FLYING THROUGH THE PLUME OF ENCELADUS. C. C. Porco[1,2], L. Dones[3], C. Mitchell[2] [1]UC Berkeley, CA; [2]Space Science Institute, Boulder CO; [3]SwRI, Boulder, CO.

Introduction: The Saturnian moon Enceladus has been found by Cassini to be home to a sub-ice-shell liquid water habitable zone that reaches the surface through deep fractures and erupts to form an extensive plume towering over the south polar region; e.g., [1]. As a result of these exciting results, Enceladus is now an object of great astrobiological interest and a target for the 2017 New Frontiers planetary mission call.

Various mission designs would be productive at Enceladus, but the ones most likely to fit the New Frontiers budget involve Cassini-like plume fly-throughs and the collection of plume material for onboard analysis. Mission designs require knowing how much solid material can be captured. Current, published estimates of the density and distribution of plume material, from *in situ* [2,3] and remote sensing [4] investigations, are discrepant.

We report the first results from an ongoing program to determine, through photometric analysis of Cassini ISS images, the nature of the plume and the number density, spatial and size distributions of its icy particles, and to reconcile the published estimates.

Data and Analysis: We use the Cosmic Dust Analyzer (CDA) results from the 2009 E7 100-km and 2015 E21 50-km altitude flybys, and the only published remote sensing particle density results, obtained in late 2005 by the VIMS near-infrared instrument. The Enceladus plume is highly spatially variable in 3 dimensions [1]. It also varies diurnally in mass with Enceladus' orbital position, or mean anomaly (MA) [5,6]; recently it has been found to vary with a 4-year and maybe an 11-year periodicity [7]. No sound comparisons of observations, cross-instrument or otherwise, can be made without due consideration of these variabilities. Consequently, the images we selected have mean anomalies, times of acquisition, and sub-spacecraft longitudes similar to the non-ISS observations. Images were calibrated to I/F. Brightness scans of ~ 9 km vertical height were made horizontally across the plume at altitudes from 25 to 500 km. These scans were converted into particle number and mass densities by assuming a Mie scattering law for water-ice, appropriate for the high phase angles of our images. We did each photometric conversion twice: One each for differential particle size distributions having an exponent of q = -3 and q = -4. We concentrate on 50- and 100-km altitudes.

Results: It is clear in Table 1 that the ISS remote sensing results, to within factors of 2, agree with those obtained by CDA for both E7 and E21 flybys at the appropriate altitudes, if we average our q= -3 and q = -4 results. (CDA found a q = -3.5 size distribution). ISS results, however, disagree with those of VIMS: we find number densities at a 50-km altitude ~ 4x smaller, despite looking at the same mean anomaly, from the same Enceladus sub-spacecraft longitude (to within ~ 10º), and within ~2 months in time. We are currently unsure of the reason, but note that VIMS instrument spatial resolution is very much coarser than that of ISS.

We find that both CDA and ISS are likely, in a single transect of the plume at a MA ~ 100º and the 50 km altitude, typically chosen for New Frontiers mission designs, to collect on a 1 m^2 collecting plate ~ 3 x 10^6 particles with r > 1.5μ or ~ 1 to 2 μL. Also in Table 1, we include results from images taken at the bottom (MA ~ 344º) and the peak (MA ~ 209º) of the diurnal cycle. A 50-km transect through the heart of the plume would net, for q ~ -3.5 and all particle sizes, ~0.5 μL at the bottom of the cycle to ~5 μL at the peak. [Later in the mission these numbers decrease.]

TABLE 1: COMPARISON OF ISS, VIMS AND CDA PLUME OBSERVATIONS

Instrument	MA (º)	Altitude (km)	Transect or Volume # Densities (r > 1.5μ)	ρ (r >1.5μ) (g/m^3)	Transect (all) ($\mu L/m^2$)
VIMS	100	50	~ 2800/m^3*	--	--
ISS 'VIMS'	100	50	660/m^3*	7 x 10^{-9}	1.7
CDA E7	265	100	2 x 10^6 /m^2	--	--
ISS 'E7'	269	100	2.5 x 10^6 /m^2	1 x 10^{-9}	0.6
CDA E21	103	50	3 x 10^6 /m^2	--	2
ISS 'E21'	100	50	6 x 10^6 /m^2	8 x 10^{-9}	1.3
ISS early min	344	50	13/m^3	2 x 10^{-9}	0.5
ISS early max	208	50	250/m^3	3 x 10^{-8}	5
ISS late min	320	50	7/m^3	9 x 10^{-10}	0.4
ISS late max	209	50	130/m^3	2 x 10^{-8}	3

NOTE: ISS results are averages for q=-3 and q=-4 size distributions; * for r > 0.5μ.

References: [1] Porco C. C. et al. (2014) Astron J, 148:45. [2] Ye et al. (2014) JGR Space Phys, 119, 6294–6312. [3] Kempf S. et al. (2016) AGU abst. [4] Hedman et al. (2009) Ap.J, 693, 1749–1762. [5] Hedman et al. (2013) Nature, 500, 182. [6] Nimmo, F. al. (2014 Astron J, 148:46. [7] Nimmo, F. et al (2016) AGU abst.