RECONNAISSANCE COMPOSITIONAL MAPPING OF THE ICY SATELLITES OF JUPITER EUROPA AND GANYMEDE: EARLY RESULTS.

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Introduction: The icy satellites of Jupiter Europa and Ganymede are prime exobiological targets owing to the possibility of a sub-surface briny ocean deeply buried under a kilometers-thick crust mainly composed of water ice [1,2]. These oceans remain tidally and radiolithically heated, respectively by Jupiter and the satellites' silicate core, and may provide a habitable environment for extremophiles [3,4]. The current habitability of these oceans is however dependent on their geochemical states (salinity, pH, temperature), which still remains unconstrained. The possibility for sub-surface habitability can be explored by looking at surface minerals which may have formed at depth in contact with the ocean and brought up due to a tectonically active surface [4]. Using the NIMS/Galileo imaging spectrometer, hydrated salts in addition to water ice and other putative compounds were detected on the surfaces of Europa and Ganymede for which an endogenic origin was proposed [5], thus providing a first geochemical constraint. The upcoming ESA L-class mission JUICE to the Jupiter system and its ambitious payload will address this question, in particular through compositional remote sensing in the near infrared.

JUICE is scheduled for launch in the early 2020s. In the meantime, we have started a compositional mapping campaign of the icy moons using ground-based, high angular resolution observations from the Very Large Telescope in Chile. The goal is to improve on the NIMS global compositional survey but also to refine the science goals and technical requirements of the upcoming JUICE mission and proposed near-infrared imaging spectrometer payload (MAJIS).

Ground-based compositional mapping: We have obtained 19H of telescope time with the SINFONI/UT4 and NACO/UT4 instruments for the compositional mapping of Europa and Ganymede. Both provide near diffraction-limited hyperspectral imaging in the near infrared either through integral field spectrometry (SINFONI, 1.35-2.47 µm) or slit scanning (NACO, 3.1-4.2 µm). By combining the two data sets, the satellites are globally mapped at 4 longitudes and at a spatial resolution of ~100-150 km/pixel. This ground-based survey provides lower spatial resolution than the NIMS global survey (by a factor 1.5-2) but a much higher spectral resolution (factor 20), as well as higher signal-to-noise spectra (a main drawback of NIMS). The spectra are corrected for telluric lines and calibrated to relative radiance using a solar analogue star.

Early results: Composite spectra of Europa have been reduced to test the potential of this survey. Preliminary results (Figure 1) show that the high signal-to-noise spectra obtained here can provide definite identification of minerals and chemical compounds suspected in the noisier NIMS and earlier ground-based spectra of the icy moons [5,6]. Crystalline water ice bands are easily identifiable (blue lines), as well as sulfur dioxide frosts (red lines). The analysis of weaker absorption lines is ongoing and may provide constraints as to the minimum signal-to-noise required at different wavelengths for the proposed MAJIS instrument. In addition, modeling of the water absorption and endmember extraction methods are being implemented to 1) better characterize the state of the water ice (grain size, temperature, cristallinity), and 2) attempt to identify non-icy compounds other than hydrated salts and SO_2 frost.

Perspective: Data on Ganymede is still being collected (Figure 2) and is analyzed alongside Europa. SINFONI spectra exhibit crystalline water ice signature with spatial variations correlated to large geological structures. The next step will be to include the 3rd icy satellite, Callisto. Less differentiated than the other major Jovian satellites, Callisto has a large non-ice component which still hasn't been fully characterized. A tentative detection of phyllosilicates of the serpentine class was made [6] and requires confirmation, particularly because serpentinisation is a well constrained process on Earth that is expected to occur at the interface between the silicate core and the brine ocean.

References: [1] Dalton, J. et al., SSR, 153(1-4), 113-154 (2010). [2] Sohl, F. et al., SSR, 153(1-4), 485-510 (2010). [3] Marion, G et al., A*strobiology*, 3(4), 785-811 (2003). [4] Greenberg, R. et al., JGR, 105(E7), 551 (2000). [5] McCord, T. et al., Icarus, 209(2), 639-650 (2010). [6] Calvin, W. & Clark, R., Icarus, 89, 305-317 (1991). [7] Mastrapa, R. et al., Icarus, 197(1), 307-320 (2008).

