Circumbinary exoplanets: a new science case for LISA

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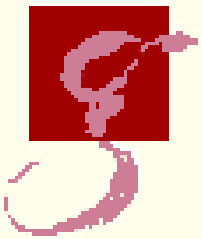

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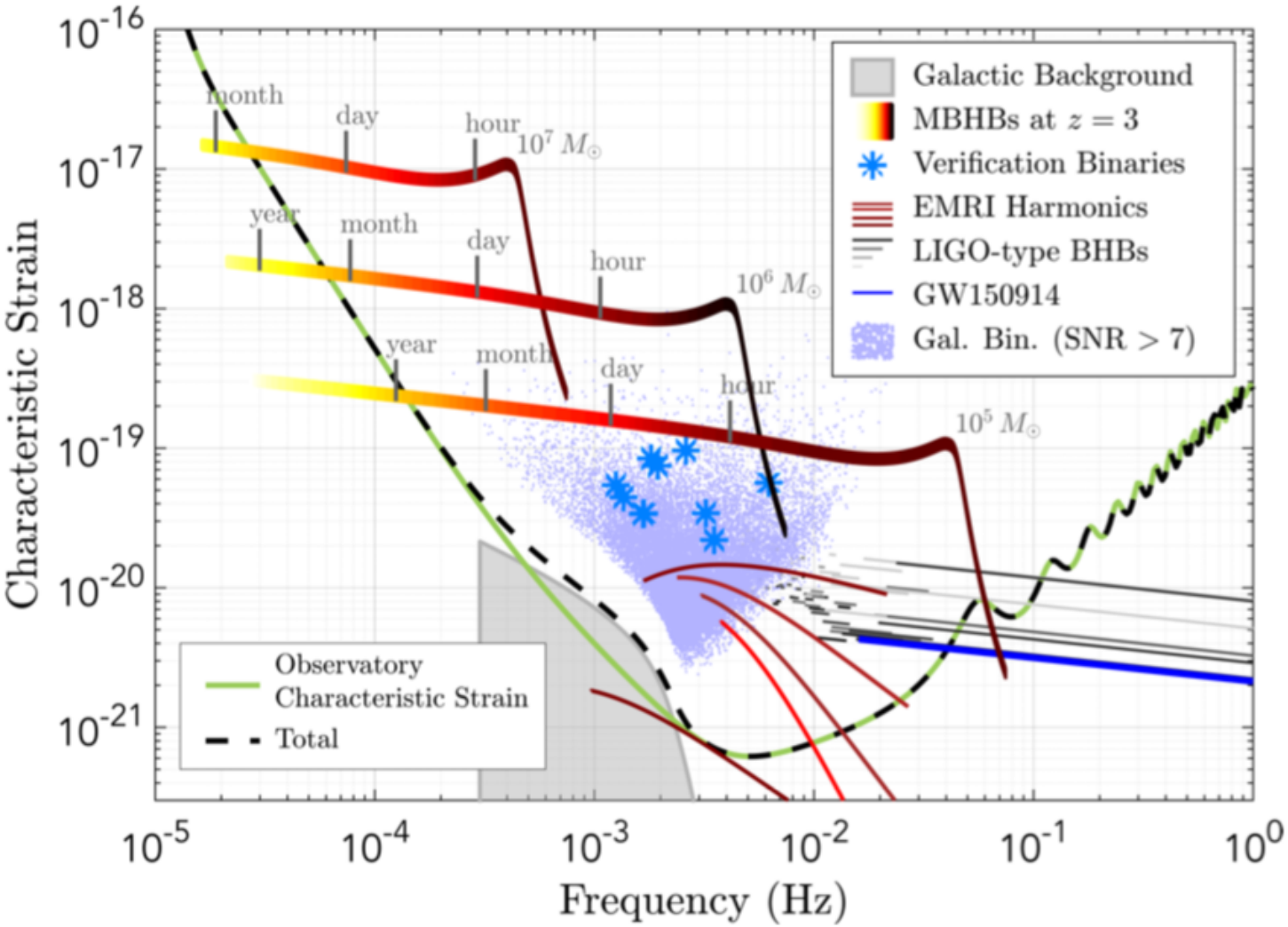
[arXiv:1812.04330]

