



Jet Propulsion Laboratory
California Institute of Technology

NN-EXPLORE

NASA-NSF Exoplanet Observational Research

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Presented to the NASA Exoplanet Analysis Group (ExoPAG)

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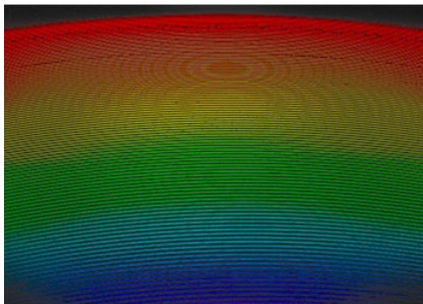
WIYN/NEID and Guest Observing (GO)

The NEID spectrograph is commissioned on the 3.5-meter WIYN telescope on Kitt Peak, Arizona with opportunities for guest observing on WIYN.



Southern RV Observing Opportunities

Radial velocity observing time in the southern hemisphere is available for US institutions on SMARTS/Chiron and MINERVA-Australis.



NASA-NSF EPRV Initiative

NASA and NSF are pursuing a new effort in Extreme-Precision Radial Velocity (EPRV).

NN-EXPLORE (NEID)



ExoPlanet Exploration Program

- NN-EXPLORE established with 2015 addendum (entitled “*Use of the WIYN Telescope for the NASA-NSF Partnership for Exoplanet Observational Research*”) to the 2008 Memorandum of Agreement (MOA) on Space, Earth, and Biological Sciences Cooperative Activities between NSF and NASA.
 - NASA
 - Funded the development of the NEID spectrograph, telescope port adapter, and facility modifications.
 - Funds the instrument operations and maintenance, the Guest Observer (GO) and Guaranteed-Time Observing (GTO) programs, and the data processing and data archive.
 - NSF
 - Provides the 40%-time of WIYN (~120 nights/year) for NN-EXPLORE.
 - Funds telescope operations and maintenance.
 - Operates the time allocation committee (TAC) for all proposals.

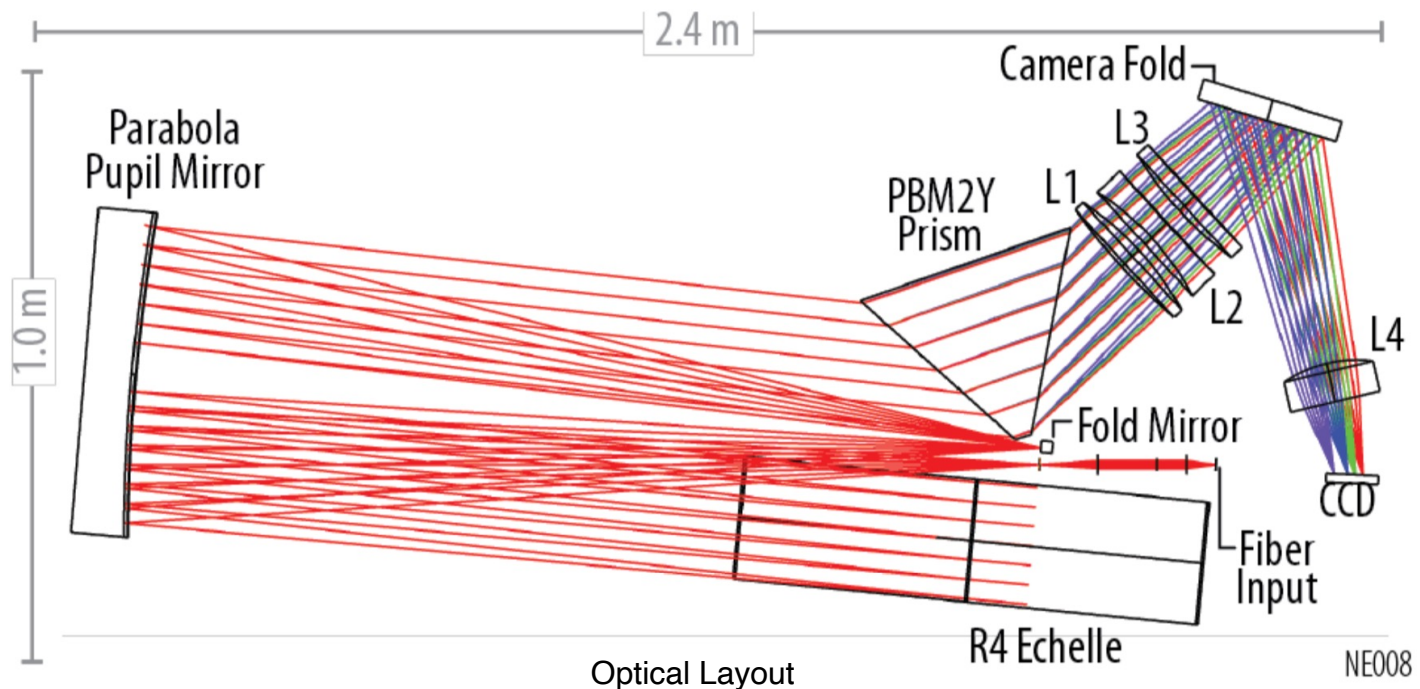
For NN-EXPLORE GO opportunities see:

<https://noirlab.edu/science/observing-noirlab/proposals/call-for-proposals>

NEID Spectrograph

NEID - NN-EXPLORE Exoplanet Ivestigations with Doppler Spectroscopy (O'odham for "to discover/visualize")

- Precision radial velocity of **~27 cm/s**
- **380 nm - 930 nm** bandwidth (RV coverage for F-M stars and stellar activity indicators)
- $R = 100,000$ spectral resolution of bright ($V < 12$) stars
- e2v 9k x 9k CCD with $10 \mu\text{m}$ pixels
- **Environmental chamber with $P < 10^{-7}$ torr and $\Delta T < \pm 1$ mKelvin**
- **Laser Frequency Comb calibration**



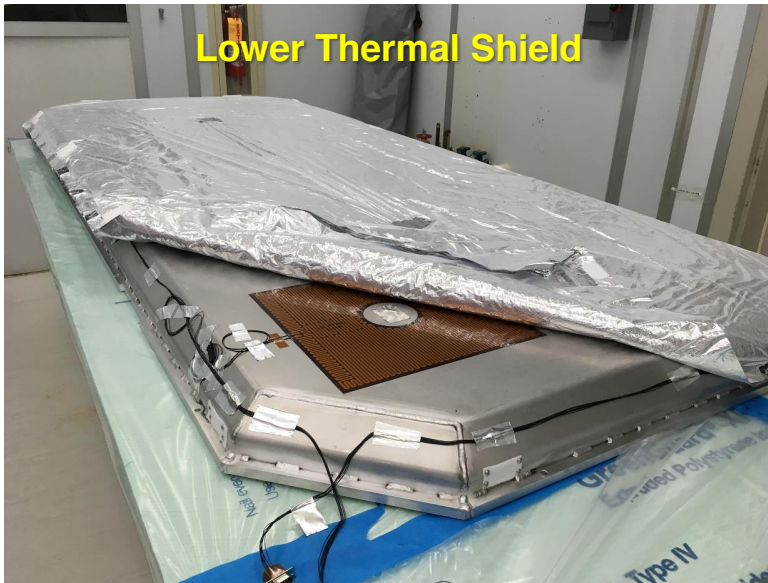
NEID Chamber



MLI Blanket Fit-Up



Lower Hood and LN2 Tank Assembly



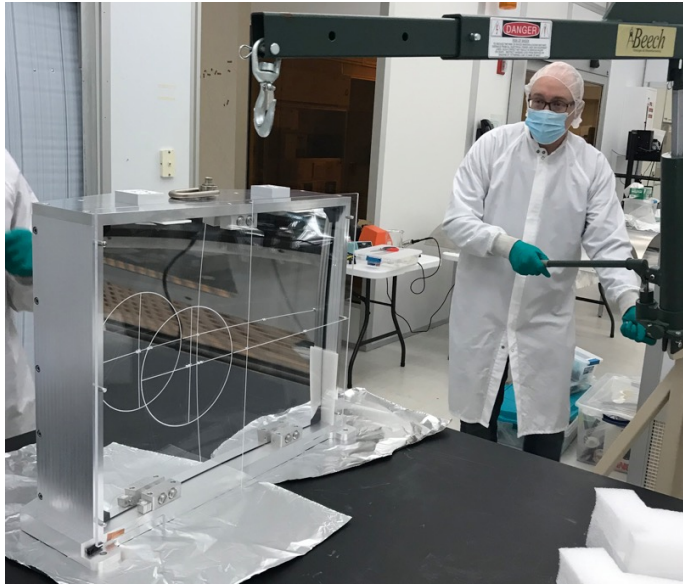
Lower Thermal Shield



