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Orbital Evolution of Planetesimals due to the Galactic Tide 2

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The Oort cloud is a spherical comet reservoir surrounding the solar system. There is general agreement that the Oort cloud comets are the residual planetesimals of planet formation. The standard scenario of the Oort cloud formation consists of two dynamical stages: (1) giant planets raise aphelia of planetesimals to the outer region of the solar system and (2) the galactic tide, passing stars, and giant molecular clouds pull up their perihelia. We have already reported the results of the numerical study of the first stage in other meetings. Here we show the orbital evolution of planetesimals by the galactic tide. Planetesimals with large aphelion distances change their perihelion distances toward the outside of the planetary system by the galactic tide and become members of the Oort cloud. We consider only the vertical component of the galactic tide. The effect of the galactic tide on the planetesimals with semimajor axes of tens of thousands of AU is about one thousandth of the solar gravity. The timescale of the orbital evolution is about hundreds of millions of years.

Under the axisymmetric potential, some planetesimals initially with i(inclination) less than about 30deg may show the librations around omega(argument of perihelion)=pi/2 and 3pi/2. This is called Kozai mechanism. The ecliptic comets satisfy this condition. The alternate increases of e(eccentricity) and i of Kozai mechanism are effective to make the Oort cloud. The secular perturbation theory can demonstrate the Kozai mechanism and we can understand the motion of the planetesimals analytically.

As explained by the Kozai mechanism, the orbital evolutions of the planetesimals under the galactic tides strongly depend on the initial omega and i. However, it does not strongly depend on e. We suppose that the distribution of the initial omega is uniform and know the distribution of the semimajor axis by our previous numerical calculations. Using these distributions of the initial conditions, we can discuss the property of the Oort cloud statistically. In other words, we can estimate the distribution of the planetesimals which construct the Oort cloud and come back again to the planetary region.

We show the applications of Kozai mechanism to the galactic tide and discuss the properties of the Oort cloud and the extra-solar comet clouds by the results of the numerical calculations.