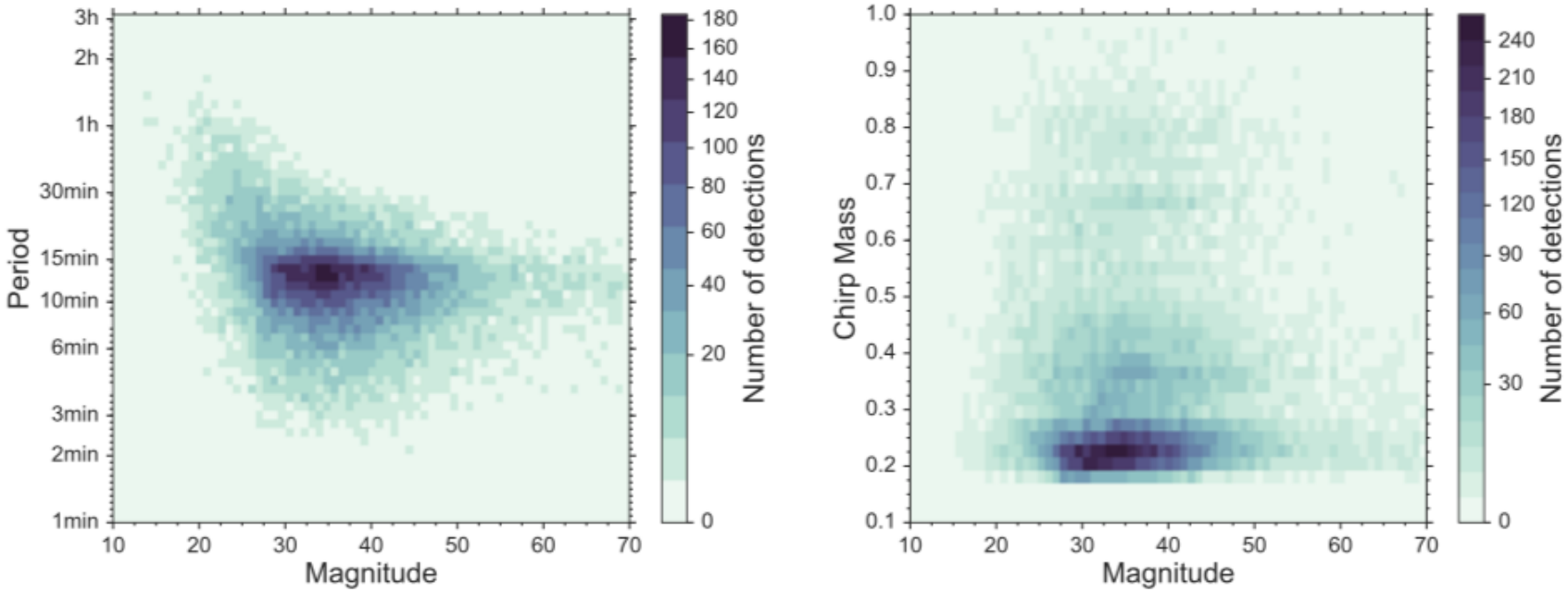
LISA GW sources



[LISA call paper, arXiv:1702.00786]

