POLAR AND TROPICAL AURORÆ: AND THE ISOAURORAL DIAGRAM

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I. INTRODUCTION

It is a pleasure to be among those who pay tribute to the long, distinguished and devoted scientific career of Dr. K. R. Ramanathan, President of the Association of Meteorology (part of the International Union of Geodesy and Geophysics), on the occasion of his sixtieth Birthday. The topic here discussed is closely related to the subject (Terrestrial Magnetism) chosen by him for his Presidential Address to the Physics Section of the Indian Science Congress in 1939—one of the many branches of geophysics to which he has given fruitful attention.

The aurora polaris or polar light is observed commonly in high latitudes in both hemispheres, as the northern lights or aurora borealis, and the southern lights or aurora australis. Its panoramic beauty and changing form, colour and position much enhance the interest of the night sky in those regions, even to primitive human minds; and to those who know something of its origins and its widespread associations—with the distant sun, and with the geomagnetic field proceeding from deep within the earth—its delights are intellectual as well as visual.

India is far from the usual regions of its appearance; but on very rare occasions it has been seen there, at least in the more northerly parts; and I am told that there are passages in the sacred literatures of India that are interpreted as referring to the aurora borealis. Though the aurora is rightly named polar, it is a phenomenon not wholly withheld from tropical gaze, either north or south of the equator. When visible from the tropics the aurora may justly be accorded the name tropical; in general, if not invariably, on the rare occasions of its occurrence the aurora tropicalis and the aurora polaris are one phenomenon. It is one to which, on account of its rarity in India, little attention has been given even by the atmospheric physicists of India; but part of the purpose of this paper is to propose that records of its observation from India should be searched for among the
dusty records of the past—from newspaper files and archives of events of former decades—because of their value and interest to-day.

2. **The Isochasmic Diagram (Fritz)**

Herman Fritz, Professor at the Eidgenössische Polytechnic at Zürich, was one of the founders of the science of auroral morphology—the study of the geographical distribution of auroral appearance over the earth, and of its changes in the course of the day, the year and the sunspot cycle. In 1873 the Vienna Academy of Sciences (Wissenschaften) published his great catalogue (Verzeichniss) of aurora borealis (and australis), the result of immense labours of compilation of auroral reports derived from very widespread sources, indicated therein. Already in 1866 he had found from his studies that the frequency of visibility of aurora does not increase steadily towards higher latitudes, but that there is a line or zone of maximum frequency of visibility, along which the aurora can be seen on every clear dark night; this is called the **auroral zone**. It is a nearly circular oval of radius about 23° angular or over 1,500 miles linear, centred not at the geographical pole, nor at the north pole of magnetic dip (76° N., 102° W.), but at a point that can be identified as the pole of the **geomagnetic axis** of the earth (79° N., 70° W.); this point may therefore also be called the **auroral centre**. The frequency of visibility of aurora decreases on proceeding either north or south from this zone. As Fritz remarked on p. 67 of his treatise "Das Polarlicht" mentioned below, the existence and rough position of the auroral zone had already been realized many years earlier by Muncke, who wrote an article "Nordlicht" in the second edition of J. S. T. Gehler's *Physikalisches Wörterbuch*, 1825–1845; and in 1860, E. Loomis, in "Silliman's" *American Journal of Science and Arts*, 30, 79–100, clearly indicated that the frequency of auroral visibility has a zone of maximum, and published a tentative diagram showing a maximum zone in which the average yearly number of visible auroral nights is 80, and inner and outer bordering zones in which the number is 40; Loomis's position for the auroral centre was about 83° N., 60° E. or about 5° distant from the more accurate position found by Fritz. Added 14 Jan. 1953.

