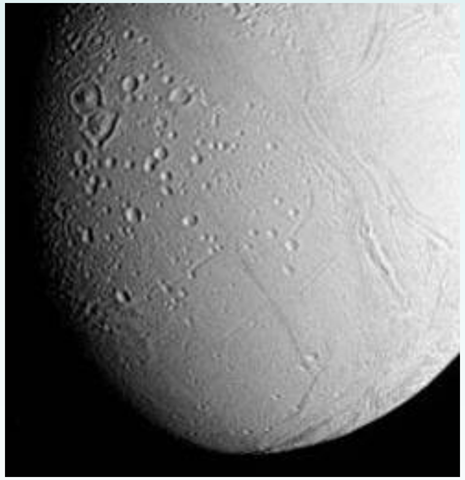
S08 First Targeted Enceladus Flyby

Enceladus: What we know on the eve of EN 003



Bonnie J. Buratti, Rosaly Lopes, and Amanda Hendrix

"The SOST Leadership"

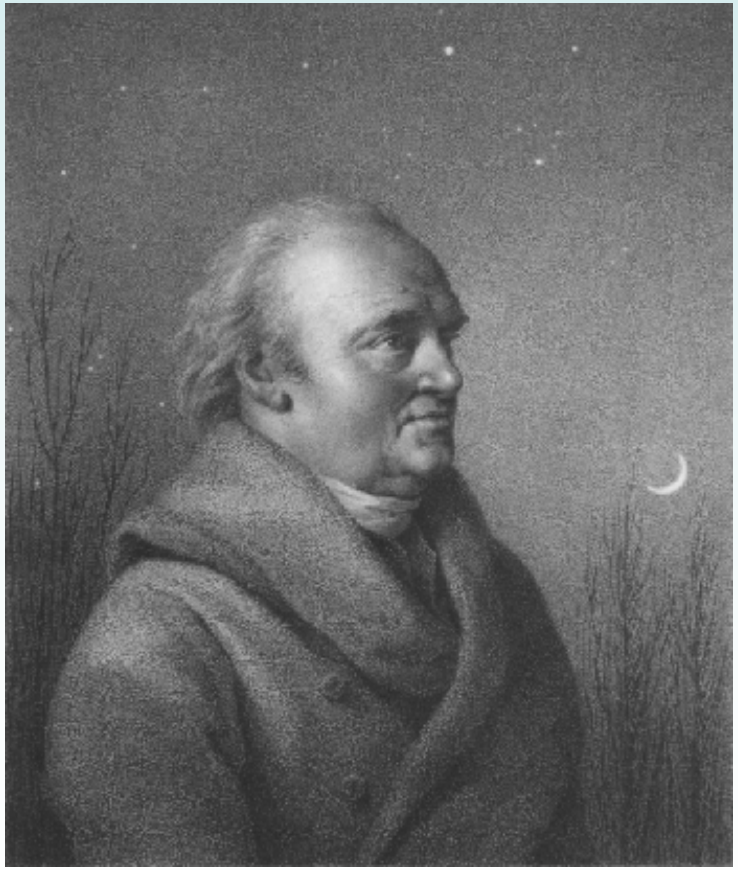
Feb 9, 2005 preview

Properties of Enceladus

Distance from Saturn (10^3 km)	238
Period (days)	1.37
Radius (km)	249
i	0
e	0.004
Density (gm/cc)	1.2
Geometric albedo	1.0 (the highest of anything!)
Discovered	1789 (Herschel)
Composition	Water ice (R. Clark et al.,1983)

Outer Planet Satellites in Perspective

Discovery of Enceladus



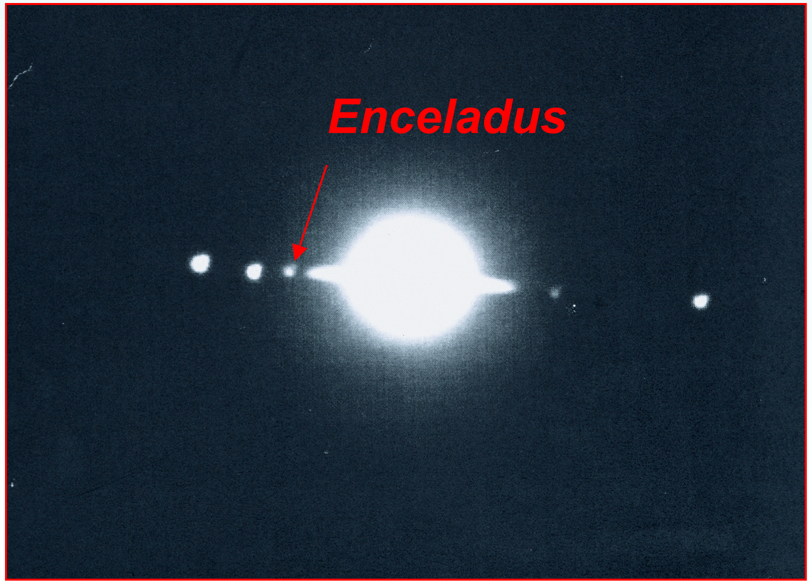
William Herschel

Herschel's telescope, built in 1783; Enceladus was discovered during the next ring plane crossing.

Enceladus during the last ring plane crossing (1997)

- **Ground based studies of Enceladus (and Mimas) are extremely difficult because of scattered light from Saturn.**
- **Most discoveries prior to Voyager, and between Voyager and Cassini, were made during ring plane crossings**

Mimas
From Voyager



Saturn and its five inner medium sized satellites during RPX (1997) Image obtained on the Palomar 60-inch.

Key Questions

1. What is the composition of the surface? Are ammonia and other volatiles present (ammonia decreases the melting point dramatically: it is the only reasonable way to create liquid in the interior)? Are there any identifiable opaque materials (minerals, organics)?
2. Why is Enceladus so bright?
3. Is Enceladus currently active? If it is, what is the energy source?
4. How did the plains and grooves form? When were they formed (crater counts)? What are the main geological and geophysical processes?

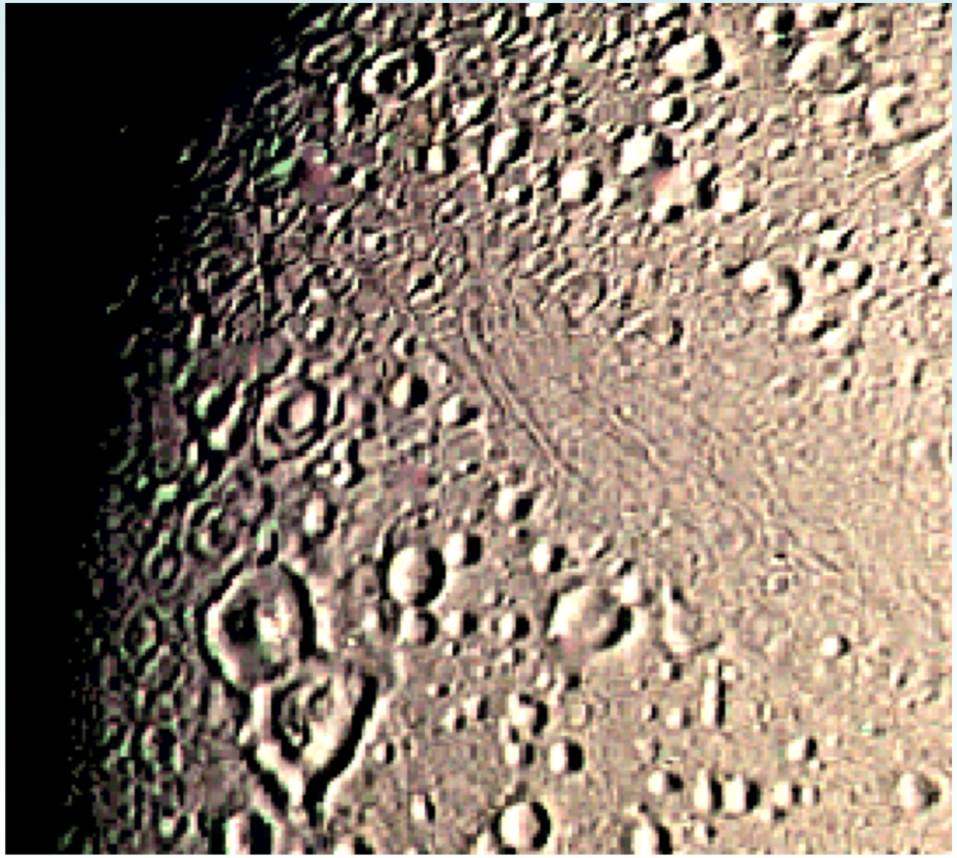
Key Questions, cont'd

5. What is the relationship between Enceladus and the E-Ring?
6. What is the particle environment around the satellite?
7. What is the satellite's dynamical history? Has its orbit been more eccentric in the past?
8. What is the interior structure of Enceladus?

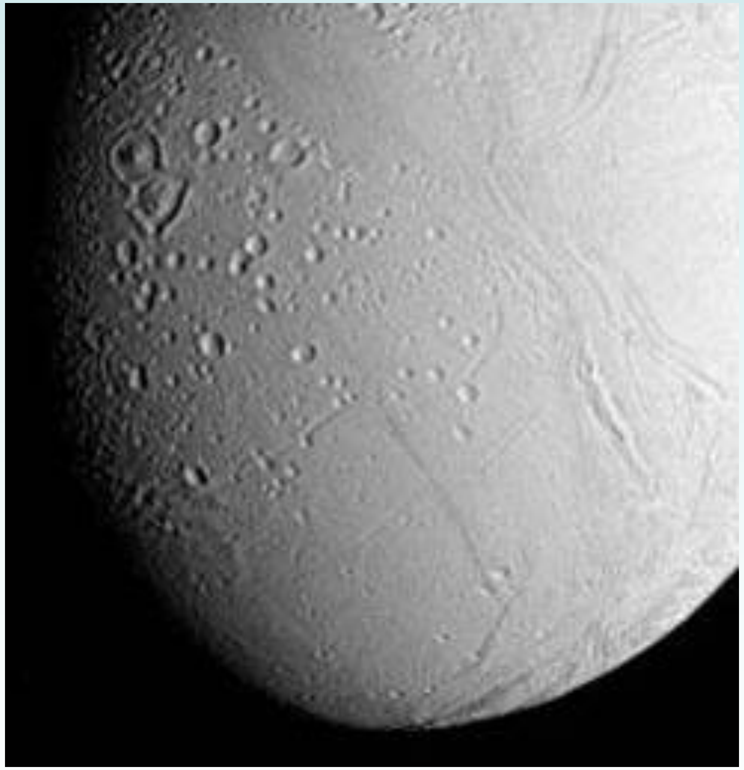
The geologic history of Enceladus

Geophysial processes and things to notice:

Crater relaxation; large central peaks; subduction (note craters at edge of ridges); extensional faults; crater counts in plains; analogies to Ganymede, Titan, etc.

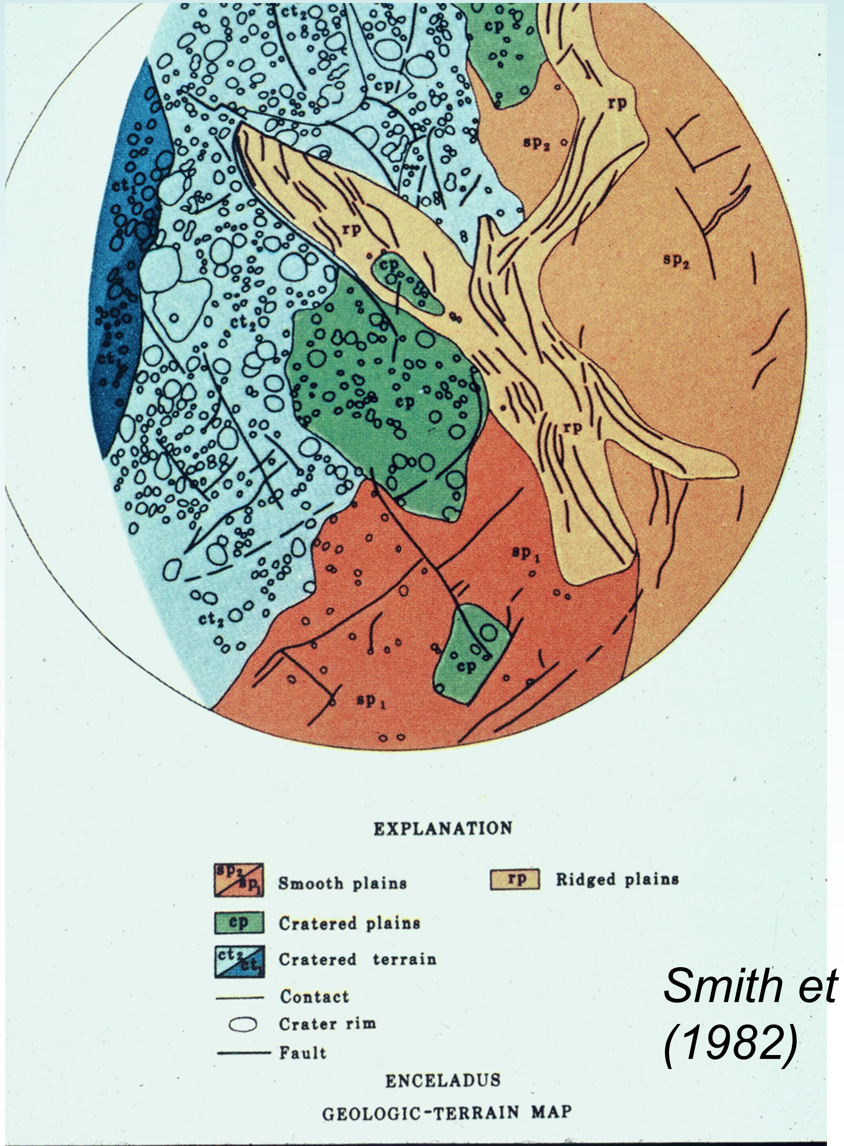


Geologic terrains of Enceladus and albedo



Terrain	*Age (BY)*	B_o
Smooth plains	<0.8	0.82±0.01
Cratered terrain	~3.9	0.84±0.02
Ridged plains	<0.8	0.84±0.01
Cratered plains	~3.6	0.84±0.01

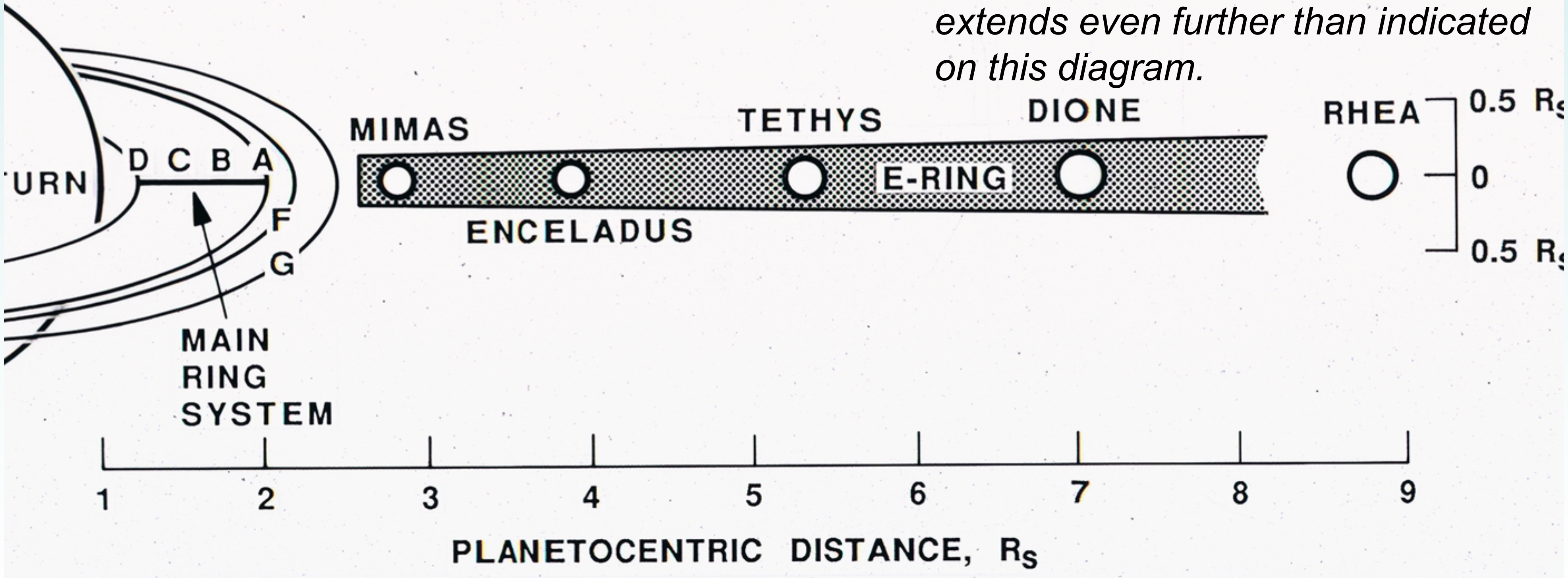
Buratti (1988)



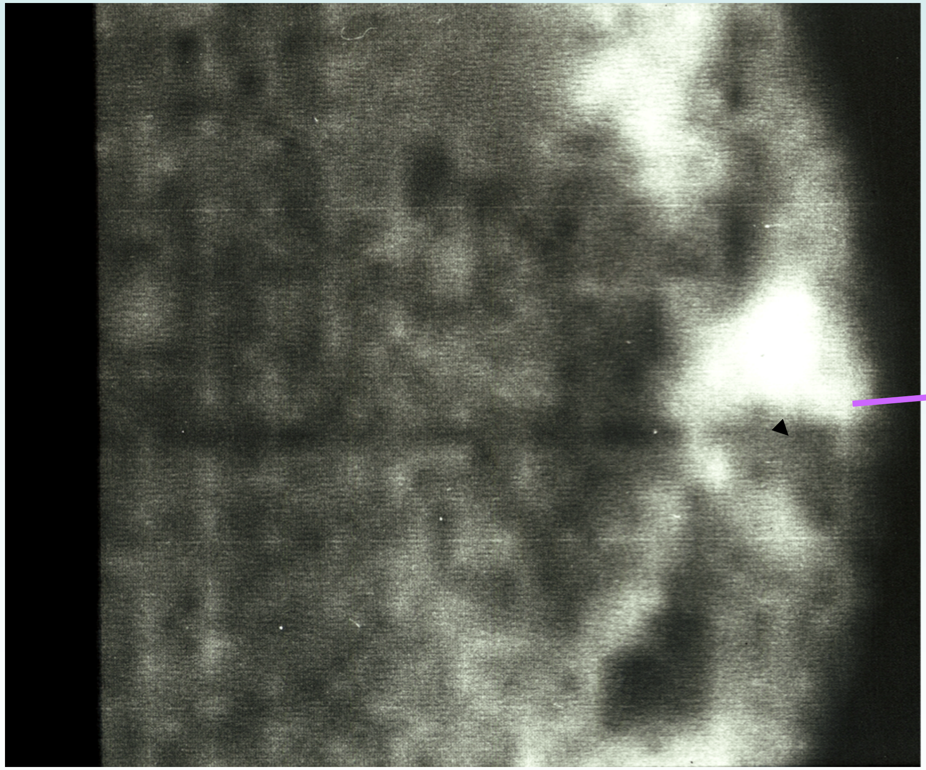
Smith et al. (1982)

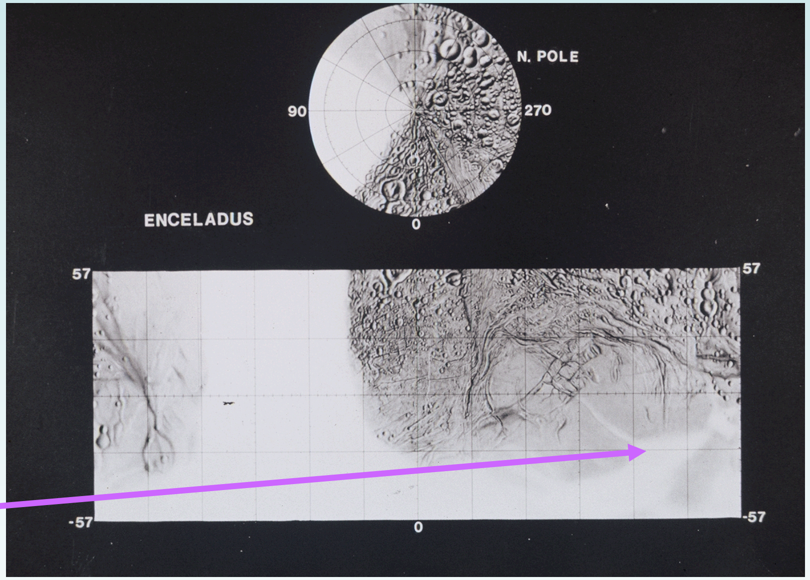
THE FIVE INNER MEDIUM SIZED SATELLITES OF SATURN

Cassini suggests the E Ring extends even further than indicated on this diagram.



Enceladus and its environment





Do particles from the E-ring interact with the other satellites (cf. sulfur and sulfur dioxide from Io; exogenic particles on Iapetus)?

Is the feature above evidence for activity???
Is Enceladus the source of the E Ring?

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	1000
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	100
074	30 June 2008	99,000

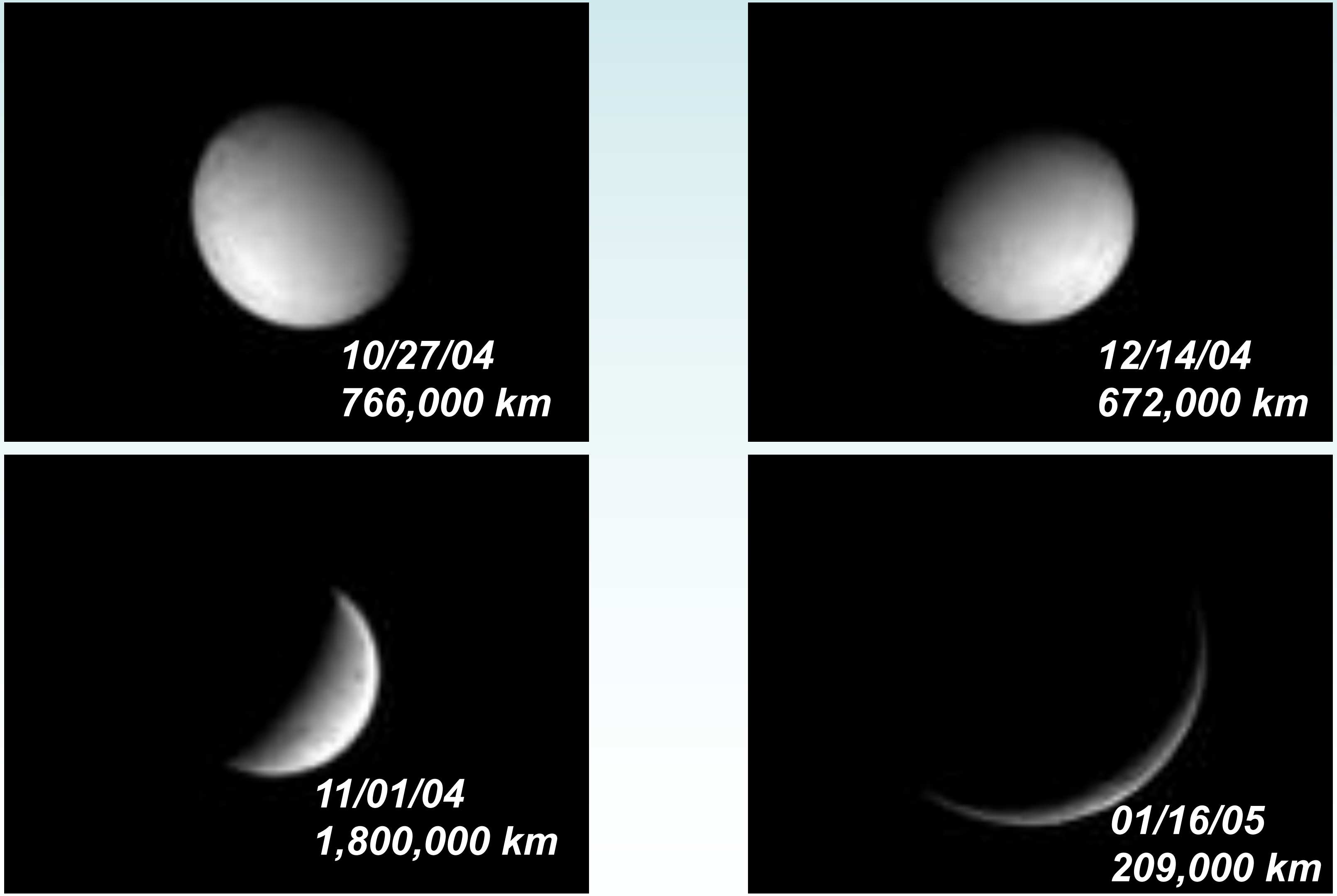
(Table is based on the previous reference tour.)

Two people standing about 350 feet away

The closest Voyager flyby was 90,000 km

The same people 3 feet away:
This analogy is equivalent to the comparison of Voyager and
003 EN

Enceladus as seen by Cassini so far



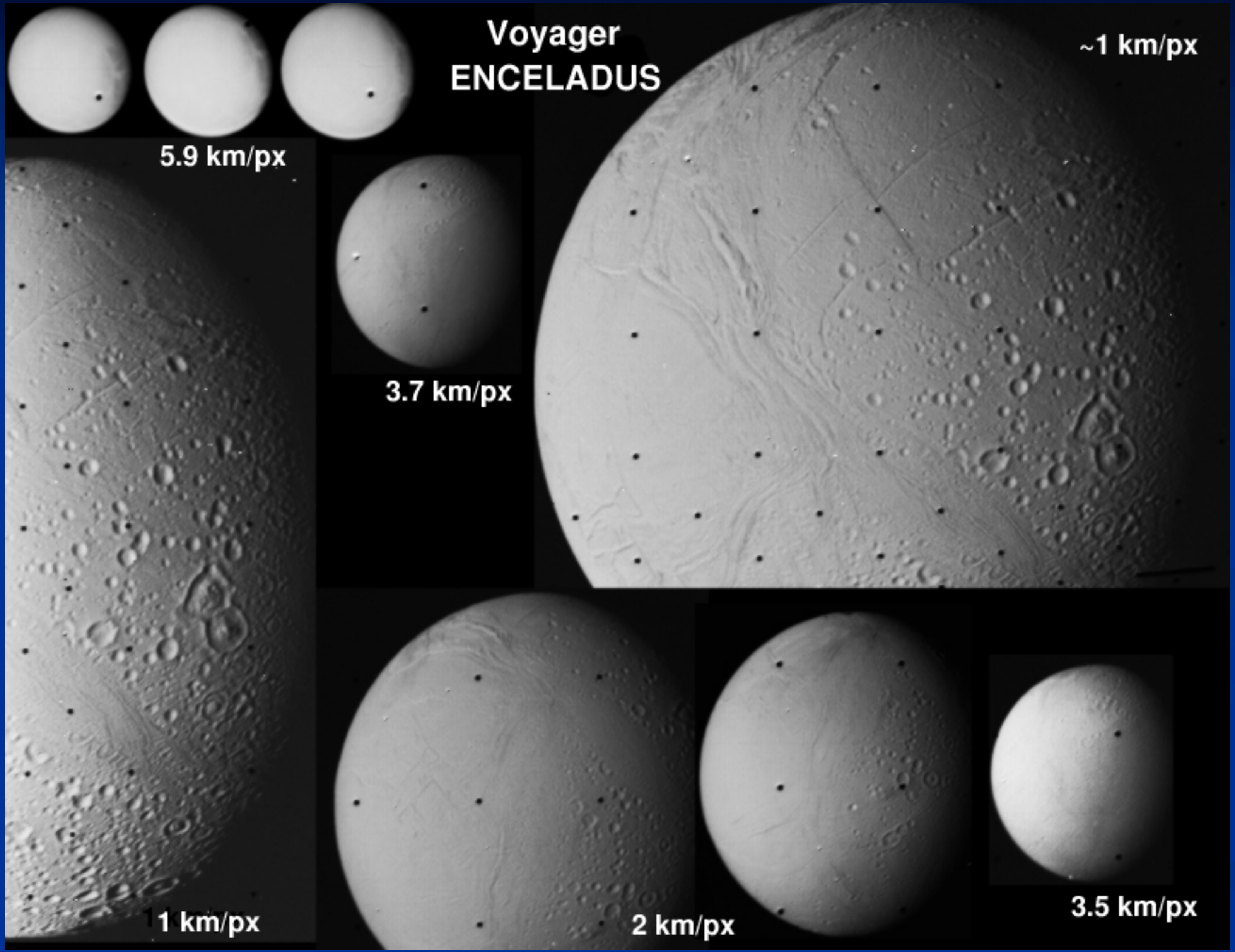
Enceladus 003 Flyby
ISS OBSERVATIONS

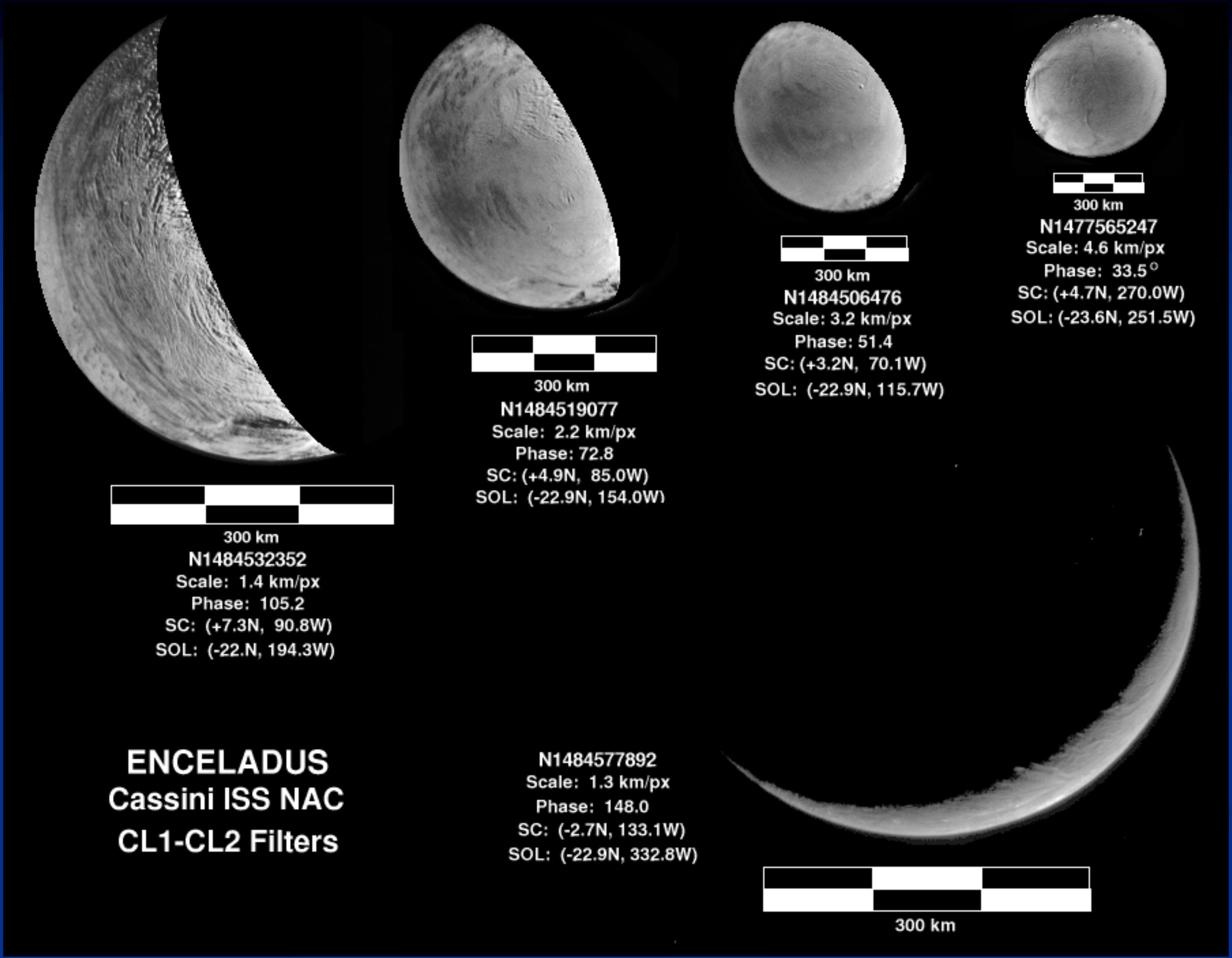
Paul Helfenstein
Cornell University

9 February, 2005

Acknowledgments

- Tilmann Denk (Freie Univ., Berlin)
- Thomas Roatsch (DLR)
- Peter Thomas (Cornell)
- Pam Smith (Cornell)
- Pauline Helfenstein (Cornell)
- Jon Proton (Cornell)
- Emma Birath (CICLOPS)
- Nicole Martin (CICLOPS)
- Ben Knowles (CICLOPS)


