Analyzing propeller gaps in Cassini NAC images (M10)

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Hydrodynamic simulations of asymmetric propeller structures in the Saturnian ring system (M11)

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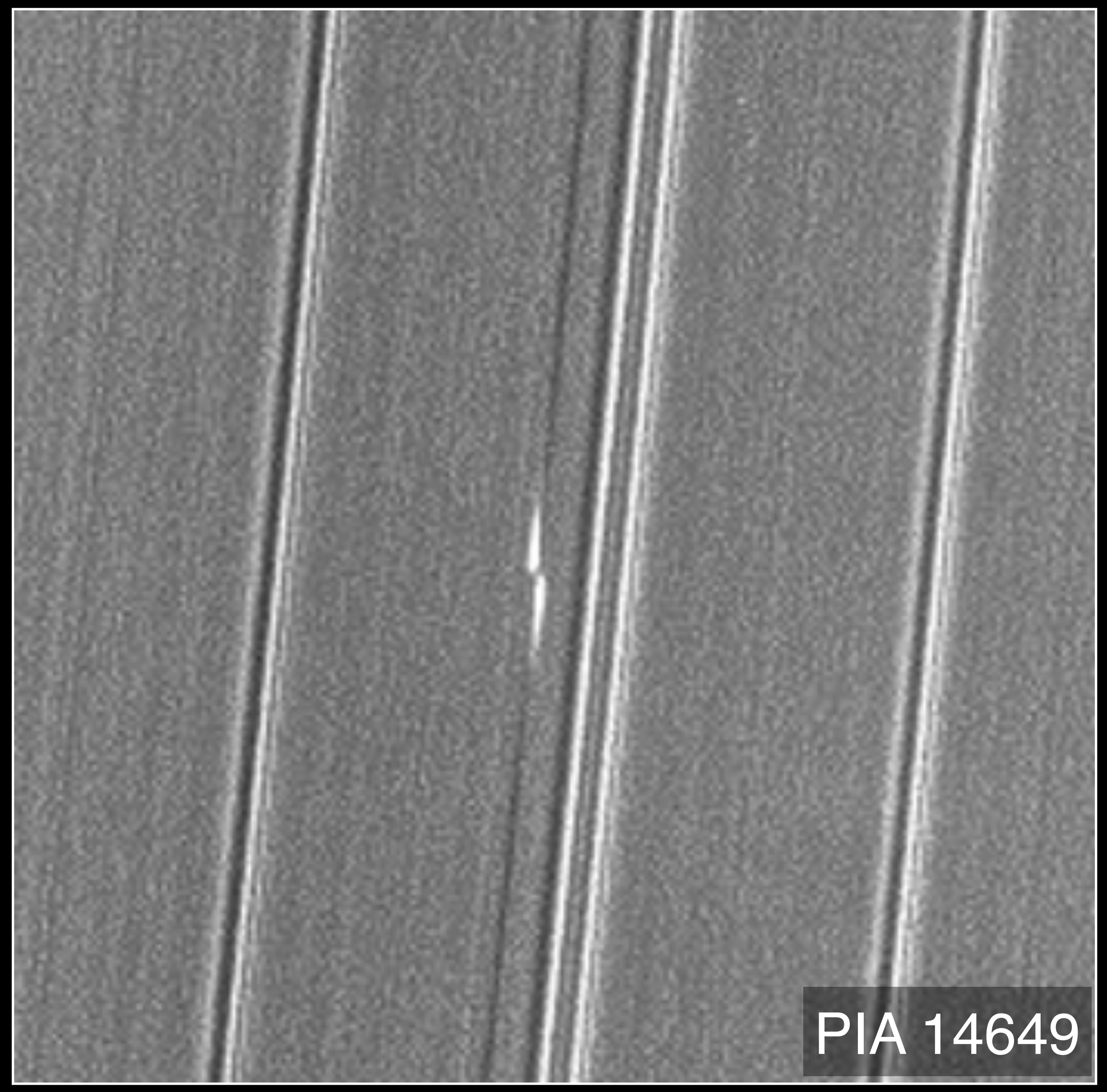
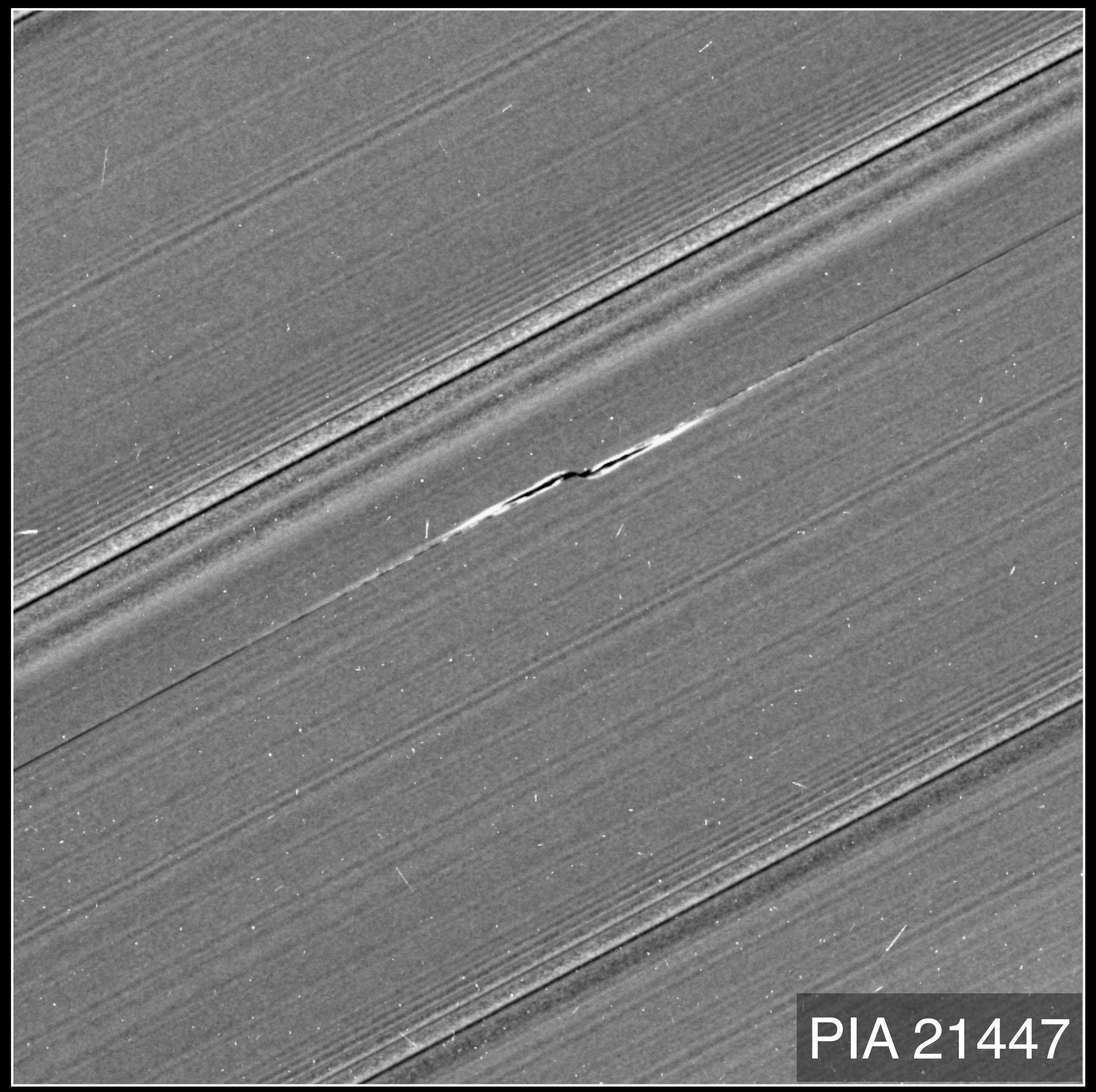
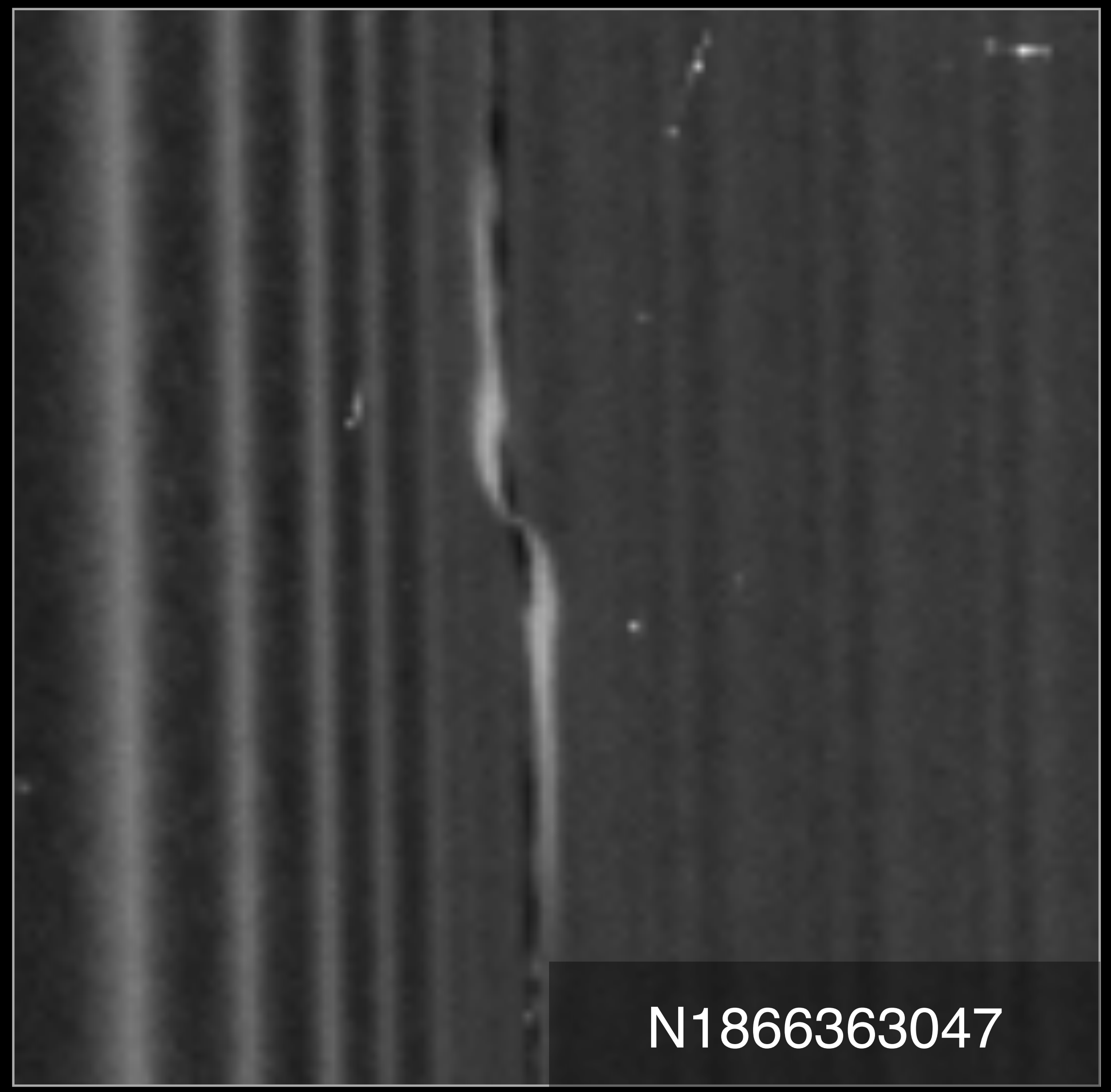
Propeller gaps in NAC images







