THE ASSOCIATION OF PULSATING AND FLAMING AURORAS WITH COMPLETE IONOSPHERIC ABSORPTION AT MACQUARIE ISLAND

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Summary

Records of simultaneous auroral observations and ionosphere soundings at Macquarie Island (geomagnetic lat. —61·7°) show that pulsating or flaming auroras are frequently accompanied by complete absorption of the vertically incident waves. However, the nocturnal variations of frequency of occurrence of these two phenomena are markedly different in form.

I. OBSERVATIONS

Heppner, Byrne, and Belon (1952) have reported that at College, Alaska, a pulsating aurora at the zenith is frequently associated with complete absorption of vertical incidence radio waves. Pulsating and flaming auroral displays were observed at the Australian National Antarctic Research Expedition Station at Macquarie Island (lat. 54° 30′ S., long. 158° 57′ E., geomagnetic lat. —61·7°, magnetic dip 78°) on 48 nights between August 14, 1950 and April 15, 1951 (Parsons and Fenton 1953), and on 36 of these nights simultaneous ionospheric records were obtained with the vertical incidence automatic variable frequency recorder (Cohen 1952 ; Jeffrey 1953). Ionospheric soundings which took 2 min for the sweep from 1 to 13 Mc/s were made every 10 min, and all these records have been rescaled and matched with the corresponding auroral observations. Auroral observations were made sporadically and time interpolation of auroral observations to coincide with ionosphere recorder timing was often necessary. However, interpolation was considered valid only when the pulsating or flaming state was constant and interpolation was never made over a period greater than 5 min. The ionosphere recorder programme was controlled by a synchronous motor run from the Macquarie Island Station power mains and, owing to unavoidable power frequency variations, the times of recording are not as reliable as those appertaining to the auroral observations. The errors in simultaneity are not considered to be appreciable and their effect on the results should be negligible.

The auroral observers reported (Parsons and Fenton loc. cit.) : " Pulsating and flaming auroras were usually associated with very intense displays. Almost invariably confined to the northern sky or the region close to the zenith, they usually took the form of diffuse surfaces or scattered remnants of previously brighter draperies or coronas. The intensity was seldom very great. On no occasion did pulsating or flaming forms appear until a display had been in

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progress for some considerable time and on several occasions such forms were observed to persist until dawn.

Flaming auroras exhibited a general tendency for an upward sweep towards the magnetic zenith. Regular wave-like variations were infrequent but were of two distinct types, one in the nature of waves which brightened scattered areas of glow momentarily as they passed, the other in the form of a succession of regular arcs sweeping rapidly in a direction normal to their orientation. These latter were almost invariably directed towards the magnetic zenith but on one occasion very distinct waves following each other at intervals of about one second swept from approximately 20° south of the zenith to low in the northern sky."

II. Results

(*a*) *Pulsating and Flaming Auroras Associated with Complete Absorption*

Table 1 shows the results of an analysis of all reported pulsating or flaming auroral forms with simultaneous ionosphere soundings. On not one occasion were F echoes present without E_s and on the great majority of occasions when E_s was present F echoes were blanketed. An aurora in a region up to 10° in radius centred on the geographical zenith is classed as a zenith aurora.

Table 1

Occurrence of complete absorption during specific auroral displays*

Condition of the Sky	Total No. of Ionospheric Traces	Percentage of Traces showing Complete Absorption
Pulsating or flaming aurora	182	62
Zenith pulsating aurora ..	80	61
Non-zenith pulsating aurora	53	60
Zenith flaming aurora ..	17	65
Non-zenith flaming aurora ..	31	65

* The average percentage occurrence of absorption for all occasions irrespective of auroral appearance is 18 per cent.

