A Compact Pair of Giant Planets near the 2:1 Mean Motion Resonance around TOI-3850

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A Multi-Planet Warm Jupiter System Revealed by TTVs

TOI-3850 b ($P_b = 14.48$ d, $R_b = 12.1\ R_\oplus$) is a transiting **warm Jupiter** $\left(R_p > 8\,R_\oplus, 10\text{ d} < P < 100\text{ d}\right)$ initially detected by TESS. Its transit times show strong deviations from a linear ephemeris, or **transit timing variations (TTVs),** revealing the gravitational influence of an additional companion. The ~512 d TTV super-period and ~1 hr amplitude suggest the unseen companion lies near a **first-order mean motion resonance (MMR),** consistent with the 2:1 configuration, where the inner planet completes approximately two orbits for every one orbit of the outer planet.

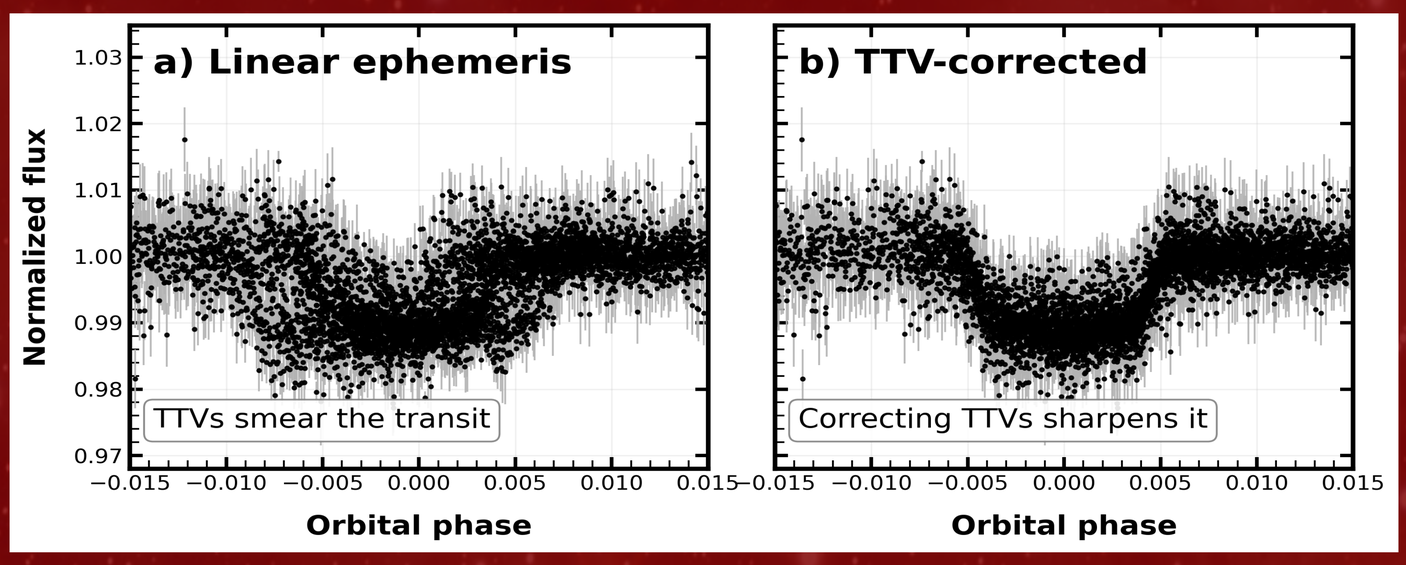

Figure 1: Photometric transit observations of TOI-3850 b phase-folded without (a) and with (b) accounting for TTVs.

Characterization from a Joint RV + TTV Fit

We jointly model the MAROON-X radial velocities (RVs) and TTVs using **`RadVel`** and **`TTVFast`**. The combined fit reveals the presence of **two Saturn-mass planets** on nearly circular orbits.

