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Improving Io Plasma Torus models using Galileo Doppler data

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The Io Plasma Torus (IPT) is a toroidal cloud of plasma, centered on the centrifugal equator of Jupiter at Io's orbital distance, that induces a path delay and a carrier frequency shift on radio frequency signals. Juno is currently orbiting Jupiter in a highly eccentric, 53.5-day orbit, with a perijove altitude of about 4000 km. During each perijove pass, Doppler measurements between Juno and the Earth are acquired for about eight hours centered around Jupiter's closest approach. Due to the orbital geometry, the radio frequency signal crosses the IPT, yielding a non-dynamical Doppler shift, that, if not properly calibrated, can be a potential source of bias in the Jupiter estimated gravity field coefficients.

During the first perijove pass (conventionally named PJ01), a direct measurement of the downlink plasma contribution was possible by transmitting downlink signals at X and Ka-band coherent with a common X-band uplink. During the perijove passes dedicated to gravity investigations (currently PJ03, PJ06, PJ08, and PJ10) a dual-frequency link at X and Ka band allows to calibrate about 75% of the total plasma contribution on the signal, including the one due to the IPT. During non-gravity dedicated perijove passes a communication link at X band only is available, so that the signal due to the IPT can be corrected only using a model of its internal electron density distribution.

Here we propose to improve the model already available in the literature using radio science Doppler data from other space missions, such as Galileo. NASA's Galileo spacecraft arrived to the Jupiter system on December 1995 and studied the Galilean satellites, Jupiter and its magnetosphere, for the following 8 years. However, the orbiter's umbrella-like High Gain Antenna (HGA) failed to correctly deploy, so that the spacecraft was able to operate using only the low-gain antenna (LGA) at S band, with its downlink data rate being much lower than originally planned. Moreover, this prevented any dual-frequency calibration of the radio link that could have corrected the dispersive signal induced by the IPT, potentially affecting the radio science experiment results.

We re-analyzed Galileo Doppler measurements acquired by the Deep Space Network during the flybys of the Galilean satellites, using a local orbit determination fit, highlighting the presence of residual un-modeled signatures. The signatures were compared to the expected Doppler signal due the IPT, computed using models already available in literature, suggesting that the IPT can be effectively calibrated, removing the residual signatures, adjusting some of the model parameters.