(*b*) *Time and Seasonal Variations*

All the hourly records of the sporadic E-region between August 1950 and April 1951 inclusive during the hours when auroras could have been seen if the meteorological conditions were favourable were analysed to determine the percentage of observations when complete absorption was present. (The maximum amount of twilight in which an aurora may be seen is somewhat subjective and therefore the time limits when an aurora was seen by Parsons and Fenton were taken as a guide—roughly the period is when the Sun is lower than 12° below the horizon.) Complete absorption was seen to vary with hour and with month. The dashed line in Figure 1 shows the variation of percentage

of observations showing complete absorption with time of day for all days, independent of their magnetic character.

The magnetic character of the days on which simultaneous pulsating and flaming aurora or both and ionosphere records were made is shown in Table 2.

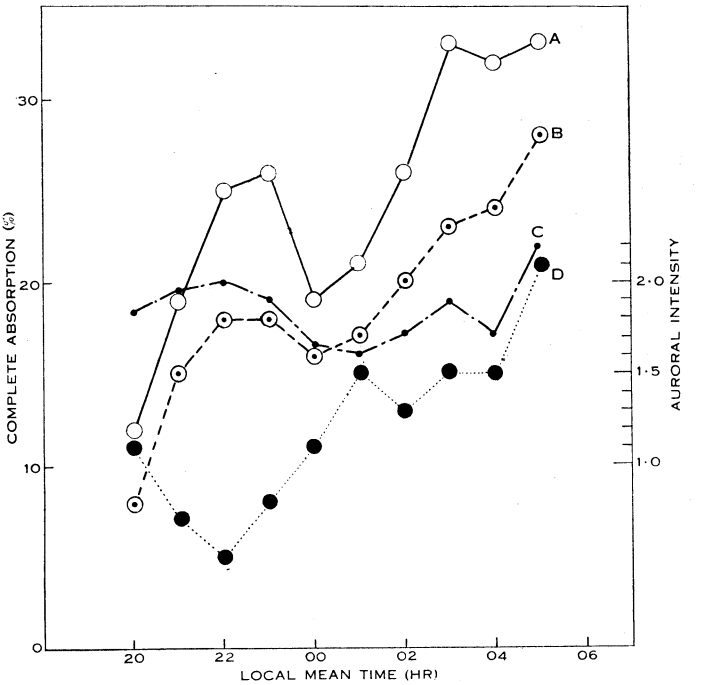

Fig. 1.—Curve *A*, nocturnal variation of percentage of observations showing complete absorption for the period August 1950 to April 1951 at Macquarie Island for all days except the 10 magnetically quiet days ; curve *B*, as curve *A* except that it includes all days of each month ; curve *C*, nocturnal variation of auroral intensity at Macquarie Island for the period May 1950 to April 1951 ; curve *D*, as curve *B* for College, Alaska for period September 1950 to April 1951.

Hourly E_s records for days other than the 10 quiet days of each month have been analysed revealing complete absorption characteristics as shown by the full line curve of Figure 1.

TABLE 2

MAGNETIC CHARACTER OF DAYS ON WHICH PULSATING AND FLAMING OR BOTH AURORAS OCCURRED

Magnetic Character	No. of Observations
5 disturbed days of the month ..	9
5 quiet days of the month ..	1
10 quiet days of the month ..	3
" Normal " days	24

For comparison, the dotted line curve of Figure 1 shows the percentage of observations showing complete absorption at College, Alaska, for the hours between the end of civil twilight and the beginning of civil twilight for every day of the period September 8, 1950 to April 16, 1951. Also for comparison is the

