RADIO ECHO OBSERVATIONS OF METEOR ACTIVITY IN THE SOUTHERN HEMISPHERE

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Summary

A further analysis has been made of 32,000 meteor echoes obtained during 1953 by radar apparatus operating at a frequency of 69 Mc/s. Monthly and annual mean diurnal rate curves have been drawn, revealing a strong similarity between southern and northern hemisphere results. It is concluded that most meteoric matter incident on the southern hemisphere, down to magnitude $+4\cdot5$, is confined to direct orbits closely following the plane of the ecliptic.

Subsequently the sensitivity of the equipment was increased to yield echo rates much higher than the equivalent visual rates. Analysis of the results obtained during February and March 1956, which are normally regarded as being months devoid of showers, reveals discrete radiant activity near the helion and antihelion positions. This result largely removes the former distinction between shower and sporadic meteors, since many of the meteors previously regarded as sporadic represent the upper limit of showers of minor-sized particles.

I. Introduction

A survey of meteor activity in the southern hemisphere was carried out during 1953, using conventional radar methods (Ellyett and Roth 1955). Radiants were calculated by the Clegg technique (1948), from range-time plots of meteor echoes. A rotatable beam aerial was used, directed respectively $22\frac{1}{2}$ °N. and $22\frac{1}{2}$ °S. of W. on alternate days. These radiant results, together with the known northern hemisphere shower data, showed that the major percentage of all showers, from either hemisphere, lay fairly close to the plane of the ecliptic. The southern results, representing meteors down to a magnitude of $+4\cdot5$, have now been further analysed in terms of monthly and annual mean diurnal rates, and show that most of the activity in the southern hemisphere arises from particles having direct orbital motion of low inclination.

Following this work, a departure has been made from the usual technique (Lovell, Banwell, and Clegg 1946; Hawkins and Almond 1952; and others) of maintaining the radar rate closely similar to the visual rate. The visual rate is essentially a property of the eye rather than of the total incident meteor flux. The sensitivity of the present radar equipment, operating at 69 Mc/s, has therefore been increased in order to record a much higher rate of specular reflections from small meteors. Approximate radiants, determined from the total rates, have shown that meteors appearing as sporadic at sensitivities equivalent to visual become part of a definite shower distribution at a higher

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sensitivity. This largely removes the former distinction between shower and sporadic meteors, since most of the meteors previously regarded as sporadic represent the upper limit of showers of minor-sized particles.

II. Monthly and Annual Mean Diurnal Rates

The aerial system and radar equipment used for the 1953 southern hemisphere meteor survey have already been fully described (Ellyett and Roth 1955). It is therefore sufficient to state that pulses of 75 kW peak power and 3·5 μsec duration were radiated at a frequency of 69 Mc/s and a recurrence rate of 145/sec. The aerial power gain was 75 compared with a half-wave dipole; and the receiver, of bandwidth 300 kc/s, had a noise factor of 6·8 dB.

A sporadic meteor has been defined as one which cannot be associated with any definite radiant. Monthly mean diurnal curves of sporadic meteor rate at 72 Mc/s have been given by Lovell (1954) for the northern hemisphere, over a 2-year period from October 1949 to September 1951.*

Owing to the complexity and degree of interlocking of the southern hemisphere night meteor showers in the June-August period and the still doubtful nature of a number of the more minor radiants, it has not proved possible in this case to separate the showers from the sporadic background. Groupings of longer-range meteors stand out clearly on range-time plots, and provide identification of most showers, but at the lower ranges such groupings overlap and mix randomly with sporadic meteors. Attempts to remove the meteors associated with any particular radiant become arbitrary and subjective. It has, however, gradually become recognized that shower meteors, at the visual observing level, constitute but a small proportion of the total influx. This has been noted for visual showers by Öpik (1934) and by Levin (1955). Hawkins (1956*a*), using radar equipment at a frequency of 72 Mc/s and a sensitivity similar to the present survey, finds that showers form less than 5 per cent. of the total number of incident meteors. The shape of the monthly mean rate curves at approximately the visual rate level should therefore not be altered greatly by including meteors belonging to showers. Such curves for 43·5 °S. latitude are given in Figure 1.

Equipment failure occurred in May 1953. Consequently the graphs for May 1954, obtained at the same equipment sensitivity, have been included, but have not been used in further analyses.

A strong general similarity is immediately evident between northern and southern hemisphere activity. In particular both groups show minimum activity in February, a progressive rise to June, almost comparable activity in July, and an intermediate rate in the second half of the year. The similarity of activity in the two hemispheres removes any possibility of appreciable ionospheric control of the recorded meteor rate.

