Comet tales from India.
1: ancient to medieval*

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Abstract

This work is about sightings and astronomical observations of comets made from the Indian region, until the 18th Century. The sources of the information are some classic texts and historiographies, publications and records of institutions and chronicles and accounts by some individuals. The quest has enabled us to bring forth a number of interesting but hitherto lesser known or unknown observations of comets from India. These include a handful of discoveries too that are not yet part of the cometographies.

1. INTRODUCTION

Since times immemorial, people have seen providence in situations developing in the sky, namely the conjunction of planets, eclipses, meteors and comets. Historians have often traced history from the celestial phenomena, particularly the eclipses, the conjunctions and the apparitions of comets, recorded in chronicles and other sources. The significance of these records is inestimable. This work is about sightings and astronomical observations of comets made from the Indian region, until the 18th Century. The sources of the information presented here are some classic Indian texts and historiographies, publications and records of institutions and chronicles and accounts by some individuals. The chief sources of information since the beginning of the 17th Century are the communications of some Jesuit priests in India, a number of travelogues and inscriptions. The telescope arrived in India soon after its invention in Europe in 1609 and was put to astronomical use, initially sporadically.

The quest has enabled us to bring forth a number of interesting but hitherto unknown observations of comets from India. These include a handful of discoveries too. Some of the material presented here has not yet entered the cometographies, by Pingré (1783, 84), Williams (1871), Hasegawa (1979), Vsekhsvyatskii (1964) and Kronk (1999).

1.1. Tracing history from astronomical events in Indian works

In old times, the sight of a comet evoked fear and awe but also made for an extraordinary description in many cultures. There is an embarrassing silence in the Indian literary texts and chronicles over their occurrences. There are hardly any real time observations or phenomenology of the unusual celestial events, until the end of the 15th Century. The pre-telescopic astronomy comets we have come to know of were all visually bright and therefore at visual magnitudes of ~ 5 to 6 mag. or brighter at the most vantage points in the course of their apparition. In the Indian texts, which comet is the oldest one on record?

The *Vedānga Jyotisha* (*VJ*; *Vedānga* – limb of the *Veda*) is the earliest Indian astronomical composition. Composed by Lagadha, ca. 1180 BCE (Sarma 1984), when writing was yet to be, its formulary amazes us with the subject matter it tackles. It was later redacted by an anonymous person circa 400 BCE (Subbarayappa and Sarma 1985, p. xxii). The *VJ* has two recensions. The first one belongs to *Ṛgveda* and has 36 stanzas. It is a manual for computing the civil calendar and determining times for the performance of various rituals. The *VJ*

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focuses mainly on the motion of the Sun and the Moon. It speaks of their location with respect to the 27 *nakshatras* (the lunar mansions) at specific times and the times when the Sun crosses equator, determination of the equinoxes, variation of the day length etc. The calendar is luni-solar where the Sun fixes the seasons and the Moon fixes the dates and the moments. The lunar calendar keeps correspondence with the solar year through the provision of adding intercalary months at certain intervals, twice in five years period. The *VJ* contains no guidelines to computation of eclipses. It does not take the visible planets in its purview that came to be considered in later Indian astronomical texts only. The *Mahābhārata* (400 BCE – 400 CE; Winternitz 1977, p. 465), Kautilya's *Arthashāstra* (320-300 BCE), the *Garg Samhitā* (ca. 100 BCE; its oldest version being in the Ist Century CE according to Pingree 1963), the *Paitāmaha Siddhānta* as presented by Varāhamihira in the *Pancha Siddhāntikā* (505 CE) etc. all followed the astronomical system in the *Vedānga Jyotisa* (Sarma 1984, p. 12). The Indian astronomy texts zodiacs begin to figure in belong to the period 100 CE- 400 CE. Their astronomy is pre-*Surya Siddhānta*, i.e., prior to the great advances in mathematical astronomy that began to be made from 400 CE.

The Classical Age in the history of India, also known as the *Gupta Age*, commenced in the 4th Century with the coronation of the king Chandragupta I (320 CE) and flourished until the time of the king Yashovarman of Kannauj (740 CE). It was an age of enlightenment that produced the most monumental works in literature, philosophy, mathematics, astronomy and sciences. In the astronomical works, there is nothing on comets. In the literary or religious works, there is near absence of any reference inspired by the apparitions of bright and great comets of history. Where there is an exception, it is not possible to ascertain if it is a metaphor or a reflection of an apparition. Without the basics – the dates, forms and the asterisms these were seen near or moved through, it is difficult to make correspondence with the sightings made elsewhere.

The Islamic historical records of the medieval period have been better in this respect. Recording such events in the political history was a well-established tradition in the 'Middle East' empires. It continued uninterrupted for a long time and even travelled to India. North India was dominated by the Mughal Empire during the 16th and 17th centuries. The Mughal chronicles mention a number of solar and lunar eclipses, fireballs and even comets. The emperors took occurrence of eclipses and comets quite seriously and even sought remedial measures. Towards close of the 18th century, the Muslim rule was already tottering. There were no more political histories to be written and the tradition of recording naked-eye observations of unexpected phenomena came to an end.

2. COMETS IN ANCIENT INDIAN TEXTS

The *Ṛgveda* is the oldest sacred book of the Hindus. A work in progress since 1500 BCE until ca. 900 BCE (Kochhar 2000, p. 222), it is a collection of 1028 hymns, composed by a number of priest families. The hymns include invocation of gods, the ritual hymns and description of battles, etc. In the *Ṛgveda* and some later Indian compositions like *Atharva Veda, Parāsara Samhitā* (*samhitā* – collection of hymns), *Mahābhārata* and the *Purāṇas* etc., a certain word *ketu* appears that is used in the sense of an *utpāta*, meaning a serendipitous/unusual phenomenon such as a comet or a meteor. However, their astronomical content is flimsy.

The first major work that delves at some length into the *ketus* is the *Bṛhat Samhitā* an encyclopaedic tract on astrology and other subjects composed in 505 CE by Varāhamihira (485-587 CE; Bhat 1986). It deliberates on eclipses, planetary movements, cloud formation and other natural phenomena etc. In a chapter *Ketuchāra*, Varāhamihira provides a morphological description of the *ketus* that about resemble features noticed in comets. He draws from earlier works like the *Nārada Samhitā* but does not write from actual observations. He even acknowledges periodicity in comet apparitions but the figures cited are

on presumption only. Varāhamihira states that it is not possible to determine mathematically the rising or setting of the *ketus* (comets) since there are three different categories of *ketus*, namely, celestial, atmospheric and terrestrial. The celestial *ketus* are seen amid the stars in the firmament whereas the atmospheric ones are those seen on flag staffs, weapons, trees and mansions, etc. The terrestrial ones differ from those described above. Varāhamihira describes numerous forms and, amazingly, presents a taxonomy that covers a thousand *ketus*.

Among the many *ketus*, Varāhamihira describes an interesting form, the *chalaketu* (*chala* for moving) that makes its appearance in the west direction. Of all the forms, *chalaketu* is the only *ketu* that stands out with as much astronomical content. It has a crest. It is raised a digit high and has its head directed southwards. As it moves northwards, it grows in length. It touches the *Seven Ṛshis* (Sages), *Dhruva* (pole star) and the *nakshatra Abhijit* (Vega). The *chalaketu* traverses half the length of the sky and then turns back to set in the south. That *might* be about a comet but there is nothing to suggest any real time observations. The description suggests its becoming circumpolar at some point of its journey. Going through accounts of comets in Kronk (1999) sighted during the period 675 BCE– 505 CE, we do find a few prominent comets that could fit this description. The few whose orbits have been determined are C/400 F1, C/418 M1 (the eclipse comet) and C/442 V1. Among the three, the comet C/400 F1 seen in the year 400 CE comes nearest the description. But that proves nothing. There is at least one comet in our lifetime, noticeable naked eye that leaves an indelible mark on the mind. In Varāhamihira's lifetime, there were 33 comets on records. He may not have observed them all but he could not have ignored the visit of the Halley's Comet in 530 CE. There is no commentary on it from any quarters.

Vallālasena (Ballāl Sena) the ruler of Bengal who ascended the throne in 1160 CE deserves mention here for his great interest in astronomy. He was a learned man who engaged in observations, determined winter and summer solstices and considered celestial phenomena in a tome *Adbhutasāgara* that he began in 1168 CE. After his death, the work was completed by his son Lakshmaṇasena. *Adbhutasāgara* is composed on the lines of the *Bṛhat Samhitā.* It too has a chapter on *ketus* including reference to *dhūmketus* but mirrors *Bṛhat Samhita* in its treatment. There is nothing that may even remotely suggest of comets actually observed. Among the prominent comets in the times of the Senas, the Halley's Comet rose in the year 1066 CE (1P/1066 G1) and in 1145 CE (1P/1145 G1).There are references to *dhūmaketus* in many Sanskrit texts that have been dated but it is difficult to associate any to the comets seen in the times. There are comets mentioned in the great epics *Mahābhārata* and *Rāmāyana* also. We take these up here below, only because the references have attracted the scholars from time to time.

2.1. A comet reference in the epic *Mahābhārata*

In the *Bhīshmaparva* of the epic *Mahābhārata*, the sage Vyāsa narrates at length to the king Dhrutarāshtra the worrisome circumstances developing just as the royal siblings with their armies stand face to face in the battlefield. The sage points to the many ominous terrestrial and celestial circumstances like the peculiar planetary postures, two consecutive eclipses at an unusual interval of thirteen days and a monstrous comet all indicative of disruption of the world order. The stanza 3:3:13 in the *Epic* alludes to the appearance of a *dhūmaketu* (comet) thus:

Dhūmaketurmahāghorāh Pushyam chakramya tishthati,
senayorasivam ghoram karishyati mahāgraha.

{A formidable comet has seized the *Pushya nakshatra* and is stationed there; this great *graha* will cause great havoc to both the armies}.

The *Pushya nakshatra* mentioned above is a lunar mansion, represented by the star δ Cancri. The information is insufficient and any interpretation requires complex issues to address such as the state of knowledge of astronomy and the sciences as also the feasibility. The Sage's prognosis, concern and warnings did not stop the Great War that went on for eighteen days. The age of the War is not known. According to some, the war, if there was one, may have taken place in the window 1400 BCE - 1000 BCE (Majumdar et al. 1990, p. 251). The *Epic* was composed much later and the astronomical references are even later interpolations. The astronomy here is pre-*Siddhāntic*, < 400 CE. The Sage's premonitions involve all the conceivable ominous situations in the sky. That cannot be from prescience. A few scholars identify the comet in the *Mahābhārata* as the Halley's Comet (1P/Halley). We may ask, when did this comet pass near the *Pushya (*δ Cancri)? Over the writing period of the *Epic*, the comet did so in several of its returns, namely those in 12 BCE, 141 CE, 295 CE, 451 CE and 530 CE. However, as the astronomical circumstances in the *Bhīshmaparva* are self-inconsistent, the eclipses and the comet described therein are unidentifiable.

2.2. A comet in the Buddhist text *Divyāvadānam*

The reference to a comet in a particular *nakshatra* as ominous is not unique to *Mahābhārata*. There is a near identical reference in the *Shardūlakarnāvadānam* in the Buddhist Sanskrit text *Divyāvadānam* (200-350 CE Vaidya 1959; Ist Century CE Pingree 1981, p. 68); here, *divya* – divine*, avadāna* – narrative. It speaks of a comet in *Pushya - Dhūmaketurmahābhagah pushyamarūdha tishthati….* - O, sir! When a comet occupies *Pushya* there is defeat in attacks from all four quarters (Stanza 466). This may be a general reference but its being *Pushya* specific arouses curiosity. In this case, it could be the memories of the Halley's Comet seen in 141 CE. The significance of *Pushya* lies in the longitude of its beginning (93°20'), thus a marker of the Summer Solstice point. The comet first seen on 26 March was still very bright when it passed by *Pushya* on 26 April evening. However, before that, the brilliant object passed also by *Uttarabhadrapada* (γ Pegasi) on the morning of 13 April, *Asvini* (*β Arietis*) on 19 April morning*,* and *Krittikā* (Pleiades) on 21 April evening. The next notable comet until 200 CE is 109P/188 O1 Swift-Tuttle seen in 188 CE that passed very close by the Earth but not near *Pushya*.

2.3. A comet in the epic *Rāmāyana*

Sage Vālmīki's epic *Rāmāyana* (300 BCE – 200 CE; Winternitz 1977, p. 516-7) is the story of Lord Rāma. Vālmīki, as the legend goes, belonged to Lord Rāma's age. The *Epic* contains references to a few astronomical circumstances, those at the time of his birth, around when he is banished to the forests for 14 years, the great march of his army to 'Lanka', the abode of the demon king Rāvaṇa and the war with him, etc. Rāma's period is indeterminable. There is a horoscope featuring in the *Epic* but it is an interpolation since the zodiacs came to India from Alexandria along with the Hellenistic astrology around the middle of the Ist Century CE. It presupposes that this knowledge existed in Lord Rāma's times. In a later chapter, the *Yuddhakānda* that narrates Rāma's battle with Rāvaṇa, there is reference to a comet near a particular *naksatra* (Vālmiki 1991, **6**:4:52-53, p. 678), as follows:

'*Nairritam nairritanam cha nakshatram abhipīdyaté*,
Mūlam mūlavata sprushtam dhupyaté dhūma ketunā,
Sarvam cha aetad vināshāya rakshasanam upasthitam',

i.e., the *nakshaatra Mūlam* of the *rākshasas* (demons) is badly situated such that it is touched by a *dhūmaketu* (comet) that has arisen with tail of light and is bedeviled by it. All this has come to be for the destruction of the *rākshasas* because those who are destined so, their own *nakshatra* is inflicted by a *graha'*.

What comet passed over the *Mūlam* (λ Scorpii)? Among the comets recorded since antiquity until the year 200 CE, the only comet that comes close is C/-146 P1. It was discovered by the Chinese on the evening of 6 August 147 BCE 20º south of the *Fang* (β, δ, π, ρ Scorpii) and described as a 'tangle star'. According to Hasegawa (1979), the comet had passed its perihelion on 28 June; *q*=0.43 AU, *i*=71º. It passed closest by the Earth on 3 Aug (0.143 AU). The comet was seen on 7 Aug northeast of *Hsin* (α, σ, and τ Scorpii; *Jyestha*) and on 8 Aug north of *Wei* (ε, ξ, η, ι, κ, λ and μ Scorpii) when it had a tail extending to 60º. The comet C/-146 P1 was then trailing the Sun, moving northeast and possibly its tail touched *Mūlam*. That would be around the time of its discovery. If the observation in the *Epic* is for real, the comet, an evening object, must have been seen by its author around the same point of time as the Chinese.

2.4. A *Sangam* Age reference to *a star in flames*

A *Sangam* Age Tamil classic *Purananuru* (also *Puram*) carries reference in the verse 229 to the appearance of an unusual object in the sky. To the poet, it is portending imminent death of the Cheran king Mantaran Cheral Irumborai. The *Sangam* – an assembly of poets, was established by the Pandyan kings at Madura. The earliest *Sangam* literature was oral, composed between 100 BCE and 250-300 CE regarded as a period of prosperity, enlightenment and literary accomplishments. The poetry was initially secured on palm leaves and, as the script for the language evolved, into anthologies in the 8th – 9th centuries. *Puranānuru* is part of the *Ettuthokai* (The Eight Collections), one of the anthologies of the Third *Sangam*. It contains 400 poems composed by about 150 poets and is a valuable source of social history of the times. Most of the *Puram* poems are from the 2nd Century (Majumdar et al 1990, pp. 291-300; Zvelebil 1992, Ch 4).

The Wikipedia (2010) entry on the king Mantaran Cheral Irumborai gives a brief on his history, citing also from the verses 20, 22, 32, 53 and 229. Its anonymous writer considered the astronomical reference in the *Puram 229* to be alluding to a comet seen in the month of March-April and identified it with the Halley's Comet in its apparition of 141 CE around February-April first week:

"Seven days after a bright comet appeared in the sky, amidst the Mesha constellation, past midnight on the first leg of the starday of Krittikai in the month of Panguni in the first quarter of Anusham (PN: 229), with North star going down on the west, Moolam rising from the east and Mrigasirisha wandering above towards north and east of the port of Tondi, Mantaran Cheral Irumborai died suddenly", Thus the prediction of an imminent loss for the kingdom by the council of *Vaanaviyal Kanidar* (ancient Tamil astrologers) came to be agonisingly true".

The verse *Puram 229* is probably the first record of a celestial apparition in an Indian literary composition that has a specific astronomical content. The question is if it can be dated. The composer describes the night sky using *naksatras* to stress the significance of a certain event. Planets and eclipses do not figure in here. So, was it the apparition of a comet or a fireball? The words as in the verse that come close are *kanaiyeri* – ball of fire, and *orumīn* – a star with tail.

The many translations of the Tamil poem by scholars invariably bring in zodiacs to a place and an era that did not yet know them. The celestial circumstances by themselves do not settle the dates. In my preliminary study, a comet rather than a meteoroid fits the circumstances. If it was a comet, the Halley's Comet of 141 CE is a strong contender. However, its apparition appears to be somewhat out of step with the description of the night sky. The king may have died somewhat earlier than the Halley's Comet reached its moments of glory. There is no other comet known within several decades on either side of this apparition that would have been as spectacular and qualify for similar mention. This work is in progress.

2.5. A comet in the *Mrcchchhakatikam*

Mṛichchhakaṭika (Stenzler 1947) composed by Śūdraka (2nd – 5th Century CE) is one of the oldest yet most regarded of the Sanskrit dramas. It carries references to certain astronomical circumstances. Its Act VI refers to the placement of some of the planets in certain houses. The description is horoscopic and with an ominous tilt. Hermann Jacobi examined the astronomical information and contended that the Act could not have been written before the 4th Century CE.

In the Act IX of *Mṛichchhakaṭika*, there is reference to a comet and the planets Mars and Jupiter. This circumstance has not been explored. Chārudatta, the protagonist is implicated in the murder of his lover Vasantasenā and stealth of her ornaments. He is produced before a judge and is convicted. In the course of his trial, *Adhikāraṇika* (the Judge) at some point (Act IX, 33) exclaims

Angārakaviruddhasya prakshīṇasya Bṛhaspatéha |
Graho yayamaparah pārshvé dhūmaketurivotthitaha ||

'What misery! By the side of an emaciated Jupiter whose adversary is Mars, this other planet like a comet has arisen'.

It is not certain if the two circumstances in the play were imagined or were inspired from actual celestial occurrences. I have examined the circumstances and computed the planetary positions using modern planetary theory models. All through 100 BCE-600 CE, the celestial configuration in the Act VI obtains only on 9 November 309 CE and on 29 November 546 CE, though not as exactly as presented in the text. The astronomical circumstances in the Act IX involving the comet and the two planets apparently have only one match in the cometographies, namely, in the apparition of the Great Comet of October 191 CE. The two astronomical circumstances are mutually exclusive.

It appears that, rather than the circumstances, the astronomy in the play can define the window of Śūdraka's period better. A work *Yavanajātaka* is the first composition in Sanskrit presenting Greek astrology and horoscopy where solar zodiacs appear; according to Mak (2013), this work may be dated > 22 CE. *Mṛichchhakaṭika* can only be later than the *Yavanajātaka*. In the Act IX, the planets Mars and Jupiter come about as adversaries. The two planets as adversaries is a concept of Greek astrology that flowed into India prior to which the two were regarded friends. We find the two designated as friends in a later astrological text *Vṛddhayavanajātaka* of Mīnarāja (300-325 CE). This suggests that *Mṛichchhakaṭika* should be earlier than *Vṛddhayavanajātaka*. The *Mṛichchhakaṭika* may belong to late 3rd - early 4th Century CE, a window consistent with the considerations of history and literature.