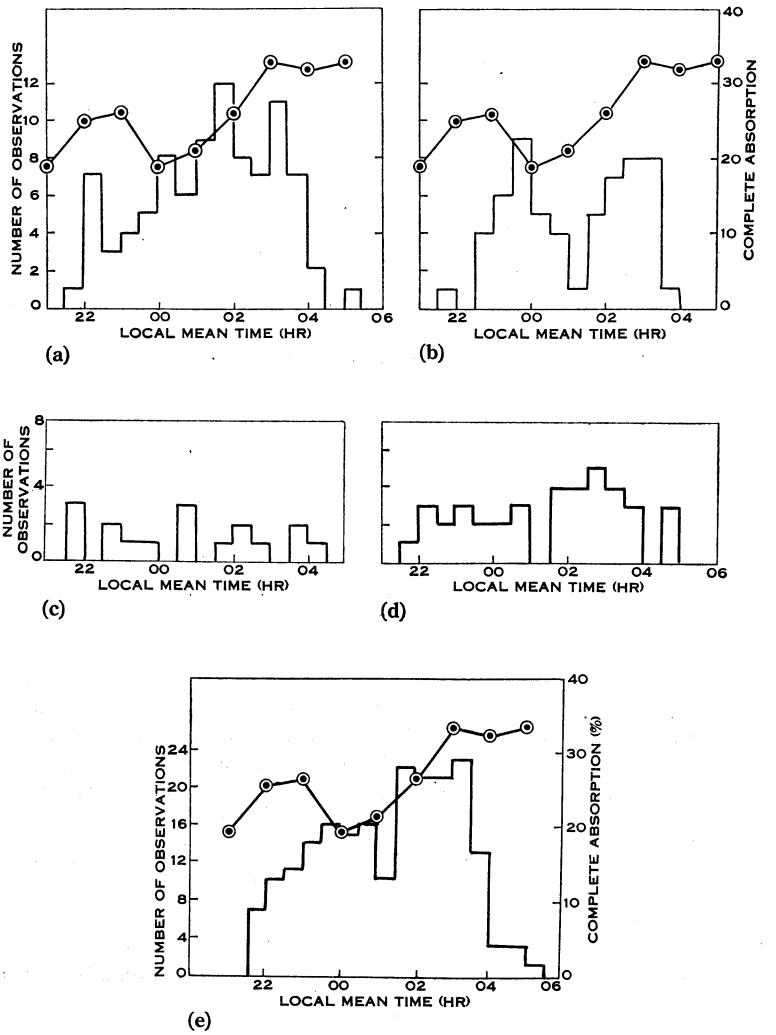

Fig. 2.—Nocturnal variation of observations of zenith and non-zenith pulsating and flaming auroras at Macquarie Island during the period August 1950 to April 1951. Curve *A* of Figure 1 is superimposed for comparison. (*a*) Zenith pulsating auroras ; (*b*) non-zenith pulsating auroras ; (*c*) zenith flaming auroras ; (*d*) non-zenith flaming auroras ; (*e*) all pulsating and flaming auroras.

broken line curve of Figure 1 (Jacka 1954) which shows the nocturnal variation of intensity of the aurora at Macquarie Island between May 1950 and April 1951. This curve gives the intensity of the brightest display (any form, any direction), observed during each hour, centred on the hour L.M.T.

The time of occurrence of pulsating and flaming forms is shown in Figures 2 (*a*)-(*e*) inclusive where the ordinates show the number of observations occurring within ½ hr periods. Superimposed on Figures 2 (*a*), (*b*), and (*e*) is the full line curve of Figure 1.

Figure 3 shows the monthly variation of occurrence of pulsating and flaming auroras and of total absorption for both 1950–51 and 1951–52 during hours when auroral observations were possible. The pronounced equinoctial effect may be exaggerated because less hours were available for observation in December and January than in other months.

