TALES FROM INDIA. 1: METEOR SHOWERS IN CLASSICAL AND COLONIAL SOURCES

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Abstract: Meteor phenomena are always fascinating and capture popular attention. This paper reports results of a search for references to and records of meteor showers observed in the Indian region, until the close of the nineteenth century. The sources explored were the Indian classics and chronicles, institutional reports and accounts by individuals, including those published in professional journals. We found very few references to such events in the classical sources. The earliest datable references that we found were in Shuka's *Rajatarangini* (Perseids or Leonids, 1533), Abu'l Fazl's *Akbarnama* (Alpha Capricornids or Delta Aquarids, 1592) and in Krishnaji Sabhasad's account of the life of Chhatrapati Shivaji Maharaj (Leonids, 1680). The subsequent accounts belong to the nineteenth century. Some of these are about sporadic meteors, while others are about meteor showers. The earliest published report is of the November Leonid meteor shower of 1832. We also came across a strong meteor shower on 10 September 1841 reported in the 13 September issue of the *Englishman* newspaper. We believe this is the September Epsilon Perseids, a minor shower known to peak on 9/10 September. This 1841 observation is 37 years before the September Epsilon Perseids were first described by William Denning, in 1878. We believe that such records can be of great value in fine-tuning time-lines in Indian history and understanding the dynamics of meteoroid streams.

Keywords: Meteor showers, September Epsilon Perseids, Indian meteor references, Shuka's *Rajatarangini*, the *Akbarnama*, Krishnaji Sabhasad, Chhatrapati Shivaji Maharaj, 'Prince Rupert's drops', Dr George Buist, Charles Michie Smith.

1 INTRODUCTION

Since times immemorial people have seen providence in circumstances developing in the sky, namely the conjunctions of planets, eclipses, meteors and comets. Scholars have often traced history from these celestial phenomena as referred to in religious texts, chronicles and other sources. Obviously, the significance of these records is inestimable.

We have for some time been researching the records of comets and meteor phenomena observed from the Indian region. The sources explored are some Indian classics, publications and records of institutions, the chronicles and the accounts of some individuals. Our quest revealed a number of interesting and hitherto unknown observations of comets from India (see Kapoor 2018).[1] The present series of papers is designed to explore Indian sources that refer to meteoric phenomena, dating up to the close of the nineteenth century. In the present paper, we bring together information about the observations of meteor showers that we have been able to identify. We have not included sporadic meteors that occurred around certain dates, for which a number of reports exist, even though some of these may have been part of shower events. These, and other Indian accounts of meteoric phenomena, will be dealt with in subsequent papers.

In what follows, we have chosen to retain the old names/spellings of the places used in the various historical accounts in order to maintain the historical flavour.

2 METEORS AND METEOR SHOWERS

Meteors, the shooting stars that we often see in the night sky heading in some direction and leaving a streak of light lasting a few seconds, are visitors from space. These are caused by meteoroids—small stony masses that range in size from dust grains to small asteroids (i.e., from ~30 micrometers to ~1 metre). Most visible meteors appear in the atmosphere at heights between 90 and 120 km.

Commission F1 (2017) of the International Astronomical Union, explains that

> The meteor phenomenon can be caused by a meteoroid, an asteroid, a comet or any solid matter with the appropriate combination of velocity, mass and mean-free-path in a planetary atmosphere.

A meteor that is brighter than absolute visual magnitude $M_V = -4$ (at a height of 100 km) is referred to as a 'fireball' and if it explodes as a 'bolide'. An exploding meteor brighter than magnitude $M_V = -17$ is referred to as a 'Superbolide'. 'A meteoroid stream' is a group of meteoroids in space that have similar orbits and a common origin.

Some meteoroids survive the journey after the ablation stops in the atmosphere and fall to the ground. These objects are referred to as 'meteorites', and may weigh from a few grams to many kilograms. There are numerous instances of meteoritic falls all over the globe.

Over the last few centuries many meteorites have been seen to fall in India, and there are many examples in museums and other institutions, and in private collections. Orbital analyses reveal that the great majority (i.e. 99.8%) of all known meteorites worldwide originated in the asteroid belt, with the rest from the Moon and Mars (NASA Science, 2022). As meteorites are pristine material with a composition similar to that of the early Solar System, they are extremely useful in throwing light on its history, and also on the establishment of life here on Earth.

2.1 Meteor Showers

A meteor shower is produced by meteoroids of the same meteoroid stream. The showers are periodical or annual, and sometimes they can present a fascinating spectacle and are eagerly waited for. Early in the nineteenth century, comets and the recently discovered asteroids were acknowledged as part of the Solar System. The nature of a comet tail was still controversial: was it an appendage or an emanation? In 1812 and 1836, respectively, the German astronomers Heinrich Wilhelm Olbers (1758–1840) and Friedrich W. Bessel (1784–1846) suggested that comet tails were composed of solid particles that suffered a repulsive force in a direction away from the Sun (for details, see Festou et al., 2004).

In contrast, until the close of the eighteenth century, astronomers believed meteors to be meteorological phenomena. With time, one began to see also a certain periodicity in the enhanced meteor activity. It was the Italian astronomer Giovanni Schiaparelli (1835–1910; Figure 1) who first showed in 1866 the connection of a meteor stream with a comet by comparing their orbits. He gave the name Perseids to the shower seen emanating from the direction of the constellation of Perseus (Figure 2) in the month of August, called until then the August meteors (Hughes 1995). Then there also was the shower seen in November that seemed to emerge from the direction of the constellation of Leo. Schiaparelli noted that the Perseid and the Leonid meteor showers coincided with the paths of comets 1862 III (109P/Swift–Tuttle) and 1866 I (55P/Temple–Tuttle), respectively. This clearly indicated that comets were losing solid material as they orbited the Sun.

Since Schiaparelli's time, many more meteor showers have been identified and named after the constellations they were seen to radiate from. In order to distinguish showers emanating from the same constellation, they are named after the star nearest the radiant.

Although we see a shower appearing to originate from a specific point in the sky, the approach is in fact along parallel lines. These are sections of their orbits round the Sun and the divergence happens because of perspective only. Meteor showers are periodic, and related to the Earth's passage through the meteoroid streams. In most cases, the source is a comet, except for a few instances where an asteroid might be a non-active cometary fragment.

Figure 1: The drawing by Achille Beltrame of Giovanni Schiaparelli that appeared on the first page of the weekly Italian newspaper *La Domenica del Corriere* on 28 October 1900 (after Anonymous, 1900).

3 ROMANCING THE STONES AND THE IRON MASSES: METEORITES IN THE EARLY NINETEENTH CENTURY

Early in the nineteenth century, meteors and meteor showers were not yet properly understood. The meteorites that were recovered on the ground eventually ended up in the hands of chemists and geologists, were subjected to chemical analysis, and their composition was compared with terrestrial rocks. The 'falling stones' and the 'iron masses' had yet to belong to the realm of astronomy. However, towards the close of the eighteenth century, perceptions had begun to change and geologists and astronomers began thinking that meteorites came from asteroids, comets or from interstellar space.

Ernst Florens Friedrich Chladni (1756–1827; Figure 3) was a natural scientist and musician. He is regarded as the founder of acoustics, and of meteoritics as a science. He was drawn to the 'fallen masses' in 1793 when

Figure 2: The Perseid Meteor Shower of 12 August 2015 as photographed by the NASA Wide-field Meteor Camera Network in the skies over Huntsville, Alabama (courtesy: NASA).

Figure 3: A lithograph of Ernst Florens Friedrich Chladni by Ludwig Albert von Montmorillon (1794–1854) (commons.wikimedia2.org/wiki/File:Echladni.jpg).

he contacted Georg Christoph Lichtenberg (1742–1799) about a fireball that the latter had seen in November 1791 from Göttingen. Chladni searched for and studied many eye-witness accounts of objects falling from the sky over the centuries. His research revealed many cases where the appearance of a fireball was followed by the fall of a stony or an iron mass to the ground. In 1794, Chladni recorded his insightful observations about the nature of meteorites in a book, *Über den Ursprung der von Pallas Gefundenen und Anderer ihr Ähnlicher Eisenmassen und über einige Damit in Verbindung Stehende Naturerscheinungen* (*On the Origin of the Iron Masses Found by Pallas and Other Similar Ones, and on Some Natural Phenomena Connected with Them*). He proposed (Chladni, 1794) that meteors, fireballs and falling meteorites (stones and iron masses) were manifestations of the same phenomenon caused by the entry of a solid extra-terrestrial object from deep space into the Earth's atmosphere. His suggestions were based on 18 historical eye-witness accounts, from CE 56 to CE 1785. His work, however, did not find acceptance in the relevant fora at the time (Marvin 1996). The French Academy of Science did not acknowledge that stones could fall from heaven until a large shower of thousands of stony meteorites over L'Aigle in Normandy on 26 April 1803 finally convinced men of science about their reality (*ibid*.). Around that time, the laboratory analyses of fallen masses by Edward Howard and Comte de Bournon were reported. They found mineralogical and chemical similarities among the fallen masses, but they also noted big differences with terrestrial rocks, and they concluded that meteorites were from the sky and could not be from the Earth (Howard et al., 1802). The discoveries of minor planets, beginning with Ceres in 1801, filled the Titius–Bode gap between the orbits of Mars and Jupiter and made astronomers re-evaluate their perceptions of the Solar System. These discoveries enthused Chladni, as he used to think that a planet was located just there, and in his book he even suggested that the falling masses may be the debris of this disrupted planet (Marvin 1996).

In the meanwhile, a major meteor shower occurred on the morning of 12 November 1799, which was seen in many parts of the world. Newton (1864a) produced reports of the same phenomenon observed from many different places (also see Kronk, 2014: 270–272). Among these, the observations by the Prussian polymath Alexander von Humboldt (1769–1859) and his companion, the French botanist Aimé Bonpland while in Cumaná in Venezuela stand out. They witnessed thousands of fireballs and shooting stars, all moving from North to South. Here is von Humboldt's description:

> From half after two in the morning, the most extraordinary luminous meteors were seen in the direction of the east … They filled a space in the sky extending from due east 30° to north and south. In an amplitude of 60° the meteors were seen to rise above the horizon at E.N.E. and at E., to describe arcs more or less extended, and to fall towards the south, after having followed the direction of the meridian. Some of them attained a height of 40°, and all exceeded 25° or 30° … All these meteors left luminous traces from five to ten degrees in length, as often happens in the equinoctial regions. The phosphorescence of these traces, or luminous bands, lasted seven or eight seconds. Many of the falling stars had a very distinct nucleus, as large as the disk of Jupiter, from which darted sparks of vivid light. The bolides seem to burst as by explosion; but the largest, those from 1° to 1° 15' in diameter, disappeared without scintillation, leaving behind them phosphorescent bands (trabes) exceeding in breadth fifteen or twenty minutes. The light of these meteors was white, and not reddish, which must doubtless be attributed to the absence of vapour and the extreme transparency of the air … Almost all the inhabitants of Cumana witnessed this phenomenon, because they had left their houses before four o'clock, to attend the early morning mass. They did not behold these bolides with indifference; the oldest among them remembered that the great earthquakes of 1766 were preceded by similar phenomena. (Ross, 1852: 351–353).

The phenomenon lasted over two hours. Humboldt went about to collate reports from many different places and found that the same event had been seen at the equator in South America, Labrador and Germany. He found that the event had a simultaneous and vast geographical spread, 60° in latitude and 91° in longitude. Most interestingly, the oldest local inhabitant in Cumaná recalled having witnessed a similar occurrence preceding an earthquake in 1766. Much later, Newton (1864a) and Adams (1867) showed that these intense displays peaked every 33.25 years. We now refer to these as 'meteor storms' rather than conventional 'meteor showers'.

Enhanced meteoric activity was next witnessed on the mornings of 13 November 1831 and 13 November 1832 from many places in Europe and Asia, but it was the great meteor storm of 13 November 1833 that became a turning point (see Figure 4). It stimulated astronomers to further explore meteoric phenomena. The time was just right, as this research was in step with progress in astronomy and the physical sciences.

The Leonid meteor storm of 1833 was seen across the United States. Denison Olmsted (1791–1859; Figure 5), Professor of Natural Philosophy and Astronomy, Yale College, who himself had observed the event said:

> Probably no celestial phenomenon has ever occurred in this country, since its first settlement, which was viewed with so much admiration and delight by one class of spectators, or with so much astonishment and fear by another class. (Olmsted, 1834: 363).

The 'other class' got truly terror-struck. Stepping out of their homes, and amid the ringing church bells they lay on the ground thinking that the world was going to end. Olmsted collated all the possible information on the "Meteoric Phenomenon" from the general public through an appeal he placed in the *New Haven Daily Herald*. He got an overwhelming response from far and wide, including from ships at sea, giving vivid and very informative accounts with every possible detail. Twining (1834) a Civil Engineer and for-

Figure 4: This famous depiction of the 1833 Leonid meteor storm was actually produced in 1889 for the Adventist book *Bible Readings for the Home Circle.* This engraving by Adolf Vollmy was based upon an original painting by the Swiss artist Karl Jauslin, which in turn was based on a first-person account of the 1833 meteor shower by a minister, Joseph Harvey Waggoner, on his way from Florida to New Orleans (http://toto.lib.unca.edu/findingaids/mss/hayes_merwin_letters/default_merwin_m.htm; Wikimedia Commons).

merly a Tutor at the Yale College who had observed the meteors of 13 November from a few minutes past five till day also made an independent compilation. What struck Olmsted was that most of the observers found the meteors shooting from a common centre in the sky. It happened to lie in the direction of the constellation of Leo, where "… it appeared stationary, accompanying that constellation in its diurnal progress." The intense shower had lasted about 4–5 hours, a duration long enough to notice that the radiant too had moved with the fixed stars, east to west. Here were the most important findings of the event which pointed to the cosmic nature of the meteor swarm. Olmsted concluded that the origin of the meteors of 13 November lay beyond the limits of the Earth's atmosphere and that the meteors were combustible bodies that got caught in the Earth's gravity and fell towards it in nearly parallel lines and burnt in the lower part of the atmosphere with great rapidity. Later, recalling the shower of November 1832, he suggested that the November 1833 shower was annual (Olmsted 1834a). He made an important observation that

> … so far as we can gather any knowledge of the material of the nebulous matter of comets, and of that composing the meteors of Nov. 13th, they appear to be analogous to each other. (Olmsted, 1834b: 162).

Olmsted's work became a great influencer.

