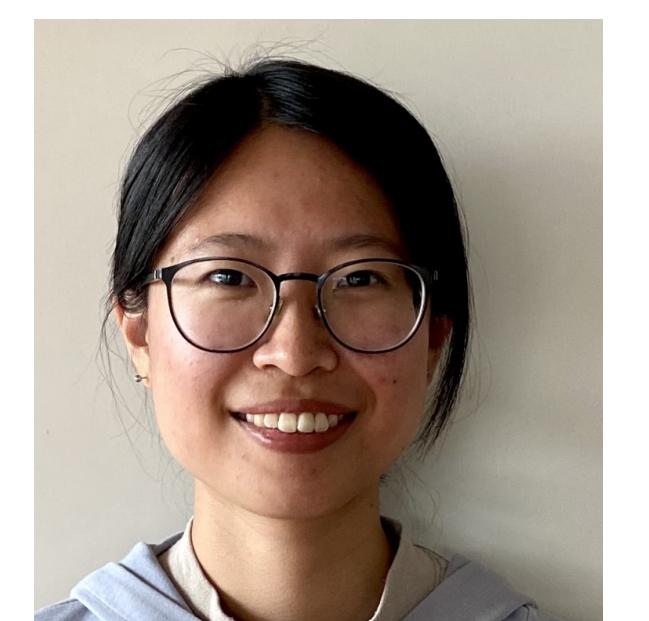


Future Exoplanet Direct Imaging Instruments: Simulating spatial light modulator-based pixelated focal-plane coronagraphy



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Introduction

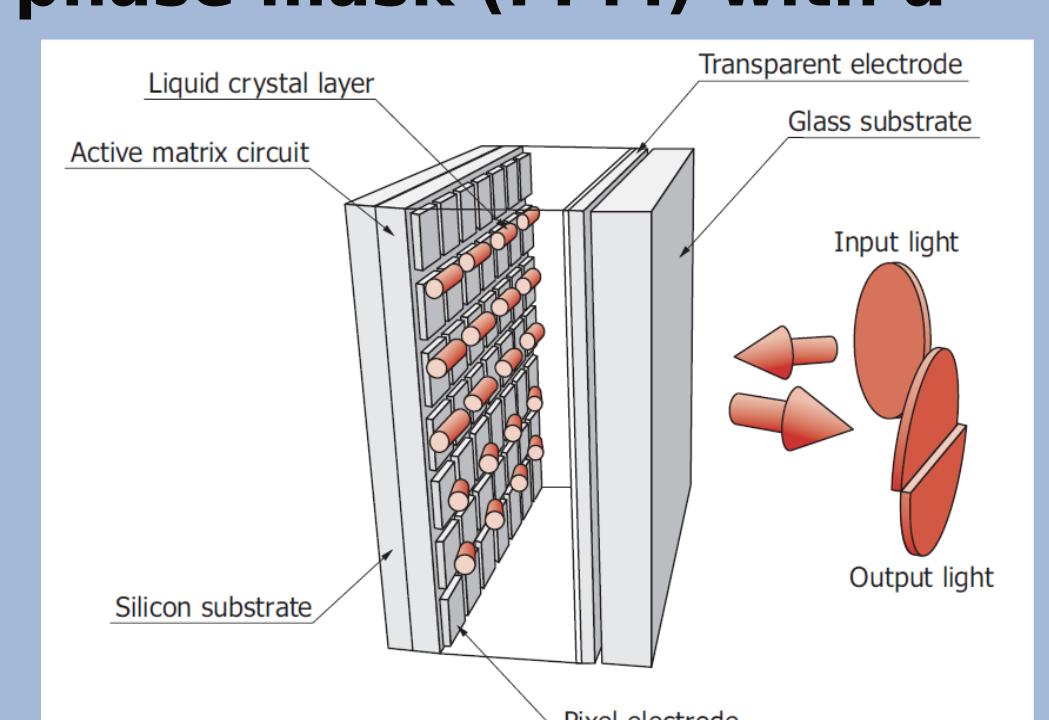
The Programmable Liquid-crystal Active Coronagraphic Imager for the DAG telescope (PLACID) instrument is a novel exoplanet direct imaging facility [1], which was recently delivered to the Turkish 4-m DAG telescope with first light anticipated by the end of 2024. We hereby present our early simulation results obtained with our Python-based toolbox, exploring the impacts of various design parameters to generate a pixleated focal-plane phase mask (FPM) with a Spatial light modulator (SLM):

