Co-designing coronagraph and LOWFS

Focal plane mask requirements

Focal plane mask should be designed to satisfy LOWFS and coronagraph requirements.

LOWFS :

High efficiency (conversion from photon to signal)
Easy implementation (small optics)
No non-common path errors

Coronagraph :

Polychromatic performance
→ more rings in focal plane mask → **light is diffracted at larger distance from pupil in Lyot stop**
→ residual diffracted light should be a gentle function of wavelength to facilitate polychromatic control by DM(s)
High contrast
Small IWA (→ small focal plane mask → **poor LOWFS sensitivity beyond lowest order modes**)

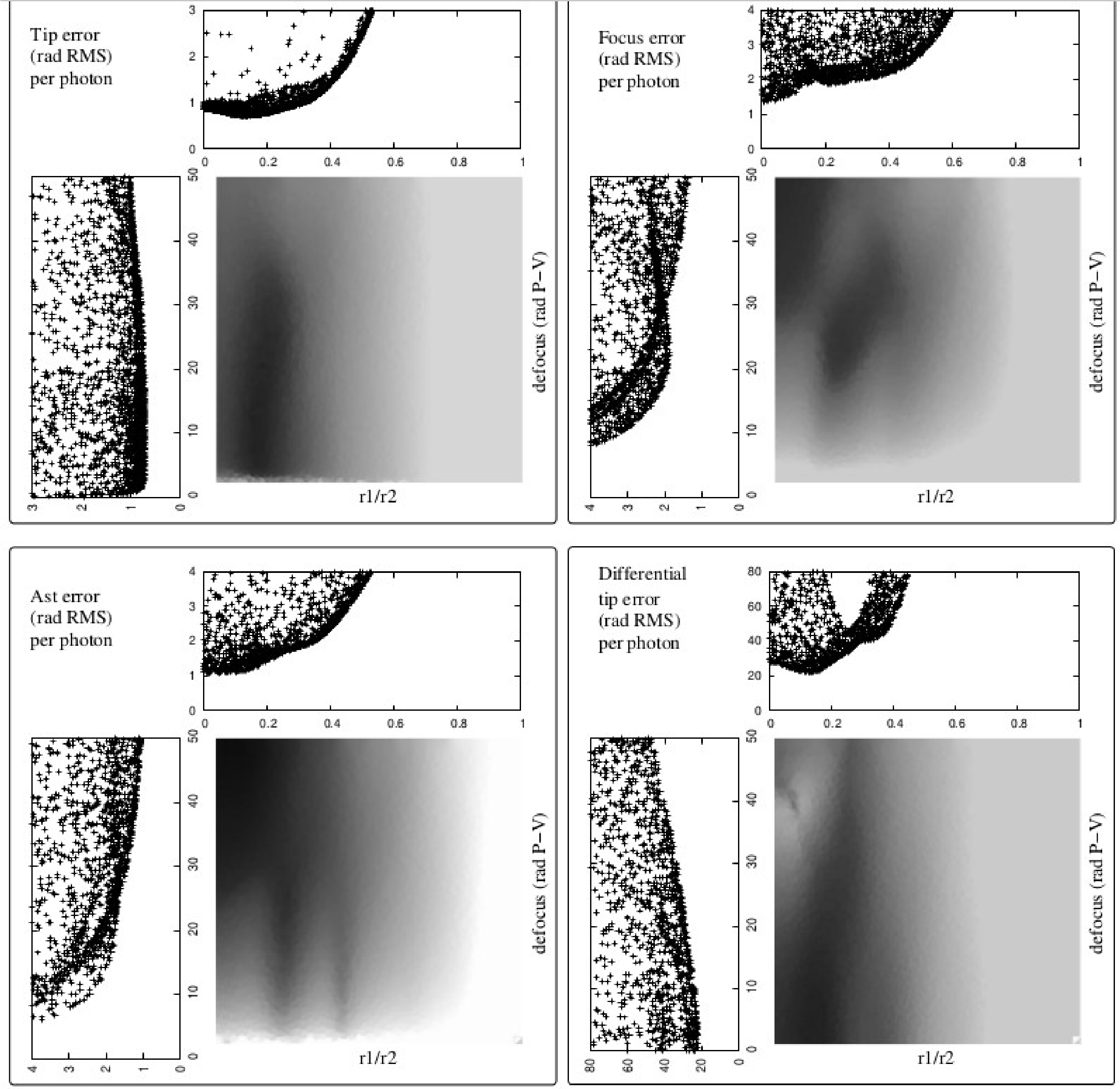
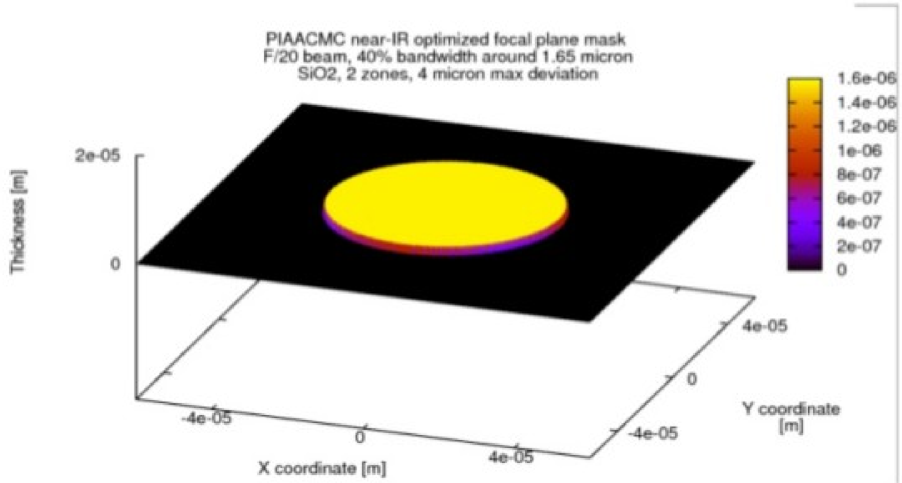
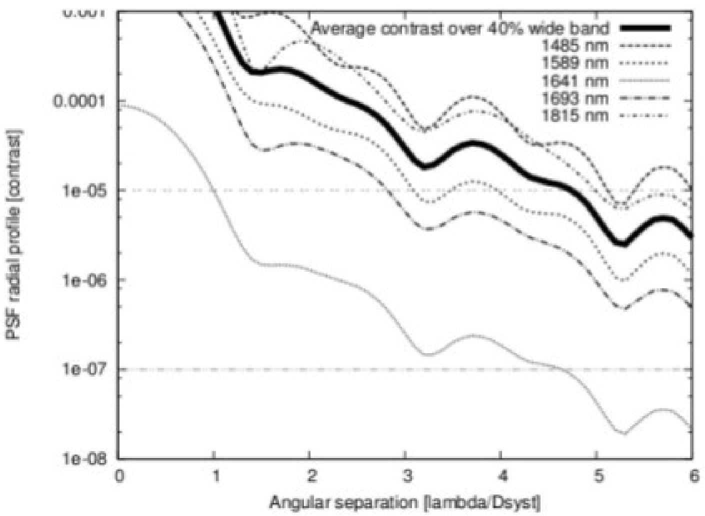
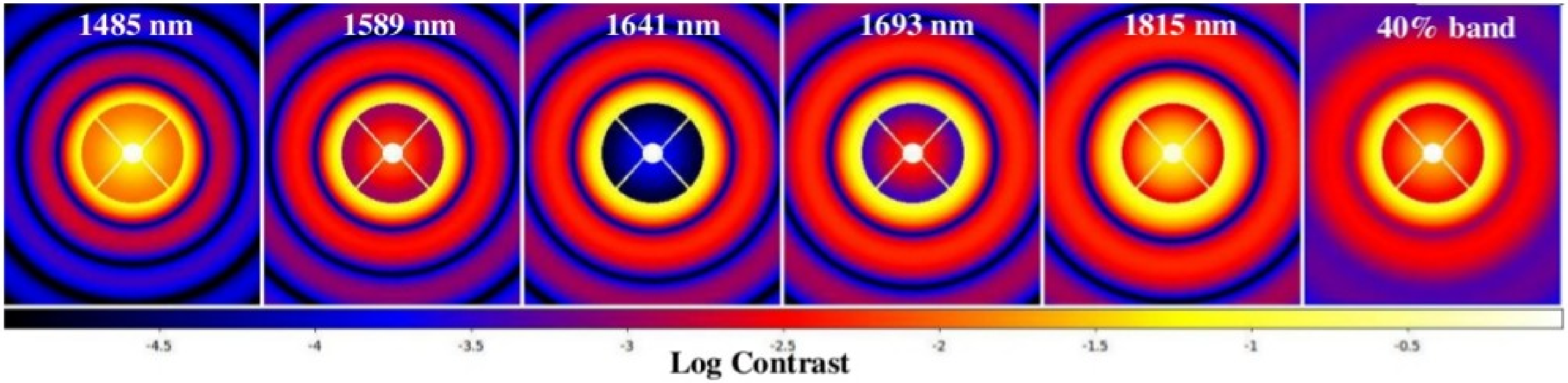


