One XMRI to find SgrA*'s spin and mass

Verónica Vázquez-Aceves[1], Yiren Lin[2], Alejandro Torres-Orjuela[3]

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1 Institute of Applied Mathematics, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, 100190 Beijing, China.
2 Astronomy Department, School of Physics, Peking University, Beijing 100871, China.
3 MOE Key Laboratory of TianQin Mission, TianQin Research Center for Gravitational Physics & School of Physics and Astronomy, Frontiers ScienceCenter for TianQin, Gravitational Wave Research Center of CNSA, Sun Yat-Sen University (Zhuhai Campus), Zhuhai 519082, China

SgrA* spin and mass estimates through the detection of an extremely large mass-ratio inspiral

Estimating the spin of SgrA∗ is one of the current challenges we face in understanding the center of our Galaxy. By detecting the gravitational waves (GWs) emitted by an XMRI around SgrA* will allow us to measure the mass and the spin of SgrA* with unprecedented accuracy.

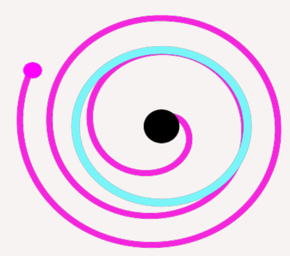
The general Scenario

In a dense stellar system like a nuclear clusters. Two-body relaxation processes slowly change the angular momentum and energy of the objects orbiting the massive black hole (MBH) at the center of these systems.

When a brown dwarf's (BDs) orbit is perturbed by two-body processes such that it becomes highly eccentric, it reaches very close distances to the MBH at pericentre and emits gravitational waves (GWs).

If, after one pericentre passage, the orbit shrinks to a critical semimajor axis (a_{crit}), the orbit now evolves only due to gravitational waves emission and inspirals to the MBH. This system is known as Extremely Large Mass-ratio Inspiral, or XMRI.

$a_{crit} \sim 10^{-4} - 10^{-3}$ pc



Inspiral

XMRIs at the center of our Galaxy

We can estimate how many XMRIs are in the center of our Galaxy by first estimating the event rates by integrating the number of sources n(a), in a volume defined from the minimum distance at which we expect to find at least one brown dwarf, a_{min}, to the critical semimajor axis.

$$\dot{\Gamma}_i \simeq \int_{a_{min}}^{a_{crit}} \frac{dn(a)}{T_{rlx}(a)\ln(\hat{\theta}_{lc}^{-2})}$$

and then, multiplying the event rates by the merger timescale of the sources

$$N_{tot} = \dot{\Gamma}_{XMRI}(a_{crit}) \times T_{GW}.$$

XMRIs evolves only due to GW emission, so we can determine how many XMRIs we have at a given semimajor axis and eccentricity (Peters 1964)

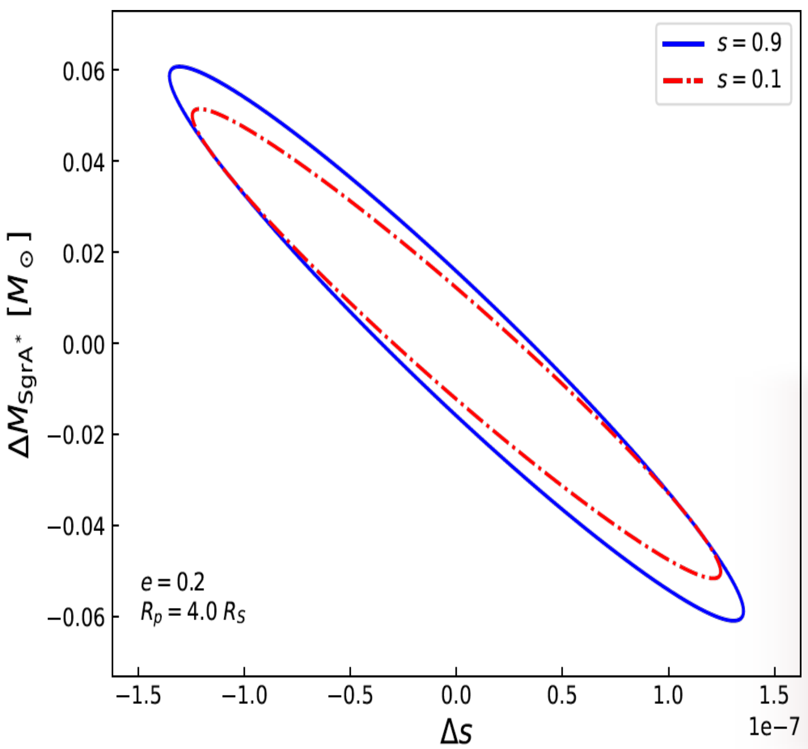
We take into account the spin of the MBH (SgrA*), which in this case, is unknown. So, we choose two representative values s=0.1, and s=0.9, to estimate the number of XMRIs.

SgrA* spin	e	$\dot{\Gamma}_{XMRI}$ [yr^{-1}]	N_I	N_{II}
0.1	0.999	1.306×10^{-7}	2	30
0.9	0.9999	1.181×10^{-6}	2	49

Table 1. Event rates ($\dot{\Gamma}_{XMRI}$), and number of circular sources (N_I) and eccentric sources (N_{II}) in band for XMRIs with a fixed orbital inclination of $i = 0.1$ rad and an eccentricity $e \approx e_{max}$ for two different spin values.

These XMRIs have a SNR of ~50 in the eccentric case, and of ~1200 in the circular case. So XMRIs are loud and abundant sources on our galactic center.

Measuring the spin and mass of SgrA*



For the cases shown in Table 1, we obtain the waveform with a PN2.5 code based on Barack & Cutler (2004)and Fang & Huang (2020), to later perform a Fisher matrix analysis [Coe 2009] to estimate how accurately the spin and the mass of SgrA* can be measured.

The size of the error ellipses shown in the left and right side tells us how accurate the parameters can be measured, while the inclination shows the correlation between parameters (spin and mass)

Detecting just one XMRI will allow us to measure the mass ofSgrA with an accuracy ranging from 0.6 to 3 solar masses, while the spin can be measured with an accuracy between1.5x10^{-7} and 4x10^{-4}.

The spin magnitude of SgrA has an impact on the number of XMRIs. Different scenarios are worth exploring as there is currently no restriction on the spin of SgrA .