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The Lyrid Meteor Stream: Orbit and Structure

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Abstract A filamentary structure in the Lyrid meteor stream based on photographic orbits available in the IAU Meteor database is identified and studied. About 17 Lyrids are found in the database and the stream mean orbit is derived. The shower radiant is compact, of a size $2° \times 1.5°$. Applying a stricter limiting value for the Southworth-Hawkins D-criterion, two distinct filaments in the stream, on a short and a long period orbit, are separated. To confirm their consistency as filaments, their orbital evolution over 5,000 years is investigated.

Keywords Lyrid meteor stream · Meteoroids · Photographic meteor orbits

1 Introduction

The April Lyrids are known as producing a weak meteor shower with a visual ZHR at maximum of about 5–10. However, occasionally they exhibit an enhancement of activity, exceeding 100 meteors per hour (Lindblad and Porubčan 1992). The maximum generally appears on April 21–22 with the radiant at a right ascension of 272° and declination of 34°. The stream is genetically associated with comet C/1861 G1 Thatcher. By looking in the literature for the Lyrid outbursts reported in the last two centuries, remarkable features are found. For example, it is evident that all the peaks were of a short duration (2 h maximum) and at almost the same solar longitudes, approximately a quarter of a day before the annual peak (Lindblad and Porubčan 1992). These occasional activity enhancements indicate a filamentary structure in the stream.

Older observations also seem to indicate a 12-year periodicity of the enhanced Lyrid maxima (Guth 1947). Arter and Williams (1995) looked for an explanation of the observations, and the results of a study of the stream's evolution in which model particles were released from comet Thatcher indicate an occurrence of higher density parts of the stream in a 12-year cycle (Arter and Williams 1997).

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2 Orbit and Filaments of the Lyrids

In the present catalogues of meteor orbits, the most accurate observations come from photography. However, there is only a small number of accurate orbits available for a detailed analysis of the Lyrid stream. Kresák and Porubčan (1970) for their analysis of the shower radiant and orbit had at their disposal only seven Lyrids. Lindblad and Porubčan (1991) derived the mean orbit of the stream and motion of the radiant on the basis of 14 Lyrids.

The current version of the Meteor Data Center catalogue of photographic orbits contains the orbital elements of 4,581 meteors (Lindblad et al. 2005). The catalogue has increased by about 1,000 new orbits. This provided a chance to derive a more precise mean orbit and radiant of the stream.

Lyrid stream members were identified by using a computerized stream search procedure utilizing the Southworth-Hawkins *D*-criterion (Southworth and Hawkins 1963). For a limiting value of $D = 0.20$, 17 meteors belonging to the Lyrids, from the period April 21 to 25, were found. The Lyrid radiant daily motion and radiant ephemeris derived from the 17 stream members is

$$\alpha = 272.3^\circ + 0.802^\circ(L_s - 32.5^\circ), \delta = 33.4^\circ - 0.155^\circ(L_s - 32.5^\circ) \quad (1)$$

The daily motion in right ascension and declination was found by a least squares solution; L_s is the solar longitude of the time of observation for equinox 2000.0, and 32.5° is the solar longitude of the maximum activity. The size of the radiant area corresponds to the dispersion of the orbits and thus to the stream structure: the Lyrid radiant, allowing for the daily motion and centered on the α and δ given by (1), reaches a size of about $2^\circ \times 1.5^\circ$.

We have also searched for possible filaments in the stream by lowering the limiting value of D. For $D = 0.025$ two separate groups in very different orbits (short and long period ones) were obtained. Each filament is formed by four meteors, but in filament 2 meteor 048C1 is on a hyperbolic orbit and was therefore excluded from the sample. The mean orbits of the filaments are listed in Table 1 together with the mean Lyrid orbit. Table lists also the orbit, theoretical meteor radiant (α, δ) and geocentric velocity (V_g) of comet Thatcher. As the semimajor axes of Lyrids have a range corresponding to orbits from very short period up to hyperbolic ones, the mean a in Table 1 was calculated from the mean e and q.

In the next step we have verified the reality of the filaments by making a backward integration of their orbits. The two filaments and Lyrid mean orbit were numerically

Table 1 Orbital elements and radiants of the Lyrid filaments, mean Lyrid orbit and comet C/1861 G1 Thatcher (eq. 2000.0), with corresponding standard deviations *s.d.*

Object	Q [AU]	a [AU]	q [AU]	e	i (°)	ω (°)	Ω (°)	π (°)	α (°)	δ (°)	V_g [km/s]	n
filament 1	21.4	11.15	.914	.918	79.2	216.0	31.6	247.6	271.4	33.0	46.26	4
s.d.	-	-	.002	.018	.4	.3	.7	.8	.4	.2	.14	
filament 2	141.4	71.15	.925	.987	80.4	213.0	32.8	245.8	273.0	33.3	47.35	3
s.d.	-	-	.002	.009	.1	.4	.7	.2	.5	.2	.11	
mean orbit	91.2	46.05	.921	.980	79.7	213.8	32.5	246.3	272.3	33.4	47.03	17
s.d.	-	-	.007	.072	1.0	1.6	1.0	1.5	1.3	.6	.91	
Thatcher	110.4	55.682	.9207	.9835	79.77	213.45	31.87	245.32	272.0	33.5	47.08	-

