3-MICRON BAND PROPERTIES OF ENCELADUS' PLUME PARTICLES: TEMPORAL VARIATIONS AND THEIR CHARACTERIZATION Deepak Dhingra[1], Matthew M. Hedman[1] and Roger N. Clark[2], [1]Department of Physics, University of Idaho, Moscow, ID 83843, USA (deepdpes@gmail.com; mhedman@uidaho.edu), [2]Planetary Science Institute, Tucson, AZ 85719, USA (rclark@psi.edu).

Introduction: Systematic spectral trends in the particle component of Enceladus' plume hold potential clues about the role of subsurface environment in the generation and evolution of the plume. Cassini mission's multi-sensor observations of the water vapor and particle components of Enceladus' plume, spanning more than a decade, have provided us a rich dataset to study the plume properties. Here, we identify and characterize multiple trends in the near infrared spectra of the plume particles to explore their possible causes and implications.

Data and Methods: We have utilized the near infrared observations of the plume made by the Visible and Infrared Mapping Spectrometer (VIMS) instrument onboard Cassini mission [1]. The observations selected for our study were made at relatively high phase angles (generally greater than 155°). Other aspects of the observations taken into account are the integration times, orbital phase (location of Enceladus around Saturn) and spacecraft-target distance. After optimizing for all these aspects, selected observations were subsequently corrected for background (due to the instrument and the E-ring).

The generally low signal-to-noise characteristics of these observations make it challenging to extract reliable trends directly. Accordingly, we are developing a methodology to enable extraction of a smoothed spectrum that can then be used to derive various spectral parameters for evaluating possible trends.

The varying spectral character of the plume: The large number of plume observations obtained at different times provides a great temporal dataset. It has led to the discovery of systematic changes in the brightness of the plume [2] during Enceladus' orbit around Saturn (coming close and going further away) as well as the gradual fading of the plume during Cassini's observations spanning 12 years [3].

We are investigating the detailed spectral character of these temporal observations and have noted subtle differences across multiple observations at different spatial resolution [4]. There are 3 principle types of variations (example spectra shown in Figure 1):

a) 3-micron water-ice band shape differences.

b) Shifting of the inflexion point between the short-wavelength (1-2.5µm) spectral slope and the 3-micron water-ice absorption band.

c) Short-wavelength (1-2.5µm) spectral slope differences.

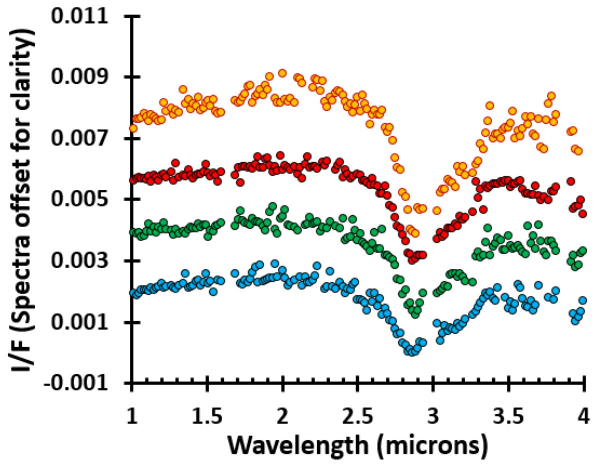

Figure 1 VIMS observations of the plume made during different time periods. The spectra from top (orange) to bottom (blue) correspond to observations: V1635817738, V1635814561, V1635816762 and V1635816274.

Insights from spectral modeling: The observed subtle variations in the plume spectra are challenging to analyze due to signal-to-noise limitations. Mie-scattering-based model spectra (Figure 2) are able to closely reproduce the observed spectral variations by varying the grain size distribution within a narrow range. We are using these model spectra as a template for developing suitable parameters to evaluate any spectral trends and correlations.

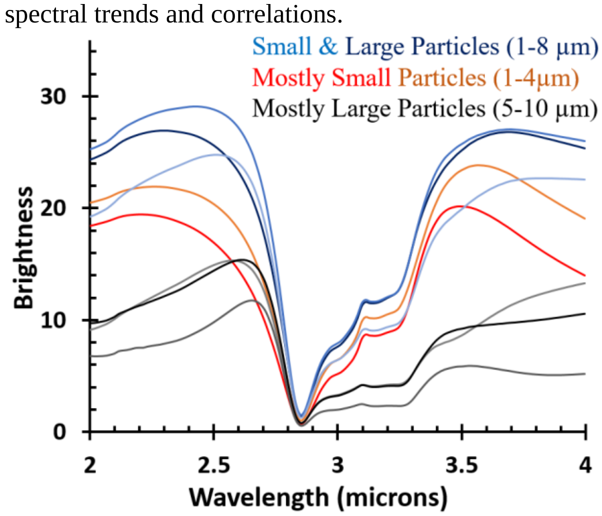

Figure 2 Model spectra of crystalline ice at 100K at a phase angle of 160° generated using Mie-scattering theory. Note the shifting inflexion point around 2.6-2.7 µm, its peaked vs gently sloping nature as also the changing character of the 2.85 µm absorption band.

