Impact of Tides on the Potential for Exoplanets to Host Exomoons

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Tokadjian & Piro (2020), AJ, 160, 194

Why Exomoons?

Moon Effects on Planet Habitability

- Stabilizes planet obliquity: A planet's tilt may vary by as much as 90 degrees without a stabilizing factor like a moon.

- Can break planet-star tidal locking: A moon may prevent a planet from having one side facing its star at all times.

- Drives tidal heating within planet: This can help cycle important gases through tectonic activity and preserve the dynamo effect / magnetic field by preventing core cooling.

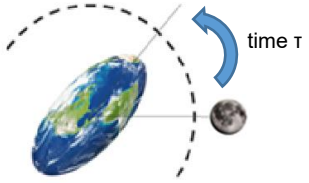
- Life on the exomoon itself: Especially important for gas giants with no solid surface

Methods

We sample 1,766 single planet systems from the NASA Exoplanet Archive, classifying them by composition into Rocky, Neptune-like, and Jupiter-like. We integrate the equations of motion forward in time, incorporating the chosen tidal lag model, to obtain the moon survivability time for each planetary system. The resulting scatter plots are shown to the right. We are especially interested in habitable zone planets that have the potential to host an exomoon for more than 1 Gyr, indicated by the rectangle formed in the upper part of the scatter plots.

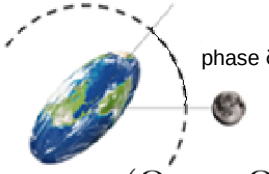
Tidal Lag Models

Constant Time Lag (CTL)



$$N \propto \tau(\Omega_m - \Omega_p)$$

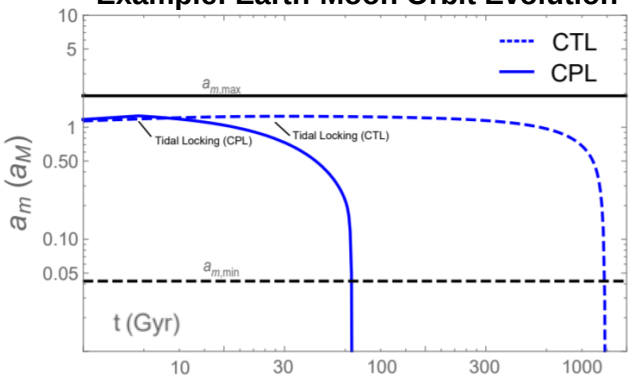
Constant Phase Lag (CPL)



$$N \propto \frac{\mathrm{sgn}(\Omega_\mathrm{m} - \Omega_\mathrm{p})}{Q}$$

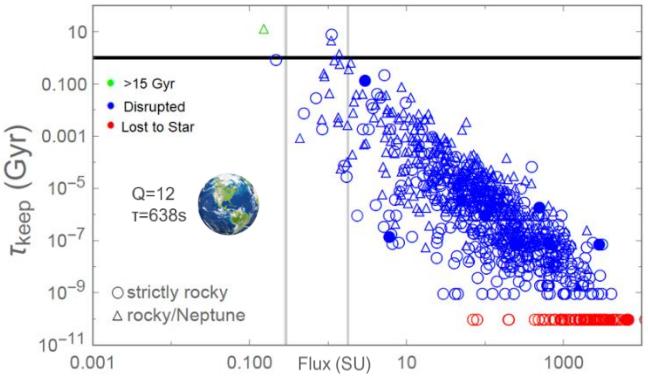
In CTL, it takes a constant time, τ, for the bulges to appear. The torque between planet bulge and moon weakens over time as the planet rotation and moon orbit synchronize. In CPL, the bulge makes a constant angle with the line joining the moon. Torque is constant in this model and depends on the quality factor, Q, of the planet.

Example: Earth-Moon Orbit Evolution

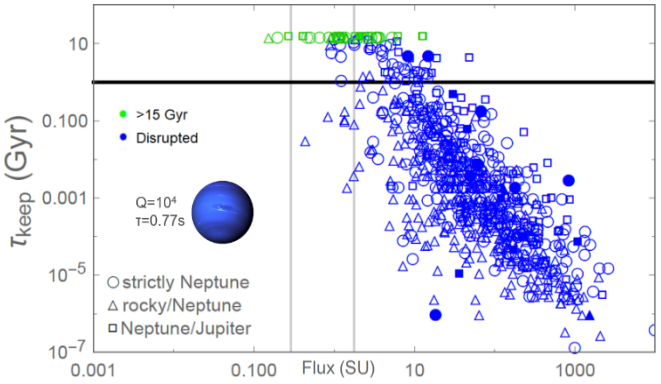


CTL and CPL models applied to the Earth-Moon system. For each case, the moon is initially pushed outwards until it tidally locks to Earth, then begins spirals inwards until it is tidally disrupted after 68 Gyr (CPL) or over 1000 Gyr (CTL).

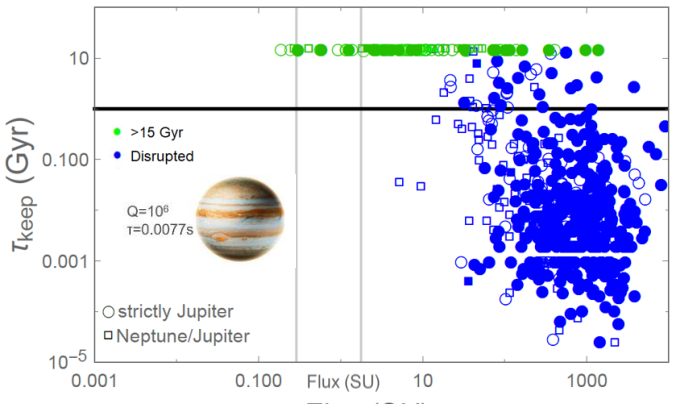
Final Results CPL



Moon retention times using the CPL model applied to Rocky exoplanets. The symbol shape shows the composition of the planet, color represents the fate of the moon, and filled/empty are planets that have/don't have a mass estimate.



Moon retention times using the CPL model applied to Neptune-like planets. Because these planets are much less dissipative, the timescales are generally longer.



Moon retention times using the CPL model applied to Jupiter-like planets. These planets are the least dissipative, so they are able to hold a moon for a relatively long time.

Results & Conclusions

We find that there are at least 36 habitable zone planets with the potential to host an exomoon for greater than 1 Gyr. This list includes Kepler-1625b, which hosts the only exomoon candidate, and it is stable for longer than a Hubble time. Our results may help provide targets for future observation and shed insight on planet structures with unknown composition.

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