National Aeronautics and Space Administration

VORTEX FIBER NULLING FOR TARGETED EXOPLANET CHARACTERIZATION WITHIN THE DIFFRACTION LIMIT

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Program: Topical R&TD

Project Objective:

Vortex fiber nulling (VFN) is a new method for detecting and spectroscopically characterizing exoplanets at small angular separations (<λ/D).

In this R&TD, we proposed to:

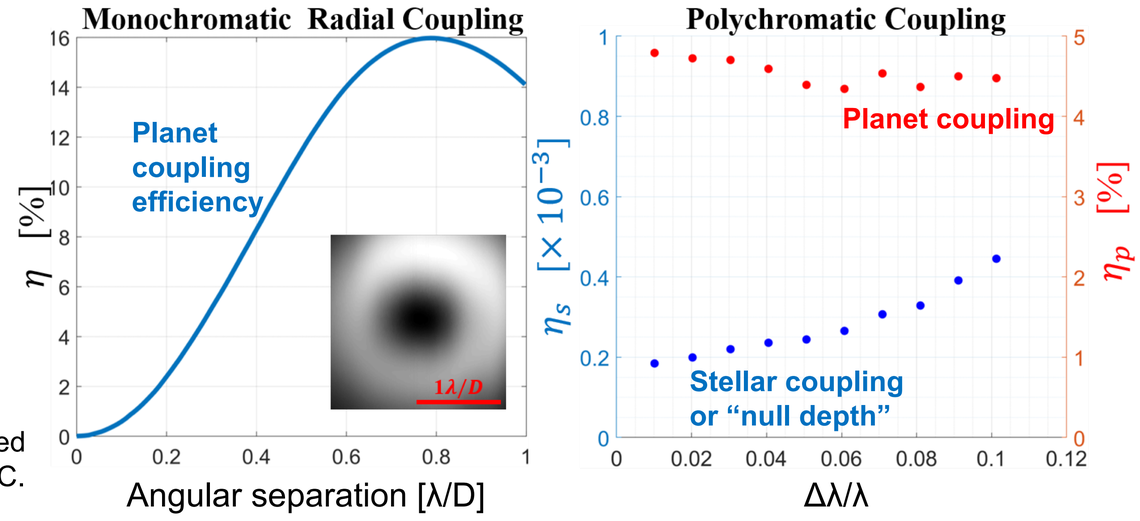
- Carry out optical breadboard demonstration of VFN in monochromatic and polychromatic light.
- Build and test a prototype VFN instrument compatible with the Keck Planet Imager and Characterizer (KPIC) instrument at W.M. Keck Observatory.
- Test closed loop wavefront control algorithms designed to achieve and maintain null depths on the order of 1e-4 on current and future ground- and space-based telescopes in the lab.

FY18/19 Results:

Monochromatic Lab Demo:
635nm Laser Light
Planet Coupling = 16%
Null Depth = 6×10^{-5}

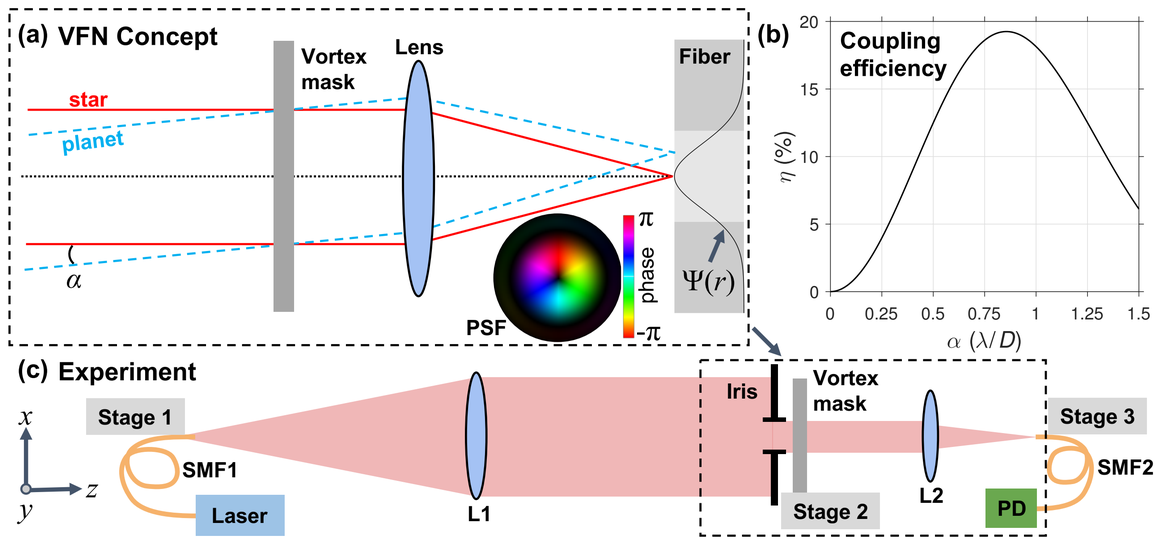
Polychromatic Lab Demo:
10% Bandwidth @790nm
Planet Coupling = 4.5%
Null Depth = 4×10^{-4}

