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by Gerald S. Hawkins and Richard B. Southworth

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THE REGRESSION OF THE NODE OF THE QUADRANTIDS[1]

By Gerald S. Hawkins[2] and Richard B. Southworth[3]

Between January 2 and 4 each year the earth passes through the Quadrantid meteor stream, a shower comparable in intensity to the Perseids of August and the Geminids of December. The radiant is located in the obsolete constellation of Quadrans Muralis, from which the stream takes its name, which is a position close to the junction of the modern constellations Draco, Hercules, and Bootes. Unlike the Perseids and Geminids, the Quadrantid stream is of short duration and most of the activity is confined to a period of 24 hours. The exact time of maximum of the shower defines the point at which the orbit of the stream intersects the orbit of the earth, or, in the case of the Quadrantids, the descending node of the stream.

The Quadrantids move in a direct orbit of high inclination so that we would expect perturbations by the planets to cause a slow regression of the node. Thus the regression of the node is also of interest from the point of view of celestial mechanics. Visual observations have been made on the shower over the past 100 years, but these are necessarily sparse because of its short duration and because of the winter weather conditions at the time of maximum. In 1953 the Super-Schmidt cameras of the Harvard Meteor Project made photographic observations on this stream. Radar observations, which of course are independent of cloud, daylight, and other adverse seeing conditions, are also available on a continuous basis since 1950. In this paper we present the best material available for determining the time of maximum of the Quadrantid shower and its changes through the years 1835 to 1954.

Table 1 contains recent determinations of the time of maximum activity and of the duration of the Quadrantid shower. The position of the earth in its orbit is used to measure the times of maximum in order to have a fixed scale. This position is designated by the angle, measured at the sun, between the earth and the vernal equinox of 1950, i. e., the heliocentric longitude of the earth referred to the equinox of 1950. At this season the earth moves 1°02 in longitude per day.

Only since 1921 have the visual Quadrantid observations been sufficiently homogeneous to permit grouping data from different sources to construct a curve of shower activity. Prentice (1940) has published the results of the principal meteor watches carried out by the British Astronomical Association in the first week of January each year from 1921 to 1940. He has graphed the hourly rate, that is, the number of Quadrantids visible in one hour to a single visual observer in clear weather, as a function of the orbital position of the earth, and has obtained a well defined point of maximum. In this paper, we have corrected Prentice's data according to the following precept. Other things being equal, the number of meteors of one stream that strike the atmosphere above a given area on the earth will be very nearly proportional to the sine of the angular elevation of the radiant point above the horizon. The position of the Quadrantid radiant is known within at most five degrees, and its angular elevation is readily computed for any time and place of observation. Observed rates have thus been corrected to the rate which would have been observed had the radiant been in the

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TABLE 1.—*Maximum and duration of Quadrantid shower*

Year	*Method of observation*	*Source*	*Earth's longitude at maximum (Equinox 1950)*	*Duration**
1921–40	Visual	Prentice (1940)	102°92	0°56
1951	Radar	Millman and McKinley (1953)	102. 74	0. 14
1950–52	Radar	Hawkins and Almond (1952)	102. 60	1. 3
1953	Radar	Bullough (1954)	102. 66	1. 0
1954	Photographic	This paper	102. 52	≤1. 0

*Length of time (measured by sun's longitude) that hourly rate of shower was more than half the maximum hourly rate.

zenith, but all other circumstances unchanged. This corrected rate is a more reliable measure of the activity of the shower, while the uncertainties of the correction itself, though not trivial, can hardly affect this investigation. Prentice's results, corrected as described, are shown in figure 1.

