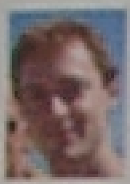

Precise Radial Velocimetry in the Near-Infrared with T-EDI

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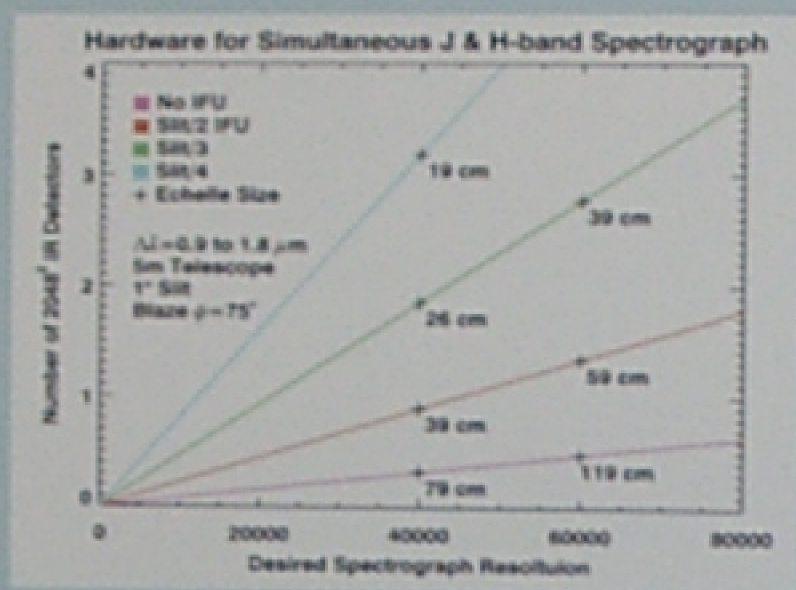
Abstract

Precise Near-Infrared Radial Velocimetry enables the detection of extrasolar planets around late-type stars too faint in the visual for V-band exoplanet surveys. Current high-resolution near-IR spectrographs lack meter/sec precision because of the inability to calibrate systematic errors. The TripleSpec Externally Dispersed Interferometer (T-EDI) uses an interferometer before a moderate-resolution spectrograph to shift the systematic requirements from the spectrograph to the optical path difference in a fixed-delay interferometer, which can be calibrated with a laser metrology system. T-EDI is scheduled for commissioning on the Palomar 200" Hale Telescope in October of 2007 with a design goal of 10m/s RV precision.

High-Resolution Near-Infrared Spectroscopy for Precise Radial Velocimetry

Requires either a highly stable, single-mode spectrograph analogous to HARPS in the visual (Lovis et al. 2006), or a precise calibrant spectrum analogous to an iodine absorption cell (Butler et al. 1993).

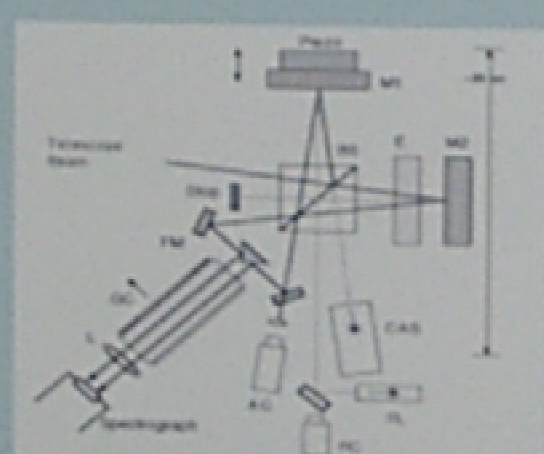
For large simultaneous bandwidth, a stable single-mode near-IR spectrograph is very costly in terms of detector space and echelle size:

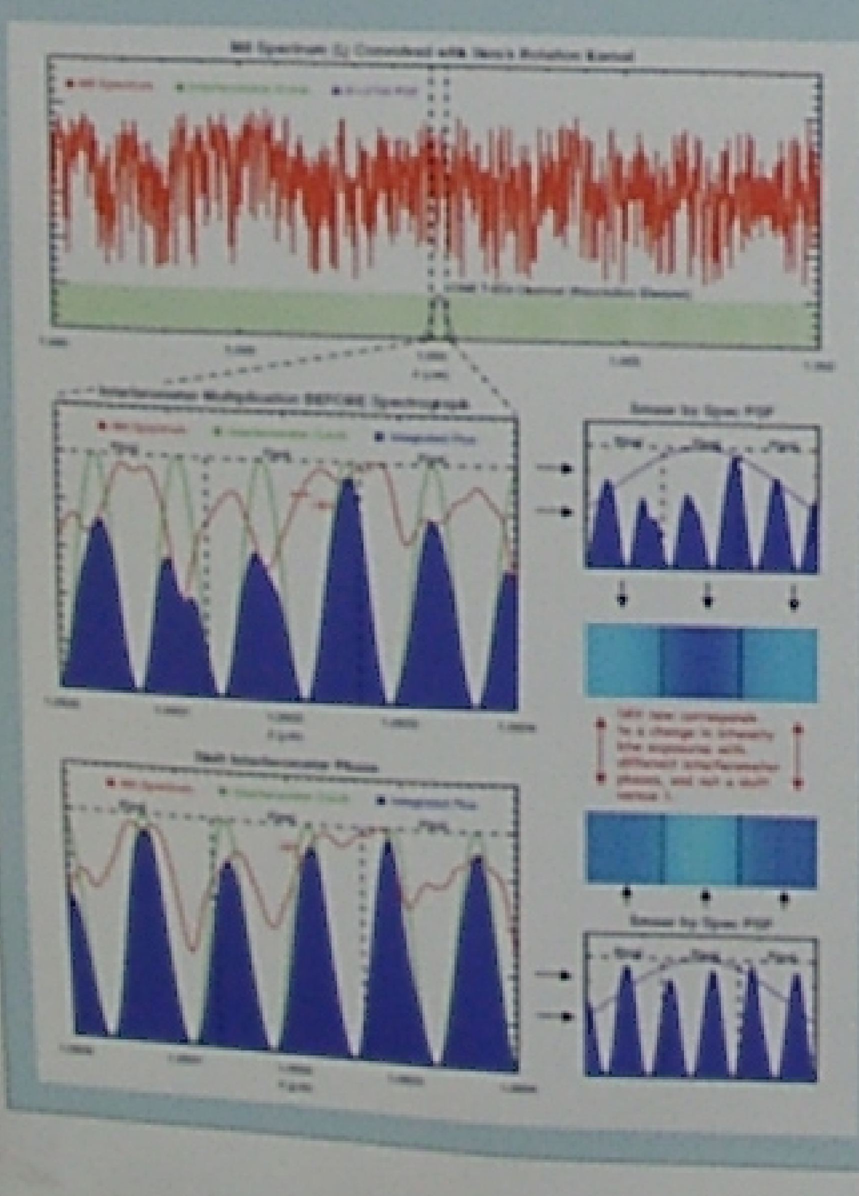


It is not currently understood whether a multi-mode Near-IR spectrograph can be calibrated with a gas cell analogous to iodine in the visual.

The TripleSpec Externally Dispersed Interferometer (T-EDI): An Enabling Technology

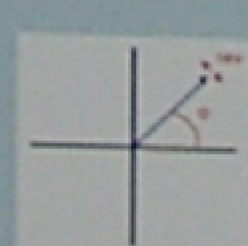
T-EDI is a combination of a fixed-delay interferometer and a *moderate* resolution spectrograph (R≈2700) covering J, H and K bands on the Palomar 200" Hale Telescope (Edelstein et al. 2006, Wilson et al. 2004). The combination shifts stability and calibration requirements from the spectrograph onto the optical path difference of the interferometer, which is calibrated with laser metrology:





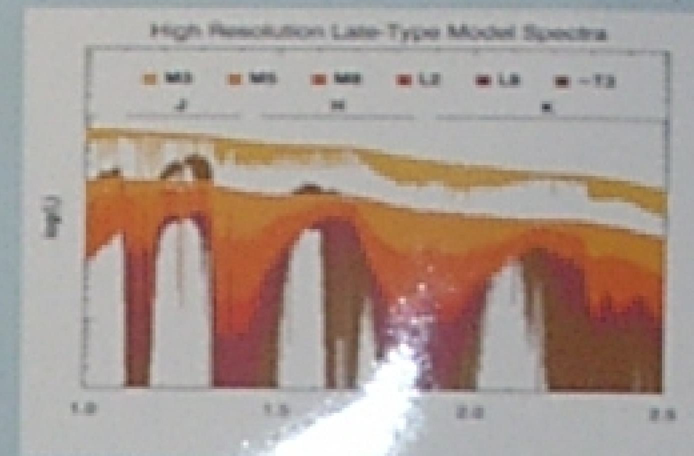
The interferometer multiplies the spectrum by a sinusoidal comb before dispersing the light with the spectrograph.

By the shift theorem, a Doppler shift in the spectrum is identical to a change in the phase of the interferometer comb. With three phased-stepped exposures, we can construct a phasor for each channel:



By shifting the systematic error onto a well-calibrated interferometer comb, T-EDI enables precise radial velocimetry in the near-IR.

