
Struttura, processi dinamici e formazione del sistema di anelli di Saturno

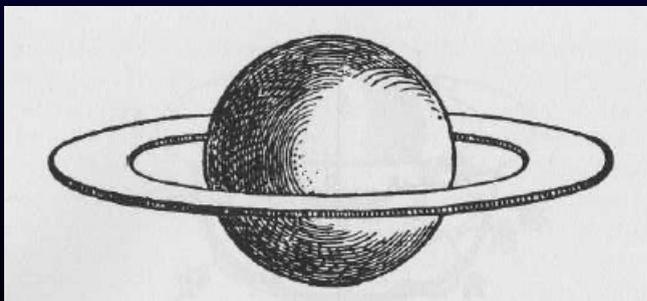
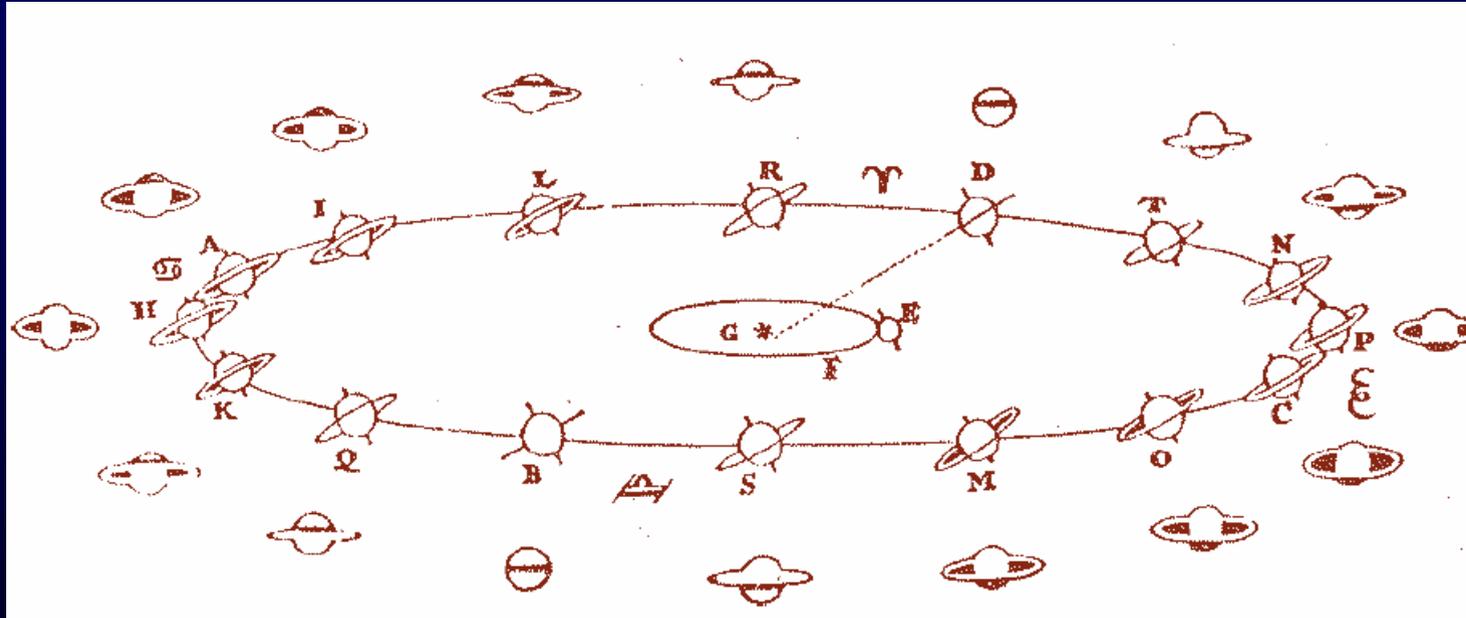
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Indice della lezione

1. Storia
2. Gli anelli planetari nel Sistema Solare
3. Morfologia degli anelli di Saturno
4. Teoria di Roche e processi dinamici
5. Risonanze ed interazioni anelli-satelliti
6. Interazioni polveri-campi e.m.
7. Cassini: risultati

1. STORIA



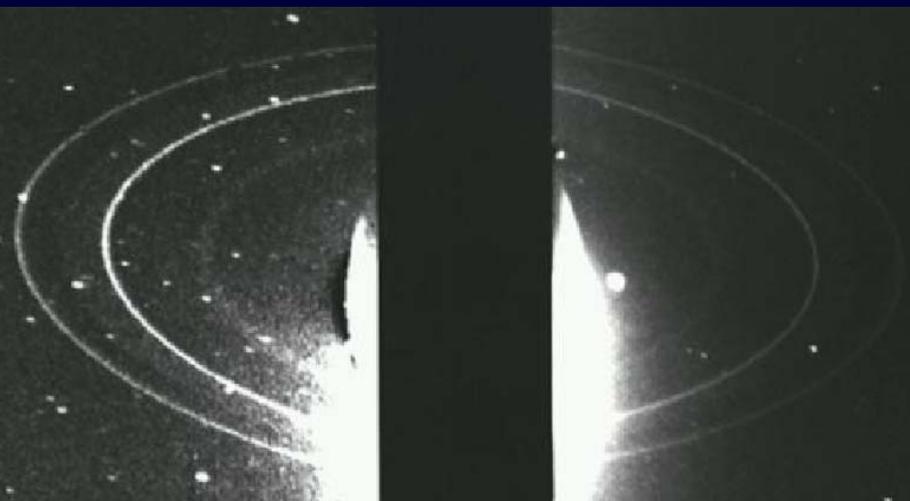
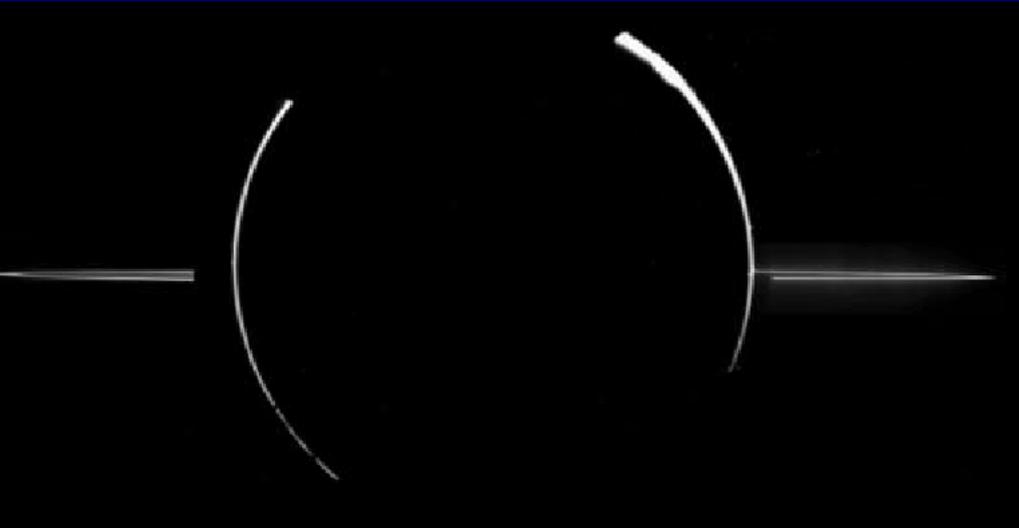
Cronologia 1

- (1610) Galileo: «Altissimum planetam tergeminum observavi».
- (1659) Huygens: «Annulo cingitur, tenui, plano, nusquam cohaerente ad eclipticam inclinato».
- (1675) Cassini osserva una divisione scura che separa l'anello in due parti.
- (1787) Laplace dimostra che per essere stabile l'anello non può essere solido.
- (1856) Maxwell: «The final result, therefore, of the mechanical theory is, that the only system of rings which can exist is one composed of an indefinite number of unconnected particles, revolving round the planet with different velocities according to their respective distances».
- (1895) Keeler scopre la rotazione differenziale del disco mediante osservazioni spettroscopiche.

Cronologia 2

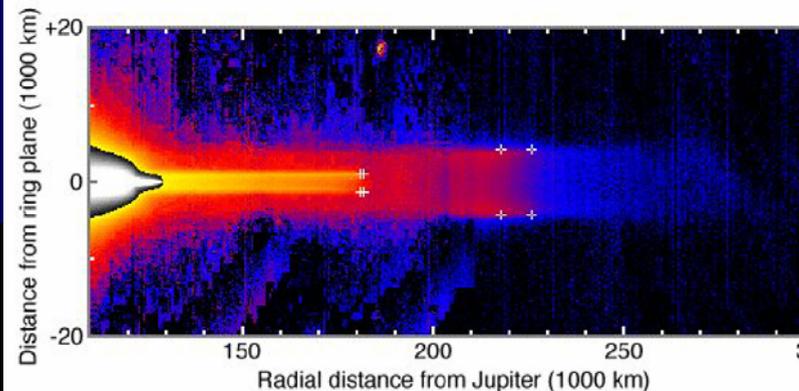
- (1910) Poincarè dimostra che collisioni inelastiche provocano l'appiattimento del disco.
- (1977) Scoperta degli anelli di Urano (occultazione stellare, Elliot, KAO).
- (1974-79) Osservazione degli anelli di Giove (Pioneer 10 - Voyager).
- (1980-81) Sonde Voyager a Saturno.
- (1984) Scoperta degli anelli di Nettuno (occultazione).
- (1986) Voyager 2 ad Urano.
- (1989) Voyager 2 a Nettuno.
- (2004-2008) Cassini a Saturno.