Various design choices:

1. Spatial sampling (per λ/D units in the focal plane)
2. Phase resolution (a typical SLM has 8-10 bits grey level)

Assumptions:

1. Monochromatic Light
2. Perfect linear $0-2\pi$ phase mapping of n bits grey levels
3. Perfect wavefront (no WFE, SR = 1)
4. No 2nd effects (e.g. ghost reflection, pixel crosstalk etc.)



Spatial Sampling

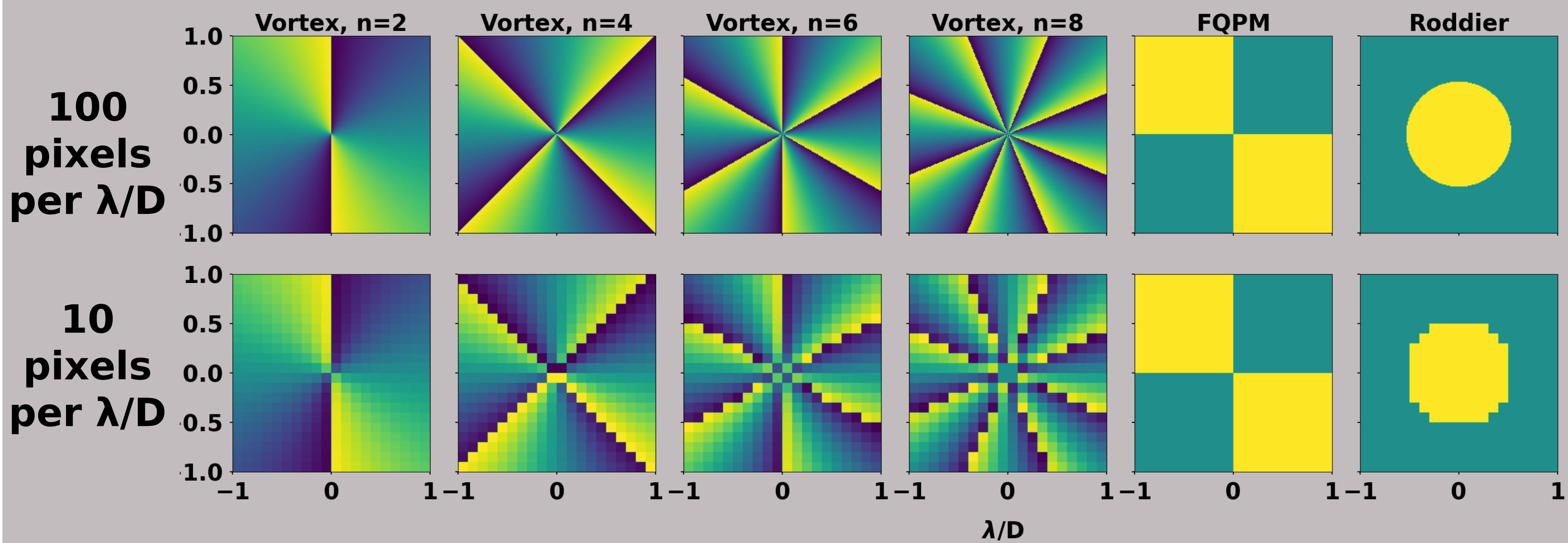


Figure 1, Example of most commonly used FPMs with two different spatial samplings in the focal-plane. The top row FPMs are displayed with 100 pixels per λ/D (max. allowed in our simulations), while the bottom row FPMs are generated with 10 pixels per λ/D (actual PLACID configuration).

