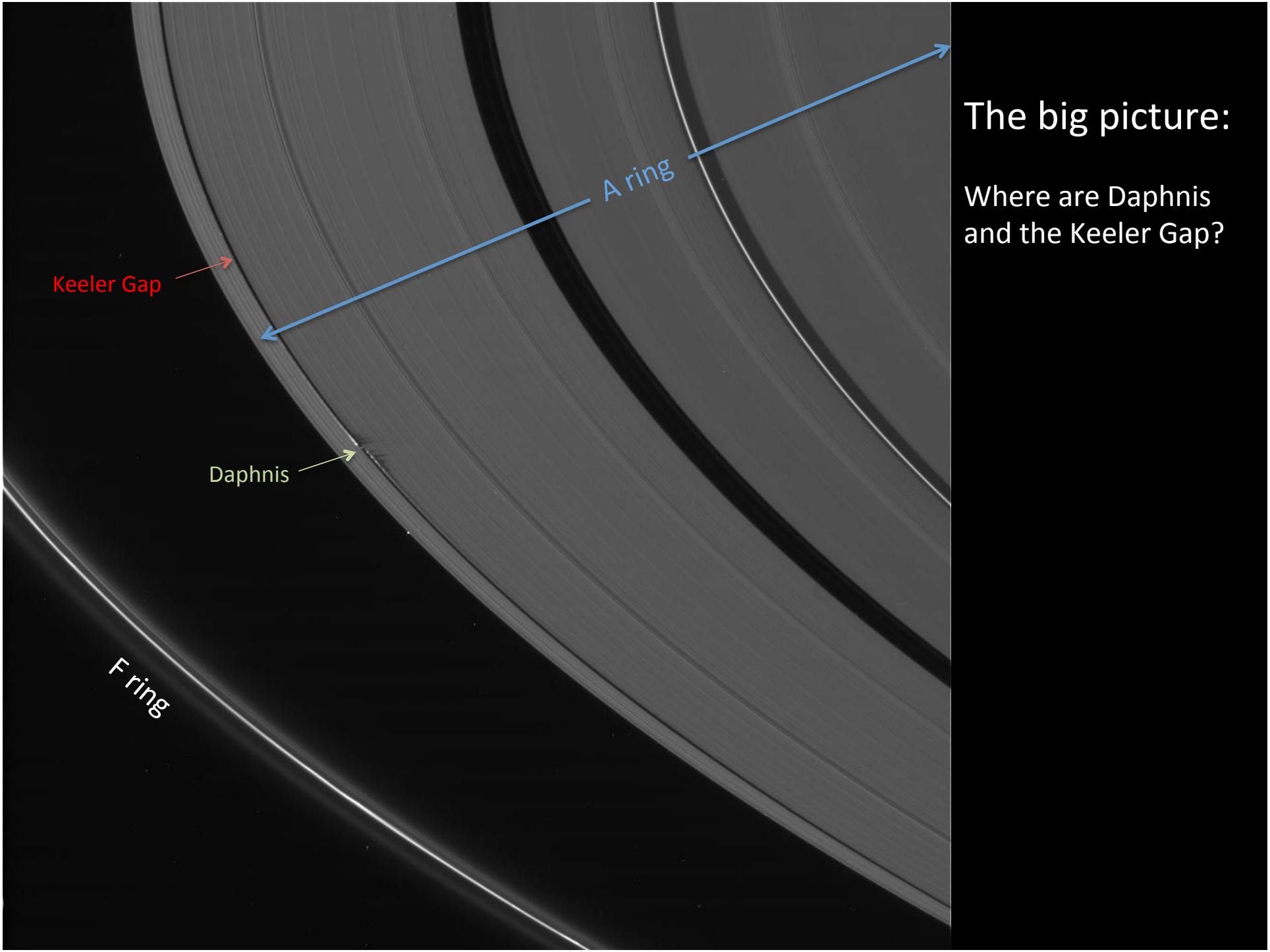
What happens to the Keeler gap when Daphnis decides to move out ?

