Boom and Bust Cycles in Saturn's Rings?

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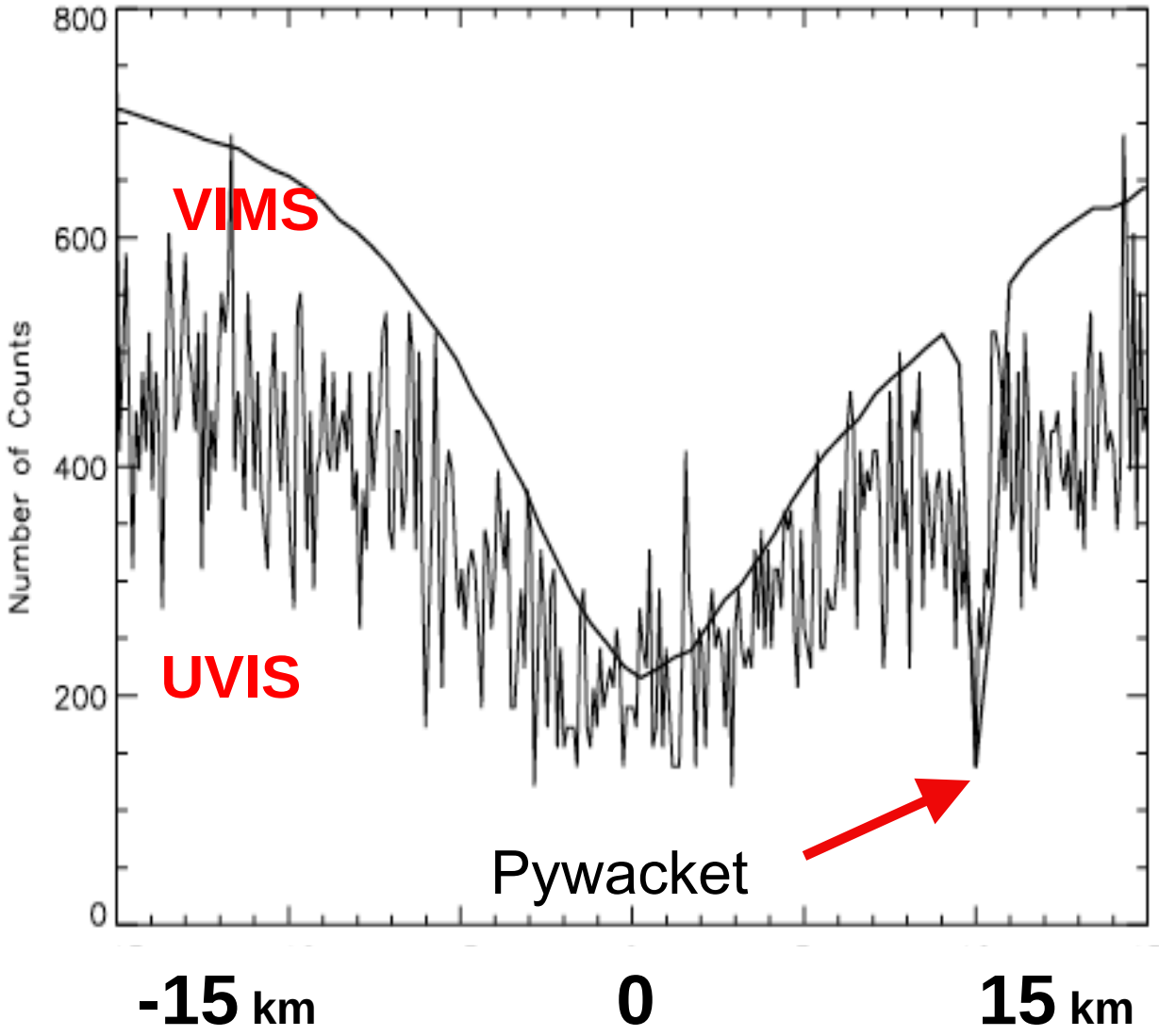
23 February 2010

