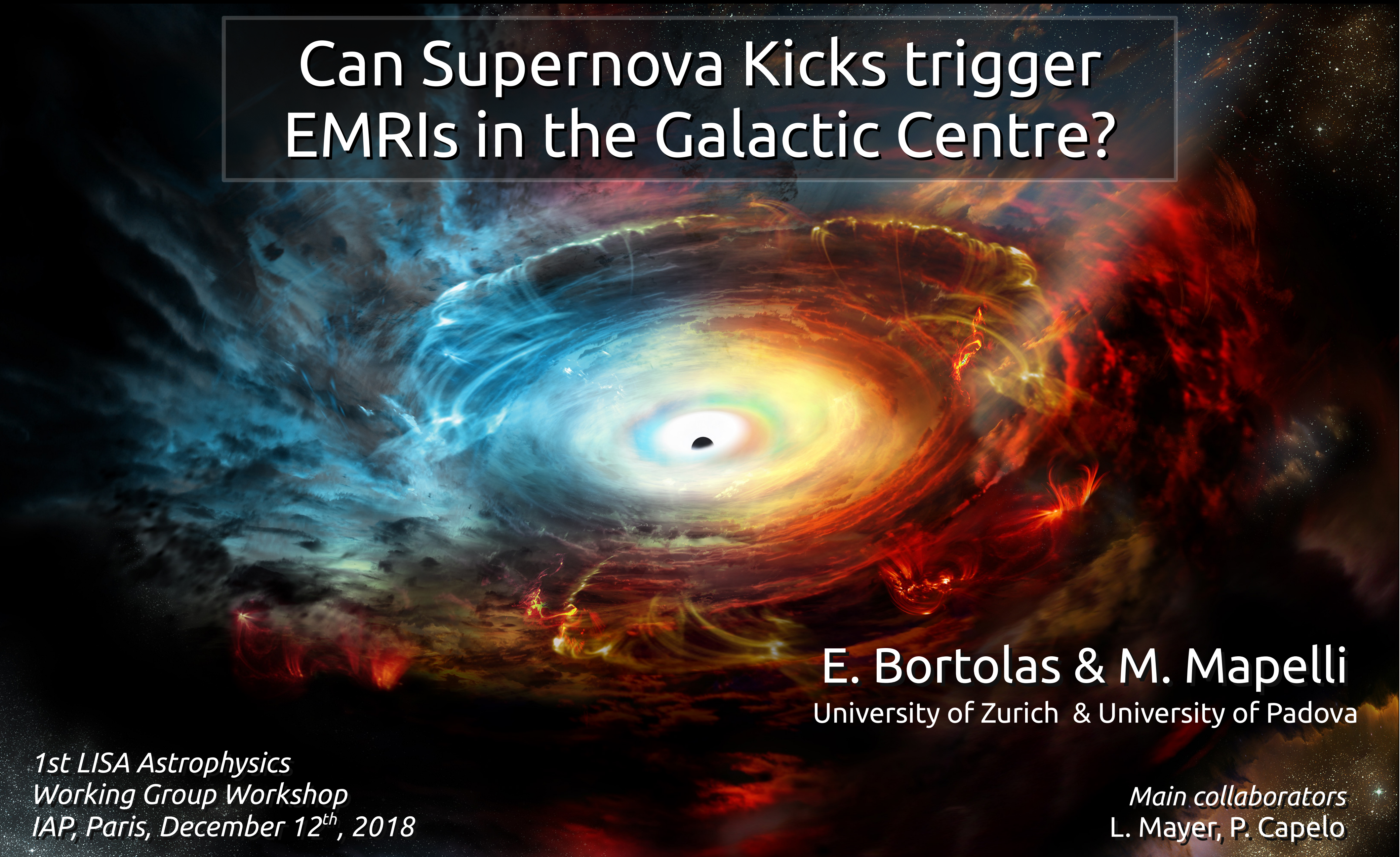

Can Supernova Kicks trigger EMRIs in the Galactic Centre?

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Main collaborators
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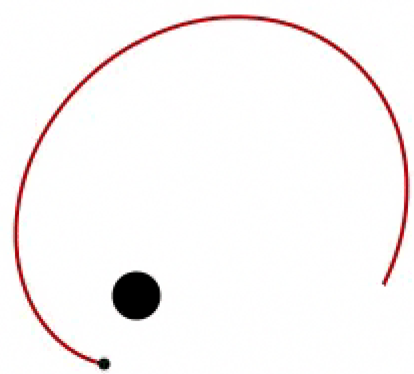
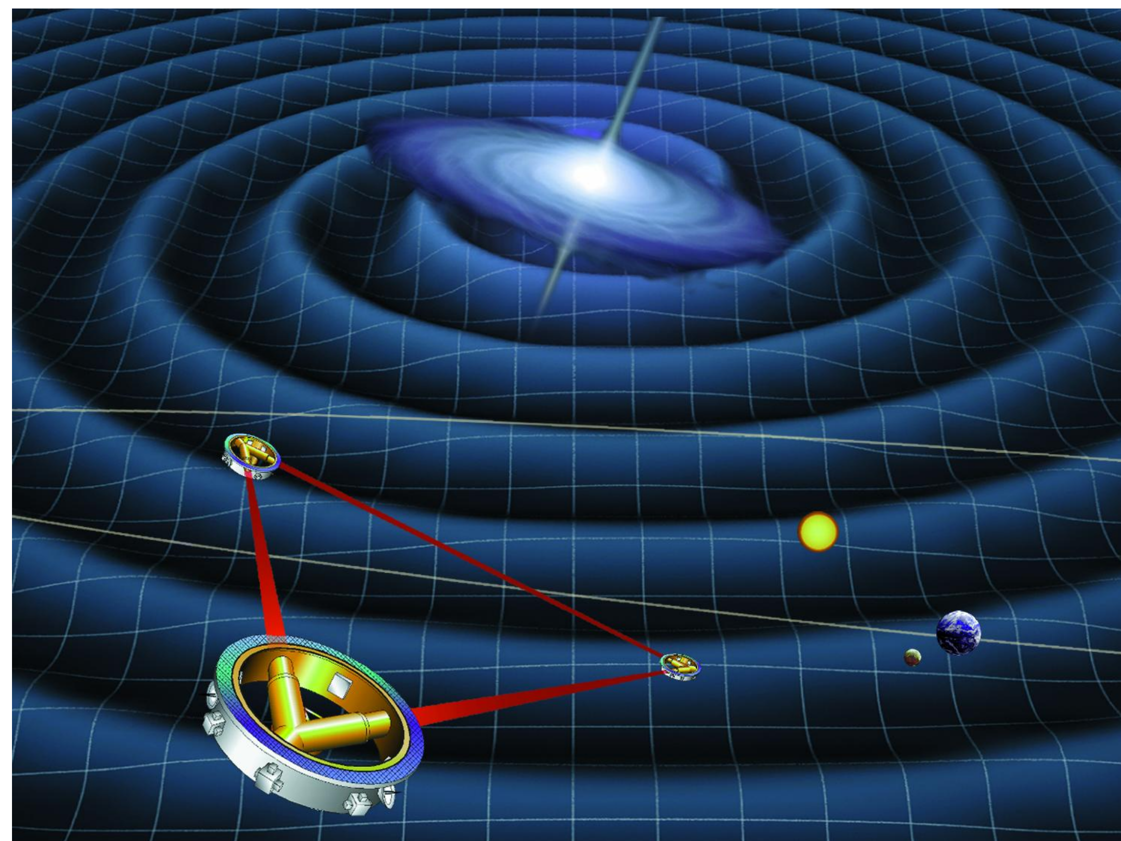
Extreme mass ratio inspirals (EMRIS)



