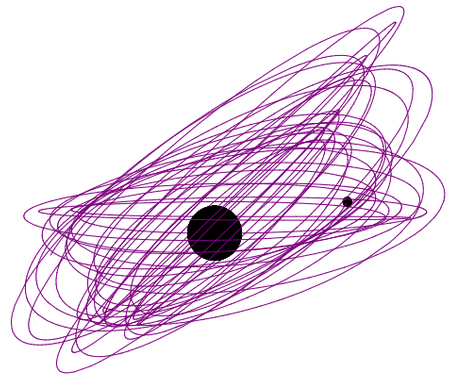
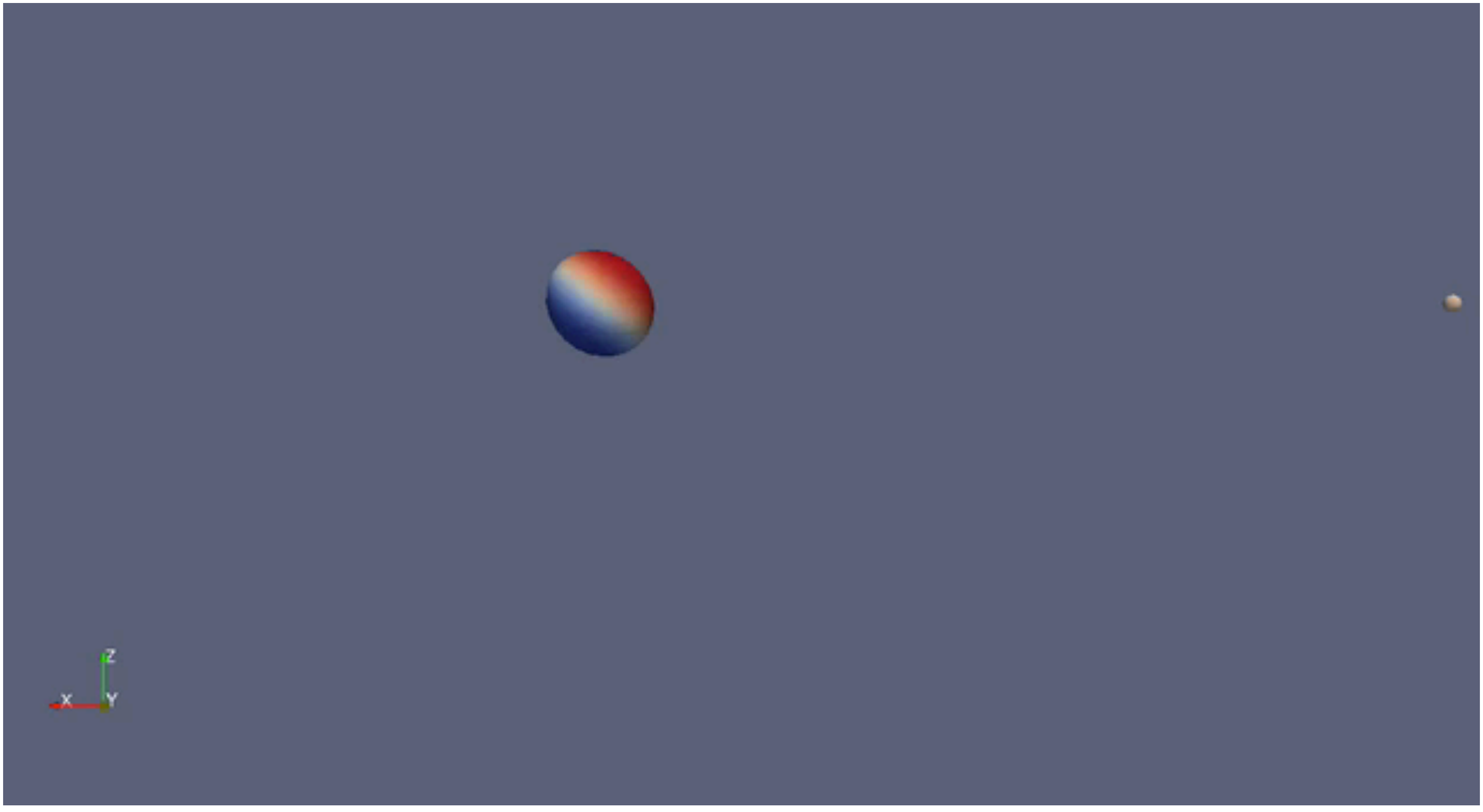
Generic simulations for self-force comparisons

Aaron Zimmerman,
Adam Lewis, Harald Pfeiffer (CITA)

