



Planet hosting Non axisymmetric features in ~~protoplanetary~~ discs: or not vortices? The quest ~~continues...~~ Is starting again!



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Palm Cove, July 2019

Contents

- What are non-axisymmetric features?
- Current understanding of their physical origin
 - Vortex scenario
 - Massive companion scenario
- Recent developments for the massive scenario:
 - Characterization of the disc dynamics
 - Finding a criterion for horseshoe formation....



Non-axisymmetric features in planet forming discs

Thanks Nienke!



Why interesting?

**Dust is trapped in the overdensity,
Does this promote planet formation?**

Vortex scenario

- RW Instability (~ Kelvin Helmholtz + rotation) i.e. Vortices (Lyra + 2009; Van der Marel+ 2013), **LOW** viscosity

$$\alpha_{ss} \approx 10^{-5}-10^{-4}$$

- Deadzones (Regaly+ 2012, 2017)
 - Weak Magnetic fields (Ruge+ 2016)
- Planets (Ataiee + 2012)

Koller + 2003; Li, Li, Koller + 2005; De Val-Borro + 2007
Lin & Papaloizou 2011; Lin 2012



Mechanism: instability triggered by vortensity gradient.
Pressure perturbation induced by a planet or by an
accretionally inactive zone creates the conditions for the instability

Massive companion scenario

- **Massive companion**

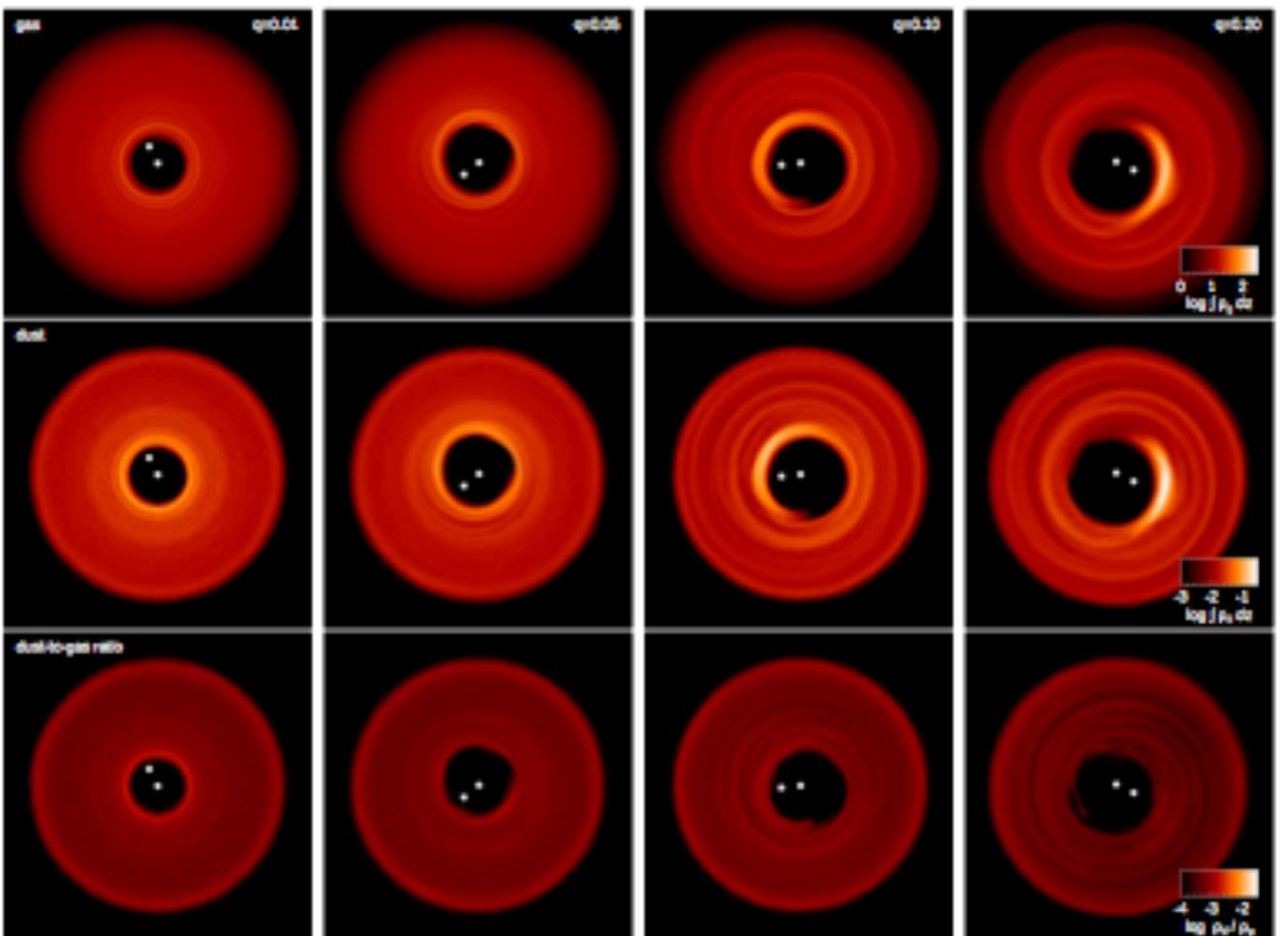
- Black hole simulations: larger mass ratios, larger viscosity
(Shi+ 2012, Farris+ 2014, Ragusa+ 2016, Miranda+ 2017)

