A Solar Feed for NEID

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INTRODUCTION

NEID is a new high-resolution, optical-NIR spectrograph designed for extreme-precision radial velocity (RV) work for exoplanet detection, with an instrumental precision goal of 27 cm/s. It is currently in the process of being commissioned at the 3.5m WIYN telescope at Kitt Peak National Observatory. (See also the main presentation by Instrument PI Mahadevan).

Despite advances in instrumental precision, RV "jitter" from stellar activity limits detection of planetary signals to the ~1 m/s level, and can even masquerade as planets.

Solar feed systems are becoming common tools for precision RV instruments to study of activity-driven RV variations. These devices spatially scramble incoming the sunlight to obtain disk-integrated light, to mimic that from an exoplanet host star.

Such a data set facilitates many paths forward – more robust activity indicators, line-by-line sensitivity, comparison with disk-resolved solar observations, etc. In addition, solar data carries many of the same instrumental signatures as stellar data, allowing a better understanding of any instrumental "quirks".

We have designed and integrated a solar feed for NEID, which will produce a rich solar data set, enabling us to explore stellar jitter mitigation and instrumental stability.

METHODS

The "telescope" portion of the solar feed has three major components:

- **Automated solar tracker** with active guiding loop. Tracks passively if lock-on is lost (e.g. due to clouds). Highly weather-resistant.
- **Custom optics housing** with a 3" lens and an integrating sphere for spatial scrambling. Coupled to optical fiber to NEID.
- **Pyrheliometer** as quick-look cloud sensor, and also verification for exposure meter during testing. Effectively a directional bolometer.

The exterior components were chosen or fabricated to tolerate rain, wind, dust, etc., and wired into the WIYN lightning suppression system.

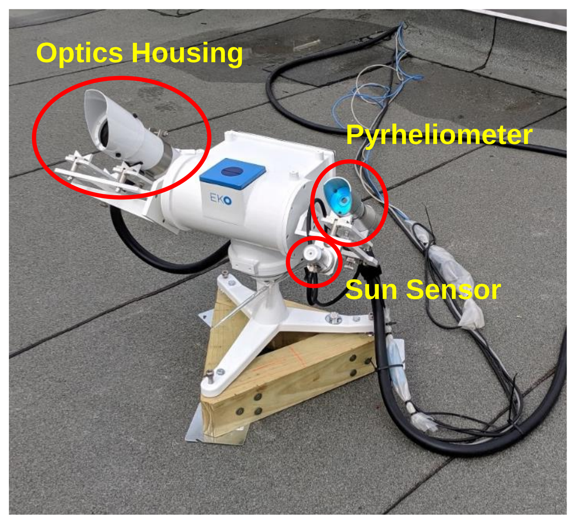

Fig. 1: The "telescope" portion of the NEID solar feed, with major components labeled. The thick black tubing attached to the optics housing encloses the optical fiber. This picture was taken during laboratory testing of NEID at Penn State; there are a few minor changes as compared to the final configuration.

Fig. 2: The solar feed (red box) installed on the control building of the WIYN 3.5m. This location permits an unobstructed view of the sky above airmass 2 throughout the year and is accessible for periodic maintenance.

