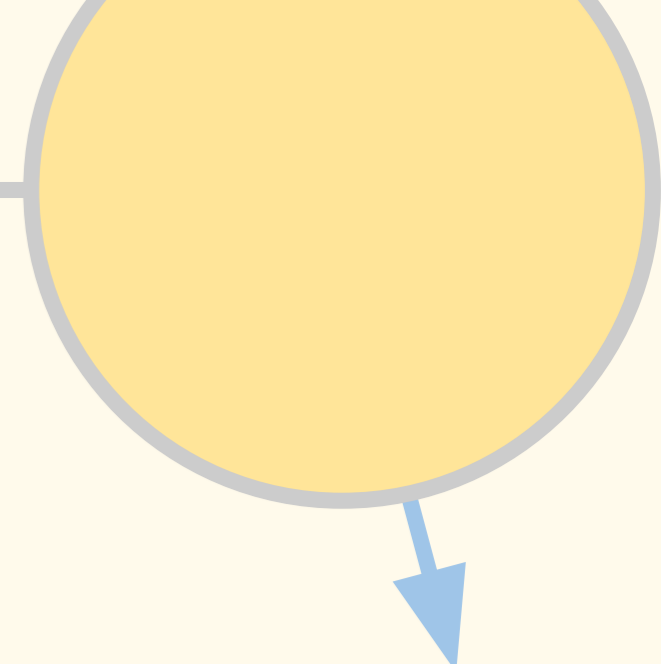


# AN ALIGNED SUB-NEPTUNE REVEALED

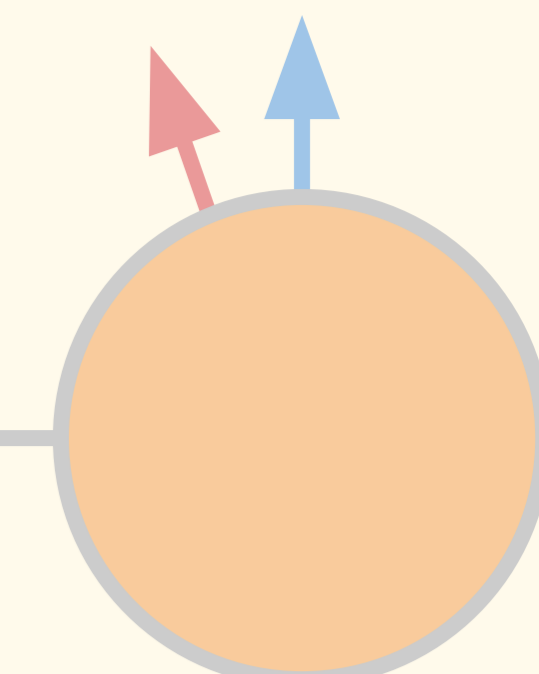
