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Investigation of the atmospheres of Europa, Ganymede, and Callisto with PEP/JUICE

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The Particle Environment Package (PEP) suite of instruments has been proposed for the JUICE mission, which contains sensors for the comprehensive measurements of electrons, ions and neutrals. One of the instruments for neutral particles is the Neutral and Ion Mass spectrometer instrument (NIM). NIM is a time-of-flight neutral gas and thermal ion mass spectrometer and is optimised for exospheric investigations. Full mass spectra (1 – 1000 amu, m/Δm = 1100) are recorded with high cadence, typically every 100 s, and during flybys even at 1 s cadence. In a 5-s spectrum the detection threshold is 10^{-16} mbar (about 1 cm^{-3}).

Various physical processes are acting on the surfaces of Jupiter's icy moons (Europa, Ganymede, Callisto) to promote material from the surface into the exosphere. These are thermal desorption (sublimation), photon stimulated desorption, ion-induced sputtering, and micro-meteorite impact vaporisation (Wurz and Lammer, 2003; Wurz et al., 2010). At Europa, sputtering is the most important surface release process (Johnson et al., 2009), which releases all species present on the surface more or less stoichiometrically into the exosphere, allowing to derive the chemical composition of the surface from the exospheric measurements. However, the chemical composition of the surface is modified by the bombardment of energetic electrons and ions, and the ultraviolet radiation. For example, species like H_2, O_2, H_2O_2 or O_3 begin to be produced in the top surface layer and are later released into the exosphere by various means. Also, the co-rotation plasma's electrons and to a smaller extent the UV photons cause fragmentation and ionisation of molecules at some locations in these exospheres.

We calculated the expected densities for established and expected species in Jupiter's icy moons exospheres. We find that for the planned JUICE trajectories near these moons that NIM will record most known species because of NIM's high sensitivity, even in the presence of the severe radiation environment at Europa. With NIM's dynamic range of 10^5 one can measure even the D/H ratios during flybys. NIM offers the possibility of detection of yet undiscovered species, with the likely candidates from the non-ice materials Mg, Al, Si, and Ca, that will help understand the mineralogical composition of the surfaces of the moons. NIM's high mass resolution, range and sensitivity are critical in contributing to the habitability assessment of Europa by being able to investigate localised patchy regions of the exosphere indicative of sub-surface venting and to resolve chemical composition.