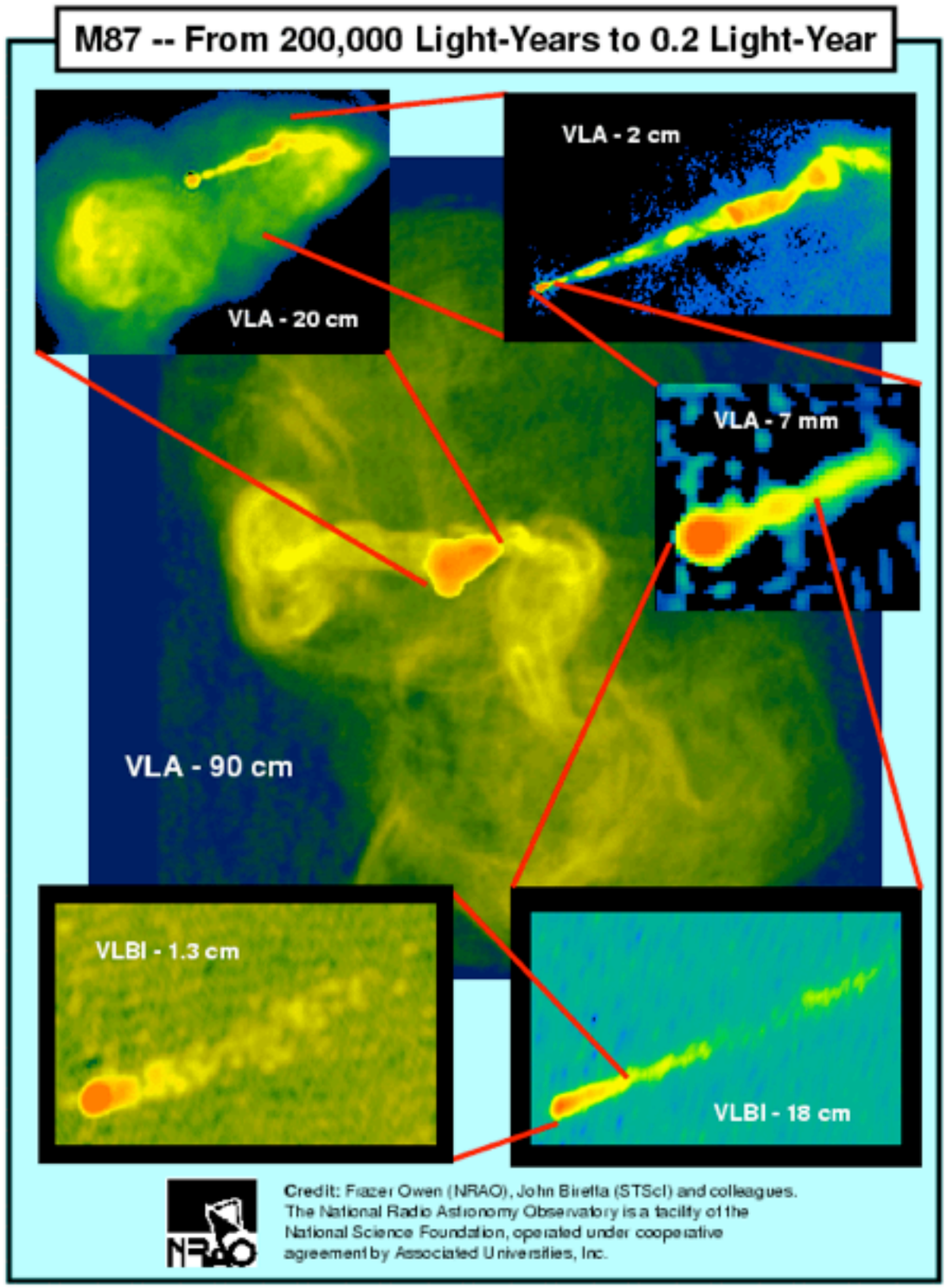
# Reorienting SMBHs

Prateek Sharma, IISc

Ref: Babul, Sharma, Reynolds, ApJ arXiv:1209.5748