Phase Resolution

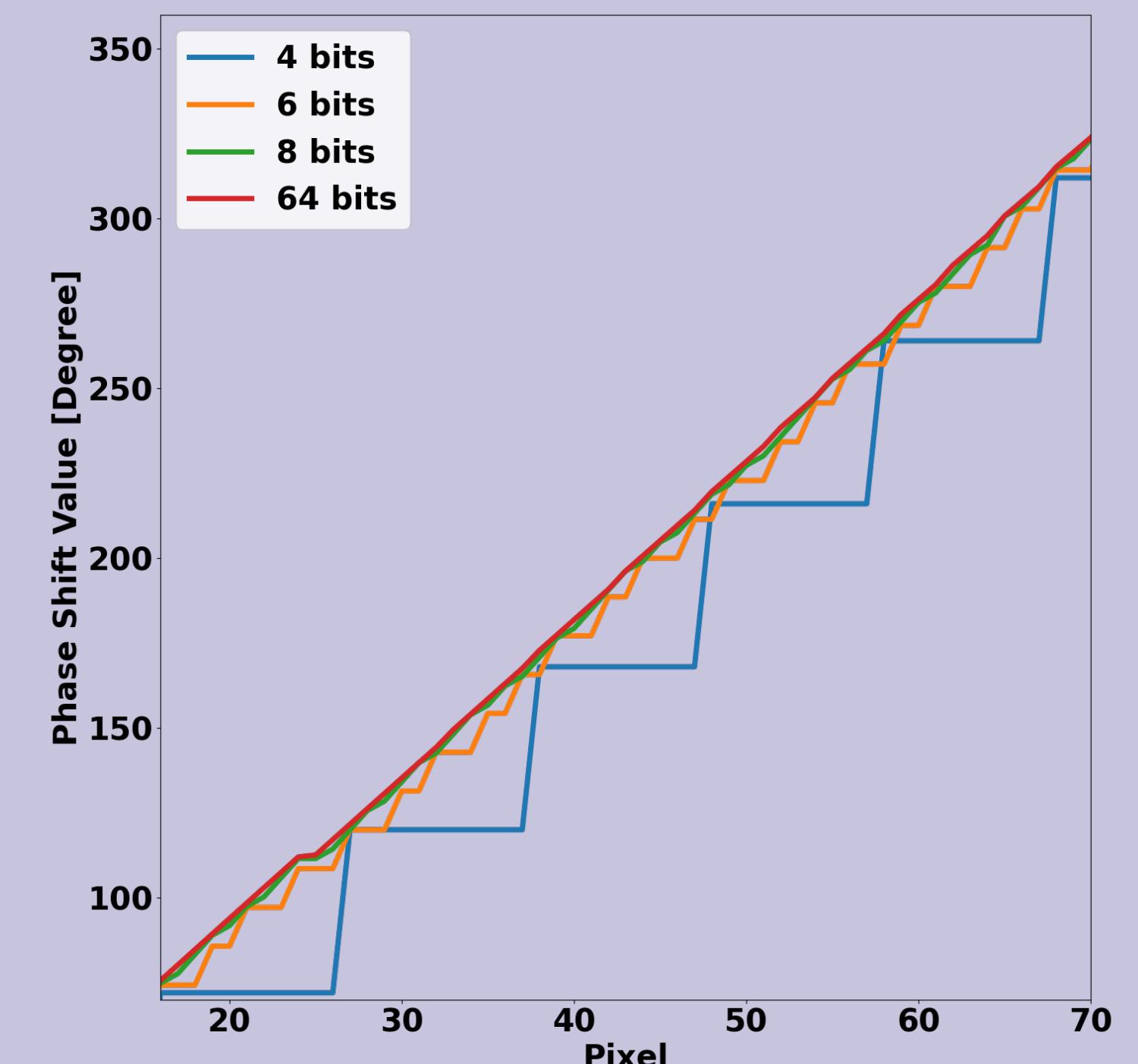


Figure 2, Impact of limited phase resolution for generating e.g. a phase ramp. Most commercially available SLM panels (include the one in PLACID) have 8-bits resolution (10 bits in rare instances).