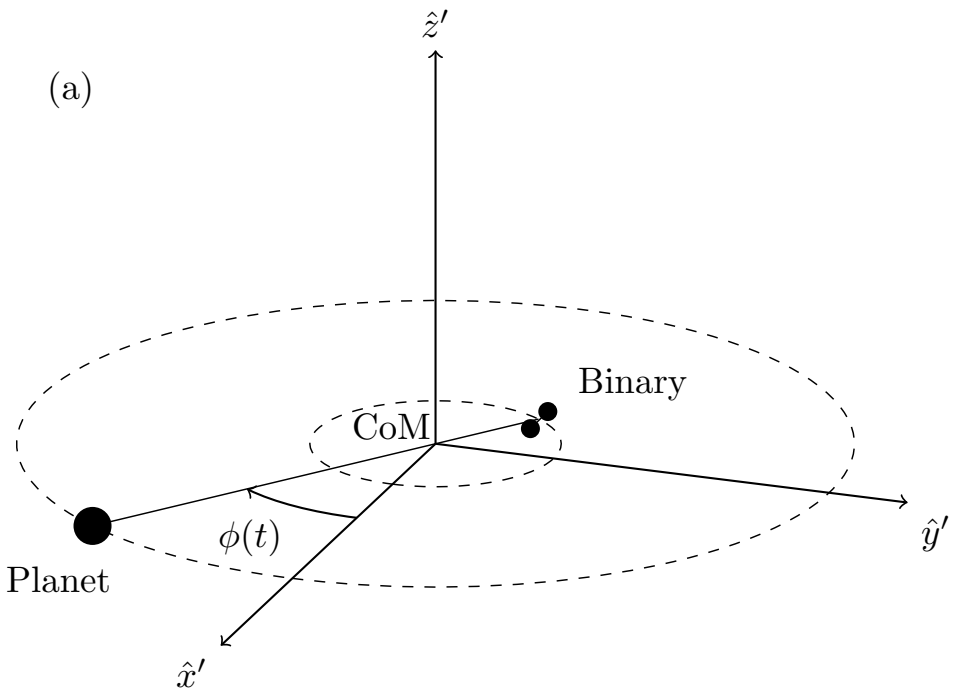
White dwarf binaries with LISA

LISA will detected 25×10^3 Galactic white dwarf binaries



[Korol *et al*, arXiv:1703.02555]

WD binaries perturbed by a circumbinary companion



Some of these WD binaries may be perturbed by a third circumbinary orbiting object.

The center of mass of the WD binary will move on a Keplerian orbit.

[Robson *et al*, arXiv:1806.00500]

WD binaries perturbed by a circumbinary companion

The GW frequency of the WD binary will be modulated through the Doppler effect

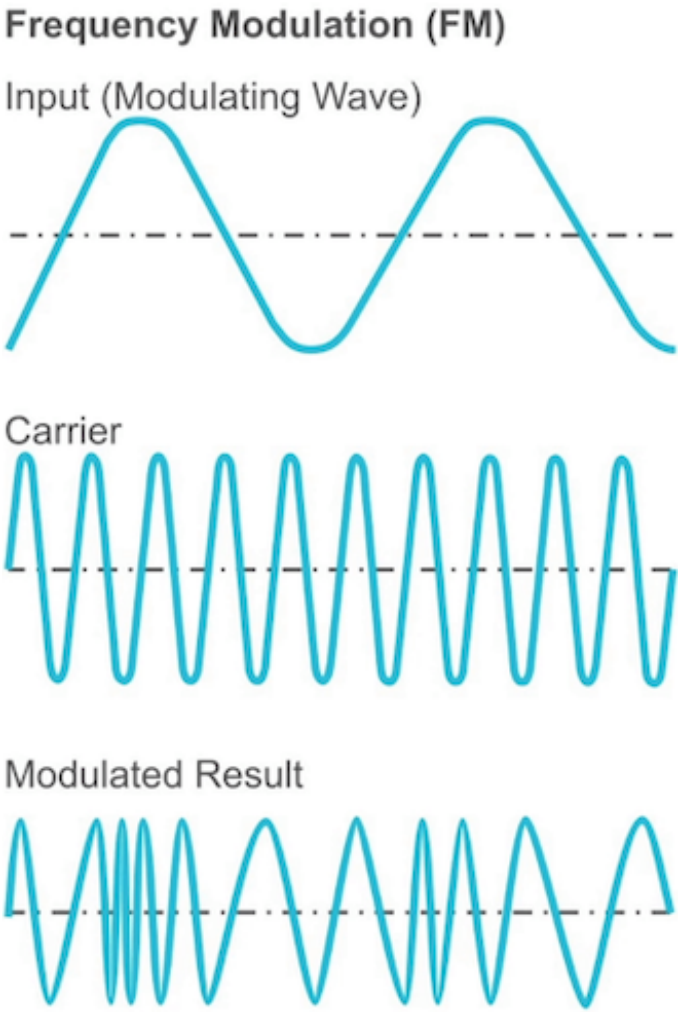
$$f_{\rm obs}(t) = \left(1 + \frac{v_{\rm com}(t)}{c}\right) f_{\rm gw}(t)$$

where (assuming circular orbits)

$$f_{\rm gw}(t) = f_0 + f_1 t + \mathcal{O}(t^2) \quad \text{and} \quad v_{\rm com} = -K \cos\left(\frac{2\pi t}{P_p} + \varphi_0\right)$$

$$K = \left(\frac{2\pi G}{P_p}\right)^{\frac{1}{3}} \frac{M_p}{(M_b + M_p)^{\frac{2}{3}}} \sin i$$

WD binaries perturbed by a circumbinary companion



The CoM motion

$$v_{\rm com} = -K \cos\left(\frac{2\pi t}{P_p} + \varphi_0\right)$$

modulates the GW signal

$$f_{\rm gw}(t) = f_0 + f_1 t$$

similarly to FM broadcasting.

