Hybrid modeling of Callisto's environment interaction with the Jovian magnetosphere

Thomas Le Liboux*[1,2], Ronan Modolo[2], Nicolas André[1,3], and François Leblanc[2]

[1]Institut de recherche en astrophysique et planétologie – Institut National des Sciences de l'Univers, Centre National de la Recherche Scientifique, Université de Toulouse – France

[2]Laboratoire Atmosphères, Observations Spatiales – Université de Versailles Saint-Quentin-en-Yvelines, Institut National des Sciences de l'Univers, Sorbonne Universite, Centre National de la Recherche Scientifique – France

[3]Institut Supérieur de l'Aéronautique et de l'Espace – Université de Toulouse, ISAE-SUPAERO – France

Résumé

Callisto is the furthest of the four Galilean moons, orbiting at a distance of around 26.3 Jovian radii from Jupiter. Composed of equal parts rock and ice, the moon has a tenuous atmosphere dominated by O2 and CO2 (Carlson, 1999; Cunningham et al., 2015), as well as an ionosphere characterized by densities of up to 10ˆ4 cmˆ–3 (Kliore et al., 2002). The moon's environment interacts with the Jovian magnetosphere (surface weathering, Alfvén wings, etc.), whose physical characteristics vary greatly during its orbit, with a wide excursion in magnetic latitude. Due to a time-varying magnetic environment, electromagnetic induction occurs at Callisto in its ionosphere, but also in a potential subsurface liquid ocean, as it was observed by NASA's Galileo mission during flybys of the moon (Zimmer et al., 2000; Cochrane et al., 2025). While the JUICE and Europa Clipper missions plan to carry out several flybys of Callisto, the interaction between the moon and Jupiter's magnetosphere remains poorly understood. Simulations describing the neutral and ionized environments of the Jovian satellite must therefore be set up. These simulations will use the LatHyS hybrid multi-species parallel 3D model (Modolo et al., 2016, 2018) already used to describe the environment of Ganymede in particular. The Larmor radii of freshly generated pick-up ions of O2+ and CO2+ being larger than the moon radius, a kinetic approach for the ion dynamic is more appropriate than a fluid model and enables the capture of asymmetries in Callisto's plasma interaction. Due to its rather dense ionosphere, a self-consistent resistivity model has been developed for the simulations. In addition to this, different neutral atmosphere inputs are used: a spherically symmetric model as well as adapted outputs from an EGM exospheric simulation of Callisto. Simulations incorporating these new features will be presented for various magnetospheric positions of the moon.

*Intervenant