Evidence for Primordial Alignment: Insights from Stellar Obliquity Measurements for Giants in Compact Systems

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Misalignment: Nature or Nurture?

Stellar obliquity — the angle between the spin axis of a star and the orbital axis of its planet(s) — is a powerful tracer of a planetary system's evolutionary history.

A large fraction of **hot Jupiters** and **sub-Saturns** are observed to have high obliquities, which may have been excited through **violent dynamical pathways** such as high-eccentricity tidal migration. However, recent evidence that some planets may form misaligned[1] complicates interpretation of the obliquities we observe today, as their primordial distribution is unknown.

The tight orbital configurations of **compact multi-planet systems** preclude violent histories[2], allowing them to trace the natal disk plane. The growing sample of giants in such systems, especially the often-isolated hot Jupiters, can now be leveraged to study their primordial spin-orbit distribution for the first time. We report measurements of the projected obliquity λ via the **Rossiter-McLaughlin** (RM) effect for three such planets: two sub-Saturns, TOI-5126 b and TOI-5398 b, and one hot Jupiter, TOI-5143 c.

Measuring Stellar Obliquity

We perform in-transit radial velocity (RV) observations of our three targets using the high-resolution NEID spectrograph on the WIYN 3.5m telescope to capture the RM effect. We combine our RVs with two-minute TESS light curves and other data available from our targets' discovery papers[3,4,5] to perform a **global RM fit** and **obtain λ**.

Data

Transit Photometry

TESS, CHEOPS, Teide, CTIO, FLWO, McDonald Observatory

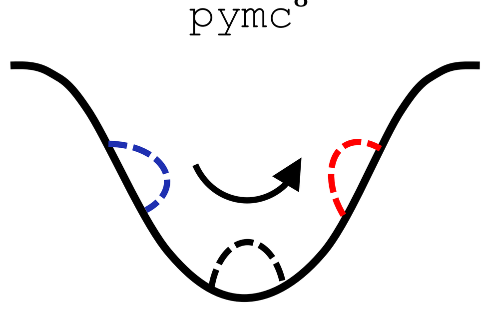
Radial Velocities

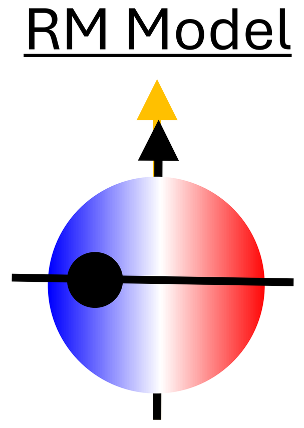
NEID, Harps-N

RM Model

Doppler Shadow

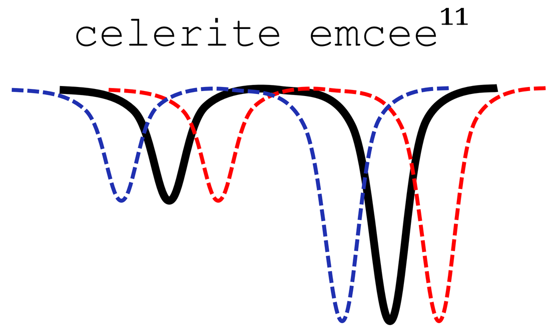
exoplanet[6] celerite[7] pymc[8]





RV Anomaly

allesfitter[9] tracit[10] celerite emcee[11]



Three Compact Giant Systems in Alignment

Figure 1a.