2. GLI ANELLI PLANETARI NEL SISTEMA SOLARE



Giove

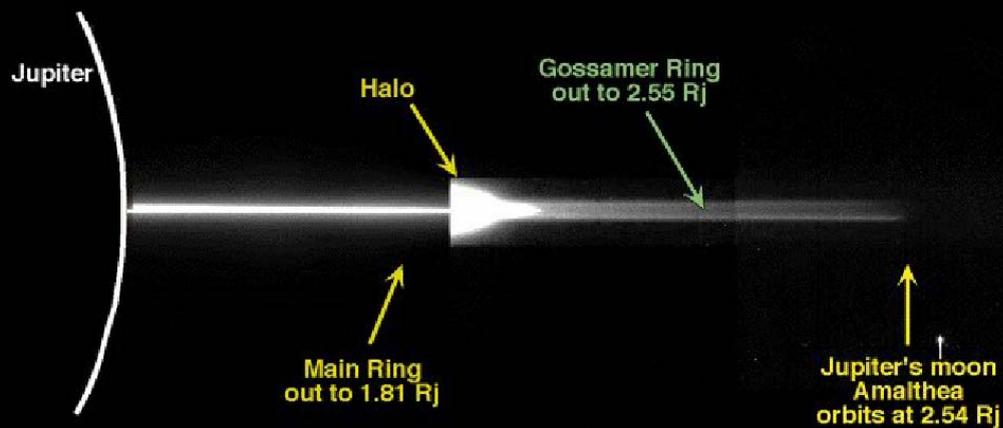
De Pater *et al.*, 1996



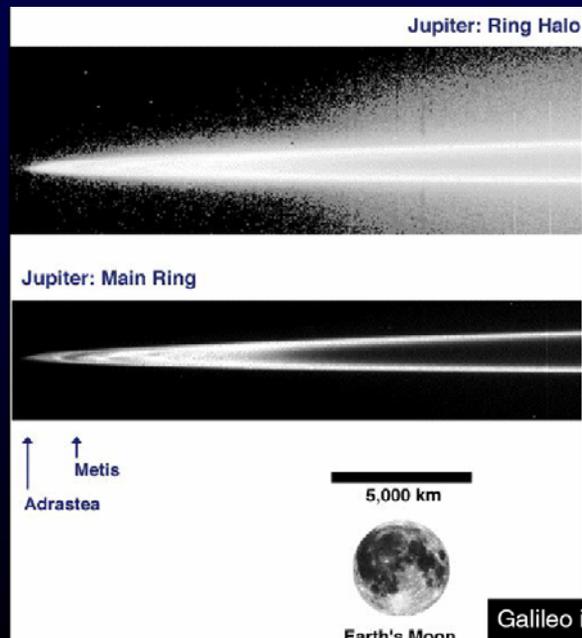
Standard image sensitivity

10 times sensitivity

20 times sensitivity

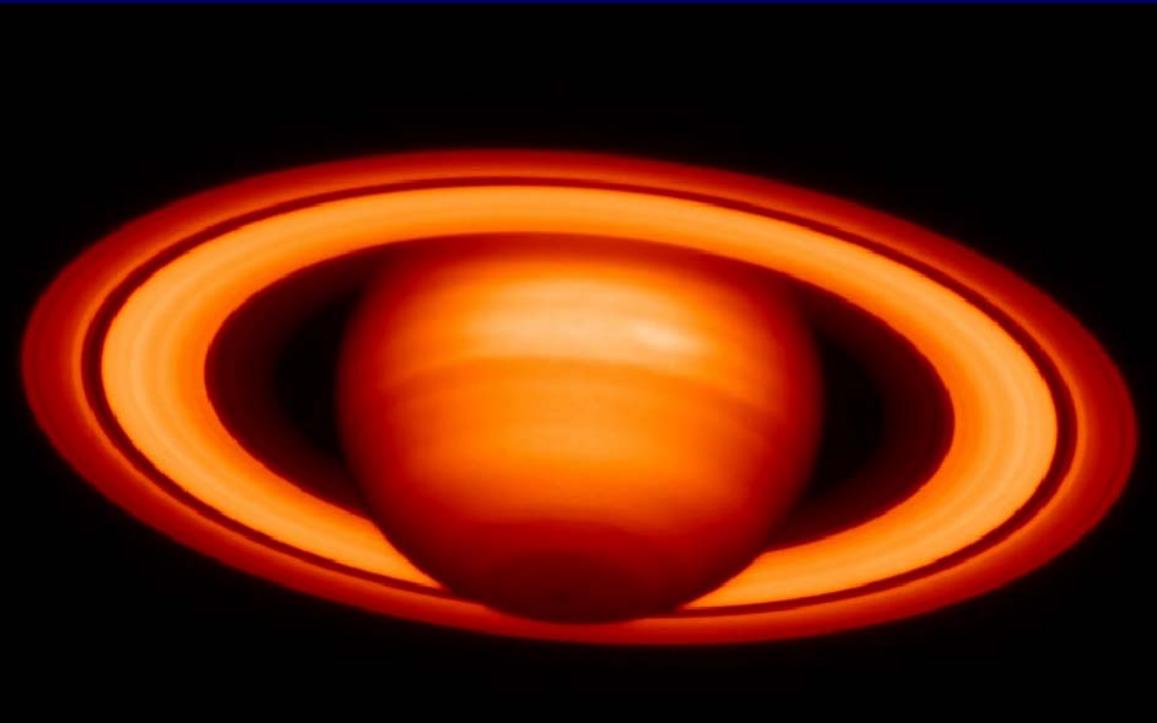


Galileo images, 1996

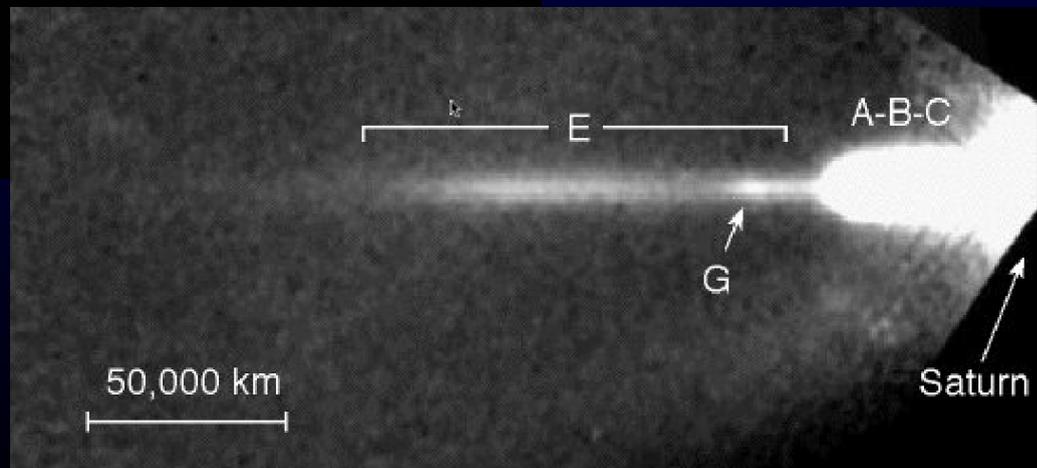
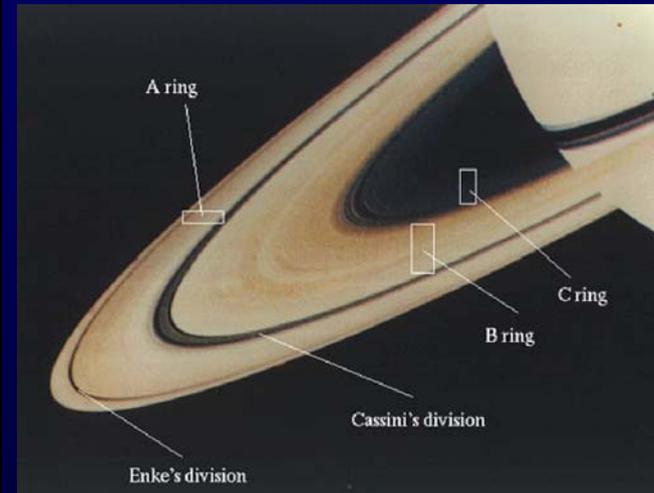


Galileo images, 1996

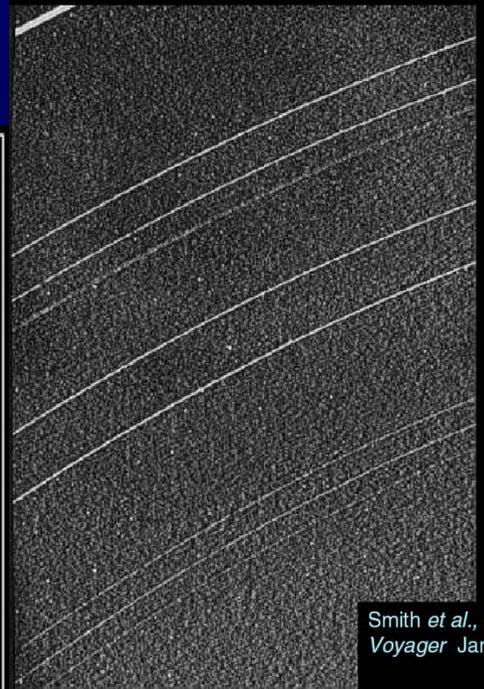
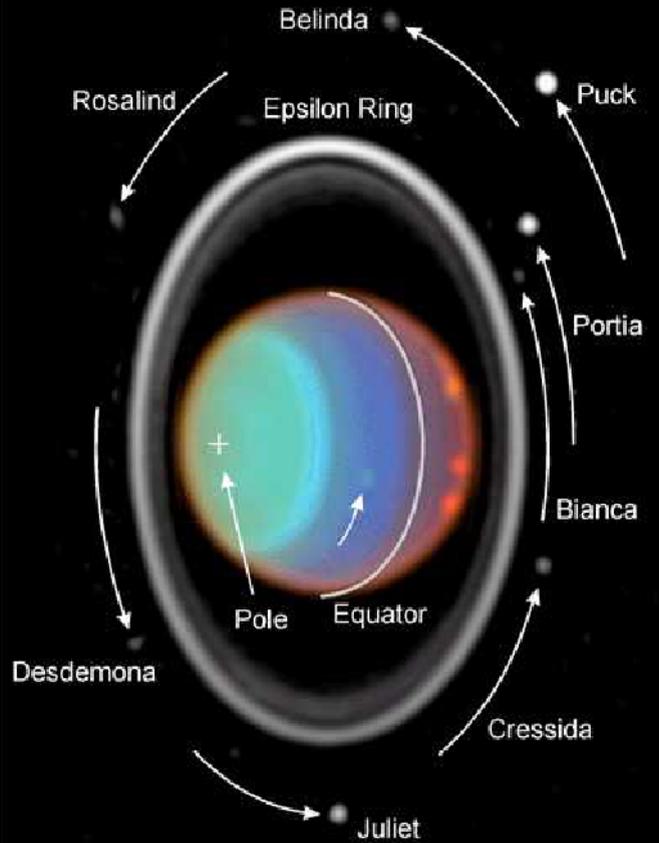
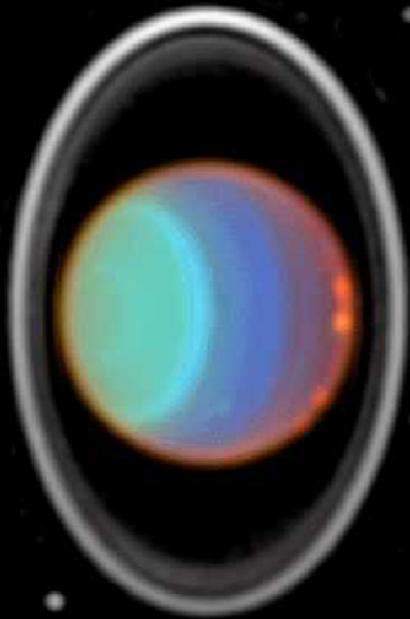
Saturno



VLT/NACO 2001



Urano



Smith et al., *Science*,
Voyager January 1986

Uranus • July 28, 1997

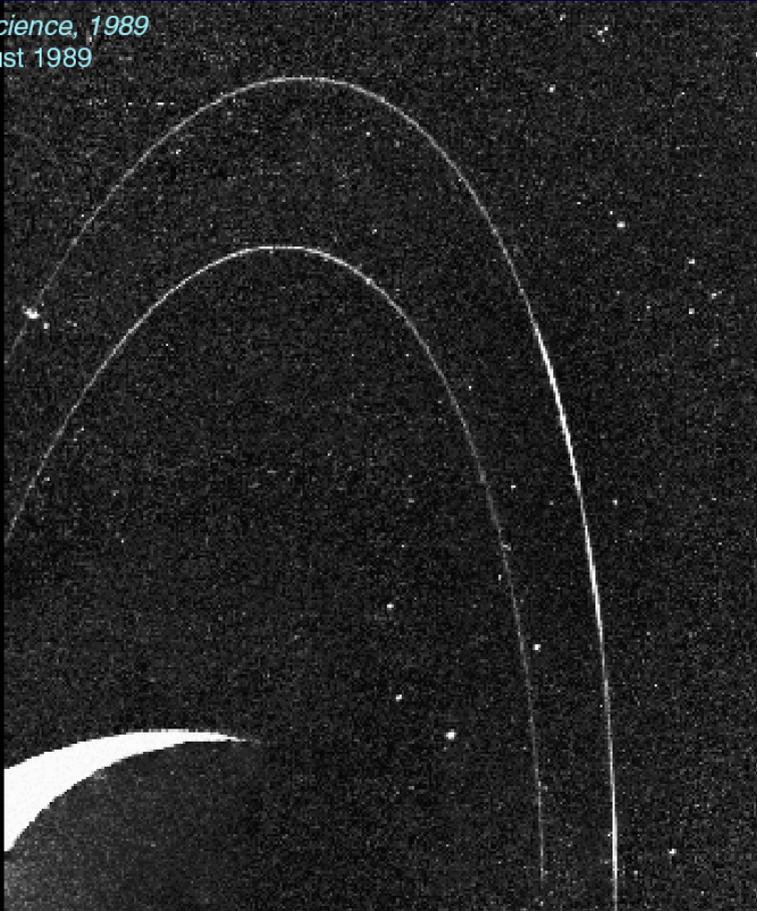
HST • NICMOS

RC97-36a • November 20, 1997 • ST ScI OPO

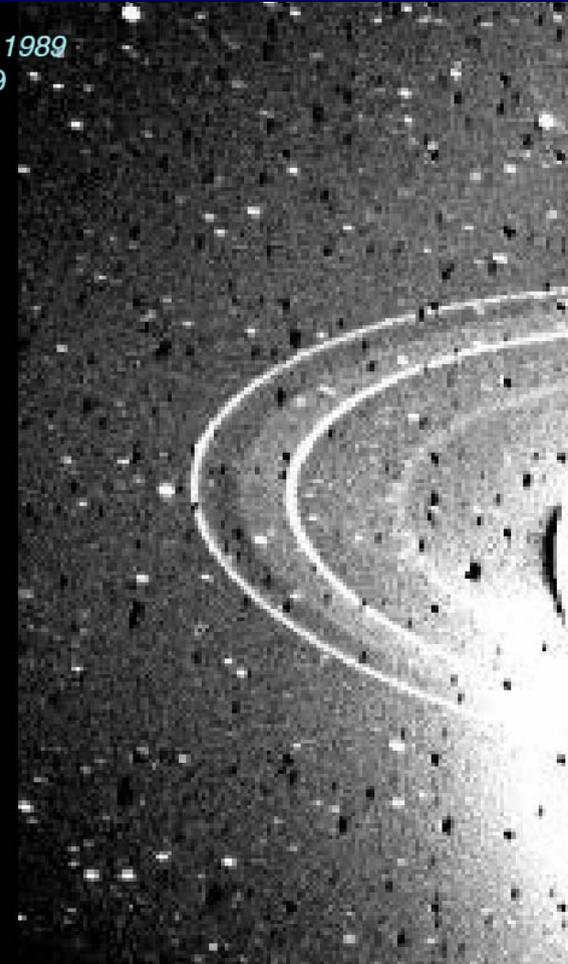
Karkoschka (University of Arizona Lunar & Planetary Lab) and NASA

