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Astronomy

TOTAL SOLAR ECLIPSE OF FEBRUARY 16, 1980

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The circumstances leading to total solar eclipses have been described, and the relationship of the eclipse parameters with the orbital elements discussed. Details of the total eclipse on Feb. 16, 1980 are given, and the general nature of experiments planned* are outlined.

TOTAL solar eclipses are of vital importance in investigations concerning the sun, the earth and near environment, when observations leading to key discoveries are often possible. The events provide opportunities for study of several features of the sun and solar-terrestrial relations, which are impossible under normal circumstances.

Total solar eclipses are not really rare, but in spite of this, very few people have a chance of witnessing a total solar eclipse in their entire lifetime. An order of magnitude calculation indicates that the chance of a total eclipse being visible at any place is once in 360 years. The reason behind this paradoxical situation is that total solar eclipses are visible only over narrow strips on the earth's surface, never more than two to three hundred kilometres wide, and very often, much narrower. The oceans take a major share of this area of visibility, and inaccessible regions reduce the possibility of scientific teams making observations on a considerable number of events. The remaining events are keenly observed by teams who make their preparations years in advance. The total phase of the visible eclipse lasts for a few minutes, with every second unfolding some secrets of nature and several valuable observations are recorded.

The geometry of eclipses is well known; total eclipses are seen over areas on the earth's surface where the moon's umbral shadow cone intersects. This spot of totality moves with the eastward motion of the moon; the combined effects of earth's sphericity, rotation and annual motion and the moon's orbital motion results in generally curved forms of the loci of this spot. These are termed the tracks of totality. The shadow cone intersects the earth's surface first at the sunrise point; one sees a totally eclipsed sun rising at this location. The spot of totality keeps moving generally eastwards and finally leaves the earth's surface at the sunset point. A few eclipses in the polar regions have tracks of slightly different nature, which arise due to the peculiar geometrical configurations of the shadow cone and the curvature of the earth.

A few points are worth recalling in this connection. First, although the size of the sun and the moon are widely different, by a quirk of fortune, their relative distances are such that the mean angular sizes of both, are almost equal which is about 0°5′ in the sky. Had the moon been slightly smaller in size, or a bit further away, we would have never seen a total eclipse on the face of the earth.

*The experiments were conducted accordingly.

Secondly, the orbit of the moon around the earth, and that of the earth around the sun are not coplanar; there is a small angle of about 5°08′ between the two planes. The moon's orbit crosses the plane of the ecliptic at two nodes. A solar eclipse is possible, only when a new moon occurs very close to these nodes. Lunar orbital plane has a precession motion—and the nodes continuously shift westwards making a complete revolution in 18.6 years.

Thirdly, the synodic period of the moon is not an exact sub-multiple of an eclipse year (the earth revolutions as measured from the lunar nodes) and as a result the eclipses do not repeat themselves every year. But in a period of 18 years and 11 days (or 10 days depending on whether the number of leap years in the period is 4 or 5) and 8 hours the lowest common multiple of the two periods is almost achieved; the positions of the sun, the earth and the moon almost become identical and the eclipses repeat at this interval. This periodicity was noticed by the early Greeks and the cycle was named "*Saros*" by Edmund Halley. By another coincidence the line of apsides joining the perigee and apogee positions of the moon's orbit makes slightly more than two complete rotations by this time, so that the apparent size of the moon also assumes a value comparable to the previous eclipse. The net result is that at *Saros* interval not only the eclipses repeat, but are similar insofar as their tracks and durations are concerned. Only difference is that, because of the residual 8hrs over the full number of days in this period, the adjacent eclipse tracks are shifted westwards by about 120° in longitude. We may, however, note that all these coincidences are not exact, and slight differences in the parameters of the eclipse events at *Saros* intervals are present.

The eclipse of February 16, 1980 belongs to a family of *Saros*, whose recent members have the following characteristics :

i) They were completely total and have a maximum duration of slightly over 4 minutes.

ii) Their tracks lay at low latitudes, running west to east with a northward curvature.

The immediate previous eclipse of this *Saros* occurred on February 4–5, 1962, with track running over the Indonesian Islands, New Guinea and the Pacific Ocean. The sixth earlier eclipse of the same *Saros* number (No. 130) happened on 12th December, 1871. Its track crossed India over the southern part of the peninsula. Tracks of the eclipses of this *Saros* from 1871 are shown in Fig. 1.

