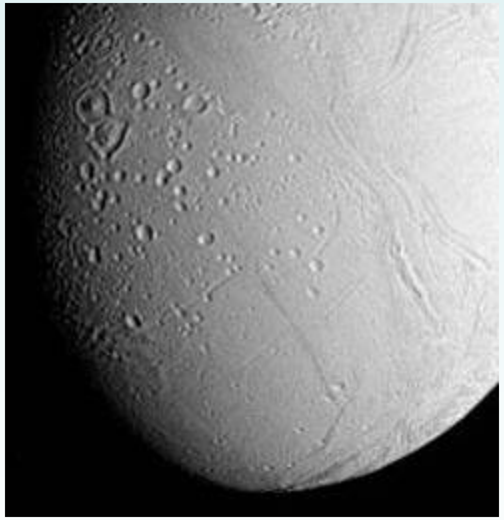
Overview of Rev 88 and 91 Enceladus flybys (E5 and E6): into the plume and over the South Pole



Bonnie Buratti, Amanda Hendrix, Rosaly Lopes, and Nora Kelly

"The SOST Leadership"

Oct. 3, 2008 preview

XM Enceladus Flyby Summary

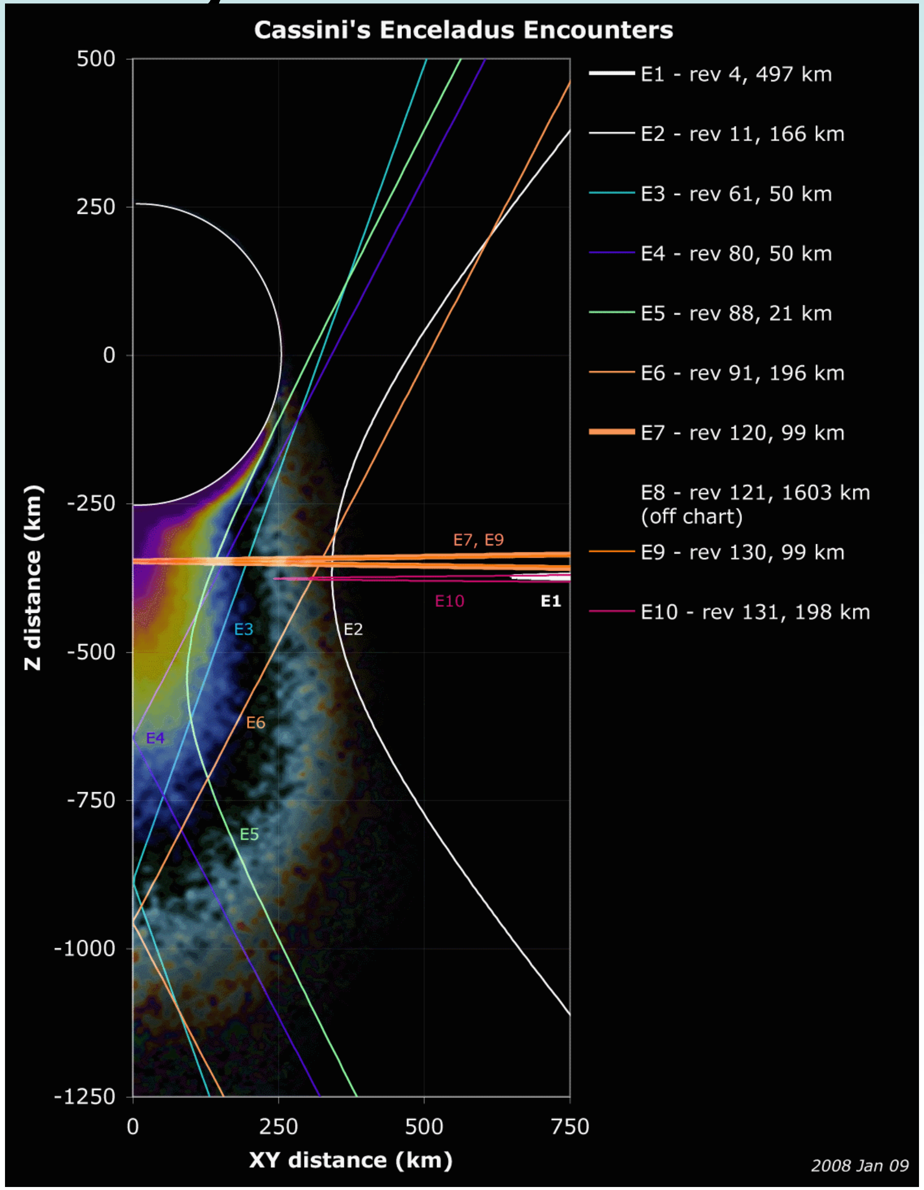
Date	rev	Speed km/s	Altitude (km)	Orbit Inclination	C/A science emphasis
12-Mar-2008	61	14.3	50	High	Plume sampling **E3**
11-Aug-2008	80	17.7	50	High	S. pole remote sensing **E4**
9-Oct-2008	**88**	**17.7**	**21**	**High**	**Plume sampling** **E5**
31-Oct-2008	**91**	**17.7**	**196**	**High**	**S. pole remote sensing** **E6**
2-Nov-2009	120	7.7	96	Low	Plume sampling **E7**
21-Nov-2009	121	7.7	1560	Low	S. pole remote sensing **E8**
28-Apr-2010	130	6.5	96	Low	S. pole gravity **E9**
18-May-2010	131	7	246	Low	Plume solar occultation **E10**

Adapted from John Spencer

Note: The Rev 91 flyby (E6) is not targeted.

Trajectory

- Rev 88 involves a passage into the plume to optimize MAPS objectives
- Rev 91 involves a passage over the south pole to investigate the nature and variability of the active areas with ORS instruments

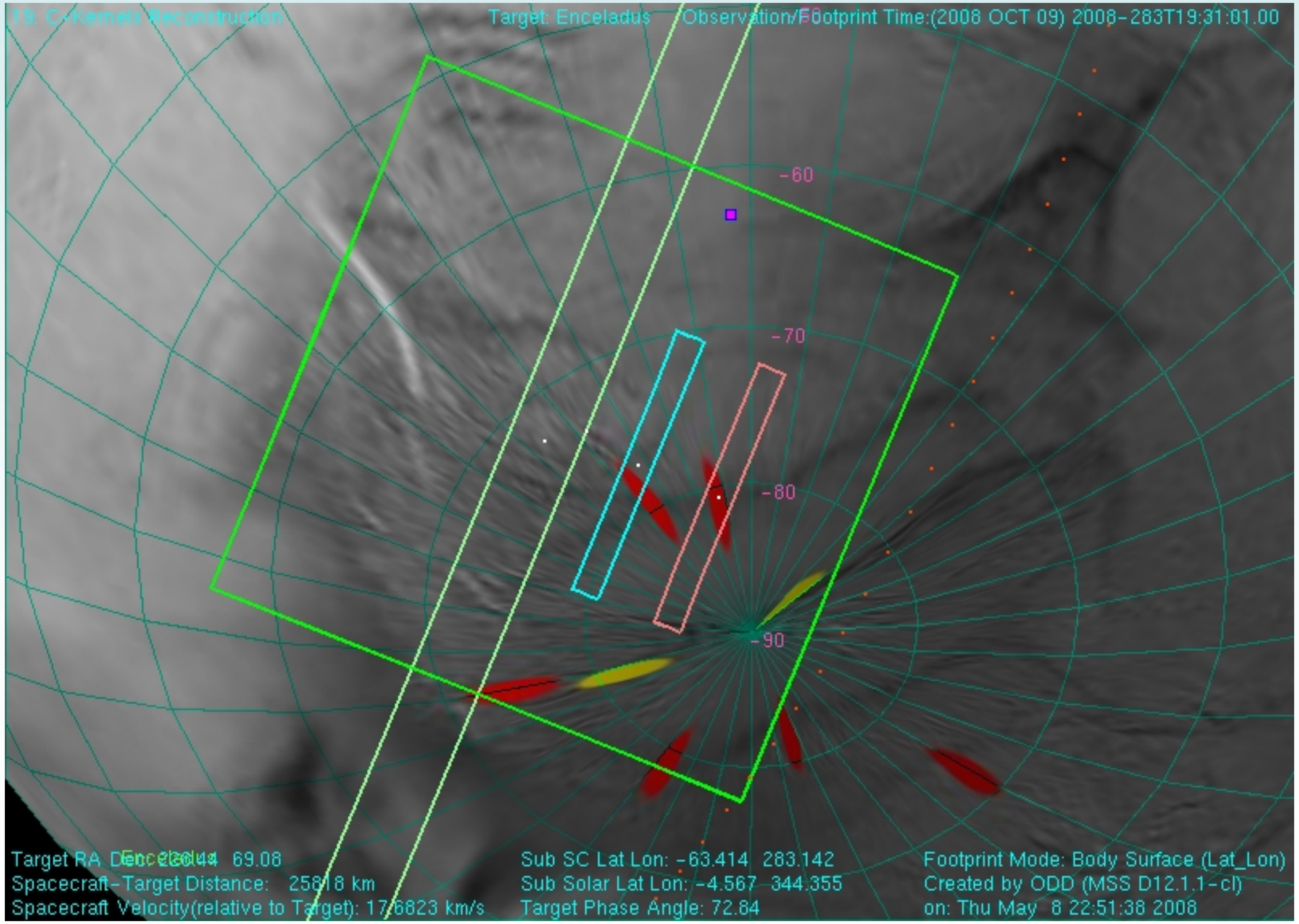


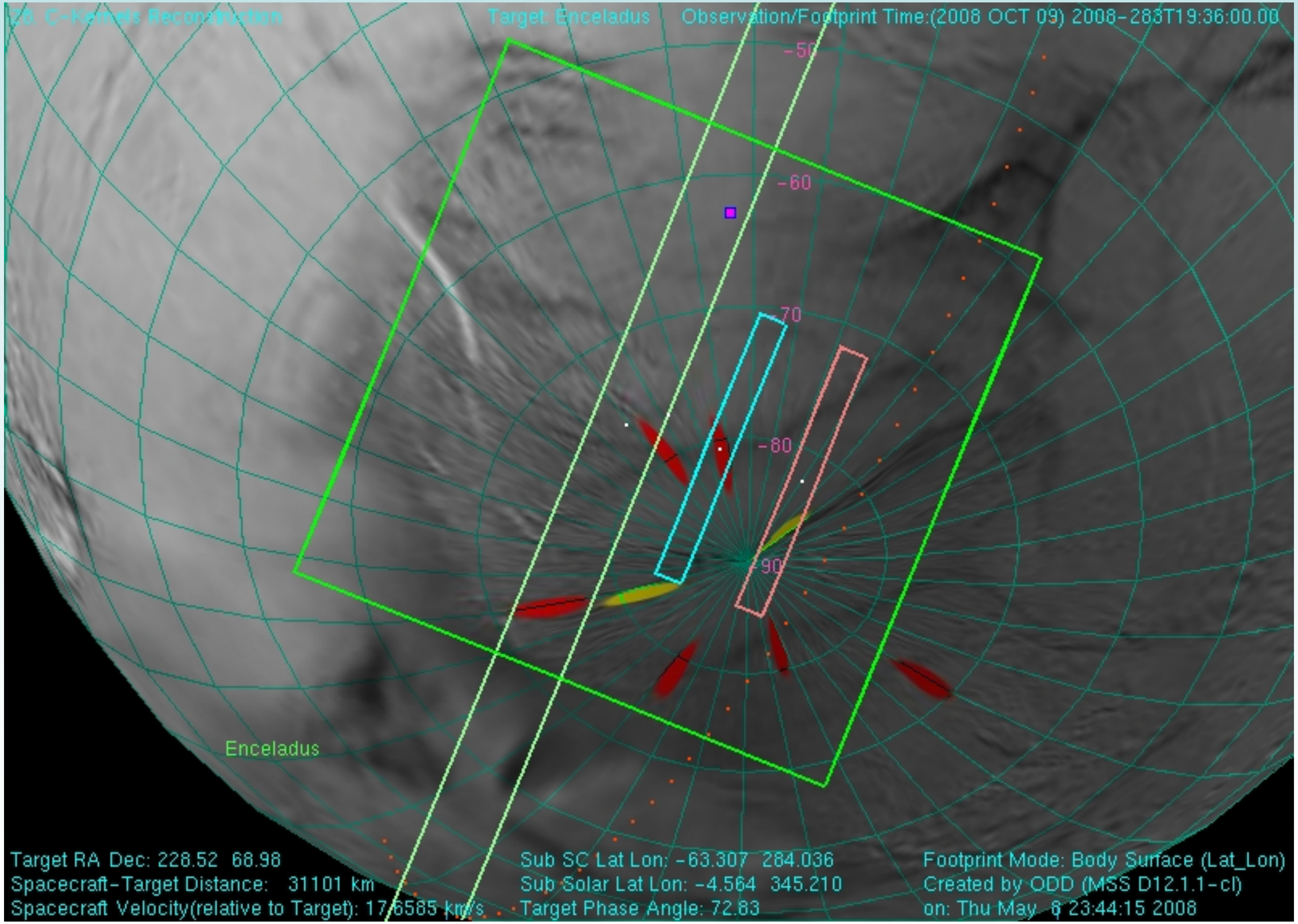
Main scientific objectives (E5)

- Radar scatterometry 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 ~20 km from the surface to determine the nature of the material coming from the plumes, its relationship to the E-ring, and the mechanism for its release
- CIRS observations of the warm-up after solar eclipse to determine the heat capacity and textural properties of the regolith
- ISS global and regional imaging to determine global geology, context for other observations, and possible changes
- Search for variability in the plumes and particle environment

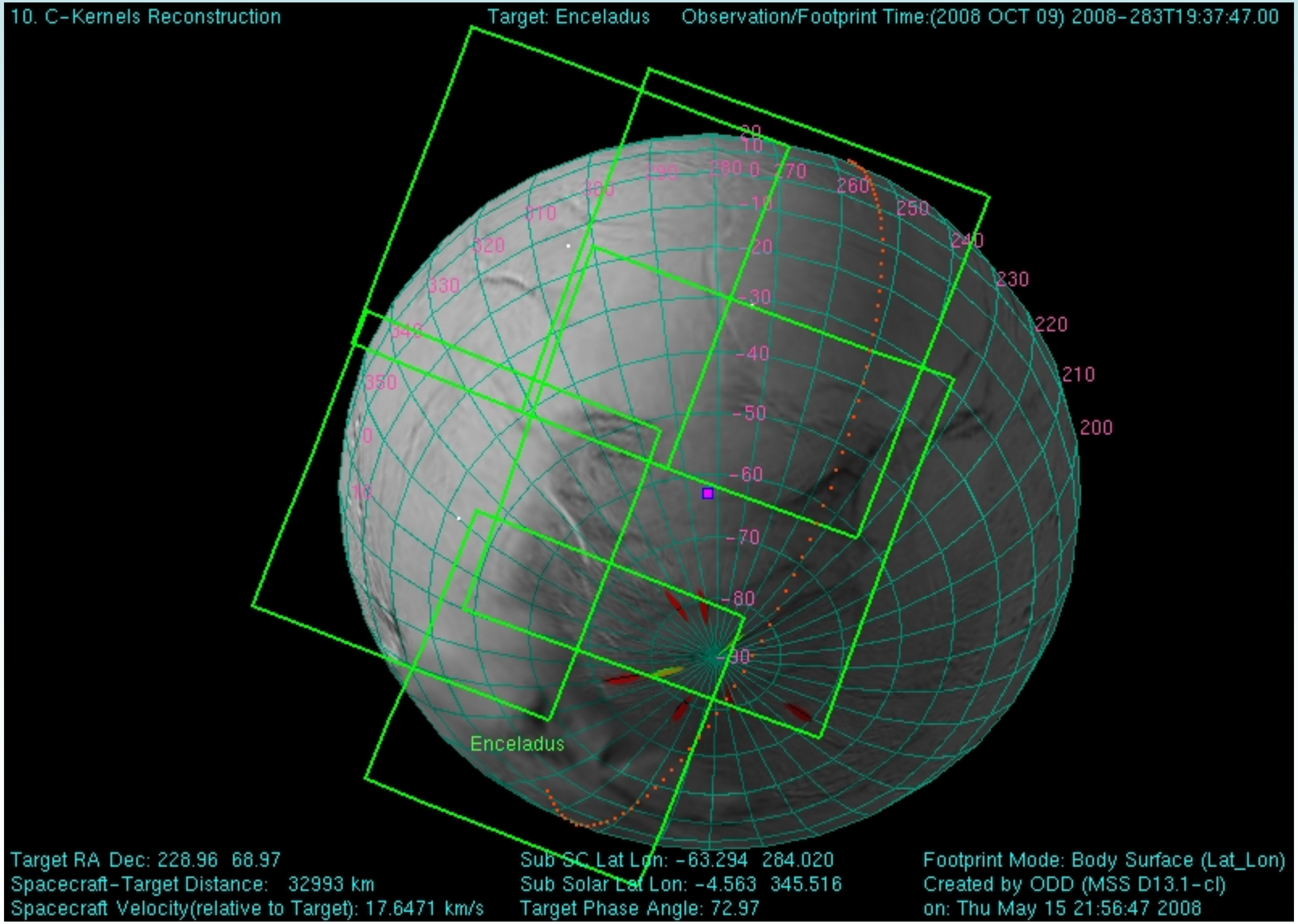
Main scientific objectives (E6)

- Radar scatterometry 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; determination of upper limits on the temperature of the plumes
- MAPS examination of the particle environment at ~200 km from the surface to determine the nature of the material coming from the surface, its relationship to the E-ring, the mechanism for its expulsion, and the size distribution of the particles with distance from the vent.
- ISS meter-scale imaging of the tiger stripes to determine their nature and the mechanism for plume activity; global and regional mapping to determine the geologic history of Enceladus including the existence of possible remnant tiger stripes
- CIRS observations of the warm-up after solar eclipse to determine the heat capacity and textural properties of the regolith; observations of hot spots to determine their temperature and detection of any changes from the previous flyby
- Search for variability in the plumes and particle environment


19. C-Kernels Reconstruction
Target: Enceladus
Observation/Footprint Time:(2008 OCT 09) 2008-283T19:31:01.00
-60
-70
-80
-90
Spacecraft-Target Distance: 25818 km
Spacecraft Velocity(relative to Target): 17.6823 km/s
Sub SC Lat Lon: -63.414 283.142
Sub Solar Lat Lon: -4.567 344.355
Target Phase Angle: 72.84
Footprint Mode: Body Surface (Lat_Lon)
Created by ODD (MSS D12.1.1-cl)
on: Thu May 8 22:51:38 2008



ZB: C-Kernels Reconstruction
Target: Enceladus
Observation/Footprint Time:(2008 OCT 09) 2008-283T19:36:00.00
-50
-60
-70
-80
-90
Enceladus
Target RA Dec: 228.52 68.98
Spacecraft-Target Distance: 31101 km
Spacecraft Velocity(relative to Target): 17.6585 km/s
Sub SC Lat Lon: -63.307 284.036
Sub Solar Lat Lon: -4.564 345.210
Target Phase Angle: 72.83
Footprint Mode: Body Surface (Lat_Lon)
Created by ODD (MSS D12.1.1-cl)
on: Thu May 6 23:44:15 2008


10. C-Kernels Reconstruction
Target: Enceladus
Observation/Footprint Time:(2008 OCT 09) 2008-283T19:37:47.00
Enceladus
Target RA Dec: 228.96 68.97
Spacecraft-Target Distance: 32993 km
Spacecraft Velocity(relative to Target): 17.6471 km/s
Sub SC Lat Lon: -63.294 284.020
Sub Solar Lat Lon: -4.563 345.516
Target Phase Angle: 72.97
Footprint Mode: Body Surface (Lat_Lon)
Created by ODD (MSS D13.1-cl)
on: Thu May 15 21:56:47 2008