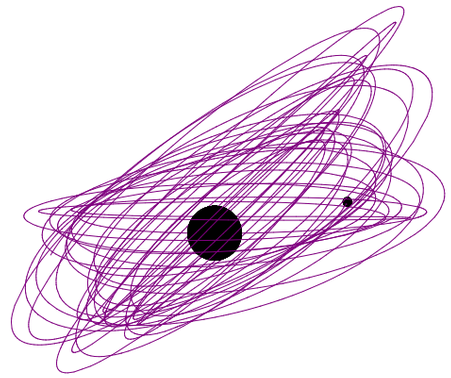
Capra 18
June 30, 2015

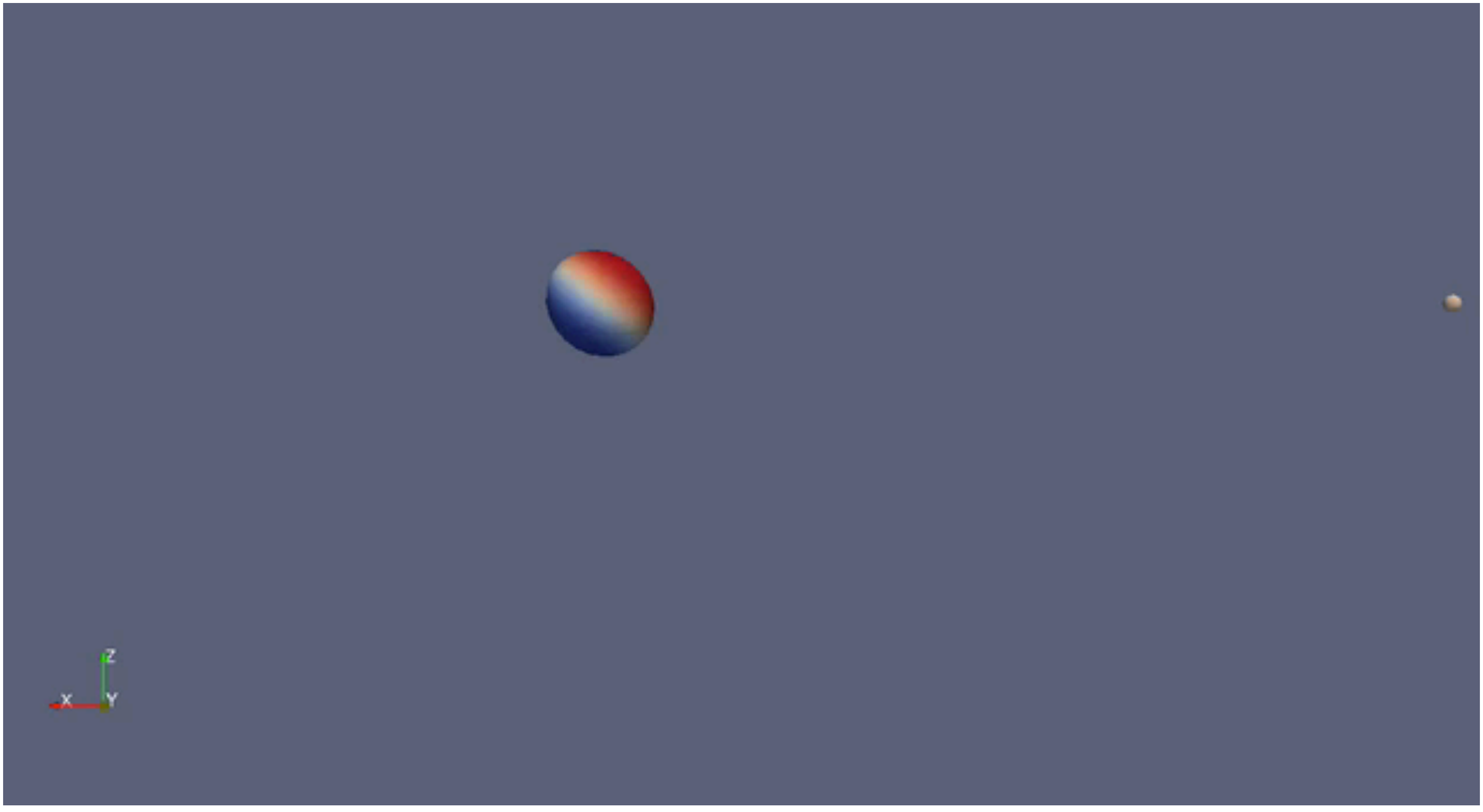
What we can do: generic inspirals





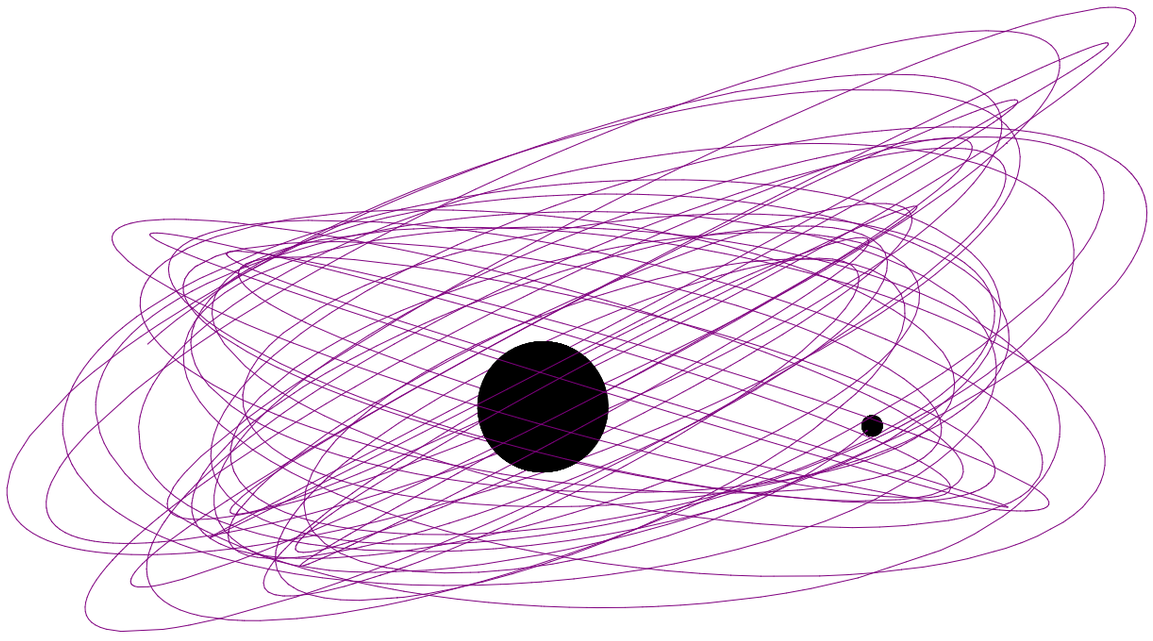
What we can do: generic inspirals





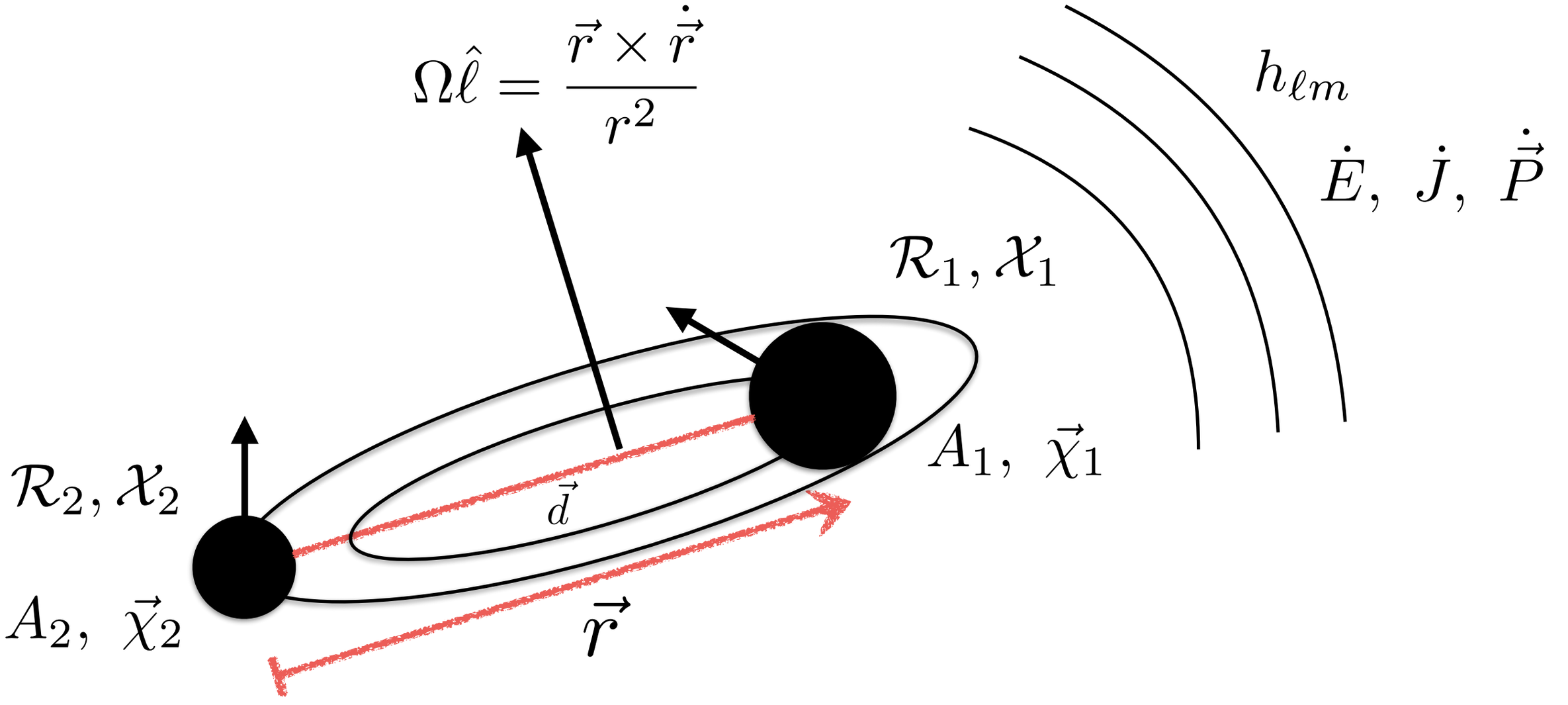
Comparisons to self-force

- Compare to geodesic and SF invariant quantities
- Determine regime of validity of SF
- Calibrate analytic models (EOB, etc)



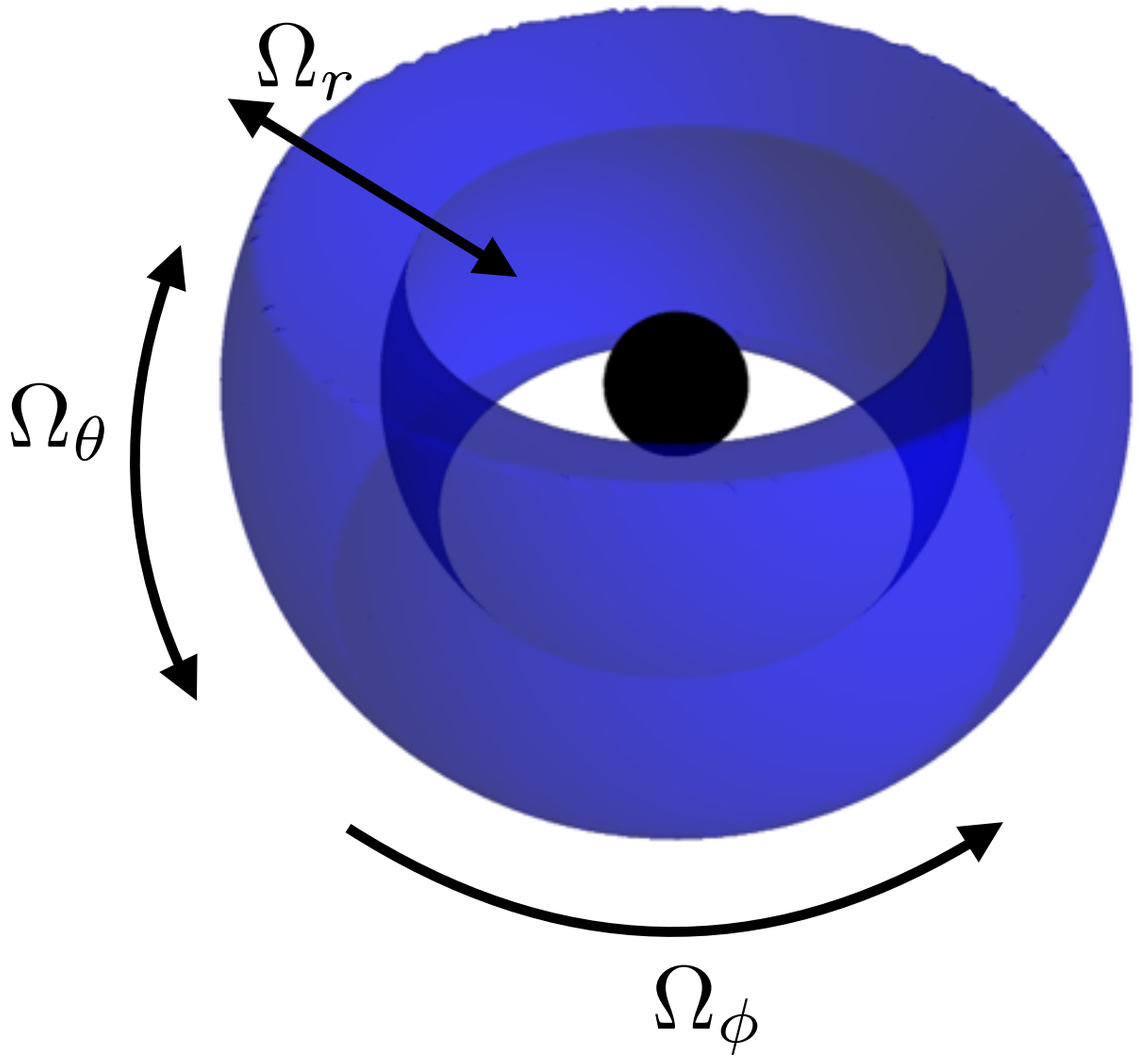
$$q = 7,\ \chi_1 = 0.8,\ \chi_2 = 0,$$
$$\mathcal{N}_\phi \approx 55,\ \mathcal{N}_r \approx 41$$

What do we get from NR?



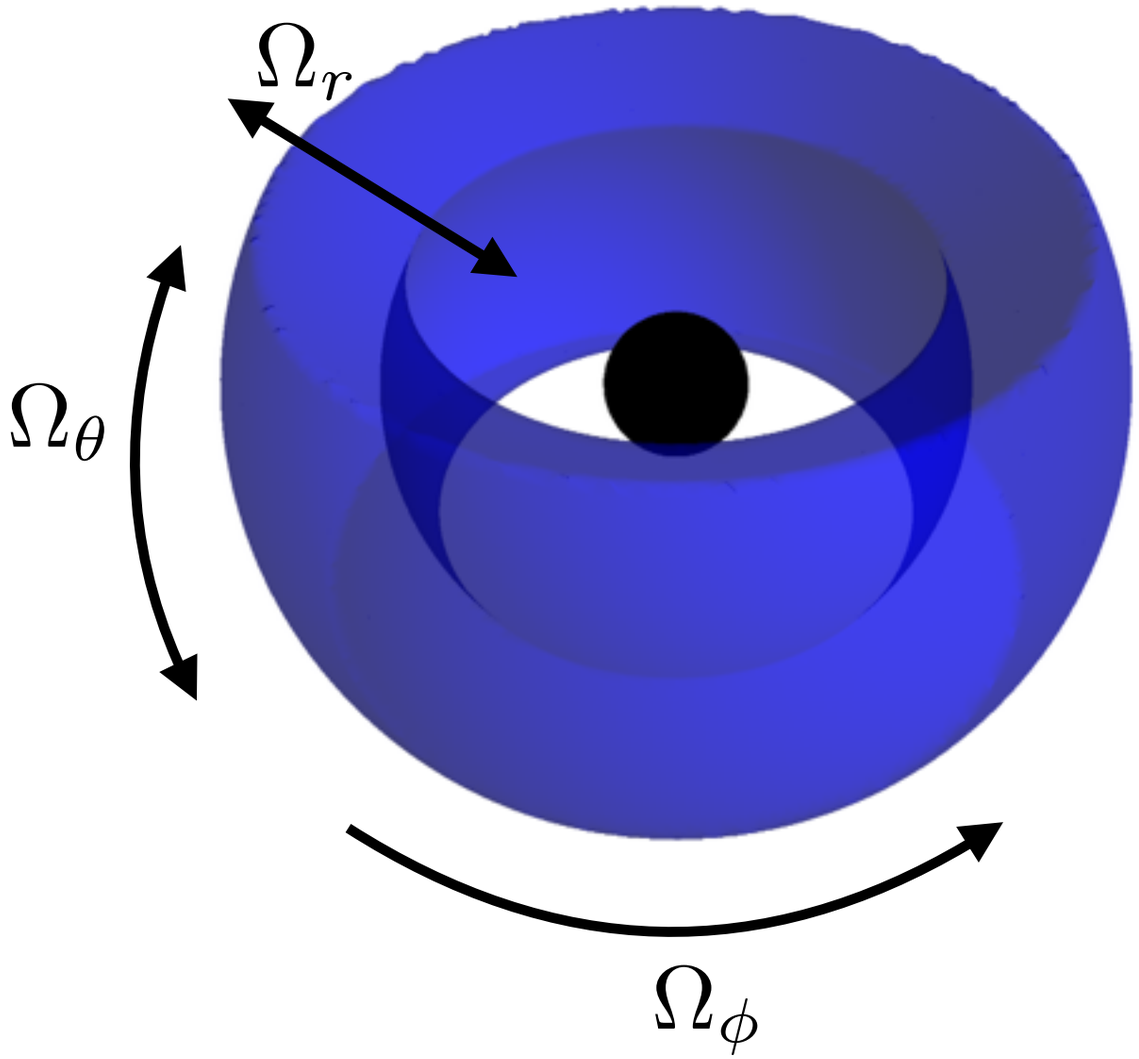
Mapping to geodesic motion

$$(p,\, e,\, \iota) \leftrightarrow (\mathcal{E},\, \mathcal{L}_z,\, \mathcal{Q})$$



