Compositional Mapping of Saturn's Satellites with Cassini VIMS

Dr. Roger N. Clark
Cassini Visual and Infrared
Mapping Spectrometer
(VIMS)

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Denver, Colorado

Compositional Mapping of Saturn's Satellite Dione with Cassini VIMS and Implications for Dark Material in the Saturn System

This Charm talk is based on a paper of the same title being submitted to the Icy Satellites Cassini *Icarus* special issue

Authors:

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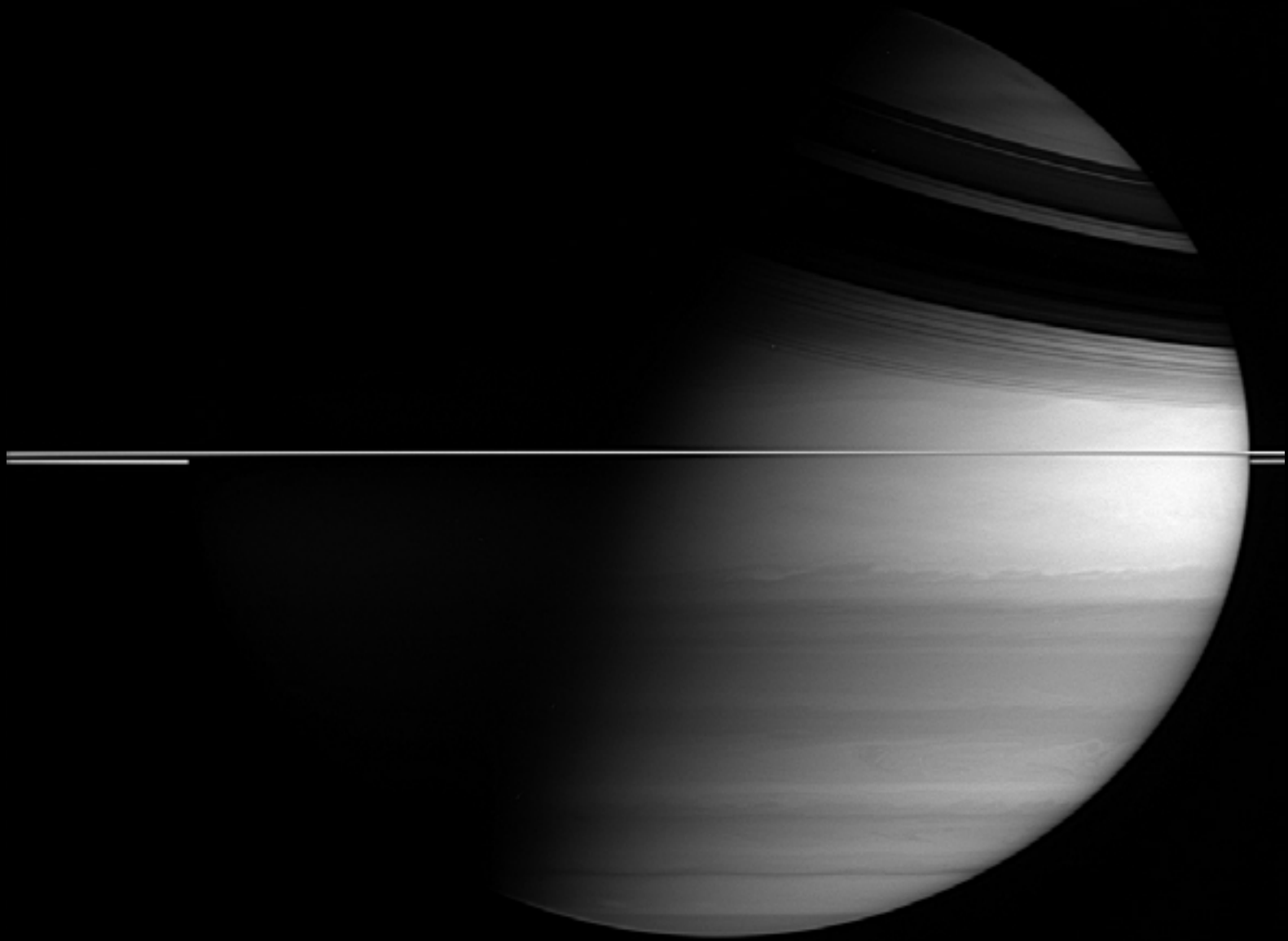
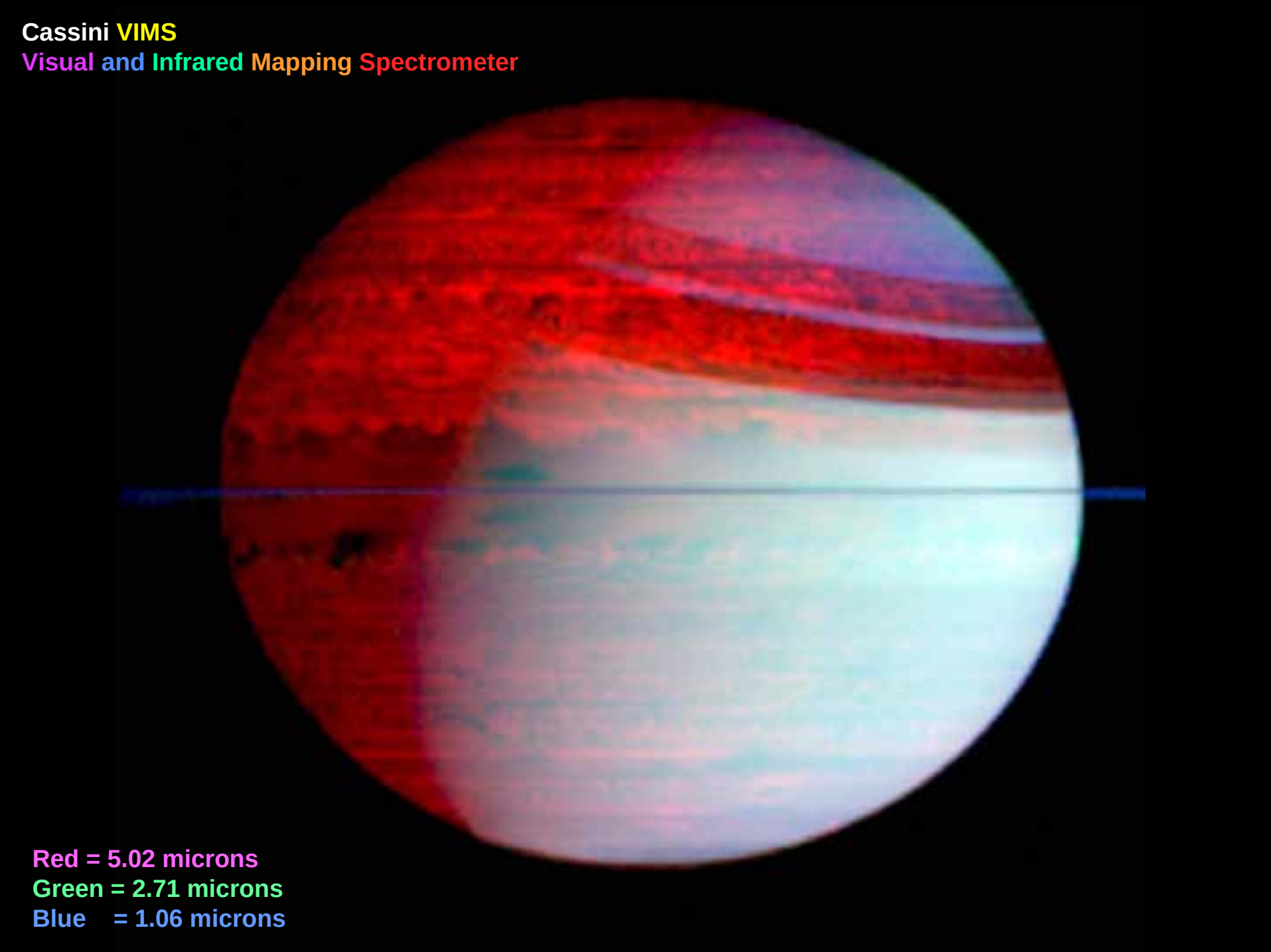
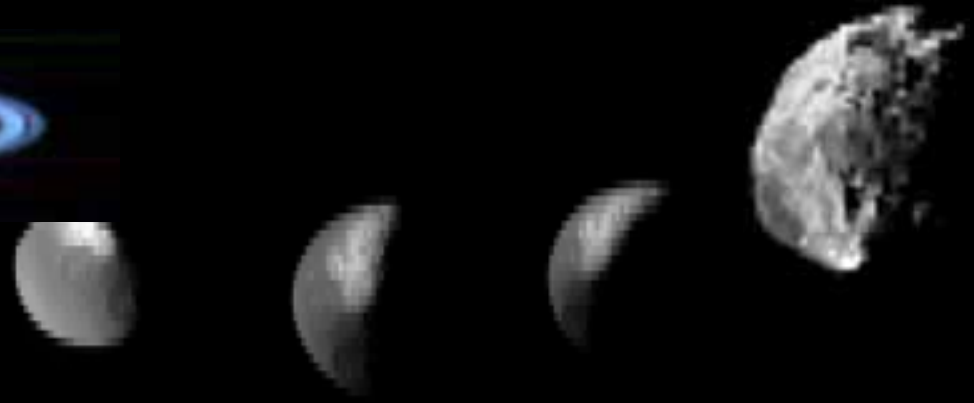
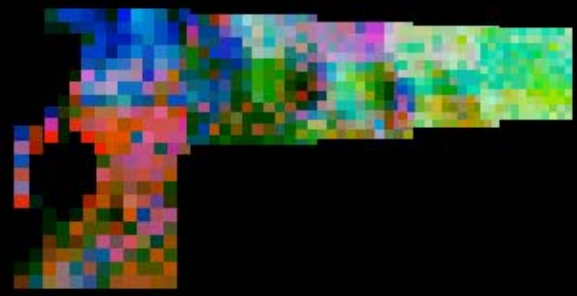
Light passing through Cassini division
Saturn
Mimas
C Ring Shadows
B Ring Shadow
F Ring
A Ring

Cassini ISS:
Imaging Science Subsystem




Cassini VIMS
Visual and Infrared Mapping Spectrometer
Red = 5.02 microns
Green = 2.71 microns
Blue = 1.06 microns



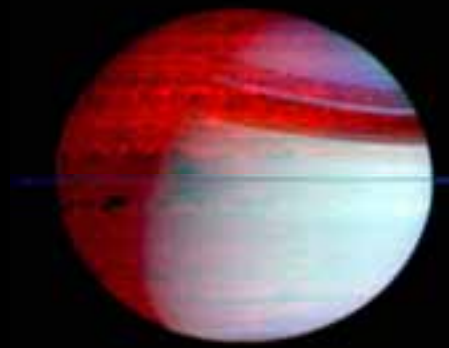


RGB Mineral Map:
Red =CO2 at 4.26 microns
Green = 1-micron albedo
Blue = 2-micron Ice

VIMS

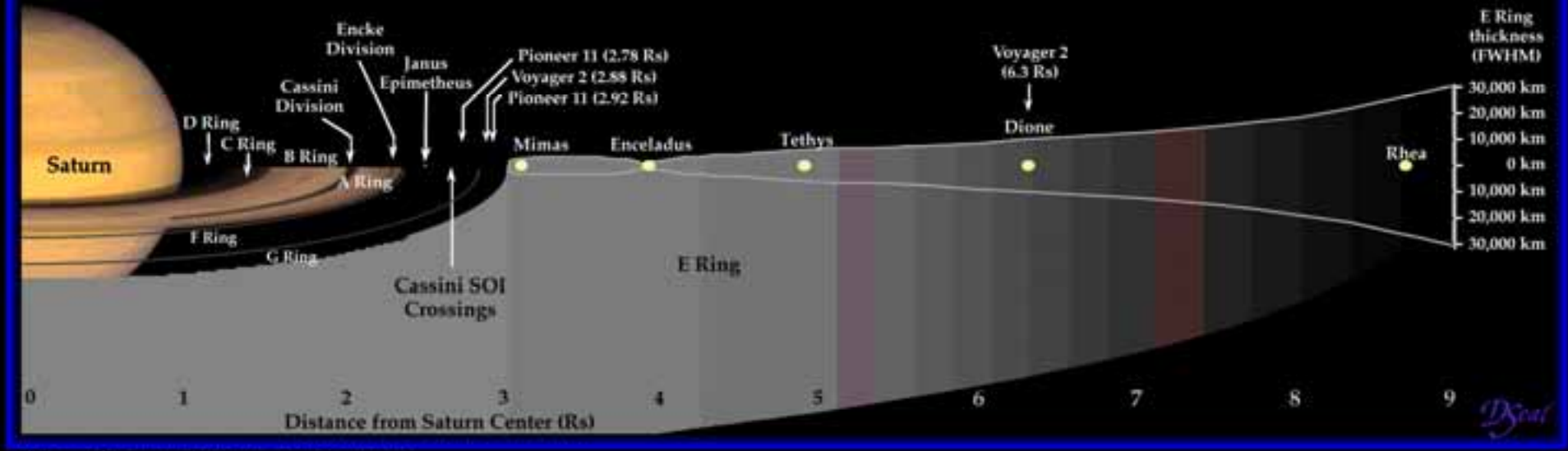
Visual and Infrared Mapping Spectrometer

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



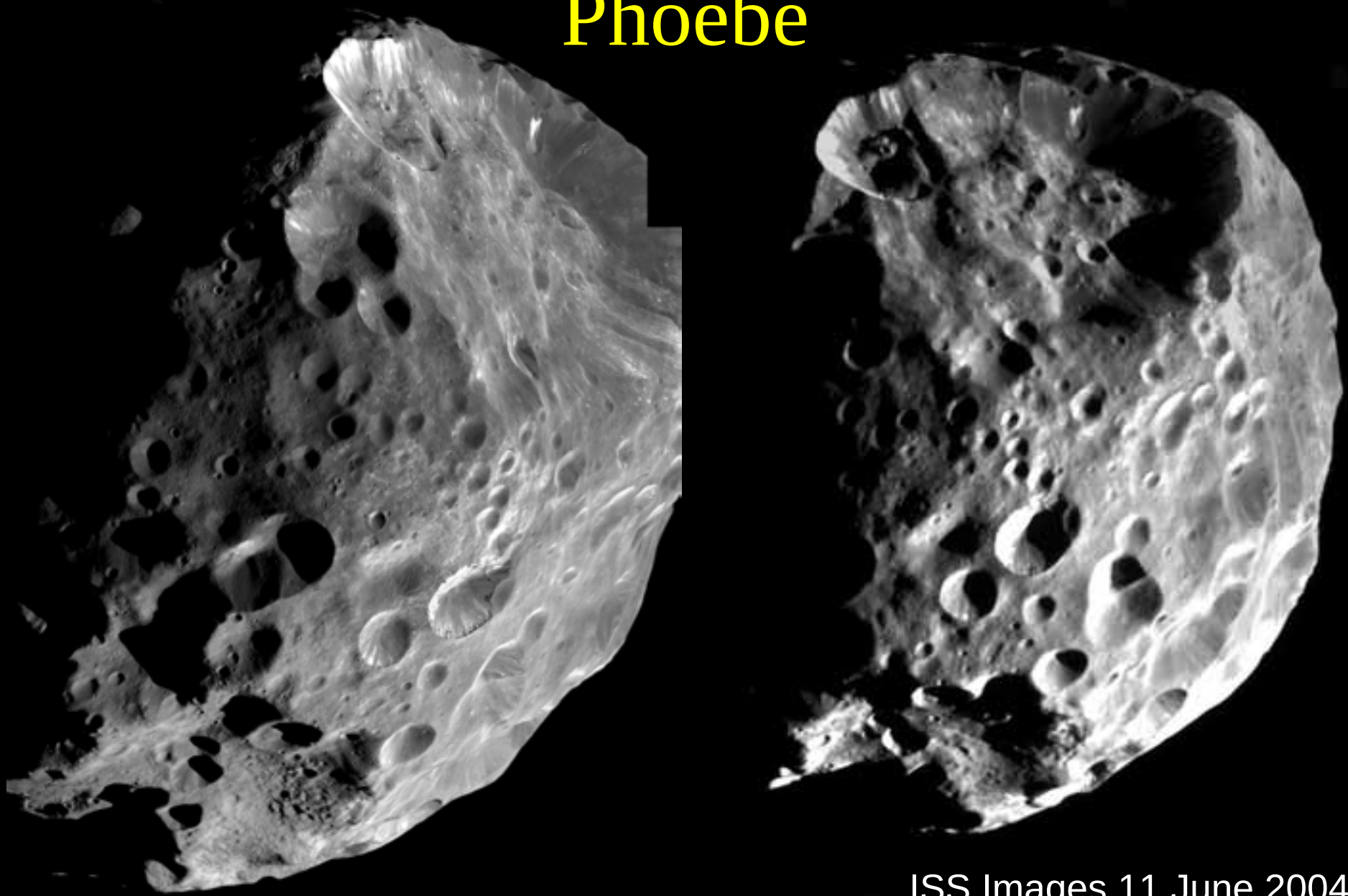
Saturn's Satellites and Ring Structure

Not shown:				
	Pan	2.22 Rs	Titan	20.3 Rs
	Atlas	2.28 Rs	Hyperion	24.6 Rs
	Prometheus	2.31 Rs	Iapetus	59.1 Rs
	Pandora	2.35 Rs	Phoebe	214.9 Rs