Three new parameters can be determined from the signal:

$$P_p \quad \varphi_0 \quad K$$

LISA parameter estimation

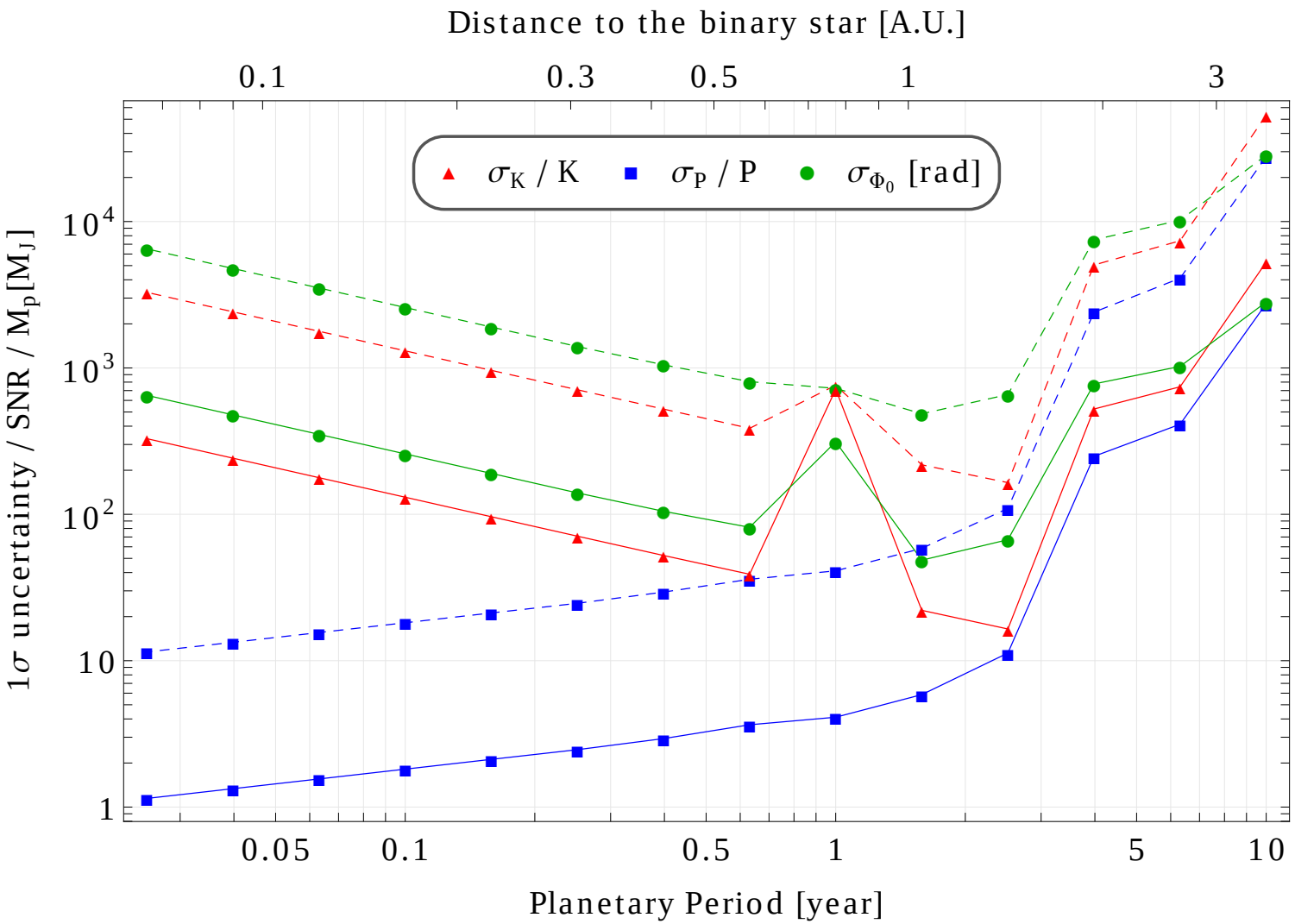
To explore detectability in the parameter space we performed a simple Fisher matrix analysis under the following assumptions:

- Circular orbits
- Planetary period much larger than WD binary period $P_p \gg P_b$
- Detached WD binaries (no accretion/mass exchange)
- 4 year LISA mission duration

We moreover restricted the parameter space by looking only at

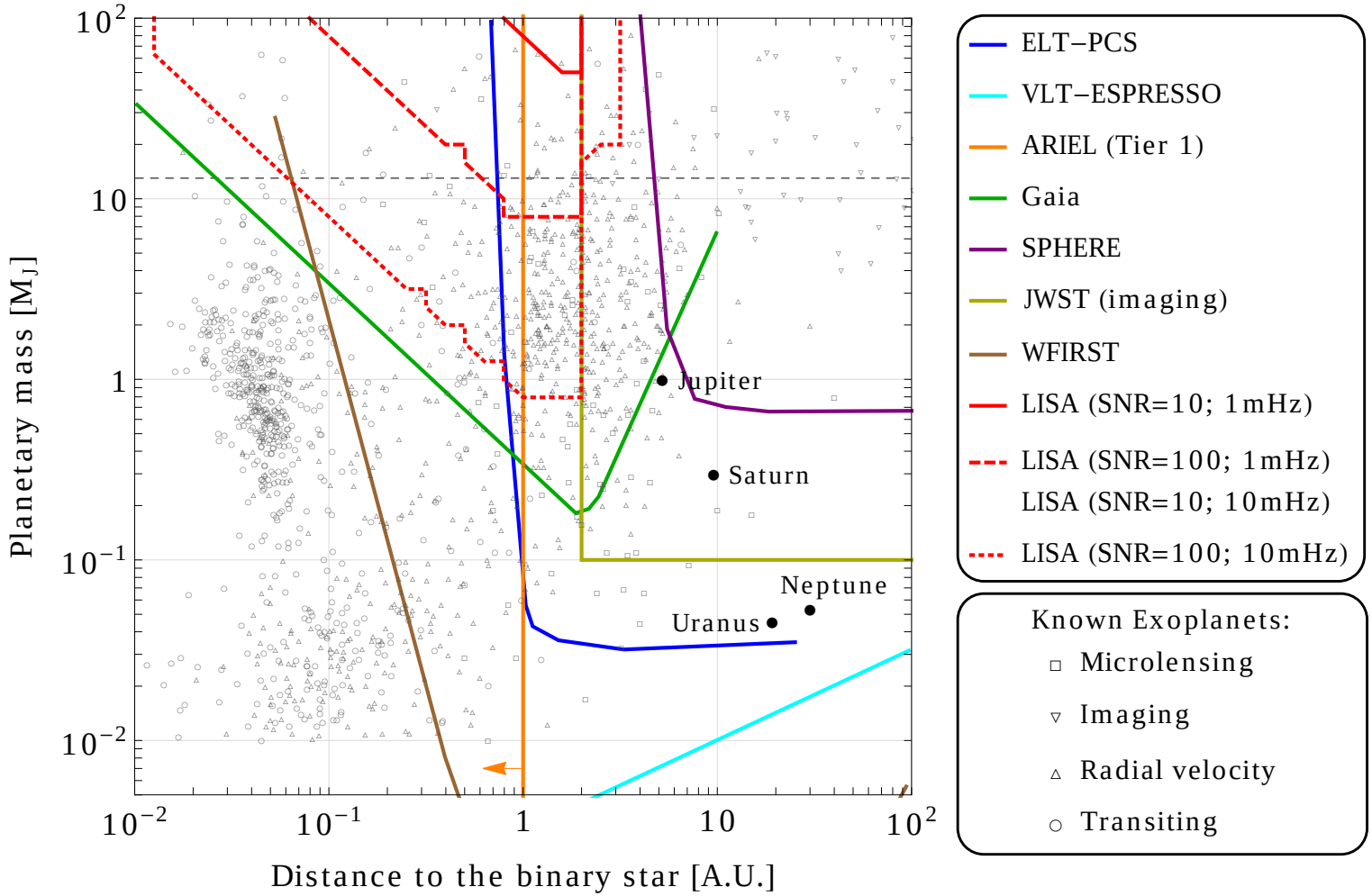
- Equal mass WD binaries with $\mathcal{M}_c = 0.2\,M_\odot$
- Random sky location and WD orbital inclination
- Most favourable planetary orbital inclination ($i = \pi/2$)
- Fixed planetary initial phase ($\phi_0 = \pi/2$)

