MAVIS update: WFSing and control

Preliminary Design Status

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MAVIS (AO) OVERVIEW

<u>MCAO</u> Assisted Visible Imager and Spectrograph

- **8 LGS** 40x40 SHWFS,
- Up to **3 NGS**: 1x1 or 2x2 SHWFS

- **3 DMs**:
  - VLT UT4 DSM @ 0 km,
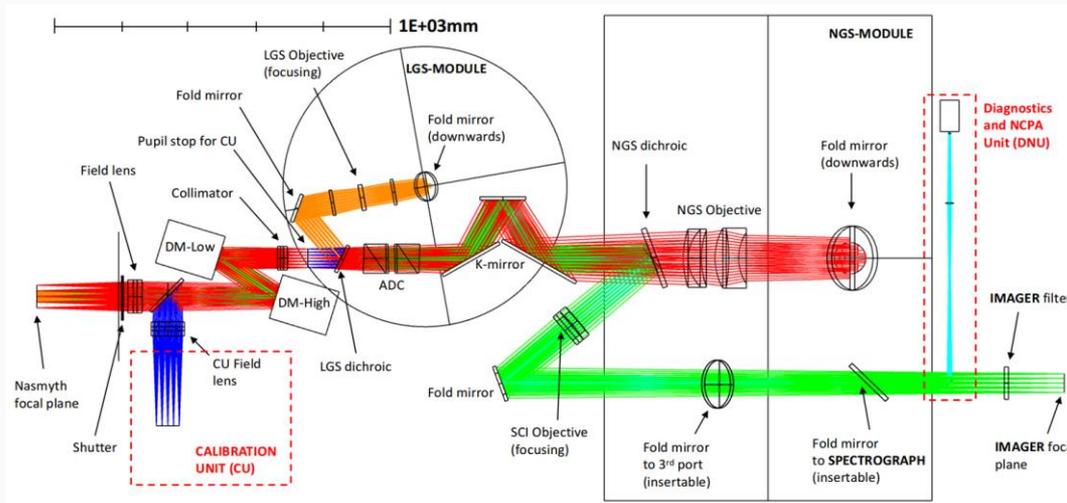 - ALPAO DM3228 @ 6.5 km,
  - ALPAO DM3228 @ 13 km.
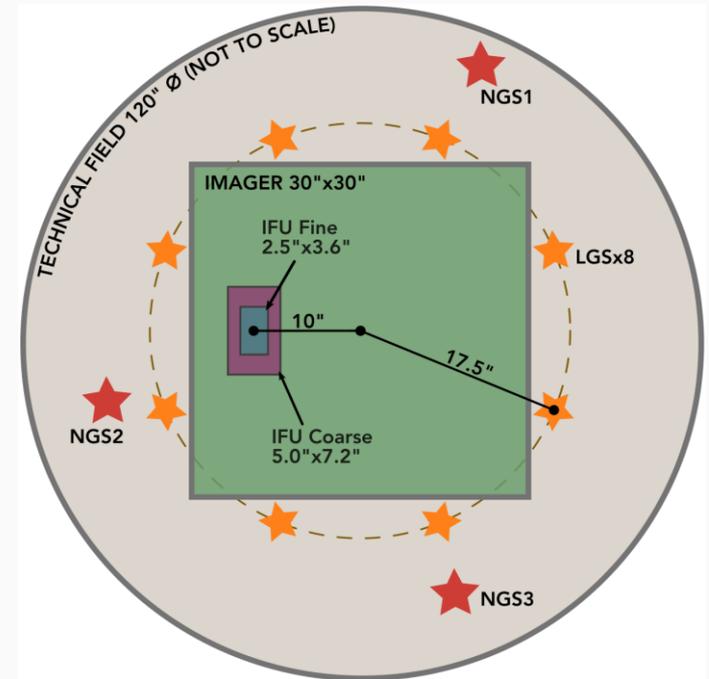

Figure 1: MAVIS optical path

Figure 2: MAVIS field of view

MAVIS fun* stuff:

- **Super-resolution LGS WFSing optimisation,**
- **Tomographic NCPA calibration,**
- Real-time atmospheric profiling,
- 1x1/2x2 switchable NGS WFSing,
- Control schemes:
  - Predictive Learn & Apply (PL&A),
  - Minimum Mean Square Error (MMSE),
  - Linear Quadratic Gaussian (LQG).
- LGS jitter control,
- And more…

*subjective

SUPER-RESOLUTION WFSING

- Diversity in WFSs improves AO performance,
- Automatically achieved for *most* layers, but <u>not</u> for ground layer,
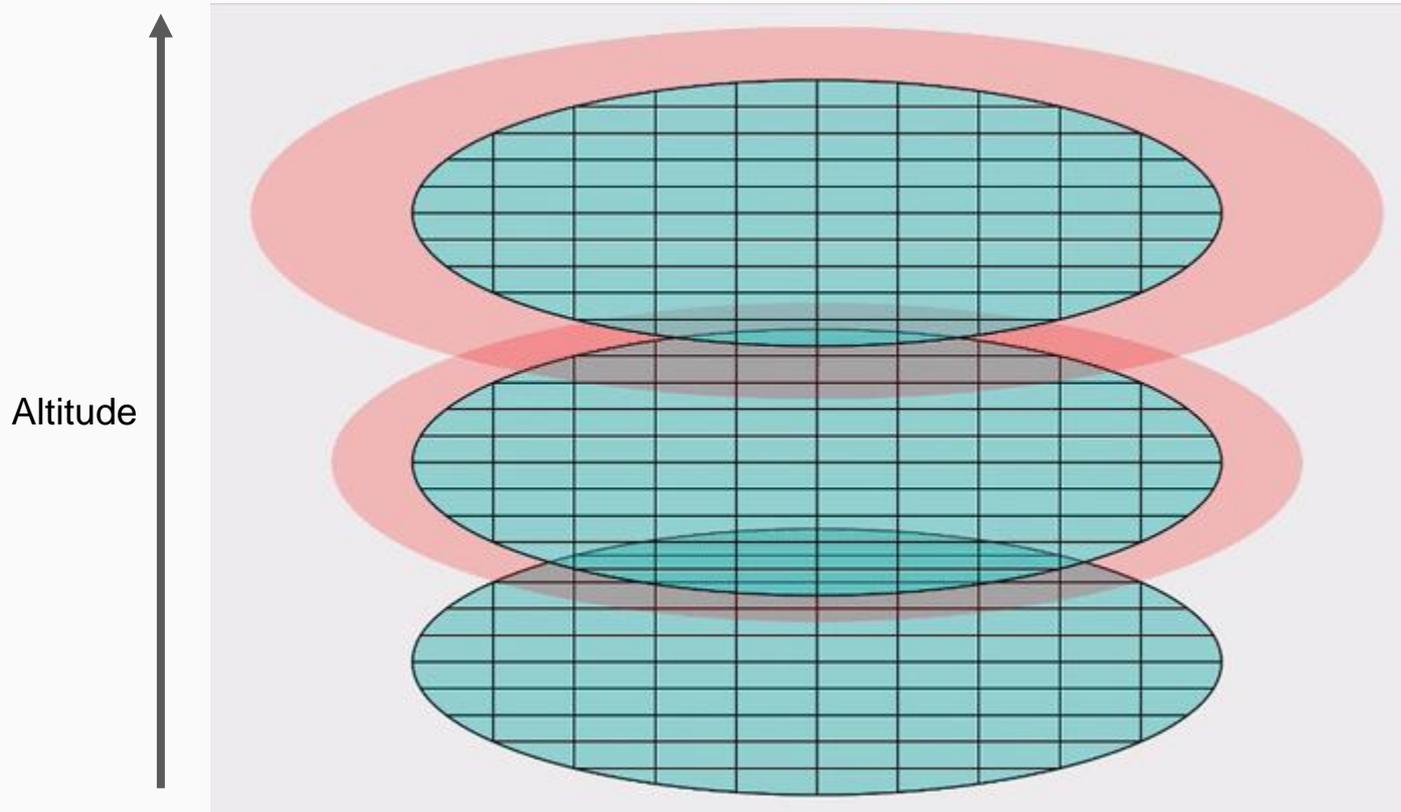- Rotating WFSs allows super-resolution on ground layer.

