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Searching for Planets Orbiting Late-type Stars with the TripleSpec Externally Dispersed Interferometer

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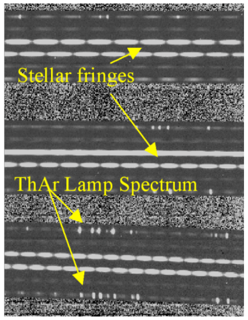
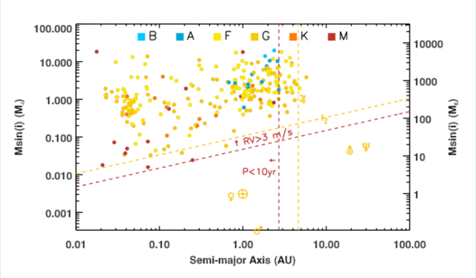


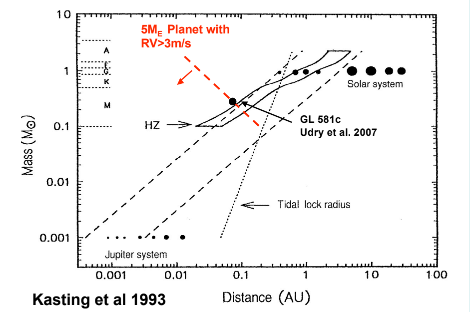
Abstract

The TripleSpec Externally Dispersed Interferometer (TEDI) is the combination of a fixed-delay interferometer and a moderate-resolution near-IR spectrograph covering J, H and K bands simultaneously, all mounted on the Cassegrain focus of the Palomar 200-inch Hale Telescope. The fixed-delay interferometer boosts the radial velocity precision of the spectrograph to enable detection of exoplanets using the Doppler technique. The interferometer/spectrograph combination is particularly well suited for *infrared* radial velocimetry, where conventional high-resolution spectroscopy is hampered by large systematic errors. We will use TEDI to search for exoplanet companions orbiting mid-to-late M dwarfs, which are 100x brighter in the infrared vs. the optical. TEDI is currently in its science verification phase.

Exoplanet Detections with the Radial Velocity Technique (exoplanet.eu)

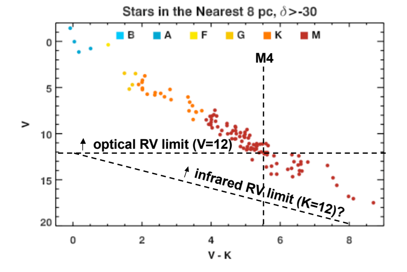


Msini(i) vs. semi-major axis for all of the exoplanets detected with the radial velocity technique as of May 1st, 2008, color-coded according to the spectral type of the host star (A and B-type used for evolved intermediate-mass stars). The yellow dashed lines correspond to a constant RV amplitude of 3 m/s and a period of 10 yrs around a solar mass star, the red dashed lines are the same but for an M5V star (~0.2M_{sol}).

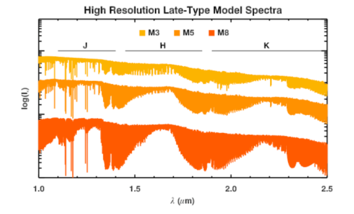


Habitable zone vs. orbital distance and stellar host mass calculated by Kasting, Whitmire & Reynolds (1993). The red dashed-line corresponds to a 3 m/s radial velocity signal induced by a 5 M_{Earth} planet neglecting inclinations effects. Clearly, this level of radial velocity precision on mid-to-late M dwarfs will enable detection of potentially habitable planets. The potentially habitable planet Gliese 581c (Udry et al 2007), orbiting an M3V star, is plotted for comparison. Note that these planets would be within the tidal lock radius, calculated by Kasting et al. assuming Earth-like age and parameters.

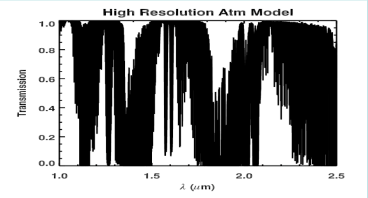
M Dwarfs in the Solar Neighborhood



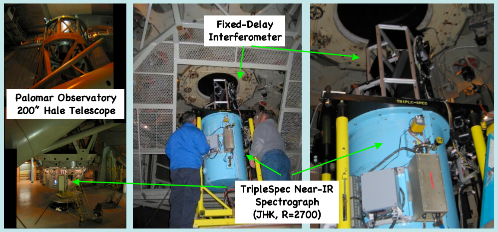
Apparent V magnitude vs. (V-K) color for northern stars in the nearest 8 parsecs, from the 8 Parsec Sample (Reid et al. 1999). Assuming a limit of V~12 for optical radial velocity surveys to get <10 m/s precision (Endl et al. 2006), the nearby dwarfs later than M4 are extremely faint for optical methods to achieve m/s precision. However, supposing the same limit in K band, where M dwarfs are significantly brighter, the nearby mid-to-late Ms become accessible.



High resolution models of M dwarfs atmospheres (provided by Travis Barman using PHOENIX code) show many absorption lines across J, H and K due to molecular rotational and vibrational modes which are sustained at the lower temperatures. It is no coincidence that the Earth's atmosphere contains similar lines, mainly from water vapor, which complicates infrared radial-velocimetry. Plotted is a model of the Earth's transmission spectrum provided by Henry Roe:



TripleSpec Externally Dispersed Interferometer

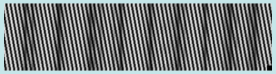


Pictures showing the TEDI on the 200-inch Hale Telescope mounted at the Cassegrain focus.

High resolution (R=100000) image of M5 model spectrum showing absorption lines with high radial velocity signal.

Same spectrum at TripleSpec resolution (R=2700). Radial Velocity signal is significantly decreased.

2.3 microns showing 10 TripleSpec resolution elements



High resolution showing the effect of the fixed-delay interferometer.

At TripleSpec resolution the interferometer beats with the stellar lines to produce a Moiré pattern retaining high radial velocity signal.

Absorption lines introduced by the Earth's atmospheric transmission can be calibrated by taking TEDI spectra of flat sources (A & B stars). However, unresolved mixing between the earth's atmosphere and stellar lines cannot be fully calibrated out. On the top is a calculation of the systematic radial velocity error introduced by unresolved mixing using the full J, H and K bands for various stellar types. The error bars correspond to expected photon noise for a 10 min exposure on a J=10 star. On the bottom is the same plot, except using smaller bands with an average transmission of >95%. The systematic error is reduced, with the photon noise increased.