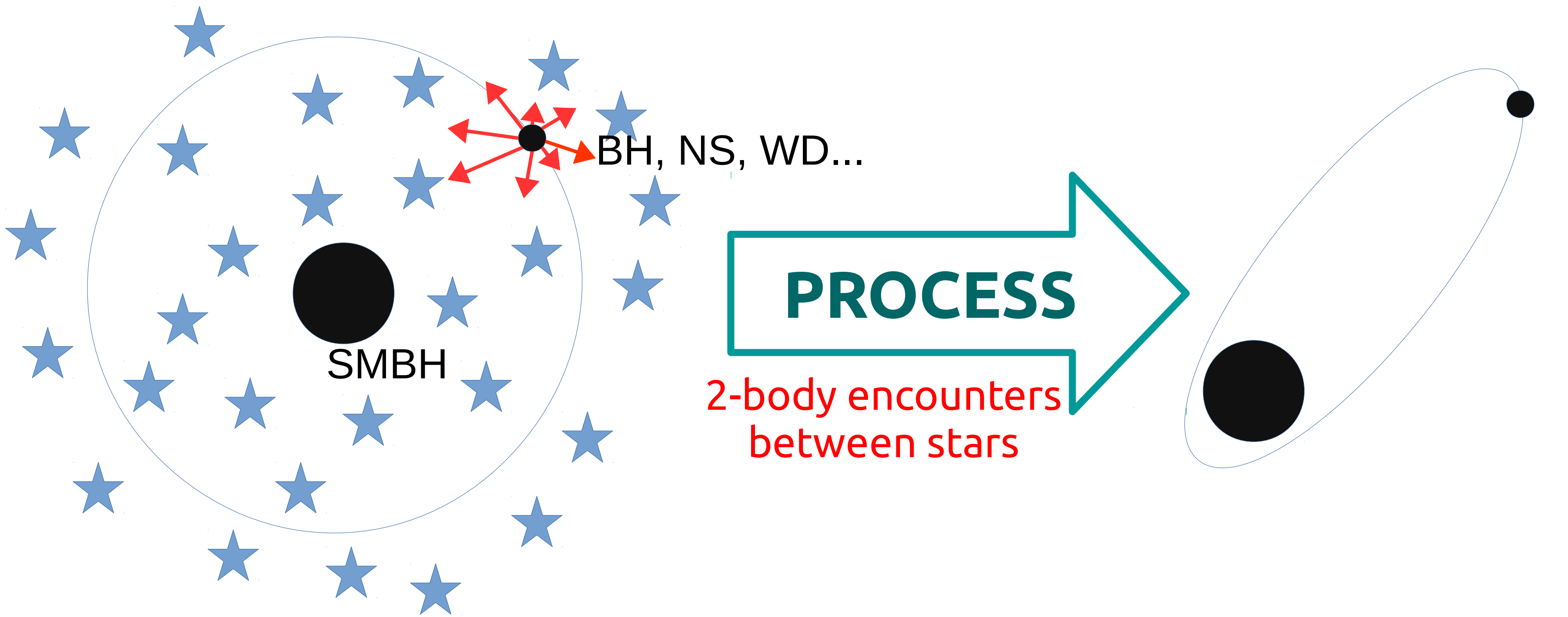
GW induced decay of a stellar mass compact object onto a SMBH

Observable by the LISA mission, ~10^5 orbits!
(Amaro-Seoane+2017)



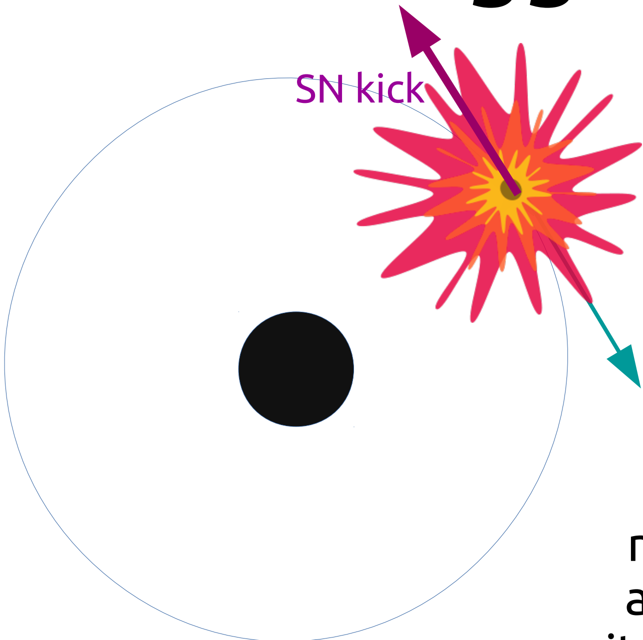
Will give us unprecedented information on SMBH masses, spins and host environment + GR tests
(Amaro-Seoane+2007, Gair+2013, Barausse+2014)

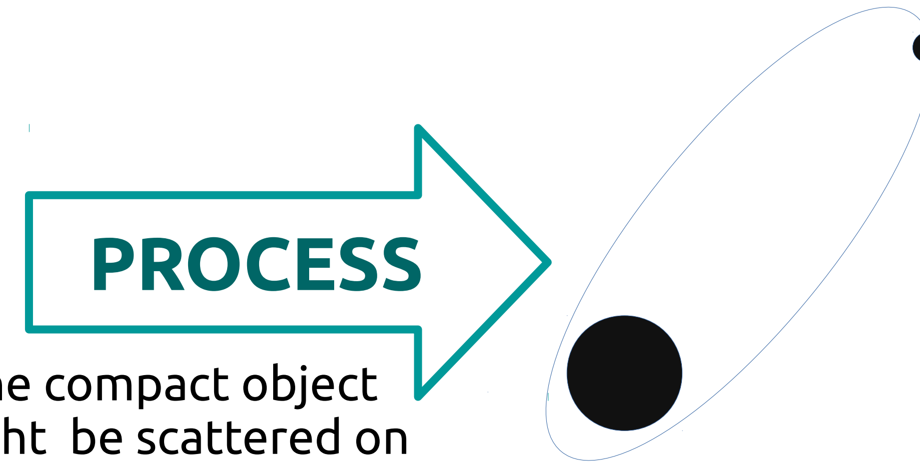
How to trigger EMRIs in the LISA band?



