Science Highlights and Progress Towards the 10 cm/s Threshold from the NEID Earth Twin Survey

Paul Robertson, on behalf of the NEID Team

NEID Basics

Telescope: WIYN 3.5m Telescope @ KPNO

Waveband & Resolution: Near UV → Near IR @ R~115K

Measurement Precision: <50 cm/s (specified)

Science Operations Since: July 2021

Telescope Scheduling: Queue

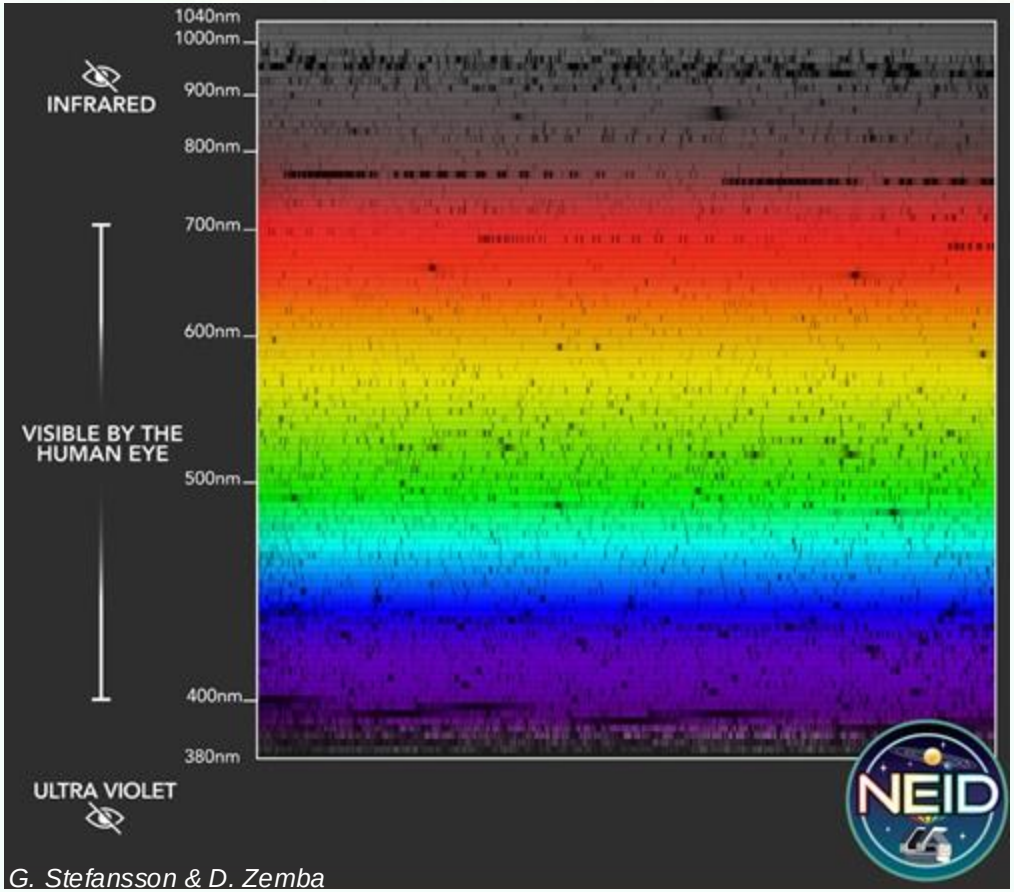
Two Observing Modes:

- High Resolution (R~115,000)

  Highest precision RVs on bright targets (V<12)
  Simultaneous Cal

- High Efficiency (R~60,000)

  Faint targets (V<16)
  Poor weather



The NEID Team

NEID Architects

Chad Bender, Cullen Blake, Scott Diddams, Taran Esplin, Qian Gong, Arvind Gupta, Samuel Halverson, Fred Hearty (PM), Shubham Kanodia, Kyle Kaplan, Daniel Krolikowski, Dan Li, Andrea Lin, Sarah Logsdon (IS), Emily Lubar, Suvrath Mahadevan (PI), Michael McElwain, Andrew Monson (SE), Joe Ninan, Colin Nitroy, Leonardo Paredes, Jayadev Rajagopal, Lawrence Ramsey, Paul Robertson (PS), Arpita Roy, Christian Schwab, Gudmundur Stefansson, Ryan Terrien, Jason Wright

