HIGH SPATIAL AND SPECTRAL RESOLUTION NEAR-INFRARED MAPPING OF GANYMEDE AND CALLISTO WITH ESO/VLT/SINFONI.

N. Ligier[1,2], J. Carter[2], F. Poulet[2], Y. Langevin[2], J. H. Shirley[3]. [1]School of Physical Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK. [2]Institut d'Astrophysique Spatiale, Univ. Paris-Saclay, 91405 Orsay Cedex, France. [3]Jet Propulsion Laboratory, California Institute of technology, Pasadena, CA 91109, USA. Contact: nicolas.ligier@ias.u-psud.fr

Context: The diversity of icy Galilean satellites and their strong exobiological potential due to their respective subglacial oceans [**1**], enticed NASA to conduct the ambitious Galileo mission in the late 90s. Significant science advances have been made thanks to this mission, but many questions remain unanswered. In this context, the space agencies ESA and NASA plan to visit once again the Jovian system during the next decade with the JUICE mission (ESA) and the « Europa Multiple-Flyby Mission » (NASA). In preparation of these missions, and more specifically of the infrared imaging spectrometer MAJIS of the JUICE mission [**2**], a ground-based observations campaign has been performed with the near-infrared imaging spectrometer SINFONI (SINgle Faint Object Near-infrared Investigation) of the Very Large Telescope on Europa [**3**], Ganymede and Callisto. We present here the first results concerning the global spectral properties of the two outermost moons: Ganymede and Callisto.

Dataset: The SINFONI instrument combines an adaptive optics module and an imaging spectrometer in the near-infrared. It allows to resolve the icy moons with a spatial sampling of 12.5 x 12.5 milli-arcsec (~40 x 40 km^2 projected on their surfaces) and a spectral resolution R~1500 in the H+K bands (1.45–2.45 µm). Observations were carried out near opposition to maximize the angular resolution, resulting in angular diameter varying from 1.62 to 1.78 arcsec for Ganymede and 1.48 to 1.52 arcsec for Callisto. In both case, the angular diameter of the moons are larger than SINFONI's 0.8 arcsec field of view (FoV). Thus, to fully cover their disk, each observation is composed by a mosaic of 10 overlapping frames (**Figure 1**). In order to perform a global scale study similar to the one already published on Europa [**3**], Ganymede and Callisto were both observed at four different dates with overlapping areas. These areas will permit to normalize the reflectance level of the different observations.

Physical properties of the moons' surfaces: Following the acquisition, a series of processing steps need to be implemented to get calibrated reflectance spectra suitable for spectral modeling. The main one is the photometric correction which aims to solve geometric effects. Contrary to Europa, we show that neither Ganymede nor Callisto possess a surface with a Lambertian behaviour (**figure 2**). The over-rated level of reflectance of the pixels at the edges of Ganymede's and Callisto's disk are likely the result of strong back scattering due to their much more rugged topography than that of Europa. By the time of the meeting, we will have investigated this issue. Tests using the Minnaert function will have be carried out.

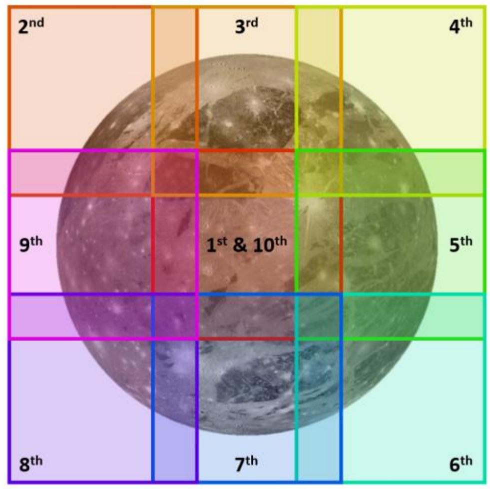

Figure 1. Observational mosaic for Ganymede. Each mosaic's piece corresponds to a FoV of 0.8 arcsec.

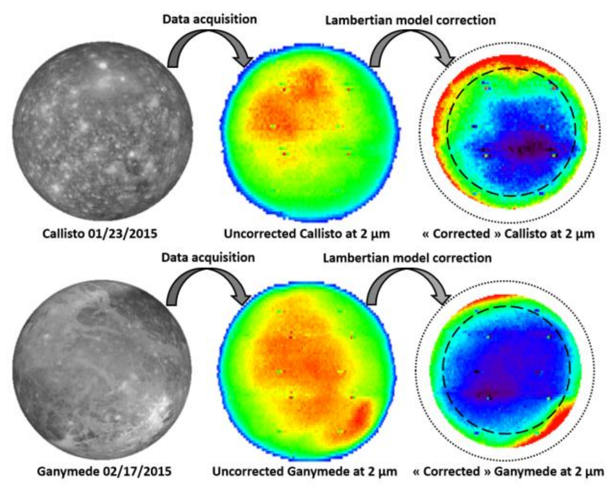

Figure 2. Tests on the photometric correction. Between 40° (dashed circles) and 90° (dotted circles) of latitude, the reflectance level of the final images is overestimated. Otherwise, geomorphological units, such as Osiris crater on Ganymede, exhibit an higher reflectance at 2 µm than their surrounding terrains.