Planetary parameters error estimation



[Tamanini & Danielski, arXiv:1812.04330]

Synergy with EM observations



[Tamanini & Danielski, arXiv:1812.04330]

Implications

LISA will test a yet unprobed population of exoplanets (orbiting compact WD binaries):

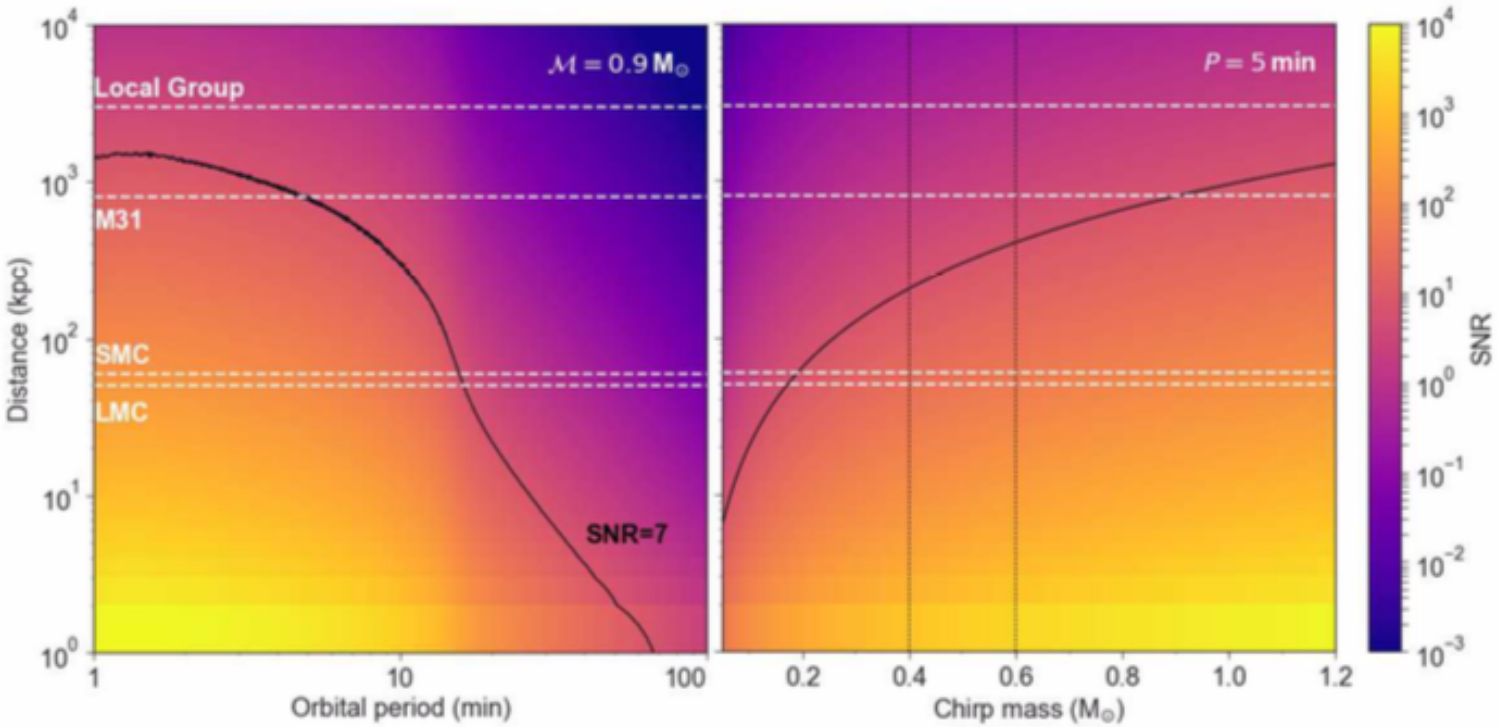
- If it exists: up to tens/hundreds of new exoplanets
  - First generation or second generation?
- If it does not exists: no detections
  - Constraints on final stages of planetary evolution

In any case LISA will enable us to gather constraints on planetary evolution models and on the final stages of the life of an exoplanet.

