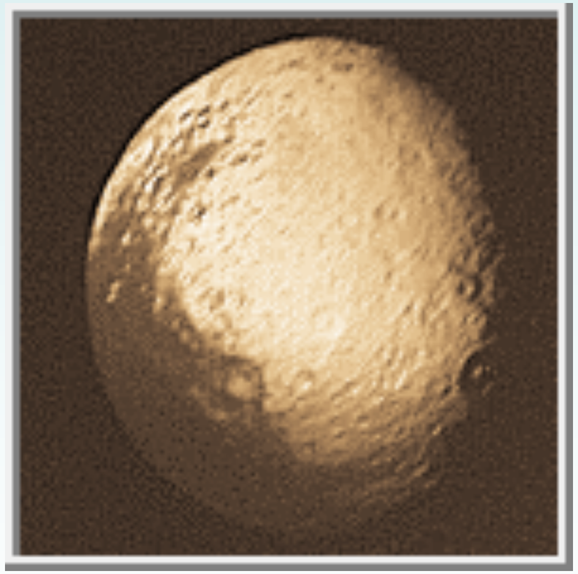
S07: Iapetus plus three untargeted flybys of Mimas, Enceladus and Rhea

Iapetus: What we know at the end of 2004



Bonnie J. Buratti, Amanda Hendrix, and Rosaly Lopes

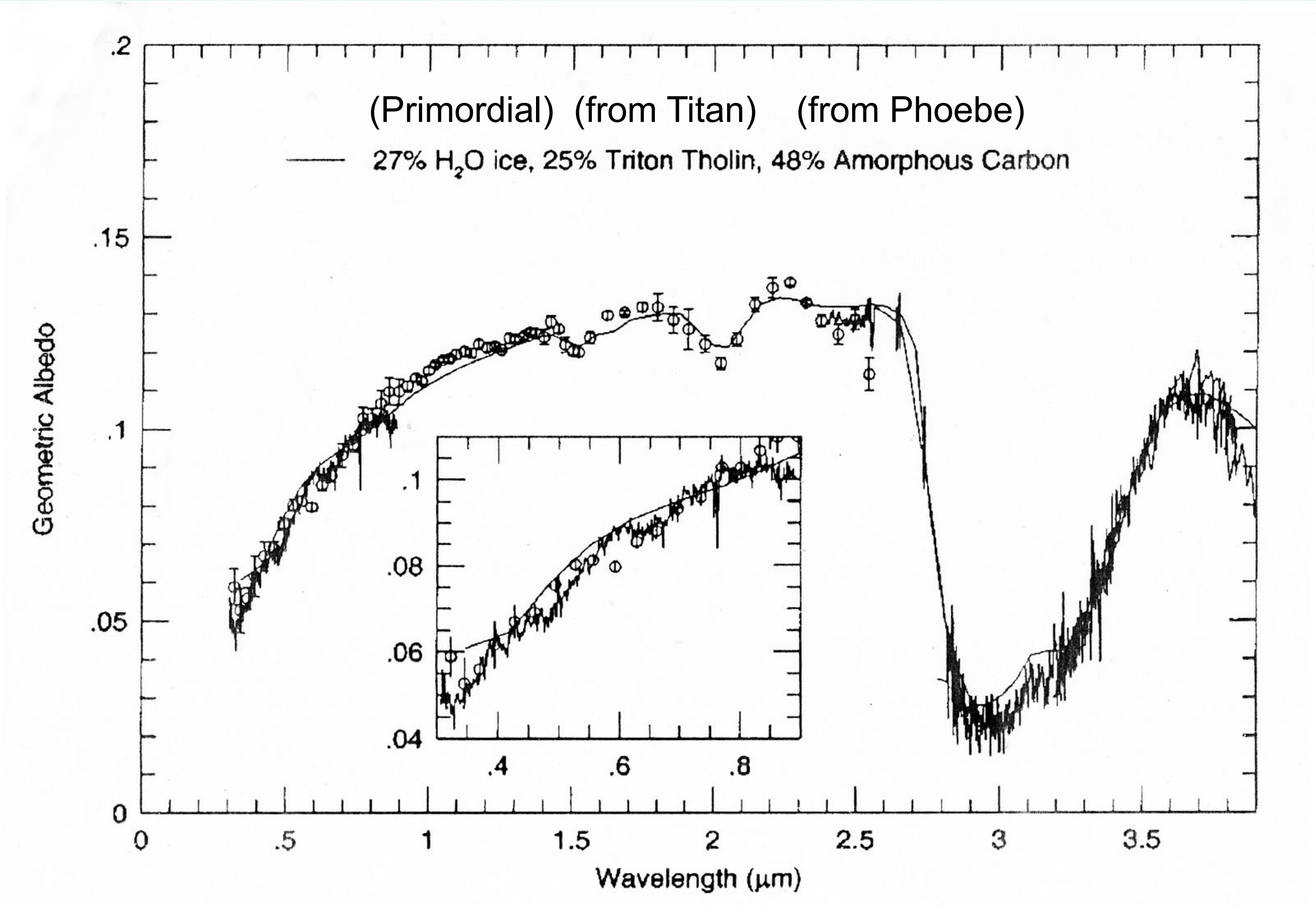
The "SOST Leadership"

Vitals

Iapetus	
Distance from Saturn (10^3 km)	3,561
Period (days)	79
Radius (km)	718
i	14.7
e	0.028
Density (gm/cc)	1.2
Geometric albedo	0.02-0.6
Discovered	1671 (Cassini)

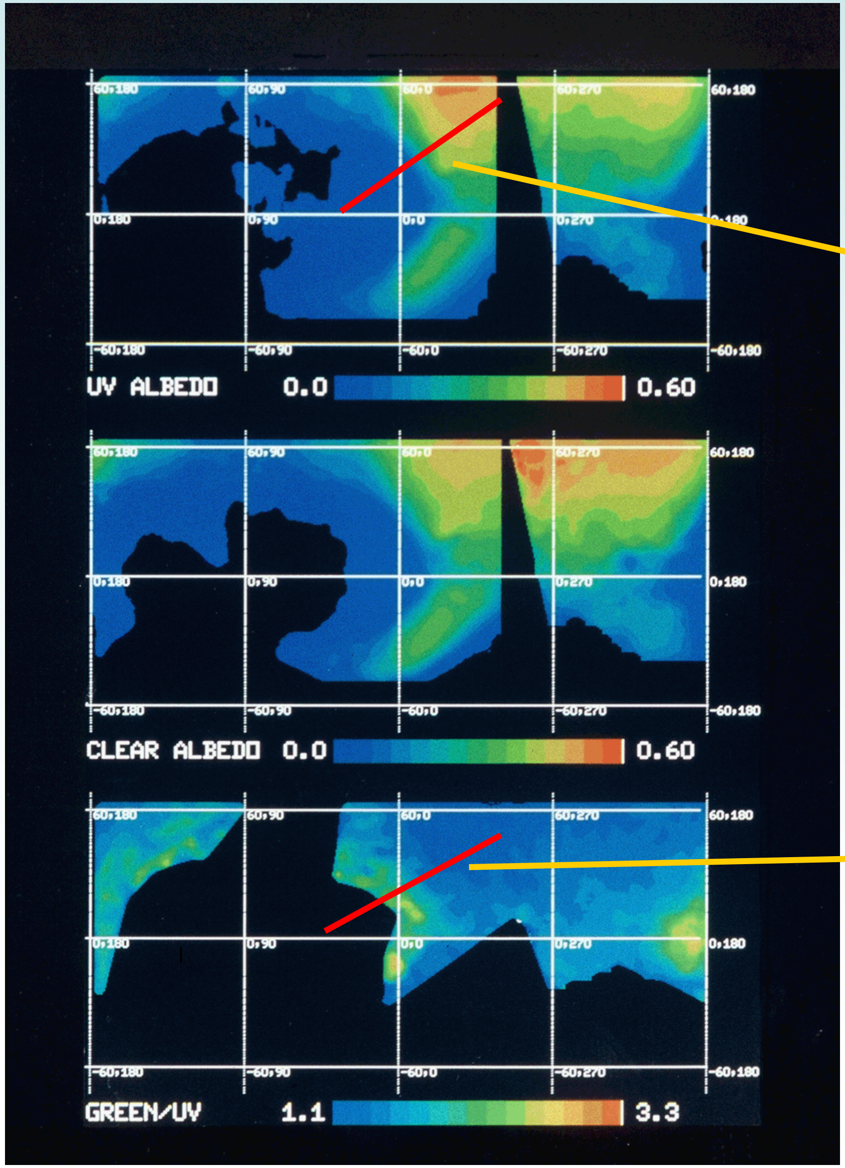

JEAN·DOMINIQUE·CASSINI

Compositional mixing model (Owen et al., 2001)

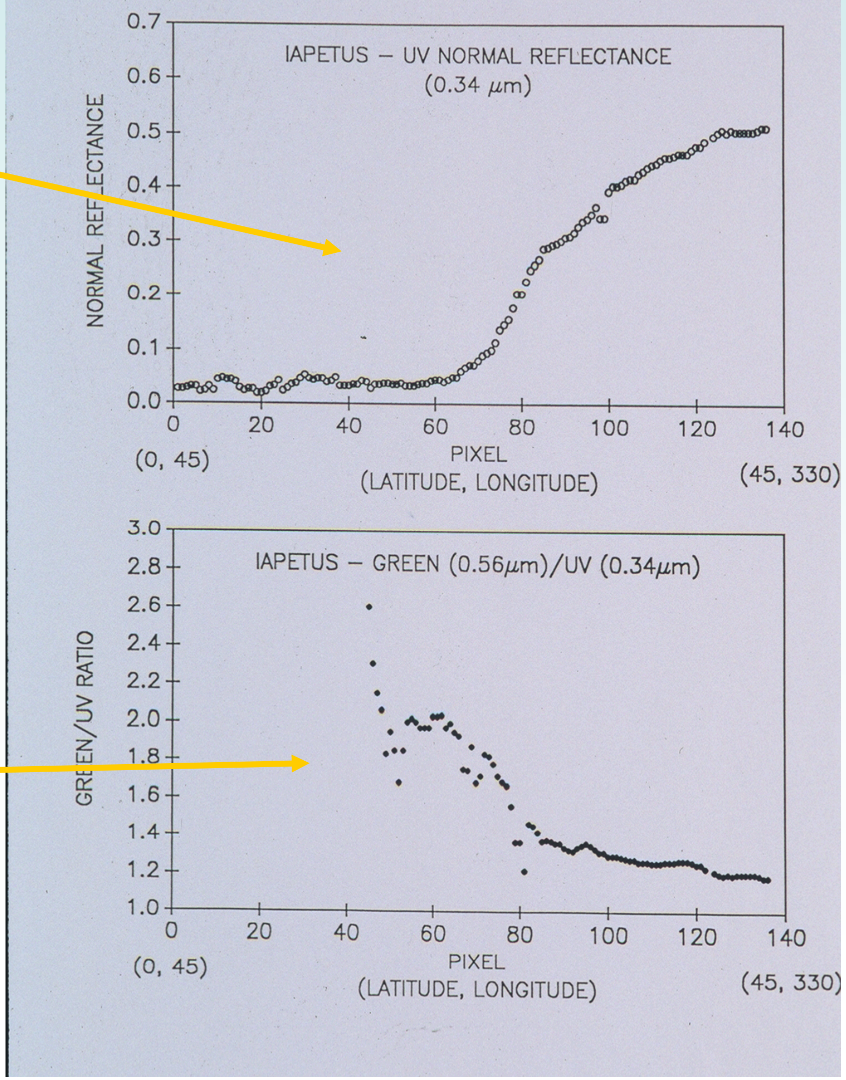


CO_2 discovered in July data by VIMS

The evidence, continued



Buratti and Mosher, 1995, Icarus **115.**



“Discovery of 12 Satellites of Saturn exhibiting orbital clustering”, Gladman et al., *Nature* **412**, 163 (2001).

Saturn's irregular satellites : Mean orbital elements

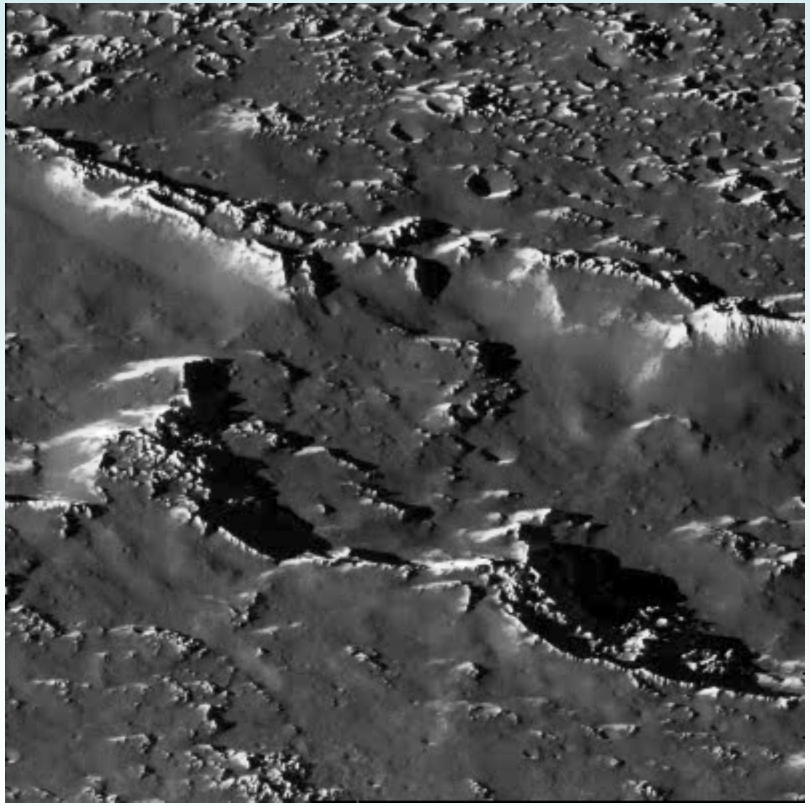
Satellite	$a(10^6\text{km})$	e	$I(°)$	$P(\text{yr})$	m_R	$R(\text{km})$
			34-degree inclination group			
S/2000 S 4	18.2	0.54	33.5	2.53	22.1	7
S/2000 S 10	17.5	0.47	34.7	2.35	23.0	4
S/2000 S 11	17.9	0.38	33.1	2.43	20.5	13
			46-degree inclination group			
S/2000 S 2	15.2	0.36	45.1	1.88	21.3	10
S/2000 S 3	17.3	0.27	45.4	2.26	20.1	16
S/2000 S 5	11.3	0.33	46.1	1.23	22.0	7
S/2000 S 6	11.5	0.32	46.6	1.24	22.6	5
			S/2000 S 8 alone			
S/2000 S 8	15.7	0.27	153.0	2.00	23.6	3
			Phoebe group			
Phoebe	12.94	0.163	174.7	1.51	16.4	110
S/2000 S 1	23.1	0.34	173.1	3.59	21.7	8
S/2000 S 7	20.1	0.45	175.9	2.92	23.9	3
S/2000 S 9	18.5	0.22	167.4	2.57	23.8	3
S/2000 S 12	19.7	0.12	175.8	2.84	23.9	3

Does this process occur anywhere else?

The accretion of material onto the leading sides of outer planet satellites should occur wherever outer retrograde satellites are found:

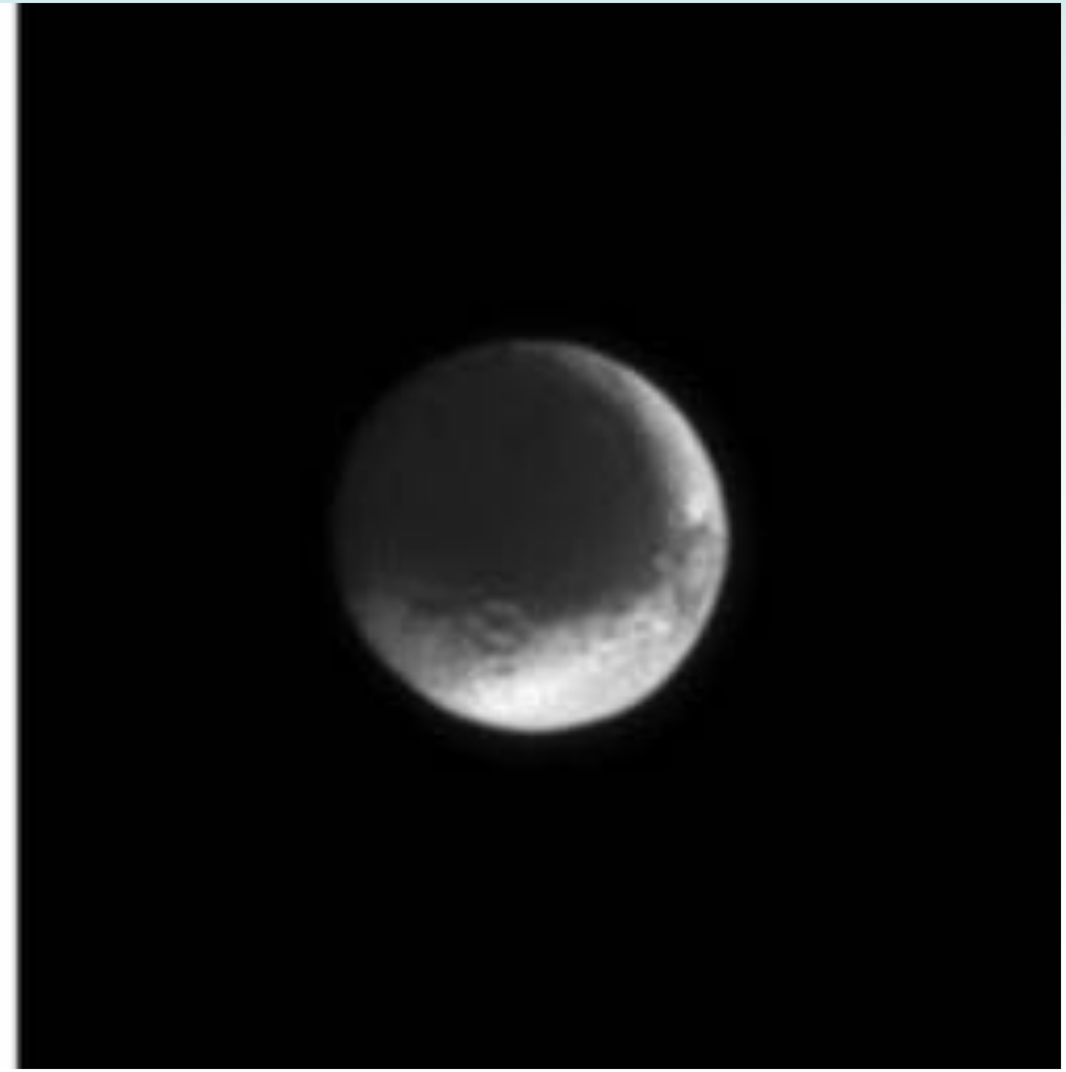
1. ***Callisto*** (Bell et al., 1985): leading side is darker (except right at opposition)

2. ***Uranian satellites***: Leading sides seem to be darker and redder (Buratti and Mosher, 1991), and the effect increases with distance from Uranus



Galileo image of Callisto

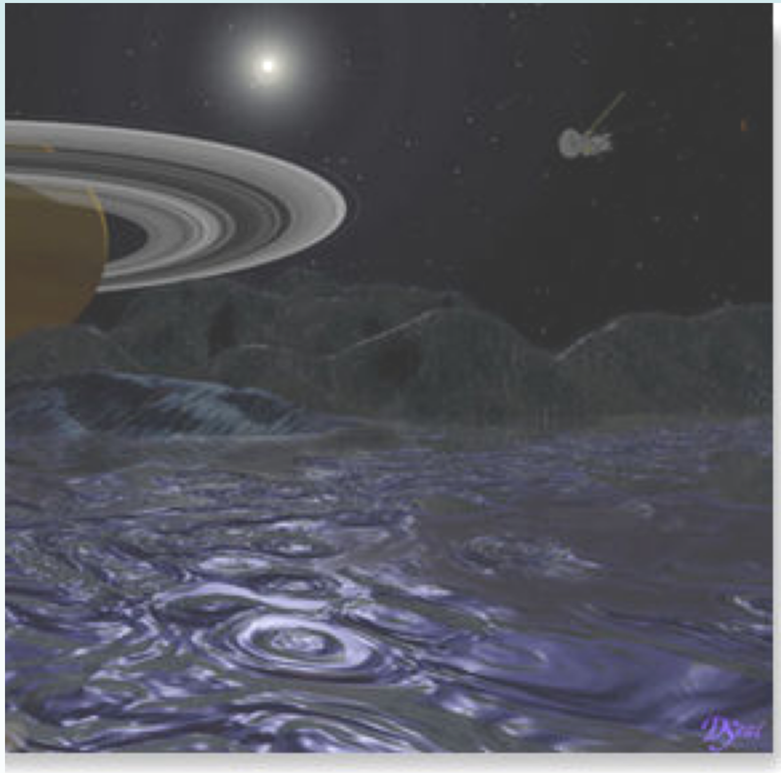
A Sneak Peak in July



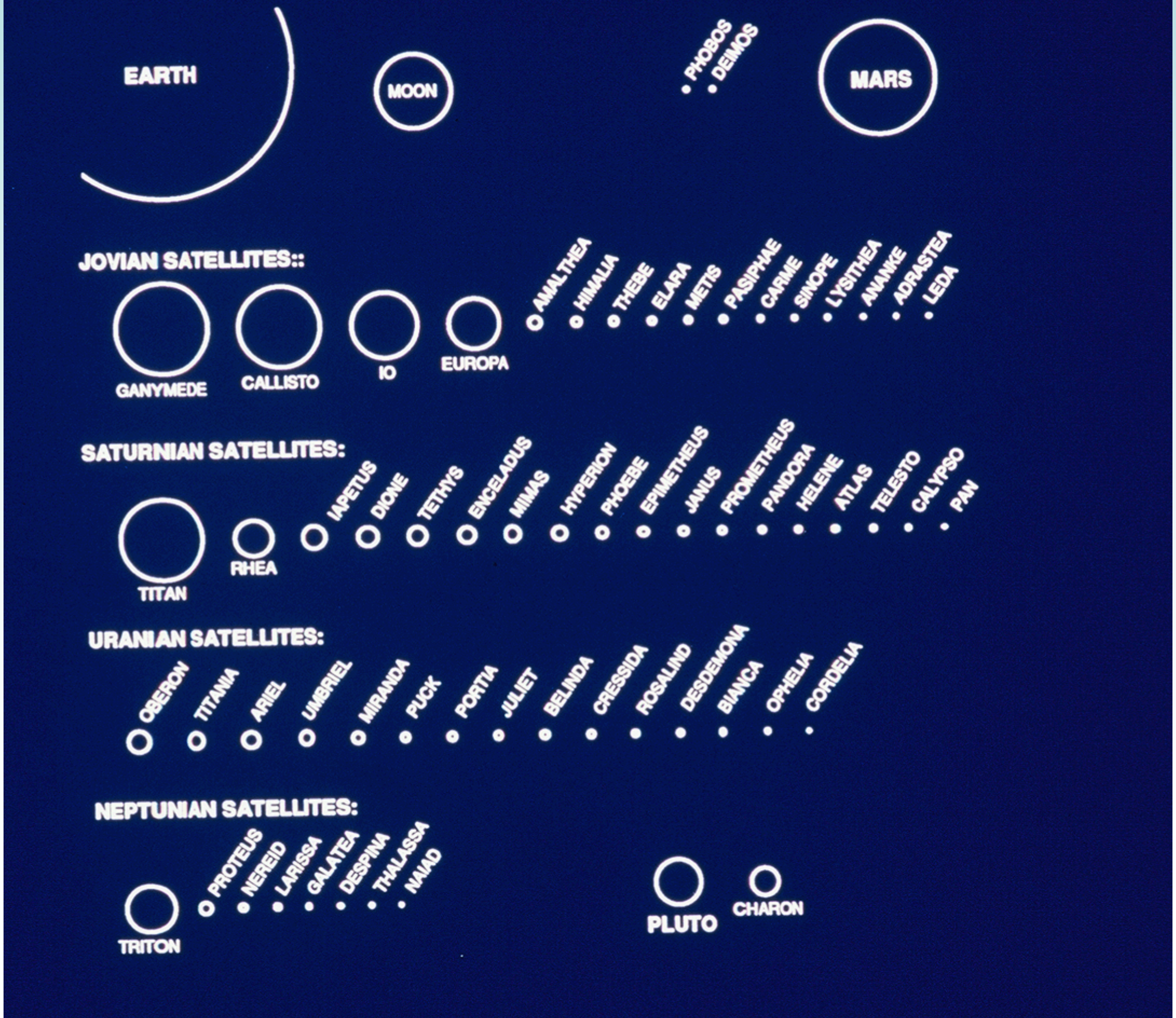
The Iapetus flyby in context

Summary of Flybys

Satellite	Flyby date	Closest approach (km)
Phoebe	2004 June 11	2000
Iapetus 1	2004 Dec 31	124,000
Hyperion	2005 Sept 26	1000
Iapetus 2	2007 Sept 10	1000



A scene on Iapetus, with Cassini observing in the background, created by electronic artist and Cassini Mission Lead Dave Seal


EARTH
MOON
PHOBOS
DEIMOS
MARS
JOVIAN SATELLITES::
GANYMEDE
CALLISTO
IO
EUROPA
AMALTHEA
HIMALIA
THEBE
ELARA
METIS
PASIPHAE
CARME
SINOPE
LYSITHEA
ANANKE
ADRASTEA
LEDA
SATURNIAN SATELLITES:
TITAN
RHEA
IAPETUS
DIONE
TETHYS
ENCELADUS
MIMAS
HYPERION
PHOEBE
EPIMETHEUS
JANUS
PROMETHEUS
PANDORA
HELENE
ATLAS
TELESTO
CALYPSO
PAN
URANIAN SATELLITES:
OBERON
TITANIA
ARIEL
UMBRIEL
MIRANDA
PUCK
PORTIA
JULIET
BELINDA
CRESSIDA
ROSALIND
DESDEMONA
BIANCA
OPHELIA
CORDELIA
NEPTUNIAN SATELLITES:
TRITON
PROTEUS
NEREID
LARISSA
GALATEA
DESPINA
THALASSA
NAIAD
PLUTO
CHARON

Best Voyager images of Iapetus

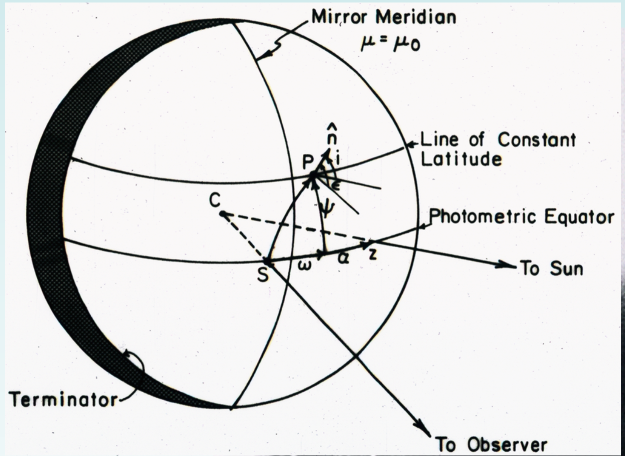
Iapetus has "*a period of apparent Augmentation and Dimunition, by which period it becomes visible in its greatest Occidental digression, and invisible in Its greatest Oriental digression*"

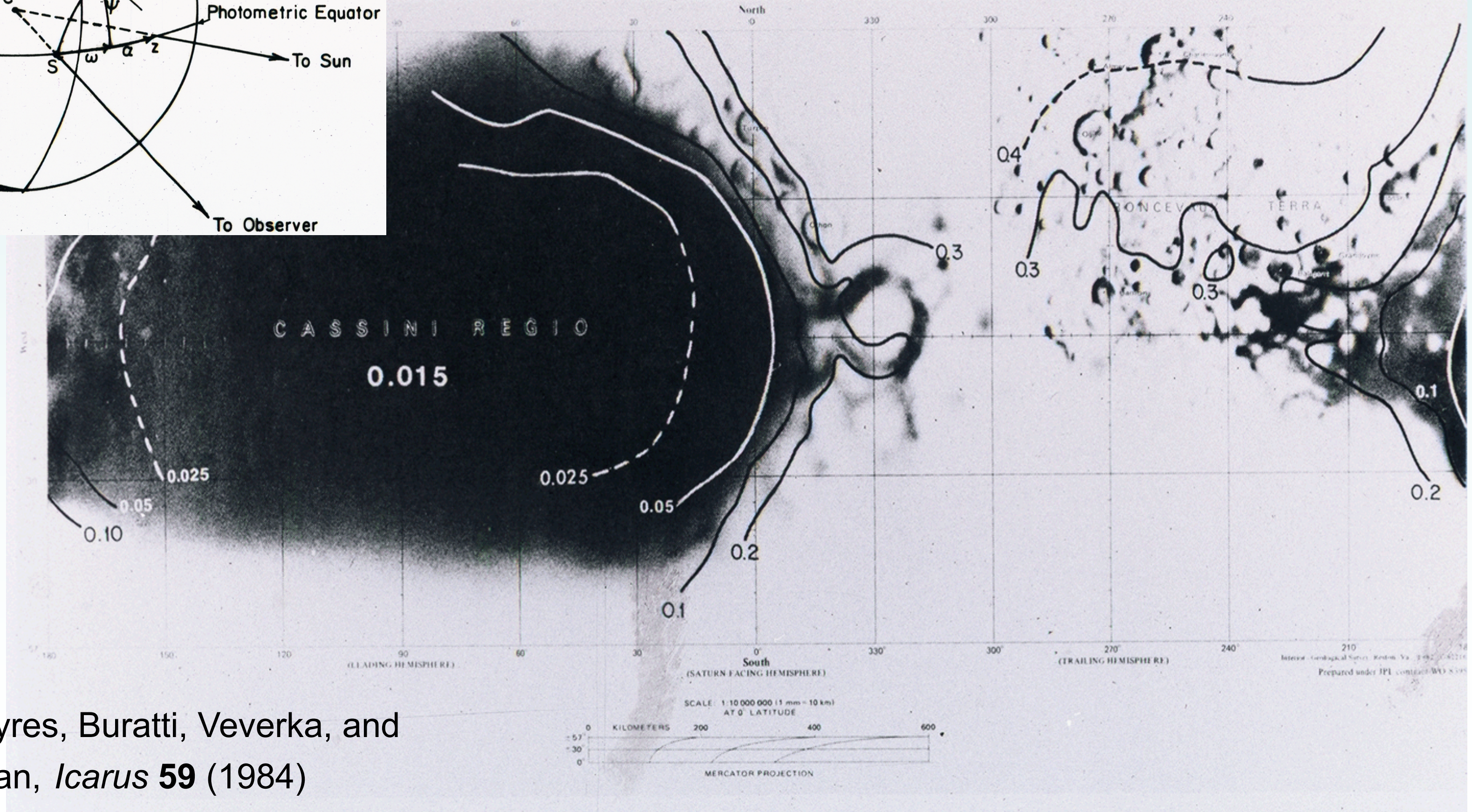
- G.D. Cassini (1671)