Voyager
ENCELADUS
~1 km/px
5.9 km/px
3.7 km/px
1 km/px
2 km/px
3.5 km/px

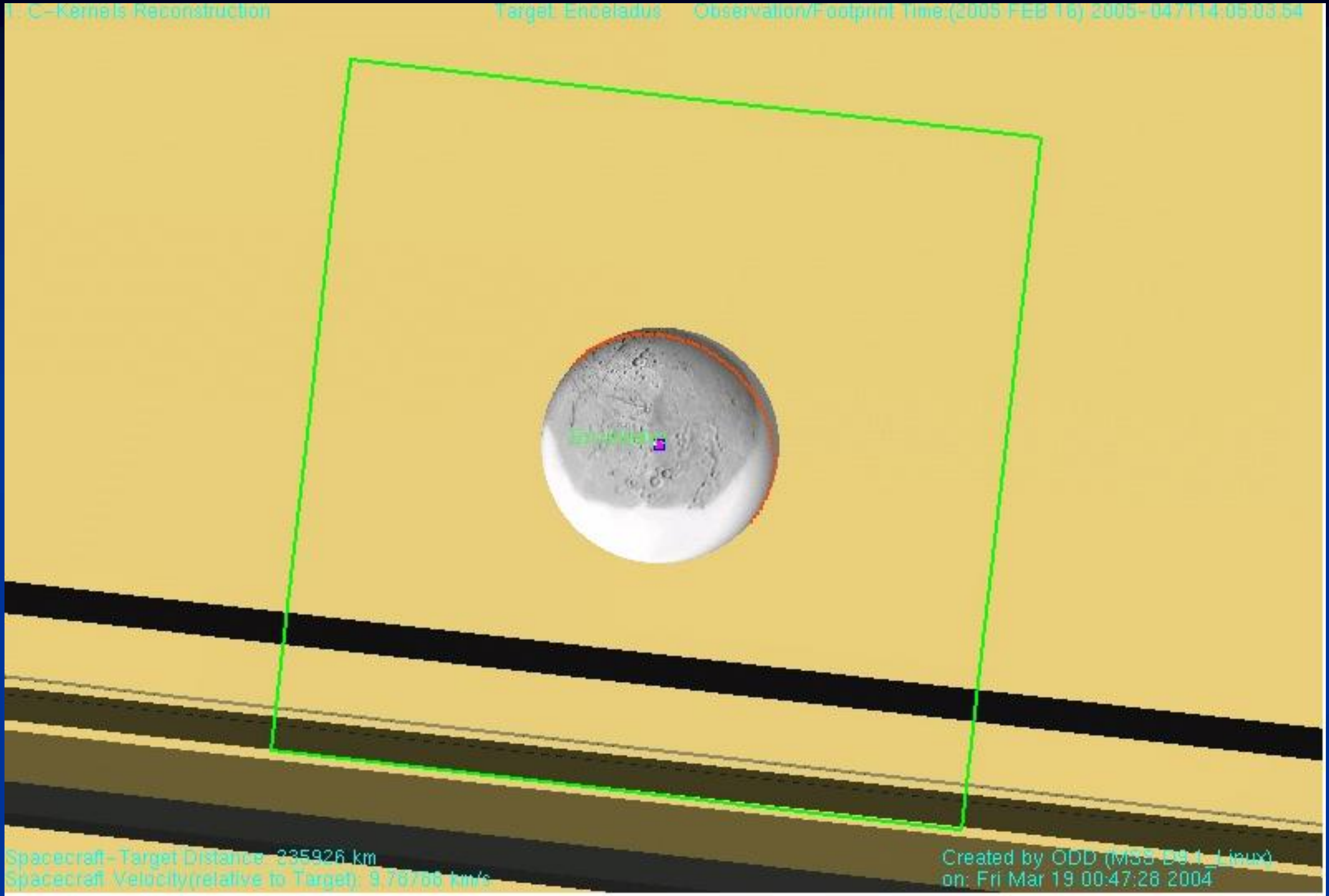

300 km
N1477565247
Scale: 4.6 km/px
Phase: 33.5°
SC: (+4.7N, 270.0W)
SOL: (-23.6N, 251.5W)
300 km
N1484506476
Scale: 3.2 km/px
Phase: 51.4
SC: (+3.2N, 70.1W)
SOL: (-22.9N, 115.7W)
300 km
N1484519077
Scale: 2.2 km/px
Phase: 72.8
SC: (+4.9N, 85.0W)
SOL: (-22.9N, 154.0W)
300 km
N1484532352
Scale: 1.4 km/px
Phase: 105.2
SC: (+7.3N, 90.8W)
SOL: (-22.N, 194.3W)
ENCELADUS
Cassini ISS NAC
CL1-CL2 Filters
N1484577892
Scale: 1.3 km/px
Phase: 148.0
SC: (-2.7N, 133.1W)
SOL: (-22.9N, 332.8W)
300 km

E3 SCIENCE OBJECTIVES: OBSERVATION NAMING CONVENTION

- Surface Geological Features (GEOLOG, REGMAP)
- Geodesy, Topography, Geomorphology (LIMTOPO, STEREO, MORPH)
- Photometric/Polarization Properties (PHOTOM, HIPHASE, LOPHASE, ZEROPHASE, OPPSURG, PHOTPOL)
- Color Variations (GLOCOL, ROTCOLOR, COLOR, LONPHA)
- Eruptive Plume Searches (PLUME)

E03 ENCELADUS:
ISS REQUESTS

ObsReqID	StartT	Duration	EpochReference	EpochDelta
ISS_003EN_GEOLOG001_PRIME	2005-047T13:55:00	000T00:40:00		
ISS_003EN_GEOLOG002_PRIME	2005-047T15:49:00	000T00:40:00		
ISS_003EN_GEOLOG003_PRIME	2005-047T16:29:00	000T00:30:00		
ISS_003EN_LIMTOP004_PRIME	2005-048T02:15:29	000T00:50:00	GMB_E003_Enceladus	-000T01:15:00
ISS_003EN_ENCDUST001_CDA	2005-048T03:05:29	000T00:55:00	GMB_E003_Enceladus	-000T00:25:00
ISS_003EN_PLUME001_PRIME	2005-048T11:30:29	000T01:14:26	GMB_E003_Enceladus	+000T08:00:00
ISS_003EN_094W091PH001_PRIME	2005-049T14:10:00	000T00:25:00		
ISS_003EN_166W096PH001_PRIME	2005-049T20:15:00	000T00:30:00		
ISS_003EN_310W101PH001_PRIME	2005-050T09:01:00	000T00:10:00		
ISS_003EN_022W088PH001_PRIME	2005-050T16:50:00	000T00:25:00		
ISS_003EN_310W090PH001_PRIME	2005-051T18:20:00	000T00:35:00		

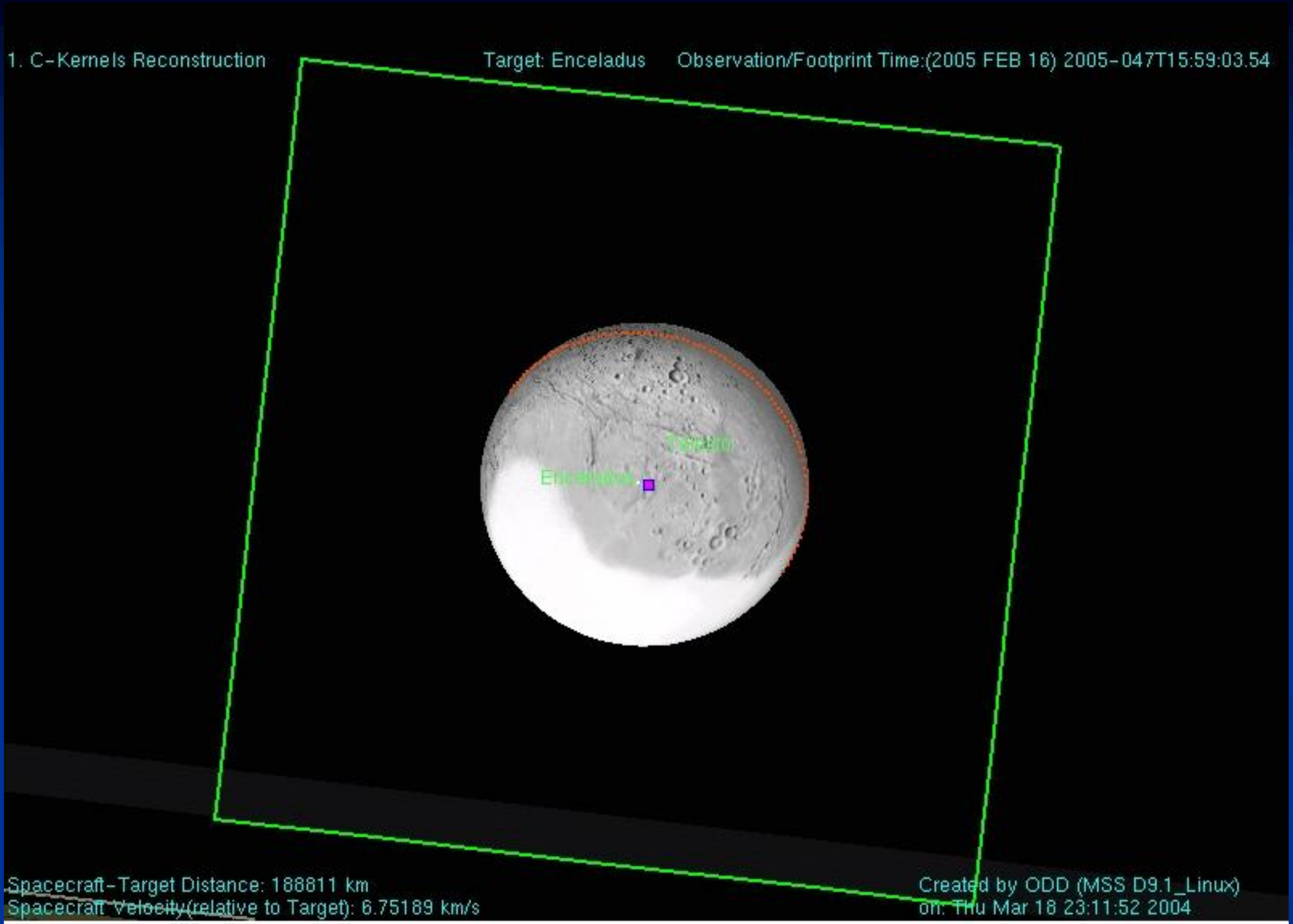


ISS_003EN_GEOLOG001_PRIME

START: 2005-047T13:55:00   DUR: 00:40:00
ISS_NAC to Enceladus, +X to NSP
Est. DATA VOL: 25.166 Mb
RANGE: 242953 km   Scale: 1.4 km/px
Phase Angle: 27.9
Subspacecraft Point: (-1N, 174W)

IMAGES

NAC CL1-CL2 (2x2 SUM)
NAC CL1-UV3 (2x2 SUM)
NAC CL1-IR1
NAC CL1-IR3
NAC P0-,P60-,P120-GRN

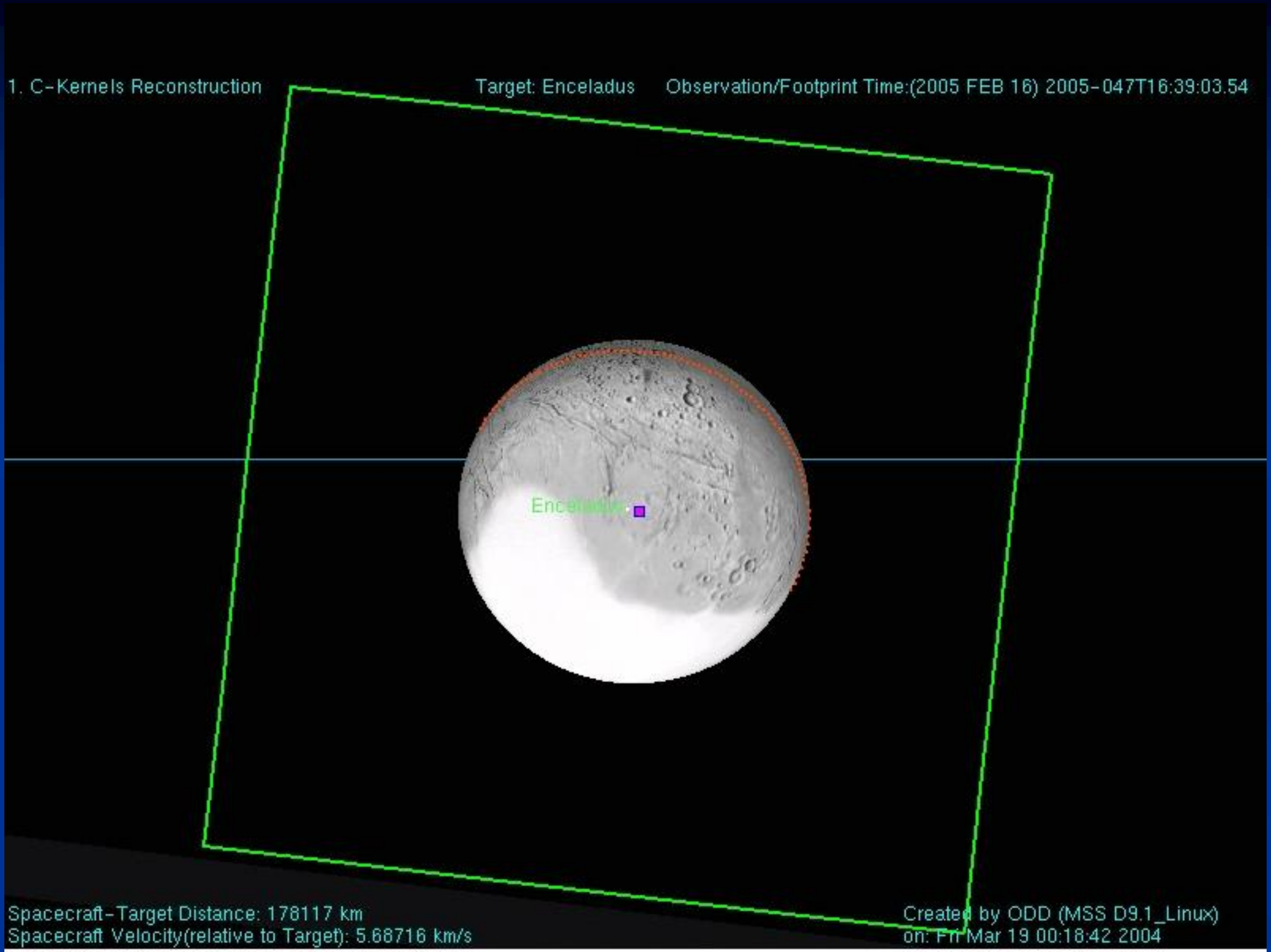


ISS_003EN_GEOLOG002_PRIME

Start: 2005-047T15:49:00 Dur: 00:40:00
ISS_NAC to Enceladus, +X to NSP
Est. Data Volume: 25.166 Mb
Range: 193639 km Scale: 1.1 km/px
Phase Angle: 23.7
Subspacecraft point: (-1N, 203W)

IMAGES

NAC CL1_UV3
NAC CL1_IR1
NAC CL1_IR3
NAC P0_, P60_, P120_GRN

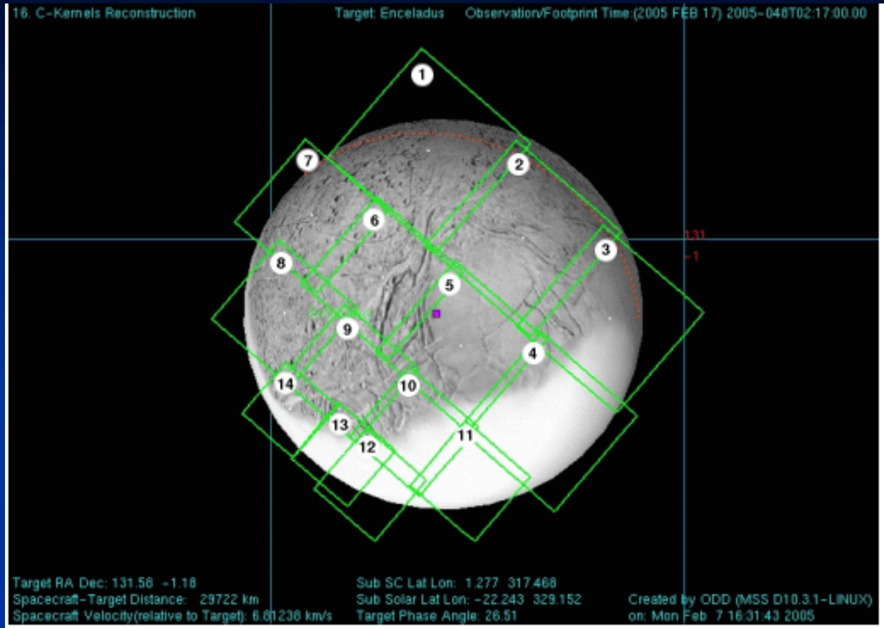


ISS_003EN_GEOLOG003_PRIME

Start: 2005-047T16:29:00 Dur: 00:30:00
ISS_NAC to Enceladus, +X to NSP
Est. Data Vol.: 25.1658 Mb
Range: 182327 km Scale: 1.3 km/px
Phase Angle: 22.6
Subspacecraft point: (-1N, 214W)

IMAGES

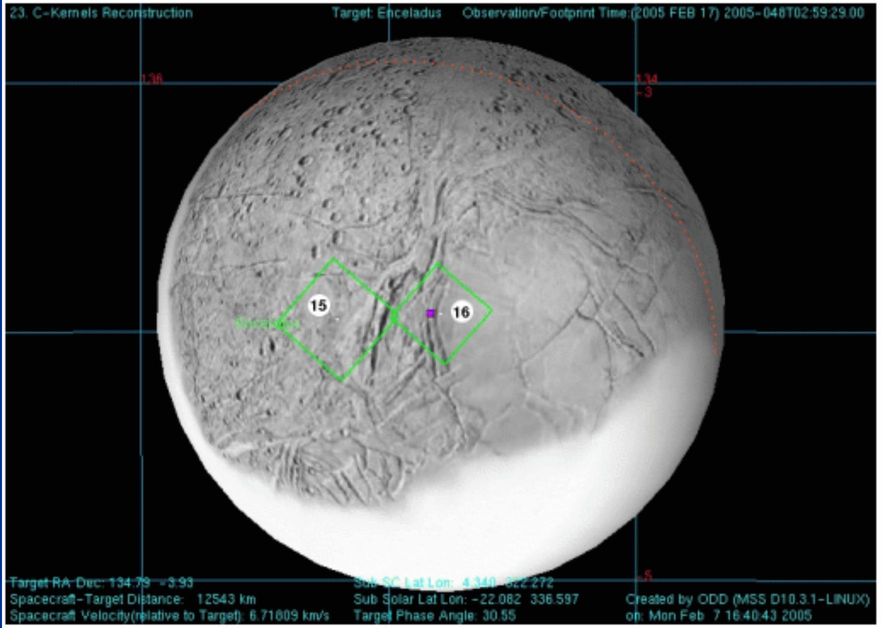
NAC CLR_UV3
NAC CLR_IR1
NAC CLR_IR3
NAC P0_, P60_, P120_GRN

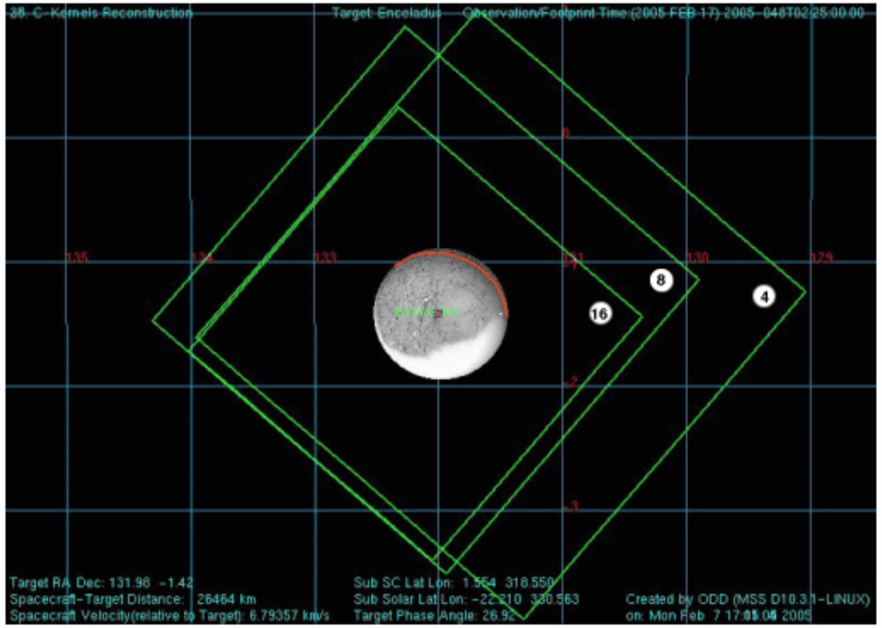


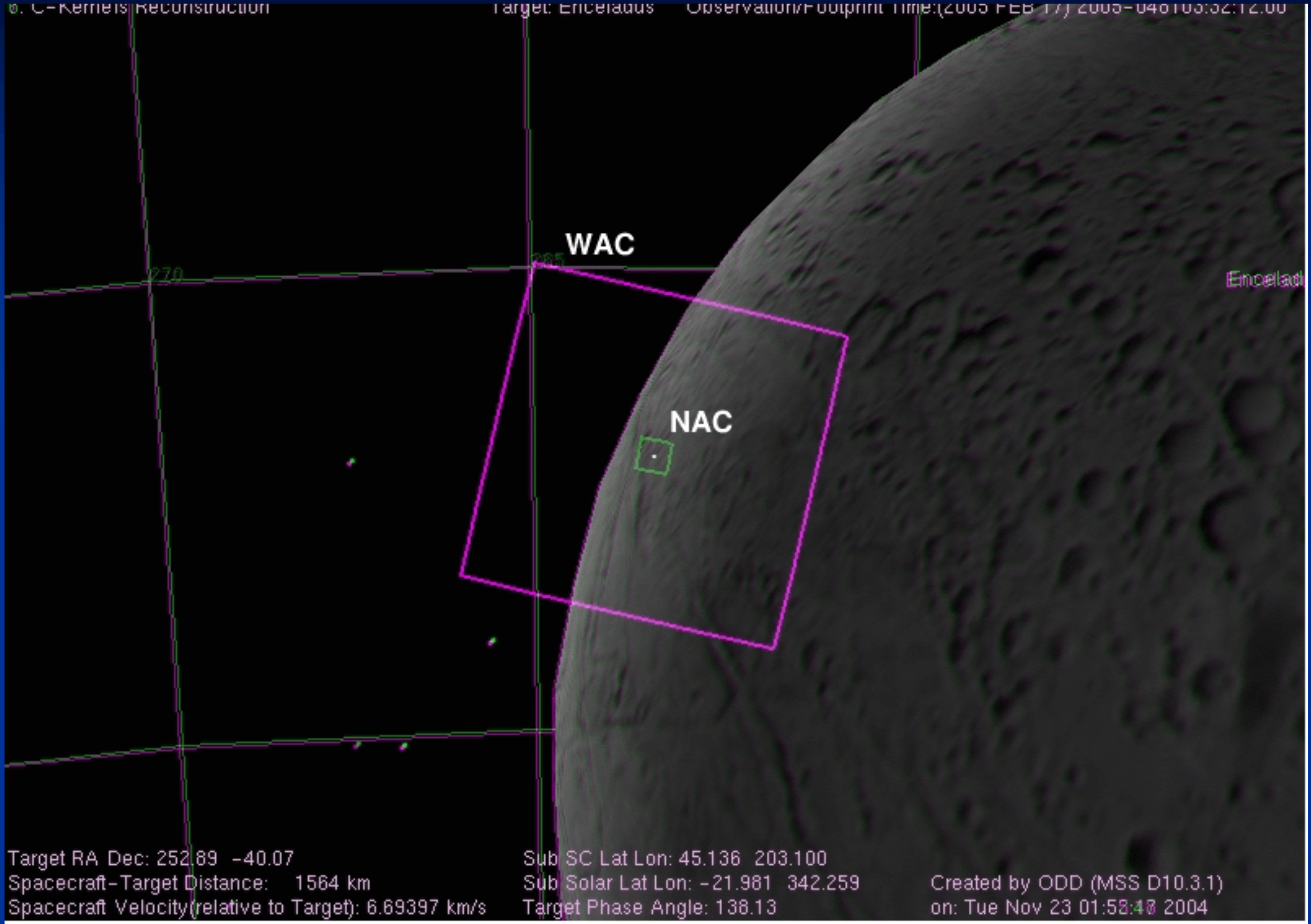
ISS_003EN_LIMTOP004_PRIME

Start: GMB_E003_Enceladus -000T01:15:00 (2005-048T02:15:29) Dur: 00:50:00
NAC to Enceladus, -X to RA/DEC (198/-47) Est. Data Volume: 88.0804 Mb
Range: 30341 km to 10146 km Scale: 175 m/px to 50 m/px
Phase Angle: 26.4 to 32.1 Subspacecraft Point: (1N, 315W) to (6N, 320W)

F	DWELL	FILTERS	F	DWELL	FILTERS
1	00:02:08	NAC CL1_CL2	9	00:02:05	NAC CL1_CL2
2	00:02:05	NAC CL1_CL2	10	00:02:04	NAC CL1_CL2
3	00:02:04	NAC CL1_CL2	11	00:02:04	NAC CL1_CL2
4	00:02:17	BOT CL1_CL2	12	00:02:31	NAC CL1_CL2
5	00:02:05	NAC CL1_CL2	13	00:02:05	NAC CL1_CL2
6	00:02:25	NAC CL1_CL2	14	00:02:04	NAC CL1_CL2
7	00:02:04	NAC CL1_CL2	15	00:03:06	NAC CL1_CL2 NAC CL1_UV3 NAC CL1_GRN NAC CL1_IR3
8	00:02:35	BOT CL1_CL2	16	00:02:00	NAC CL1_CL2





