# The F Ring

## One of Saturn's Most Puzzling Rings

**Nicole Albers**

Josh E. Colwell

Larry W. Esposito

Bonnie K. Meinke

Miodrag Sremčević

Nicole.Albers@lasp.colorado.edu

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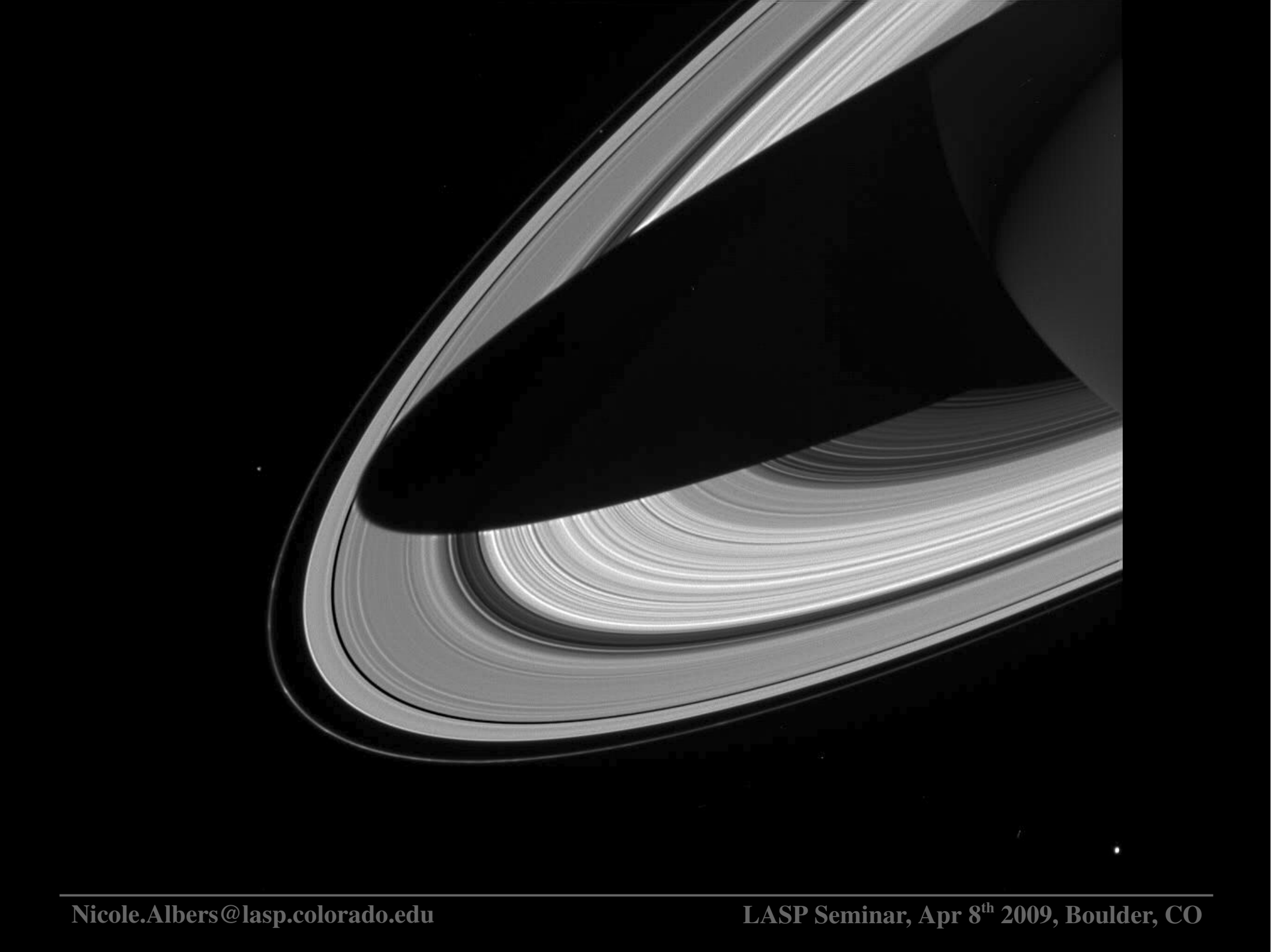
# The Inner Saturnian System



# Prometheus

[132.6, 79.0, 61.4] km

0.47 g cm$^{-3}$

139,380 km

synchronously rotating

*INNER STRAND(S)*

**F RING CORE**

*OUTER STRAND(S)*

Roche lobe axes

densities

orbital distance

Porco et al. (2005)

*INNER STRAND(S)*

**F RING CORE**

*OUTER STRANDS(S)*

# Pandora

[103.2, 79.6, 64.0] km

0.5 g cm$^{-3}$

141,720 km

synchronously rotating

*Increasing Radial Distance to Saturn*

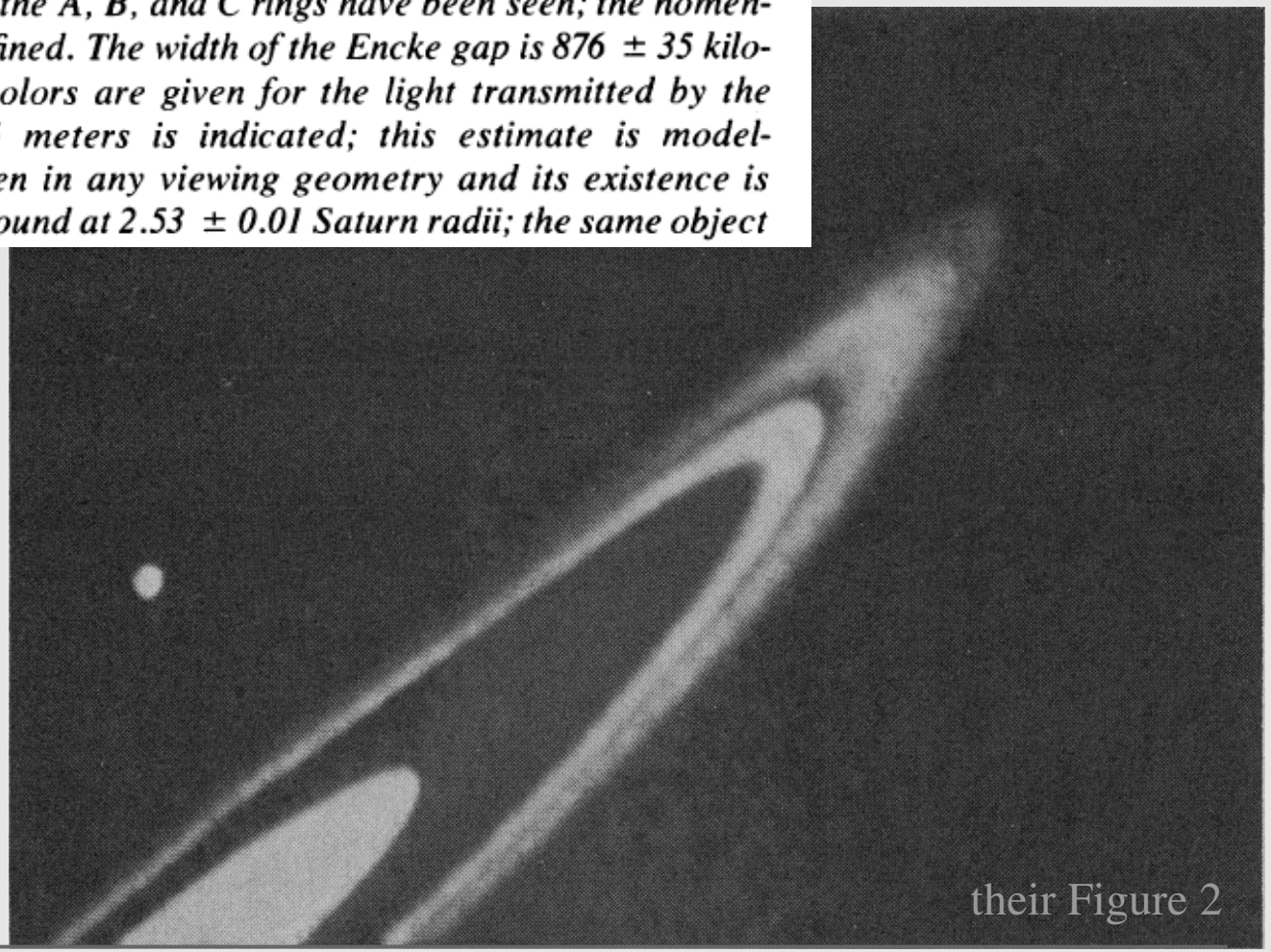
# Pioneer 11 discovers the F ring

**Imaging Photopolarimeter on Pioneer Saturn** Gehrels et al. (1980)

Abstract. *An imaging photopolarimeter aboard Pioneer 11, including a 2.5-centimeter telescope, was used for 2 weeks continuously in August and September 1979 for imaging, photometry, and polarimetry observations of Saturn, its rings, and Titan. A new ring of optical depth $< 2 \times 10^{-3}$ was discovered at 2.33 Saturn radii and is provisionally named the F ring; it is separated from the A ring by the provisionally named Pioneer division. A division between the B and C rings, a gap near the center of the Cassini division, and detail in the A, B, and C rings have been seen; the nomenclature of divisions and gaps is redefined. The width of the Encke gap is 876 ± 35 kilometers. The intensity profile and colors are given for the light transmitted by the rings. A mean particle size ≲ 15 meters is indicated; this estimate is model-dependent. The D ring was not seen in any viewing geometry and its existence is doubtful. A satellite, 1979 S 1, was found at 2.53 ± 0.01 Saturn radii; the same object*

max opt. depth: $2 \times 10^{-3}$
width of less than 800km

Already then, the clumpiness of the F ring was observed.