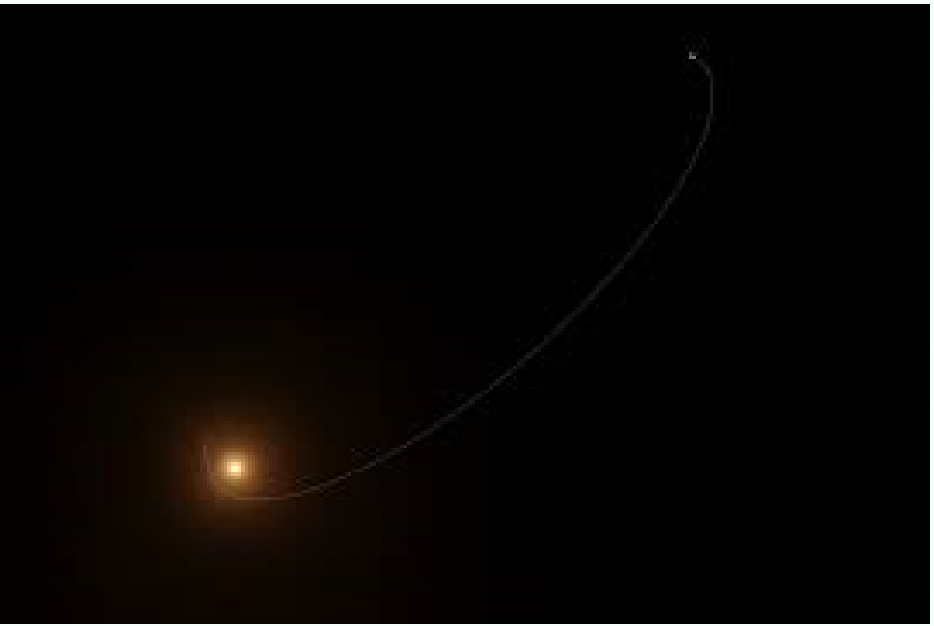
NEID Builders

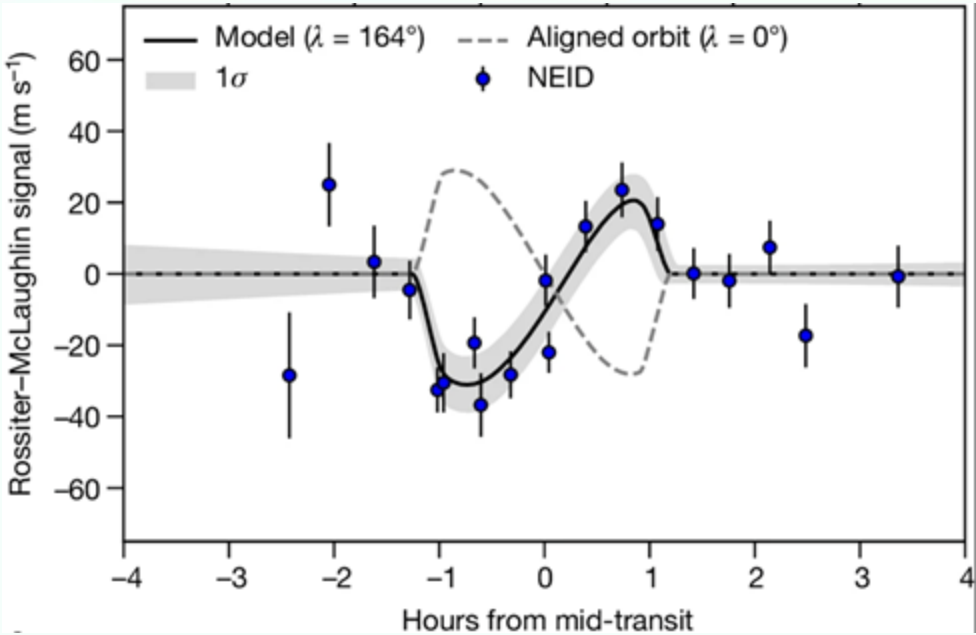
Lori Allen, David Ardila, John Callas, Sean Carey, Robert Christensen, Emily Hunting, Kurt Jaehnig, Ming Liang, Sai Mannan, Robert Marshall, Jeffrey Percival, Noah Rivera, Fernando Santoro, Heidi Schweiker, Michael Smith, Erik Timmerman, Marsha Wolf

NEID Science Team

Corey Beard, Thomas Beatty, Caleb Cañas, Abhijit Chakraborty, Rebekah Dawson, Megan Delamer, Jiayin Dong, Rachel Fernandes, Evan Fitzmaurice, Eric Ford, BJ Fulton, Christian Gilbertson, Mark Giovinazzi, Elizabeth Gonzalez, Te Han, Rae Holcomb, Elise Koo, Jonathan Jackson, Ravi Kopparapu, Jessica Libby-Roberts, Jack Lubin, Jacob Luhn, Kristo Ment, Jaime Montes, Michael Palumbo, Winter Parts, Jacob Pember, Pranav Premnath, Christian Robles, Claire Rogers, Emily Safsten, Dan Stevens, Suhani Surana, Blaise Tiong, Nick Tusay, Sharon Wang, Alex Wise, Jinglin Zhao

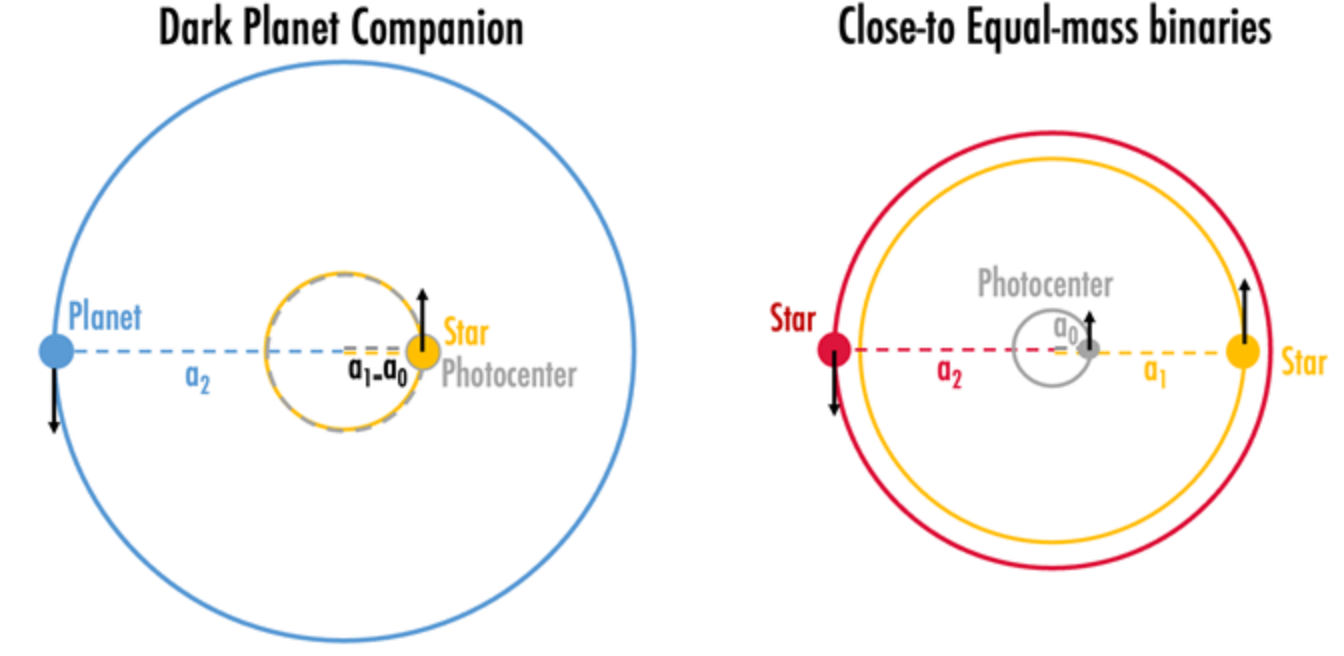
Science Highlights: Planet Migration in Progress





