

Astronomy 405

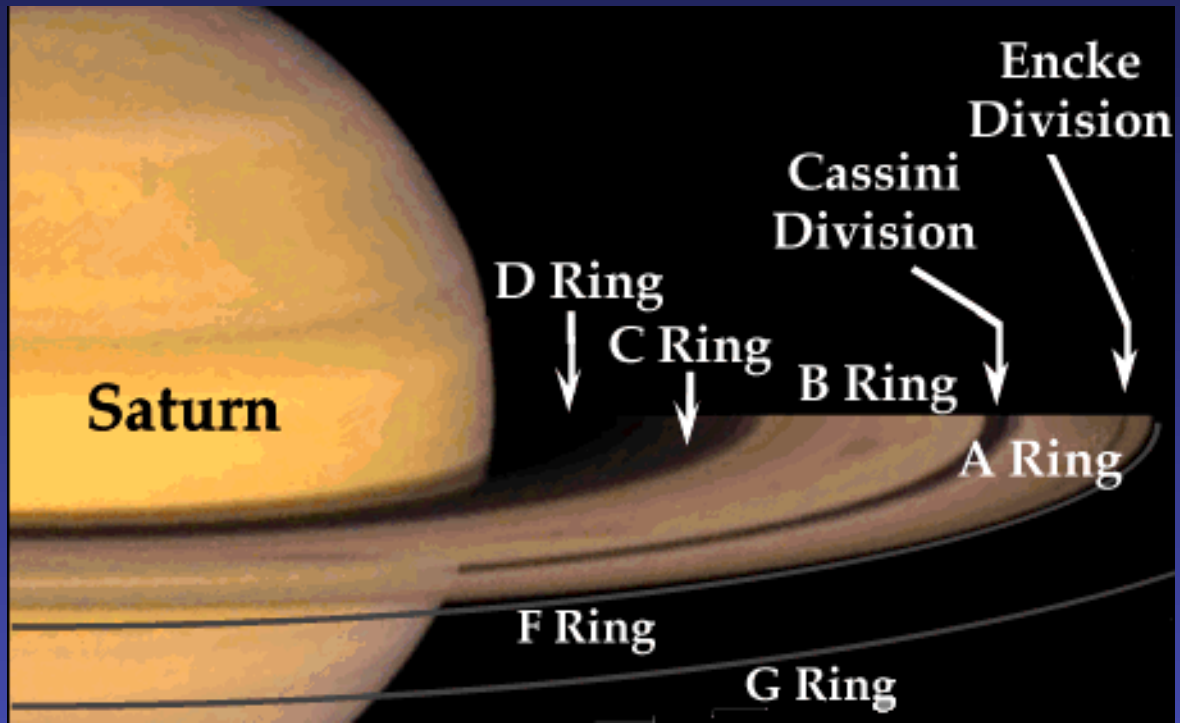
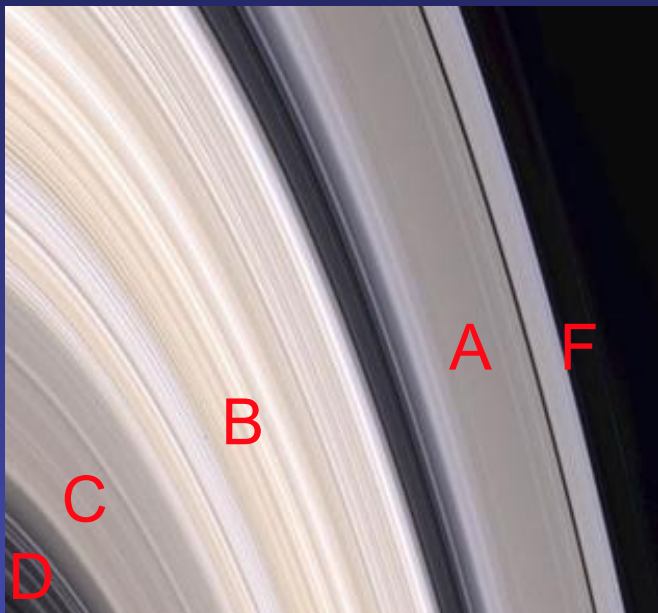
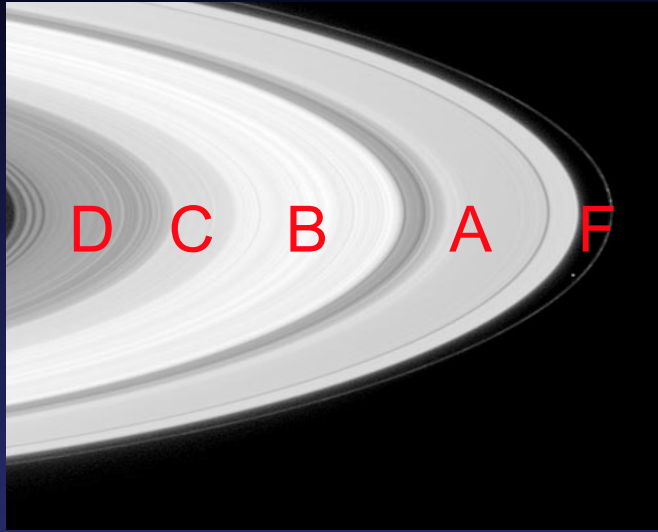
Solar System and ISM