Mapping to geodesic motion

$$(p,\, e,\, \iota) \leftrightarrow (\mathcal{E},\, \mathcal{L}_z,\, \mathcal{Q})$$



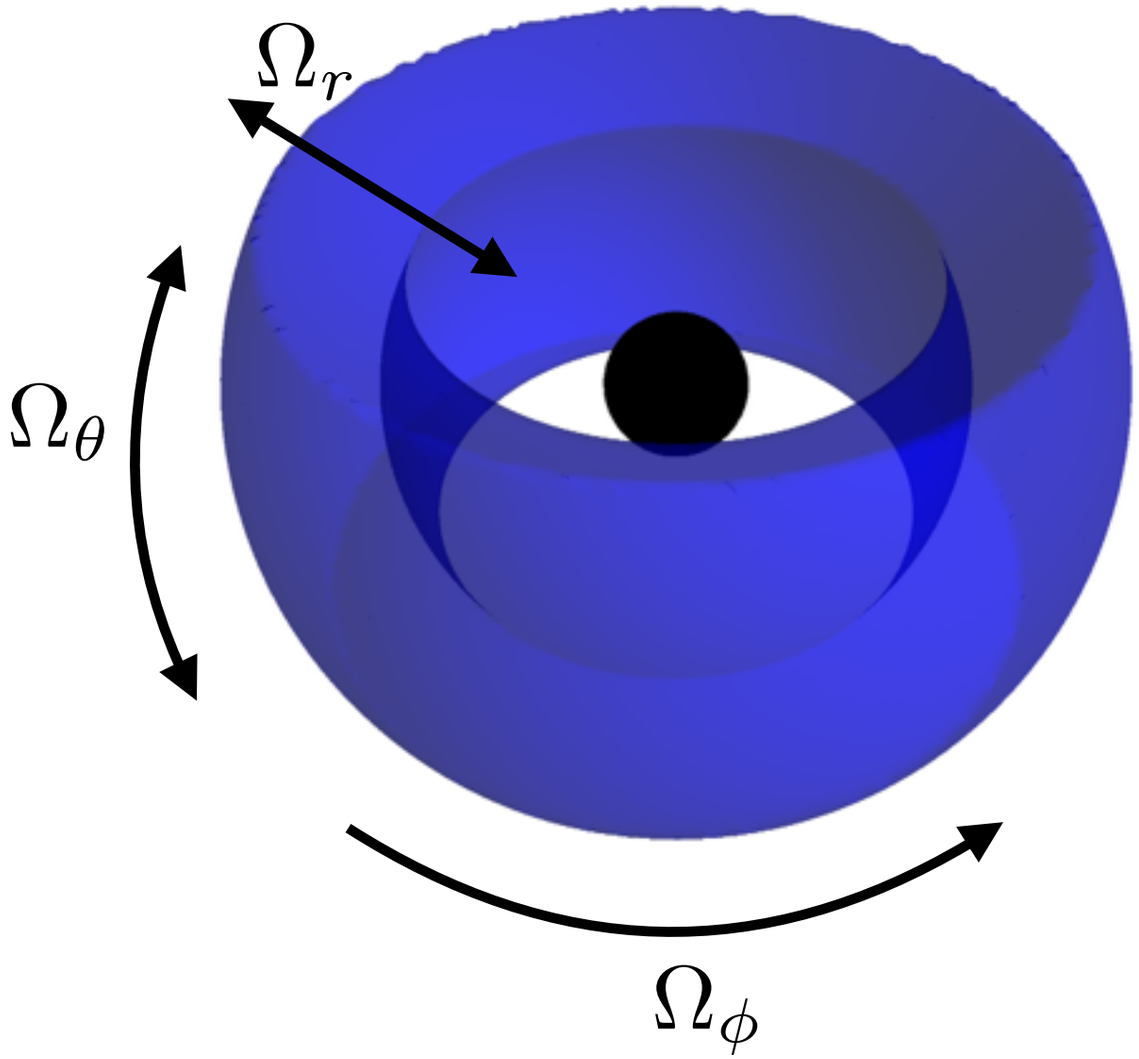
$$p \to \Omega_\phi \qquad (e, \iota)$$

$$\frac{\Omega_\theta}{\Omega_\phi} \qquad \frac{\Omega_r}{\Omega_\phi}$$

$$\Omega_a \to \Omega_a + \delta\Omega_a$$

Mapping to geodesic motion

$(p,\, e,\, \iota) \leftrightarrow (\mathcal{E},\, \mathcal{L}_z,\, \mathcal{Q})$



$p \to \Omega_\phi \qquad (e, \iota)$

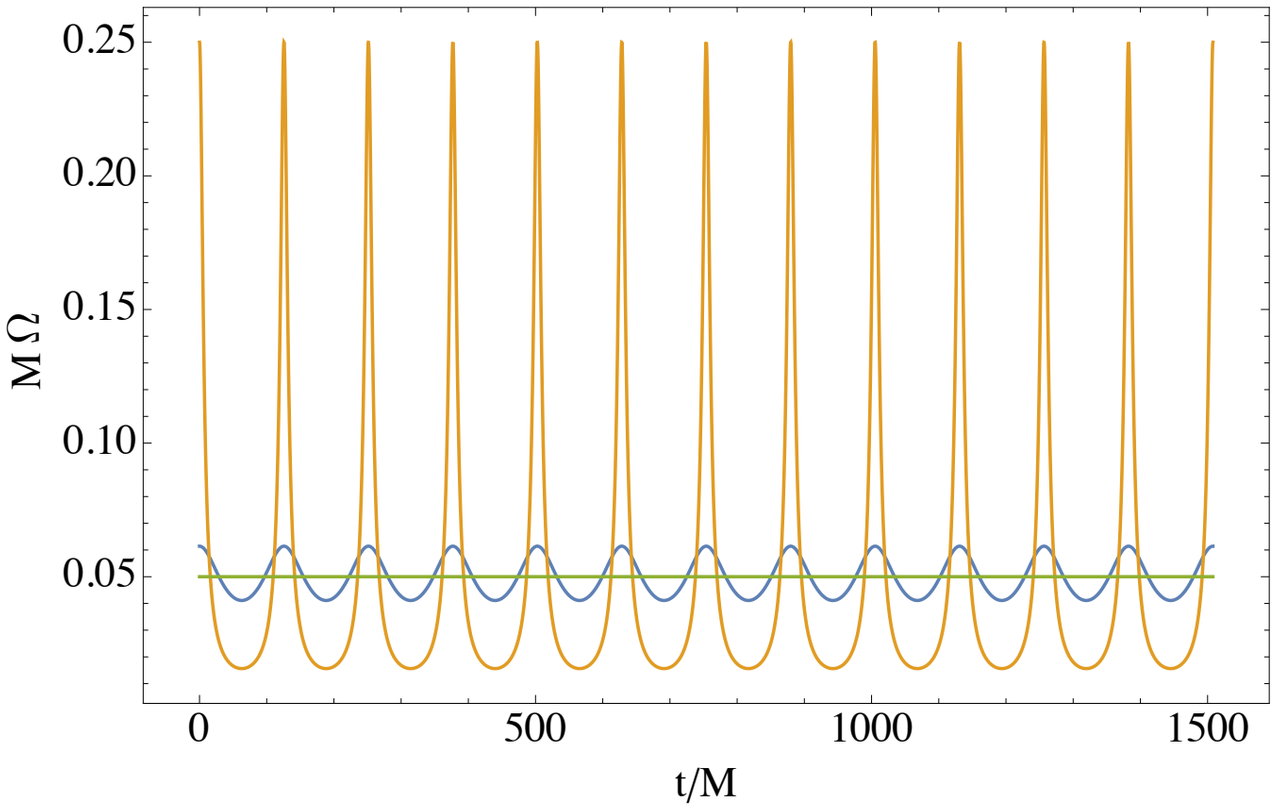
$$\frac{\Omega_\theta}{\Omega_\phi} \qquad \frac{\Omega_r}{\Omega_\phi}$$