Rev. 88, 91 CIRS Enceladus Preview

John Spencer, John Pearl,
Marcia Segura

October 2nd 2008

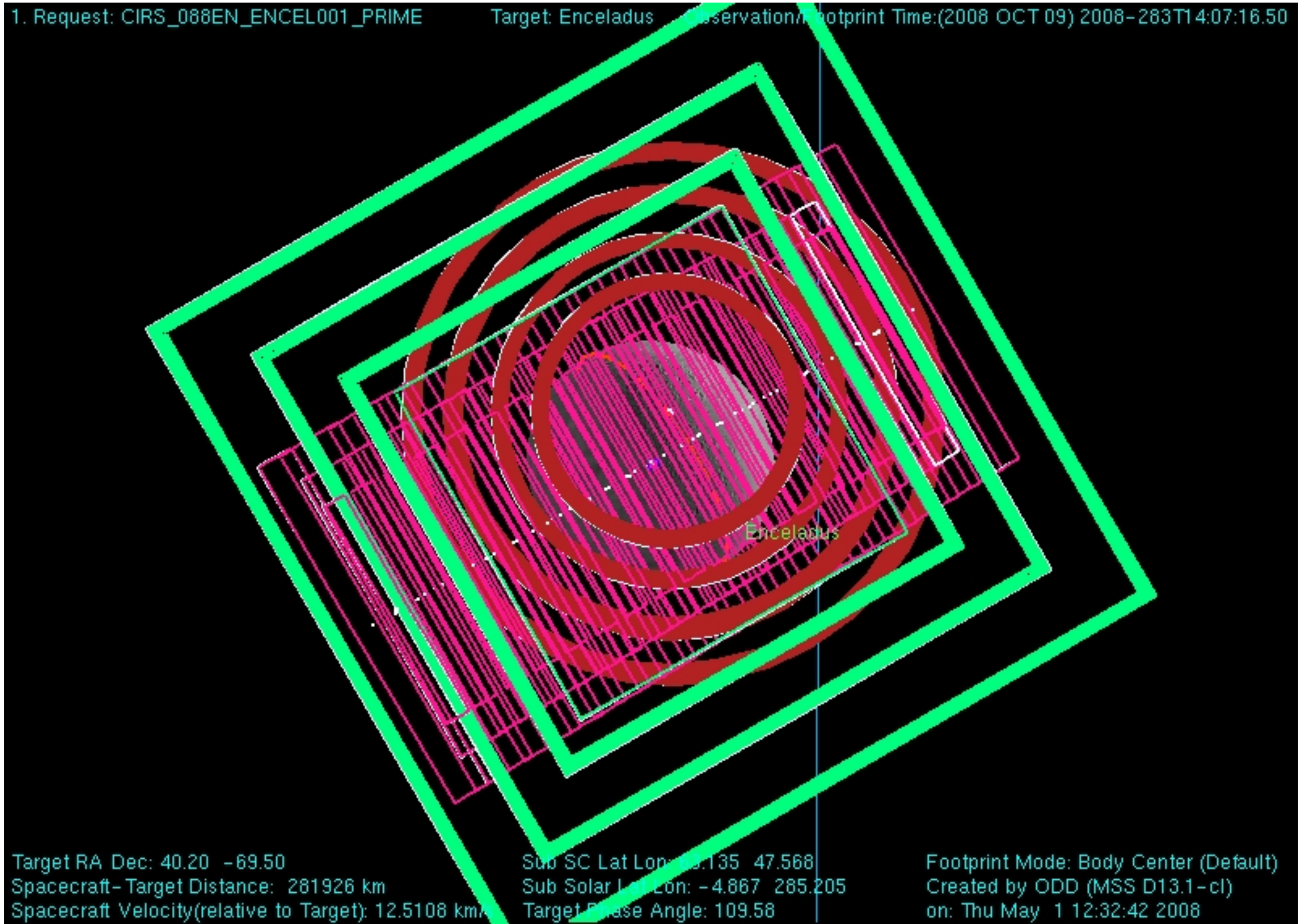
Rev. 88, 91 CIRS Enceladus Preview

John Spencer, John Pearl,
Marcia Segura

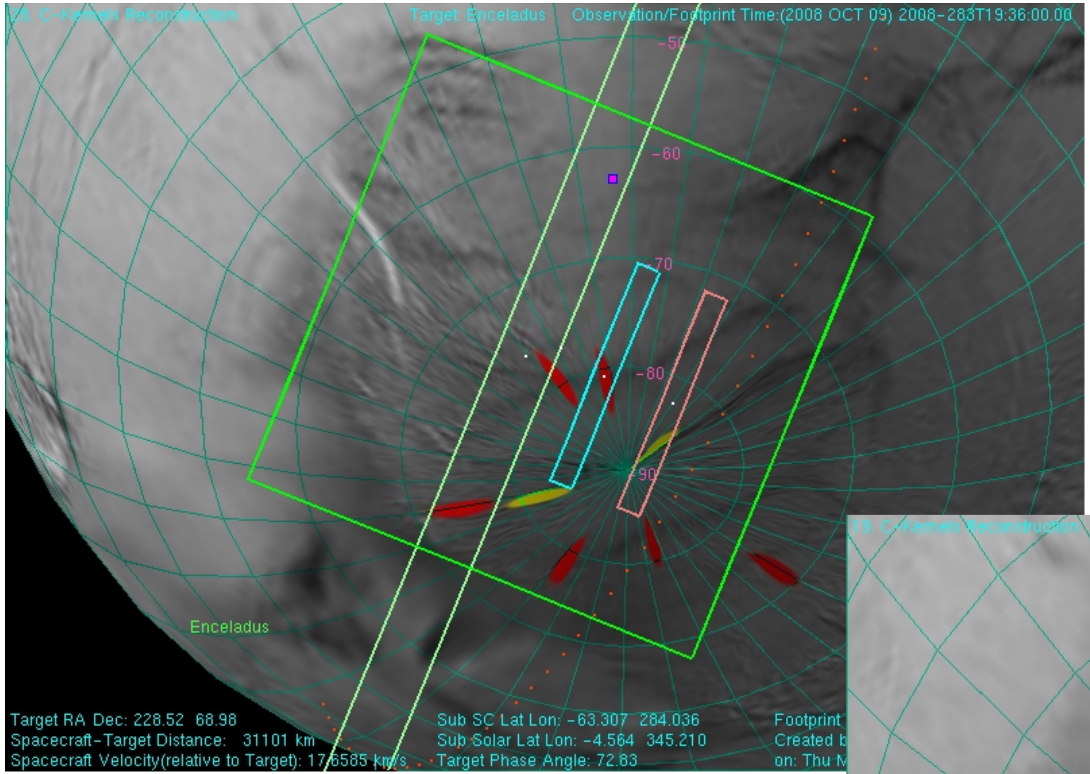
October 2nd 2008

CIRS_088EN_ENCEL001_PRIME

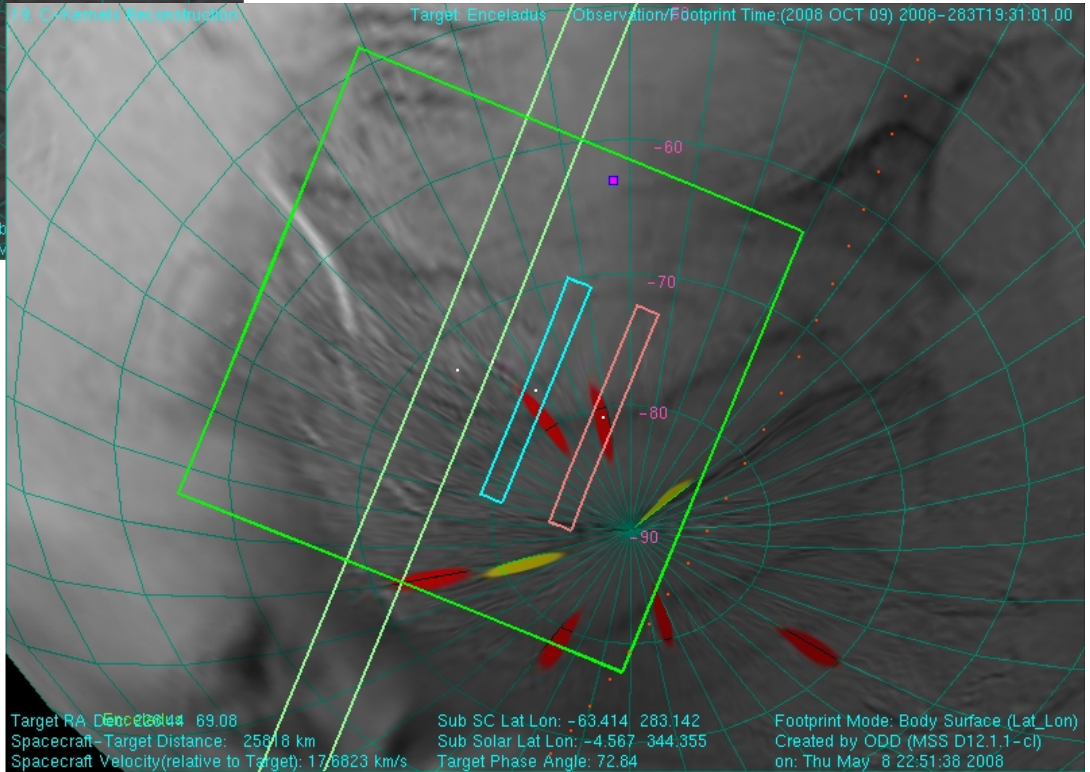
- Successive FP1 stares, FP3 scans, NAC stares



ISS_088EN_ENCELCA001

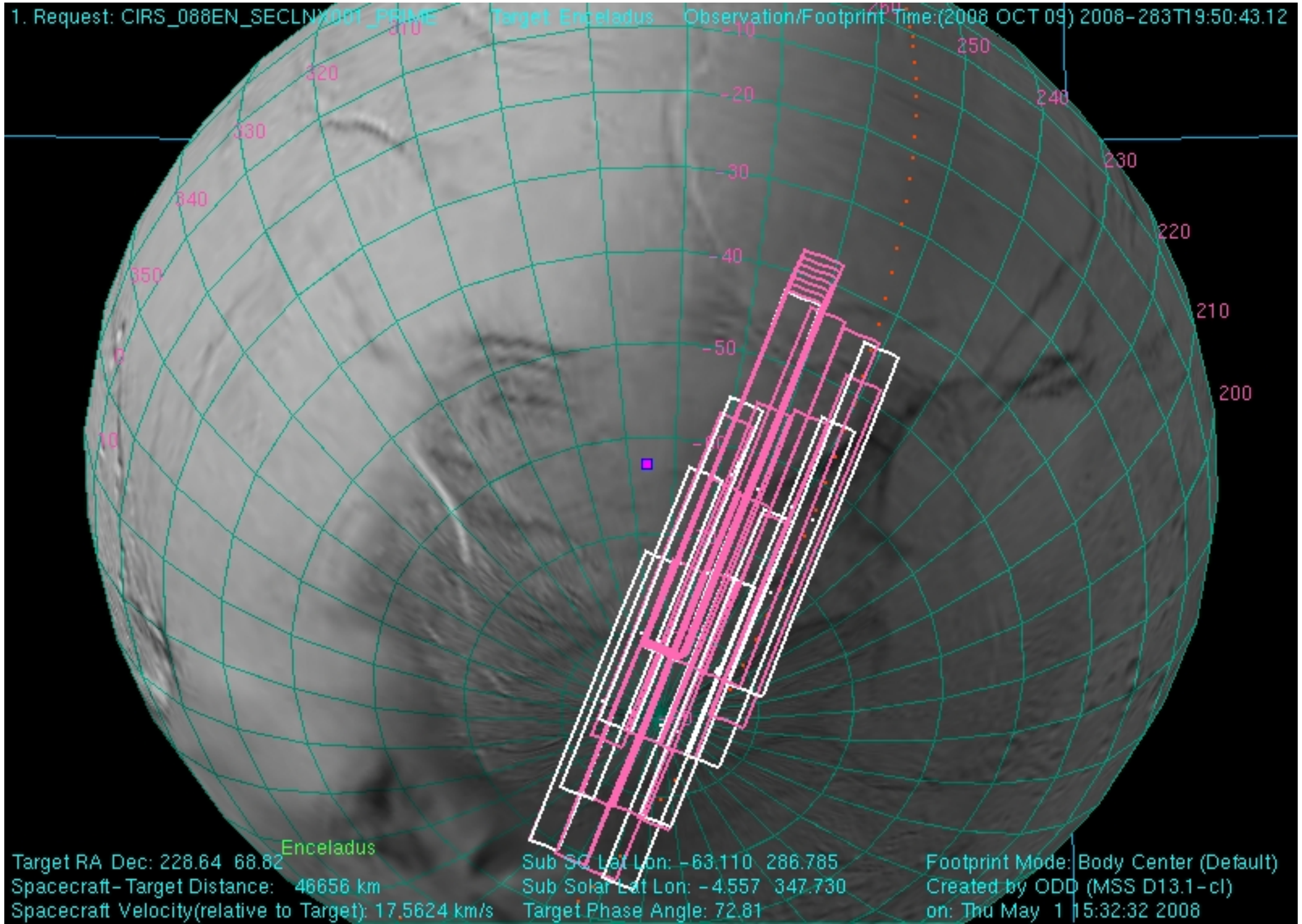


- 19:31 - 19:36
- FP3, FP4 on plume source III, Damascus Sulcus
- 7.5 - 9.0 km resolution



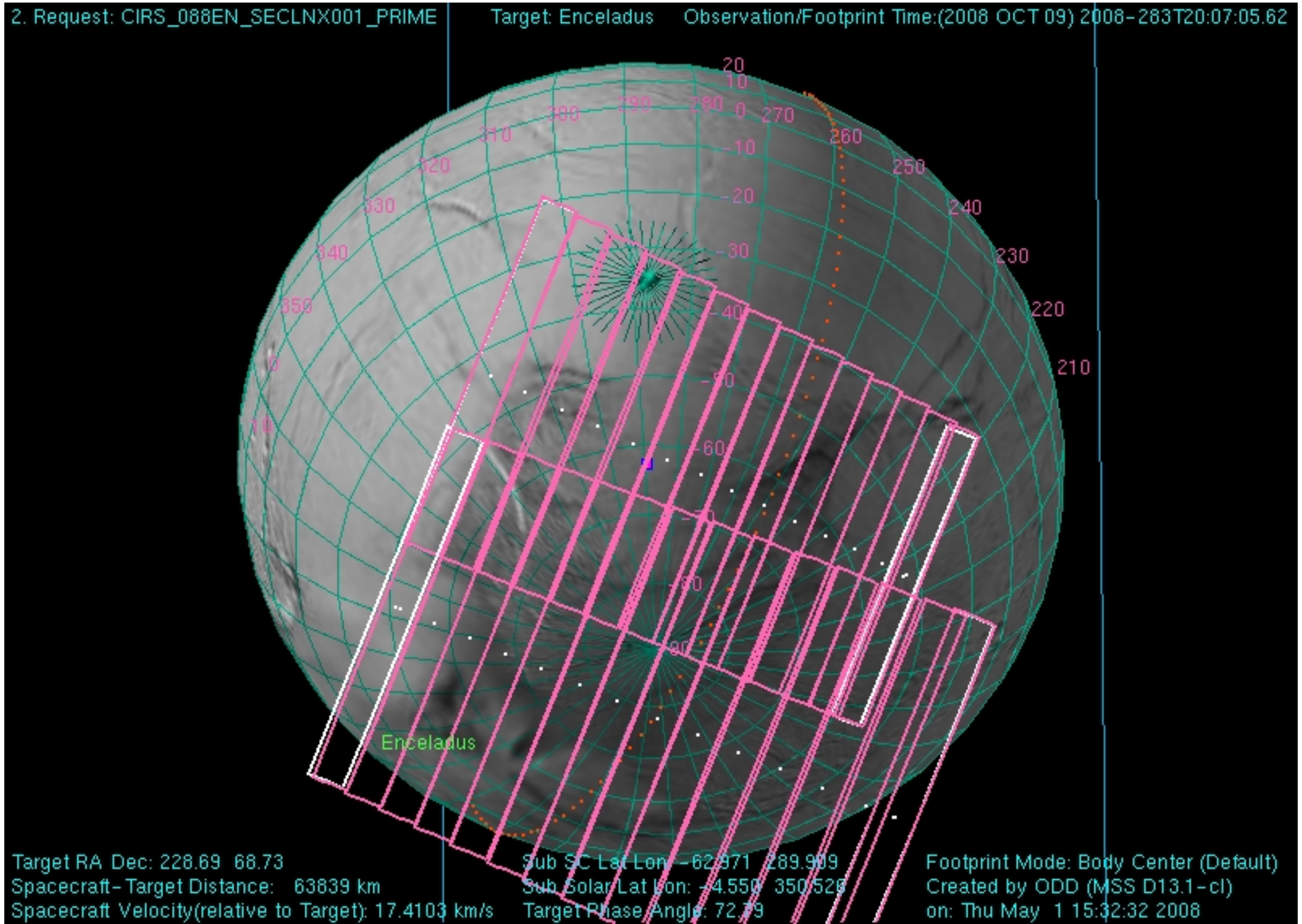
CIRS_088EN_SECLNX001

- Eclipse disappearance: 19:52
- 19:50 - 20:06: “Super-resolution” dither of Damascus and Baghdad



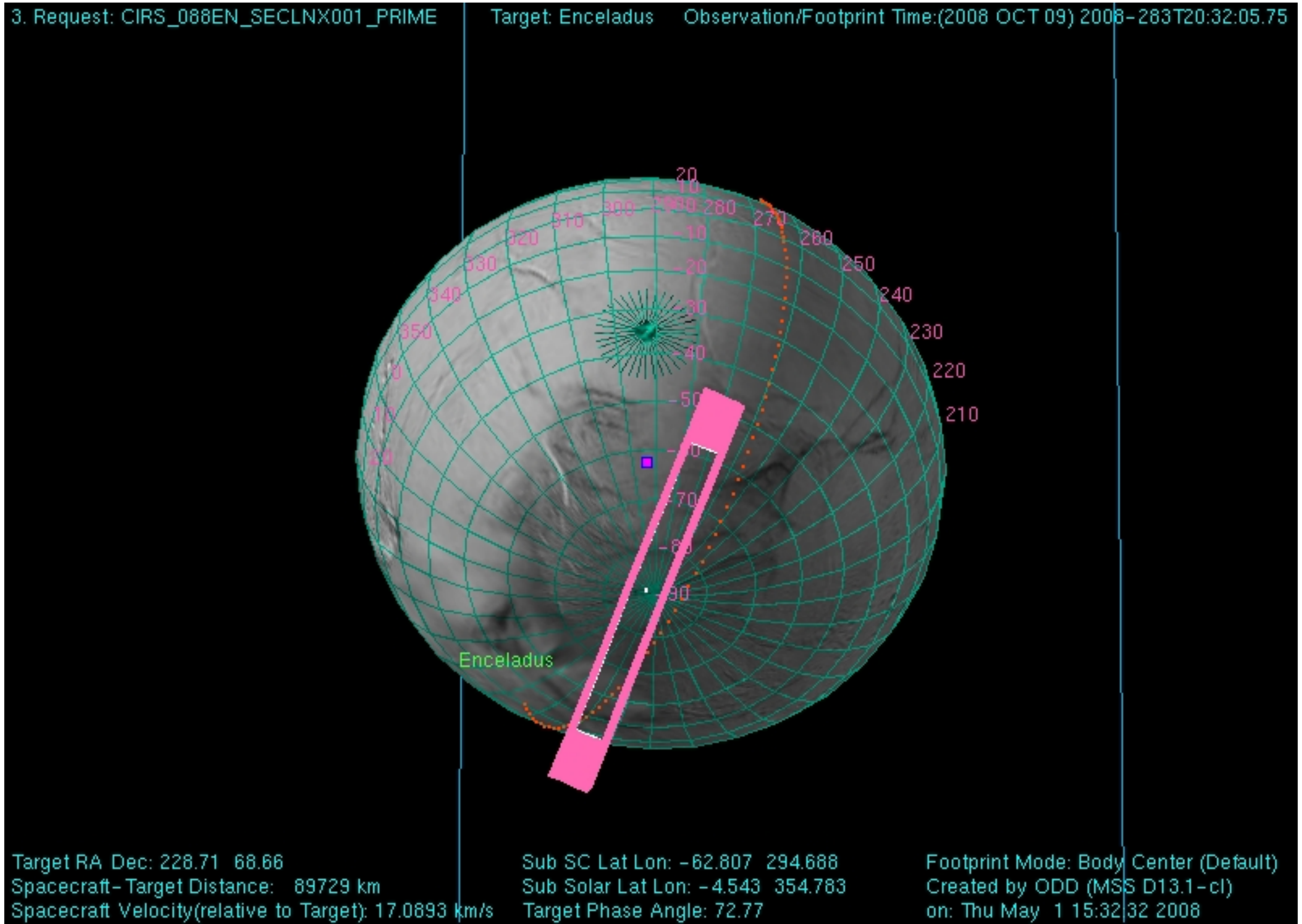
CIRS_088EN_SECLNX001

- 20:07- 20:31 2-swath scan of south pole at 6 μrad/sec
  - Fill in gaps in spatial coverage, look for time variability
  - 18 - 26 km resolution



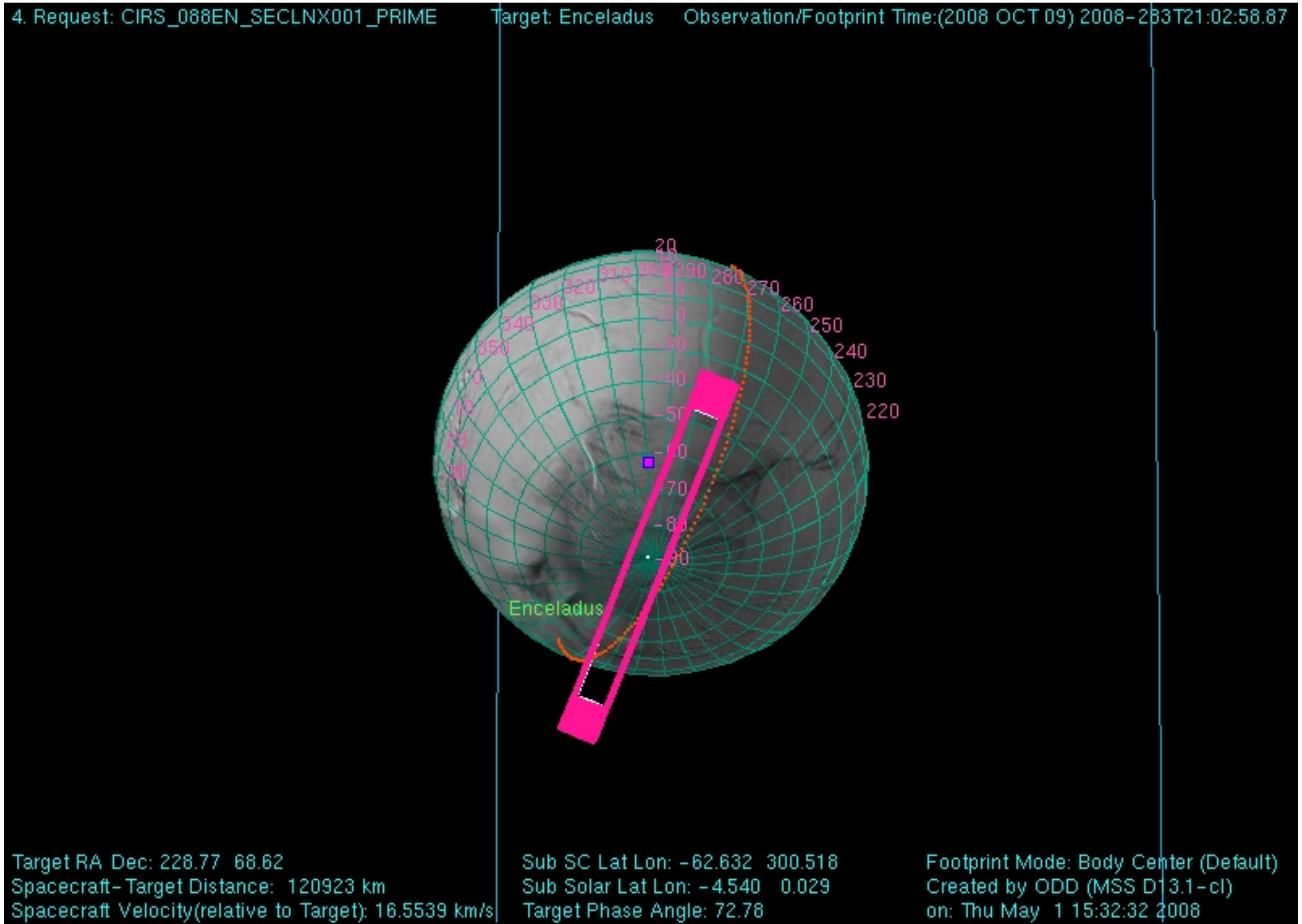
CIRS_088EN_SECLNX001

- 20:31-21:02 29-minute stare with FP4 at 88 S, 0 W
- Transition back to wheels occurs during this stare



