EXPERIMENTAL AND THEORETICAL STUDY OF RADIOMETEORS

Jean Delcourt
Centre de Recherches en Physique de l'Environnement
Terrestre et Planétaire
Issy-les-Moulineaux, France

Abstract. We study the long-term evolution of the orbits of meteoric particles subjected to planetary perturbations and to Poynting-Robertson drag. Solar wind erosion of the particle is considered. We compute the long-period elliptic elements of the meteoric orbit when it intersects the orbit of the Earth. We compare experimental results with those of the dynamical study.

INTRODUCTION

From photographic meteors to faint radio meteors, that is from large to small masses, one observes an increasing number:

- of small values of semi-major axis a
- of small values of eccentricity e
- of larger inclinations and even of retrograde orbits.

A serious difficulty is to convert the observed distributions of orbital parameters into corrected distributions, that is orbital parameters having masses between m_{min} and m_{max} and whose perihelion and aphelion distances are respectively less than one AU and greater than one AU (m_{min} due to sensitivity; m_{max} due to saturated signals). Lebedinets (Kascheev et al. 1967) has shown how the different methods of correction used by different observers may introduce apparent discrepancies. Whatever the experimental bias, and the imperfections of the correction methods, one finds in the observed and corrected distributions, when going from photographic to radio meteors:

- an increasing number of small eccentricities for small semi-major axes
- an increasing number of large inclinations, the greater the smaller the semi-major axes, the eccentricities, and the masses.

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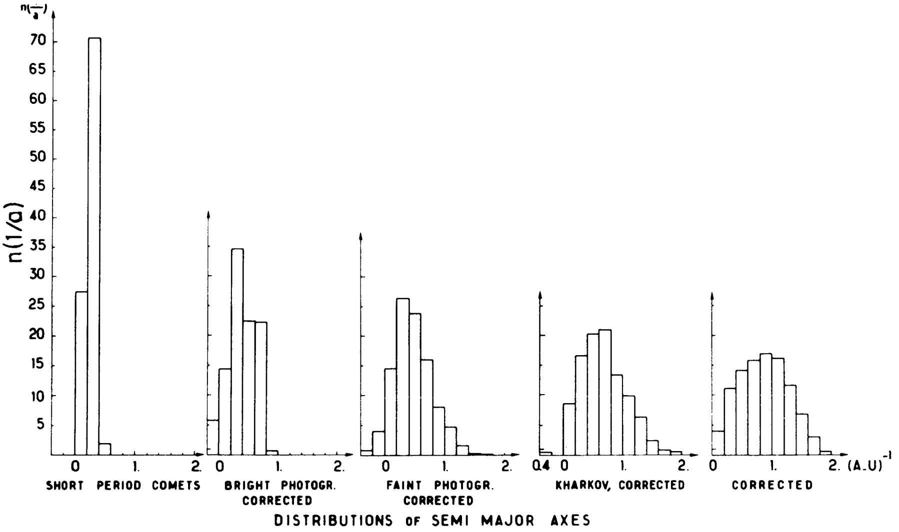

Fig. 1. Corrected distributions of inverse semi-major axes

Figure 1 gives the corrected distributions of semi-major axes for: short period comets, bright photographic meteors of magnitude between -3 and 0 (Whipple, 1954), faint photographic meteors of magnitude between 1 and 3 (McCrosky and Posen, 1961), radio meteors of magnitude between 5 and 7 (Kascheev et al. 1967) and our own observations with an estimated minimum magnitude between 8 and 9. One observes more values less than 1 AU.