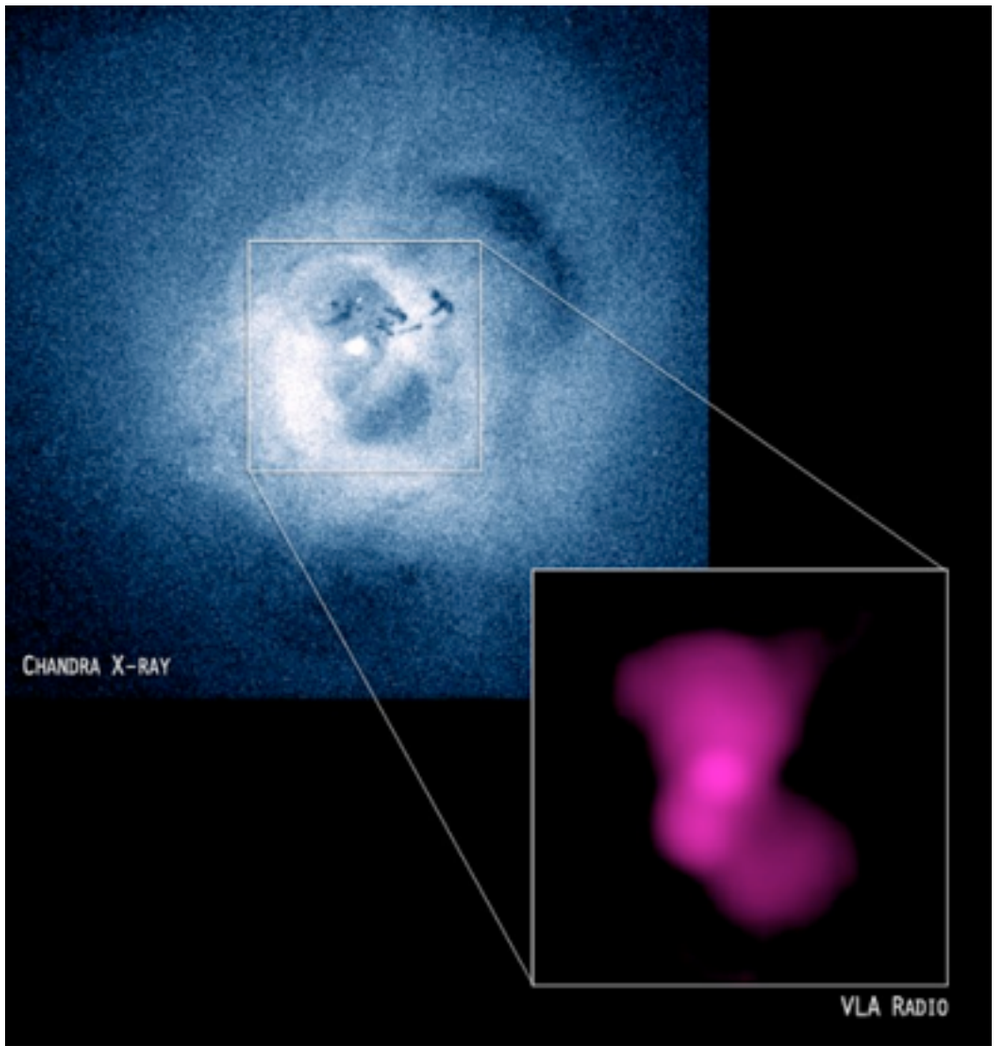
# Rapidly reorienting jets




jet direction seems to be changing over ~ 100 Myr