Estimates from propeller gaps:

Radial separation: Hill radius (moonlet mass)

Azimuthal evolution: viscosity (mass diffusion)

Images showing propeller gaps:

Bleriot, Santos-Dumont, Earhart

Mostly lit side, some unlit side

Can propeller gaps detect radial propeller-moonlet wandering?

Simple kinematic model for propeller wandering

- Influence of moonlet limited to small area around the moonlet $\longrightarrow$ retardation of gap shape
- Semi-major axis change $\longrightarrow$ different mean motion

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  ⟶ retardation of gap shape
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Shape follows instantaneously

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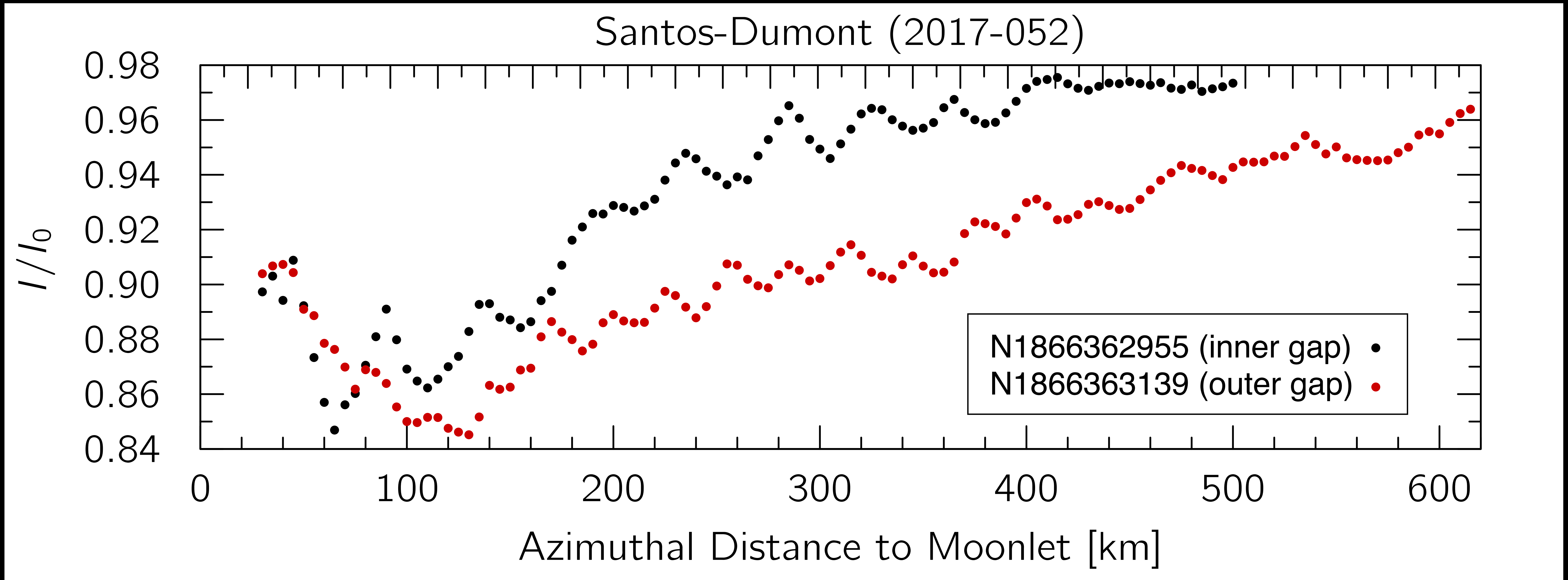
Important Timescales:

