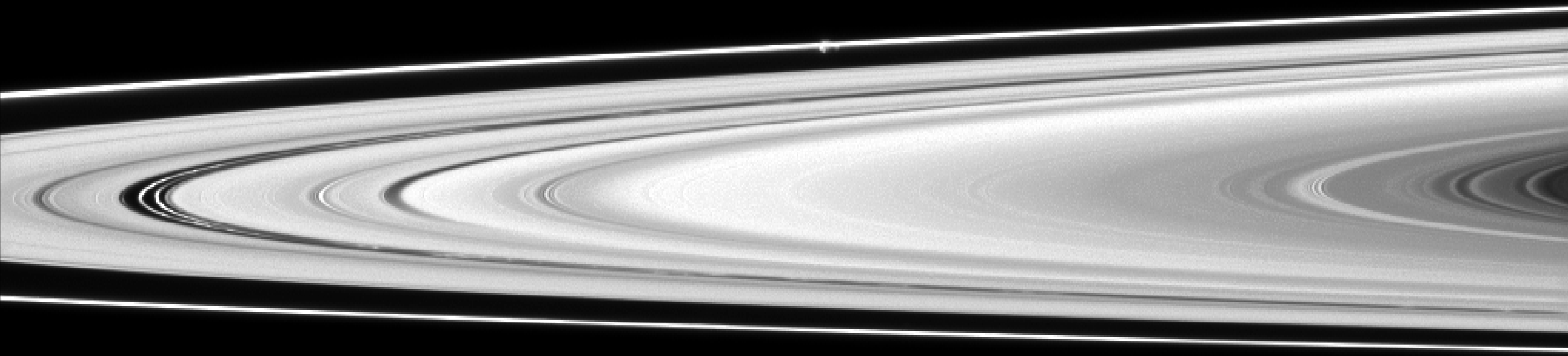
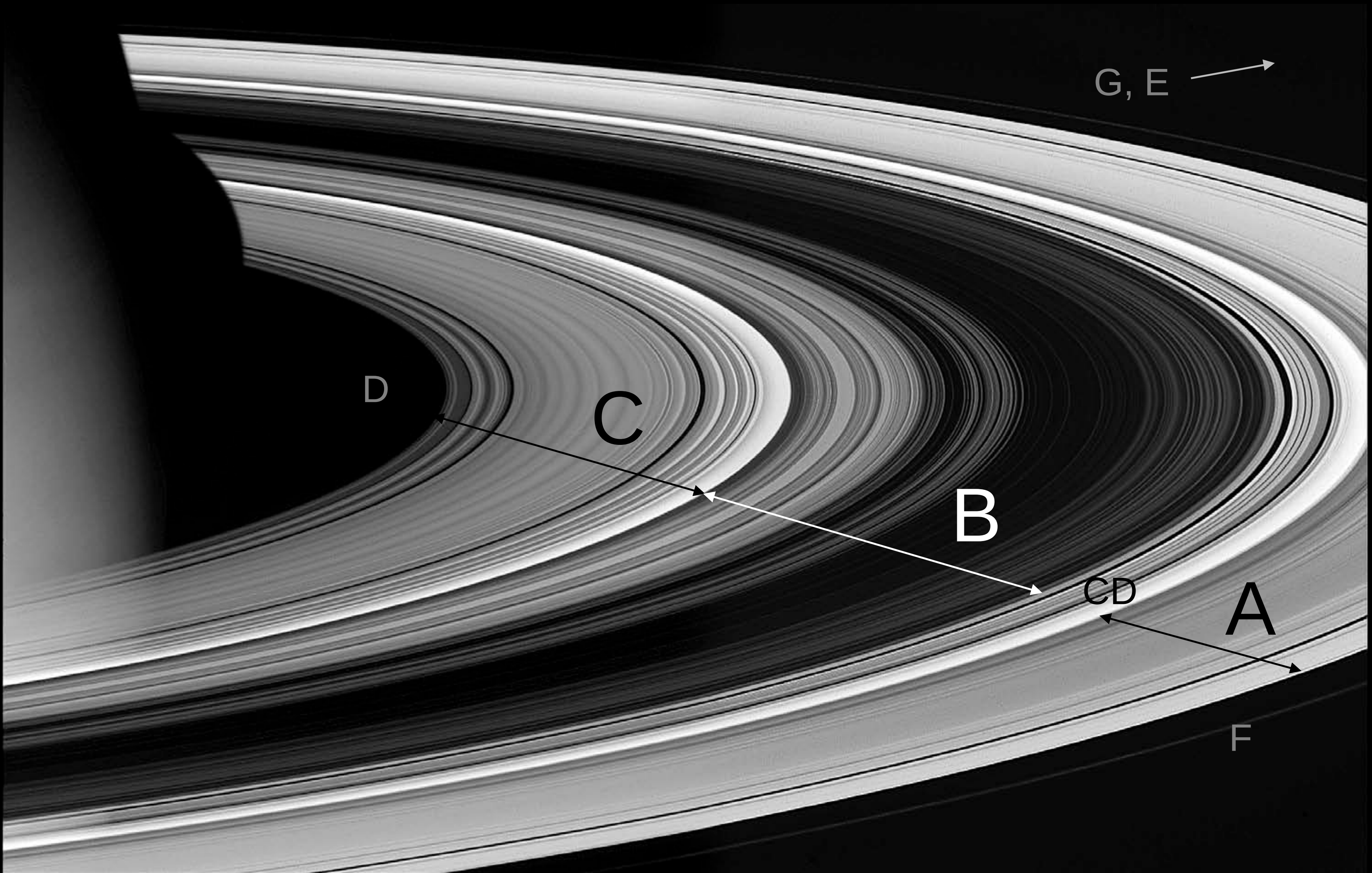
Cassini 8-year CHARM review
Rings and Dust

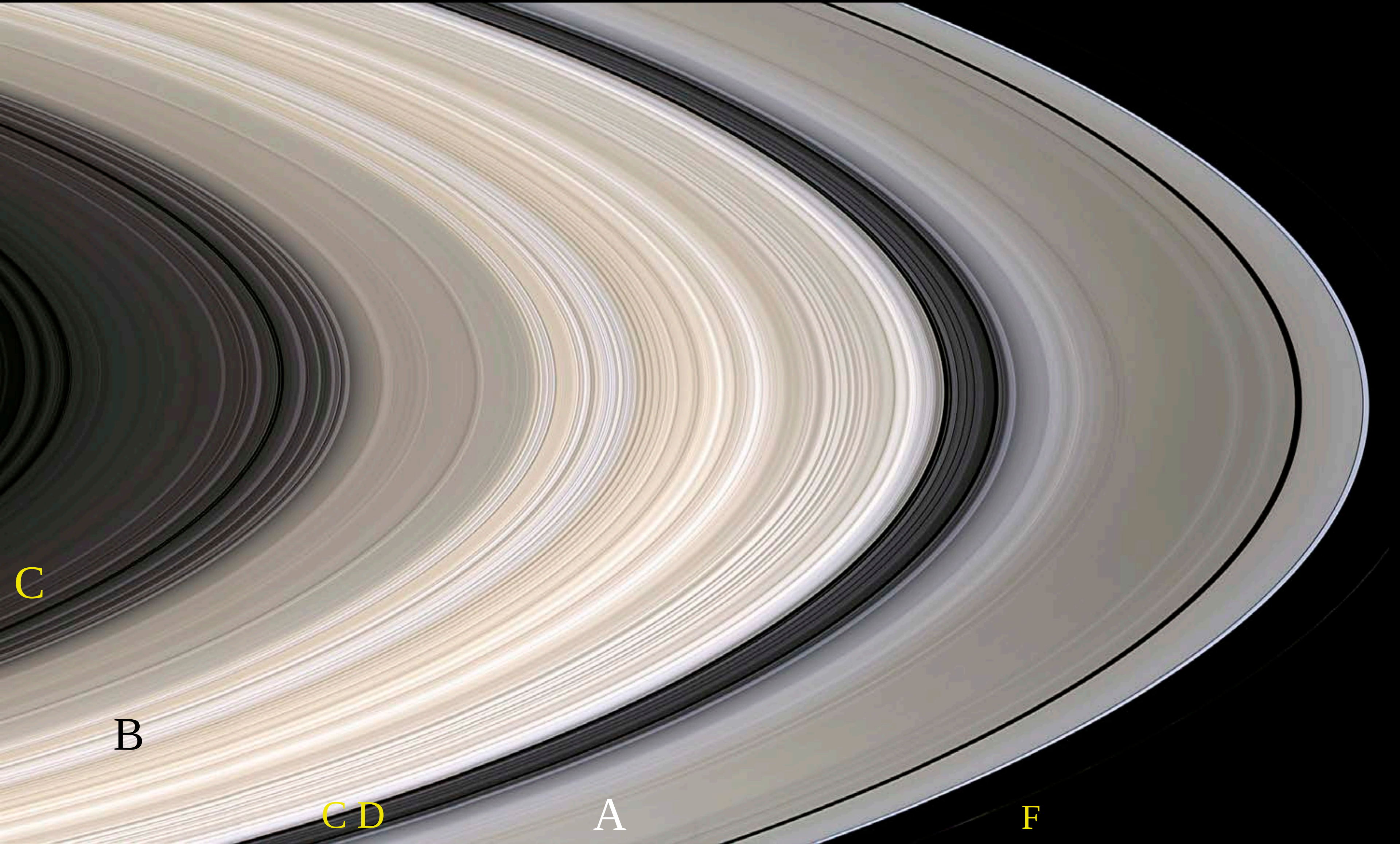
Jeff Cuzzi



The Dark Side



Away from the Dark Side



Progress this year

- **Finally! Back out of the equator plane**

- Giant “propeller” objects (several hundred m): their orbits are changing;
  - “Migrating” radially? Librating longitudinally? Walking randomly?

- The F ring
  - ISS: moonlets crashing into F core created new strands and clumps
  - New observations of ring show clumps have already disappeared!
  - New studies of “mini-jets” - small moonlets with low velocities in core

- Compositional variations connect rings and moons

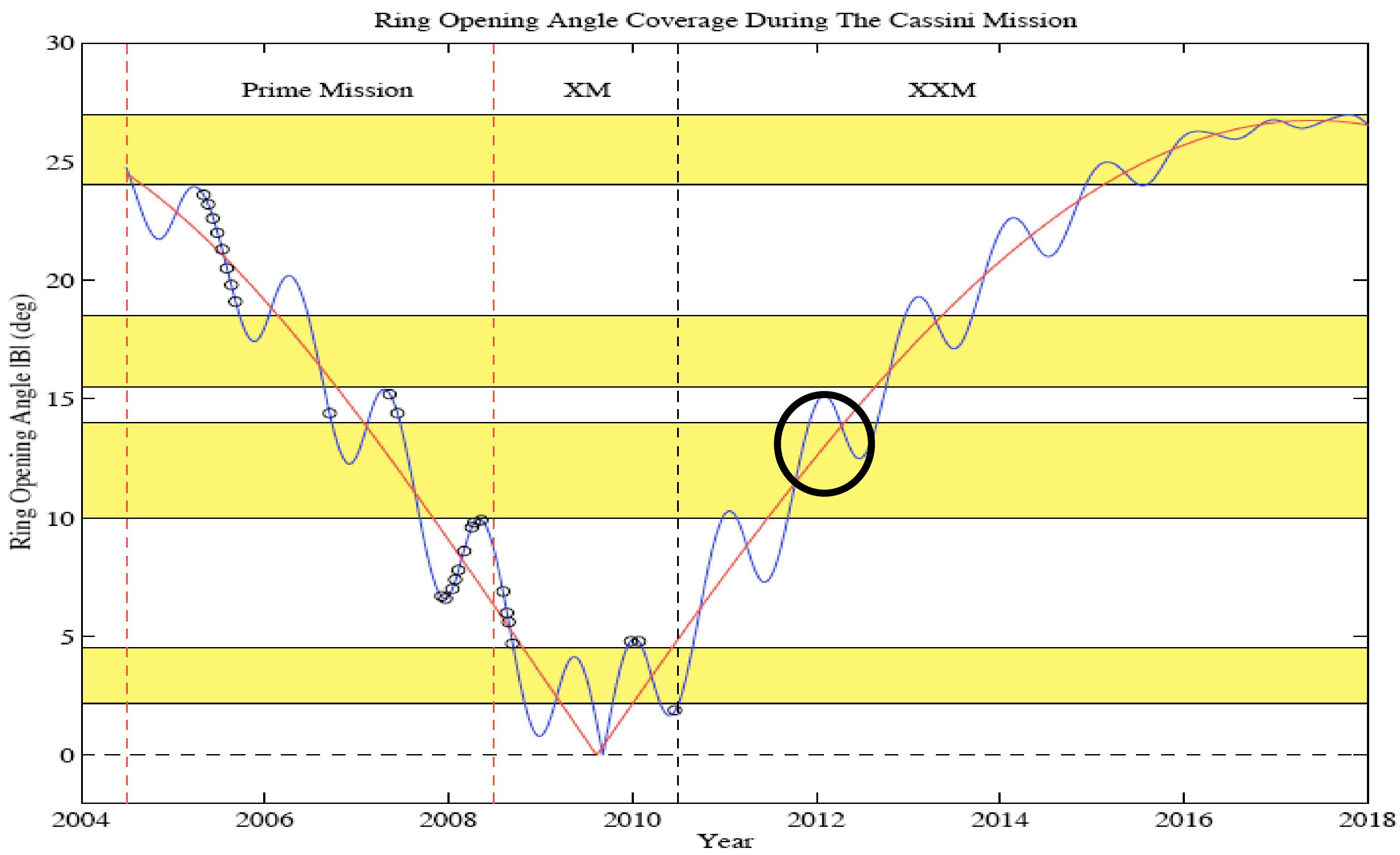
- Statistics of stellar occultations reveal significant particle size variations

- “Predator-prey” model of creation/disappearance of big clumps in B ring

- New thermal models of ring particles in densely packed rings

- E ring structure seasonally driven by sunlight!