their Figure 2

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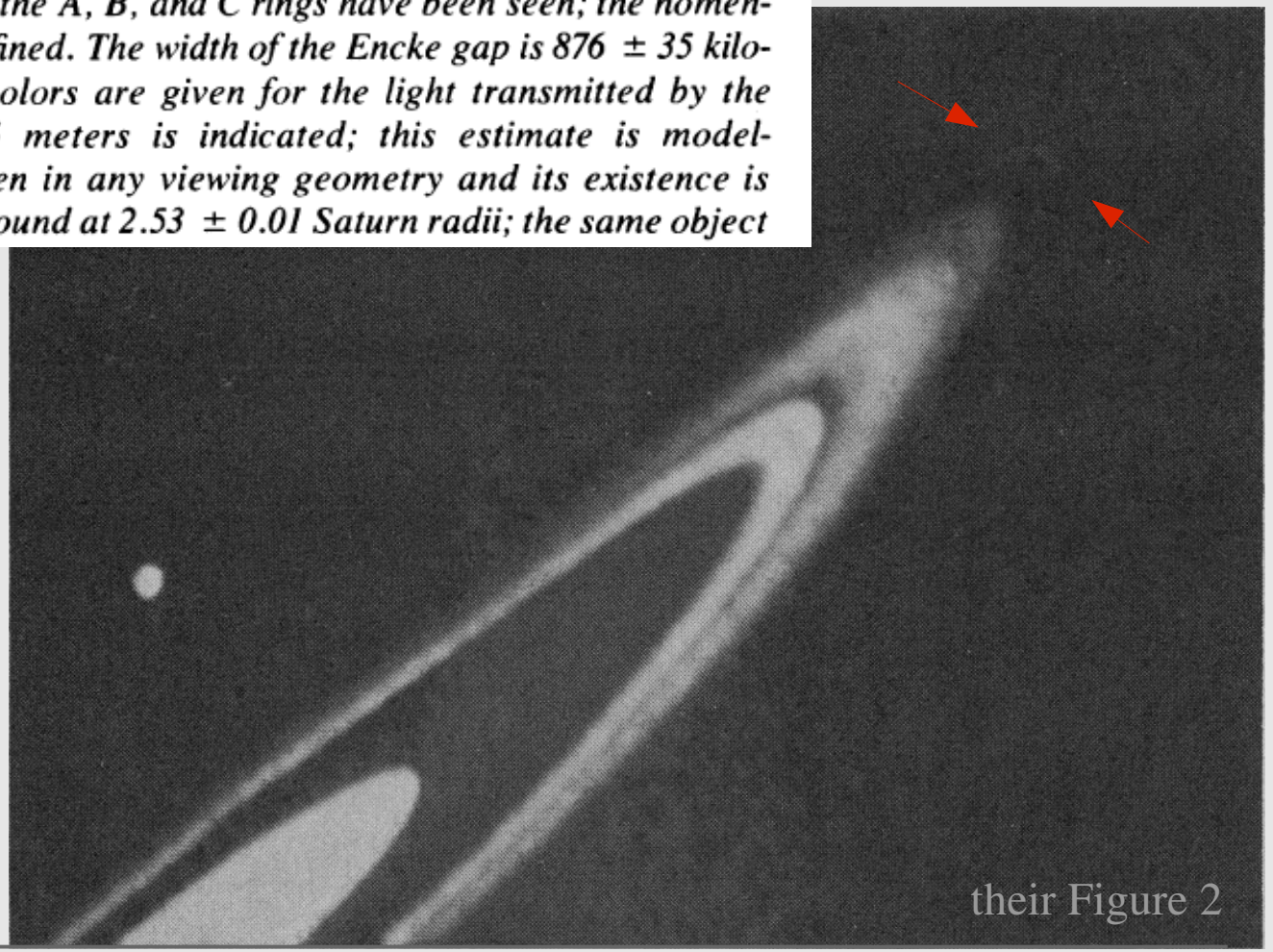
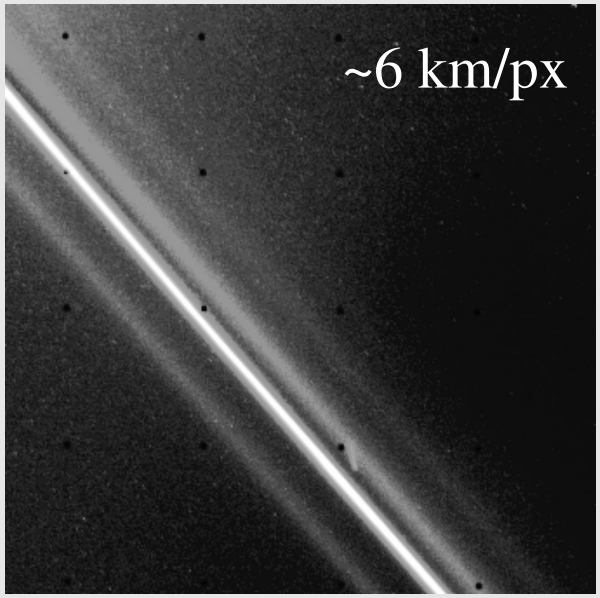
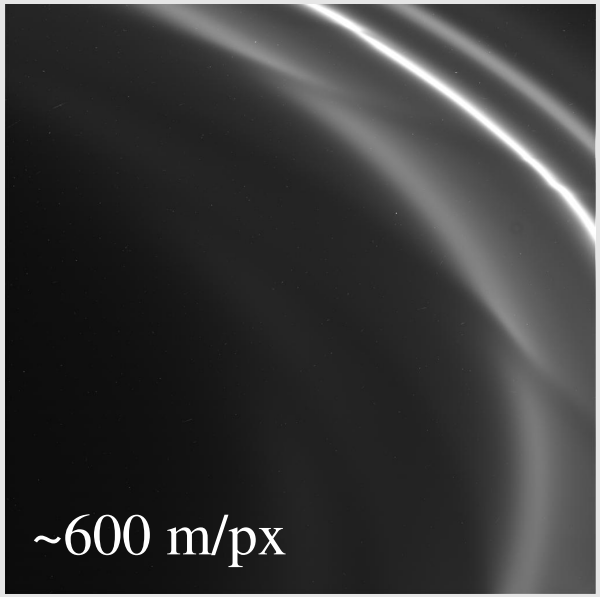
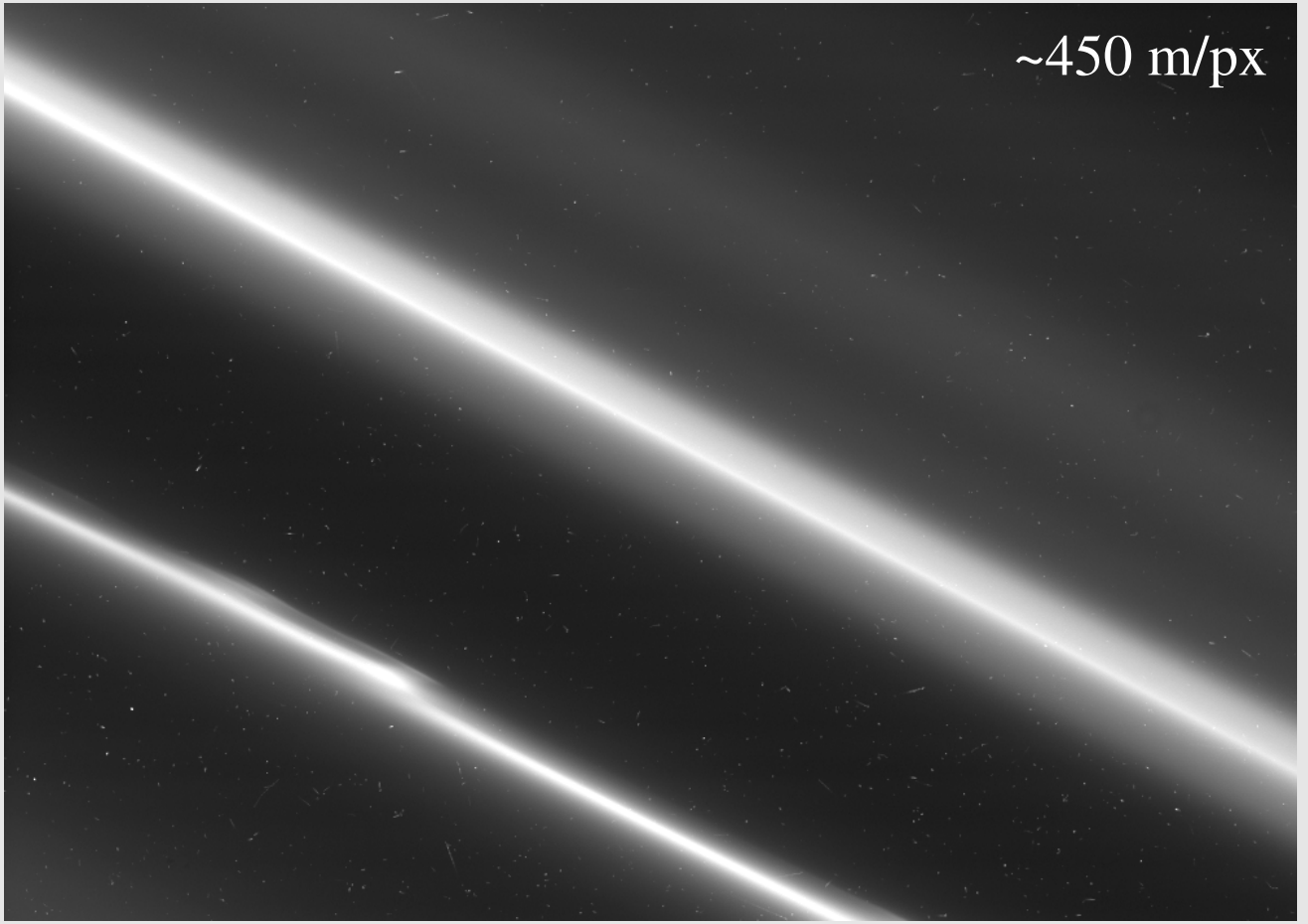


