LENSE-THIRRING PRECESSION DURING TIDAL DISRUPTION EVENTS

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Tidal Disruption Events (TDEs)

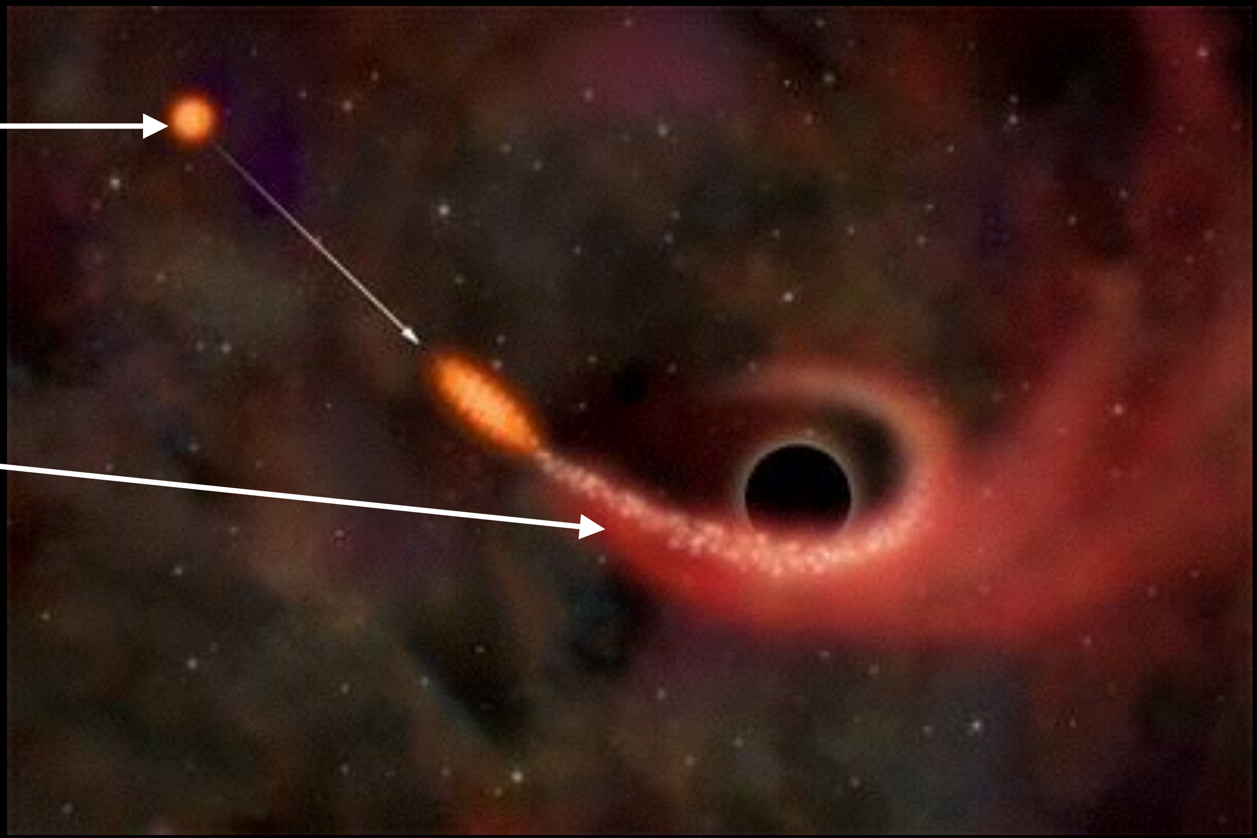
Star wanders too close to a SMBH $\longrightarrow$ torn apart by its tidal field (Rees 1988)

$$r_{\rm t} \approx 0.47\,{\rm au}\,(M_6/m_*)^{1/3} x_*$$

Impact parameter $\beta = r_{\rm t}/r_{\rm p} \gtrsim 1$ $\longrightarrow$ disruption