$$q \gtrsim 0.1; \alpha = 0.1$$

- We performed a dust+gas sim for different mass ratios

$$q = \{0.01; 0.05; 0.1; 0.2\}$$

$$\alpha_{ss} = 0.005-0.01$$



Ragusa, Dipierro, Lodato, Laibe & Price 2017

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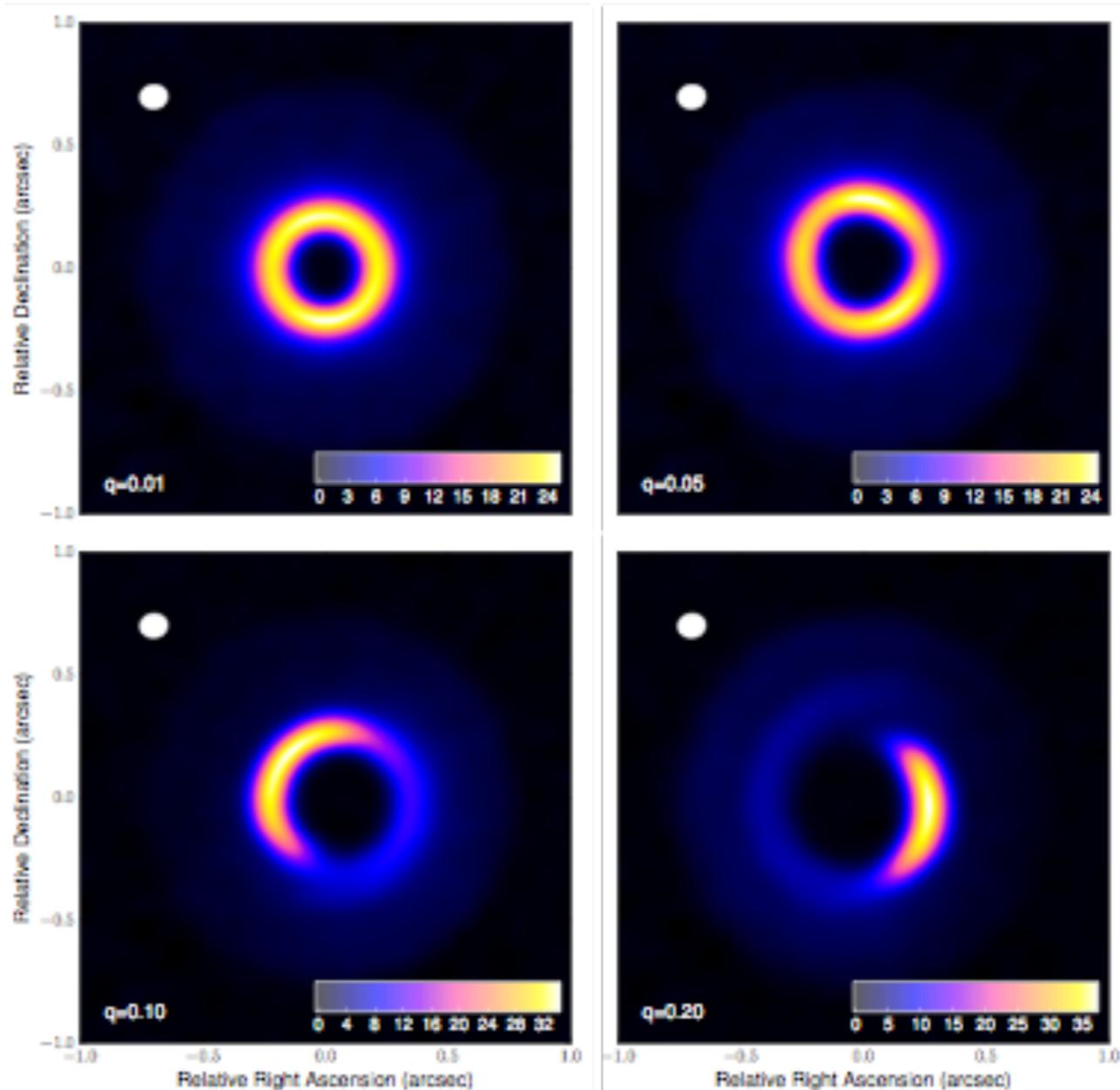
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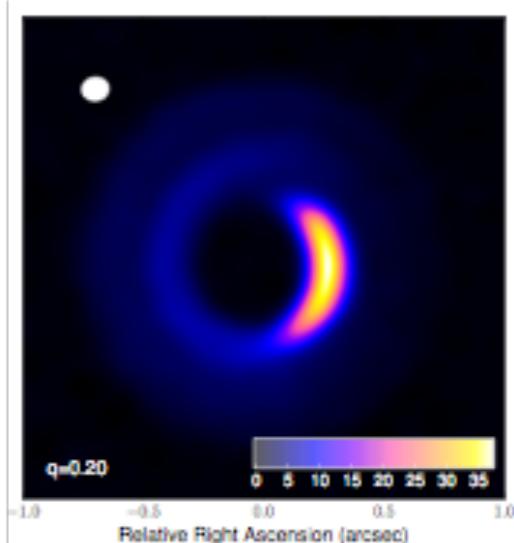
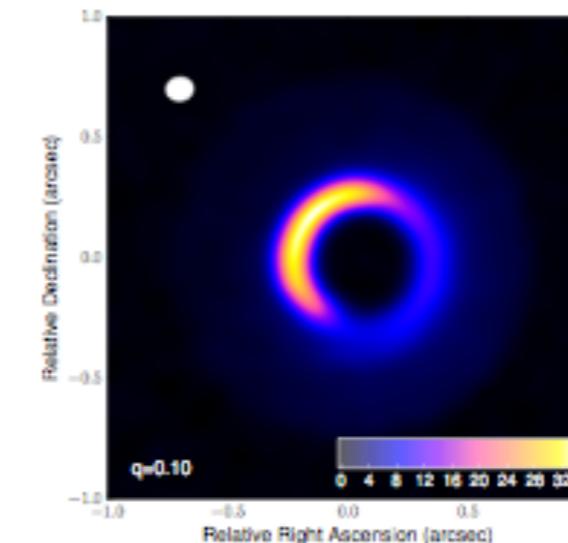
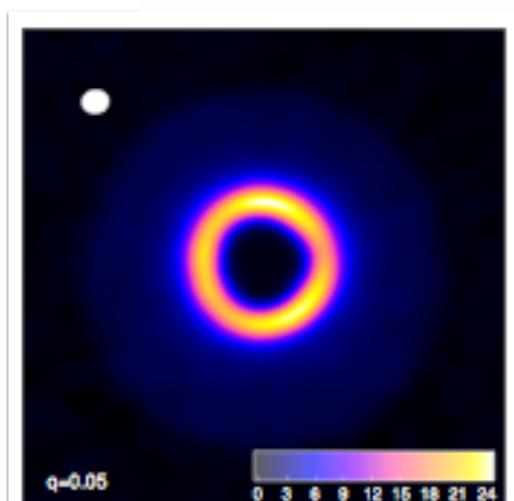
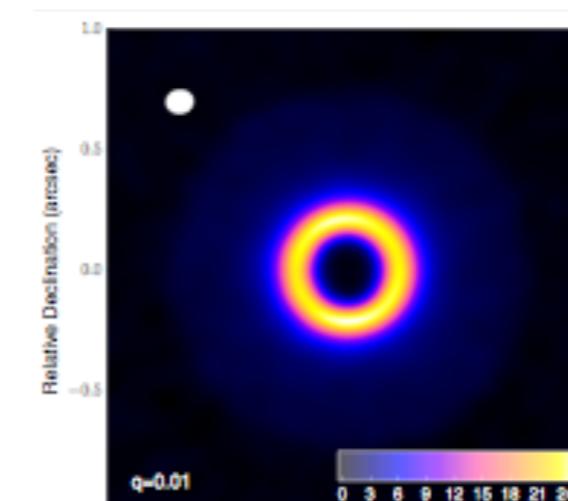
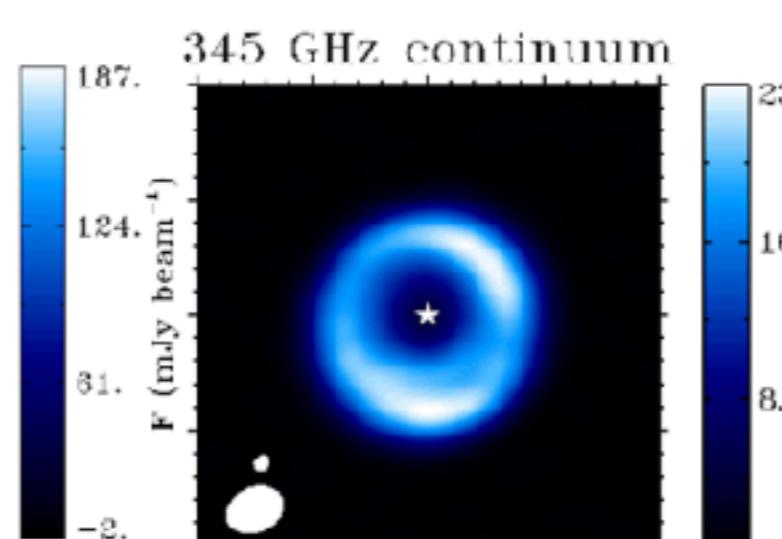
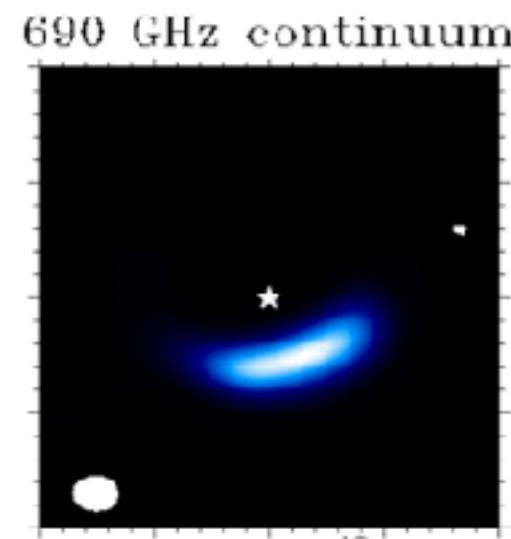
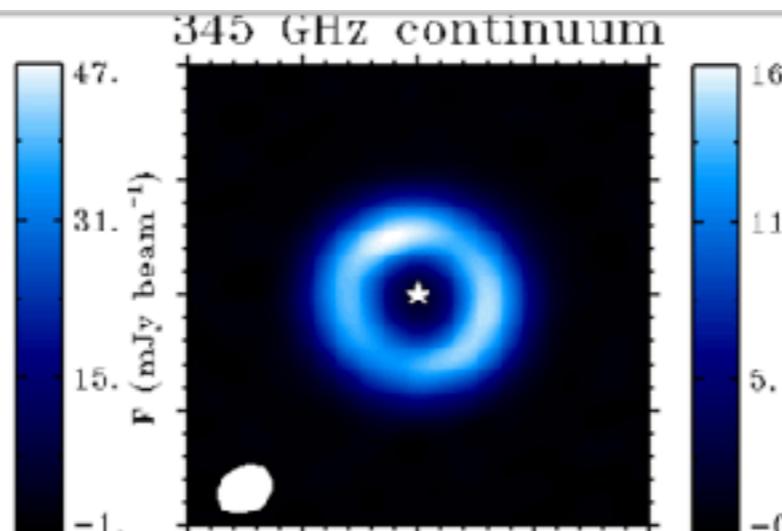
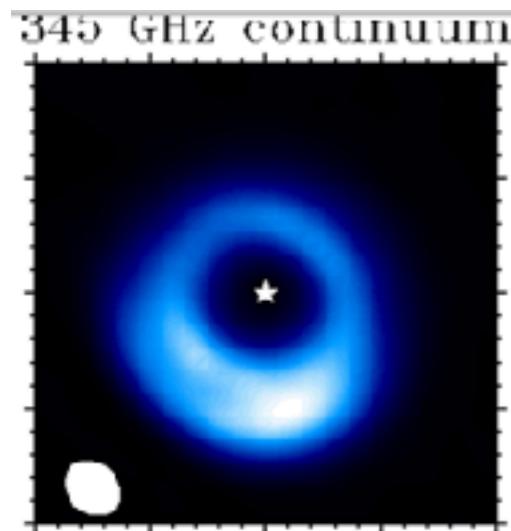
- ALMA Images (Band 7, 0.1")



- Should we see the companions?

Ragusa, Dipierro, Lodato, Laibe & Price 2017

Pretty cool, uh?!