Lecture 12

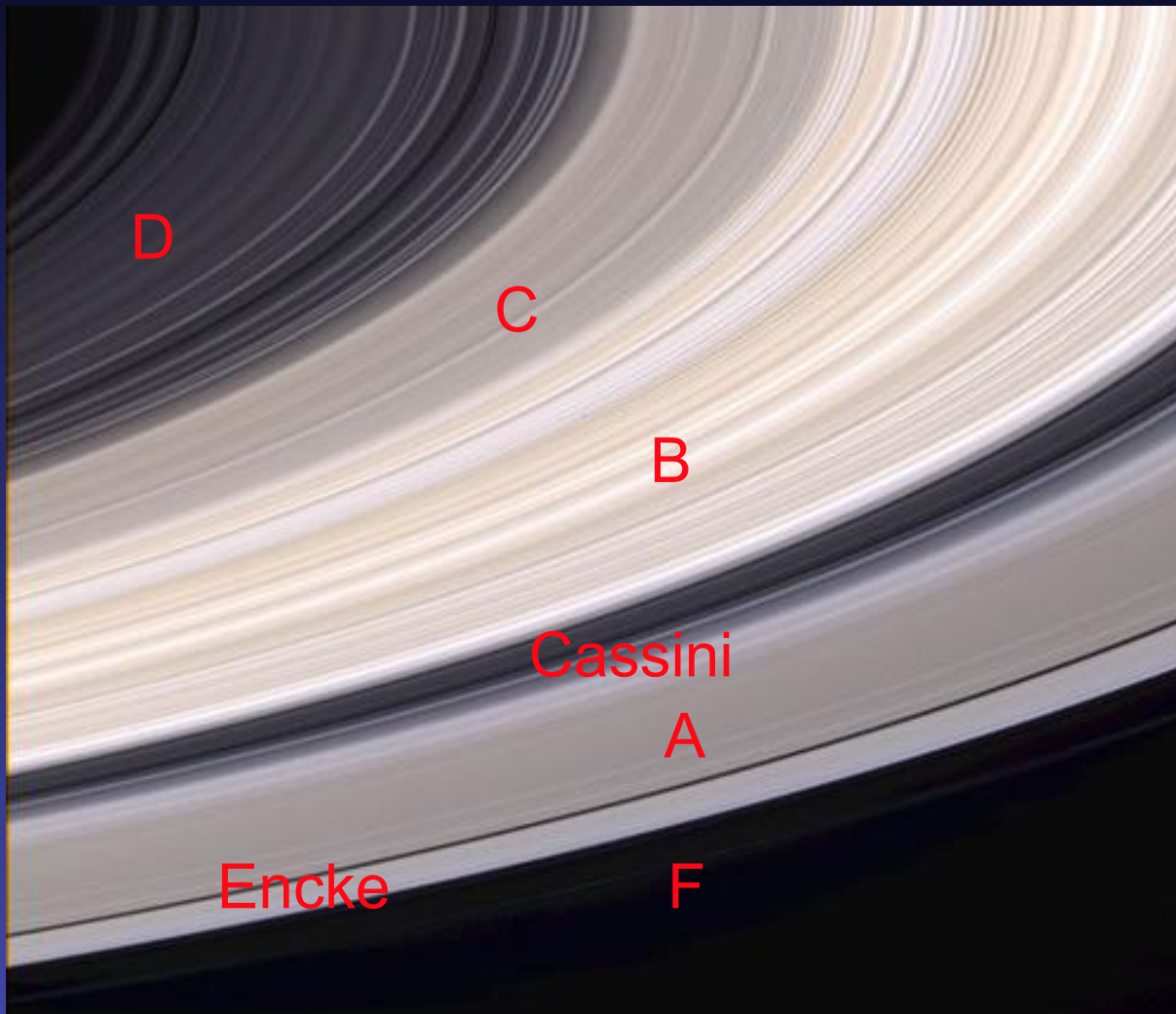
Ring Systems

February 11, 2013

Saturn's Rings



Rings are resolved into ringlets.
Cassini division still contains ringlets.
Encke gap is empty.



Ring	D (Rs)
D	1.00-1.21
C	1.21-1.53
B	1.53-1.95
Cassini	1.95-2.03
A	2.03-2.26
Roche L.	2.04
F	2.33
G	2.8
E	3-8

Roche limit:

$$r < f_R (\rho_p / \rho_m)^{1/3} R_p$$

The disk of Saturn's rings is only a few meters thick.
The vertical ripples make it look like 1 km thick.
Because of the thinness, the optical depth is only 0.1-2.