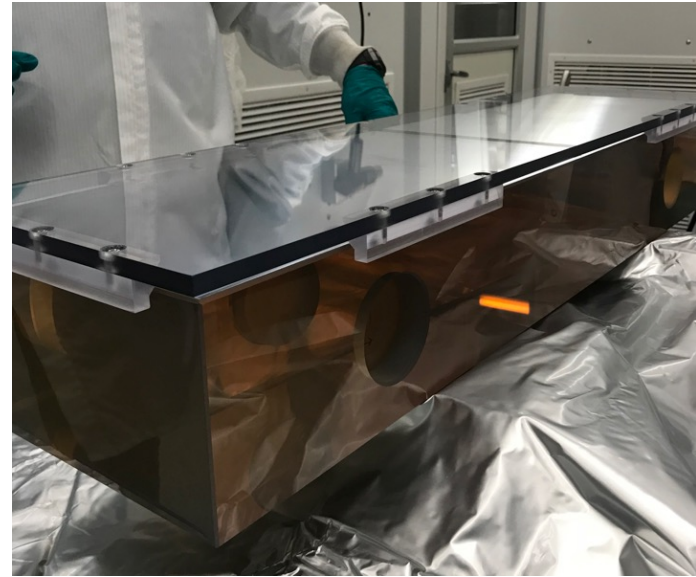
NEID Chamber

NEID Large Optics

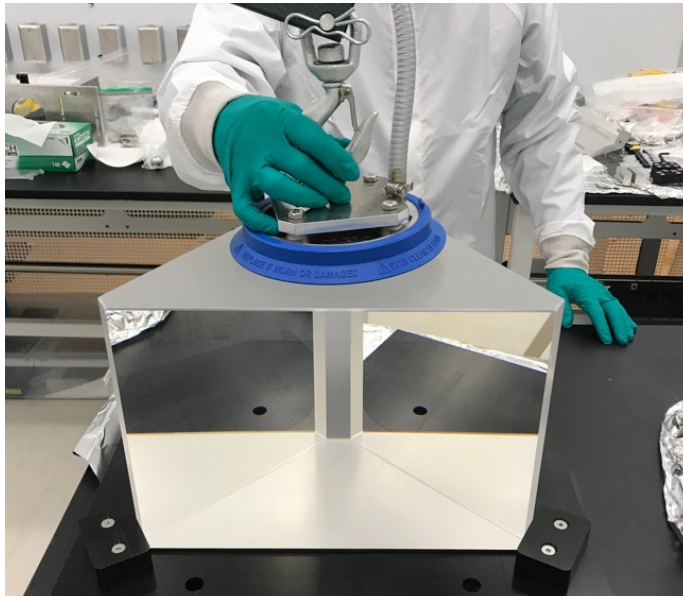
Off-Axis
Paraboloid



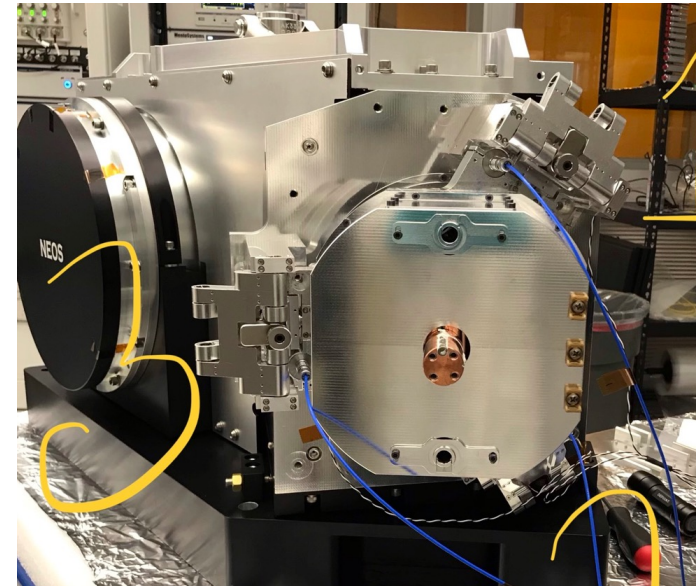
Echelle
Grating



Prism



Camera



NEID Spectrograph



WIYN 3.5-m at Kitt Peak



ExoPlanet Exploration Program



Facility Refurbishment at WIYN



ExoPlanet Exploration Program



**New cleanroom facilities
for the spectrograph and
