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Monte Carlo Simulation of Callisto's Exosphere

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Whereas Callisto's surface has been mapped as early as in 1980 by the two Voyager missions, Callisto's tenuous atmosphere, also called an exosphere, was not directly observed until the Galileo mission in 1999. The Galileo Near-Infrared Mapping Spectrometer detected a CO_2 signal up to 100 km above the surface [Carlson, Science, 1999]. Radio occultation measurements, also conducted by Galileo, led to the detection of an ionosphere with inferred densities much higher than can be explained by the measured CO_2 exosphere, though [Kliore et al., J. Geophys. Res, 2002]. Insight about Callisto's exosphere is expected to be boosted by the Neutral Ion Mass Spectrometer (NIM) of the Particle Environment Package (PEP) on board the planned JUpiter ICy moons Explorer (JUICE) mission, which will conduct the first-ever direct sampling of the exospheres of Europa, Ganymede, and Callisto.

To ensure that NIM's mass resolution and mass range will be sufficient for NIM to detect most expected species in Callisto's exosphere, we model said exosphere ab initio. Since Callisto is thought to consist to about equal parts of both icy and rocky components [Showman and Malhotra, Science, 1999], we model particle release from an icy as well as from a mineral surface separately. For the ice component, we investigate two different compositions, for reducing and oxidising conditions, which find analogy in the initial gas phase conditions in the solar nebula [Mousis et al., Planet. Space Sci., submitted]. For the non-ice material, the mineral surface, we investigate surfaces with compositions similar to CI chondrites and L/LL type chondrites, both of which have been suggested to represent Callisto's non-ice material best [Kuskov and Kronrod, Icarus, 2005 and Moore et al., Cambridge University Press, 2004]. For all mentioned materials, we compute density profiles for particles released by either surface sublimation or ion induced sputtering up to an altitude of 100'000 km. Our results show that close to the surface the sublimated particles dominate the day-side exosphere, however, their density profiles (with the exception of H and H2) decrease much more rapidly with altitude than those of the sputtered particles, thus, the latter particles start to dominate at altitudes above $\sim$1000 km. Since the JUICE flybys are as low as 200 km above Callisto's surface, NIM is expected to register both the sublimated as well as sputtered particle populations. Our simulations show that NIM's sensitivity is high enough to allow the detection of particles sputtered from the icy as well as the mineral surfaces, and to distinguish between the different composition models.