Main Models for Albedo Dichotomy

Model	Pros	Cons	Refs
Geologic resurfacing	Infill of dark crater floors; clean edge (?)	Hemispheric pattern	Smith et al. 1982
Accretion from Phoebe	Hemispheric pattern	Color	Soter 1974
As above + volatization	Hemispheric pattern; color?	The math	Cruikshank et al. 1983; Squyres et al., 1984; Bell et al. 1985; Buratti and Mosher, 1995
Accretion from Titan or Hyperion	Pattern and spectra	Low albedo	Matthews 1992; Vilas et al. 1996; Jarvis et al. 2000; Owen et al. 2001
Meteoritic erosion	Hemispheric pattern	Low density (1.2gm/cc)	Cook and Franklin 1970; Wilson and Sagan, 1995, 1996
Accretion of D-type material from outer retrograde satellites	Hemispheric pattern and spectra	Sufficient source; Phoebe not red	Cruikshank et al. 1983; Buratti et al. 2002, 2004; Black et al., 2004 (general exogenic)

Evidence for the exogenic model: if corrections are made to the intensity to account for viewing geometry, we get:

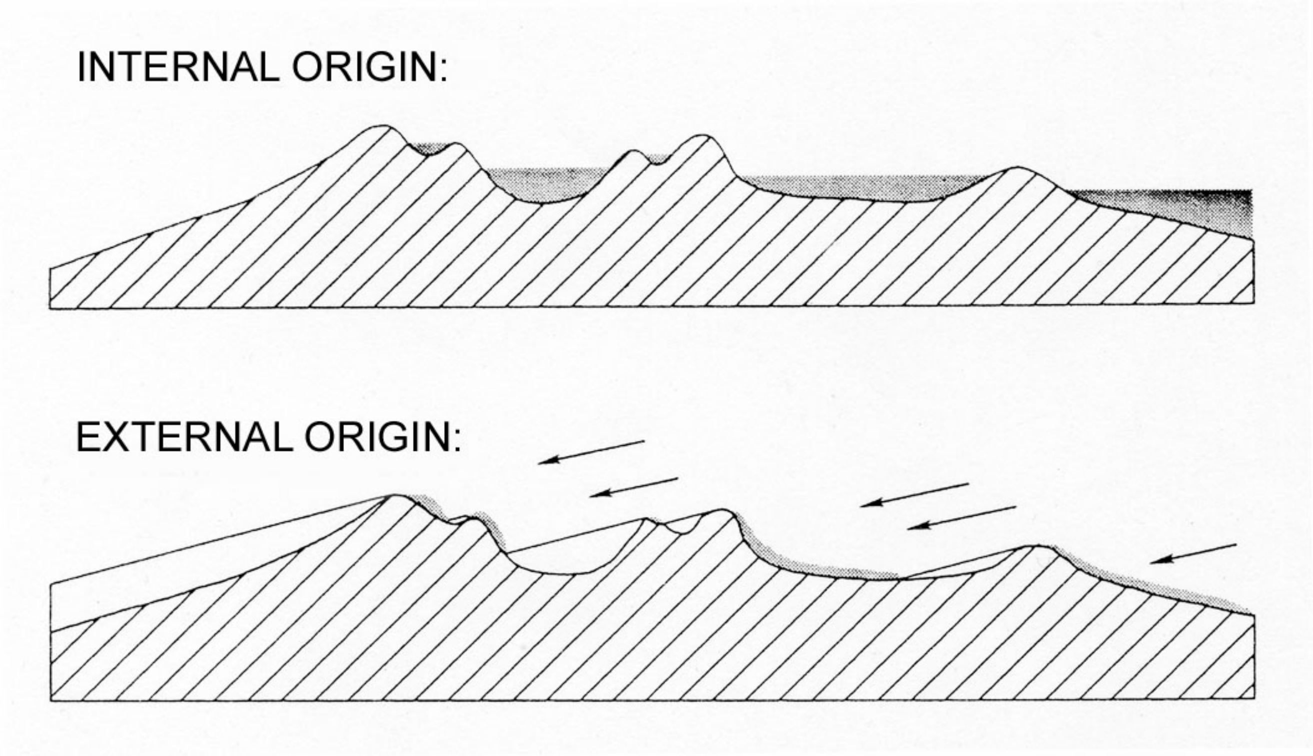




Squyres, Buratti, Veverka, and Sagan, *Icarus* **59** (1984)

FIG. 8. Reflectance contours on Iapetus. Contours give $f(20°)/2$. Slight mismatch between measured position of contours and location of some features on the airbrush map is probably due to the preliminary nature of airbrush map and the lack of a control net at the time of its creation.

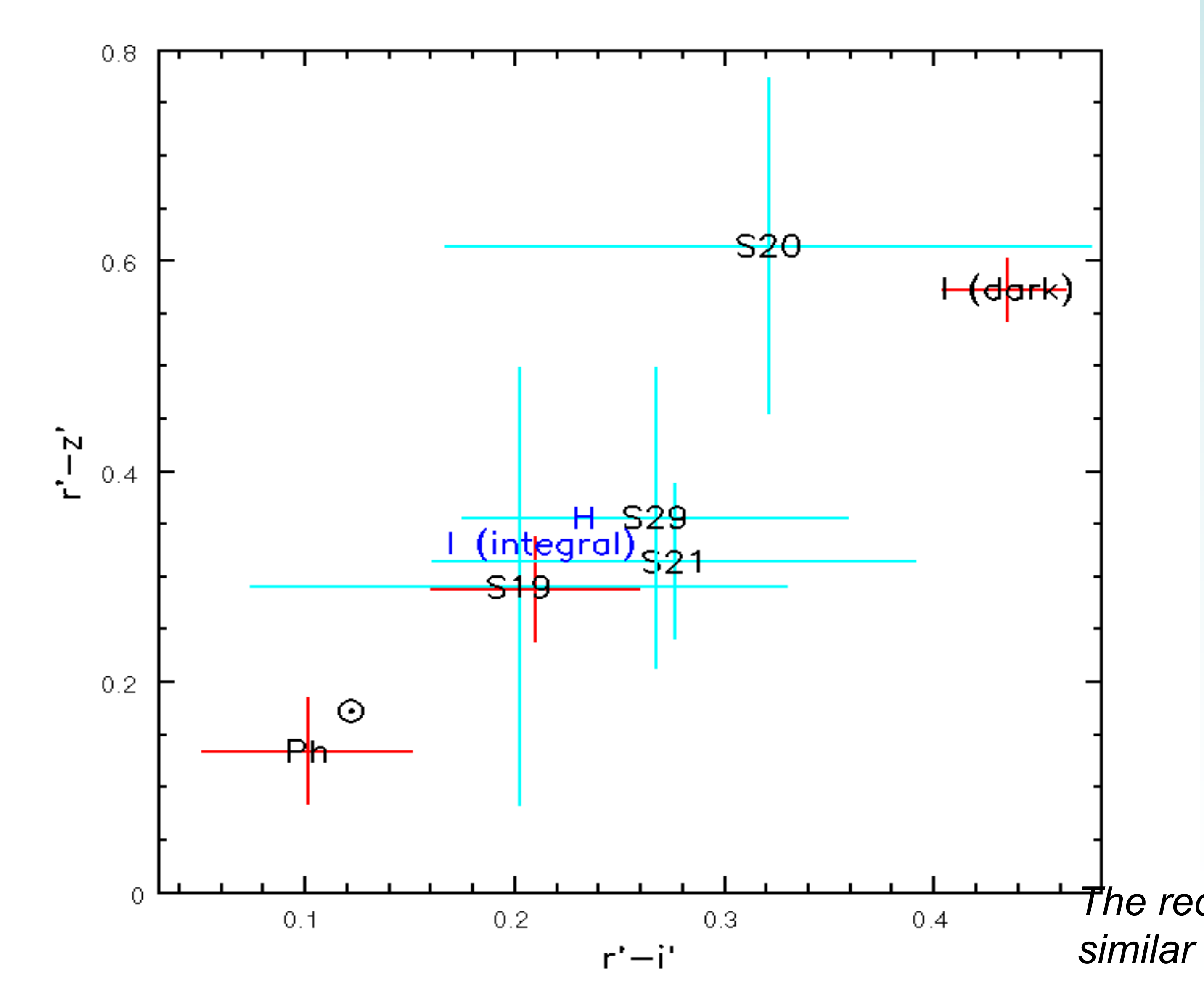
The dark floor craters



Bell et al., 1984, argue that the dark floor craters are not really evidence for the endo-genic model; it depends on the details of how the dark material is distribu-ted on the surface.

But where does the dark material come from?

Color of the small satellites

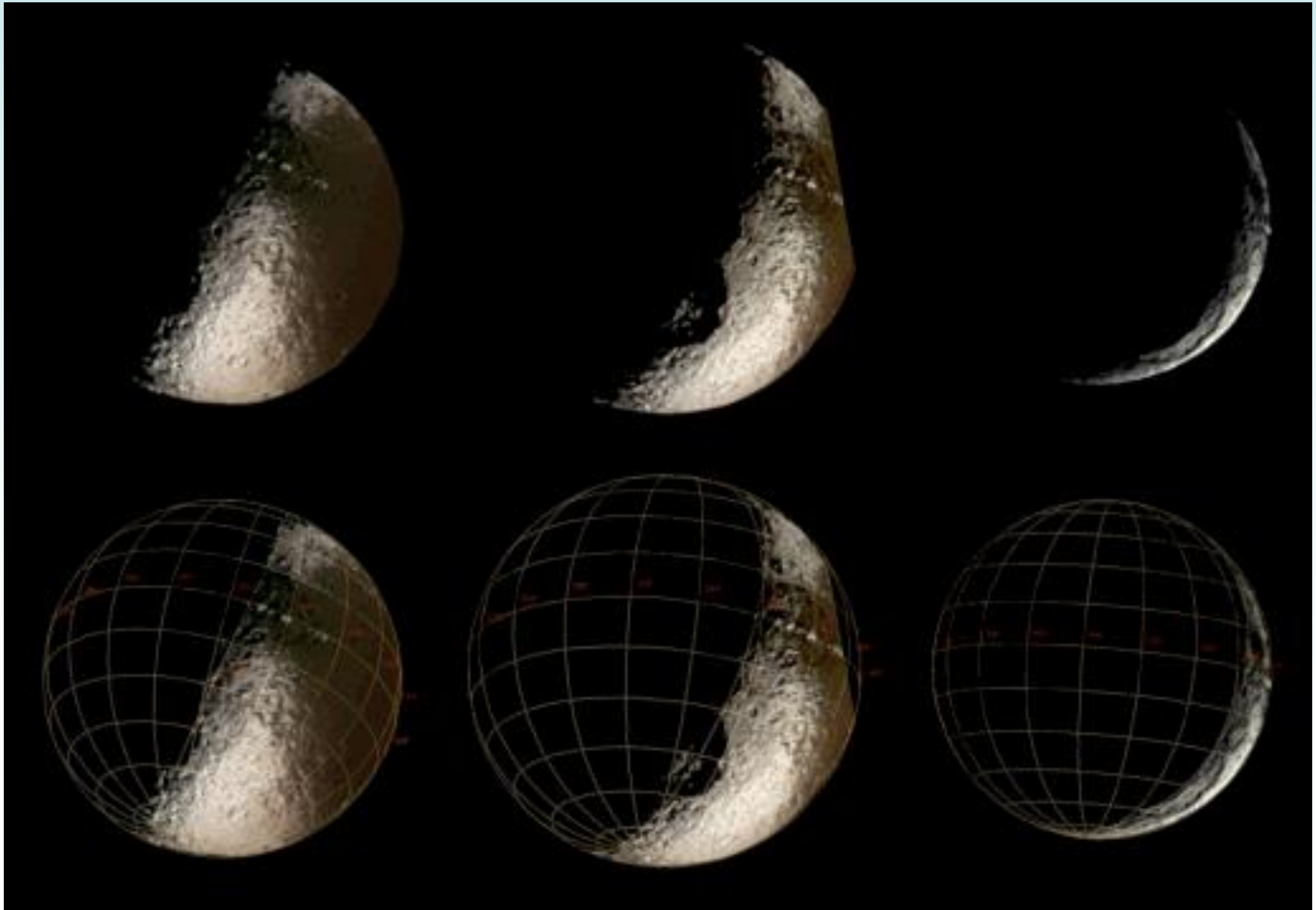


The red color is similar to the dark material on Iapetus

Summary of main questions to be answered by flyby

- **What is the composition of the dark material and how is it related to other dark material in the Saturnian system, comets, asteroids, KBOs, etc.(*VIMS, UVIS, CIRS, ISS*)? Is it prebiotic?**
- **What volatiles are present? (*VIMS, UVIS*)**
- **What is the surface texture of Iapetus as a function of position and depth (*CIRS, RADAR, ISS*)**
- **What geologic processes have led to the current state of Iapetus, and how are geologic forms related to the composition? (*all*)**
- **What are its bulk properties? (*all*)**
- **What is the dust and particle environment like around Iapetus? (*all MAPS*)**

Another Sneak Peak in October



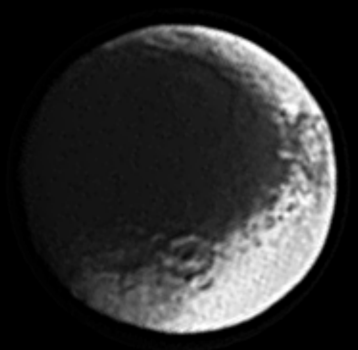
ISS Observations of Iapetus

(B/C Encounter, New-Year‘s Eve 2004/05)

Tilmann Denk

Iapetus Preview Meeting, JPL, Pasadena

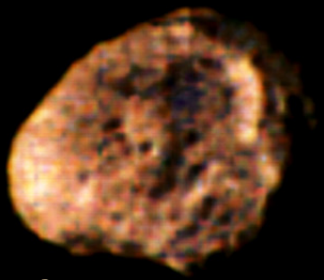
Talk request: ISS_00BIA_TILTALK001_PRIME
Start UTC: 2004-355T16:45 UTC (Dec 20)



Cassini

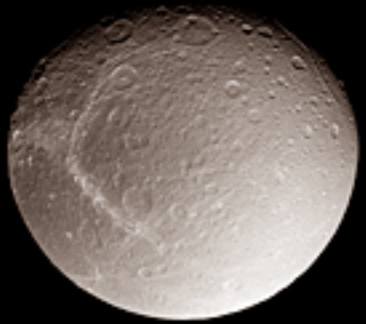
Gezielte Monde-Vorbeiflüge

(...und sehr wichtige ungezielte Vorbeiflüge)

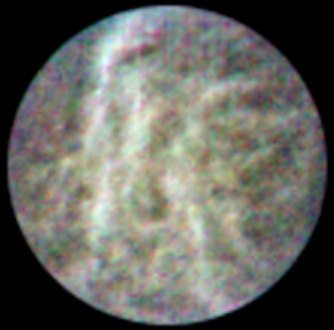


1x Hyperion
(Sep 2005)

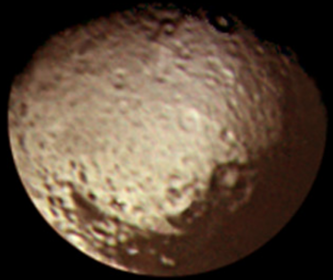
3x Enceladus
(Mrz 2005)
(Jul 2005)
(Mrz 2008)
(Feb 2005)



1x Dione
(Okt 2005)
(Sep 2007)



1x Rhea
(Nov 2005)
(Aug 2007)



1x Iapetus
(Sep 2007)
(Silvesternacht 2004/5)

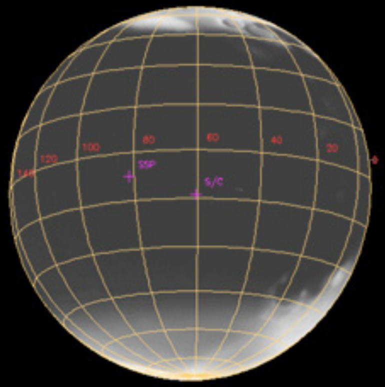
1x Phoebe
(11 Jun 2004)

Iapetus data up to Dec 2004

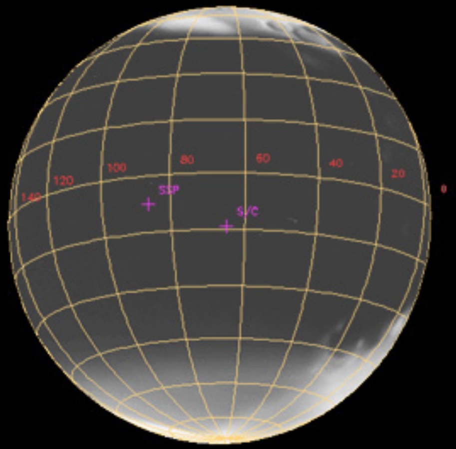
Best Iapetus from Voyager
(northern anti-Saturn side)
(178 pxl diameter, 81° phase)

Best Iapetus's leading side
in July data
(81 pxl diameter, 10° phase / 96 pxl diameter, 54° phase)

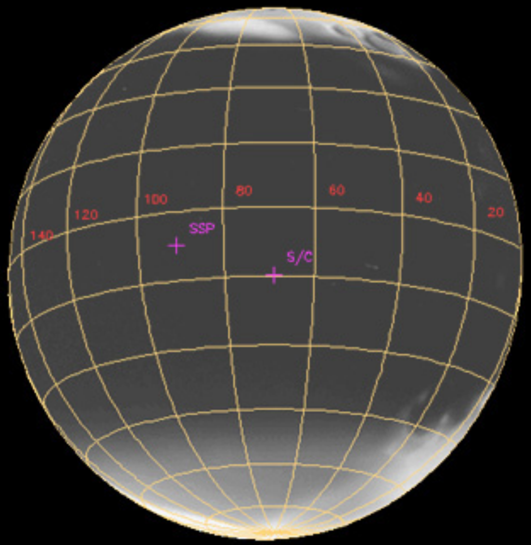
Best Iapetus so far
before X-mas 2004
(215 pxl diameter, 111° phase)



OPNAV DOY 360 opportunity
(220 pxl diameter, 22° phase)



OPNAV DOY 361 opportunity
(258 pxl diameter, 22° phase)



OPNAV DOY 362 opportunity
(313 pxl diameter, 22° phase)

100 pxl

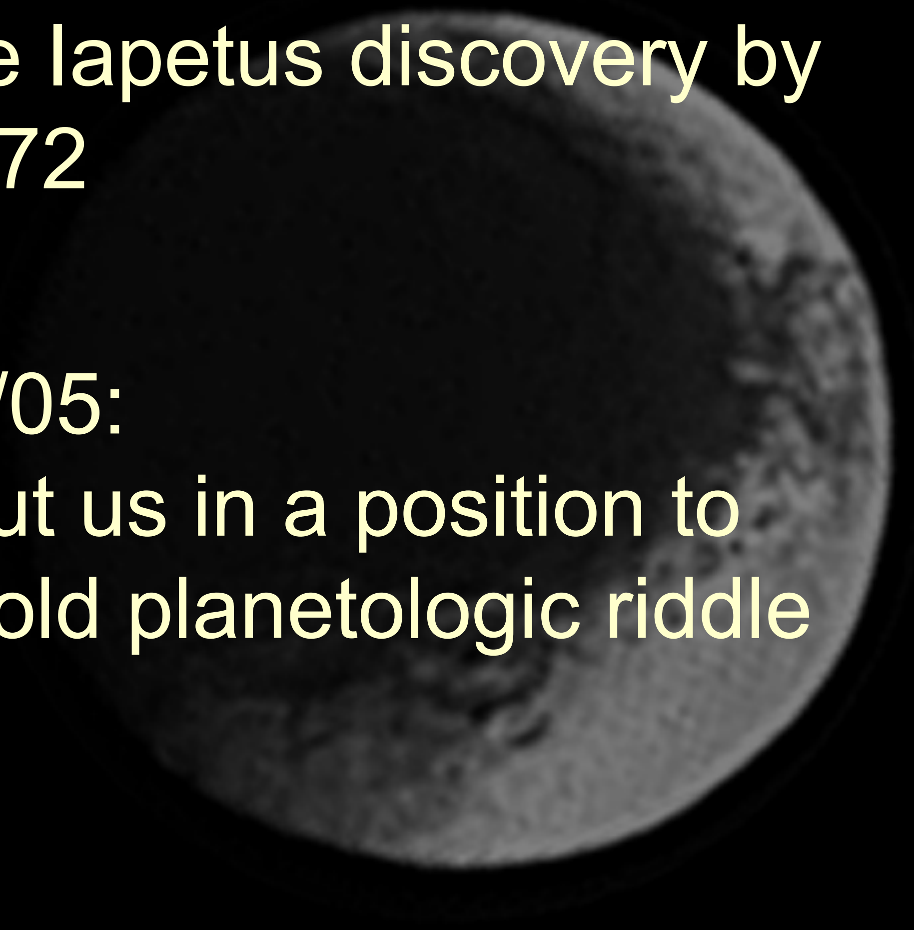
ISS Scientific Goals (2)

- Endogenic processes on the surface??
- Large impact structures
- Mapping of color units (0.25 to 1.0 µm); search for small-scale color variations
- Comparison to other satellites (esp. crater distribution, color, crater morphology)
- Geologic history of Iapetus, in particular origin of hemispheric dark/bright dichotomy

Global albedo dichotomy

- Problem known since Iapetus discovery by J.D. Cassini in 1671/72

- S.C. Cassini in 2004/05:
  B/C data set *might* put us in a position to solve this 333 years old planetologic riddle eventually

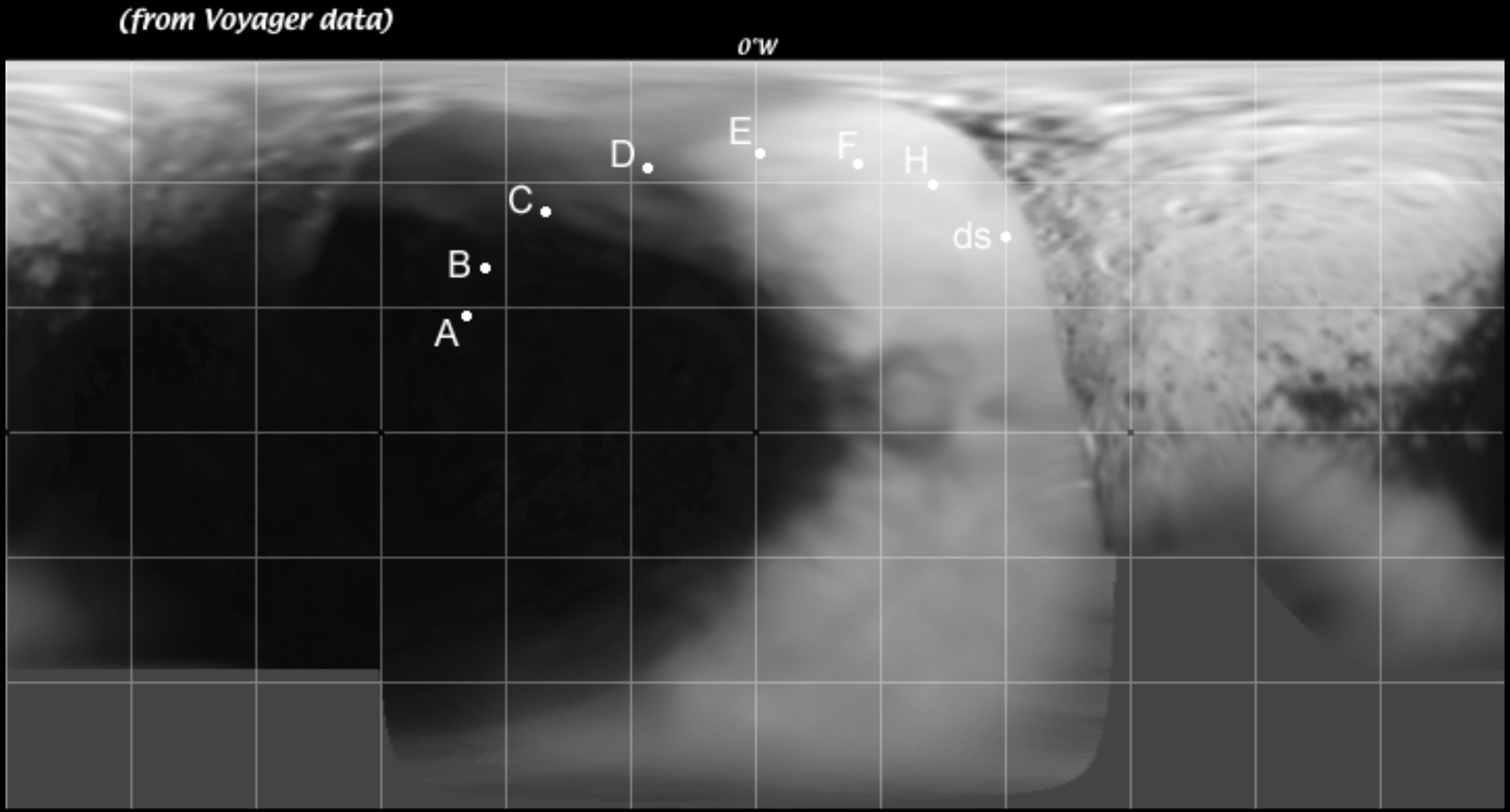


ISS Iapetus B/C Observations Overview (1)

- Flyby near apoapse rev 00B → 00C
  => very slow flyby (Iapetus passes the S/C)
  => hours & hours of observation time

- *Changed reference trajectory:*
  Flyby now at ≥117,500 km altitude
  over northern „Voyager“ terrain
  => best ISS resolution: 705 m/pxl
  => ~10x better than October data

Sub-S/C location map



ISS Iapetus B/C Observations Overview (4)

Mapping

- All 8 prime requests contain full-disk clear-filter imaging
- 2 shutters per footprint (in most cases):
  1 long exp. time for dark material,
  1 short shutter for bright surface
- Robustness against pointing uncertainties
- WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS Iapetus B/C Observations Overview (6)

Graylight Imaging

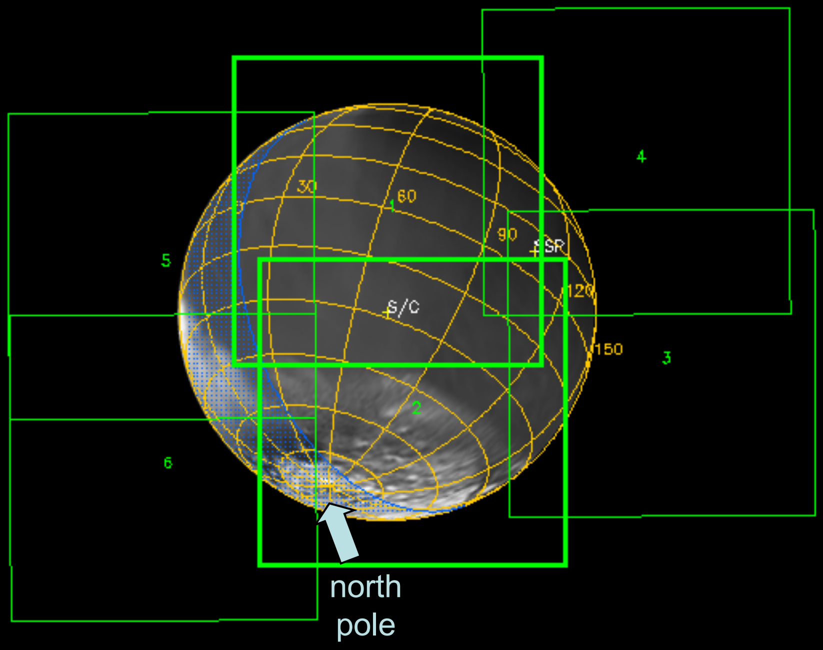
- Observations of bright terrain in „Saturn shine“ (requests LIMBTOPOD and later)
- Rationale: Some regions near „moat feature“ will never be nicely visible during 4-year tour => B/C graylight obs. >5x higher resolution
- Full-resolution and summation mode (2sum) imaging; clear filter; most exposure times 46s, 82s, or 180s

ISS Iapetus B/C Observations Overview (7)

Dust Search

- Experimental observations of Iapetus environment at high phase
- Phase = 140° (was >165° in old ref. traj.)
- Summation mode (4sum) shutters in clear and polarizer filters

ISS_00BIA_GLOBCOLA001_PRIME
(2004-366T01:53 UTC; 00:42 hrs)



Trigger #	2157
Telemetry Rate	S&ER5a (40)
number footprints	6
number of images	**61**
total Data Volume (predict)	282 Mb

2x3 clr (1x2 color) mosaic

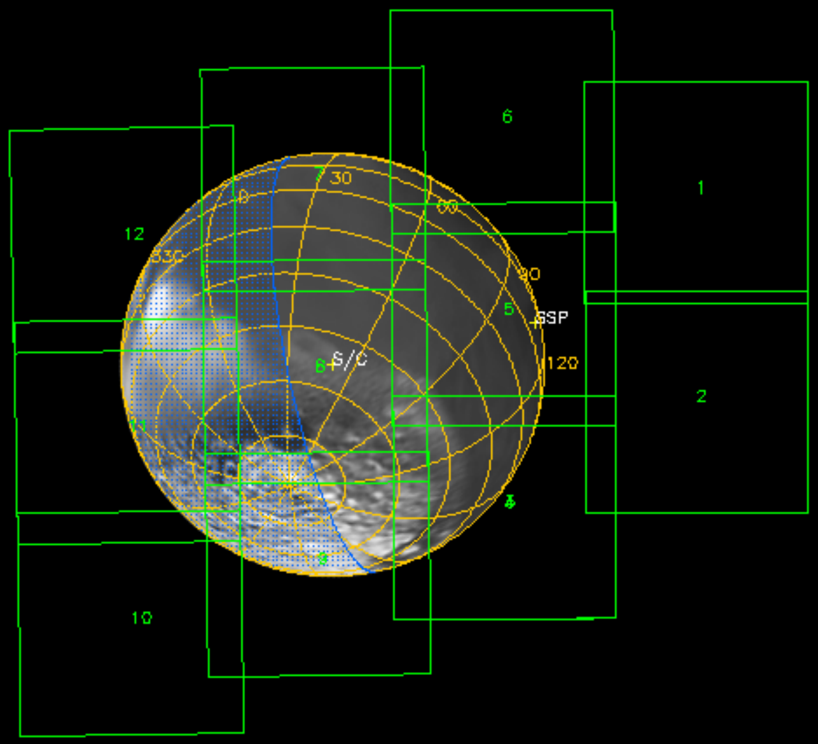
170000 km alt.; **1.0 km/pxl** (NAC 1sum);
d_IA=1410 pxl; 50 deg phase;
sub-S/C lat/lon = +29/70;
sun illuminates surface from left

Clear filters: 2 NAC shutters per footprint:
180 ms (bright) and 1.2 sec (dark terrain)

1x2 multi-color mosaic with substantial overlap:
Southern footprint (ftprt 1): 12 col, 3 pol NACs;
shutter times "optimized" for dark terrain.
Northern footprint (ftprt 2): 20 col, 6 pol NACs;
shutter times "optimized" for bright terrain;
4 WAC IR polarizers.

WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS_00CIA_GLOBMAPC001_PRIME
(2004-366T14:00 UTC; 00:30 hrs)



Trigger #	2159
Telemetry Rate	S&ER3 (24)
number footprints	11
number of images	**24**
total Data Volume (predict)	97 Mb

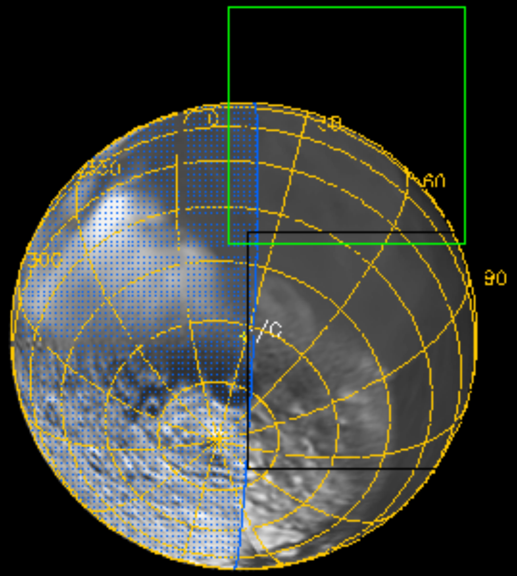
2+3x3 NAC clr mosaic

122500 km alt.; **740 m/pxl;**
d_IA=1950 pxl; 78 deg phase;
sub-S/C lat/lon = +54/50;
sun illuminates surface from left

2 NAC shutters per footprint (except #1 and2):
220 ms (bright) and 1.5 sec (dark terrain)

WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS_00CIA_COMPD001_VIMS
(2004-366T19:00 UTC; 02:00 hrs)



Trigger #	2998
Telemetry Rate	S&ER3 (24)
number footprints	1
number of images	**13**
total Data Volume (predict)	76 Mb

1x1 NAC color mosaic

117500 km alt.; **705 m/pxl;**
d_IA=2050 pxl; 94 deg phase;
sub-S/C lat/lon = +64/24;
sun illuminates surface from left

10 NAC color frames + 3 polarizers

Center of ftprt over dark terrain
==> long exp times selected

Highest resolution color of BC flyby

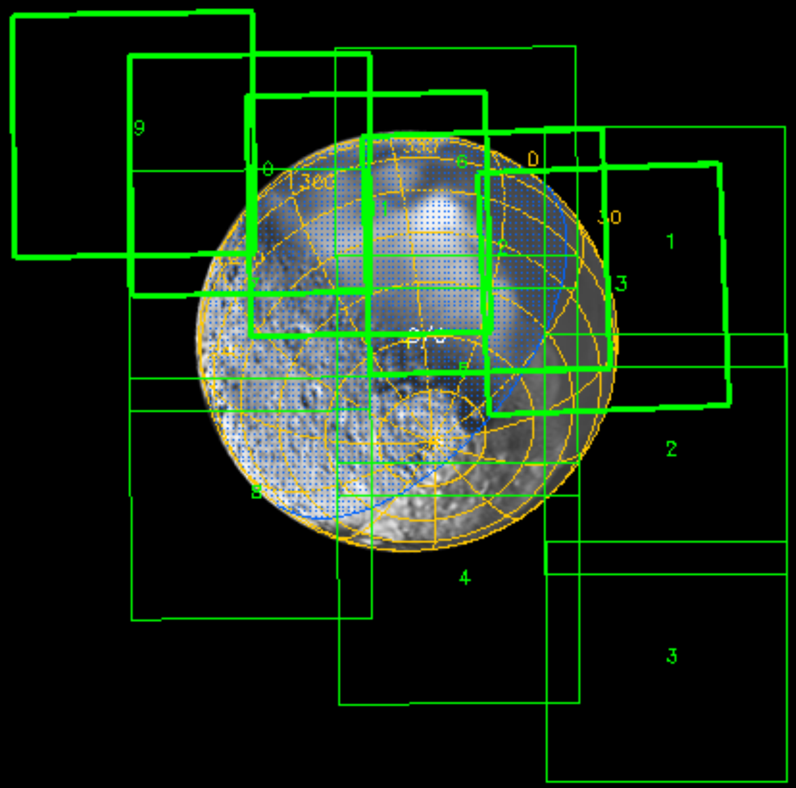
ISS_00CIA_COMPE001_VIMS
(2004-366T22:30 UTC; 02:00 hrs)

Trigger #	2162
Telemetry Rate	S&ER3 (24)
number footprints	1
number of images	**4**
total Data Volume (predict)	14 Mb

1x1 WAC color context

WAC 4-color context for LIMBTOPOE
(Vio, Grn, Ir1, Ir3; **7.2 km/pxl**).
Sun illuminates surface from left.

ISS_00CIA_GRAYLITEH001_PRIME
(2005-001T04:00 UTC; 01:00 hrs)



Trigger #	2165
Telemetry Rate	S&ER3 (24)
number footprints	13
number of images	**34**
total Data Volume (predict)	123 Mb

3+3+2 NAC clr mosaic

136000 km alt.; **820 m/pxl** (NAC 1sum);
d_IA=1760 pxl; 123 deg phase;
sub-S/C lat/lon = +60/319;
sun illuminates surface from left (Saturn also)

2 NAC shutters per footprint:
320 ms (bright) and 2.0 sec (dark terrain)

1x4 NAC mosaic for graylight imaging
(4 shutters/ftprt; 1sum and 2sum)

WAC 4-color context (Vio, Grn, Ir1, Ir3)

More Iapetus in Nominal Tour

Planned Cassini flybys at Iapetus (selection)*

Date	min. altitude	best ISS pixel scale	visible hemisphere**
Jul 2004	2,500,000 km	15 km/pxl	CR, southern bright terrain, SP
Oct 2004	1,110,000 km	6.7 km/pxl	anti-Saturn side (western CR), SP
31Dec04/ 01Jan05	117,500 km	710 m/pxl	northern CR, high northern latitudes
Nov 2005	416,000 km	2.5 km/pxl	eastern and central CR, north. bright terrain
Jan 2006	879,000 km	5.3 km/pxl	eastern CR and trans. zone, "moat" partially
Apr 2006	603,000 km	3.6 km/pxl	leading side, SP
Sep 2007	~1,270 km#	~12 m/pxl	CR (high phase), trailing side (low phase)

*...Included are all flybys in 2004 and all flybys below 10^6 km altitude until June 2008.

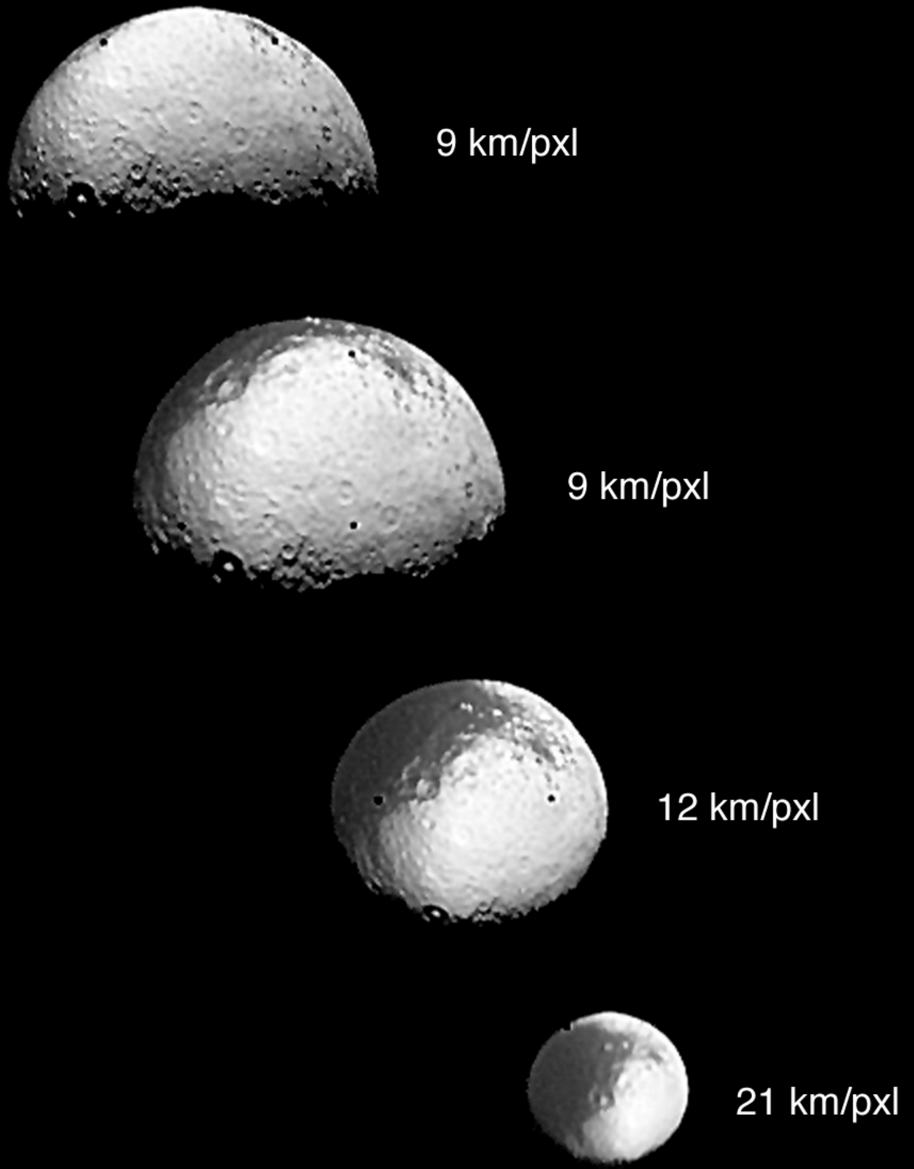
**...CR = Cassini Regio (dark material hemisphere); SP = south pole.

#...10 Sep 2007: targeted flyby altitude not fixed yet; might be between ~1000 and ~1400 km.

Content

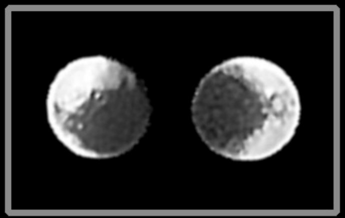
- Context to other satellite flybys
- Context to previous imaging data (Voyager, Cassini)
- ISS scientific goals
- ISS Iapetus B/C observations overview
- Detailed mosaic designs
- More Iapetus in nominal tour
- Summary

Voyager Iapetus



ø ≈ 1500 km

100 pxl



ISS Scientific Goals (1)

- Global properties: Size, shape, density
- Characterization of surface morphology:
  - Surface features in general (basins, craters, scarps, mountains(?), what else?)
  - Regional topography
  - Stratigraphy (terrain relative ages)
  - Nature of dark terrain (blanket thickness, material behavior at slopes, search for holes in blanket, craters, ages, ...)

About the Albedo-Dichotomy Origin

(table taken from my DPS 2004 talk)

Possible classification of Iapetus global albedo dichotomy origin hypotheses:

1. Exogenic origin/ dust is coming in over long time

(a) Dark grayish dust from Phoebe hits Iapetus's leading side and gets chemically altered/ reddened (Soter 1974, Burns *et al.* 1979, 1996; Hamilton 1997)

(b) Dark reddish dust from smaller retrograde outer saturnian satellites covers Iapetus's leading side (Buratti et al. 2002)

2. Asymmetric exogenic influence removes thin ice veneer from leading side, but not from trailing side and poles

(a) Viewpoint of orbit mechanics:

(a1) Circumsaturnian dust is the cause (from Phoebe or other outer Saturnian satellites) (Cruikshank *et al.* 1983; Bell *et al.* 1985; Buratti and Mosher 1995)

(a2) Interplanetary micrometeoroid flux is the cause (Cook and Franklin 1970; Squyres and Sagan 1983; Wilson and Sagan 1996)

(b) Viewpoint of physical processes on the surface:

(b1) Exposing of the dark subsurface layer by bright material erosion (Cook and Franklin 1970; Wilson and Sagan 1996)

(b2) enrichment of formerly intimately mixed dark material due to sublimation of the bright ice component (Cruikshank *et al.* 1983; Bell *et al.* 1985; Buratti and Mosher 1995)

(b3) synthesis of the dark material by chemical/irradiation processes made possible by bright icy material erosion (Squyres and Sagan 1983)

3. Exogenic origin/ dust and debris originates from a major single event

(a) from collision with reddish Hyperion (Matthews 1992, Marchi *et al.* 2002)

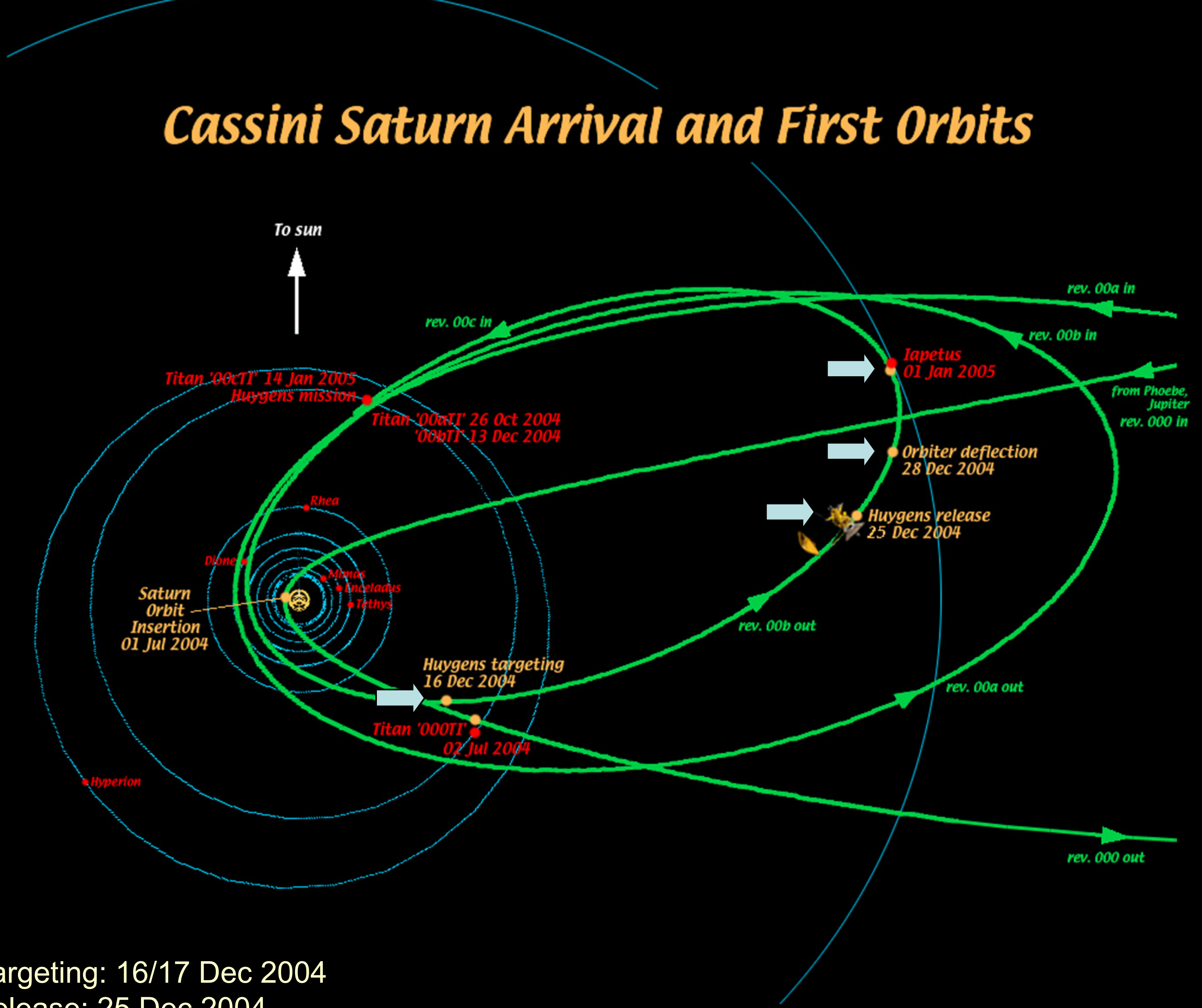
(b) from collision with Iapetus itself (Tabak and Young 1989)

(c) from collision of an outer saturnian satellite with a heliocentric object with the result of a retrograde debris cloud crossing Iapetus's orbit (Denk and Neukum 2000)

(d) material comes from Titan (Owen *et al.* 2001)

4. Endogenic origin: Dark material from interior (Smith *et al.* 1981, 1982)

Cassini Saturn Arrival and First Orbits



Huygens targeting: 16/17 Dec 2004
Huygens release: 25 Dec 2004
Cassini deflection: 28 Dec 2004
MIA uplink: 29 Dec 2004
Iapetus observations: 31 Dec 04 – 02 Jan 05

ISS Iapetus B/C Observations Overview (2)

- Naming convention:
  - GLOBCOL = global color
  - GLOBMAP = global mapping
  - LIMBTOPO = limb topography
  - GRAYLITE = Saturn-shine imaging
  - DUSTSEAR = Iapetus environment imaging
- A, B, C, D, E, F, H ... time order
- However: New reference tour made these discriminations somewhat obsolete

ISS Iapetus B/C Observations Overview (3)

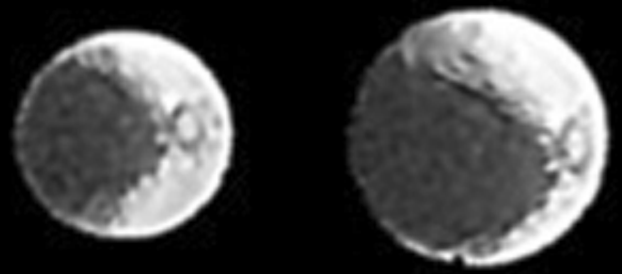
- ISS spatial resolution:
  1.0 km/pxl @ 50° phase (2004 Dec 31 02:00 UTC)
  710 m/pxl @ 93° phase (2004 Dec 31 19:00 UTC)
  1.1 km/pxl @ 140° phase (2005 Jan 1 14:00 UTC)
- ISS: 8 full-disk mosaics, 5 NAC-color ftprts., 288 frames total
- Iapetus size @ C/A: >2000 NAC pxl

ISS Iapetus B/C Observations Overview (5)

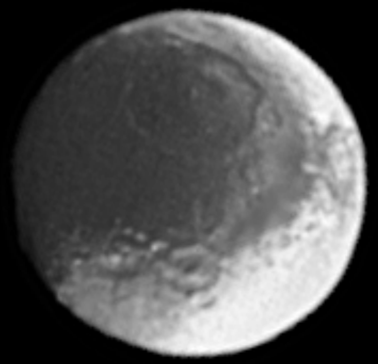
Color

- GLOBCOLA: 1x2 multi-color/polarizers mos.
  - southern ftprt. dark-material optimized
  - northern ftprt. bright-material optimized
- COMPD_VIMS: 1x1 10-color, 3-pol mosaic over dark hemisphere; 705 m/pxl
- LIMBTOPOD, GLOBMAPF:
  - 4-color shutters (2sum; Uv3, Grn, Ir1, Ir3)
  - Were added very late to cover trailing side

Saturn-facing Hemisphere



Voyager 1 data (1980)



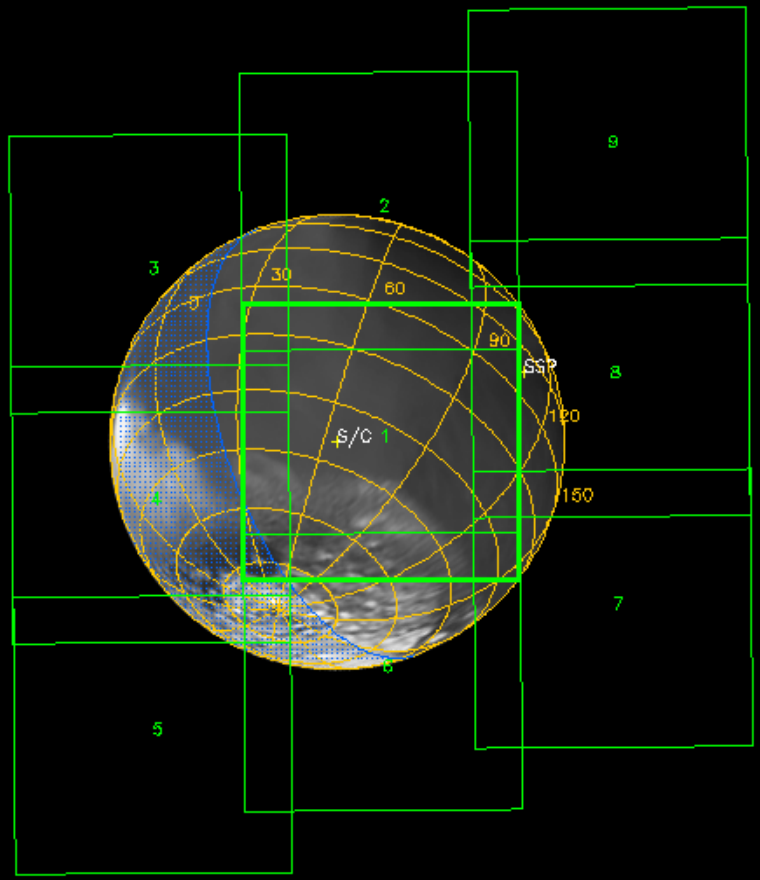
Cassini observations
(July 2004)

Cassini in October 2004
in “Saturn shine”
9.3 km/pxl; 44° “phase”;
sub-S/C lat/lon = 0°/316°

Content

- Context to other satellite flybys
- Context to previous imaging data (Voyager, Cassini)
- ISS scientific goals
- ISS Iapetus B/C observations overview
- Detailed mosaic designs
- More Iapetus in nominal tour
- Summary

ISS_00CIA_LIMBTOPOB001_PRIME
(2004-366T08:00 UTC; 00:30 hrs)



Trigger #	2158
Telemetry Rate	S&ER3 (24)
number footprints	9
number of images	**22**
total Data Volume (predict)	93 Mb

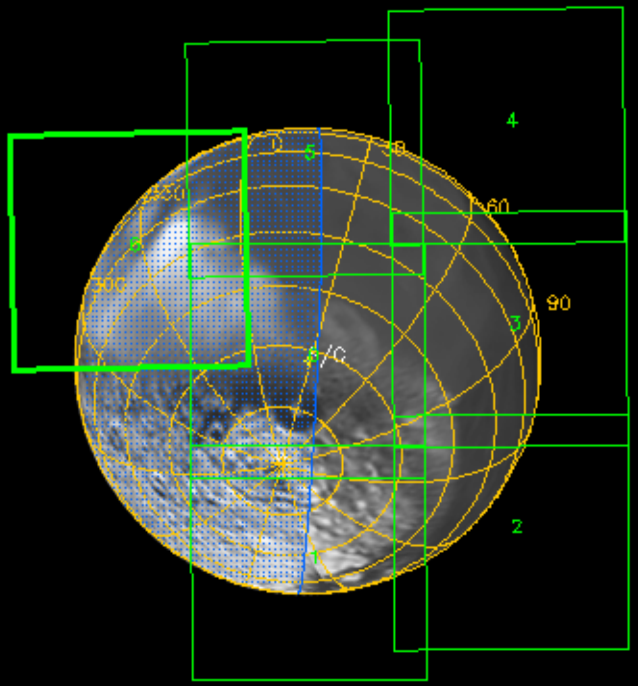
3x3 NAC clr mosaic

142000 km alt.; **850 m/pxl;**
d_IA=1690 pxl; 62 deg phase;
sub-S/C lat/lon = +40/64;
sun illuminates surface from left

2 NAC shutters per footprint:
220 ms (bright) and 1.2 sec (dark terrain)

WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS_00CIA_LIMBTOPOD001_PRIME
(2004-366T18:30 UTC; 00:30 hrs)



Trigger #	2160
Telemetry Rate	S&ER3 (24)
number footprints	7
number of images	**26**
total Data Volume (predict)	92 Mb

2x3 NAC clr mosaic

117500 km alt.; **710 m/pxl** (NAC 1sum);
d_IA=2040 pxl; 93 deg phase;
sub-S/C lat/lon = +63/27;
sun illuminates surface from left

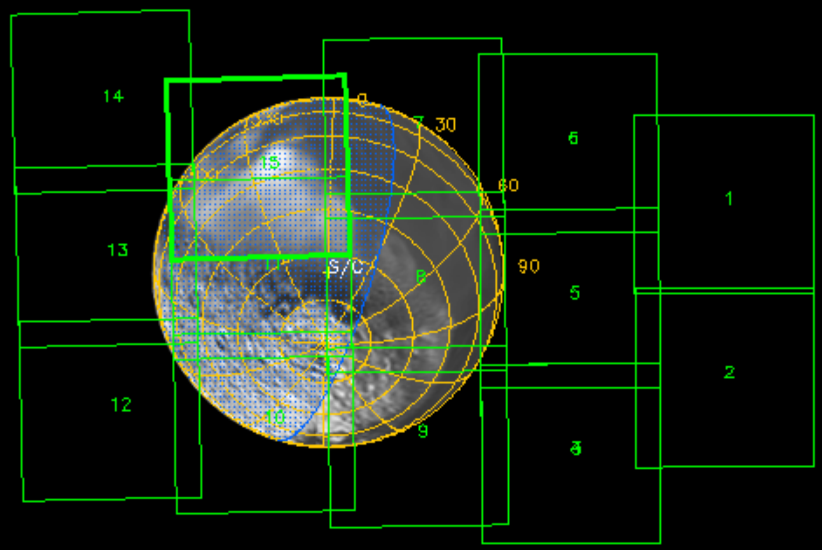
2 NAC shutters per footprint:
260 ms (bright) and 1.5 sec (dark terrain)

Ftprt 1: 4-color NAC 2sum (getting mini-piece of trailing side)

Last ftprt: graylight imaging
(6 long exp NAC; 1sum and 2sum)

WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS_00CIA_LIMBTOPOE001_PRIME
(2004-366T22:00 UTC; 00:30 hrs)



Trigger #	2161
Telemetry Rate	S&ER3 (24)
number footprints	14
number of images	**26**
total Data Volume (predict)	100 Mb

Approx. 2+3x4 clr mosaic

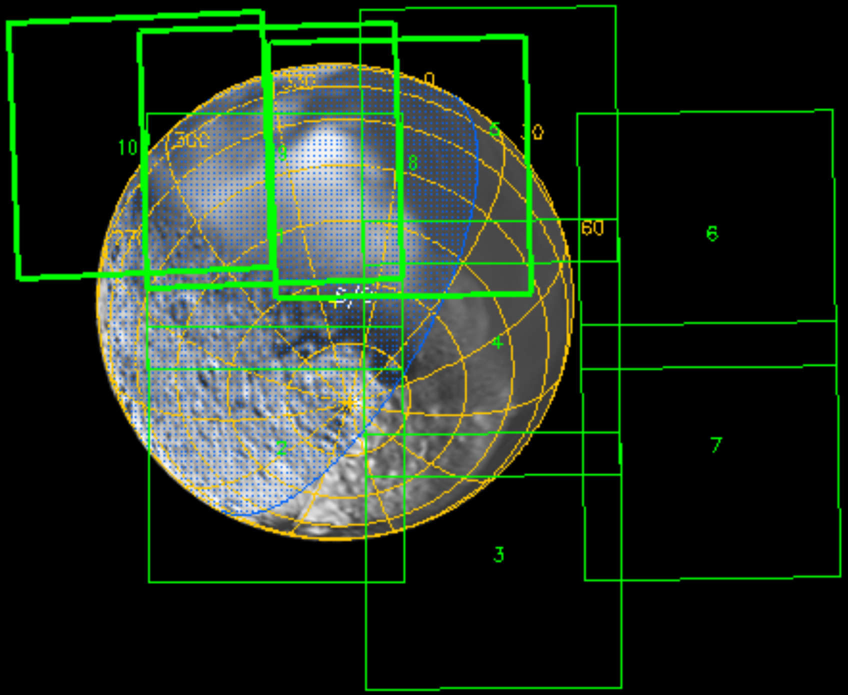
120000 km alt.; **720 m/pxl** (NAC 1sum);
d_IA=1990 pxl; 105 deg phase;
sub-S/C lat/lon = +66/359;
sun illuminates surface from left

2 NAC shutters per footprint (except #1, 2, 13, 14):
260 ms (bright) and 1.8 sec (dark terrain)

Last ftprt: Includes graylight imaging
(2 long exp NAC; 1sum and 2sum)

WAC context is in VIMS_COMPE

ISS_00CIA_GLOBMAPF001_PRIME
(2005-001T01:00 UTC; 01:00 hrs)




```
Trigger #                              2163
Telemetry Rate                         S&ER3 (24)
number footprints                      10
number of images                       41
total Data Volume (predict)            149 Mb
```

2+3+2 NAC clr mosaic

126000 km alt.; **760 m/pxl** (NAC 1sum);
d_IA=1900 pxl; 115 deg phase;
sub-S/C lat/lon = +64/335;
sun illuminates surface from left

2 NAC shutters per footprint:
320 ms (bright) and 1.8 sec (dark terrain)

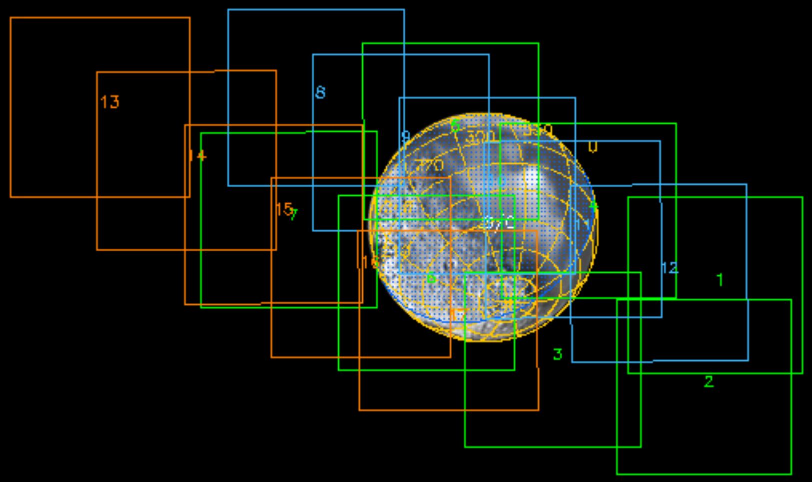
Ftprt #2: 4-color NAC 2sum (get small piece of trailing side)

1x3 NAC mosaic for graylight imaging
(6, 7, 6 long exp/ftprt; 1sum and 2sum)

WAC 4-color context (Vio, Grn, Ir1, Ir3)

ISS_00CIA_DUSTSEAR001_PRIME
(2005-001T13:30 UTC; 01:00 hrs)

"crescent" part
"graylight" part
"dust-search" part



Trigger #	2166
Telemetry Rate	S&ER5a (40)
number footprints	17
number of images	**37**
total Data Volume (predict)	81 Mb

176000 km alt.; **1.06 km/pxl** (NAC 1sum);
d_IA=1355 pxl; 140 deg phase;
sub-S/C lat/lon = +47/300;
sun illuminates surface from left

Crescent imaging: 7 NAC-frames clr mosaic (most 1sum)
2 NAC shutters per footprint:
380 ms (bright) and 2.0 sec (dark terrain)

Graylight: 1x5 NAC clr mosaic (1sum and 2sum)
3 NAC clr shutters per footprint

Dust search: 1x5 NAC mosaic (4sum)
1 clr plus 1 P0/clr shutter/ftprt

Summary

- 2nd best Iapetus of tour
- 10x higher resolution than all previous data
- 8 full-disk mosaics, 288 frames total
- ISS NAC pixel size up to 710 m/pxl;
  Iapetus size up to >2000 NAC pxl
- Solution of the dark/bright dichotomy riddle??
  (This option makes the B/C data set quite unique!)
- Help finding out best observation strategy for
  Sep 2007 targeted flyby (another 100x closer)

- Many thanks to all involved people who made
  these observations possible

Cassini

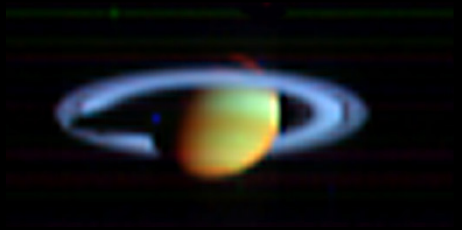
VIMS

S07 Iapetus

Cassini

VIMS

S07 Iapetus



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 Iapetus Science

Identification of minerals and other materials on the surface of Iapetus.

