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Energetic ion depletions near Europa and Io: the effect of plumes and atmospheric charge exchange

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Introduction

The flux of energetic ions (protons, oxygen and sulfur) near the Galilean moons were measured by the Energetic Particle Detector (EPD) on the Galileo mission (1995 - 2003). Near Galilean moons (such as Io and Europa) depletions of the energetic ion flux, of several orders of magnitude, were identified.

Such energetic ion depletions can be caused by the absorption of these particles onto the moon's surfaces or by the loss due to charge exchange with neutral molecules in the atmospheres or potential plumes. To interpret the depletion features in the EPD data, a Monte Carlo particle tracing simulation has been conducted. The expected fluxes of the energetic ions are simulated under different scenarios including those with and without an atmosphere or plume. By comparing the simulated flux [YF1] to the EPD data, we investigate the cause of the depletion features with particular focuses on Europa and Io flybys.

Results

For Europa we report the following findings:

- For flyby E12 we find that a global atmosphere should produce a depletion region along the trajectory that is symmetrical to the closest approach, for energetic protons in the energy range of 80-220 keV. No such feature is visible in the data. Upper limits of the atmosphere are consistent with surface densities (10^8 cm^{-3}) and scale heights (50-350 km) of previous studies. We find that a depletion of energetic protons (80-220 keV) occurring before closest approach is consistent with the field perturbations associated with a plume. This plume features coincides in time with the plume reported by Jia et al., 2018.
- For flyby E26 we find that the depletions of energetic protons (80-220 keV) are consistent with a

simulation that takes into account the perturbations of the fields as calculated by an MHD simulation and atmospheric charge exchange. Furthermore, a depletion feature occurring shortly after closest approach is consistent with the field perturbations associated with a plume, located near the plume reported by Arnold et al., 2019.
- From these investigations, we confirm, independently from previous reports, that the Galileo spacecraft could have passed near plumes.

For Io we report the following results:

- We identify regions of proton (80-220 keV) depletions during Io flybys I24, I27 and I31 extending beyond one Io radius. The depletions features are not consistent with Io as an inert body. We investigate atmospheric charge exchange as a cause for the depletions.