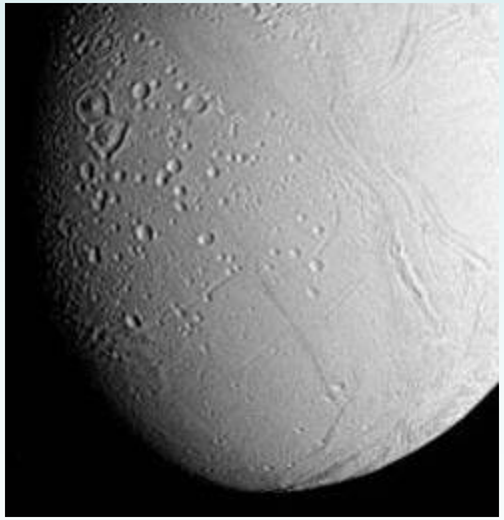
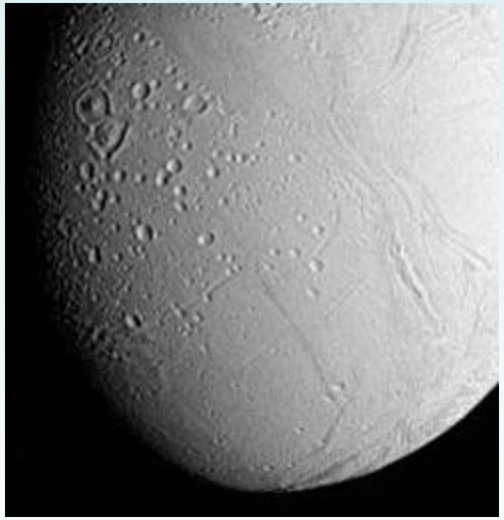
Overview of Rev 61 Enceladus targeted flyby: into the plume



Amanda Hendrix, Bonnie Buratti, Rosaly Lopes, and Nora Kelly
“The SOST Leadership”

Feb. 22, 2008 preview

Overview of Rev 61 Enceladus targeted flyby: into the plume



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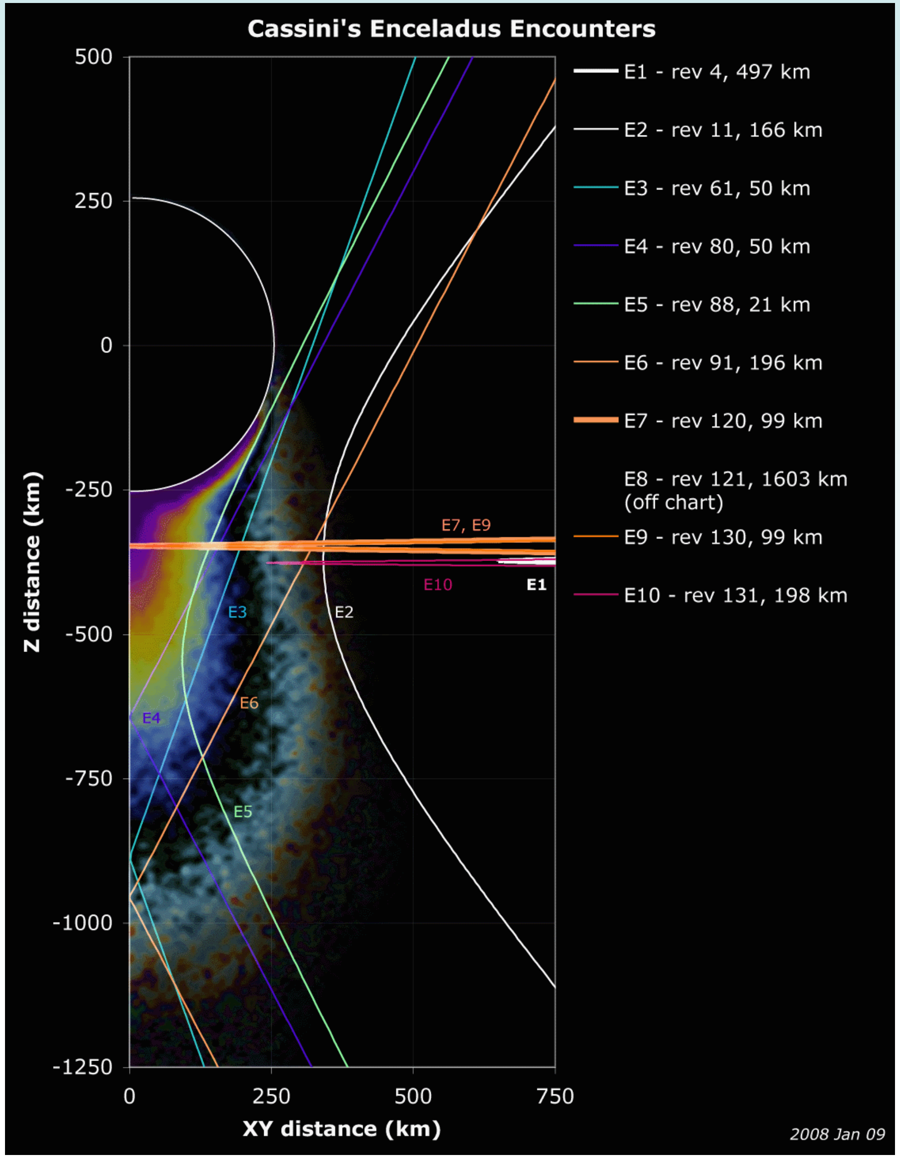
Summary of Major Enceladus flybys

Rev	Date	Distance (km)
003	17 Feb 2005	1200
004	9 March 2005	500
005	29 March 2005	64,000
008	21 May 2005	93,000
011	14 July 2005	175
028	8 Sept 2006	40,000
032	9 Nov 2006	94,000
047	28 June 2007	90,000
050	30 Sept 2007	88,000
061	12 March 2008	50
074	30 June 2008	99,000

(Distances are based on an earlier reference tour.)

Trajectory

- Rev 61 involves a passage into the plume (although later observations will go even deeper)
- Closest approach does not occur during the plume passage



Main scientific objectives

- Radar scatterometry of both hemispheres to determine cm-scale roughness and radiometry to understand the energy balance
- VIMS compositional mapping to determine the identity of volatiles, organics, and minerals, and place them within a geologic context
- MAPS examination of the particle environment at 50 km from the surface to determine the nature of the material coming form the surface and its relationship to the E-ring
- ISS meter-scale imaging to determine the geologic history of Enceladus, including possible remnant tiger stripes; first good view of north polar regions (is all of it heavily cratered?)
- CIRS observations of the warm-up after solar eclipse to determine the heat capacity and textural properties of the regolith; observations of hot spots and determination of any changes from the previous flyby
- Search for variability in the plumes and particle environment

Enceladus 3 Preview

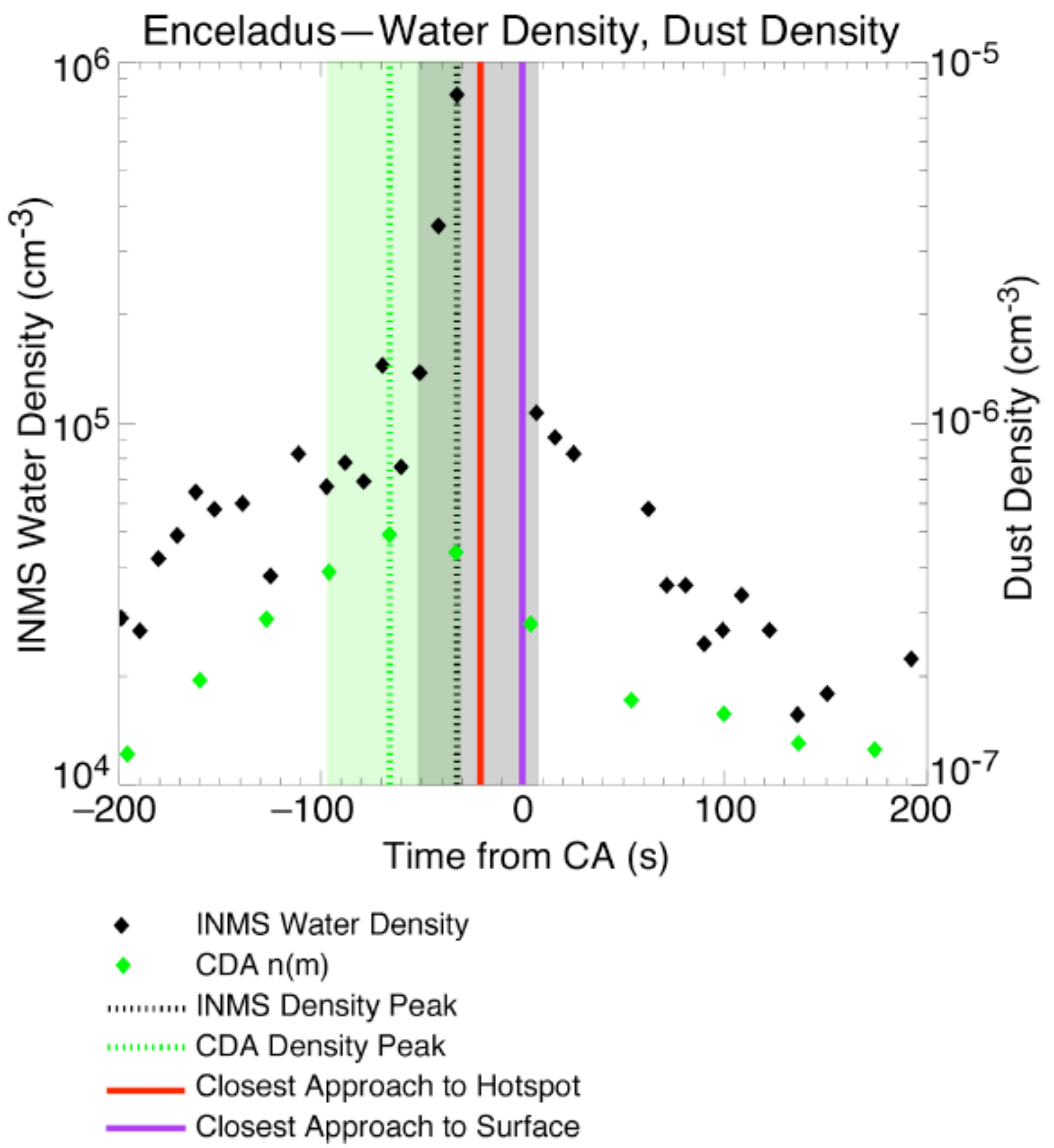
INMS
J. Hunter Waite

Enceladus 3 Preview

INMS

J. Hunter Waite

Comparison of INMS H_2O and CDA Particle Densities

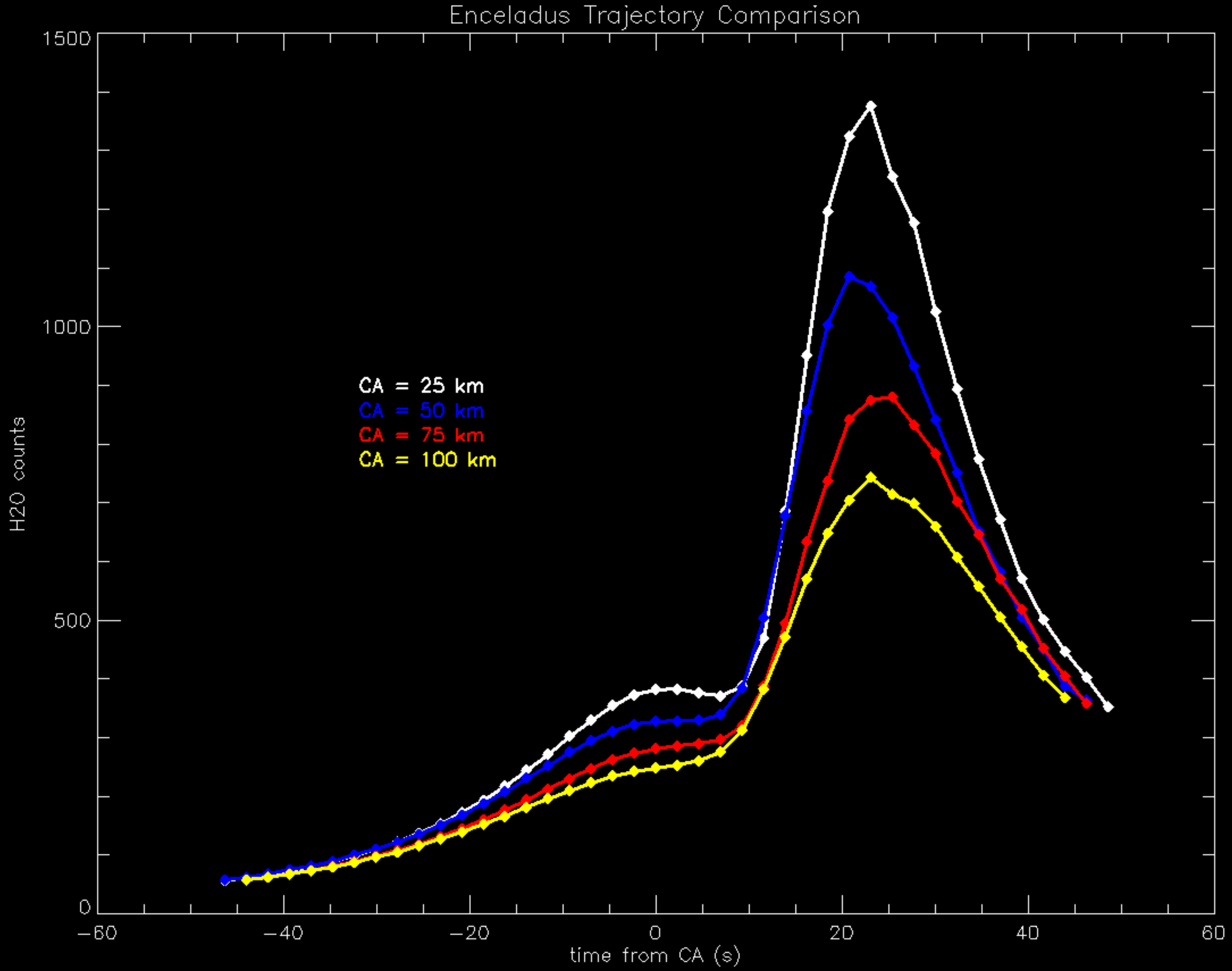


Previous Results

*From INMS Science paper, March 2006

species	min abundance	max abundance	error	best fit (#4) abundance	best fit (#4) error
H_2O	0.9070	0.9150	0.0300	0.8964	0.1398
CO_2	0.0314	0.0326	0.0060	0.0279	0.0115
CO or N_2	0.0329	0.0427	0.0100	0.0229 **(N_2)**	0.0125
CH_4	0.0163	0.0168	0.0040	0.0135	0.0105

Mass 28 peak (CO or N_2) has undergone the most change, falling in abundance to make room for other species


Enceladus Trajectory Comparison
CA = 25 km
CA = 50 km
CA = 75 km
CA = 100 km
H20 counts
time from CA (s)
0
500
1000
1500
−60
−40
−20
0
20
40
60

What can INMS do with improved S/N

- Determine the difference in composition of the plume source versus the global source
- Measure NH_3(?) and H_2
- Distinguish between N_2 and CO
- Measure minor hydrocarbon species
- Measure noble gases?
- Determine O and N isotopic ratios?

Separate Source Profiles?

E2 encounter data exhibits asymmetry in spectral signature

- Plume source- data taken <500 km prior to CA
- Global source- data taken <500 km after CA

Species	Plume Source Abundance (error)	Global Source Abundance (error)
H_2O	0.8920 ± 0.1540	0.9350 ± 0.3430
CO_2	0.0300 ± 0.0104	0.0183 ± 0.0146
CH_4	0.0141 ± 0.0089	0.0114 ± 0.0146
C_2H_4	$(4.03 \pm 3.85) \times 10^{-3}$	$(0.781 \pm 3.05) \times 10^{-3}$
N_2	0.0164 ± 0.0087	0.0258 ± 0.0210
Kr	$(0.936 \pm 1.84) \times 10^{-3}$	$(5.95 \pm 8.64) \times 10^{-3}$
H_2	0.0418 ± 0.0370	X

Encounter	Plume Source Error Improvement	Global Source Error Improvement
E3 (50 km)	2.29	2.20
E3 (75 km)	2.13	2.08
E3 (100 km)	1.99	2.01

According to our current model projections, our improved counting statistics will improve our abundance errors (left) by the factors shown above

Improvement in Detection Capabilities for H_2, NH_3, N_2

Trajectory Closest Approach to surface	minimum detectable abundance of NH_3 (relative to H_2O)	minimum detectable abundance of H_2 (relative to H_2O)	N_2 abundance (relative to CH4) necessary to differentiate from CO	C2 group detection: mass 26 counts relative to 2 sigma error + noise
Previous Encounter	8.8% ∇	9.2% +	893% *	32.1%
25 km	2.17%	2.27%	220%	137%
50 km	2.34%	2.45%	238%	135%
75 km	2.52%	2.64%	256%	125%
100 km	2.71%	2.83%	275%	109%

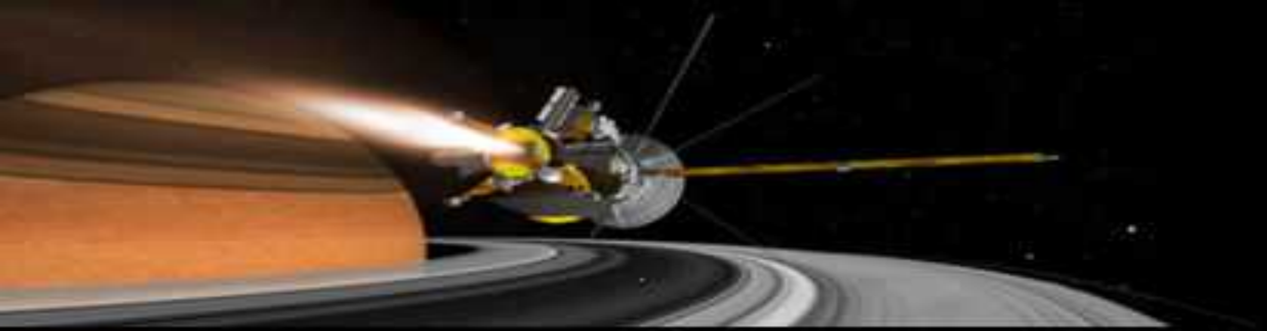
∇ Maximum observed NH_3 abundance relative to H_2O was 1.4%

+ Actual observed H_2 abundance relative to H_2O was 4.1%

* Actual observed N_2 abundance relative to CH_4 was 136%

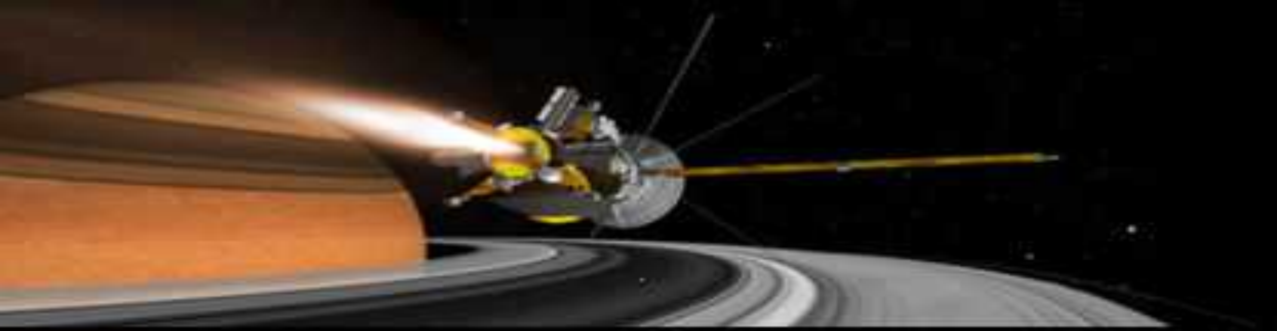
Science Summary

- INMS can make significant improvements in determining the composition of the gas surrounding Enceladus.
- INMS and CDA can separate the plume and global sources of material at Enceladus and determine the differences in gas and dust composition.



Rev. 61 Enceladus flyby: CDA preview

S. Kempf, R. Srama, G. Moragas-Klostermeyer,
and the CDA team



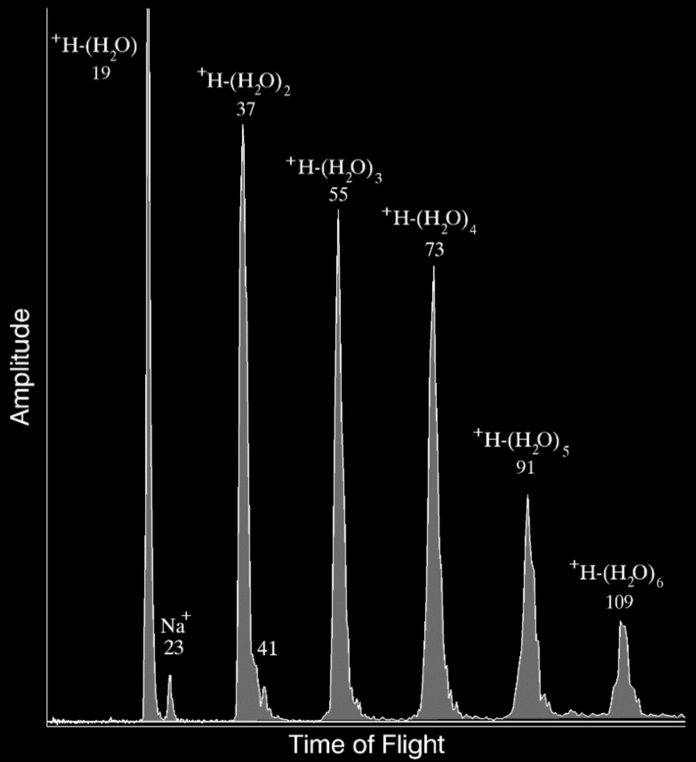
cosmic dust analyser

Max-Planck-Institut für Kernphysik

CDA identified two ring particles composition types

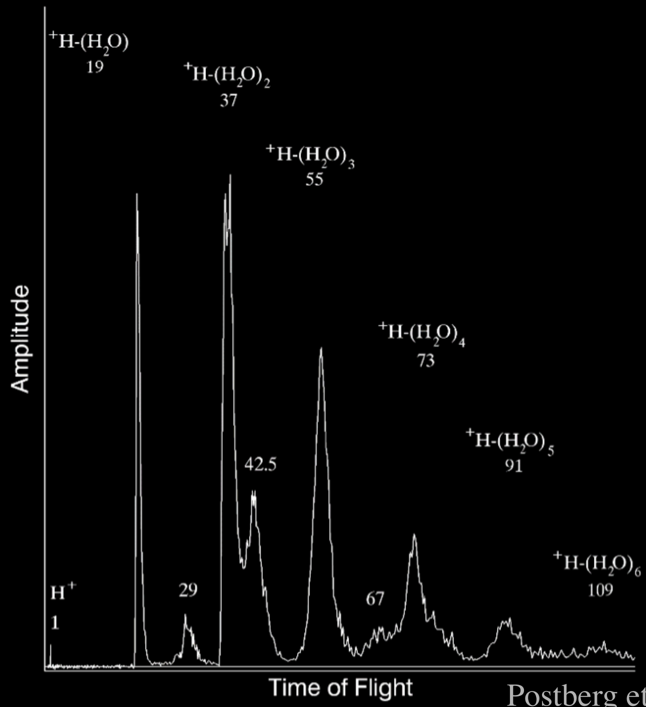
Type I: Pure water ice

Enceladus surface (?)

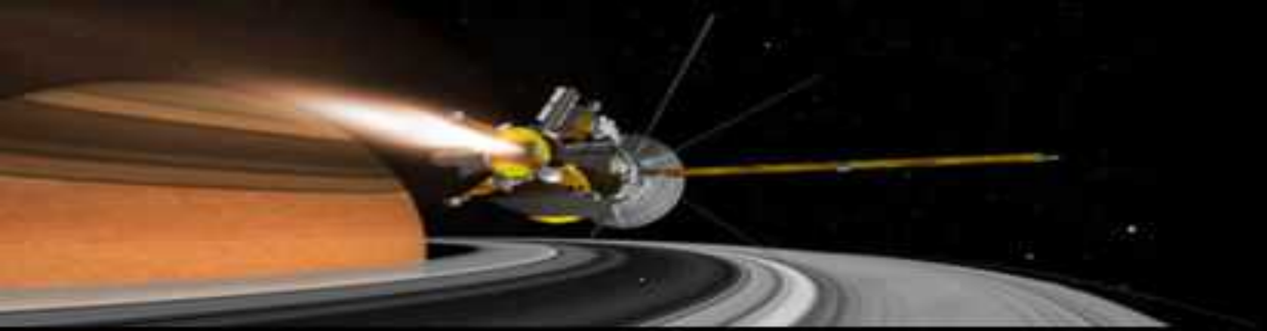


Type II: Water ice + impurity

Enceladus plumes (?)



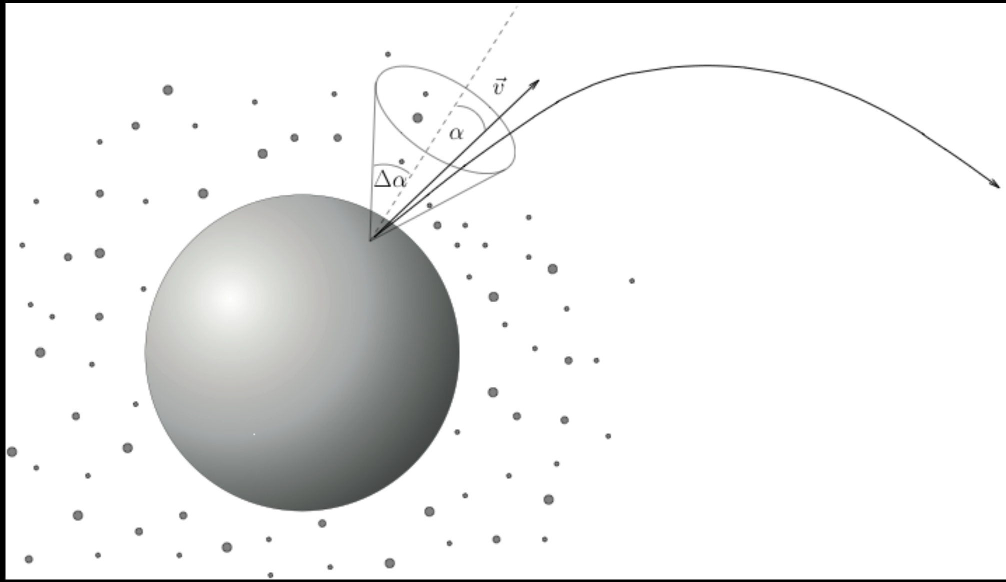
Postberg et al., 2008, Icarus

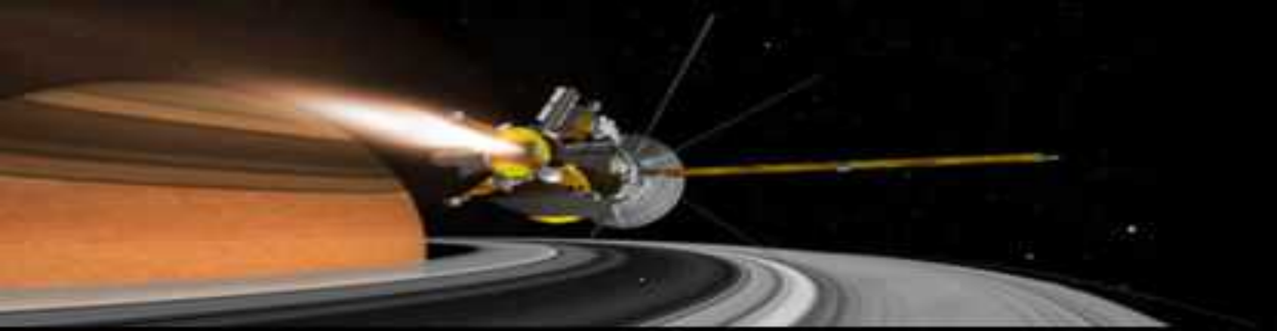


Type I Particles

Origin: Enceladus surface ejecta splashed up by meteoroid impacts (?)

- If so, all ejecta particles should by type I
- Enceladus surface ejecta only dominate dust flux very close to the moon’s surface outside the plumes

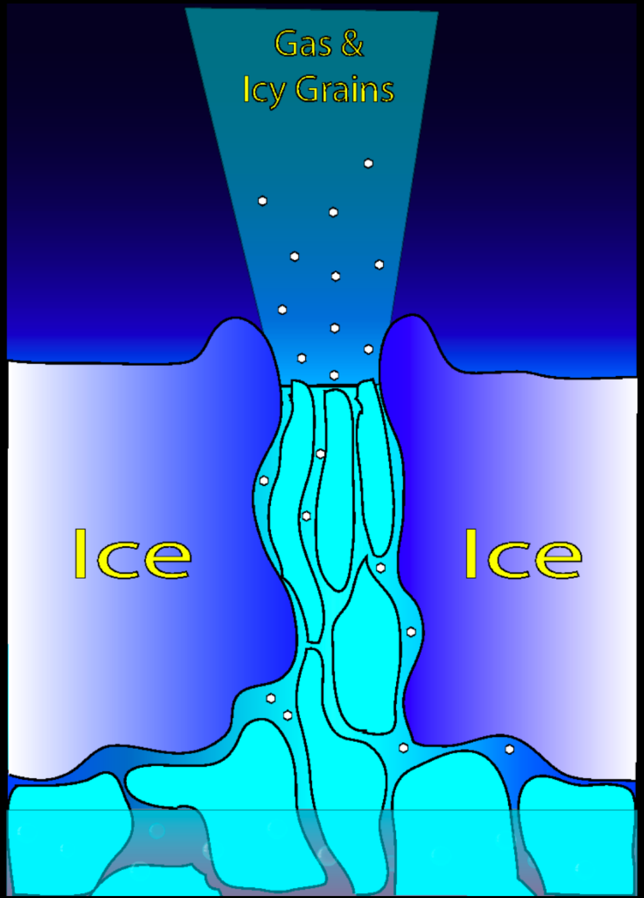


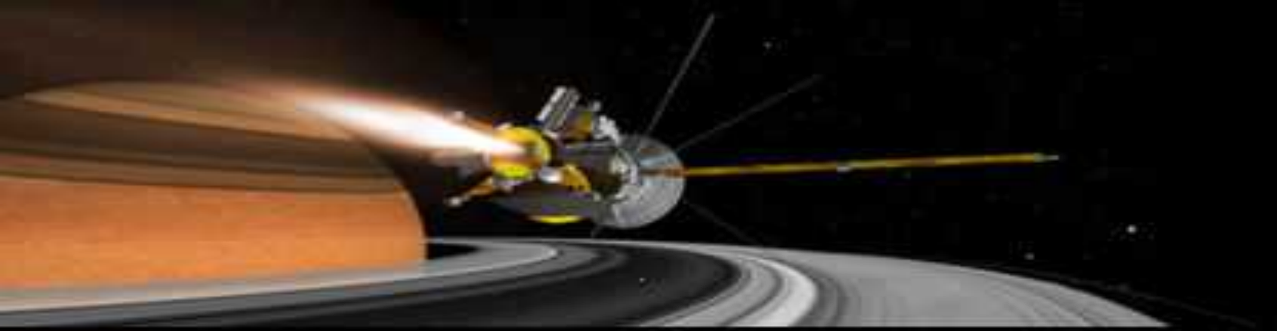


Type II Particles

Origin: Enceladus dust plume (?)

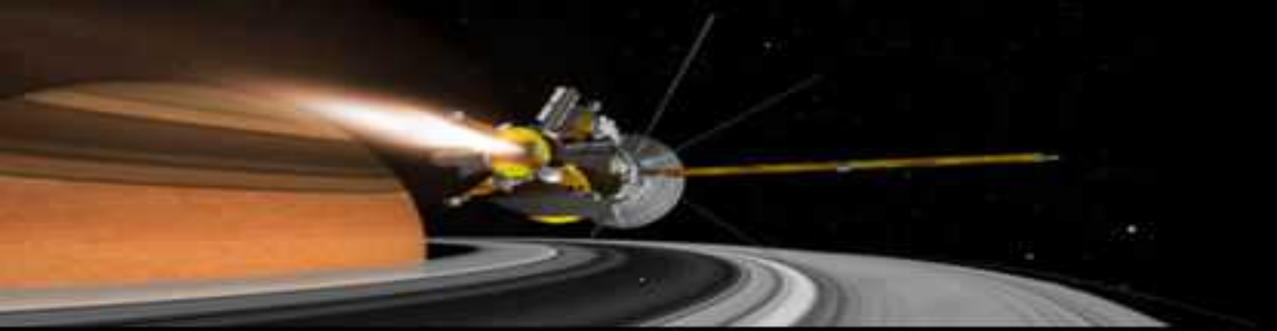
- Impurities embedded in the Type II particles are condensation seeds of these particles?
- If so, most of the plume particles should be of Type II





Main Goal of Rev. 61 Flyby:

- Determine composition of Enceladus surface ejecta (CDA DA detector)
- Determine composition of Enceladus plume particles (CDA DA detector)
- Measure number density and size distribution of both, surface ejecta and plume particles (CDA HRD detector)

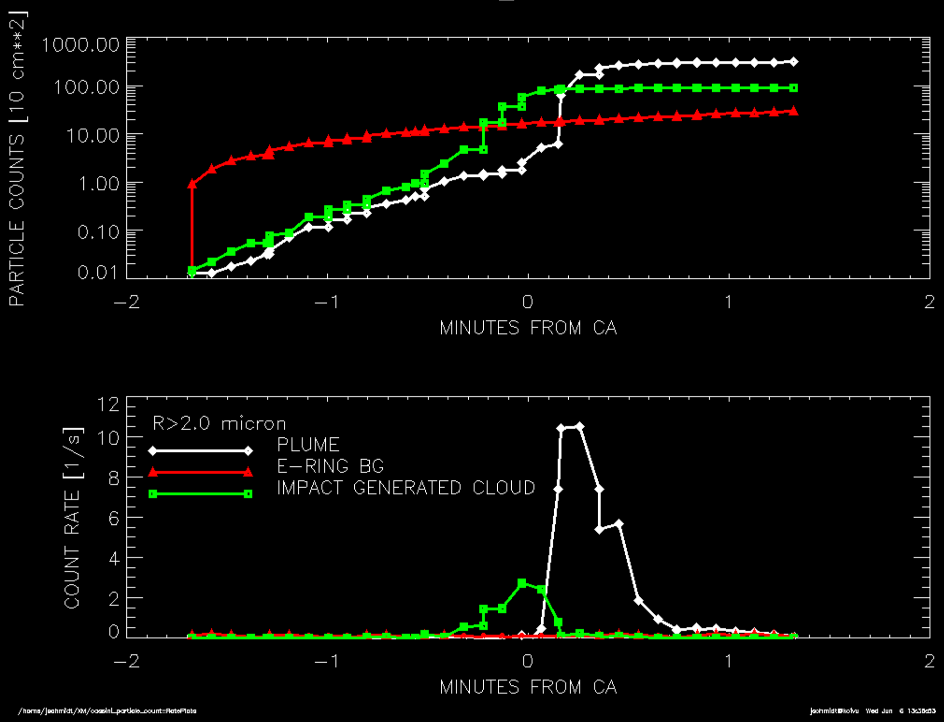


cosmic dust analyser

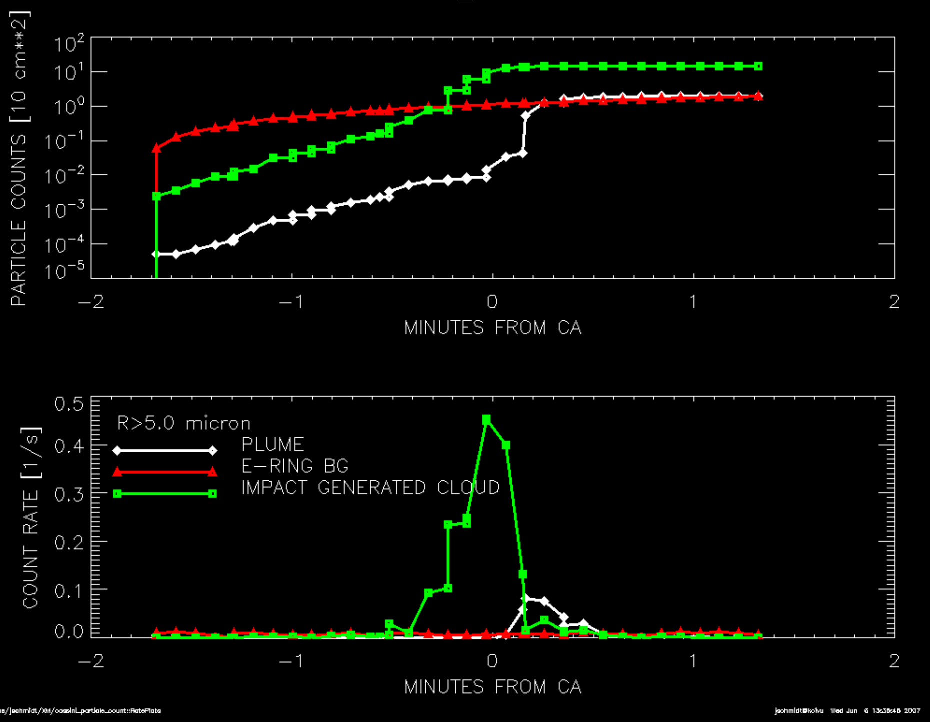
Max-Planck-Institut für Kernphysik

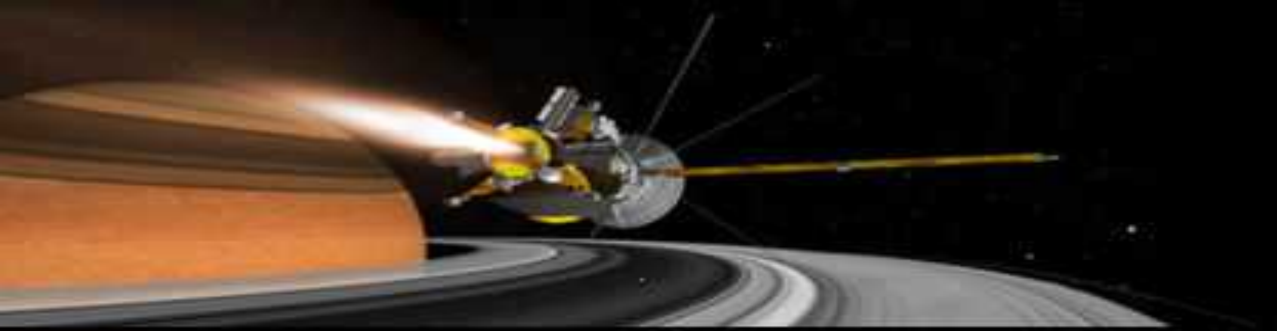
Predictions for rev. 61 Enceladus flyby

2 μm particles

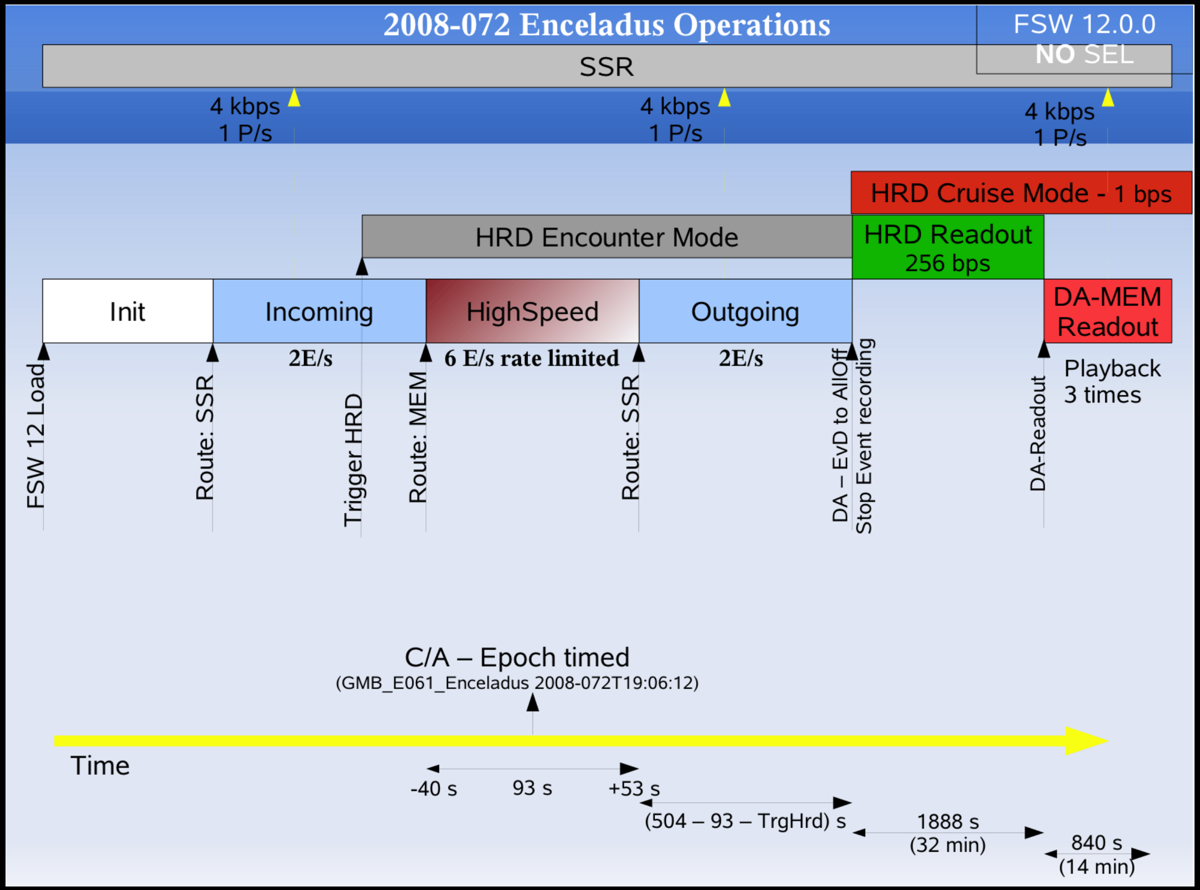


5 μm particles





CDA observation design



- use special FSW:
  - Records only mass spectra
  - 6 spectra/second
- Surface ejectas dominate flux for about 100s
  - Spectra recorded during this phase are stored in internal memory and transmitted to SSR after the flyby
- HRD is operated in 0.2s time bins encounter mode