The French mathematician–astronomer–physicist François Arago (1786–1853) went on to endorse his findings and views, saying:

> … it has been ascertained that even though they are inflamed in our atmosphere, it is not from it that they originate, but that they come from without. This direction, which is their most habitual one, seems diametrically opposed to the movement of the earth in its orbit!
>
> It is desirable that this result should be established by the investigation of a numerous series of observations. (Arago, 1836: 33).

The Leonid meteor storm of 1833 spurred the search for and identification of other showers in the times to come. In 1841, the French mathematician Michel Chasles (1793–1880) published a catalogue of the "Apparitions d'étoiles filantes en masse" ("Appearances of meteor showers") recorded over six centuries, from CE 538 to 1223. Chasles observed that:

> The ancient chroniclers that I have visited use various expressions to designate the apparitions that we call shooting stars: they say stellæ cadentes; acies igneæ; hastæ igneæ; globi ignei; igniculi similes stellis; they still say that the sky is red and that it is raining blood, or else that signs are appearing. Modern writers have translated acies igneæ as armies on fire ... We will translate acies by spears … The expression hastæ igneæ, which some chroniclers use to designate the same phenomenon, justifies the meaning I give to the word acies by translating it into spears. Be that as it may, it seems to me beyond doubt that these multitudes of lances of fire, or armies on fire, which have been seen traversing the sky, are those meteors which we call shooting stars …
>
> Some chronicles tell of crosses appearing in the sky or on men's clothes. Perhaps it was the appearances of shooting stars that gave rise to these stories presented in a miraculous form: nevertheless I will not mention them. (Chasles, 1841: 499; my English translation).

Figure 5: A painting of Denison Olmsted by Nathaniel Jocelyn (1796–1881) made in New Haven, Connecticut in 1833 (photograph courtesy: Yale University Art Gallery).

When referring to the event of 1223, Chasles (1841: 507) states: "From Bologna we see a miraculous rain of blood falling on Rome; those who see it and hear it are amazed."

As per the *Catalogue* of Chasles (1841: 508), the reported apparitions of *d'étoiles filantes en masse* in the various months fared thus: January (0), February (10), March (9), April (7), May (4), June (1), July (0), August (1), September (1), October (6), November (2) and December (5). Chasles specifically spoke about the November meteors. On this, he made a very insightful observation:

> We note in the Catalogue above the almost total absence of apparitions in November, when they are currently periodic annually. We are led to conclude from this that the plane of the orbit of these asteroids which we see around 13 November, experienced a considerable displacement, and that it is as a result of this disturbance that, nowadays, they have become visible in November …
>
> It is also said, on several dates, that the phenomenon appeared in previous years. This denotes the periodicity that has been observed for several years in this singular phenomenon. (Chasles, 1841: 509; my English translation).

The picture that began to emerge was that there were innumerable small solid bodies moving around the Sun. Their swarms were concentrated in some meteoric zones through which the Earth passed once a year and the planetary perturbations deflected the meteors. The meteors shone by exerting great pressure on the Earth's atmosphere (Vaughan, 1855: 27). This chain of thought culminated in Schiaparelli's monumental work through 1867–1871 that firmly connected meteor showers with comets.

3.1 A Few Notable Meteor Showers

In an ancient lore, a certain meteor shower has been referred to as the 'Fiery Tears of St. Lawrence' because it occurs about the time of St. Lawrence's Feast, on 10 August, the day that he was burnt at the stake in CE 258 (Kirsch, 1910). This is an old name for a particular meteor shower, the Perseids, which occurs close to the Feast Day.

The parent body of the Perseids is Comet 109P/Swift–Tuttle (1862 III), with a mean orbital period of 133.8 years. The Perseid-stream is inclined to the ecliptic at about 114.9°, where its orbit is far away from perturbing planets. This leaves the Perseid-stream to be affected mostly by the Earth's gravitation. The node of its orbit is quite stable, changing very slowly, which almost entirely due to the precession of the equinox (Hughes and Emerson, 1982).

The earliest identification of the Perseids as a meteor shower is recorded in Chinese chronicles on CE 17 July 36 (*ibid.*). With the passage of time, the recorded activity shifted to later dates. In CE 1581, for instance, the activity occurred on 26 July Julian (*ibid.*). Recall that the Gregorian Calendar was introduced in 1582 to reform the Julian Calendar by neutralizing the accumulated error of thirteen centuries of time-keeping, which amounted to ten days. The reformed calendar began when the last day of the Julian Calendar Thursday, 4 October 1582 was followed by the first Gregorian day Friday, 15 October 1582, without affecting the cycle of weekdays. With that, the date of the maximum activity of the Perseids moved into early August. Thus, the association of the Perseids with the St. Lawrence's Feast can be only as old as a few centuries. Currently, the epoch of the peak activity is centred around 12–13 August. The radiant lies in Perseus, at Right Ascension (RA): 46.8° and Declination (Dec.): +58°, just below the *W* of Cassiopeia; the Zenith Hourly Rates (ZHR) is ~100.

The velocity with which a meteoroid enters the Earth's atmosphere can range from the escape velocity (11.18 km/sec) to ~70 km/sec (Hughes and Williams 2000). As for the Leonids, their motion is retrograde and the Earth enters the stream nearly head-on so that their geocentric speeds are high, like 70.8 km/sec, about 250 times faster than the speed of sound in the upper atmosphere. The Leonid meteor storms are famous for being among the most spectacular fireworks in the night sky (Newton 1864a).

The great Leonid meteor storm seen in the year 1833 on 12–13 November has become a legend for its spectacular display. The peak ZHR was estimated at 60,000 / hr (Brown, 1999: 289). The storm evoked great public interest. Storms matching this strength occurred in 1866 and 1867. Volume 27 (1867) of the *Monthly Notices of the Royal Astronomical Society* (*MNRAS*) reveals this excitement through the numerous reports of the observers of the November 1866 storm, some of which were contributed by well-known astronomers and prominent observatories in England.

According to Newton (1864a), the Leonids can be traced back to the morning of CE 13 October 902 (see Dick, 1998: Table 1). But the 33-year Leonid Meteor Storms have also disappointed, when astronomers expected much higher ZHRs. This happened in 1899 and 1933, peak years in the cycle, but the shower made a spectacular show in 1966, on 17 November (Figure 6). Yet it once again failed to meet expectations in 1998 and 1999.

The parent body of the Leonids is Comet 55P/Tempel–Tuttle (orbital period = 33.2226 yrs). The comet was discovered independently on 19 December 1865 and 6 January 1866 by E.W. Liebrecht Tempel, and by H.P. Tuttle, respectively (Kronk, 2003: 343). The perihelion of the orbit is at 0.976575 au and the orbital inclination (i = 162.49°) is such that the comet intercepts Earth's orbit almost exactly. The comet thus comes quite close to the Earth every few visits. As a consequence, the

Figure 6: The Leonids in 1966 (http://starchild.gsfc.nasa.gov/docs/StarChild/solar_system_level2/1966_leonids.html; accessed 1 .2April 2022 (image: NASA).

the streams left behind are still dense when they encounter the Earth's atmosphere. The shower is known for its 33.25 years peaks. The Leonid radiant is at RA 154°, Dec. +21.6° and the ZHR (for regular showers only) is ~15.

In late April, the Lyrids are the major meteor shower today. The radiant lies in the direction of the constellation Lyra, near the bright star Vega. Johann Galle (1812–1910) mathematically showed in 1867 that these were associated with the periodic comet Thatcher (C/1861 G1; orbital period = 415 yrs) and traced them as far back in Chinese records as 16 March 687 BCE (Galle, 1867). The Lyrids might be as old as 1.5 million years (Arter and Williams, 1997). The Lyrids are low-activity showers in most years (visual ZHR ~10–20) but in some year show up with much enhanced activity, producing the so-called 'Lyrid fireballs'—which are consistently brighter than Venus. Some can be so bright as to cast shadows for a fraction of a second and leave a smoky train behind that persists for minutes after the transient event (The Lyrid meteor showers, https://www.spaceweather.com/; accessed 3 June 2011). The meteor activity period is 14–26 April, peaking around 21–22 April, and observable from midnight to predawn. The radiant is at RA 272°, Dec. +33.3°, and the ZHR is ~18.

The Eta Aquarids and Orionids, with radiants in the directions of Aquarius and Orion respectively, are both associated with the Comet 1P/Halley.

The Geminids were discovered first by Robert Greg in December 1861 (Jenniskens, 2006). They peak on 14 December with a ZHR ~150, and last about a day; the radiant is at RA 113.2°, Dec. +32.5°, close to Castor. There is some activity that is spread over 22 days (Jenniskens, 2006). The parent body of the Geminids is not a comet but an Apollo asteroid and defunct comet 3200 Phaethon (1983 TB), about 5.1 km in size that was discovered by Simon Green and John K. Davies on 11 October 1983 in the IRAS (Infrared Astronomy Satellite) data on moving objects. Its period is 1.436 yrs and aphelion at 2.403 au (JPL, 2022). This means that it enters the asteroid belt between 2.2 and 3.2 au. Phaethon was the first asteroid to be connected to a meteor stream. However, it does not develop cometary features while nearing the Sun. With a perihelion of 0.14 au, Phaethon crosses the orbits of Mars, Earth, Venus and Mercury, at which point its temperature reaches about 1025 K. A notable finding about the Geminids is that their activity (ZHR) since discovery has been gradually increasing, as a result of the change in Phaethon's orbit due to planetary perturbations (*ibid.*).

A large number of meteoroid streams (showers) are known today. As of June 2022, the International Astronomical Union Meteor Data Center (IAU MDC) Meteor Showers Database had 966 of them, of which 112 are formally designated (IAU MDC, 2022; see also Jopek et al., 2021). This paper has used the radiant positions (J2000) from the pages of the IAU Meteor Data Center (MDC).

For updates on the meteor showers, one should consult Jenniskens (2006) and Kronk (2014), the webpages of IAU Meteor Data Center (IAU MDC, 2022), the American Meteor Society, and the International Meteor Organization.

4 METEORS, METEOR SHOWERS AND METEORITES IN INDIAN CLASSICS

Down the ages, eclipses, comets, fireballs and earthquakes all evoked fear in many cultures. Arab legends refer to the shooting stars as firebrands that the angels hurled at the *Jinns* who were ever eager to peep into heaven.

The *Ṛgveda*, the oldest Indian text, a work in progress through 1500 BCE–900 BCE (Kochhar, 2000), is a collection of 1028 hymns, composed by a number of priest families. The hymns include invocation of gods, ritual hymns and descriptions of battles, etc. In the *Ṛgveda* and some later compositions like the *Atharvaveda*, the *Parāsara Samhitā* (*samhitā* means a collection of hymns), the *Mahābhārata* and the *Purāṇas*, etc., the word *ketu* appears and is used in the sense of an *utpāta*, meaning a serendipitous/unusual phenomenon such as a comet or a meteor.

The first major work that delved in some depth into the *ketus* was the *Bṛhat Samhitā*, an encyclopaedic tract on astrology and other subjects compiled in CE 505/550 by Varāhamihira (CE 485–587). The celestial *ketus*, he says, are seen amid the stars in the firmament, whereas the atmospheric ones are those seen on flag staffs, weapons, trees and mansions, etc. (see Bhat, 1986).

The first definite word on meteor showers also comes from Varāhamihira, in the chapter on the signs of meteors (Bhat, 1986: Chapter XXXIII). Varāhamihira says that there are five categories of meteors, *Dhiṣṇyā* (ignescent balls), *Ulkā* (meteors), *Ashani* (thunderbolts), *Vidyuta* (lightening) and *Tārā* (shooting stars), and he gives a brief description of each. Furthermore, if they fall in clusters from the middle of the sky, they portend the death of the ruler and destruction of the country (Bhat, 1986: XXXIII: 11).

Vallālasena's *Adbhutasāgara* (CE 1168), which is patterned after the *Bṛhat Samhitā*, repeats Varāhamihira, but also quotes from the *Droṇaparva*, *Mausalaparva* and *Ādiparva* of *Mahābhārata* about thousands of *ulkās* spreading fire falling to the ground (Jha, 2006: 542, 545).

Historical references to meteors, meteor showers and meteorites begin to appear in Indian works from the middle of the fifteenth century, namely in the *Rājataranginī* (*The River of Kings*) and Mughal chronicles. Meteor showers are a visual delight, and are seldom accompanied by noise that will scare people. However, in our quest for meteor showers in Indian writings, we have come across only three references so far. The subsequent references begin from the nineteenth century only. This should not come as a surprise, since this is more or less true of European sources also, where only a handful of records were found prior to recent centuries. Figure 7 shows a map of India, where locations that feature in this study are marked.

The oldest known 'Fall and Find' case is the reference by Jahāngīr (1569–1627), the Fourth Mughal Emperor, who wrote in his journal *Tūzūk-i Jahangīrī* about the fall of an iron meteorite in a village in Jalandhar district in the Punjab on 30 *Farwardīn*, in his 16th regnal year (Rogers and Beveridge, 1914: 204–205). This is equivalent to 19 April 1621 in the Gregorian Calendar. The iron that was extracted from the site weighed 1.93 kg (Blochmann, 1869: 167–168). The meteorite broke under the hammer, and the sword-maker crafted two sword blades, a dagger and a knife for the Emperor. To make these weapons he used three parts of iron from the meteorite and one part terrestrial iron. One of these weapons, the coveted dagger, is now in the Smithsonian Institution's Freer and Sackler Galleries in Washington, D.C. in the United States (Sabri, 2012).

There are many 'Fall and Find' reports from the nineteenth century to which we shall return in a subsequent paper.

