no guarantee that it is the date to be accepted.

IV. Review of Selected Works

Although there are nearly fifty works, all of which discuss the date of the *Mahābhārata* war based on astronomical events to some extent, four of these have been selected for purposes of simulation and verification by using the Planetarium software. Two of them are very recent and have been authored by well-known astrophysicists, but in reality use very few astronomical references in the epic and propose different dates. Kochhar[19] gives a date of 955 BCE and Sidharth[20] proposes a date of 1311 BCE. The third work to be discussed is that of Sengupta,[21] who considers only four major events in the basic set and proposes a date of 2449 BCE. Finally, the work of Professor Raghavan[22], together with the present work, both of which regard all the astronomical references in the epic to be important, will be considered.

(a) Kochhar's Work

Kochhar mentions that there are more than one hundred and fifty references to astronomical phenomena in the epic and lists many of them. These include: (i) Saturn is vexing *rohiṇī*, (ii) Jupiter is harassing *rohiṇī,* (iii)

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[19] KR p.49

[20] SBG p.117

[21] Sengupta

[22] Raghavan

Rāhu has seized the moon, (iv) lunar eclipse took place on the *kārtīka* full moon, and (v) a solar eclipse on the following new moon, separated by a mere thirteen days. But, he holds the view that it is not possible to single out verses referring to astronomical events, which are contemporaneous with the war. He, therefore, ignores most of them as nothing more than poetic imagery of cosmic events to imply the violation of *dharma.* The only event he considers belonging to that epoch is a total solar eclipse that would have been seen in the northwest part of India, and mentions two possible dates for such an event: 4th July, 857 BCE and 4th October, 955 BCE. Figures 4 and 5 show the simulations using SkyMap Pro for these dates. On the basis of simulations using the SkyMap Pro, July 857 BCE date can be ruled out because the solar eclipse occurs in the month of *āṣāḍha* and is quite far removed from *mārgaśira*. The 955 BCE date can be ruled out for the following reasons: the solar eclipse occurs two days after the equinox on October 2, 955 BCE and it takes place in the month of *āśvayuja*. It occurs in the *nakṣatra viśākha* and not in *jyeṣṭha.* The planetary positions are as follow: Jupiter is near *bharaṇi* and Saturn is near *śravaṇa,* Mercury and Venus are near *jyeṣṭha.* Figure 6 shows that the winter solstice that year occurs on December 30, 955 BCE and on the *kṛṣṇa trayodśī*, not in the *śukla pakṣa,* as described in the epic. In short, none of the astronomical events actually occurring during this year match the ones given in the epic.

(b) Sidharth's Work

The astronomical references considered by Sidharth are of a general nature such as the five-year yuga concept (of the *vedāṅga jyotiṣa*) and winter solstice occurring at *dhaniṣṭha*. He considers the significance of the symbolism of identifying *Bhīṣma* with the sun. The only event Sidharth also considers is a total solar eclipse for which he gives a date of June 24, 1311 BCE. However, simulations using the planetarium program SkyMap Pro (Figure 7) show that there was no possibility of an eclipse occurring on that date. For, the new moon was on the 14th June 1311 BCE and the full moon was on the 29th June 1311 BCE. Assuming that the date is actually 14th, rather than the 24th, which might have been just a typographical error, there does occur a solar eclipse but at 4:00 am, hardly the time for it to be visible. Furthermore, the simulations

show, that it occurs in the wrong month for the total solar eclipse witnessed during the war, the summer solstice is yet to occur that year on July 5, 1311 BCE.

It is disappointing therefore, to see so little astronomical evidence discussed in the works of two astrophysicists. Even the little evidence there is based on a single eclipse event, which, as will be shown later, can not yield a reliable date. Moreover, the planetary positions on the projected dates are completely at variance with those described in the epic.