2.6. The comet in *Dnyāneshwari* (*Gyāneshwari*)

Gyāndeva, or Sant Gyāneshwara (Dnyāneshwara 1275-96), was a great saint poet and reformer and is highly revered for his *Dnyāneshwarī* or *Bhāvārtha Dīpika*, an interpretation in poetry of the great philosophy in the *Bhagwad Gītā* for the masses who could not follow Sanskrit. It is regarded as one of the greatest works in Marathi literature. One of the stanzas from the *Dnyāneshewarī* (**16**:319; Dandekar 1953, p. 620) carries the word *ketu*:

'Udaijaṇé ketūchén jaisén, vishwā anishtāchi doshén,
Janmatī té taisé, lokān ātūn',

meaning that a comet brings along misfortune to the world. The *Dnyaneshwarī* is considered to have been completed in 1290 (Bhandarkar 1884). The question is: was the comet reference

inspired by a sighting? The comets of relevance here are those of 1277, 1282 and 1285 but none of these was significant enough. The only comet that can be considered in this phase is that of the year 1293, namely, C/1293 V1. It was discovered on the morning of 20.8 November by the Koreans and last seen on 22.8 December. The comet finds mention in the Chinese and Japanese texts too (Kronk 1999). It is a parabolic comet with q=0.78 AU, i=30°; it passed its perihelion on 28 Oct 1293 and closest by the Earth on 22 November from 0.1795 AU. At its best, it had shown up with a tail just ~1º long. The next comet worth a note was the Halley's (1P/1301 R1) itself. Thus, if the *Dnyāneshwarī* meant it, it can be C/1293 V1 only.

2.7. Comet references in the Kashmiri chronicle

There are a few comet references to be found in the Kashmiri chronicles. The great Sanskrit work *Rājatarangiṇī* (The River of Kings) by Pandit Kalhaṇ written during the years 1148-50 CE chronicles the rulers of Kashmir from the earliest times, the King Gonanda I regarded by him as contemporary of the king Yudhishthira of Mahābhārata, until the reigning king Jayasimha (1127-50/59?). The tradition was continued, centuries later, by Jonarāja (ca. 1389-1459 CE), his disciple Srīvara covering 1459-86 CE and Prāgyabhatta and his disciple Shuka until 1586 CE when Kashmir was annexed by Jalāl-ud-dīn Akbar to the Mughal Empire. The dates in the *Rājatarangiṇī* texts are in the *Laukika* calendar that begins from the March/April of 3076 BCE. To recall, Islam came to Kashmir in early 14th Century.

The *Rājatarangiṇī* under different authorships cites a few instances of eclipses and comet apparitions. That makes *Rājatarangiṇī* the first Indian work of history where references made to the celestial circumstances can be subjected to a cross check with other sources. Surprisingly, Kalhaṇ himself missed out referring to a spectacular Halley's Comet (1P/1145 G1) that appeared during mid-April - early July in 1145 CE and the celestial sensation would have been fresh in popular memory.

The first comet reference in the *Rājatarangiṇī* belongs to the king Zain-ul-Ābidīn's reign who ruled Kashmir during 1420-70 CE. He is considered one of the most enlightened Muslim rulers in India. He was a learned man, a poet with command over Persian, Hindi, Kashmiri and Sanskrit, who encouraged scholarly pursuits (Singh 1976, p. 7). However, the last 20 years of his rule were not peaceful due to the tussle among his sons for the throne, an unsparing famine in 1460 and then the devastating floods. The apparition of the comet with a long tail and how it was seen as a portent to the turbulent times for the king and the people is described by Srīvara in the stanzas 1.7.10-18 (Kaul 1966, p. 78-79). The first two of the stanzas reads so:

Ityātankāgamé seturhetuh sarvajanakshayé,
athottaradishā rātrau dhūmaketurdrshyata (1.7.10)

dīrghapuchchhochchhalatkantitatketukapatād
kālen drughaṇam kshiptam kshayāyev mahīkshitām (1.7.11)

Dutt (1986, p. 153) condenses the elaborate description in the stanzas to

'A comet was seen at night in the north. Its long tail was of resplendent beauty. For a period of two months the comet was visible in the clear sky…The people saw signs of a severe calamity to the country…'.

Srīvara sees in it God's wrath who in the shape of the bright tailed form has thrust his scimitar to destroy the kings. He also mentions of eclipses of the Moon and Sun that occurred within a fortnight. To add to the severity further, the Sun transited into the next sign on an

inauspicious day (1.7.16). This scared the people into believing the circumstances as portents of doom. Sultān Zain-ul-Ābidīn who faced long drawn out tribulations in life died in 1470.

According to Kak (2008), the *Rājatarangiṇī* carries references to three comets and identifies these as C/1468 S1, the Halley's Comet 1P/1531 P1 and C/1533 M1 respectively. The first of these, namely C/1468 S1 belongs to Zain-ul-Ābidīn's reign. Elsewhere, the comet was first noticed on 17.8 Sept in Ursa Major by Chinese astronomers and independently observed by the Japanese and in Europe. By 21 Sept, it showed up as a white-blue object with a tail 30º long. The comet passed closest by the Earth on 1 Oct from 0.6691 AU and brightened up to its maximum on 2 Oct when it reached a visual magnitude m_V ~1-2. It passed its perihelion on 7.3 Oct UT and was last sighted on 18.4 November (Kronk 1999).

What can the Sun's transit on an inauspicious day mean? After the comet of 1468 was first spotted, the sign the Sun moved into was Scorpio, i.e., passed the longitude 210º, on 14th October (03:36 UT, Friday). In Islam, the sign of Scorpio is evil and implies affliction to the populace. In the Hindu system, a calculation suggests that the *Vraschika Samkrānti* (the passage into the zodiac Scorpio) would have taken place on 29th of October, 22h12m, Saturday, Ujjain time. We can not know which astrological system the author *pandits* referred to – the Islamic or the Hindu astronomical. In fact, through the comet's visibility phase, the Sun had traversed both: it first moved into the tropical sign and then passed into the sidereal zodiac. Being a Hindu, how Srīvara meant it to be is not clear.

Slaje (2012, pp. 33-48) on the other hand identifies the first comet in the *Rājatarangiṇī* as the Halley's Comet 1P/1456 S1, while dismissing that of 1468. It was first seen on the morning of 26.8 May, passed closest by the Earth on 18 June and was last seen on 8.83 July UT. In this case, the Sun passed the solstice on the 12th June (14:45 UT, Saturday) to enter the sign of Cancer and turn southwards. As per the Hindu calendar, the *Karka Samkrānti* (transit into Cancer) would have taken place on the 28th of June, 23h29m, Monday. That for the Hindus marks beginning of *Dakshiṇāyana* – an uncharitable period.

The comets of 1456 and 1468 were both bright and spectacular. These fit in but the eclipses suggested by Kak (2008) and Slaje (2012) to have followed the apparition do not. We dismiss the penumbral eclipses from consideration since these are not counted in the traditional astronomers' calculation. The commoners most often do not notice a penumbral. In Fred Espenak's Eclipse Tables, the first relevant eclipse-pair is that of 3 July (lunar) and 18 July 1460 (solar), both partial in Kashmir. Post 1468, the first relevant pair is that of the partial solar of 25 Feb 1476 and the total lunar of 10 Mar 1476. That suggests that Srīvara clubbed the celestial circumstances postscript though these were far apart in time. The comet of 1468 would be fresh in memory and if it was the Sun's position in Scorpio that added to people's apprehensions, then the comet C/1468 S1 is it.

A *ketu* reference occurs in Shuka's *Rājatarangiṇī* (Singh, 1976, p. 147, *sloka* 47) corresponding to the *Laukika* year 4607 (≡1531 CE). This reference is made in the context of the bearing of a signage (banner) in the likeness of a *ketu* by the bride of a brave Kācha Chakravarti to show her displeasure over his marching out to a distant place to fight the enemy forces. This is interpreted by Dutt (1986, p. 369) as the appearance of a comet in the west and by Kak (2008) as the Halley's Comet (1P/1531 P1). However, there is no additional information or phenomenology here. Halley's Comet would rather evoke a stronger response whereas Shuka's *ketu* reference seems to be terminological only. Having settled that, the mystery remains how Shuka missed a spectacular Halley's Comet, followed by yet another one in 1532, whereas he became more effusive about a bright comet that arose a year later.

A later reference to a comet in Shuka's *Rājatarangiṇī* (Singh 1976, p. 177-8; *Sloka* 88-90) corresponding to the *Laukika* year 4609 rests on a firmer ground. He describes the turbulent times when a Kāskar army attacked Kashmir in late 1532 and created havoc through the

months of Jan- March of 1533. The Kāskars were barbarians who came from hilly areas between Afghanistan and Chitral. The Kashmiris rose to fight the Kāskars and peace returned later with the latter's departure, as also that of the Mughal invaders under Mirza Haidar, by truce with the daughter of the king given in matrimony. This happened towards the end of the month of Shawwāl 939 AH (≡24 May 1533 CE) / *Jyestha* of the *Laukika* year 4609 (beginning 25 May 1533). Then, as if to torment the people, there arose a comet in the eastern and western sky, seen all night. Shuka speaks about the great famine that year and relates it to the fall of stars on the fields from the sky all over around the harvest time of rice when the comet was seen again.

That should be about the comet C/1533 M1. As per the Korean records, the comet was first seen on the morning of 27 June. It had passed its perihelion on 15.417 June UT. A doctor Rainer Frisius found that the comet was circumpolar on 9 July and it was later seen on the evening of 12 July at an altitude of 7º. The Chinese recorded sighting a 'broom star' in the constellation of Auriga on 1 July in the morning that had reached a visual brightness of 0 mag. Seen in Europe, its head shone brighter than Jupiter on 7 July while on 21 July, it showed up with a tail that measured 15° in length (Vsekhsvyatskii 1964). It passed the closest by the Earth on 2 August from 0.4211 AU and was last seen on 16.5 Sept (Kronk 1999).

The observation that stars fell from the sky is interesting. It suggests of a meteor shower. The reference assumes significance for Perseids, associated with the comet 109P/Swift-Tuttle (*P*=133.28 yr; JPL) and known to mankind since the last two millennia, are observed in between 17 Jul – 24 Aug. The showers peak in the period 9-14 Aug and have shown a consistency with little variation in numbers. Today keen observers focus on the midnight of 12/13 Aug while the constellation rises. But, that is not as simple as it seems. Hughes and Emerson (1982) in their study of the Perseids have shown how the epoch of the maximum activity of the showers has changed in the course of about two millennia as a result of progression in the descending node of the orbit of the Perseids due almost entirely to the precession of the equinox. The earliest recorded date of the showers is 17 July 36 CE. In contrast, their peak activity in 1980 was on 12.3 August. There are no observations on record in the year 1533 and so we interpolate between the on-record dates for the 1451 and 1581 showers. These dates are 27 Jul (5 Aug Gregorian) and 26 Jul (5 Aug Gregorian) respectively. There are different estimates of the comet's tail around these dates. Gasser reported a tail 5º whereas the Chinese noted a tail 10º long (Kronk 1999). We have no other meteor shower as prominent as the Perseids around the time of the comet's high visibility. The Kashmiri chronicles are qualitative about the timeline here but if the celestial fireworks in Shuka's description are the Perseids, the date of the record should be around their peak activity, viz., 27 July 1533 (Julian), give or take a few nights. The Full Moon was on the 4th August. This suggests that the best view of the showers as well as the comet was available since the latter was approaching the Earth passing it closest on the 2nd. Until 5 August the comet was a morning object.

That may be the first record of a meteor shower in an Indian chronicle.

Notably, the *Rājataraṅgiṇīs* (1148-1586) feature only two bright comets and relate their apparitions to turbulence in political and civil life. No other comet including the Halley's appearing through the entire period of their writing receives such a mention. The chronicles being the first dateable works, such references could have served an important purpose. Eclipses as ominous occurrences have ruled Indian life through the ages. There is hardly an eclipse here related by the authors to current affairs of the ruler or the state of the people. There is nothing on planetary conjunctions either. A grand conjunction of the seven luminaries took place on 4 Feb 1524 when all the planets lay within ~25º of each other. This included the notorious *Rahu* (the ascending node and counted as a planet) to make the conjunction into the most dreaded of them all, the *ashtagraha yoga*; there was also an annular

solar eclipse that day (not visible over India). Thanks to printing technology, the apocalyptic prognostications of the grand conjunction of 1524 charged all of Europe in a collective scare but it did not register with Shuka.

2.8. The comet in the scripture *Sri Guru Granth Sāhib*

The great poet-saint Guru Nānak (1469-1539 CE) was the founder of Sikhism. The Sikhs' sacred book *Sri Guru Granth Sāhib* (SGGS) comprises of the teachings of their Gurus (the Teachers) including several other saints. Its final redaction was prepared by the tenth Sikh guru, Guru Gobind Singh (1666–1708). Two celestial occurrences find place in the incidents related to Guru Nānak or in his teachings. The first one referred to as *lammā tārā* (long star) figures in a hymn in the *Sri Guru Granth Sāhib* and the other a solar eclipse that occasioned while Guru Nānak was visiting Kurukshetra, a pilgrimage centre for the Hindus.

In the teachings of the Sikh Gurus, one finds a beautiful blend of spiritual poetry and of music which all the Gurus were great connoisseurs of. The first guru Guru Nānak observed natural phenomena very keenly and wove some of them into his poetry metaphorically. In his hymns set in *Tukhāri*, a *rāga* (a scale of notes) sung in the evening, he refers to the rising of a *long star* in the sky (*SGGS*, *First Mehl*, pp. 1110-11) so:

Tara chadhiya lamma kiu nadari nihalia Ram ||
Sewak puur karma Satiguru sabadi dikhalia Ram ||
[The meteor shoots across the sky. How can it be seen with the eyes? The True Guru reveals the Word of the *Shabad* (group of hymns) to His servant who has such perfect karma].

A few lines later, Guru Nānak repeats the reference:

Nanak haumai mari patine tara chadhiya lamma |
Gurumukhi jagi rahe chooki abhimani Ram|
(O Nanak, killing his ego, he is satisfied; the meteor has shot across the sky. The Gurumukhs remain awake and aware; their egotistical pride is eradicated).

The word *tārā*, translated above as meteor, actually means a star so that the phrase *Tārā chadhiyā lammā* that literally means 'a long star has risen' would refer to a comet rather than a meteor that does not 'rise' and is only a momentary spectacle. Could the phrase - *a long star has risen* mean a fireball? Such an event will be accompanied by a sonic boom and may even harm structures and people. A great meteor shower would register but then the scriptural observation would be different from the above. The *long star* referred to in the phrase should be a comet, and most probably the Halley's Comet in its apparition in 1531. It was seen first by the Chinese on the morning of 4.8 August with a tail of over 1° when it would have been in the constellation of Auriga. The apparition is historic for another reason when Apianus showed in his famous work *Cosmographia* from five consecutive observations of the comet during 13-17 August that its tail was always directed away from the Sun. The comet passed closest to the Earth on 14 August from a distance of 0.4414 AU and its perihelion on 26.239 August (UT). It was last seen on 8.5 September UT as an evening object. The comet was sighted for 34 days on.

The desired clue to the goings on in the sky is probably vested in a phrase that can mean it only when the comet is in ascendance – in brightness and in form. The lines in the *Sri Guru Granth Sāhib* that follow the ones quoted last suggest this out - *Night and day, it is dawn for them; they merge in the True Lord. The Gurmukhs are merged in the True Lord; they are pleasing to His Mind*. To see in these verses a parallel with the celestial form may be subjective but, in its pre-perihelion phase, the *long star* was surely getting progressively spectacular and appearing to rush for a grand union with the lord of the sky, the Sun.

After 14 August, the comet would be moving away from the Earth and gradually lose in brilliance. We may therefore take the comet to have been noticed around the times it flew by the Earth when with its noticeable movement and the developing form and brilliance it would have made a lasting impression. That makes it to be in the period 10 -14 August. We presume clouds of a rainy season permitted the sighting, early in the morning and near the horizon, and more than once. After 14 August, the comet headed southeast moved up high into the evening sky losing some brilliance.

The other notable comets appearing in Guru Nānak's lifetime are: C/1490 Y1 discovered on 31.5 December by the Chinese in the evening in the constellation of Vulpecula, C/1499 Q1 discovered on 16.6 August by the Chinese in Hercules, C/1500 H1 discovered on 7.8 May by the Chinese near the Capricornus-Aquarius-Pisces region, C/1506 O1 discovered on 31.5 July by the Chinese within the region around Draco-Ursa Major-Camelopardalis and, after the Halley's, the bright comet of late 1532. There is no comet in Guru Nānak's lifetime that would have been as magnificent as the Halley's. This is significant considering that the record of sighting of a comet in an Indian scripture has so far not been identified.

Notably, eclipses, whether of the Sun or the Moon, were considered auspicious occasions when the Hindus throng to the nearest river, engage in ceremonial ablution and oblation and offer charity. Among these, Kurukshetra, a holy place associated with Lord Kṛshna and Mahābhārata, holds the highest significance and referred to in the ancient texts like the *purāṇas.* Of the many eclipses occurring in between the relevant period of 1498-1521 during which Guru Nānak undertook long journeys to spread his mission, the solar eclipse of 13 January 1507 is the most probable one. The eclipse is historical in the sense that it is the first observational record of an eclipse in India to be depicted in a 19th Century mural at the Gurudwārā Bābā Atal Sāhib Ji at Amritsar. Elsewhere, I have discussed these references in detail (Kapoor 2017).

2.9. Sant Eknāth on comets

We come across in a Marāthī epical poem *Eknāthī Bhāgawata* by Sant Eknāth (1533-99; Datta 2006), the great religious Marāthī poet and social reformer, two verses 6.282 and 30.69 on his sighting of three comets. Apparently, these are all at one time. The epic is an erudite exposition on the Canto XI of the *Bhāgavata Purāṇa*, a Hindu religious work. The three comets are described thus (30.69):

'*Gagani ugavalé trividhketu, dandaketu, dhūmaketu,*
Shikhāketu ati adbhuta, divasā disat sarvāhi',
'there arose in the sky three comets, namely *dandaketu, dhūmaketu. Shikhāketu* is spectacular, visible in the day.'

The description in the other poem is very similar. Herein, *dhūm* means smoke and *danda* means staff. Wagh (1989) identifies the last one, *Shikhāketu*, with the Great Comet of 1577.

The identification seems to be in order but if the *Eknāthī Bhāgawata* was composed during 1570-73 as is believed (Datta 2006), then the verses on comets might be later interpolations only, perhaps by the poet himself after viewing the Great Comet that went on to become a sensational daylight object. There are only two comets during the stated period of composition of the *Bhāgwata,* the one seen in November 1570 and that of 1573. There is no information from elsewhere on the former comet except that it was seen from Europe whereas the latter is reported in a Chinese text as a broom star seen during July in Pisces (Hasegawa 1979). The next in line is the comet of 1576. However, none of these was so significant as to merit description as an *adbhuta* (spectacular) object. Therefore, it is as well that the *Eknāthī Bhāgawata* was open until at least end of 1577. Around the times of its discovery, the Great

Comet was a low declination object. It is likely to have been spotted by the poet around then only. What is remarkable is his terminology for comets that must have come from his exposure to traditional tracts such as the *Bṛhat Samhitā* etc.

