LENSE-THIRRING PRECESSION DURING TIDAL DISRUPTION EVENTS

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SUMMARY

- Supermassive black holes
- Tidal Disruption Events (TDEs) theory
- Accretion discs structure
- Lense-Thirring rigid precession
- Precession period
- Alignment
- Conclusions and outlook

SUPERMASSIVE BLACK HOLES

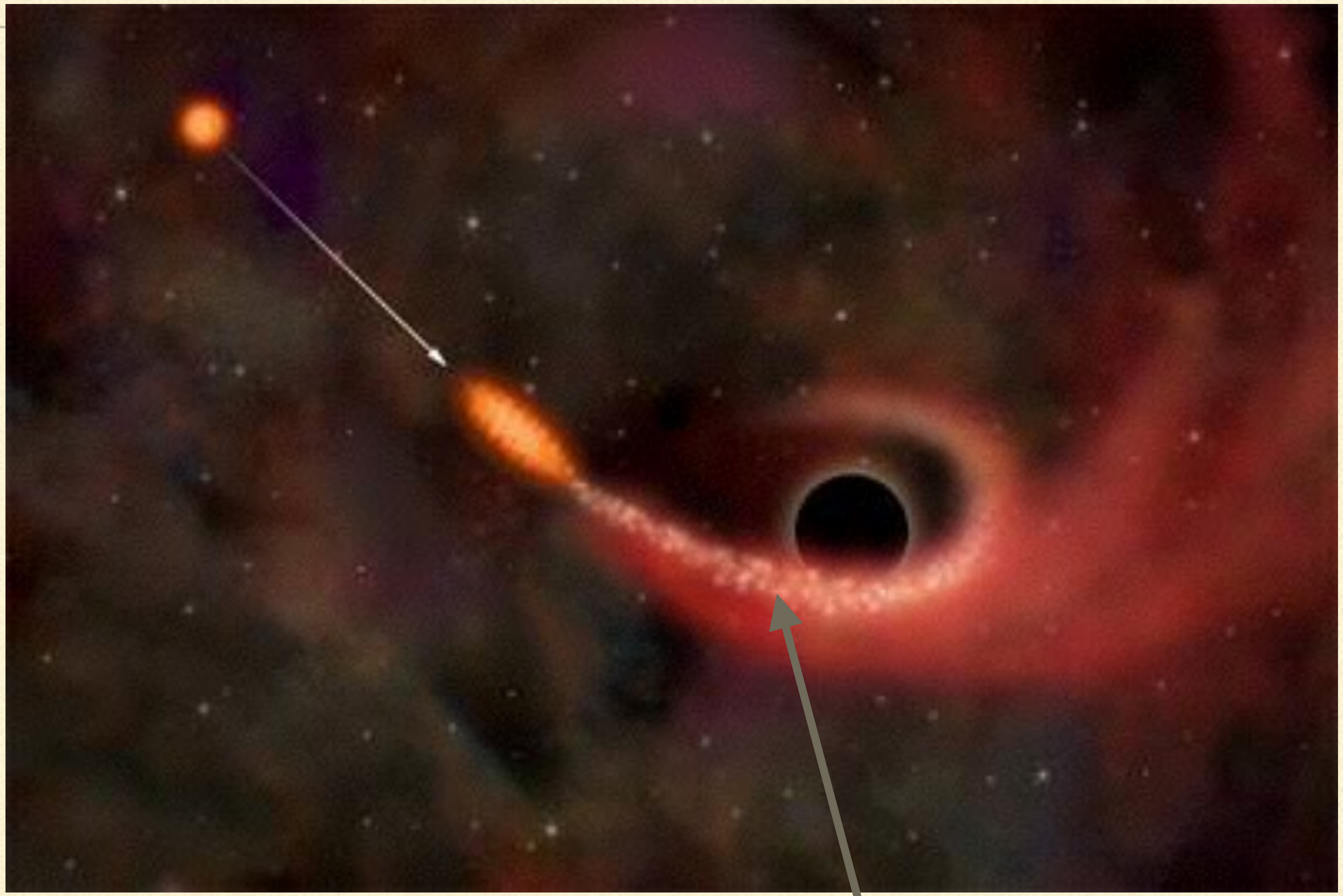
- Widespread presence in center of quiescent galaxies (Sgr A* in our Milky Way) and active galactic nuclei (AGNs)
- Supermassive $10^6 - 10^9 M_\odot$
- Investigate central regions of AGNs
- Quiescent black holes turned on by Tidal Disruption Events (TDEs)
- Three parameters : mass, spin and charge