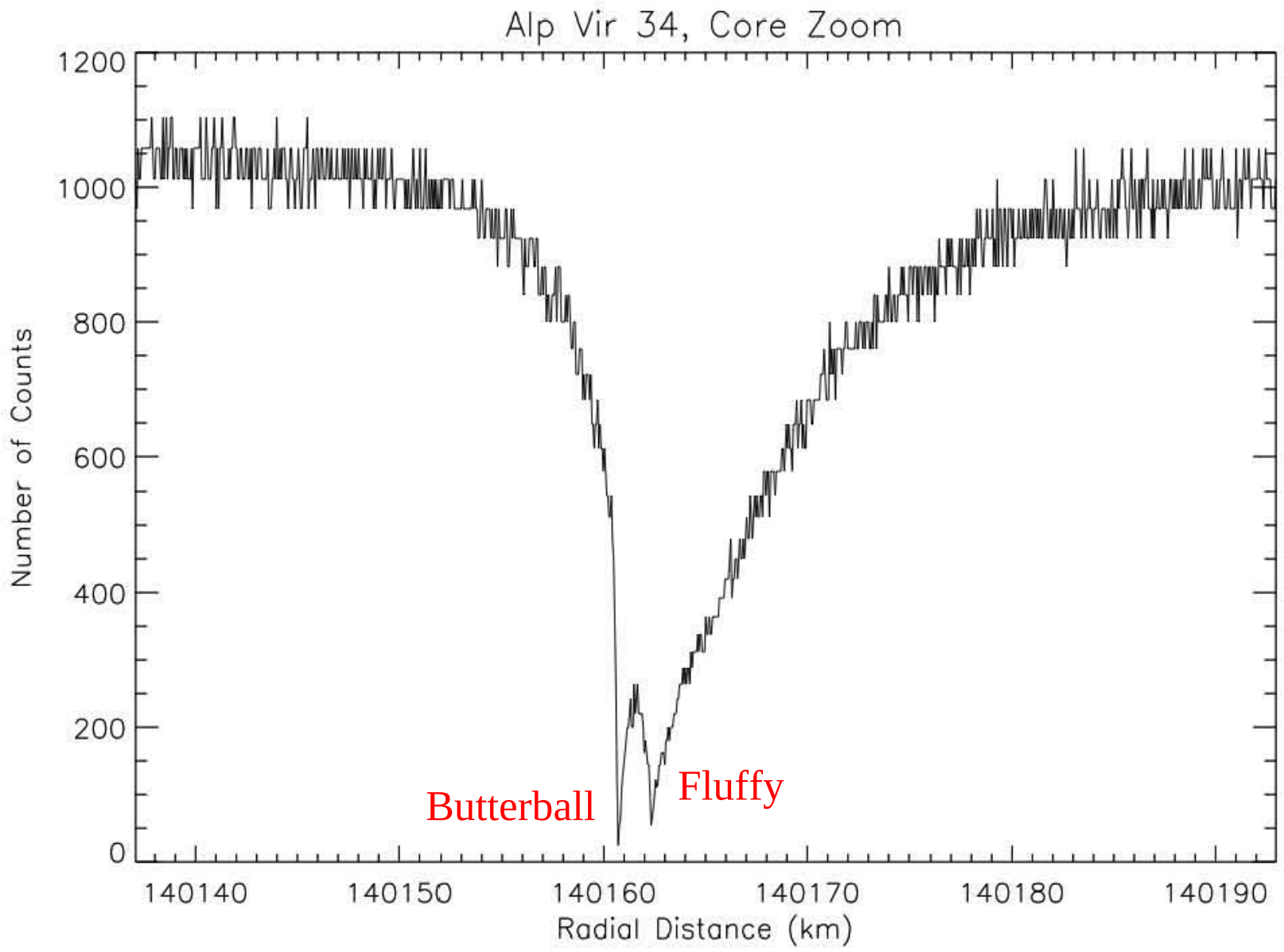
Features in F ring

- Esposito etal (2008) identified 13 statistically significant features
- These were interpreted as temporary clumps and a possible moonlet, ‘Mittens’
- Meinke etal (2009) now catalog 39 features from the first 103 stellar occultations
- For every feature, we have a location, width, maximum optical depth (opacity), nickname

F Ring Search Method

- Search was tuned for the VIMS-confirmed event:
  - Optimal data-bin size
  - τ threshold