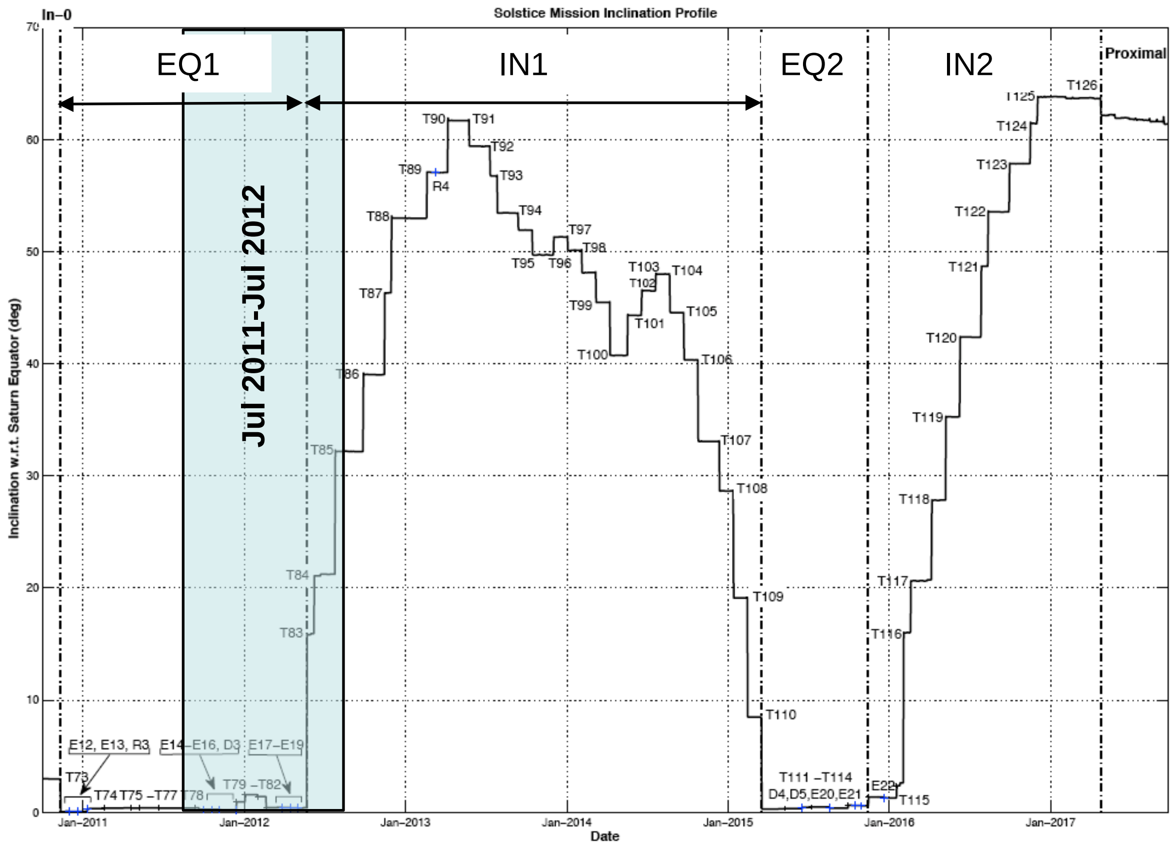
Changing Seasons

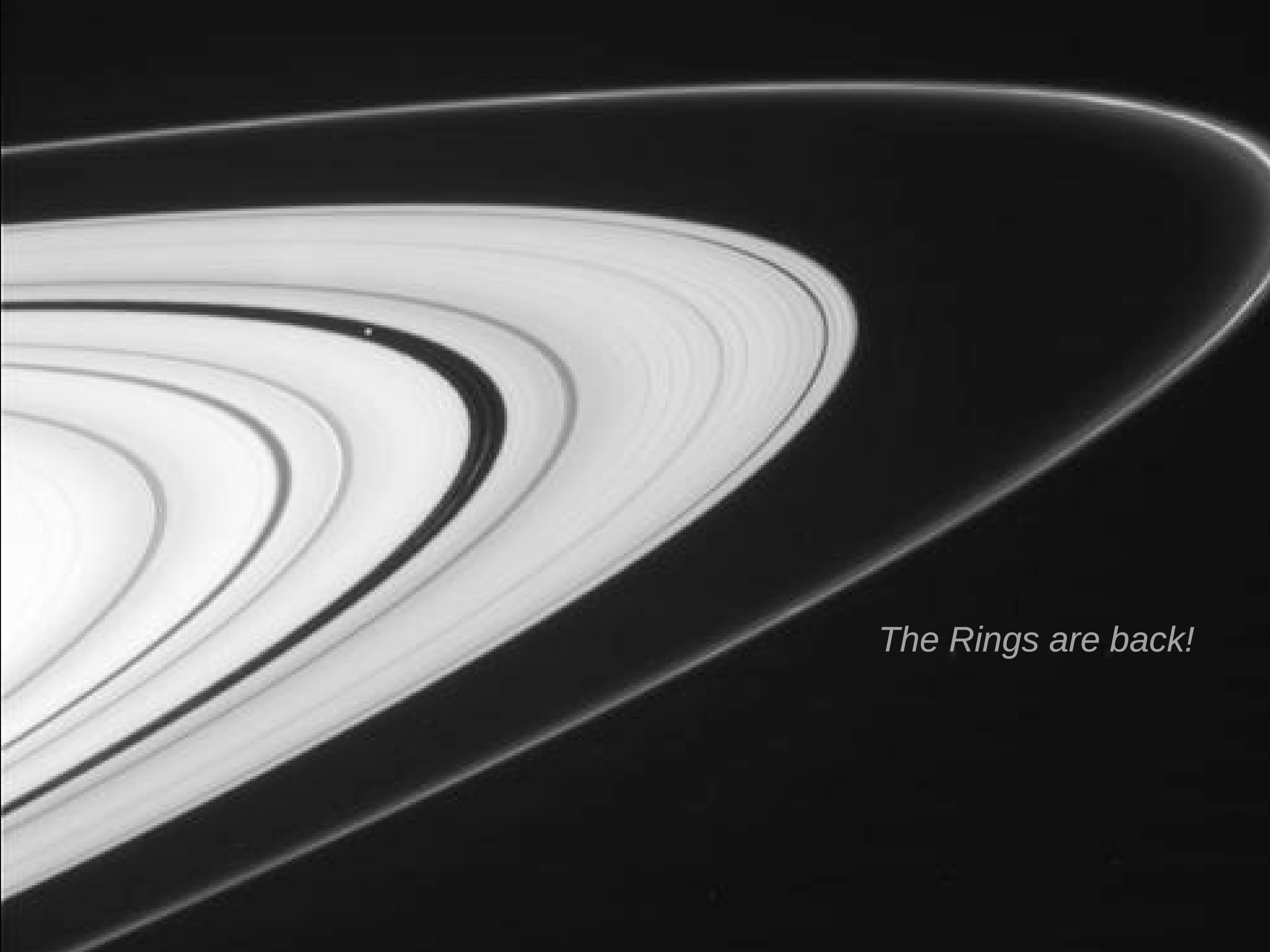


Opening angle affects insolation, ring temperature, RSS transmission, spoke occurrence frequency, diffuse ring structure

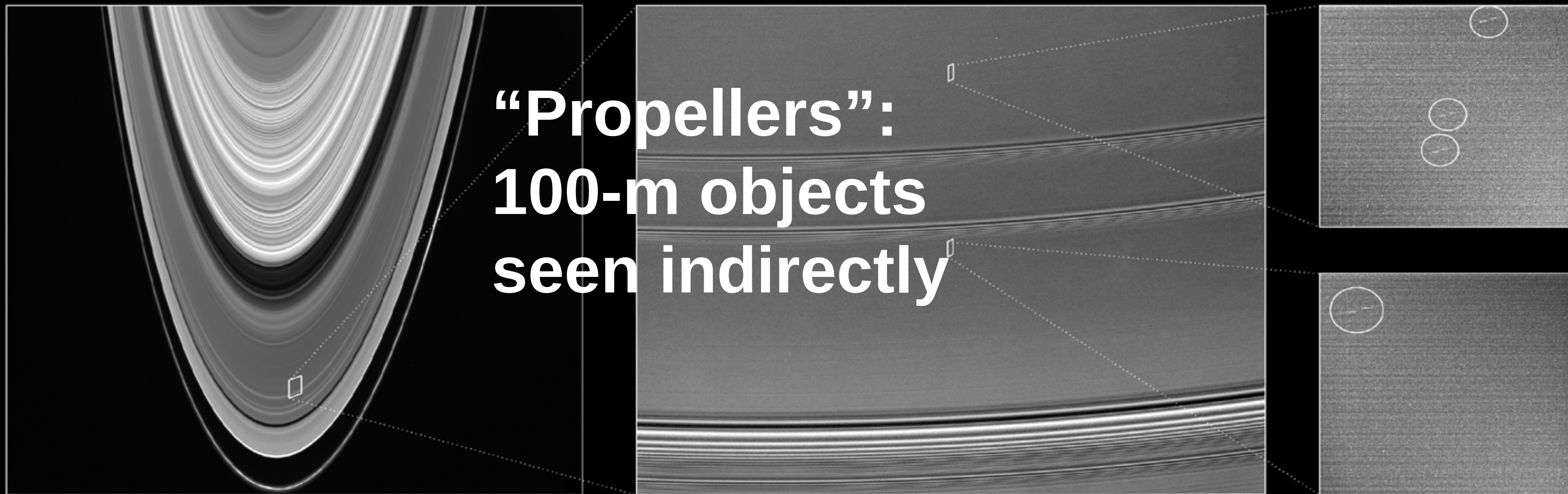
Mission Phase

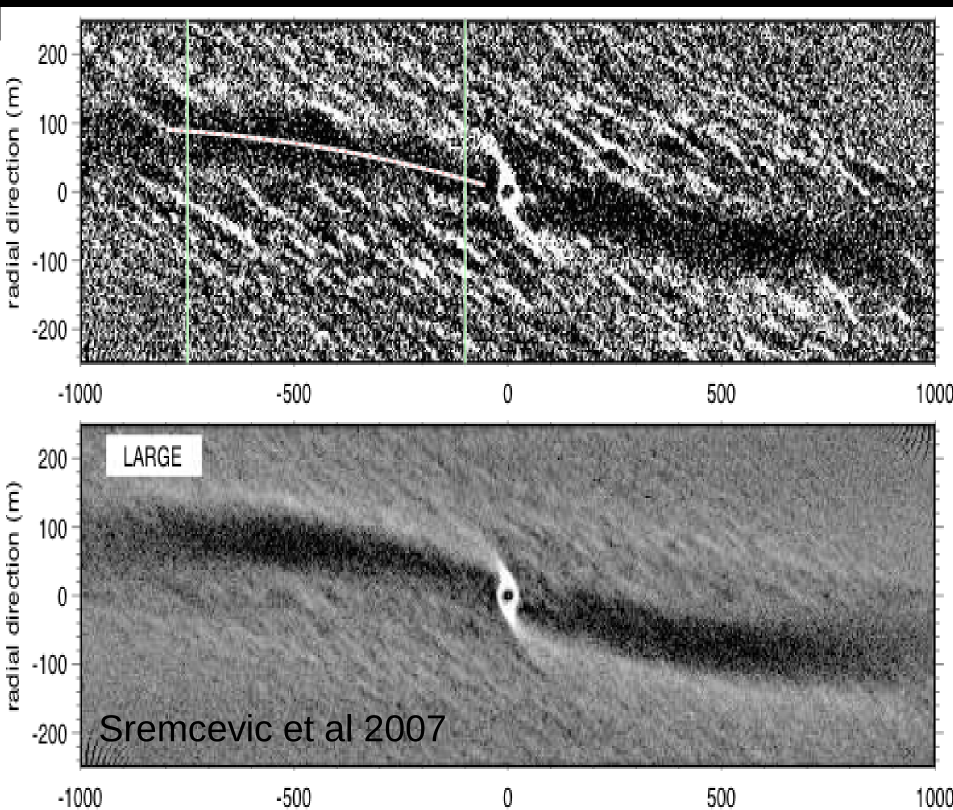
The eagerly awaited first rings observations of IN1 began in June 2012

