On the origin of the 1982 Lyrids burst

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Abstract. The 1982 Lyrid enhanced activity burst was an exceptional event, with the dense cloud of meteoroids lagging of about 120 years the parent comet Thatcher (1861 I) .An explanation of its origin is therefore intrigue. Here we present a simplified approach to the solution of this problem. The most probable size of the cloud of meteoroids was estimated by two different ways, leading to a radius of about 90 000 km. The cloud is supposed to origin in a secondary source that separated from the comet of about 71 revolutions ago (30 000 years). Derived ejection velocities of the Lyrid cloud particles from the secondary source are very low ones from 1.7 to 3.9 ms^{-1}. These values enable to suppose that disintegration of the chunk into dense Lyrid cloud might occure within two years before the observed burst on the pre-perihelion arc immediately preceding the 1982 Lyrid strong shower.

Key words: meteors – comets

1. Introduction

The Lyrids belong to the few meteor showers that displayed occasionally high activity in this century. The reported Lyrid bursts occured in a very narrow interval of solar longitudes, preceding the normal activity maxima (Lindblad & Porubčan 1992). The last such event was observed in 1982 (Adams 1982; Porubčan & McIntosh 1987). The peak of very short duration of about 50 minutes was caused predominantly by small particles. This was documented by a high value of the mean magnitude of 3.62 as reported by visual observers (Adams 1982) and confirmed by a high value of mass distribution index of 2.21 as derived from radar observations (Porubčan & Hajduková 1988). Dense meteoroids clouds exhibiting the bursts are usually situated close to the parent comet.Their

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origin can be explained by recent ejection of the particles from the cometary nuclei still not dispersed by normal meteor shower evolutionary process.

Quite different situation is observed at the bursts of Lyrids, especially at the 1982 one, when the corresponding cloud had to be very far from the parent comet Thatcher (1861 I), since the burst occured about 120 years behind the comet with its orbital period of 415 years. A scenario of a possible origin of the 1982 Lyrid burst was proposed by Porubčan and Štohl (1992). According to this, the particles had their origin in a secondary larger chunk loosed from the comet Thatcher earlier. The chunk could disintegrate later on, producing a cloud of non-ejected meteoroids moving in similar orbits for a relatively longer time. With a simple assumption of an ejection velocity of 1 ms^{-1} at the perihelion in the direction of the comet motion, not taking into account any other effects, it was estimated that the chunk had to separate from the comet some 36 revolutions, i.e. about 15 000 years earlier.

In this paper we present a more detailed analysis of the 1982 Lyrid observational data obtained by the Springhill meteor radar, with a more complex approach to the explanation of the origin of this exceptional phenomenon.

2. Activity and mass distribution of meteoroids

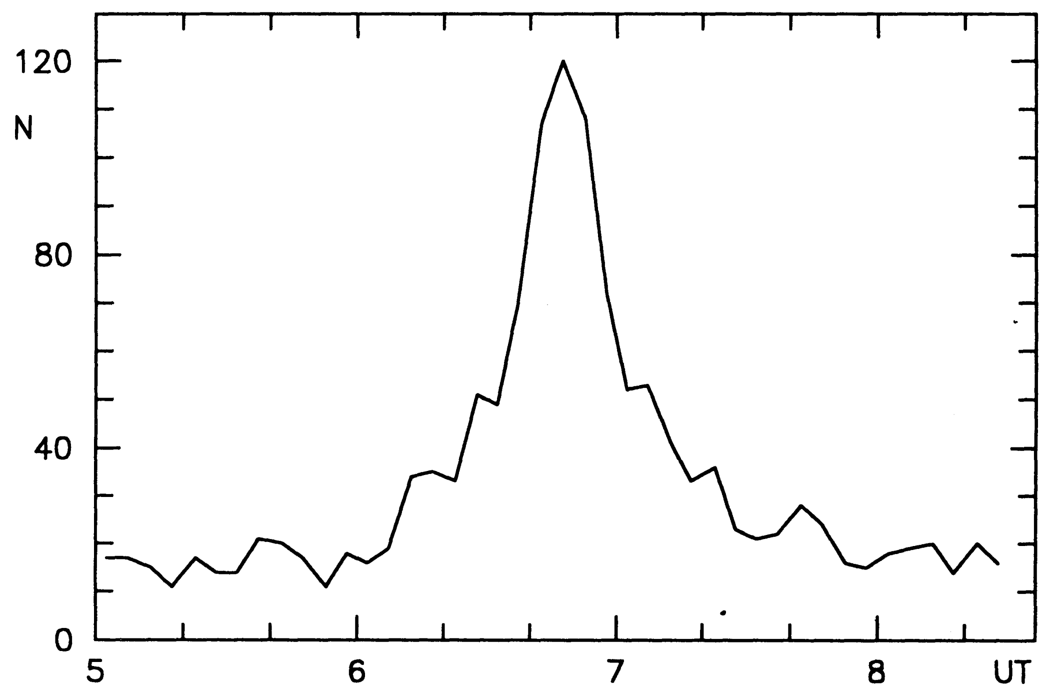

Figure 1. Meteor echo rates in 5-minute intervals (all echoes) derived from the Springhill radar observations on April 22, 1982.