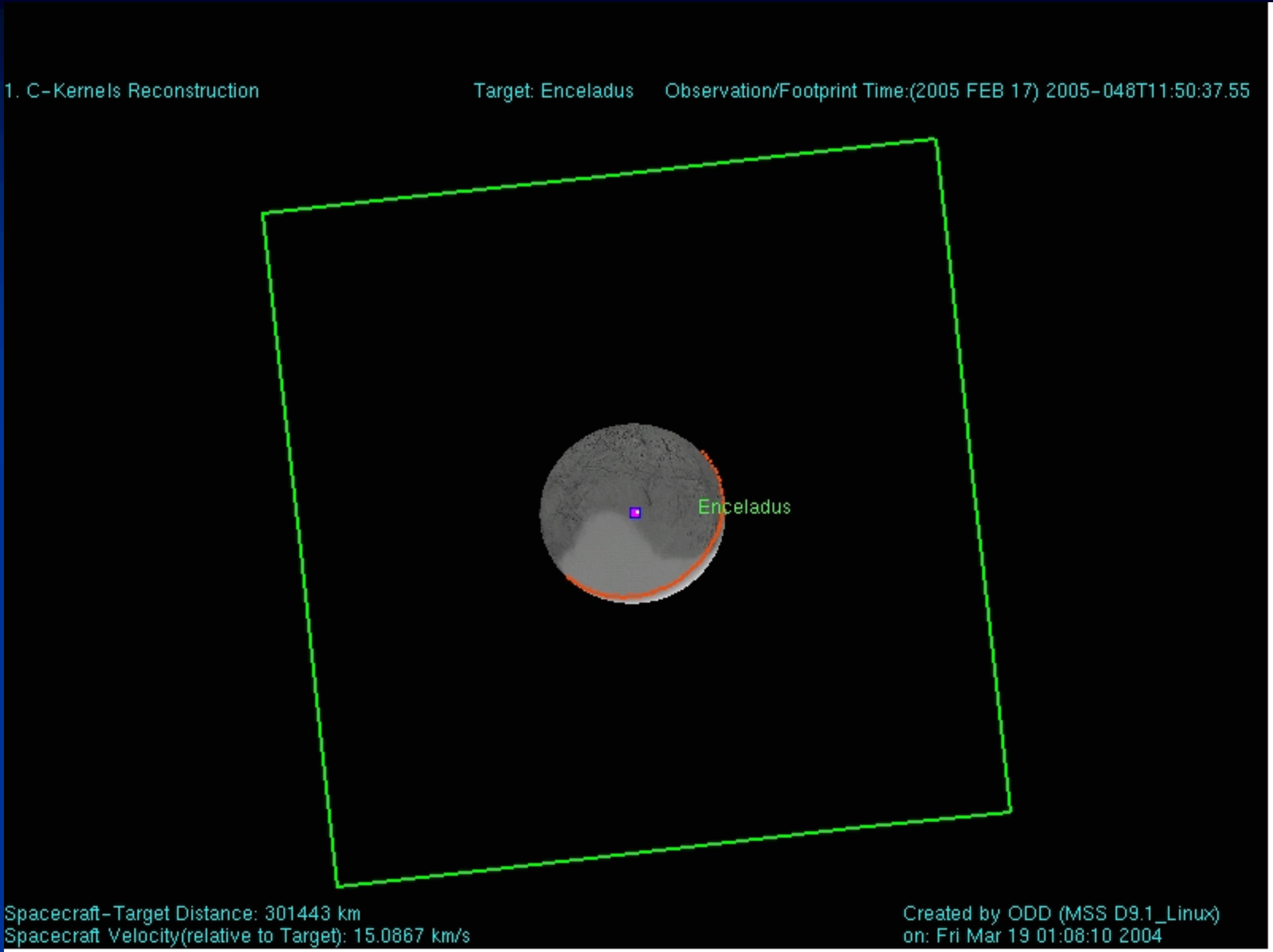


ISS_003EN_ENCDUST001_CDA

Start: GMB_E003_Enceladus-00:25:00 Dur: 00:55:00
NEG_Y to RA/DEC (263.4, -37.1), NEG_X to RA/DEC (62.3, -51.0)
Est. Data Volume: 37.75 Mb, Telemetry Mode: S&ER2
Range: 1566 km Scale: 9m/px (NAC), 90m/px (WAC)
Phase Angle: 138.4
Subspacecraft Point: (48N, 203W)

IMAGES

Eight (8) BOTSIM's CL1_CL2
One (1) WAC CL1_CL2



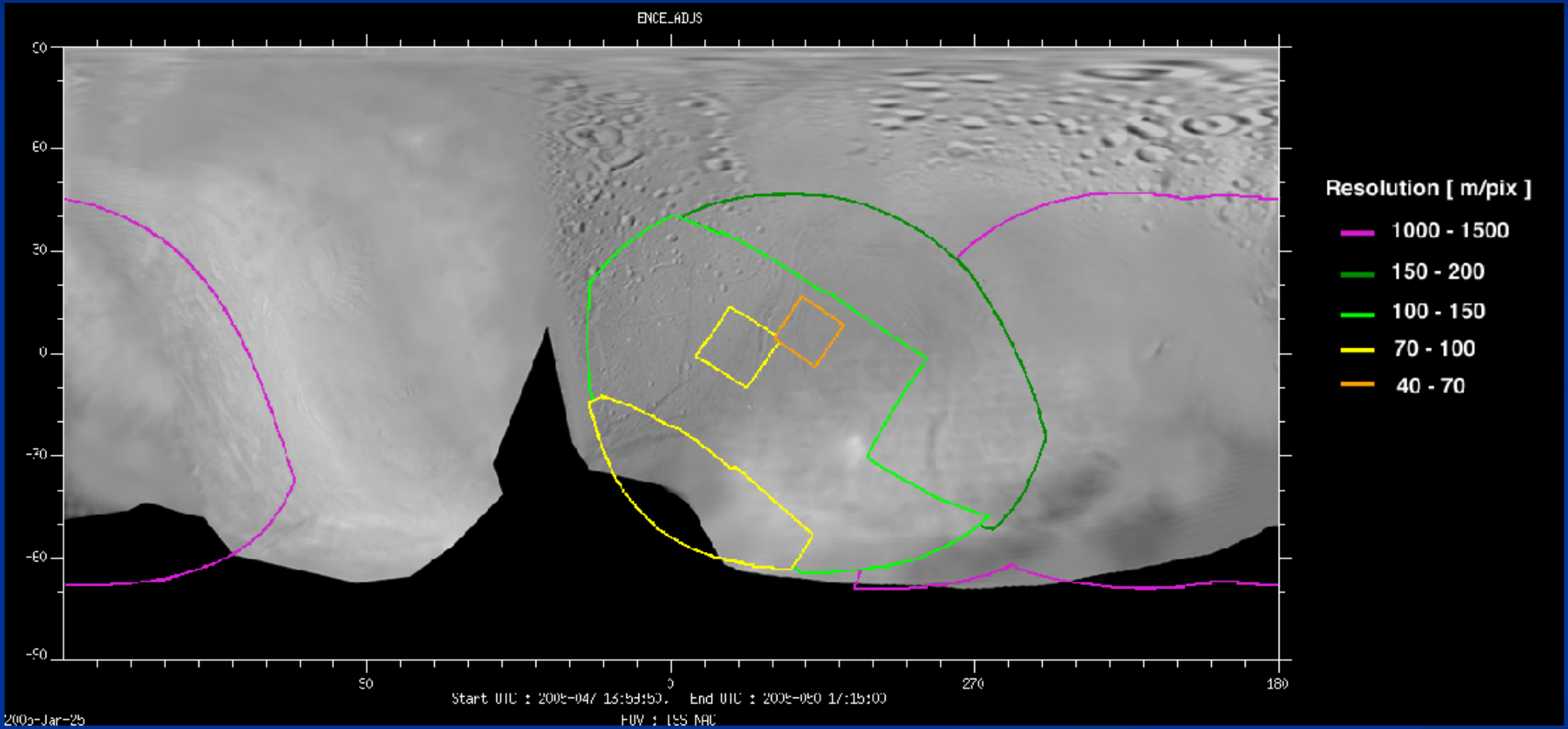
ISS_003EN_PLUME001_PRIME

Start: GMB_E003_Enceladus+08:00:00   Dur: 01:14:26
ISS_NAC to Enceladus, POS_X to NSP
Est. Data Volume: 83.886 Mb
Range: 282606km to 349285km   Scale: 1.6 km/px to 2.0 km/px
Phase Angle: 153.9 to 152.0
Subspacecraft Point: (1N, 234W) to (1N, 244W)

IMAGES

Set 1: Nominal surface exposure
NAC CL1_UV3, CL1_IR1, CL1_IR3
+ NAC GRN Polarizers
Set 2: Above filters for I/F = 0.005
Set 3: Above filters for I/F = 0.05
Set 4: Above filters for I/F = 0.10
Set 5: NAC CL1_CL2 (3 frames)
1s, 10s, 100s exposures

Summary of E3 Flyby Coverage



UVIS Science at Enceladus

C. J. Hansen, A. Hendrix

9 February 2005

UVIS Science at Enceladus

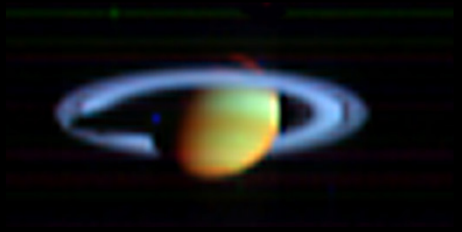
C. J. Hansen, A. Hendrix

9 February 2005

Cassini

VIMS

S08 Enceladus



VIMS

Visual and Infrared Mapping Spectrometer

- 0.35 to 5.2 microns in 352 wavelengths
- IFOV: 0.5 x 0.5 mrad (standard)
- 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.

VIMS Enceladus Science

Identification of minerals and other materials on the surface.

Mapping the abundance, and grain sizes of surficial materials.

Grain-Size Mapping

Reflectance from 0.35 to 5.2 microns

Phase function

surface microstructure

Bond albedo

Temperatures > 120K

VIMS_003EN_ENCELADUS006_PRIME.a

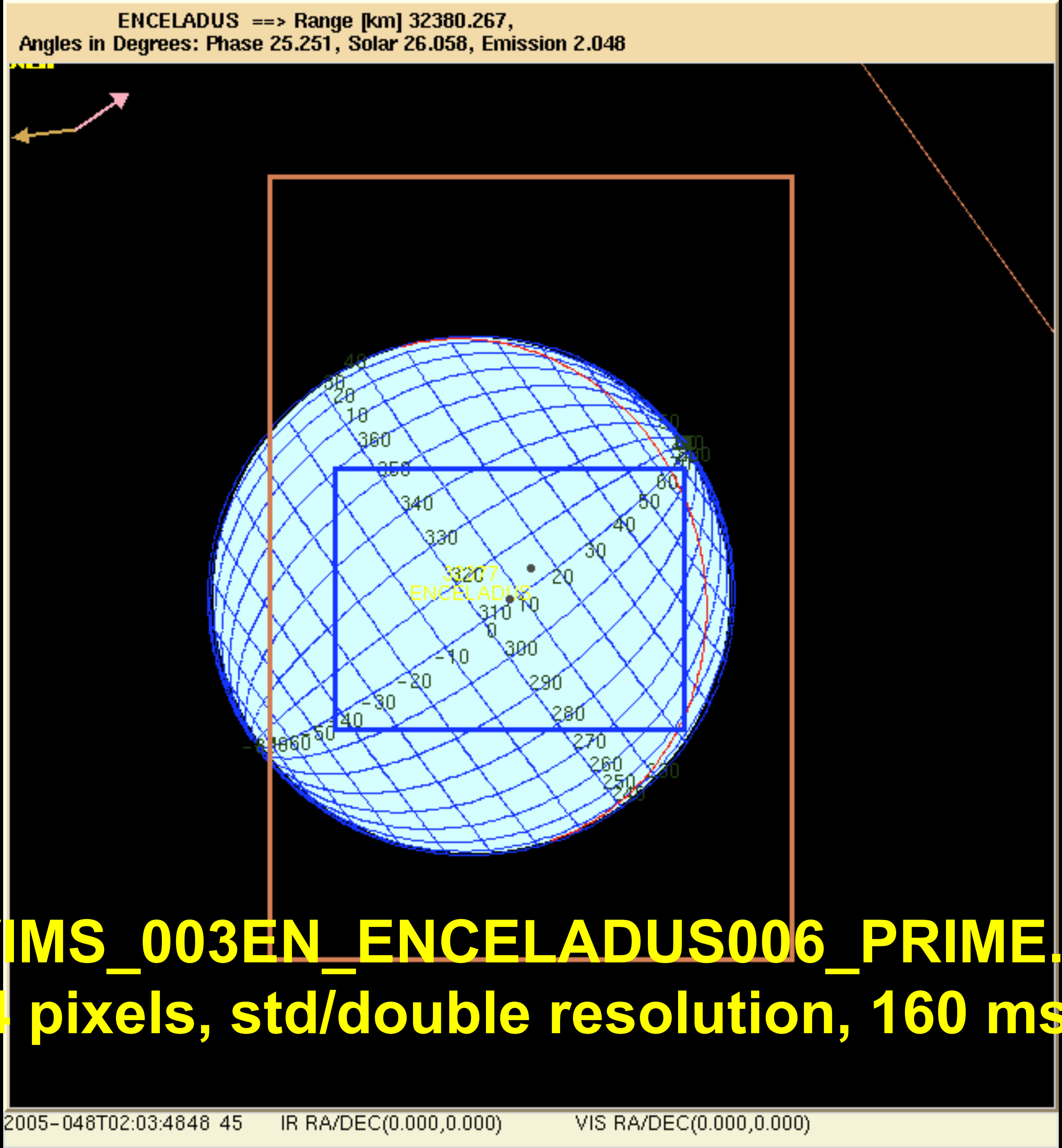
32x54 pixels, std/double resolution, 160 ms/px IR

VIMS_003EN_ENCELADUS006_PRIME.b

32x54 pixels, std/double resolution, 640 ms/px IR

VIMS_003EN_ENCELADUS006_PRIME.c

64x64 pixels, triple/double resolution, 80 ms/px IR

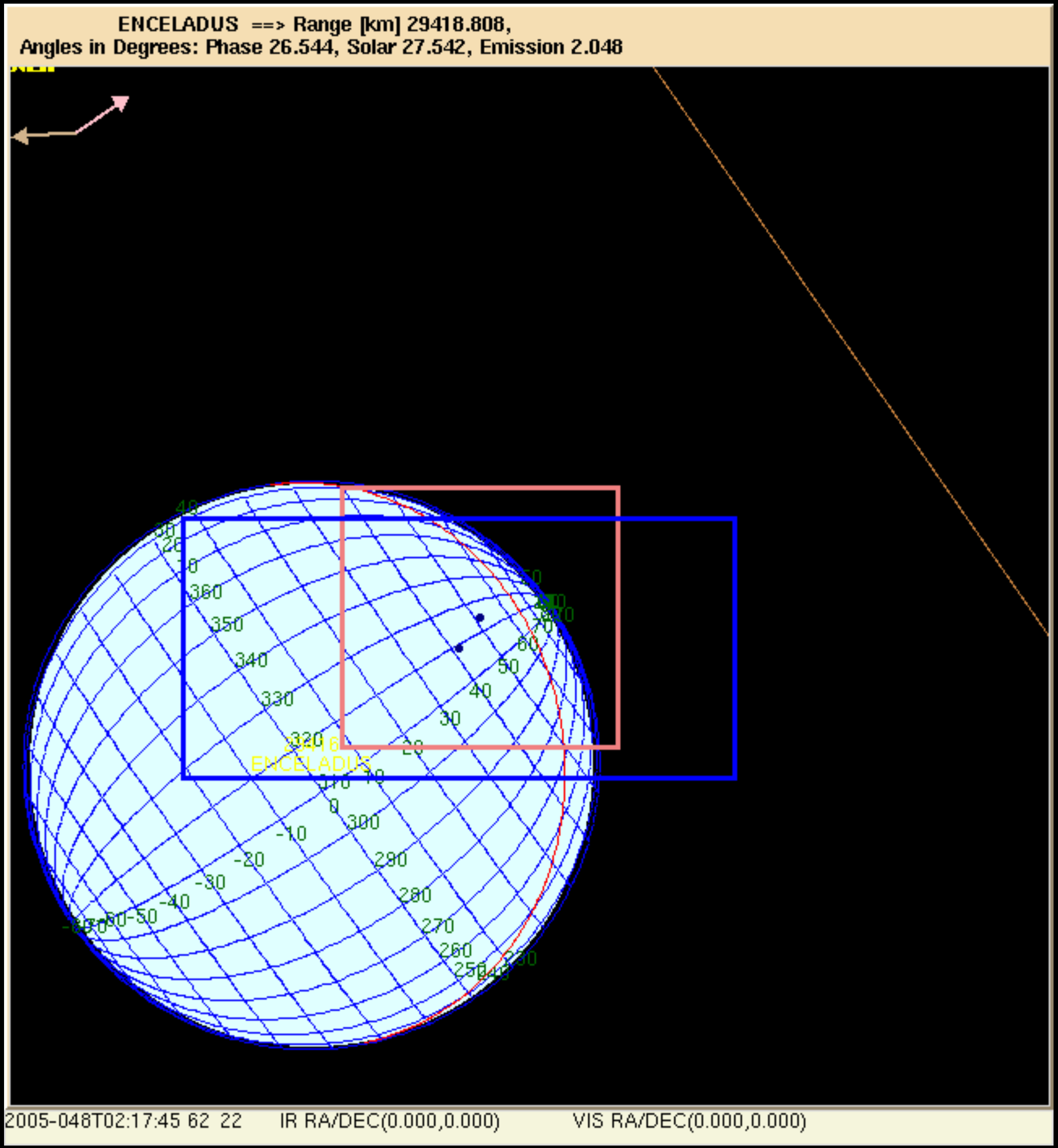


VIMS_003EN_ENCELADUS006_PRIME.d

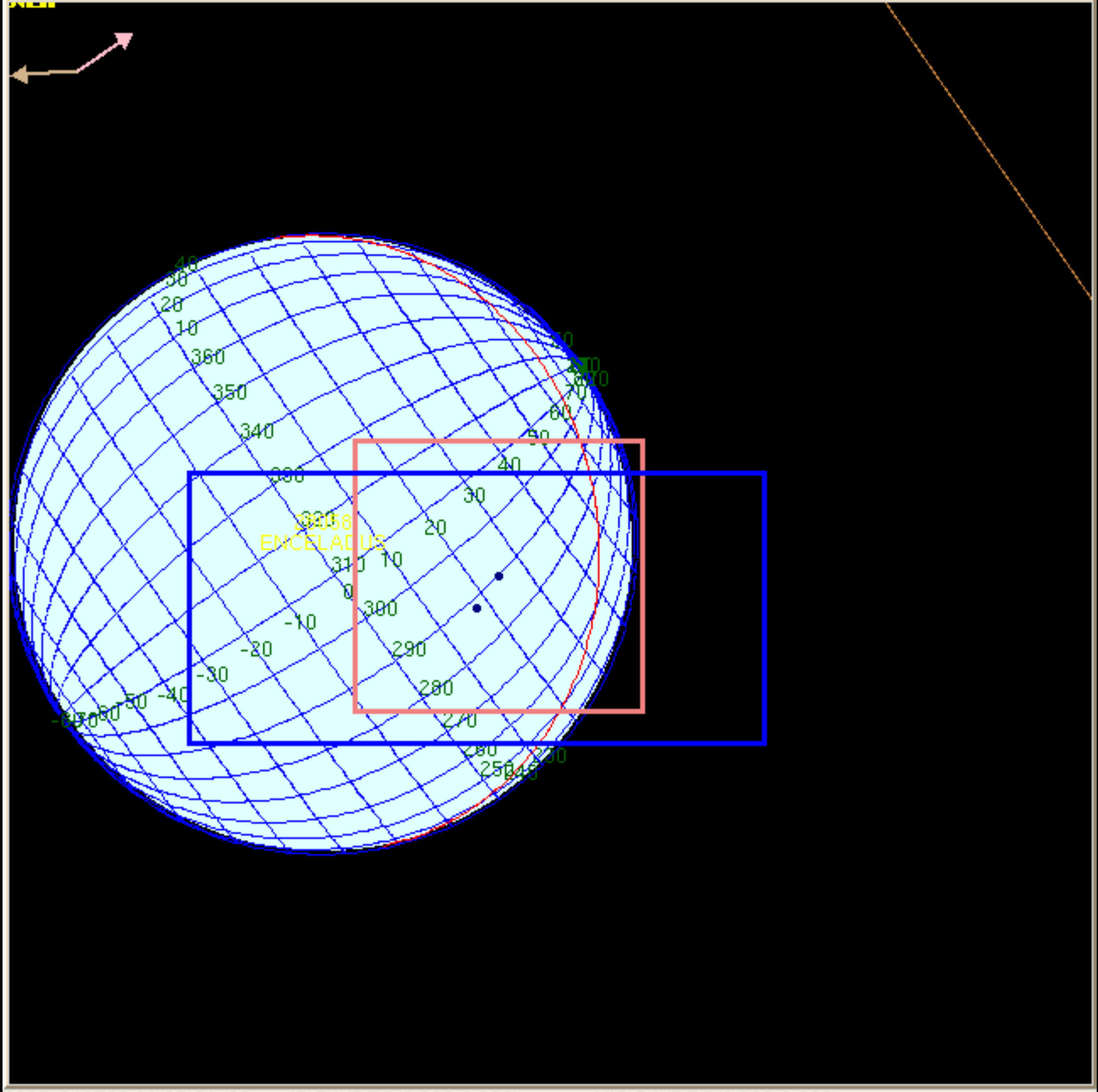
48x64 pixels, std/double resolution, 160 ms/px IR

VIMS ISS Rider up to closest approach 048T2:15

- 16 frames 16x34 pixels (some 22x44, 20x38), all double resolution IR.
- 160 ms /pixel (IR)
- About 9,000 spectra from this observation set.
- Up to 5x10 km pixel IR, 3.6 km/pixel vis

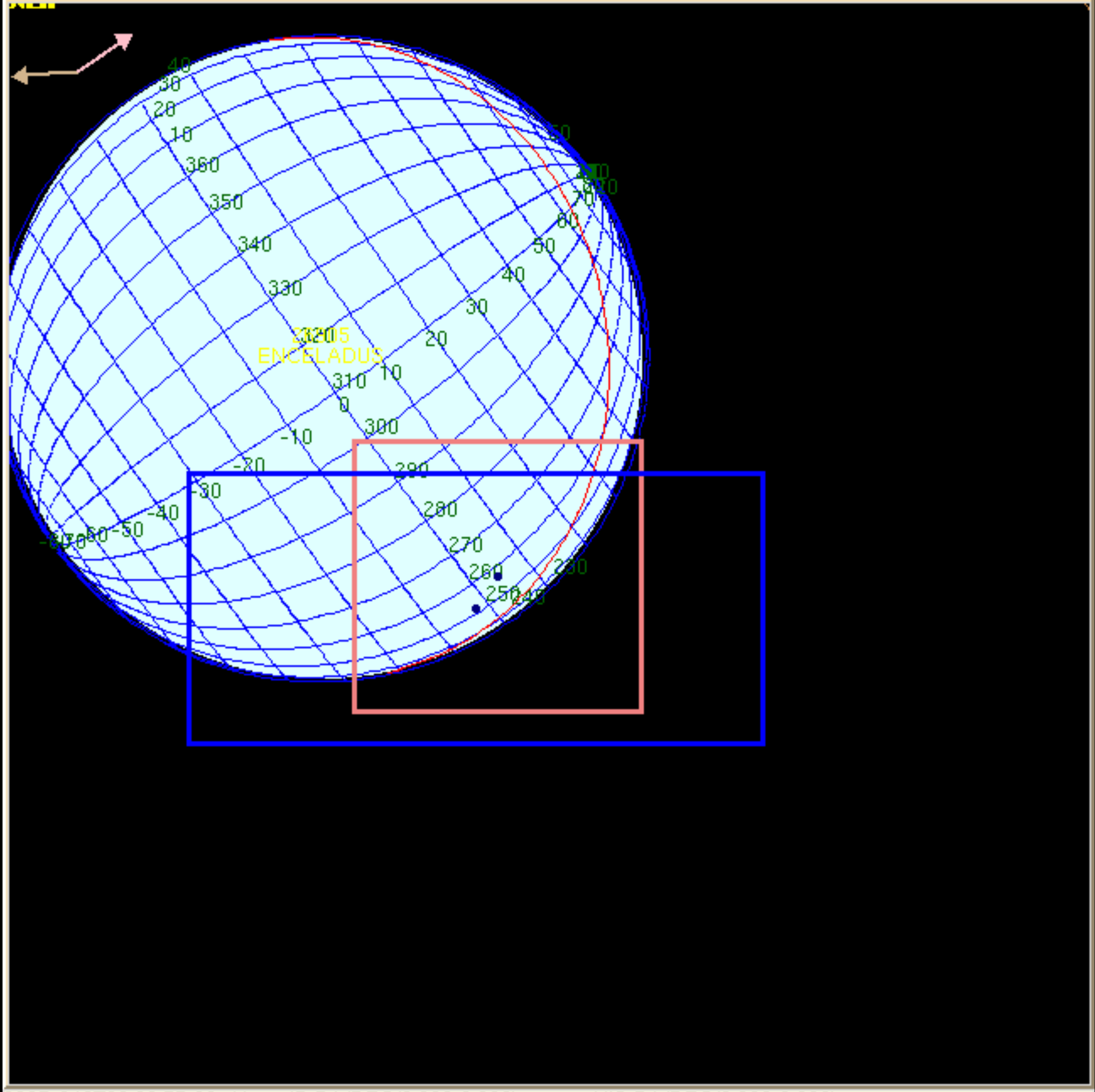

ENCELADUS ==> Range [km] 29418.808,
Angles in Degrees: Phase 26.544, Solar 27.542, Emission 2.048
ENCELADUS
2005-048T02:17:45 62 22
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

ENCELADUS ==> Range [km] 28060.640,
Angles in Degrees: Phase 26.709, Solar 27.720, Emission 2.049

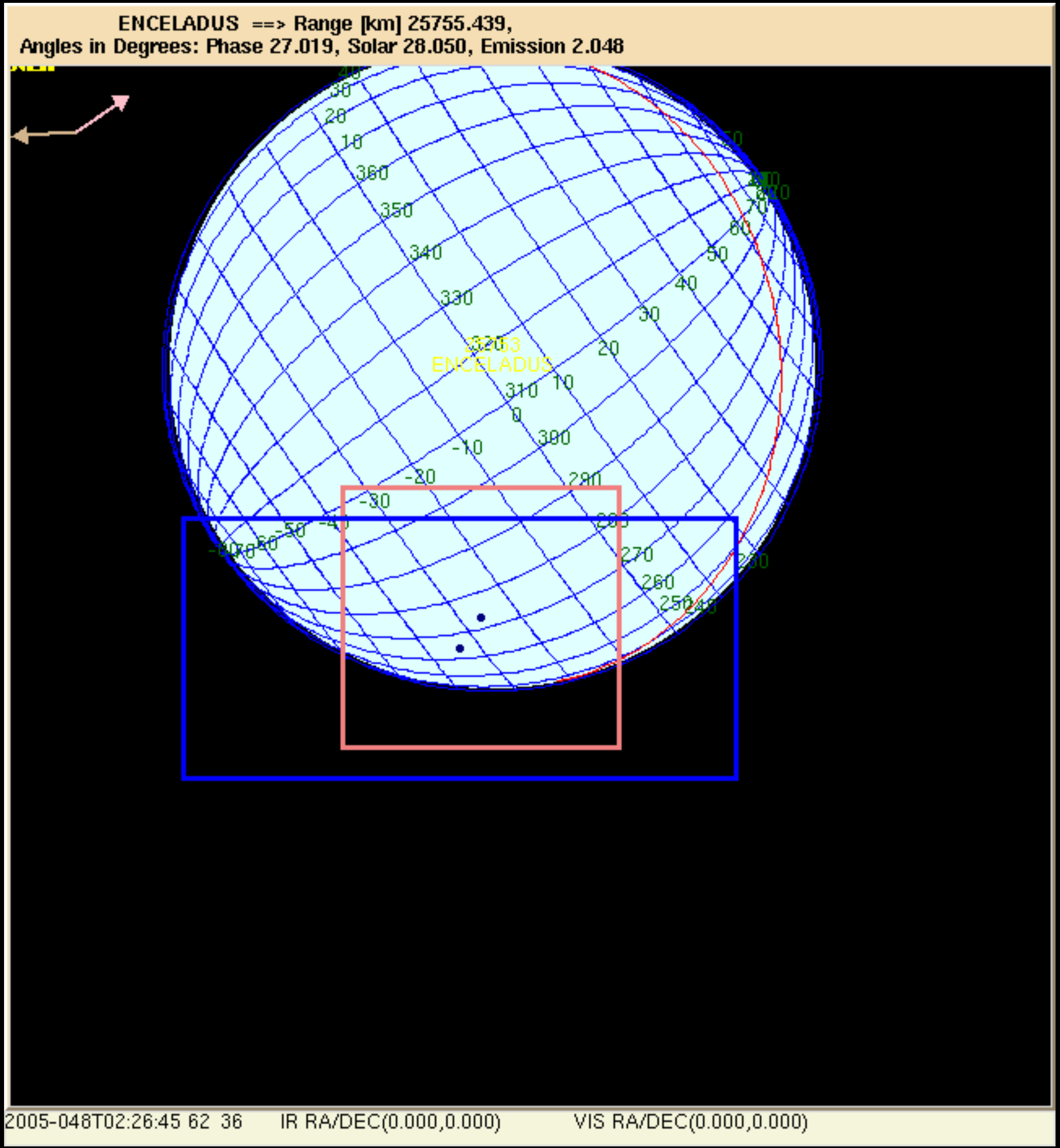


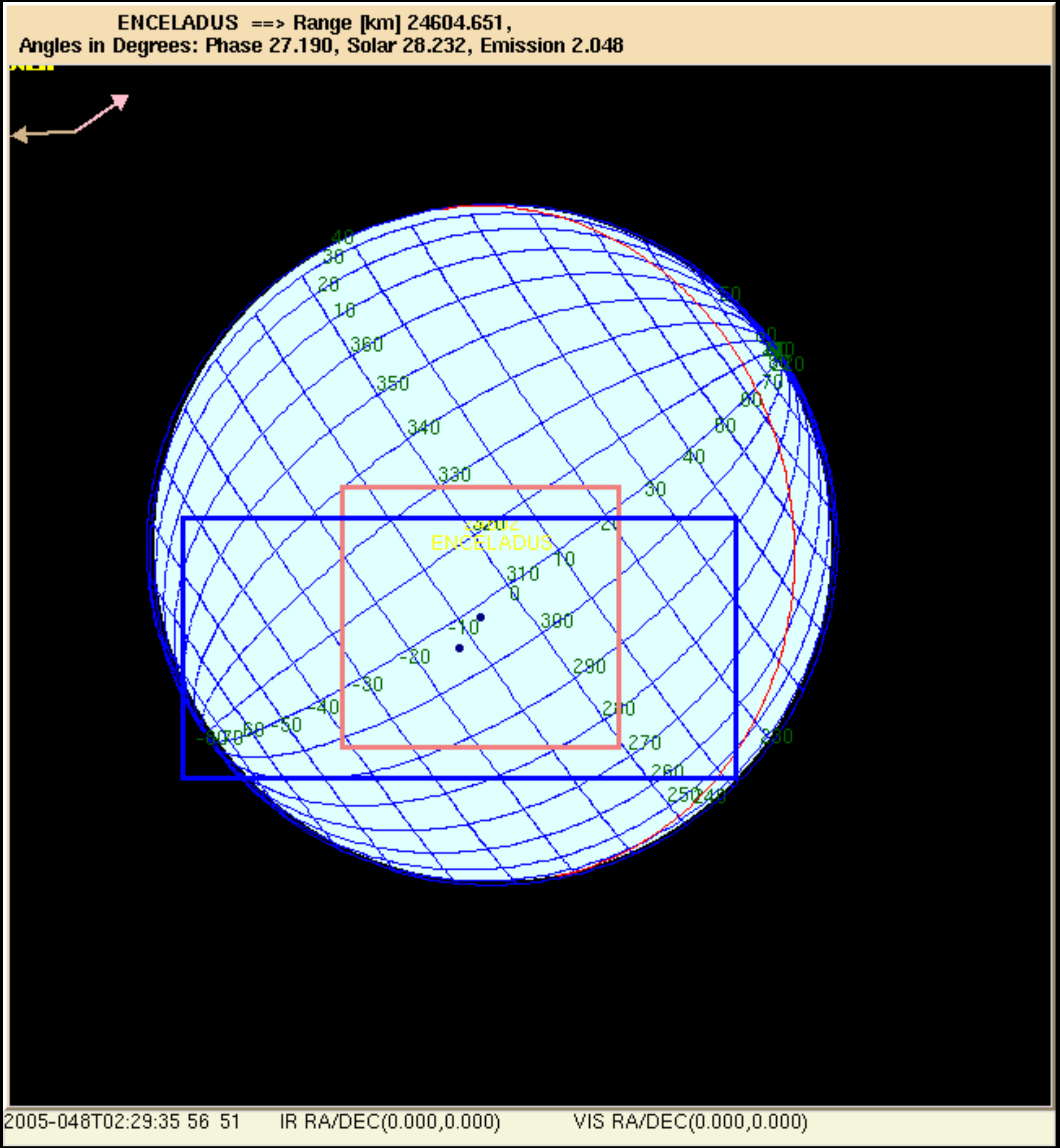
2005-048T02:21:05 61 23 IR RA/DEC(0.000,0.000) VIS RA/DEC(0.000,0.000)