Mapping the abundance, and grain sizes of surficial materials.

Grain-Size Mapping

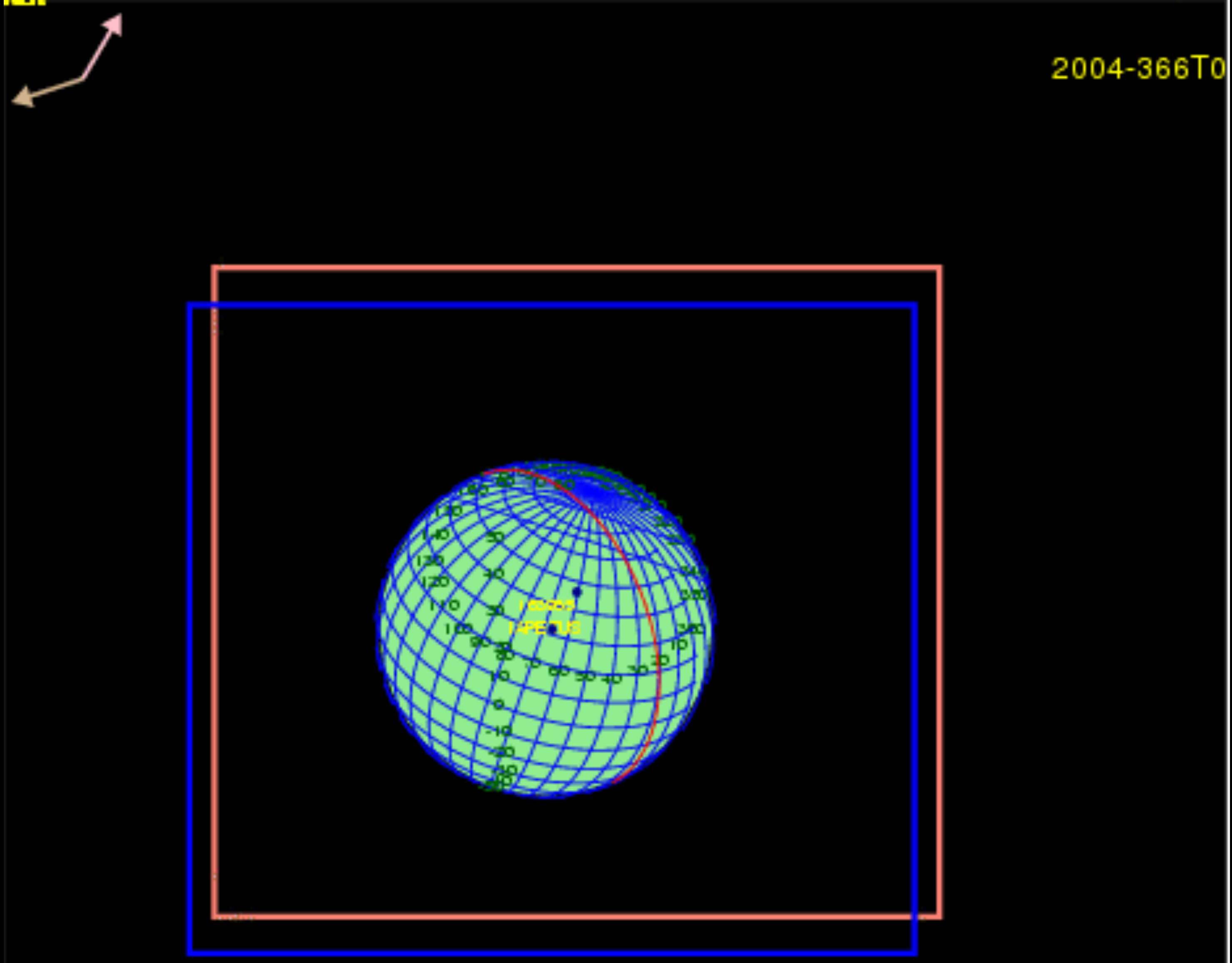
Reflectance from 0.35 to 5.2 microns

Phase function

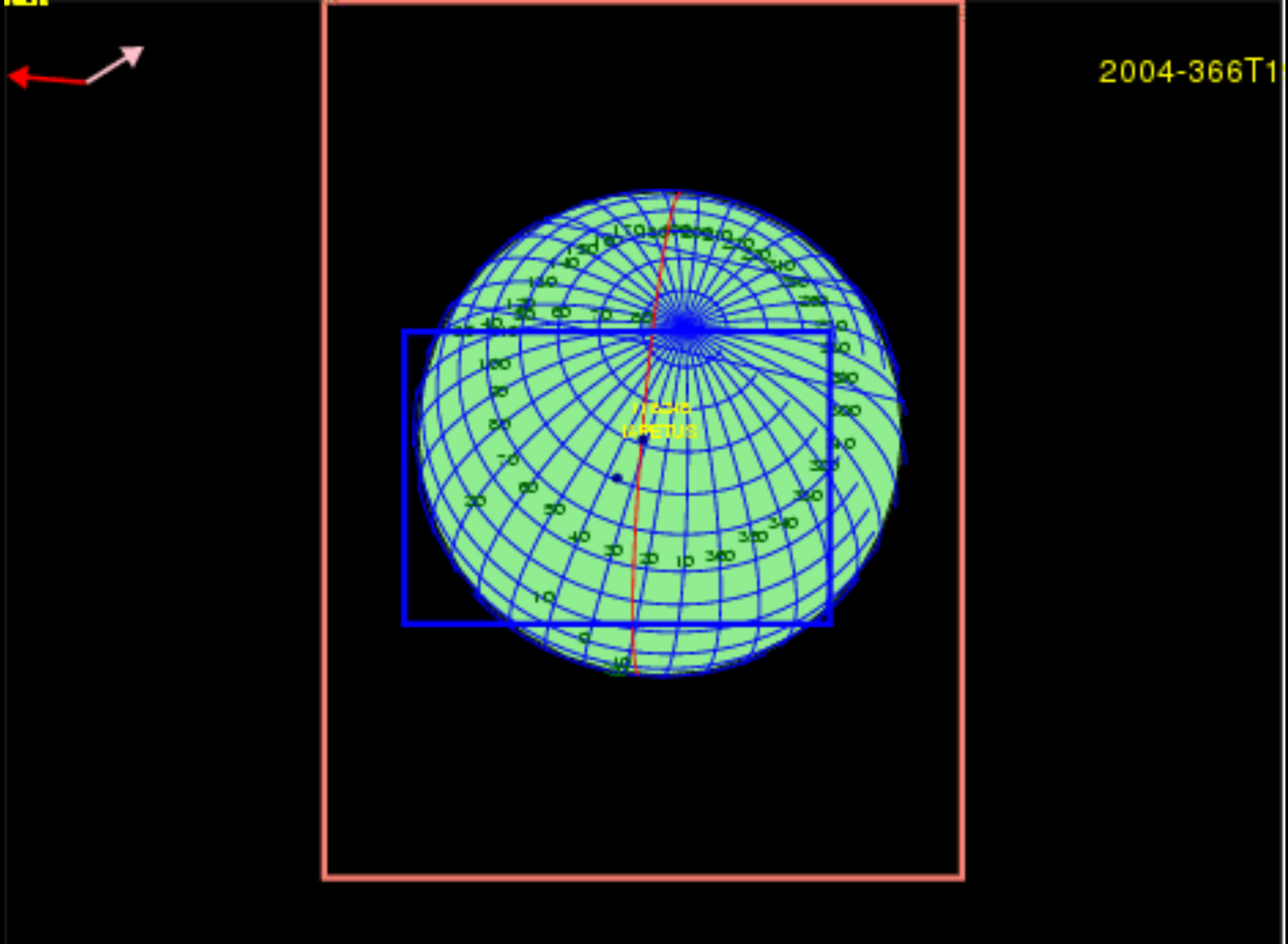
surface microstructure

Bond albedo

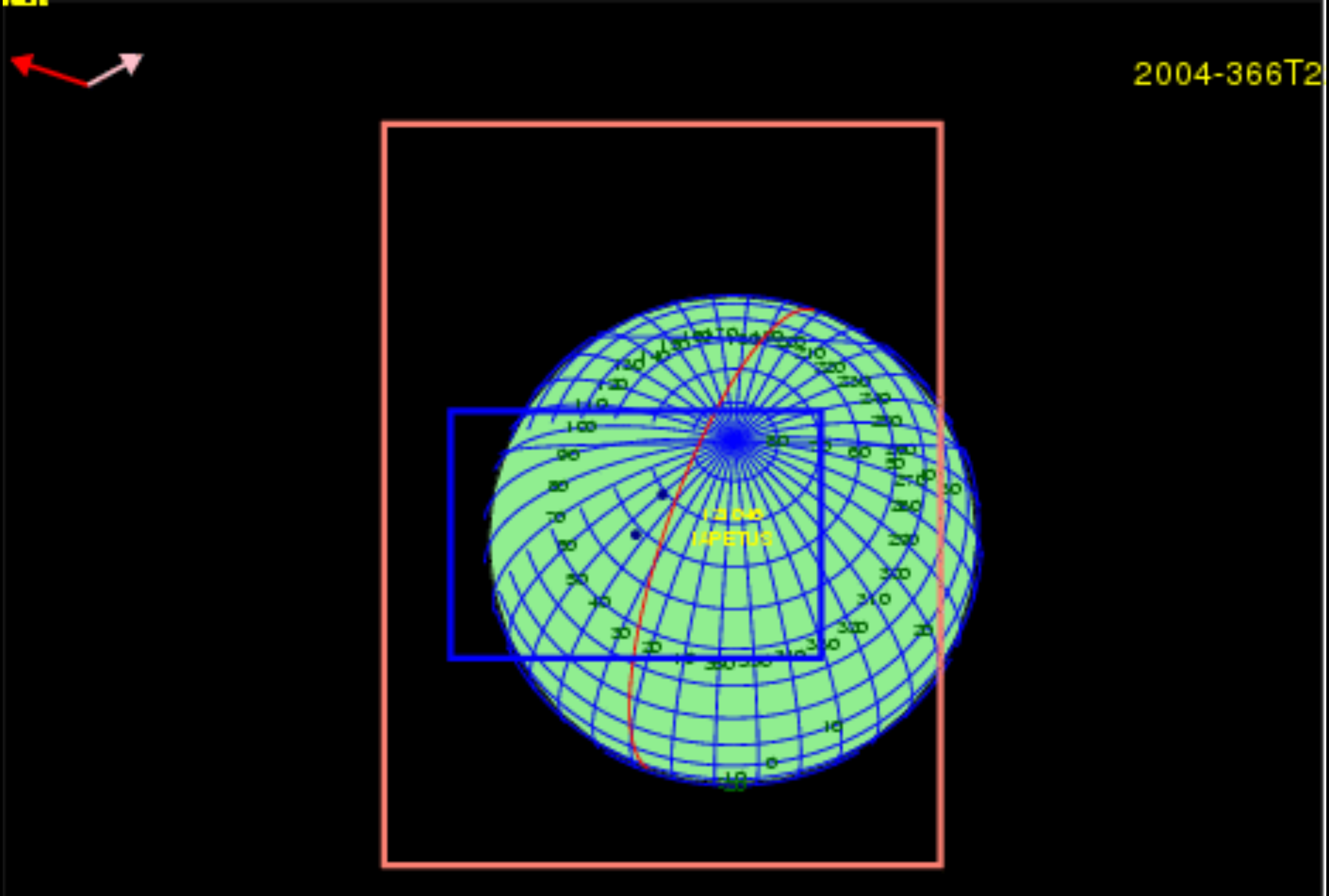
Temperatures > 120K



VIMS_00BIA_COMPA001_PRIME_2004-366T03:34:06
to
VIMS_00BIA_COMPA001_PRIME_2004-366T04:01:21



VIMS_00CIA_COMPD001_PRIME_2004-366T19:02:40
to
VIMS_00CIA_COMPD001_PRIME_2004-366T20:40:04



VIMS_00CIA_COMPE001_PRIME_2004-366T22:33:00
to
VIMS_00CIA_COMPE001_PRIME_2005-001T00:23:10

CIRS Iapetus Preview: Rev B/C

(2004-366T02:35 to 2005-001T13:30)

J. Pearl, J. Spencer, M. Segura

20 Dec. 2004

CIRS Rev B/C Iapetus objectives

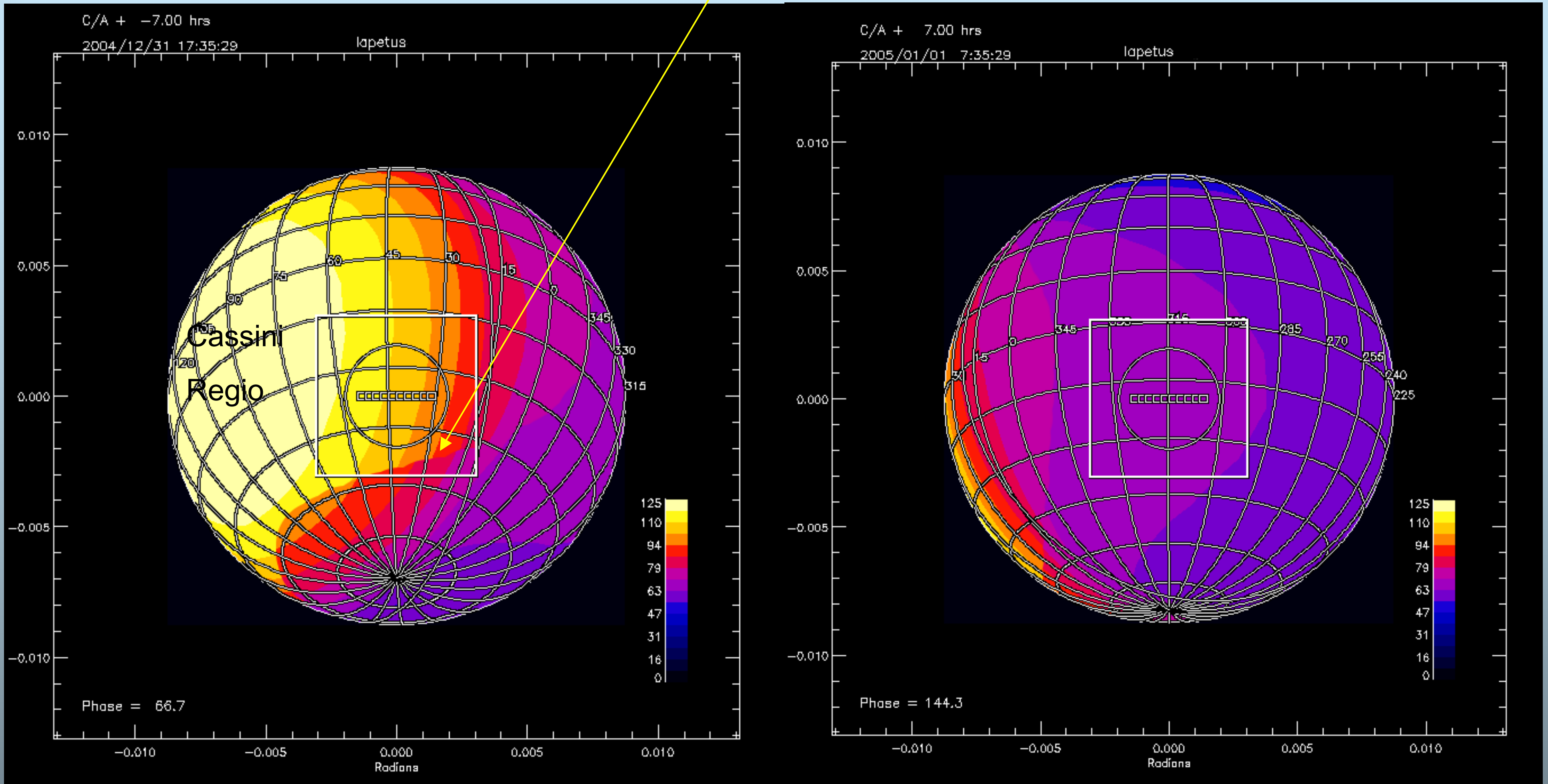
- Surface temperature mapping.
- Evaluate surface thermal inertias for dark, bright regions.
- Search for spectral signatures of surface components.

CIRS Observation Timeline

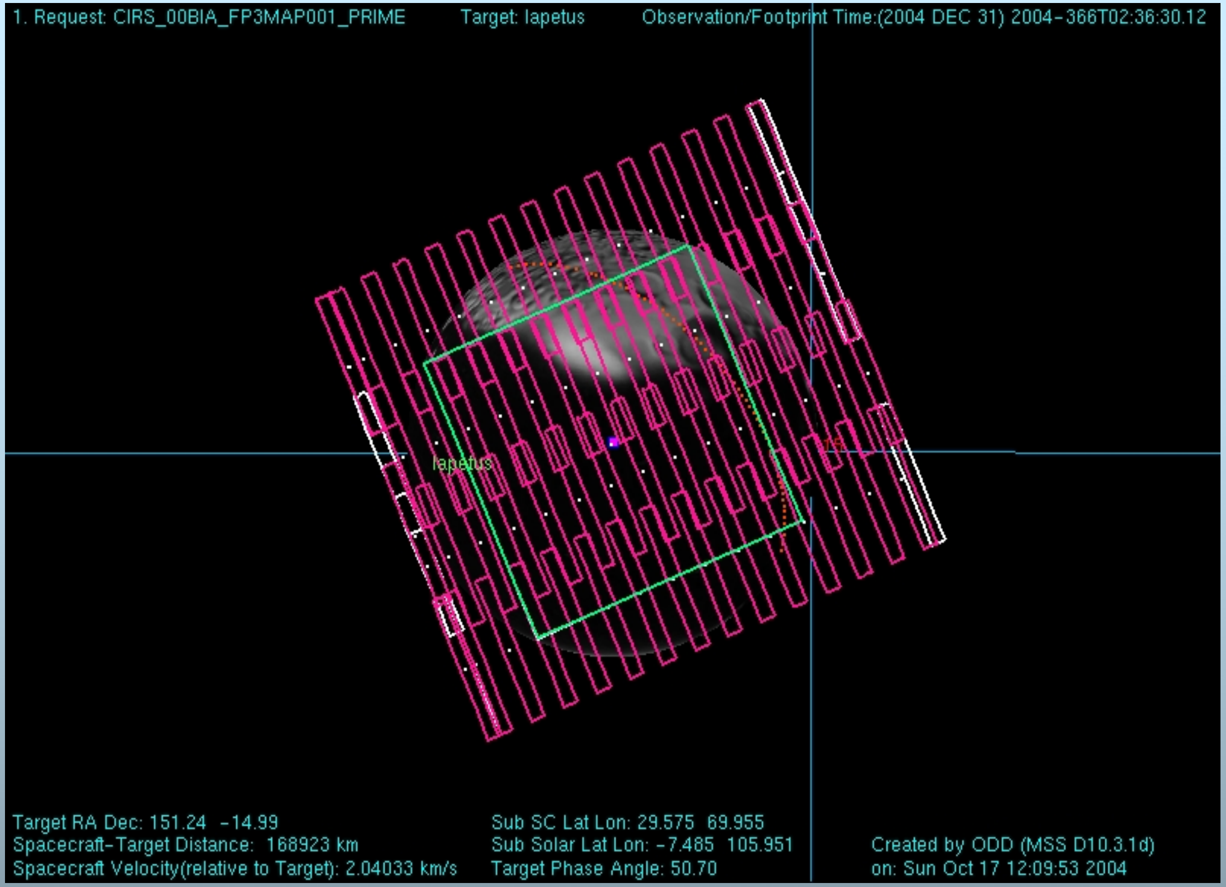
Request	Start Time	End Time
CIRS_00BIA_FP3MAP001_PRIME	2004-366T02:35:00	2004-366T03:32:00
CIRS_00CIA_FP3DSKMAP001_PRIME	2004-366T14:30:00	2004-366T18:30:00
CIRS_00CIA_FP13MAPS001_PRIME	2004-366T21:00:00	2004-366T22:00:00
CIRS_00CIA_FP13MAPS002_PRIME	2005-001T00:30:00	2005-001T01:00:00
CIRS_00CIA_FP13MAPS003_PRIME	2005-001T02:00:00	2005-001T04:00:00
CIRS_00CIA_FP13MAPS004_PRIME	2005-001T12:00:00	2005-001T13:30:00

Expected Temperatures

- -7, +7 hours from c/a for the old trajectory
  - New trajectory is north of the equator, twice as distant
- Note model temperature discontinuity at the bright/dark boundary
  - Bright polar and trailing sides are typically ~10 K colder



CIRS_00BIA_FP3MAP001_PRIME

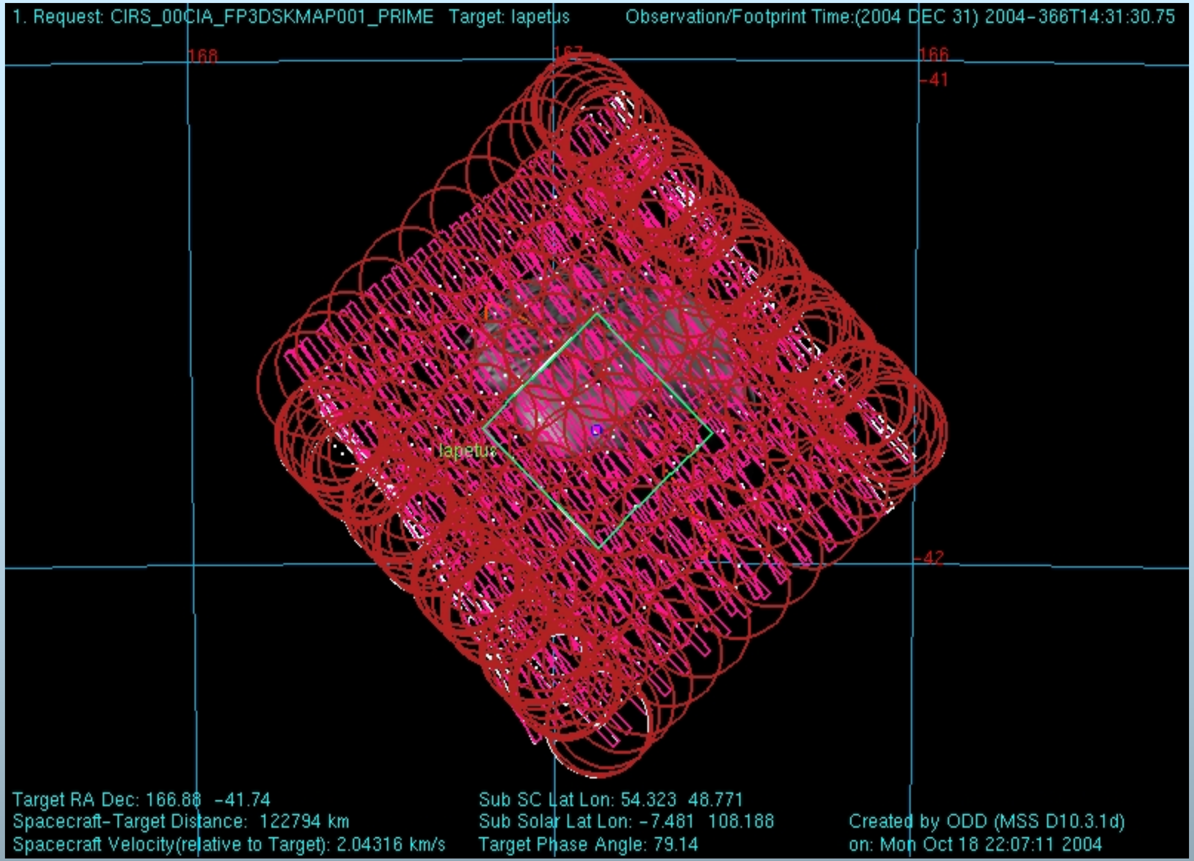


Duration=00:57
AD=8.5 mrad
Sub S/C=(29, 070),
LT=14.4
ϕ=51^{o}

Disk map; Cassini Regio (subsolar point $T_s \approx 125$ K)

(1)

CIRS_00CIA_FP3DSKMAP001_PRIME



Duration=04:00

AD=11.7 mrad

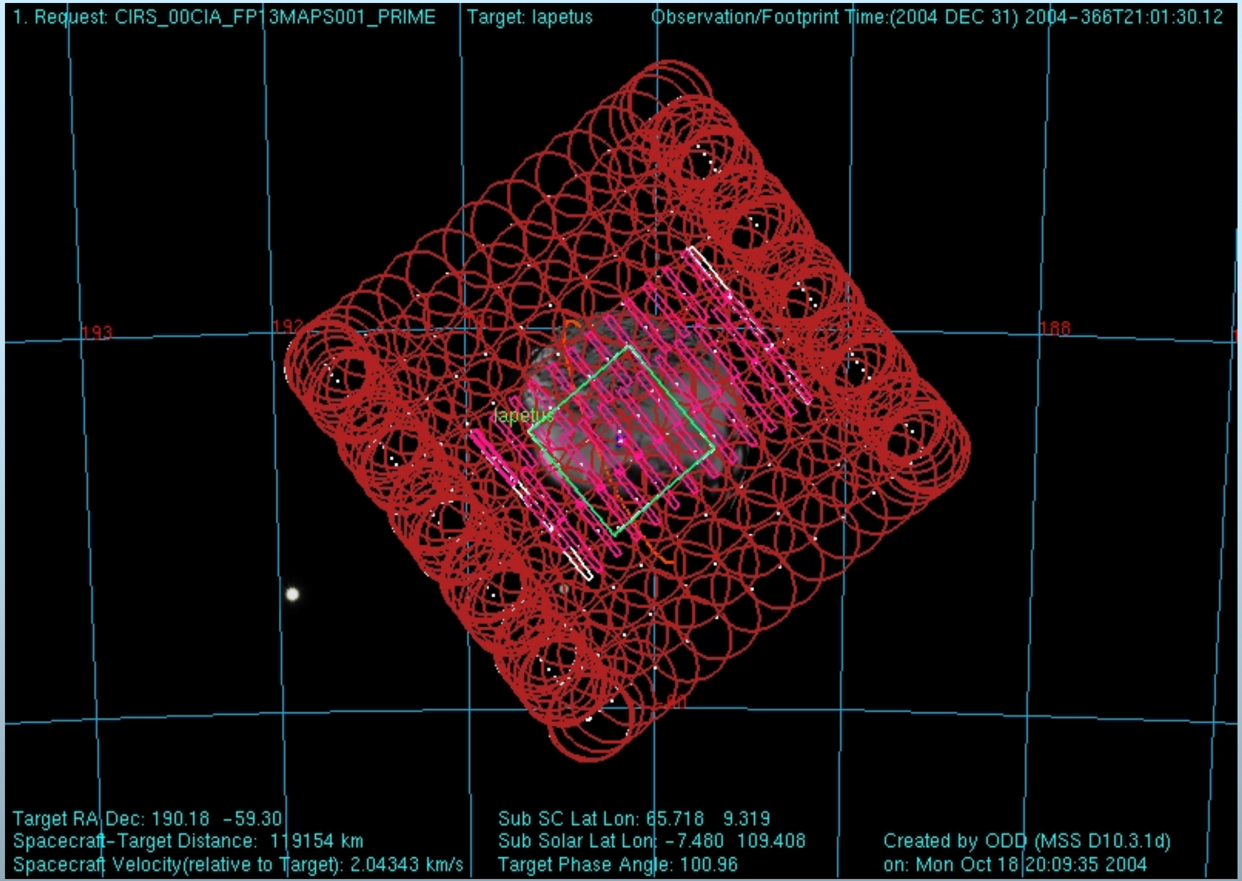
Sub S/C=(54, 049),
LT=15.9-17.4

$\phi = 79^{o}$

Disk map of late afternoon, early evening midlatitudes

(2)