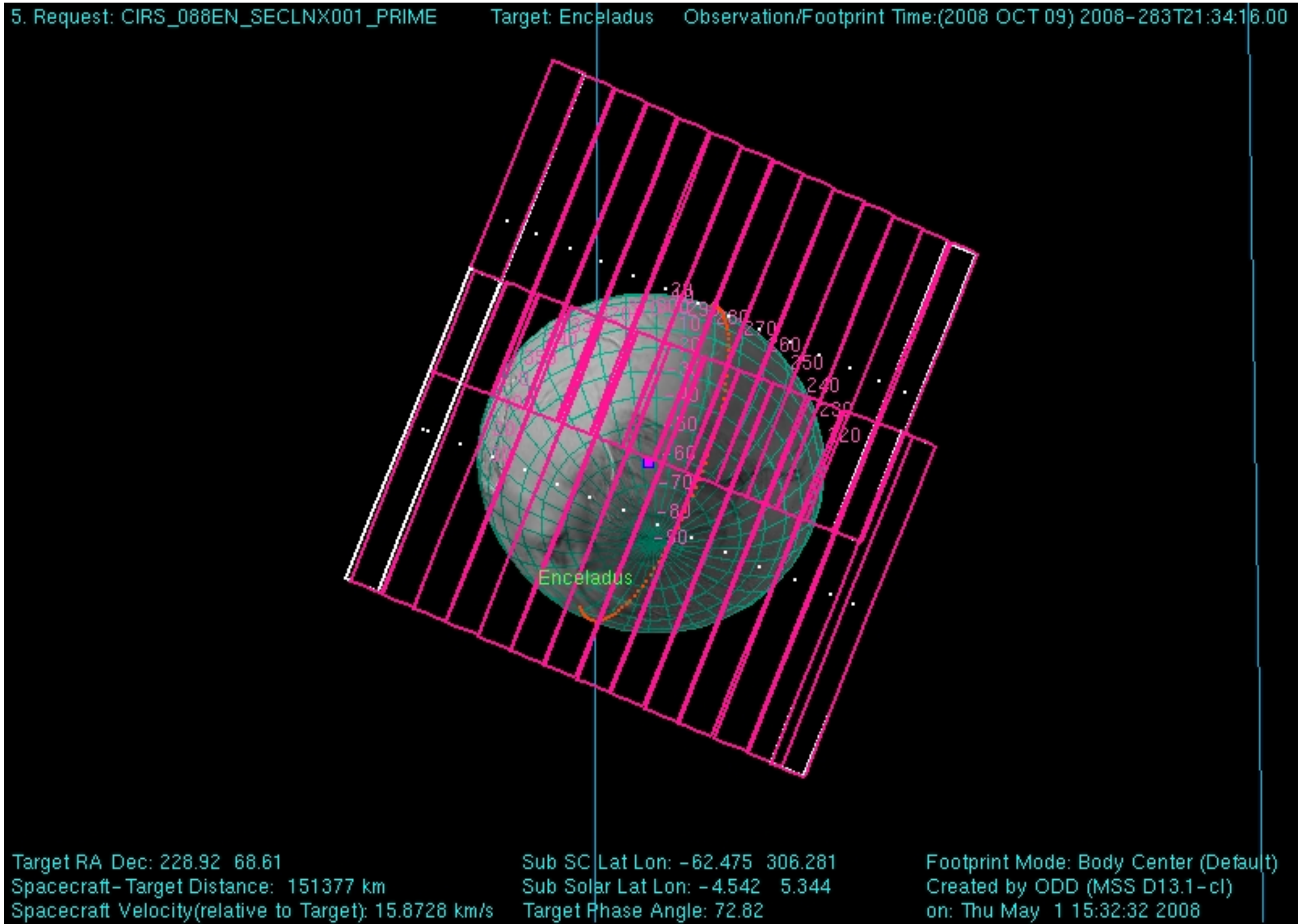
CIRS_088EN_SECLNX001

- 21:03 - 21:33 30-minute stare with FP3 at 88 S, 0 W
- NAC support image at 21:20



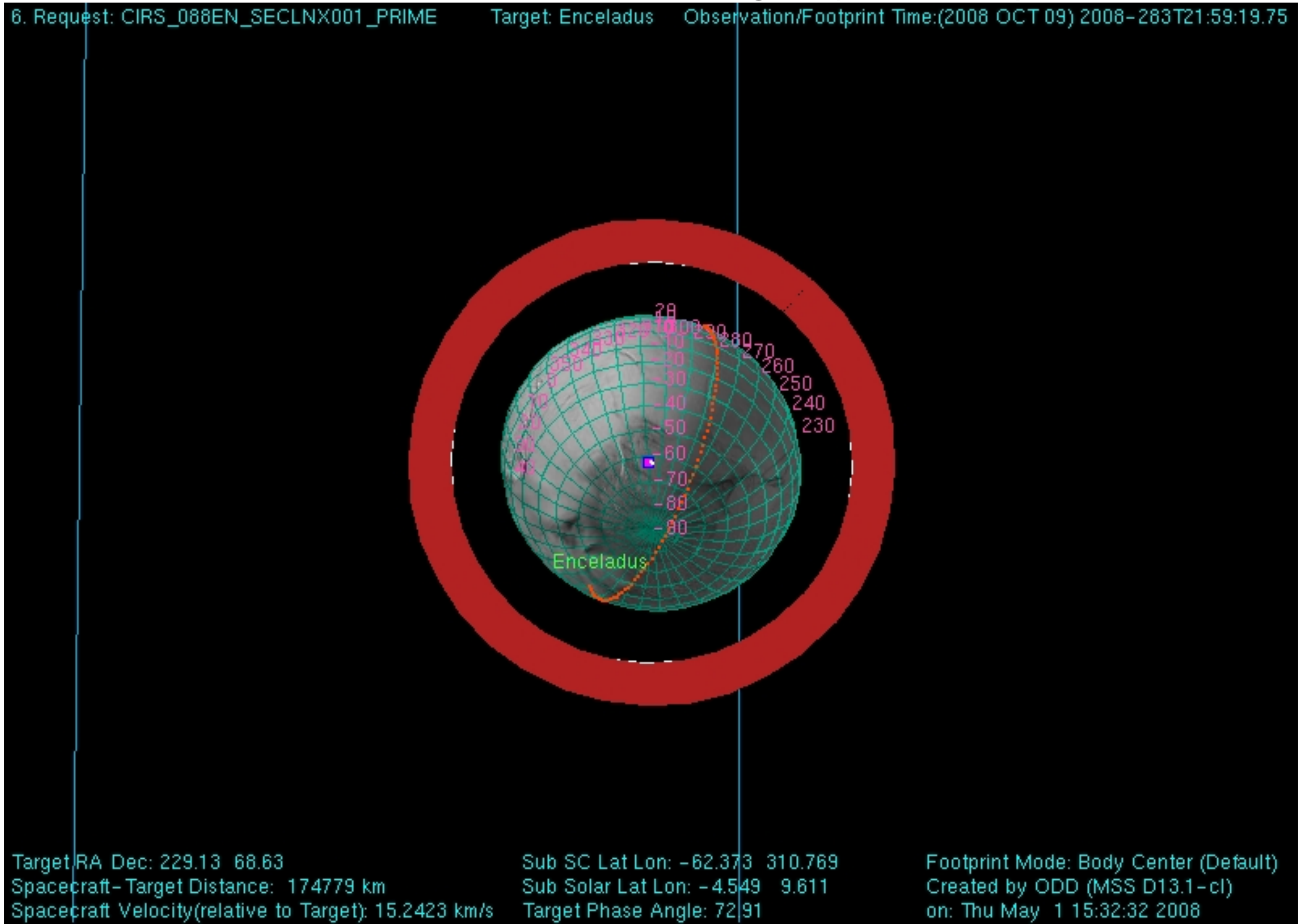
CIRS_088EN_SECLNX001

- 21:35 - 22:00: FP3 global map
- 47 km resolution



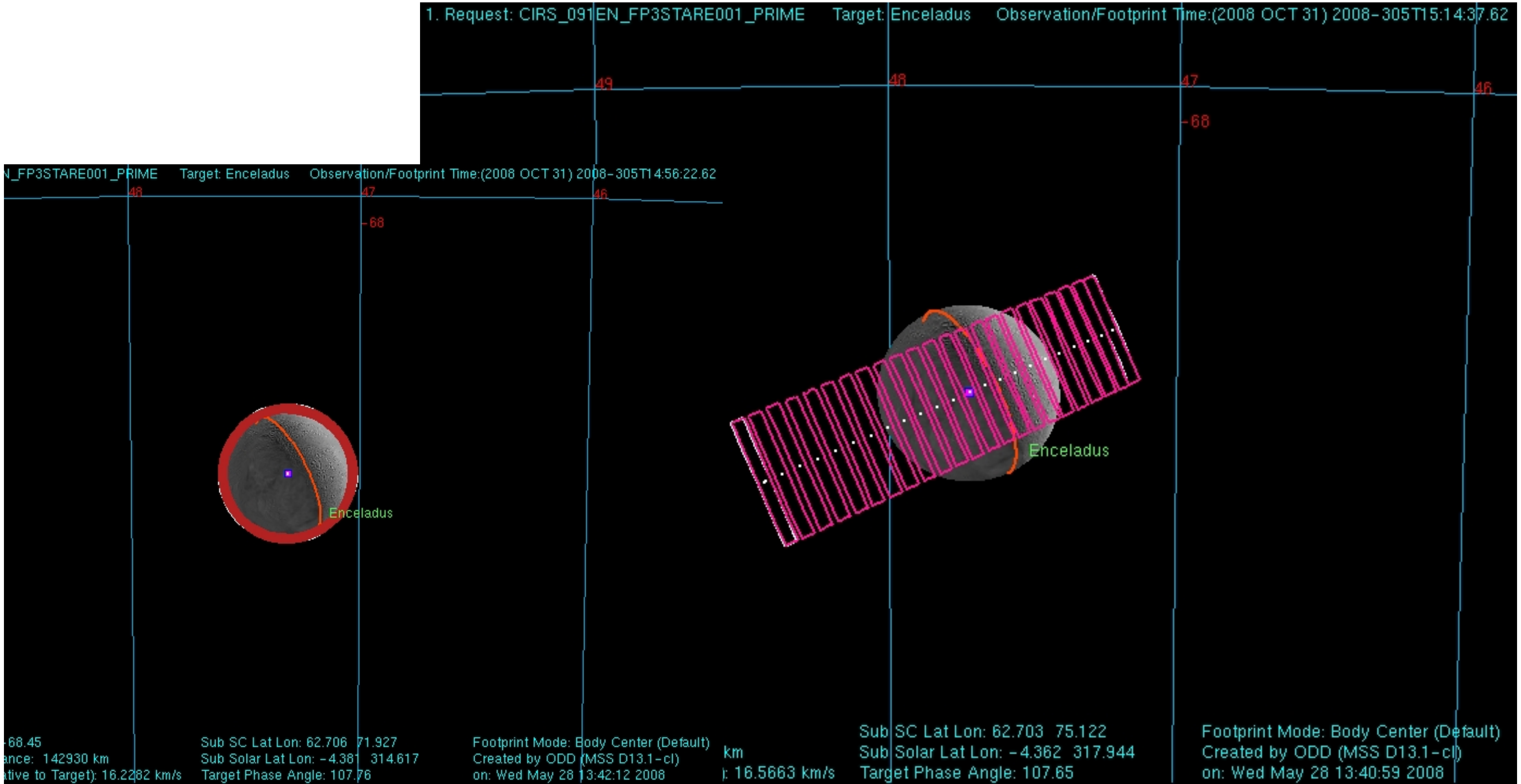
CIRS_088EN_SECLNX001

- 21:59 - 22:40: FP1 stare centered on Enceladus, for eclipse reappearance (at 22:23)
  - WAC support image at 22:35
- 22:40 - 23:09: NAC to Enceladus for other ORS
- 23:12 - 00:05; FP1 stare centered on Enceladus, for remaining eclipse warmup
  - WAC support image at 23:40



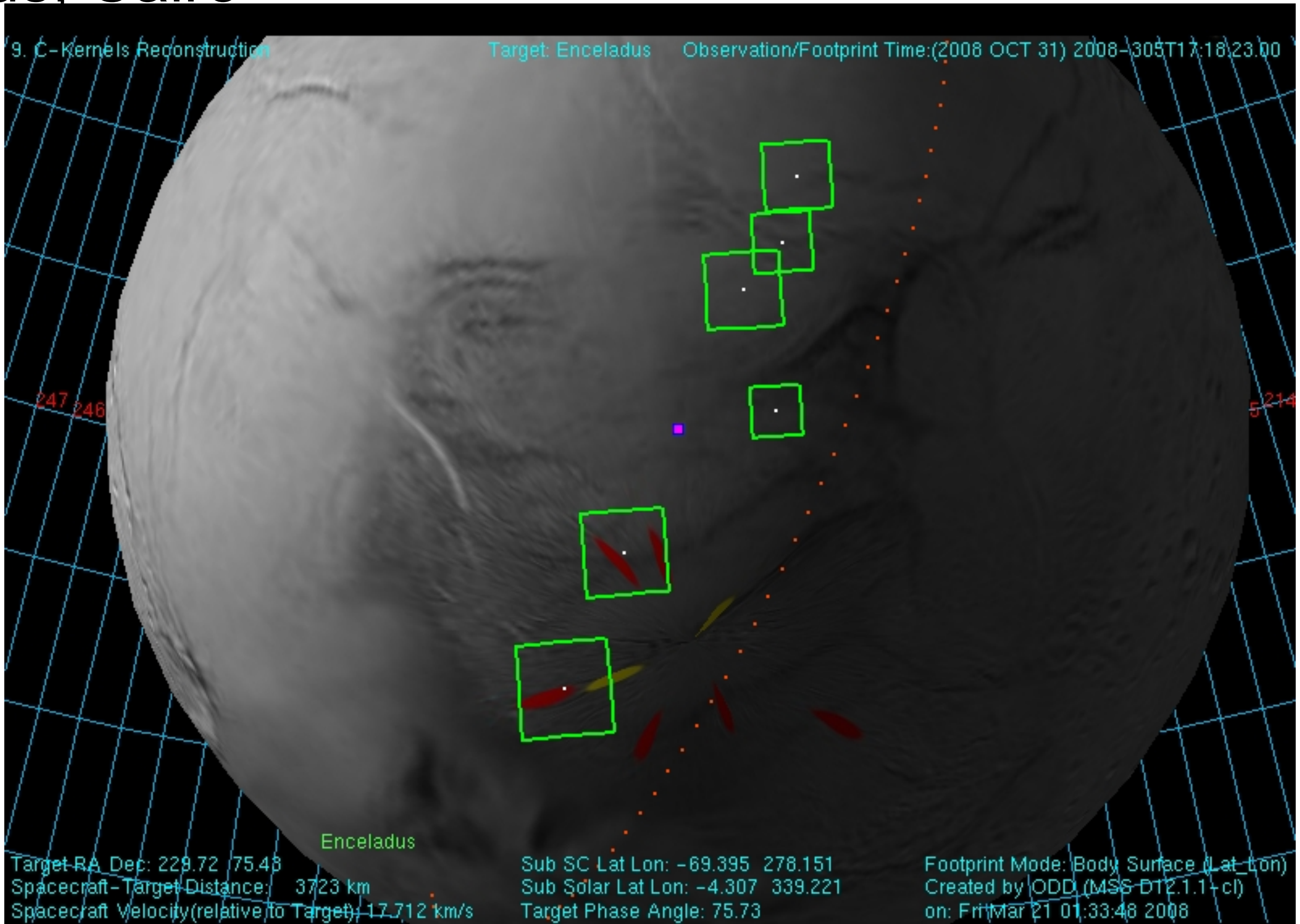
CIRS_091EN_FP3STARE001_PRIME: Rev 91 Approach

- 13:15 - 16:03
- Series of FP1 stares, FP3 stares, FP3 scans



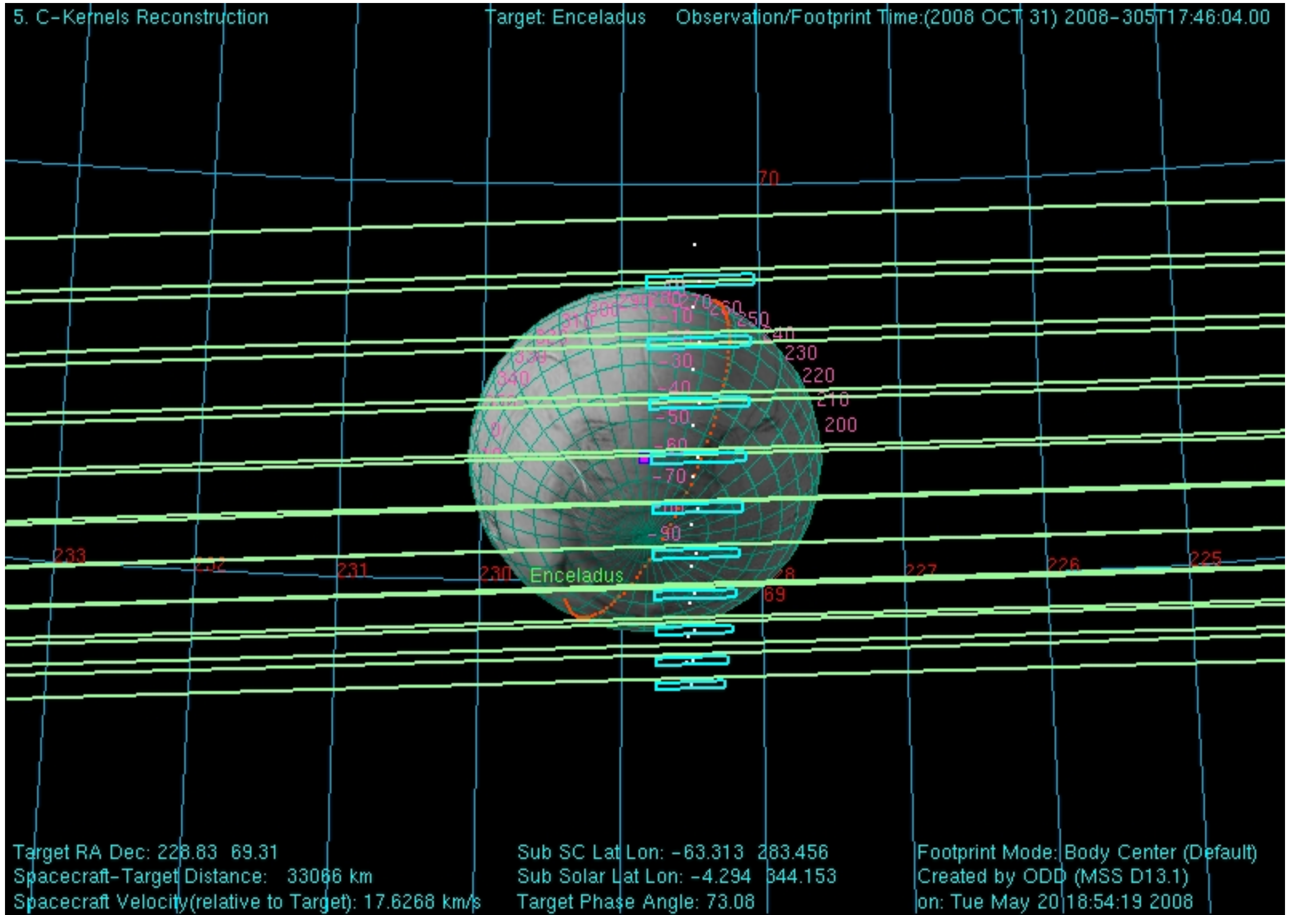
ISS_091EN_ENCELCA001 Riders

- “Skeet shoot”
- FP3 on Damascus, Cairo



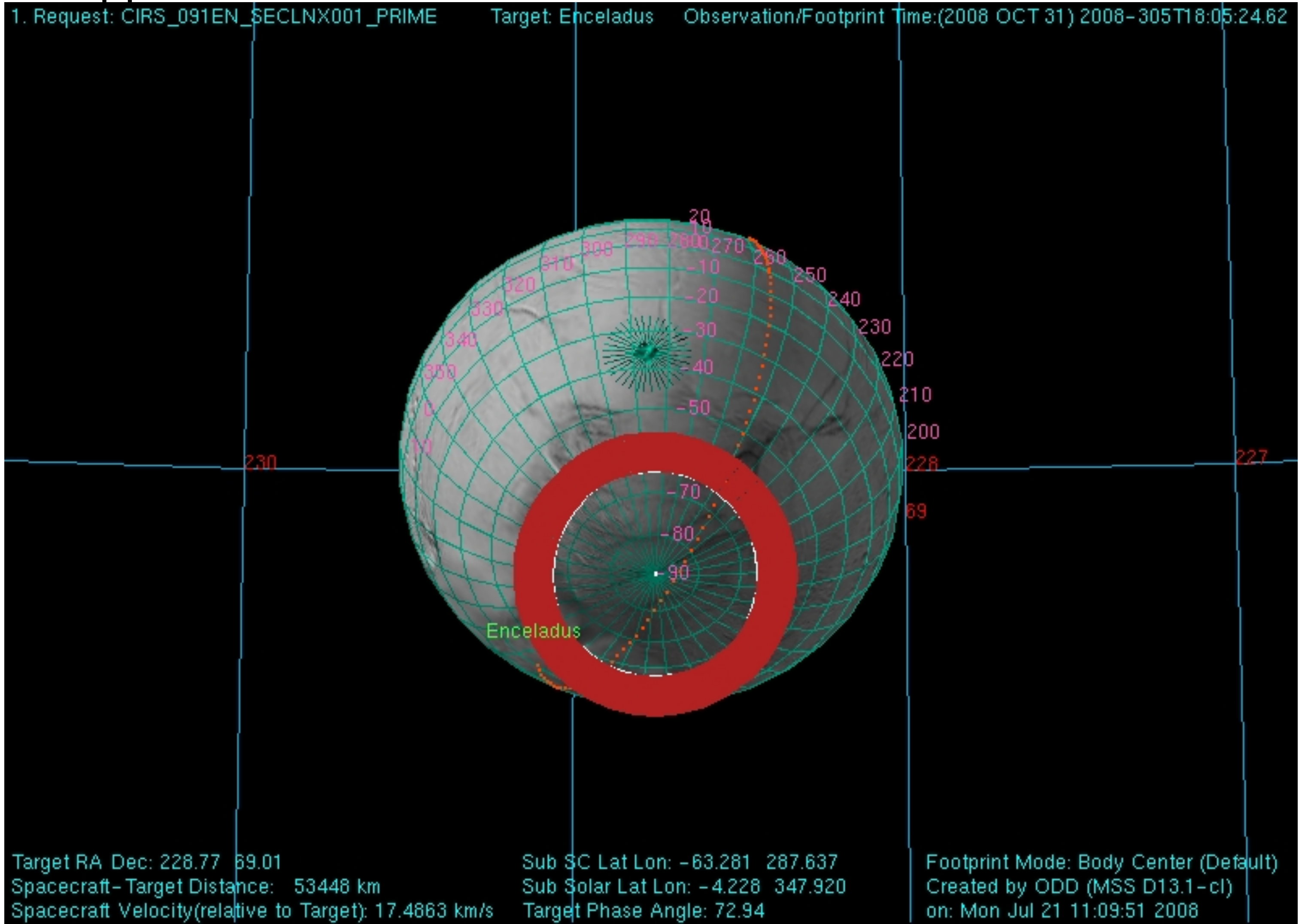
UVIS_091EN_ICYMAP002 Rider

- 17:45 - 18:05
- Positioned for “gap fill” in high-resolution FP3 mapping of the south polar region



