THE ETA AQUARID METEOR SHOWER

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Abstract. On the basis of 240 000 radar echoes observed during the Eta Aquarid meteor shower period in 1958—1967 at the Springhill Meteor Observatory the activity of the shower is examined and hourly rates are tabulated. New value of $\lambda_{\odot} = 45.0$ for the date of peak activity has been deduced and a core of the shower, with higher density of particles has been found at $43.0 < \lambda_{\odot} < 47.0$. A dependence of the hourly rate of echoes on the shower radiant elevation is established.

1. Introduction

Structural characteristics of the Eta Aquarid meteor stream based on the extensive observational material (visual and radar) from the years 1910—1971 were shown elsewhere (Hajduk, 1973). The density variations along the orbit of the stream and across the stream have been demonstrated.

The present analysis will show some details concerning the shower activity variations, the size distribution of meteor particles, the contribution of larger particles to the shower activity in the dependence of the shower radiant elevation and a comparison of these effects with similar ones observed for the other meteor showers.

2. Observations

The data used in this analysis have been obtained at the Springhill Meteor Observatory during the period of the Eta Aquarid shower in 1958—1967. A total number of 240 000 radar meteor echoes observed in 670 hours between May 1 and May 10 was taken under investigation. A part of the data has been published by Millman and McIntosh (1964) in their Meteor echo statistics (years 1958—1962) and by Hajduk (1973). The unpublished part of the data are used with the permission of the Herzberg Institute of Astrophysics of NRC of Canada with a mutual cooperation of its Upper Atmosphere Research Section and the Department of the Interplanetary Matter of the Astronomical Institute of the Slovak Academy of Sciences. The radar equipment of the Springhill Meteor Observatory has been described by Neale (1966); the observations were made by the patrol radar with an omnidirectional antenna.

3. The Shower Activity

The mean hourly rates of echoes determined from 7-hour intervals, centred at the time of the transit of the shower radiant through the meridian are shown in Fig. 1, along the solar longitude for each year. Variation of the shower activity in different years and the variation of the position of the maximum rate in the solar longitude for consecutive returns of the shower have been analysed in the previous paper (Hajduk, 1973). We can see from Fig. 1 that the proportion of echoes with duration $\tau \geq 1$ s, corresponding to the same intervals does not follow always the mean activity of the "all echoes". However, the scatter of the data is rather large to deduce from this real changes of the size distribution of particles across the stream in individual returns. In spite of this, the summary of data leads to the elimination of the scatter and shows quite clearly a core of a more dense part of the stream, where the contribution of larger particles is higher than in the other parts of the stream (see Fig. 2). Each point represents here a mean value of the hourly meteor echo rate deduced from a 7-hour observational interval, centred to the time of the shower radiant culmination over the Springhill Meteor Observatory ($t_{\text{culm}} = 07{:}35$ LT $= 13{:}35$ UT). The position of all points, along the solar longitude for the particular years (1958—1967), has been reduced to the equinox 1950, using tables of Guth

