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Simulating Enceladus' plumes

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The Cassini mission revolutionized our vision on the habitability of our solar system. While the icy moons orbiting Jupiter and Saturn were supposed to be cold and inert objects well outside the habitable zone (where water can be found liquid), Cassini showed that Saturn's moon Enceladus is very active, with a warm interior heated by tidal forces (Choblet et al. 2017), allowing the presence of an ocean under a km-thick icy crust (Thomas et al. 2016). This ocean escapes through geysers (plumes) from the icy surface. Plumes' material reaches escape velocity and goes into orbit around Saturn, forming the E ring. One characteristic of the plumes is their very large velocities, reaching 700-900 m/s (Yeoh et al. 2016), highlighting that plumes are due to (an adiabatic) expansion of the gas through a nozzle like crevasse. Cassini performed many fly-bys through the plumes, measuring their composition and characteristics and showed that the ocean under the icy crust is salty, fed by ongoing hydrothermal activity (Postberg et al. 2009, 2011, Hsu et al. 2015 and Waite et al. 2017) and contains COMs, i.e. complex organic molecules (Postberg et al. 2018a). Plumes are mainly composed of water vapour and 10% of icy grains by mass (Kempf et al. 2018). These icy grains are formed due to nucleation of water.

We have developed a fluid dynamics model based on Schmidt et al. (2008), to describe the plumes characteristics along icy crevasses that could exist on Enceladus. This model accounts for particle production generated from homogeneous nucleation, particle growth, wall accretion and sublimation and the viscous interaction with the walls. The wall interactions, reservoir conditions and the geometry of the channel are studied to reproduce some characteristics of the plumes observed by Cassini. Icy crevasses' geometry will evolve with time due sublimation of ices from the walls or accretion onto the walls. The evolution of the geometry of the crevasses and the effect on the plumes' characteristics has been determined with our model. In parallel, we developed an experimental setup to study the effect of the nozzle geometries on the plumes characteristics and to verify experimentally that under the icy moon's conditions (pressure, temperature) a plume reaches hypersonic/supersonic velocities.

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