Assessing the feasibility of detection and characterization of organics on Europa's surface via NIR spectroscopy

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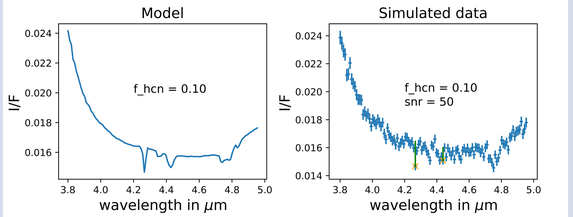
Motivation

- A key component of constraining the habitability of Europa's subsurface ocean is to detect and characterize organics in endogenic deposits on Europa's surface, also a key goal for Europa Clipper [1].
- Organics have not been detected yet on Europa's surface, but the expectation for their abundance from theoretical studies and observations of other outer solar system bodies is around 0.01 to 1%.

Methods

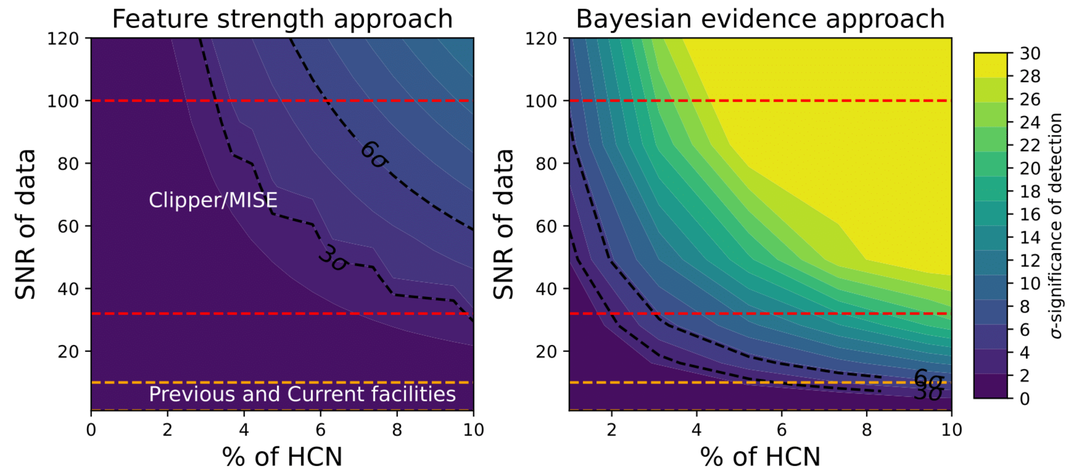


- Using HCN as a simple test case, we simulate reflectance spectra of HCN and water ice mixture with the Hapke model [2], at MISE's spectral resolution and with added Gaussian noise.
- We use two approaches to evaluate the 'detection significance' of HCN: a) average strength of its sharpest features b) comparing Bayesian evidence of models [3] with and without HCN

Results

- Comparison of 'detection significance' of HCN at varying SNR of data and abundance of HCN clearly shows that, at the same spatial scale, **Europa Clipper will have a superior capability of picking out organic features in the NIR,** as compared to current and previous ground based and space facilities, including JWST.
- The Bayesian evidence-based detection technique not only increases the confidence of detection, especially when there are candidate species with overlapping features.

Spectroscopic features of organics at trace abundances should be detectable at high confidence in the 3-5 μm wavelength region, via Europa Clipper's MISE spectrometer



Left: Simulated spectra of HCN mixed with water show that within the expected SNR limits of MISE in the 3-5 μm region, HCN's sharp features are detectable at 3σ confidence if HCN's abundance is at least a few percent. *Right:* **A complementary detection technique based in Bayesian statistics significantly improves the 3σ detection threshold, from a few % abundance down to 1% abundance or less.**

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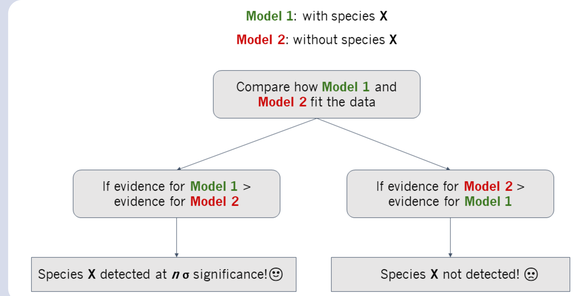
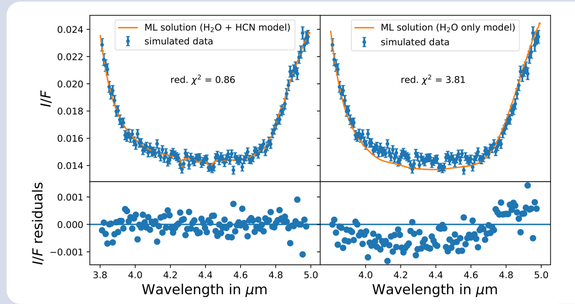
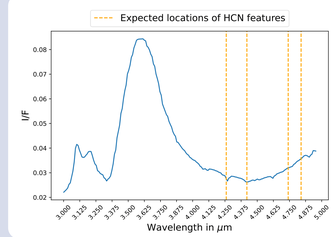
What is the Bayesian evidence-based detection methodology?



How is a Bayesian framework able to pick out weak signals of trace species?



What happens in the presence of other trace species?



- This spectrum is a mixture of 90% H_2O, and 1% each of HCN, C_2H_2, C_2H_4, C_2H_6, C_3H_6O, CH_3OH, NH_3, C_2N_2, CO_2 and SO_2 at an SNR of 100.
- The wavelengths at which prominent HCN features are expected to be present (orange lines in the figure), overlap with prominent features of C_2H_2, C_2H_4, C_2H_6, C_2N_2 and C_3H_6O
- **A Bayesian evidence-based analysis results in a detection of HCN at ~ 7σ confidence.**

Acknowledgements

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References

[1] Bender et al. (2019), DOI: 10.1117/12.2530464 [2] Hapke (2012), DOI: 10.1017/CBO9781139025683 [3] Mishra et al. (2021), DOI: 10.3847/PSJ/ac1acb