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The distribution of meteor orbits in the long-period meteor streams

M. Hajdukova Jr.
Astronomical Institute of the Slovak Academy of Sciences, Bratislava, Slovakia (Maria.Hajdukova@savba.sk)

Abstract

The present work is based on an analysis of 64 650 precisely-determined meteor orbits collected in the Japanese meteor shower catalogue from video observations by SonotaCo [5]. The shower meteor data have been analysed with the aim of determining the orbits' distribution in major meteor streams with heliocentric velocities close to the parabolic limit, in which the errors in the velocity determination correspond to large differences in $1/a$. As the value of semimajor axis a is very sensitive to the value of the heliocentric velocity v_H, especially near the parabolic limit, any error in the determination of v_H can push the orbit over the parabolic limit and create a group of meteoroids apparently moving in hyperbolic orbits.

1. Introduction

The distribution of meteor orbits within meteor stream tells us about its structure, resulting from the mechanism of its formation and evolution, and gives us signatures of the ejection velocities of the stream members from the parent body. However, the original dispersion velocities are smeared by much larger measuring errors, as well as by a number of other effects, from which, for the widely dispersed annual meteor showers, the planetary perturbations is the most influential. A complete study of the real dispersion of orbital elements in meteor streams and of the ejection and dispersion velocities, made by Kresák [3, 4], showed that the real ejection velocities are two or three orders of magnitude smaller than the measuring errors and they are comparable with the dispersion produced by planetary perturbations integrated over several revolutions. In a study of the meteoroid orbits perturbed by collisions with interplanetary dust, made by Trigo-Rodríguez et al. [6], meteor orbits of a high accuracy were analysed and a presence of Leonid meteoroids with peculiar orbits (a much-lower geocentric velocity than usual and thus different orbital elements) was detected. The analysis showed that the most reasonable explanation for this orbital behaviour is collisions with micrometeroids belonging to the zodiacal dust cloud, which could reduce the orbital speed of the meteoroid and produce shorter period meteoroid orbits.

2. 'High speed' shower meteors and hyperbolic orbits

It is obvious that the occurrence of hyperbolic orbits among shower meteors is a consequence of errors in the measured parameters. Detailed analysis [1, 2] of hyperbolic orbits in the Japanese TV catalogue, as well as in the catalogues of the IAU Meteor Data Center, has confirmed this opinion and shown that hyperbolic orbital elements of meteors, which belong to known meteor showers, are a consequence of errors, mainly in the determination of their velocity and radiant position. The meteoroid streams with long periods of several decades to centuries have heliocentric velocities v_H close to the parabolic limit $v_p = \sqrt{2}v_0$ where v_0 is the Earth's velocity. The observational errors of those meteor streams greatly exceed the real deviations from the parent comet's orbit. The mean heliocentric velocity of the Lyrids (41.92 kms^{-1}) differs from the parabolic limit by 0.2 kms^{-1} only, in comparison with that of the Perseids, which differs by 0.4 kms^{-1}. For the Orionids and Leonids, this difference ($\Delta v = v_H - \sqrt{2}v_0$) is 0.62 kms^{-1} and 0.71 kms^{-1} respectively. Hence, a small error in the velocity determination may result in a designation of hyperbolicity of orbit.

As was mentioned above, extreme observed orbital differences between the members of a stream could be, in a few cases, a consequence of collisions or interplanetary perturbations. The first approximation showed that the hyperbolicity of none of the stream meteoroids from the SonotaCo shower catalogue was caused by planetary perturbations.

3. The accuracy of velocity measurements

There are different reasons for errors in the heliocentric velocity, such as the instrumental effects, measuring errors, irregularities in the atmospheric deceleration, errors in radiant determination and timing errors affecting the subtraction of the motion of the earth from the geocentric velocity to find the heliocentric velocity. All these different sources of error vary widely in importance and cannot be readily separated from each other. They create a hyperbolic population which does not really exist. The apparent hyperbolicity of these orbits is caused by a high spread in velocity determination, shifting a part of the data through the parabolic limit. These meteoroid orbits represent the high-velocity tail of an error distribution, and they disappear if only high-accuracy orbits are analysed.

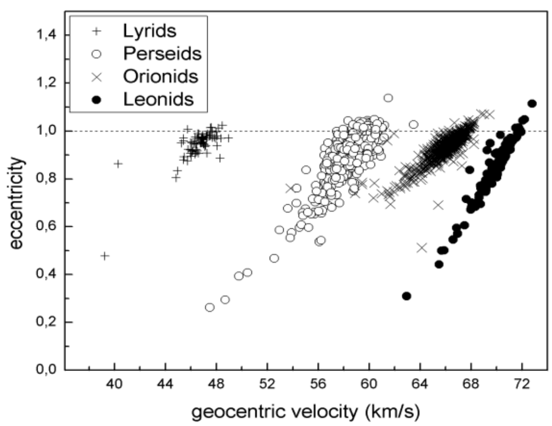

Figure 1: A spread in the eccentricities and velocities of the four meteor showers selected from the investigated TV catalogue. The velocity spread and thus the orbital spread in individual streams is to a large extent a consequence of uncertainties resulting from errors in the determination of the meteor velocity and of the direction of its motion in the atmosphere.

4. Summary and Conclusions

The present work, based on an analysis of shower data collected in the Japanese TV meteor shower catalogue [5] shows the distribution of meteor orbits in the long-period meteor streams derived from the hyperbolic orbits of stream meteors, where an excess over the parabolic value implies measuring errors. There is a widely-observed orbital dispersion in all showers having heliocentric velocities close to the parabolic limit. From the high proportion of hyperbolic orbits in the analysed streams, it has been shown that a major part of the observed differences in the semimajor axes within meteor streams is not due to a real dispersion of orbits but due to measuring errors.

Acknowledgements

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