The second author has determined the time of photographic maximum of the 1954 shower from records obtained with the Baker Super-Schmidt cameras in New Mexico. A maximum hourly rate of 13 meteors, photographed by at least one of the cameras, occurred between 0330 and 0530 Mountain Standard Time on Jan. 3, 1954. The hourly rate was less than one on the preceding and following nights. The variation in rate during the early morning of January 3 does not differ significantly from the variation that would be predicted by the change in elevation of the radiant alone. A photographic rate of 13 with these cameras corresponds to a visual rate of approximately 26. The photographic data appear in table 1 with an assumed duration of one day at one-half or more of maximum hourly rate. Fisher (1930) has published a complete summary of the published Quadrantid observations prior to 1927. Table 2 contains all observations in his list (except those also included in Prentice's analysis) which yield a corrected rate of at least 20 Quadrantids per hour for a time recorded with an uncertainty of two hours or less. These observations are not direct measures of the time of maximum activity of the Quadrantid shower. The rates are very high compared with those in figure 1, however, and

TABLE 2.—*Hourly rates of Quadrantids**

Year	*Date*	*GCT*	*Observed rate*	*Corrected rate*	*Earth's longitude (Equinox 1950)*
1859	January 2	22^{h}5	~60	~260	103°35
1863	2	23. 6	48	48	102. 86
1864	2	23.	50–60	192–231	103. 09
1864	3	0. 7	60?	130?	103. 16
1872	2	23. 6	21	70	103. 05
1873	2	6.	37	41	103. 07
1878	2	4. 2	34	44	102. 57
1879	2	6. 4	>42	>44	102. 54
1880	2	20.	11	61	102. 85
1880	3	0. 5	6	~60	103. 04
1894	2	19. 2	40	160	103. 26
1897	2	5. 2	64	85	102. 66
1903	3	20. 2	8. 5	42	102. 96
1903	4	2. 8	60?	98?	103. 24
1904	4	5. 2	>20	>24	103. 09
1908	3	17. 2	6. 8	28	102. 55
1908	4	16. 7	12. 6	52	103. 54
1909	3	5. 4	180	210	102. 80
1922	3	6. 7	40–50	57–71	103. 03

*When the hourly rate was less than 20, the observations are not included.