R. Tajeddine, M. S. Tiscareno, M. M. Hedman,
P. D. Nicholson, R. G. French, J. A. Burns

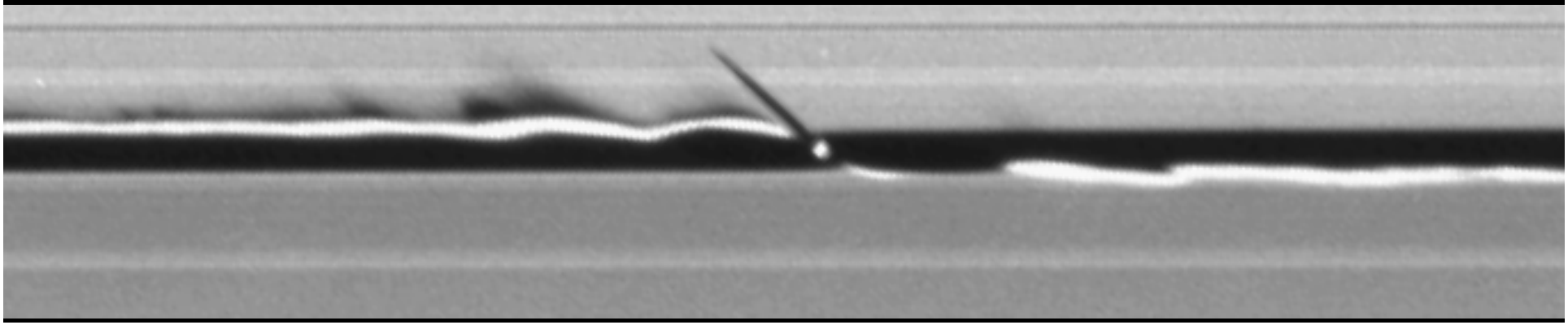


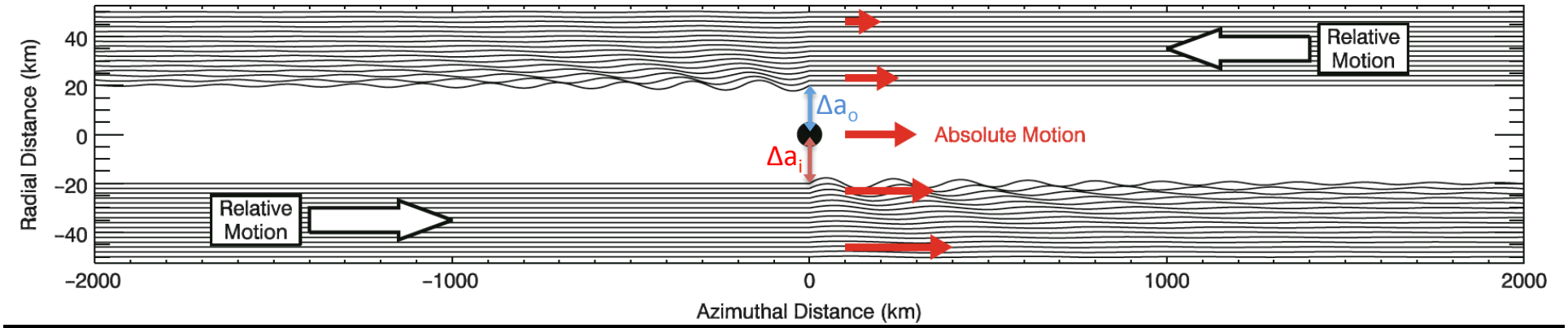
The big picture:

Where are Daphnis and the Keeler Gap?

Closer Look

The eccentricities of ring particles are excited by Daphnis' close encounter





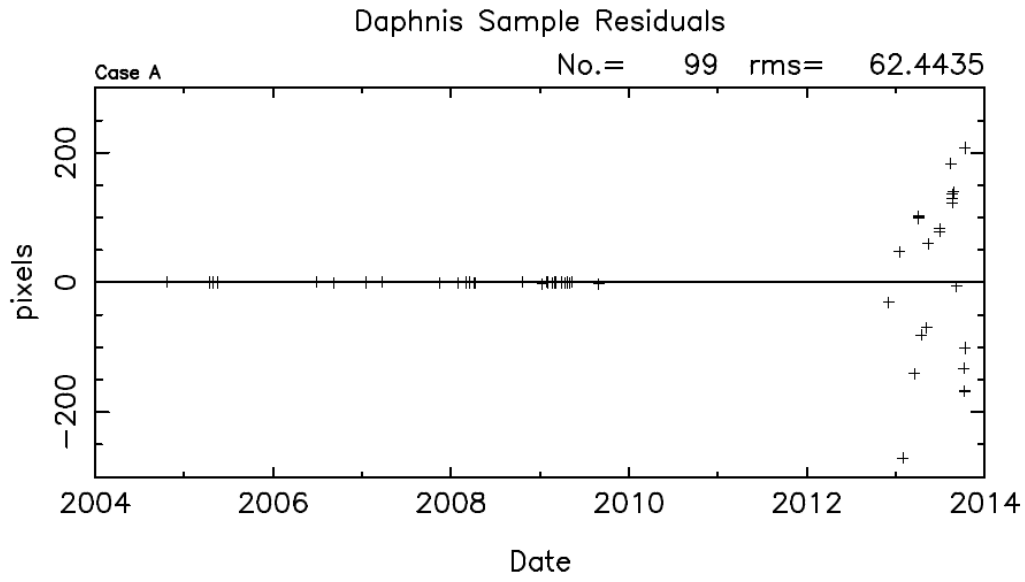
Wavelength of the wakes produced in the outer edge:

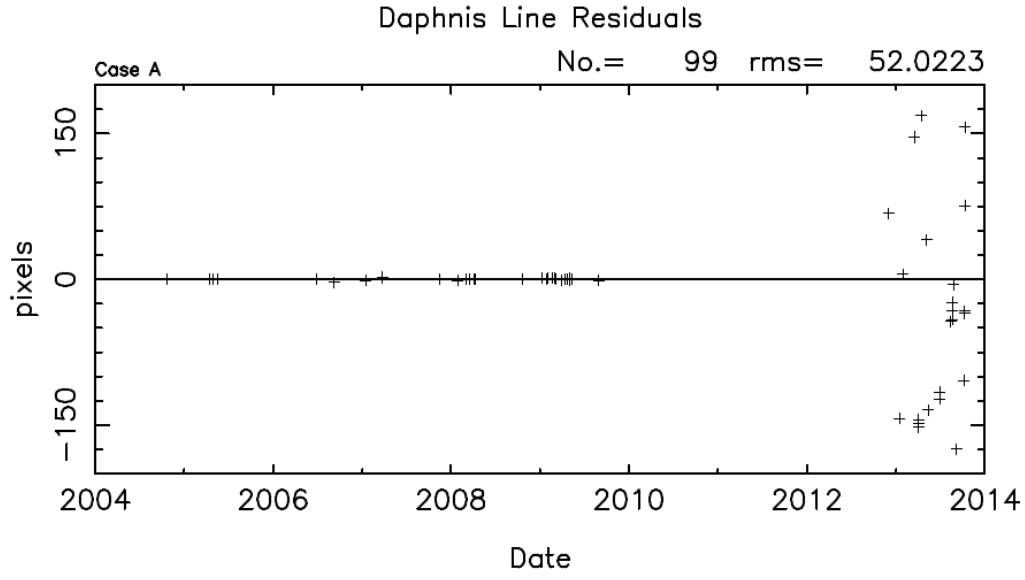
$\lambda_o = 3\pi\Delta a_o$

Wavelength of the wakes produced in the inner edge:

$\lambda_i = 3\pi\Delta a_i$

Daphnis' orbit from astrometry

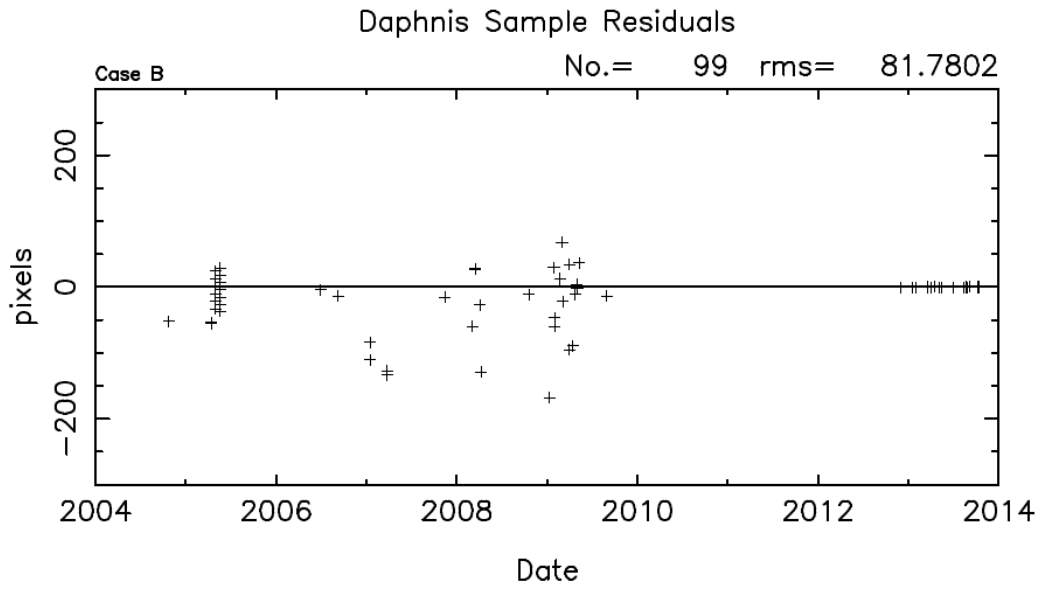


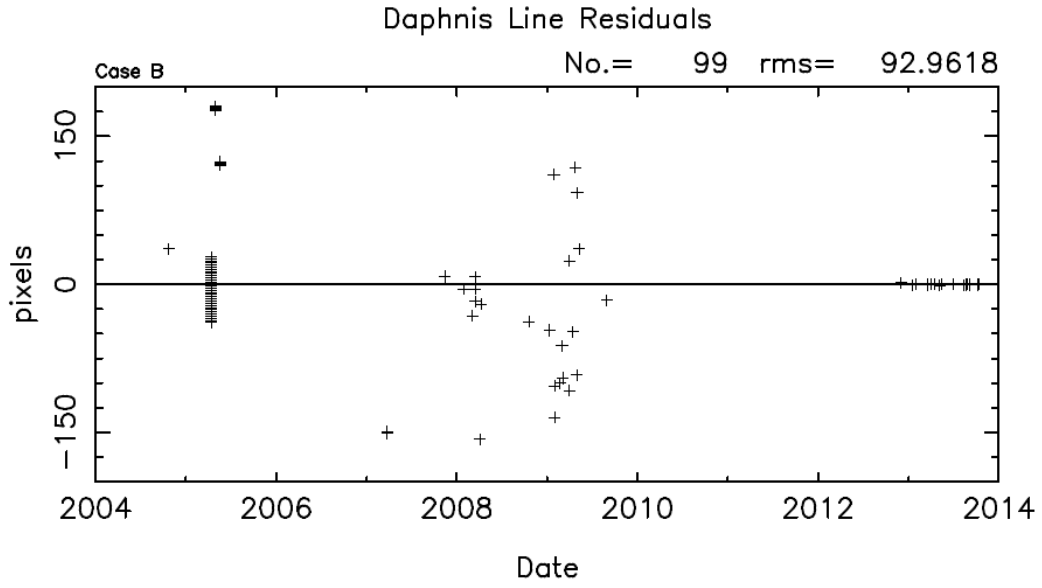


- Daphnis' orbit fits well to astrometric data before 2010.
- The residuals to the observations after 2012 become poor.

