The Cause of Dark Lunar Eclipses

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This paper presents a survey of dark lunar eclipses and also of the problems which they create in assigning their possible causes in either astronomical or meteorological terms.

INTRODUCTION

The recent letter by Cicely M. Botley[1] and the still more recent paper by Peter Bicknell[2] both raise the matter of noticeably dark total lunar eclipses and the factors which cause them. The two most notable factors can be agreed to be the stratospheric dispersion of volcanic dust following major eruptions and a still, as yet unexplained, mechanism linking the brightness of lunar eclipses with the sunspot cycle which, of course, averages 11 years in duration.

A third factor could be the dustiness introduced into the atmosphere by the major annual meteor showers such as the Lyrids, Perseids and Geminids. However, with the normal performances of those showers, the influence which they would exert upon lunar eclipse brightness is minor in comparison with major volcanic eruptions and the sunspot cycle.

Ideally one should be able to interpolate the relative influence of volcanic activity with that of the sunspot cycle as regards the brightness of specific lunar eclipses. In that way, cause and effect could be formulated in precise terms, but as I will show in the course of this paper, the eclipses themselves sometimes fail to obey the expectations of such relationships.

EARLY RECORDS

Records of lunar eclipses for Britain go back as far as the seventh century AD, and an example of what could be a dark eclipse, akin to the two in 1964 and those of 1982 July and December, occurred within the first 100 years of Britain's lunar eclipse records. The first lunar eclipse recorded as seen in the British Isles was in AD 690, when we are told that "the Moon was turned to the colour of blood"[3].

Coming to what might be our earliest dark eclipse, George Chambers says[4] that on the night of 753 January 23 "the Moon was covered with a horrid black shield". Chambers gives no reference for this and regards it as a dark eclipse. The Reverend S. J. Johnson[5] goes further as regards references but merely mentions Tycho Brahe and Calvisius without giving precise locations in their records of the event. Chambers assumes this eclipse to be total but Oppolzer[6] gives it as only a large partial eclipse of 10·9 digits and also with mid-eclipse at 01h 19m on the 24th and not as stated by Chambers on the 23rd. (According to the digit system, eclipses do not become total unless they attain 12·0 digits.)

According to Chambers, the Anglo-Saxon *Chronicle* says regarding the total eclipse of the Moon on 1110 May 5 that "the Moon appeared in the evening brightly shining and afterwards by little and little its light waned so that as soon as it was night it was so completely quenched that neither light nor orb not anything at all of it was seen. And so it continued very near until day and then appeared full and brightly shining. It was on this same day a fortnight old. All the night the air was very clear and the stars over all the heaven were brightly shining. And the tree-fruits on that night were sorely nipt." This is certainly an early English record of a dark totality.

TELESCOPIC EXTINCTIONS

However all of these eclipses happened before the invention of the telescope. For the totally eclipsed Moon to be invisible even with a sizeable telescope is of course the ultimate criterion of darkness. Not even the famous dark totalities of recent times in 1964 and 1982 managed to attain that. A very small visual margin always stood against the utter telescopic extinction of the Moon. For the attainment of such a totality we have to turn to that of 1761 May 18 as observed by Wargentin at Stockholm. He said[7] that "The Moon's body had disappeared so completely that not the slightest trace of any portion of the lunar disc could be discerned either with the naked eye or with the telescope, although the sky was clear and the stars in the vicinity of the Moon were distinctly visible in the telescope".

EFFECTS OF VOLCANIC ACTIVITY

Regarding the possible effects of volcanic dust upon the darkness of total lunar eclipses, the parameter which is of major interest is the 'Dust Veil' index.

This criterion was devised by H. H. Lamb[8] to assess the relative amounts of dust produced by differing volcanic eruptions. Among the dust veil indices, the Krakatoa volcanic eruption of 1883 ranks at an arbitrary 1000. It stands high in the index but is certainly not the largest. Cosigüina in 1835 holds the top position on the index with 4000. However, dust is only a limited proportion of the ejecta in volcanic eruptions. Cosigüina, the central American volcano, is famous for covering great stretches of the sea with pumice. In spite of its high index figure, it is clear that the ejection of dust was generally lateral rather than vertical, as it failed to reach the stratosphere and did not produce the strangely coloured suns and moons, and sunrises and sunsets which were observed around the world after the Tambora eruption of 1815 and the Krakatoa eruption of 1883. In those cases, the dust was carried around the world by the regular velocity of the stratospheric winds and was filtered through the troposphere. With the high dust veil index of 3000 for the eruption of Tambora in 1815, we have a ready explanation of the darkness of the total lunar eclipse of 1816 June 10 as observed by Beer and Mädler. Both of the total eclipses of the Moon in 1884 were dark following the Krakatoa eruption. The first was observed by Dufour[9] as a dark eclipse from Bantiman in Java on April 9. The second was widely observed on October 4 from Europe and Britain. Although it is often regarded as a dark eclipse, Willard Fisher disputes the degree of darkness and says that it was not as dark as its popular reputation suggests.

Two total eclipses of the Moon happened during 1902 which was a year of considerable volcanic activity. The sequence of the three chief eruptions was Mount Pelée with a dust index of 100, Soufrière with 300 and Santa Maria with 600, which is over half the 1000 for Krakatoa. The activity of these volcanos was in the period from May until October. The two total eclipses of the Moon happened on April 22 and October 16, hence the first of them appeared before the eruptions.