How to trigger EMRIs in the LISA band?

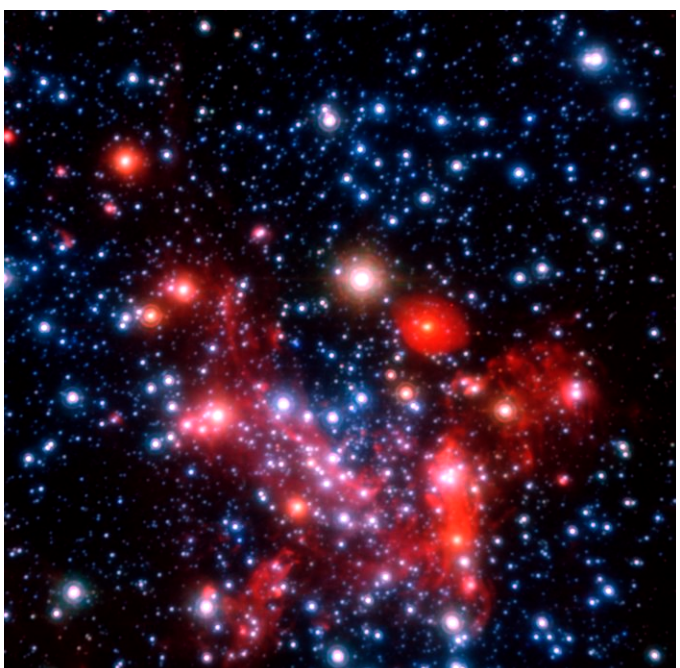
We propose a new recipe





The compact object might be scattered on an EMRI orbit owing to its **supernova natal kick**

Star forming nucleus, SMBH with mass between 10^4 and 10^7 Msun

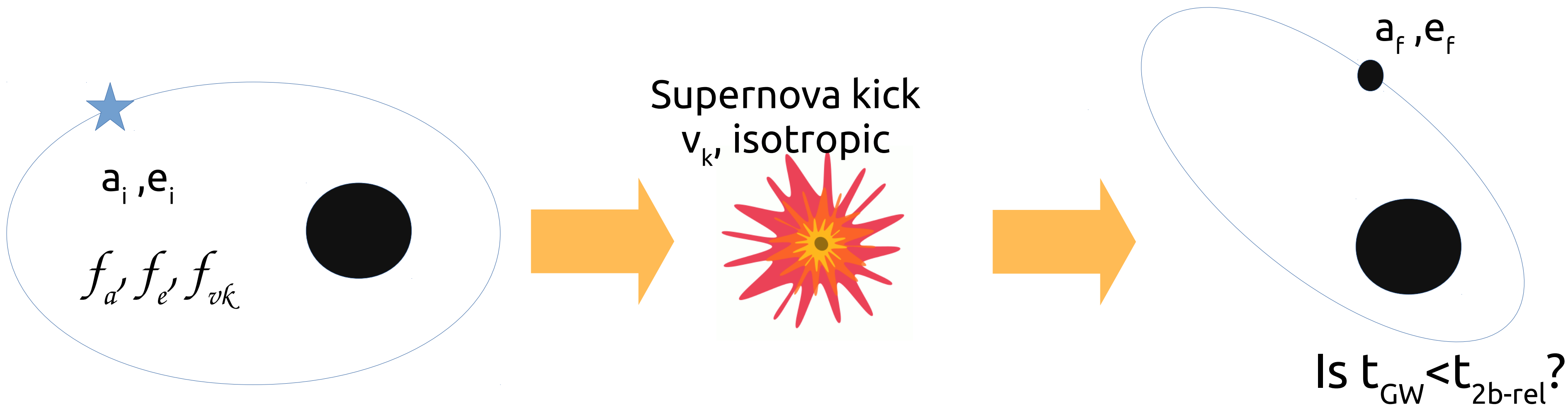


SN kicks in the Galactic Centre!

- Evidence of *central star formation* (e.g. Habibi+2017)
- SMBH with 4 million Msun (e.g. Schoedel+2002)
- 100-200 young stars (Clockwise disk)(Yelda+2014)
- S-cluster of B stars (Ghez+2003)
- Best known nucleus (only 8 kpc away)
- Top heavy mass function (Lu+2013)