Nettuno

Smith *et al.*, *Science*, 1989
Voyager August 1989



Smith *et al.*, *Science*, 1989
Voyager August 1989



3. MORFOLOGIA DEGLI ANELLI DI SATURNO

● 7 Anelli:

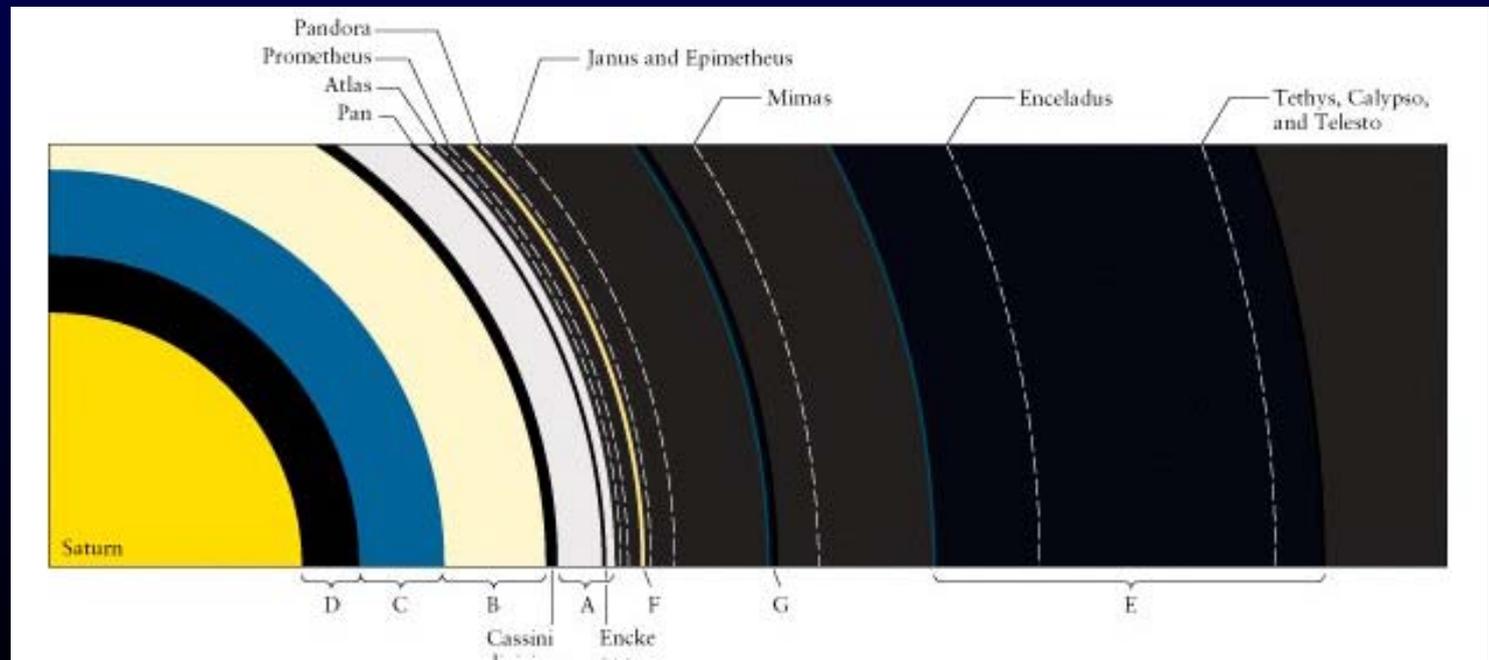
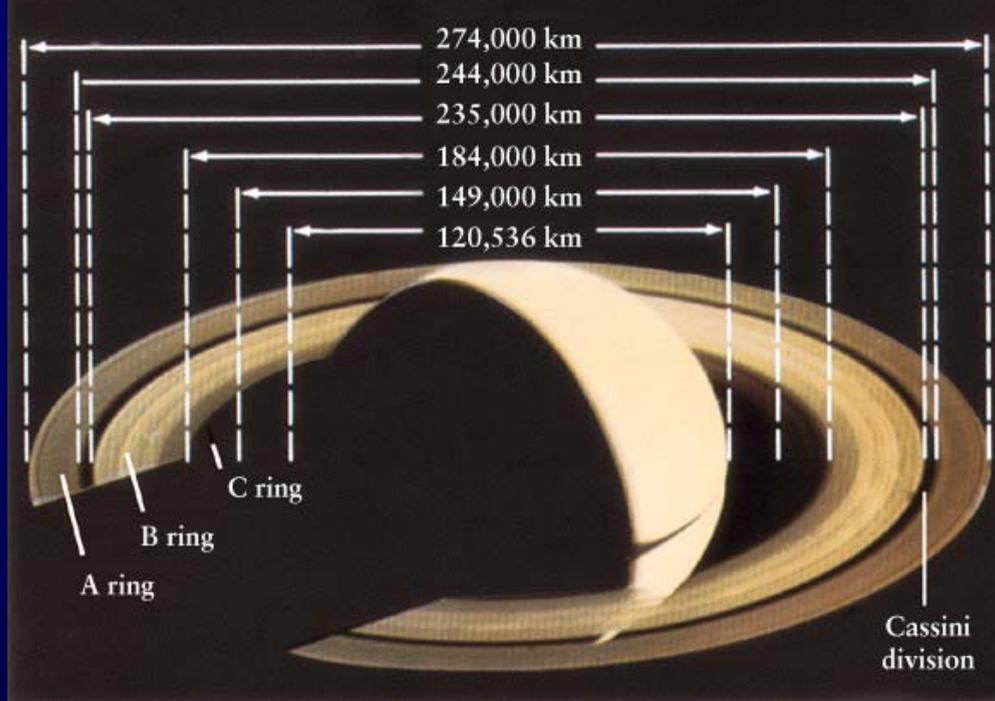
- A
- B
- C
- D
- E
- F
- G



● 5 Divisioni & Gap

- Divisione di Cassini
- Encke Gap
- Keeler Gap
- Huygens Gap
- Maxwell Gap





Saturn's Satellites and Ring Structure



All bodies are to scale except for Pan, Atlas, Telesto, Calypso and Helene, whose sizes have been exaggerated by a factor of 5 to show rough topography.



Strutture degli anelli di Saturno

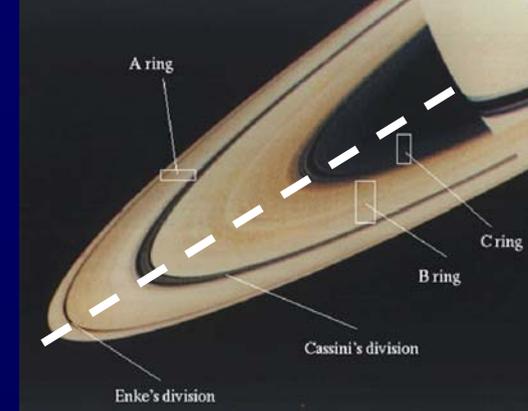
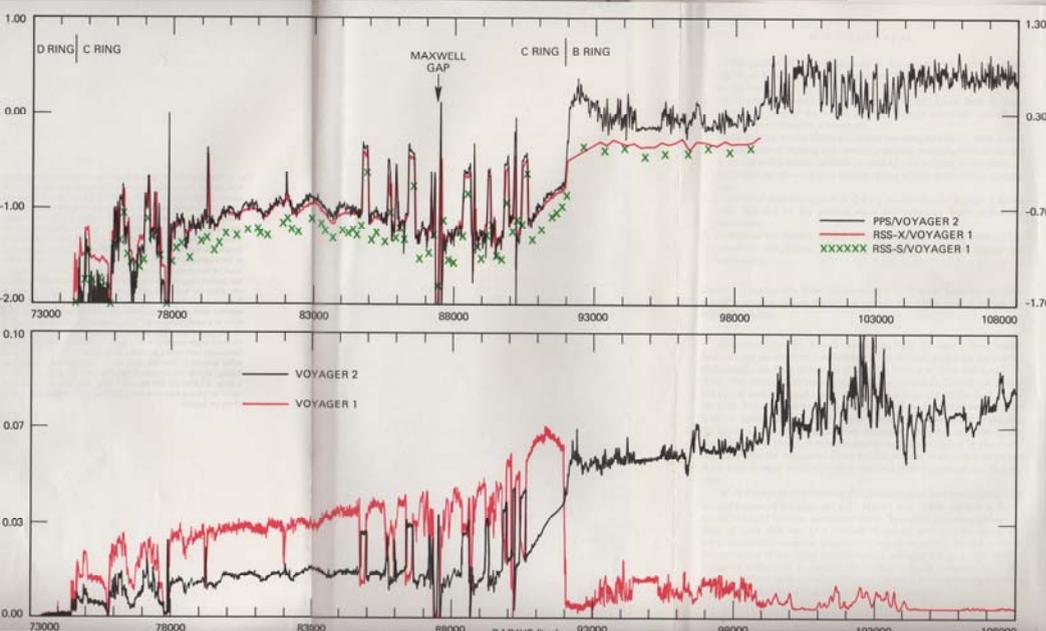
Struttura	Bordi		Dimensioni particelle	Profondità ottica	Commenti
	Interno (km)	Esterno (km)			
Anello D	66900	74658	μm	10^{-5}	Stretti ringlets a 67580 e 71710 km.
Anello C	74658	91975	mm - m	0.05 - 0.35	Plateaus isolati circondati da deboli anelli
Titan Ringlet	77871	77896			Ringlet eccentrico situato in una gap dell'anello C
Maxwell Ringlet	87491	87555			Ringlet eccentrico situato in una gap dell'anello C
1.470 R _s Ringlet	88716	88732			Ringlet eccentrico situato in una gap dell'anello C
1.495 R _s Ringlet	90171	90232			Ringlet eccentrico situato in una gap dell'anello C
Anello B	91975	117507	cm - 10m	0.4 - 2.5	Comprende strutture a tutte le scale spaziali. E' l'anello di Saturno più opaco.
Divisione di Cassini	117507	122340	cm - 10m	0 - 0.1	Divide gli anelli A e B. Contiene diverse strutture aventi bassa profondità ottica.
Huygens Ringlet	117825	118185			Ringlet eccentrico situato vicino al bordo interno della Divisione di Cassini.
A Ring	122340	136780	cm - 10m	0.4 - 1.0	Anello uniforme con molteplici onde di densità e di risonanza indotte dai satelliti.
Encke Gap	133410	133740		0	Gap nell'anello A aperta intorno all'orbita di Pan.
Keeler Gap	136510	136550		0	Gap vuota situata presso il bordo esterno dell'anello A.
Anello F (core)	140219		$\mu\text{m} - \text{cm}$	0.1 - 1	Ringlet eccentrico contenente gruppi e nodi. Bordi radiali 140194 - 140244 km.
Anello G	166000	173200	$\mu\text{m} - \text{mm}$	10^{-6}	Debole anello di polvere
Anello E	180000	480000	μm	10^{-6}	Debole anello di polvere comprendente le orbite di diversi satelliti, da Mimas a Dione. Presenta una maggiore densità vicino all'orbita di Encelado. Spessore massimo di circa 30000 km.