One point of difference is in the May, June, July activity, which is greatest in the day-time hours in the northern hemisphere and during the night hours in the southern hemisphere. The northern daylight streams do not reach a

* See also Hawkins (1956*b*).

high elevation at 43·5 °S. and are overshadowed by the strong southern night radiants which occur at a mean declination of about $\delta = -20°$.

Following Lovell (1954), the observations shown in Figure 1, representing 32,000 echoes, although in some months not as complete as desired, have been used to obtain the annual mean curve for the diurnal variation of meteor rate. This curve is given in Figure 2 (*a*), from which Figure 2 (*b*) was obtained by normalizing, or giving equal weight to each month. Marked maxima occur in

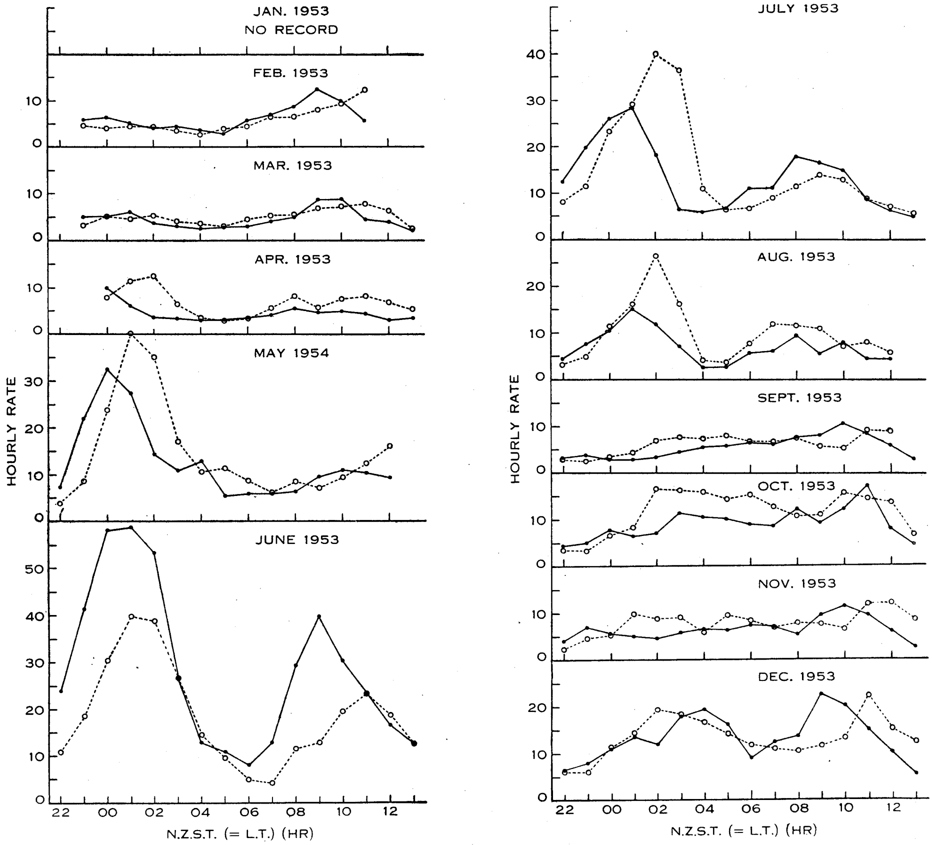


Fig. 1.—Monthly mean diurnal rates of meteor activity.
○ - - - ○ Southerly aerial. ●——● Northerly aerial.

the curves at mean times of $01^{h}\ 25^{m}$ and $10^{h}\ 10^{m}$ L.T. In this respect the result is almost identical with that obtained in the northern hemisphere. Both the 1949–50 northern survey and the 1953 southern survey show a similar lack of symmetry of the maxima about the apex of the Earth's way.

The northern maxima have been recognized (Almond, Davies, and Lovell 1952, 1953 ; Hawkins 1956*a*) as being due to meteors from near the helion and the antihelion directions, and hence represent a group of meteors moving in direct low inclination low eccentricity orbits. A surprising feature of the southern results is the almost complete absence of a peak at 0600 hr L.T.

Consequently, since the aerial polar diagram was similar to that used by Hawkins, and since showers have been included, the conclusion must be that the greater part of *all* meteoric matter incident on the southern hemisphere, down to the survey magnitude of $+4 \cdot 5$, is confined to direct orbits closely following the plane of the ecliptic.