Van der Marel+ 2016

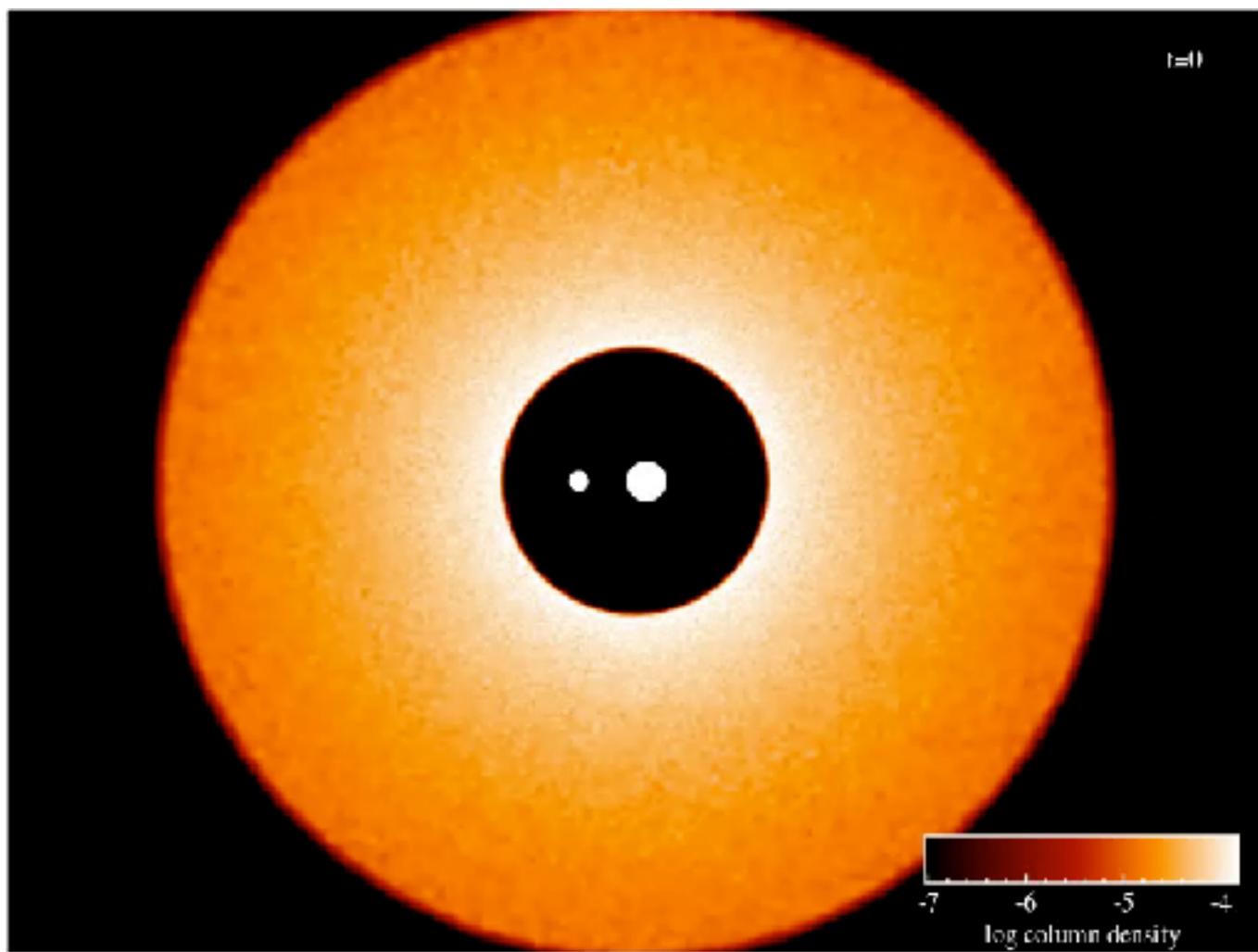
See Josh Calcino's
T-Shirt

ALMA simulated images,
Ragusa+ 2016

Recent developments

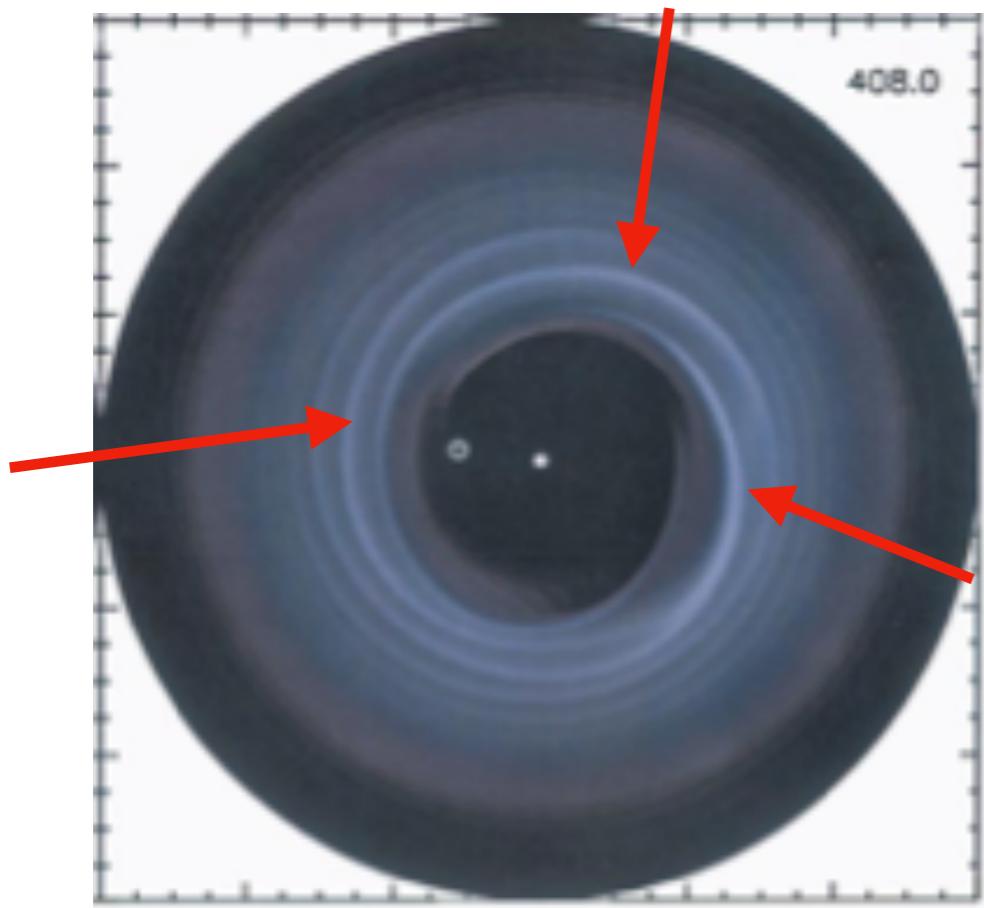
- Study physical origin of horseshoes

- Excitation of 1:? ELR resonance ($m=3$ spiral)

