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MONTE CARLO MODELING AND METEOR SHOWERS

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Prediction of short-lived increases (by several orders of magnitude) in the cosmic dust influx, the concentration in lower thermoshpere of atoms and ions of meteor origin and the determination of the frequency of micrometeor impacts on spacecraft are all of scientific and practical interest and all require adequate models of meteor showers at an early stage of their existence. A statistical probability (Monte Carlo) model of meteor matter ejection from a parent body at any point of space was worked out by BABADJANOV et al., (1980) and KATASEV and KULIKOVA, (1971) on the basis of the hypothetical appearance of meteor matter in space due to cometary nucleus disintegration. The direction and magnitude of the rate of meteor particle ejection from the parent body at a given point were modeled. The orbital element deviations from the elements of the parent comet orbit were then estimated and mean statistical orbit of a meteor stream formed by meteor particles ejected with specified velocities defined. Statistically reliable calculations were compared with the actual orbital element set of the particular meteor stream under study. This allowed evaluation of the general trends of orbital element changes taking place during meteor stream formation. (These become more obvious the further the ejection point gets from the parent orbit perigee point.) It also served to set limits to possible ejection velocities responsible for the formation of a particular meteor stream and to define more accurately the orbit region where the process was most likely to occur.

According to the scheme described, the formation of ten well known meteor streams was simulated and the possibility of genetic affinity of each of them with the most probable parent comet was analyzed. Some of the results are presented in Table 1.

Table 1

Name (Shower-Comet)	Orbital Region	Ejection Rate (m/s)
Draconids - Giacobini Zinner	0 - 90°	5-50
Leonids - 1866 I	0 - 30°	0, 25-1, 0
Taurids - Encke	80 - 90°	$\approx$ 350
Perseids - 1862 III	30°	$\approx$ 100
Lyrids - 1861 I	0°	> 150 - 160
Andromedids - Biela	0°	> 1,000
Orionids - 1910 II (Halley)	0°	> 350
η - Aquarids - 1910 II (Halley)	0°	< 5
Ursids - 1939 X	0°	for δa 150-200?
	0°	for angular > 1,000
α - Capricornids - 1954 III	0°?	> 1,000

To gain a better agreement of real and modeled calculations for large time intervals, the effect of a variety of gravitational and non-gravitational effects should be considered. To eliminate a number of restrictions, a statistical probability version of our algorithm was proposed to take into account the effect of solar radiation re-emission by the spinning spherical particle. This made it possible to investigate the behavior of meteor particles with both direct and retrograde rotation and to estimate the solar infall time of these particles.

It has turned out that the theoretically expected removal of meteoroids with direct axial rotation away from the Sun for particles with a radius of no more than k cm does not occur. Such meteoroids merely decelerate their falling into the Sun as compared with meteor particles of retrograde rotation. It is only at very close distances to the Sun (about 0.01 a.u.) that this effect appears comparable in value to other effects caused by solar radiation.

When comparing cometary and meteor stream orbits, it should be kept in mind that both single and successive matter ejections result in an impulse which affects the cometary nucleus in the direction opposite to the outflowing substance motion. This effect has been supposed to be the cause of the observed irregular changes observed in certain cometary orbital elements, no matter what the nature of the outflowing substance. A mathematical algorithm to calculate the perturbing acceleration components in three mutually perpendicular coordinates was suggested by SEKANINA (1968) for an arbitrarily rotating spherically-symmetric nucleus with a fixed rotation axis relative to the orbital plane. However, his derived solutions appear rather complicated and call for very accurately chosen initial assumptions.

A statistical probability variation of the algorithm was developed that helps to determine the outflow direction cosines by means of a combination of random numbers and variation (within specified limits) of mass of the ejected matter. The ejection velocities used here follow from the conditions of a particular meteor stream formation and its connection with a given comet. They were obtained through the ejection simulation described above. The calculations were made for comets Giacobini-Zinner and Encke with $r \leq 2$ a.u. and for comets 1954 III and 1910 II, in particular for the case when ejection occurred at cometary orbit perigee. Maximal deviation of orbit elements from their original element system caused by the ejection impulse are given in Table 2.

The cometary motions changes thus obtained, even though they define more accurately a part of the divergencies existing between orbital elements of parent comets and meteor streams, cannot really account for them. This is particularly true of angular elements. The orbital semi-major axis is subjected to the greatest changes under the dynamical effect. The eccentricity is less affected. The spatial orientation of cometary orbit when the affinity of a particular meteor stream and comet is ascertained is sometimes considered invariable. However, ejection effects may not be solely responsible. There are also non-gravitational changes in cometary motion. For instance, EVDOKIMOV (1984) reported non-gravitational changes in semi-major axis for comet Giacobini-Zinner of $-0,12 \times 10^{-3}$ a.u., $0,1 \times 10^{-3}$ a.u. for 1972 and 1979 respectively. To make these results agree with the modeled ones, meteor matter ejection must be assumed to occur in the perigee region for 23 days non-stop, a duration which seems hardly possible.

Table 2

Comet in Perigee	Ejection rate (m/s)	δa (a.u.)	δe	$\delta\Omega$ (rad.)	δi (rad.)	$\delta\omega$ (rad.)
Encke	400	$0,4303\times10^{-4}$	$0,2967\times10^{-5}$	$0,2529\times10^{-6}$	$0,6074\times10^{-6}$	$0,1234\times10^{-5}$
Giacobini-Zinner	25	$0,3638\times10^{-6}$	$0,2834\times10^{-7}$	$0,1845\times10^{-8}$	$0,6433\times10^{-8}$	$0,1444\times10^{-7}$
1954 III	600	$0,4307\times10^{-4}$	$0,2662\times10^{-5}$	$0,6353\times10^{-7}$	$0,2103\times10^{-6}$	$0,2414\times10^{-5}$
1910 II	100	$0,2513\times10^{-3}$	$0,4575\times10^{-6}$	$0,2690\times10^{-6}$	$0,3225\times10^{-7}$	$0,3351\times10^{-6}$

There is no doubt that this method of research is convenient and useful. The possibility of developing new models, more elaborate and even better simulation of the natural processes makes it possible to tackle the solution of problems that cannot be resolved otherwise.

References

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