Externally Dispersed Interferometry for the Mt. Palomar Doppler Planet Search

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Abstract: A fixed-delay interferometer placed in series with Cornell's planned TripleSpec near-infrared spectrograph at Mt. Palomar's 200 inch telescope will greatly improve its Doppler velocity precision and effective spectral resolution. Phased-stepped data are taken with a uniform phase across the beam, allowing 1-pixel high beams such as in echelle grating spectroscopy, 1-dimensional imaging spectroscopy, or with densely packed multiple targets placed along the slit.

OCIS codes: (300.6300) Spectroscopy, Fourier Transform; (300.6310) Spectroscopy, Heterodyne

Externally Dispersed Interferometry (EDI) is a relatively new technique[1-17] for boosting the resolution and stability of spectrographs measuring Doppler radial velocities or broadband high resolution spectra. A fixed-delay interferometer placed in series with a spectrograph. Multiplication by the sinusoidal interferometer transmission heterodynes narrow spectral features down to lower spatial frequencies along the dispersion direction, forming beats or moire pattens in the spectrum (Fig. 1). These carry spectral information otherwise unresolvable by the spectrograph used alone (Fig. 2). The moire patterns shift in phase in proportion to the stellar Doppler velocity.

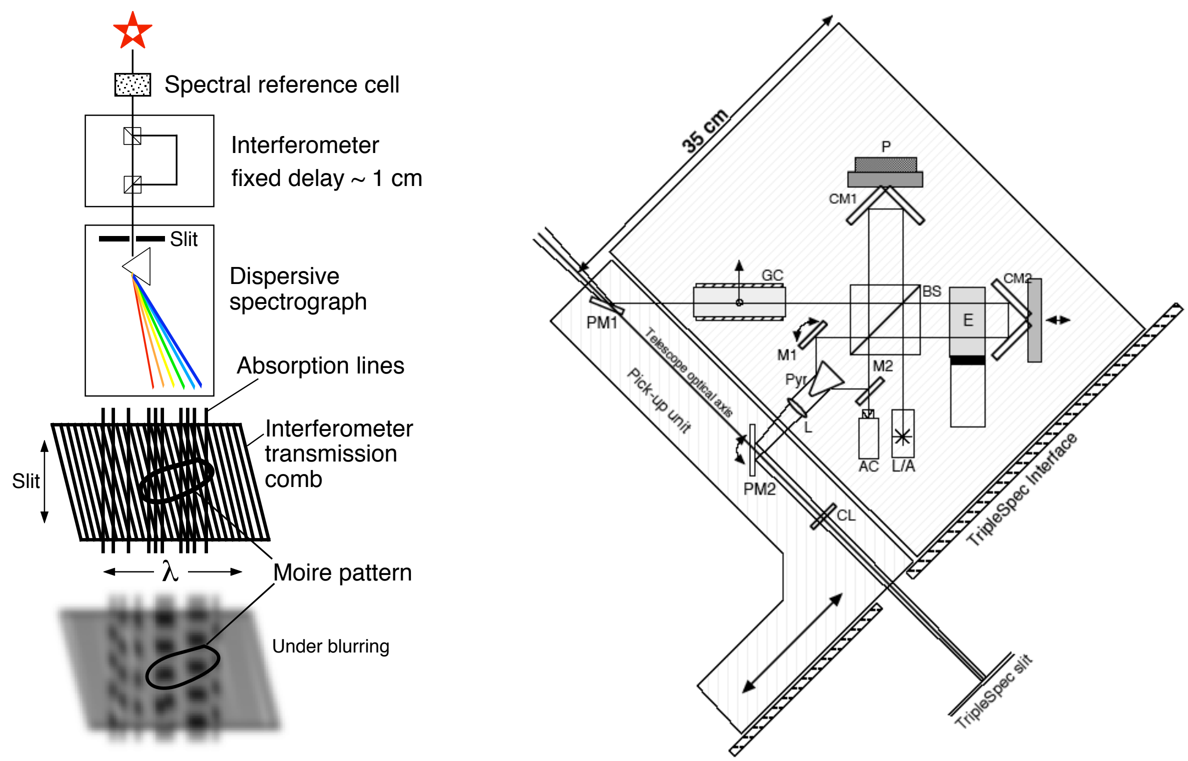

Fig. 1. [Left] Method of externally dispersed interferometry (EDI). The moire patterns containing Doppler and high resolution information are detectable even under spectrograph blurring. "Multiphase" data taking mode is shown. [right] Schematic of an EDI for Mt. Palomar 200 inch[12, 14].