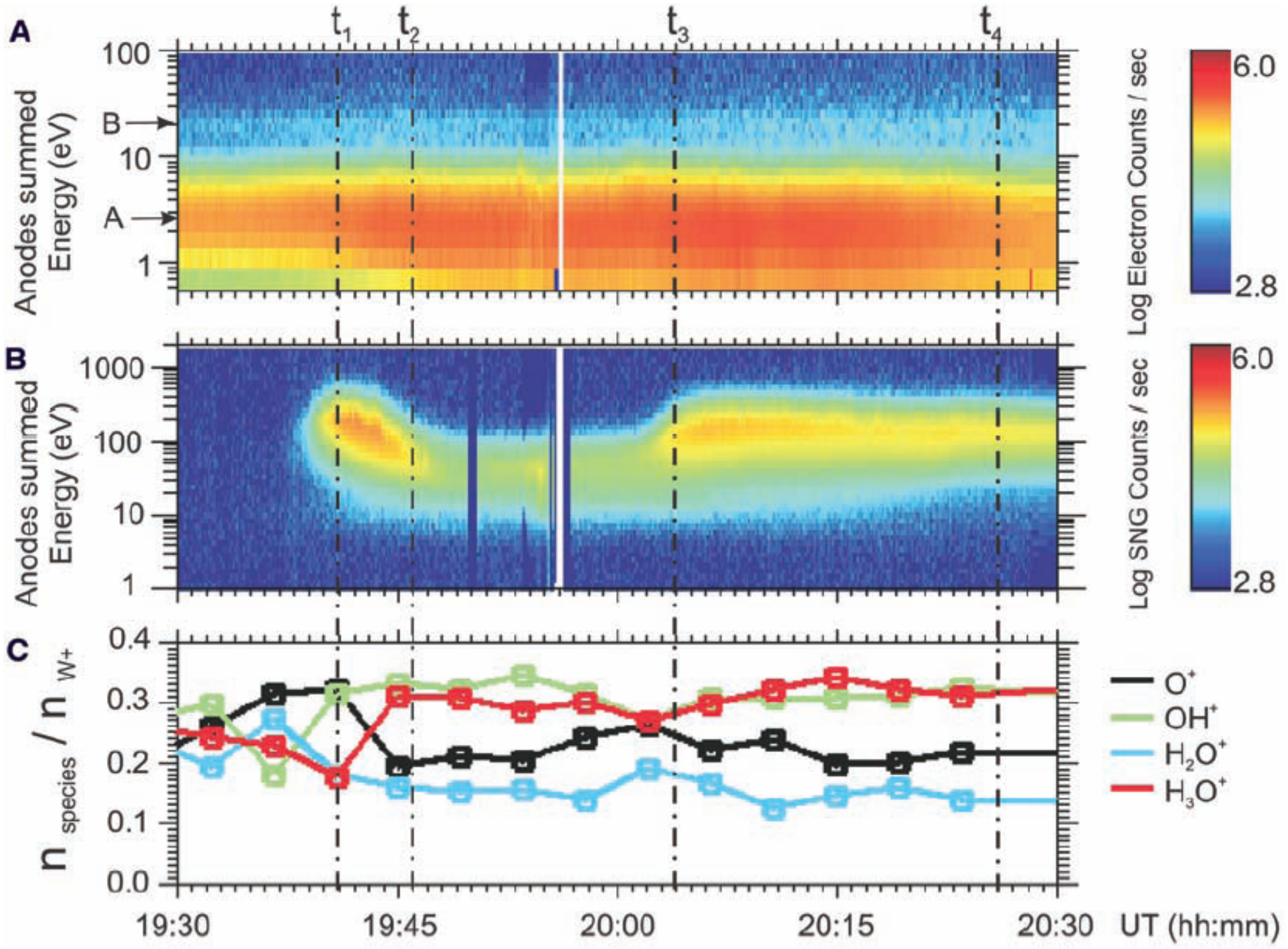
CAPS Preview of the 61EN (E3) Enceladus Encounter

CAPS spectra from 11EN (July 14, 2005)

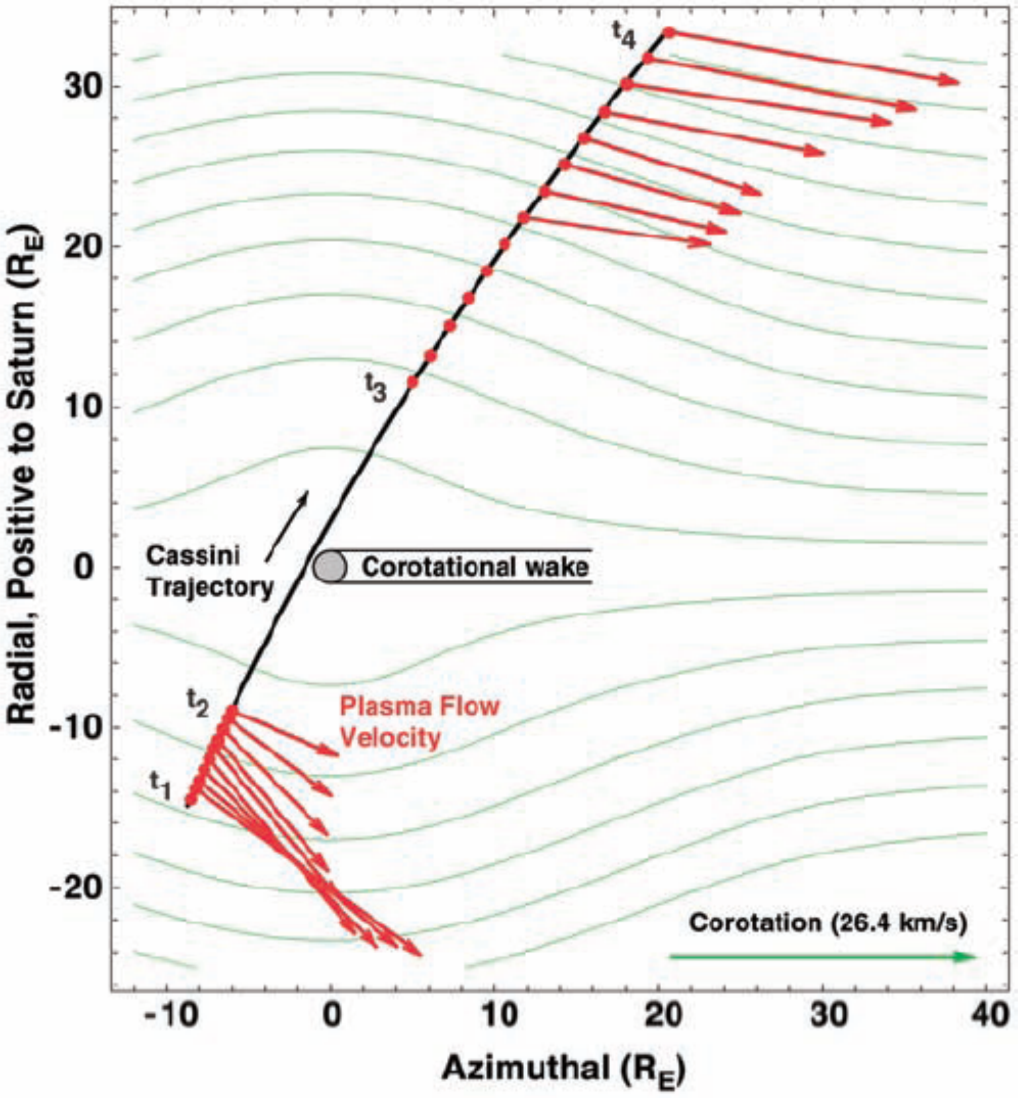
Electrons

Ions

Derived water group abundance

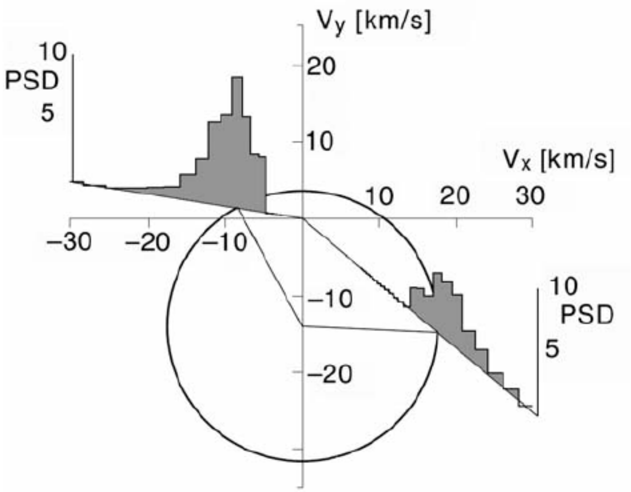


Ion flow field from CAPS data



- From Tokar et al., 2006
- No CAPS actuation during the encounter
  - Avoided time aliasing
  - 1 component of **v** unconstrained
- Fixed n_e to constrain fits
  - n_e from RPWS
- Significant perturbations over 25 R_E from Enceladus

Plasma source at Enceladus

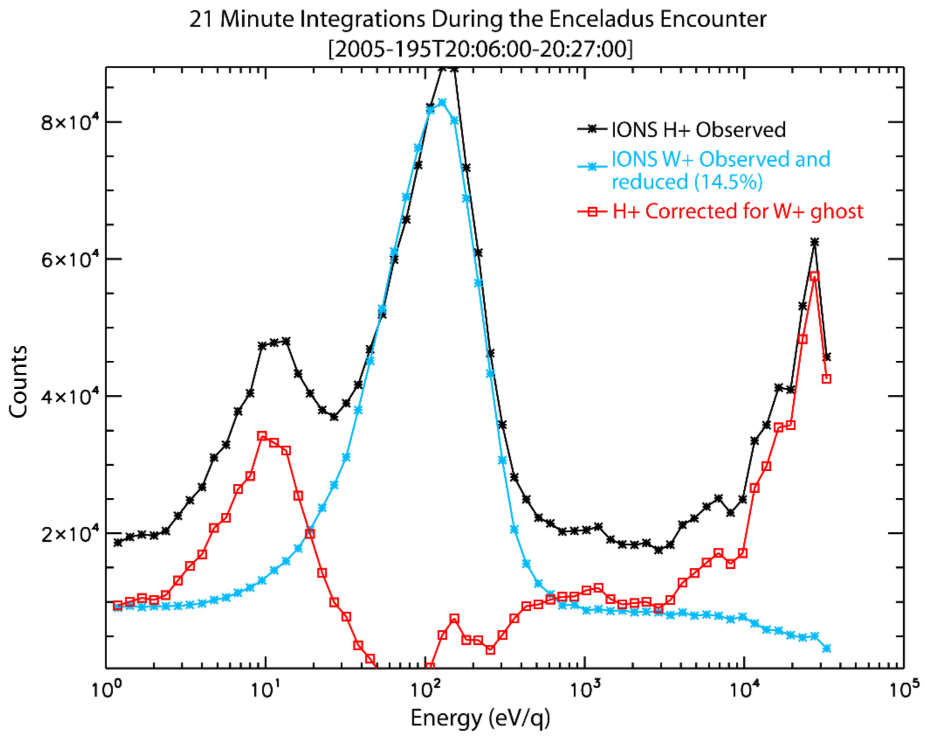


- W^+ ring-beam distribution observed at 11EN c/a
- Direct evidence of fresh ion production
- Also implies flow slowed to ~14 km/s
- No direct evidence ion N^+

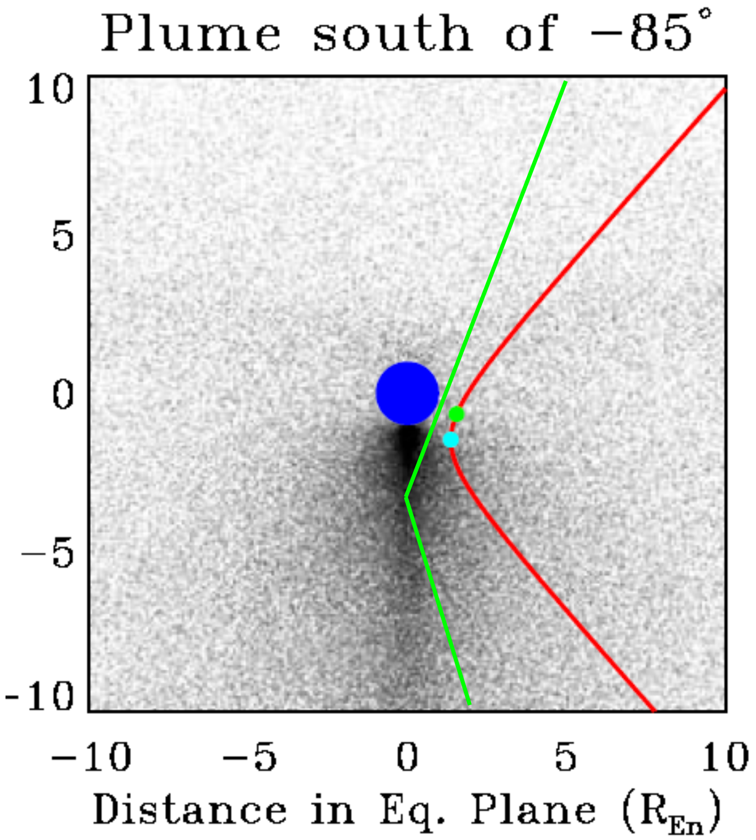
- Theoretical model and comparison to CAPS data
  - ~100 kg mass loading
    - Pontius and Hill, 2006
- Much higher than other estimates
  - Model & comparison to MAG data: <3 kg
    - Khurana et al., 2007
  - Plume model & CE rates: 2-3 kg w/ 10^{28} s^{-1} neutral source
    - Burger et al., 2007

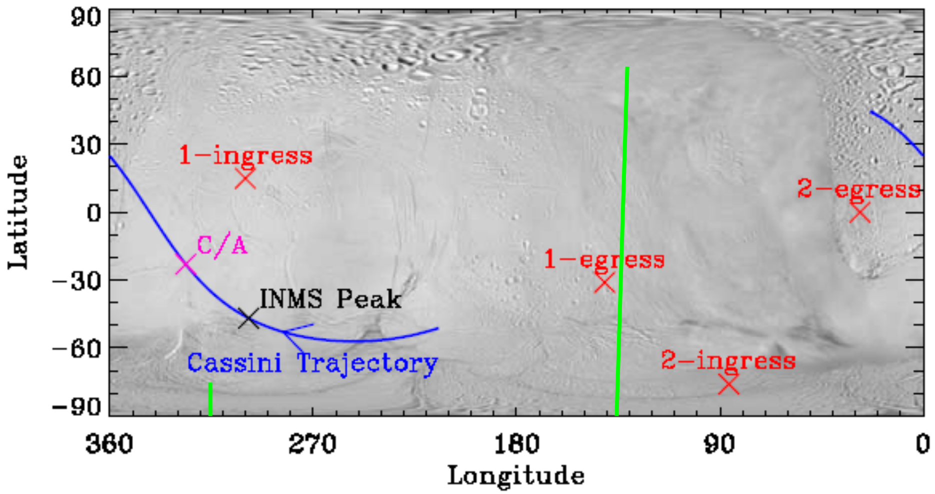
Hot H^+ population near Enceladus

- Seen during 11EN
- Previously masked by much higher water group flux
- Energy of 10-30 keV
  - Or higher?
- Peak inside Enceladus' orbit
  - May not be associated w/ Enceladus
- From Paty et al., 2007 Fall AGU



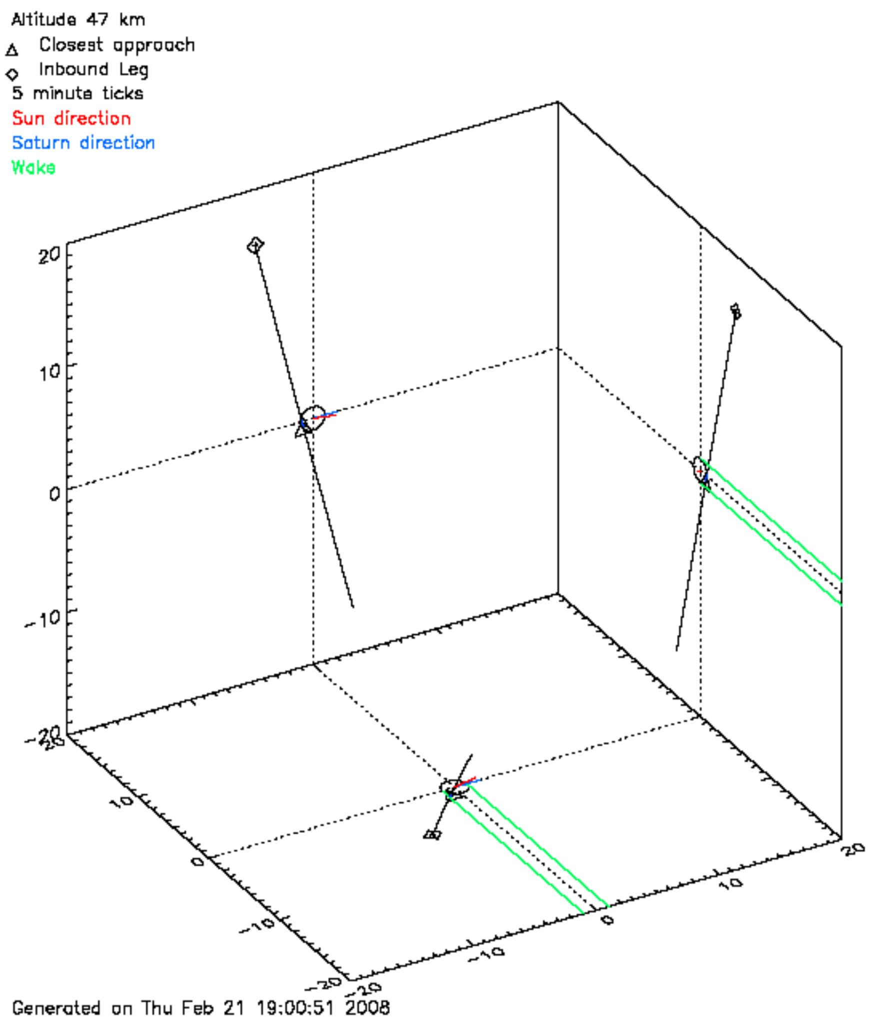
Comparison of 11EN and 61 EN





From Burger et al. 2007
with 61EN added

61EN (E3) encounter geometry

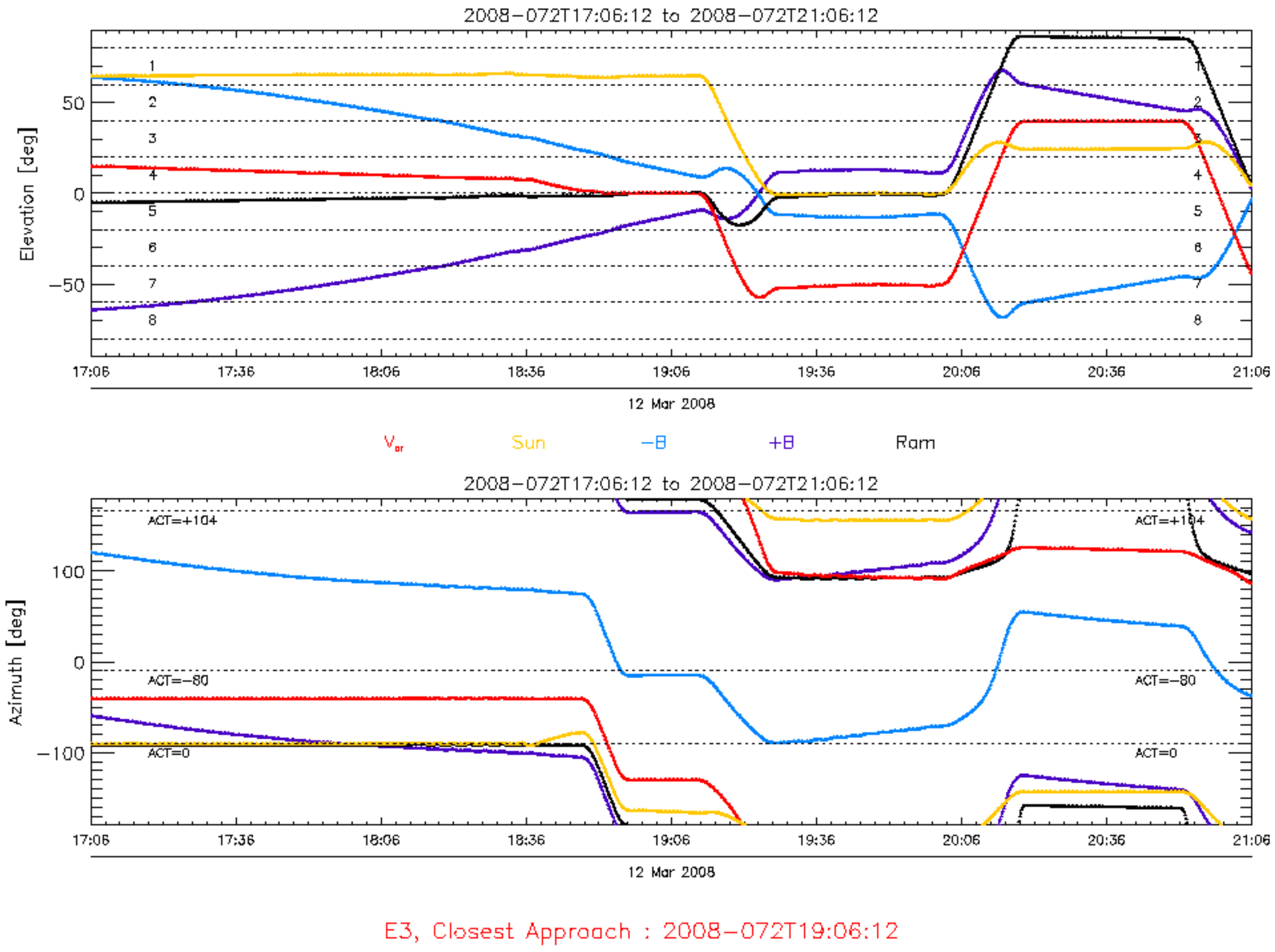


- 2008-072 (March 12) 19:06
- Approach from north pole
- 50 km altitude at c/a
  - c/a at –20º lat, 135º lng.
- Crosses center of plume
  - 641 km altitude
  - c/a + 58 seconds
- 16 kbps data ±30 minutes
- Very fast encounter
  - v_{sc} = 14.4 km/s = 3.46 R_E/min

61EN (E3) Enceladus pointing

- CAPS prime pointing for -21 to +5 minutes
  - Time on target –10 to +5 min
  - In body radii, 34 R_E inbound to 17.5 R_E outbound
- Pointing puts neutral ram & corotation in X-Z plane
- Encounter is too fast for actuation (17.4 s/R_E)
  - Full ACT sweep=204 s, minimum (28^o) sweep=52 s
- Actuator rammed at +90^o from –15 to +10 min.
  - Ion data will see peak of unperturbed or slowed flow
  - Ion data will not see peak of a flow deflected to the sides
  - Electron data covers 5^o to 90^o pitch angle
- 4s (58 km) resolution ion data
- 2s (29 km) resolution for electrons

61EN (E3) Enceladus pointing plot

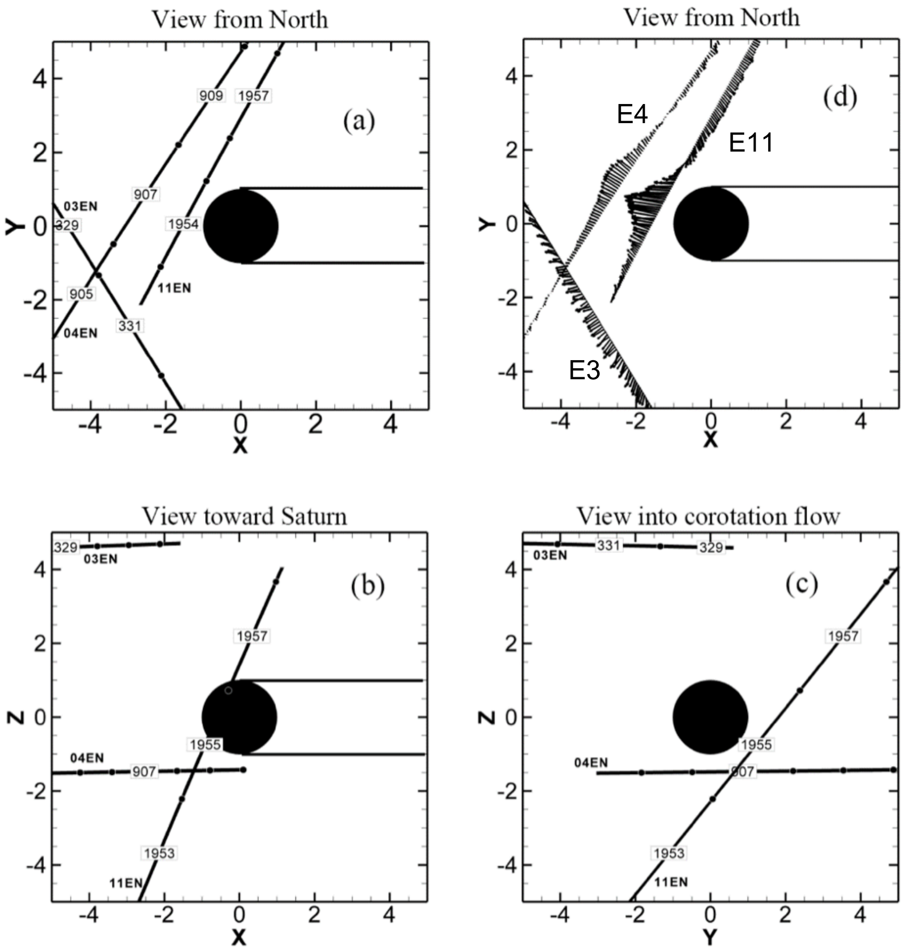


REV 61 Preview: MAG

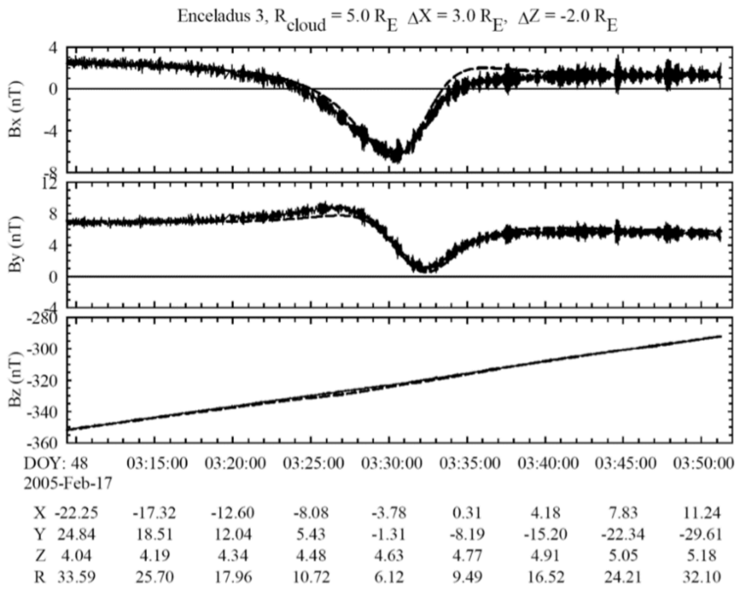
Krishan Khurana

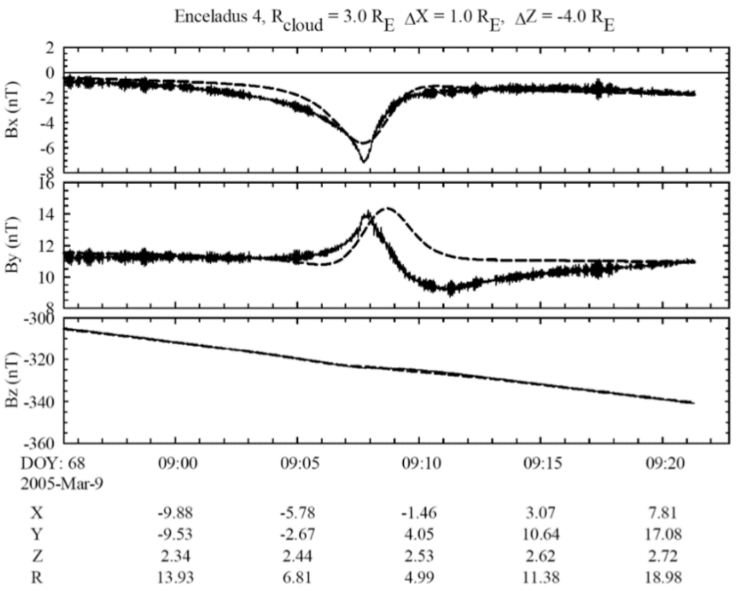
Previous flybys

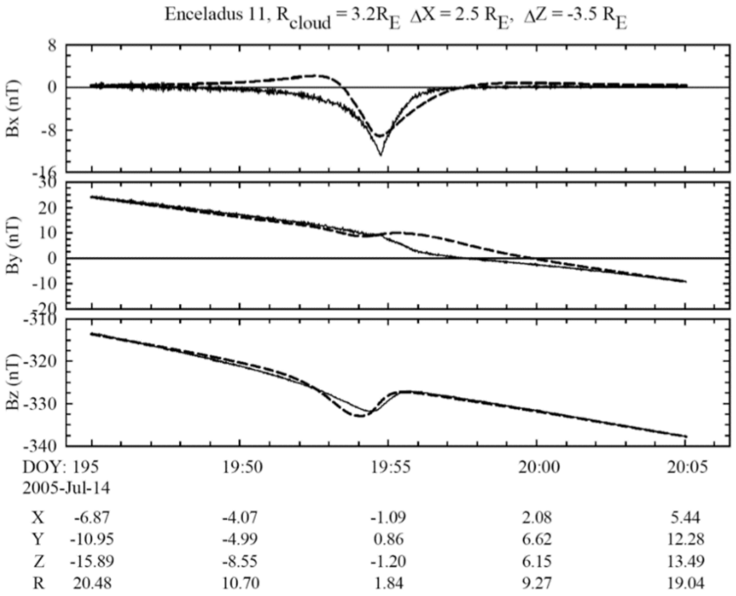
- E3, E4 and E11 were all upstream flybys.
- E3 flyby was above Enceladus and MAG data suggested the possibility of a dynamic atmosphere.
- E4 and E11 provided the evidence that the source of the magnetic signature was below Enceladus.

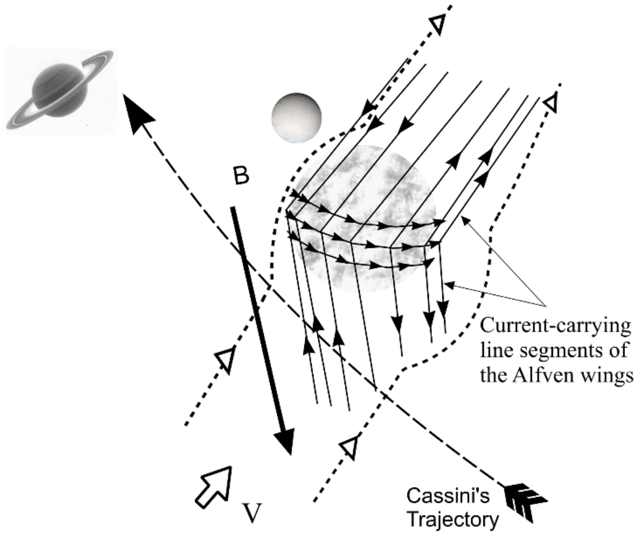


Biot Savart Modeling with a shifted large obstacle below Enceladus









Rate of Mass loading deduced from interaction current

$$J_y = q\dot{n}\rho_L = \dot{n}mv_\perp / B$$

$$I_y = \iint J_y dX dZ = \frac{\dot{M}v_\perp}{Bl_y}$$

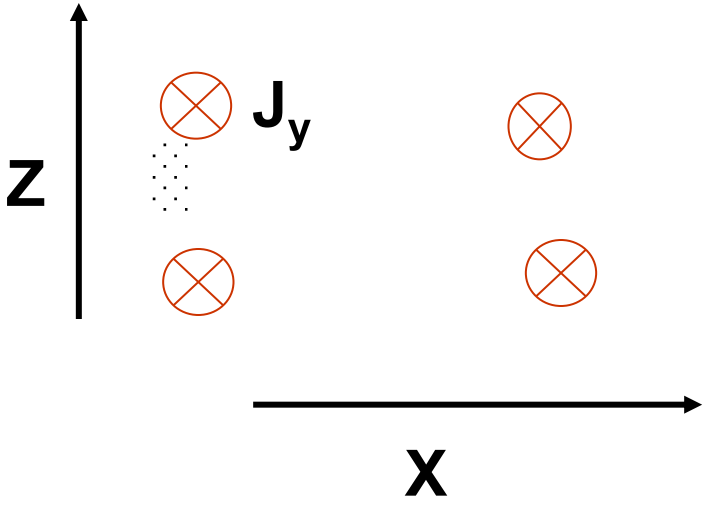
where $\dot{M} = \iiint \dot{n}m \, dX \, dY \, dZ$

or $\dot{M} = \dfrac{Bl_y I_y}{v_\perp} =$

$$\frac{320\text{x}10^{-9}\text{x}1500\text{x}10^{3}\text{x}1.0\text{x}10^{5}}{26x10^{3}}$$

$$\dot{M} = 0.6 - 2.8 \, \text{kg/s}$$

After Chris Goertz



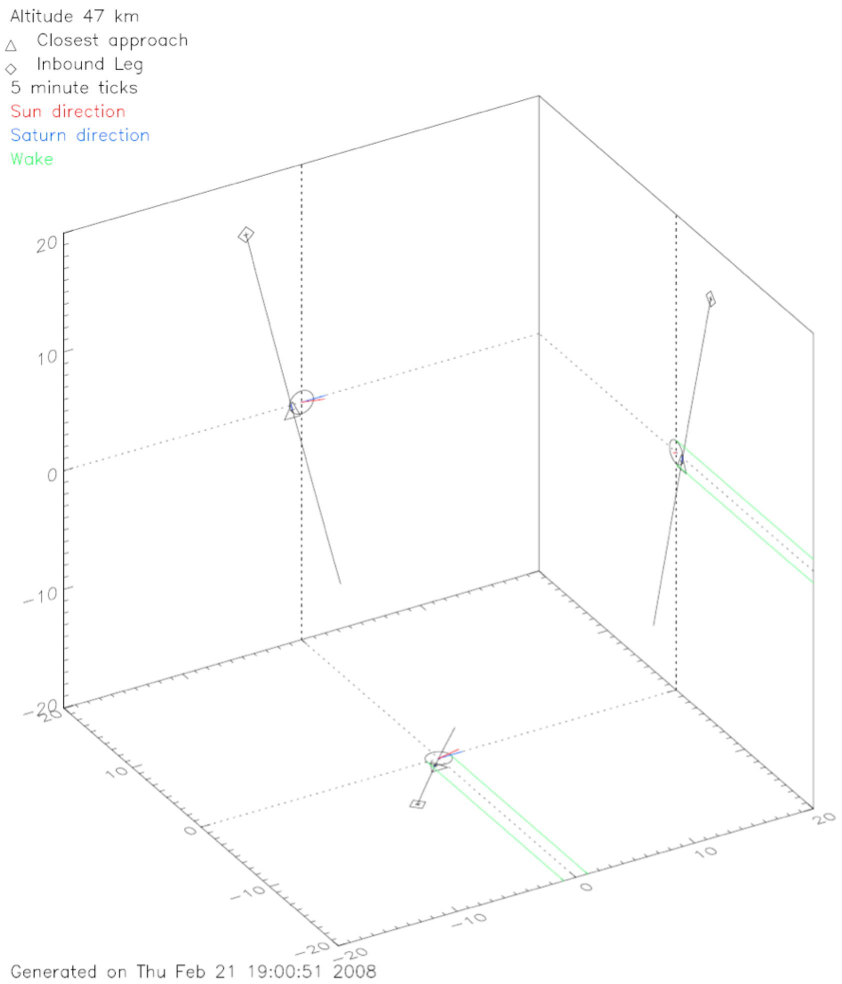
The rate of mass-loading can be related to the current passing through the mass-loading region. Surprisingly, the total amount of mass loading implied is quite low.

Science objectives for E61 trajectory

- Determine the variability of plasma loading from Enceladus's south pole plume by modeling the magnetic field signature.
- Determine whether Enceladus generates an induced magnetic field from a subsurface ocean.
- Determine the composition of plume material from measurement of ion cyclotron waves in the magnetic field measurements.

Assessment of E61 Trajectory

- Finally, a downstream pass!
- Ideal for characterizing picked-up populations and determining the amount of plasma pick-up occurring locally.
- Not ideal for ion cyclotron wave studies because waves are tightly confined to the equatorial plane of Saturn where Cassini will spend very little time.
- The close flyby distance is suited for looking for induction signal from an ocean. The expected induction amplitude ~ 1-2 nT, which is buried in the ~ 10 nT perturbation from plasma interaction.