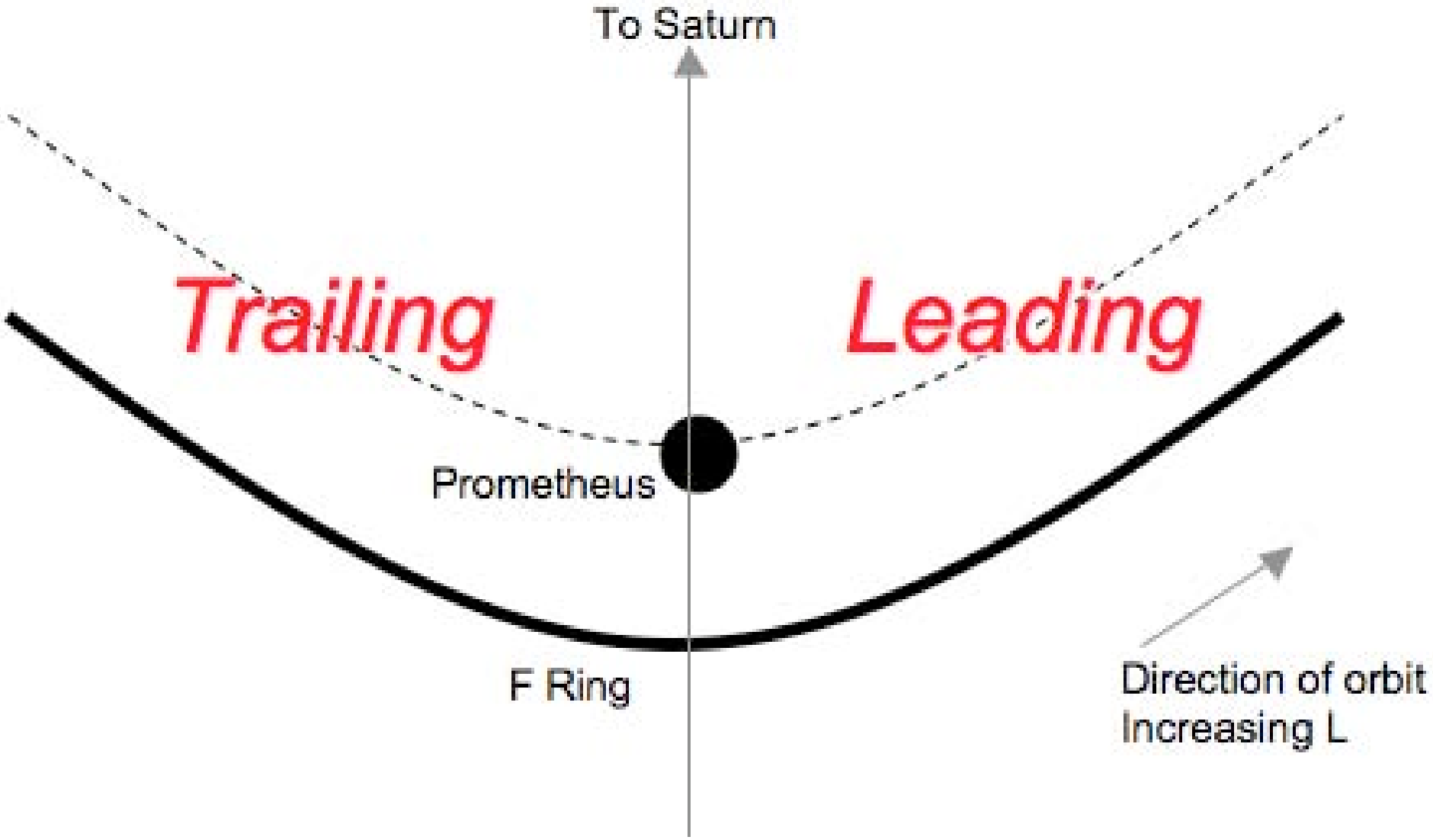


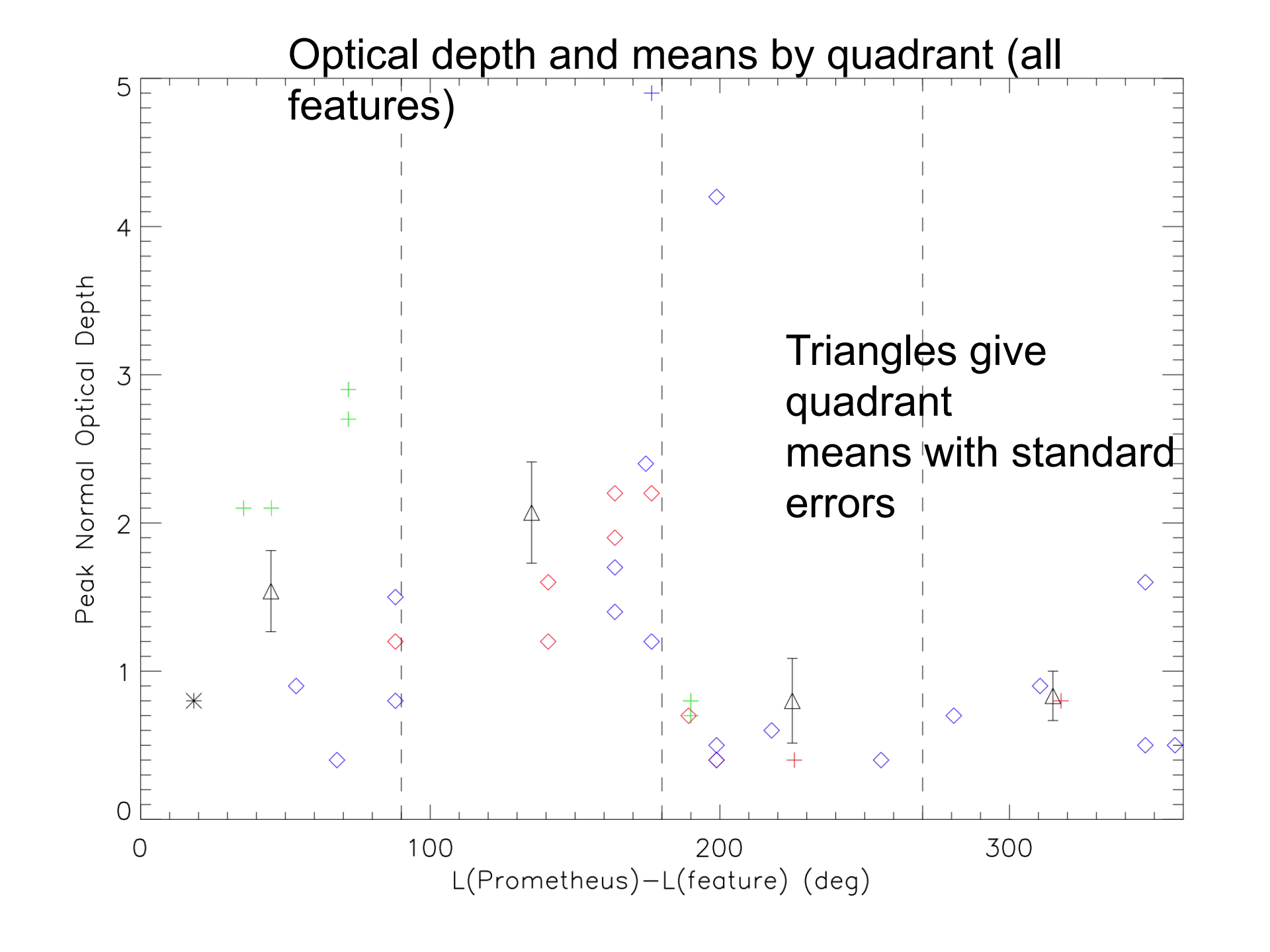

Alp Vir 34, Core Zoom
1200
1000
800
600
400
200
0
Number of Counts
140140
140150
140160
140170
140180
140190
Radial Distance (km)
Butterball
Fluffy


opacity

Kittens show dependence on Prometheus-relative longitude

- Opacity increased in quadrants following Prometheus passage
- Linear fit to Prometheus-relative longitude has correlation $r = 0.49$
- Synodic period is 68 days

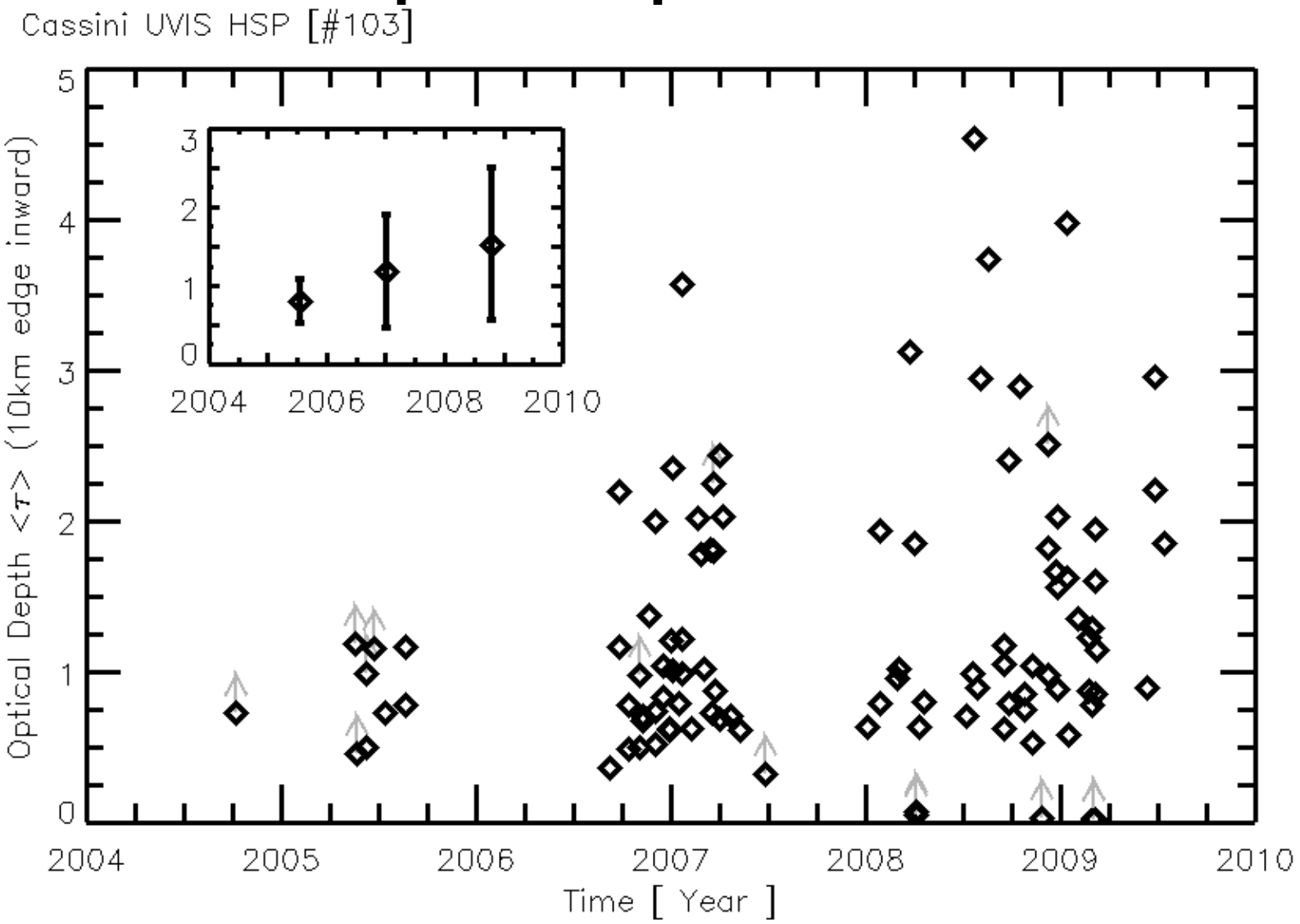

To Saturn
Trailing
Leading
Prometheus
F Ring
Direction of orbit
Increasing L


Optical depth and means by quadrant (all features)
Triangles give quadrant means with standard errors
Peak Normal Optical Depth
L(Prometheus)−L(feature) (deg)
0
1
2
3
4
5
0
100
200
300

