PROPERTIES OF THE VAPOR RELEASE FROM ENCELADUS' TIGER STRIPES FROM MODELING AND CASSINI INMS DATA.

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Introduction: Since their discovery [1], the vapor plumes emanating from the south pole of Enceladus have been imaged and sampled with every opportunity. Cassini has passed Enceladus 19 times, with most of the trajectories going through the plume. The Cassini Ion and Neutral Mass Spectrometer (INMS) has confirmed that the vapor plumes of Enceladus release water and other volatiles into the space over the south pole of Enceladus[2]. The constituents of the plume provide insight into the subsurface composition of Enceladus, as their sources are ultimately tied to some region below the surface. Further, understanding the dynamics of their release from the surface provides information that can be related to the subsurface acceleration mechanisms.

Variability in the water vapor emanating from the south polar region of Enceladus stems from factors that affect the source rate or the release parameters of the vapor. Understanding of the variability and the factors that influence it provides insight into the mechanism producing the plume. Variability was first based on magnetometer data gathered during the first three Enceladus encounters[3] and later found in the molecular emissions as measured by Cassini INMS (Ion and Neutral Mass Spectrometer) [4]. Recently, VIMS observations of the dust to link plume variability to the mean anomaly of Enceladus indicates that tidal forces may modulate the emissions [5].

The Cassini INMS profiles of volatiles in the plumes of Enceladus show variations from flyby to flyby [6]. Owing to the different geometries of the flybys, temporal and spatial variations are necessarily convolved in the data. We present a model that can be used to decouple spatial variability from temporal variability in the distribution of material in the vicinity of Enceladus.

Model: A model that was developed for the Earth's Moon [7] and applied to the vapor plumes resulting from spacecraft impacts on the Moon [8] was adapted for application to the distribution of vapor at altitude over Enceladus [9]. The model is a Monte Carlo model that follows particles using the equation of motion under Enceladus' gravity. It neglects collisions, rotational effects, and Saturn's gravity. This is a simplification used to demonstrate some basic principles of the distribution of exospheric particles emitted from Enceladus' jets. The expected influences of these simplifications on the model results are discussed.

A model run consists of initializing a set of usually 100,000 particles with position and velocity vectors representative of the jets. These particles are propagated through time without collisions under the influence of Enceladus' gravity using a 4th order Runge-Kutta algorithm. The particles continue until they reach the Hill Sphere at a distance of 949 km from Enceladus. The very few particles that return to the surface of the moon before escaping are considered trapped on the surface and are no longer followed. Photodissociation, charge exchange and electron impact ionization loss processes are neglected.

A large number of discrete sources of varying magnitude contribute to the plume[10]. [11] triangulated the sources from multiple views and reported 8 primary sources. In some model runs, the initial locations are evenly distributed between those 8 sources. However, we have also programmed in the option of having the source locations to be spread out along the lengths of the tiger stripes [12]. The run that uses the tiger stripes as the initial location is identified below.

The initial velocity for each particle is selected from a drifting Maxwellian distribution, which is comprised of 2 components that are added in vector form. The first component is the bulk velocity of the jet. For every particle coming out of a single jet, the bulk velocity is set to the same magnitude and direction. The default setting is to use the directions presented in [11]. However, this is allowed to change to better reproduce observations. The second velocity component is the thermal contribution. The thermal component varies from particle to particle. The magnitude of the thermal component is selected from a Maxwell Boltzmann distribution at the assigned temperature of the jet gases. The direction is selected from an isotropic distribution in 4 pi steradians. The bulk velocity vector and the thermal velocity vector are added for each particle to comprise the initial velocity.