WITH **MAROON-X**



K2-290



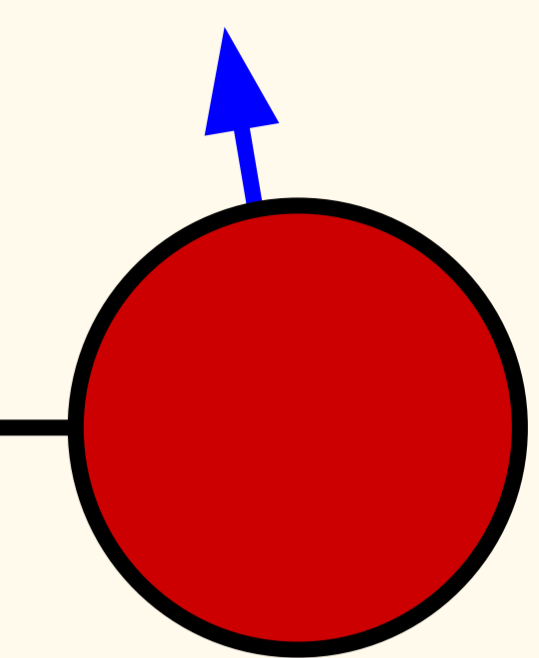
TOI-942



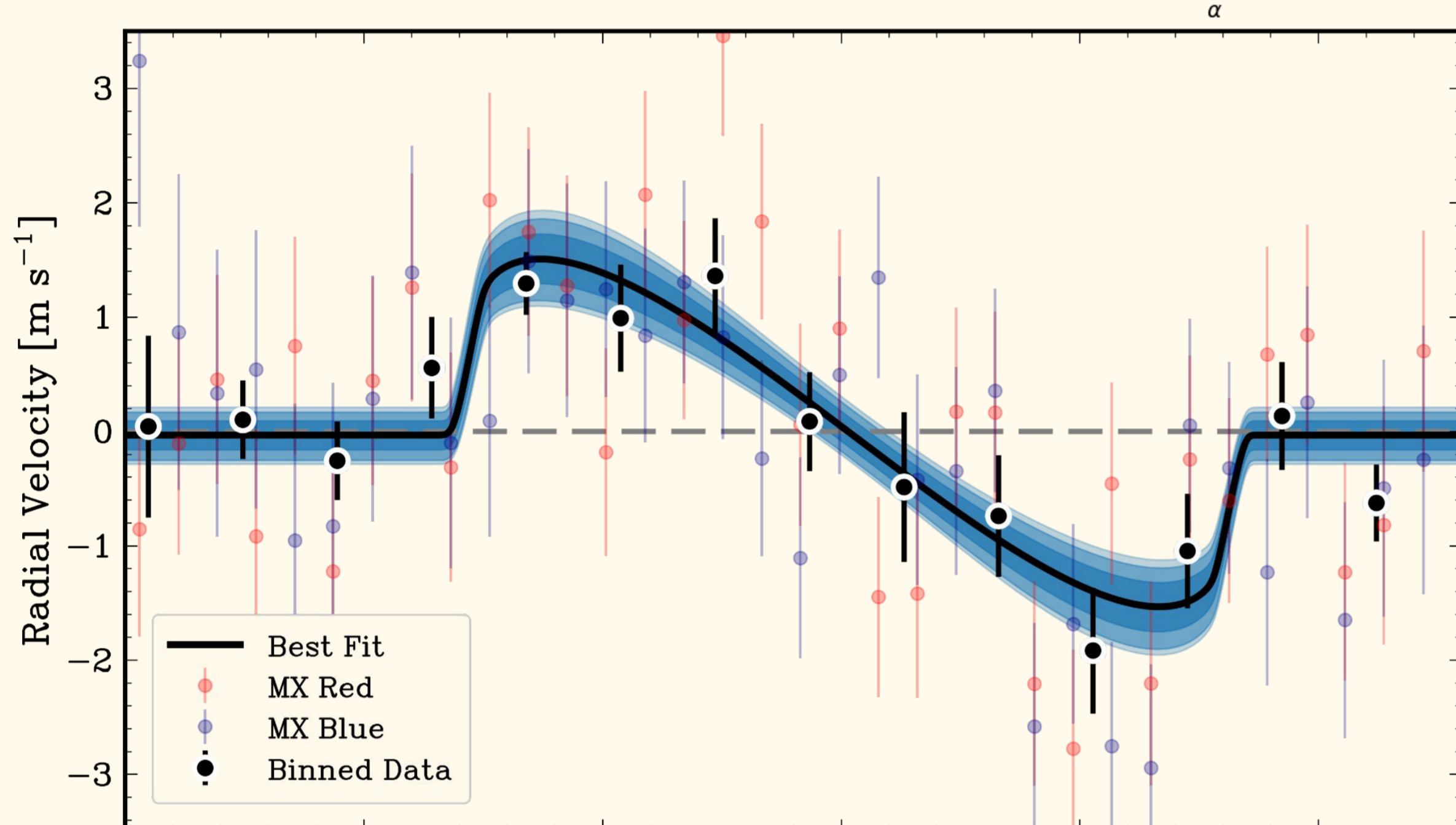