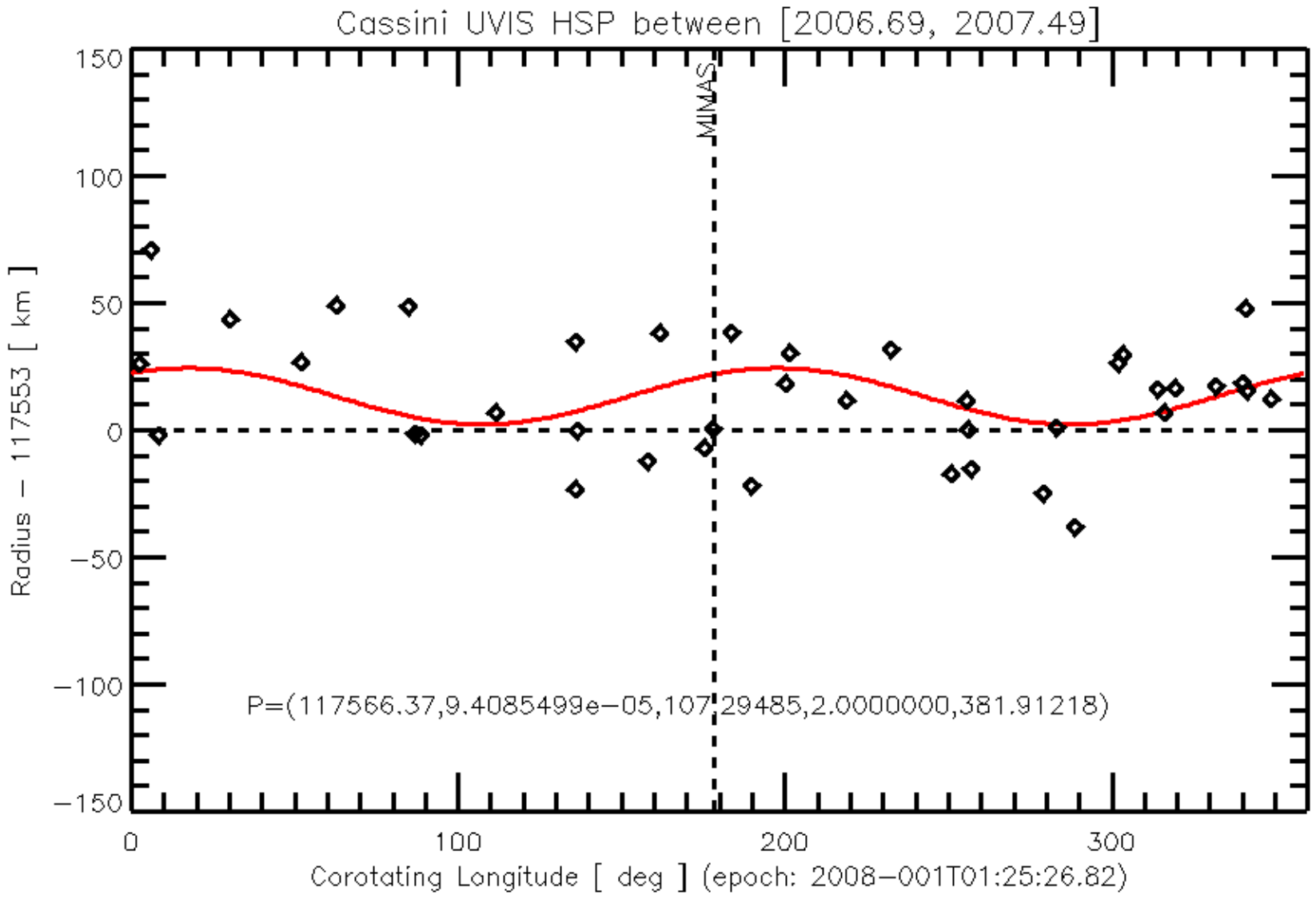
B ring edge is highly variable

- Optical depth is correlated with Mimas location and increasing since 2004
- Edge location intermittently fit by m=2 (elliptical) pattern, with variable phase lag