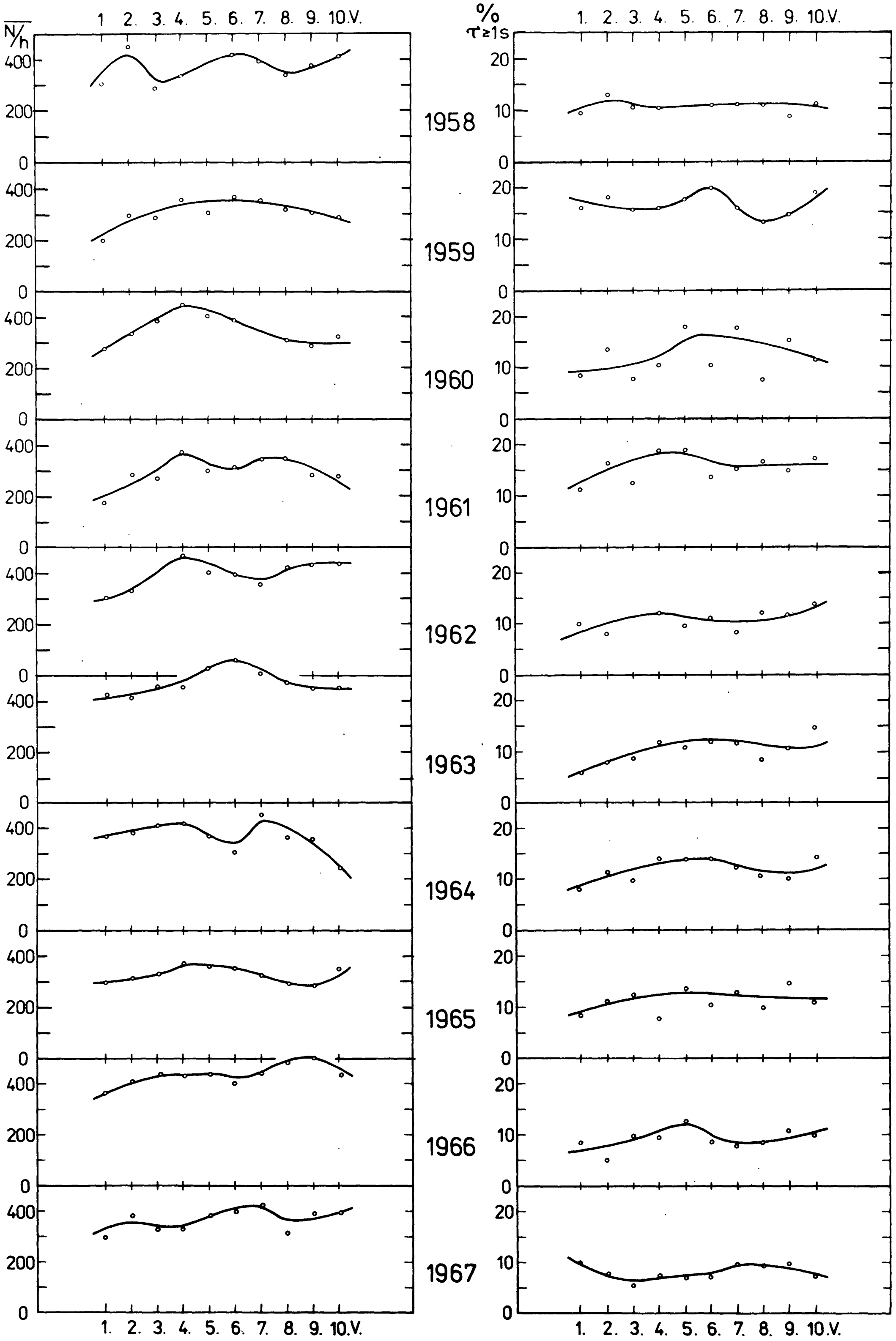

Fig. 1. Left: Mean hourly rates *N*/h of meteor echoes (from 7-h interval, centred to 07:30 h EST) during the shower activity for different years. Right: proportion of echoes with duration $\tau \geq 1$ s to all echoes (for the same observations).

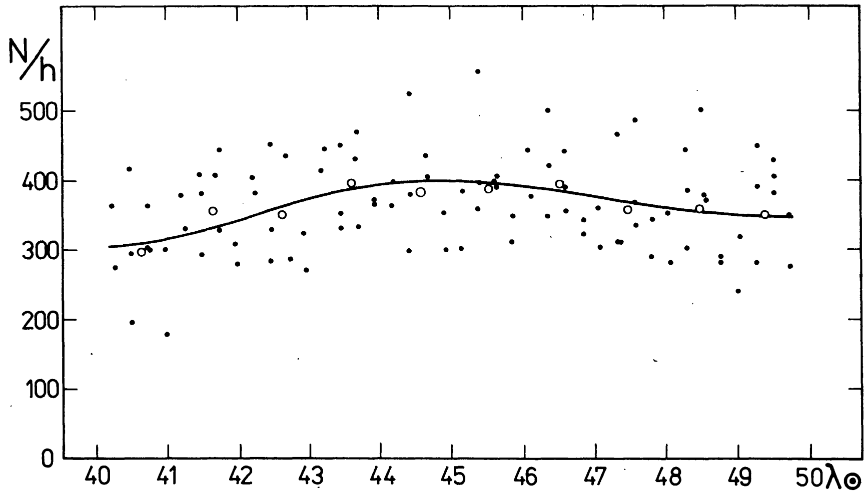

Fig. 2. Mean hourly rates N/h of meteor echoes reduced to the solar longitude λ⊙ 1950. Points: averages from 7-h intervals of a particular day and year; circles: averages from 10 years for a particular day.