1. Time ring particles need to azimuthally travel trough the gap
2. Timescale for the radial wandering of the moonlet

Azimuthal gap evolution: Santos-Dumont



Observation geometry:

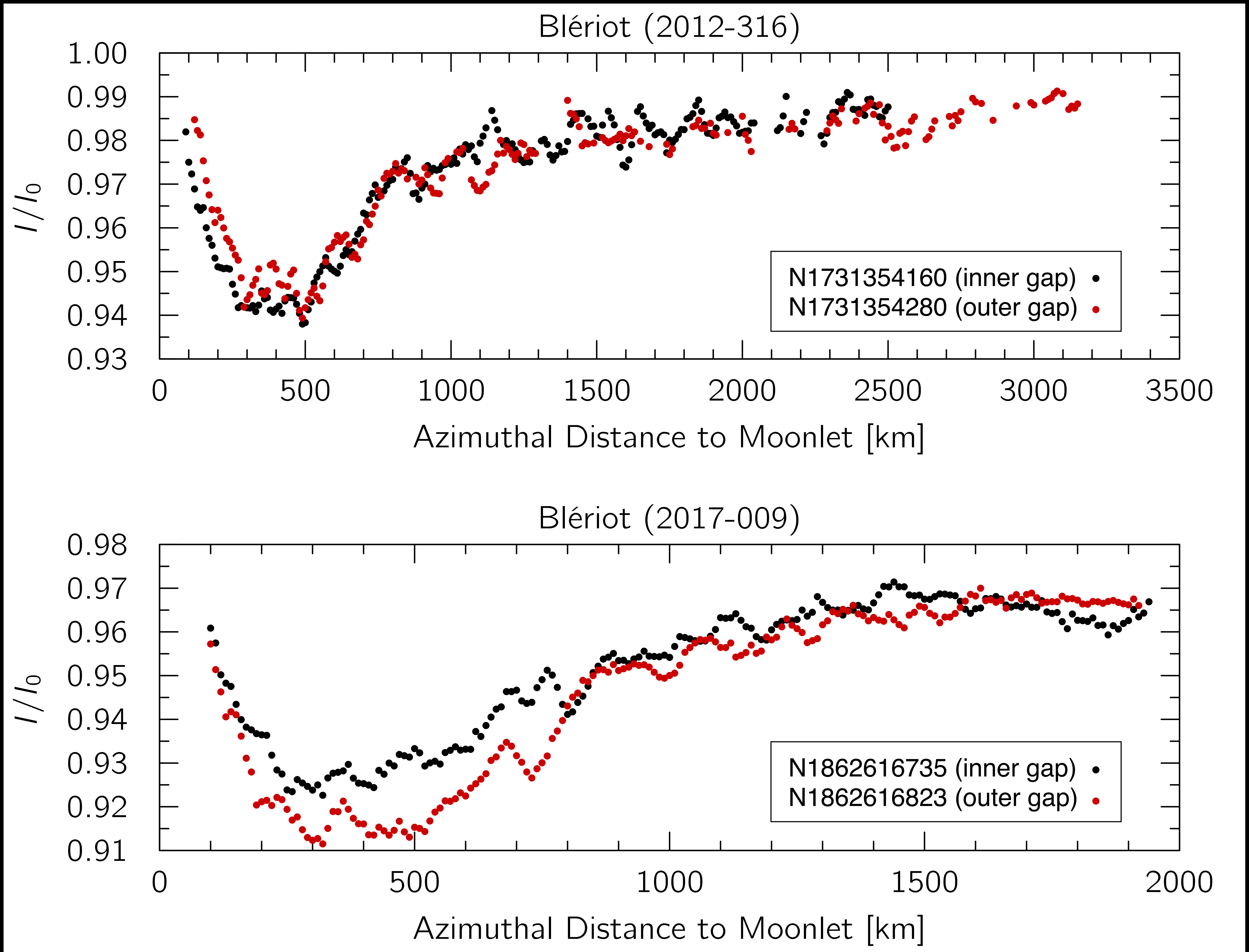
Image shows lit side of the ring

Sun elevation angle: 27 deg

Obs. elevation angle: 49 deg

Phase angle: 58 deg

Azimuthal gap evolution: Blériot



Observation geometry:

Image shows lit side of the ring

Sun elevation angle: 16 deg

Obs. elevation angle: 38 deg

Phase angle: 55 deg

Observation geometry:

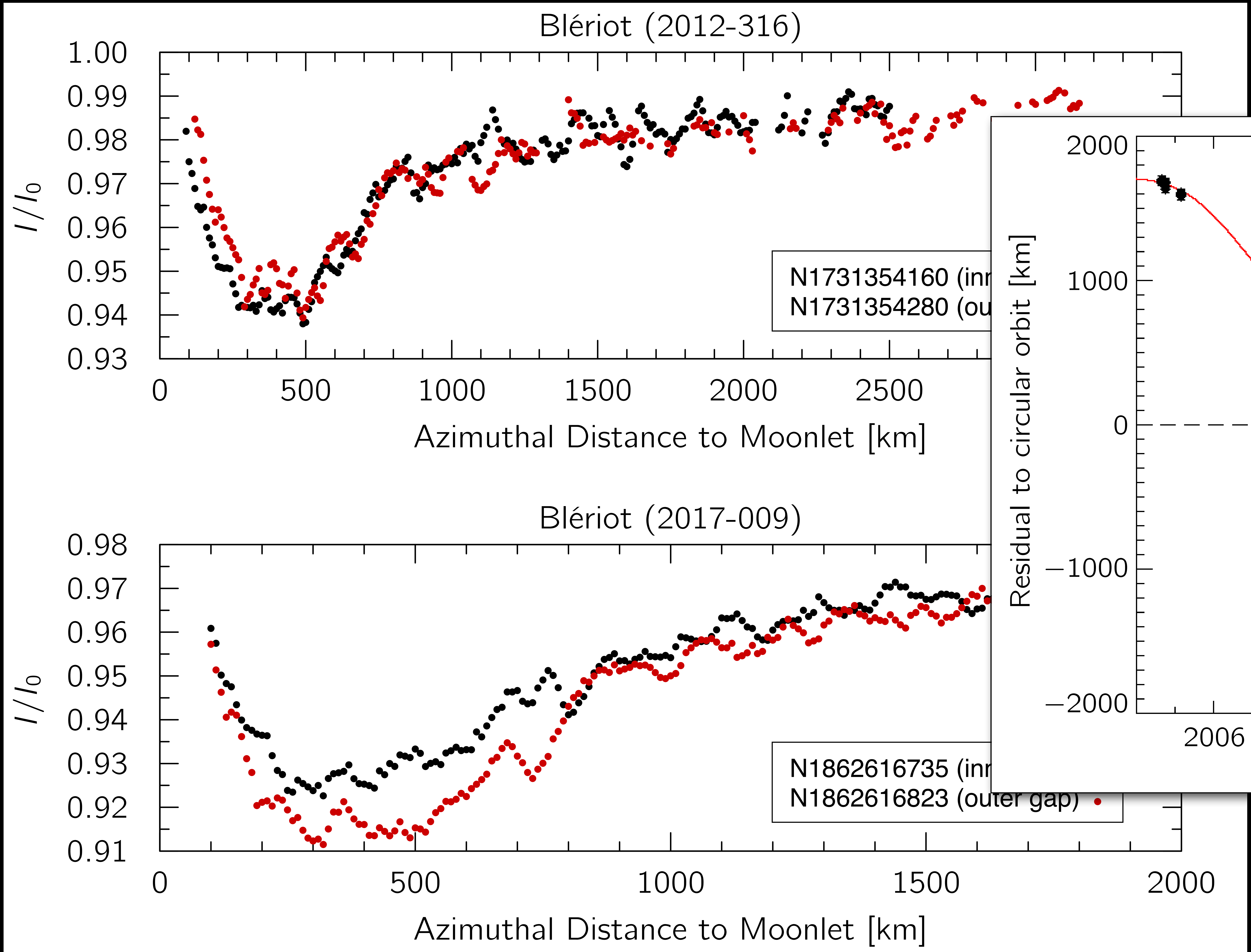
Image shows lit side of the ring

Sun elevation angle: 27 deg

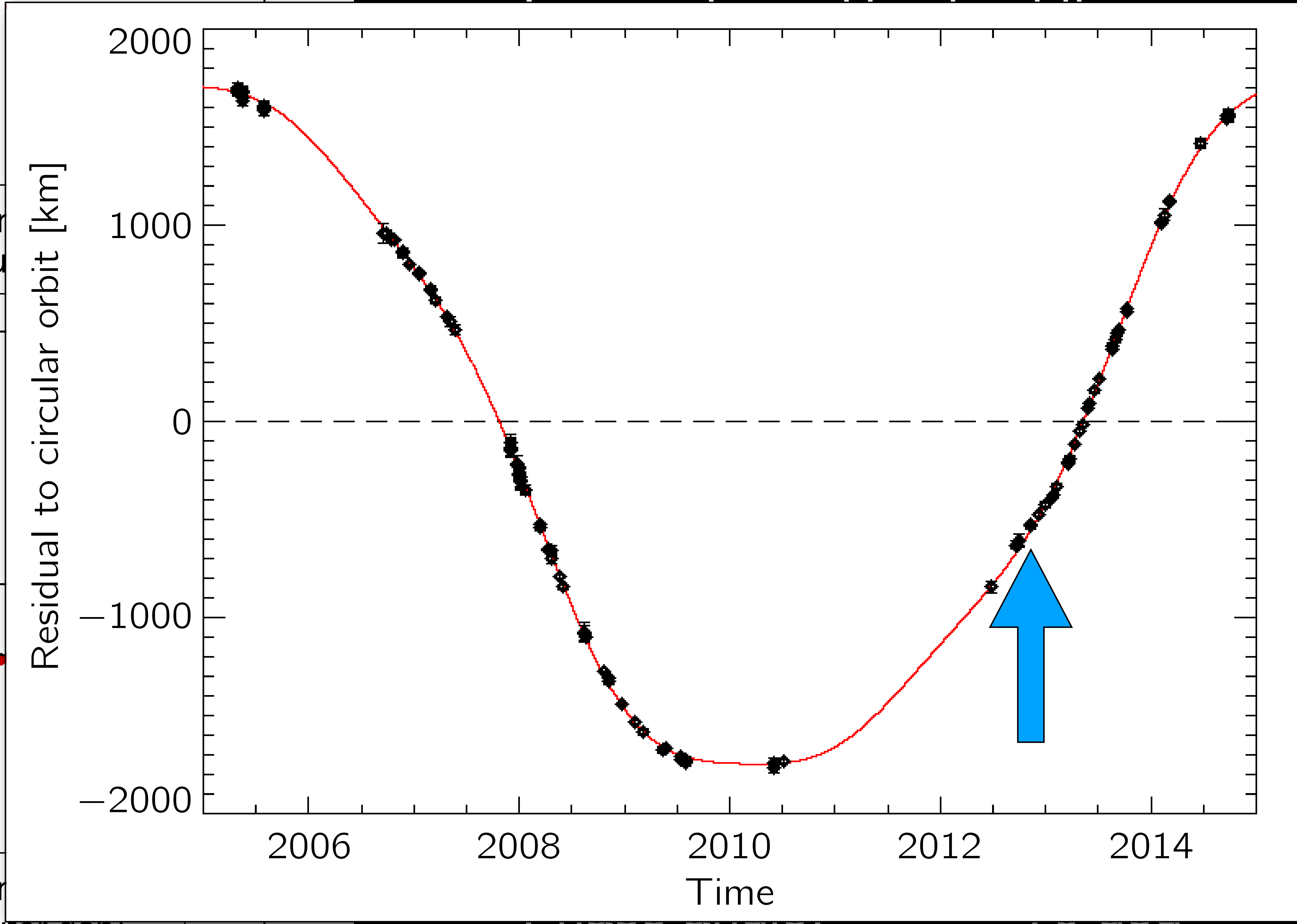
Obs. elevation angle: 70 deg

Phase angle: 79 deg

Azimuthal gap evolution: Blériot



Observation geometry:



Central Questions

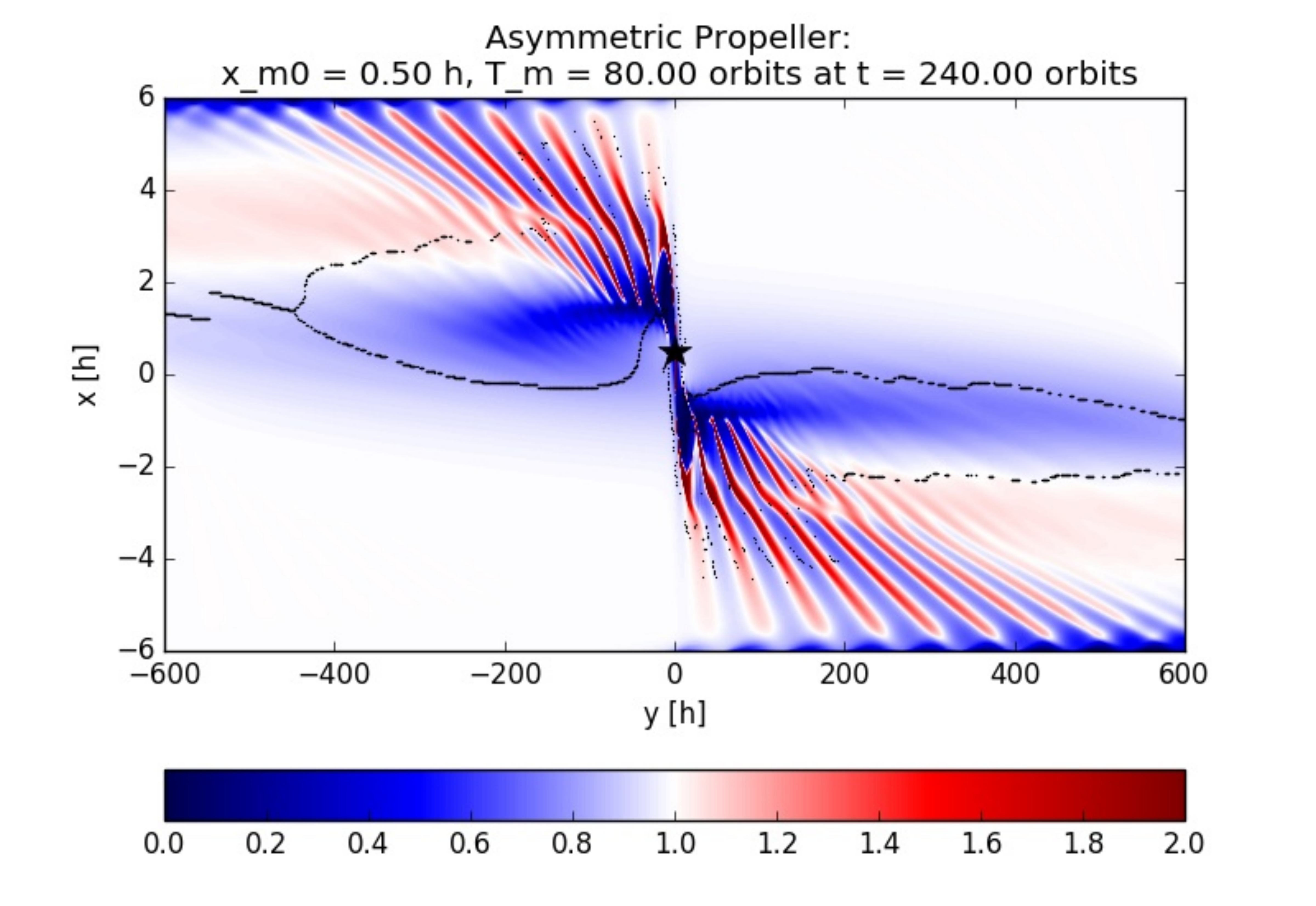
- How does the Propeller react to the additional motion of the central moonlet?
- What are suitable gap properties to quantize the asymmetry of the propeller gaps?
- For which parameters of the moonlet motion is the asymmetry detectable in Cassini ISS images?

