WATER-ICE PARTICLES IN ENCELADUS' PLUME EXHIBHIT CONTRASTING ALTITUDINAL TRENDS IN LAUNCH VELOCITIES: IMPLICATIONS FOR SAMPLING BY FUTURE MISSIONS

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Introduction: Enceladus' plume represents a direct sample of the subsurface ocean and holds important clues about the habitability of life as all three basic requirements for life to originate, namely, liquid water, energy and organic material are present at this planetary body [1-7]. Detailed characterization of the plume material has important bearing on its sampling by future missions to Enceladus searching for clues of life.

We are using infrared observations of the plume made by the visual and infrared mapping spectrometer (VIMS) onboard Cassini mission [8] to characterize the water-ice particle component and understand the observed trends. In particular, we are using limited high spatial resolution observations to characterize the distribution of plume particles closer to the surface (< 50 km).

Obtaining Launch Velocity Trends of Ice Particles at Different Altitudes: Water-ice particles within Enceladus' plume are launched at different velocities. Larger particles get lofted at lower velocities (due to their larger size) compared to the smaller particles [9]. The particle size distribution of the plume therefore influences the observed launch velocities at any given altitude. Based on high altitude (> 50 km) observations of the plume, the number of particles launched at a given velocity falls off linearly with increasing altitude [9, 10]. However, our observations of the plume particles near the surface (< 50 km) suggest a contrasting trend in the particle launch velocities.

Particle Launch Velocity Trends at Lower Altitudes (<50 km): Particle launch velocity trends obtained closer to Enceladus' surface were found to drop off much more steeply than at higher altitudes (> 50 km). Our analyses of the high spatial resolution observations allowed us to analyze trends from individual source fissures (i.e. eruptions along Cairo, Baghdad and Damascus), in addition to the bulk plume properties (Figure 1). Interestingly, although all three sources exhibit the steepening of the velocity trends at lower altitudes compared to higher altitudes, they do not do so to the same extent. We have also validated the steeper vs gentler slope of the velocity trends using independent observations made by the imaging science subsystem (ISS) instrument onboard Cassini mission.

Interpreting Launch Velocity Trends: The observed trends in particle launch velocities with altitude provide an interesting array of possibilities to explore.

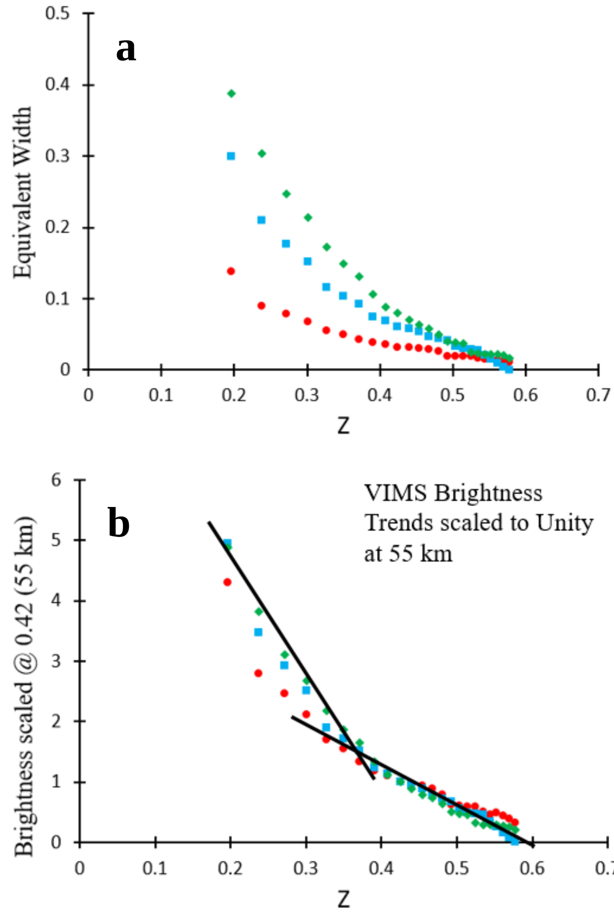

Figure 1 Plume brightness profiles with respect to altitude capture contrast in launch velocity trends. (a) Brightness profile trends derived for eruptions along Cairo (red), Baghdad (blue) and Damascus (green). A distinct break in slope around Z =0.4 is noticed. Z is a measure of particle launch velocity and is given by Z = sqrt[z/(z+r_E)], where r is the radius of Enceladus and z is the altitude above the surface. (b) Plume brightness profiles scaled to unity at Z=0.42 to compare the trends for the three fissure eruptions. Note that while Damascus and Baghdad exhibit similar trends, Cairo trends are noticeably different.

The steepening of the launch velocity trends at lower altitudes is potentially due to the influence of abundant large particle population which would fall-off rapidly with altitude as few of the larger particles get lofted to high altitudes. In contrast, smaller particles are lofted to much higher altitudes leading to a gentler drop-off trend. The observed contrasting trends potentially indicate at least two particle populations within Enceladus' plume and therefore there is likely spatial heterogeneity in the water-ice particle size component with altitude.

Does size sorting leads to compositional sorting? Another interesting possibility associated with the different particle size population is compositional sorting. Apart from water-ice, the plume is known to comprise of organic material, salt-rich grains as well as silica nano grains [7,11]. Based on measurements by the cosmic dust analyzer (CDA) instrument onboard Cassini mission, three different compositional varieties (Type I, II, III) of grains have been detected with additional sub-components [7, 12]. In addition, compositional stratification of the plume has also been suggested based on these observations. Our observations of potentially two particle populations at different altitudes not only supports the compositional stratification hypothesis, it might also be able to provide clues to the reason behind compositional stratification.

It is possible that particles of any given composition have a preferred size range. Accordingly, the particle size may be influencing the dominant composition of a given size fraction. In other words, size sorted grains might lead to compositional sorting. It would not only affect the grain composition but also any possible association of the grain with other compositional species such as mixture of ice and organics.

Implications for Sampling by Future Missions: In addition to the compositional stratification suggested earlier [7], our observations of potentially size-stratified plume have important implications for its sampling by future missions. In addition, it should be noted that the degree of size stratification is spatially variable based on the analysis of individual source fissures. A representative sample of the plume would thus, likely require sampling at multiple altitudes as well as over individual fissures.

References:

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