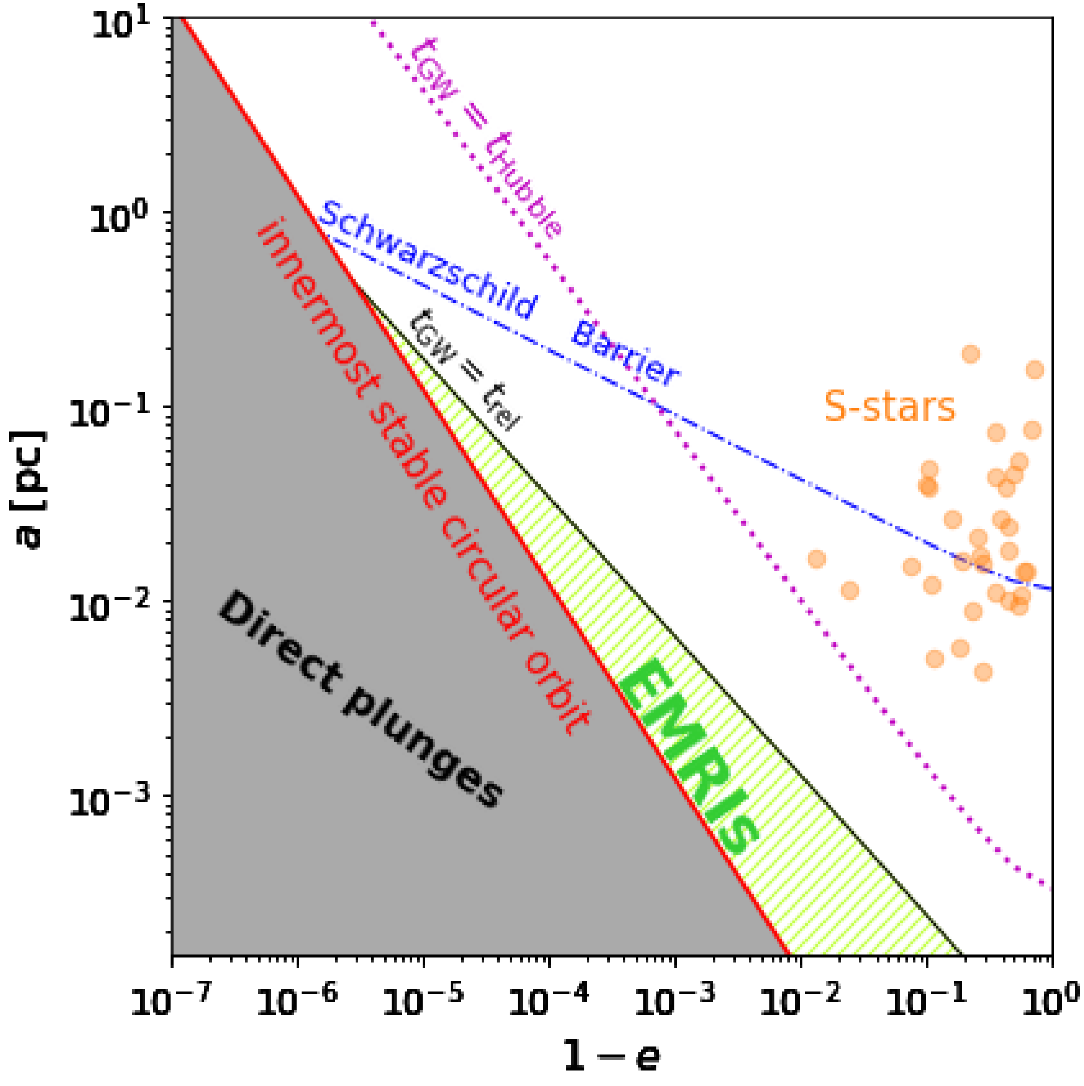
Bortolas & Mapelli, to be submitted

Numerical approach



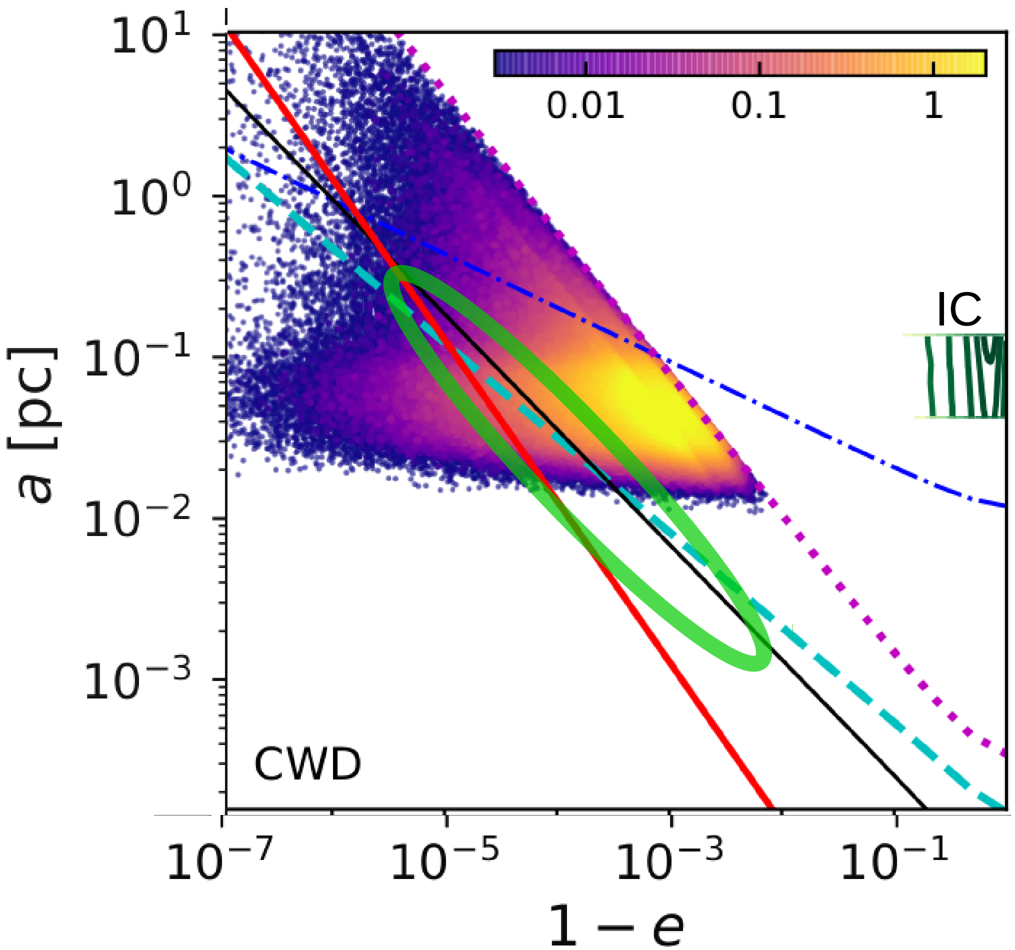
- **Everything happens in the Galactic Centre**
- **Monte Carlo approach** for distributing initial orbital parameters and kick velocities
- 4.3×10^6 Msun SMBH
- Single stars, M>9 Msun
- PARSEC stellar evolutionary tracks (Bressan+ 2012, Spera+2015)
- *Maxwellian velocity kicks with σ=265 km/s* (Hobbs+2005) with and without slow down prescriptions for black holes

Where to produce EMRIs



Clockwise disk

■ 0.04-0.13 pc ■ Top-Heavy IMF ■ Gaussian eccentricity distribution ■ Fast BH kicks (Yelda+2014, Do+2013)