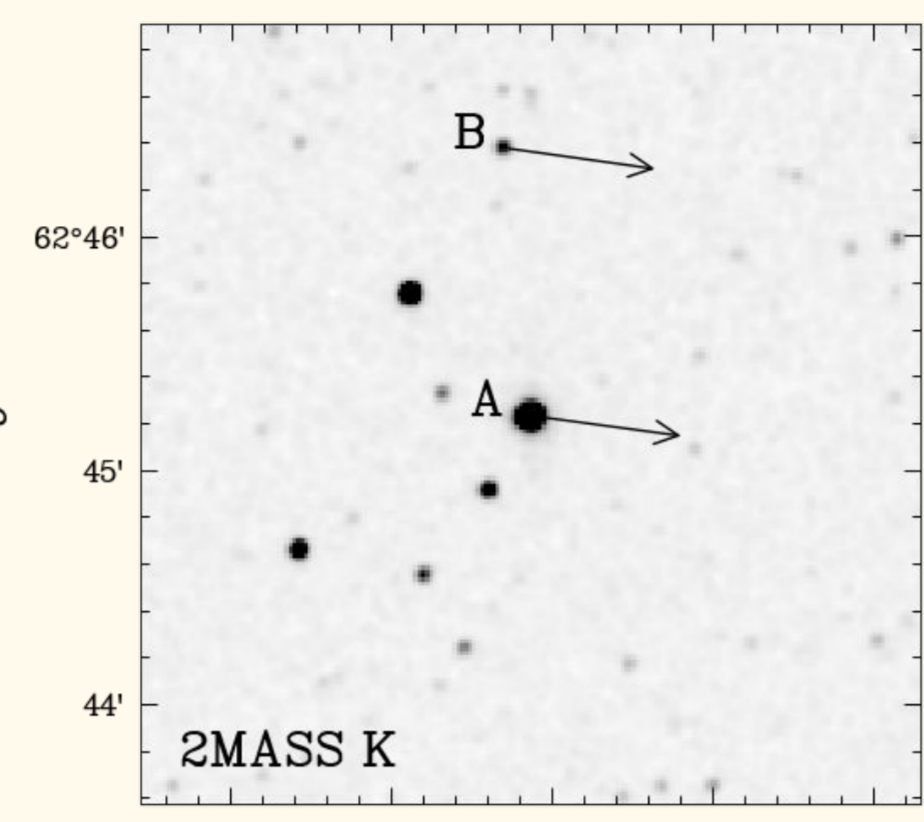
## AND A TENDENCY TOWARDS ALIGNMENT FOR SMALL PLANETS

