Development of an Ultra-Stable Mid-Infrared Detector Array for Space-Based Exoplanet Transit Spectroscopy

Johannes Staguhn (Johns Hopkins University / NASA - GSFC), PI

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 biosignatures 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 5 and 15 microns is probably the best available band for this science, because the band contains spectral lines of methane, ozone, and nitrous oxide. The coexistence of those in a planet's 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. However, current mid-IR detectors are based on impurity band conduction (IBC) devices such as Si:As detectors, which have significant problems with stability. As a result, those detectors are not expected to provide the required stability of ~ 5 ppm needed for a reliable detection of the aforementioned spectral lines. While efforts are under way to improve IBC detectors, it is unclear how far the performance can be improved.

Here we propose the development of an ultra-stable mid-IR Array Spectrometer demonstration for Exoplanet Transits (MIRASET), which includes a calibration system that, as we show, is required to achieve the minimum 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 be intrinsically very stable and 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. This project will include the development of a high-accuracy calibration system with a stable reference source which itself will be monitored by an out of band (0.5 µm) photo-diode at a wavelength at which the precision of this measurement exceeds that of an in-band calibration. This scheme will allow for real time monitoring of the detector gain, 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 main questions: "are we alone?"