

Saturn's Strangest Ring

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Queen Mary, University of London

CHARM Telecon

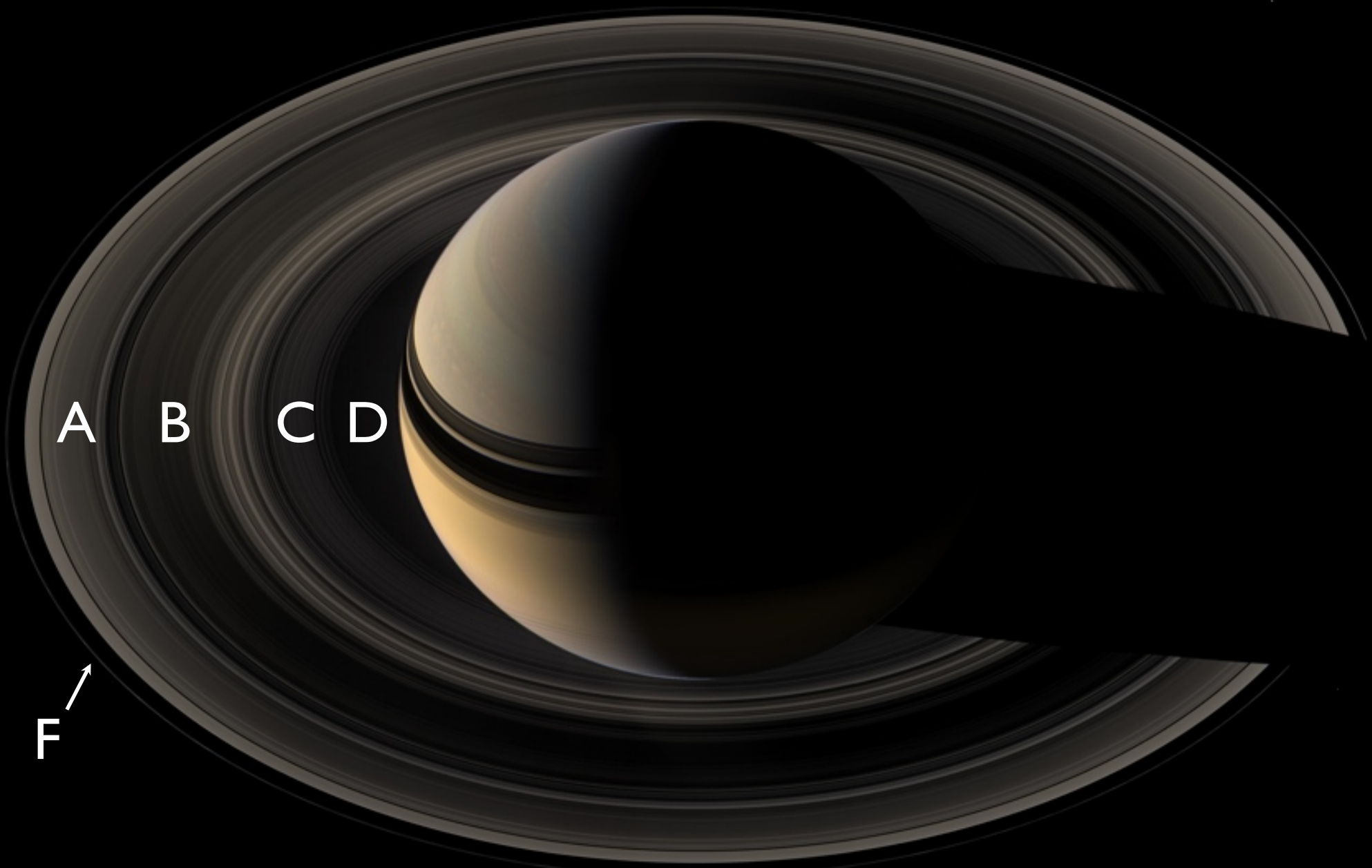
May 25th, 2010

PIA09803



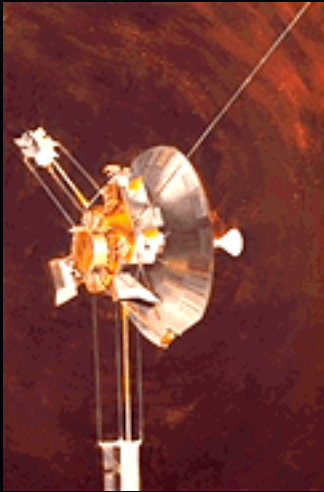
Outline

- Pioneer II, Voyager and HST observations of the F ring
- Cassini observations of the F ring
 - Objects in the vicinity of the F ring
 - The effect of Prometheus
 - Evidence for embedded objects
- Conclusions

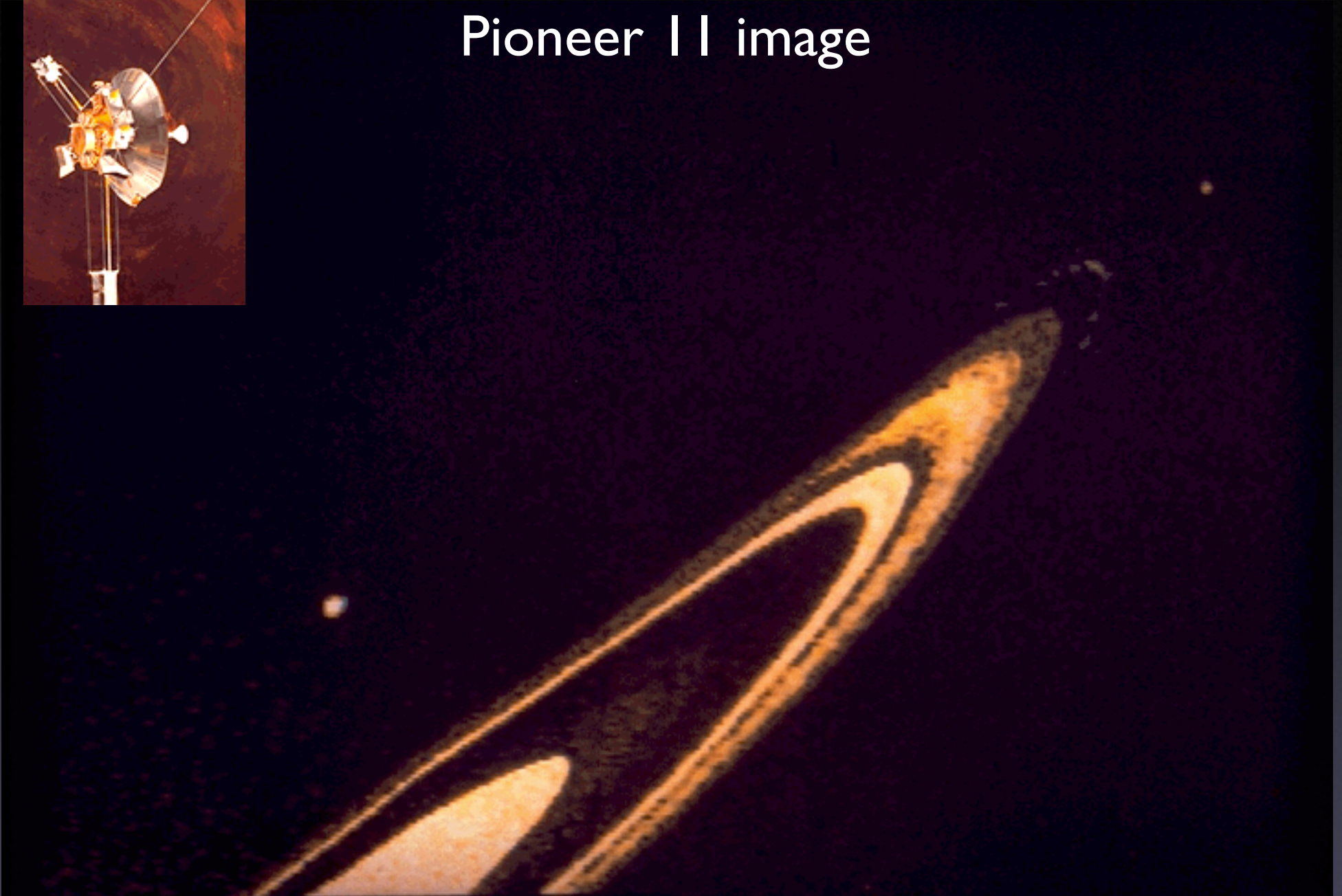


A B C D

F ↗

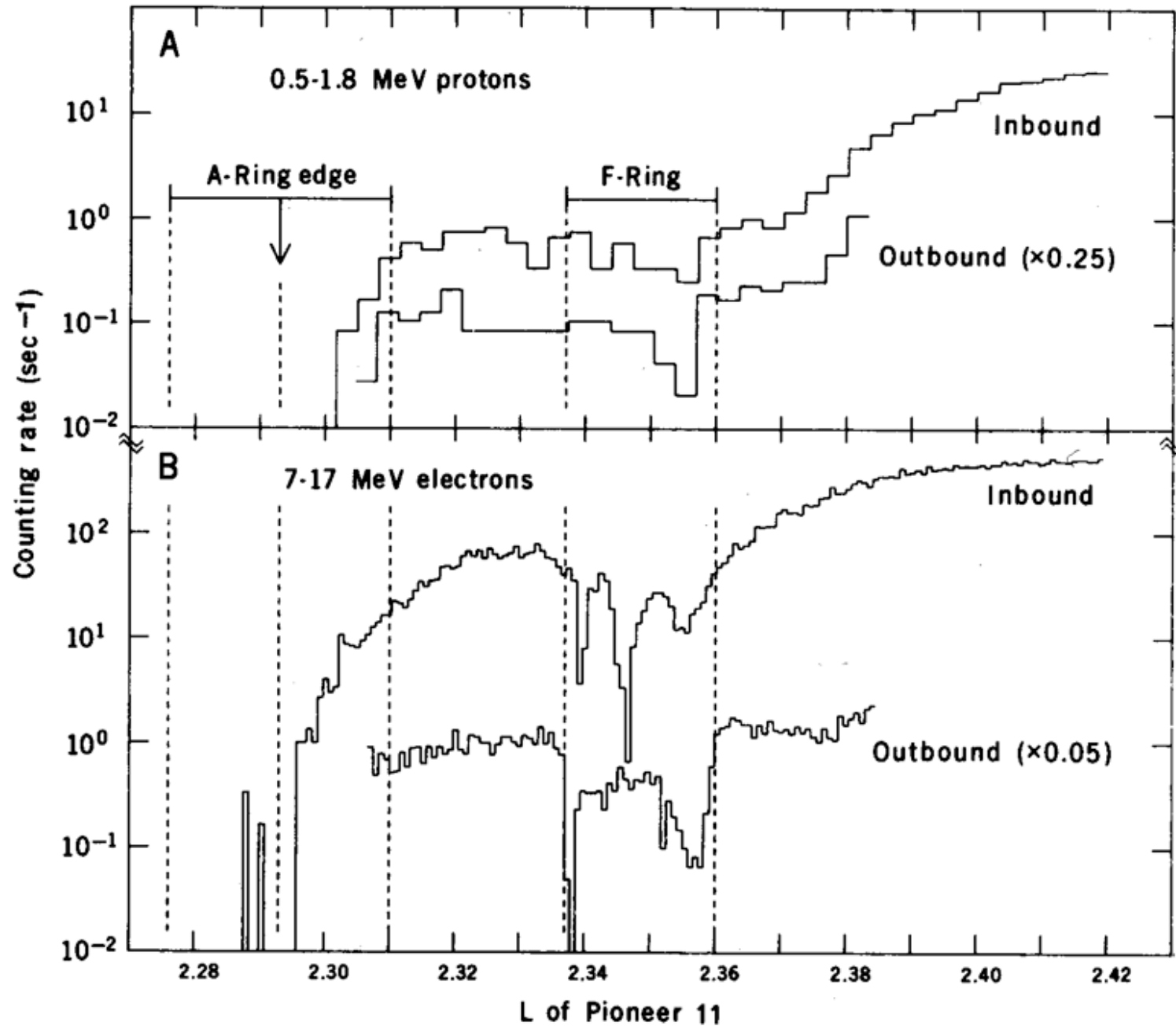


Pioneer 11 image



Gehrels et al. (1980)

Pioneer 11 charged particle data

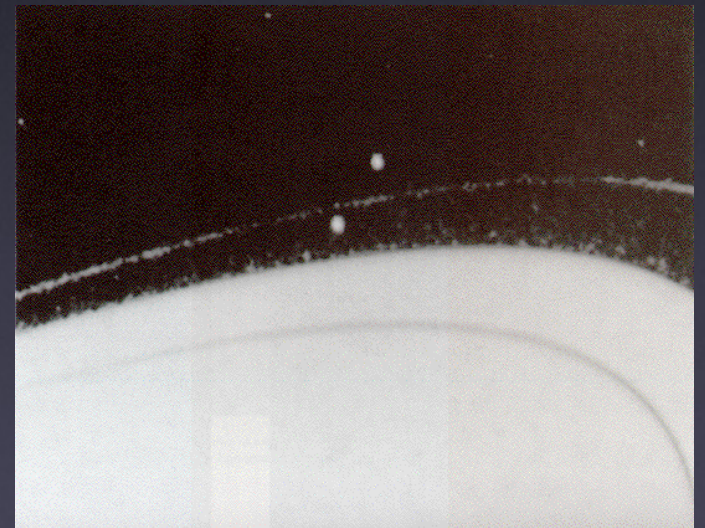


Voyager I image
showing:

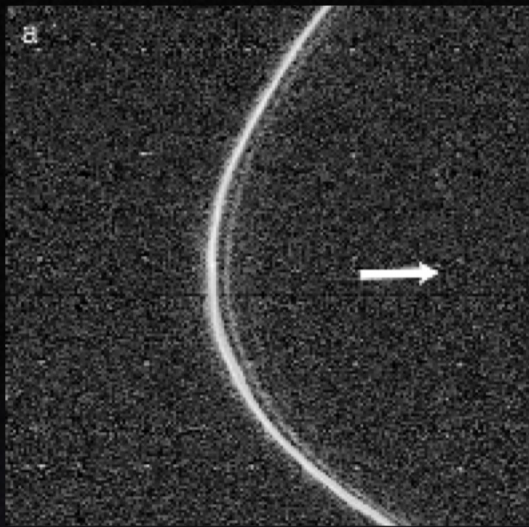
“braids”

“clumps”

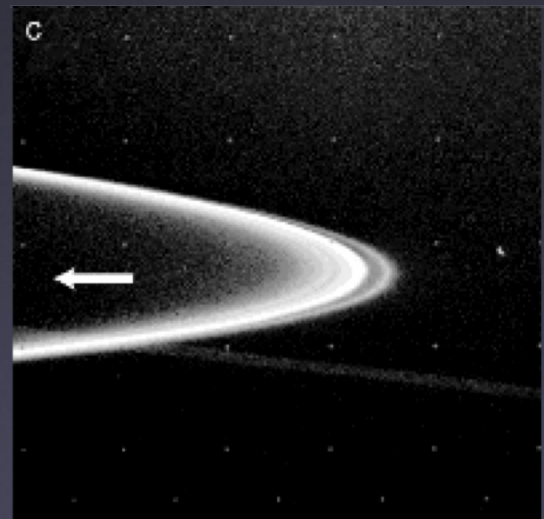
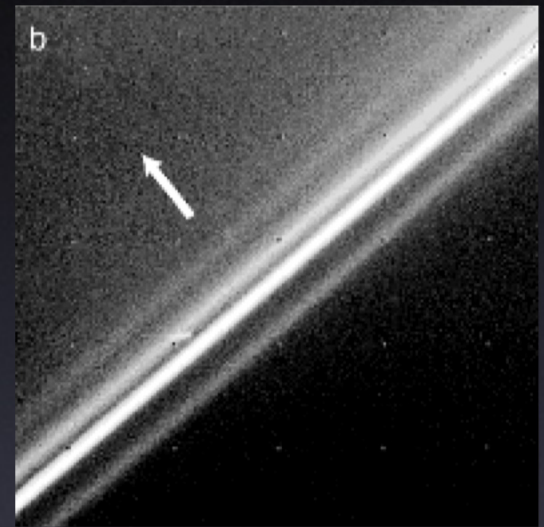
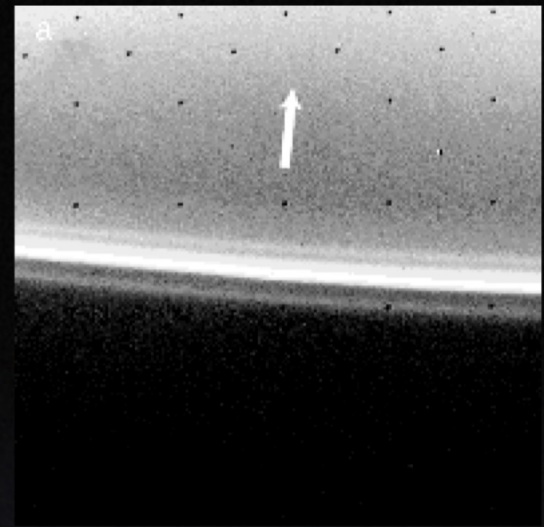
“kinks”



Voyager 1
Nov 1980



Voyager 2
Aug 1981



Murray, Gordon &
Giuliatti Winter
(1997)

Pandora

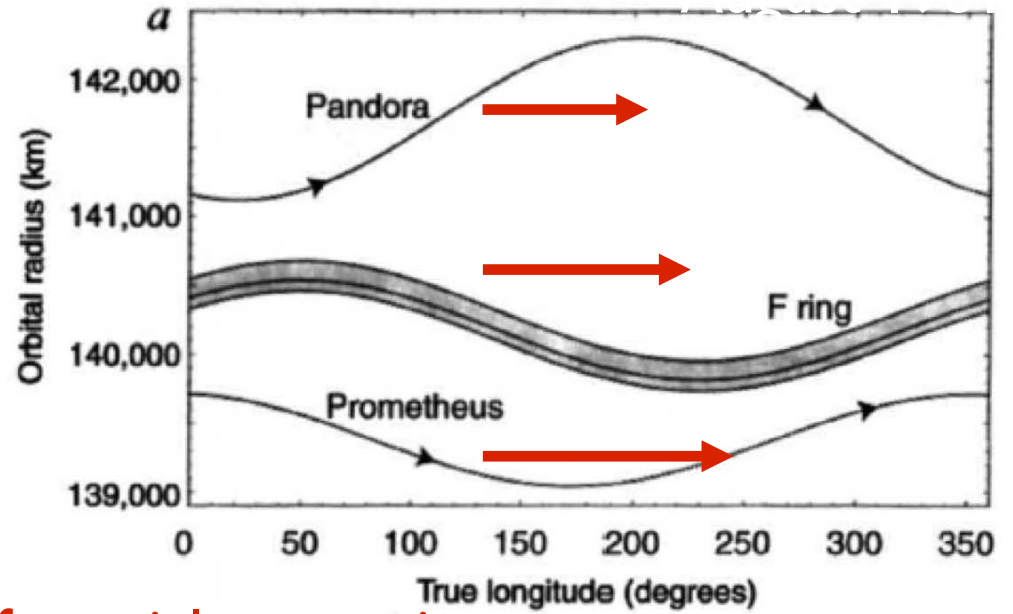


PIA07632

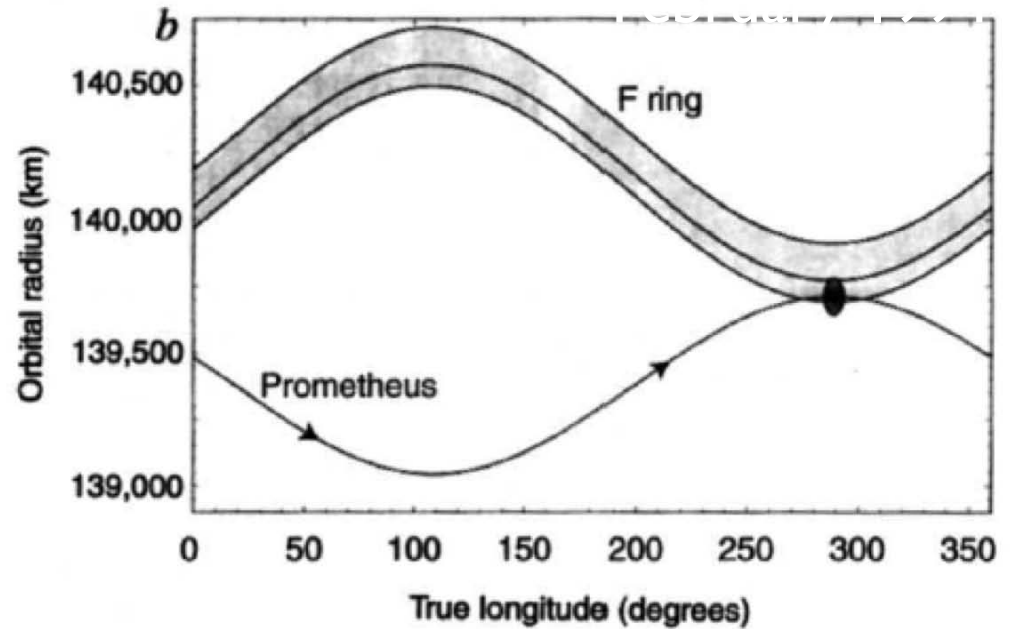
Prometheus



PIA07549



differential precession

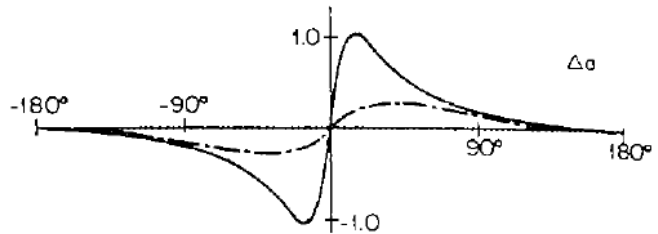


Murray & Giuliatti Winter (1996)

