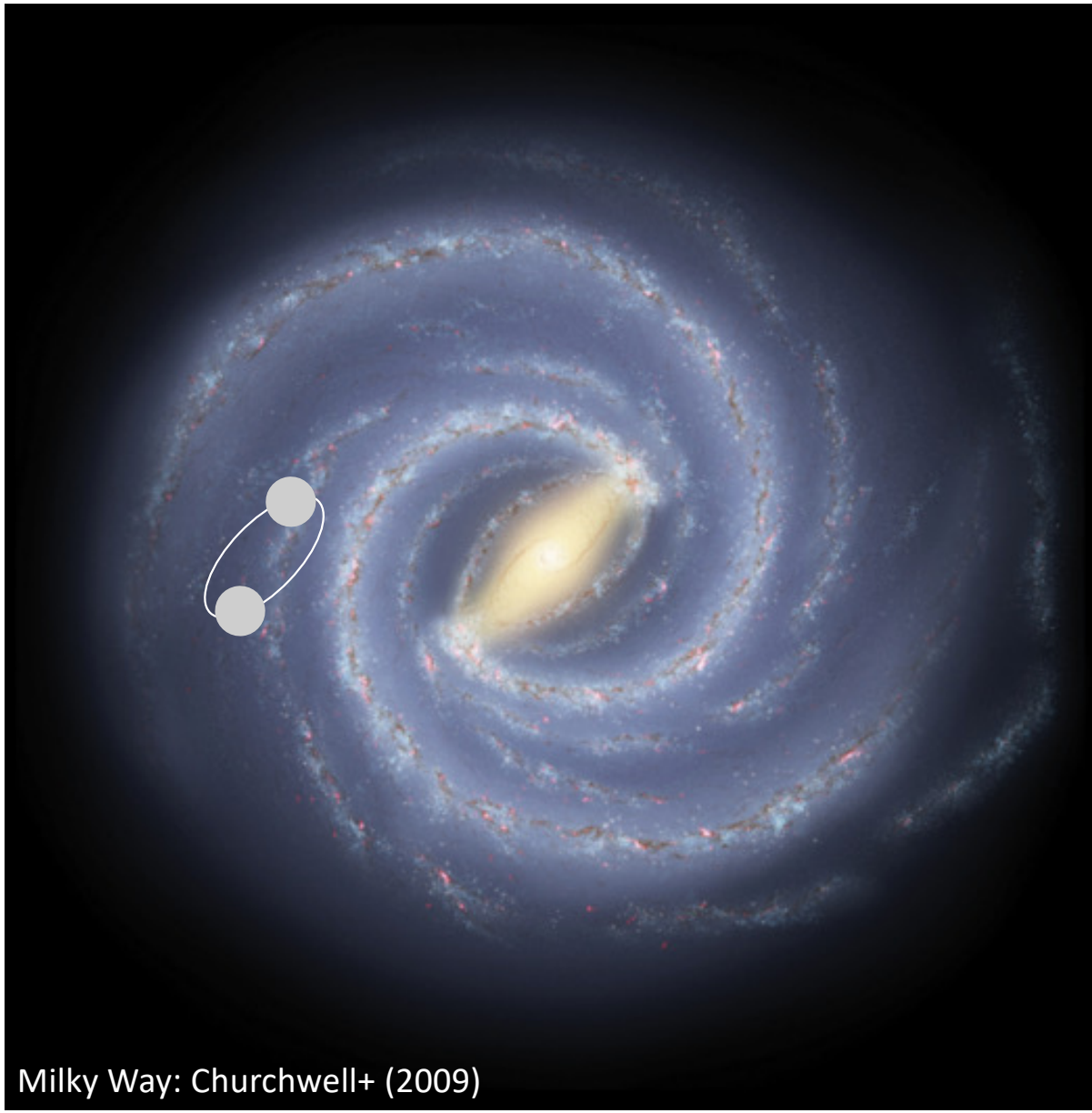


Mergers of Wide Binaries Induced by the Galactic Tide

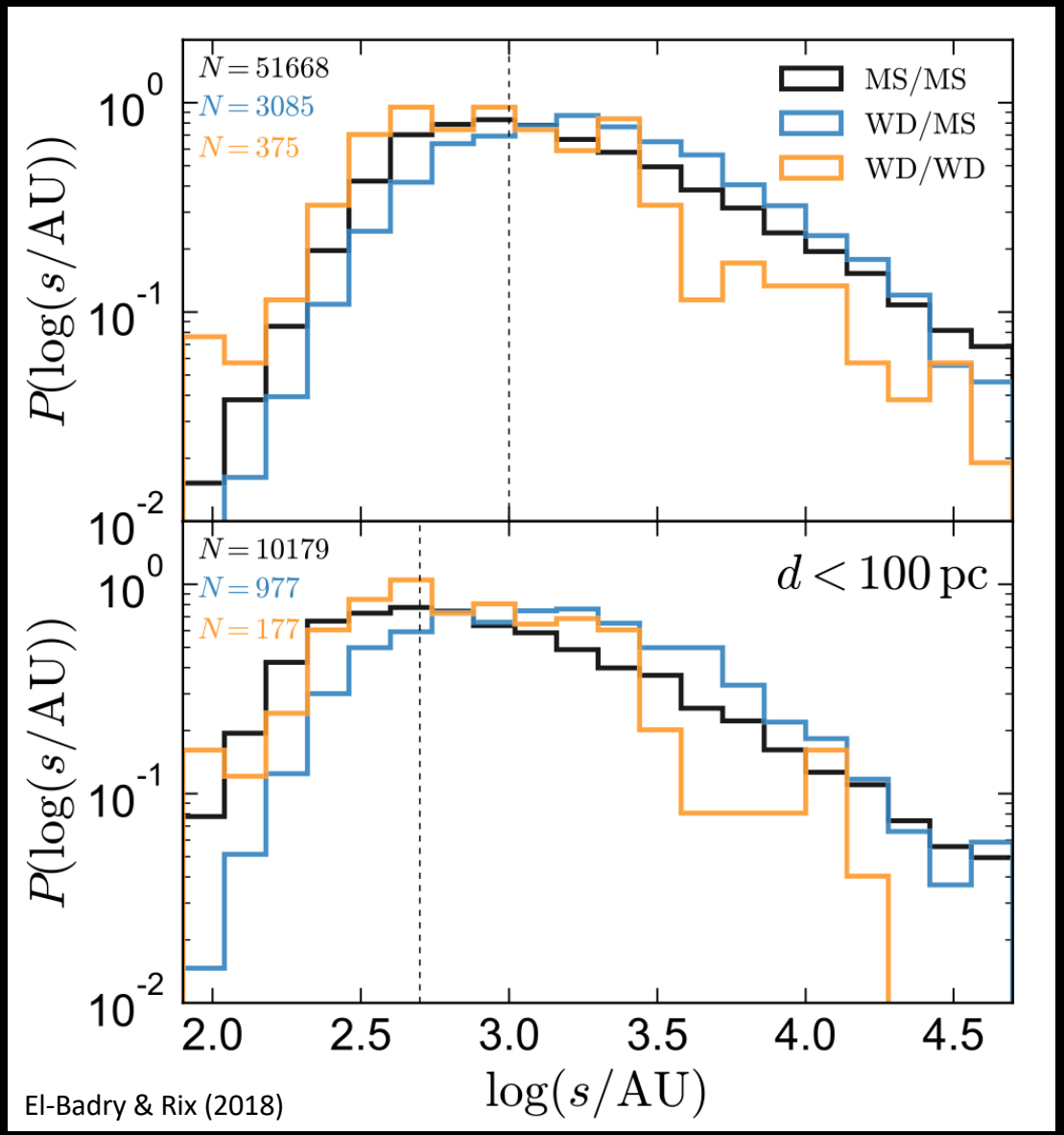
Jakob Stegmann, MPA fellow

LISA Astrophysics WG Meeting

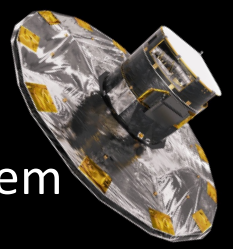