It is interesting to note that the supernova burst of November 1572 in Cassiopeia, one of the few seen in our Milky Way and called Tycho's Nova, had taken place during the years of the composition. It rose in visual brightness to daytime visibility matching that of Venus. There is no word on it in any literary composition.

3. THE MUGHAL RECORDS OF CELESTIAL EVENTS

Through the 16th and the 17th Century, traditional astronomy in the north India received patronage from the Mughal Emperors when amalgamation of the Islamic astronomy and the Indian astronomy – more specifically the observational techniques and instruments of the former and the computational techniques of the latter, paved the way for accurate astronomical observations. There was no clear division between astrology and astronomy and astronomy enjoyed attention mainly for the calendar or the *quibla*. The powers that be were always concerned about the auspiciousness of the celestial circumstances as their journals and memoirs bear this out.

3.1. The *Akbarnāmā* and the great comet of 1577

Abū'l Faḍl (1551-1602), the celebrated prime minister of the third Mughal Emperor Jalāluddīn Mohammad Akbar (1542-1605; r. 1556-1605) was a scholar who possibly has no parallel. The *Akbarnāmā* he wrote is a highly acclaimed biographical account of the Emperor where he has mentioned the Emperor's interest in the study of astronomy. Faḍl's writings reveal his own awareness and grasp of the physical sciences. The *Āīn-i-Akbari* (institutes of Akbar), the third volume of the *Akbarnāmā* is a great documentation of life - material and spiritual. It describes geography, cosmogony, the Hindu philosophy and the way of life, its customs and beliefs and languages in good measures and draws parallels with the Greek scientific knowledge and cosmogony. Referring to the *Sūrya Siddhānta*, Abū'l Faḍl introduces to us the heavens and the Earth etc. At the heart of the discussion is the presumption that the Earth is spherical and that at its centre lies the centre of the Universe.

In the *Akbarnāmā*, in the part relating to the expedition of the Emperor from Rajasthan to Punjab, Abū'l Faḍl records the appearance of a comet in the twenty-second year of Akbar's reign (i.e. 985 AH). During the journey from Ajmer to Punjab, they camped at Mahrot (now Marot, in Nagaur district) on the 9th of Ābān, at Amber (now Amer, part of Jaipur) on the 27th of Ābān, and so on, passing subsequently through Kot Putli, Narnaul, Delhi and other centres. Thus, the comet was first noticed before the Royal entourage reached Amber. From the recorded date, Abū'l Faḍl turns out to be an independent discoverer of one of the most famous comets in history - the Great Comet of 1577 (C/1577 V1). He writes (Modi 1917, p. 70 and p. 74):

"On the day Arad (Arshisang), the 25th of the Ilahi month Aban, at the time when the sun made his conspicuous appearance in the sign Scorpio, this heavenly sign (i.e. the tailed comet) kindled its brilliant face in the sign of Sagittarius, faced towards the west (and) inclined towards the north. It had a long tail. It had reached such a limit, that in many towns they saw it for five months…"

According to Aristotle (384-322 BCE), comets were dry and warm exhalations in the upper atmosphere that belonged to the sublunary sphere, vide his *Meteorologica* (ca. 330 BCE). For the Islamic astronomers too, comets and meteors were atmospheric rather than heavenly phenomena and were mostly ignored. However, Ja'far b. Muḥammad Abū Mash'ar (787-886 CE), the famous Persian astronomer, astrologer and philosopher considered comets celestial.

Writing about the appearance of a tailed star in the western skies after sunset, Abū'l Faḍl introduces the subject first, observing that comets belong to the realm of physical sciences. The commentary is prefaced with a description of formation of vapour versus steam rising from the Earth by the heat caused by the rays of the Sun. As a formation from vapour rising from the Earth, a comet is thus a terrestrial meteorological phenomenon. He treats meteors too but distinct from a comet. These references assume significance in view of the fact that observations from Europe of the very same comet made a decisive impact on the course of astronomy.

Another Mughal courtier 'Ārif Quandahārī also recorded appearance of a comet on the night of Thursday, 25 Sha'aban, 985 A.H. The phrase *night of Thursday* shall mean the day post-sunset of which the following morning is a Thursday. Quandahāri's observation belongs to the evening of Wednesday. The likely UT of the observation is 6.5 November 1577, for the time of observation is just after sunset.

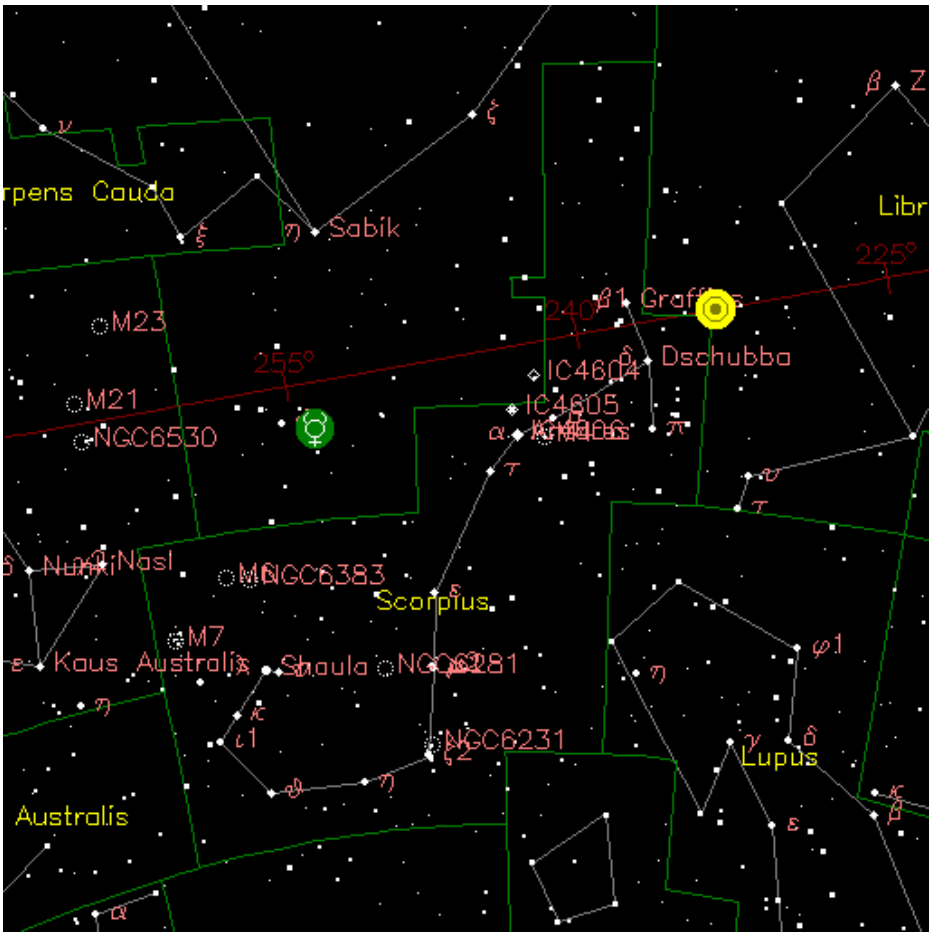


Figure 1. Scorpio region as at sunset on 05 November 1577, 12:05 UT, Tuesday; the comet is where the aim point is in a 45° field (base star map from *Your Sky*).

I computed the apparent position and altitude of the comet in the sky with respect to the Earth's true-equator and the meridian containing the Earth's true equinox of date, and also that of the Sun, as seen from Amber (26°58′ N, 75°51′ E). The Figure 1 shows the Scorpio region as at sunset on 05 November 1577, 12:05 UT, Tuesday; the comet would have been where the aim point is in a 45° field. As the observations are in order, we have Abū'l Faḍl and 'Ārif Quandahārī among the earliest few to have independently recorded on 5 November and 6 November 1577 respectively the apparition of the spectacular tailed form. Full details are given in Kapoor 2015a).

3.2. Jahāngīr and the great comets of 1618

The year 1618 in astronomy was a unique one in that it presented three bright apparitions in quick succession. The comets created enough sensation and belong to the era when Galileo's telescopic observations had created a paradigm shift in our perception of the heavens and Johannes Kepler was introducing a fundamental change in mathematical astronomy by redefining planetary orbits around the Sun. In what follows is an account of the observations of two of the three great comets of 1618 made from India, namely, C/1618/ V1 and C/1618 W1. This turned into a unique occasion indeed when the same targets of opportunity were followed, independently, by astronomers of two very different cultures and observations recorded quantitatively (Kapoor 2016).

Figure 2. A margin drawing from the folio of Jahangir's Album: An astrologer surrounded by his equipment - astrolabe, zodiac tables and an hour glass; period: early 17th century (Courtesy: Werner Forman Archive/Naprestek Museum, Prague).

Jahāngīr, the fourth Mughal Emperor of India, recorded in the *Tūzūk-i Jahāngīrī* (Memoirs of Jahāngīr), appearance of two comets during the royal course from the town of Dohad in Gujarat to Agra, the capital city of the Empire, via Ujjain in the thirteenth year of his accession, i.e., 1027 A.H. Jahāngīr's *memoirs* clearly demonstrate his interest in astronomy and the level of accuracy reached in the observations. We find the recorded information in excellent agreement with modern computation. Jahāngīr's astronomers used instruments like astrolabes, sundials, sandglasses and accurate *ghati-yantra* (water driven clocks; clepsydras), vide Figure 2. The following passage from Jahāngīr's memoirs *Tūzūk-i Jahāngīrī* (Rogers and Beveridge 1909, 1914) carries his observations:

"On Saturday the 18th (Aban), the camp was at Ramgarh. For some nights before this there appeared, at three *gharis* before sunrise, in the atmosphere, a luminous vapour in the shape of a pillar. At each succeeding night it rose a *ghari* earlier. When it assumed its full form, it took the shape of a spear, thin at two ends, and thick in the middle. It was curved like a sickle, and had its back to the south, and its face to the north. It now showed itself a watch *(pahar*) before sunrise. Astronomers took its shape and

size by the astrolabe, and ascertained that with differences of appearance it extended over twenty-four degrees. It moved in high heaven, for it was first in Scorpio and afterwards in Libra. Its declination (*harakat-i-arz*) was mainly southerly.

Sixteen nights after this phenomenon, a star showed itself in the same quarter. Its head was luminous and its tail was two or three yards long, but the tail was not luminous. It has now appeared for eight nights; when it disappears, the fact will be noticed, as well as the results of it."

The *memoirs* mention a number of halts en route, including Ramgarh from where the first observation was made. These are not readily identifiable but the Persian and A.H. dates in the *memoirs* help us follow the royal traverse from Ahmedabad to Agra, through Dohad and Ujjain.

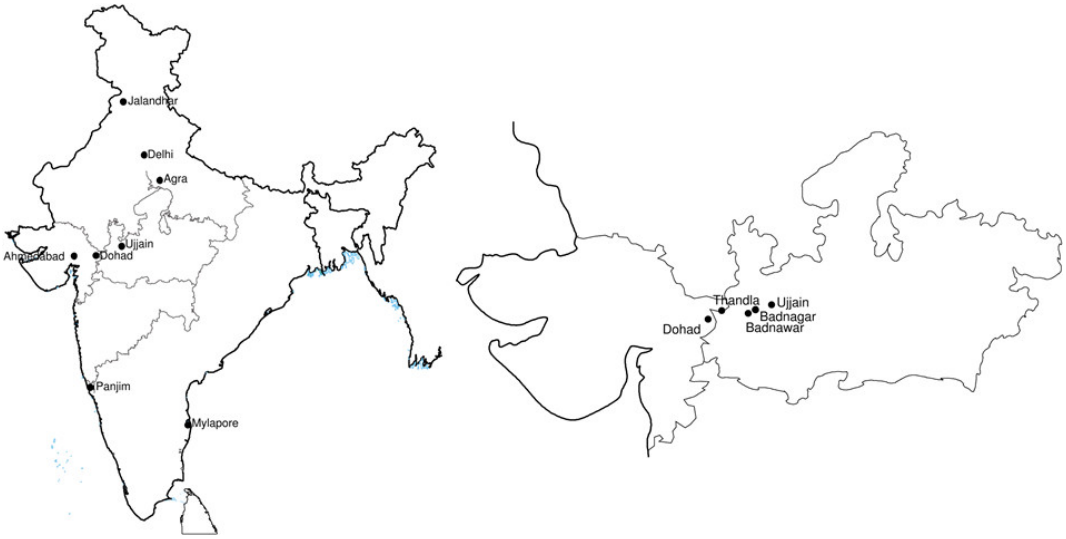


Figure 3. India's outline maps to show the stipulated royal route; the map on the left shows the prominent locations mentioned in the present paper; the map on the right depicts certain modern locations in the states of Gujarat and Madhya Pradesh that might have been on or near the stipulated route Jahāngīr took from Dohad to Agra through Ujjain in 1618.

We have looked into the *District Census Handbooks* (DCH) of the *Census of India 2011* released in 2015 by the Registrar General & Census Commissioner, India, of the districts of Dohad in the state of Gujarat and Jhabua, Dhar and Ujjain in western Madhya Pradesh. It is these districts, spread roughly along a west-east corridor, through which the stipulated route must lay. In the respective census listings, we do find a *Ramgarh* in the Thandla block of Jhabua district in Madhya Pradesh (DCH *Jhabua*, p. 60). The Figure 3 shows the royal route on which a few modern places of the state most likely fall.

The epoch of the observation as read off the *memoirs* is 72 min before sunrise. Since the Sun rose at 01:13 UT at Thandla (read Ramgarh) that day, this would make the observation at 00:01 UT, 10 November, 1618. Sixteen *nights* later than the 18th of Ābān, and therefore on the morning of 26 November, Jahāngīr observed a second comet, now designated 1618 II. It then lay in Libra. This one was a Great Comet and the third bright comet of the year. According to Yeomans (2007), the brightest magnitude was reached on 29 November, at 0 -1. From the recorded dates, Jahāngīr turns out to be an independent discoverer of two great comets appearing one after the other on 10 November and 26 November 1618 respectively.

The heliocentric worldview of Copernicus (*De Revolutionibus*, published in 1543) arrived in India much later. This knowledge did rest with the Jesuits missionaries of the times but, involved as they were in their missions at several places in India, their primary goal was to

spread the Christian faith. The heavenly sightings in 1618 threw up a rare opportunity for discussion across the board. There were instances of past apparitions duly recorded in many Muslim texts but there is nothing in the *memoirs* to suggest of any interaction that may have taken place on the present apparitions among Jahāngīr's astronomers or with the Jesuits who visited his court. On the conceptual side, Jahāngīr's writings take an exceptional departure from the conventional wisdom. There is no concern expressed for any untoward consequences because of the apparitions or pause the royal traverse.

4. NEW ASTRONOMY TO THE FAR EAST: A PASSSAGE THROUGH INDIA

The telescope arrived in India soon after its invention in Europe in 1609 and was put to astronomical use, initially sporadically. In the 17th Century, the chief sources of astronomical information are the communications of some Jesuit priests in different parts of India and a number of travelogues.

The 16th Century Goa was an important centre of long distance trade with the West. Under the Portuguese empire, the role got only wider, turning Goa into a political, cultural and religious central engine of the Portuguese India. The activities of all the religious orders that arrived in succession to spread Christian faith received backing of the Portuguese government. The Jesuits, in Goa ever since 1542, developed an economic framework and acquired land and houses to be able to continue in their mission to spread the faith. Many Jesuits of the times were mathematicians, geographers and astronomers and in their missions to different parts of the world carried with them the new European science as well. Missionaries headed Far East needed to set sail from Lisbon, with a stop-over at Goa, the capital of the Portuguese India, and Macao, the Portuguese commercial base farther out in the East overcoming very unkind circumstances. The voyages from Lisbon to Goa took six months and one headed to Macao had to stop over here for another six months when winds became favourable again.

4.1. Telescope comes to India

The story of the telescope reached the Indian shores quick enough. Father Antonio Rubino (Antonius Rubinus, 1578-1643), a Jesuit missionary in Goa, hearing of the invention initiated efforts in 1612 to acquire one from Rome. He is understood to have first introduced the telescope in India (Udias 2003). However, no details on this part are available. On the other hand, in 1616 the Emperor Jahāngīr received a spyglass as a gift from Sir Thomas Roe (Huff 2010, p. 12) but he never directed it towards the sky. Then, we come across accounts about the observations of bright comets 1618 III and 1618 II by Father Venceslaus Pantaleon Kirwitzer (1588-1626), later joined by Adam Schall von Bell (1591-1666) from Goa (Nature 1878).

As part of a group of missionaries led by Nicolas Trigault (1577-1628) deputed to China that included Giacomo Rho (1592-1638), Johannes Schreck-Terrentius (also Terrenz; 1576-1630) and Adam Schall, Fr. Kirwitzer set sail aboard San Carlos from Lisbon in April 1618 (Leitao, 2008, p. 107) and braving the rigours of the voyage, sickness aboard and death of five of the 22 China missionaries, sailed into Goa on 4 October 1618. The group was carrying a few telescopes and some measuring instruments and a large number of books. Along with Terrenz and Adam Schall, Kirwitzer had subsequently proceeded to China, setting sail on 15 May 1619 and reached Macao on 22 July 1619. In 1621, Terrenz presented the Emperor with a telescope as gift.

4.2. Fr. Kirwitzer's Treatise

Fr. Kirwitzer, joined by brother Jesuits, observed the two bright comets from Goa. Their first observations also correspond to the discovery dates of the comets. The same comets were followed by Father Antonius Rubinus then in Cochin.

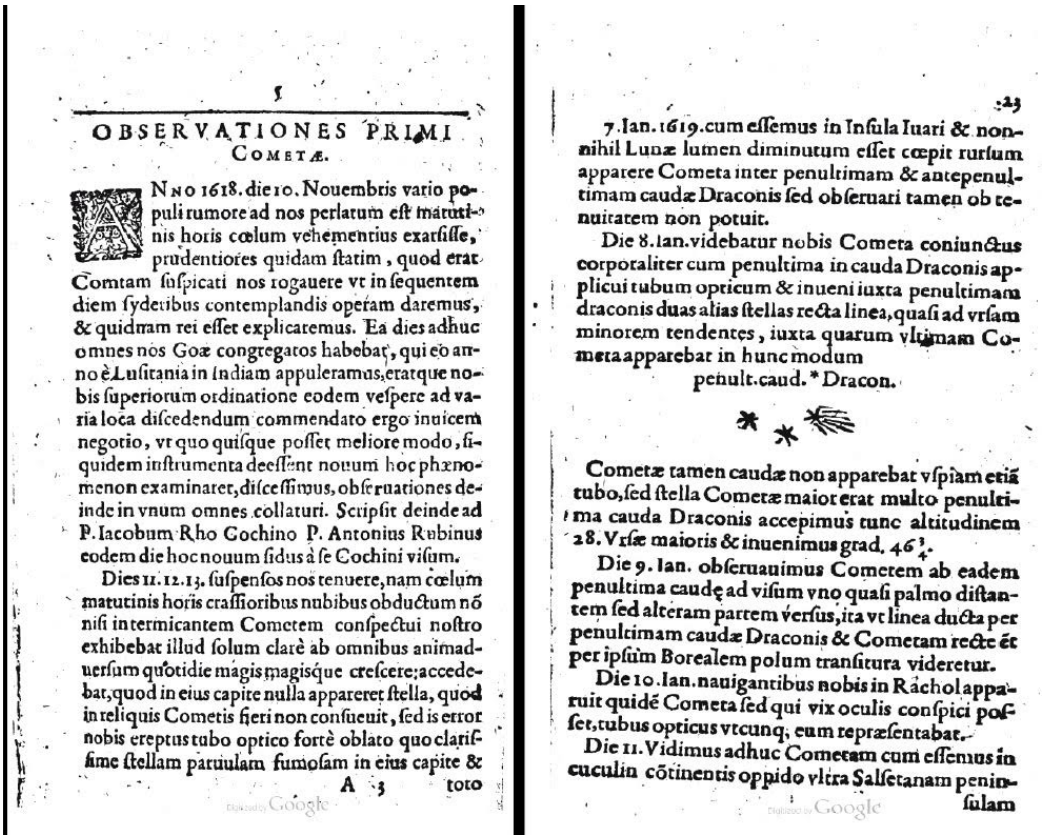
35. D. 44.

