TOI-880: A Dynamically Cold, Aligned, Coplanar Multi-Planet System -– Adding to the Demographic Portrait of Compact, Multi-Transiting Systems

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Introduction & Motivation

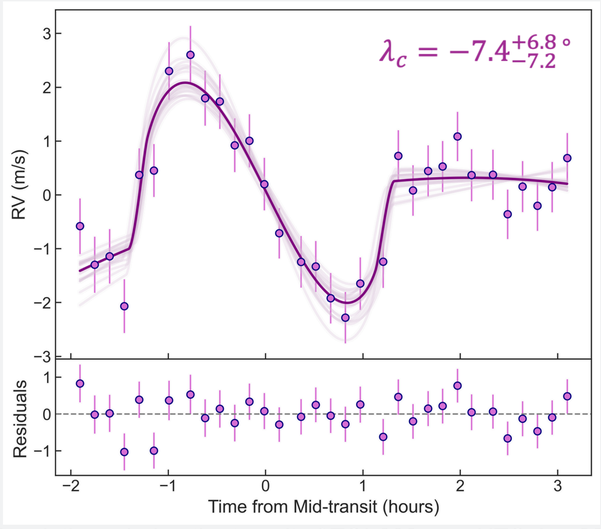
- Stellar obliquity (λ) is a key tracer of planetary system architecture and evolution.
- Multi-transiting systems provide a unique demographic window into quiescent formation channels.
- Measuring λ in these systems helps distinguish whether obliquities arise from:
  - Localized tilting of a single planet's orbit, or
  - Global misalignments involving the entire protoplanetary disk or host star.

TOI-880 System at a Glance

- **K-dwarf star,** Teff = 5050 ± 100 K, [Fe/H] = +0.23
- Hosts three transiting planets detected by TESS:
  - TOI-880 b: 2.19±0.11 R_{earth}, P = 2.6 days
  - TOI-880 c: 4.95±0.20 R_{earth}, P = 6.4 days
  - TOI-880 d: 3.40±0.22 R_{earth}, P = 14.3 days
- It's compact & near-coplanar, typical of Kepler-like multis.

Spin-Orbit Alignment via Rossiter–McLaughlin Effect

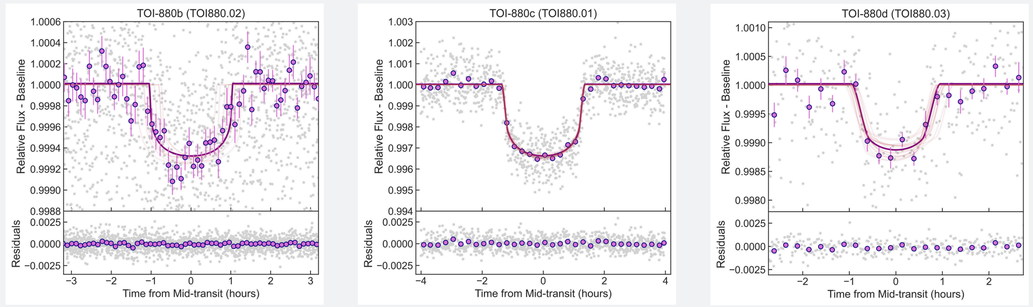
- Measured for TOI-880 c using Keck Planet Finder (KPF).
- Sky-projected obliquity:
- $\lambda_c = -7.4^{+6.8}_{-7.2}$°, consistent with an aligned, prograde orbit.
- Low $vsini_\star$ and lack of rotational modulation → slow stellar spin → minimal nodal precession.



The RV variations during the transit of TOI-880 c on UTC Jan 20, 2024.

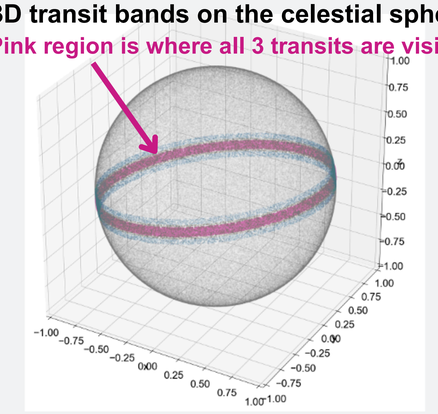
Coplanarity and Dynamical Architecture

- TESS transit modeling yields planet inclinations: b ~87.8°; c ~88.2°; d ~88.16°
- Mutual inclinations $\lesssim 2°$, consistent with **dynamically cold systems.**
- Monte Carlo simulations show that multi-transit geometry **strongly disfavors higher mutual inclinations.**



*Data from TESS sector 33 at 2-min cadence. The fitted model is from the *allesfitter* pacakge.