Periodi orbitali - Masse

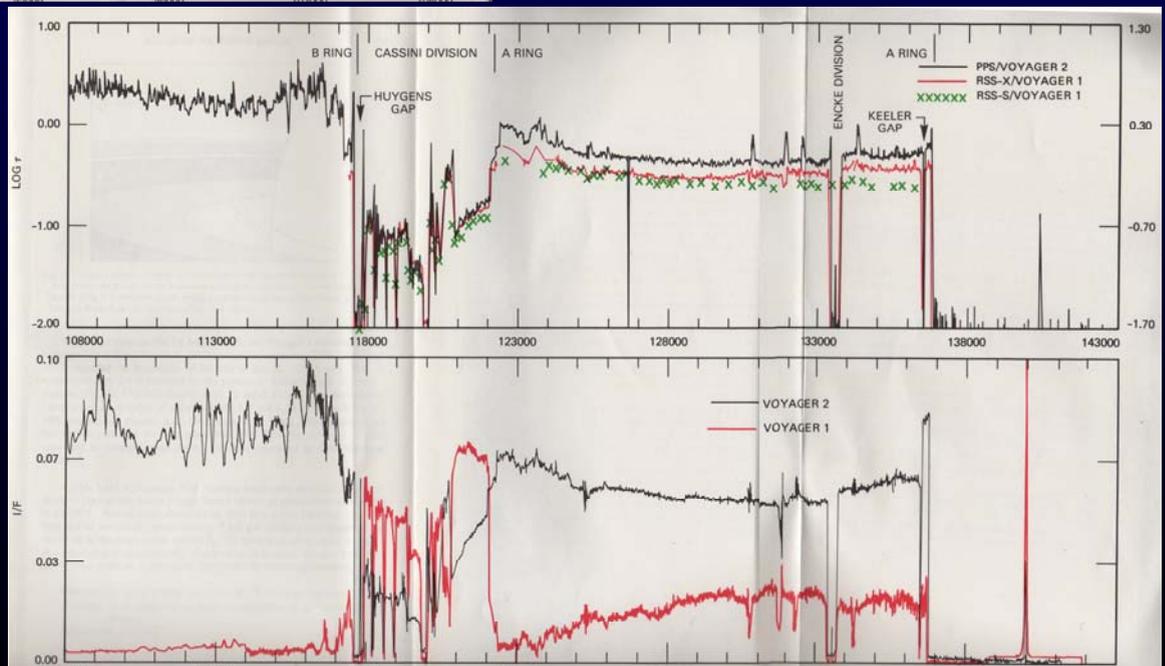
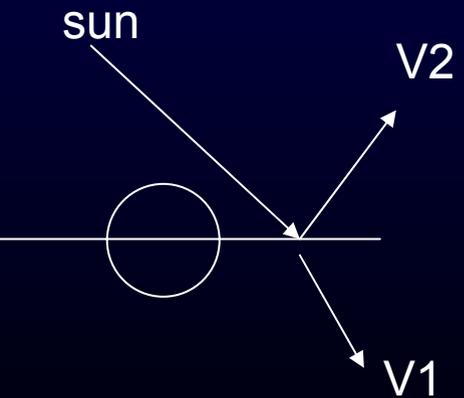
Struttura	Raggio (R _S)	Frequenza orbitale Ω (10 ⁻⁴ s ⁻¹)	Periodo orbitale
Anello D in	1.11	3.554	4 h 54 m 30 s
Anello D out	1.235	3.028	5 h 45 m 50 s
Anello C in			
Anello C out	1.525	2.207	7 h 54 m 30 s
Anello B in			
Anello B out	1.949	1.528	11 h 25 m 00s
CD in			
CD out	2.025	1.442	12 h 6 m 12 s
A in			
A out	2.267	1.218	14 h 19 m 46 s
F	2.324	1.176	14 h 50 m 28 s
G	2.82	0.878	19 h 52 m 43 s
E in	3.0	0.8	21 h 49 m 00s
E out	8.0	0.2	3 d 15 h 16 m 00 s

Struttura	Massa (M _S)
Anello D	?
Anello C	2 · 10 ⁻⁹
Anello B	5 · 10 ⁻⁸
CD	10 ⁻⁹
A	1.1 · 10 ⁻⁸
F	?
G	10 ⁻¹⁷
E	?

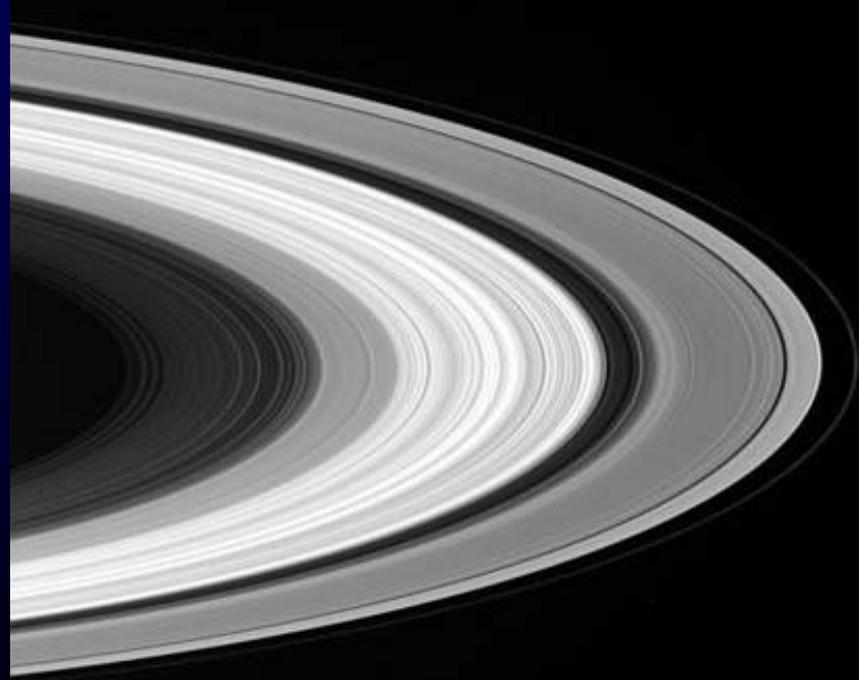
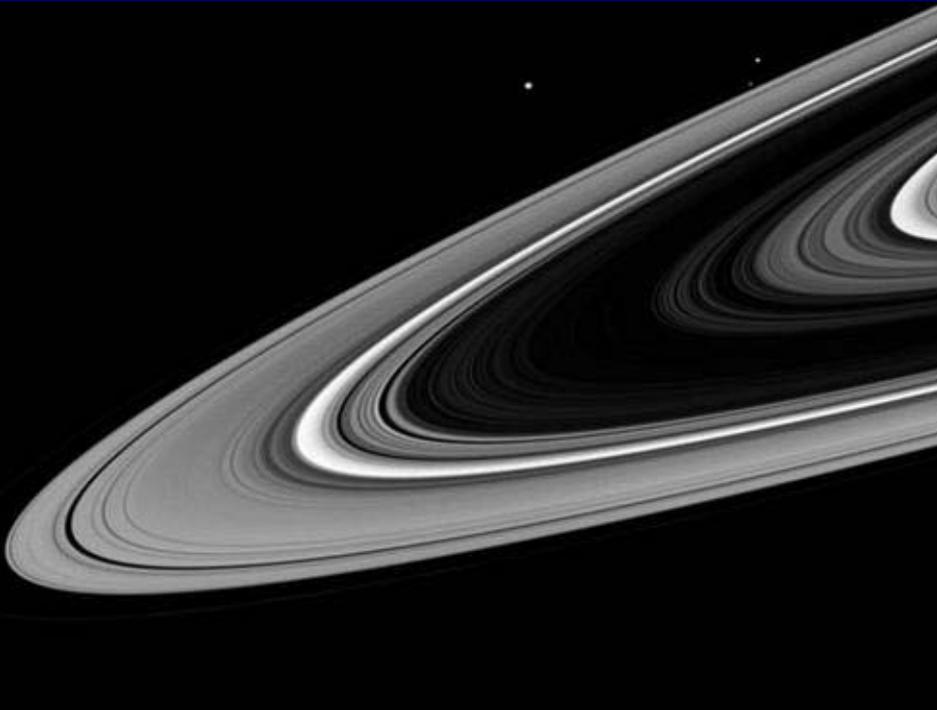
Profili radiali



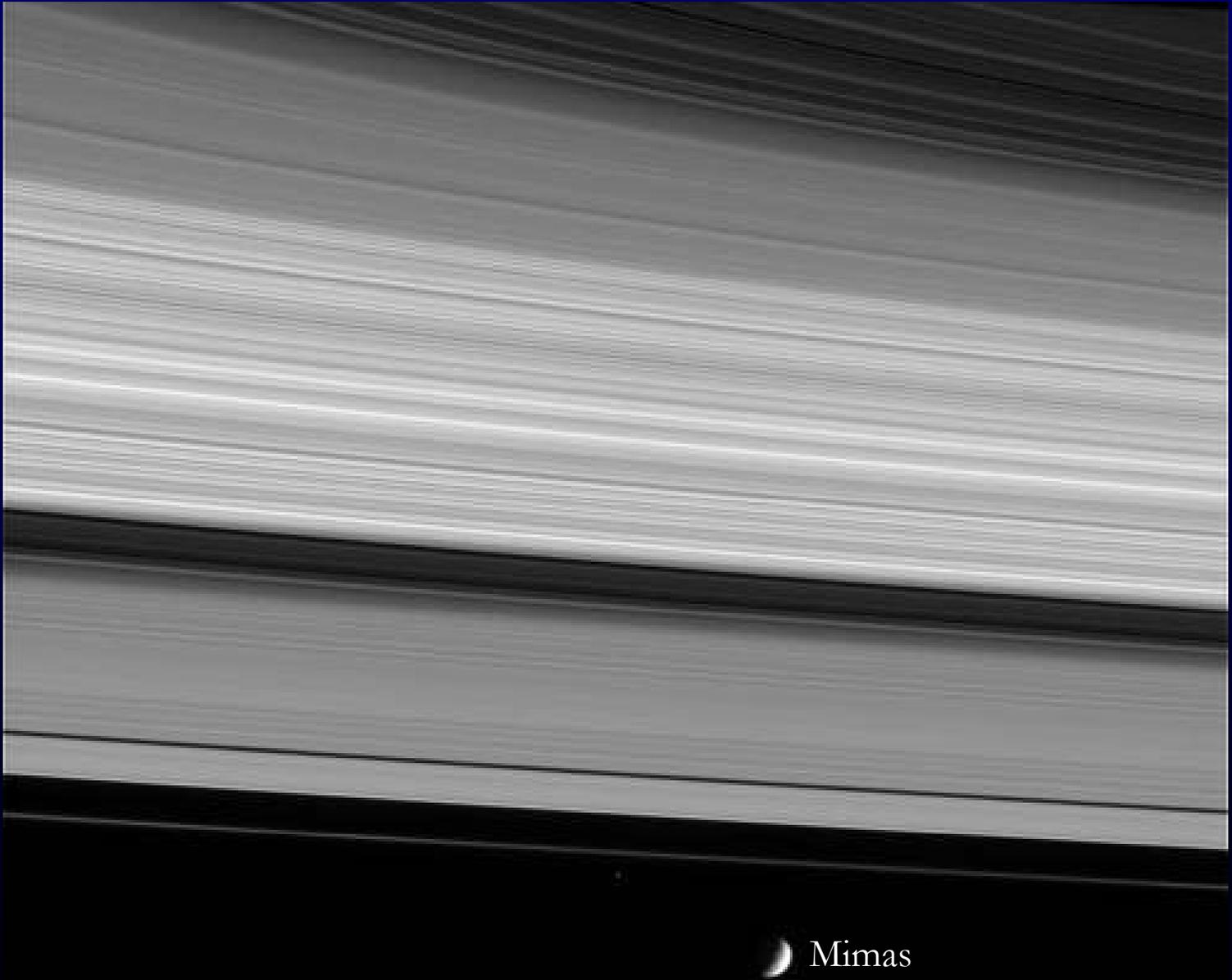
PPS (260 nm)
 RSS X (3.6 cm)
 RSS S (13 cm)