$$\Omega_a \to \Omega_a + \delta\Omega_a$$

- Invariant measures (e, ι)
- Dissipation: fit out

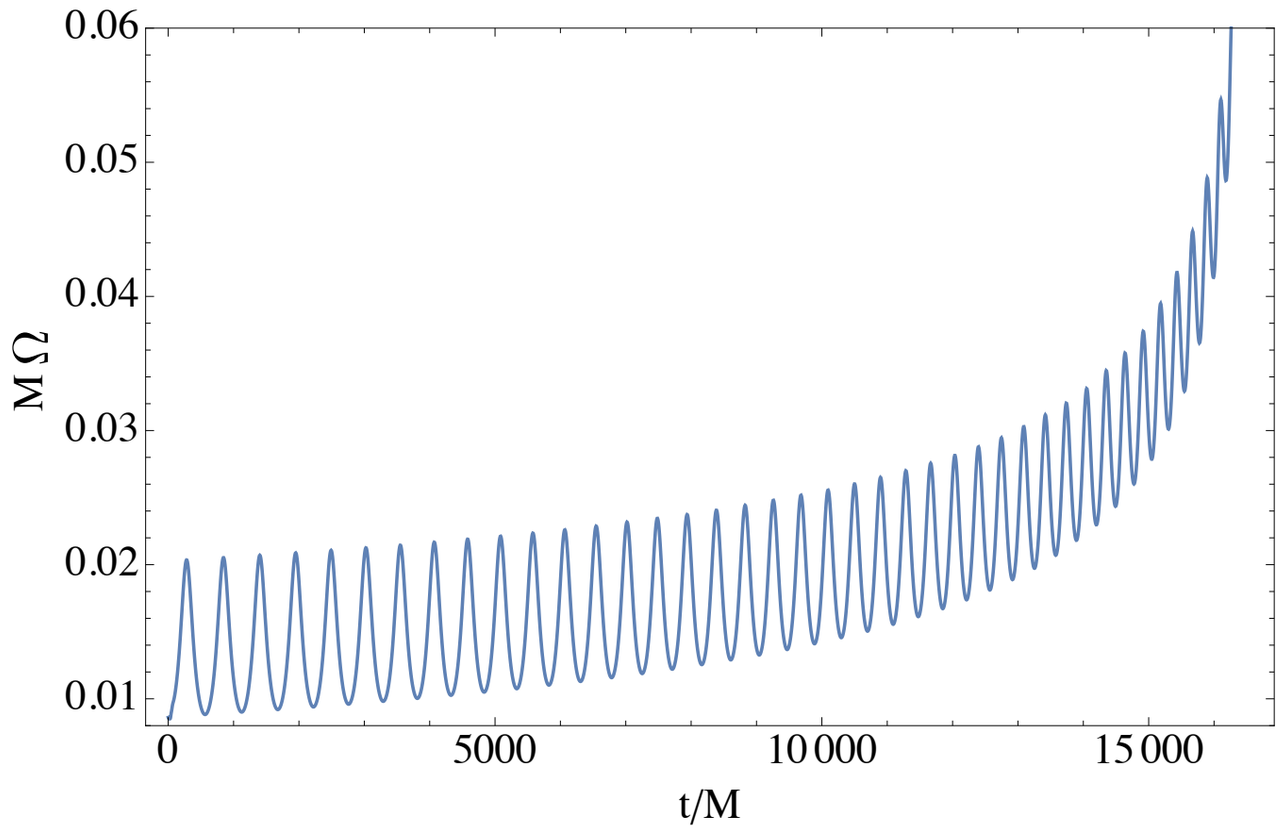
Fitting out inspiral

- Fundamental frequencies averaged quantities



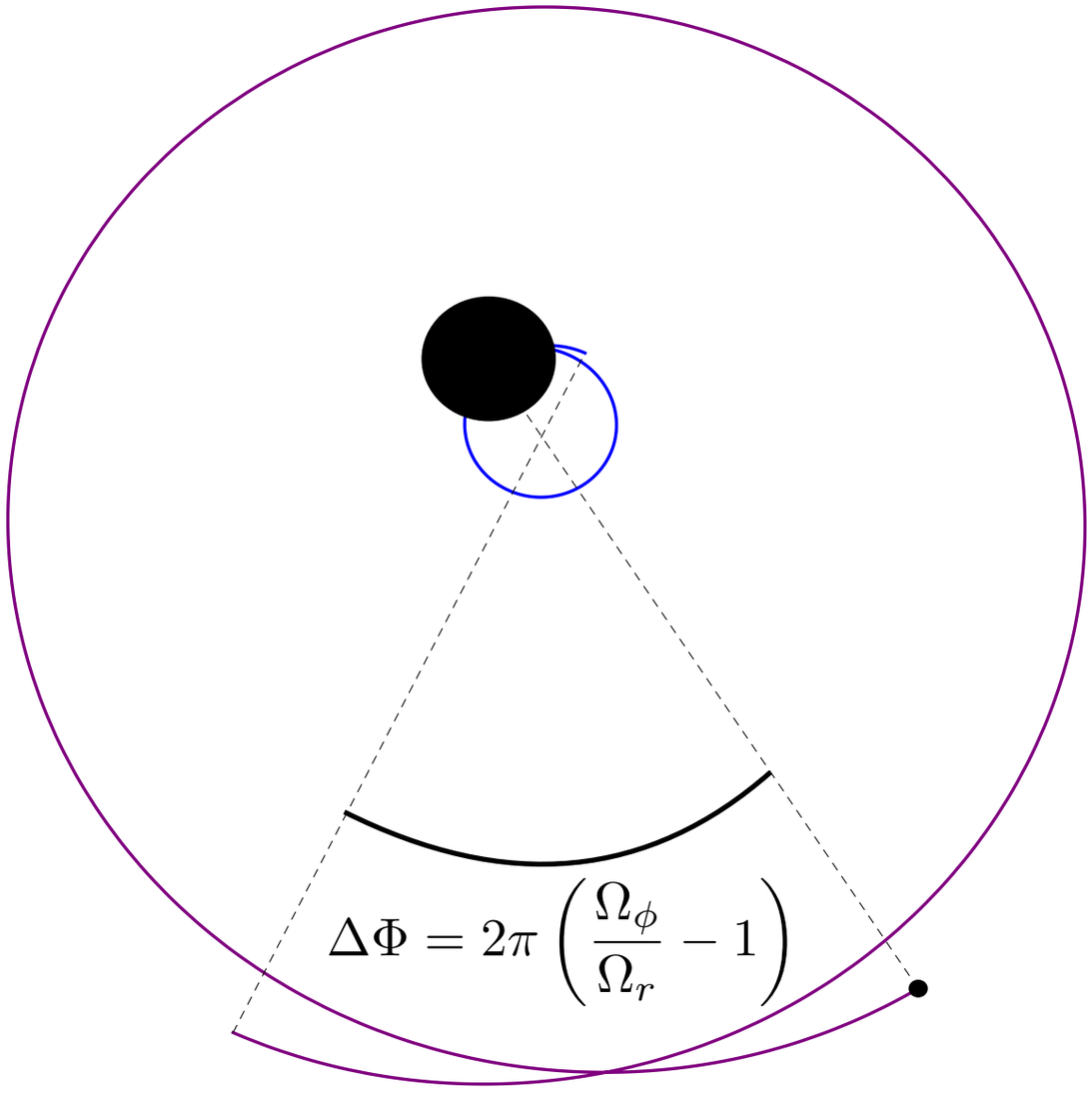
Fitting out inspiral

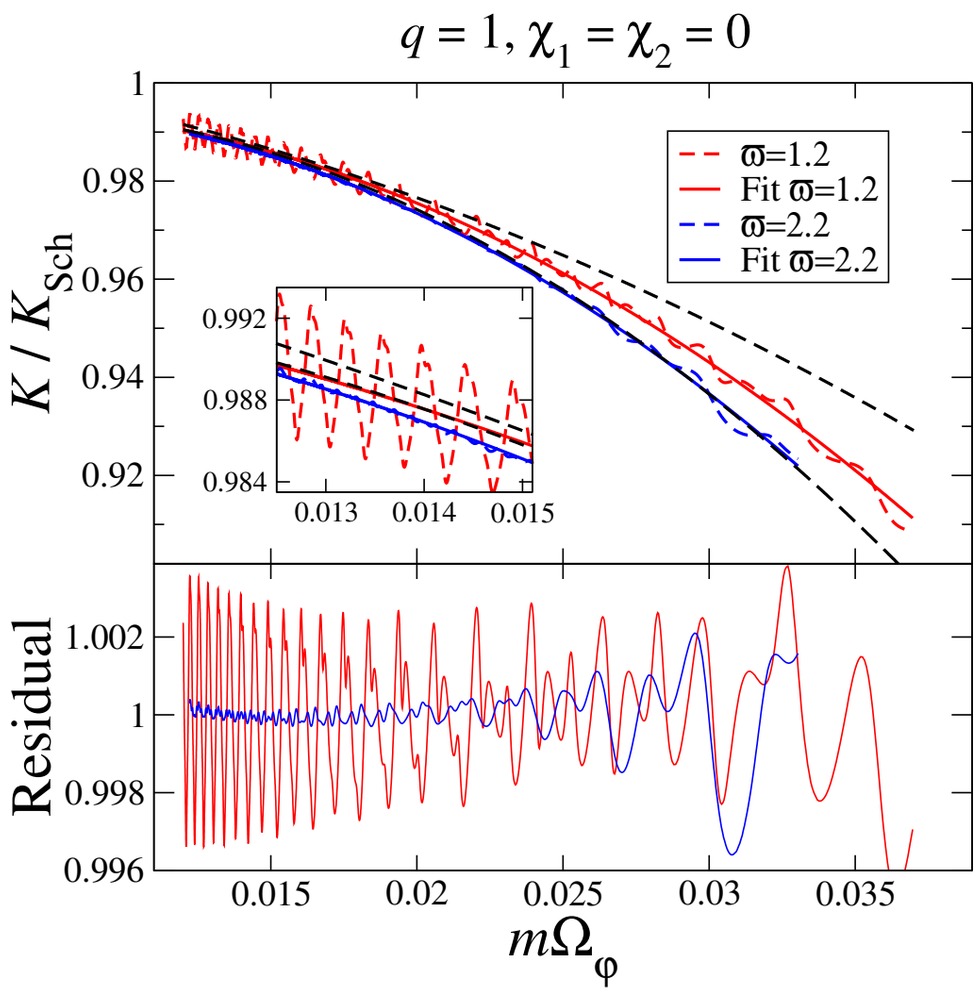
- Fundamental frequencies averaged quantities
- Cannot remove dissipation
- Need to fit out or orbit average