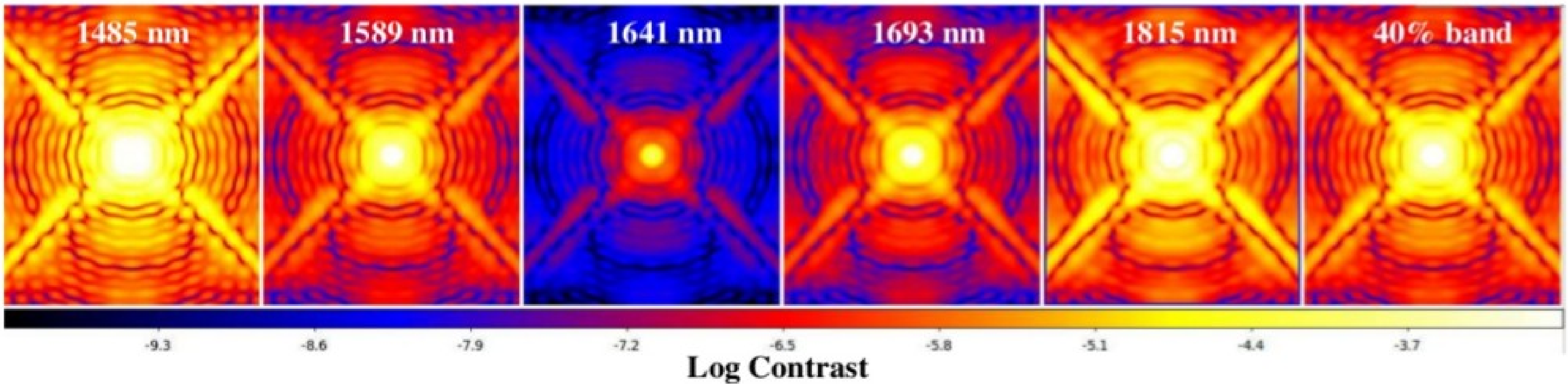
Fig. 7.— Tip (top left), focus (top right), astigmatism (bottom left) and differential tip (bottom right) sensitivity of the CLOWFS as a function of the relative size of the opaque disk in the focal plane mask (r_1/r_2) and the CLOWFS defocus distance. The sensitivity map is shown as a grey scale 2D map and the corresponding projection on the r_1/r_2 and $defocus$ axes are shown as plots above and to the left of each 2D map. Sensitivities are measured as the dispersion on a sample of 10^5 uncorrelated measurements with 10^6 photons at the telescope entrance each, and are shown here scaled to one photon (equal to the dispersion multiplied by the square root of the number of photon).