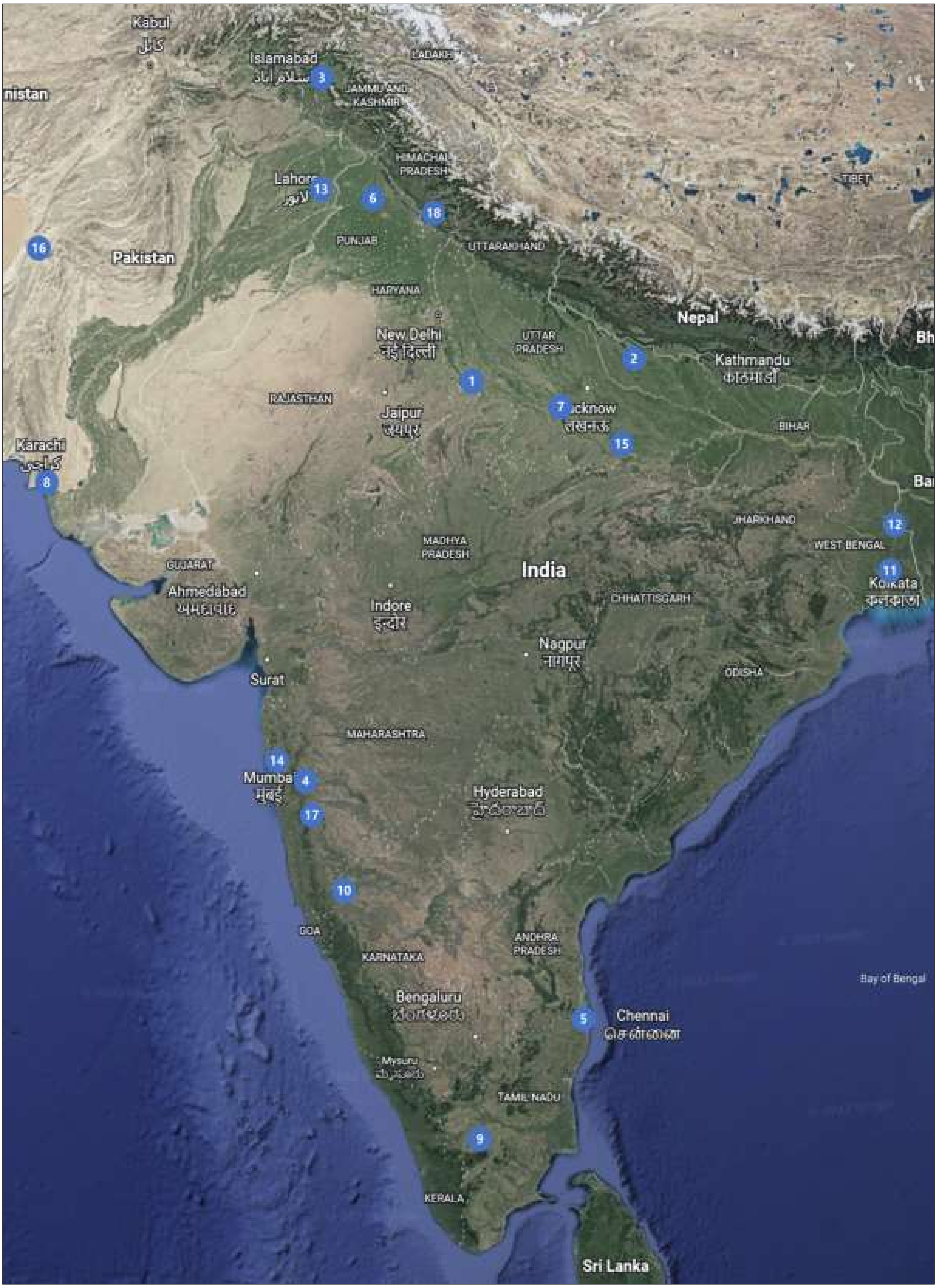


Figure 7: Locations in India and Pakistan mentioned in the text: 1 = Agra (Uttar Pradesh), 2 = Balrampur (Uttar Pradesh), 3 = Baramulla (Jammu & Kashmir), 4 = Bhor Ghat (Maharashtra), 5 = Chennai (Tamil Nadu), 6 = Jalandhar (Punjab), 7 = Kanpur (Uttar Pradesh), 8 = Karachi (Pakistan), 9 = Kodaikanal (Tamil Nadu), 10 = Kolhapur (Maharashtra), 11 = Kolkata (West Bengal), 12 = Krishnanagar (West Bengal), 13 = Lahore (Pakistan), 14 = Mumbai (Maharashtra), 15 = Prayagraj (Uttar Pradesh), 16 = Quetta (Pakistan), 17 = Raigad Fort (Maharashtra), 18 = Shimla (Himachal Pradesh) (made from Google My Maps; map modifications: R.C. Kapoor).

.1 Reference to a Meteor Shower in the *Rājataranginī*: The Perseids or the Leonids?

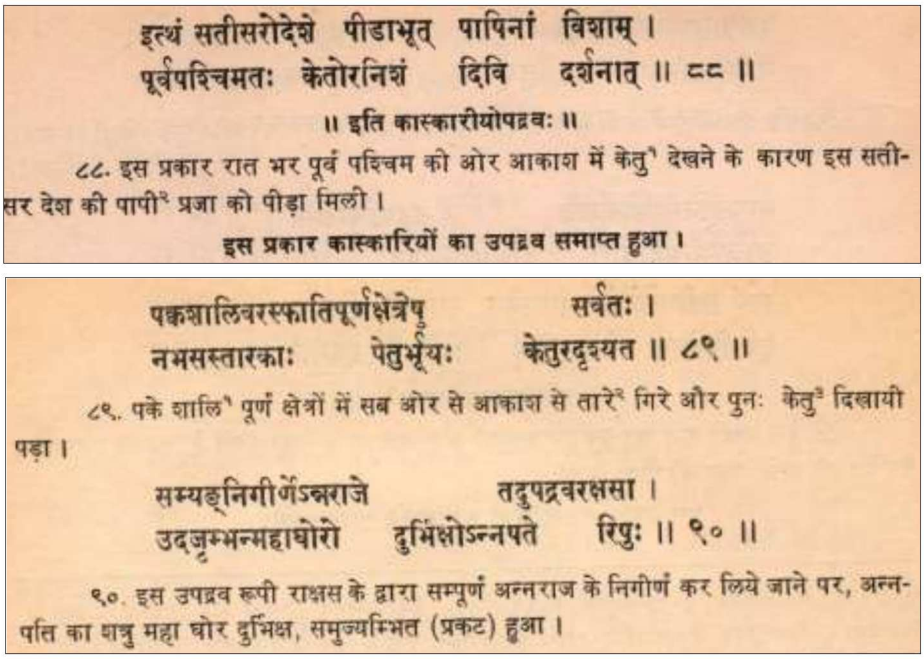
The great Sanskrit work, the *Rājataranginī* (*The River of Kings*) by Pandit Kalhaṇa, written during the years CE 1148–1150, chronicles the rulers of Kashmir from the earliest times, i.e. King Gonanda I, who is regarded as a contemporary of King Yudhishthira of the *Mahābhārata*, until the reign of King Jayasimha (1127–1150/59?). Centuries later it was continued by Jonarāja (CE ca. 1389–1459). His disciple, Srīvara, then covered the period CE 1459–1486, and Prāgyabhatta and his disciple, Shuka, expanded the coverage until CE 1586 when the Mughal Emperor Jalāl-ud-dīn Akbar (CE 1542–1605) added Kashmir to his Empire. The dates in the *Rājataranginī* texts are in the *Saptarshi* or *Laukika Kāla*. The years are *Chaitrādi*, and the months mostly *Pūrṇimānta*. This era begins from March/April in the year 3076 BCE (Kielhorn 1891: 149–154). The *Pūrnimānta* is the Full Moon ending month that starts one fortnight earlier than the *Amānta*, the New Moon ending month.

The *Rājataranginīs* contains references to three comets, which Kak (2003) identifies as C/1468 S1, Halley's Comet (1P/1531 P1) and C/1533 M1. All three have already been researched (see Kapoor, 2018), but the last of these comets is connected with a meteor shower and therefore concerns us here.

Shuka's *Rājataranginī* (Singh, 1976: 168) describes the turbulent times when a Kāskar army attacked Kashmir in late CE 1532 and created havoc during the months of January through March 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 when the latter departed Kashmir and when a truce was negotiated with Mughal invaders under Mirza Haidar. This happened towards the end of the month of Shawwāl 939 AH (i.e. CE 24 May 1533). Then, as if to torment the people, a comet appeared in the sky, and was visible all night (Singh, 1976: 177–178, stanzas 88–90; see Figure 8). Shuka also speaks about a great famine that year:

> … calamity befell the sinful people in the Satīsara country, and a comet was seen continually in the sky … Thus the ravages of the Kāskārians took place. Stars fell from the sky on the fields where the full harvest of rice was ripening, and a comet became again visible … this calamity devoured the grains; and there happened a great famine, the destroyer of food. (Dutt, 1986: 373).

The comet was C/1533 M1, which was first seen in Korea on the morning of 27 June. It had already passed perihelion on 15.417 June UT. The Dutch astronomer Gemma Frisius (1508–1555) noted that the comet became circumpolar on 9 July. It was later seen in the evening on 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 brightened up to a visual brightness of 0 mag (Kronk, 1999). Seen from Europe, its head shone brighter than Jupiter on 7 July,



इत्थं सतीसरोदेशे पीडाभूत् पापिनां विशाम् ।
पूर्वपश्चिमतः केतोरनिशं दिवि दर्शनात् ॥ ८८ ॥

॥ इति कास्कारीयोपद्रवः ॥

८८. इस प्रकार रात भर पूर्व पश्चिम की ओर आकाश में केतु[1] देखने के कारण इस सती-सर देश की पापी[2] प्रजा को पीड़ा मिली ।

इस प्रकार कास्कारियों का उपद्रव समाप्त हुआ ।

पक्वशालिवरस्फातिपूर्णक्षेत्रेषु सर्वतः ।
नभसस्तारकाः पेतुर्भूयः केतुरदृश्यत ॥ ८९ ॥

८९. पके शालि[1] पूर्ण क्षेत्रों में सब ओर से आकाश से तारे[2] गिरे और पुनः केतु[3] दिखायी पड़ा ।

सम्यङ्निगीर्णेऽन्नराजे तदुपद्रवरक्षसा ।
उदजृम्भन्महाघोरो दुर्भिक्षोऽन्नपते रिपुः ॥ ९० ॥

९०. इस उपद्रव रूपी राक्षस के द्वारा सम्पूर्ण अन्नराज के निगीर्ण कर लिये जाने पर, अन्न-पति का शत्रु महा घोर दुर्भिक्ष, समुज्जृम्भित (प्रकट) हुआ ।

Figure 8: Screenshots from Singh (1976: 177 and 178) showing stanzas 88 to 90. For details, see the text.

while on 21 July the comet displayed a 15° tail (Vsekhsvyatskii, 1964: 104–105). It passed closest to the Earth on 2 August, at a distance of 0.4211 au, and was last seen on 16.5 September (Kronk, 1999: 303).

The observation that stars fell from the sky is interesting. The reference suggests a meteor shower (or possibly a meteor storm). But which shower: the Perseids or the Leonids? As we have seen, the Perseids are associated with Comet 109P/Swift–Tuttle (Schiaparelli, 1867) and are observed between 17 July and 24 August. The shower currently peaks during the period 9–14 August, and has shown little variation in the ZHR over time. As a result of the precession of the equinox, the peak activity of the shower has shifted from around 17 July in CE 36 to 12.3 August in 1980. There are no records for the year 1533, but there are records of the showers in 1451 and 1581, on 27 July and 26 July (Julian Calendar), respectively. There are different estimates of the comet's tail around these dates in 1533: Gasser reported a tail of 5°, whereas the Chinese noted a 10° tail (Kronk, 1999: 303). The *Rājataranginī* gives no timeline here but if the meteor shower mentioned by Shuka was the Perseids, then this would date to around the peak of the shower activity, viz., 27 July 1533. Full Moon was on 4 August, which suggests that the best views of the meteor shower and the comet occurred a little earlier, not long before the comet was closest to the Earth (which occurred on 2 August). The comet remained a morning object until 5 August.

The other possibility is the Leonids. Referring to Dick (1998: 11–14), Table 1 reports that a meteor storm was visible during 24–26 October 1533, which was seen from Europe, China, Korea and Japan (c.f. Newton, 1864a: 384; Yeomans, 1981). Nearer home, rice is traditionally grown in a major part of India. As the crop is water intensive, the main season for its cultivation is *kharif*, and the sowing is done during the months of June or July and the crop is harvested in November–December. In the *Rājataranginī*, Suka speaks of *pakva shāli*, which refers to the ripe crop of rice (stanza 89 in Figure 8). This stanza implies that the crop was ready to be harvested, so the meteor shower would have to be the Leonids. But what was the comet—which was reportedly 'seen again'? It could not have been C/1533 M1 which was last seen in September, and no other naked eye comet has been reported for CE 1533. Yet it was this mysterious comet that reputedly affected the rice crop and caused a great famine. Perhaps there is a conflation of chronologies here, and it was the impact of Comet C/1533 at and soon after the planting of the rice crop that was seen to act negatively on the harvest, thereby causing the famine. This interpretation allows us to associate both the October 1533 meteor storm and Comet C/1533 M1 with Shuka's *Rājataranginī* narrative.

We see that Shuka's narrative contains the first datable record of a meteor shower mentioned in an Indian chronicle, even if the exact time of the year during CE 1533 is uncertain. The Perseids rather than the Leonids more comfortably fit the accumulated data. Note that we have arbitrarily chosen Baramulla, in the Union Territory of Jammu and Kashmir, to represent this narrative in Figure 7, given that it was the gateway to the Kashmir Valley at that time.

4.2 Chronicling Comets, Eclipses and Falling Stars

Unexpected phenomena like eclipses, comets, meteors and earthquakes were regarded ill omens for rulers and emperors and so were routinely monitored by historians and chroniclers. Recording such events in the political histories was a well-established tradition in the empires of the Middle East. The tradition of recording 'politically significant' cosmic events continued uninterrupted for a long time, and, not surprisingly, included India.

North India was dominated by the Mughal Empire during the sixteenth and seventeenth centuries. Its chronicles mention a number of solar and lunar eclipses, comets and fireballs. The rulers took these occurrences seriously and sought remedial measures. Shaikh Abū'l Faḍl (1551–1602) came to the court of the Mughal Emperor Jalāl ud-Din Muḥammad Akbar (1542–1605; ruled 1556–1605) in CE 1575. He was a great scholar, having trained in the traditional as well as the natural sciences. He wrote the *Akbarnāmā*, the official biographical account of Akbar (Figure 9). It is an encyclopaedic work, written in Persian, where Abū'l Faḍl presents a worldview that is amazingly scientific.

