Zooming in on Saturn's Rings July 2013

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Highlights of the Preceding Year*

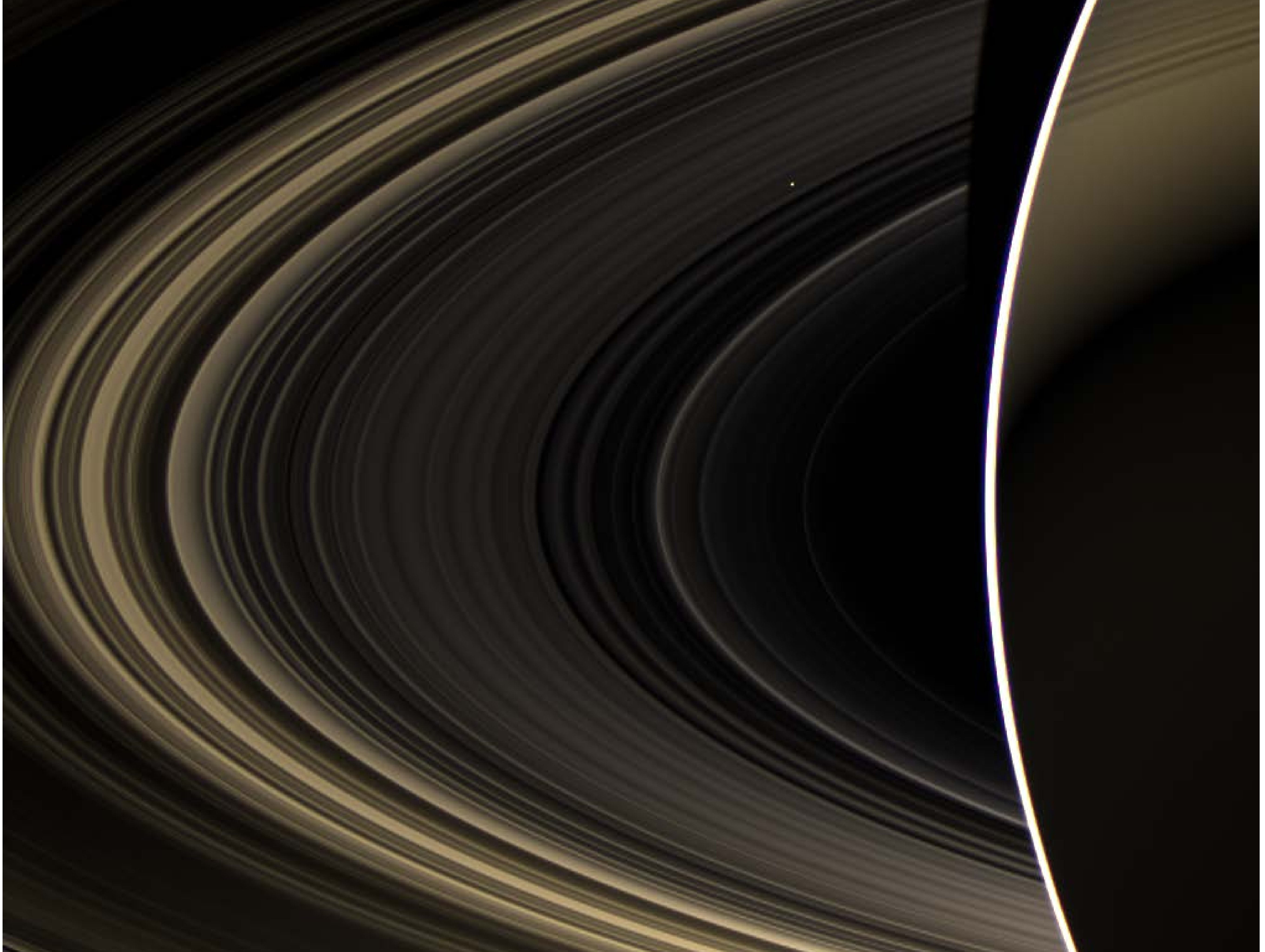
A. Detection of meteoroid impacts on the rings

B. Clumping and fragmentation observed on many length and time scales - implications for ring moon interactions, particle dynamics, ring age.

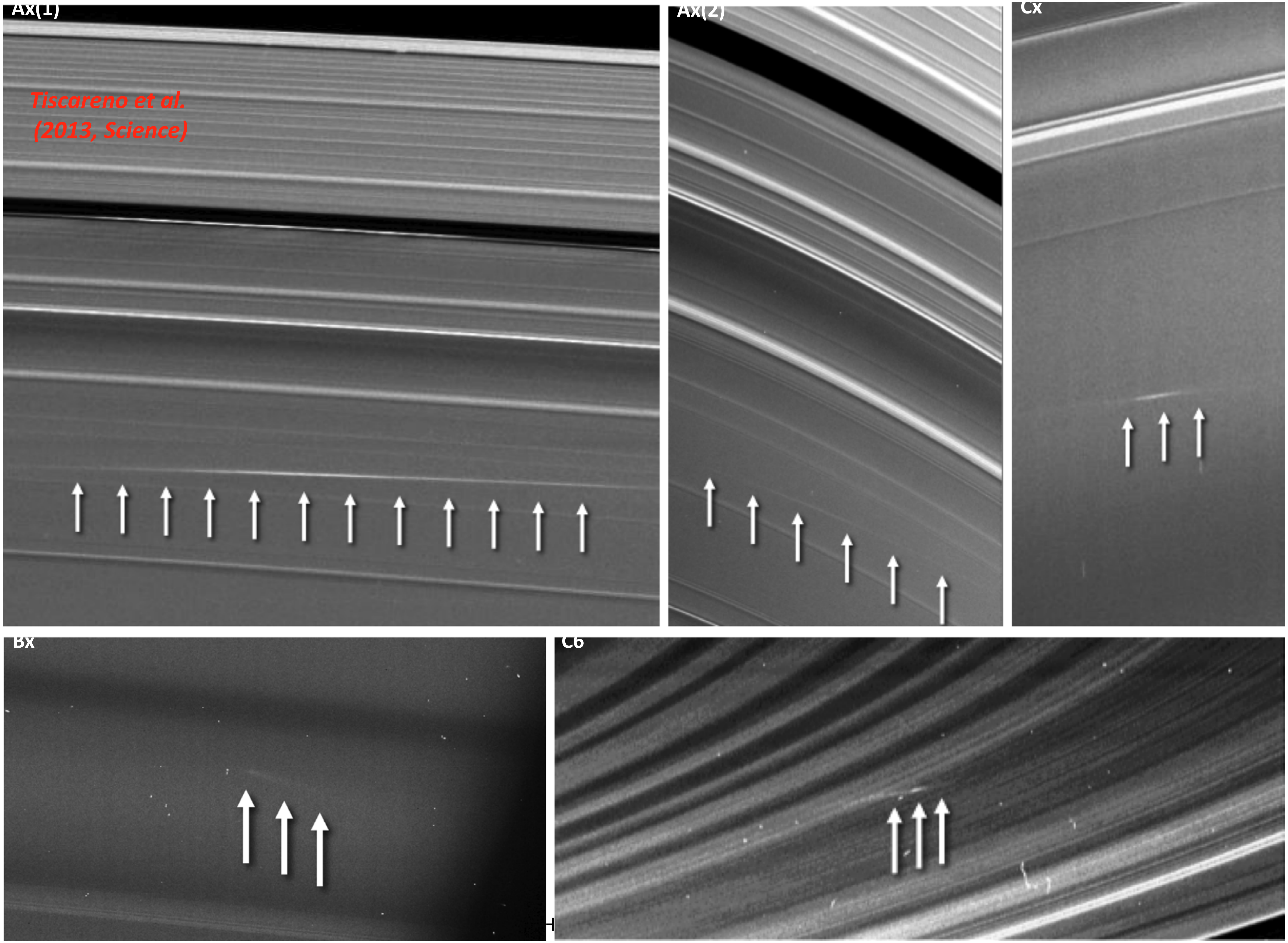
C. Probing Saturn's interior with ring waves

D. Dynamics of Encke Gap ringlets

*An incomplete list!