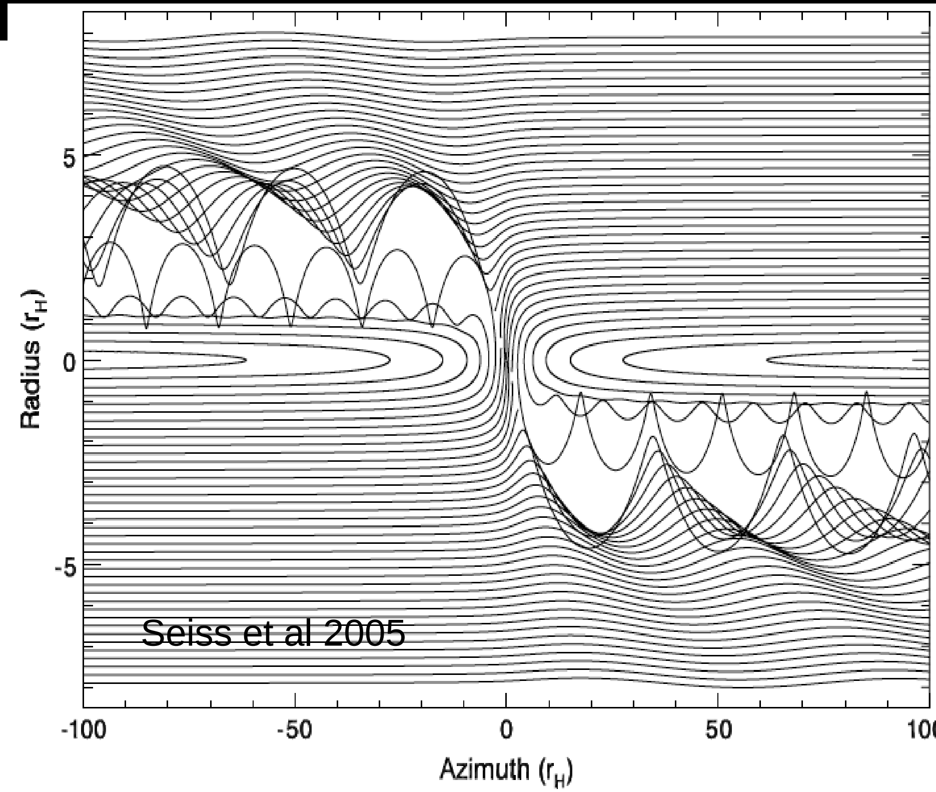


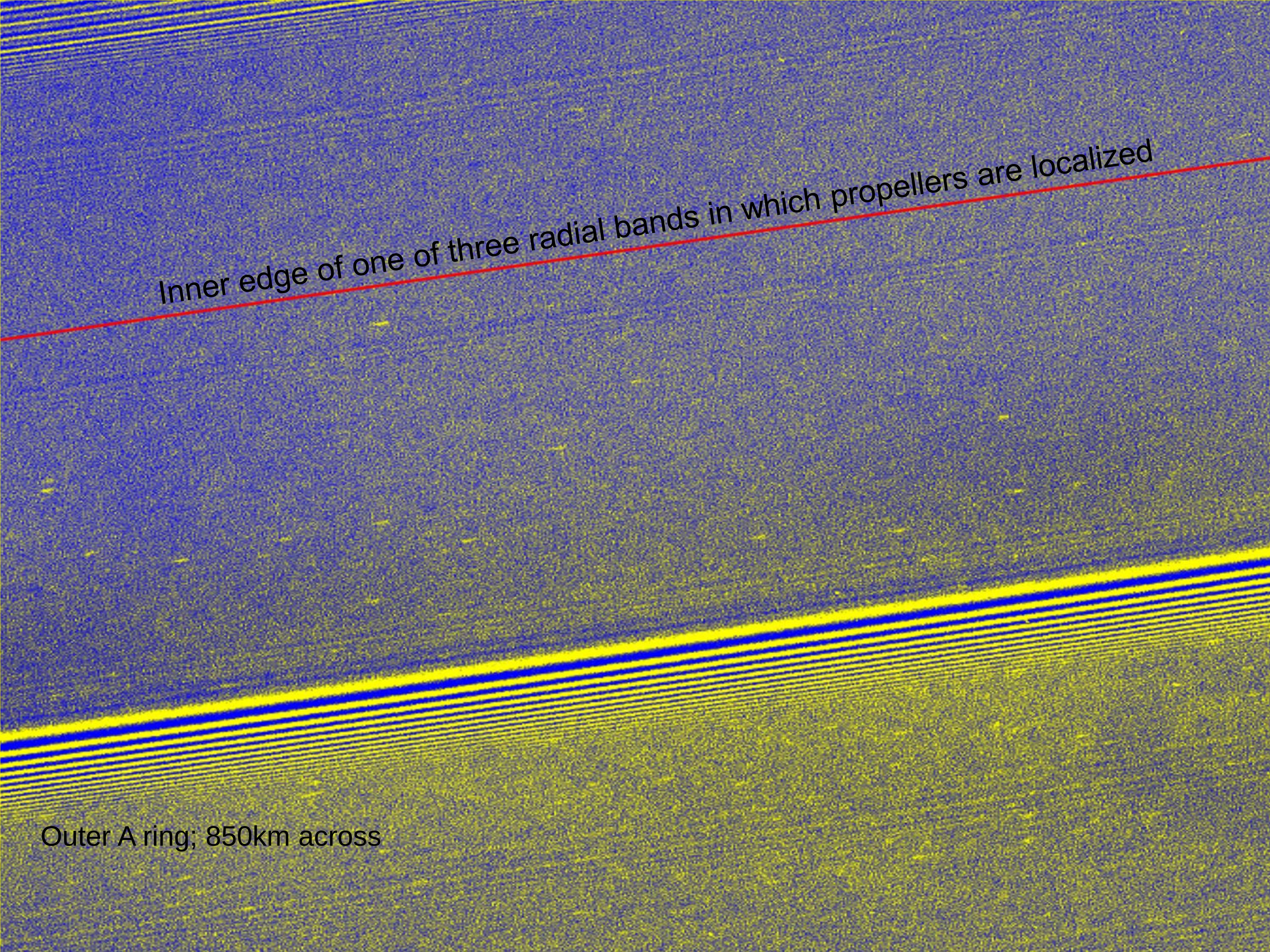

The Rings are back!

“Propellers”: 100-m objects seen indirectly

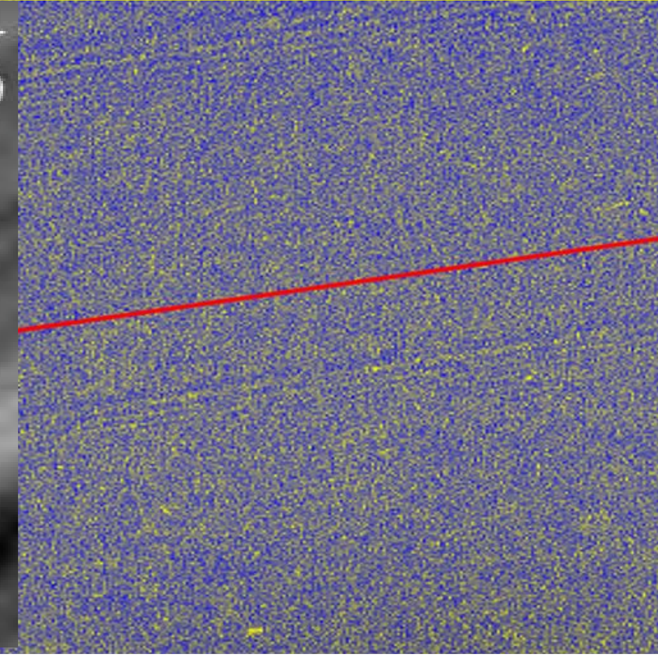


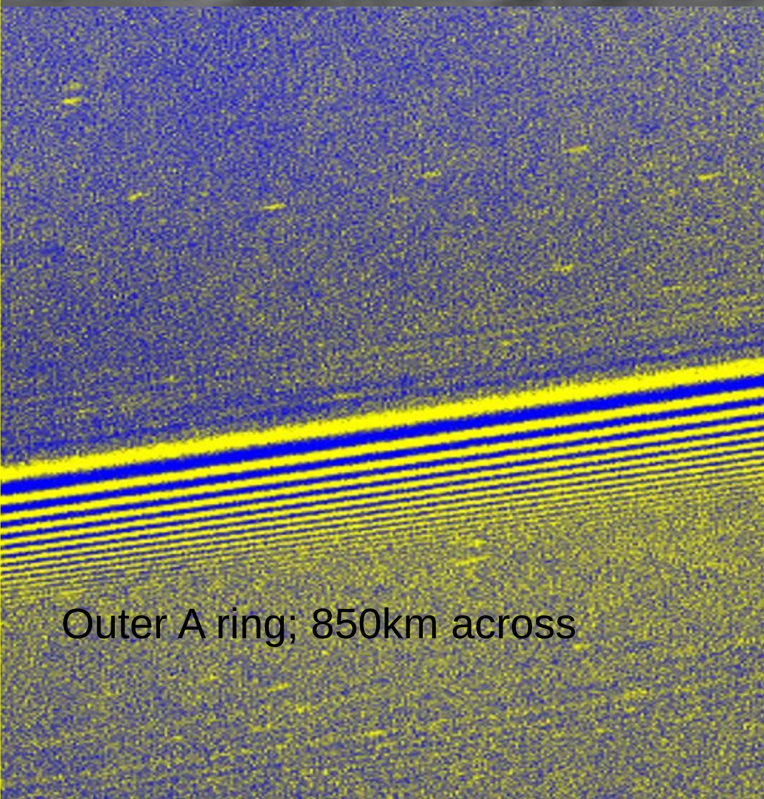


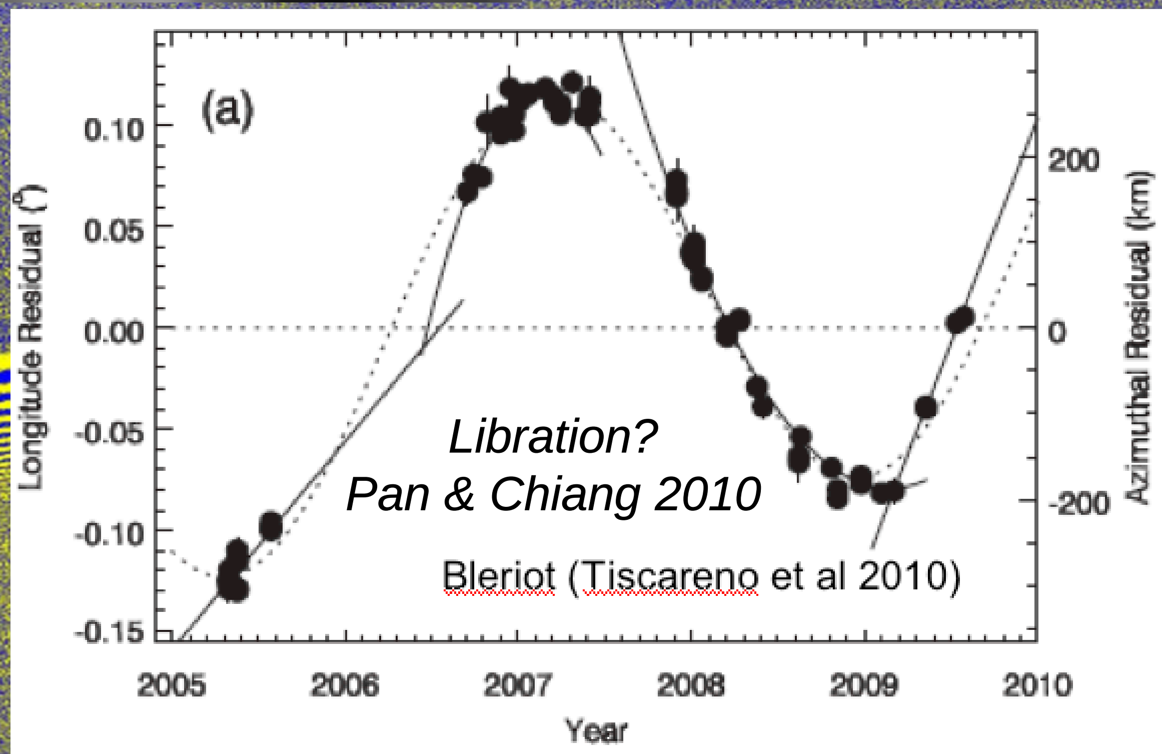



Inner edge of one of three radial bands in which propellers are localized
Outer A ring; 850km across

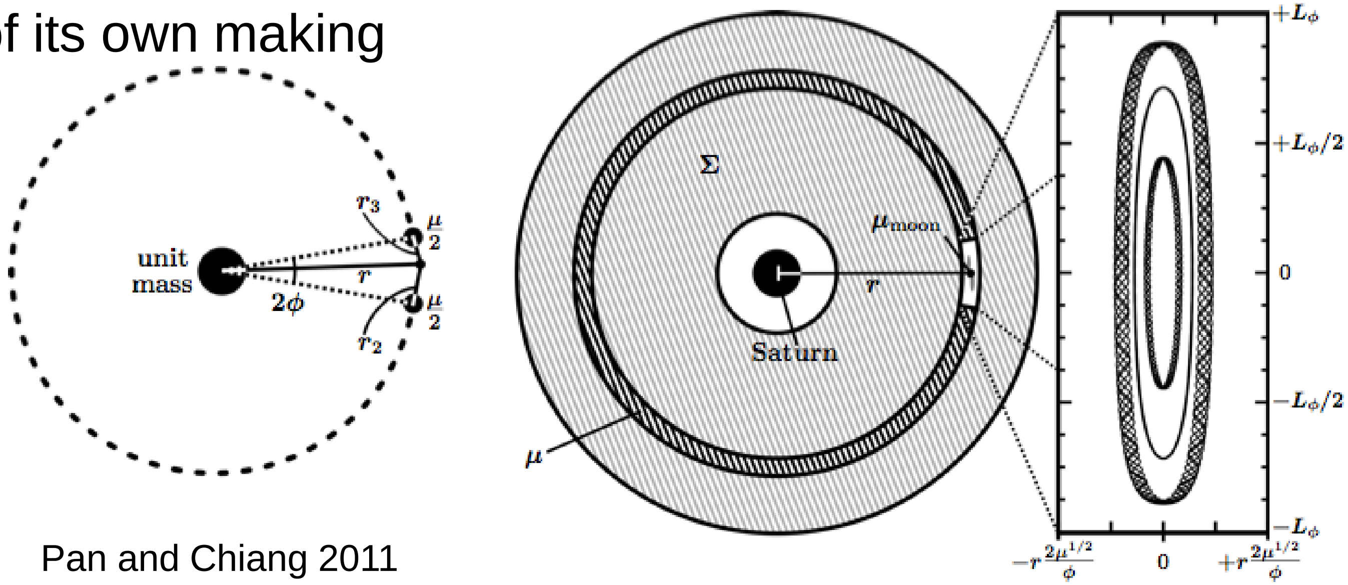

Cassini image of propeller
"Earhart" taken August 13, 2009



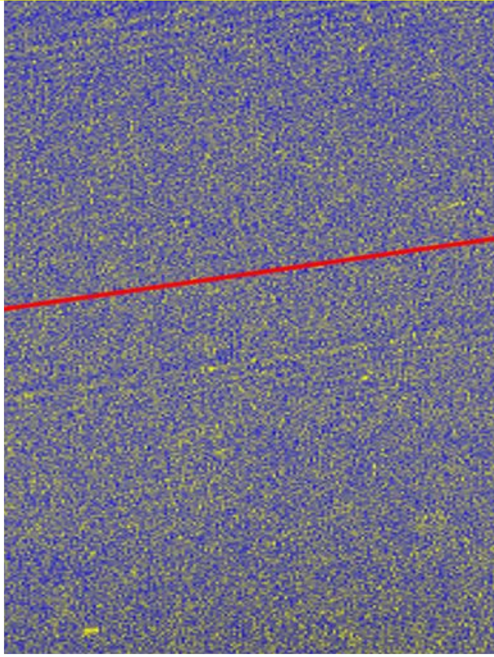

Outer A ring; 850km across

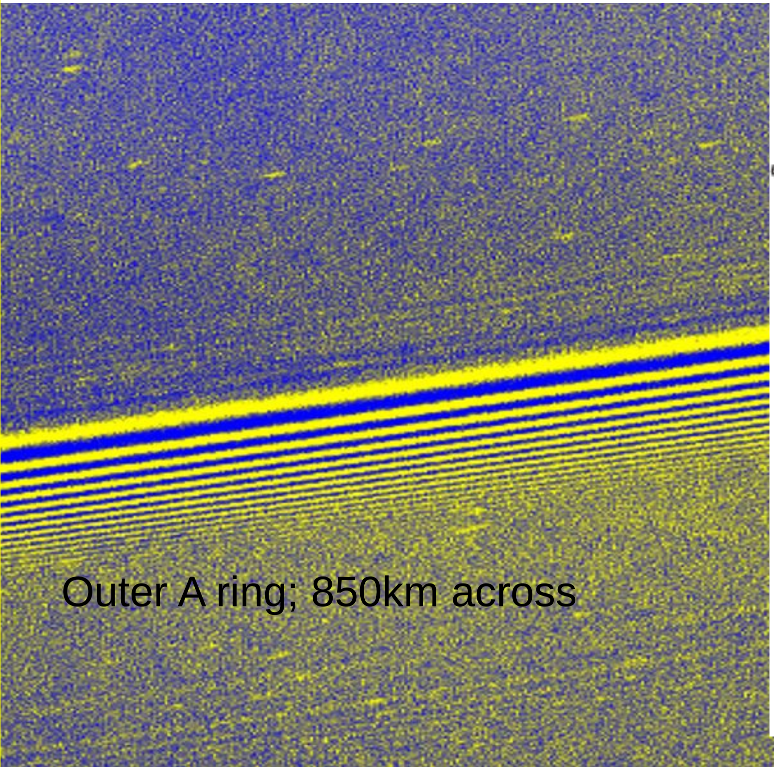

(a)
0.10
0.05
0.00
-0.05
-0.10
-0.15
Longitude Residual (°)
200
0
-200
Azimuthal Residual (km)
2005
2006
2007
2008
2009
2010
Year
Libration?
Pan & Chiang 2010
Bleriot (Tiscareno et al 2010)