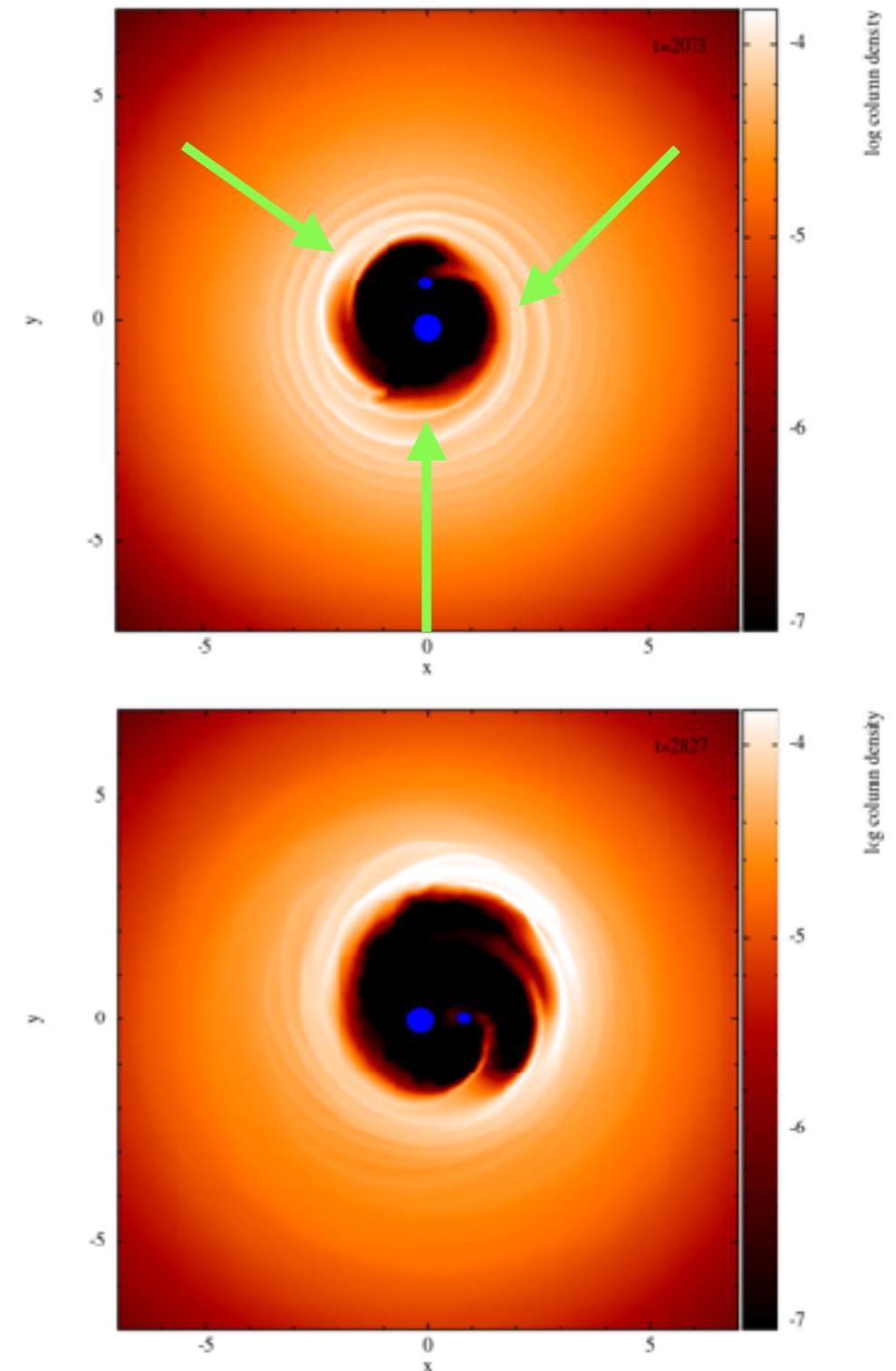


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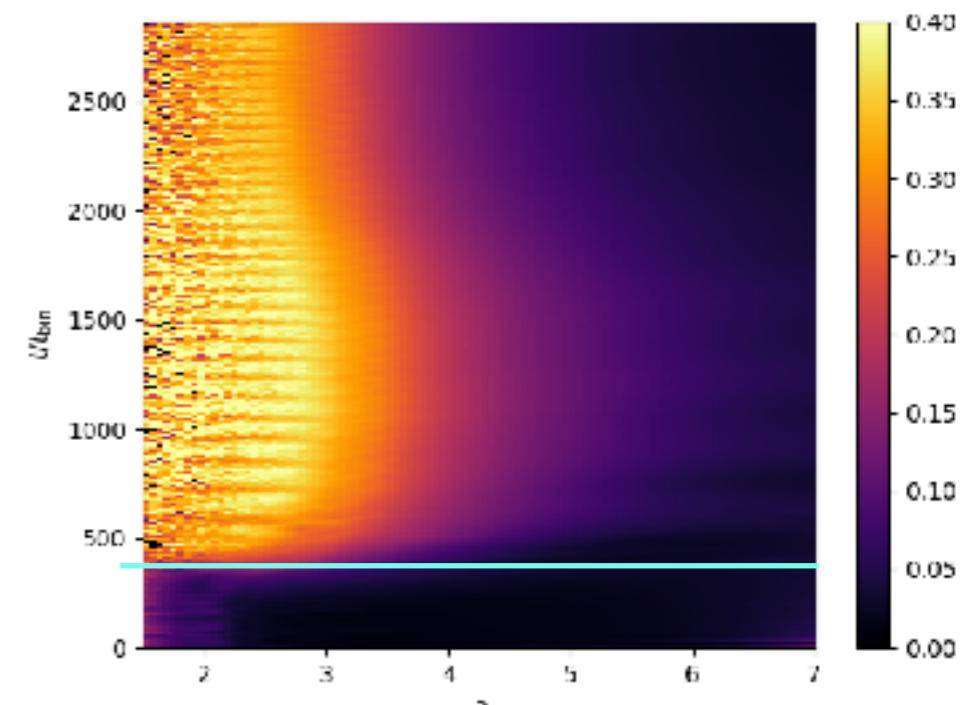
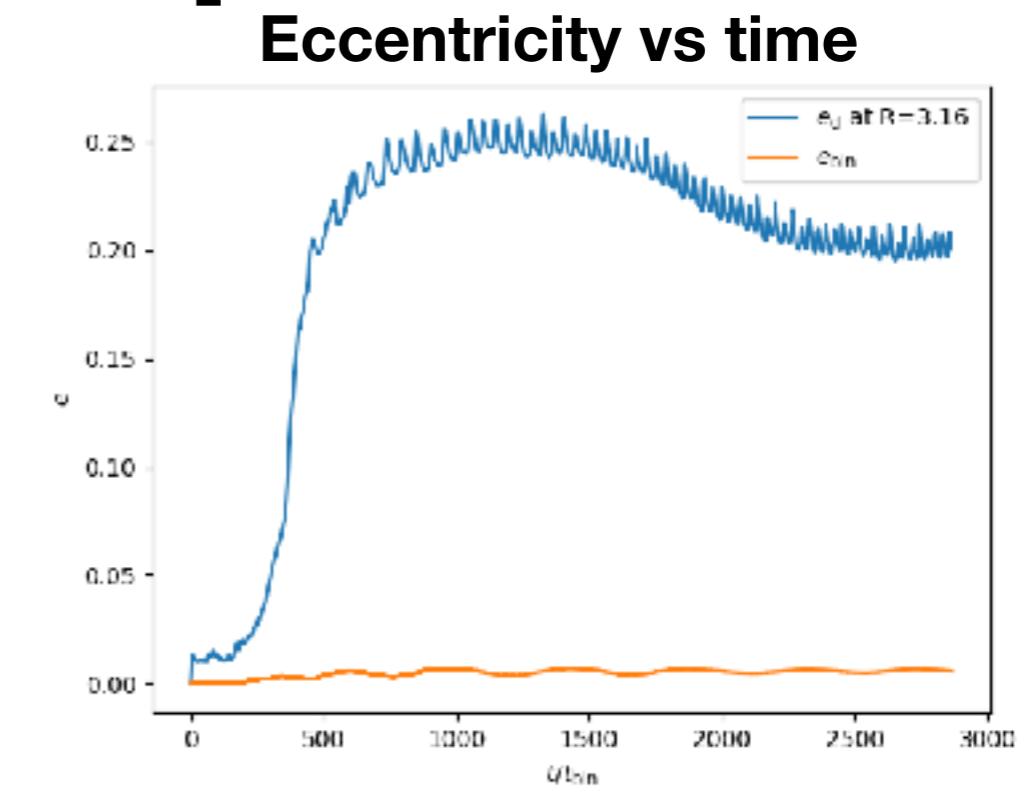
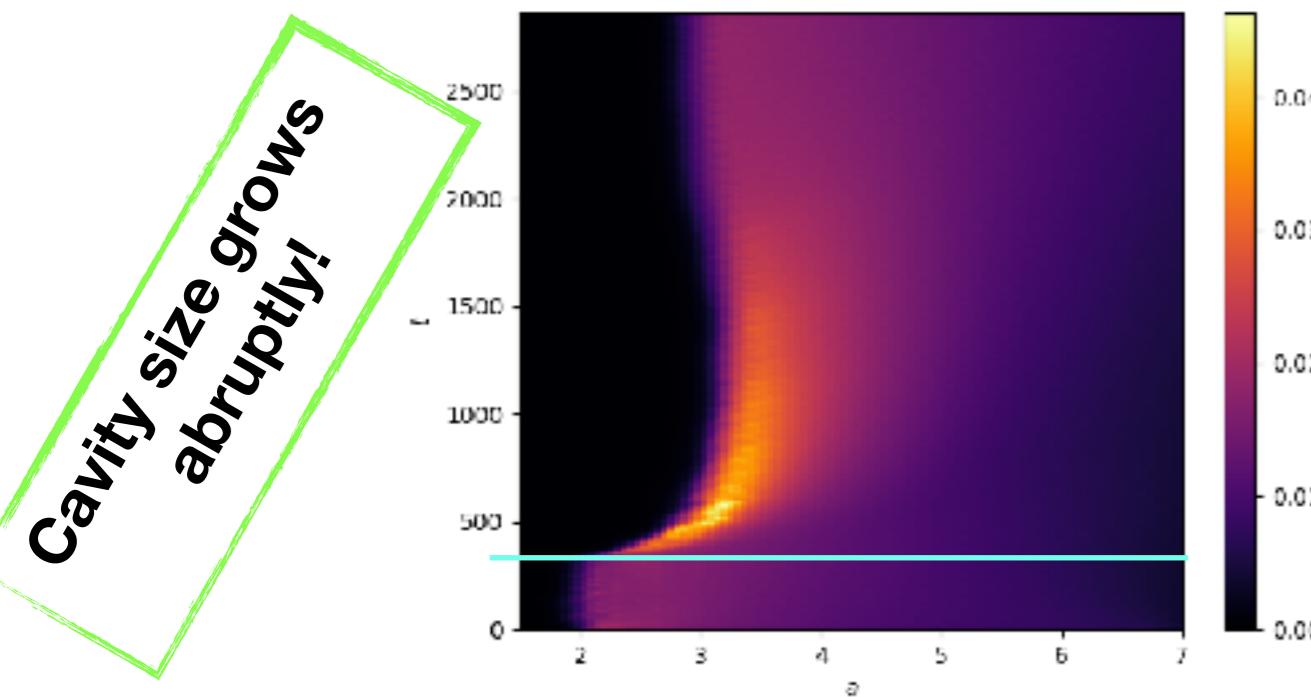


