EXPLORING THE LOWER PLANET SIZE BOUNDARY OF PLANETARY HABITABILITY.
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The search for exoplanets has been more successful than could ever have been imagined prior to the detection of the first exoplanet: today there are over 4000 confirmed planets and many more awaiting confirmation. While the abundance of planet discoveries outside our solar system has been a huge benefit to the study of exoplanets, it has caused an extra problem in the search for habitable planets: Of the many targets in the habitable zone of their star, which are the best candidates to observe to try and detect signs of life? With limited resources for follow-up observations it is important to find ways to refine the list of potentially habitable planets to those that are the most likely to be habitable. This project aims to help refine this list by exploring the lower planet size limit of habitability. While there have been many studies that have attempted to determine the size at which a rocky planet will become a gas giant, very few have looked at the lower size boundary of potentially habitable terrestrial planets. While there is evidence to suggest that Mars was only able to retain surface liquid water for the first ~0.5 Gyrs, we are far from understanding how surface water retention varies as a function of planet size. What surface pressure is needed to maintain sufficient atmospheric volatile’s so that liquid water can exist on the surface of the planet? How small can a planet be and still retain sufficient atmosphere to support life? At what size does cooling of a planet reduce its magnetic field so it can no longer effectively protect its atmosphere from solar winds? And when will the cooling of the planet reduce the tectonic plate motion to a point where carbon cycling is no longer sufficient? These are examples of some the questions that are being addressed in this project. We start by developing scaling laws for the smaller than Earth, or “sub-Earth” sized planets to determine what we can expect for planets between Mars and Earth size. These scaling laws include expected changes in a planet’s interior composition, atmospheric composition, surface pressure, planet cooling and subsequent tectonic plate immobility, and methods of atmospheric escape. These Scaling Laws will then be tested using exoplanet modelling tools: ROCKE-3D [1] and VPLanet [2]. ROCKE-3D (Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics) is a three-dimensional General Circulation Model (GCM) that models the atmospheres of Earth, the terrestrial Solar System planets and rocky exoplanets (See Figure 1). VPLanet is a 1D model that simulates tidal heating, atmospheric loss, radiogenic heating, magnetic field generation, and climate of planets. Using both VPLanet and ROCKE-3D in conjunction with the scaling laws developed in the beginning of the project, the internal and external processes of Earth that are thought to be essential to maintaining habitable conditions will be explored for sub-Earth sized planets. Preliminary simulation results and scaling laws will be presented in this poster along with an outline of the next steps in the project.

Figure 1: A ROCKE-3D simulation output of the mean surface temperature of TRAPPIST-1 e, a sub-Earth sized planet in the HZ of its star. Here the simulated planet is tidally locked, resulting in an uneven distribution of heat on the surface of the planet. By varying many parameters that can affect Earths habitability, ROCKE-3D can help place constraints on planetary habitability scenarios.

References: