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Analysis of the D-criteria

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Abstract

In this report the D-criteria, which can be used to determine the genetic relationships of small bodies with their parent bodies in the solar system, are estimated. Drummond (1981), Southworth-Hawkins (1963), Jopek (1993), Dynamic (Kalinin et al., 2007) and Holshevnikov (2007) D-criteria were analysed. It was found that the Drummond criterion is less sensitive to errors of observations and its upper limit does not exceed 0.2. The Southworth-Hawkins and Jopek D-criteria are more stable and have good convergence. Limiting values, which vary in the range of 0.3–0.6 (except for the Lyrids), were determined on the basis of the analysis of six meteor showers for the Southworth-Hawkins and Jopek criteria.

1. Introduction

Under the influence of many cosmogenic factors the evolution of orbits of small bodies of the Solar System leads to the formation of meteoroid complexes. A set of criteria is used to find the genetic relationships. The criteria are based on the determination of the Tisserand constant or D-criteria as functions of the distance between the bodies' orbits in the five-dimensional phase space of elements of orbits. There are several problems. Firstly, which criteria should be used for the research, as they can be unstable in the different geometries of orbits or can give ambiguous results? Secondly, what maximum limiting value of the criterion should be taken under which values would allow the assumption that two bodies are genetically linked?
Limiting values of the criteria are estimated on the basis of modelling of the meteoroid complexes for a given mechanism of the particle ejection from a parental body. Several works devoted to the evolution of modelling of meteoroid swarms have been published recently. In the case of using these models the limiting values of the criteria are directly dependent on the velocity of a fragment's emission. In addition a model of the subsequent orbit evolution does not consider all factors and features which affect the particles' dispersion in the swarm. As a result the real values of the D-criteria obtained from the observational data of the orbits of the meteors differ from the theoretical ones even taking into account the errors of the observations. The comparison of theoretical and observational data will make it possible to determine the limiting values of D-criteria for each meteor stream and to use them successfully for genetic identification of the small bodies for solving various astronomical problems.

2. Analysis of D – criteria

The most commonly used D-criteria and their variations have been studied using catalogues of meteor orbits. They are of the Astronomical Institute of the Czech Republic for 1998–2001 (TV-1), video catalogues of the Dutch Meteor Society for 1991–2002 (TV-2), and also the photo catalogue of the Dutch Meteor Society for the years 1981–1993.
We analysed the following D-criteria: the Southworth-Hawkins ($\boldsymbol{D_{SH}}$) criterion [7], the Drummond (D_D) criterion [1], the Jopek (D_{JOP}) criterion [4], the Dynamic criterion (D_{mov}) [3],the Holshevnicov criterion $\boldsymbol{D_X}$ [2].
The Dynamic criterion (D_{mov}) takes into account the deviation of the elements of the orbit of the particle ejected from the cometary nucleus in three dimensions.
According to Holshevnicov criterion $\boldsymbol{D_X}$**,** the distance dimension is taken into account by introducing a scale factor that is commensurable with the orbits size. According to Holshevnicov, in the criterion $\boldsymbol{D_X}$ the dimension of a distance is taken into account by introducing a scale factor which is commensurable with the size of orbits
The D-criterion does not take into account the gravitational and non-gravitational perturbations of orbits, which is why μ, ν quasi-stationary parameters are used along with the D-criterion. Quasi-stationary parameters are related to the Tisserand's parameter T. Tisserand's parameter is given by [5]

$$T = a^{-1} + 2\,a_j^{-2/3}\,[a\,(1-e^2)]^{1/2}\cos i$$

For quasi-stationary parameters for Jupiter we have:

$$\mu = a^{1/2}\,(1-e^2)^{1/2}\cos i = const,$$

$$\nu = e^2\,(0.4 - \sin^2\omega\,\sin^2 i) = const,$$

Calculations show that the relative ***μ, ν*** parameters change their values by no more than 5% during 10000 years [6].
The catalogues of the meteor orbits obtained by photographic and television methods were used to compare the criteria; the meteor orbits were already assigned to a particular stream in the catalogues.
The limiting values of the criteria were obtained for the Lyrid, Perseid, Orionid, Leonid, Draconid, Ursid, and Geminid streams. The choice of the streams is decided by good observation statistics and a wide variety of medium-sized orbits of the streams according to the size of the major semi-axis and an inclination to the ecliptic.

3. Summary and Conclusions

The Drummond criterion is less sensitive to errors of the observations; its upper limit is lower than the values of the other criteria and does not exceed 0.2 for almost all the streams. The D_{SH}, D_{YOP} criteria and ν parameter are settled and their values have a good convergence within the stream.

According to Southworth – Hawkins and Jopek criteria and ν values, limits were obtained and they vary in the range of 0.3-0.6 (except for the Lyrids). For Southworth – Hawkins criterion on the result of the formation modeling and swarm evolution were obtained: Perseids - the ejection rate is up to 600 m/s, 500 years after the ejection; Orionids – up to 250 m/s, at the time of ejection; Leonid – up to 2,5 m/s, at the time of ejection; Draconid – up to 50 m/s, at the time of release [3].

References

[1] Drummond, J. D. (1981) Icarus, 45, 545-553, 1981.
[2] Holshevnikov, K.V., Titov V.B. (2007) 1 - 180.
[3] Ishmuhametova, M.G. etc. (2009) Solar System Research, 2009, Vol. 43, No. 5, V. 43, № 5, 438–442.
[4] Jopek T.J. (1993) Icarus, V. 106, Issue 2, 603–607.
[5] Kalinin, D.A., Kulikova, N.V. (2007) Conference works “Near – Earth astronomy”,177-185.
[6] Shestakov, I.S. (1994) Small bodies complexes of the Solar System, Astron. Vertn., V. 28, № 6, 70-82.
[7] Southworth, R. B., Hawkins, G. S., (1963) Smithson. Contrib. Astrophys. 7, 261–285.