Outline

- Inventory of planetary rings
- What are rings, and how do they work?
- The Cassini mission to Saturn
- Latest results from Cassini at Jupiter
Rings of Jupiter
Features in Saturn's Rings

Rings within rings...

Twisted, braided rings...
More Features in Saturn's Rings

'Spokes' appearing and disappearing

Symmetry and Asymmetry
Rings of Neptune
Rings of Uranus
Ring Dynamics Equation Sheet
(complete)

\[ F = ma \]
\[ F = \frac{GMm}{r^2} \]
A Brief Ring History

1. Satellite in orbit around planet is disrupted by collision
2. Collision triggers a cascade of collisions
3. Small dust produces visible ring
   ‘If Saturn’s rings were made of bricks, they’d be invisible!’

   Typical ring age: ~ 100 Myr ~ 1% age of solar system (short!)

   Each ring particle is a small satellite in orbit around the planet
Kepler's third law: The further away a satellite is from a planet, the lower its speed.

If a satellite is weak, the inside and outside edges are pulled in different speeds, pulling the satellite apart. Effect is largest near the planet.

Particles inward of ‘Roche radius’ spread to form ring, or Particle outward of Roche radius stick to form satellites
Open Problems in Ring Dynamics

Are rings really young?

How variable are the rings?

What do individual ring particles look like?

How do ring systems interact with the space environment?

Why are ring systems so different?

If it’s so simple, why haven’t we solved everything yet?

We don’t know the values of key parameters of the solar system!

Numerical simulations can reproduce but not explain results!
The Cassini Mission to Saturn

Spacecraft will orbit Saturn and study atmosphere, rings, and satellites for 4 years.

Spacecraft has 13 instruments:
- Infrared, visible, ultraviolet cameras
- Spectrometers
- Radar
- Dust detector
- Magnetometers
- Plasma detectors
- Probe (six instruments)

'Lambdaorghini of spacecraft'
Cassini Mission to Saturn - Statistics

$2.5 \text{ B}
\sim 150 \text{ associated scientists, 500 engineers}

6000 \text{ kg Cassini orbiter (NASA)}
    
300 \text{ kg science instruments}
    
3000 \text{ kg propellant}

1000 \text{ kg Huygens atmospheric probe (European Space Agency)}
    
30 \text{ kg science instrument}

Funding start: 1989
Launch: October, 1997 on Titan IV, 1 M kg
Arrival: July 1, 2004
End of mission: July 1, 2008

Data returned: \sim 1 \text{ gigabyte/day for 4 years}

Cassini will return more data than all previous interplanetary spacecraft combined!
Why send a spacecraft?

*In situ* measurements possible
- Probe, dust detectors, etc

Fine *spatial resolution*
- Spatial resolution \( \sim \frac{(\text{Distance to object})(\text{wavelength})}{(\text{mirror size})} \)

Hubble Space Telescope: 100" mirror to see \( 10^9 \text{ km/pixel resolution} \)

Cassini: tiny, 8" mirror (!) to see 1 km/pixel resolution

Disadvantages of spacecraft
- Costly
- Inflexible
- Can't fix it!
Cassini Science Targets

Saturn and Rings

Titan

Icy Satellites

Magnetosphere
Titan

Does Titan have oceans? Earth only place in SS with liquid Europa perhaps sub-surface liquid

Atmosphere of methane, nitrogen

Much atmospheric chemistry

Could Titan support life?
Cassini Jupiter Flyby
December 30, 2000

Cassini flew past Jupiter, used it for a gravity-assist flyby

New Jupiter atmospheric movies!

New ring movies!

New images of small satellites!

Io volcanoes glowing in eclipse!

Cruise science (coming up in April!)
Imaging of dust from asteroid belt (‘Zodiacal dust’)
Search for rings around Mars