The primary constituent of the vapor plumes is water [2]. However, the interaction between water and the walls of the INMS complicates producing a spatial profile of the water density using in situ sampling from the INMS [13]. The spatial profiles of minor species with molecular mass 44 and 28 are measured by INMS. The u=44 species presumably is CO_2. The u=28 species may be N_2 or CO, or some combination of the two. The model does not include losses from photolysis, charge exchange, or other collisional processes. Therefore the only important parameter to signify the species is its molecular mass because it influences the thermal velocity. The INMS measurements of mass 44 and 28 species can be used as a proxy for

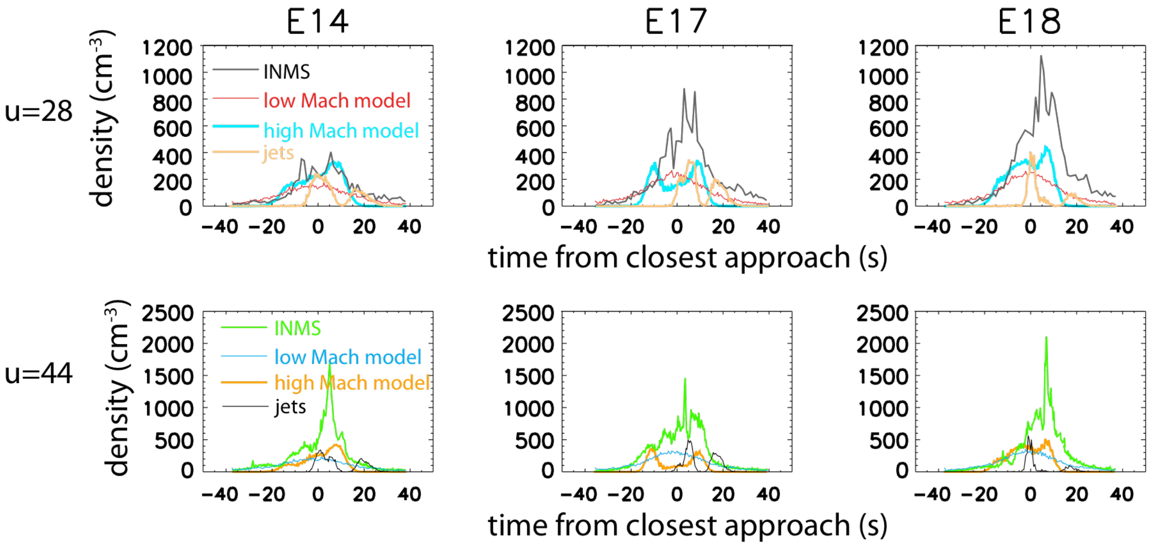

Figure 1. Comparison of low Mach number model and high Mach number model to INMS data for 3 Casssini passes. These passes are nearly parallel to each other and to the tiger stripes. There are density enhancements observed near closest approach that can't be explained with either high Mach number flow coming from the tiger stripes or low Mach number flows coming from the tiger stripes. Many of these line up with previously identified sources.

water. The model is used to simulate each of these three species separately. The relative source rates of the different species can be folded in after the simulations by including a spatially constant scaling factor.

Results: Model runs have addressed some of the enigmatic observations from the INMS, including differences in the temporal profiles of the ratio of mass 44 to mass 28. These are found to be the effect of proximity to source regions and the higher columnation of higher mass material than lower mass material. Most of the enhancements in the INMS observations correspond to crossing the tiger stripes or closest approach to strong jets. However, some jets are clearly not observed in the INMS data, indicating that they are either not directed in the previously inferred direction or are not active during the Cassini flyby. The background ramp up is used to determine the plumes emanating along the length of the tiger stripes, which is found to be substantial. The small scale structure is used to identify specific jets and their relative strength. Differences in the mass 28 and mass 44 channels are used to constrain the effective temperature of the vapor.

References: [1] Dougherty et al., Science 311, 2006. [2] Waite et al., Science 311, 2006. [3] Saur et al.. GRL 35, 2008. [4] Smith et al., JGR 115, 2010. [5] Hedman et al., Nature 456, 2013. [6] Perry et al., submitted to Icarus. [7] Crider and Vondrak, JGR 105, 2000. [8] Hurley, JGR 116, 2011 [9] Hurley et al., submitted to Icarus [10] Hansen et al., Nature 456, 2008. [11] Spitale and Porco, Nature 449, 2007. [12] Spencer and Nimmo, Ann. Rev. Earth Plan. Sci. 41, 2013. [13] Teolis et al. JGR 115, 2010.