(From Jacobson, 2014, DDA)

Daphnis' orbit from astrometry





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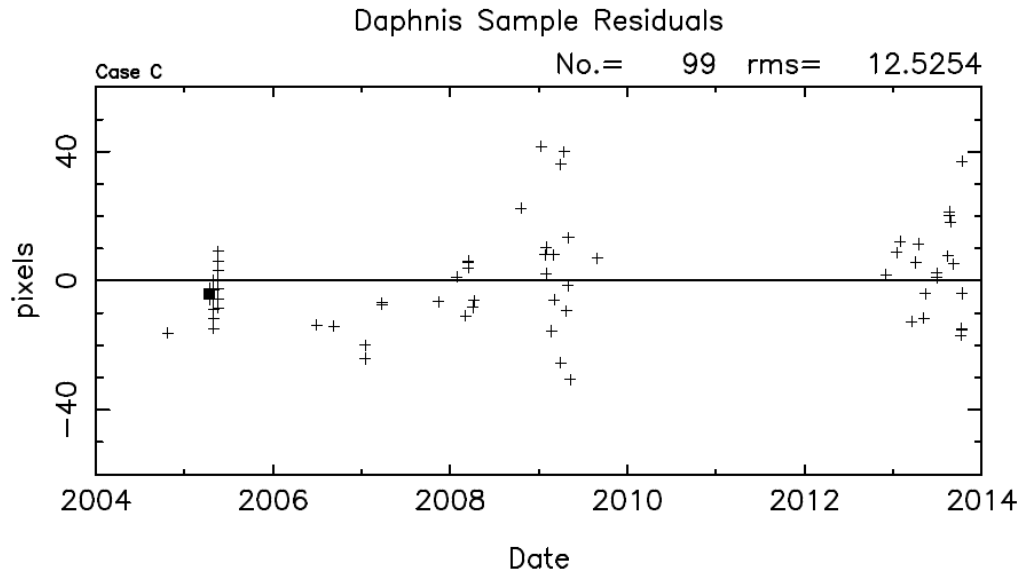
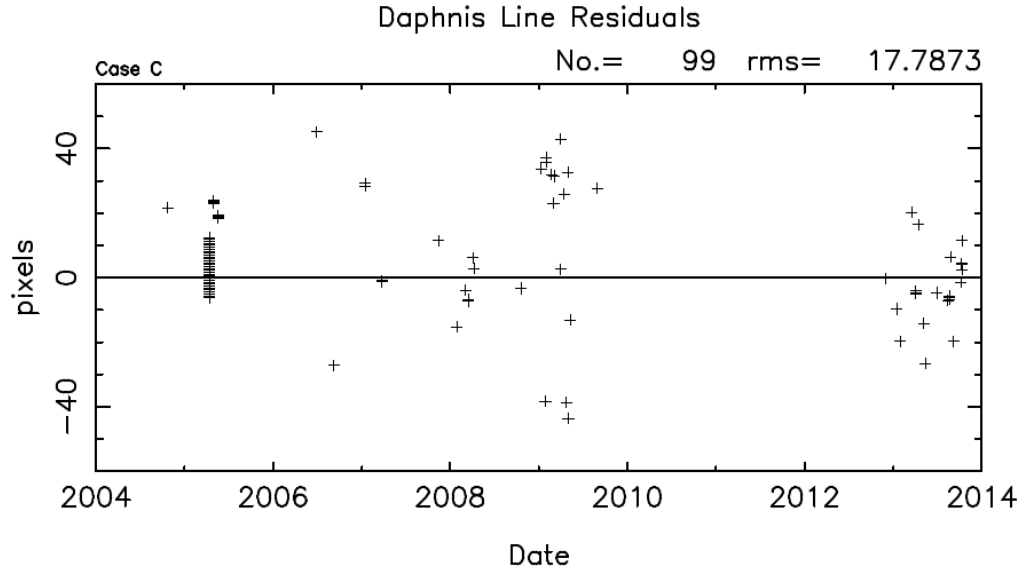
Daphnis' orbit from astrometry





Attempt to fit a single orbit to all the data yields large residuals.

(From Jacobson, 2014, DDA)

Daphnis' orbit from astrometry

Daphnis Planetocentric Equatorial Elements

Element	Orbit A	Orbit B	Orbit C
Epoch JD	2453302.5	2455431.5	2453302.5
a(km)	136504.2 ± 0.8	136507.5 ± 1.5	136472.4 ± 0.7
$e(\times 10^3)$	0.0114 ± 0.0060	0.0163 ± 0.0096	0.4002 ± 0.0051
ϖ(deg)	243.0 ± 33.7	306.2 ± 39.0	98.4 ± 0.7
λ(deg)	281.9424 ± 0.0027	171.5596 ± 0.0105	282.4028 ± 0.0013
i(deg)	0.0021 ± 0.0007	0.0009 ± 0.0009	0.0646 ± 0.0006
Ω(deg)	319.1 ± 15.3	88.6 ± 97.4	337.9 ± 0.3
$d\lambda/dt$(deg/day)	605.979153 ± 0.000002	605.978425 ± 0.000010	605.978790 ± 0.000001
$\dot{\varpi}$(deg/yr)	1084.53	1084.53	1084.53
$\dot{\Omega}$(deg/yr)	−1079.27	−1079.27	−1079.27
Energy$(\mathrm{km/s})^2$	1.042197×10^{12}	1.042202×10^{12}	1.041668×10^{12}
	Before 2010	Since 2012	All data

Unrealistic

Implication: Daphnis moved out by about 3 km sometime between 2010 and 2012 !