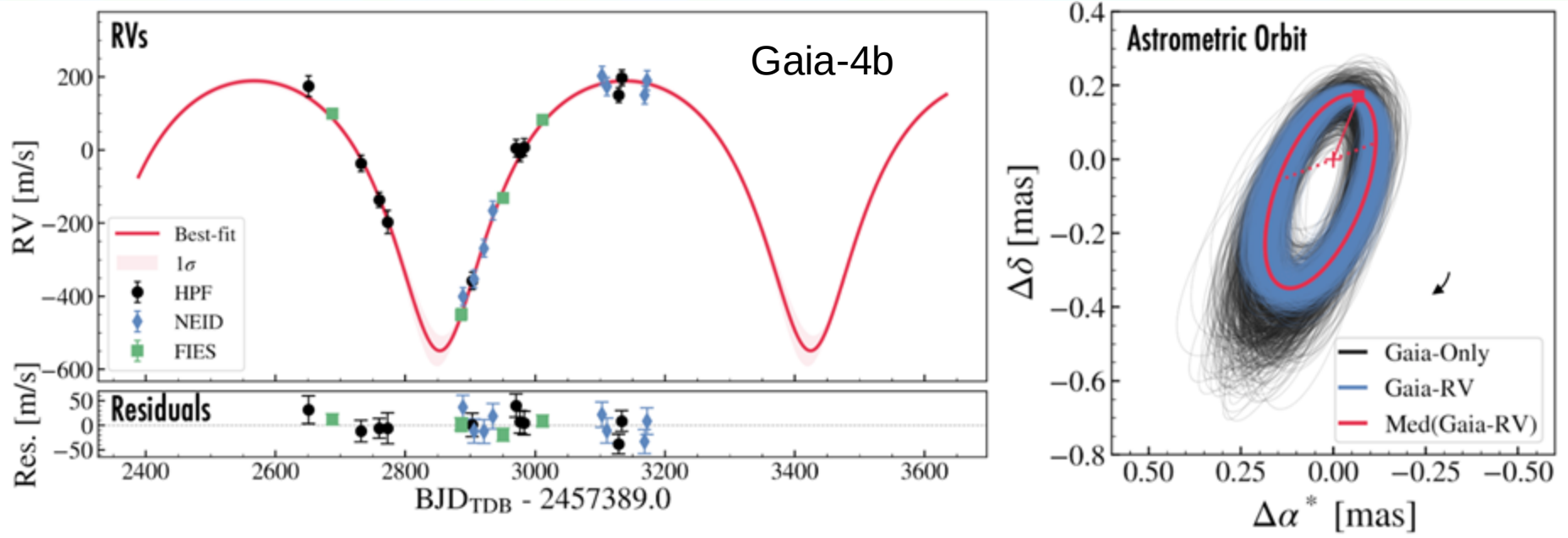
TIC 241249530b: single-transiting TESS exoplanet recovered w/ queue-scheduled NEID observations. Most eccentric transiting planet, retrograde orbit! (Gupta et al., *Nature*, 2024a; video credit: Abigail Minnich, PSU)

Science Highlights: Gaia + NEID



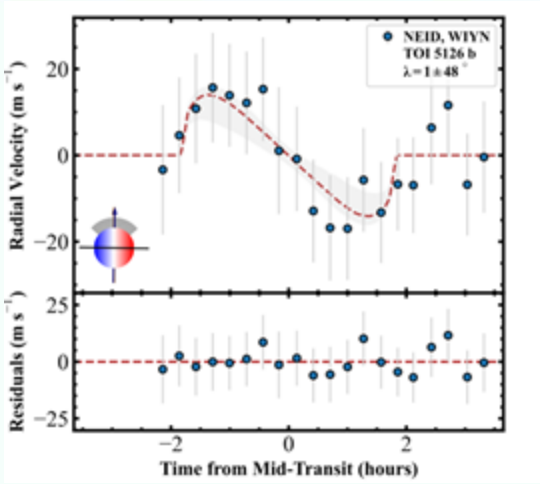
Astrometric exoplanet detections are subject to false positives from near-equal-mass binaries; RVs are required to confirm discoveries.

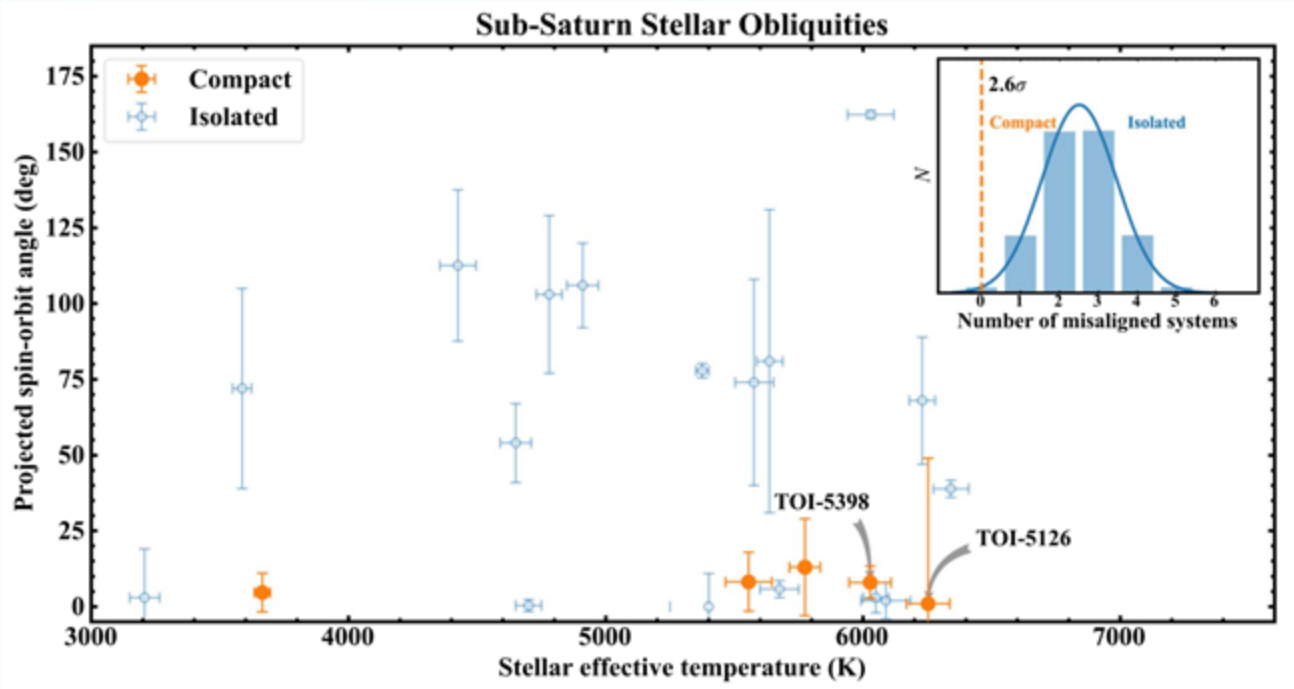
Science Highlights: Gaia + NEID



Precise, queue-scheduled NEID RVs confirming the **first astrometric exoplanet discoveries** from Gaia (Stefansson et al. 2025, in press)!

Science Highlights: The Origins of Obliquity





Statistical samples of obliquity measurements offer insight into exoplanet orbital evolution (Radzom et al. 2024).

The NEID Earth Twin Survey (NETS)

GTO program led by the NEID instrument team. High-cadence observations of bright, quiet nearby stars to detect terrestrial-mass exoplanets.