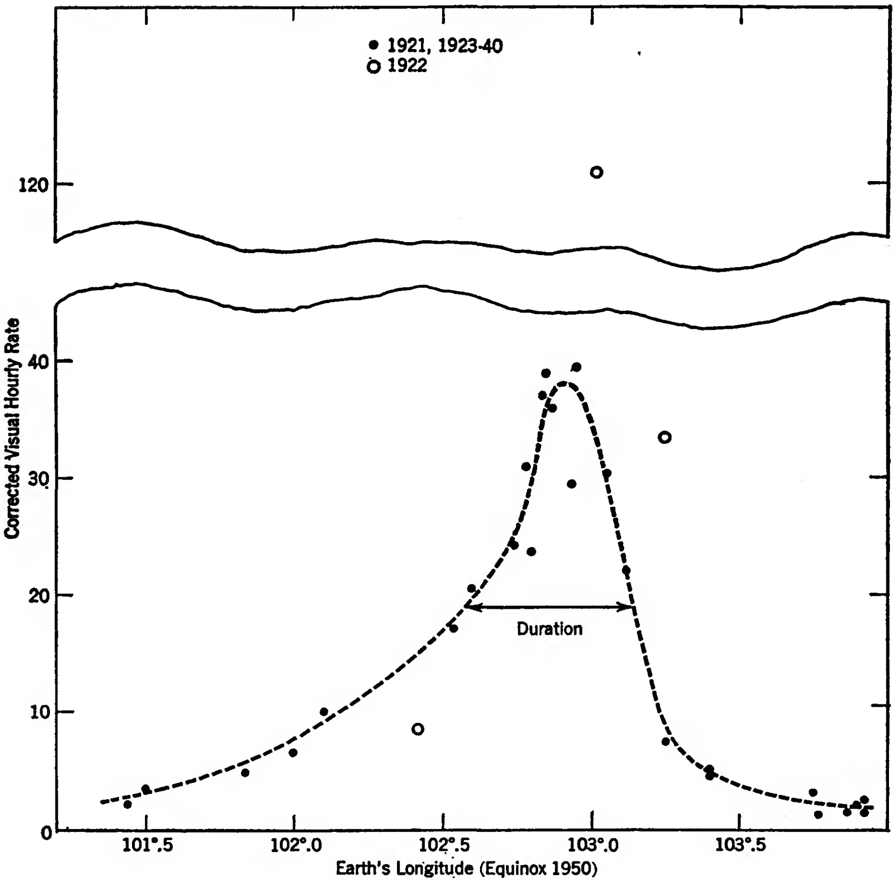

FIGURE 1.—Corrected visual hourly rate of the Quadrantid meteor stream, plotted against the longitude of the earth at time of observation.

in view of the measures of duration in table 1, it is clear that these rates were observed at times not more than a few hours distant from the time of maximum.

The earliest observations that can be identified with some confidence as referring to the Quadrantid shower appear in table 3. Most of them report only that an uncommon number of meteors was seen at a particular place on a particular night. In order to analyze these observations, it has been necessary to assume a specific time of night. South of 55° north latitude, the Quadrantid radiant rises very little above the horizon until after midnight and does not reach maximum elevation until after dawn; consequently most Quadrantids are seen after midnight. For this reason, 3 a. m. local time has been assumed, except for Bossekop at 70° north latitude where the radiant elevation varies relatively little, and except where the time is more specifically reported. Some of these observations are published in several places; the authority cited is the one on whom most reliance is placed. The double entry for the year 1835 represents divergent reports of the same observation.

Figure 2 plots the measures of the epoch of maximum Quadrantid activity in tables 1 to 3 against the year of observation. Data from table 1 appear as crosses, from table 2 as solid circles, and from table 3 as open circles. The graph clearly shows a downward trend: the straight line drawn through the points corresponds to a mean regression of the node of

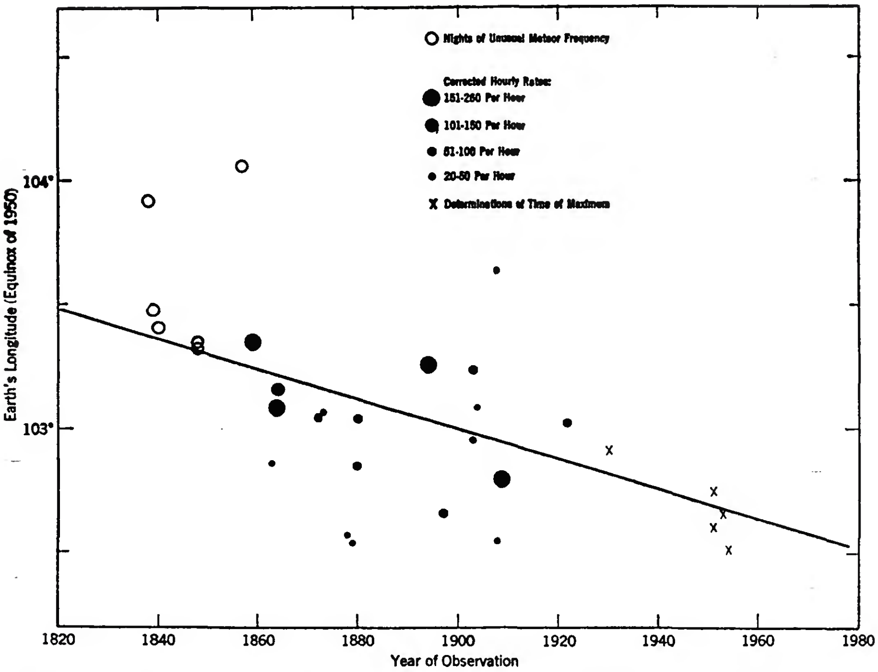

FIGURE 2.—The earth's longitude corresponding to the maximum of the Quadrantid meteor stream, as observed in various years.

0°006 per year. Recent observations of the Quadrantids in 1956 (Hines and Vogan, 1957) are consistent with this conclusion.

