National Aeronautics and Space Administration

Postdoc Research

Measuring the Masses of the TOI-700 Planets with ESPRESSO

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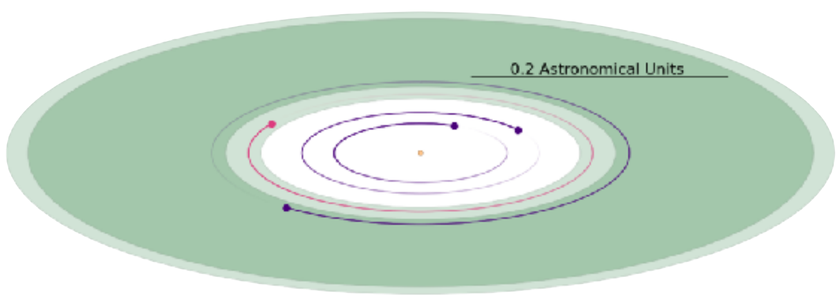
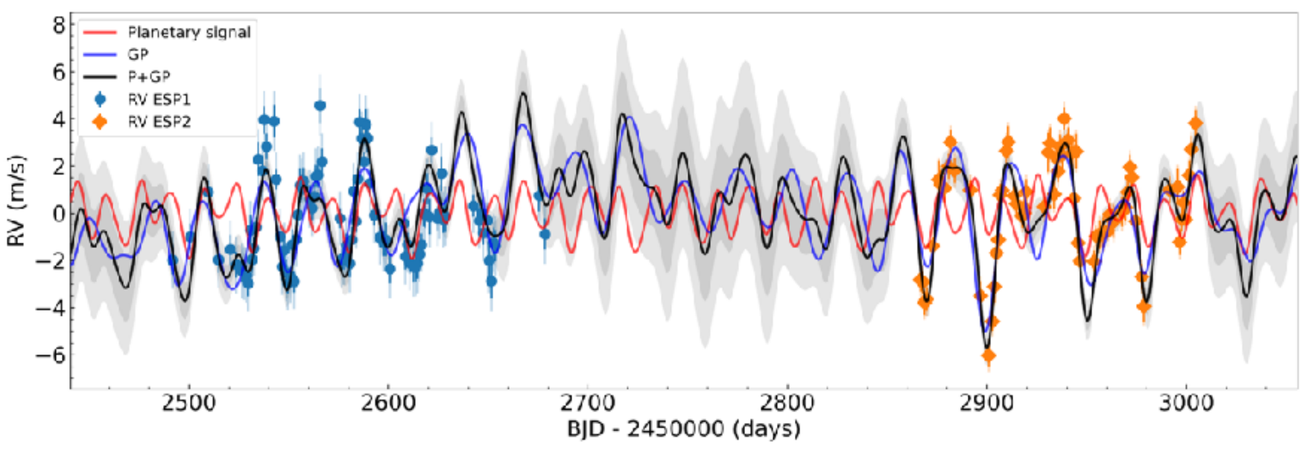
Background

TOI-700 is an exoplanet system with 4 known transiting planets discovered using data from NASA's TESS mission. TOI-700 e and d reside in the star's Habitable Zone. We want to characterize the planets in this system to the best of our abilities, particularly the two Habitable Zone worlds, furthering NASA's search for life elsewhere in the Universe.

PLANET	RADIUS (EARTH RADII)	ORBITAL PERIOD (DAYS)	SEMI-MAJOR AXIS (AU)	ESTIMATED RV SEMI-AMPLITUDE (CM/S)
TOI-700 b	0.91	9.98	0.068	60
TOI-700 c	2.60	16.05	0.093	340
TOI-700 e	0.95	27.81	0.134	35
TOI-700 d	1.07	37.42	0.163	60