The *Akbarnāmā* makes a specific reference to the occurrence of a large number of shooting stars on a single night. This happened in the thirty-seventh year of emperor's reign (1000 AH), soon after Mirzā Jānī Beg, the ruler of Thattā, Sind, had lost in the battle to the Mughal army and surrendered Siwistān (now Sehwān) in order to make peace with Akbar. The historic city is home to the shrine of the thirteenth century Sufi saint Lāl Shāhbāz Qalandar. It was while writing about the post-treaty proceedings that Abū'l Faḍl mentioned

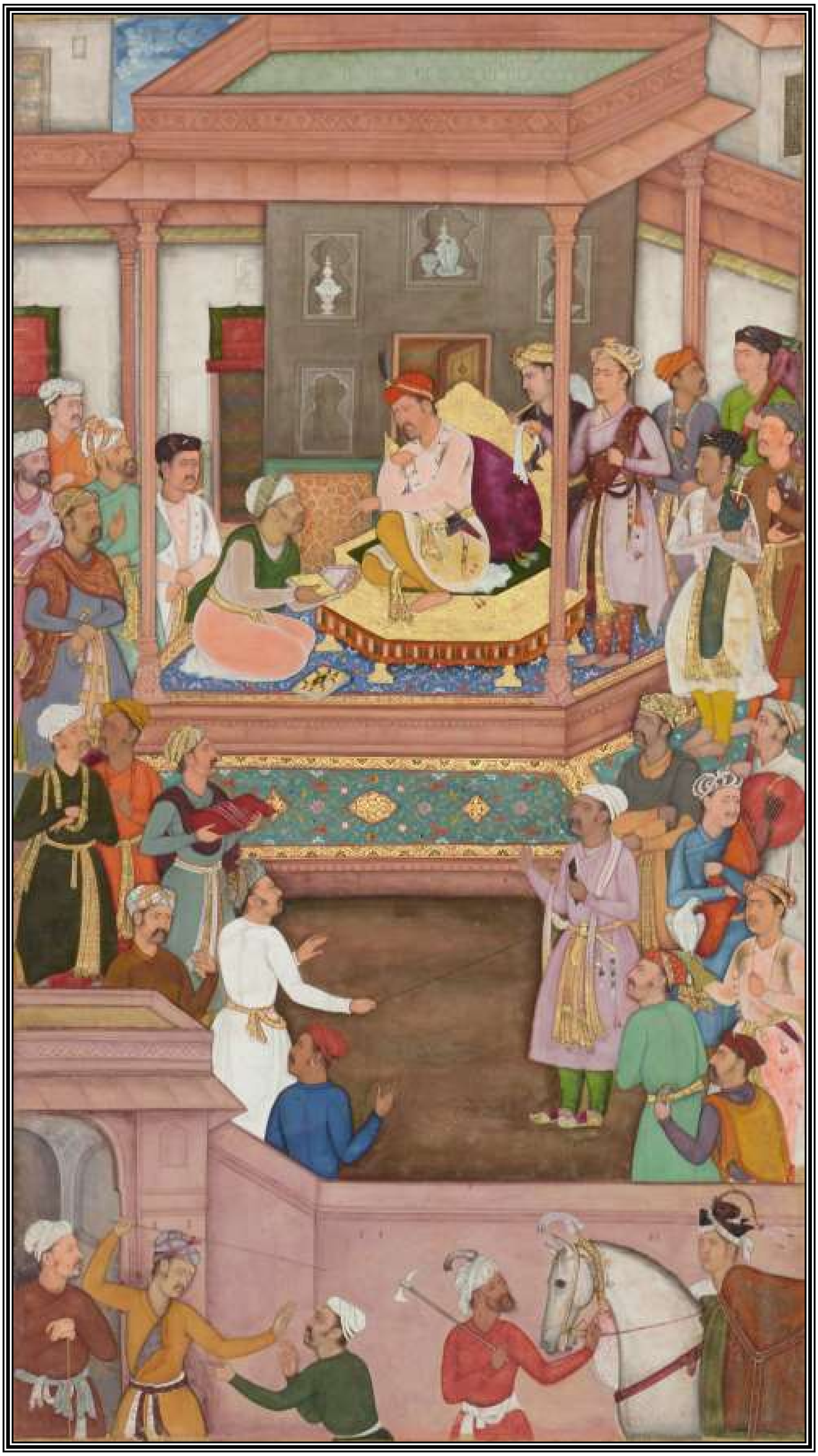


Figure 9: A Mughal miniature showing Abū'l Faḍl presenting the *Akbarnāmā* to Emperor Akbar; painted by Govardhan (fl. 1596–1640) between 1603 and 1605 (Wikimedia Commons).

the meteors:

> On 22 Tīr, Prince Sultān Daniel [Dāniyāl] took leave in order to capture Qandahār. As the guardians of that country were not equal in strength to the Mirzās, this jewel of fortune (Daniel) was sent there. He crossed the Rāvī, and alighted in the garden of Rām Dās. On 24th (Tīr), 4th July 1592, H.M. [Akbar] set off to Kashmīr, and his first stage was this same garden. On the 27th, 300 little stars [*sitāracha*] fell from west to east. The Indian astronomers represented that if the first stage exhibited such an appearance they should return and set out again at a chosen hour. The Shāh and the Shāhzādā were obliged to go back. (Beveridge 1897–1939(III): 942).

The converted date above is as in Beveridge's translation. The "garden of Rām Dās" is not identifiable as there is no place with this name near the river in Lahore today. Possibly, a certain garden had come to be known after Guru Rām Dās (1534–1581), the 4th Sikh guru who had founded the holy city of Amritsar in 1577. He was born in Chuna Mandi in Lahore, a few kilometres from the eastern bank of Rāvī and has a Sikh shrine "Gurudwārā Janam Asthan Guru Rām Dās" built at the location believed to be his birth place. Recall that the capital of the Mughal Empire had moved to Lahore from Fatehpur Sikri near Agra. The latter had served as the capital of the Empire from its founding in 1570 until 1585 (Majumdar, 2007a: 125). Subsequently, it moved back to Agra in 1599, and Akbar ruled from this city until his death on 17 October 1605 (Julian Calendar, or 27 October in the Gregorian Calendar).

The reference in the *Akbarnāmā* to the fall of "300 little stars" is about a meteor shower. The only other detail is the date of the event. Since it was seen in the month of July, one might think of the Perseids, which then occurred in late July. However, the date of the Lahore event, 27th *Tīr*, corresponds to 8 July 1592 in the Julian Calendar (or 18 July in the Gregorian Calendar). That means the observation was made on the evening of 7–8 July. This differs from the peak of the Perseids by about 19 days. Hughes and Emerson (1982: 40) give the dates of recorded Perseids activity from 36 CE until 1980: in 1581 the Perseids peaked on 26 July (Julian Calendar) and in 1590 on 6 August (Gregorian Calendar). It follows that in 1592 the peak occurred on the night of 5–6 August.

In Indian historical accounts, this is the second record of a meteor shower.

In 1922–1923, interesting correspondence appeared in the pages of *Nature* about the meteors referred to in the *Akbarnāmā*. Beveridge (1922: 667) stated that it is not clear from the Persian text if it was during the day or at night, "… but presumably it was the night or at least the evening, for the meteors would not be visible during the day." He suggested that Abū'l Fazl's date "27th day of Tīr O.S." might correspond to about 28 July 1592, and thought that the shower was the Perseids. He reasoned that this phenomenon was not seen in Europe because it was possibly daytime, or the nights were foggy. He surmised that William Shakespeare (1564–1616) who had written "… about the close of the sixteenth century of certain stars shooting madly from their spheres …" may have learnt about this celestial display from sailors and other travellers from the East.[3]

Responding to this, J.K. Fotheringham (1923: 774–775) from the University Observatory at Oxford observed:

> The date, Tīr 27, belongs to the Tārīkh-i Ilāhi, or Divine Era, which was used by Abū'l Fazl, and must not be confounded with other calendars in which the same month names occur.
>
> In a study assisted by Mr. Beveridge's courtesy I have examined a large number of dates belonging to this era, and I find that each year was made to begin at the sunset following the vernal equinox, and, so far as the dates can be tested by the days of the week or by an astronomical phenomenon, each month would appear to have been made to begin at the sunset following the entrance of the sun into a sign of the zodiac. There is one instance, however, where a month is made to begin one day earlier than it should according to this rule. According to this rule Tīr 27 should begin at the twenty-seventh sunset after the summer solstice, which in the year 1592 would be on July 7 of the Julian calendar or July 17 of the Gregorian calendar, and I infer that the meteors were observed on the night of July 17-18 of the Gregorian calendar. There is no reason to suspect an error of more than one day in this date. In his translation of Abū'l Fazl's Akbarnāmā Mr. Beveridge identified Tīr 24 of that year with July 4 of the Julian calendar, and I take it that July 28 in his letter to NATURE was a *lapsus calami*.

Fotheringham looked into the peak dates of the Perseids and found that they had not changed over the course of the last millennium, whereas the shower in 1592 fell nineteen days ahead. He concluded that "… this raises a doubt whether it was really a Perseid shower at all or some otherwise unknown shower ..." (Fotheringham, 1923: 775).

William Denning (1848–1931) then made

the following observations:

> WITH reference to Dr. Fotheringham's interesting comments in NATURE, June 9, p. 774, on the probable shower of Perseids in 1592, I thought it best to accept the date kindly sent to me by Mr. Beveridge, as it fell near the time when a shower might be expected to occur. However, the shower of 1592 appears to have been 19 days earlier than the correct time, and this (with another reason stated later) at once throws doubts on the identity of the display with the true Perseids. (Denning, 1923: 848).

To this, Beveridge (1923: 57) responded offering an alternate meaning to a Persian word *khāwar* in the original to also mean east, "… and so it may be that the passage in the Akbarnama means that the meteors were travelling from east to west and not from west to east." Denning (1923) stated that the apparent motions of the meteors moving west to east must have been slow. The Perseids move nearly east to west and are a swift class, at a velocity of 61 kilometres per second. He added that there are many rich showers of non-Perseids and suggested three possible showers, with positions at 303°, –9° near Alpha Capricorni (25 July–6 August), 339°, –11° in Aquarius (26 July–2 August) and 291°, +60° in Draco (21–25 August), respectively. Denning described these as a strong shower, rich display and nice shower, respectively.

Looking up the IAU MDC (2022) and Kronk (2014), the showers that correspond to Denning's positions would be the Alpha Capricornids (IAU #00001 CAP; ZHR ~6; peak: 31 July), the Southern Delta Aquariids (#00005 SDA; ZHR ~18; peak: 29–30 July) and the July Gamma Draconids (#00184 GDR; ZHR ~1, peak: 28 July), respectively. Their ZHRs are very low. Furthermore, the peaks differ from the July 1592 event by ~12 days. In the present context, any of these showers could answer for the event since the corresponding constellations rise one after the other late in the evening during the latter half of July. However, given the lack of additional details, the identity of Abū'l Faḍl's July meteor shower remains elusive.

4.3 A Comet and Shooting Stars in the Life of Chhatrapati Shivājī Mahārāj

Chhatrapati Shivājī Mahārāj (1630–1680) was the founder of the Marātha Empire. After he died, his biography was written in Marāthi in 1694 by Krishṇājī Anant Sabhāsad, as told by Mahārāj's second son Srimanta Rājārām Mahārāj (1670–1700) (Sarkar, 1920: 6). Sabhāsad titled a particular passage "Naisargika utpāta" ("Natural calamity"), which reads:

> The Mahārāj passed away. That day the Earth trembled. There arose a comet in the sky.[4] There were ulkāpāta (shooting stars) in the sky. During the night a pair of rainbows appeared. Digdāha (the fiery glow at the horizon) was seen in the eight directions. (Sabhasad, 1987: 99; my English translation).

Horoscopes of Chhatrapati Shivājī Mahārāj (Apte et al., 2003) reveal that he was born on 1 March 1630 (Gregorian), while the solar eclipse of 30 March (Gregorian)[5] is reported to have preceded his demise by a fortnight, which we therefore can date to 13 April 1680 (Gregorian). Although there was no comet visible at the time of his death, Sabhāsad's passage can only refer to the Great Comet of 1680 (C/1680 V1), which was the sole comet recorded in 1680. It was the first comet to be discovered telescopically, on 14 November, by Gottfried Kirch from Coburg in Germany, and at the time it had no tail. It first became a naked eye object a few days later, on the morning of 19.8 November in the Philippines, and soon after was sighted in other countries as well (including India). The Chinese first saw it on 22 November, when it displayed a 1° tail. On 27 November it was seen in Rome, and its tail had grown rapidly and was 15° long (Kronk, 1999). On the basis of this cometary identification, the meteor shower referred to by Sabhāsad can only be the Leonids.

The annual activity of the Leonids meteor shower currently peaks around 17/18 November, but the date of the peak is shifting. Brown (1999: 289: Table 1) provides details of Leonid showers observed between 1799 and 1999, where a shift ~2.5 days in the epoch of peak activity every hundred years can be noticed. At the end of each cycle the Leonids occur later and later since the node of the stream is prograding along the ecliptic plane. Extrapolating to the late seventeenth century, the Leonids should have been peaking around 9 November. Therefore, that must be the date for the *Ulkāpāta* (shooting stars) described by Sabhāsad, whereas Comet C/1680 V1 was probably first seen around 22 November when it had developed a noticeable tail. This would also rank as an independent Indian discovery.

Sabhāsad's account thus ranks as the third record of a meteor shower recorded in the classical Indian literature. And, although the Great Comet of 1680 was observed from many parts of the world (see Kronk 1999), nowhere else is there a record of a meteor shower witnessed just a few days before the appearance of the comet.

Finally, although the Indian poetic and the historical references correlate, we cannot eliminate the possibility that Sabhāsad's reference to the meteor shower contains some poetic license in order to add effect to the authors' description of the calamitous conditions in the country at the time, and the death of a great king. While eclipses and comets have been used in history to heighten impact related to prominent figures, the use of a meteor shower in this way is rarely heard of. For example, Chasles (1841) documents almost ninety meteor showers recorded between CE 538 and 1223, but he notes that only two of these were associated with the deaths of notable people.

5 FALLING STARS: THE NINETEENTH CENTURY ACCOUNTS FROM INDIA

Nineteenth century India witnessed great political upheaval but also the blossoming of the Renaissance. Through the efforts of several prominent people it saw the publication of European science in various Indian languages. English education had already struck root, and so had the shaping of school curricula and the publication of low-priced school books in English and Indian languages (see Majumdar, 2007b: Chapter II).

A great step was taken in astronomy in India when towards the end of the eighteenth century a modern astronomical observatory was established in Madras. It was a private one, established in 1786 by William Petrie (1747–1816), an officer with the East India Company (EIC). That was the beginning of modern observational astronomy in India. The Company took over the Observatory in 1789, and in 1792 it was moved to new premises at Nungambakkam. In the following decades, other astronomical observatories were founded in different parts of India, at Bombay, Calcutta, Trivandrum, Lucknow, Poona and Vishakhapatnam (for details, see Kochhar and Orchiston 2017).

On the popular front, a number of reports about 'irregular celestial phenomena' (eclipses, comets, meteors, meteorites, meteor showers, as well as earthquakes) were published in newspapers, magazines and scholarly journals. These accounts came largely from British engineers and educationists, and included insightful information about meteoric events, which shed light on their likely nature, or how they were perceived.

5.1 Dr Buist and "On Meteors in India"

Many observations of bright meteors and the fall of meteorites made in different parts of India were published in the *Journal and Proceedings of the Asiatic Society of Bengal*, *MNRAS* and the *Annual Reports of the British Association for the Advancement of Science* (BAAS).