5th November 2024

MAX PLANCK INSTITUTE
FOR ASTROPHYSICS

Milky Way: Churchwell+ (2009)



El-Badry & Rix (2018)



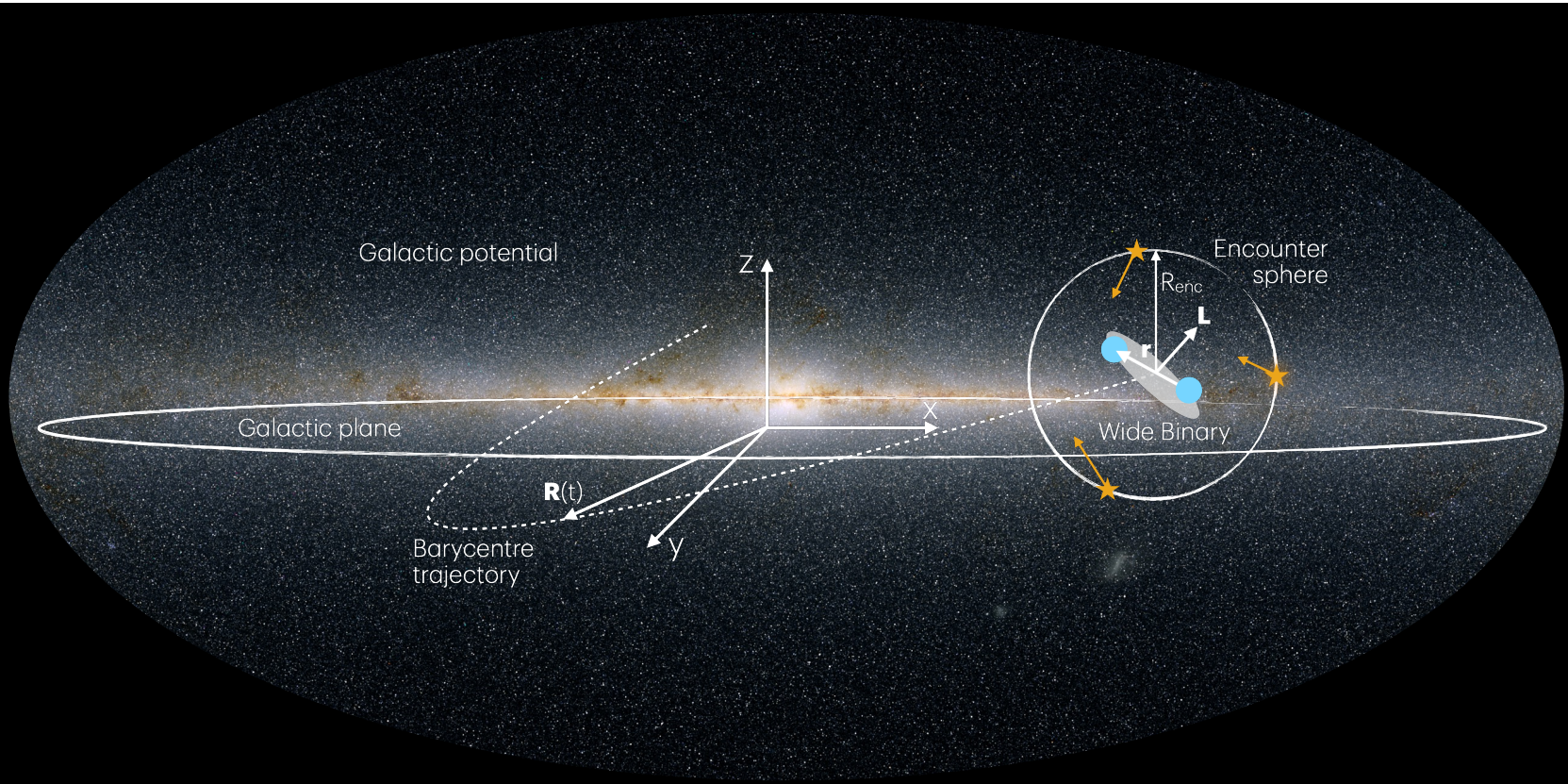
Gaia detected thousands of them via common proper motion