CIRS_00CIA_FP13MAPS001_PRIME



Duration=01:00

AD=12.1 mrad

Sub S/C=(66, 010),

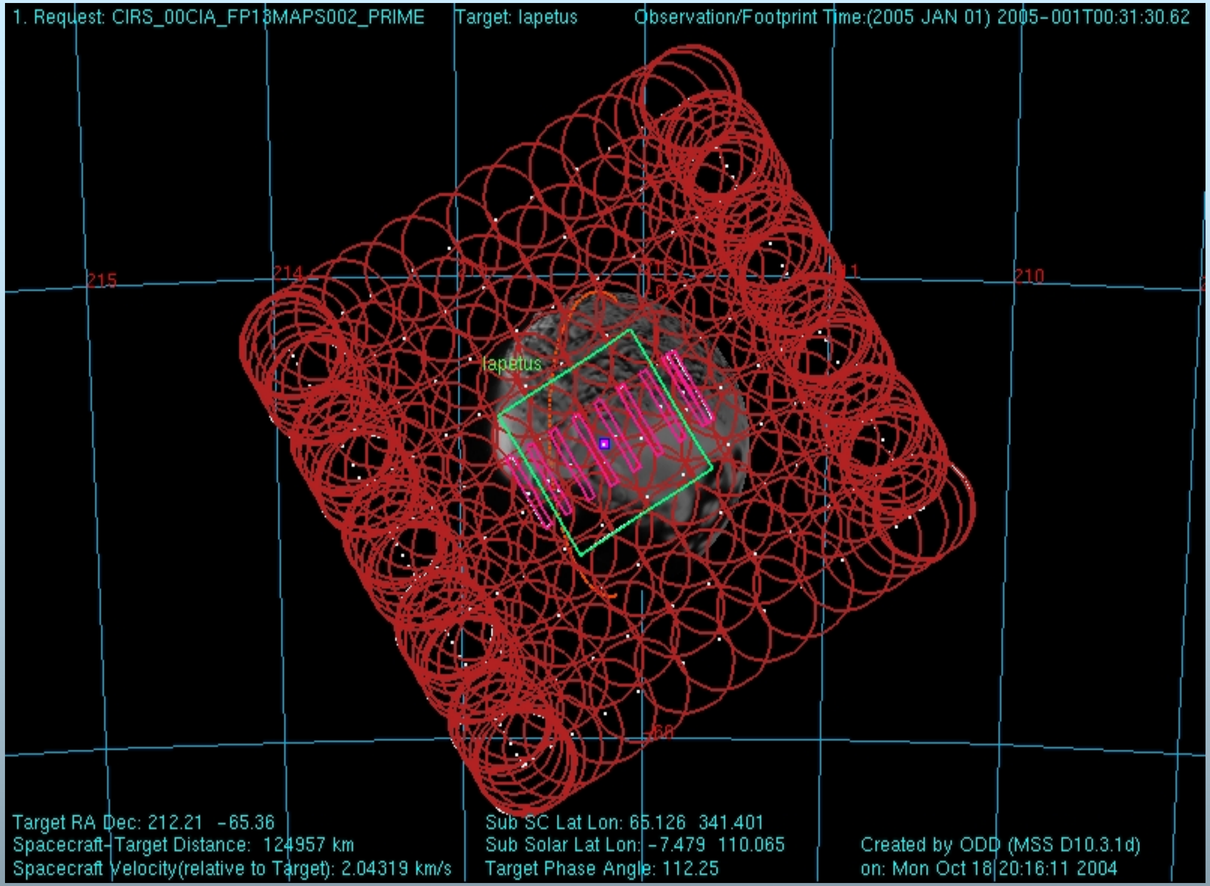
LT=18.6

ϕ=101^{o}

Disk map of polar Latitudes

(3)

CIRS_00CIA_FP13MAPS002_PRIME



Duration=00:30

AD=11.5 mrad

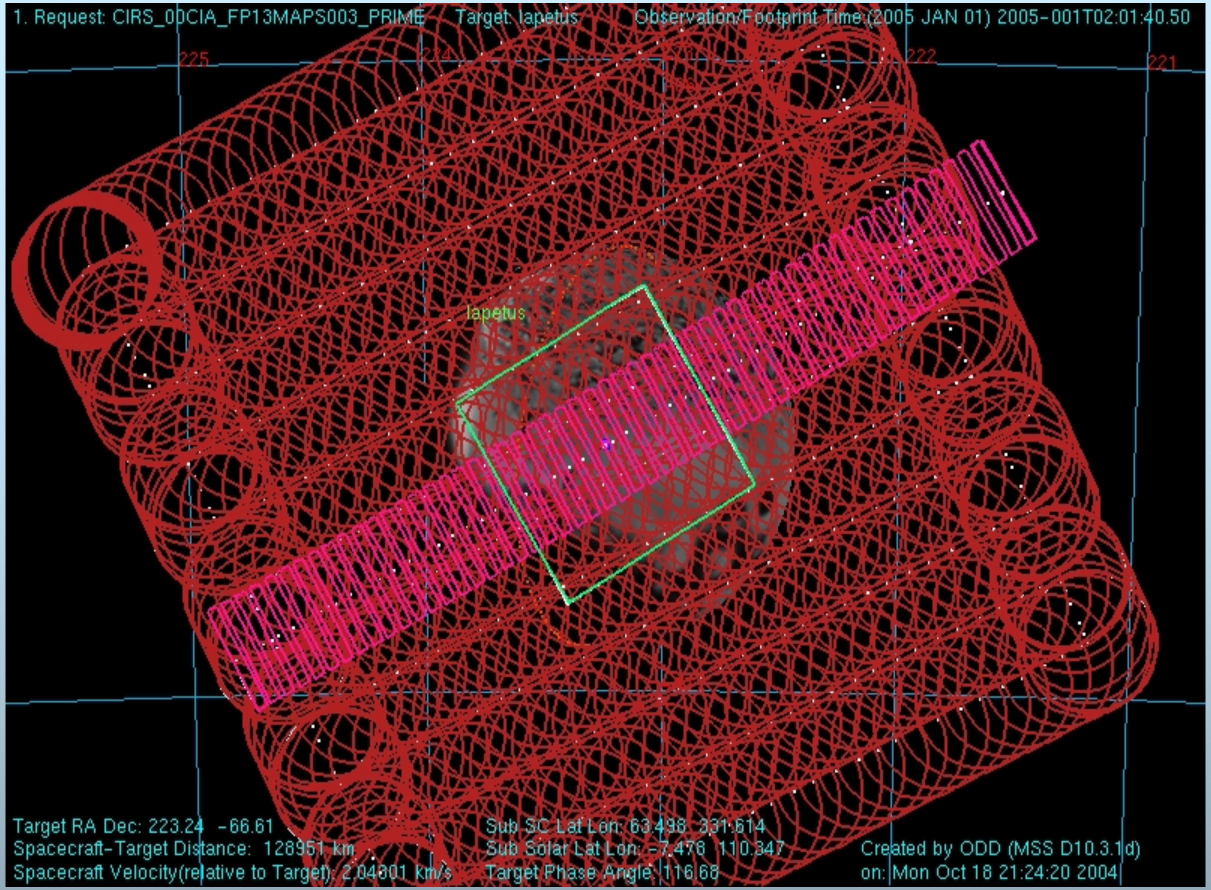
Sub S/C=(65, 342),
LT=20.5

ϕ=112°

Disk map, scan of nighttime high and polar latitudes

(4)

CIRS_00CIA_FP13MAPS003_PRIME



Duration=02:00

AD=11.1 mrad

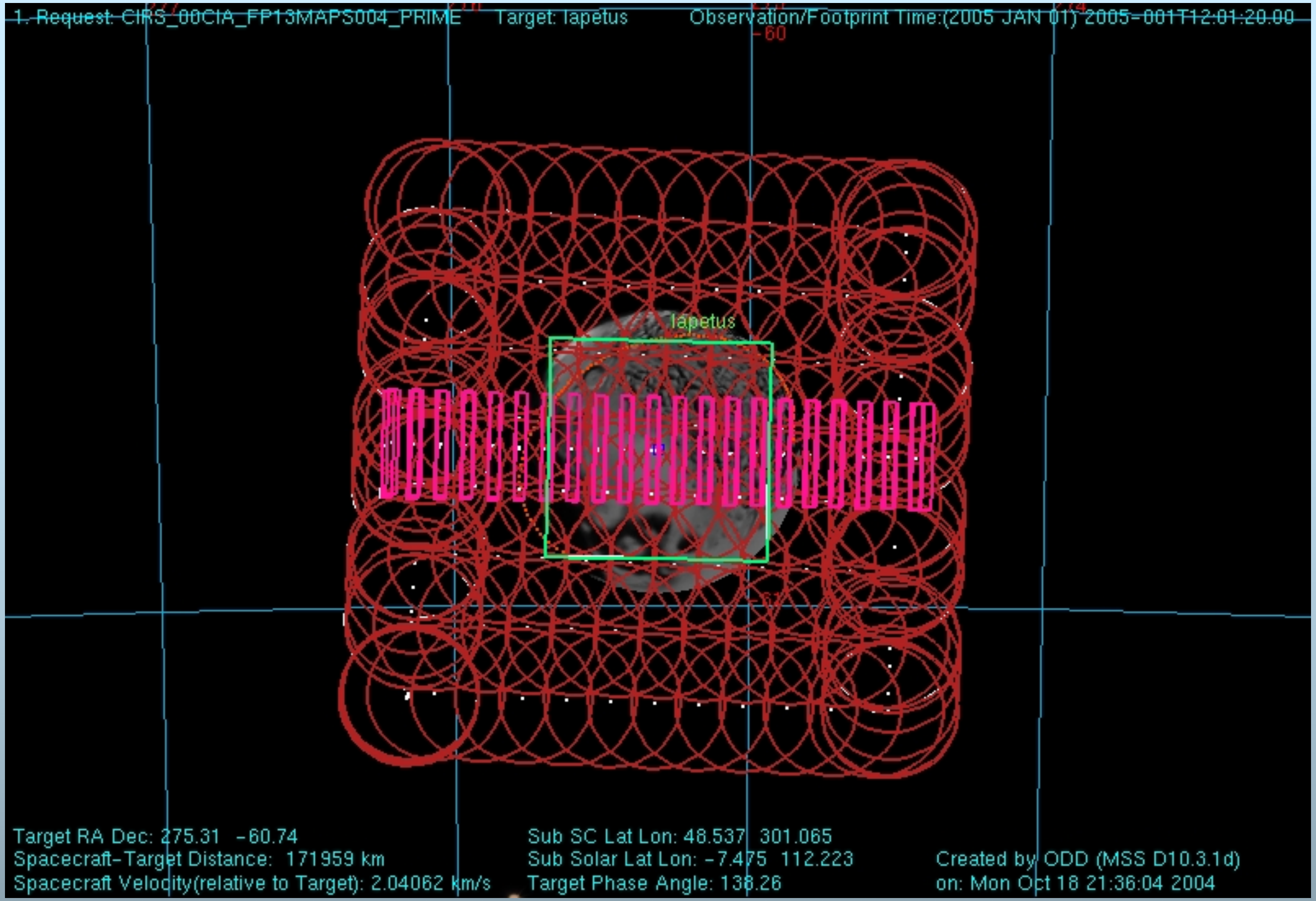
Sub S/C=(64, 332),
LT=21.2

ϕ=117°

Disk map, scan of nighttime high and polar latitudes (Roncevaux Terra)

(5)

CIRS_00CIA_FP13MAPS004_PRIME



Duration=01:30

AD=8.4 mrad

Sub S/C=(49, 301),
LT=23.4

ϕ=138^o

Disk map, scan of nighttime high and polar latitudes (Roncevaux Terra)

UVIS Science at Iapetus

C. J. Hansen, A. Hendrix

20 December 2004

Iapetus 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

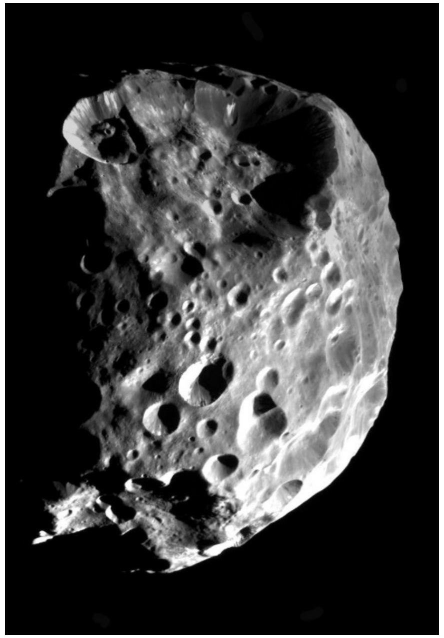
General

- The surface albedo of Saturn’s icy satellites is affected by radiation darkening 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’s radiation exposure is 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 uv maps will be compared to surface age derived from crater counts.
- 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.

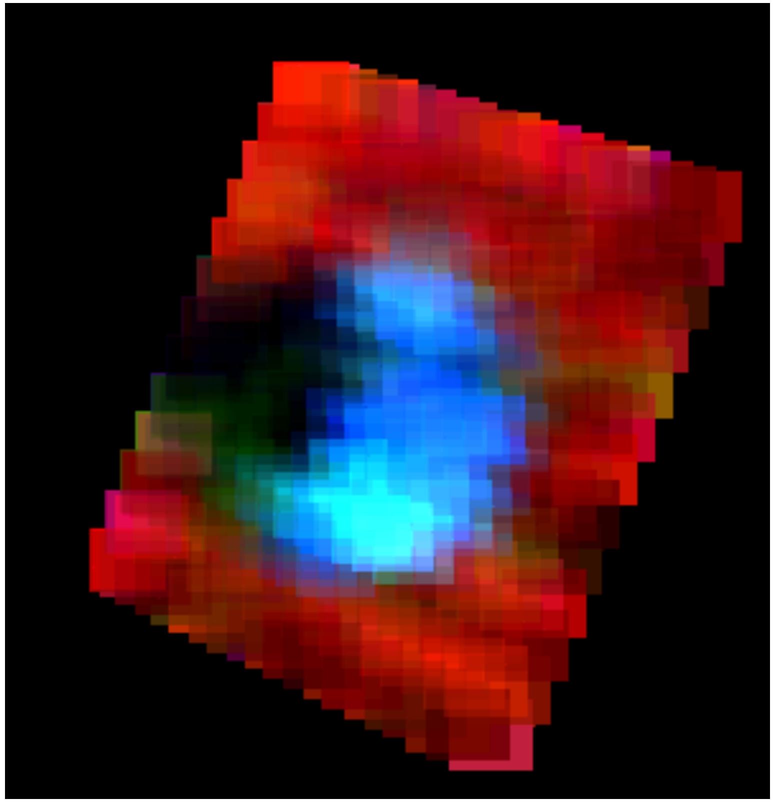
Iapetus

- Iapetus, Phoebe and Hyperion all orbit mostly outside Saturn’s magnetosphere (except for time in the magnetotail), thus provide the important end cases of primarily exposure to the solar wind
- UVIS uv albedo maps will be produced. We will look for uv albedo differences that correlate to geologic ages derived from the imaging data and analyze deviations between our data and crater counts that might suggest more recent modification to the exposed surface skin

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)

Surface Composition and Chemistry

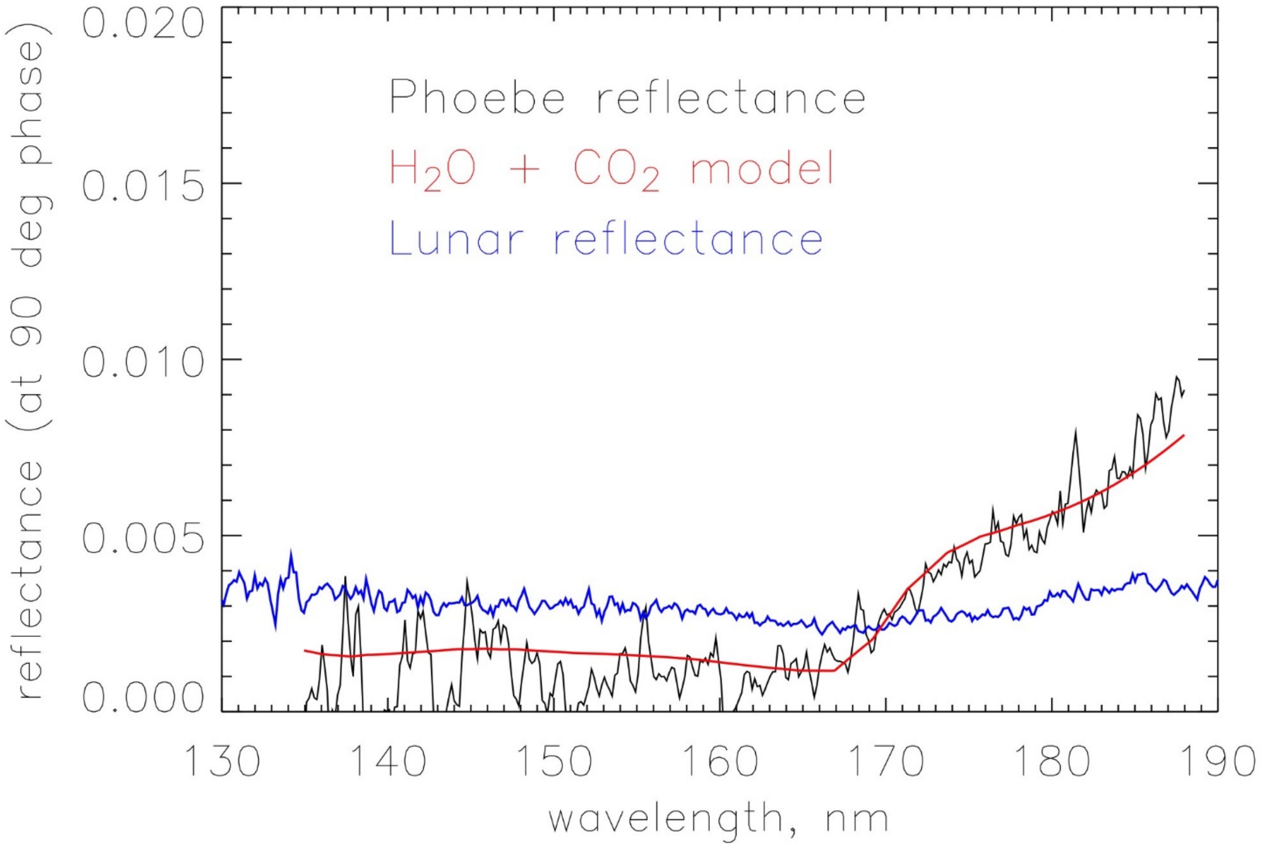
General

- Surface composition and the existence of an atmosphere are affected by sputtering processes. Investigation of photolysis and radiolysis of water ice is currently a very active area of research, propelled by 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. Further charged particle interactions produce ozone and hydrogen peroxide.
  - 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 were at longer uv wavelengths than UVIS.)
  - 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 and distribution varies.

Iapetus

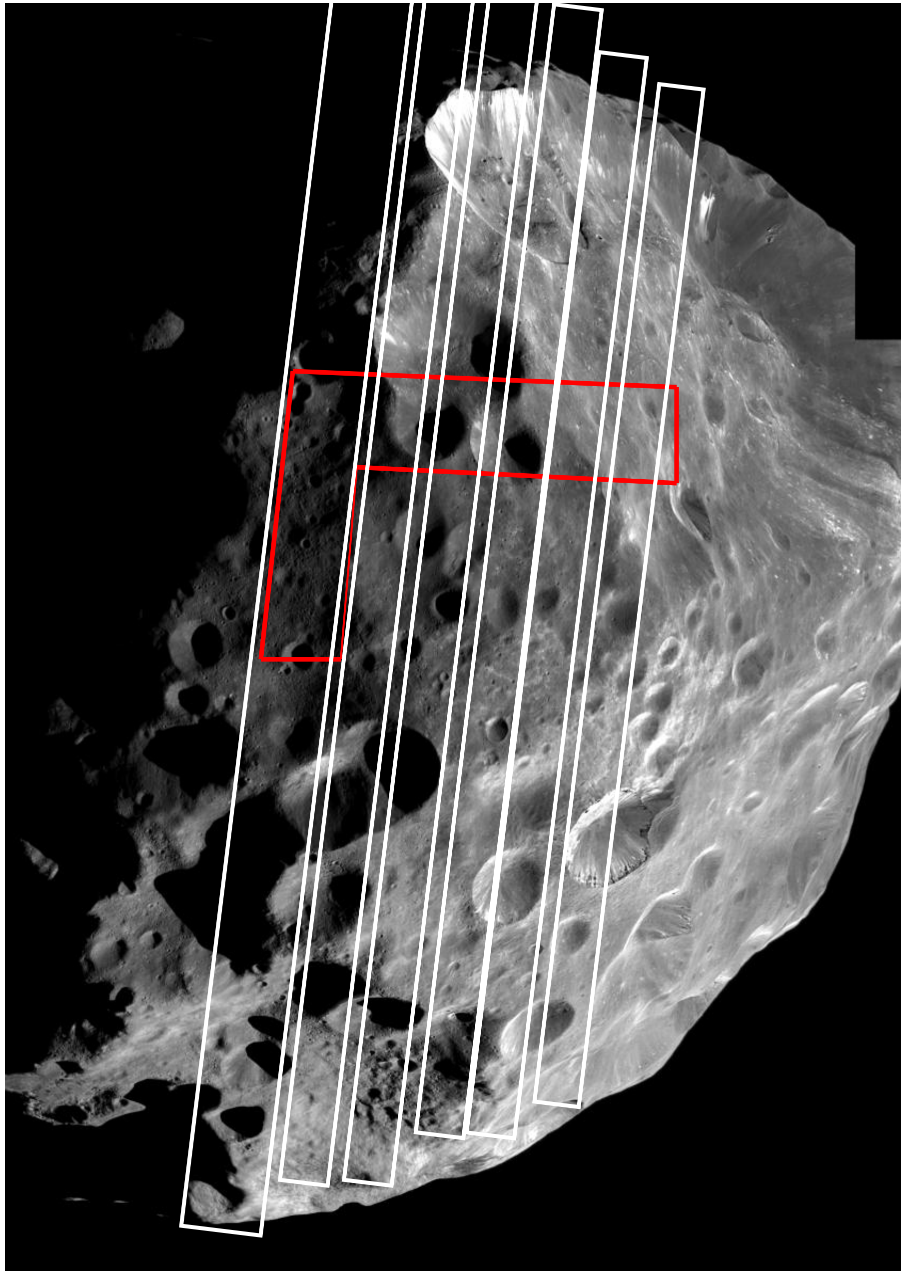
- The dramatic albedo difference between the dark and bright sides of Iapetus has been attributed to endogenic or exogenic processes – but which is it? How similar is the composition of the dark side of Iapetus to Phoebe? UVIS reflectance spectra of Iapetus will be compared to Phoebe.
- UVIS spectra may show evidence of CO_2, ammonia, or other interesting species. The amount and distribution of water and other ices will be mapped. The dark and bright sides of Iapetus will be compared.

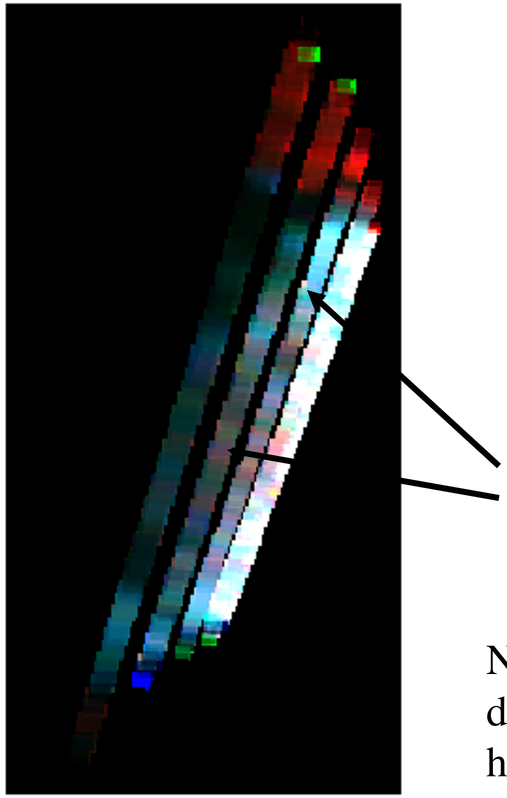
Phoebe's Disk-Integrated FUV reflectance spectrum



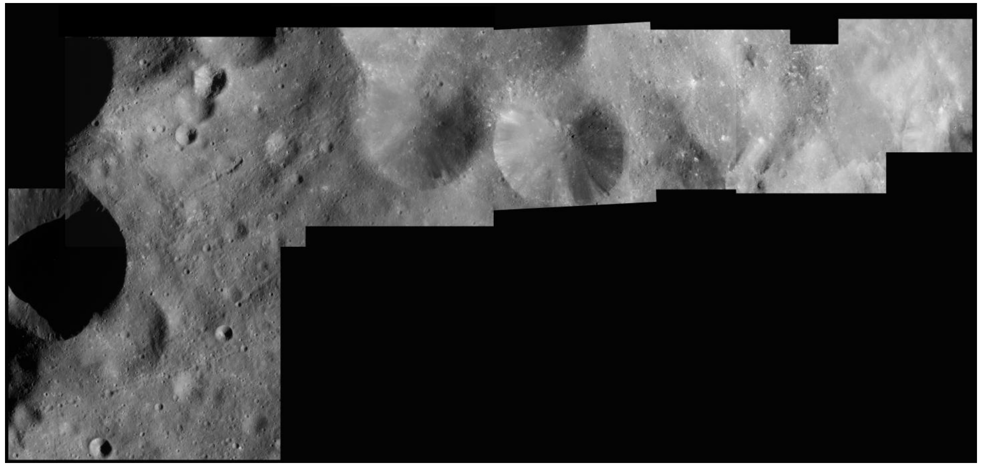
H_2O, CO_2 frosts contribute to Phoebe's FUV spectrum; other (dark) materials unknown at this time - similar to C ring non-ice material

ISS_000PH_HIRESC

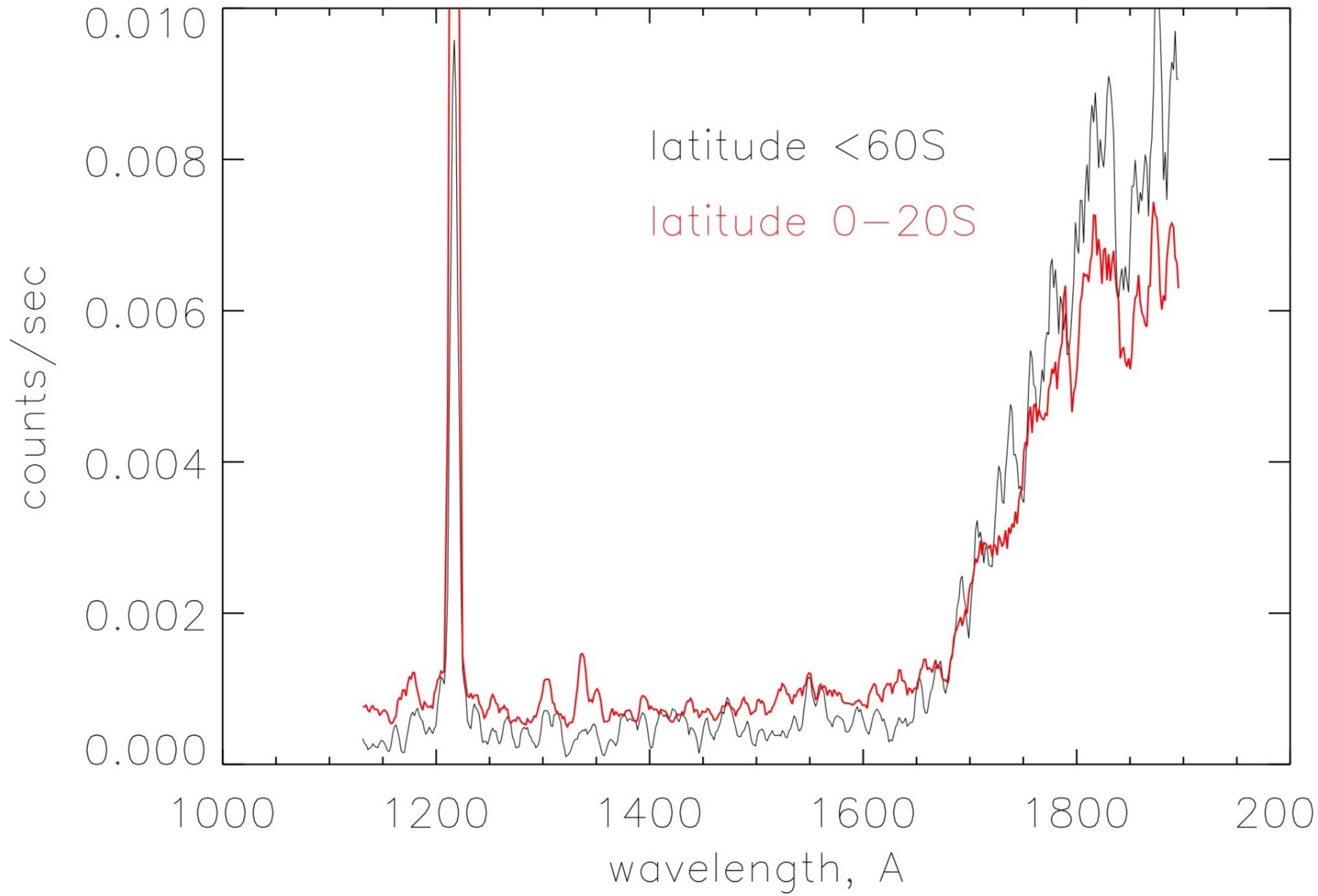




Note brightness
difference between
high and low latitudes



Phoebe’s spectral variations with latitude



Latitude Variations on Phoebe

(No strong correlation with solar incidence angle)

