Forced libration of Ganymede including the visco-elastic tidal deformation

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From spacecraft observations and interior thermal modeling, Ganymede has been expected to possess a global ocean beneath its ice shell. To confirm an existence of the ocean, the JUICE (JUpiter ICy moons Explorer) mission has been prepared by ESA (The European Space Agency) and the spacecraft will be launched in 2022. After arriving at Jupiter system, the JUICE spacecraft is going to make several flybys Europa and Callisto and finally will orbits around Ganymede. During orbiting around Ganymede, the spacecraft will obtain several kinds of scientific data, for instance, surface topography from GALA (GAnymede Laser Altimeter) and surface images from JANUS (camera system). These data will provide important information about the tidal responses of Ganymede.

The tidal responses, e.g., tidal deformation and rotational variation, are caused by the gravitational force of other bodies such as a mother planet. The rotational variation includes libration, obliquity variation, nutation, and precession. In this study, we focus on the libration which is a spin rate variation caused by a torque acted on the aspherical degree-2 order-0 shape of the satellite. The libration changes the centrifugal force of a satellite and affects the tidal deformation. Inversely, tidal deformation affects the aspherical shape of the satellite.

Although Van Hoolst et al. (2013) has modeled the interaction of the tidal deformation and the libration, their tidal deformation models were simplified. In order to estimate an actual libration, we model 5-layered Ganymede interior and use the visco-elastic tidal deformation model constructed by Kamata et al. (2016). Our interior model consists of five layers, which have a homogeneous density and rigidity in each layer. The viscosities of the ocean, the high-pressure ice mantle, the rock mantle and the metallic core are homogeneous in each layer, and the viscosity of the ice shell is not homogeneous and depends on a radial temperature variation.
As a typical case, we use interior parameters which are the ice shell thickness of 155 km, the ice shell density of 940 kg/m^3 , the ocean thickness of 1 km, and the ocean density of 1050 kg/m^3 . Then we also use the three sets of a shell rigidity and a shell viscosity (1) 0.1 GPa and 10^{12} Pas, (2) 0.1 GPa and 10^{17} Pas, and (3) 10 GPa and 10^{17} Pas, respectively. The results for the libration amplitude are 34.1 m, 34.1 m, and 37.5 m respectively. As a conclusion, our calculation of the visco-elastic libration infer that the reference viscosity of ice (temperature-dependent viscosity of ice at a melting point) doesn’t affect the amplitude of the shell libration. The ice rigidity affects the amplitude of the shell libration of order of a few meters.

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