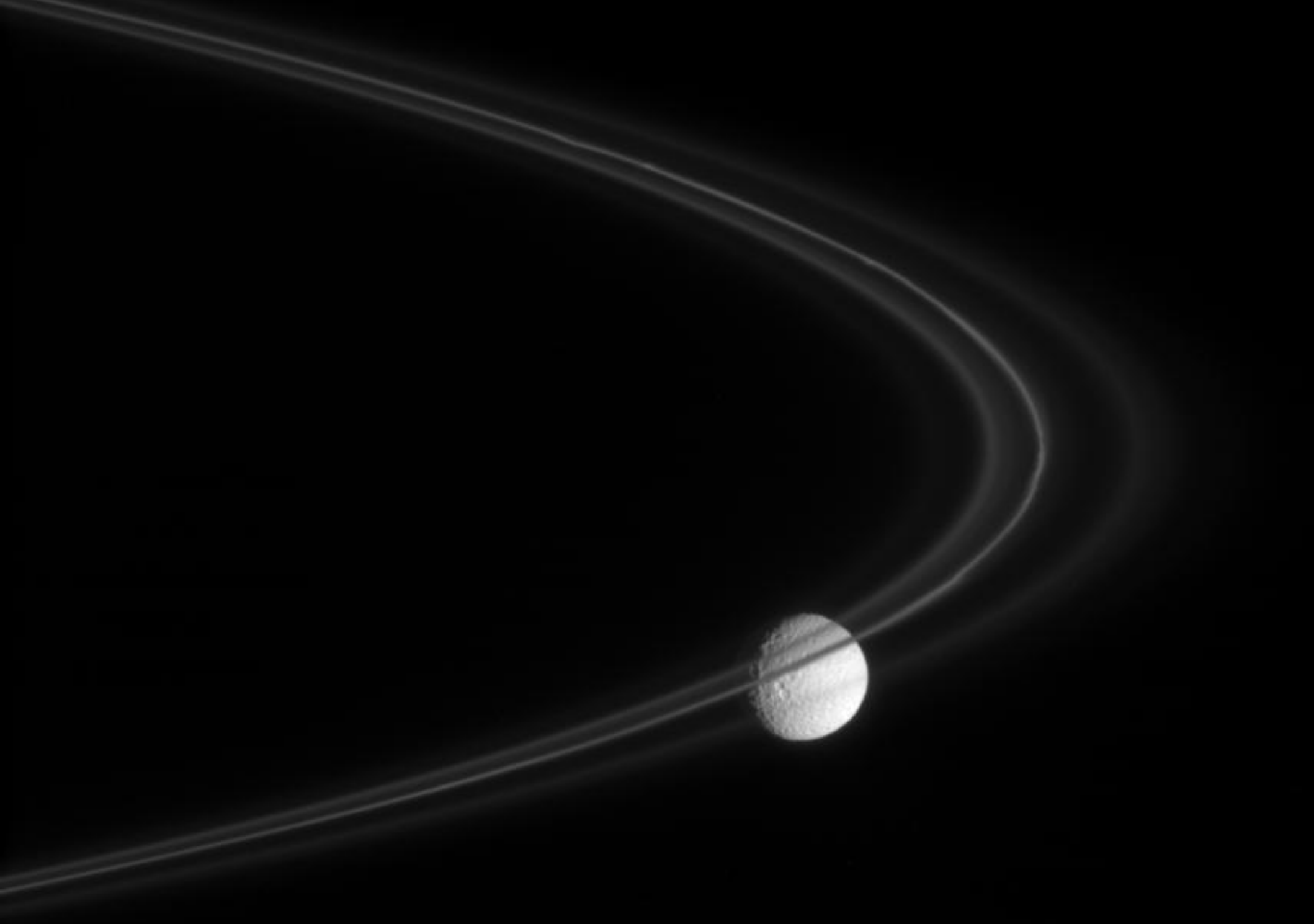
their Figure 2

# Solving the F ring puzzle: From Voyager to Cassini





# Cassini UVIS observations

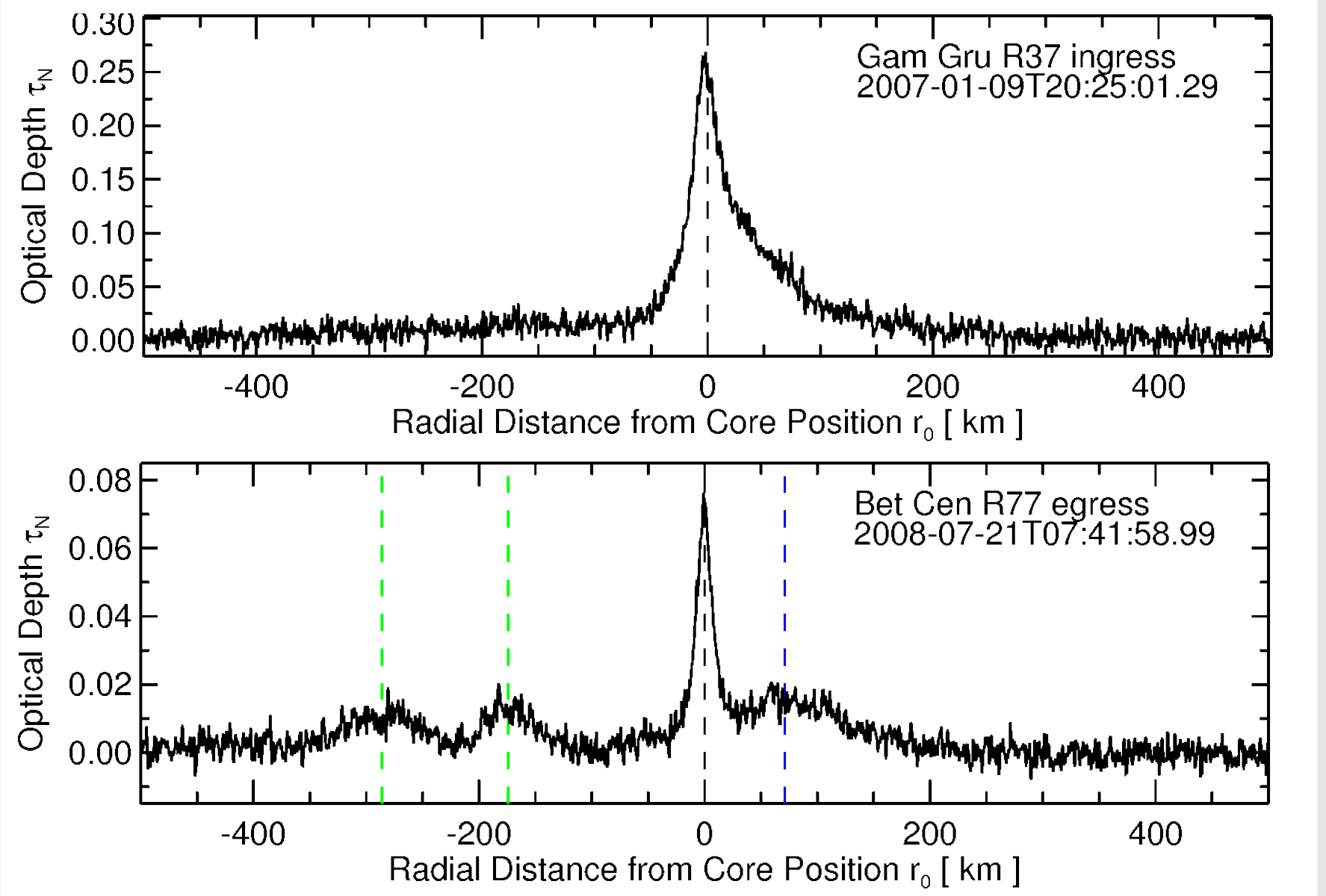
- Cassini UVIS ***H***igh ***S***peed ***P***hotometer is one of four optical channels with an effective wavelength of ~150nm and support multiple integration periods between 1-8ms [Esposito et al. (2005)]

- UVIS recorded 117 stellar occultation profiles of Saturn's F ring ring to date with unprecedented resolution of down to tens of meters sampling the rings at essentially random locations

- Various viewing geometries, in contrast to previous spacecraft and Earth-bound observations, but also the extended observation time allow to study ring phenomena to great detail:
  sg-wakes [Colwell et al. (2006)] , density wave librations [Sremčević et al. (2008)]

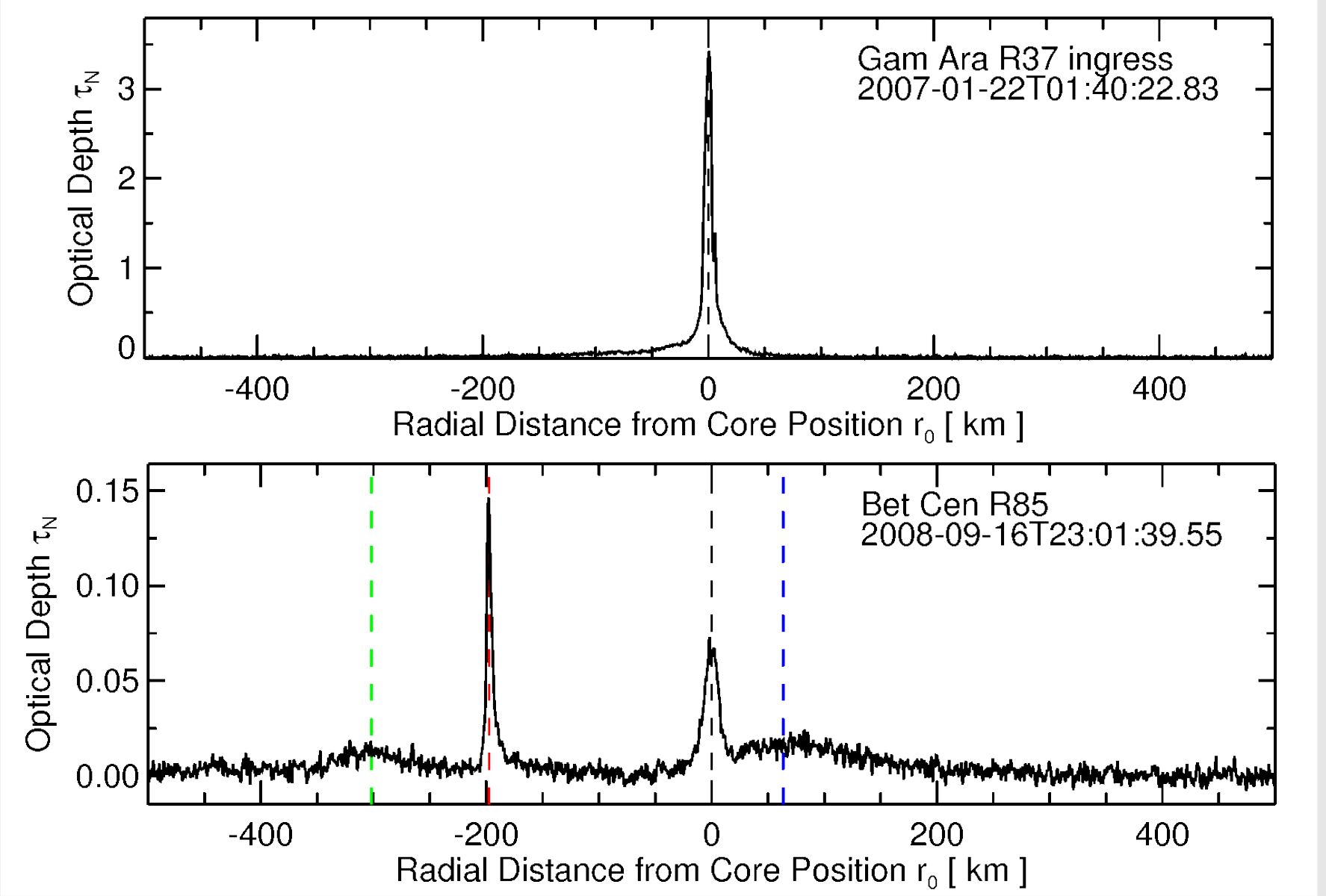
- But the time variable, dynamic nature of the F ring means: random occultations yield seemingly random profiles

# UVIS F ring profiles (1): Expected finds




UVIS occultations resolve F ring strands for the first time

# UVIS F ring profiles (2): Unexpected finds



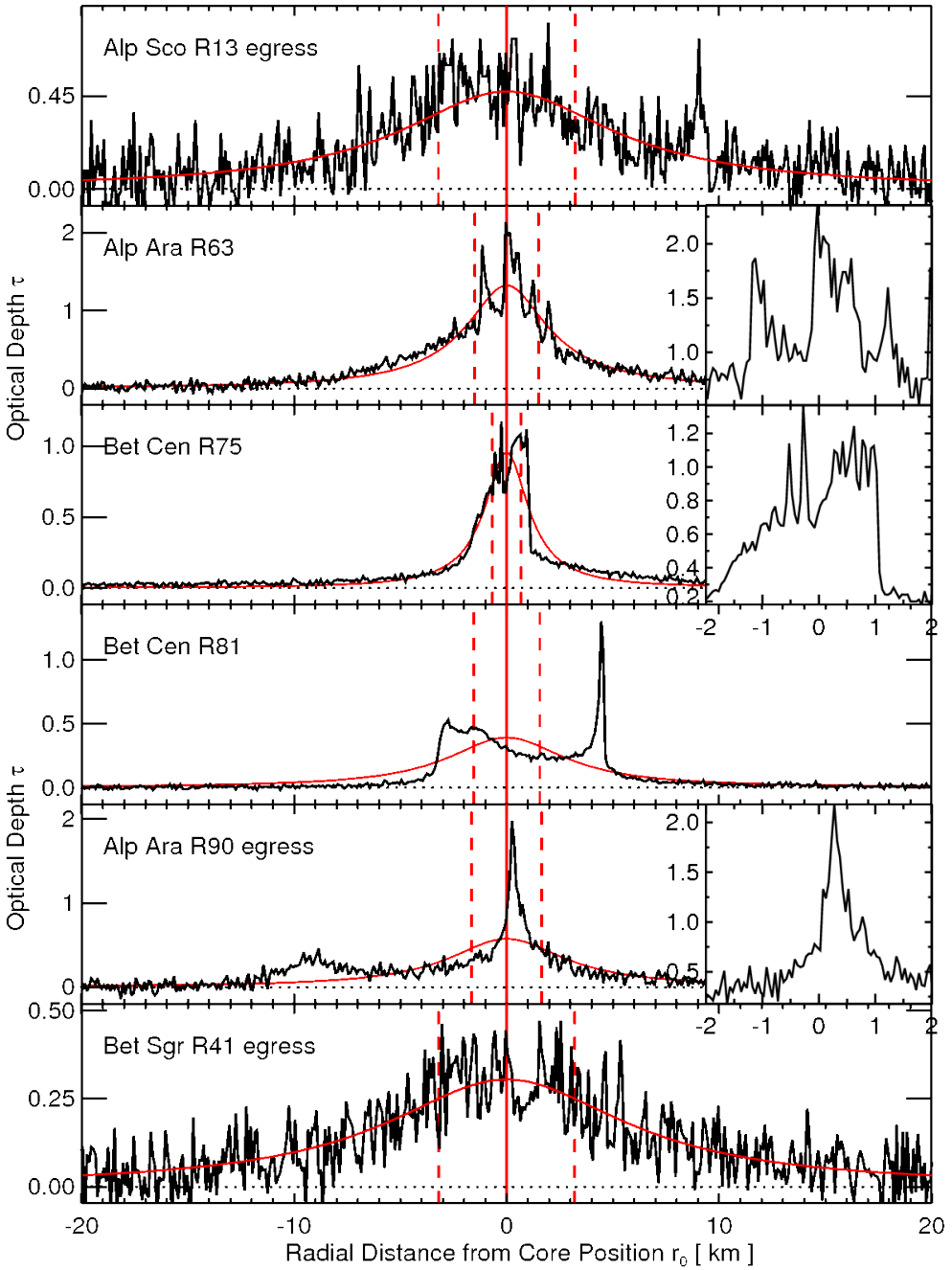

New F ring component and higher optical depths than expected

# THE F RING CORE

THE F RING STRANDS

THE F RING CONSTITUENTS

# F ring kinematics (1): Finding the F ring core




Fit Lorentzian (or eqv. Gaussian)