TIDAL DISRUPTION EVENTS

Star wander close enough to a supermassive black hole to be torn apart by its tidal force.
Tidal radius (Rees,1988)

$$r_{\rm t} = \left(\frac{M}{M_*}\right)^{1/3} R_* = 0.47{\rm AU}\left(\frac{M_6}{m_*}\right)^{1/3} x_*$$

$$\beta = r_{\rm t}/r_{\rm p} \gtrsim 1$$



1. Very bright flares, super-Eddington in the early phases
2. Lasting a week or a month
3. Luminosity declines with $t^{-5/3}$

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

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

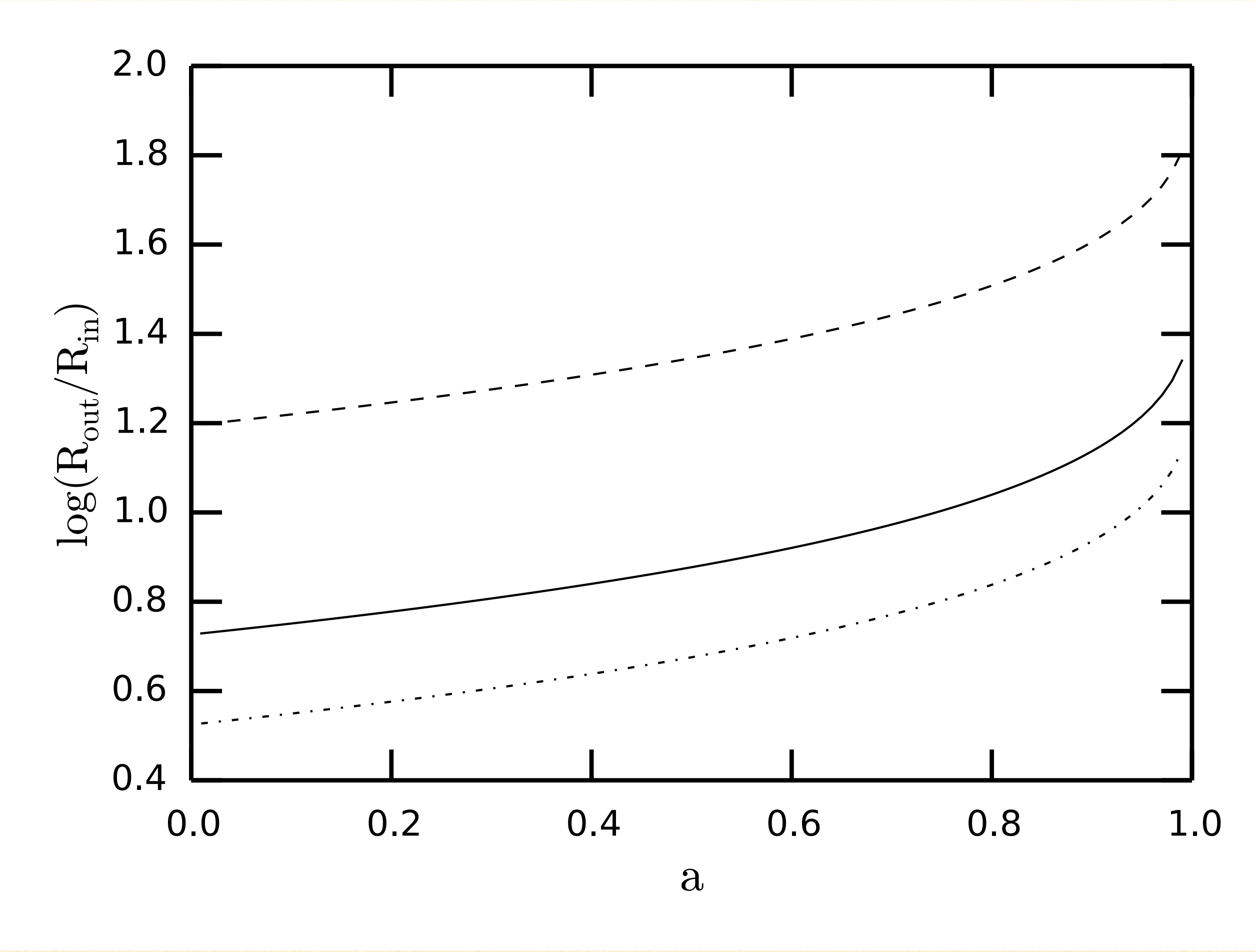
ACCRETION DISC

Stellar debris orbits circularization $2r_{\rm t} = r_{\rm out} \longrightarrow r_{\rm in} = r_{\rm ISCO}$

Narrow accretion disc.