$f_{>10^2\,\mathrm{AU}} \gtrsim 1 - 10\%$

https://gea.esac.esa.int/archive/

We know that s>1e5 AU gets disrupted by the galaxy (e.g., Jiang & Tremaine, 2010)!

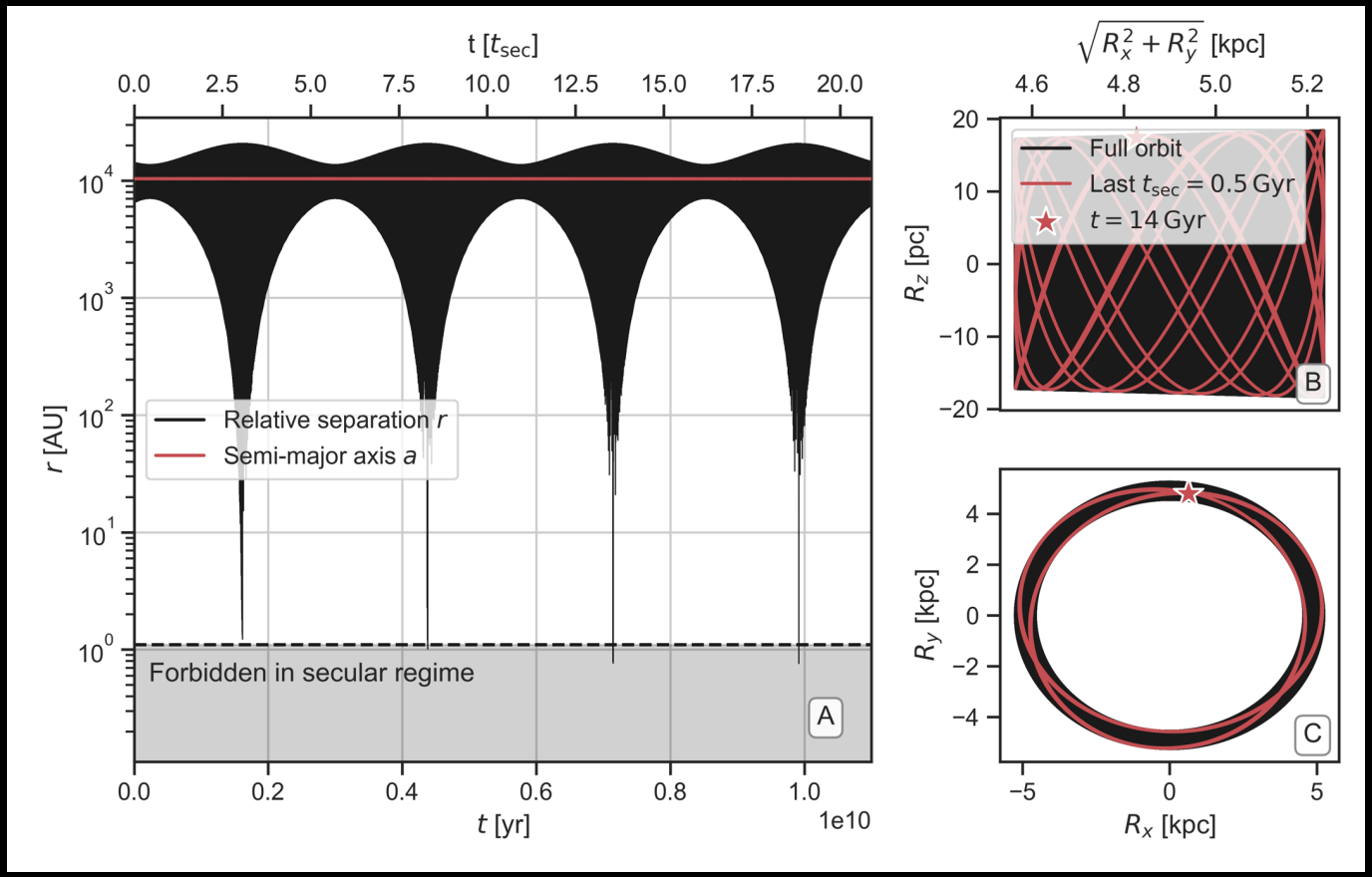
What happens below s<1e5 AU?