PIAACMC contrast without achromatization: 1e-4 raw contrast across 40% band

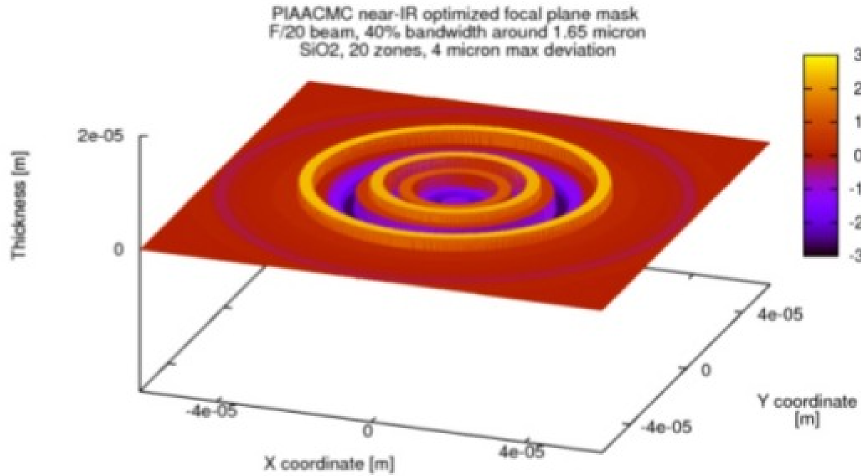


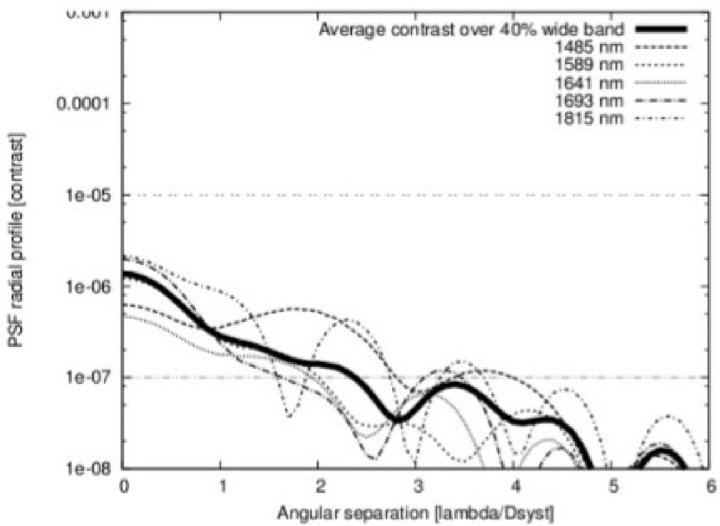


