Measurement of Surface Composition for the Icy Galilean Moons via Neutral and Ion Mass Spectrometry from Orbit with JIMO

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Magnetometer measurements now suggest that all three large icy moons of Jupiter may have an underground ocean [1]. The morphology and the color variations of Europa's surface are suggestive that materials from its ocean may have modified the surface in geologically recent times. In addition, an evaporite has been suggested to be present on Europa's surface that may have come from a subsurface ocean [2], but this has been questioned [3,4]. There is evidence, however, for the presence of organics on some of these satellites [5,6]. Hubble Space Telescope (HST) and Galileo Orbiter observations have identified atmospheric products of irradiation processes, O_2 on Europa and Ganymede, and CO_2 on Callisto. The most recent HST observations [7] show potential correlations of atmospheric species (O, H) to hemispherical variations in surface composition. Recently we have put the known constituents on the three icy satellites into context examining their commonality in going from Europa to Callisto [4].

The effect of radiation on the carbon- and sulfur-containing compounds present in these icy surfaces have been described [4,8]. If radiolytic oxidants and hydrocarbons are somehow transported from the irradiated surface through the Europa ice crust to the ocean underneath, they could play a supporting role for evolution and survival of ocean life forms. Although there could be endogenic sources of sulfur, the surface of Europa appears from leading/trailing asymmetries in albedo and composition to be greatly affected by implanted sulfur. Similarly, while CO_2 and carbonates on the three icy satellites are likely to be radiation decomposition products of excavated meteoroid debris, it is also possible that they are products of subsurface organics. To better describe the ultimate sources, the chemical pathways in the local radiation environment need to be unraveled. Mass spectrometry is the least ambiguous way to study the radiation induced chemical pathways on these icy satellite surfaces.

Compositional measurements of Europa's ionized sputter-produced atmosphere might be able to determine the presence of materials from a subsurface ocean including biomaterials [9]. The Cassini Magnetosphere Imaging Instrument (MIMI) has detected [10] a neutral cloud located at Europa's orbit that is likely consisting of sputtering products. Determination of surface composition through the measurement of sputtered materials is a laboratory technique known as secondary ion mass spectrometry (SIMS). Such techniques can be used to detect both volatile and nonvolatile organics produced by sputtering or ablation.

Magnetospheric ion sputtering is an important source of neutrals at the icy Galilean satellites [9,11-14]. These neutrals are subsequently ionized in the ambient plasma and can be readily detected by an ion mass spectrometer. Although this source of ions is relatively robust at Europa, the ions are rapidly accelerated in the local field. Therefore, direct detection of neutrals is preferable since it would allow better spatial correlation of the material composition with surface features. Since neutral mass spectrometers have significantly lower sensitivities, larger fluxes are typically needed. Therefore, laser ablation of the surface and collection of surface materials is desirable and may be possible with the power available on the proposed Jupiter Icy Moons Orbiter (JIMO) mission. Xe ions are very efficient sputtering agents (~10^4 H_2O molecules/ion). These ions, created by the spacecraft engine, or charged particulates, could be accelerated and directed toward the surface to increase the yields so that a neutral mass spectrometer could be used.

In this paper, we will provide insights into mass spectrometer requirements. In addition, we will describe the modeling of the neutrals ejected from likely surface materials and their ionization rates in the Jovian environment. We will use such models to connect the mass spectra measurements of the freshly formed ions to surface composition. We will also discuss what possible compositional signatures are for endogenic materials other than water ice. Finally, since a goal is to identify material composition with surface features, we will describe the transport of neutrals ejected from the surface prior to detection by either an ion or neutral mass spectrometer.

Reference:

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