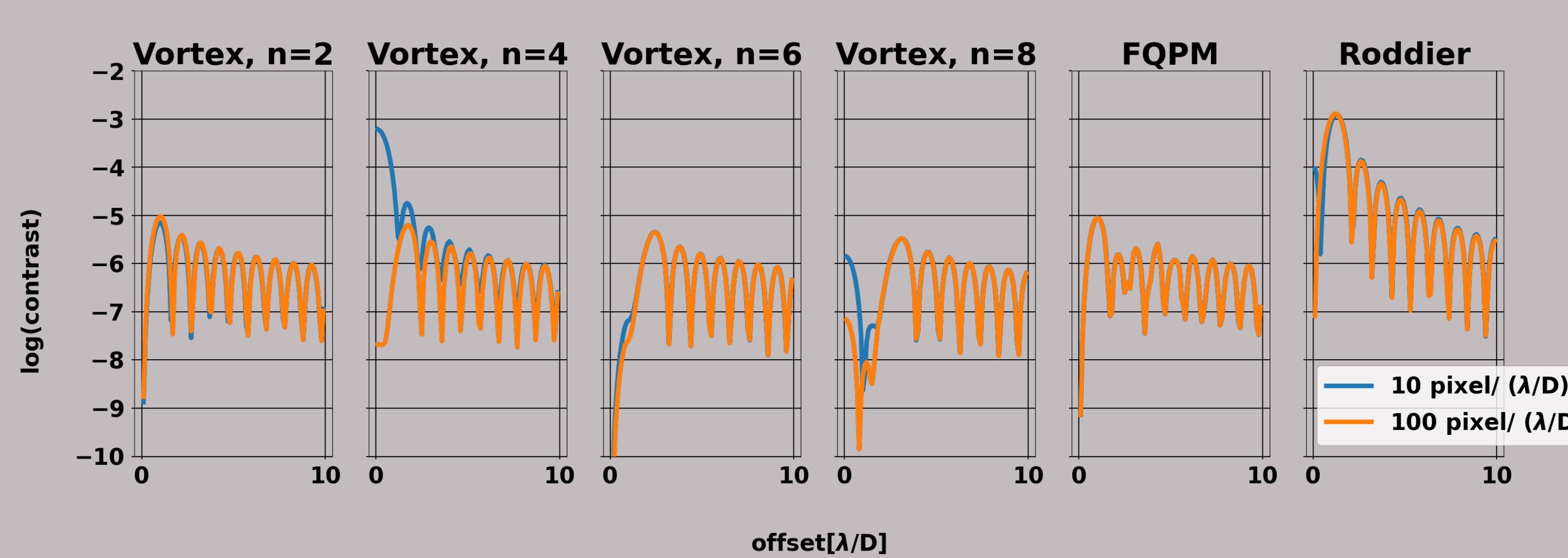


Figure 3, Post-coronagraphic focal-plane contrast for the 2x6 different FPMs of Figure 1.

- ★ A sampling of 10 SLM pixels per λ/D seems sufficient in most cases.
- ★ Vortex phase masks with charge 4 and 8 on-axis contrast are most affected by poorer spatial sampling.