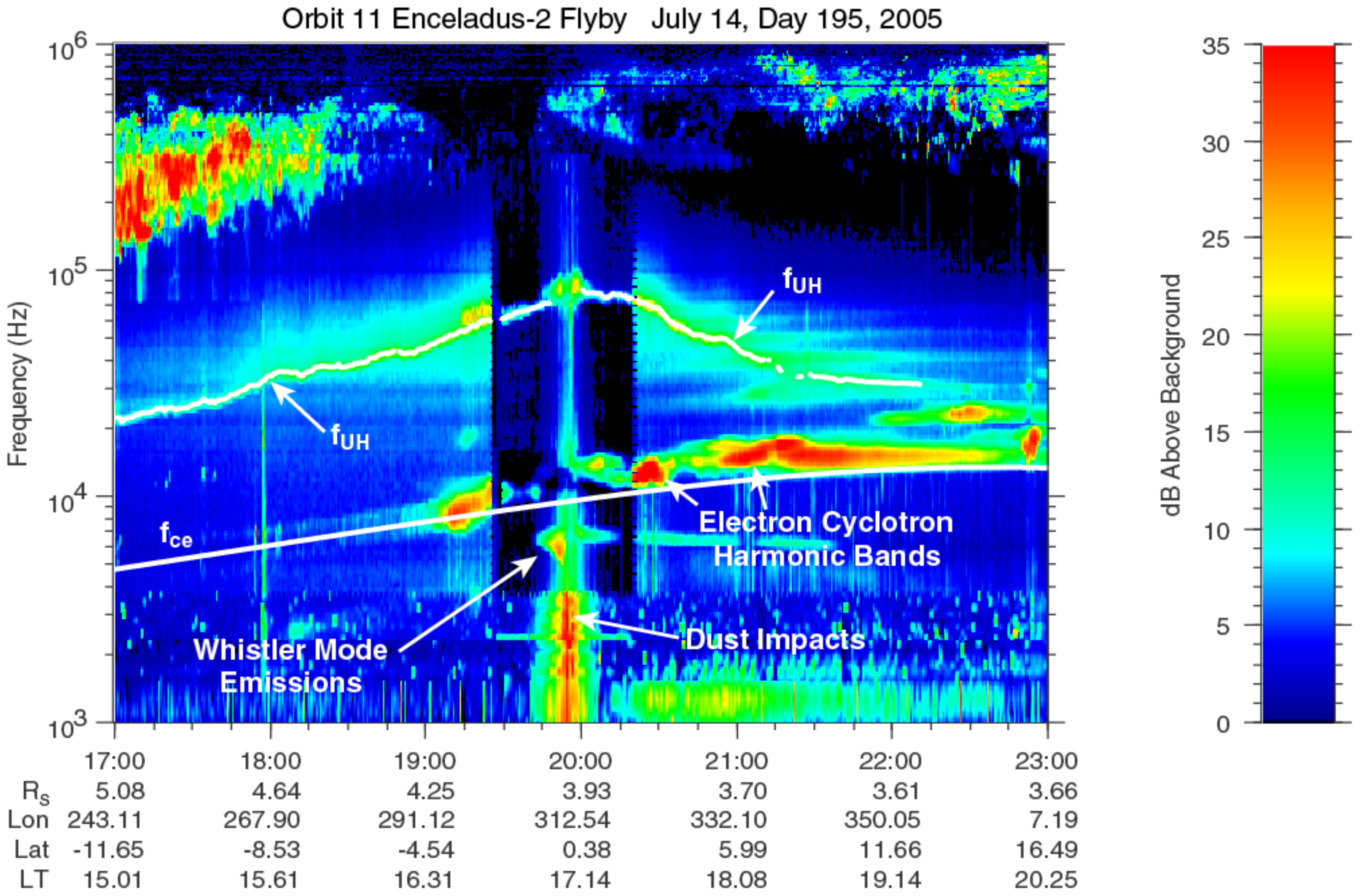


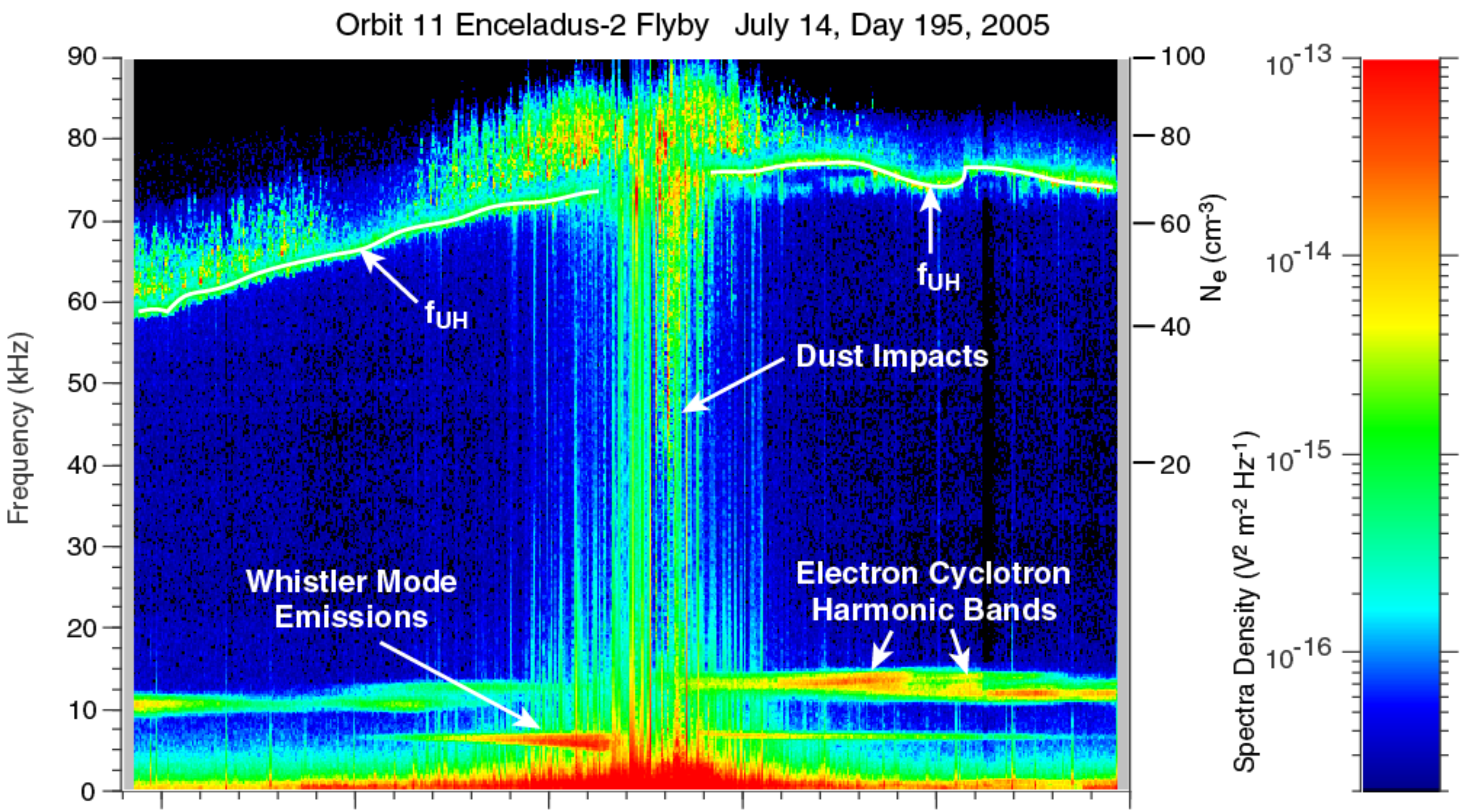
Rev. 61 Enceladus 3 Preview: RPWS

W. S. Kurth, for the RPWS Team

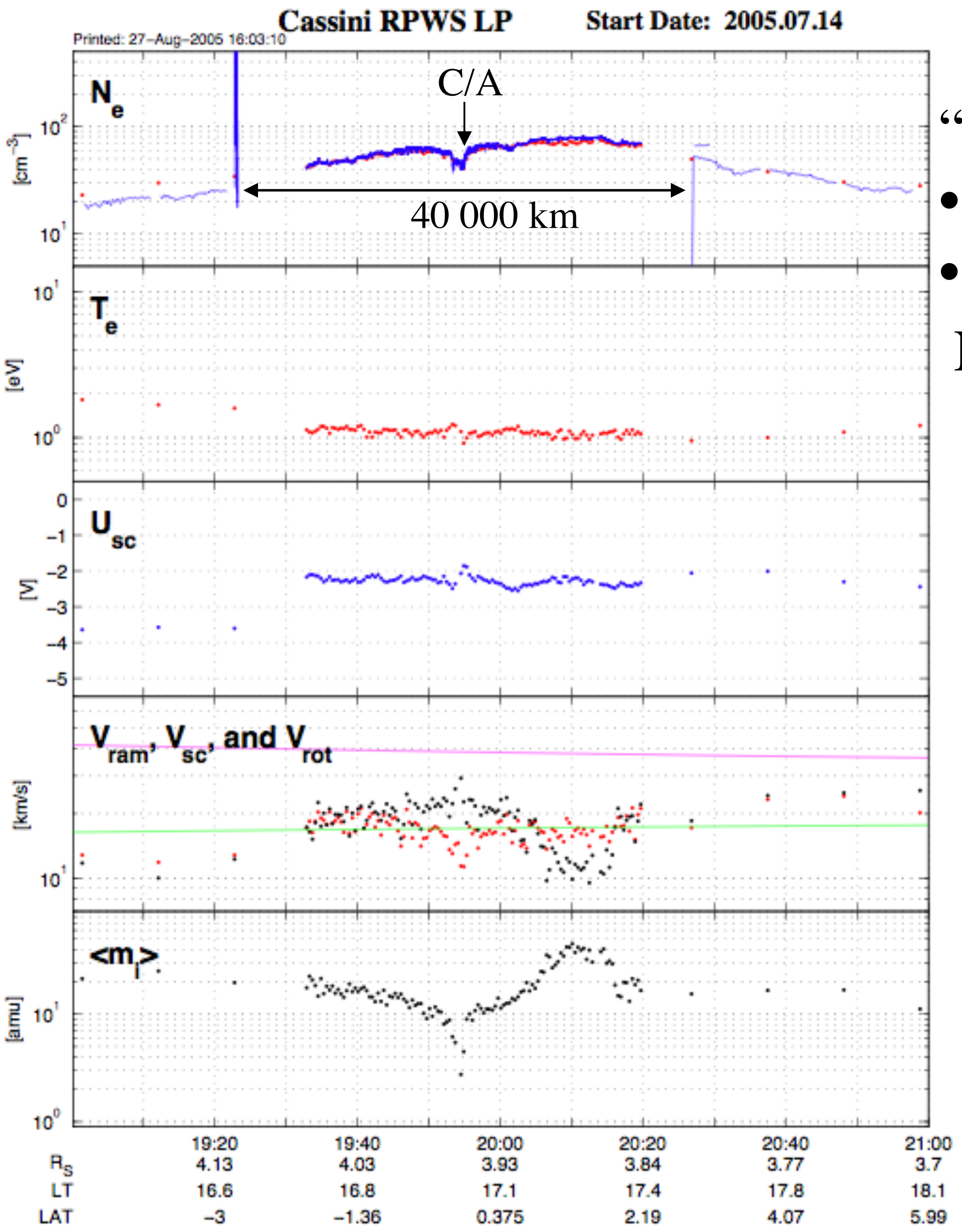
22 February 2008

Variation of electron density (f_{UH}) is a function of Saturnian latitude; no obvious strong peak close to Enceladus - no **local** source of fresh plasma. This suggests water from the moon is distributed in a torus and is slowly ionized from the torus as opposed to locally.





UT	19:30	19:40	19:50	20:00	20:10	20:20
R_{En}	49.40	29.95	10.58	9.18	28.55	48.00
Lon	206.19	209.70	219.86	17.81	27.15	30.50
Lat	-49.13	-49.86	-52.72	41.46	46.10	46.88
LT	15.04	14.92	14.37	3.96	3.46	3.36



Enceladus, July 14

"Smooth" undisturbed profiles

- No wake signatures
- No shock signatures

N_e = 60-80 cm^{-3}, SOI: 40 cm^{-3}

T_e = 0.9 - 1.2 eV

U_{sc} = -1.9 to -2.5 V

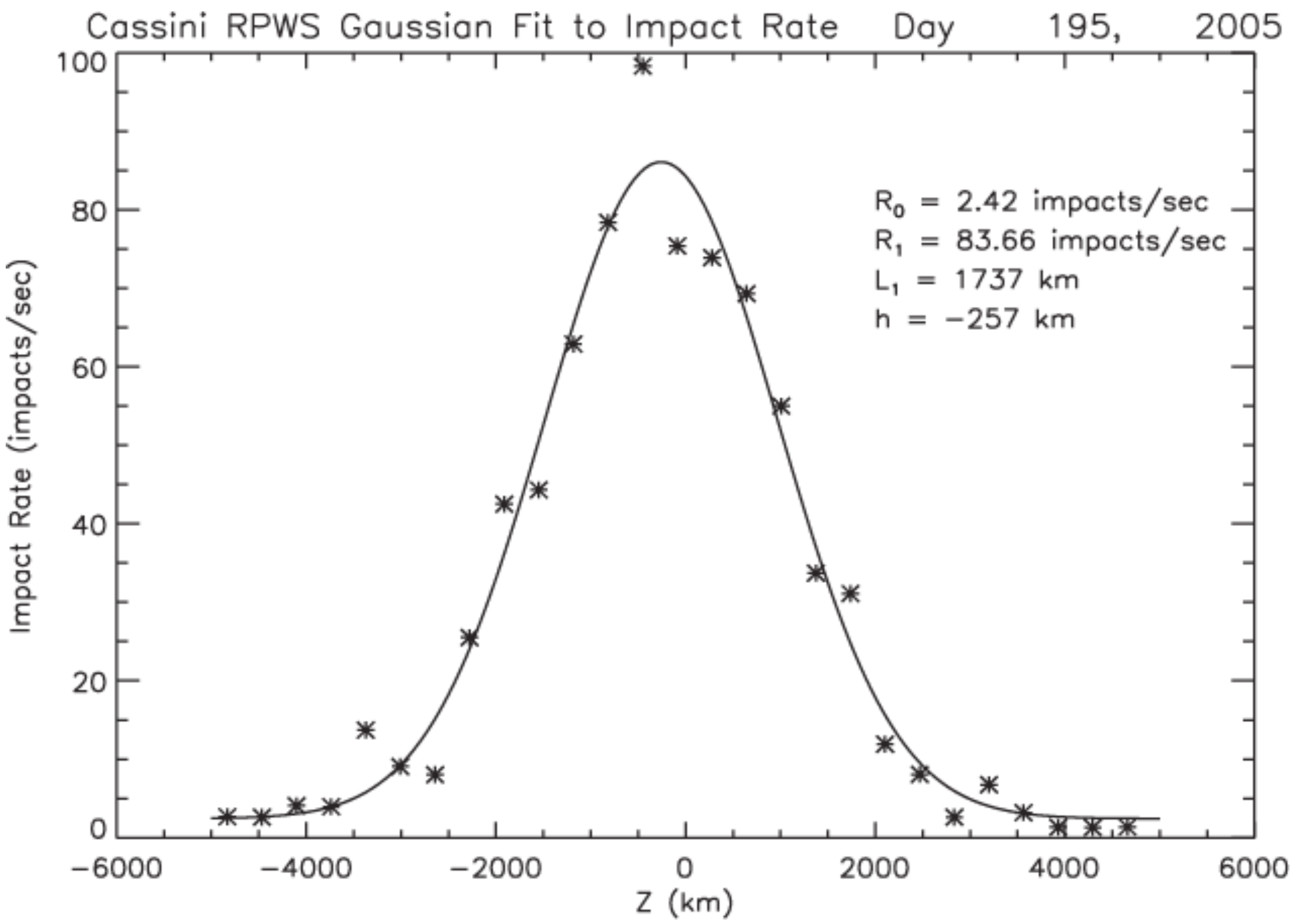
V_{H2O+} < 8 km/s rel. S/C

T_{H2O+} < 6 eV

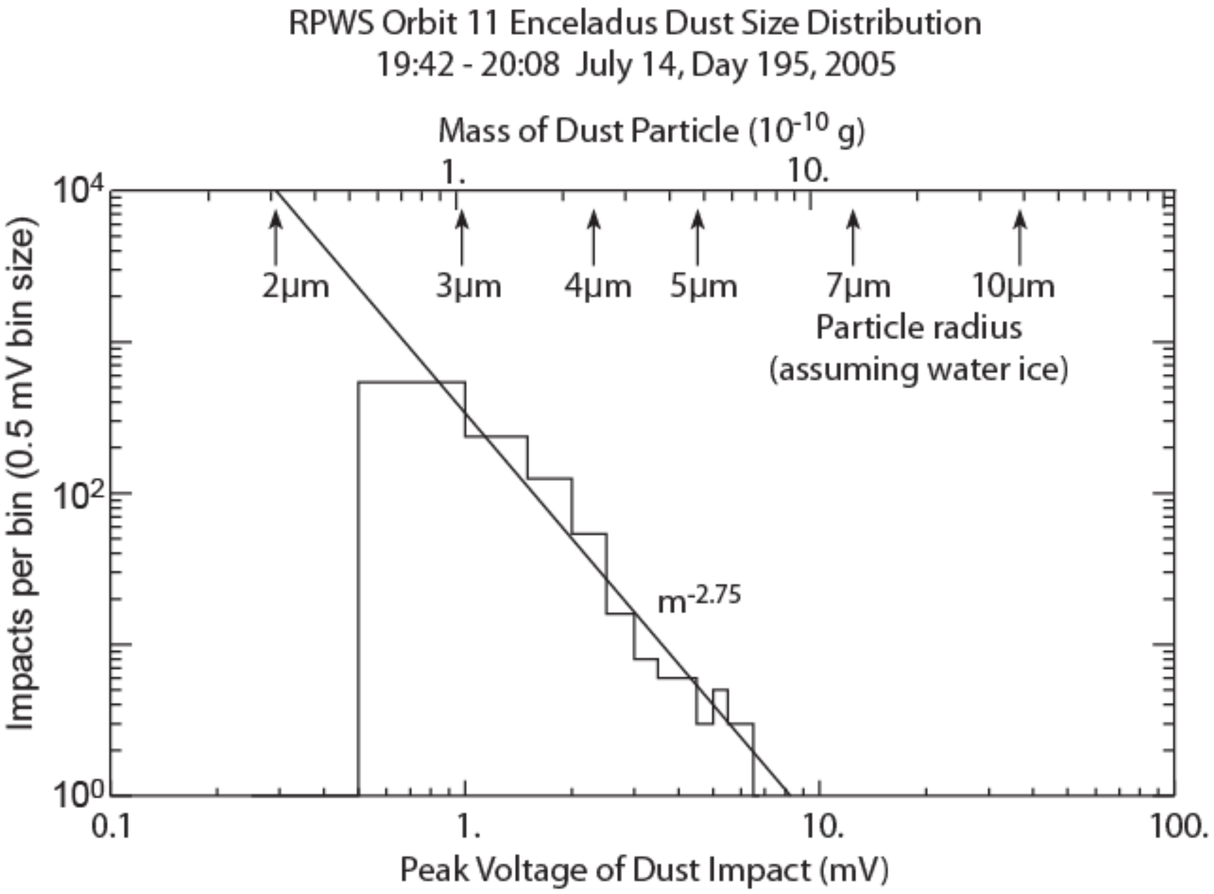
Richardson, 1995: ~10 eV

$\langle m_i \rangle$, water group ions

Dust impacts from E2 are reasonably fit with a Gaussian but with a strong outlier just before closest approach.



The size distribution from RPWS observations is similar to the distribution of E-ring particles.



Enceladus Dust Summary

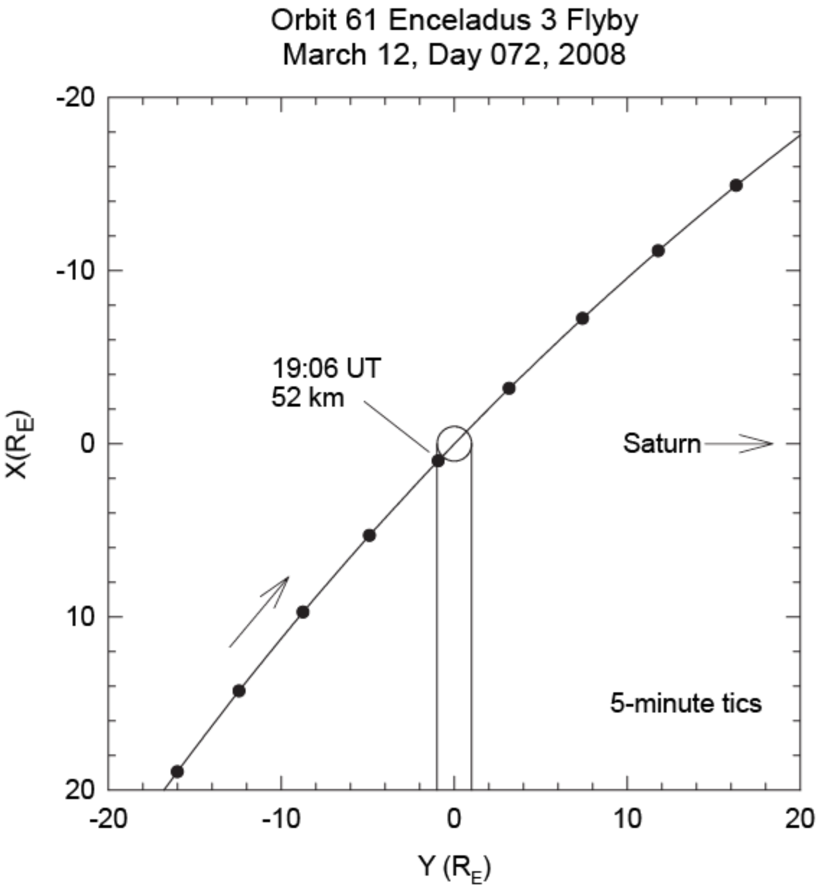
- RPWS is sensitive to ice particles of radius >2.4 microns in the E ring.
- Impact rates during the orbit 11 (E2) flyby are somewhat larger than other E ring crossings at Enceladus' orbit, by a factor of ~2.
- Size distributions in the peak of the E ring average $m^{-2.8}$ – the same is found during the E2 flyby, suggesting the plume particle size distribution is very similar to the main E ring.

RPWS Science Questions

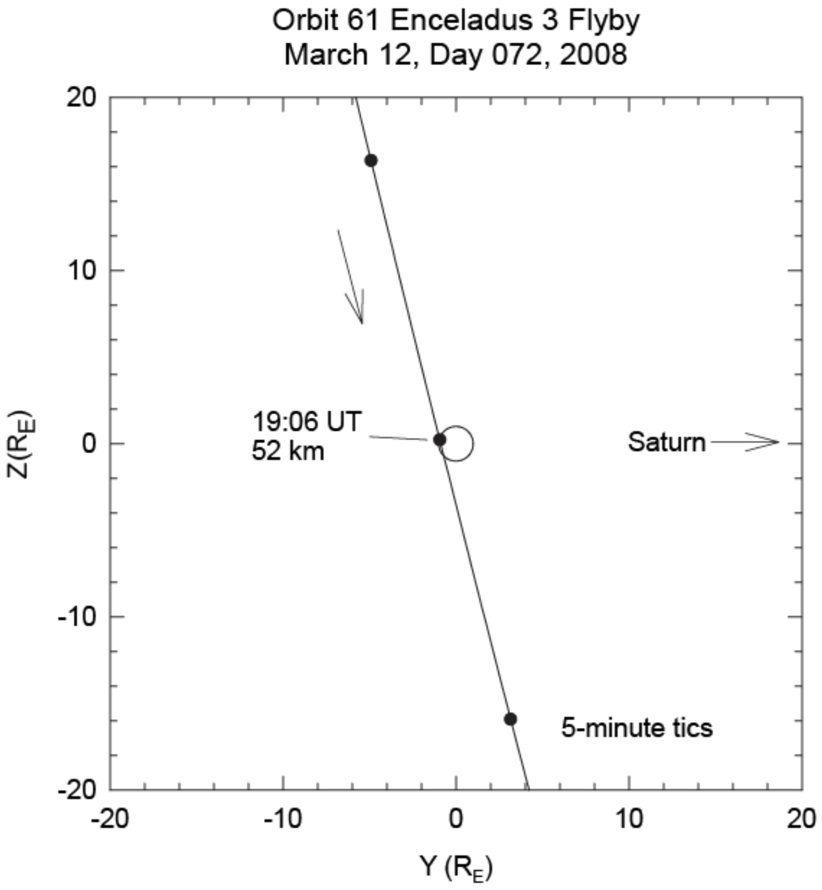
- Is there evidence for local ionization (other than charge exchange) in the plumes?
- What is the flux and size distribution of dust from the geysers?
- How does Enceladus interact with its magnetospheric environment?

RPWS Measurement Objectives

- Measure the thermal plasma environment
  - Electron density from the upper hybrid resonance frequency
  - Electron density and temperature from Langmuir probe measurements (along with other diagnostics)
- Measure plasma waves associated with the magnetospheric interaction with Enceladus
- Measure the flux of micron-sized particles associated with Enceladus and its geysers

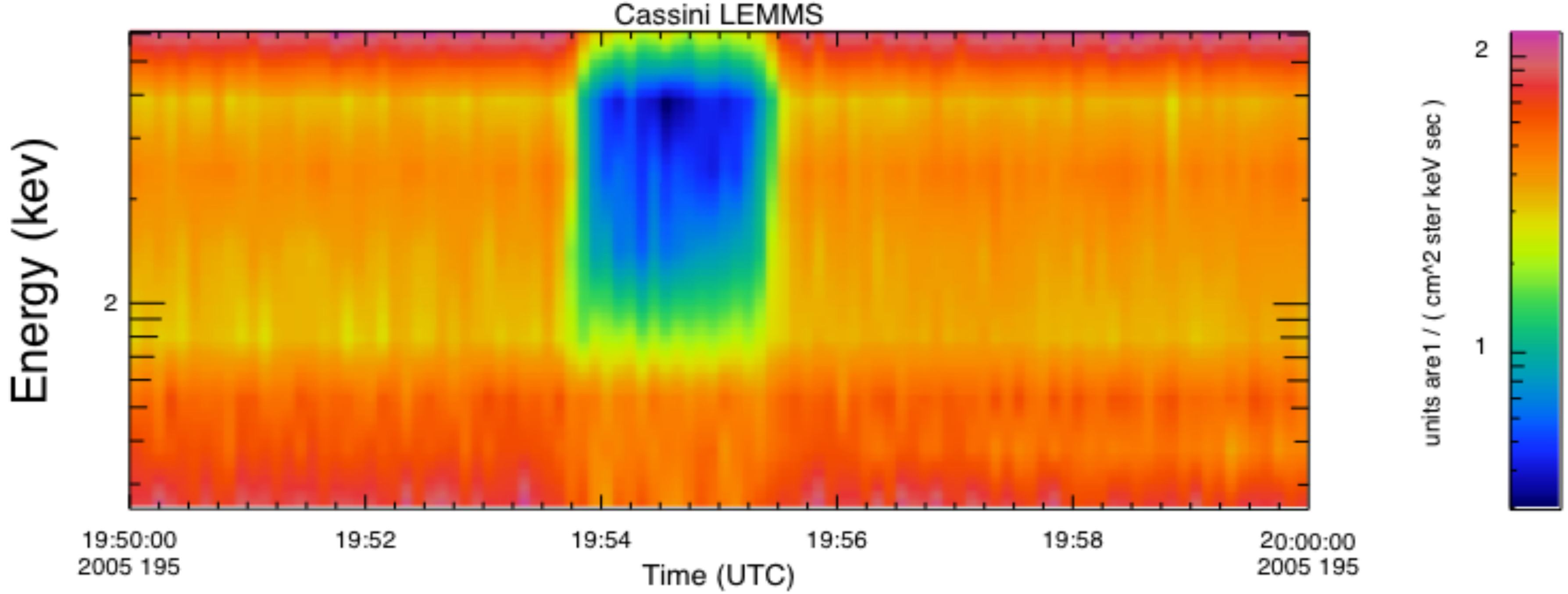


Orbit 61 Enceladus 3 Flyby
March 12, Day 072, 2008
19:06 UT
52 km
Saturn
5-minute tics
X(R_E)
Y (R_E)
-20
-10
0
10
20

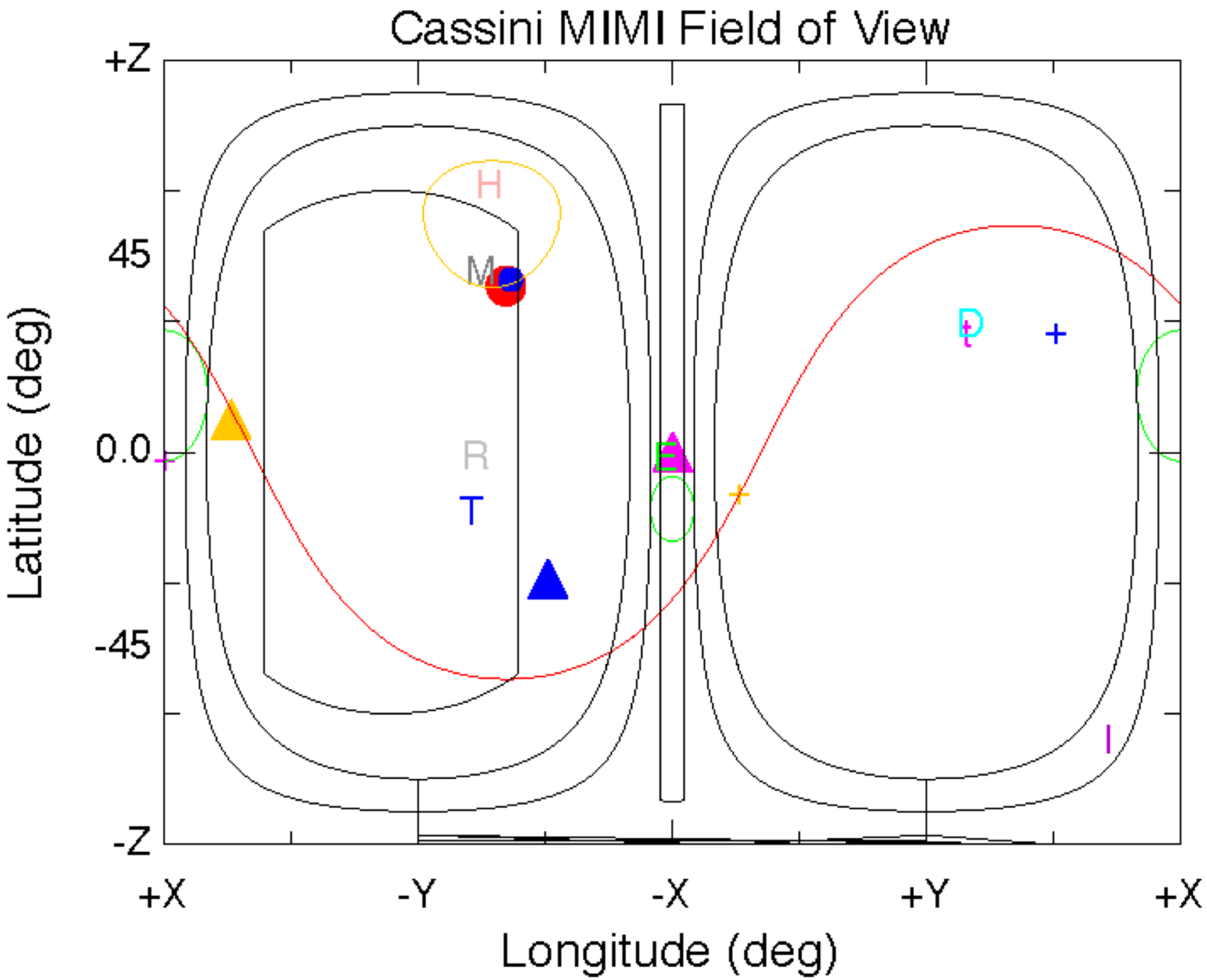


Orbit 61 Enceladus 3 Flyby
March 12, Day 072, 2008
19:06 UT
52 km
Saturn
5-minute tics
Z(R_E)
Y (R_E)
20
10
0
-10
-20

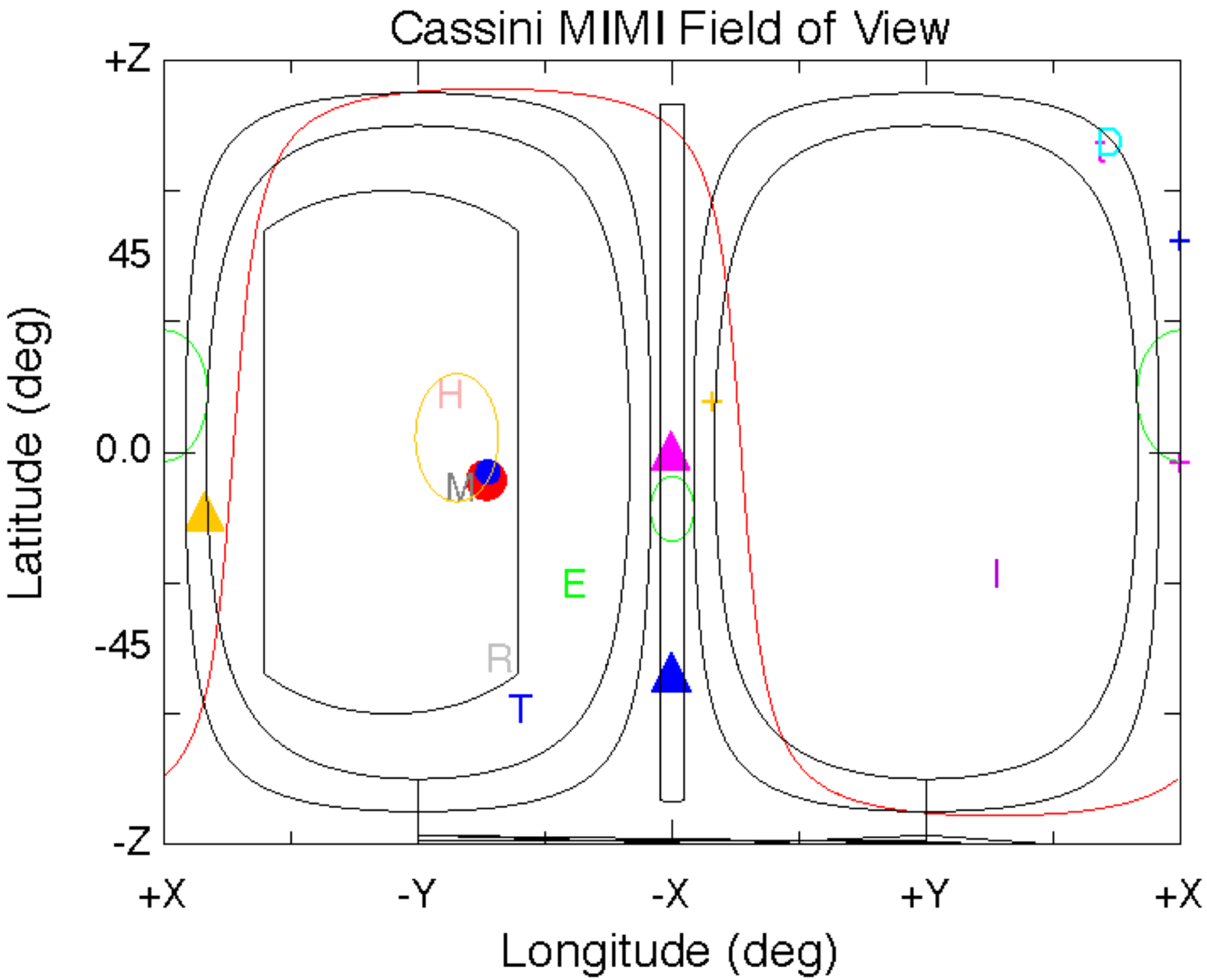
Electron Signature, upstream of flux tube, 011EN. The energy at which the absorption begins is a measure of the local convection velocity ,balanced by the electron gradient/curvature drift velocity



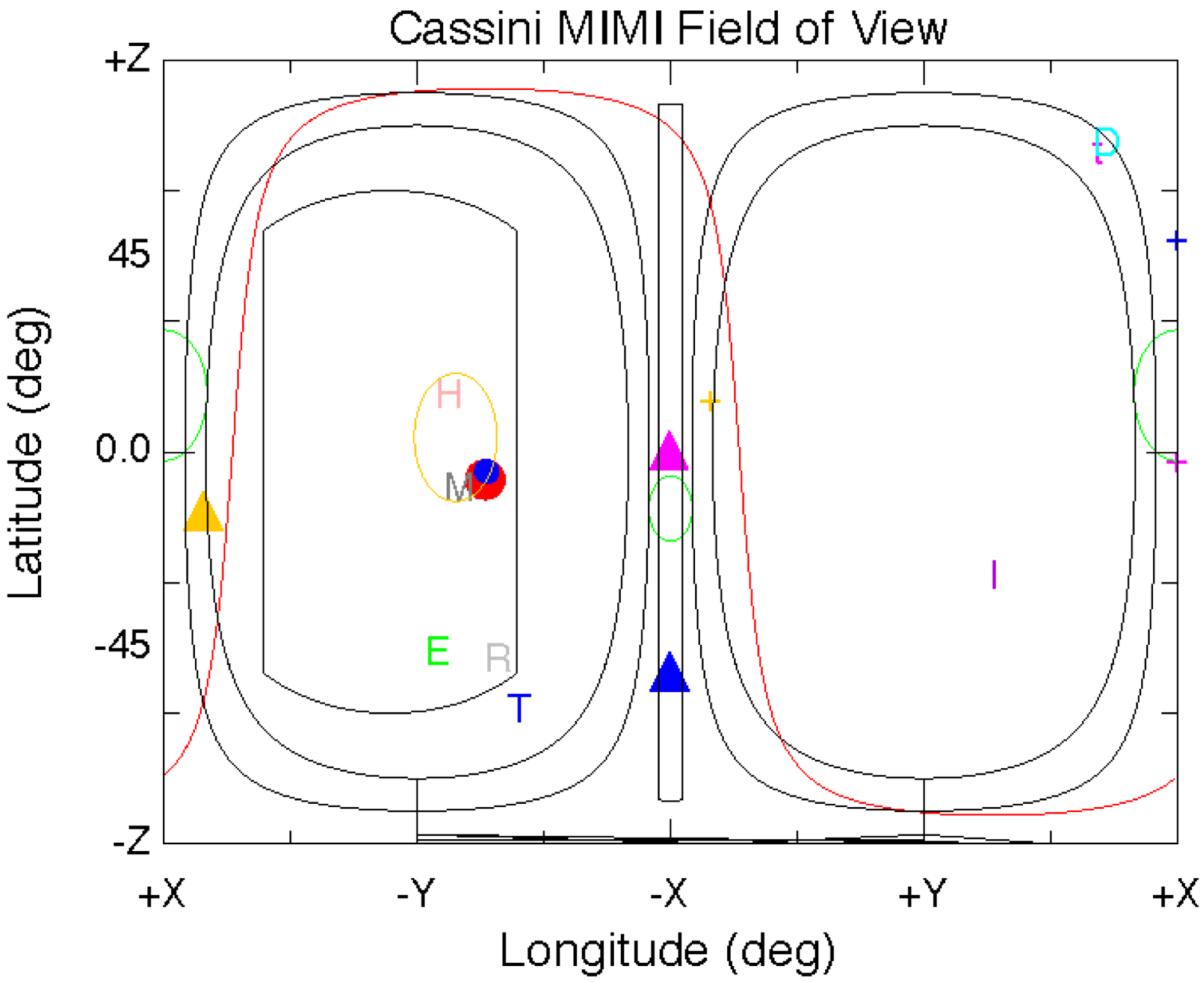
061EN will be on the wake side, downstream - a nice complement to 011EN, as the signature should be restricted to low energies. If the convection velocity is identical, the transition energy should also be identical.