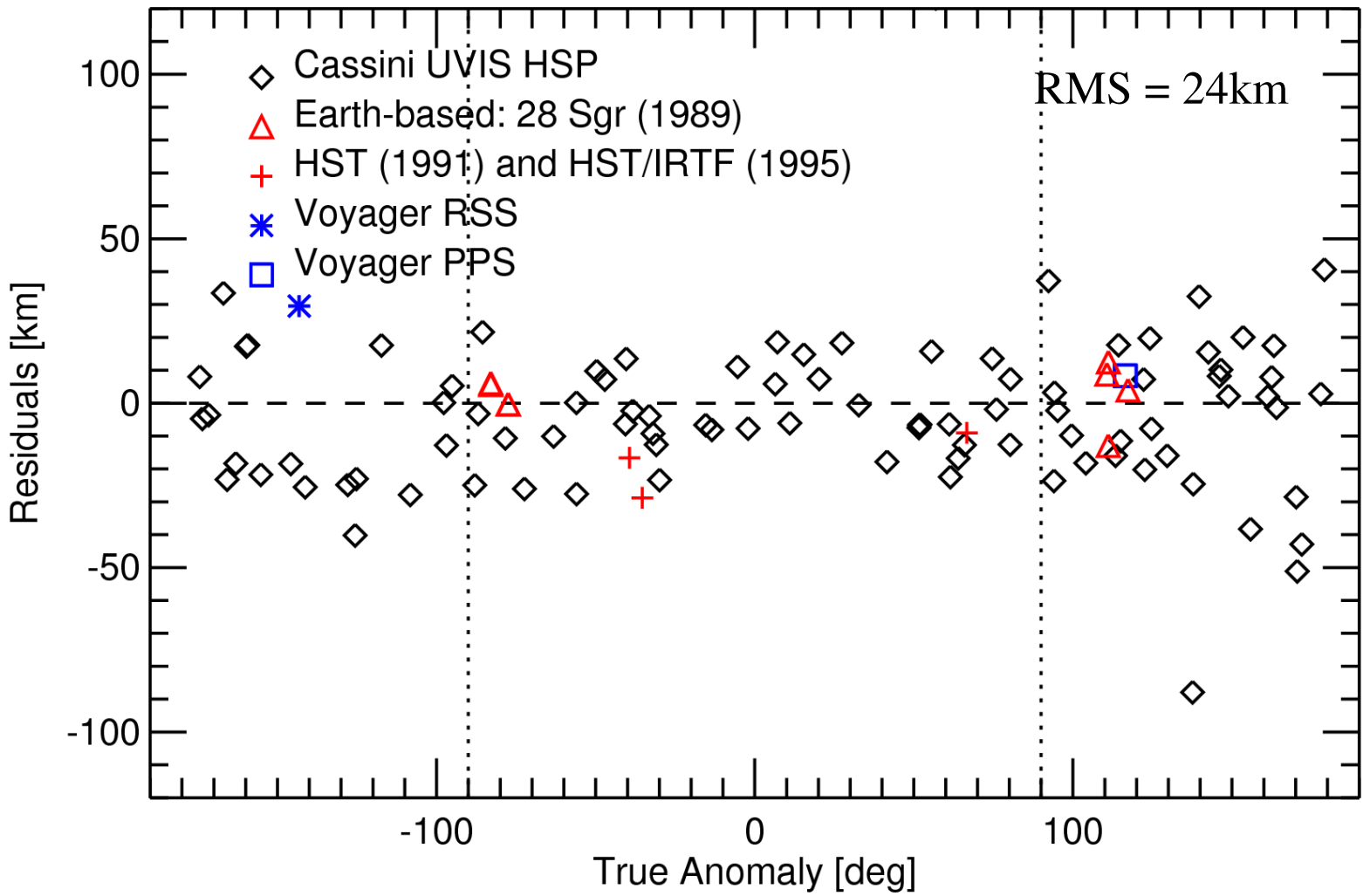
$$L(r) = \frac{W}{\pi} \frac{(HWHM)}{(HWHM)^2 + (r - r_0)^2}$$

Method is robust and applicable to core and strands alike

As expected, the F ring core location differs more than expected from an eccentric orbit.

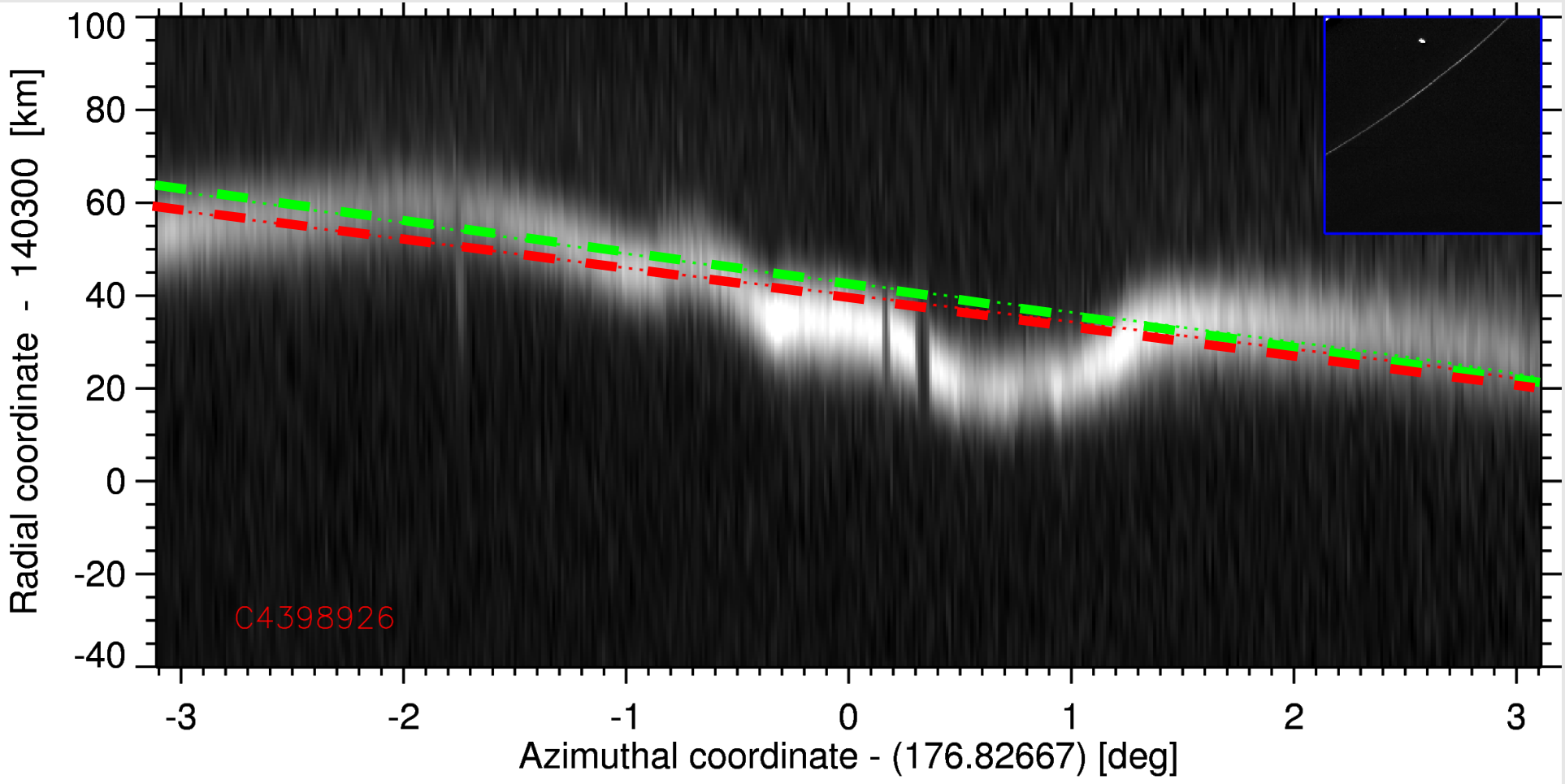
Inferred event times are then used to model the orbit kinematics.

# F ring kinematics (2): Fitting an orbit model



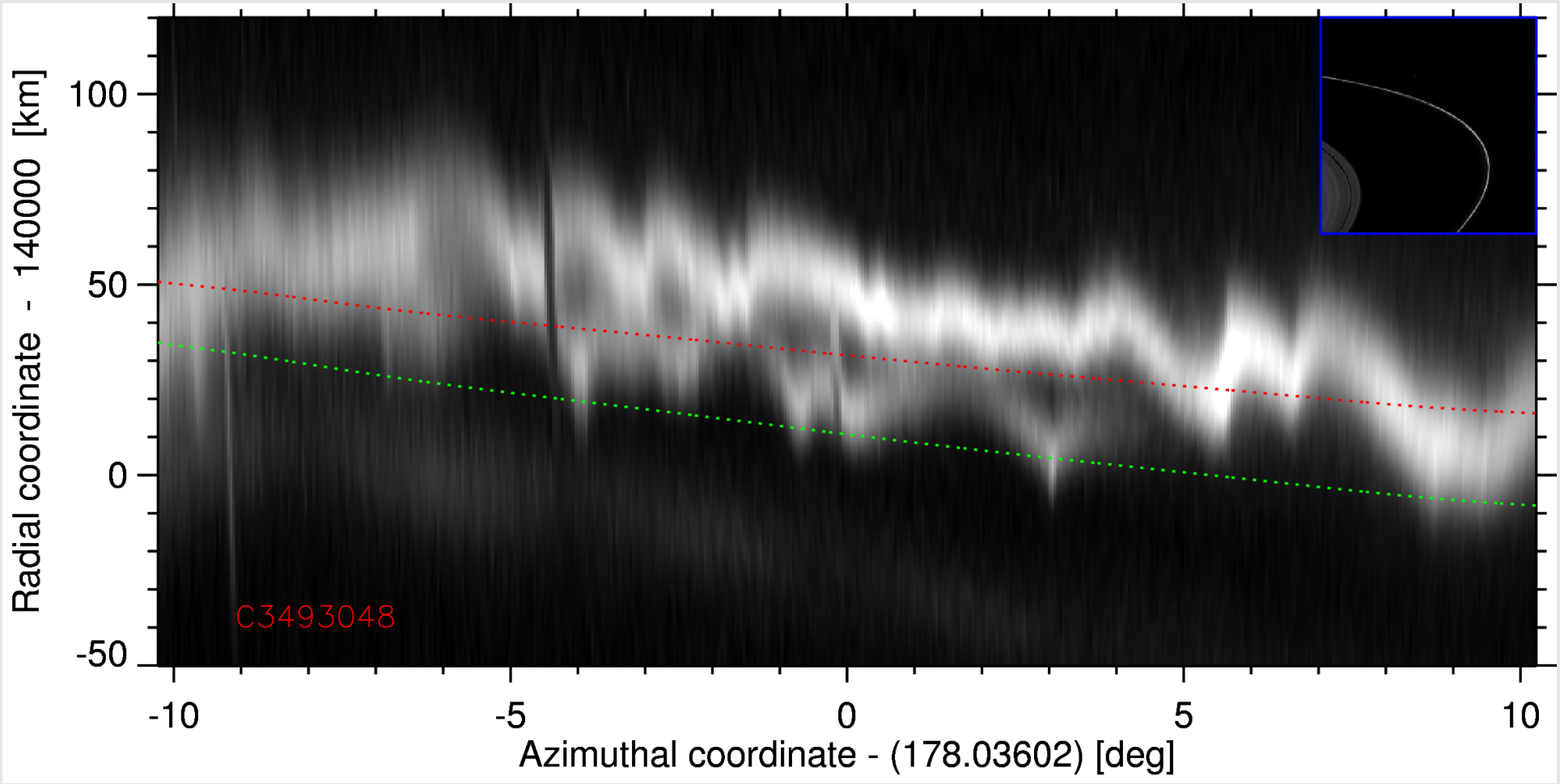

UVIS confirms that F ring core is well-described by an inclined freely precessing ellipse with vertical excursion of ~15km