(From Jacobson, 2014, DDA)

What happens to the Keeler gap?

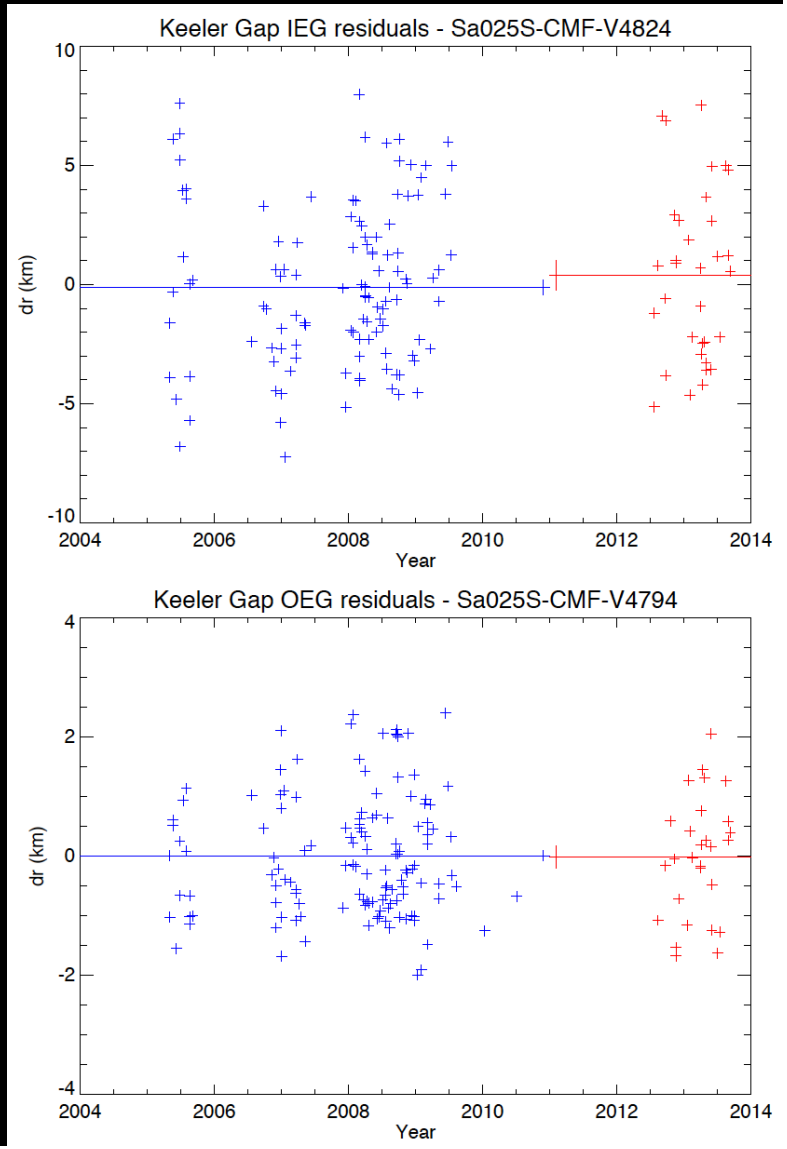
- If Daphnis is shepherding the gap edges, then both should also change radii by 3 km. *EVENTUALLY*

- Fits of Occultation data to the gap edges do NOT detect any movement.

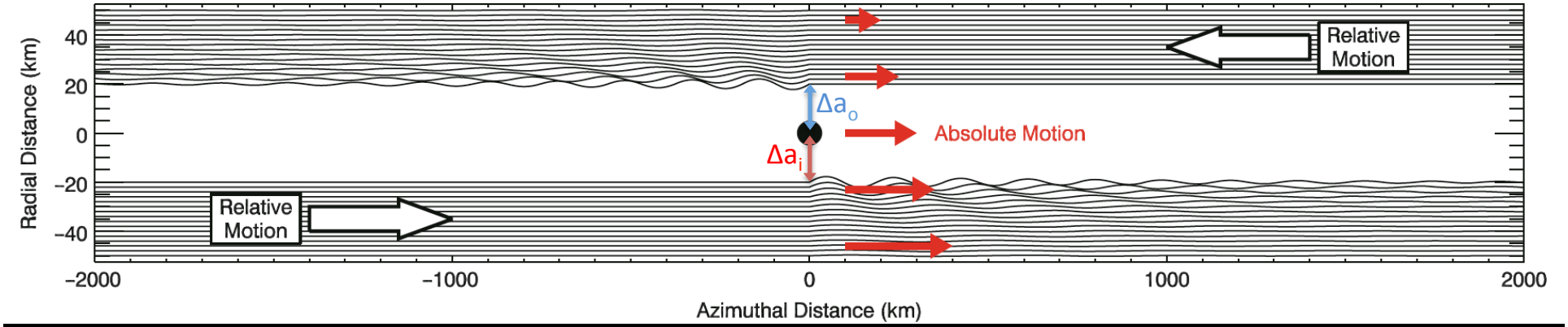
The fits suggest the following radii for edges :
Inner edge a = 136484.83 ± 0.3 km
Outer edge a= 136522.18 ± 0.1 km

The viscous spreading time scale for Δa = 3 km is
Δt ~ 20 years

Occultation data



What happens to the wakes on the Keeler gap?