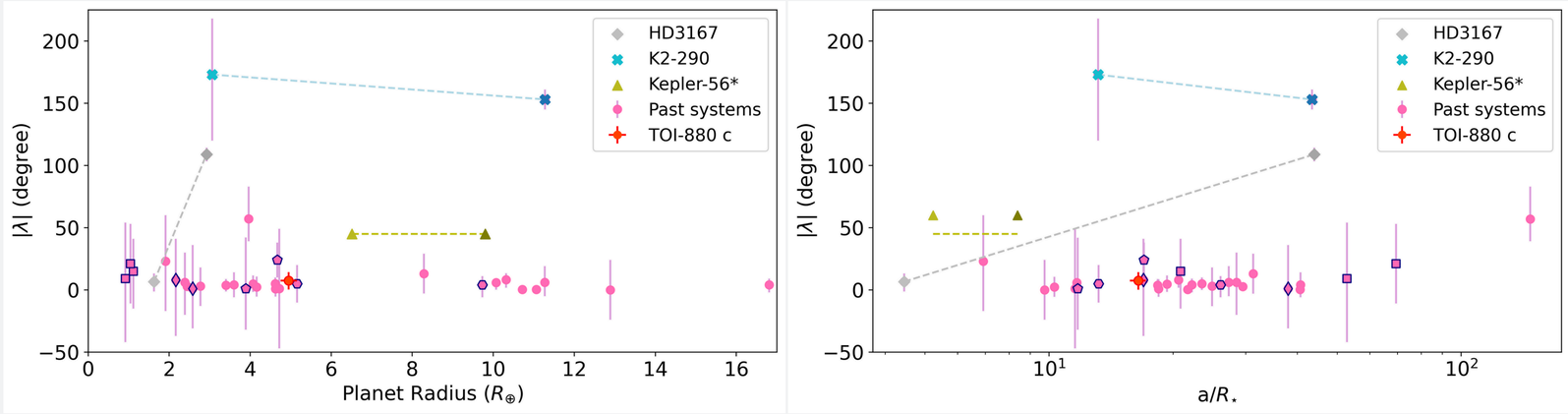
3D transit bands on the celestial sphere.
Pink region is where all 3 transits are visible.



Only ~1% chance a random observer can see all 3 planets transit if mutual inclination ≥7°.

Exoplanet Demographics: Multi-Transiting Systems

- There are ~25 multi-transiting systems have obliquity measurements to date.
- Vast majority are well-aligned, suggesting that **compact, coplanar** architectures dominate.
- TOI-880 adds a new datapoint that reinforces the idea that low mutual inclinations and low obliquities co-occur in multi-transiting systems.
- **Misaligned exceptions include:**
  - **K2-290**: Both its 2 transiting planets are in retrograde, misaligned orbits (Hjorth+, 2021); It's in a triple-star system.
  - **Kepler-56**: The core is misaligned with its 2 planets, but the envelope is aligned with them (Ong+, 2024).
  - **HD 3167**: Claimed high mutual inclination; recent studies by Teng et al. (2025) challenged this.
- Misalignments may arise from: External companions (e.g., distant stars); Core-envelope decoupling; Magnetic star–disk tilt; Planet–planet scattering; Disk turbulence or chaotic accretion; Primordial disk misalignment.
- **If we leave out HD 3167 in the figure below, the trend in obliquity of multi-transiting systems is:**
  - **Most compact, multi-transiting systems tend to be coplanar and well-aligned, similar to TOI-880.**
  - **K2-290 and Kepler-56 represent a minority population of coplanar but misaligned planetary system.**



The sky-projected obliquity |λ|. Systems with λ measured using more than one planet are shown as points of the same symbol with dark-blue edges.