In 1874 he gave a map showing **isochasms** or lines of equal frequency of (nights of) auroral visibility; these oval lines lay outside the auroral zone, and were approximately parallel to it; they indicated the places along which aurorae could be seen 100, 30, 10, 5, 1 and 0.1 times per year (in the average over many years). Inside the auroral zone he drew only one line (not an isochasm), along which the aurora is visible as often to the north as to the south—the line of 'neutral' directivity of auroral visibility (Fig. 1).
In 1881 he published his famous treatise "Das Polarlicht", describing these and allied researches by himself and others, and summarizing the auroral knowledge and speculations of that time.

3. Modern Isochasmic Diagrams (Vestine, Snyder)

Though Fritz's diagram was constructed by a simple method lacking in some refinements, it was a most valuable contribution to geophysics; and it was not superseded until, after 80 years, Vestine produced a modern isochasmic diagram, constructed by improved methods, and based not only on the data collected by Fritz—extending from 503 B.C. to 1872 August—but also on the new data furnished by the two International Polar Years (1882/3 and 1932/3), and by many other modern sources. The auroral zone and the six outer isochasms given by Fritz needed some but not much amendment; and Vestine not only gave 9 instead of 6 outer isochasms, but also 4 inner isochasms; the innermost has a radius rather less than half that of
the auroral zone, and corresponds to 50 nights of auroral visibility per average year.

The outermost isochasm given by Vestine, as by Fritz, was still for 0.1 visible occurrence per average year. In the longitudes of India it lies nearly along the circle of latitude 47°, far to the north of India.

A year later, Vestine and Snyder published a valuable isochasmic map for the aurora australis. Besides showing the southern auroral zone, two inner and three outer isochasms were drawn; the outermost corresponds to 5 visible occurrences per average year; the material on which this diagram is based is far less than that which underlies the northern diagram.

4. NEED FOR ISOAURORAL DIAGRAMS

Valuable as are these important diagrams, they need to be supplemented by a new kind of auroral diagram giving isoauroral lines or isoaurores. These are defined as lines at all points along which there is the same frequency of (nights of) auroral occurrence above the point, instead of the same frequency of visibility from the point. Though to the general public such diagrams might not be of such direct interest as the isochasmic diagrams, they would represent more precisely the geographical distribution of occurrence, and would be of greater value to the auroral theorist, by indicating the extreme limits of latitude of occurrence which auroral theory, however satisfactory it may become for the ordinary high latitude aurore, must also be able to explain.

The conception of the isoauroral diagram is obvious when once presented, but (so far as I know) it was a novel conception when it first occurred to me in the summer of 1950, while I was Research Associate at the California Institute of Technology, working on a U.S. Signal Corps contract. Dr. Vestine, with whom I corresponded on the matter, while concurring in the importance of such a diagram, emphasized the magnitude and difficulty of the task of its preparation.

Since then I have referred to the isoauroral diagram in several lectures on the aurora, and also in correspondence with Mr. J. Paton of the University of Edinburgh (Director of the Auroral Section of the British Astronomical Association), in connection with his plans for the extension of auroral observation in Britain, and also elsewhere, by British air pilots. I have particularly stressed the importance of observers recording occasions when they see aurora lying or passing overhead; in the case of such zenithal occurrences, the latitude of the aurora is unambiguously determined; when the
elevation of the aurora above the horizon is less than 90°, its determination is of great value for use with any similar determinations made by observers situated to the north or south, though it may be difficult always to be sure that the measured elevations refer to the same time and same point of the aurora; without such simultaneous observation from more than one place, the measurement of the elevation (and azimuth) of auroral points does not determine the location of the point unless its height is known. The Norwegian observations of auroral heights—particularly those by Störmer and Harang—show that though there is a normal statistical distribution of height (varying, however, with latitude, e.g., as between Northern and Southern Norway), there are special types of aurorae—not necessarily recognizable at sight—whose height distribution departs considerably from the normal.

Next in definiteness to observations of overhead aurorae are pairs of observations of the same aurora from two places, from one of which it is seen to the south, and from the other to the north, indicating that the true latitude of the aurora lies between those of the stations: the respective values of the elevations above the southern and northern horizons will determine the true latitude at least approximately, as well as giving (a perhaps less accurate value of) the height.