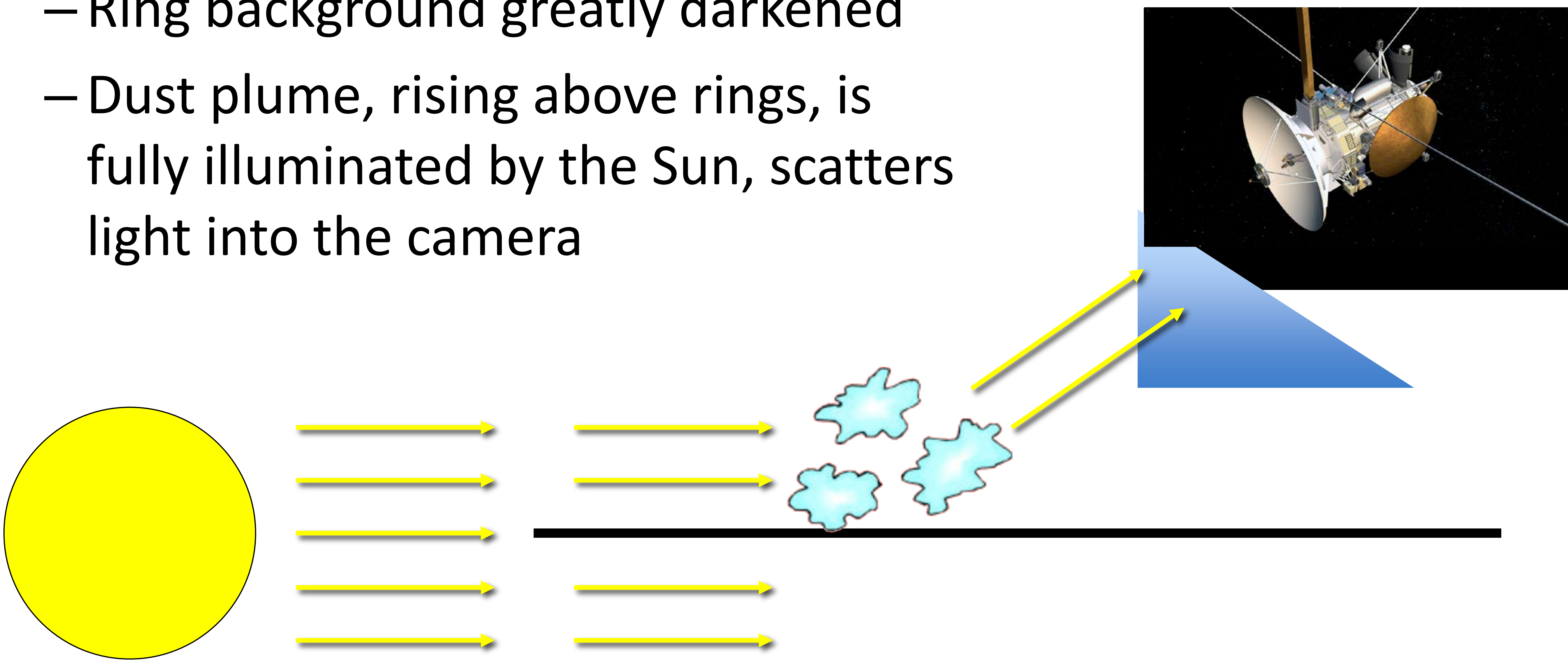


Meteoroid Impacts on Rings

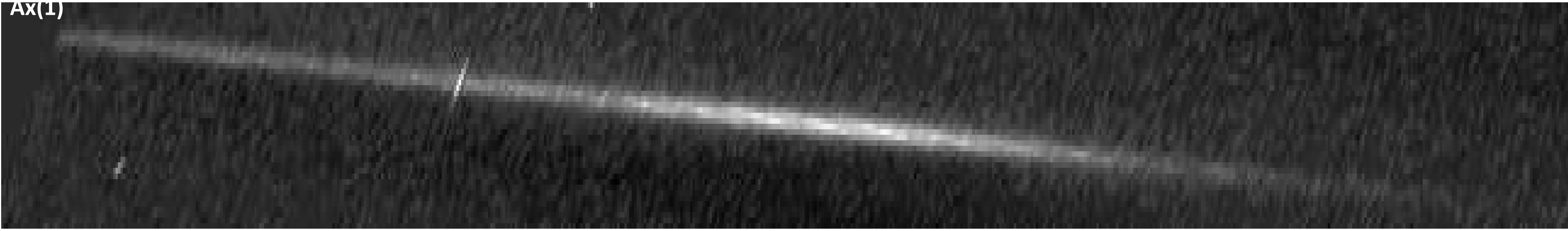


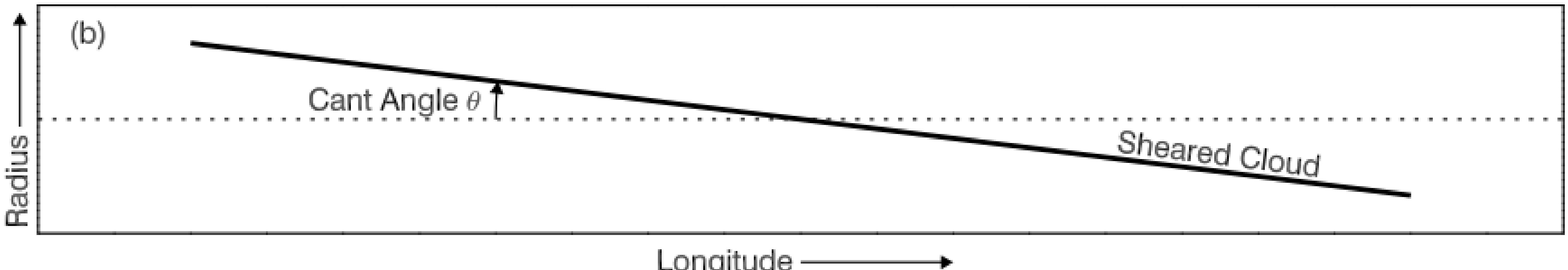
Seeing Impact Ejecta

- Saturn equinox occurred in 2009 (once in 15 yr)
- Sun shines on rings edge-on
  - Ring background greatly darkened
  - Dust plume, rising above rings, is fully illuminated by the Sun, scatters light into the camera

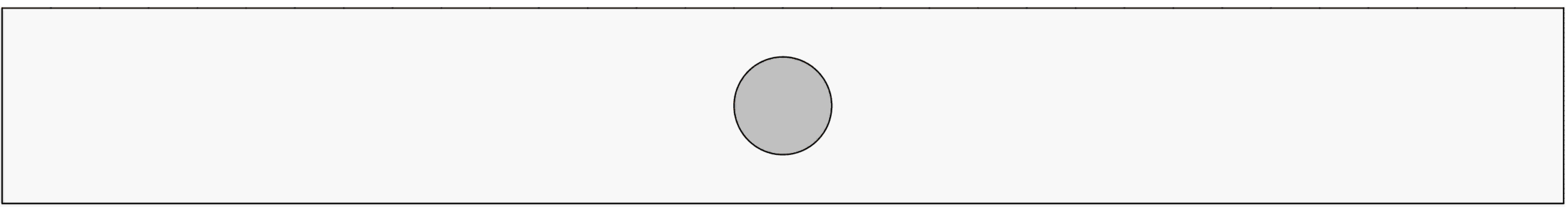


Time Elapsed Since Impact





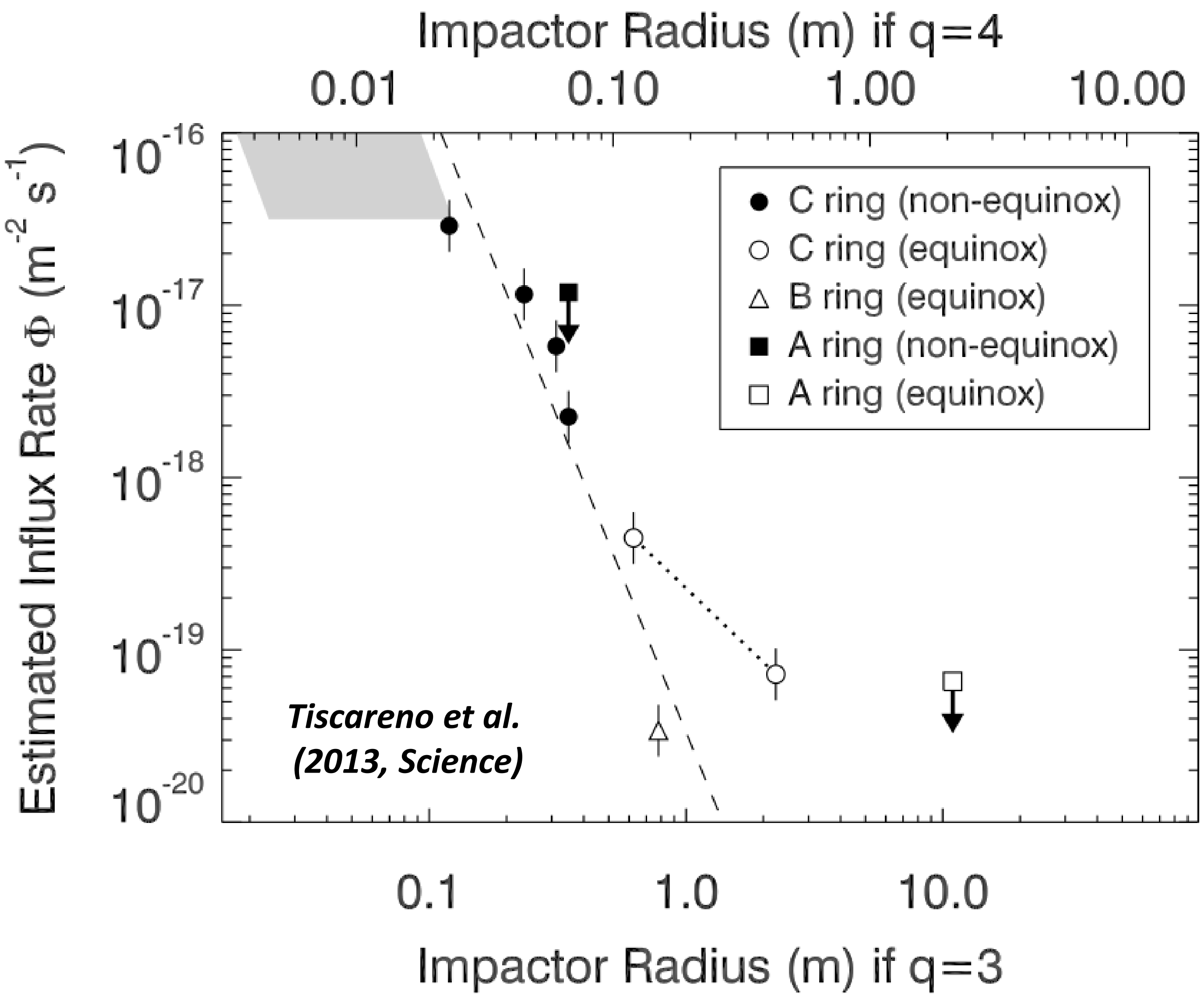
Cartoon representation of shearing ejecta cloud:

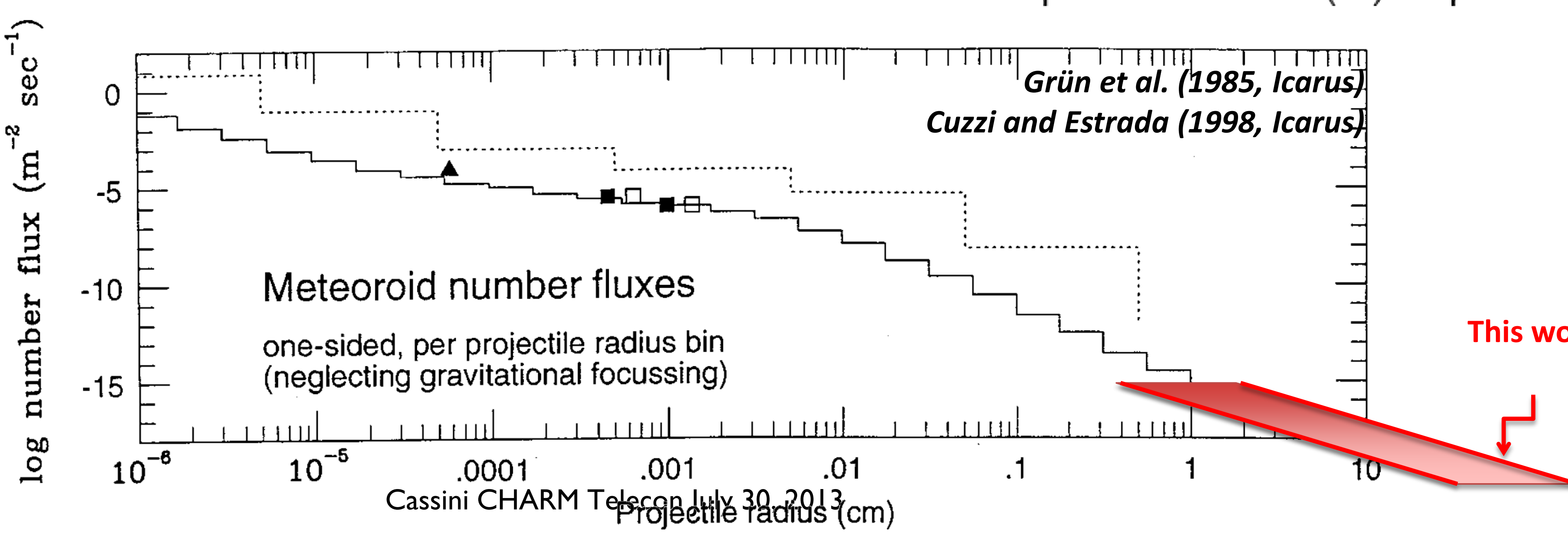


Multiple observations of same cloud with this shearing model confirms that clouds are shearing out from an initial spot.