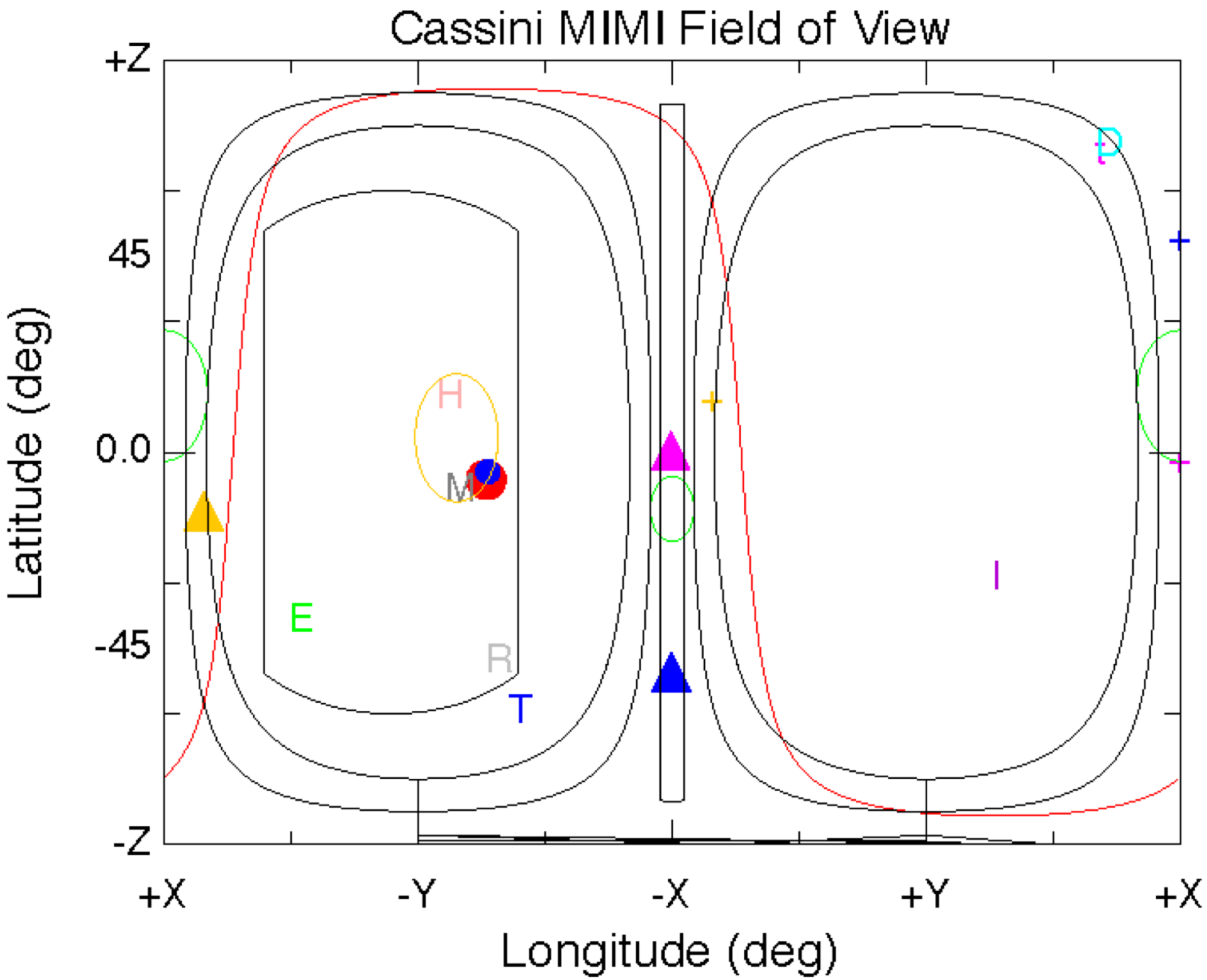


Cassini MIMI Field of View
+Z
45
0.0
-45
-Z
Latitude (deg)
+X
-Y
-X
+Y
+X
Longitude (deg)
H
M
R
T
D
I

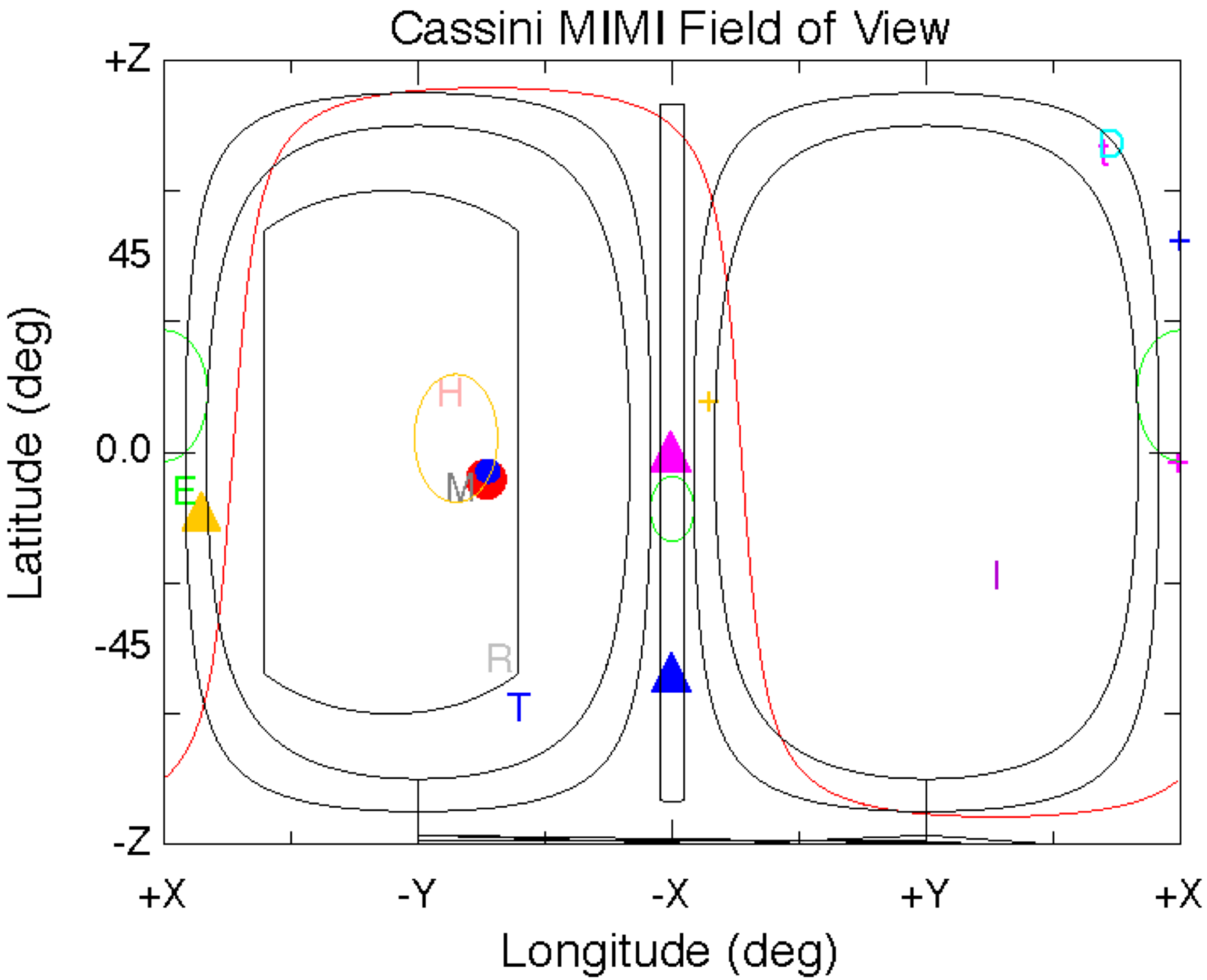


Cassini MIMI Field of View
+Z
45
0.0
-45
-Z
Latitude (deg)
+X
-Y
-X
+Y
+X
Longitude (deg)
H
M
E
R
T
I


Cassini MIMI Field of View
+Z
45
0.0
-45
-Z
Latitude (deg)
+X
-Y
-X
+Y
+X
Longitude (deg)
H
M
E
R
T
P
I



Cassini MIMI Field of View
+Z
45
0.0
-45
-Z
Latitude (deg)
+X
-Y
-X
+Y
+X
Longitude (deg)
H
M
E
R
T
P
I



Cassini MIMI Field of View
+Z
45
0.0
-45
-Z
Latitude (deg)
+X
-Y
-X
+Y
+X
Longitude (deg)
H
M
E
R
T
I

Rev. 61 Enceladus: CIRS Preview

John Spencer, John Pearl, Marcia Segura, and the CIRS team

SOST, February 22nd 2007

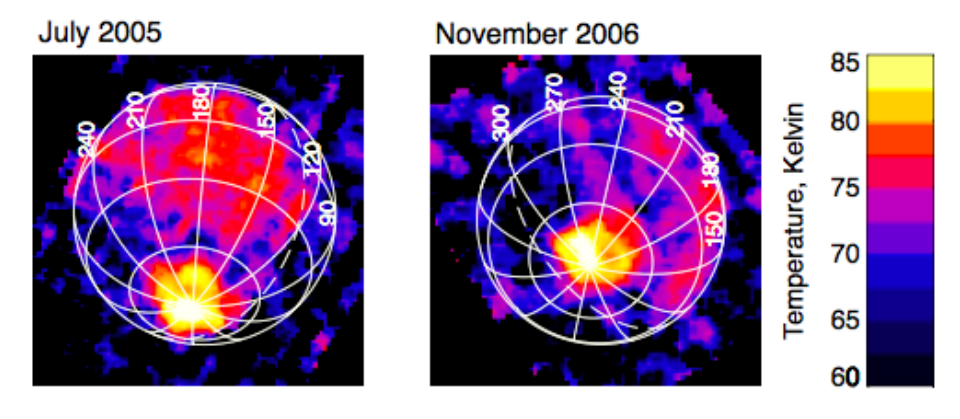
Rev. 61 Enceladus: CIRS Preview

John Spencer, John Pearl, Marcia Segura, and the CIRS team

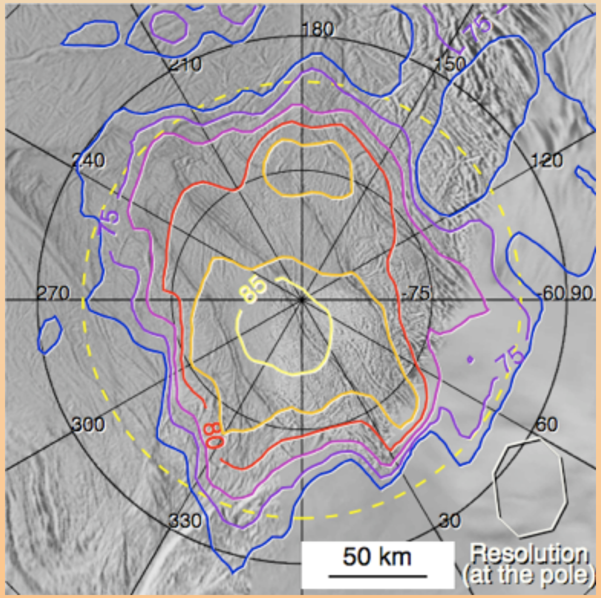
SOST, February 22nd 2007

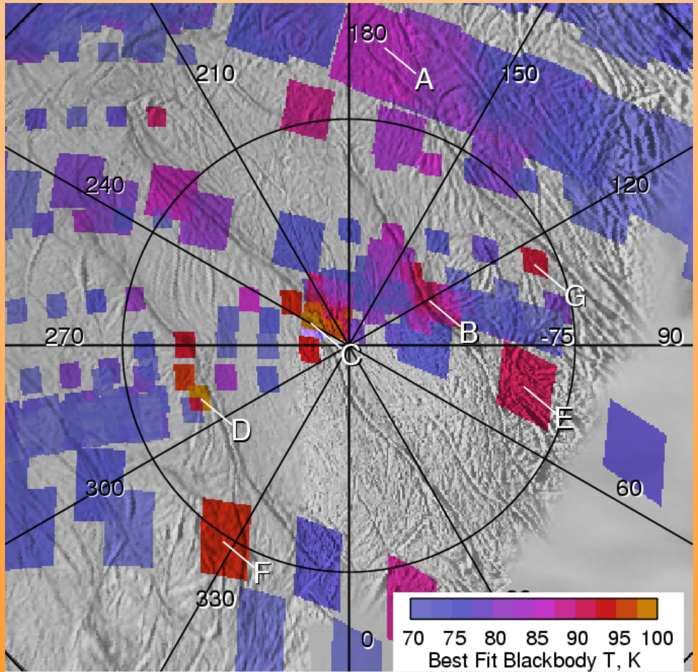
Previous Enceladus South Polar Observations

- Rev. 11 Global FP3 map
  – Spatial resolution 23 x 32 km
- Similar map on Rev. 32
  – Spatial resolution 32 x 35 km



- Scattered ridealong FP3 observations
  – Spatial resolution ≥ 6km
- No useful FP1 (long wavelength) south polar observations





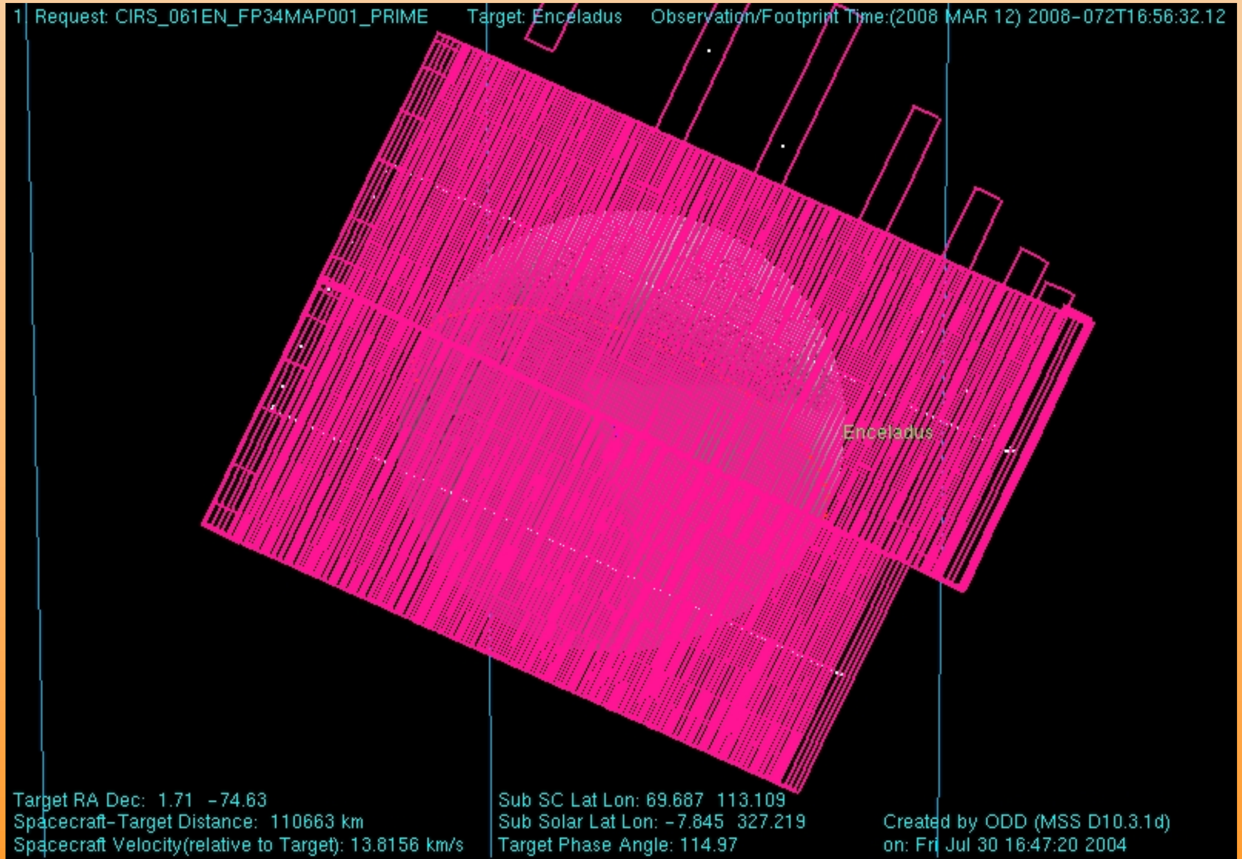
Goals for Rev. 61

In rough order of decreasing importance

- Contiguous FP3 (10 - 16 μm) maps of tiger stripes at 3x - 5x improved spatial resolution (4 - 10 km)
  - Map sources of endogenic heat, pathfind future observations
- 6-minute FP3 integration on a known hot spot ("C")
  - Improved temperature constraints, constrain plume source mechanisms
- FP1 (16 - 500 μm) spectroscopy of south polar region and surroundings in eclipse
  - Constrain total heat flow for geophysical models
- FP1 eclipse egress observation
  - Thermophysical properties (helps to constrain heat flow)
- FP1 northern hemisphere approach map
  - Thermophysical properties (helps to constrain heat flow)
- FP3 search for northern hemisphere hot spots on approach
  - Understand global distribution of geological activity

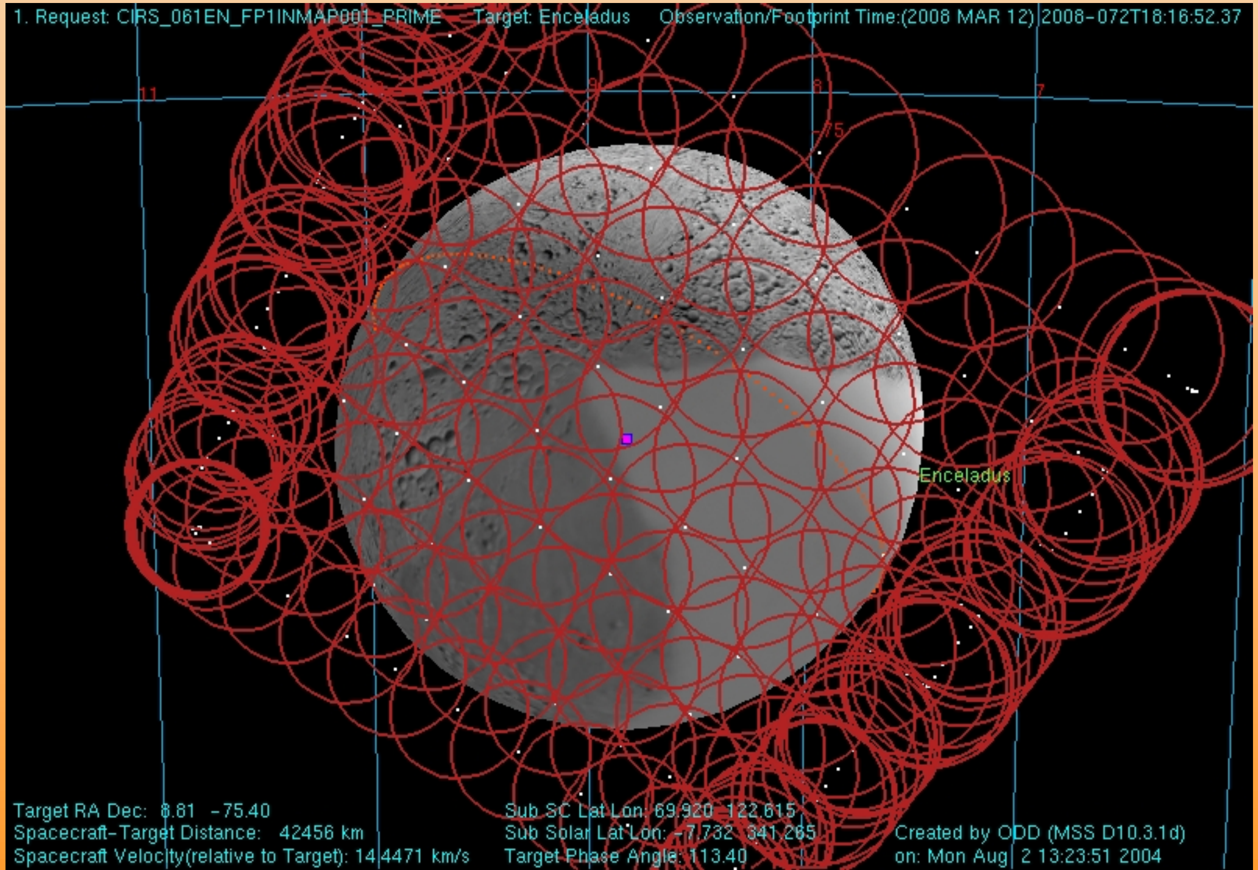
CIRS_061EN_FP34MAP001

- C/A-02:30 → C/A-01:53 (16:36 - 17:13)
- Scan northern hemisphere with FP3, FP4 for
  - Endogenic hot spots
  - Passive thermal emission



CIRS_061EN_FP1INMAP001

- C/A-00:59 → C/A-00:41 (18:07 - 18:25)
- Map northern hemisphere with FP1 for thermophysical properties (bolometric albedo, thermal inertia)

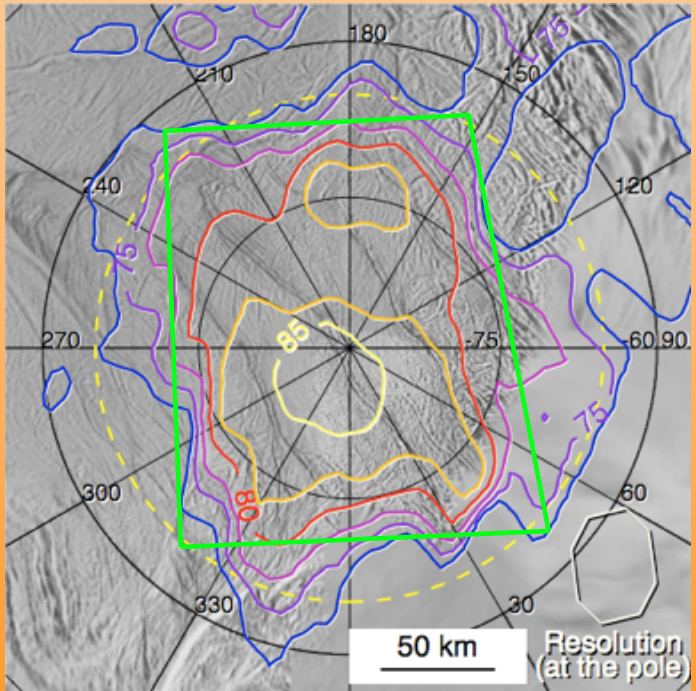


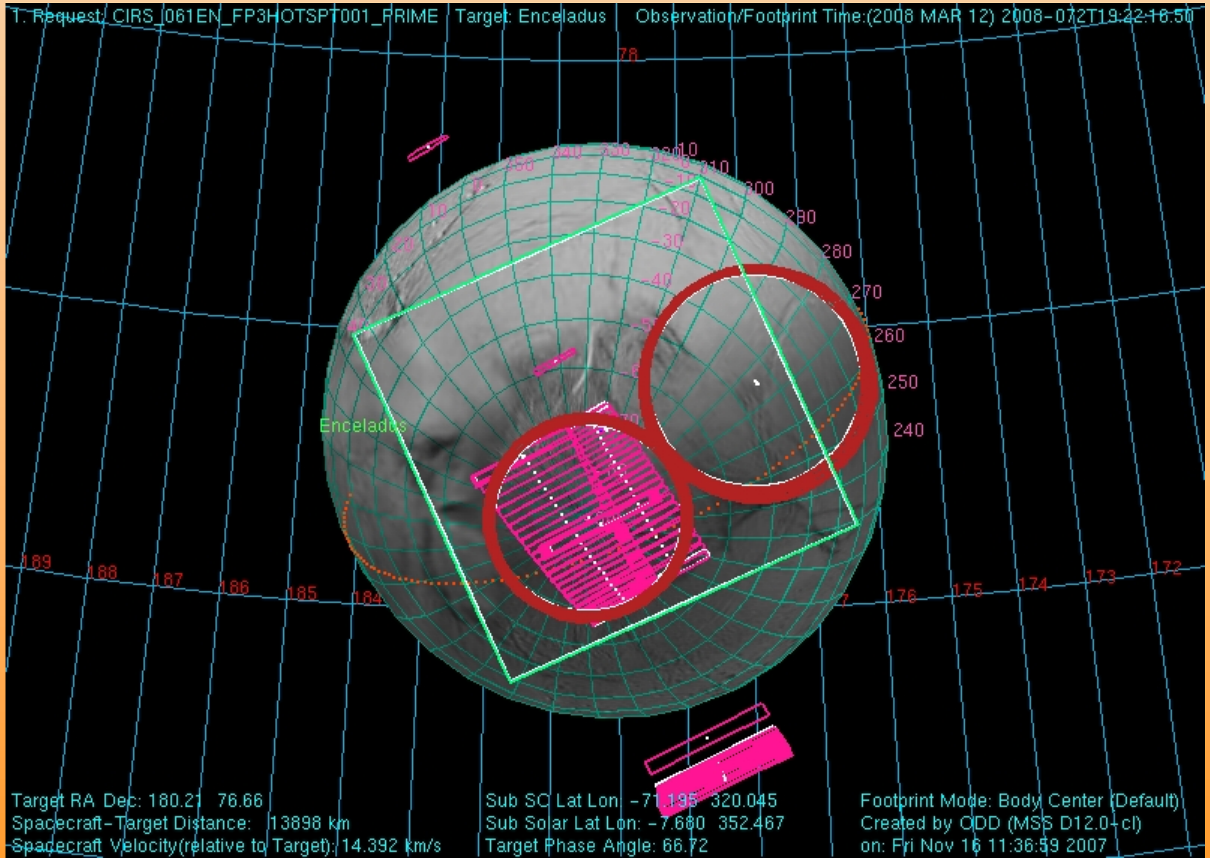
CIRS_061EN_FP3HOTSPT001, start

Saturn eclipse helps eliminate radiation from passively-heated regions

- 19:11:12, +00:05:00 Begin turn from MAPS C/A attitude
- 19:21:37, +00:15:25 Complete turn, with FP3 at 330 W, 70 S
- 19:22:12, +00:16:00 Begin FP3 tiger stripe map (range 13,831 km, FP3 resn. 4.1 km)
- 19:43:25, +00:37:13 End FP3 tiger stripe map (range 32,110, FP3 resn. 9.6 km)

FP3 coverage, compared to Rev. 11 map

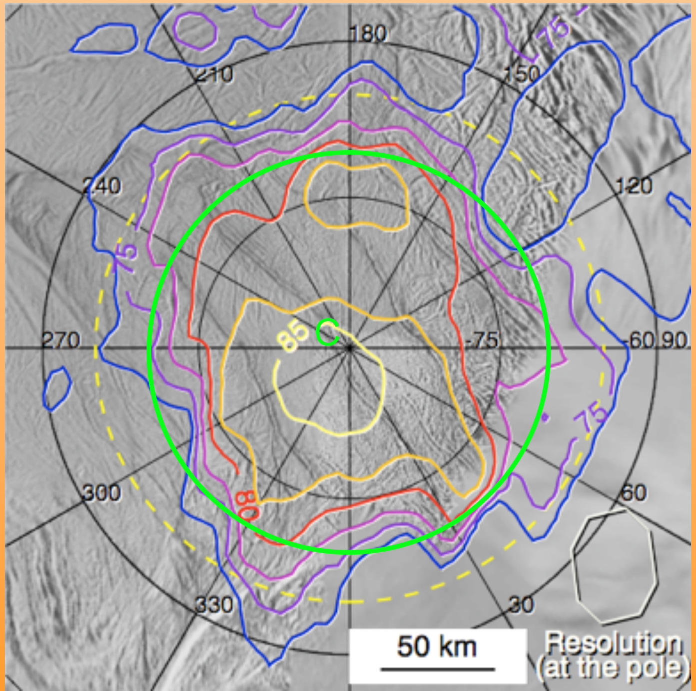


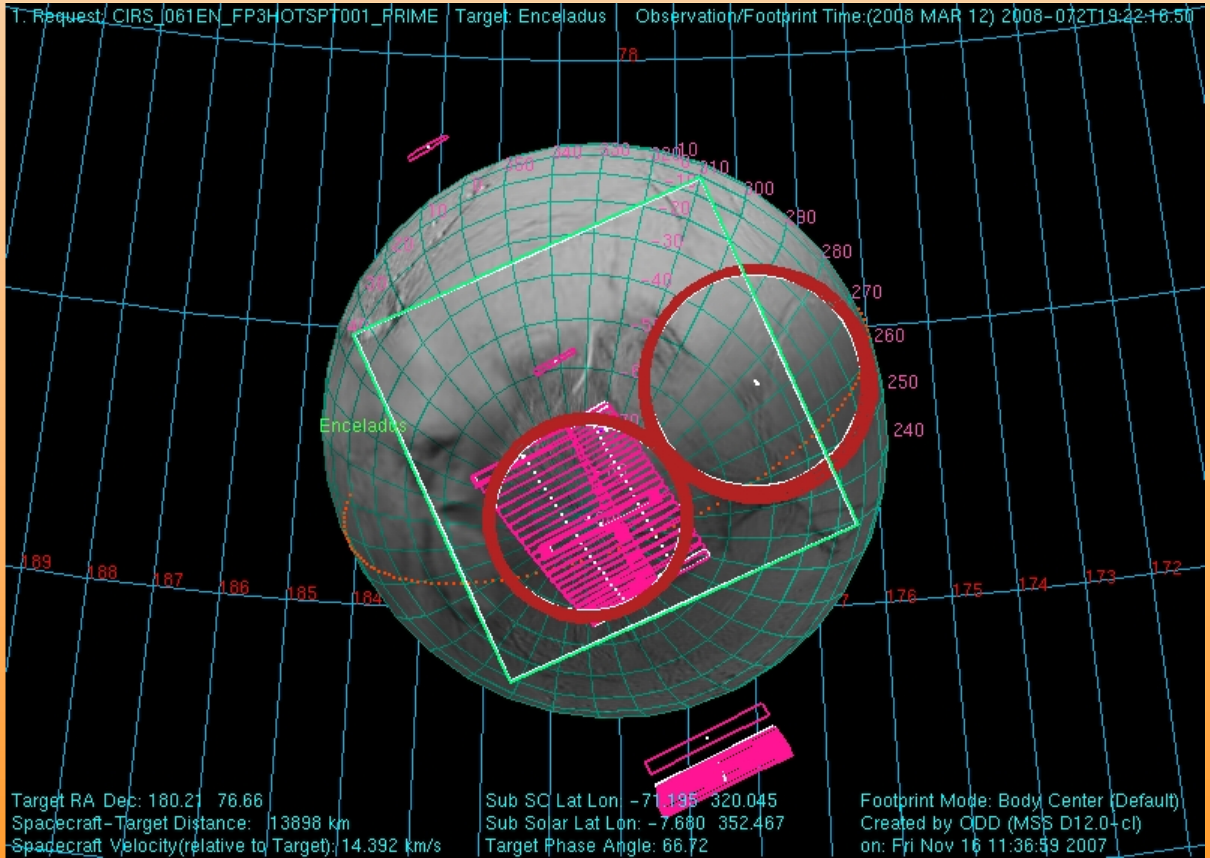


CIRS_061EN_FP3HOTSPT001, Contd.

- 19:44:10, +00:37:58 Begin FP3 stare at plume source “VI”, hot spot “C” (87 S, 236 W). (range 32,754 km, FP3 resn. 9.8 km)
- 19:50:26, +00:44:14 Offset FP1, FP3, to sky for calibration
- 19:55:36, +00:49:24 Begin FP1 stare at south pole, for long-wavelength heat flow
- 20:02:32, +00:56:20 Begin FP1 stare at 44 S, 285 W, for passive subtraction
- 20:09:08, +01:02:56 End observation

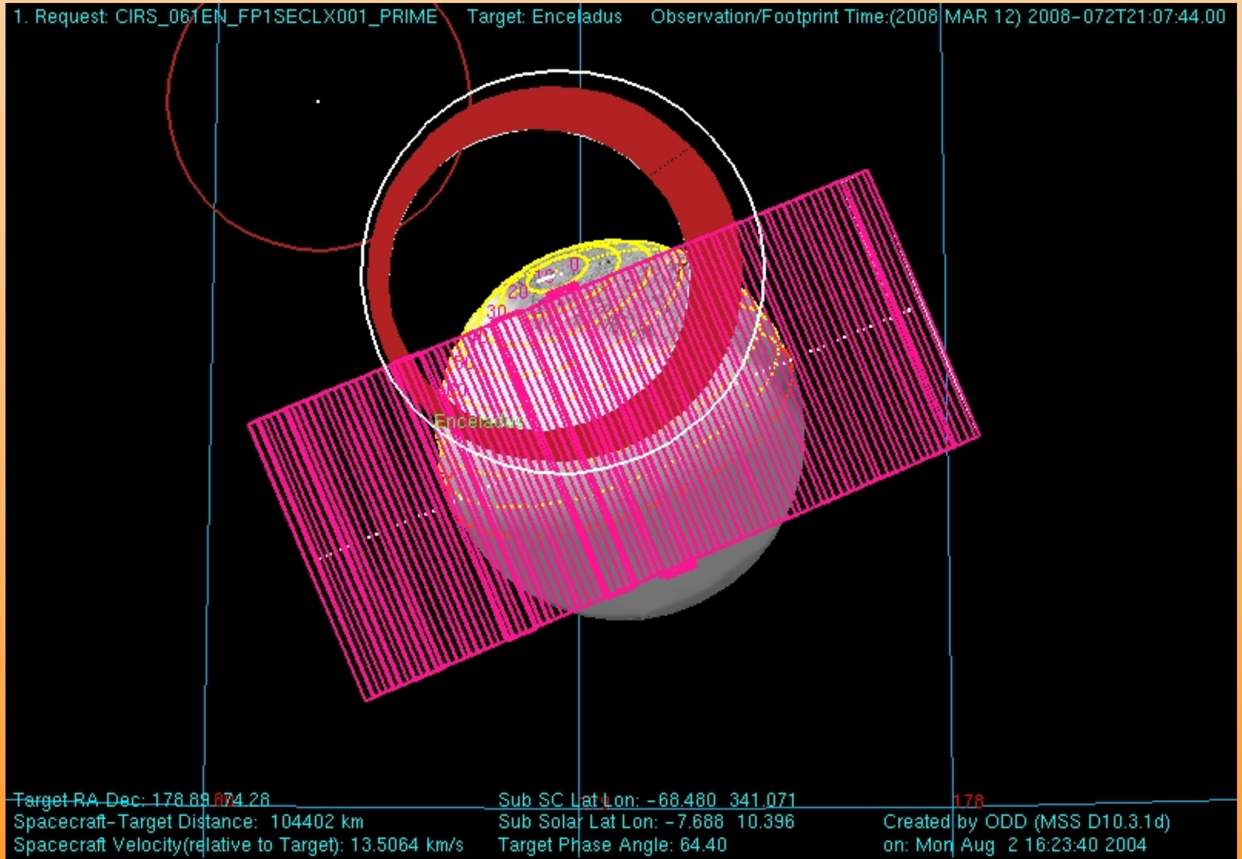
Spot “C” location, FP1 south polar FOV





CIRS_061EN_FPSECLX001

- C/A+01:48 → C/A-02:55 (20:54 - 22:01)
- FP1 stare at eclipse reappearance (at 21:18) for thermophysical properties
- FP3 scan of the south polar region



REV 61 ENCELADUS ISS OBSERVATIONS

Paul Helfenstein
Cornell University
February 22, 2008

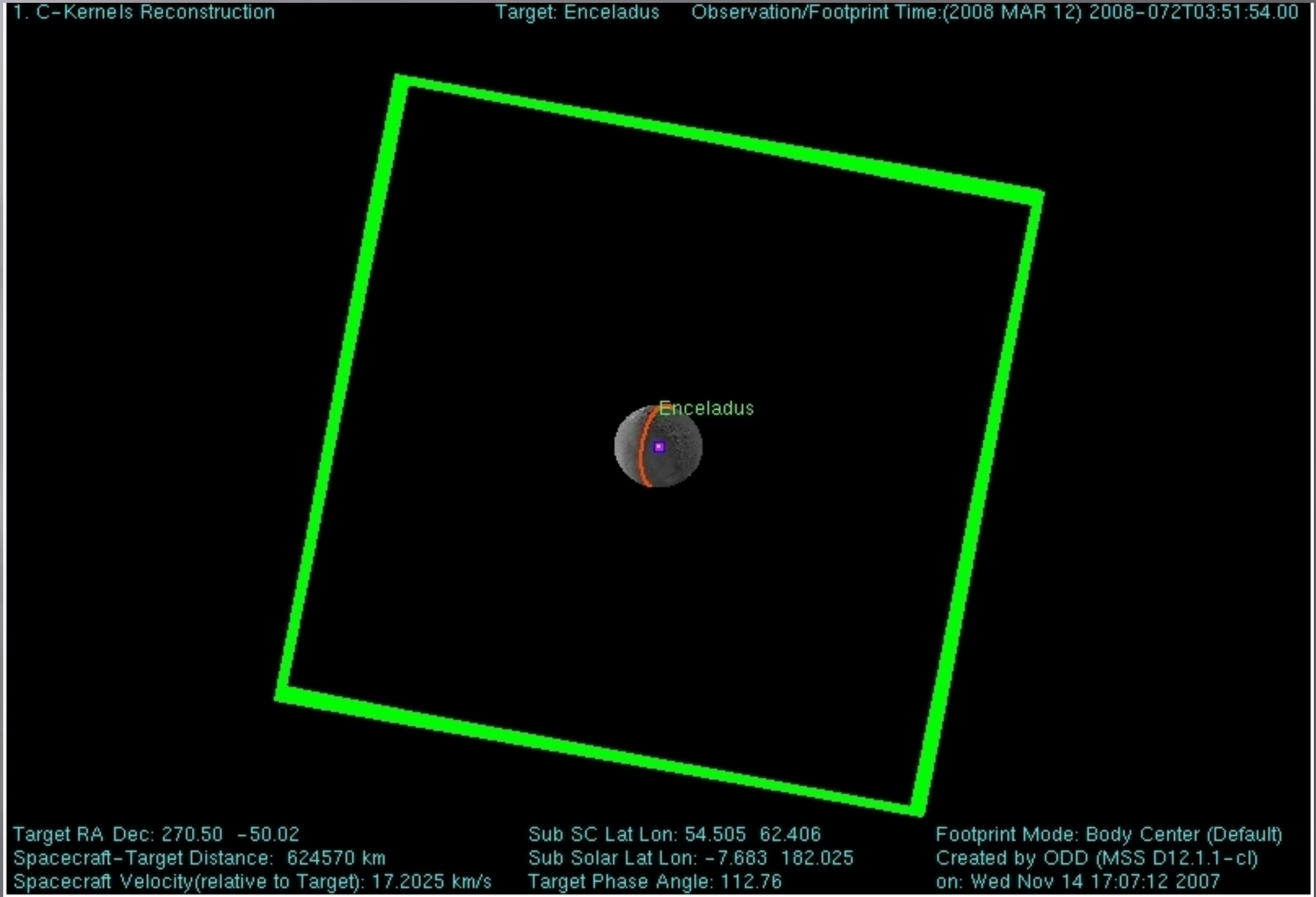
OBSERVATION TYPES

- Pre-Flyby North Polar Imaging
  - Low-resolution "whole-disk" imaging for spectrophotometry and polarization mapping
  - One ISS Prime 3-Panel mosaic of North Polar region
- Just after Closest Approach
  - Experimental imaging of tiger stripes during eclipse to search for any possible luminescence
- Post-Flyby "Voyager-Class" imaging of South Polar region

