Exoplanet Exploration Program Technology: Decadal Survey Testbed, Segmented Coronagraph Design and Analysis, Mission Roadmap

Brendan Crill
Deputy Program Chief Technologist

Nick Siegler
Program Chief Technologist

NASA Exoplanet Exploration Program
Jet Propulsion Laboratory – California Institute of Technology

This work was conducted at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration,
© 2018 California Institute of Technology. Government sponsorship acknowledged
The Decadal Survey Testbed

• New coronagraph vacuum testbed facility to be commissioned in the large High Contrast Imaging Testbed 40’ chamber this year
• Aim to achieve $1 \times 10^{-10}$ contrast levels
Unique features of the DST

• Simple optical layout, minimize number of reflections
• Low CTE carbon composite bench
• 16-zone thermal control (including DM), MLI shrouds
• Well-characterized DM
• Jitter reduction: vacuum-compatible isolation stages
• LOWFS/C with DM mounted on a fast piezo tip-tilt stage
Decadal Survey Testbed plans

**Phase I - Commissioning (clear, unobscured pupil; static demonstration)**

- Using a Hybrid Lyot Coronagraph architecture with an unmasked circular pupil, demonstrate a $360^\circ$ annular dark hole from $3$ to $9 \lambda/D$ in a $10\%$ bandpass centered at $550$ nm with mean contrast $\leq 10^{-10}$.

**Phase II – Segmented Telescope (segmented, obscured pupil; static demonstration)**

- Using a TBD coronagraph, add a TBD segmented pupil mask and demonstrate a $360^\circ$ annular dark hole from $3$ to $9 \lambda/D$ in a $10\%$ bandpass centered at $550$ nm with mean contrast $\leq 5e-10$ (TBR).

**Phase III – Segmented Telescope (segmented, obscured pupil, dynamic demonstration)**

- Same as Phase II but now with a segmented telescope simulator and a disturbance source.
DST first light by next month:
DM installed this summer
Segmented Coronagraph Design and Analysis (SCDA) study

- SCDA study is evaluating coronagraph designs for future large on-axis, segmented space telescopes

- Groups at Arizona, Ames, GSFC, STScI, JPL, Caltech, are designing coronagraphs to achieve $10^{-10}$ contrast -> maximize scientific yield

- Evaluate designs against a common set of metrics (such as robustness, manufacturability, does coronagraph place unrealistic demands on telescope)

- APLC design so far is the most successful architecture, though obtaining excellent throughput and IWA is still a challenge

- Apodized vortex designs for centrally obscured pupils are sensitive to stellar diameter

- PIAACMC design can be used for longer wavelengths (where stellar size is less of a problem)
Lessons from SCDA

Study of relative merits of possible segment configurations
see 2016 report by Feinberg et al. on ExEP website
Lessons from SCDA

Pupil obscuration from secondary mirror + supports is extremely important for determining coronagraph throughput

For example APLC designs see a large performance dropoff when secondary mirror diameter exceeds ~30% of the primary mirror diameter

Figure courtesy of K. St Laurent
Lessons from SCDA

Inscribed diameter of primary mirror matters more than circumscribed diameter

Coronagraph throughput increasing

From Soummer et al (2017) SCDA report

If segment gaps are small, segmentation itself doesn’t matter much

Entrance pupil  Pupil-plane apodizer

From Ruane et al JATIS (2018)
SCDA next steps

- Lab tests of masks underway
- Robustness metrics for wavefront errors are being developed and designs will be evaluated against them
- FALCO (joint DM / apodizer optimizer) code public release imminent
- Designs to be tested within same PROPER software framework
- Many results to be presented at Austin SPIE: joint SCDA paper planned for this fall
Please visit the NASA ExEP website for more details:

https://exoplanets.nasa.gov/exep/