Chemical properties of moons' surfaces: Generally speaking, Callisto and Ganymede exhibit similar spectral signatures, but Callisto spectra are flatter than those of Ganymede (**figure 3**). Our first analysis reveals that these spectra are largely dominated by water-ice absorption: two broad absorptions at 1.5 µm and 2.0 µm, and one narrower at 1.65 µm. The latter one is diagnostic of the crystalline form. The depth of this absorption is much more pronounced for Ganymede than Callisto, suggesting a higher abundance of crystalline ice for the former. This result is opposed to the one of a previous study based on Galileo/NIMS data [**4**], but a thorough investigation needs to be performed to confirm this.

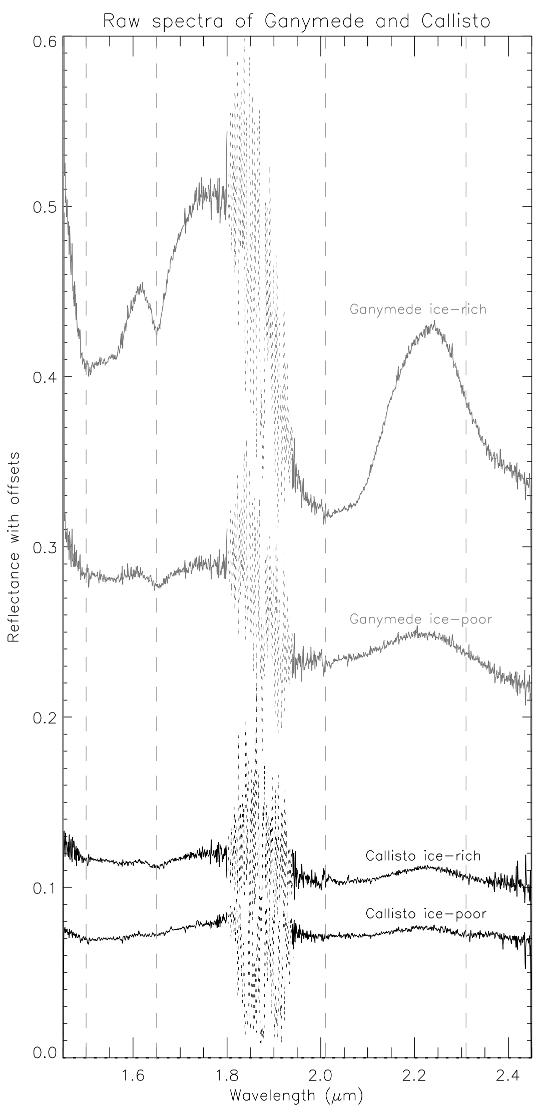

Figure 3. Different spectra of Ganymede (on top, grey) and Callisto (bottom, dark). The principal spectral features are characteristics of H_2O-ice, probably mostly crystalline as suggested by the 1.65 µm absorption.

In terms of distribution, the chemical composition of both satellites seems to be dominated by an hemispherical dichotomy due to Io's plasma torus implantation: while the leading hemispheres are dominated by water-ice absorptions, the trailing hemisphere generally exhibits only very weak ice signature (especially Callisto) thus highlighting the domination of an unindentified, non-ice component. As for Europa, this component may be sulfuric acid in hydrated form [**3, 5**], or it may be hydrated salt minerals, as $MgSO_4$ and Na_2SO_4, derived from their respective briny subglacial oceans [**6**]. Otherwise, a very weak absorption at 2.31 µm seems to be observed in few spectrum of Callisto (**figure 3**, ice-poor spectra). This absorption may be indicative of a Mg-OH bearing mineral as serpentine, a silicate altered by liquid water. Interestingly, this absorption was tentatively detected in a few NIMS spectra [**7**]. By the time of the meeting, we will try to lift the veil about the existence and possible nature of this spectral feature. Global mapping and linear spectral modeling using a set of end-members similar to those used in [**3**] are envisioned.

References: [**1**] Sotin et al., (2004), Comptes Rendus Physique 5, 769. [**2**] Langevin et al., (2014), LPSC XLV, Abstract #2493. [**3**] Ligier et al., (2016), The Astronomical Journal, 151, 6. [**4**] Hansen & McCord, (2004), JGR, 109, E01012. [**5**] Carlson et al., (2005), Icarus, 177, 461. [**6**] McCord et al., (2001), Science, 292, 1523–1525. [**7**] Moore et al., (2004), *Jupiter: The Planet, Satellites and Magnetosphere* (book), 397–426