The Effect of Orbital Configuration on the Possible Climates and Habitability of Kepler-62f

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Photo: Martin Cox

A Potentially Habitable World

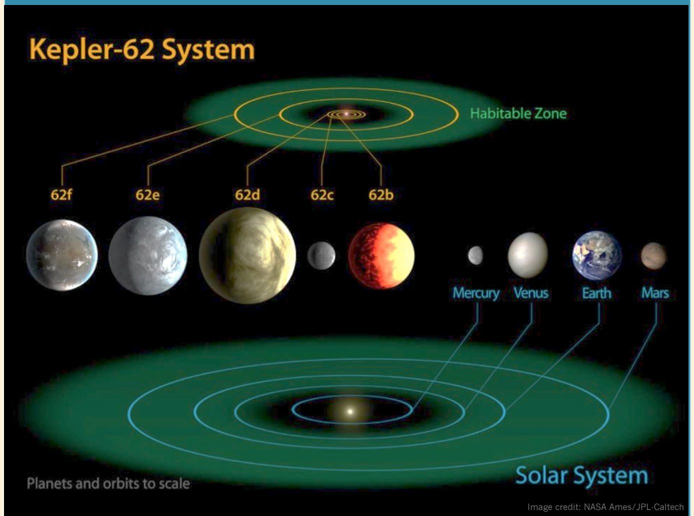


Fig. 1 – The Kepler-62 system consists of five closely spaced planets orbiting a K-dwarf star 1200 light years away. Kepler-62f (1.41R_E) sits near the outer edge of the habitable zone, with a relatively low incoming stellar insolation (40% of what Earth receives from the Sun). However, the planet could avoid freezing with a sufficient greenhouse effect.

A Good Prospect for a Habitable World

- Using an *n*-body model, we identify $0.00 \leq e \leq 0.32$ as the range of stable initial eccentricities possible for Kepler-62f.
- Kepler-62f could be habitable for a fairly wide range of plausible CO_2 concentrations, or in a low-CO_2 scenario, rare but possible orbital configurations.
- If Kepler-62f is synchronously rotating, more than 3 bar of atmospheric CO_2 would likely be required for open water at the substellar point, and atmospheric stability on the night side of the planet. [2].

Abstract

Using *n*-body model constraints as well as tidal model simulation results as input to three-dimensional (3D) global climate model (GCM) simulations, we find multiple plausible combinations of orbital and atmospheric properties that permit surface liquid water on the potentially habitable planet Kepler-62f [1].

Where there could be water, there could be life...

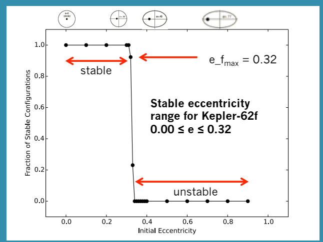


Fig. 2 – Fraction of stable configurations after a 10^6-year HNBody integration for initial eccentricities between 0.0 and 0.9 for Kepler-62f. The eccentricities of all other planets in the Kepler-62 system were set to zero.

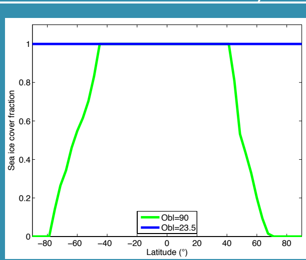


Fig. 3 – Sea ice cover fraction as a function of latitude for Kepler-62f after 160-year LMD Generic GCM simulations. With **3 bar of CO_2 in the atmosphere**, open water is only possible at the **maximum stable initial eccentricity** (e = 0.32), and an **extreme obliquity** (90°), with an Earth-like rotation rate.

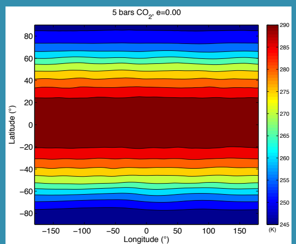


Fig. 4 – Surface temperature as a function of latitude for Kepler-62f with **5 bar CO_2** in the planet's atmosphere. **Open water is present throughout the entire stable eccentricity range**, $0.00 \leq e \leq 0.32$.

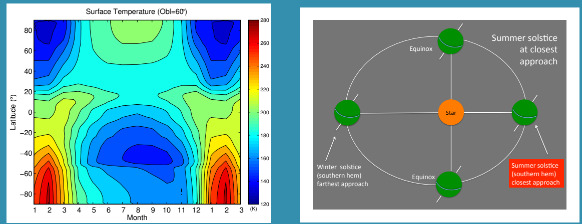


Fig. 5-6 – Surface temperature as a function of the month of the year for Kepler-62f (left) after 40-year CCSM4 GCM simulations, assuming a 12-month annual cycle, **Earth-like CO_2**, an **obliquity of 60°** and an **eccentricity of 0.32**. **Temperatures reach above freezing during southern hemisphere summer months.** This is because we have assumed a specific orbital configuration (right), where **the angle of the vernal equinox with respect to pericenter is 90°**, similar to Earth (102.7°). This maximizes the effects of high obliquity and eccentricity, and **could melt ice sheets formed during colder seasons.**

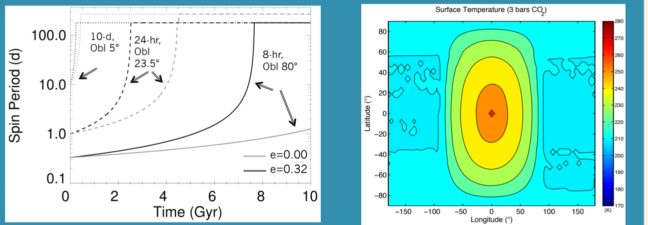
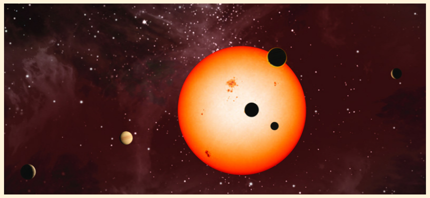


Fig. 9-10 – Left: Evolution of the spin period for Kepler-62f, using the Constant Phase Lag model. **Only the extremely fast-rotating and high-obliquity cases do not tidally lock within 5 Gyr. Right:** Surface temperature for a **synchronously-rotating** Kepler-62f with **3 bar of CO_2** in the atmosphere. The planet is globally ice-covered, the substellar point is just above freezing, and **the night side is right at the condensation limit for CO_2** at this surface pressure.



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