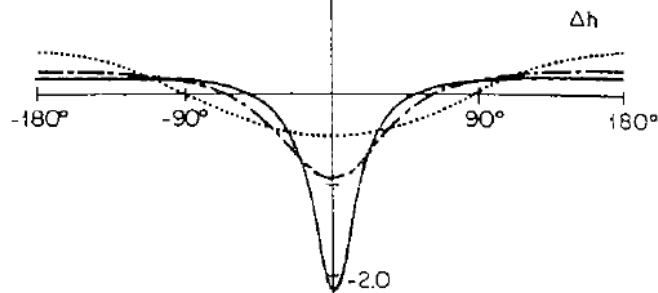
Gravitational effect of close satellite

Showalter & Burns (1982)

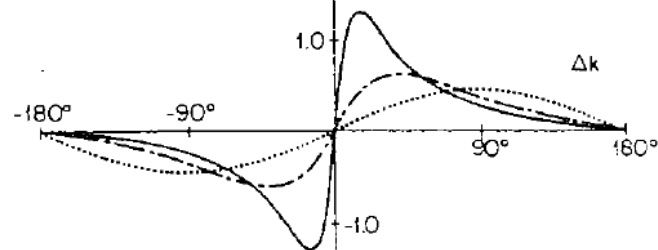
Δa



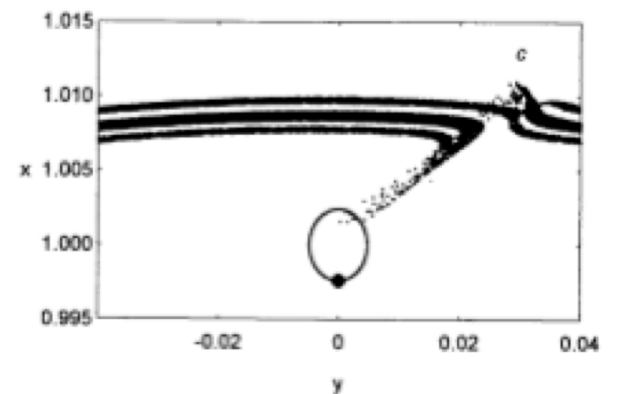
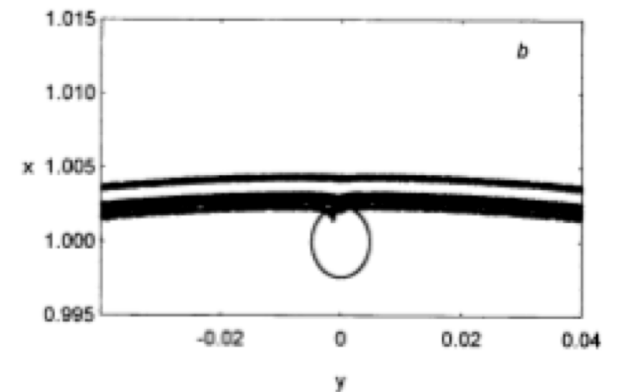
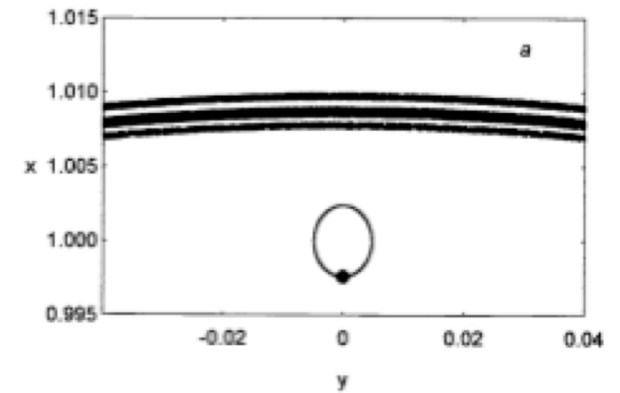
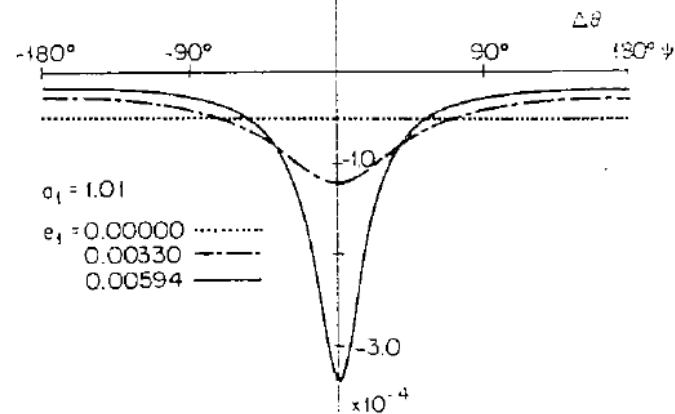
Δh



Δk

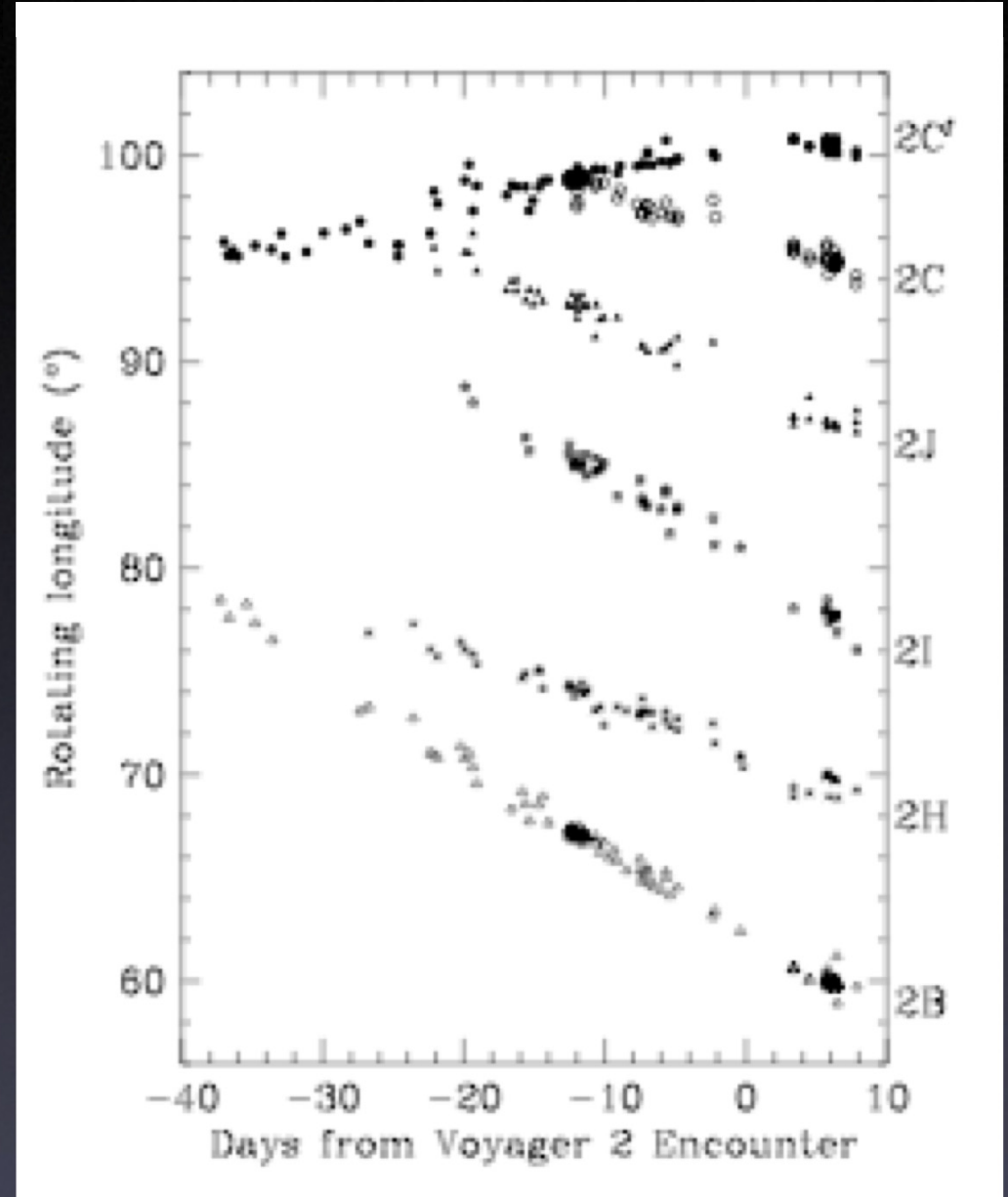
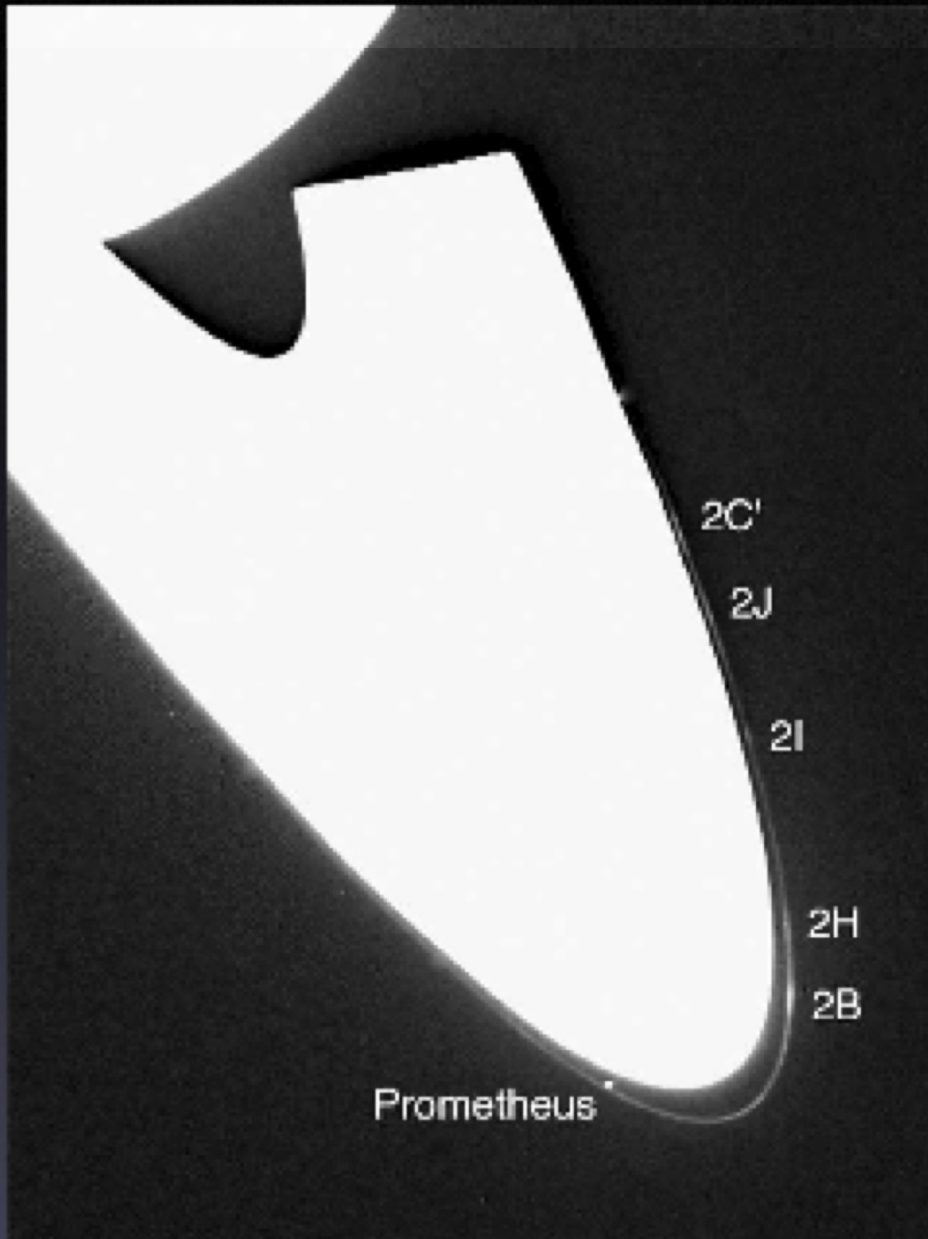


$\Delta \theta$

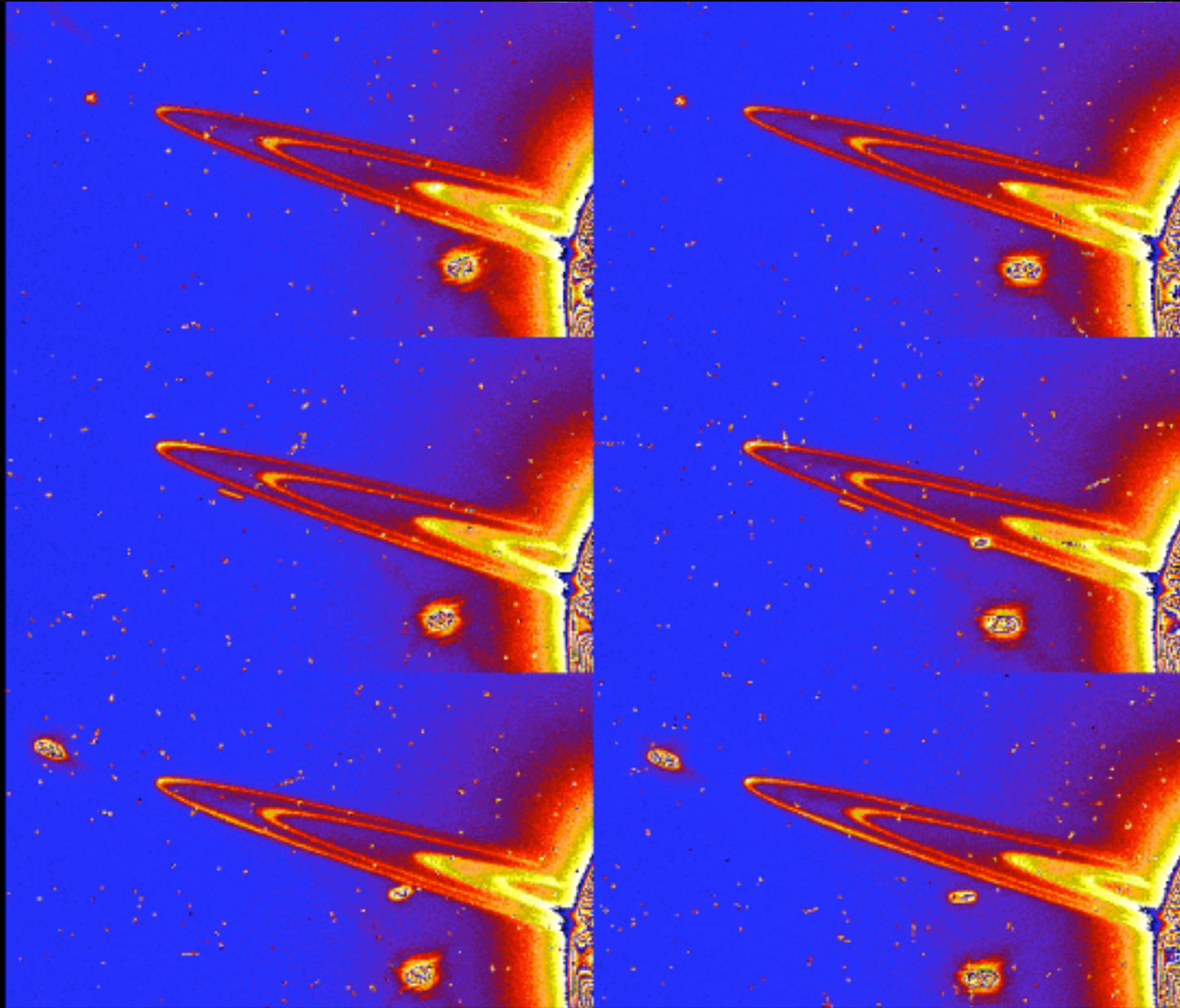


Giuliatti Winter, Murray & Gordon (2000)

Tracking clumps in the F ring



Showalter (2004)

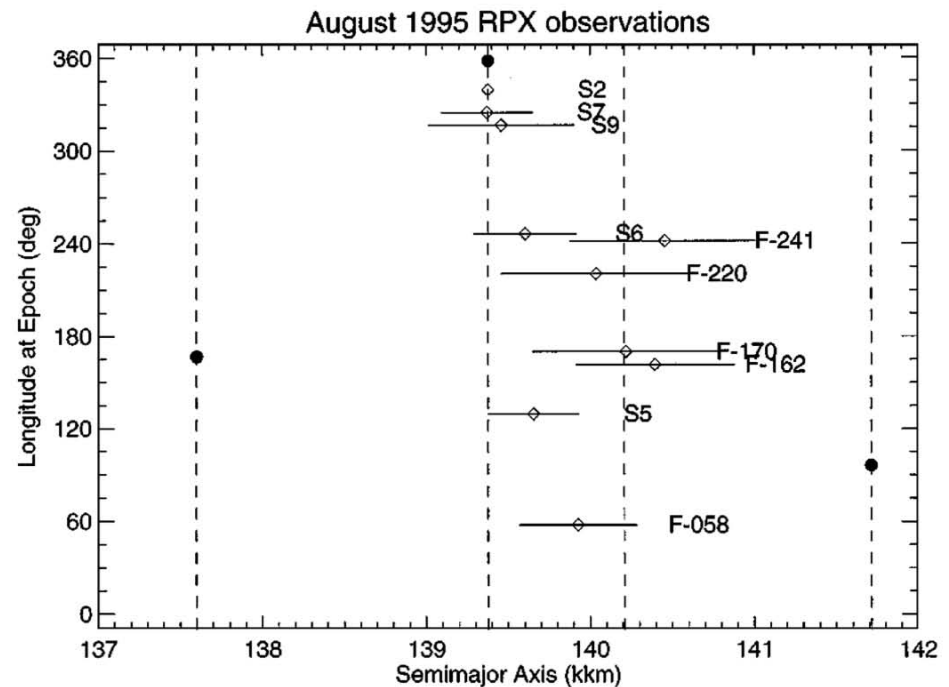
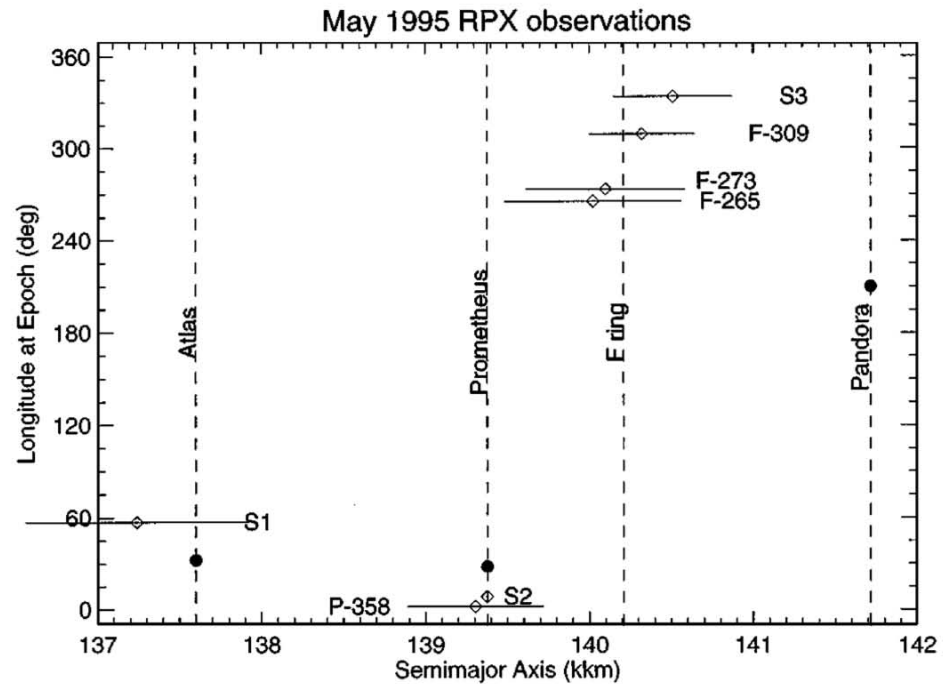