It may, however, be remembered that at any time several *Saros* series are operative. One *Saros* number designates only one eclipse in eighteen years, whereas there are between two to five solar eclipses every year. Of course, a majority of them are partial, still a large number are of central type (total or annular). The tracks of all total eclipses over the past twenty years are shown in Fig. 2. It may be seen that the track of totality of February 16, 1980 eclipse starts at a point over the South Atlantic Ocean. From here, the shadow moves almost due East with a slight anticlockwise curvature of the track till the eastern coast line of Africa is reached. By this time, the direction of movement is towards North-East and the shadow reaches the west coast of India after traversing the Indian Ocean and the Arabian Sea. It moves across the peninsula, reaching the coast of

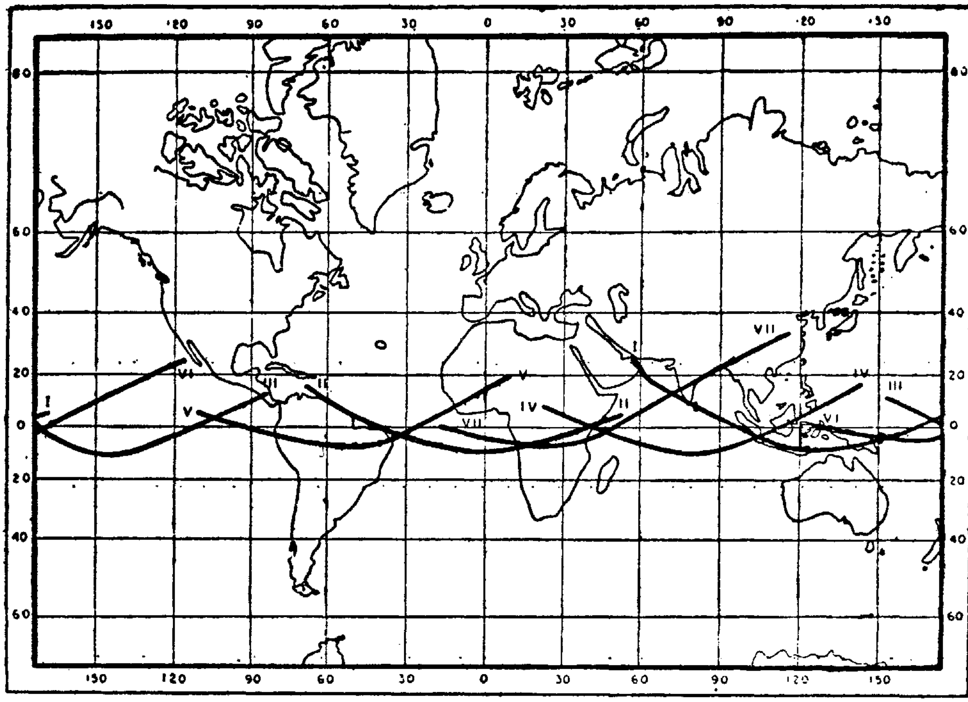

FIG. 1. Eclipses of *Saros* No. 130. 1871–1980. (I) Dec. 18, 1871; (II) Dec. 22, 1889; (III) Jan. 3–4, 1908; (IV) Jan. 14, 1926; (V) Jan. 25, 1944; (VI) Feb. 4–5, 1962; (VII) Feb. 16, 1980.

Bay of Bengal, traverses a short stretch of the Bay and then crosses over narrow strips of land in Bangladesh, Eastern India and Burma before leaving the earth's surface over Southern China.

This is the track of total phase of the eclipse; the partial phase can be seen over a much wider area on the earth's surface. Fig. 3 shows the areas of visibility of the partial eclipse on that day.

The track of totality over India is shown in more detail in Fig. 4. The urban centres of population where the eclipse would be visible include Karwar, Hubli-Dharwar, Gadag and Raichur in Karnataka, Nalgonda, Mahboobnagar and Khammam in Andhra Pradesh, Koraput, Berhampore, Puri and Bhubaneswar in Orissa. The centre of totality would pass directly over the sun-temple at Konarak, before going over the Bay.

Although the shadow traversed the Indian land mass towards the end of its track, the viewing conditions were very good. The altitude of the sun at totality over the Westcoast was about 39°. Over Puri, the totally eclipsed sun was 23° above horizon. Table I gives the altitudes of the sun at mid totality from places lying close to the centre of track of totality in India. The climatological conditions inferred from last several decades records indicate a high possibility of clear skies over the entire track.