calibration system**



**Extensive new HVAC
system for stable
environmental control**

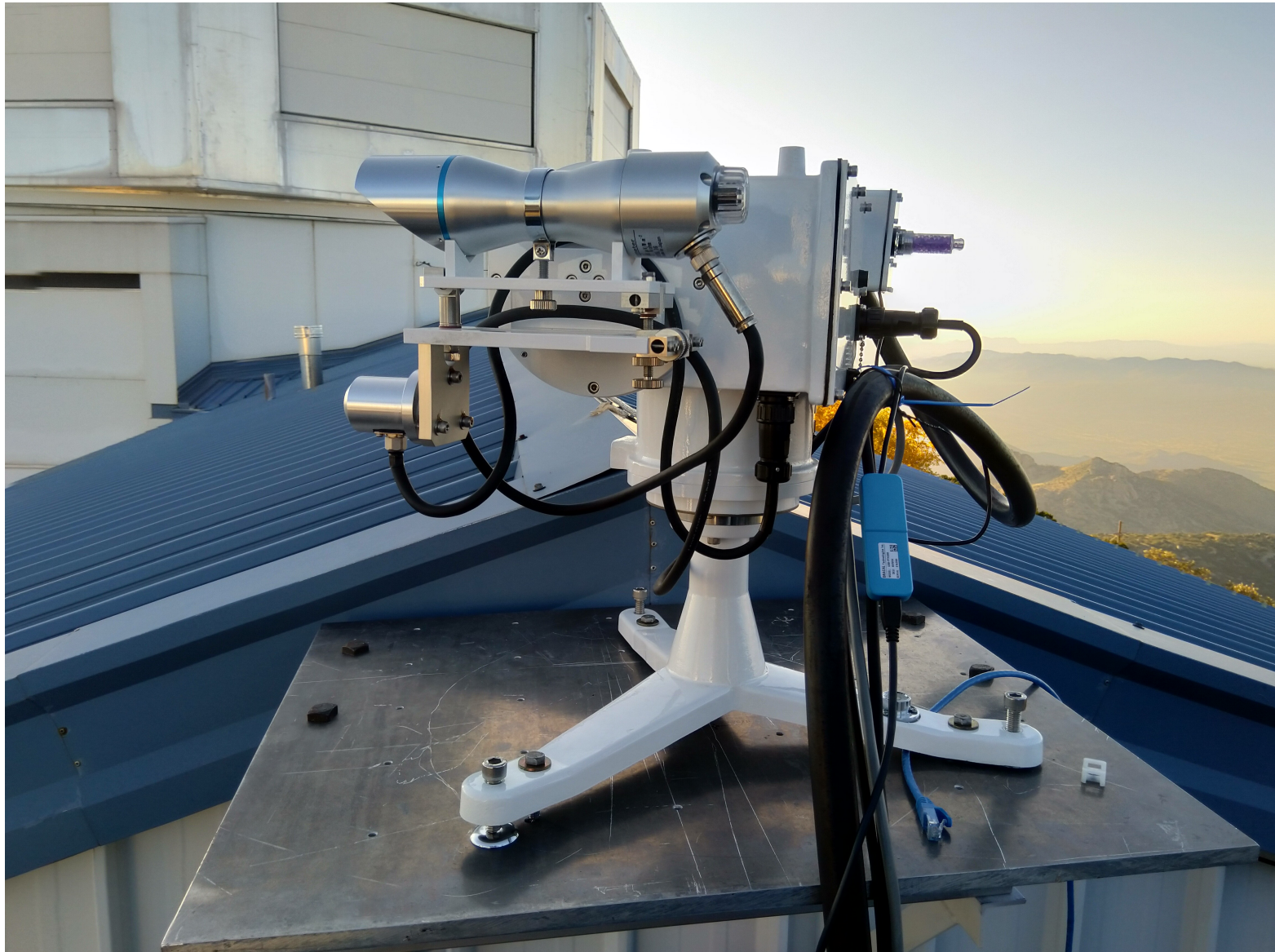
WIYN Telescope Port Adapter



NEID Solar Telescope



ExoPlanet Exploration Program



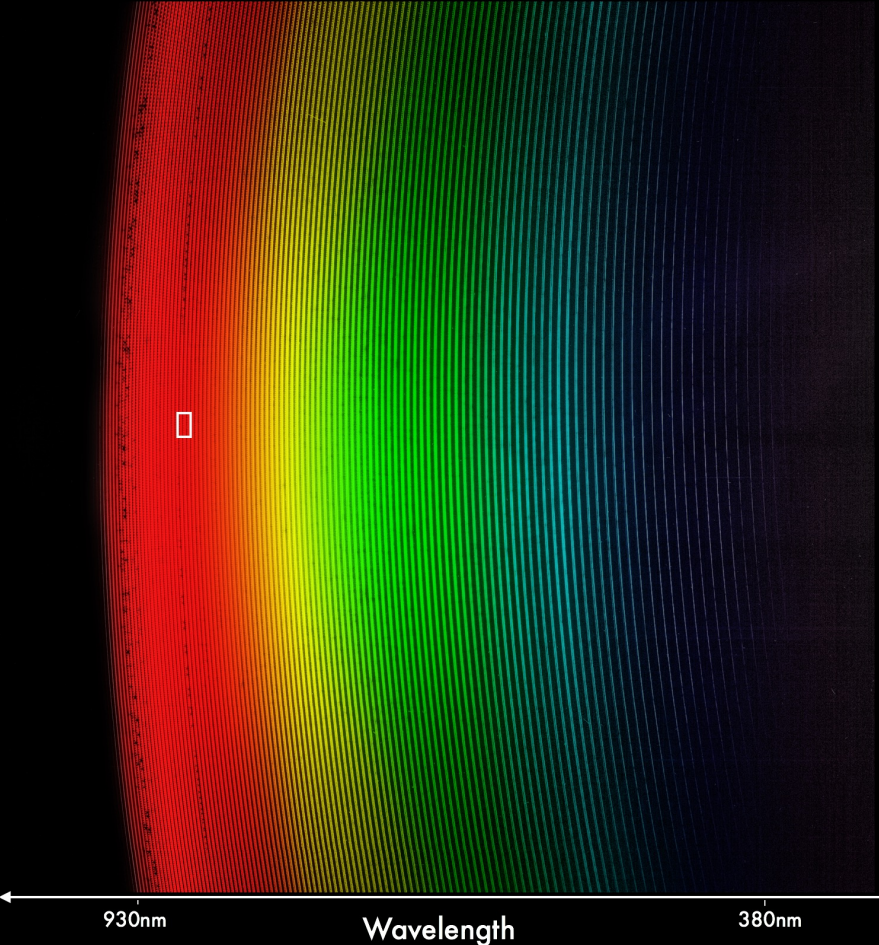
NEID First Light



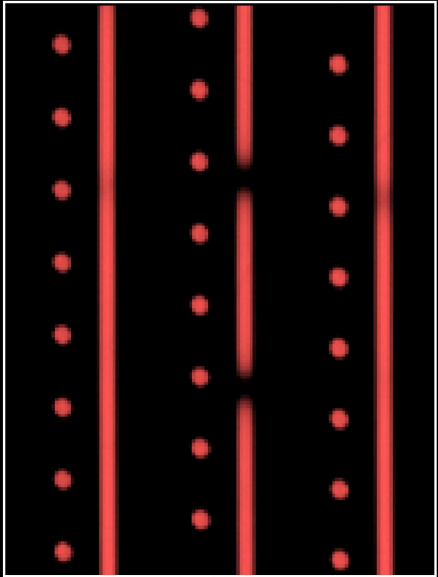
ExoPlanet Exploration Program



NEID First Light: 51 Pegasi



NEID Order Trace



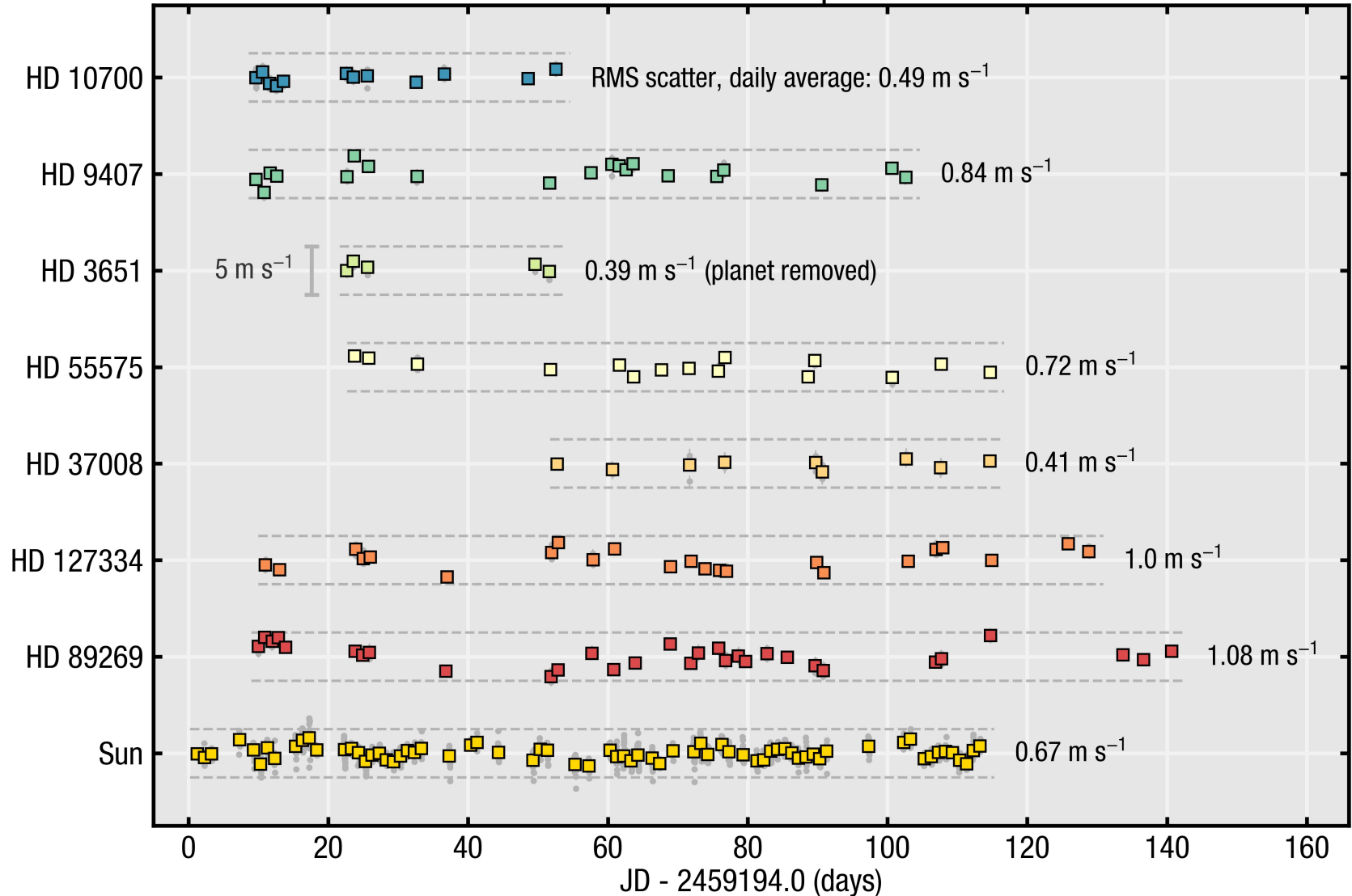
Calibration
Science
Sky

NEID Commissioning Performance



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NEID RV standard star performance



NEID Papers Already



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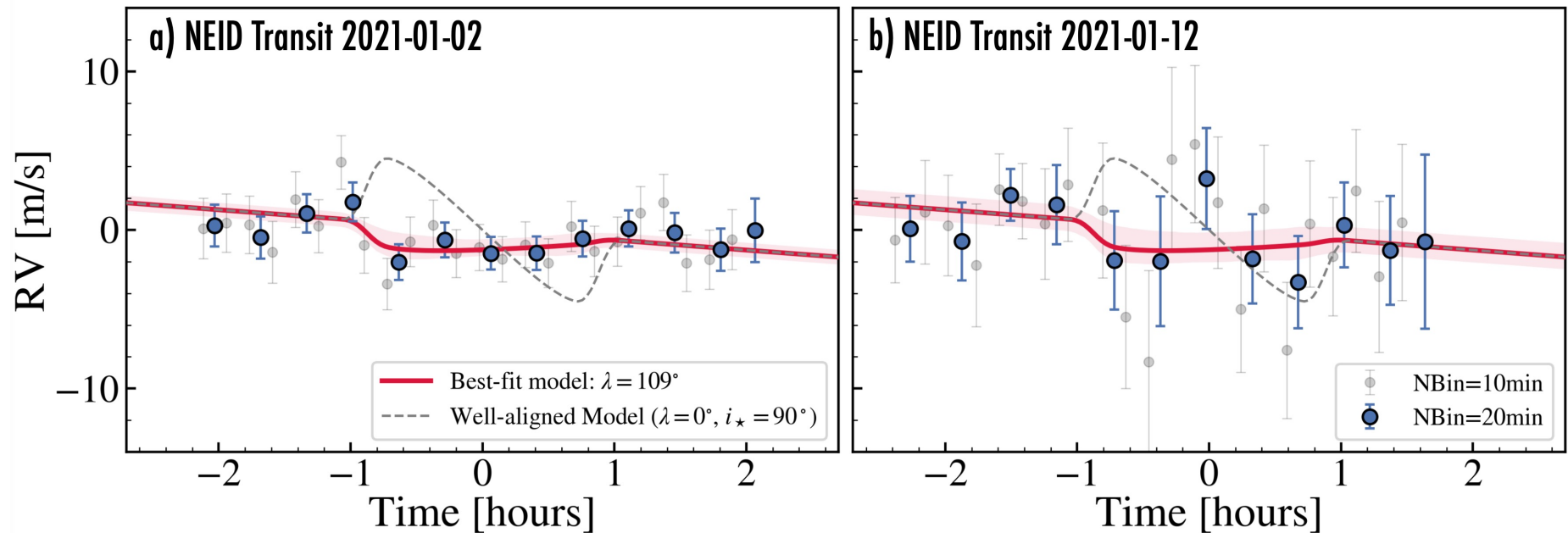
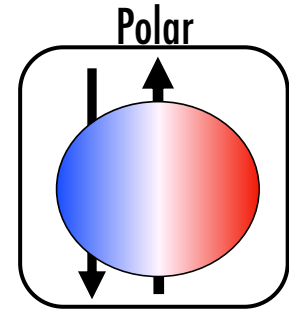
- Four NEID papers submitted/published in the first six months:
 - Stefansson et al. *RM Observations of Warm Neptune GJ3470*
<https://arxiv.org/abs/2111.01295>
 - Wang et al. *RM observations of WASP-148*
<https://arxiv.org/abs/2110.08832>
 - Lin et al. *Solar Telescope Description*
<https://arxiv.org/abs/2112.05711>
 - Dong et al. *RM Observations of TOI-1268b*
(submitted, but not on arxiv yet)