star $\longrightarrow$

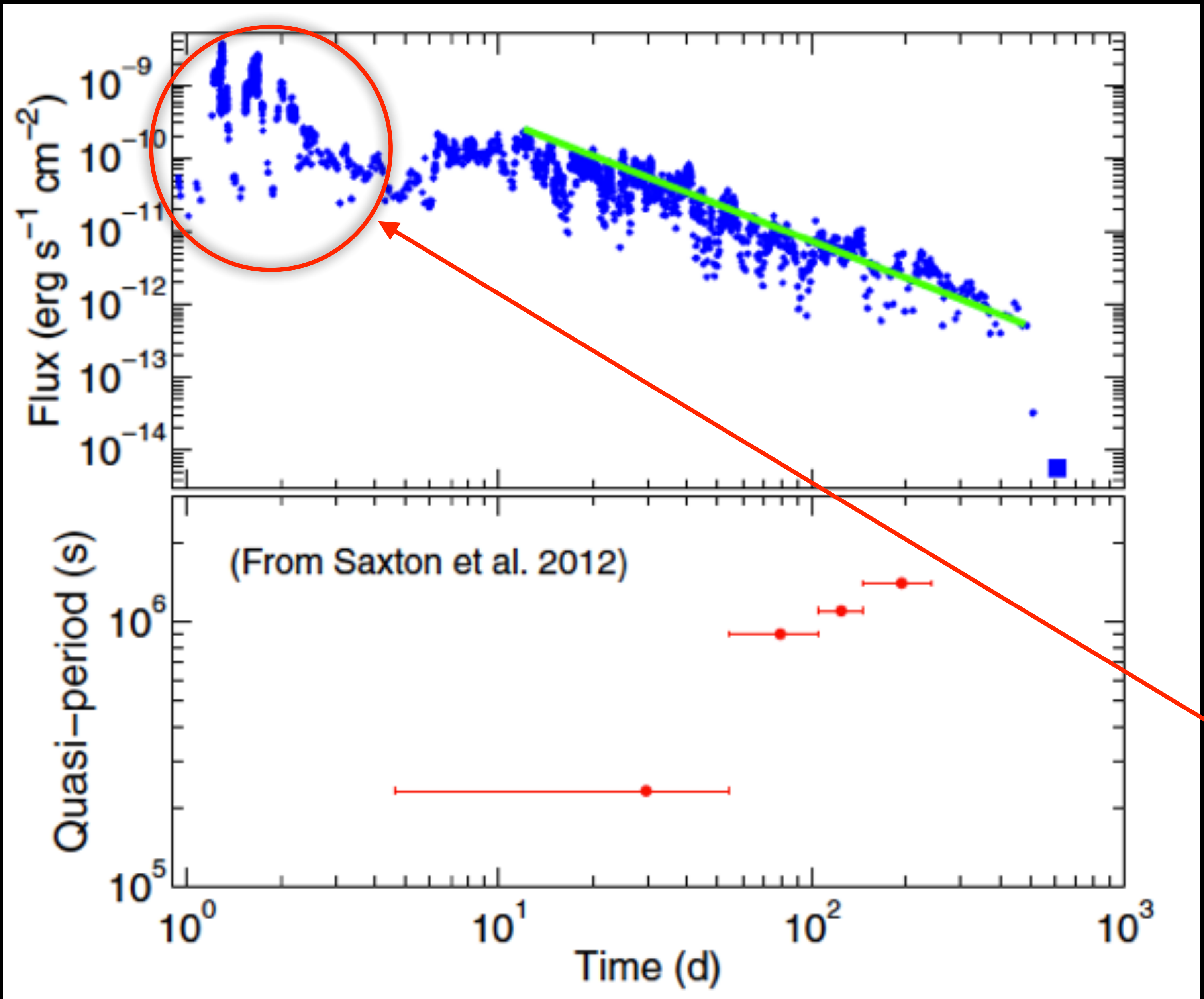
stellar debris coming back to pericentre after $\longrightarrow$



$$t_{\rm min} \approx 41\, M_6^{1/2} m_*^{-1} x_*^{3/2}\,{\rm d}$$

$$\dot{M}_{\rm fb} = \dot{M}_{\rm p} (t/t_{\rm min})^{-5/3}$$

Tidal Disruption Events (TDEs)



Swift XRT data - 0.3-10 keV light curve Sw J1644+57

- Very bright flares, super-Eddington in the early phase
- Last weeks
- Luminosities declining with $t^{-5/3}$