Papaloizou+ 2001



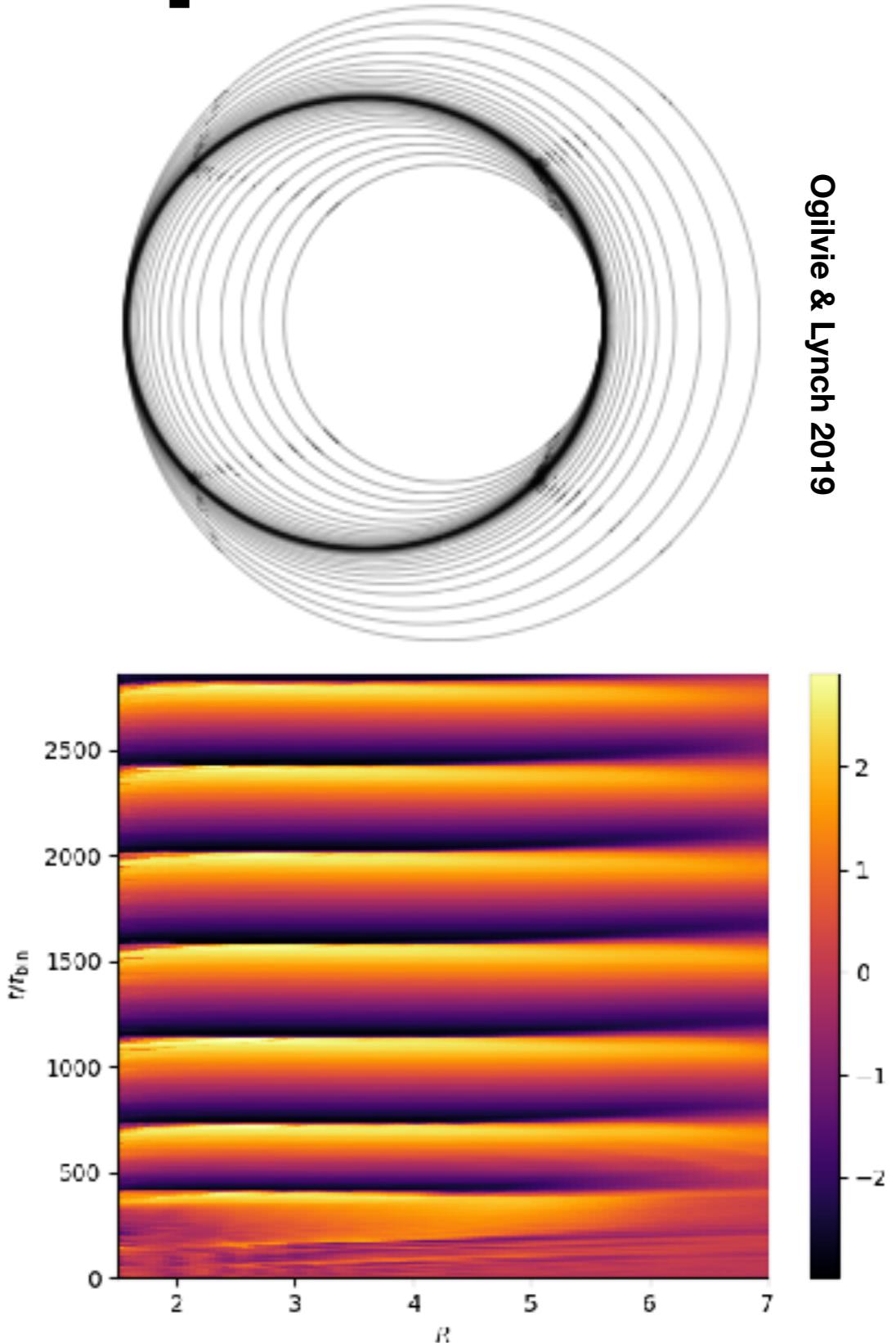
Recent developments

- Study physical origin of horseshoes
 - Excitation of 1: $\sqrt{3}$ ELR resonance ($m=3$ spiral)
 - Unstable growth of cavity eccentricity

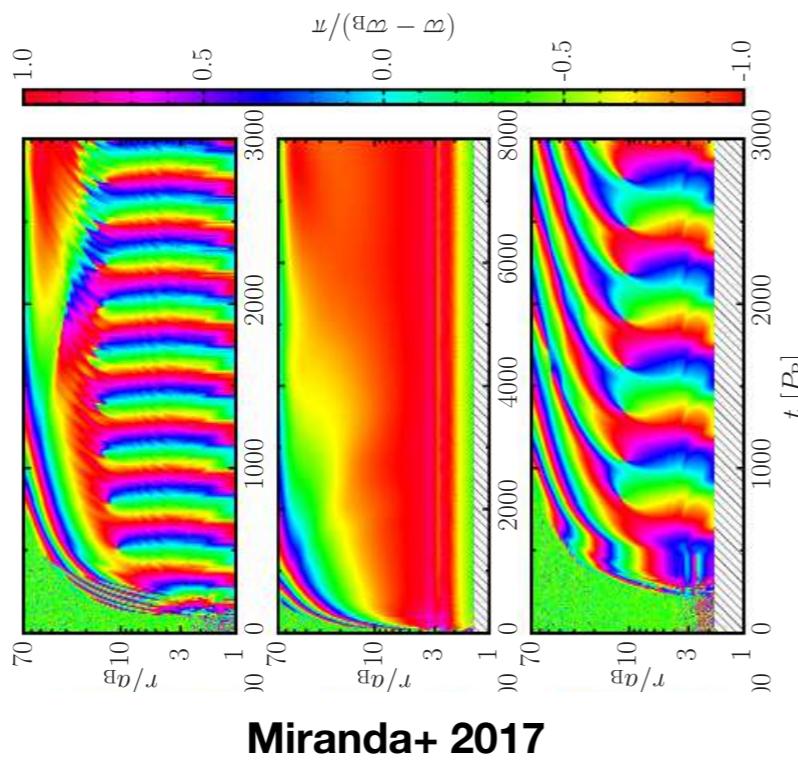


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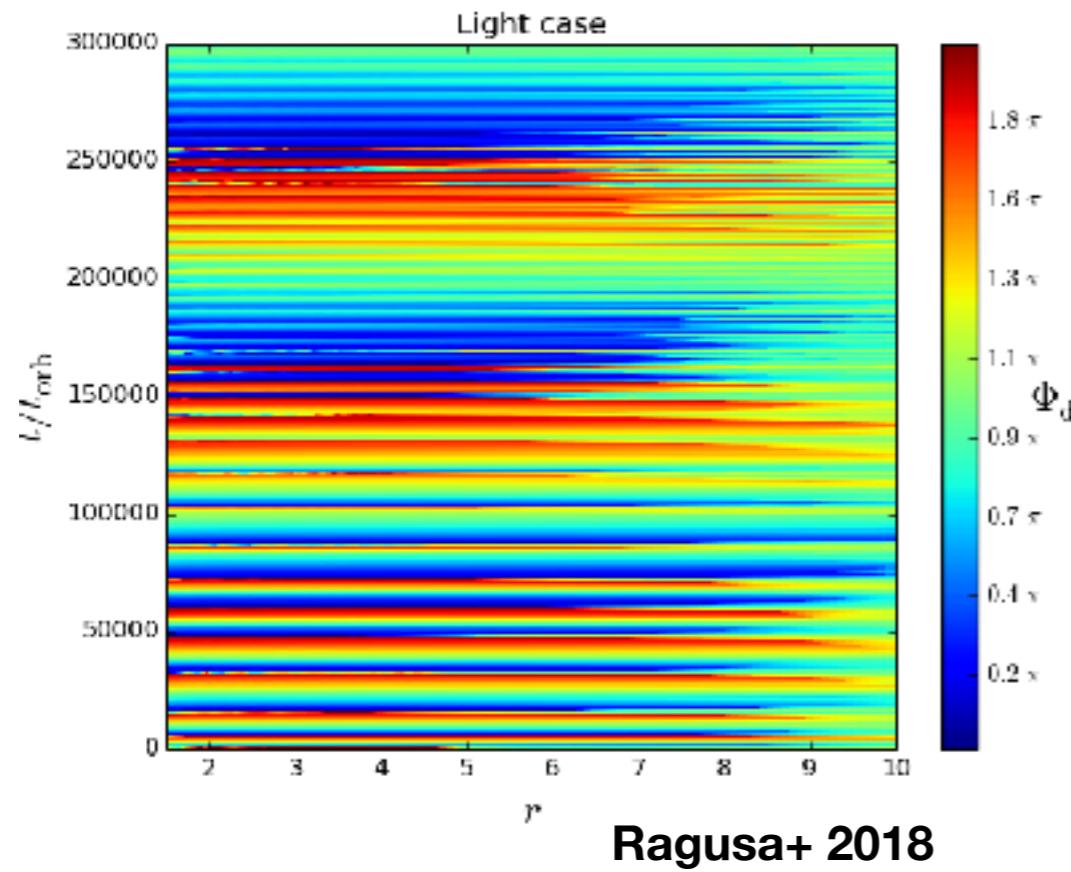
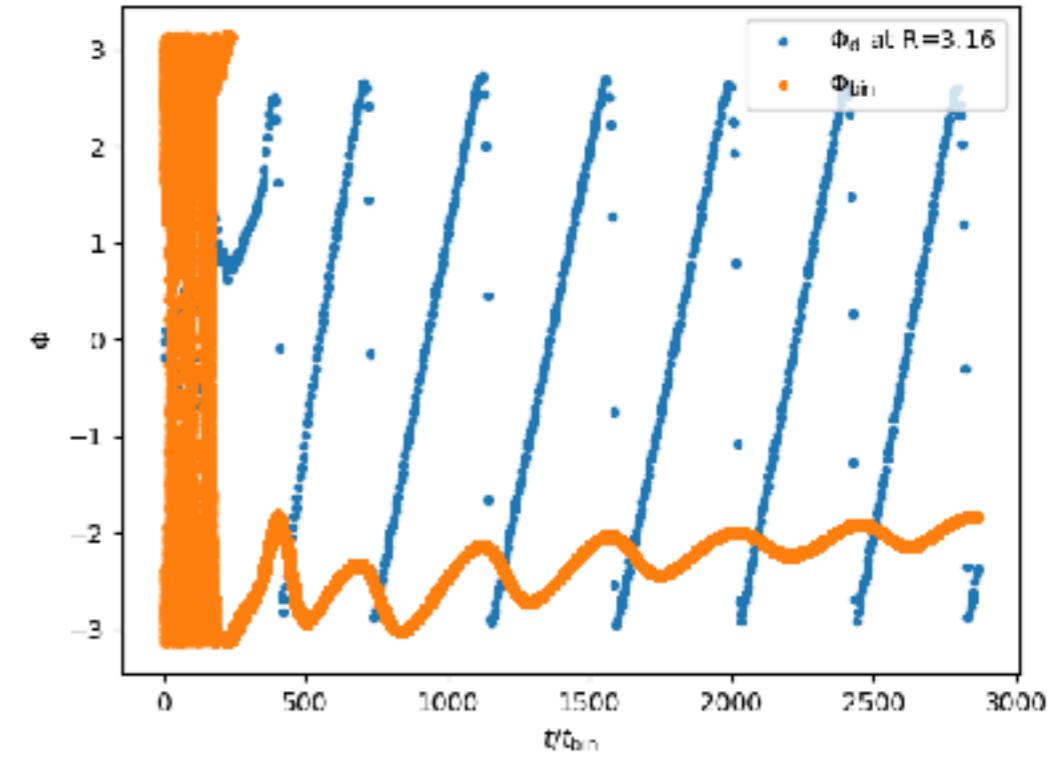
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 - Unstable growth of cavity eccentricity
 - Disc undergoes rigid precession



