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The gravity field of Ganymede after the *Juno* Extended Mission

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Abstract

The *Juno* Extended Mission (EM) presents the first opportunity to acquire gravity measurements of the Galilean satellites after the Galileo mission, ended almost 20 years ago. On June 7th, 2021, *Juno* will flyby Ganymede with a closest approach altitude of ~1050km and a relative velocity of ~18.5 km/sec. This will be the first time that a probe acquires gravity measurements of Ganymede since December 28th, 2000, when *Galileo* performed G29, its last flyby of this Galilean moon.

In total, the *Galileo* probe performed 6 flybys of Ganymede, among which only 4 had coherent two-way S-band Doppler tracking during the closest approach, and could be used to estimate the gravity field of Ganymede. The very first analysis of these data, used only two flybys, G1 and G2, and estimated J_2 and C_{22} applying the hydrostatic equilibrium constraint ($J_2/C_{22} = 10/3$) (*Anderson et al., 1996*). The analysis concluded that Ganymede's internal structure is likely formed by a metallic core surrounded by a silicate mantle enclosed by an ice shell. A subsequent gravity field analysis was unable to fit all tracking data (G1, G2, G7 and G29) without including a high degree gravity field nor obtain a physical interpretation of the results (*Schubert et al., 2004*). These problems could be solved only by adding mass anomalies to the dynamical model of Ganymede's interior (*Anderson et al., 2004; Palguta et al., 2006).*

This new encounter, (G34), during *Juno's* EM, offers the possibility of improving the knowledge on the gravity field of Ganymede. The gravity field of a body can be estimated through the reconstruction of the probe's trajectory during a close encounter, exploiting the dynamical Doppler shift of a highly stable microwave carrier, induced by the relative motion between the DSN stations on the Earth and the probe. During G34, through which *Juno* will also perform a radio occultation experiment, the spacecraft will use simultaneously the X/X and X/Ka radio links. An accurate range-rate noise budget led us to the conclusion that we can expect an accuracy of 0.025 mm/s, at 60 s integration time, compatible to the accuracy acquired during PJ13 and PJ27, where the same radio link configuration was adopted. By comparison, the *Galileo* range-rate data had an accuracy of 0.34 mm/s, because of the use of S-band link and the onboard Low Gain Antenna. Moreover, this link configuration allows to use the multi-frequency link calibration technique to remove the downlink plasma contribution, preventing biases from local dispersive noises as the possible Ganymede's ionosphere or the Io plasma torus.

Nevertheless, our results from a covariance analysis indicate that, by itself, G34 cannot provide an improvement to the current knowledge on Ganymede's interior structure, being only able to constraint the hydrostatic ratio J_2/C_{22} to the ~45%. This is mainly due to the flyby characteristics, and in particular the high relative velocity. However, a joint analysis with the coherent S-band radio tracking data of the *Galileo* spacecraft (Figure 1), acquired more than 2 decades ago, represents an opportunity to shed some light on the gravity field of this Galilean satellite.

Preliminary results from numerical simulations, performed using JPL's orbit determination program, MONTE (*Evans et al., 2018*), using a setup similar to the one used for Jupiter's gravity determination (*Durante et al., 2020*), indicates that the hydrostatic ratio J_2/C_{22} could be constrained to within ~10% (1-sigma).

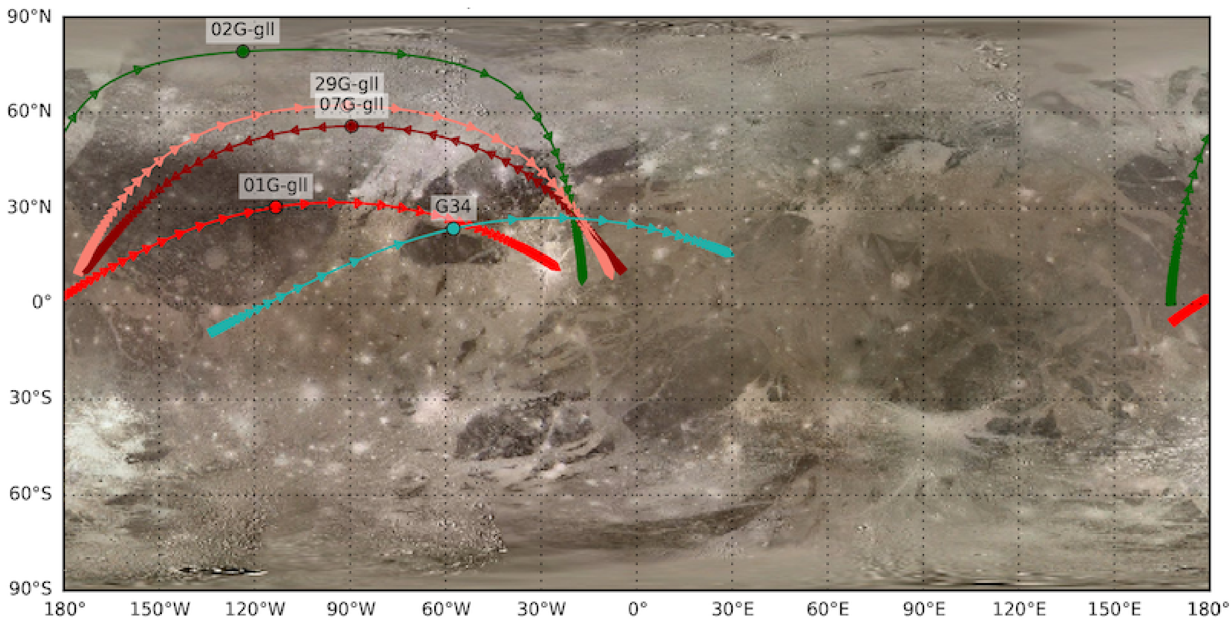

Figure 1: Juno and Galileo ground-tracks over Ganymede during the different encounters. The ticks are separated by 60 s.

This work will present an updated gravity field of Ganymede, showing the possible implications in terms of interior modelling. This will be the outcome of a joint analysis of all the available real data acquired during G34 and the *Galileo* flybys, applying modern orbit determination techniques used in the past in the *Cassini* gravity analyses (*Durante et al., 2019, Zannoni et al., 2020*). The real data used in this analysis will be the last gravity measurements of Ganymede acquirable until future flybys, of Juice and Europa Clipper missions, in the next decade.

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