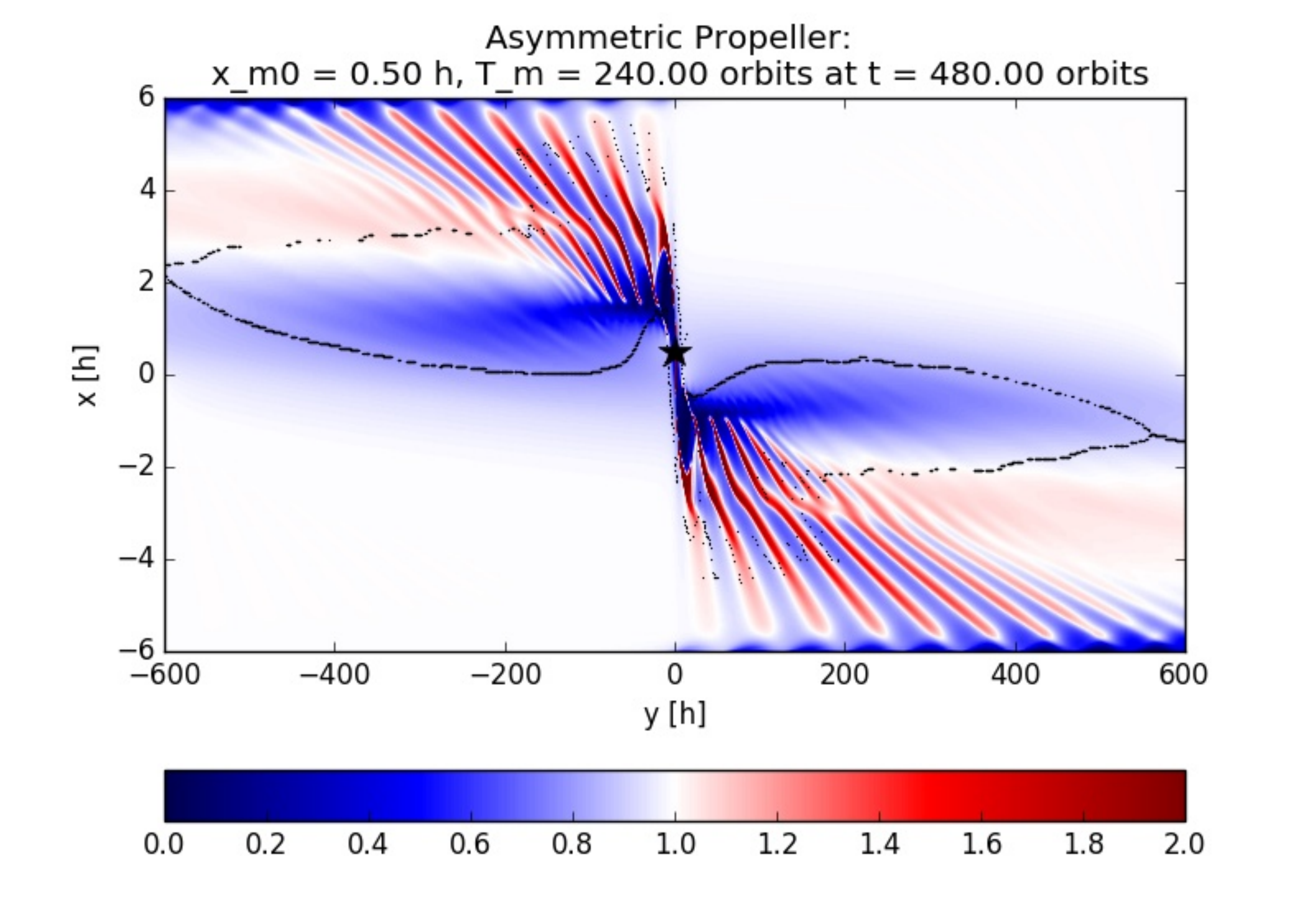
The Model

- Use isothermal hydrodynamic simulation routine from Seiß et al. (2017, Arxiv) to simulate a moonlet in the granular environment of Saturn's rings
- We simulate a moonlet with a Hill radius of 400m to make asymmetry predictions for the giant trans-Encke propellers
- The parameters in the simulation are chosen to fit the A ring conditions
- Let the moonlet librate around its mean orbital position with fixed amplitude and period

Asymmetric Propellers - Timescales Matter

The moonlet libration clearly breaks the point-symmetry of the propeller structure, where the gap passage time T_{gap} strongly influences the strength of the asymmetry!

