A hot Jupiter progenitor on a super-eccentric, retrograde orbit

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TIC 241249530 b

TIC 241249530 b is a transiting warm Jupiter ($M = 4.98\ M_J$, $R = 1.19\ R_J$) orbiting an F-type dwarf star with a period of $P = 166$ d and an eccentricity of $e = 0.94$. The planetary orbit is more eccentric than that of any other known transiting exoplanet. Initially detected with TESS, this planet was confirmed and characterized with a combination of photometric (ARCTIC) and RV (NEID, HPF, HARPS-N) data.

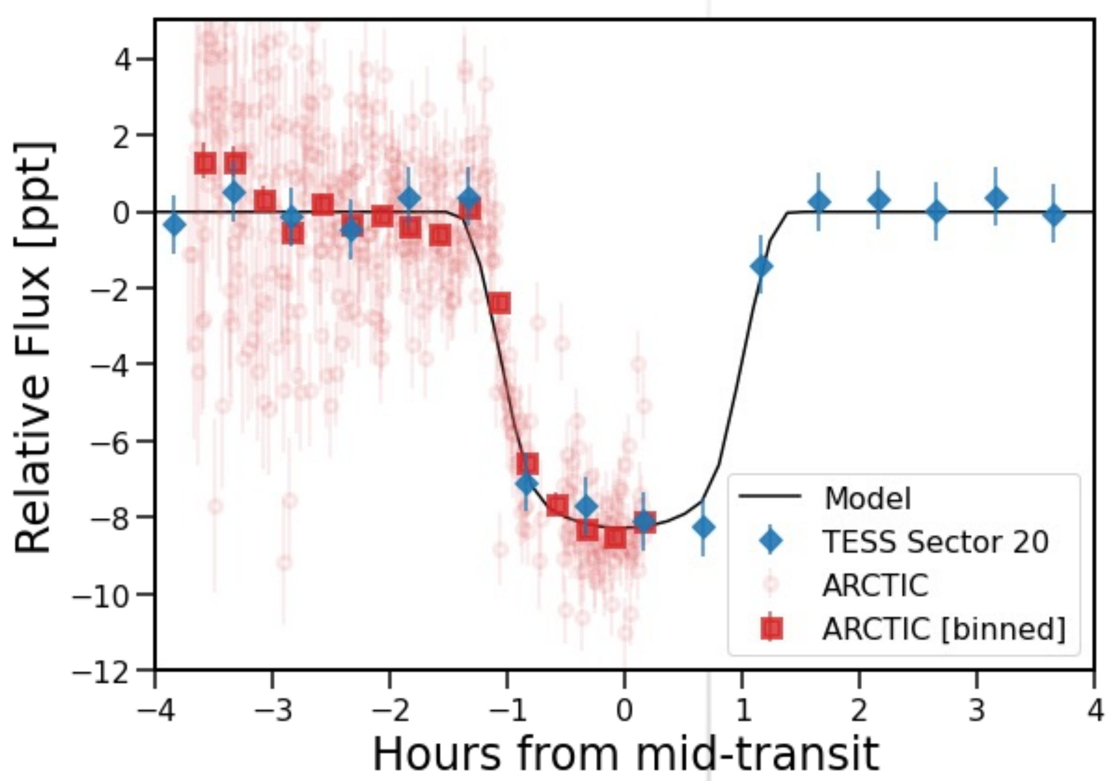
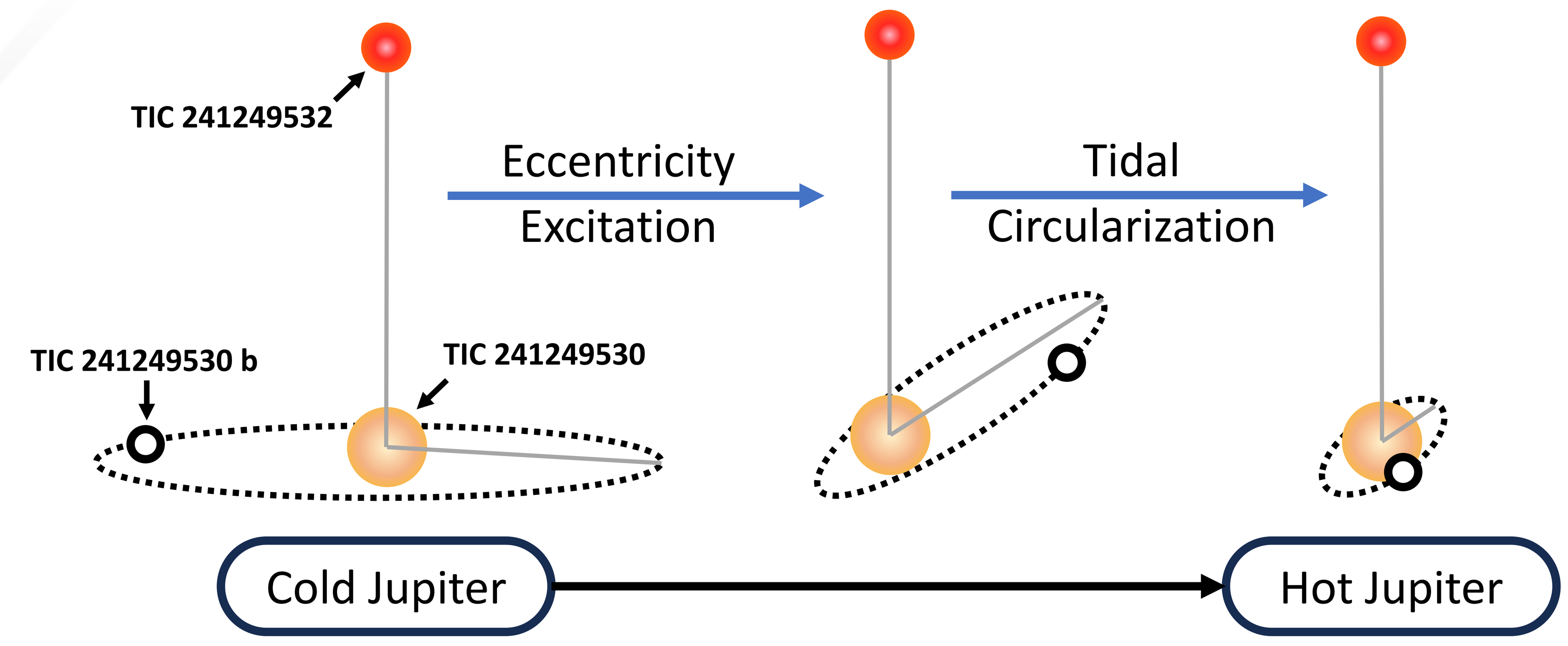