Saturn

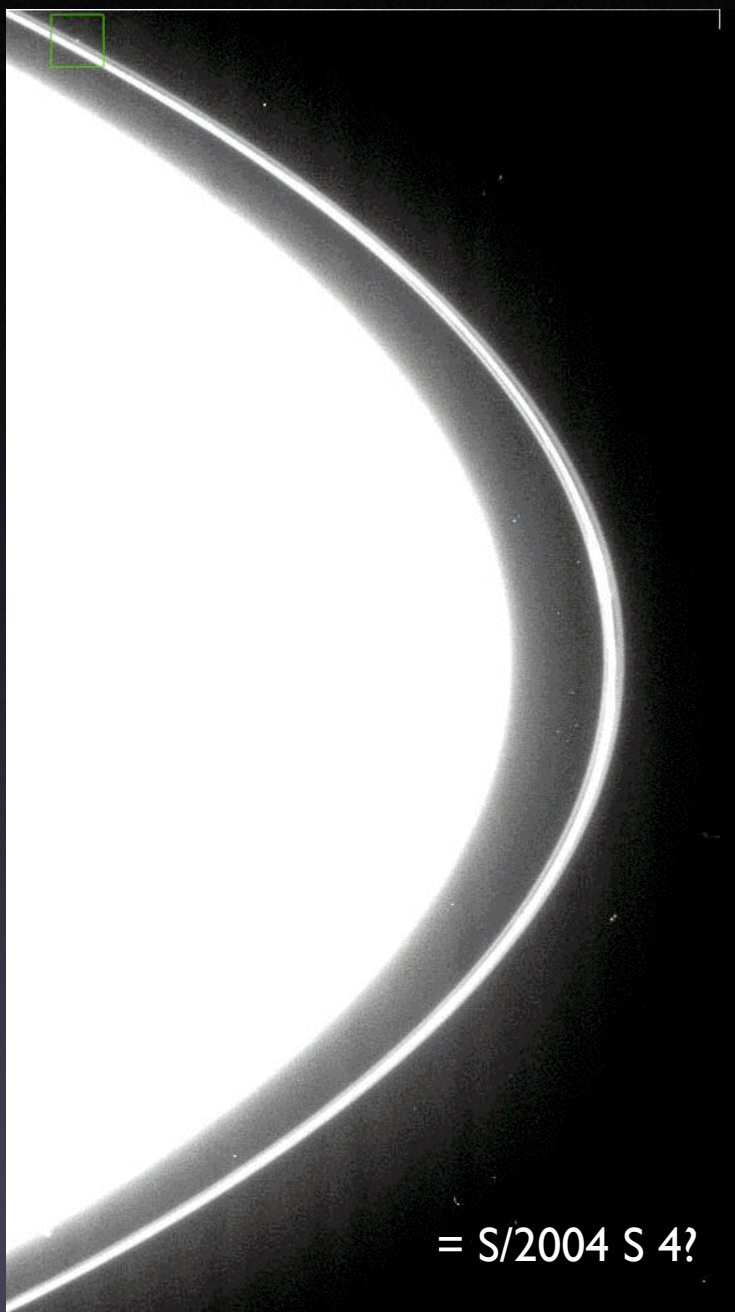
PRC96-18b · ST ScI OPO · April 26, 1996
P. Nicholson (Cornell) and NASA

HST · WFPC2

Ring Plane Crossing Observations (McGhee et al. 2001)



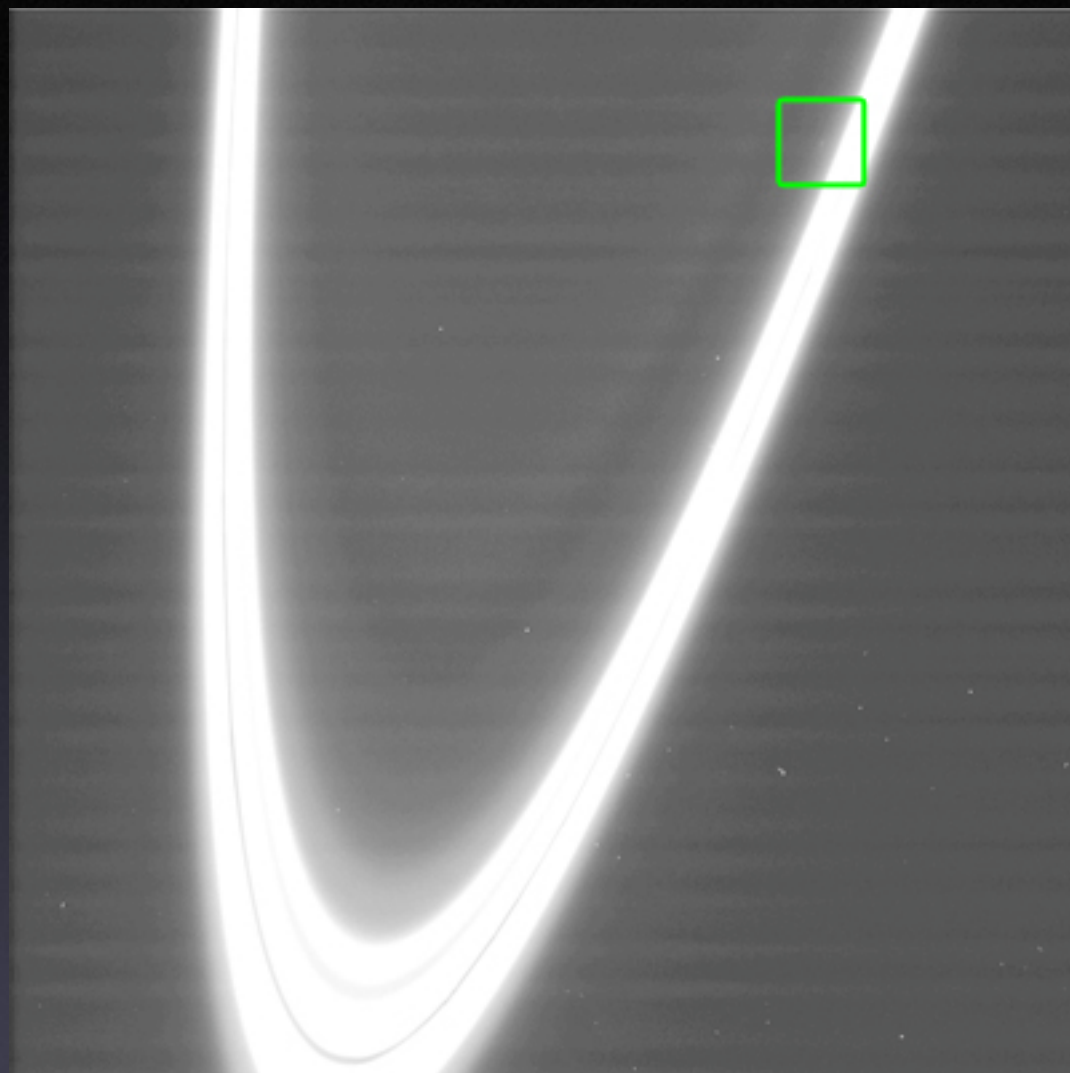
S/2004 S 3



= S/2004 S 4?

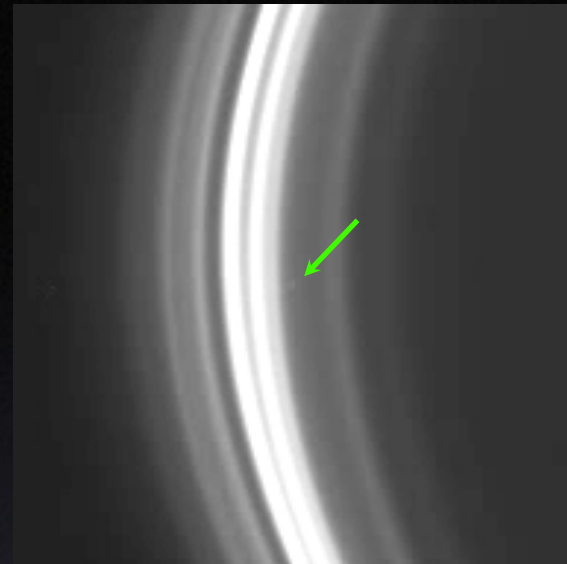
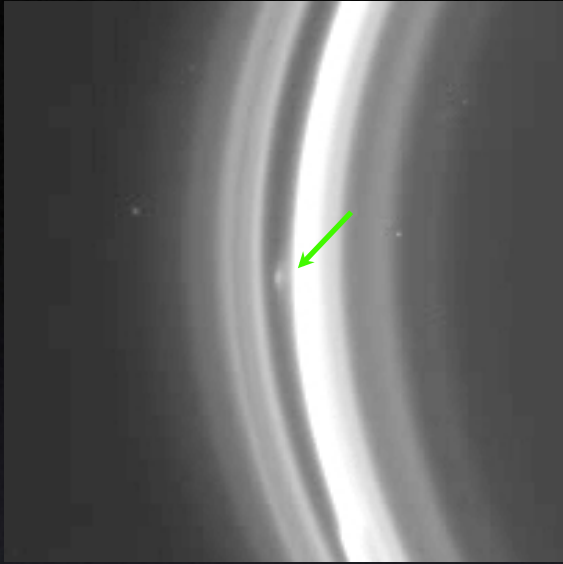
June 2004

S/2004 S 6

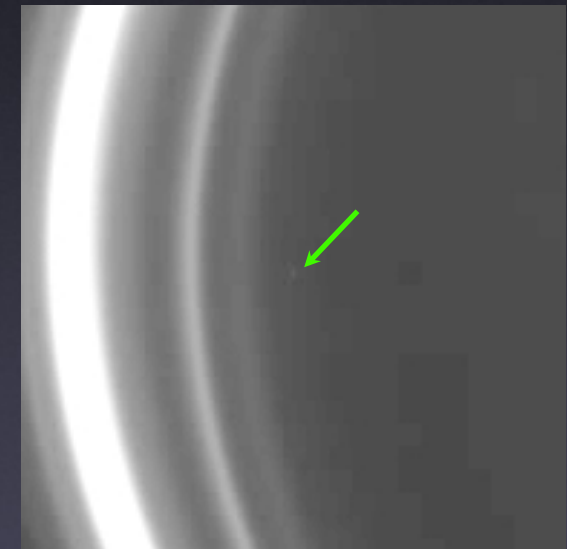
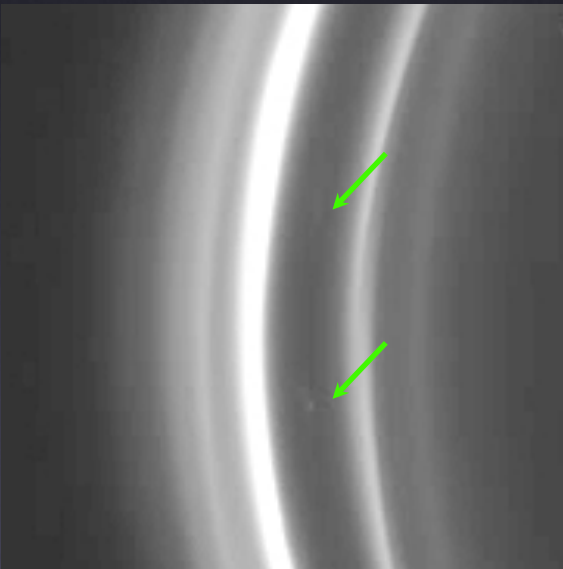


October 2004

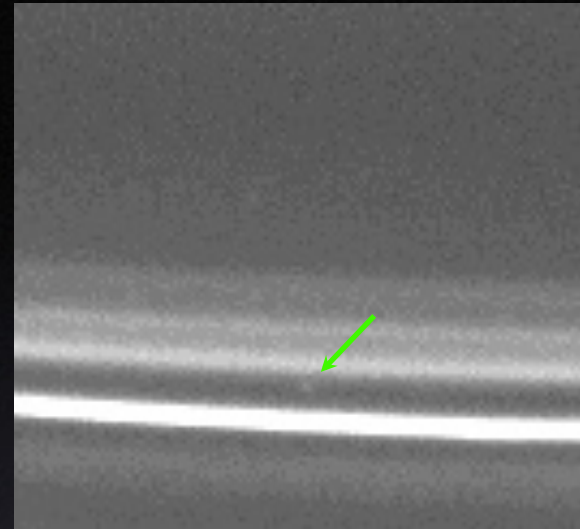
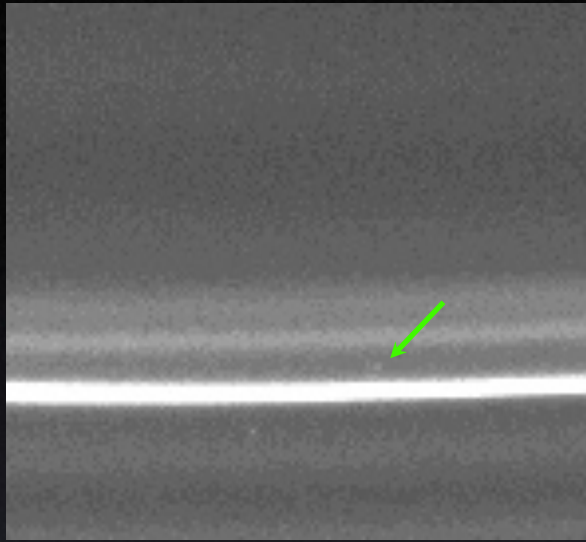
2005 DOY103 Detections



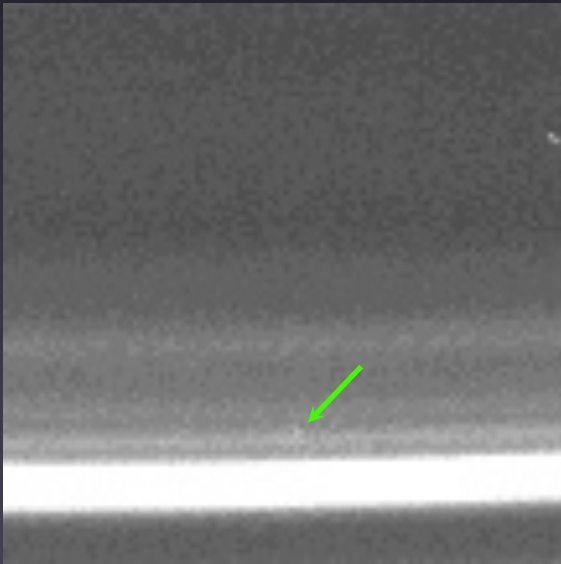
typically
~90
detections
of
each
object



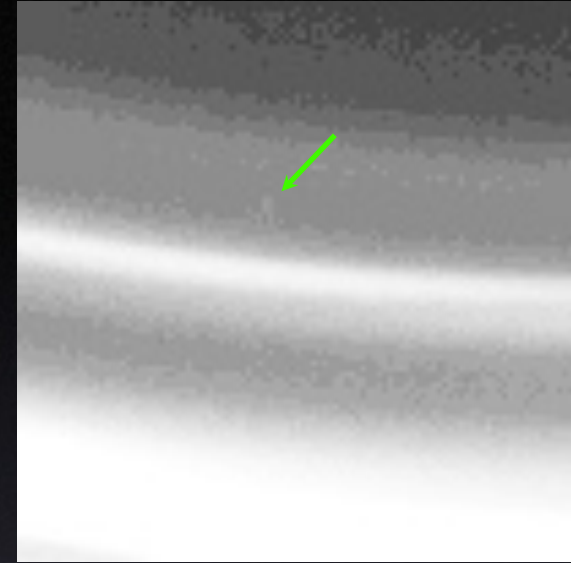
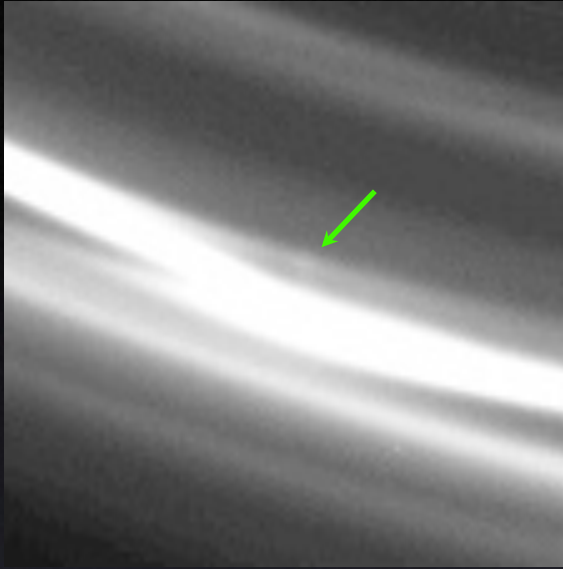
2005 DOY121 Detections



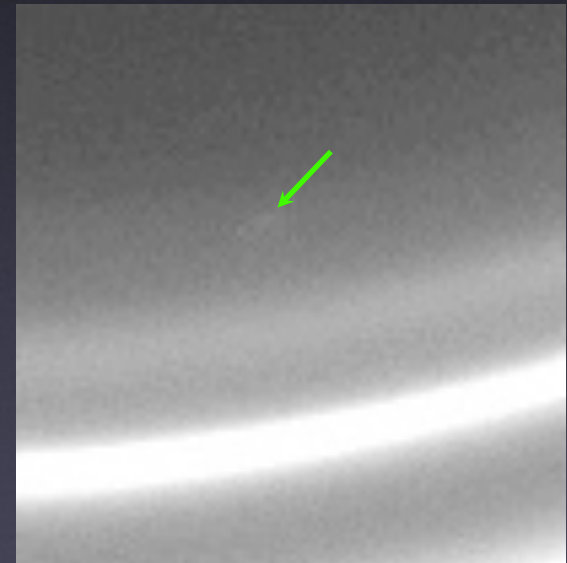
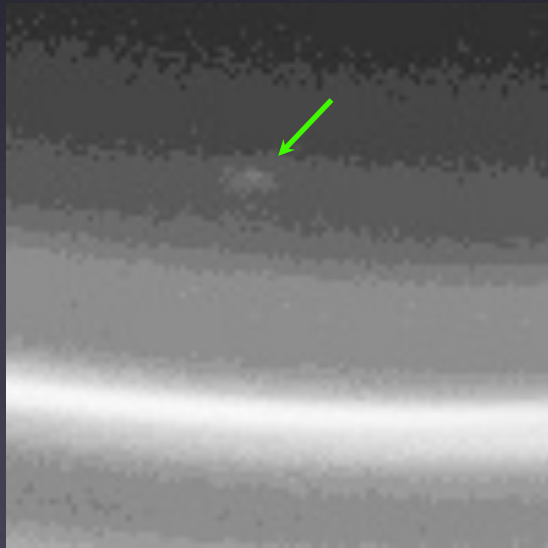
typically
~6
detections
of
each
object