OBSERVATIONES
COMETARVM
ANNI 1616.
IN INDIA ORIENTALI FACTÆ A
Societatis Iesv Mathematicis in Sinense Regnum
nauigantibus ex itinere eo delatis.
Ad eiusdem Societatis Mathematicos & alios amicos
Europæos transmissæ.
PER P. WENCESLAVM PANTA-
leonem Kirwitzer, eiusdem nauigatio-
nis Comitem.

VRSELLIS
Excudebat Ioan. Theobald. Schön-
wetter.
ANNO 1620.

Figure 4. The cover page of Fr. Kirwitzer's treatise (digitized by The Austrian National Library 2014; Google Books).

Figure 5. 'The world's oldest surviving, securely-datable telescope', 1617, with the Kunstgewerbemuseum / Staatliche Museen zu Berlin; cloth and paper; maker unknown. 'Main tube and five draws of pasteboard. Each draw covered in marbled paper; end tube and ring stops in silk velvet embroidered by gold thread. Collapsed, rings and end tube form cylinder with common outer diameter (48mm), common feature of other early scopes'; picture and description adopted from http://dioptrice.com/telescopes/782 .



5

OBSERVATIONES PRIMI COMETÆ.

ANno 1618. die 10. Nouembris vario populi rumore ad nos perlatum est matutinis horis cœlum vehementius exarsisse, prudentiores quidam statim, quod erat Comtam suspicati nos rogauere vt in sequentem diem syderibus contemplandis operam daremus, & quidnam rei esset explicaremus. Ea dies adhuc omnes nos Goæ congregatos habebat, qui eo anno è Lusitania in Indiam appuleramus, eratque nobis superiorum ordinatione eodem vespere ad varia loca discedendum commendato ergo inuicem negotio, vt quo quisque posset meliore modo, siquidem instrumenta deessent nouum hoc phænomenon examinaret, discessimus, observationes deinde in vnum omnes collaturi. Scripsit deinde ad P. Iacobum Rho Cochino P. Antonius Rubinus eodem die hoc nouum sidus à se Cochini visum.

Dies 11. 12. 13. suspensos nos tenuere, nam cœlum matutinis horis crassioribus nubibus obductum nõ nisi intermicantem Cometem conspectui nostro exhibebat illud solum clarè ab omnibus animaduersum quotidie magis magisque crescere; accedebat, quod in eius capite nulla appareret stella, quod in reliquis Cometis fieri non consueuit, sed is error nobis ereptus tubo optico fortè oblato quo clarissime stellam paruulam fumosam in eius capite &

23

7. Ian. 1619. cum essemus in Insula Iuari & nonnihil Lunæ lumen diminutum esset cœpit rursum apparere Cometa inter penultimam & antepenultimam caudæ Draconis sed obseruari tamen ob tenuitatem non potuit.

Die 8. Ian. videbatur nobis Cometa coniunctus corporaliter cum penultima in cauda Draconis applicui tubum opticum & inueni iuxta penultimam draconis duas alias stellas recta linea, quasi ad vrsam minorem tendentes, iuxta quarum vltimam Cometa apparebat in hunc modum

penult. caud. * Dracon.

Cometæ tamen caudæ non apparebat vspiam etiã tubo, sed stella Cometæ maior erat multo penultima cauda Draconis accepimus tunc altitudinem 28. Vrsæ maioris & inuenimus grad. $46\frac{1}{4}$.

Die 9. Ian. obseruauimus Cometem ab eadem penultima caudę ad visum vno quasi palmo distantem sed alteram partem versus, ita vt linea ducta per penultimam caudæ Draconis & Cometam recte ęt per ipsum Borealem polum transitura videretur.

Die 10. Ian. nauigantibus nobis in Rachol apparuit quidé Cometa sed qui vix oculis conspici posset, tubus opticus vtcunq; eum repræsentabat.

Die 11. Vidimus adhuc Cometam cum essemus in cuculin cõtinentis oppido vltra Salsetanam peninsulam

Figure 6. Pages 5 and 23 from Fr. Kirwitzer's book of 1620, on his observations of two bright comets that appeared in November 1618. Both the pages carry reference to the use of a *tubo optico / tubus opticus* for viewing the comets. This is the first documented evidence of use of a telescopic device in astronomical observations from India (Source: The Austrian National Library; Google Books).

Fr. Kirwitzer presented a detailed description of his observations of the spectacular tailed forms as they first appeared in the morning skies of November 1618 one after the other in a monograph in Latin, entitled *Observationes Cometarvm Anni 1618. In India Orientali Factæ A Societatis Iesv Mathematicis in Sinense Regnum Nauigantibus ex itinere eo delatis* (Kirwitzer 1620). It was published in Ursellis by Schönwetter in 1620 (Figure 4). The treatise remained virtually lost through the centuries until digitized a few years ago by the Austrian National Library. The treatise is short, consisting of 24 pages only.

The treatise is of great importance as it reports first ever modern astronomical observations carried out in India, as also that it records the first ever use in India of an optical device for astronomical observations soon after the introduction of telescope to astronomy. Fr. Kirwitzer and his brother Jesuits deserve credits on other counts - as independent discoverers of the two great comets in succession as also the first independent users of an optical device for observing comets outside Europe (Figure 6). Baichun (2003) has provided illustrations of several astronomical instruments carried by Trigault et al. to China as also of those made there subsequently. One may look up Bolt and Korey (2010) for examples of the telescopes of early 17th Century starting from the earliest surviving device, that of the year 1617 (Figure 5). These consist of a main tube and a number of draw tubes.

Fr. Kirwitzer in his treatise refers to the places from where the Jesuits made astronomical observations. The one named Rachol (pronounced Rashol) is mentioned as being 5 leagues away from Goa (i.e., Old Goa). It is a town in Salcete peninsula, south of Panjim (now Panaji) and 7 kilometres north-east of Margao. Fr. Kirwitzer records in detail what the observers saw

and measured, namely, the altitudes and azimuths, angular distance from stars like Spica etc. in *grad* (degrees), and the observers' visual impressions including difficulty from illumination due to the Moon and sunlight. The observations are presented systematically and appropriately divided in two sections for each comet. He also included the observations made by the brother Jesuits at other stations.

Figure 7. The cross-staff as depicted in Pedro de Medina's 1552 treatise *Regimento de Navegacion* (Wikimedia Commons).

In those times, astronomers observed position and direction of the tail and indicated position of the comet with respect to many nearby fixed stars whose position was already determined. The main idea was to determine position of the comet in the ecliptic and its movement. While indicating the positions, Fr. Kirwitzer also refers to the *informi* (unformed) - the field stars not grouped with other stars into a constellation.

The few astronomical instruments the Jesuits in transit were able to access were an *astrolabium* (astrolabe) and a *radium astronomicum* (astronomical radius, i.e., cross-staff) of the Goa College. A cross-staff consists of a staff with a smaller, sliding transversal arm, generally made of wood but sometimes of brass and bearing a scale that could read degrees directly (Figure 7).

All through, Fr. Kirwitzer's treatise contains records of observations only, at times adding a phenomenological description. There is no theorizing about comets and there is nothing about where they belong, etc. While summing up, Kirwitzer (1620, p. 24) notes that

"For a fuller understanding of those observations, it remains to make known the true longitude and latitude of the places where the observations have been done. However, we have not seen yet any Moon Eclipse and from others nothing we learned that we can accept with confidence, we will work diligently in order no latitude and longitude of this or other places of Asia remain unknown. In the meanwhile we will supply to this lack and any other: easily we will relay on Johannes de Barros, prince of Portuguese Historians."

Fr. Kirwitzer's observations are discussed in full detail in Kapoor (2016).

4.3. The early instances of use of telescope in India for astronomy

The next incidence of use of a telescope to observe an astronomical event from the Indian soil dates to 1651. This is about the observation of transit of the planet Mercury across the disk of the Sun by Jeremiah Shakerley (1626 -1655) from Surat. What telescope, timing device and the method of observation (see below) he used is, however, not known (Kochhar 1989). Shakerley was a great admirer of Jeremiah Horrox (1619-1641), an English astronomer and the first to predict and observe the transit of Venus of 4 December 1639 Greg. Johnson (1874, p. 100) describes Shakerley's venture so:

'In 1651, a young Englishman, Jeremiah Shackerley, made a voyage to Surat, to observe a transit of Mercury, which his calculations told him would not be visible in England. It is satisfactory to know that he was successful in his wishes'.

The planet transited the Sun on 24 October 1651 (3 November 1651 Greg). The transit circumstances, adopted from Fred Espenak's tables, are as in the Table 1:

Table 1
The transit of Mercury of 3 Nov. 1651

Ist Contact	IInd	Greatest	IIIrd	IVth	Sun RA	Dec
23:07	23:09	00:52	02:35	02:38	14.540 h	-15.01 deg

The timings are in UT and suggest that Shakerley had 80 minutes in which to view the event, since the Sun rose that day at Surat (21°10'N, 72°54'E) at 01:15 UT, with the transit already past its 'greatest' phase. Wing (1669, p. 312) provides a brief but glorious description of the conjunction, cross checking with the ephemeris of the Sun and Mercury to find that Shakerley saw it in India just as it was predicted by him in a colloquium. Wing observing *conspexit Mercurium in circulo disci Solis post Telescopium depictum* points to the conjunction seen by projection.

4.4. The bright comet of 1652

Shakerley in his communication of January 15, 1652-3 to Henry Osborne in England presented results of his calculations and observations of the transit of Mercury. He described in the letter his observations in 1652 of a comet also. As Chapman (1990, p. 9) wrote:

"India was stimulating to Shakerley, and conducive to him making his own independent observations, for on December 8th, 1652, he recorded the appearance of a comet. It was 'first observed to blaze amongst the stars of Procyon in the lesser dog, with a quick and lively flame, the tayle of which extended itself northwards to the quantity of three or four degrees', though this soon diminished as it grew fainter, eventually disappearing in the constellation of Cygnus. Although it was his ' misfortune not to have instruments to observe to any purpose' he was able to determine that the comet's head never exceeded 5' of arc in diameter. Shakerley also enquired of Osborne whether the comet had been visible in England, and what predictions European astrologers may have drawn from it".

The comet as mentioned should be C/1652 Y1 and the date Julian. The corresponding Gregorian date is 18 December. It was a bright comet but in modern cometographies, Shakerley's observations do not figure. The comet was discovered by Jan van Riebeeck from the Cape of Good Hope as an evening object on 16.8 Dec 1652 (Full Moon on 15 Dec), in the constellation of Puppis east-south-east from the head of Orion and nearly 80° above the horizon. He described it in his journal as a 'strange star with a tail; the tail extending northwards right on the knees of the giant and the head mostly to the south about 10 degrees away' (Cooper 2003). He observed it until 24 Dec by which time the tail had lost some sheen.

The comet had passed its perihelion on 13.153 Nov UT, and was last observed on 20 Jan as noted by Knobel (1897, 1918) from the book of an anonymous author who may have observed it from Cologne from 19 Dec onwards. The comet has q= 0.8475 AU, i = 79.º461 (JPL).

Was Shakerley an independent discoverer of the comet? That seems like it. He was favourably placed to do so as the comet was a low declination object when discovered. Besides, he was equipped with a telescope, then among the very few in Asia. We presume he would often stargaze with it.

The comet, on a parabolic path, had on 16 December reached quite close to the Earth (0.15 AU) and was moving, rapidly, north-west. It passed closest to the Earth from 0.1284 AU on 19 December at about 23:30 UT. It would be at its brightest then. For the perspective, we present the respective positions of the various objects in the sky as at Surat, at 15:30 UT, on the various dates, vide Table 2.

On 16 Dec, the comet rose in the east at about 15:30 UT, the Moon having risen at 13:40 UT and still quite bright. On 17 Dec, the comet rose ~ 14:40 UT, the Moon rose at 14:42 UT. On 18 Dec, the comet rose earlier than the Moon, at ~ 13:45 UT while the Moon rose later at 15:40 UT. The evening of 18 Dec offered the best window for the observation though the earlier dates are as much possible.

Table 2
The comet position in the sky at Surat

	r	Δ	Alt	Az (S-W)
Dec 16, 1652				
Comet	1.046	0.157	0.172	318.30
Sun	0.983	-40.453	76.719	Set
Dec 17, 1652				
Comet	1.057	0.143	8.289	317.572
Sun	0.983	-40.345	76.657	Set
Dec 18, 1652				
Comet	1.067	0.133	19.328	314.265
Sun	0.983	-40.235	76.604	Set

The other few who discovered the comet in the days to come did so from Europe. Peter Mundy observed it on 18 Dec from Penryn in England, Arcieri on 19 Dec from Rome, Johannes Hevelius on 20 Dec from Danzig (now Gdansk) who found it equal to Moon in size though not as bright (Bard 1832) and Riccardo de Albis on 21 Dec from Rome, followed by the Chinese on 22 Dec (Kronk 1999).

4.5. The comet of 1665 (C/1665 F1)

There is a reference to a comet in the travelogue of the famous French traveller Jean Baptiste Tavernier (1605-89), the Baron d'Aubonne and a jewel trader that appeared in the year 1665. Tavernier who pioneered trade with India made six voyages to the East in between 1631 and 1668. During the sixth, he left Isfahan on 24 Feb 1665 to come over to India. He landed at Surat on 5 May, with a stock of precious stones, goldsmith's works etc. He met the Emperor Aurangzeb (b. 1618; r. 1659-1707) on the 12th of September. His travelogue of 1676 was translated by Valentine Ball (Tavernier 1925). Ball was the brother of the astronomer Sir Robert S. Ball and was with the Geological Survey of India during 1864-81. He provided a footnote as follows to the description by Tavernier in his travelogue of the Emperor Aurangzeb afflicted with the comet. Tavernier's description runs thus:

"Since Aurangzeb, who reigns at present, has occupied the throne of the Moguls, which he usurped from his father and brothers, he has imposed on himself, as I have said, a severe form of penance, and

eats nothing which has enjoyed life. As he lives upon vegetables and sweetmeats only, he has become thin and meagre, to which the great fast which he keeps have contributed. During the whole of the duration of the comet of the year ------[1], which appeared very large in India, where I then was, Aurangzeb drank only a little water and ate a small quantity of millet bread; this so much affected his health that he nearly died, for besides this he slept on the ground, with only a tiger's skin over him, and since that time he never enjoyed perfect health".

The foot note '1' to Tavernier's account reads so:

'This comet, if, as many suppose, was first seen in Europe at Aix, on the 27th of March of that year. It lasted four weeks, and had a tail 25 deg long. Its orbit was computed by Halley (vide Chambers's Astronomy, 'Catalogue of Comets', No. 64). Terry refers to two great comets which appeared while he was at the Mogul's Court in the month of November, 1618. They were followed by drought and famine'.

That is about the comet now designated C/1665 F1. As given in Vsekhsvyatskii (1964), the comet was first seen in Nurenberg on 26 Mar, in the morning of 27 March in Aix-en-Provence in France, and so on. The Chinese recorded it soon thereafter (Kronk 1999). It had a tail 30° long as noted on 10 April as reported from Jena. The comet passed its perihelion on 24.719 April though it was last seen on 20.8 April only; q=0.10649 AU, i= 103.893 (JPL).

Ever since Aurangzeb ascended the throne on 1 *Dhu-al-Qa'dah* 1068 AH (31 Jul 1658 Greg), there arose bright comets in 1661 and 1664 too that should be in memory still. Of these, the comet of the previous year, namely, C/1664 W1 made a matching spectacle. First seen on 17.9 Nov, it passed closest by the Earth on 29 Dec from 0.1699 AU and showed up with a tail 35° long on the 27th. The comet faded by February next and was last seen on 20.83 March 1665 (Kronk 1999). The Emperor, one may say, was already under influence of the evil blazers, and then came this one.

Incidentally, Tavernier had shown and sold a number of his most precious stones to Aurangzeb and as a gesture was shown those in the possession of the Emperor, including the 280 ct great diamond (Tavernier 1925). This is about the famous stone that in 1739 was plundered by Nādir Shāh, who upon first seeing it exclaimed *koh-i-noor* (the mountain of light), from the Emperor Aurangzeb's descendant Muḥammad Shāh. The diamond's traverse has a history of its own; http://www.diamonds-are-forever.org.uk/kohinoor-diamond.htm.

4.6. The Great Comet of 1668 (C/1668 E1)

In the telescopic era, the next astronomical observation of a comet from India is that of the Comet 1668. It was in fact a Sungrazer, with a perihelion q=0.0666 AU, motion direct that passed its perihelion on 28.08 Feb UT. The comet was discovered on 3.8 March at the Cape of Good Hope as an evening object, on 5 March in Lisbon and on 5.9 March by Fr. Valentine Estancel in Brazil (Vsekhsvyatskii 1964, Kronk 1999). According to Lynn (1882), only its tail was visible in Europe and that too was first noticed in Lisbon on 5 March. When observed from Rome, its tail was reported to be over 30° long on 9 March. According to Yeomans (2007), it reached a maximum magnitude 1-2 on 8 March.

According to Marsden (1967), the comet was observed from 9 to 21 March (5 mag.) from Goa by a Belgian Jesuit Fr. Gilles-Francois *de Gottignies* who made most careful observations during 9.6-17.6 March UT every day. The observations were later used in 1901 fruitfully by H.C.F. Kreutz. Calculations of its orbit were made by Thomas Henderson in 1843 on the basis of the comet's track shown against the background stars made in an engraved map 'as observed at Goa' during the period 9-21 March (Lynn 1882). Henderson (1843) came to possess the map entitled *Observationes Goæ habite circa Phanomenum coeleste, qupd apparuit Menæ Marlio Anno 1668 Romano Miscæ ad P. AEgidius Franciscum*

de Gottignies in Collegio Romano Matheseos Professorem. Henderson had noted that in the map the comet was depicted just by straight lines, and to each was affixed the date of the observation. The observations would have been made since 5 March itself as the map carried dates from 5th March to the 8th March also. During this period, the comet's head was sunk below the horizon. According to Lynn (1882), these maps were sent over to Father Aegidius Franciscus de Gottignies, a mathematics professor at the Collegio Romano, Rome. Lynn quotes Henderson observing that 'the map is rather a rough one, as I find, on examining the relative positions of the stars which are laid down, errors amounting sometimes to a degree.' About the *map*, Henderson goes on – 'I think it probable that it formed part of the work entitled "*AEgidius Franc. de Gottignies de figures Cometarum qui an. 1664, 1665, 1668 apparuerunt cum animadversionibus & tabulis in aes incisis. Rome. 1668*".'