(c) Sengupta's work

The third work to be considered is by the veteran scholar Sengupta[23] who had proposed a date of 2449 BCE on the basis of extensive astronomical analysis. He uses these basic facts: (i) there was a new moon at *jyeṣṭhā* before the war broke out, (ii) the sun turned north in eighty days, one day before *Bhīṣma*'s expiry, (iii) on the eve of the first day of the war, the moon was 13 days old and in conjunction with *kṛttikā*, (iv) on the 18th day of the war, moon was 31 days old and was in conjunction with *śravaṇa*. He uses several methods of calculations and comes up with dates between 2432 BCE and 2450 BCE. He chooses 2449 BCE as being the most probable date. He actually provides a calendar for the war as staring on November 4, 2449 BCE and ending on November 21, 2449 BCE.

Sengupta has not used any astronomical data from the chapter 141 of *udyogaparva* (*Kṛṣṇa-Karṇa samvāda*) or from chapter 3 of *Bhīṣma* parva. He has the harshest criticism of the verses quoted earlier in the section on astronomical references:

> *"All this is hopelessly inconsistent astrological effusions of evil omens fit for Mother Goose's Tales only."*

As to the occurrence of two eclipses one after another within thirteen days, he says

> *"We can not put any faith in any statement of this chapter of the Mahābhārata."*

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[23] SPC p.24

He thinks that the event of two consecutive eclipses actually occurred two years before the war the lunar eclipse falling on August 30, 2451 BCE followed by the solar eclipse on September 14, 2451 BCE. He calculates and gives the actual positions of the planets on three dates October 14, 2449 BCE, November 3, 2449 BCE and November 21, 2449 BCE. He concludes that the statements in the *Mahābhārata* regarding planetary positions are full of truths and fiction, and that he alone has been able to avoid fiction and to accept the true astronomical events in arriving at the date of 2449 BCE for the war.

Simulation using the SkyMap Pro (Figure 8) shows that there was indeed a new moon at *jyeṣṭha* on October 21, 2449 BCE. But, Saturn was at *kṛttika* and *Jupiter* at *rohiṇī.* These planetary positions are at variance with the positions given in the epic. Since the positions in the epic do not agree with his calculations, Sengupta terms the former as simply evil omens fit for Mother Goose's Tales. Simulations also show that there was indeed a lunar eclipse on August 30, 2451 BCE. and a solar eclipse on September 14, 2451 BCE. However, the solar eclipse occurred just after midnight! Moreover, the interval between the lunar eclipse and the solar eclipse exceeds fourteen days. Moreover, as seen in figure 9, the winter solstice occurs on Jan 8, 2448 BCE, but it is *kṛṣṇa pañcamī* and not *śukla pañcamī* as described in the text.

Sengupta gives a few dates and describes astronomical phenomena occurring on those days obtained by strenuous calculation (no computers were available to him at that time). For example, he finds *jyeṣṭha amāvāsya* on October 21, 2449 BCE and solar and lunar eclipses on August 30, 2451 BCE and September 14, 2451 BCE. His calculations are accurate in the sense that SkyMap Pro also reproduces the very same phenomena on the dates given by Sengupta. The planetary positions found by using SkyMap Pro also agree with those given by Sengupta, but they do not agree with the ones described in the epic. While this shows that Sengupta has made accurate astronomical calculations, the results of his calculations are nothing like the astronomical phenomena described in the epic. Either (i) the dates postulated by Sengupta are on the mark and the descriptions given in the epic are fictitious, or, (ii) the dates given by Sengupta are off the mark and the epic descriptions are correct. Not surprisingly Sengupta takes the position, like many scholars who

have attempted to use the astronomical references in the epic, of regarding the descriptions of the epic as fiction. It is the considered opinion of this author that it is Sengupta's proposal that has to be rejected.

(d) Raghavan's work

Finally, the work of the eminent mathematician-astronomer Raghavan[24], who also had proposed a date of 3067 BCE, will be considered. He alone takes seriously the descriptions given by *Karṇa* of the astronomical events in *udyogaparva*. He believes the sequence of two eclipses occurring within a period of thirteen days to be genuine events actually observed. He gives a chronology of events starting with the departure of *Kṛṣṇa* on the diplomatic mission to *Hastināpura*. According to him the war started on November 22, 3067 BCE. Simulations of the views of the sky on the dates given by Raghavan show spectacular agreement with the descriptions given in the epic and are as follow.