Results Provide New Information on Large Impactors in the Outer Solar System

- First empirical influx rate for cm-to-m-size particles in the outer solar system
- Consistent with sparse prior knowledge





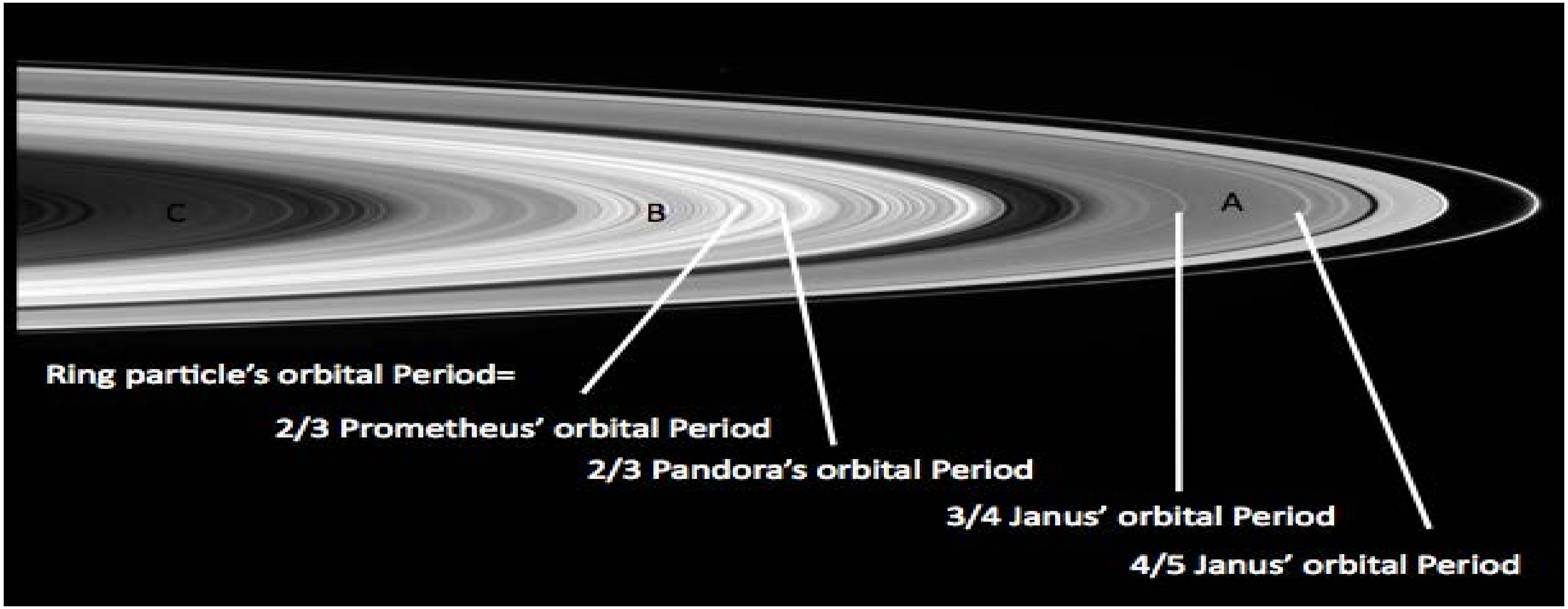
Cassini CHARM Telecon July 30, 2013

Clumping and Fragmentation

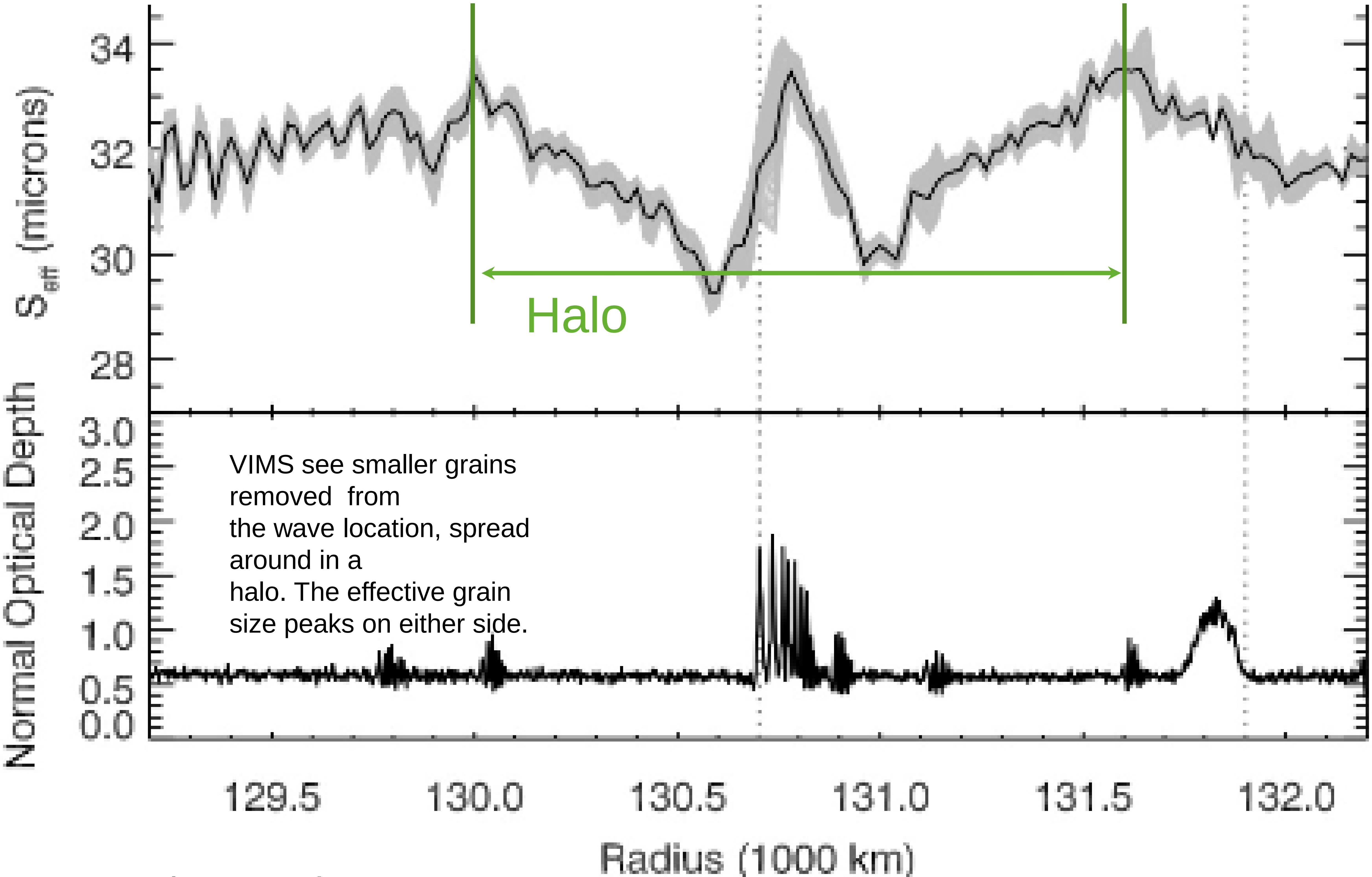
- Multiple lines of evidence showing clumping and fragmentation of particles and aggregates throughout the rings.

Cassini Observed 'Haloes' in Saturn's A Ring

- Bright annuli were seen by VIMS and UVIS at Saturn Orbit Insertion
- Found at strongest density waves



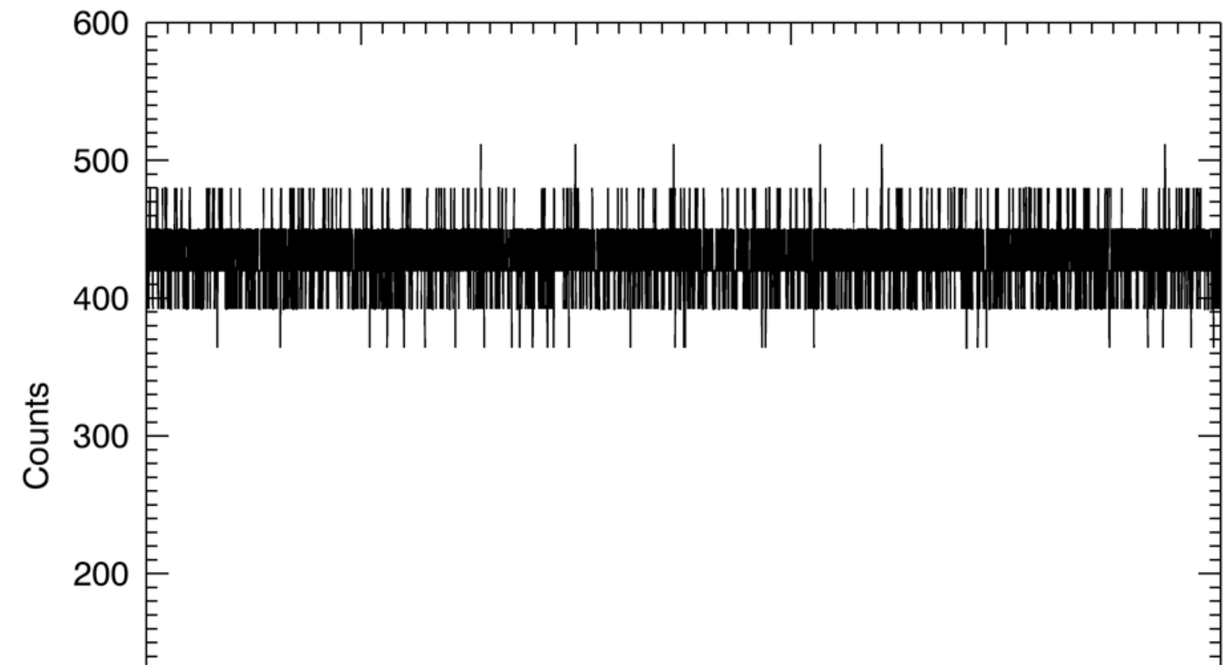
VIMS effective grain size at Janus 5:4 resonance