$$\Omega = a_0(t_c - t)^{a_1} + a_2 \cos\left[a_3 + \Omega_r(t - T)\right]$$

Periastron precession

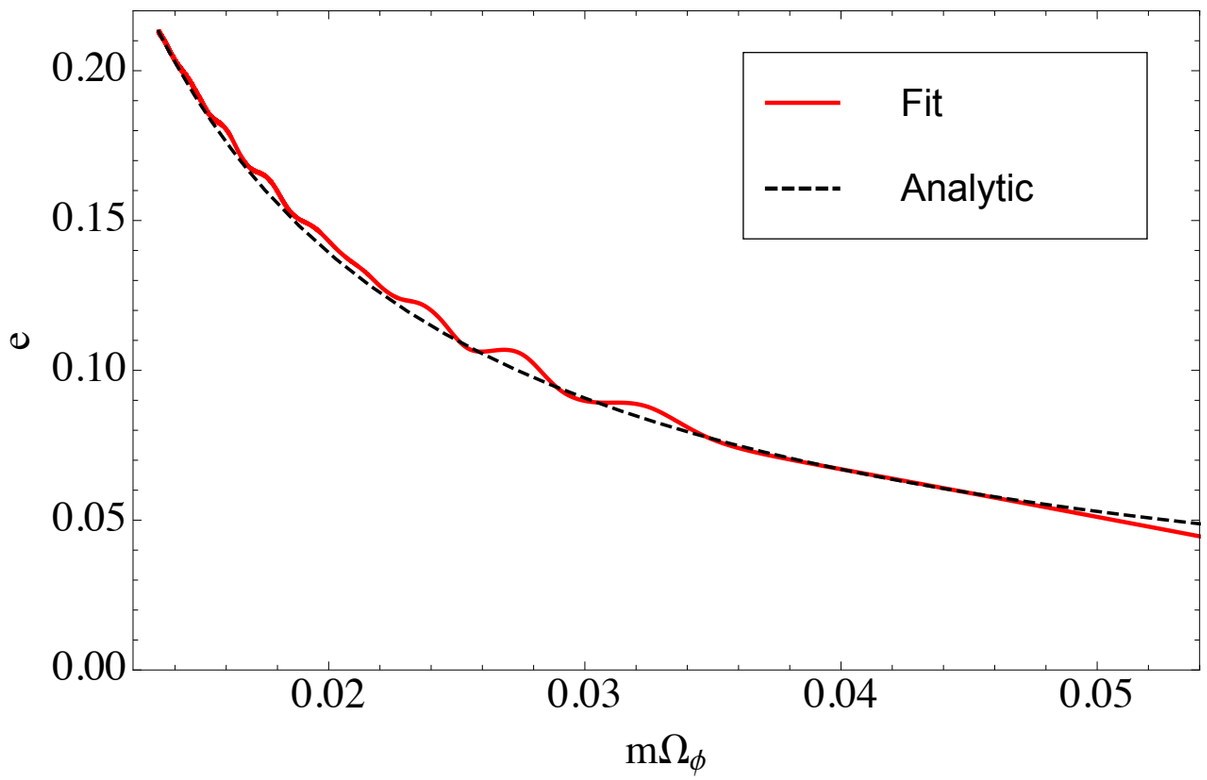


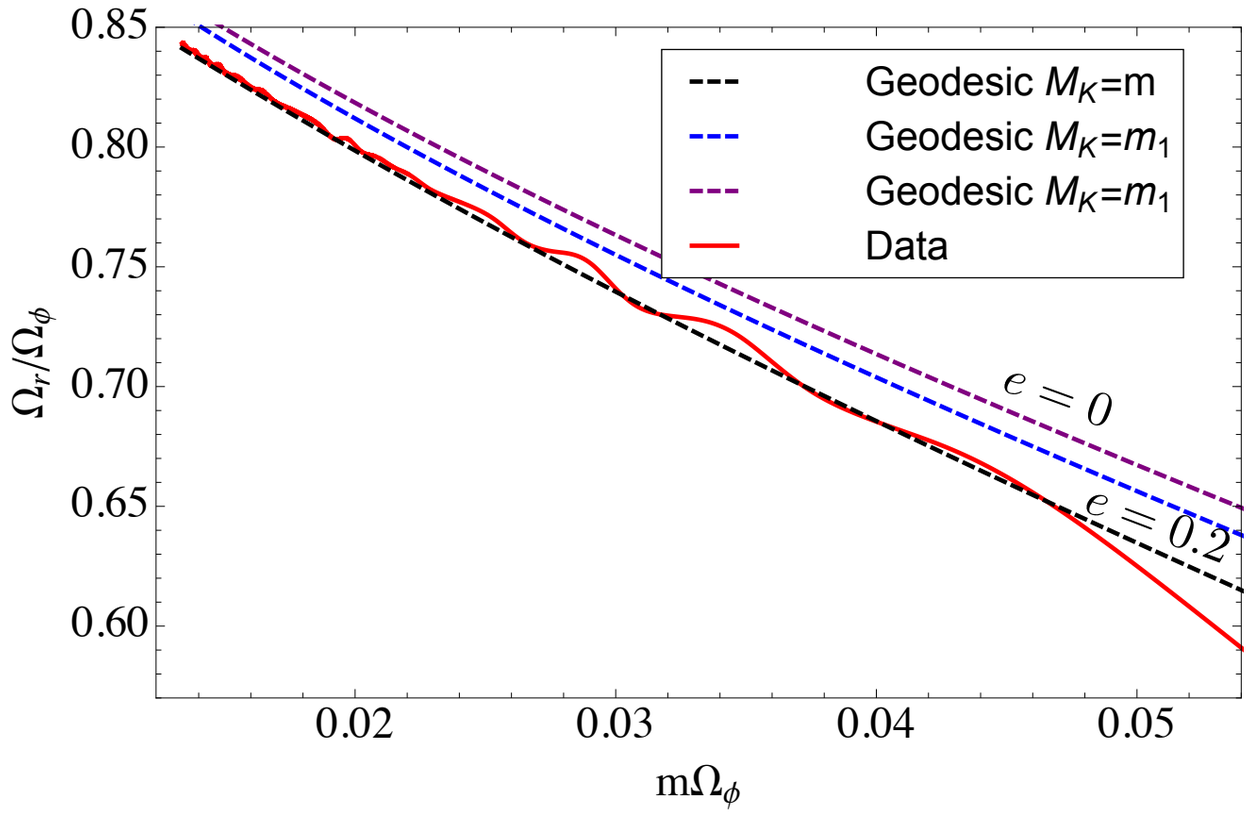


Le Tiec et al. (2013)

Periastron precession

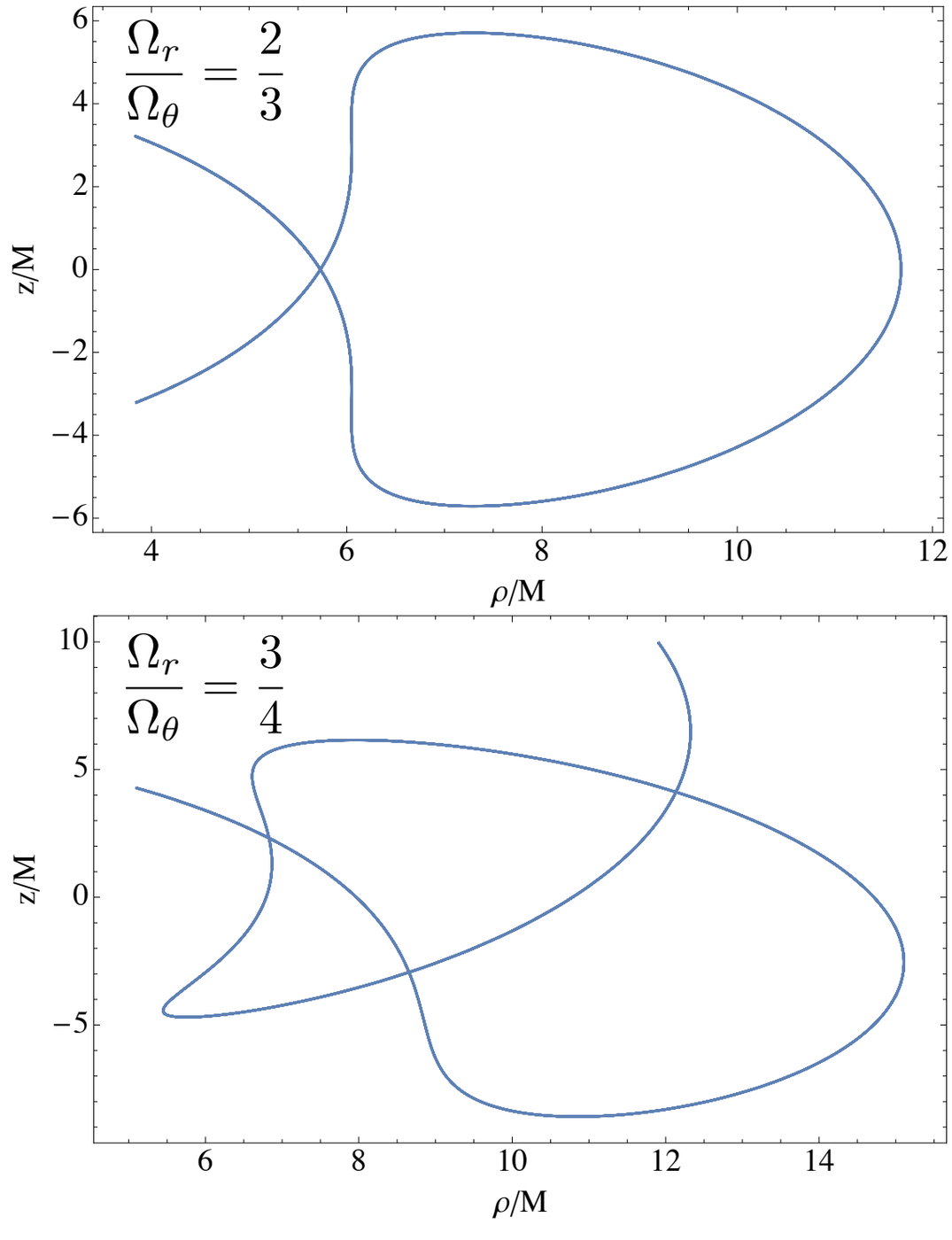
$$q = 7,\ \chi_1 = 0.8,\ \chi_2 = 0,\ \iota = 40^\circ$$





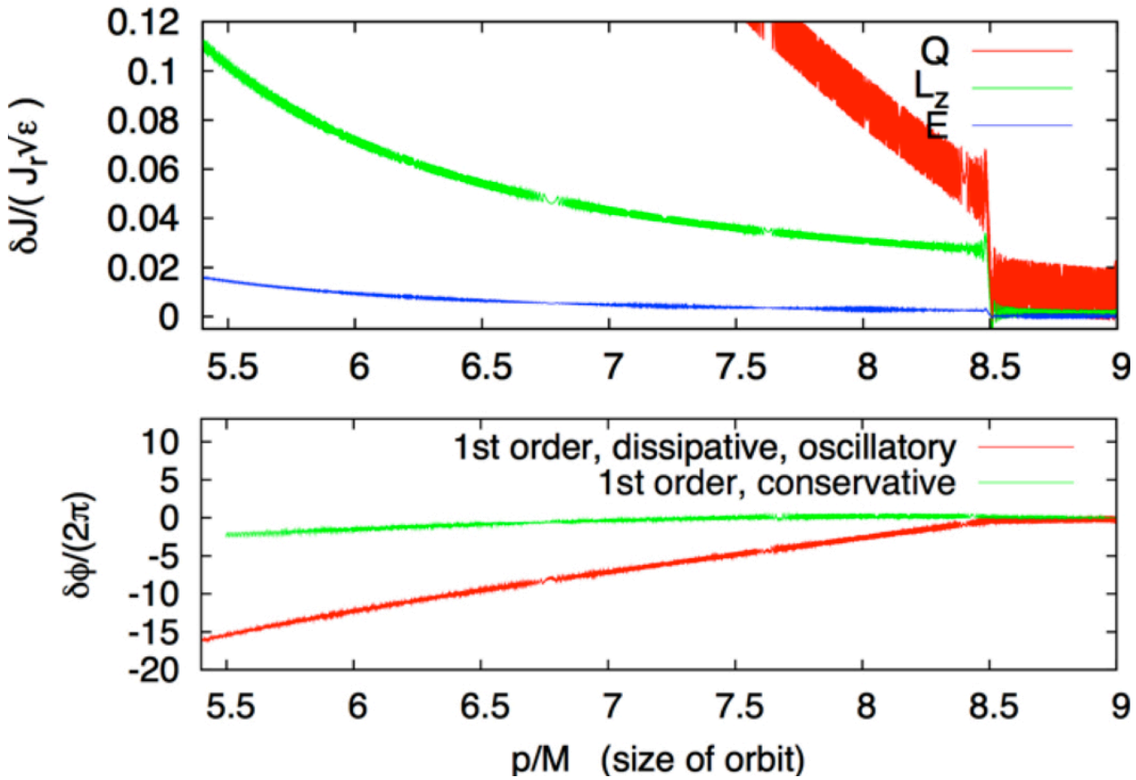
Resonant orbits

- Resonances: secular accumulation of SF
- Resonant kicks (Hirata, van de Meent)
- Large corrections to inspiral (Flanagan & Hinderer 2012)



Resonant orbits

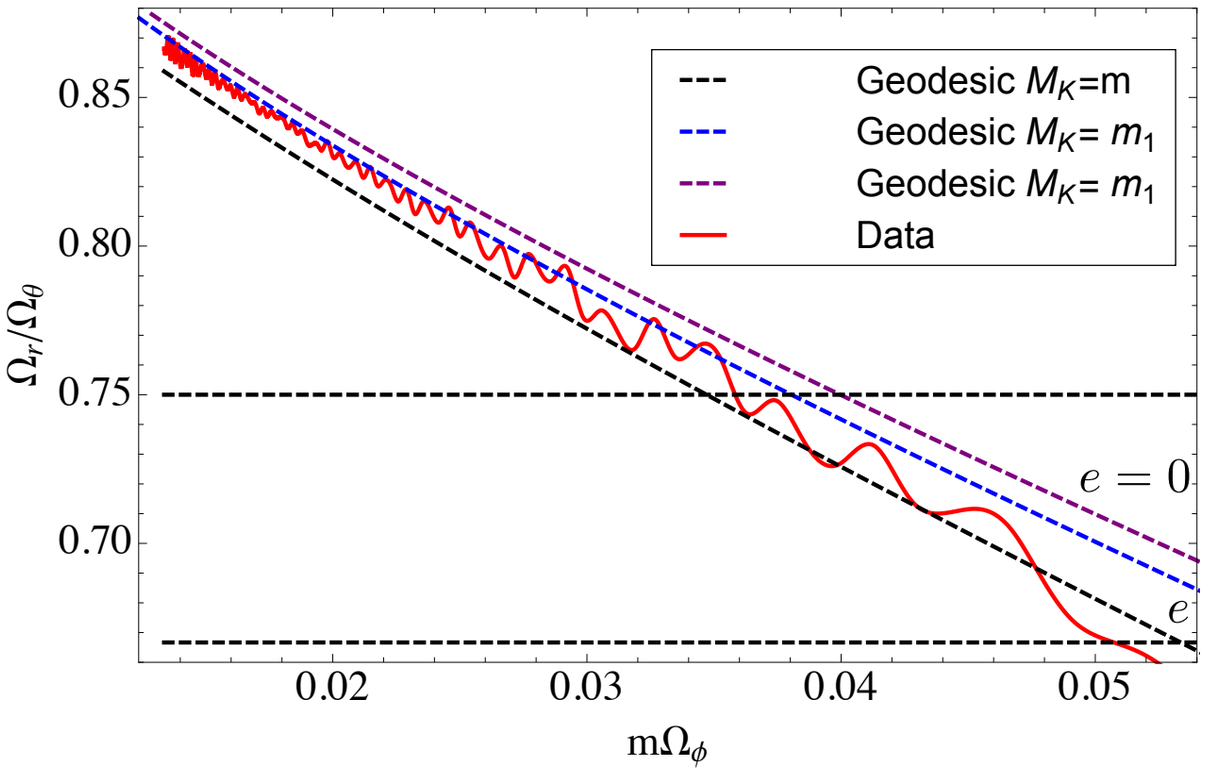
- Resonances: secular accumulation of SF
- Resonant kicks (Hirata, van de Meent)
- Large corrections to inspiral (Flanagan & Hinderer 2012)