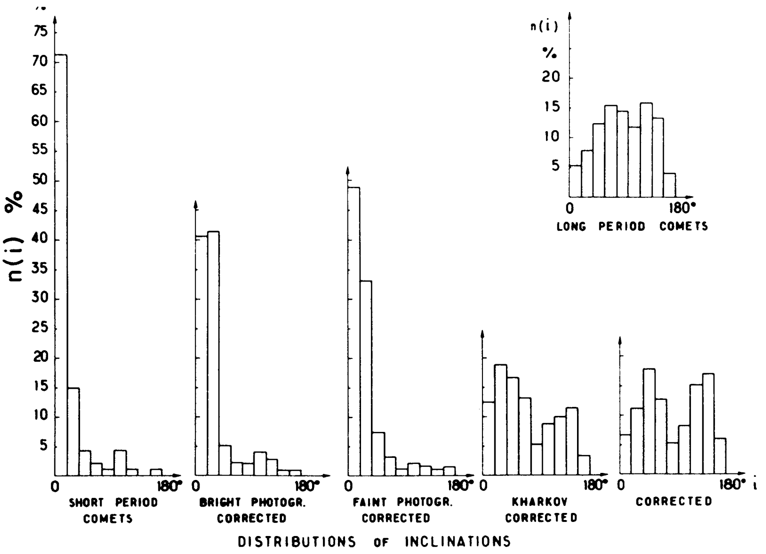

Fig. 2. Corrected distributions of inclination

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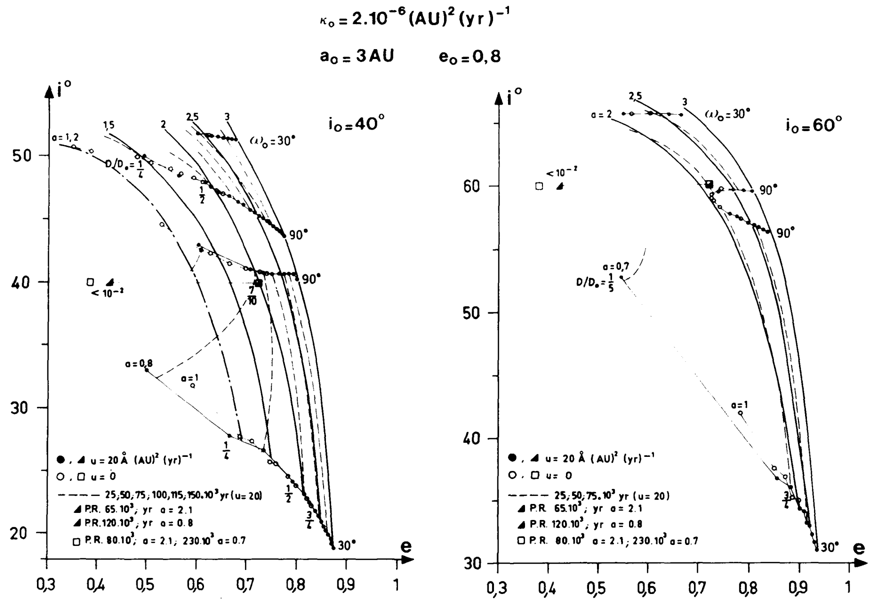
Figure 2 gives the corrected distributions of inclinations for the same cases and also for the long period comets.

In the following, we will try to interpret some characteristics of the observational results. In the frame of restricted three body problem, we study the long period evolution of radio meteor orbits under Jovian perturbations and Poynting-Robertson solar force.

The usual objections presented for neglecting the Jovian perturbations are: the periods of long term variations in eccentricity and inclination are large compared to the physical lifetime of the radio meteor particle. The collisional mechanism certainly operates in planetary rings, in young meteor streams etc. But we believe that destructive collisions are relatively rare for orbits with moderate and large inclinations. A separate analytical study of the purely gravitational three body problem with large eccentricities and inclinations (to be published in Celestial Mechanics) shows that large variations of e and i may be reached in relativity short times, about one thousand years.

The theoretical assumptions of our numerical study are: circular orbit for Jupiter - equivalent spherical particle whose diameter is much larger than the wavelength of solar radiation - no electric charge on the particle (Lorentz scattering is effective for smaller particles, whose diameters are less than 5 μm, Lamy) - no collisional effect on the trajectories - the particle is subjected to solar wind erosion.



ᶠig. 3. i vs e diagrams for evolution of meteor orbits. See text.

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Elliptical elements of the meteoric orbit are calculated when this orbit intersects the Earth orbit. For a given orbit, the detection of a radio meteor is a random event which depends on the position relative to the Earth. Figure 3 is an (e,i) representation. Each intersection is represented by a point (small open circles for the no erosion case). The orbits associated with the points in the figure become less and less probable with time (right to left in the figure). Each (e,i) diagram gives only the points corresponding to $\omega_o = 0°$ (or 30°) and to $\omega_o = 90°$. For $0<\omega_o<90°$, the points would lie in the intermediate domain. Equal semi-major axis lines are shown by the full (or dash-dot) curves. Iso-epoch lines are shown in dashed curves (erosion case only). Full triangles and open squares correspond to a purely Poynting-Robertson evolution. Here, the initial value κ_o yields a P-R acceleration 10^{-3} times the Jovian perturbative acceleration. We have used a somewhat large value of the erosion coefficient: 20 Å AU^2 yr^{-1}.

CONCLUSIONS

Observed eccentricities may be larger than initial ones (not explained by the P-R effect).

Orbits with small semi-major axes and large eccentricities can be explained by sufficiently large κ and large inclinations (as we have obtained with κ_o = 10 and 10^2 times the value of our figure 3).

Orbits with large inclinations have small orbital lifetime.

Jovian and P-R evolution leads to shorter lifetimes than the purely P-R evolution, (it depends on e_o and i_o).

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