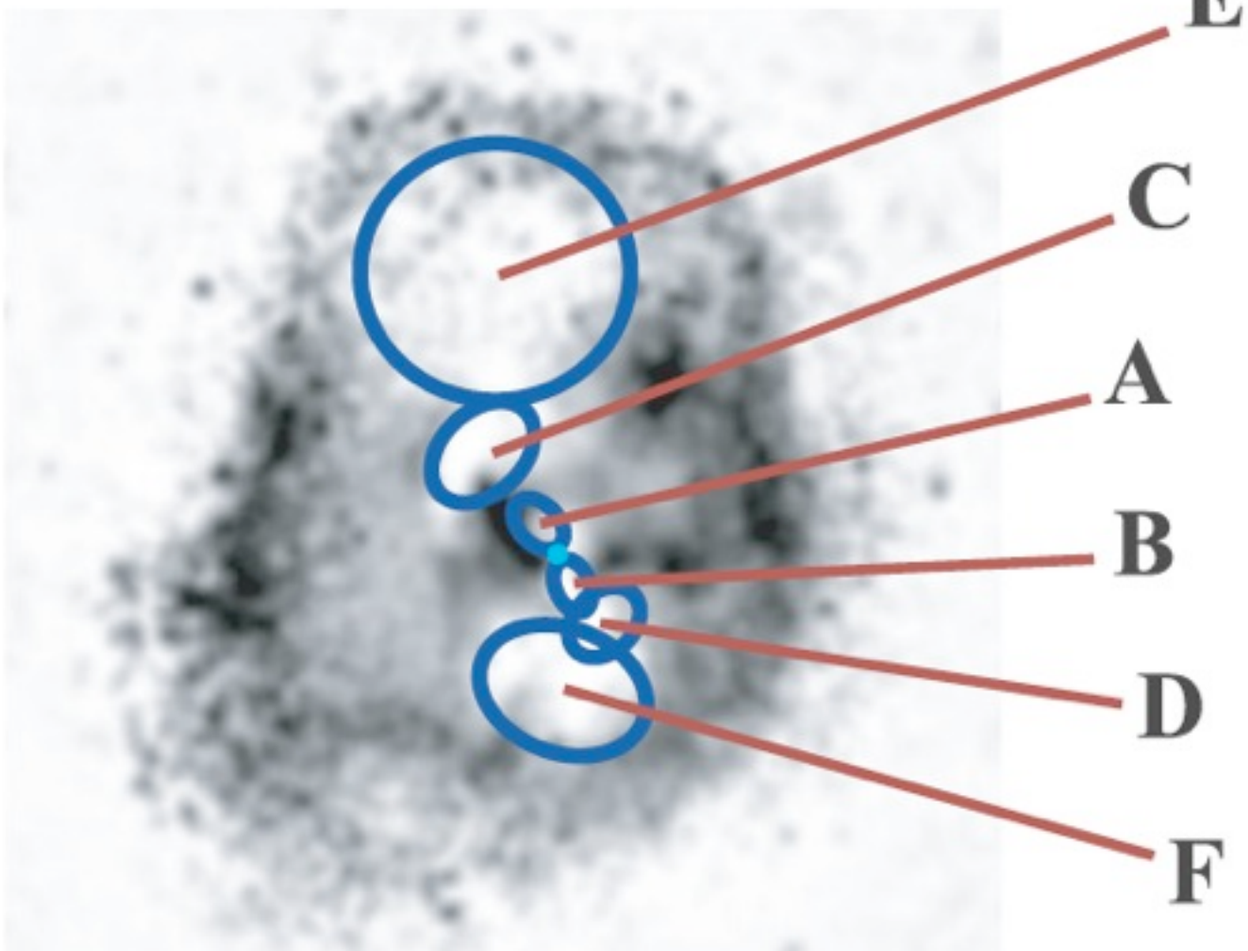
good for *isotropic heating* of the ICM

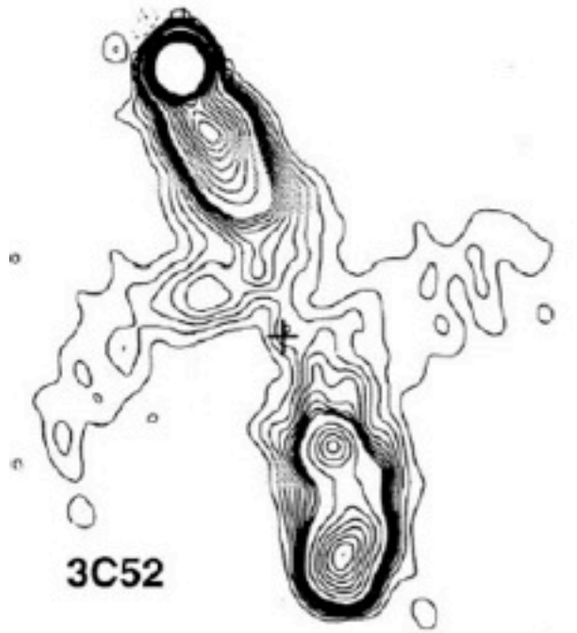
What causes this?