Wavelength of the wakes produced in the outer edge:
$\lambda_o = |3\pi\Delta a_o|$

Wavelength of the wakes produced in the inner edge:
$\lambda_i = |3\pi\Delta a_i|$

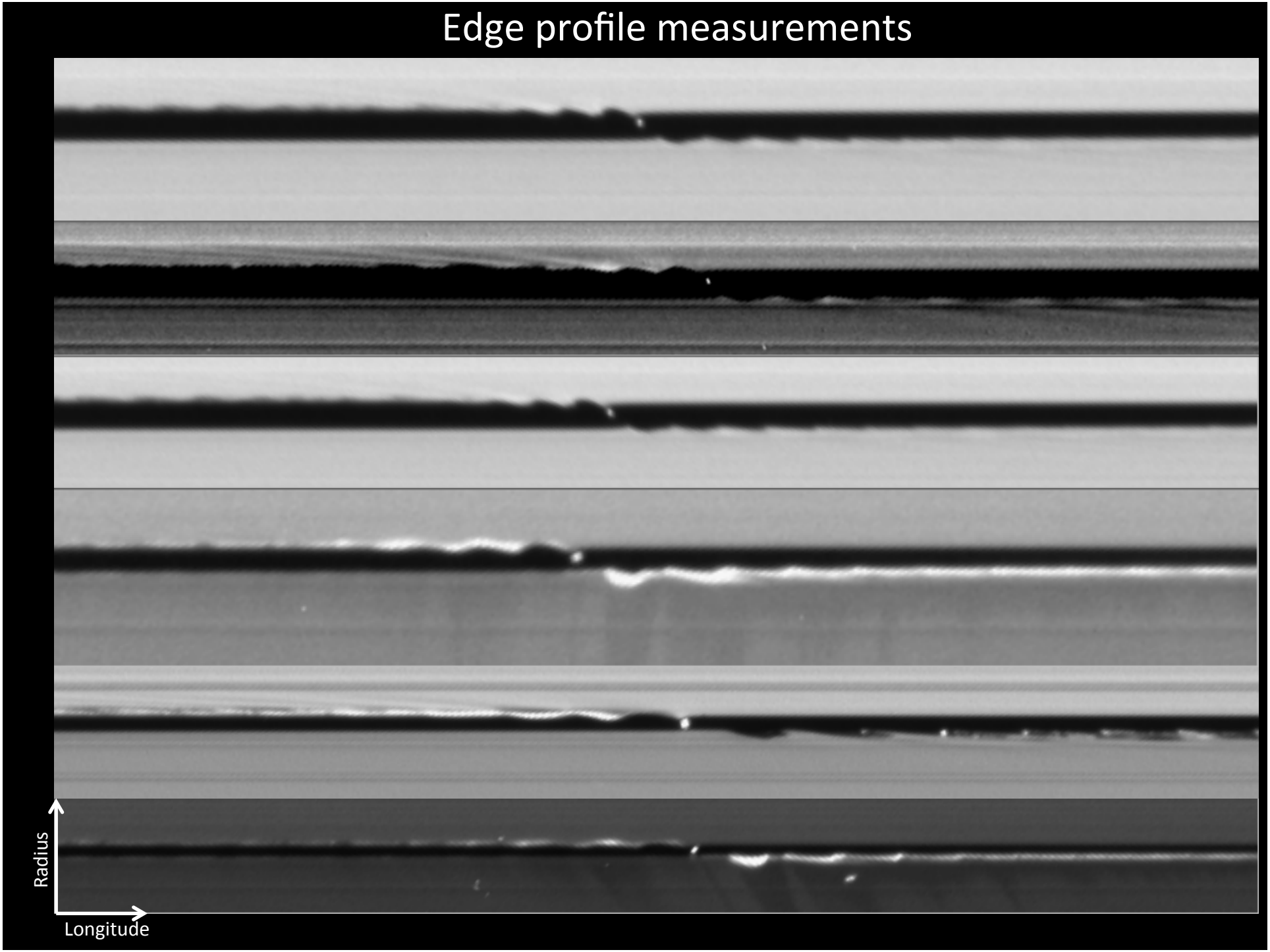
If $\Delta a_o < \Delta a_i$ Then $\lambda_o < \lambda_i$

The wavelength on the outer edge should be shorter than that on the inner edge.