The activity curve of the 1982 Lyrid burst during 3.5 hours around the peak is shown in Fig. 1. It depicts 5-minute intervals of all reducable echoes observed by the Springhill patrol radar, down to the duration of 0.2 sec. The peak itself occured at 06:49 UT on April 22 (solar longitude 31.380, epoch 1950.0), with 33 echoes in one minute. Striking is the symmetry of the activity curve and also very short duration of the whole event, with 22 and 50 minutes between half and quarter maximum levels, respectively. The whole enhanced Lyrid activity lasted about 75 minutes (06:10-07:25 UT) as is evident from Fig. 1.

Mass distribution of meteoroids in this cloud, studied earlier by Porubčan and Hajduková (1988) in more general terms, is studied here in smaller intervals, distributed symmetrically with respect to the peak. The mass index has been only derived from overdense echoes of duration $\geq$ 0.4 sec., since the echoes shorter than 0.4 sec. as read off the film cannot give any confident results. The method of the mass index determination is the same as the one applied by Porubčan and Hajduková (1982). The results are presented in Table 1.

UT	t_{min}	s	$n(\tau \geq 0.4)$
05:05-06:05	60	1.53	23
06:05-06:35	30	1.74	64
06:35-06:45	10	2.29	67
06:45-06:50	5	2.16	52
06:50-07:00	10	2.09	73
07:00-07:30	30	1.62	93
07:30-08:30	60	1.27	51

Table 1. Variation of the mass exponent s within the 1982 Lyrid burst for echoes of durations $\geq$ 0.4 seconds.

We are firmly confident that because of the method used the values of s given in Table 1 refer to shower meteors only, not contamined by sporadic echoes. They confirm that a very high contribution of small particles occured in the 1982 Lyrid burst. An interesting fact is that the time distribution of s around the peak is a little assymetric. The highest value of s falls into the 10-minute interval preceding the peak itself (s = 2.29) . The low value of $s = 1.27$ in the last one-hour interval (07:30-08:30 UT) is due to high contribution of long-enduring overdense echoes in this interval. The assymetric feature of the mass index distribution shows that the spatial distributions of particles with different sizes in the cloud are not identical.

3. Disintegration of the secondary source

Let us first try to estimate the size of the secondary meteoroid source. As follows from the observations, the Earth passed through the 1982 Lyrid dense cloud in about 75 minutes, which corresponds to a distance $b = 133\ 000\ km$.

Provided that the particles ejected from a secondary source filled up a sphere of radius r_o , the Earth crossed the sphere along a cord b (within an interval from 0 to $2r_o$). The average cord of a sphere can be estimated as the height of a cylinder having the same cross-section and volume. The length of this cord is $4r_o/3$ and, consequently, the most probable radius of the Lyrid cloud can be estimated to about 100 000 km.

Another way how to estimate the size of the cloud can be deduced from the observed activity curve. Assuming that the particles were escaping from the source surface isotropically and at an approximately equal rate, the spatial density of meteoroids in the cloud would be inversely proportional to the radius of a sphere surface (the radius equals to the distance from the source). The ratio between the peak rate and the rate at both ends of the whole enhanced activity interval is $f_m/f_o = 120/25 = 4.8$. From this simple model follows $f_m/f_o = r_o^2/r_m^2$, with r_o being the radius of the cloud and r_m the distance of the Earth from the center of the cloud at the peak of activity. Then, the radius can be found as $r_o^2 = r_m^2 + (b/2)^2$,which is about 75 000 km.

Both approaches of the estimation of the 1982 Lyrid cloud size, are based on rather simple presumptions, they lead to similar values. We thus accept $r_o = 90\ 000$ km as the best estimated value of the radius of the cloud.

Let us turn now to the derivation of the time of the origin of the Lyrid cloud particles and of their separation velocities. These values were estimated on the basis of our knowledge about beginnings of active processes in the cometary nuclei. Although most of the active processes on comets take place at small heliocentric distances, in the region of the perihelion, there are known also cases in which comets were active at considerable distances from the Sun, e.g. Comet P/Halley at distance of 14.3 AU (Hainaut et al 1991). Detailed analysis of the behaviour of P/Halley on the pre-perihelion arc of its orbit (Svoreň 1987) has shown that the onset of sublimation started at 6.5-7.0 AU. The variations of photometric exponents of long-period comets (Svoreň 1986) have also indicated a change from an activity to a non-active stage at or beyond 7.0 AU. The probability of active processes on comets evidently increases at smaller heliocentric distances. That is why the ejection velocity of the Lyrid cloud particles has been derived for three different beginnings of its activity, at 7.0, 5.5 and 4.0 AU, respectively (cf Table 2).