Target list & selection function described in Gupta et al. 2021

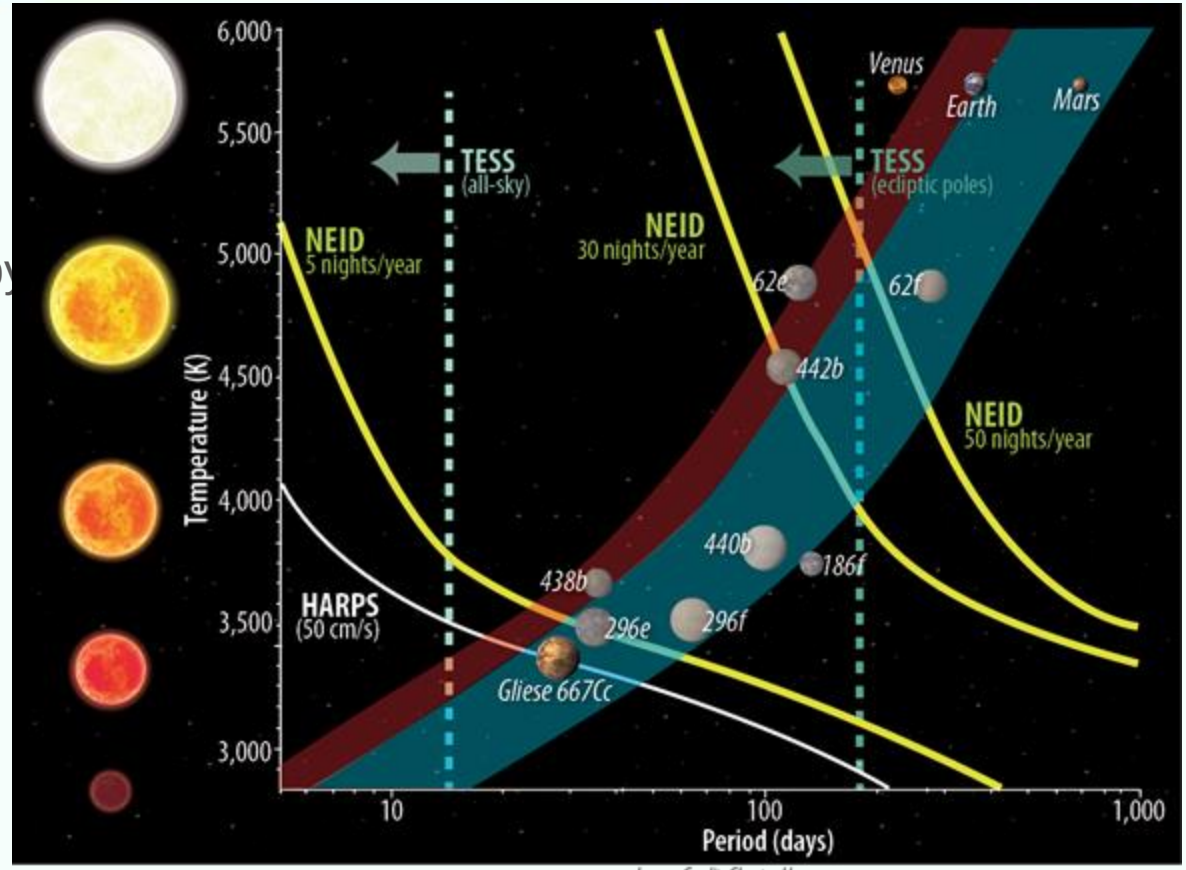
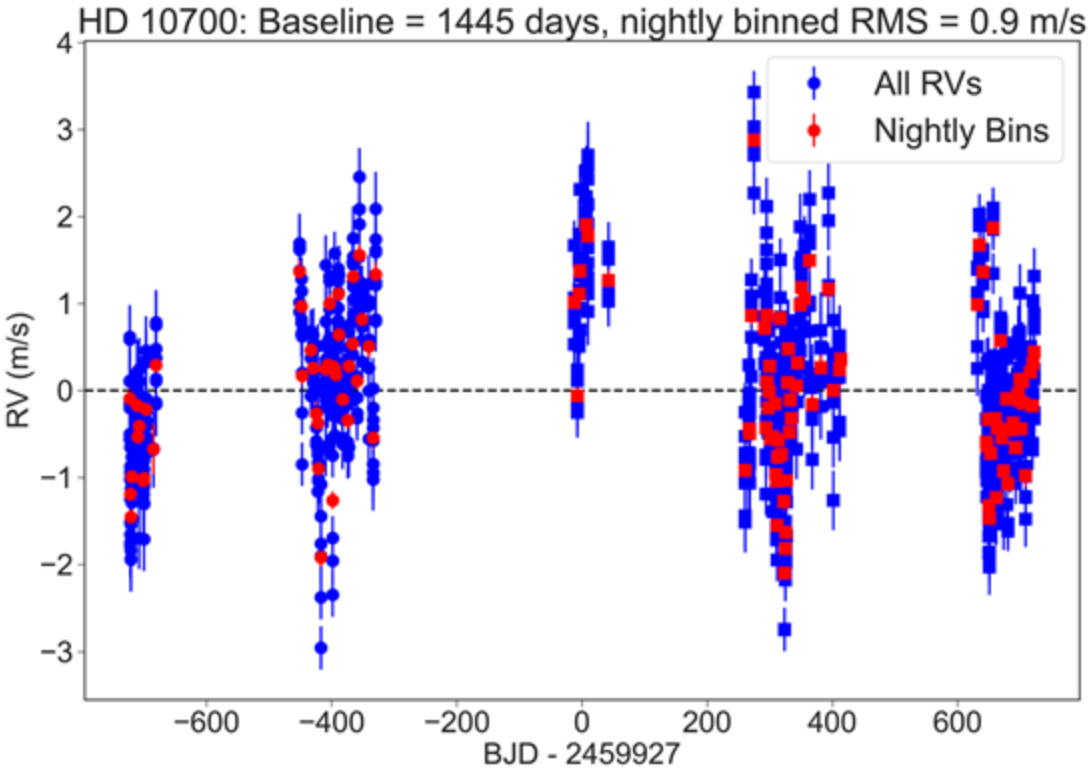