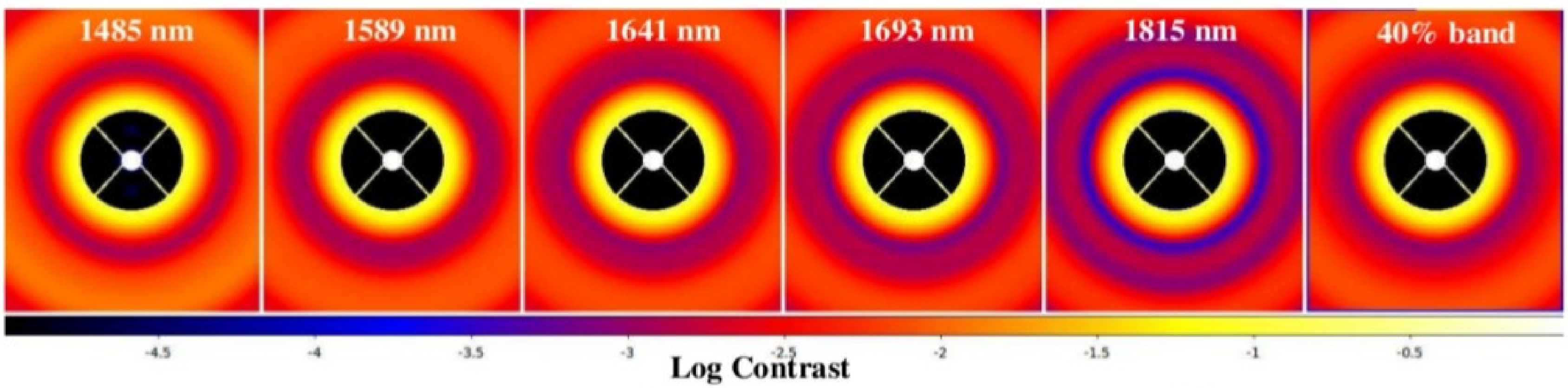


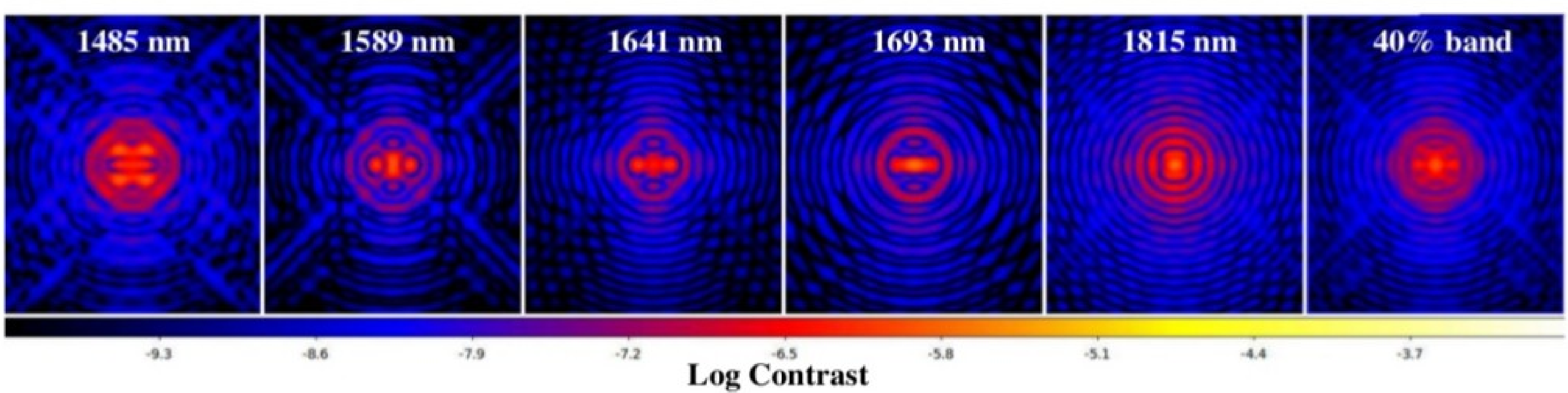


Example: PIAACMC designed for 1e-7 raw contrast across 40% band → 20 zones required