Mr. Paton has emphasized some of these points in his circulars to observers. It may be hoped that through his efforts, and those of leaders in continental Europe, America and the Soviet Union, a more widespread network of auroral observers will be developed; the observations of air pilots will be of special value, because they are free from the limits imposed in the past by cloud cover. In this work the new techniques of radio observation of aurorae will also play a useful part. In a decade or so, with such more continuous and more quantitative observations, it should be possible to accumulate a body of auroral statistics surpassing in value all the long records of the past—so far as concerns geomagnetic latitudes above about 55°. This should permit the construction of the northern isoaurorae from the auroral zone down to this geomagnetic latitude; and the development of civil and military aviation over the northern polar cap will assist in the delineation of the inner isoaurorae, within the zone.

The delineation of the southern isoaurorae, around the south geomagnetic axis pole or auroral centre, is bound to lag behind, owing to the less favourable disposition there of habitable land, and the sparsity of land, sea and air traffic south of geomagnetic latitude — 55°.
The isochasm approximately coinciding with the circle of geomagnetic latitude 55° corresponds nearly to the visibility of about ten aurora in an average year, according to Fritz and Vestine.

**The Enumeration of the Isoaurores**

The general nature of the isoauroral diagram can easily be inferred. Our present knowledge, especially that embodied in the isochasms, suggests that the frequency of auroral occurrence is a function mainly of geomagnetic latitude, though the apparent fact that the auroral zone and isochasms are not truly circular signifies that geomagnetic longitude is a minor independent variable of the auroral frequency function. Hence the isoaurores may be expected to have almost if not exactly the same form as the isochasms; to this extent the patterns of the two diagrams will be closely similar. The difference will lie in the enumeration of the frequencies, isochasmic and isoauroral, associated with the same curve. Outside the north auroral zone, auroræ boreales are most commonly seen to the north; they differ among themselves in height (and in consequent range of visibility). At the frequently occurring lower limit of height of 100 km. an auroral point can be seen (if the sky is clear and the view is open down to the horizon) from a distance of over 1,120 km. or about 700 miles, corresponding in latitude to about 11°; even though an aurora may not be noticed unless it is elevated at least 5° above the horizon, yet, owing to the fact that it is likely to extend at least a few tens of km. above 100 km., it will contribute to the isochasmic frequency over a belt of latitude, to north and south of itself, at least 22° wide. If auroræ occurred at one definite height, it would be possible by a fairly simple mathematical transformation to derive the isoauroral numeration of the isochasmic curves from their isochasmic numeration; the actual height-frequency distribution of auroræ makes this a far more difficult task,—indeed, at present it is not feasible, because of the sparsity of reliable height determinations for auroræ in geomagnetic latitudes below about 60°.

It is at least clear that for geomagnetic latitudes less than about 65°, most of the auroræ seen will lie to the north, and the isoauroral frequency, of those lying actually above the places along a given isochasm, will be less than the isochasmic frequency. The ratio of the isoauroral to the isochasmic frequency is likely to decrease from nearly one, for the auroral zone itself, to zero at the geomagnetic equator; and similarly it is likely to decrease within the auroral zone, with increasing geomagnetic latitude, to some value as yet unknown, but perhaps significantly different from zero, at the auroral centre.
This implies that the number $N$ associated with the isoaurorae will decrease more rapidly, in passing both northwards and southwards from the auroral zone, than the isochromatic number; or in other words, for equal increments of $N$ the isoaurorae will lie more closely towards the zone than do the isochasms.

6. ISOAURORES AND ISOCORONES

The isoaurore numbered $N$ is the locus of places above which some auroral luminosity is observable on $N$ nights per year over the average of a long period of years. This simple conception can of course be elaborated; for example, an isoauroral diagram may be drawn for a particular local time, or a particular season, or a particular sunspot epoch; and one can imagine a continuous series of diagrams, permitting cinematographic representation of the variation of (average) frequency of overhead aurorae, with respect to local time, season or sunspot epoch.