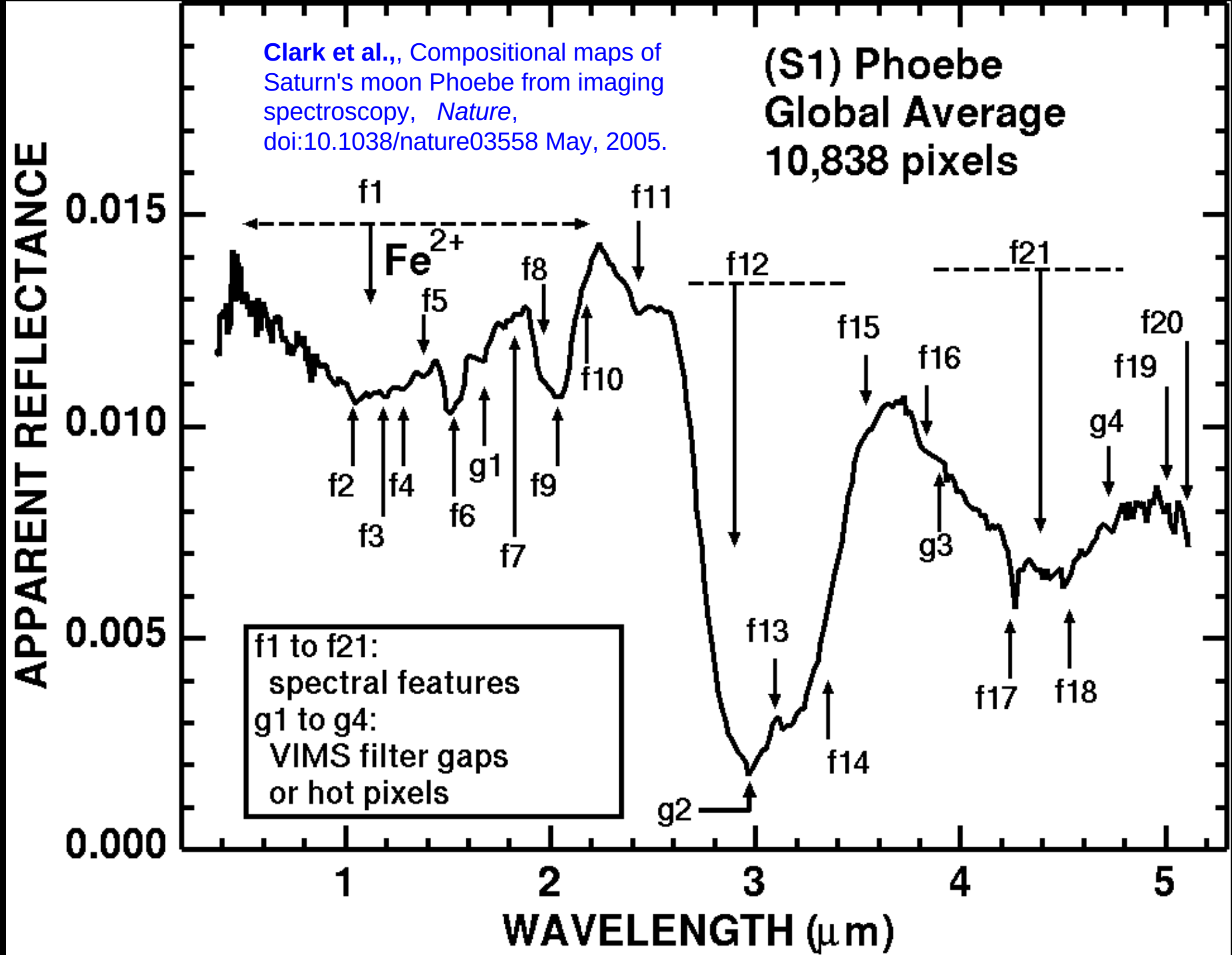


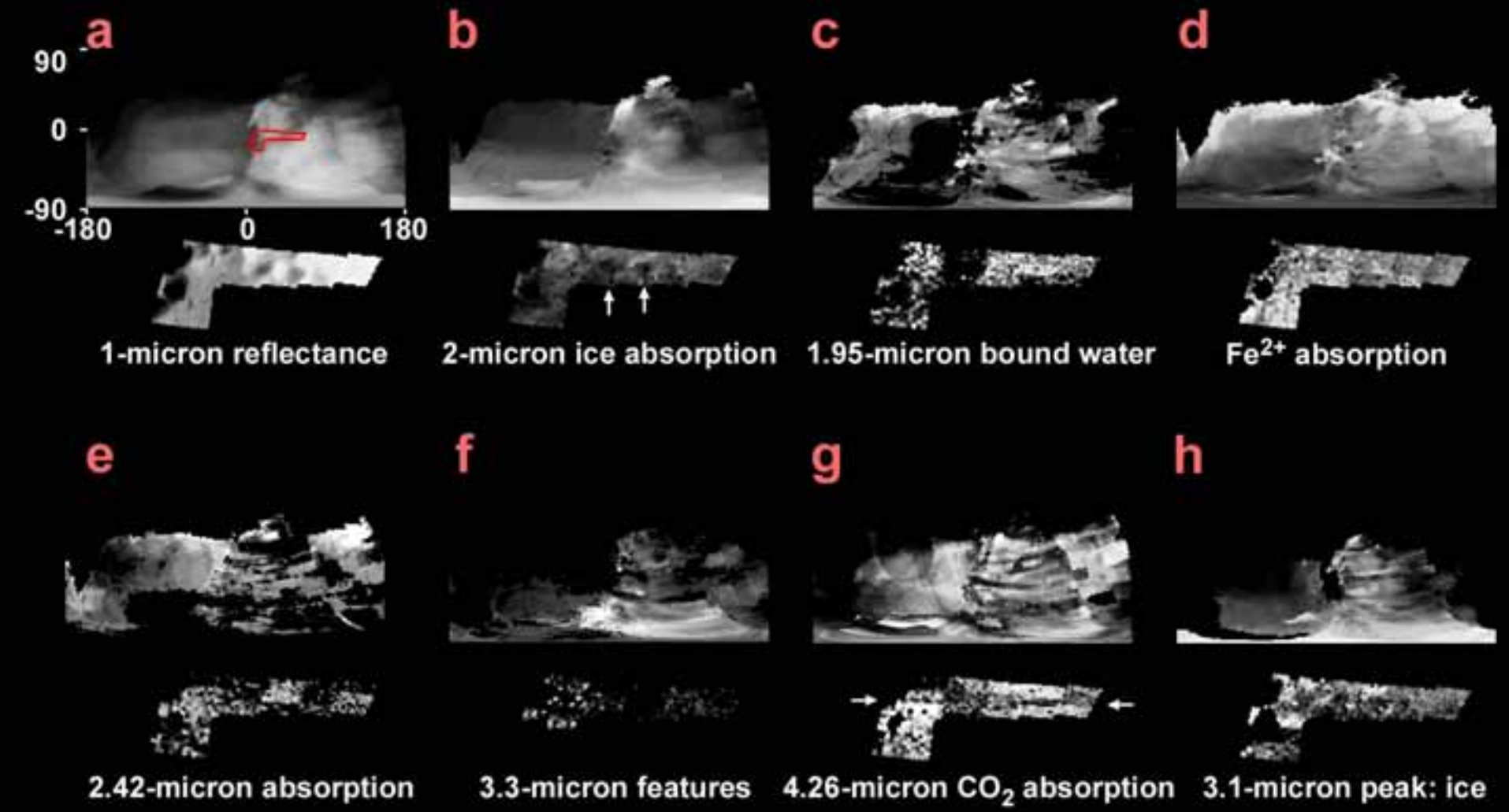
This graphic is available in color if required.

Phoebe

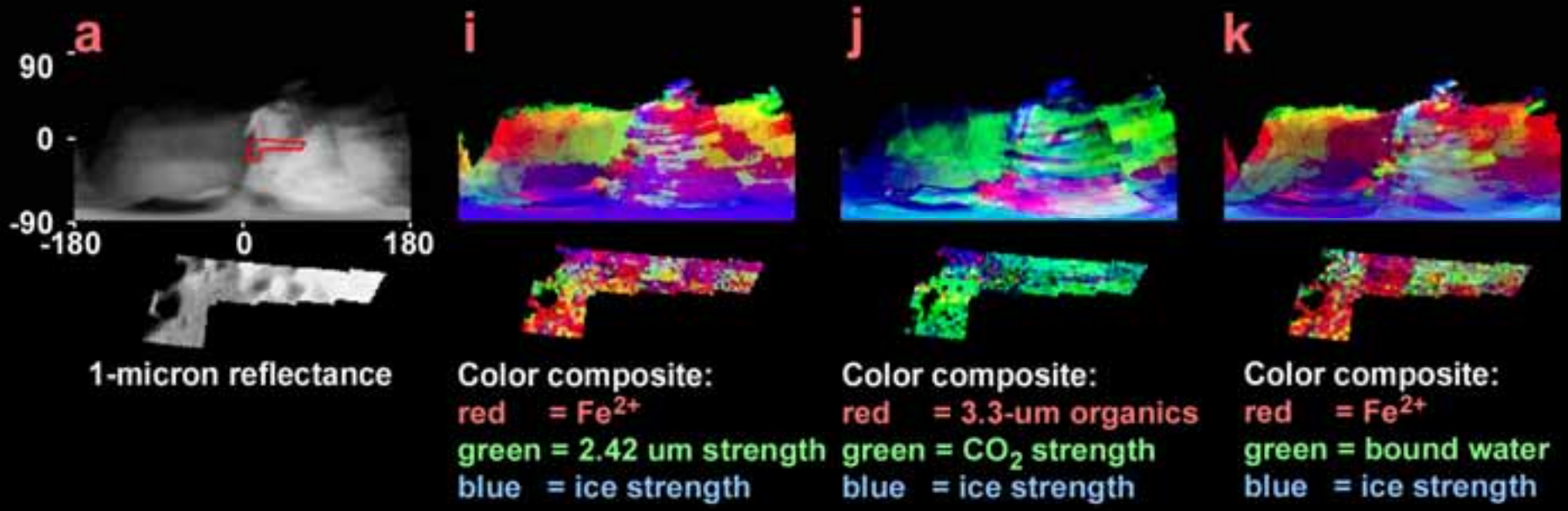


ISS Images 11 June 2004


Clark et al., Compositional maps of Saturn's moon Phoebe from imaging spectroscopy, Nature, doi:10.1038/nature03558 May, 2005.
(S1) Phoebe
Global Average
10,838 pixels
APPARENT REFLECTANCE
0.015
0.010
0.005
0.000
1
2
3
4
5
WAVELENGTH (μm)
f1
Fe2+
f2
f3
f4
f5
f6
g1
f7
f8
f9
f10
f11
f12
f13
g2
f14
f15
f16
g3
f17
f18
f19
g4
f20
f21
f1 to f21:
spectral features
g1 to g4:
VIMS filter gaps
or hot pixels

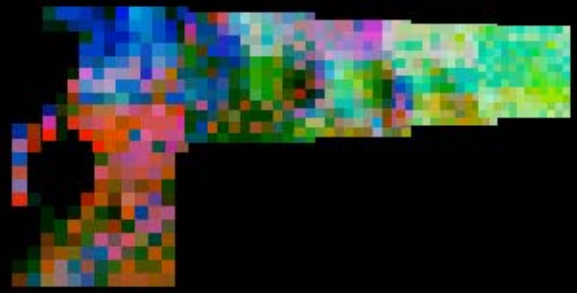


Clark et al.,, Compositional maps of Saturn's moon Phoebe from imaging spectroscopy, *Nature*, doi:10.1038/nature03558 May, 2005.



Clark et al.,, Compositional maps of Saturn's moon Phoebe from imaging spectroscopy, *Nature*, doi:10.1038/nature03558 May, 2005.

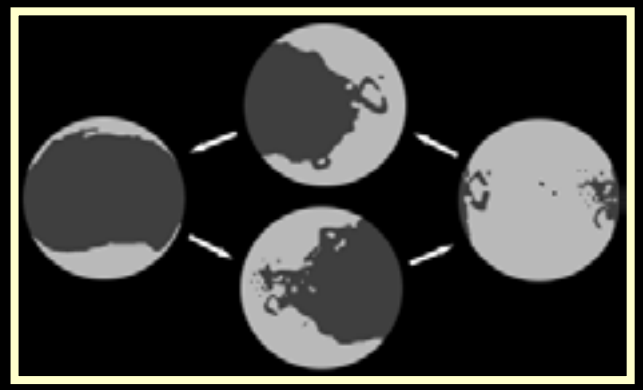
Detection of Multiple Components on Phoebe with VIMS



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

- Water Ice
- Bound Water
- Trapped CO_2
- Broad 1-micron feature (Fe^{2+})
- 2.2-micron feature (probable Al-OH, phyllosilicates)
- 2.42-micron feature (cyanide compounds?)
- 3.3-micron features (probable organics)
- 3.6 micron feature (origin ?)
- Broad 3.8-micron feature (origin ?)
- Broad 4.5-micron feature (origin ?)
- 4.51-micron feature (probable Nitrile, a CN compound)

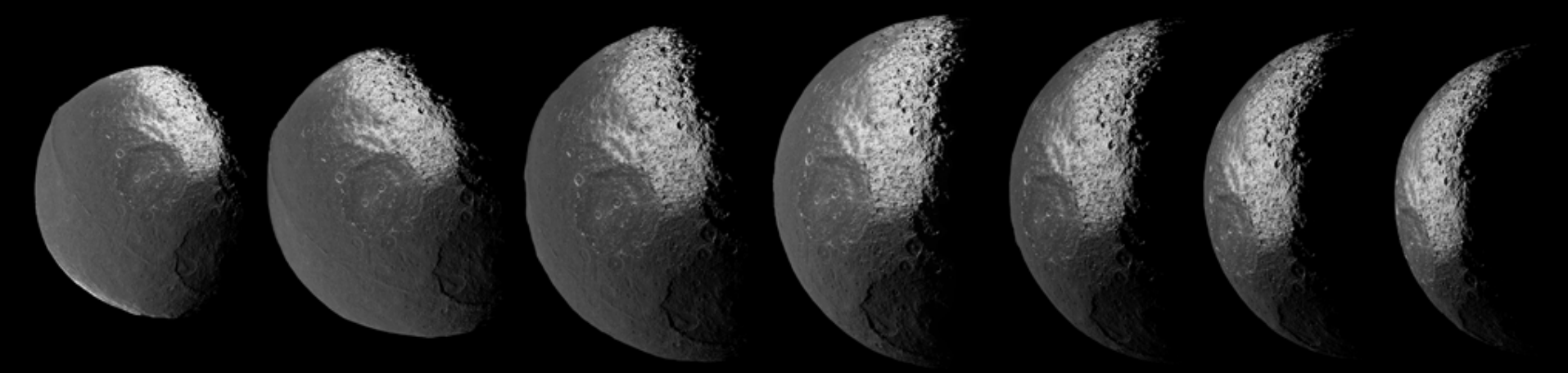
Iapetus



730 km in radius
inclined orbit (15°)
59 R_S orbit
extremely dark leading hemisphere

ISS_00CIA_GLOBCOLA001 (1030 m/pxl)