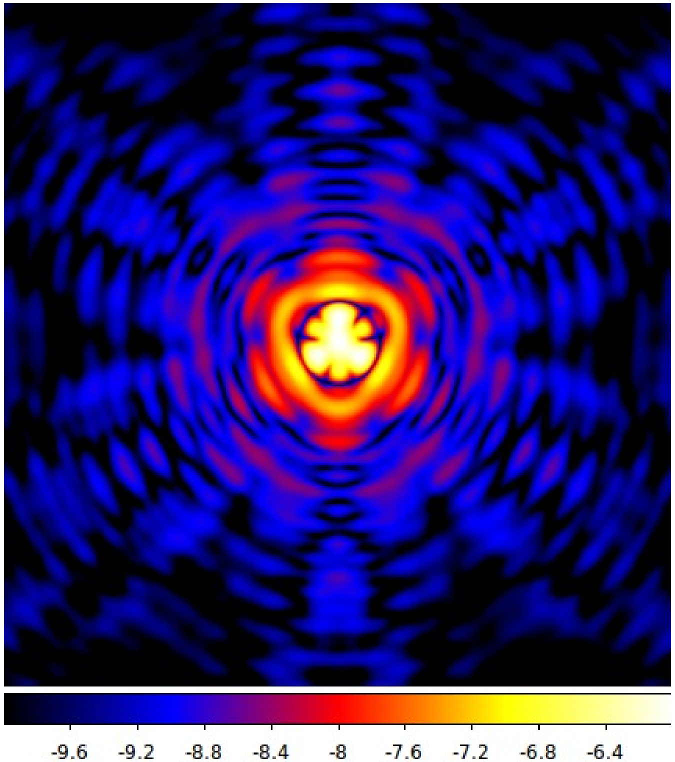




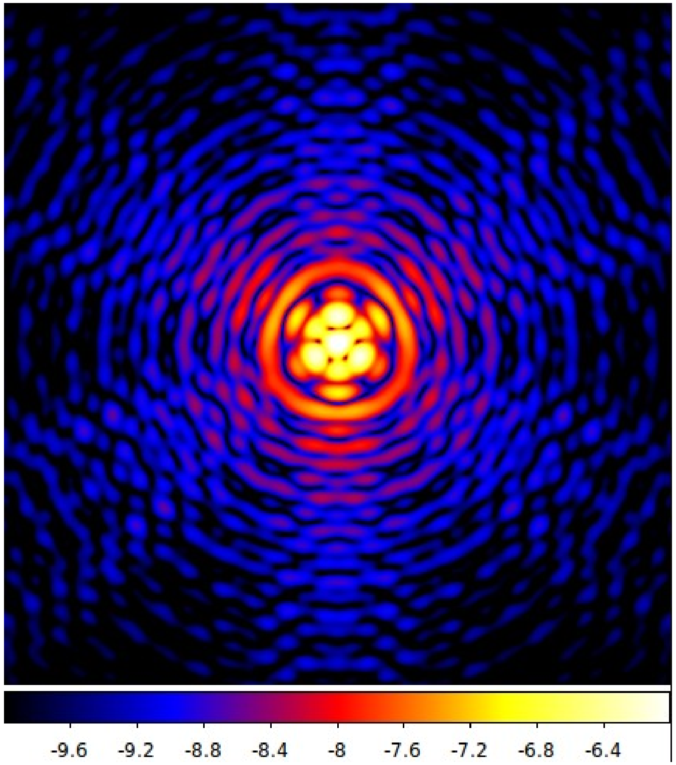




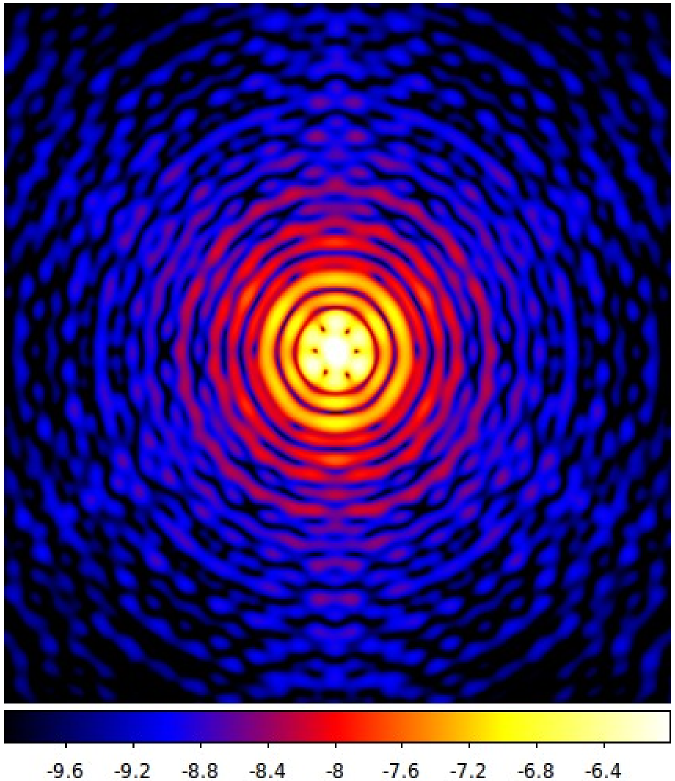
Design for centrally obscured telescope