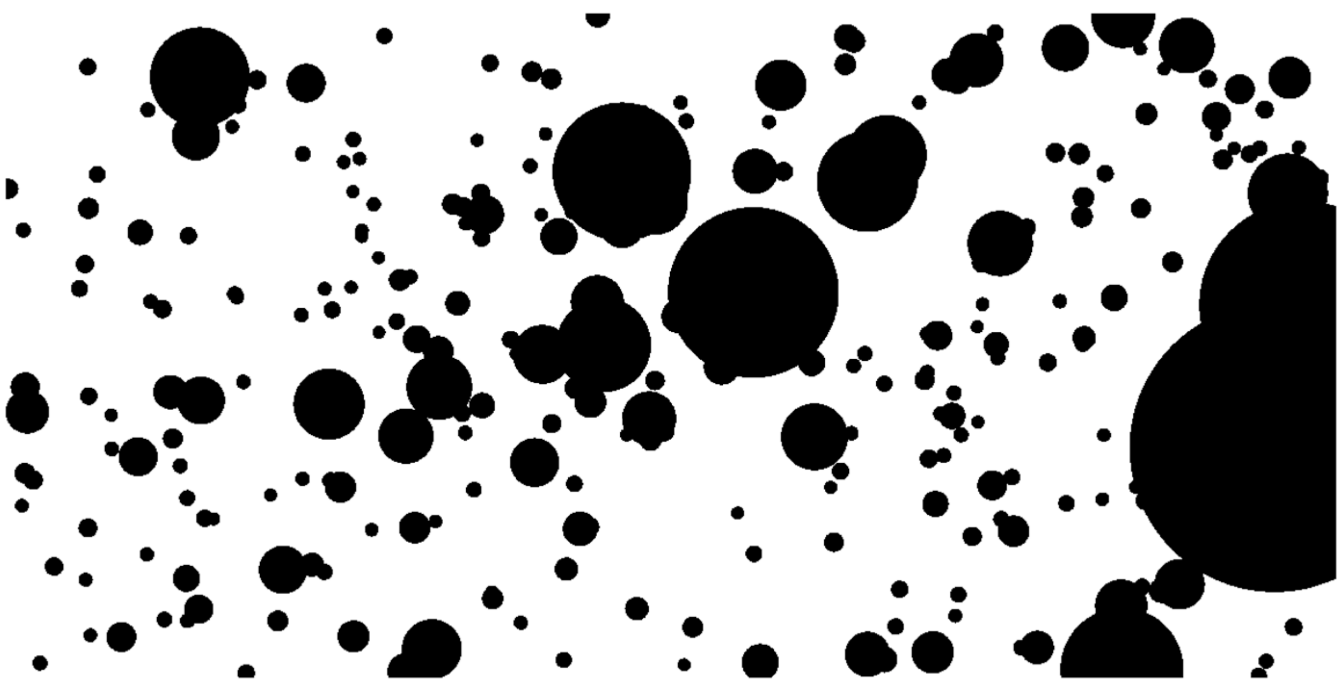


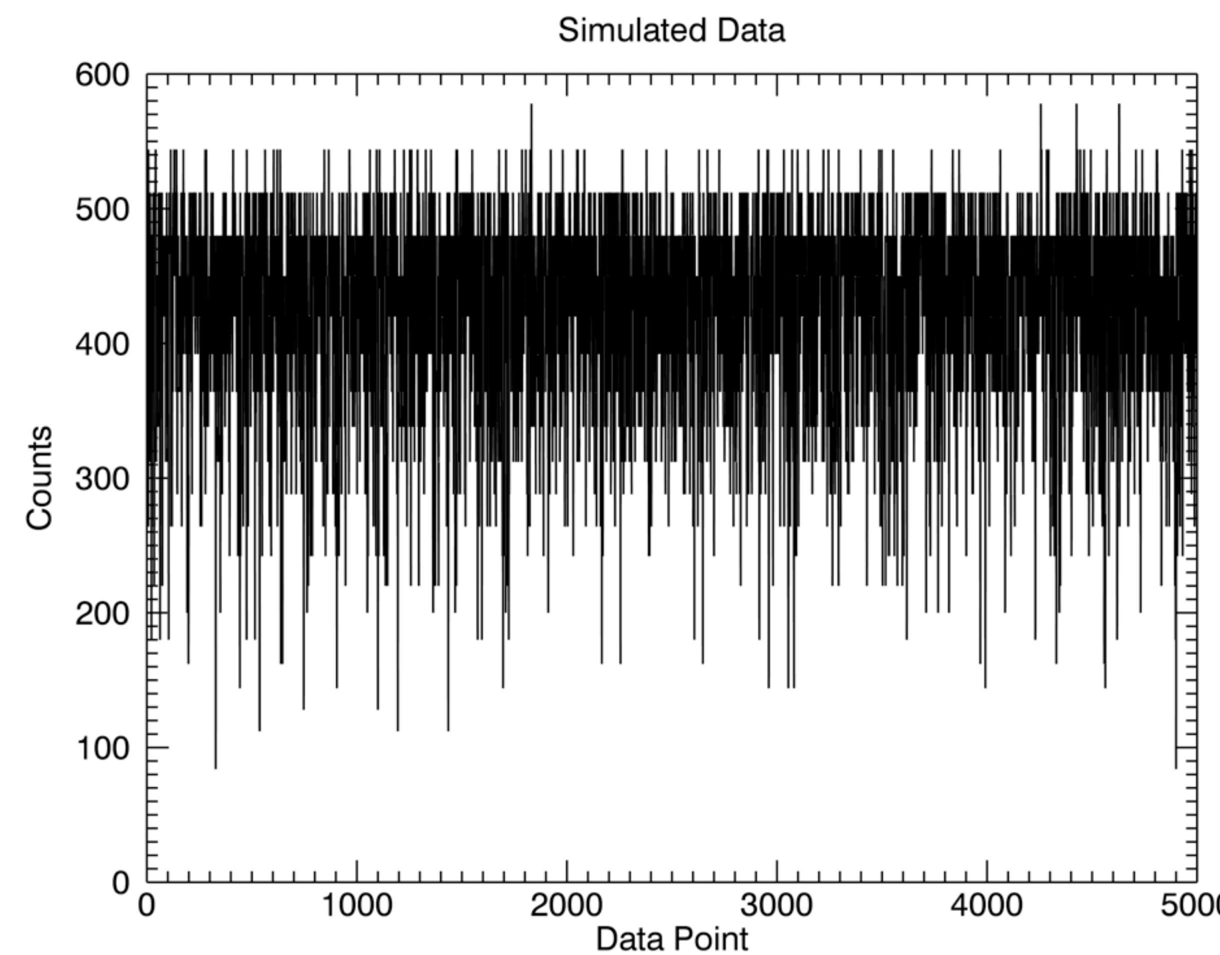
From Hedman et al. Icarus 2013a

UVIS Stellar Occultation Statistics Help Measure Particle Sizes:

If the rings look like this, the variance is small.



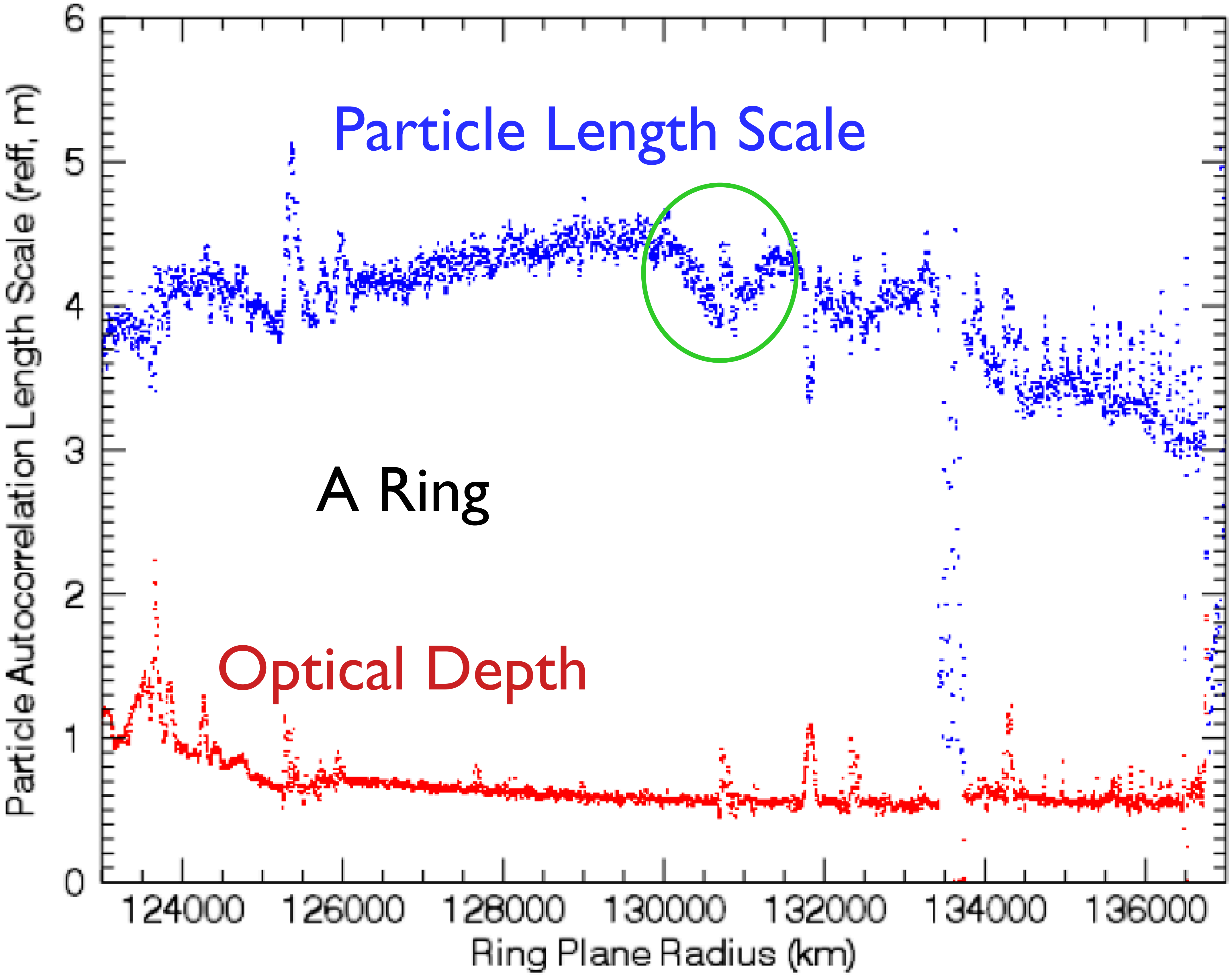




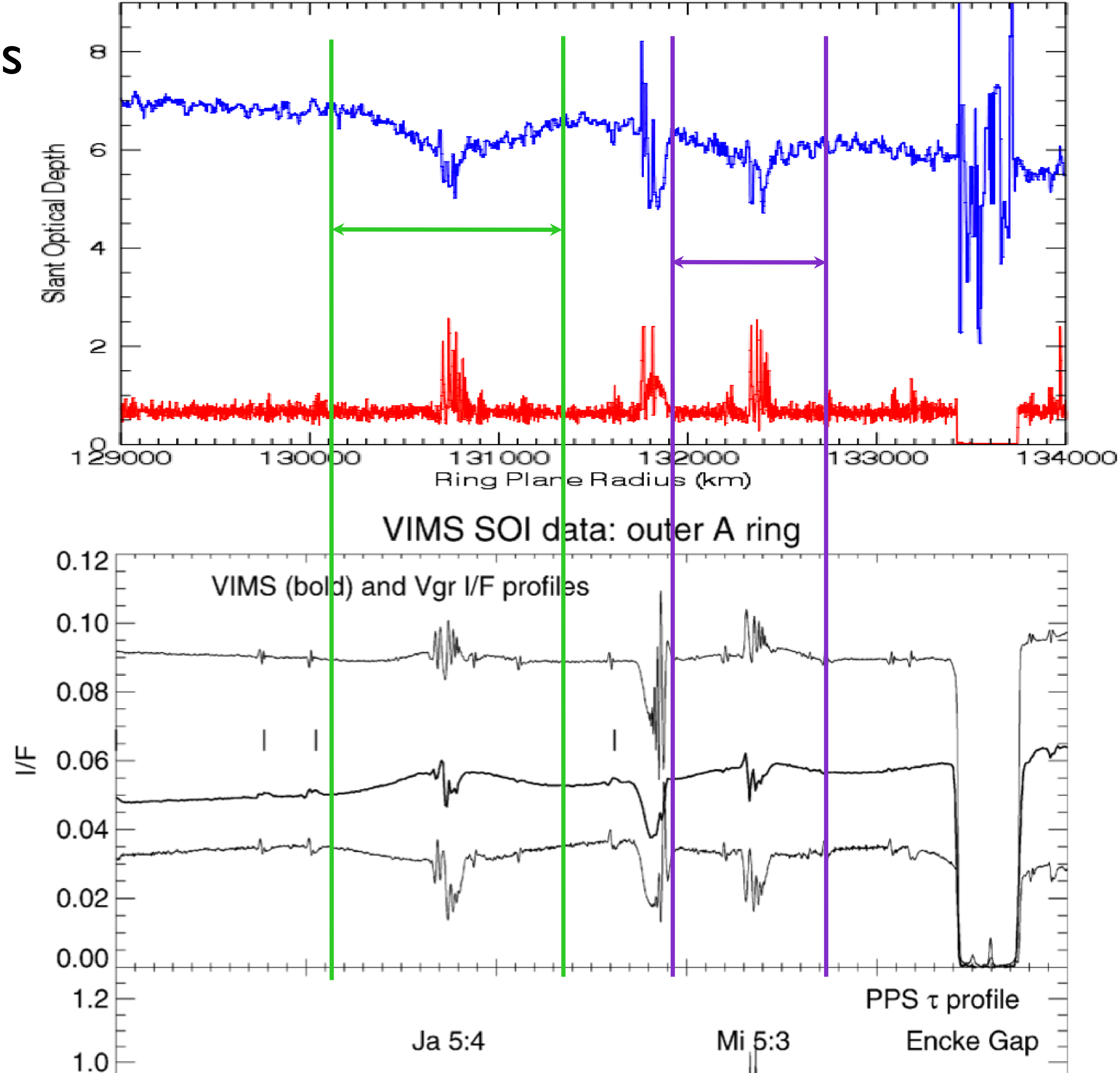
If the rings look like this, the variance is large.

Colwell et al. 2012.