Fig. 1: Transit detections of TIC 241249530 b with TESS (blue) and ARCTIC (red). No transits were detected in the other TESS sectors in which the star was observed.



Perturber-coupled High-e Migration

Our simulations show that Lidov-Kozai oscillations, driven by angular momentum exchange with the stellar binary companion, TIC 241249532, could have excited the eccentricity of the planetary orbit. The present eccentric orbit carries the planet near enough to the host star to facilitate tidal dissipation, causing the orbit to shrink and circularize.

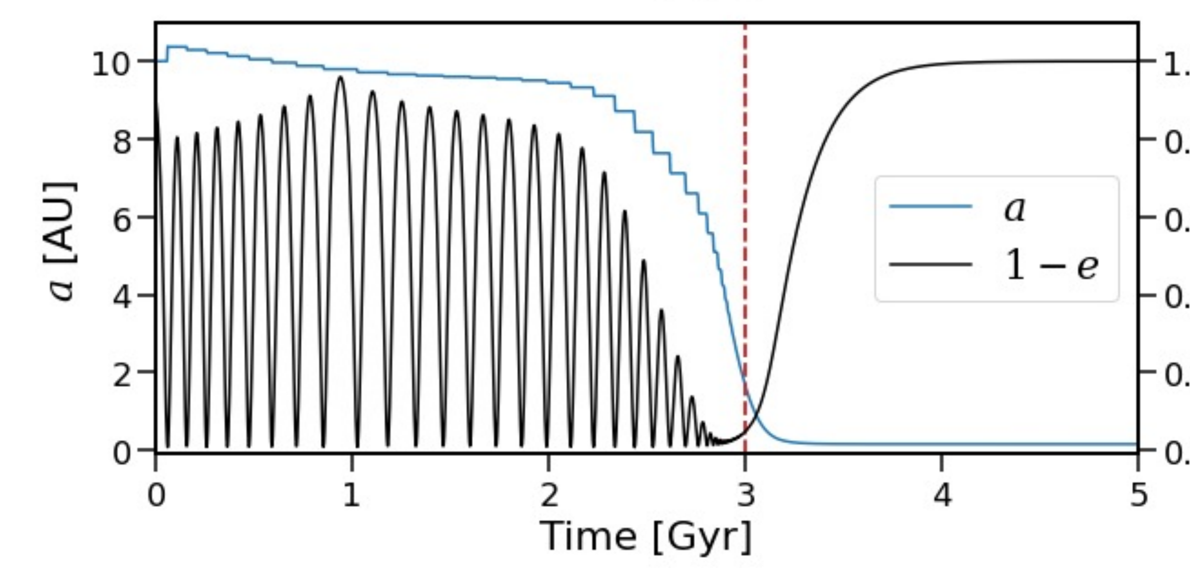


Fig. 2: Evolution of the semi-major axis (blue) and eccentricity (black) of the orbit of TIC 241249530 b. The current age of the system is indicated by the red dashed line; Lidov-Kozai oscillations have recently been quenched and the planet will remain on its present tidal circularization track.

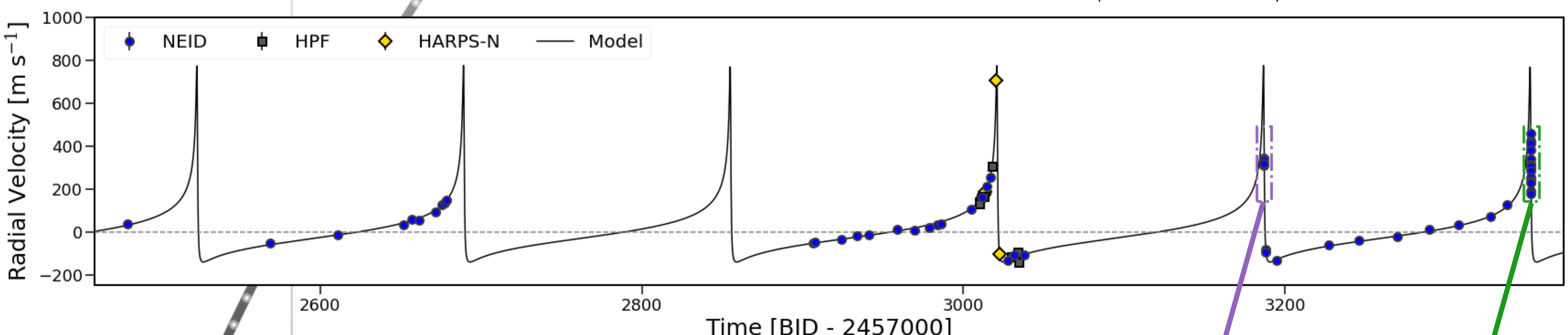


Fig. 3: Radial velocity measurements of TIC 241249530. The RV curve is consistent with a highly eccentric orbit, with periastron passage occurring just hours before each transit. Two sets of data were taken while the planet was transiting.

Spin-orbit Misalignment

In-transit radial velocity measurements allow us to probe the alignment of the planetary orbit and stellar spin via the Rossiter-McLaughlin effect. The projected spin-orbit misalignment is $\lambda = 164 \pm 8°$. The stellar inclination, $i_\star$, is not known, precluding a robust measurement of the true obliquity, Ω. Still, we find Ω to be $> 83°$ for all possible values of $i_\star$, and $\Omega > 90°$ with 99.5% confidence for $\cos i_\star\ U(0,1)$.