Described by fluidodynamics equations:

- centrifugal balance $\Omega^2 = \left(\frac{GM}{R^3}\right)$
- hydrostatic equilibrium $H = c_{\rm s}/\Omega$
- viscosity $\nu = \alpha c_{\rm s} H$



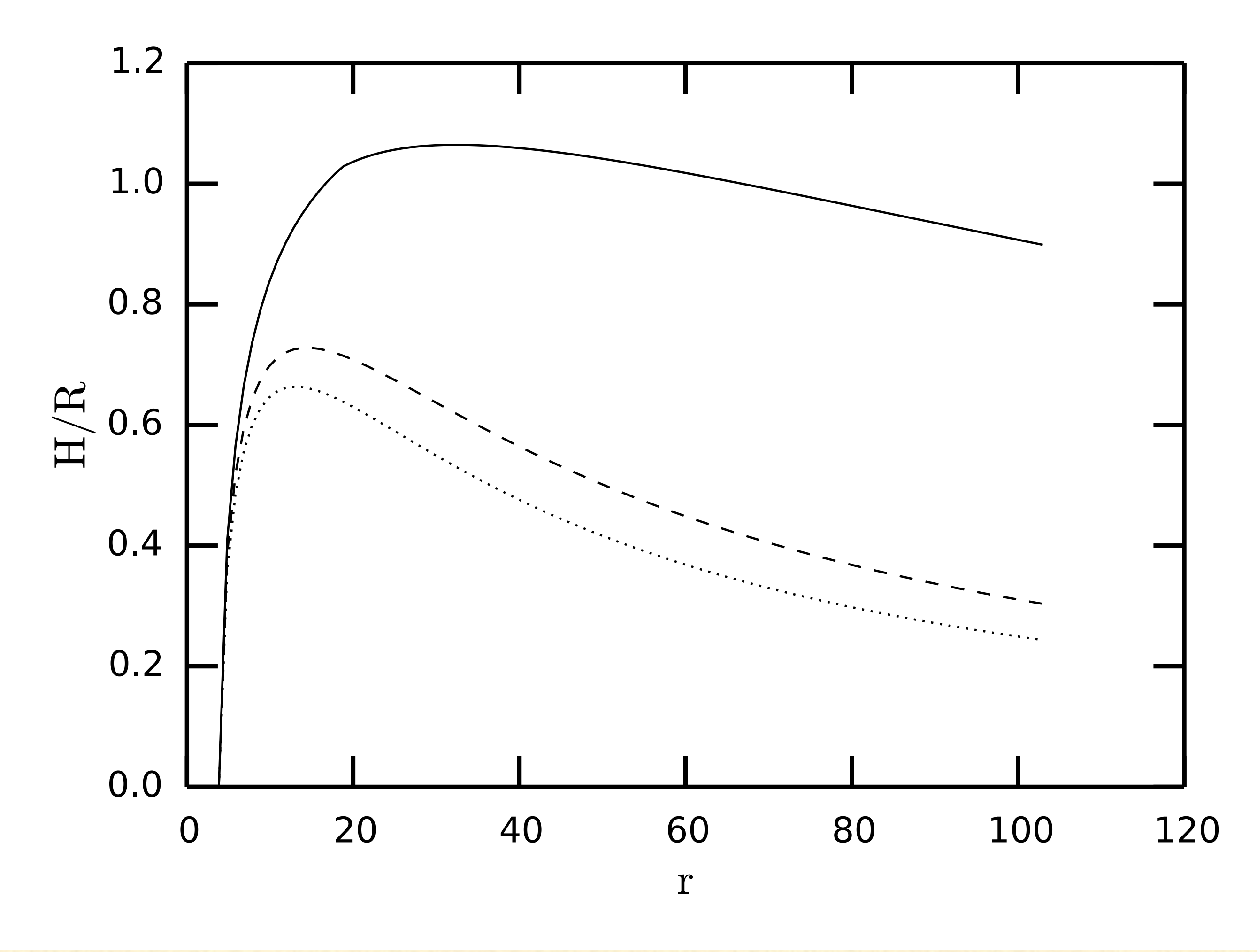
ACCRETION DISC

Super-Eddington accretion ⟶ hot thick disc

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

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

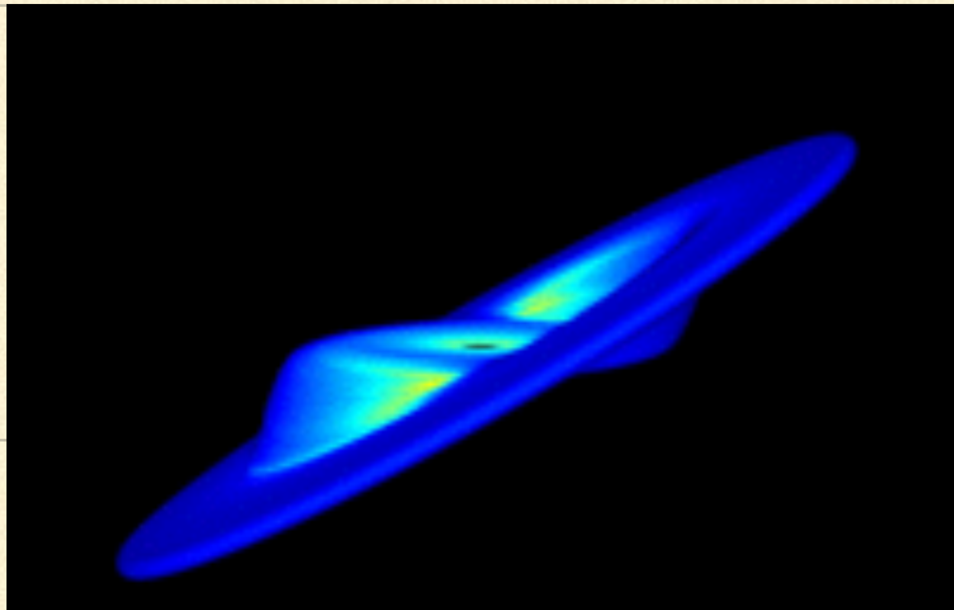