Image Credit: Chester Harman

Flat-line highlights: tau Ceti

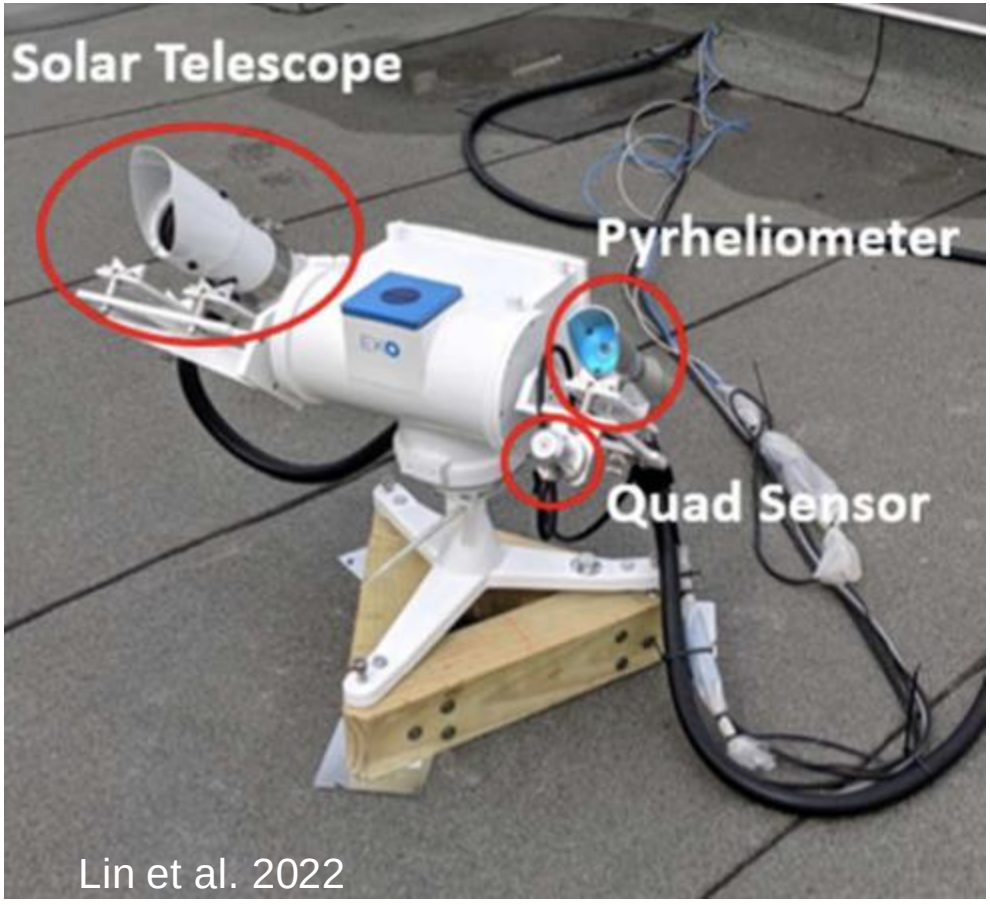


On-sky stability (instrument + star) < 1 m/s over ~1500 days!

RVs presented with *only* a SNR cut and a zero-point offset.

RMS has *decreased* by 10% over the past year. Benefits of continued pipeline improvement; DRP 1.4 just released!

