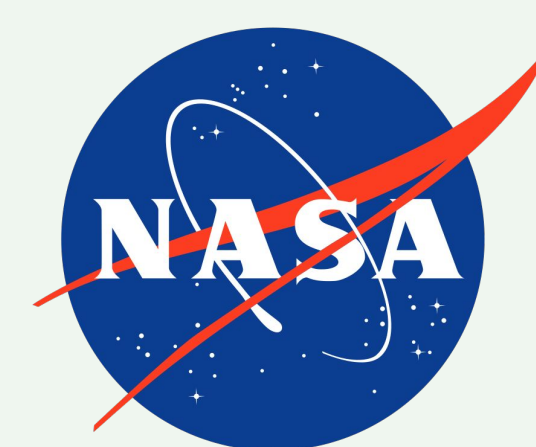


Relaxing stability requirements on HWO by suppressing sensitivity to specific modes

¹Jordan Diaz, ²Ruslan Belikov, ¹Emiel H. Por, ¹Rebecca Jensen-Clem
¹University of California, Santa Cruz, ²NASA Ames Research Center



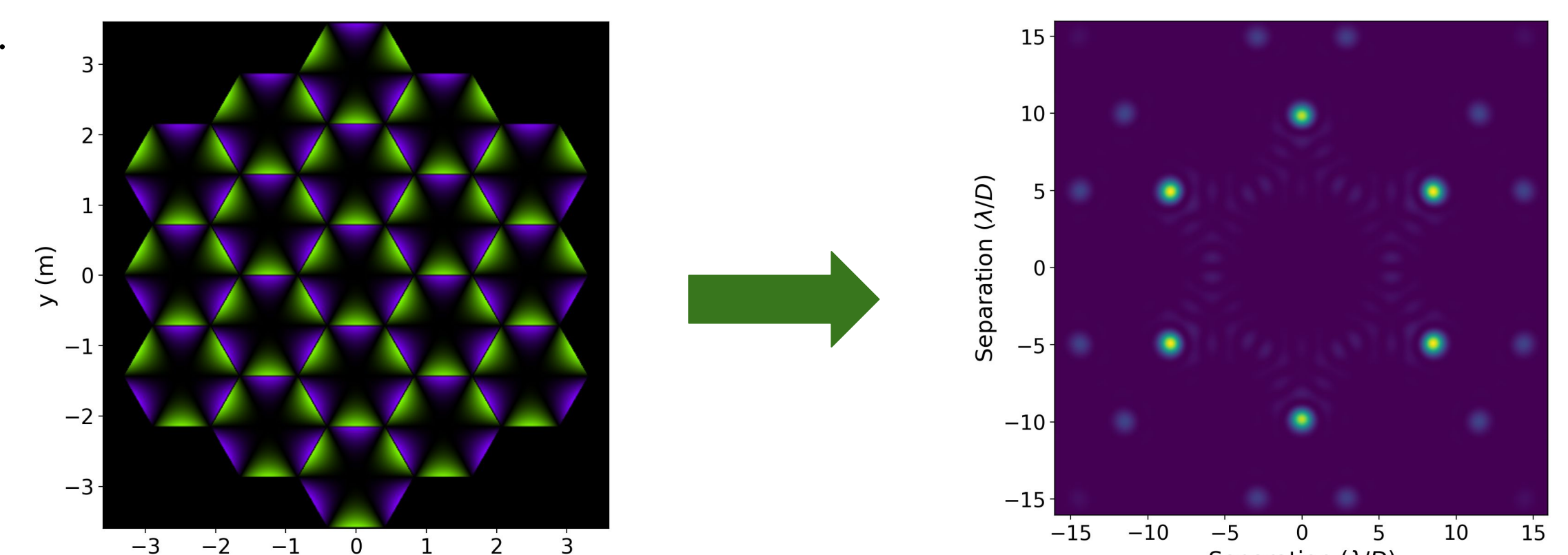
UNIVERSITY OF CALIFORNIA
SANTA CRUZ



Motivation

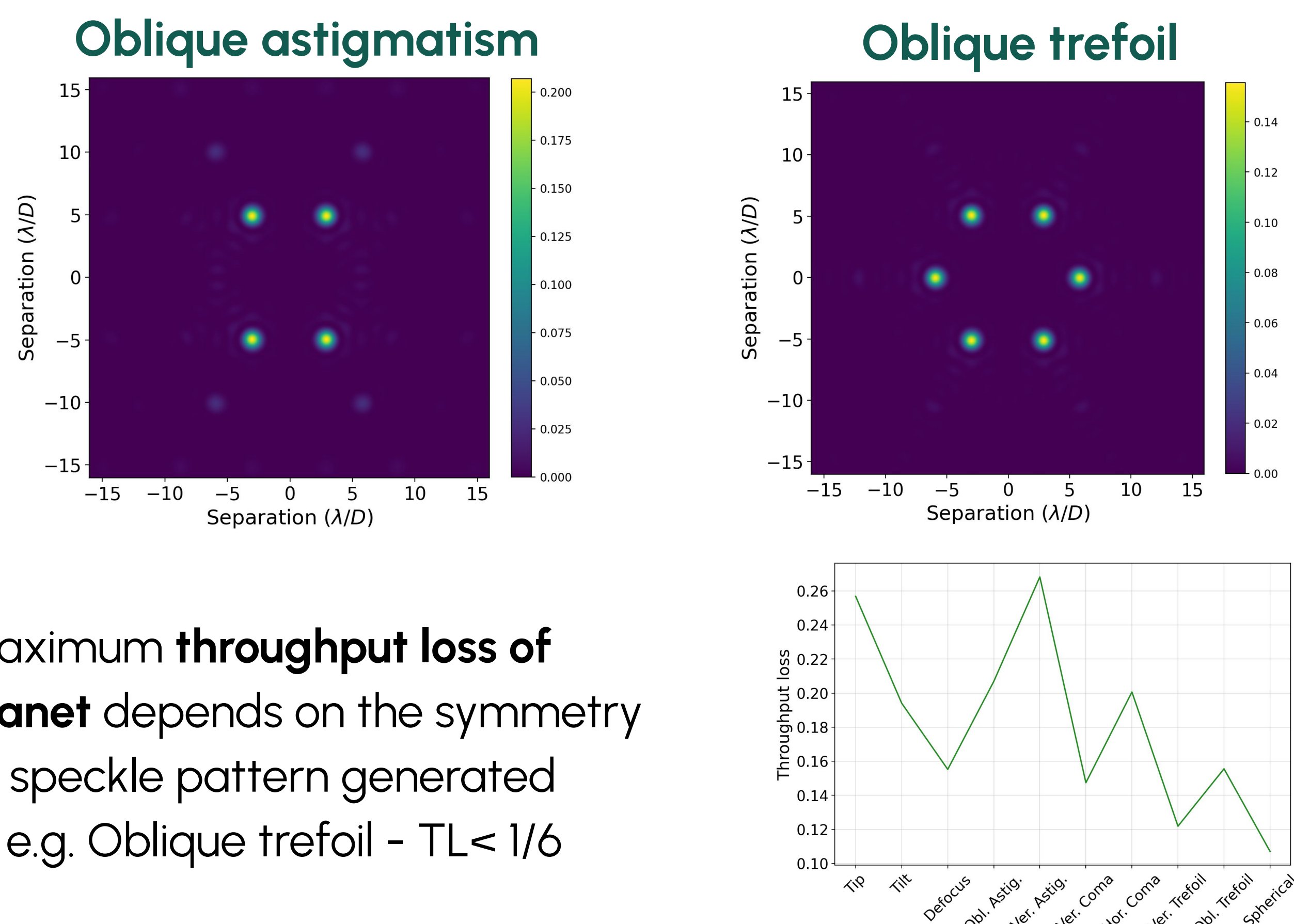
- One of the Habitable Worlds Observatory (HWO) goals is to achieve contrast levels of 10^{-10} in order to detect exoEarths in the visible, requiring wavefront stability on the order of picometers.
- Current traditional coronagraph designs are inefficient compared to theoretical limits and are highly susceptible to wavefront aberrations, thus an approach to make HWO's Coronagraphic Instrument (CI) more robust is needed or the coronagraph itself.
- Consider a coronagraph with the capability to remove any specific set of modes in the incoming field.
 - How would this relax stability requirements and what impact would it have on expected science yield?

Segmented aberrations

- Global variations (from mechanical or thermal sources) perceived identically by EAC 1 segments generate a set of speckles in the focal plane.
 
- Energy of PSF is distributed across speckles → Suppression of mode would have an impact on throughput of a planet

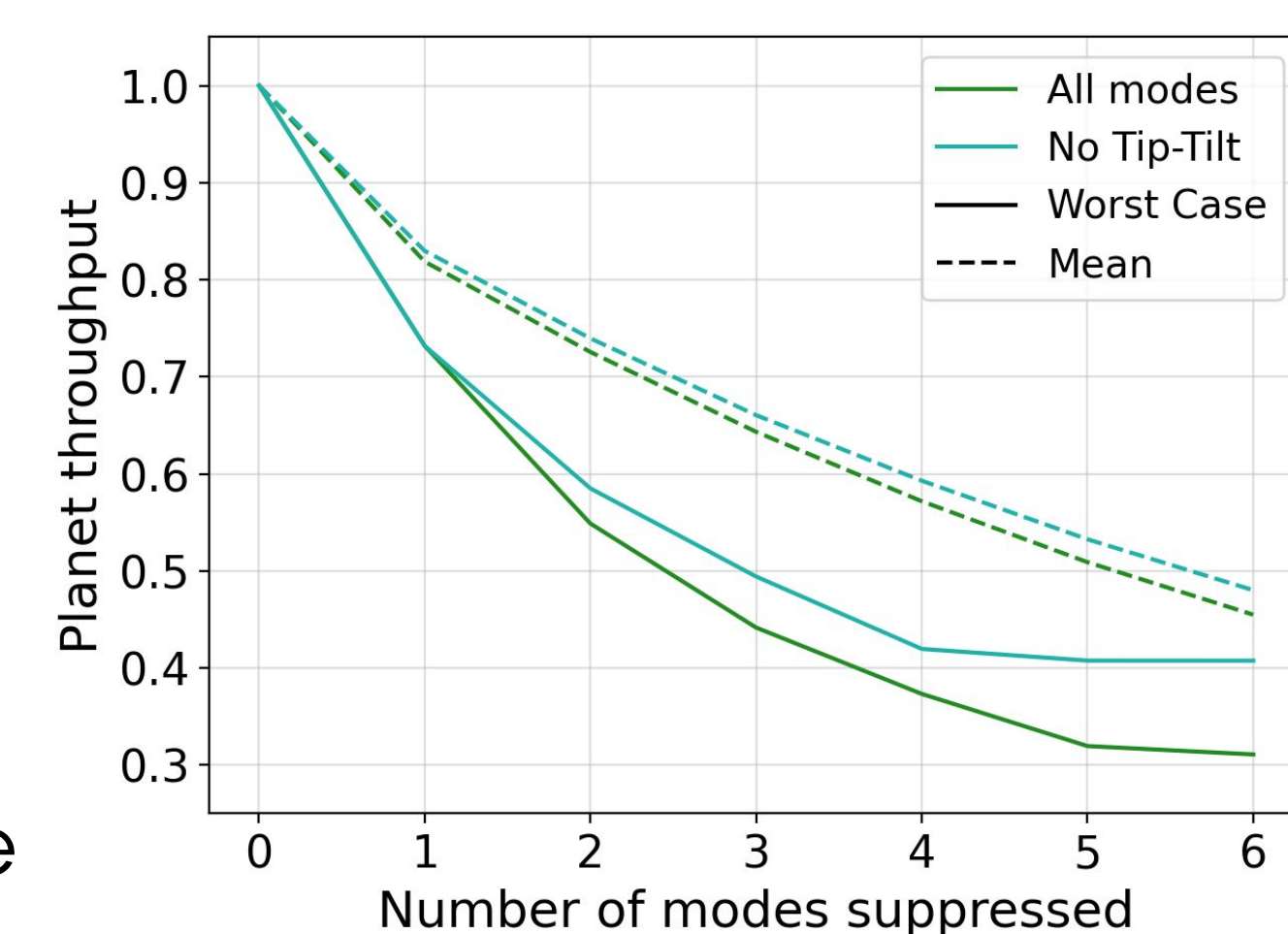
Planet throughput cost and the *mode zapper* coronagraph

- We map the **throughput loss** as a function of a planet's position over the field of view for each Zernike aberration from tip to spherical ($j=2-11$)



- Maximum **throughput loss of planet** depends on the symmetry of speckle pattern generated
 - e.g. Oblique trefoil - TL < 1/6

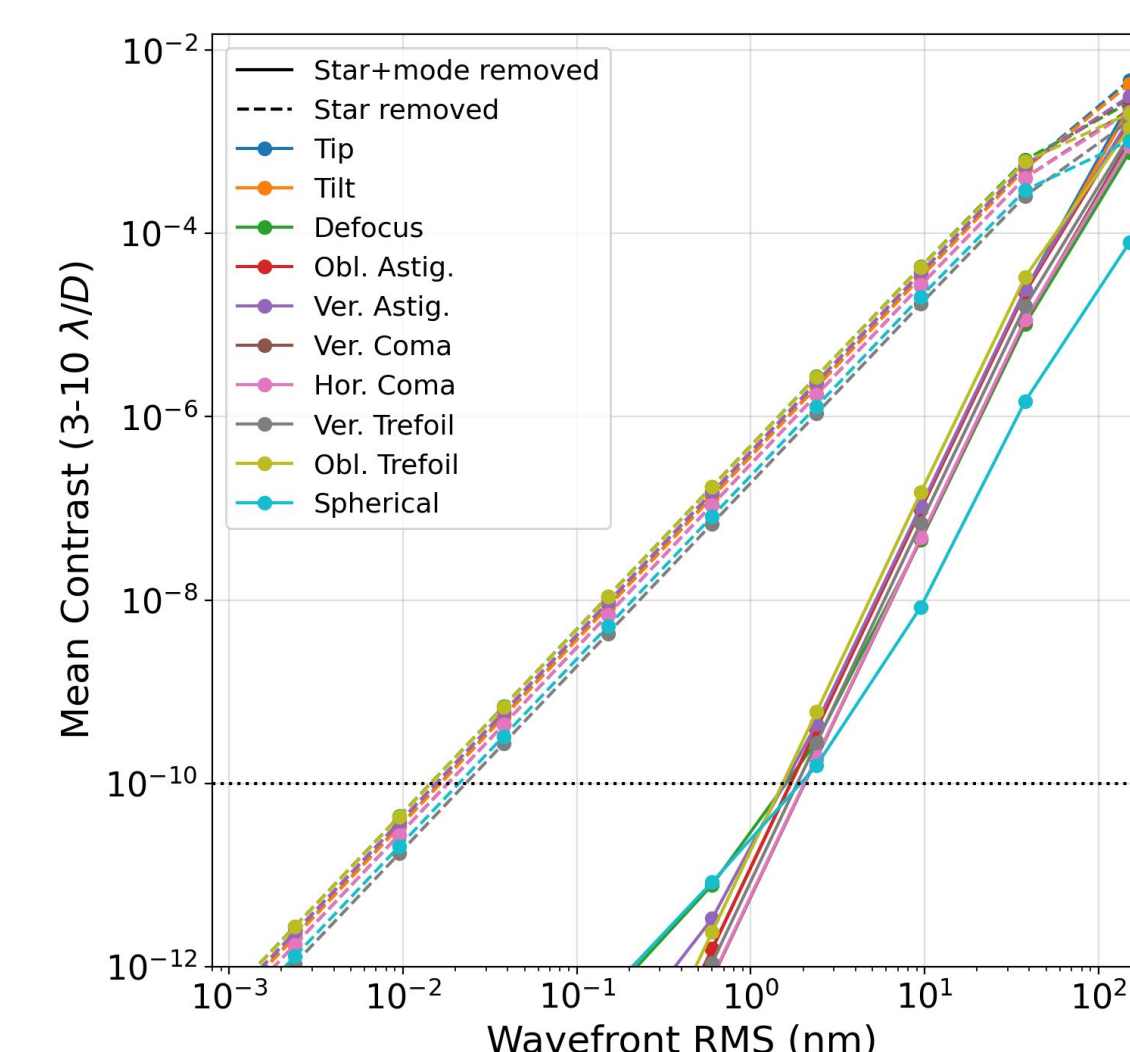
- How many modes can we block simultaneously before a companion's throughput is significantly deteriorated?
- We compute a planet's throughput for all possible combinations of modes and the worst case scenario (speckles over planet location)



5 modes blocked
 → 50% throughput

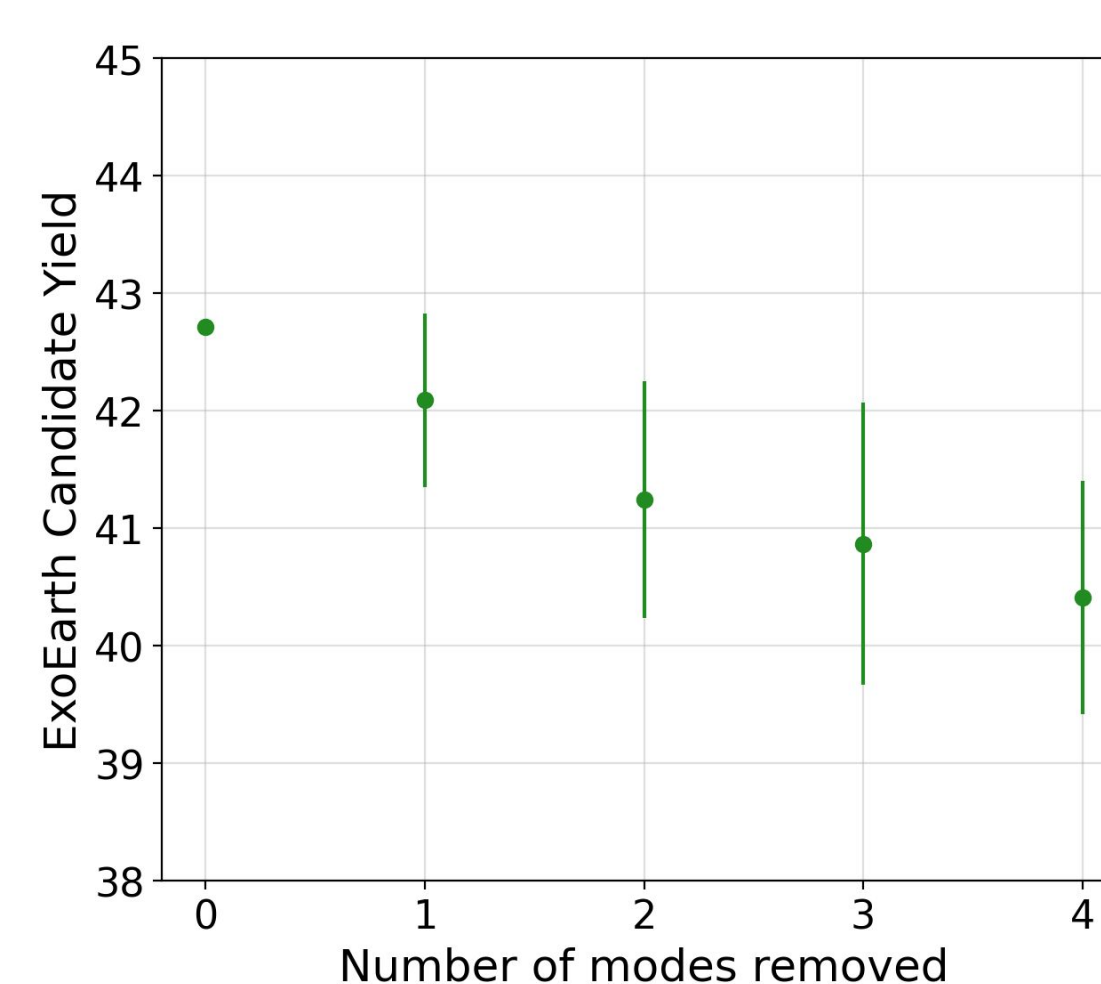
- We define a **mode zapper** coronagraph which blocks central star and suppresses a set of modes
- We compute sensitivity to low order aberrations and compare with a star-blocking-only coronagraph

Mode zapper relaxes wavefront stability requirements to reach 10^{-10} contrast to ~ nm level



Impact on expected science yield

- We implement the *mode zapper* coronagraph in the Coronagraph Design Survey Pipeline (Belikov et al. 2024) to create Yield Input Packages for calculating exoEarth yield with the Altruistic Yield Optimizer (Stark et al. 2014, 2019, 2024)
- A 6th order optimal coronagraph is used as reference and the *mode zapper* functionality is added to it in order to investigate how exoEarth yield deteriorates as a function of modes suppressed simultaneously



Science yield is reduced <6% when 4 modes are removed

Future work

- Photonic integrated circuits (PICs) provide an avenue to approach the performance of optimal coronagraphs (see Sirbu et al. 2024)
 - Based on results from this study, converge on a high-level design of a PIC required to adequately block these modes
- Publication coming later this year!