# Comparison to Voyager imaging (1)



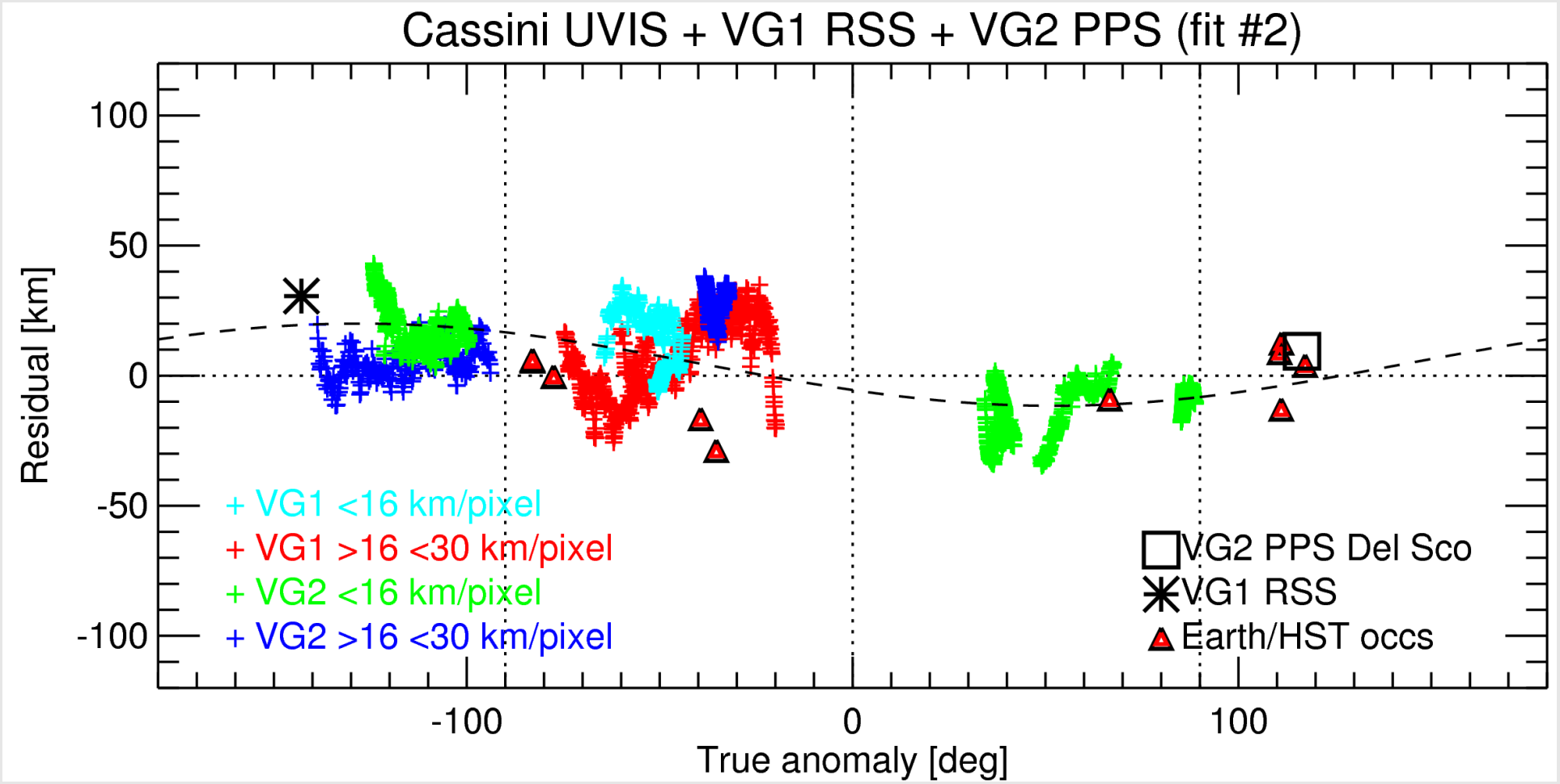

Also consistent with deviations of ~50km reported in Cassini ISS images.
[Murray et al. 2005)]

# Comparison to Voyager imaging (2)



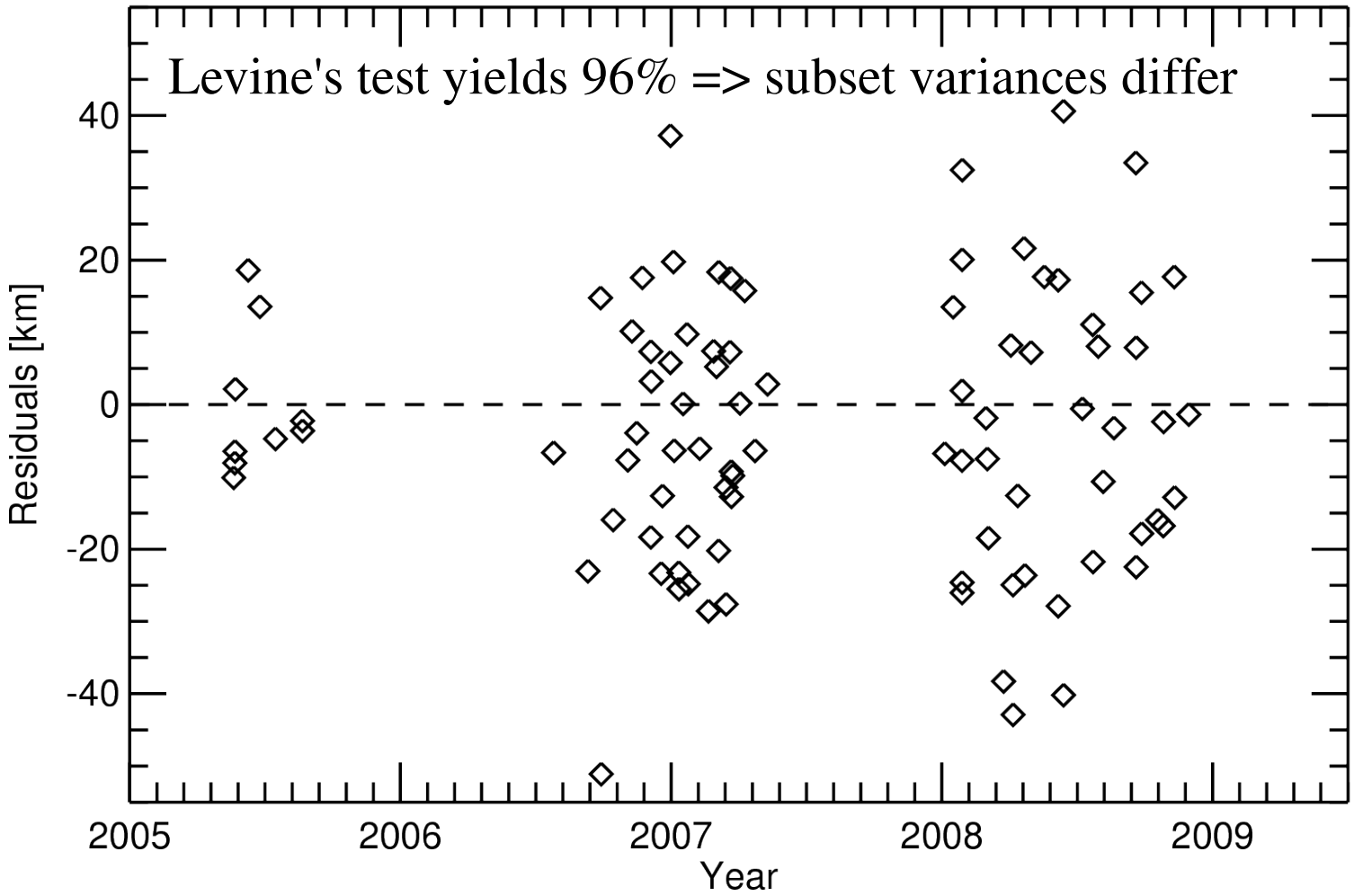

UVIS fit residuals represent the expected F ring kinks seen in Voyager and Cassini imaging, most likely a result of the Prometheus' influence. Residuals are also consistent with the inferred spread of clump mean motions [Showalter (2004)].

# Comparison to Voyager imaging (3)



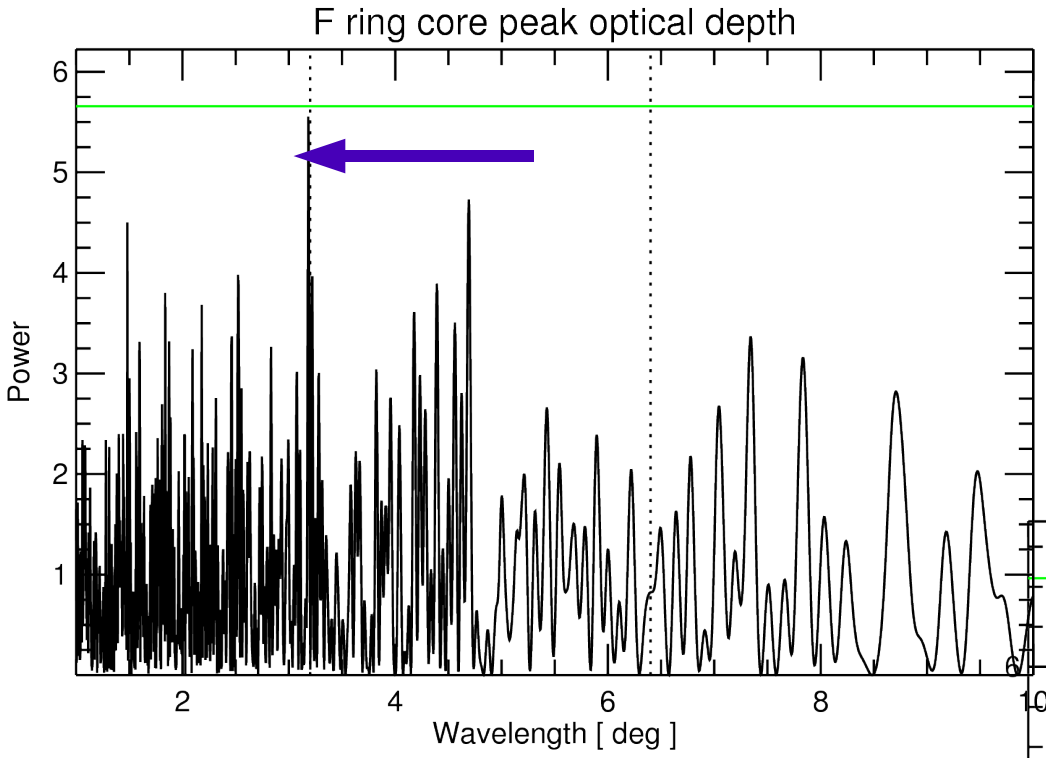

Moreover, Cassini UVIS fit residuals are consistent with Voyager ISS, PSS, and RSS, and Earth-based observations, implying no temporal orbit changes.

# F ring core: Prometheus' signature (1)

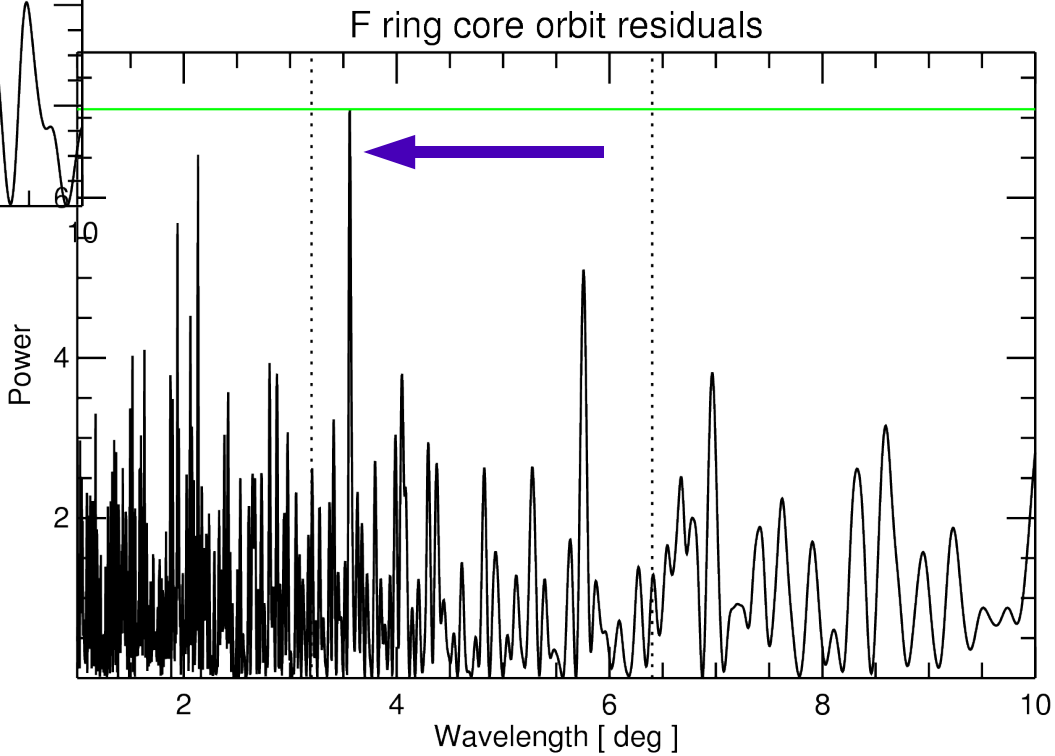



Increasing residual variance is coinciding with the apse anti-alignment in Dec 2009 and consequently larger moon-induced perturbations.

