Exploring Giant Planets and Exomoons in the Habitable Zone

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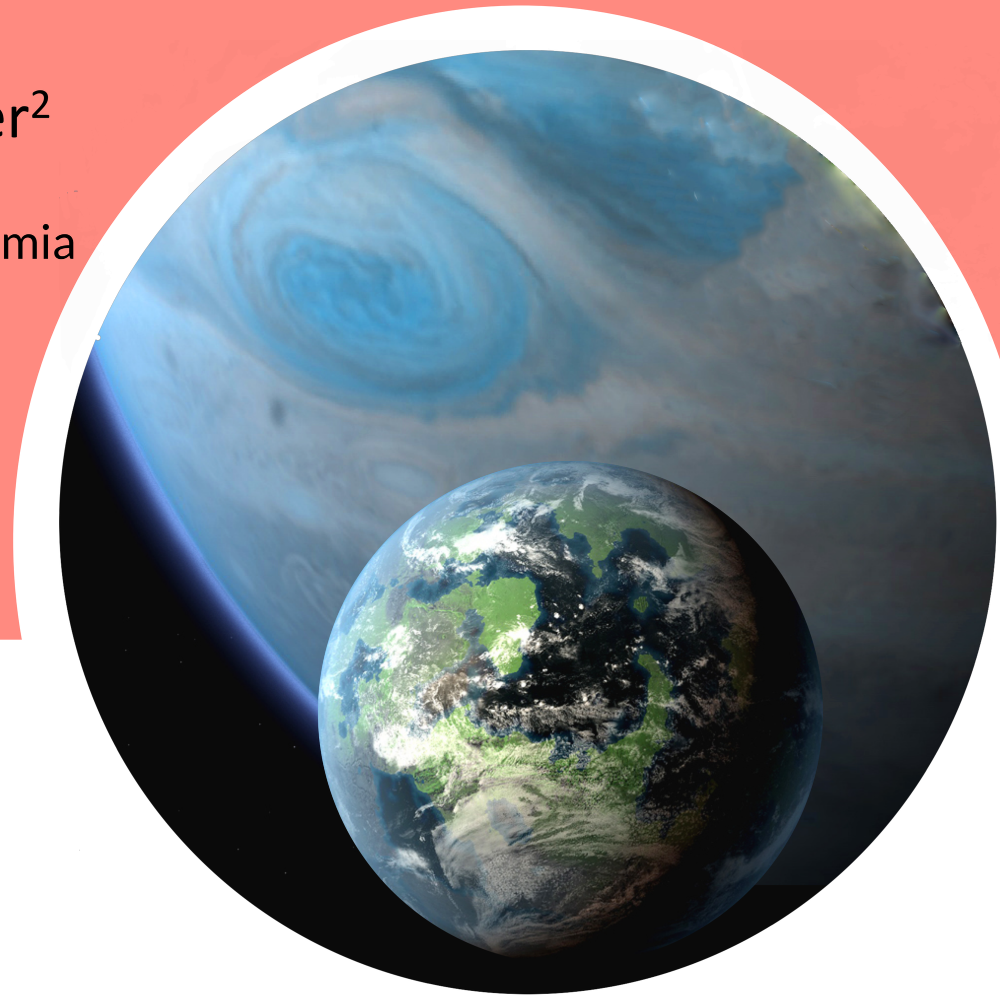
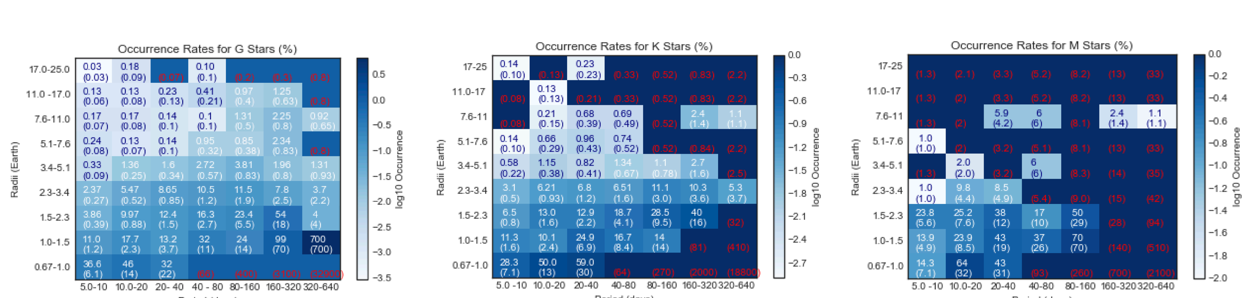


Motivation

In a recent study[1] we determined the occurrence rates of giant planets ($>3R_{\oplus}$) in the habitable zone (HZ) of their star and the subsequent potential occurrence rates of exomoons residing in the HZ. These moons, should they exist, will offer new ways to understand the formation and evolution of these planetary systems as well as widen the search for signs of life in the universe.
We then made a list of known radial velocity (RV) detected giant planets in the HZ and ran their RV data through RadVel[2] to confirm their orbital solution and look for linear trends.

Methods

As the occurrence rates of these moons are directly related to the occurrence of their giant planet hosts in the HZ, we estimated the frequency with which we would expect to find giant planets in the HZ using the inverse-detection-efficiency method



Figures 1,2,3: Binned planet occurrence rates for G, K, M stars respectively as a function of planet radius and orbital period. Planet occurrence is given as a percentage along with uncertainty percentage (in brackets). For bins without planets we compute the uncertainty, and thus upper limit (in red) by including one detection at the center of the bin.