Anelli in trasmittanza vs riflettanza

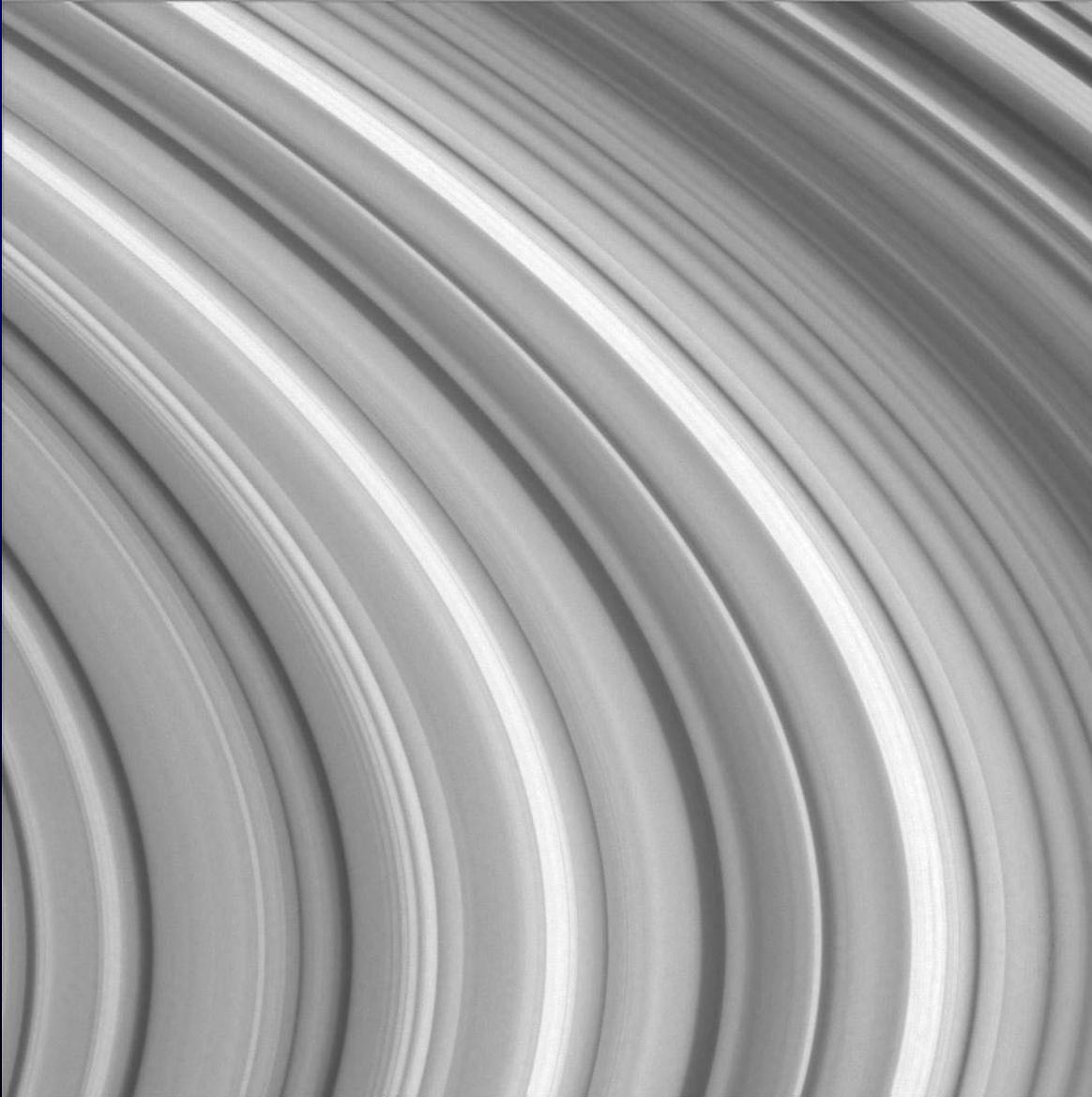


Anello A

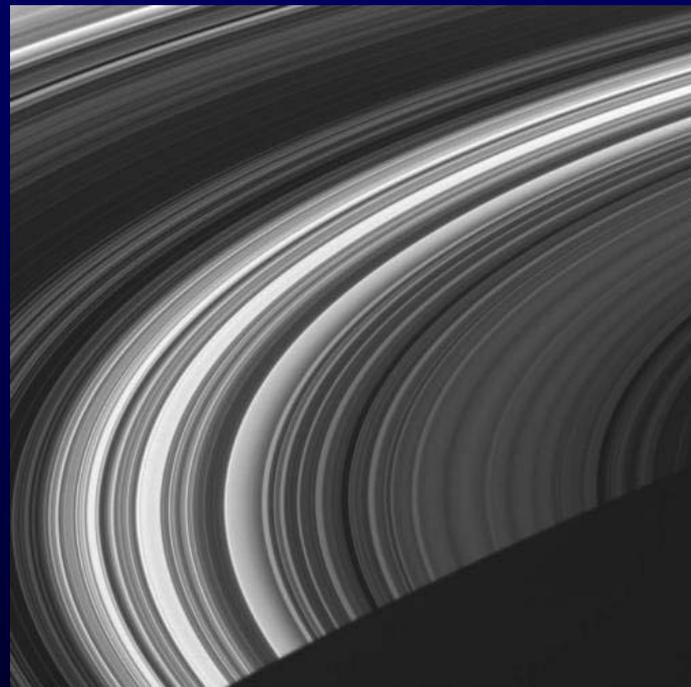


Mimas

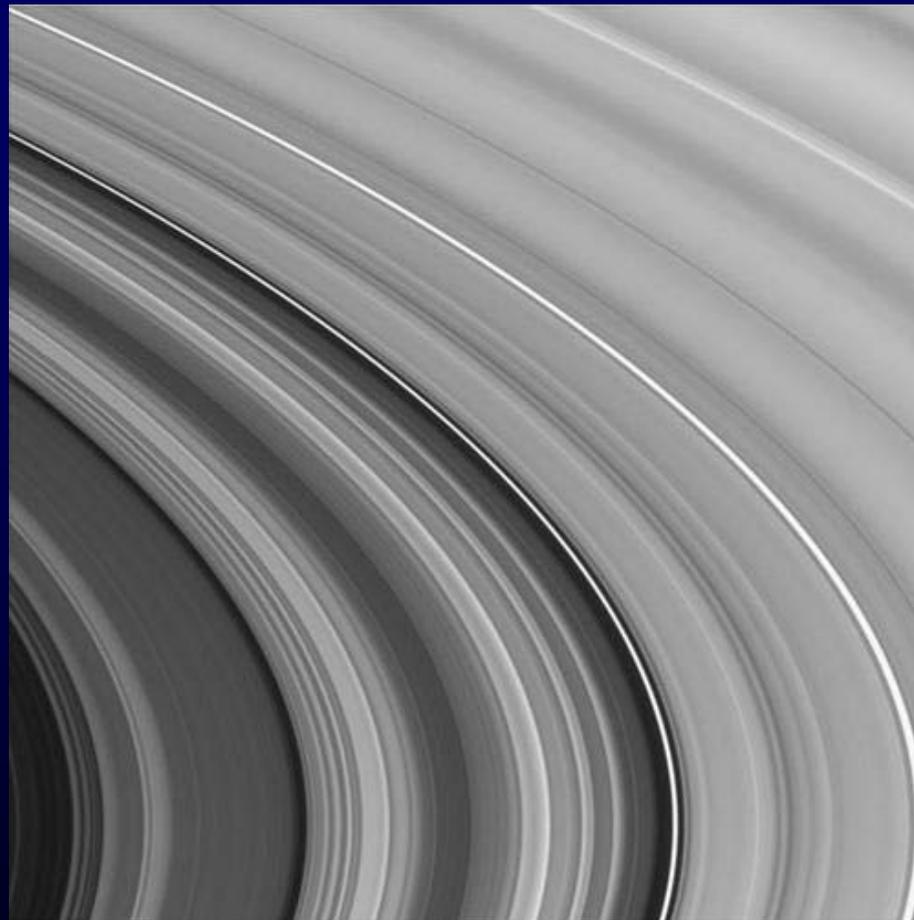
Anello B



Anello C



In trasmittanza

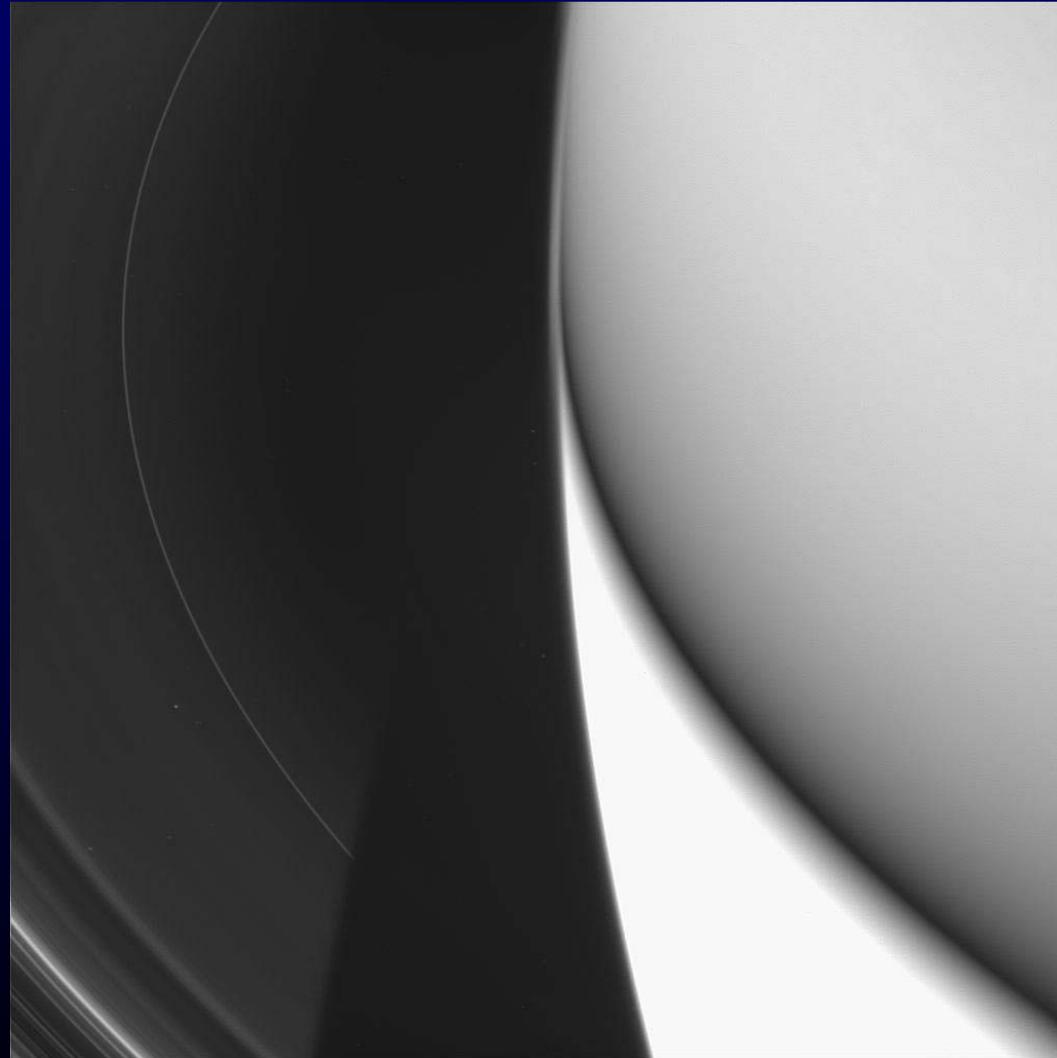


Colombo gap-ringlet

$R = 75.000 \text{ km}$

Anello D

D68



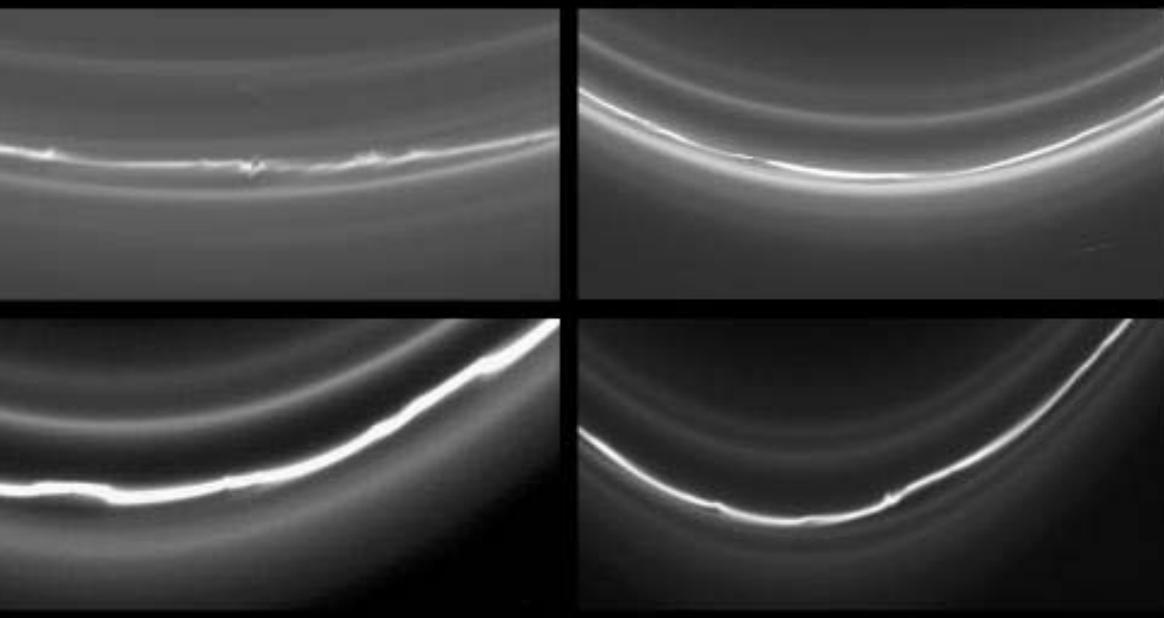
Anello composto
prevalentemente da polveri

