The Pathfinder High Resolution NIR Spectrograph at the Hobby Eberly Telescope: Exploring Radial Velocity Precision in the NIR with an Un-cooled Instrument

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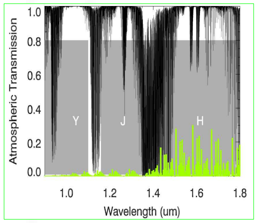
Abstract

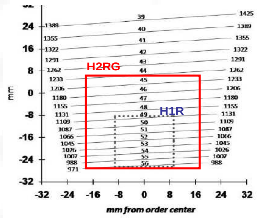
Precision radial velocities in the Near-infrared to detect low mass planets around mid to late M dwarfs require a stable high resolution infrared spectrograph with a good wavelength calibration source. We present commissioning results with the Pathfinder instrument at the 9m Hobby-Eberly telescope demonstrating on sky observations with a high spectral resolution (R~50,000) fiber fed instrument in the NIR and 10-20m/s velocity precision. The fiber coupled Pathfinder prototype instrument has been designed from the ground up to enable high precision spectroscopy. Precise calibration of the instrument drift is accomplished using a uranium-neon hollow cathode lamp fed down a simultaneous calibration fiber. The Pathfinder is a warm bench spectrograph, made possible using thermal blocking filters and glasses that enable Y & J band observations with an un-cooled instrument. The configurability and accessibility of Pathfinder, coupled with its temperature stabilized fiber fed design, enables many tests to understand the limitations of precision RV in the NIR, and overcome potential obstacles. Frequency combs calibration sources that are now under development can easily be fed into the Pathfinder instrument. The high resolution near infrared capability will be critical for exoplanet searches and characterization. Improvements in velocity extraction algorithms, and telluric correction, are expected to improve the achievable precision.

The Pathfinder Spectrograph: Spectral Format & Coverage



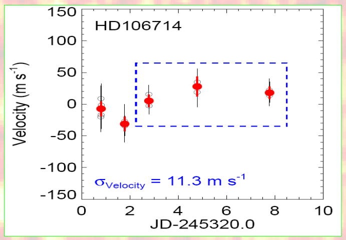
Atmospheric Transmission, Emission (in green) and NIR bands.

The Pathfinder Spectrograph has been designed to cover the Y band part of the NIR, where M dwarfs have deep absorption features that encode significant radial velocity information. The Y band in particular has low telluric absorption and low OH emission. Pathfinder is an uncooled fiber -fed spectrograph that has been designed to deliver a spectral resolution of R~50,000 with a 4.4 pixel sampling of the resolution element. Thermal blocking interference filters coupled with a PK50 glass filter enable Pathfinder to observe in the Y and J without the need for a cooled pupil.

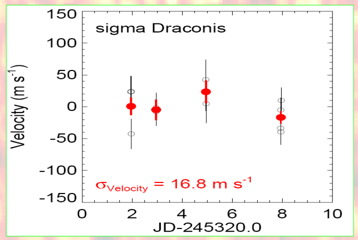


Spectral Format of the Pathfinder with the current Hawaii-1 dector, and with the future upgrade to a H2RG detector

Radial Velocities obtained on Reference Stars at the HET May'10

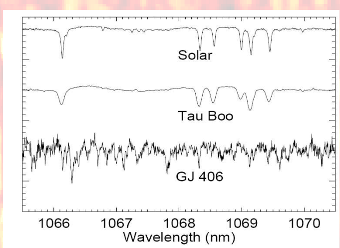


The giant star HD106714 is known to be stable to ~10m/s (Hekker et al. 2006). Binned velocities from 3 nights show a scatter of 11.3 m/s. Including the first two nights (where the instrument was still thermally stabilizing) and ~23m/s for all nights.



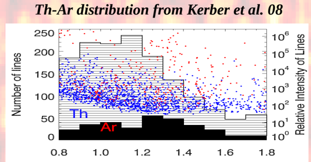
sigma Draconis, a know radial velocity stable star, was also observed during the Pathfinder HET run. The binned velocities show an scatter of ~16.8 m/s including data from all nights and all observations.