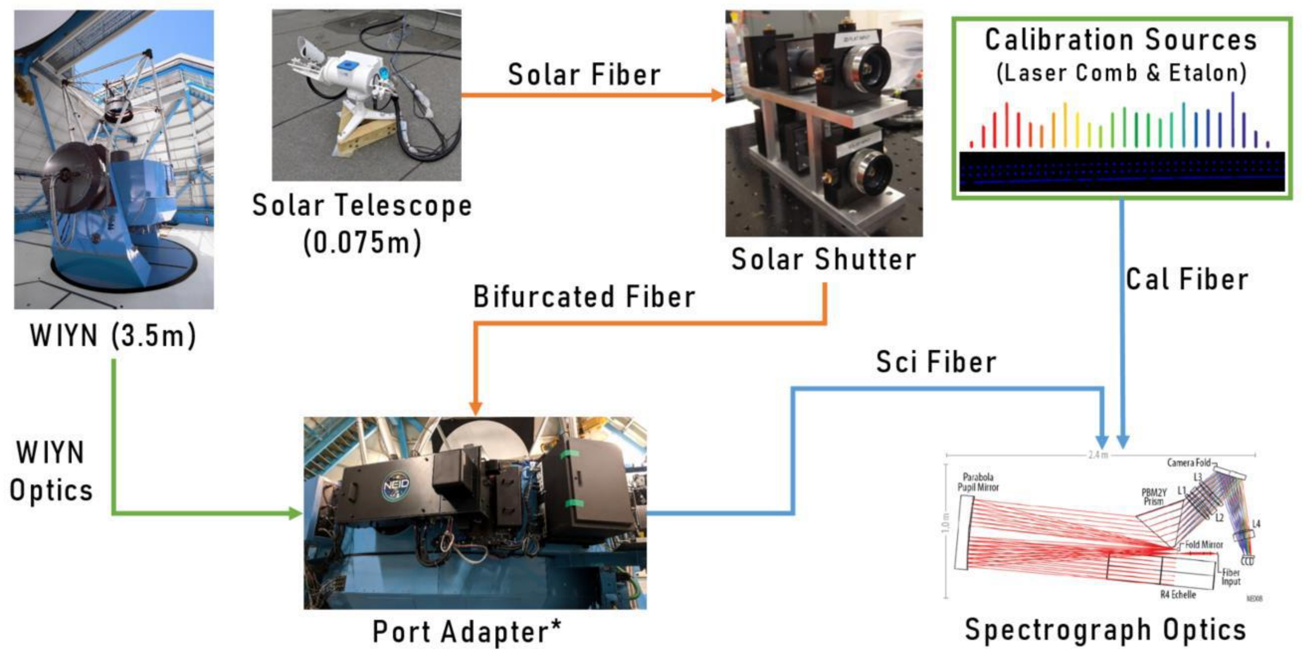

Fig. 3: Schematic of the paths for stellar light versus solar light in NEID. The paths become the same midway through the port adapter. Directing solar light through the science fiber also allows for the possibility of simultaneous calibration during solar exposures.

Sunlight is fed via fiber to a dedicated shutter in the NEID calibration bench and then up to the port adapter. We strove to make the solar light path through NEID as similar as possible to the "normal" stellar light path, to better probe instrumental idiosyncrasies.

We are in the process of implementing daily automated solar data collection, as outlined below.

Time	Event
9 AM	Morning calibration sequence finishes Change NEID to "solar mode", start taking solar data
10 AM	LN2 fill, keep taking solar observations straight through
~3:30 PM	Stop taking solar data, revert NEID to "normal mode"
4 PM	Afternoon calibration sequence starts

RESULTS

The NEID solar feed was used briefly during final laboratory testing of the spectrograph, then permanently installed at WIYN in Nov. 2019. A few short opportunities for solar data were available in Feb. 2020 during NEID commissioning.

The first results are encouraging. Over ~1 hour on a clear day, we see a σ_{RV} of 28 cm/s when roughly binned to the 5-minute solar p-mode period. This upper limit on NEID instrumental precision compares very favorably with the target precision of 27 cm/s, especially given an unknown RV noise contribution from the solar feed itself.