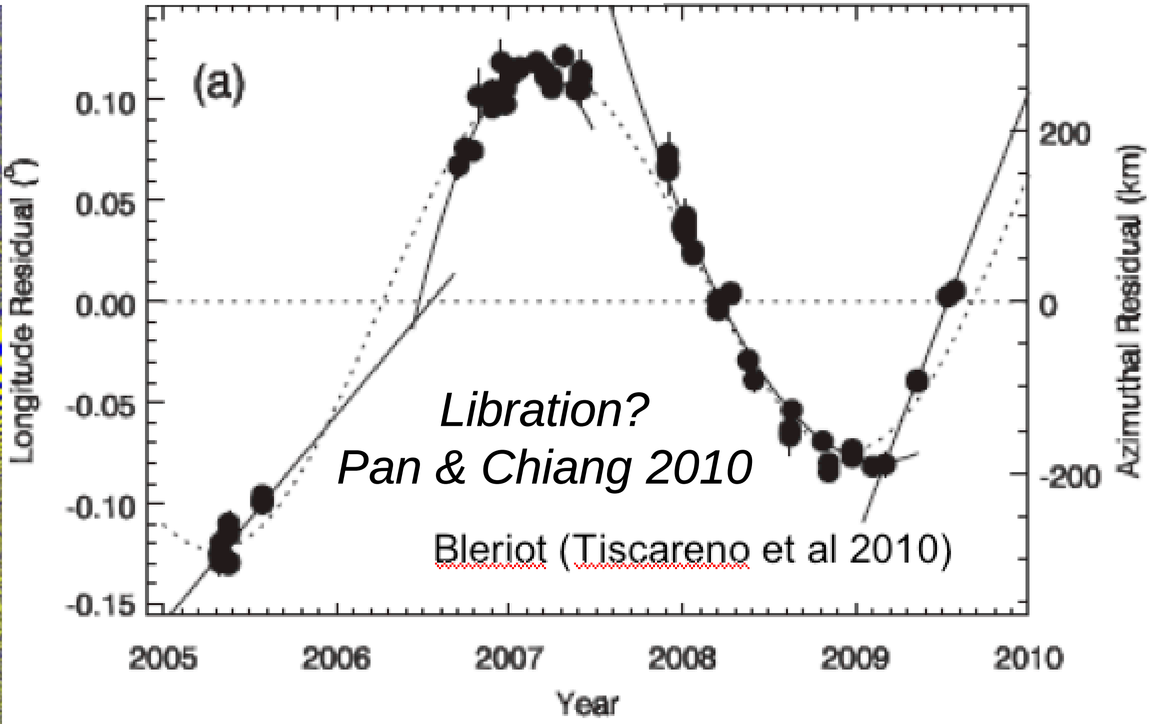
Object librates in a “mass hole” of its own making



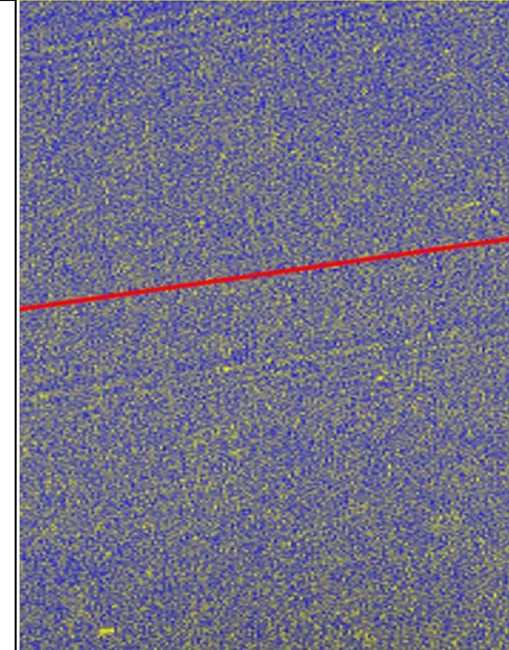
Pan and Chiang 2011

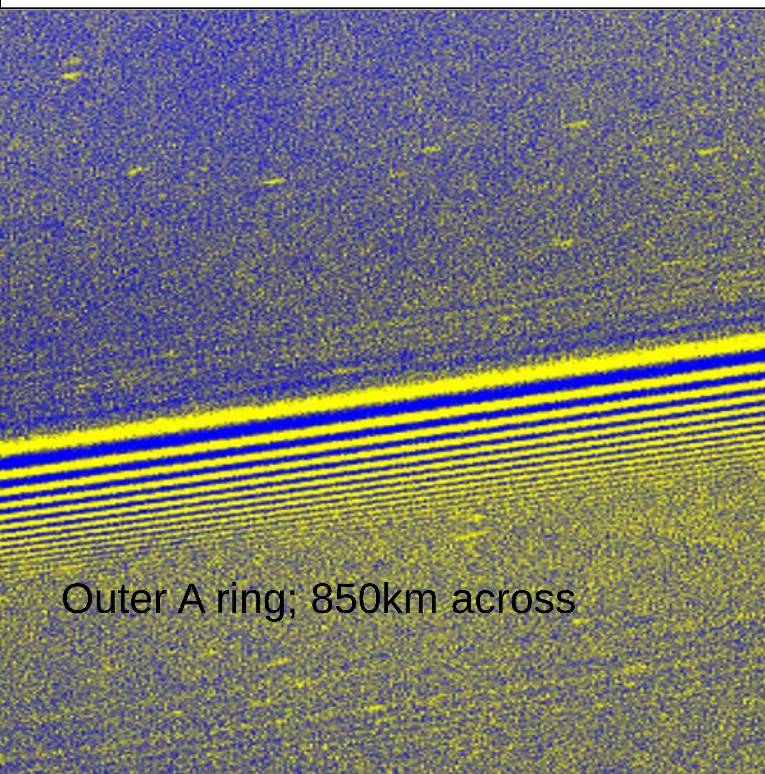


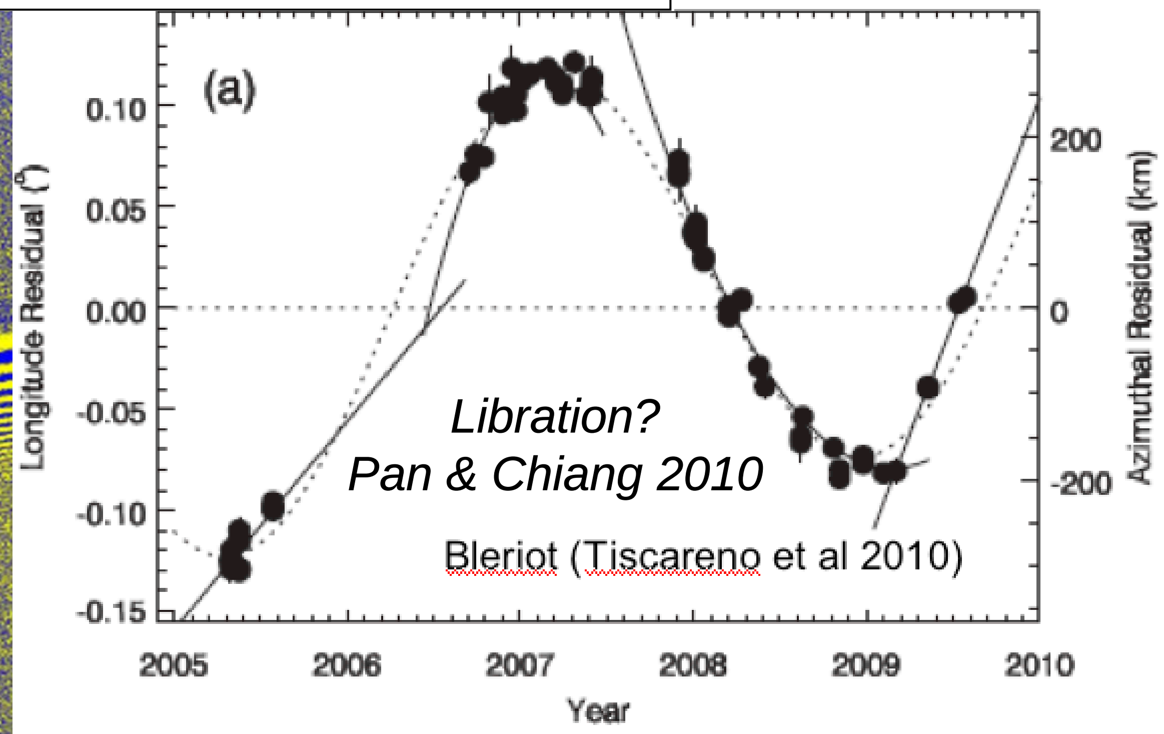




More recent studies (Pan and Chiang 2011, Rein et al 2011, Pan et al 2012) lean more towards "Brownian Motion" type orbital excursions by random encounters with large ring particles, self-gravity wakes, etc. Might require overly high surface mass density though. Tiscareno et al (2012) suggests large, sporadic perturbations by extrinsic impacts, followed by relaxation to equilibrium. New observations now being made.







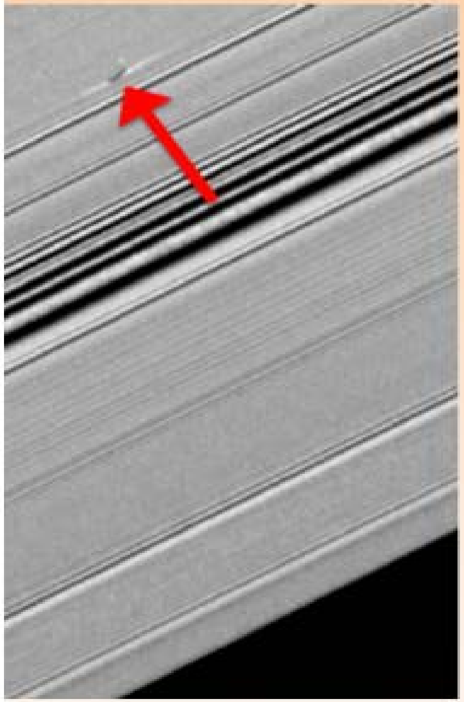
ISS: Propellers Recovered

For years scientists have tracked this propeller, nicknamed "Sikorsky," which is about 50 kilometers long and marked with red arrows here.

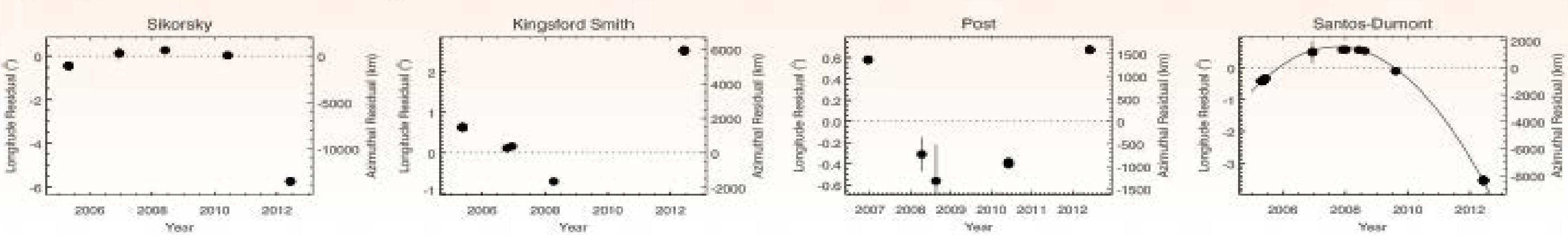
- These three Cassini images, captured June 5, 2012, show, for the fist time in two years, a propeller-shaped structure created by an unseen moon in Saturn's A ring.
- These images are part of a growing catalogue of "propeller" moons that, despite being too small to be seen, enhance their visibility by creating larger disturbances in the surrounding fabric of Saturn's rings.
- Propellers and other details of Saturn's rings are greeting scientists for the first time in two years, after Cassini's orbit took the spacecraft out of Saturn's equatorial plane in the spring of 2012, making face-on views of the rings possible again.