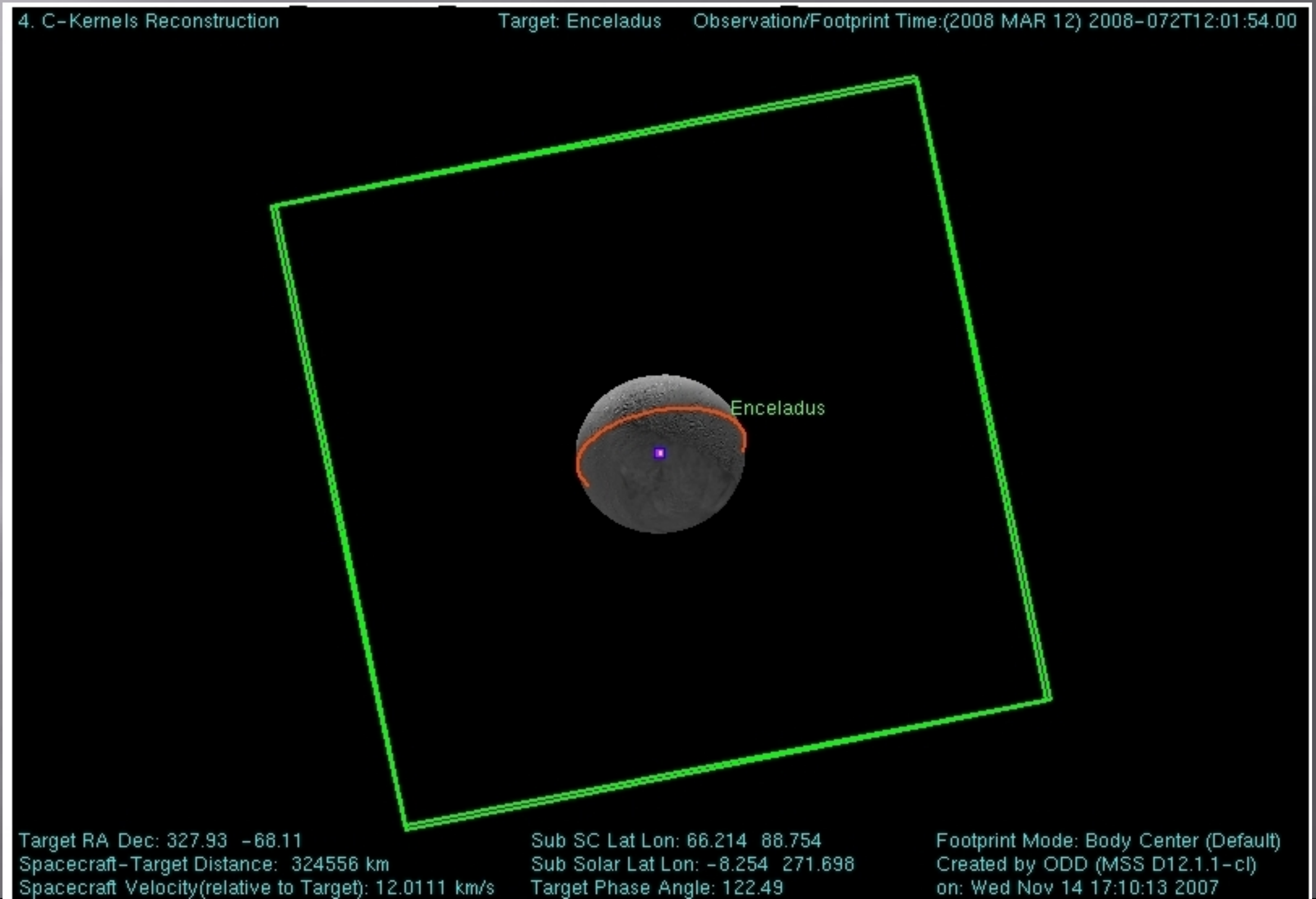
List of ISS Requests

ObsReqID	StartT	Duration
ISS_061EN_ENCELADUS001_VIMS	2008-072T03:31:12	000T08:55:00
ISS_061EN_PHOTPOL001_PRIME	2008-072T12:26:12	000T02:10:00
ISS_061EN_FP34MAP001_CIRS	2008-072T16:36:12	000T00:37:00
ISS_061EN_ENCELADUS002_VIMS	2008-072T17:13:12	000T00:27:00
ISS_061EN_ICYMAP002_UVIS	2008-072T17:40:12	000T00:27:00
ISS_061EN_REGMAP002_PRIME	2008-072T18:25:12	000T00:19:30
ISS_061EN_FP3HOTSPT001_CIRS	2008-072T19:11:12	000T00:59:00
ISS_061EN_FP1SECLX001_CIRS	2008-072T20:54:12	000T01:07:00
ISS_061EN_ICYLON006_UVIS	2008-072T22:01:12	000T02:13:00

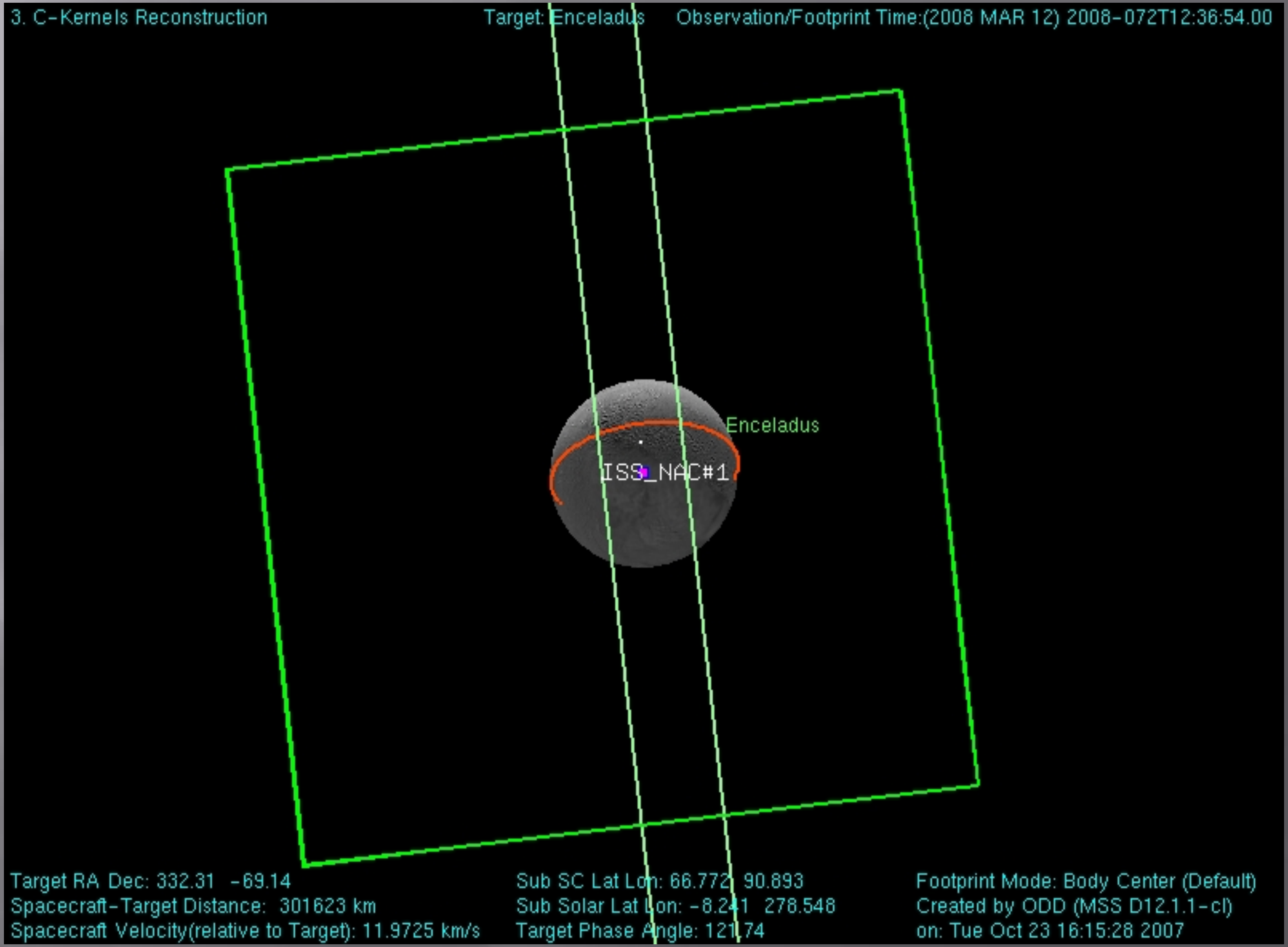
ISS_061EN_ENCELADUS001_VIMS



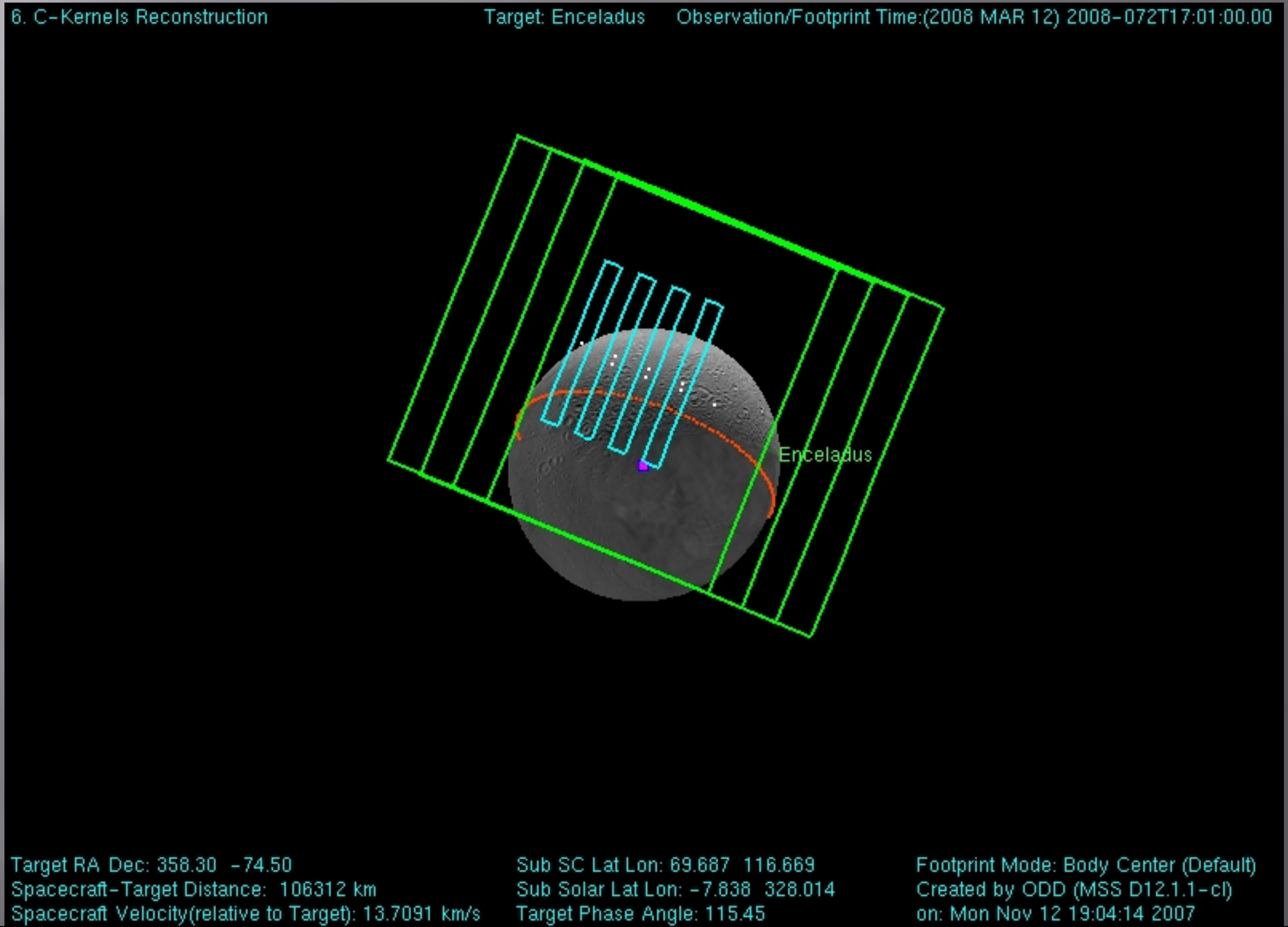
ISS_061EN_ENCELADUS001_VIMS



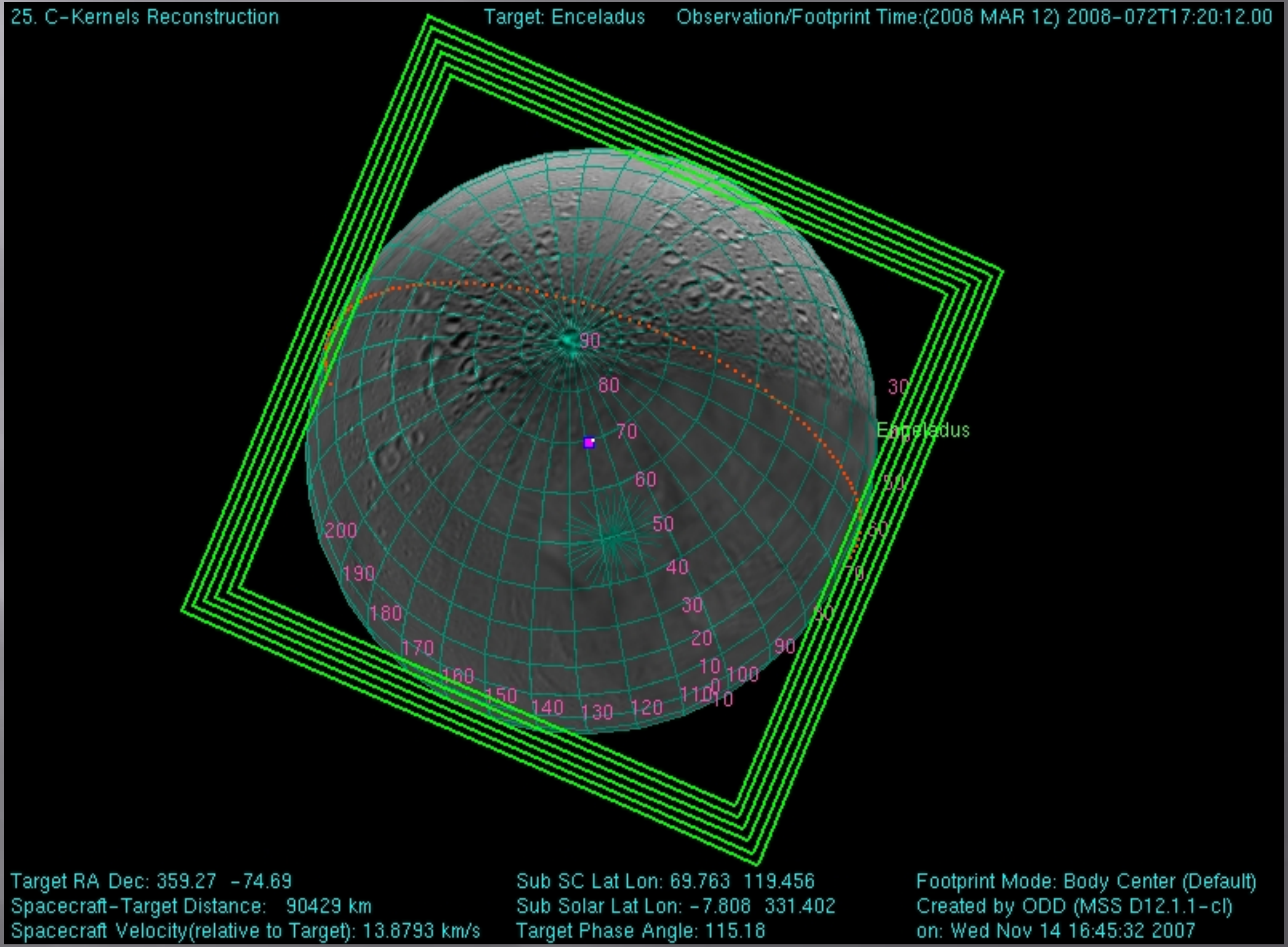
ISS_061EN_PHOTPOL001_PRIME



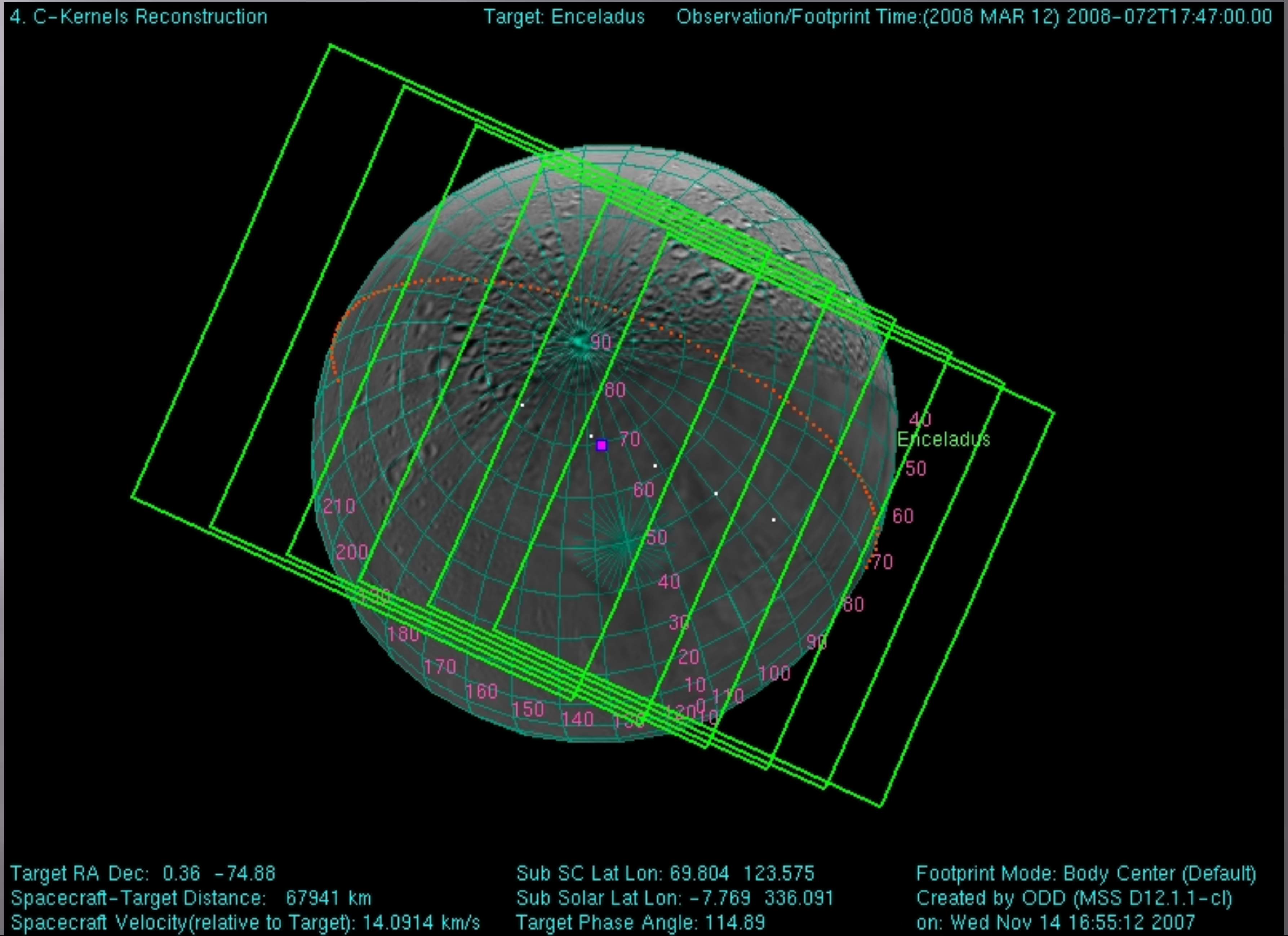
ISS_061EN_FP34MAP001_CIRS



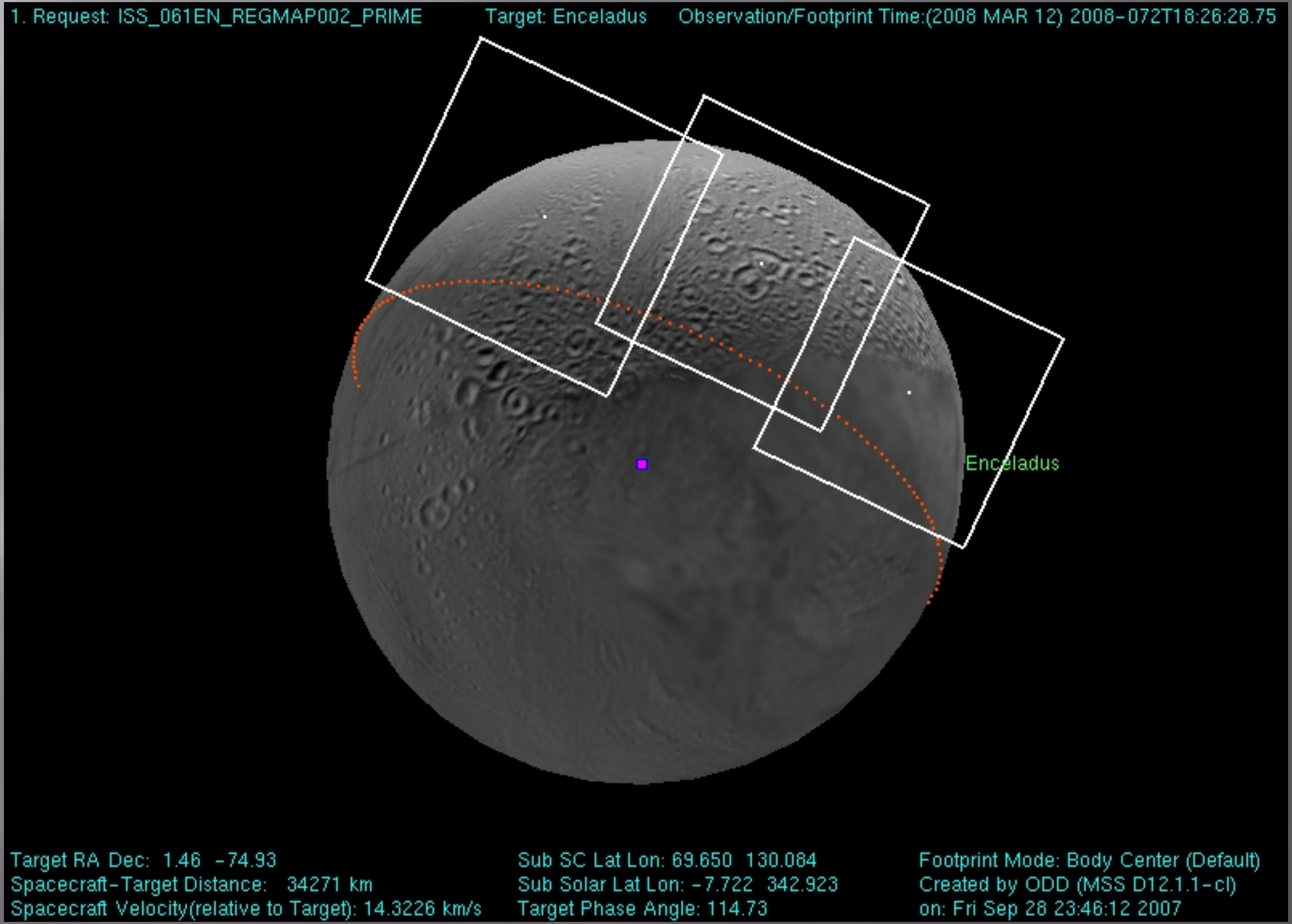
ISS_061EN_ENCELADUS002_VIMS



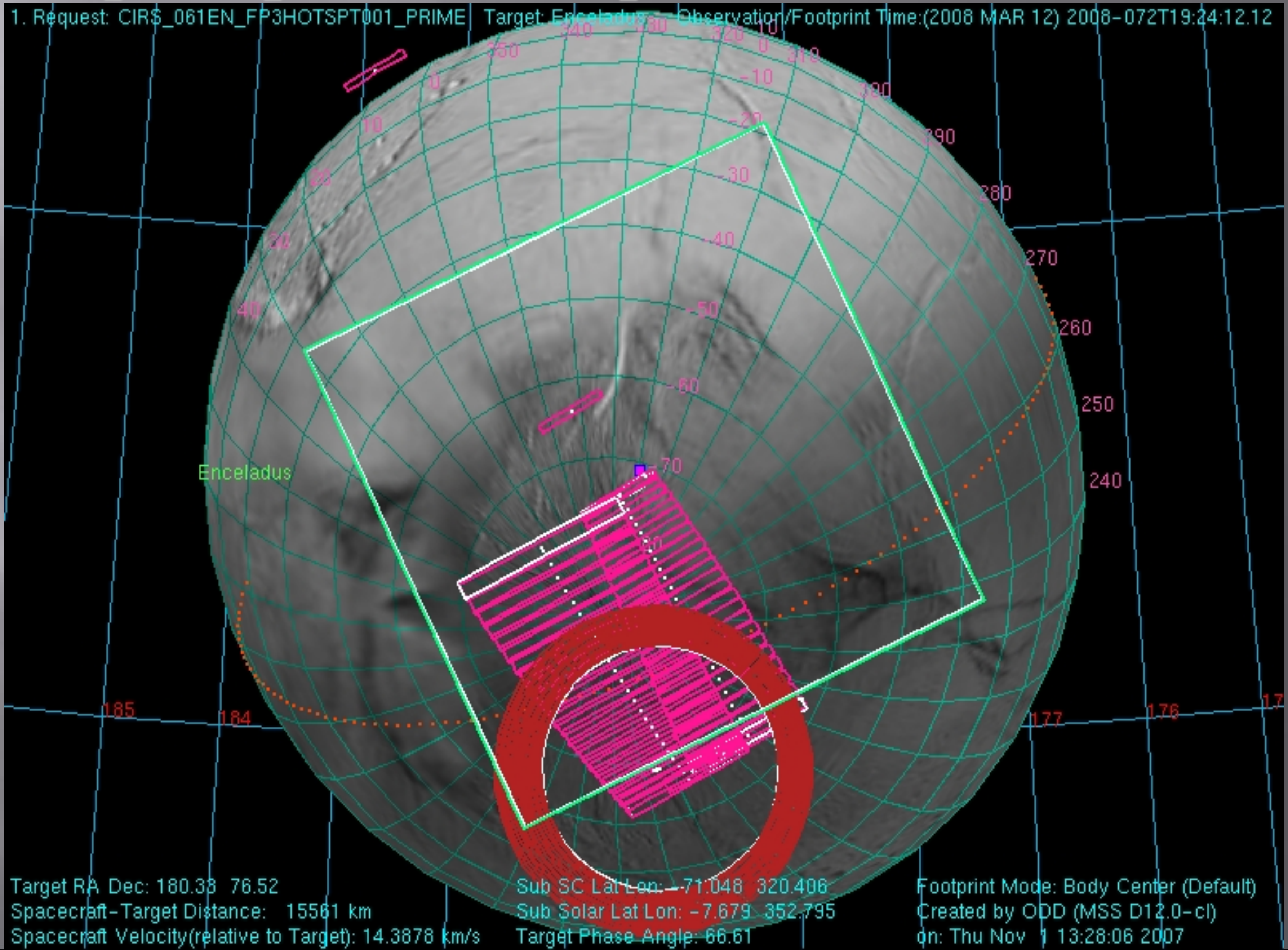
ISS_061EN_ICYMAP002_UVIS



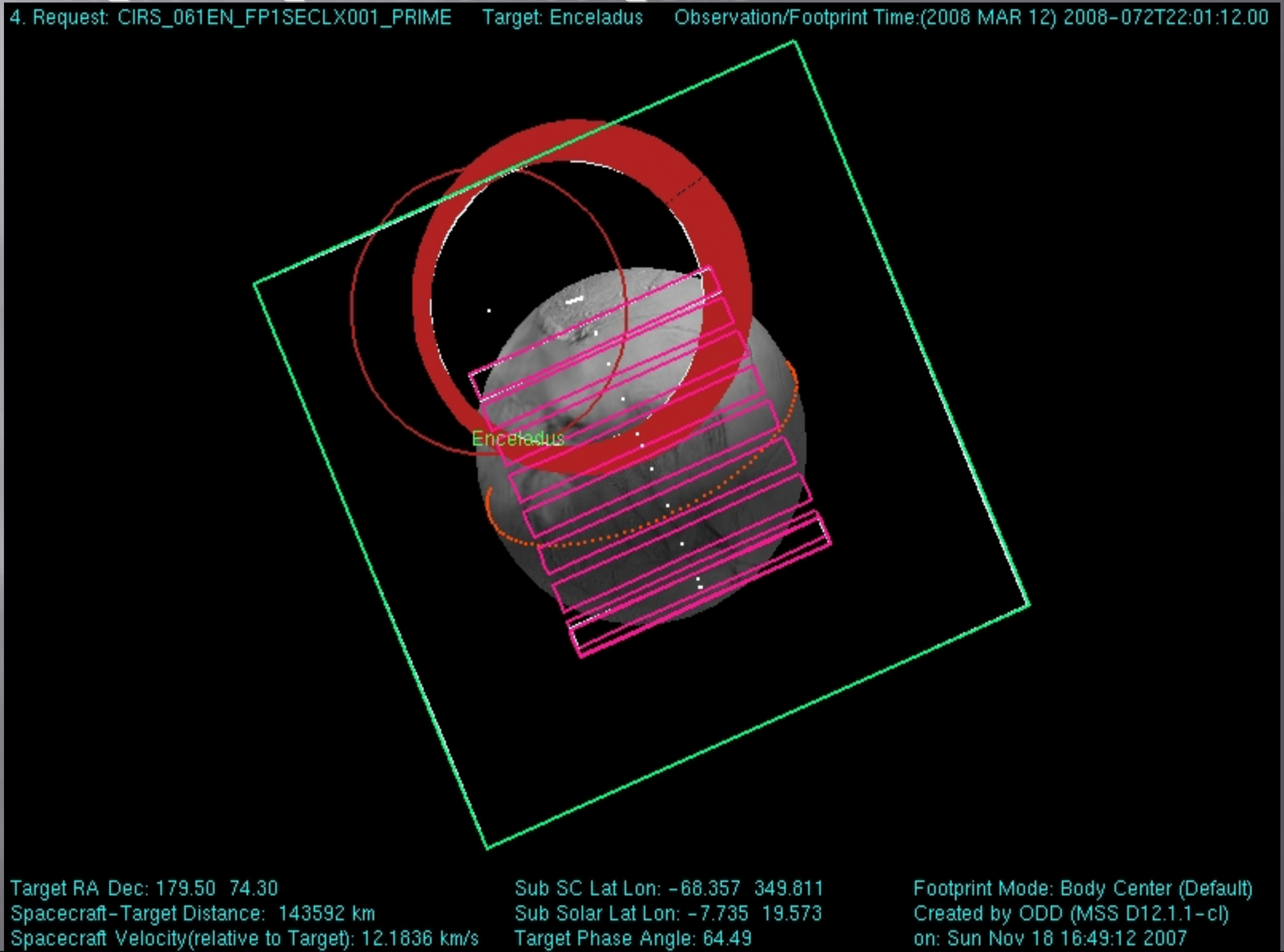
ISS_061EN_REGMAP001_PRIME



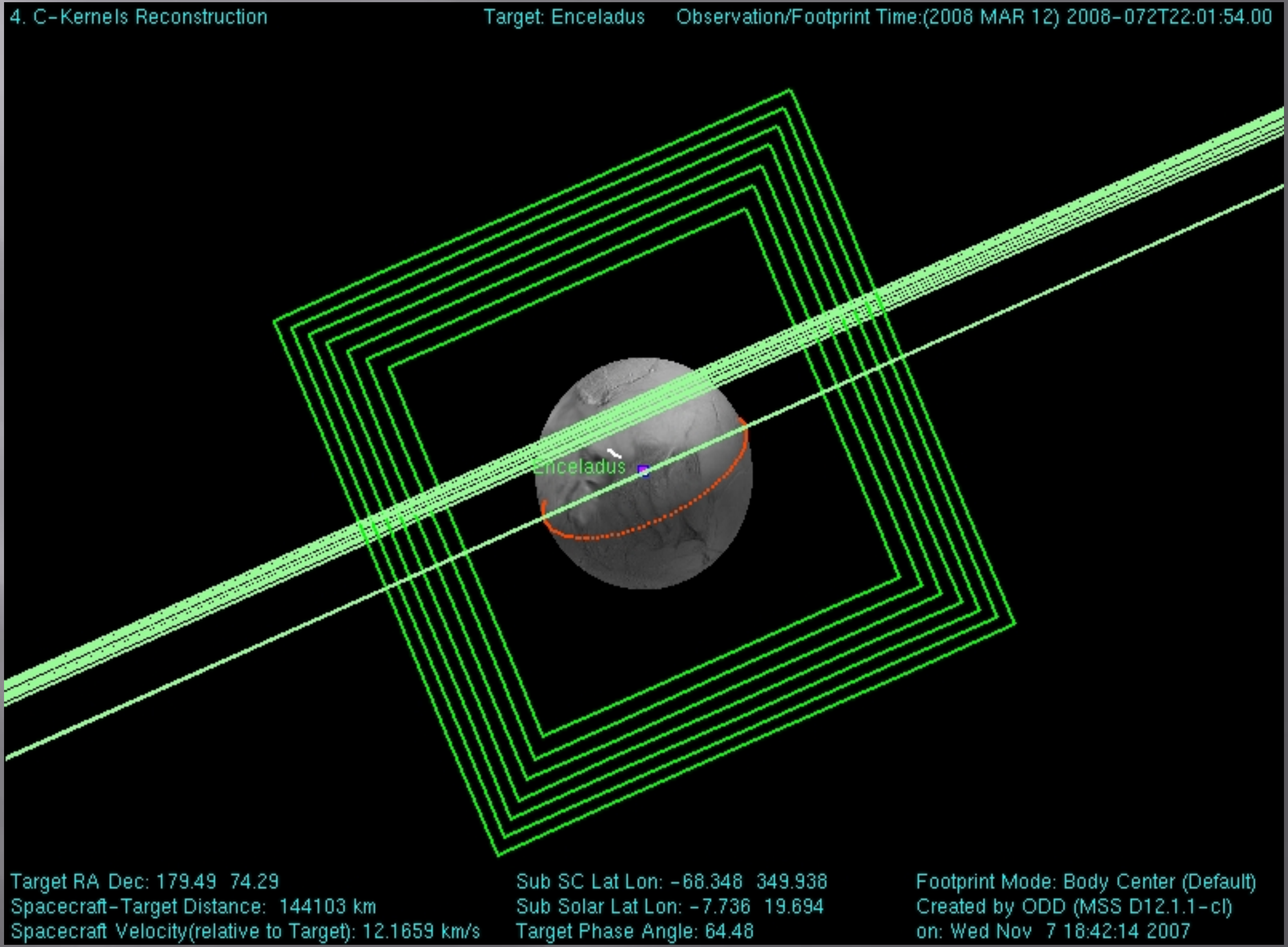
ISS_061EN_FP3HOTSPT001_CIRS



ISS_061EN_FP1SECLX001_CIRS



ISS_061EN_ICYLON006_UVIS



Enceladus 61: Preview of Cassini RADAR Observations

Steve Ostro

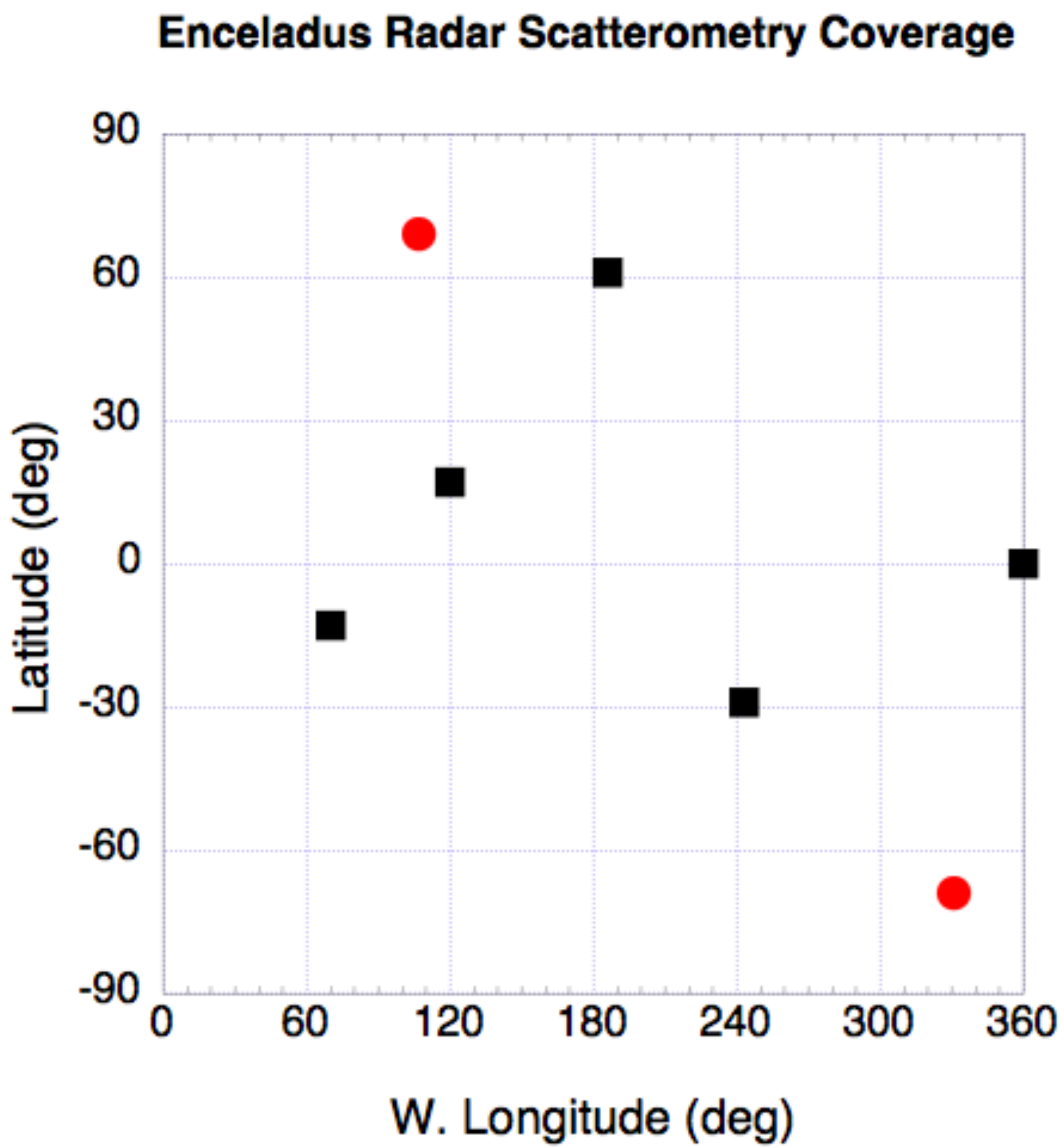
(for the Cassini RADAR Science and Instrument Operations Teams)

JPL, Feb. 22, 2008

The RADAR Instrument

- Wavelength: 2.2 cm
- Polarization: same linear as transmitted (SL)

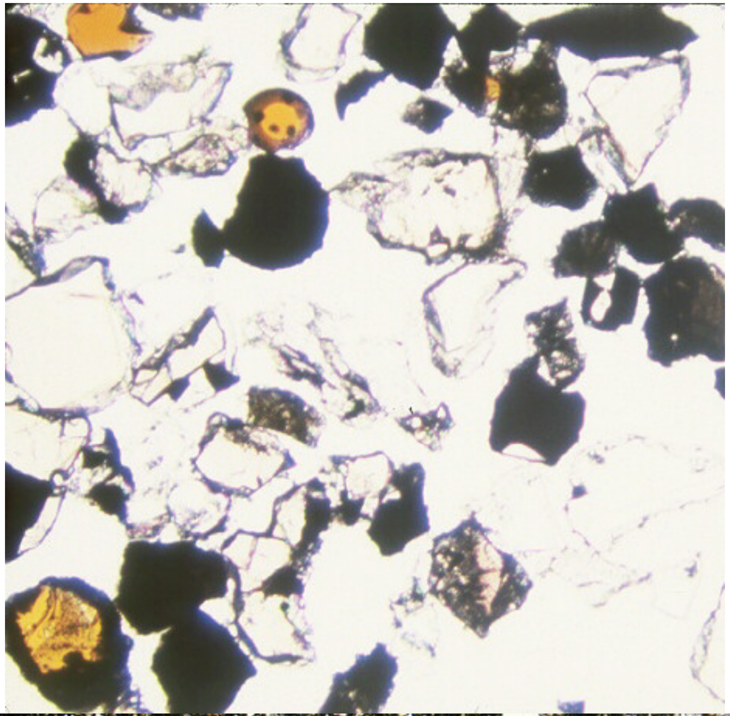
		Lat	W.Lon	Min Beam Size	Min Range (km)	Radar Albedo
EN	3	0°	360°	2.1	165480	1.09
EN	4	-13°	70°	1.1	83059	1.41
EN	28	61°	186°	2.1	162678	1.50
EN	32	-29°	243°	1.2	90772	1.59
EN	50	17°	120°	1.5	119321	1.61
ENC	61 in	69°	108°	1.5	126266	?
ENC	61 out	-70°	331°	0.9	69869	?