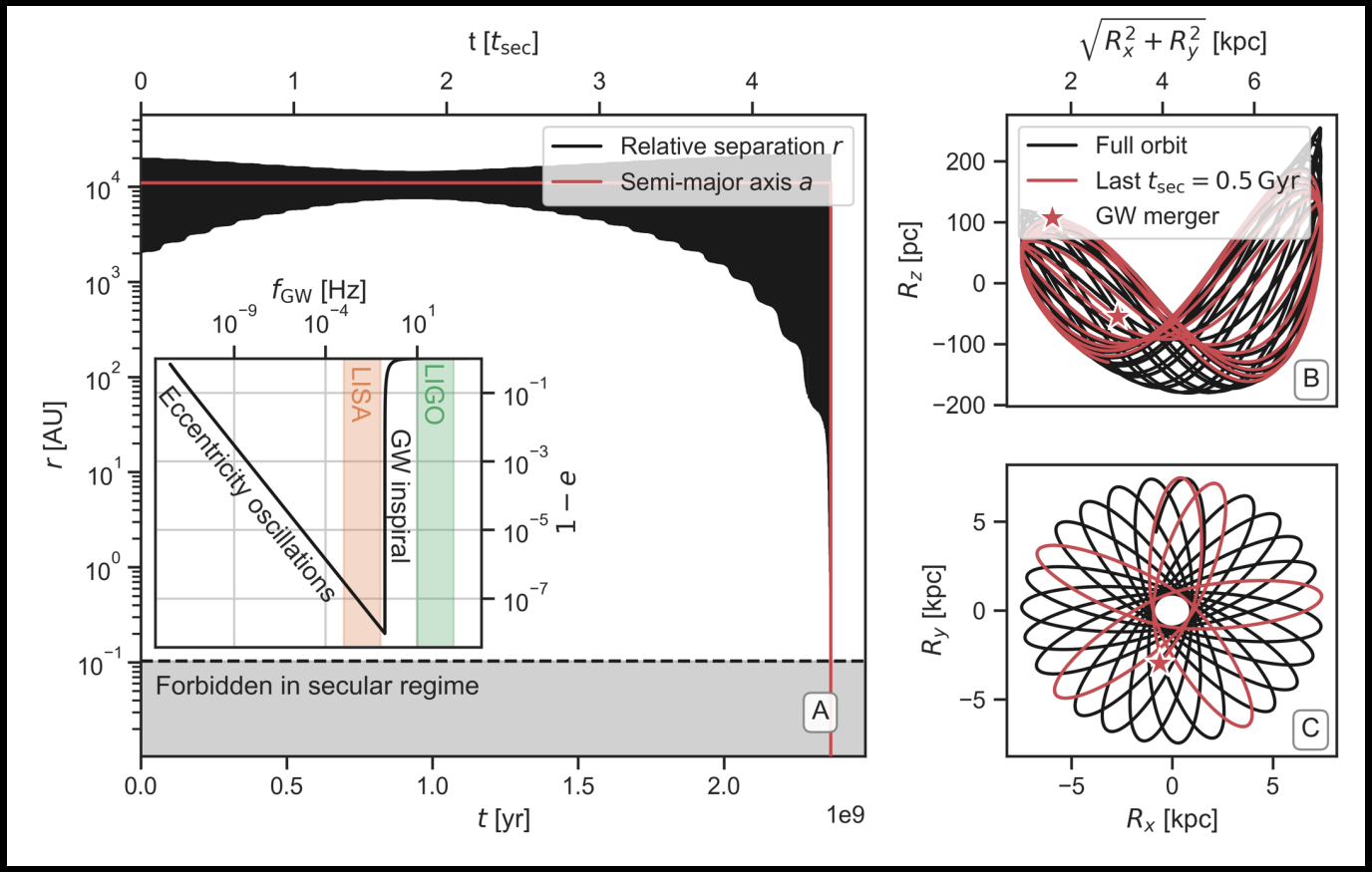
- Direct *N(=2)*-body integrator MSTAR (Rantala+ 2020)
  - Gragg-Bulirsch-Stoer extrapolation technique
  - 3.5pN corrections
- A population of field binaries with $10^2 < \frac{a}{\mathrm{AU}} < 10^5$ (Wagg+ 2022)
- Modified to include
  - external Galactic potential (Price-Whelan+ 2024)
  - fly-bys (Hamers & Tremaine 2021)

$$\boldsymbol{a}_{1,2} \mathrel{+}= \nabla\Phi|_{\boldsymbol{r}_{1,2}}$$

$$\Phi = \Phi_{\mathrm{Disk}} + \Phi_{\mathrm{NFW}} + \Phi_{\mathrm{Bulge}} + \Phi_{\mathrm{Nucleus}}$$

