Genetic analysis of the meteor showers and asteroids

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Abstract: Using the video catalogues of the Perseids, Ursids, and Lyrids meteor showers having genetic connections with comets, the Geminids, Alpha Capricorni, and Taurids having genetic connections with asteroids, and the Kappa Cygnids and Delta Cancrids of unknown origin, the objects with magnitude higher than +3 were studied. The analysis of coordinates of the meteor showers’ radiant distribution in relation to their magnitudes showed that the Lyrids has the smallest ellipse of the spread of the radiant positions, with 4° by 8°; for the k-Cygnids the deviation is the greatest, with 28° by 28°; for the other showers, it is between 7° and 10°. The main attention is paid to the determination of structural parameters of the Lyrids meteor shower.

1. Introduction

The Earth as well as the other planets and their satellites regularly collides with space bodies [1]. The Earth’s collision with a space body comparable with Tunguska meteorite of 50 meters in size occurs once in a hundred years. Larger meteoroids of 10 to 100 meters in size due to their low luminosity, high extraterrestrial velocity, and uncertainty of their entrance into the Earth’s atmosphere are the real danger for our planet [2]. Many asteroids and comets investigated are genetically related to meteor showers. On the basis of observations, the simulation models of the distribution of sporadic meteors and meteor showers were produced. According to [3], there are 106 known meteor showers. For 21 of them parental bodies are comets, for 5 of them parental bodies are asteroids, and 80 meteor showers are not identified with their parental bodies. These small celestial bodies are called orphans.

According to the modern theory, the formation of a meteor shower is genetically related to the evolution of the near-solar comet which was transformed into an asteroid under the influence of the temperature and gravity of the Sun [4]. The change in the temperature gradient in the perihelion of the orbit of a small celestial body causes its destruction and the formation of a meteor shower [5]. The causes of the destruction of a parental body (centrifugal and tidal processes, collisions, inactive or active stages of evolution) affect the structure of a meteor shower [6].

Currently, the questions of various types of small bodies’ genetic connections are important for the construction of their evolution theory [7, 8]. The comet C/1861 G1 is considered to be a parental body for the Lyrids meteor shower (LMS) and its sidereal period is 415 years. LMS is of low activity during the year and may be observed between April, 16 and April, 25. The first observations of the meteor shower were taken in 687 B.C. An interesting feature of the Lyrids meteor shower is that its activity in the certain years increases. This process cannot be explained by the influence of solar activity when C/1861 G1 approaches the Sun. The increase in LMS activity is not the result of C/1861 G1 approaching the Earth due to the comet’s orbital period. The increased intensity of LMS was recorded in 1803, 1922, 1946, and 1982. One of the reasons for this phenomenon is that Jupiter’s gravity affects the dynamics of LMS components with a period of 12 years [9, 10, 11]. Another explanation of the anomalous values of LMS activity relates to the shower’s spin-orbital dynamics.

To study the dynamics of the Lyrids meteor shower the methods of constructing the simulation numerical evolutionary models of LMS as well as their prediction estimates are used.

2. The analysis of the Lyrids’ structural parameters

Using the time series of observations of the Lyrids meteor shower taken between 1900 and 2007 one may determine the parameters as follows: $r$ – distribution of the meteor shower’s luminosity gradient, $S$ – distribution of meteor density at the full shower, $ZHR$ (zenithal hourly rate) – parameter describing the meteor shower’s activity and showing the number of meteors that could be seen by an observer per hour.
Figure 1. Distribution of $S$ over a period between 1987 and 2007. X-axis – solar longitude, Y-axis – averaged values of $S$.

Figure 2. Distribution of $S$ in various years. X-axis – solar longitude, Y-axis – averaged values of $S$.

In figure 1 the parameters $S$ are averaged within each year and given for the periods 1987–1999 and 2000–2007 separately. As it is seen from the figure, there is a good agreement between the parameters $S$ within the error limits. The solid line corresponds to the averaged values of $S$ for LMS at the period between 1987 and 2007. For the values of solar longitude from $31^\circ$ to $33^\circ$ there are most reliable observational data and the averaged values of $S$ are therefore indicated by the dashed line. Figure 2 shows distribution of $S$ in various years.

In our studies, the data on the Lyrids meteor shower taken from the International Meteor Organization was used. The observations between 1987 and 2007 are taken as they are the most reliable and statistically supported ones.
To determine the distribution of the parameter $S$ in relation to the averaged periods of the solar longitude, we used the formula (1):

$$ S = 1 + 2.5 \lg r, $$

where $r$ is determined by the meteor shower’s luminosity gradient during an observational night.

### 3. Analysis of ZHR parameters.

In figure 3 are given the values of ZHR averaged over periods 1900–1963, 1990–2000, 2001–2007, and 1900–2007 and plotted at intervals 0.5°–1° of the solar longitude scale.