This conclusion receives strong support from the photographic work of Whipple (1954), where both stream and sporadic meteors in the northern hemisphere are shown to be highly concentrated within an inclination of 35°. Kresák (1955) has reached a similar conclusion from a study of northern telescopic meteors. There are of course a number of very well-known high inclination northern showers. The possibility of similar southern showers cannot yet be ruled out, as surveys are incomplete. Likewise high inclination northern sporadic meteors are observed (Whipple 1951, 1954), which again may have their counterpart in the south. Nevertheless, the greater proportion of both sporadic and shower meteors in the southern hemisphere appear to be ecliptical.

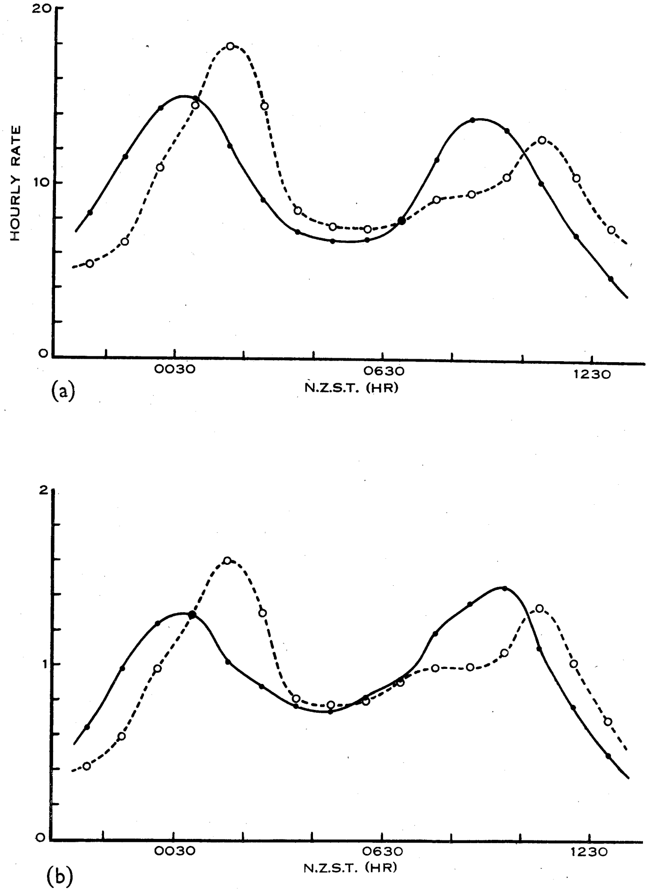


Fig. 2 (*a*).—Annual mean diurnal rate of meteor activity.
Fig. 2 (*b*).—Normalized annual mean diurnal rate.
○ - - - ○ Southerly aerial. ●——● Northerly aerial.

The only other known estimate of southern hemisphere radar rates, in this case for a mixture of sporadic meteors and minor showers, was obtained by Weiss (1955). His theoretical calculations on background meteors are based on a uniform distribution of radiants and activities. All the experimental evidence described above indicates an anisotropic distribution : hence theoretical rate curves calculated on an isotropic basis are no longer valid. Insufficient experimental data have been published by Weiss to make possible any significant comparison with the present results.

III. Showers of Minor Particle Size

(a) *Experimental Method*

Following a study of the requirements for maximum echo rate detection (Ellyett and Fraser 1955), it was decided to realize more fully the capabilities of the present radar equipment. This involved the sacrifice of all parity with visual rates. High-rate experiments were carried out during February and March 1956 ; the rate being achieved by increasing the pulse width from 3·5 to 26 μsec. The receiver noise figure was kept at the relatively poor value of 6·8 dB to ensure that cosmic noise variations did not influence the meteor rate.

These two months were chosen to correspond with the period of minimum meteor activity. The northern curves of monthly mean diurnal activity (Lovell 1954) show very little sign of the helion and antihelion maxima during these months ; and no appreciable showers occur. The 1953 southern curves do give a definite but small indication of a mid-morning activity. McIntosh (1935) records a very weak visual Corona Australis shower in mid March, but otherwise there are no significant showers known for this period in the southern hemisphere.