Halo Signature in Particle Autocorrelation Length

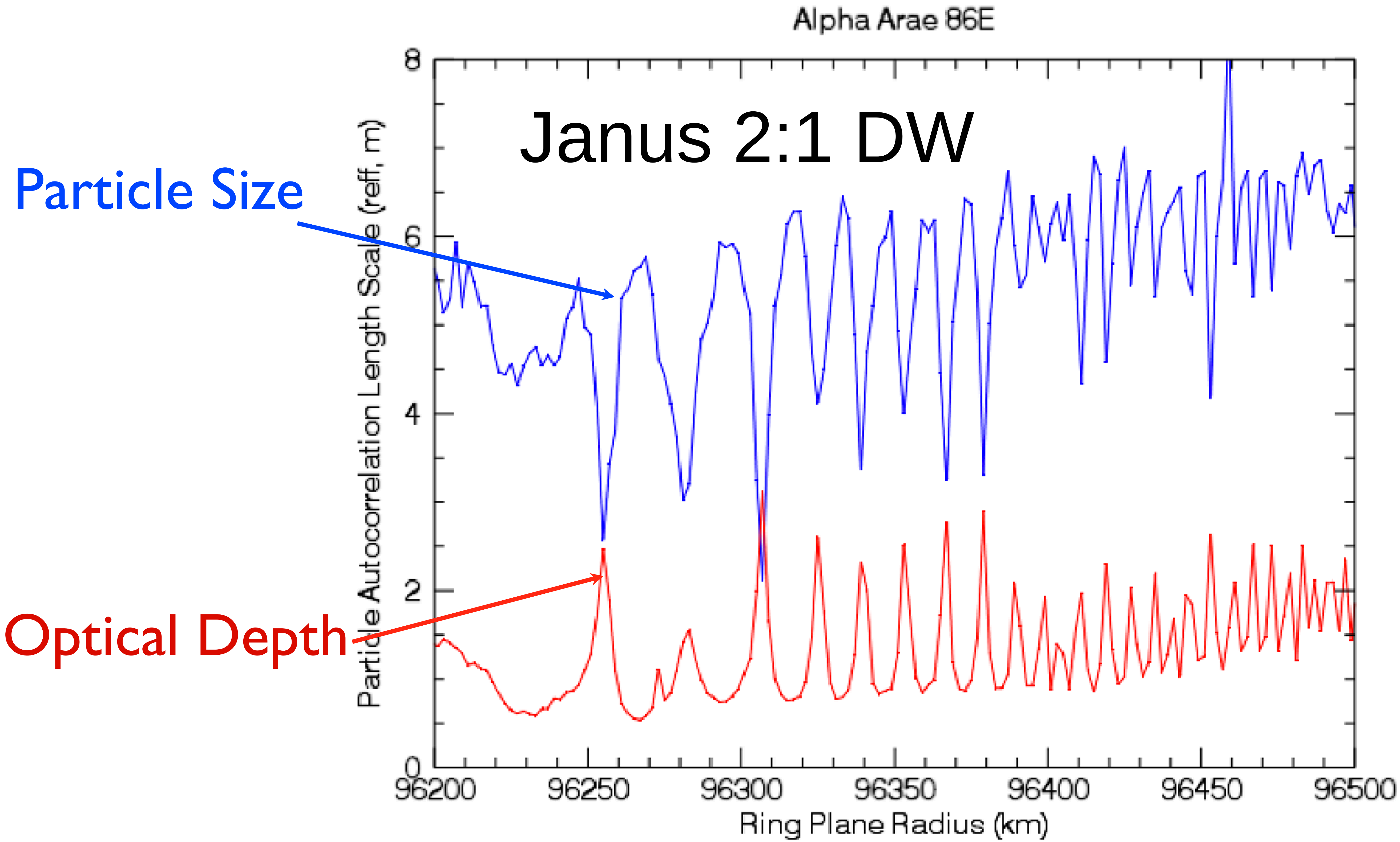


Haloes

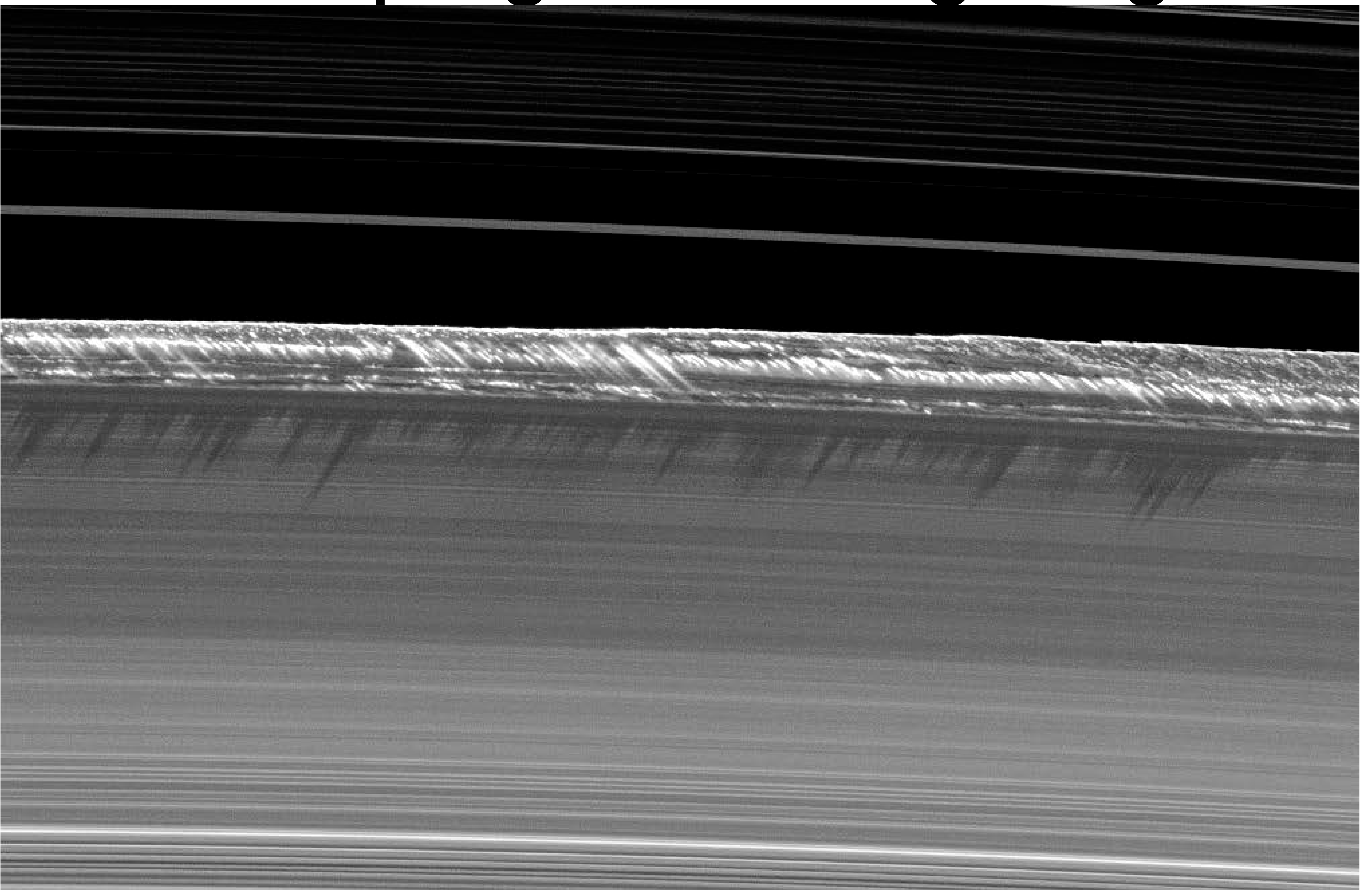


Slant Optical Depth
8
6
4
2
0
129000
130000
131000
132000
133000
134000
Ring Plane Radius (km)
VIMS SOI data: outer A ring
VIMS (bold) and Vgr I/F profiles
I/F
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1.2
1.0
PPS τ profile
Ja 5:4
Mi 5:3
Encke Gap

Particle Scale in Waves

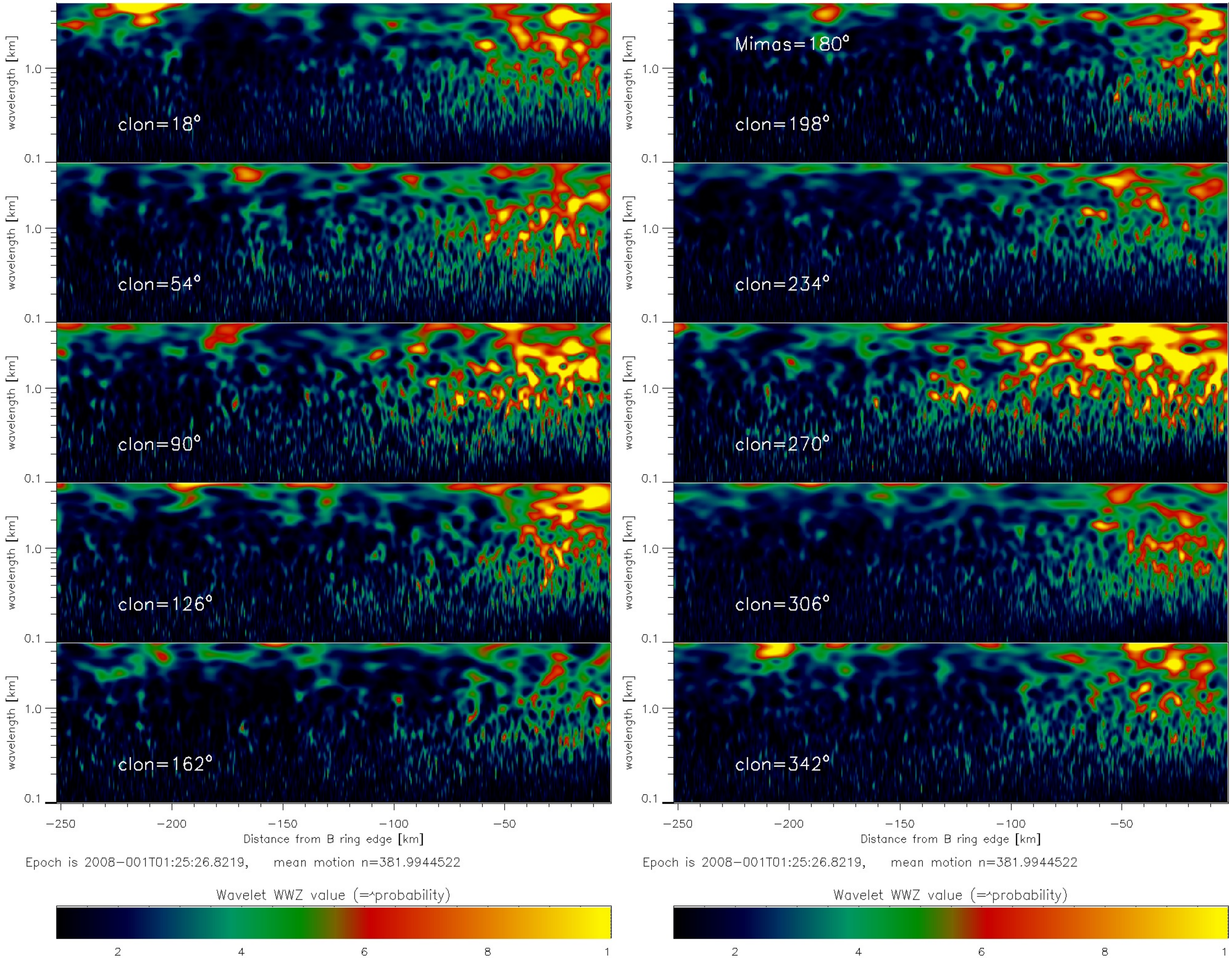


Clumping at B Ring Edge



Periodic clumping and disaggregation at the B ring edge.