Optical depth over time



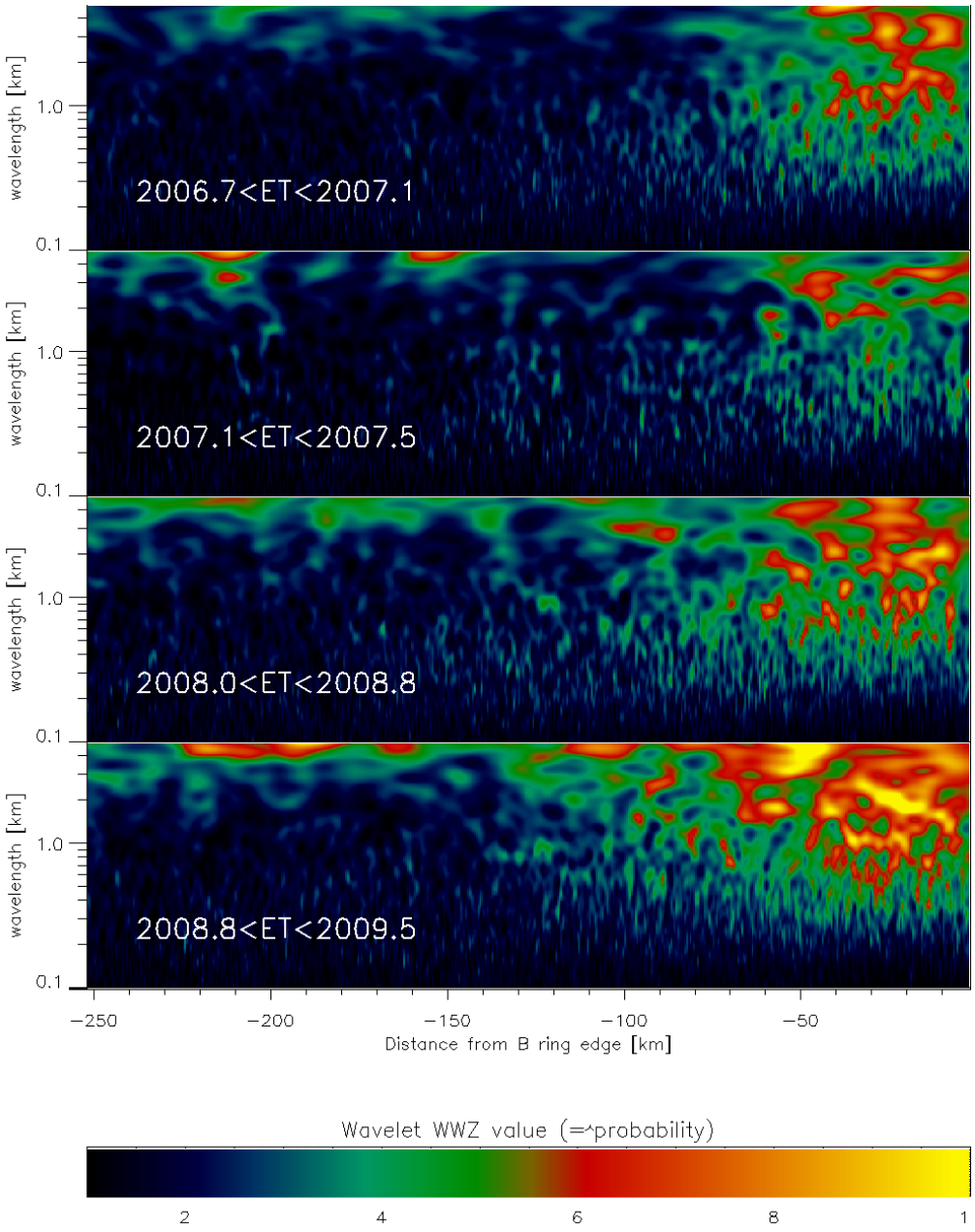
No m=2 pattern 2006-07

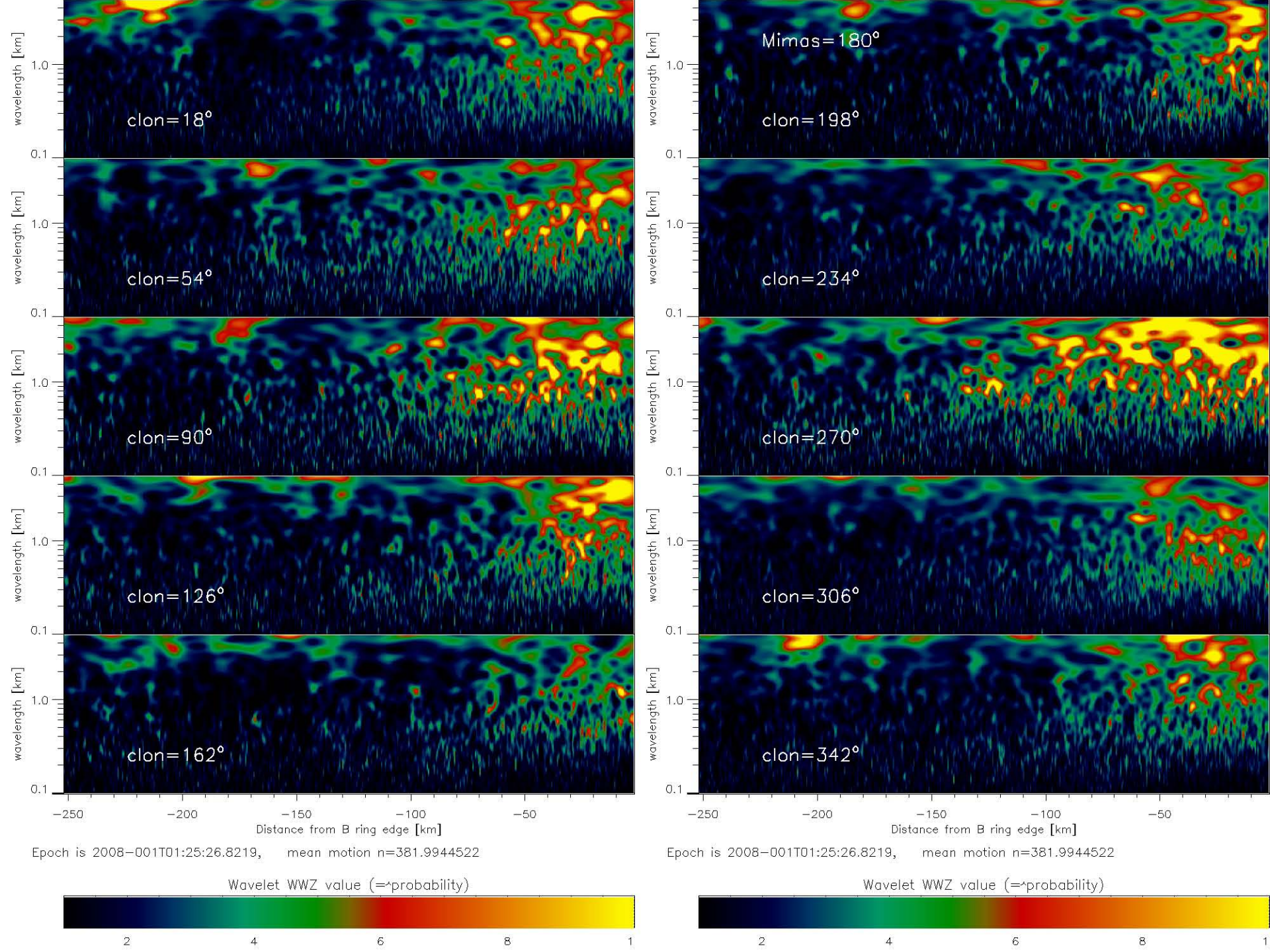


Sub-km structure seen in wavelet analysis varies with time, longitude

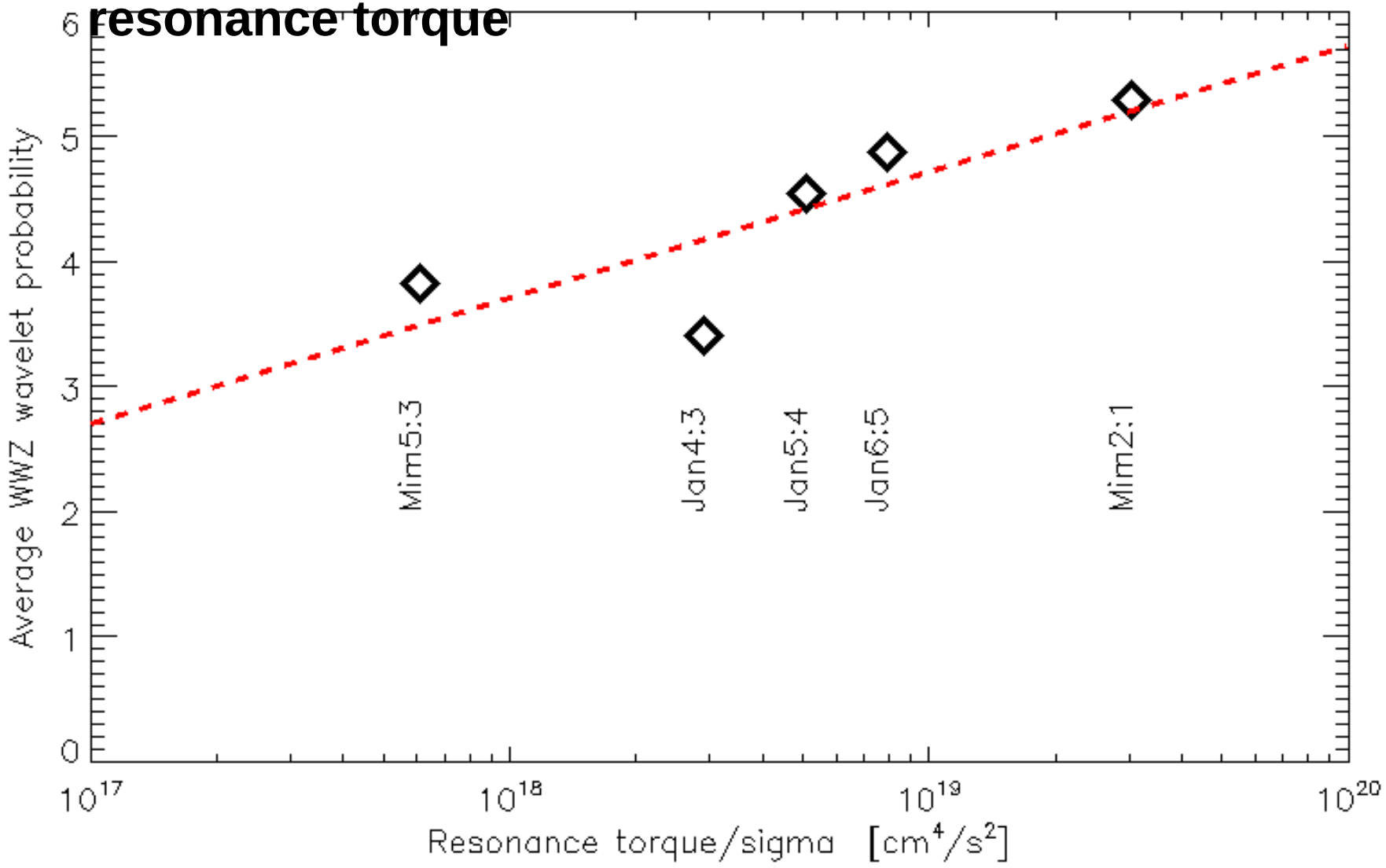
- Wavelet analysis from multiple occultations is added in a probabilistic manner to give a significance estimate
- For the B ring edge, the significance of features with sizes 200-2000m increases since 2004; and shows maxima at 90 and 270 degrees ahead of Mimas
- For density waves, significance correlated to resonance torque from the perturbing moon