The idea can also be extended in association not with time but with auroral character; for example, $N$ may refer to the average frequency of auroral coronas observed at the observing stations; in this case the auroral location considered is not in the celestial but in the magnetic zenith, whose celestial elevation varies with latitude; such lines may be called isocoronal or isocorones. Similarly isoaurorae may be delineated for red aurorae, or for auroral arcs crossing the zenith.

The $N$ coronae associated with an isocorone $N$ outside the northern auroral zone will be overhead at places somewhat to the south of the isocorone. At these places other (non-coronal) aurorae such as arcs may also occur; hence at these places the isoauroral number will exceed $N$. As the isoauroral number increases with latitude (up to the auroral zone), its value for the isocorone $N$ will a fortiori exceed $N$. Hence the isoaurore $N$ must lie outside the isocorone $N$.

It is an interesting subject of enquiry to determine the lowest geomagnetic latitude at which auroral coronæ appear.

7. ISOAURORES BELOW GEOMAGNETIC LATITUDE 55°

As suggested in § 4, energetic widespread observation of aurorae above geomagnetic latitude 55° may in a decade or so enable reliable isoaurorae to be drawn for the region between this latitude and the auroral zone. Below 55°, however, where aurorae occur only rarely, a longer period of observation is necessary. A future of unknown duration may be expected to provide the data for the complete construction of the isoauroral diagram;
but if it is desired to construct a provisional diagram now or in the near future, recourse must be had to past records.

From these I hope soon to evaluate the isoaurores over England down to its southern limits, in geomagnetic latitude about 53°. Even so limited a task involves much searching among old periodicals and other records. My experience leads me to think there may be a wealth of auroral information scattered throughout such sources, including old newspapers which in some cases may have long lapsed and been forgotten. This material may become more numerous the higher the latitude, up to the limits where settlement and civilization becomes sparse. Where aurorae are common it is not worthwhile delving into such sources, but with decreasing latitude and auroral frequency, the task becomes more worthwhile, and also more limited, in the sense that the dates for which a search is likely to be fruitful are already known from existing catalogues of aurorae and magnetic storms.

Of course much of the old records brought again to mind by such a search will be vague and unquantitative, and therefore of little value. Here and there however, reliable definite items of information will accrue, which will help in reconstructing at least some 'picture' of the development in time of the position, form and colour of the past aurore, for use in the construction of a provisional isoaauroral diagram.

**INDIAN AURORÆ**

Particular interest attaches to the most extreme aurorae, whose range of visibility has extended even into the tropics. Owing to the obliquity of the geomagnetic axis, such extension is easier in and near the longitudes of the auroral centres (70° W. in the north, and 110° E. in the south) than midway between. India, with a range of longitude from about 70° to 90° E., is rather unfavourably placed for auroral observation; the geomagnetic (gm.) latitude there is about 10° less than the geographic (gg.), e.g., for Bombay, 72°·8 (E.) it is 9°·5 (gm.) as against 18°·9 (gg.), and for Madras, further east (80°·2), it is 3°·1 (gm.) as against 13°·1 (gg.). In the north, India and Pakistan, including Kashmir, extend to about 25° geomagnetic latitude, nearly the same as Tokyo; at the best, therefore, the expectation of aurorae visible from India is very low. This however, imparts exceptional importance to any that have been seen there.

Fritz's catalogue lists only two such, and one of these (*Verzeichnis*, p. 160) refers to "an aurora-like appearance seen near the western horizon from Benares on 1847 November 11; I have now looked up his sources which give the additional information (though without an indication whence the report came) that the appearance was like a comet's tail, and later took
a snake-like form and disappeared in 10 minutes. In his *Polarlicht*, (p. 61) Fritz terms this observation "somewhat questionable", and this view is supported (in the absence of clearly favourable evidence) by the fact that in general, when aurorae appear beyond their usual range of latitude, they are exceptionally brilliant and widespread in that range, and are accompanied by magnetic storms and strong earth currents. These associated phenomena were apparently not observed on 1847 Nov. 11, though on that date (as on very many others) aurora was observed at New Haven, Conn., U.S.A., and at Jakobshavn (N. Greenland). The Benares report probably refers to a somewhat long-lasting meteor trail.