(1939). The means of the 10-year observation for a particular degree are marked by circles in Fig. 2. The mean values of the proportion of echoes with duration $\tau \geq 1$ s to all echoes are seen in Fig. 3.

This result corrects the values of the Working list of meteor streams published by Cook (1973) and also the McKinley's date of peak activity (McKinley, 1961, Table 6.1). The days of peak activity are centred by McKinley to $\lambda_\odot$ = 43 and extends ±5 days and by Cook to $\lambda_\odot = 42.4$ with the points of half maxima at $\lambda_\odot$ 39 and 45. The difference in the position of the date of peak activity of the shower between the Springhill data, presented here and the shower list's mentioned above takes 1 or 2 deg respectively, or even more, when we locate the peak date in the middle of a stream core shown in Fig. 2, e.g. at $\lambda_\odot = 45$. This is close to the value $\lambda_\odot = 44.3$ as given by Millman and McKinley (1963).

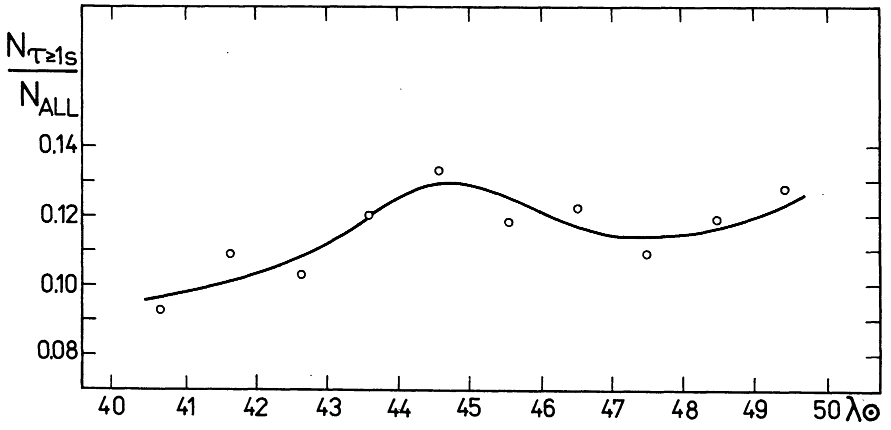

Fig. 3. The proportion of echoes with duration $\tau \geq 1$ s to all echoes reduced to the λ⊙ 1950. (Mean values, corresponding to circles in Fig. 2.)

Having into account that the stream is very wide and that the Earth crosses the stream in more than 20 days (Cook, 1973) and even the durations of peak days of the shower according to the McKinley (1961) takes ten days, the identification of a core, corresponding to only 4 days is of a significant value.

The location of this core of the maximum shower activity (for the all echoes and the proportion of echoes with duration $\tau \geq 1$ s) corresponds to $\lambda_\odot$ 43—47 (e.g. May 4—7 including), with maximum of brighter meteors at $\lambda_\odot$ 44.7.

The obtained results are valid not only for fainter radar magnitudes, but for visual meteors also, as the meteor echoes of the duration $\tau \geq 1$ s are beyond the range of visual magnitudes (Millman and McKinley, 1956). Moreover the summary of the observed peak activity days of visual observations of the Eta Aquarid shower show quite clearly (see Hajduk 1973, Fig. 1) that the mean peak date appears not less than 2 days later than it is stated in Cook's Working list.

The difference of the shower activity between the four degrees corresponding to the stream core and the surroundings is small (about 1.15 : 1 for all meteors and 1.25 : 1 for echoes with $\tau \geq 1$ s) but doubtless. It confirms also the flat maximum of the shower.

4. Dependence of the Echo Rate on the Shower Radiant Elevation

The Eta Aquarid meteor shower moves through the local meridian at 07 : 35 h (LT), reaching a zenith distance $z = 50°$ for the Springhill Meteor Observatory. Changes in the shower radiant elevation with the time of observation can be seen in Fig. 4 below. A 7-hour observational interval, centred to the time of the shower radiant culmination was used to study the dependence of the meteor echo rate on the shower radiant elevation. The difference between the used Eastern Standard Time (EST) and the local time (LT) for the Springhill Observatory (lat. 45° 21 N, long. 75° 38 W) is negligible. The sumary data for the particular years are listed in Tables 1—3, whereas details (for each date used) can be found in Table 4. A fairly large difference in the hourly rates of echoes observed during the different years can be seen here, however the mean values the total 10-year interval show a very consistent set of values, yielding the dependence with the radiant elevation. The 10-year mean values of the hourly rates of all echoes, seen in Fig. 4, follows exactly the change of the radiant zenith distance.