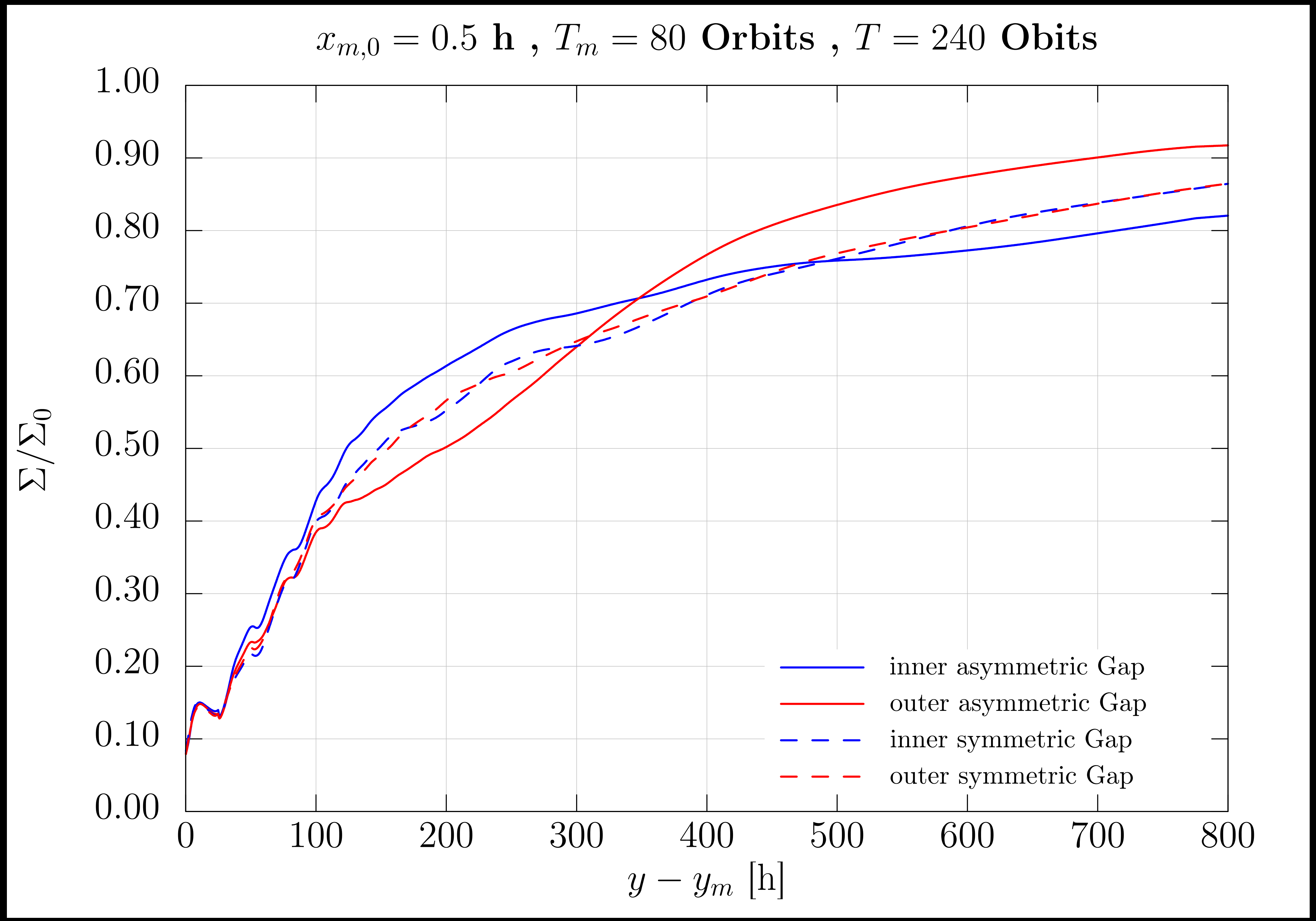


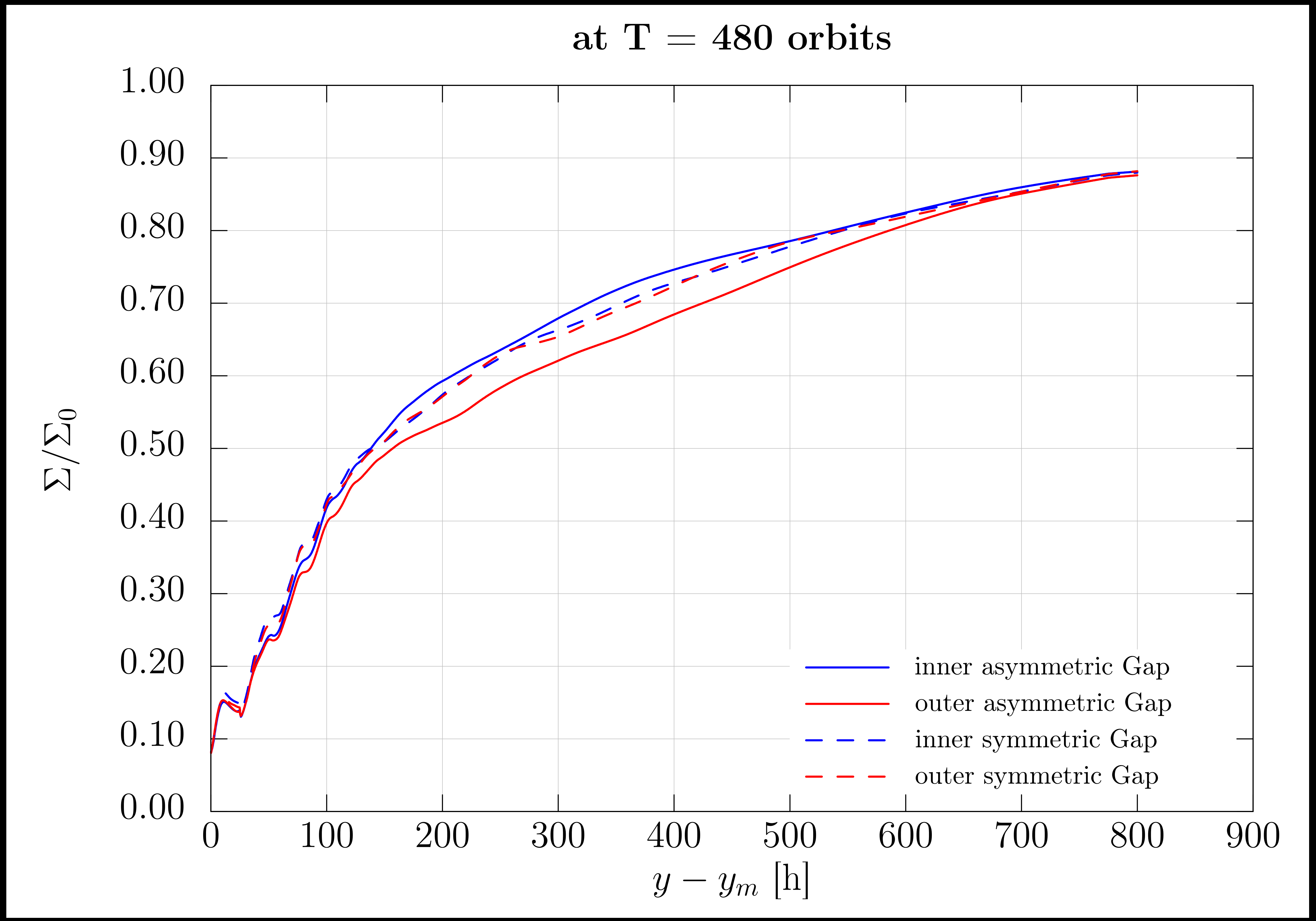


Asymmetric Propellers - Timescales Matter

The retardation effect effects the azimuthal gap relaxation and makes the asymmetry visible in the gap profiles.