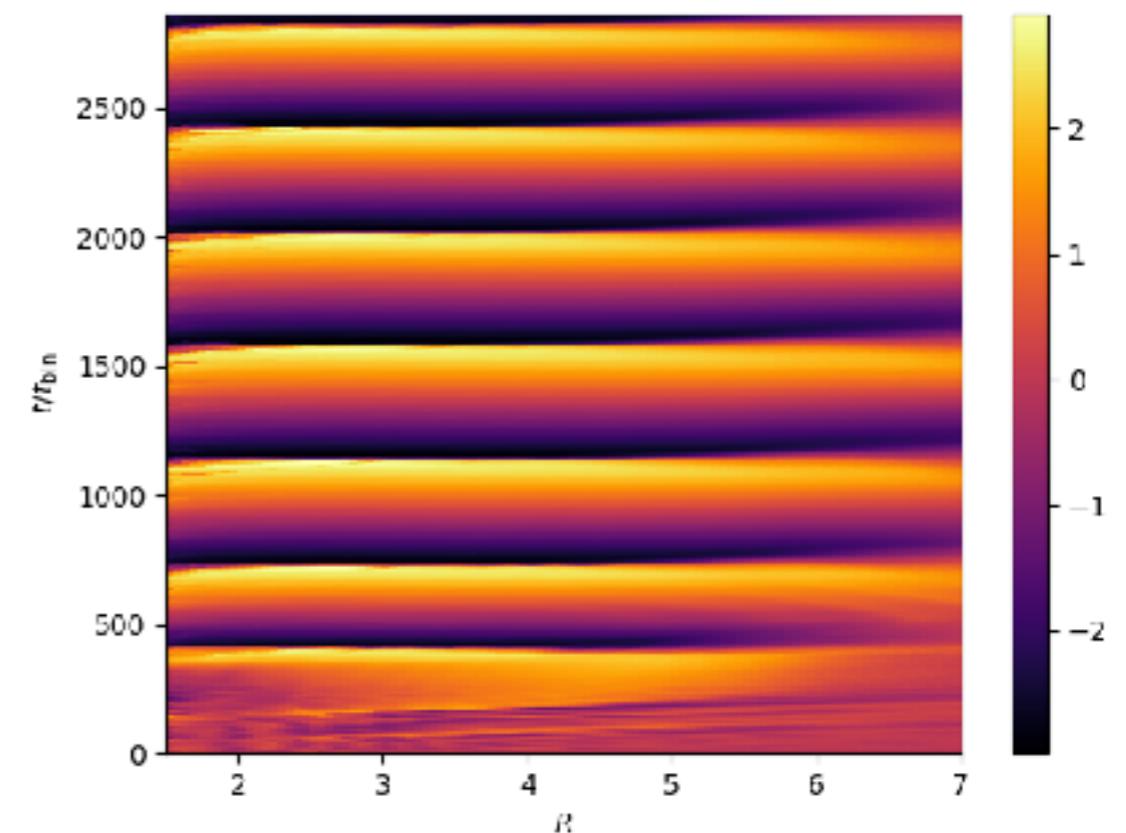
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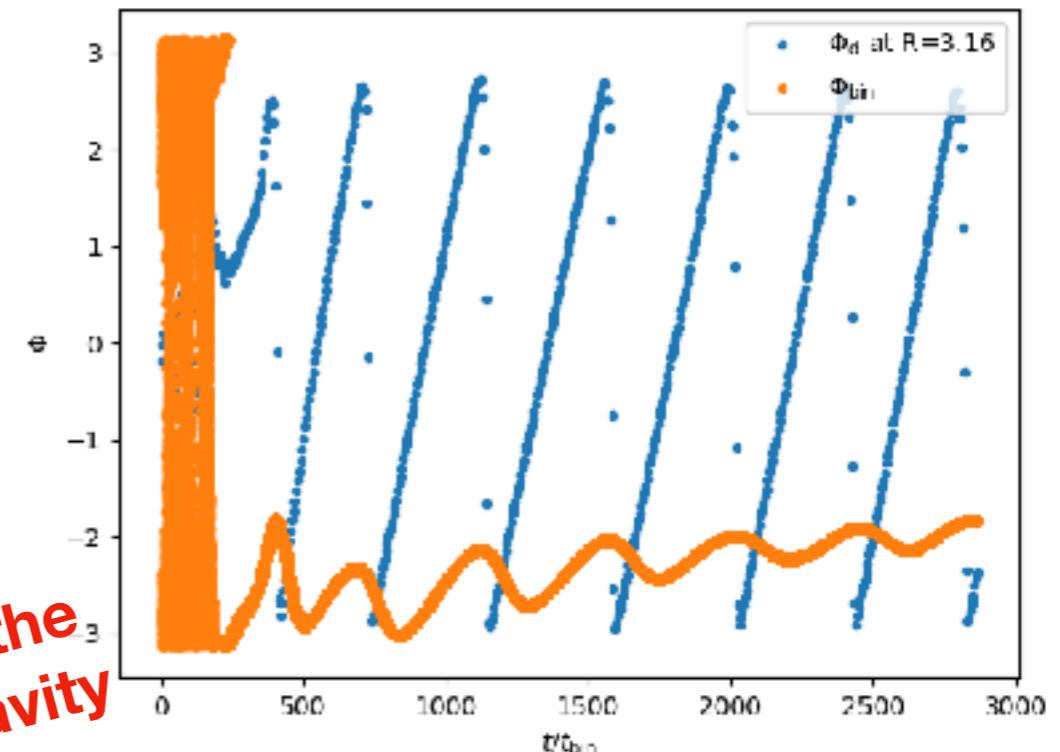
Miranda+ 2017