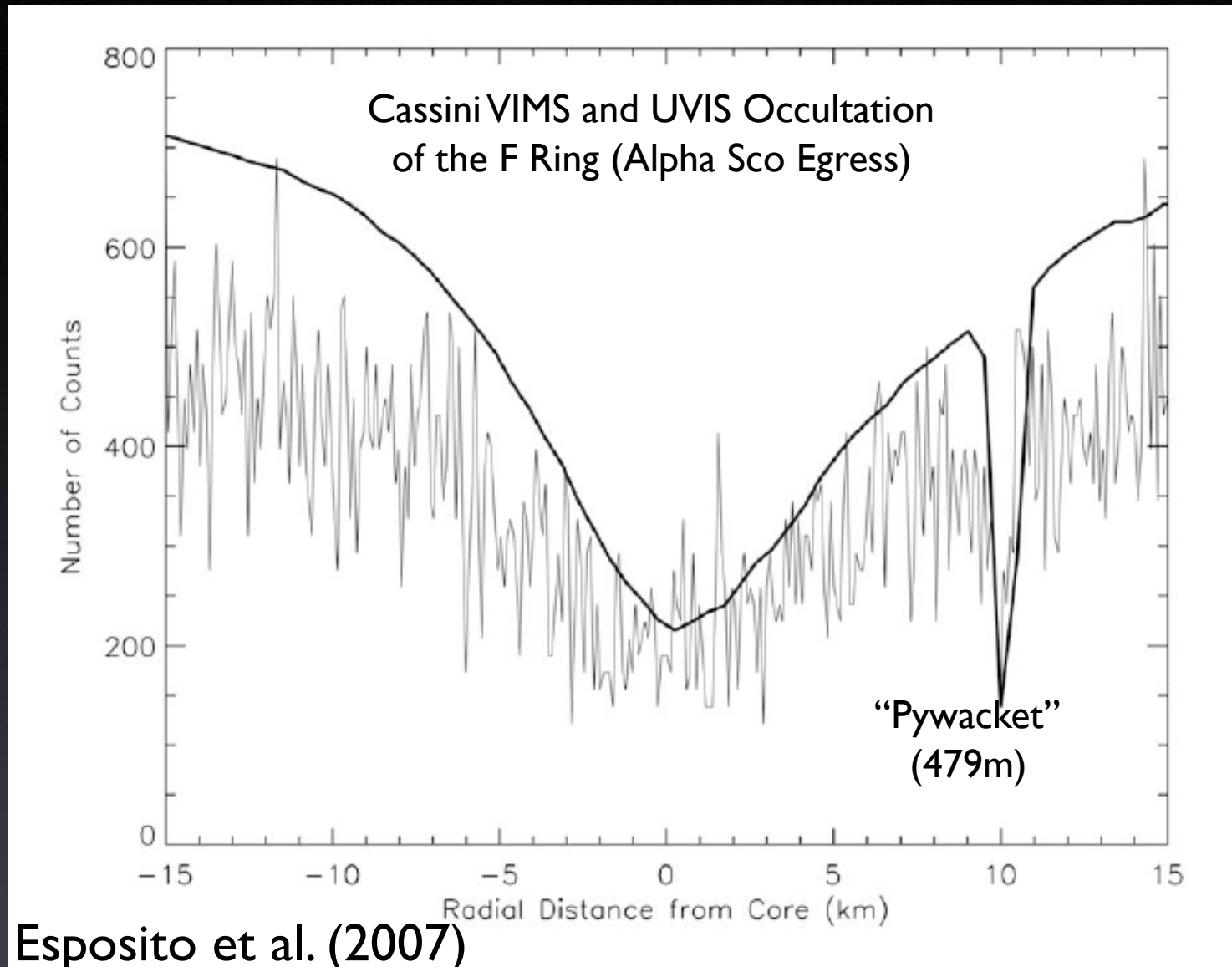
2005 DOY 123,4 Detections



typically
~6
detections
of
each
object



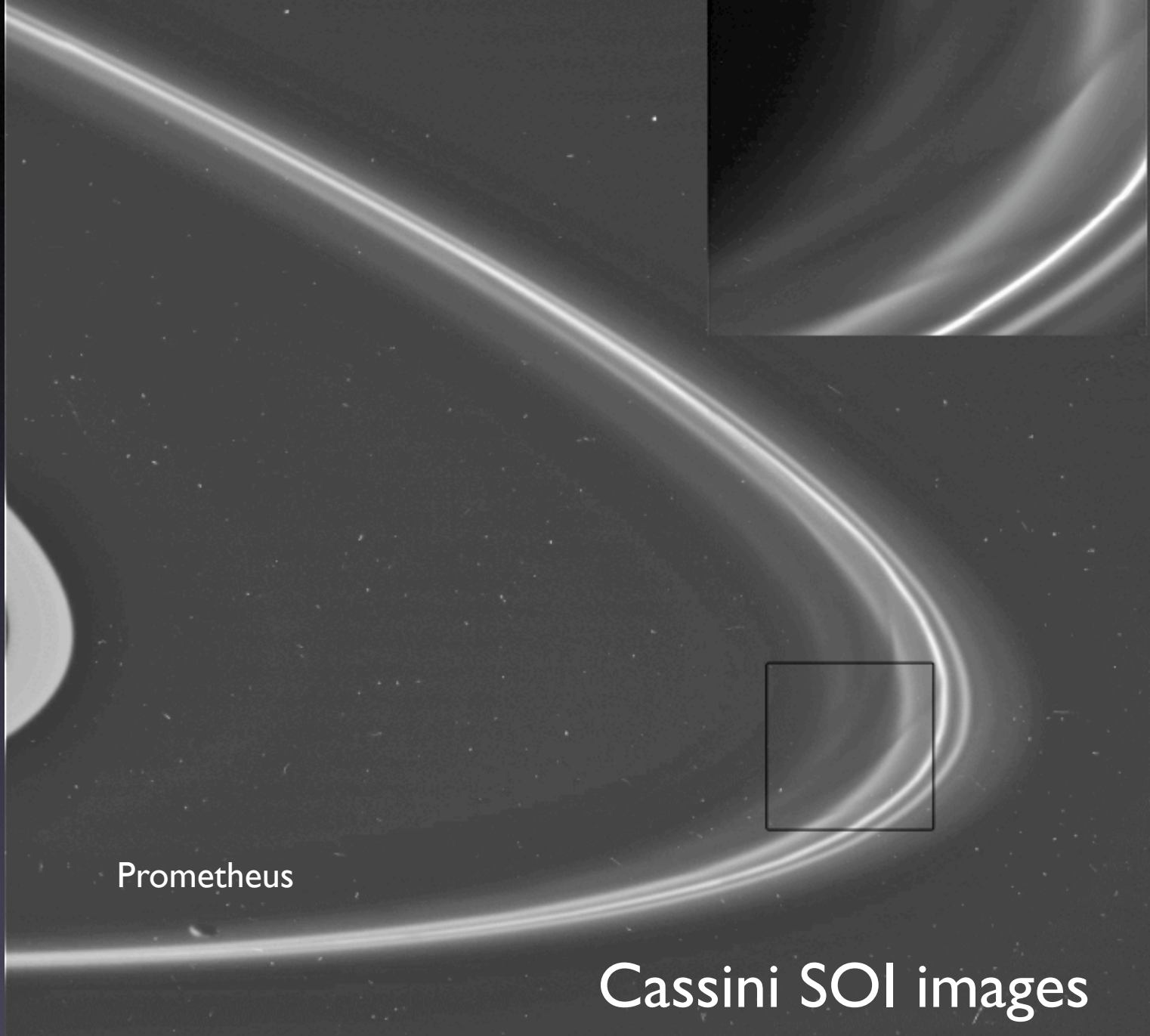
Evidence for Additional Objects Near F Ring Core



13 objects detected, all within ~ 10 km from core;
mostly semi-opaque; sizes in the range 30 m – 9 km

WAC

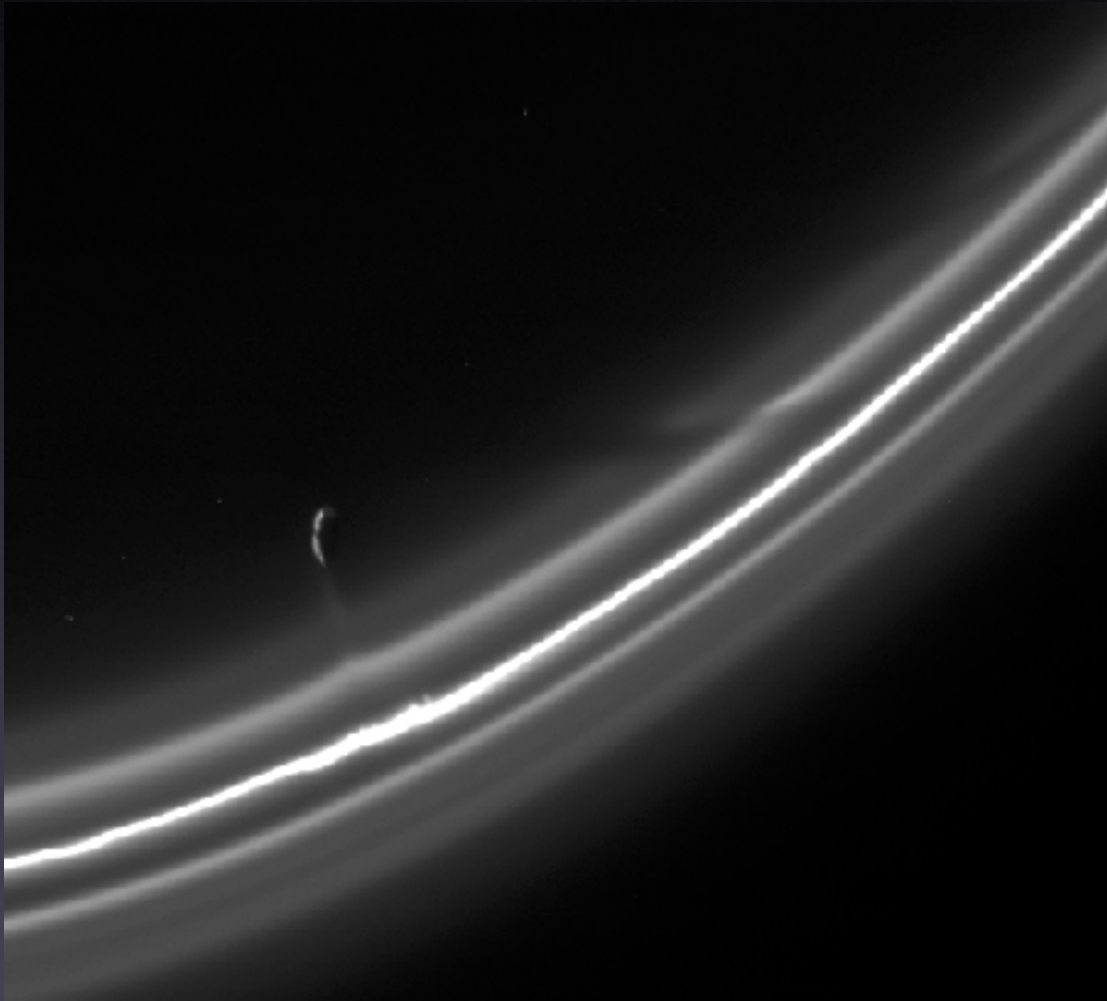
NAC



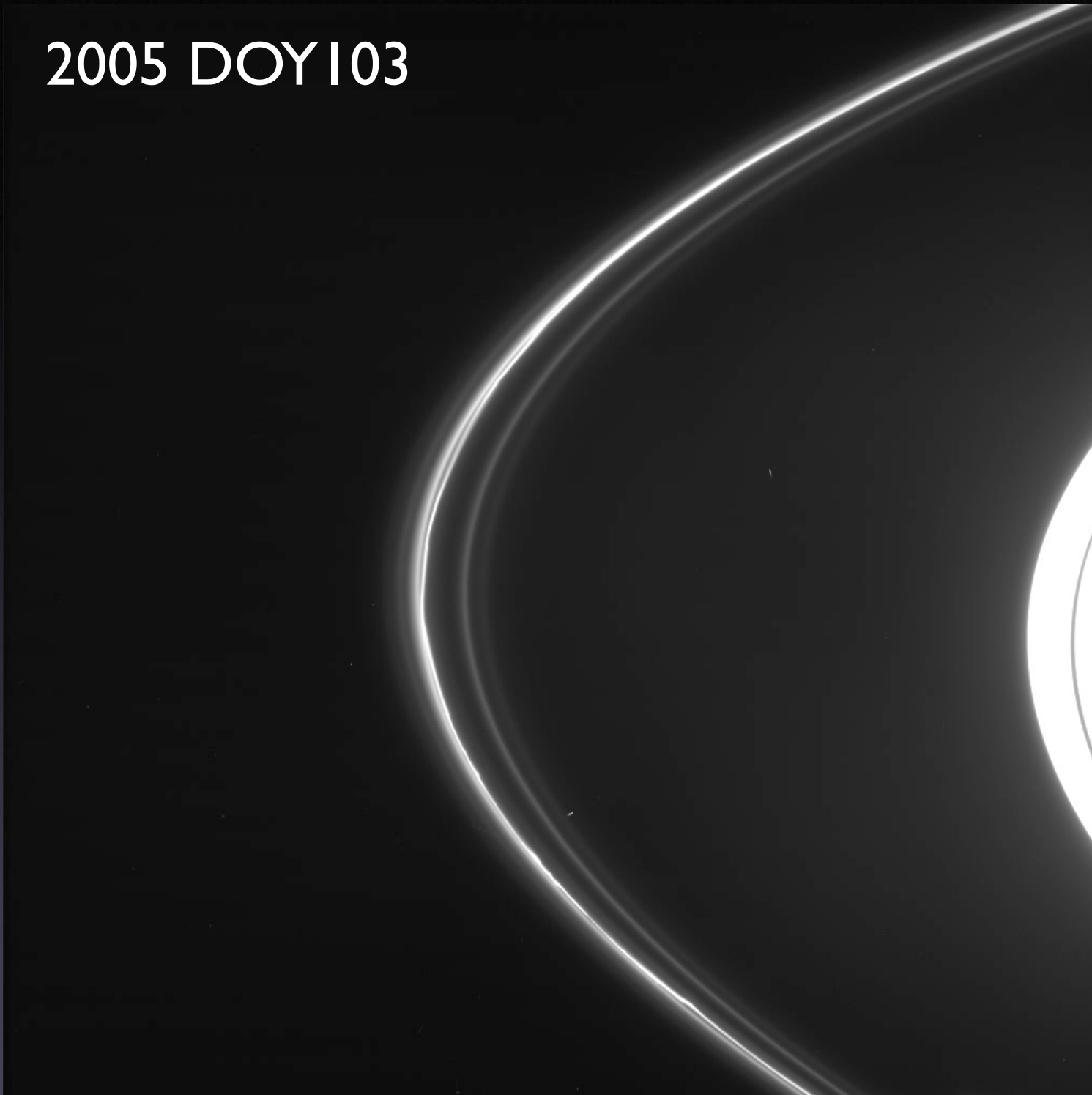
Prometheus

Cassini SOI images

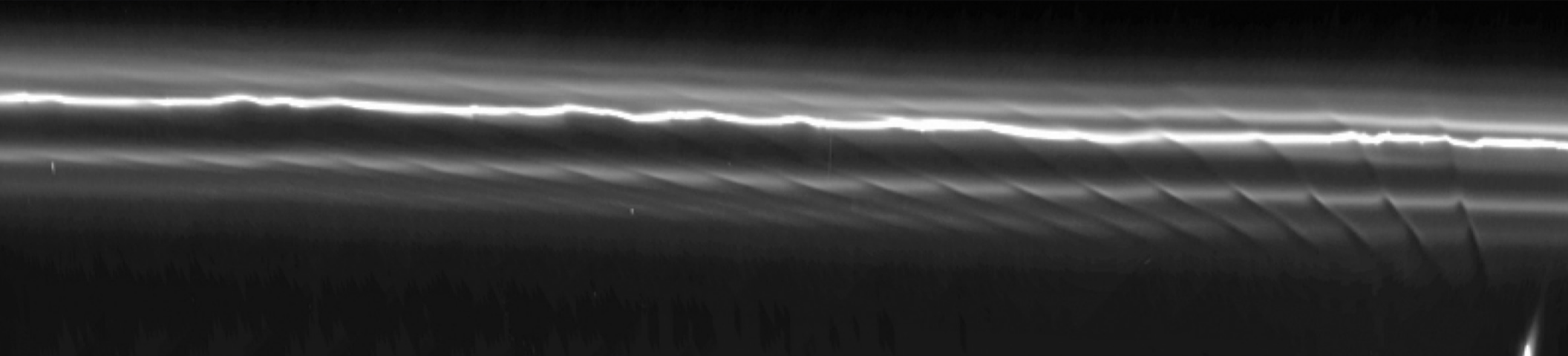
Production of “streamers” and “channels” by Prometheus



2005 DOY 103



Sheared channels in F ring



Pr

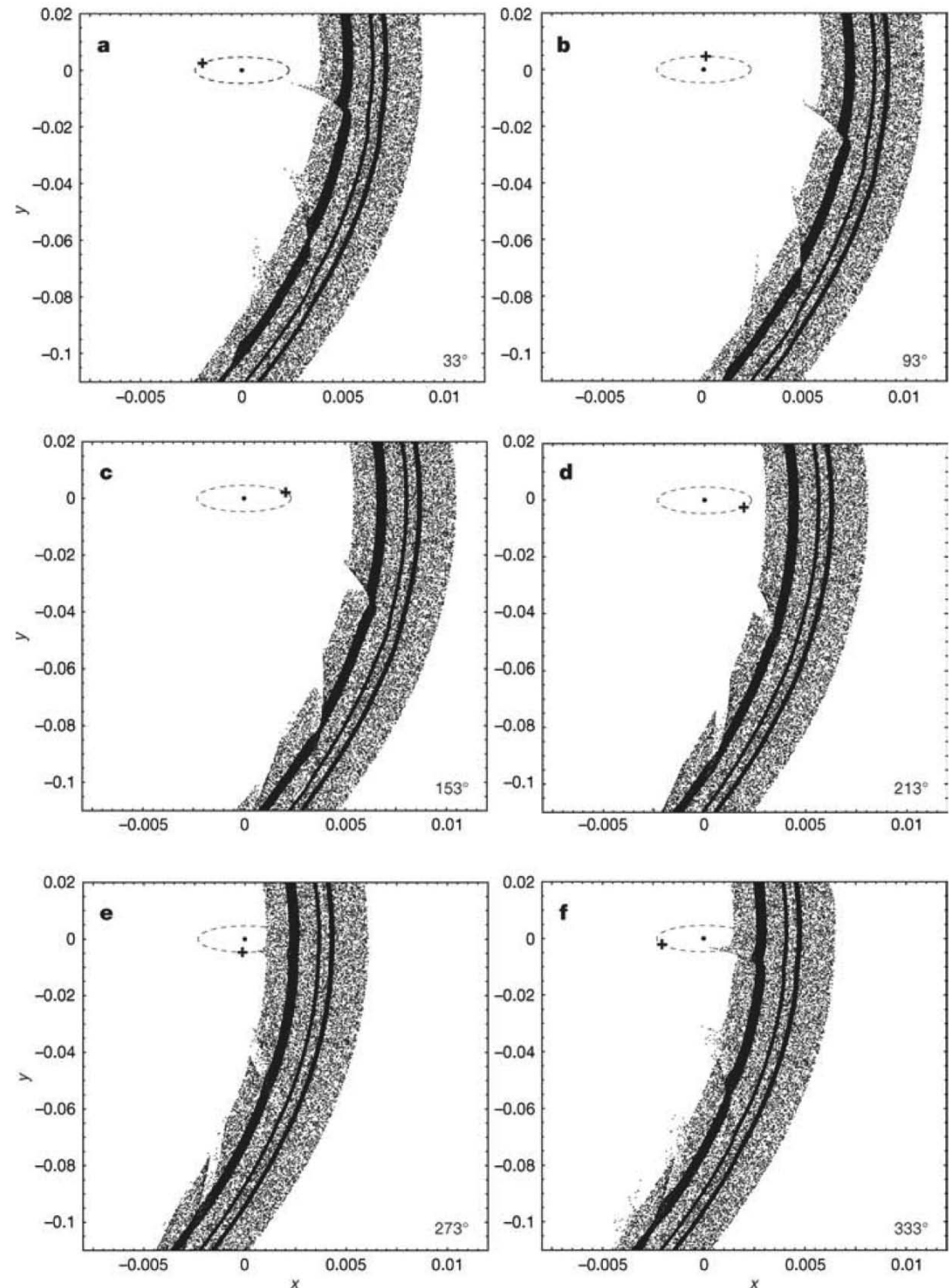
2005 DOY 103 FMOVIE

Numerical simulation of Prometheus interacting with F ring particles



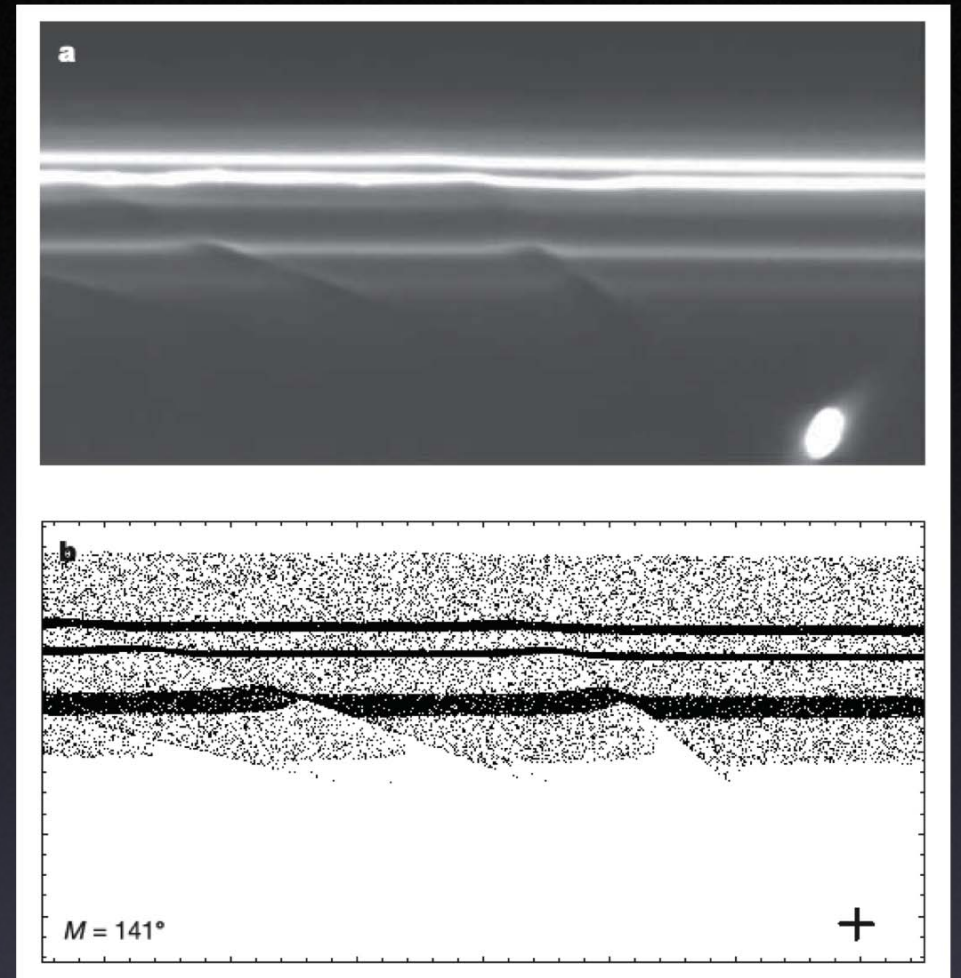
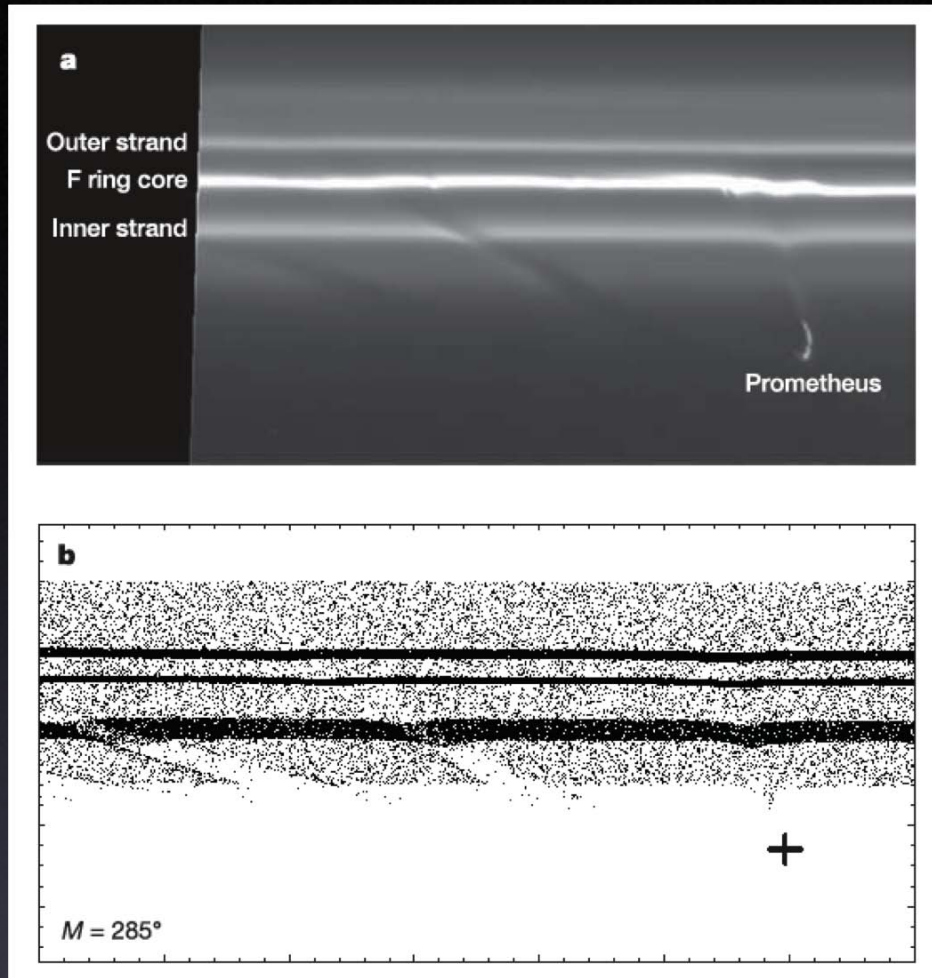
Frame is moving with the average speed of Prometheus