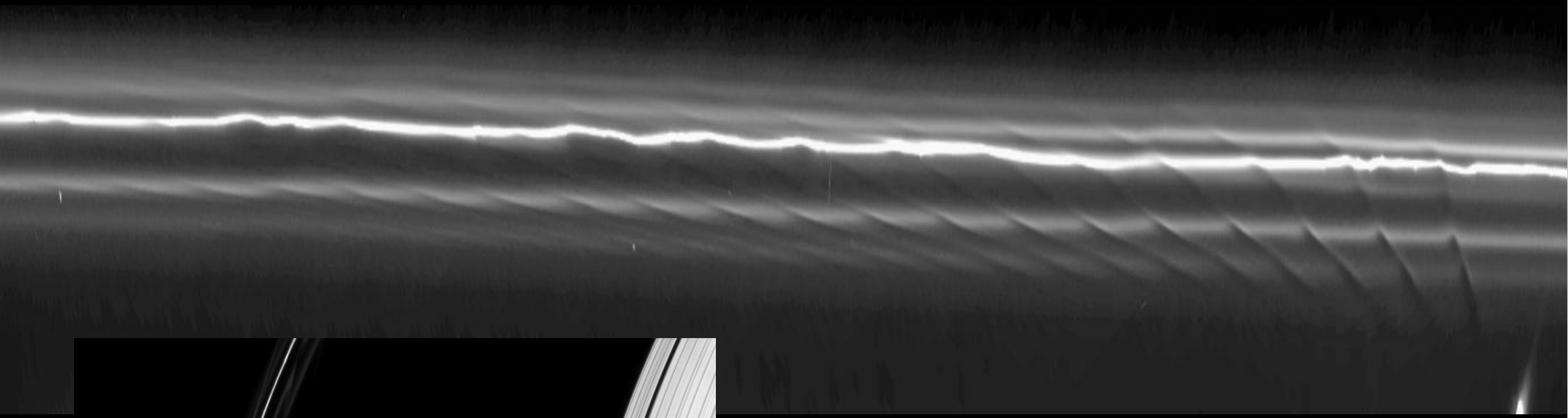
# F ring core: Prometheus' signature (2)




Peak optical depth shows expected 3.2deg peak in power (but only 60%)




Curiously, residuals show a significant peak in power (90%) but at 3.5deg

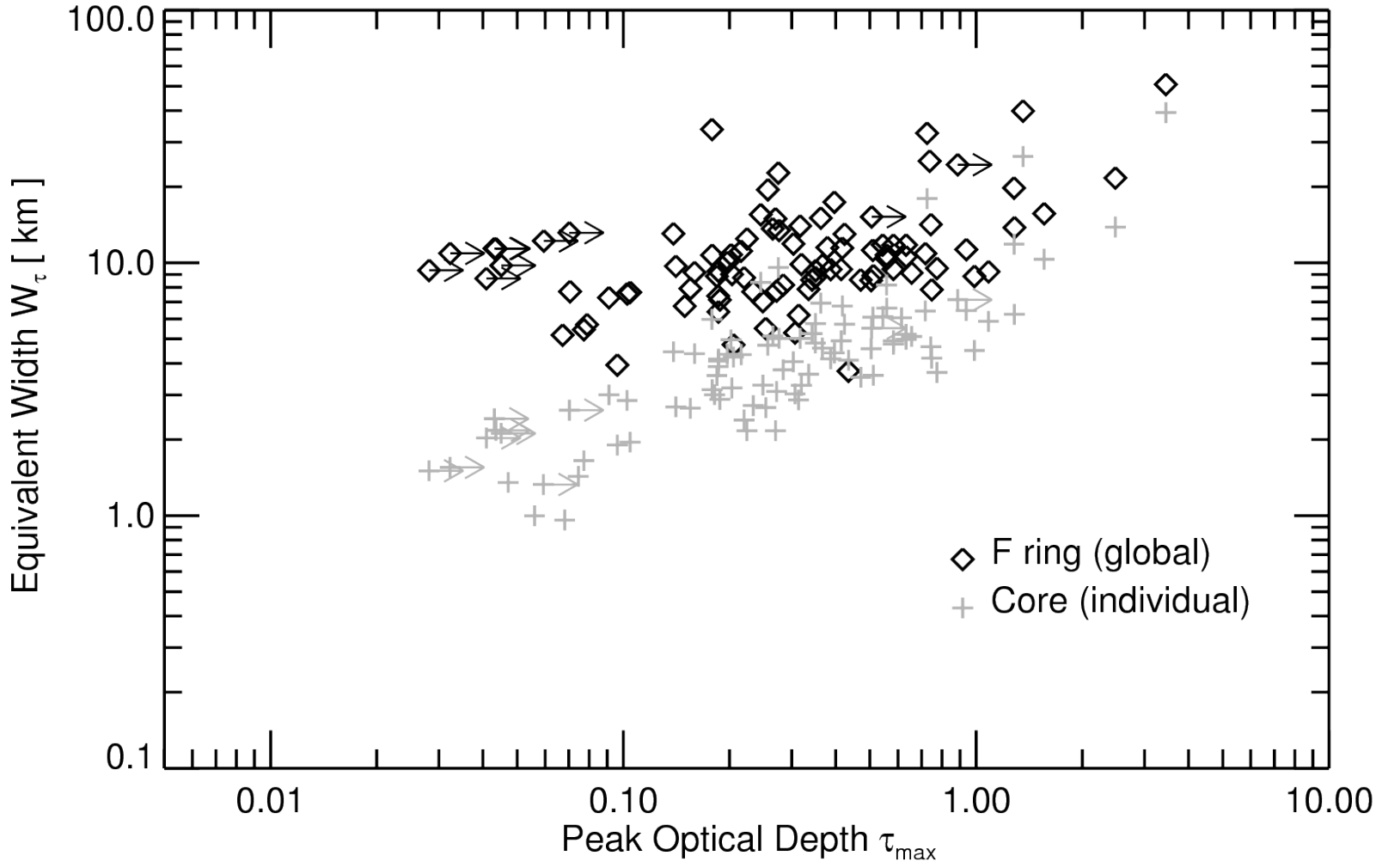


THE F RING CORE

# THE F RING STRANDS

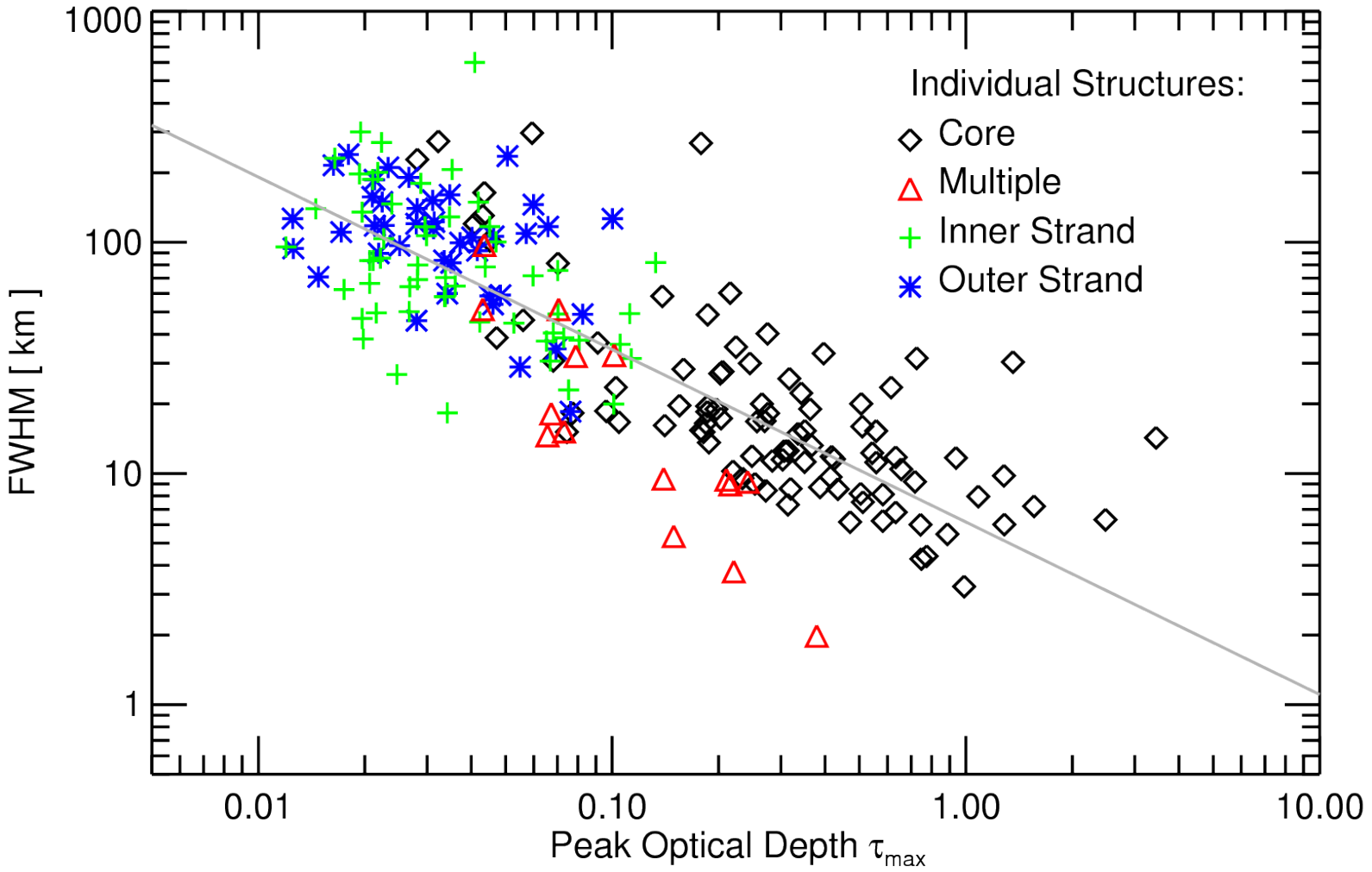
THE F RING CONSTITUENTS

# The F ring: Morphology (1)




Strands contribute significant part of the opacity (cross-section), consistent with them being predominantly dust filaments.