According to Raghavan, *Kṛṣṇa* departs for *Hastināpura* on September 26, 3067 BCE (Figure 10) and arrives at *Hastināpura* on September 28, 3067 BCE, on *bharaṇi* day. Figure 11 shows the view of the sky clearly showing the moon at *bharaṇī*. It may be noted that Saturn is at *rohiṇī.* Figure 12 shows the view of the sky on October 8, 3067 BCE, the day of *uttara phālguṇī,* when after the failure of his mission, *Kṛṣṇa* rides out with *Karṇa.* It is then that he says that there will be *amāvāsyā* in seven days. Figure 13 shows the new moon on October 14, 3067 BCE occurring at *jyeṣṭha* referred to in the epic "*saptamāccāpi divasād ...*" (also considered by Sengupta to be a key astronomical factor). It has been verified that there was a solar eclipse on that day (*rāhurarka mupeṣyati..*). The figure clearly shows Saturn at *rohiṇi*. This is exactly as described in the epic. All other scholars regard this to be astrological because their own calculations fail to reproduce it. Figure 14 shows that there was a lunar eclipse on September 29, prior to the solar eclipse on October 14. Figure 15 shows the retrograde motion of Mars that had taken place a little earlier. Mars goes retrograde before reaching *jyeṣṭhā*, and at the time of conversation with *Karṇa* it is prograde again and past *anūrādhā.* Figure 16

[24] RKS p. 12

shows the view of the sky on November 22, 3067 BCE the starting day of the war according to Raghavan. Figure 17 shows that the winter solstice occurs on Jan 13, 3066 BCE, and figure 18 shows the view of the sky on the day of of *Bhīṣma's* expiry. January 17, 3066 BCE is the date of *Bhīṣma*'s expiry and it is *māgha śukla aṣṭamī*.

As seen in the figures, the basic set of astronomical events described in the epic are shown to agree with those occurring on the dates given by Raghavan. Starting from the day of *Kṛṣṇa*'s departure on a peace mission to *Hastināpura,* to the day of *Bhīṣma*'s death, the *tithi*s and *nakṣatra*s on these dates agree with those given in the epic. The planetary positions on the dates given by Raghavan also show remarkable agreement with those given in the epic. The present work also proposes the same date on the basis of additional considerations to be discussed later.

V. Other astronomical references including those from *Bhīṣma* and *Droṇa parva*

The remaining astronomical references from the selected list will be considered now. On the eve of the war, *Vyāsa* describes ill omens seen by him to *Dhṛtarāṣṭra*. These references, most of which are astrological in nature, are found in the *Bhīṣma parva*, and have been discounted by scholars. However, the simulations show that the references are also consistent with the other astronomical references, and that some of these must be understood in terms of astrological terminology. There are also astronomical references in the *Droṇa parva* at the time of the fight between *Aśvatthāma* and *Ghaṭotkaca* on the fourteenth night of the war. Finally, there is the circumstance of *Balarāma's* return. These will be discussed along with the simulations.

(a) Lunar eclipse on *kārtika* full moon

alakṣeprabhayāhīnaṃ paurṇamāsīṃ ca kārtikīṃ/

candro abhūdagnivarṇaśca padmavarṇe nabhasthale//(VI. 2. 23)

Here in (VI.2.23), *Vyāsa* is referring to the eclipse on *kārtika* full moon, the moon was hardly visible, devoid of glory, with a firish tinge and the sky was

of lotus hue. The lunar eclipse took place on the 29th of September as already shown in figure 14, and it was a penumbral eclipse. The moon would have a brownish tinge and so would the sky, entirely as described by the sage *Vyāsa.*

rohiṇīṃ pīḍayanneṣasthito rājan śanaiścaraḥ/

vyāvṛttaṃ lakṣma somasya bhaviṣyati mahadbhayaṃ//(VI.2.32)

In (VI.2.32), Vyāsa is referring to the fact that Saturn is at *rohiṇi*, already shown in figure 11. The moon is lacking the usual luster indicating the impending disaster.

