Evolution of the planetary obliquity with the orbital evolution of the satellite

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We have numerically calculated the evolution of the planetary obliquity due to the tidal interaction with the planetary satellite. We have investigated the stability of the planetary obliquity and its final state.

Planetary satellite play an important role for the motion of the planetary spin. Satellite gains the orbital angular momentum through the tidal interaction with the planet, so that it recedes from the planet. On the other hand, the planet is decelerated because it loses their spin angular momentum. The planet's obliquity also evolves. It is shown that the Earth's obliquity have been increasing through the tidal interaction with the Moon (e.g., Goldreich 1966,Touma & Wisdom 1994). Since tidal evolution strongly depends on the mass of the satellite, the evolution of the planetary obliquity would also depends on its satellite mass.

The satellite accelerates the precession motion of the planet's spin axis. Currently, on account of the gravitational torque due to the Moon, Earth's spin precession is about 3 times faster than the precession without the Moon. As a result, the spin axis of the Earth can avoid the spin-orbit resonance (e.g., Laskar et al. 1993). Spin-orbit resonance is the 1:1 resonance between the precession of the obliquity and that of the orbital plane that induces large change in obliquity. The precession speed of the planet's spin would vary with the orbital evolution of its satellite.

In this study, we have numerically simulated the evolution of the satellite's orbit, rotation frequency and obliquity of the planet in consequence of the tidal interaction. We assumed the system with the host star, planet and its satellite. In the calculation, we included the dissipation of gravitational tide due to the host star. The planetary obliquity increases with the evolution of the satellite's orbit. If the mass of the satellite is as large as the Moon, the obliquity inclines to 40-50 degrees within 10^5-10^8 years. However, the evolution of the obliquity near the co-rotation point with the satellite depends on the tidal model. If the mass of the satellite is smaller than the Moon's mass, the obliquity hardly change. We also investigated the evolution of the precession frequency. In the talk, we show the detail of our calculation and discuss the stability and the final state of the planetary obliquity.