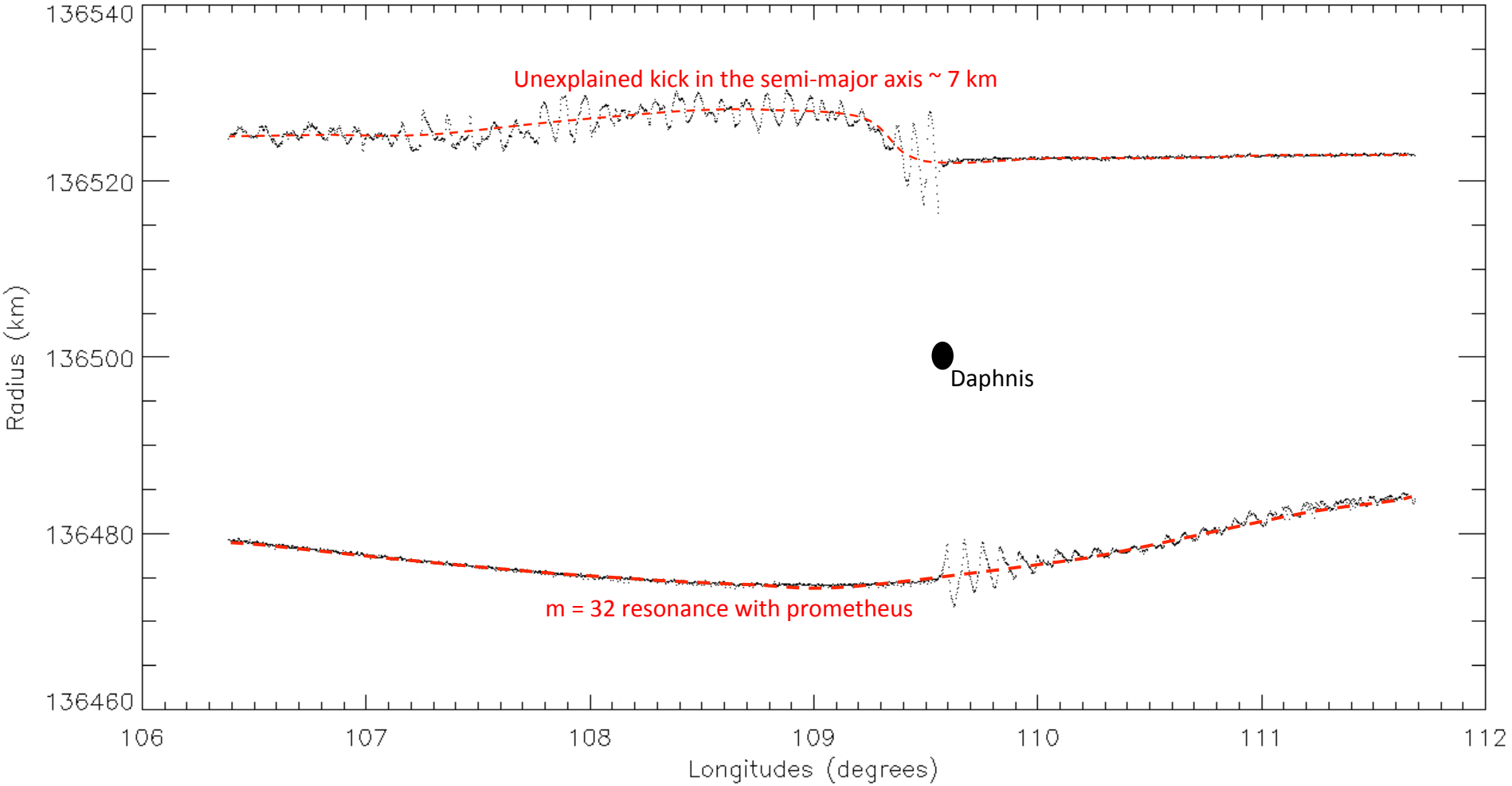
From the occultation (for edges) and Jacobson's orbits A & B (for Daphnis), we have:

	Before 2010	After 2012
Δa_o(km)	18	14.7
Δa_i (km)	-19.4	-22.7
Predicted λ_o(km)	170	139
Predicted λ_i (km)	183	214