Implications

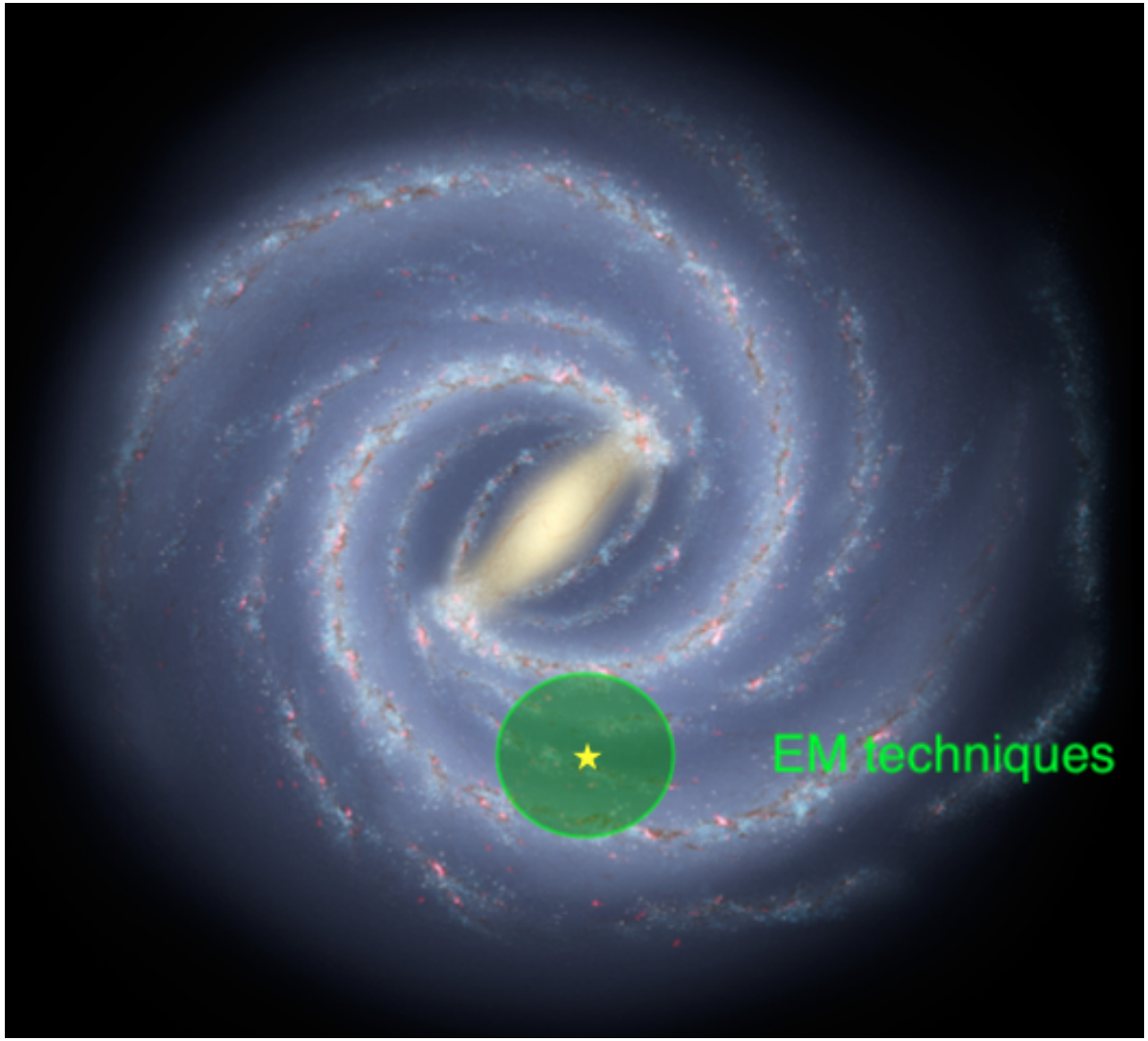
LISA may detect exoplanets everywhere in the Galaxy and even in nearby galaxies (e.g. Magellanic Clouds).

Overcome the selection problem of EM observations which are limited to Solar neighbourhood or Galactic bulk.

