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Plasma IMS Composition Measurements for Europa and the Other Galilean Moons

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NASA and ESA are planning the joint Europa Jupiter System Mission (EJSM) to the Jupiter system with specific emphasis to Europa and Ganymede, respectively. The Japanese Space Agency is also planning an orbiter mission to explore Jupiter's magnetosphere and the Galilean satellites. For NASA's Jupiter Europa Orbiter (JEO) we are developing the 3D Ion Mass Spectrometer (IMS) with two main goals which can also be applied to the other Galilean moons, 1) measure the plasma interaction between Europa and Jupiter's magnetosphere and 2) infer the 4π surface composition to trace elemental [1] and significant isotopic levels. The first goal supports the magnetometer (MAG) measurements, primarily directed at detection of Europa's sub-surface ocean, while the second gives information about transfer of material between the Galilean moons, and between the moon surfaces and subsurface layers putatively including oceans. The measurement of the interactions for all the Galilean moons can be used to trace the *in situ* ion measurements of pickup ions back to either Europa's or Ganymede's surface from the respectively orbiting spacecraft. The IMS instrument, being developed under NASA's Astrobiology Instrument Development Program, would maximally achieve plasma measurement requirements for JEO and EJSM while moving forward our knowledge of Jupiter system composition and source processes to far higher levels than previously envisaged.

The composition of the global surfaces of Europa and Ganymede can be inferred from the measurement of ejected neutrals and pick-up ions using at minimum an *in situ* payload including MAG and IMS also fully capable of meeting Level 1 mission requirements for ocean detection and survey. Elemental and isotopic analysis of potentially extruded oceanic materials at the moon surfaces would further support the ocean objectives. These measurements should be made from a polar orbiting spacecraft about Europa or Ganymede at height $\sim$ 100 km. The ejecta produced by sputtering of the surfaces of Europa and Ganymede has been shown to be representative of the surface composition [2,3]. Level 2 science on surface geology and composition can then be further enhanced by addition of the following: 3D Ion Neutral Mass Spectrometer (INMS), 3D plasma electron spectrometer (ELS), and hot plasma energetic particle instrument.

The measurement approach is to alternate between times measuring pickup ions and times measuring plasma and magnetic field parameters along the spacecraft trajectory. By measuring the pickup ion energy, arrival direction and mass-per-charge, the ion can be traced back along the ejection trajectory to the approximate area of origin if the 3-D electric field and magnetic field are known. *In situ* observations of plasma flow velocities and vector magnetic fields can be used to determine the local convective electric field ($\mathbf{E} = \mathbf{-VXB}$) along the spacecraft trajectory. By combining this information with models of the magnetospheric interaction with Europa [3,4], one can generate 3D maps of the electric and magnetic field and compute the trajectories of the pickup ions back to the surface or exospheric points of origin. In the case of Ganymede there is the additional complexity of its own internal dipole magnetic field, while Io's volcanic activity introduces the complexity of a highly structured denser atmosphere. Callisto with its less globally extended exosphere will have a simpler interaction than for Europa (i.e., more like our moon). We will discuss these differences in light of the above proposed technique. Finally, the INMS observations and neutral exosphere models are needed to estimate production rates of pickup ions. The hot plasma measurements are needed to correct for sputtering rates which can be time dependent and electron plasma

observations for electron impact ionization rates. Instrument characteristics, field-of-view requirements, modes of operation and effects of radiation on instrument functionality will be discussed.

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