$$\dot{m} = \dot{m}_{\rm fb}$$



Radiation pressure dominated

$$\Sigma = \Sigma_0 r^{-3/5} f^{3/5}(r)$$

LENSE-THIRRING EFFECT


Lodato & Price (2007)

Star orbit inclined with respect to the supermassive black hole spin $\longrightarrow$ precession of the disc annuli

$\Omega_{\rm LT} \propto R^{-3}$ $\longrightarrow$ warped disc

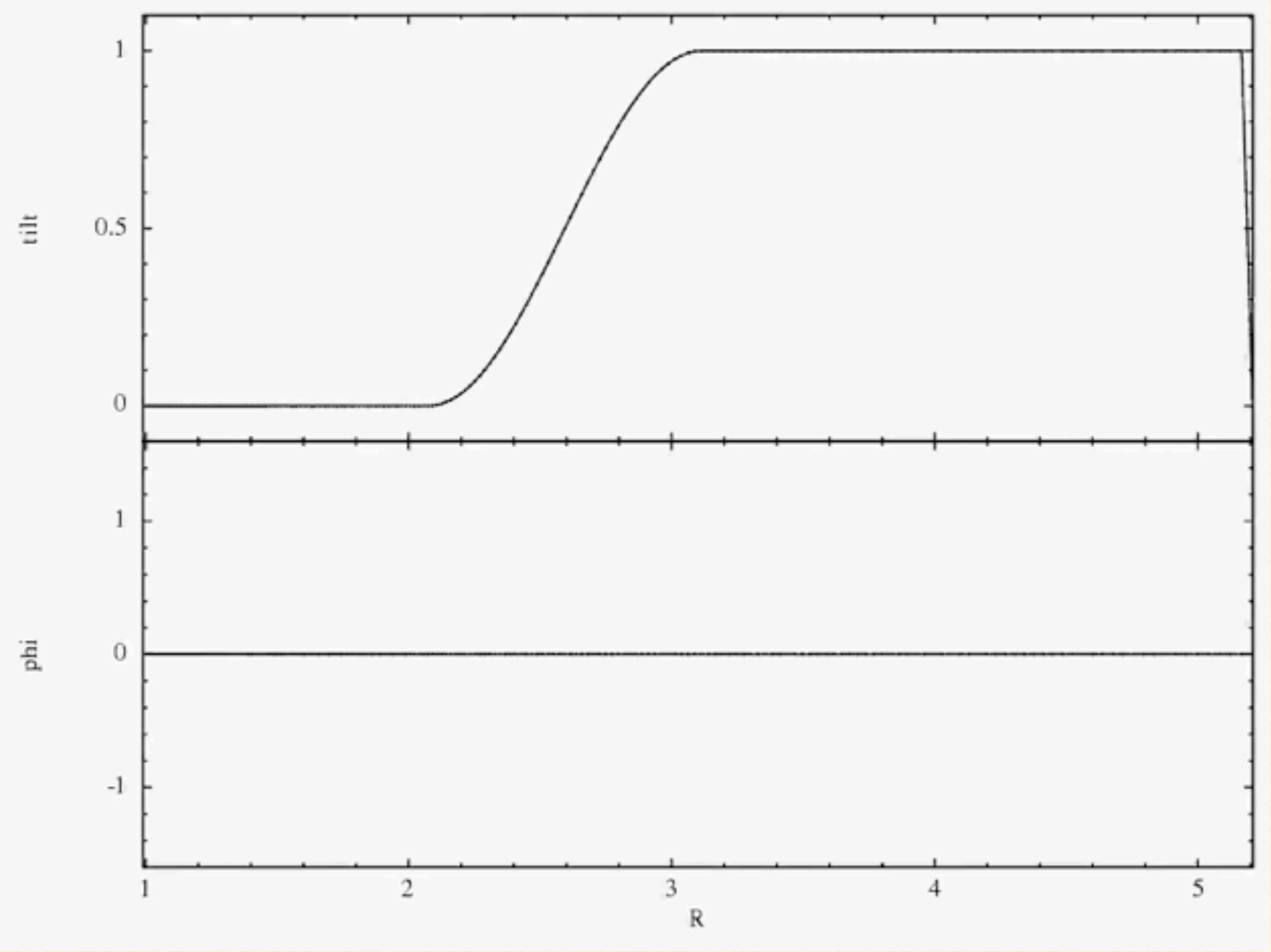
In thick discs warp propagation occurs in a wave-like regime at half the speed of sound