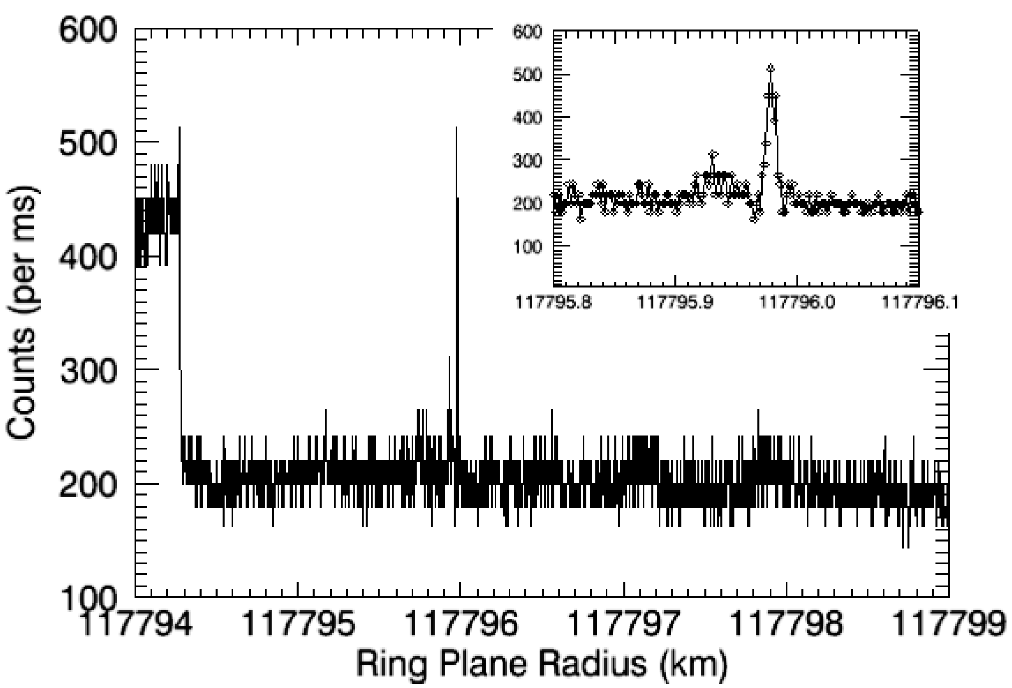
Esposito et al. 2013

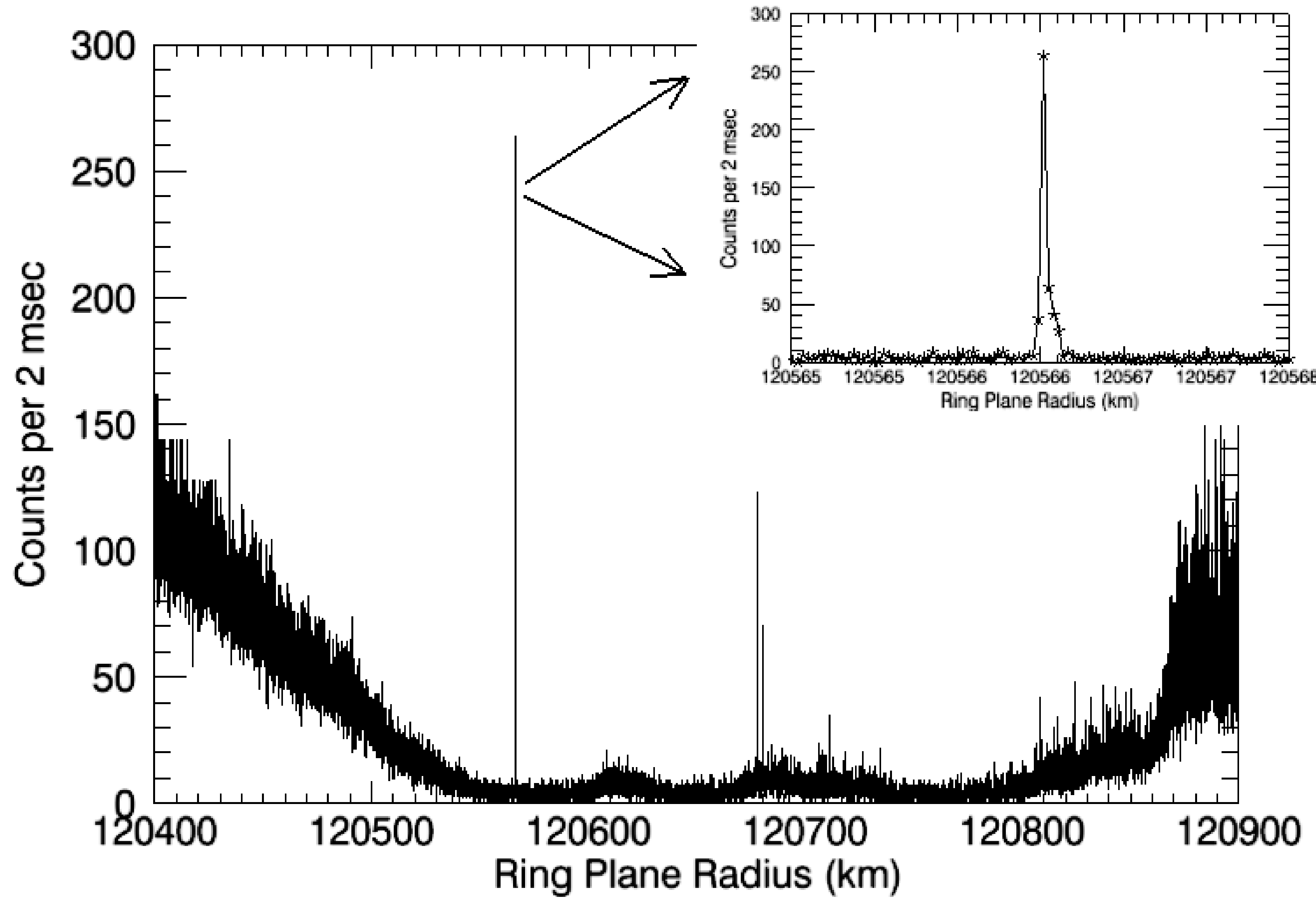


Dozens of “Ghosts” Observed in C ring and Cassini Division

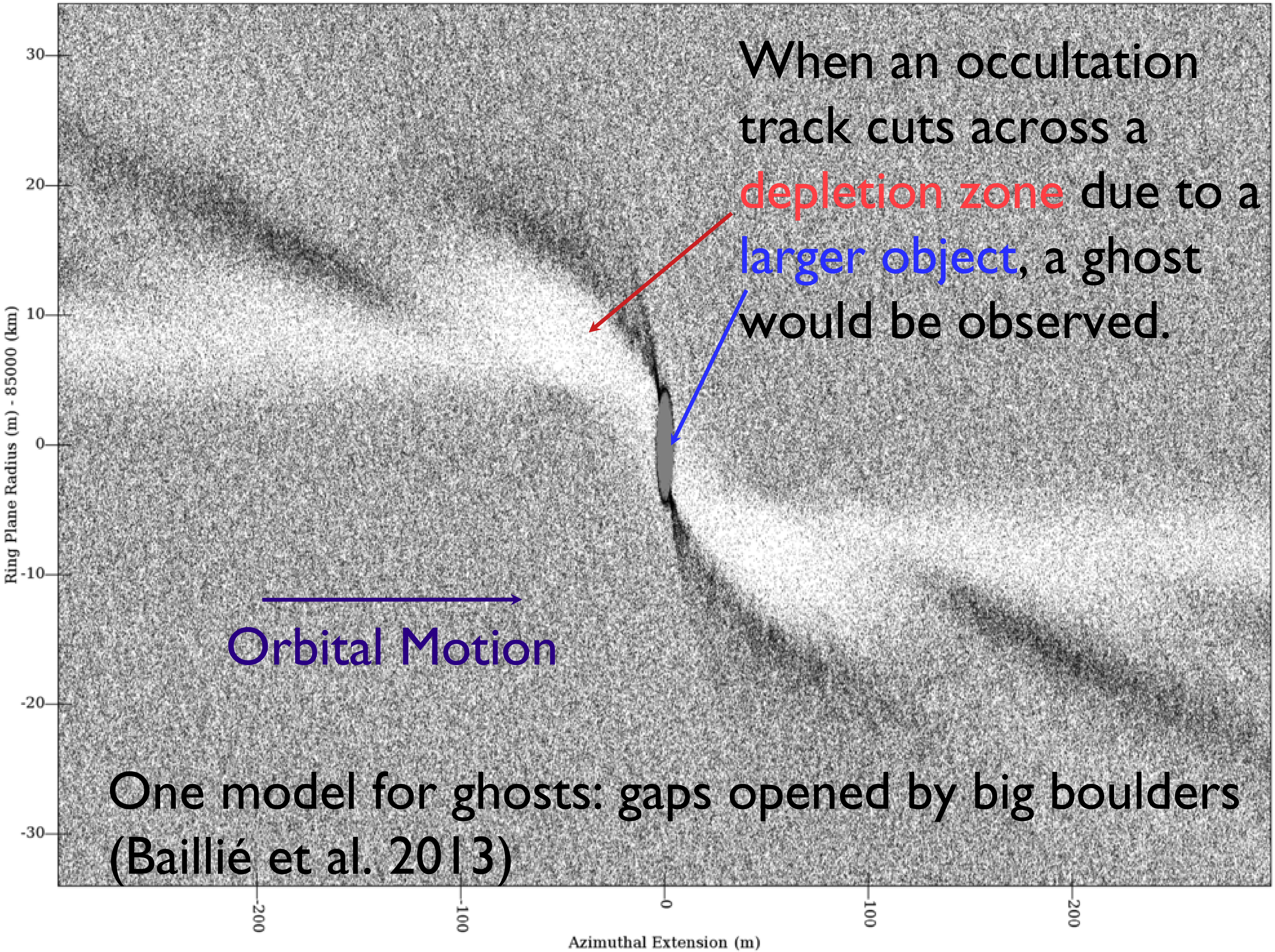
Baillié et al. (2013) analyzed small clear holes in the rings in UVIS stellar occultation data.

Cassini Division
Huygens Ringlet





Cassini Division “Triple Band”


When an occultation track cuts across a depletion zone due to a larger object, a ghost would be observed.
Orbital Motion
One model for ghosts: gaps opened by big boulders (Baillié et al. 2013)
Ring Plane Radius (m) - 85000 (km)
30
20
10
0
-10
-20
-30
-200
-100
0
100
200
Azimuthal Extension (m)

F Ring Clumps and Collisions

Attree et al. 2013

"Mini-jet" dynamics indicate origin is collision with local moonlet.