Certain observations of the Quadrantid shower show that in particular years, and perhaps in particular places, the maximum hourly rate is much greater than the normal maximum rate. In figure 1, Prentice's data for 1922 clearly exhibit this phenomenon. In some cases these unusually high rates occur for only a few hours; at Jodrell Bank the maximum rate in 1953 was approximately three times the maxima seen in 1950 to 1952, and apparently, as also in figure 1, only the peak of the frequency curve was much higher than normal. In such an event the duration, when measured between the times at which the rate was one-half of the maximum rate, is

TABLE 3.—*Nights of unusually high meteor frequency*

Year	*Date*	*Place observed*	*Assumed local time*	*Earth's longitude (equinox 1950)*	*Authority*
1835*	Jan. 2–3 after midnight	Mornez, Switzerland	3^h	103°68	Wartmann (1841)
	Jan. 1–2 4 a. m. to dawn	Mornez, Switzerland	5^h4	102. 76	Fisher (1930)
1838	Jan. 2–3 after midnight	Near Geneva, Switzerland	3^h	103. 92	Wartmann (1841)
1839	Jan. 2–3	Bossekop, Norway	24^h	103. 48	Fisher (1930)
1840	Jan. 2–3 towards morn.	Ghent, Belgium	3^h	103. 41	Quetelet (1861)
1841*	Jan. 2–3 or 3–4	Switzerland?	3^h	104. 15 or 105.17	Fisher (1930)
1848	Jan. 2–3	Parma, Italy	3^h	103. 33	Fisher (1930)
1848	Jan. 2–3	Aachen, Germany	3^h	103. 34	Fisher (1930)
1857	Jan. 2–3	England?	3^h	104. 06	Fisher (1930)

*Entry omitted in figure 2.

shorter. Millman and McKinley (1953) have suggested that the short duration observed in 1951 was probably due to a similar abnormal concentration. Their actual maximum hourly rate cannot be compared with visual rates, however, without a detailed determination of the sensitivity of their equipment.

Almost all of the visual hourly rates in table 2 exceed the maximum, 38 Quadrantids per hour, of the curve of activity drawn in figure 1. Since low hourly rates do not indicate the time ot maximum of the shower, they have been omitted from table 2 and figure 2; nonetheless the average of all Quadrantid corrected rates reported before 1921 (Fisher, 1930) is 52 meteors per hour. No significant correlation with year of observation is to be found in these reported rates; they do not tend to decrease from 1859 to 1920. In the absence of any regular program of observation, the appearance of few or no Quadrantids is unlikely to have been reported. The evidence, therefore, does not support an hypothesis of decreased average Quadrantid activity, and the visual rates before 1921 probably refer principally to years of uncommon activity. Also most of the observations in table 3 probably represent uncommon years, since a normal maximum rate of approximately 40 per hour would not have appeared remarkable in an era when the Leonids had displayed 500 per hour, and the Perseids were showing 150 per hour.

Years of unusual Quadrantid activity represent, on the simplest hypothesis, condensations or regions of unusually high density in the otherwise nearly uniform distribution of meteors along the orbit of the Quadrantid stream. The observations do not determine how exactly these condensations follow the same orbit as the continuous stream, but no significant deviation has been seen. In particular, the 1922 measures in figure 1 do not indicate such a deviation, since the difference in longitude between the highest 1922 measure and the peak of the curve is almost exactly the regression of the node in the nine years between 1922 and the mean date, 1931, of the other measures in the figure. It is concluded that the node of the observed portion of the Quadrantid meteor stream has regressed steadily since its discovery, at the rate of 0°6 per century, and that there are isolated streams of meteors embedded in the continuous stream.

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Abstract

Observations of the longitude of the descending node of the Quadrantid meteor stream from 1838 to 1954 are assembled and discussed. It is concluded that the majority of the older observations were made in years of unusually high activity. The descending node of the observed stream has regressed 0°6 per century.

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