![Figure 3. Values of ln (ZHR) for LMS averaged over 1901–1972 (…), 1990–2009 (-), and 2001–2007 (--). The solid line corresponds to the average value of ln (ZHR) for the period 1901–2007.](image)

In figure 4 are plotted the maximum values of ZHRmax parameters over the period between 1901 and 2007. As it is seen in the figure, the highest values of ZHRmax correspond to 1922, 1923, and 1982. The period of influence by Saturn’s gravity of 27 years on the shower’s activity discovered by V.A. Maltsev [3] has not been confirmed, as the ZHRmax parameter is moderate in 1952.

As a result, we may draw the following conclusions. For solar longitude 32,19° ± 0.04° the lowest value of the parameter $S$ is 1.54 ± 0.02 (figures 1–2). The estimation of the ZHR averaged value at the intervals 1900–1963, 1900–2000, 2001–2007, and 1900–2007 shows that the highest values of the parameter are observed at the same solar longitude 32,326° ± 0.107 (figure 3). There are 2 periods of the LMS’ increased intensity – approximately 10–12 and 60 years.

![Figure 4. Values of ln (ZHR) over period between 1901 and 2007.](image)
4. Analysis of the Perseids, Lyrids, Geminids, Delta Capricorni, Kappa Cygnids, and Delta Cancrids

The study of the meteor showers genetically connected with comets has shown that the orbital parameters of a meteor shower correlate with the ones of a parental comet [3].

Based on this conclusion one may increase the number of determined parental bodies among asteroids which are the result of faded comets’ evolution. The procedure of establishing cometary parental bodies for the Perseids, Lyrids, and Ursids and asteroid parental bodies for Alpha Capricorni, Taurids, and Geminids [8] was carried out. Using the method given in [3] we analyzed luminosity gradients for the meteor showers as follows: Delta Capricorni, Lyrids, Perseids, Geminids, SCC and NCC branches of Delta Cancrids, and Kappa Cygnids. At the study, we used television meteor catalogues of the showers whose luminosity is higher than 3 in magnitude.

The luminosity gradients of the meteor showers were determined. The meteors were distributed for luminosity. The correlation between masses and orbital parameters of the meteoroids was established.

Among the meteor showers studied the Lyrids has the smallest radiant scatter ellipse (4° × 8° in α, δ). The Kappa Cygnids has the greatest area of radiant scatter (28° × 28° in α, δ). For the rest of the meteor showers the radiant scatter area is between 7° and 10°. For the Delta Capricorni, Kappa Cygnids, Lyrids, and Perseids meteor showers, when right ascension rises, there is an increase in declination. For the Delta Cancrids and Geminids there is no such correlation found.

All the meteor showers studied have no subradiants, and the entire radiation zone of the meteors is evenly filled with radiants. For the Alpha Capricorni, Kappa Cygnids, Perseids, Geminids, and Lyrids there is a dependence between the absolute stellar magnitude of the meteoroids and radiants’ positions and orbit parameters of the meteor showers. For the Delta Cancrids meteors are simultaneously observed in southern SCC and northern NCC branches, the branches’ radiants are accurately distributed on both right ascension and declination but do not coincide [12].

5. Summary and conclusions

The analysis of structural parameters of the orphan meteor showers is necessary both to determine their parental body and to construct a theory of their evolution. For these purposes the studies of the showers should be conducted at the full range of activity, i.e. at maximum and minimum values of luminosity.

With the purpose of studying the Lyrids meteor shower the observations taken over the period of 106 years were analyzed. As a result, 2 periods of its maximum activity were found – 60 and 12 years. According to [11] the reason for these periods depends on resonance processes 1:5 and 1:1 (periods of 11.7 and 59.4 years respectively). When these periods coincide, there is the maximum activity of the shower (1922 and 1982) [13].

For LMS the study of meteors’ density distribution variations in the full shower (parameter S) did not confirm the correlation with the 12-year period of maximum activity. The values of the parameter S determined are in a good agreement with the results of other authors [14]. The fact that the values of S for LMS over the period between 1922 and 1982 (60-year activity period of LMS) exceed the shower’s mean activity gradient may be explained by the influence of small components of the meteor shower [15].

It should be noted that over the period exceeding 60 years, there has been no great increase in the activity of LMS [16]. In the last 10 years the increase in the Lyrids’ intensity has been recorded only with radar methods [17]. As it was mentioned above, the increase in the activity of LMS may depend on the presence of meteor components of low mass.

It is also worth emphasizing that the radiants of all the meteor showers studied are evenly distributed. For the Perseids, Lyrids, Geminids, Alpha Capricorni, and Kappa Cygnids there is a strong correlation between the meteors’ magnitude, orbit structure, and radiant position. There are no pronounced subradiants in the distributions of the meteor radiants [18]. Some single branches of the SCC and NCC of the Delta Cancrids meteor shower are observed simultaneously between January, 1 and January 31, but their radiants do not coincide and are well determined through right ascension and declination.
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