Rates during February were maintained at about 1000 to 2000 echoes in each daily 16-hr observing period. This rate corresponds to a limiting magnitude of +7·5. Because of the known deficiency of large meteors throughout this period of the year, the limiting magnitude may be above +7·5, since this value has been calculated by a rate comparison method. In the first 6 days of March, and after the 14th day an intermediate rate of about 625 echoes per 16 hr was maintained. From March 7 to 14 the rate was held at the low value of 175 per 16 hr, which is comparable with the 1953 survey rate.

Construction of high-rate range-time plots from the echoes on the photographic film becomes impossibly time-consuming. An example of such a plot is given in Figure 3. Drawing the usual vertical line for each meteor would completely obscure all the lower range echoes. It is difficult, by inspection of plots such as Figure 3, to find radiant groupings.

The method which was adopted for both the intermediate and the high rates is shown for the intermediate-rate plot of Figure 4 (*a*). Such plots were not normally made, but only the rate was read from the film directly, over half-hourly periods, to give the result shown in Figure 4 (*b*). Owing to the random nature of the occurrence of meteor echoes, even within a shower group, there will be statistical fluctuations in the echo rate. Consequently the half-hourly rate curve was smoothed in groups of three consecutive values, the central value being weighted by a factor of 2. Since the minimum width of a significant radiant peak is of the order of 1·0–1·5 hr, it was considered unwise to smooth over more than three values.

Approximate radiants can be obtained from families of these daily curves. (A simple method of obtaining accurate radiants from high-rate plots has since been devised, and forms the basis of a subsequent paper.)

(*b*) *Results*

The rate curves obtained, of which a selection is given in Figure 5, reveal a mid morning peak of activity persisting right through February, and still apparent, although shifted slightly in position, during most of March. The time displacement of the peak between the records from the two aerial positions

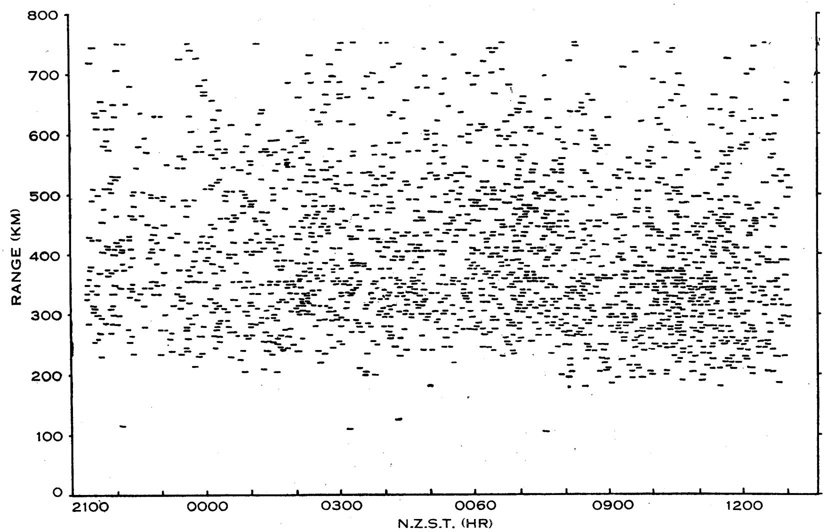
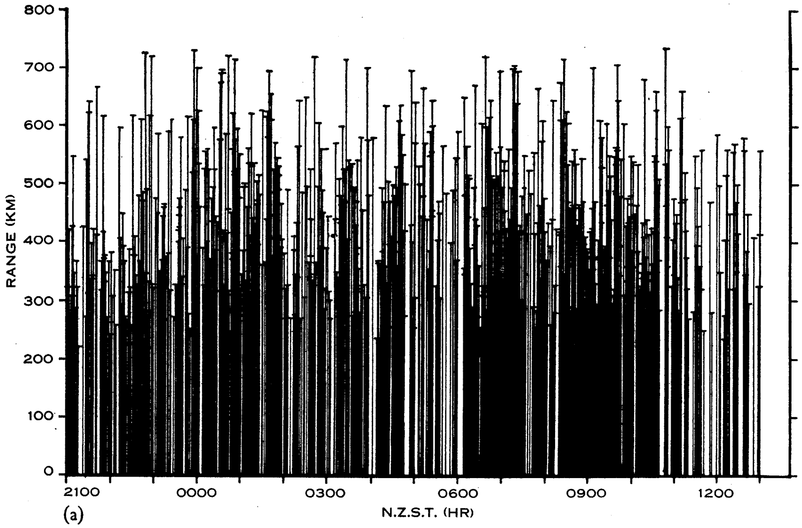


Fig. 3.—Range-time plot, February 4–5, 1956. Aerial azimuth 292½°.

was constant enough to prove that the cause was neither instrumental nor terrestrial. Some prominent but less regular peaks were also present between 0000 and 0400 hr L.T.