Anello E

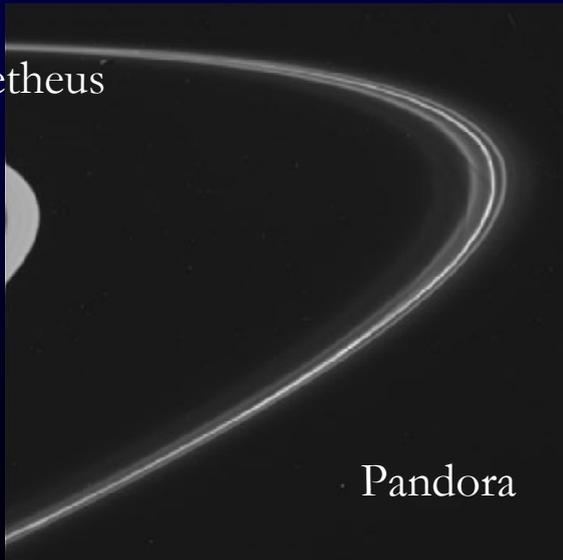


Anello tenue e diffuso composto prevalentemente da acqua ed ossigeno emessi da Enceladus

Anello F



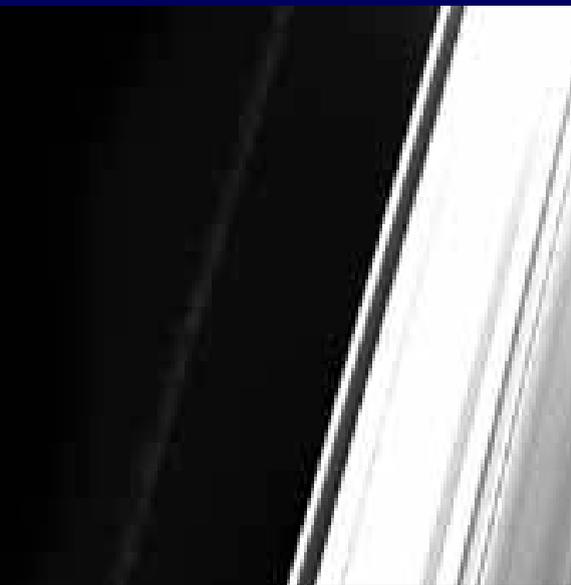
Prometheus



Pandora

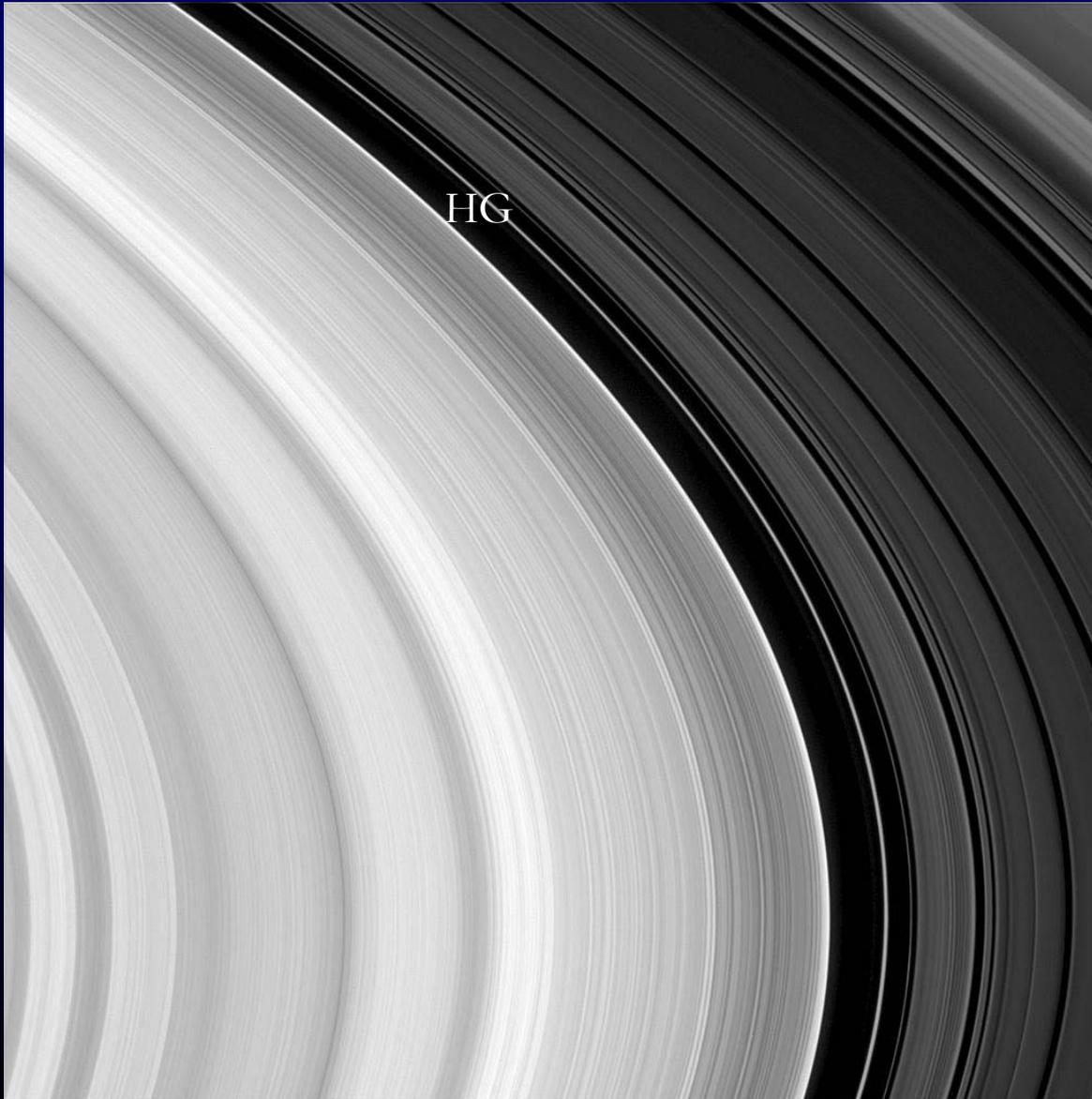
Pandora

Anello G

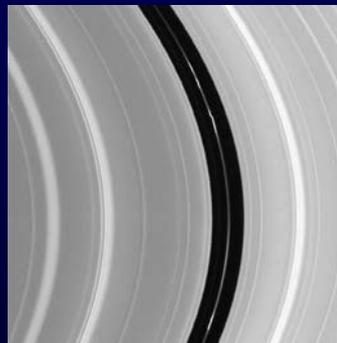
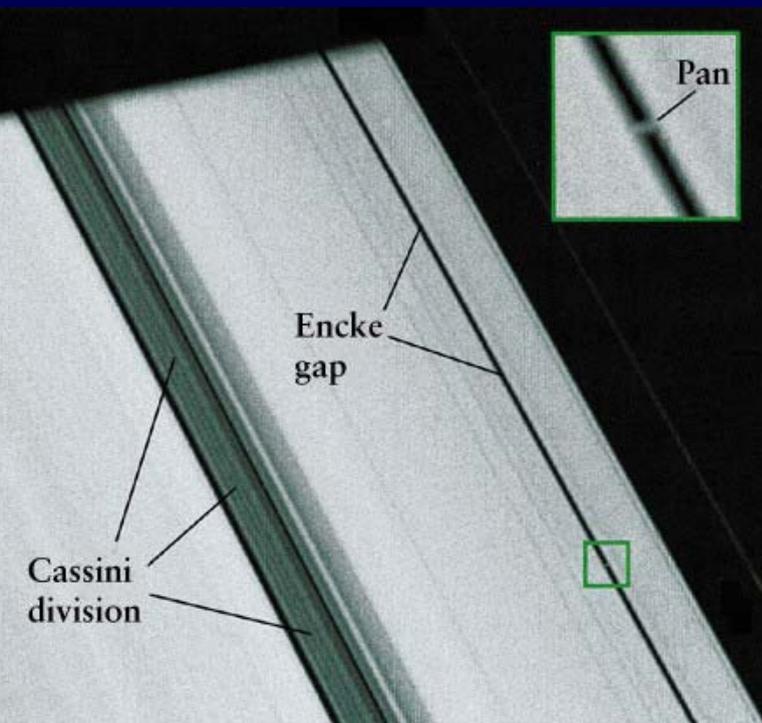
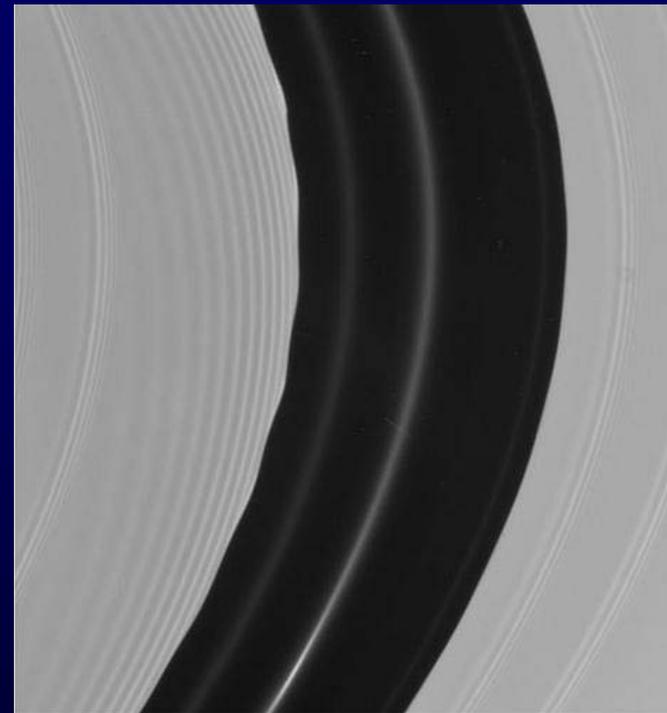
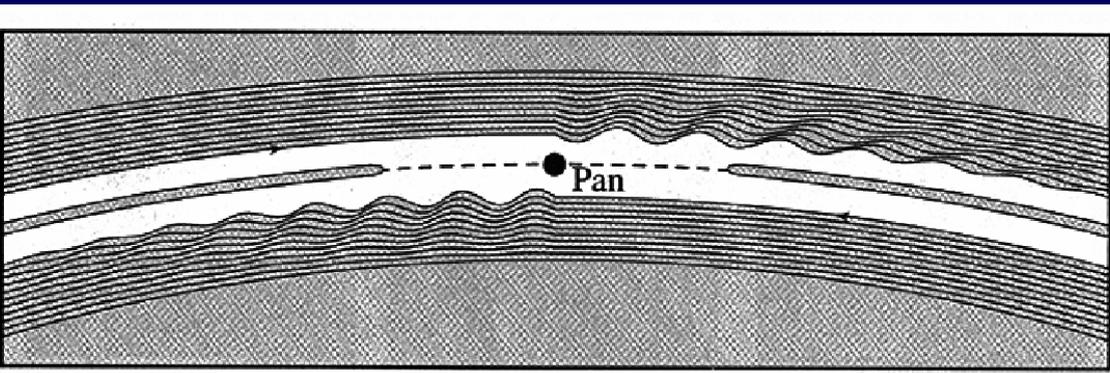