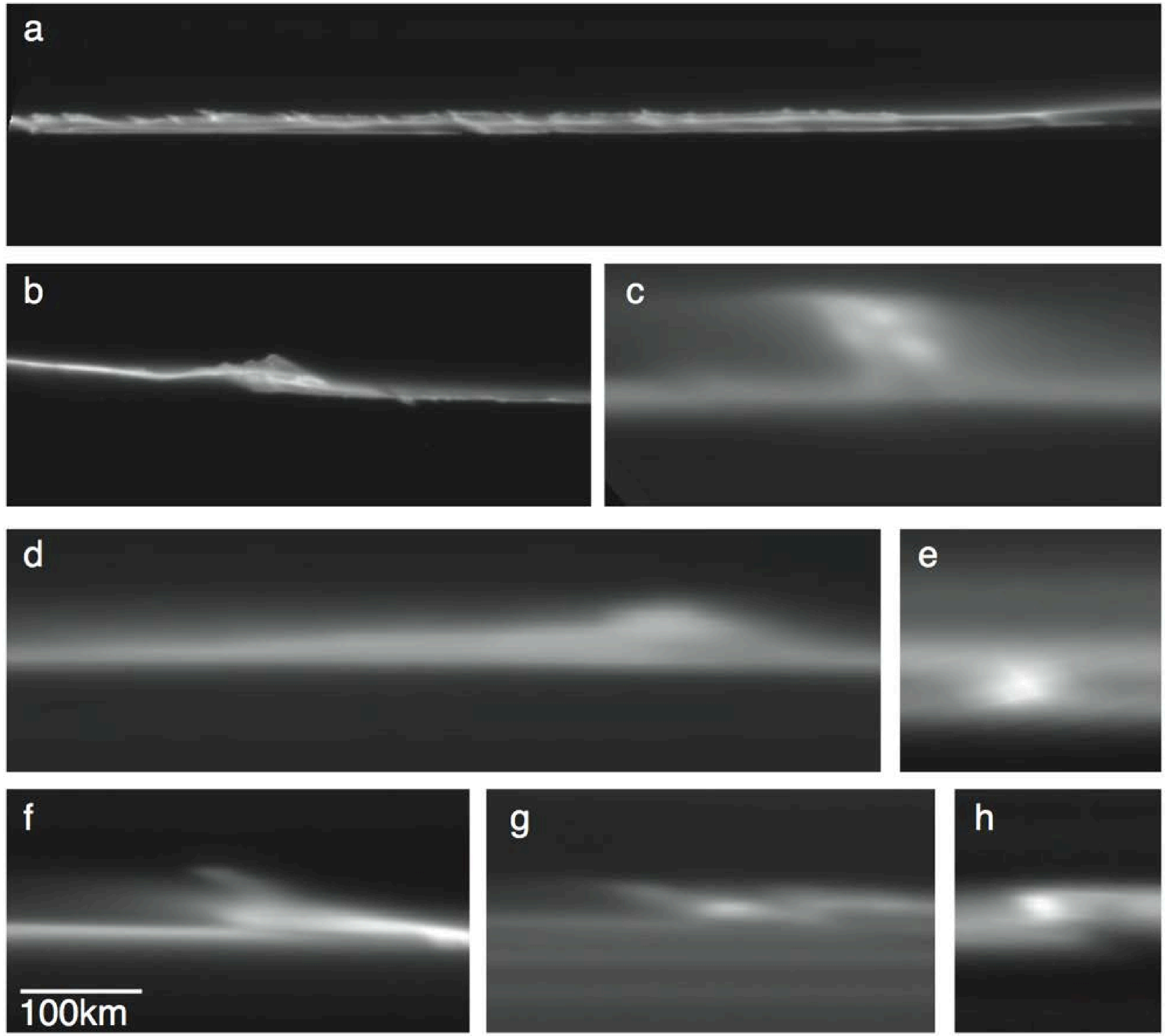


Figure 3: Complex features re-projected in a radius/longitude frame to the same scale. (a) numerous small mini-jets in N1537899083 and (b) N1537898708. Complex and poorly resolved mini-jets in (c) N1589620046 and (d) N1493639016 and possible object in (e) N1627640563. Complex mini-jets in (f) N1605531856, (g) N1623226701 and unknown feature in (h) N1601512734. Contrast has been adjusted in each case to enhance visibility.

Predator-Prey Model of Clumping and Disaggregation

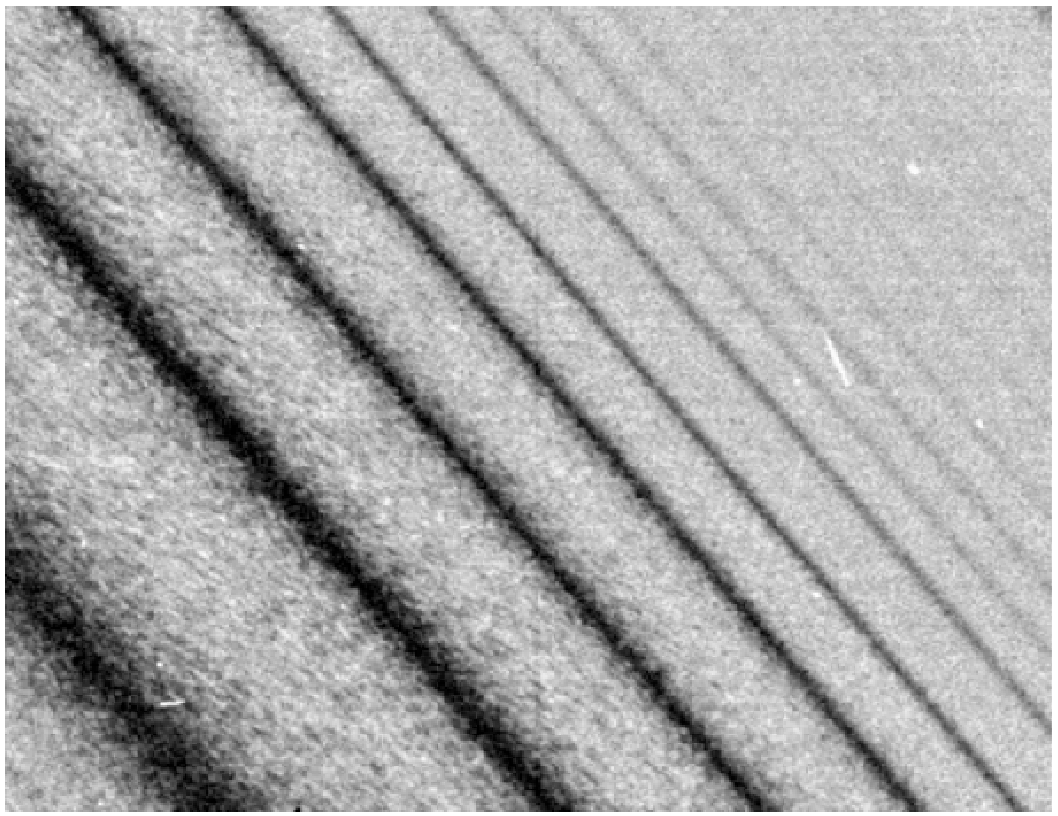
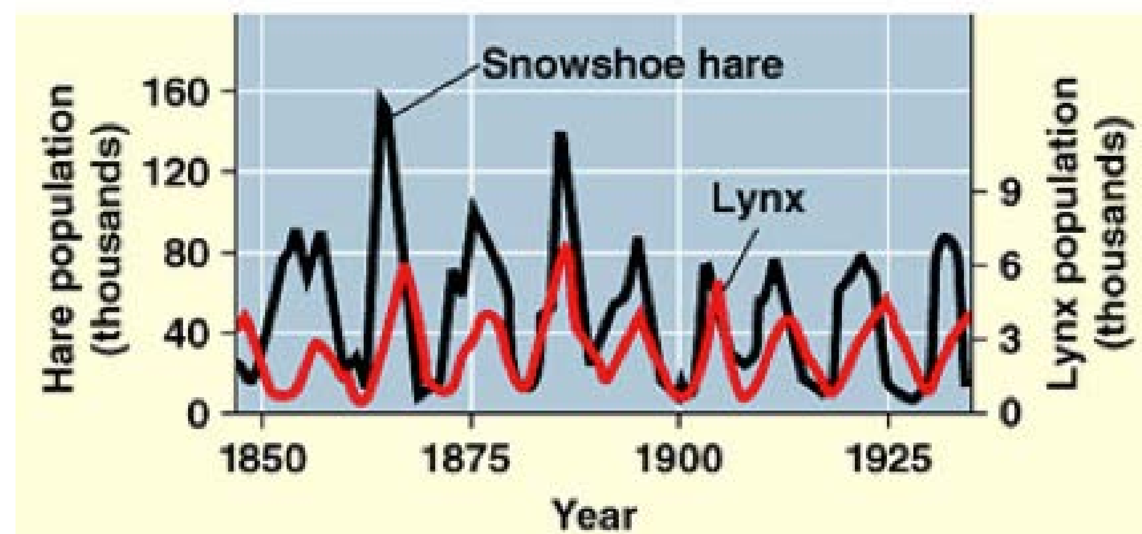


Image of ‘straw’ (above) shows that clumps form in the strongest resonances, as predicted by the Predator-Prey model: these clumps stir the collision speed, eroding the particles’ regolith.



Bright haloes seen by UVIS and VIMS are created when small grains are knocked off ring particles in collisions excited by a nearby moon: in the stirred regions, the grains make a halo around the density wave. The stirring creates a cycle of collisions whose and higher speeds that resembles the economic ‘boom-bust’ cycle or the populations of predator and prey in an ecological system.

Esposito et al. 2013

Kronoseismology: Probing Saturn's Interior with Waves in the Rings

Several waves have been identified in the C ring with stellar occultations that do not correspond to satellite resonances.

New results from Hedman and Nicholson (2013) link some of these waves to oscillations in Saturn's interior!

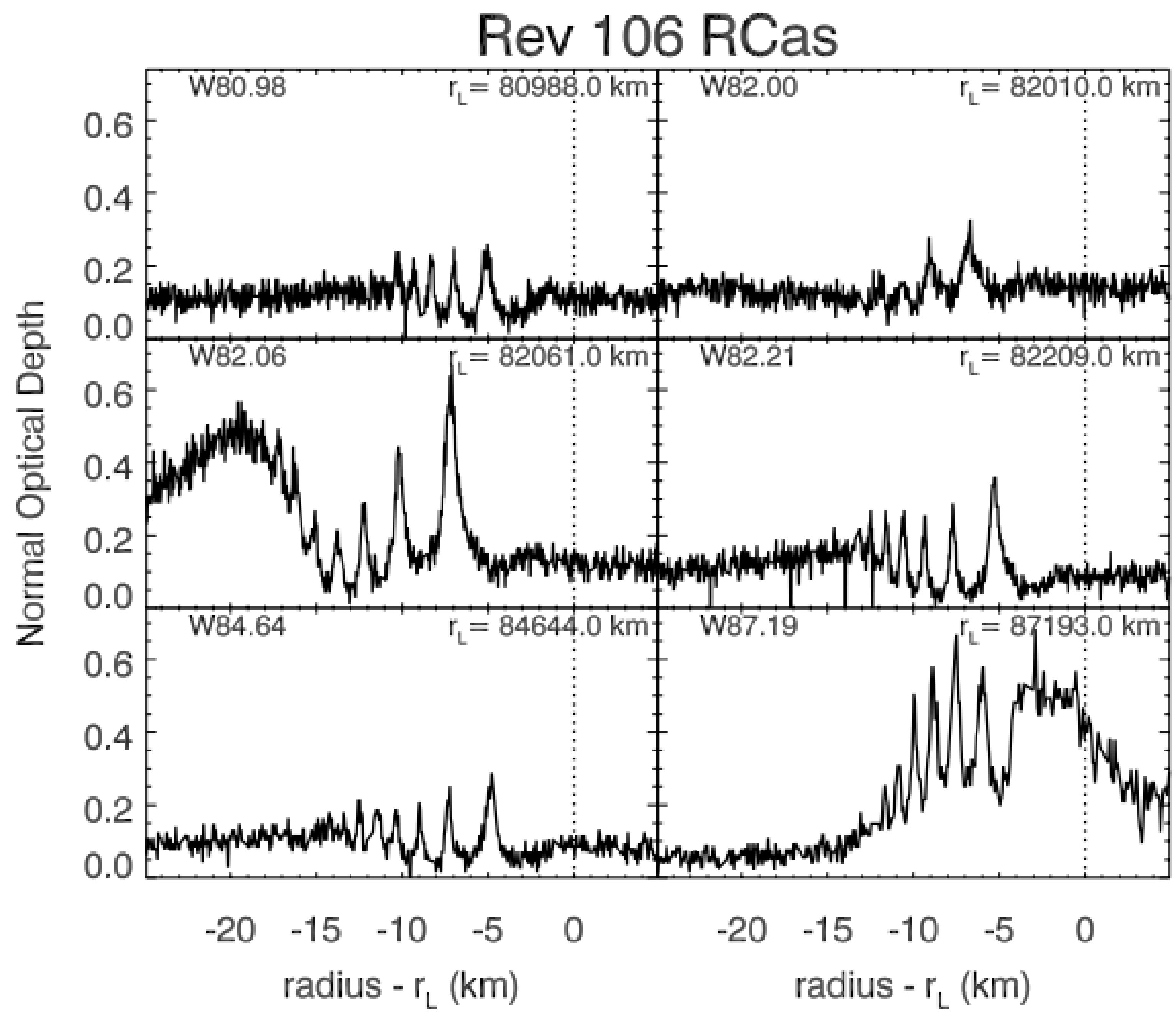
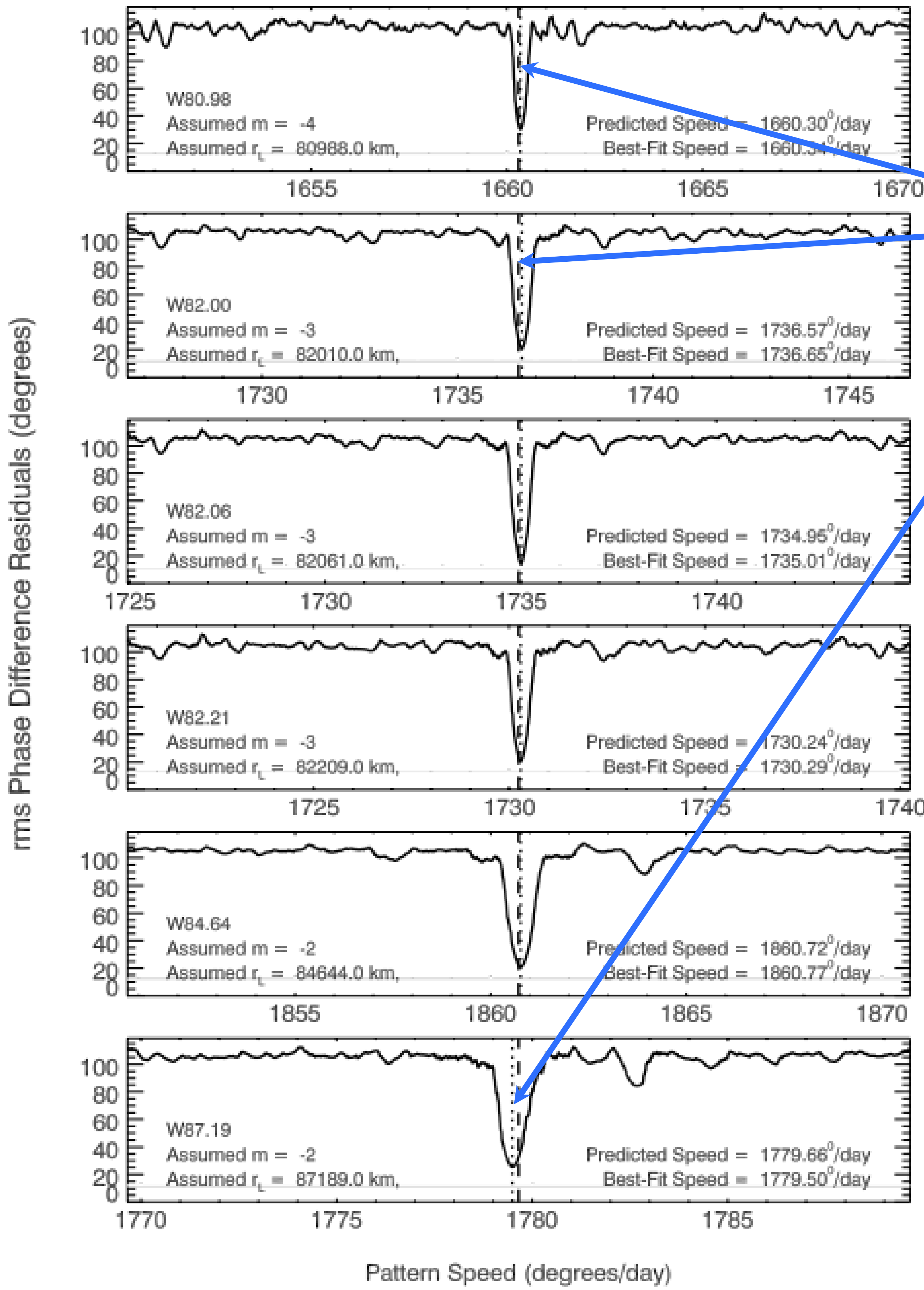