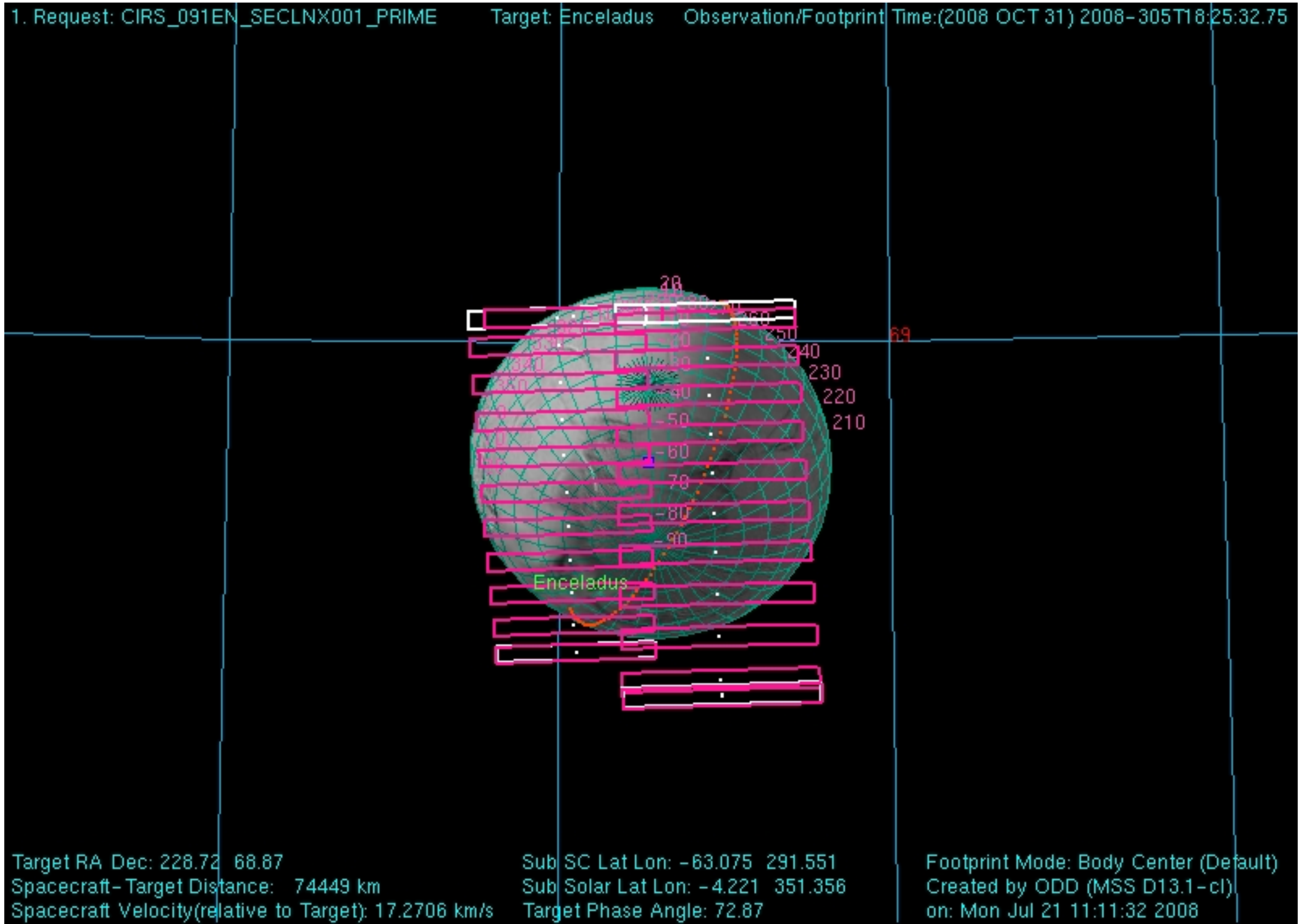
CIRS_091EN_SECLNX001

- 18:04 - 18:24: FP1 stare at south pole for total south polar heat flow
  - Eclipse disappearance at 18:05



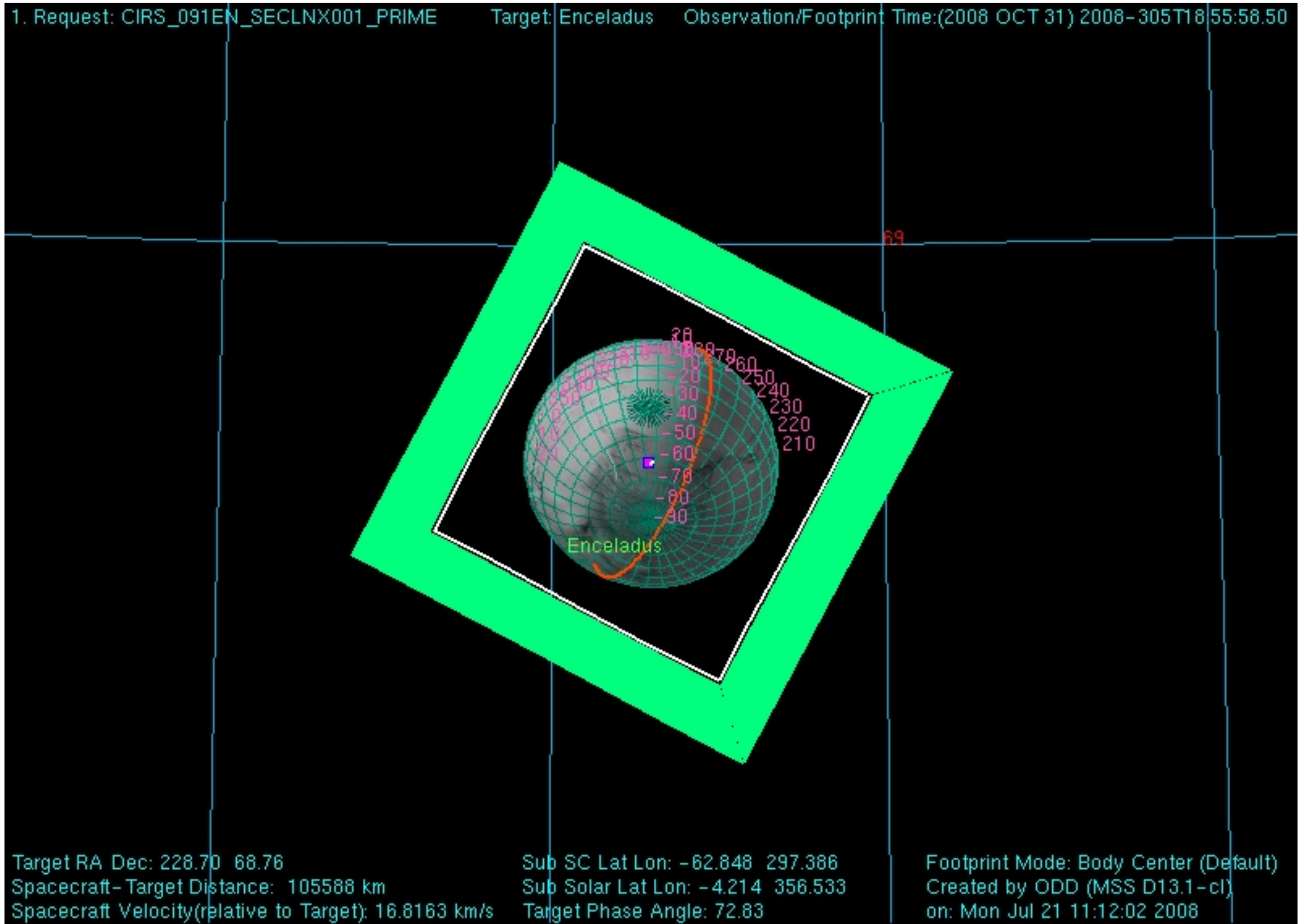
CIRS_091EN_SECLNX001

- 18:24 - 19:04: FP3 global map, 12 μrad/sec



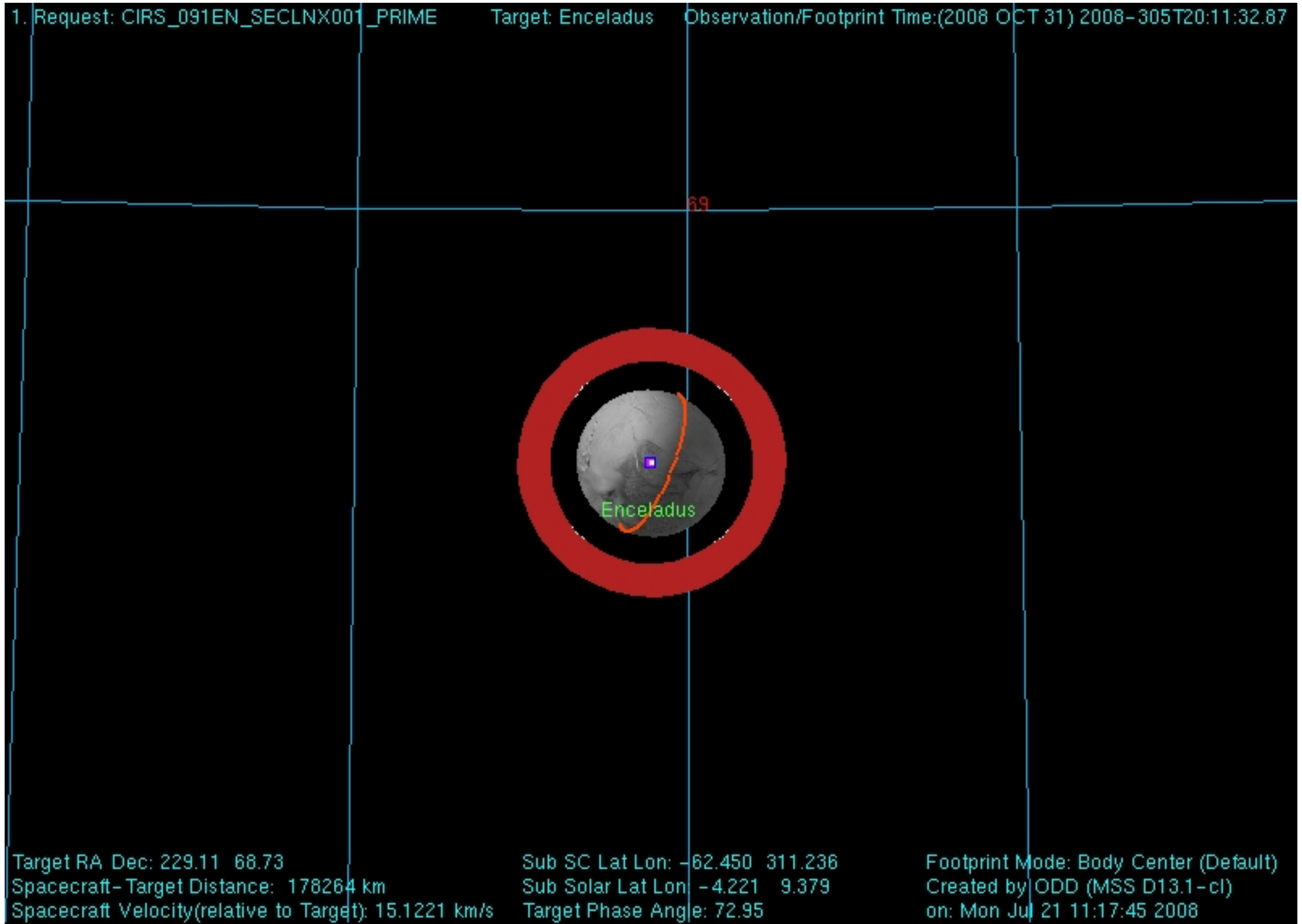
CIRS_091EN_SECLNX001

- 19:04 - 19:44 FP3 stare at S. Pole
- Include secondary axis turn to NEG_X to Sun



CIRS_091EN_SECLNX001

- 19:44 - 20:14 Pair of global FP3/FP4 scans
- 20:14 - 21:14 FP1 stare at disk center for eclipse reappearance (at 20:37)



Enceladus Rev 88 and 91
UVIS Goals and Observations

C. Hansen and A. Hendrix

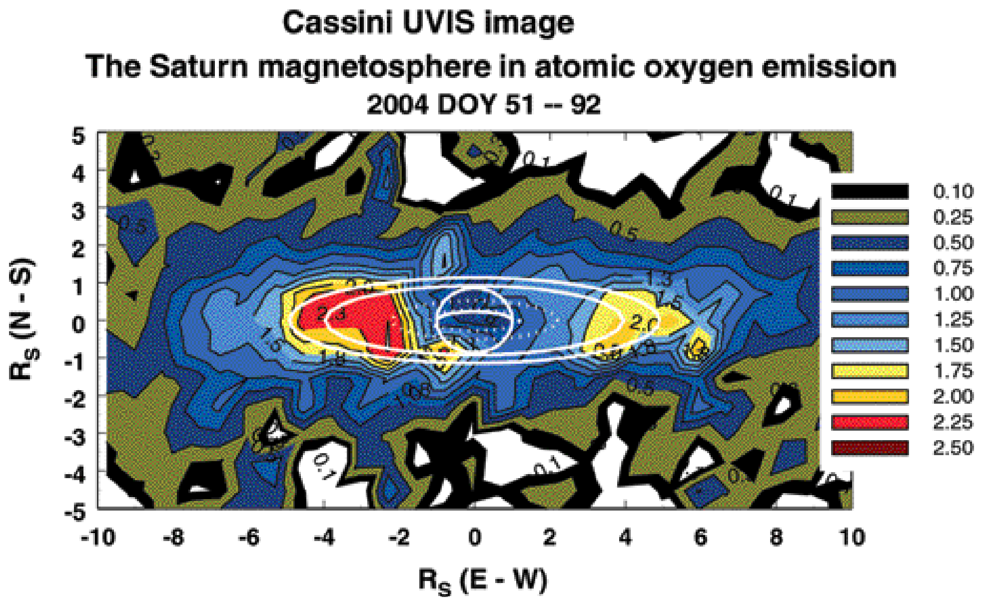
3 October 2008

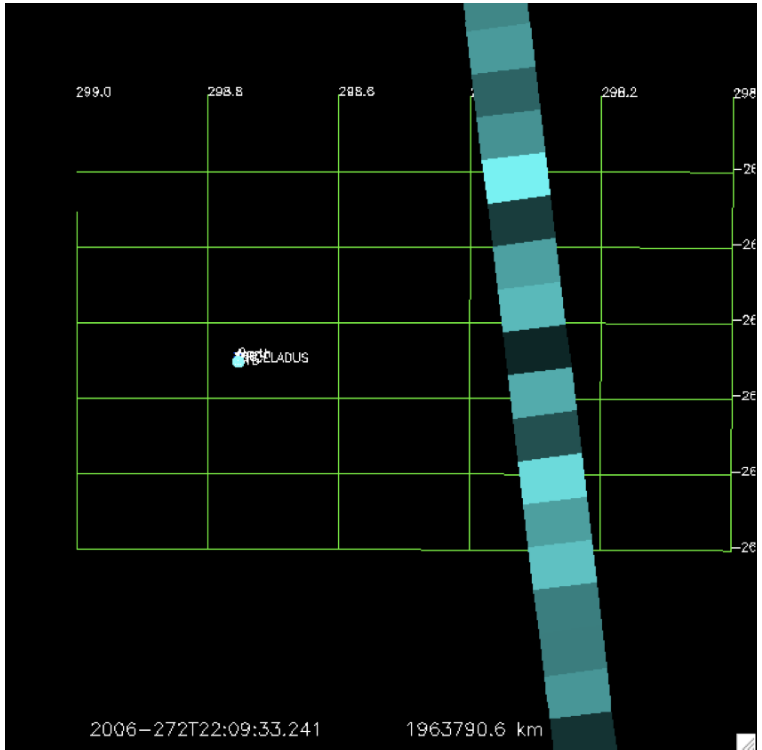
UVIS Objectives

- UVIS has two goals for these Enceladus flybys
  - Map the state of the volatiles in the near vicinity of Enceladus (oxygen emissions)
    - **Rev 88**, ICYLIMB, -2 hr to -1 hr, bracketed by two ICYATM's at -12 hr and + 5 hr
    - **Rev 91**, three ICYATMs at -8 hr, +5 hr, and +21 hr
  - Map the surface reflectivity at ultraviolet wavelengths to characterize new / old terrain via grain size
    - **Rev 91**, ICYMAP at +30 min

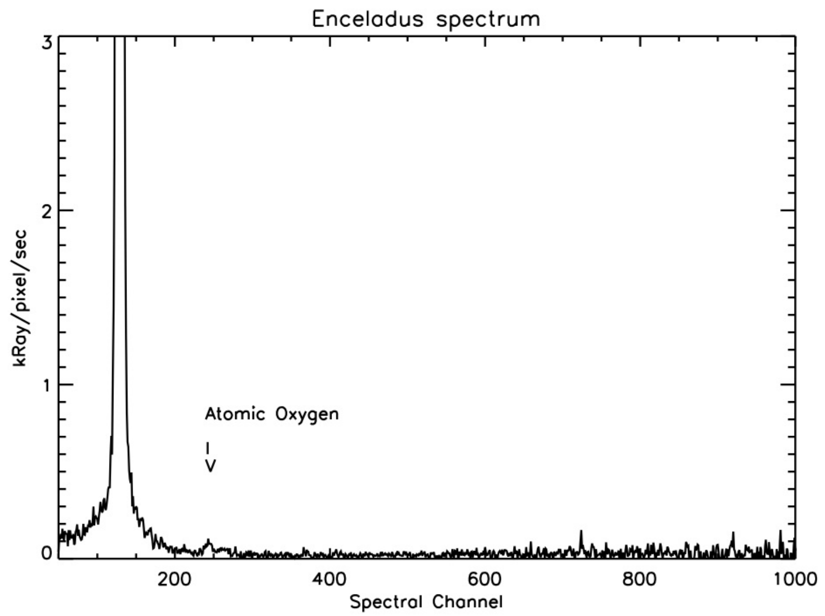
Enceladus Observation Suite - Volatiles

- System scans show variable atomic oxygen in Saturn's system
- Localized scans across Enceladus give higher resolution picture of the distribution of oxygen
- Link to highest resolution to characterize the eruptive state
- Execute *routinely* to monitor Enceladus' activity *remotely*
- High resolution limb scans