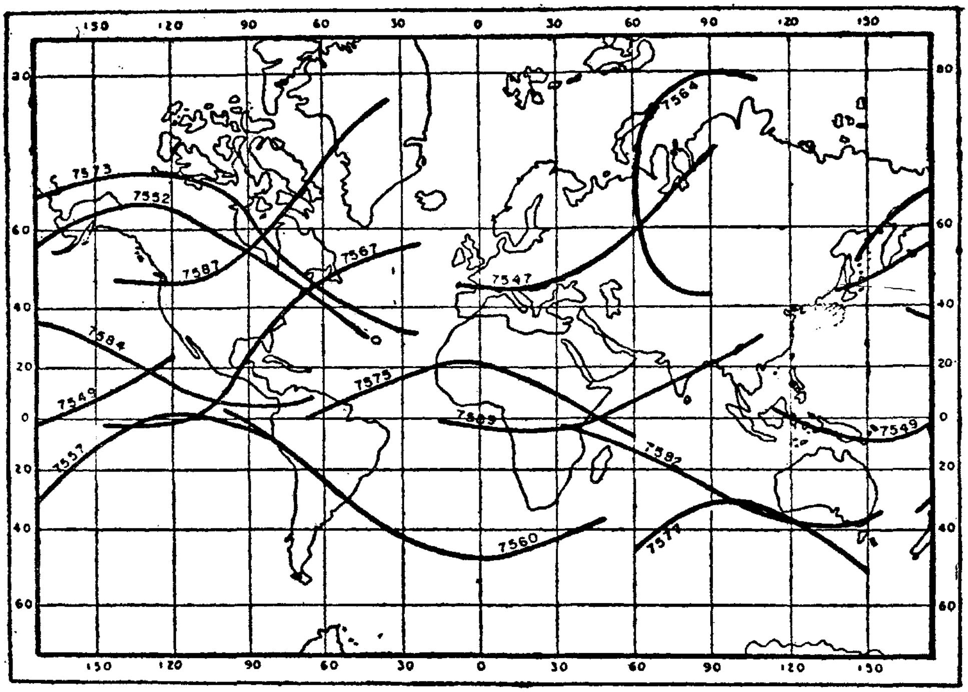

FIG. 2. Total solar eclipses since 1960. 7547 1961 Feb. 15; 7549 1962 Feb. 4–5; 7552 1963 July 20; 7557 1965 May 30; 7560 1966 Nov. 12; 7564 1968 Sep. 22; 7567 1970 May 7; 7573 1972 July 10; 7575 1973 June 30; 7577 1974 June 20; 7582 1976 Oct. 23; 7584 1977 Oct. 12; 7587 1979 Feb. 26; 7589 1980 Feb. 16.

The conditions are in marked contrast with the two earlier total solar eclipses which visited India in the present century. The first happened on 21st August 1914, when totality occurred at sunset over Baluchistan, then a part of India. The second occurred on 30th June 1954, when the shadow track starting over Canada ended again at sunset, over the Rajasthan desert. In the dust-laden atmosphere of mid-summer, and the sun barely above horizon, optical observations of the total phase were practically impossible. On that count, the eclipse of 16th February 1980 was the first total eclipse of the present century, that was visible from India, when not only important scientific observations were possible, but also showed the full glory of the eclipsed sun.

The last time such an opportunity happened was on 22nd January 1898, when the shadow track crossed Maharashtra and Central India. From their base at Ratnagiri, the British Expedition for the first time obtained the near ultraviolet spectrum of the solar chromosphere. John Evershed, a member of this team who joined the Kodaikanal Observatory six years later, was destined to make several discoveries about the solar atmosphere; one of his famous discoveries concerning motion of gases around sunspots, bears his name in golden letters in astronomical literature. The 1898 eclipse is also memorable from another point