ENCELADUS ==> Range [km] 26907.446,
Angles in Degrees: Phase 26.859, Solar 27.880, Emission 2.049

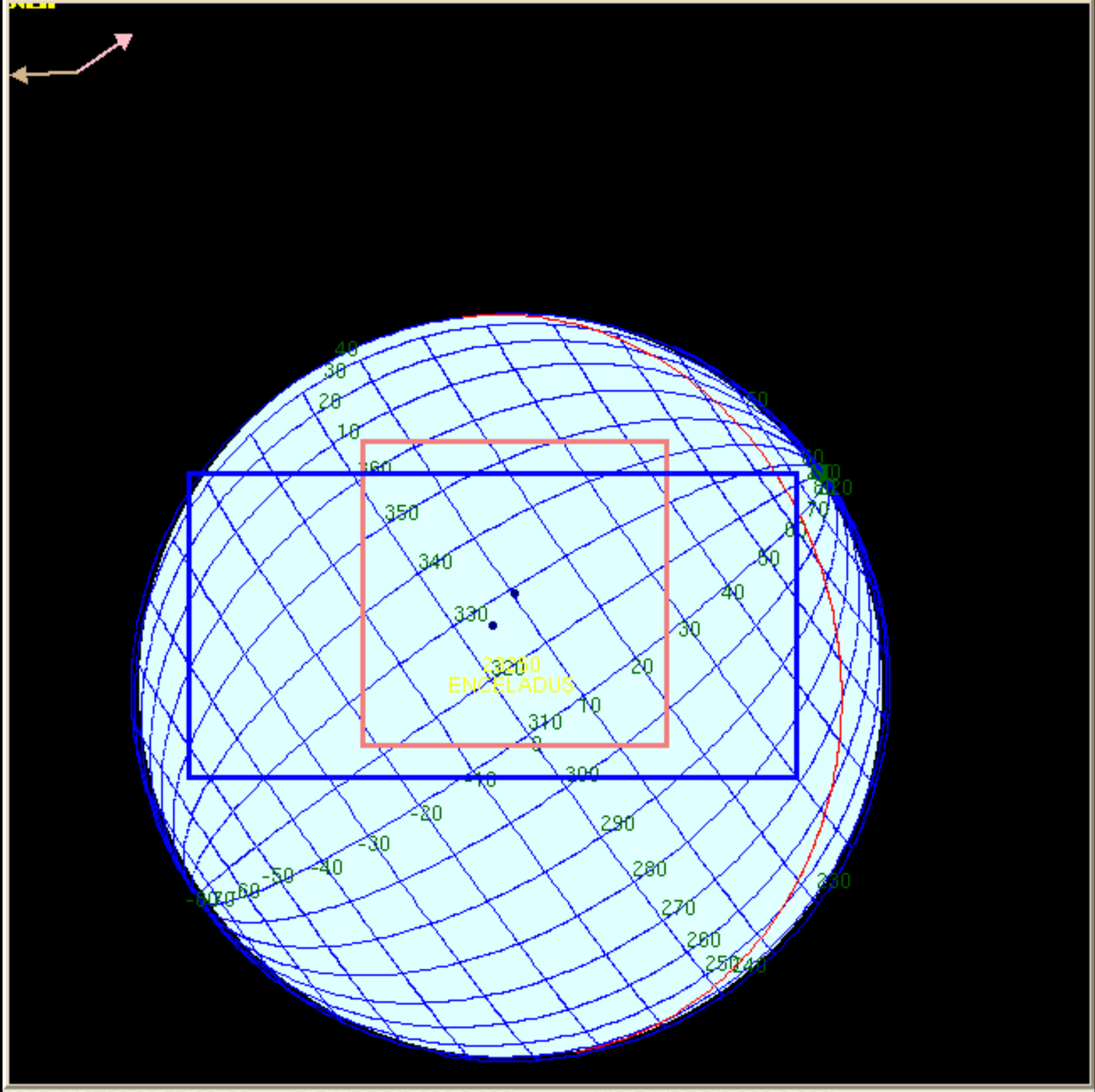


2005-048T02:23:55 63 41 IR RA/DEC(0.000,0.000) VIS RA/DEC(0.000,0.000)


ENCELADUS ==> Range [km] 25755.439,
Angles in Degrees: Phase 27.019, Solar 28.050, Emission 2.048
ENCELADUS
2005-048T02:26:45 62 36
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

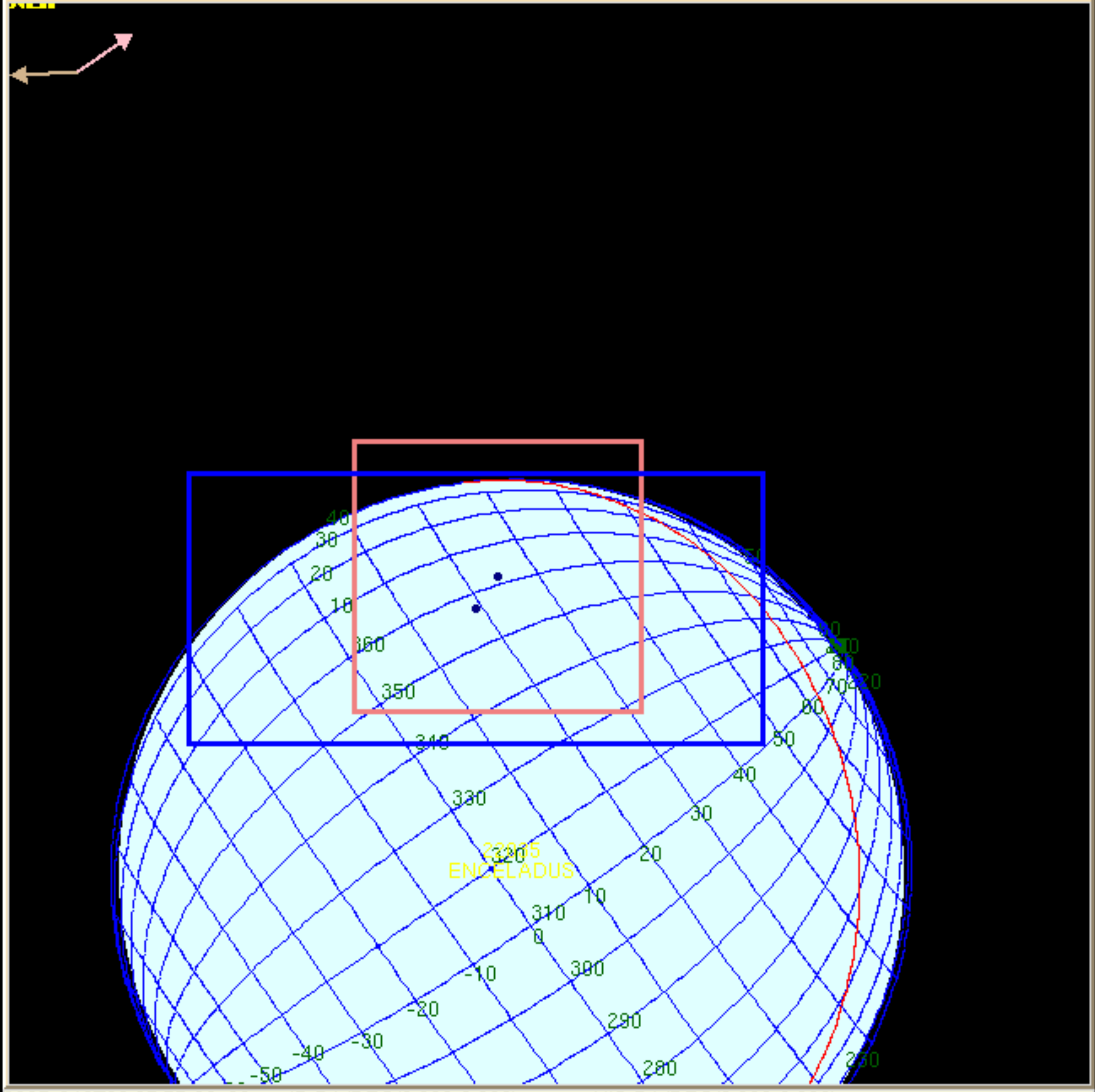

ENCELADUS ==> Range [km] 24604.651,
Angles in Degrees: Phase 27.190, Solar 28.232, Emission 2.048
ENCELADUS
2005-048T02:29:35 56 51
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

ENCELADUS ==> Range [km] 23252.384,
Angles in Degrees: Phase 27.409, Solar 28.464, Emission 2.047

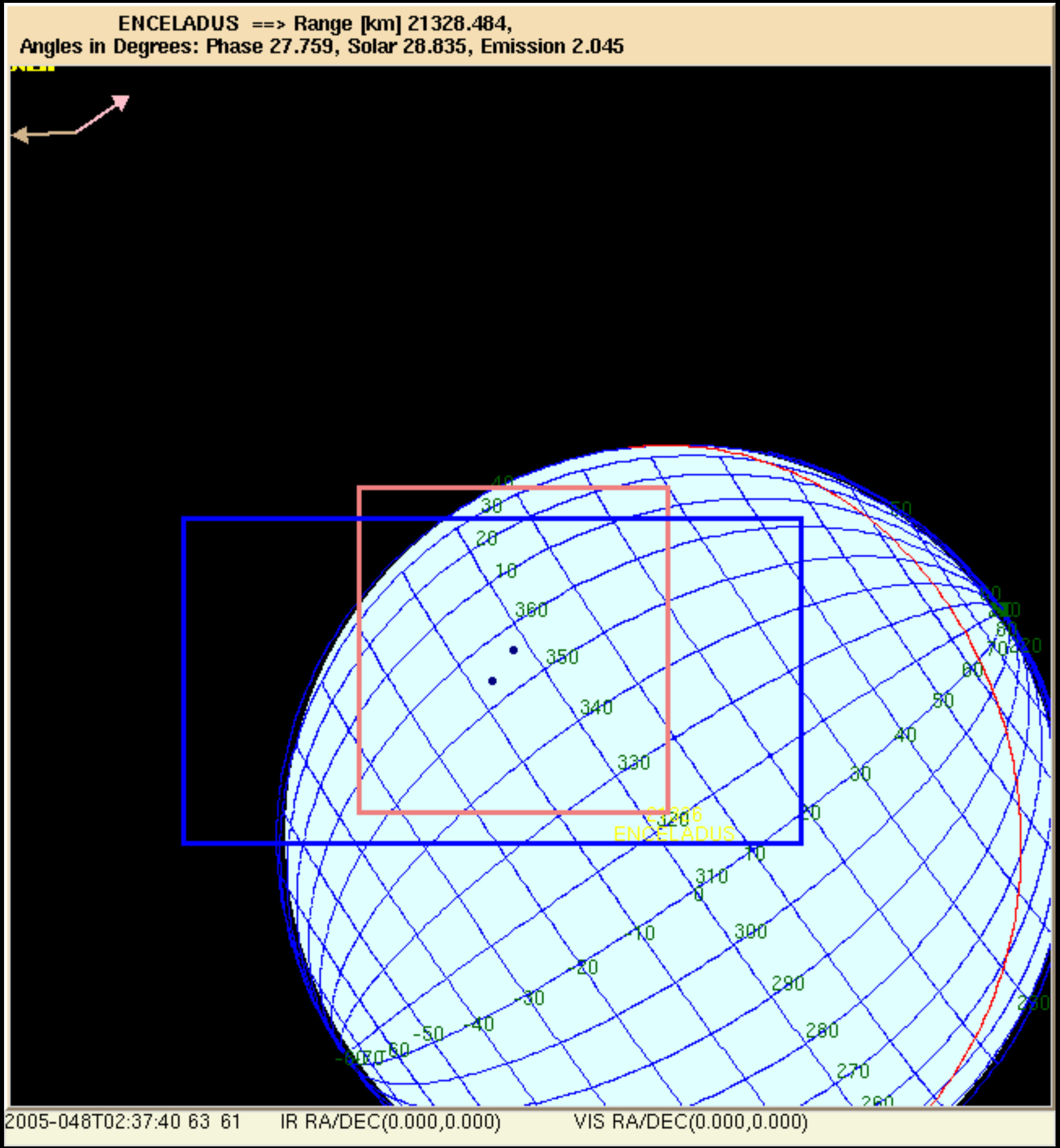


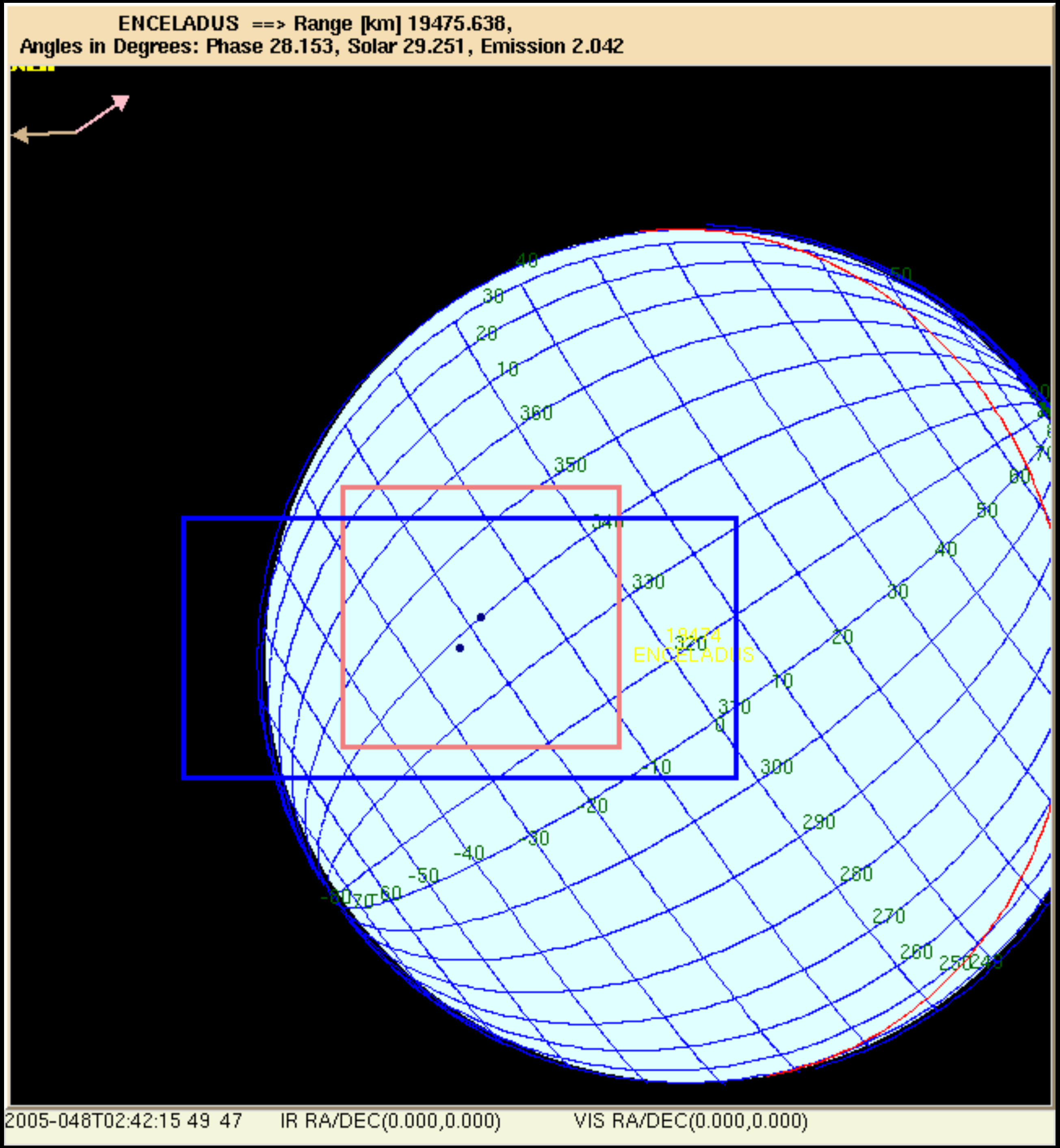
2005-048T02:32:55 63 63   IR RA/DEC(0.000,0.000)   VIS RA/DEC(0.000,0.000)

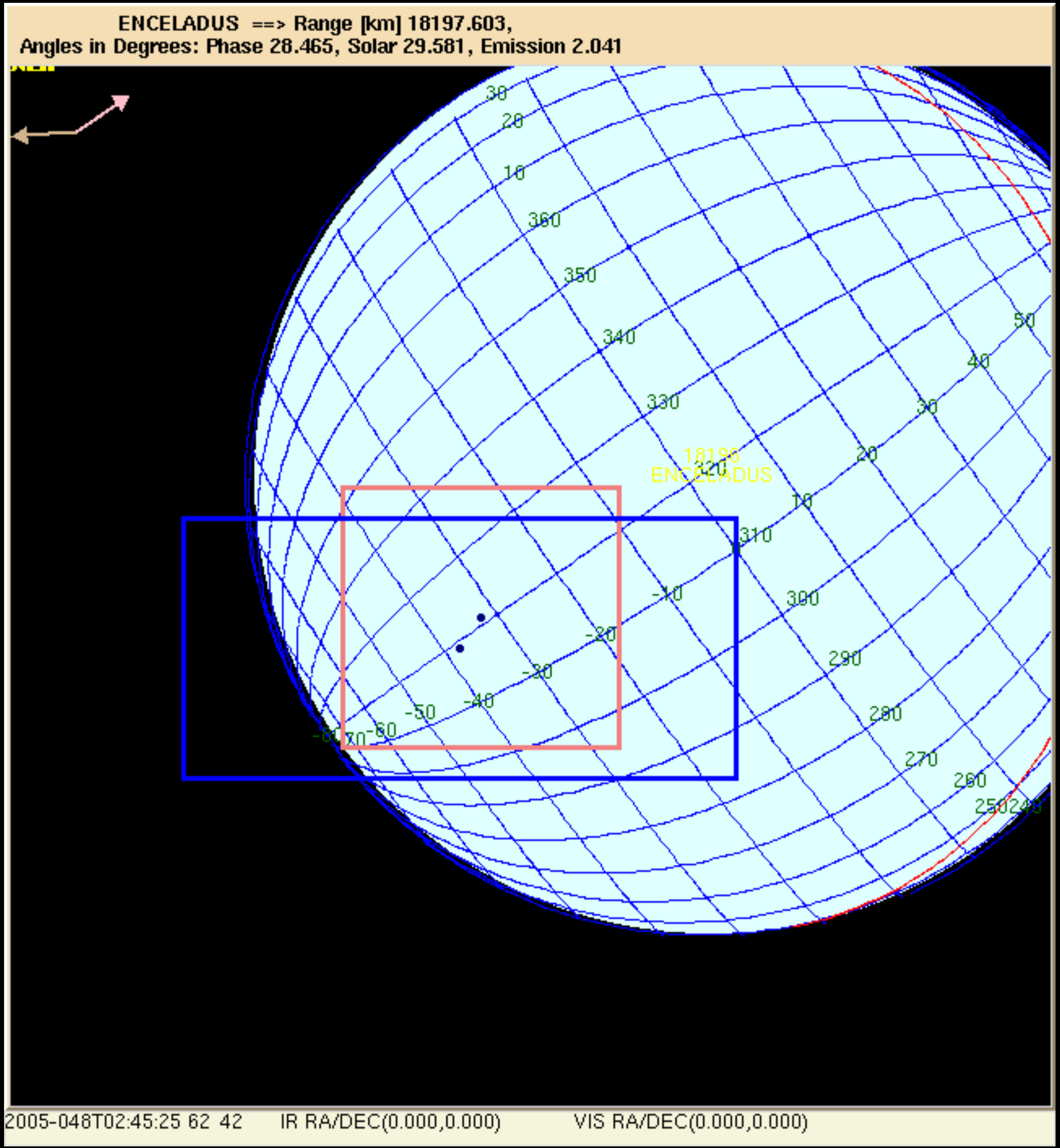
ENCELADUS ==> Range [km] 22036.861,
Angles in Degrees: Phase 27.624, Solar 28.692, Emission 2.046

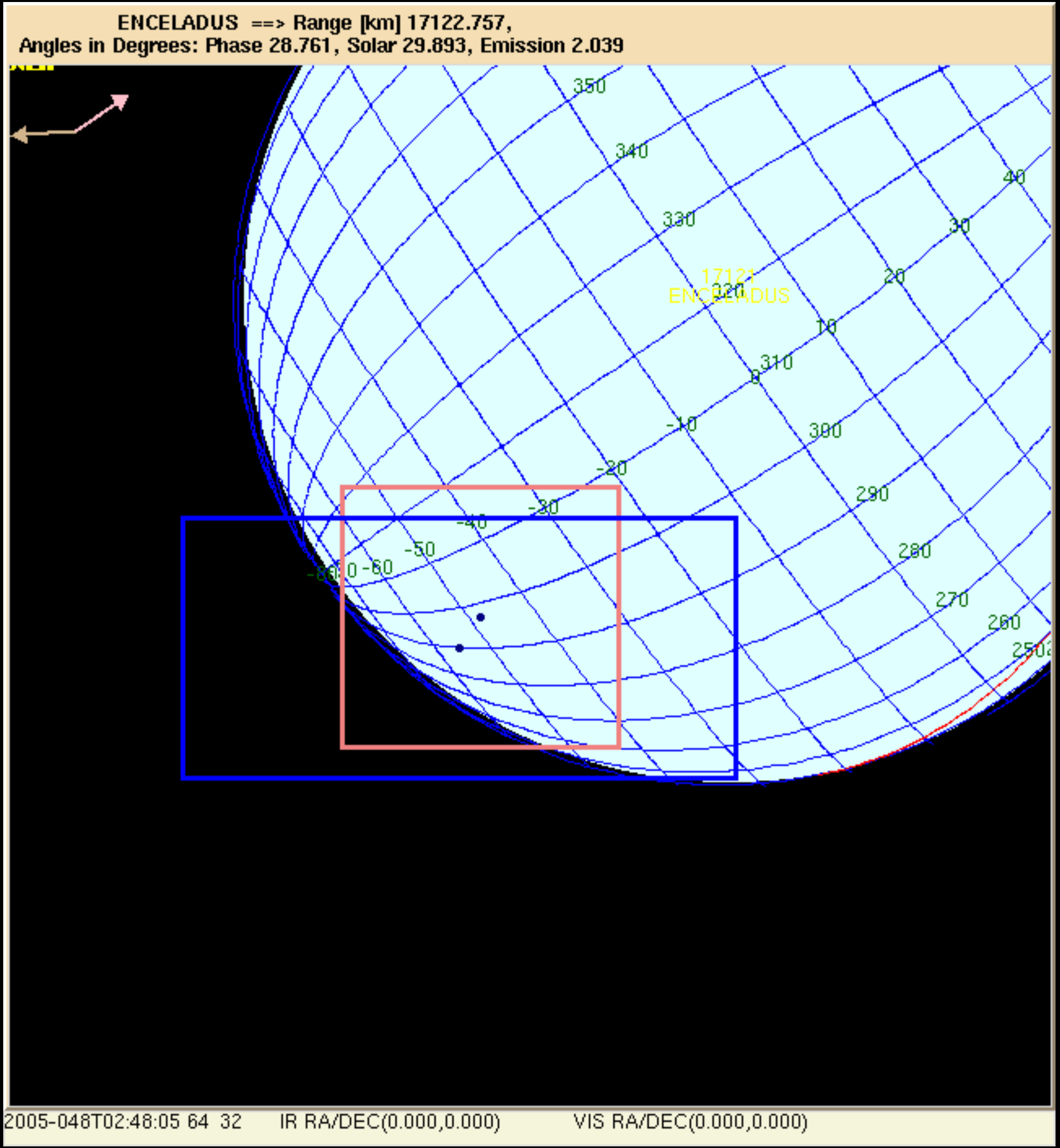


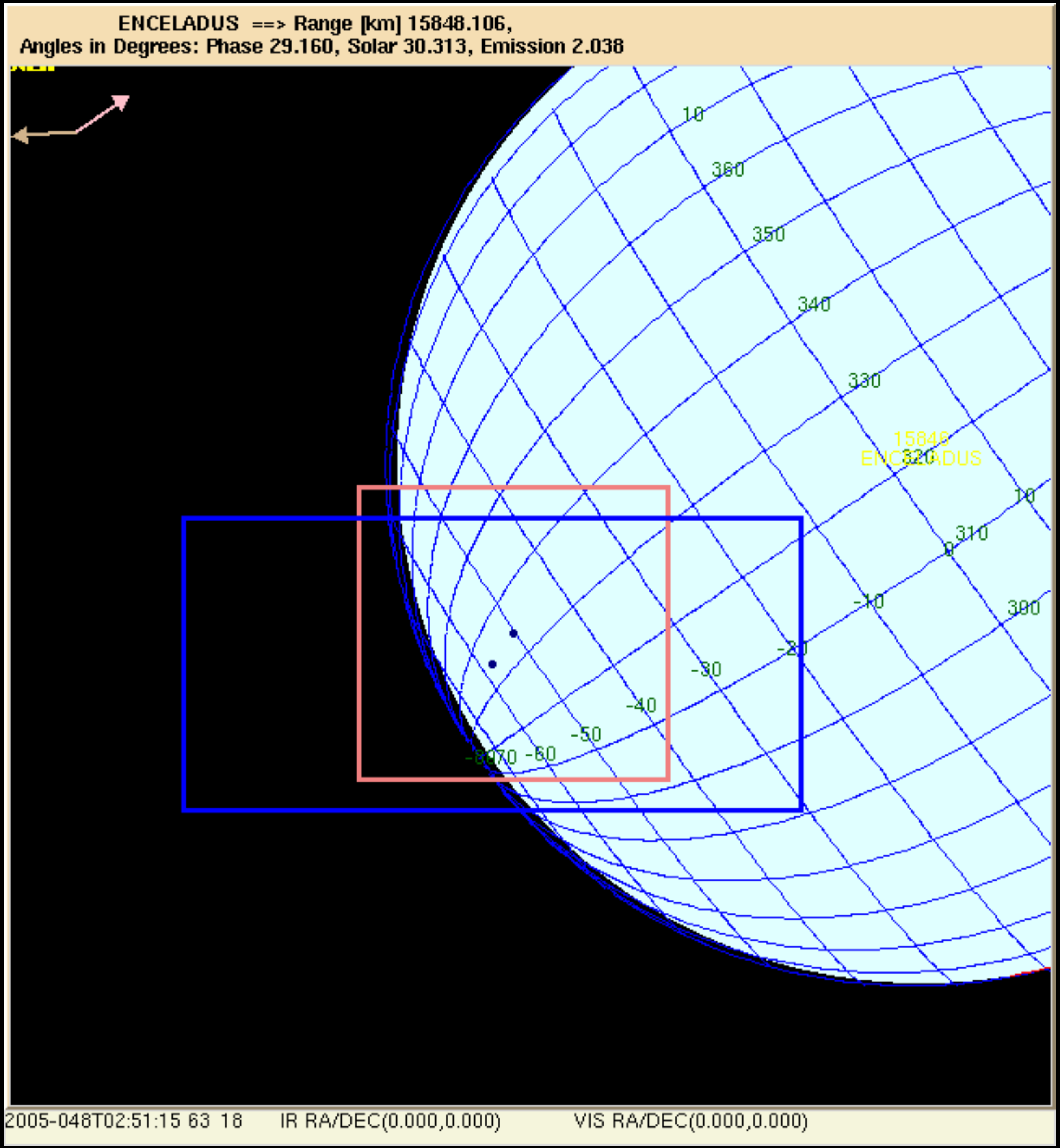
2005-048T02:35:55 63 33 IR RA/DEC(0.000,0.000) VIS RA/DEC(0.000,0.000)

