EPSC Abstracts
Vol. 13, EPSC-DPS2019-596-1, 2019
EPSC-DPS Joint Meeting 2019
© Author(s) 2019. CC Attribution 4.0 license.

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Compositional mapping of Europa with VLT/SPHERE

Oliver R. T. King (1), Leigh N. Fletcher (1), Nicolas Ligier (2)
(1) University of Leicester, UK (ortk1@le.ac.uk), (2) Open University, UK

Abstract

VLT/SPHERE observations of Europa's anti-Jovian hemisphere provide high spatial resolution, low spectral resolution image cubes from 0.95 to 1.65 µm. Data reduction, including using the Oren-Nayar reflectance model to photometrically correct the images, allows accurate mapping to high incidence and emission angles (∼70°). Initial compositional mapping results show strong similarities to previously observed Galileo/NIMS spectra of Europa therefore permitting global-scale compositional mapping of icy satellites from ground-based facilities.

1. Introduction

Europa is the second of the Galilean moons from Jupiter. Its surface is composed of water ice, with significant contamination from sulphuric acid hydrates and potentially salts [2, 9]. Infrared spectra from the Galileo orbiter Near-Infrared Mapping Spectrometer (NIMS) [4] provide the highest spatial resolution IR spectra of Europa but with limited coverage in many locations. In recent years, ground-based adaptive optics observations in the infrared with Keck/OSIRIS [2] and VLT/SINFONI [9] have provided new insights into the distributions of surface materials on Europa.

2. Data and method

Observations of Europa were taken during VLT/SPHERE [1] science verification in December 2014. Only Europa's anti-jovian hemisphere was observed, with a sub-observer longitude of 192°W. Data was taken in `IRDIFS_EXT` mode, allowing simultaneous imaging with the Integral Field Spectrograph (IFS) and Infrared Differential Imaging Spectrometer (IRDIS) sub-systems of the SPHERE instrument. The IFS [5, 11] produces image cubes with 38 wavelength channels from 0.95 to 1.65 µm ($R \sim 30$). It has a high spatial resolution, with a pixel size of 7.46 mas/px, corresponding to ∼25 km/px at Europa. Accounting for diffraction, this allows features ∼150 km across to be resolved. For example, Europa's largest lineae (at ∼225°W, ∼45°N) are resolved in Figure 1. The use of image deconvolution will further improve the spatial resolution of our data. IRDIS produced simultaneous imaging through two filters, with transmissions centred on 2.11 µm and 2.25 µm, as shown in Figure 2.

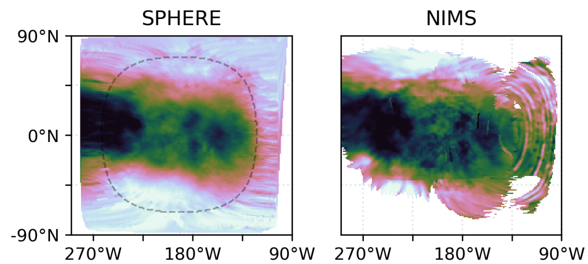

Figure 1: Comparison of IFS data with selected NIMS data with similar coverage and resolving very similar features. Images show normalised 1.30/1.51 µm spectral ratio. Brighter colours represent larger values of the ratio, indicative of higher water ice fraction. The dashed line represents an emission angle of 70°.

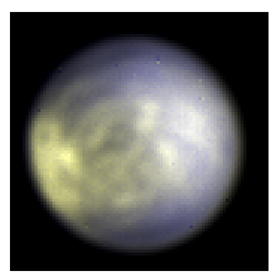

Figure 2: Two colour image of IRDIS observation of Europa, yellow is 2.11 µm and blue is 2.25 µm. Blue areas are cleaner, less contaminated ice.

