

The First Habitable Zone Earth-sized Planet from TESS (Validation of the TOI-700 System)

Intro2Astro Week6 Assignment

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Abstract - This document presents the discovery and validation of a three-planet system orbiting the nearby M2 dwarf star, TOI-700. Located just 31.1 parsecs away, TOI-700 lies within the TESS continuous viewing zone, allowing for extensive observation across 11 sectors. This data revealed three planets with radii ranging from 1 to 2.6 R_{\oplus} and orbital periods of 9.98, 16.05, and 37.43 days. Through a combination of ground-based follow-up and rigorous diagnostic tests, common astrophysical false-positive scenarios were ruled out, successfully validating the planetary system.

The outermost planet, TOI-700 d, has a radius of $1.19 \pm 0.11 R_{\oplus}$ and is located within the conservative habitable zone of its host star, receiving approximately 86 % of the stellar flux Earth receives, is an excellent target for future observations. Ongoing and future observations by TESS during its extended mission are expected to provide further constraints on the system's parameters and aid in the search for additional planets.

1 A Major Discovery: An Earth-like World in Our Cosmic Neighborhood.

Scientists have made an exciting discovery: a system of three planets orbiting a nearby star named TOI-700. The most thrilling part of this discovery is that one of these planets, called TOI-700 d, is about the same size as Earth and orbits in its star's "habitable zone." This is often called the "Goldilocks zone," where conditions are just right—not too hot and not too cold—for liquid water to potentially exist on the surface, a key ingredient for life as we know it. This discovery was made using NASA's TESS space telescope, which hunts for planets by watching for tiny, regular dips in a star's brightness caused by a planet passing in front of it.

2 RESEARCH METHODOLOGY

The research methodology involved several key steps to confirm the existence of the TOI-700 planetary system and characterize its star and planets.

2.1 TESS Observations

The primary data source was the TESS Science Processing Operations Center (SPOC) pipeline, which collected high-precision photometric data at a 2-minute cadence. TESS observed TOI-700 for 11 sectors (1, 3-11, 13) between July 2018 and July 2019, allowing for the initial identification of the three transiting planet candidates (TOI-700.01, .02, and .03).

2.2 Vetting and Validation

To rule out false-positive scenarios, the data were subjected to rigorous vetting. The SPOC pipeline's Data

Validation module performed multiple diagnostic tests, including odd/even transit depth comparisons and difference image centroiding. An additional, independent validation was performed using the Discovery and Vetting of Exoplanets (DAVE) automated pipeline. Both pipelines confirmed that the transit signals originated from TOI-700 itself.

3 CONCLUSIONS

The discovery and validation of the three-planet system orbiting TOI-700 is a significant achievement in the search for habitable worlds. This paper, the first in a series, provides a robust characterization of the system, confirming the existence of TOI-700 d, an Earth-sized planet within its star's habitable zone. The host star's low activity level makes this system a prime target for future atmospheric studies, offering a rare opportunity to investigate a potentially rocky planet under stable stellar conditions. While TOI-700 d presents a challenging target, its larger companion, TOI-700 c, is an excellent candidate for detailed characterization with the James Webb Space Telescope. Future TESS observations will provide additional data to further constrain the system's parameters, promising new insights into the dynamics and architecture of this remarkable planetary system.

NOMENCLATURES

A	=	Amplitude
C_d	=	drag coefficient
f_e	=	linearization coefficient
K_i	=	modification factor

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