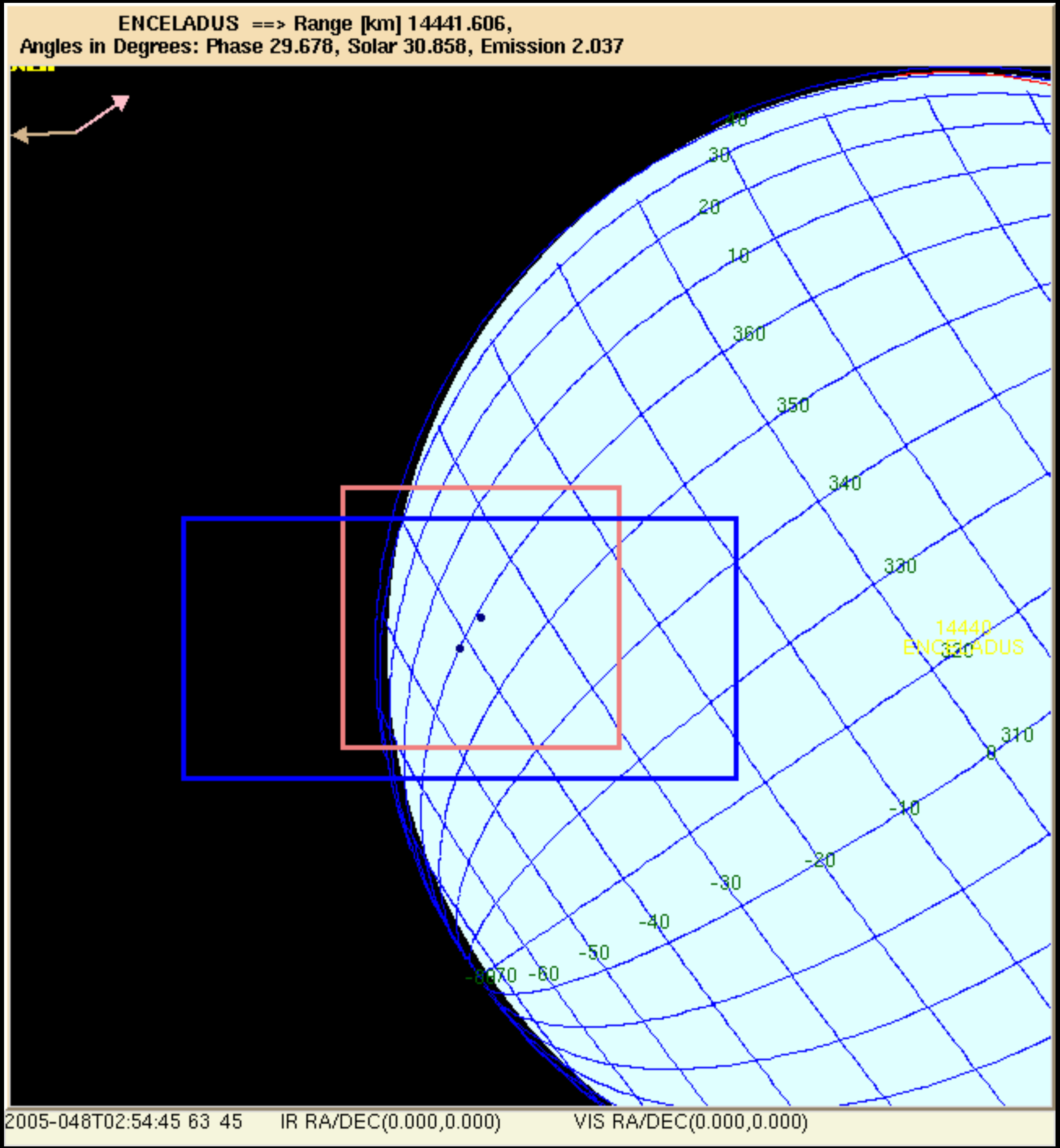

ENCELADUS ==> Range [km] 21328.484,
Angles in Degrees: Phase 27.759, Solar 28.835, Emission 2.045
ENCELADUS
2005-048T02:37:40 63 61
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)


ENCELADUS ==> Range [km] 19475.638,
Angles in Degrees: Phase 28.153, Solar 29.251, Emission 2.042
ENCELADUS
2005-048T02:42:15 49 47
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

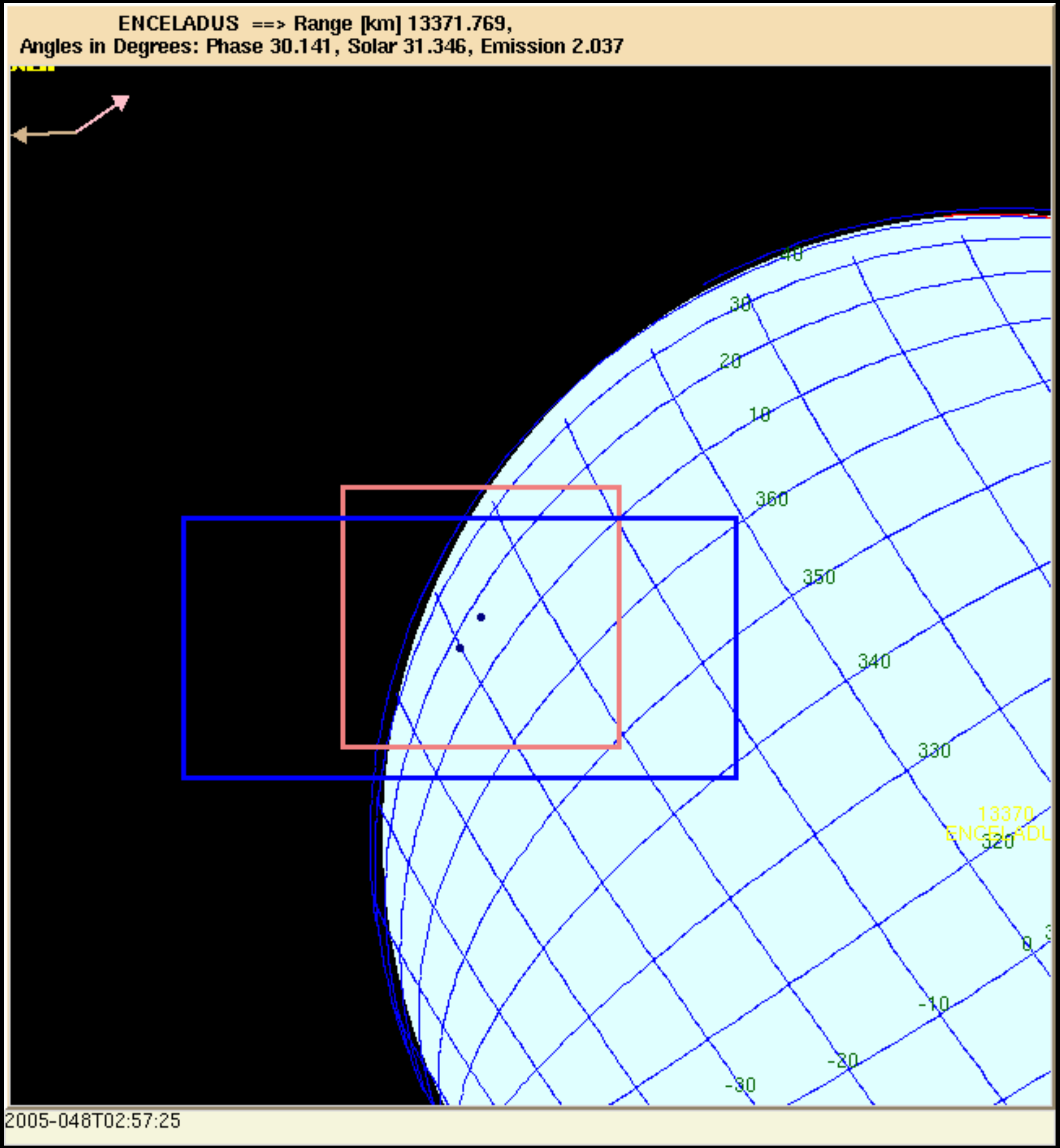

ENCELADUS ==> Range [km] 18197.603,
Angles in Degrees: Phase 28.465, Solar 29.581, Emission 2.041
ENCELADUS
2005-048T02:45:25 62 42
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

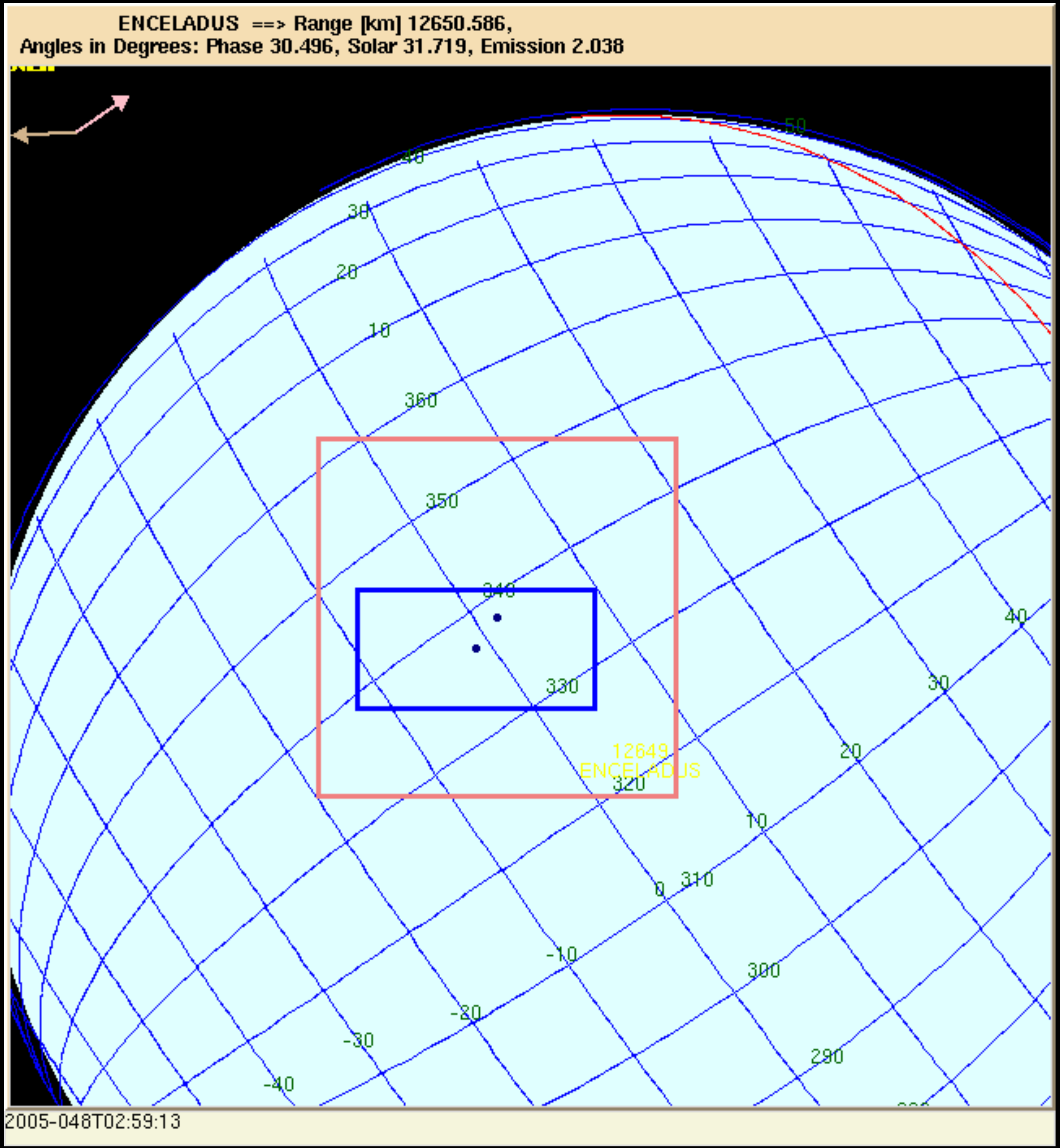

ENCELADUS ==> Range [km] 17122.757,
Angles in Degrees: Phase 28.761, Solar 29.893, Emission 2.039
350
340
330
320
310
300
290
280
270
260
40
30
20
10
0
-10
-20
-30
-40
-50
-60
17121
ENCELADUS
2005-048T02:48:05 64 32
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)


ENCELADUS ==> Range [km] 15848.106,
Angles in Degrees: Phase 29.160, Solar 30.313, Emission 2.038
10
360
350
340
330
15848
ENCELADUS
10
310
0
300
-10
-20
-30
-40
-50
-60
2005-048T02:51:15 63 18
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)

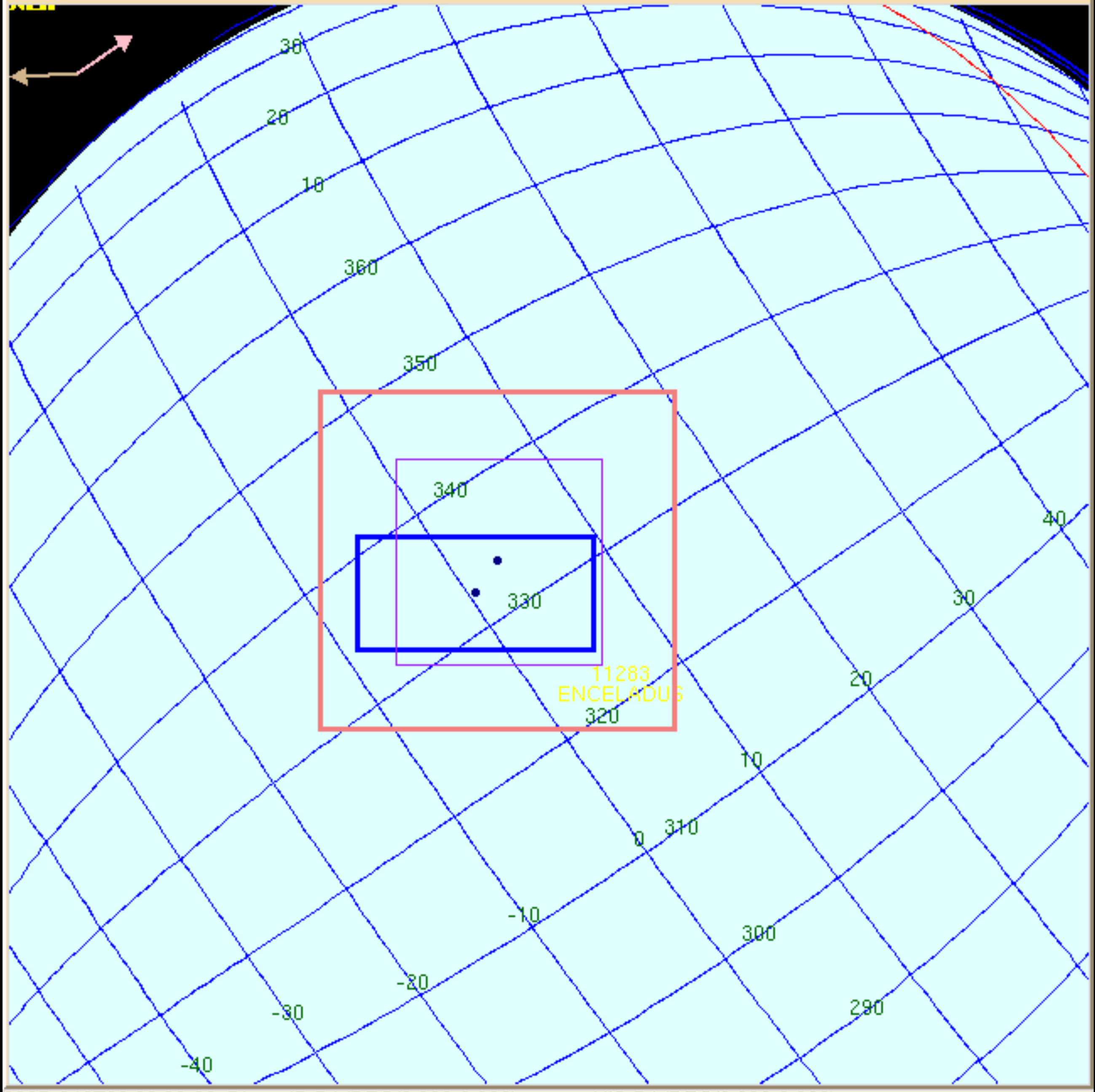


ENCELADUS ==> Range [km] 14441.606,
Angles in Degrees: Phase 29.678, Solar 30.858, Emission 2.037
40
30
20
10
360
350
340
330
14440
ENCELADUS
310
0
-10
-20
-30
-40
-50
-60
2005-048T02:54:45 63 45
IR RA/DEC(0.000,0.000)
VIS RA/DEC(0.000,0.000)


ENCELADUS ==> Range [km] 13371.769,
Angles in Degrees: Phase 30.141, Solar 31.346, Emission 2.037
40
30
20
10
360
350
340
330
13370
ENCELADU
320
0
-10
-20
-30
2005-048T02:57:25


ENCELADUS ==> Range [km] 12650.586,
Angles in Degrees: Phase 30.496, Solar 31.719, Emission 2.038
50
40
30
20
10
360
350
340
330
320
310
300
290
0
-10
-20
-30
-40
40
30
20
10
12649
ENCELADUS
2005-048T02:59:13

ENCELADUS ==> Range [km] 11284.070,
Angles in Degrees: Phase 31.290, Solar 32.554, Emission 2.041



2005-048T03:02:38 63 51 IR RA/DEC(0.000,0.000) VIS RA/DEC(0.000,0.000)

CIRS Enceladus Preview: Rev 3

(2005-047T13:55 to 2005-048T12:45)

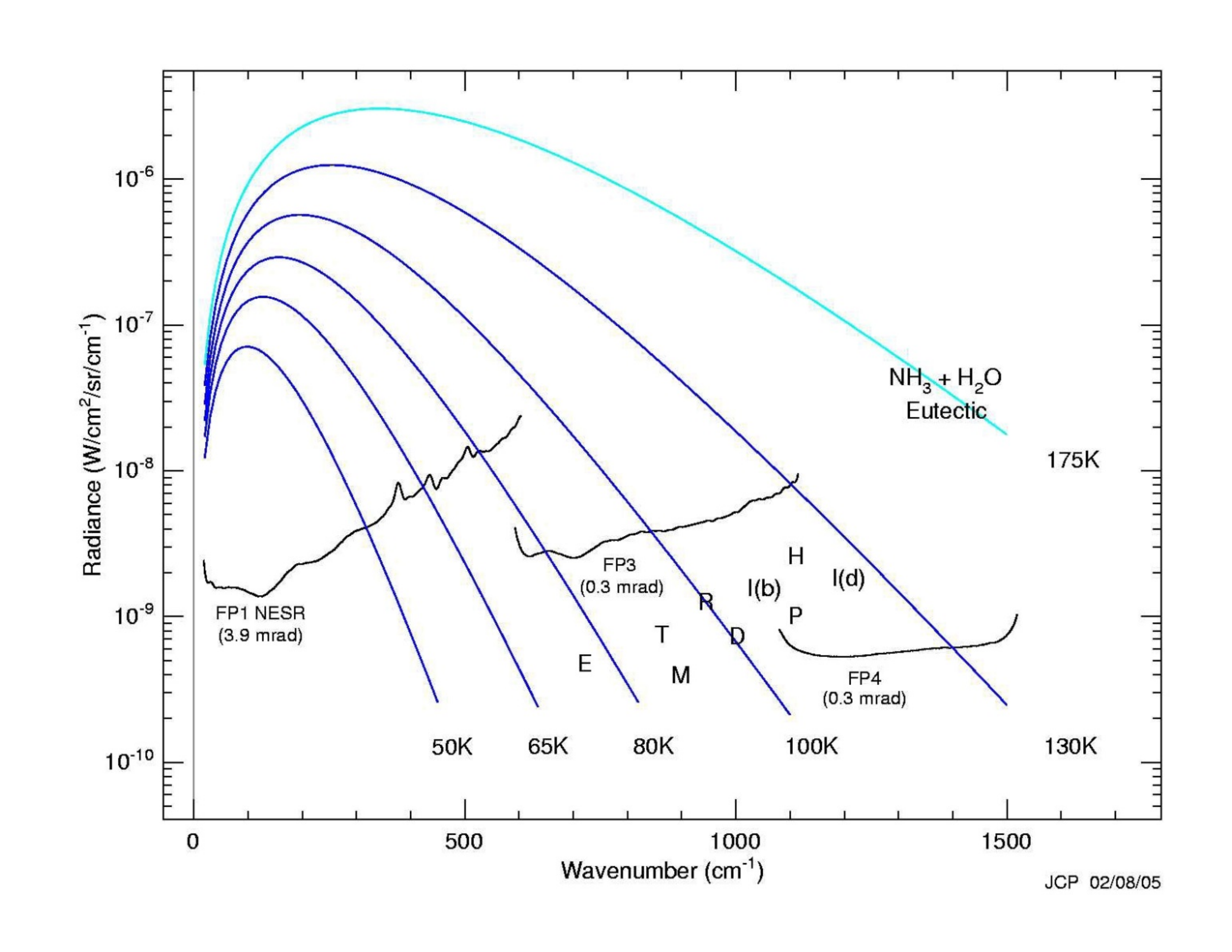
J. Pearl, J. Spencer, M. Segura

9 Feb. 2005

CIRS Objectives for 003EN

- Map surface temperature; determine thermal inertia.
- If active sources are present, determine spatial distribution and energy output.
- Search for spectral signatures on surface and in plumes to determine composition.

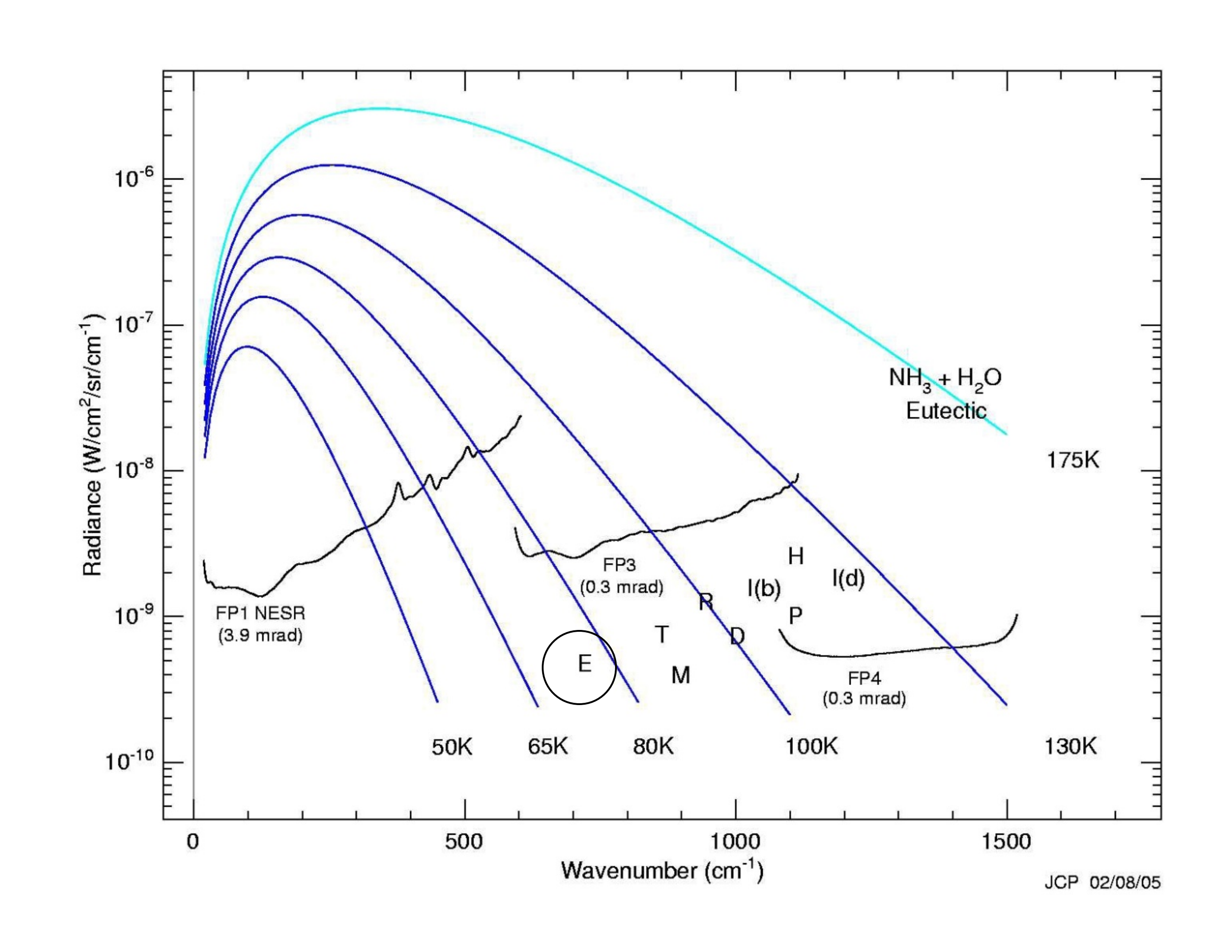
CIRS Detection Capabilities



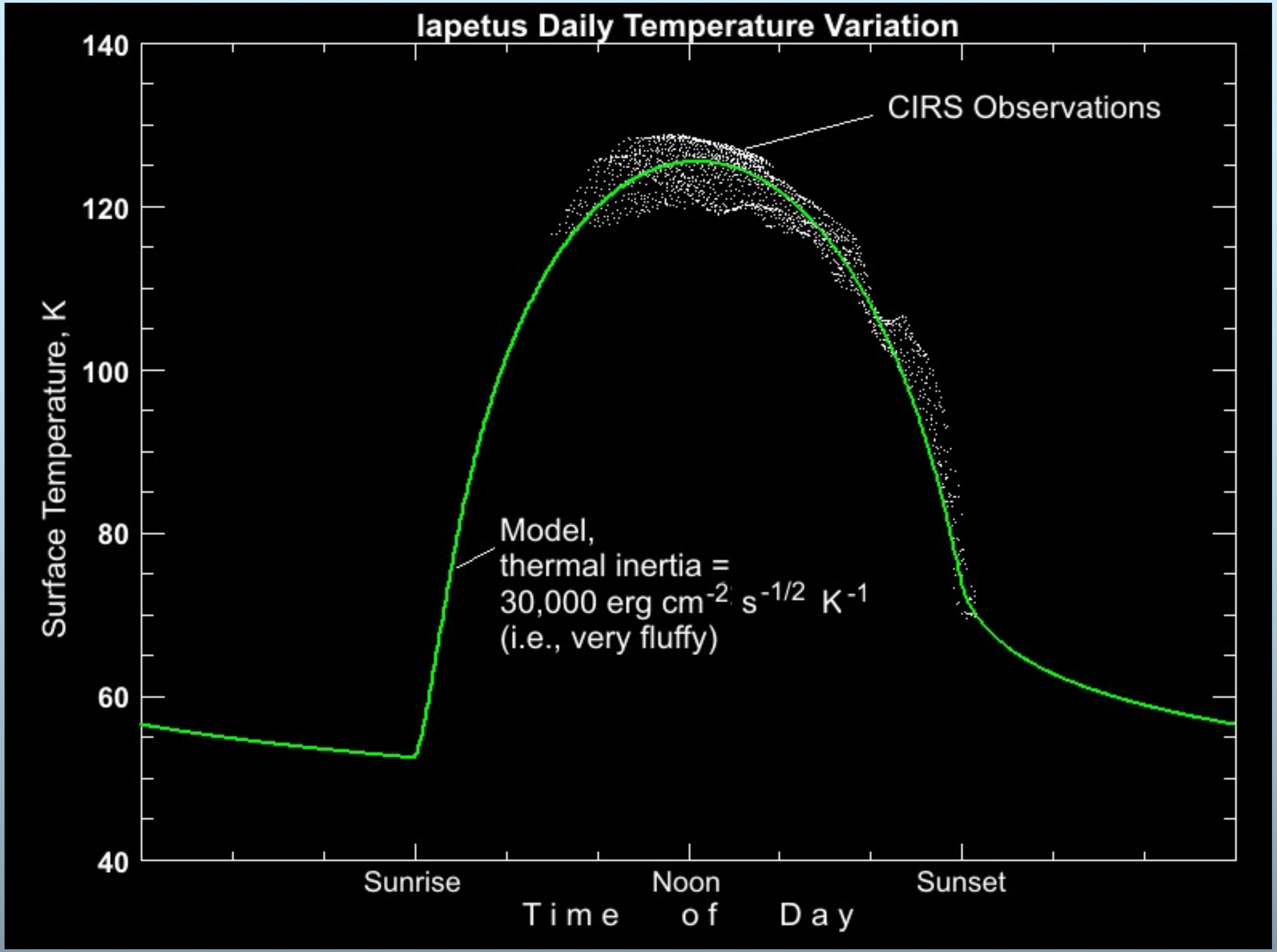
Cold Enceladus

- Enceladus is highly reflective, and therefore absorbs little solar energy.
- As a consequence, Enceladus is the coldest of the Saturnian satellites, never warmer than 75K at noon.

CIRS Detection Capabilities



Thermal Inertia (Iapetus)

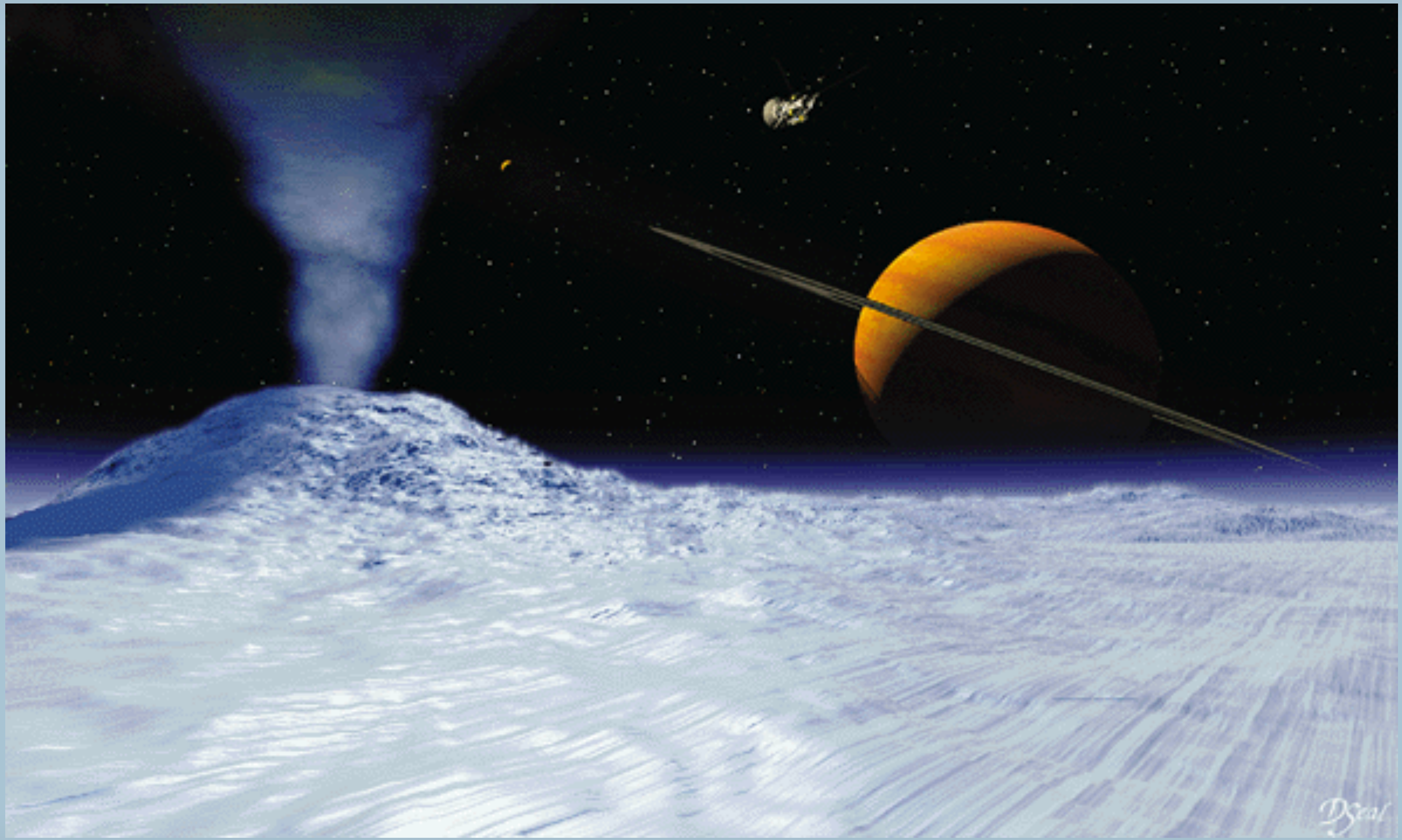


Enceladus: Source of the E-Ring?