The other case noted by Fritz (*Verzeichnis*, p. 244 for aurora borealis, p. 255 for aurora australis) was that of 1872 Feb. 4, discussed in § 10. This case cannot be doubted, and is of great interest.

Prof. D. S. Kothari in 1949 kindly drew my attention to another report of an aurora seen from India, and recorded by Joseph Dalton Hooker. This report is reproduced in § 8 and discussed in § 9.

It seems to me somewhat unlikely that the aurora has been altogether beyond visibility, at least in northern India, before and since 1872. I think it is much to be desired that a future auroral watch be kept, by professional and amateur astronomers and naturalists in northern India, and that warning should be broadcast when solar disturbance makes it somewhat probable that a magnetic storm and a great auroral manifestation may occur: so that the occasions when there is some chance of observing another Indian aurora may not be missed. Further, I would suggest that the newspapers and other periodical literature and records in Lahore and other northern centres should be searched for auroral references, particularly relative to the dates of the greatest aurorae and magnetic storms of the past century and a half.

8. Hooker's Auroral Report (pointed out by Dr. D. S. Kothari)

On the night of 1848 Feb. 14, J. D. Hooker with three companions (Messrs. Williams, Haddon and Theobald) were on the east bank of the Soane River, at 24° 52' N., 84° 22' E., altitude 345 feet, in geomagnetic latitude 13° 6' N. The sky was calm and clear, the moon three quarters full, and bright.

At 9 P.M. they saw about 30 "lancet beams rising in the north-west, from a low luminous arch, whose extremes bore W. 20° S., and N. 50° E.; altitude of upper limb of arch 20°, of the lower 8°. The beams crossed the zenith, and converged towards S. 15° E. The extremity of the centre
one bore S. 50° E., and was 45° above the horizon. The western beams approached nearest the southern horizon. All the beams moved and flashed slowly, occasionally splitting and forking, fading and brightening; they were brightly defined, though the milky way and zodiacal light could not be discerned, and the stars and planets, though clearly discernible, were very pale."

"At 10 P.M., the luminous appearance was more diffused, the upper limb of the arch less defined; no beams crossed the zenith, but occasional beams appeared here and faded away."

"Between 10 and 11 P.M., the beams continued to move and replace one another, as usual in aurorae, but disappeared from the south-east quarter, and became broader in the northern hemisphere; the longest beams were near the north and north-east horizon."

"At 10-50 P.M., the dark band had increased so much in breadth that the arch was broken up in the north-west, and no beams appeared there. Eighteen linear beams rose from the eastern part of the arch, and bore from north to N. 20° E."

"Towards 11 P.M., the dark band appeared to have replaced the luminous arch, the beams were all but gone, a few fragments appearing in the N.E. A southerly wind sprang up, and a diffused light extended along the horizon."

"At midnight, I saw two faint beams to the north east, and two well-defined parallel ones in the south-west."

9. DISCUSSION OF HOOKER’S REPORT

Though Hooker’s book was published in 1854, its mention of observation of an aurora clearly remained unknown to Fritz, whose Catalogue does not include it; but on p. 161 it notes that on 1848 Feb. 14, aurorae were observed at Christiania (now Oslo), where Hansteen saw a strong arc between 9 and 10 P.M. local time (about 5 hours later than Hooker’s first observation), and at Montreal and Toronto, Canada.