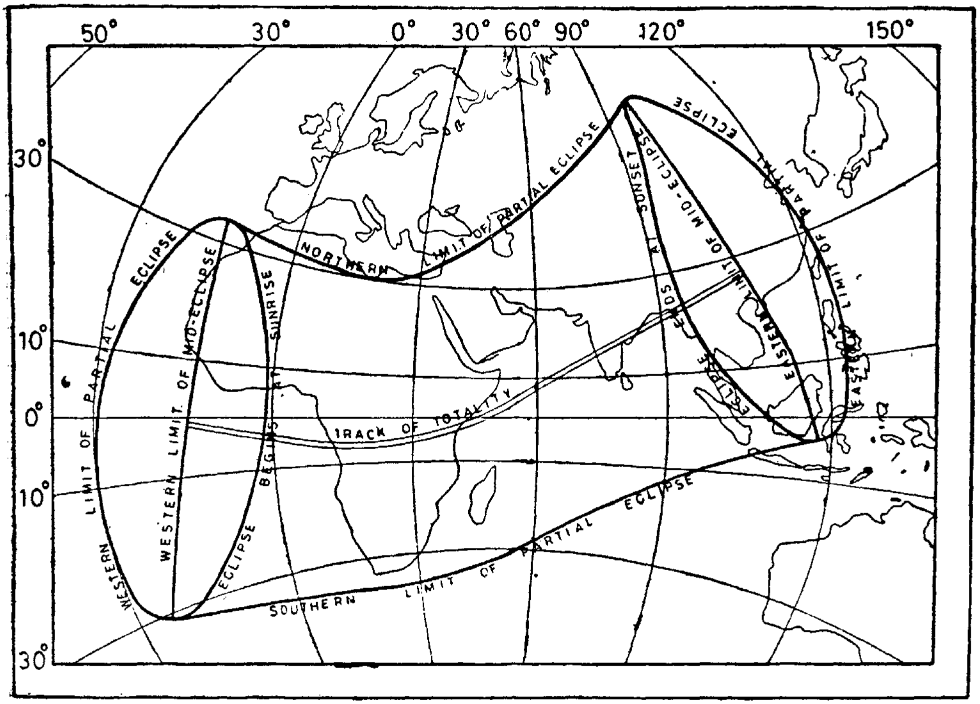

FIG. 3. Track of totality.

of view; for the first time an expedition team led by an Indian Scientist successfully carried out a series of observations. The leader was Professor N. D. Naegamvala, of Poona, who set up the observing team at Jeur in Maharashtra.

Observations carried out during a total solar eclipse can be broadly classified into four major groups : (1) observations of the eclipsed sun; (2) observations of geophysical effects; (3) observations taking advantage of the very low illumination around the sun; and (4) biological responses.

Most decided advantage in the observations of the eclipsed sun is bestowed on the group observing in the optical region. The few minutes of totality is the only period when valuable data about the corona and the chromosphere can be obtained from a ground based location. In spite of the availability of space platforms, the eclipse observations still provide the finer measurements of these features.

Radio observations do not have this full advantage of eclipse conditions; partly, because no total radio eclipse is ever seen from the surface of the earth. The size of the radio sun being much larger, only a part of the emitting source is blocked. Nevertheless, the eclipse observations provide means of studying distribution of small bright regions on the sun, with a higher degree of accuracy than that obtained by normal means.

For geophysical observations the eclipse provided a useful condition in which the responses of our terrestrial atmosphere could be studied. Sudden covering

