



## NASA SBIR 2020 Phase I Solicitation

### S2.01 Proximity Glare Suppression for Astronomical Direct Detection of Exoplanets

Lead Center: JPL

Participating Center(s): GSFC

Technology Area: TA8 Science Instruments, Observatories & Sensor Systems

#### Scope Title

Control of Scattered Starlight with Coronagraphs and Starshades

#### Scope Description

This subtopic addresses the unique problem of imaging and spectroscopic characterization of faint astrophysical objects that are located within the obscuring glare of much brighter stellar sources. Examples include planetary systems beyond our own, the detailed inner structure of galaxies with very bright nuclei, binary star formation, and stellar evolution. Contrast ratios of one million to ten billion over an angular spatial scale of 0.05 - 1.5 arcsec are typical of these objects. Achieving a very low background requires control of both scattered and diffracted light. The failure to control either amplitude or phase fluctuations in the optical train severely reduces the effectiveness of starlight cancellation schemes.

This innovative research focuses on advances in coronagraphic instruments, starlight cancellation instruments, and potential occulting technologies that operate at visible and near infrared wavelengths. The ultimate application of these instruments is to operate in space as part of a future observatory mission concepts such as the Habitable Exoplanet Observatory (HabEx) and Large Ultraviolet Optical Infrared Surveyor (LUVVOIR). Measurement techniques include imaging, photometry, spectroscopy, and polarimetry. There is interest in component development and innovative instrument design, as well as in the fabrication of subsystem devices to include, but not limited to, the following areas:

Starlight Suppression Technologies:

- Hybrid metal/dielectric and polarization apodization masks for diffraction control of phase and amplitude for coronagraph scaled starshade experiments.
- Low-scatter, low-reflectivity, sharp, flexible edges for control of solar scatter in starshades.
- Low-reflectivity coatings for flexible starshade optical shields.
- Systems to measure spatial optical density, phase inhomogeneity, scattering, spectral dispersion, thermal variations, and to otherwise estimate the accuracy of high-dynamic range apodizing masks.
- Methods to distinguish the coherent and incoherent scatter in a broadband speckle field.

Wavefront Measurement and Control Technologies:

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- Small stroke, high precision, deformable mirrors and associated driving electronics scalable to 10,000 or more actuators (both to further the state-of-the-art towards flight-like hardware and to explore novel concepts). Multiple deformable mirror technologies in various phases of development and processes are encouraged to ultimately improve the state-of-the-art in deformable mirror technology. Process improvements are needed to improve repeatability, yield, and performance precision of current devices.
  - Multiplexers with ultra-low power dissipation for electrical connection to deformable mirrors
  - Low-order wavefront sensors for measuring wavefront instabilities to enable real-time control and post-processing of aberrations.
  - Thermally and mechanically insensitive optical benches and systems.

#### Optical Coating and Measurement Technologies:

- Instruments capable of measuring polarization cross-talk and birefringence to parts per million.
- Polarization-insensitive coatings for large optics.
- Methods to measure the spectral reflectivity and polarization uniformity across large optics.
- Methods to apply carbon nanotube coatings on the surfaces of the coronagraphs for broadband suppression from visible to near infrared (NIR).

#### References

See SPIE conference papers and articles published in the Journal of Astronomical Telescopes and Instrumentation on high contrast coronagraphy, segmented coronagraph design and analysis, and starshades.

#### Websites:

- Exoplanet Exploration - Planets Beyond Our Solar System: <https://exoplanets.jpl.nasa.gov>
- Exoplanet Exploration Program: <https://exoplanets.nasa.gov/exep/>
- Goddard Space Flight Center: <https://www.nasa.gov/goddard>

**Expected TRL or TRL range at completion of the project:** 3 to 5

#### Desired Deliverables of Phase II

Prototype, Analysis, Hardware, Research

#### Desired Deliverables Description

This subtopic solicits proposals to develop components that improve the footprint, robustness, power consumption, reliability, and wavefront quality of high-contrast, low-temporal bandwidth, adaptive optics systems. These include ASIC drivers that easily integrate with the deformable mirrors, improved connectivity technologies, as well as high-actuator count deformable mirrors with high-quality, ultrastable wavefronts.

It also seeks coronagraph masks that can be tested in ground-based high-contrast testbeds in place at a number of institutions, as well as devices to measure the masks to inform optical models. The masks include transmissive scalar, polarization-dependent, and spatial apodizing masks including those with extremely low reflectivity regions that allow them to be used in reflection.

The subtopic seeks samples of optical coatings that reduce polarization and can be applied to large optics, and methods and instruments to characterize them over large optical surfaces.

Finally, for starshades, the subtopic seeks low reflectivity and potentially diffraction-controlling edges that minimize scattered sunlight while also remaining robust to handling and cleaning. Low-reflectivity optical coatings that can be applied to the surfaces for the large (hundreds of square meters) optical shield are also desired.

#### State of the Art and Critical Gaps

Coronagraphs have been demonstrated to achieve high contrast in moderate bandwidth in laboratory

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environments. Starshades will enable even deeper contrast over broader bands but to date have demonstrated deep contrast in narrow band light. The extent to which the telescope optics will limit coronagraph performance is a function of the quality of the optical coating and the ability to control polarization over the full wavefront. Neither of these technologies is well characterized at levels required for  $1e10$  contrast. Wavefront control using deformable mirrors is critical. Controllability and stability to picometer levels is required. To date, deformable mirrors have been up to the task of providing contrast approaching  $1e10$ , but they require thousands of wires, and overall wavefront quality and stroke remain concerns.

### **Relevance / Science Traceability**

These technologies are directly applicable to the Wide Field Infrared Survey Telescope (WFIRST), coronagraph instrument (CGI), and the HabEx and LUVOIR concept studies.