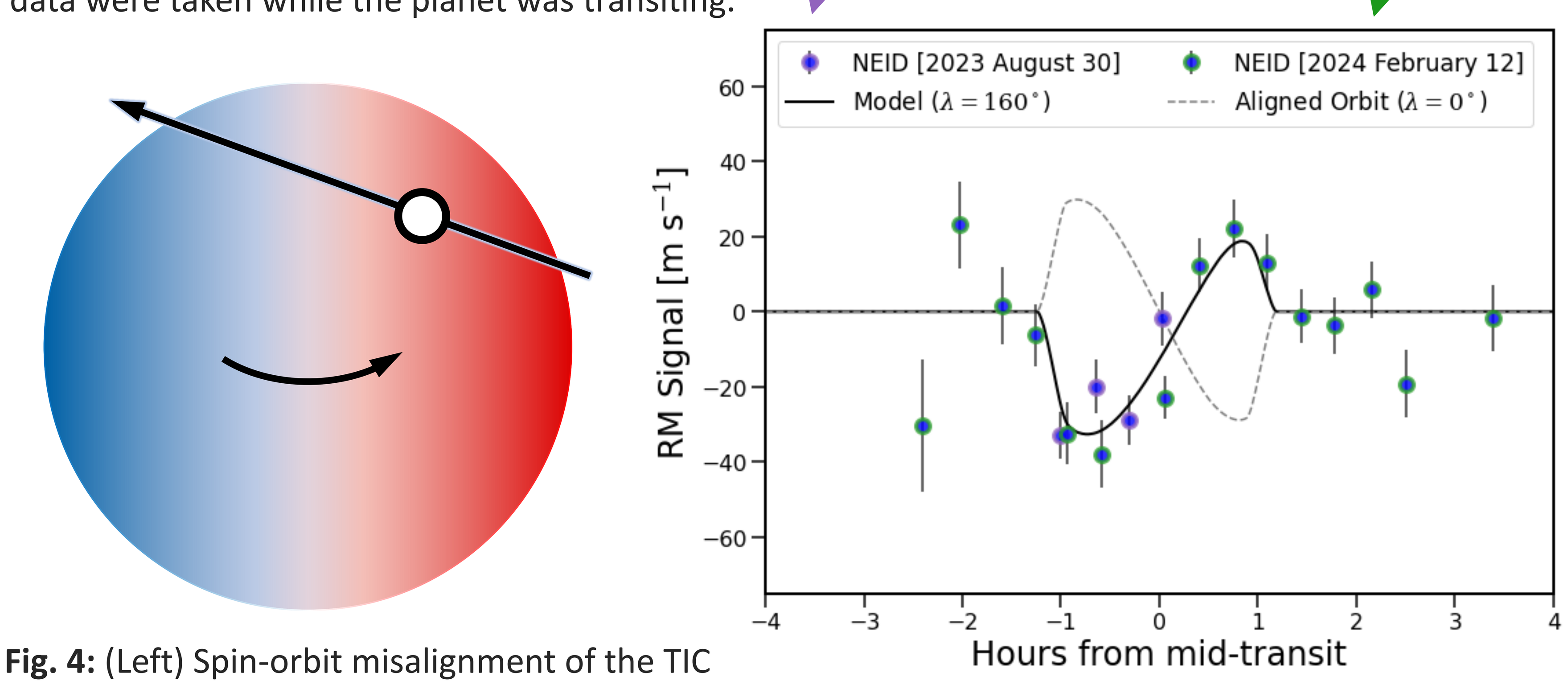