Alex Polanski (Lowell Observatory, apolanski@lowell.edu), Ian Crossfield, Andreas Seifahrt, Jacob Bean, Jonathan Brande, Karen Collins, David Coria, Akihiko Fukui, Norio Narita, Julian Sturmer, Steven Giacalone, David Kasper

TOI-1759



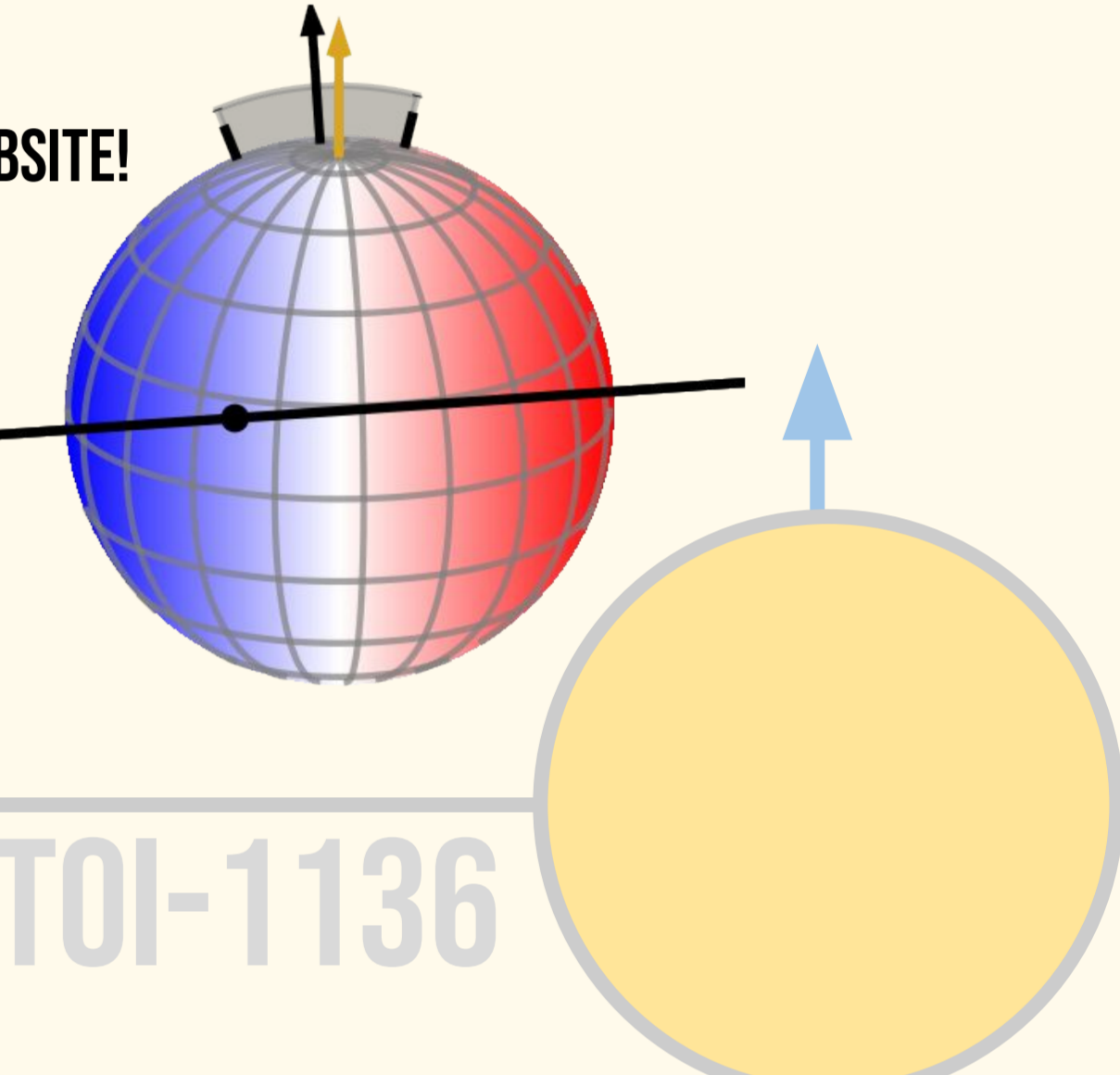
TOI-1759 b is a  $3.25 R_{\oplus}$  sub-Neptune characterized in previous works. This  $7-12 M_{\oplus}$  mass planet orbits an early M dwarf every 18 days. TOI-1759 also has a co-moving companion with a projected separation of  $\sim 2,700$  AU.



The sky-projected angle between a planet and its host star's rotation axis ( $\lambda$ ) is a key tracer of a system's formation history. Observations of the Rossiter-McLaughlin effect with high-resolution spectroscopy has enabled obliquity measurements of hundreds of planets most of which being hot-Jupiters. However, the evolution of HJs is likely distinct from that of smaller planets. The lower mass and larger separation for most known planets makes it far less efficient to realign with their host star, should misalignments occur. Growing the sample of small planet obliquities will be necessary to explore the primordial alignment distribution.

Using the MAROON-X spectrograph, we obtained in-transit spectroscopy of TOI-1759. The radial velocities reveal a  $\sim 1.5 \text{ m s}^{-1}$  amplitude velocity anomaly. A joint fit with TESS and ground-based photometry show TOI-1759 b to have a projected obliquity  $\lambda = -4^{\circ} \pm 18^{\circ}$  – the longest period single sub-Neptune with an obliquity measurement.