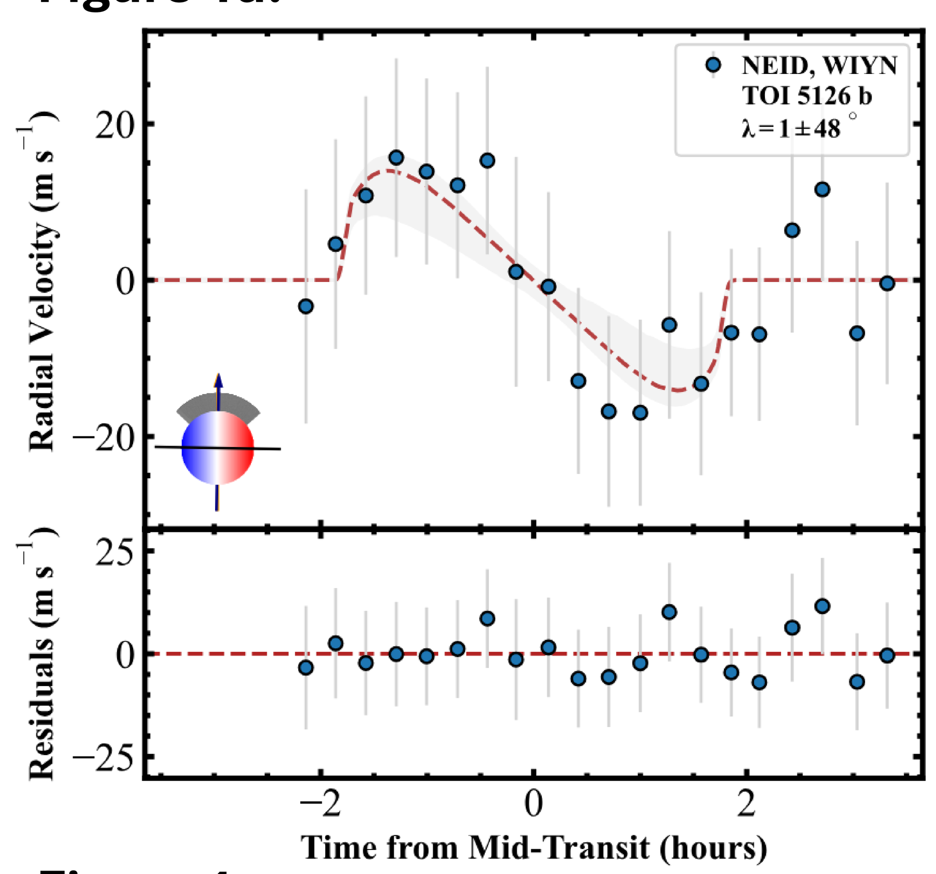


Figure 1b.