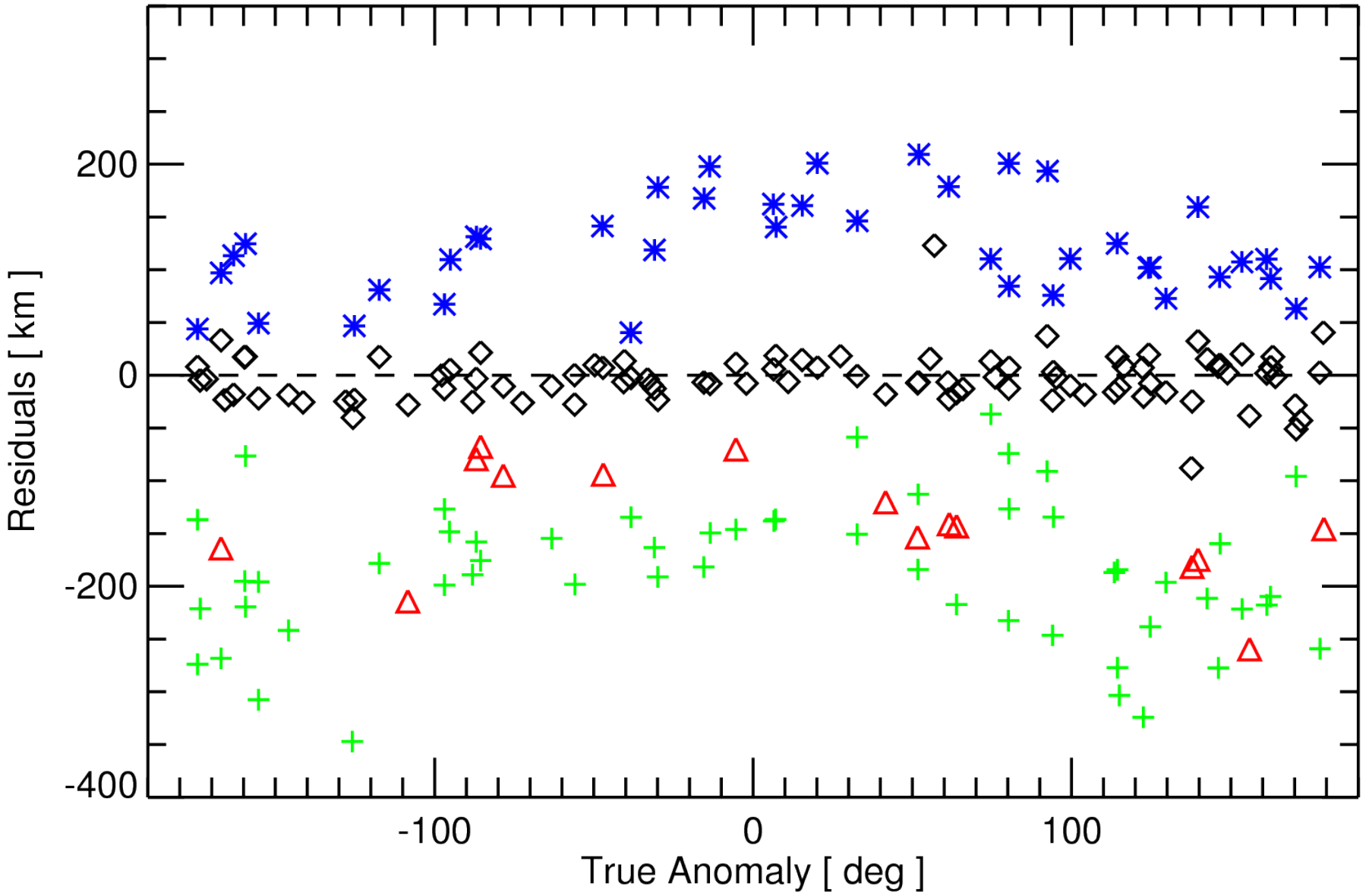
# The F ring: Morphology (2)




=> *Strands:* broad, optically thin structures

*Core*: narrow (on average 10km) with significant optical depth.

# F ring as seen by Cassini UVIS




Albers et al. (2010, in rev)

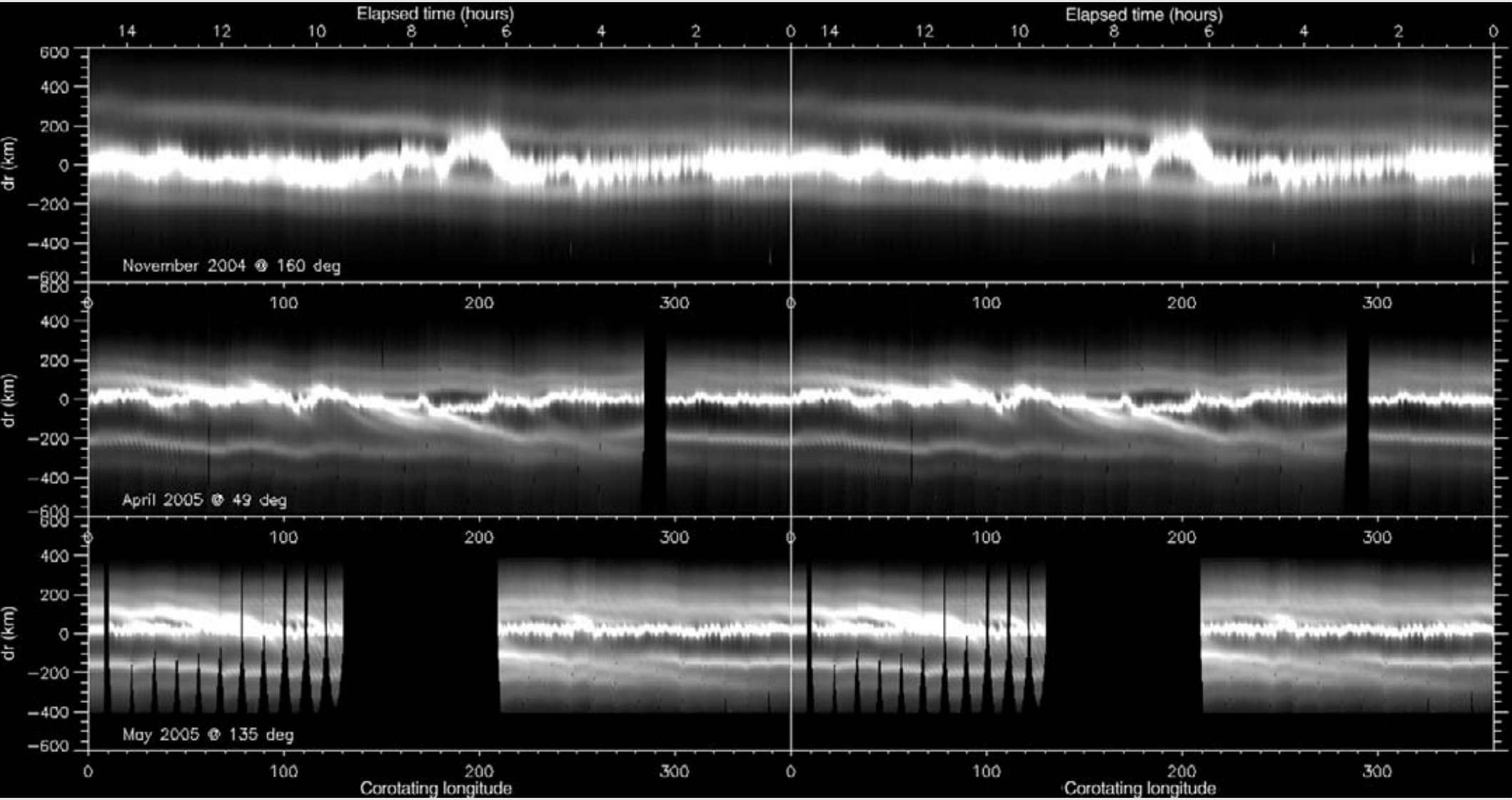
# F ring component detections

| Structure | Season 0 [2005-2006] | Season 1 [2006-2008] | Season 2 (paper) [2008-2008-332T] | Total (paper) | Season 2 [2008-2009-239T] | Total |
|---|---|---|---|---|---|---|
| Core (#occs) | 9 | 42 | 42 | 93 | 65 | 116 |
| F-ii | 0 | 0 | 15 | 15 | 19 | 19 |
| Inner | 7 | 16 | 32 | 55 | 58 | 81 |
| Outer | 4 | 19 | 18 | 41 | 28 | 51 |
| Multiple Inner | 2 | 3 | 19 | 24 | 29 | 34 |

Table 1: All F ring components

- Strand activity has been constantly increasing, consistent with the registered F ring core residual trend
- 80% of multiple inner strands occurred after the F-ii appeared
- 40% of F-ii have a larger optical depth than the F ring core
- 3 known core misidentifications (good indications for yet more, without necessarily having large residuals)

# F ring strands




Charnoz et al. (2005)

But UVIS data do not match a simple kinematic spiral.

THE F RING CORE

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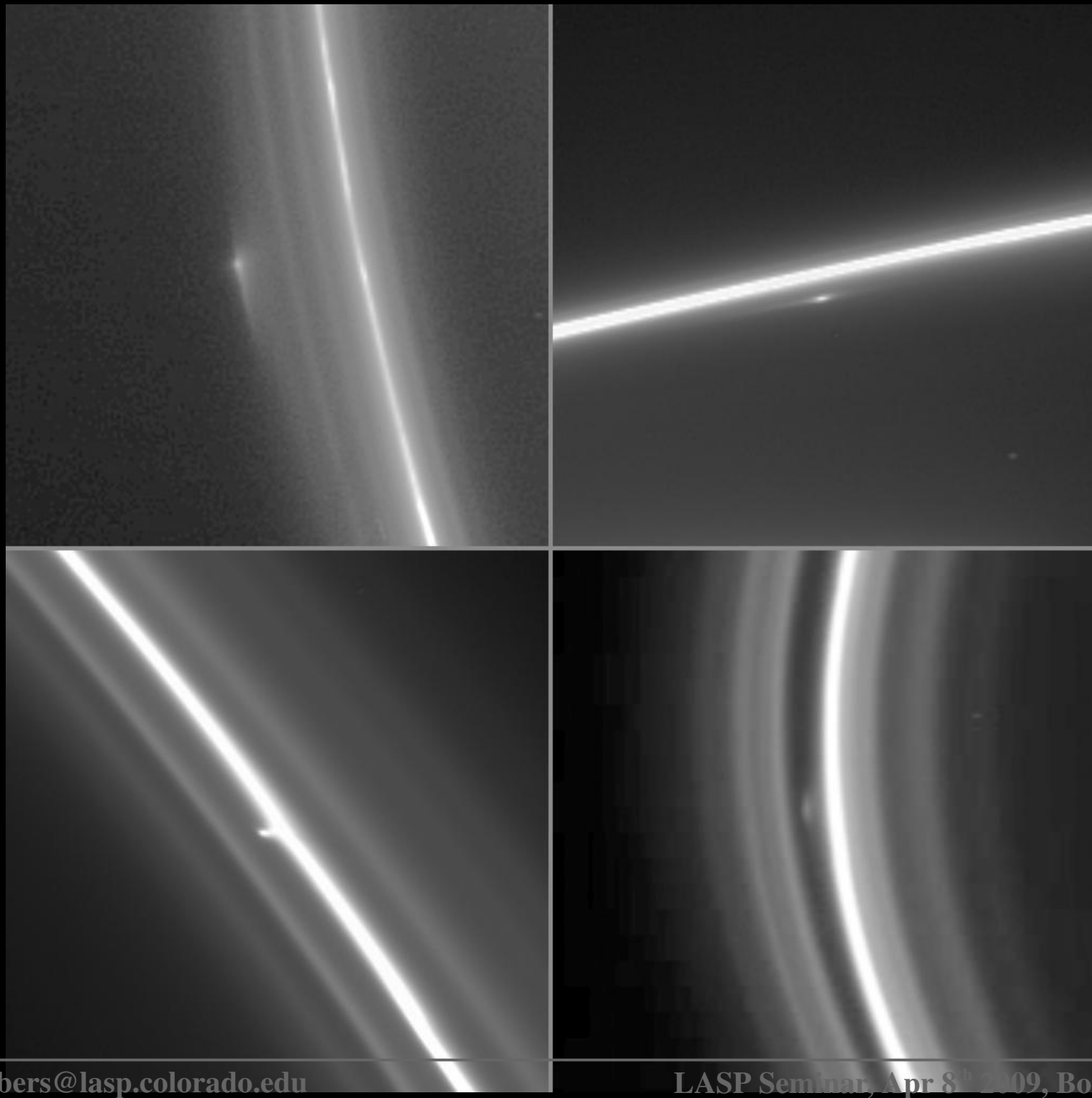
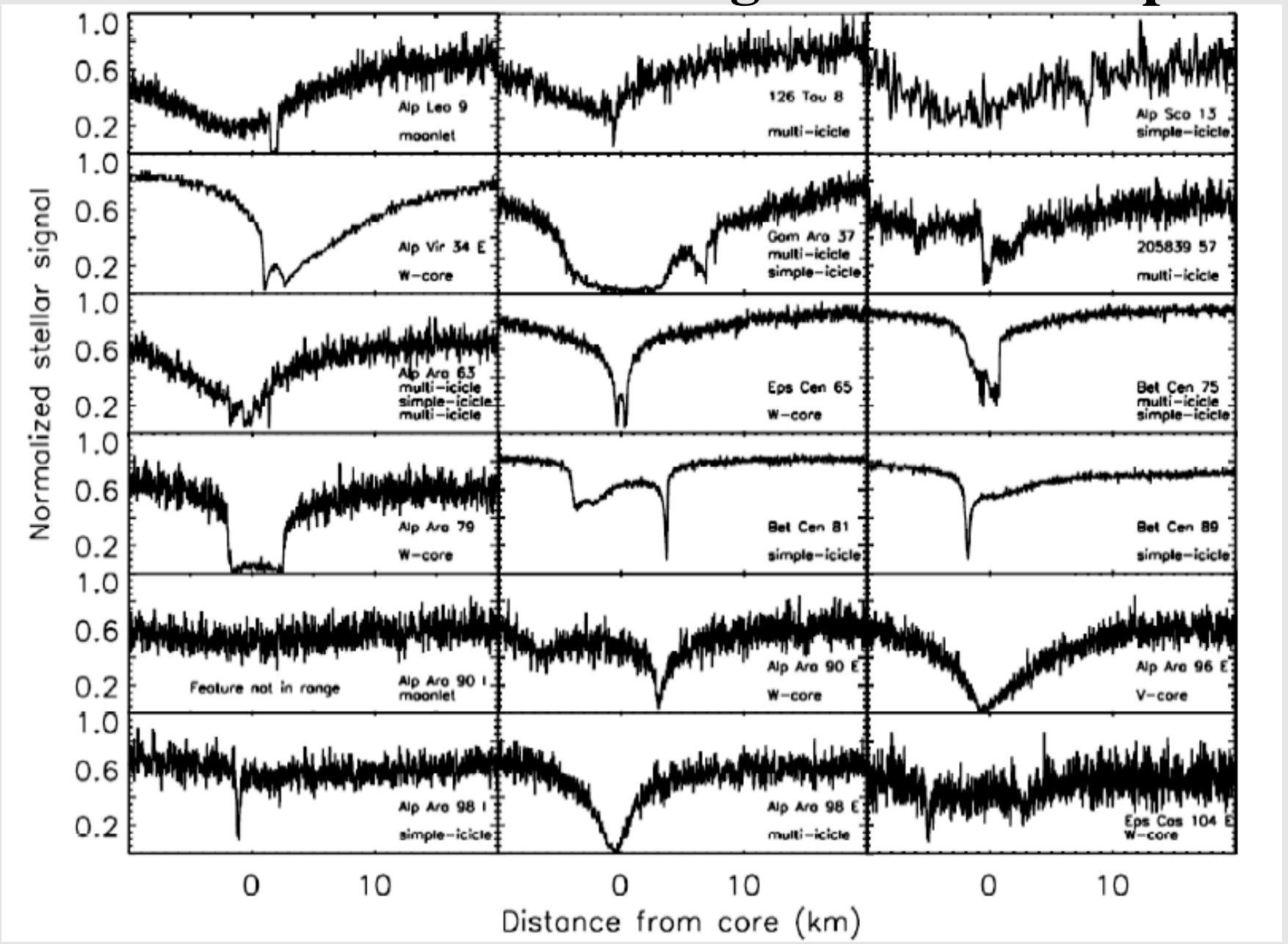
# THE F RING CONSTITUENTS