The NEID Solar Telescope

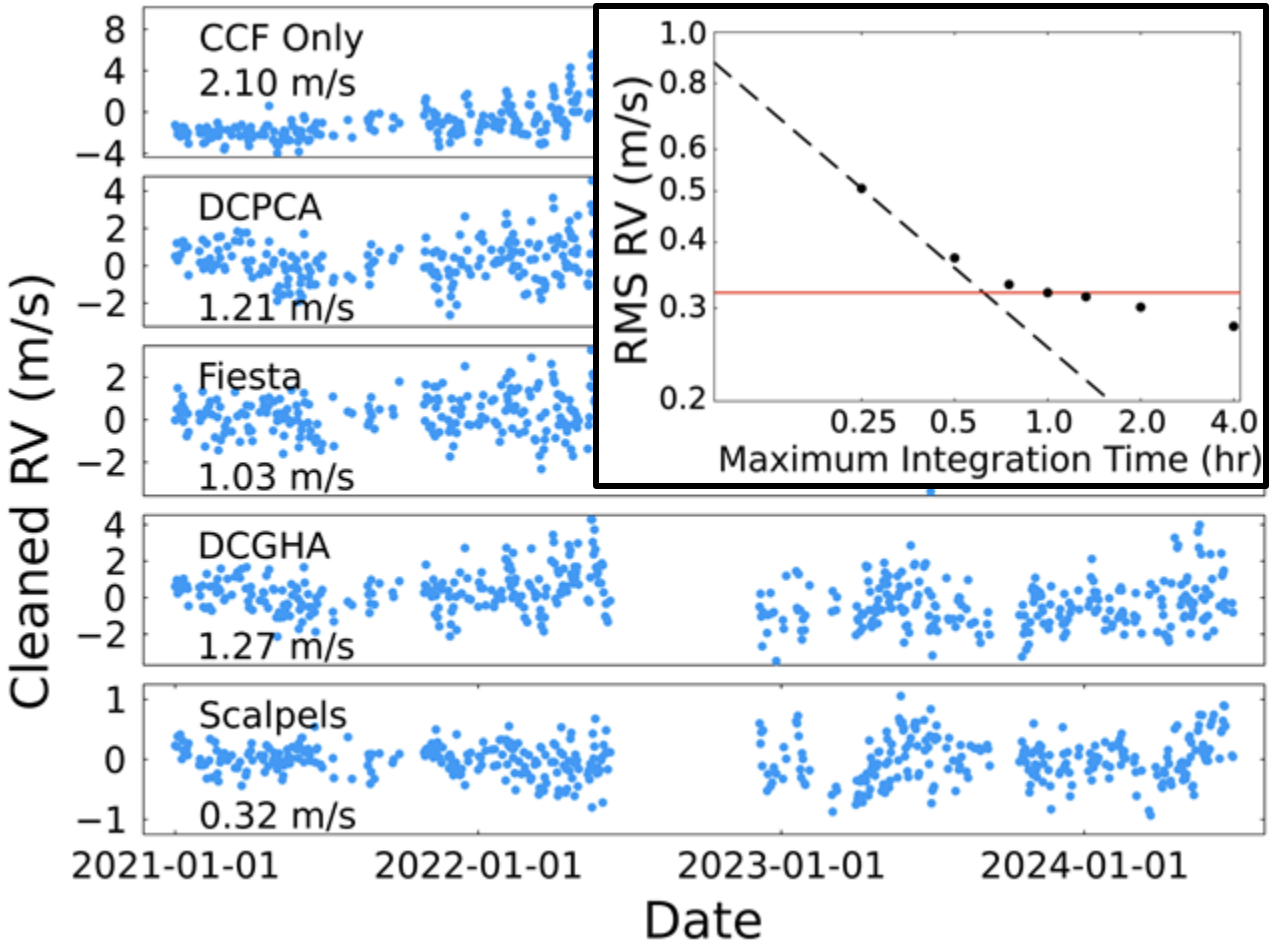


Lin et al. 2022

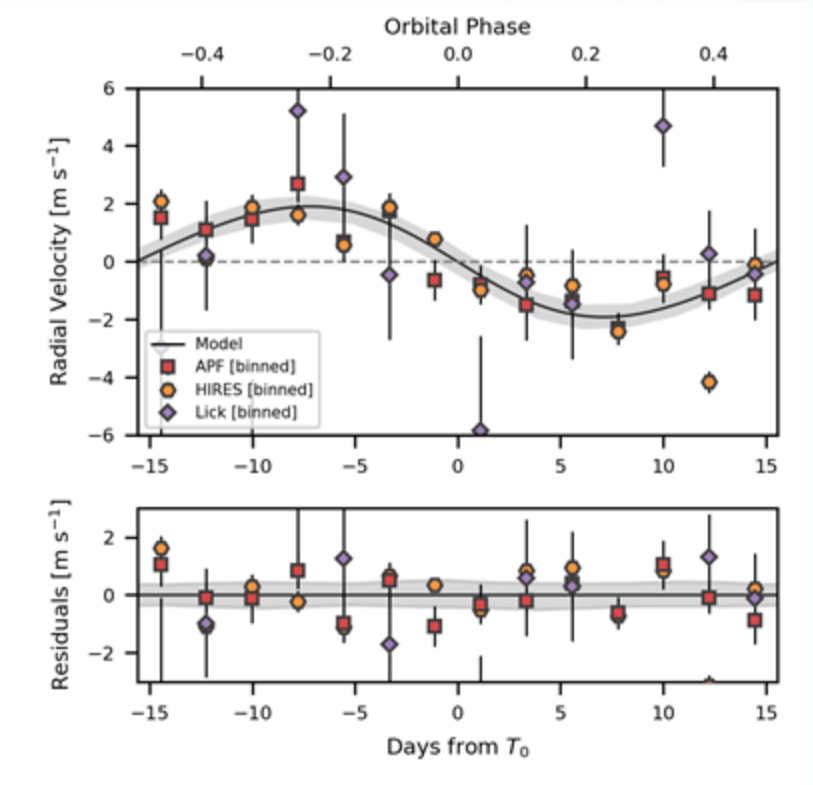
Pushing Through the Jitter Barrier

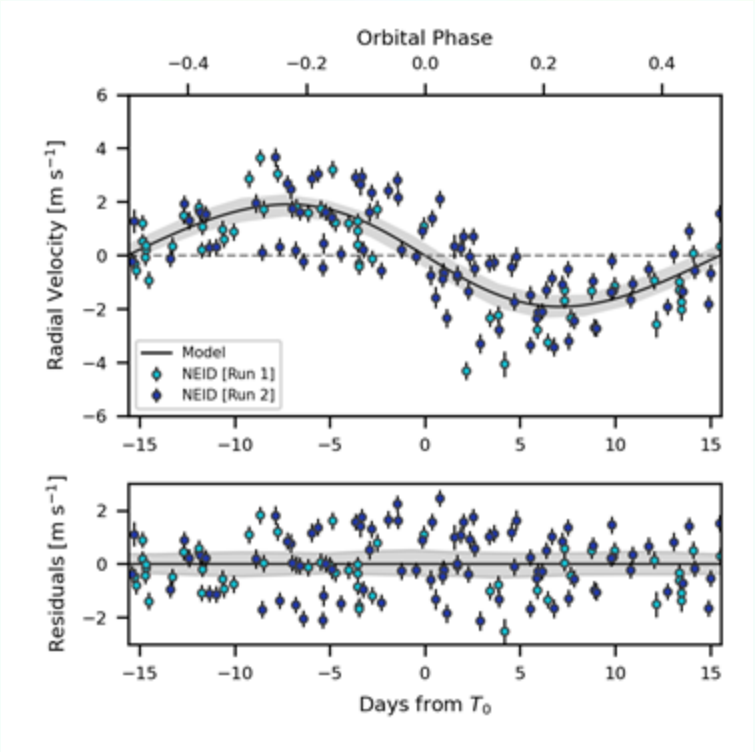
Scalpels: spectral shape analysis technique which isolates shifts from pure translation vs. line shape changes (Collier-Cameron et al. 2021).

Applied to Solar RVs, reduces RV scatter to near measurement uncertainty (Ford et al. 2025, submitted).



