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An assessment of the determination of the tides and the rotation state of Ganymede with JUICE radio science experiment

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Besides being the largest natural satellite known in the Solar System, Ganymede most likely also has the most differentiated internal structure of all satellites.Ganymede is thought to have an external water/ice layer subdivided into three sublayers: an outer ice shell, a global liquid water ocean, and a high pressure ice mantle. The presence of a water layer is supported by the possible detection of an induced magnetic field with the Galileo spacecraft. The metallic core is divided into a solid (inner core) and a liquid (outer core) part. Between the water/ice and the metallic layers, a rock mantle is expected.

The JUpiter ICy moons Explorer (JUICE) mission led by ESA is planned to be launched in 2022. The spacecraft is expected to enter in orbit around Ganymede in september 2032. The Ganymede Tour will alternate elliptic and circular phases at different altitudes. The circular phases at altitudes of a few hundred kilometers are dedicated partly to the study of the internal structure such as the determination of the extent and composition of the ocean and of the surface ice shell. The payload of the spacecraft comprises the radio science package 3GM (Gravity and Geophysics of Jupiter and the Galilean Moons) that will be used to measure the Doppler effect on radio links between the orbiter and the Earth which will be affected by the gravity field of Ganymede.

The gravity field of Ganymede is the sum of the static hydrostatic field (related to the secular Love number k_f), of the periodically varying field due to tidal deformations (related to the tidal Love number k_2 and the tidal dissipation factor Q), of the periodically varying field due to change in the rotation state (variations in the rotation rate and in the orientation of the rotation axis), and of the non-hydrostatic field that may be due to mass anomalies. The tidal and rotation parameters depend on the internal structure of the satellite (density, size, rheological properties of the different layers) in a non-trivial way. Our aim is to assess for which internal structure quantities of Ganymede information can be retrieved from Doppler effect measurements.

The Doppler effect is modelled by the relative radial velocity between the orbiter and the terrestrial observer, considering the tides and the rotation state of Ganymede, together with the strong attraction exerted directly by Jupiter on the orbiter. The modelisation neglects some effects such as a possible atmospheric drag and a possible non-hydrostatic part of the gravity field. We aim to answer questions as “Is it possible to separate the tidal and rotational signals?”, “What is the optimal orbital configuration?”. The inversion of the simulated noised data is done by the least square method. An interesting configuration has to maximise the effect of the tides and of the rotation on the Doppler signal, in order to maximise the constraints inferred on the internal stucture of Ganymede. It also has to correspond to a quite stable quasi-circular orbit as required for the circular phases of the Ganymede tour.