VU Logo

Music of the Spheres: the gravitational wave signal from exoplanets

CalTech Logo

William Gabella[1], Katelyn Breivik[2],Yilen Gomez Maqueo Chew[3],Kelly Holley-Bockelmann[1,4], Brittany Kamai

Fisk Logo

1-Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235 USA
2-Department of Physics and Astronomy, Northwestern University, Evanston, IL 60202 USA, also Center Interdisciplinary Exploration and Research in Astrophysics (CIERA), Evanston, IL 60202 USA
3-Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510, Ciudad de México, México
4-Department of Physics, Fisk University, Nasvhille, TN 37208 USA
5-Division of Physics, Math and Astronomy, California Institute of Technology, Pasadena, CA 91125 USA

NW Logo

UNAM Logo

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 $f=n*f_0$ / GW Power Equiv. Circ. orbit at $f=2f_o$

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

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

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 $n=[1,2,3...]$.

References

P. C. Peters and J. Mathews, "Gravitational Radiation from Point Masses in Keplerian Orbit," Phys. Rev. **131** (1963) 435;
M. Maggiore, "Gravitational Waves: Volume 1: Theory and Experiment," Oxford Univ. Press, 2008;
Amaro-Seoane et al., "Triplets of supermassive black holes: astrophysics, gravitational waves and detection," Mon. Not. Royal Astro. Soc. **402** (2010) 2308;

junk like my 8.5x11 rectangle for layout Darn my TexMaths is not working

Abstract