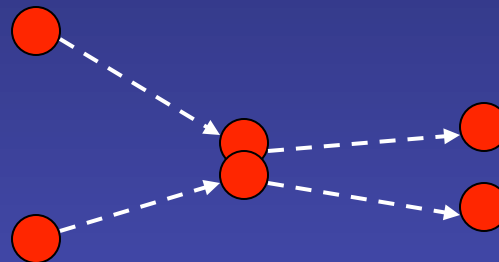
Optical depth = thickness / mean free path

Mean free path = $(n \sigma)^{-1}$,

where n = particle number density

σ = cross section = πa^2

The rings are thin because inelastic collisions between particles with differently inclined orbits tend to eliminate the vertical component and leave only the orbital motion along the plane.



Most particles in Saturn's rings have sizes from a few centimeters to a several meters.

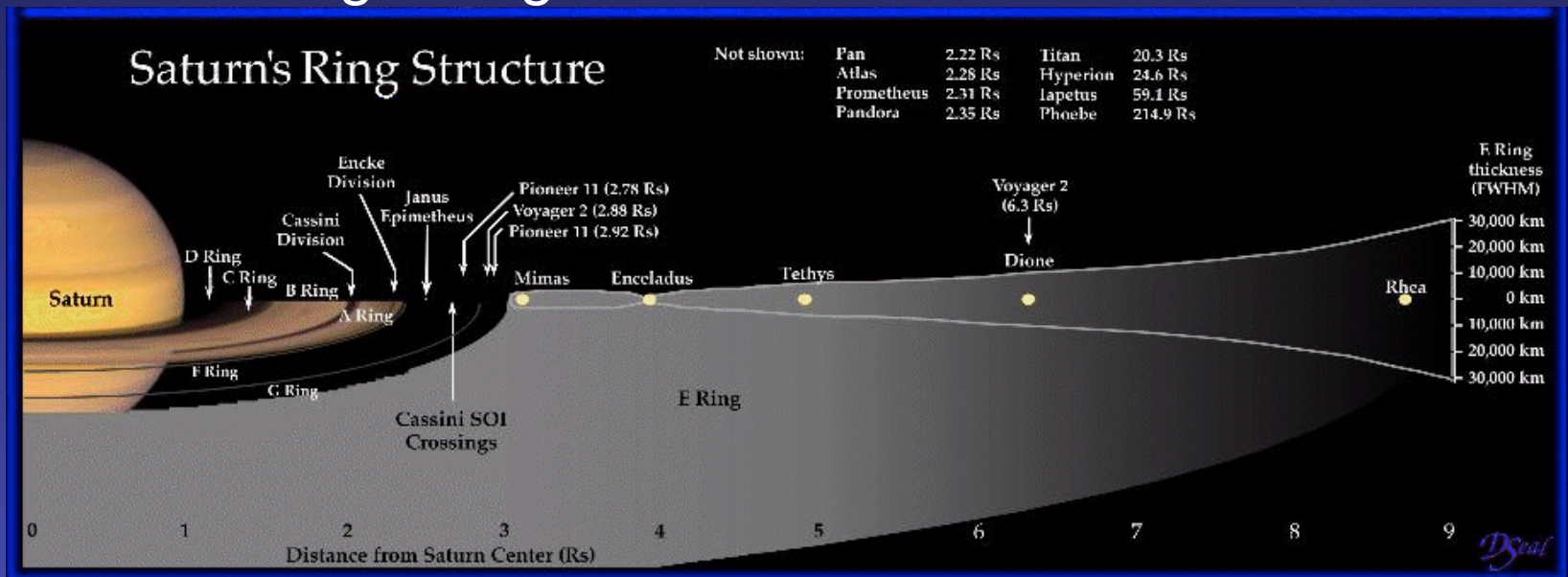
Dust particles a few microns large also exist.