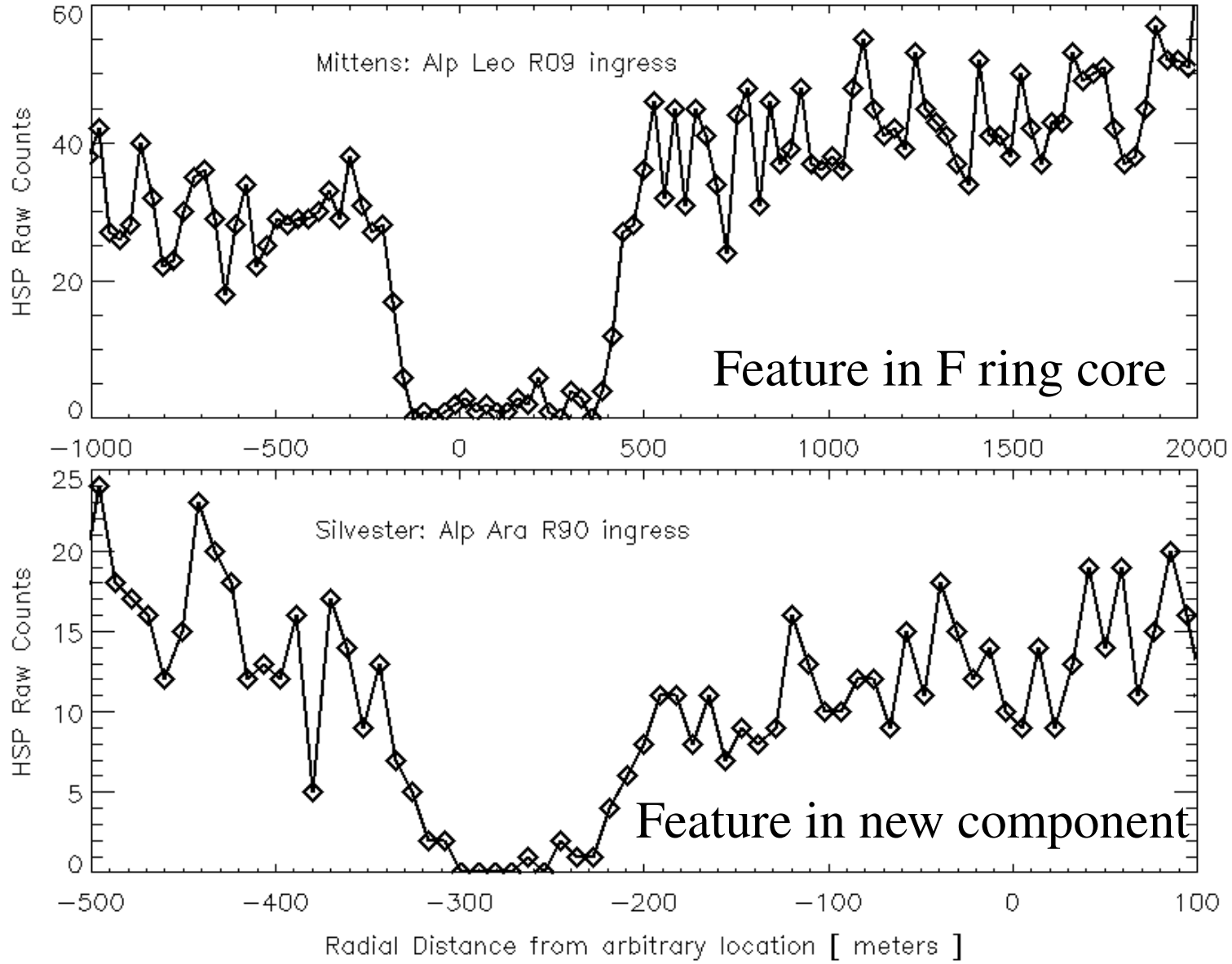


# Direct evidence for F ring moonlet/clumps



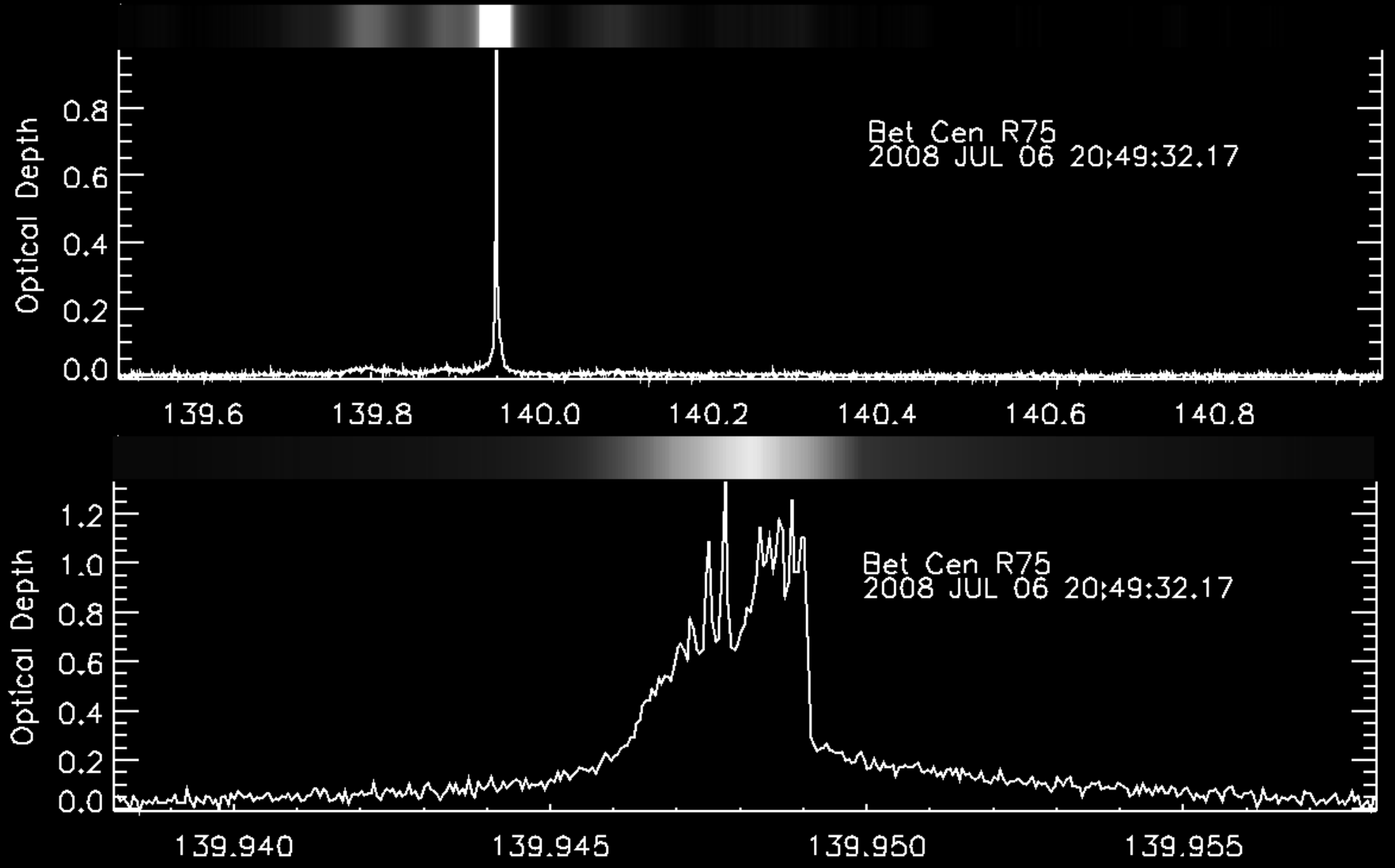

Meinke et al. (2010, in prep)

# Opaque events in the F ring




Meinke et al. (2010, in prep)

# Indirect evidence for F ring moonlet?




Albers et al. (2010, in review)

# Summary

Unexpected structural variations on timescales ranging from a few hours to a few years of hours suggest that rings are more dynamic

**F ring core:**

- Prometheus locally perturbs the F ring without altering the ring's kinematics; causing different activity levels; but the actual ring confinement is still not fully understood
- But new component's core resemblance is not understood

**F ring strands:**

- Predominantly dusty, “short-lived” structures
- Each strand carries the fingerprint of its creation in it kinematic properties. Understanding these will shed light on the F ring core size distribution

**F ring clumps:**

- Livetimes and distribution are crucial in understanding growth processes in the rings