TOI-3850 b (Transiting): $P_b = 14.48\text{ d}, R_b = 12.1\ R_\oplus, M_b = 112 \pm 20 M_\oplus$

TOI-3850 c (Non-transiting): $P_c = 29.85 \pm 0.01\text{ d}, M_c = 90 \pm 15 M_\oplus$

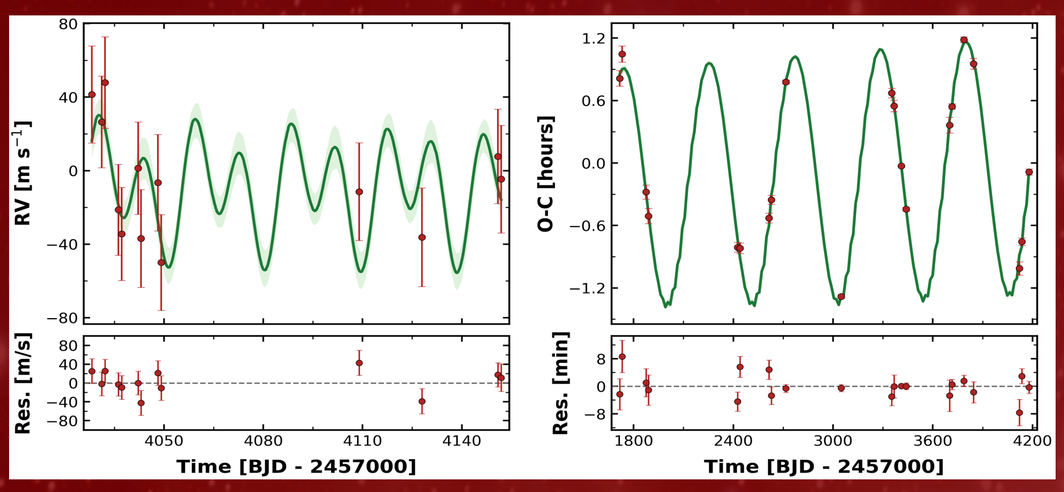

Figure 3: Joint RV + TTV fit to the MAROON-X RVs and observed TTVs.

Dynamical Evolution

Direct N-body integrations with **`REBOUND`** show that the system is **stable across 99.3% of the posterior**. While the planets lie close to the 2:1 MMR, only 8.8% of the posterior samples display libration of the first-order resonant angles. The system is hence near, but **not locked, in the exact 2:1 resonance**. Variations in the system's sky-projected geometry could cause TOI-3850 c to **transit in the near future**: ~50% of samples transit within the next 27 years.

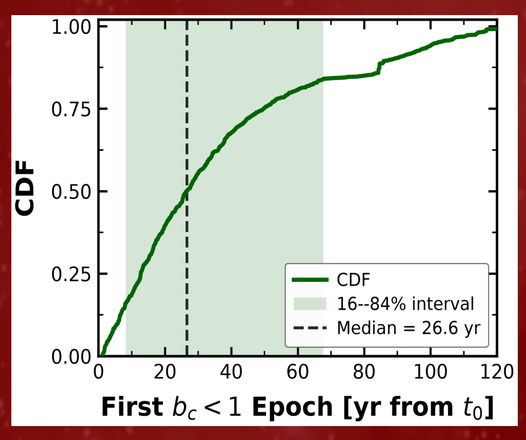

Figure 5: Cumulative distribution function (CDF) of the first time TOI-3850 c transits.

Vetting and Ruling Out FPs

Several false positives (FPs) can mimic planetary transits. These mainly include **eclipsing binaries (EBs),** background **eclipsing binaries (BEBs)** and **stellar variability**.

EBs: TRES reconnaissance spectroscopy constrains $K < 150$ m/s, ruling out a stellar-mass eclipsing companion

BEBs: ground-based photometry detects the transit on-target; TESS centroiding is consistent with TOI-3850; SAI speckle imaging detects no companion stars

Stellar Variability: periodogram analysis gives a rotation period of $P_{\text{rot}} \approx 6$ d; no significant activity is detected at either planetary period