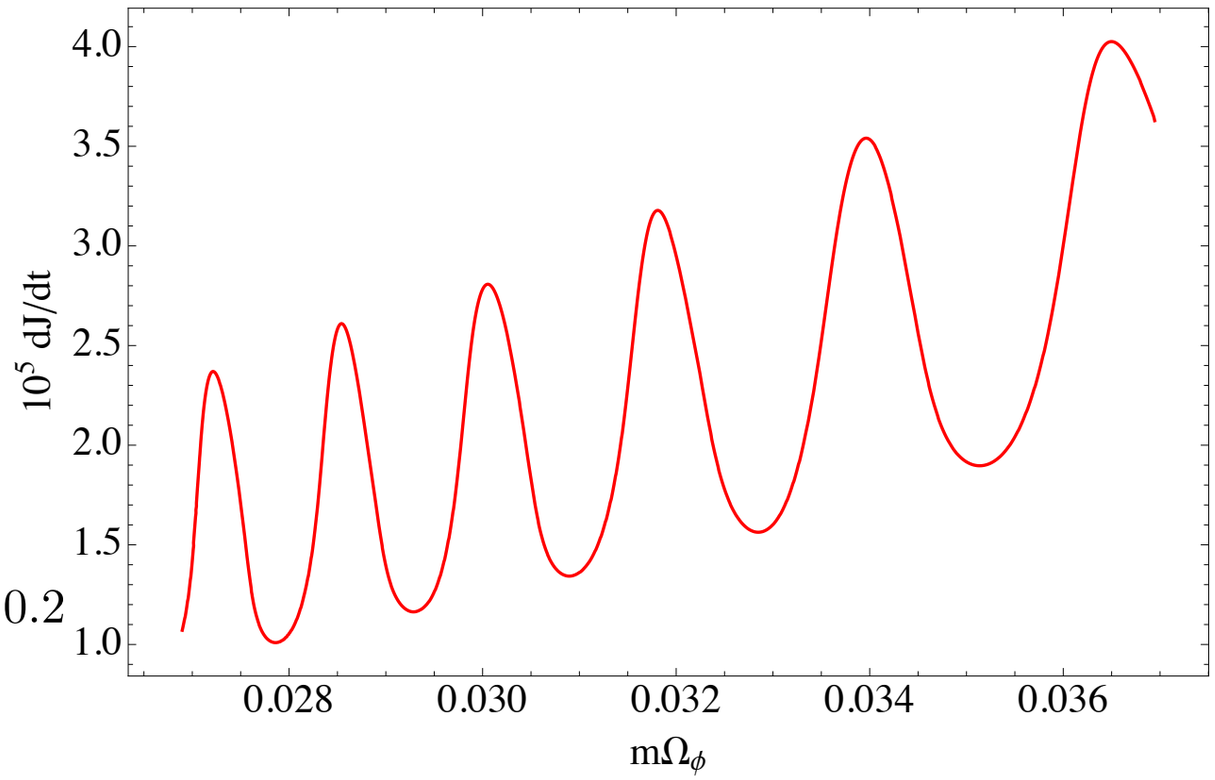


Flanagan and Hinderer (2012)

Resonant orbits

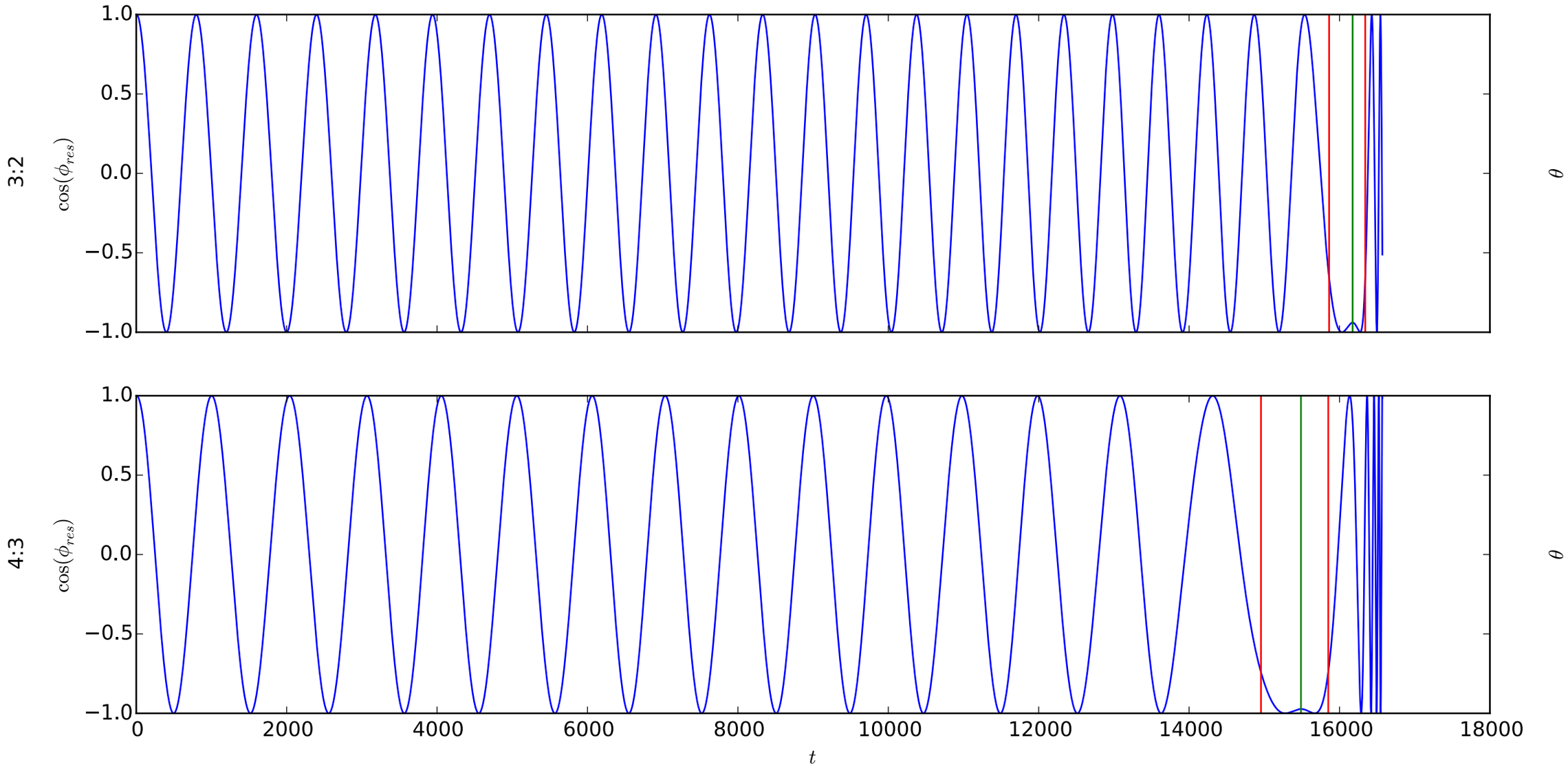
$$q = 7,\ \chi_1 = 0.8,\ \chi_2 = 0,\ \iota = 40^\circ$$