We note elsewhere that Fr. Gilles-Francois *de Gottignies* (1630-1689) was professor of mathematics at the Collegio Romano from 1662 to 1689 (Mancosu 1996) and is credited with having observed comets of 1664, 1665 and 1668 (Consolmagno 2006). If he visited Goa is not clear from his biographies. The different accounts suggest that the references above should be to the same person. Ravene (1897) notes in respect of the comet of 1668,

'the observations having been made by some Jesuits of Collegio Romano while stationed in Goa. We have a calculation of the orbit by Henderson, and I have deduced some elements which satisfy in a more or less degree the observations, but do not satisfy me, and, last of all, it has been shown that the great comet of 1843 will completely satisfy these positions'.

Lynn (1882) however was not confident of Henderson's orbit calculation that he said did not duly represent the observations and was affected by many errors. England (2002) notes that precise positions of the comet's head were taken during the period 5 –21 March by Gottignies at Goa. Moreover, during the period 5-20 March, the comet was viewed from Surate (Surat) too (Pingré 1784, p. 22). Who then were the observers at Rome, Goa and *Surate*? Fr Gilles-Francois de Gottignies - the observer from Goa, as also the unknown observer from Surat, are to be credited with an independent discovery of the comet.

In this matter, an 1843 publication *Estratto della osservazioni fatte sulla cometa del 1668*, in Italian, needs taking a look at as it clears the mist around the actual observer in Goa. It was written 'for the sake of science' by a *Padri* of the Society of Jesus (Padri 1843). The prologue says:

"In the circumstance, where everything leads us to believe that this year's comet 1843 is the same as that of 1668, it will not be useless to gather in one body the observations made then on this comet by some of our Fathers, and scattered here and there in works of not easy acquisition. Indeed stimulated by the investigations of several astronomers, there we hasten to publish it for the sake of science".

The Padri put together the various communications on observations of the comet of 1668 made in Europe, Goa and Brazil. The part from Goa is reproduced here:

"From the city of Goa our Father Giuseppe Candone sent to Rome the report of the phenomenon he saw, and the same published in the *Giornale dei Nazari* of April 1670 as follows:

"This observation is communicated to us by Fr. Francesco Gottignies, Mathematician of the Roman College, which Father Cardone received from the same name with a letter from Goa dated 12 May 1668. The phenomenon appeared on the 4th of March, but by the observer it was not seen until the 5. Is there any who saw it on the 3rd, but with doubt. On 9 it appeared all out of the horizon and about 35 degrees long: it ended up sharp in the part near the horizon: in the widest part it was one degree: on 18 then the extremes began to be eclipsed, and disappeared due to the splendor of the Moon due to which it remained invisible till 22".

"Even if in the *IIIrd Giornale* of 1668 the observations made in Rome were recorded in the days that the clouds allowed, it is not to omit to mention those that Fr. Gottignies gave to you, so that the comparison with the aforementioned in Goa can be better seen. He observed the phenomenon 35 degrees long and one wide, unlike the comets because it had no head; and its width was almost uniform everywhere, except in the extremities, which were narrower. On 9, 10, 12 of March it spread from the star of Eridani according to Ticone to the star of Balena, fourteenth according to the same. On 9 it seemed a little further from the Equator than the aforementioned star: on 10 it had almost the same distance; and on the 12th it had approached the Equator: on 18 it passed over the first and third stars of the ear of the Hare, and over the ninth and tenth of Grienberger's Eridani, on which day it was less visible than on 10 for the splendor of the Moon. On 19 it moved away from the star, which it had almost reached on 18, towards the Equator and the East. «

. . . . . from the 18th to the 21st the light of the Moon remained visible to the end than towards the middle; clear sign (Fr. Gottignies says) that the appearance was different from the comet that has head, like the two comets of 1664 and 1665; because the parts near the head were always more visible in the light of the moon, and much more the head. . . . and in Goa where it was observed (the phenomenon) right from the5th until the 22nd of March it is impossible that the head had not been seen if it had been there; especially since the observers used every diligence to recover it.

«. . . . . There was no sensible parallax. For in Goa's observation (March 18) as we can see in the figure attached here the right phenomenon comes up grazing on one side the first and third star of the ear of the Hare, and on the other side the ninth and tenth star of Eridani: and all this was observed and noted in Rome on the same day.

For a better understanding of Goa's observation here is the figure extracted exactly from the drawing in paper that Fr. Candone sent "(*Giornale de Letterati*, Day IV, April 30, 1670, pages 51 and 52).

This card, which we here faithfully report, is missing in almost all the copies of this rare Journal found in public libraries in Rome, from which we can clearly see that it has been removed and robbed. It is desirable that this fact be added to those many others, which can serve to excite vigilance never overwhelming who is in charge of such public establishments."

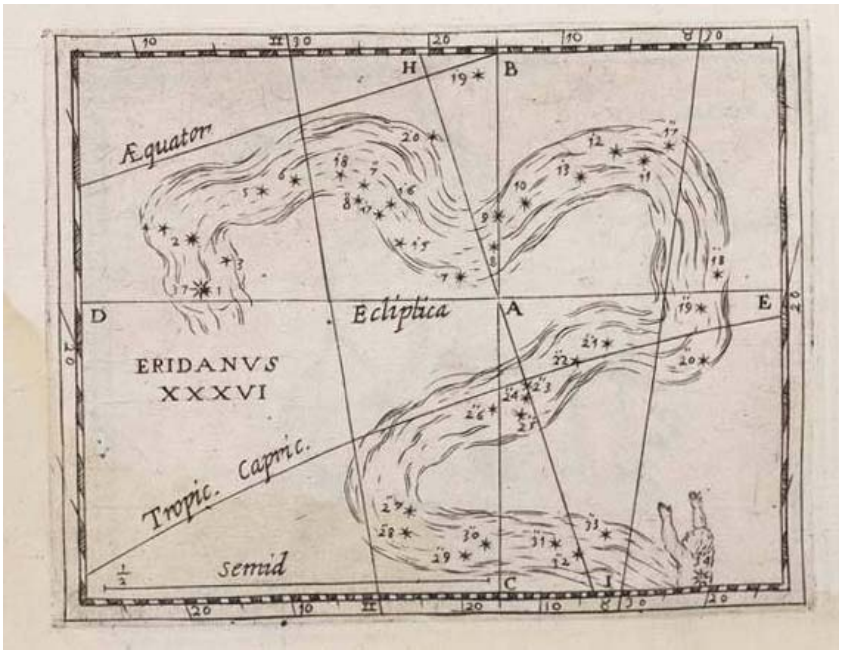


Figure 8. *Fluvius, Eridanus vel Nilus* in Christof Grienberger's *Catalogus....* (from Stoppa 2016).

The said figure is not there in Padri's (1843) text. Note that the constellation of Eridanus zigzags from the equator down to about -60° where Achernar (α Eridani) is (Figure 8). The

Giornale dei Nazari was the first Italian literary journal, started by Francesco Nazari, Rome, in 1668. As for the word *Ticone*, the astronomer Tycho Brahe was called *Ticone* in the past centuries; Baleno (Whale) is Italian for Cetus, the adjoining constellation. Christopher Grienberger (1561–1636) was an Austrian Jesuit and Professor of Mathematics at the Collegio Romano. His work *Catalogus veteres affixarum Longitudines, ac Latitudines conferens cum novis. Imaginum Caelestium Prospectiva duplex ...* was published in 1612. It contained astronomical tables and maps relating to 21 numbered northern constellations, 12 zodiacal constellations and 15 numbered southern constellations. It also included the new northern constellations of *Antinous* and *Berenices Crinis*; these, however, were not numbered (see Stoppa, 2016). These new constellations were first added to the existing 48 Ptolemaic constellations by the cartographer Casper Vopel (1511–1561) in 1536, but *Antinous* was later abandoned.

It is not clear if a telescope was used by Fr. Gottignies in his observations. The reference to Grienberger suggests him having been duly equipped including some catalogue and a sky atlas.

4.7. The Great Comet of 1680 (C/1680 V1

This spectacular comet was the first one to be discovered with a telescope, by Gottfried Kirch from Coburg in Germany on 14.1 November in the constellation of Leo. Soon after the discovery, the comet brightened up as to be seen unaided. It was first sighted naked eye in the morning sky on 19.8 Nov from the Philippines (Full Moon on 5 Dec). It passed its perihelion on 18.4876 Dec from q=0.006222 AU (i=60º.6784), became a trailing object by 19 Dec and was last seen, by Isaac Newton (1643 – 1727) with a telescope, on 19.96 March 1681 (Kronk 1999). It passed closest by the Earth on 1 Dec from 0.4214 AU and on 4 Jan 1681 from 0.4895 AU. Edmund Halley had seen this comet from Paris, with Cassini (Lynn 1910).

This comet proved a milestone in our understanding of the comets in more than one way. First, Georg Dorffel in his remarkable observation put forth an explanation for the comets seen in pairs, one in the morning and the other in the evening (see, Festou et al. 2004 for detail). The comet drew great attention from Newton and his friend Edmund Halley (1656-1742) alike. Newton showed in his monumental work *Philosophiae Naturalis Principia Mathematica* (the mathematical principles of natural philosophy; 1687) that if heavenly bodies were attracted by a central mass in the inverse proportion of square of their distance from it, they would follow a path in the shape of one of the conic sections. – a circle, an ellipse, a parabola or a hyperbola. Newton had observed the comet naked eye and followed it up with a telescope for long. He used the observed positions of the comet to show that its orbit was nearly a parabola (see Heidarzadeh 2008 for details). Halley subsequently carried the application of Newton's law of gravitation to the observations of twenty four comets of history and showed that one of these was periodic and therefore its return predictable. That was a remarkable finding. He did not live to see it do so but the comet did return in 1758 and subsequently got named after Halley. He also expressed that some other comets too are periodic that do an *encore* and that all comets are members of the Solar System (Hughes 1987).

The famous travelogue of Dr John Fryer (1650-1733), *A New Account of East India and Persia Being 9 Years' Travels 1672-1681*, carries description of his travels to the East made during the years 1672-81 (Fryer 1698/1992). He had graduated in medicine from the Trinity College in 1671. In the travelogue, Fryer records his observations of the state of science and medicine, flora and fauna, the lands, the culture and society, trade and manufactures etc. in India and Persia. His narration of sighting a 'wonderful Sign in the Heavens' that he dated 'The 25th Jan. our Ships Setting sail then from Swally Hole' makes for an interesting reading. This is about the celebrated comet of 1680, also known as Newton's Comet. Swally Hole was

East India Company's anchorage near the roadstead at the mouth of the river Tapti (ancient name Tapi), near Surat. Of the Comet he had this observation to make:

'Animadversion; which beginning the Twentieth of *November*, disappeared, not till the latter end of *January*, which enters on the next year, that within the space of our *Europe* Fleet may bring you the Rise and Fall of the most prodigious Comet I ever was witness to[1]; or it may be oldest Man alive. What makes me the more willing is, that I may have your Account over Land, whether it was visible in *England*, and what observations our prying world have made thereon'.

Fryer further notes:

'Eleven degrees from the Earth *South-East*, a terrible flaming Torch was seen in the skies in *Capricorn*, near the head of *Sagittarius*, darting it's Rays upwards to the stars; at first not above two Ells in a small Stream, but day by day as it inclined to the Horizon, the Flame grew longer but slenderer; it rose first at Three in the Morning, and so later and later till the Sun out-shone it; and as if it had circled the Globe, at last it arose and set at Night, after the Sun was down, when we beheld it W.N.W (west-north-west) which was on the Evening of the Twelfth of *December*, and about Seven at Night; at first no bigger than a man's hand from its coming forth of the Horizon, which thence arose with a might Fulgor or shining Light for more than Nine Degrees as big as a Rainbow, towards the highest point of the Hemisphere; or to speak more truly, like a Pillar of Fire, whose Basis, whether for its tardy rise, or the Clouds gathered about the Atmosphere, I could not discern till the Seventeenth, it setting about Nine of the Clock, but after that time it ascended above the Horizon, and passing the middle of the Heavens (which afore it seemed to enlighten after Seven) as it grew higher it lost of its brightness and Splendour, but looked more fiery. *January* the 16th, 1681 it had attained its Zenith, when about the Noon of Night it vanished and so by degrees at last it came to nothing'.

'While this was reigning, several in the Hole and Buzzar at *Swally*, attested they saw two Moons; others of our *English*-men out a Hunting after Sun-set, saw an unusual Star of the bigness of the Sun, which must certainly be this fiery Ejaculation, striking obliquely upwards, being equally thick until its highest part had stretched its self into a Column. It pointed towards the North, and whether it be Meteor, Comet or Exhalation, it is certainly ominous; and since they disclaim its influence here, I wish it may not affect our *Europe* Kingdoms'.

Incidentally, the footnote *1* (by the travelogue's editor) on p. 174 of Fryer's travelogue identifies the comet with Newton's comet, of 1680. The footnote also cites the *Madras Records*, wherein Wheeler (1861) while describing the events of the year 1680 comments that the only other event which is worth noting is the appearance of the celebrated comet of 1680, known as Newton's Comet. The apparition was duly recorded in the consultation book of the Agency as follows

'Wednesday, 22nd December 1680. The Blasing star which in the middle of this month (December) appeared in the evening just at the setting of the sun, and does now appear 15 Degrees above the horizon, at half an hour after six at night, the tail pointing to the north-east 65 degrees long'.

The dates recorded by Fryer and the writer of the Madras Records are Julian.

Niccolao Manucci (1639-1717) was a famous Italian traveller and writer. A Venetian, Manucci was a physician. He had come over to India in 1656 where he spent most of his life, including serving in the Mughal Court for long. In 1656, he found employment as an artilleryman in the service of the Moghul prince Dārā Shikoh, Emperor Shāh Jehān's eldest son. After Dārā was executed by Aurangzeb, Manucci joined Rājā Sawāi Jai Singh's artillery. He travelled through India widely as circumstances forced him to relocate often, to move later to Madras. In his memoirs, he presents a revealing account of life of his times. The following narration is taken from the Introduction by W. Irvine to Manucci's highly acclaimed *Storia do Mogor* (the history of Mughals; in three volumes; first published in 1907) that describes his

sighting of a comet in 1680 (Manucci 1907, Vol I). The comet referred to is C/1680 V1. The passage cited below is intentionally long, for the perspective:

'During 1677 (III. 264, 265) he made his home at Bandora, on Salsette Island, nine miles north of Bombay fort. Having lost his money in a bad speculation, Manucci was during 1678-1682 obliged to try his fortunes once more at the Mogul court. He returned to Dihli, where, through a court chamberlain, he was called in to attend one of Shäh 'Älam's wives, and, having cured her of a gathering in the ear, the lady interested herseif in his affairs and procured his appointment by that prince as one of his physicians. This must have been subsequent to January 30, 1678, the date on which Shäh Älam returned to Delhi from Kabul. On September 28, 1678, Shäh 'Älam was made governor of the Dakhin, and Manucci went there in his train. He says once that he was at Ägrah in 1679, and possibly the occasion was on this march to the Dakhin. On September 6, 1679, Shäh 'Älam's thirty - seventh birthday, they were at Aurangäbäd; but not long before this (December 18, 1678) Jaswant Singh of Jodhpur had died in Kabul, and Aurangzeb, after failing to seize one of the rajah's infant sons, resolved on the conquest of the Jodhpur State. Shäh Älam was recalled to take part in the campaign, and the prince (Manucci with him) passed the rains of 1680 at Ujjain (II. 204). In January 1681, they joined the main army at Ajmer, having seen a comet on their way (December 24, 1680). Prince Akbar had just fled (January 13, 1681), and had raised the Standard of revolt. On the 26th Shäh 'Älam was sent in pursuit, and remained on this duty until the end of March (1681). Some sort of peace was patched up with the other Räjputs, Akbar escaped to the Mahrattahs in the south, and, in consequence, on September 15, 1681, Aurangzeb began his first march towards the Dakhin, a country from which he was destined never to return'.

4.8. A comet in a Marāthi poem of Samartha Rāmdās

There is a reference to the appearance of a comet in a poem by the great saint poet Samartha Rāmdās (1608-1682). The poem, in Marāthi, goes as:

'*Akasmāta māgé Bhūmīkampa jhālā,*
Nabhamāji tārensi sendā nighālā',

i.e., suddenly sometime ago, there was an earthquake and a star with pigtail (comet) rose in the sky'. Samartha Rāmdās was spiritual guide of Chhatrapati Shivājī Mahārāj (1627/30-1680), the founder of the Marātha Empire, who greatly influenced the latter. His poetry is devoted to Lord Rāma. The poem above most likely relates to Shivājī Mahārāj's demise in 1680. We find a similar expression in his biography, first written in 1694 by Krishṇājī Anant Sabhāsad as told by Shivājī's second son Srimanta Rājārām Mahārāj (1670-1700) then at the Jinji fort, and considered a most valuable account in Marāthi on Shivāji's life (Sarkar 1920). Sabhāsad titles the particular passage as *Naisargik utpāta* (natural calamity) and says (Kulkarni 1987, p. 99):

'*Rājiyanché dehāvasāna jhālé. Te divashi Prithvikampa jāhālā. Gagann dhūmaketu udeylā, Ulkāpāta ākāshāhūn jhālā. Rātrī jod indradhanushyén nighālīn…*'',

'the Mahārāj passed away. That day the Earth trembled. A comet arose in the sky. There was *ulkāpāta* (the shooting stars) from the sky. In the night appeared rainbows in pair'.

The comet reference in the poem of Samartha Rāmdās is most probably about the great comet of 1680. Though believed by some, it can not be about the Halley's Comet of 1682, discovered on 24.4 August, since the saint poet had passed away months before its appearance that year. From astronomical considerations of several of his horoscopes, Apte et al. (2003) deduce the date of birth of Shivājī Mahārāj to be 1 March 1630 (Greg). Further, considering the circumstances of the solar eclipse of 30 March (Greg) that preceded his demise by a fortnight, they affix his demise on 13 April 1680 (Greg). The eclipse was of magnitude 0.8 at Raigad. It was a total eclipse down south, postmeridian, and the path of

totality passed over Kasargod, Mahe, Mandya, Mysore, Salem, Pondicherry and Chidambaram. Around the latter dateline of Shivājī Mahārāj, there is no recorded appearance of a comet. There is only one comet on record that year, the great comet of 1680, first sighted naked eye in the morning sky on 19.8 Nov in the Philippines. That being so, the meteoric fall referred to above could be the Leonids. Their activity in the present times peaks around 17/18 November, past the midnight. That suggests sighting the comet around its discovery date. For example, seen from the Raigad Fort (18º14′2.69"N, 73º26′24.83"E) the capital of Shivājī Mahārāj since 1674, the comet would be high in the eastern skies - on 18 Nov, 00 UT, at *Alt* 62°, *Az* 104° (N-E) and on 19 Nov, 00 UT, at 60º, 105º (N-E) respectively. However, the two celestial events were consecutive. The Leonid streams peak is shifting. The Table 1 in Brown (1999: 289) provides details of Leonid showers between 1799 and 1999, where a shift by three days in the epoch of the peak every hundred years can be easily noticed. In the present case, the Leonids in the late 17th Century should have been peaking around 9/10 November. Other observers have not mentioned meteoric fall around the discovery of the comet. Nevertheless, the poetic reference remains in order.

This is the second record of a meteor shower in an Indian work of literature.