quasi-periodicity in the light curve of the event

$t_{\rm p} \simeq 2.7 {\rm days}$

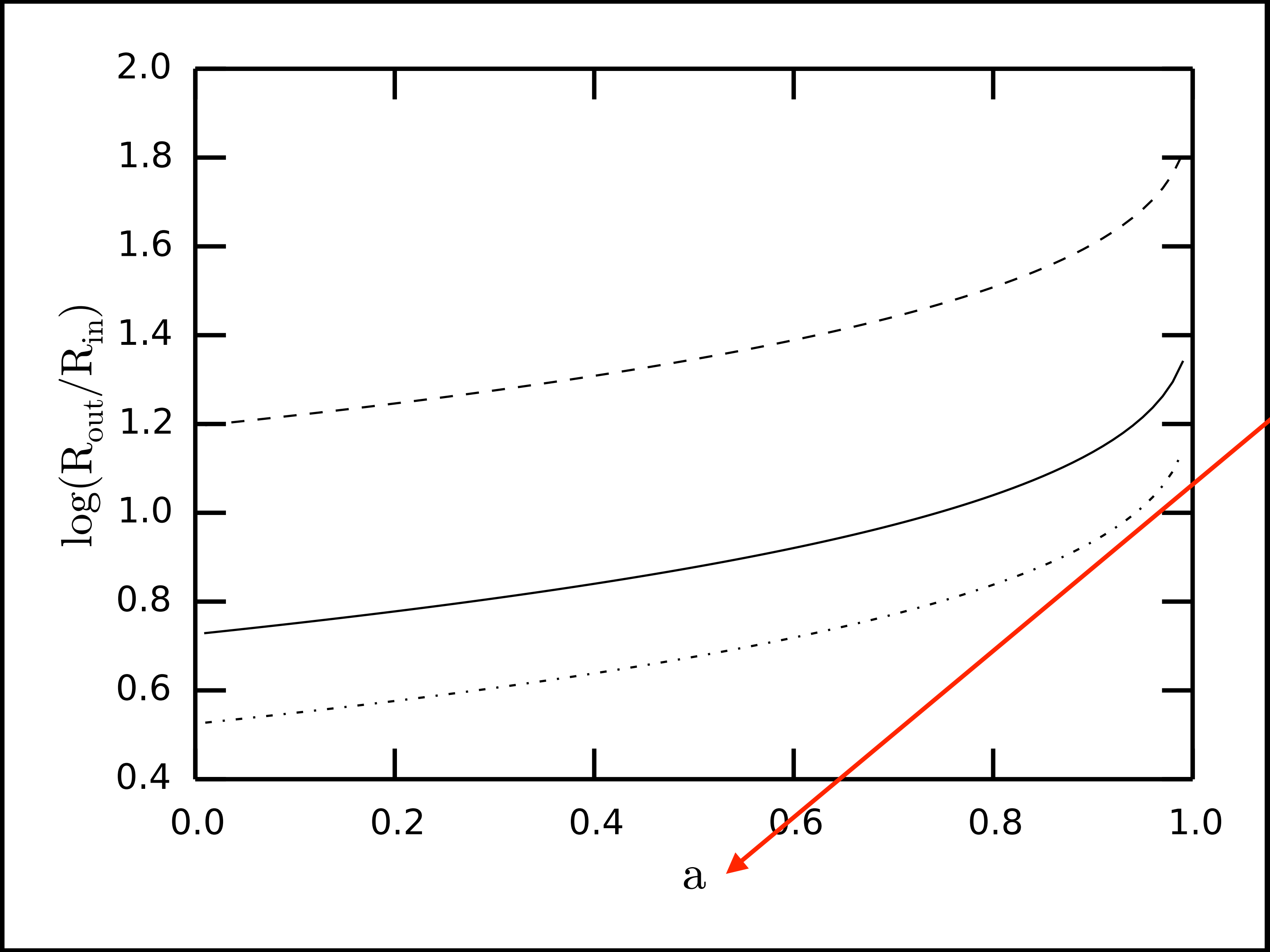
Could it be the disc rigid precession causing the jet precession? (Stone & Loeb 2012, Lei et al. 2013, Shen & Mazner 2014)

Accretion disc

Stellar debris orbits circularize at $r_c \simeq 2r_t$ and form an accretion disc (Bonnerot et al. 2015)

$$r_{out} = 94 M_6^{-2/3} \longrightarrow r_{in} = r_{isco}$$

Black hole spin



→ Narrow disc (radiation pressure dominated)