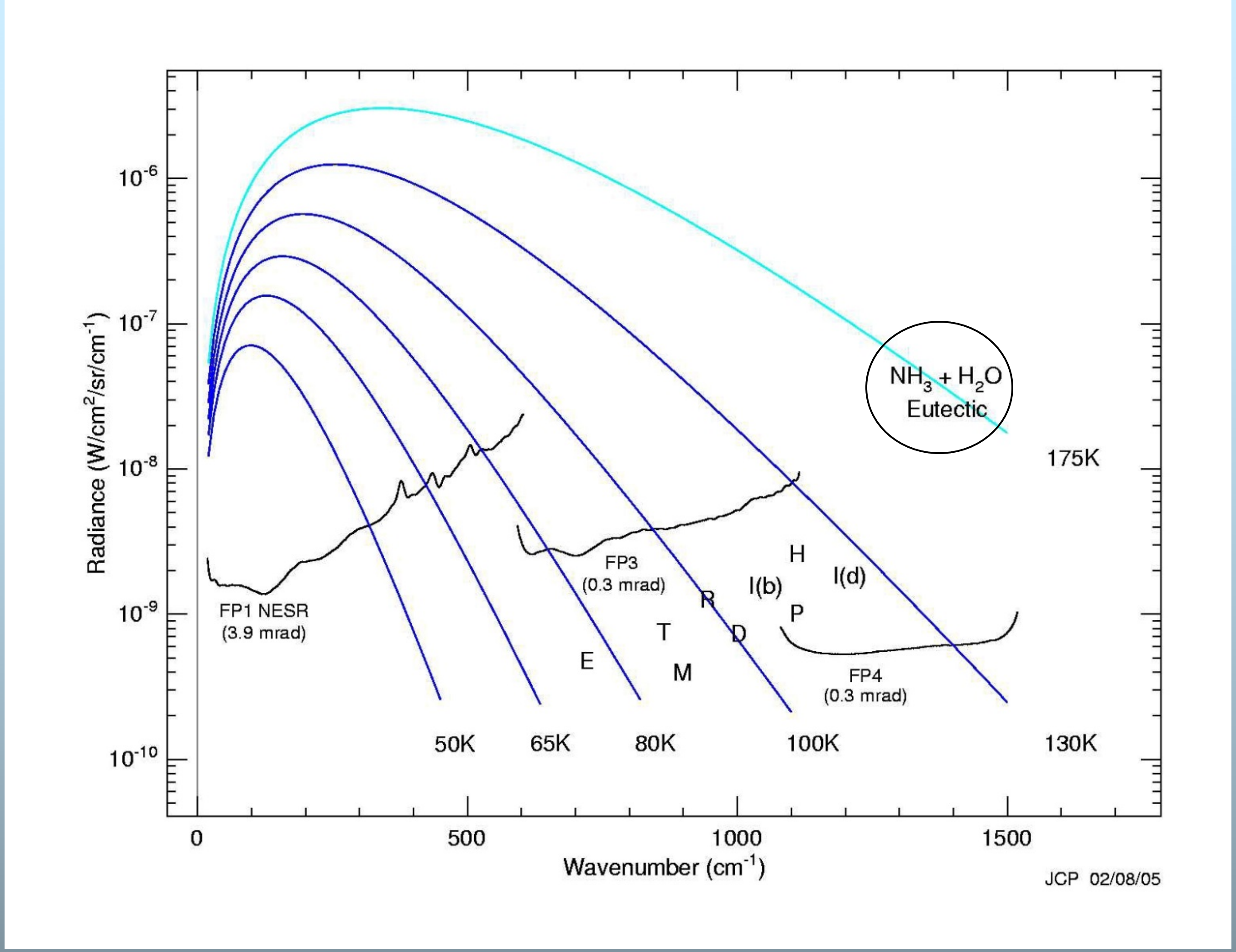
- Self-sustaining? Impacts, and confinement of particles by gravitational and electrostatic forces, maintain the ring.
- Endogenic? Eruptive activity provides ring material.

And if Enceladus IS Active?

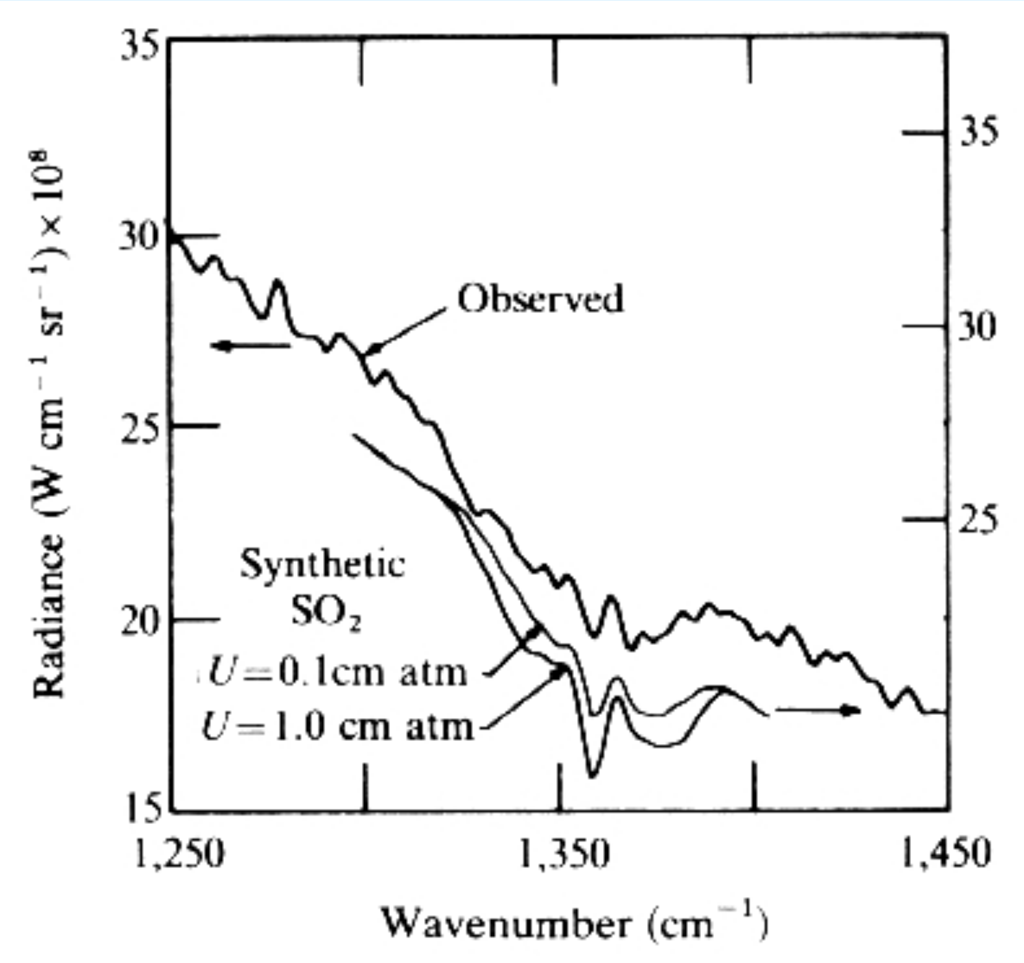
- Effusive ammonia-water solution may flood like “hot lava.”
- Violently erupting ammonia-water solution may produce plumes, particles for E-ring.



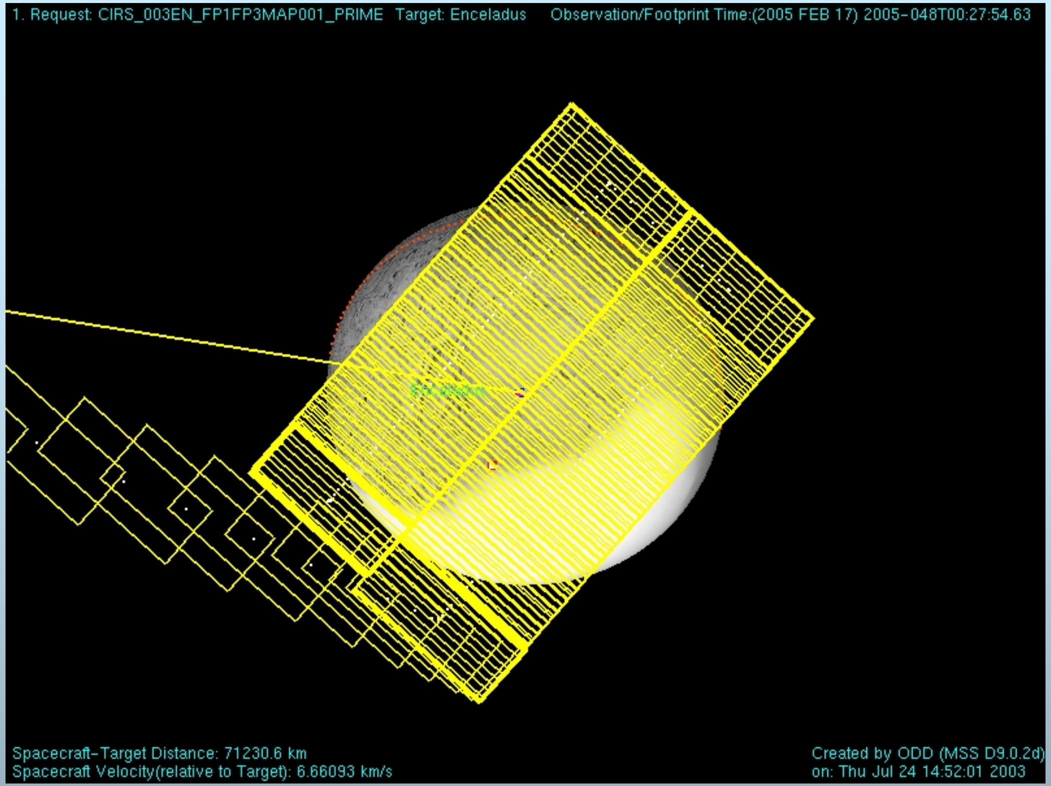
CIRS Detection Capabilities



Detecting Loki's Plume on Io



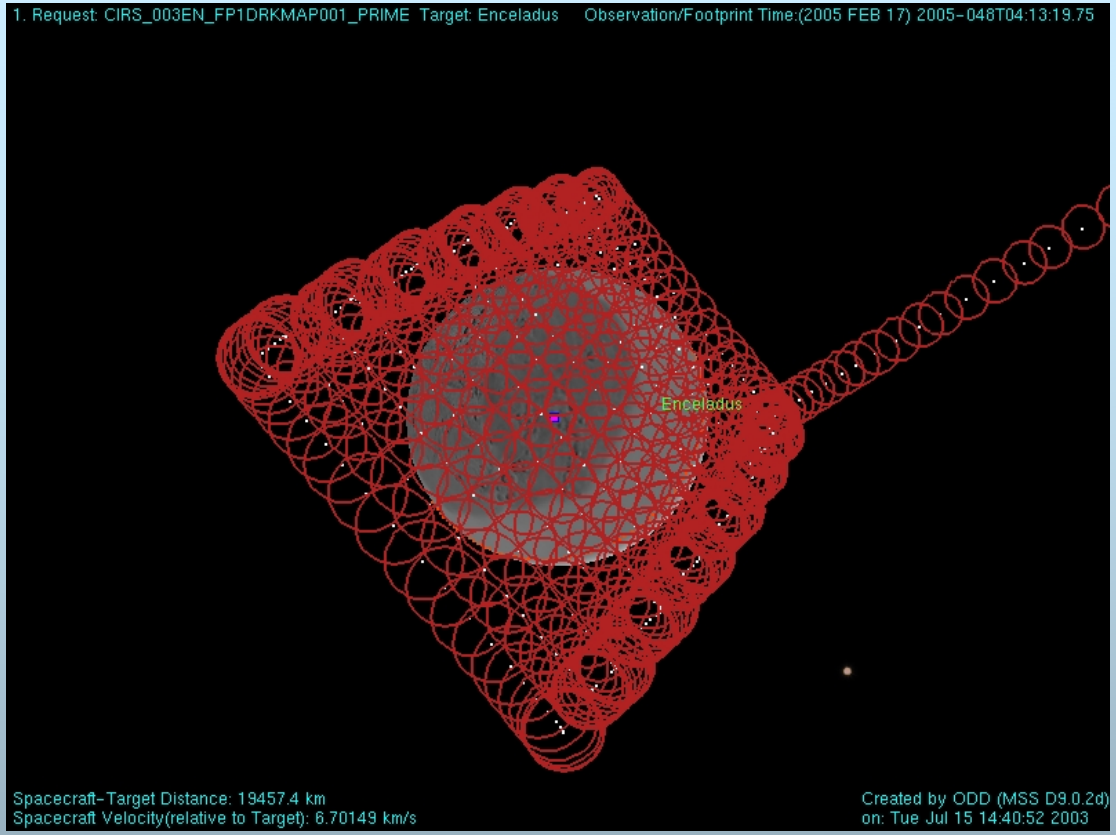
CIRS_003EN_FP1FP3MAP001



Duration=01:15
AD=6-10 mrad
Sub S/C=(0, 305),
LT=11.0
ϕ=24^{o}

Disk map to search for "hot spots"

CIRS_003EN_FP1DRKMAP001

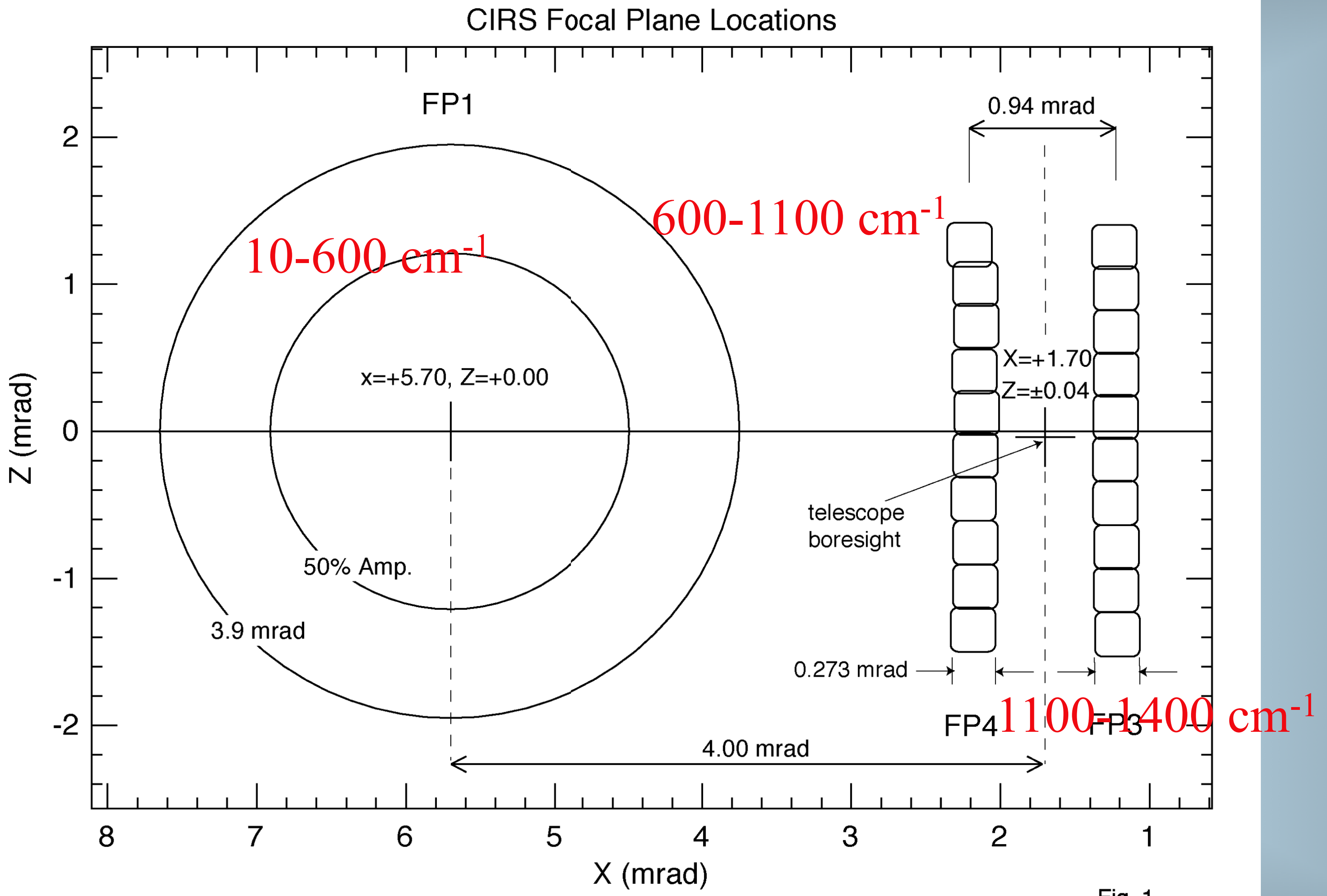


Duration=01:00
AD=43-14 mrad
Sub S/C=(0, 164),
LT=01:00
$\phi=160^o$

Disk map for thermal inertia determination; search for passive thermal anomalies.

Summary: CIRS

- Map surface temperature; determine thermal inertia.
- If active sources are present, determine spatial distribution and energy output.
- Search for spectral signatures on surface and in plumes to determine composition.



CIRS Focal Plane Locations
FP1
0.94 mrad
600-1100 cm-1
10-600 cm-1
x=+5.70, Z=+0.00
X=+1.70
Z=±0.04
telescope
boresight
50% Amp.
3.9 mrad
0.273 mrad
FP4
1100-1400 cm-1
FP3
4.00 mrad
Z (mrad)
X (mrad)
2
1
0
-1
-2
8
7
6
5
4
3
2
1

Fig. 1

Table 1: CIRS Instrument Characteristics

Telescope Diameter (cm):	50.8		
Interferometers:	<u>Far-IR</u>	<u>Mid-IR</u>	
Type:	Polarizing	Michelson	
Spectral range (cm^{-1}):	10 - 600	600 -1400	
Spectral range (μm):	17 - 1000	7 - 17	
Spectral resolution (cm^{-1}):	0.5 to 15.5	0.5 to 15.5	
Integration time (sec):	2 to 50	2 to 50	
FOCAL PLANES:	<u>FP1</u>	<u>FP3</u>	<u>FP4</u>
Spectral range(cm^{-1})	10 - 600	600 - 1100	1100 - 1400
Detectors	Thermopile	PC HgCdTe	PV HgCdTe
Pixels	2*	1 x 10	1 X 10
Pixel FOV (mrad)	3.9	0.273	0.273
Peak D*(cm $Hz^{1/2}$ W^{-1})	4×10^{9}	2×10^{10}	5×10^{11}

Data Telemetry Rate (kbs)	2 & 4
Instrument Temperature (K)	170
Focal Planes 3 & 4 Temperature (K)	75 - 90

ÑÑÑÑÑÑÑ

* Single FOV, two polarizations

Preview of Cassini RADAR Observations of Enceladus

Steve Ostro

(for the Cassini RADAR Science and Instrument Operations Teams)

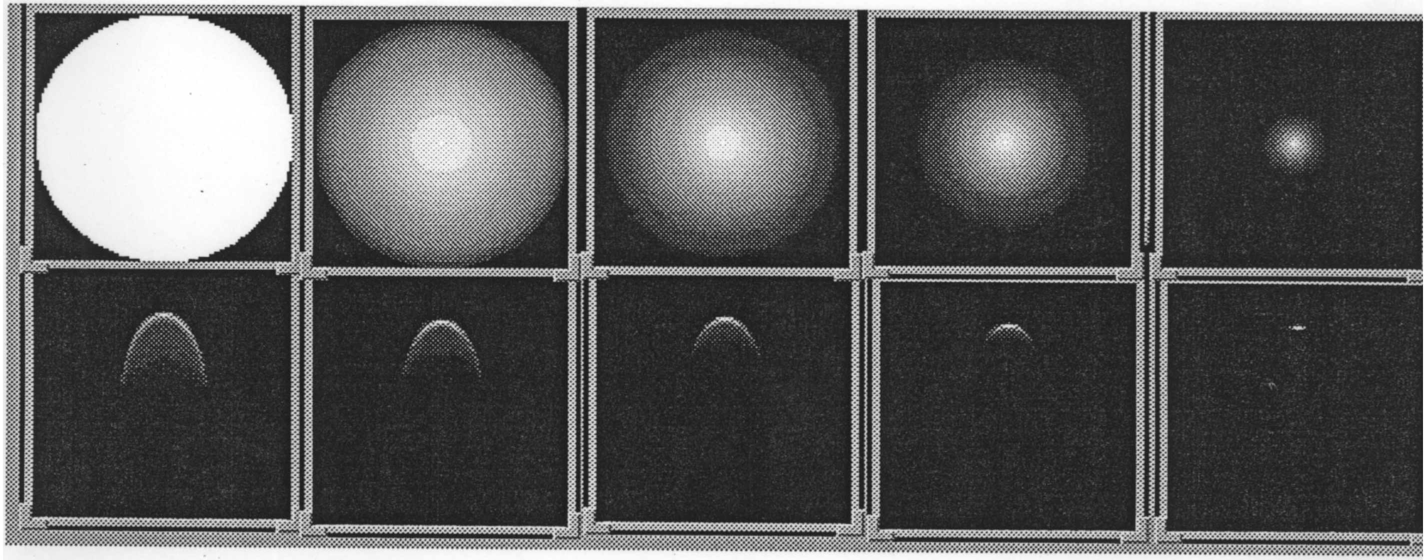
JPL, Feb. 9, 2005

The RADAR Instrument

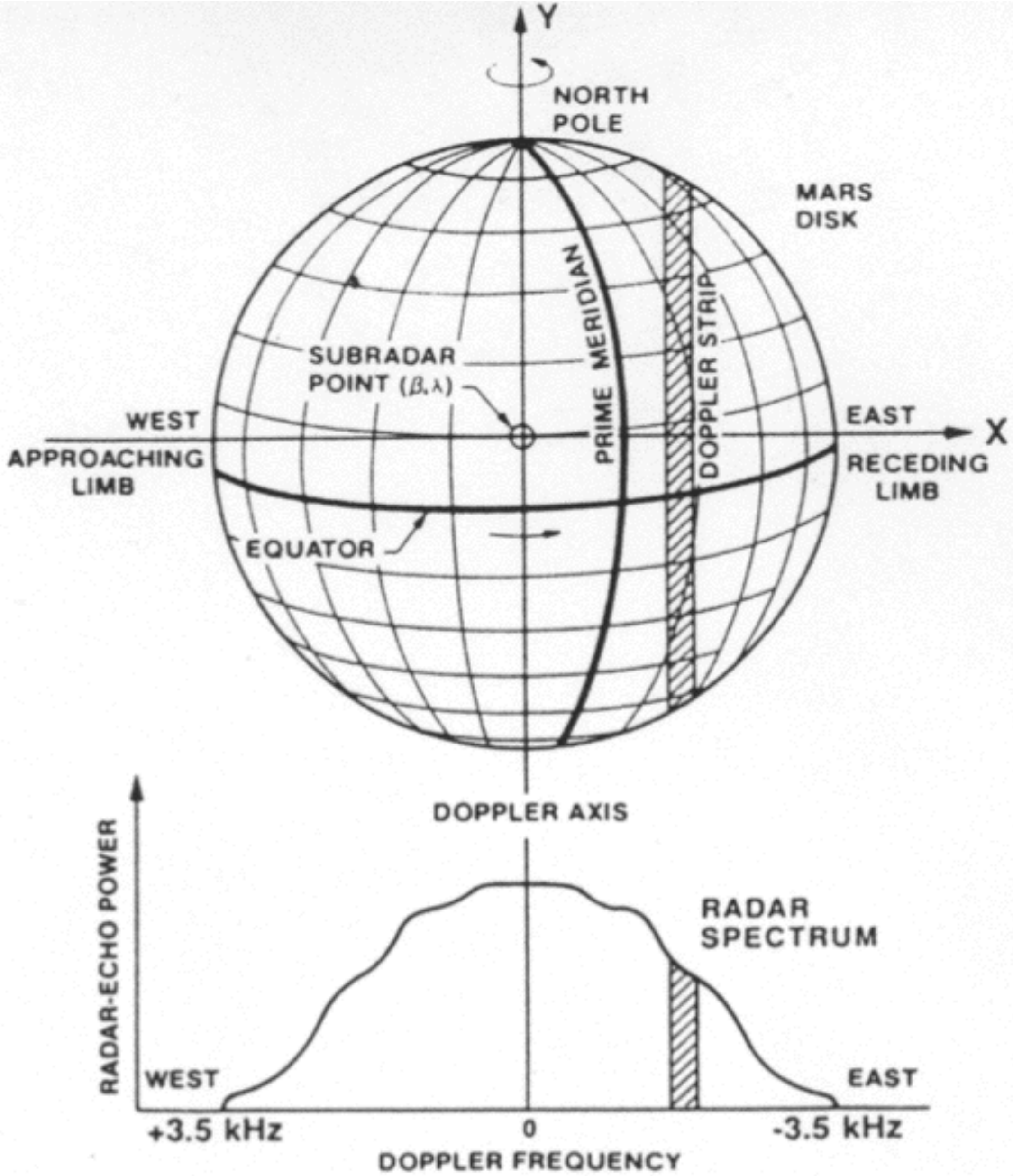
- 13.78 GHz
- 2.176 cm
- 46 watts
- “SL” polarization

