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Music of the Spheres: the gravitational wave signal from exoplanets

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Abstract

We focus on a class of sources that has been largely ignored in the science case for the Laser Interferometer Space Antenna (LISA), a joint ESA/NASA space-based gravitational wave mission set to launch in 2034: stellar-exoplanet systems. These systems are a billion times closer, if much less massive, than say supermassive black holes, making exoplanets a potentially observable source class. With typical orbital periods of decades, most exoplanets would emit gravitational radiation at much lower frequencies than the current design of LISA. However, exoplanet surveys have unveiled a surprisingly rich variety of systems, from highly eccentric orbits to hot Jupiters to pulsar planets. Here, we investigate the gravitational wave signal from known exoplanets and predict the total signature of exoplanetary systems in the Milky Way.

Motivating Question

How weak are exoplanets in gravitational waves? If very weak individually, there are so many, and so close to us, will LISA see this as background?

Theory - GWs from Binaries

Masses in orbit exhibit a time-changing mass quadrupole moment and therefore emit GWs (Peters and Mathews, Maggiore). Averaged over a full orbit, they define the function

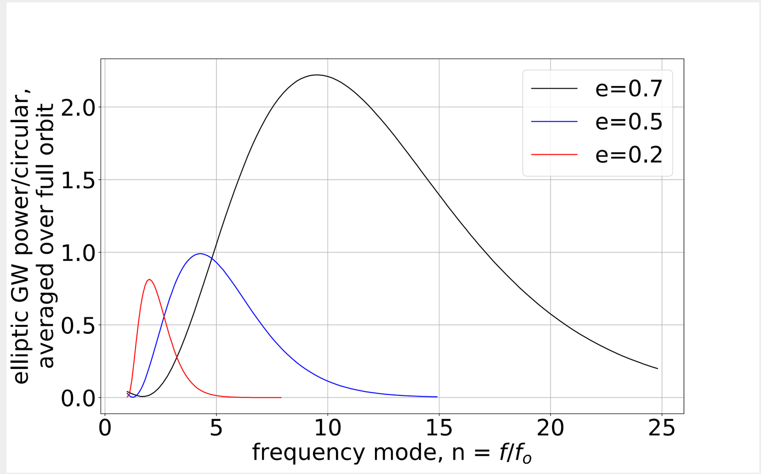
$g(n,e)$ = GW Power at $f=n*f_o$ / GW Power Equiv. Circ. orbit at $f=2f_o$

And following Amaro-Seoane et al., the dimensionless strain can be written

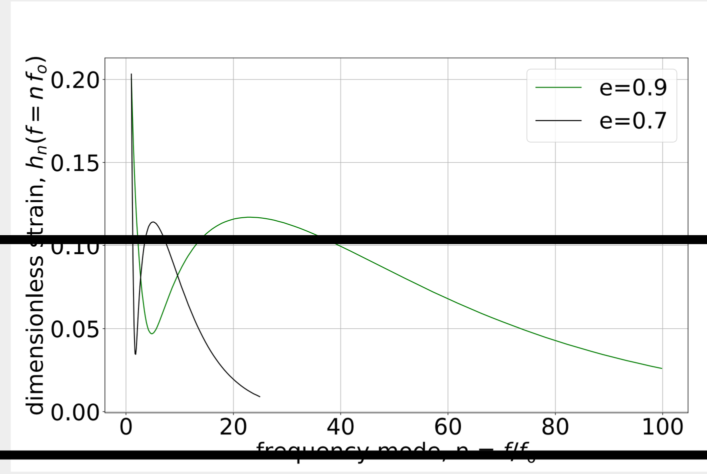
$$h_n = \left(\frac{G^{5/3}}{c^4}\right) 2\sqrt{\frac{32}{5}}\, \frac{\mathcal{M}^{5/3}\,(2\pi f_0)^{2/3}}{r}\, \frac{\sqrt{g(n,e)}}{n}$$