- At longer UV wavelengths
  - Poles - brighter
  - Mid-latitudes - darker
- At shorter UV wavelengths
  - Poles - darker
  - Mid-latitudes - brighter (and emission features stronger)
- => Spectral reversal
- Must have material at poles that is bright at long UV wavelengths, dark at short UV wavelengths.
  - H_2O + red material??
  - Conversely, mid-latitudes are spectrally *bluer* than poles

Tenuous Atmospheres / Exospheres

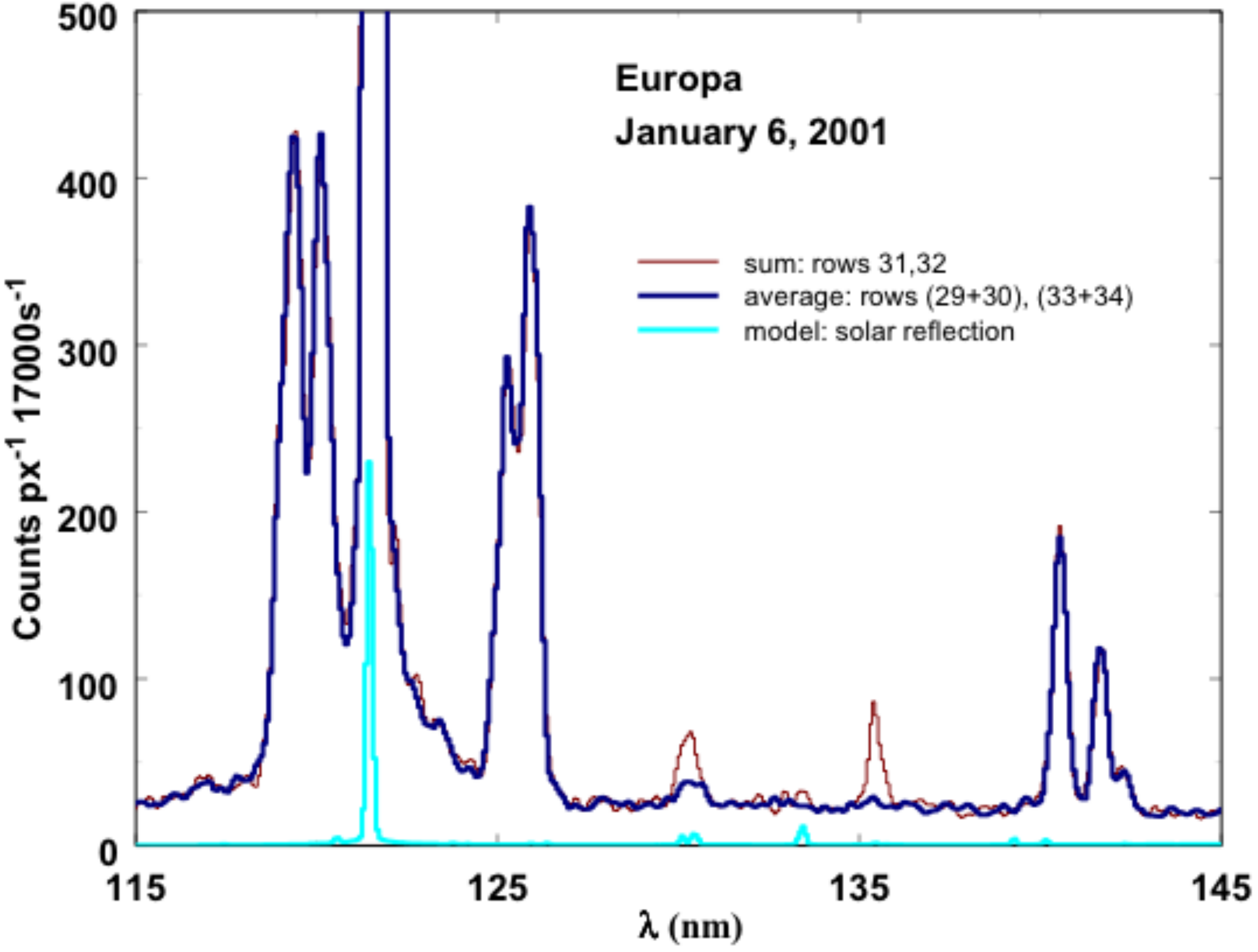
General

- Molecules are sputtered and sublimated from the surfaces of the icy satellites. By determining the composition of these exospheres we may determine surface composition. Molecules sputtered from the surface are a source of neutrals in and influencing the magnetosphere. We will look for oxygen atmospheres created by processes analogous to Europa. Determination of atmospheric density, and source and loss rates of atmospheric molecules feeds into models of the magnetospheric interaction. Of particular interest are trace constituents such as NH_3 or CH_4. For example, an ammonia-water ice composition has been proposed to explain the young geology on Enceladus.

Iapetus

- 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.

Europa Oxygen Features



Preview of Cassini RADAR Observations of Iapetus

Steve Ostro

(for the Cassini RADAR Science and Instrument Operations Teams)

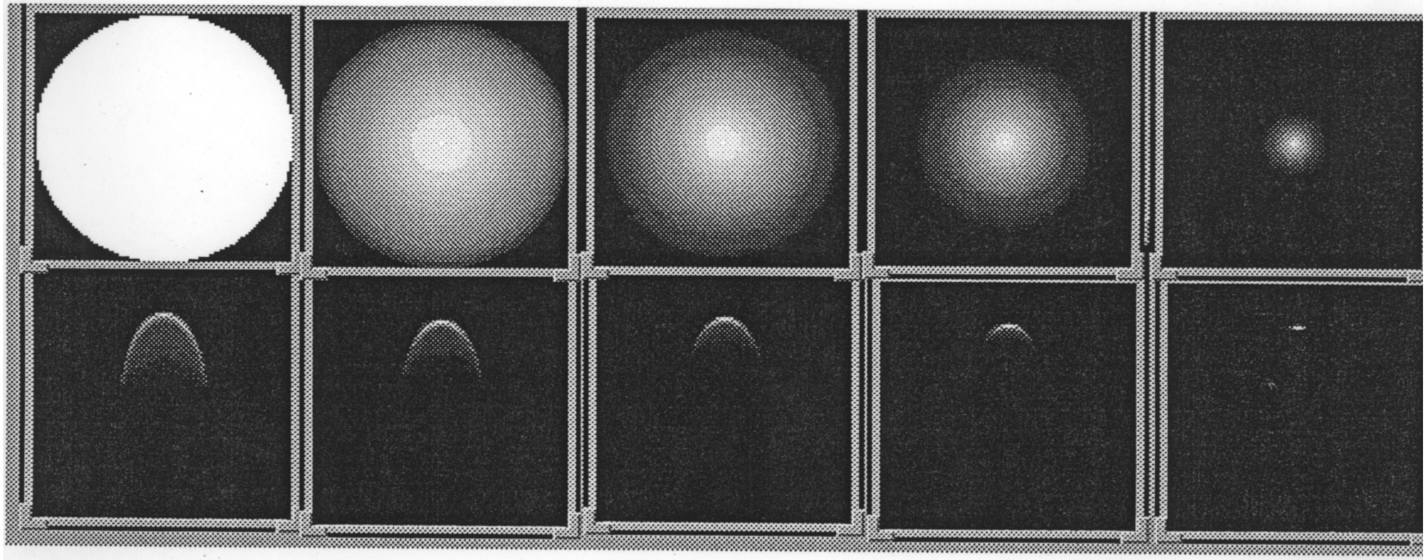
JPL, Dec. 20, 2004

The RADAR Instrument

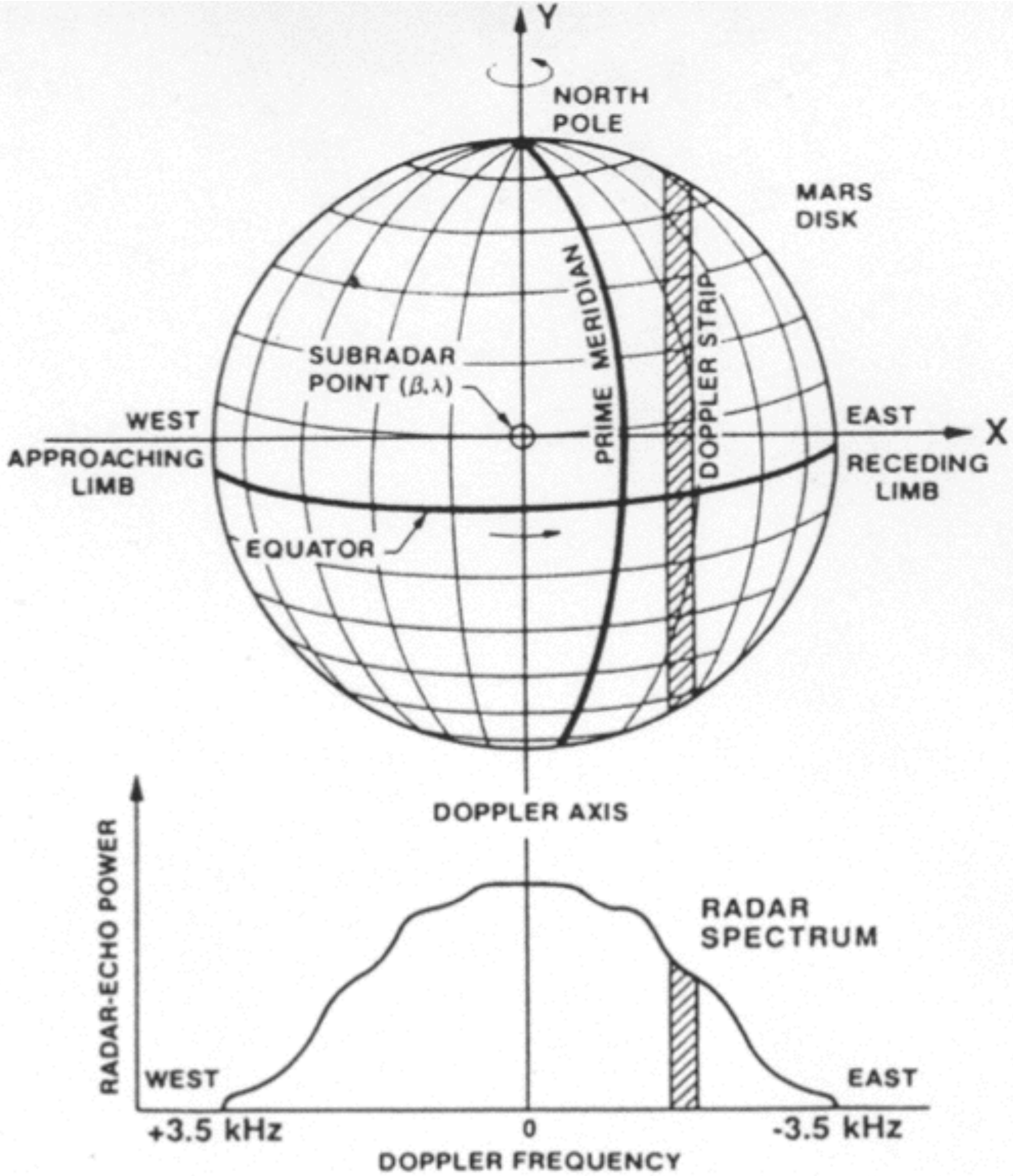
- 13.78 GHz
- 2.176 cm
- 46 watts
- “SL” polarization

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

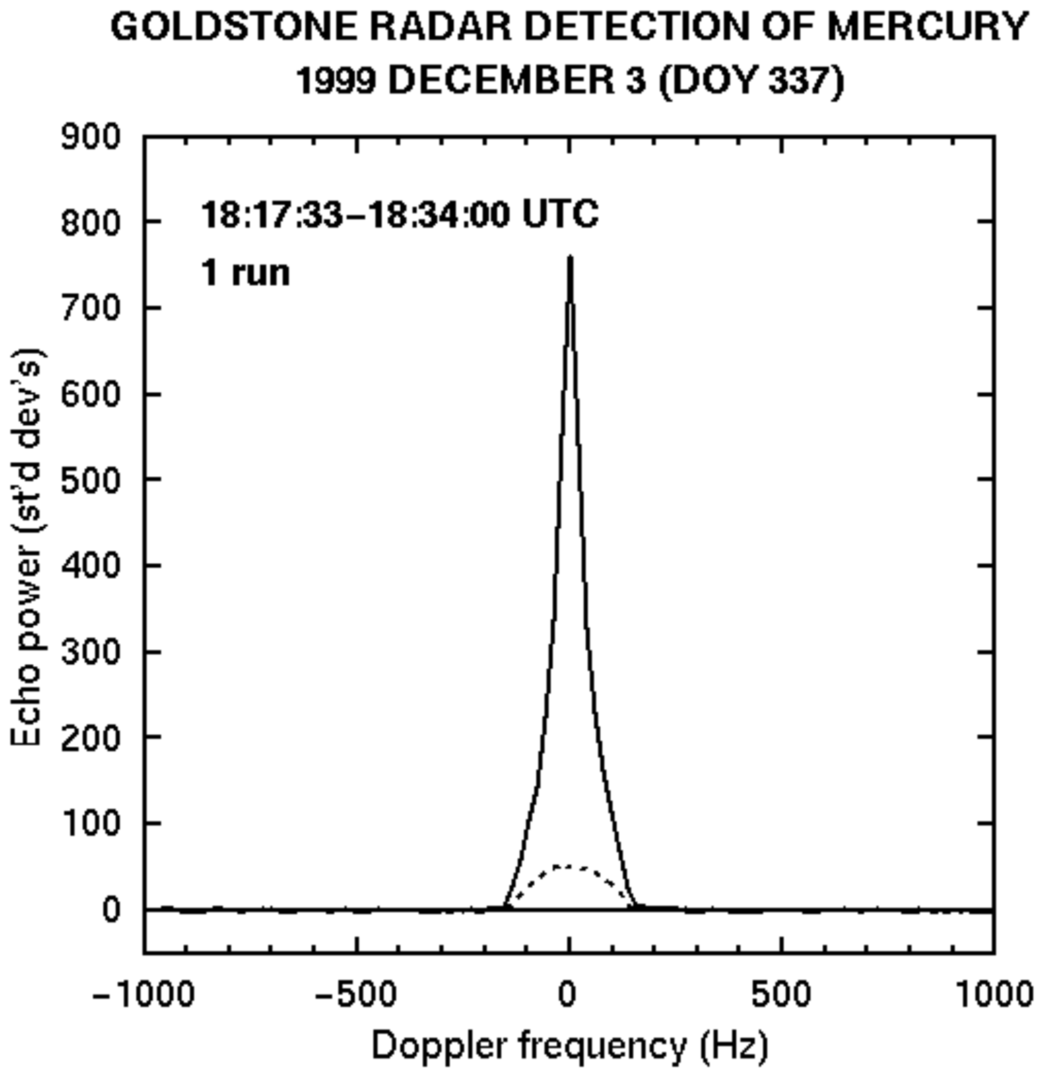
$n = 1$ 2 4 10 100

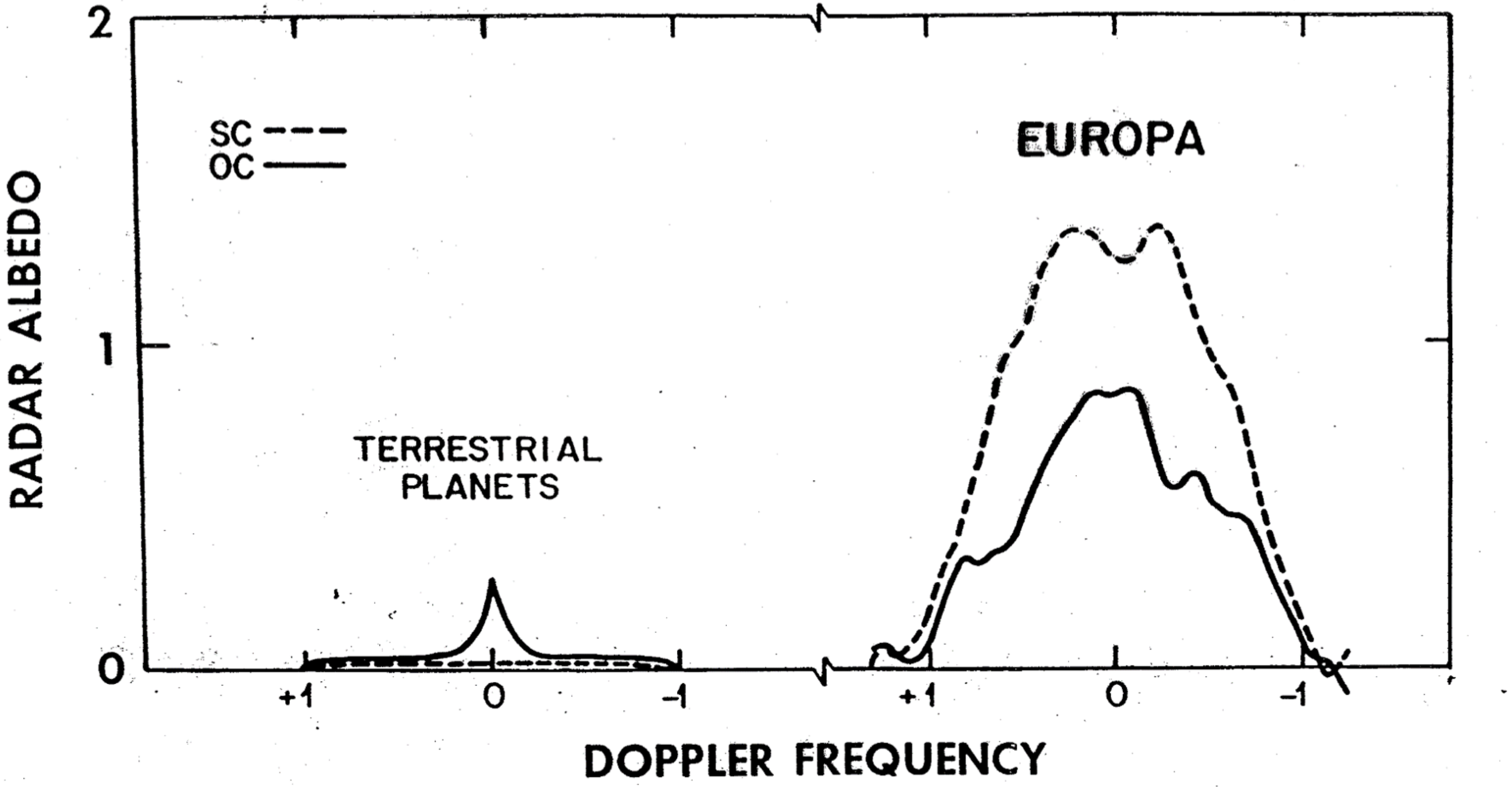


55° 45° 35° 24° 8°



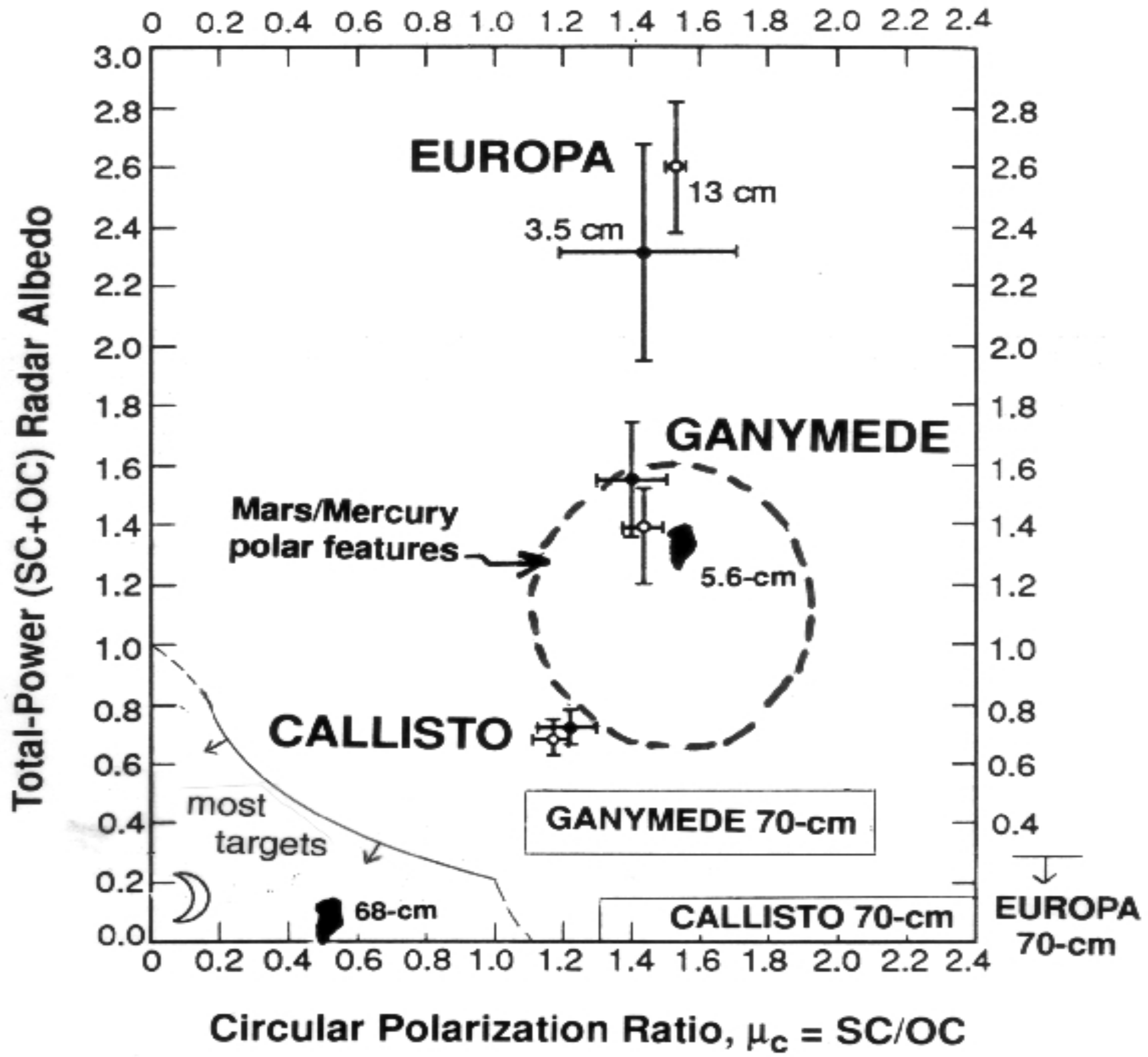
Y
NORTH
POLE
MARS
DISK
PRIME MERIDIAN
DOPPLER STRIP
SUBRADAR
POINT (β,λ)
WEST
APPROACHING
LIMB
EAST
X
RECEDING
LIMB
EQUATOR
DOPPLER AXIS
RADAR-ECHO POWER
RADAR
SPECTRUM
WEST
EAST
+3.5 kHz
0
-3.5 kHz
DOPPLER FREQUENCY

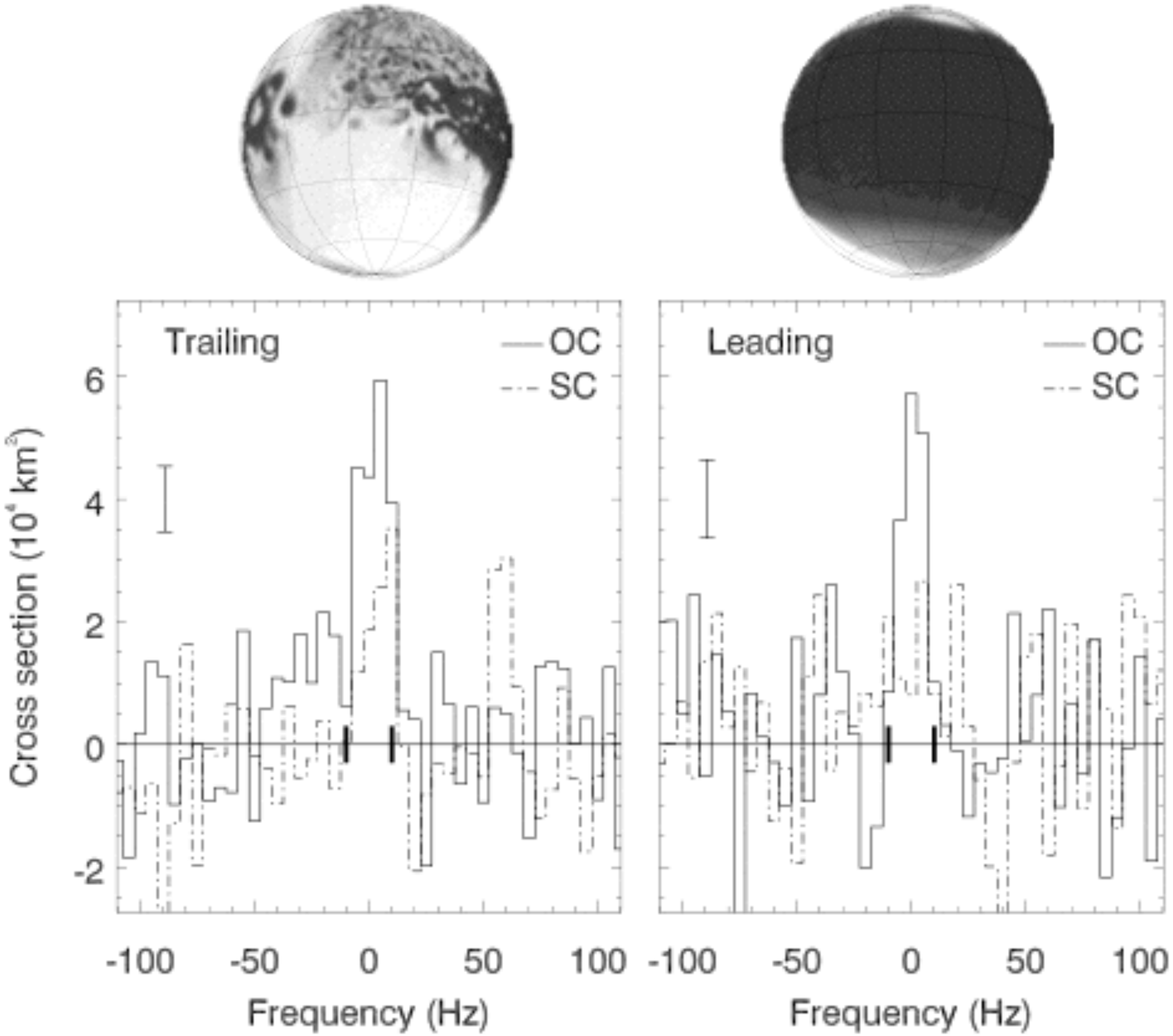

GOLDSTONE RADAR DETECTION OF MERCURY
1999 DECEMBER 3 (DOY 337)
18:17:33–18:34:00 UTC
1 run
Echo power (st'd dev's)
900
800
700
600
500
400
300
200
100
0
−1000
−500
0
500
1000
Doppler frequency (Hz)



