Laser Focus World

Astro-comb enables search for Earth-like planet

June 5, 2008--A new technique using lasers may soon enable the identification of Earth-sized planets around stars like our Sun, say scientists from Harvard and MIT (both Cambridge, MA).[1] Until now, the search for exosolar planets using the periodic Doppler shift of stellar spectral lines has been limited by the precision of wavelength-calibration sources and the lack of useful spectral bands they cover. The periodic Doppler shift method, which has been an important contributor to the discovery of nearly 300 massive, gas-giant-type, exosolar planets since the mid-90s, enables the detection of the very slight movement of a spectral line on a spectrograph, when the light of a parent star shifts its radial velocity, and therefore its apparent wavelength, due to a tug from an orbiting planet.

The existing precision of this technique is limited by the choice in wavelength-calibration sources, typically thorium-argon lamps or iodine absorption cells, to only 60 cm s^{-1}. This is enough resolution to detect a planet of 5 Earth masses (compared to Uranus at 14.5 Earth masses) in a tight, Mercury-type orbit around a Sun-like star. But planets more like Earth would be smaller and further out from their parent star than Mercury, requiring a resolution on the order of 5 cm s^{-1}. Existing wavelength-calibration sources also have few spectral bands in the red to near-infrared (IR) wavelength range needed to detect planets around M-type stars and dark matter.

Laser frequency combs can offer stability and useful spectral bands in the optical and IR, but existing systems have not been well-matched with astrophysical spectrographs. The new technology developed at Harvard and MIT uses an adaptation of a laser-frequency comb called an astro-comb to enable precision as high as 1 cm s^{-1} in astronomical radial velocity measurements, which should enable the discovery of a 1-Earth-mass planet in an Earth-like orbit (see figure, above). The astro-comb is a filtered laser comb linked to an atomic clock and powered by an octave-spanning, 1 GHz mode-locked Ti:sapphire femtosecond laser, or source comb. To see the tiny spectral line shifts like those indicating Earth-like planets, the source beam passes through a Fabry-Perot (FP) cavity that filters out undesirable comb lines. The source comb/FP combination also increases the line spacing to approximately 1 Å (40 GHz) over a range of more than 1000 Å, providing an ultrastable wavelength-calibration device that is well matched to high-resolution astrophysical spectrographs (see figure, below).

The FP cavity itself is stabilized using an injected diode laser centered on the rubidium D1 line at 7947 Å via a dichoric-atomic-vapor laser lock. The finesse of the FP cavity at that wavelength is approximately 250, consistent with the estimated theoretical limit. The optical output beam is directed into a single-mode fiber and in laboratory tests is measured using an optical spectrum analyzer. The width of the lines is set by the optical spectrum analyzer's resolution of 8 GHz. The resulting linewidth of each comb line is less than 1 kHz, expected to be stable to 1 cm s^{-1} on a timescale of several years. With the low frequency noise in the astro-comb line spacing of less than 3 kHz Hz-1/2, the output spectrum is more than two orders of magnitude more stable than the already-stable FP cavity. The astro-comb increases the ability to detect a planet's spectral line Doppler shift by ten times, or to within one part in a trillion. Development of the astro-comb was led by Ronald Walsworth of Harvard and Franz Kaertner of MIT. Chih-Hao Li was first author on the collaboration's recently published report of successful tests of the astro-comb.

"We are at the cusp of a new era in planet searches," says Li. "With this technology we are developing, astronomers will finally have the Doppler shift sensitivity to detect and help characterize other Earth-like worlds."

The group plans to test the astro-comb at telescopes on Mt. Hopkins in Arizona this summer, and further refine the technique. Further plans involve the installation of an improved version at the New Earths Facility currently under construction in the Canary Islands of Spain, to be completed in 2010.

By Valerie C. Coffey

REFERENCES
1. C.-H. Li et al., *Nature* 452, 610 (2008).

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