31 December 2004

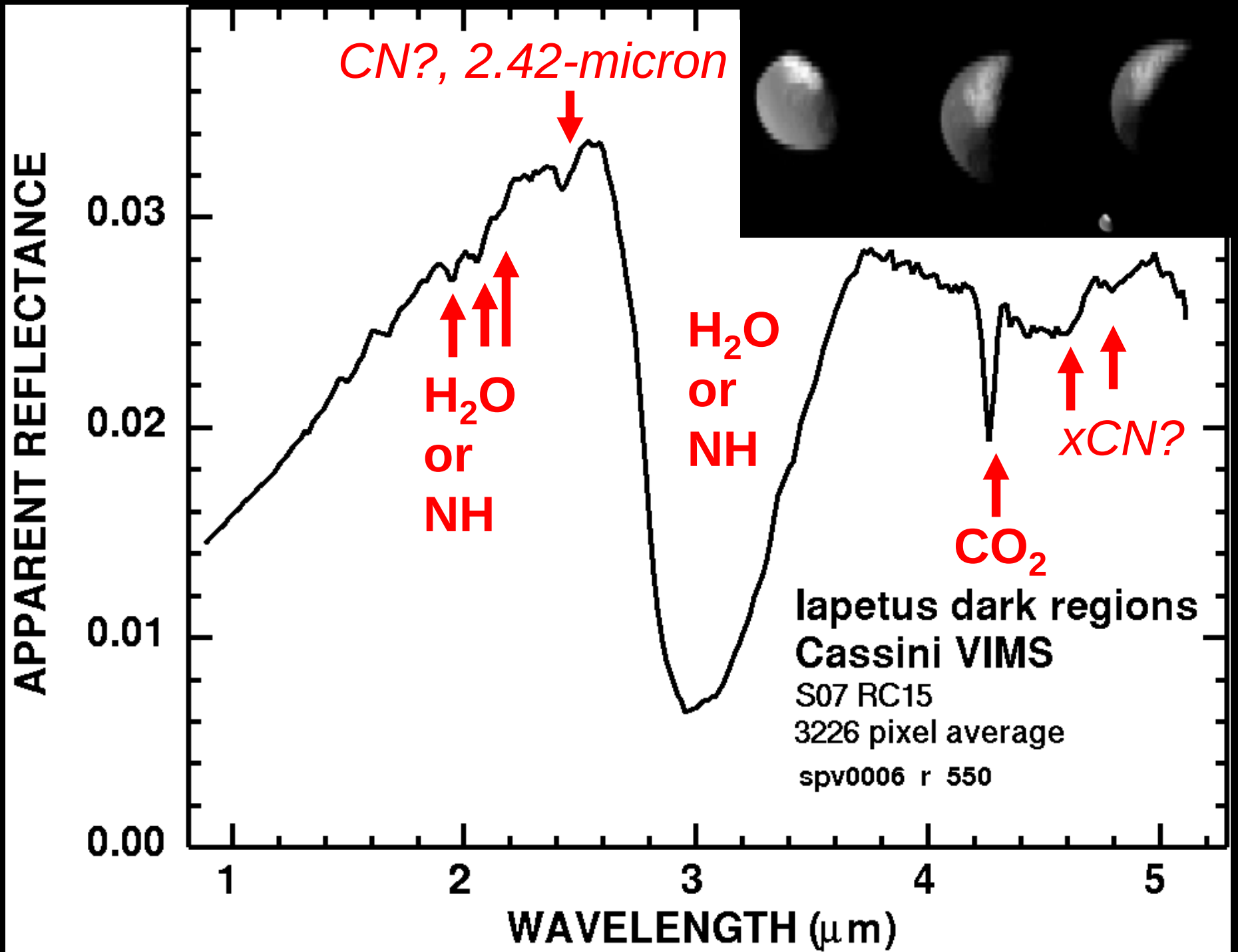


- What is the source of Iapetus' striking albedo dichotomy?
  - Iapetus' leading hemisphere is dark (~4%) and reddish
  - Iapetus' trailing hemisphere is bright (~60%) and contains water ice
- Endogenic source?
- Exogenic source?

  Phoebe? Hyperion? Titan (tholins)?
- Why is Iapetus' orbit inclined?
- What is the source of the equatorial "belt"?
  - ~2000 km long chain of mountains, 20 km high (65,000 feet)
  - Aligned along the equator

Iapetus

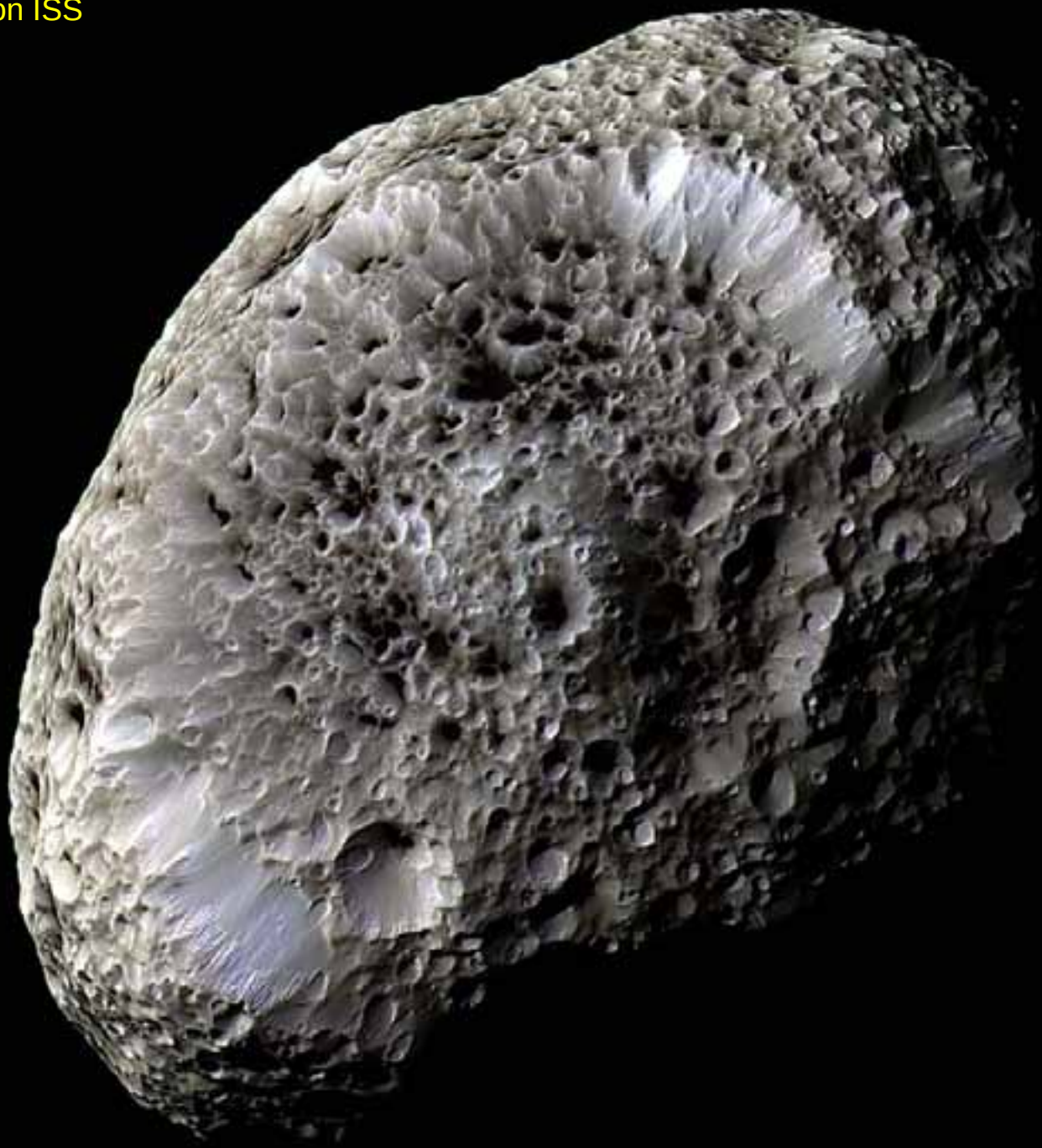
Dark material streaks
in transition zone


CN?, 2.42-micron
H2O or NH
H2O or NH
CO2
xCN?
Iapetus dark regions
Cassini VIMS
S07 RC15
3226 pixel average
spv0006 r 550
APPARENT REFLECTANCE
0.00
0.01
0.02
0.03
1
2
3
4
5
WAVELENGTH (μm)

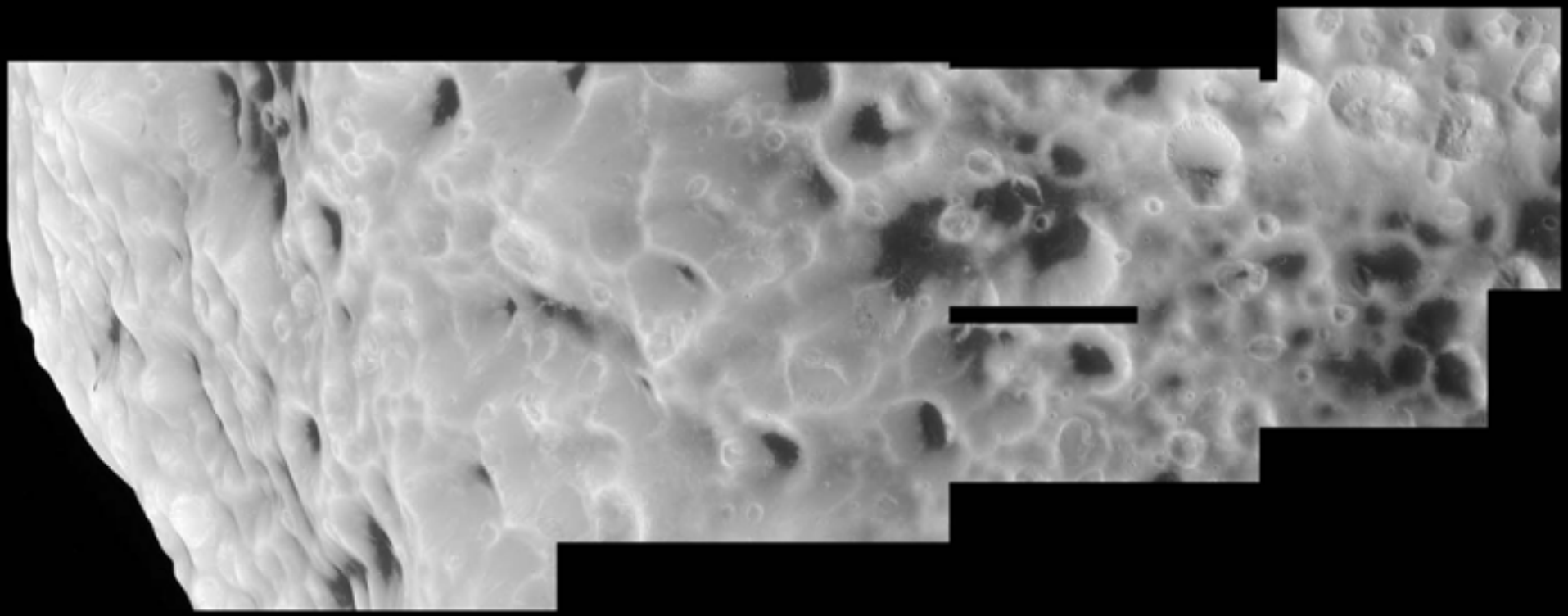
VIMS Iapetus Conclusions

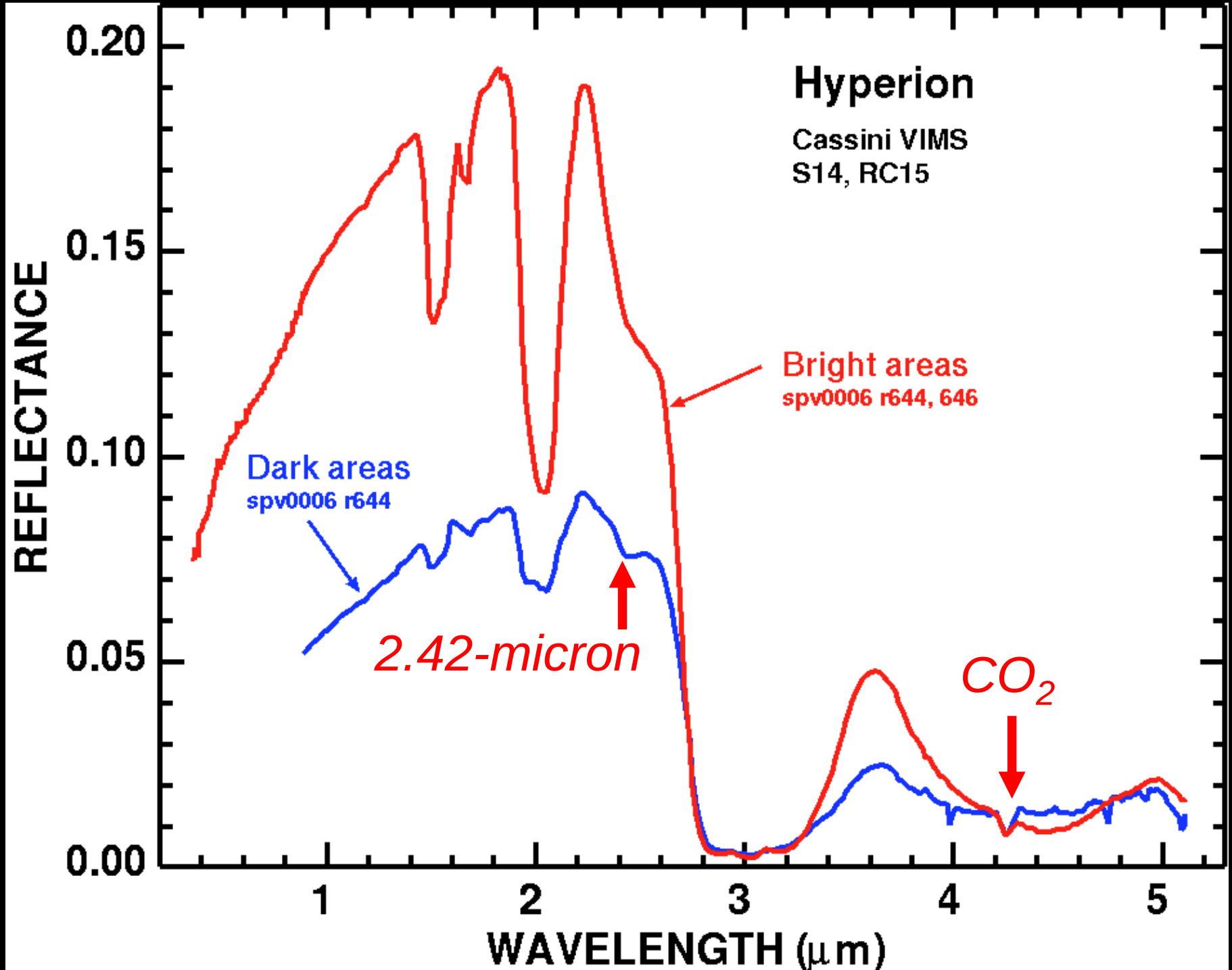
- **Several compounds are common on both Phoebe and Iapetus:**
  - **Cyanide(?) Compounds (2.42 and 4.7-4.8 micron features)**
  - **Trapped CO_2 (4.26 microns)**
  - **Bound Water as well as H_2O, trace organics.**
- **But Phoebe has more diversity in compounds *(detected so far)* including Fe^{2+}, probable nitriles.**
- **Iapetus has CO_2 frost but Phoebe does not.**