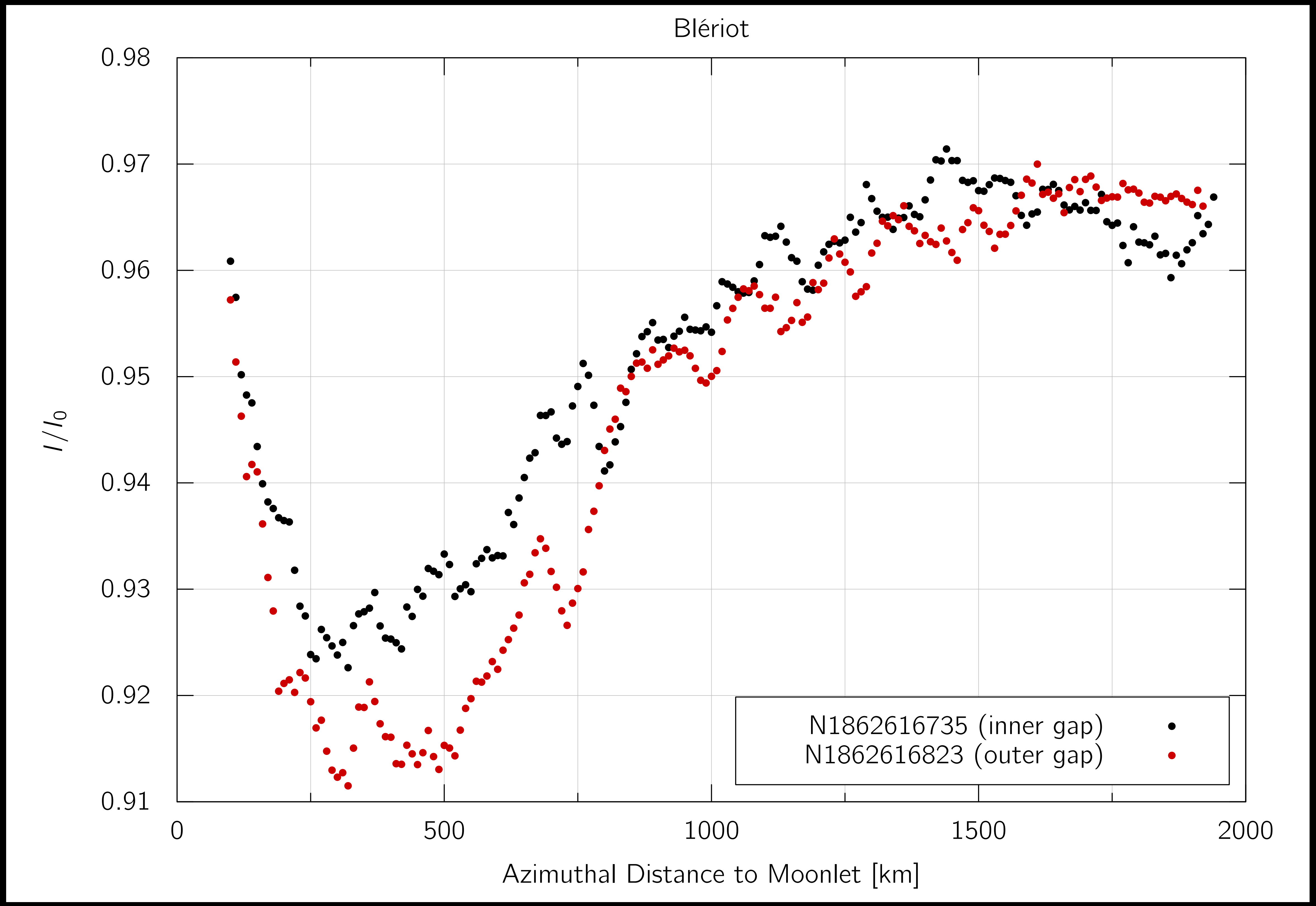
Crossing points are caused at the turning points of the radial moonlet libration!

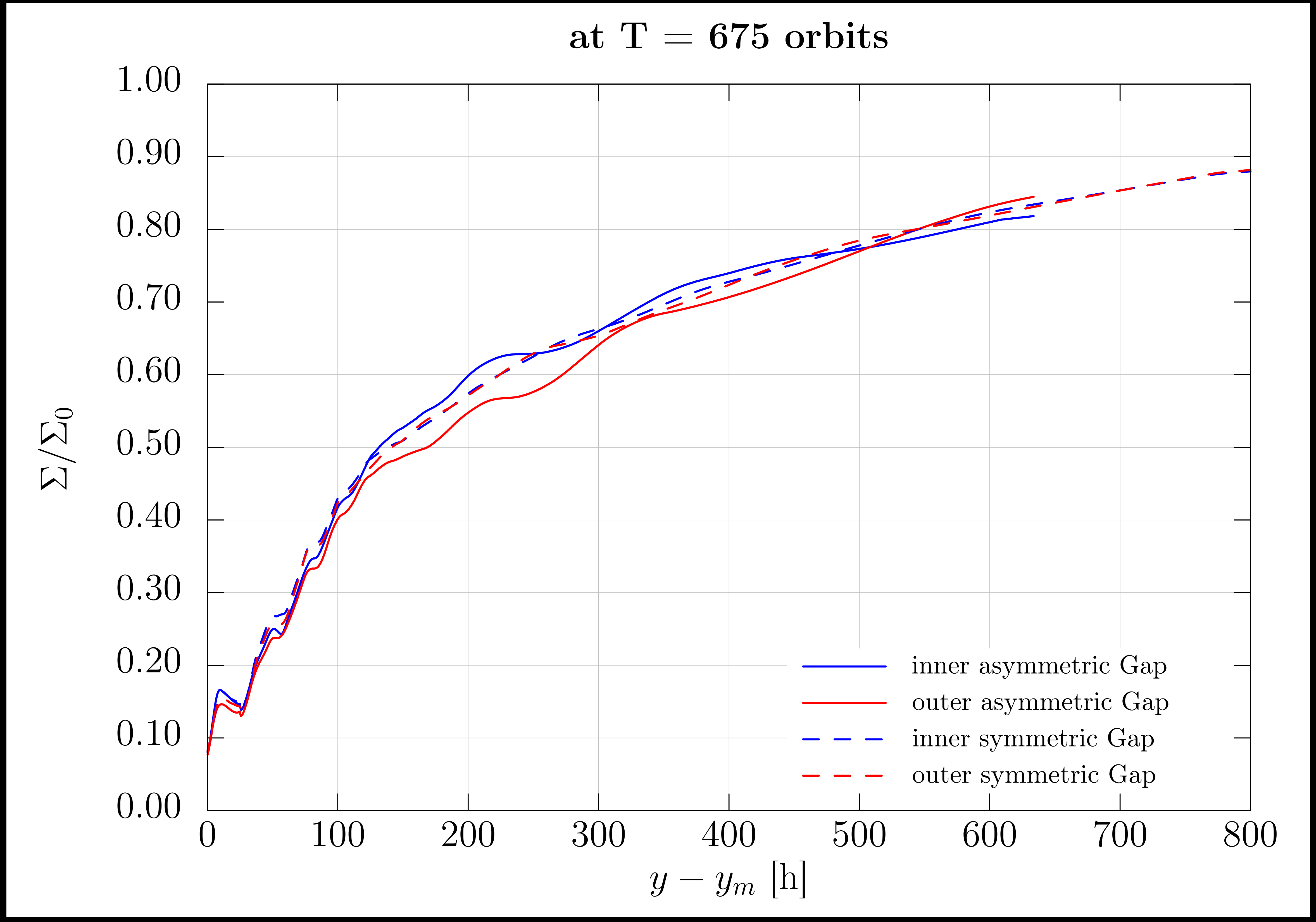




Application to the Propeller "Blériot"