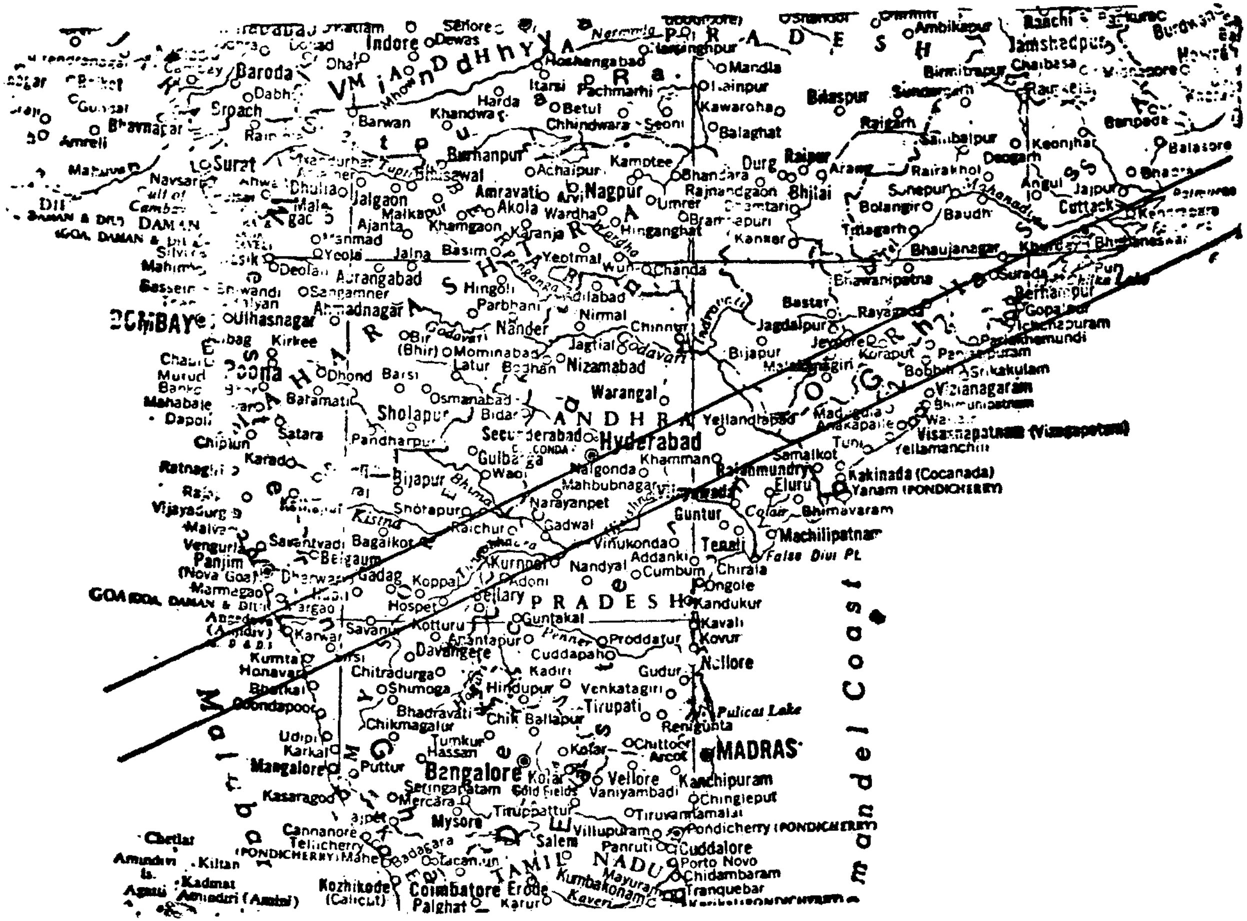

FIG. 4. Track of totality over India,

TABLE I

Altitudes of the sun at mid totality

Mid totality		Location	Lat.	Long.	Approx. duration	Altitude
U.T	I.S.T.					
$10^h\ 11^m$	$15\ 41^m$	Ankola	14°40′	74°8′	2^m50^s	39°
10 13	15 43	Gadag	15°25′	75°38′	2^m45^s	37°
10 16	15 46	Raichur	16°12′	77°21′	2^m40^s	35°
10 19	15 49	Nalgonda	17°04′	79°16′	2^m33^s	32°
10 26	15 56	Puri	19°48′	85°49′	2^m13^s	23°

and uncovering of the ionizing sources on the sun provided experimental step functions, whose effect on the ionosphere gave valuable information about the physical and chemical processes of the formation of ionized layers. Sudden changes in the radiation flux induced peculiar responses in the lower atmosphere, from which properties of these layers could be critically studied.

The unusual conditions of low sky brightness during totality provided opportunities for search of faint comets, asteroids etc. which normally escape attention at other times. Experiments for the verification of some aspects of the Theory of Relativity are being conducted in almost every eclipse since 1919; small shifts in the positions of stars close to the eclipsed sun's limb as predicted by the theory are sought to be measured.

Biological responses of plants and animals are another field in which experiments were conducted. The unusual conditions of darkness at midday evoked changes in behavioural pattern in some species, which were of extreme interest to studies of this discipline.

One particular aspect of the biological response problem although not formally studied deserved a special mention; and that is the psychological effects of this unusual event. Every eclipse observer carries in his mind the experience of living through a dream. In the last few moments prior to totality, the light faded rapidly, bands of shadow moved all around and stars appeared in the sky. The eclipsed sun changed appearance from a thin crescent to a string of bright points like a diamond necklace: then the pink chromosphere flashed out and totality began. For a few minutes, the bright halo surrounding the eclipsed sun became the most glorious object in the star-studded midday sky. The entire sequence of events was so unusual that it left a deep lasting impression on all viewers' minds. Then, after a lapse of a few minutes a reverse sequence of events rushed through to herald the end of nature's grandest show.

To sum up, total solar eclipses provide rare opportunities for study of nature and this event was visible from Indian soil on 16th February, 1980 after a lapse of almost a century.

Note: As the article refers to a past eclipse as on date, few editorial changes have been made with the author's consent.