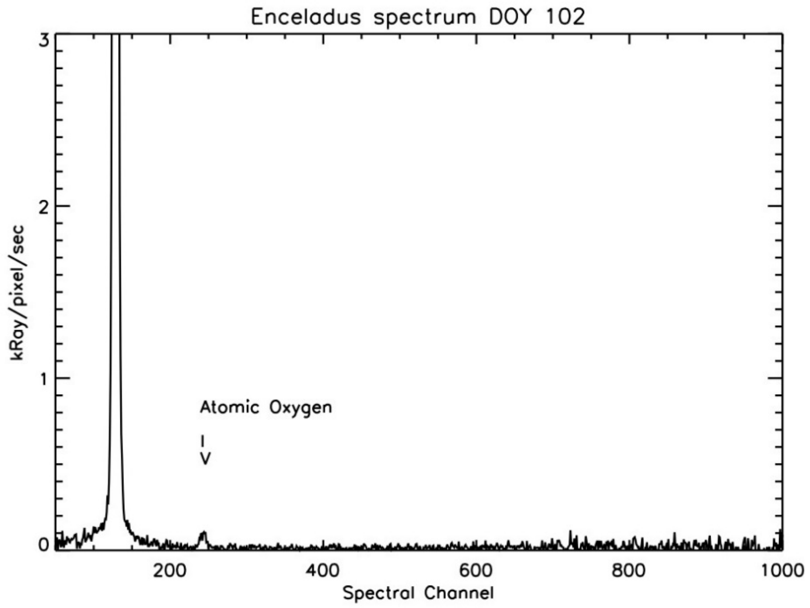




Comparative spectra

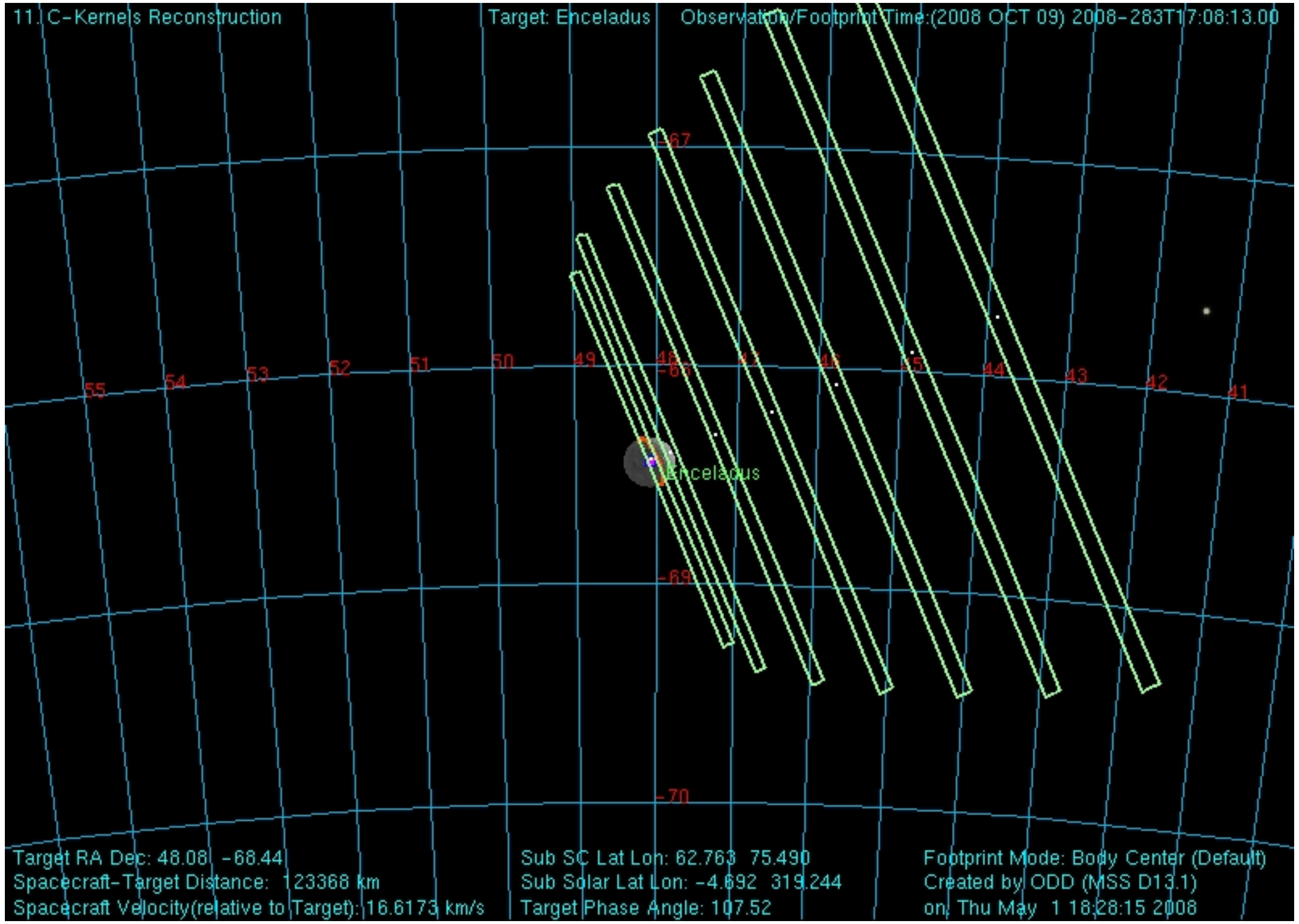


2006 DOY 272



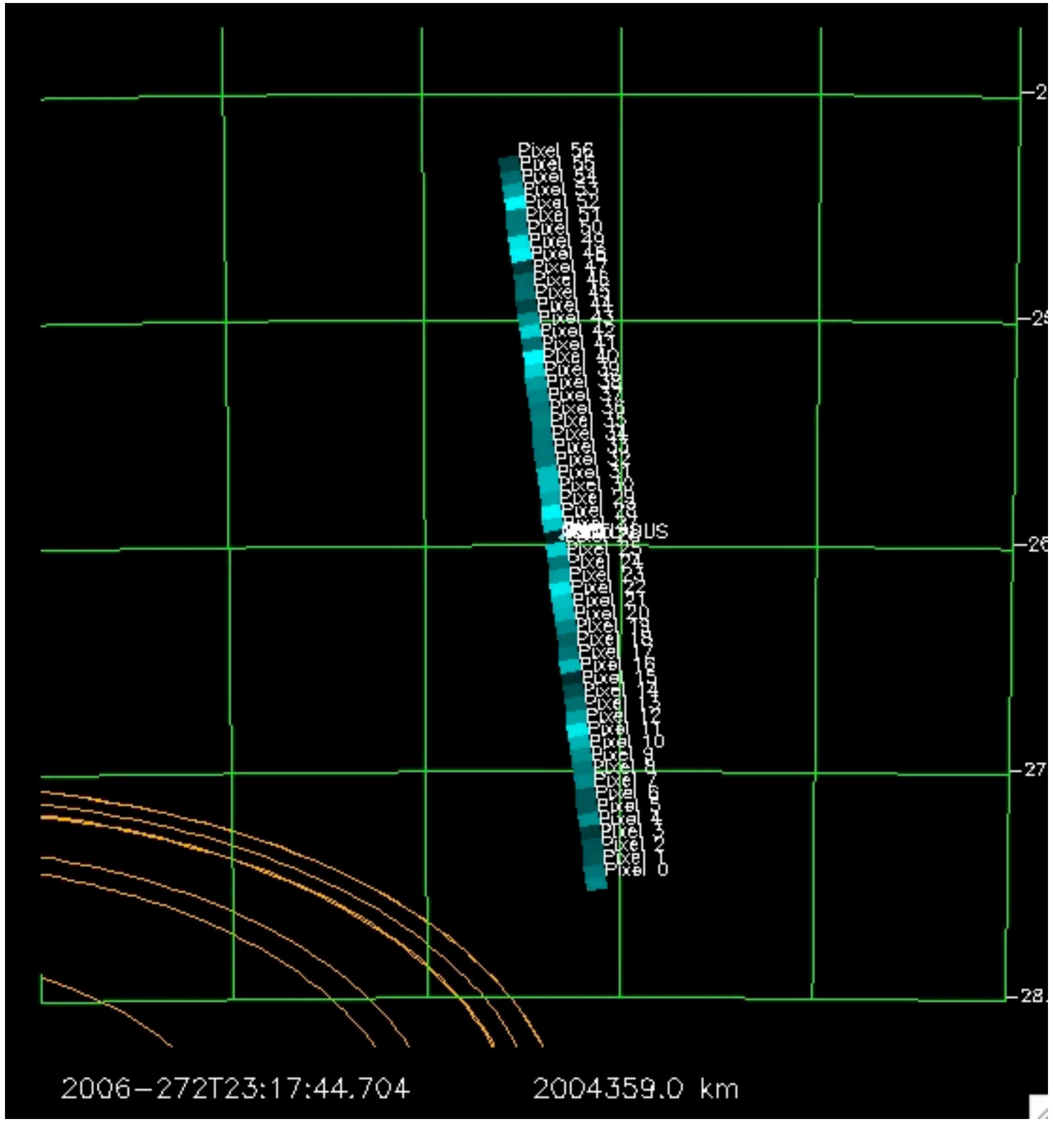
2007 DOY 102

Rev 88 - Volatiles

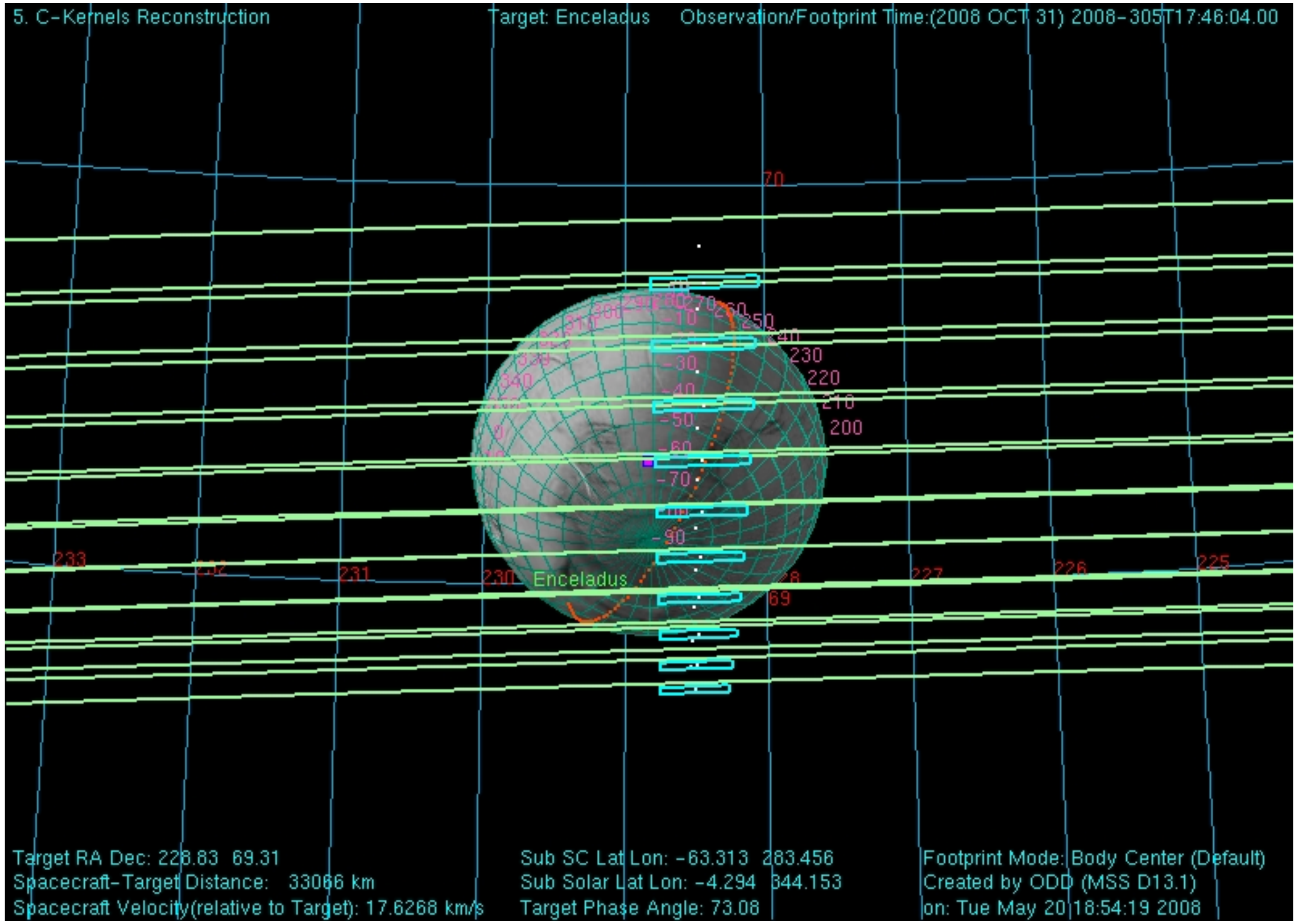


- Limb scan to look for volatiles

Enceladus Volatiles - ICYATM

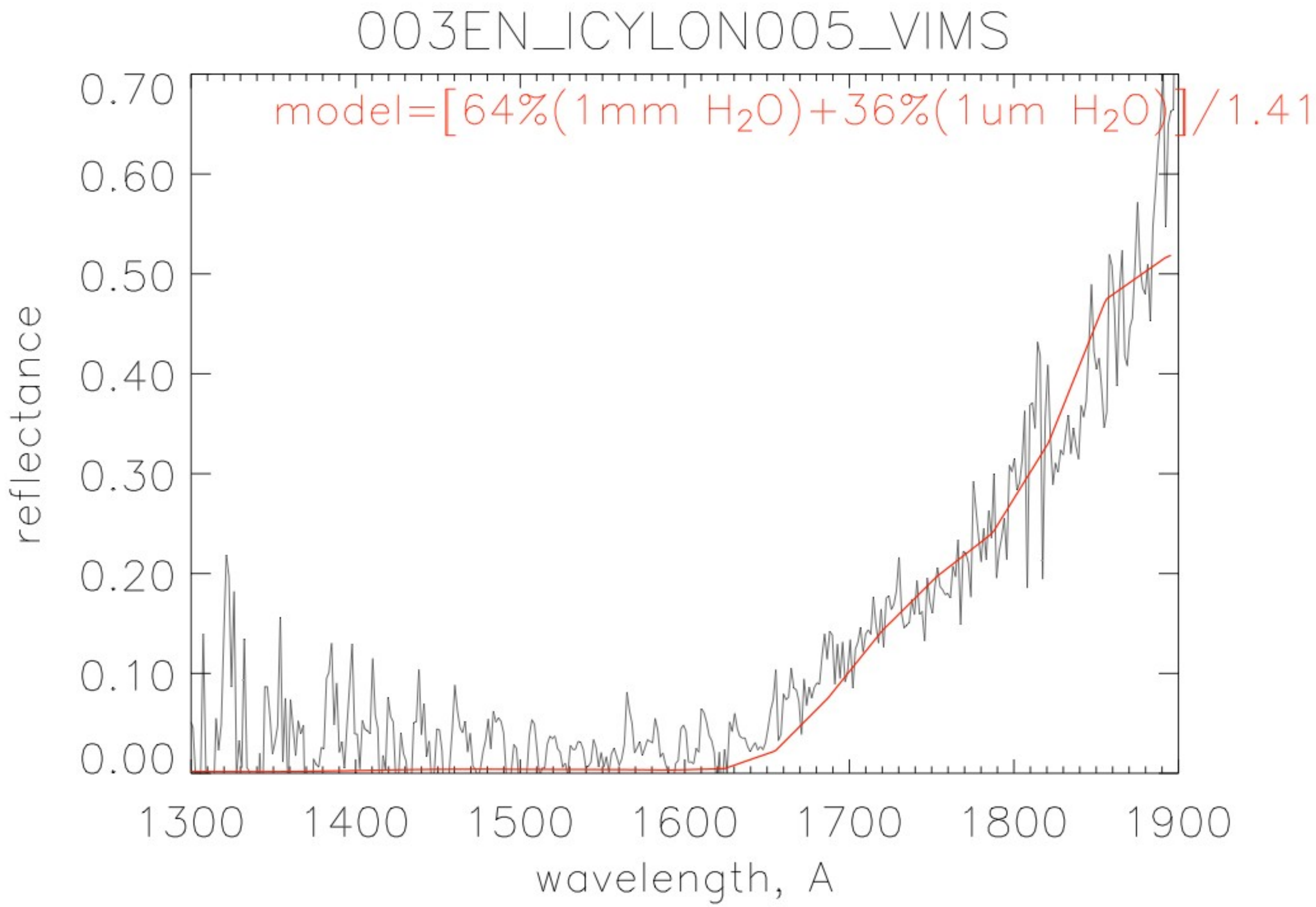


Rev 91 Surface Reflectivity



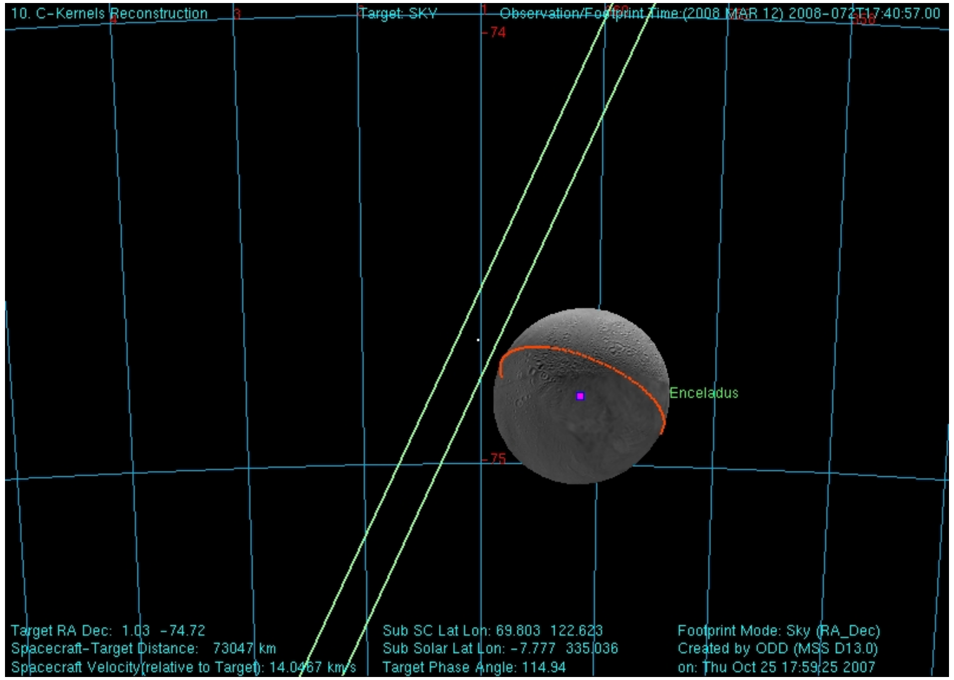
- ICYMAP of southern hemisphere

UV Spectrum

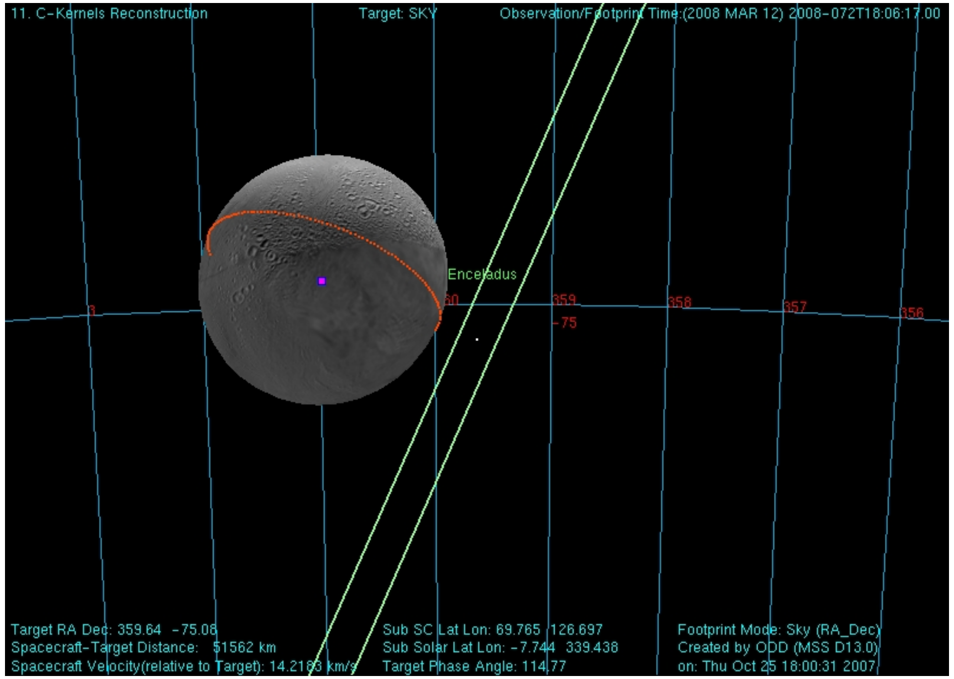


003EN_ICYLON005_VIMS
model=[64%(1mm H2O)+36%(1um H2O)]/1.41
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
reflectance
1300
1400
1500
1600
1700
1800
1900
wavelength, A

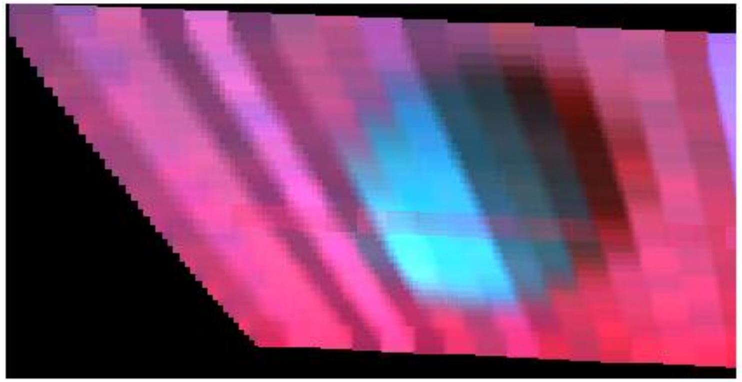
ICYMAP Example



Start of scan



End of scan



VIMS

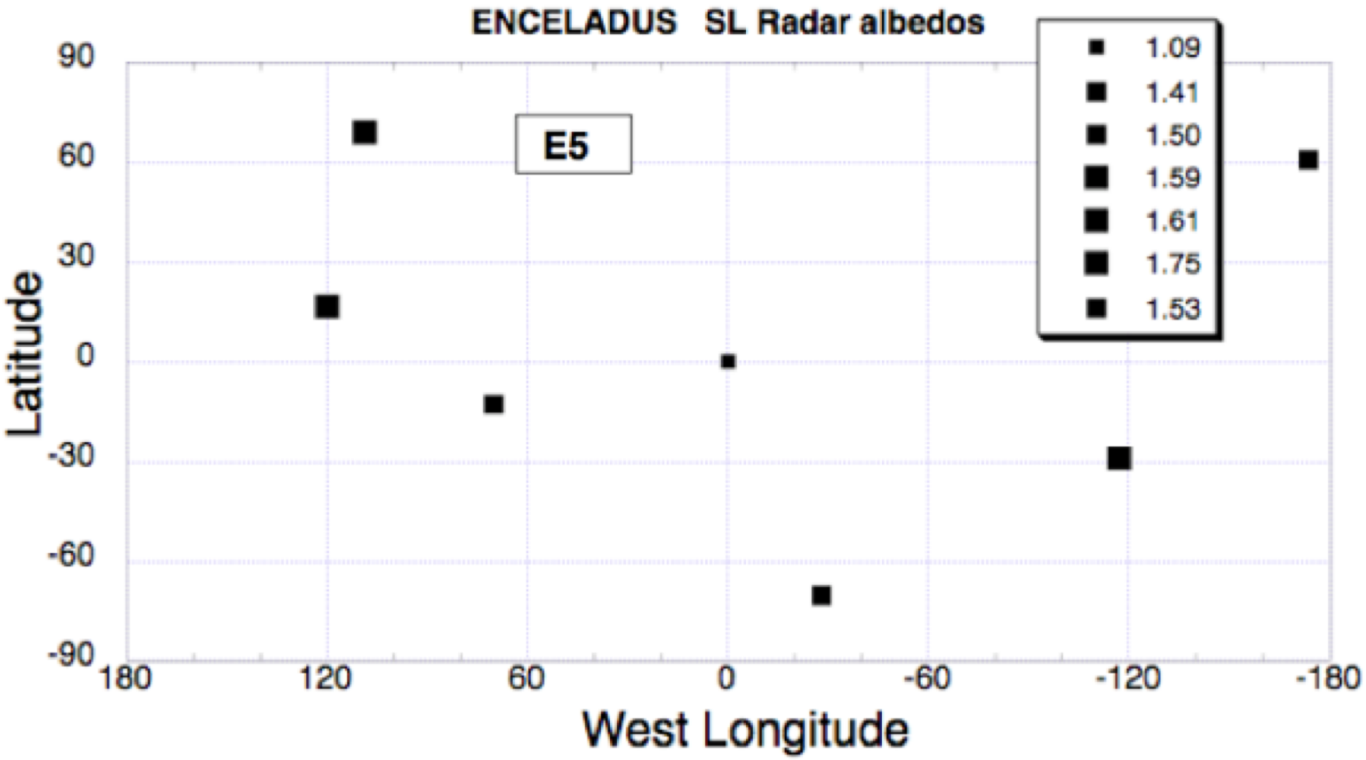
Visual and Infrared Mapping Spectrometer