ISS: Propellers Recovered

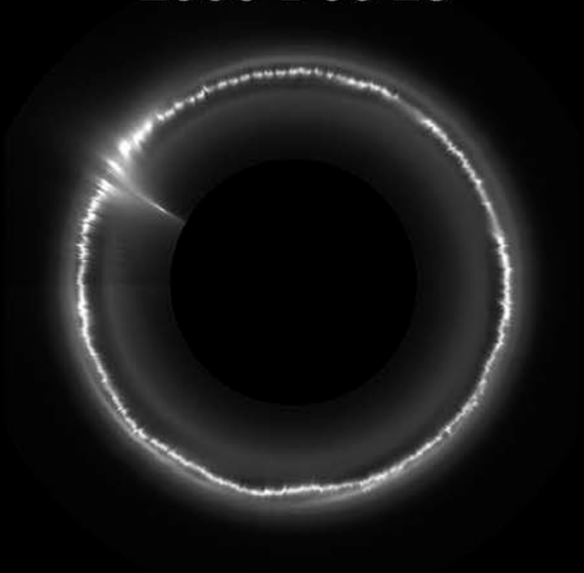
New Propeller Survey



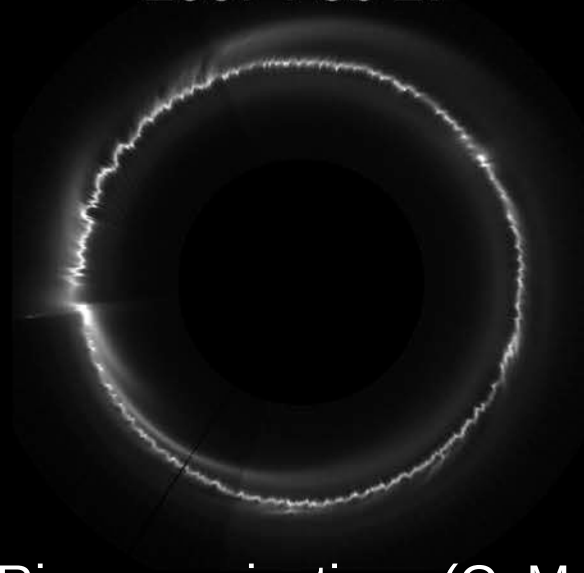
- Several known propellers were recovered
  - At least two were several degrees from prediction
  - All long-lived propellers show non-keplerian motion
  - Consistent with Type I behavior + periodic "kicks"
- More propellers were found where we didn't know to look for them
  - Probably knocked into new orbit since last obs
  - We will immediately begin re-targeting these
- Theorists continue to work with these Cassini data, drawing connections to protoplanets and exoplanets



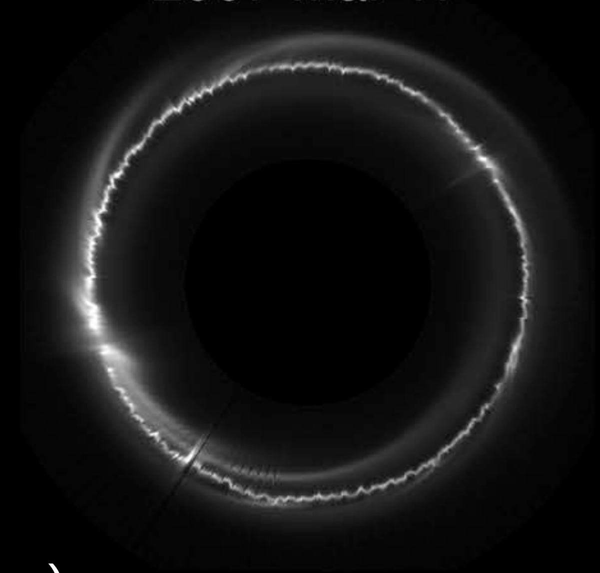
2006 Dec 23



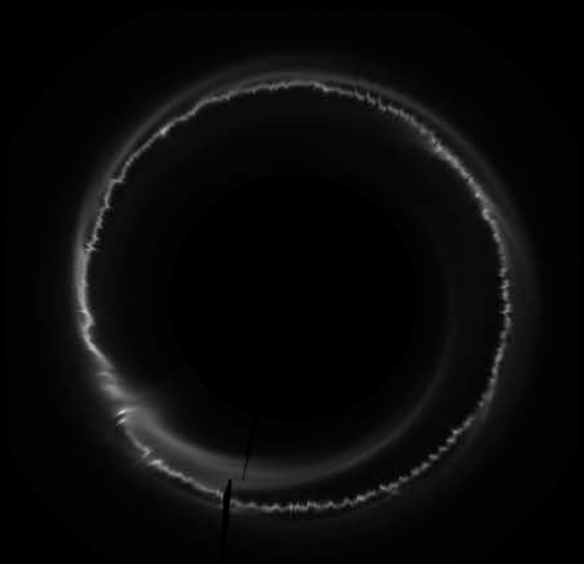
2007 Feb 27



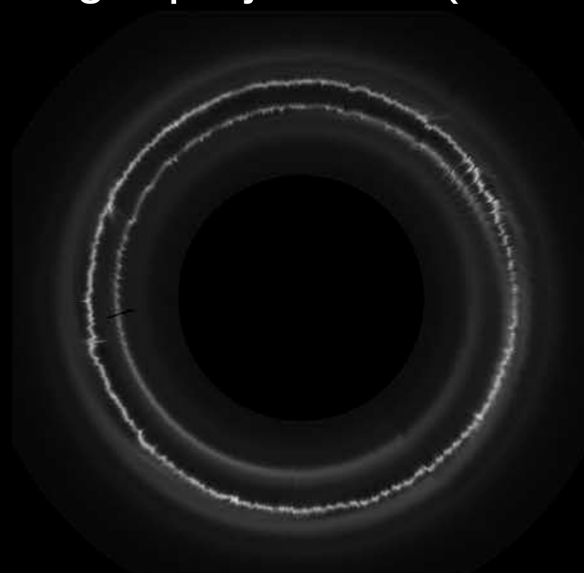
2007 Mar 17



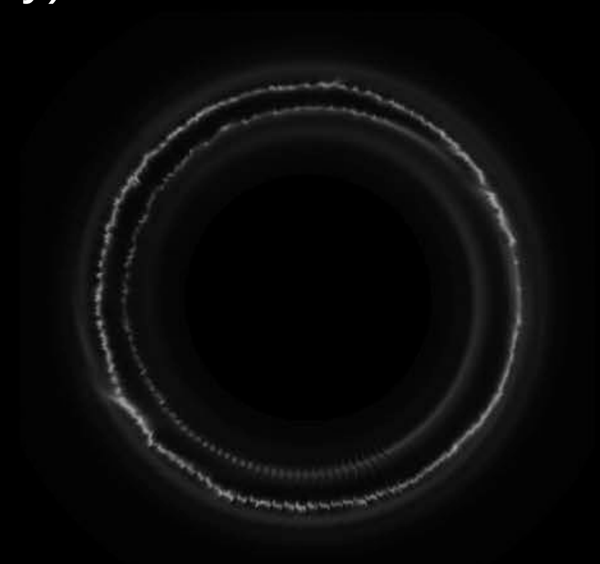
F Ring reprojections (C. Murray)