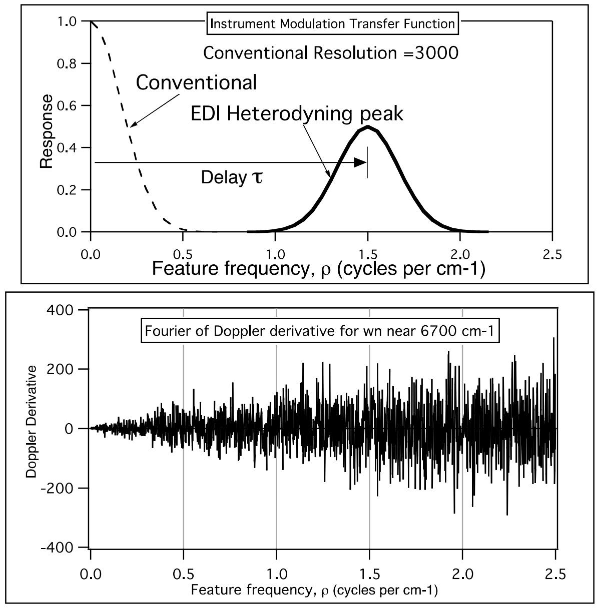

Fig. 2. [Top] Instrument response in Fourier domain for conventional (dashed peak) and EDI heterodyning (bold peak). [Below] Fourier transform of derivative of a stellar spectrum (nonrotating, theoretical[15]), indicating ability to elicit a Doppler signal. The conventional instrument response is limited to the region near the origin, and thus does not overlap much Doppler content. In contrast, for the EDI the peak is at higher feature frequencies (selected by the delay) where the stellar Doppler content is greater. Thus the EDI has a much larger Doppler sensitivity. Stellar rotation will attenuate the highest feature frequencies, reducing the optimum delay.

EDI dramatically reduces the resolution and stability requirements of the associated spectrograph. Recently, a new planet has been found by a University of Florida group[13, 16, 17] using the EDI technique on a low resolution spectrograph otherwise insufficient to reliably detect planets. Concomitant EDI advantages are reduced spectrograph engineering constraints, higher throughput, compactness and low mass, easier environmental control, and dramatically less expense. With EDI it is now feasible to place a sensitive Doppler spectrograph system on a small airborne or spaceborne platform, passively detecting the radial motion of sunlit targets. Previously, such instruments would weigh several tons and be of few meters scale.

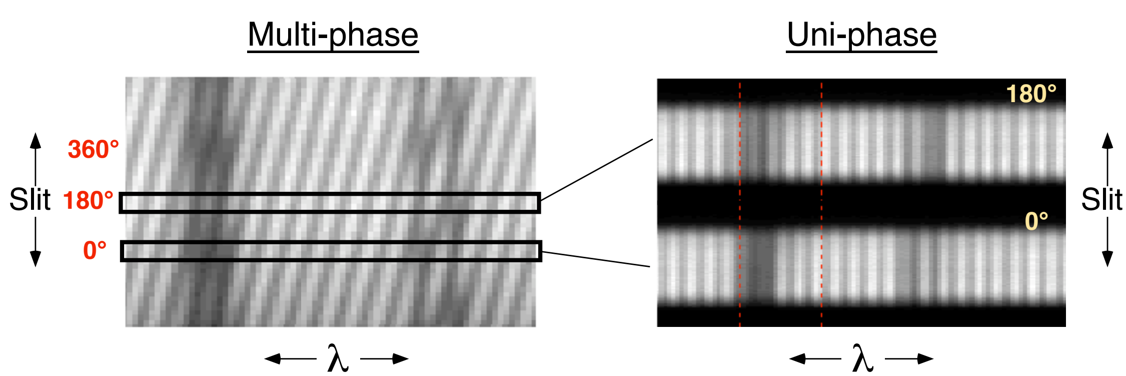

Fig. 3. Two modes of acquiring phased fringing spectra: in **multiphase** (left), the interferometer phase varies along the spectrograph slit to acquire all phases at once. In **uniphase** (right) the phase is spatially uniform within each of two complementary (0° and 180°) interferometer outputs, and both phases are incremented once versus time via piston motion of an interferometer mirror to acquire 90° and 270° phase data. (A minimum of three phase samples around the circle are needed to separate the moire and ordinary spectral components.)

A National Science Foundation funded project is underway to place an EDI on the TripleSpec near-infrared spectrograph[18] being constructed by Cornell University at the Mt. Palomar 200 inch telescope, to search for planets around cool stars[12, 15, 14]. Since the TripleSpec is an echelle spectrograph that uses the transverse dimension on the CCD chip to detect multiple grating orders, the EDI data will be taken in the "uniphase" mode instead of "multiphase" mode typical of previous linear grating spectrograph EDI's (Fig. 3). The uniphase mode is technologically interesting because it allows essentially 1-pixel high beams not possible with the multiphase mode, (where the phase varies spatially across many pixels). This in turn allows 1-dimensional imaging spectroscopy, or the dense placement of multiple sources along the instrument entrance slit with minimal spacing between sources.

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