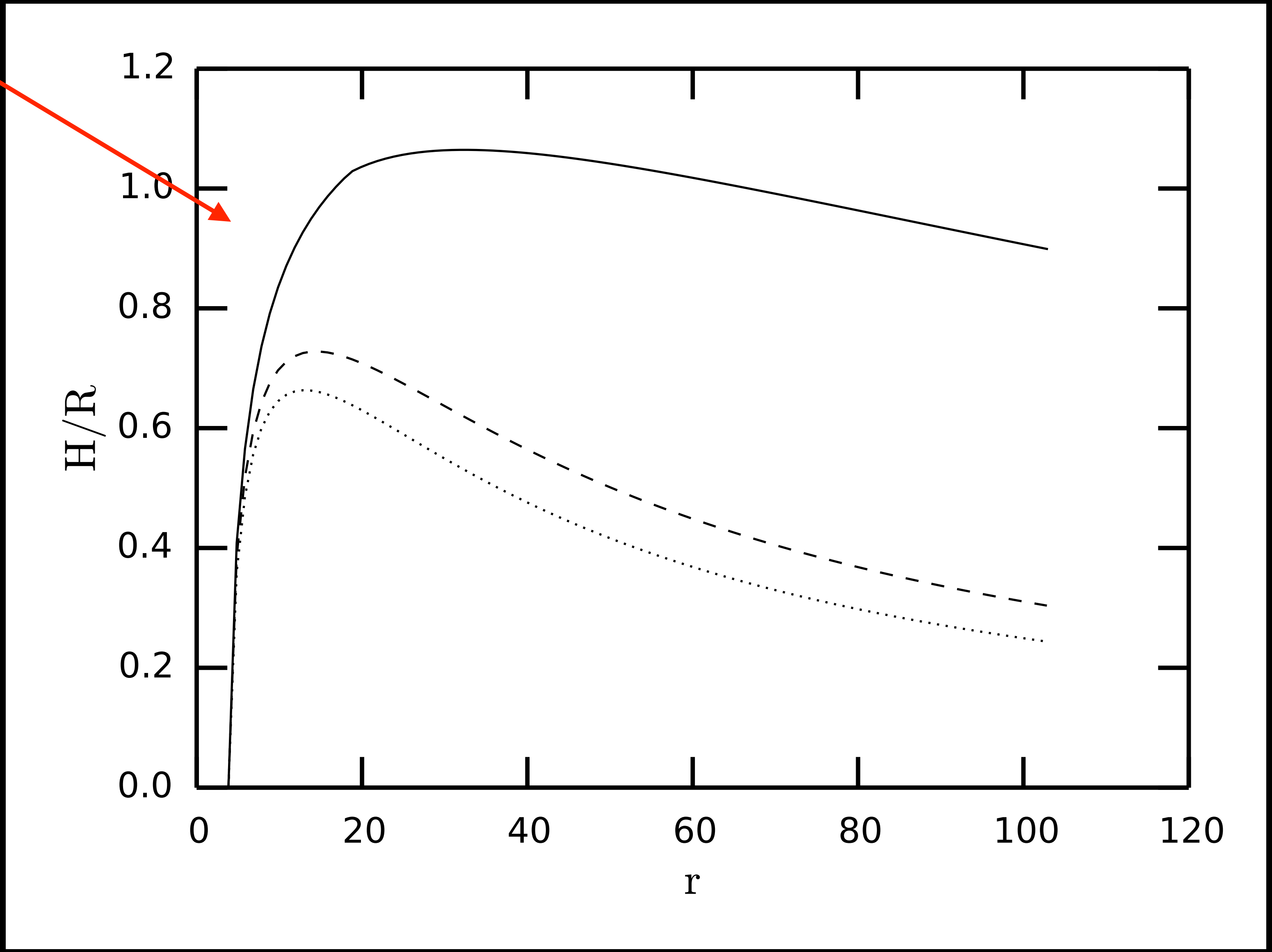
Accretion disc

Super-Eddington ($\dot{m} = \dot{M}/\dot{M}_{\rm Edd} \gtrsim 1$) accretion in the early phase, the disc is hot and then it is expected to be thick.

$$\frac{H}{R} = \frac{3}{2}(2\pi)^{1/2}\,\eta^{-1}\,\dot{m}\,r^{-1}f(r)\,K(r)^{-1}$$

$$\dot{m} = r/r_{\rm in}$$

$$\dot{m}_{\rm fb} = \dot{m}_{\rm p}(t/t_{\rm min})^{-5/3}$$



Warp

Stellar orbit inclined with respect to the black hole equatorial plane

⟶ coupling between the disc and the black hole angular momenta.