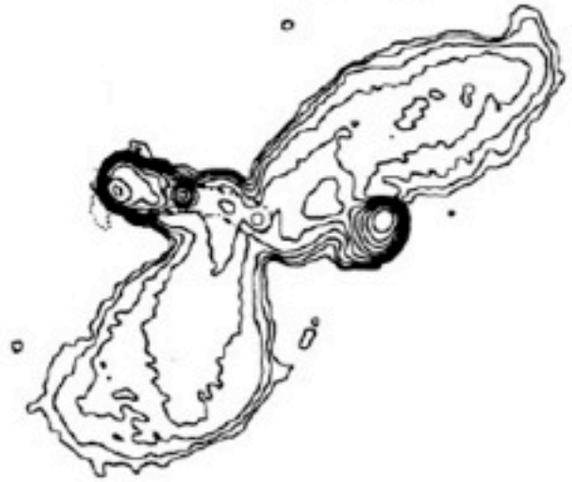
# Many examples

Hydra A





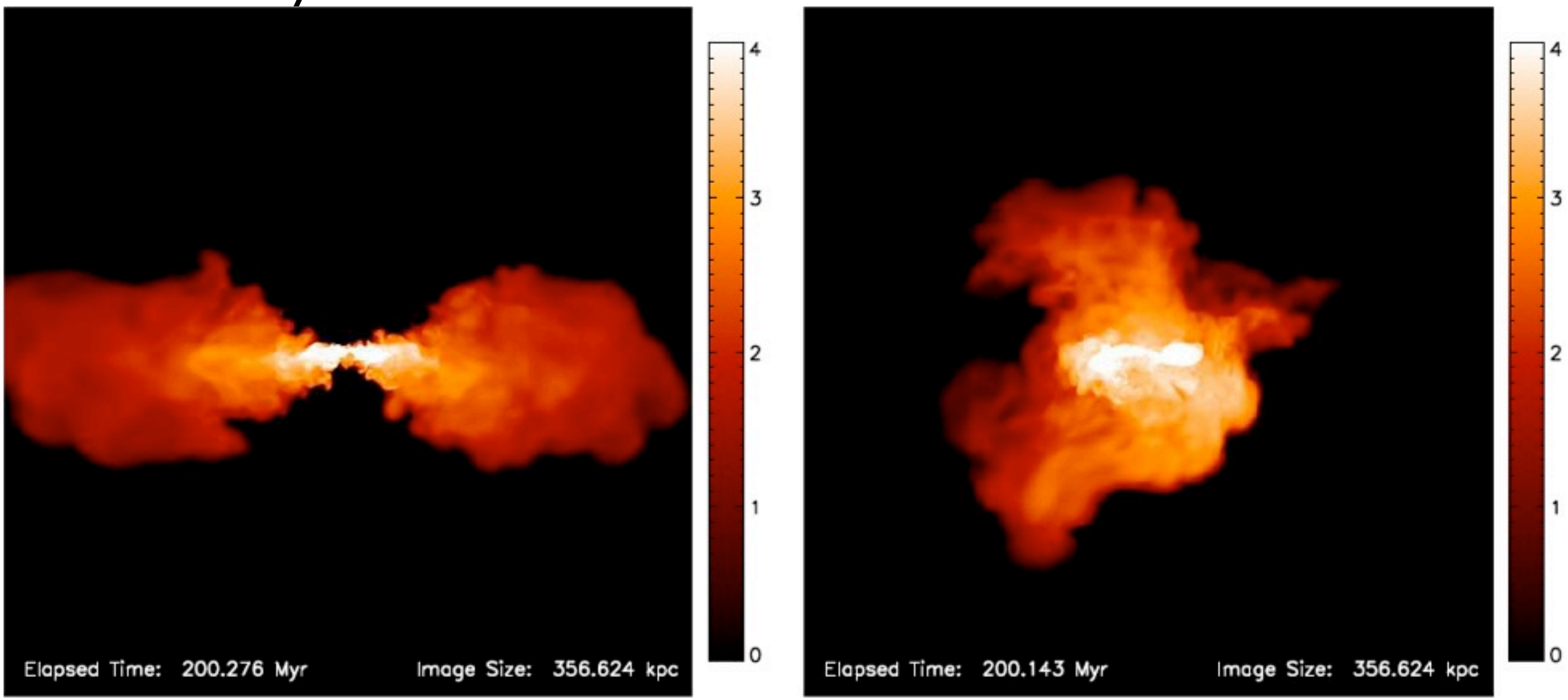




X-shaped radio galaxies

# ICM weather?

idealized hydrostatic ICM *[Morsony et al. 2010]* turbulent ICM

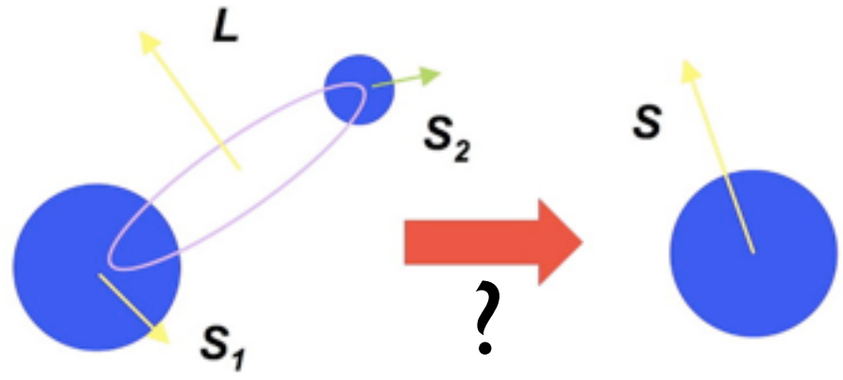



requires unrealistically large velocities!

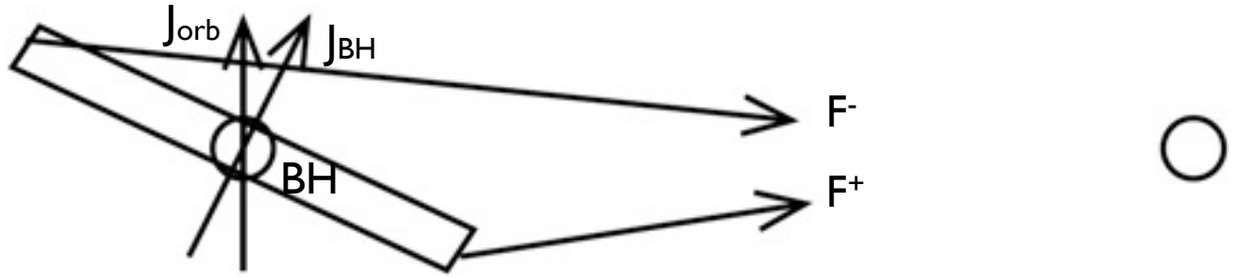
# Changing BH spin

*[Merritt & Ekers 2002]*