The perturbing effect of Prometheus



Murray et al. (2005)

Comparison of simulation with Cassini images



Murray et al. (2005)

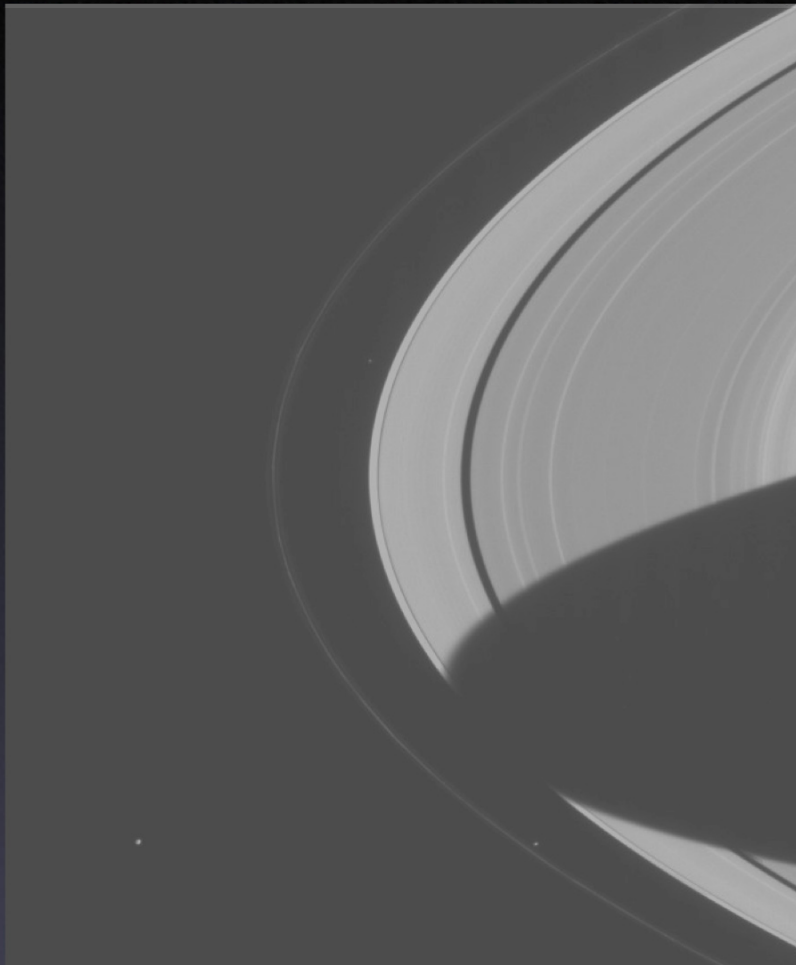
Prometheus perturbing the F ring



ISS_033RF_FRSTRCHAN001_PRIME

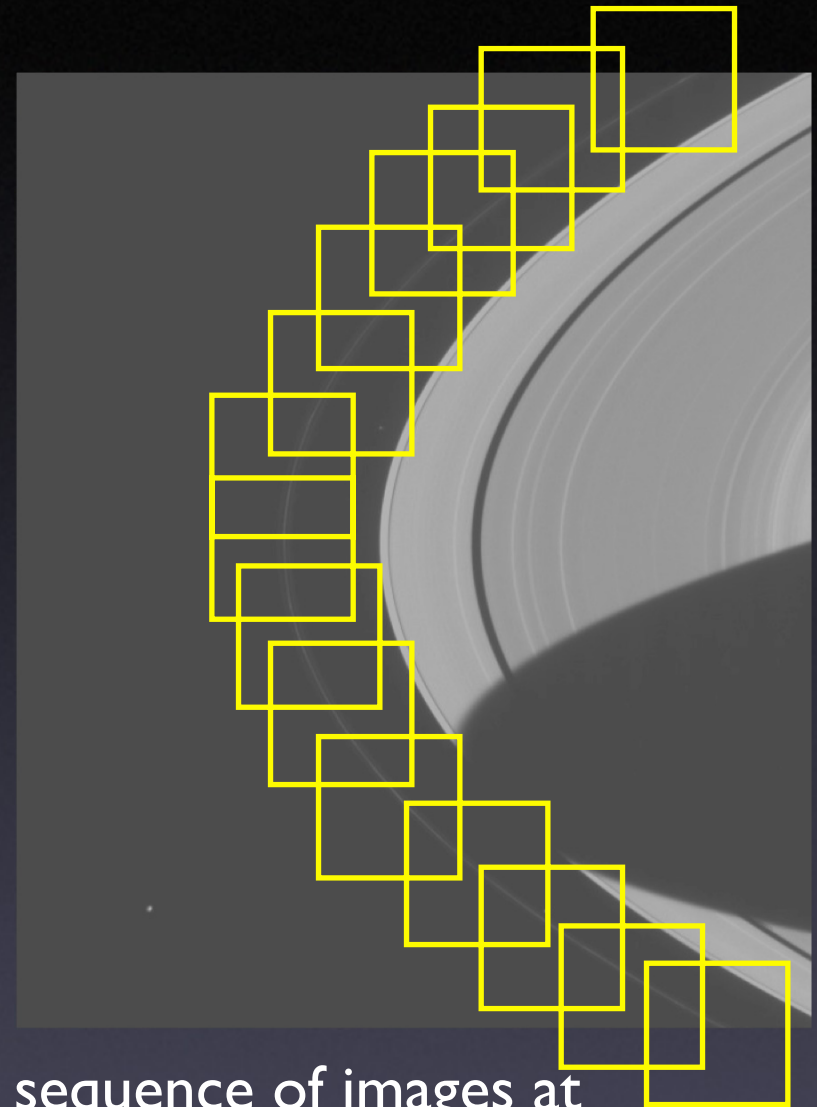
Two Ways To Obtain Longitudinal Coverage

“FMOVIE”



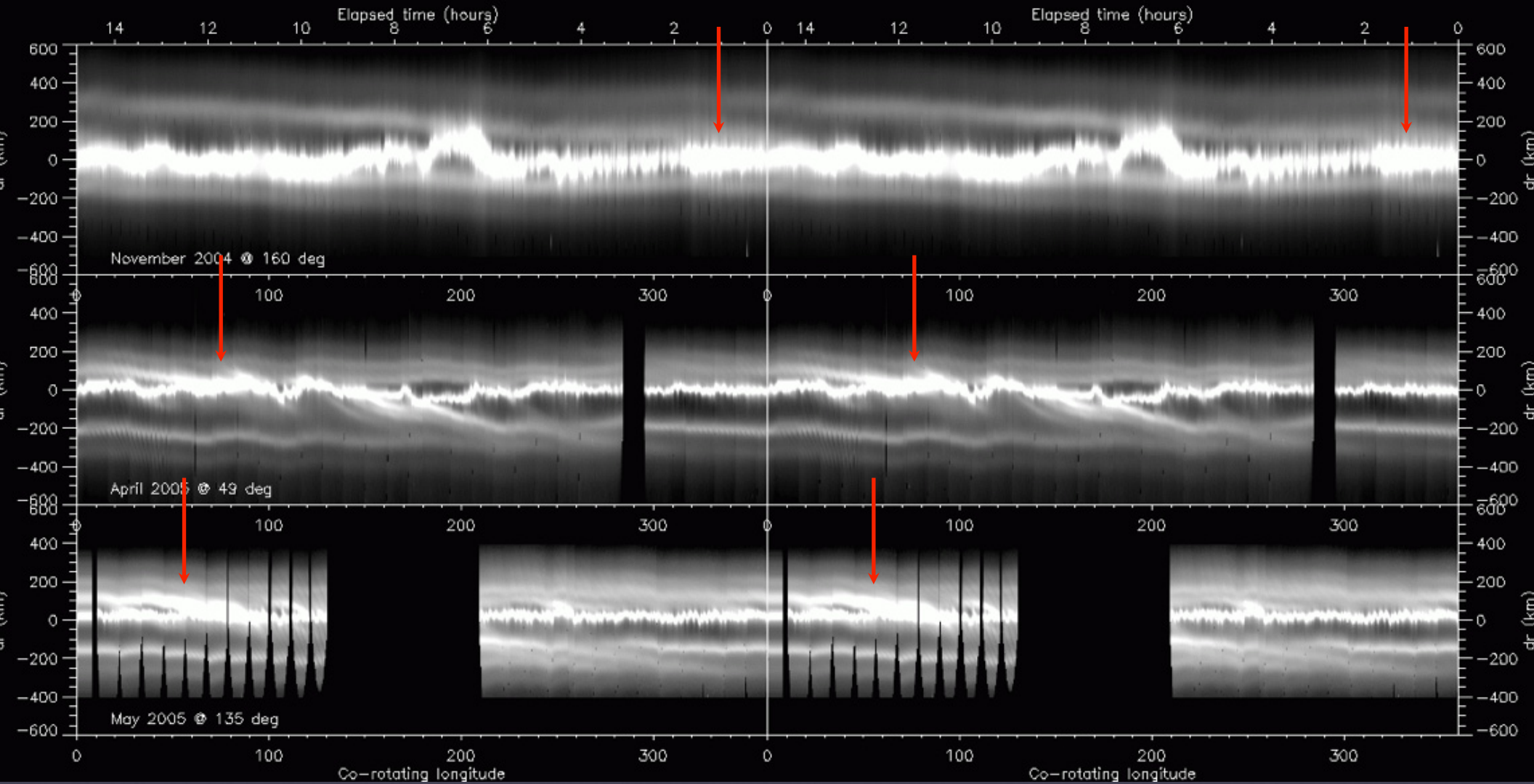
sequence of images at
near-constant inertial
longitude

“AZSCAN”

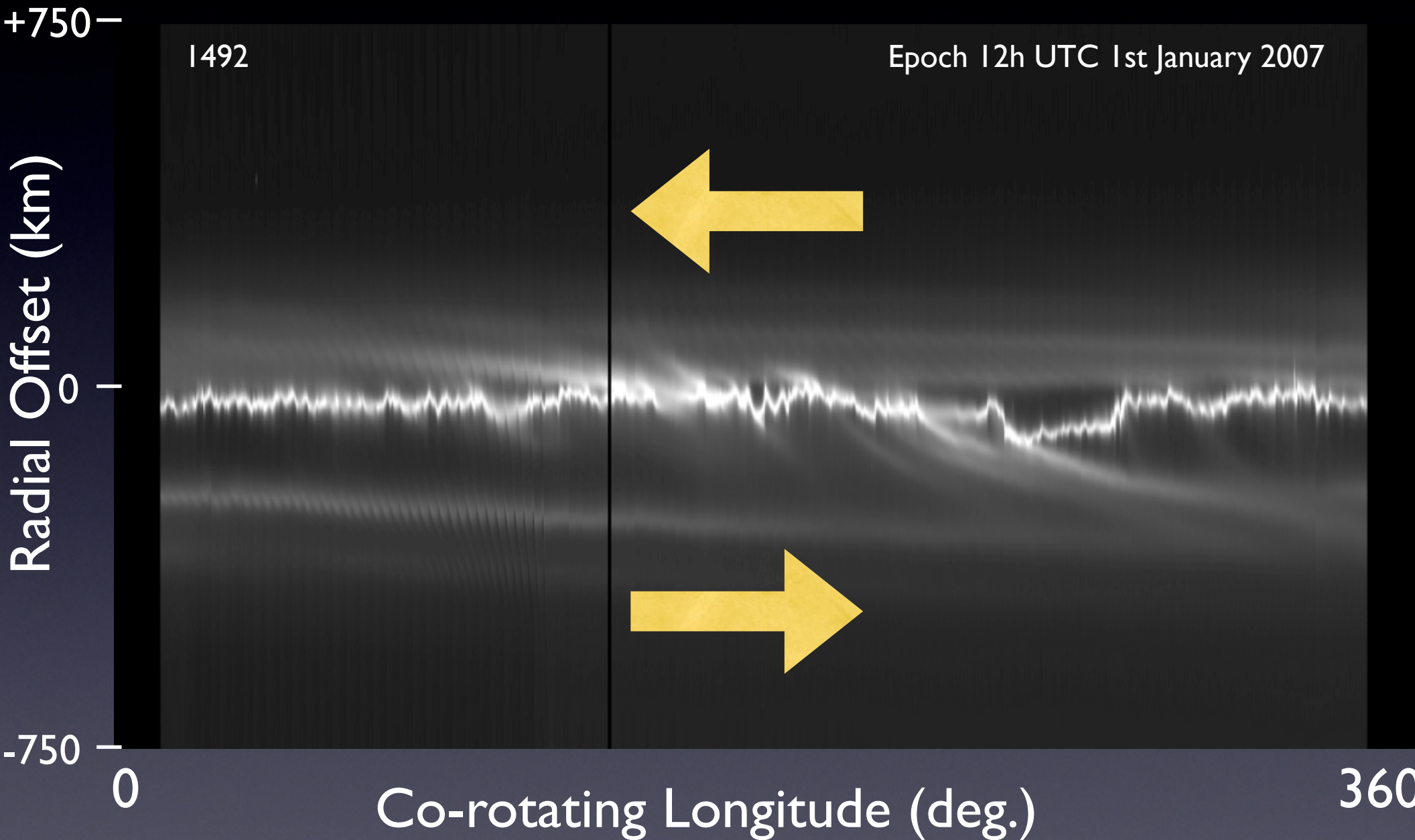


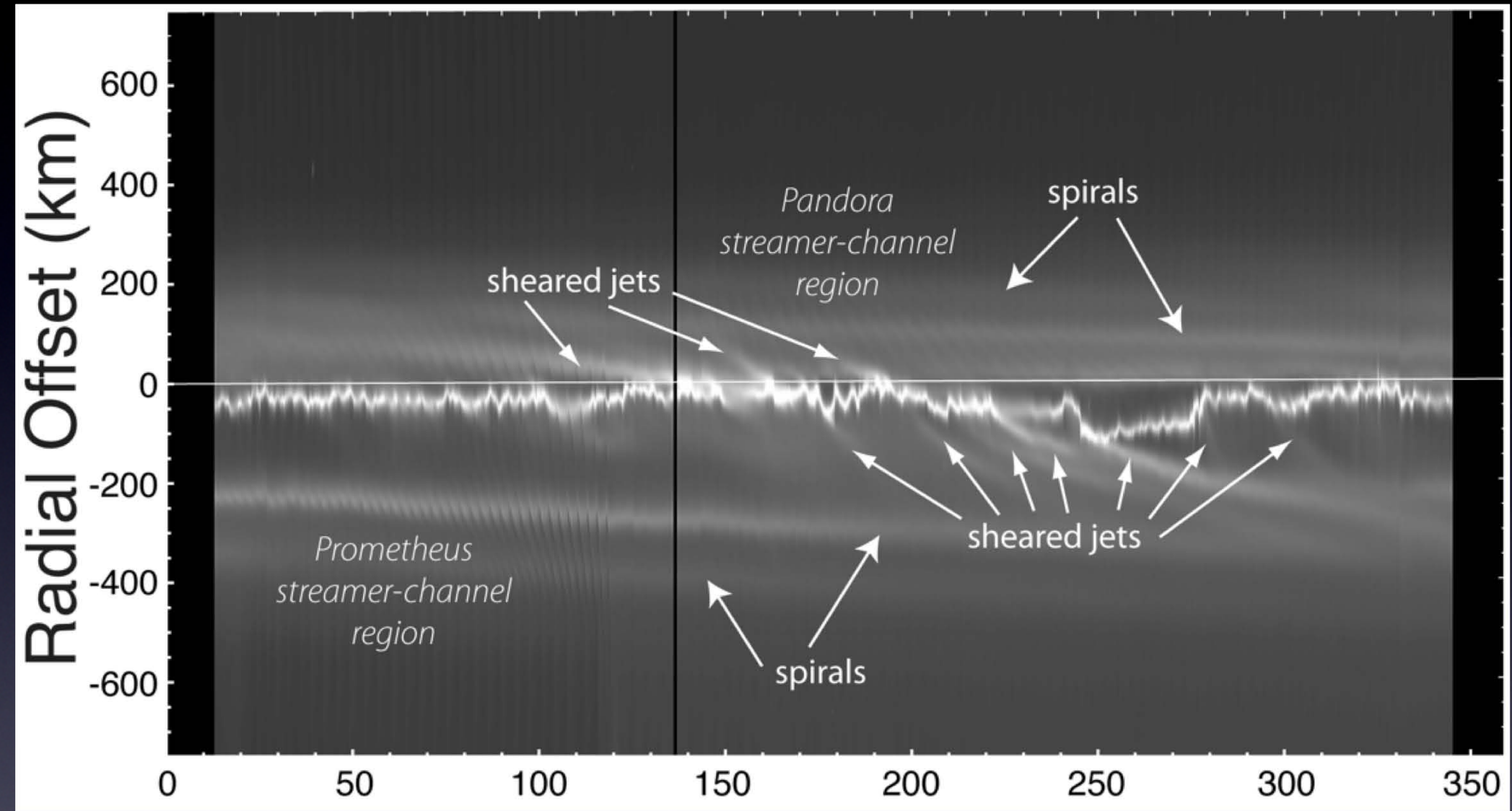
sequence of images at
various inertial
longitudes