Designed the hardware required to enable a VFN mode on KPIC.

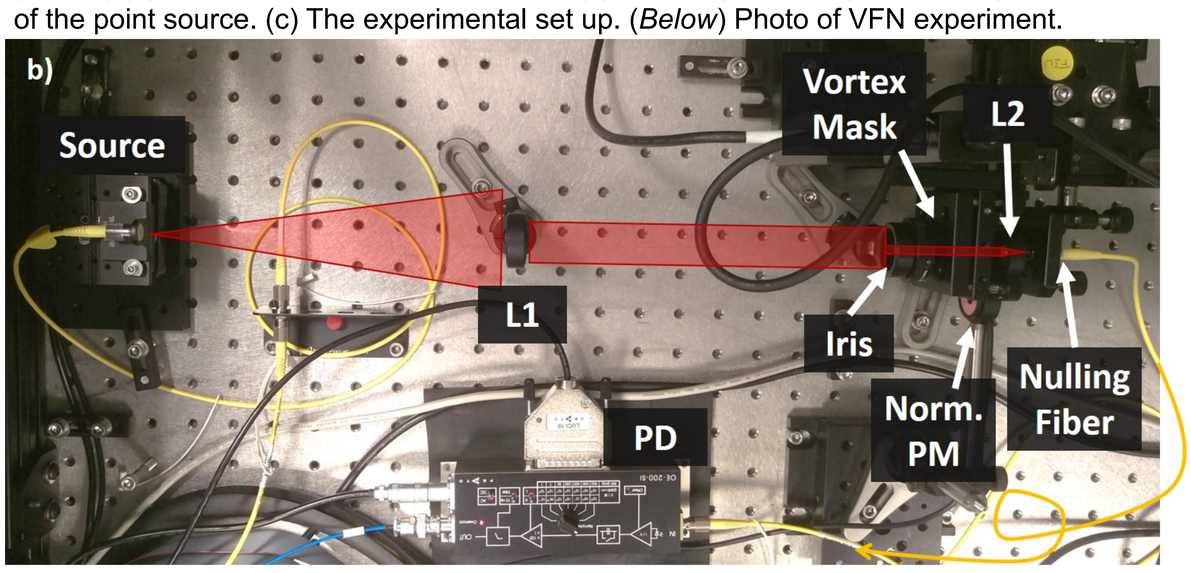


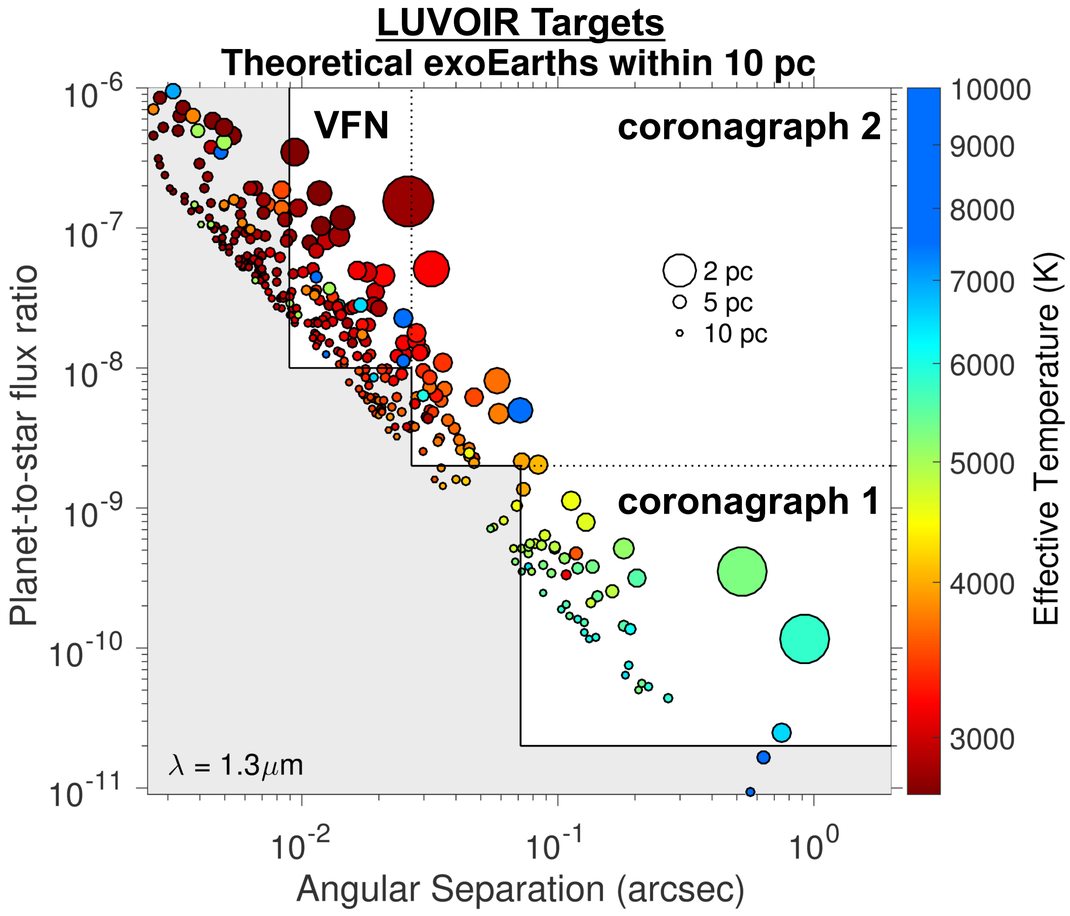
Benefits to NASA and JPL (or significance of results):

- VFN is a enhancing technology for planned high-contrast imaging instruments on space-based mission concepts such as LUVOIR, HabEx, and OST.
- VFN will potentially lead to new, significant science capabilities including the characterization of planets within the current inner working angle thereby enabling exoplanetology around cool M-type stars, as well as enabling the detection of methane in the near-infrared (1.7-1.8 μm), a critical biosignature when combined with oxygen and water.
- VFN would drastically increase the total number of exoplanets characterized in the near infrared with the space-based mission concepts.
- With a 15 meter space telescope, VFN would detect key biomarkers in 10s of hours of integration time without the typical overhead associated with wavefront control for imaging.
- VFN can also be deployed on current and future ground based telescopes, such as Keck, TMT, and GMT.



(*Above*) (a) Schematic of a VFN instrument. (b) Coupling efficiency versus angular separation of the point source. (c) The experimental set up. (*Below*) Photo of VFN experiment.





The planet-to-star flux ratio of theoretical Earth radius planets in the habitable zone of all stars within 10 pc versus their angular separation from their host star. The size of the marker encodes the distance to the target and the color represents the effective temperature of the host star. VFN accesses close-in planets orbiting cool stars.

Publications:

Ruane, G., Wang, J., Mawet, D., et al., "Efficient Spectroscopy of Exoplanets at Small Angular Separations with Vortex Fiber Nulling," *Astrophys. J.* 867(2), 143 (2018).

Echeverri, D., Ruane, G., Jovanovic, N., et al., "Vortex fiber nulling for exoplanet observations. I. Experimental demonstration in monochromatic light," *Opt. Lett.* 44(9), 2204-2207 (2019).

Ruane G., Echeverri D., Jovanovic, N., et al., "Vortex fiber nulling for exoplanet observations: conceptual design, theoretical performance, and initial scientific yield predictions," *Proc. SPIE* 11117, 1111716 (2019)

Echeverri D., Ruane, G., Jovanovic N., et al., "The vortex fiber nulling mode of the Keck Planet Imager and Characterizer (KPIC)," *Proc. SPIE* 11117, 111170V (2019)

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