Parameterization of the spectral trends: Based on the model spectra and the VIMS observations of the plume, we have identified 4 spectral parameters (shown in Figure 3) that could be evaluated across plume observations. Many of these parameters change systematically and could therefore be useful in understanding the character of the plume, namely the particle component. For example, the inflexion point is predicted to systematically shift to longer wavelengths and become sharper (i.e. peaked) with increasing grain sizes.

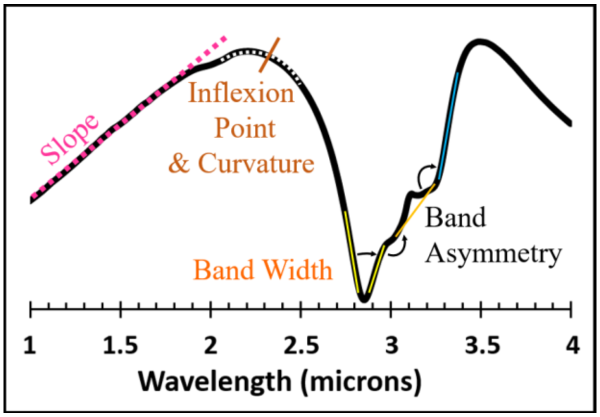

Figure 3 Potential spectral parameters aimed at capturing the temporal variations in the plume properties.

The subtle nature of the spectral variations however, necessitate further processing of the plume spectra before any spectral parameters can be extracted. We are in the process of developing such a methodology. The original VIMS spectrum (Figure 4a), after background removal, is smoothed by fitting different segments of the spectrum with polynomials (Figure 4b). The obtained smooth spectrum can then be used for extraction of various parameters and also can be compared with models (Figure 4c) to understand the nature of the plume particles. Our preliminary results show that different parts of the VIMS spectrum are matched by different segments of model spectra. This may mean that our model spectra are not sufficiently extensive. However, another interesting possibility could be that the VIMS spectrum needs a combination of multiple particle size distributions, produced by several simultaneous eruptions [5] that collectively form the plume.

References: [1] Brown, R. H., et al. (2004) *Space Sci. Rev.*, **115**, 111 [2] Hedman et al., (2013) *Nature*, **500**, 182 [3] Ingersoll et al., (2017) *Icarus*, **282**, 260. [4] Dhingra et al. (2015) 46th *LPSC*, Abst. #1648. [5] Porco et al. (2014), *AJ*, **148**,45

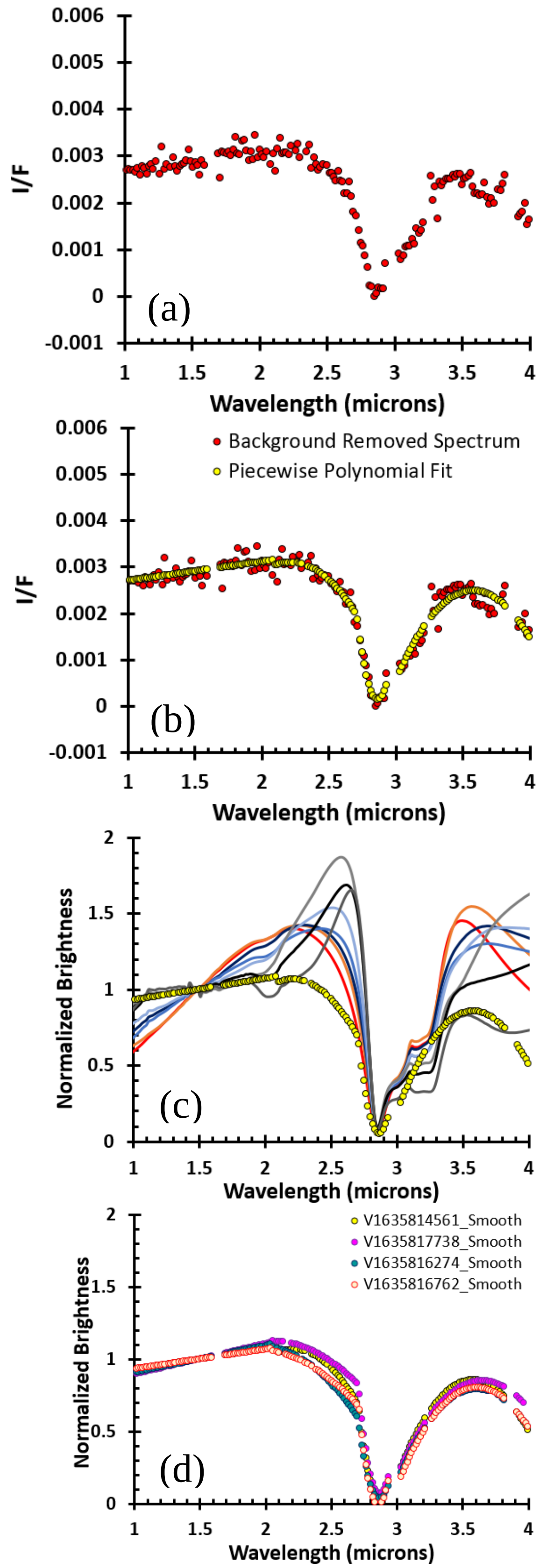

Figure 4 Illustration of the analysis methodology. (a) Original VIMS spectrum (b) Spectral smoothing (preliminary) (c)-(d) Characterization & comparison.