Spiral structure of F ring strands



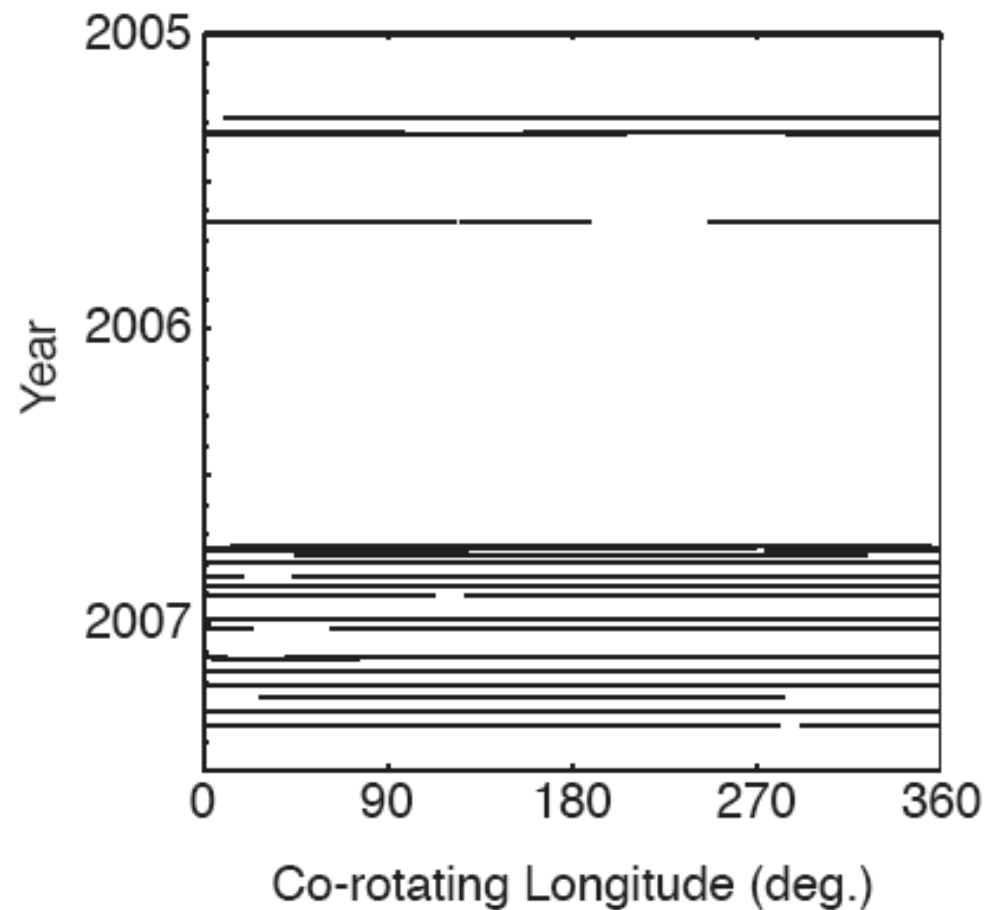
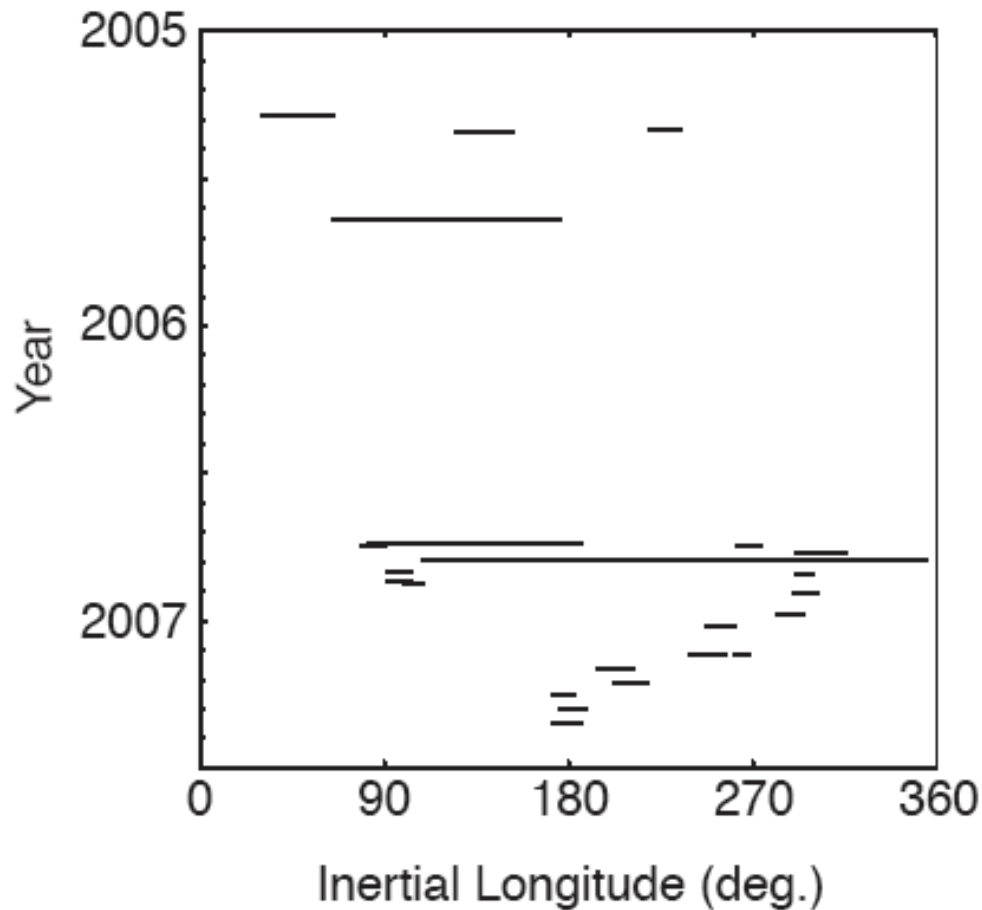
Sample Mosaic of F Ring (2005 DOY103) Co-rotating with F Ring's mean motion





Colwell et al. (2009)

Cassini ISS F Ring Longitudinal Coverage 2005–2007



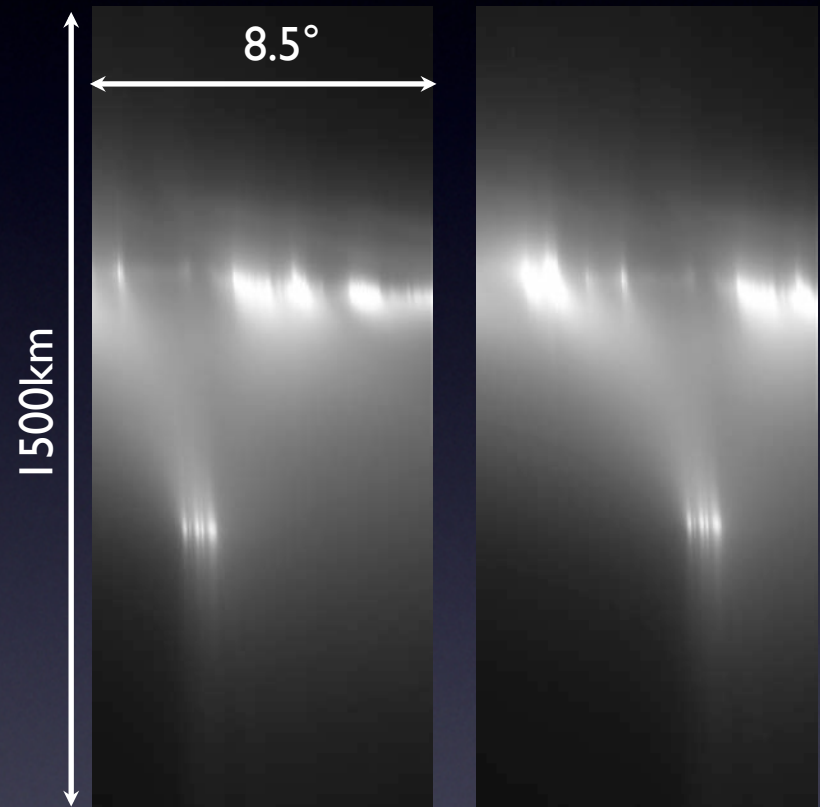
Evidence for Larger Objects Near the F ring

Major event in F ring between 2006 DOY329 and DOY357



PIA08863

Reprojected Images



N1545564196

N1545564642

radial motion ~ 200 km/h outwards

Detections of S/2004 S 6

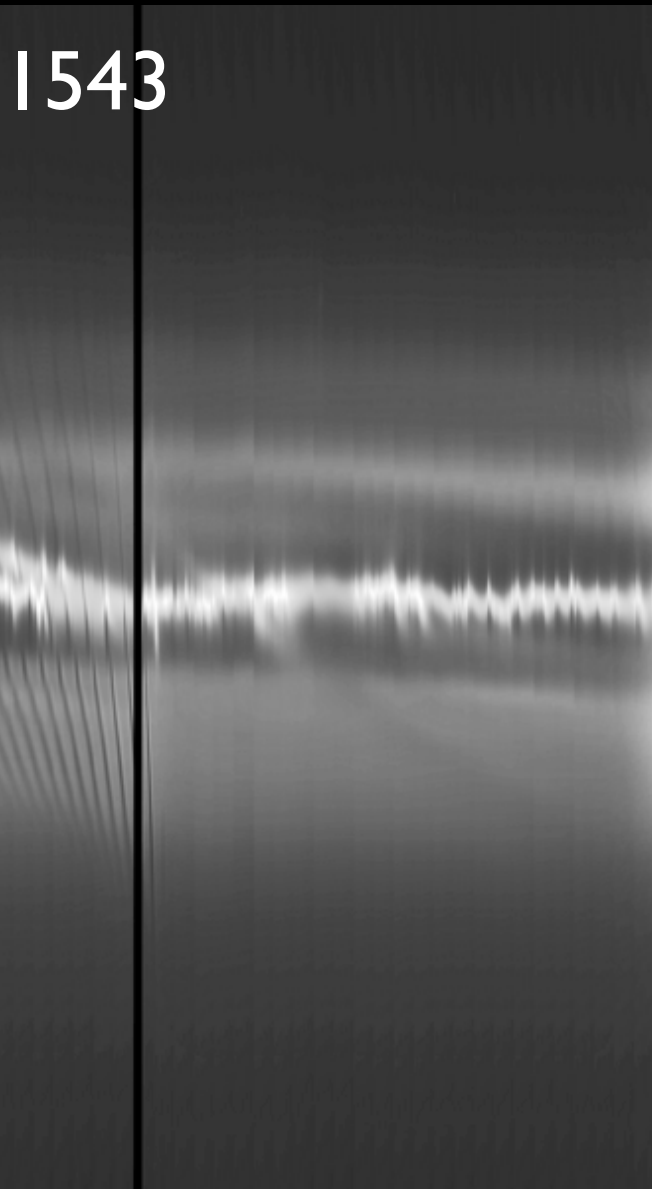
2005 DOY 172



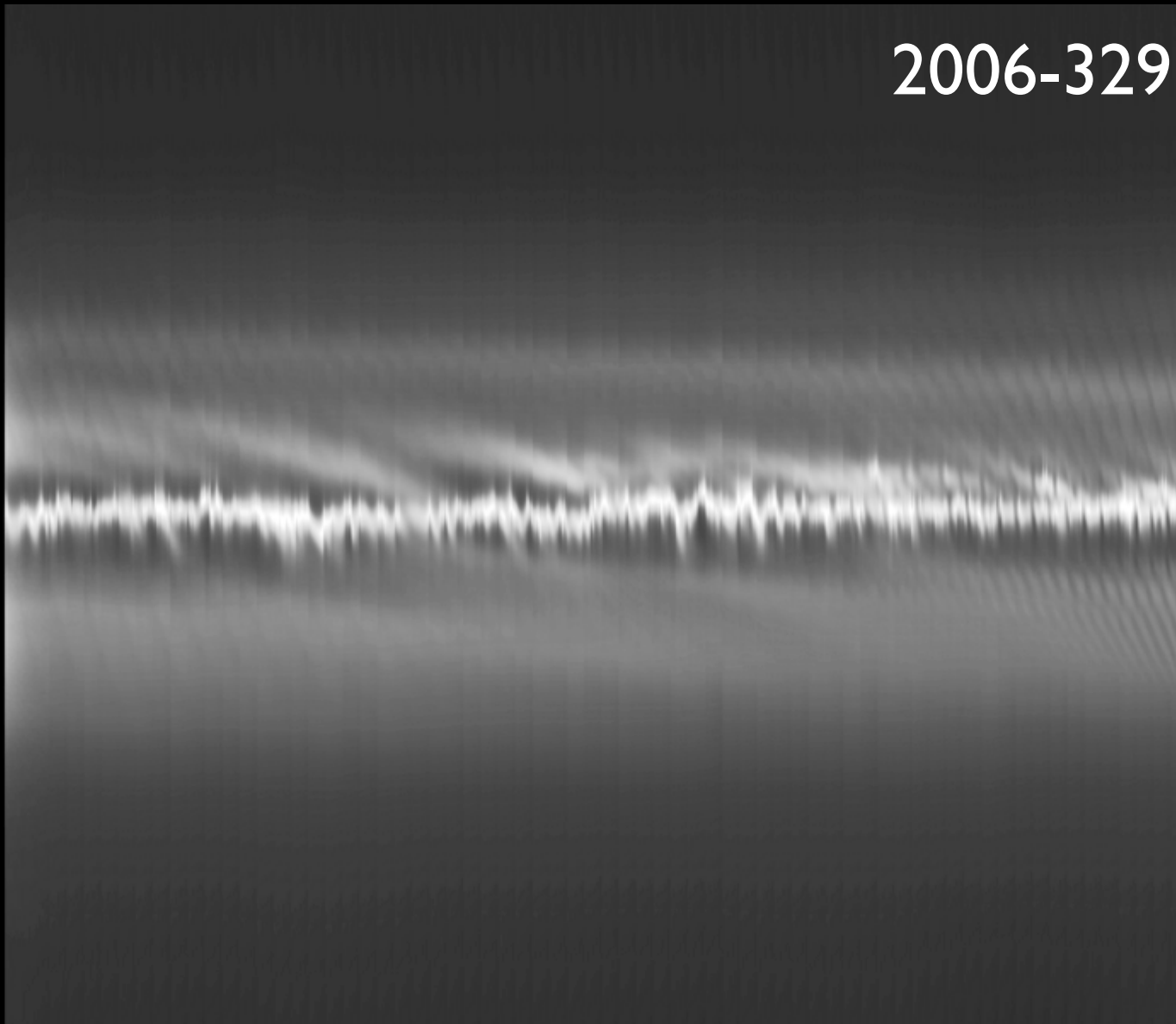
2005 DOY 180



1543

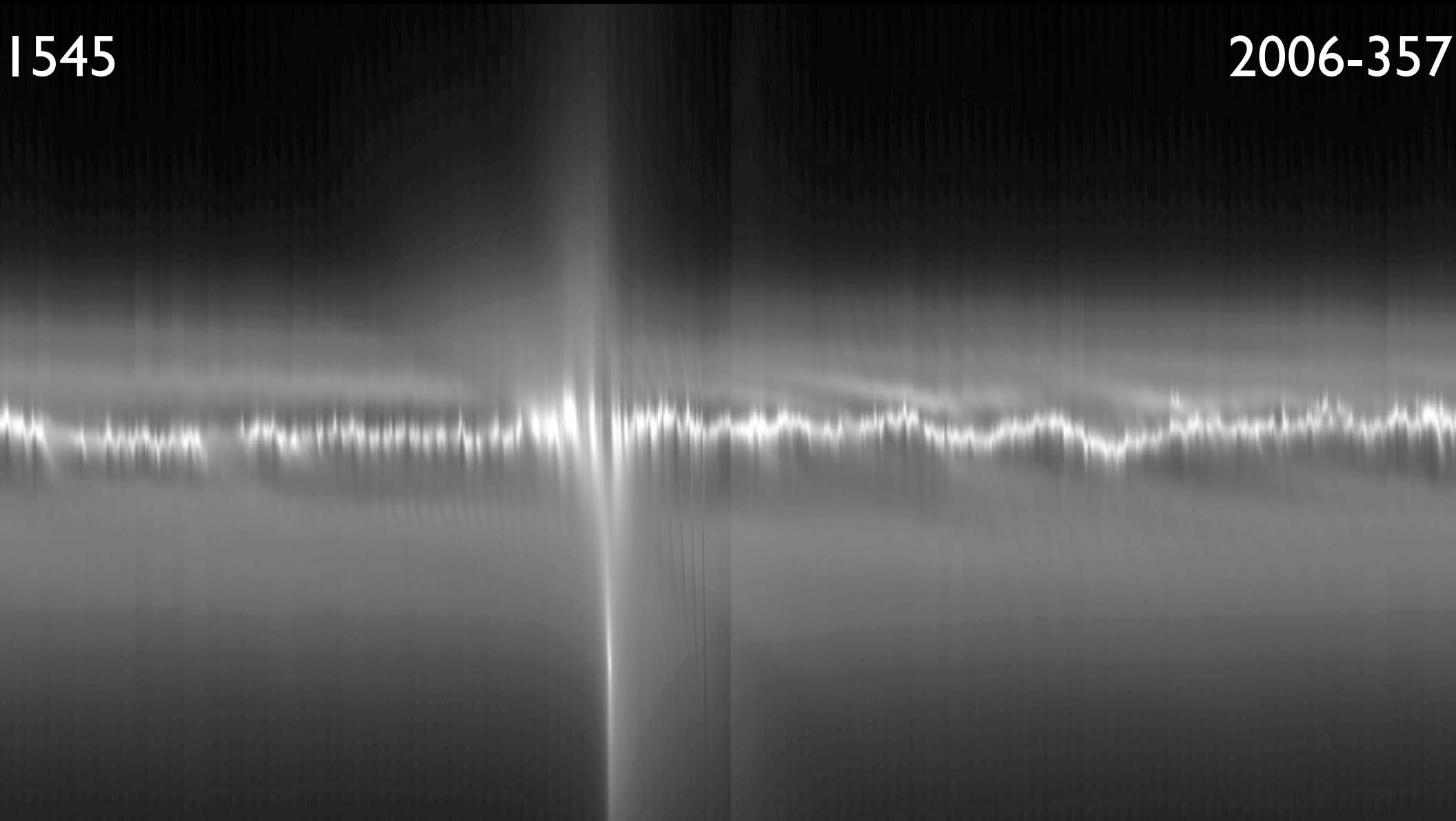


2006-329



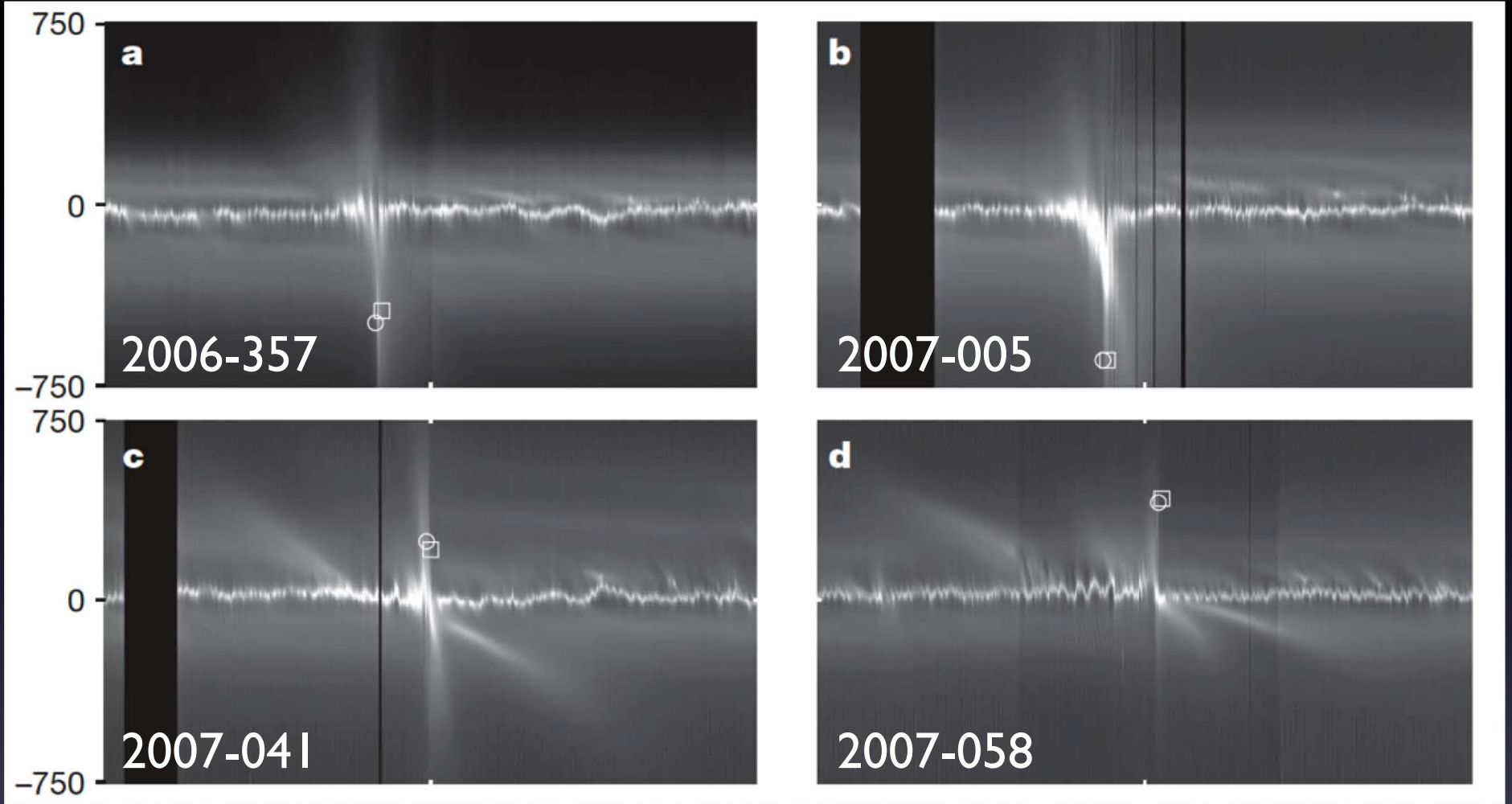
1545

2006-357



Passage of S/2004 S 6

Radial Offset (km)