Kilometer-sized objects may also exist.

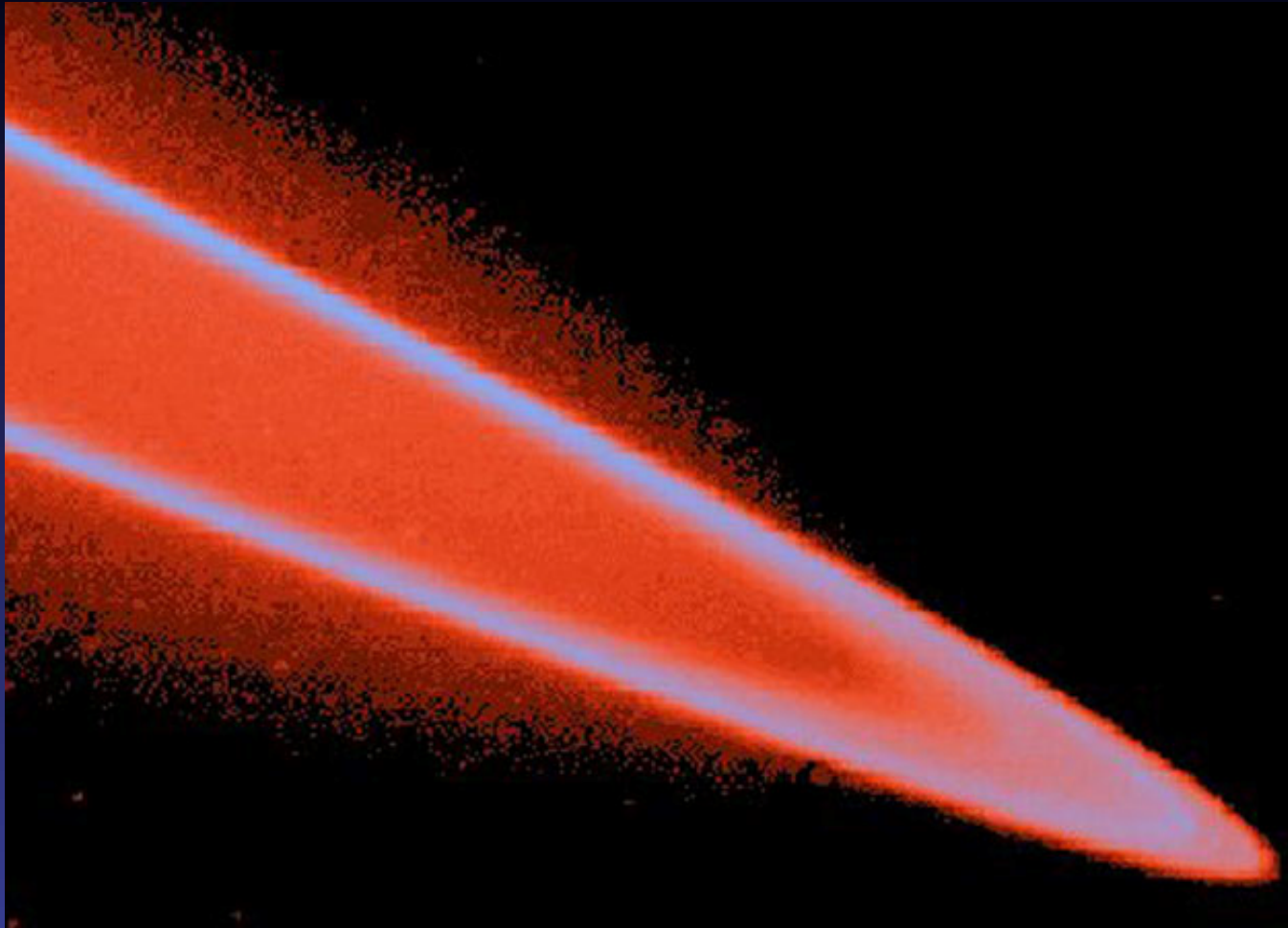
Material in Saturn's rings are very reflective, with albedos of 0.2-0.6.

