**An Assessment of Organics Detection and Characterization on the Surface of Europa with Infrared Spectroscopy** Ishan Mishra[1,2], Nikole Lewis[1], Jonathan Lunine[1], Kevin P. Hand[2] [1]Department of Astronomy, Cornell University, [2]Jet Propulsion Laboratory, California Institute of Technology.

**Introduction:** A key problem in Europa science is to constrain the presence and abundance of chemical species present in trace amounts, especially organics, on the surface of this icy moon of Jupiter [1]. Europa's young surface tells us that there is an active exchange of materials between its surface and its ocean, and hence improving our understanding of the surface composition of Europa serves as a proxy for understanding its ocean's composition and helps assess its habitability. Upcoming missions like the James Webb Space Telescope (JWST), Europa Clipper and JUICE will provide high quality data in key wavelength regions that might contain signatures of organics.

However, a systematic study to assess the feasibility of detection of various classes of organics given the different instrument parameters has not been performed. The goals of our project are to 1) simulate reflectance observations of organics in a background of water ice for varying SNR and 2) develop an analysis framework that can help quantify the detection and characterization of trace organics with high confidence.

**First Steps:** We started with a simple case of simulating reflectance spectra of hydrogen cyanide (HCN), a spectroscopically simple organic compound, in a background of water ice. Next, the band depths of the sharp HCN features were calculated and compared with an assumed background noise. This provides a rudimentary estimate of the detection significance of HCN. We then proceeded to evaluate this detection significance for varying amounts of HCN and for varying SNR of observation, resulting in a heatmap as shown in Figure-1. Our main takeaway from this work is that even with this rudimentary way of evaluating the significance of detection of of species of interest, Europa Clipper's MISE should able to provide us a strong detection ($>3\sigma$) for a few percent of HCN, which is at the higher end of what we expect the concentration of organics might be on Europa's surface [2].

**Current Work:** To further improve our ability to tease out weak signals of organics in spectroscopic data and push our abilities to confidently detect them down to fraction of percent abundance values, we are currently testing a Bayesian inference framework. This framework uses Bayesian evidence as a metric to evaluate the presence of a species in the data [3]. Essentially, the fits of two models to the given data are compared – one in which the species of interest is present and another without the species of interest. If the former model outperforms the latter by a significant margin, we conclude that there is strong evidence for the presence of the species of interest in the given data.

The advantage of using such a framework, which is based in spectral fitting analysis, is that to evaluate the presence of a given species, the framework considers the effect of the said species at all wavelength channels, instead of just regions with sharp features. Because of being spectrally rich, organics can have a noticeable effect on the continuum of the mixture's reflectance spectrum and taking that into account can help us increase our confidence in their presence/absence.

Using our Bayesian framework on simulated data, we have produced heatmaps of detection significance like Figure-1 (next page) for various classes of organics, using representative compounds that have C=C, C≡C, C-H and C-O bonds. Our Bayesian analysis provides $3\sigma$ detection of MISE spectra of ~1% by abundance organics in a water ice background. We also consider an example with all trace species mixed together, with overlapping features, and our framework is able to retrieve strong evidence for all of them and also provide constraints on their abundance. These results are promising for Europa Clipper's capability to detect trace organic species, which would allow correlations to be drawn between the composition, and geological regions with endogenic material, like linea, chaos terrains and plume deposits.

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**References:** [1] Blaney, D. L. et al. (2017) *LPS,* Abstract *#2244*. [2] Hand, K.P. et al. (2009) *Europa (eds. Pappalardo, R. T., McKinnon, W. B. & Khurana, K. K.) 589–630,* University of Arizona Press. [3] Mishra, I., et al. (2021), *PSJ,* 183.

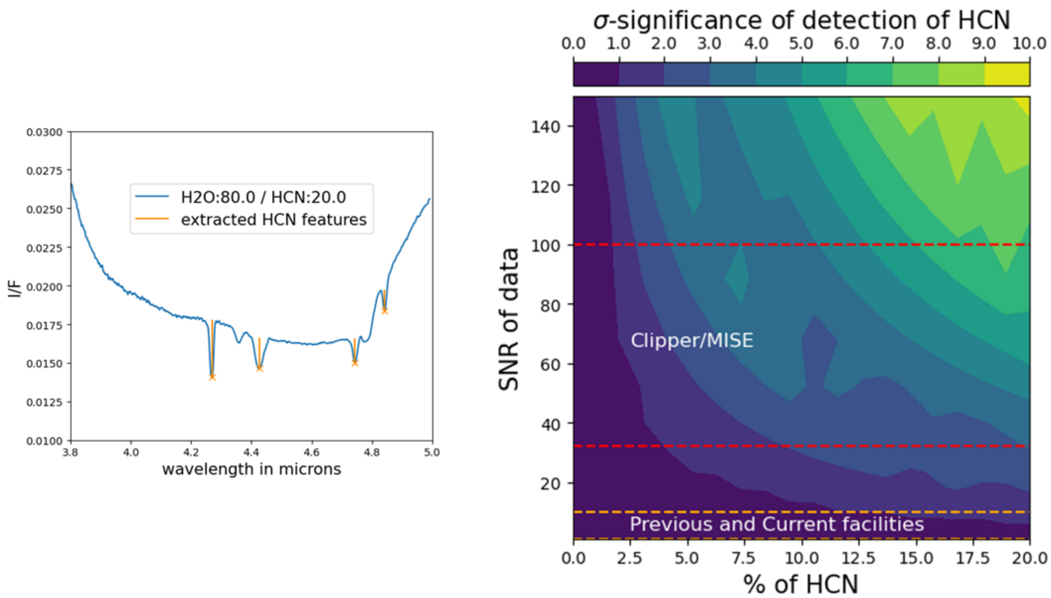


Figure-1: *Left:* A simulated reflectance spectrum of 80/20 % mixture of water ice and HCN. The HCN features and their depths are marked with vertical orange lines. *Right:* A heatmap where the significance of detection of HCN in a background of water ice is shown as a function of abundance of HCN on x-axis and SNR of observation on the y-axis. The expected SNR limits of Europa Clipper's MISE instrument in the near-infrared region is shown in the dashed red lines, while the SNR capabilities of previous and current facilities, that include space and ground-based facilities, is highlighted in the orange dashed lines.