Accounts of such events were collated and communicated from Bombay by Professor Arthur Bedford Orlebar (1810–1866) and Dr George Buist (1805–1860; Figure 10) to the BAAS. These were the formative years of the subject of meteor astronomy and the two gentlemen had possibly sensed the need for deeper studies of these phenomena. This

Figure 10: Dr George Buist, photographed in 1845; https://www.npg.org.uk/collections/search/portrait/mw00897/George-Buist (image: Wikimedia Commons).

must be seen in the context of how one communicated with Europe at that time, when fast channels of communication had yet to emerge. Steamships were already operating on several international routes. The first steamship from England to round the Cape of Good Hope and arrive at Indian shores was S.S. *Enterprise*, which reached Calcutta in December 1825. The voyage took 13 weeks, instead of the promised 10 weeks, but made history. In 1837, with the initiative of the EIC, a connection also began via the Middle East, bringing down the travel time considerably (Marshall, 1997). That helped people in India get up-to-date information on scientific progress and opinion, and send their own news back to 'Mother England'. The opening of the Suez Canal in 1869 shortened the travel time even further. Communication using the electric telegraph was introduced to India in 1850. In the following year the EIC began to use it and, within a few years, the telegraph had connected many far-off places in India. Telegraph lines from London to India had been laid via the Caucasus and connected in January 1870, first to Calcutta and then to Bombay and Madras (see Karbelashvili, 1991).

Arthur Orlebar was Professor of Natural History at Elphinstone College that had been founded in Bombay in 1835. Orlebar and Buist were both associated with Colaba Observatory, which the EIC established in Bombay in 1826 at the southern end of the island of Upper Colaba for the purpose of meteorological and astronomical observations and timekeeping (Gawli et al., 2015: 110). There were a few instruments available to Orlebar, and systematic observations in astronomy, meteorology and magnetism commenced in late 1841.

Buist (1849: xli) succeeded Orlebar, and was in charge of the Observatory from January 1842 until March 1845. He was a Scottish journalist and also a science teacher. In 1839, he became Editor of *The Bombay Times* and *Journal of Commerce* and stayed with the paper for 20 years. *The Bombay Times* had its audience in Europe. Together with two other newspapers, these papers merged in 1861 and were named *The Times of India*. Buist was a member of the Bombay Branch of the Royal Asiatic Society and published several scientific papers in the Society's *Journal*. Dr Buist was elected a Fellow of the Royal Society in 1846.

For several years, Buist collated information on meteors and meteorites received from many contacts scattered throughout India, including accounts published in newspapers, and he contributed to the series on observations of meteors published in the Annual Reports of the Meetings of the BAAS. For several years, these records were prepared by the Reverend Baden Powell, Savilian Professor of Geometry at Oxford, until his last in June 1860, and later they were continued by other astronomers. In the BAAS Annual Report for 1851, Powell (1851: 91) tabulated records of meteors seen up to August 1849. The table contained several entries for bright meteors and meteoritic falls observed in India.

In 1850, a remarkable compilation titled "On Meteors in India" was published by Dr Buist. It contained information about the numerous meteors and meteoritic falls reported from different parts of the country during the first half of the nineteenth century. It was published in the *Transactions of the Bombay Geographical Society* (Buist, 1850a). It included detailed accounts of sporadic meteors observed from as early as 1815 until the middle of 1850, and of meteorites found in various places in India. Added to this valuable compilation was the correspondence between Sir John Herschel, Michael Faraday and others about the circumstances of the fall and recovery of certain meteorites and their chemical composition. He also included an illuminating paper by Denison Olmsted, who wrote as follows about the meteor shower of November 1836:

> For six years in succession, there has been observed, on or about 13 November of each year, a remarkable exhibition of shooting stars, which has received the name of the 'Meteoric Shower' … Does not the recurrence of this phenomenon for six successive years, at the same period of the year, plainly show its connection with the progress of the earth in its orbit? (Olmsted, 1836: 386; 392).

Buist's report included also papers that addressed fundamental questions about the motion of the meteors and their height in the atmosphere; the nature of 'periodic meteors' by Wartmann and Quetelet (1837); and chemical analyses of a few meteorites.

5.2 The Earliest Nineteenth Century Shower On Record

The earliest example of the falling stars mentioned in "On Meteors in India" dates to 1832. It was a report from Bulrampore (Balrampur) and Agra, dated 18 November 1832 in the *India Gazette* that spoke of numerous meteors seen on the same night (Buist, 1850a: 199–200):

> Meteors of 13th November 1832, observed at Bulrampore and Agra. – The 'Indian Gazette' contains extracts from two letters, one from Bulrampore, in the Jungle Mehauls, the other from Agra, communicating accounts of a very remarkable atmospherical phenomenon.
>
> Camp Bulrampore, 13th Nov.- During our march this morning, the sky presented a most brilliant spectacle. Innumerable meteors were flying in every direction, and some of them the most beautiful I ever saw. They appeared to burst finer than the finest sky-rockets, leaving a long line of various-coloured light in the heavens behind them, which remained several minutes, and vanished gradually. I never saw anything like it before, and I should think it not a common thing in India; for I have travelled frequently at different hours of the night, and never before witnessed a similar phenomenon."

> Agra, 18th Nov. – Some nights ago, there was a most extraordinary appearance in the heavens. The sky was all one blaze, owing to the number of falling stars.
>
> The same phenomenon was seen, at the same time, at the three presidencies.

The Moon was waning gibbous, and 20 days from New Moon. The event in the above reports was referred to as an 'atmospheric phenomenon'. The observers were not named. No information on the Camp Bulrampore could be found. According to Brown (1999: Table 1), in 1832 the Leonid meteor shower peaked on 13.2 November. Note that, an unusual display of meteors in the early hours of 13 November that year was also witnessed throughout Europe and the Middle East.

5.3 The August Meteors, and the September Epsilon Perseids Over Calcutta

There is a report from Professor James Middleton of the Hindu College[6] of his observations of a meteor event in August that he made from Calcutta and published in the pages of the *Journal of the Asiatic Society of Bengal* (Middleton 1840: 495–496). He had observed the meteors on Saturday 10 August 1839 that he said were commonly called 'aerolites'. He expected that the phenomenon would also have been seen from other locations in India and if these observations could be pooled together, that would have scientific value to understand these mysterious bodies. Middleton gave a good detail of the curved paths taken by the aerolites, their brilliance (one of which was as bright as Venus), their direction, the changing elevation and their speed of motion. His general impression was that:

> First, they all appeared at points in or near the prime vertical. Secondly, their common vanishing limit was about 30° above the horizon. Thirdly, their path appeared to be parallel and lying from north to south. Fourthly, their velocities appeared to be equal.
>
> I may mention, in conclusion, that no sound was observable either on their appearance, progress, or disappearance.

That was on a dark night, just past New Moon. Middleton's account was about the Perseids, although these had yet to be named as such.

Buist (1850a: 202; c.f. Powell 1851: 121) published another report from Calcutta of a meteoric event witnessed in the early hours of 10 September 1841. It appeared in the *Englishman*[7] of 13 September:

> No. 30. *Meteors of 10th September 1841, observed at Calcutta.* – About two in the morning on Friday last, innumerable meteors of surprising beauty were perceptible in the heavens. Vast myriads of shooting stars were seen darting through the air in S.S.W. direction, leaving a long and brilliant train of light. The whole atmosphere was illuminated, and at one period the light was so great, as to have enabled a person to read the smallest print with the utmost facility. This magnificent spectacle was visible during a period of ten or twelve minutes. – *Englishman*, Sept. 13.

The observer is not named. The date corresponding to the "Friday last" in the above is 10 September, when the Moon was 24 days from New Moon. The direction "S.S.W." suggests that the meteors were shooting from the N.N.E. In that direction, the prominent constellations that happen to be up in the sky at around two in the morning were Cassiopeia, Perseus and Auriga, in order of their rise-times. However, this observation was not of the August Perseids.

Early September is the time of the Alpha Aurigid, the September Epsilon Perseid and the September Lyncid meteor showers (IAU #208 SPE). The Alpha Aurigids is a minor shower, associated with the comet C/1911 N1 (Kiess). It is active between 28 August and 5 September and peaks on 1 September, with a ZHR of ~6. The shower was first noticed in 1935. A spectacular display was witnessed recently, on 1 September 2007.

The September Epsilon Perseids are seen during 5–21 September with peak on 9/10 September. The radiant lies in the direction of the star Epsilon Persei. This, too, is a minor shower, with a ZHR of ~5, although enhanced activity with bright fireballs is sometimes seen, most recently on 9/10 September 2013. This shower was first described by the British meteor authority William Denning in 1878, and was named by him in 1882 (Gajdos et al., 2014). The parent body of the shower is not known but Shrbený and Spurný (2019) suggest that it might be a long-period comet in a retrograde orbit, with a period of a thousand years.

The September Lyncids is a weak shower that peaks around 10/11 September, with a radiant in the constellation of Lynx. However, in September, this constellation rises around four in the morning, and it takes two hours to reach a reasonable altitude above the horizon.

Of the three known early-September meteor showers the most likely shower witnessed in 1841 was the September Epsilon Perseids. In Calcutta on 10 September 1841 at 2 a.m. local time, the star Epsilon Persei was at an altitude of ~53° and an azimuth of ~53° (in the

N-E). *Prima facie*, the meteoric event reported in the *Englishman* should be the September Epsilon Perseids, which were first reported in England and named by William Denning in 1878, 37 years later.

5.4 The November Meteor Showers Over Simla in 1841

Captain J.T. Boileau, F.R.S., R.E. (1805–1886; Cavendish, 1995; Figure 11), was the Superintendent of the Magnetic Observatory in Simla when he reported observations of the periodic meteor shower that was seen on the night of 12/13 November 1841. His report incorporates also the impressions of his assistants:

> The observed recurrence of numerous meteors on the same night, during a series of years, having led to a belief in their periodicity; it has been become a special duty at all the fixed Magnetic Observatories to watch for their appearance, on the dates in question; the nights of the 10th August, and of 12th November, have afforded the most remarkable instances of their recurrence, both as regards their number, and the regularity of the phenomenon. (Boileau, 1841: 964–966).

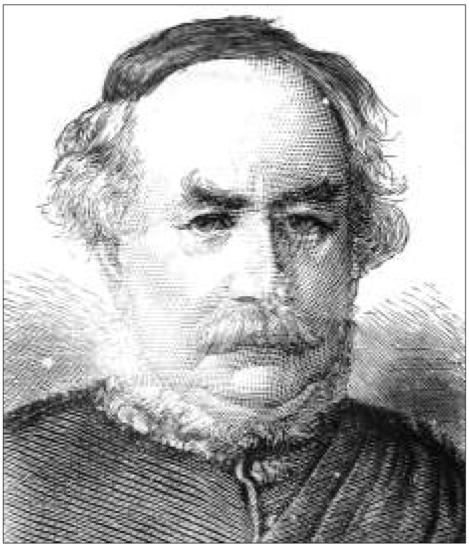


Figure 11: Major-General J.T. Boileau, F.R.S. (after Anonymous, 1886).

This is about the November Leonid meteor shower. While the show commenced before midnight, there were plenty of brilliant meteors to report post-midnight also, until a time close to daybreak. They even noted down the timings, elevations and the direction of movement of the meteors against the background constellations and prominent stars. The night was clear and dark, with no interference from moonlight, it being close to New Moon. Notably, there was only one meteor to report on the evening of the 13th, but none for several nights before the 12th. Boileau (1841: 966) even noticed changes in the readings of the Declination Magnetometer in the course of the phenomena and he made notes.

Born in Calcutta, John Theophilus Boileau (Figure 11) trained under the Irish physicist Humphrey Lloyd at Trinity College, and was the EIC's choice in 1839 to set up a Magnetic Observatory at Simla (now Shimla). Boileau began making magnetic and meteorological observations immediately after his arrival in India in late 1840. He was elected a Fellow of the Royal Society in 1840, and subsequently of the Royal Astronomical Society.

5.5 The Perseids Over Allahabad in 1842

There is a report by Captain Robert Shortrede (1800–1868), 1st Assistant with the Great Trigonometrical Survey of India on meteor activity that occurred on 10 August 1842 and was recorded at Allahabad (Prayagraj). At the outset, Shortrede (1842a: 959–962) made an important point, namely, to compare these observations with corresponding observations to be carried out at Agra. He mentioned that the gentleman who had actually suggested the observations to be undertaken was unable to do so owing to sickness. This "gentleman" is not identified. Shortrede also spoke of the advantage of relatively clear skies in India compared to other parts of the world.

Shortrede says that, through practice, he was confident of being able to quickly make visual estimates of the altitudes and azimuths of the meteors, within acceptable errors of ~5° in altitude and 15° in azimuth. This he facilitated by duly arranging his observing cot East-West in a place open to the sky on which he could lie down in comfort, with a faint oil light on the ground to enable him to read his watch and make quick notes to accompany his meteor timings.

The first thing he noted was the westerly course the meteors took in or near the Zodiac. That is because when he began, the constellation of Perseus was rising in the N-E, and the Moon had set. The observations were made from 11:18 until 14:49 hr (astronomical time), by which time it had clouded over. Shortrede (1842a) prepared a table recording the directions the meteors took with respect to some prominent stars in the night sky. A few of the meteors he noted were quite bright. He made positional references also with respect to Jupiter, which was high up. We find that at 18 UT that night, Jupiter's altitude and azimuth were, respectively, 36° and 209°. Shortrede's

(1842) observations were published in the *Journal of the Asiatic Society of Bengal* and were included in Buist's (1850a: 204) compilation.

Major-General Robert Shortrede was a Fellow of the Royal Astronomical Society. In 1844, he published a very useful book, *Logarithmic Tables to Seven Places of Decimals*, over which he had laboured for nine years. This included logarithmic sines and tangents for every second of a circle, a table of astronomical refractions, etc. In 1845, he published a paper on the attraction of the Himalayas affecting the northern end of the Great Arc (Anonymous, 1869). Interestingly, in 1841, he had stumbled upon a remarkable arrangement of numbers 1 to 16 inscribed in a 4 × 4 square in a temple in a hill fort at Gwalior. The inscription bore the date 1540 VS (CE 1483). Shortrede named it the 'Magic Square'. The numbers in the square had a rhomboid property about which he said:

> … in every way, whether vertically or horizontally, or diagonally, the sum of the numbers is 34 … The whole displays considerable ingenuity, and in connection with the date, may be of use as indicating the former state of arithmetical knowledge. (Shortrede, 1842b: 292–293).