Ragusa+ 2018

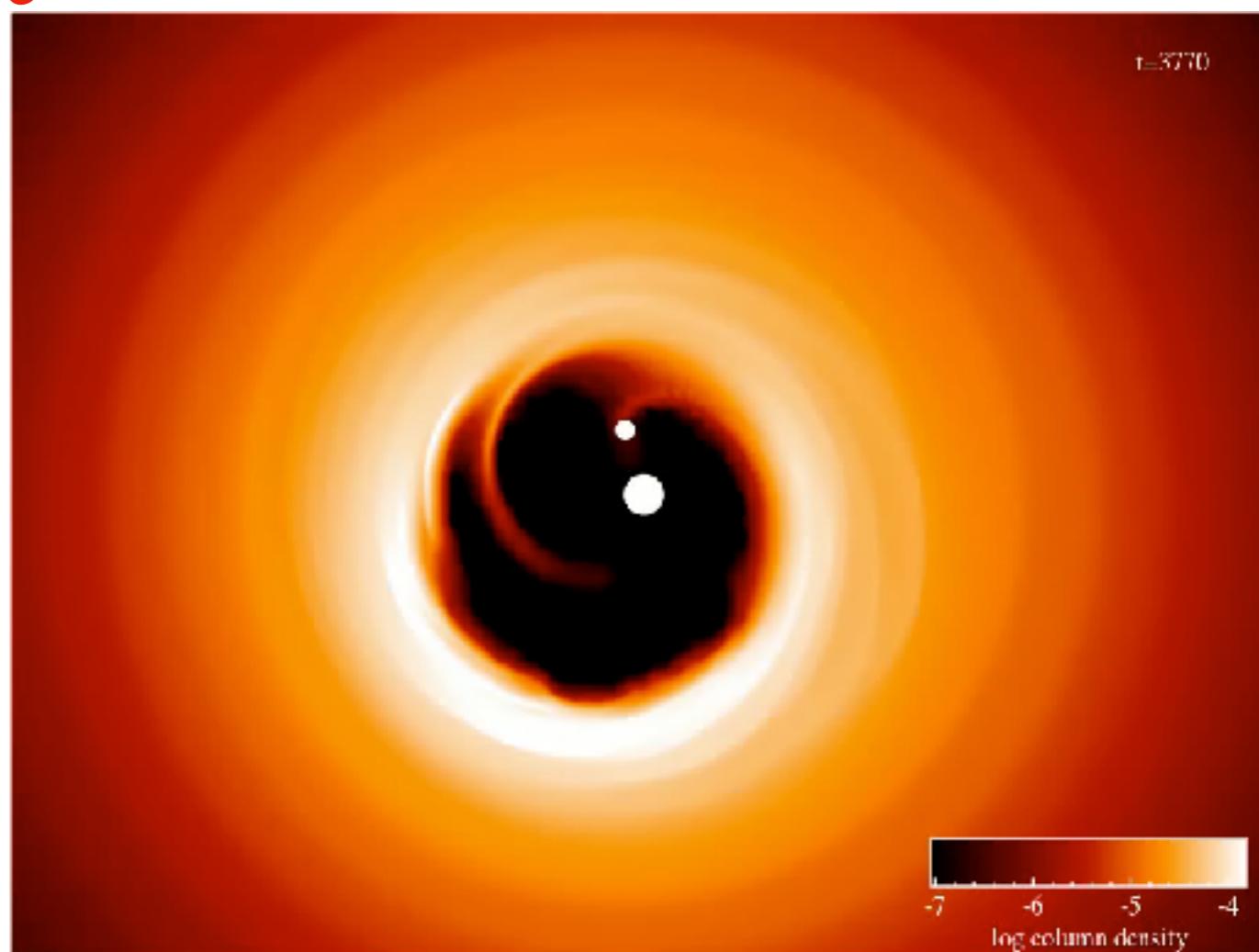


Pericentre phase vs time



Recent deve

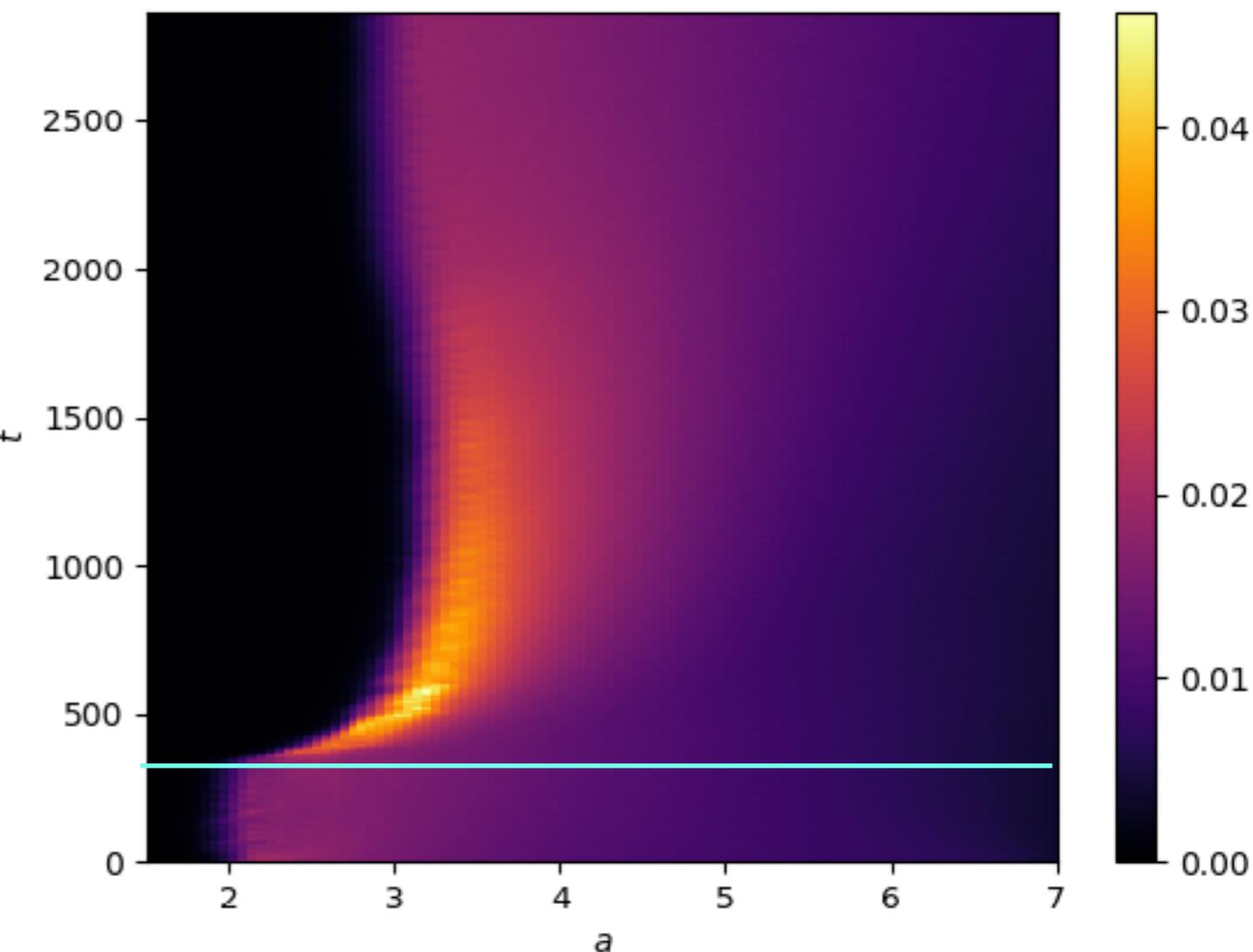
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 - Unstable growth of cavity eccentricity
 - Disc undergoes rigid precession
 - Horseshoe “dies” after ~ 1000 orbits (depends on viscosity) —> then eccentric feature



WORK IN PROGRESS

Recent developments

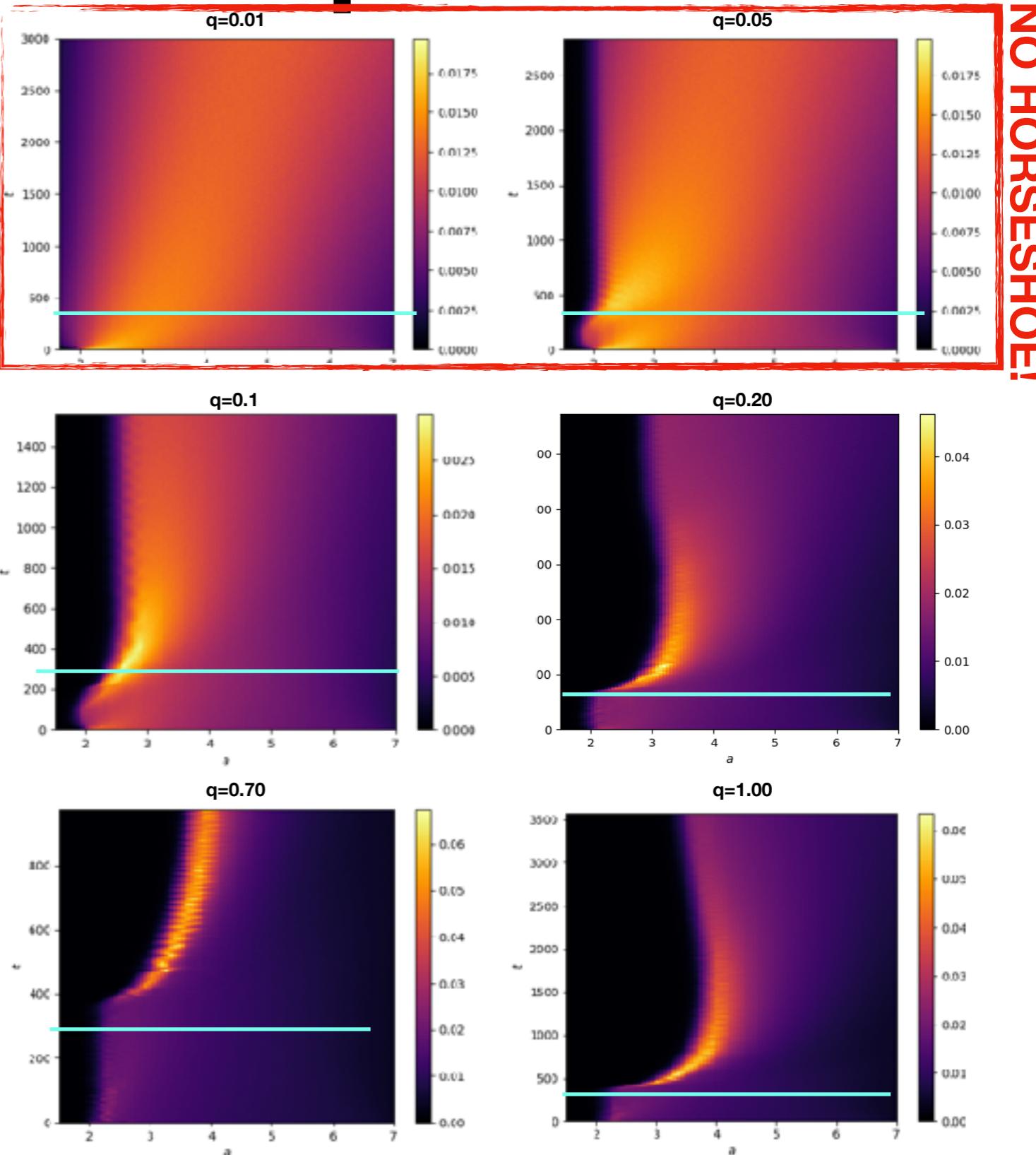
- **Finding a criterion for horseshoes formation**
 - Spanning the parameter space
 - Mass ratio
 - Pressure profile
 - Density profile
 - Disc mass
 - alpha