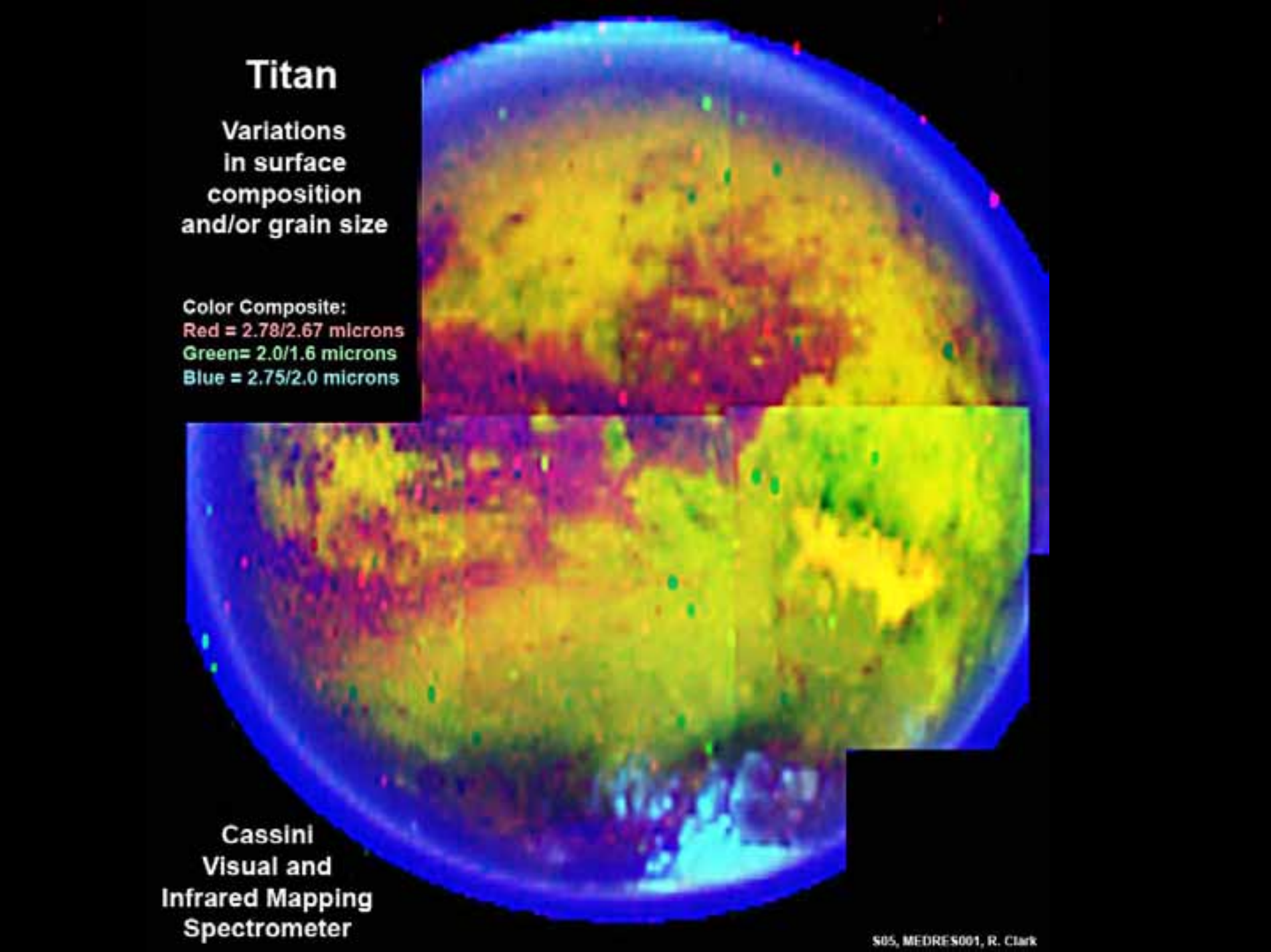
Hyperion ISS



Hyperion ISS

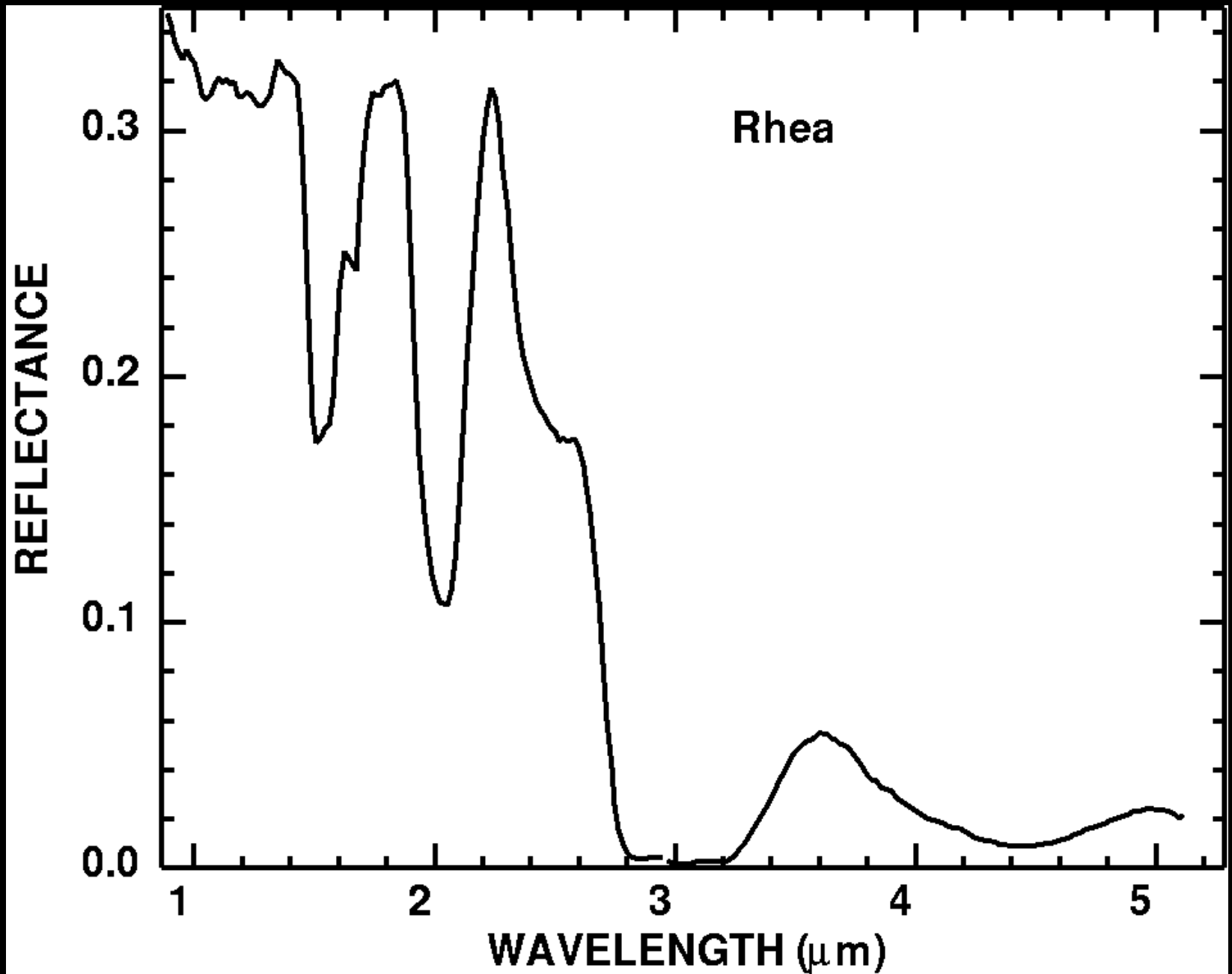



Hyperion
Cassini VIMS
S14, RC15
Bright areas
spv0006 r644, 646
Dark areas
spv0006 r644
2.42-micron
CO_2
REFLECTANCE
WAVELENGTH (μm)
0.20
0.15
0.10
0.05
0.00
1
2
3
4
5


Titan
Variations in surface composition and/or grain size
Color Composite:
Red = 2.78/2.67 microns
Green= 2.0/1.6 microns
Blue = 2.75/2.0 microns
Cassini Visual and Infrared Mapping Spectrometer
S05, MEDRES001, R. Clark


Targeted flyby on Rev 18 (ORS+RSS+RADAR);
Quasi-targeted flyby on Rev 49 (ORS+RADAR)
Rhea
765 km in radius
8.74 R_S orbit
light wispy streaks on anti-Saturn hemisphere

Rhea: all Ice

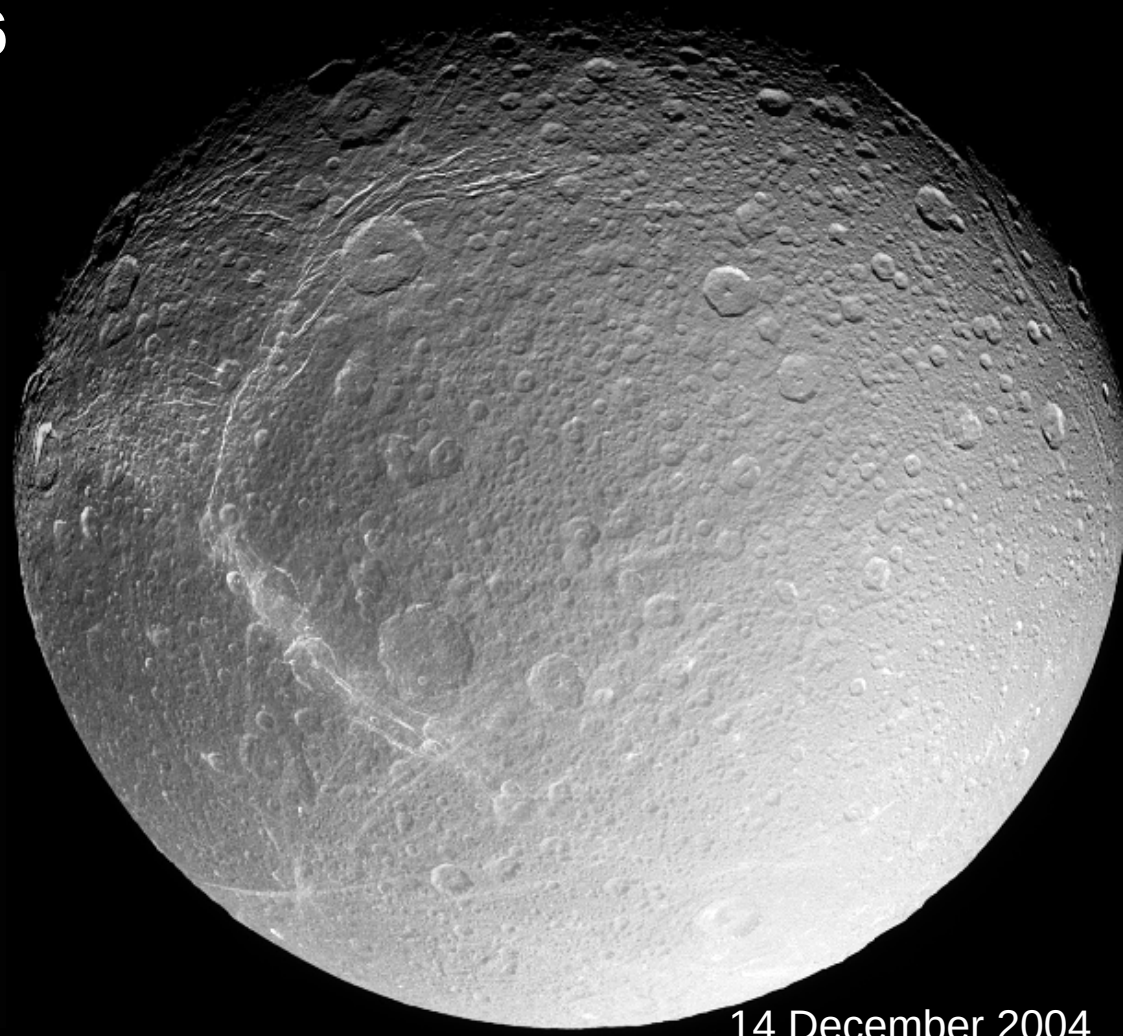


Dione:

Targeted flyby on Rev 16

(ORS, RSS, RADAR)

Close flyby on Rev 50

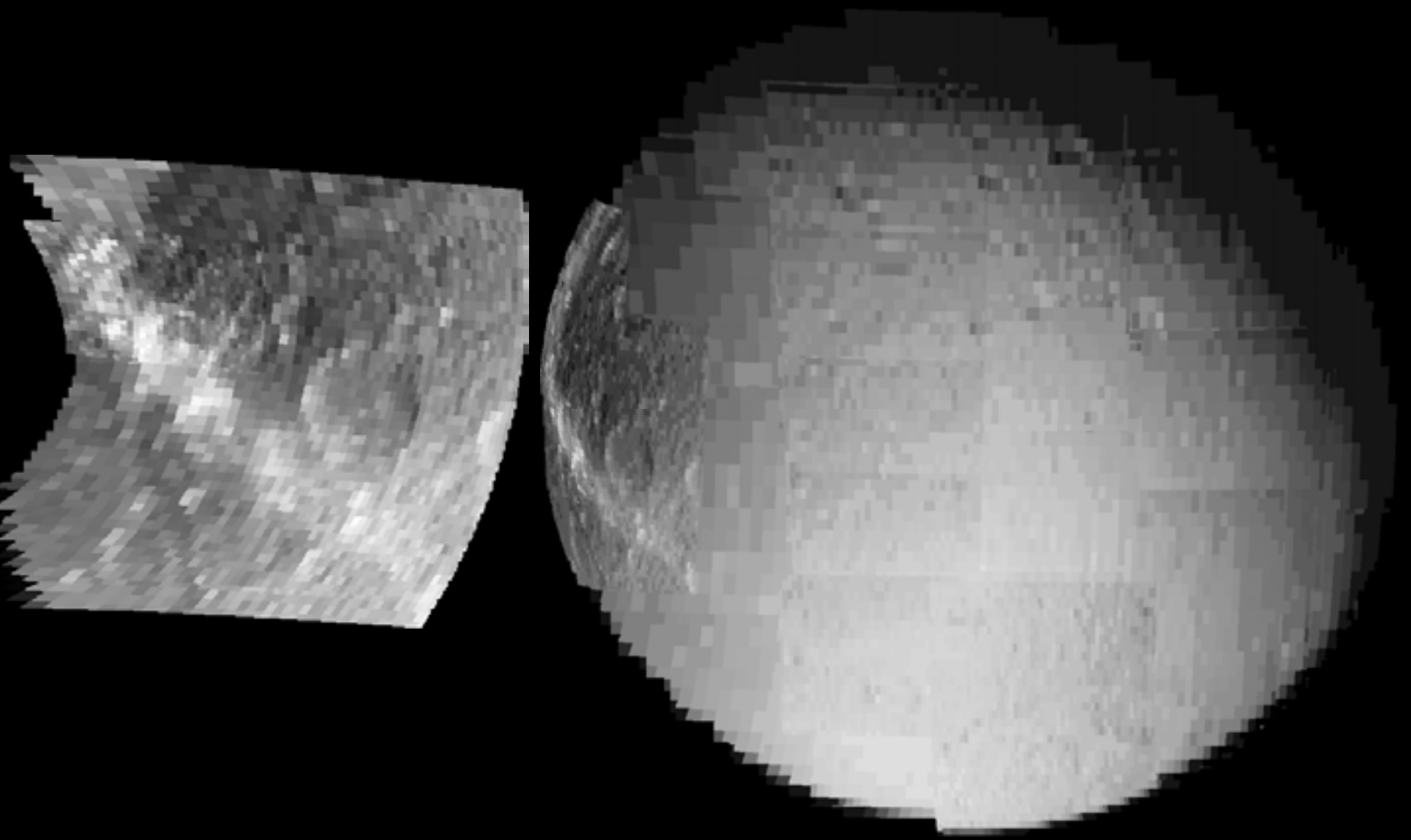


14 December 2004

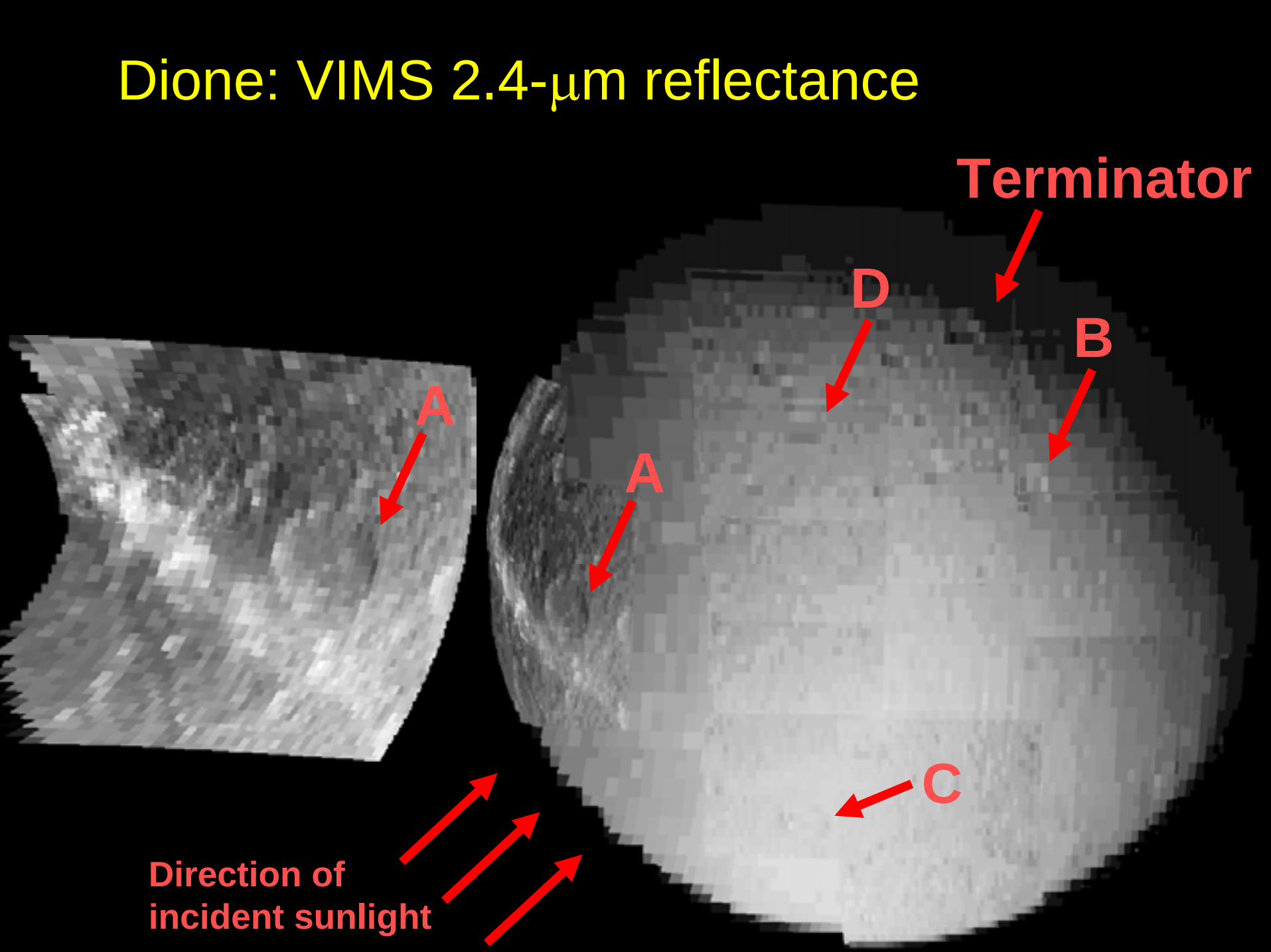
560 km in radius
6.26 R_S orbit

light wispy streaks on trailing hemisphere.

