Planetary and Space Science 118 (2015) 48–53

Contents lists available at ScienceDirect

Planetary and Space Science

journal homepage: www.elsevier.com/locate/pss

On the orbital evolution of the Lyrid meteoroid stream

Leonard Kornoš [a,*], Juraj Tóth [a], Vladimír Porubčan [a,b], Jozef Klačka [a], Roman Nagy [a], Regina Rudawska [a]

[a] Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Mlynská dolina, 842 48 Bratislava, Slovakia
[b] Astronomical Institute of the Slovak Academy of Sciences, Dubravská cesta 9, Bratislava, Slovakia

ARTICLE INFO

Article history:
Received 20 January 2015
Received in revised form
13 April 2015
Accepted 4 May 2015
Available online 16 May 2015

Keywords:
Meteor showers
Meteoroid streams
Comet
Parents
April Lyrids

ABSTRACT

A detailed analysis of the Lyrid video orbits from the EDMOND database is performed. Applying selective methods, the weighted mean orbit and mean geophysical parameters are derived. The occurrence of orbits with the semimajor axes smaller than 35 AU, in comparison with the value of 55 AU of the parent comet Thatcher, is about 80%, in the set of higher quality data of the Lyrids in the EDMOND database.

The gravitational orbital evolutions of Thatcher and modelled particles ejected in five perihelion passages of the comet in the past are studied. Both, orbits of the comet and modelled particles, are under quite strong disturbing influence of Jupiter, Saturn and Earth. After the integration to the present, the mean theoretical radiants, the mean geocentric velocities and periods of activity of particles approaching the Earth's orbit were calculated. The mean orbits of the modelled streams of particles ejected from different perihelia match well the mean Lyrid orbit from the IAU MDC and the observed video Lyrids from the EDMOND database. The particles released in the two oldest simulated perihelion passages of the parent comet are most responsible for the occurrence of the Earth-crossing orbits with the semimajor axes smaller than 35 AU, but no one below 20 AU.

The influence of non-gravitational effects, mainly solar radiation, may shorten semimajor axis of a submilimeter particle with density of 0.3 g/cm^3 by more than half during an evolution of 50 000 years. A common influence of gravitational perturbations and non-gravitational effects can provide a dynamical way to the short-period orbits. However, this process is for millimeter and larger particles (video and photographic) less effective.

1. Introduction

The April Lyrids are a regular meteor shower, mostly of weak activity, observed between April 14 and 26. The shower maximum appears on April 21–22 ($L_S = 32.4°$), with a visual zenithal hourly rate of 5–10 meteors. However, occasionally, an enhanced increase in activity exceeding 100 meteors is observed, as in 1922, 1946, 1982 (Lindblad and Porubčan, 1992). Moreover, the 20th century outbursts apparently appear in 12 year intervals, as suggested by Guth (1947) and Arter and Williams (1997).

The Lyrid meteoroid stream is associated with the comet C/1861 G1 Thatcher. Its orbit is almost perpendicular to the ecliptic, with a revolution period of 415 years. The comet was observed only in 1861, and its orbit was determined by Oppolzer, on the basis of 187 observations within the arc of 149 days (http://ssd.jpl.nasa.gov/sbdb.cgi).

In the study made by Porubčan and Kornoš (2008), two distinct groups of orbits, the short-period and long-period, were recognized in the Lyrid meteoroid stream. The groups were probably formed under the gravitational influences of two dominant bodies, Jupiter and Saturn. In the study by Tóth et al. (2011), a more complex structure of the Lyrids was found and possible resonances in the mean daily motion with giant planets were identified.

Piffl et al. (2014) indicated a significant prevalence of orbits with semimajor axes $a < 32$ AU in the Lyrids, obtained from video observations. In the present study, we examine what is a proportion of such orbits in the video meteor database EDMOND and whether they can evolve from the parent comet, using modelled particles ejected during several perihelion passages of the comet in the past, or as a consequence of non-gravitational effects.

2. The Lyrids' orbit

For our analysis, the European viDeo MeteOr Network Database (EDMOND) of video meteor orbits was used (Kornoš et al., 2013, 2014). The database is a result of cooperation and data-sharing

---

* Corresponding author.
E-mail address: kornos@fmph.uniba.sk (L. Kornoš).

http://dx.doi.org/10.1016/j.pss.2015.05.001

among several European national networks, including the Video Meteor Network of the International Meteor Organization. In April 2014, a new 5th version of the EDMOND, containing 145 830 video meteor orbits, was generated.

In the first step, 1069 Lyrids were selected, utilizing a simple radiant-geocentric velocity selection method. All meteors which appeared around the Lyrid maximum within an interval of ±15 days, an area of ±10° around the mean radiant and ±10% around the mean geocentric velocity were extracted from the database. The mean values of the radiant and the geocentric velocity of the Lyrids were taken from the IAU MDC list of meteor showers (Jopek and Kaňuchová, 2014).

At present, we use the UFO software (SonotaCo, 2009) to capture and analyze meteors and for orbit determination. To obtain a subset of higher quality data, stronger criteria consisting of several parameters defined in the *UFOOrbitV2* manual (http://sonotaco.com/soft/UO2/UO21Manual_EN.pdf), were applied to the set of 1069 Lyrids. The used filter parameters are as follows: the duration of the trail, $dur > 0.3$ s; the difference between 2 poles of ground trajectory planes, where a plane is defined by the atmospheric trajectory of the meteor and the center of the Earth according to one of the stations, $dGP < 0.1°$; the overlap percentage of trails observed from two stations for a particular meteor, $Gm\% > 50\%$; and the convergence angle – the angle of two planes, where a plane is defined by the atmospheric trajectory of the meteor and one of the used stations, $Q_c > 20°$.