Scientific Motivation - Extrasolar Planet Detection around M, L and T-type Stars



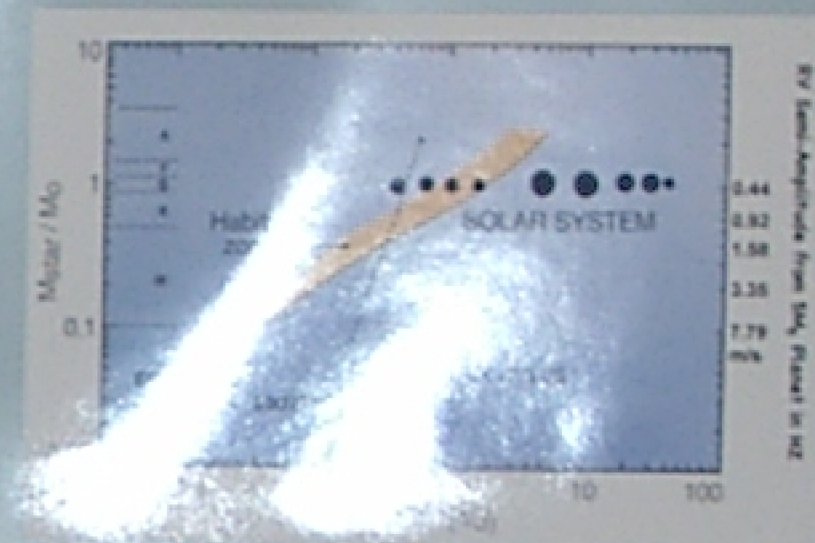
Late type stars have blackbody peaks in the near-IR and contain many absorption features due to chemical transitions in their photospheres.

The depth and breadth of the features provide very high signal-to-noise for detecting the Doppler shift due to the stellar reflex motion induced by an orbiting extrasolar planet:

from exoplanets.org

M Dwarfs in particular are compelling targets for searching for potentially habitable extrasolar planets, especially since the discovery of a 5 M_{Earth} (Msini) planet orbiting Gliese 581, a relatively bright M3 star (Udry et al 2007).

M dwarf habitable planets are close in, with short orbital periods and induce relatively large stellar reflex motions due to the small mass of the host star.

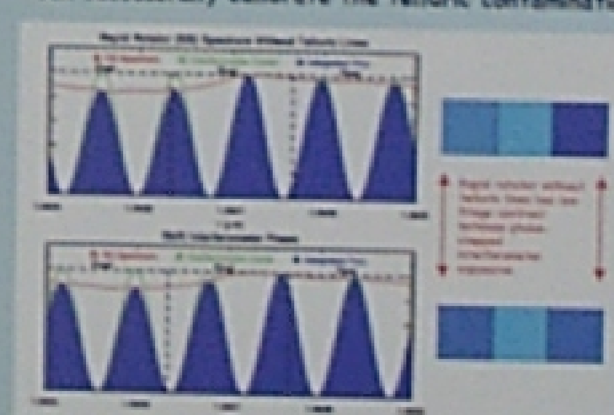


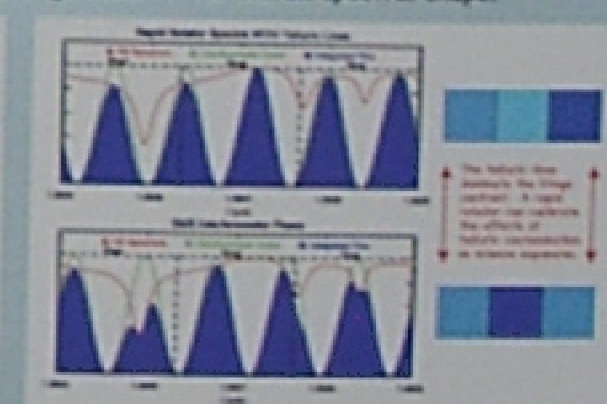
From Kasting et al. 1993, with Gliese581c and radial velocity (RV) Semi-amplitude induced by a 5 Earth-mass planet orbiting within the habitable zone (HZ)

M dwarfs are typically 10 times brighter in the near-IR than in the visual with many more absorption features. Precision radial velocity measurements in the near-IR will dramatically extend the reach of current visual RV surveys on M type stars, and enable surveys of later L and T-type stars.

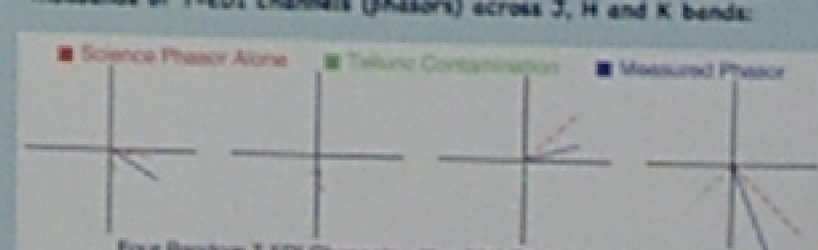
Telluric Contamination and Variability

Telluric contamination can be calibrated using the "standard star" technique of measuring a known or flat spectrum (A or B-type star). Instead of measuring lines, however, T-EDI measures fringe contrast imposed by the interferometer. ANY star with low fringe contrast (rapid rotating stars with low activity) can successfully calibrate the telluric contamination, regardless of the overall spectral shape.





The telluric calibration spectrum represents a phasor addition to the science spectrum for each T-EDI channel. Variation in the telluric phasor due to change in airmass or winds will average out over the thousands of T-EDI channels (phasors) across J, H and K bands:



The calculated covariance between a shift in the telluric lines and a shift in the late-type stellar spectra is only ~10%. That is, a 20m/s Doppler shift in the telluric lines would be degenerate with a 2m/s Doppler shift of the star.

Acknowledgements

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