(b). Planets or Comets?

abhīkṣṇaṃ kampate bhūmiḥ arkam rāhustathāgrasat/

śveto grahastathācitrāṃ samatikramya tiṣṭhati// (VI.3.11)

In the first half of (VI.3.11), *Vyāsa* refers to intermittent quivering of the earth and the solar eclipse, which took place on October 14. In the second half of the *śloka*, some scholars have translated *śveta graha* as Venus, but Venus is at *dhaniṣṭha* and not *citrā,* and thus find it inconsistent. A variant reading has *ṣyāmo* in the place of *śveto*, thus referring to *budha.* The planet *budha,* which had been retrograde before reaching *citra* became prograde while passing that nakṣatra. This can be seen in figure 19. According to Raghavan, *citra nakṣatra* is associated with *candra vaṃśa* in a number of places in the epic and the motion of *budha* in *citra* forebodes the destruction of the *kuru*s. In view of this, the reading variant from the critical edition gives better agreement with the simulation. *Karṇa* also refers to *'citrāṃ pīḍayate grahaḥ'* in (V.141.9) cited earlier. However, it is more likely that *śvetaḥ* refers to one of the comets, as indicated by the following discussion.

Vyāsa refers to a terrible comet which has invaded the territory of *puṣya:*

dhūmaketurmahāghoraḥ puṣyamākramya tiṣṭhati/ (VI.3.12)

Earlier, *Karṇa* had referred to a copious fall of meteorites:

*divāścolkā patantyetāḥ..*in (V.141.9).

The sky diary (figure 20) from the software RedShift showed that there was indeed a copious fall of meteorites in October 3067 BCE, and that the parent body of the meteorites was the Halley's comet. It would be tempting to identify the comet Vyāsa refers to with the Halley's comet. Figure 21 shows that the position of Halley's comet was near *puṣya* just as Vyāsa describes it. However, its brightness could not be confirmed as two software programs give vastly different estimates of brightness, although the positions are given correctly. It was not clear whether the Halley's comet was visible at that time.

The following six references have caused much confusion among the scholars as they try to understand it verbally.

senayoraśivaṃ ghoraṃ kariṣyati mahāgrahāḥ/

maghāsvaṅgārako vakraḥ śravaṇeca bṛahaspatiḥ// (VI.3.13)

bhagaṃ nakṣtramākramya sūryaputreṇa pīḍyate/

śukraḥ proṣṭhapadepūrve samāruhya virocate/

uttaretu parikramya sahitaḥ samudīkṣyate//(VI.3.14)

śyamograhaḥ prajvalitaḥ sdhūmaḥ sahapāvakaḥ/

aindraṃ tejavsvi nakṣatraṃ jyeṣṭhamākramya tiṣṭhati//(VI.3.15)

dhrvaḥ prajvalito ghoramapasavyaṃ pravartate/

rohiṇīṃ pīḍayantau tāvubhau ca śaśibhāskarau/

citrasvātyantare caiva dhiṣṭhitaḥ paruṣo grahaḥ//(VI.3.16)

vakrānuvakraṃ kṛtvā ca śravaṇe pāvakaprabhaḥ/

brahmarāśiṃ samāvṛtya lohitāṅgo vyavasthitah//(VI.3.17)

These references are clearly astrological in nature and must be understood from the point of ancient Indian astrology. Professor Raghavan explains that the ancient Indian astrological concepts of *Vedhā* and *pīḍā* must be used in this context. However, it appears that the list of astronomical entities here refers not to planets, but to comets. According to *Varāhamihira,* hundreds of comets were known and classified by the astronomers *Garga, Parāśara and Asitadevala*. *Garga* is considered to be a purohit of the *yādavās*. It is known that *Asitadevala* is the brother of *Dhaumya*, the chief purohit of the *Pāṇḍavā*s. The accounts given by the ancient sages about comets have been summarized by *Varā*hamihira in B*ṛhatsaṃhita* cited below. *śveta, śyāma, dhūma, ghora, paruṣa*, etc are all names of *ketus* (comets) of different kinds according to *Garga* and *Parāśara* and their malefic effect depends on the *nakṣatra* which they are afflicting. In addition, there are comets, which are labeled as the sons of Sun, Moon, Jupiter, Saturn, *Budha, Aṅgāraka, Agni*. Unfortunately, these comets are also referred to by the same names as the parent planets in the epic by Vyāsa. Thus, *śaśi, bhāskara, bṛhaspati, sūryaputra,* etc in these ślokas refer to comets, which are considered to be the sons of the moon, the sun, Jupiter and Saturn. They do not refer to planets. Thus the positions described in the above *śloka*s refer to the positions of comets and not those of the planets. Therefore, there is no inconsistency at all. The planetarium simulations actually show a large number of comets in all the positions described in the epic, as will be shown later.