5. MODERN ASTRONOMY IN THE 17TH CENTURY INDIA

The coming of Shakeley's telescopic observations to light took away the first use credit attributed to French Jesuit Fr. Jean Richaud (1633-1693) who, several decades later, had carried out astronomical observations at Pondicherry with a 12 ft telescope (Kameswara Rao et al. 1984). Fr. Jean Richaud was a member of the group of fourteen French Jesuits, named the *Mathematiciens du roi de France* Louis XIV and led by Fr. Guy Tachard (1648-1717), that went on a diplomatic cum scientific mission to Ayutthaya, Siam (now Thailand) in March 1687 on an invitation from the king Somdet Phra Narai (1633-88). They arrived in Bangkok in October 1687 bringing along telescopes, quadrants, astronomical ring, microscopes, pendulums, thermometers and barometers etc. as gifts for the King. The King himself was well-read with keen interest in astronomy and had an observatory of his own. It was built in 1685 at Wat San Paolo that was a Jesuit church on the outskirts of the then capital Louvo and the predecessor to the present day National Astronomical Research Institute of Thailand (NARIT) in Chiang Mai. Due to unwelcome developments at the Palace in May 1688, the Jesuits were expelled who then left in November 1688 for India. It was a very tough and troubled journey through sea. Only three survived among whom Fr. Richaud arrived in Pondicherry on 1 February 1689 along with Fr. Jean Bouchet (1655-1732) and Charles Dolu (1655-1740), a natural philosopher (Louyat 1982).

At Pondicherry, Fr. Richaud resumed astronomical activity. The discovery of the brightest star in the constellation of Centaurus, α Centauri, as being a double by Fr. Richaud on 19 December, 1689 from Pondicherry with telescope makes for an astronomically significant incident in the history of astronomy in India. It was from here that he made observations of the comet of December 1689 also (Louyat 1982). These observations were reported in the *Memoires de l'Academie Royale des Sciences de Paris*. In fact, he is credited as one of the discoverers of the comet, a Sungrazer now designated C/1689 X1, on 8 December (Vsekhsvyatskii 1964: 121).

5.1. The comet of 1689

On 8 December, the day of his first observations, the comet lay ~7° to the south-west of τ Scorpii. Fr. Richaud (1699) noted the comet moving at great speed, by over 3° between 14 Dec and 15 Dec. For his 19 Dec observations, he writes:

'On 19, approximately at 4 o'clock in the morning, I saw the head of the comet near the leg of Lupus, it was with the star of the first leg of Centaurus a line parallel to a line drawn by the star of the first arm belly of the Crusade, the line extended parallel to the two feet of the Centaur'.

On 21 Dec, Fr. Richaud found the comet a degree from the foot of Centaurus. In his report, he goes on:

'I saw the tail at the beginning of January for two or three days without being able to distinguish the head that had dissipated entirely to our gaze', and that 'I forgot to mark that the tail was the figure of a great sword, whose tip was bent to the north, the largest party refraction near the horizon (as it was, though somewhat obliquely, from the horizon to the top) could cause this curvature. The tail sometimes occupied nearly 60 degrees of a large circle'.

It was during the course of these observations that Richaud discovered on 19 Dec that α Centauri is a double star. This discovery finds mention in R H Allen's 1899 classic *Star-names and their meanings* (p. 153). Allen quotes Baily's edition of Ulugh Beg's catalogue giving its name as *Rigil Kentaurus* that is from *Al Rijl al Kentaurus*, meaning the *Centaur's Foot*, one of the many names of α Centauri, such as Toliman etc.

From the relative immersions of satellites of Jupiter and the lunar eclipses of 4 Apr 1689 and 24 Mar 1690, Fr. Richaud determined the longitude of Pondicherry. Among the other observational accomplishments of Fr Richaud is his correct prediction of the occurrence of the lunar eclipse of 4 Apr 1689 and precise determination of latitude and longitude of São Tomé (San Thome), zodiacal light, the Magellanic Clouds and two dark patches towards the Coal Sack. Monsieur Francois Martin (1634-1706), the founder of the city of Pondicherry in 1674 and governor of the fort of Pondicherry also had witnessed the lunar eclipse of 4 Apr 1689 together with a multitude of French and Indians present (Louyat 1982).

Fr. Kirwitzer's and Shakerley's were an innovative use of the telescope while in India but Fr. Richaud made a systematic effort to introduce telescopic astronomy. He practiced and taught astronomy at the Jesuit school in São Tomé until his last (Kameswara Rao et al. 1984). Be that as it may, these instances were no trend setters for modern astronomy in India. These, however, scored several firsts.

5.2. The Comet C/1695 U1

The comet of 1695 was discovered by P. Jacob, a French Jesuit in Todos-os-Santos, Brazil who first observed it on Oct 28.3, early in the morning. The head of the comet lay in Libra while the tail reached into Virgo (England 2002). The perihelion passage had taken place on 23.768 Oct. For a small q=0.0423 AU, the comet was a Sungrazer. It approached the Solar System almost vertically, i= 93.º589.

The comet was independently discovered from Surat on 30.0 October by the French Jesuit Joachim Bouvet (1656-1730), a mathematician and astronomer (Vsekhsvyatskii 1964, Kronk 1999). His observations featured in the *Histoire. Acad. de Sciences, Paris* as part of Cassini's (1702, p. 126) write up on the comets. He cites Fr. Bouvet's observations so:

"On the same day, 30 October, at Surat, Father Bouvet, who had come from the Red Sea, perceived this headless Comet which had come half an hour before the beginning of Dusk. Its length was about 18 degrees of a great circle: the end where the head was to be, terminated in the thigh of the Raven. On the 31st at Surat it appeared a little shorter, of a more feeble light, which was attributed to the approach of the Moon: the capital extremity occults the top of the right leg of the Raven. On the first of November in Surat, it was seen better than the preceding days: it was longer, occupying the space of 22 degrees, whence it was judged that a part had been previously hidden in the rays of the Sun. Yet the

Moon was still approaching it; but as it was in its 25 day, its light had less force; its extremity on the side of the head declined towards the southern region on the side of the leg of the Raven".

The software translates the word *Crepuscule*, used by Cassini in his write up, as *Dusk* what should actually be *Dawn*. With the Horizons System, we find the comet a few degrees below Spica on 30 Oct, 00:00 UT; the last Full Moon was on 22 Oct.

Fr. Bouvet had been sent in 1685 to China as a member of the group of five French Jesuits, named the *Mathematiciens du roi de France Louis XIV* to the Chinese Emperor K'ang Hsi (Kangxi; r. 1661-1722) of the Qing Dynasty. The group arrived in Peking (now Beijing) in February 1688. Fr. Bouvet joined the royal court in 1690 where he spent a major part of his life teaching the sciences. He left China in 1693 for Europe to bring back more scientists and reached France in 1697. He returned to China in 1699 (Landry-Deron 2001). The passage to Europe was through India, and with a sojourn. In the latter half of the 16th Century, the Jesuits had ventured northwards of Goa to spread their mission and as a part of it Jesuit residences and colleges came up in Diu and Daman under the jurisdiction of the Jesuit Province of Goa. A century later, the missionary work was started at Surat. Its significance can be gauged from the fact that the town and the harbour were an important trading centre.

By 6 Nov, the tail of the comet measured ~40°. That morning, it was near β Corvi. Commenting on Fr. Bouvet's account, Pingré (1784, 2, p. 34-35) writes –

"We continued to see it every day in Surat, where on the 16th it appeared between the two more Eastern stars (β, o) of the Hydra triangle, which it left to the west on the 18th and 19th of April. It is certain that it is necessary to read November instead of April: and as, moreover, the apparent course of this Comet was retrograde, it appears that it would also be necessary to read in the East, instead of to the West. I tried in vain to combine these various observations to extract some approximation of the orbit of the Comet."

Fr. Bouvet last observed the comet on 18.9 Nov by which time it had become faint (Kronk 1999). The comet lay in Centaurus, near border with Hydra, Antila and Vela. All through the period of the observations, the comet led the Sun. It is not clear if a telescope was used in the observations.

6. CHASING STARS IN THE 18th CENTURY INDIA

The 18th Century India saw some significant, even though sporadic, efforts in astronomy in terms of facilities, literature and observations, and in related sciences. Apart from serving the prime purpose of geographical surveys, telescope was used in India through the century a number of times for observing astronomical events also.

The most notable contribution to astronomy was made when, at the instance of the then Mughal Emperor Muḥammad Shāh (r. 1719-48), the king Sawāi Jai Singh II (1688-1743) of Amber built an observatory at Delhi in 1724 consisting of unique, large-sized instruments of masonry, stone and metal to measure time and angles. This was followed by similar structures at Varanasi, Mathura, Ujjain and Jaipur. Sawāi Jai Singh's observatories were patterned after Ulugh Beg's at Samarkand. The observatories (*vedhashalas*) are epitome of Indian science and a milestone in the history of India. These received their name from *Yantra-Mantra* (instrument and theory). The degradation of the name to *Jantar Mantar* undermines their scientific and educational significance and the observatories should rightly be introduced as *Sawāi Jai Singh Vedhashālās*. The following extracted from Law (1916) speaks highly of their instrumentation and the accomplishments:

'From the observations made in this observatory, the celebrated Astronomical Tables, known by the name of Muhammad Shah, were drawn up by Mirza Khairullah and Shaikh Muhammad Muhaddis, under the supervision of Jai Singh, and the accuracy of the Tables was proved by the conjunction of two planets in 1154 A.H. (1741 A.D.) as recorded therein. In the observatory at Delhi there is a big equatorial dial which for its accuracy and magnitude was called *Samrat Jantra* by Jai Singh himself. The gnomons and the periphery of the circle are marked with degrees for determining altitudes and azimuths of the heavenly bodies. Besides this, there are two circular buildings open at the top and a small altitude-meter'.

Sawāi Jai Singh II was a great scholar of mathematics and astronomy. He had made observations with a glass telescope also, acquired standard Persian and European monographs on sciences, and initiated translations to Sanskrit from Persian. The telescope came with the astronomical mission in 1730 that he had sent to Portugal earlier in 1728-29. Then he got another one fabricated by local artisans. With it, he was thrilled to see celestial objects. He crosschecked the discoveries of Galileo and other European astronomers for himself that he noted down in the *Zīj-i Muḥammad Shāhi*. He realized that like the Moon, Venus and Mercury shine by the sunlight as they showed up with phases. With the telescope, he saw the four satellites of Jupiter and found Saturn to be elliptical in shape, not round. He also saw spots on the disk of the Sun. Their changing position led him to deduce that the Sun rotates and that the rotation period is about one year. The astronomical treatises and tables that he received from Arabia and Europe included Pere de la Hire`s *Tabulae Astronomicae, Historia Coelestis Britannica* by John Flamsteed and Ulugh Beg`s tables *Zīj Ulugh Begi*. Pandit Jagannātha Samrāt (1652- 1744) who was his chief court astronomer translated the classic works, *Tahrīr al-Majistī* [Naṣīr al-Dīn al-Ṭūsī's (1201 – 1274 CE) recension of Ptolemy's *Almagest*] and *Elements* of Euclid, from their Arabic versions into Sanskrit that were given Sanskrit names as *Siddhānta Sāra Kaustubha* and *Rekhāgaṇita* respectively (Bose et al 1971). The work *Samrāt Siddhānta* was his own (Sharma 1982). Ironically, Jai Singh's endeavours died out with him.

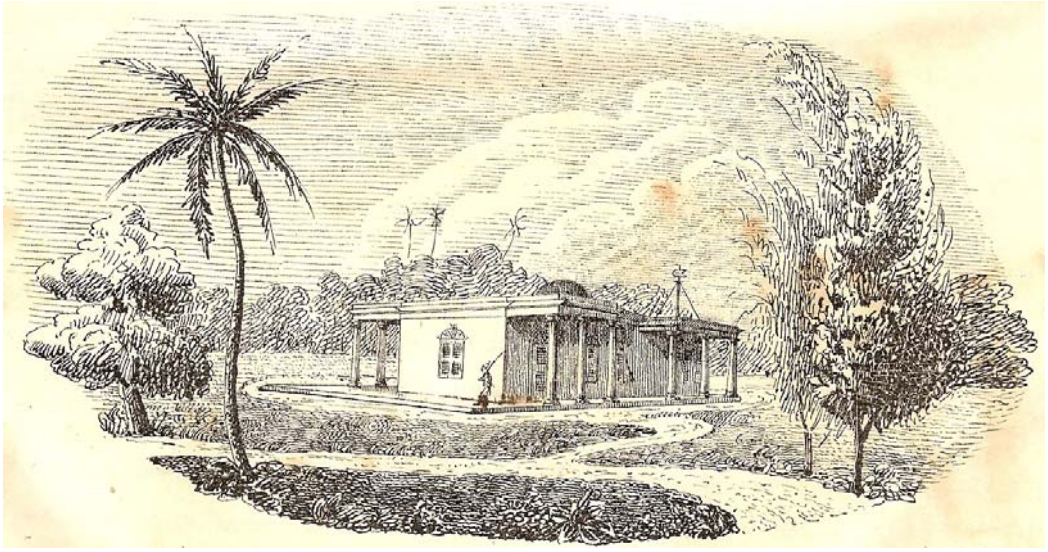


Figure 9. The Madras Observatory at Numgambakkam (1838; IIA Archives).

Then there were the Jesuit missionaries based in various parts of or travelling through the country many of whom were astronomers and geographers (Kochhar and Orchiston 2017). Some of them, like Claude Boudier, Emmanuel de Figueredo and Ströbel had come into contact with Sawāi Jai Singh. Joseph Tiefenthaler (1710-85) a Jesuit Missionary who came to India in 1743 (Sharma 1982) is said to have recorded observations of sunspots and zodiacal light. He laid great emphasis on determination of longitude and latitude of places in India as being fundamental to knowing its geography correctly. Tiefenthaler observed lunar eclipses,

on 2 Feb 1744 the occultation of Jupiter by the Moon, and the transit of Mercury of 4 Nov 1743 from Goa (Phillimore, I, p. 150). From the occultation of Jupiter by the Moon, he determined the longitude of Surat.

The British, fresh from victory in 1757 at the battle of Plassey, initiated scientific surveys to get an accurate geographical knowledge of the land. By 1765, the East India Company had more or less taken over all of Bengal. In the operations lay a great strategic value that paved the way for rich dividends in the times to come. This can be gauged from the fact that the Survey of India itself was founded in 1767 what may be termed the earliest modern scientific institution in the country. Astronomical observations were made from time to time by the Jesuit missionaries and the English surveyors for determination of latitudes and longitudes of places by observing the meridian altitudes of the celestial objects and eclipses of the satellites of Jupiter including the transits of Venus (Phillimore 1945-68). Towards the end of the Century there came up the first modern astronomical observatory in Madras (Figure 9). It was a private one, established in 1786 by William Petrie, an officer with the East India Company. That was the most significant beginning in modern observational astronomy in India.

While the two transits of Venus were observed in 1761 and 1769 from various locations in India (Kapoor 2013), the last part of the century also saw growing inclination of Persian-speaking scholars towards European sciences due to their contact and interactions with the officers of the East India Company. This resulted in the writing of books by personages like Mīr Muhammad Hussain, Mirzā Abū Tālib, Abdul Qādir Jaunpurī, Ghulām Hussain Jaunpurī and Rājā Ratan Singh Zakhmi that touched upon various scientific disciplines including astronomy and quite up-to-date at that, an activity that continued in the following century too (Ansari 2002). In one of his works probably finished in 1802, Abū Tālib talks about discoveries of Uranus, Ceres and Pallas, transits of Mercury and Venus and provides information on comets, as follows (Ansari 2002):

'The comets are numerous and three of them, possessing elliptical orbits around the Sun, have been observed more or less better [than others]. One of them has a period of 79 years and the period of the second and third are 229 and 575 years. For the latter he gives also the aphelion and perihelion distances of the comet, and even the speed of transit through the perihelion as 880,000 miles/hour'.

6.1. The comet of 1702

Niccolo Manucci in his *Storia do Mogor* describes his sighting of a comet in 1702 from Madras (Manucci 1907a). At Pondicherry the French had just re-established themselves in 1699 after conclusion of a peace treaty with the Dutch in 1697. Monsieur François Martin (1634-1706), the founder of the city of Pondicherry in 1674 and governor of the fort of Pondicherry had been facing trouble from insolent elements, in particular those active from a small earthen fort in a village by the seaside, Bamiapalam, near Pondicherry. In October 1701, informed of an imminent attack Martin took upon them and could successfully quell the menace. Ever since, Manucci says, there happened no robberies, and the route past Bamiapalam remained open. Bamiapalam was under the rule of the governor of Singy (Jinji), situated about fifteen leagues from Madras. For the sign in the sky, Manucci (1907a, p.383-384) wrote:

'Up to this time this last town (Madras), where I have made my abode, had not been troubled by war on any considerable scale, and had enjoyed pleasant enough repose. But now, in the midst of the troubles which have agitated the other settlements on this coast, we have seen the appearance in the heavens, early in the year 1702, of a long tail, which at first led us to the belief that it was a comet, and yet no head to it was visible. At length, after some days the two ends of this tail showed without any star. This celestial sign was visible from February 23 to March 6 following. The point was directed to the south, and it issued from the west; the head continued to advance towards the east. Such signs have

ever been the harbingers of approaching calamity or some revolution among men. God only knows what may come of it, but we have already begun to feel the effects of a war, the details of which I will give. To be still clear, it is necessary to begin somewhat farther back and tell you what brought it upon us'.

That is about the comet X/1702 D1 that had been observed by many but none of the observers reported seeing its head and so a precise orbit could not be deduced. It was first sighted in the evening of 20.8 Feb from ships sailing near the Cape of Good Hope and on 23 Feb from a ship in the Gulf of Pegu (Myannmar), etc. According to England (2002), the tail of the comet was observed from Bengal on 23 Feb about 30 minutes after the sunset that took 45 minutes to completely set. Kronk (1999) quotes from the 1753 work of Nicolaas Struyck, the first cometographer (1740, 1753) in history, according to whom the log of a ship *Schulp*, then sailing in the Bay of Bengal off the coast of Burma (now Myanmar) carried description of sighting of the comet on 28 Feb, with a tail 42º 46′ long. England (2002) observes that the comet must have been very bright, at mag. 0 or even brighter as it was seen in twilight at such a low elevation. The comet was suspected by H.C.F. Kreutz to be a Sungrazer. The orbits of the great comets C/1843 D1 and C/1882 R1 fitted the observations, suggesting for the comet of 1702 a perihelion passage on 15.1 Feb; q=0.01 AU (Marsden 1967).

There was another comet that followed it shortly, namely, C/1702 H1, but that is not referred to in Manucci's work. The latter was discovered by F Bianchini and Filippo Maraldi from Rome on the morning of 20.94 April and by Gottfried Kirch from Berlin on 21.03 April. This comet had passed very close by the Earth, from 0.0435 AU on 20 Apr and was last seen on 5.9 May (Kronk 1999). The comet C/1702 H1 does not fit into Manucci's description.

6.2. A comet in 1705

There is a footnote in Dr John Fryer's travelogue on p. 175 quoting Niccolo Manucci about his seeing a comet in 1705 (Manucci, 1907b, IV, p. 233). Manucci first provides a description of a devastating earthquake in Gogo (Ghogha), a British seaport town about 154 km from Bhavnagar, Gujarat**.** The earthquake that occurred in February 1705 was so terrible that it caused parting of ground for as much a length as five leagues and fissures as wide as thirty cubits. A few days later torrential rains of 'blood in drops of considerable size' lashed the region reddening the lands. 'At the same time there appeared a comet, which was visible for fifteen days'. The apparition was interpreted by Brahmins to portend the approaching death of the Emperor Aurangzeb and devastation in several parts of the Mughal Empire together with the loss of the port of Surat. The Emperor died two years later, on 3 March 1707 (Greg.).