Anello di polveri

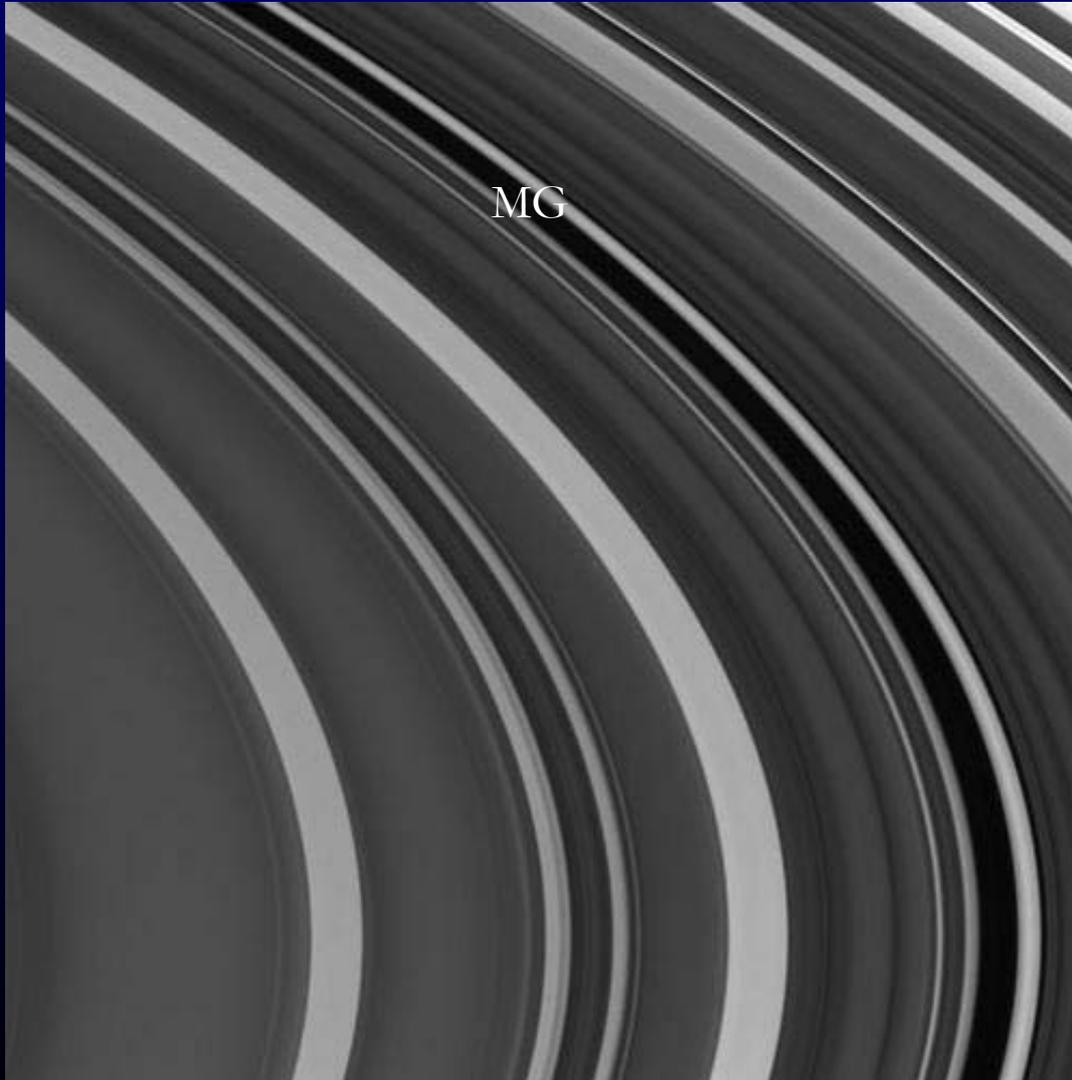
Divisione di Cassini



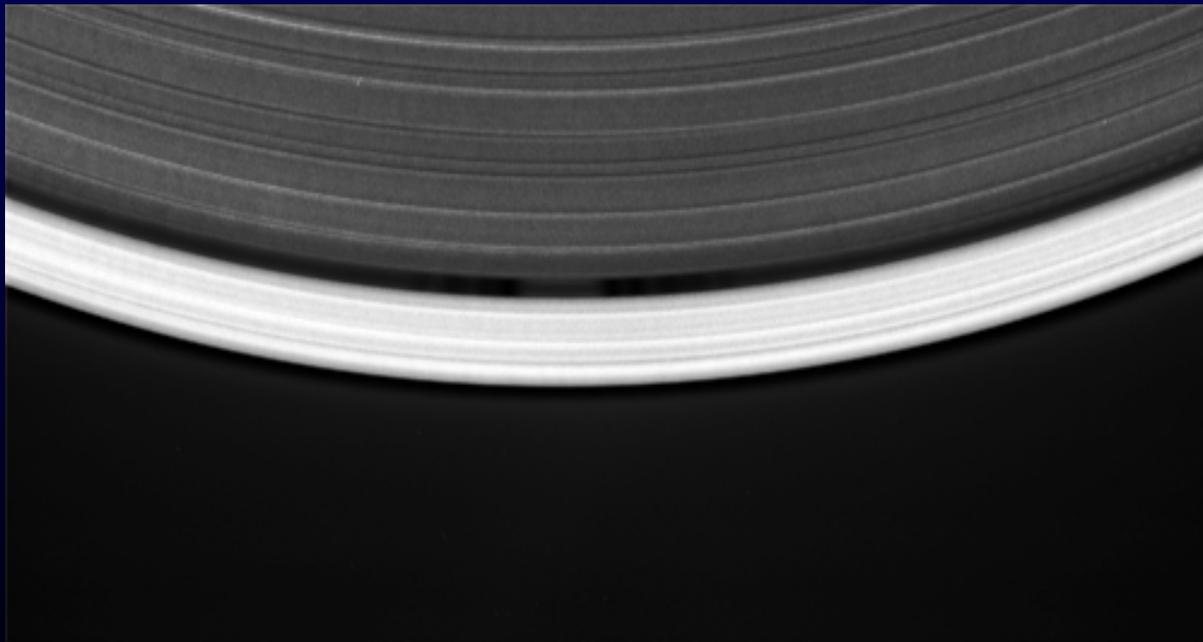
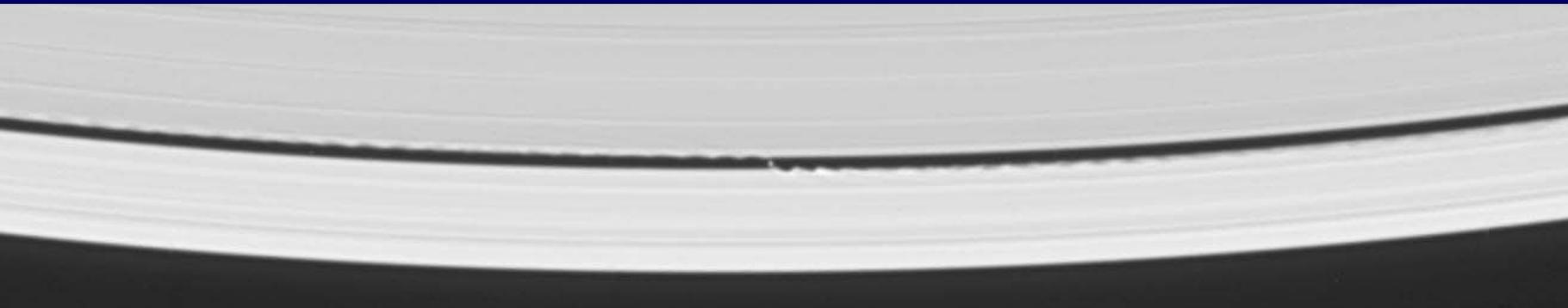
Encke Gap - Pan



Maxwell Gap

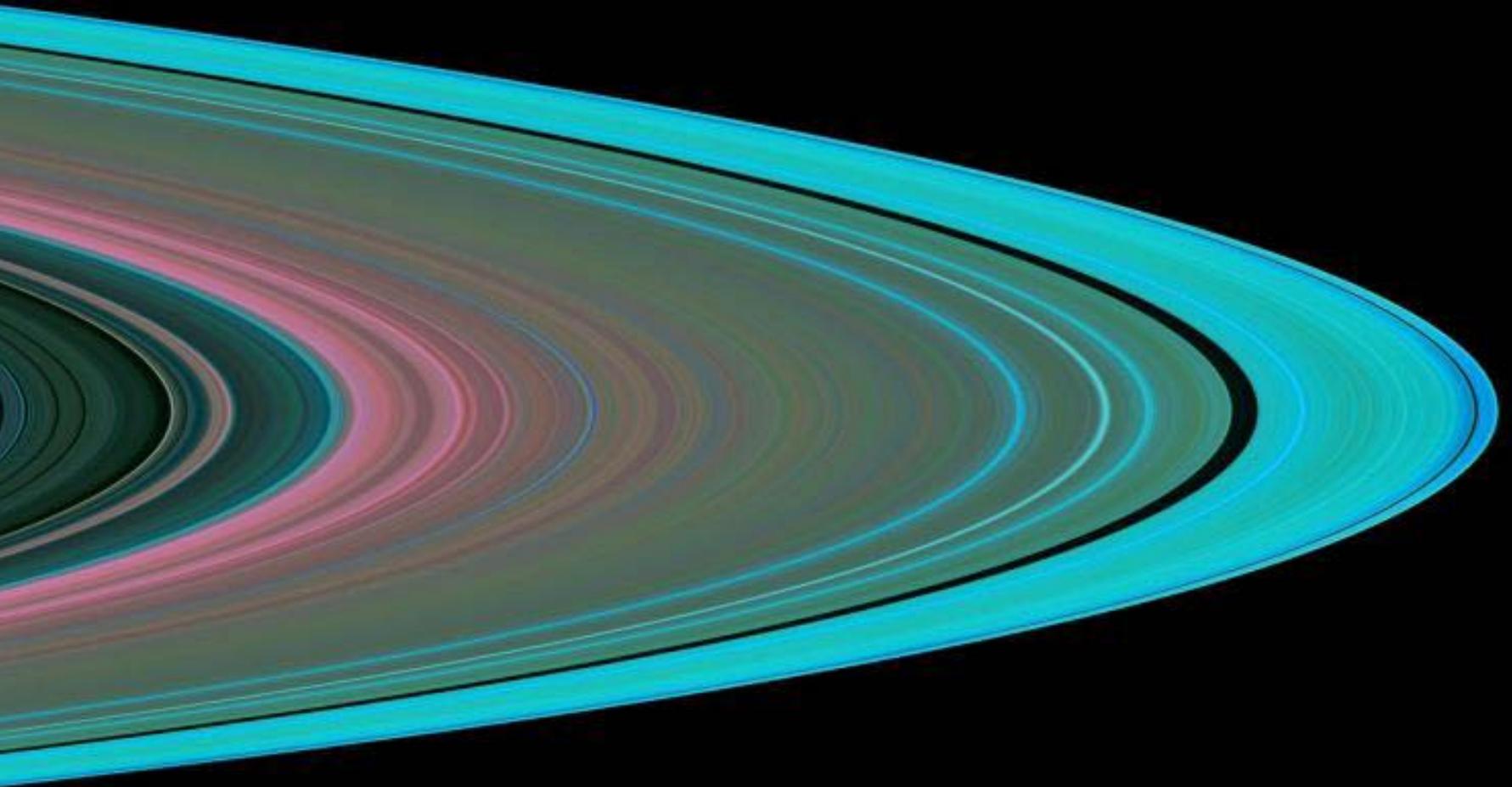


Keeler Gap



S/2005 S1 (7 km)