Additional support for this idea is given by Varāhamihira[25], who states:

citrāsu kurukṣetrādhipasya maraṇaṃ samādiśettajñaḥ/

kāśmīrakakāṃbojau nṛpatī prābhañjanena staḥ// (Bṛ S. XI. 57)

" If the afflicted *nakṣatra* be *citrā*, a wise astrologer should predict the death of the ruler of *kurukṣetra*. If it be *svāti*, it would be the kings of *kāśmīra* and *kāṃboja*"

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[25] Varāhamihira's Bṛhat Saṃhita, Part I, M. Ramakrishna Bhat, (ed.) Motilal Banarsidass Publishers Pvt Ltd. Delhi, 1995 , p 141.

This is very close to what *Vyāsa* says in (VI. 3. 11) and to what *Karṇa* says in (V.141.9) cited earlier.

It is clear, therefore, that these *śloka*s must be understood not in terms of the usual planets, but from the accounts about comets. *graha* in this context does not mean just a planet, but any celestial object that can afflict a *nakṣatra.* These ślokas are astrological no doubt, but they are not inconsistent. They reflect the ideas about comets current in those days. Modern scholars have seriously erred in regarding these as references to planetary positions and dismissing them as unintelligible astrological effusions, or, perhaps interpolations by later astronomers.

saṃvatsarasthāyinau ca grahau prajvalitāvubhau/

viśākhayoḥ samīpasthau bṛhaspati śanaiścarau// (VI.2.25)

Both *śani* and *bṛhaspati* stay for about a year at their respective positions in view of their prograde, retrograde and prograde motions. Figure 22 shows the situation as the paths of these two planets are sketched for about a year. However, they are not located near *viśākha* as it appears to be implied in this *śloka. śanaiścara* is really at *rohiṇī,* this has already been stated earlier. The author believes that (VI. 2.25) must also refer to comets. Figures 23, 24 and 25 show the paths of comets, which are retrograde near *maghā, śravaṇa* and *viśākha.* But, further research is needed to establish the knowledge base of comets and their identities in ancient Indian astronomy.

VI. Eclipses, three and not just two.

caturdaśīṃ pañcadaśīṃ bhūtapūrvāṃ ca ṣoḍaśīṃ/

imāṃ tu nābhijānāmi amāvāsyāṃ trayodaśīṃ//(VI.3.28)

candrāsūryāvubhau grastāvekamāse trayodaśīṃ/

*aparvaṇi grahāvetau prajāḥ saṃkṣapayiṣyataḥ//(*VI.3.29)

This is the famous reference to two eclipses occurring within a month with an interval of thirteen days. There was already a reference to the lunar eclipse occurring on *kārtika paurṇimā*, and of course there was a solar eclipse on the following new moon at *jyeṣṭhā.* Unfortunately, the interval between these two eclipses is fifteen days. Everybody has interpreted the reference to mean that there was a lunar eclipse followed by a solar eclipse within thirteen days. Much effort has been spent on this particular reference, including the recent study of Balakrishna, whose work is valuable in a different way.