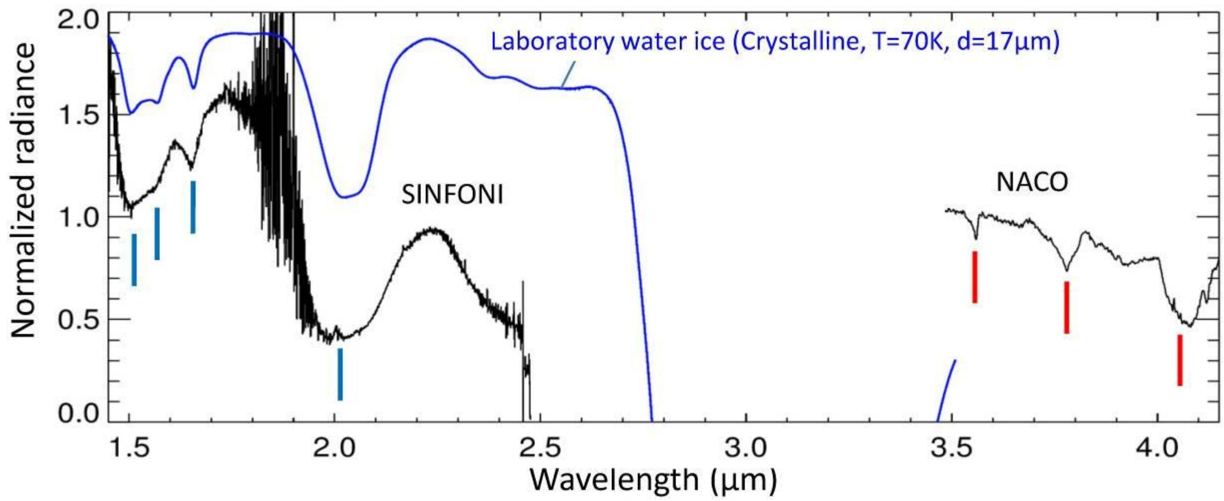

Figure 1. Composite spectrum of Europa using SINFONI (1.35-2.47 µm) and NACO (3.1-4.2 µm) showing a crystalline ice component (blue lines) and the signatures of SO_2 frost (red lines). The spectra are normalized and continuum removed for NACO. A laboratory spectrum of crystalline waster ice from [7] is shown in blue.

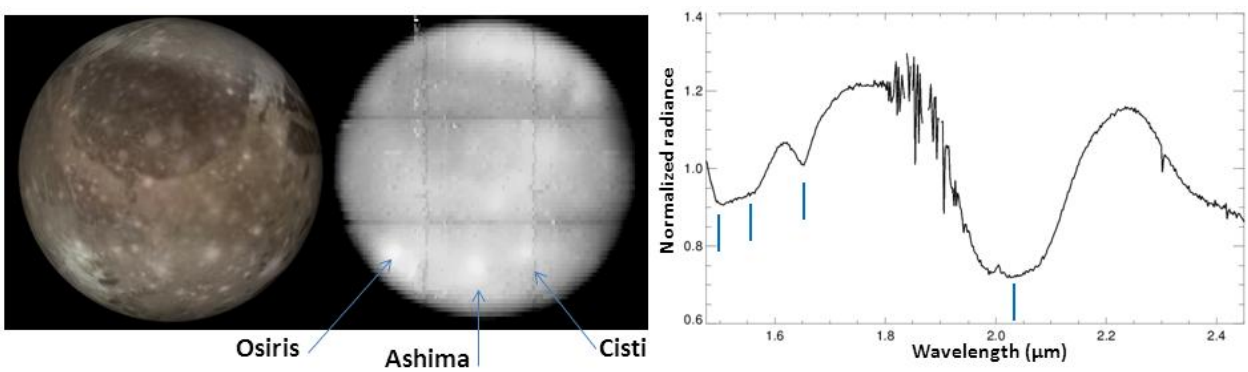

Figure 2. *Left*: Mosaic image of Ganymede at ~ 2.25 µm using SINFONI relative radiance compared to a Galileo mosaic. The bright ejecta regions around the Osiris, Ashima and Cisti impact craters are distinguishable (arrows). *Right*: spectrum extracted from a water ice-rich region.