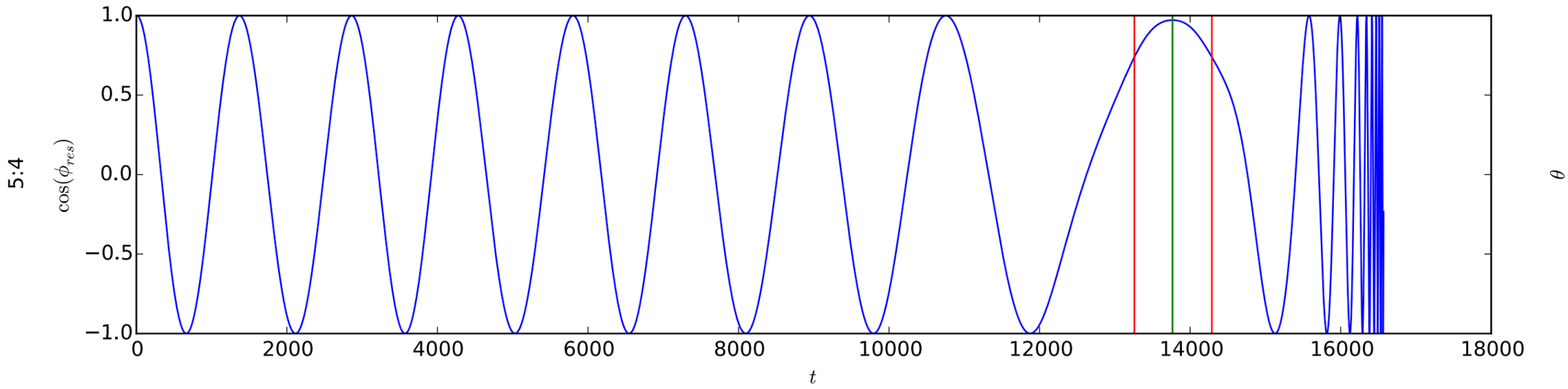
Resonant orbits

$$\cos\left[\int_{t_0}^{t}\left(k\Omega_r - n\Omega_\theta\right)dt\right]$$

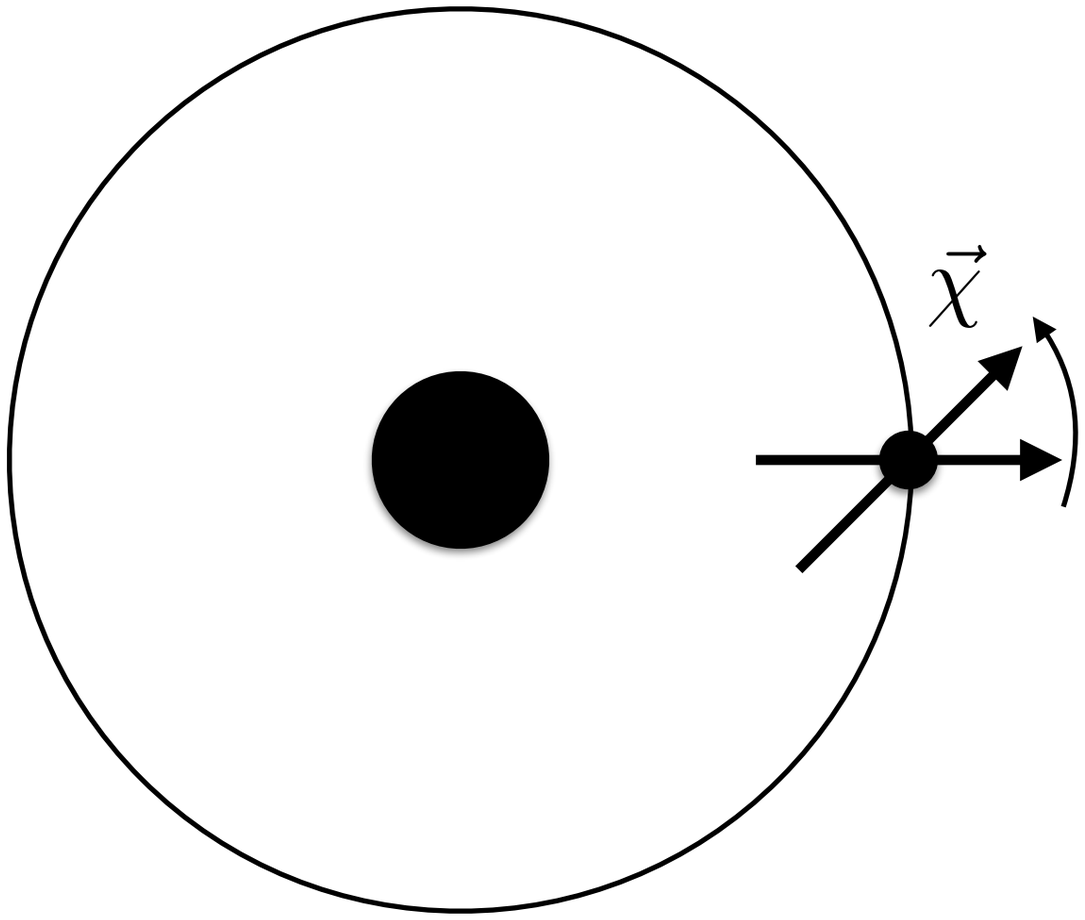


Resonant orbits

$$\cos\left[\int_{t_0}^{t}\left(k\Omega_r - n\Omega_\theta\right)dt\right]$$



Self-torque

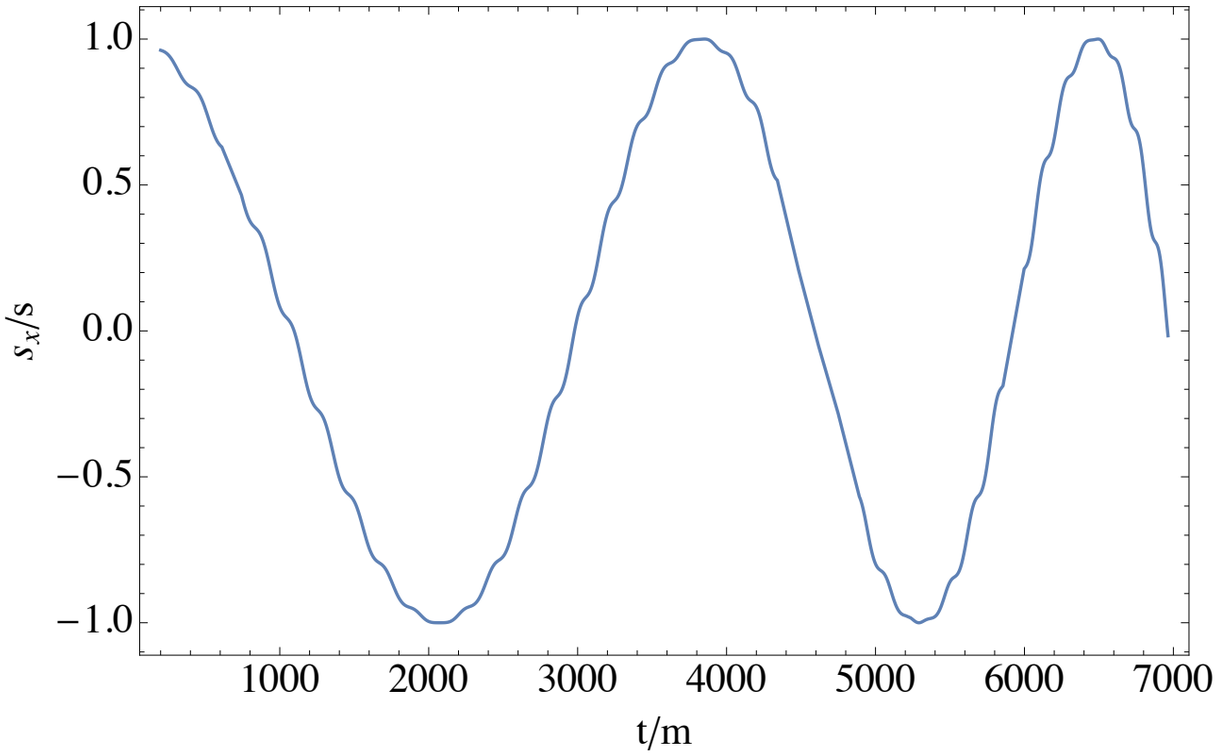


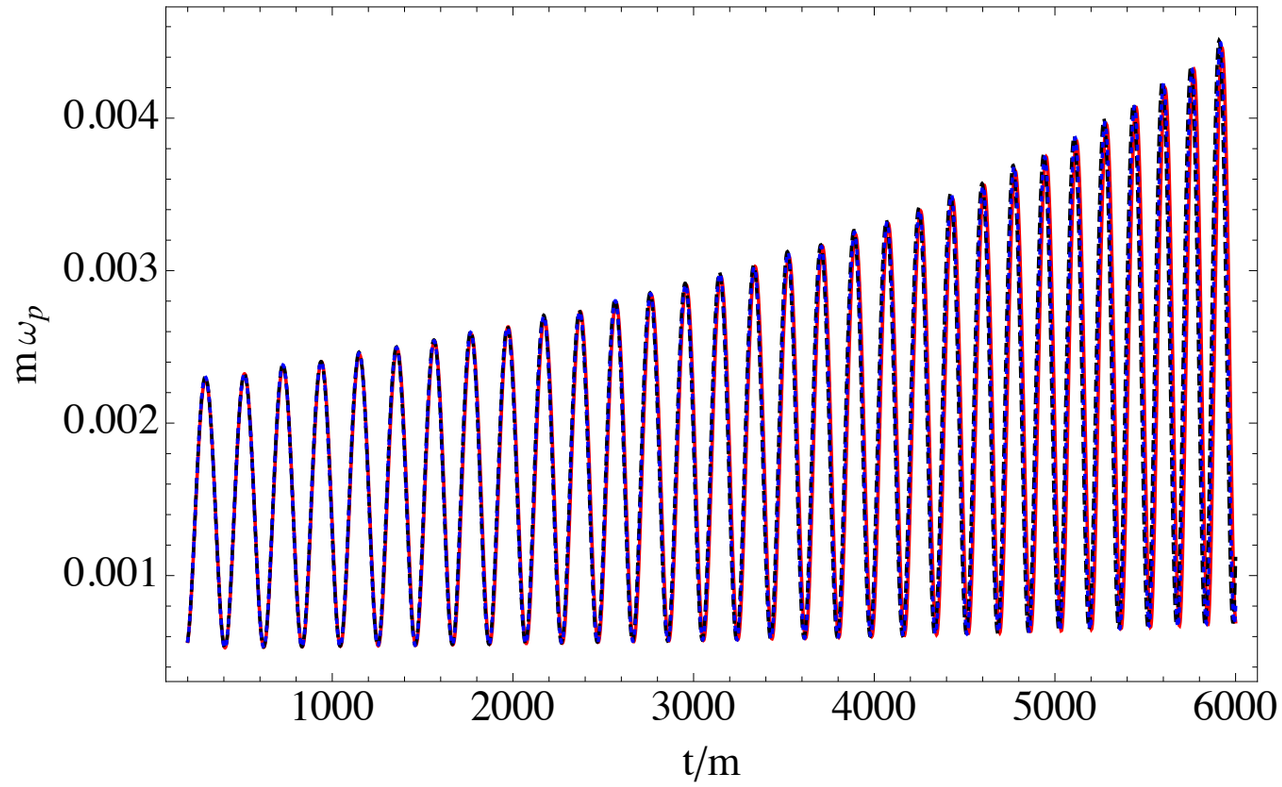
- Geodetic precession of test spin
- Compare to orbital motion
- Gauge invt quantity

$$\psi = \frac{\Delta\Phi_p}{\Delta\Phi_{\rm orb}} = \frac{\omega_p}{\Omega_\phi}$$

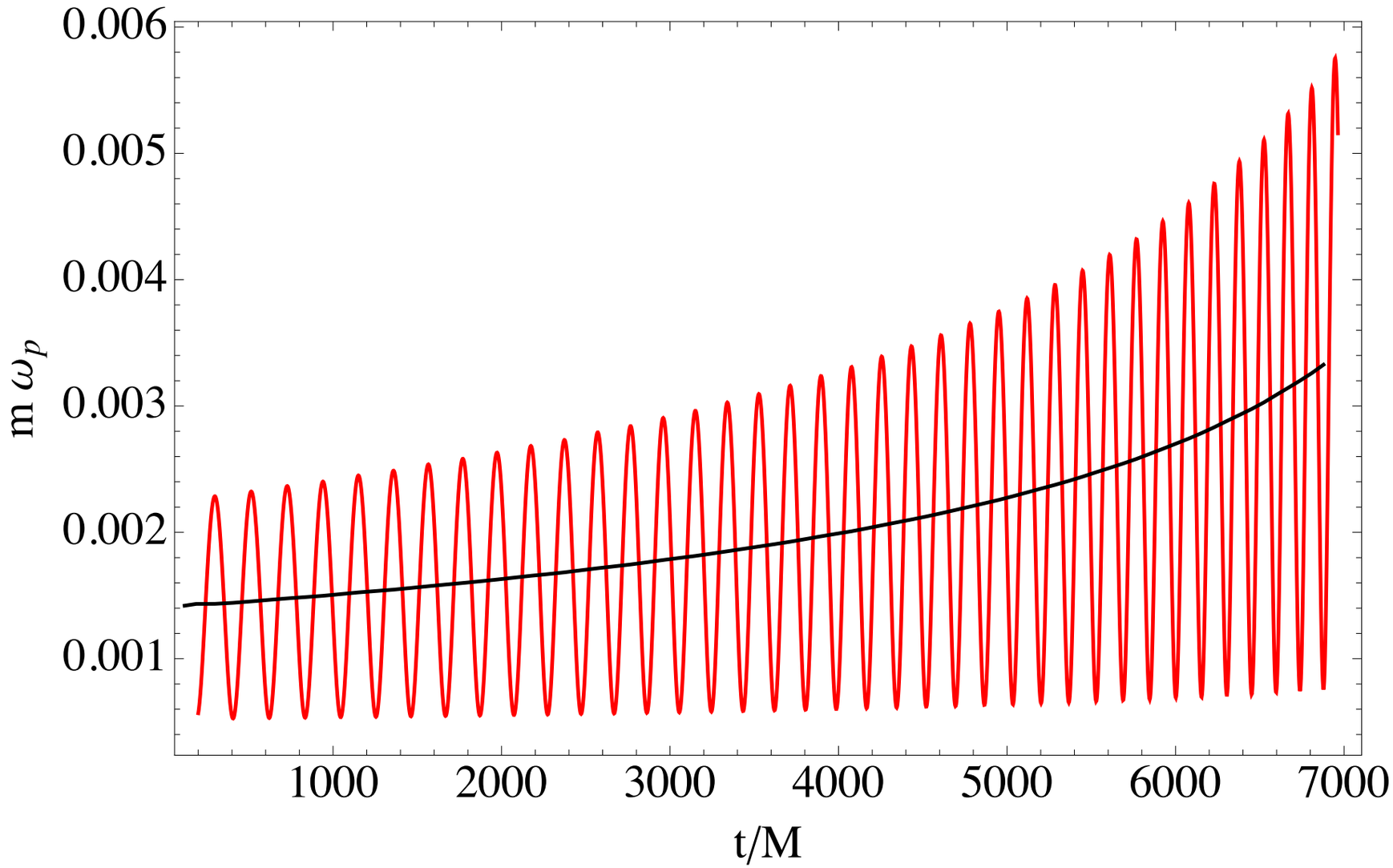
$$\frac{d\hat{\chi}}{dt} = \vec{\omega}_p \times \hat{\chi}$$