$t_{\rm w} \lesssim t_{\rm p}$ $\longrightarrow$ DISC RIGID PRECESSION

RIGID PRECESSION

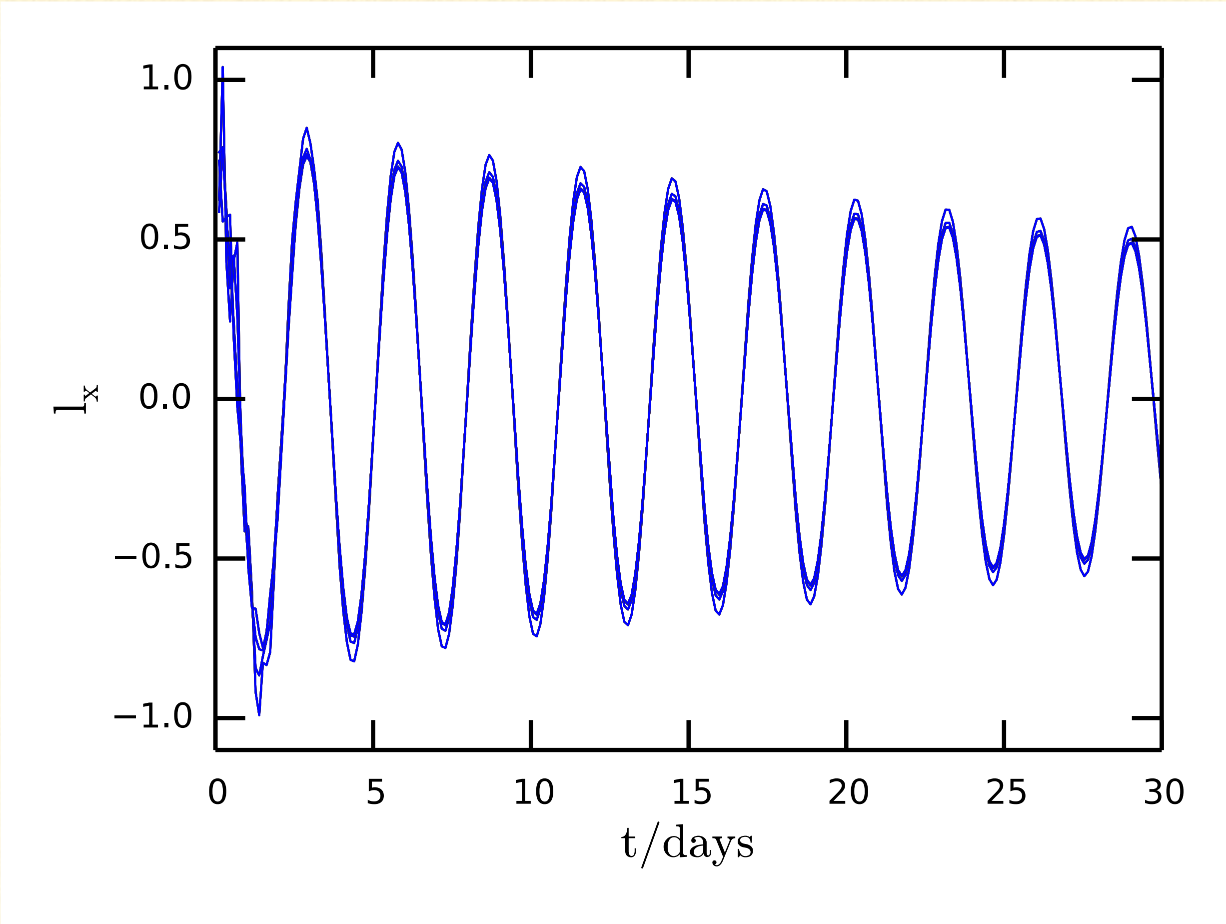
β

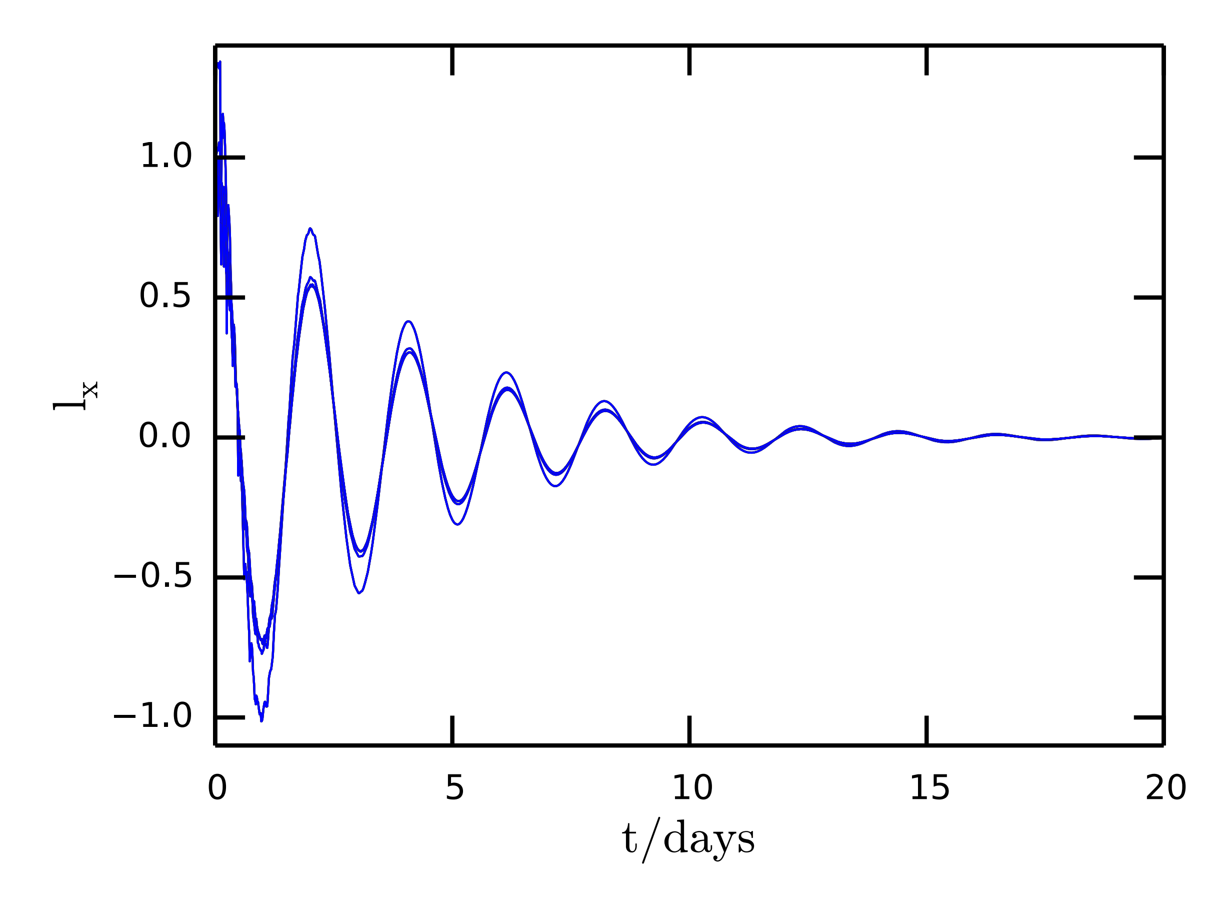
$$\phi(R,t) = \phi(R) + \Omega_{\rm p} t$$