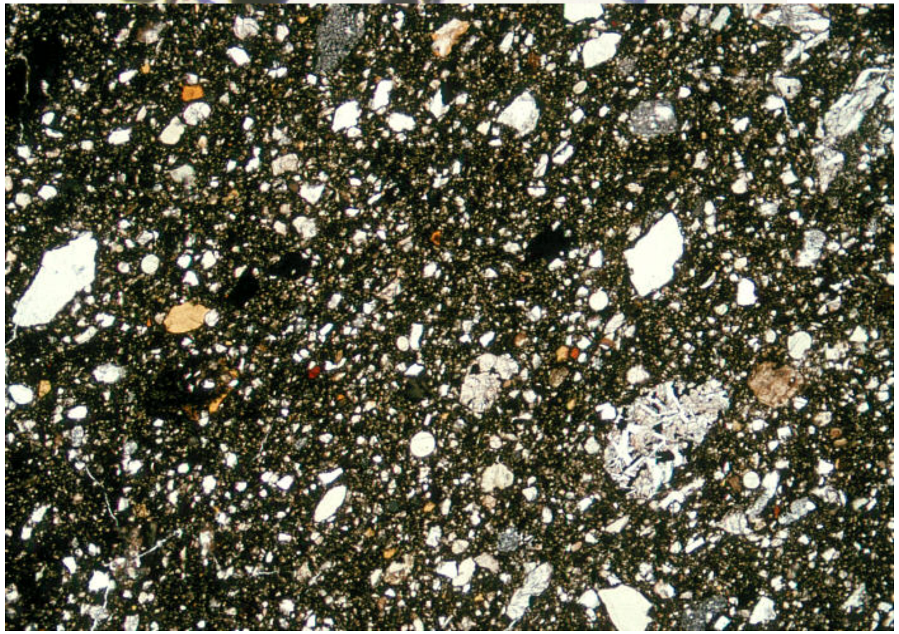


Enceladus Radar Scatterometry Coverage
90
60
30
0
-30
-60
-90
Latitude (deg)
0
60
120
180
240
300
360
W. Longitude (deg)

Coherent Backscattering

The anomalously large radar albedos and polarization ratios of radar echoes from certain icy surfaces arise from phase-coherent, <u>multiple scattering</u> within a dielectric medium that is heterogeneous **<u>and</u>** nonabsorbing.

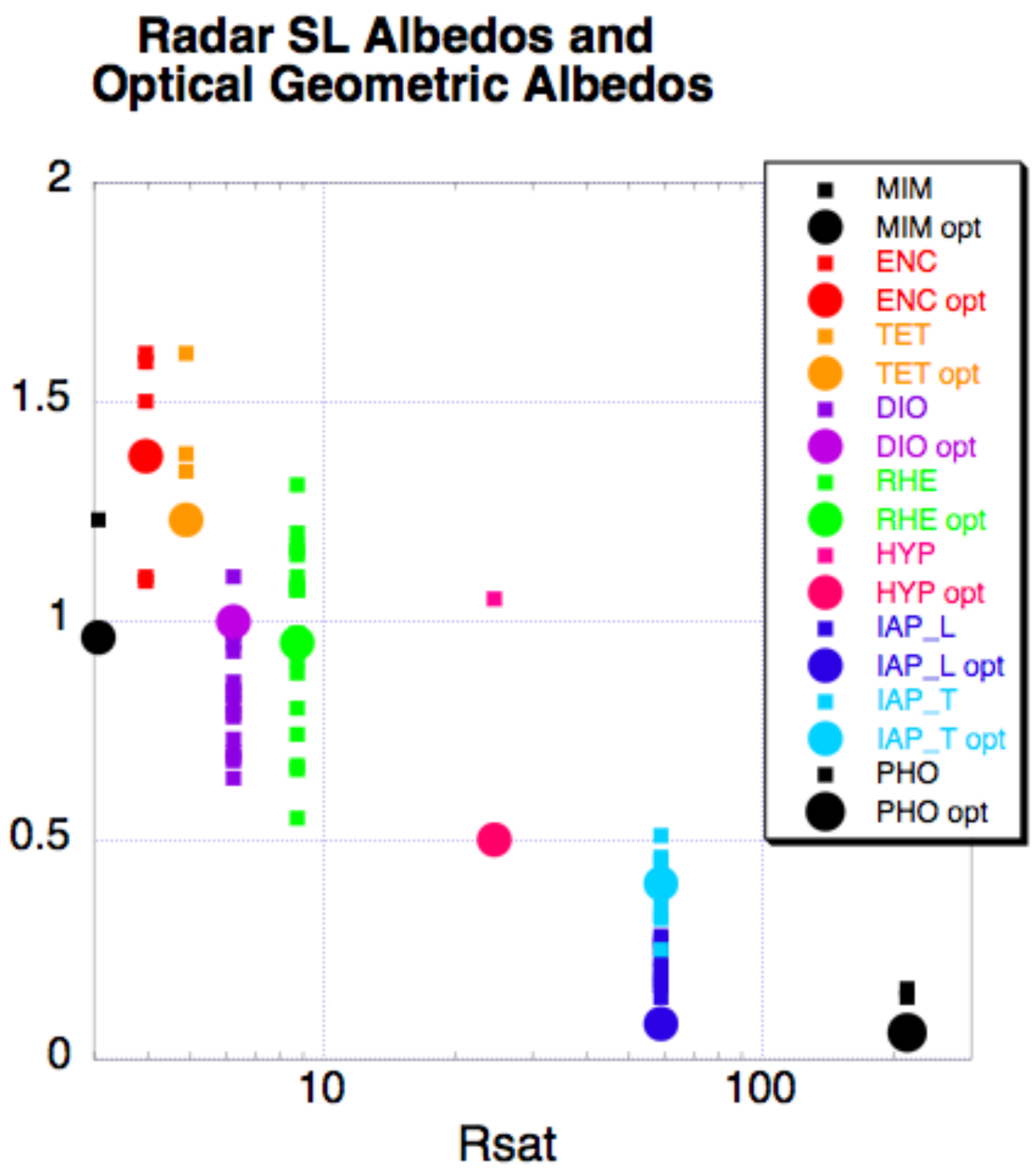




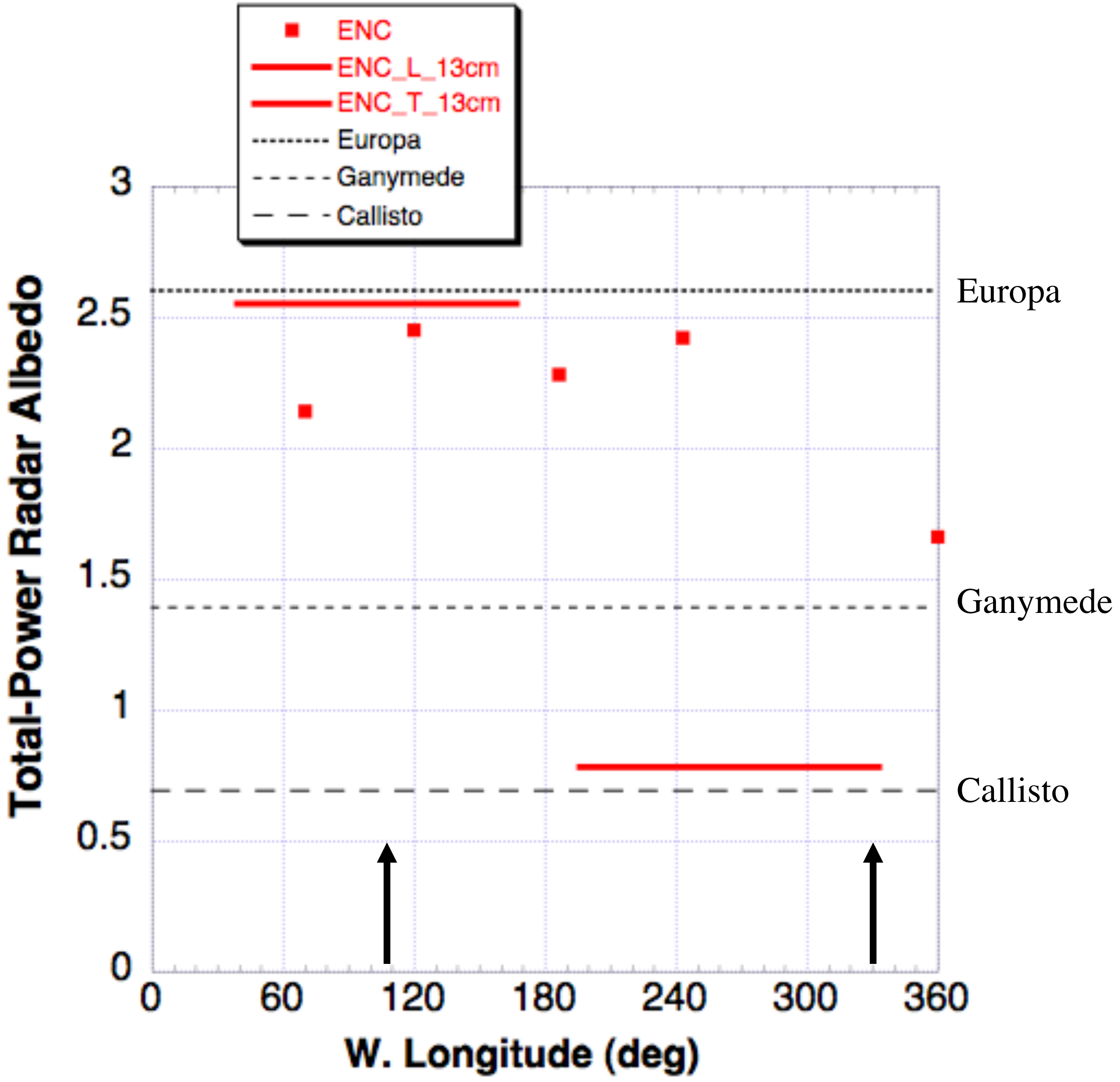
Contamination of water ice with virtually any other candidate substance decreases its radar transparency and hence the radar brightness of icy surfaces.

L_{abs} = 1/e one-way power absorption length

Material	L_{abs}/λ
Water Ice	~10,000
Earth rocks, nonmetallic meteorites	~1 to ~100
Water ice + few % lunar soil	~100
Water Ice + 0.1% ammonia (NH_3)	~1 to ~10
Hematite (Fe_2O_3)	<1
Tholin	<10



Radar SL Albedos and
Optical Geometric Albedos
2
1.5
1
0.5
0
10
100
Rsat
MIM
MIM opt
ENC
ENC opt
TET
TET opt
DIO
DIO opt
RHE
RHE opt
HYP
HYP opt
IAP_L
IAP_L opt
IAP_T
IAP_T opt
PHO
PHO opt


ENC
ENC_L_13cm
ENC_T_13cm
Europa
Ganymede
Callisto
Total-Power Radar Albedo
3
2.5
2
1.5
1
0.5
0
0
60
120
180
240
300
360
W. Longitude (deg)
Europa
Ganymede
Callisto

Enceladus Rev 061
UVIS Goals and Observations

C. Hansen and A. Hendrix

22 February 2008

Enceladus Rev 061
UVIS Goals and Observations

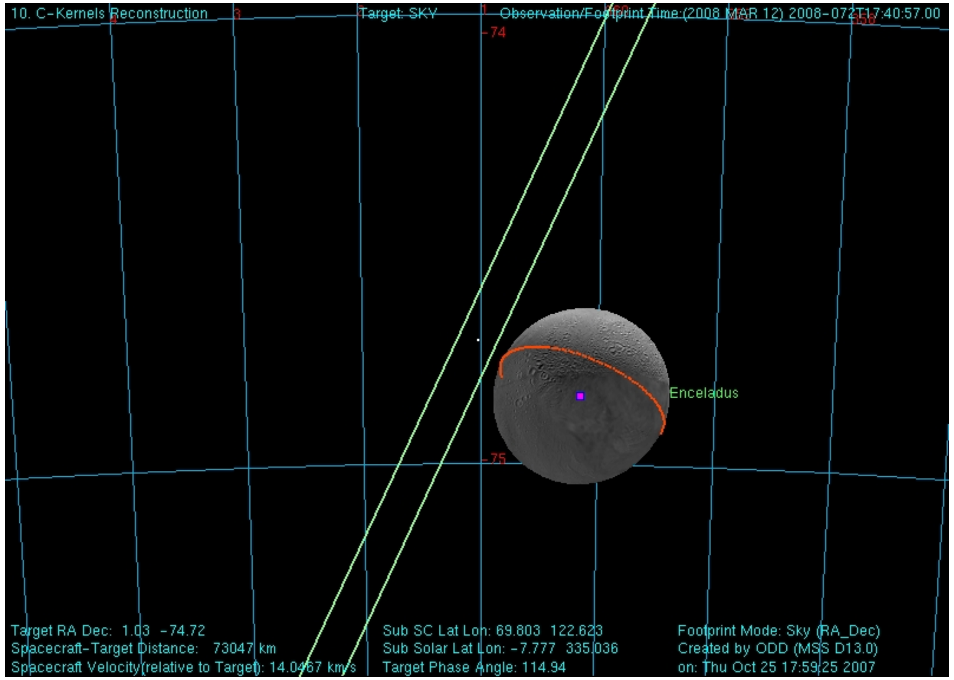
C. Hansen and A. Hendrix

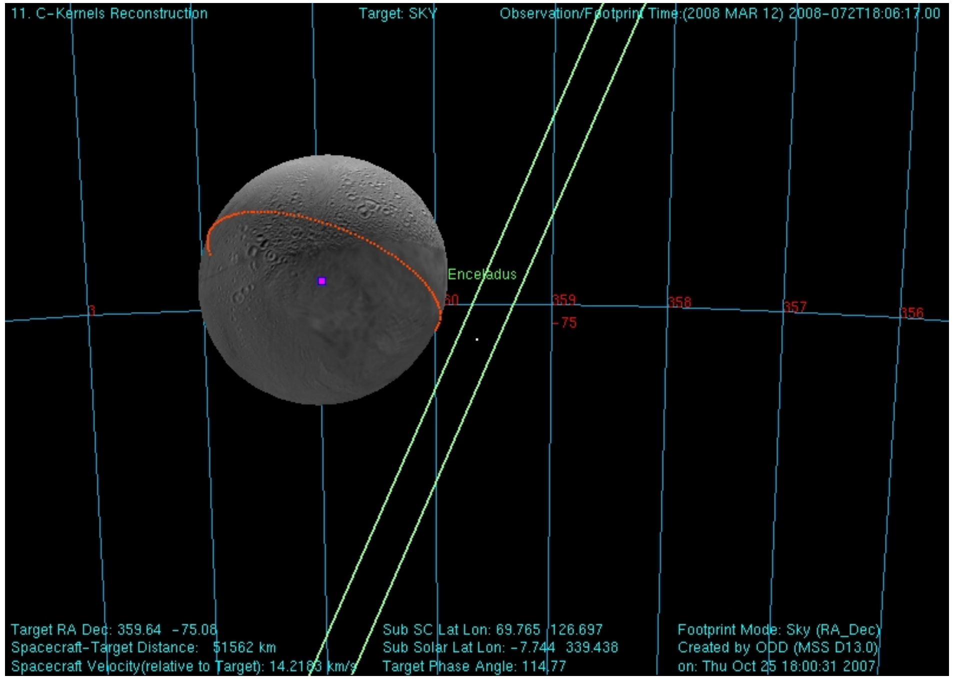
22 February 2008

UVIS Observations

- UVIS is prime for two observations
  - ICYMAP at -1:20:00, 30 min duration
    - Purpose is to map uv albedo at high resolution
  - ICYLON at +2:55:00, 2 hour duration
    - Purpose is to integrate a long time to detect volatiles

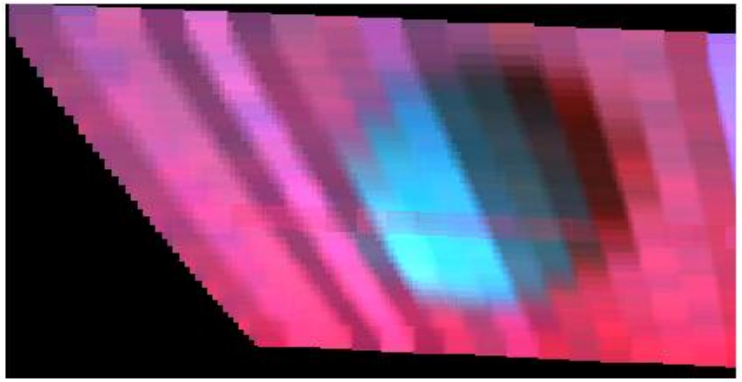
ICYMAP



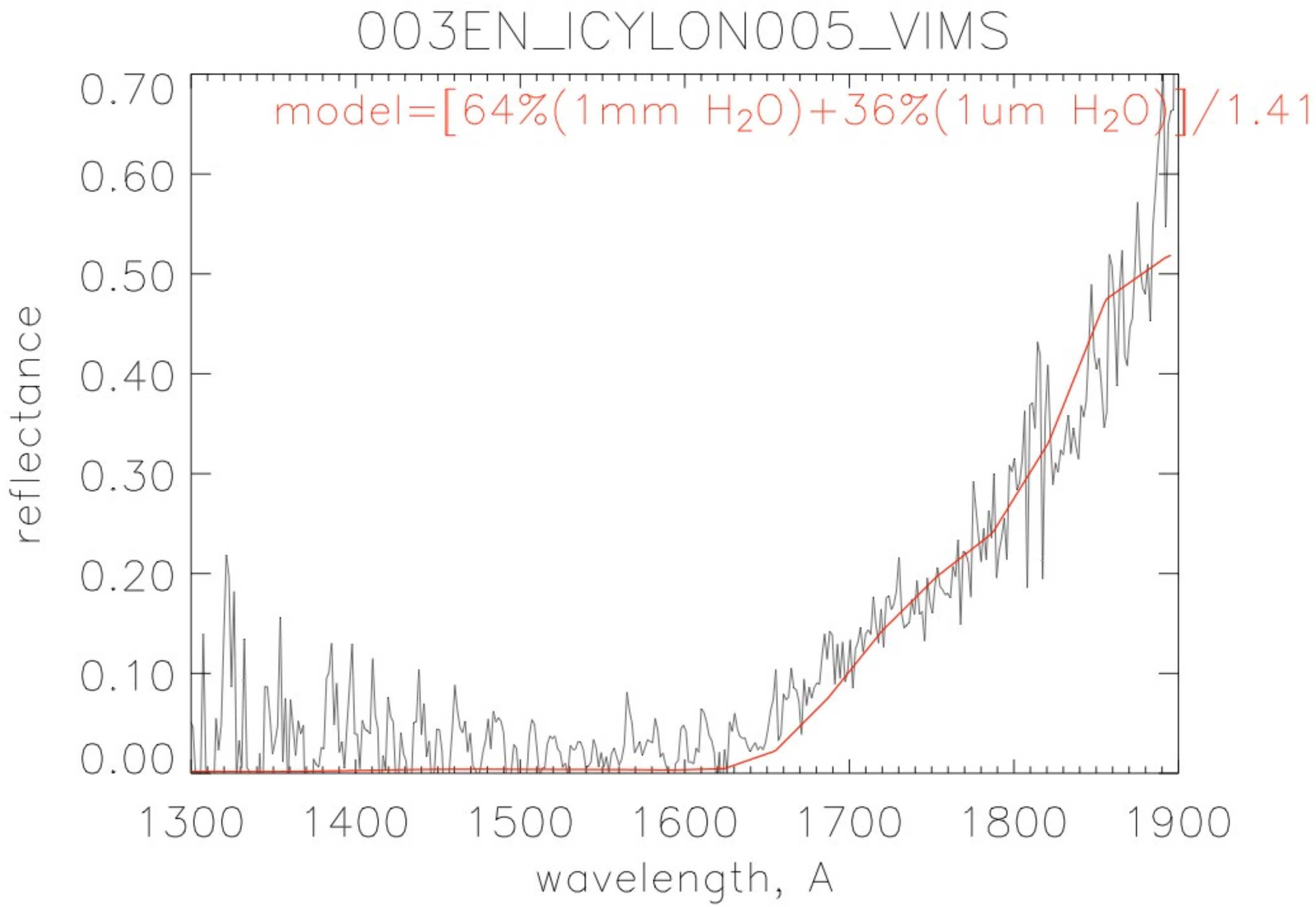


Start of scan

End of scan

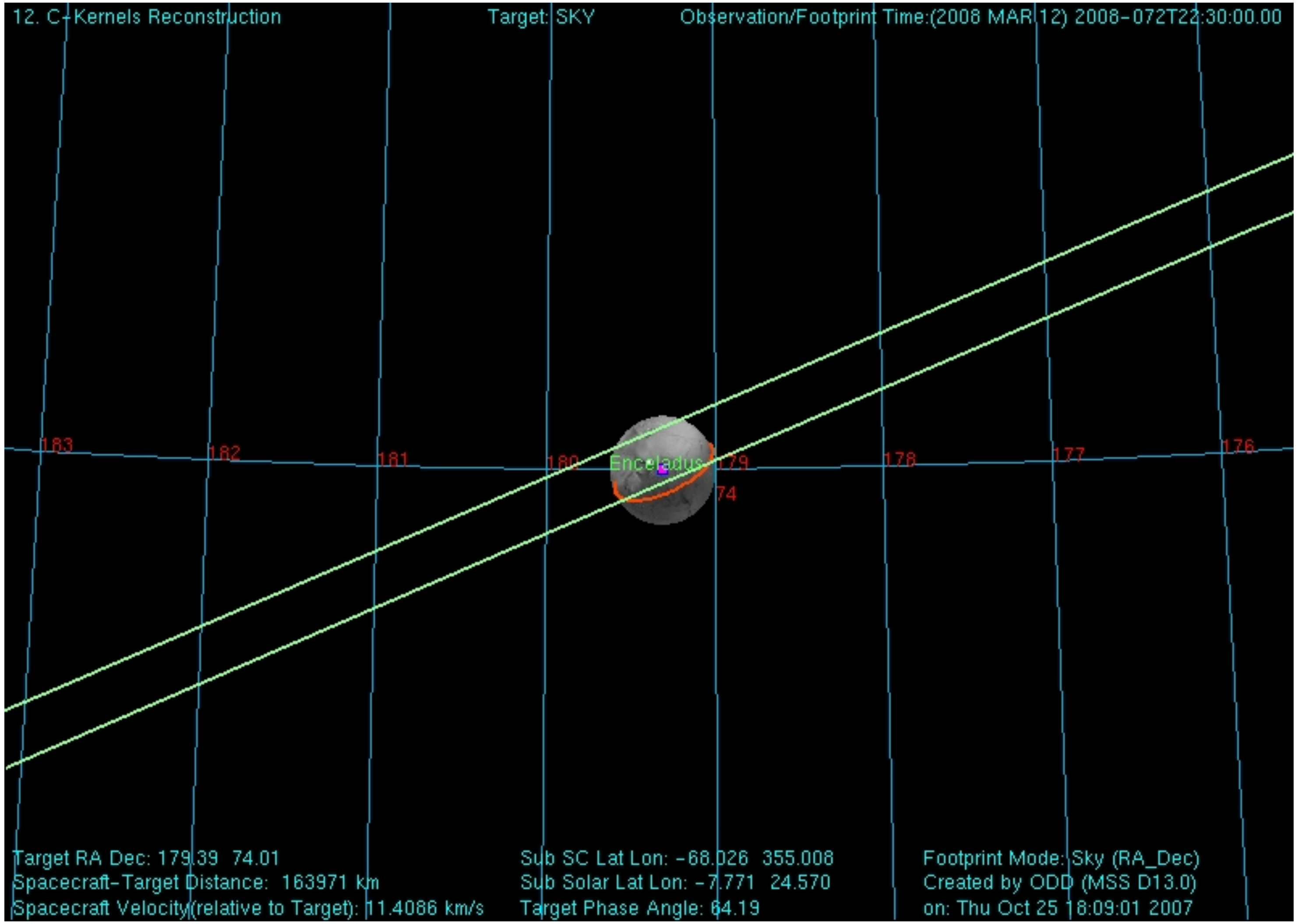


UV Spectrum



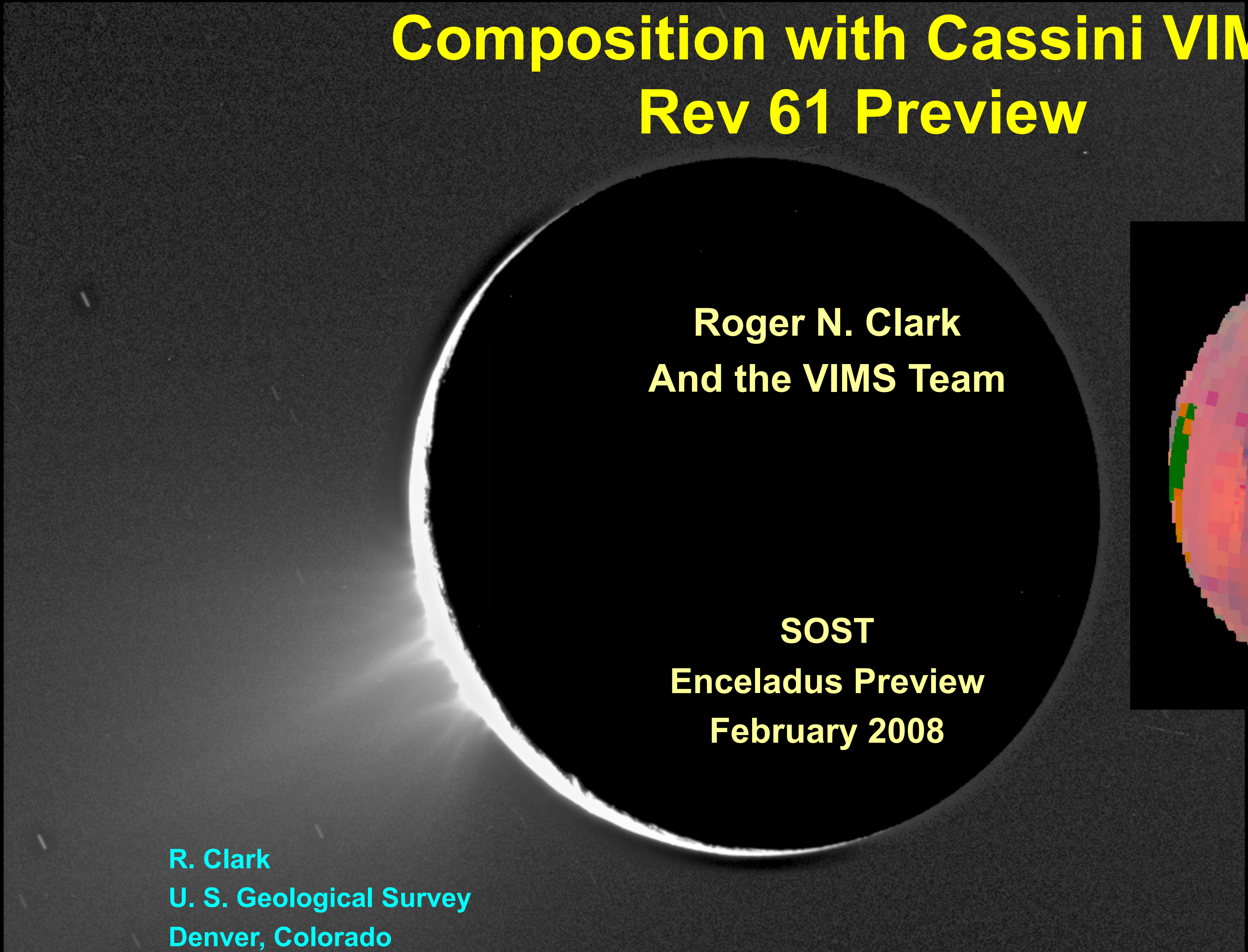
003EN_ICYLON005_VIMS
model=[64%(1mm H2O)+36%(1um H2O)]/1.41
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
reflectance
1300
1400
1500
1600
1700
1800
1900
wavelength, A

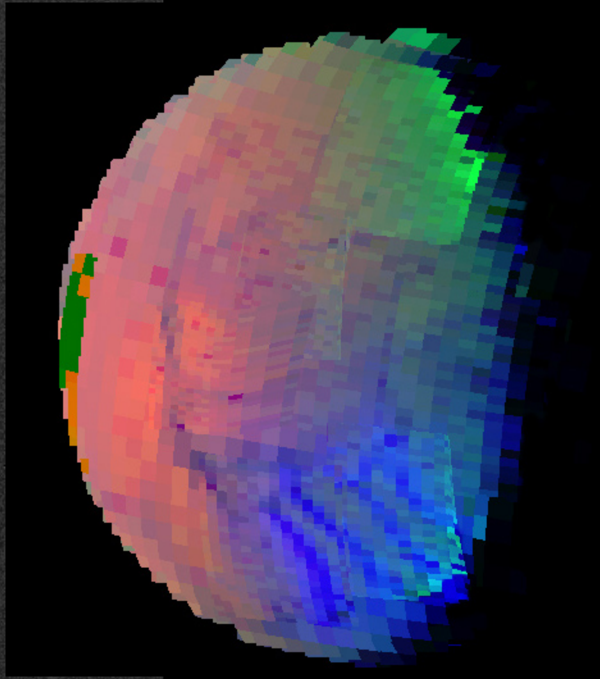
ICYLON



2 hour total integration time

Understanding Enceladus and Its Plumes: Composition with Cassini VIMS: Rev 61 Preview



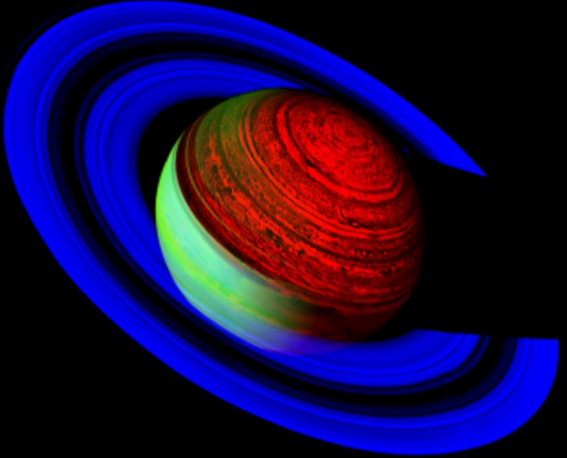


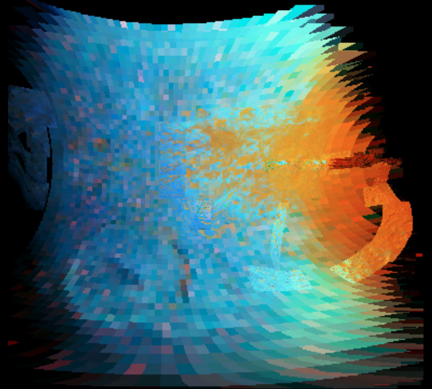
Roger N. Clark
And the VIMS Team

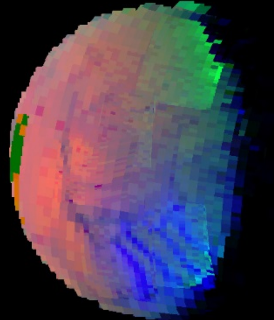
SOST
Enceladus Preview
February 2008

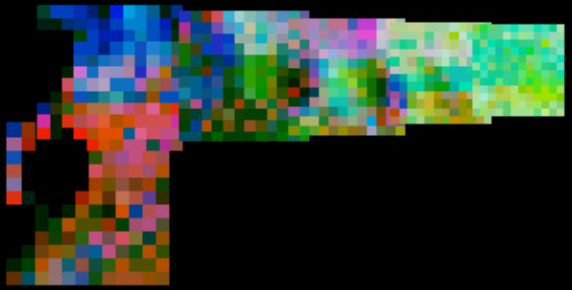
R. Clark
U. S. Geological Survey
Denver, Colorado

Cassini internal only







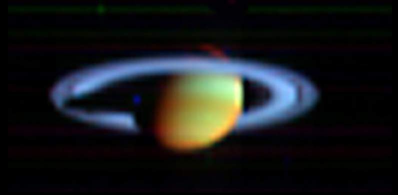


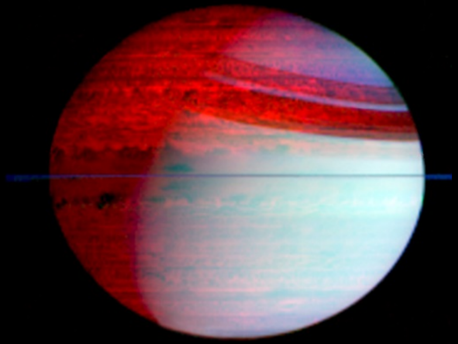
RGB Mineral Map:
Red =CO2 at 4.26 microns
Green = 1-micron albedo
Blue = 2-micron Ice

VIMS

Visual and Infrared Mapping Spectrometer

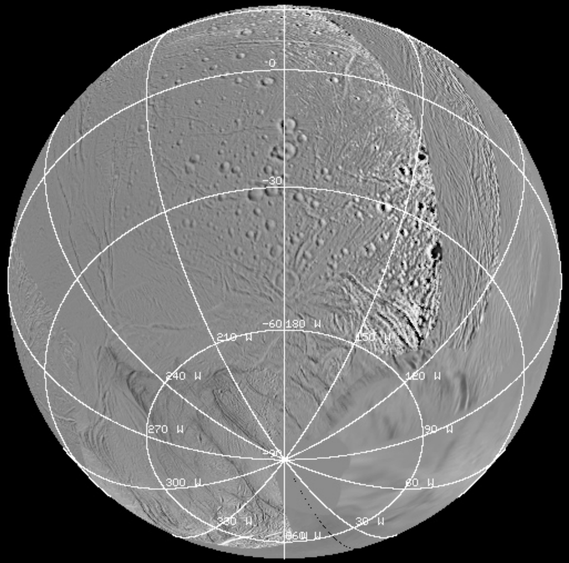
- 0.35 to 5.2 microns in 352 wavelengths
- IFOV: 0.5 x 0.5 mrad (standard)
  - (0.5 mrad = 1.7 arc-minutes)
- High resolution IR: 0.5 x 0.25 mrad
- High resolution VIS: 0.17 x 0.17 mrad
- Images up to 64 x 64 pixels square.



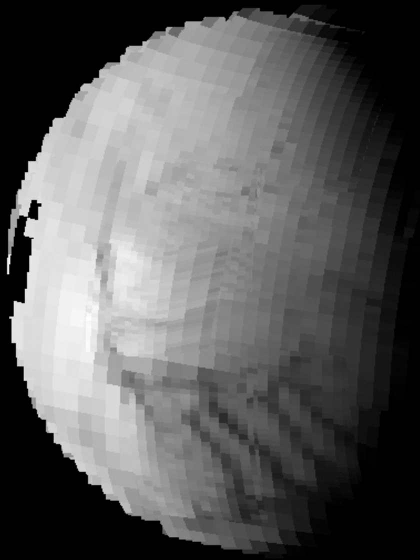


Why Study Enceladus?
(A few of many questions)

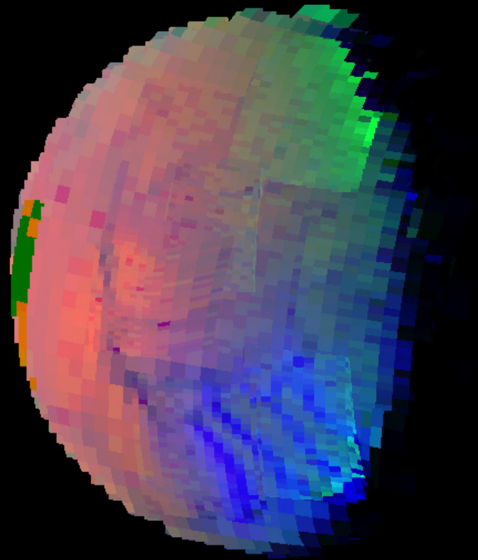
- What drives the plumes?
  - Boiling water geysers?
  - Outgassing clathrates (Kieffer *et al.*, *Science*)
- What materials (compositions and particle sizes) are contributing to the E-ring?
- What drives/drove the resurfacing?
  - Composition of the “magma”?
- Are there relic plume sources?
  - Search for composition indicators,
    - E.g. if organics are associated with vents, search for organics.
- .