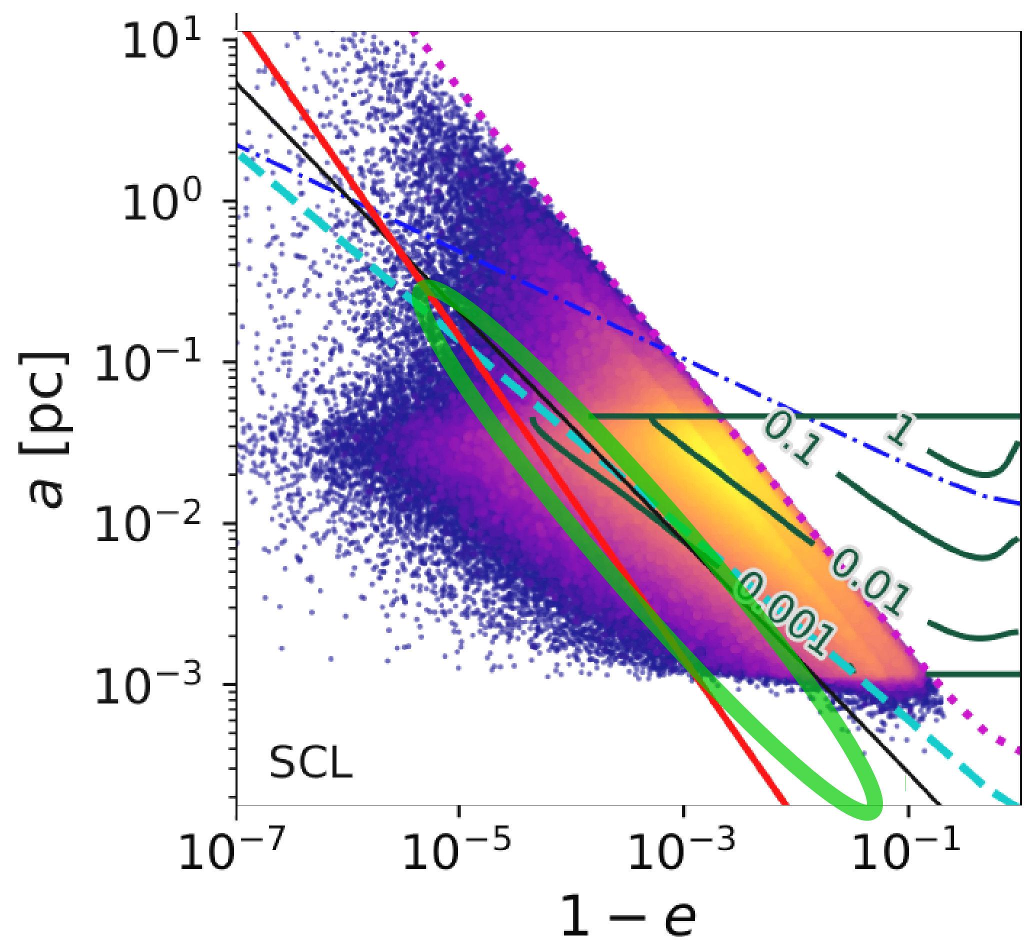


Probability (supernova remnant → EMRI):

~ 1 × 10 ⁻⁵

S-stars

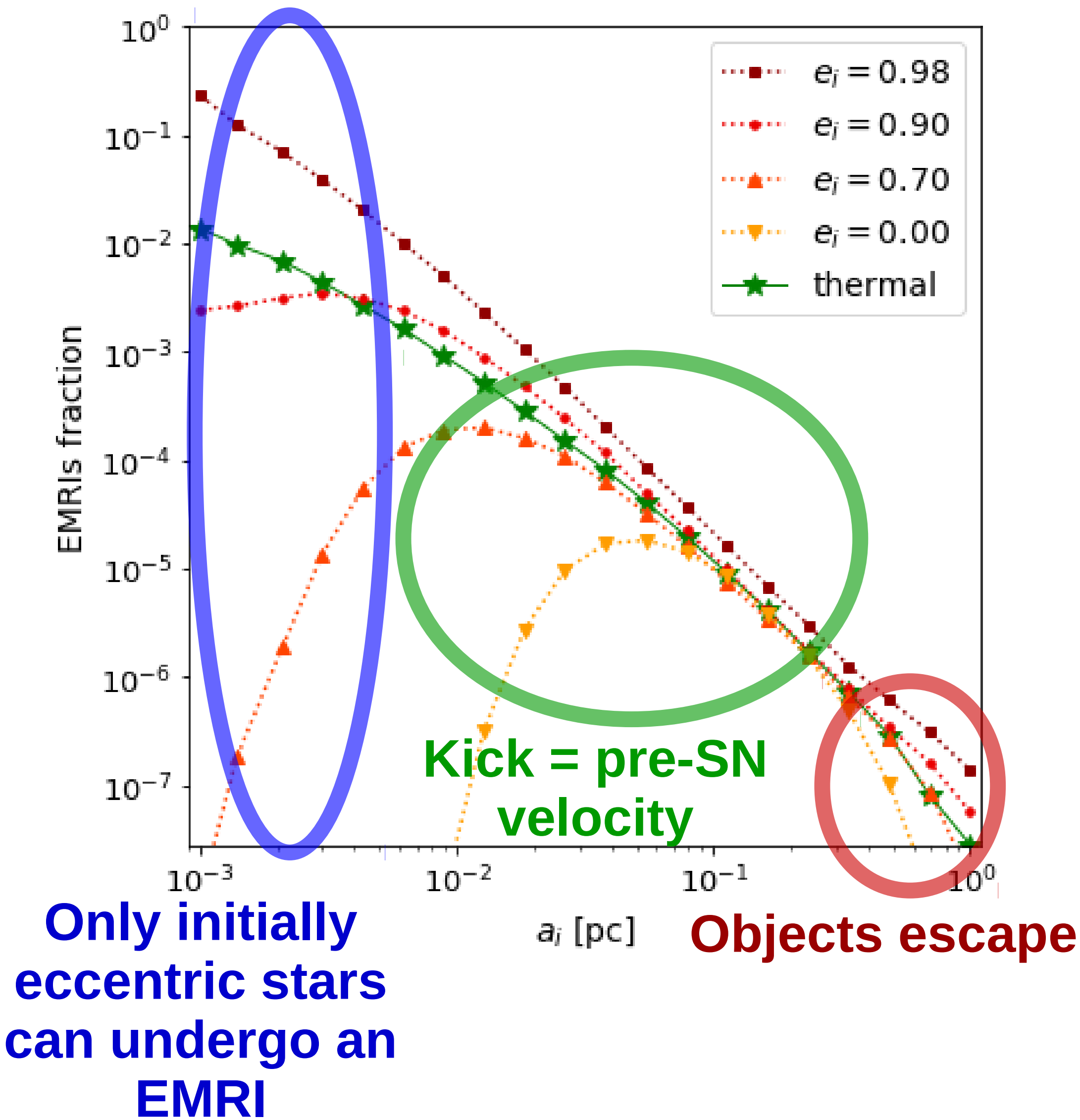
■ 0.001-0.04 pc ■ Top-Heavy IMF ■ Thermal eccentricity distribution ■ Fast BH kicks (Gillessen+2017, Habibi+2017)