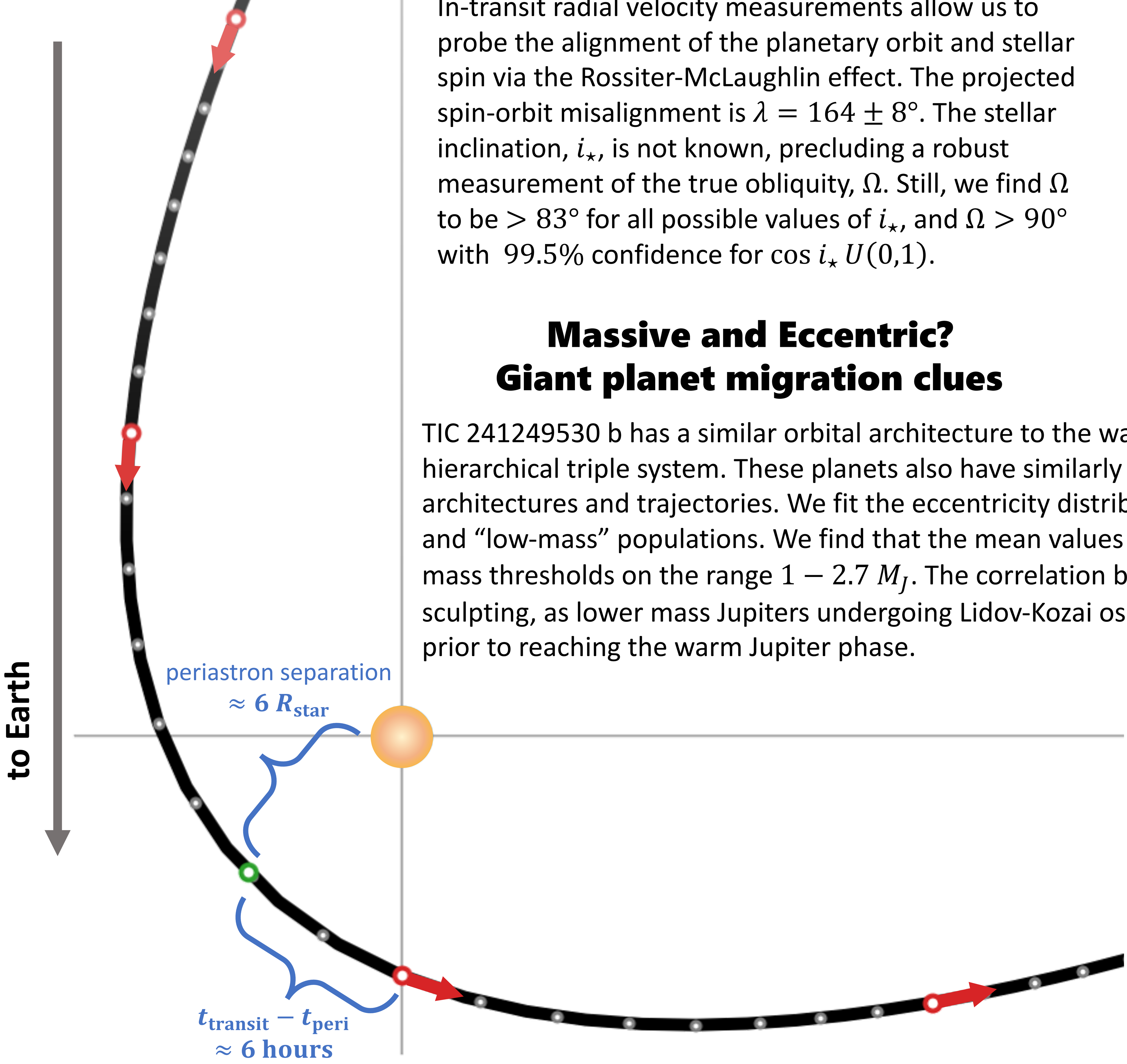