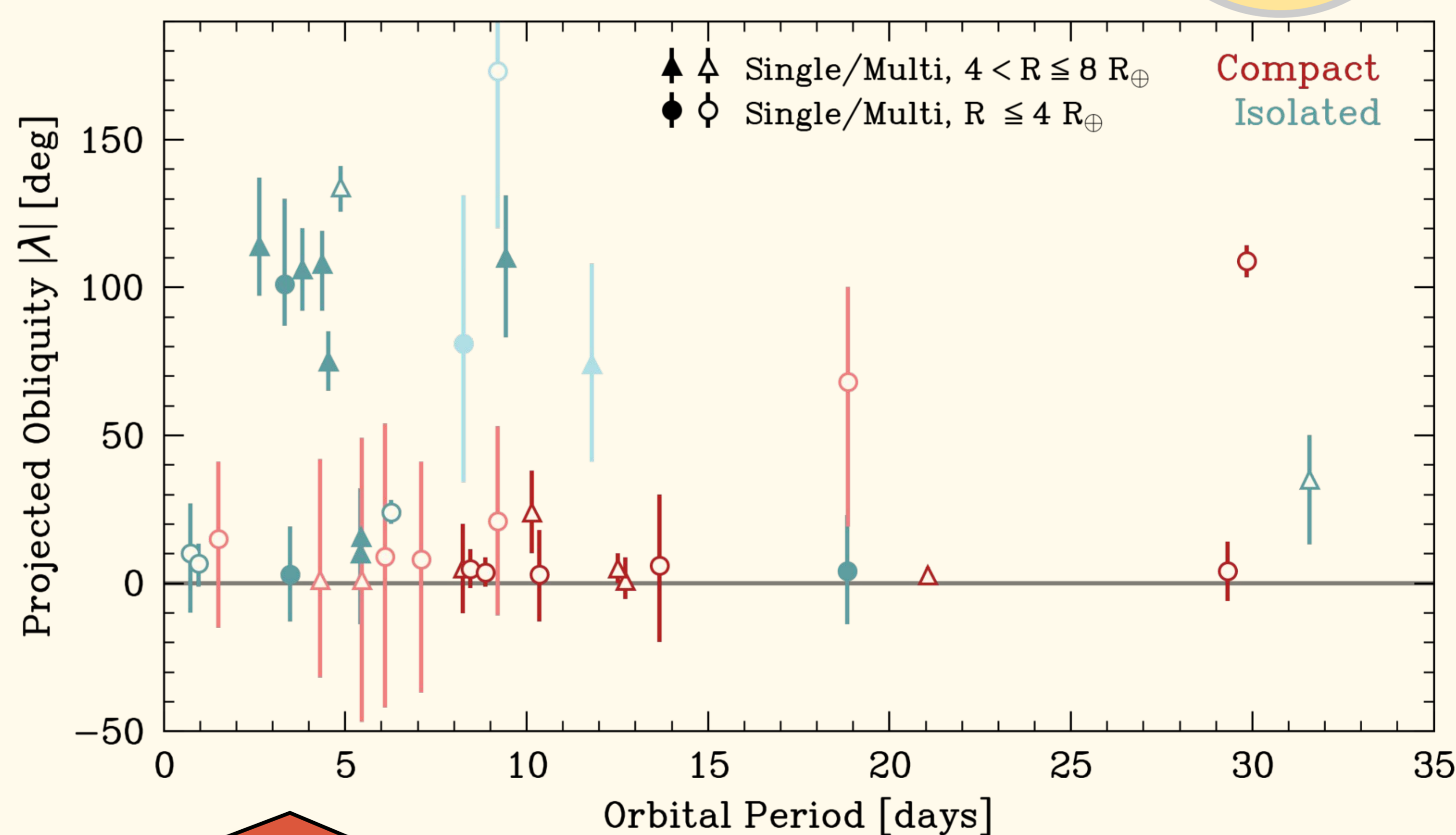
FOR RM VISUALIZATION RESOURCES, VISIT MY WEBSITE!



