Paper III: First Discovered Terrestrial-Mass Exoplanet in the Habitable Zone

Background:

One of the overarching goals of exoplanet detection is to discover planets like our own; ones that have the possibility for life. Finding these planets is the first step in being able to study life on other planets (even though we are currently rather far from being able to study these faraway objects in that much detail). “Habitable” implies that the surface of the planet is able to sustain liquid water. *To first order*, the things that dictate a “habitable” planet are the *size* and *distance* from the host star.

The **size** is important because if a planet is not massive enough (like Mercury, for example), it will have no atmosphere. Without an atmosphere, the pressure on the surface is too low and liquid water cannot exist. On the flip side, too big of a planet will have a very thick atmosphere and the planet will look more like a gas-giant (like Jupiter), which is certainly not a good environment for life. The **Distance** that the planet is from the host star effects the temperature of the planet. Closer = hotter, farther = colder. Too hot and you evaporate any water that would exist. Too cold and you freeze any possible water you might have. Thus, we have a sort of *goldilocks* situation. It has to be just the right size and just the right obit.

However, this is *only to first order,* meaning that the habitability of a planet is much more complicated in reality. Take Venus, for example. It is nearly the size of earth and only 30% closer to the Sun, yet that small difference is enough to completely change the nature of the atmosphere, making the surface extremely hot and devoid of water. So, being able to model the atmosphere is crucial for deciding whether a planet is “habitable” or not. That is exactly what this paper is about.

After reading the paper, answer the following questions:

1) Briefly discuss the models used by the authors. What separates them from previous models? What are some of the assumptions made by the authors? Do they seem reasonable? Why or why not?
2) Explain the general effects of the values the authors vary in their models, namely surface composition (ocean vs. rock) and orbit-rotation resonances (1:1, 1:2, 1:10). Explain the significance of figures 1 and 2. Why is each one in the paper? What information does each provide and how does it fit into the arguments of the authors?
3) Looking at the “Discussion” section, explain the limitations of the Author’s models. What important variables are unknown/unconstrained by observations? Explain the significance of figure 4.

Glossary:

lt-yr: “light year”; distance light travels in one year.

One-dimensional radiative-convective studies: *One dimensional* means that the models assume *spherical symmetry* such that the atmospheric properties only vary with height. In other words, the atmosphere looks the same at a given height above the surface no matter where on the planet you are. *Radiative* means that the studies take into account energy transfer due to light (or ***radiation transfer***). *Convective* means that the studies also take into account convection, which is a transfer of energy via hot “bubbles” floating up and cold “bubbles” sinking within the atmosphere.

Greenhouse effect: *Greenhouse gasses* in the atmosphere are very good at scattering *infrared light*. When light from the sun hits the atmosphere, a lot of the light makes it to the surface (e.g. visible light). This light gets absorbed and heats up the surface, which cools off by radiating its own light (all hot objects cool off this way… this is why you can *feel* heat without having to actually touch something hot!). This cooling radiation is mostly in the infrared. This light, rather than escaping, gets scattered around by the greenhouse gasses making it a lot harder to escape. These gasses act like a blanket, keeping the heat from escaping and causing the surface to increase temperature.

Resonance: When two periodic motions are in resonance, their periods are *whole number* multiples of one another. For example, a 1:3 resonance means that for every 1 cycle that one object goes through, the other object goes through 3 cycles (cycle = 1 full period of motion). ***Spin-orbit*** (or ***orbit-rotation***) resonance in is comparing the period of the planet’s spin/rotation to the planet’s orbital period around its host star.

Volatiles: These are elements that change state (e.g. liquid to gas, solid to liquid) easily, or with very little heat. Usually this applies to evaporation, such that a volatile element will be quickly evaporated when heated. If an object has a lot of volatile elements in it, you know it must *not* have been heated in the past.

Bar: this is a unit of pressure. 1 bar is the atmospheric pressure at sea-level on Earth.

Advection: the transport of a substance or property of a fluid due to its bulk motion.

Sedimented: when material sinks within a fluid/gas. In the case of this paper, it is the act of ices that condense in the atmosphere being transported to the surface.

Albedo: measure of how reflective something is. In this case, this would be light that simply “bounces off” the planet (or clouds) rather than heating it up.

Thermal Equilibrium: As the name implies, this is the balance that an object reaches between incoming energy (heat) and outgoing energy (cooling). Once an object reaches thermal equilibrium, it is by definition at a stable temperature because the rate of heating is equal to the rate of cooling.