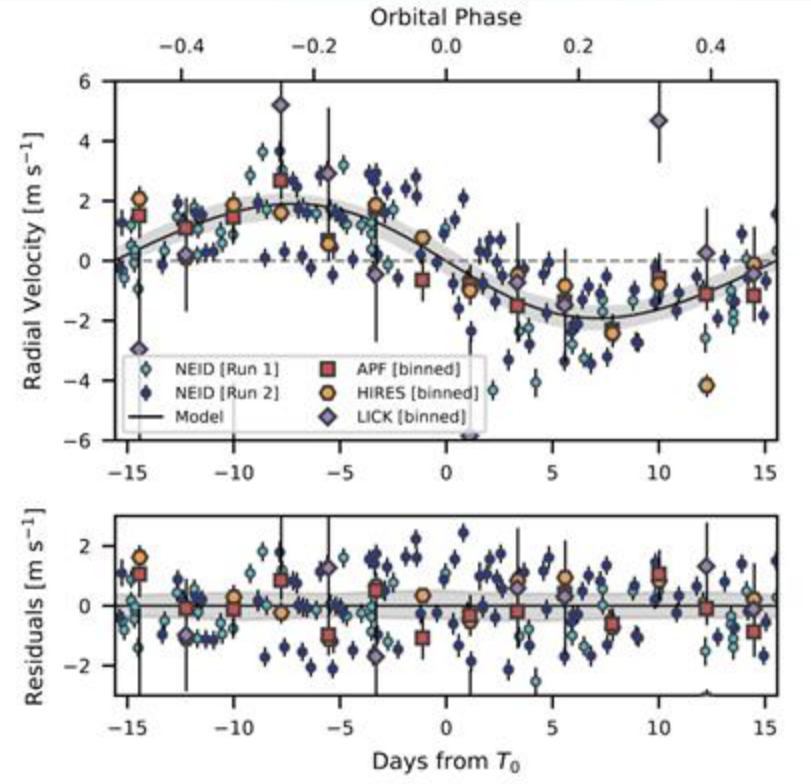
The First NETS Exoplanet: HD 86728b

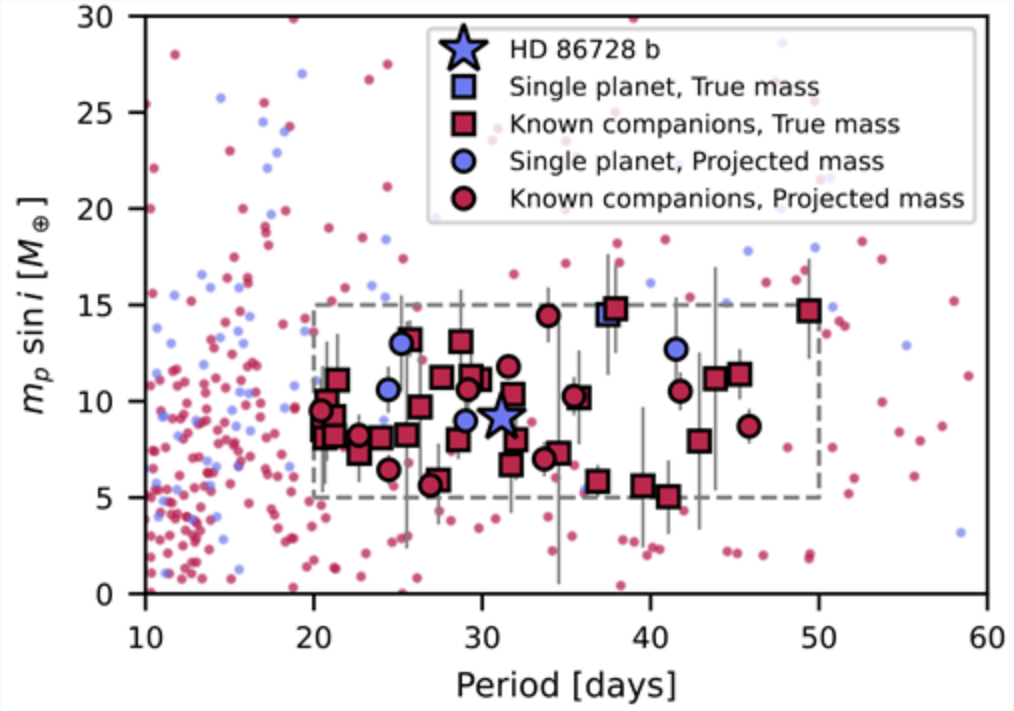




Ultra-precise NEID RVs elevate an archival candidate to a highly confident detection (Gupta et al. 2024b).

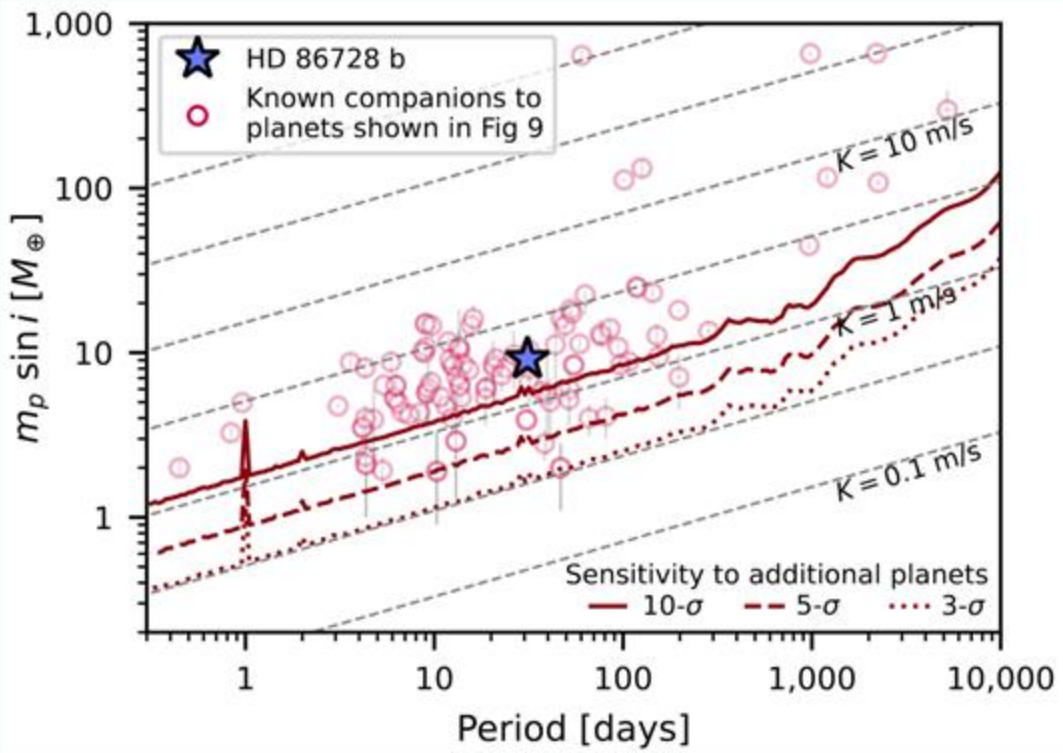
The First NETS Exoplanet: HD 86728b





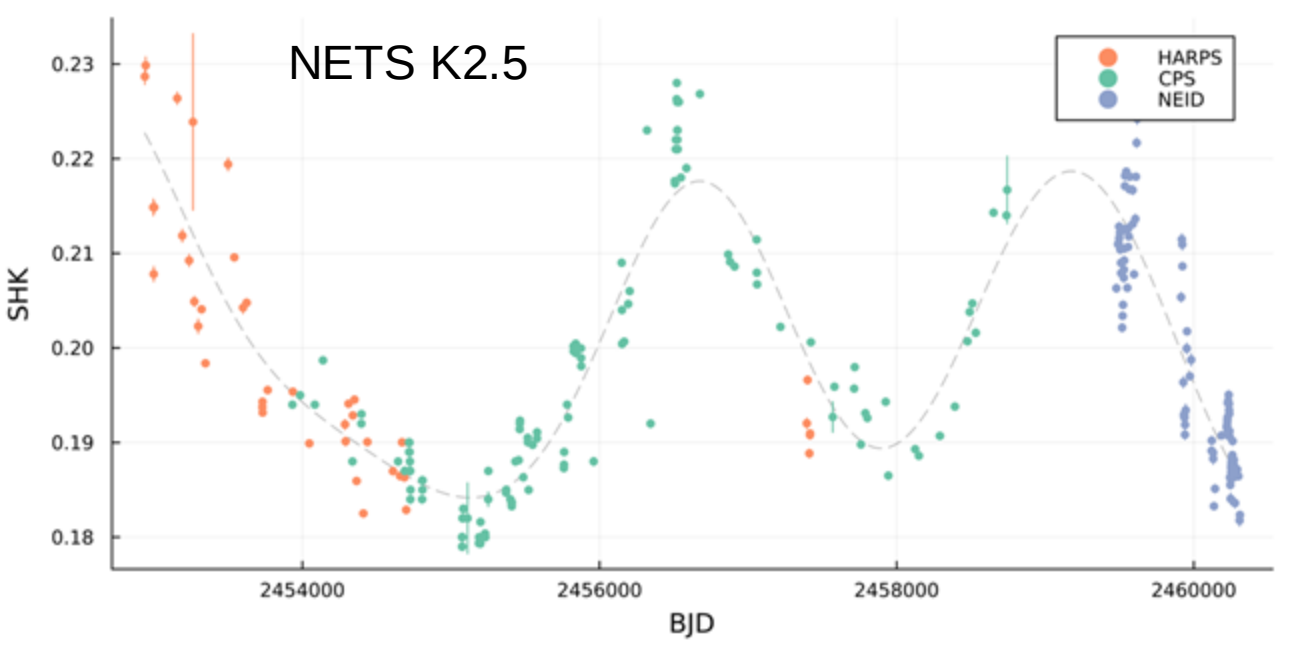
Ultra-precise NEID RVs elevate an archival candidate to a highly confident detection (Gupta et al. 2024b).