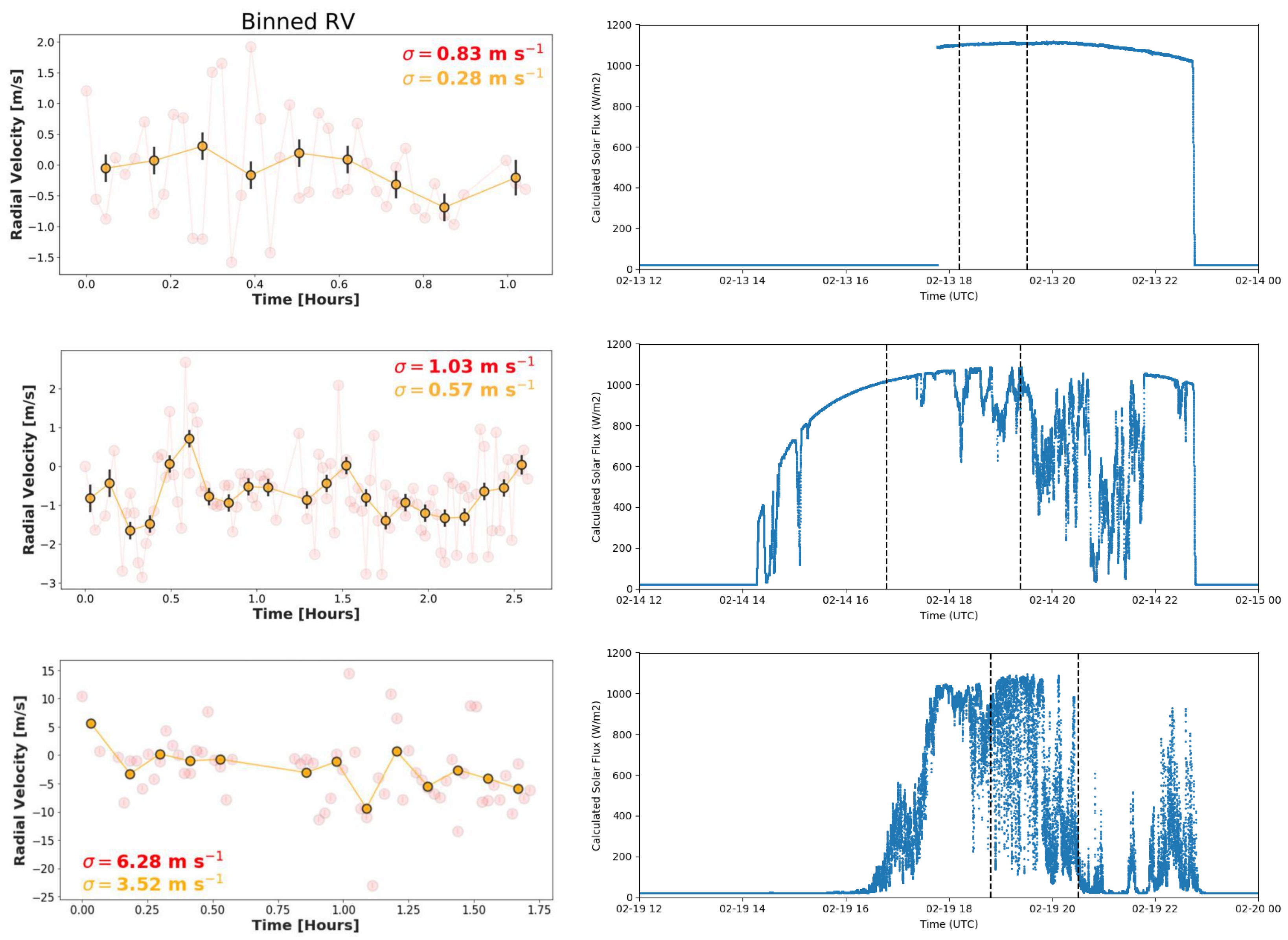

Fig. 4: *Left panels:* Solar RVs from three days of NEID commissioning, reduced by the standard pipeline. Unbinned RVs are in faded red, while yellow points have been binned to approximately 5 minutes to decrease the effect of solar p-modes.
Right panels: Pyrheliometer fluxes on the same three days, with the beginnings and ends of solar data collection marked by dashed lines. In the best observing conditions – no clouds detected – we obtain a σ_{RV} of 28 cm/s over a span of ~1 hour, very close to the NEID target instrumental precision of 27 cm/s. From the subsequent two days of solar data, we see that σ_{RV} becomes worse with increased cloudiness, as can only be expected.

CONCLUSIONS

- We have designed, built, and deployed a solar feed system for the new precision RV spectrograph NEID.
- Preliminary solar data from commissioning indicates instrumental precision of < 30 cm/s over short timespans.
- We will implement a routine of daily solar observing to generate a data set useful for studying activity-induced RV shifts and NEID instrumental effects.

Please also see our forthcoming paper in JATIS.

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