Structure increasing near B ring edge



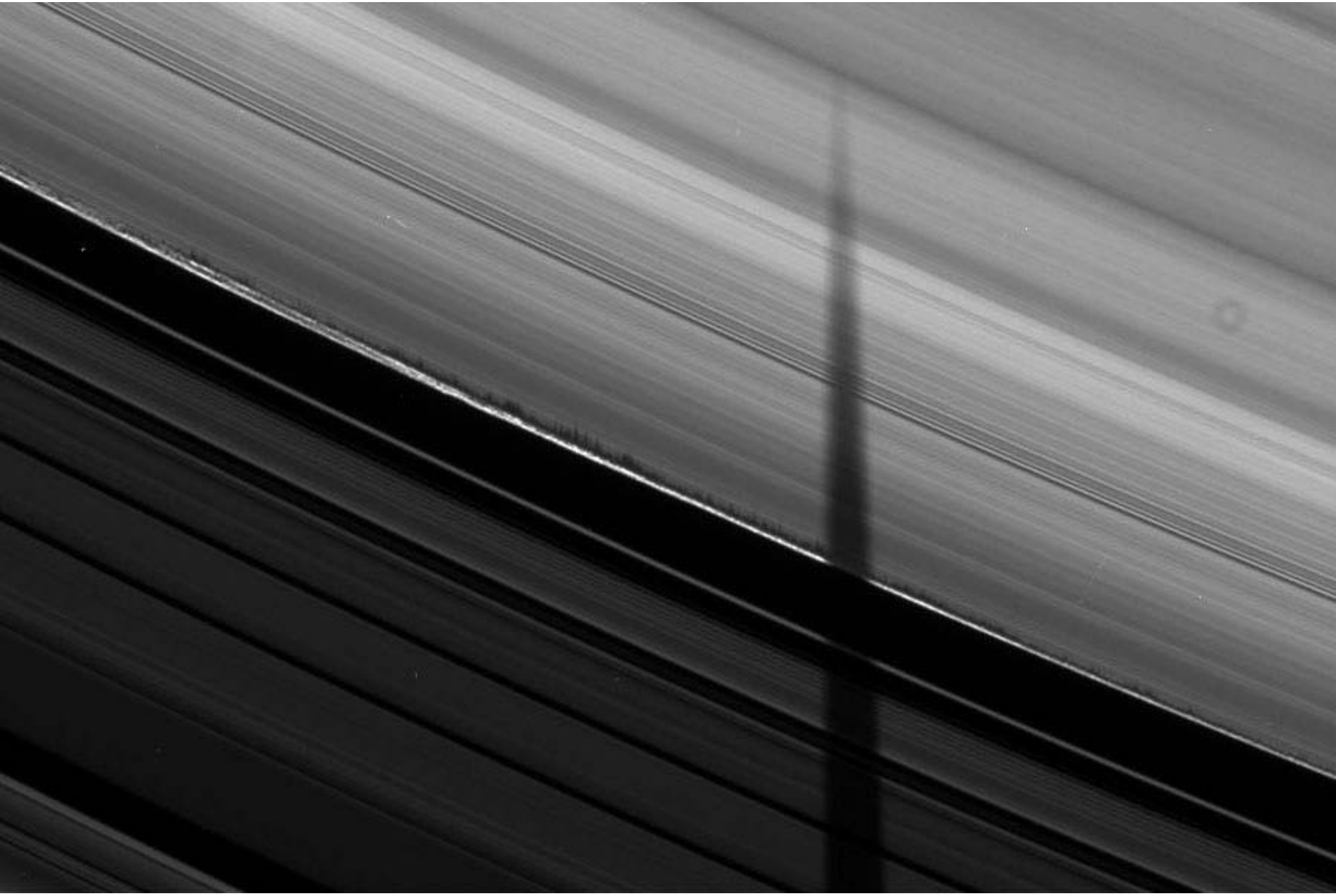

clon=18°
clon=54°
clon=90°
clon=126°
clon=162°
Mimas=180°
clon=198°
clon=234°
clon=270°
clon=306°
clon=342°
wavelength [km]
1.0
0.1
−250
−200
−150
−100
−50
Distance from B ring edge [km]
Epoch is 2008−001T01:25:26.8219, mean motion n=381.9944522
Wavelet WWZ value (=^probability)
2
4
6
8
1