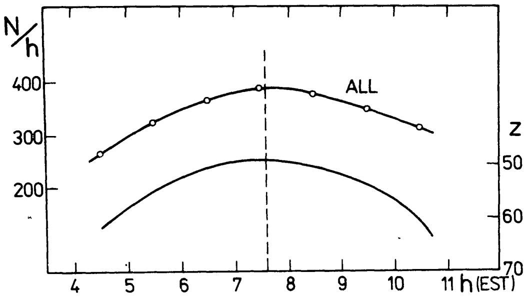

Fig. 4. Above: The dependence of the hourly rates of "all echoes" on the shower radiant zenith distance. (Mean values for 10 years, each of 10 days.) Below: Variation of the radiant zenith distance of the Eta Aquarids with time.

The dependence on the shower radiant elevation is different in case of echoes with longer durations. The mean values of the hourly rates of echoes with duration $\tau \geq 1$ s for the whole 10-year interval in dependence on the radiant zenith distance is seen in Fig. 5. The maximum rate is shifted here about 40 minutes after the meridian transit of the shower radiant. This shift in connection with a little slower decrease of the echo rate after the culmination time, causes a larger proportion of long duration echoes after the radiant culmination. This effect is clearly seen in Fig. 5 above.

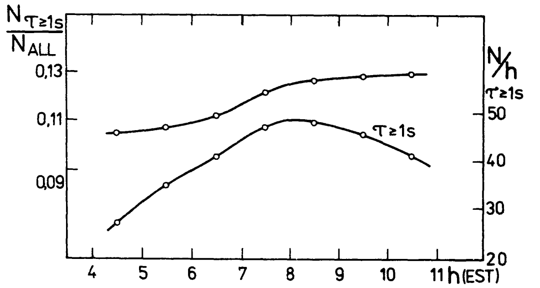

Fig. 5. The dependence on the shower radiant zenith distance for echoes with duration $\tau \geq 1$ s, and for their proportion to all echoes.

The explanation of the gradual increase of the proportion of echoes with duration $\tau \geq 1$ s and of the shift of the maximum rate of 1 s echoes may be seen in the sunrise effect on meteor trains. As it was shown by McIntosh and Hajduk (1977) and Hajduk et al. (1979) the proportion of long duration echoes increases after sunrise, corresponding to the height of the meteoric zone. For 1 s echoes is the increase in hourly rate much slower, than for very long duration echoes ($\tau \geq 8$ s), and reaches its maximum in appr. 6 hours after sunrise. As sunrise for the 90 km height above the Observatory begins at the time of the observations at about 03 : 45 h (EST), the proportion of 1 s echoes increases over the whole interval observed. A higher rate of overdense trains after sunrise has been found also by Hughes and Baggaley (1972) and Nicholson and Poole (1974) for Quadrantid meteors.

A comparison of results with dependences on the radiant elevation of Geminids and Orionids (Hajduk 1968) shows that a main factor influen-

Table 1

Mean hourly rates of all echoes

h (UT) Year	10	11	12	13	14	15	16
1958	273.3	322.7	351.2	351.3	338.0	285.2	223.3
1959	231.1	275.6	296.5	322.8	327.5	320.8	274.4
1960	247.8	310.2	328.9	341.0	374.8	300.8	296.2
1961	232.9	268.4	307.0	336.9	330.0	309.1	275.2
1962	275.2	339.6	362.4	391.1	379.3	345.5	302.6
1963	290.8	370.8	439.8	475.7	534.6	492.9	432.4
1964	289.7	318.8	356.8	329.9	343.3	348.3	333.7
1965	232.2	302.6	360.5	380.7	347.7	319.3	299.5
1966	316.3	411.8	480.1	513.8	441.8	422.6	410.1
1967	266.7	342.9	399.2	407.8	394.9	377.5	346.9
Σ	265.6	326.3	368.2	391.4	381.2	352.2	319.4

