An Ultra-Stable Mid-Infrared Sensor for the Detection of Bio-Signatures by Means of Transit Spectroscopy

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The discovery of the Trappist-1 system, which consists of an ultra cool M-dwarf star orbited by 7 planets, 3 of which are located in the habitable zone, has demonstrated that these types of planetary systems around dwarf stars are very common. Such systems are well suited for the study of exoplanets. In particular the search for bio-signatures in the atmosphere of planets in the habitable zone around M-stars will be a high-priority science goal of future space missions. The mid-infrared (mid-IR) band between 3 and 15 microns is probably the best available band for this science, because the spectral lines of methane, ozone, and nitrous oxide can be found in this spectral range. he co-existence of these constituents in a planets atmosphere would be a very strong indicator for life on the planet.

Mid-IR transit spectrometers on future space missions such as Origins Space Telescope (OST) **will be** the instrument of choice to detect these bio-signatures in exoplanets around M-dwarfs. Current mid-IR detectors are based on impurity band conduc- tion (IBC) devices such as Si:As detectors. Charge trapping in these device leads to a time and exposure dependent response. As a result, this detector class is not expected to provide the required 5 ppm stability needed for a reliable detection of the aforementioned spectral lines. While efforts are under way to improve IBC detectors, it is un-clear how far the performance can be improved.

Here we describe the development of an ultra-stable Mid-IR Array Spectrometer demonstration for the observation of Exoplanet Transits (MIRASET), which includes a calibration system that, as we show, is needed to achieve the required sensitivity for the detection of atmospheric bio-signatures in habitable-zone planets around M-dwarfs. The spectrometer will be demonstrated with arrays of Transition Edge Sensor detectors (TES). These devices are known to have a very linear response and are intrinsically very stable. Furthermore, the required detector parameters (sensitivity, dynamic range) for space based mid-IR transit spectroscopy can be easily met with existing devices. No new detector developments are required, only the absorbers need to be optimized for the wavelength range of the instrument. This project will include the development of a high-accuracy calibration system with a stable reference source which itself will be monitored in the visible (0.5μm) by a photo diode. At this wavelength the precision of the load temperature measurement exceeds that of an in-band calibration. This scheme will allow for real time monitoring of the detector gain and offset, which we anticipate will result in a background limited performance with the required stability of better than 5 ppm for the detection of bio-signatures in a designated spectrometer flying e.g. on the OST space telescope, and as such will help to answer one of NASA's prime questions: "Are we alone?"