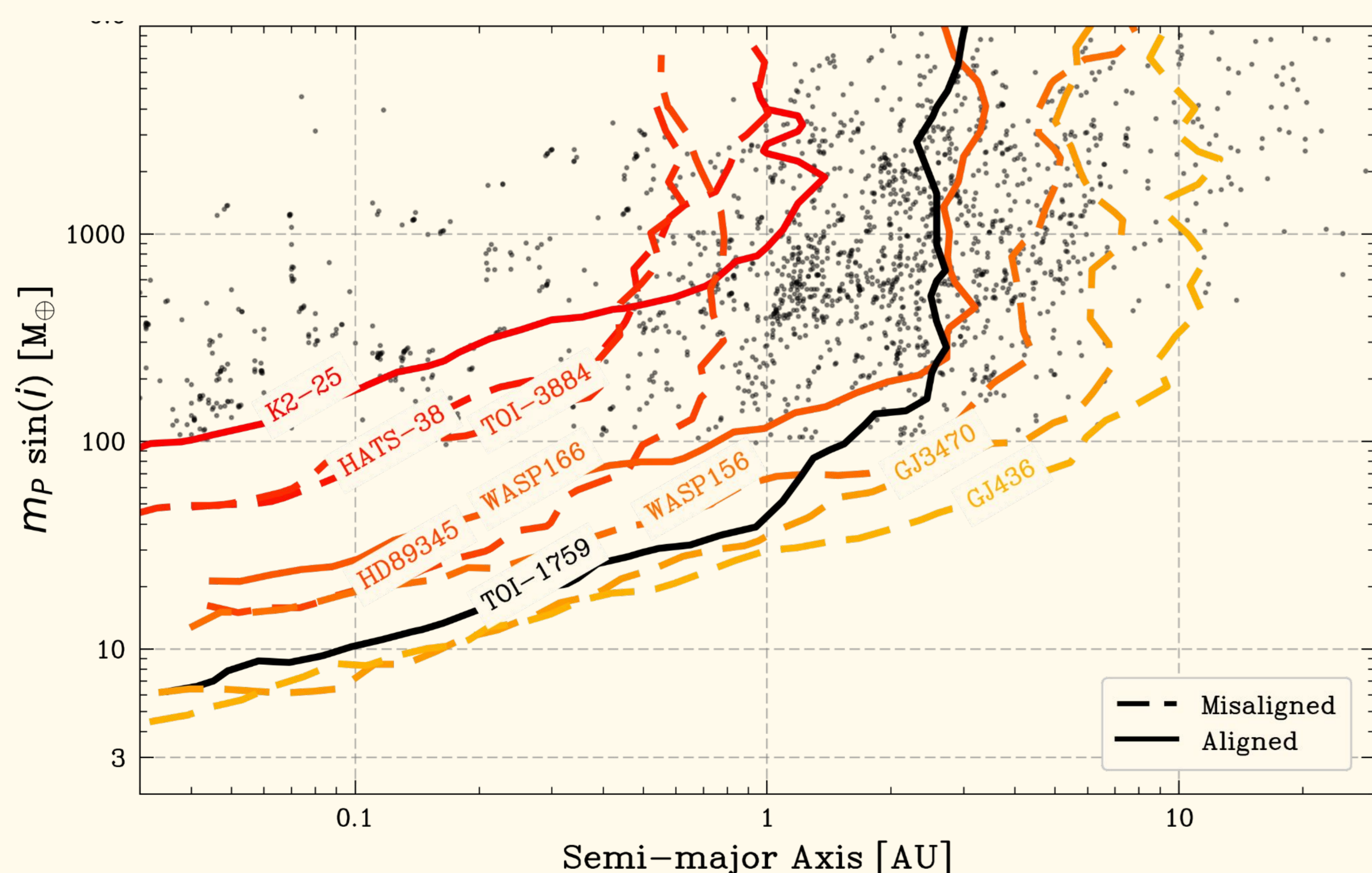
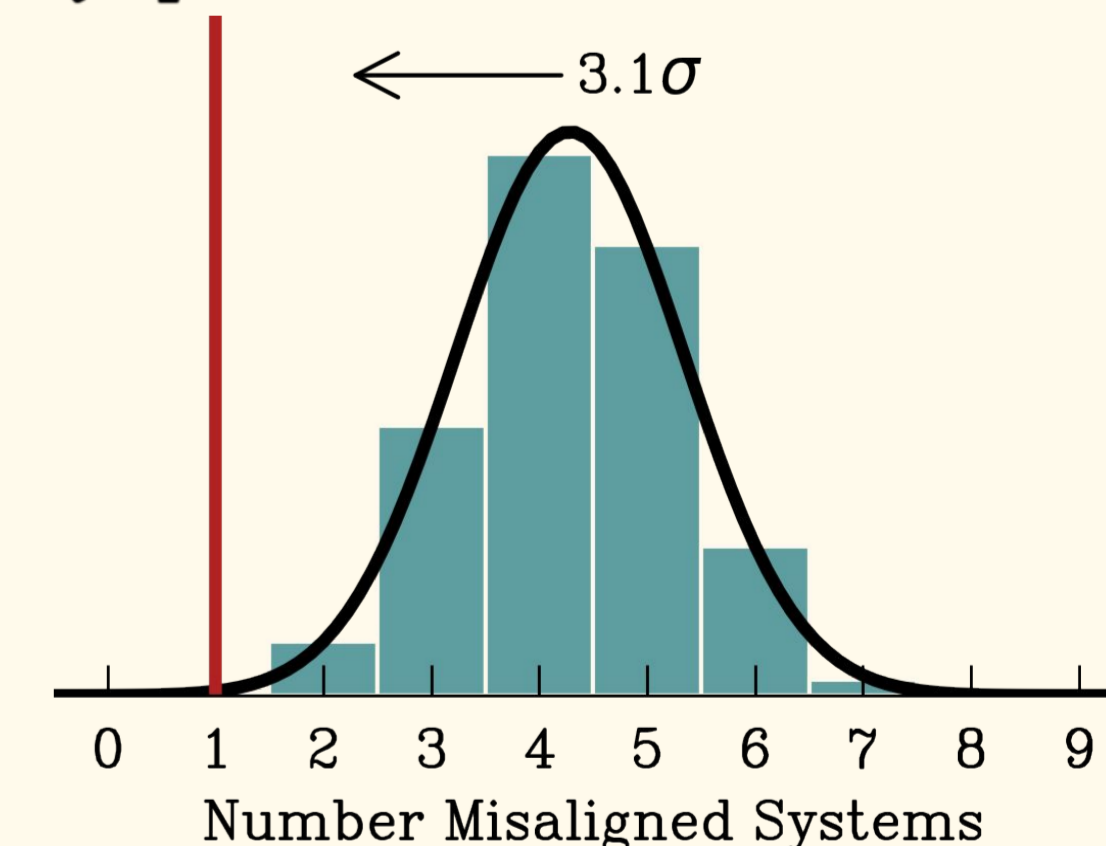
The TEPCAT shows the number of sub-Jovian ( $R < 8 R_{\oplus}$ ) obliquities is steadily growing, with nearly 40 measurements. Roughly  $\frac{2}{3}$  of these planets are closer to alignment, with many of these being sub-Neptune-sized and residing in multiplanet systems. We also see the “preponderance of polar planets” noted in previous works. Radzom et al. 2024 show that sub-Saturn planets tend to be misaligned when they lack adjacent planets within a period ratio of 4 (isolated). Here we extend that analysis to include the sub-Neptunes and super-Earths with an obliquity measurement.

**COMPACT**

**ISOLATED**



Projected obliquity vs orbital period for all planets  $R < 8 R_{\oplus}$  with measured  $\lambda$ , split into isolated and compact populations. Planets with significant misalignment are more likely to be isolated, a result that includes sub-Neptunes as well. We sample the misaligned population with replacement and find that our result is robust to  $\sim 3\sigma$  implying compact systems help keep planets aligned.



The existence of polar planets with giant companions, such as HAT-P-11 b and WASP-107 b, has supported the idea of secular interactions to excite their obliquities. However, many polar planets are in single-planet systems. We use archival RVs to set limits on possible perturbing companions in these systems.

Injection and recovery tests for single-planet systems using archival radial velocities. Black points represent known Jovians. In some cases, archival data is sufficient to detect a Jupiter-mass companion out to a few AU. For many systems however, they lack the continuous monitoring needed to detect companions that may explain their high obliquities.

TRAPPIST-1

We acknowledge the significance Mauna Kea has to indigenous Hawaiians and are grateful to be able to conduct observations from this mountain.