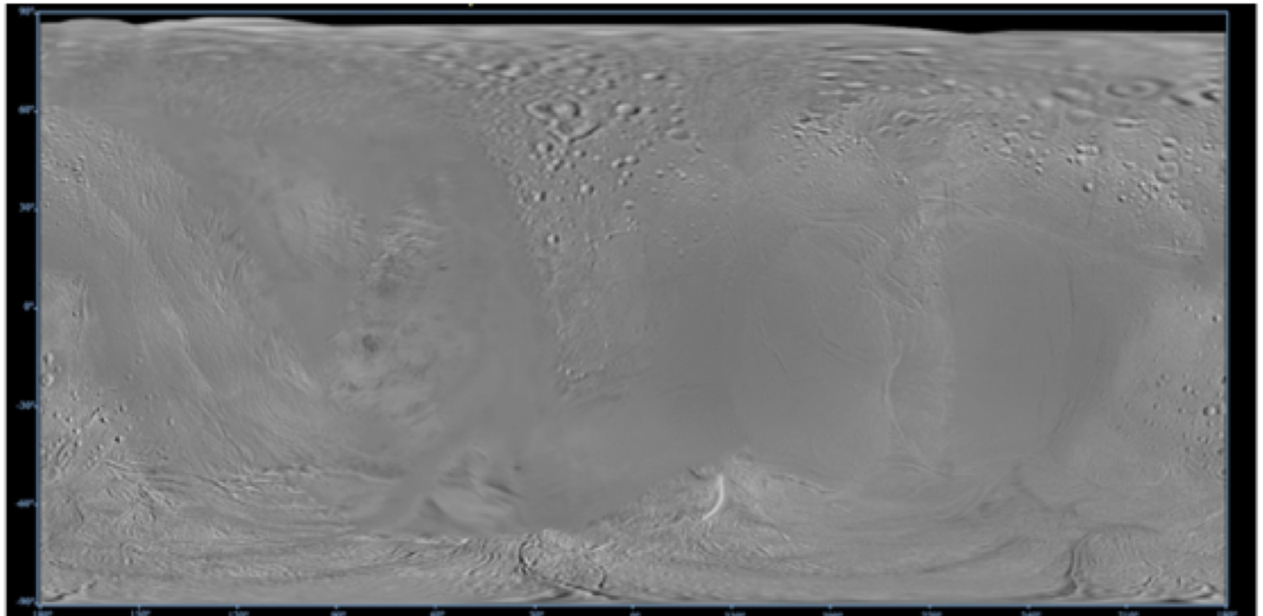
- Rev 91: VIMS has prime observations that are point and stare at -5 hours and + 4 hours when Enceladus is small.
- Rev 120: has one prime at +4 hours when Enceladus is small.
- VIMS will ride on other ORS observations doing compositional work during these fly-bys, and will search for hot spots >140K.
- VIMS will look for confirmation of weak spectral features such as those due to organics, CO2, ammonia, and other compounds.
- VIMS will also use ice spectral features to determine approximate temperatures less then 140K.
- VIMS will study phase properties and albedo.

Enceladus 5 RADAR Preview

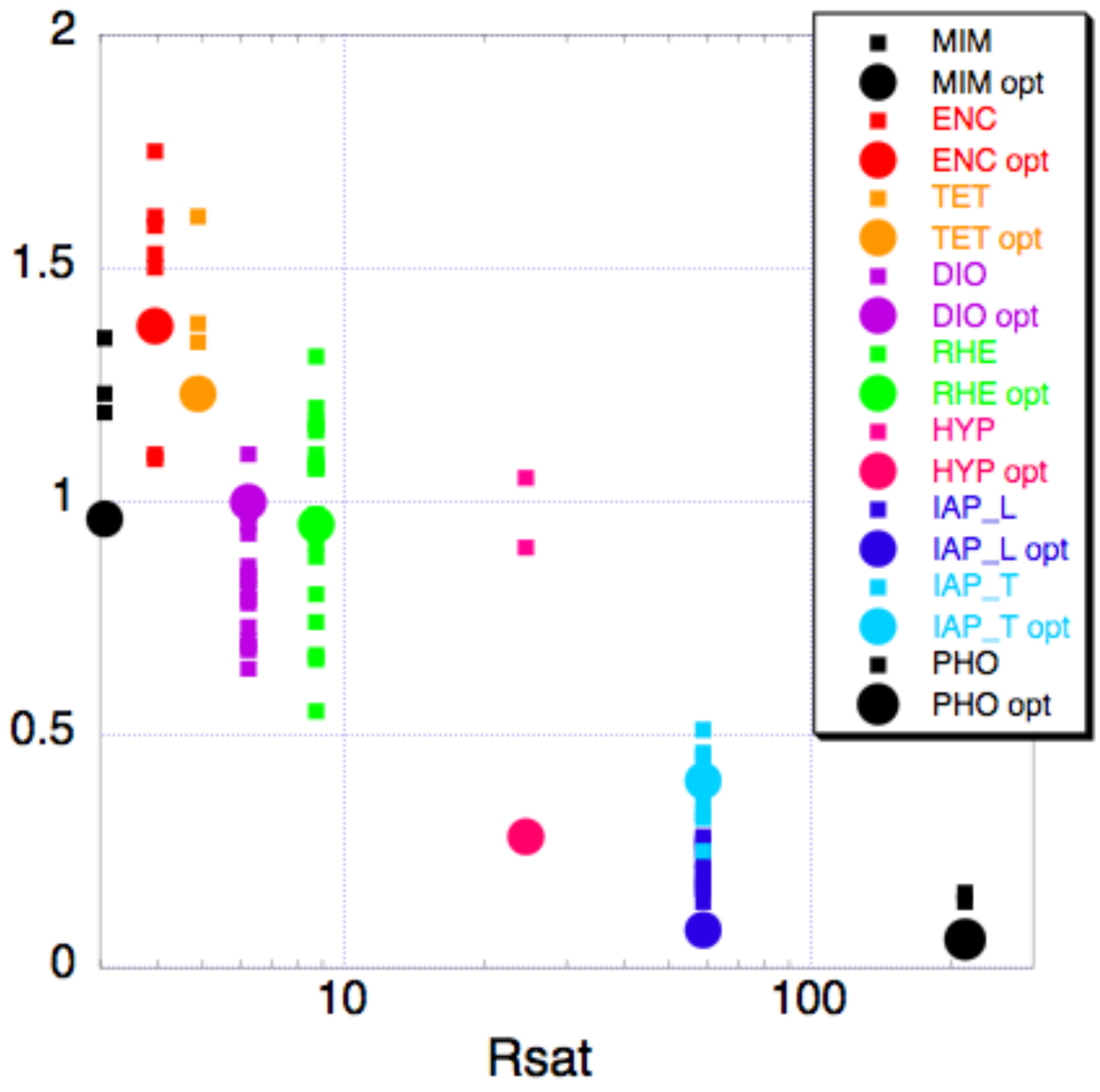
Steve Ostro
Cassini RADAR Team

Oct. 3, 2007
JPL


ENCELADUS SL Radar albedos
E5
1.09
1.41
1.50
1.59
1.61
1.75
1.53
Latitude
90
60
30
0
-30
-60
-90
180
120
60
0
-60
-120
-180
West Longitude



Radar SL-2 Albedos and Optical Geometric Albedos

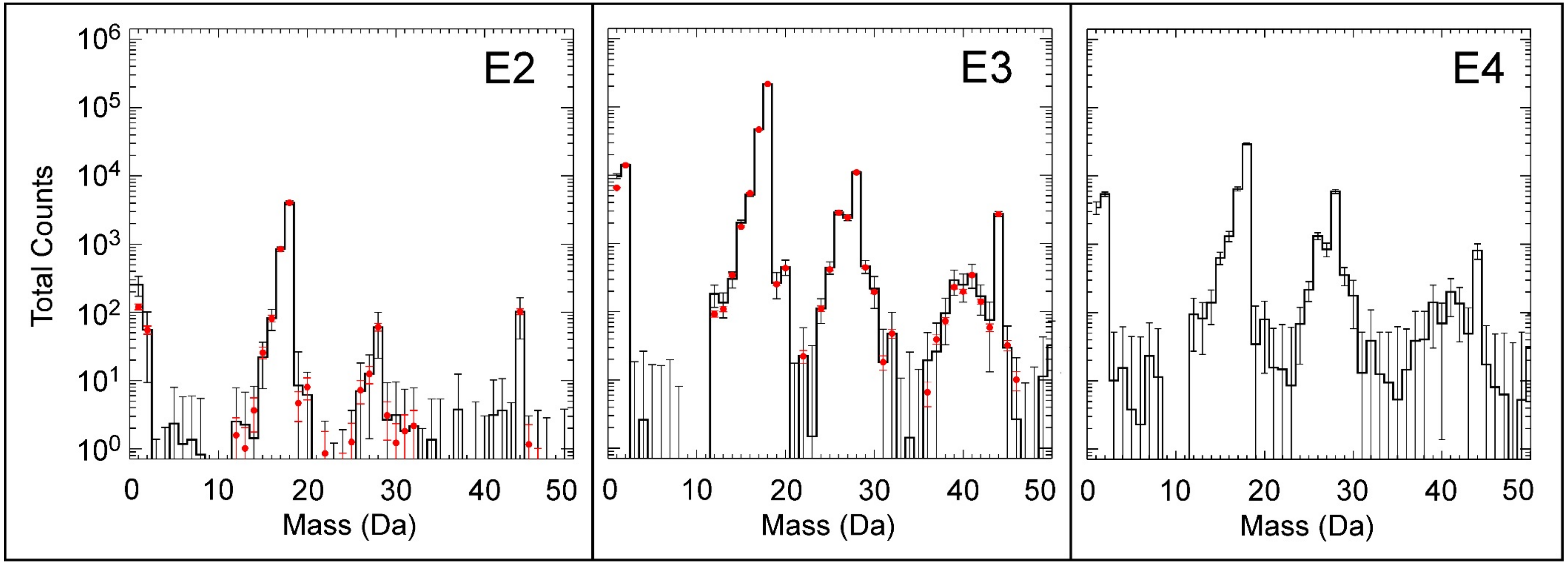


INMS Preview of E5, E6 Encounters

9/30/08

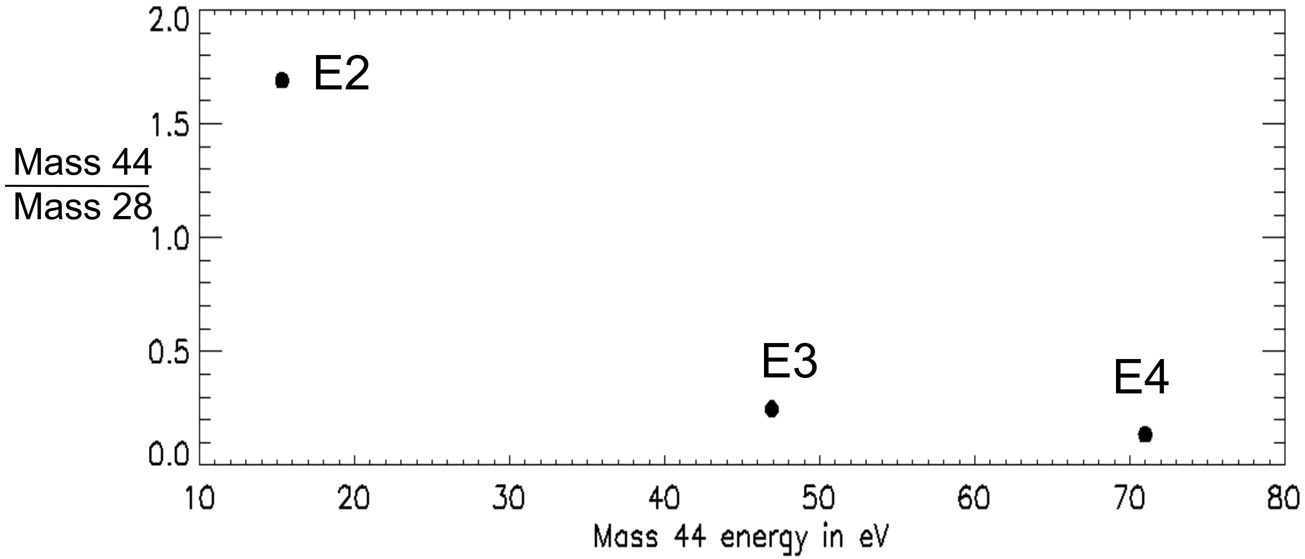
Brian Magee

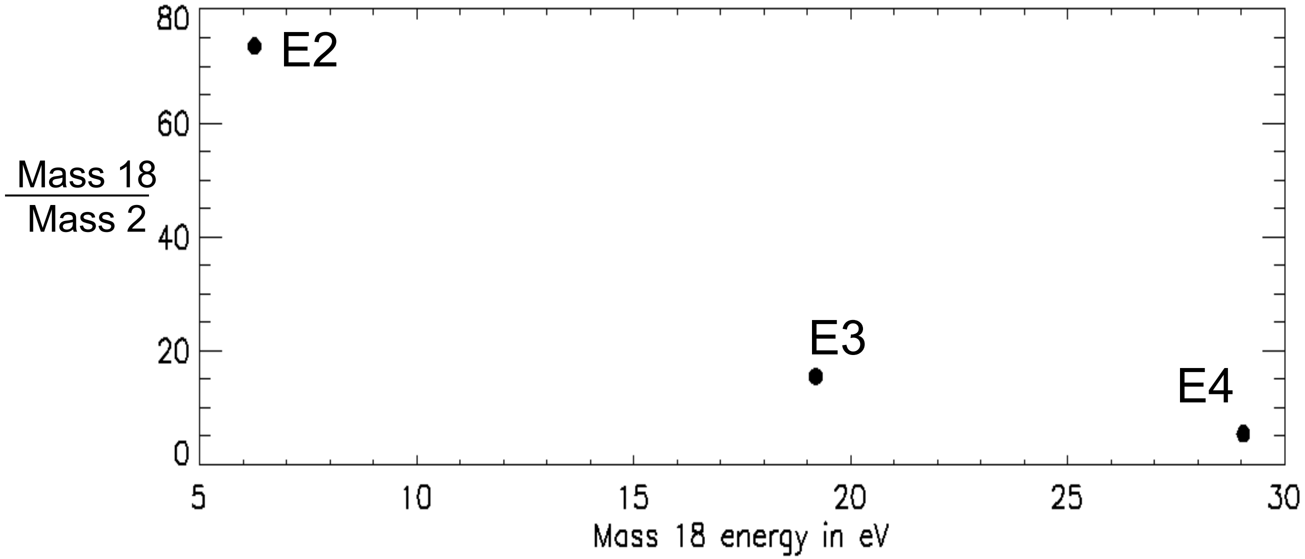
Previous Measurements: E2 to E4



- Histograms depict the summed signal for each encounter above background
- E2- poor pointing, poor sampling, high altitude
- E3- good pointing, sampling and altitude
- E4- dismal pointing, good sampling and altitude
  - Pointing precludes meaningful density calculation, however the unexpectedly strong signal can benefit composition analysis

Impact Dissociation of High Energy Particles



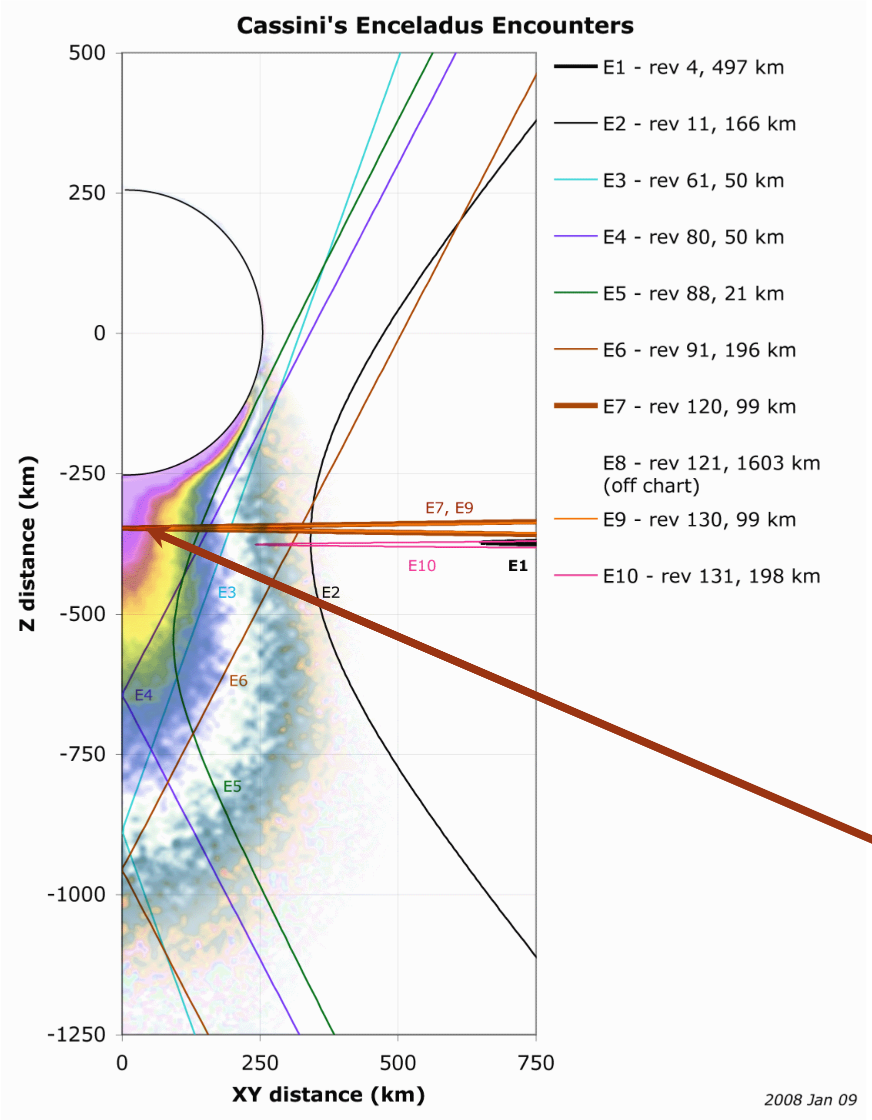


There appears to be a trend of increasing CO vs. CO_2 with speed (energy) of the spacecraft relative to Enceladus.

This trend also appears with an increase in H_2 relative to H_2O.

E5 encounter is set to have a similar speed as E4, so this phenomena can be compared. Neutral Beam observations should not be affected in this way.

Observation Geometry



- Closest targeted flybys for Cassini
  - E3 on rev 61 (done)
  - E4 on rev 80 (50 km)
  - E5 on rev 88 (21 km)
- Deepest plume penetrations by Cassini
  - E7 on rev 120
  - E9 on rev 130

E5, E6 Preview

- E5
  - Optimal pointing for E5 coupled with trajectory relative to the plume source should provide the highest signal and best composition results to date.
  - INMS will forego ion measurements to rather perform neutral beam measurements. The aim is to measure neutrals without the ‘wall effects’ of the closed-source antechamber. Neutral beam measurements have lower sensitivity so results may be limited by low signal-to-noise.
- E6
  - Low INMS expectations due to high altitude and poor pointing. However, E4 provided unexpected returns and plume signal can be detected far from the source so useful data is still a possibility.