Dixit had examined this problem about hundred years ago. He had argued that the occurrence of two eclipses within an interval of thirteen days as a possibility is noticeable only by calculation and not by observation. Since one can not get this occurrence through calculations adopting mean motions of the luminaries, he arrived at the conclusion that Indians knew how to calculate the true positions of the sun and the moon as early as the age of Mahābhārata. He also argued that since it has not been possible to observe in modern times, a 13-day *pakṣa* in which a lunar eclipse occurs first, and is followed by a solar eclipse, the calculations of Vyāsa must have been inaccurate.

Vyāsa refers to a lunar eclipse at *kārtika,* a solar eclipse at *jyeṣṭha*, and a pair of eclipses within thirteen days. But, **nowhere does he say that the interval between the *kartika* lunar eclipse and the *jyeṣṭha* solar eclipse is thirteen days.** At the time of the *kārtika* lunar eclipse, *Kṛṣṇa* was still in *Hastināpura*. Eight days had passed when he rode with *Karṇa* on *uttaraphālguni* day. He is the one who refers to *amāvāsya* occurring at *jyeṣṭha* later on the seventh day in his conversation with *Karṇa. Karṇa* knows that a lunar eclipse had occurred and that it was going to be a solar eclipse, for he says, " *somasya lakṣma vyāvṛttaṃ rāhurarka mupeṣyati.*" If the solar eclipse in *jyeṣṭha* had followed the lunar eclipse on *kārtika* full moon within a thirteen-day interval, it would have already been mentioned. Since nobody mentions it, the interval between these two eclipses must have been normal. The simulations show that to be the case.

Scholars have assumed that Vyāsa must have meant exactly that the interval between the *kartika* lunar eclipse and the *jyeṣṭha* solar eclipse was thirteen days. That there is another possibility, which has escaped the scholars became evident during the simulations. That possibility is based on the concept

of an eclipse season. The idea is simple enough. An eclipse can occur provided the sun is near a node of the moon's orbit (*rāhu, or ketu*), and the moon is in the proper phase. In fact, when the sun is near a node, usually there is a period of about one-month, when eclipses can occur if the moon attains the phase of full or new moon within that period. The eclipse season for solar eclipses is thirty-one days. The average synodic period of the moon is 29.5 days. Therefore, there will always be a solar eclipse when the sun is near a node. Since the sun crosses each node once a year, there must be at least two solar eclipses in a year. If the conditions are right, some times three eclipses can occur in an eclipse season. There was such a situation before the war. The simulations show that the lunar eclipse on September 29 at *kartika* full moon was followed by an annular solar eclipse at *jyeṣṭha*, on October 14. Then there occurred a third lunar eclipse, a penumbral one, on the following full moon on October 28. The last one occurred within an interval of less than fourteen days after the solar eclipse in *jyeṣṭha*. Such an "*aparvaṇi* " occurrence can happen only if the eclipse is a penumbral eclipse, because, for a penumbral eclipse, the interval of duration of the eclipse need not include the instant of opposition "parva". It is clear therefore, that it was this last pair of eclipses that *Vyāsa* was referring to. *Vyāsa* notices it, for he is the one who is observing the sun both morning and evening daily:

ubhe pūrvāpare sandhye nityam paśyāmi bhārata/

udayāstamane sūryaṃ kabandhaiḥ parivāritaṃ// (VI.2.20)

Here once again *kabandha* refers to comets. There appears to have been an unusual comet activity at that time. Any way, scholars should have been looking for the occurrence of three eclipses, not just two! This makes the event even more singular. The simulations show that it did happen!!

A further confirmation of this fact arises, for thirty-six years later; *Kṛṣṇa* sees the signs of destruction of the *yādavā*s:

caturdaśī pañcadaśī kṛteyaṃ rāhuṇā punaḥ/

tadāca bhārate yuddhe prāptā cādyā kṣayāya naḥ// (XIV. 3.17)

The simulations (figure 26) have confirmed that according to the sky diary in the year 3031 BCE, there was also an eclipse season with three eclipses. A penumbral lunar eclipse on October 20 was followed by an annular solar eclipse on November 5. This was followed by another penumbral lunar eclipse on November 19, within an interval of less than fourteen days, exactly as described in the epic.