Table 2

Mean hourly rates of echoes with $\tau \geqslant 1$ s

h (UT) Year	10	11	12	13	14	15	16
1958	26.2	29.9	36.7	43.3	42.0	36.2	27.6
1959	35.3	45.4	46.6	58.9	54.5	54.5	49.2
1960	25.4	31.9	36.6	46.0	52.1	42.0	37.0
1961	35.1	43.9	45.9	52.8	58.6	53.4	50.1
1962	27.1	34.1	42.0	47.2	44.0	50.8	40.6
1963	27.9	37.2	48.9	48.7	59.2	51.2	50.3
1964	32.0	34.1	40.2	47.5	43.6	43.3	47.9
1965	23.5	29.6	38.6	47.0	44.2	42.9	40.5
1966	26.8	37.9	41.9	48.1	46.7	42.9	38.6
1967	20.4	26.4	33.6	35.1	32.5	33.4	31.4
Σ	28.0	35.0	41.1	47.5	48.1	45.1	41.3

Table 3

Relative rate of echoes with $\tau \geqslant 1$ s (%)

h (UT) Year	10	11	12	13	14	15	16
1958	9.6	9.0	10.3	12.5	12.5	12.5	12.4
1959	15.4	16.6	15.9	18.3	17.7	17.0	18.0
1960	10.0	10.2	11.3	13.4	14.0	13.9	12.4
1961	13.9	15.7	14.5	15.3	17.5	17.2	17.7
1962	1.9	10.2	11.9	12.0	11.5	14.4	13.1
1963	9.4	10.2	11.0	10.1	11.1	10.3	11.6
1964	11.1	10.6	11.2	12.2	13.1	12.6	14.8
1965	10.2	9.8	10.7	12.4	13.0	13.5	13.8
1966	8.5	9.2	8.7	9.2	10.5	10.0	9.4
1967	7.7	7.8	8.4	8.6	8.3	9.0	9.2
$(\Sigma N_{\tau \geq 1} / \Sigma N_{\mathrm{all}})\ 100$	10.5	10.7	11.2	12.1	12.6	12.8	12.9

Table 4

1958

h (UT)	10	11	12	13	14	15	16
May 1	8.1	8.4	8.8	10.3	12.5	6.7	8.5
2	13.3	13.0	13.1	14.1	10.9	13.1	11.1
3	11.2	8.6	10.1	12.7	11.6	15.0	13.1
4	11.6	8.5	10.1	11.6	11.8	12.8	15.6
5	—	—	—	—	—	—	—
6	6.8	10.9	11.5	13.2	11.3	13.1	16.0
7	9.1	8.8	11.6	12.5	13.2	13.7	13.7
8	9.8	8.6	8.1	17.0	15.3	15.4	—
9	6.8	6.1	8.4	10.5	11.5	8.9	9.5
10	9.8	9.6	11.0	10.2	14.2	13.6	12.3

1959

h (UT)	10	11	12	13	14	15	16
May 1	14.2	18.5	—	—	—	—	—
2	19.2	21.3	15.0	16.8	18.9	18.4	23.8
3	13.0	13.4	17.5	15.9	18.0	15.7	13.6
4	15.4	16.2	14.4	14.8	20.7	20.7	18.5
5	19.6	19.9	18.8	17.2	15.5	14.0	19.9
6	17.1	20.5	19.9	19.6	21.1	20.4	20.1
7	11.1	11.9	16.7	19.7	19.1	13.6	14.8
8	10.5	8.8	12.1	21.7	13.7	18.0	17.4
9	17.3	15.1	10.5	17.7	14.7	18.5	16.9
10	16.7	20.5	18.4	21.2	18.6	14.1	17.3

1960

h (UT)	10	11	12	13	14	15	16
May 1	6.1	4.7	9.6	12.2	9.5	12.5	10.2
2	11.0	12.9	15.0	16.9	11.7	12.9	17.9
3	8.2	7.3	7.6	9.6	7.2	7.8	8.9
4	13.5	10.6	7.7	10.9	11.9	13.3	7.2
5	19.7	14.5	15.3	20.4	20.2	23.1	19.4
6	8.6	9.9	11.7	10.2	13.1	12.4	12.0
7	—	—	15.2	17.0	21.1	—	—
8	5.3	8.7	6.3	10.0	10.0	10.9	9.1
9	11.6	15.8	—	—	18.5	16.5	14.4
10	6.4	7.8	13.7	13.3	16.3	16.1	12.6