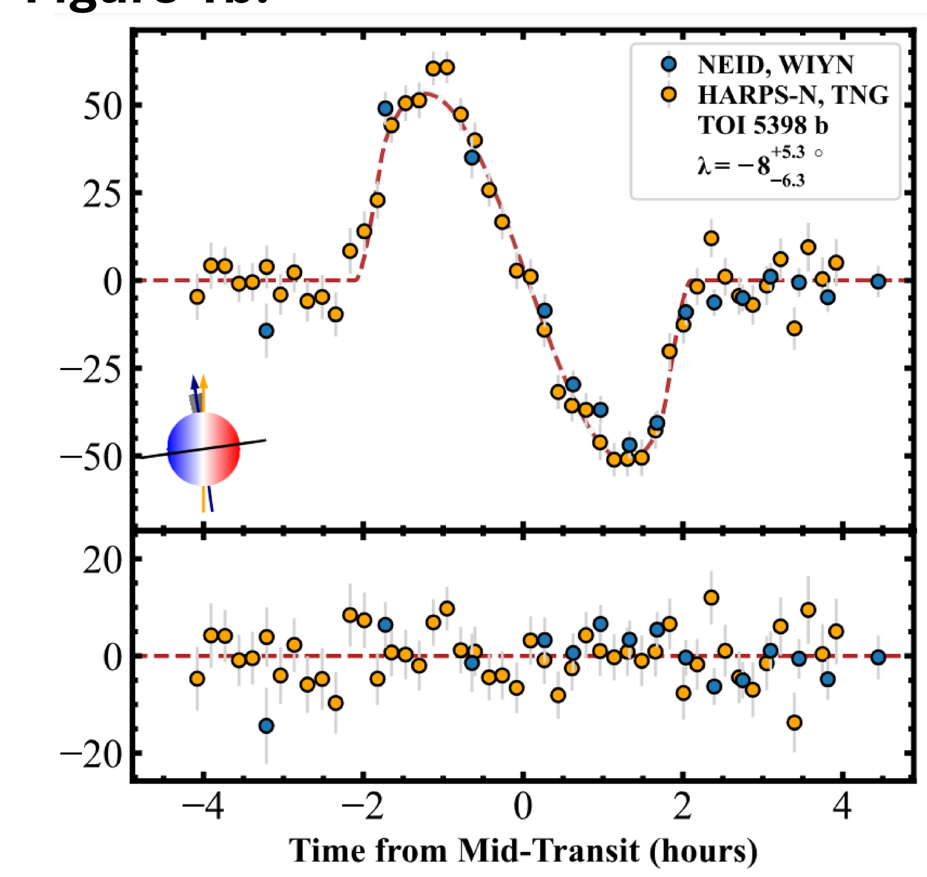
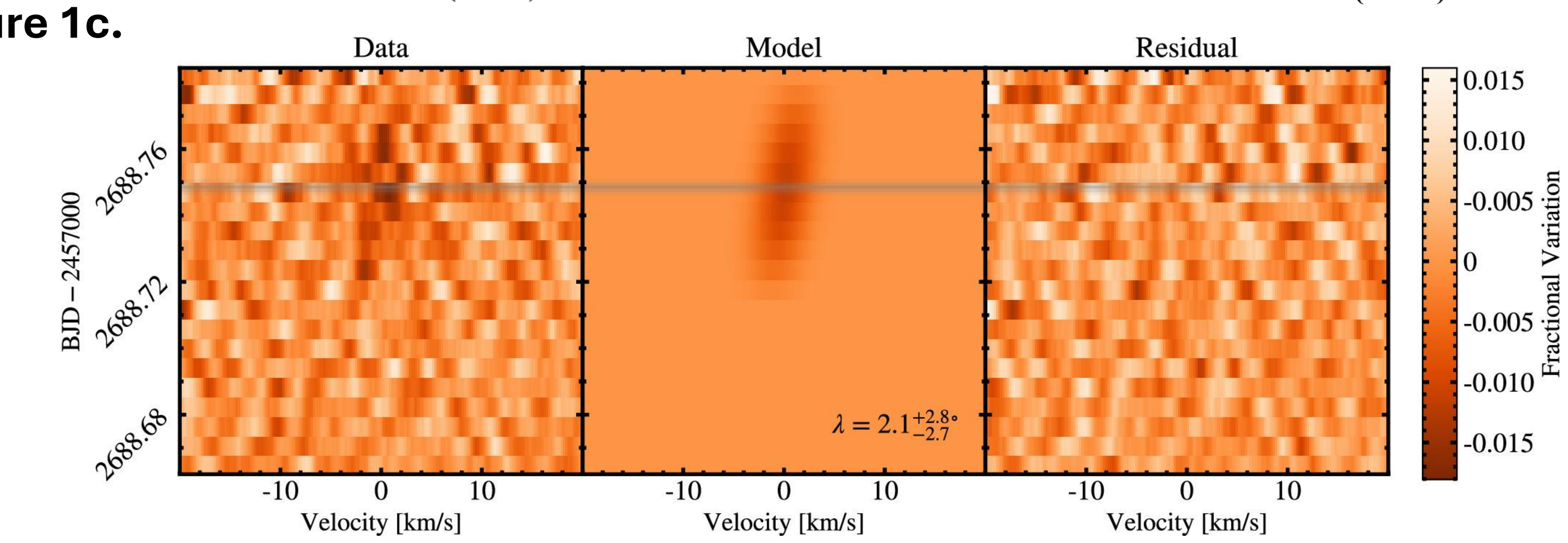


Figure 1c.



For sub-Saturns TOI-5126 b and TOI-5398 b, as is evident by the symmetrical bumps in the in-transit RVs displayed in Figures 1a and 1b, respectively, **both planets are spin-orbit aligned.**

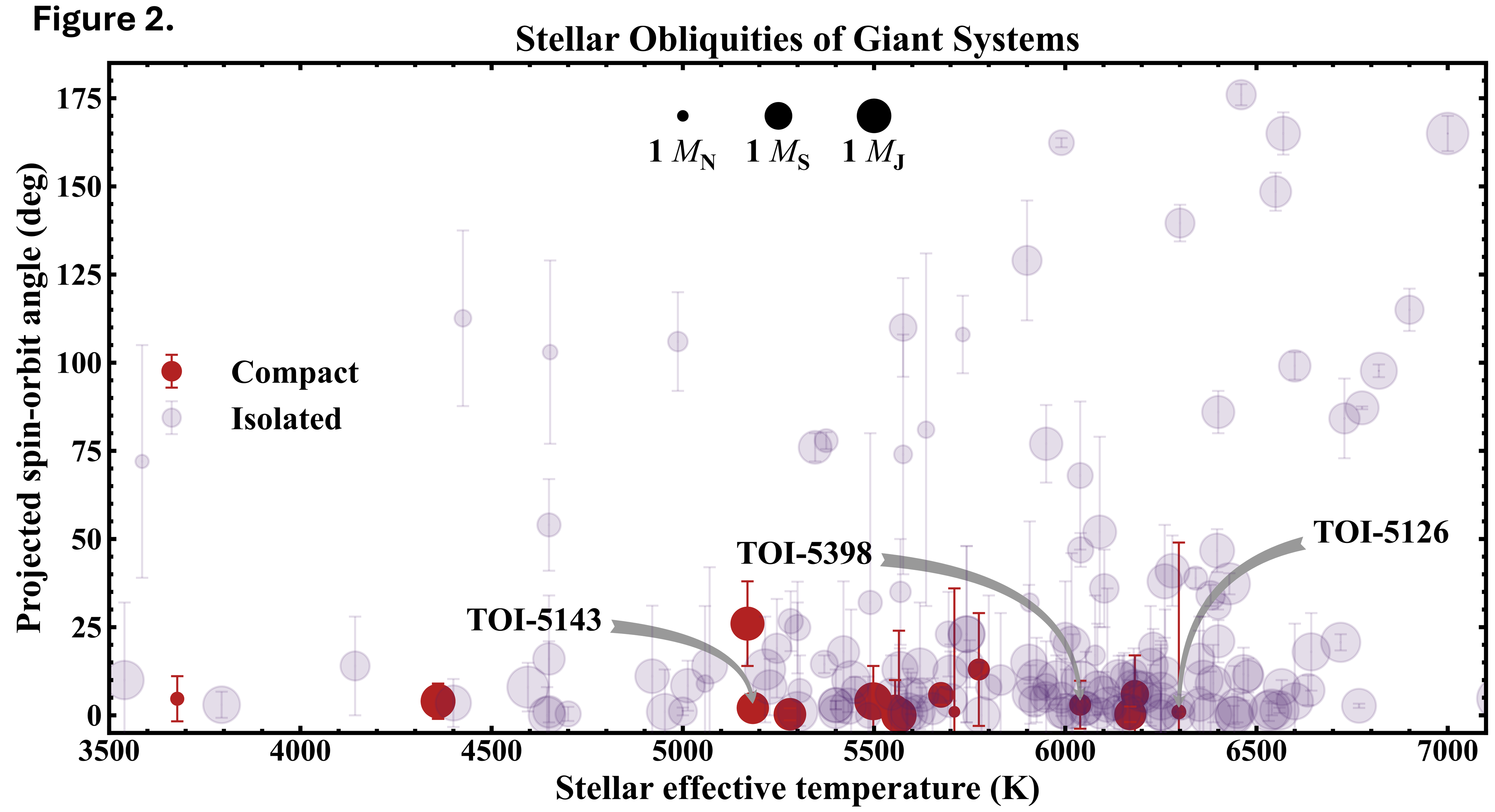
For the hot Jupiter TOI-5143 c, the diagonal Doppler shadow profile in the velocity channel map displayed in Figure 1c illustrates that **this planet is also aligned.**

Both results are published[12,13] and available via these QR codes:

Radzom et al. (2024) Radzom et al. (2025)

Significant Support for Primordial Alignment

Figure 2.



Our measurements for TOI-5126 b and TOI-5398 b enable the **first statistical verification** of the alignment of compact sub-Saturn systems (2.6σ; see also Figure 2)[12]. TOI-5143 c is **only the third** hot Jupiter in a compact system to have its spin-orbit angle measured, and all three are aligned[13].

Together, our results strongly suggest that close-in giants like **hot Jupiters form spin-orbit aligned,** providing renewed support for **violent evolutionary pathways** like high-eccentricity migration **in misaligned systems** while also affirming that giants in **compact systems have** dynamically **quiescent origins,** such as disk migration — even hot Jupiters.

References: **1.** Albrecht et al. 2022, *PASP* **134** 082001. **2.** Mustill et al. 2015, *ApJ*, 808, 14. **3.** Fairnington et al. 2023, *MNRAS*, 527, 8768. **4.** Mantovan et al. 2022, *MNRAS*, 516, 4432. **5.** Mantovan et al. 2024a, *A&A*, 682, A129. **6.** Foreman-Mackey et al. 2021, *JOSS*, 6, 3285. **7.** Foreman-Mackey 2017, *AJ*, 154, 220. **8.** Abril-Pla et al. 2023, *PeerJ-CS*, 9:e1516; **9.** Günther & Daylan 2021, *ApJS*, 254, 13. **10.** Hirano et al. 2011. *ApJ*, 742, 69. **11.** Foreman-Mackey et al. 2013, *PASP*, 125, 306. **12.** Radzom et al. 2024, *AJ*, 168, 116. **13.** Radzom et al. 2025, *AJ*, 169, 189