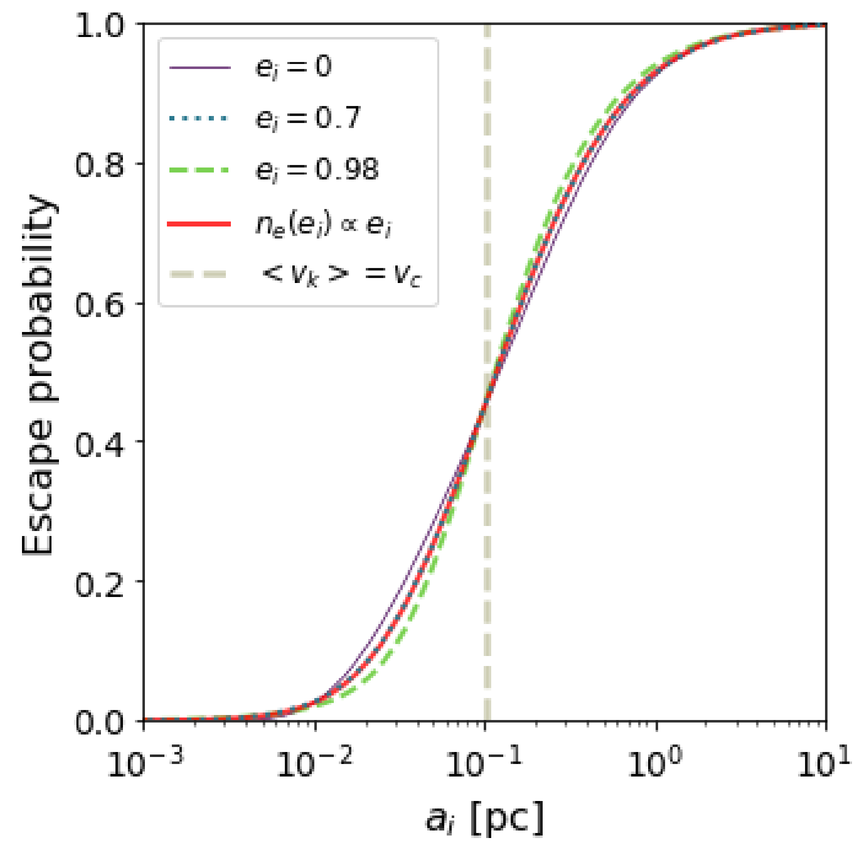
Probability (supernova remnant → EMRI):

1 × 10 ⁻⁴ − 4 × 10 ⁻⁴

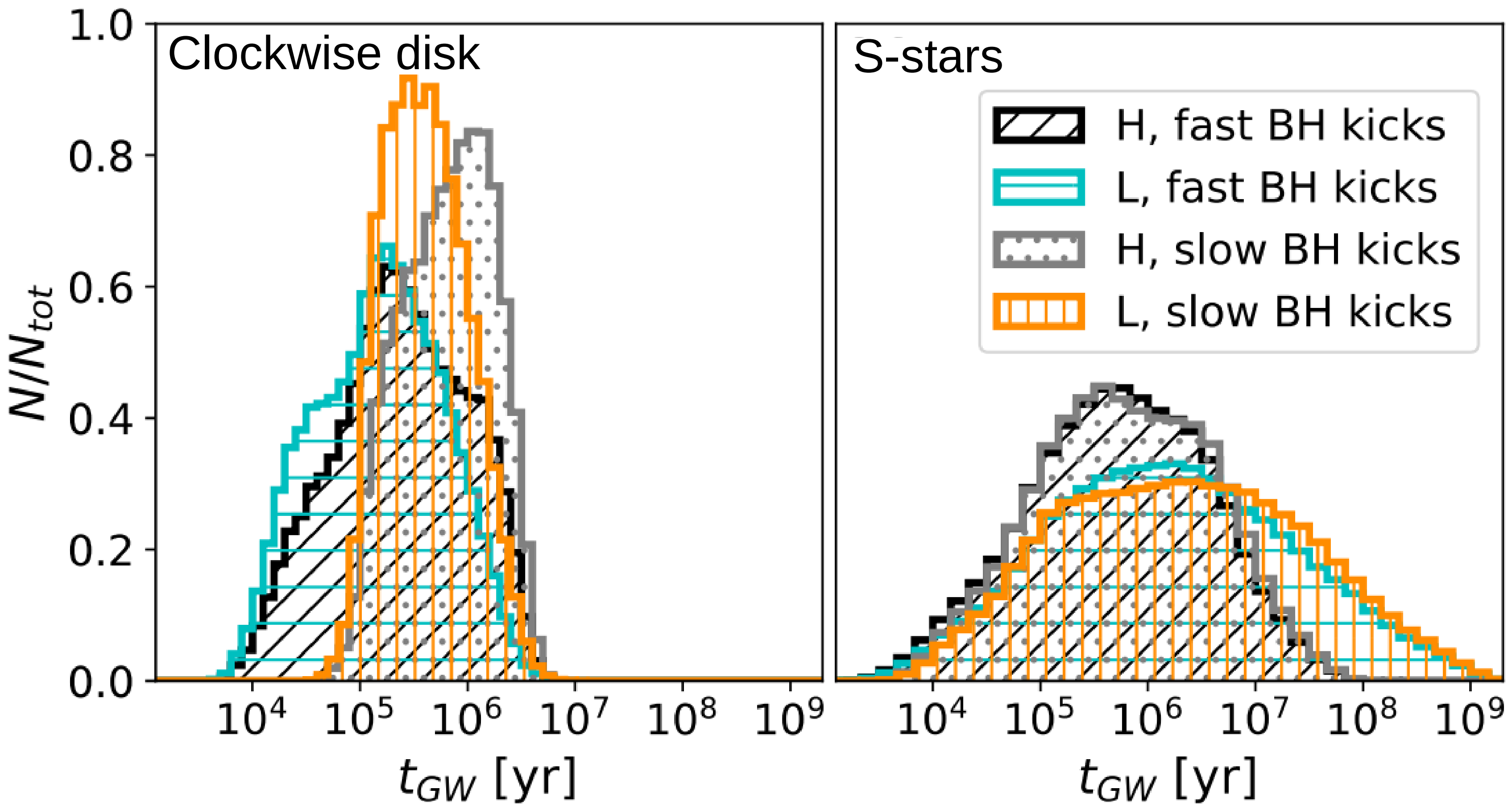
Probability for a supernova to induce an EMRI