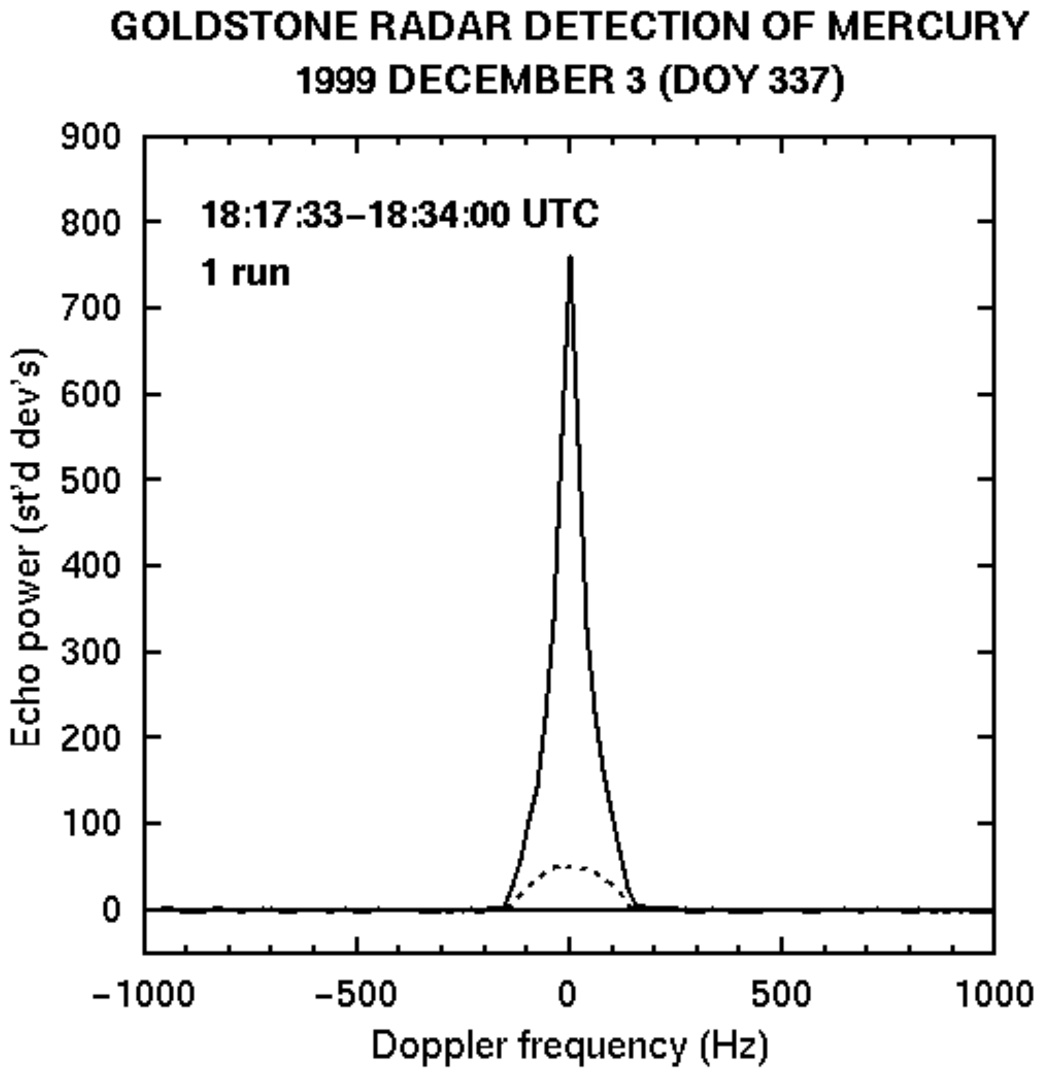
$$\sigma_0(\theta) \sim \cos^n \theta$$

n = 1 2 4 10 100

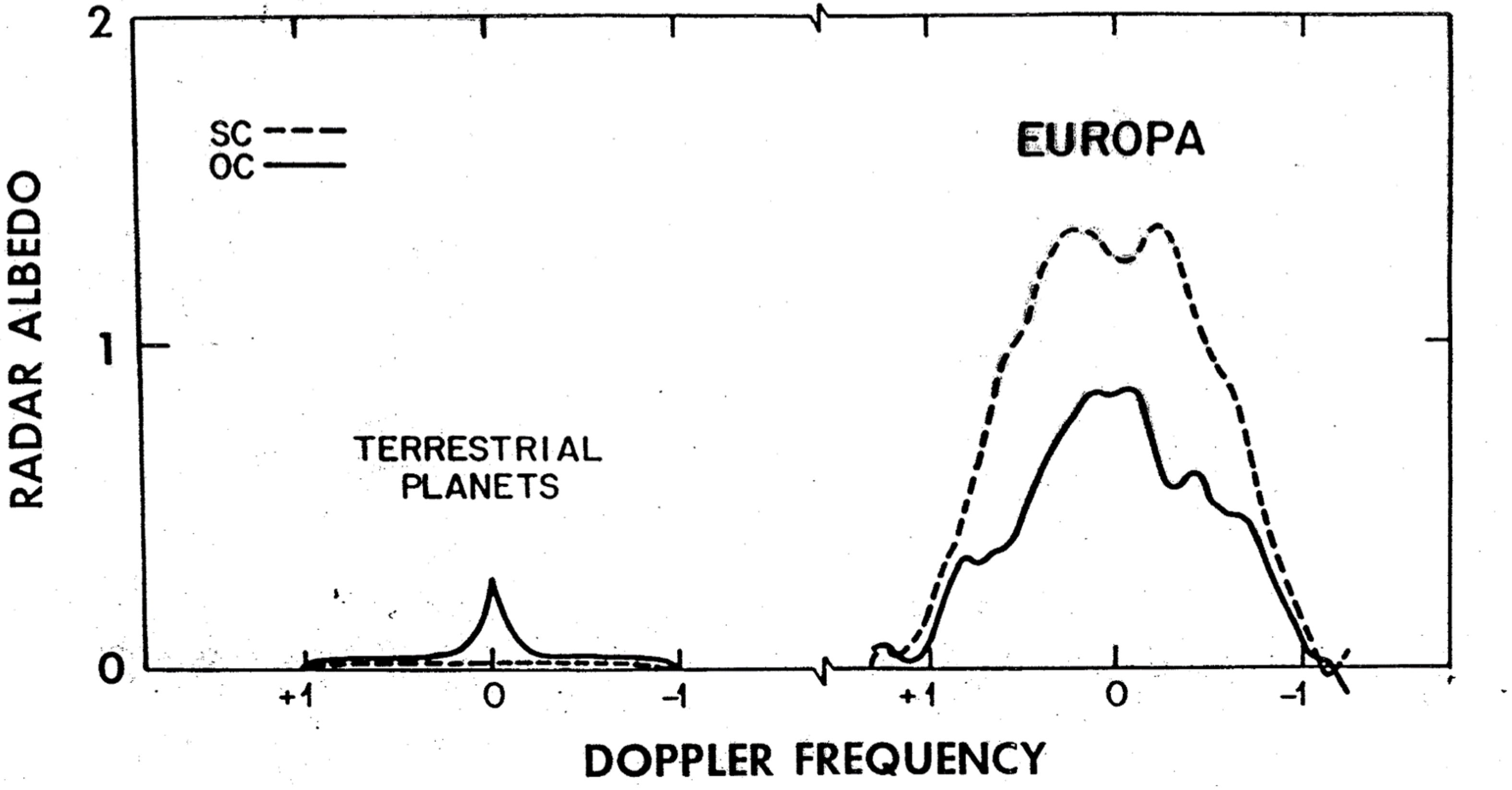


55° 45° 35° 24° 8°

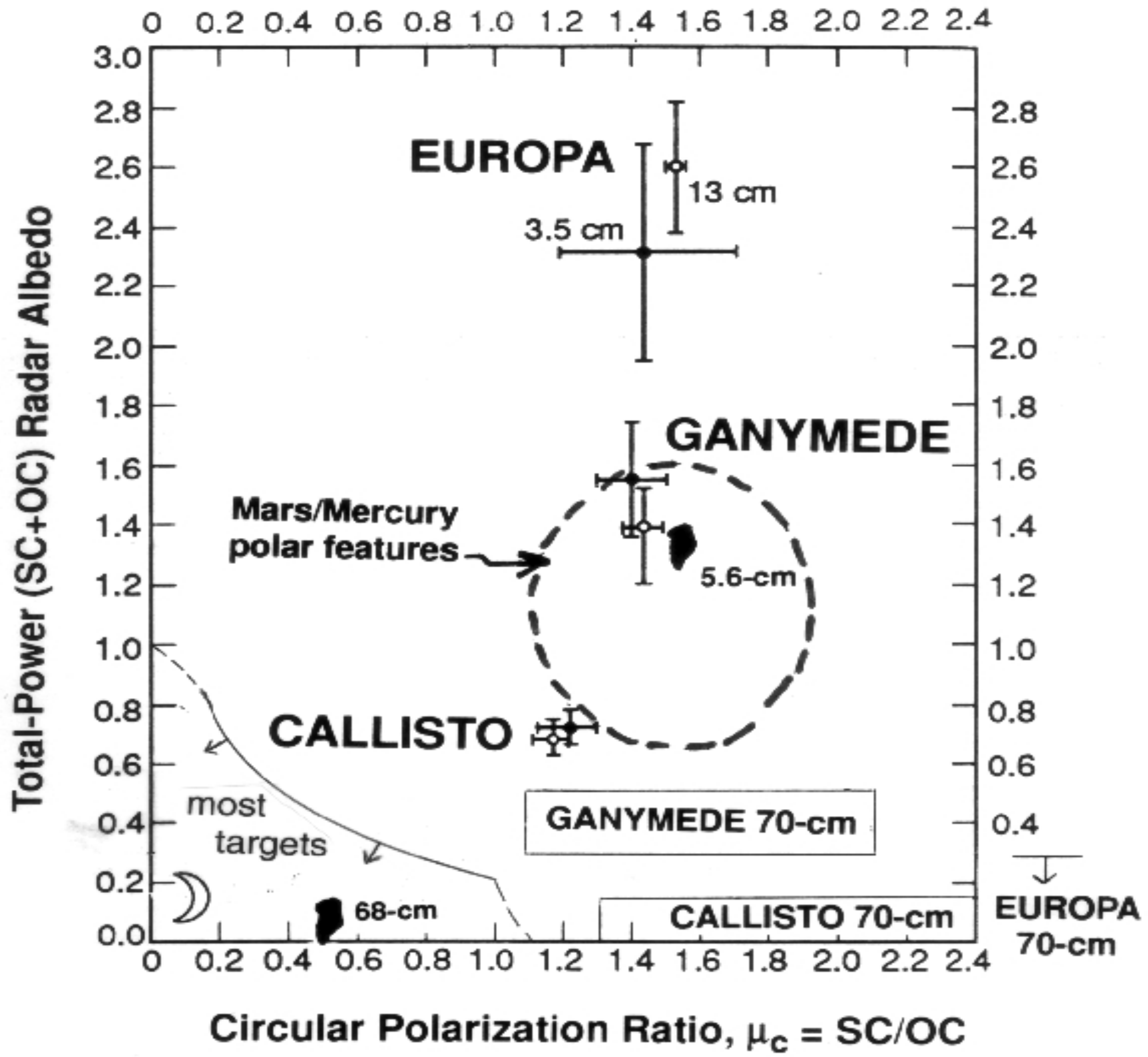

Y
NORTH
POLE
MARS
DISK
PRIME MERIDIAN
DOPPLER STRIP
SUBRADAR
POINT (β,λ)
WEST
APPROACHING
LIMB
EAST
X
RECEDING
LIMB
EQUATOR
DOPPLER AXIS
RADAR-ECHO POWER
RADAR
SPECTRUM
WEST
EAST
+3.5 kHz
0
-3.5 kHz
DOPPLER FREQUENCY



GOLDSTONE RADAR DETECTION OF MERCURY
1999 DECEMBER 3 (DOY 337)
18:17:33–18:34:00 UTC
1 run
Echo power (st'd dev's)
900
800
700
600
500
400
300
200
100
0
−1000
−500
0
500
1000
Doppler frequency (Hz)


2
1
0
RADAR ALBEDO
SC
OC
EUROPA
TERRESTRIAL
PLANETS
+1
0
-1
+1
0
-1
DOPPLER FREQUENCY

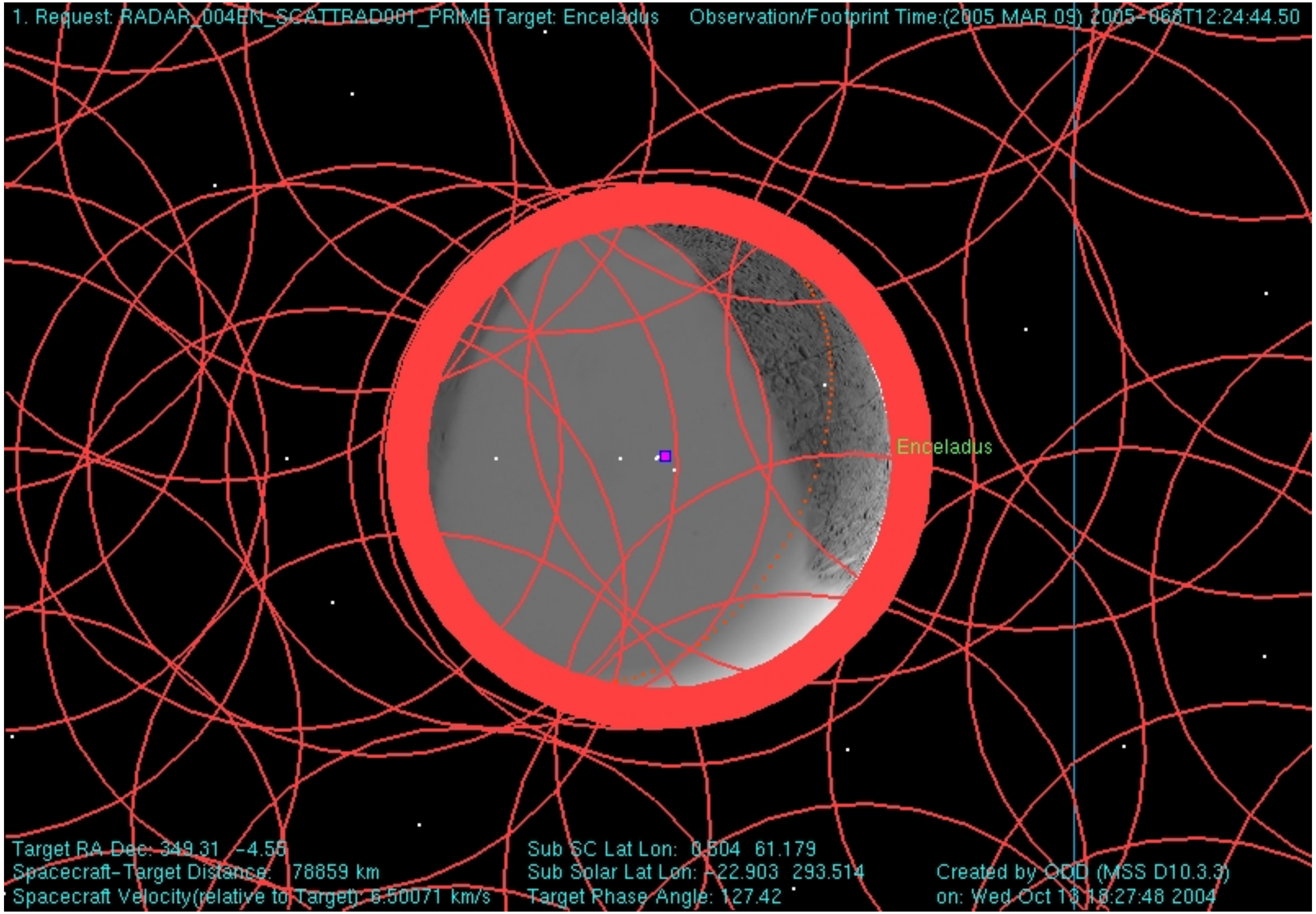
RADAR PROPERTIES

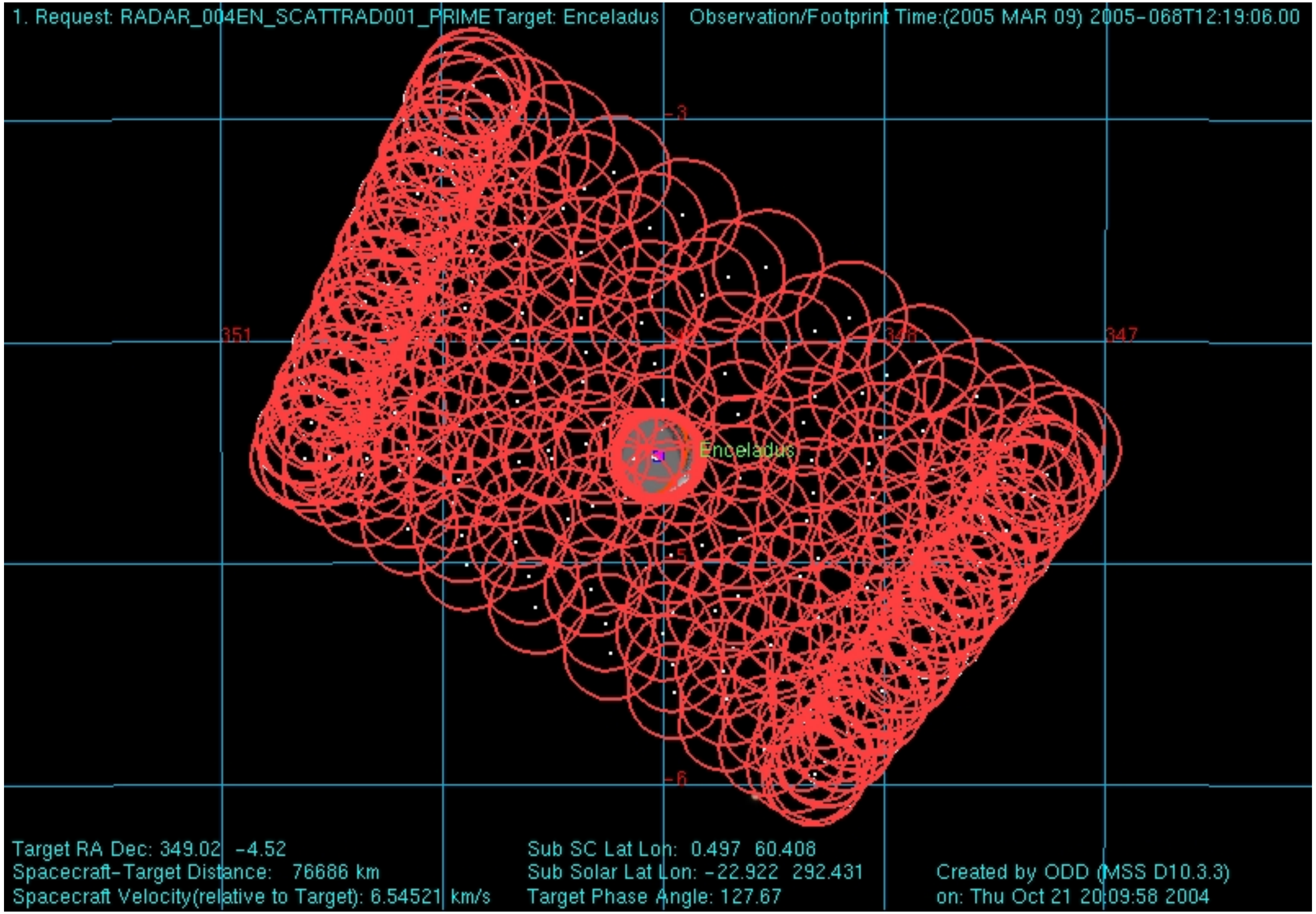


Total-Power Radar Albedos

2.30	**Europa**	
1.55	**Ganymede**	
1.32	**Rhea** (Black and Campbell 2004, *BAAS* **36**, 1123)	
0.72	**Callisto**	
0.28		**PHOEBE**
0.22	**Titan**	**PHOEBE**
0.17	**Iapetus trailing**	**PHOEBE**
0.17	**NEA average and S MBAs**	**PHOEBE**
0.16	**C MBAs**	**PHOEBE**
0.14		**PHOEBE**
0.13	**Iapetus leading**	
0.13	**smooth ice sphere w/ 30% ammonia**	
0.09	**BGFPD MBAs**	
0.08	**Moon**	
0.08	**smooth ice sphere**	
0.06	**comets**	
0.04	**smooth sphere of complex organics**	

	ENC3	ENC4		
Date	2005 Feb 17	2005 Mar 9		
E.Long, Lat	150,0 to 126,0	300,0 to 283,0		
Start-Stop	08:30 to 11:30 UT (C/A +5:00 to +8:00)	15:00 to 23:45 (C/A +3:00 to +5:00)		
Radiometry Duration	150 minutes	84 minutes		
Scatterometry Dur’n	40 minutes	36 minutes		
		c	d	e
		10 min	17 min	9 min
Detection Time	3 min	2 min	3 min	4 min
Distance, km	153,000	76,000	80,000	86,000
Beam/Diameter	2.0	1.0	1.0	1.1
Strategy (target-center stare)	tone	chirp	tone	tone

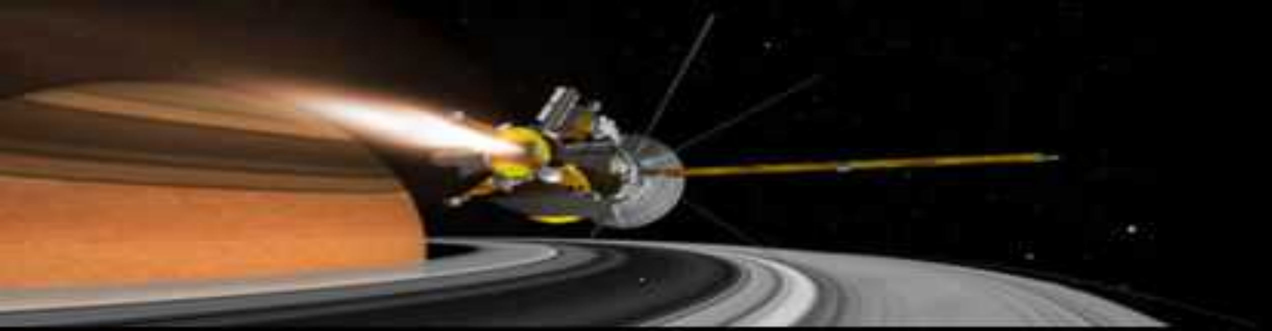

1. Request: RADAR_004EN_SCATTRAD001_PRIME Target: Enceladus
Observation/Footprint Time:(2005 MAR 09) 2005-068T12:24:44.50
Enceladus
Target RA Dec: 349.31 -4.55
Spacecraft-Target Distance: 78859 km
Spacecraft Velocity(relative to Target): 6.50071 km/s
Sub SC Lat Lon: 0.504 61.179
Sub Solar Lat Lon: -22.903 293.514
Target Phase Angle: 127.42
Created by ODD (MSS D10.3.3)
on: Wed Oct 13 16:27:48 2004



1. Request: RADAR_004EN_SCATTRAD001_PRIME Target: Enceladus
Observation/Footprint Time:(2005 MAR 09) 2005-068T12:19:06.00
-3
351
347
Enceladus
-5
-6
Target RA Dec: 349.02 -4.52
Spacecraft-Target Distance: 76686 km
Spacecraft Velocity(relative to Target): 6.54521 km/s
Sub SC Lat Lon: 0.497 60.408
Sub Solar Lat Lon: -22.922 292.431
Target Phase Angle: 127.67
Created by ODD (MSS D10.3.3)
on: Thu Oct 21 20:09:58 2004

Cassini RADAR Observations of "Icy Satellites"

Rhea	7
Enceladus	6
Dione	5 (first failed)
Mimas	4 (first failed)
Iapetus	3 (first was successful)
Tethys	2
Hyperion	2
Phoebe	1 (successful)
	30



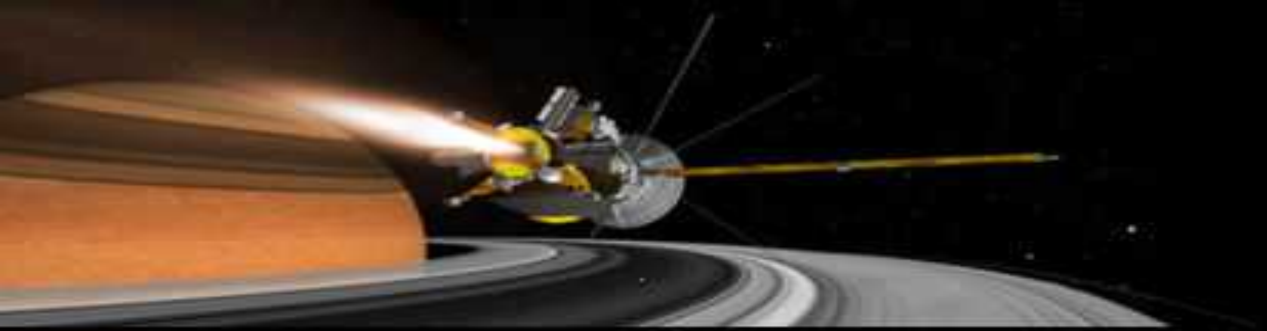
cosmic dust analyser

Max-Planck-Institut für Kernphysik

CDA @ Enceladus 3: Science overview

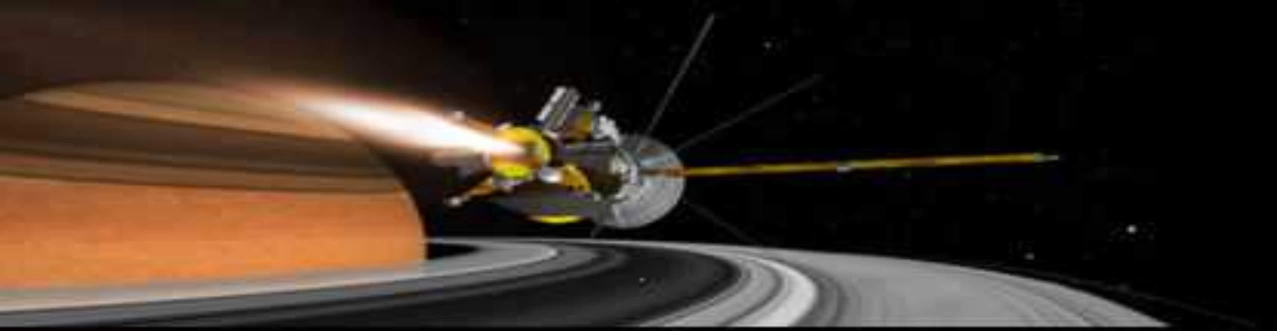
Sascha Kempf

MPI für Kernphysik, Heidelberg, Germany



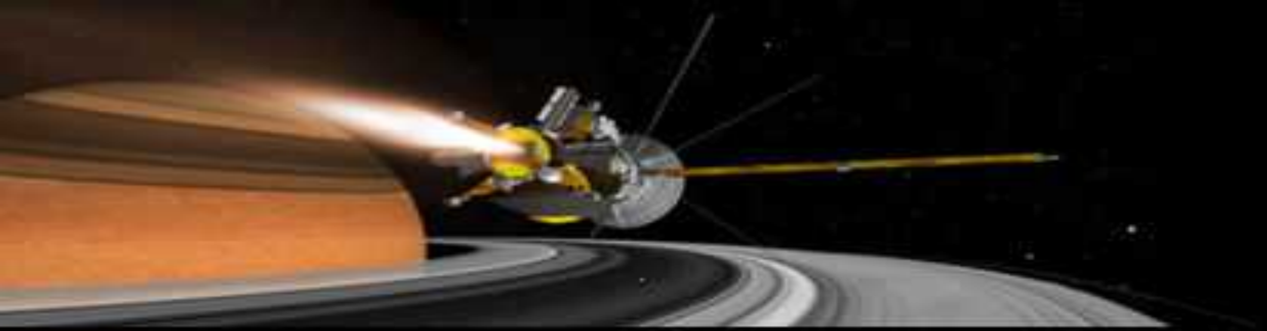
Scientific Background

- Enceladus is thought to be the main source of the E ring
  - ring particles produced by impact ejection:
    - micrometeoroids striking moon surface produce secondary dust particles
    - a few escape from the moon’s gravity and replenish the ring (Horanyi et al., 1992)
    - mass distribution of fresh dust differs significantly from ring particle mass distribution



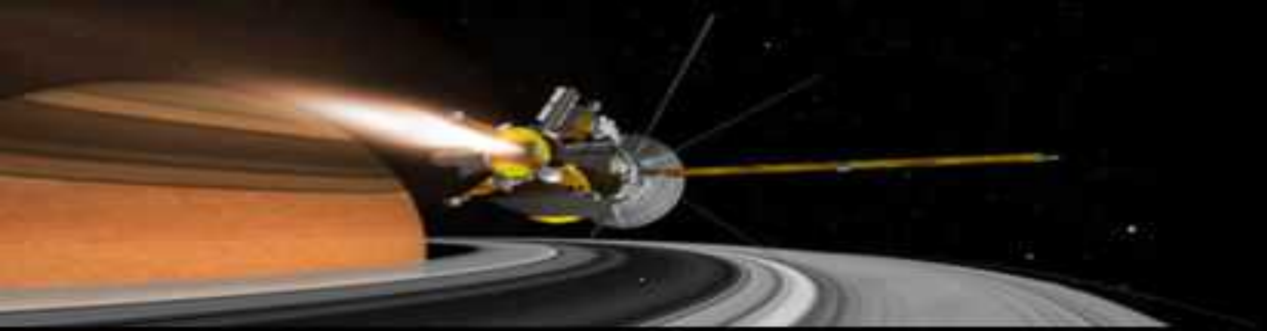
Objectives

- determine dust production rate of Enceladus
- determine mass distribution of fresh dust
- constrain source of primary meteoroid flux:
  - E ring itself
  - interplanetary particles
  - other
- elemental characterisation of Enceladus’ surface



Main idea

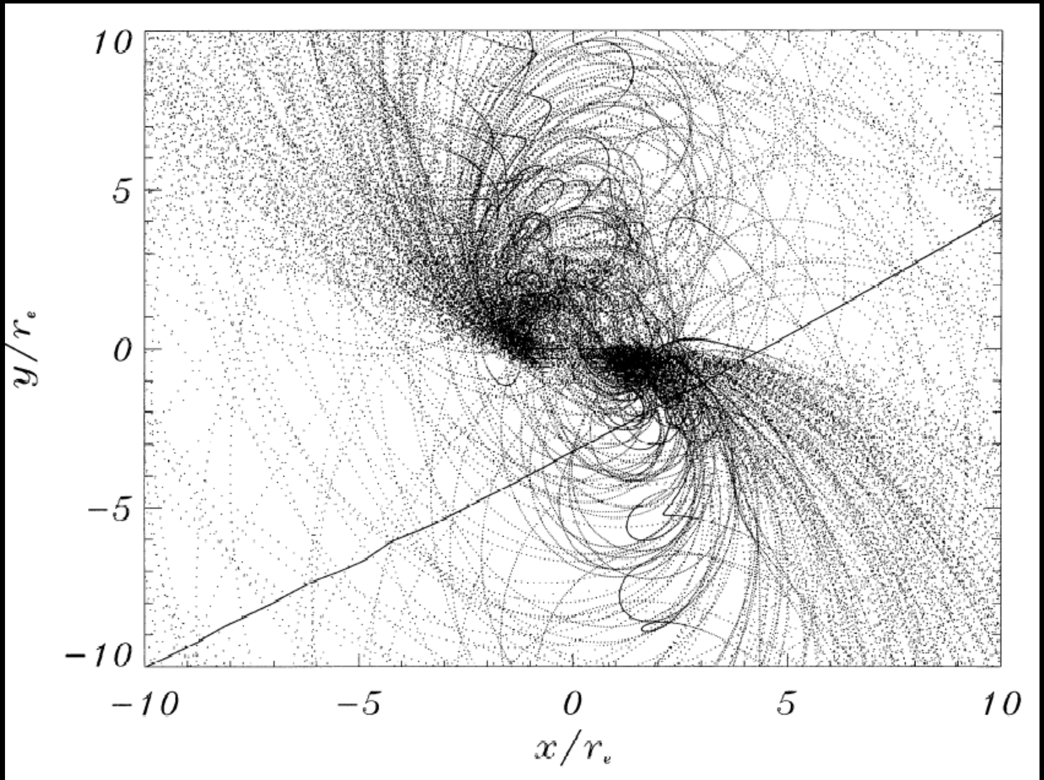
- most of the freshly produced dust remains gravitationally bound, i.e. is captured inside Enceladus' Hill sphere
- dust flux inside Hill sphere will be enhanced
- mass distribution measured inside Hill sphere is initial mass distribution of the ring