1961

h (UT)	10	11	12	13	14	15	16
May 1	10.8	10.8	12.9	11.6	10.7	13.4	11.1
2	10.2	12.4	13.0	21.4	20.3	21.1	25.8
3	8.4	12.5	13.0	12.3	15.7	14.2	15.8
4	17.7	19.6	19.3	16.0	21.7	12.1	13.9
5	19.4	22.8	19.7	14.8	19.0	17.5	15.1
6	11.9	13.3	13.9	13.0	16.8	17.6	16.5
7	17.4	16.7	12.5	14.2	16.9	23.3	20.2
8	11.6	10.8	19.0	20.5	17.2	23.3	26.4
9	18.7	16.0	11.4	13.7	18.1	16.4	16.0
10	13.2	21.7	9.8	15.6	18.5	13.3	16.5

1962

h (UT)	10	11	12	13	14	15	16
May 1	9.8	9.4	10.2	8.3	11.8	12.9	10.8
2	7.2	6.3	7.7	11.7	7.0	8.4	10.9
3	11.1	13.4	11.1	12.9	9.9	9.6	8.3
4	12.0	13.6	14.5	16.0	6.8	9.8	10.3
5	11.3	9.6	9.3	8.5	11.3	14.7	15.0
6	9.2	9.8	14.6	10.5	11.9	15.4	15.0
7	10.5	8.2	14.7	6.8	8.4	13.7	9.0
8	9.0	10.5	11.4	14.4	14.8	19.4	17.9
9	9.3	9.4	11.3	14.1	15.5	20.0	16.1
10	9.1	11.3	14.6	16.4	17.4	20.2	17.6

1963

h (UT)	10	11	12	13	14	15	16
May 1	5.8	5.8	6.3	5.7	7.8	6.1	9.1
2	8.3	8.9	10.0	7.1	6.8	10.0	8.8
3	5.6	8.7	9.1	10.4	9.9	8.5	10.2
4	11.0	13.0	13.4	11.5	11.6	11.2	10.7
5	14.2	8.5	10.5	10.6	13.3	12.4	13.7
6	—	—	—	—	12.2	10.7	14.8
7	10.4	11.5	12.2	12.8	12.3	12.3	12.4
8	8.8	5.5	11.2	7.9	10.4	9.4	12.5
9	9.9	11.8	9.9	11.4	11.0	10.3	12.8
10	10.7	17.9	16.4	13.5	15.8	12.2	11.0

1964

h (UT)	10	11	12	13	14	15	16
May 1	7.2	5.4	8.4	8.1	9.9	10.1	8.4
2	8.5	10.3	12.4	13.5	10.9	11.7	18.4
3	10.3	9.7	10.3	8.6	10.1	9.0	10.2
4	12.0	11.5	14.8	16.5	13.5	12.1	17.2
5	12.0	14.5	11.2	15.5	16.1	11.3	15.9
6	14.2	10.9	—	—	—	—	—
7	11.5	14.0	11.0	11.7	14.8	—	16.6
8	11.8	7.9	13.6	9.4	11.8	16.2	15.0
9	8.6	12.3	7.7	10.4	11.0	12.8	14.8
10	14.7	9.7	11.6	16.5	19.5	16.2	20.0

1965

h (UT)	10	11	12	13	14	15	16
May 1	7.3	7.1	6.1	12.4	9.1	8.3	10.0
2	10.3	7.8	12.4	11.1	13.7	17.1	10.0
3	13.5	11.8	12.4	11.6	14.0	12.2	10.7
4	8.6	6.0	9.4	8.2	7.1	8.1	8.0
5	10.8	10.0	16.5	15.8	12.9	14.2	17.3
6	6.7	12.2	7.9	12.3	12.6	17.7	16.8
7	10.8	9.7	10.1	15.9	18.5	21.5	19.5
8	7.3	12.3	8.1	9.1	12.4	10.3	12.7
9	15.6	12.3	13.8	14.8	16.4	12.3	18.5
10	10.9	8.7	9.9	12.3	13.1	13.1	14.1