IR spectroscopy + albedo => Mostly water-ice

However, the faint E-ring is composed entirely of dust originating from the moon Enceladus.



Voyager Discovered Jupiter's Rings



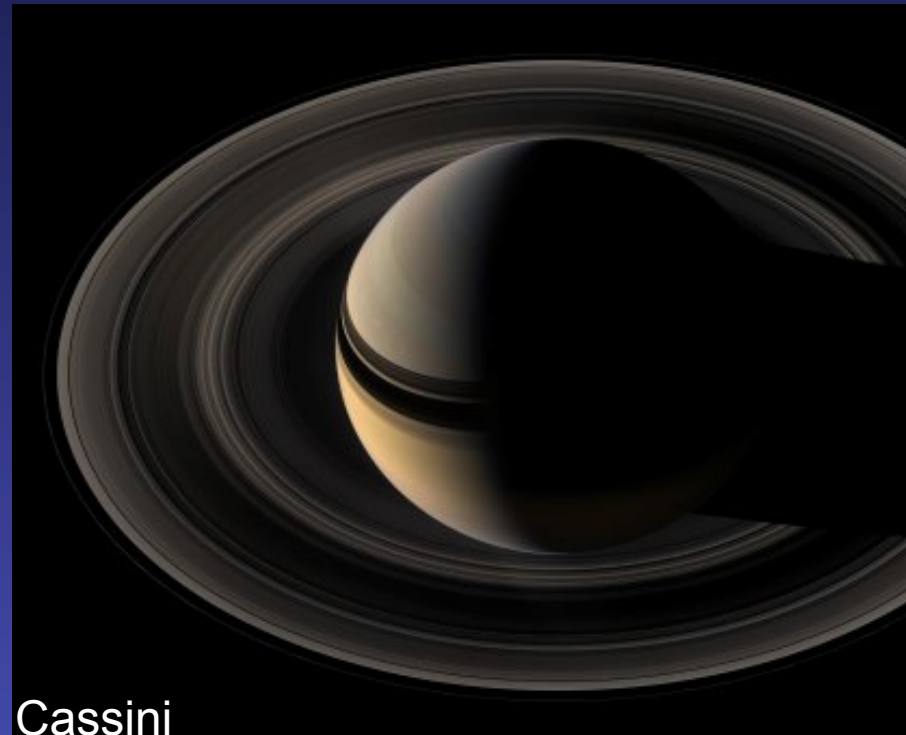
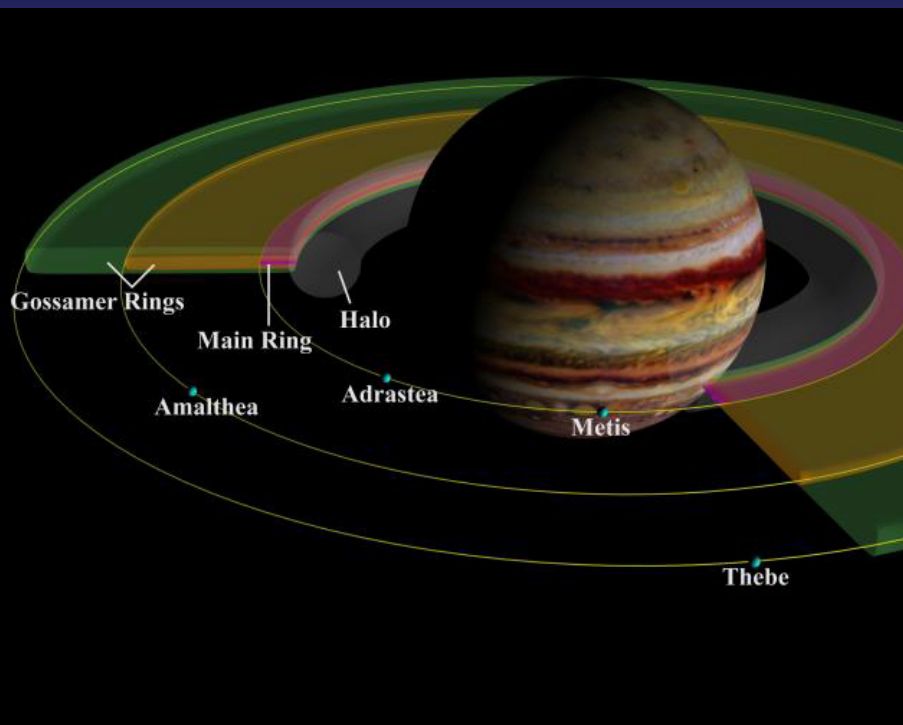
Jupiter's rings are dim because they consist of fine dust without ice. Charged particles are lifted by electromagnetic field to form the halo.