Enceladus 5 & 6 Preview: RPWS

W. S. Kurth, for the RPWS Team

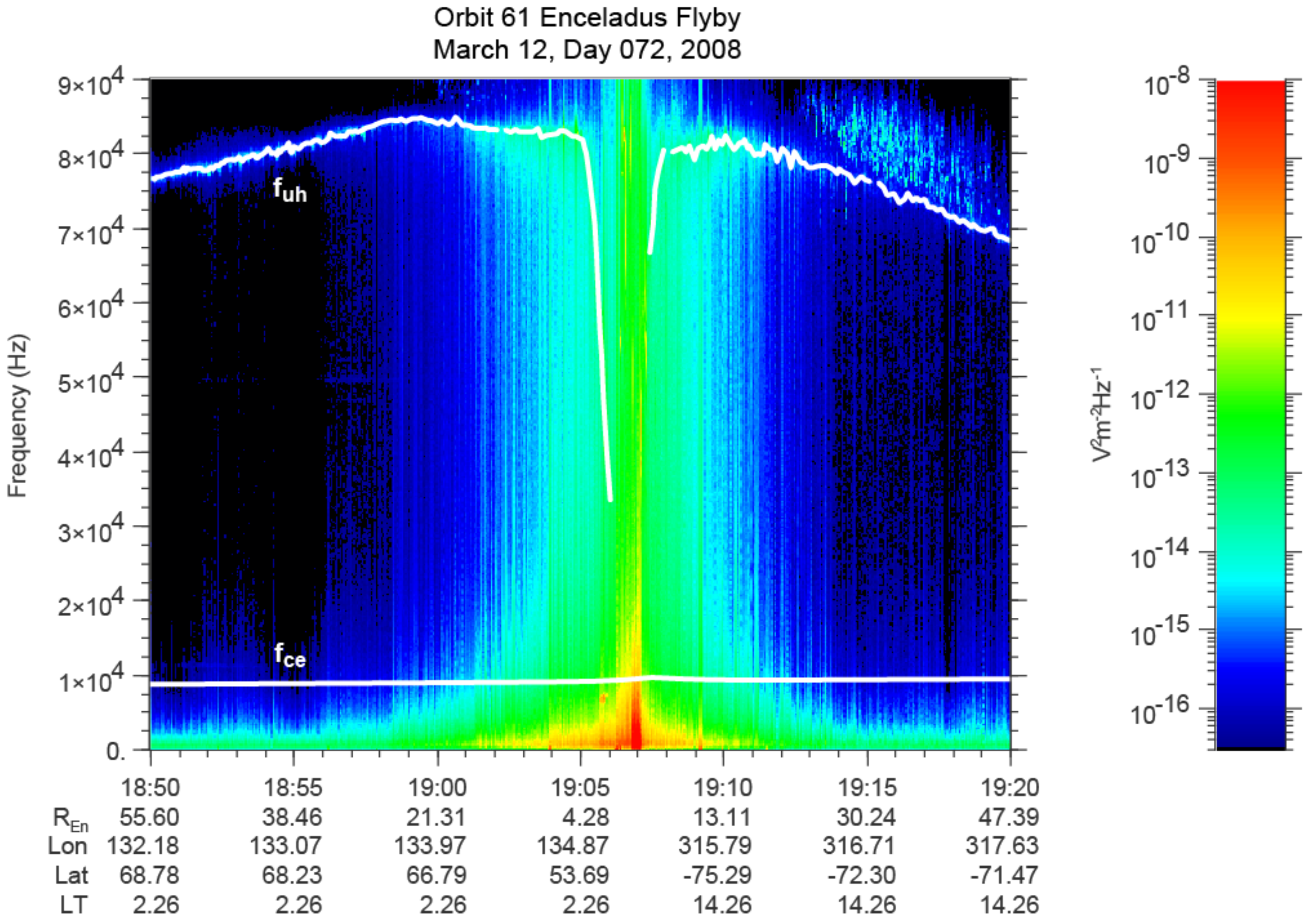
3 October 2008

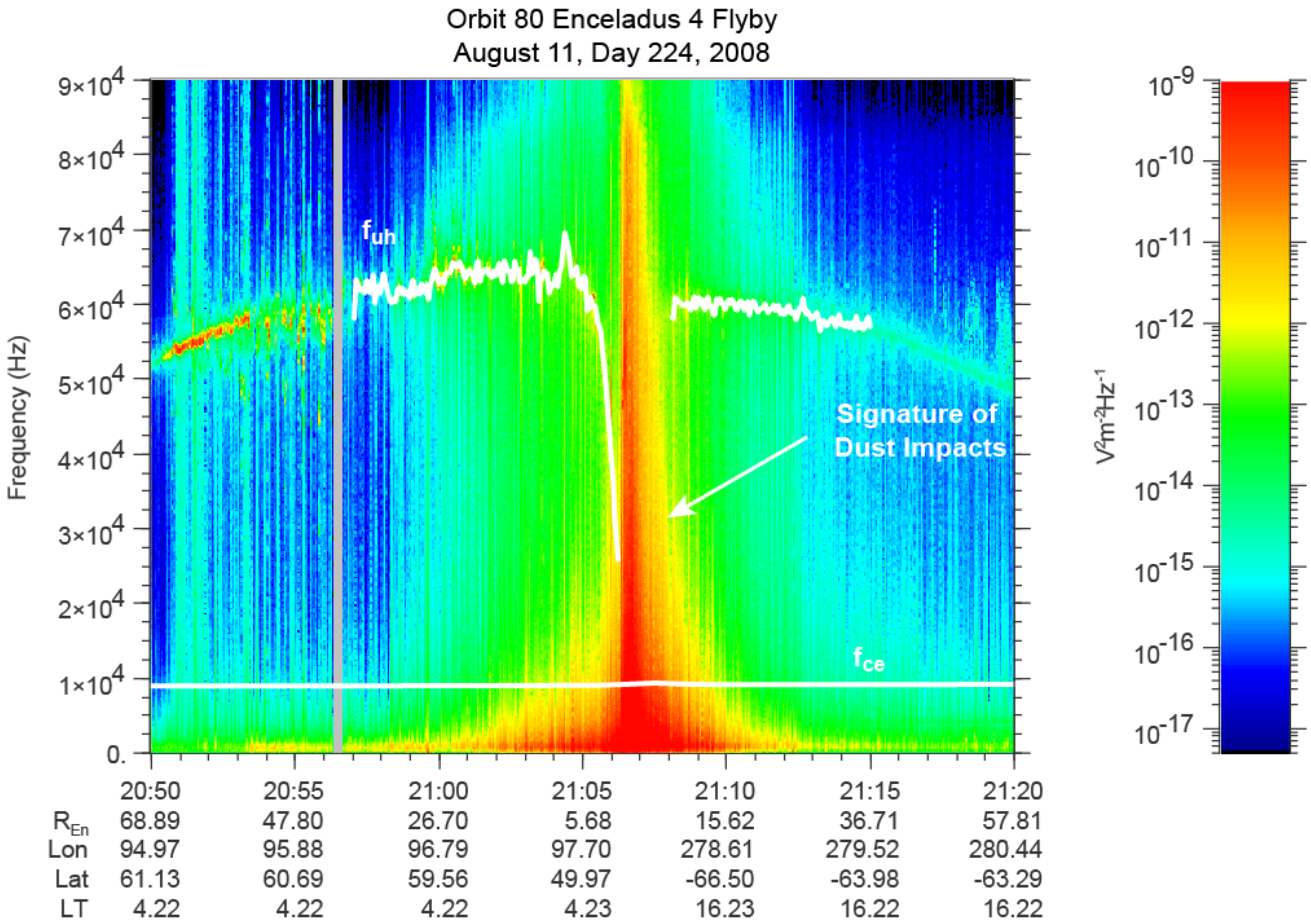
RPWS Science Questions

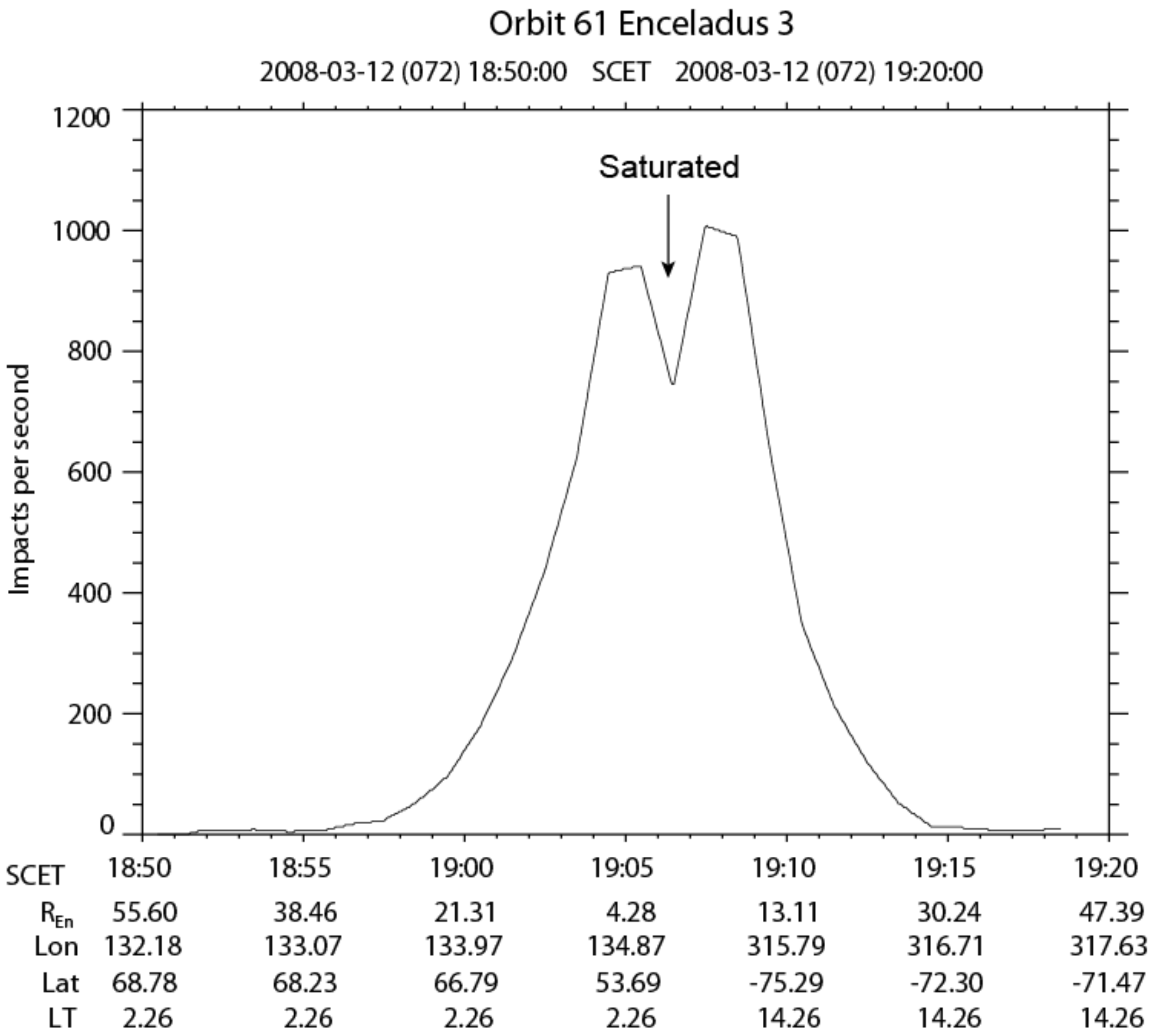
- Is there evidence for local ionization (other than charge exchange) in the plumes?
- What is the flux and size distribution of dust from the geysers?
- How does Enceladus interact with its magnetospheric environment?

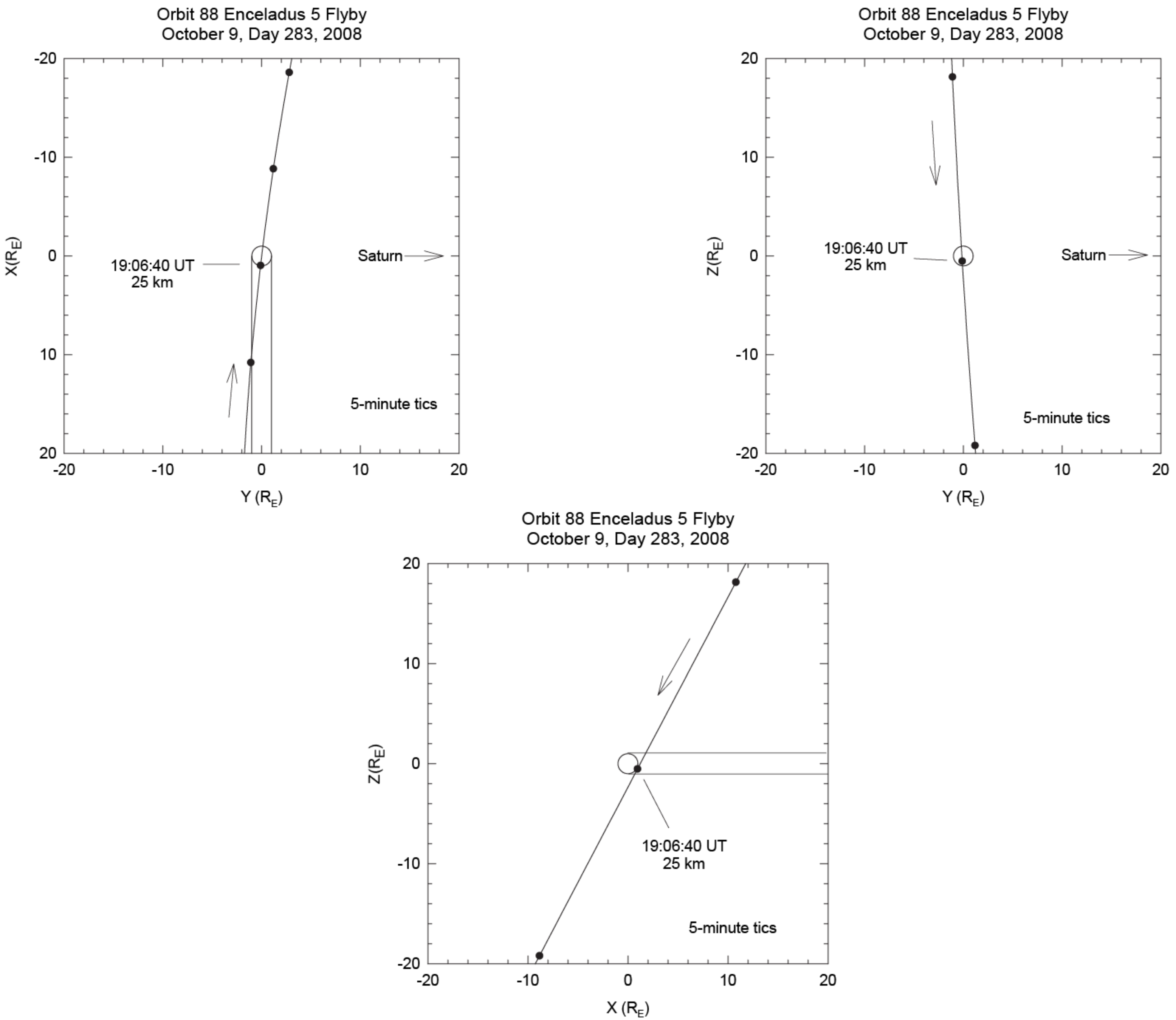
RPWS Measurement Objectives

- 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

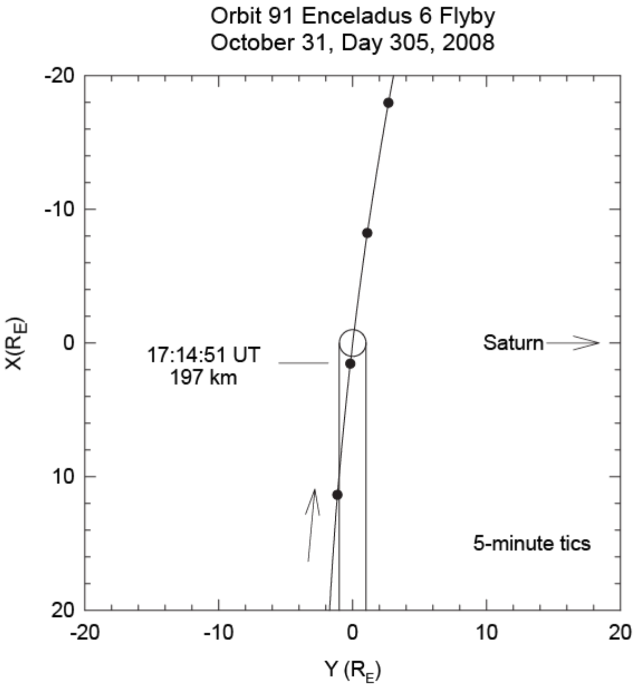

Orbit 61 Enceladus Flyby
March 12, Day 072, 2008
Frequency (Hz)
9×10^4
8×10^4
7×10^4
6×10^4
5×10^4
4×10^4
3×10^4
2×10^4
1×10^4
0.
f_uh
f_ce
18:50
18:55
19:00
19:05
19:10
19:15
19:20
R_En 55.60 38.46 21.31 4.28 13.11 30.24 47.39
Lon 132.18 133.07 133.97 134.87 315.79 316.71 317.63
Lat 68.78 68.23 66.79 53.69 -75.29 -72.30 -71.47
LT 2.26 2.26 2.26 2.26 14.26 14.26 14.26
V^2m^-2Hz^-1
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-15
10^-16

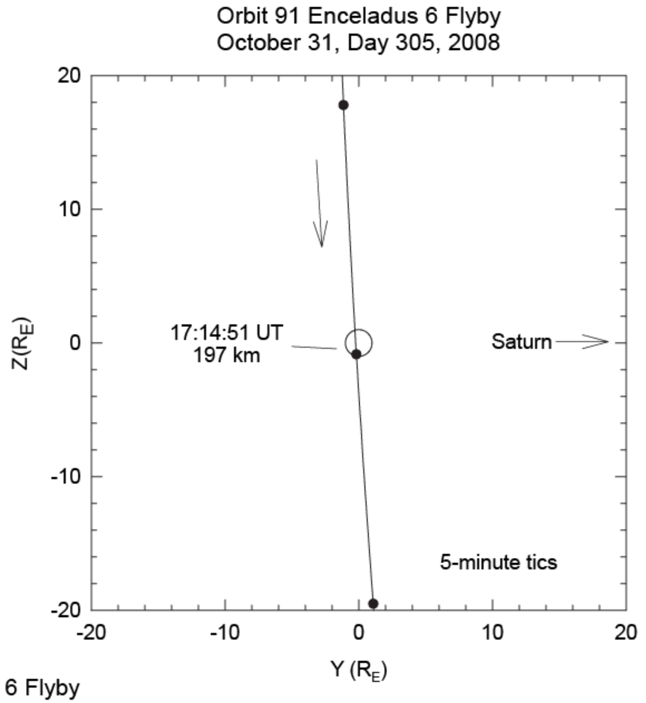

Orbit 80 Enceladus 4 Flyby
August 11, Day 224, 2008
Frequency (Hz)
9×10^4
8×10^4
7×10^4
6×10^4
5×10^4
4×10^4
3×10^4
2×10^4
1×10^4
0.
f_uh
Signature of Dust Impacts
f_ce
20:50 20:55 21:00 21:05 21:10 21:15 21:20
R_En 68.89 47.80 26.70 5.68 15.62 36.71 57.81
Lon 94.97 95.88 96.79 97.70 278.61 279.52 280.44
Lat 61.13 60.69 59.56 49.97 -66.50 -63.98 -63.29
LT 4.22 4.22 4.22 4.23 16.23 16.22 16.22
V^2m^-2Hz^-1
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-15
10^-16
10^-17

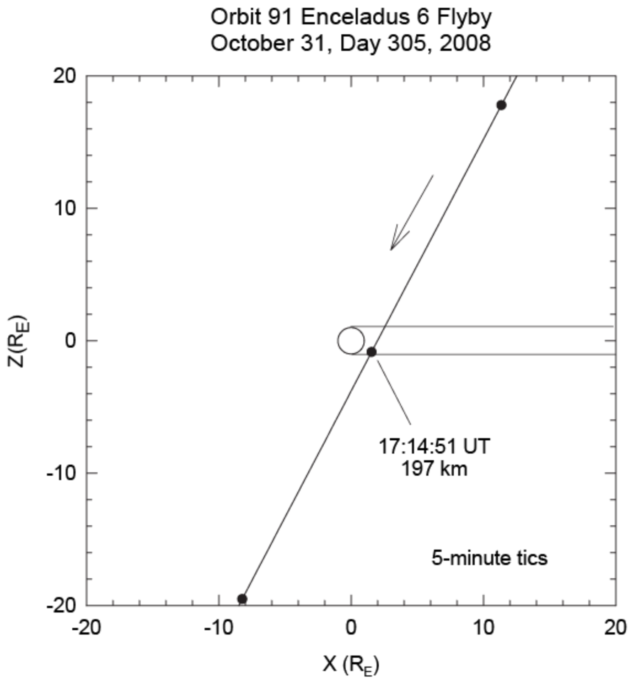

Orbit 61 Enceladus 3
2008-03-12 (072) 18:50:00 SCET 2008-03-12 (072) 19:20:00
Saturated
Impacts per second
1200
1000
800
600
400
200
0
SCET 18:50 18:55 19:00 19:05 19:10 19:15 19:20
R_En 55.60 38.46 21.31 4.28 13.11 30.24 47.39
Lon 132.18 133.07 133.97 134.87 315.79 316.71 317.63
Lat 68.78 68.23 66.79 53.69 -75.29 -72.30 -71.47
LT 2.26 2.26 2.26 2.26 14.26 14.26 14.26



Orbit 88 Enceladus 5 Flyby
October 9, Day 283, 2008
X(R_E)
Y (R_E)
19:06:40 UT
25 km
Saturn
5-minute tics
-20
-10
0
10
20
Orbit 88 Enceladus 5 Flyby
October 9, Day 283, 2008
Z(R_E)
Y (R_E)
19:06:40 UT
25 km
Saturn
5-minute tics
Orbit 88 Enceladus 5 Flyby
October 9, Day 283, 2008
Z(R_E)
X (R_E)
19:06:40 UT
25 km
5-minute tics