495 nm



523 nm



605 nm

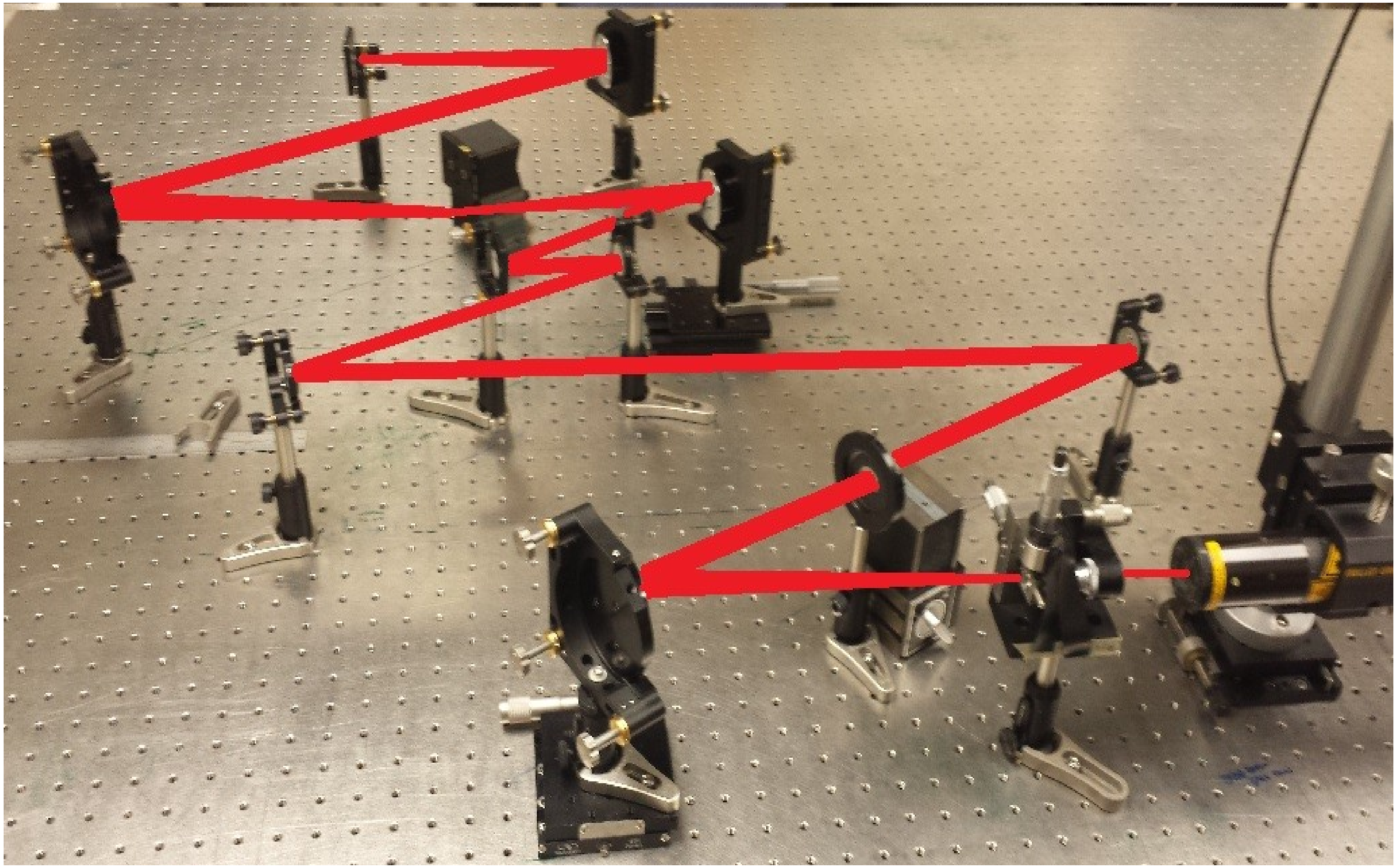
ESI effort: How will it benefit future NASA missions ?

(WFIRST-AFTA, Exo-C and beyond)

