Are Edgeworth-Kuiper Belt Objects Pristine?

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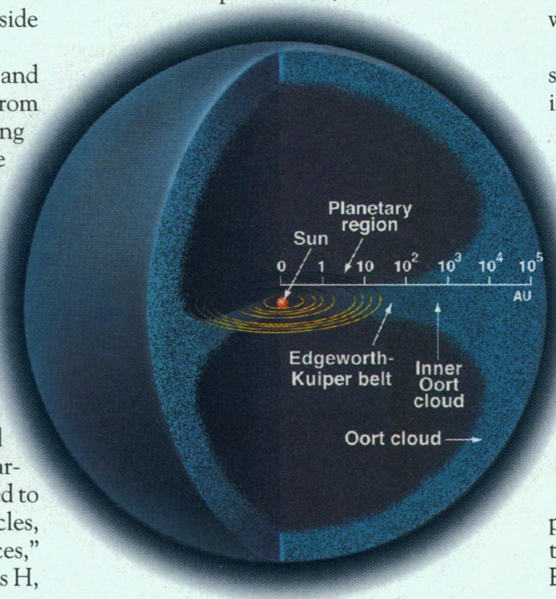
Planetary scientists believe that comets are pristine fossils from the early solar system. Because these objects contain abundant volatile elements, the argument goes, they must have evaded the destruction caused by thermal or shock reprocessing. In this issue, however, Farinella and Davis (*1*) cast doubt on the "pristinity" of comets, on the basis of their computer simulation of collisional evolution of bodies in the Edgeworth-Kuiper Belt (EKB), a comet reservoir extending outside the orbit of Neptune (*2*).

Compared to large planets, asteroids and comets preserve primordial materials from the beginning of the solar system, having suffered minimal thermal effects since their formation. Asteroids are fragments formed by collisions between parent bodies that produce some of the meteorites collected on Earth. The reflectance spectra of asteroids fall into classes and show a systematic variation in their spatial distribution. A similar classification occurs among meteorites, suggesting different degrees of thermal activity that primarily depend on their position inside the meteorite parent bodies. Comets, however, are believed to be aggregates of tiny mineral particles, coated with organic compounds and "ices," that are enriched in the volatile elements H, C, N, O, and S. It is expected that comets suffered little of the heating that would have driven off most of the volatiles.

Comets are of two types: long and short period. The major source of long-period comets (periods > 200 years) is the Oort cloud (*3*), a spherical shell of comets surrounding the solar system at a distance of a few times 10^4 to 10^5 astronomical units (1 AU = 1.5×10^8 km, the mean distance between the sun and Earth) from the sun. Some of the long-period comets become short-period ones when they fall into the inner region of the solar system and repeatedly encounter planets like Jupiter, whose gravity distorts their primary orbits. To explain the properties of short-period comets, dynamicists require hypothetical sources such as a belt at the periphery of the planetary region and the more distant and massive inner Oort cloud extending to 10^4 AU (see figure). This belt matched the idea of the swarm of remnant planetesimals just outside the solar system, proposed by Edgeworth and Kuiper (*2*).

Recently, the objects that they predicted have actually been detected. The first object, $1992QB_1$, was discovered in 1992 at 41.2 AU from the sun (*4*). Presently, more than 30 such objects have been observed between the orbit of Neptune and 45 AU. One of the remarkable characteristics of the Edgeworth-Kuiper Belt Objects (EKOs) is that many of them have nearly circular orbits about the sun with inclinations of less than 5°, as most of the planets do. This is very different from cometary orbits, which are often highly elliptical or almost hyperbolic and of large inclination. The diameters of EKOs range from 100 to 400 km, if the surface reflectivity is the same as that of comet Halley. There must also be a number of smaller objects, as well as objects farther than 45 AU, owing to the limit of Earth-based instruments that allows only objects brighter than 25th magnitude to be detected. Indeed, Hubble Space Telescope data (*5*) suggest the presence of more fainter objects.



The solar system outside of the planetary region may extend from the Edgeworth-Kuiper Belt to the inner and main Oort clouds. The detection of distant objects has reached the inner edge of hypothetical swarms of planetesimals.

What is the significance of EKOs in view of the current theory of the origin of the solar system? Models suggest that the planets formed through mutual collisions and coagulation of planetesimals. Planetesimals are small aggregates of dust grains thought to have formed in the primordial solar nebula, a disk of gas and dust revolving around the protosun. Near the sun, the density of the gas and dust must have been so high that the planetesimals could have grown to the size of the planets. In the outer nebula, however, they could not have grown fast enough because of long orbital periods and low densities of materials, before the protosun drove away the remaining gas and dust with its intense radiation and stellar wind. Thus, immature planetesimals may still hover outside the present planetary region far beyond Neptune (*6*). The discovery of EKOs has been taken as evidence of remnant planetesimals that survived without alteration of the primitive materials.

Farinella and Davis (*1*) consider collisional fragmentation and have made numerical simulations of orbital changes to EKOs by assuming their initial size distribution to be similar to that of the current asteroids. They have shown that a substantial population of the small EKOs with diameters of less than 10 km can move into the planetary region as a result of mutual, collisional scatterings. They conclude that short-period comets from the EKB are collisional fragments, which are unlikely to be pristine, volatile-rich planetesimals. They also argue that larger EKOs, which would not fragment on collision, suffer alteration near the surface.

Doubts about both EKOs and the short-period comets force us to reexamine the nature of pristinity. Spectral observations of EKOs, as have been made for asteroids, will give us clues to the degree of alteration. In addition, we do not yet know the whole structure of the EKB and beyond: Does the EKB extend to the hypothetical inner Oort cloud and the main Oort cloud? Does the pristinity of EKOs vary with distance from the sun? Identification of distant and smaller EKOs should give us answers to these questions. Our understanding of the solar system is extending not only spatially but also backward in time to the "Archean era" of the solar system as we observe objects farther and farther out.

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