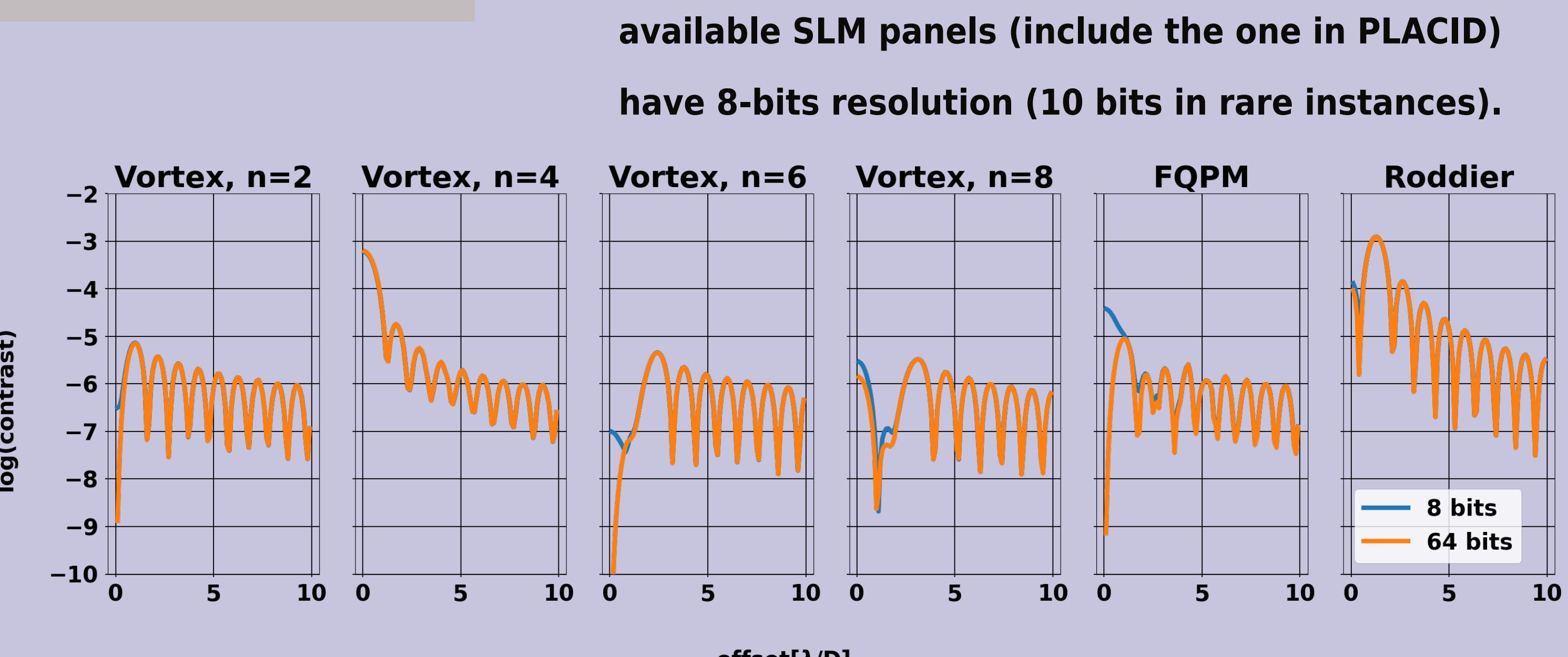


Figure 4, Post-coronagraphic focal-plane contrast curves for the 6 FPMs of Figure 1 bottom row (10 px per λ/D) for 8 bits and 64 bits (Python floating number precision).

- ★ There is no significant contrast penalty to use 8 bits phase.