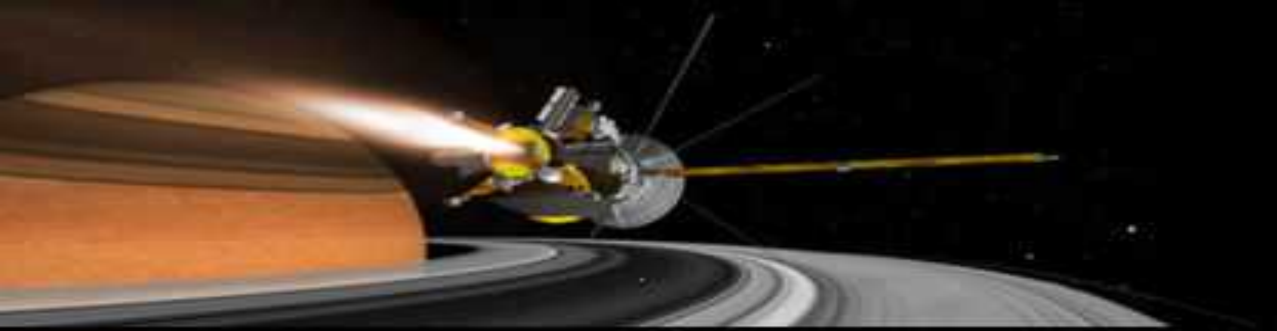
Spatial distribution of fresh dust

Spahn et al., JGR, 1999

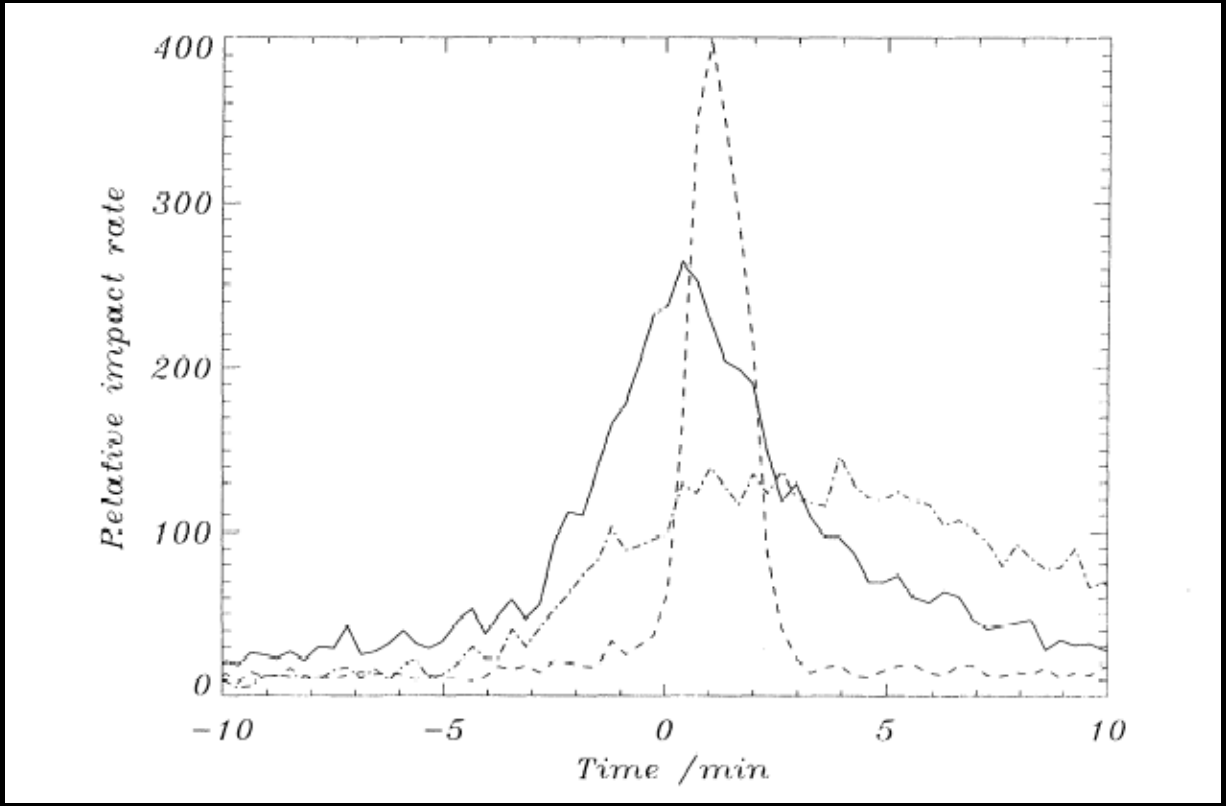
- particles are re-leased preferably into Saturn/ anti-Saturn direction
- peak rate after Enceladus c/a



Simulation of “old” E4 flyby

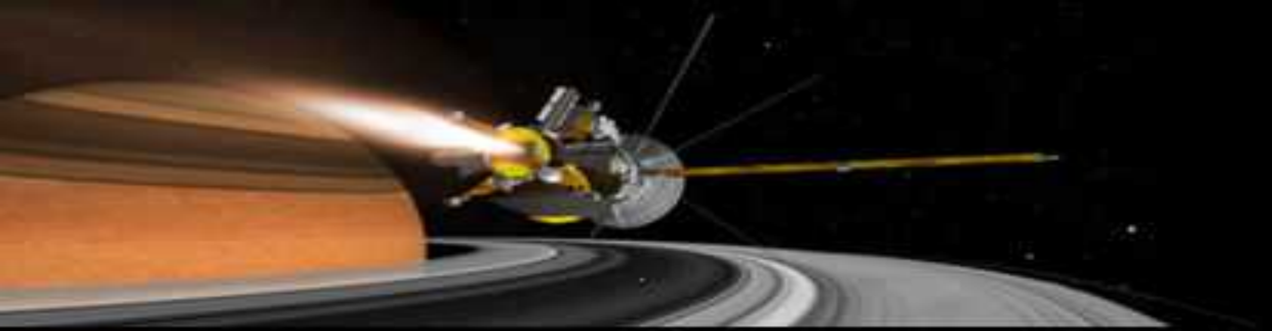


Determination of impactor source



Spahn et al., JGR, 1999

- rate as function of time constraints impactor source:
  - solid: isotropic
  - broken: E ring
  - dashed-dot: interplanetary



Caveat!

- E3 flyby is by no means optimal to meet our scientific objectives:
  - Cassini does not traverse through Hill sphere
  - pointing before Enceladus c/a not appropriate for observing bound dust
  - we did not perform enough measurements during ring plane crossings to understand the instrument performance in a dust-rich environment sufficiently

Enceladus Science Objectives

- UVIS Icy Satellite Science Objectives are to Investigate
  - Surface age and evolution
  - Surface composition and chemistry
  - Tenuous atmospheres / exospheres

Surface Age and Evolution

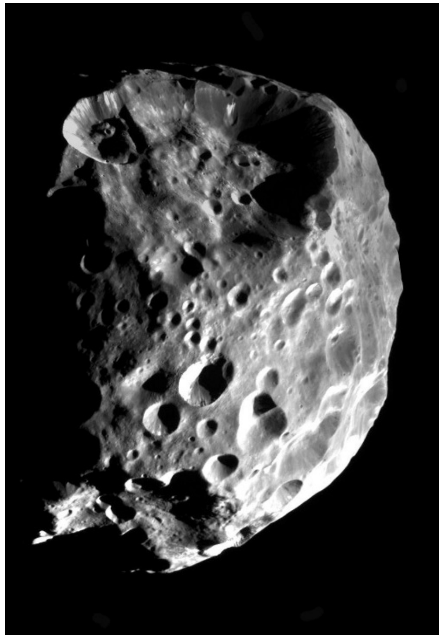
General

- The surface albedo of Saturn's icy satellites is affected by radiation and surface chemistry, and thus will vary with the amount of time a surface unit has been exposed to the magnetosphere's radiation and high energy particles. Leading / trailing side asymmetries are expected.
  - Also determined by nature of interactions (e.g. Ganymede radiation exposure affected by its own internal magnetic field)
- Moderate to high resolution global maps of the satellites orbiting in Saturn's magnetosphere will be used to analyze surface exposure, thus age. These global maps will be compared to Iapetus, Phoebe and Hyperion, which all orbit outside the magnetosphere.
- Surface microstructure will be investigated via the phase function. For example Voyager results on the albedo, color and photometric function properties of Enceladus show a degree of uniformity, regardless of surface age, that suggests the possibility of a thin ubiquitous layer of geologically fresh frost.

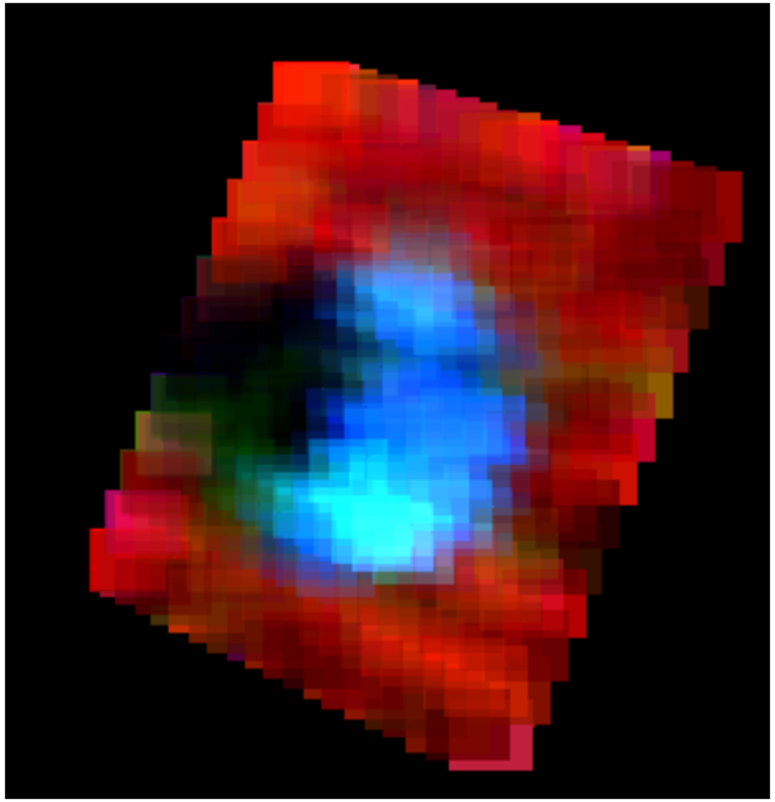
Enceladus

- Images of Enceladus suggest an extreme level of surface modification regionally. Regions of very young and very old terrain will be compared. UVIS uv albedo maps will be produced. We will look for uv albedo differences that correlate to geologic ages derived from the imaging data.
- Albedo and phase function should give us insight into Enceladus' interaction with Saturn's E ring.

Example: Phoebe UV Albedo Map



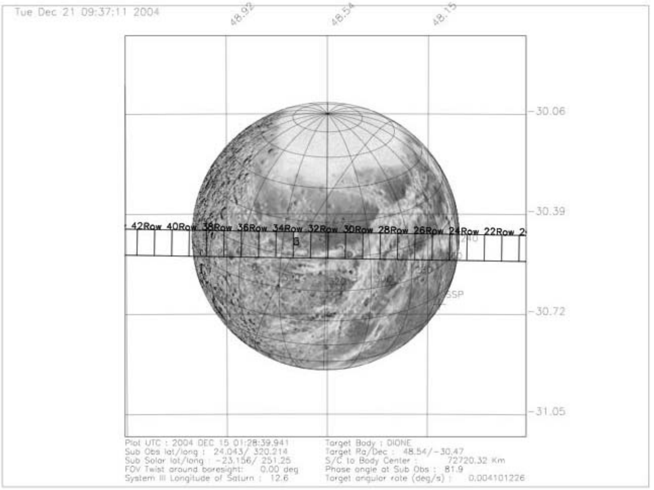
Similar geometry

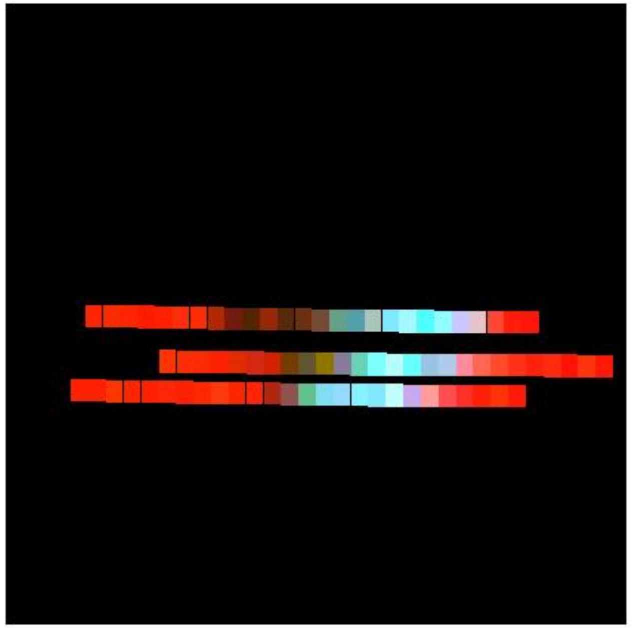


Time: C/A-01:22
Range: 31,300 km
Phase angle: 83°
Lat/Long: 21°S, 349°W

Blue/green=reflected solar
Red=background Ly-α (IPH)

Dione REGMAP





Surface Composition and Chemistry

General

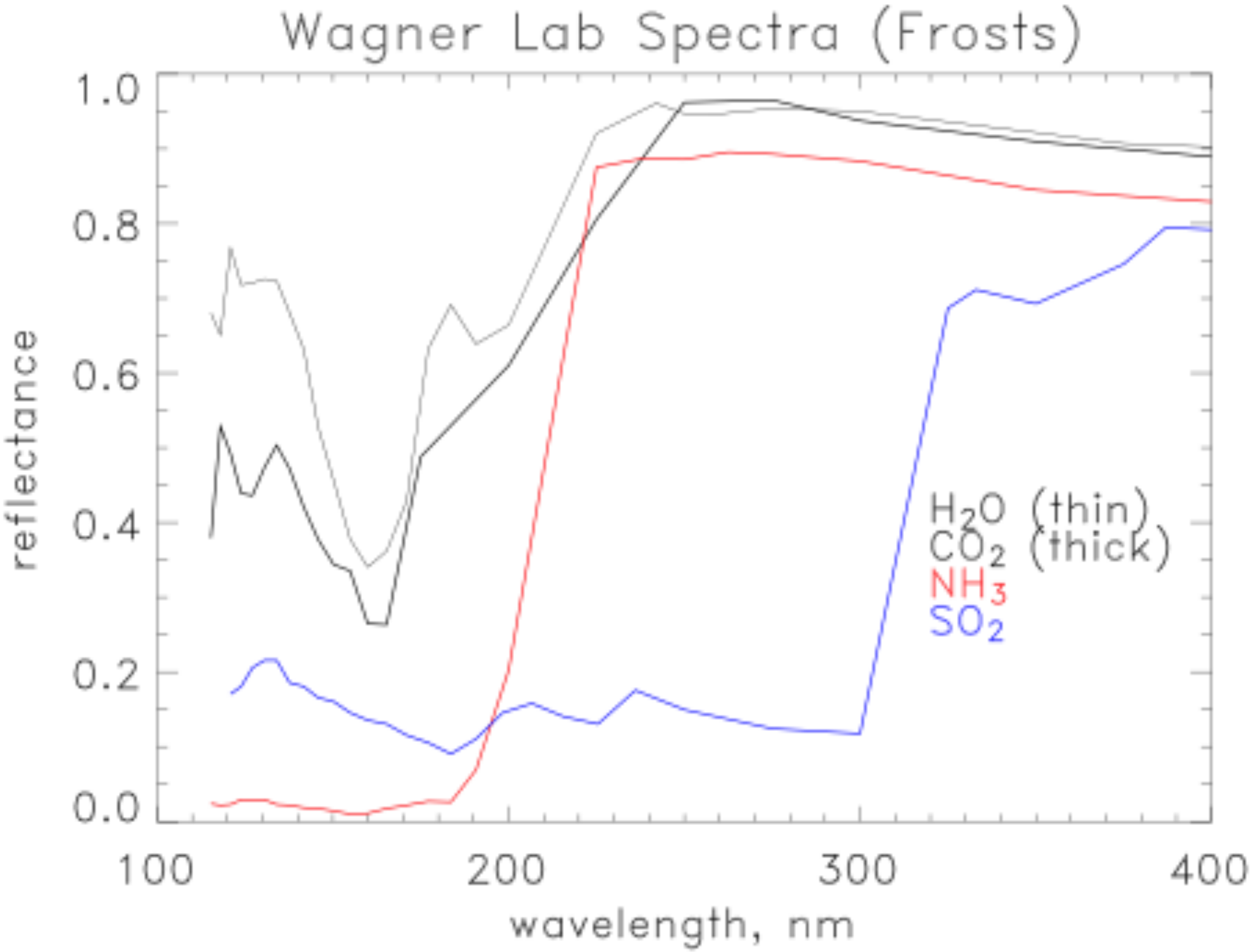
- Investigation of photolysis and radiolysis of water ice is currently a very active area of research, propelled by recent Galileo results, earth-based observations and laboratory work. UV radiation dissociates H_2O producing H, OH, H_2, O, and O_2. H and H_2 are quickly lost to thermal escape.
  - Surface composition and the existence of an atmosphere are affected by sputtering processes. Hydrogen peroxide was identified in the surface ice of Europa. Condensed O_2 has been detected at Ganymede. Spectral absorption suggestive of ozone has been detected by the Galileo UVS on Ganymede, and by HST on Ganymede, Rhea, and Dione. (Note however that these features are at longer uv wavelengths than the UVIS FUV channel.)
  - Cassini offers the opportunity to compare a suite of icy satellites even further from the sun than Jupiter's moons, in a different magnetospheric environment. Being able to compare surface ice oxygen chemistry at a variety of temperatures and radiation environments will help to investigate the process of evolution of surface composition.
- Theoretical and laboratory spectra of various ices are available (e.g. J. Wagner, G. Hansen, S. Warren) and can be compared to UVIS data to map surface composition. Water ice has been detected on all Saturnian satellites - we will show how the amount, distribution, and grain size varies.

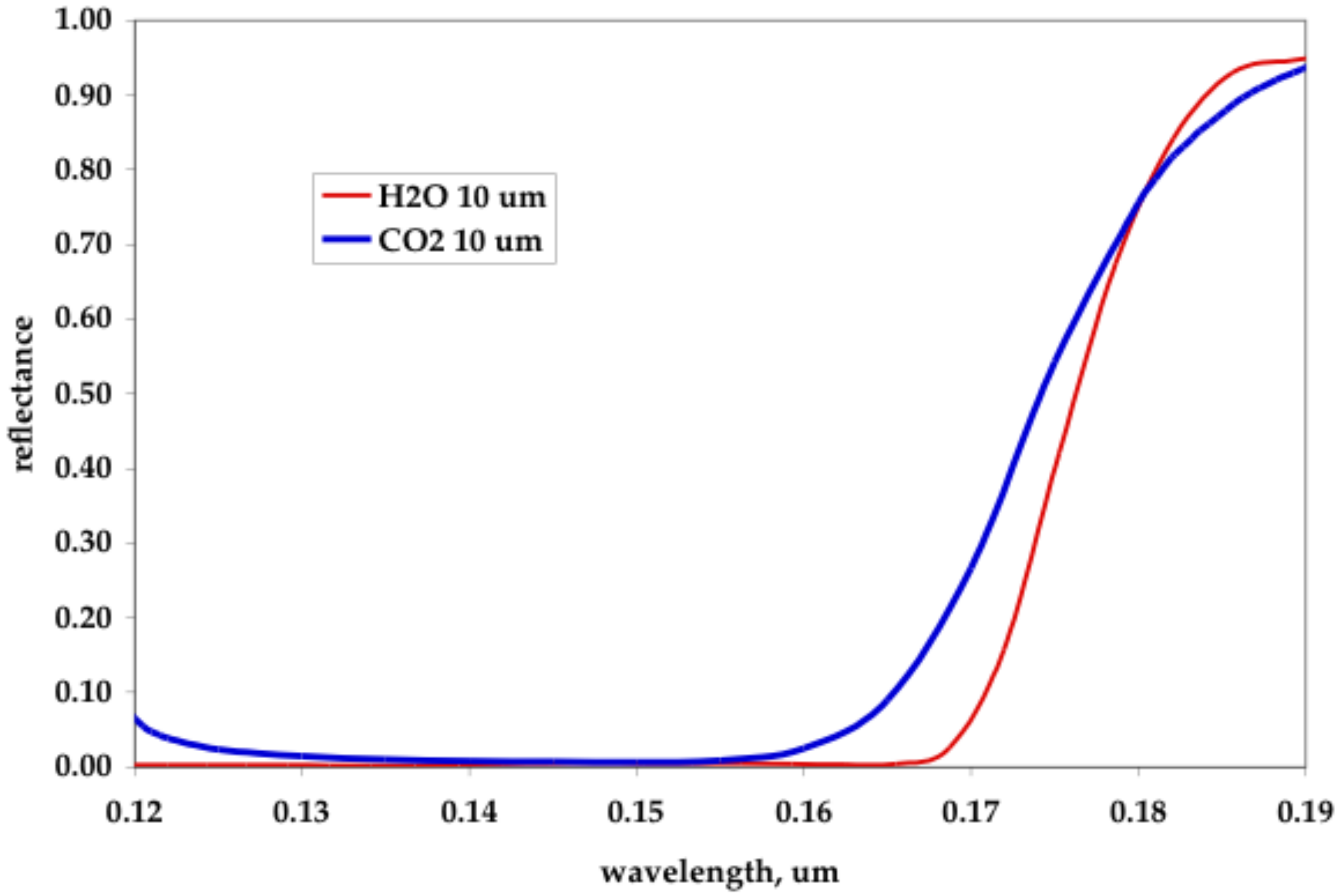
Enceladus

- Enceladus is known to have a predominantly water-ice surface. The water spectrum has a distinct upturn at FUV wavelengths, at a wavelength determined by the ice grain size. Predominant grain size will give us insight into surface modification processes.
- UVIS reflectance spectra are at shorter wavelengths than the Galileo UVS so we will be searching for somewhat different constituents. UVIS spectra may show evidence of CO_2, ammonia, or other interesting species.

UV Spectra of Candidate Materials

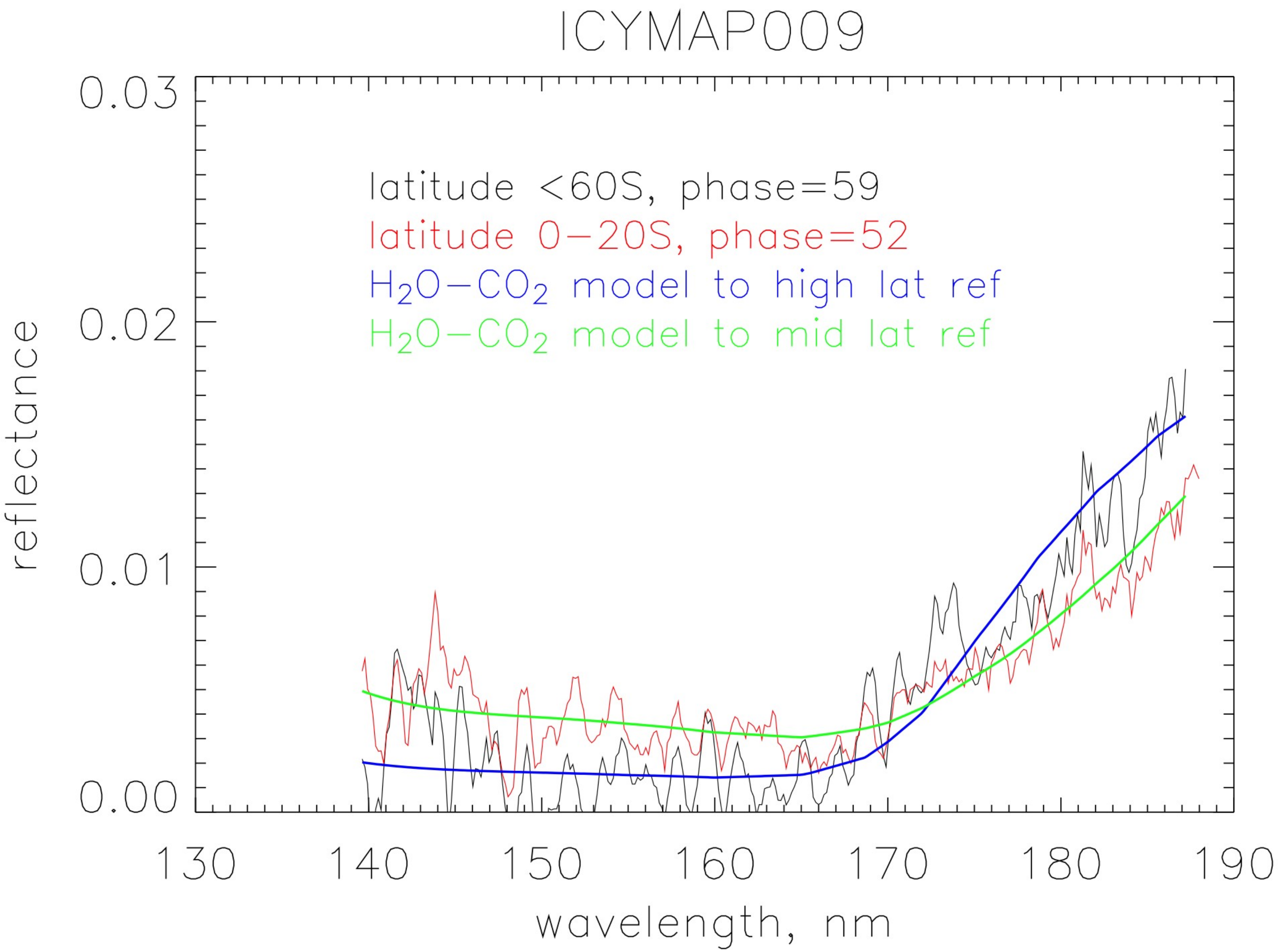
(Wagner, Hapke, Wells, 1987)



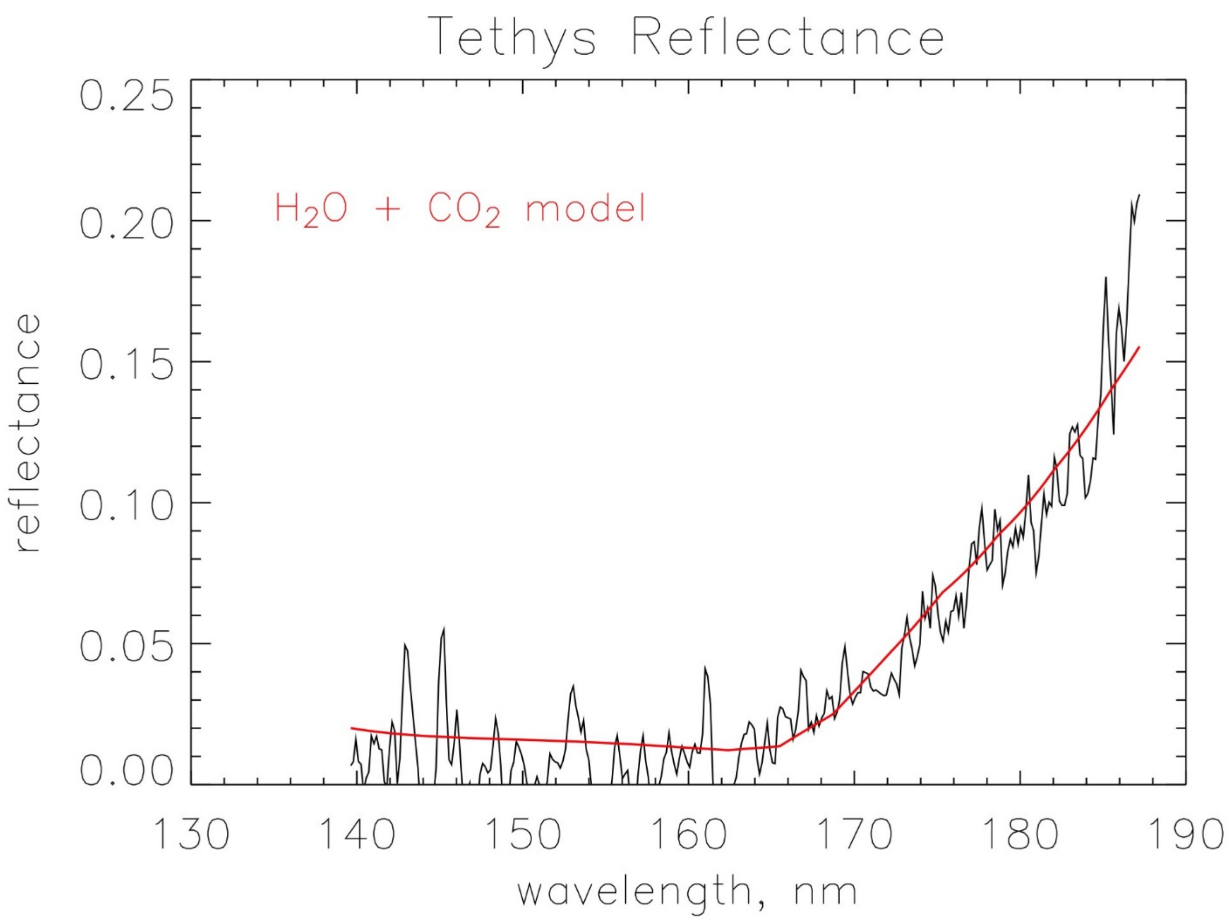


data from Gary Hansen

Phoebe's spectral variations with latitude



Tethys is ~10x brighter than Phoebe at similar phase angle



Need much more H_2O, less dark material to fit this Tethys spectrum, compared to Phoebe

α=50°

Model uses smaller H_2O grain size

Tenuous Atmospheres / Exospheres

General

- Molecules are sputtered and sublimated from the surfaces of the icy satellites. Molecules sputtered from the surface are a source of neutrals in and influencing the magnetosphere. Determination of atmospheric density, and source and loss rates of atmospheric molecules feeds into models of the magnetospheric interaction. By determining the composition of these exospheres we may determine surface composition. Of particular interest are trace constituents such as NH_3. For example, an ammonia-water ice composition has been proposed to explain the young geology on Enceladus. The existence of an atmosphere may be indicative of active surface processes, such as the volcanoes on Io or the geysers on Triton (sputtering models indicate that only Rhea has the potential to retain a sputtered atmosphere, thus detection of an atmosphere will lead us to suspect eruptive activity).

Enceladus

- Enceladus' position at the peak of Saturn's E ring has always been a "smoking gun" as a potential source of the E ring. Its regionally young geology is also a tantalizing reason to link potential active geologic phenomena to the E ring. Sputtering is not a likely source for a detectable oxygen atmosphere - theoretical yields suggest that this process is not sufficient to be an important source of volatiles.
- The UVIS stellar occultation will be analyzed for absorption features that could show the existence of a tenuous atmosphere, which would then be a strong indicator of eruptive activity
- UVIS spectra will be examined for emission features such as 130.4 and 135.6 nm (atomic and molecular oxygen), 149.3 nm (atomic nitrogen), etc.

Example: Europa Oxygen Features