5.6 The Showers of 1843, 1844 and 1849

While reporting on 12 November 1848 about a brilliant meteor leaving a luminous streak over the western skies after six in the evening, the *Benares Recorder* placed on record also the November showers seen on an earlier occasion. It said:

> It is at this particular season that these wonders of nature are most commonly observed. It was on the 13th November 1843, that the unusual showers of meteoric lights were seen here and in every part of the globe. (Anonymous, 1848).

No other details are given. The Moon was up in the sky that night (age from New Moon: 21 days).

Apart from reporting several sporadic meteors seen in different places in the country over past decades, Buist (1850a: 217–221) also referred to the observations of meteor showers made at Colaba Observatory. Specifically, the showers were of November 1843 and 1844–1845. Buist saw meteors numbering from a few to a good many, seen almost every night during the period 8–20 November 1843 and through 2–28 November 1844. He also recorded enhanced meteor activity during 14–16 November 1843, when the Moon was up in the sky, near last quarter. The following year, during 8–21 November 1844, the numbers went up much more. This time, the Moon became an interference for the night of 20/21 November only.

Buist (1850a: 221–222) also tabulated the observations of meteors made in November 1848, August 1849 and November 1849 taken at Sherah Island, Aden. He gave full details of each meteor observed, the direction it took with respect to the prominent stars, the brightness in magnitudes and the timings. However, whether it was Colaba or the Aden observations, Buist did not refer to these events as 'showers', even though it was the August and November meteor showers that he was reporting on. In fact, in a letter to Professor Powell, he exclaimed:

> Bombay, July 22, 1849.
>
> Dear Sir, - I now enclose some notices of those meteors of lesser magnitude and greater frequency noticed at Aden, by Mr. Moyes in 1843, and by my assistants while in charge of the observatory here, in 1843 and 1844 … If meteors fall over the twenty-four hours indiscriminately, the number entering our atmosphere must be immense … Our November meteors cross the sky in all directions: they very much resemble fire-flies, only they are much more swift and rectilineal in their movements. They do not alter either in apparent speed or size as they proceed; they never flame out or appear to burst; they very rarely approach the horizon, and having traversed ten or twenty-degrees of space, become lost in darkness. (Buist, 1850b: 34).

5.7 The Showers of November 1850 and April 1851

In the Proceedings of the 21st Meeting of the BAAS, Buist (1852) provided a detailed report of the meteoric events seen from India during the period June 1850–May 1851, based on data in newspapers and supplied by individuals.

Appendices 16, 23, 24, 25 and 29 in the BAAS Report carried details of the November Meteors where Buist (1852: 45–46) brought to the fore the common interest that the annual November events had generated among people who had developed fond hopes of observing them. In respect of the observations of the "… showers of falling stars …" seen in November 1850, he expressed just that sentiment:

> Most of them appear to have been disappointed in their expectations, – lost their sleep and watched in vain. Sublunary affairs, unsought things, often fall in our way, while we pursue others to no purpose. By chance we found ourselves on the morning of the 14th toiling, not up, we are thankful

> to say, but down the 'many-winding way' of the Bhore Ghaut (the mountain pass betwixt Bombay and Poonah), when we remarked numerous shooting stars, and, recollecting the period of the year, we determined to count them.
>
> In the course of one hour, from 5 to 6 A.M., thirty-eight of these aërolites passed across that part of the sky within the scope of our vision, and one bright comet-like meteor, almost at day-break, was alone worth the devotion of a whole night's watch had we been so philosophically inclined. But as we were walking, and only looking in one direction, it is probable that little more than an eighth of the celestial vault was under observation: it is not unreasonable to suppose that if the whole had been embraced at least 200 of these bodies might have been noticed … The wind was easterly at the time, and appeared to influence these astral travellers, which was generally from east to west.

About the sudden appearance of a bright comet-like meteor, which they saw at about a quarter to six, rushing from N-W to S-E and illuminating the sides and the ravine, Buist gave a vivid description:

> A dazzling nucleus, about twice the apparent diameter of Jupiter when free from refraction, with a tail about 3° in length, and nearly as luminous as the head, was seen sinking behind the crest of the Ghauts on the Khandalla side … and, gradually fading into a pale reddish light, became invisible …

Bhore Ghaut (Bhor Ghat) is a mountain passage on the crest of the Western Ghats in Maharashtra.

In Appendix 23, Buist (1852) produced a report about the striking display of the meteors seen from Mazgaon on Saturday 19 April 1851 at about ten in the evening. The meteors appeared to be shooting from a point about 15° above the N-E horizon. There were about twenty to count in a matter of half an hour or so, darting largely towards south or south-east.

> The largest of them were about the size of Venus at her brightest, and so down to mere speck of light. None of them were observed to explode, but the largest of them left long trains of light behind them.

This account had appeared in the *Bombay Times* of 24 April. Seeing this, a reader sent in his own impressions of the same event that he witnessed in Cawnpore (Kanpur), at around the same time but on Sunday, from eight to ten in the evening. He witnessed three or four meteors flying across, mainly from north towards south. There was another report in the *Bombay Times* of 6 May on the same showers, seen on 19 April from Kolhapore and described as magnificent. It said

> … the entire sky to the north was seen in a perfect blaze with meteors shooting from east to west. The phenomenon lasted about five minutes, when all was again still. (Buist, 1852: 48).

There were reports from Poona about the event seen on Sunday 20 April around 10 pm, with two or three a minute, darting from east to south-west.

In his report to the BAAS, Buist (1852: 51) added that the Mazgaon and Kolhapore observations may in reality have been made on Easter Sunday, 20 April. Importantly, Buist (1852: 50) stated that he did not remember such displays reported from such far-off places in the country, and he even suggested involving soldiers on duty to make observations in the cause of science.

In his contribution to the proceedings of the 22nd meeting of the BAAS, dated 24 July 1852, Buist (1853: 238–239) communicated to Professor Powell the many instances of meteors and fireballs that had been reported in the *Bombay Times*. He said that regretfully there were only a few events to report. He also recalled his report of the

> … extraordinary shower of meteors seen on the 19th March, 1851, at Shekārpoor, Bombay, Kholapoor, and Cawnpoor, over an area of nearly a thousand miles each way.

In the above, the month 'March' should perhaps be April. Here below is what Buist (1853: 226–227) had to add to the accounts of the meteor shower witnessed in India on 19–20 April 1851:

> Meteors. We have been favoured with the following from Madras on the subject of the shower of meteors visible all over India on the 19th or 20th of April. By a blunder of our own we mistook the Bombay date, and made it Saturday the 19th, when it ought to been Sunday the 20th; and on this night accordingly the shower was seen here, at Poona, and at Cawnpore. With all these coincidences we came to the conclusion that our Kolapore [Kolhapur] correspondent, who gave an account of them, had also mistaken the date, and that there had been one shower only. As he makes no sign of recantation, we now come to the conclusion that there were two showers on two successive nights, bearing a very close resemblance to each other. The following description is one of the most copious and clear that we have met with; it is from the pen of one of the oldest and ablest of our observers in India:
>
> On the evening of Saturday the 19th of April, I was sitting in a verandah of the

> Government House at Madras, facing to the eastward, from about ½ past 8 to ½ past 10. From the height of the verandah I could see the sky to about an altitude of 60° or 65°, and about one-fourth of the horizon between north-east and south-east. During the period above stated I counted not less than forty meteors, of different magnitudes and brightness. The flight of the whole was from north and north-east to south and south-west. Some of them commenced their flight at a point of the heavens invisible to my eye, whilst others came into sight whilst on their career, from my left-hand. Some burned out (if I may use the expression) whilst visible, and others disappeared whilst yet burning to my right-hand. I heard no explosions, though some of the largest left a bright streak or tail, the trace of which remained for several minutes. The greater part of the time it was brilliant moonlight, which detracted greatly from the effect of the meteors.

The report in the Proceedings by Buist (1853) was followed by reports of a few isolated events witnessed from different locations in India.

The major shower occurring in the month of April is the Lyrids. Notably, at the time of the observations as stated in the quote above (*ibid.*), the observer is right in stating that "… their flight at a point of the heavens [was] invisible to my eye". The Lyrid radiant that lies between the constellations of Hercules and Lyra would have risen in the N-E around 10 p.m. during this time of the year.

5.8 The Display Over Kurrachee in November 1856

In 1857, London-based *The Indian News, and Chronicle of Eastern Affairs* (see Anonymous, 1857) reported about the meteor shower over Kurrachee, dated 21 November. The name of the communicator is not clearly readable in this reference:

> NOISE IN THE AIR. - On Wednesday morning, about three o'clock, a strange rushing noise was heard in the air, passing over Kurrachee. Within an interval of two minutes the sound was heard twice – each during about ten or twelve seconds of time. The most curious thing was, that one could guess the breadth to which the "second" extended, and height of the current of air above the earth which caused it. The direction was exactly from north to south. Although the waning moon faintly illuminated the heavens, yet numerous meteors could be seen for an hour after, shooting in all directions, some going athwart each other like shells thrown at night by hostile forces. The dogs of the town, of course, immediately increased their usual wild chorus, a hundred-fold, during and immediately after the phenomena – *Kaasid*, November 21.

In 1856–1857, the Leonids should have been peaking on 13/14 November. The Wednesday morning prior to the date of filing the report could have been 12 or 19 November, but the reference to the waning Moon shows that the observations were made in the early hours on the 19th. Over Karachi, at three in the morning of 19 November the constellation of Leo was up, with the Leonids' radiant at an altitude of about 49° in the East, and the Moon in close attendance.

5.9 The Display Over Bombay in November 1858

Buist (1859: Appendix A: 12) presented reports on sporadic meteors seen over Bombay and Kolapore (Kolhapur) in 1858, along with the November showers. The relevant part of his report states:

> Luminous meteors have been singularly numerous for the past three weeks, but few of them have been seen to explode – the majority being those small bright specks which shoot across the sky in all directions, appearing and disappearing with equal suddenness and scarcely altering in size or aspect during the time they were visible … The middle of November is one of our great meteoric epochs, and the extreme purity of our sky at present renders it singularly favourable for observation.
>
> We are now in the midst of our November meteors, and the harvest of these the heavens are providing us is more abundant than it has been for many years past. The display of Friday evening was peculiarly conspicuous. They shot across the sky in all directions, and were for most part remarkable for their proximity to the earth, and the long fiery trains they nearly all left behind them … The dates most remarkable for meteoric displays are betwixt the 9th and 14th of August and of November, the 29th November being the particular day on which they are constant, regular, and conspicuous in their appearance. They are believed to be fragments of Asteroids revolving in regular orbits …

In November 1858, the Friday nearest the expected Leonid peak (13/14 November) was on the 12th. The Moon was first quarter and had set. However, what catches our attention is mention of the shower on 29 November that Buist regarded was a recurrent one. That may have been the Andromedids (or the Bielids). See Section 5.11, below

5.10 When "Rupert Drops" Fell Over Calcutta in 1833, and in 1866

While examining the timings of the displays of

November meteors between 902 CE and 1833 CE, H.A. Newton (1864b) sensed that there was a cycle the length of about a third of a century. That led him to infer that during a period of two or three years at the end of each cycle, the Earth passed through a denser part of the meteoroid stream and so a stronger shower could be expected. From his calculations, Newton (1864a: 61) predicted that

> The year in which we have most reason to expect a shower, is 1866, since the cycle of 33.25 years is probably to be reckoned from some date between November in 1832 and in 1833.

The shower predicted to take place on the morning of 13/14 November actually occurred and was widely reported. With the passage of time it would become a legend.

The famous Leonid storm of 1866 was also observed from a few places in India. William Masters from Kishnaghur, Bengal, shared his experience of the November storm in the pages of the *Englishman*, a newspaper published in Calcutta. Masters was a Professor at Kishnaghur College, 70 miles north of Calcutta. In his write-up, he also recalled the meteor shower of 1833 that he had seen from Calcutta and how he had waited for a recurrence of a similar event. Masters (1867a: 17–21), subsequently sent a detailed write-up to the Asiatic Society of Bengal on 21 November 1866:

> My attention was first drawn to these visitors to our sphere, in 1833 (I believe), when, a little before sunrise, while seated in an upper verandah in Calcutta and looking south, I observed white, pearly, flakey, I might almost say, tiny spiritual things of the shape of Rupert drops falling, as I fancied, perpendicularly down, about a yard or two apart, and about 15 succeeding each other in two or three minutes within the range of direct vision. Day followed too quickly for this exhibition to last long.
>
> Since that time I had been watching for their recurrence without success; and was on the look out for them from the 9th to the 18th instant, when only a few stragglers presented themselves. Up to 11 P.M. of the 13th, there was no sign of meteors; but at half-past 4 A.M. of the 14th instant, they were in great abundance over Kishnaghur … I looked out about half past four or a quarter to five, and observed them shooting along the sky divergingly and very rapidly, from some part of the head of *Leo major*; and by their manner of comporting themselves, was immediately convinced that we had come upon the great shoal of November. I was most interested in detecting, if possible, the precise point of divergence; and it soon became evident that, contrary to received opinion, γ *Leonis* was not the starting point. After counting fifty in about five minutes, I woke up five others to witness the phenomenon and give aid in watching and counting ... in less than half an hour, we counted four hundred and twenty … The velocity of these meteors was exceedingly great … they darted like rockets from an unseen centre … all described glowing arcs in the sky, varying from 20° to 60°; a few points of light excepted, which described scarcely 3° or 4° … No sound of any kind was heard: the light of these meteors, when they blazed out, was reddish: the trains left behind were generally broad, spreading about half a degree, glowing at first like the fresh mark of phosphorus on a wall, then quickly becoming pale like the tail of a comet, or like the mingling of muriatic acid gas and ammonia, and lasting from half a minute to one minute and a half … I looked out again at 6 A.M. before the sun rose, and saw a streak of white light, like a Rupert's drop with a long thread behind, shoot down from the direction of *Leo major*, to *Capella Alajoth* in the north west, the only star then visible. It appeared to be close at hand, and looked exactly like those of 1833, with the exception of the long thread … After as careful a survey as the circumstances would permit, I have no doubt that the centre of radiation was somewhere between the two stars in the head of *Leo major*, viz. ε and μ … Some point near γ Leonis was the diverging point in 1833; if other observers confirm my statement, some step, I imagine, will be gained towards the determination of the orbit of the November shoal.

The Moon was first quarter and set at the time of the observations. There were very few reports of the November 1866 storm from India. Except for Masters' (1867a), the *Englishman* carried no other report from India. On 27 November 1866 Buist also communicated a paper to the *MNRAS* through Sir John Herschel The contents were the same as reported in the *Englishman* but the paper added the observations of the same shower by an observer at Sealkote (Sialkot) on the intervening night of 13–14 November and those from Lahore where the meteors were seen "… to clash against each other and mount upwards again …" (Masters 1867b: 205).

