

Development Progress of wide-spectral-band combined nuller systems using the **one-dimensional diffraction-limited coronagraph (1DDLC)**

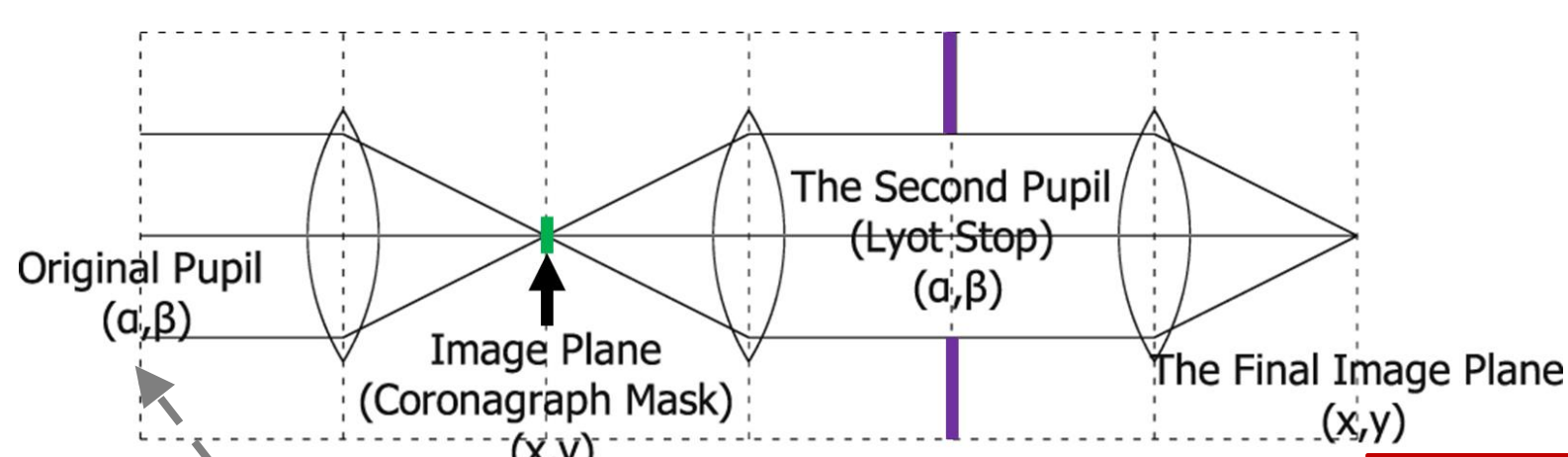
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Spectral observations of the directly detected planets require wide wavelength bands of the coronagraphic instruments. We report on the development progress of wide-spectral-band serially conjoined nuller systems using the one-dimensional diffraction-limited coronagraph (1DDLC). The 1DDLC offers promising features, such as a binary null ability like the band-limited mask coronagraph (PIAA-CMC), but its starlight-suppression performance at the diffraction-limited (about $1 \lambda/D$) separation angles is affected by spectral bandwidth. This is because speckle nulling sufficiently works for the wavelength-deviation leak only at the non-diffraction-limited separation angles. Nevertheless, in the 1DDLC, wavelengths deviated from the design wavelength introduce leaks with a flat wavefront on the Lyot-stop plane. This leak can be removed by the successive nuller. Hence, conjoined nuller systems using the 1DDLC can achieve wide spectral bands even at diffraction-limited (about $1 \lambda/D$) separation angles. So far, a monochromatic experiment without active wavefront controls demonstrated the starlight-suppression ability of the 1DDLC to at worst a 10^{-5} level. With the same experimental setup, we have also confirmed the PSF profile of the leak from the 1DDLC due to the wavefront deviation from the design-center wavelength same as the profile of the on-axis point source. In this setup, we implemented the focal-plane mask using a method similar to but different from the vector vortex mask coronagraph. The possible second-stage nuller includes photonic-integrated-circuit (PIC) nullers and fiber nullers. An experiment adopting a fiber nuller as the second stage has shown that the combination of the two nullers actually broadens the spectral bandwidth. For future demonstration of the combination of the 1DDLC and the PIC, designing a connection part between nullers is ongoing. We plan to conduct the demonstrations in cooperation with wavefront correction technologies in the future.

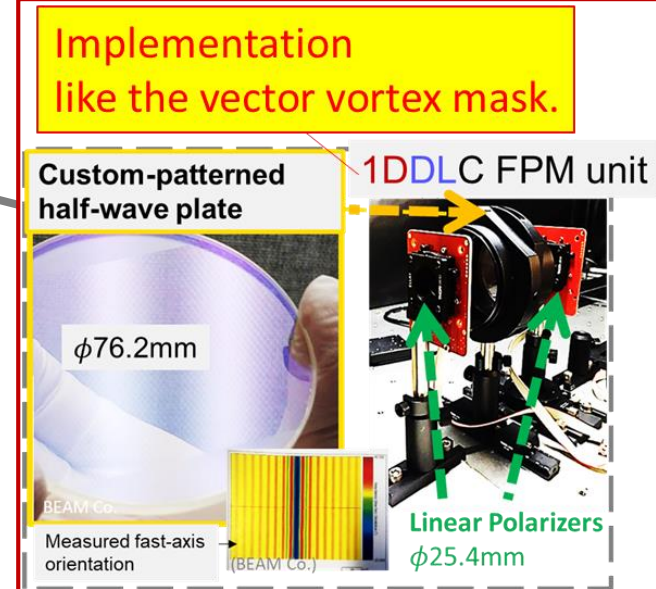
1st Stage Nuller

One-Dimensional Diffraction-limited Coronagraph (1DDLC)

A type of the Lyot coronagraph

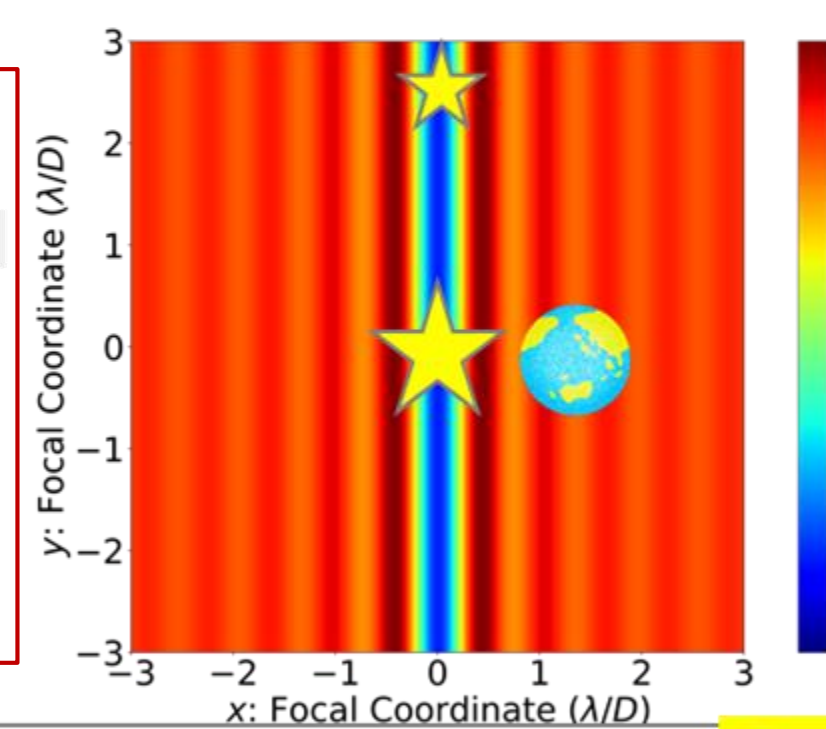


The 1DDLC works for rectangular pupils and their approximations.



Like Band-Limited Mask
One-dimensional Focal-plane mask pattern

An (amplitude + π -rad phase) mask

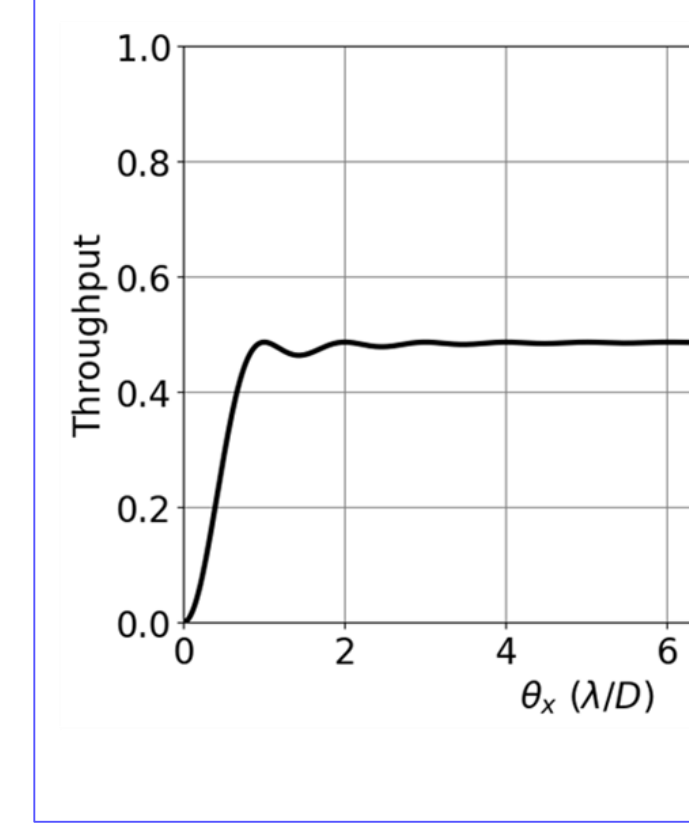


Theoretically perfect null for monochromatic line source.

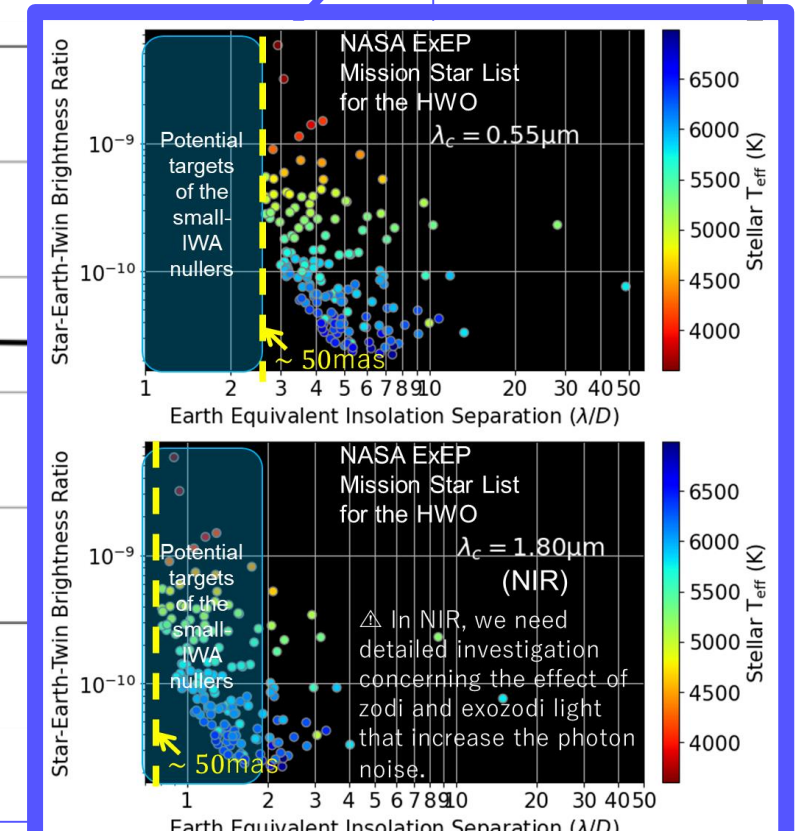
The minus signs mean $e^{\pi i} (= -1)$.

Double star nuller

Like PIAA-CMC
Diffraction-limited Planetary throughput (except for a constant factor of about 50%)

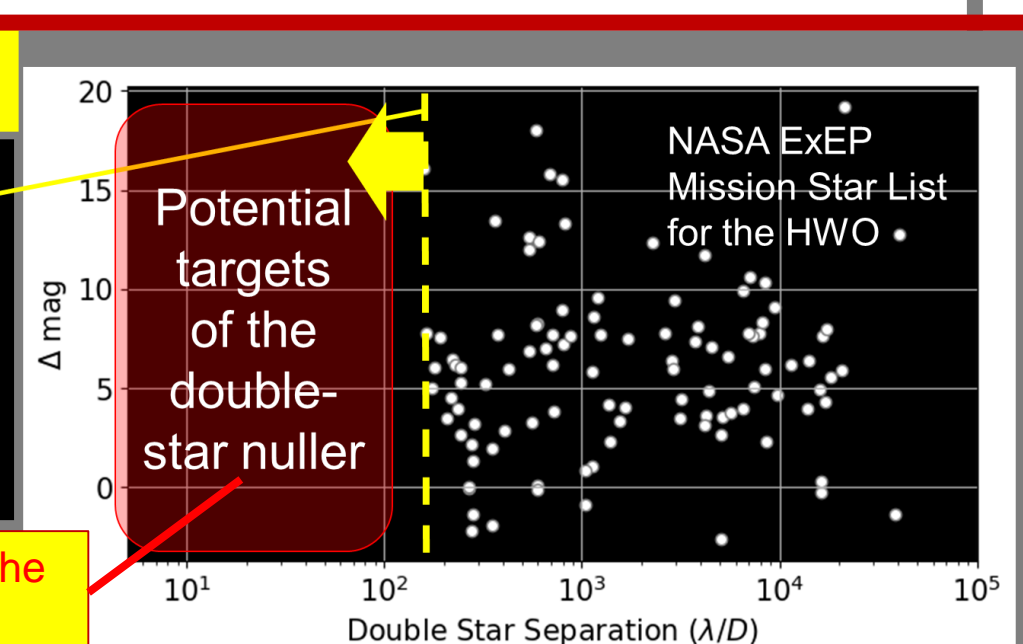


Background of the development.

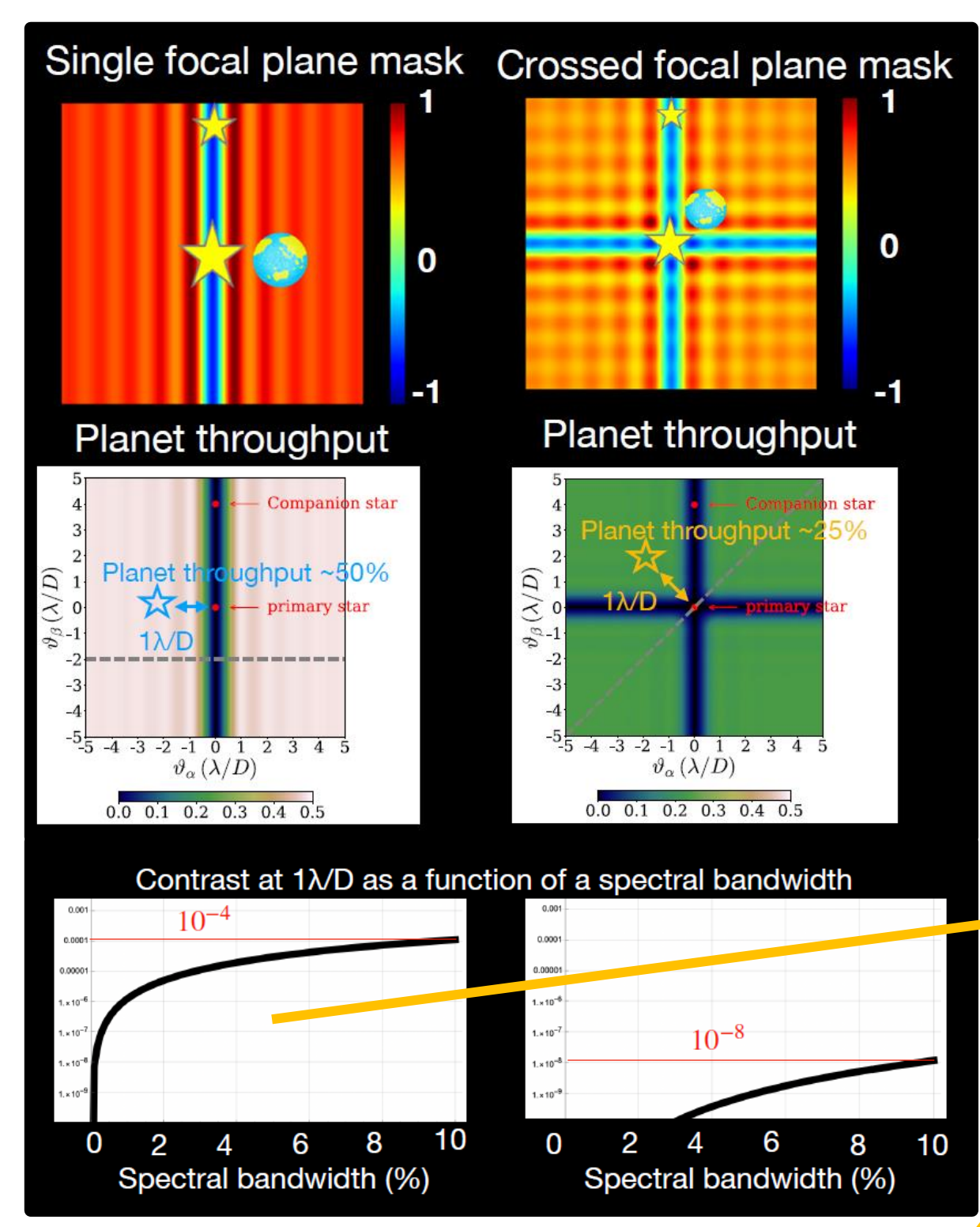


NASA ExEP Target List HWO Documentation 2023

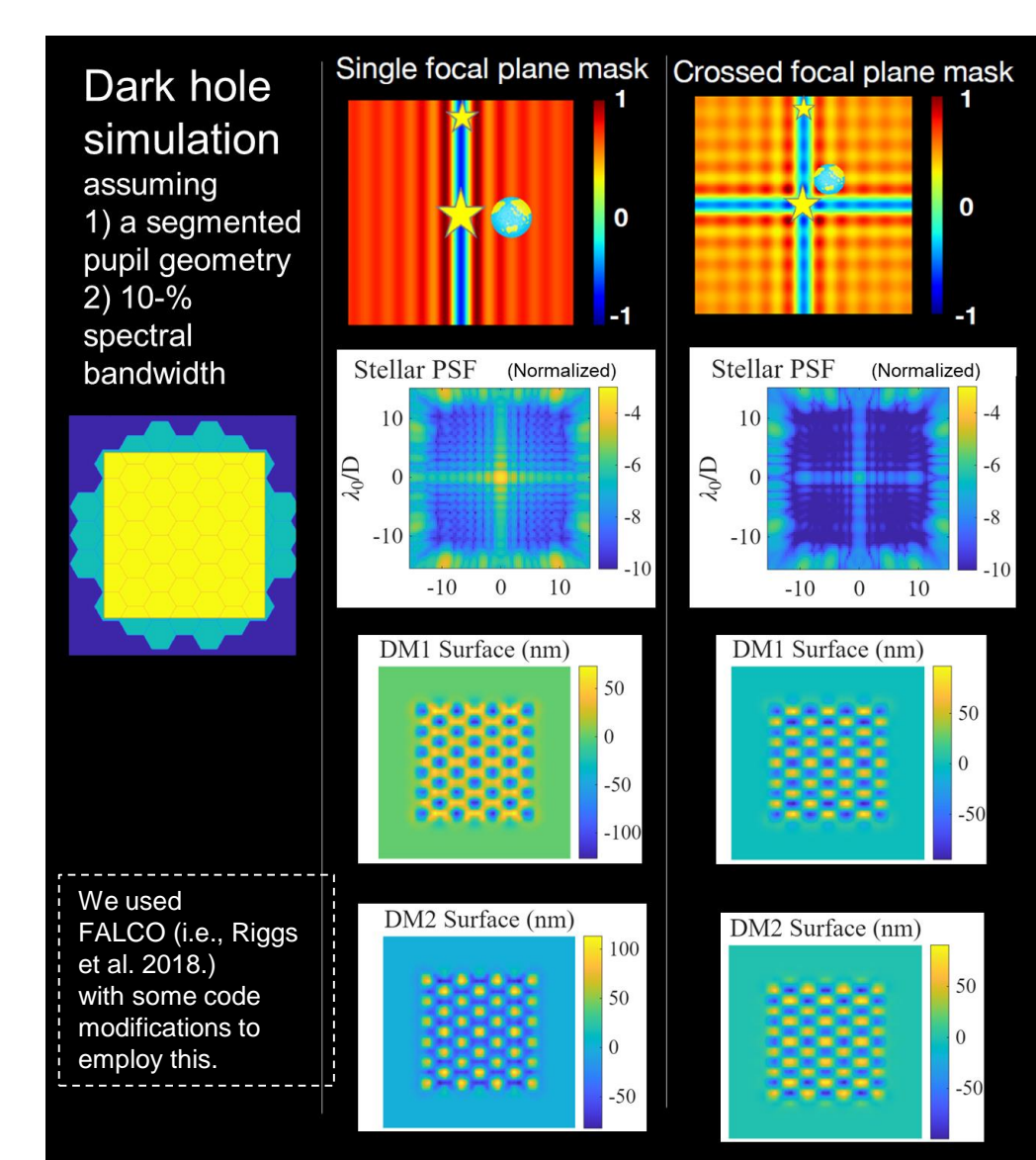
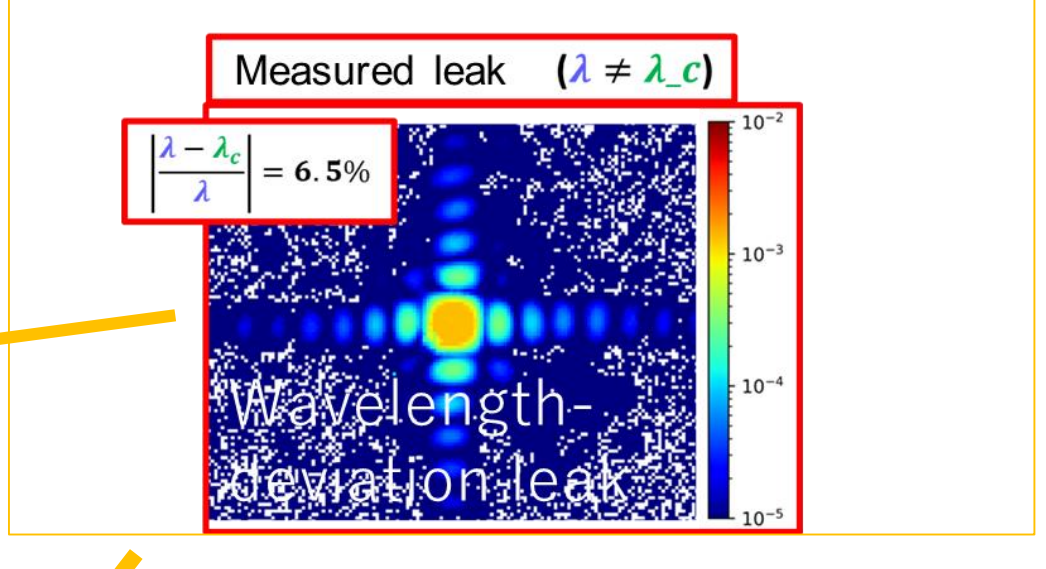
All unresolved spectroscopic binaries and binaries with separations < 3'' are excluded from the list, under the assumption that they will prove too challenging a problem for starlight suppression.



Background of the development.



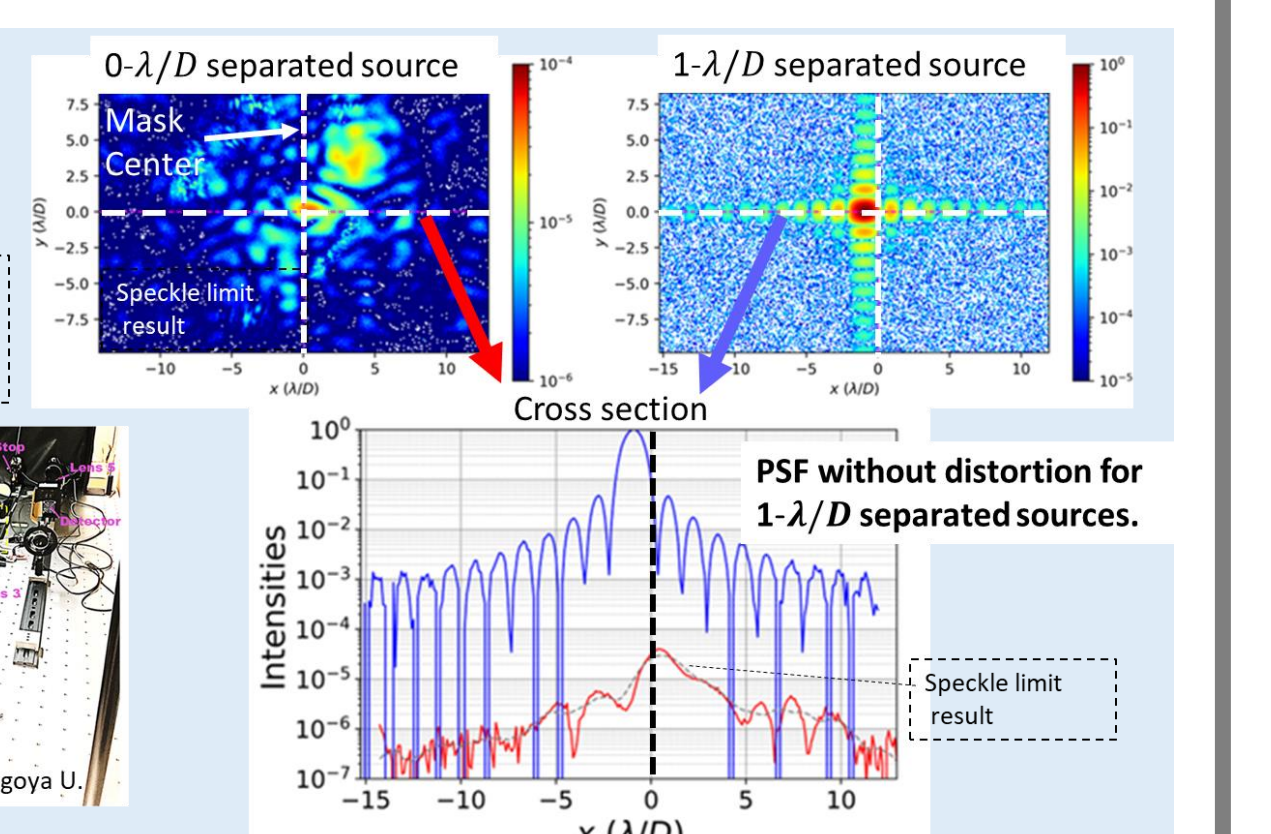
Another nuller after the 1DDLC can null the 1DDLC's leak



Prototype Experiment

Itoh et al. 2023 PASP

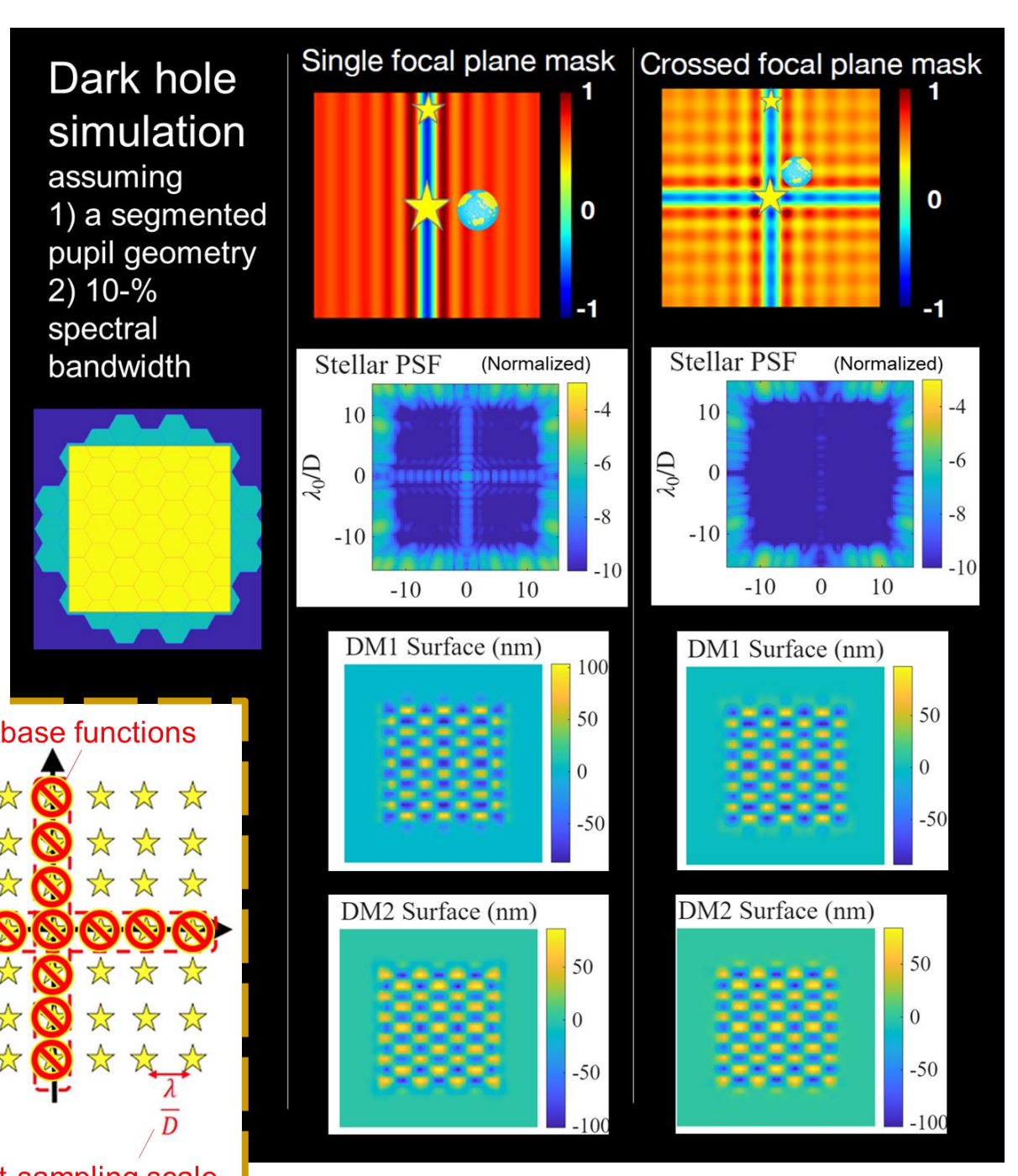
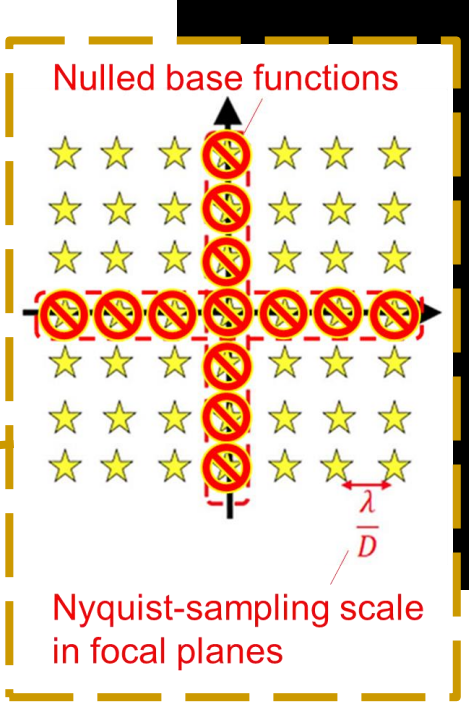
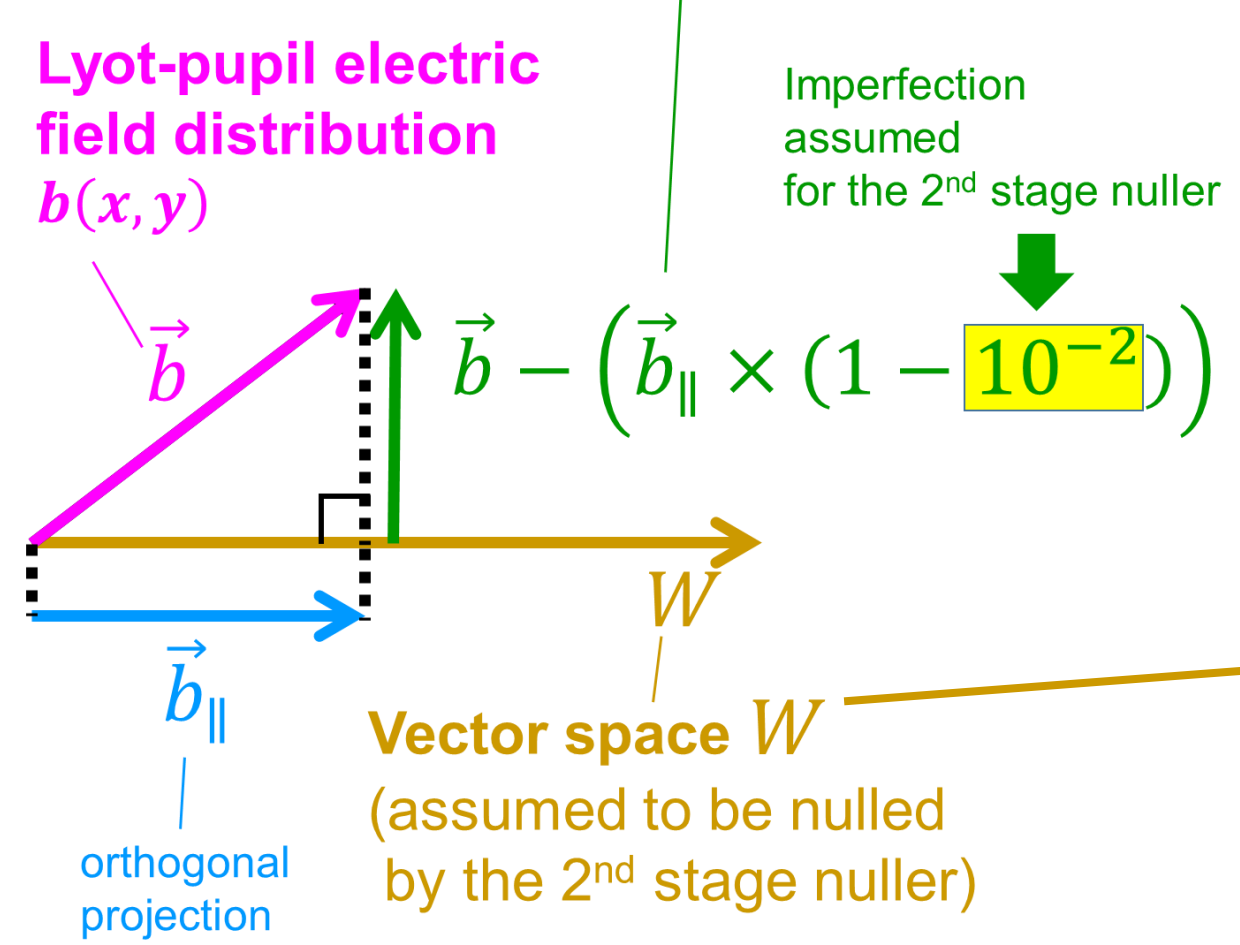
no wavefront correction, monochromatic source, point source



Combined Nuller Simulation

Output field of the assumed 2nd stage nuller

Result



2nd Stage Nullers (Under Investigation)

Photonic-IC Nuller
Fiber Nuller