Fig. 4: (Left) Spin-orbit misalignment of the TIC 241249530 system, and (Right) Rossiter-McLaughlin signal. The in-transit radial velocity data show that the orbit is misaligned, with the planet orbiting counter to the projected direction of the stellar spin.

Massive and Eccentric? Giant planet migration clues

TIC 241249530 b has a similar orbital architecture to the warm Jupiter HD 80606 b ($P = 111$ d, $e = 0.93$), which also resides in a hierarchical triple system. These planets also have similarly large masses (> 4MJ), suggesting that mass may play a role in their shared architectures and trajectories. We fit the eccentricity distributions of all transiting warm Jupiters, dividing the sample into "high-mass" and "low-mass" populations. We find that the mean values of these two distributions are statistically distinct, differing by $3 - 5\sigma$ for mass thresholds on the range $1 - 2.7\ M_J$. The correlation between high mass and high eccentricity may be an artifact of dynamical sculpting, as lower mass Jupiters undergoing Lidov-Kozai oscillations are more likely to be tidally disrupted early on, prior to reaching the warm Jupiter phase.



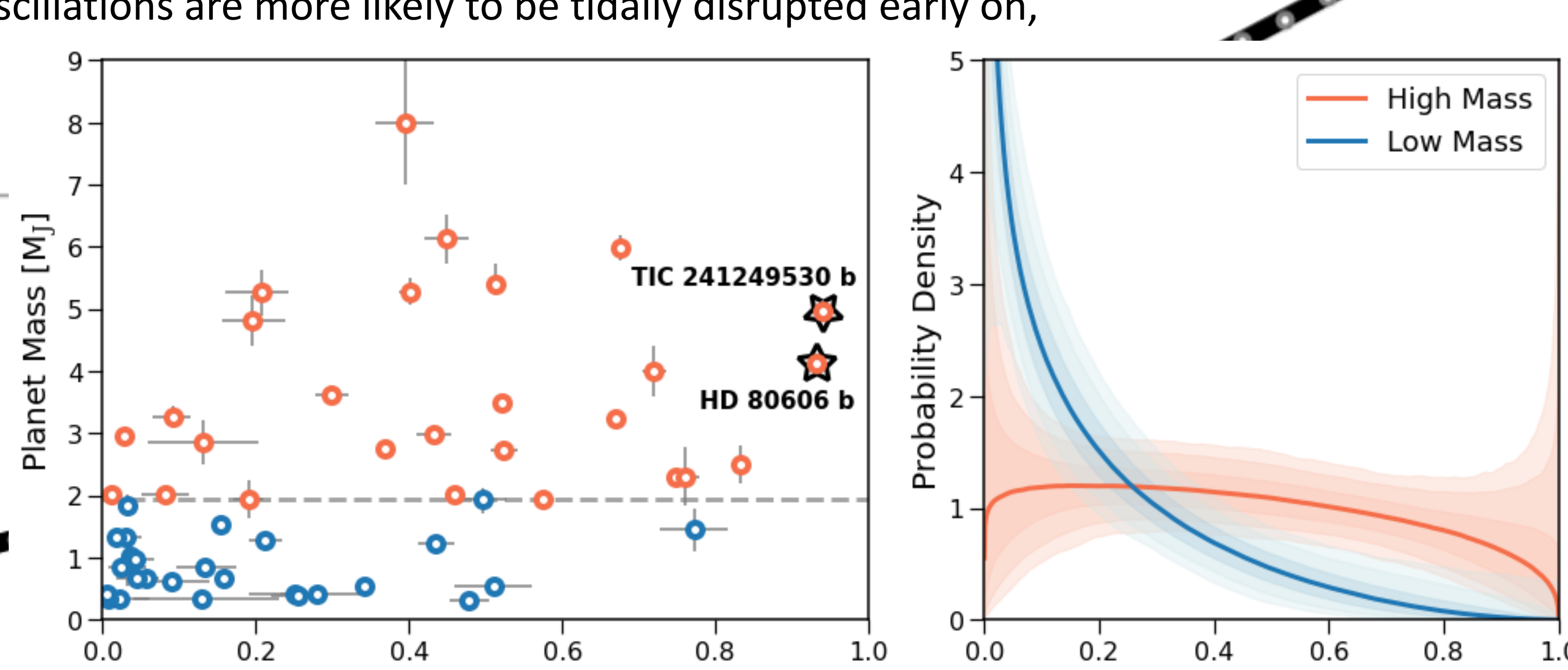


Fig. 5: (Left) Masses and eccentricities for transiting warm Jupiters, and (Right) best-fit eccentricity distributions for the population. High-mass warm Jupiters have significantly higher eccentricities than do their lower mass counterparts.