2007 Apr 18

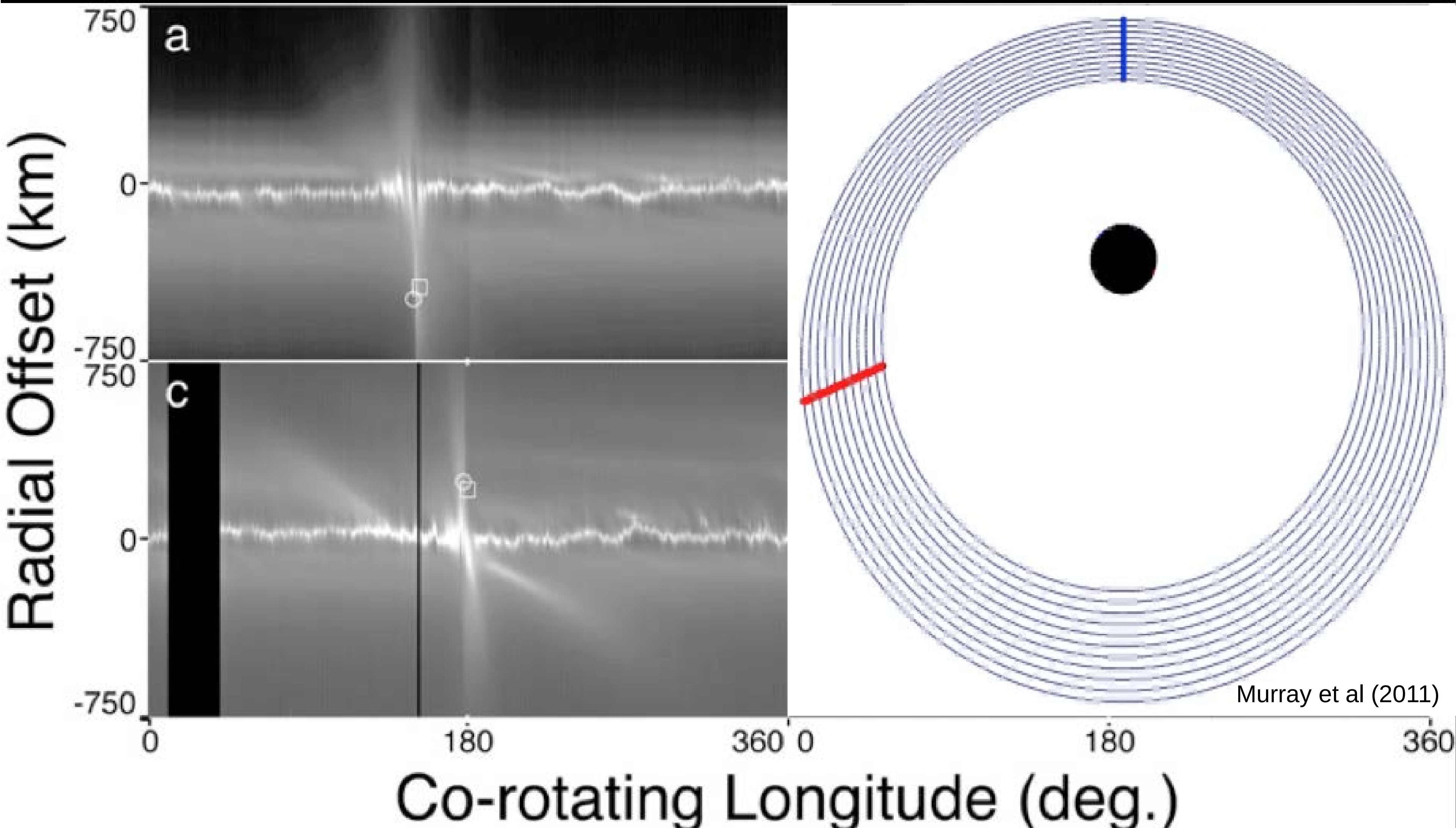


2008 Jan 7



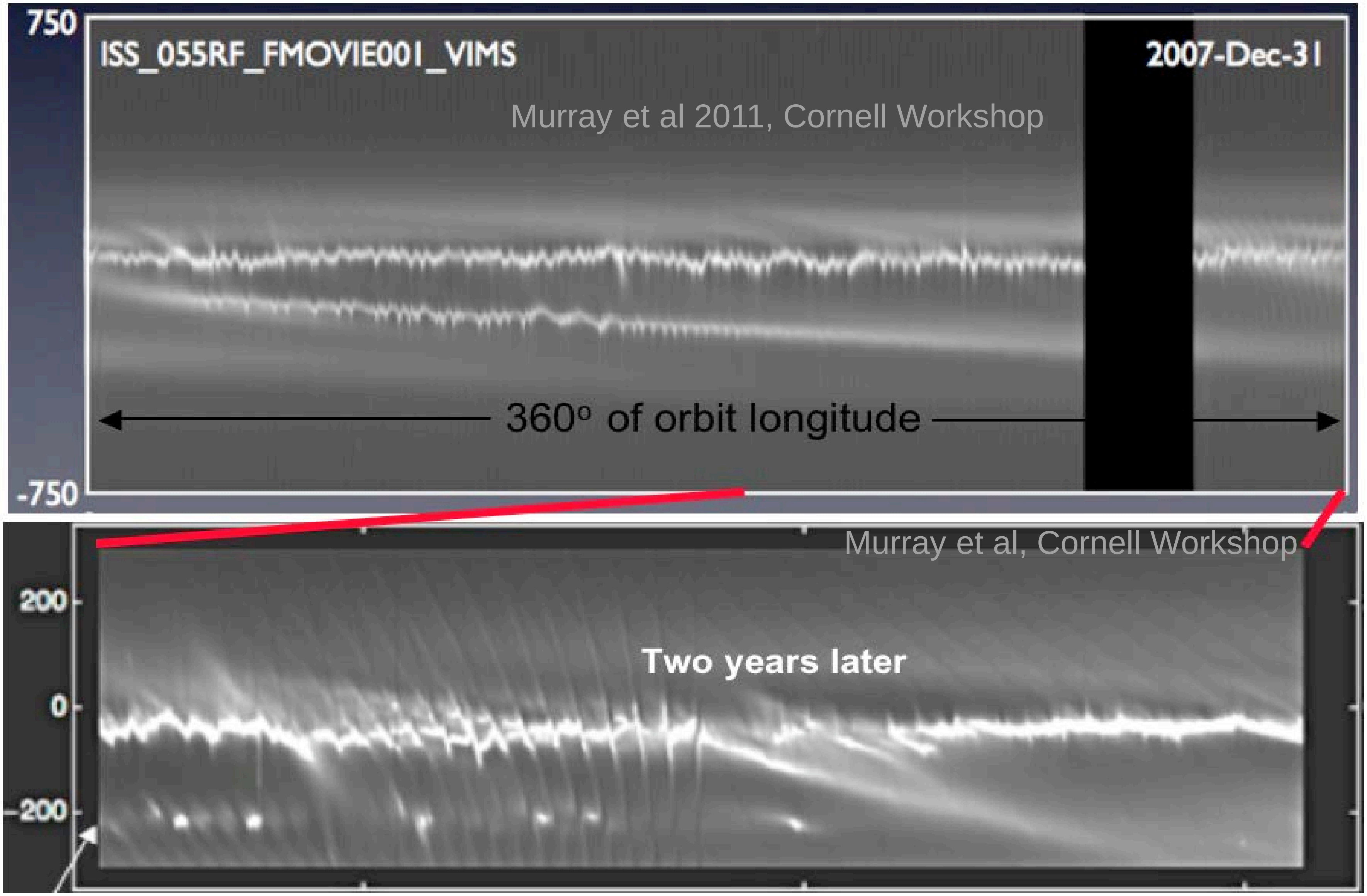
2008 Feb 24

Association of Jets with S/2004 S 6



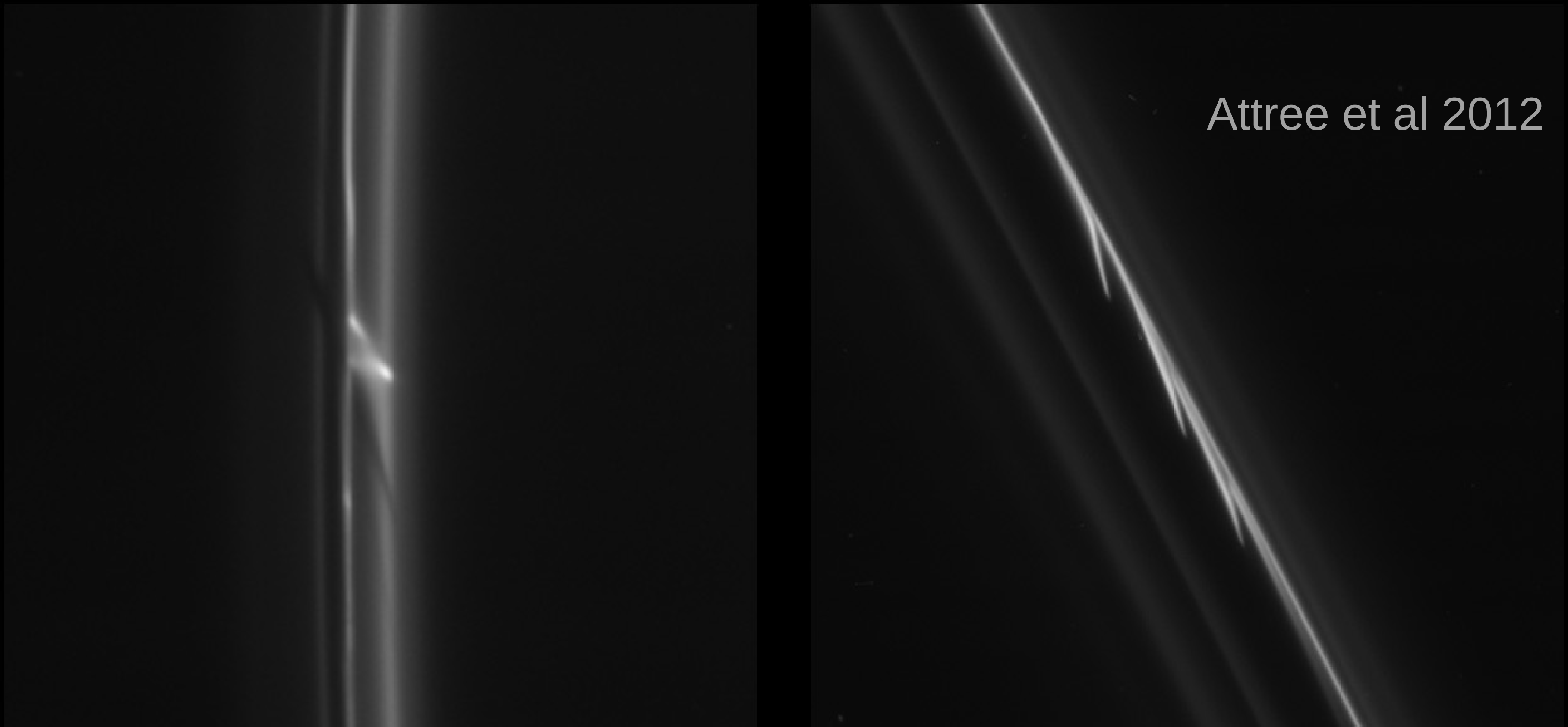
Murray et al. (2008)

F Ring: Collision leads to new strand and moonlets(?)

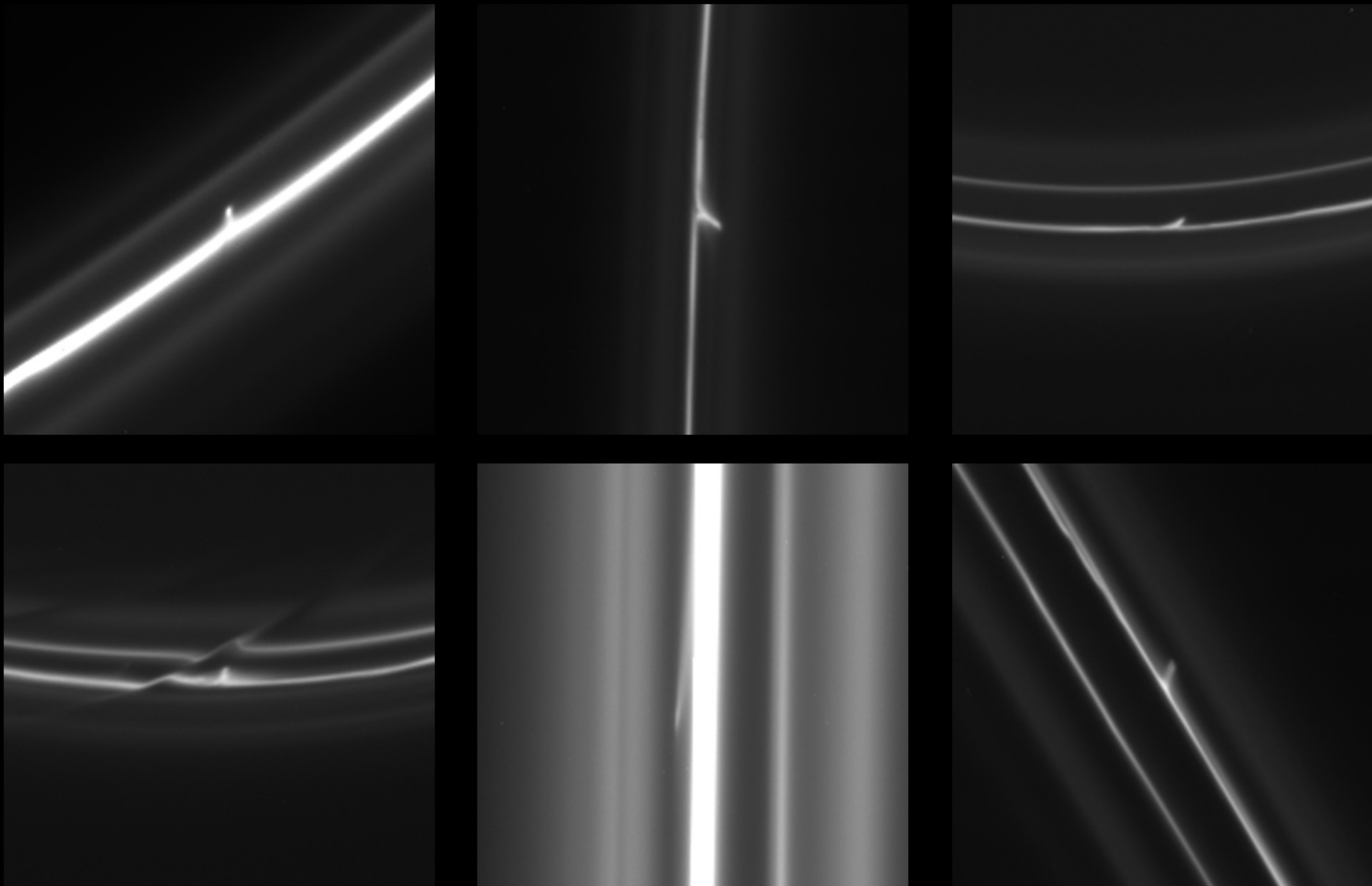


ISS: Tiny Objects Populate Saturn's F Ring

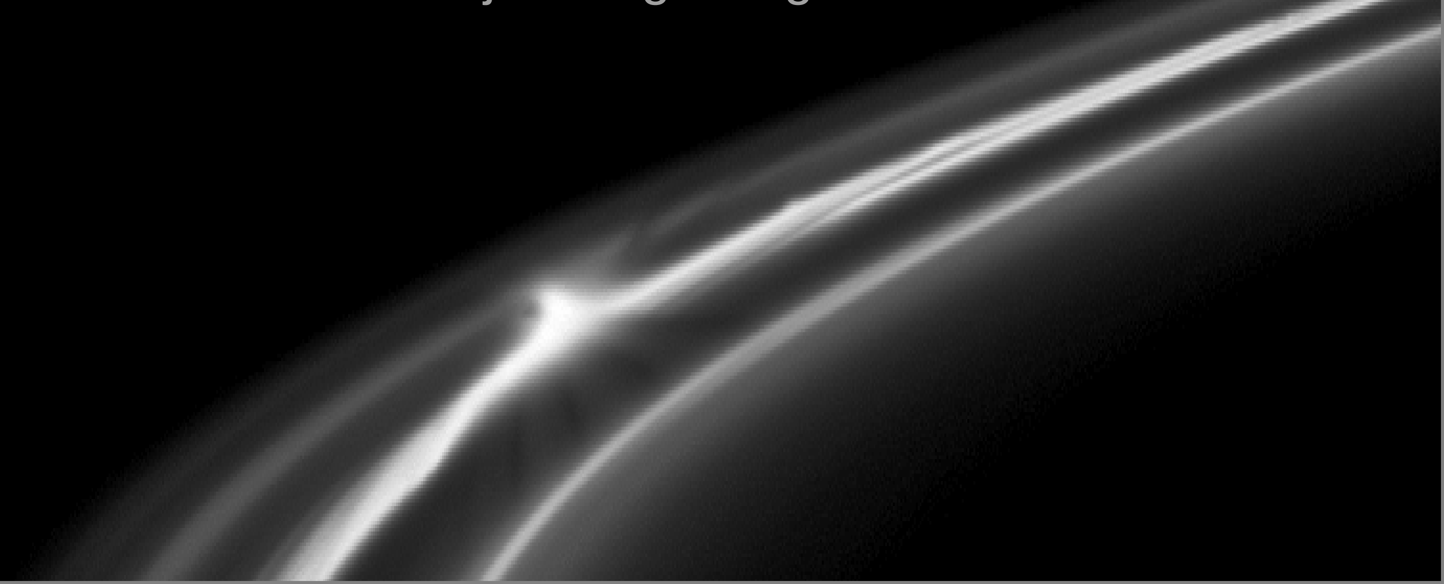
Evidence has been found for hundreds of tiny, 1-km-sized bodies punching through Saturn's thin F ring, leaving glittering trails of icy particles behind them. Scientists have seen more than 500 of these kinds of trails, or "mini-jets," in images collected by Cassini from 2004 to 2011. In some cases, the objects traveled in packs, creating mini-jets that looked quite exotic, like the barb of a harpoon. Other new images show the entire F ring, showing the swirls and eddies that ripple around the ring from all the different kinds of objects moving through and around it.

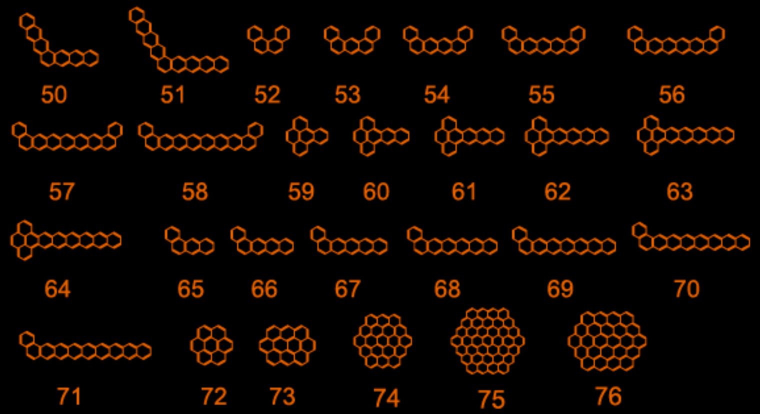


More mini-jets (Attree et al 2012)



Final image of F ring taken just before Cassini entered EQ1 (Oct 2010). New F Ring imaging (since beginning of IN1) shows this clump, caused by a higher-velocity collision, has largely dissipated. Expectation (speculation) is for increased activity in the next year or two, based on analogy with HST observations 5-6 years after prior close passage of Prometheus to F Ring (see CHARM-7). Core seems a little more “excited” now, but observations are just beginning.

