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# Doppler Planet Search with a Novel High-Efficiency Spectrometer

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An important method currently used by astronomers to detect extrasolar planets is to search for a slight Doppler shift in starlight spectra, having a duration of several days to 30 years. The shift is caused by wobble of the star due to the gravitational pull of the planet. Jupiter-sized and Saturn-sized planets at Jupiter-like or Saturn-like orbits create 12 m/s- and 3 m/s-wobbles, respectively, and an Earth-like planet, 0.1 m/s. The 3 m/s best resolution of current grating spectrometers is insufficient to reliably detect sub-Jupiter planets. Their complicated instrument response is susceptible to drifts and is time consuming to calibrate. Their highly individualized character makes consistency over long orbit planet searches problematic. Their low light collection efficiency restricts current observations to bright stars.

The purpose of this project is to evaluate a new kind of spectrometer we have invented, which is superior for the Doppler planet search in particular, and may lead to other useful applications in spectroscopy and metrology in general. This project will enhance LLNL's capabilities in advanced instrumentation and diagnostics (e.g., Doppler-based velocimetry) essential to the Stockpile Stewardship Management Program and the nonproliferation effort. This *crossfringing spectrometer* is a hybrid of an interferometer and a low-resolution spectrometer. The interferometer provides Doppler detection at 1 m/s or better with a dramatically simpler and standardized instrument response. The low-resolution spectrometer increases fringe visibility over interferometers used alone, and improves light collection efficiency over traditional high resolution spectrometers. A larger slit opening can be used, increasing the field of view 200 times over current planet search spectrometers. The increased field of view allows efficient light collection, use of wider optical fibers, tolerance to blurry star images, and multi-object viewing. The instrument can be more compact (the size of a TV set) and can be launched into space.

In FY98, we built a prototype crossfringing spectrometer from off-the-shelf optics and have taken preliminary data on sunlight. Although its eventual use will be at an observatory on starlight, many operational aspects of our instrument can be tested in FY99 on sunlight in our lab at LLNL, seeking evidence of the 12 m/s tugging of the Earth by the moon. Figure 1a shows a small subset of the fringing solar spectrum. Figure 1b explains that overlap of a slanted fringe comb created by the interferometer with the vertical solar absorption lines creates moiré fringes, which shift vertically under Doppler shift. The moiré fringes remain visible even when the spectrometer slits are opened wider than Fig. 1a, to increase light collection. The intensity profile of the fringes is a sinusoidal function, as shown in Fig. 1c, having only 3 degrees of freedom (phase, amplitude, and vertical offset), which simplifies calibration and allows standardization. This is in contrast with current spectrometers with complicated instrument functions having thousands of degrees of freedom, all of which need to be accurately calibrated. Sunlight passing through an iodine vapor cell provides absolute wavelength calibration.

In FY99, algorithms are being created to unwrap the broadband phase shift of the interferogram to a resolution of 1/10000th of a wave, corresponding to Doppler shift of 1 m/s. (This is 20 times the resolution of monochromatic interferometry, and corollary applications to high precision metrology will be investigated.) The optical arrangement will by modified to anticipate use on starlight. Preliminary trials at Lick Observatory are anticipated.

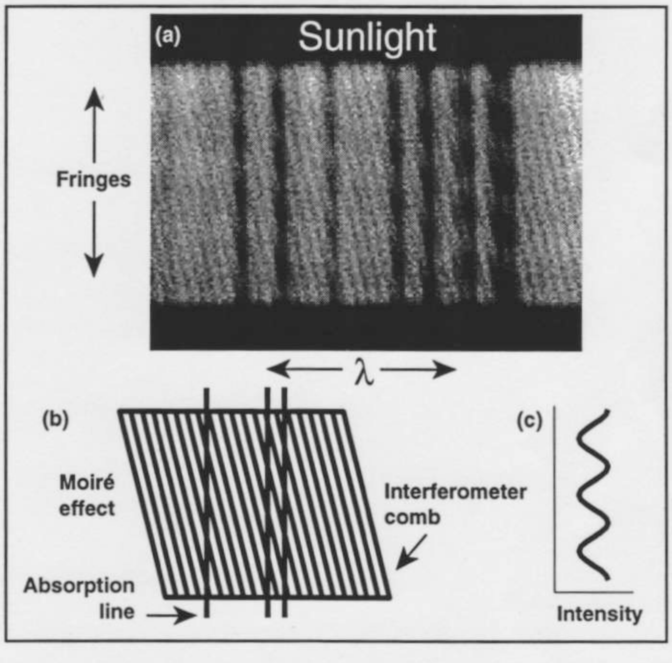


**Figure 1a. Solar absorption lines seen through crossfringing instrument. Figure 1b. Overlap of finely spaced interferometer fringe comb with absorption lines creates moiré fringes, which have sinusoidal vertical intensity profile shown in Fig. 1c, where a Doppler shift manifests in vertical translation of moiré pattern.**