DYNAMICS OF LONG PERIOD COMETS

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The appearance of Halley's Comet in 1985-86 and the related emphasis on research on physical models of cometary nuclei, led to a more moderate pace for the dynamical studies of the Oort cloud and the motion of long-period comets this year. Specific areas studied included the dynamical evolution of cometary showers as a result of stars passages through the inner Oort cloud and the possible relationship to observed stepwise mass extinctions at geological boundaries, revised estimates for the total mass of comets in the Oort cloud as a result of lessons learned from the spacecraft encounters with Halley's Comet, and study of the possible dynamical sources for the short-period comets in the solar system as part of a wider study of physical processing of cometary nuclei prior to their becoming visible comets.

The work on cometary showers used a Monte Carlo simulation of the evolution of cometary orbits under a combination of planetary, nongravitational, and stellar perturbations, and with physical removal by disruption, sublimation of all volatiles, and collision. A major cometary shower lasts about 2 to 3 Myr after the initial perturbation, with peak flux rates of about 9,000 comets crossing the Earth's orbit per year (600 times the usual flux). The average comet makes 8.5 returns with an average lifetime of about 0.8 Myr. Such an intense random shower would be caused by a one solar mass star passing 3,000 AU from the sun, would be expected perhaps once every 500 Myr, and might produce on the order of 20 significant impacts on the Earth.

The actual mechanism for initiating showers was found to be quite interesting. As compared with Hill's (1981) simple loss cone analysis, it was found that the total number of comets entering the planetary region was somewhat less, and the fraction perturbed to small perihelia (Earth-crossing orbits) was lower still. In addition, the intensity of showers dropped off sharply with more distant stellar passages, roughly as the inverse square of the encounter distance. The number of comets peturbed into the inner solar system is very much a function of the distribution of orbital semimajor axes in the inner Oort cloud; the figures above reflect an inner cloud that is only modestly centrally condensed. If the distribution of orbits in the cloud is steeper then distant encounters would be less effective at inducing large numbers of comets into cometary showers.

The timescales for cometary showers and that for disruption of terrestrial environments as revealed in the fossil record at extinction boundaries, are comparable. This does not prove a causal relationship and may be entirely coincidental, but it does demonstrate that comet showers may provide a plausible explanation for some biological extinction events. The main problem with this hypothesis is that extinctions are roughly 10 times more frequent than the expected rate of major cometary showers.

The estimated mass of comets in the Oort cloud has increased dramatically as a result of the revised estimate for typical cometary albedos based on the Halley spacecraft encounters. The term "dirty snowball" has tended to mislead people into thinking that comets were relatively bright objects, perhaps gray in color. In fact, comets are really "frozen mudballs" with the low albedo of their non-volatile constituents. While lowering the albedo causes an increase in the mass estimate, other factors such as shape, improved population estimates based on new dynamical modeling, and the fraction of active area on the nucleus, serve to reduce the total mass estiamte. Using a revised albedo of 0.05 based on the Halley encounters, it was found that the mass of comets in the outer, classical Oort cloud was 25 Earth masses, and the mass of the inner Oort cloud which serves as a reservoir to replenish the outer cloud is perhaps 250 Earth masses. The latter estimate is highly uncertain because of the lack of detailed dynamical modeling of the inner Oort cloud to date. Also, present attempts to estimate the density of cometary nuclei based on modeling of nongravitational forces on Halley are still highly uncertain.

The question of the source of the short-period comets is one that has taken on new meaning becaue of the proposed spacecraft missions to comets. To interpret the cosmochemical record found in comets it is necessary to know where they formed, and where they have been since their formation. Halley results have already shown that the comet appears to have formed from the same material as the rest of the planetary system. But the dynamical history of Halley prior to its being peturbed into its present orbit remains a mystery. The classical view is that short-period comets are long-period comets from the Oort cloud, captured by Jupiter perturbations. Recently, it has been shown that the inner Oort cloud should provide a dynamically more efficient source as comets trickle across Neptune's orbit and are passed down by planetary perturbations into the inner solar system. However, Halley's retrograde orbit argues against this (for Halley only) because the comets derived from the inner Oort cloud should be in direct orbits. Because of the chaotic nature of cometary orbit evolution, and the large number of comets we have to deal with, it is difficult to rule out any dynamical path for the origin of Halley or any other short-period comet. Work on this problem will continue.