The Evidence of an Early Stellar Encounter in Edgeworth-Kuiper belt

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The total mass of the classical Edgeworth-Kuipter belt, which consists of objects with semimajor axes of 42-48AU and perihelia beyond 35AU, contains about 1/10 Earth masses. This value is much lower than the total mass of solid material in the region of the minimum-mass solar nebula,

which is 10 Earth-masses. Moreover, the classical Edgeworth-Kuiper belt has the component whose inclinations are 0.2-0.6 radians, which is called the hot population. We investigate the influence of a stellar encounter on the Edgeworth-Kuiper belt objects through numerical and analytical orbital calculations. We find that a close stellar encounter with the pericenter distance of 80-100AU and the inclination with respect to the initial protoplanetary disk of 50-70 degrees, can explain the observed depletion and the ormation of the hot population. Such a stellar encounter can highly pump up ccentricities of objects beyond 40AU and

then their perihelia migrate within 35AU.

These objects are strongly scattered by Neptune at the current position (30AU) after the stellar encounter. Objects with perihelia beyond 35AU remain in the classical Edgeworth-Kuiper belt region. We find that the amount of the objects with perihelia beyond 35AU is about 1% of initial one, which is consistent with the observed depletion.

We also investigate the orbital evolution of objects after the stellar encounter due to the gas drag force by the solar nebula.

We analytically derive changes in semimajor axes, eccentricities, and inclinations due to the gas drag. Our derived expressions are valid even for objects having large eccentricities and inclinations like Edgeworth-Kuiper belt objects. Gas drag is effective mainly for objects with high eccentricities beyond 40AU. In the minimum-mass solar nebula model with the life time ~ 10^7 years, the orbits of objects in the classical Edgeworth-Kuiper belt region (semimajor axes of 42-48AU and perihelia beyond 35AU) do not change due to gas drag strongly. Thus, the amount of objects in the classical Edgeworth-Kuiper belt region

is of the order of 1% of the initial value and the hot population keeps having the high inclinations, after the orbital evolution due to gas drag. On the other hand, the objects with large eccentricities and small perihelia migrate to the inside of 30AU. The objects may be supplied to inner region and help the growth of planets. If the gas nebula has a higher density than the minimum-mass solar nebula,

samimajor axes and eccentricities and inclinations of objects are damped due to the gas drag strongly. After the orbital evolution due to the gas drag, the amount of objects in the classical Edgeworth-Kuiper belt region increases and inclinations of the hot population are damped. It is found that the nebula density

comparable to or smaller than the minimum-mass solar nebula in outer region is plausible to explain the amount of classical Edgeworth-Kuiper belt objects

and inclinations of the hot populations

after the excitation due to a stellar encounter.