But one would expect an aurora thus visible in India to be a very outstanding one, visible at many other places down to and even beyond the same low latitude, and associated with a very great magnetic storm. Enquiries on the latter point elicited from Dr. S. L. Malurkar, Director of the Bombay Observatory, and from the Astronomer Royal, the information that 1848 Feb. 14 was not a day of great magnetic disturbance at Bombay or Greenwich (at that time, some years before automatic photographic recording was introduced, the magnetic instruments were read by eye only,
thus no continuous record was available). The Catalogue of Fritz shows that there was no worldwide auroral display on that night.

What, then, should one think of Hooker's account? He mentions in his book (1854) that "the appearances are as noted in my journal at the time". He added: "They so entirely resembled auroral beams, that I had no hesitation at the time in pronouncing them to be such. This opinion has, however, been dissented from by some meteorologists, who consider that certain facts connected with the geographical distribution of auroras (if I may use the term), are opposed to it. I am well aware of the force of these arguments, which I shall not attempt to controvert; but for the information of those who may be interested in the matter, I may remark that I am very familiar with the aurora borealis in the northern temperate zone, and during the Antarctic expedition was in the habit of recording in the logbook the appearance presented by the aurora australis. (My companions), who were also witnesses of the appearances on this occasion, considered it a brilliant display of the aurora".

These statements, and the excellent objective quantitative record of the appearance, so like the best descriptions of undoubted aurorae, indicate that what Hooker and his companions observed was an objective phenomenon, and give some confidence that it was in fact an aurora. On this interpretation, it was one which was unusual in that the area over which it seems to have appeared was limited. As far as I know, there are few if any other such well authenticated "limited-area" low-latitude aurorae. However, as the arch rose to an elevation of 20°, and as the 'beams' (more commonly called rays) crossed the zenith into the southern half of the sky, it seems almost impossible that they should have escaped all other observation (despite the bright moon) over the great area within whose range of visibility they must have been presumed to lie. This would almost certainly have included Allahabad, Benares and Patna, not improbably Cawnpore, Lucknow and Calcutta, and perhaps Delhi. I would suggest that the newspapers published shortly after 1848 Feb. 14 in these cities should be examined to find any references they may contain to this phenomenon.

The year 1848 was certainly a year of exceptional auroral frequency, and a sunspot maximum year of decidedly high sunspot number; it included six (an unusually large number of) crimson aurorae, which rarely occur at other sunspot epochs (Fritz, Polarlicht, p. 135). This adds to the probability that what Hooker observed was a real aurora.

Incidentally this reference to red aurorae calls to mind the one surprising omission in Hooker's report, the absence of reference to the colour
of the beams and arches; this suggests that his aurora was not crimson, or he could scarcely have failed to say so.

However, this Section raises anew the question of the appropriate meaning of the word *aurora*. The late Lord Rayleigh introduced the term *nonpolar aurora* to signify what is now more often called the *night airglow*—or light of the night sky as seen at times of geomagnetic calm, or uncomplicated by the polar aurora associated with the entry of particles into our atmosphere from outside. Though patches of special luminosity—sometimes emitting the sodium 'lines'—are at times seen in the night sky, the night airglow usually differs greatly in appearance and distribution from the aurora polaris, which Hooker's aurora so strongly resembled, though its apparently isolated regional character seems to distinguish it sharply from almost all other auroræ seen in low latitudes. The only other low-latitude account I have come across at all similar to Hooker's, is one by A. Poey, Director of the Havana Observatory, Cuba, 23° 9' N., 76° 3' W.; 34° 3' gm. N. On the night of 24/5 March 1860 he saw from Havana an aurora to the east, of arc form, showing marked undulations and fluctuations, and appearing and disappearing over an interval of 5 hours—11 P.M. to 4 A.M.—as recorded in the *Comptes Rendus*, 1860. Fritz mentions this in his *Verzeichniss*, but records to other aurora seen elsewhere on that night.—Dr. C. T. Elvey informs me that he will shortly publish an account of some unusually definite forms of the night airglow seen from Texas.—Added 14 Jan. 1953.