NEID Rossiter-McLaughlin Results



ExoPlanet Exploration Program

NEID reveals that the warm Neptune GJ 3470b—orbiting a nearby bright low mass star—has a polar orbit



The true obliquity constrained to be $\psi = 98_{-10}^{+20}^\circ$.

Southern Radial Velocity



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SMARTS/Chiron



AAT/Velocite



MINERVA-Australis

| Facility | 2019A | 2019B | 2020A | 2020B | 2021A | 2021B | 2022A | 2022B | 2023A |
|--------------------------|---------|----------|----------|---------|---------|---------|---------|---------|---------|
| SMARTS/Chiron | 392 hrs | 407 hrs | 80 hours | 280 hrs | 300 hrs | 300 hrs | 300 hrs | 300 hrs | 300 hrs |
| AAT/Velocite | | 5 nights | 5 nights | | | | | | |
| MINERVA-Australis | | | | 300 hrs | 300 hrs | 300 hrs | 300 hrs | 300 hrs | 300 hrs |

- NASA funds the observing time at each observatory.
- NSF operates the TAC for all proposals.
 - The NASA time on SMARTS/Chiron funded as an inter-agency transfer (IAT) through NSF.
- Program expected to continue through 2027A.
 - See <https://noirlab.edu/science/observing-noirlab/proposals/call-for-proposals>

Extreme-Precision Radial Velocity (EPRV)



ExoPlanet Exploration Program

- National Academies Exoplanet Science Strategy:
 - "NASA and NSF should establish a strategic initiative in extremely precise radial velocities (EPRVs) to develop methods and facilities for measuring the masses of temperate terrestrial planets orbiting Sun-like stars."
- Formed an EPRV working group of international experts.
 - Eight sub-groups (Science, Error Budget, Instrumentation, Stellar Variability, Strategies, Analytics, Resource Evaluation and Tellurics)
 - Three face-to-face workshops (St. Louis, New York, Washington)
 - Dozens of teleconferences
- Developed an EPRV roadmap recommended plan and presented it to NASA and NSF on 2020-03-24 and published the EPRV Working Group Final Report on 2021-08-04.

See: https://exoplanets.nasa.gov/internal_resources/1556/ and https://exoplanets.nasa.gov/internal_resources/2000/



EPRV Early Steps



ExoPlanet Exploration Program

- PRV data in the NExSci community archive.
 - NEID solar data collected daily and publicly released through the NExSci community archive.
 - NEID standard stars publicly released.
(See <https://neid.ipac.caltech.edu>)
- NSF funded 17 new awards in EPRV instrumentation and technology in FY20 and FY21.
- NASA funded eight 2-year EPRV Fundamental Science ROSES Solicitation D.17 awards.
<https://nspires.nasaprs.com/external/solicitations/summary/init.do?solId={8BEF2D63-6E33-C28A-B68B-8EF929B90D74}&path=open>
- Updating the NASA/ApD Technology Gap List with EPRV
 - e.g., advanced photonics, visible AO/single-mode fiber, gratings, calibration standards, detectors, etc.
- Hired an EPRV investigation scientist at JPL.
- Forming an EPRV research coordination network.
 - To be initiated with the first EPRV solicitation PIs.
 - Interagency, interdivisional, interdisciplinary, international, intergenerational
 - Initial tag-up with PIs held on July 29, 2021.
- Expect to issue a Data Challenge incorporating NEID solar data in about a year.

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