The Effects of a Stellar Encounter on Edgeworth-Kuiper Belt

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We investigate the influence of a stellar fly-by encounter on the Edgeworth-Kuiper belt objects through numerical orbital calculations, in order to explain both mass depletion and high orbital inclinations of the classical Edgeworth-Kuiper belt (CEKB) objects, which have semimajor axis of 42--48AU and perihelia beyond 35AU. The observationally inferred total mass of the CEKB is ~ 1/10 Earth masses, which is only ~0.02 of

that extrapolated from the minimum-mass solar nebula model.The CEKB consists of bimodal population: ``hot population'' with inclinations ~ 0.2-0.6 radians and ``cold population'' with i ~ 0.1. The observationally suggested difference in size and color of objects between the two populations may imply different origins of the two populations. We find that both the depletion of solid materials in the CEKB and the formation of the hot population are accounted for by a single close stellar encounter with pericenter distance of 80-100AU and inclination relative to the initial protoplanetary disk ~50-70 degrees.

Such a stellar encounter highly pumps up eccentricities of most objects in the CEKB and then their perihelia migrate within 35AU. These objects would be removed by Neptune's perturbations after Neptune is formed at or migrates to the current position (30AU). Less than 10% of the original objects remain in stable orbits with small eccentricities and perihelion distances larger than 35AU, in the CEKB, which is consistent with the observation. We find that inclination of the remaining objects are as large as that of the observed hot population. We also investigate orbital evolution of objects due to gas drag after the stellar encounter. Objects with high eccentricities migrate to inside of 30AU and the population of objects become so small beyond 30AU that Neptune's migration may stop at ~ 30AU, because the migration is caused by the scattering of objects. The depletion by the stellar encounter extends deeply into ~30-35AU, which provides the basis of the formation model for the cold population through Neptune's outward migration by Levison and Morbidelli (2003, Nature 426, 419-421). The combination of our model with Levison & Morbidelli's model could consistently explain the mass depletion, truncation at 50AU, bimodal distribution in inclinations, and differences in size and color between the hot and the cold populations in the CEKB.