RIGID PRECESSION

$a = 0.9 \ \ M = 10^6 M_\odot$

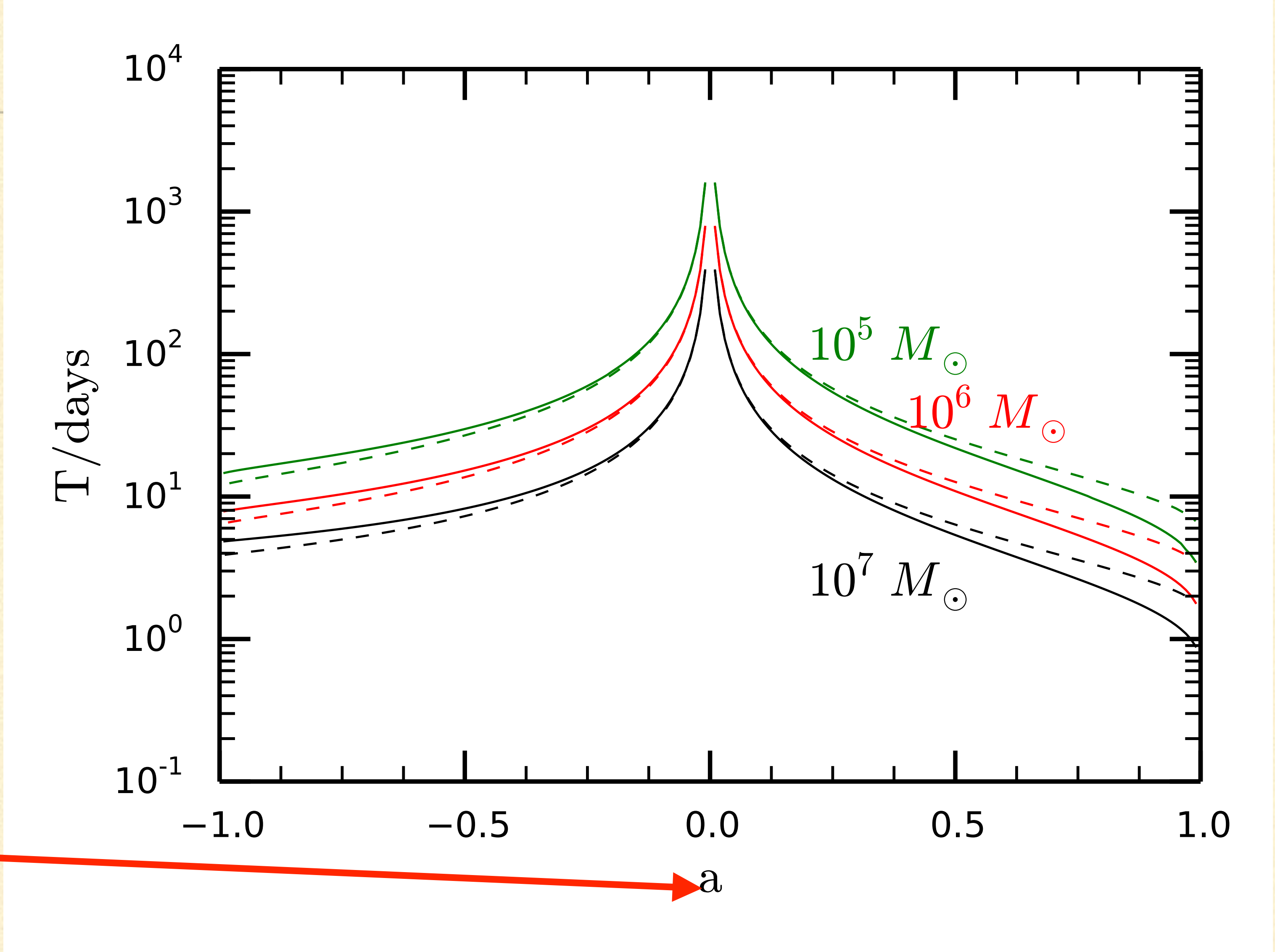




$a = 0.7 \ \ M = 10^7 M_\odot$

PRECESSION PERIOD

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

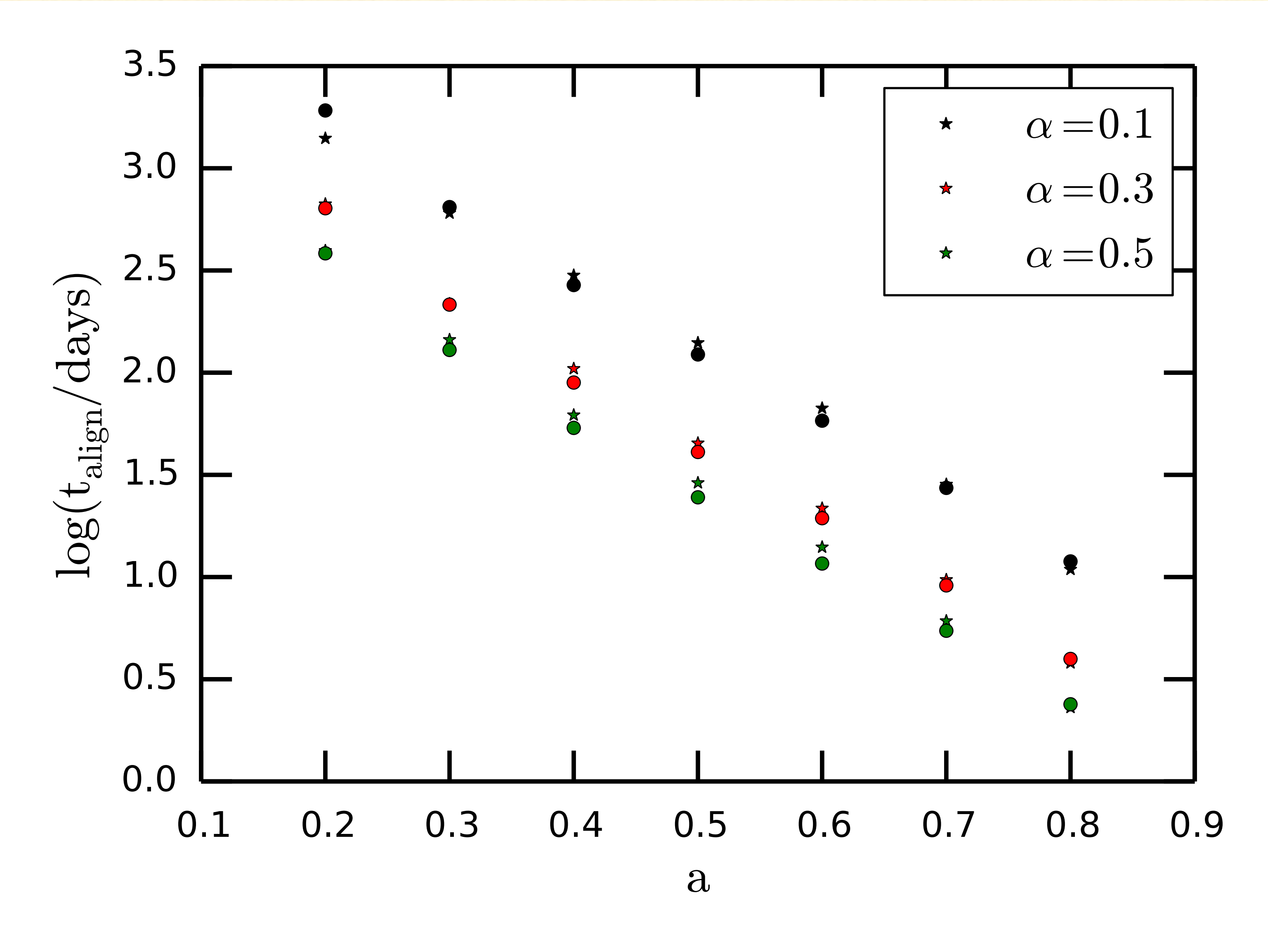


TDE light curve: mass and period

spin

Link between an observable (period) and the supermassive black hole spin value!

ALIGNMENT



Very low spin values:

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

For $a \gtrsim 0.3$:

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

CONCLUSIONS AND OUTLOOK

- Development of a model in order to link the measurement of an observable to the value of the supermassive black hole parameters (Franchini et al. 2015, MNRAS, submitted)

- Investigation of rigid precession criteria (Nixon, Leicester)

- Application to QPOs in LMXBs (Motta, Oxford)

- Full 3D hydrodynamics simulations (SPH) of the system evolution (Price, Melbourne)

THANKS FOR YOUR ATTENTION