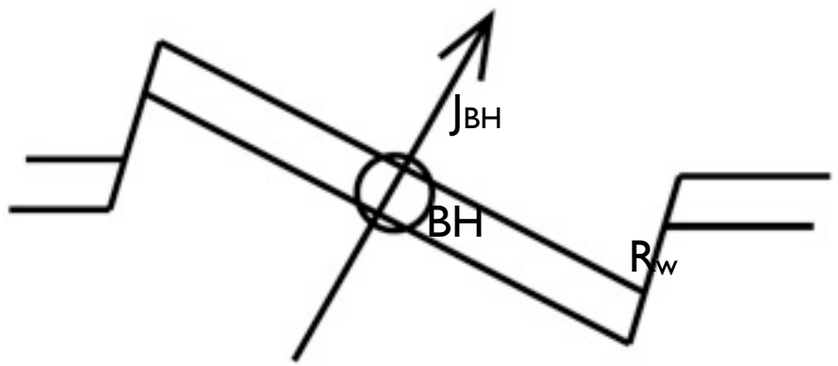
spin flips due to BH mergers
problem: SMBH mergers are uncommon



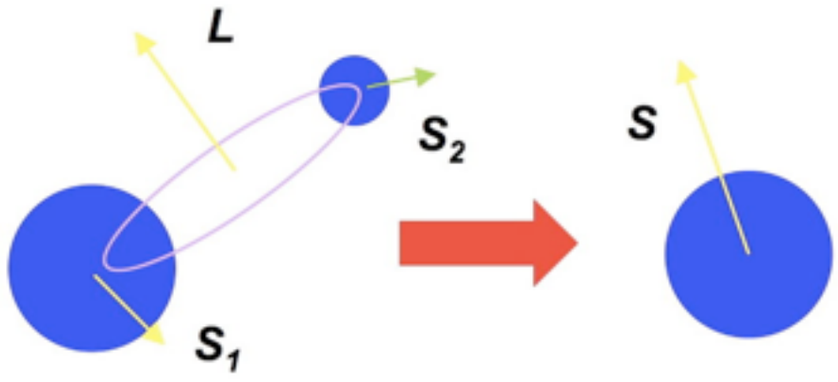

binary BH (spin-orbit) precession,
precession of inner accretion disk
problem: requires a binary SMBH;
rarely see jets from both BHs




accretion disk slewing via Lense-Thirring
/Bardeen-Petterson effect
problem: require thin disk, should shine
as a quasar