Probability for a compact remnant to be ejected by the supernova



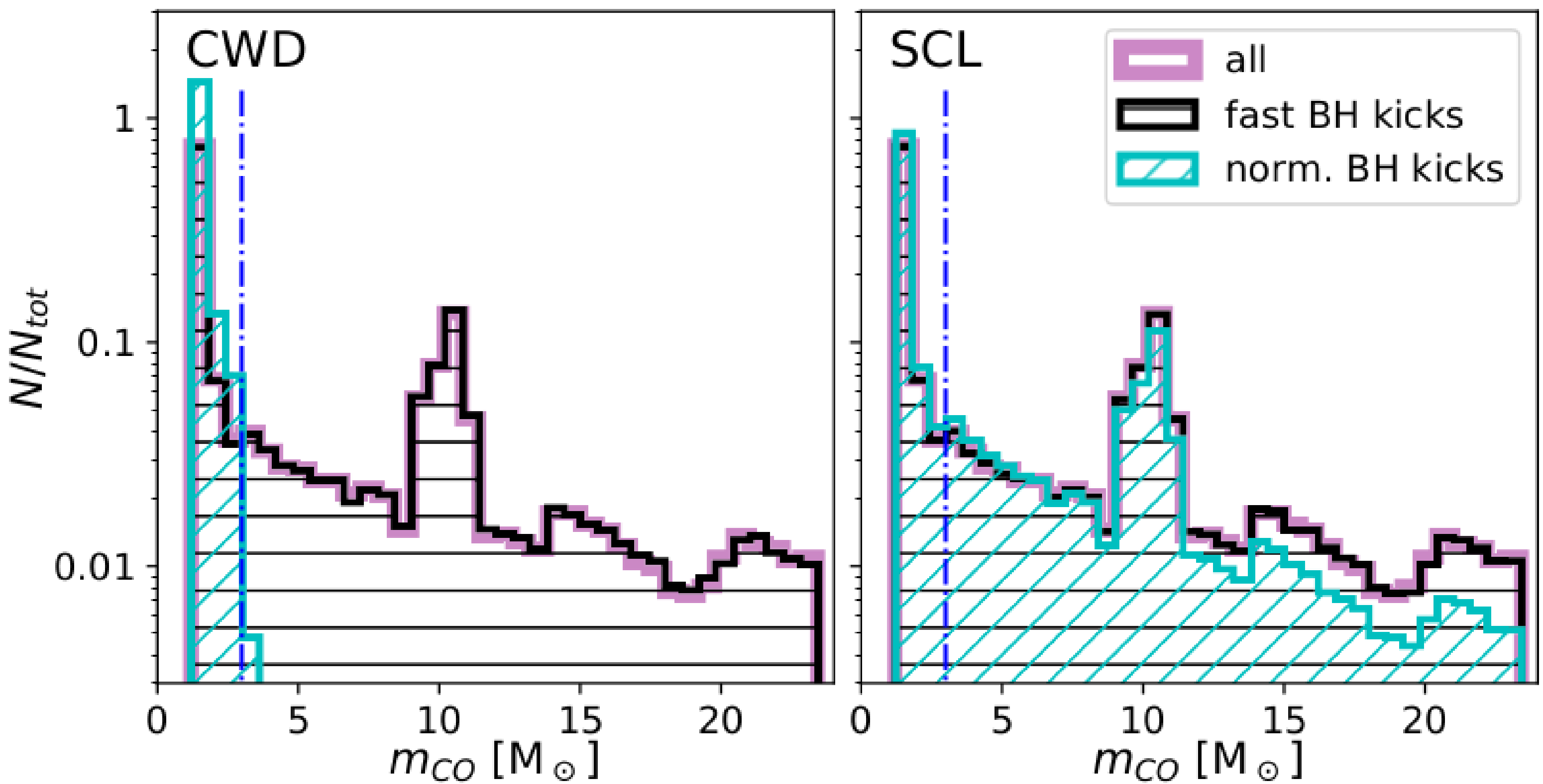
Inspiralling timescales



Typically of the order of ***million years***:
comparable to the lifespan of the most massive stars
and to the age of the young stars in the Galactic Centre!

Supernova EMRIs mass function

Clockwise disk (low initial ecc)   S-stars (thermal initial ecc)



'Fast' BH kick prescriptions = original population:

50% stellar BHs, **50%** neutron stars

'Normalized' BH kick prescriptions:

1% stellar BHs, **99%** neutron stars (clockwise disc)

40% stellar BHs, **60%** neutron stars (S-stars)

Supernova EMRIs: let's count them!

Probability (supernova remnant → EMRI):

$1 \times 10^{-5} - 4 \times 10^{-4}$

To be multiplied for (accounting for mass function, star formation rate...)

2×10^{-5} /yr

▶ **up to 10^{-8} /yr /Milky Way!**

(cf. up to 10^{-7} /yr owing to standard relaxation process)

Considering the density of Milky Way-like galaxies (0.0116 Mpc^{-3}, Kopparapu+2008)

▶ *Rate of* ***0.1*** **Gpc^{-3} yr^{-1}** *Supernova EMRIs*

LISA will detect EMRIs up to z~1

▶ ***Up to 1-30 LISA detections per year***

Conclusions

- **Supernova kicks induce EMRIs production in star forming nuclei hosting SMBHs**

- The typical EMRI production timescale is of the order of Myr, i.e. comparable to the lifespan of massive stars and the young stars in the Galactic Centre

- Assuming natal kicks of stellar black holes to be slower than those of neutron stars, most SN-driven EMRIs involve neutron stars

- Our estimate suggests ~10% of EMRIs in Milky-Way like galaxies may be induced by supernova kicks, and we expect up to a few events every year