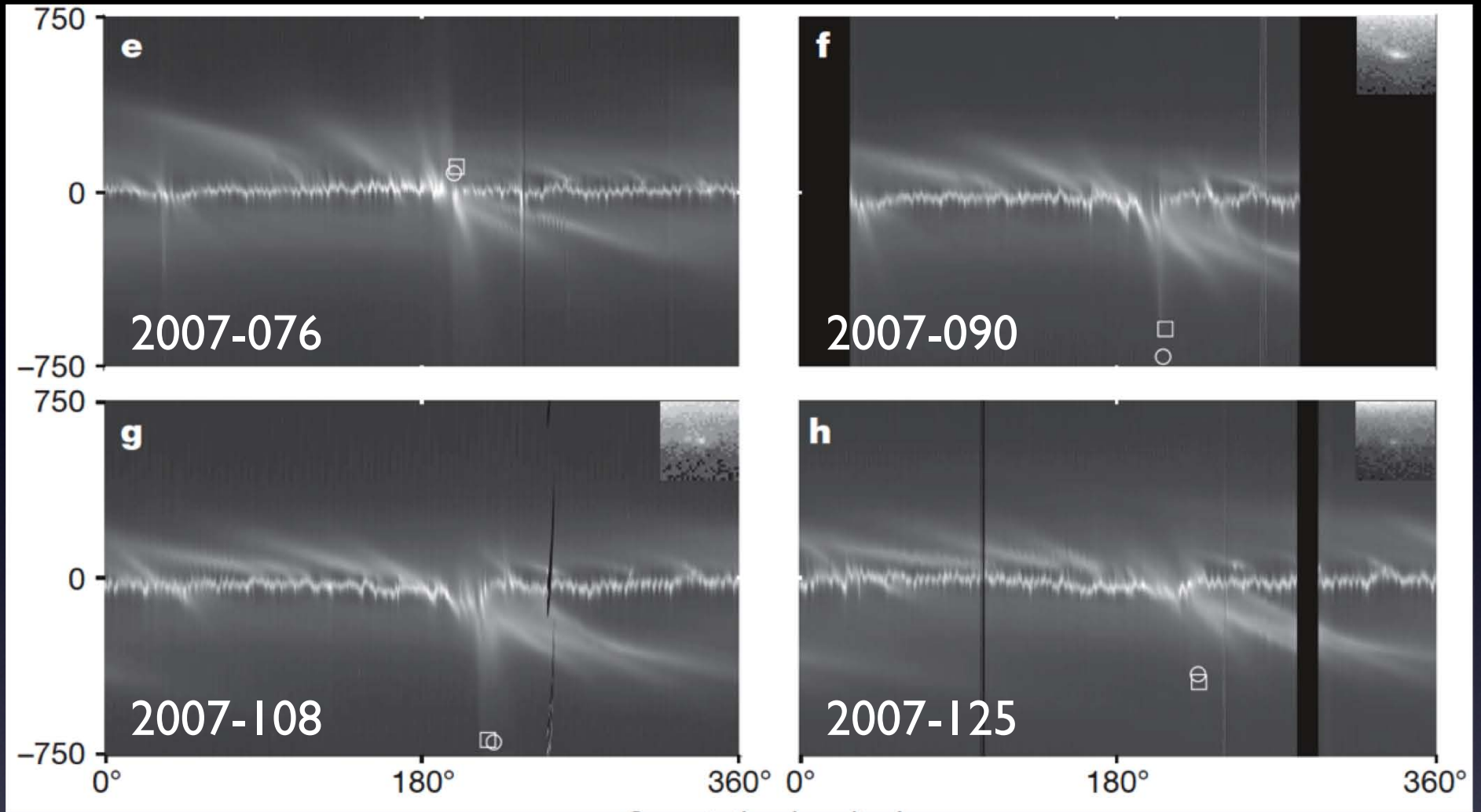


Co-rotating Longitude

Murray et al. (2008)

Passage of S/2004 S 6

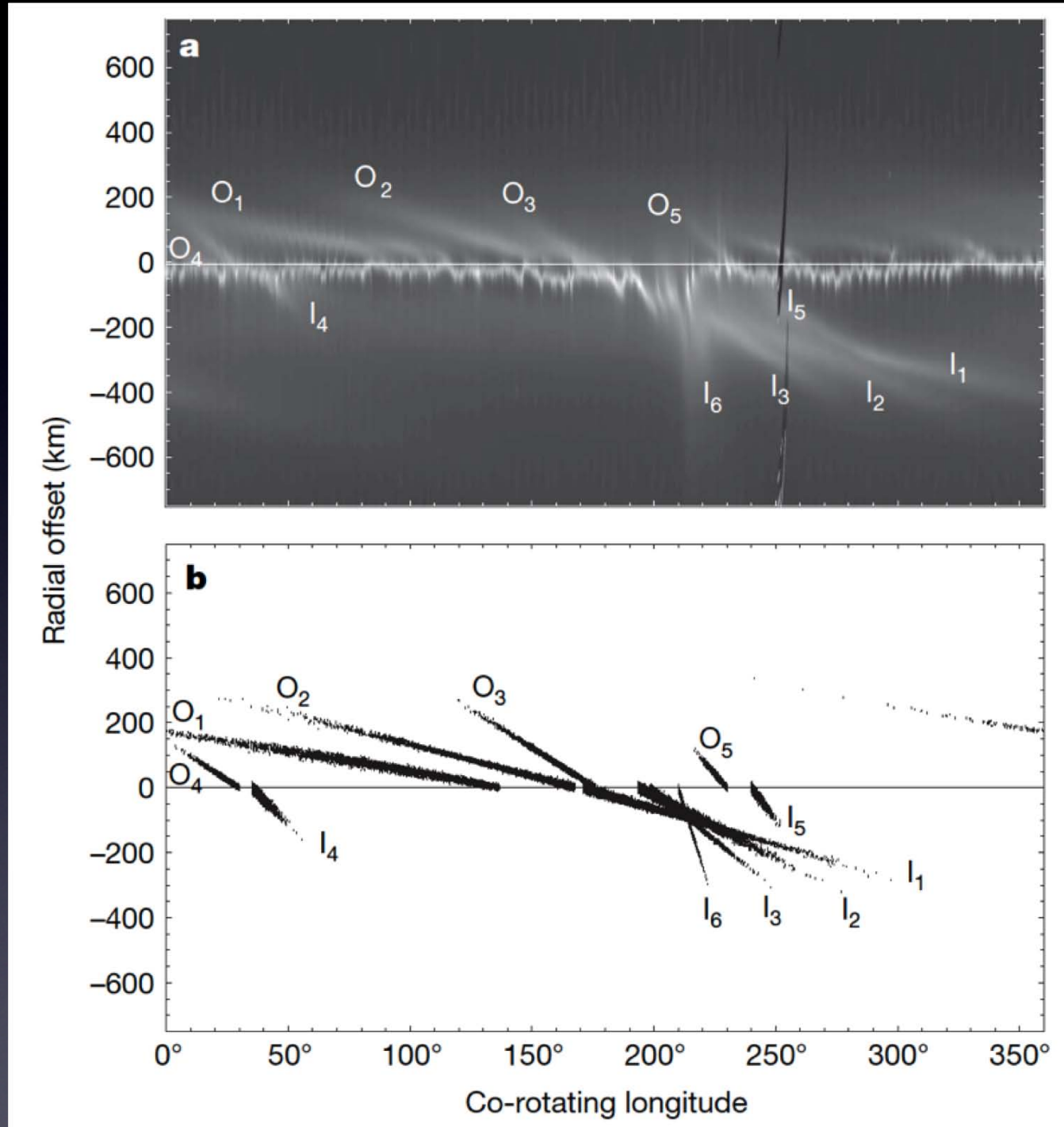
Radial Offset (km)



Co-rotating Longitude

Murray et al. (2008)

Comparison of mosaic with jet simulations

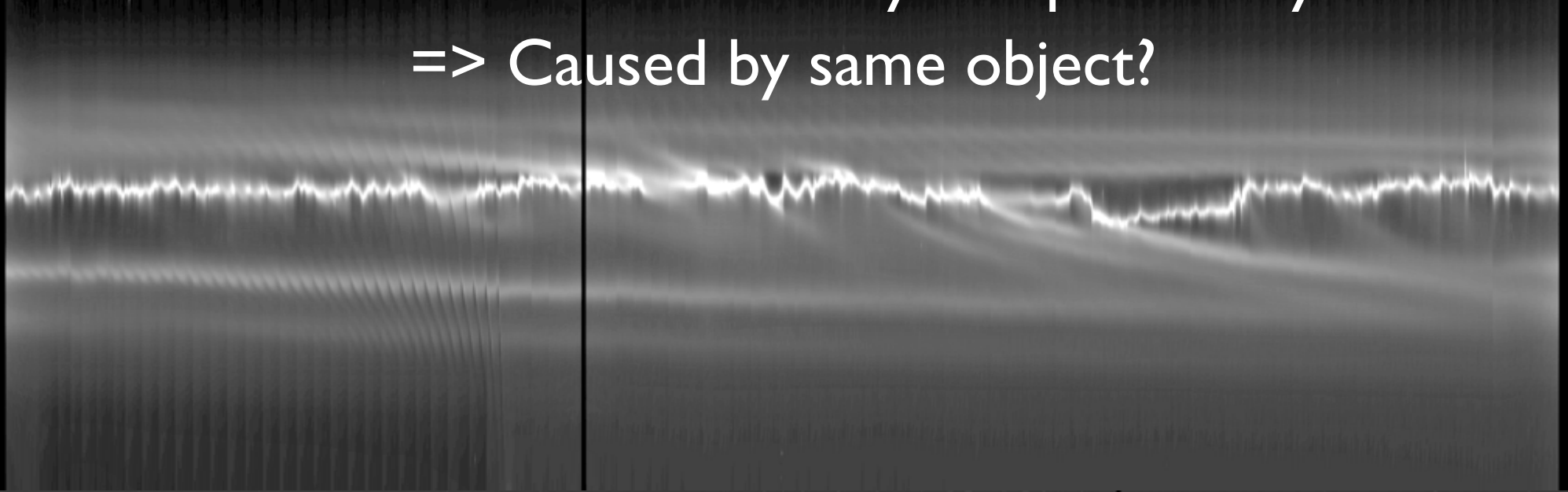


Murray et al.
(2008)

1492

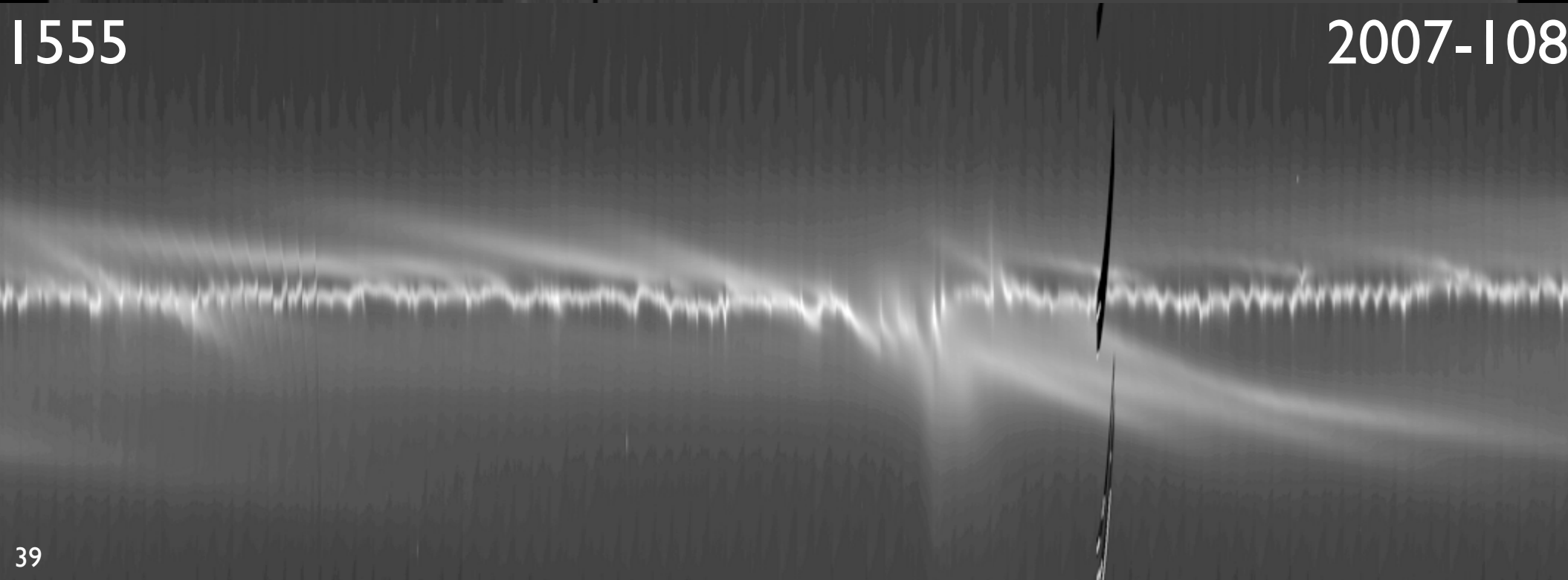
Gross features of F ring are similar
to those that existed 2 years previously
=> Caused by same object?

2005-103



1555

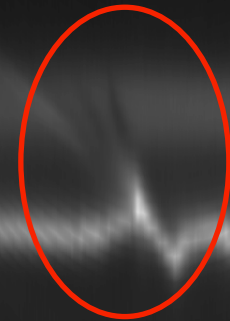
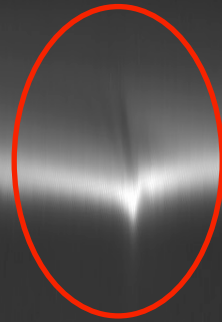
2007-108



NI538169712

NI55287157

NI557039476



Evidence For Embedded Objects in Core
(examples of “fans”)

Effect of embedded satellite on circular orbit

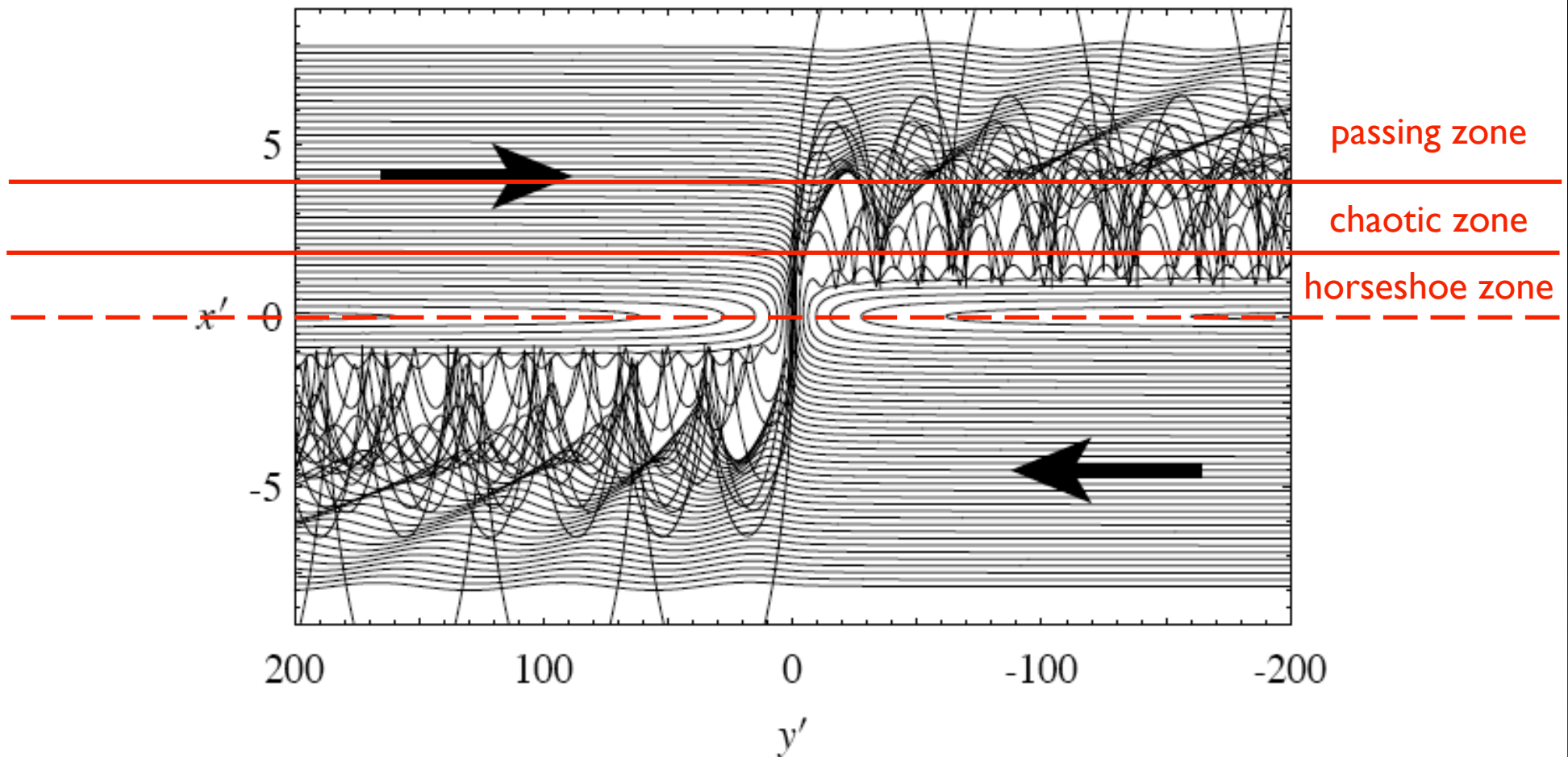
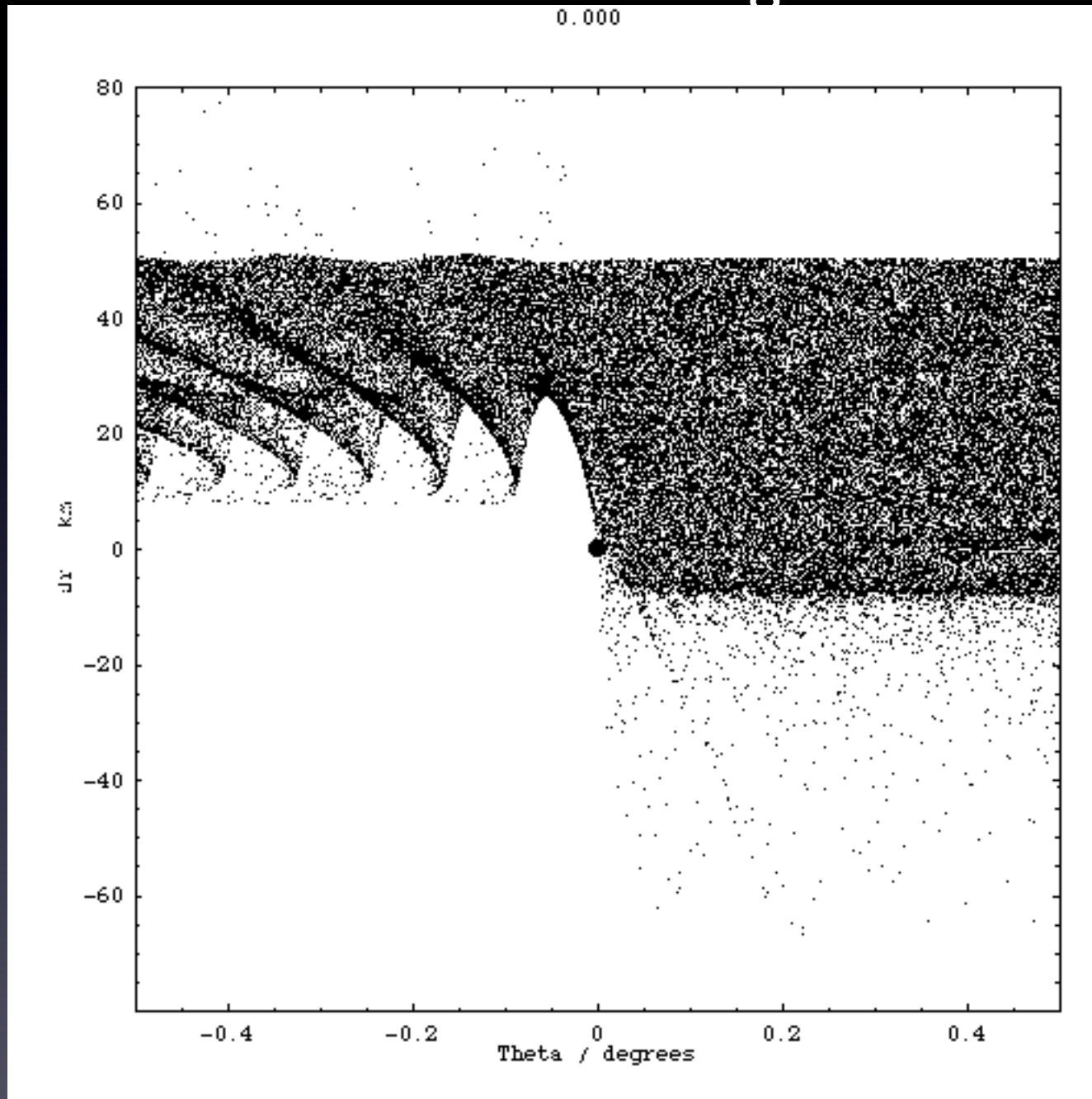
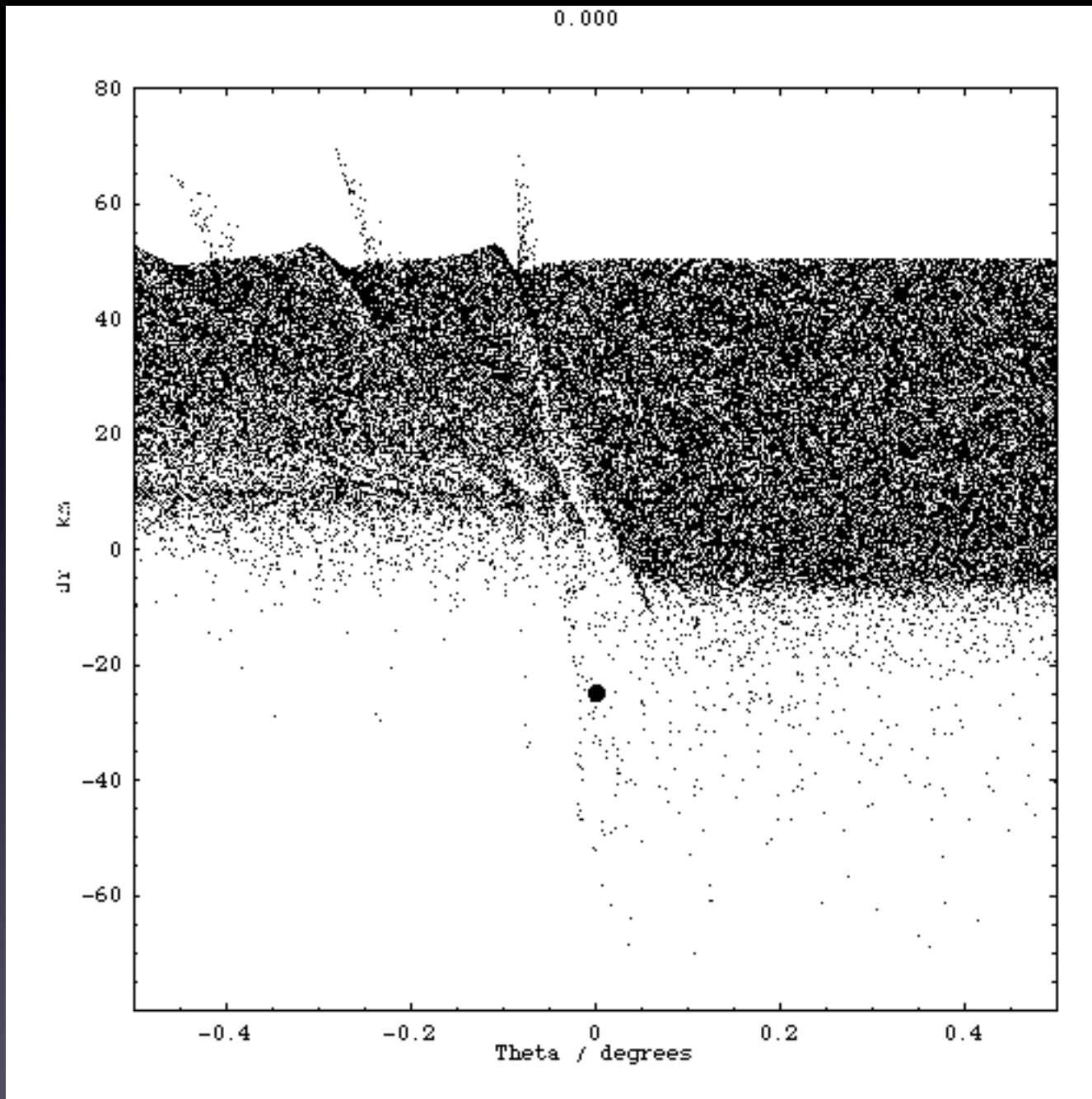