Spin evolution

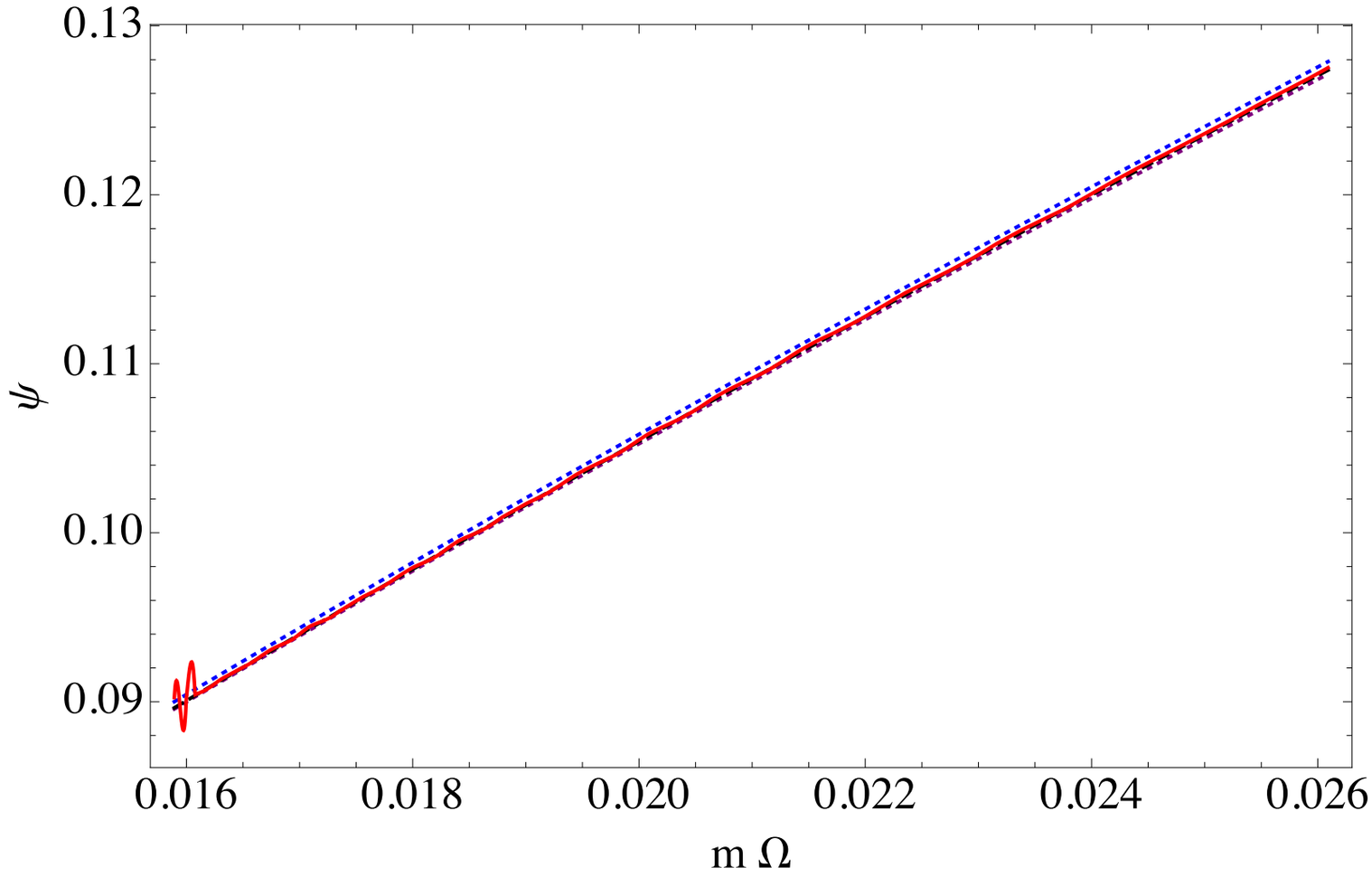




Spin evolution

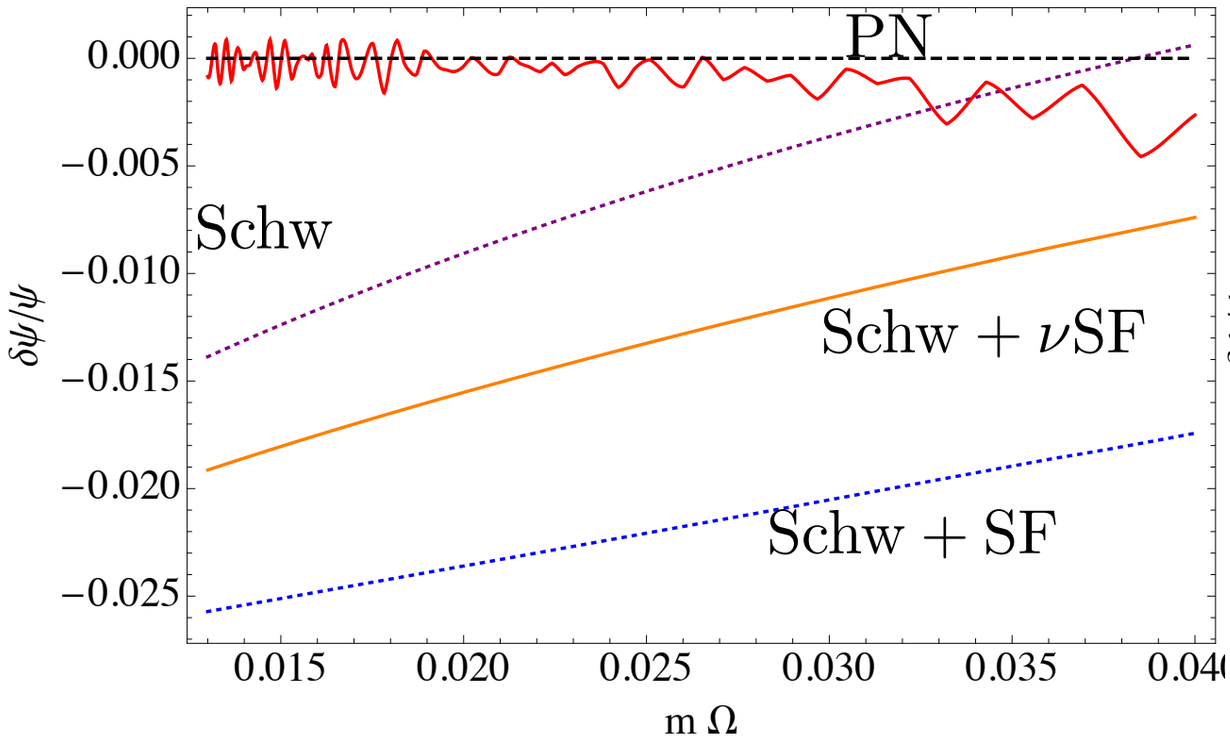


Self-torque comparison

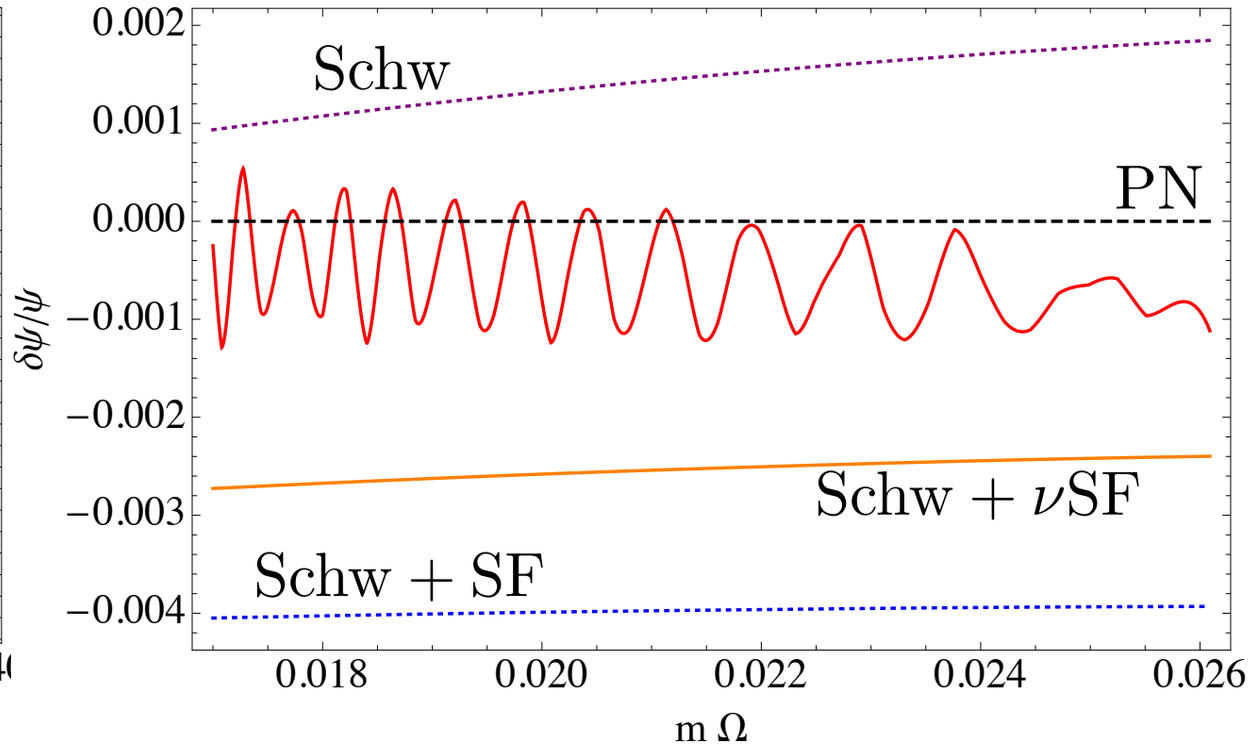


$q = 6$

Self-torque comparison



$q = 2$



$q = 6$

Future work

- Higher mass ratios
- New geometric invariants
- Compare to eccentric SF
- Better spin measurement?
- Dissipative SF