The TOI-700 System



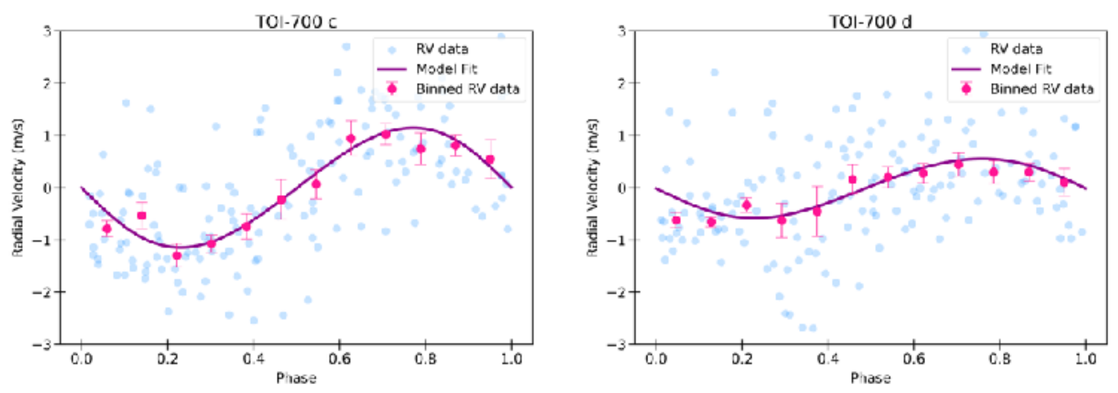


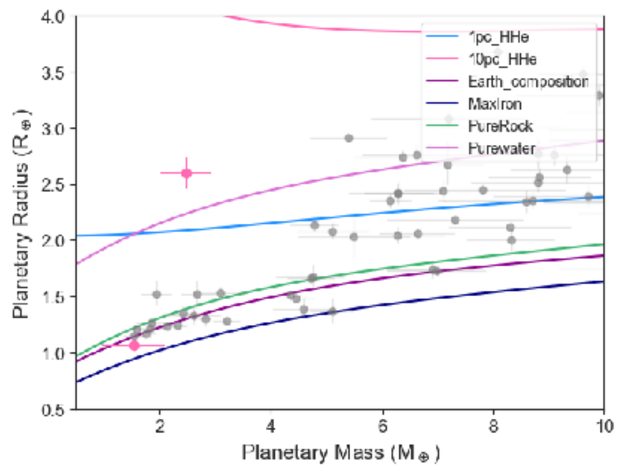
Objectives

This project aims to characterize the planets in the TOI-700 system by measuring their masses via radial velocity observations; as the planets and the star orbit their common center of mass, we measure the shifts in the spectral line of the host star that are induced by the planets. Mass measurements will allow us to determine the planets' compositions and assess the prospects for follow up observations to study their atmospheres.

Approach and Results

TOI-700 has a 54 day rotation period which shows up in the radial velocity data of the star. In order to distinguish between the signal from the star, and those induced by the planets, we have to carefully treat the stellar activity. We fit the radial velocity data with a multi-dimensional Gaussian process (see figure above). We simultaneously fits both the radial velocities and the FWHM measurements to model the stellar activity using `pyaneti`. Here are the preliminary results. We were able to determine the mass of TOI-700 c to be 2.5 +/- .45 M_{Earth} and TOI-700 d to be 1.5 +/- .5 M_{Earth}.





Significance of Results/Benefits to NASA/JPL

These results show that TOI-700 c is a low density planet, with a large hydrogen/helium envelope. This makes TOI-700 c is a great target for transmission spectroscopy measurements with NASA missions like JWST, Pandora, ARIEL/CASE. Furthermore, TOI-700 d is consistent with an Earth-like composition, making it an enticing target for future follow up to study its atmosphere and search for biosignatures.

Future Work

We plan to apply for more time to improve our measurements of planets c and d, as well as get mass measurements for b and e. We are working to determine which activity indicators will be the most helpful in this data analysis. We are also exploring different methods of data extraction including CCF-based, template matching, and line-by-line analyses. TESS recently re-observed TOI-700 for an additional 9 sectors of data as a part of Cycle 5. We will use this additional photometry to inform our RV modeling efforts and search for additional transits.

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Publications and Acknowledgements:

- The First Habitable-zone Earth-sized Planet from TESS. I. Validation of the TOI-700 System (Gilbert+ 2020)
- The First Habitable-zone Earth-sized Planet from TESS. II. Spitzer Confirms TOI-700 d (Rodriguez+ 2020)
- The First Habitable-zone Earth-sized Planet from TESS. III. Climate States and Characterization Prospects for TOI-700 d (Suissa+ 2020)
- A Second Earth-sized Planet in the Habitable Zone of the M Dwarf, TOI-700 (Gilbert+ 2023)
- Measuring the Masses of the TOI-700 Planets with ESPRESSO (Gilbert+ in prep)

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