Fig. 3.30. Particle trajectories obtained by solving the scaled form of Hill's equations. The perturbing mass is located at the origin and the L_1 and L_2 points are at $y' = 0$, $x' = \pm 1$. The particles were all started with $\dot{x}' = 0$ (i.e. in circular orbits) at $y' = \pm 200$. The arrows indicate their direction of motion before encountering the perturber.

5km satellite on circular orbit at edge of 50km-wide ring

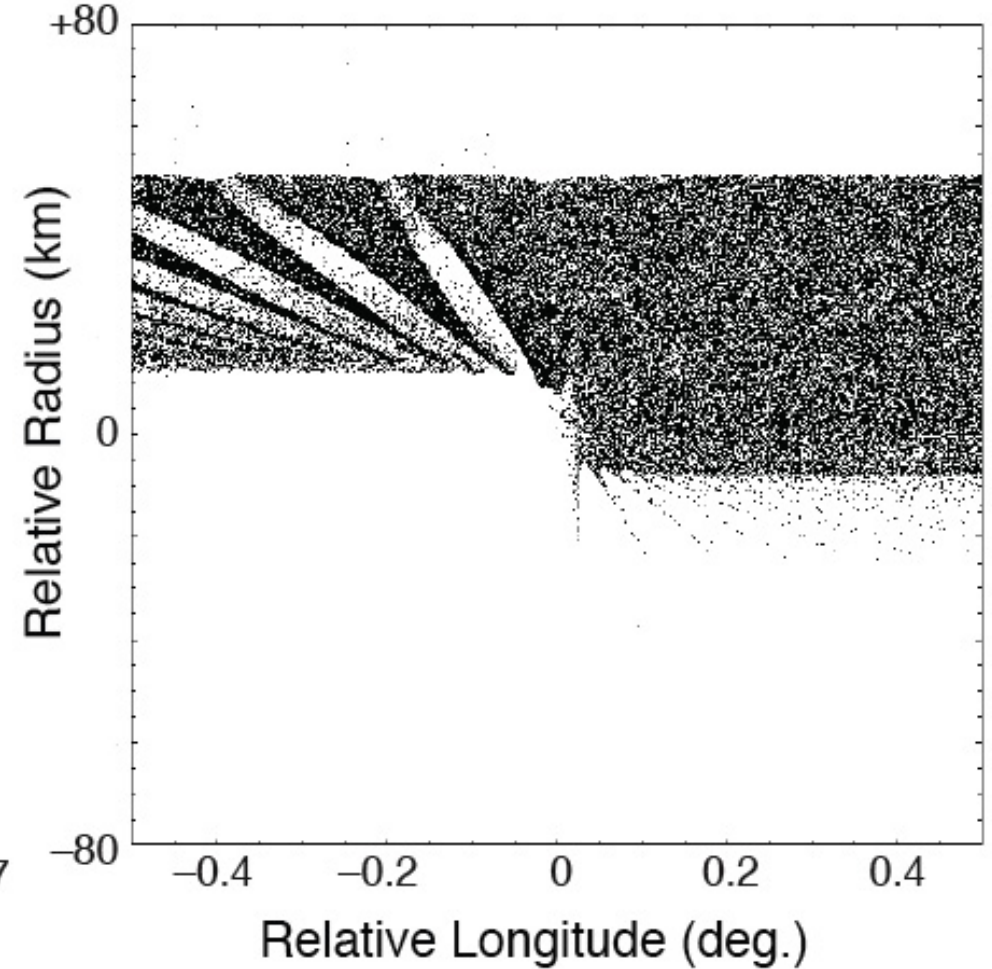
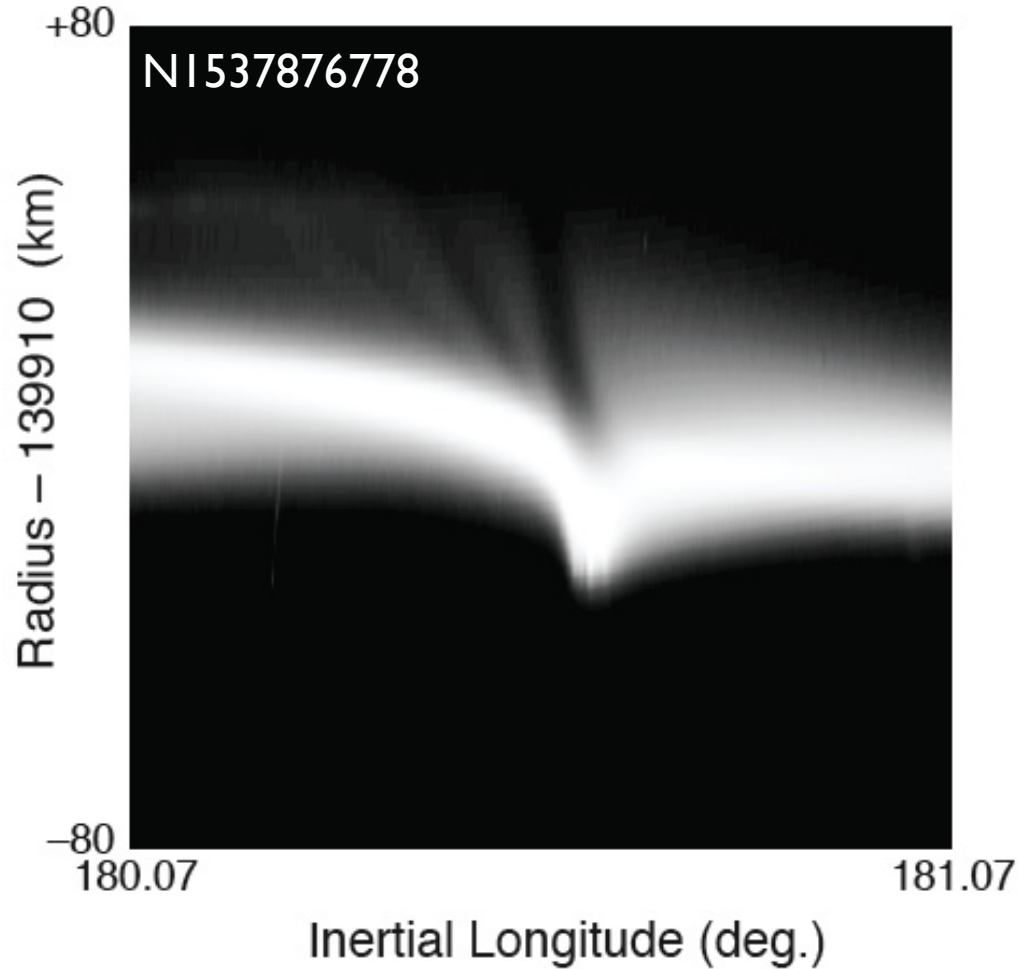


5km satellite on 4ϵ eccentric orbit at edge of 50km-wide ring



Comparison of image with integration

Murray et al. (2008)



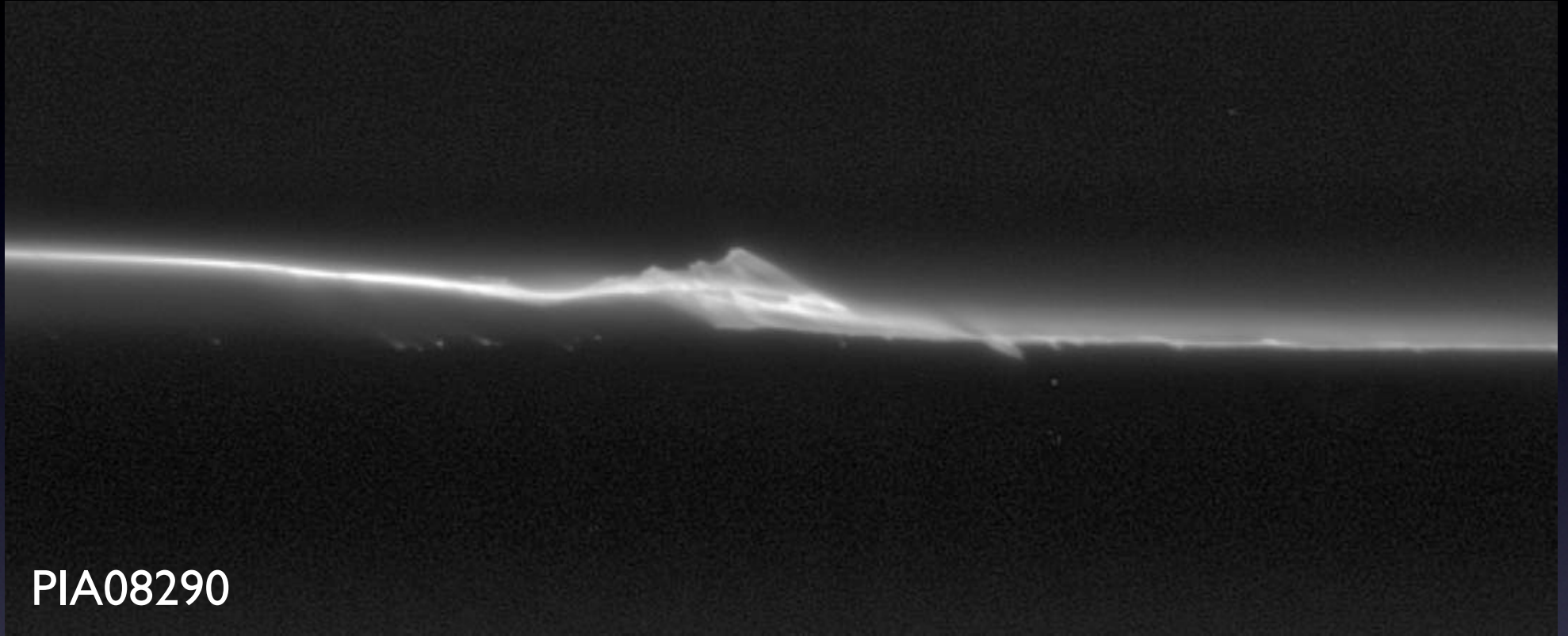
Embedded object on eccentric orbit perturbs adjacent material which acts like a tracer for the gravitational effect of the object — entirely analagous to the mechanism by which Prometheus creates channels in the F ring



PIA09782

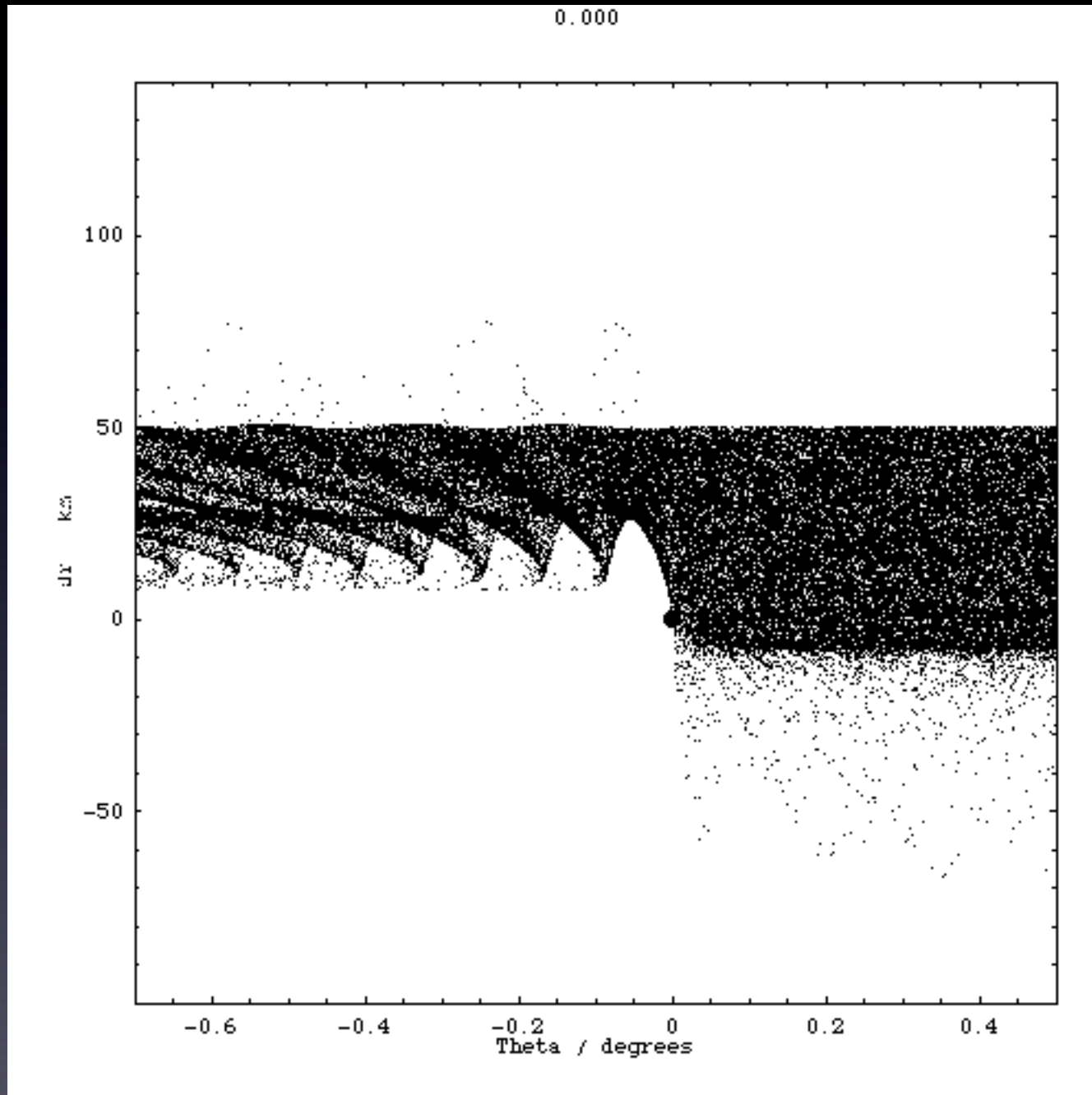
Reprojected image showing “fans”





PIA08290

Embedded satellite plus Prometheus conjunction

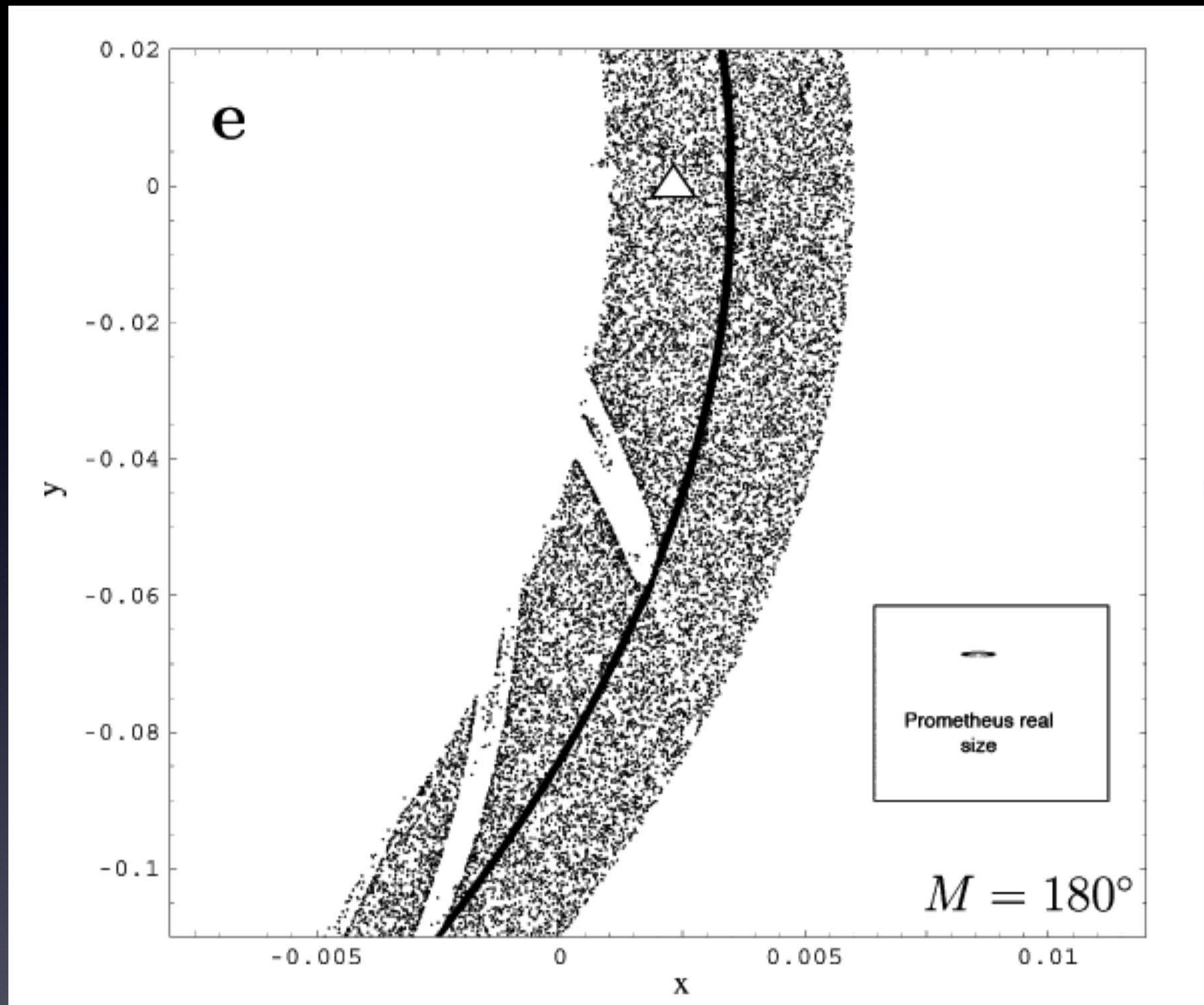


PIA 10593



Prometheus

Numerical simulation



Chavez (2009)

Conclusions

- There exist several hundred small (radius < 1 km) moonlets/clumps in the vicinity of the F ring
- Prometheus creates the “streamer-channel” structures in the F ring
- Collisions between objects (such as S/2004 S6) and the core lead to jet formation
- The “fans” suggest the presence of embedded objects which themselves get perturbed
- The complex nature of the F ring can be understood by relatively simple processes