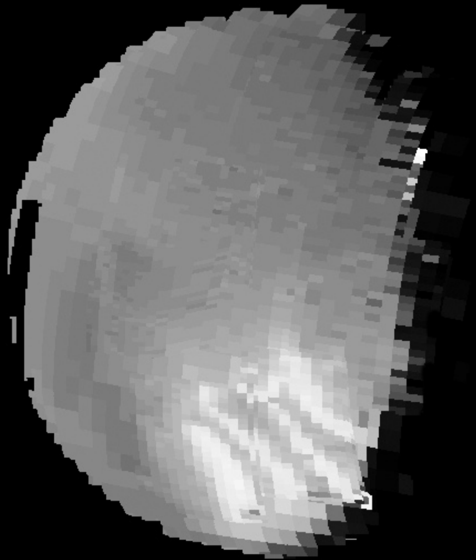
ISS Reference



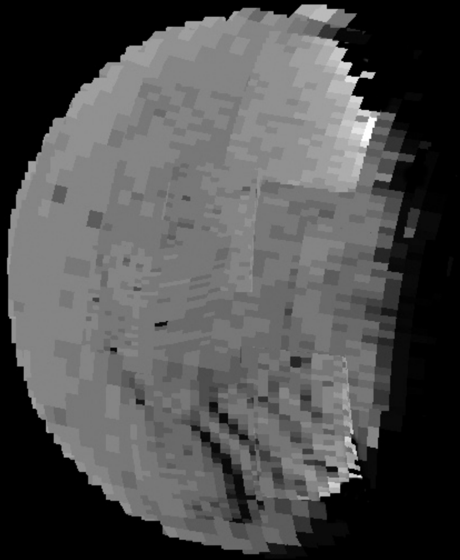
2.2-micron Reflectance



Color composite:
Red = 2.2-micron Reflectance
Green=3-micron Ice
Blue = 2-micron Ice

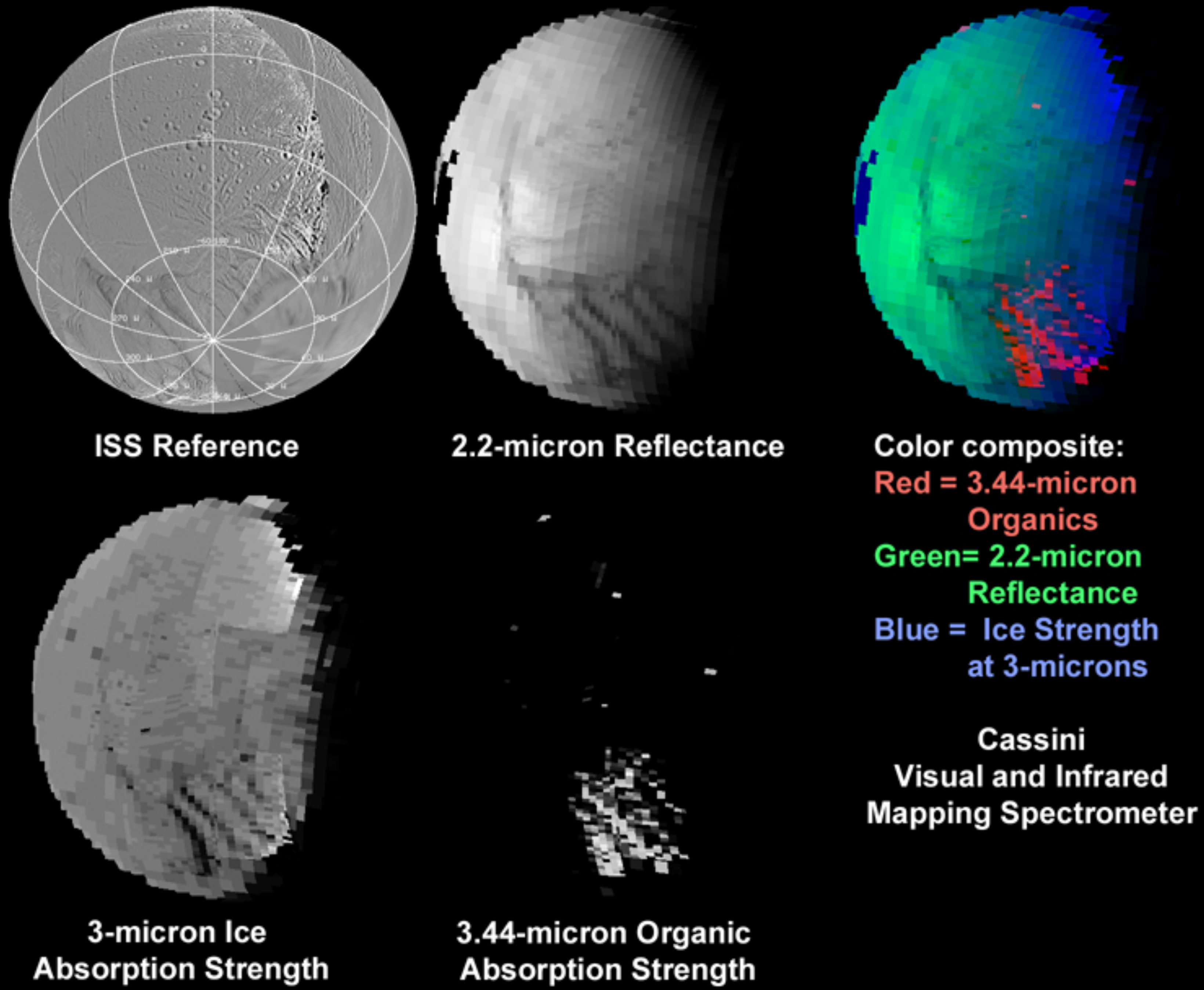


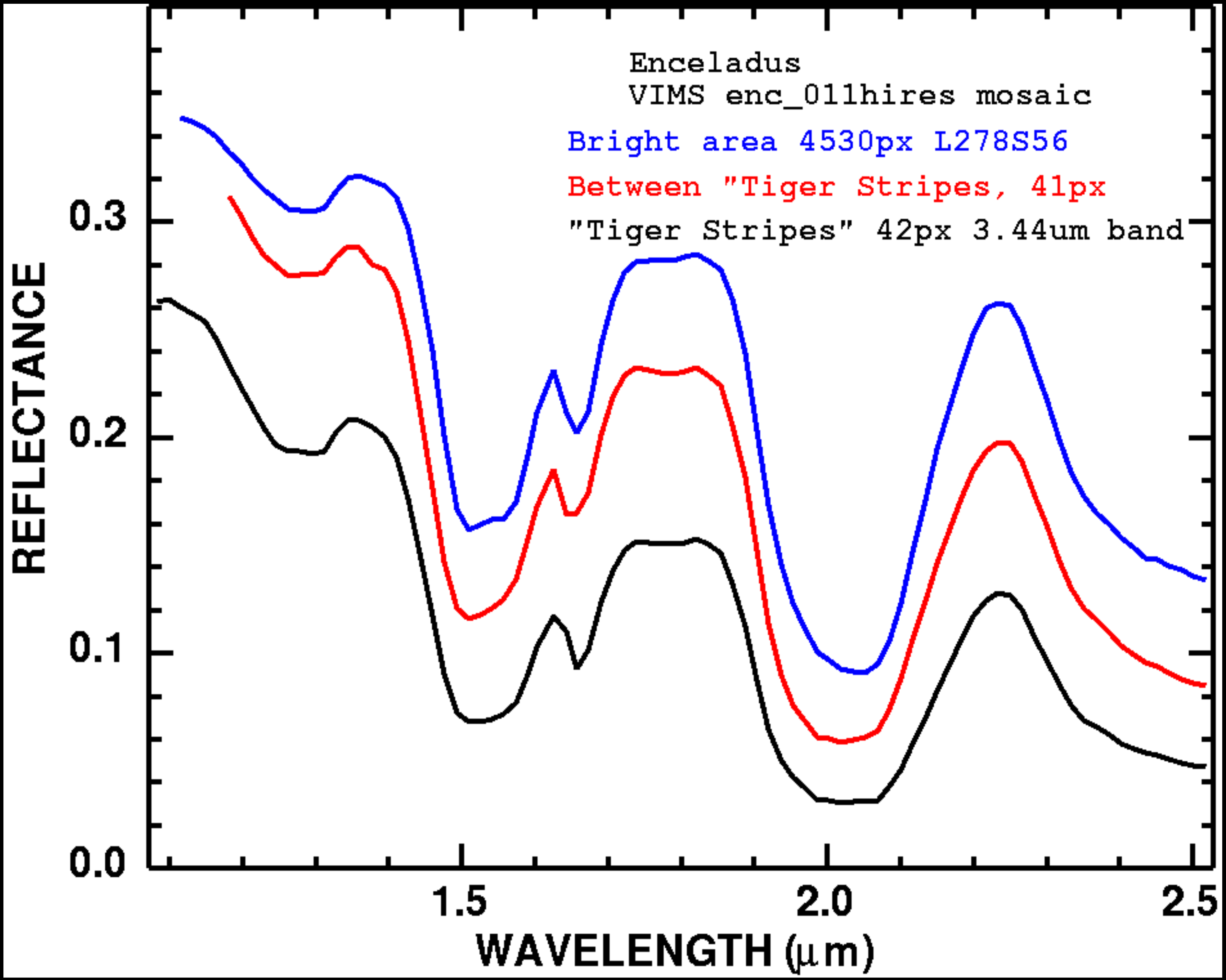
2-micron Ice Absorption Strength

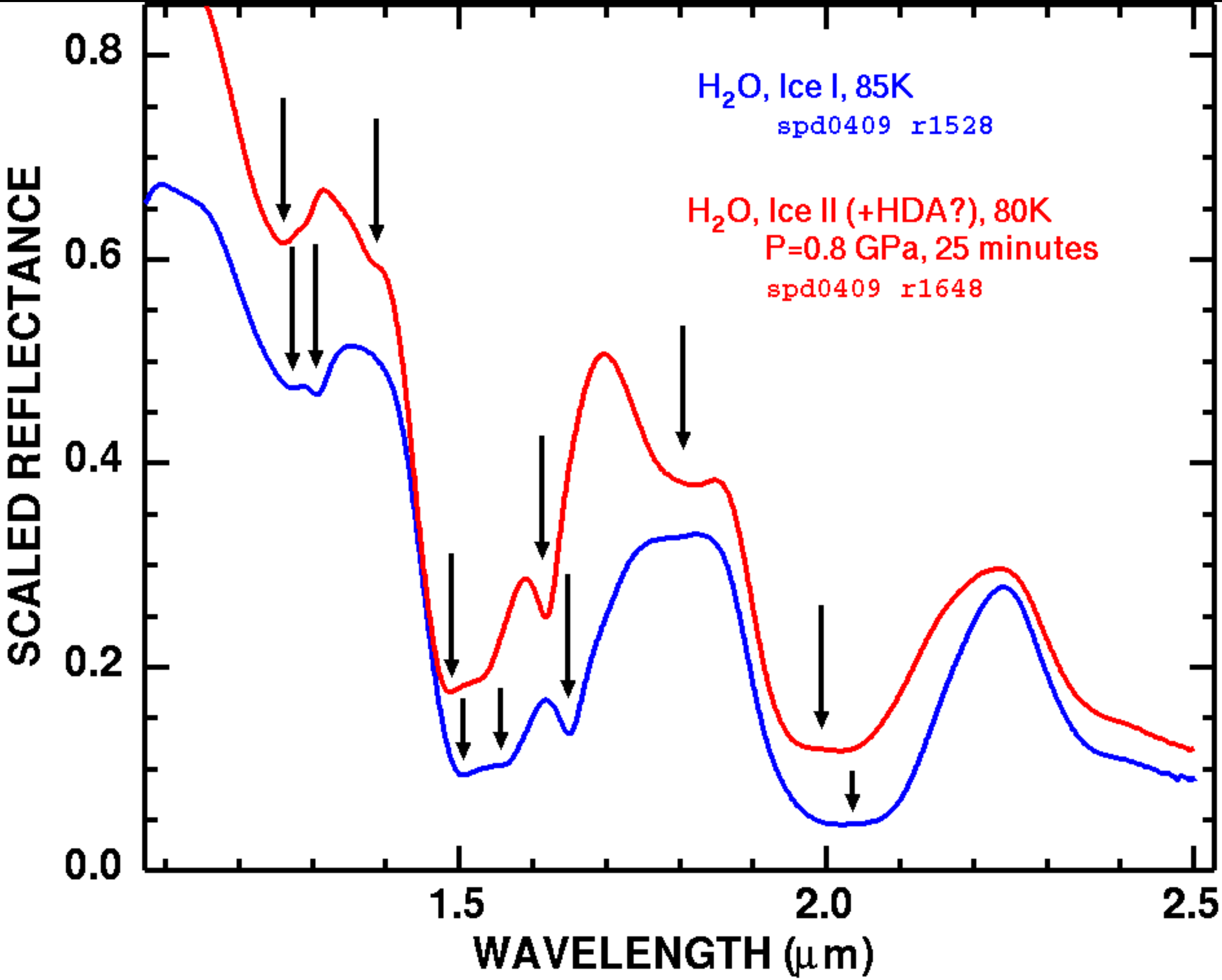


3-micron Ice Absorption Strength

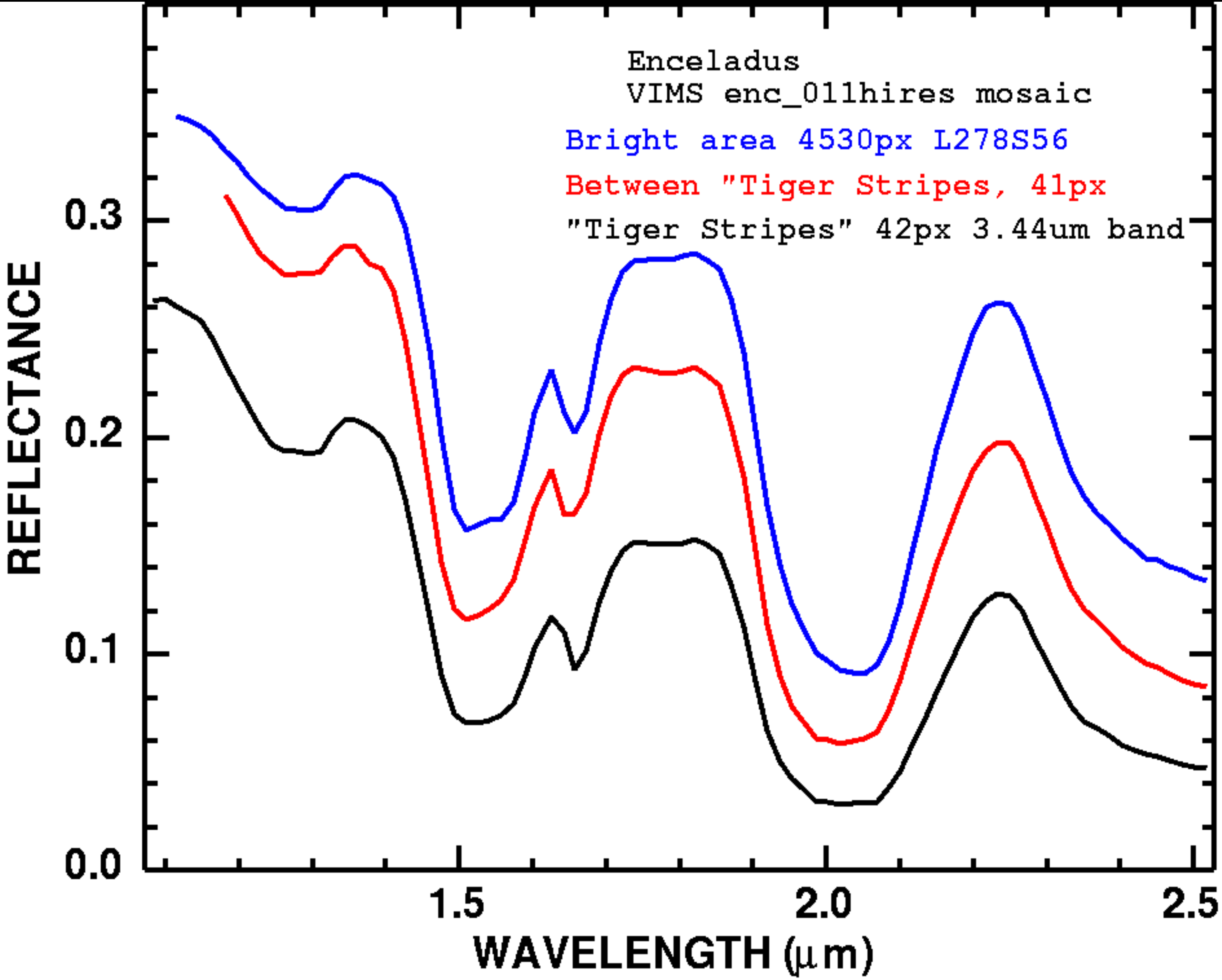
Cassini Visual and Infrared Mapping Spectrometer

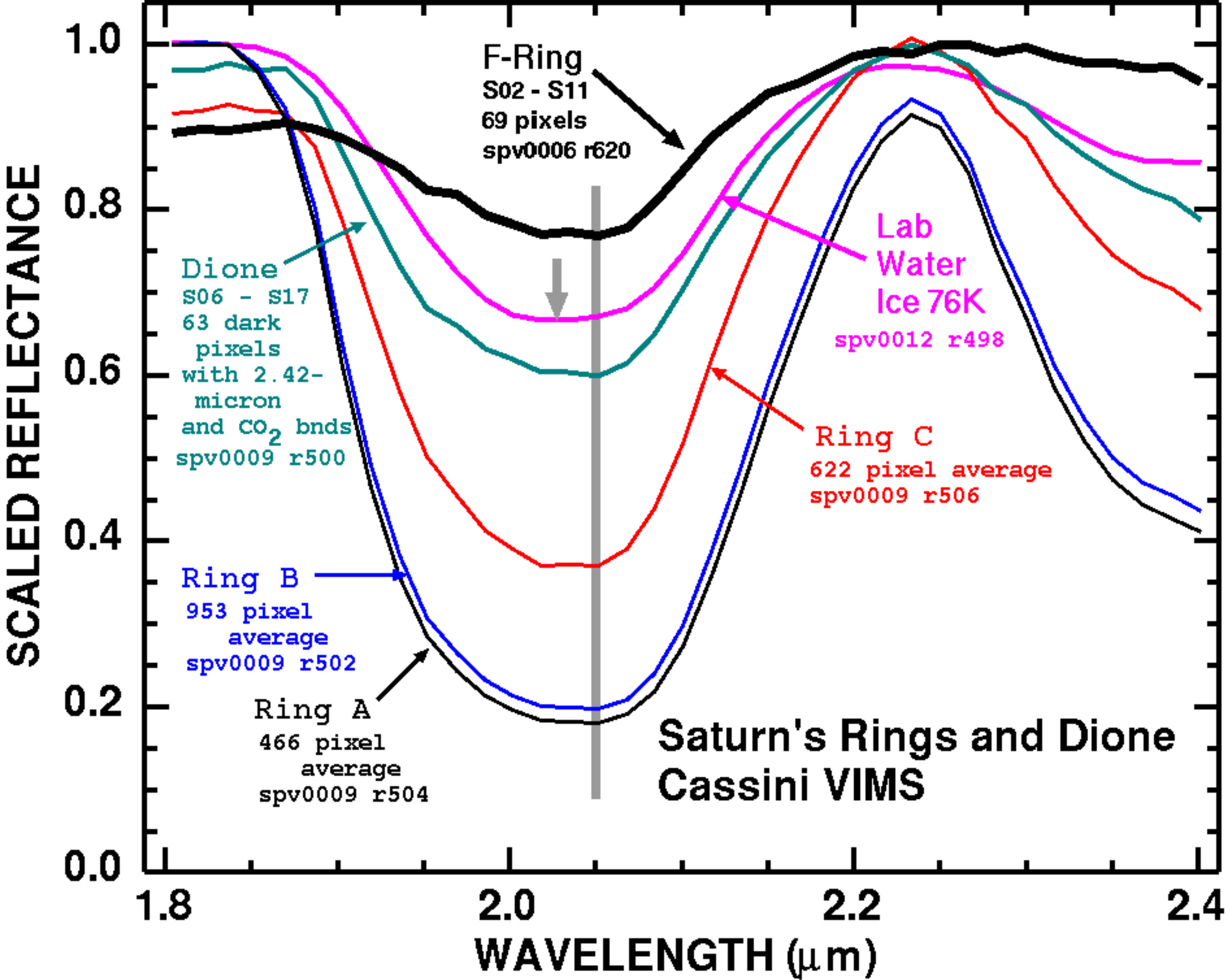

ISS Reference
2.2-micron Reflectance
Color composite:
Red = 3.44-micron Organics
Green= 2.2-micron Reflectance
Blue = Ice Strength at 3-microns
3-micron Ice Absorption Strength
3.44-micron Organic Absorption Strength
Cassini
Visual and Infrared
Mapping Spectrometer


Enceladus
VIMS enc_011hires mosaic
Bright area 4530px L278S56
Between "Tiger Stripes, 41px
"Tiger Stripes" 42px 3.44um band
REFLECTANCE
0.0
0.1
0.2
0.3
1.5
2.0
2.5
WAVELENGTH (μm)

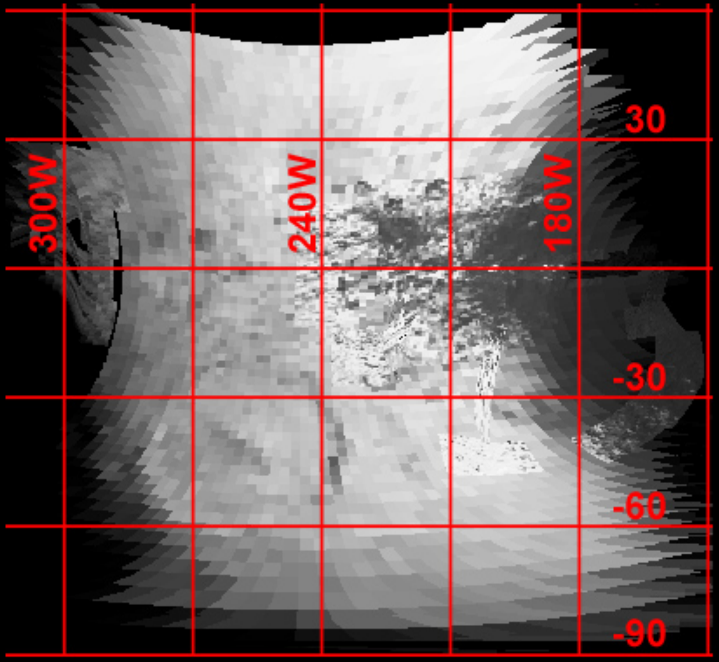


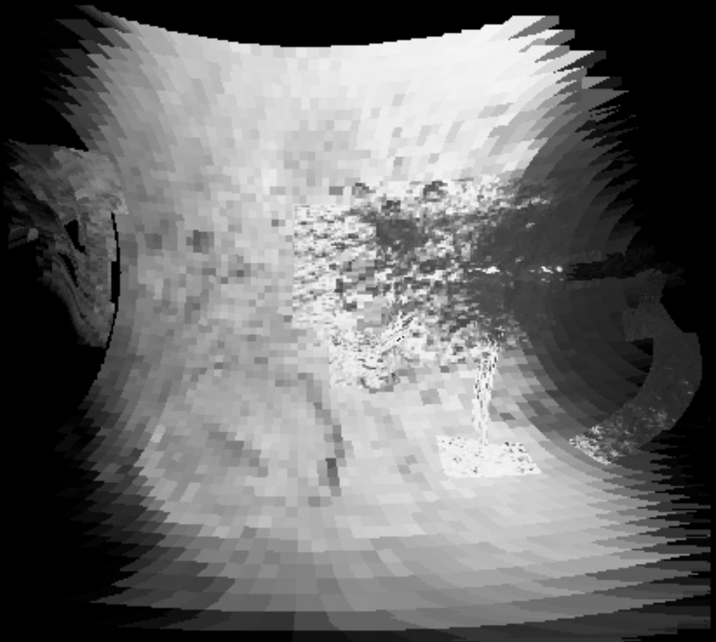
H2O, Ice I, 85K
spd0409 r1528
H2O, Ice II (+HDA?), 80K
P=0.8 GPa, 25 minutes
spd0409 r1648
SCALED REFLECTANCE
0.0
0.2
0.4
0.6
0.8
1.5
2.0
2.5
WAVELENGTH (μm)


Enceladus
VIMS enc_011hires mosaic
Bright area 4530px L278S56
Between "Tiger Stripes, 41px
"Tiger Stripes" 42px 3.44um band
0.3
0.2
0.1
0.0
REFLECTANCE
1.5
2.0
2.5
WAVELENGTH (μm)


SCALED REFLECTANCE
1.0
0.8
0.6
0.4
0.2
0.0
1.8
2.0
2.2
2.4
WAVELENGTH (μm)
F-Ring
S02 - S11
69 pixels
spv0006 r620
Dione
S06 - S17
63 dark
pixels
with 2.42-
micron
and CO2 bnds
spv0009 r500
Lab
Water
Ice 76K
spv0012 r498
Ring C
622 pixel average
spv0009 r506
Ring B
953 pixel
average
spv0009 r502
Ring A
466 pixel
average
spv0009 r504
Saturn's Rings and Dione
Cassini VIMS

The Iapetus rev 49 fly-by was the only opportunity in the Cassini mission to resolve, in detail, surface features that may shed light on the origin of the dark material, and the data are living up to expectations.



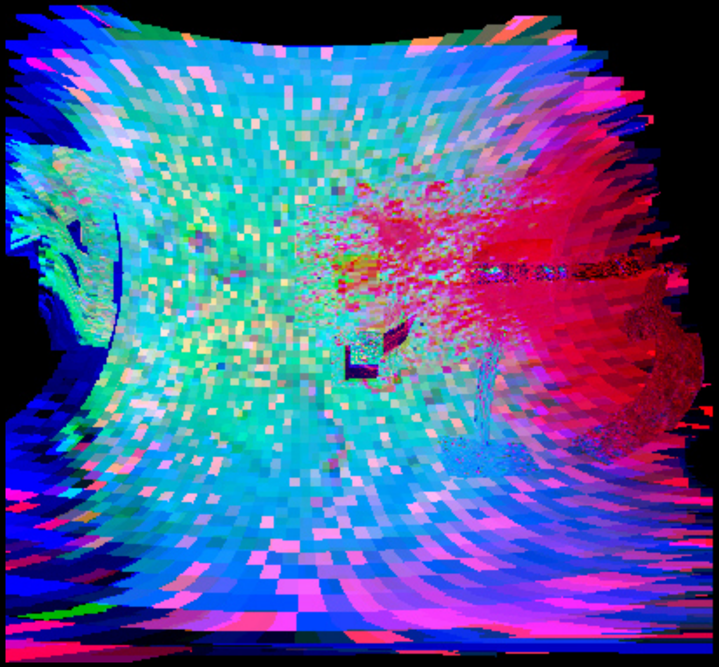


VIMS 1.75-micron Reflectance

Iapetus

Cassini Rev 49 fly-by

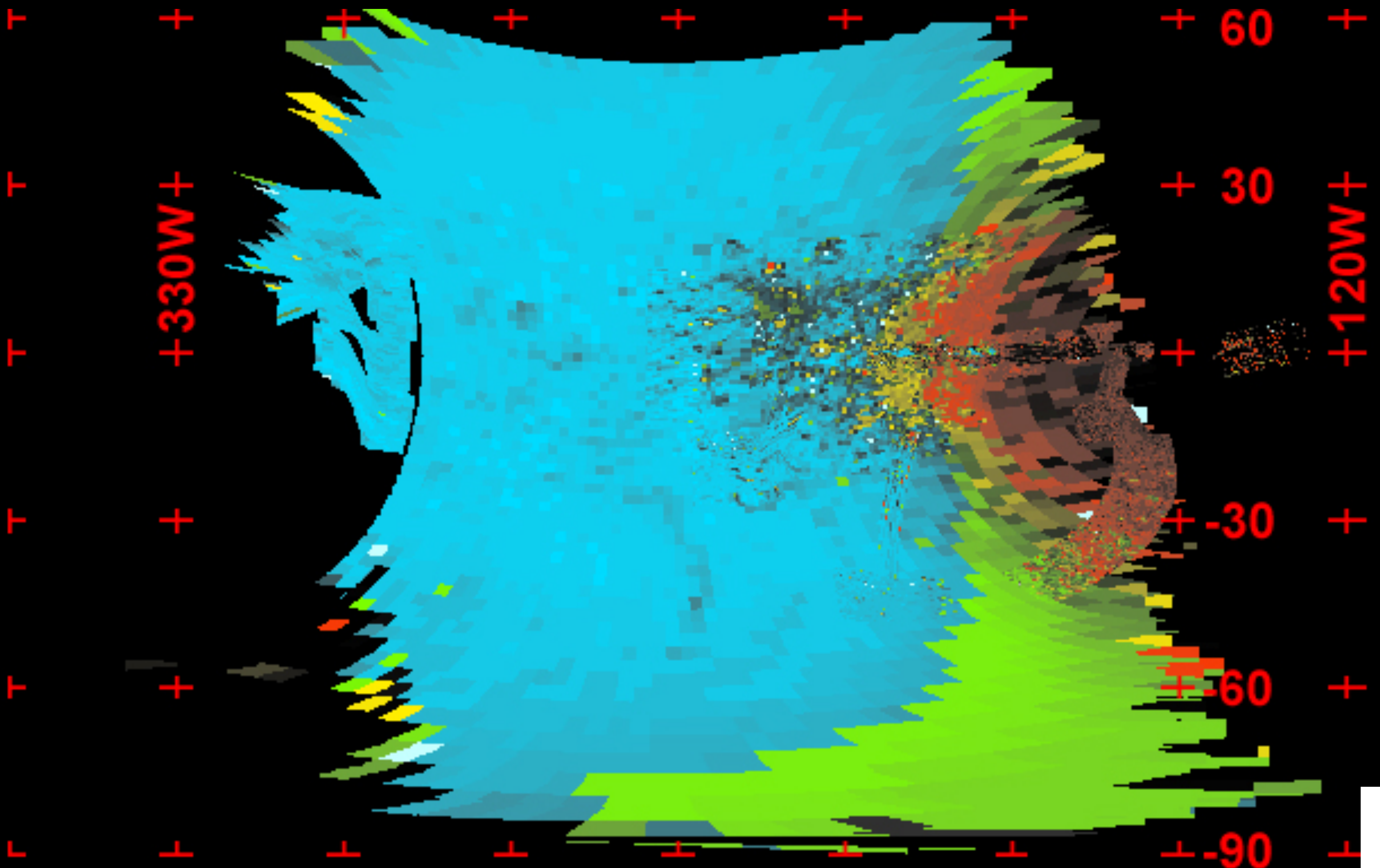
Ice, dark material and CO_2 in the dark material dominate this spectral map. Small dark particles in the ice create Rayleigh scattering.



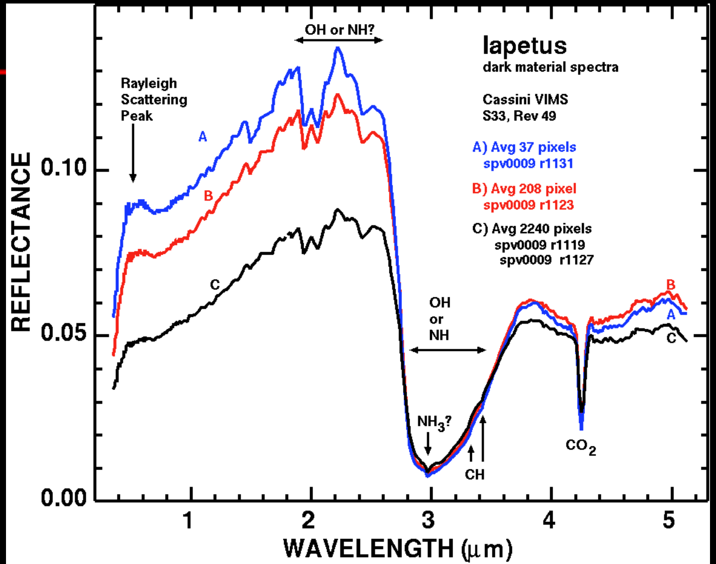
VIMS Composition Map
Red = CO_2 Strength
Green = H_2O Ice strength
Blue = Rayleigh scattering strength (indicates sub-half-micron particles dispersed in the surface)

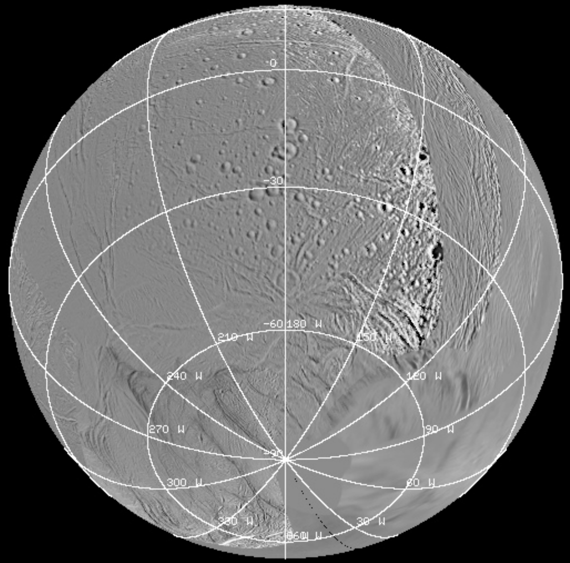
Iapetus
Cassini Rev 49 fly-by

VIMS Composition Map

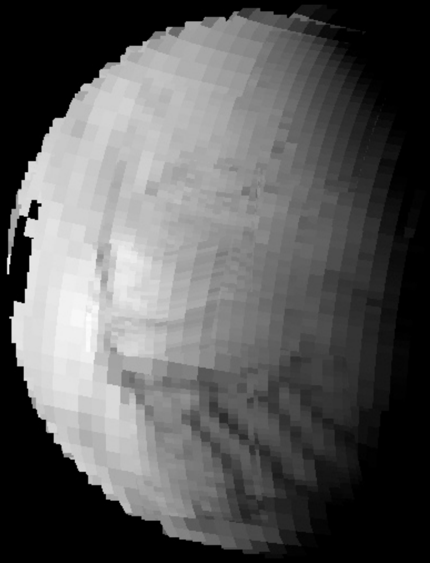


- 1.95, 2.05, 2.15-micron triplet (Dark region material)
- 1.95, 2.05, 2.15-micron triplet + Ice (Dark region material)
- Water Ice (asymmetric 2-micron absorption)
- Water Ice, slight 2-micron asymmetric absorption
- Water Ice, medium grained, 2-micron symmetric absorption

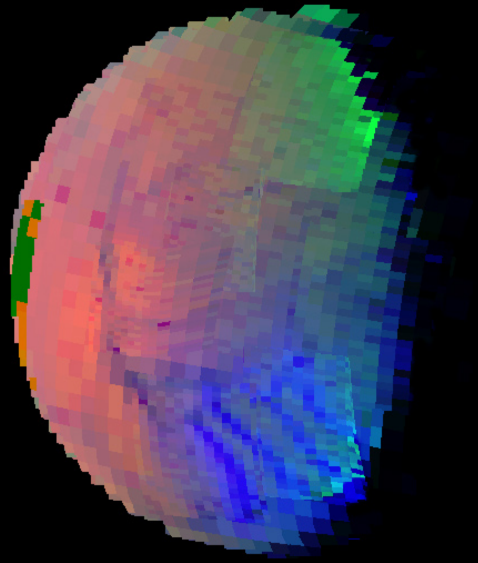




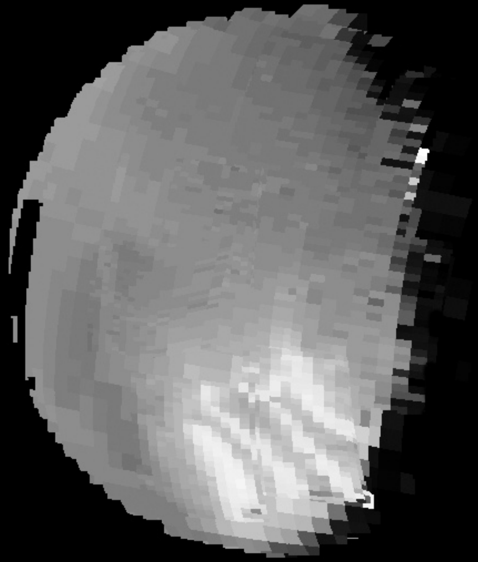
ISS Reference



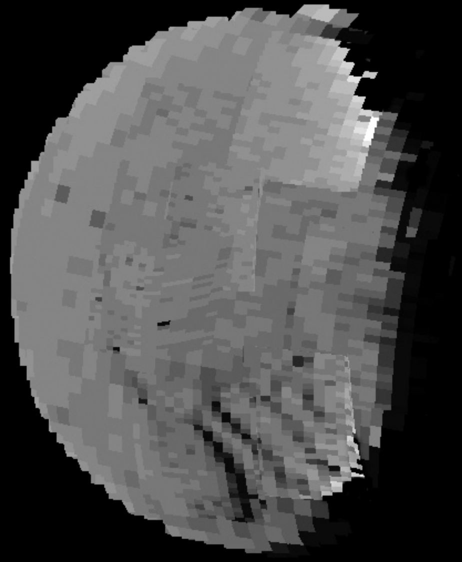
2.2-micron Reflectance



Color composite:
Red = 2.2-micron Reflectance
Green=3-micron Ice
Blue = 2-micron Ice

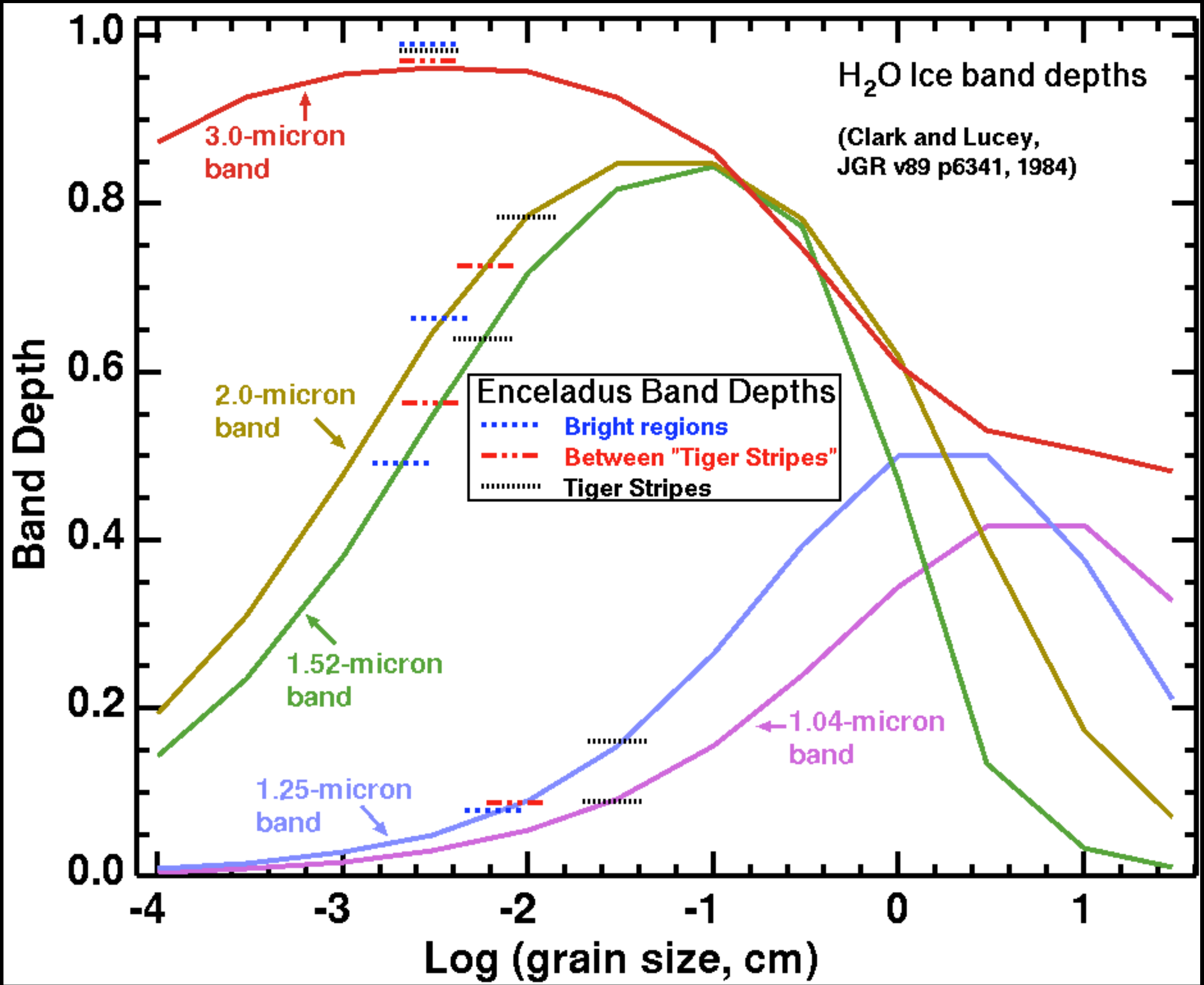


2-micron Ice Absorption Strength



3-micron Ice Absorption Strength

Cassini
Visual and Infrared
Mapping Spectrometer


H2O Ice band depths
(Clark and Lucey, JGR v89 p6341, 1984)
Enceladus Band Depths
Bright regions
Between "Tiger Stripes"
Tiger Stripes
3.0-micron band
2.0-micron band
1.52-micron band
1.25-micron band
1.04-micron band
Band Depth
0.0
0.2
0.4
0.6
0.8
1.0
-4
-3
-2
-1
0
1
Log (grain size, cm)

Conclusions

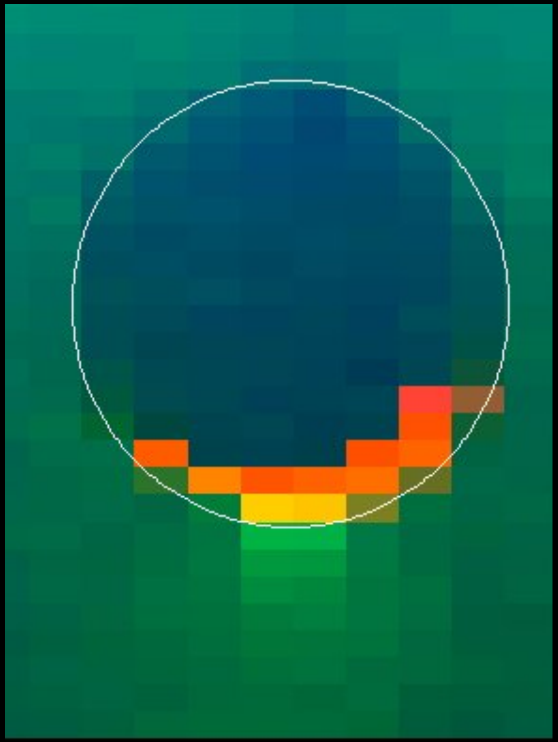
- Bright areas: 20 to 65 micron ice grains.
- Between Tiger Stripes: 35 to 100 microns.
- Tiger Stripes: 60 to 300 microns.
- Some fine (~30 micron) grains in all areas.

Derived Grain Sizes (microns)

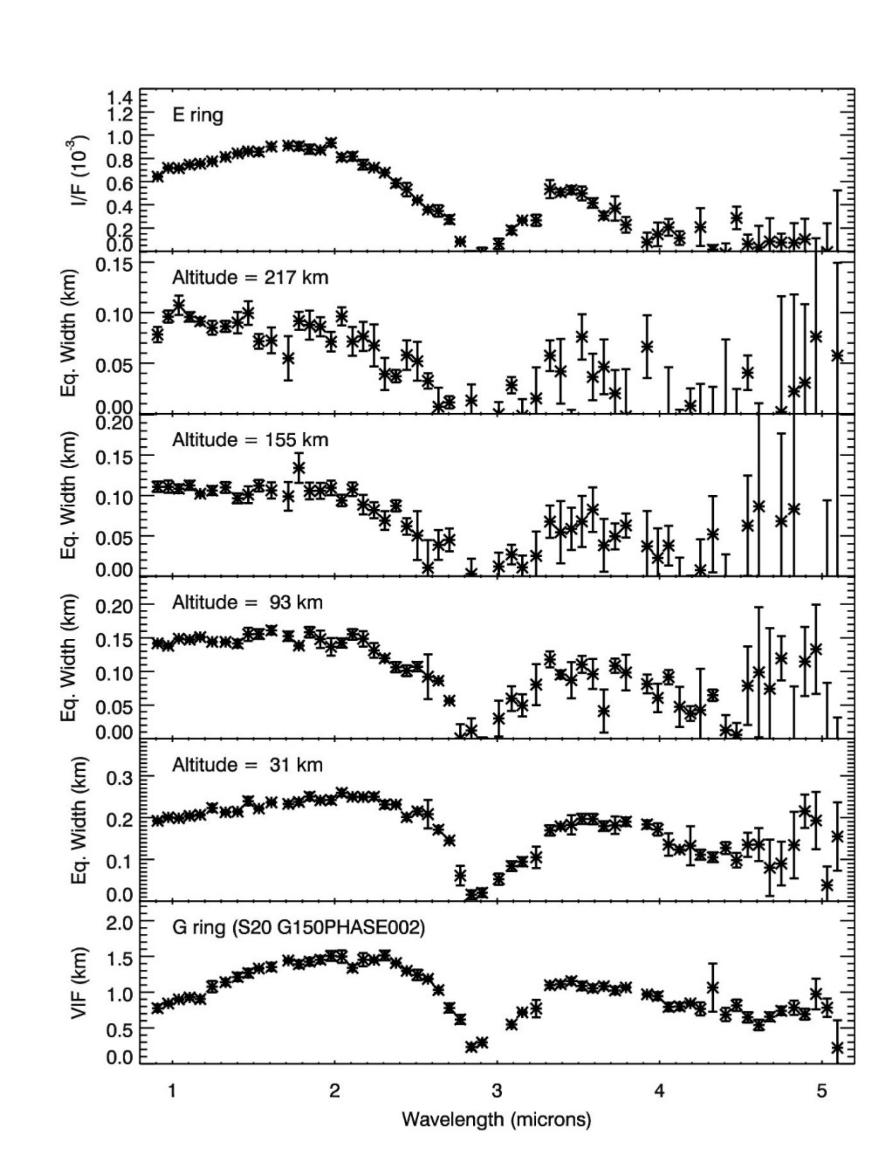
`	1.04-micron band	1.25-micron band	1.5-micron band	2.0-micron band	3.0-micron band
Bright areas		65	20	35	~30
Between “Tiger Stripes”		~100	60	35	~30
“Tiger Stripes”	280	320	100	60	~30

New insights into Plume dynamics and hazards from VIMS

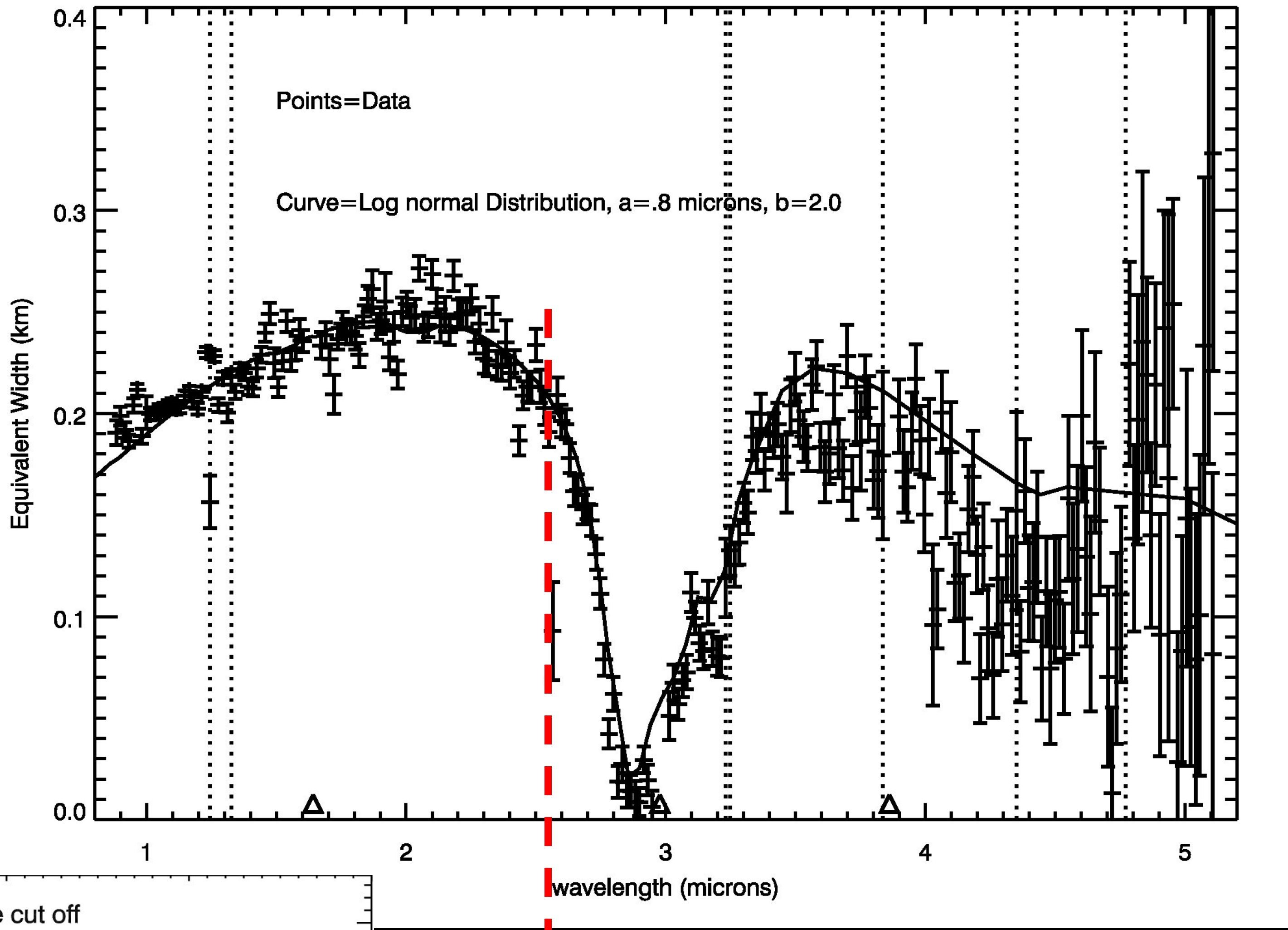
EPWG 1-28-08

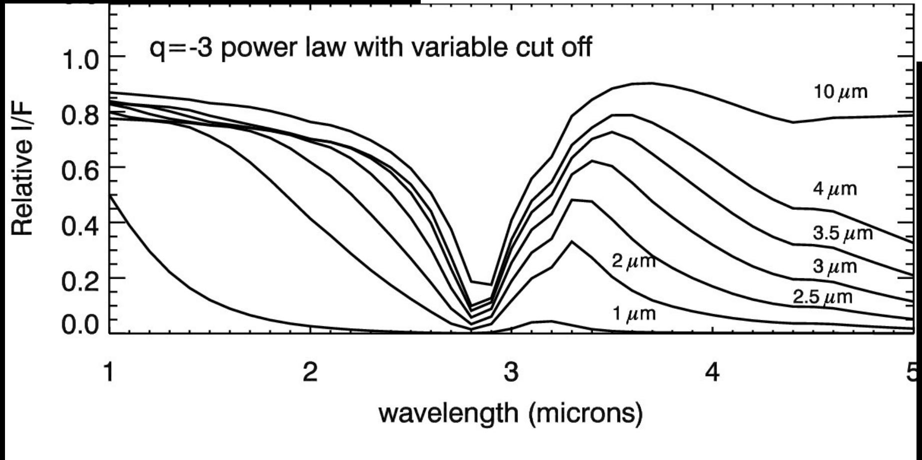


From Matt Hedman

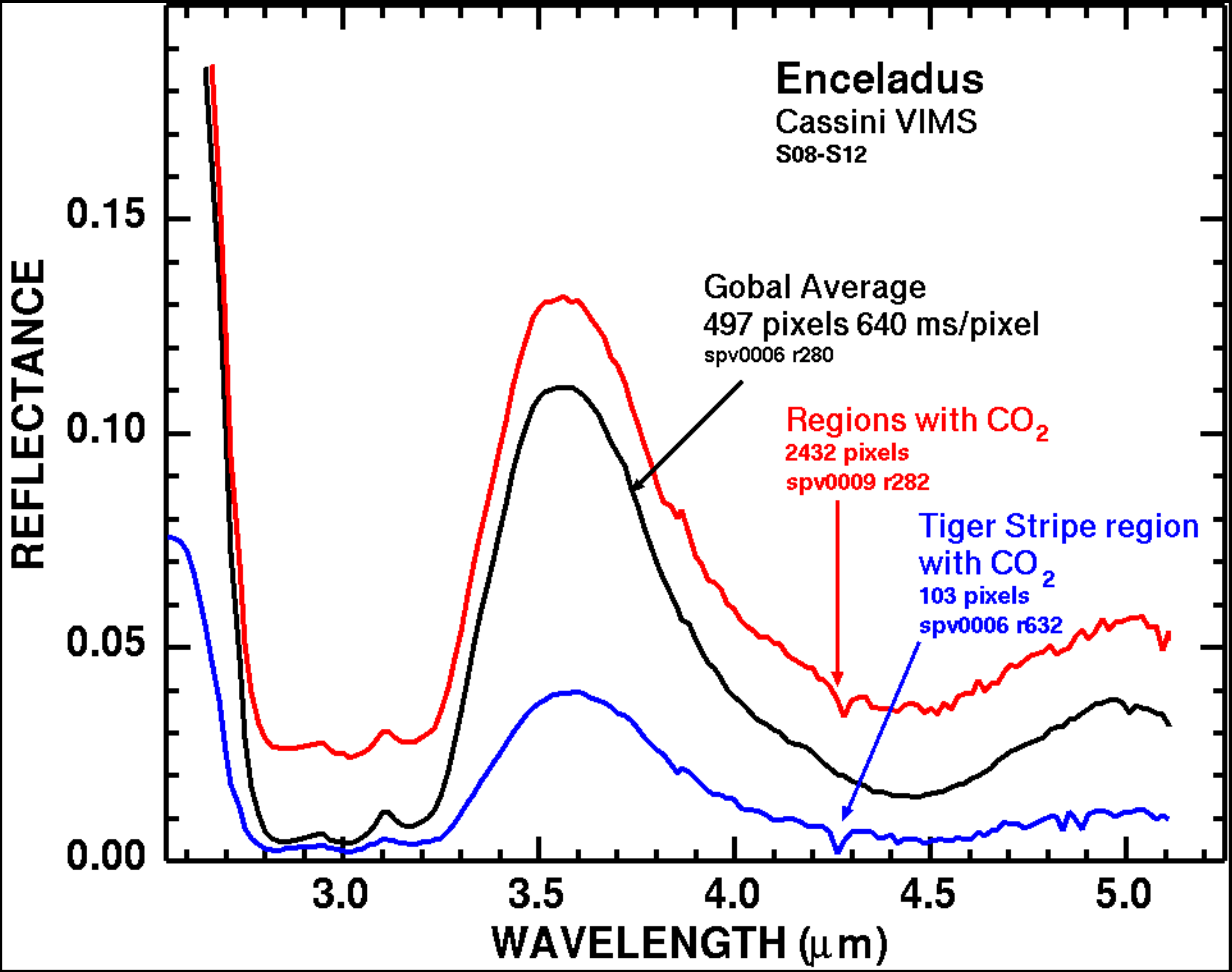


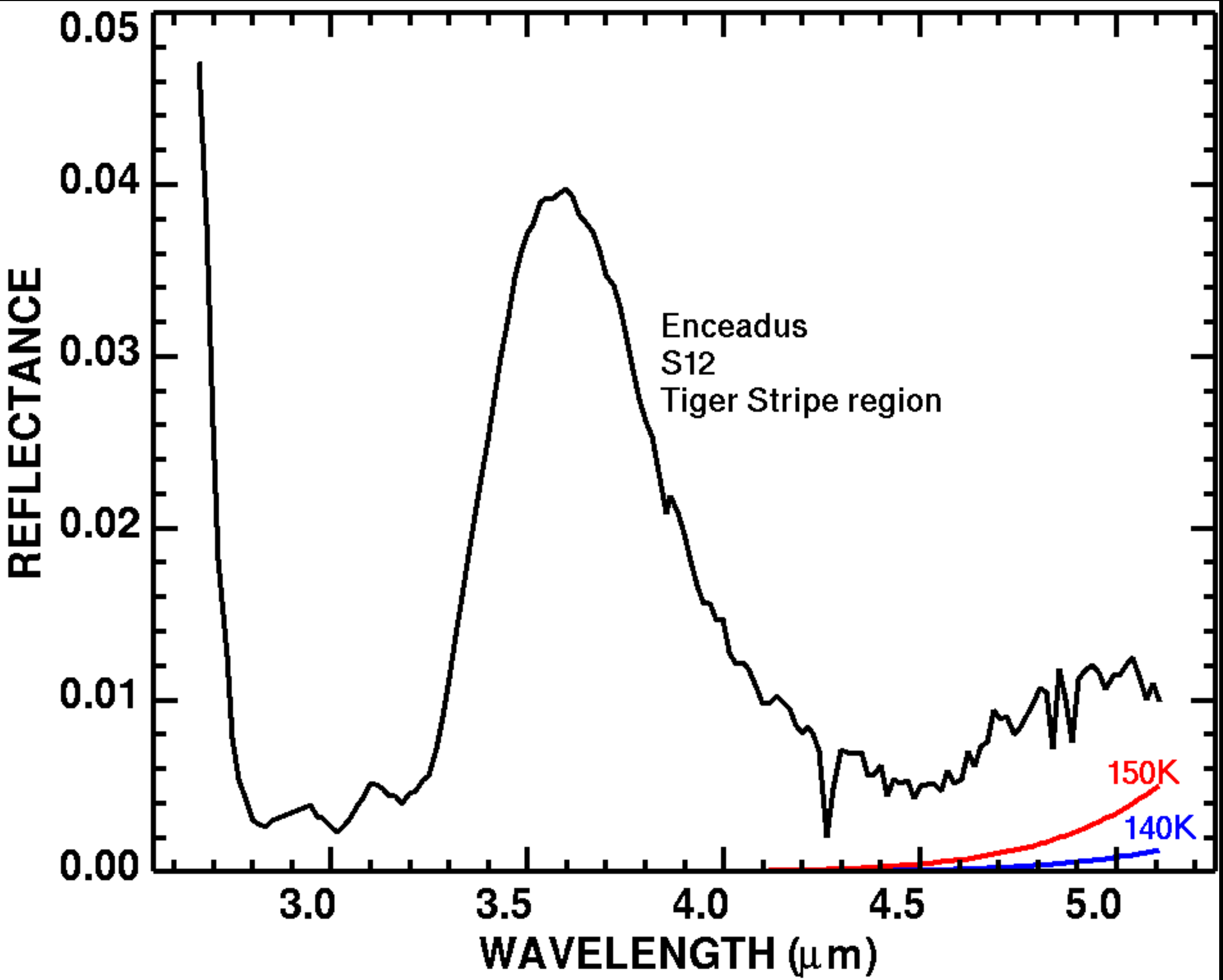
Plume particle size modeling



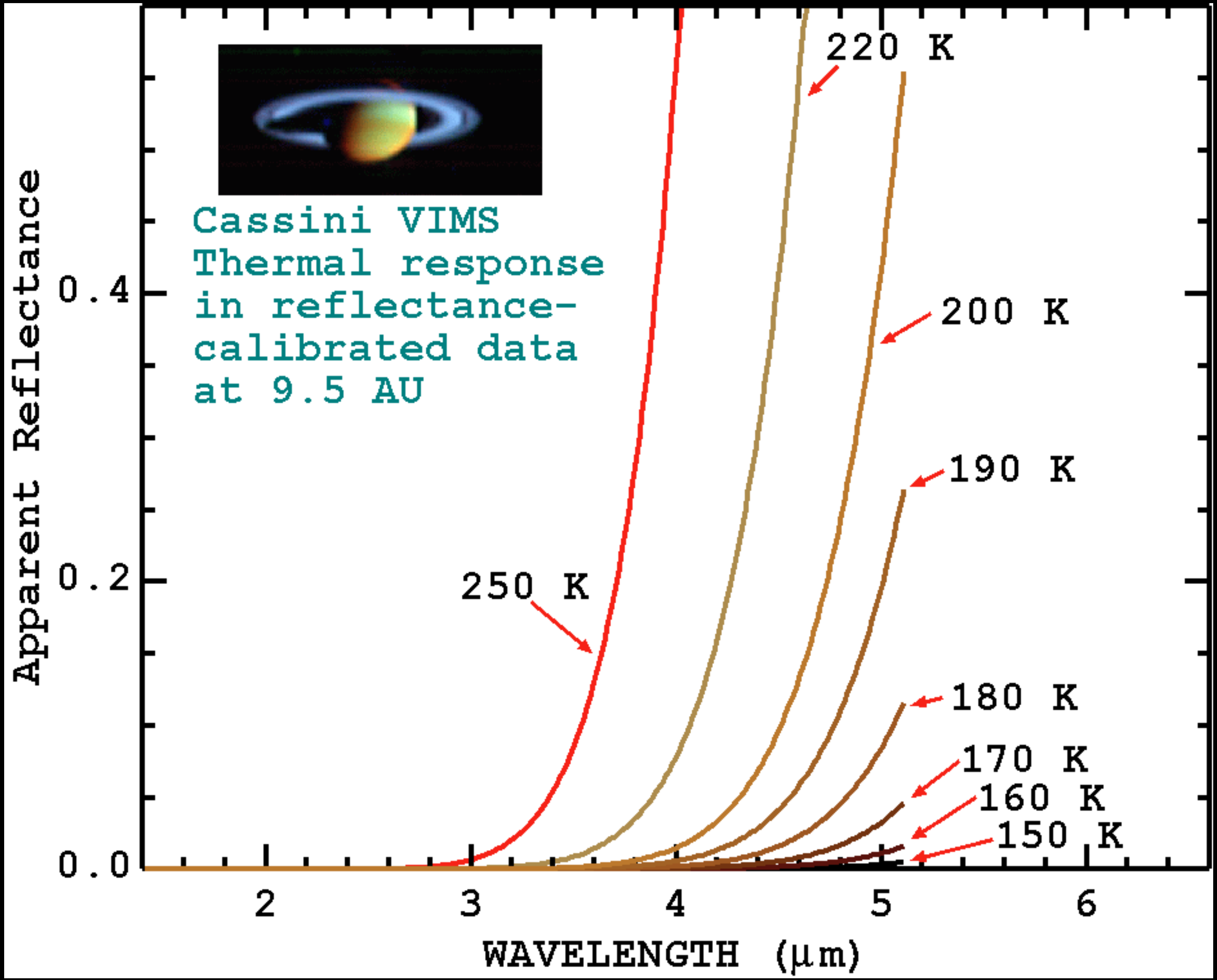


From Matt Hedman


Enceladus
Cassini VIMS
S08-S12
Gobal Average
497 pixels 640 ms/pixel
spv0006 r280
Regions with CO_2
2432 pixels
spv0009 r282
Tiger Stripe region
with CO_2
103 pixels
spv0006 r632
REFLECTANCE
0.15
0.10
0.05
0.00
3.0
3.5
4.0
4.5
5.0
WAVELENGTH (μm)



REFLECTANCE
0.05
0.04
0.03
0.02
0.01
0.00
3.0
3.5
4.0
4.5
5.0
WAVELENGTH (μm)
Enceadus
S12
Tiger Stripe region
150K
140K

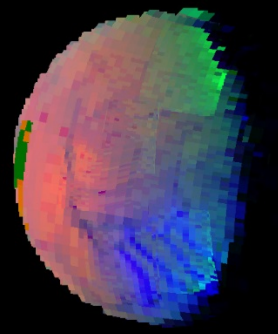

Cassini VIMS
Thermal response
in reflectance-
calibrated data
at 9.5 AU
Apparent Reflectance
0.0
0.2
0.4
2
3
4
5
6
WAVELENGTH (μm)
250 K
220 K
200 K
190 K
180 K
170 K
160 K
150 K

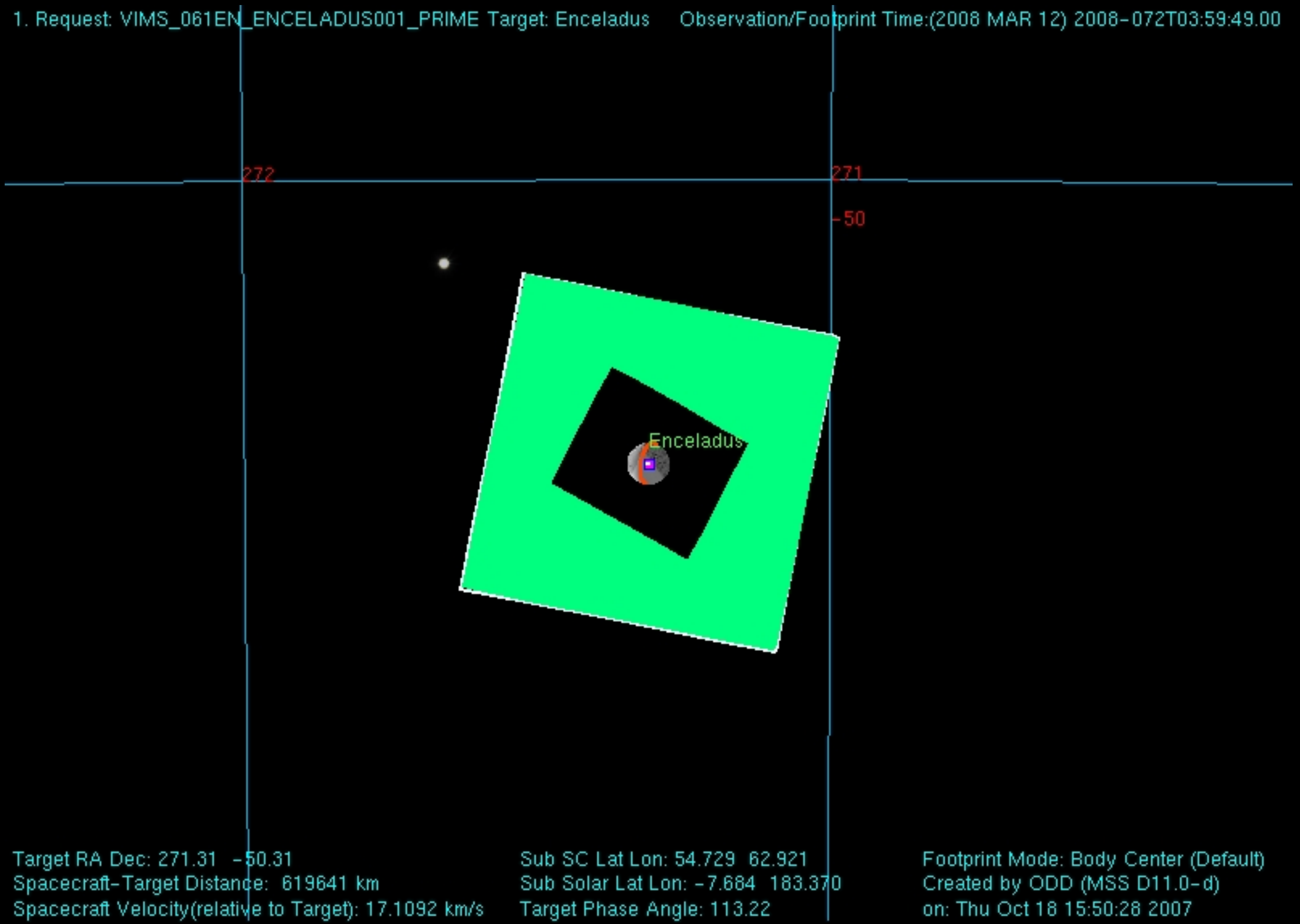
Rev 61 Observations

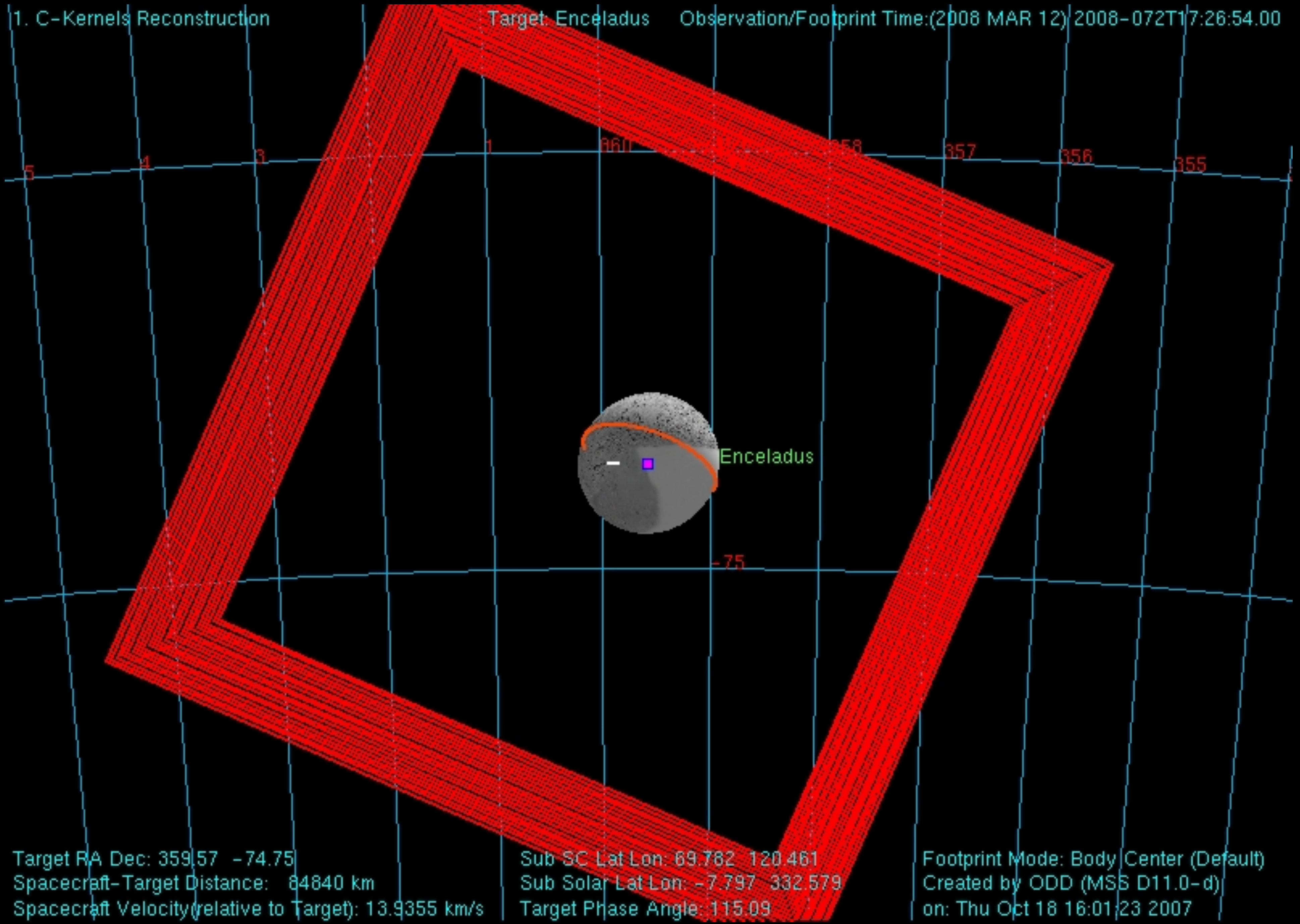
Rev 61: VIMS has only 2 prime Enceladus observations, all at a great distance.

Point and stares.

VIMS rides on other observations.

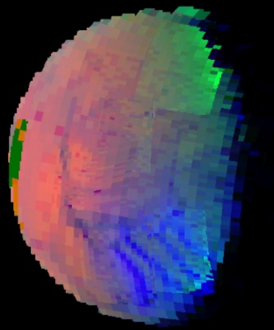



1. Request: VIMS_061EN_ENCELADUS001_PRIME Target: Enceladus
Observation/Footprint Time:(2008 MAR 12) 2008-072T03:59:49.00
272
271
-50
Enceladus
Target RA Dec: 271.31 -50.31
Spacecraft-Target Distance: 619641 km
Spacecraft Velocity(relative to Target): 17.1092 km/s
Sub SC Lat Lon: 54.729 62.921
Sub Solar Lat Lon: -7.684 183.370
Target Phase Angle: 113.22
Footprint Mode: Body Center (Default)
Created by ODD (MSS D11.0-d)
on: Thu Oct 18 15:50:28 2007



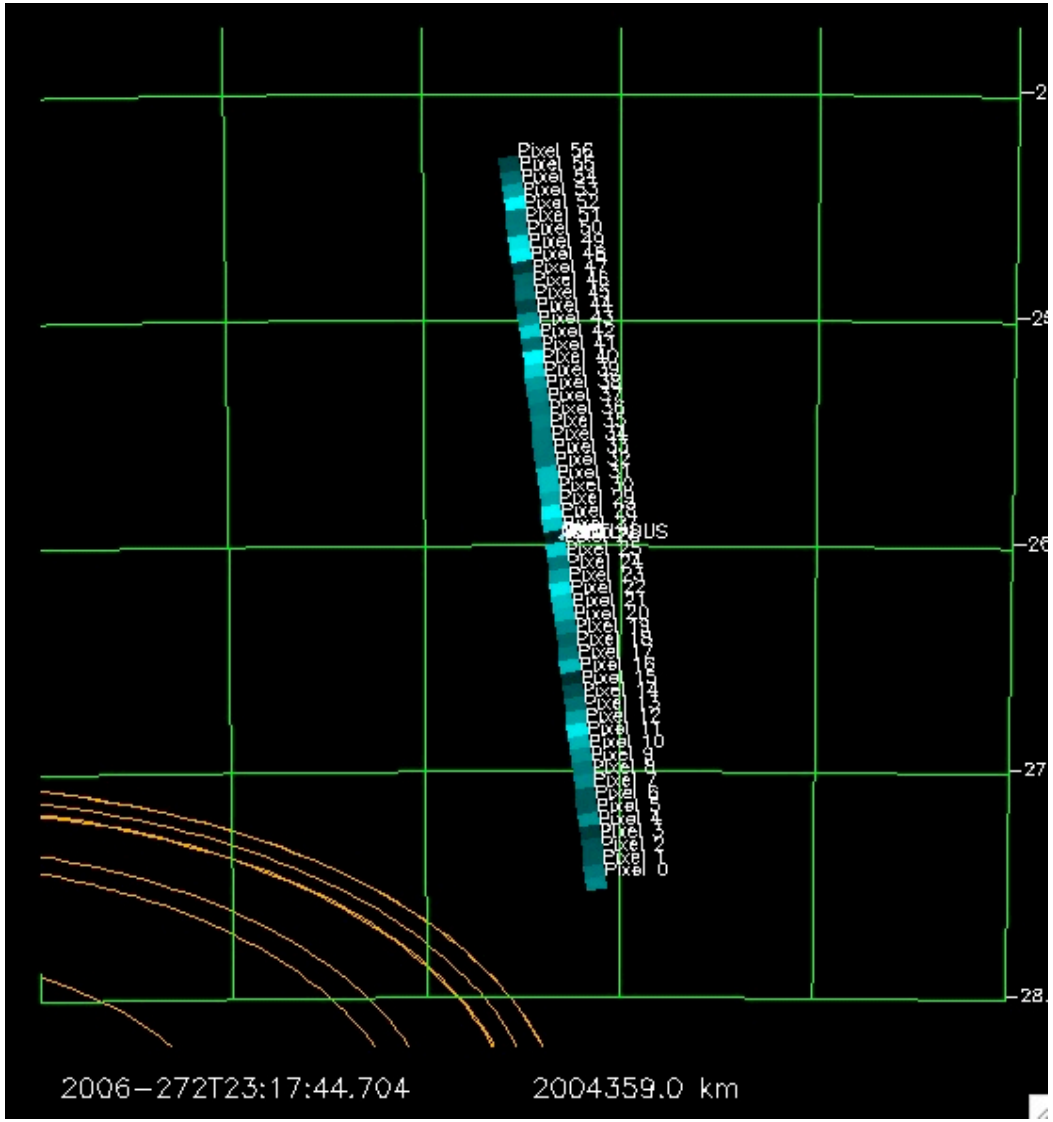
1. C-Kernels Reconstruction
Target: Enceladus
Observation/Footprint Time:(2008 MAR 12) 2008-072T17:26:54.00
5
4
3
1
360
358
357
356
355
Enceladus
-75
Target RA Dec: 359.57 -74.75
Spacecraft-Target Distance: 84840 km
Spacecraft Velocity(relative to Target): 13.9355 km/s
Sub SC Lat Lon: 69.782 120.461
Sub Solar Lat Lon: -7.797 332.579
Target Phase Angle: 115.09
Footprint Mode: Body Center (Default)
Created by ODD (MSS D11.0-d)
on: Thu Oct 18 16:01:23 2007

Conclusions

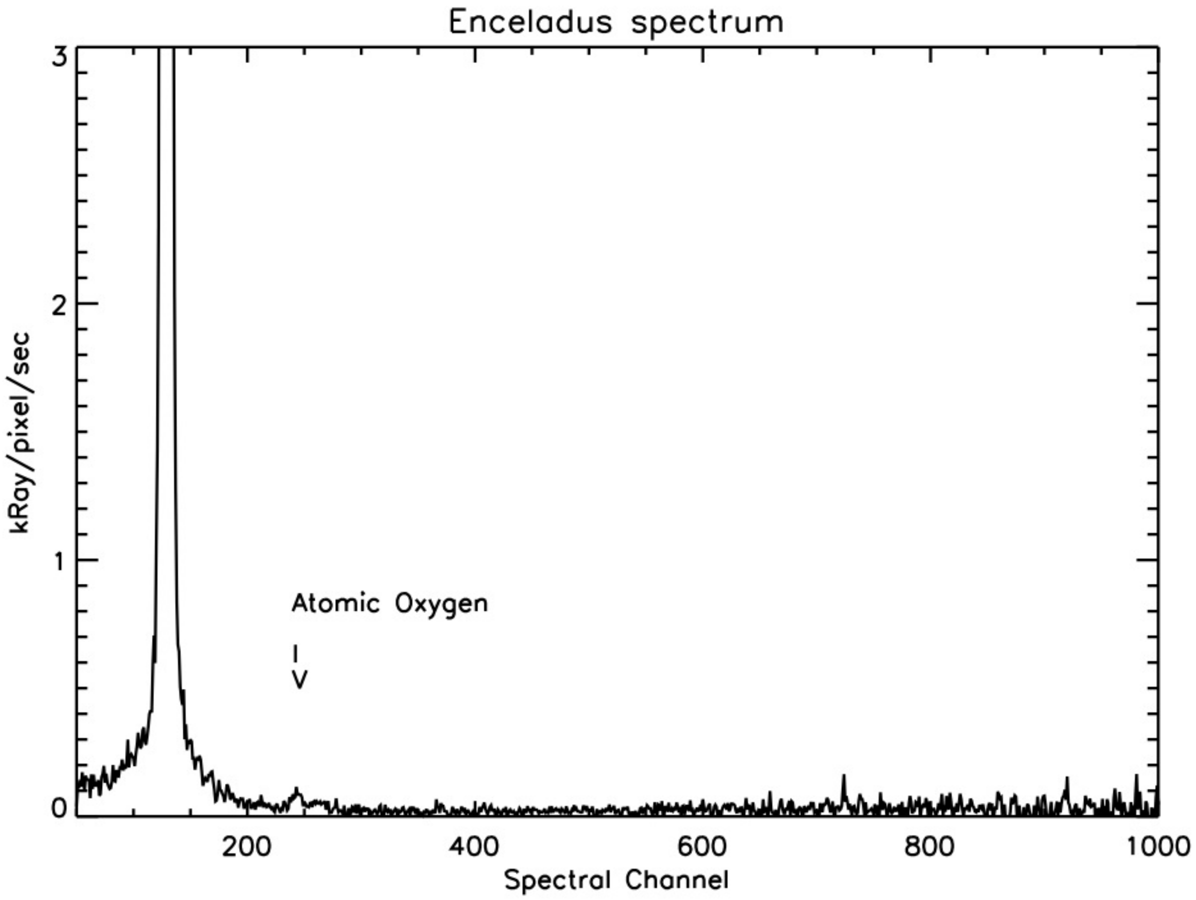


- VIMS Compositional and thermal mapping is critical to understanding the origins of Enceladus and its plumes.
- VIMS will map:
  - Water ice grain size and ice crystal structure.
  - CO_2
  - CH (organics).
  - Ammonia (NH_3).
  - Clathrates.
  - Fine grained iron powder.
  - Search for other compounds.
  - Rayleigh scattering is caused by tiny particles causing a blue reflectance peak.
  - Thermal hot spots.

Enceladus Volatiles



Comparative spectra
2006 DOY 272



Comparative Spectra
2007 DOY 102