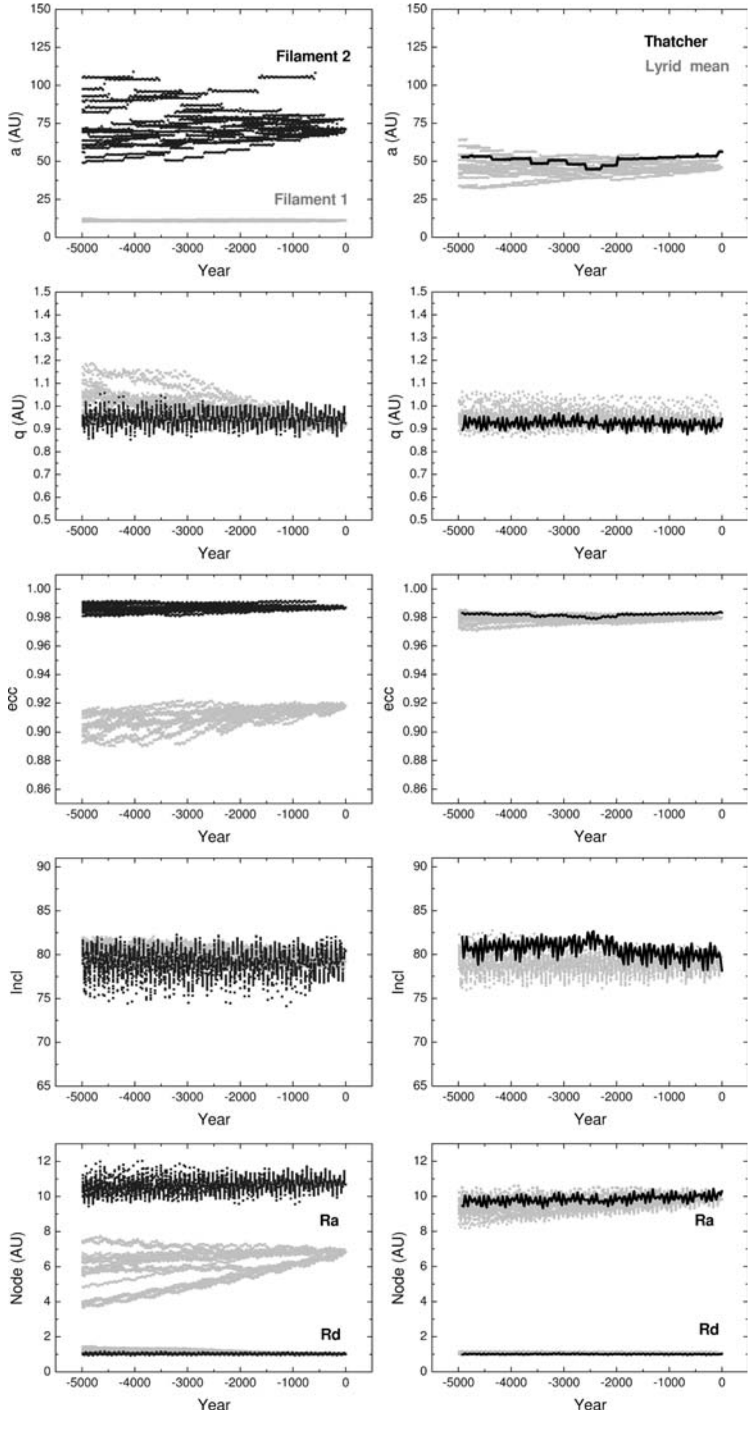

Fig. 1 Orbital evolution of the Lyrid filaments 1 and 2 (left plots), the Lyrid mean orbit and parent comet Thatcher (right plots) over the last 5,000 years

integrated back 5,000 years. In this integration, each orbit is represented by 18 modeled particles distributed equidistantly by 20° in mean anomaly.

The orbital evolution of filaments 1 and 2 and the mean Lyrid orbit, as well as that of comet Thatcher, is shown in Fig. 1, where the plots show the evolution in semimajor axis a, perihelion distance q, eccentricity e, inclination i and heliocentric distances Ra and Rd of the ascending and descending nodes over the last 5,000 years.

3 Discussion and Conclusions

In the present study the stream and comet are analysed from a short-term point of view (5,000 years). The orbit of the stream and comet are shown to be relatively stable. The Lyrids are influenced by three dominant bodies that are shaping the structure of the stream: Jupiter, Saturn and Earth.

Filament 1 (April 21–22, mean $L_s = 31.6°$) coincides quite well with the outburst peak preceding the annual maximum (Lindblad and Porubčan 1992) and is more influenced by perturbations. The ascending node of the filament is at a heliocentric distance of 6.8 AU and exhibits a relatively large dispersion caused by the strong influence of Jupiter. Several modeled particles have repeated close approaches to the Earth and Jupiter during the period of integration.

Filament 2 (April 22–23, mean $L_s = 32.8°$) is closer to the annual maximum. The evolution of the mean Lyrid orbit and filament 2 is rather stable. Both orbits undergo similar evolution, almost identical with the evolution of the parent comet Thatcher. The ascending nodes are close to the orbit of Saturn. A few modeled particles have close approaches to Saturn and Earth.

In conclusion, we have identified two filaments among photographic Lyrid meteor orbits. They are moving in very distinct orbits with mean periods of revolution of about 40 and 600 years. The filaments are result of gravitational modification of the stream structure by planets and are influenced mostly by Jupiter with a significant contribution from Saturn. The descending nodes of all the investigated orbits are stable and close to the Earth's orbit during the whole period of integration.

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