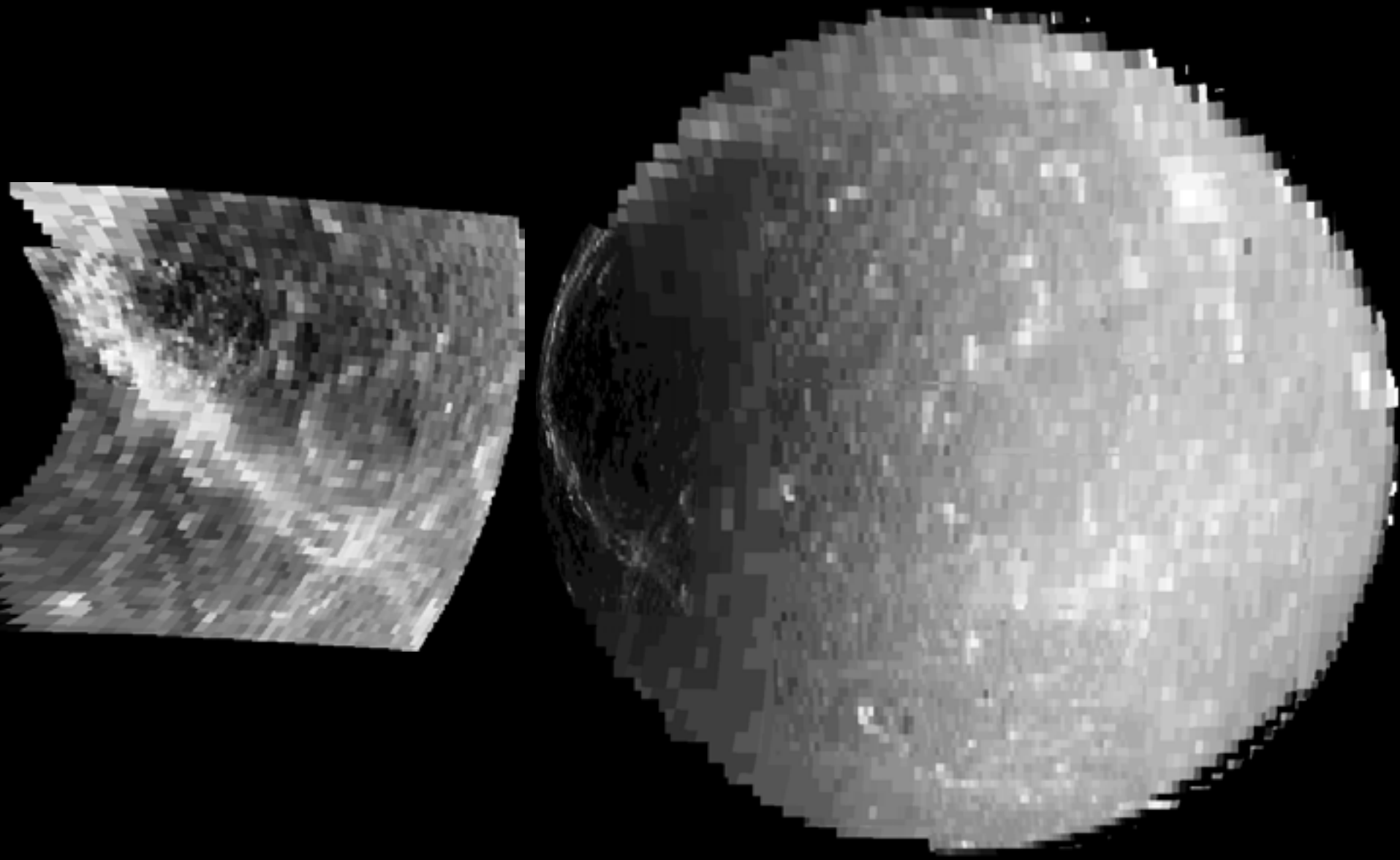
Dione: VIMS 2.4-μm reflectance



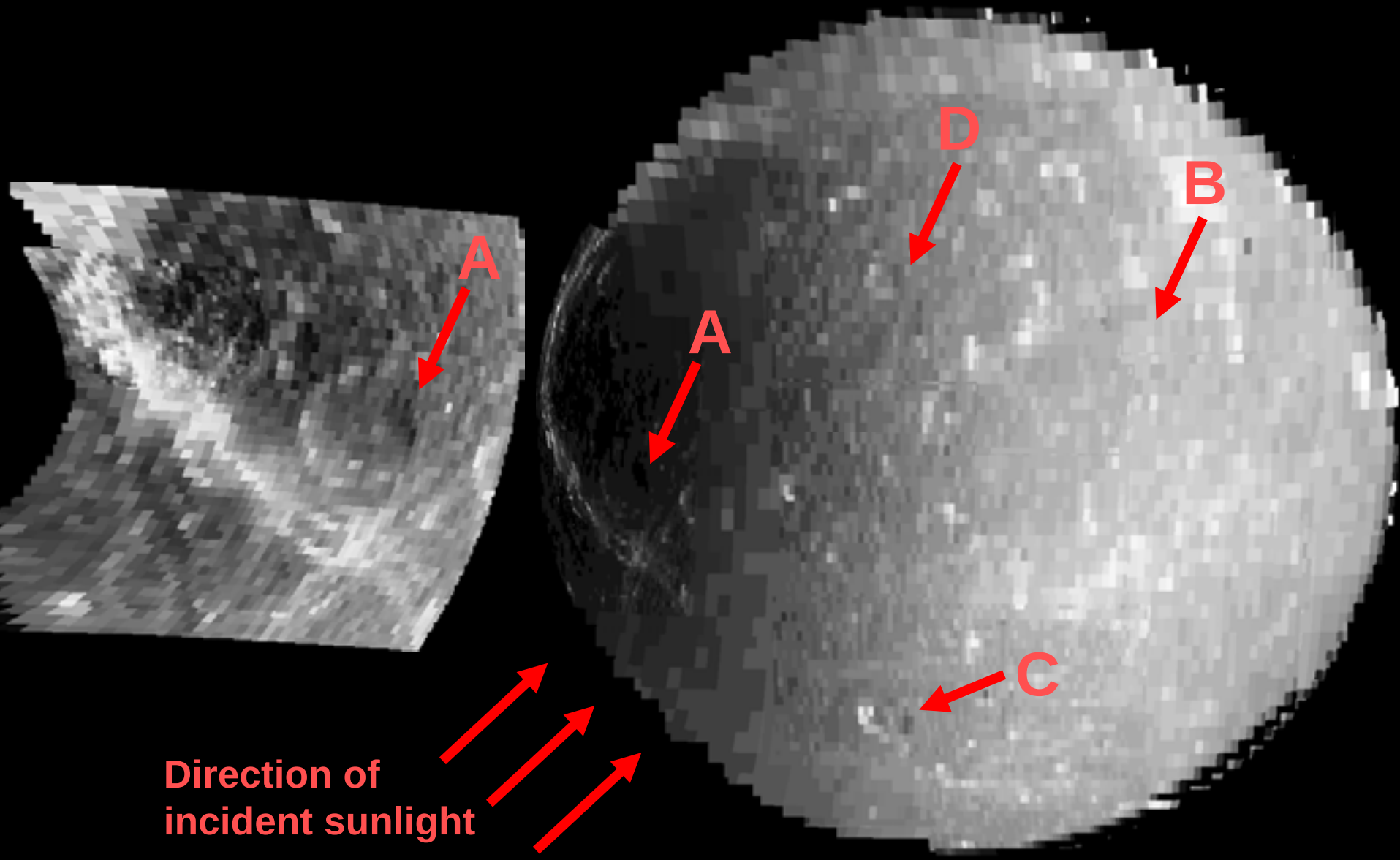
Dione: VIMS 2.4-μm reflectance

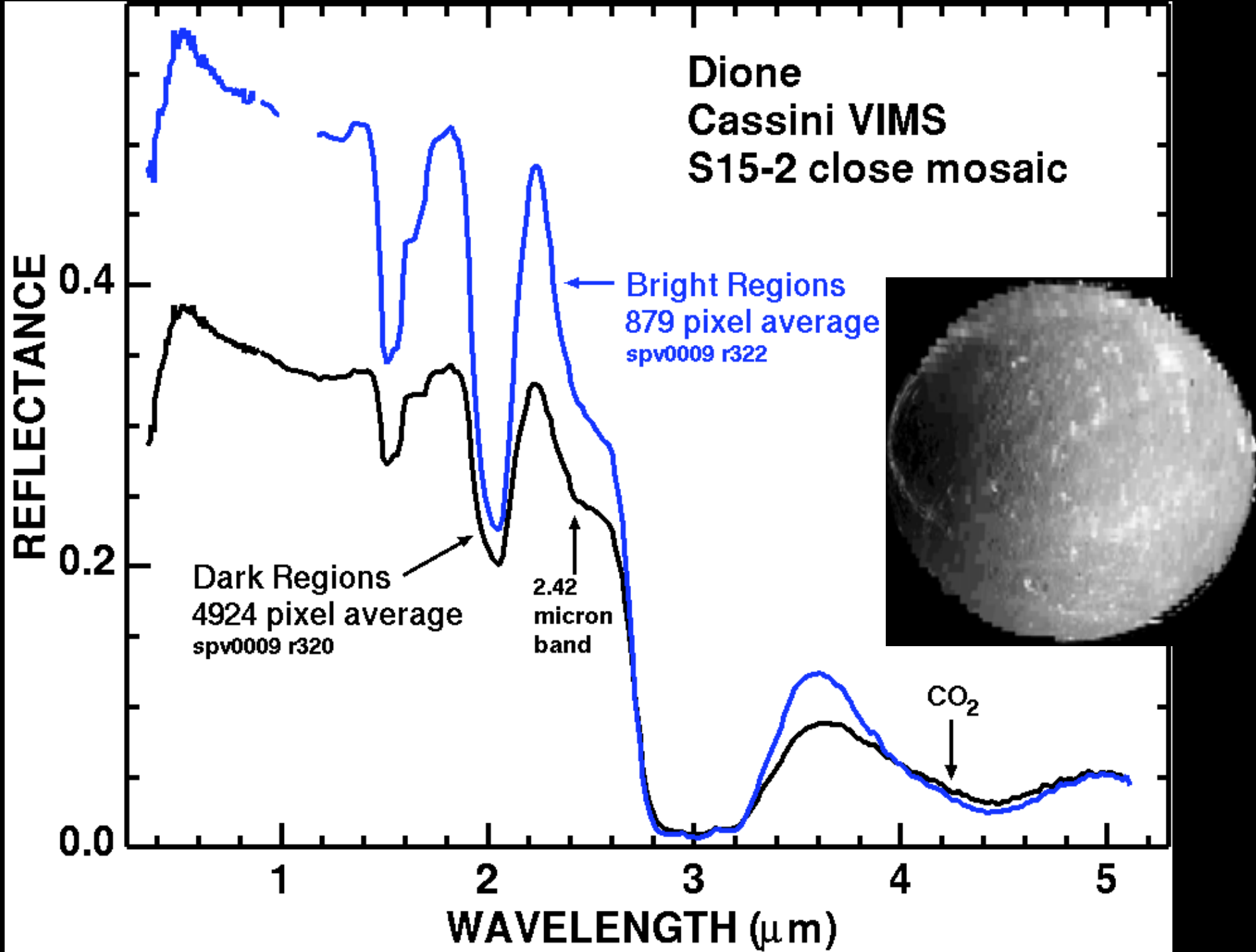


Dione: VIMS 2.0-μm ice band strength



Dione: VIMS 2.0-μm ice band strength




Dione
Cassini VIMS
S15-2 close mosaic
Bright Regions
879 pixel average
spv0009 r322
Dark Regions
4924 pixel average
spv0009 r320
2.42
micron
band
CO_2
REFLECTANCE
0.0
0.2
0.4
1
2
3
4
5
WAVELENGTH (μm)

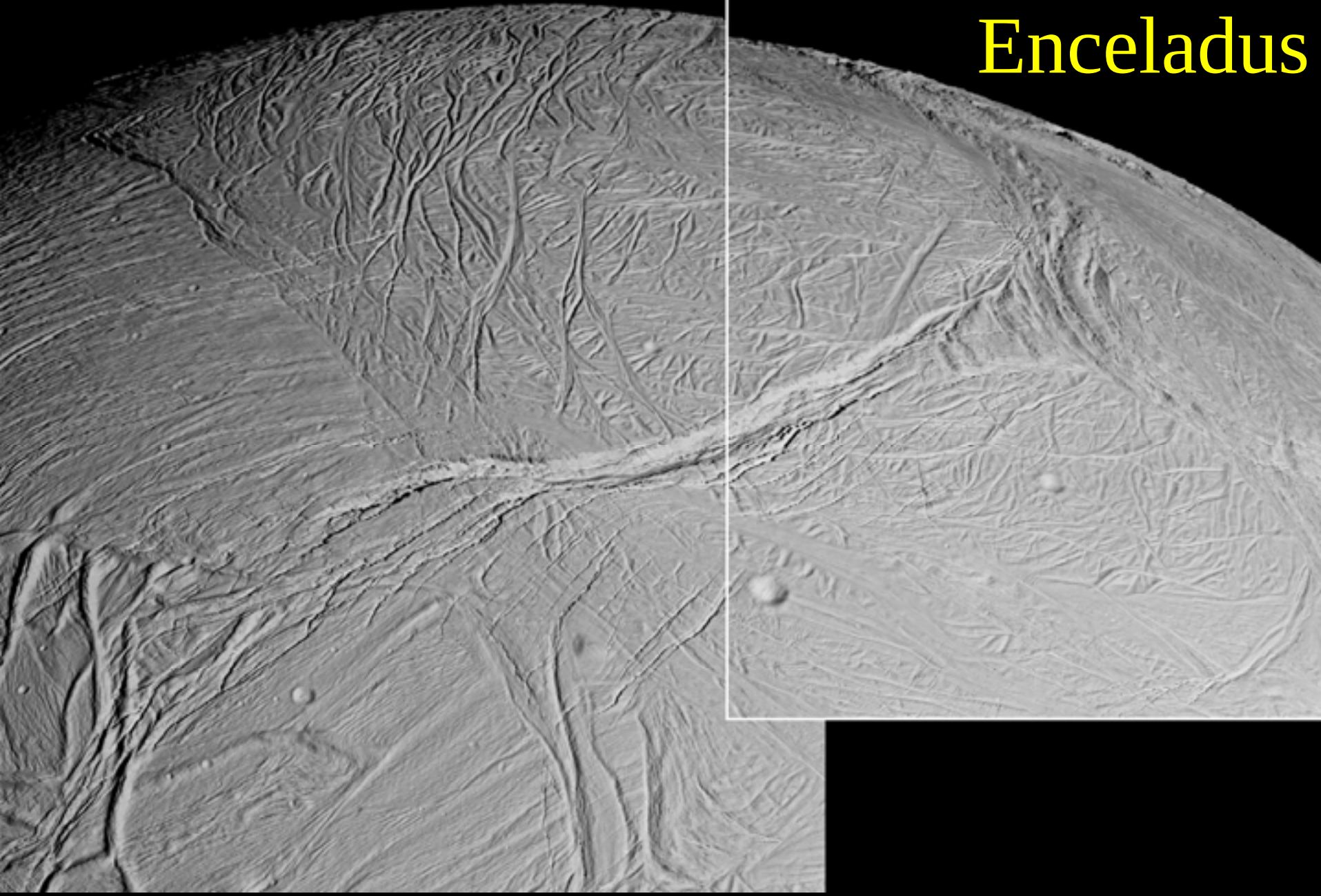
Enceladus

- **Is Enceladus currently geologically active? YES!**
- **Is Enceladus a source of the E-ring? YES!**
- **Composition?**
- **What is the source of grooved terrain?**
  - **Tectonism?**
  - **Cryovolcanism?**
  - **Expansion/contraction?**

260 km in radius
3.95 R_S orbit
Possible source of E-ring
Very bright surface.
Enceladus:Dione in 1:2 resonance