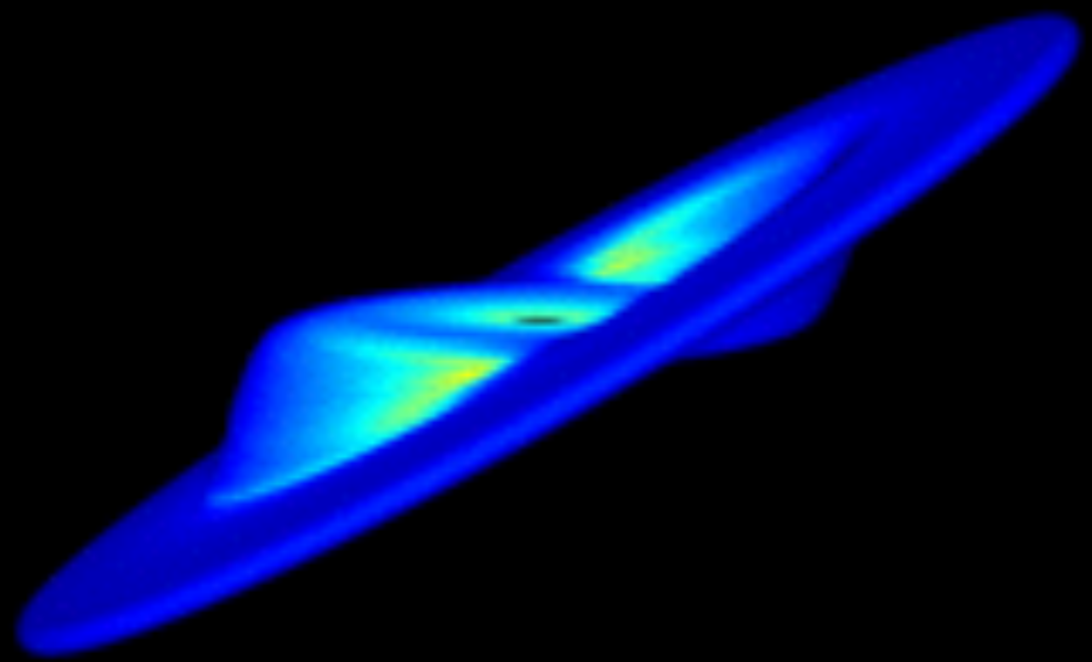
Lense-Thirring effect $$\mathbf{\Omega}_{\rm LT} \simeq \frac{2G\mathbf{J}_h}{c^2 R^3}$$