Vsekhsvyatskii (1964), Hasegawa (1979) and Kronk (1999) list no comet for the year 1705. Manucci's own description of the comet in the travelogue does not give times of its observations and positions in the sky and whether the sighting was a morning or an evening one. Could Manucci's comet be the one seen in early 1706? This comet (C/1706 F1) was indeed a low declination object and touched its highest declinations in March. It was a faint object. However, it does not solve the mystery of the comet of 1705 that nobody else saw.

6.3. The Comet C/1723 T1

The next instance of observations with a telescope relates to the comet of 1723. This comet was discovered near the horizon by Gian-Priamo and Ignatius Kegler, a French missionary in Peking, on the morning of 11 Oct as a m=+3 object with a tail 4º long. It was independently discovered on the 16th Oct in Lisbon and by William Saunderson on 17th Oct (Greg.) at Bombay. Hind (1852, p. 146) gives Saunderson's date as 12 October. Crossat, a Jesuit in Cayenne, saw the comet on 15th of October as a 3^{m} star with a tail 7º.5 long. Kronk (1999) attributes to the Chinese the comet's discovery on 10.8 Oct in the constellation of Columba as

recorded in the text *Ch'ing shih kao*. At the time of discovery, the comet had already passed its perihelion, on 28.128 Sept UT; q=0.999 AU. It passed closest by the Earth on 14 Oct from 0.1036 AU. The comet had begun to trail the Sun 14 Oct (Greg) onwards.

Its period is not given and the comet 1723 is most likely among the non-returning ones. Edmund Halley had seen the comet naked eye on the evening of 20 October, describing it 'not much unlike a star of the third magnitude' (Kronk 1999). The Full Moon occurred on 14 Oct/12 Nov.

The comet was sighted by Saunderson (1726) at Bombay first, most likely, on 5 Oct. The communication 'Mr. William Saunderson's communication of his observations through 'Dr. Halley, Astron. Reg. R.S.S.', to the Royal Society dated 12 Sept 1725 read thus –

'In the Month of October 1723, being riding at *Bombay*, a Brightness in the Heavens appear'd to a Right Line, for but very little to the Eastward of one) with *Lyra* and the Bright Star in the *Eagle*, being about 50° distant from the last; and on *Monday* the 7th following it had advanced 10° toward the *Eagle*, moving towards it in the forementioned direction, from the S.E. Quarter.'

Saunderson had a six-foot glass. In the communication, he tabulated his observations for the period 7 – 19 Oct taken between 9 and 10 hours at night that show how the position of the comet changed with respect to the Eagle's Heart from 40°00′ south on 7 Oct to 11°40′ south on the 19th. He noted further –

'At first it looked only like one of the White Spots called the *Magellanic Clouds*, the Space filling the Field of a Six-foot Glass. Afterwards I saw the Head in the Center of the illuminated Space, which did not look with much Brightness; but appeared largest on the 10th of *October*, decreasing gradually both in its Bulk and Motion from that time until the *25th*, at which time I could find no Appearance of it with the fore-mentioned Glass. N.B. From the *20th* to the *25th* it had nearly the fame Place in the Heavens, seeming to move directly from the Earth…'

The dates in Saunderson's communication are Old Style (Julian calendar). The date of first recorded observation 7 Oct 1723 Monday corresponds to 18 Oct 1723 Monday (Gregorian)**.** Generating the apparent positions of the comet on a few crucial dates from the Horizons system, we have the comet positions as in the Table 3.

Table 3
The positions of the comet of 1723 on different dates

Date (Greg)	UT	*r*	*Δ*	Alt	Az (S-W)
Comet					
1723-Oct-16	16:00	1.048	0.132	34.017	11.600
1723-Oct-18	16:00	1.059	0.187	42.633	32.933
1723-Nov-05	16:00	1.193	0.822	33.017	79.117

Above, r is Heliocentric and Δ the geocentric distance, in AU. Saunderson (1726) would have made his first observation on 16 Oct (5 Oct Julian), and as he says 'between 9 and 10 at Night', presumably around 16:00 UT (sunset 12:46 UT). That day he would have found the comet aligned with Lyra while 50° south of Altair. As per the positions in the Table above, the comet would have lain about a degree north of γ Grucis and 10º north of Alnair (α Gru**).** By 18 Oct (7 Oct Julian), the date of his first recorded observation, the comet had moved north-west by about sixteen degrees towards the Eagle. By the last day of his observation (5 Nov, Greg) when he actually could not view it, the comet had reached a location some 10° south east of Altair, and ~ 4º north-east of θ Aquilae. A cross check with the computed ephemeris of the comet corroborates Saunderson's observation that from 'the 20th to the 25th' (Julian) the comet was apparently motionless and so was moving directly from the Earth.

In the same communication, Saunderson (1726) also briefly describes his lunar eclipse observations that he saw at Gomroon in Persia. Another communication from him that appeared in the *Philosophical Transactions* (Vol. XXXI, pp. 120) was – 'Observations on the Variations of the Needle in the Baltic, Anno 1720'.

6.4. The Comet C/1737 C1 (1737 I)

This comet was discovered on 6.99 Feb by Rose Fuller in Jamaica. Fuller's communication says 26 Jan, presumably a Julian date. The comet passed its perihelion on 30.847 Jan (Kronk 1999). On 9 Feb, it was seen in sunlight in Lisbon and Gibralter with a tail 7º long. The comet was seen with the naked eye until 18 March (Vsekhsvyatskii1964); q=0.22282 AU, i= 18.326, e=1 (JPL).

John Anthony Sartorius, a missionary at Madras (now Chennai) first saw the comet 1737 I on 13 Feb with a telescope having 10 or 11 feet focal length (Kronk 1999). Sartorius was the first missionary sent in 1730 from England to India by an English Missionary Society. Soon he became proficient in Tamil language of which he made a lexicon also. About a year before his death on 27 May 1738, Sartorius had moved to Cuddalore with Geister, a German Missionary (Westcott 1897). The comet observations would have been made when Sartorius was still at Madras. An extract from his letter dated 'Feb. 9. 1736-7 V.S.' (Sartorius 1737) to Mr Bayer at Petersburgh concerning the comet appeared in the *Phil. Trans*. *RS London* after a translation from German by C.M. R.S. Sec., together with other communications on the same. It read so:

'For seven Days last past, about 7 Hours *Vesperè* there hath appear'd a dim Comet, as we took it to be: It is feen in the Weft, under *Venus* towards the S.W. It looks through a Tube of 10 or 11 Feet long, like a dim or pale Planet; its Tail tends upwards. What do the Astronomers in *Europe* say of it, if it hath been seen there'.

With the Horizons System and Solar System Live, we find the respective apparent positions of the comet and the Sun as at Madras. The positions in the Table 4 are for a perspective.

Table 4
The positions of the comet of 1737 on different date

Date (Greg)	UT	*r*	*Δ*	Alt	Az
Comet					
1737-Feb-13	12:43	0.501	1.056	28.300	79.200
Sun			0.988	-0.374	76.504 Setting
Mercury			0.862	16.838	80.219 Up
Venus			1.071	40.098	81.529 Up
Moon			58.7 ER	24.085	-102.029 Up
Comet					
1737-Feb-20	12:45	0.676	1.072	37.767	78.733
Sun			0.990	-0.419	79.029 Setting
Mercury			0.698	9.572	83.786 Up
Venus			1.024	40.940	86.193 Up
Moon			57.5 ER	-71.656	-91.449 Set

On the 13 Feb evening, the comet lay in Aquarius near the Pisces-Aquarius-Cetus borders, with Venus about 12º N-E from it.

Rose Fuller's communication dated 'Spanish-Town, Mar.1. 1736-57' appears on the same page of the *Phil. Trans*. as extract of the letter of Sartorius. It mentions of the comet 'first perceived about the 26th of *January,*'… 'in the West first of all, some Degrees below and directly under *Venus:* Every Night it appear'd nearer to that Star, but inclined Northerly. …' .

The date 9 Feb in Sartorius' letter and 26 Jan in Fuller's letter are Julian. For the perspective, the Full Moon occurred on 15 Feb.

6.5. The bright comet of 1742

There is record of a comet in the writings of an 18th Century Indian historian Sayyid Muḥammad 'Alī al-Ḥusaini that he says appeared in 1154 A.H. (1741-42). No astronomical detail of the observation is given. Sayyid al-Ḥusaini was a Persian scholar and political historian. He wrote in 1759-60 a history of the Timur dynasty, *Tārīkh -i Rāḥat Afzā*, covering the period 1359-1759 (Khan 1948). In it, he mentions a detonating fireball in the year 1155 A.H. (1742-43) and an earthquake in 1171 A.H (1757-58)[1]. More importantly, he records the occurrence of a comet

"In the year 1154 A.H., a star with tail appeared at evening in the West, during the months of S*hawwāl, Dhu-al-Qa'dah* and *Dhu-al-Ḥajjah*. Afterwards it made its appearance in the East, during the early morning, for a few days in the month of *Muḥarram* 1155 A.H.".

In the cometographies of Vsekhsvyatskii (1964) and Kronk (1999), there are no records of a comet in 1741. The only comet that can match the description above is the one that appeared early in 1742. Its exact discovery as Kronk (1999, pp. 403-5) comments 'is somewhat open to debate'. The circumstances suggest Muḥammad 'Alī to be an independent discoverer of the bright comet of 1742, now designated C/1742 C1.

The comet C/1742 C1 was a bright one, having a parabolic orbit and inclination 112º.948, motion retrograde; it passed its perihelion on 8.696 February 1742 and the closest by the Earth from 0.3334 AU on 7 March. It was noticed first in the southern skies from the Cape of Good Hope (Hind 1852, p. 147) where the first records date 5 February 1742 that also state that the comet had been seen on several nights before (Kronk 1999). The comet was moving northwards and by March became visible in the northern skies when it was widely observed. In Europe, the comet was first seen by William Whiston, Isaac Newton's successor as Lucasian professor of mathematics, in England on 1.2 March. By 8 March, it had developed a tail 8°-9° long with its head at about 2 mag. The comet became circumpolar by 11 March when it could be seen throughout the night. By April 1742, it became strenuous to view the comet unassisted. The comet was observed last, telescopically, on 7 May (Kronk 1999).

Muḥammad 'Alī's sightings of the comet

Muḥammad 'Alī does not specify any date of the month of S*hawwāl*. His last recorded sightings are in the initial days of the month of *Muḥarram* 1155 A.H. and made early morning. I shall take these to be the few days following *Muḥarram* 1 (≡7 March 1742 Greg., Wednesday), i.e., from the morning of 8 March.

In light of the history of observations of the comet made from the Cape and Europe, Muḥammad 'Alī's initial observations assume significance. These are also very critical to the observer's location. The observation was made from Burhānpur (21°25'N, 76°19'E; in modern Madhya Pradesh). For one at Burhānpur, it is necessary to ascertain if the comet was observable so early, i.e., 9 December onwards. I get that Muḥammad 'Alī,s first recorded sighting would have to be before mid-December. However, this time around, the comet – Sun altitude difference is not very favourable and naked eye observation in the month of S*hawwāl* is not possible at all.

In early February, the comet rises in the nautical twilight but no longer a challenge to the unaided eye. On 5 February, it rises a half hour earlier, at 00:22 UT when the estimated visual magnitude improves further to 2.7 mag. With the Sun still 16º below horizon, the sky is dark

and a view of the comet in the astronomical twilight is surely possible, it being a New Moon that day.

The reference to an evening sighting of *a star with tail* followed by another apparition in the mornings can come from actual observations only. It implies that Muḥammad ʻAlī was well read and had some exposure to the relevant literature. More importantly, the observation that it is the same comet suggests of a rare perception. It overarched the canonical knowledge and whatever practical astronomy he may have known, for, the inference is independent of the Western tradition. Only, his description has turned out to be correct selectively.

Must we take Muḥammad ʻAlī's first sighting of the comet only in 1742 it is likely to have been around the times it was first recorded – on 5 February 1742 at the Cape of Good Hope. That makes Muḥammad ʻAlī an independent discoverer of the comet (Kapoor 2015b). The next reported sighting of the comet in February is on the 27th and 28th only, by two Dutch navigators on a ship in the Indian Ocean. It would have been easier had Muḥammad ʻAlī mentioned also the constellation or any bright star in the vicinity.

6.6. Dr. Halley's Comet 1759 I (1P/1758 Y1)

In the year 1456 ... a Comet was seen passing Retrograde between the Earth and the sun... Hence I dare venture to foretell, that it will return again in the year 1758. - Edmund Halley {*A Synopsis of the Astronomy of Comets* (1705), 22}

The 27th apparition of the Halley's Comet was the first ever predicted return of a comet and it was Edmund Halley (1656-1742) who made the prediction on the basis of Newton's laws of gravitation. Halley was computing orbits of comets that had been observed between the years 1337 to 1698. He saw great similarities in the orbits of the comets of 1531, 1607 and 1682. He regarded these as the same comet that had returned repeatedly and surmised that the comet of June 1456 was a previous apparition too. The intervals were similar and if these slightly differed, he attributed that aspect, significantly, to the influence of Jupiter. Keeping that in mind, Halley predicted that the comet should return in late 1758 or early 1759. He did not live to see the comet return for real but the prediction made it the most awaited apparition in history. Searches for the comet that was destined to be christened the Halley's Comet began in 1757 itself. As Lynn (1910) has put it, Halley had had only one view of the comet in its apparition of 1682 after his return from Italy to England through France. Recounting the comet's story, Dr Lardner (1835) wrote that:

'In 1757, Lalande proposed to Clairaut, the calculation of Halley's comet which was expected to return speedily. They were assisted by a French lady, the wife of a chronometer maker. The calculation was enormous, because the orbit must be divided into degrees, and each degree requires as great a calculation as the whole orbit. They tell us, that they were employed from morning to night, not excepting meal hours, incessantly for six months in this computation. Clairaut was so nervous that he hurried his calculation before the Institute, although he had not completed it. He stated, that the comet would reach its perihelion on the 4th of April, but that it might be seen sooner. Voltaire has said, that the philosophers did not go to bed in the beginning of the year, so anxious were they to observe it'.

Clairaut as referred to above is the distinguished mathematician Alexis Clairaut (1713-65).

The comet returned indeed. It was recovered by a farmer and amateur astronomer Johann Palitsch from Prohlis in Germany in the constellation of Pisces on 25 Dec 1758 with a telescope of eight feet focus (Hind 1852). The finding was confirmed only on 20 Jan 1759. The comet was well observed ever since its discovery and widely noticed by several acclaimed observers. It passed its perihelion on 13.0623 March 1759. Kronk (1999) gives a fairly detailed account of the apparition. Charles Messier viewed it from Paris with a telescope first on 21.74 Jan 1759. Observing conditions in Europe were not favourable in

February due to strong twilight, the waxing Moon and the comet's position in the sky. In mid-February, Messier could watch it again with a telescope. On 1 April, Messier spotted it in the morning skies a few degrees above the horizon with a 25° long tail. The comet reached its brightest mag. at 1.19 as it passed closest to the Earth from 0.1222 AU on 26 April. It had just turned to move swiftly north-west after having touched its southern-most declination of -71º in Apus near the border with Triangulum Australis. From 27 April, the comet began to trail the Sun. It continued to be a naked eye object throughout May, gradually slowing down in its apparent motion to become near stationary and fading out to 5.4 mag. by 2 June while it reached Sextans.

With this return as predicted, the comet provided the most cogent proof of the strength of physical theory - the laws of universal gravitation. Dr Lardner (1835) further observed,

'Now, although Clairaut was not quite correct as to the day, the only wonder is, that he should have been so accurate, for as he said, when a body traverses a space of 1500,000,000 of miles beyond our sphere of observation, how do we know but that some other planet may act upon it and influence its course. In 26 years the planet Herschel was discovered, which it was proved, did actually operate in producing the effect which Clairaut had surmised'.

While Dr Lardner wrote that, the planet Neptune, itself the first planet found from mathematical analysis of unexplained deviations in the orbit of the planet Uranus rather than by observation, was yet to be discovered in 1846, on 23 September.

While the Halley's Comet lay below the horizons in Europe, it was observed by M de la Nux from Bourbon Island in the Indian Ocean, and from India on 28 March. It was a French Jesuit Gaston-Laurent Coeur-doux (1691-1779) who while at Pondicherry independently found the comet at 04 hrs in the morning (local time). Coeur-doux was a Jesuit missionary, a naturalist and linguist and the first to demonstrate similarity between Sanskrit, Latin and Greek, as also German and Russian. His letter of 29 Sept 1759 to *L'Academie Royale des Sciences, Paris* (Coeur-doux 1760), translated reads thus:

'It was not until 28th March that we noticed, for the first time at four o' clock in the morning, a Comet that seemed to have been present for a long time, given its width and the length of its tail that extended to several degrees; the comet appeared to be at the east of the Aquarius constellation, and with respect to Pondichery, at about the same vertical as the brightest star of the southern shoulder of Aquarius, but a little to the north of this vertical'.

The observations were made with the help of a semi-circle 10 inches in diameter placed perpendicularly on a circle of the same size, and using an 18-inch telescope. Coeur-doux noted that

'Since the Comet was then visible in Europe, we did not think we would be able to observe it closely, more so because for several days its movement was almost indistinguishable. Towards the 9th of April, it appeared as if it had considerably accelerated….'.

After mid-April, the comet moved quite fast through the southern skies, more to the advantage of southern observers. On the 25th of April, at 4 a.m. the comet stood 12° 40' above the horizon, making

'a straight line with the Peacock eye and the clear of the Southern Triangle, that is, the closest to Bird of Paradise, and they seem to be equidistant from each other….The following two days were extraordinarily busy, and we thought, given the great speed at which the comet was traveling to the south, that it would completely disappear from our sight. On the 28th, a little while after sunset, we spotted the Comet to the east of our meridian….'

At 9:52 pm, Coeur-doux found its elevation on the horizon at 30° 30'. According to him, a line from the two stars to the west of the Raven would just about intersect the Comet. On the 30th at 7:28:30 pm, the Comet appeared at an elevation of 44° 9' on the horizon. The tail of the Comet stretched to over 10° and its apparent diameter seemed to diminish proportionally with its elevation towards the north. Coeur-doux observed the Comet last on 4 May 1759 when at 07:29 pm, it showed up at an elevation of 59° 54'. He discontinued the observations reasoning that the elevation of the Comet had become very high and so, astronomers in Europe would be able to carry out more accurate observations.

While describing his observations, Coeur-doux also refers to the seconds' watch that belonged to Fr. Boudier – as falling behind by 45 seconds in 24 hours on the 30th Apr, delayed by 2 minutes and 30 seconds on the 2nd of May for it had not been wound the previous day and falling behind by 1 minute and 30 seconds on the 5th.