# Spin flips




$$\mathbf{S}_1 + \mathbf{S}_2 + \mathbf{L}_{\rm orb} = \mathbf{S} + \mathbf{J}_{\rm rad}$$

crucial for angular mom. distr. of SMBHs

retrograde orbits have large $L_{orb}$ => low BH spin for many random mergers

fast spin if major mergers & gas accretion dominate

faster spin => LSO close in and larger accretion efficiency

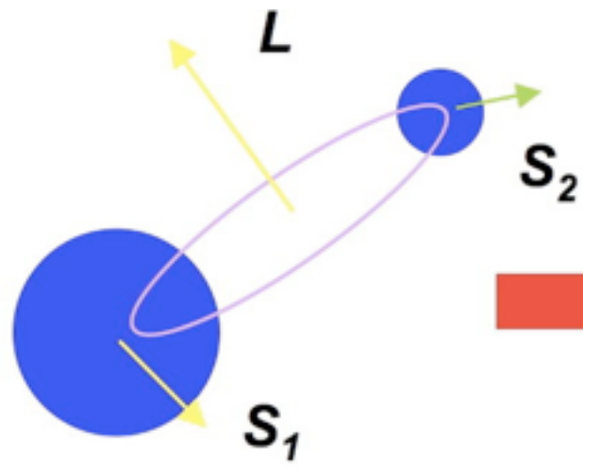
orbital angular momentum before plunge at ISCO (derived from PN approx.)

easier to spin up non-rotating BHs; spinning BHs are stable gyroscopes

for rotating BHs $M_2/M_1>0.2$ required to change spin

GW losses imp. when $M_1 \sim M_2$ (requires NR)

# Binary BH precession




PN 2.5 approx.: spin-spin & spin orbit precession

$$\frac{d\mathbf{S}_1}{dt} = \frac{1}{a^3}\left[\left(2+\frac{3m_2}{2m_1}\right)\mathbf{L}_{\rm orb} - \mathbf{S}_2 + 3\left(\hat{n}\cdot\mathbf{S}_2\right)\hat{n}\right]\times\mathbf{S}_1$$

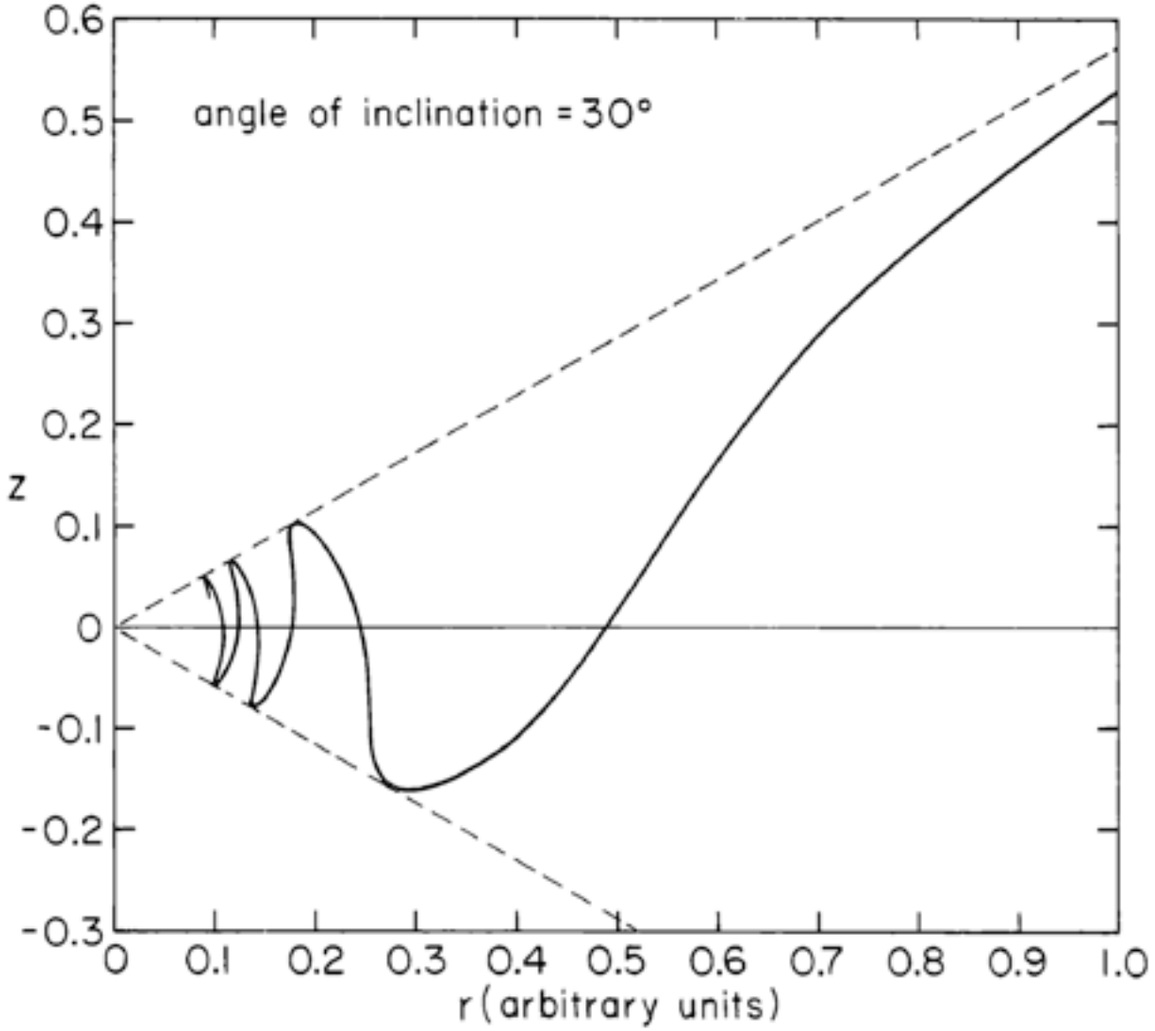
$$t_{\rm BH,prec} \sim 2.4\times10^7\ {\rm yr}\left(\frac{\mathcal{A}}{1\ {\rm pc}}\right)^{5/2} M_{\bullet 9}{}^{-3/2}$$