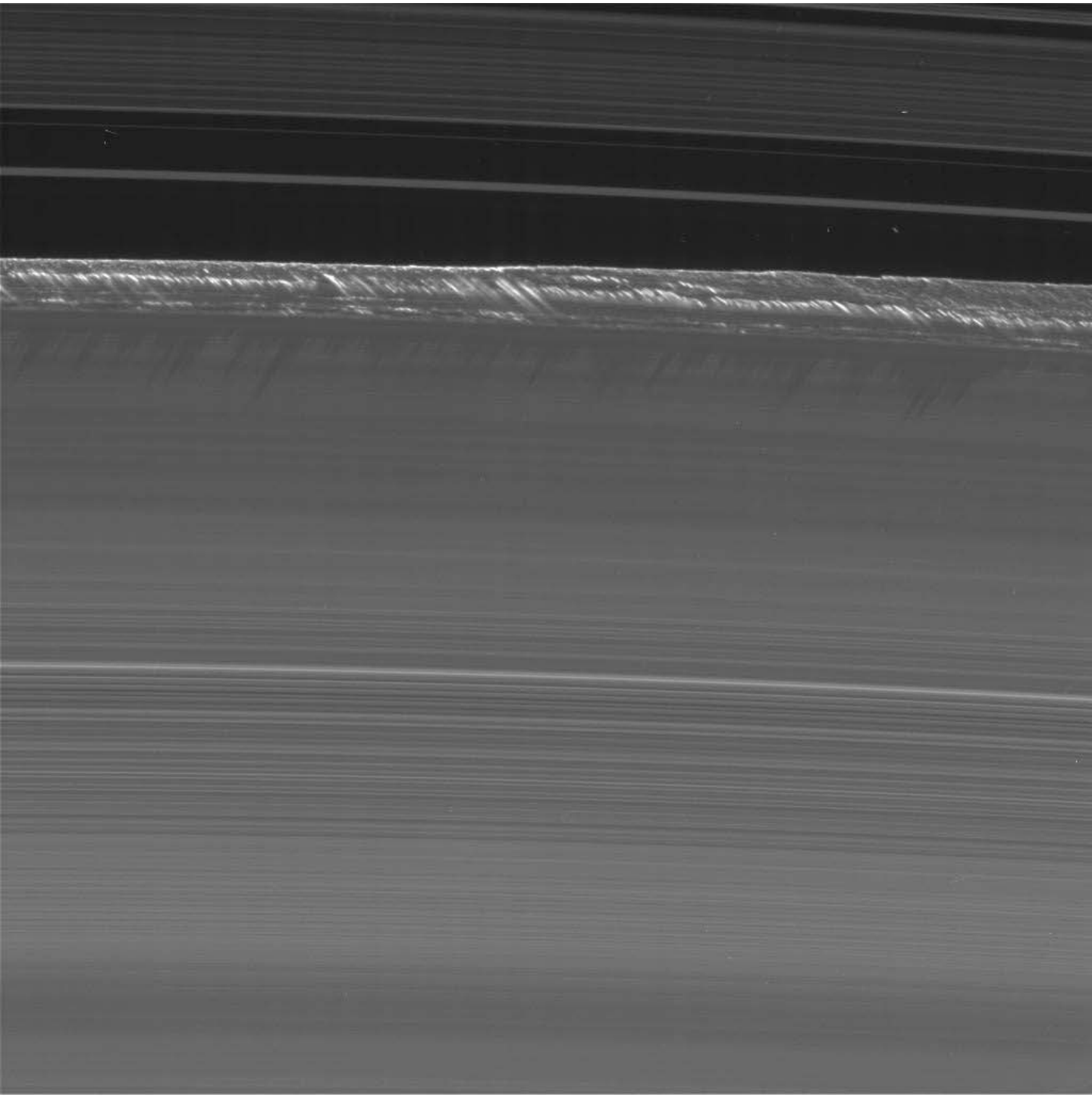
Density wave sub-km feature structure strength vs. resonance torque



Observational Findings

- F ring kittens more opaque trailing Prom.
- B ring edge more opaque leading Mimas
- Sub-km structure, which is seen by wavelet analysis at strongest density waves and at B ring edge, is correlated with torque (for density waves) and longitude (B ring edge)
- Variance in B ring location and in the strength of sub-km structure is increasing since 2004
- The largest structures could be visible to ISS

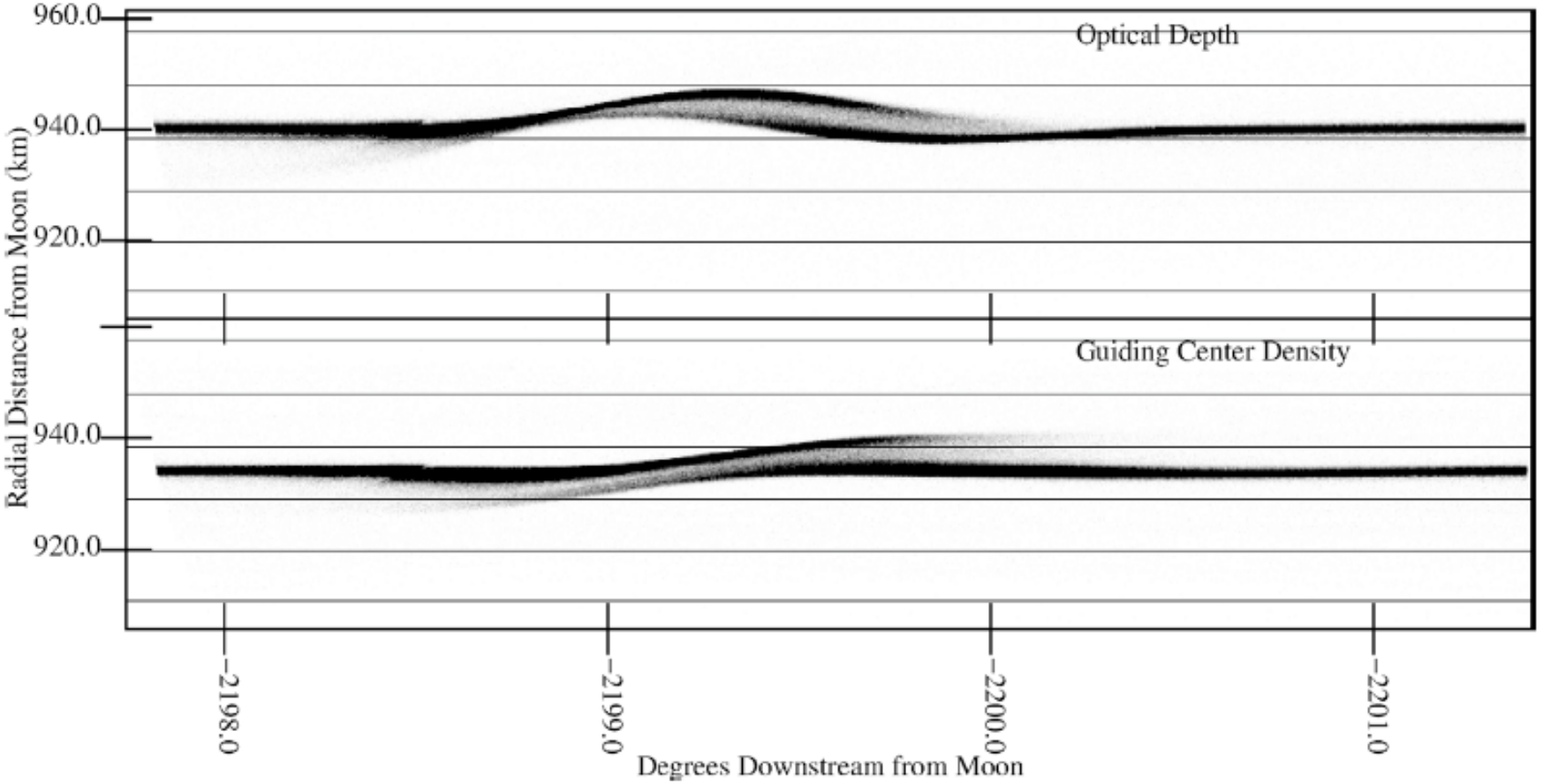




Possible explanations

- The chaotic behavior arises from the resonant forcing on ring particles that causes them to jam together, like ‘traffic jams’ seen in the computer simulations (Lewis and Stewart 2005)
- Attraction among the ring particles creates temporary clumps that further disrupt the rings around them