Dimensioni particelle



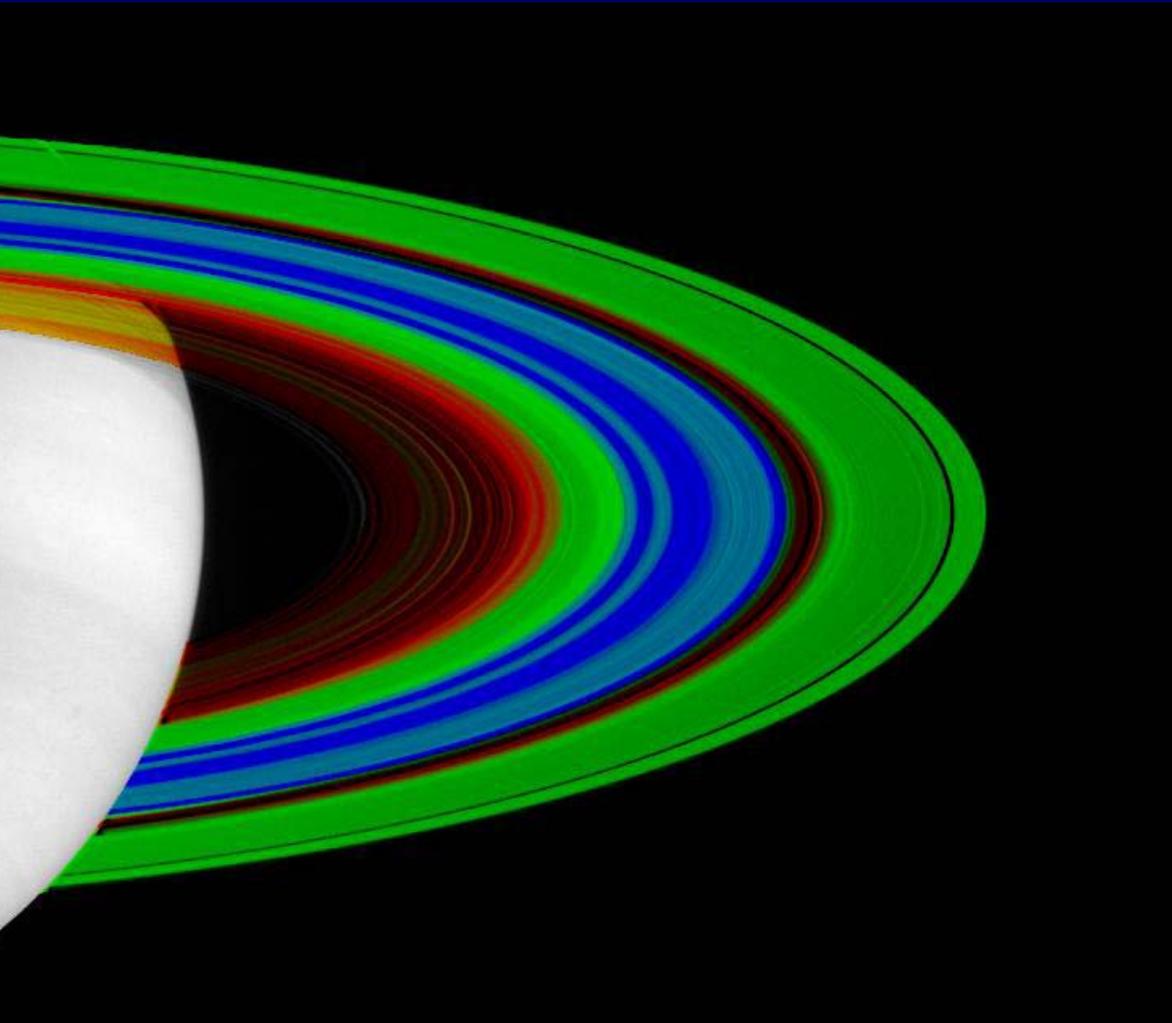
Cassini RSS (0.94, 3.6, 13 cm) (bande Ka, X, S) misura in occultazione.

Rosso: regioni a prevalenza di particelle con diametro > 5 cm;

Verde-Blu: regioni a prevalenza di particelle con diametro < 5 cm;

HC: regioni a prevalenza di particelle con diametro < 5 cm;

Temperatura



Cassini CIRS

Rosso $T=110$ K

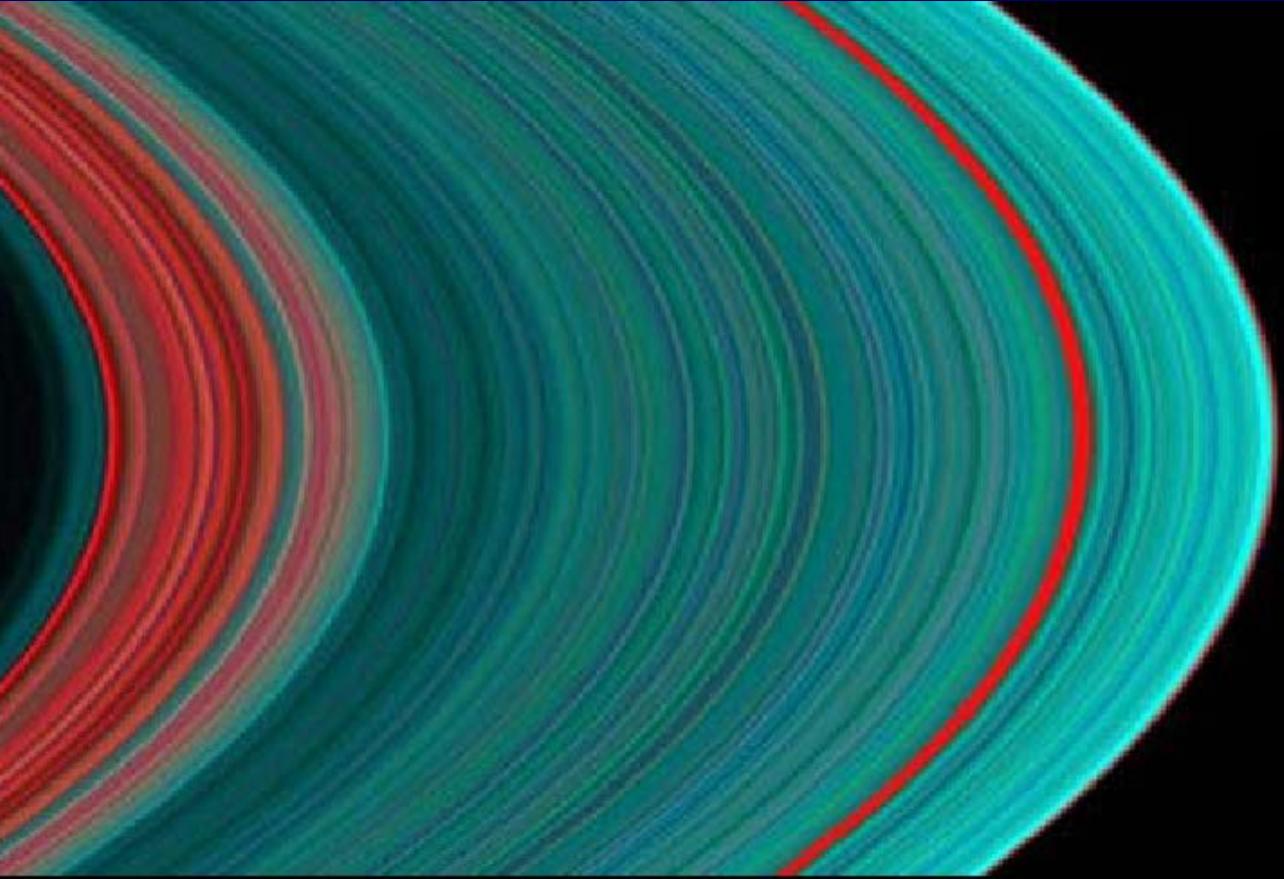
Verde $T=90$ K

Blu $T=70$ K

CD ed anello C sono le regioni più calde.

Anello B (centro) regione più fredda.

Composizione

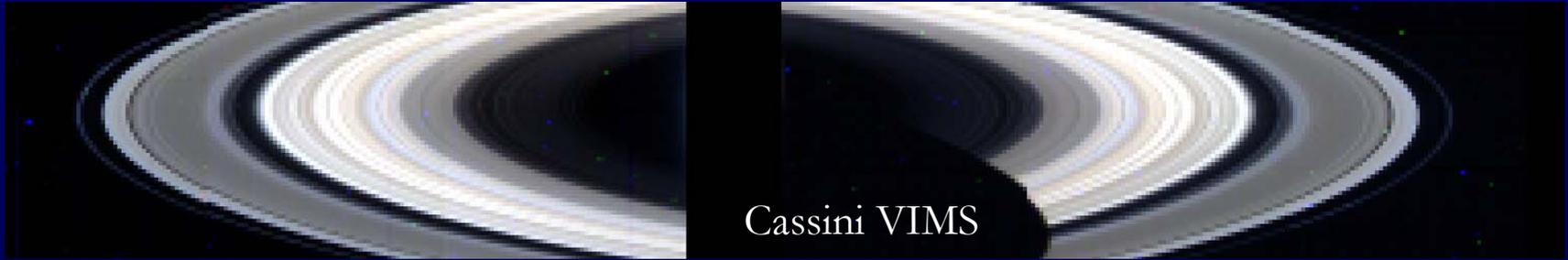


Cassini UVIS

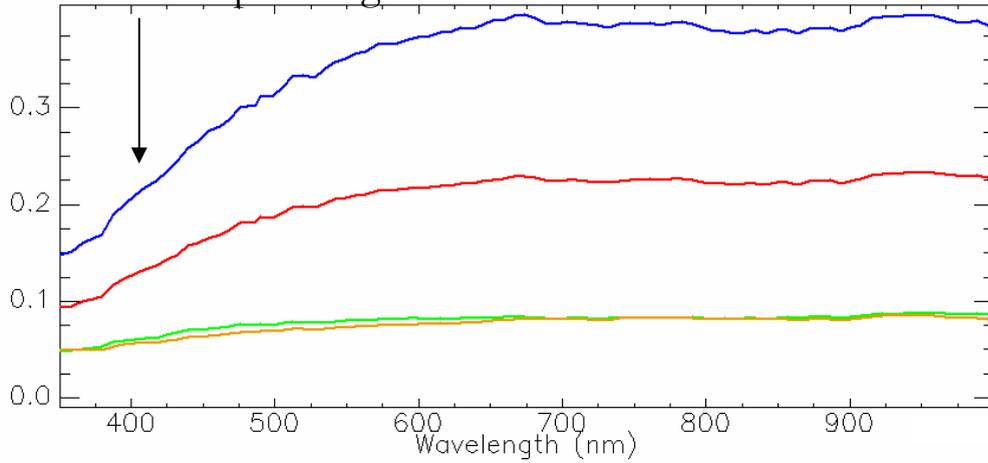
Turchese: ghiaccio d'acqua

Rosso: contaminazione
sostanze organiche (toline)

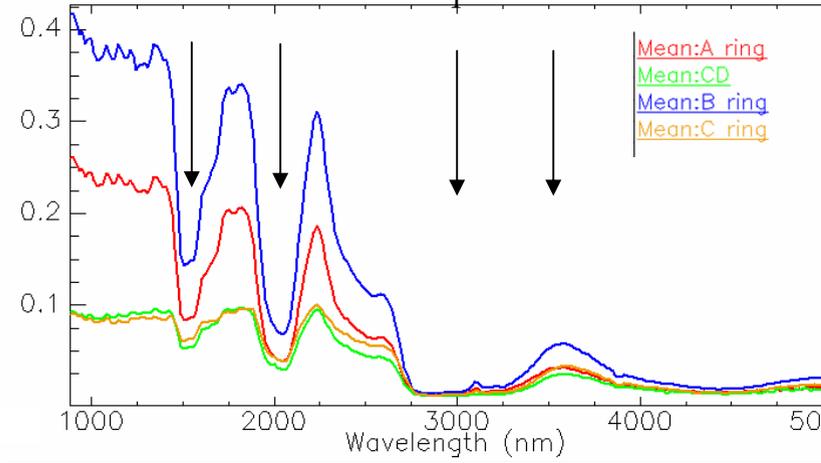
Composizione



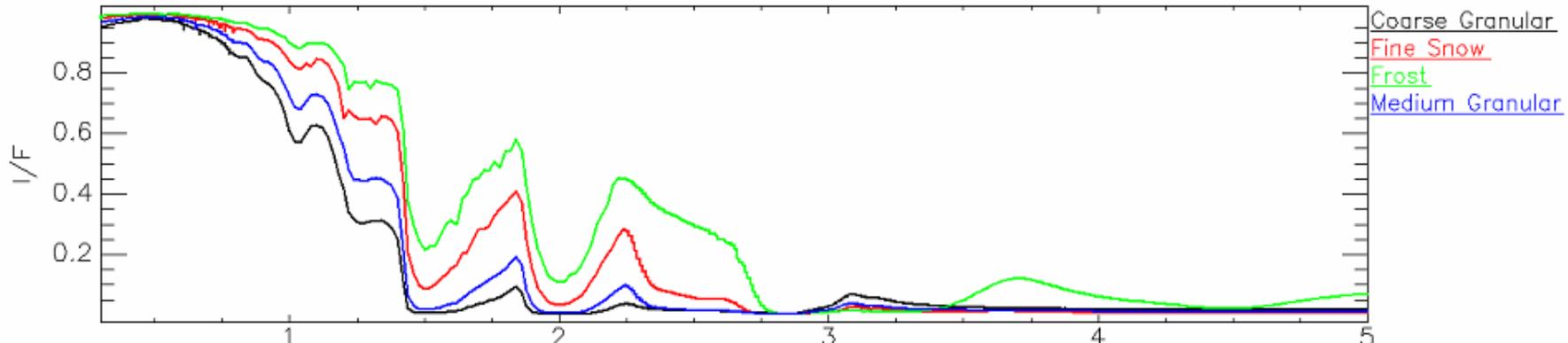
Toline – Composti organici



Ghiaccio d'acqua



Water Ices



Atmosfera

- La radiazione solare provoca la fotodissociazione dell'acqua presente negli anelli provocando la presenza di una tenue atmosfera di acqua e suoi derivati (OH , H_2). Questi composti vengono intrappolati dall'intenso campo magnetico di Saturno.
- Un effetto analogo è dovuto ad Enceladus (anello E) ed agli altri satelliti.