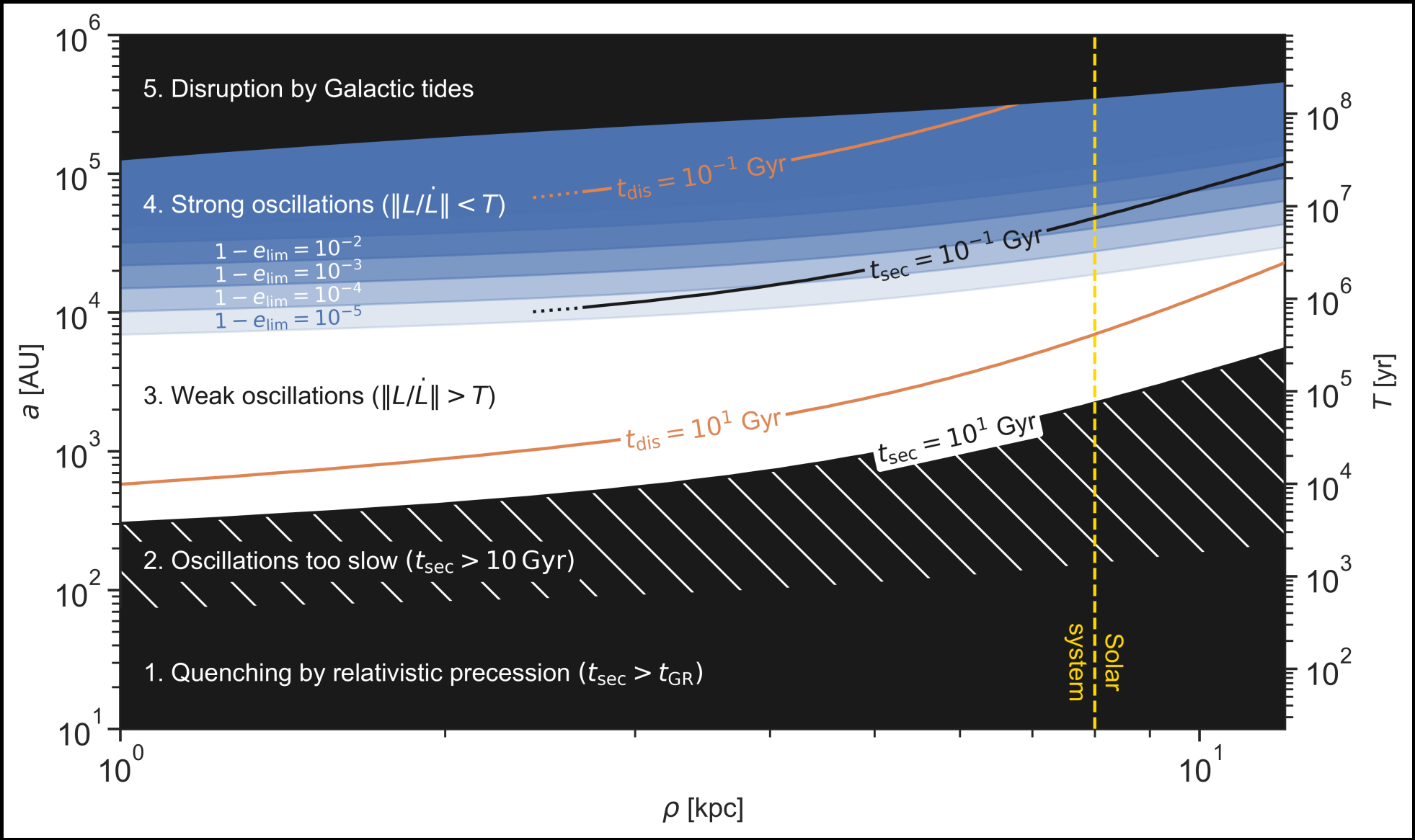


Galactic torques induce long-term oscillations of the binary eccentricity

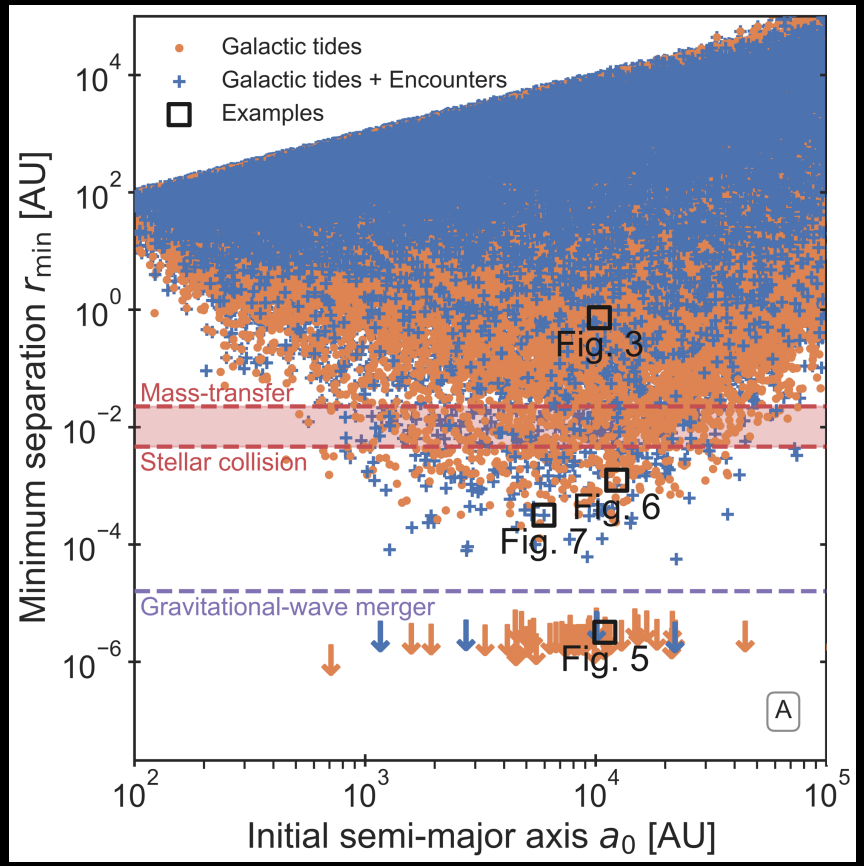


The Galaxy can drive mergers of wide binary compact objects

At high eccentricities, galaxy can easily torque away all orbital ang. mom. ($e \to 1$)


5. Disruption by Galactic tides
4. Strong oscillations ($\|L/\dot{L}\| < T$)
$1 - e_{\rm lim} = 10^{-2}$
$1 - e_{\rm lim} = 10^{-3}$
$1 - e_{\rm lim} = 10^{-4}$
$1 - e_{\rm lim} = 10^{-5}$
$t_{\rm dis} = 10^{-1}$ Gyr
$t_{\rm sec} = 10^{-1}$ Gyr
3. Weak oscillations ($\|L/\dot{L}\| > T$)
$t_{\rm dis} = 10^{1}$ Gyr
$t_{\rm sec} = 10^{1}$ Gyr
2. Oscillations too slow ($t_{\rm sec} > 10$ Gyr)
1. Quenching by relativistic precession ($t_{\rm sec} > t_{\rm GR}$)
Solar system
a [AU]
T [yr]
ρ [kpc]
10^{0}
10^{1}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}

Closest approach in simulation



Partial RLOs

$\sim\mathcal{O}(10^{-3})$ stellar collisions

$\sim\mathcal{O}(10^{-4})$ GW mergers

Extreme eccentricity excitations

Galactically-perturbed WBs could significantly contribute to range of transient phenomena:

BBH mergers vs. LIGO

$\mathcal{R}\sim\mathcal{O}(0.1)\ \mathrm{yr}^{-1}\mathrm{Gpc}^{-3}$

MS-MS collisions vs. LRNe

$\mathcal{R}\sim(10^{-5})\ \mathrm{yr}^{-1}\mathrm{Mpc}^{-3}$

WD-WD collisions vs. SNIa

$\mathcal{R}\sim\mathcal{O}(10^{-5})\ \mathrm{yr}^{-1}\mathrm{Mpc}^{-3}$

Summary & Outlook

Galactically-perturbed wide binaries significantly contribute to

- **GW merger events**
- **Stellar collisions** (cf. Kaib & Raymond, 2014)

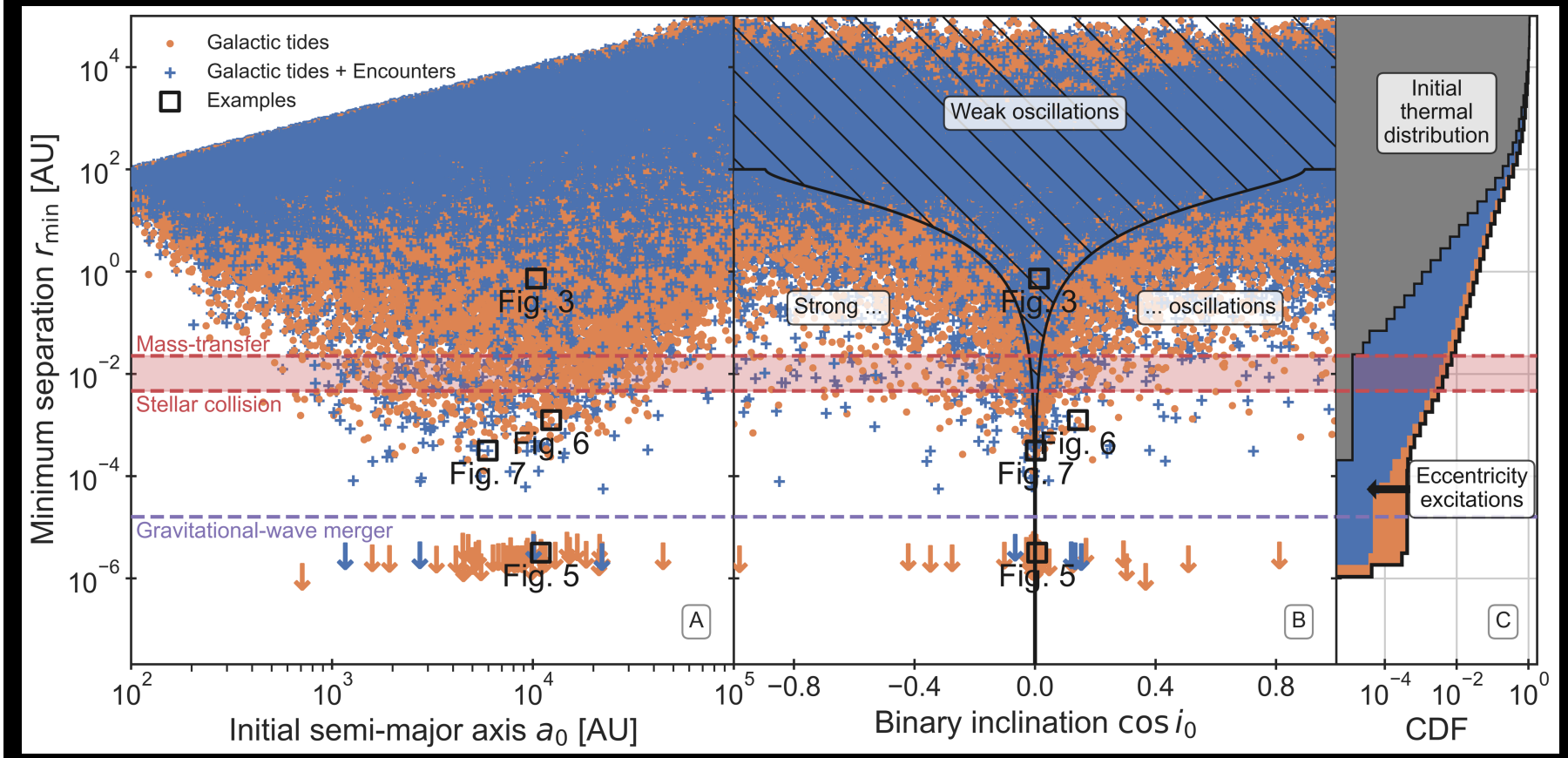
… with minimal assumptions about stellar binary physics (no mass-transfer/tides)

Future work:

- Triples with wide outer companion
- LIGO/LISA signatures of Galactically-driven mergers (BBHs/NSs/WDs)

Jakob Stegmann *et al* 2024 *ApJL* **972** L19
Co-authors: A. Vigna-Gomez, A. Rantala, T. Wagg, L. Zwick, M. Renzo, L. van Son, S. de Mink, S. White

Back-up slides



Partial RLOs

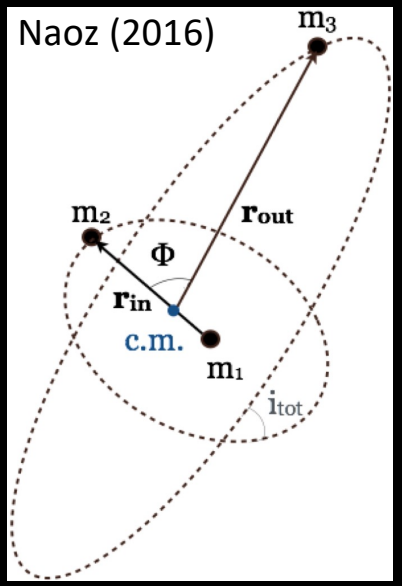
$\sim\mathcal{O}(10^{-3})$ stellar collisions

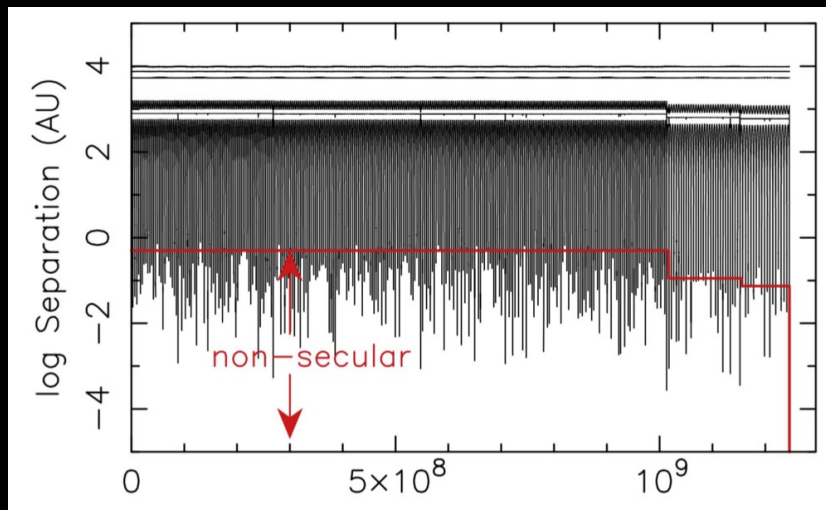
$\sim\mathcal{O}(10^{-4})$ GW mergers

Extreme eccentricity excitations

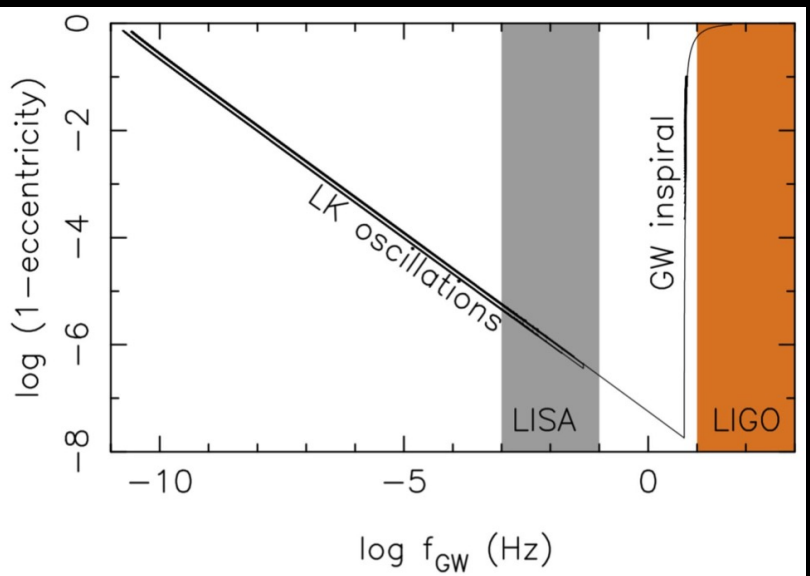
Completely analogue to Lidov-Kozai in triples:

Naoz (2016)





Antonini+ (2017)



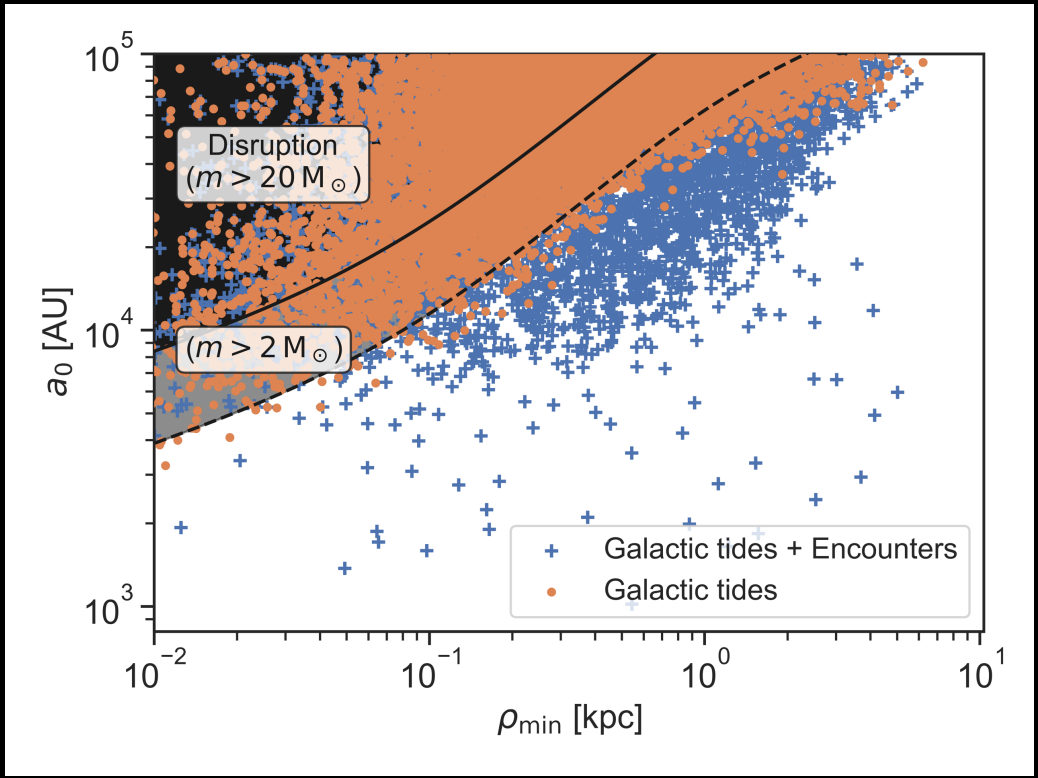
Non-secular extreme eccentricities if:

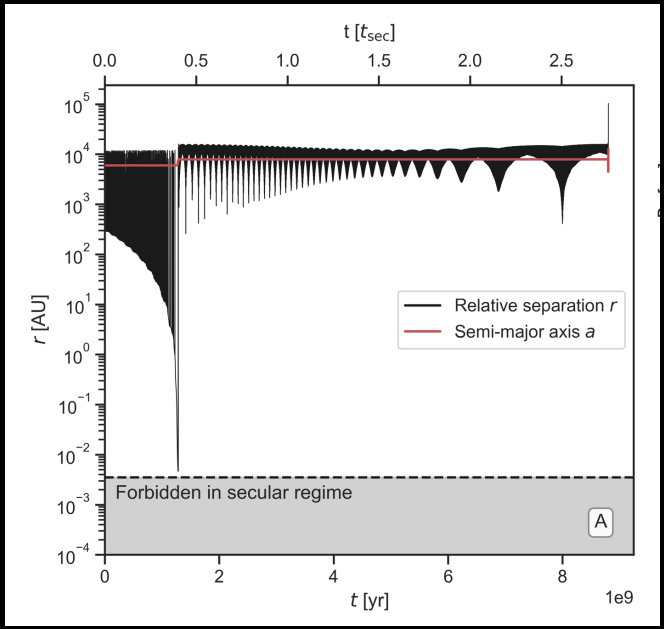
$$\left|\frac{1}{L}\frac{dL}{dt}\right|^{-1} < T \Rightarrow \boxed{\sqrt{1-e} < T^2\left|\Phi_{ij}\right|}$$

Special case of triples (Antonini+ 2014):

$$\sqrt{1-e_{\rm crit}} \equiv 5\pi\frac{m_3}{m_1+m_2}\left[\frac{a_1}{a_2(1-e_2)}\right]^3$$

Disruptions





Binaries get disrupted if they exceed Hill radius at “Galactic periapsis”