Resulting subset of 125 Lyrids was used to determine the mean values of the orbital elements and geophysical parameters. The core of the stream was searched for by applying Eq. (4) derived by Welch (2001). The equation was used in the form

$$\rho_j = \sum_{i=1}^{N}\left(1-\frac{D_{ij}^2}{D_c^2}\right); \quad D_{ij} \le D_c, \qquad (1)$$

where ρ_j is a group density at a point j in orbital element space, D_{ij} is the value obtained for the i-th meteor in the Lyrid's list by comparing its orbit with the orbit which initiates the j-group, D_c is the threshold value that determines the dynamical similarity among meteor orbits, and N is the number of all meteors in the data set. The procedure creates a group of meteors around each meteor orbit from the examined shower, fulfilling the condition of the limiting value of D_c. On the basis of Eq. (1), the value of the density (ρ_j) is determined for each group and its highest value we consider for the core of the stream.

In this way, using as distance function the D_{SH} criterion (Southworth and Hawkins, 1963) for the limiting value $D_c=0.1$, the core of the stream consisting of 85 m from a set of 125 Lyrids, was derived. Following, the weighted mean orbit, the solar longitude, the radiant position and the geocentric velocity of the stream were determined. The weight was determined by $(1 - D_{ij}^2/D_c^2)$ according to Welch (2001). The mean values with their standard deviations are listed in Table 1 and compared with the IAU MDC parameters of the Lyrids and with the orbit of comet Thatcher.

Table 1
Mean values of parameters: solar longitude (L_S), radiant position (RA, Dec), geocentric velocity (V_g) and orbital parameters of 85 Lyrids from EDMOND database together with standard deviations in the second row. For comparison, the orbit of Lyrids from IAU MDC (according to Dutch Meteor Society) and of the comet Thatcher are also presented.

Source	L_S	RA	Dec	V_g	q	e	ω	Ω	i
EDMOND	32.1	272.1	33.3	46.5	0.919	0.941	214.5	32.1	79.4
±	0.7	1.2	0.5	0.6	0.006	0.032	1.3	0.7	1.1
IAU MDC	32.4	272.0	33.3	46.6	0.921	–	214.3	31.8	79.6
Thatcher					0.921	0.983	213.4	31.9	79.8

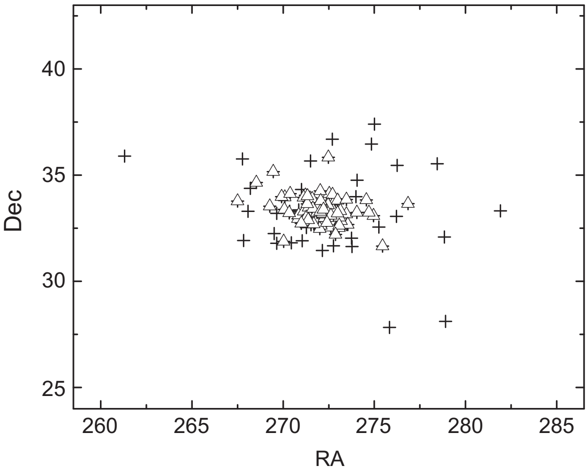

Fig. 1. Radiant positions of initial 125 Lyrids (+) and 85 Lyrids (△) selected by Welch (2001) method, representing a core of the stream in EDMOND database.

Comparison of all 125 Lyrids with the 85 orbits selected by the Welch method is demonstrated in Fig. 1 by the radiant positions, and in Fig. 2 by histograms of the semimajor-axes, the geocentric velocities, the perihelion distances and eccentricities. The significantly more compact radiant and less dispersed distributions of 85 Lyrids (filled columns) show the core of the stream from the EDMOND database. The orbital elements, the argument of perihelion, the longitude of ascending node and inclination show similar behavior. In agreement with the paper by Piffl et al. (2014), selecting higher quality orbits, a prevailing number of orbits with semimajor-axes under 32 AU (~78%) are observed and as well as proportion of orbits with $a < 20$ AU is high, about 68%.

3. Numerical integrations

We studied simulations of the Lyrid meteoroid stream by means of numerical integrations of modelled particles, using Everhart's integrator RA15, from the package Mercury 6 (Chambers, 1999). Several experimental integrations of the comet Thatcher, performed from the year 1861 for 50 000 years to the past and then back to the year 1861, showed that it is not possible to reproduce the initial comet orbit. This is only possible for a time span of about 4100 years.

As a result, we made some tests with three integrators from the Mercury package – the Bulirsch–Stoer (BS), RA15 (Radau) and the symplectic integrator MVS. Since the integrations can technically only be performed in one direction in time, each test consisted of two parts. Firstly, the comet orbit was integrated backwards in time, and secondly back from the past to the present. We followed the results after each unidirectional integration and also compared the initial orbit with the final one after the integration back.

It turned out that the results of the integrations for the tested comet differ; they depend on the chosen integrator, but also, within a particular integrator, they depend on a specific perihelion passage, on the selected accuracy parameter, and on predetermined intervals of the outputs. We tested the output intervals in the range from every 100 days to the output only in two moments, the start and the end of the integration. Indeed, setting a particular output interval forces the integrator to modify its own integration steps to match the output moments.

The model of the Solar System used in the integrations included 8 planets, the Moon as a separate body, and the most influential asteroids: Ceres, Pallas, Vesta, and Hygiea (Galád, 2000). During the experiments, we reduced the model to 8 perturbing