Development of a Method for Exoplanet Imaging in Multi-Star Systems

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We propose to continue the technology advancement of Multi-Star Wavefront Control (MSWC), which is a method to directly image planets and disks in multi-star systems such as Alpha Centauri. This method works with almost any coronagraph or external occulter and requires little or no change to existing and mature coronagraph and wavefront control hardware. With an additional super-Nyquist mode, it also enables high contrast imaging beyond the outer working angle of a deformable mirror, enabling imaging of extended disks around single as well as suppressing wider separated multi-star systems.

We have previously identified wavefront control as the fundamental starlight suppression challenge for multi-star systems where the companion is close enough or bright enough where it cannot simply be removed in post-processing. We developed MSWC as a solution to this challenge and advanced it to TRL3. This consisted of lab demonstrations of dark zones in two-star systems, validated simulations, as well as simulated predictions demonstrating that with this technology, contrasts needed for Earth-like planets are in principle achievable.

The work proposed here consists of several elements, designed to advance Multi-Star Wavefront Control to TRL4+, as well as to demonstrate it on the sky with the Subaru Coronagraphic Extreme Adaptive Optics System (SCExAO). The first element is the simulation of MSWC. We will simulate MSWC with a variety of coronagraph designs for LUVOIR, HabEx, and other missions, as well as real targets, including photon noise and telescope jitter. This will develop the algorithm further and prove that Earth-like level contrasts are achievable in realistic scenarios. In addition, we will also carry a simulation effort of the lab in parallel with lab demonstrations, in order to validate the simulations as well as to gain a better understanding of the lab limiting factors. The second element is the laboratory testing of MSWC with a coronagraph and in broadband light. The goal is to demonstrate performance approaching the raw contrast requirements of missions like LUVOIR and HabEx, tune the algorithm for optimal performance with real hardware, and prepare it for a subsequent TRL5 test in vacuum. The third element is an on-sky test with the Subaru Coronagraphic Extreme Adaptive Optics system (SCExAO). Although many of the challenges on the ground are different from those of space missions, a ground test will still provide valuable information about how well our method works with a real telescope and on real targets, and help eliminate certain risks related to approximating real targets and a real telescope in the lab.

The main impact of this work is that it enables direct imaging of planetary systems and disks around multiple star systems as well as extends high contrast capability beyond the Nyquist-limited outer working angle of the DM, at essentially no additional hardware cost or changes to existing mission concepts, most notably LUVOIR and HabEx, but it also can be used with almost any other direct imaging concept such as Exo-C, EXCEDE, ACESat, etc. It will multiply the science yield of any direct imaging mission. Furthermore, it potentially enables the detection of biomarkers on Earth-like planets (if they exist) around our nearest-neighbor star, Alpha Centauri. The ability to directly image the αCen system in high contrast also enables the study of a planetary and disk system in much higher detail than for any other star, because αCen is a particularly low-hanging fruit many times closer and brighter than the next closest star of K-type or earlier.