Laboratory Demonstration of Multi-Star Wavefront Control in Vacuum

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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 nominal outer working angle of a deformable mirror, allowing imaging of wider separated multi-star systems, as well as larger disks and wider planetary systems around single stars. We have previously identified off-axis star leakage induced by surface aberrations as the fundamental starlight suppression challenge for multistar systems. Aberrations are usually removed using a wavefront control system based on deformable mirrors, and MSWC enables doing this in the presence of multiple stars. We have advanced MSWC to TRL 3, and are on track to advance it to TRL 4 before the start of this work. This consisted of computer-based demonstrations of high contrast on binary stars using MSWC with WFIRST, LUVOIR, and HabEx; 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 on LUVOIR and HabEx.

The work proposed here aims to advance MSWC to TRL 5 (component-level) by testing it with a simple generic coronagraph and layout, making it ready for system-level TRL5 tests specific to different missions and their specific coronagraphs and layouts. As our “simple generic” coronagraph, we plan to use the classical Lyot coronagraph at JPL’s High Contrast Imaging Testbed (HCIT). It has recently achieved better than <4e-10 in 10% broadband for single stars, and we will leverage this performance to test the operation of MSWC with binary stars at deep contrasts. At the end of year 1, our goal is to demonstrate at least 3e-9 raw contrast in monochromatic light, and at the end of year 2, in 10% broadband light. Our tests will simulate several potential binary star targets of interest to HabEx, LUVOIR, and WFIRST, including Alpha Centauri. Our work plan is also compatible with a variety of coronagraphs being tested at HCIT. If there is time remaining after reaching our milestones, we can proceed to demonstrate MSWC with additional coronagraphs towards system-level TRL5 for specific missions.

The main impact of this work is that it enables existing mission concepts to image planetary systems and disks around binary star systems, as well as extends high contrast capability beyond the Nyquist-limited outer working angle of the DM, with little or no hardware modifications. This will improve the quantity and quality of available targets, and enhance the science output. Furthermore, it enables the detection of biomarkers on potential Earth-like planets around our nearest-neighbor star, Alpha Centauri. The ability to directly image the aCen system in high contrast also represents an opportunity to study an exo-planetary system in much higher detail and SNR than for any other sun-like star, because aCen is many times closer and brighter than the next closest sun-like star.