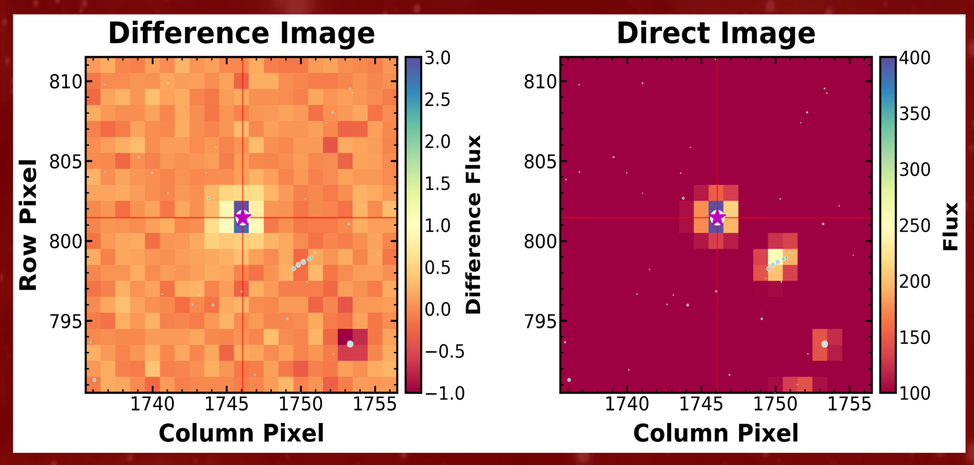

Figure 2: TESS difference image shows the difference between the average in- and average out-of-transit pixel values. The centroids of both the difference and direct images are consistent with the position of TOI-3850.

Architecture of the TOI-3850 System

Isochrone analysis suggests TOI-3850 is a **young** ($\tau_\star \approx 0.9$ Gyr), **moderately active** G0 dwarf star. The nearly circular ($e_b \approx 0.02, e_c < 0.02$) and coplanar orbits ($\Delta i \approx 4.6°$) are consistent with a **dynamically quiescent migration history**. The two planets are found just *wide* of exact resonance ($P_c/P_b \approx 2.06$), a configuration compatible with **disk-driven migration**.

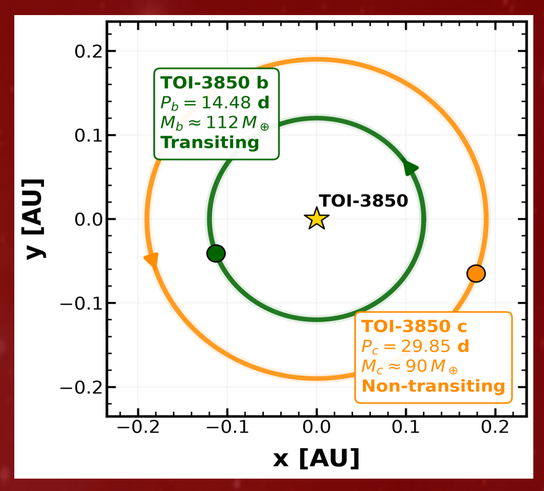

Figure 4: Orbits of TOI-3850 b and TOI-3850 c.

Population Context: A Rare Find

Compact systems containing multiple giant planets are intrinsically rare. Only 11 other confirmed systems have multiple Saturn-mass planets $\left(M_p > 0.25\ M_J\right)$ with orbital separations $\Delta a < 0.20$ AU.

TOI-3850 b is a favorable target for follow-up atmospheric characterization, with a transmission spectroscopy metric (TSM = 58) higher than 87% of all warm Jupiters. Future comparative atmospheric studies with Ariel could test whether lone and multi-planet warm Jupiters have distinct atmospheric properties.

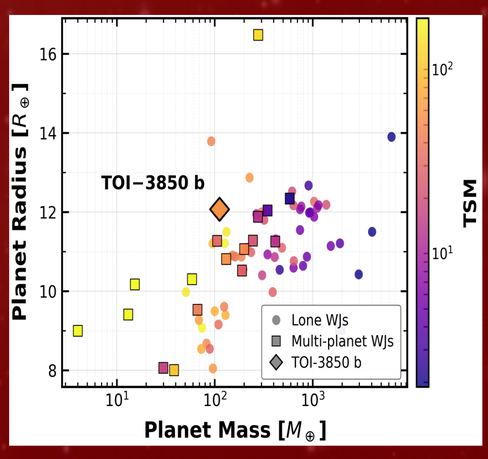

Figure 6: Radius-mass diagram for all confirmed warm Jupiters. The color scale is set by their transmission spectroscopy metric (TSM).

Acknowledgments

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Background image credit: ESO
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