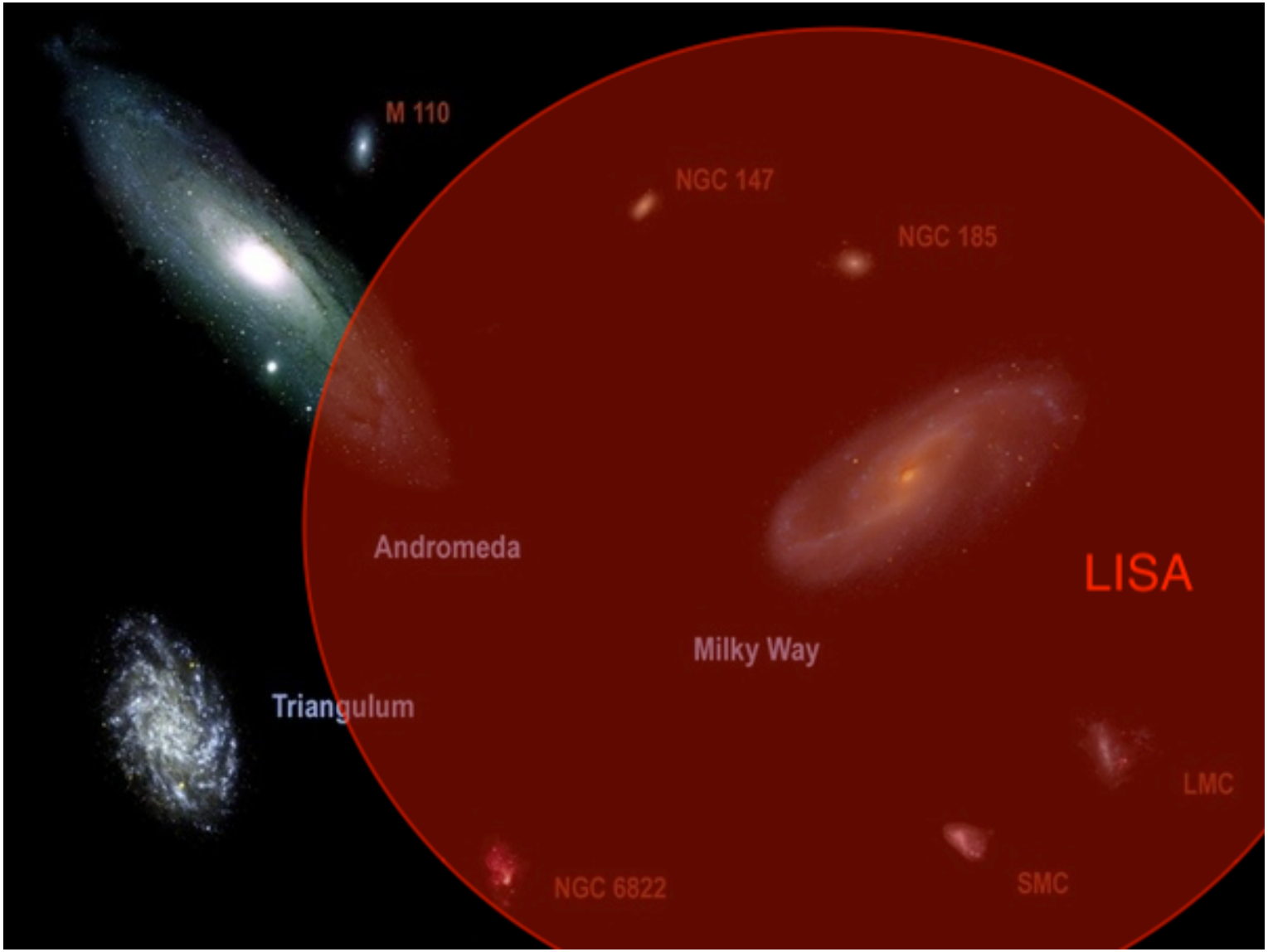


[Korol *et al*, arXiv:1808.05959]

Implications



Implications



Conclusions

- LISA will hear tens of thousands of Galactic WD binaries
- Circumbinary companions down to Jupiter masses can be detected through the Doppler frequency modulation of the GW signal
- LISA observations will:
  - Test a yet unprobed population of circumbinary exoplanets
  - Provide useful information for planetary evolution theories
  - Have nice synergy with future EM observations
  - Observe in the whole Milky Way and in nearby galaxies, bypassing EM selection effects