15 February 2005

Enceladus



15 February 2005

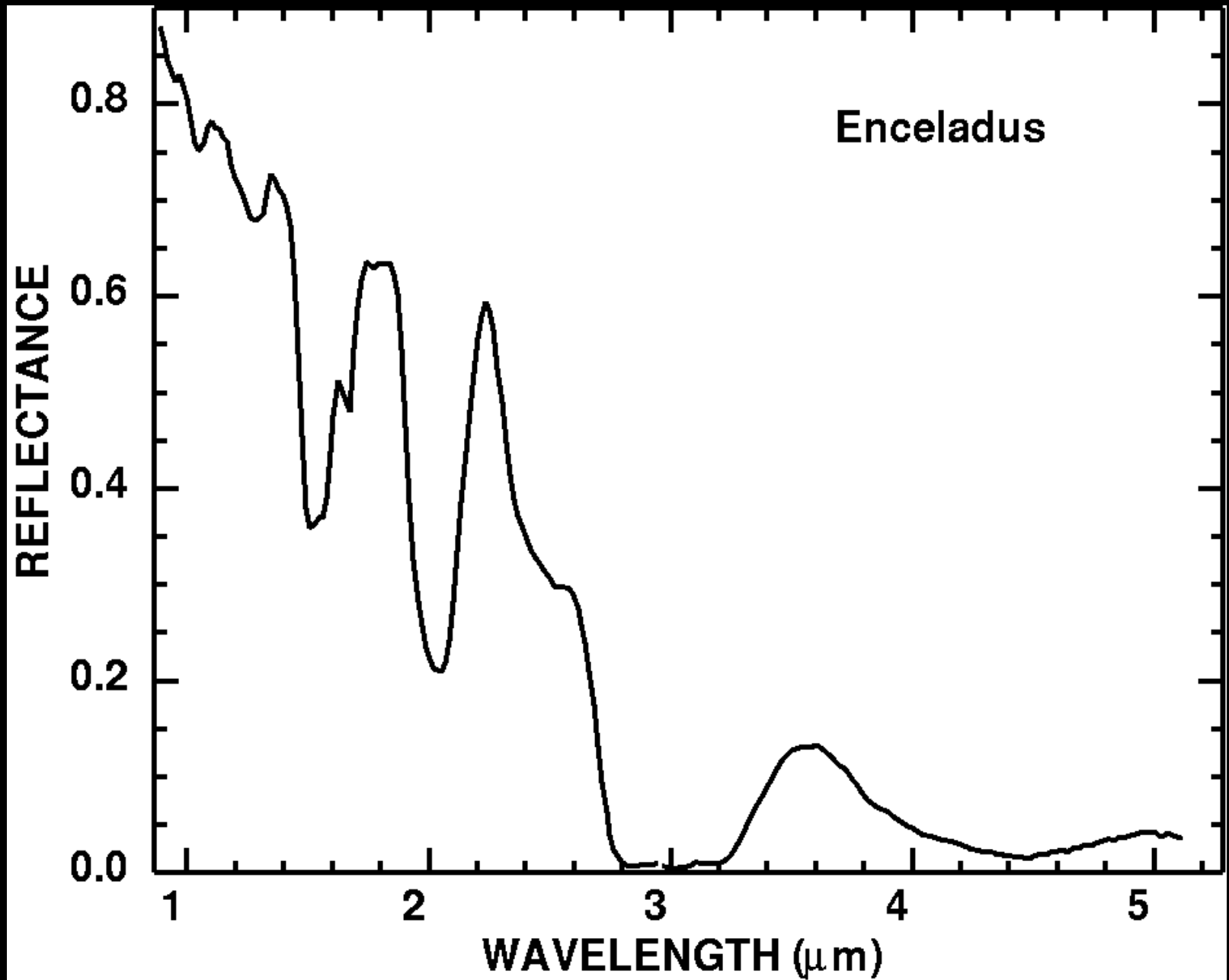
Enceladus

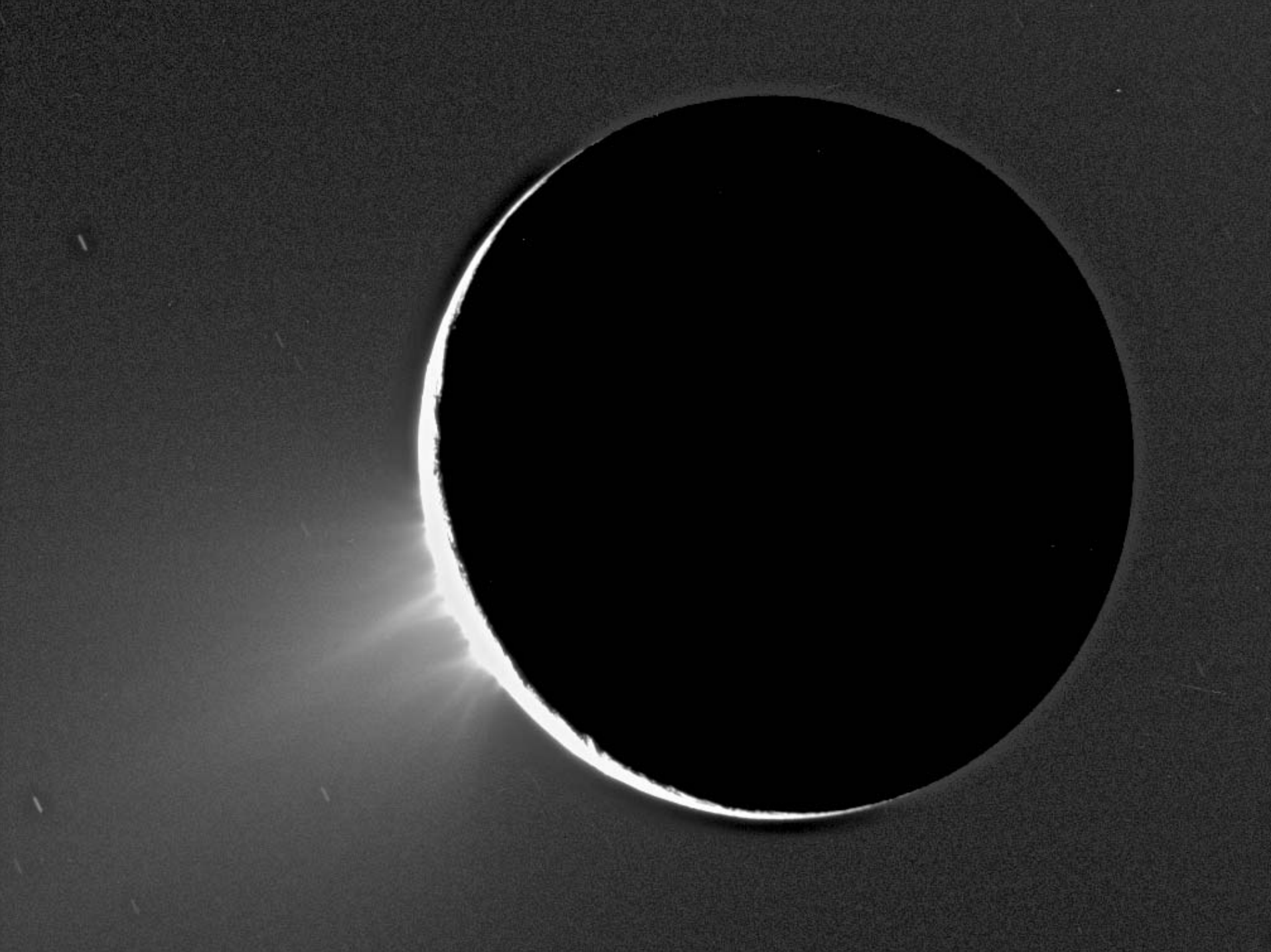
Notice “soft” craters

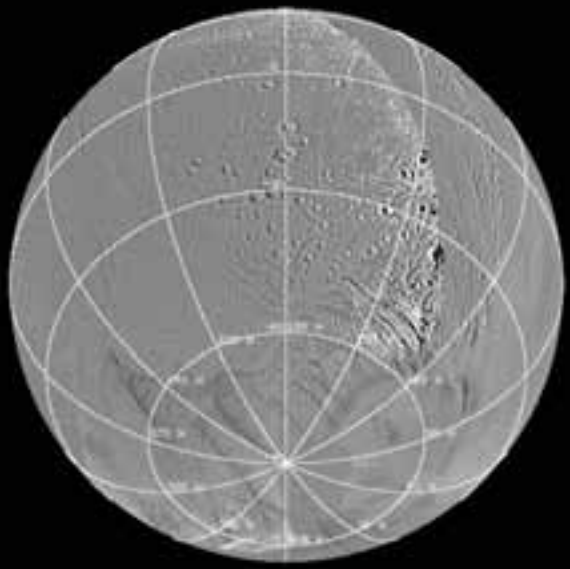
30 m/pixel

9 March 2005

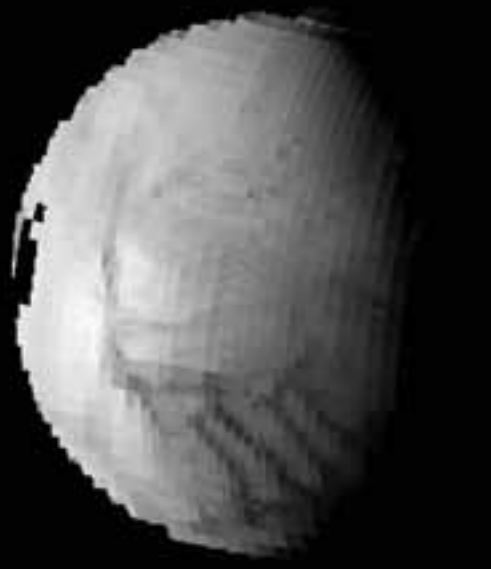
Enceladus: nothing but Ice…….?