In order to find the coordinates of the radiant from which the mid-morning activity originated, assuming that there was only one radiant, the times of occurrence of the maxima were tabulated in weekly groups after reduction to a datum day. The declination was found from the average time difference between the maxima in each aerial. Range-time plots, adapted for the southern hemisphere from Clegg (1948), indicated that the time of local transit would occur approximately 1 hr after the mean of the times of maxima in the two aerials. In this way the Right Ascension was found. With this method of analysis, the maximum error should not exceed $\pm 5°$ in declination, and $\pm 10°$ in Right Ascension. The results are given in Figure 6, together with radiant positions of definite southern showers which occur at other months of the year (Ellyett and Roth 1955).

The newly found activity, of which some hint was given in the 1953 monthly diurnal curves, is again close to the plane of the ecliptic. It seems probable that there are either one or two fairly diffuse continuing radiants present which



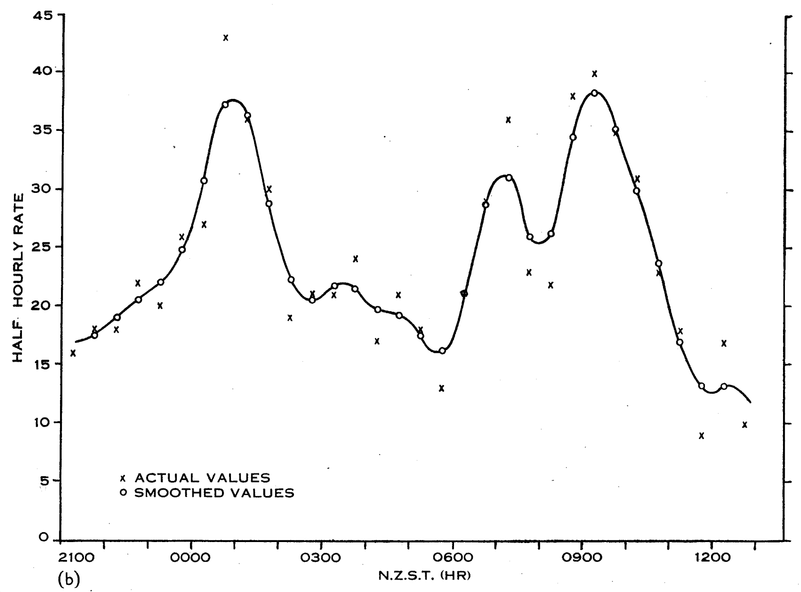


Fig. 4 (*a*).—Range-time plot, March 21–22, 1956, 2130–1230 hr. 736 echoes. Aerial azimuth 292½°.

Fig. 4 (*b*).—Smoothed half-hourly rates, March 21–22, 1956. Aerial azimuth 292½°.

have a tendency to shift with the Sun. The diffuseness of the radiant is indicated by the breadth of the peak on the rate curve.

A major fact emerging from these results is that small, random-looking groupings on the low-rate curves, which in the past have been regarded as due to sporadic meteors, build up, at the higher rates, into definite peaks with all the characteristics of meteor showers. This can be seen by comparing the rate curves of Figure 5. These new showers agree with low inclination direct motion groupings of meteoric matter and contain very few particles large enough to be detected by radar of low sensitivity. Such a type of shower might well