Lyot stop sizing and SNR

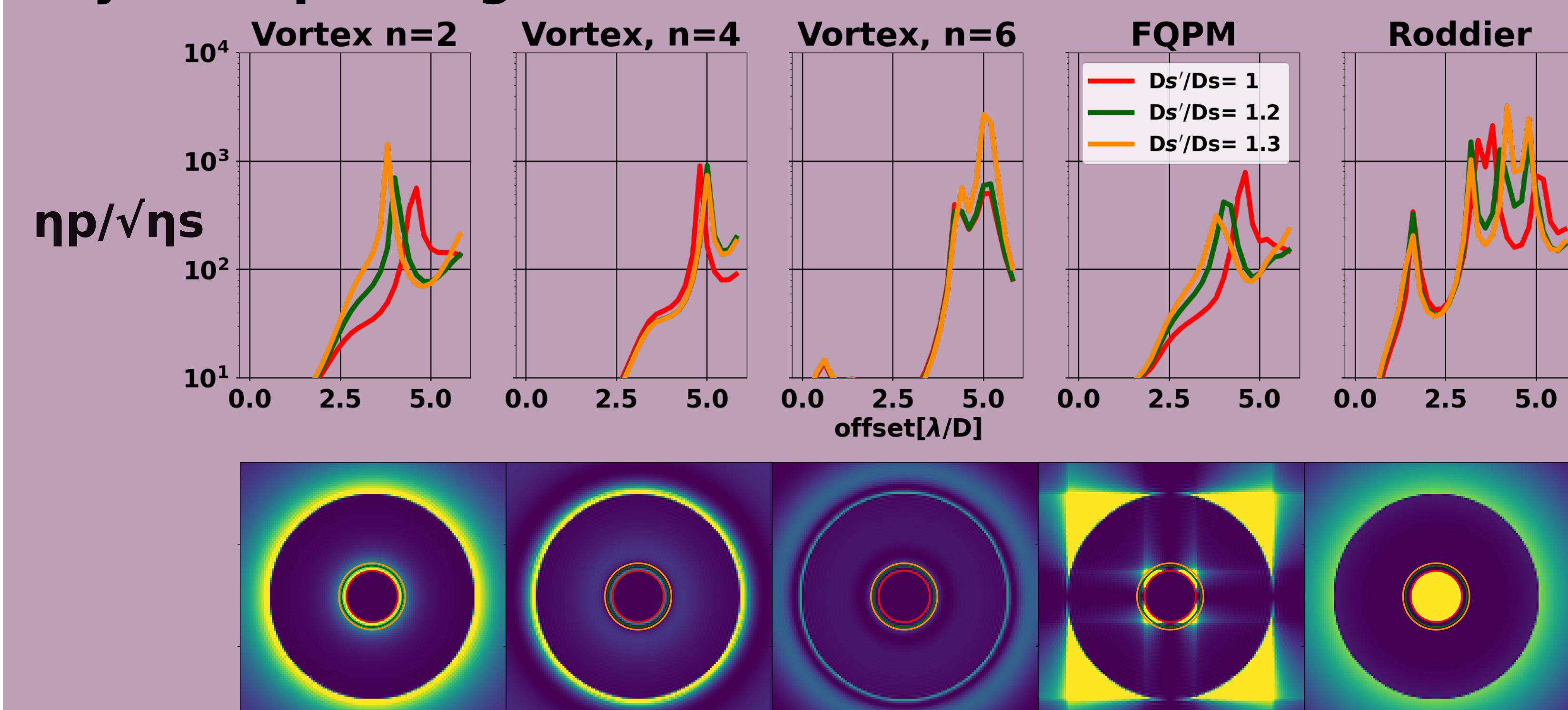


Figure 5,
(Top row) $\eta_p/\sqrt{\eta_s} \sim \text{SNR}$ [2] with different lyot central obstruction oversizing factors D_s'/D_s for the DAG telescope pupil, with η_p being the throughput of the planet, and η_s the one of the central star.

(Bottom row) Post coronagraphic intensity distribution in the Lyot pupil-plane (before the lyot stop), with the coloured circles depicting the Lyot stop secondary masks for the various cases.

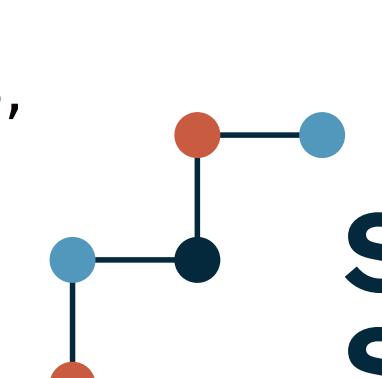
- ★ Each FPM coronagraph has a different optimal Lyot Stop.

Future work

- ★ Broadband simulation (typ. 20%).
- ★ Impacts of WFE, SLM calibration errors, pixels-level phase jitter, pixel crosstalk etc..
- ★ Zonal temporal phase-shifting for time-domain CDI.

References:

- [1] Kühn, J., Jolissaint, L., Bouxin, A., & Polychronis Patapis, Proceeding of SPIE, 114511S, (2021), <https://doi.org/10.1117/12.2562579>
 [2] Ruane, G., Riggs, E., Mazoyer, J., Por, E. H., Mamadou N'Diaye, Huby, E., ... Guyon, O. Proceeding of SPIE, 106982S, (2018), <https://doi.org/10.1117/12.2312948>



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