Table 2 shows that the derived ejection velocities are within an interval of reasonable, commonly aceepted values ($1 - 10\ ms^{-1}$). Therefore, it might be

r	t	u
7.0	588	1.7
5.5	416	2.4
4.0	262	3.9

Table 2. Ejection velocities u (in ms^{-1}) for various heliocentric distances r (in AU) and corresponding durations of the cloud formation t (in days).

concluded that the disintegration of the secondary source occured on the pre-perihelion arc, preceding not more than two years the 1982 Lyrid strong shower.

4. Separation of a secondary nucleus from the parent comet

To estimate the time elapsed from the separation of the secondary source from its parent Comet Thatcher (1861 I) we have accepted following presumptions:
- the secondary source was separated from the parent comet at the perihelion,
- the fragment is large enough for the radiation pressure not to be taken into account,
- the fragment escaped along the tangent to the cometary trajectory.

The delay with which the fragment follows the comet is determined by the change in orbital period resulting from the change in the semi-major axis a .The change in semi-major axis per one revolution, not taking into account planetary perturbations and second-order terms, is given by

$$\Delta a = \frac{1+e}{1-e}\, 2a\, \frac{v_t}{V_q} \tag{1}$$

where e is the eccentricity, v_t is the ejection velocity of the fragment and V_q is the perihelion velocity of the comet.

From the Catalogue of cometary orbits (Marsden 1989) for Comet Thatcher we have $e = 0.983465$, $q = 0.9207$ AU , which gives $a = 55.6819$ AU and $V_q = 43.73\ km\ s^{-1}$.

According to Sekanina (1982), who investigated in detail each of the 21 known splittings of the comets, the velocity of separation was never greater than a few meters per second. In the well documented cases, the velocity of separation is between 0.26 and 2.27 ms^{-1}, with the median value of 0.50 ms^{-1}.

We applied all the three values for the derivation of the parameters listed in Table 3.

v_t ($km\ s^{-1}$)	Δa (AU)	ΔP (sider.year)	N (revolutions)
2.6×10^{-4}	0.0794	0.889	136
5×10^{-4}	0.1527	1.710	71
2.27×10^{-3}	0.6934	7.785	16

Table 3. Change of semi-major axis per revolution Δa and corresponding change of orbital period ΔP for different values of the velocity of separation v_t . Both the parameters Δa and ΔP are given relatively to the orbital elements of Comet Thatcher (1861 I).

We assume that the Lyrid cloud particles move in the same orbit as the parent comet but displaced in time along the orbit path. The perihelion passage time of the particles, T = 1982 May 14.8556, was iteratively adjusted until the minimum particles-Earth distance was determined. The same method was used by Yeomans (1981) to investigate Leonids. The delay in the moments of the perihelion passage by the parent comet and that of the Lyrid cloud is 120.9396 sidereal years. This value, together with values of the orbital period change ΔP enables to derive values N given in the last column of Table 3; N are the numbers of the revolutions needed to accumulate the observed delay of the particles cloud in the positions on the orbit.

We can conclude that the separation of the secondary source of the Lyrid cloud from its parent Comet Thatcher occured 16 - 136 revolutions ago, with the most probable value of 71 revolutions, i.e. about 30 000 years earlier. It is about twice as much as was suggested earlier (Porubčan & Štohl 1992) on the basis of very simplified assumptions.

5. Conclusions

(1) The values of the mass index s show that there occured a very high contribution of small particles in the 1982 Lyrid burst. The time distribution of s around the peak is a little assymetric. The highest value of s falls into the 10-minute interval immediately preceding the peak itself ($s = 2.29$). The assymetric feature of the mass index distribution shows that the spatial distributions of particles with different sizes in the cloud are not identical.

(2) The whole enhanced Lyrid activity lasted about 75 minutes.

(3) The most probable size of the corresponding cloud of meteoroids was estimated by two different ways, giving the best estimate of the radius of about 9×10^4 km.

(4) Derived ejection velocities of the Lyrid cloud particles from its immediate parent body, which is assumed to be a secondary source are very low, from 1.7 to 3.9 ms^{-1}. These values enable to suppose that disintegration of the fragment into dense Lyrid cloud occured within about two years before the time of the observed shower on the pre-perihelion arc immediately preceding the 1982 Lyrid strong burst.

(5) The delay in the moments of the perihelion passage by the parent comet and that of the Lyrid cloud is 120.9396 sidereal years. We thus conclude that the separation of the secondary source of the Lyrid cloud occured 16 - 136 revolutions ago, with the most probable value of 71 revolutions, which corresponds to about 30 000 years.

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