Jupiter's Rings

Toroidal halo, main ring, and gossamer ring. Up to $3 R_J$.

Meteoroids colliding with tiny moons to replenish the dust.

Jupiter eclipsing the Sun

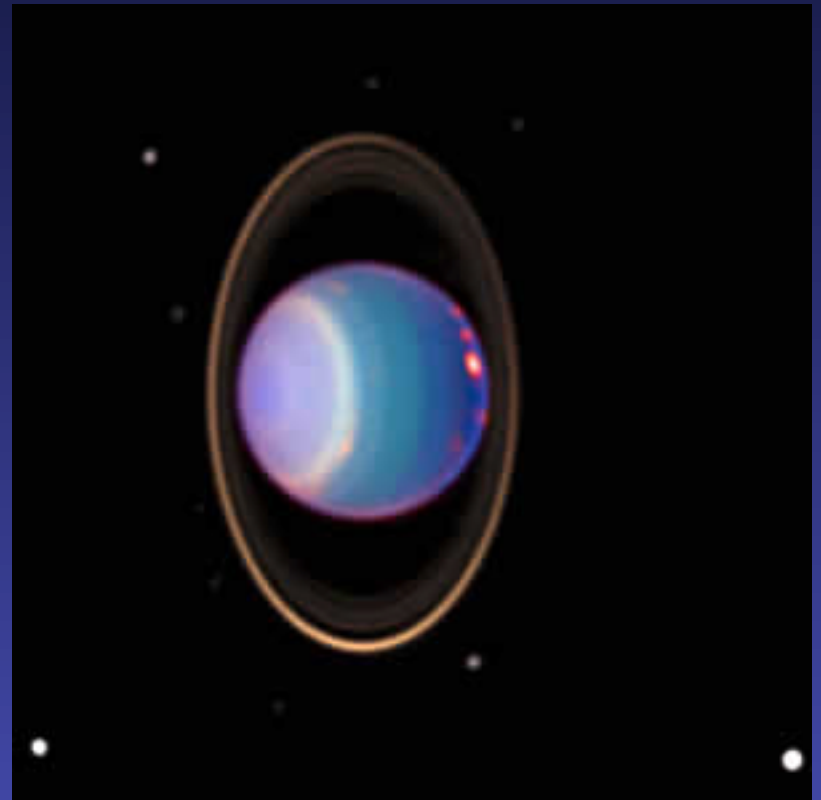


Rings of Uranus

First discovered from ground-based observations of occultation of stars by Uranus.

Rings are thin, similar to Saturn's F-rings.