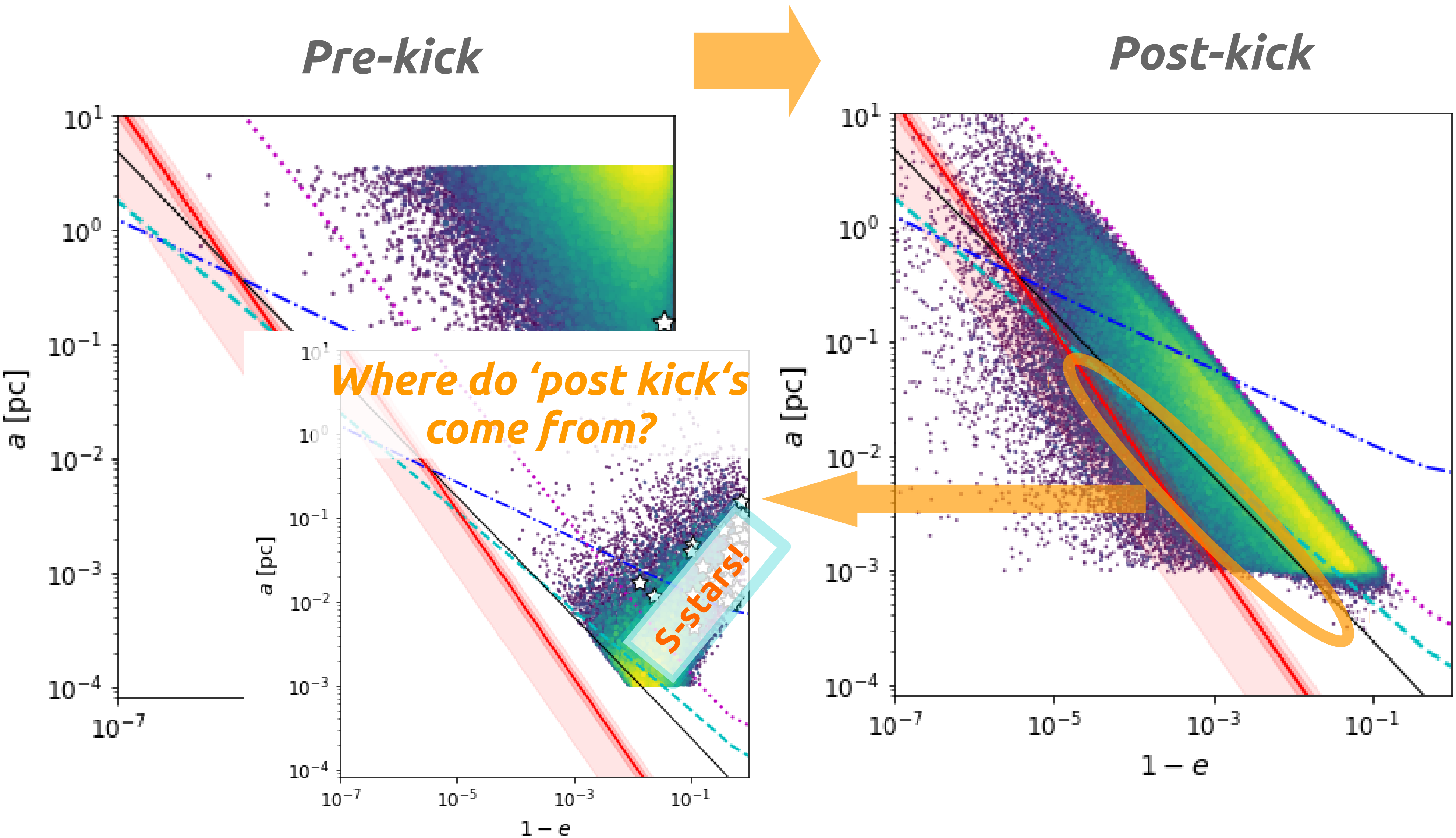
Bortolas & Mapelli, to be submitted

General Case

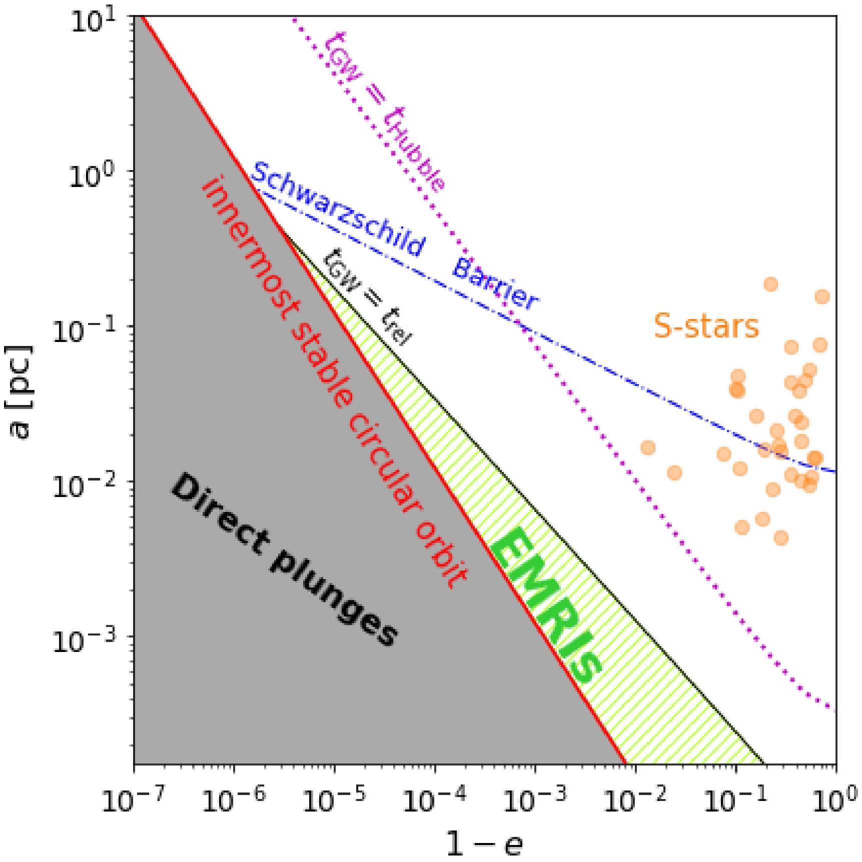
■ 0.001 – 3.5 pc ■ Thermal eccentricity distribution

■ Power law density, **$\rho \propto r^{-2}$** ■ Top-Heavy & **Kroupa**+2011 IMF

■ Normalized and **not normalized** black hole velocity kicks



Population	EMRIs, H	EMRIs, L	direct plunges	unbound
CWD	1.4×10^{-5} (6.8×10^{-6})	8.1×10^{-6} (4.1×10^{-6})	9.9×10^{-6} (4.9×10^{-6})	0.396 (0.199)
SCL	3.2×10^{-4} (2.7×10^{-4})	4.2×10^{-4} (3.7×10^{-4})	9.8×10^{-5} (9.0×10^{-5})	0.118 (0.059)
CP-G	2.4×10^{-6} (1.2×10^{-6})	1.5×10^{-6} (7.3×10^{-7})	2.2×10^{-6} (1.2×10^{-6})	0.750 (0.408)
CP-T	3.7×10^{-5} (2.9×10^{-5})	6.4×10^{-5} (5.6×10^{-5})	1.0×10^{-5} (1.0×10^{-5})	0.760 (0.411)
SP-G	6.6×10^{-7} (3.4×10^{-7})	2.8×10^{-7} (1.4×10^{-7})	1.0×10^{-6} (6.4×10^{-7})	0.836 (0.462)
SP-T	2.2×10^{-6} (2.1×10^{-6})	2.2×10^{-6} (1.9×10^{-6})	1.6×10^{-6} (3.2×10^{-6})	0.847 (0.464)



Population name	Label	$a_{i,\min}$ [pc]	$a_{i,\max}$ [pc]	γ_i
CW disc	CWD	0.040	0.13	1.93
S-cluster	SCL	0.001	0.04	1.10
concentr. profile, GE	CP-G	0.001	1.00	2.00
concentr. profile, TE	CP-T	0.001	1.00	2.00
shallow profile, GE	SP-G	0.001	1.00	1.25
shallow profile, TE	SP-T	0.001	1.00	1.25

Structure	Already in 'EMRI' region of ph. space		SN-EMRIs from 'EMRI'		COs staying in 'EMRI'	
	H	L	H	L	H	L
SCL	1×10^{-5} (1×10^{-5})	1×10^{-4} (1×10^{-4})	1% (1%)	8% (15%)	24% (28%)	29% (47%)
CP-T	4×10^{-6} (4×10^{-6})	3×10^{-5} (3×10^{-5})	3% (4%)	20% (35%)	29% (31%)	37% (55%)
SP-T	6×10^{-8} (6×10^{-8})	6×10^{-7} (6×10^{-7})	1% (1%)	8% (14%)	24% (30%)	31% (48%)