The First NETS Exoplanet: HD 86728b



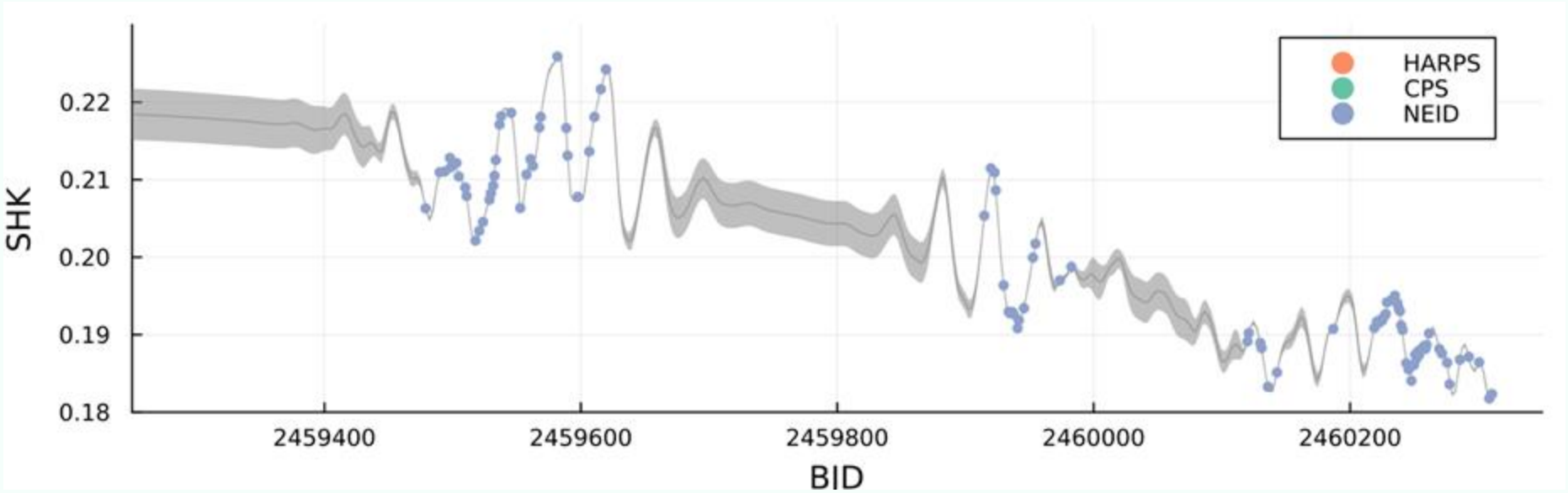
Ultra-precise NEID RVs elevate an archival candidate to a highly confident detection (Gupta et al. 2024b).

Astrophysical Insight on Jitter



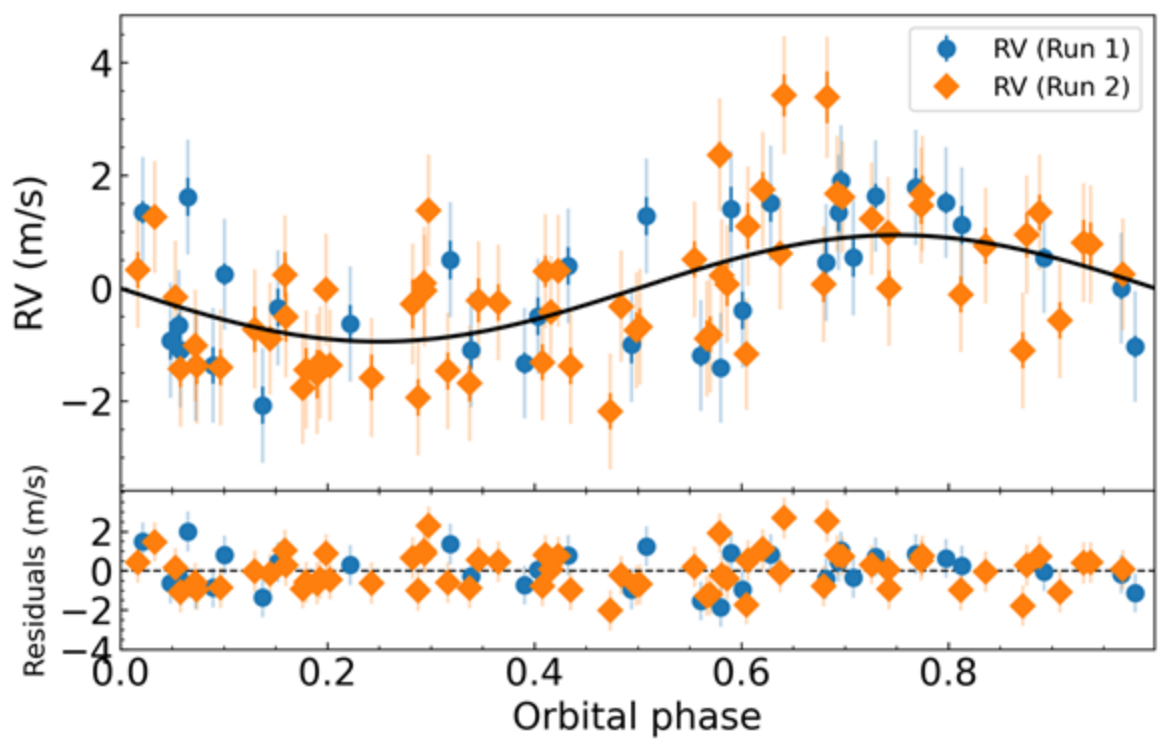
Stable instrument, multiple high-SNR activity indicators facilitate a plethora of options for mitigating jitter (e.g. Burrows+ 2024, Gilbertson+ 2024, Siegel+ 2024, Beard+ 2024).

Astrophysical Insight on Jitter



Stable instrument, multiple high-SNR activity indicators facilitate a plethora of options for mitigating jitter (e.g. Burrows+ 2024, Gilbertson+ 2024, Siegel+ 2024, Beard+ 2024).

New Planets Incoming!



Stable instrument, multiple high-SNR activity indicators facilitate a plethora of options for mitigating jitter–which enables exoplanet discoveries!

Lessons Learned from NEID and NETS

- NEID's excellent stability and queue-scheduled observing are enabling transformative science across the exoplanet research spectrum.
- The jitter barrier is tractable with sufficient SNR, cadence, and analysis techniques.
- The NETS survey is producing exoplanet discoveries, and meaningful limits, with more to come.
- **With significant investments of time, discoveries at the 10 cm/s level are accessible!**

Lessons Learned from NEID and NETS

The 50 cm/s threshold has clearly been broken for the Sun, with evidence growing that this is the case for other stars.

The 10 cm/s threshold may be within reach already. Determining for sure will require significant amounts of telescope time to:

- Reduce photon noise
- Increase raw detection sensitivity
- Extend time baselines.

Earth Twins are within reach, even with the current spectrometer generation!

Backup slides

NETS cadence