Edge profile measurements

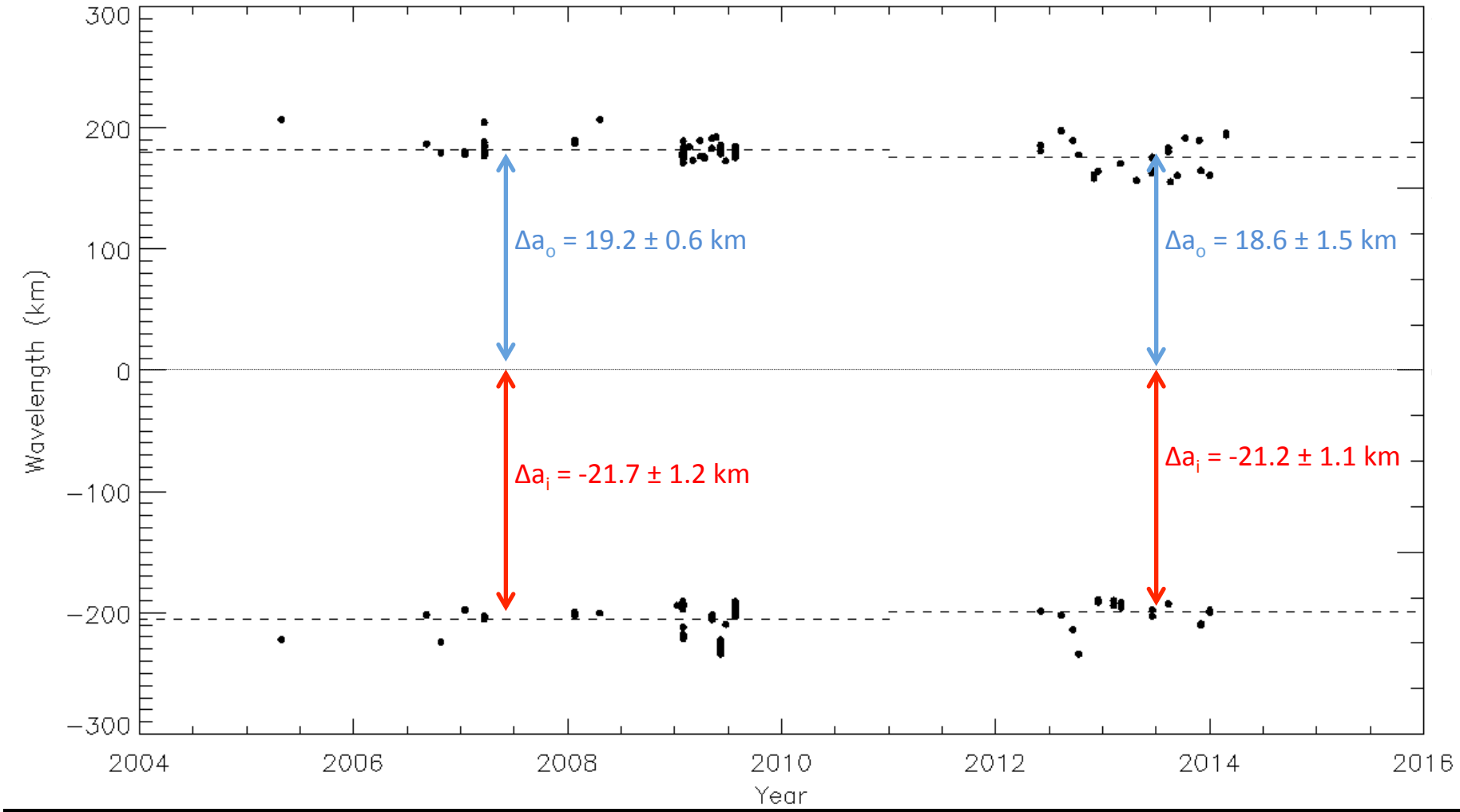


Edge profile



We measure the edge profiles, and then use wavelet transform to determine the mean wavelength of the inner and the outer wakes.

Wavelength analysis



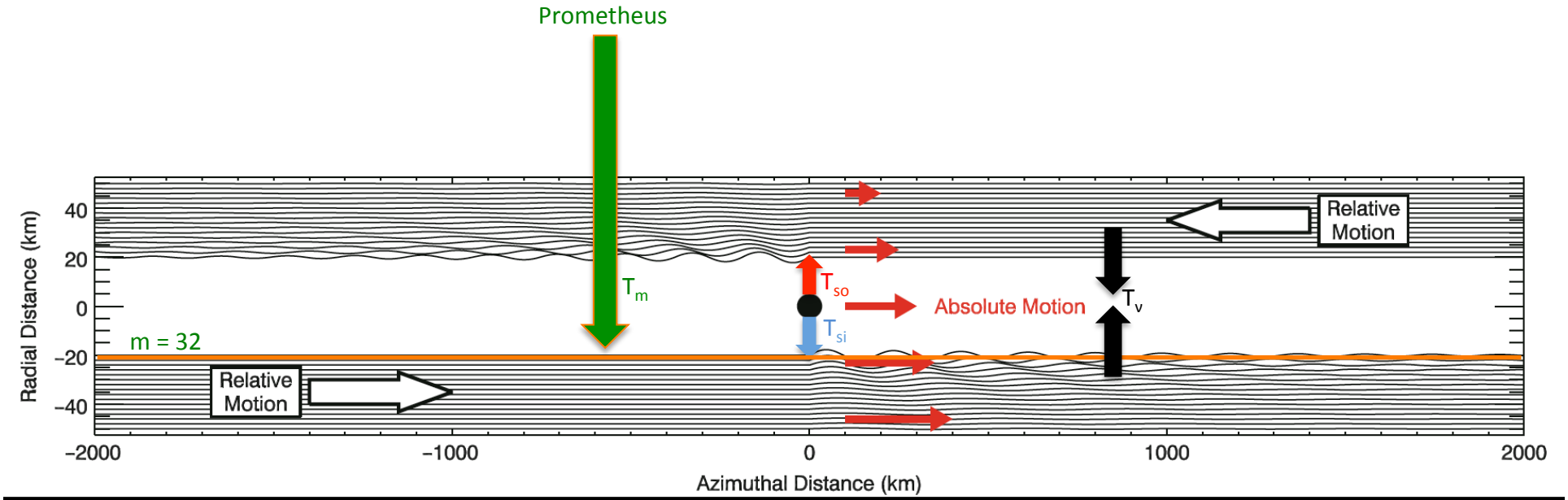
The wavelength analysis does NOT show any evidence of Daphnis' change of orbit.

We confirm that $|\Delta a_i| > \Delta a_o$

Prediction	Before 2010	After 2012
Δa_o(km)	18	14.7
Δa_i (km)	-19.4	-22.7

Torques on edges

Why $\Delta a_o < \Delta a_i$?



$$\left.\begin{aligned} T_v &= T_{so}(\Delta a_o) \\ T_v &= T_{si}(\Delta a_i) + T_m \end{aligned}\right\} \; T_{so}(\Delta a_o) = T_{si}(\Delta a_i) + T_m \xrightarrow{T_s \,\alpha\, 1/\Delta a^3} \Delta a_o < \Delta a_i$$

Conclusion

- Fit of Daphnis' orbit suggests an increase of 3 km in its semi-major axis.
- The fits of the occultation data to the Keeler gap edges do not suggest a change in the rings' radii, consistent with the predicted spreading time.
- Wavelength analysis of the wakes on the inner and the outer edges do not show any evidence of Daphnis' change of orbit.
- Unexpected, if Daphnis has moved and the edges have not.
- More work needs to be done to have better estimates of uncertainties.