The dust veil index for the eruption of Agung in 1963 was 800 and is sufficient to explain the great darkness of the last lunar eclipse of 1963 and the two eclipses of 1964. After a Saros cycle the two former eclipses were again affected in a like manner from the eruption of El Chichon. The index figure for the eruption of Makyan in the Molucca Islands in 1760 was 250 and is not sufficient to explain the abnormally great darkness of the total lunar eclipse of 1761 May 18 as observed by Wargentin.

The eruption of Laki in Iceland in June 1783 was the most massive European volcanic eruption during historical times. From the point of view of the lava output it stands as an absolute world record as it amounted to about 25 cubic kilometres of lava covering as much as 565 square kilometres. The lava output was in the form of two tremendous streams which were up to 64 kilometres long and up to 183 metres deep. The dust veil index, though not a world record, is still the greatest for any European volcanic eruption. It stands as high as 750 and is therefore comparable with that of 800 for Agung in 1963.

The dust from the eruption of Laki spread itself over the skies of Europe, Africa, Asia and America. On June 25 the dust reached Moscow, and it reached Syria before the end of June. It was noticed from the Altai mountains on July 1. The dust certainly reached the stratosphere in great quantities. "The air of the lower regions did not appear to be its vehicle for at certain points it came with a north wind and at others with east and south winds. Travellers found it on the highest summit of the Alps. Abundant rains and the strongest breezes did not dissipate it. Its density was in some places so great that the sun was not visible in the morning till at the height of twelve degrees above the horizon. During the rest of the day the solar orb appeared red and the eye could readily encounter his beams in the meridian."[11]

Cowper[12] writing from Olney on June 13 thus refers to the condition of the dust-shrouded Moon as follows: "At eleven last night the Moon was a dull red; she was nearly at her highest elevation and had the colour of heated brick." According to Gilbert White[12] "The Sun even at noon looked as blank as a clouded Moon". In the south of France the Sun was not visible till it was 17 degrees above the horizon. The haze was reported as lasting over Europe until the end of 1783 September.

With both the Sun and the Moon being so dramatically affected as regards their visibility by the volcanic dust in 1783 we have every reason for expecting the total eclipse of the Moon of 1783 September 10 to be a very dark one in the form of a complete black out. However the actual records of that eclipse do not show that to be the case. According to *The London Magazine Enlarged and Improved*[14] an observer who merely signs himself W.G. gives his observations of that eclipse. He made his observations of the eclipse from Tower Street, London. He notes that totality began at 22h 40m and that during totality the Moon was obscured by the fogginess of the air. The eclipse was therefore not an outstandingly dark one.

It will be remembered that the letter by Cicely M. Botley mentions a TLP seen from France during the total eclipse of the Moon of 1884 October 4. It is, however, not the only known example of a TLP seen during a lunar eclipse as the total eclipse of 1783 September 10, more than 100 years previously, furnishes us with another example. *The Universal Magazine of Knowledge and Pleasure*[15] gives the following details about both the eclipse and the TLP "A phaenomenon occurred on Wednesday night during the eclipse which is no less likely to attact the notice and agitate the judgment of the curious and

learned than some others that have lately occurred. Some gentlemen at Chelsea observing the progress of the moon's eclipse with glasses that are in use for the more critical inspection of the celestial bodies when the total eclipse of that luminary had taken place: a star whose brightness and magnitude had attacted the notice of the company as being so near the moon, on a sudden gradually appeared as if retiring higher in the great expance; after which there was clearly perceived round the eclipsed planet a kind of constellation equal in light and size to that which is by astronomers termed Saturn's ring; it continued observable till the left or eastern side of the planet began to recover herself from the umbra of the eclipseing object and was at one period very clearly distinguished by the naked eye. Whether a constellation or a concomitant of the lunar star, time and experience only can determine."

ECLIPSES AND THE SUNSPOT CYCLE

The relationship between the sunspot cycle and the brightness of lunar eclipses was discovered by Danjon in 1920. Following the sunspot minimum the eclipses are darkish but slowly increase in brightness with the increase in sunspots. They continue to do so right past the sunspot maximum until about the next sunspot minimum, when the eclipses abruptly decline to their minimum brightness. In contrast to the sunspot cycle itself, the rise to maximum takes far longer than the decline to minimum. It is still a mystery as to why the relationship exists. It is easily overridden for several years at a time by the influence of dust from major volcanic eruptions. For instance, the very dark total eclipse of 1816 June 16, as observed by Beer and Mädler after the eruption of Tambora in 1815, happened in a year of sunspot maximum. Edward Emerson Barnard, observing from Yerkes observatory, described the second eclipse of 1902 as the darkest totality of the six total eclipses he had observed. The general conclusion of many observers, however, is that the totalities were not as dark as we might have expected from the amount of dust thrown up in the previous eruptions. Possibly the dust failed to reach the stratosphere and therefore failed to be dispersed completely around the Earth.

The possibility raised in the paper by Peter Bicknell[2] that prolonged dearths of sunspots such as the medieval minor minimum and the Maunder minimum are responsible for long series of dark total lunar eclipses, is one which cannot be proved because of the lack of systematic data. The Maunder minimum spanned 70 years, from 1645 to 1715. Against the above contention can be placed the observation of one of the brightest total eclipses observed during the Maunder minimum, namely the one observed at Avignon on 1703 December 23.[10] This is however merely one eclipse, and proof or disproof rests upon finding the average brightness of all the total lunar eclipses during the 70 years of the Maunder minimum, and comparing them to an equivalent period of 70 years afterwards. In other words we would require to have details of the brightness of two groups of as many as 100 eclipses each.

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