VII. The proposed Date of the Astronomical events

For a solar eclipse to be an annular eclipse, the moon's apparent size must be smaller than that of the sun, hence it must be at or very near the apogee. For the next lunar eclipse to occur with an interval of less than 14 days, the sun must be moving fastest, i.e., the sun must be at or very near an equinox. There is evidence[26] to show that the equinox occurred near *jyeṣṭha* at the time of the war. Therefore, the eclipse at *jyeṣṭha* would occur close to the date of equinox with the additional constraint that the moon be near its apogee. This puts extremely stringent astronomical conditions to be satisfied, but they were satisfied at the time of the War. It is seen that in 3067 BCE, the equinox was at *jyeṣṭha,* a solar eclipse occurred in *jyeṣṭha*. Therefore, 3067 BCE is proposed as the date of the war. This date is identical to the date given by Raghavan. As has been demonstrated, the simulations corresponding to this date agree with practically every astronomical reference in the epic.

VIII. Miscellaneous

maghāvishayagaḥ somastaddinaṃ pratipadyata/ (VI.17.2)

Vyāsa is describing here the position of the moon on the eve of the war. Some scholars have interpreted this to mean that the moon was in *maghā,* and hence infer a contradiction in the epic. According to the simulation, moon was in *bhraṇi* that day, as seen in figure 16. The presiding deity of *bharaṇi* is

[26] This follows from the fact *Bhīṣma* expired soon after the winter solstice, on *māgha śukla aṣṭami* and it was *rohiṇi nakṣatra* on that day. It follows therefore, the new moon day just before the solstice was *zatabhiṣa*, where the sun was near winter solstice. It follows that sun would have been near *jyeṣṭha* at the time of equinox.

yama, whose realm is the *pitṛloka*, and *pitṛ*s are the deities of *maghā*. Thus *maghāviṣayagaḥ* refers to moon in *bharaṇi*. Thus there is no contradiction.

catvāriṃśadahānyadya dve ca me niḥsṛtasyavai/

puṣyeṇa saṃprayātosmi śravaṇe punarāgataḥ//(IX.33.5)

This is the statement made by *Balarāma* to *Kṛṣṇa*. He says, "forty two days have passed since I left (on pilgrimage). I set off on the day of *puṣya nakṣatra* and have returned on the day of *śravaṇa*." Figures 27 and 28 show that *Balarāma* left on Nov 1, 3067 BCE and returned on Dec 12, the *nakṣatras* being exactly as described in the epic.

Finally, on the night *Ghatotkaca* was killed,

tribhāgamātraśeṣāyāṃ rātryāṃ yuddhamavartata/

The moon rose at about 2:00 am. Figure 29 shows that was indeed the case.

IX. Reliability and Limitations of the Simulations

The simulations provided by the Planetarium software are extremely reliable and they are based on the most recent star catalogues and planetary information. However, some caution has to be exercised in using the programs to extrapolate to dates going back several thousands of years. For example, the periods of revolution of the moon and the other planets are known accurately to six decimal places. The sixth is somewhat uncertain. When the date is extrapolated to 3000 BCE, that is a period of 5000 years, some 60000 complete revolutions of the moon have been considered, but only 200 revolutions of Saturn. Now, the accuracy of the last decimal digit is very important for the moon, but not for the planet Saturn. Thus, in a simulation corresponding to 3000 BCE, the extrapolated position of Saturn is very reliable, but that of the moon is somewhat uncertain. This is clearly evident in simulating the exact moment of new moon, for example. There is a spread of about 12 hours among the times for the new moon given by the SkyMap Pro, Red Shift and Cybersky. The Sky is off by seven days! There is another factor to be considered. This has to do with the slowing of the earth's rotation by about

0.001" per century. This may look very small, but introduces considerable uncertainty of about 12 hours in the occurrence of an eclipse when extrapolated to 3000 BCE. This implies that one can not calculate the occurrence of a solar eclipse within an accuracy of several hours. This would in turn cause the location of a total solar eclipse also uncertain. It should be emphasized however, that the occurrence of the eclipse itself is quite certain. What is uncertain is the exact location where it occurs. In view of the uncertainty in location, it would be very difficult to choose a date based on the occurrence of an eclipse at a given location. In the present work, therefore, it is considered sufficient if the eclipse occurred, and not much weight was given to the exact location of visibility. The eclipse was only one of the many criteria used for acceptability.