Fr. Boudier referred to above is the French Jesuit and astronomer Fr. Claude Boudier (1686-1757). He came over to the French mission at Chandernagore in 1719, a French Colony since 1673 in the Hooghly District. Equipped with 6 feet- and 17 feet- telescopes, a 2 feet- quadrant and some other instruments, a group of Jesuit astronomers under Boudier had commenced astronomical observations beginning 1730 that included solar and lunar eclipses (Udias 2003). In 1734, he had taken a long journey to visit Jaipur together with Fr. Francis Pons (1698-1752) on an invitation from Rājā Sawāi Jai Singh II. He had carried a 17 feet long telescope and an astronomical clock along. He had even measured latitudes, and from observations of Jupiter's satellites, longitudes of the towns that fell *en route*. He recorded the solar eclipse of 3 May 1734 that he observed from Delhi (Sharma 1982). Notably, the path of totality passed over Mumbai, Nashik, Ahmednagar, Rajahmundry, Kakinada and Vishakhapatnam etc. Delhi saw the eclipse at a 0.7 magnitude with C1 at 10:46 UT and C4 at 12:45 UT.

Coeur-doux's communication nowhere relates the apparition of the comet to Halley's prediction nor does it use a phrase 'Halley's Comet'. The right honours were first conferred by the French astronomer Abbe de La Caille, sometime in May 1759. A decade later, Charles Burney (1726-1814), the music historian most well known for his 'History of Music', had this to say – 'The comet of 1759 is known throughout Europe by the name of Dr Halley's Comet' (Hughes 1987).

The reader can find poetic echo of an astronomical prediction in a poem by Victor Hugo on Halley's Comet entitled '*la Cométe*, 1759', reproduced by *The Observatory* in its August 1910 issue, p. 341-2:

'*Il avait dit:--Tel jour cet astre reviendra*. *Quelle huée* !.., meaning *He said such a day this star will return. What a hoot* !.....'

After Edmund Halley, J F Encke successfully predicted in 1820 the return of a comet in 1822, now appropriately named 2P/Encke. Encke's Comet has the shortest period of them all, 3.28 yrs.

6.7. Le Gentil and the Comet of 1769 (C/1769 P1)

The comet of 1769 (C/1769 P1) was discovered by Charles Messier (1730-1817) on 8 August 1769 from Paris in the course of his dedicated search for comets. The great comet, in Messier's own words in his Memoirs of 1808 (*1769 Grande comète qui a paru à la naissance de Napoléon le Grand, découverte le 8 aôut 1769 et observée pendant quatre mois par M Messier*) 'preceded the birth of Napoleon the Great by 7 days…'. Messier possibly believed that comets were premonitions to events on the Earth and in William Smith's words as quoted

by H. Frommert in his biography of Messier, it was 'the last comet put astrologically before the public by an orthodox astronomer' (Meyer 2007). By 25 August, the comet visible to the naked eye had developed a tail 10° long. Messier describes his observations of the impressive comet in his Memoirs citing de la Nux having measured from Isle de Bourbon a tail 97° long. It passed closest by the Earth on 11 September from 0.32296 AU and passed its perihelion on 8.1204 October; q=0.122755 AU i=40°.7338. It was last observed on 3 December. There is a detailed description in Kronk (1999) of its observations made from various locations.

In India, the comet was observed from Pondicherry by Guillaume Le Gentil (1725-1792), a French astronomer who had originally set sail in 1760 to come over to India to follow the transit of Venus of 6 June 1761 from Pondicherry, then in French possession. Caught in the Seven Years' War between the French and the British, he could not make it for the British had taken Pondicherry just while the frigate he was aboard appeared before Mahe on the Malabar shores. They decided to turn back to set sail to Isle de France (now Mauritius). Le Gentil could make observations of the transit from a moving ship but with measurements hardly of value (Hogg 1951).

The transits of Venus are very rare, about 12 in a millennium and occur after 8, 105.5, 8 and 121.5 years and so on, either in June or in December. After the telescope, the first of the transits of Venus as predicted by Kepler happened on 7 December 1631. Looking through his *Tabulæ Rudolphinæ*, the British astronomer Jeremiah Horrox (1618-41) deduced the next one to be on 4 December 1639 and actually observed it. It was James Gregory in 1663 and later Edmund Halley in 1691 who proposed that from the timings of ingress and egress of a transit of an inner planet observed from different locations on the Earth one should be able to determine solar trigonometric parallax and deduce an unprecedentedly precise measure of distance to the Sun. Halley died in 1742. The next transits of Venus were to happen in 1761 and 1769. As the time drew near, the forthcoming transits evoked great scientific interest in Europe to observe these from different locations of the globe. Le Gentil who had been inducted into astronomy by Jacques Cassini at the Paris Observatory at a young age and grew to be a dedicated astronomer was in the French expedition that was part of an international collaboration for the purpose. Disheartened but not giving up having ventured so far from France, Le Gentil knew that the next transit was due on 4 June 1769 and so determined to stay around and observe it. The intervening period spent in drifting and sails was sufficiently trying but he eventually returned to Pondicherry on 27 March 1768, well in time to be able to observe the transit that to his misfortune was clouded out. The British too had prepared for and had observed both the transits from various locations in India (Kapoor 2013).

Hogg (1951) in her four part essay presents an insightful description of the travails of Le Gentil from his memoirs in French, namely, *Voyage dans les mers de l'Inde…* (Le Gentil 1779). She calls his eleven year voyage to the Indian Ocean to observe the transit of Venus of 1761 and then of 1769 as the longest lasting astronomical expeditions in history. Pondicherry in the mean time had its own tryst with its occupants. When he landed, it was under French occupation. M. Law, the 'Governor General for the King of all the French establishments in India', accommodated him well and asked him to go around next day, find a suitable site and build an observatory (Figures 10 and 11).

In the *Tome Premier* of his *Voyage…*, Le Gentil (1779) writes about how the observatory came up (p. 353-6). It got ready by 11 June. He carried there his instruments, the quarter-circle (quadrant) and clocks, and his effects, saying 'It was my home and my retreat during my stay in Pondicherry' (Le Gentil 1779, p. 354). It was the British of Madras who provided Le Gentil with an excellent telescope, an achromatic three feet long to observe the transit. Here he began with taking correspondent altitudes of the Sun, and determining latitude and longitude of Pondicherry. In the course of his work, he had an exposure to Indian astronomy too. He marvelled at the fine art of eclipse calculations by the locals and even tried to learn it.

A local Tamil Brahmin computed for him in three quarters of an hour's time using shells, and tables from his memory, the circumstances of a lunar eclipse of 30 August 1765 that Le Gentil had observed from elsewhere. Upon cross checking with the tables of Tobias Mayer that were considered the most accurate, he was astonished to find the Tamil giving the eclipse duration short by only 41 sec, in contrast to Mayer's tables that gave a duration longer by 68 sec (Neugebauer 1975, II, p. 620). Le Gentil found computation of solar eclipses much more difficult to comprehend and master.

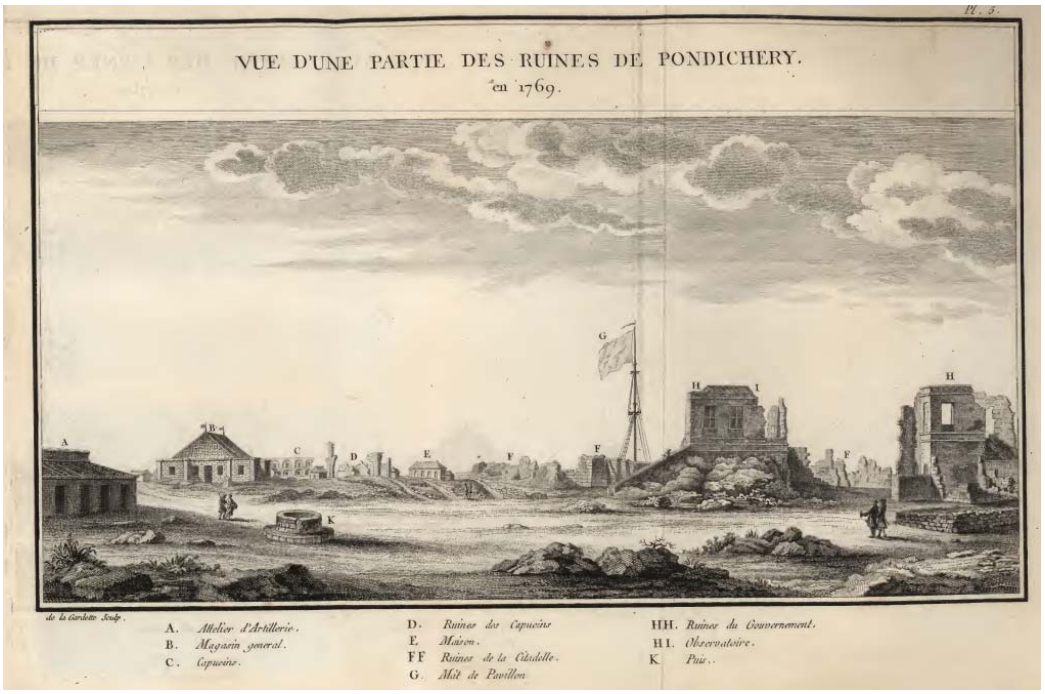


Figure 10. The ruins of Pondicherry in 1769, as seen from the north. Le Gentil set up his observatory in the ruins of the former Governor's palace, in the structure to the right of the flag pole (Image adopted from Le Gentil 1779).

Le Gentil (1779) writes about his (pp. 464-73) observations of the comet, noting

"During the month of August, there appeared a comet that I observed as much as I could afford the time & the fever that I was attacked for the first time….. I will only report those which could serve to discover whether the Comet had a sensible parallax. I made three observations of this kind; I am sure that I would have had more, if the weather had been more favorable to the Observations…"

He describes the first sighting as follows,

"It had been a long time since the Comet was visible when I began to observe it; not only is Heaven almost always covered in Pondicherry during the month of August, but I must make my return to France in the first days of the month of October: my observations were finished, I had finished the last ones on the length of the simple Pendulum on July 27th. I made my arrangements for my departure, when the sentinel of the guard-house came to warn me, on the feast day of St. Louis, that he had perceived the night before, a great trail of light in the sky, between the clouds, and that time at four o'clock, they had seen from the guard-house a large star with a long tail; that his comrades had told him that it was a comet, and that it was necessary to come and give me notice of it. On this report I was attentive; but I spent a fortnight idle with M. de Willems, *Major des Troupes*. Finally, on the 30th, the sky was a little clearer of clouds, and we perceived the long tail of the Comet. This tail occupied more than 30 degrees in Heaven: I compared the Comet to a few Stars of the Bull".

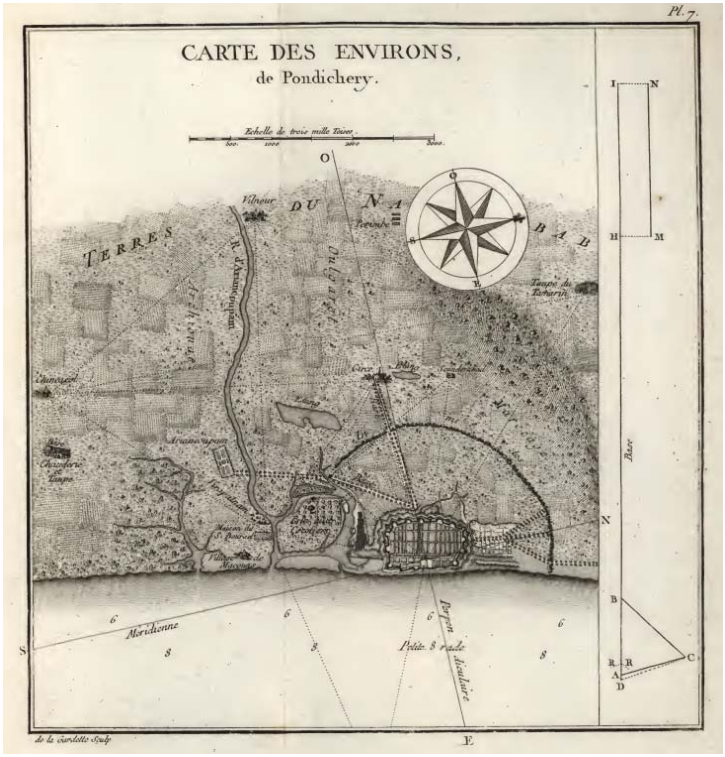


Figure 11. Pondicerry as in 1769 (Le Gentil 1779).

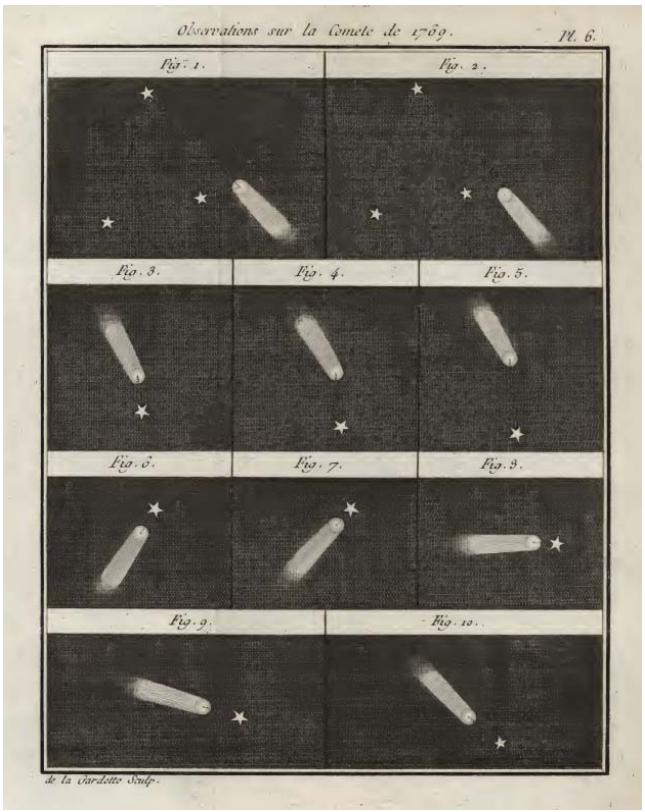


Figure 12. Le Gentil's shows with sketches of the comet and the star field how the separation between a particular star in the field of view and the comet head changed in a matter of minutes. Here, the Figs.1 and 2 depict the situation on 1 Sept, Figs 3-5 on 9 Sept and Figs. 6-10 on 12 Sept. (Le Gentil 1779).

In the month of September, Le Gentil was able to see the comet three to four times only, then once after its conjunction with the Sun at the end October and next on 2 November. By then, the tail had diminished in length. Before the conjunction, the tail that stretched more than 40° now measured barely 5°.

For the 1 September observation with *ma lunette de 15 pieds* (my 15 foot telescope), he found the comet, in comparison to the Andromeda Nebula, to have 'the same density, the same diameter, and to be as badly finished as this Nebula'. He made observations of correspondent heights of the upper edge of the Sun to determine the *True Noon* to the last second, a moment that occurred a bit earlier with the days. He specifies angular distances of a few stars of Taurus and the field stars in terms of the diameter of the Comet. In the course, he measured how the Comet took certain time to drift a distance. For example, on the 9th September, he found the comet taking 12 '15" of time to move away from a star in the field of view by an amount equal to its diameter. He made several sketches of the position of the comet with respect to adjacent stars at specific epochs. The Figure 12 has several of such sketches drawn to show how on the respective days, the comet moved among stars in a matter of minutes; within it, the Figs.1 and 2 depict the situation on 1 September, Figs. 3-5 on 9 September and Figs. 6-10 on 12 September. On 8 September, he found the tail of the comet more than 40° long; it was of very great density for more than 20°. On the 11th, he observed

"The tail of the Comet has very visibly reached the three shapeless Stars in the front feet of the Monoceros, on the confines of the Milky Way; so it occupied about 20 degrees. The Comet appeared like a star between the second and the third magnitude, very pale. In the telescope, no nucleus was visible; there was a sort of disheveled Nebula, but very clear, and transparent, much more so than the Nebula of Andromeda."

The 12th of September witnessed the most favourable weather when he could see the tail of the Comet in a form not seen till then:

"It was going to confine to the Stars of Orion's sword, which had an extent of more than 35 degrees…. These are the most interesting observations I have been able to make on the Comet. I find one made in Paris by M. Messier, correspondent of the one I made on the 9th. This observation is unique, in that we have compared the Comet to the same Star, M. Messier & I, and almost to the same moment…"

He further observes (Le Gentil 1779, p. 521),

"On the 30th and 31st of October, were beautiful and charming days, not too hot; the Sun has always appeared lightly covered with a rare and transparent cloud…..Until the 4th of November, we had nearly same temperature; but it must be remarked that the horizon has always been covered at sunset by heavy storm clouds, and that I have been able to observe the Comet only twice".

What did he communicate to the locals about comets and the transit of Venus that he had originally come for, so far? The Halley's Comet should be lingering in their memories, and now, just past the extraordinary conjunction of Venus with the Sun, there was yet another bright apparition. However, none of it moved the traditional astronomers. What they actually thought about his activity is revealed in Le Gentil's comments as follows (Le Gentil 1779, p. 42):

"The Brahmins do not know anything of Comets: Indians believe that they are signs of Heaven's wrath. They were astonished to see me spend part of the nights watching the comet that appeared in 1769; they asked me a lot about the cause of this phenomenon….In spite of their contempt for us, and the faith of their idea of our knowledge; although this Brahmin, who had come to visit me from afar, showed the greatest indifference in seeing my instruments of Astronomy; although he seemed very little flattered by the explanation I gave him of the use of the quadrant for astronomical observations;

however, my prediction, in the name of the Comet, which appeared in August and September, 1769, struck him; it made the same sensation on the minds of all the Indians of Pondicherry. I had announced, during the month of September, that this Comet, after it ceased to appear in the morning towards the end of the month would return near mid-October at seven o'clock in the evening, and we would see the tail turned in the opposite direction to that which it had when we saw it in September. What finally surprised them was to see this Comet in the evening, at the end of October & in the early days of November, in accordance with that I predicted them, as well as all Pondicherry.

Even though the Brahmins do not observe, they can trace the Meridian line by means of the gnomon; they use it whenever they are building a pagoda, because their religion teaches that temples are oriented according to four cardinal points; so that the four faces of pyramids that serve as entrance & gateways to their pagodas, are North & South, East & West".

Le Gentil was appreciative of the sky conditions at Pondicherry when he observed (Hogg 1951) –

'The nights at Pondicherry are of the greatest beauty in January and in February; you cannot have any idea of the beautiful sky which these nights offer until you have seen them. I had nowhere seen Jupiter so well with my telescope of fifteen feet (focal length) as I did there….'.

It is not clear if Le Gentil knew that the year 1769 would actually see two transits. Even so, he was not rightly placed to observe the transit of Mercury that fell on 9/10 November 1769. The transit ended on the morning of 10 November 1769. The IVth Contact was at 00:12 UT, just before the Sun rose at Pondicherry - at 00:38 UT. Had he known it, he would surely have gotten in the observation mode, vide his *Voyage*, p. 358:

"I remember that we saw so many differences between all the observations that have been made of Mercury's passage on the Sun, in 1753, that we do not dare to give one of them in preference to the other, without having it, above all, subject to the most critical examination."

8. EPILOGUE

The next comet observation from India I know of relates to the Great Comet of 1807 by Capt. John Warren (1769-1830). He was Acting Astronomer of the Madras Observatory during the years 1805-11 when the Astronomer John Goldingham went on leave to England. The work on the observations of comets made in India in the 19th and 20th century is in progress.

'Comet tales from India' is the author's ongoing search since 2009 for the records of cometary sightings from the Indian region, since antiquity until 1960, where available data, however minimal, permits identification of the comet. Here is hoping that more comets from the period will join the narrative.

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