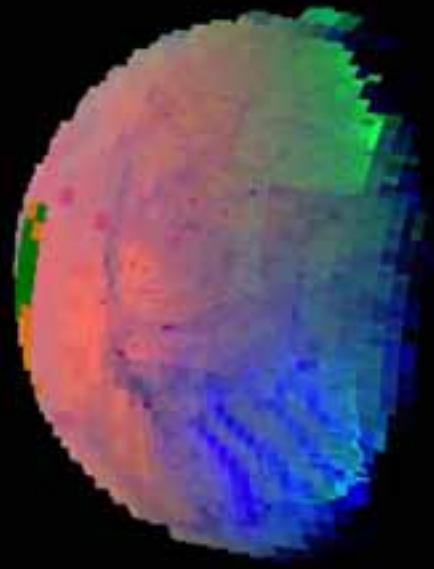




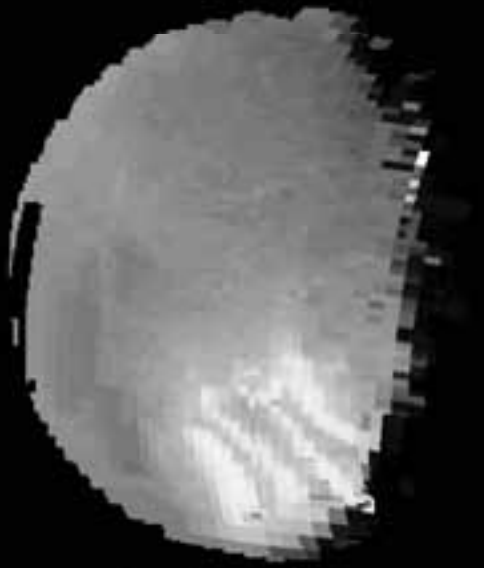
ISS Reference



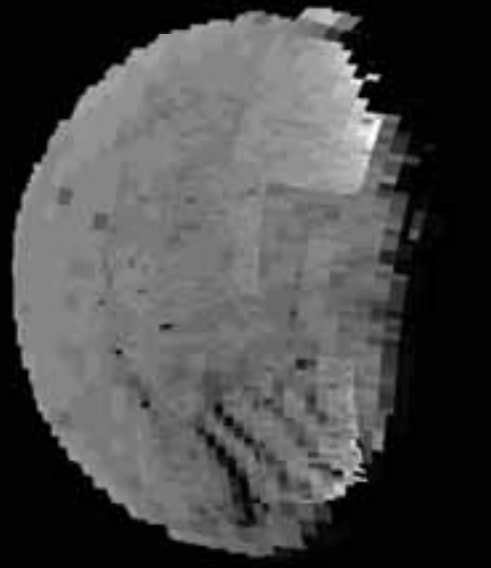
2.2-micron Reflectance



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

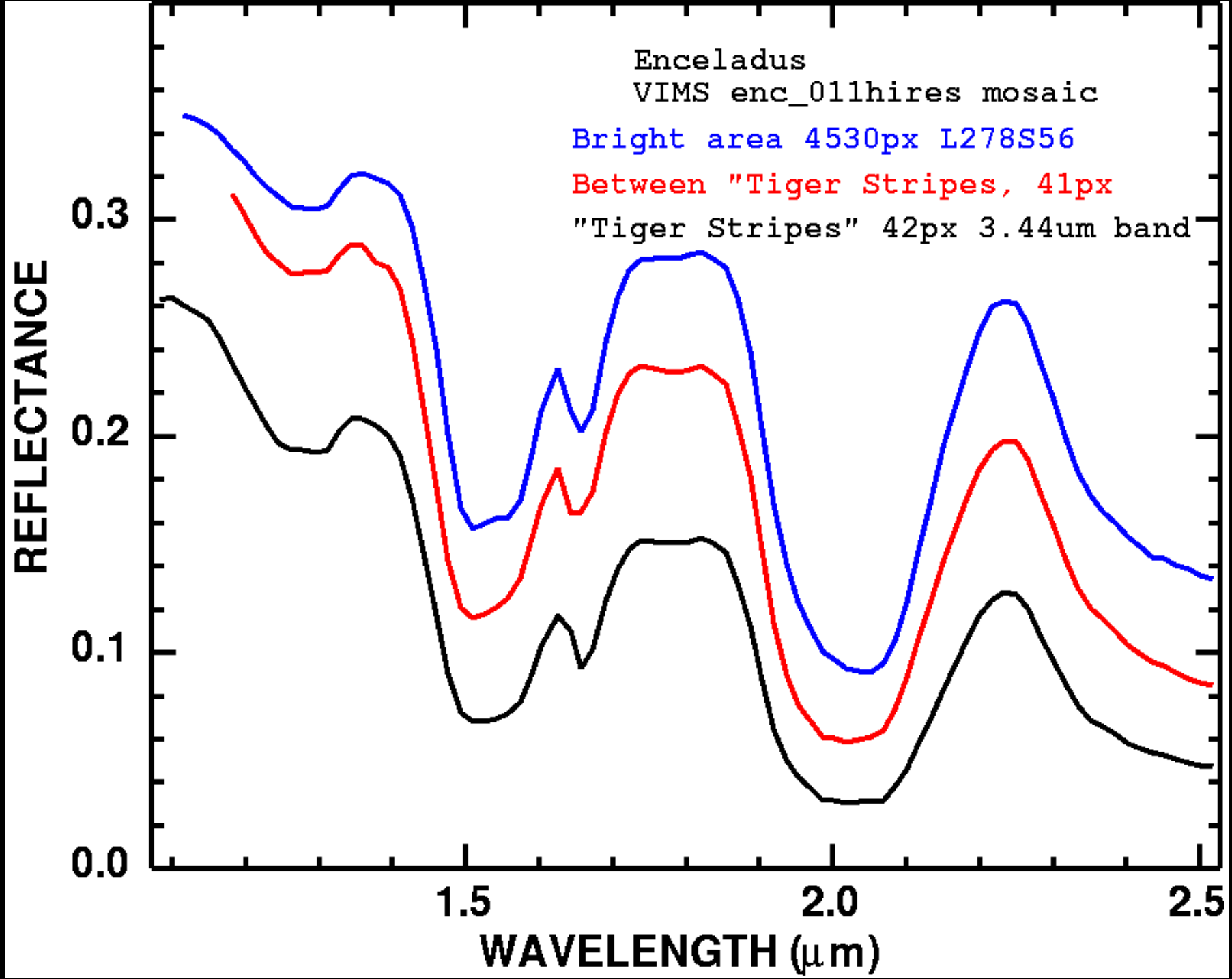


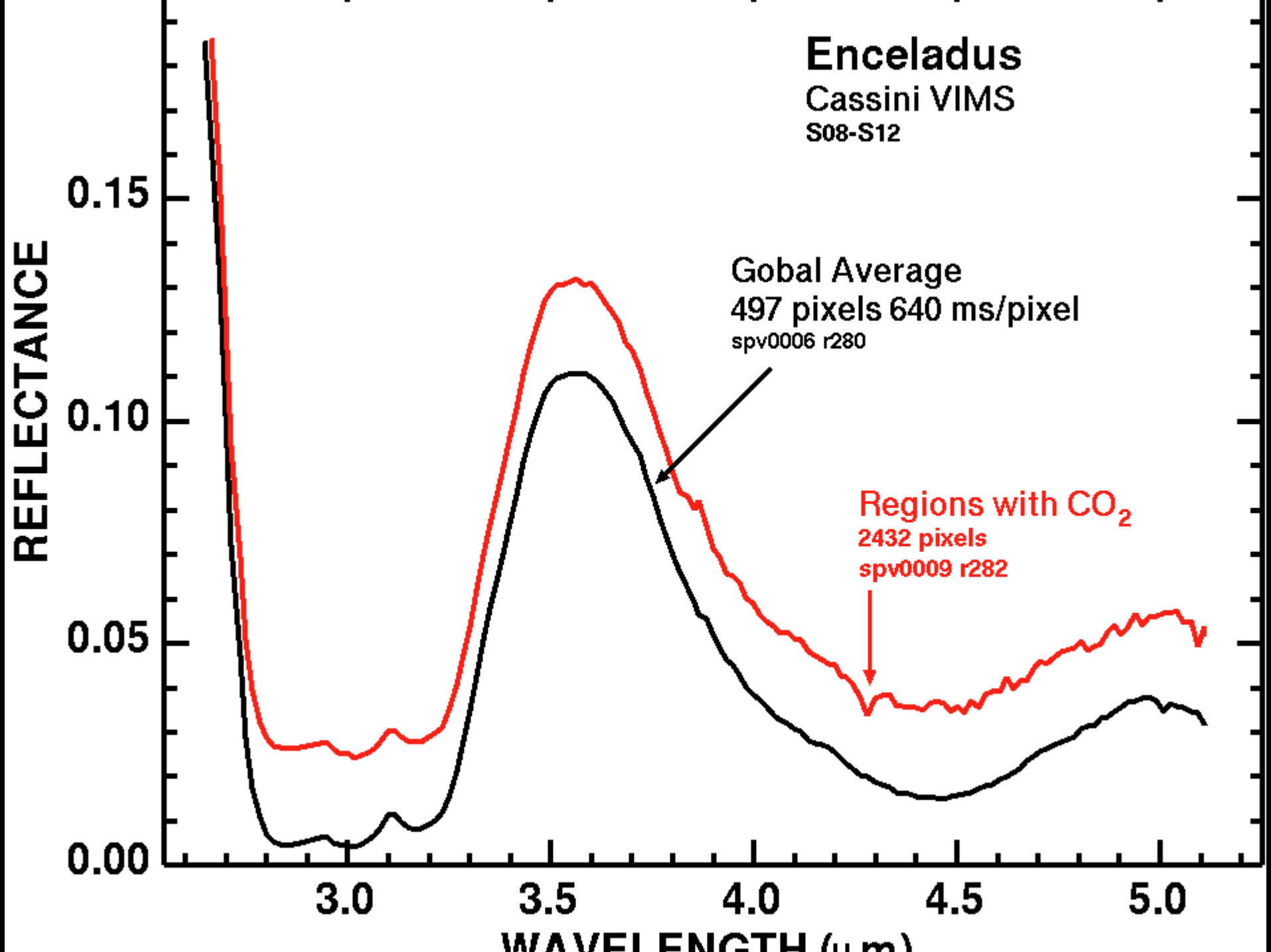
2-micron Ice Absorption Strength

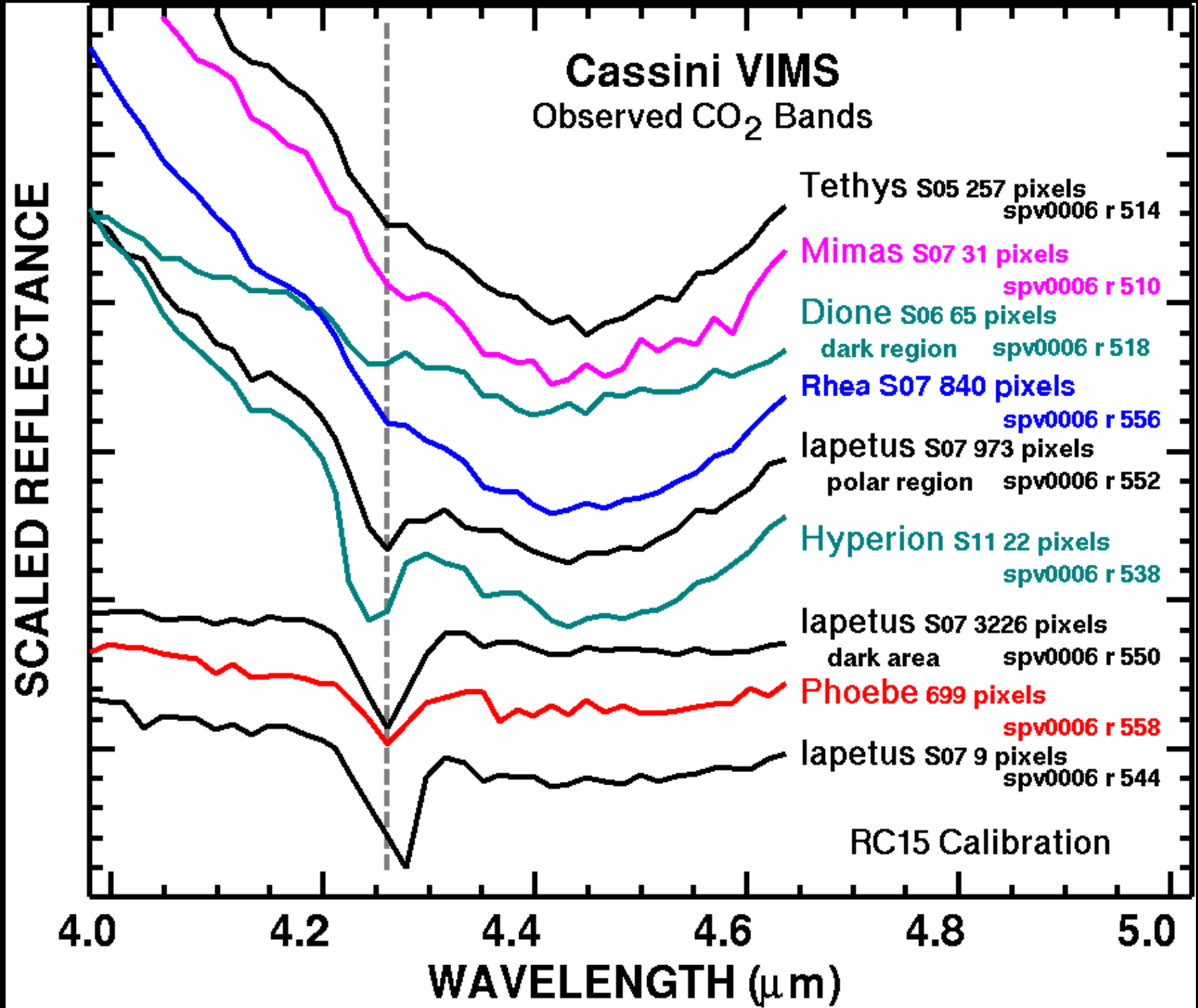


3-micron Ice Absorption Strength

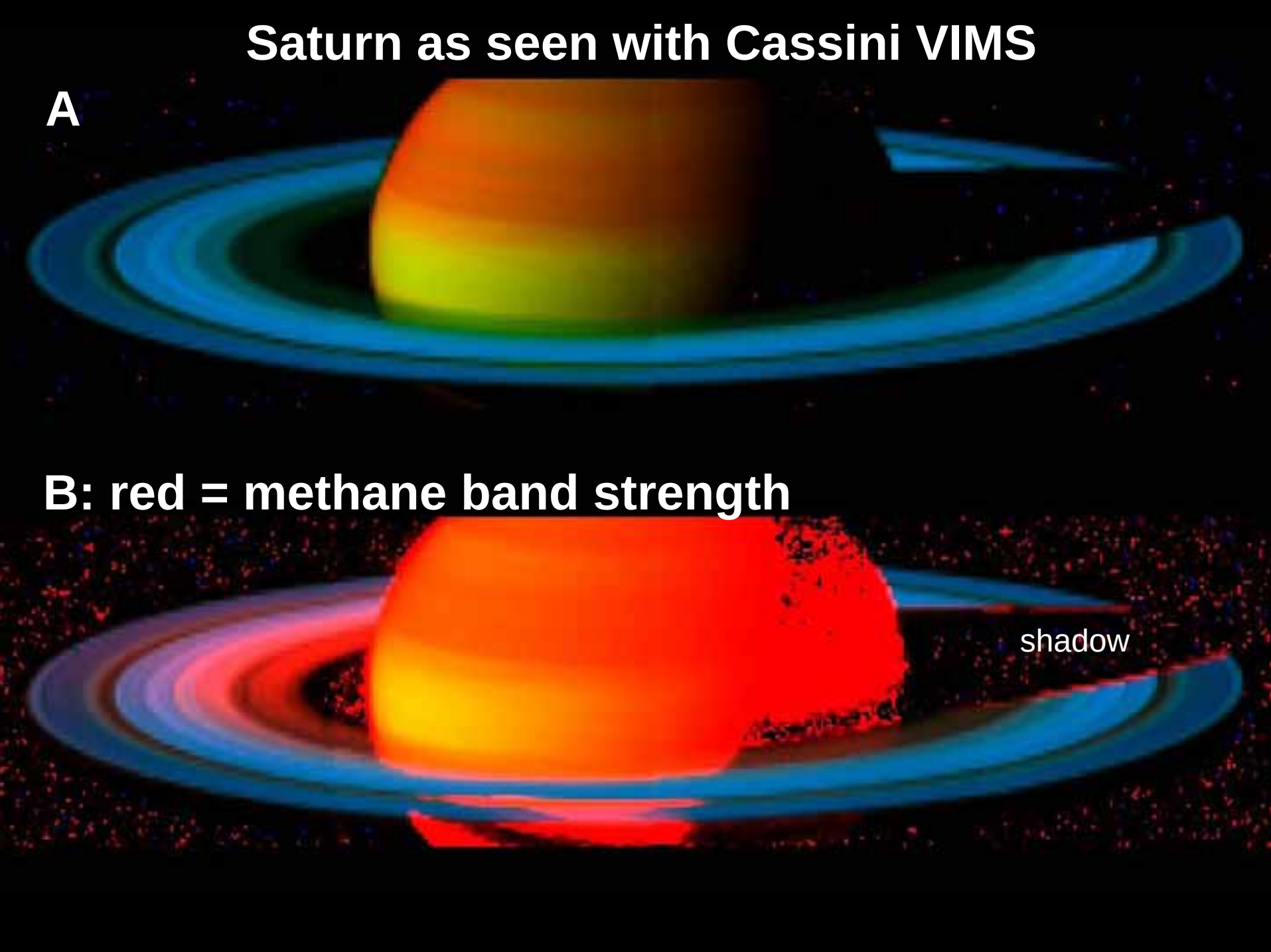
Cassini
Visual and Infrared
Mapping Spectrometer


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

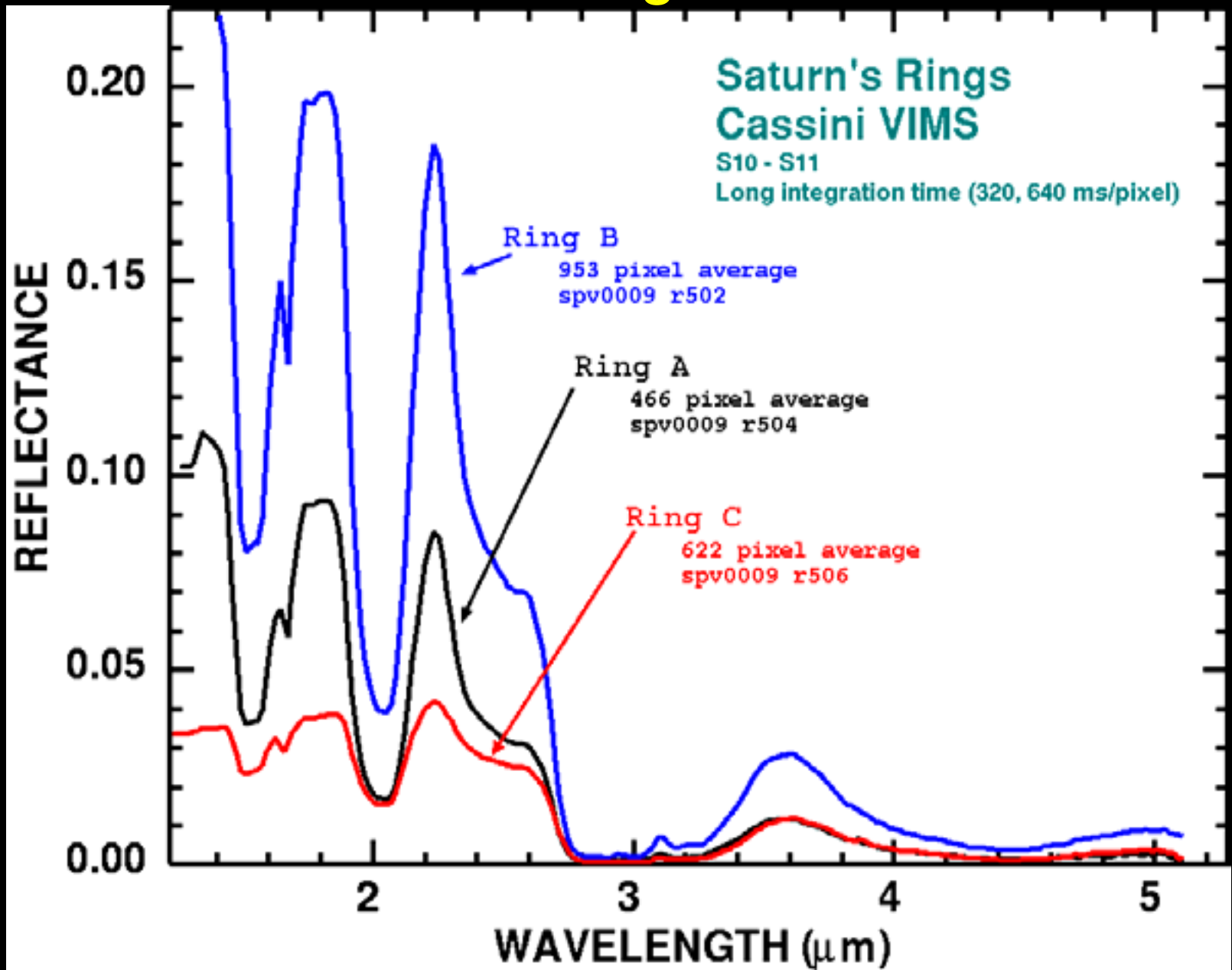

Enceladus
Cassini VIMS
S08-S12
Gobal Average
497 pixels 640 ms/pixel
spv0006 r280
Regions with CO_2
2432 pixels
spv0009 r282
REFLECTANCE
0.00
0.05
0.10
0.15
3.0
3.5
4.0
4.5
5.0
WAVELENGTH (μm)