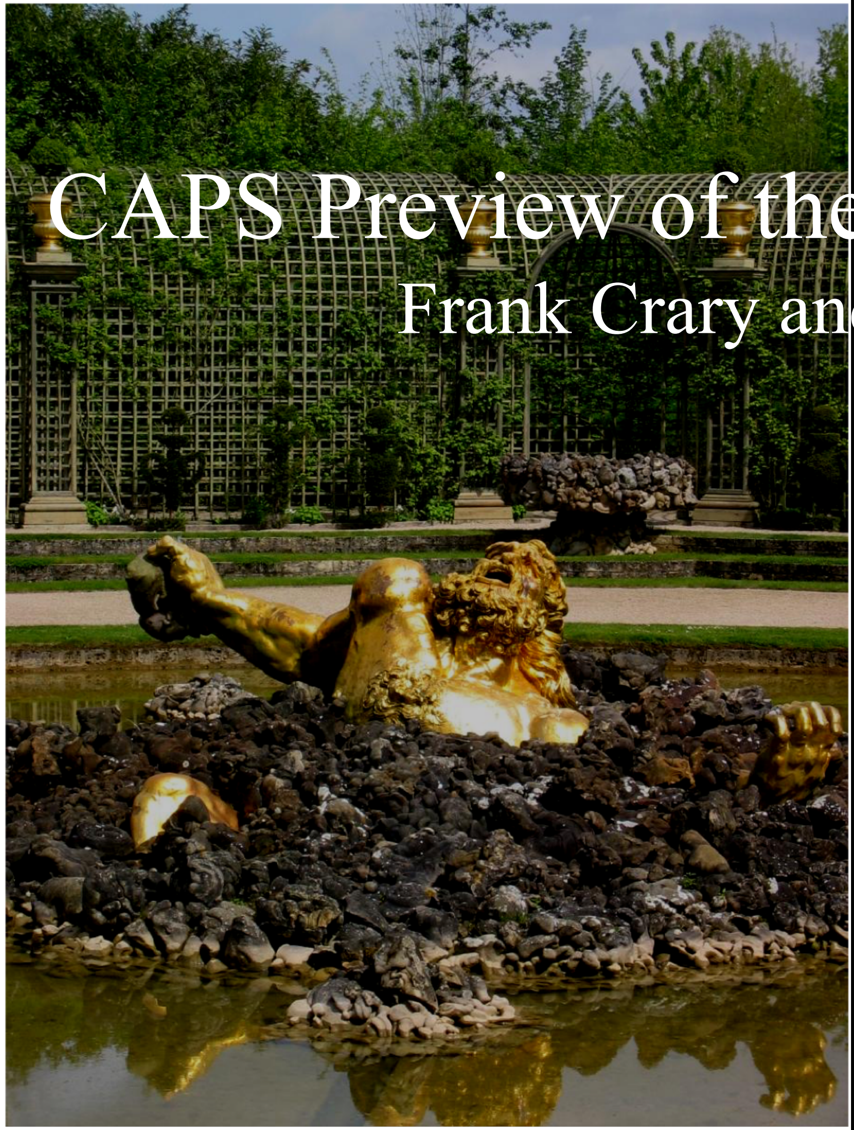

Orbit 91 Enceladus 6 Flyby
October 31, Day 305, 2008
X(R_E)
Y (R_E)
17:14:51 UT
197 km
Saturn
5-minute tics

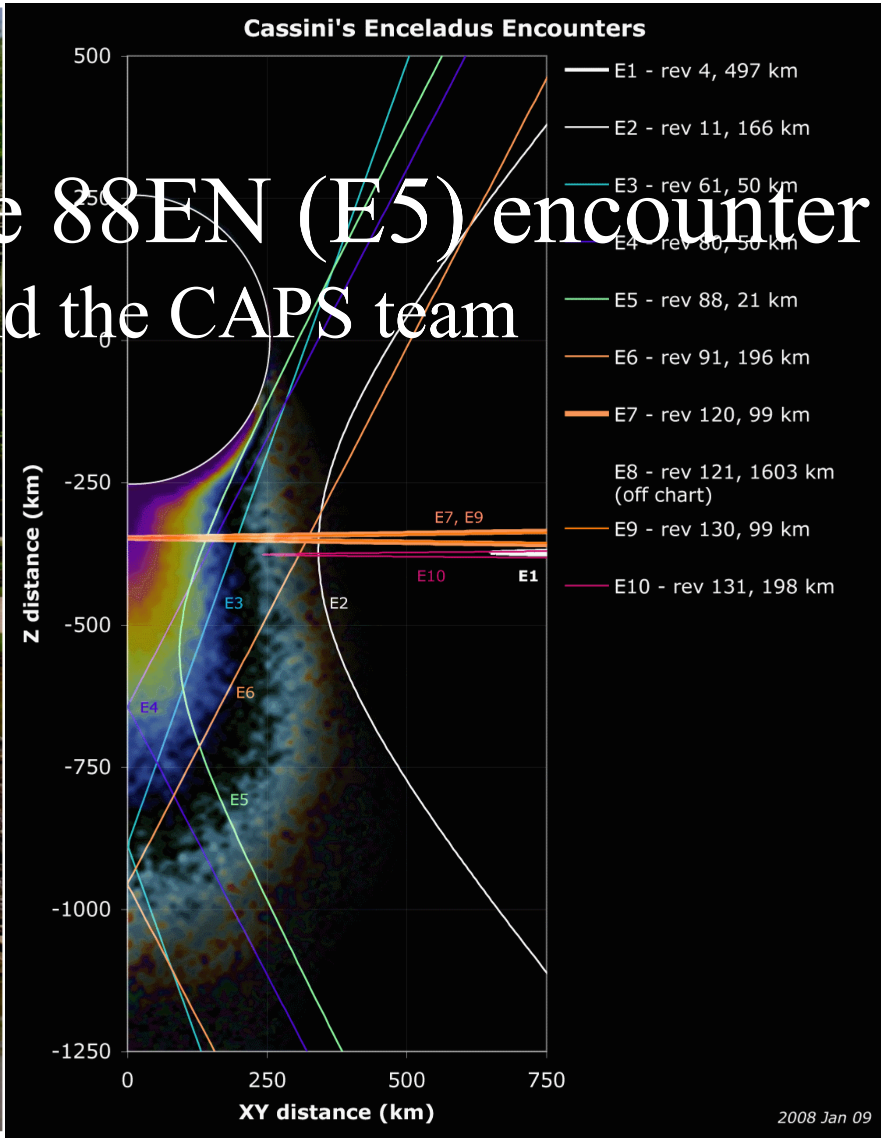

Orbit 91 Enceladus 6 Flyby
October 31, Day 305, 2008
Z(R_E)
Y (R_E)
17:14:51 UT
197 km
Saturn
5-minute tics


Orbit 91 Enceladus 6 Flyby
October 31, Day 305, 2008
Z(R_E)
X (R_E)
17:14:51 UT
197 km
5-minute tics

CAPS Preview of the 88EN (E5) encounter

Frank Crary and the CAPS team





E5/E6 preview meeting
3 October, 2008

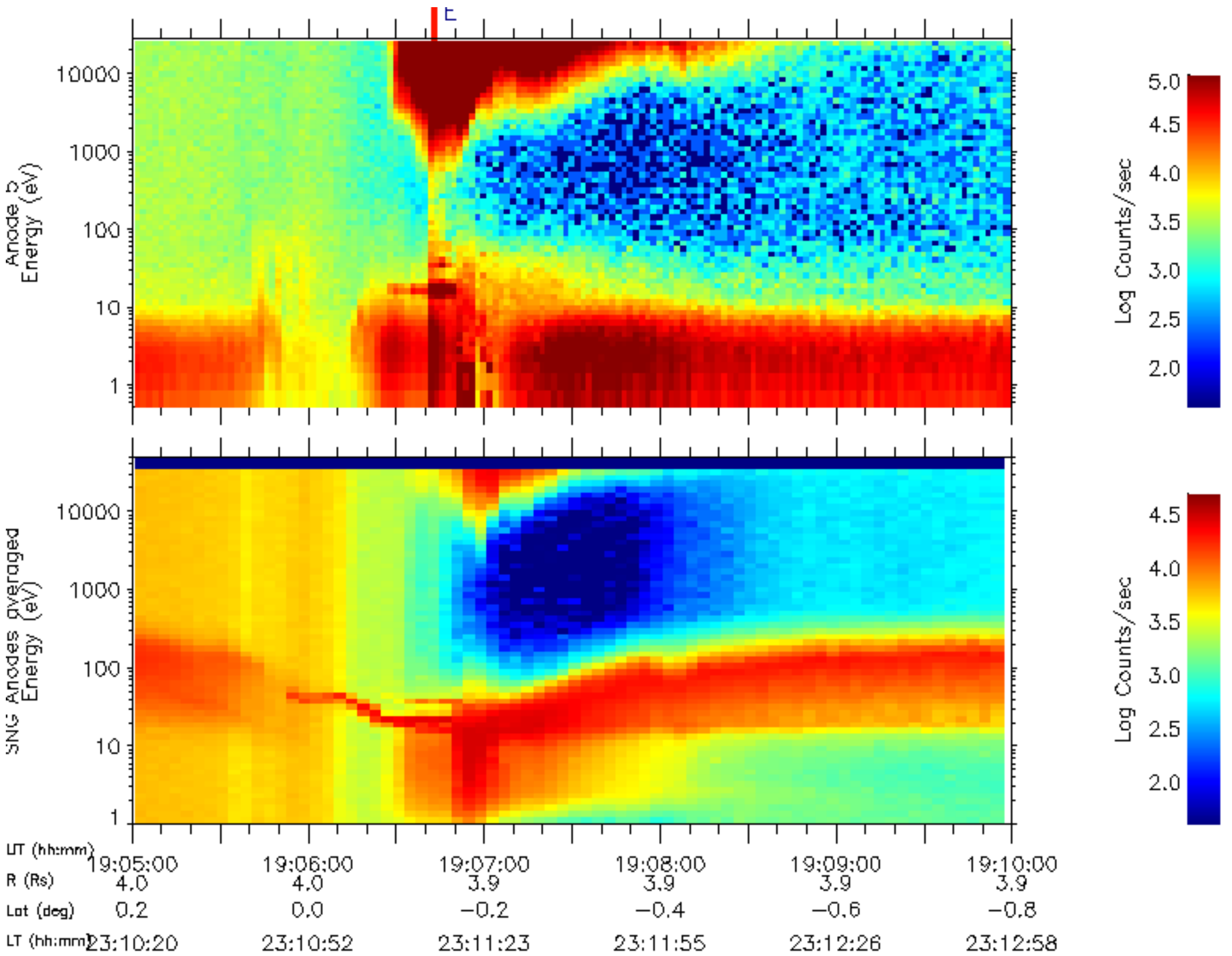
CAPS Enceladus measurements

- Encounter is too fast for actuation (~20 s/R_E)
  - Full ACT sweep=204 s, minimum (28°) sweep=52 s
- Pointing put neutral ram & corotation in X-Z plane
  - Ion sensors viewed peak of unperturbed or stagnated flow
  - Ion sensors could not observe deflected to the sides
  - Electron data covers 0° to ~110° pitch angle
- 4s (58 km) resolution ion data
- 2s (29 km) resolution for electrons
- On 88EN, IBS (high res. ion sensor) covering 1-67 eV
  - Will observe cold ionospheric population
  - Set tighter limits on degree of stagnation in flow

CAPS overview spectrograms

Electrons

Ions

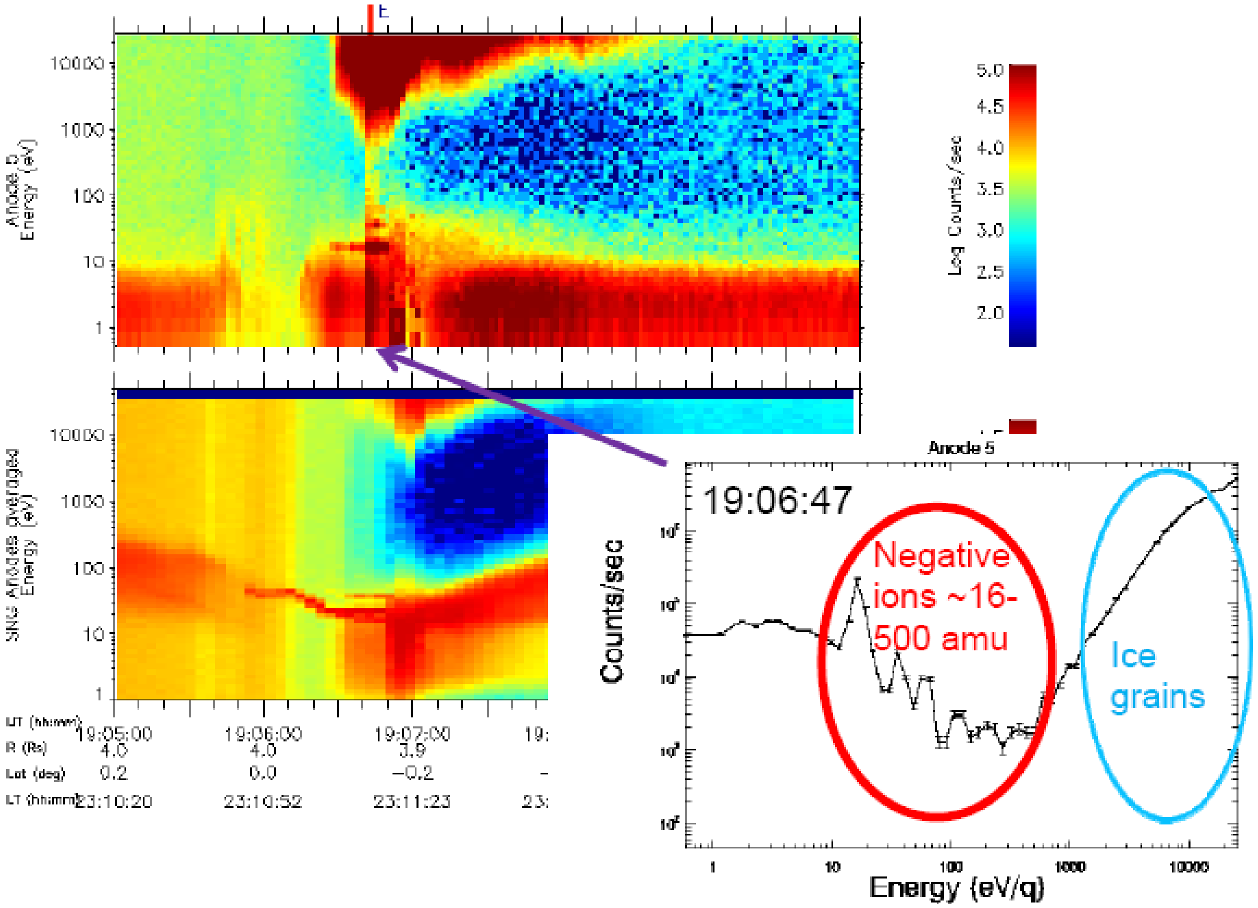


E5/E6 preview meeting
3 October, 2008

Enceladus – actuator fixed
Negative ions also seen at Earth, comets, Titan; Europa?

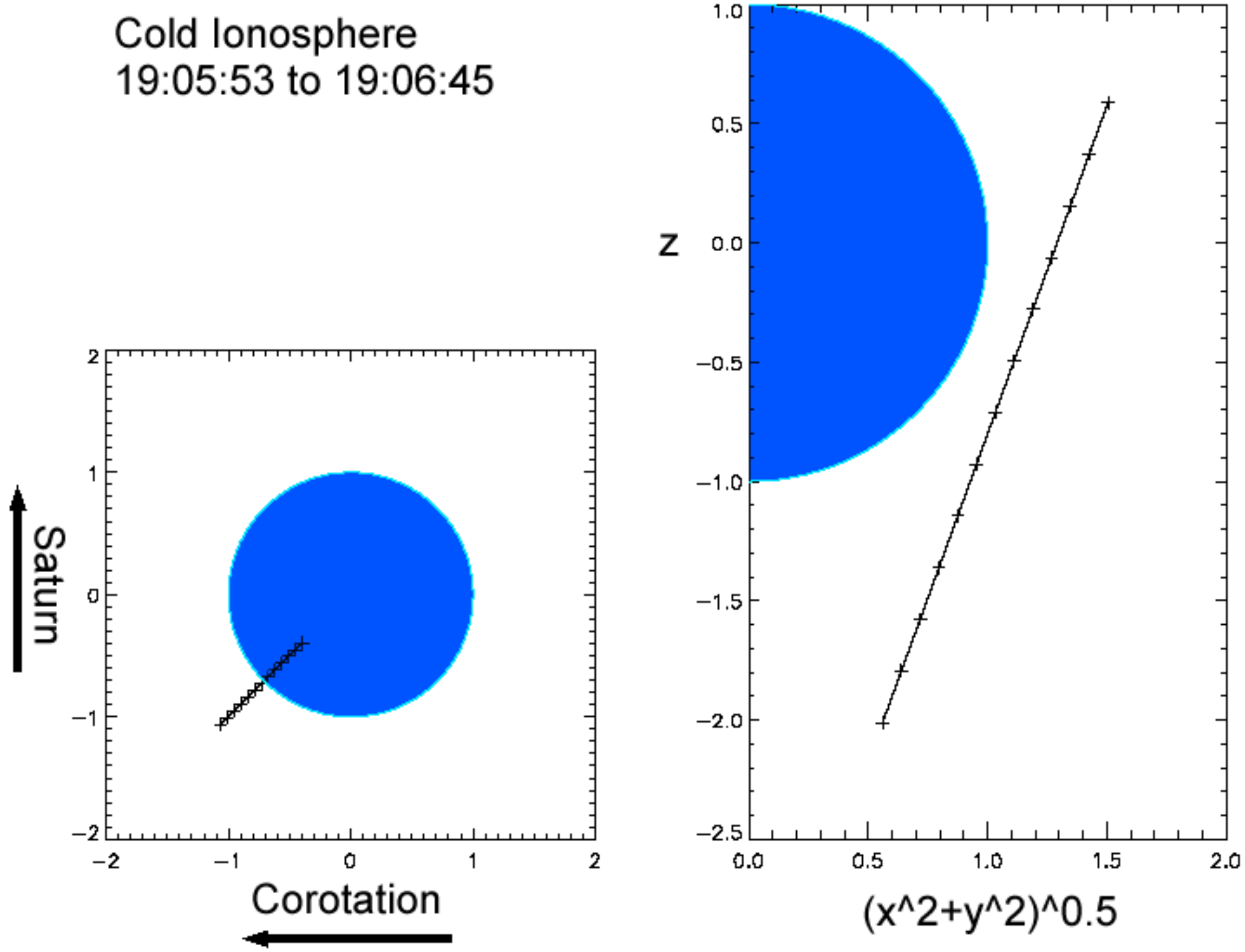
Electrons

Positive ions

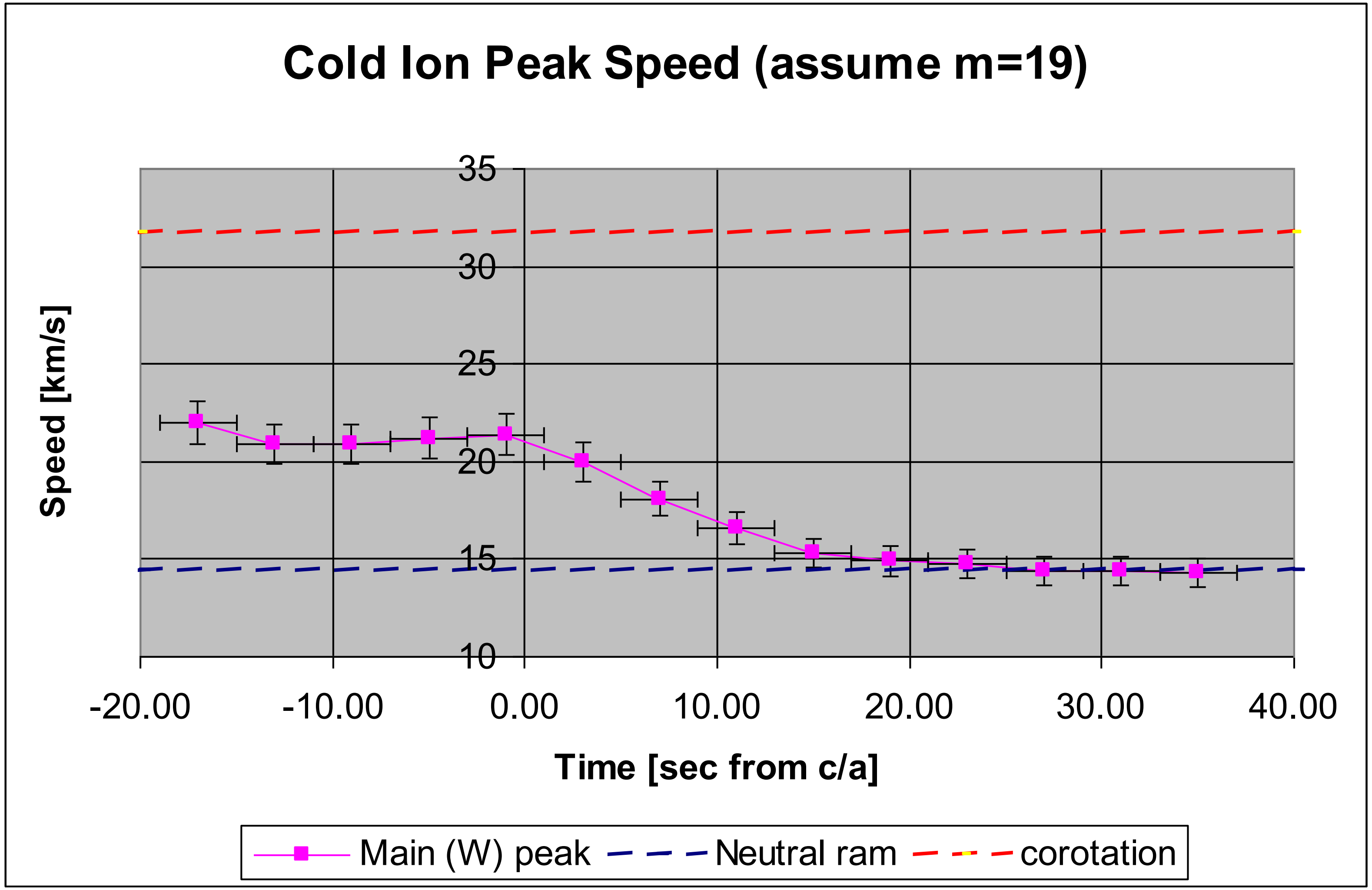


E5/E6 preview meeting
3 October, 2008

Location of cold ionosphere



Inferred ion velocity



Properties and implications of the ionosphere

- Densities of 0.2 – 1.2 cm^{-3}
- Energy corresponds to mass 19±2 AMU
  - Less if flow is not completely stagnated
- Heavier ion present in south/near plume
  - Mass of 35 ±5 AMU
- Negative ions with similar mass also observed
- Global ionosphere from sputtering in (nearly) stagnated flow
- Ions slowly flow out of (nearly) stagnated region & accelerate t
- Cold ⇒ Pickup energy is low (< 2 eV)

  ⇒ Near stagnated flow (< 5 km/s, 20% corotation)
- Alfven relation: $|\Delta B| = |B\ \Delta v\ /\ v_A| \sim 40$ nT
  - $\Delta v = 25$ km/s, B = 330 nT, $v_A = 208$ km/s
  - ~30 nT reported by MAG
- Requires shielding of convection electric field
  - Implies >30 kA current system (per Alfven wing)
  - Assuming 1 R_E current system, more if current system is larger
- Current system extends beyond 1.5 R_E