1966

h (UT)	10	11	12	13	14	15	16
May 1	8.0	6.6	9.4	8.4	9.8	5.7	4.9
2	4.0	4.6	5.1	4.9	7.6	6.3	4.6
3	12.5	7.6	7.4	10.1	11.8	10.6	12.1
4	7.9	9.7	11.3	8.1	11.3	9.6	7.2
5	12.7	11.6	10.5	14.7	13.9	11.8	13.5
6	10.1	11.7	7.0	6.7	9.8	9.4	9.0
7	6.1	8.4	6.8	7.4	10.5	12.1	9.1
8	6.2	9.4	8.9	8.4	9.5	8.4	8.9
9	13.0	12.1	10.7	10.9	8.7	15.3	14.3
10	4.9	10.0	9.5	12.8	12.3	10.5	10.0

1967

h (UT)	10	11	12	13	14	15	16
May 1	10.9	13.3	7.3	10.7	8.8	11.3	11.3
2	5.1	4.9	12.4	8.2	7.7	5.6	9.8
3	5.9	4.1	5.8	4.5	6.9	7.0	6.3
4	5.3	9.5	7.9	6.9	8.5	9.1	7.8
5	6.4	5.9	6.6	10.6	5.4	10.2	7.7
6	3.5	6.5	8.5	7.1	9.5	9.6	8.7
7	12.7	11.1	6.5	10.2	9.5	8.9	9.7
8	7.9	7.5	11.4	10.4	9.1	13.4	13.2
9	10.3	8.4	11.8	9.4	8.7	7.2	9.4
10	8.5	6.3	6.2	7.8	8.7	7.3	7.8

cing this dependence is very probably the diurnal variation of meteor echo rates, different for the different levels of echo durations. Hence the difference in the time of culmination of the shower radiant changes the form of the variation of the proportion of long duration echoes with the radiant elevation. An analysis of more showers would confirm this result.

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Súhrn

Práca obsahuje výsledky radarových pozorovaní meteorického roja Eta Akvaríd v rokoch 1958—1967 na Springhill Meteor Observatory v Ottawe, Kanada. Na základe získaných údajov 240 000 meteorických ozvien sa určil priebeh aktivity roja. Napriek zmenám v polohe maxima aktivity oproti dĺžke slnka v jednotlivých návratoch sa ukázalo, že existuje dostatočne výrazná zóna maximálnej aktivity roja pre $43{,}0 < \lambda_{\odot} < 47{,}0$. Stred aktivity roja zodpovedá hodnote $\lambda_{\odot} = 45{,}0 \pm 0{,}1$, čo predstavuje korigovanie dosiaľ všeobecne prijímaných hodnôt (42,4 až 43,0) až o 2 stupne. Analýza závislosti frekvencie ozvien od zenitovej vzdialenosti radiantu roja ukázala úplnú zhodu rastu frekvencie s výškou radiantu pre súbor všetkých ozvien, avšak prejavilo sa posunutie asi o 40 minút pre ozveny s trvaním vyše 1 sekundy. Odvodený rast podielu dlhotrvajúcich ozvien aj po kulminácii radiantu sa v práci vysvetľuje sunrise-efektom.

МЕТЕОРНЫЙ ПОТОК ЭТА АКВАРИД

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Резюме

Работа содержит результаты радиолокационных наблюдений метеорного потока Эта Акварид в период с 1958 по 1967 гг. установкой Метеорной обсерватории в Спрингхилл, Оттава, Канада. Построена кривая активности потока по данным 240 000 метеорных эхо. Состояние максимума активности потока изменяется по годам, но найдена средняя зона максимальной активности потока по солнечной долготе $43{,}0 < \lambda_{\odot} < 47{,}0$, с средней долготой $\lambda_{\odot} = 45{,}0 \pm 0{,}1$. Этот результат представляет поправку к принимаемым до сих пор значениям величины $\lambda_{\odot} \sim 42{,}4 - 43{,}0$ более 2 градусов. Анализ зависимости часового числа эхо от зенитного расстояния радианта потока показал согласие увеличения часового числа метеоров с высотой радианта для всех эхо, но появилось смещение в 4 минут для эхо с длительностями более 1 сек. Увеличение релятивного числа длительных эхо после кульминации радианта объясняется эффектом восхода солнца.