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Detecting Europa's water plumes with JUICE's particle instruments

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The repeated eruptions of water plumes on Europa have been suggested based on Hubble observations, Keck observations and in-situ magnetic field data from Galileo (Roth et al., 2014; Sparks et al., 2016, 2017, 2019; Jia et al., 2018; Arnold et al., 2019; Paganini et al., 2019). The possibility that such plumes could transport material from Europa's subsurface, or from water reservoirs contained in the ice layer (Vorbuger and Wurz 2021), creates an unprecedented opportunity to sample Europa's subsurface environment and investigate its habitability. The JUpiter ICy moon Explorer (JUICE) is scheduled to make two flybys of Europa, one over the Northern and one over the Southern hemisphere, with the closest approach at 400 km altitude.

In this work we investigate the detectability of such water plumes using the Neutral Mass Spectrometer (NIM) and the ion mass spectrometer Jovian Dynamics and Composition analyser (JDC) of the Particle Environment Package (PEP) on JUICE. Using a Monte Carlo particle tracing model we simulate the density distribution of the plume and simulate the measured signature with NIM and JDC along the two JUICE flyby trajectories.

We show that H_2O molecules and H_2O^+ ions of the plume can be detected during the JUICE flybys. We also investigate the detectability of the plume source as a function of location on the surface of Europa and as a function of the plume mass flux. We find that the plume reported by Roth et al., 2014 is the most likely to be detected, even at the lowest mass fluxes, and that the first JUICE flyby has the best coverage of all the presumptive plume sources. Using a DSMC simulation of the plume we comment on the effect of intermolecular collisions in the plume and demonstrate that such collisions will reduce the detectability of the plume.

Lowering the altitude of this flyby will contribute to an increased chance of detecting the presumptive plume sources, and should be prioritized over lowering the other flybys if any deltaV is available. Furthermore, we also investigate the separability of the plume from Europa's asymmetric water atmosphere and discuss the influence of the instrument pointing and operations on the plume detectability.