Warp propagation in the bending wave regime since the disc is thick

$$H/R \gtrsim \alpha$$

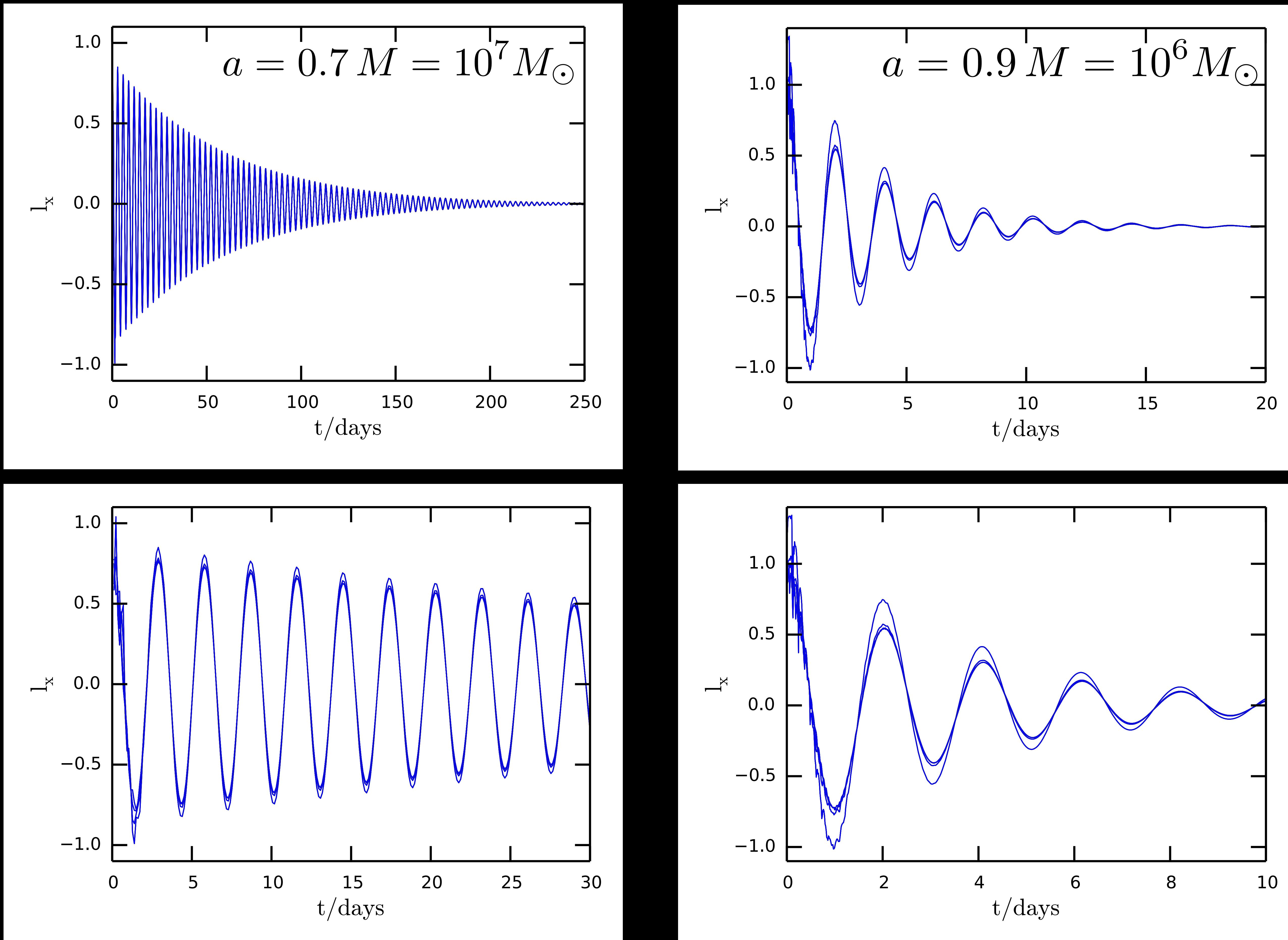
Propagation with half the sound speed

$$t_{\rm w} = \frac{2}{\Omega}\left(\frac{H}{R}\right)^{-1}$$



Lodato & Price (2007)

Rigid precession



Precession period

Precession frequency depends on SMBH mass and spin.

observable

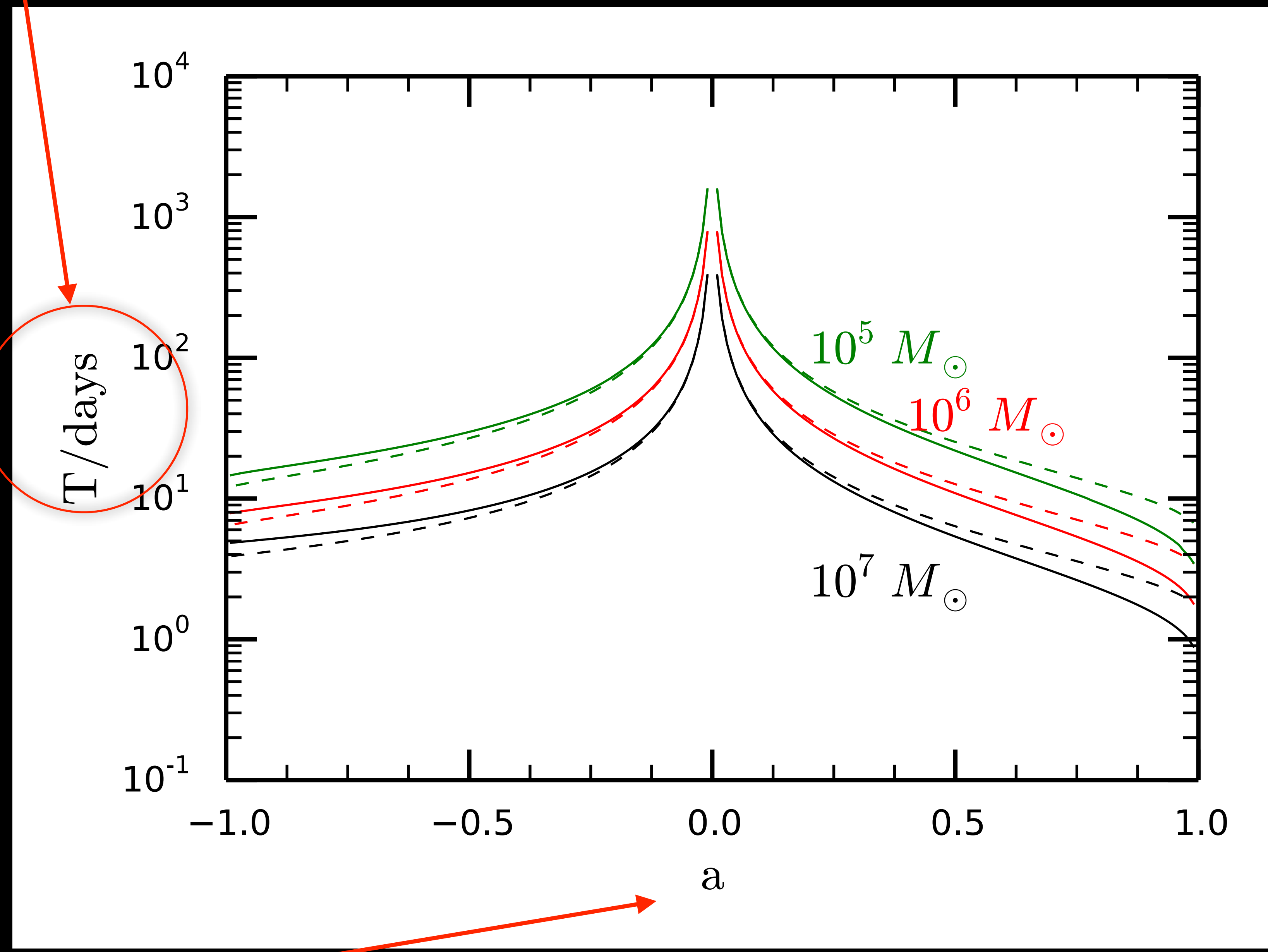
$$\Omega_p = \frac{\int_{R_{\rm in}}^{R_{\rm out}} \Omega_{\rm LT}(R) L(R) 2\pi R\, dR}{\int_{R_{\rm in}}^{R_{\rm out}} L(R) 2\pi R\, dR}$$