Results

Figures 1, 2 & 3 show the binned planet occurrence rates for G,K,M stars respectively.
Table 1 to the right shows the expected occurrence of giant planets in the HZ around each stellar type compared with the literature values of terrestrial planets in the HZ about these stars.

While **giant planets** are **less common** in the **habitable zone,** if each giant planet hosts more than one moon, **moons** in the **habitable zone** may be **more common** than **terrestrial planets.**

	G	K	M
Giant planets	6.5% ± 1.9	11.5% ± 3.1	6% ± 6
Terrestrial planets	2-22%	2-22%	~20%

Table 1: The expected occurrence of giant planets in the HZ around G,K,M stars compared with the literature values of terrestrial planets in the HZ around G,K,M stars .[3,4&5]

Results Cont…

We identified 121 giant planets with RV data in the HZ, including 88 within the conservative HZ.

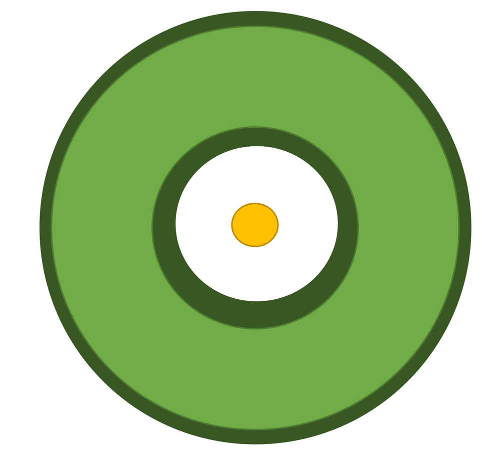


Figure 4: 121 Giant planets in the OHZ, 88 of which were in the CHZ

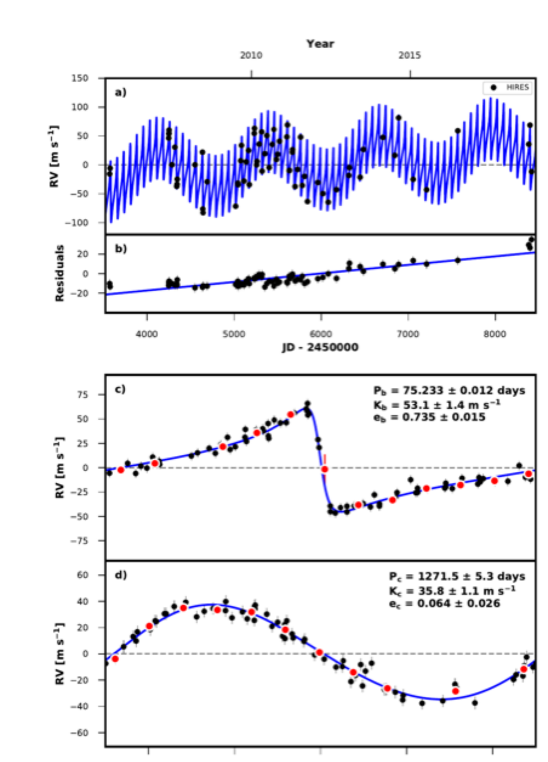


Figure 5: An example RadVel fit for one of the HZ giant planets. A strong linear trend was found for this system.

After running each planets RV data through RadVel[2] we found 52 of these systems showed indications of linear trends (>3σ). These trends could be caused by additional planets in orbit in these systems.

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Discussion

- While the results from our calculations of the occurrence rates of giant planets in the HZ reveal that giant planets are less likely to be found in the HZ than terrestrial planets, if each giant hosts more than one moon, then the number of moons in the HZ may be equal to or even more numerous than terrestrial planets.
- The significant number of giant planets in the HZ that show indications of linear trends suggest that it may be common for giant planets in the HZ to have additional long period large planets in orbit in the same system, and that this may contribute to the evolution and eventual position of these planets within the HZ. **Additional RV observations of some of the most promising of these candidates are currently underway.**

It may be common for **giant planets** in the **habitable zone** to have **additional long period giant planets** in the same system.

References: 1. Hill, M.L., Kane, S.K., Seperuelo Duarte, E., Kopparapu, R.K., Gelino, D.A., & Wittenmyer, R.A. 2018, 'Exploring Kepler Giant Planets in the Habitable Zone', ApJ, 860, 1; 2. Fulton, B.J., Petigura, E.A., Blunt, S., & Sinukoff, E. 2018, 'RadVel: The Radial Velocity Modeling Toolkit', PASP, vol. 130, pp. 986; 3. Foreman-Mackey, D., Hogg, D.W., Morton, T.D. 2014, 'Exoplanet Population Inference and the Abundance of Earth Analogs from Noisy, Incomplete Catalogs', ApJ, 795, 1; 4. Petigura, E.A., Howard, A.W., Marcy, G.W. 2013, 'Prevalence of Earth-size planets orbiting Sun-like stars', PNAS, 110(48),19273-19278; 5. Dressing, C., Charbonneau, D. 2015, 'The Occurrence of Potentially Habitable Planets Orbiting M Dwarfs Estimated from the Full *Kepler* Dataset & an Empirical Measurement of the Detection Sensitivity', ApJ, 807, 1