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

RADAR PROPERTIES



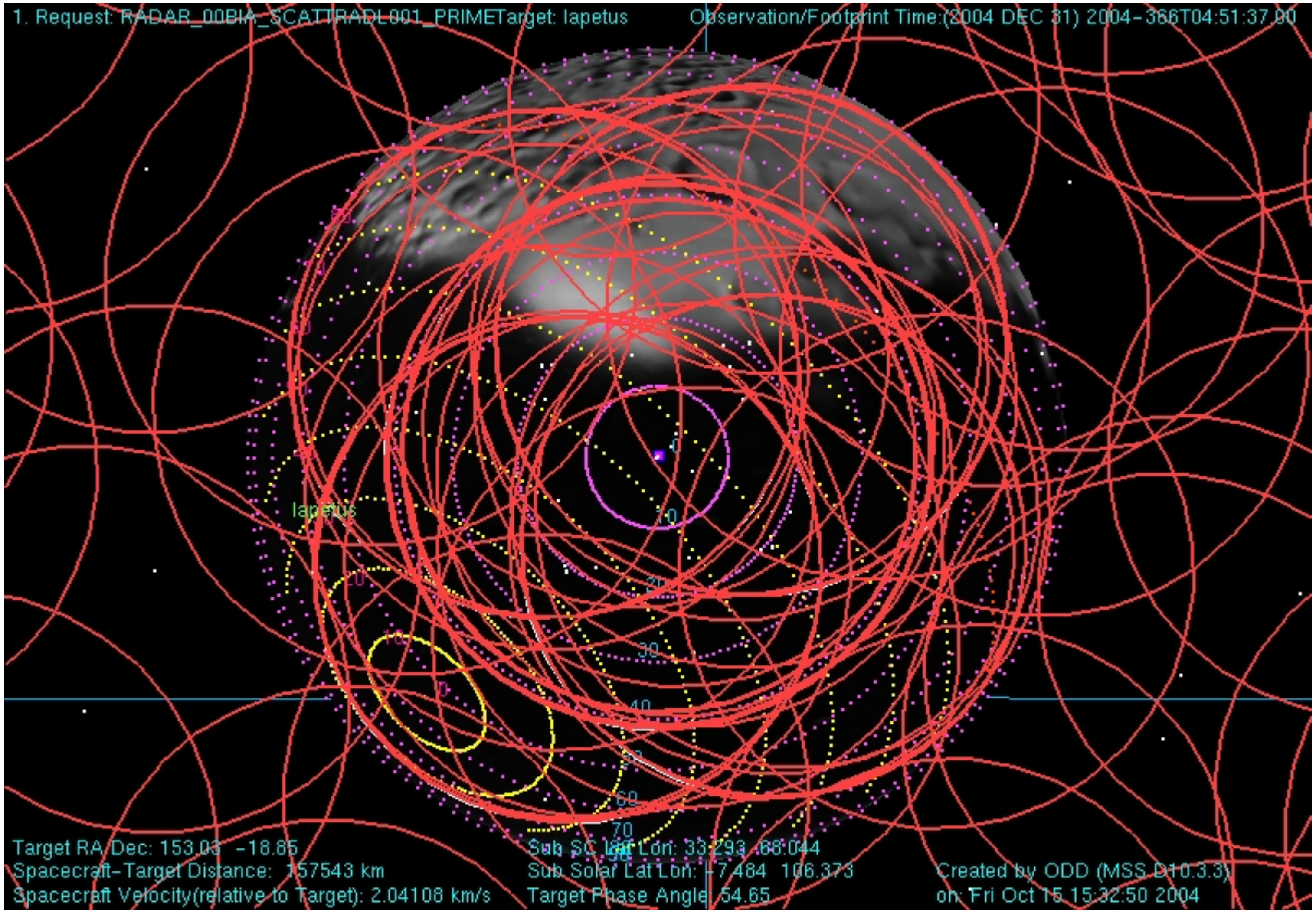


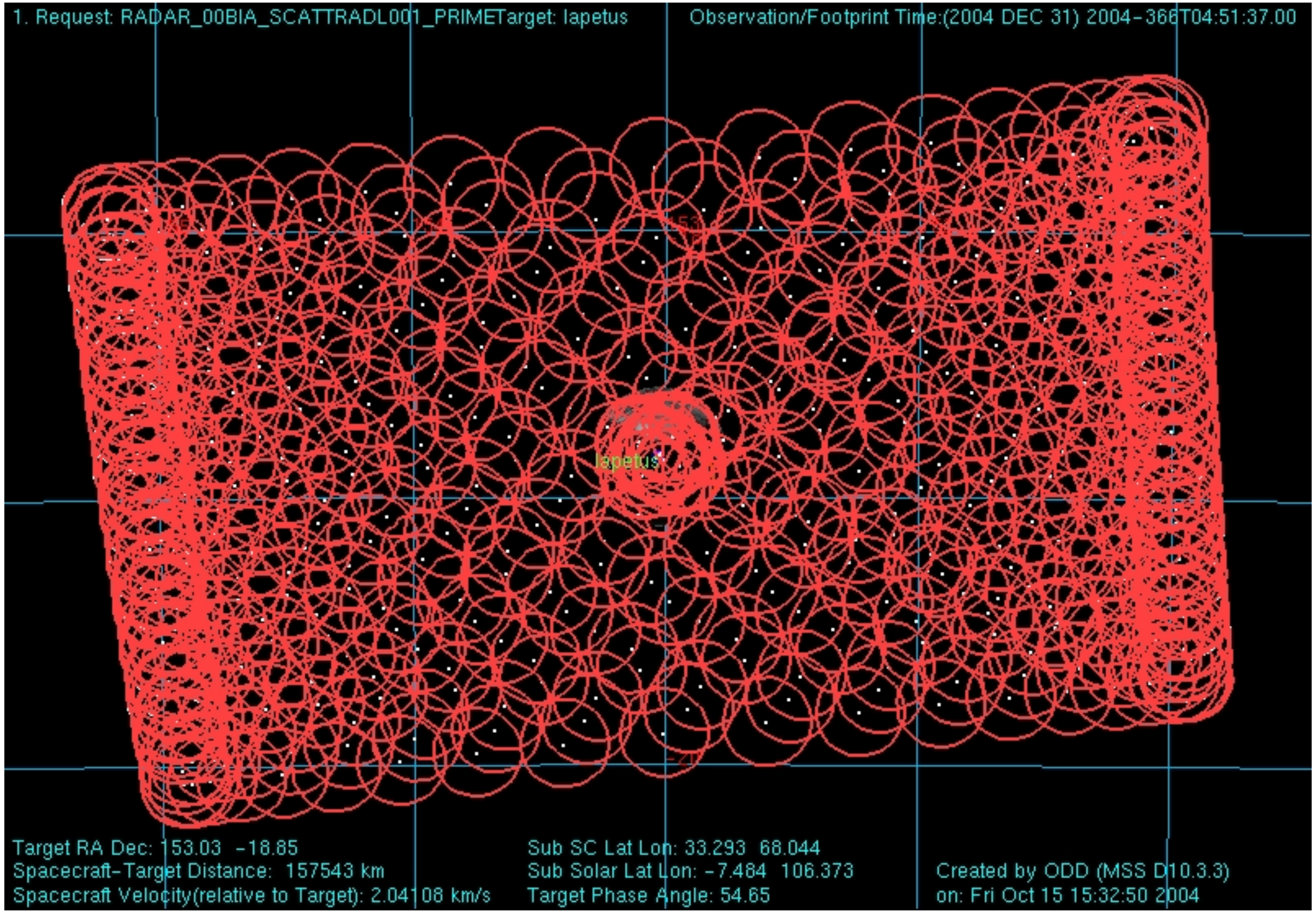
Trailing
Leading
OC
SC
Cross section (10⁴ km²)
6
4
2
0
-2
-100
-50
0
50
100
Frequency (Hz)

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	

	IAP B Inbound	IAP C Outbound
Date	2004 Dec 31	2005 Jan 1
Side	Leading (dark)	Trailing (bright)
Longitude	70 deg W	297 deg W
Ave. Distance	146,000 km	192,000 km
Duration	3 h 31 min	8 h 45 min
Start-Stop	04:29 to 08:00 UT	15:00 to 23:45
Detection Time	1 second	3 seconds
Beam/Diameter	0.67	0.87
Strategy	five-point tone, center also chirp	center tone + chirp


1. Request: RADAR_00BIA_SCATTRADL001_PRIMETarget: Iapetus
Observation/Footprint Time:(2004 DEC 31) 2004-366T04:51:37.00
Iapetus
Target RA Dec: 153.03 -18.85
Spacecraft-Target Distance: 157543 km
Spacecraft Velocity(relative to Target): 2.04108 km/s
Sub SC Lat Lon: 33.293 88.044
Sub Solar Lat Lon: -7.484 106.373
Target Phase Angle: 54.65
Created by ODD (MSS D10.3.3)
on: Fri Oct 15 15:32:50 2004


1. Request: RADAR_00BIA_SCATTRADL001_PRIMETarget: Iapetus
Observation/Footprint Time:(2004 DEC 31) 2004-366T04:51:37.00
Iapetus
Target RA Dec: 153.03 -18.85
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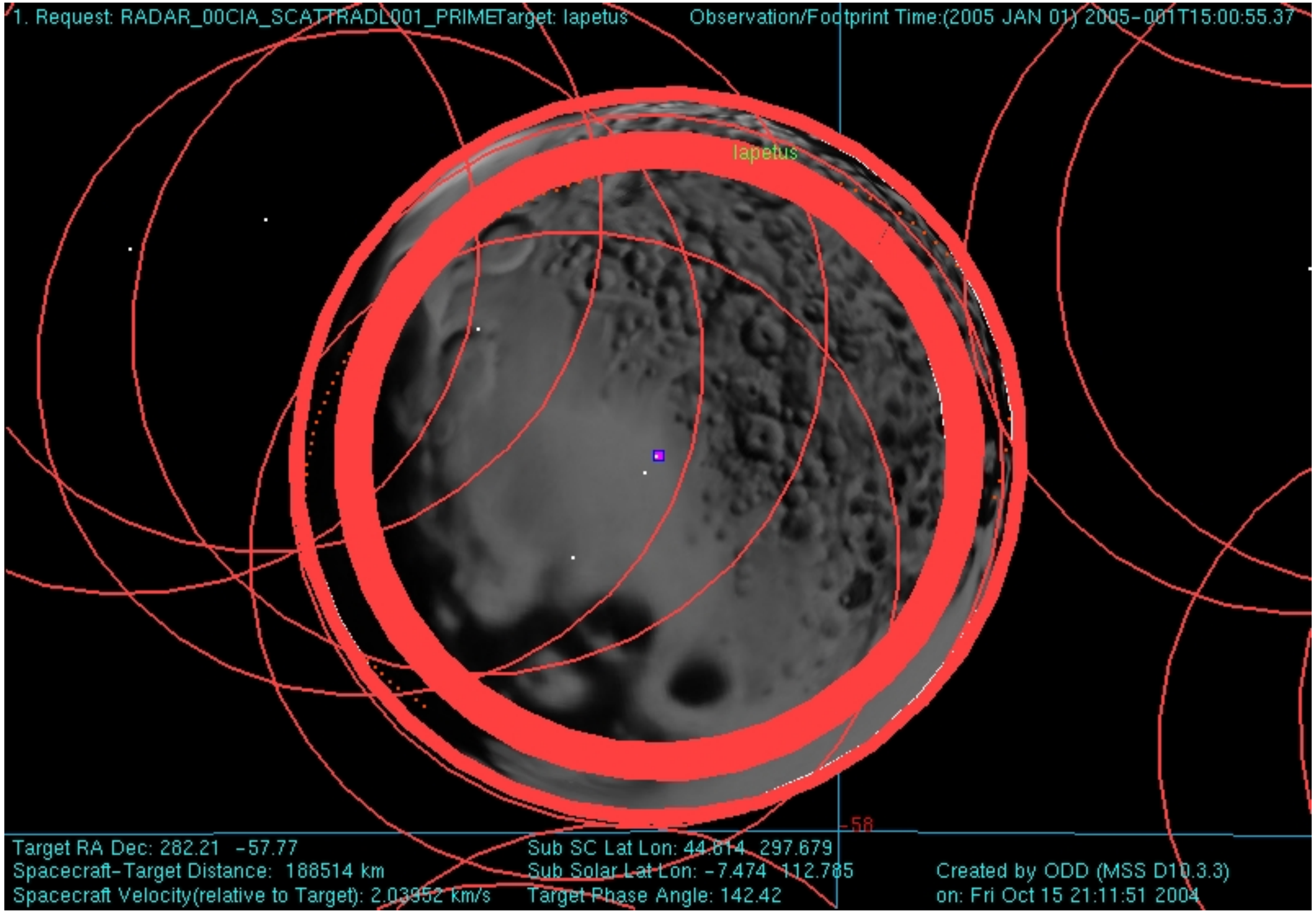
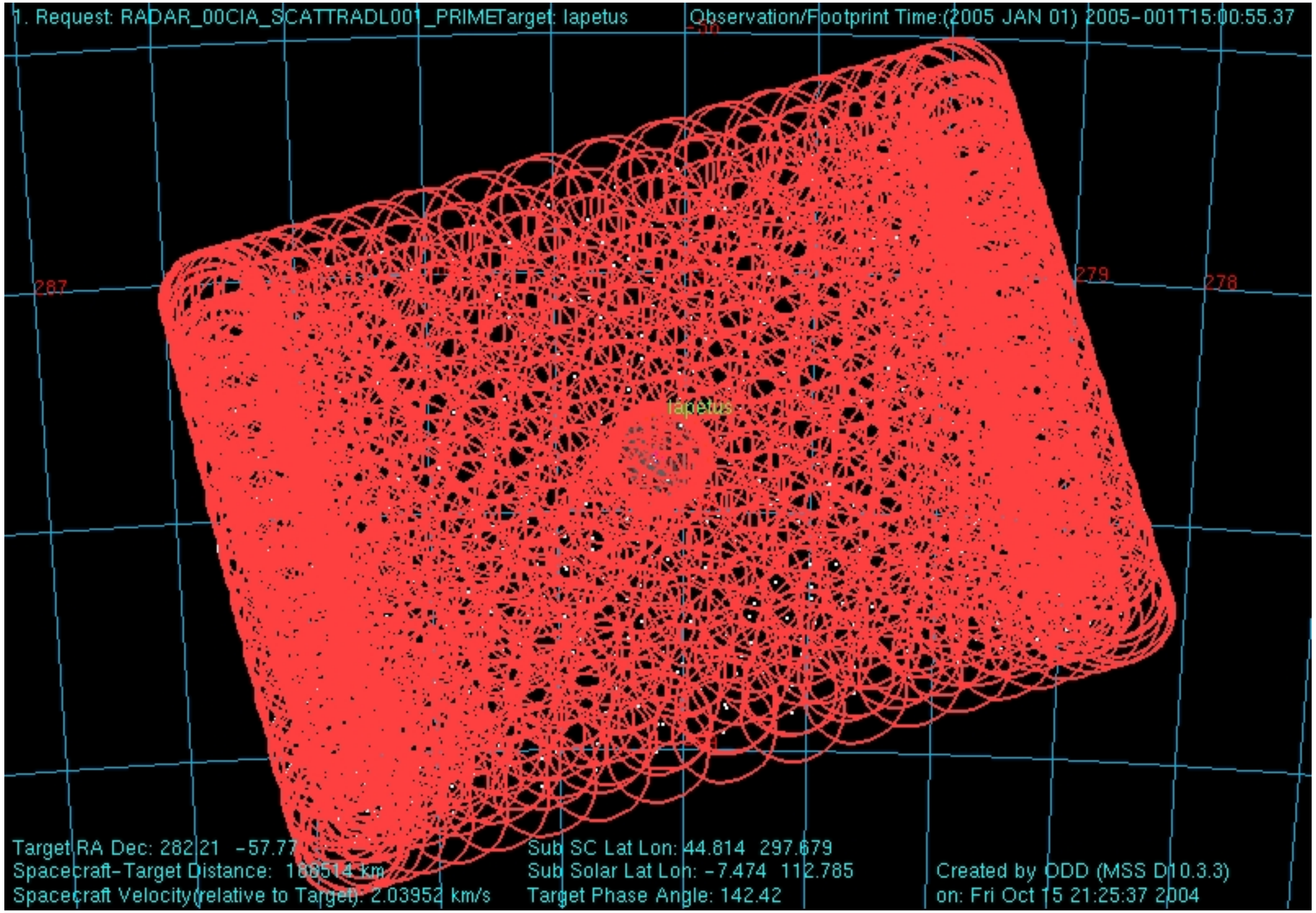
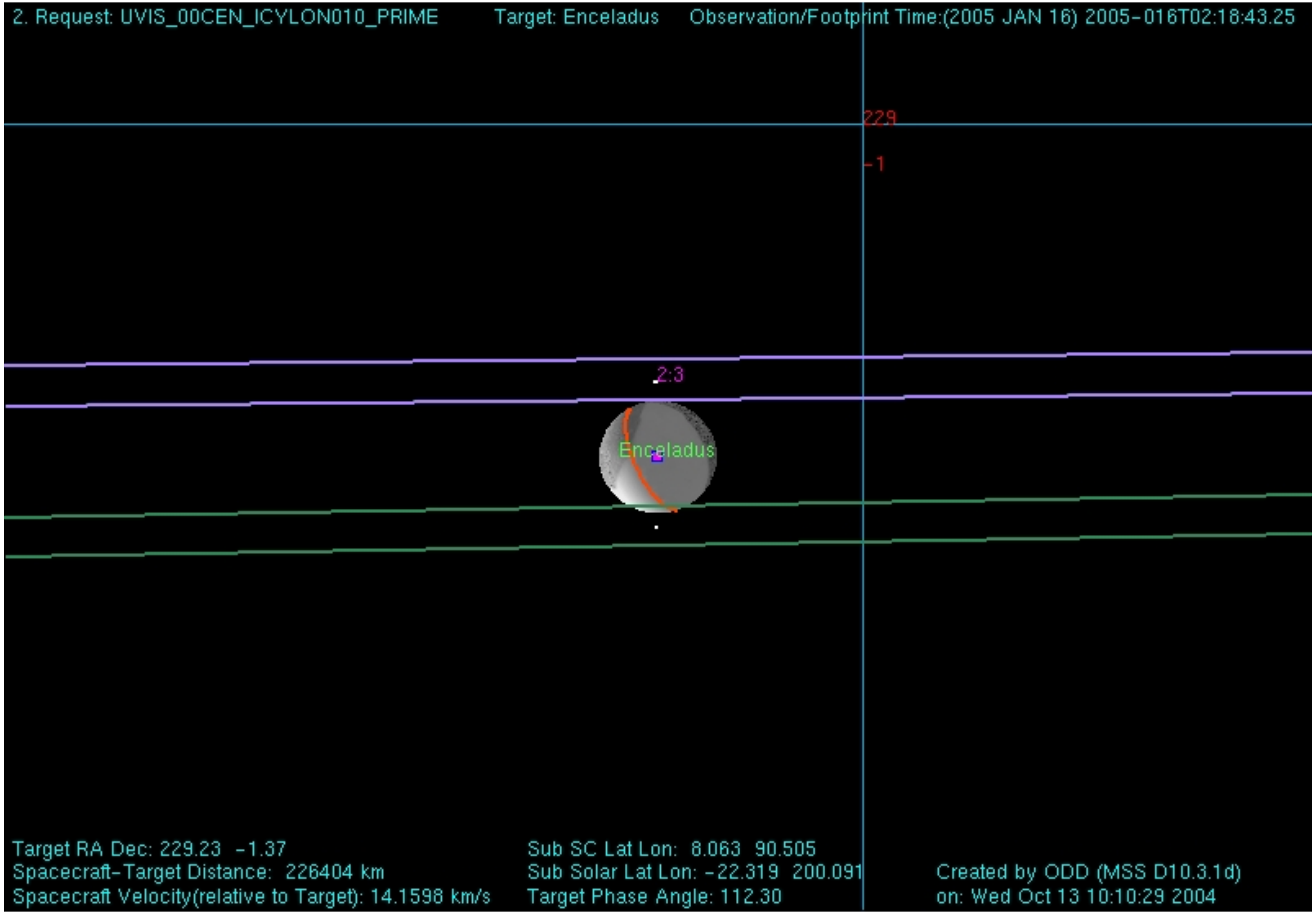
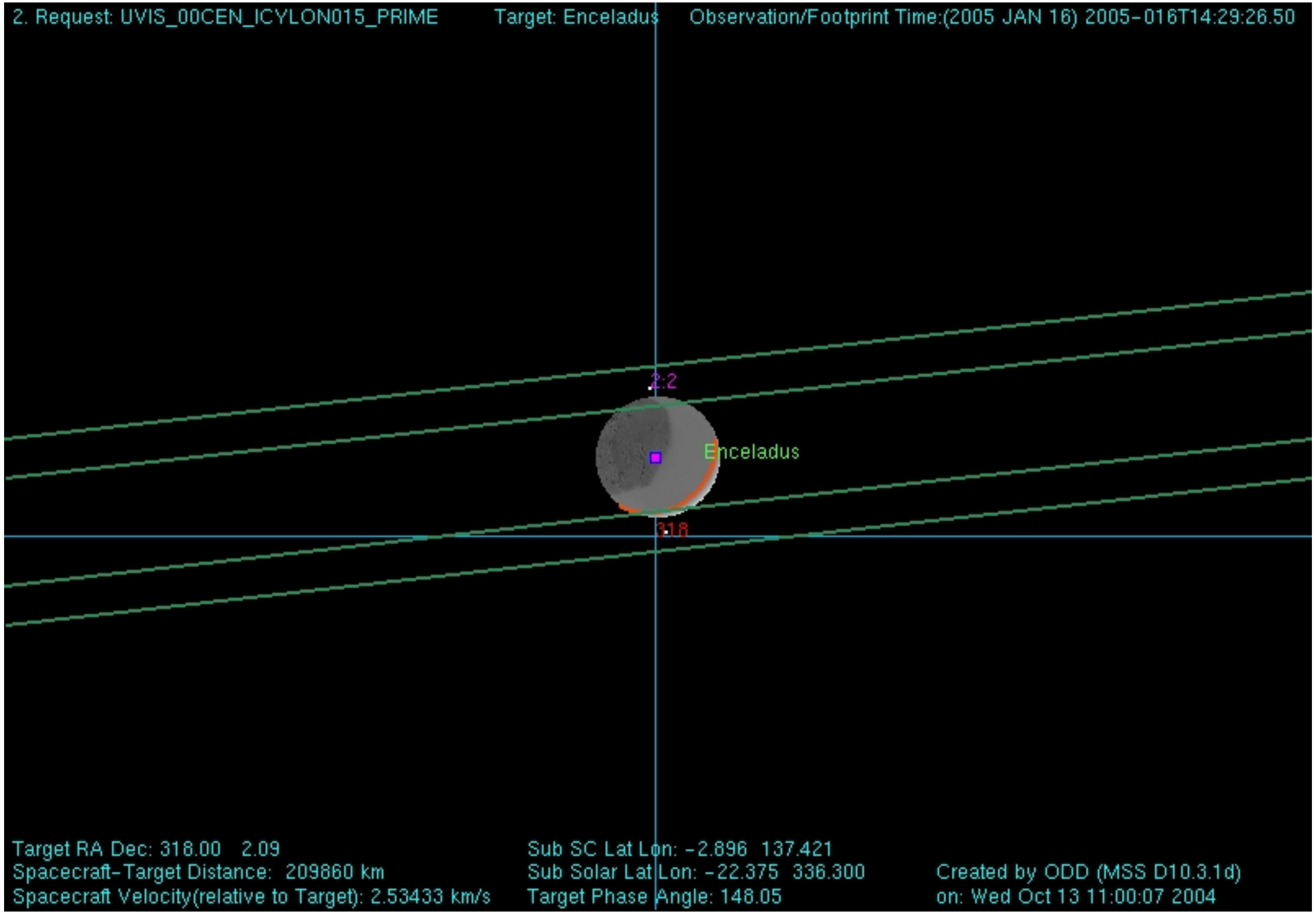
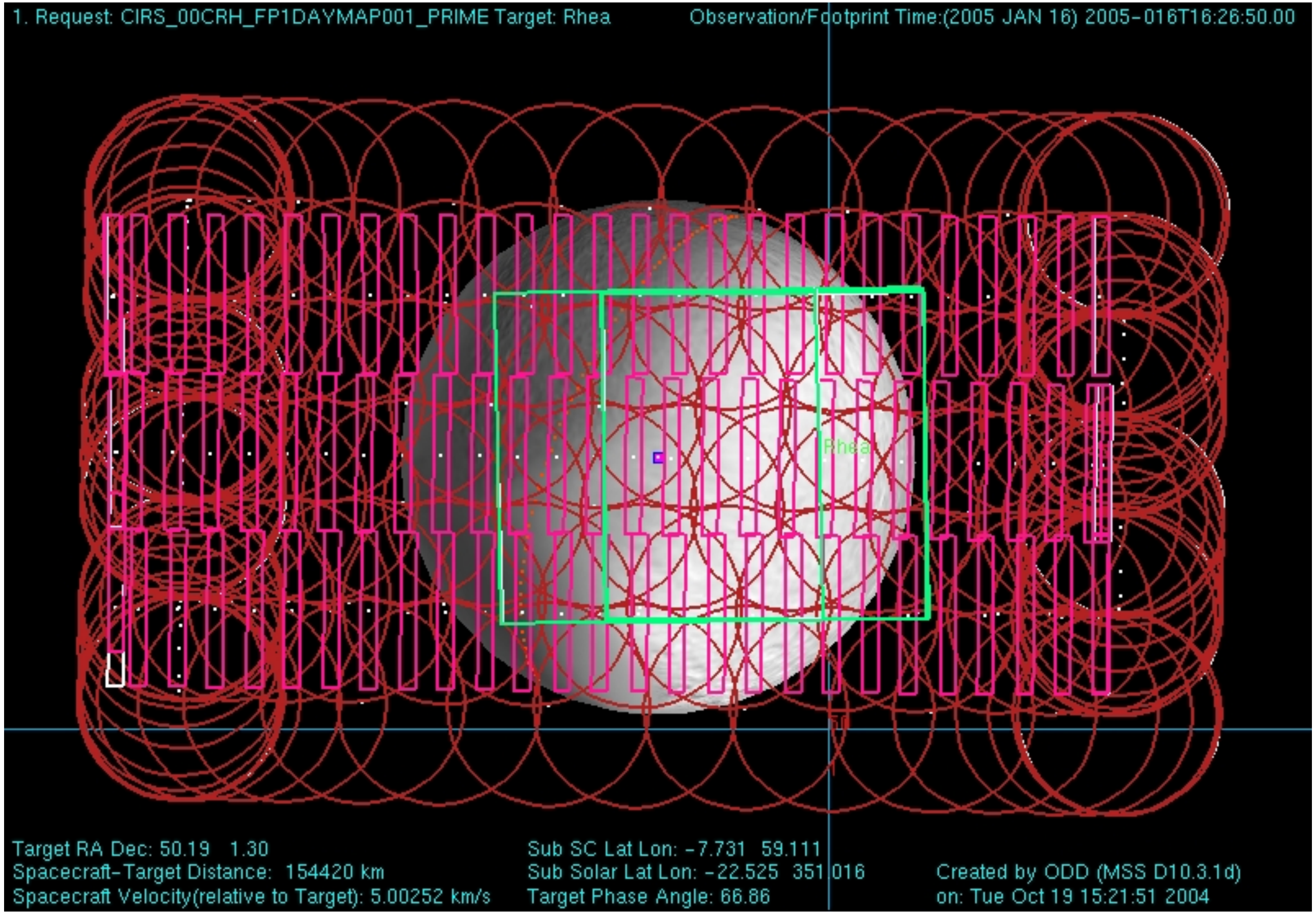

1. Request: RADAR_00CIA_SCATTRADL001_PRIMETarget: Iapetus
Observation/Footprint Time:(2005 JAN 01) 2005-001T15:00:55.37
Iapetus
-58
Target RA Dec: 282.21 -57.77
Spacecraft-Target Distance: 188514 km
Spacecraft Velocity(relative to Target): 2.03952 km/s
Sub SC Lat Lon: 44.614 297.679
Sub Solar Lat Lon: -7.474 112.785
Target Phase Angle: 142.42
Created by ODD (MSS D10.3.3)
on: Fri Oct 15 21:11:51 2004

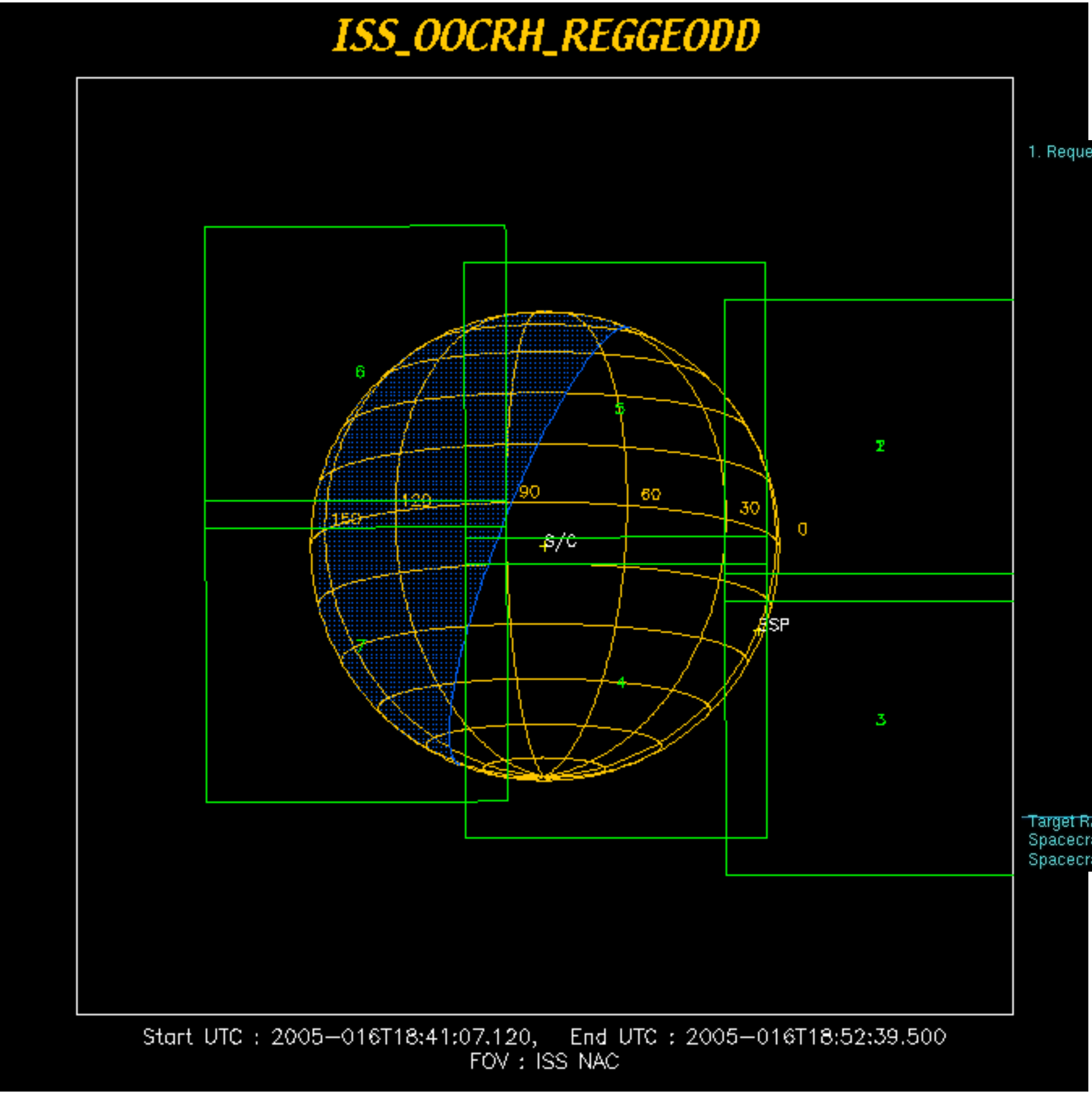

1. Request: RADAR_00CIA_SCATTRADL001_PRIMETarget: Iapetus
Observation/Footprint Time:(2005 JAN 01) 2005-001T15:00:55.37
287
279
278
Iapetus
Target RA Dec: 282.21 -57.77
Spacecraft-Target Distance: 188514 km
Spacecraft Velocity(relative to Target): 2.03952 km/s
Sub SC Lat Lon: 44.814 297.679
Sub Solar Lat Lon: -7.474 112.785
Target Phase Angle: 142.42
Created by ODD (MSS D10.3.3)
on: Fri Oct 15 21:25:37 2004

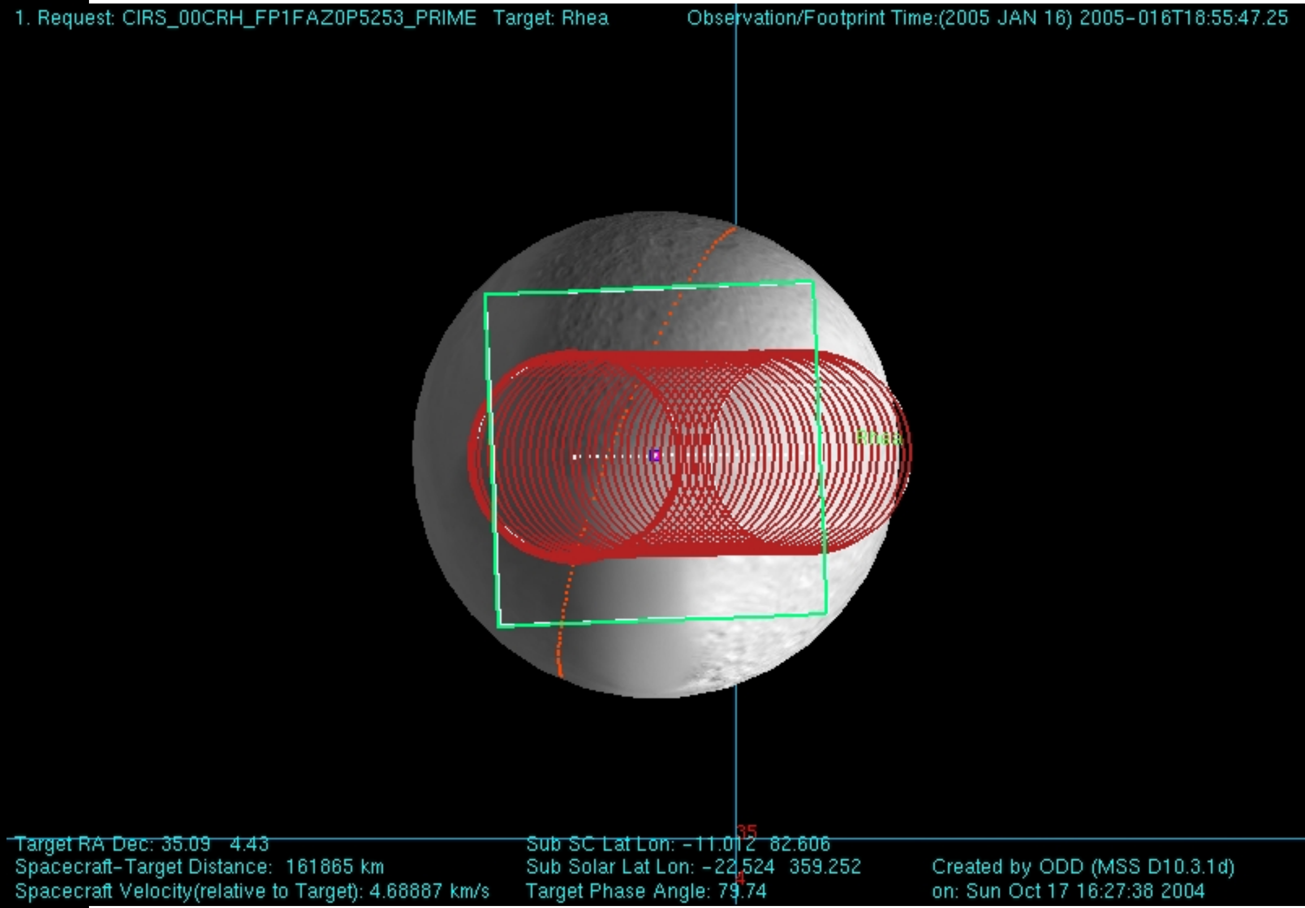
S07: Mimas, Enceladus, Rhea, Non-targeted Mosaic Designs

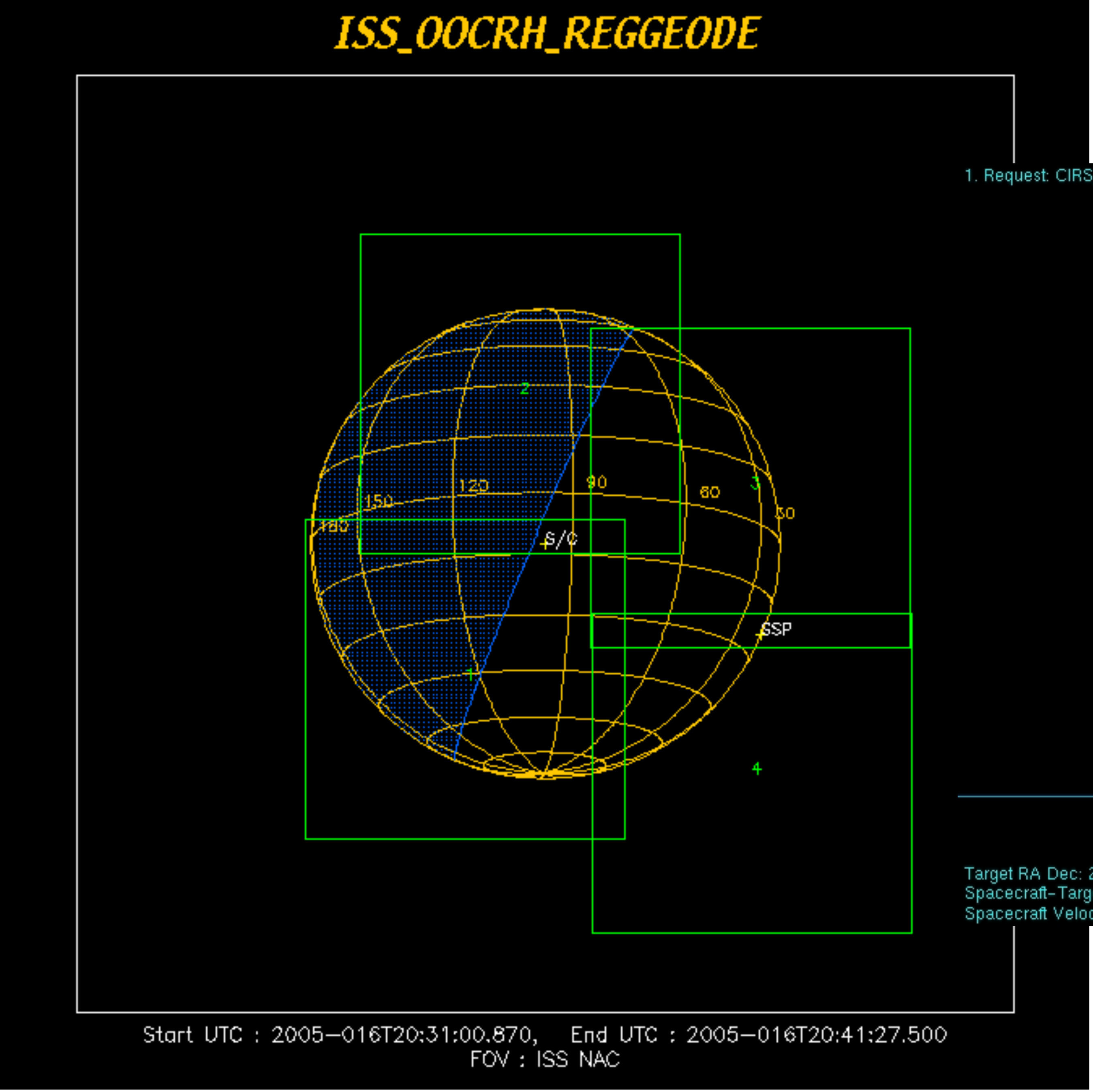

2. Request: UVIS_00CEN_ICYLON010_PRIME
Target: Enceladus
Observation/Footprint Time:(2005 JAN 16) 2005-016T02:18:43.25
229
-1
2:3
Enceladus
Target RA Dec: 229.23 -1.37
Spacecraft-Target Distance: 226404 km
Spacecraft Velocity(relative to Target): 14.1598 km/s
Sub SC Lat Lon: 8.063 90.505
Sub Solar Lat Lon: -22.319 200.091
Target Phase Angle: 112.30
Created by ODD (MSS D10.3.1d)
on: Wed Oct 13 10:10:29 2004

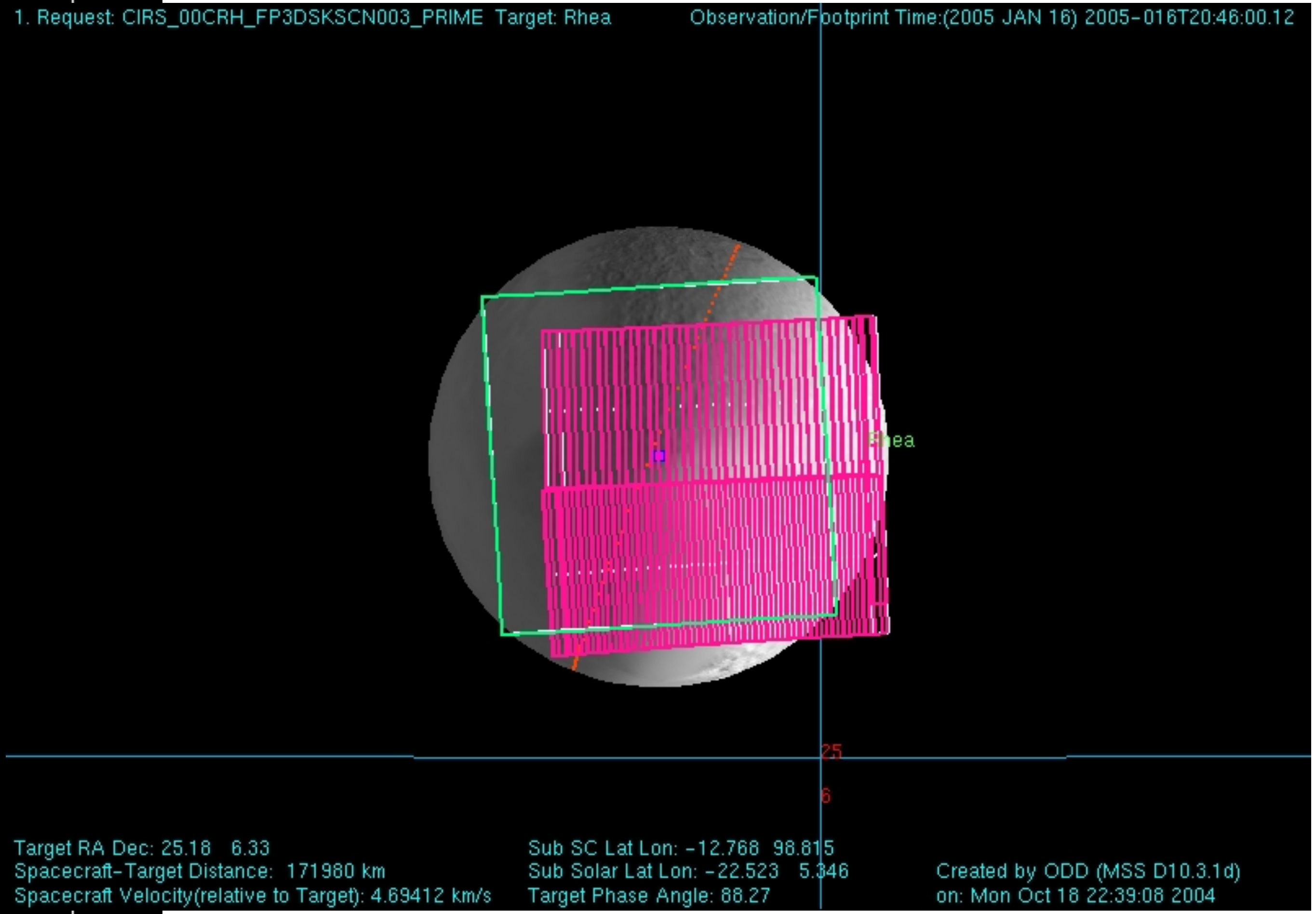

2. Request: UVIS_00CEN_ICYLON015_PRIME
Target: Enceladus
Observation/Footprint Time:(2005 JAN 16) 2005-016T14:29:26.50
Enceladus
Target RA Dec: 318.00 2.09
Spacecraft-Target Distance: 209860 km
Spacecraft Velocity(relative to Target): 2.53433 km/s
Sub SC Lat Lon: -2.896 137.421
Sub Solar Lat Lon: -22.375 336.300
Target Phase Angle: 148.05
Created by ODD (MSS D10.3.1d)
on: Wed Oct 13 11:00:07 2004

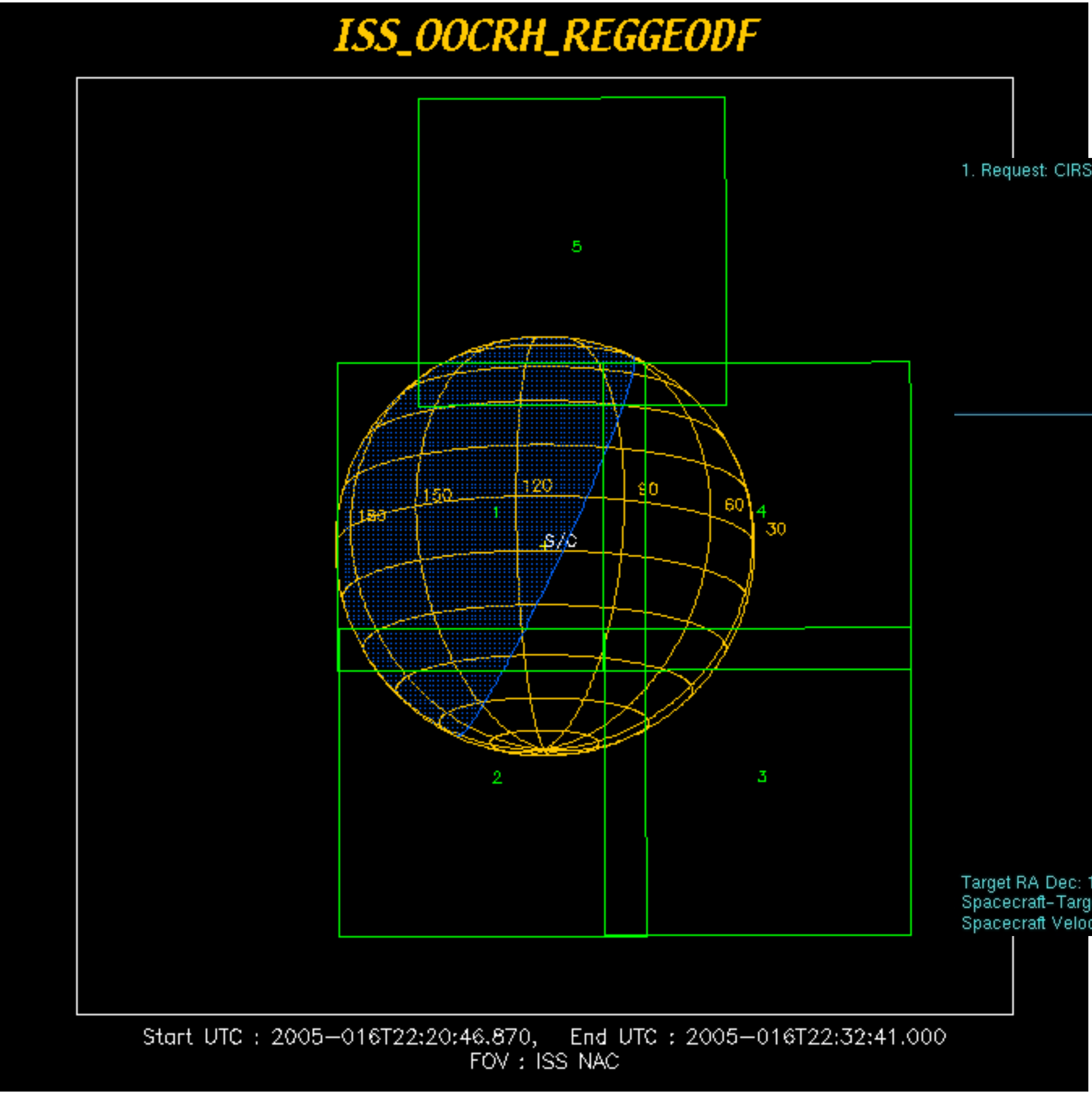

1. Request: CIRS_00CRH_FP1DAYMAP001_PRIME Target: Rhea
Observation/Footprint Time:(2005 JAN 16) 2005-016T16:26:50.00
Rhea
Target RA Dec: 50.19 1.30
Spacecraft-Target Distance: 154420 km
Spacecraft Velocity(relative to Target): 5.00252 km/s
Sub SC Lat Lon: -7.731 59.111
Sub Solar Lat Lon: -22.525 351.016
Target Phase Angle: 66.86
Created by ODD (MSS D10.3.1d)
on: Tue Oct 19 15:21:51 2004

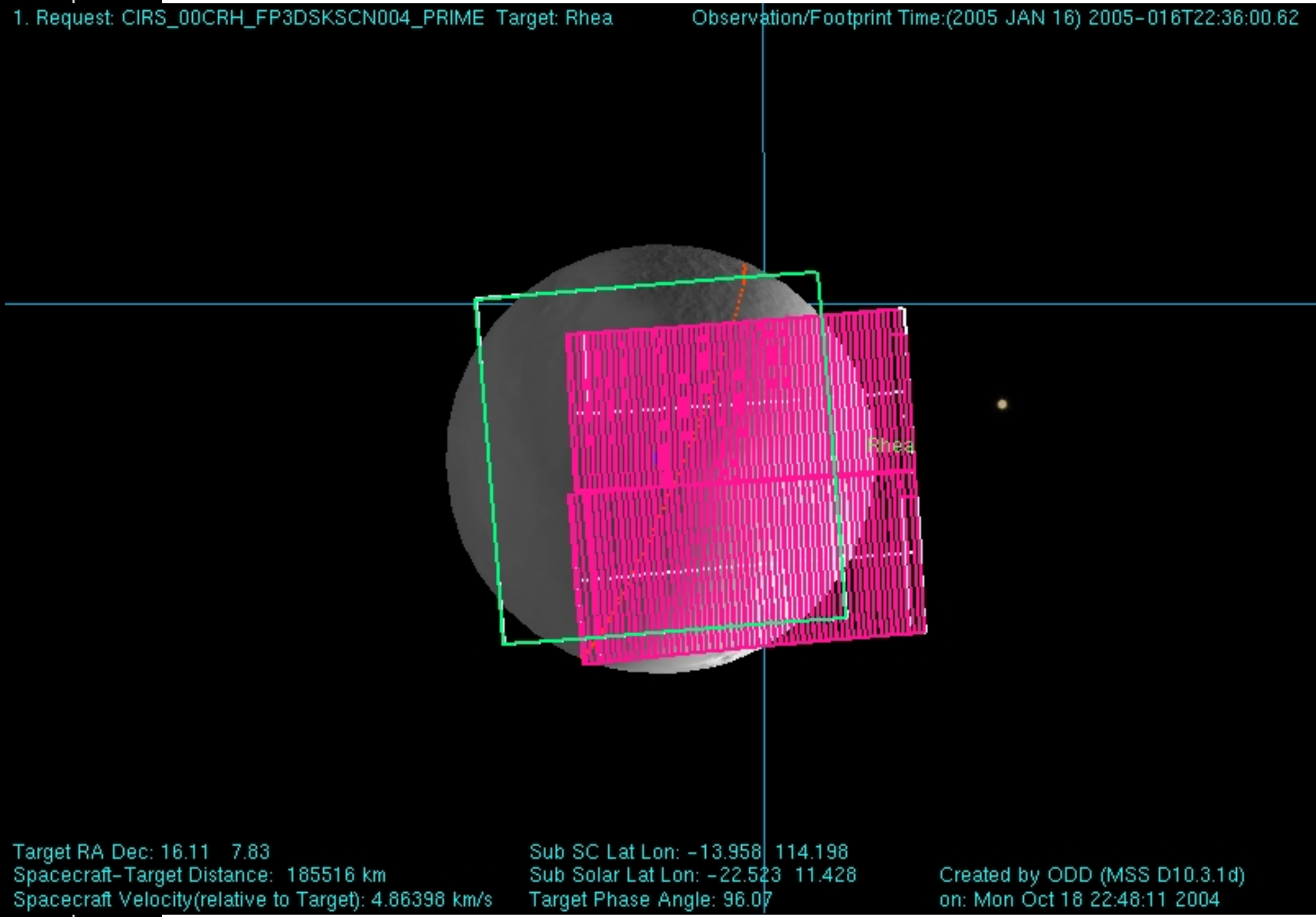

ISS_00CRH_REGGEODD
Start UTC : 2005-016T18:41:07.120, End UTC : 2005-016T18:52:39.500
FOV : ISS NAC

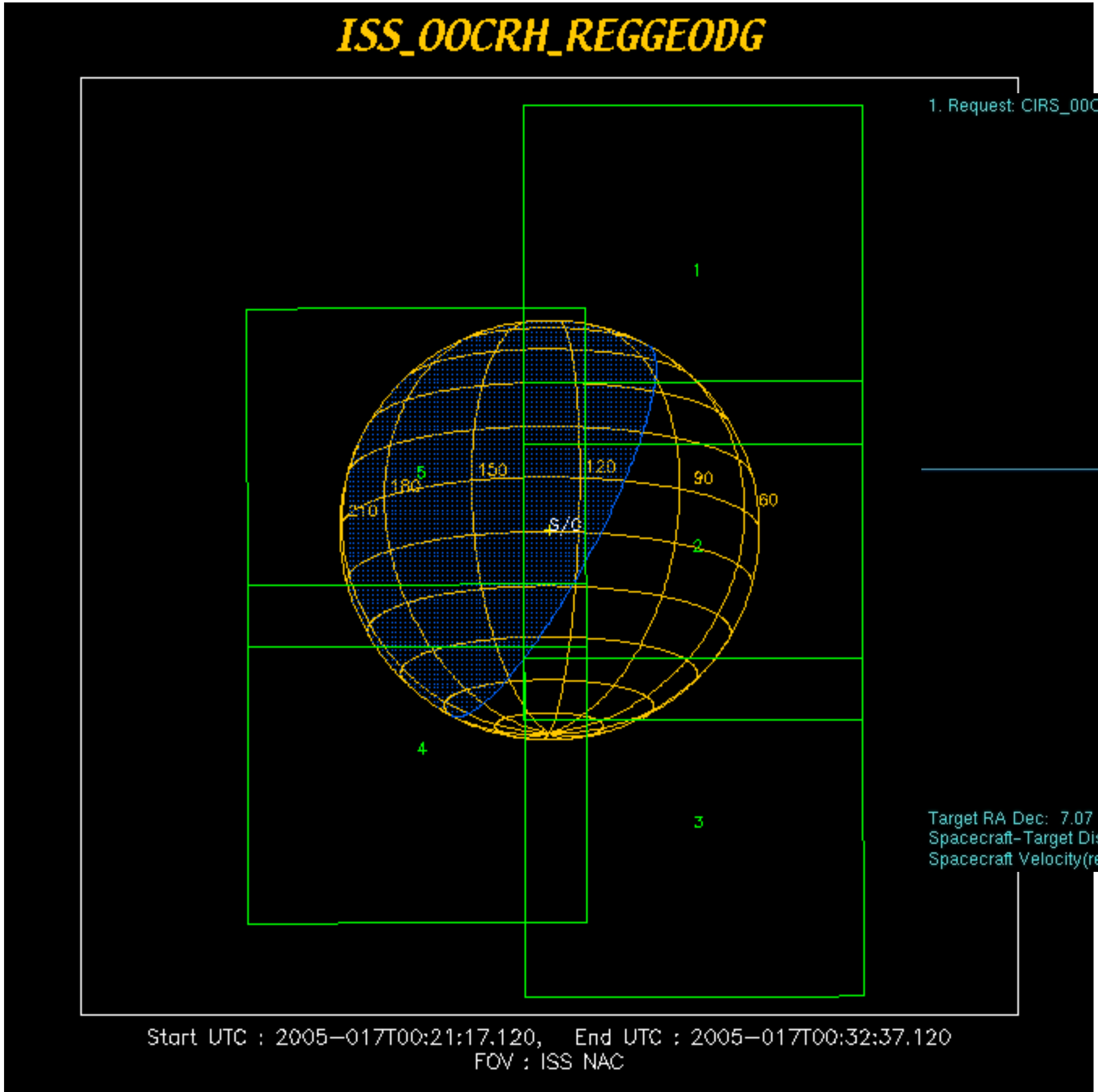

1. Request: CIRS_00CRH_FP1FAZ0P5253_PRIME Target: Rhea
Observation/Footprint Time:(2005 JAN 16) 2005-016T18:55:47.25
Target RA Dec: 35.09 4.43
Spacecraft-Target Distance: 161865 km
Spacecraft Velocity(relative to Target): 4.68887 km/s
Sub SC Lat Lon: -11.012 82.606
Sub Solar Lat Lon: -22.524 359.252
Target Phase Angle: 79.74
Created by ODD (MSS D10.3.1d)
on: Sun Oct 17 16:27:38 2004

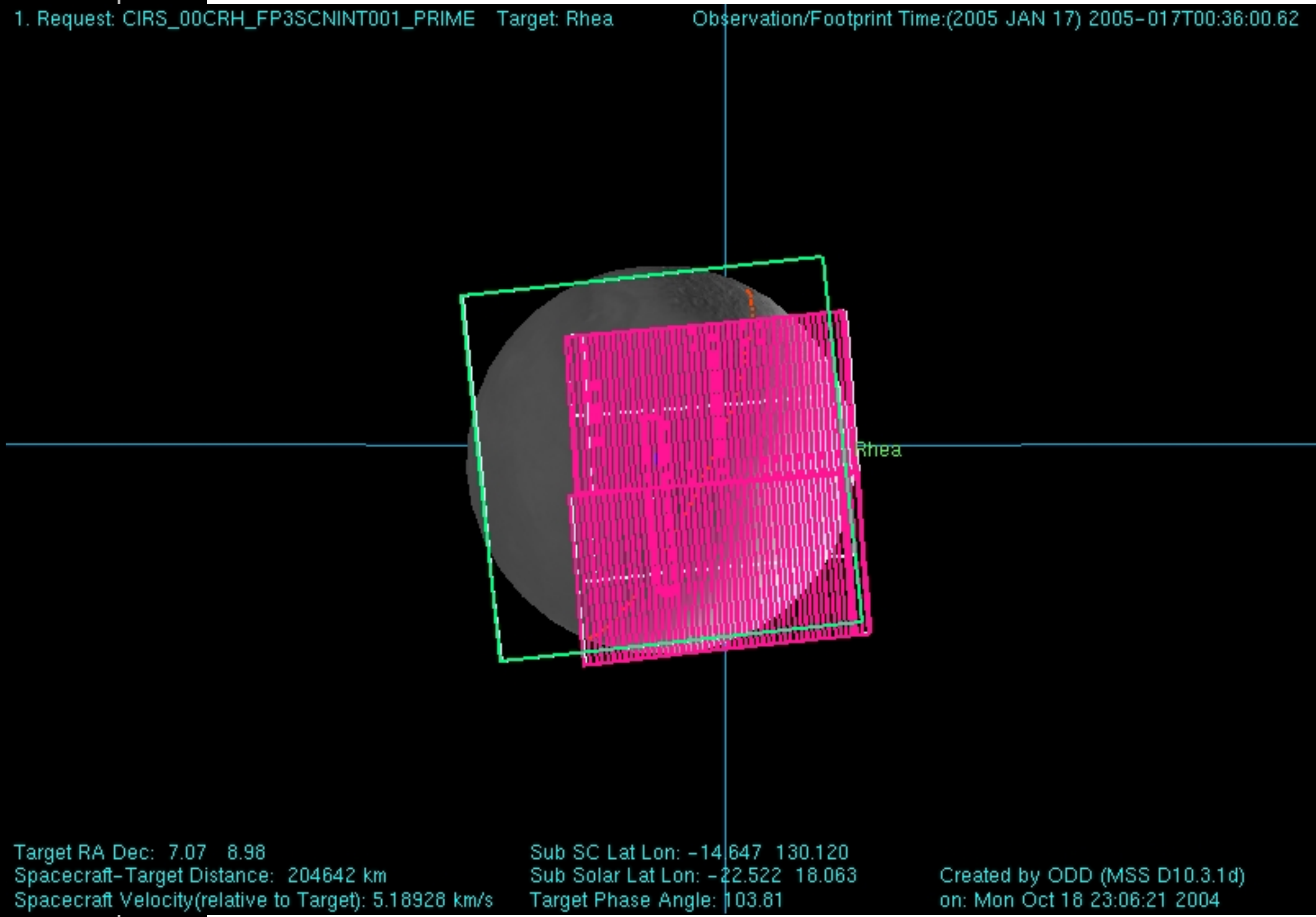

ISS_00CRH_REGGEODE
2
3
1
4
180
150
120
90
60
30
S/C
SSP
Start UTC : 2005–016T20:31:00.870, End UTC : 2005–016T20:41:27.500
FOV : ISS NAC


1. Request: CIRS_00CRH_FP3DSKSCN003_PRIME Target: Rhea
Observation/Footprint Time:(2005 JAN 16) 2005-016T20:46:00.12
Rhea
25
6
Target RA Dec: 25.18 6.33
Spacecraft-Target Distance: 171980 km
Spacecraft Velocity(relative to Target): 4.69412 km/s
Sub SC Lat Lon: -12.768 98.815
Sub Solar Lat Lon: -22.523 5.346
Target Phase Angle: 88.27
Created by ODD (MSS D10.3.1d)
on: Mon Oct 18 22:39:08 2004


ISS_00CRH_REGGEODF
5
150
120
90
60
4
30
180
1
S/C
2
3
Start UTC : 2005−016T22:20:46.870,   End UTC : 2005−016T22:32:41.000
FOV : ISS NAC


1. Request: CIRS_00CRH_FP3DSKSCN004_PRIME Target: Rhea
Observation/Footprint Time:(2005 JAN 16) 2005-016T22:36:00.62
Rhea
Target RA Dec: 16.11   7.83
Spacecraft-Target Distance: 185516 km
Spacecraft Velocity(relative to Target): 4.86398 km/s
Sub SC Lat Lon: -13.958 114.198
Sub Solar Lat Lon: -22.523 11.428
Target Phase Angle: 96.07
Created by ODD (MSS D10.3.1d)
on: Mon Oct 18 22:48:11 2004


ISS_OOCRH_REGGEODG
1
2
3
4
5
210
180
150
120
90
60
S/C
Start UTC : 2005-017T00:21:17.120, End UTC : 2005-017T00:32:37.120
FOV : ISS NAC


1. Request: CIRS_00CRH_FP3SCNINT001_PRIME Target: Rhea
Observation/Footprint Time:(2005 JAN 17) 2005-017T00:36:00.62
Rhea
Target RA Dec: 7.07 8.98
Spacecraft-Target Distance: 204642 km
Spacecraft Velocity(relative to Target): 5.18928 km/s
Sub SC Lat Lon: -14.647 130.120
Sub Solar Lat Lon: -22.522 18.063
Target Phase Angle: 103.81
Created by ODD (MSS D10.3.1d)
on: Mon Oct 18 23:06:21 2004