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THE FOURIER-KELVIN STELLAR INTERFEROMETER: EXPLORING EXOPLANETARY SYSTEMS WITH AN INFRARED SPACE MISSION

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Abstract. The Fourier-Kelvin Stellar Interferometer (FKSI) is a mission concept for a nulling interferometer for the near-to-mid-infrared spectral region. FKSI is conceived as a mid-sized strategic or Probe class mission. FKSI has been endorsed by the Exoplanet Community Forum 2008 as such a mission and has been costed to be within the expected budget. The current design of FKSI is a two-element nulling interferometer. The two telescopes, separated by 12.5m, are precisely pointed (by small steering mirrors) on the target star. The two path lengths are accurately controlled to within a few nanometers to be precisely the same. A phase shifter/beam combiner (via Mach-Zender interferometer) produces an output beam consisting of the nulled sum of the planets light and the stars light. When properly oriented, the starlight is nulled by a factor of 10^{-4}, and the planet light is undimmed. Accurate modeling of the signal is used to subtract this residual starlight, permitting the detection of planets much fainter than the host star. The current version of FKSI with 0.5 m apertures and waveband 3-8 μm has the following main capabilities: (1) detect exozodiacal emission levels to that of our own solar system (1 Solar System Zodi) around nearby F, G, and K, stars; (2) characterize spectroscopically the atmospheres of a large number of known non-transiting planets; (3) survey and characterize nearby stars for planets down to 2 Earth-radii from just inside the habitable zone and inward. An enhanced version of FKSI with 1-m apertures separated by 20-m and cooled to 40 K, with science waveband 5-15 μm, allows for the detection and characterization of 2 Earth-radius and smaller super-Earths in the habitable zone around nearby stars.

1 Discussion

The FKSI mission concept has been under development for a number of years at NASA's Goddard Space Flight Center (Danchi et al. 2003, 2007) and it has a budget that fits into the strategic mission or Probe-class category with a lifecycle cost of around $600-800 million US dollars. During the last few years technology development funded by NASA and ESA for TPF-I, Darwin, and JWST have retired most of the major risks. Most of the key technologies are at a Technical Readiness Level (TRL) of 6 or greater, which means that, if funded, FKSI could entire into Phase A within the next two years (Danchi et al. 2008). The FKSI mission is designed to answer major scientific questions on the pathway to the discovery and characterization of Earth-twins around nearby F, G, and K main sequence stars.

One of the most vexing questions is the location and amount of emission of warm dust in the habitable zone of these stars, analogous to the zodiacal light in our own Solar System. This emission around nearby stars is called exozodi emission and is measured in units relative to that of our own Solar System (SSZs). Figure 1(Left) is a comparison of the ability of ground- and space- based concepts to measure this emission for nearby solar type stars.

Another major scientific area is characterizing the atmospheres of exoplanets discovered through radial velocity and other techniques. Currently only a small fraction of exoplanet atmospheres can be studied spectroscopically using transit methods, and these exoplanets are largely the ones with short periods that are very

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close to their stars. Not being limited to transiting planets, FKSI will greatly extend the size of the sample, which will have a major impact on models of planet formation and evolution. A third area is the search for rocky planets of size 2 Earth radii or smaller in the habitable zone of nearby stars. Figure 1 (Right) displays the FKSI's capability for super-Earth detection and Figure 2 (Left) displays results for an upgraded FKSI with waveband centered at 10 μm. Figure 2 (Right) displays the discovery space of FKSI for exoplanets as a function of semi-major axis and compares it to other missions. During the coming year, it is planned to validate the capability of an enhanced version of FKSI (1-m apertures, 40 K telescope temperature, 20-m separation), which would increase the efficiency of super-Earth detection down possibly to Earth-size planets.

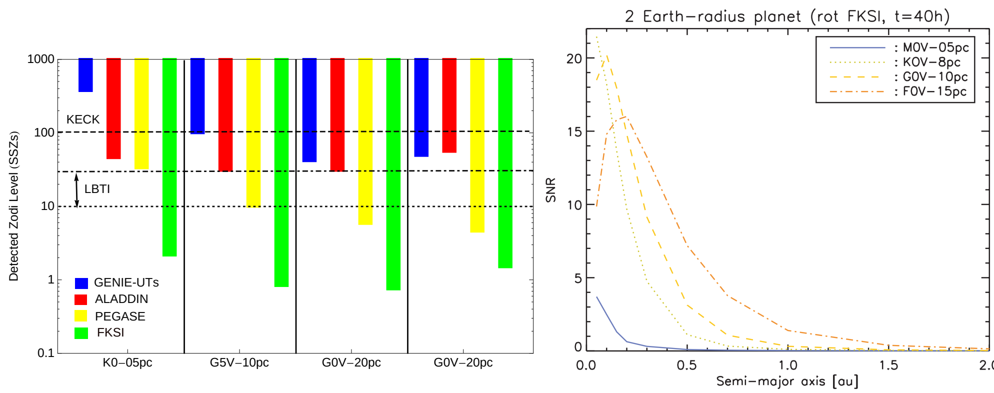

Fig. 1. Left : Comparison of exozodiacal detection limits for two ground-based concepts (GENIE with UTs on the VLTI and ALADDIN), and two space mission concepts (PEGASE and FKSI) (Defrère et al. 2008, A&A, 490, 435). **Right** : Result of a simulation for 2 Earth-radius super-Earth detection for FKSI showing that for SNR > 5, FKSI can detect many such rocky planets around nearby F, G, K, and M stars (Defrère et al. 2009, private communication).

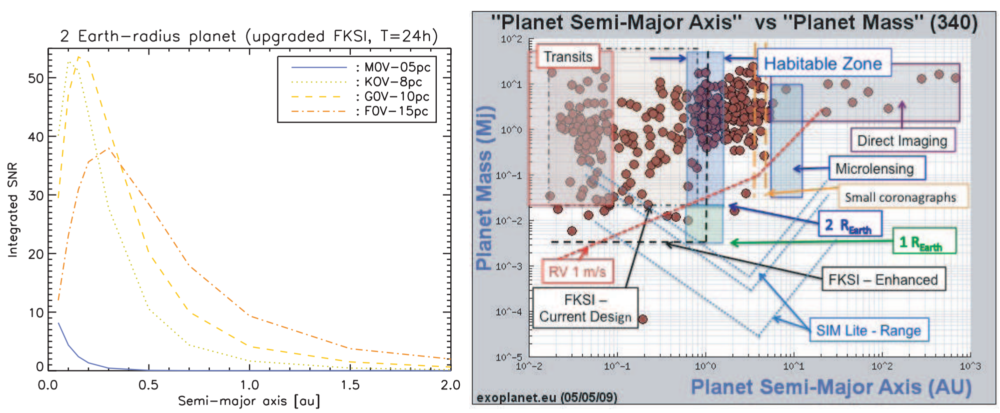

Fig. 2. Left : Result of a simulation for 2 Earth-radius super-Earth detection for the enhanced FKSI (1-m apertures, 40 K telescope temperature, 20-m separation) showing that for SNR > 5, FKSI can detect many such rocky planets *in the habitable zone* around nearby F, G, K, and M stars (Defrère et al. 2009, private communication). **Right**: Discovery space for exoplanets for FKSI compared with other mission concepts and techniques.

References

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