WORK IN PROGRESS

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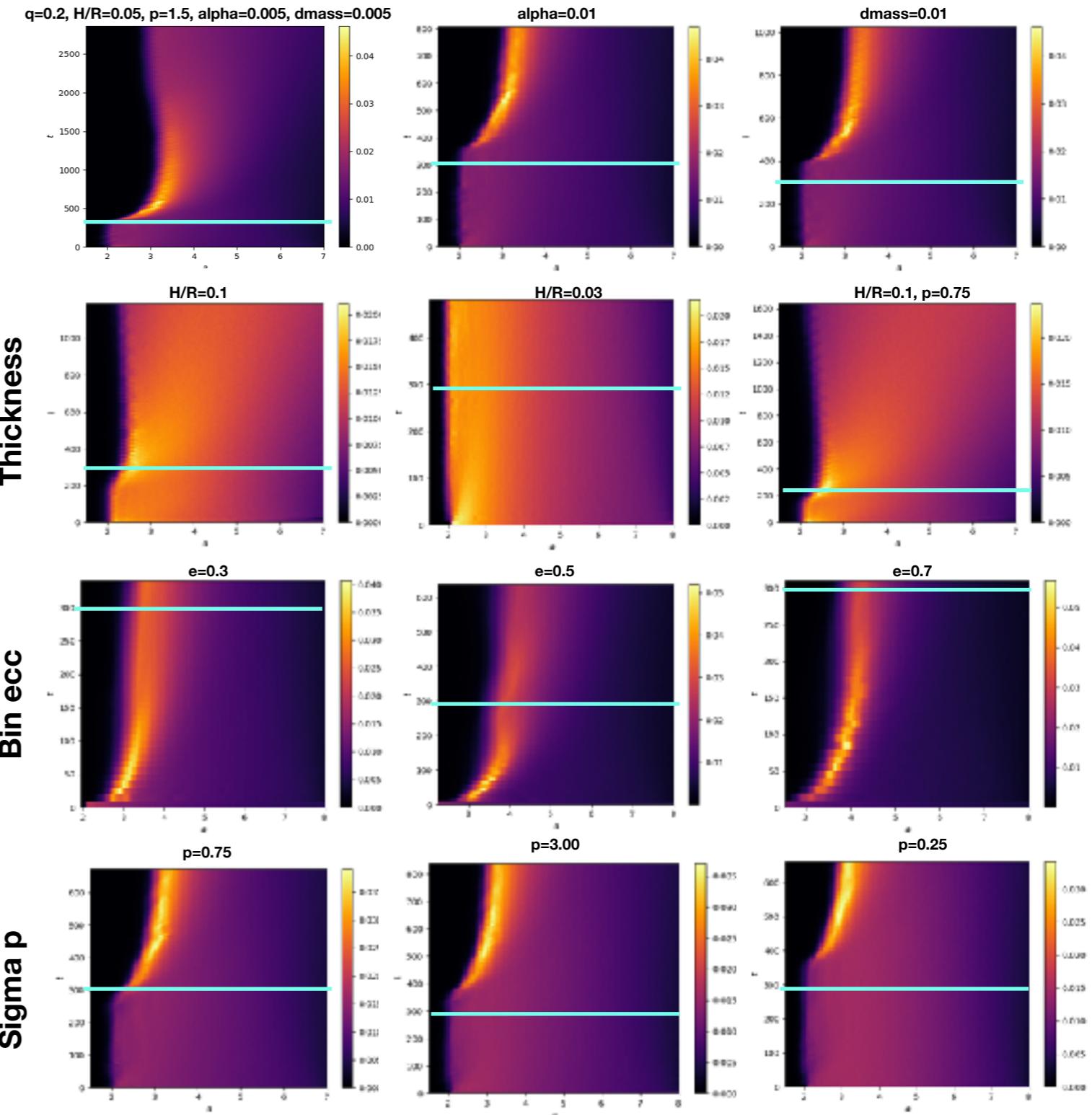
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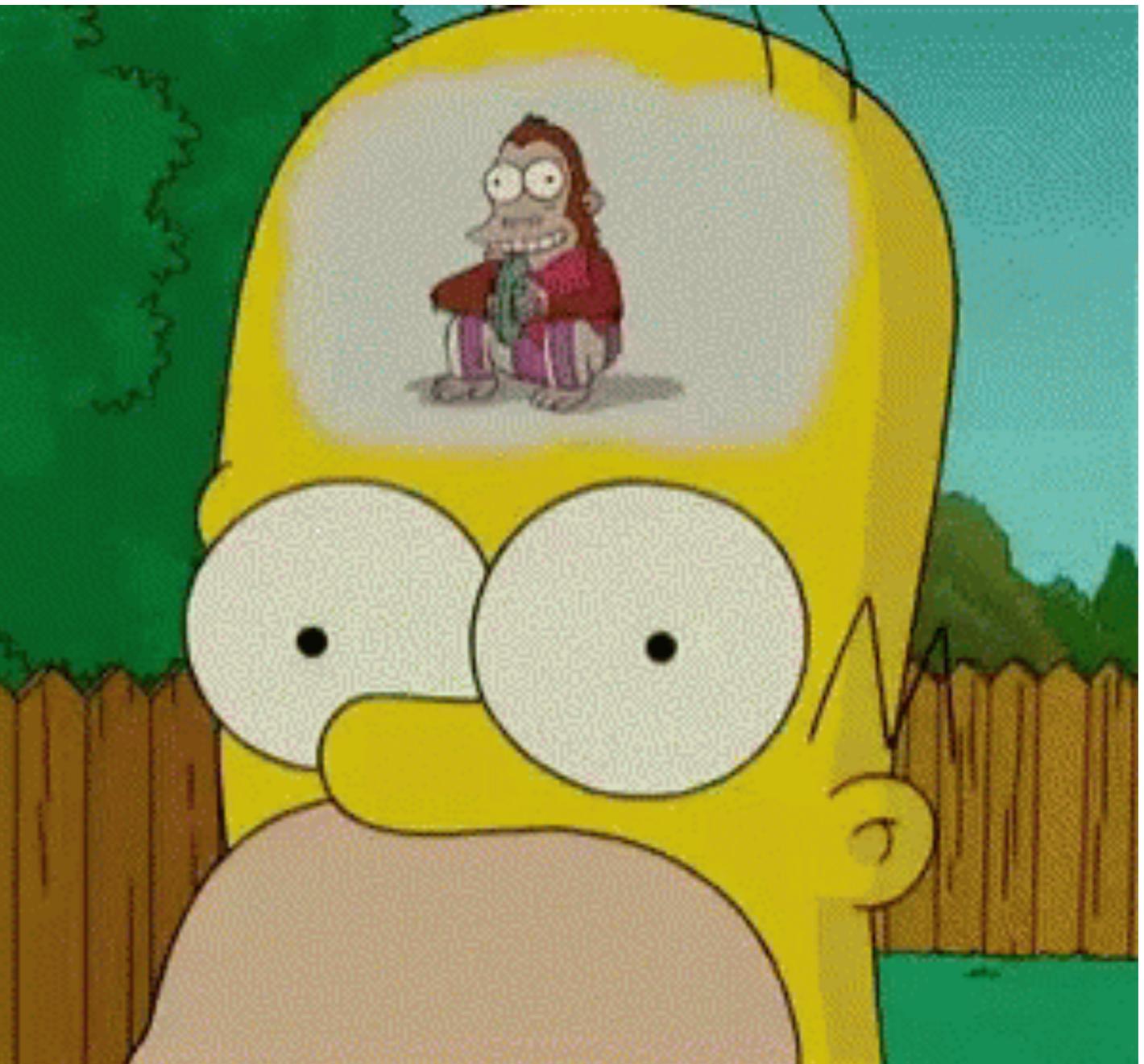
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Conclusions

- Vortices and massive companion scenario are **NOT** mutually exclusive
- Any disc with sufficiently **massive companion** will develop an **highly eccentric cavity**
- Detecting **strong cavity eccentricity** might suggest that the **massive companion scenario is in action**
- **Horseshoes** in this scenario **survive for ~1000 orbits**, then eccentric feature at the apocentre
- **Work in progress: horseshoe criterion**