F ring from Lewis & Stewart

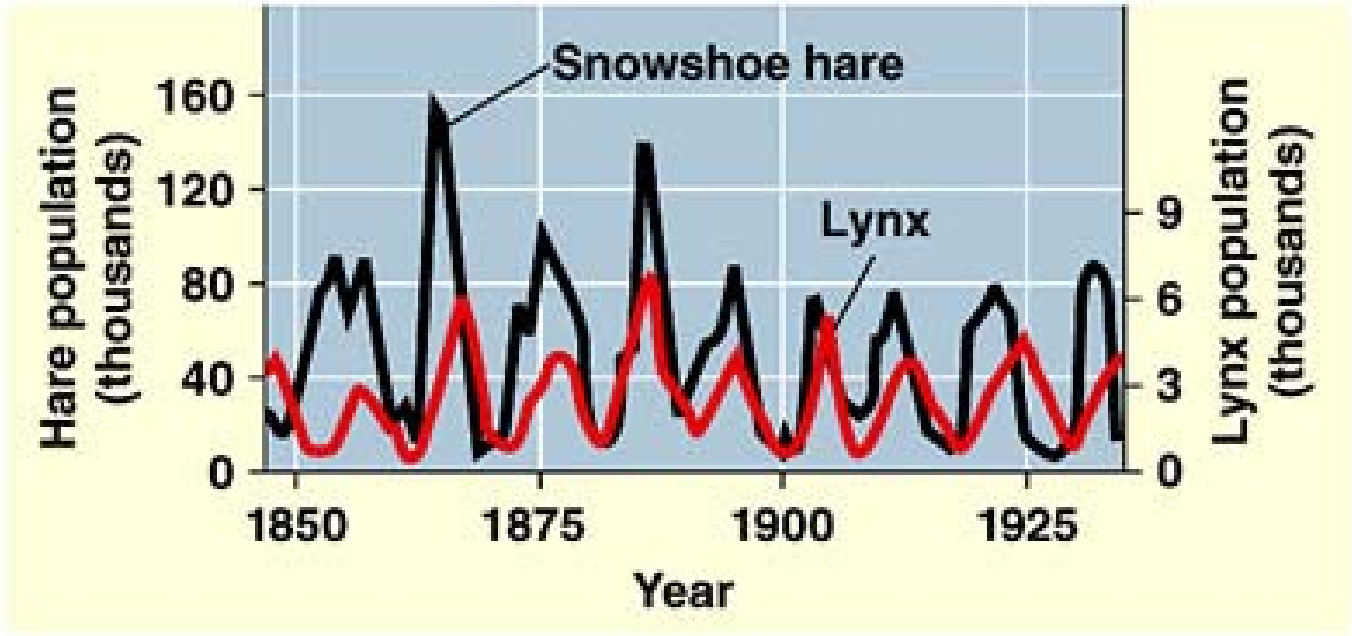


Summary

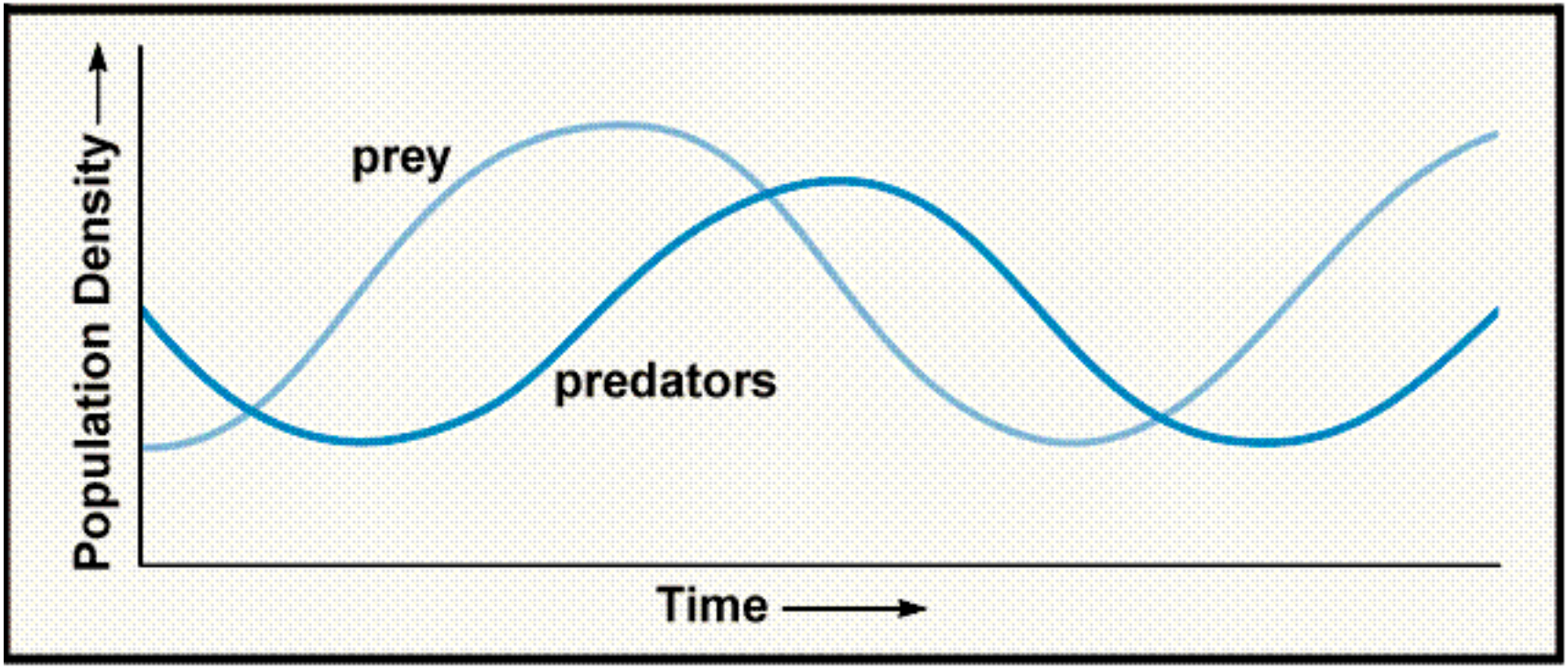
- Cassini occultations of strongly perturbed locations show accretion and then disaggregation: scales of hours to weeks
- Moons may trigger accretion by streamline crowding (Lewis & Stewart); which enhances collisions, leading to accretion; increasing random velocities; leading to more collisions and more accretion.
- Disaggregation may follow from disruptive collisions or tidal shedding

Conclusions

- Saturn's rings appear young… but we may confuse 'age' with most recent renewal!
- Like the global economy, the rings may not have a stable equilibrium for accretion; instead, boom/bust triggered by stochastic events?
- Recycling of ring material allows the rings to be as old as the Solar System



Comparison of Prey and Predators' Populations



Listener Beware!

- My explanation is speculative and not in agreement with some other proposals…
- Beurle etal consider fluid instability criterion
- Spitale and Porco emphasize normal modes (driven and free)
- Nicholson etal also prefer multi-mode model
- I prefer a random, multi-particle picture