we may have a binary companion at 1 pc
last pc problem!

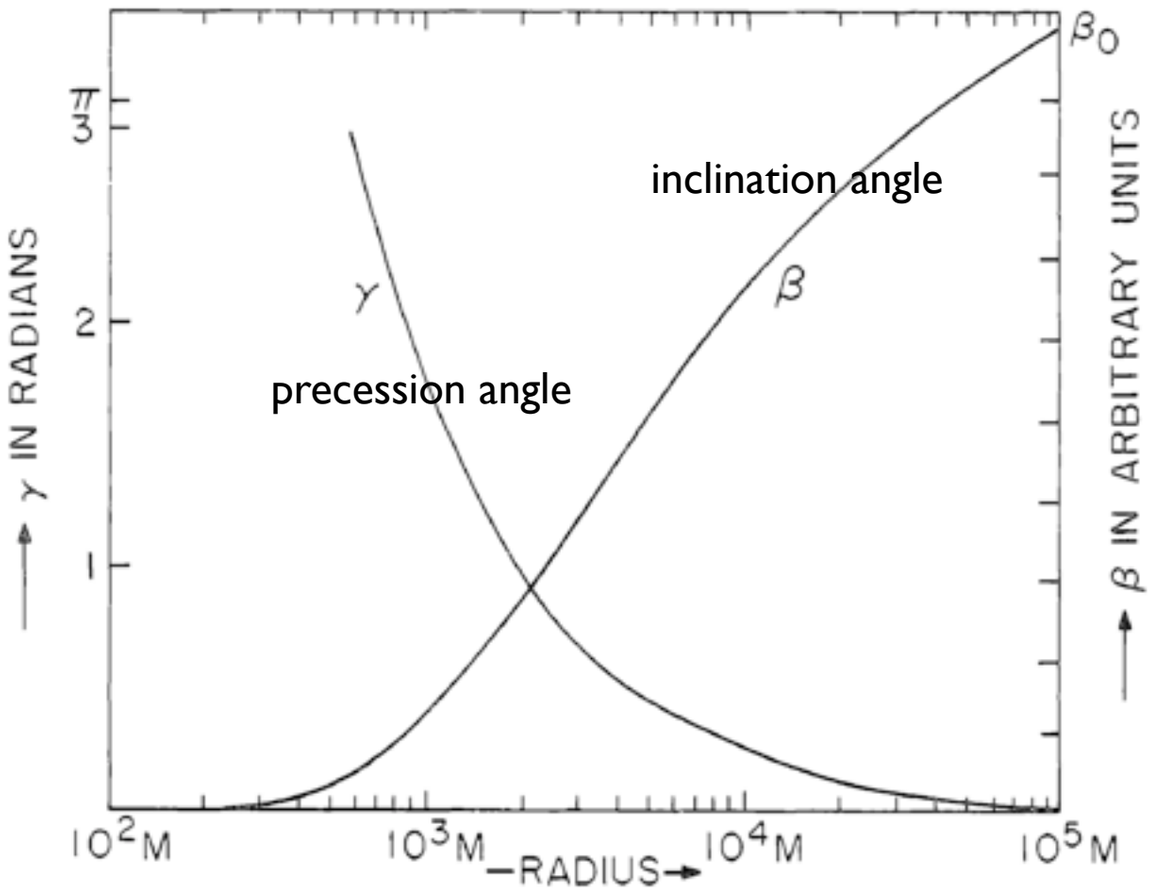
no solid evidence for binary SMBHs yet.