Through the 'Rupert drops', Masters drew a very interesting comparison. The drops are tadpole-shaped silicate glass beads known since the early seventeenth century and called 'Prince Rupert's drops' after Prince Rupert of the Rhine who had brought the unusual glass form in 1660 to his cousin King Charles II. In 1661, the King passed the beads to the 'learned society' in London for study (see Figure

12). The society had only been founded in 1660 at Gresham College, with the King as the patron, and in 1663 it evolved into 'The Royal Society of London for Improving Natural Knowledge'.

Ever since, the drops, also known as Bavarian tears, etc., have kept material scientists puzzled over their unusual mechanical characteristics. The drops are created when red-hot molten glass is quenched in cold water. The outside cools fast while the inside remains molten and cools down comparatively slowly. Their heads are so strong that they can bear the impact from a hammer without breaking. However, their tails are so fragile that bending them even lightly will not just break but pulverize the drop itself in an explosion. Why that was so remained a question for four centuries, which was solved only recently (see Aben et al., 2016). The phrase 'Prince Rupert's drop' has also been used as a metaphor.

5.11 The Great November Shower of 1866: A Tale From Madras

The November 1866 meteor storm was seen in Madras. Here is an extract of a report that appeared in *Allen's Indian Mail*, dated 27 December 1866:

> THE STAR SHOWER AS SEEN FROM MADRAS. – The *Athenaeum* says: – Those of our readers who chanced to be awake two or three hours before dawn on the morning of the 14th inst., and in a position to observe the heavens, must have had the great pleasure of witnessing meteorological phenomena of a most interesting and rare kind. We allude to a long-continued and brilliant shower of what are commonly called "shooting-stars". When this shower commenced our informant is not in a position to say; but on his awaking soon after three A.M., his attention was attracted by several flashes of bright light, succeeding each other at brief intervals, which were visible through an open window opposite to the foot of his bed. As there were clouds floating about at the time, he, in the first instance, supposed the flashes to be those of lightning; but soon after, through another window beside his cot, he saw several meteors descend in rapid succession, which led him to rise and watch the phenomena until daybreak, as he then remembered that appearances of that description often occur on a great scale during the night of 12th and 13th November. From the time he rose the starry shower was almost constant, or, at all events, but little interrupted. It proceeded chiefly from one particular quarter of the heavens, about E.N.E., where a meteoric cloud apparently existed; but flashes of light, the precise sources of which were not within the range of his vision where he stood, likewise frequently occurred, showing that the same phenomena were visible in other quarters. The great majority of those shooting-stars which he witnessed pursued nearly a similar course; but there were considerable differences in the duration of their flights, none of which approached the earth. He did not perceive any material variety of apparent magnitude; but some very decidedly more brilliant than the rest. A few left behind them faintly luminous trains, but of very evanescent nature, and the remainder displayed nothing of that kind. The three brightest which he beheld shot across the sky after the day had well broken, and presented a very radiant aspect, notwithstanding the growing light of morn. He saw no sign of explosion, neither heard any sound. But for the clouds floating here and there he would doubtless have seen a great many meteors than he did; indeed, he did observe many flashes behind lighter portion of the cloudy veil. Two other friends, whose avocations had taken them abroad very early in the morning of the 14th inst., witnessed these mysterious phenomena from St. Thome, and they describe the celestial exhibition as having been of a very splendid and imposing description. It is to be hoped that her Majesty's distinguished astronomer at Madras, who has always shown much ready kindness in enlightening the public with reference to astronomical and other subjects connected with his important office, will favour them with some account of his own observations on the late occasion, as he and his establishment are sure to have been on the watch for the spectacle, which usually happens more or less at this season of the year, and is visible from all parts of the globe. It has of late years excited extraordinary interest in the philosophical world, by reason of the periodical appearance of these shooting-

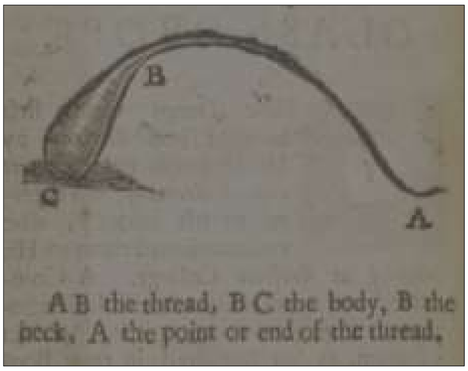


Figure 12: A diagram from the research paper "Account of the Glass Drops" that Sir Robert Moray presented to the Royal Society in 1661 (after Moray, 1661: 354).

> stars in unusually great numbers; but the older men of science also largely speculated regarding the nature and cause of them, which are now as then very far from being even approximately understood. In fact, the whole question is wrapt in such deep obscurity that only conjectures, as numerous as contradictory, have yet been arrived at. (Anonymous, 1866: 1012).

The *Athenæum* was an English periodical, published in London from 1828 to 1921. In the report above, the "informant" is not identified. As if to answer his observation that "the older men of science also largely speculated regarding the nature and cause of them", as we have seen it was the Italian astronomer Giovanni Schiaparelli (1867) who cracked the mystery. In 1862 he had compared the orbits of the August meteor shower and Comet 1862 III[8] and found them similar, and subsequently he was able to link the Leonid meteor showers (and the 33-yr 'storms') to periodic comet 55P/Tempel–Tuttle. For the development of Schiaparelli's ideas about comets and meteor showers see Buffoni et al. (1990).

5.12 And the Geminids in 1866?

In his report on the November 1866 meteors, Professor Masters (1867a) referred to observing meteor showers during 27–29 November and early in the morning on 12 December. He gave details about these latter observations in the sequel to his communication of 21 November 1866 to the Asiatic Society of Bengal, concluding that they emanated from a different radiant position and therefore were not Leonids:

> As a sequel to my letter of the 21st ultimo regarding the November meteors, I beg to forward the following particulars. The 27th to the 29th November, and 7th to 12th December, are dates of observation for meteors of a similar kind; but diverging meteors were not seen again or detected till 2½ A. M. of the 12th December; they might have come on at an earlier hour of that date, and they appear to have passed off by 3 A. M.
>
> They shot divergingly and with great rapidity, not from a point near γ or ε Leonis, but some point to the westward of these, between ζ in the muzzle of Leo Major and the small stars in the foot of the Lynx and the tip of its tail; some point about 29° or 30° of north Declination, and 136° of Right Ascension. They darted out at the rate of about three per minute; were small, described short and thin arcs of light, and left no traces: hence it was difficult to fix with any degree of precision upon the exact point of divergence. Some showed themselves only as moderate blazes or bursts of light about 40° or 50° from this point, without any visible arc of light or course. A bright meteor with a long train shot across the area of divergence from nearly due south to north, or from Alphard in Hydra to θ in Ursa Major. This display of meteors had nothing brilliant or exciting in it: but notwithstanding its tameness, I think it should be recorded. (Masters, 1867b: 20–21).

Was the event of 12 December the Geminids? The Moon, then an evening crescent, had set. The position in the sky inferred by Masters was not very distant from the radiant of the Geminids which is near the star Castor in Gemini. This received some independent support through a paper by the Irish astronomer John Birmingham (1867: 205–206), which appeared next to Masters' (1867b: 202–205) paper in the same issue of the *MNRAS*. Birmingham's paper also was about meteors that he observed on the evening of 12/13 December 1866. Observing from Millbrook, Tuam, he had seen the meteors shooting south from Gemini, and some "… proceeding from other places in the neighbourhood of Gemini … diverging to every point in the heavens …"

Note that a meteor shower around this same date had previously been reported: after B.V. Marsh in Philadelphia and R.P. Greg in Manchester independently observed a shower on 10–11 December 1862, this was acknowledged as an annual display and assigned the name 'Geminids'. This shower is seen in the North-Eastern sky through 6–19 December between 2–3 a.m. local time, peaking during 13–14 December. As we have already noted, it is associated with an asteroid, 3200 Phaethon (1983 TB), rather than a comet.

5.13 The November 1885 Meteor Shower Seen From Quetta, Agra and Bombay

There are reports of a remarkable meteor storm seen in November 1885 from Quetta in Beluchistan (now in Pakistan), and in Agra and Bombay.

Major A.C. Bigg-Wither reported accidentally observing a grand meteor shower on 27 November from Quetta (67° 5′ E; 30° 12′ N). At 10 p.m. local time, he noted that the shower was incessant and that over the entire visible sky there were six to eight meteors every second (Bigg-Wither 1886: 121). The radiant appeared to be at the zenith and close to the well-known Andromeda Nebula. The shower appeared symmetrical, and the meteors were not very bright, typically like stars of the 3rd magnitude, with a few as bright as 1st magnitude, and moving over arcs of 8° to 10°

in angular span. The Moon was then in last quarter and was up.

Archibald Cuthbert Bigg-Wither (1844–1913) was an engineer with the Indus Valley Railway. At age 17, he went to India and was attached to the 52nd Light Infantry. In 1865 he entered Thomson Engineering College for Officers at Roorkee (now the Indian Institute of Technology, Roorkee), and passed with honours, and was awarded two gold medals and a thousand rupees. In 1885 he was stationed at Quetta. Bigg-Wither had been a keen astronomer since his younger days, and maintained a private observatory with a 5-inch refracting telescope and a transit circle. He observed the transit of Venus on 9 December 1874 from Mooltan (now Multan, in Pakistan), and gave local visitors a chance to watch the transit live (Anonymous, 1914; Kapoor, 2014).

The 27 November meteor storm was also seen from Bombay, beginning at 8 p.m. "… and lasting with great brilliancy for eight hours" (Anonymous, 1874: 391). The names of the observers are not given in this report.

There is another report of the same storm, seen from Agra on 27 November. It came from Major G. Strahan, who first noticed the event at 7:20 p.m. local time. The meteors were so numerous that he found it impossible to count them. The peak occurred at around 9:30 p.m. but until 11:30 p.m. the shower continued with unabated intensity. A few meteors could still be seen around 2 a.m. Half of the meteors seen were as bright as stars of 3rd magnitude, but a few reached 1st magnitude and left reddish trails. Noticing some "… almost stationary meteors …" in the sky, Strahan (1886: 121–122) estimated that the radiant was halfway between γ Andromedæ and 51 Andromedæ, at RA 1h 45 m, Dec +46°.

Colonel George E. Strahan (1839–1911; E.H.H., 1912; Kapoor, 2014), Royal Engineers, had served the Survey of India and observed the transit of Venus on 9 December 1874 from Lahore and the Great September Comet of 1882 (C/1882 R1) from Mussooree.

Interestingly, the 27 November meteor storm also was witnessed by W. Wickham (1886: 120) from near Oxford. He said the night was dark and cloudy but at about 5:35 p.m., he noticed "… repeated bursts of light behind the clouds." The densest was from the direction of Cassiopeia, the radiant being south beyond Alpha Cassiopeiæ. About 6:15 p.m., he saw thousands of meteors ending with a bright burst, many bright like a 1st magnitude star, the others fainter. In the same issue of the *MNRAS* there also was a communication from Captain D. Wilson-Barker about the meteor storm of 27 November, seen at a rate of around 600 / minute between 9:30 and 10 p.m. from Suez. He saw the numbers reduce considerably by 3 a.m., and the following evening the activity was much less.

It turned out that this sensational storm was widely observed and reported, in the pages of *Astronomische Nachrichten*, *Nature*, *The Observatory* and *Comptes Rendus*, etc. (Figure 13). For an analysis of these observations, one should consult Newton (1886), who calculated that the peak hourly rate was around 75,000!

This exceptional meteor shower was named the Andromedids (and also Bielids), as the radiant was located in the constellation of Andromeda. The source of the shower was identified as Comet 3D/Biela, a Jupiter-family comet. As the nuclei of comets are fragile, there have been many occasions when the nuclei are known to have broken up at perihelion. Comet 3D/Biela was one such case.

Wilhelm von Biela (1782–1856) had discovered the comet that bears his name on 27 February 1826 (Kronk, 2003), with a perihelion (q) of 0.879073 au, an orbital inclination (i) of 13.2164° and a period of 6.646 years (JPL, 2022). Biela noticed that its orbit resembled the orbits of comets seen in 1772 and 1805, and he suggested that the comet had a period of 6.75 years. During its four visits between 1826 and 1852 the period of the comet averaged 6.62 years, with q = 0.8606 au. The comet was not detected during its 1839 return. To the great surprise of astronomers, at its 1846 apparition the comet arrived split into two components, A and B, which were about 1′ apart (Kronk, 2003: 157). Both of these showed up again at the 1852 apparition, but this time they were about half a degree apart. Yet the two components possessed similar orbital elements. This nuclear splitting created a great sensation among astronomers. After the show in 1852, the comet did not turn up during the next two expected apparitions. It was not at a suitable position during the 1859 return, but on the next return, in 1865–1866, it was favourably placed but could not be found. So, astronomers assumed that it had fragmented completely (see Kronk, 2014: 258).