10. **THE INDIAN AURORA OF 1872 FEB. 4**

The aurora of 1872 Feb. 4 was certainly one of the greatest on record; Fritz in his Catalogue (p. 244) mentions two places in India where it was observed, Bombay (gm. lat. 9° 5') and Lahore (31° 34' N.; 74° 21' E.; gm. lat. 22° 1'). He adds that Jannsen was observing in Ceylon (7° N. gg.) that night, and does not mention seeing an aurora. In *Polarlicht* (pp. 32, 151) Fritz mentions also Raikote (30° 39' N.; 75° 35' E.; gm. lat. 21° 1') with Bombay and Lahore. He does not give his sources for these Indian observations; *Nature* (1872, 5, 323) quotes from a letter of Feb. 5 by George Draper, of the British Indian Submarine Telegraph Company, that the aurora was visible at Bombay, but without details of the Bombay auroral observations; and I have been unable to find (as yet) any useful details about the Indian observations at the above three places, in any literature accessible to me in England.

However, at my request, Dr. S. L. Malurkar kindly made a search in the great Bombay newspaper *The Times of India* for some days after 1872 Feb. 4, and supplied me with four extracts from the issues for (a) Feb. 6,
(b) Feb. 12, and (c, d), Feb. 15; for Feb. 15 there were two reports, one of them (c) being taken from the Delhi Gazette for Feb. 12. I have no space to reproduce these extracts here; I hope to use them in a future study of this aurora, together with a great amount of material from other parts of the globe. But I may mention that all four reports contained useful information relating to observations from Bombay, Rawal Pindi, Madhopore and Jacobabad. They also mentioned that the aurora had been visible from the following other Indian places, Lahore, Mooltan and Sukkur, and, outside India, from Aden. (The geomagnetic latitude of Aden, 9°, seems to be slightly less than that of Bombay, and the Aden observation, thus noted from a newspaper, constitutes, as far as I yet know, the record extension of auroral visibility towards the geomagnetic equator.)

Professor S. K. Mitra has at my request kindly sought for Calcutta references to this aurora; the Journal of the Asiatic Society for 1872 and 1873 contains no mention of this aurora. The Statesman files in Calcutta are incomplete before 1875, but I hope may be searched from London files.

I would suggest to scientists of India that it is worthwhile to continue the search for Indian observations of this aurora, south as well as north of Bombay, with the aim of determining the southern limit of its visibility over India, and all quantitative details as to geometry and times, that may contribute to our knowledge of this remarkable event. I hope similar searches will be made in the records of other countries, and in nautical records, for low-latitude observations of this aurora (although a number of such are already in hand).

In addition, similar Indian data for other great aurorae might be looked for, with particular reference to the following:

1859 Aug. 28-Sep. 4.
1882 Nov. 17-21.
1903 Oct. 31-Nov. 1.
1909 Sep. 25.
1921 May 13-16.
1938 Apr. 16.

I hope also that a lookout for future auroral appearances visible in India may be kept, as suggested in § 7.

**SUMMARY**

(1) After describing the isochromatic diagrams of Fritz and Vestine, which map the distribution of frequency of auroral visibility from any point on
the earth, it is pointed out that there is a need for a new type of *isoauroral* diagram, showing *isoaurores* or lines of equal frequency of *occurrence above* any terrestrial point. The nature and "enumeration" of the isoaurores is discussed.

(2) The few auroræ which have been reported as visible from India are discussed: namely (1) one reported from Benares on 1847 November 11, (2) one reported by J. D. Hooker as seen on 1848 Feb. 14, from a point on the Soane River at 24° 52' N., 84° 22' E.—the validity of both these reports has been questioned—and (3) the undoubted case of the aurora of 1872 Feb. 4, seen as far south as Bombay, and from many more northerly points in India and elsewhere.

(3) An appeal is made for a search by Indian scientists for material relating to Indian observations of these and possibly other auroræ.

**REFERENCES**

2. ———— .. *Vierteljahrschrift der Naturforschenden Gesellschaft in Zürich*, 1867, 12.