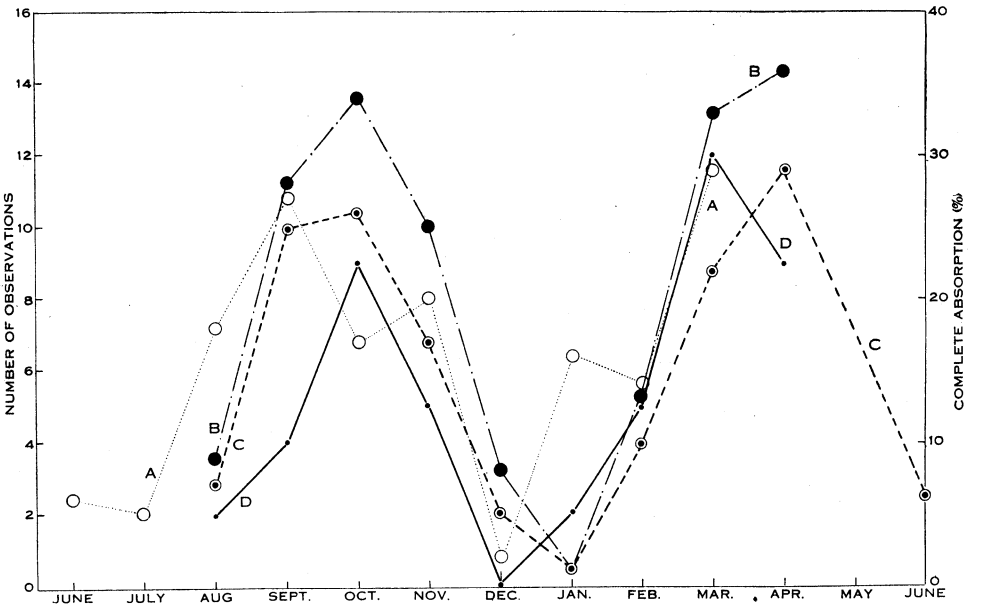

Fig. 3.—Curve *A*, seasonal variation of observations showing complete absorption during " auroral hours " for 1951-52 at Macquarie Island ; curve *B*, as curve *A* except that it refers to all days except the 10 magnetically quiet days of each month for 1950-51 ; curve *C*, as curve *B* except that it refers to all days of each month ; curve *D*, seasonal variation of observations of pulsating and flaming aurora at Macquarie Island for the period August 1950 to April 1951.

III. Discussion of Results and Conclusions

Table 1 and Figure 1 indicate that the percentage of traces showing complete absorption during pulsating and flaming auroral displays or both is at least twice the highest average percentage for any hour and may be compared with the results of Heppner, Byrne, and Belon (*loc. cit.*), who found 72 per cent. complete absorption from 239 traces during pulsating aurora at the zenith. The average percentage of traces showing complete absorption for all hours and all months at Macquarie Island is 18 per cent., while at College it is 14·5 per cent. It is interesting to note that the maximum frequency of occurrence of pulsating aurora near the zenith is at about 0200 L.M.T. at both locations. It is interesting also to note that non-zenithal and zenithal pulsating and flaming auroras give similar ionosphere absorption percentages at Macquarie Island.

The maximum of the full line curve of Figure 1 at about 2300 L.M.T. (which is also local mean magnetic midnight) and the minimum 1 hr later do not appear on any of the aurora occurrence diagrams of Figures 2 (*a*)-(*e*); indicating that neither this maximum nor minimum is a general enhancement or depression due to the occurrence or absence of pulsating or flaming auroral forms. Similarly it may be seen that such auroral forms are not most frequent when complete absorption is greatest. We may say simply that the occurrence of pulsating and flaming auroral forms or both is often accompanied by complete absorption of vertical incidence waves. There is a closer resemblance between the nocturnal variations of intensity of the aurora and frequency of occurrence of complete absorption than there is between frequency of occurrence of pulsating and flaming auroras and complete absorption.

It is impossible to assess the effect of cloud on the results. Macquarie Island is characterized by extreme cloudiness and rapid changes in cloud cover, and even on nights that are not completely overcast the overwhelming majority has a period when the sky is at least 7/8 clouded for some period. Of 244 nights between August 14, 1950 and April 15, 1951, 205 nights had a period of at least 7/8 cloud between 0000 L.M.T. and 0200 L.M.T.

The author is not able with confidence to join Heppner, Byrne, and Belon in saying that " absorption begins with the appearance of pulsating aurora and ends whenever it is replaced by non-pulsating aurora ", because no clear-cut minute to minute association of auroral forms and absorption or abnormal *E* occurrence has been found. Cloud interference considerably reduced the number of observations and while the remaining observations give some support to the above thesis there is also evidence to the contrary.

IV. Acknowledgments

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