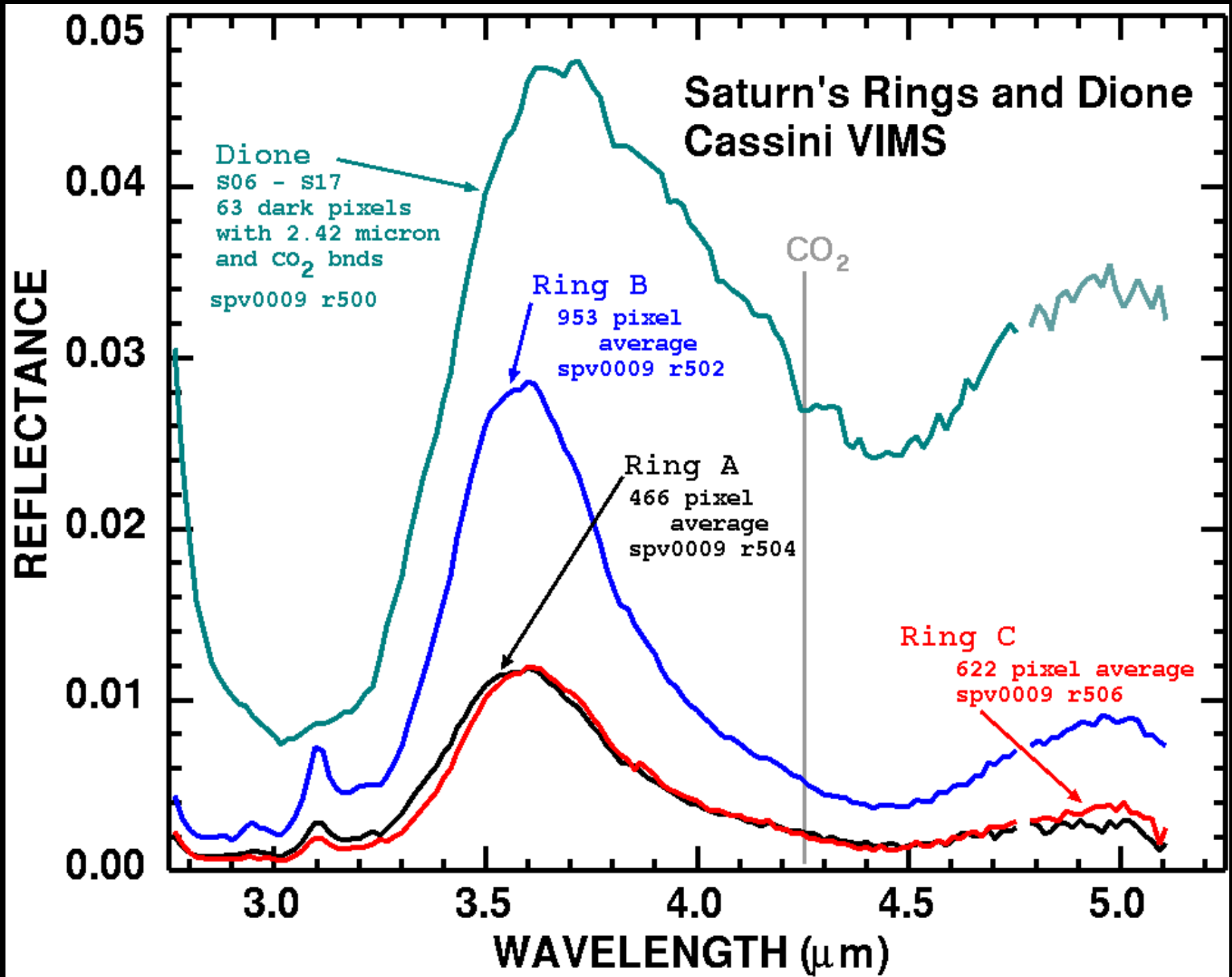

Cassini VIMS
Observed CO_2 Bands
SCALED REFLECTANCE
WAVELENGTH (μm)
4.0
4.2
4.4
4.6
4.8
5.0
Tethys S05 257 pixels
spv0006 r 514
Mimas S07 31 pixels
spv0006 r 510
Dione S06 65 pixels
dark region spv0006 r 518
Rhea S07 840 pixels
spv0006 r 556
Iapetus S07 973 pixels
polar region spv0006 r 552
Hyperion S11 22 pixels
spv0006 r 538
Iapetus S07 3226 pixels
dark area spv0006 r 550
Phoebe 699 pixels
spv0006 r 558
Iapetus S07 9 pixels
spv0006 r 544
RC15 Calibration

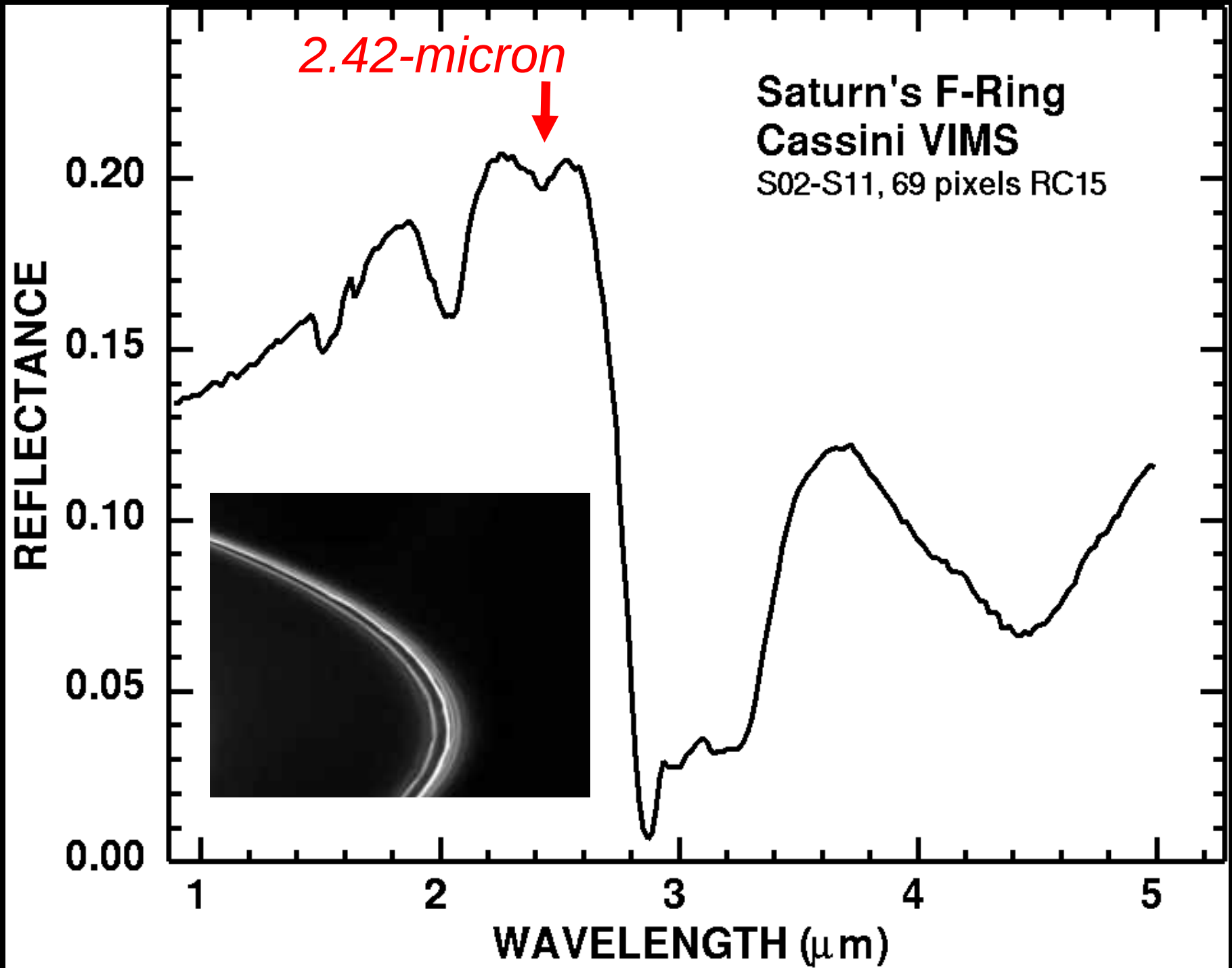
Saturn as seen with Cassini VIMS

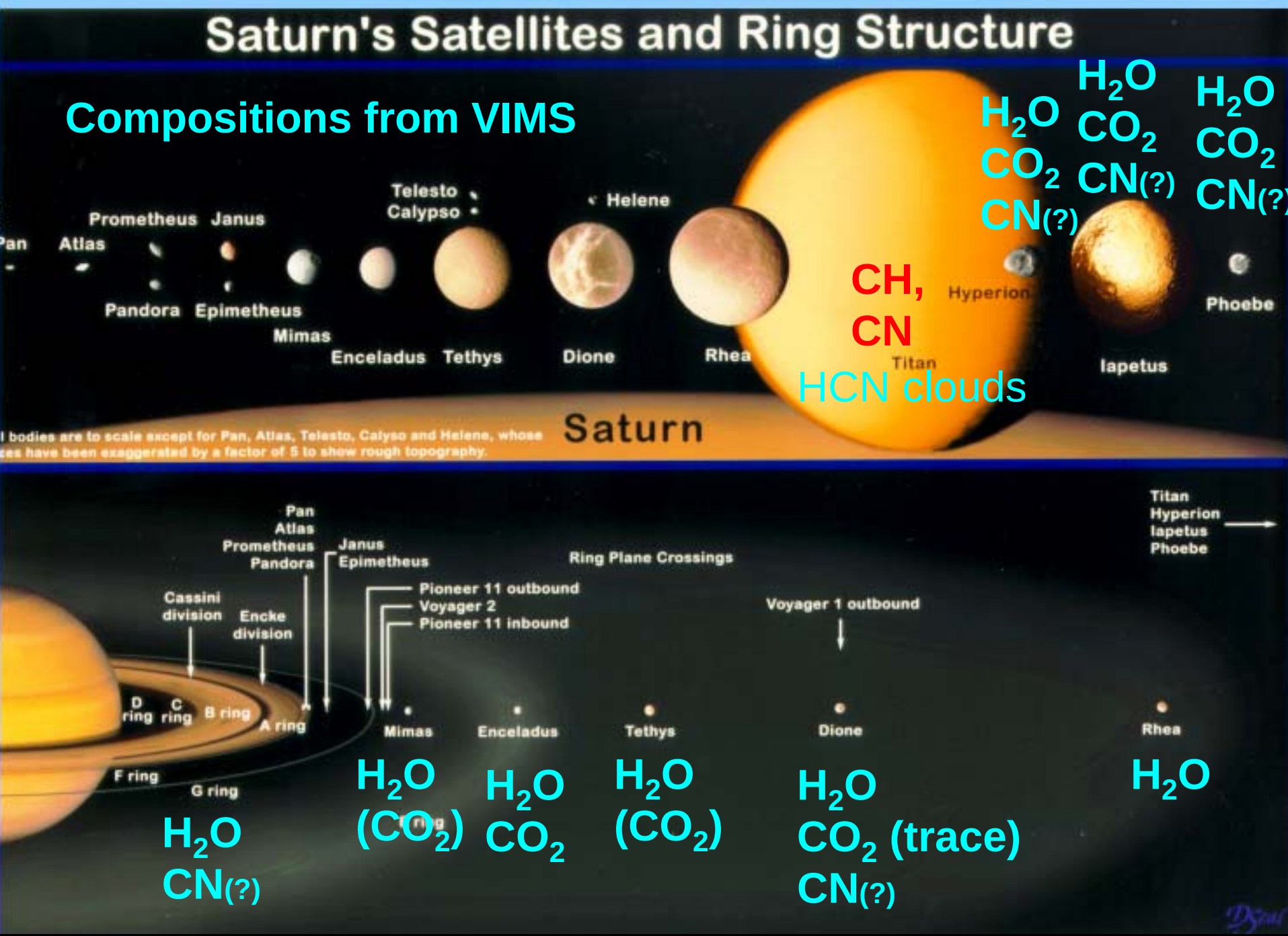


VIMS spectra of Saturn's rings show classic Ice signatures.



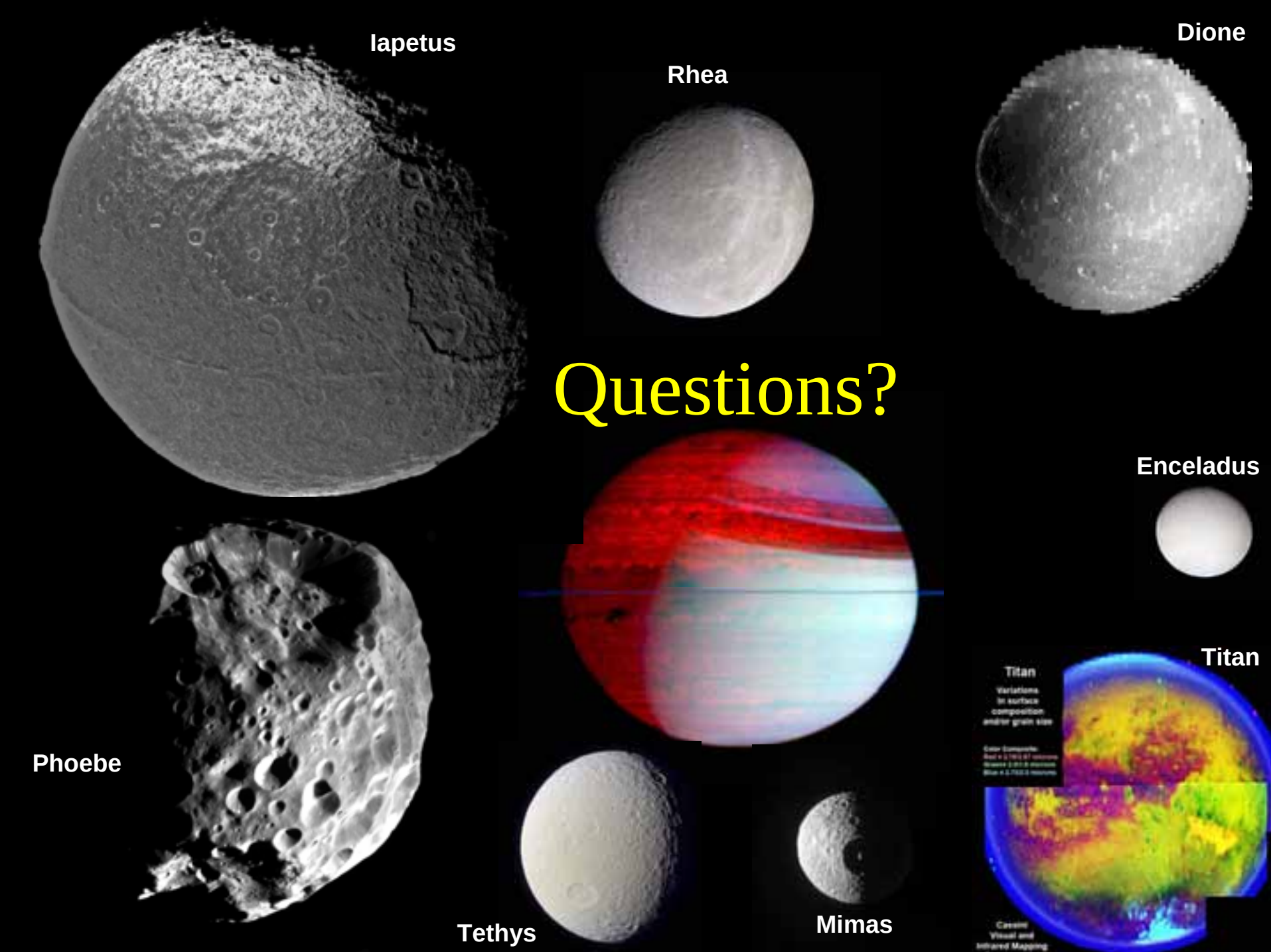

Saturn's Rings and Dione
Cassini VIMS
Dione
S06 - S17
63 dark pixels
with 2.42 micron
and CO2 bnds
spv0009 r500
Ring B
953 pixel
average
spv0009 r502
Ring A
466 pixel
average
spv0009 r504
Ring C
622 pixel average
spv0009 r506
CO2
REFLECTANCE
0.05
0.04
0.03
0.02
0.01
0.00
3.0
3.5
4.0
4.5
5.0
WAVELENGTH (μm)


2.42-micron
Saturn's F-Ring
Cassini VIMS
S02-S11, 69 pixels RC15
REFLECTANCE
0.20
0.15
0.10
0.05
0.00
1
2
3
4
5
WAVELENGTH (μm)


Saturn's Satellites and Ring Structure
Compositions from VIMS
Pan
Atlas
Prometheus
Janus
Pandora
Epimetheus
Mimas
Telesto
Calypso
Enceladus
Tethys
Helene
Dione
Rhea
Titan
Hyperion
Iapetus
Phoebe
H_2O
CO_2
CN(?)
CH,
CN
HCN clouds
Saturn
l bodies are to scale except for Pan, Atlas, Telesto, Calyso and Helene, whose
zes have been exaggerated by a factor of 5 to show rough topography.
Pan
Atlas
Prometheus
Pandora
Janus
Epimetheus
Ring Plane Crossings
Pioneer 11 outbound
Voyager 2
Pioneer 11 inbound
Voyager 1 outbound
Titan
Hyperion
Iapetus
Phoebe
Cassini division
Encke division
D ring
C ring
B ring
A ring
F ring
G ring
E ring
Mimas
Enceladus
Tethys
Dione
Rhea
H_2O
CN(?)
H_2O
(CO_2)
H_2O
CO_2
H_2O
(CO_2)
H_2O
CO_2 (trace)
CN(?)
H_2O

Conclusions

- **Saturn's satellites are dominated by icy surfaces with trace materials:**
  - **Compounds with 2.42-micron feature (cyanide compounds? Or ???)**
    - **Seen on Phoebe, Iapetus, Hyperion, Dione and the F-ring**
  - **Trapped CO_2 (4.26 microns)**
    - **All objects where we have adequate signal-to-noise ratios, but generally stronger further from Saturn. (SO FAR: NOT IN THE RINGS)**
  - **The presence of the 2.42-micron feature throughout the Saturn system implies:.**
    - **The dark material is compositionally similar throughout the system.**
    - **Common origin?**
    - **The pattern of dark material on Dione implies an external origin.**


Iapetus
Rhea
Dione
Questions?
Enceladus
Titan
Titan
Variations in surface composition and/or grain size
Phoebe
Tethys
Mimas