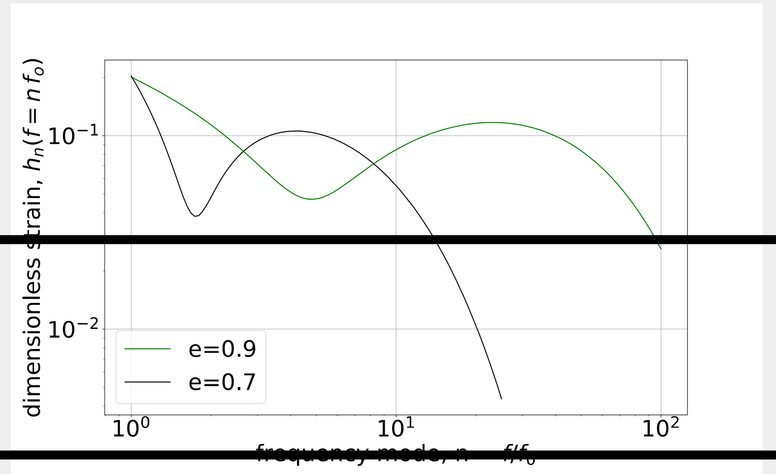
where the mass is the "chirp mass" and is $m_1^{3/5}m_2^{3/5}/(m_1+m_2)^{1/5}$, and h_n is at a multiple of the orbital frequency f_0, nf_0 and $n=[1,2,3...]$.

g(n,e) RatioGW Power elliptical to circular



$$h_n \propto \sqrt{g(n,e)}/n$$

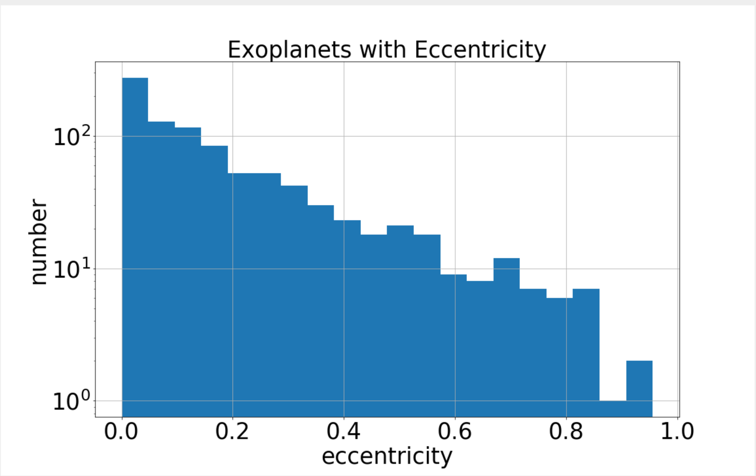


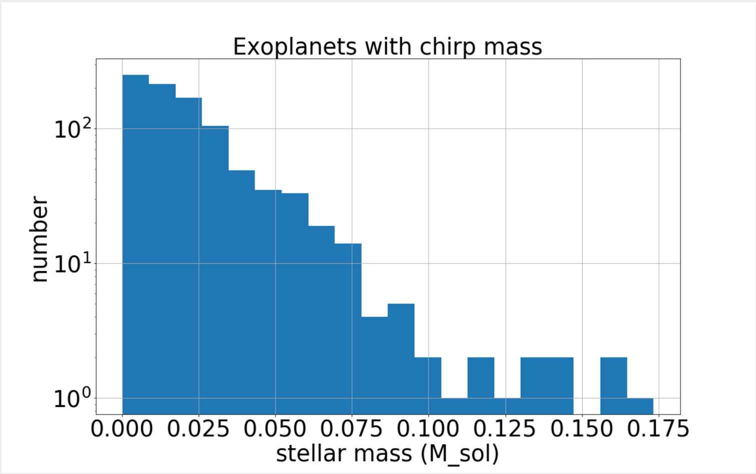


NASA Exoplanet Archive

https://exoplanetarchive.ipac.caltech.edu/
3711 Confirmed Planets as of 8 April 2018
For GW strain calculation we need the following attributes:
m_1 stellar mass, st_mass
m_2 planet mass, pl_bmassj
r distance to system, st_dist
e orbital eccentricity, pl_orbeccen
P orbital period, pl_orbper
a orbital semi-major axis, pl_orbsmax

Which leaves **910** exoplanets that we can use for GW calculations.





LISA Sensitivity / Noise

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al signature of exoplanetary systems in the Milky Way.

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junk like my 8.5x11 rectangle for layout
Darn my TexMaths is not working
Three rectangles on previous slide are guides, delete when done

stuff

and more stuff

$h_n \propto \sqrt{g(n,e)}/n$

Abstract

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POR MI RAZA HABLARA EL ESPIRITU