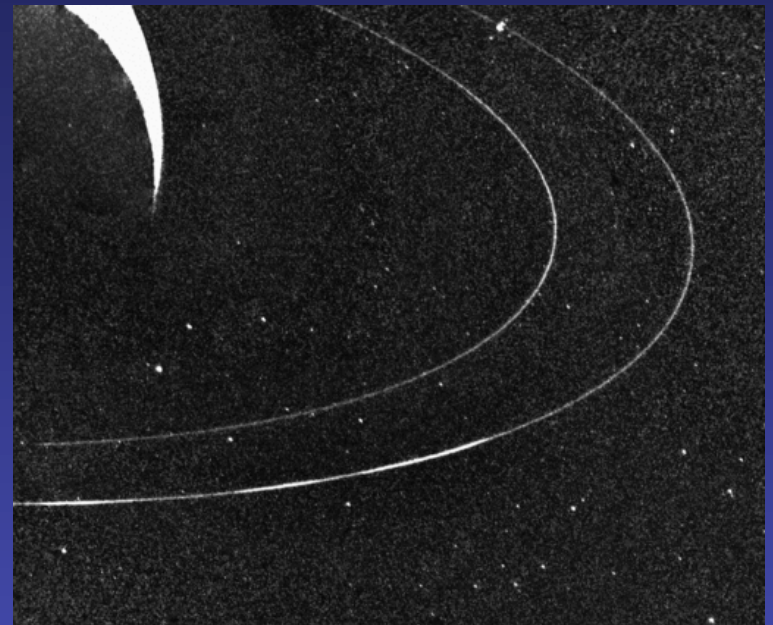
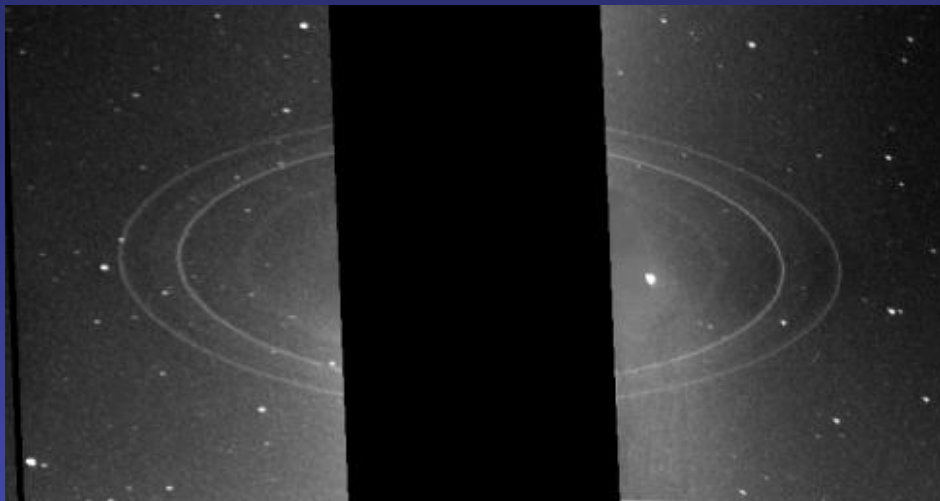
Small albedo ~ 0.01 ; rings contain mostly dust.



Rings of Neptune

Neptune's rings were also discovered from observations of occultation of stars. Some rings consist of arcs.

Voyager 2 images show the rings.



Physical Processes Affecting Ring Systems

Collisions

- maintains the thinness of the rings.

Keplerian shear

- faster inner particles collide with slower outer particles; the inner particles slow down and move inward, while the outer particles are accelerated and move outward.

Shepherd moon

- F-ring is shepherded by Pandora and Prometheus
- Pandora (outside) pull particles back (move inward)
Prometheus (inside) pull particles forward (move outward)

Orbital resonances

- resonances can enhance or deplete particle concentrations
- 2:1 resonance between Mimas and Cassini division
gravitational perturbation => elliptical orbit => crossing orbit
=> relocation into other rings

Shepherd Moons



(see video)

Physical Processes Affecting Ring Systems

Spiral density waves

- gravitational perturbations cause particles at different orbital radii to bunch up, higher density leads to more collisions, Keplerian shear then causes the density near resonance orbits to decrease.

Plasma drag

- particles interact with the planets magnetic field plasma
inside the synchronous orbits => slow down and spiral in
outside the synchronous orbits => speed up and spiral out

