TIP: A Terahertz Interferometer for Planets – A Concept Study

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The extraordinary discoveries of planets around nearby stars in recent years have opened up an exciting new field of research – the search for extrasolar planets. Studies of these planets are revealing new information about the star and planet forming processes, and have brightened the likelihood of the detection of Earth-like planets in our galaxy. Current extrasolar planet finding research is carried out mostly at optical wavelengths. Planet-finders use various techniques such as direct detection, where the faint light reflected by the orbiting planetary body is detected by nulling of the central bright star; or indirect detection, where the orbital variations or the wobbling of the central bright star is measured to identify the unseen companion. However, there are major limitations to both these techniques. In the first case, the brightness ratio between the star and the planet is in the range of 90 to 120 dB for our solar system not including Pluto, making nulling very difficult even for relatively bright planets at short orbital radii, not to mention planets at large separation distances where the reflected light is extremely weak. In the second case, due to sensitivity and time limits, only massive planets orbiting close to the star can be detected.

NASA is developing technologies for planet finding missions at near-infrared frequencies. The planned Terrestrial Planet Finder Interferometer (TPF-I) is a space-based 4-element interferometer centered at 10 μm wavelength where the 280 K black-body curve peaks. However, as can be seen from Fig. 1, at wavelengths around 10 μm the starlight is approximately 70 to 100 dB brighter than the planets for the solar system, making nulling still a very difficult task. At longer wavelengths, however, the brightness ratio is much more favorable for nulling (40-60 dB), and is more sensitive to planets at large separation distances where the reflected light from the planet is weaker and the black-body peaks at longer wavelengths, as shown in Fig. 1. Therefore, a space-based interferometer with modest baselines at terahertz frequencies will offer substantial advantage for finding planets around nearby stars.

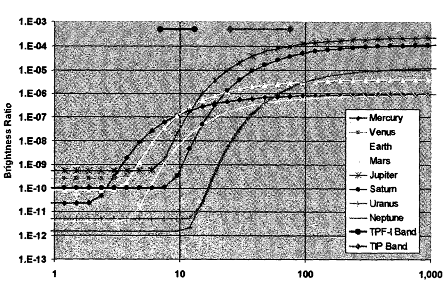

Fig.1 Brightness ratio of different planets in our solar system compared to the sun using a simple model of blackbody radiation and reflected starlight.

In this study paper, we identify the scientific potential, technology drivers, and system requirements for undertaking a planet finding mission using interferometry from 4 to 12 THz (25-75 μm). We will show that a 4-element interferometer with 4 m antenna diameter, < 1 km baseline, and direct detector instruments with realistic NEP has the potential of detecting Earth-like planets out to ≈ 15 pc with only 24 hours of integration. Modest resolution (R=20) spectroscopy will also be possible with such an instrument.

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