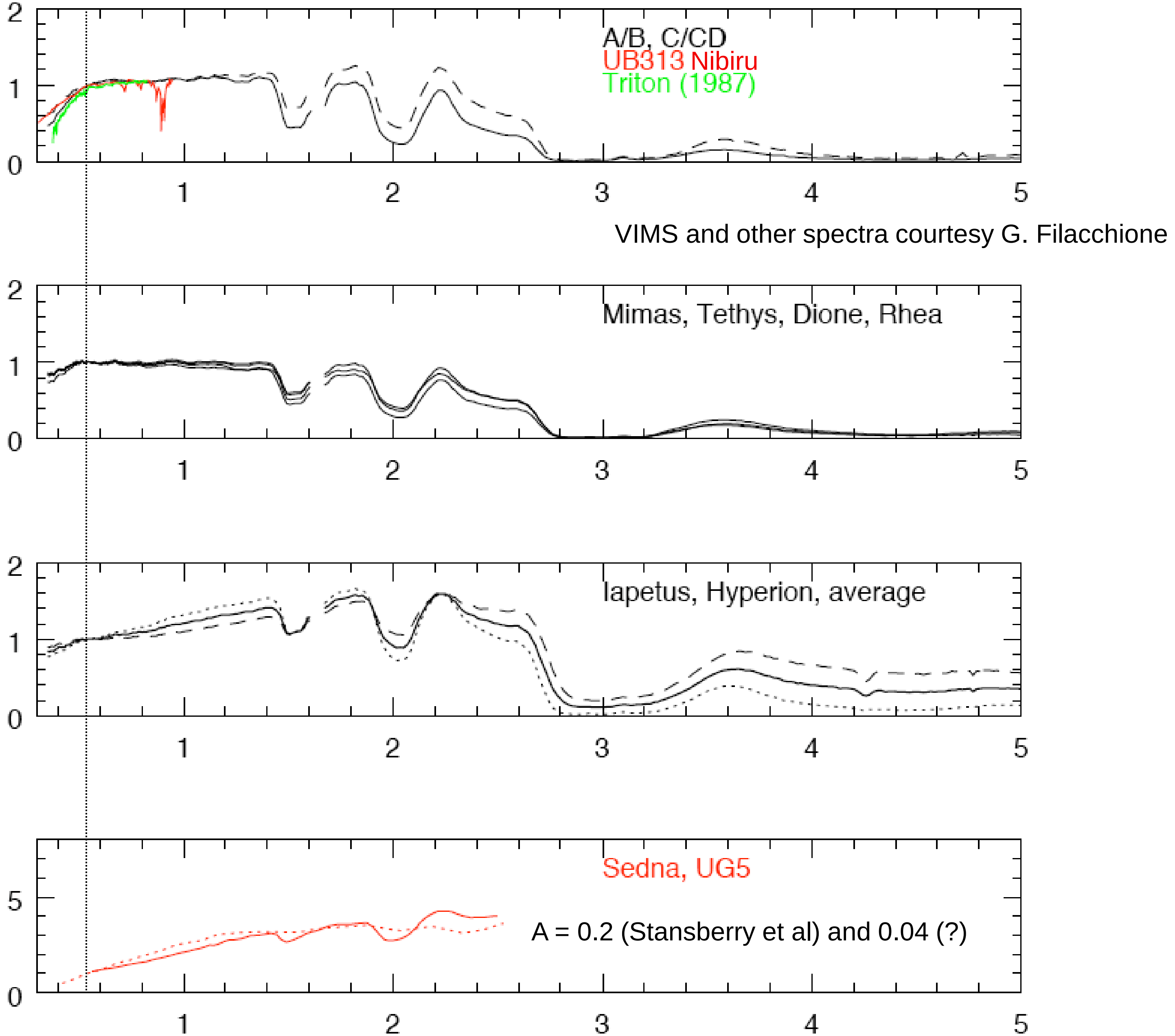




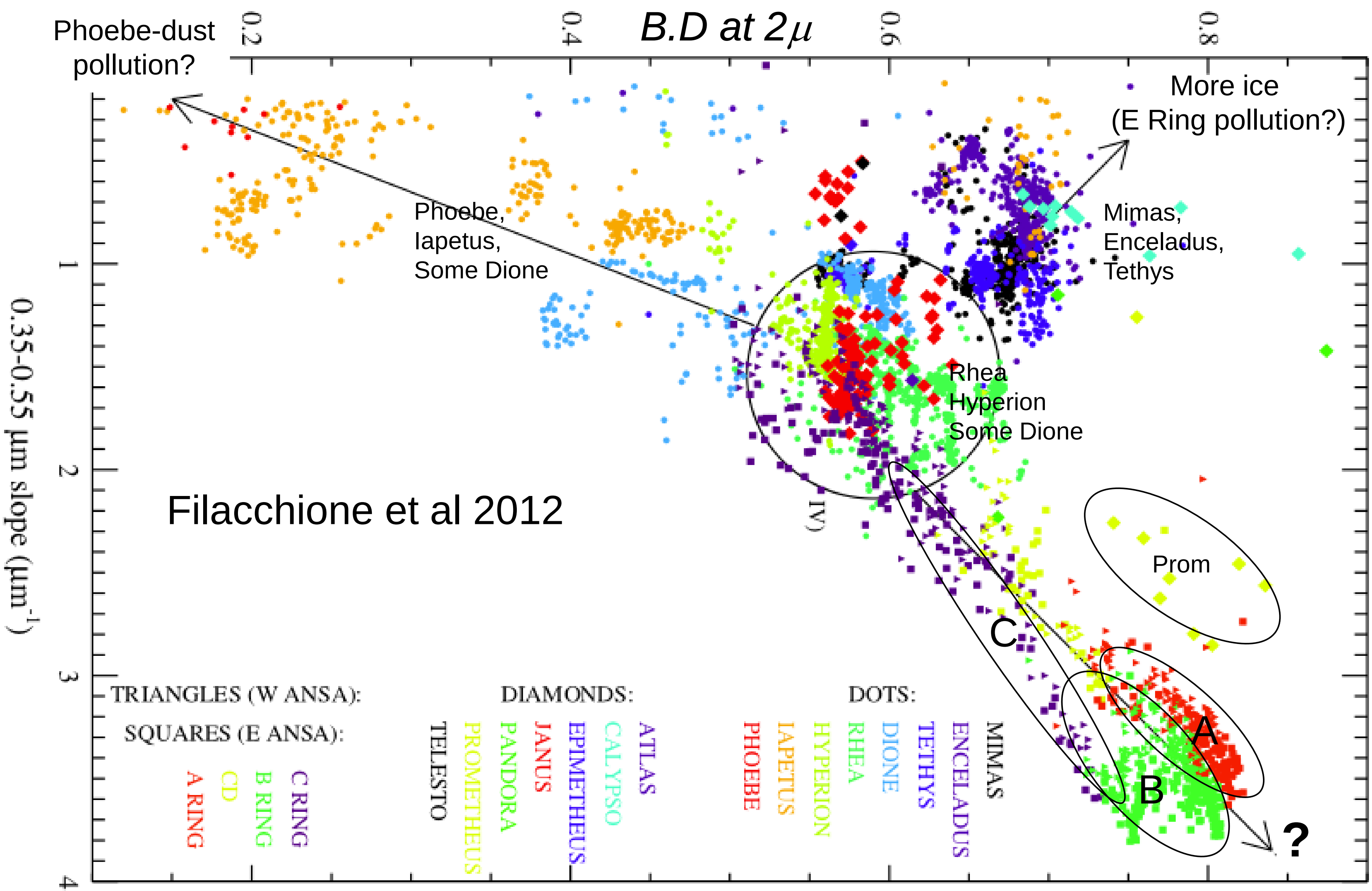
Why are the rings reddish?
“organic” or inorganic origin?
Lack of spectral features
Suggests nano-inclusions

Cuzzi et al 2010; Saturn from Cassini-Huygens

Comparison of rings with other icy obects

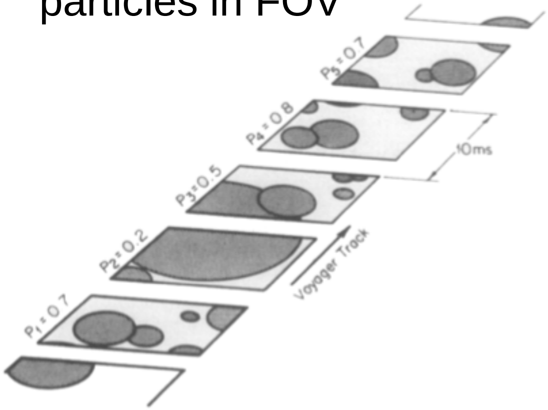


Composition of rings and moons in the Saturn system, regarded together, suggest at least three different influences: pure ice, reddish material or process, and dark, colorless material. Main rings differ systematically. C Ring and CD may differ due to due to increasing pollution (by meteoroids, not Phoebe dust). Why the rings (and Prometheus) are so much redder remains a puzzle.

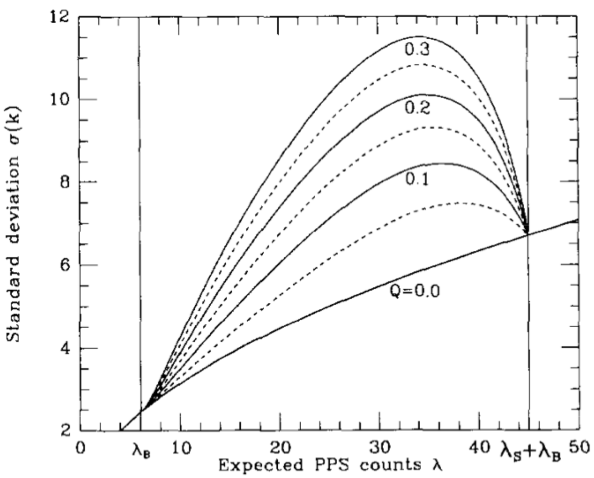


Particle size variations from stellar occultations

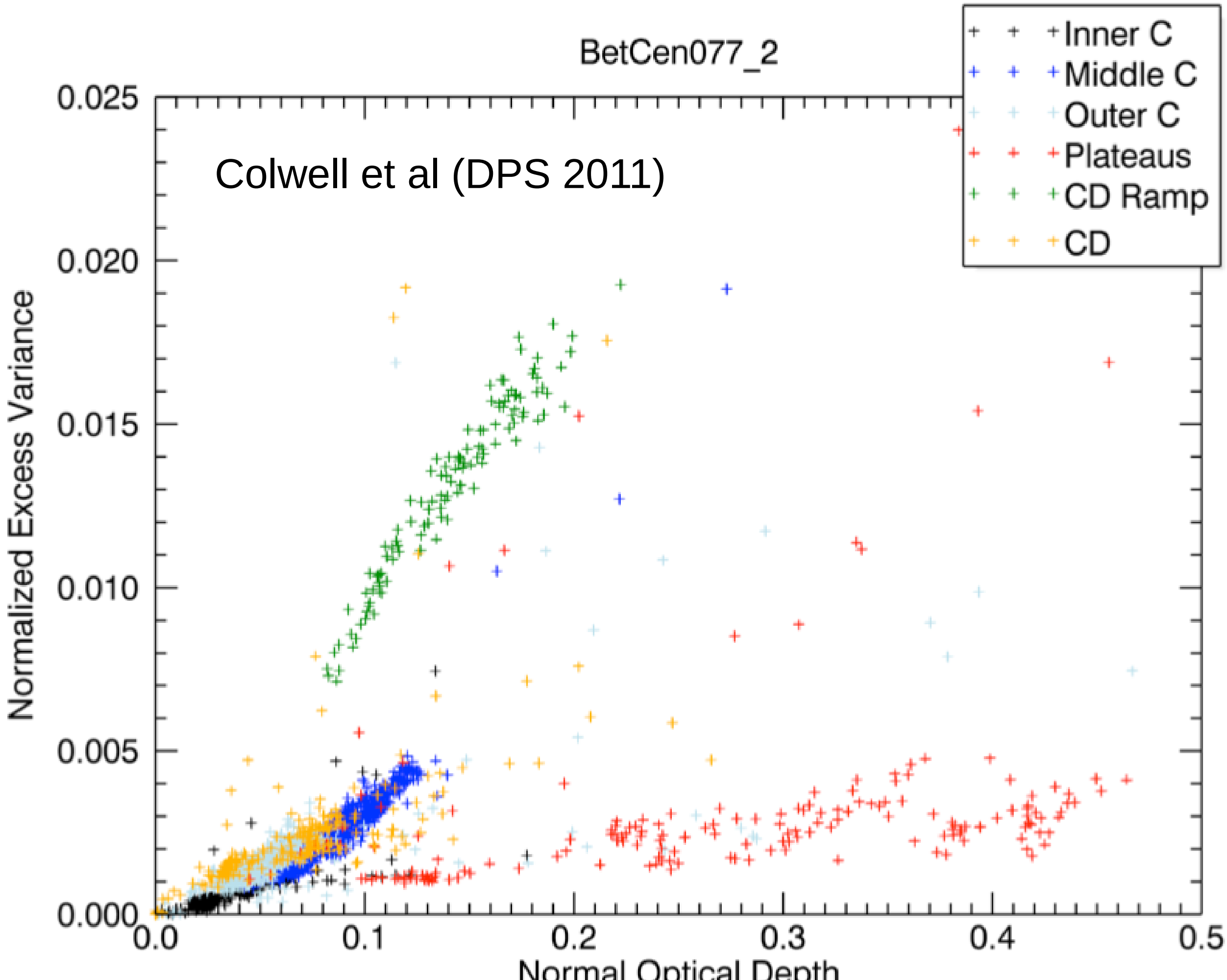
Non-Poisson fluctuations in stellar occs come from large particles in FOV



Showalter and Nicholson 1990



Strong regional variation in upper limit of particle size. Smallest particles in C Ring "plateaus" (red).



UVIS:Clumpy ring structure tied to compressions by moons

Esposito et al (2012) have developed a "predator-prey" model for emergence and erosion of clumpy structure in the rings, as driven by perturbations from nearby moons or resonant compression caused by moons further away. The model tends to predict the maximum clumpiness at nearly 180 degrees away from the strongest compressive perturbations.