Atmospheric drag

- collision with the outer atmosphere of planet
=> slow down and spiral inward

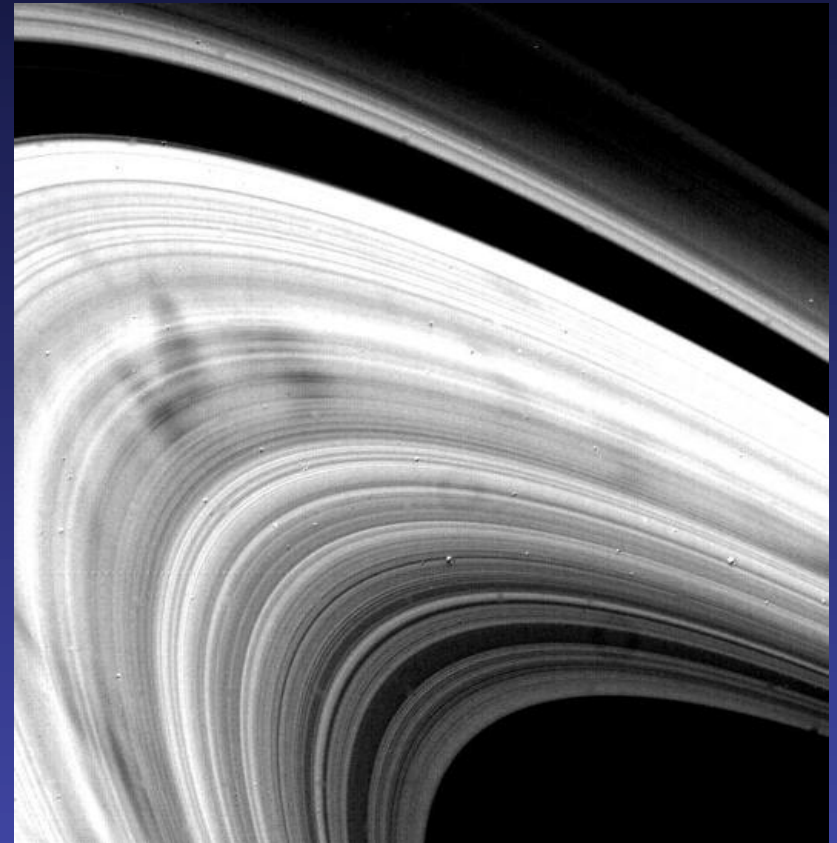
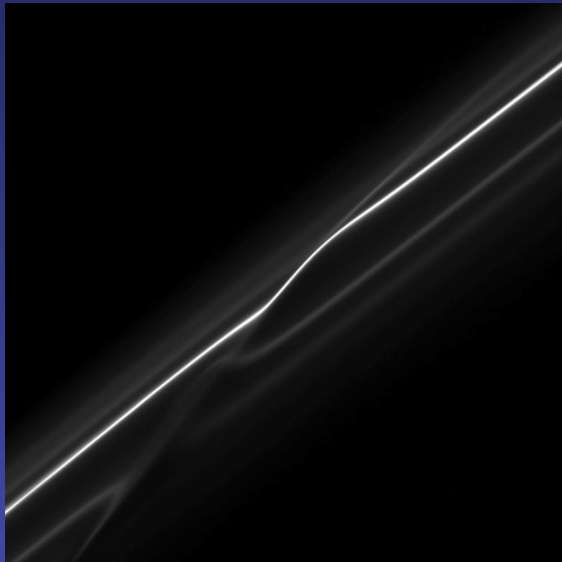
Physical Processes Affecting Ring Systems

Radial spokes

- charged dust particles are lifted out of the orbital plane by the planet's magnetic field

Warping

- gravitational influences of the Sun and the planet's moons.



The Poynting-Robertson Effect

- particles absorb sunlight but radiates preferentially in the forward direction
=> slow down, spiral in

$$v_x = \frac{v'_x + u}{1 + uv'_x/c^2} = u$$

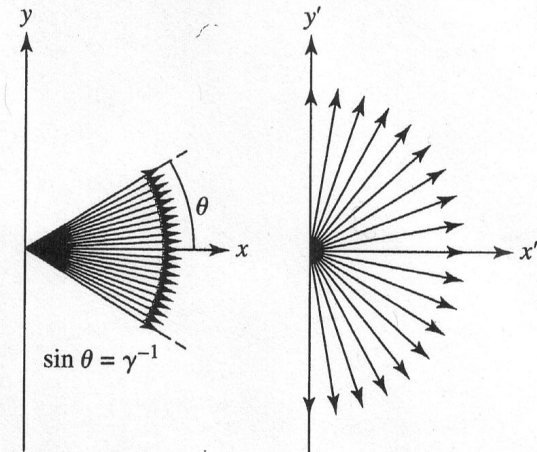
$$v_y = \frac{v'_y \sqrt{1 - u^2/c^2}}{1 + uv'_x/c^2} = c \sqrt{1 - u^2/c^2}$$

$$v_z = \frac{v'_z \sqrt{1 - u^2/c^2}}{1 + uv'_x/c^2} = 0.$$

$$v = \sqrt{v_x^2 + v_y^2 + v_z^2} = c$$

is the speed of the light ray measured in frame S . Thus

$$\sin \theta = \frac{v_y}{v} = \sqrt{1 - u^2/c^2} = \gamma^{-1},$$



(a) S

(b) S'