SPECTRAL CHARACTERIZATION OF SPATIALLY RESOLVED WATER ICE PLUMES AT ENCELADUS USING CASSINI VIMS DATA

Deepak Dhingra, Matthew M. Hedman, Roger N. Clark and Phillip D. Nicolson
1Department of Physics, University of Idaho, Moscow, ID 83844 (deepdpes@gmail.com),

Introduction: The plumes of vapor and water ice emerging from Enceladus' south pole [e.g. 1] represent an unprecedented window into the interior of an icy satellite. Cassini data analysis and modeling efforts have provided a great deal of information about various aspects of this phenomenon including the role of tides in facilitating plume activity [e.g. 2, 3], the presence of organics [e.g. 4], the occurrence of discrete plume sources [e.g. 5] and their episodic nature [e.g. 6] and the possibility of local sea or global ocean under the moon's icy crust [e.g. 7, 8].

Here, we investigate the spectral properties of the individual plume signals along four major source fractures (Alexandria, Baghdad, Cairo and Damascus) located in the south polar terrain (SPT) using data from the Visual and Infrared Mapping Spectrometer (VIMS). This instrument obtains images of a scene at 352 wavelengths between 0.35 and 5.2 microns [9]. Previous studies of the VIMS data sets have documented trends in the typical particle size distribution with altitude [e.g. 10] and variations in the total particle flux that are likely due to tidal forces acting on the moon [e.g. 3]. While these earlier investigations focused on relatively low-resolution observations, this work focuses on the highest-resolution VIMS data sets.

High Spatial Resolution VIMS Data of Enceladus' Plumes: VIMS made three very high spatial resolution observations (better than 10 km/pixel) of the plumes at high phase angles (>150 degrees). In some cases, plumes along all the fractures were covered in a single observation while in other cases, complete coverage was split across several observations. These observations were made between November 2009 and August 2010, and each consisted of a series of “image cubes”, which were mosaicked together to obtain a spatially coherent view of the plumes.

Data Processing and Sources of Uncertainty: Owing to the weak signal from plumes, care must be taken to isolate the relevant plume signals from the background E-ring and various instrumental artifacts, which produce varying background levels in the image-cubes. Since we are dealing with numerous observations that were mosaicked together, different parts of the image may have slightly different background values. Thus, subtracting a single background spectrum does not necessarily isolate the desired signal. On the other hand, it can be difficult to estimate and subtract backgrounds from individual images due to their small spatial size. In order to mitigate the effects of these background effects, backgrounds were estimated based on at least 2 different regions and the outputs were compared to ensure consistency of results.

Spectral Analysis of Plume Material: The high spatial resolution of the dataset allows us to compare the spectral character of the plume material emerging from different fractures. Several spectral properties of the plumes have been evaluated across multiple observation geometries and at different spatial resolutions. These observations are all obtained at relatively high phase angles and the plume has a very low optical depth. Hence, the observed light is mostly scattered by diffraction around individual ice grains in the plume.

Results: Preliminary analyses reveal some promising aspects of the plume spectra which could help identify possible differences in their composition and physical properties (e.g. particle size):

i) Shape of the 3 µm absorption band – All the spectra show a strong absorption band around 3 mi-
crons that can be attributed to water ice. However, some of the plumes have a more asymmetric absorption band. This asymmetry is mostly seen in the long wavelength part of the absorption and is probably sensitive to the fraction of large (>5 micron wide) particles in the plume. This feature could therefore provide information about the largest particles that can be launched from beneath Enceladus’ surface.

ii) Slope of the Short-wavelength IR Region – The slope of the spectra between 1-2.5 µm shows variation across the plumes along different fractures. It also seems to be correlated to the asymmetry of the 3 µm absorption band. This slope is sensitive to the distribution of particles in the few-micron size range, and so provides complementary information about the plume’s particle size distribution.

iii) Character of the Band Minimum – The band minimum of all the plumes across multiple observations is centered at 2.85 microns. Thus far, we have not observed any major variations in this band position. The precise location of this band minimum depends on the optical constants of the ice grains, and is particularly sensitive to whether the ice is in an amorphous or crystalline state. Reliable detection of band minimum differences would require observations with high signal to noise ratio.

Implications: These preliminary observations provide the first glimpse of possible spectral variability in the plumes along four major fractures (tiger stripes). These observations could represent spatial variability in the character of the plume sources and includes differences in the local plume composition, eruption conditions as well as temporal variations.


**Figure 2** Spectral variability amongst plumes along individual fractures (offset for clarity).