In 1991, Babadzhanov et al. (1991) re-examined the orbit of Comet 3D/Biela and confirmed that its orbit lay close to that of the Leonid stream. These authors firmed up an earlier suggestion by Bosler and Roure (1937) that splitting may have come about because the comet happened to pass through the more

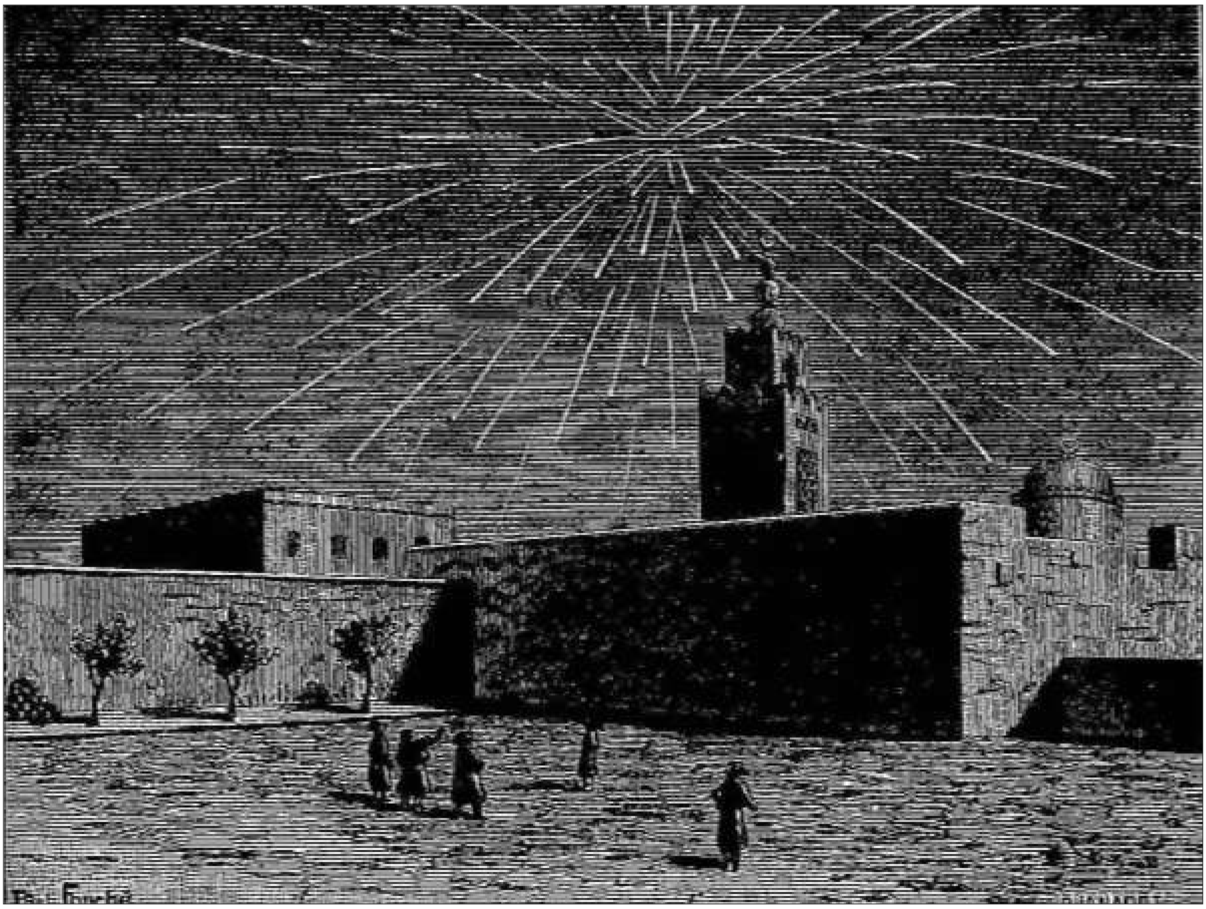


Figure 13: Shooting stars of 27 November 1885; from a sketch made at the Kasbah of Tunis, by M. Portanier, dated 21 January 1892 (Wikimedia Commons).

densely populated parts of the Leonid meteor stream. In its return in 1846, the components were separated by a mere 0.0265 au. The orbit of Biela has a low inclination (~13°) and motion is direct, while that of the Leonid stream is 163°. The comet thus met the stream about head on, at a relative velocity of ~68.5 km/sec, so in all probability the nucleus suffered high-energy impacts from massive meteoroids. According to these authors, the splitting may actually have taken place during the 1832 apparition, because the two major components needed a long time interval to drift apart by as much as noticed in 1846 (Babadzhanov et al., 1991). On the expected return of Comet 3D/Biela in 1872, Edmond Weiss calculated that the Earth would pass through a section of meteoroid stream on 28 November, which would give rise to a meteor shower. Indeed, there was a meteor storm at this time, and the Italian meteorologist and astronomer Padre Francesco Denza, Director of the Montcalieri Observatory, wrote that

> … in some parts of the sky there seemed a real rain of fire … Most probably the large meteoric stream or cloud which produced this remarkable shower of falling stars last evening belongs to a part of this comet; so much the more likely when we consider that only yesterday the earth passed through one of the two nodes of this comet's orbit. (Denza 1872: 122).

The meteor storm was seen emanating from a point close to γ Andromedæ. It had been widely witnessed on the night of 27 November 1872, after sunset. After observing the shower Newton (1872: 122) commented:

> The character of this display, and the previously observed division of the comet into two parts, will, I doubt not, incline astronomers to the opinion of Dr Weiss and others, who think that the shooting stars are products of the disintegration of already moving in closed orbits, rather than to the opinion of Prof. Schiaparelli that they are drawn from the stellar spaces into long parabolic currents. The latter hypothesis presents difficulties which I cannot explain.

The spectacular show of the Bielids in 1872 (Figure 14) as a result of the Earth's passage through the debris of the Comet was followed by another meteor storm in 1885 (Figure 13). The hourly rate reached in these two events had been estimated at 6000 / hr and 15,000 / hr respectively. There were nota-

Figure 14: A painting of the meteoric storm of 27 November 1872 as seen over France, after Guillemin, 1877 (image: https://www.amsmeteors.org/2018/11/outburst-of-the-andromedids-in-2018/).

ble showers again on 24 November 1899 and 21 November 1904 also. After a century's lull in its activity, the shower returned in 2011 during 3–5 December with enhanced activity, reaching a ZHR of ~50. Numerical simulations of the orbit of the comet indicated that on this occasion the Earth was near the 1649 stream (Wiegert et al., 2012: 77).

The Andromedids are now weak. Due to gravitational perturbations, the orbit of the meteor stream has drifted away from the Earth's orbit. The radiant is now located at the border of Cassiopeia and Andromeda. The Bielid showers are listed by the IAU as "December Phi Cassiopeiids (DPC) #446." They are active between 1–10 December, peak on 6 December, and with the radiant at RA 19.5° and Dec. +57.7° (J2000). A ZHR of about 200 has been predicted for the December Phi Cassiopeiids on 2 December 2023 (Lundsford, 2020; Wigert et al., 2012: 78).

6 METEOR SHOWERS MENTIONED IN MADRAS AND KODAIKANAL OBSERVATORY REPORTS

We have looked into the Madras MS Records of Madras Observatory, held by the Archives at the Indian Institute of Astrophysics in Bengaluru. These are hand-written and cover the period 1794–1812. The records are largely a compilation of official correspondence between the Observatory and the EIC, the Surveyor-General and the Chief Secretary to the Government, Madras. There are reports of the routine business, about the Observatorys' instruments, and about the observations of the eclipses of the Jovian satellites made to determine the longitude of Madras with everincreasing accuracy. Captain John Warren (1769–1830), the Acting Astronomer between 1805 and 1811, mentions his observations of the Great Comets of 1807 and 1811 but, in his and also in subsequent reports from Madras Observatory, meteor showers do not find a place.

However, near the turn of the nineteenth century, the Annual Reports of the Madras and Kodiakanal Observatories do report observations of meteor showers. But the reports are of the Leonids only, and are routine and without detail.

The Report on the activities of the Madras Observatory for 1898–1899 (IIA Archives) men-

Figure 15: Charles Michie Smith (courtesy: IIA Archives).

tions that observations of the November meteors (the Leonids) were made on four nights by Government Astronomer, Charles Michie Smith (1854–1922; Figure 15) and K.V. Siva Ramaiah, following the plan of international observations issued by Harvard College Observatory (HCO). The observations were sent to Professor Edward C. Pickering, Director of the HCO, to be published together with the observations reported from elsewhere. The details of the Leonid watch in 1898 and the plan for the anticipated show in 1899 were presented in the October 1899 issue of *Popular Astronomy* by Edward's younger brother, William Pickering (1899), who stated that the 1898 shower was widely observed during 12–16 November from across the globe:

> This was in part due to the fact that a large number of observers, especially in the remote longitudes, had courteously offered their services in reply to the request of the Harvard College Observatory.

The results in brief were published in HCO Circular No. 35.

Pickering (1899: 395) stated that in 1899 the shower was expected to reach its peak on 15 November, at 18h GMT so observers needed to observe from the evening of 13 November through until the evening of 17 November.

The Leonids of 1899 were observed at Kodaikanal Observatory (Figures 16 and 17; 10° 14′ N, 5h 10m E; height ~7700 ft) by Charles Michie Smith along with his assistant K.V. Sivarama Aiyar, and at Madras Observatory by Professor R. Ll. Jones, assisted by S. Solomon Pilllai and S. Sitarama Aiyar (Michie Smith, 1900: 262–264). The observational records were made within the area of Professor Pickering's map. The tabulations

Figure 16: Kodaikanal Observatory in 1905 (courtesy: IIA Archives).

Figure 17: Kodaikanal Observatory, Indian Institute of Astrophysics. The building housing the Library is in front. Top left is the "Spectro", housing the spectroheliograph; the Solar Tower Telescope Dome is in the middle (photograph: R.C. Kapoor, 1989).

gave details of the time-wise counts and brightness estimates, beginning in the early hours of 14 November and through three successive nights, using Madras Mean Time. The Indian observers saw more meteors from midnight of 15/16 November until the early morning, at both Kodaikanal and Madras Observatories. Michie Smith's Report included observations made in Assam at the Mission House in Karimganj by the Reverend Oswald O. Williams. These observations corresponded to the local mean time, "49^{m} fast of Madras mean time". The Reverend observed many meteors on the evening of 14/15 November, but the following night he was clouded out, and he had nothing to report on 16/17 November. Brown (1999: 293) comments that "… observations from India beginning only 3 hr later show little or no significant activity." In retrospect, the Leonids were predicted to storm in November 1899, but this failed to happen (Dick, 1998).

In his Report on the Kodaikanal and Madras Observatories for the years 1900–1901, Michie Smith (1901) mentions that: "A watch was kept for the Leonids on November 15, 16 and 17, but the weather was unfavourable and only a very small number of meteors were seen."

Meanwhile, the Perseids are conspicuously absent from the observational reports of Madras and Kodaikanal Observatories, possibly because the South-West Monsoons were active through June–September.

7 CONCLUDING REMARKS

Meteors are transient objects. Sporadic meteors are seen throughout the year. A fireball, or a superbolide with a sonic boom, is a rare event and is only witnessed from within a limited region. On the other hand, meteor showers are recurrent, and may be captivating spectacles (e.g. the Leonid meteor storms), but in fact most showers are unspectacular quiet events. However, they usually are visible from over a very large area of the Earth. In this paper we reviewed the reported observations of meteor showers made in the Indian region from antiquity through to the turn of the nineteenth century. The sources we explored were Indian classics and chronicles, institutional reports and accounts by individuals, including those published in newspapers and professional journals.

The earliest references to meteor showers that we found were in chronicles from the sixteenth century in Shuka's *Rājatarangiṇī* and in the *Akbarnāmā*, and from the seventeenth century in Krishṇājī Anant Sabhāsad's account of the life of Chhatrapati Shivājī Mahārāj. These references are about actual events and are datable. Subsequent accounts came from the nineteenth century, where several intense meteor storms were reported in detail. These reports appeared in newspapers and in professional journals, at home and abroad. The earliest such report was of the Leonid meteor storm of 1832.

In our search, we also came across observations of a strong meteor shower seen on 10 September 1841, which was reported in the 13 September issue of the *Englishman*, a prominent Calcutta daily newspaper. We believe this account described the September Epsilon Perseids, a minor shower that is known to peak on 9/10 September. We noted that this 1841 report from India appeared 37 years before the September Epsilon Perseids were first described and named by the leading British meteor scholar, William Denning.

Indian records of serendipitous celestial phenomena are less abundant than those reported from China, Korea, Japan and the Arab world. Meteor showers are annual, but the Islamic calendar being lunar would not easily lead one to notice the periodic or annual nature of these occurrences. Comet appearances might last for days or weeks, but nearly all reports of them lack sequential observations. Islamic astronomers regarded comets and meteors as atmospheric rather than celestial phenomena, so we might assume that usually they were ignored, but in fact there are many records of comets and meteors—including showers and storms—in medieval Arab chronicles (Cook, 2008). Rada and Stephenson (1992) present such meteor records, extending from CE 571 to the nineteenth century, and show how these can throw light on the effects of long-term perturbations on meteoroid orbits.

Comets, meteors and meteor showers did not interest Indian astronomers in the same way as time-reckoning, eclipses and the motions of the Sun, Moon, stars and planets did. While fireballs and some meteor showers (and especially the Leonid meteor storms) were striking, and even captured the attention of the uninitiated, we find hardly any cultural expressions of them—in words or in images. However, the present study is merely a preliminary only, and a more exhaustive search of Indian historical records for further references to sporadic meteors, meteor showers, fireballs, bolides, and meteorite impacts is underway. Such records are important if we wish to fine-tune time-lines in history and better understand the dynamics of comets and meteor streams.

8 NOTES

1. "Comet Tales from India" is the author's ongoing search since 2009 for records of cometary sightings from the Indian region, from antiquity until 1960, where available data, however minimal, permit identification of individual comets (see Kapoor, 2018; 2019a; 2019b; 2019c; 2020a; 2020b; 2021a; 2021b; and 2021c). Research on Indian observations of comets made during the nineteenth and twentieth centuries is currently in progress.
2. "Tales from India: Meteors, Meteor Showers and Meteorites" is the author's current project searching for relevant information in Classical Indian and colonial sources. Further papers in this series are planned.
3. Shakespeare made a lot of astronomical references in his plays, including to meteors (Chappell 1945). He thought of meteors as "exhaled from the sun" and stars that are "dis-orbed". The phrase "certain stars shooting madly" cited by Beveridge (1922) is from "A Midsummer Night's Dream", a comedy in five acts, where Oberon, the king of the fairies, speaking to his servant Puck says (II.1. 153–154):

    And certain stars shot madly from their spheres,
    To hear the sea-maid's music.

    The play was published in 1600, but most likely written in 1595–1596 (RSC, 2022); see Beveridge (1923: 57) for some related comments.
4. This same comet, along with an earthquake, is also referred to in the Marāthi *sphuta sloka* (stanza) written by the great poet Samartha Rāmdās (1608–1682), who inspired the Mahārāj and acted as his spiritual guide (see Pangarkar, 1927: 468).
5. There was a total solar eclipse on the afternoon of 30 March 1680, which was visible over India. The path of totality passed over Kasargod, Mahe, Mandya, Mysore, Salem, Pondicherry and Chidambaram, but the eclipse was partial at Raigad (location 17 in Figure 7), which Mahārāj established as his capital in 1674, where it reached a maximum magnitude of 0.8.
6. Hindu College was one of the first institutions in India established in 1817 by an enlightened group led by Raja Ram Mohun Roy (1772–1833), an Indian 'Renaissance Man', to provide Western-style higher education for aspiring Indians. In 1855, it became the Presidency College of Ben-

gal, and in 2010 Presidency University, Kolkata.

7. The *Englishman* was an influential newspaper published in Calcutta at this time and was a contemporary of such prominent newspapers as the *Friend of India* and the *Bengal Hurkaru.*
8. This comet was originally classified as C/1862 O1, but is now known to be a periodic comet, 109P/Swift–Tuttle.

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