light curve

mass

period

inner radius



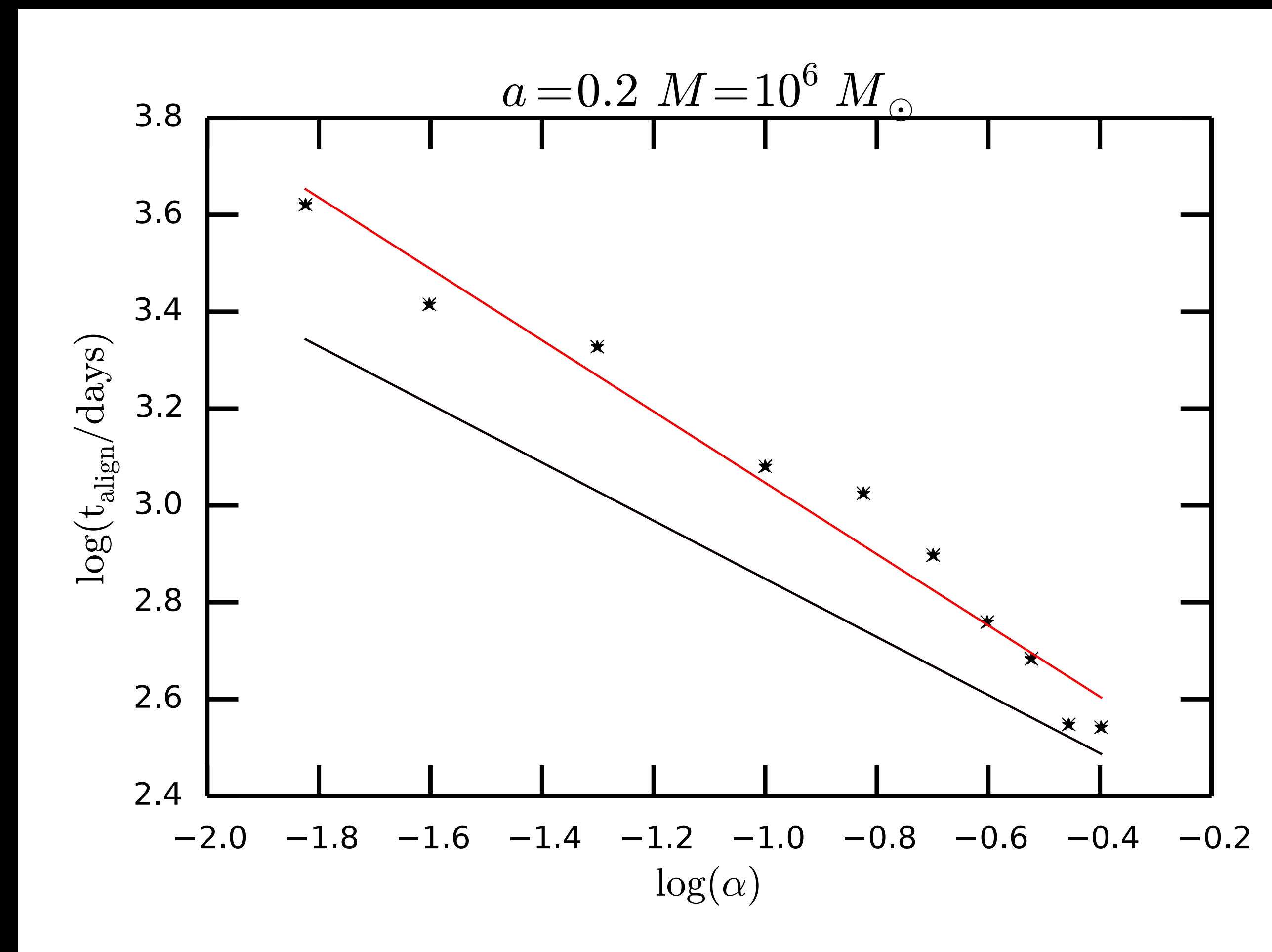
Franchini et al. (2015) (submitted)