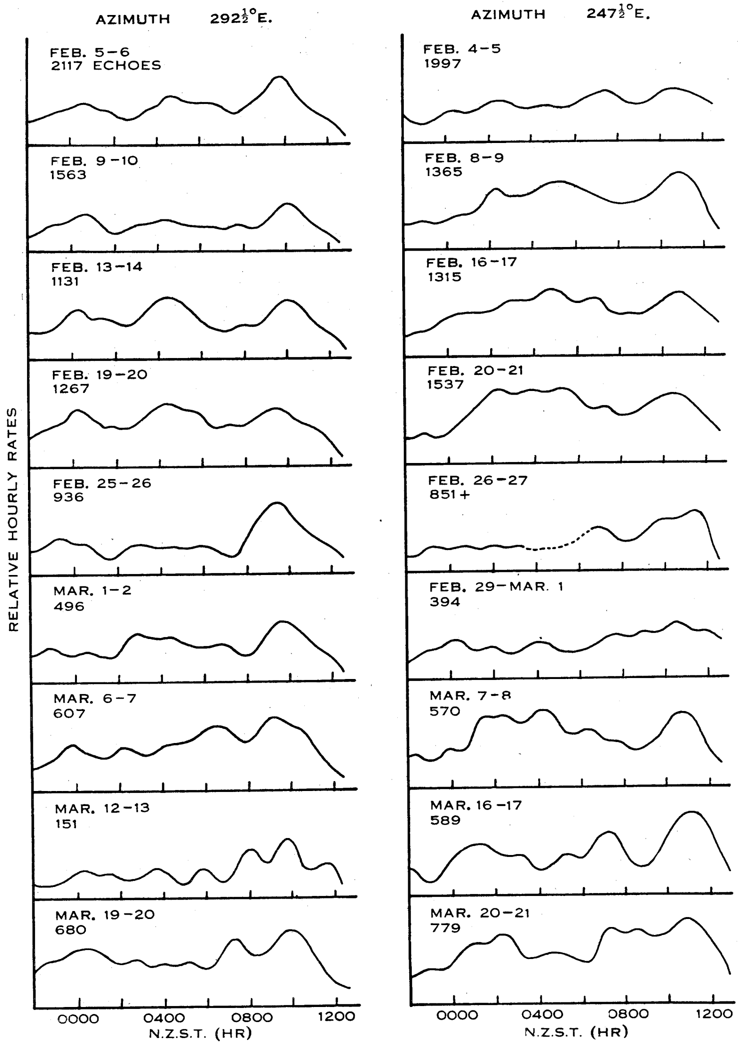


Fig. 5.—Meteor rate curves (smoothed).

be expected from the mass distributions found in the major northern showers. Generally, but not always, these showers are rich in bright meteors (Millman 1954). One exception is the day-time northern Arietid shower (Kaiser 1953) which, by its paucity of large meteors, conforms in type to the present February-March activity. Liller (1949) finds some of the northern showers are accompanied by numerous bursts of sporadic E at $3 \cdot 5$ Mc/s, while others show no bursts, and some burst maxima occur without a shower.

Again, many workers have pointed to the similarity in composition of shower and sporadic meteors (Porter 1944; Kaiser 1953). The present work would indicate that sporadic meteors must acquire a much more limited definition.

(c) *The λ Corona Australid Shower*

This shower is a rather small one, recorded visually by McIntosh (1935); and detected on radar equipment by Weiss (1955), who records a peak of activity on March 15–16. The shower is of fairly high declination (−40°/−50°), and culminates at approximately 0600 hr L.T. By a comparison of simultaneous rate curves on equipments of different sensitivities Weiss concludes that this shower is quite deficient in large meteors.

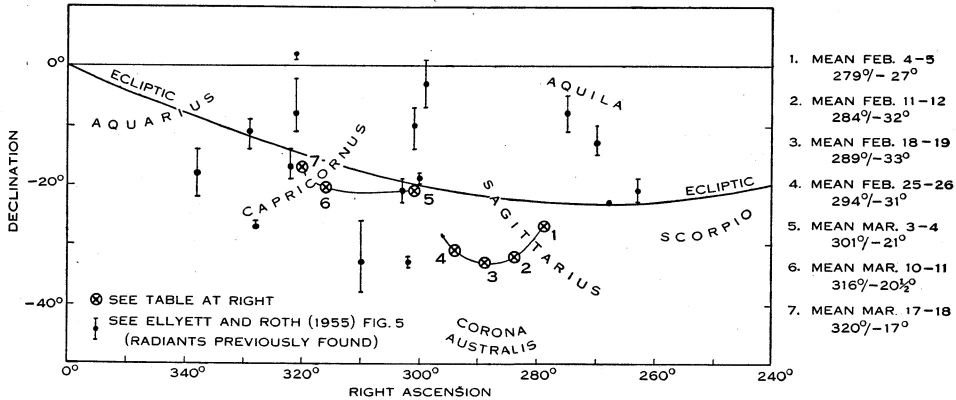


Fig. 6.—Plot and table of minor shower radiants found during February-March 1956.

During March 1956 no evidence was found for this shower. The equipment sensitivity from March 8 to 14 gave an echo rate of about 10/hr, which is equivalent to the sensitivity used by Weiss. The higher sensitivity used from March 15 to 23, giving a rate of 50 echoes/hr, also failed to reveal the shower. From these results it can only be concluded that the λ Corona Australid shower is variable in activity from year to year.

IV. Acknowledgments

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