FIG. 1.— VIMS occultation profiles of the six waves examined in this analysis. Each panel shows the ring's normal optical depth versus ring radius, which is measured in kilometers from the inferred resonance locations r_L. (For the innermost five waves, the r_L value comes from Baillié *et al.* 2011, while for W87.19 the resonance position has been adjusted to match the best-fit pattern speed of this wave, see Seciton 4.) The specific profiles shown here come from an occultation by the rings of the star R Cassiopaea, which provides our highest-resolution profiles of these waves. The raw data numbers were converted to transmission estimates by normalizing the stellar signal to unity in the middle of the Maxwell Gap (87,375-87,425 km), and then translated to normal optical depth values using the standard formula, assuming the elevation angle of the star is 56.04° above the ringplane.



Plots showing the *rms* phase difference residuals as a function of pattern speed for each of the six waves, assuming the pattern ated m-numbers. The dashed line marks the predicted pattern speed for this pattern at the resonant location provided by (2011), while the dotted line is the pattern speed that gives the minimum variance.

The message of this slide: the dashed and dotted lines agree excellently. The pattern of the observed waves matches the prediction from theory for waves due to natural oscillations of the planet's interior.

Hedman and Nicholson (2013)

Complicated Dynamics of Encke Gap Ringlets: Unexplained Movement of Some Clumps; Inner and Outer Ringlets Pushed Around by the Sun

Hedman et al. 2013b

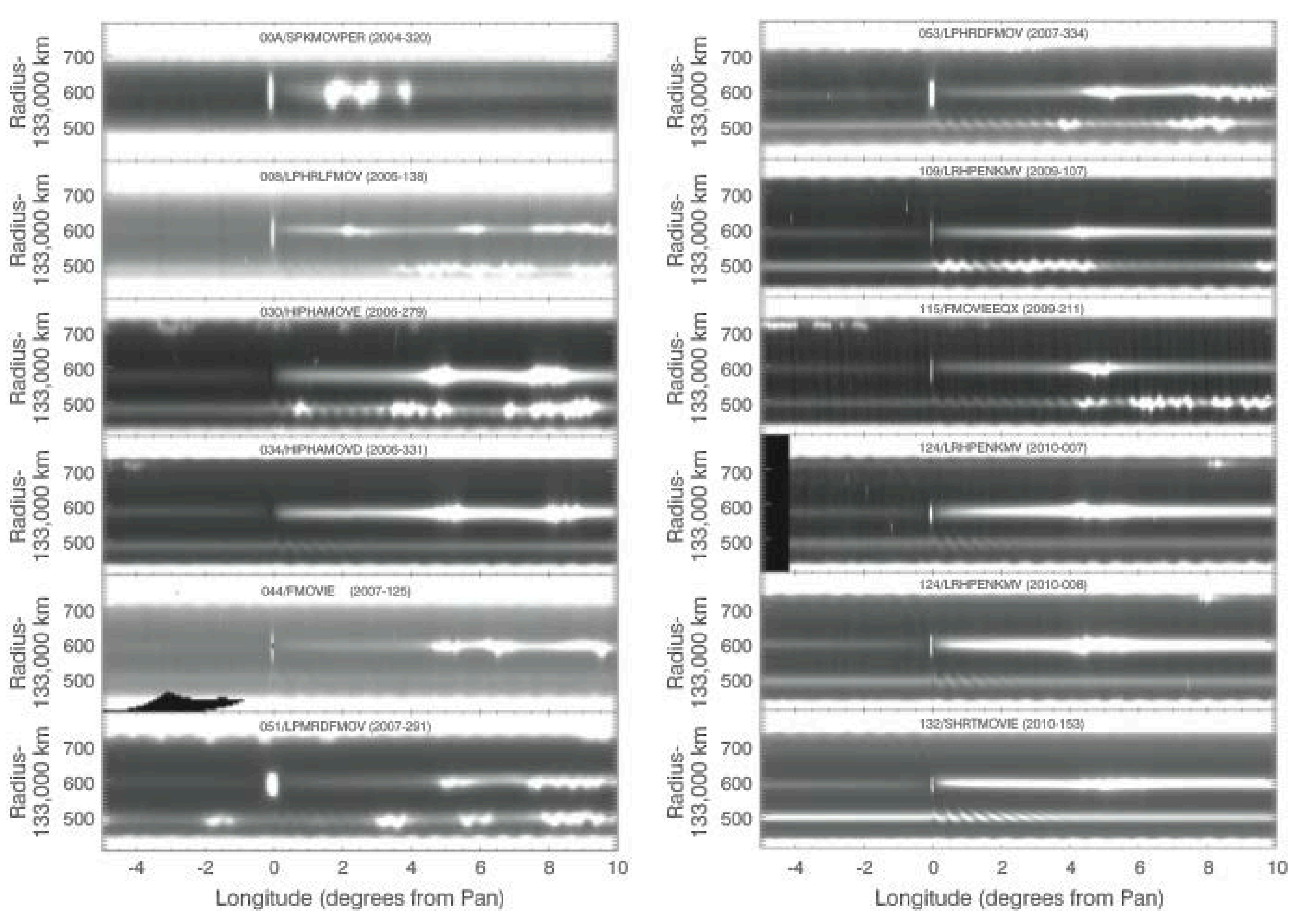
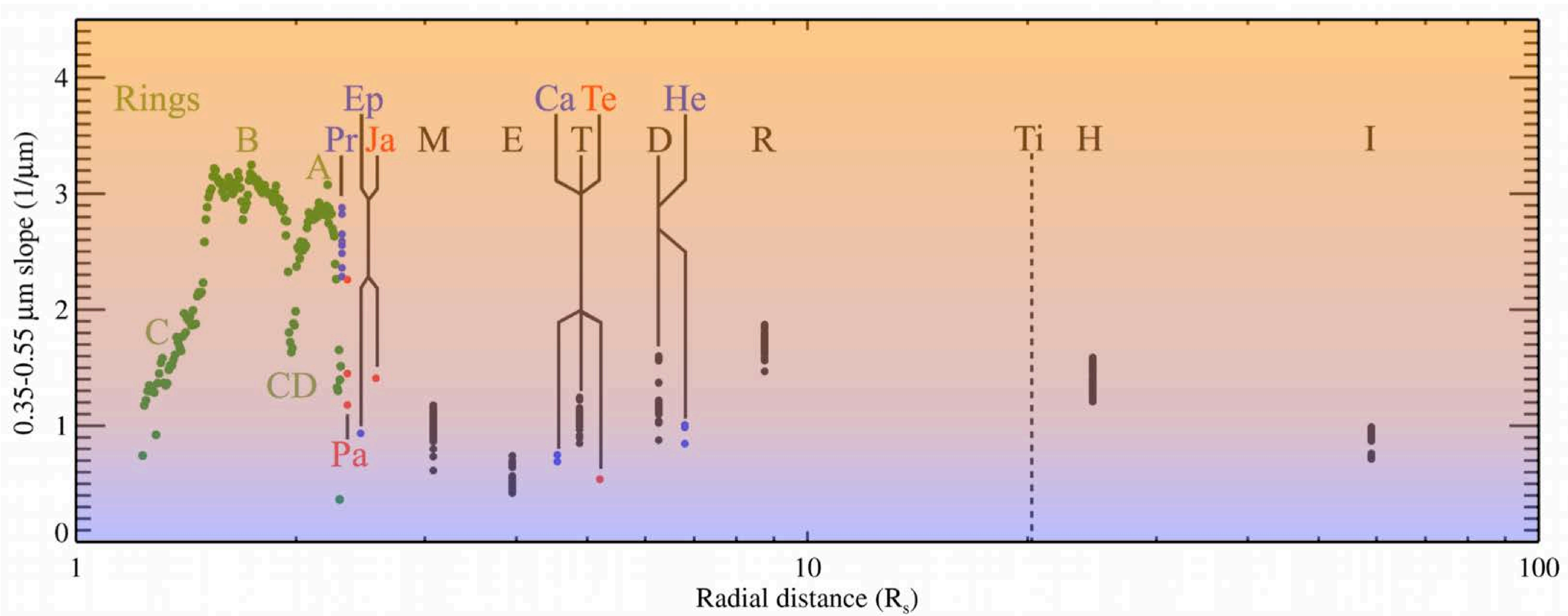


Fig. 15. Images of the regions around Pan derived from most of the observations listed in Table 1. Note the waves in the inner ringlet generated by Pan's gravitational perturbations. Whenever the disturbed part of the ringlet is clump-free, the wave damps within about 3°. By contrast, the waves in the clumpy regions can persist over 10° downstream from the moon.

Comparison of Ring and Moon Colors and Compositions



Filacchione et al. 2013

References

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- Hedman, M. M., and P. D. Nicholson 2013. *Astron. J.* **146**, Article 12.