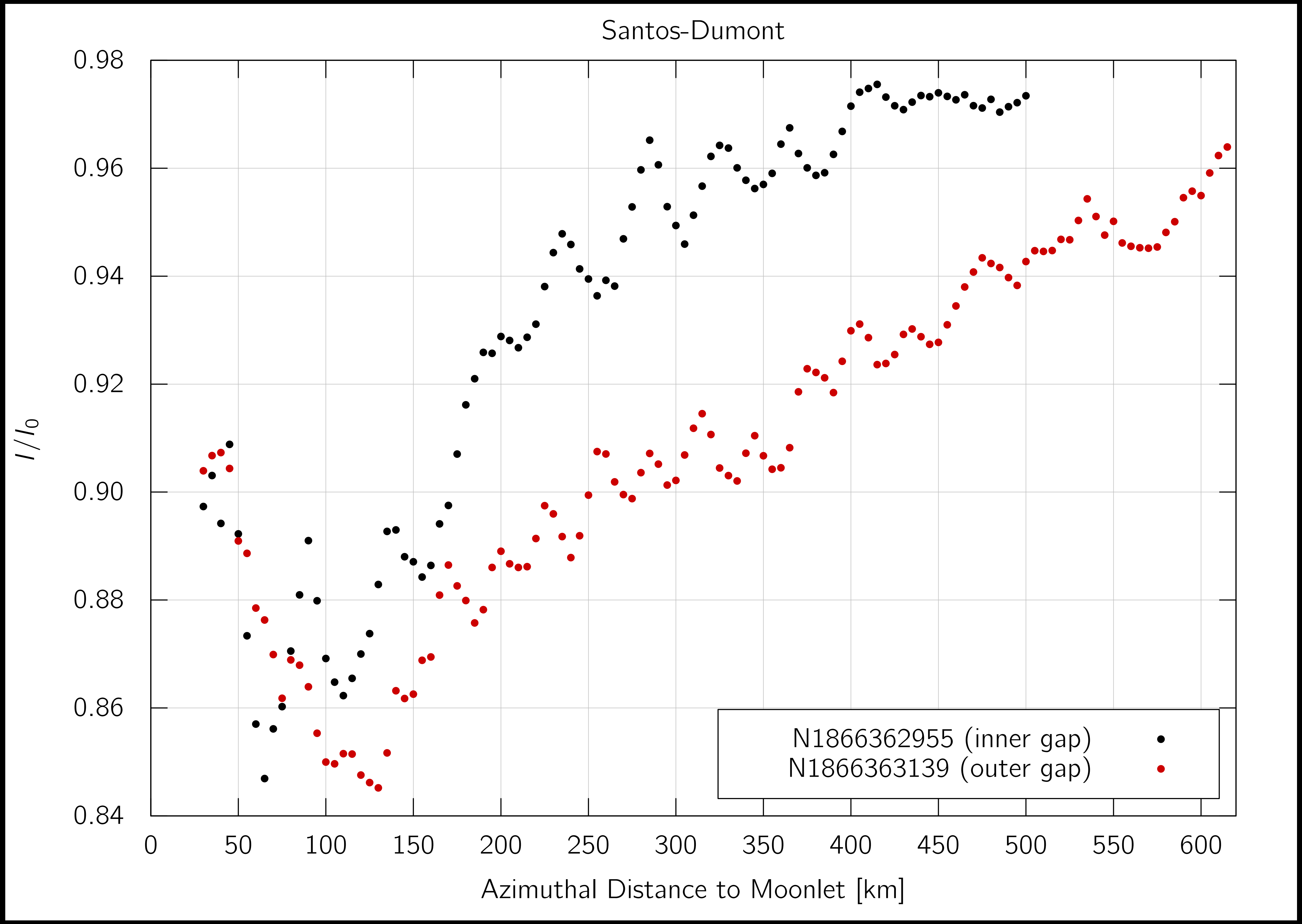
For the propeller Blériot a small asymmetry in the gap structures can be found (left). This asymmetry can be remodeled by a librating moonlet (xm=0.5, Tm=160 orbits), where the visibility of the asymmetry changes with the libration phase of the moonlet.

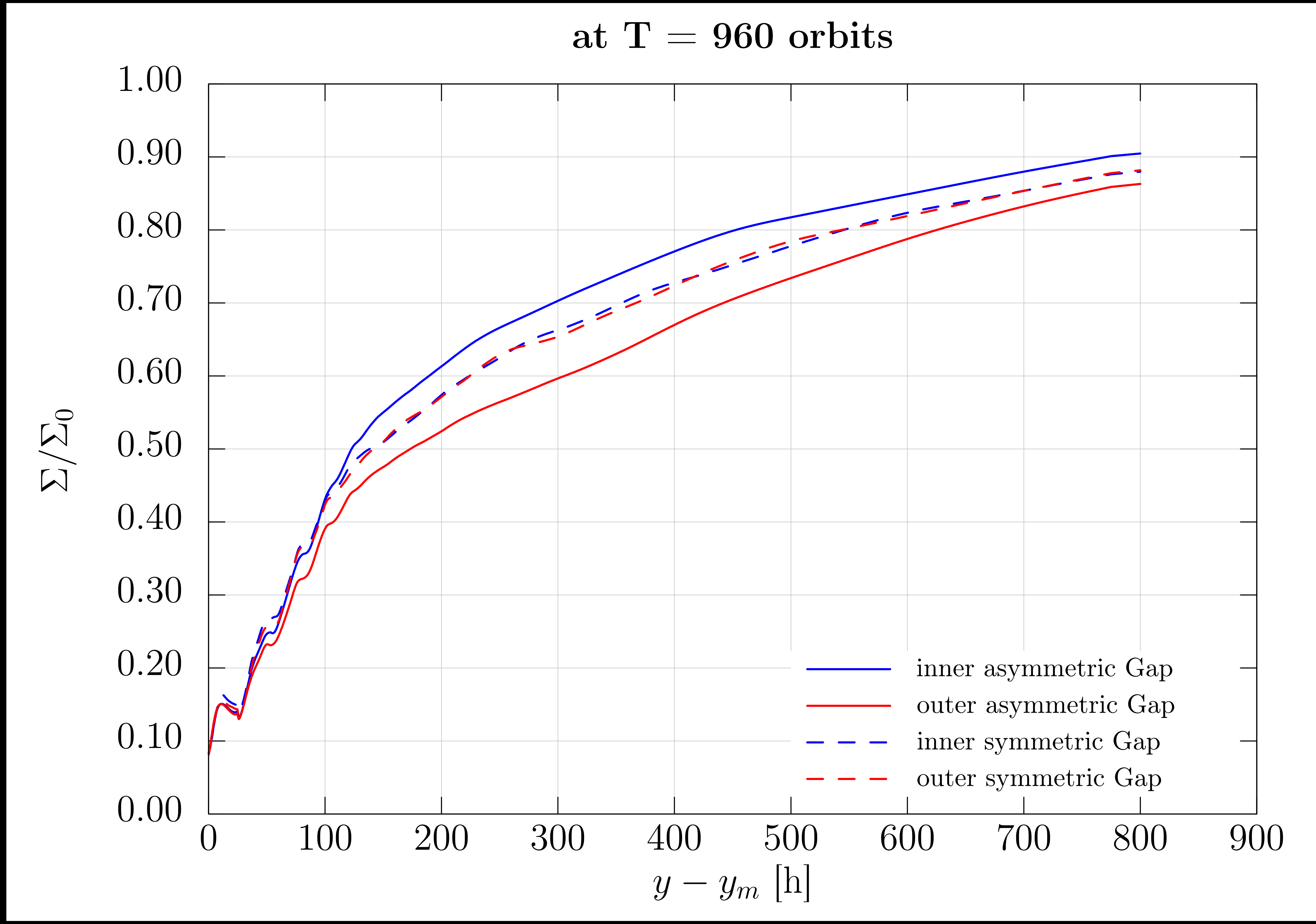




Application to the Propeller “Santos Dumont”

Like Blériot, Santos Dumont also shows an excess motion. For Santos Dumont even a larger asymmetry can be measured, which points to a larger radial amplitude of the moonlet of about 1 Hill radii.





Summary

- Cassini ISS NAC images show asymmetric propeller structures for propellers which are known to show a non-Keplerian behavior
- Clear differences in the gap lengths and depths are visible
- An underlaying motion of the moonlet can explain this asymmetry
- Our hydrodynamic simulations show, that the asymmetry of the propeller structure can be caused by a librating central moonlet
- The gap passage time T_{gap} is a critical parameter to distinguish between libration and migration of the moonlet, where for $T_m < T_{gap}$ libration can be identified.