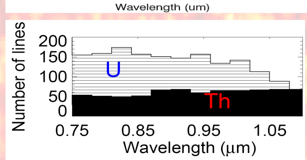
The Penn State Pathfinder instrument has already demonstrated ~7-10m/s precision on solar observations (Ramsey et al. 2008) in the lab, and is now yielding 10-20m/s on stars with the HET with preliminary reduction of the data from our commissioning run in May 2010.The Pathfinder is a warm fiber-fed bench top cross-dispersed echelle spectrograph and a very useful testbed in exploring issues affecting the extraction of precision radial velocities in the NIR such as detector systematics, calibration velocity references and telluric contamination. Pathfinder is designed with two optical fibers so that one of the fibers can be used as a velocity reference with a stable sources like a hollow cathode lamp. Since Thorium-Argon lamps have weak Thorium lines and strong Argon lines (with are not stable at 1m/s) in the NIR we have used Pathfinder to explore Uranium hollow cathode lamps. Uranium lamps are very promising for this wavelength regime since Uranium has a large number of lines in the NIR Y band compared to Thorium.



A region of the NIR spectra obtained during Pathfinder commissioning for the Sun (G2),Tau Boo (F6) and GJ406 (M6.5)

Th-Ar distribution from Kerber et al. 08

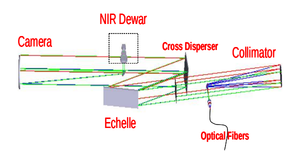




Uranium-Th line densities showing the large number of U lines in the Y band

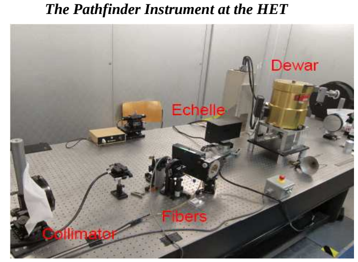
Pathfinder: Design, Schematics & Thermal Blocking

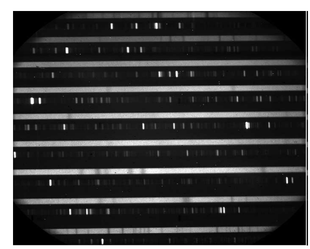
The Pathfinder has been designed as a fiber-fed cross-dispersed white pupil spectrograph with thermal blocking filter and an PK50 glass filter to minimize the thermal background. With this setup the un-cooled instrument sees a background of ~3e/s/px, easily enabling 10 minute exposures with the Hobby Eberly Telescope. The instrument uses an R3 echelle operate in-plane, and off Littrow to achieve the high dispersion. A simultaneous calibration fiber, fed with light from a uranium neon hollow cathode lamp, enables simultaneous monitoring of the instrument drift. A commercial paint mixer attached to the fibers enables the mitigation of modal noise effects.



Design of the fiber-fed Pathfinder spectrograph

The Pathfinder Instrument at the HET





Star and Calibration Fiber, simultaneous exposure

***Discussion**: The fiber-fed Pathfinder instrument coupled to the HET is a very stable high resolution NIR spectrograph. Even in this testbed form we have demonstrated the ability to achieve 10-20m/s on stars. A future upgrade to Pathfinder II, with the lessons we have learned, will substantially increase the efficiency and stability. Upgrading the current detector to a H2RG will significantly increase the wavelength coverage as well. Our goal with Pathfinder II is to attempt to achieve < 5m/s precision in the NIR.*

We acknowledge significant heritage from the Gemini PRVS proposal involving U Hertfordshire, UK ATC and Penn State. We are grateful to Hugh Jones for his input in this project. This work has been supported, in part by the Center for Exoplanets and Habitable Worlds and the Department of Astronomy & Astrophysics, Penn State. We also acknowledge support from the NASA Origins program.