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The very high meteor velocities produce an apparent interstellar population

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Abstract

The problem of the contribution of interstellar particles to the Solar System meteoroid population was a serious one from the very beginning and in spite of great progress in the development of observational techniques it still remains open. This paper, based on our analyses of meteor orbits from various catalogues of meteors obtained by different techniques, shows that the accuracy of velocity measurements and determinations leads to solutions to the problem of interstellar meteoroids. The uncertainties which result from the measuring errors make the discrimination of an interstellar meteor among the hyperbolic meteors very difficult, and impossible if, in connection with their orbital and geophysical parameters, individual cases are not checked.

1. Introduction

From the position of the whole Solar System in the Galaxy and the studies of processes in the interstellar medium, it is clear that the Solar System is not an isolated system. Its interaction with the interstellar medium should lead to the presence of interstellar particles. The substantial question is how many interstellar particles we should register, and how big their abundance is according to their mass and to their velocities. A search for interstellar particles entering the Solar System is going on at present, using different techniques, covering a mass scale of more than 20 orders, from faint particles detected by cosmic detectors up to the range of bolides detected by photographic methods. The proportion of possible interstellar particles to interplanetary ones, observed with different techniques, was found to be much higher for small particles obtained from high power radars [1, 10] and cosmic dust detectors [2, 3] in comparison with the results of photographic [5, 6] and video obser-vations [7, 9] in the range of large meteoroid particles. This contradiction may be explained by different mass distributions of interstellar and interplanetary particles [7]. In view of the present controversy, it is interesting to note that the leading opinion of the first half of the last century was that the majority (up to 80 %) of meteors are of interstellar origin. Later, by means of Super-Schmidt cameras which allowed a much more precise determination of bolide velocities, the results from the Harvard photographic program gave so few hyperbolic velocities that they raised the question of whether interstellar meteors existed at all. This history may be in some way instructive for the latest conclusions about the detection of interstellar particles, without giving reliable results on the velocity determination of those particles [4], because accurate velocity measurements lead to solutions to the problem of interstellar meteoroids.

2. The velocity determination

The semimajor axis is the orbital element which is most intimately connected with the origin of meteor particles. The value of semimajor axis a is very sensitive to the value of the heliocentric velocity v_H, especially near the parabolic limit. The equation $da = 2v_H a^2 dv_H$ shows that for a big value of the semimajor axis a even a small error in the velocity determination can change an elliptic orbit to a hyperbolic one. Thus, to identify interstellar particles requires giving reliable results on their velocity determination corresponding to the particular observation technique. Here it is useful to retrace the process of the determination of heliocentric velocity from meteor observations: from the measured atmospheric velocity through the non atmospheric velocity and the geocentric velocity to the heliocentric velocity of the meteoroid. Each of these steps tends to increase the inaccuracy of the initial data. The resulting hyperbolicity cannot be attributed at all to the interstellar origin of the particle without a proper error analysis.

3. On the frequency of interstellar meteoroids

3.1 Photographic and radar data of the IAU MDC and hyperbolic orbits

The hyperbolic meteor orbits among the 4581 photographic and 62906 radar meteors of the IAU Meteor Data Center have been analysed using statistical methods. It was shown that the vast majority of hyperbolic orbits has been caused by the dispersion of determined velocities. The large proportion (about 50%) of hyperbolic orbits among the known meteor showers strongly suggests the hyperbolicity of the meteors is not real [5]. The number of hyperbolic meteors in the investigated catalogues does not, in any case, represent the number of interstellar meteors in observational data The analysis of meteors from the most precise Harvard catalogues and their comparison with the other data sets the frequency limit for hyperbolic meteors, with excesses corresponding to the possible interstellar meteors, to 2×10^{-3} [6].

3.2 Hyperbolic meteors in the Japanese TV catalogue

The proportion of hyperbolic orbits in the TV database containing 64650 meteors, decreased significantly, after selecting only quality orbits, from 11.58% of the total number, to 3.28% of the quality selection. After an error analysis, the upper limit of the proportion of possible interstellar meteors to interplanetary ones among all investigated meteor orbits was determined to be 1.3×10^{-3}. However, the hyperbolic excesses of the heliocentric velocities in all cases are about one order less than required from the velocity distribution of neighbouring stars [7].

3. Summary and Conclusions

The error in the heliocentric velocity is a significant source of uncertainty in semimajor axes determination, and it can easily push the orbit over the parabolic limit and create a group of meteoroids apparently moving in hyperbolic orbits. Accurate velocity measurements are the basis for the search for interstellar particles. Thus, the main results concerning the identification of interstellar particles without the possibility of checking individual cases and without a proper error analysis, might need some revision.

Summarizing our analysis above, it can be concluded that, since many apparent hyperbolic orbits are presented in investigated databases, this detailed analysis has called the occurrence of interstellar meteoroids in the vicinity of the Earth into question, at least, in the range of large meteoroid particles corresponding to the used technique detections.

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