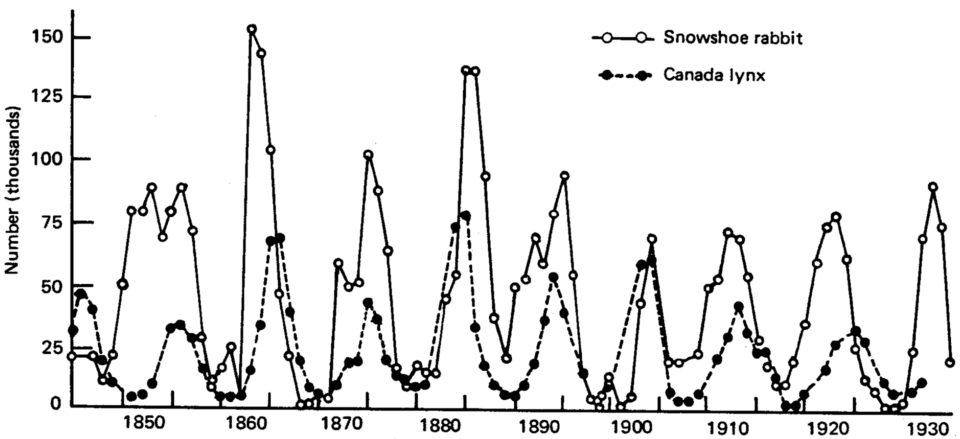
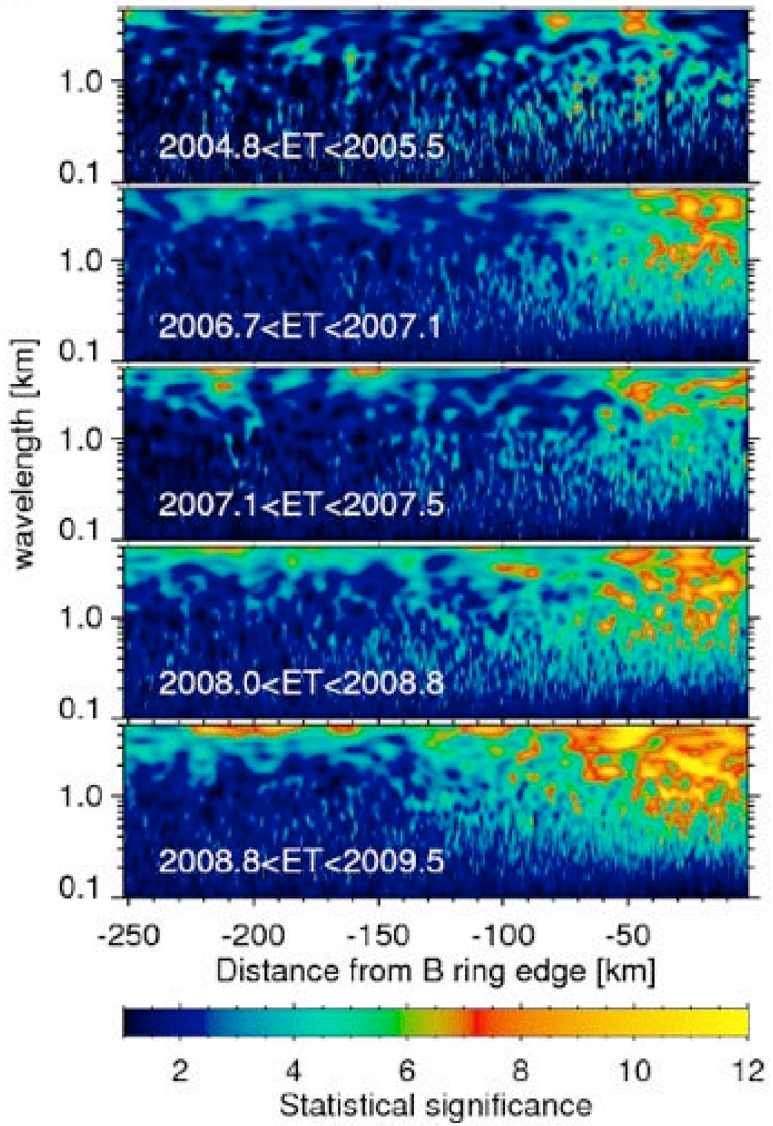
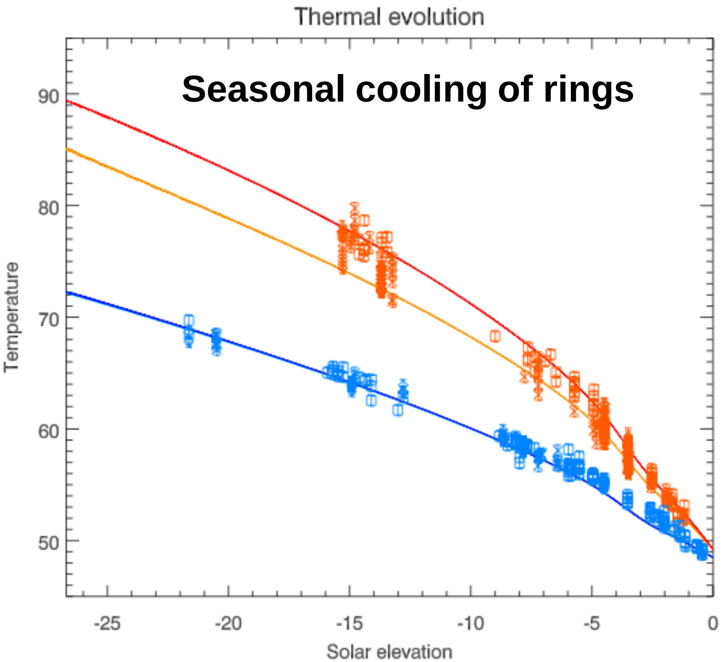


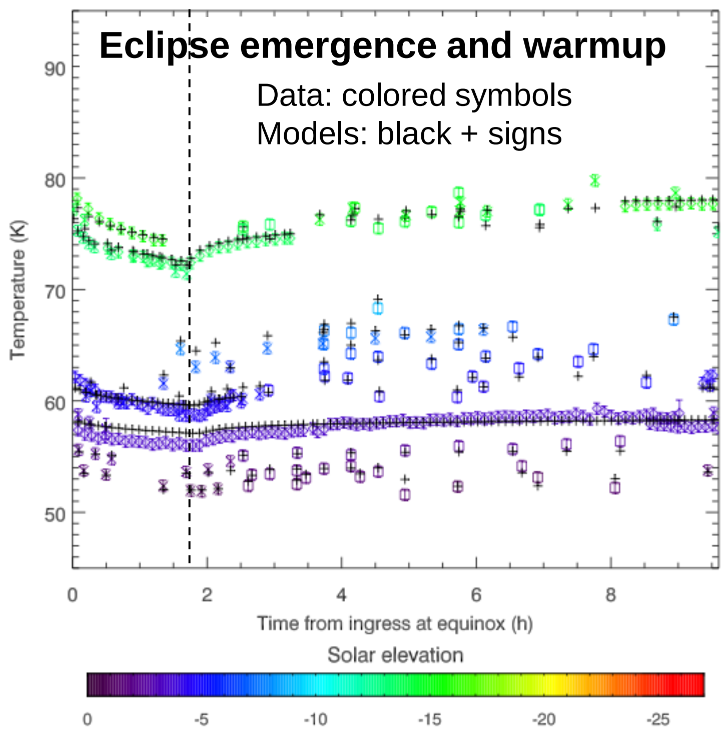
Figure 10:

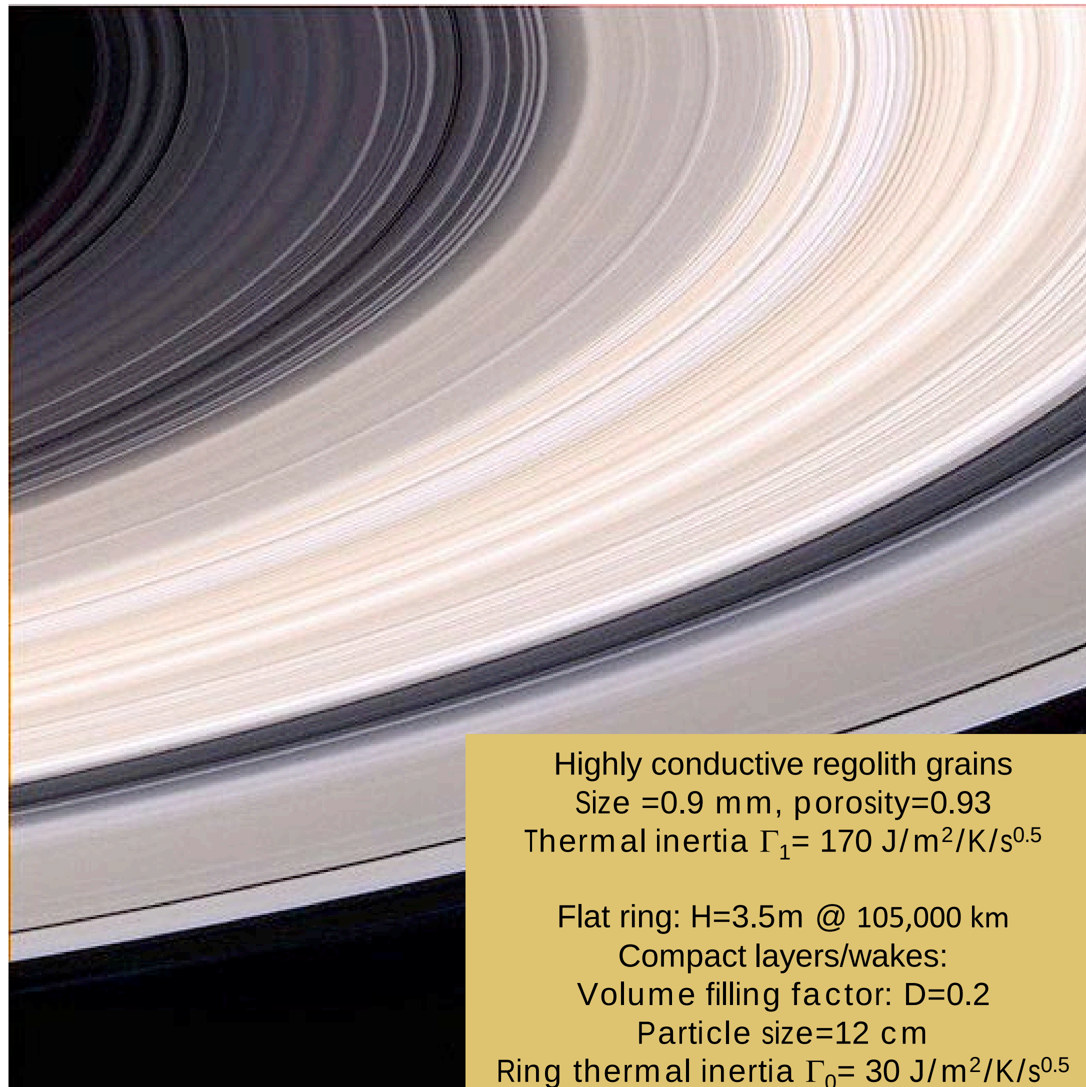


Saturn's B ring - CIRS (Ferrari & Reffet, DPS 2011)

Thermal Modeling, Vertical structure & Properties of the B ring





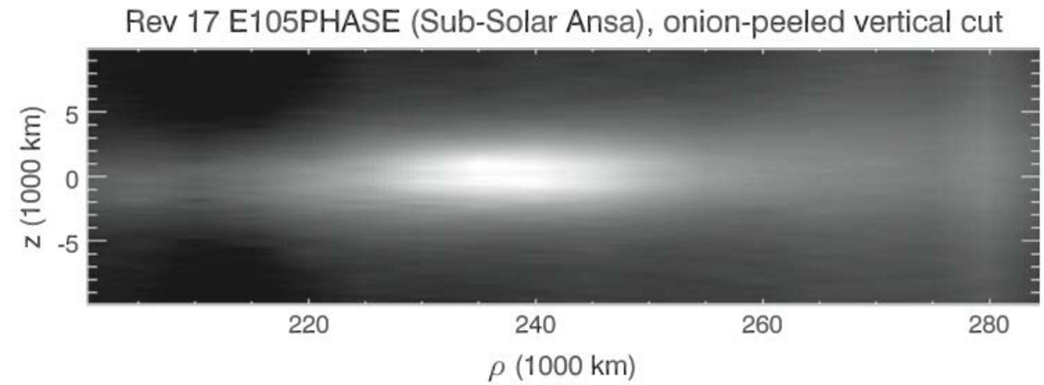


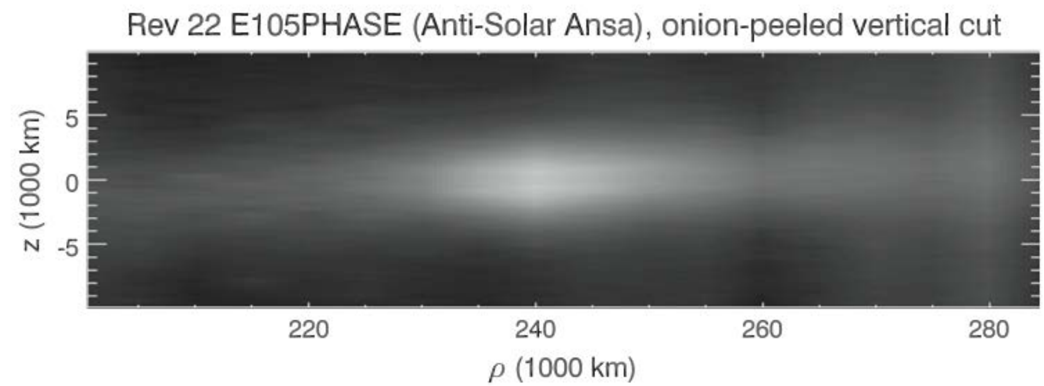
Highly conductive regolith grains
Size =0.9 mm, porosity=0.93
Thermal inertia Γ_1= 170 J/m^2/K/s$^{0.5}$

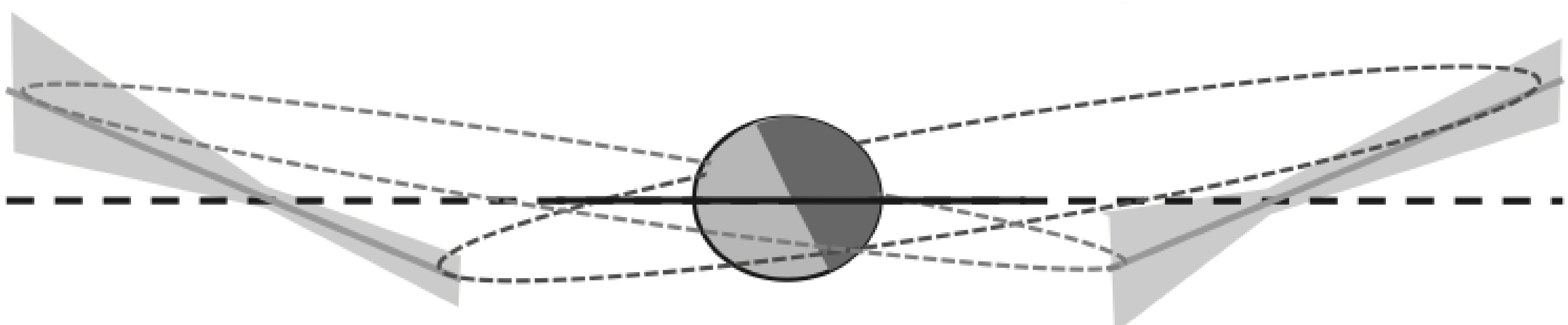
Flat ring: H=3.5m @ 105,000 km
Compact layers/wakes:
Volume filling factor: D=0.2
Particle size=12 cm
Ring thermal inertia Γ_0= 30 J/m^2/K/s$^{0.5}$

E Ring structure varies with seasons

Cassini images have shown the E Ring to be bowl-shaped, with a configuration that depends on the Sun’s elevation angle. This is because radiation pressure is most effective on small grains at their apoapses. The double-banded vertical structure in its core, near Enceladus, is due primarily to subsequent scattering by the moon of dust from the ejecta plumes. Some aspects, however, remain puzzling, such as the fact that the ring is brighter and closer to the planet on the sunward side (Hedman et al 2012).







Backup