# Lense Thirring effect

LT effect: GR effect which induces rotation




effect of viscosity




*[BP 1975]*

precession angle

$$\gamma_p \approx 2J \int_{\infty}^{r} r^{-3} (v^r)^{-1} dr$$

$$\approx 0.52 \times 10^5 \alpha^{-4/5} J_* \dot{M}_*^{-2/5} M_*^{3/5} r_*^{-8/5}$$

# Slewing disk via BP

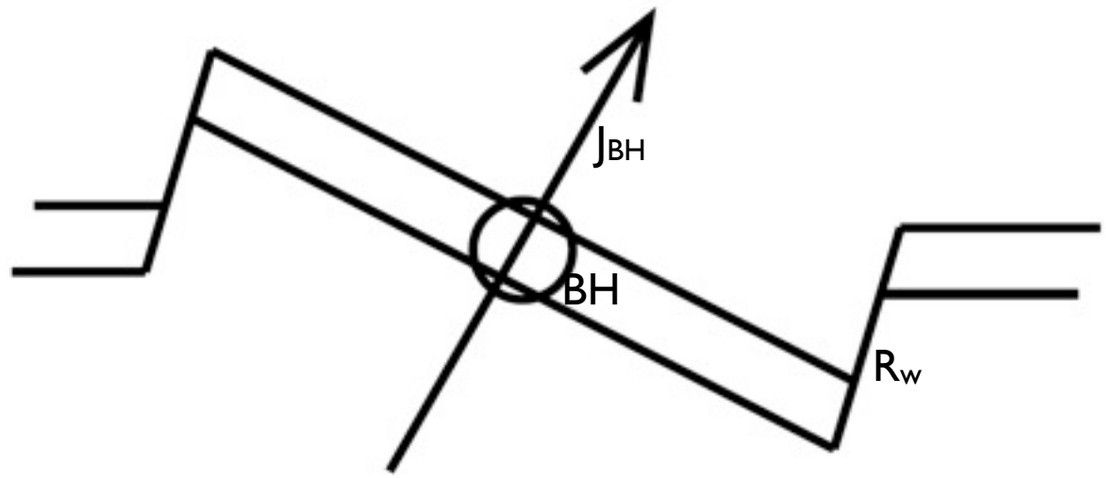
LT effect: GR effect which induces rotation

$$\vec{\tau}_{LT} \sim a(R_g/R)^3(\hat{J}_{BH} \times \vec{L})/(R_g/c)$$

$$\vec{\tau}_{visc} \sim \frac{\nu}{R}\frac{d}{dR}\left(R^3\frac{d\vec{\Omega}}{dR}\right)$$

$$\frac{R_w}{R_g} \sim \left(\frac{a}{(H/R)^2}\right)^{2/3}$$

$$t_{align} \sim t_{prec} \sim \frac{J_{BH}}{\dot{M}\Omega_w R_w^2}$$ viscosity aligns!




thin disk needed, else $t_{align} \sim t_{dbl}$ >> Myrs

S&S disk when $M_{dot} \gtrsim 0.01\ M_{dot,Edd}$ ($25 M_{sun}$/yr for $10^9\ M_{sun}$ BH)

self-gravity & fragmentation (if $M_d/M_{BH} \gtrsim H/R$) limits $M_{dot}$

short quasar phase in CC systems

accretion "events" via thin disk => slowly spinning SMBHs!