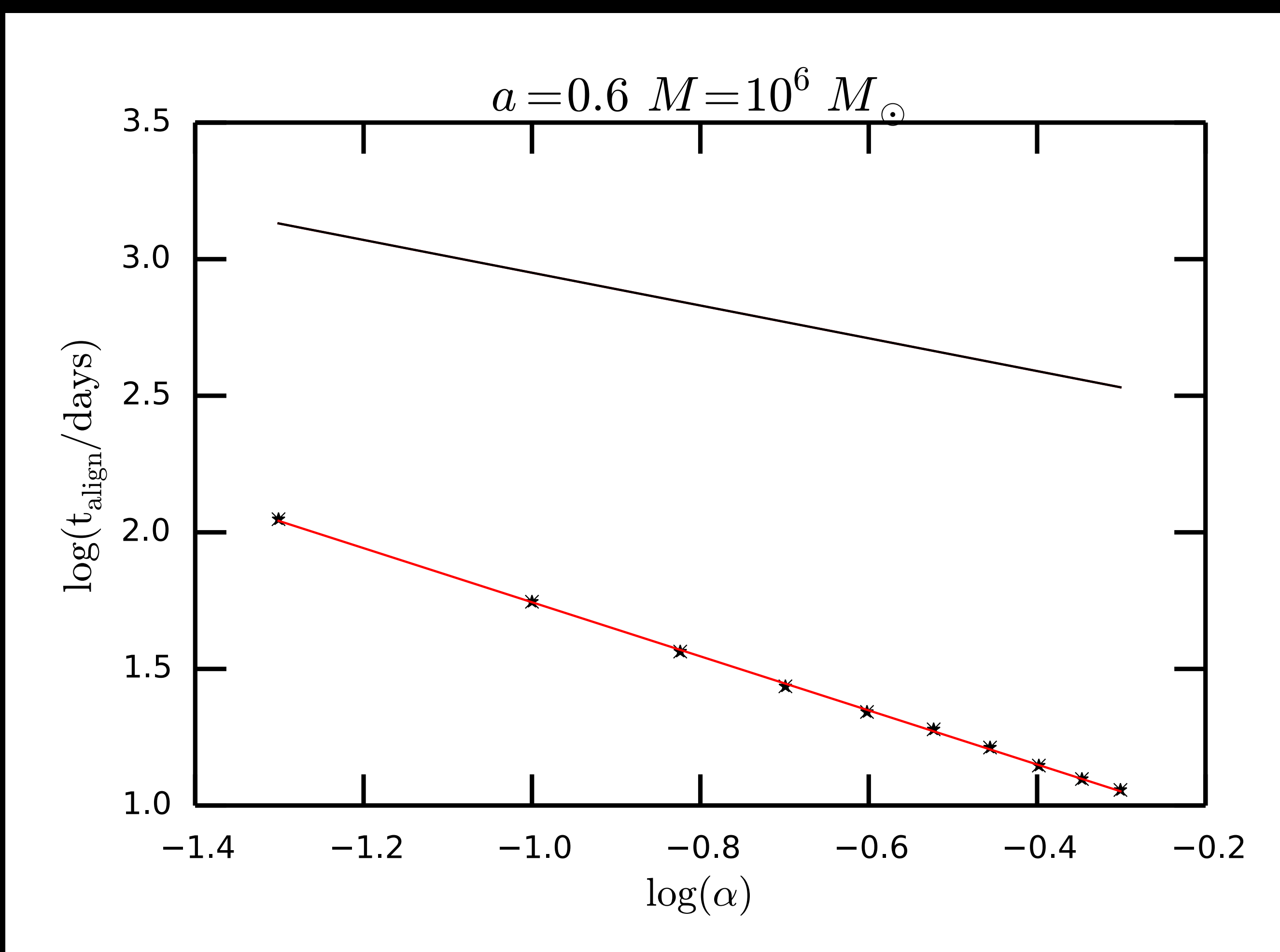
Alignment

After some time the precession stops, meaning that the disc angular momentum is aligned with respect to the SMBH spin (no longer coupling).

$$t_{\rm thin} \propto \alpha^{-3/5}$$

$$t_{\rm align} \propto \alpha^{-1}$$





Conclusions and outlook

- Calculate the precession period so that it can be linked with the SMBH spin value
- Study the alignment process

- Apply this model in the case of QPOs in LMXBs.
- 3D SPH (Smoothed Particle Hydrodynamics) simulation with the aim to study the wave propagation inside the disc more deeply

THANK YOU!