Our IFS observations have been reduced using the standard ESOREX pipeline and custom image cleaning and mapping code to produce mapped spectral cubes of Europa's anti-Jovian hemisphere. A strong regular banding pattern is introduced by the ESOREX pipeline for extended sources such as Europa, so we

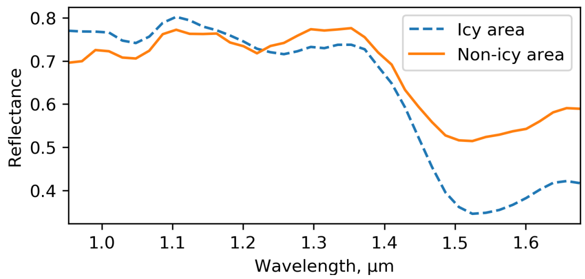

Figure 3: Example spectra of icy and non-icy areas on Europa from IFS data. Features visible in the spectra include water ice absorption around 1.04 µm, 1.25 µm and at 1.5 to 1.5 µm, and hydrated salt absorption around 1.2 µm.

developed a method using a Fourier transform filter to identify and remove this artificial pattern. Images were photometrically corrected using the Oren-Nayar reflectance model, allowing regions at large phase angles to be mapped accurately, providing significant improvements over the standard Lambertian model [12]. This allows our mapping to reach latitudes ∼70°, higher than previous studies which typically extend to 50° - 60° [2, 6, 9].

We analyse these mapped cubes by fitting to laboratory spectra from reference cryogenic libraries. The fitting routine uses linear spectral modelling to produce compositional maps for the observed hemisphere of Europa. These reference spectra include water ice [10], sulphuric acid [3], and hydrated salts [7]. We have developed an implementation of the Hapke bidirectional reflectance model [8] which we use to model a broader range of species, including distributions of ice grain sizes. We incorporate the IRDIS dual band images at 2.11 µm and 2.25 µm into our fitting routine to increase the wavelength range of our data.

3. Results

Initial comparison of our SPHERE data to Galileo/NIMS data show strong similarities (see Figure 1) and initial spectral modelling results are consistent with previously observed compositional features. These include the leading-trailing hemisphere difference in water ice fraction and the structure of non-ice material from the anti-jovian point (180°W, 0°N) to Powys Regio (∼140°W, ∼0°N). Further analysis with our refined fitting routine and expanded spectral library will aim to quantify the fractional surface composition of the various species (ices, acids and salts) and their associated uncertainties.

Acknowledgements

We would like to thank the Royal Society for supporting this work.

References

[1] Beuzit, J.-L. et al.: SPHERE: the exoplanet imager for the Very Large Telescope, arXiv preprint arXiv:1902.04080, 2019.

[2] Brown, M. and Hand, K.: Salts and radiation products on the surface of Europa, The Astronomical Journal, 145(4):110, 2013.

[3] Carlson, R., Johnson, R., and Anderson, M.: Sulfuric acid on Europa and the radiolytic sulfur cycle, Science, 286(5437):97–99, 1999.

[4] Carlson, R. et al.: Near-infrared mapping spectrometer experiment on Galileo, In The Galileo Mission, pages 457–502. Springer, 1992.

[5] Claudi, R. U. et al.: SPHERE IFS: the spectro differential imager of the VLT for exoplanets search, In Ground-based and Airborne Instrumentation for Astronomy II, volume 7014, page 70143E. International Society for Optics and Photonics, SPIE, 2008.

[6] Grundy, W. et al.: New horizons mapping of Europa and Ganymede, Science, 318(5848):234–237, 2007.

[7] Hanley, J. et al.: Reflectance spectra of hydrated chlorine salts: The effect of temperature with implications for Europa, Journal of Geophysical Research: Planets, 119(11):2370–2377, 2014.

[8] B. Hapke. Theory of reflectance and emittance spectroscopy. Cambridge university press, 1993.

[9] Ligier, N. et al.: VLT/SINFONI observations of Europa: New insights into the surface composition, The Astronomical Journal, 151(6):163, 2016.

[10] McCord, T. B. et al.: Hydrated salt minerals on Europa's surface from the Galileo near-infrared mapping spectrometer (NIMS) investigation, Journal of Geophysical Research: Planets, 104(E5):11827–11851, 1999.

[11] Mesa, D. et al.: Performance of the VLT Planet Finder SPHERE-II. Data analysis and results for IFS in laboratory Astronomy & Astrophysics, 576:A121, 2015.

[12] Oren, M. and Nayar, S. K.: Generalization of Lambert's reflectance model, In Proceedings of the 21st annual conference on Computer graphics and interactive techniques, pages 239–246. ACM, 1994.