UofA LOWFS techniques tesbed

University of Arizona tesbed designed to test LOWFS presented in this talk

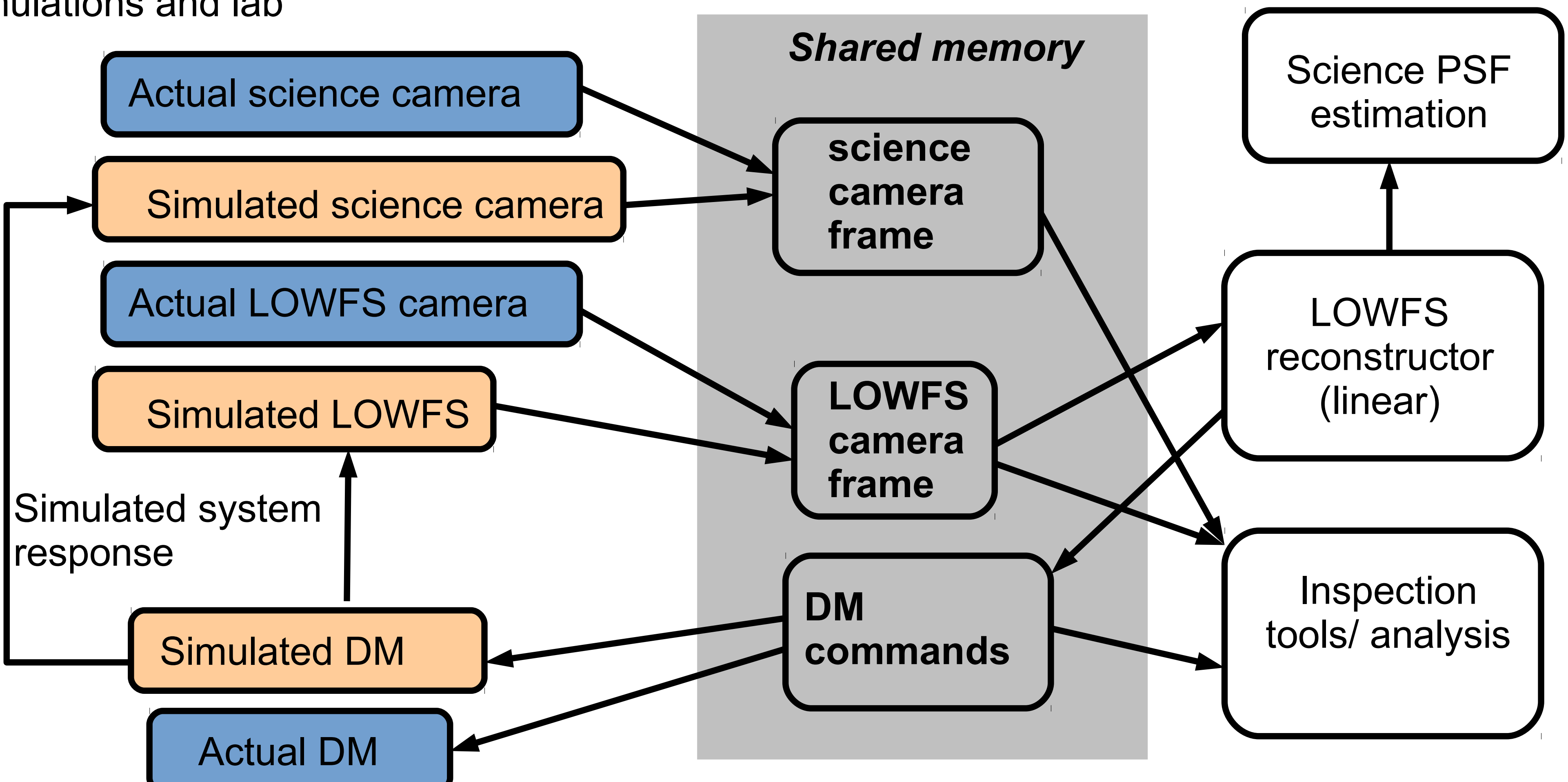
See Kelsey Miller's presentation



Software

Significant ongoing software effort to support lab testbed: camera and DM drivers + algorithms.

All software is written to be widely applicable to other groups, with well-defined interfaces to hardware (cameras, deformable mirrors). Software is written in C for speed, performance, and ease of use.
→ software can be developed and tested with or without hardware: same software runs simulations and lab



Software

Using same software for simulation and lab operation facilitates algorithm validation

→ Software will be used to explore precision level that may not be achievable in air, providing a relevant simulated test environment to validate LOWFS control and calibration strategies for AFTA and future space missions

→ We plan to implement software and algorithms at multiple testbeds operating LOWFS, and benefit from complementary experience of other groups:
- JPL HCIT LOWFS effort in support of AFTA
- NASA Ames LOWFS for EXCEDE mission technology demonstration, including linear quadratic gaussian predictive control
- ground-based coronagraph systems

→ We plan for software development to continue beyond duration of this effort

Conclusions

High science return possible if working at photon noise limit → strong incentive to understand and solve low-order aberrations and PSF calibration issues

In addition to reducing jitter and wavefront variability, instrument design should:

- Have a well-calibrated DM
- Have a LOWFS
- Have the LOWFS be as broadband as possible (more sensitive)
- Save LOWFS telemetry for PSF calibration
- Collect light outside dark hole (but contrast challenge !)
- Collect light outside nulled spectral band