It follows therefore, that those calculations, which depend for validation solely on the occurrence of a solar eclipse at a given place such as *kurukṣetra,* so long ago should be accepted with due caution. The extrapolated planetary positions, on the other hand, are highly reliable. It would seem therefore, the earlier scholars who regarded the eclipses as certain, but planetary positions as fit for Mother Goose Tales have their confidence entirely misplaced.

One can give a rough estimate of the time interval required for the repetition of the astronomical configurations given in the epic. The Saros cycle (18 tropical years and 11 days, or 223 synodic months, or 19 eclipse years) for the repetition of eclipses and the Metonic cycle (19 tropical years, or 235 synodic months) for the repetition of a given phase on a given date are well known. It follows therefore, that an event like *amāvāsya* at *Jyeṣṭha nakṣatra* would repeat after 19 years. But a total solar eclipse at *Jyeṣṭha nakṣatra* would repeat after about 340 years! Combine that with *śani* at *rohiṇi*, it would take something like 10000 ± 3000 years (allowing a generous margin of error) to repeat. This explains why the planetary configurations described in the epic and found on the date of 3067 BCE proposed here could not be found on any of the other dates proposed by scholars. Unfortunately, the Scholars have characterized the astronomical references in the epic as being inconsistent, where as the references constitute a very consistent set as shown by these simulations. Scholars have concentrated on a pair of eclipses, but they should have been

really looking for eclipse seasons with three eclipses, with two lunar ones at the ends. Such events are truly rare. For the conditions are very stringent. But the simulations show that such configurations did occur, and furthermore, occurred a second time 36 year later at the time of the *yādava* infighting, exactly as mentioned in the epic.

X. *Kaliyuga*

No account of the chronology would be complete without a discussion of the *Kaliyuga* and its beginning. In the beginning of the epic it is stated that the War took place during the transition period between *Dvāpara and Kali*:
antare caiva saṃprāpte kalidvāparayorabhūt/

samantapaṅcake yuddhaṃ kurupāṇḍavasenayoḥ//(I. 2.9)

Similarly, *Māruti* says to *Bhīma*

etat kaliyugaṃ nāma acirādyāt pravartate/(III. 148.37)

Kṛṣṇa says to *Balarāma* after *Duryodhana* was been killed:

prāptaṃ kaliyugaṃ viddhi .. /(IX.59.21)

No specific date has been mentioned for the start of the *Kaliyuga.*
In the author's opinion, a separate effort is needed to establish the correct starting date of the *Kaliyuga.* As far as determining the date of the war itself, it is not crucial.

X. Critical edition and variant readings

During the simulations it was found that at several places, a reading variant from the critical edition of the epic gave better agreement with astronomical phenomena. At some places the critical edition reading was actually misleading. For example,
sangramo yujyatām tasyām in (V. 140. 18) is better than *sangrāmaṃ yojayet tatra* found in the critical edition.

A śloka, which alone could have been sufficient to determine the date of the war, has been given by Sathe[27] et al., but is not given in the critical edition:
śuklapakṣasya cāṣṭamyāṃ māghamāsasya pārthiva/
prājāpatyeca nakṣatre madhyaṃ prāpte divākare// (XII. 47. 64)

XII. Conclusions

It has been conclusively demonstrated that the astronomical events described in the Mahābhārata show a remarkable consistency and they could have occurred at about 3000 BCE. These events must have been observed and could not have been back calculated by a clever astronomer to be interpolated into the text. The simulations of events then point to 3067 BCE as the date of the *Mahābhārata* war. This date is identical to the one given by Raghavan and appears to be the best in accounting for practically all of the astronomical references in the epic. More work is needed to establish the beginning date of *kaliyuga.* Further research is indicated in establishing the knowledge of the comets possessed by the ancient Indian astronomers.

Acknowledgements

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