Figure 3: 2 SH-WFS in super-resolution

Super-resolution LGS WFSing

- MAVIS has 8 high order WFSs,
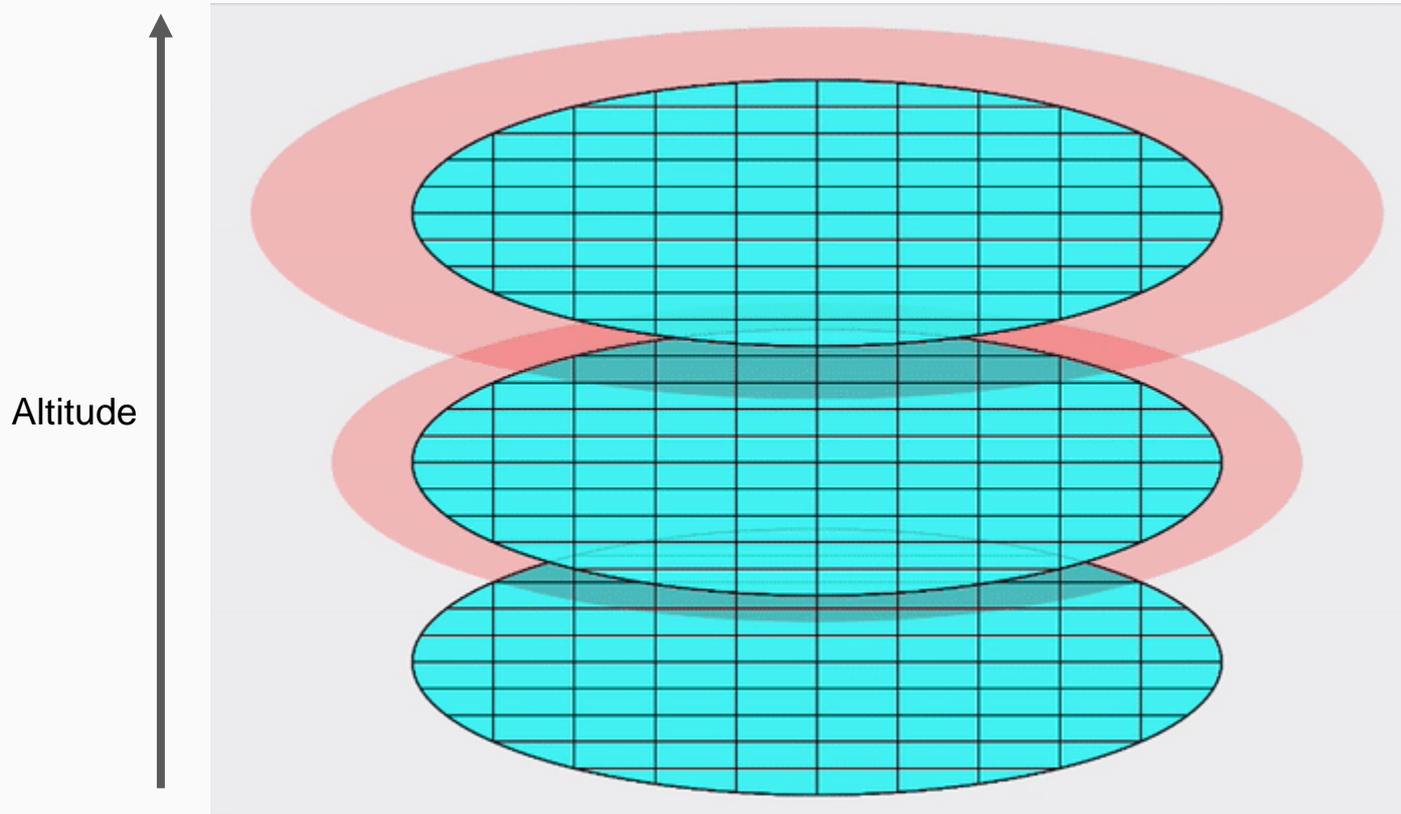- Note: if it looks like a mess, it can sense well

Figure 4: 8 SH-WFS in super-resolution

Super-resolution LGS WFSing

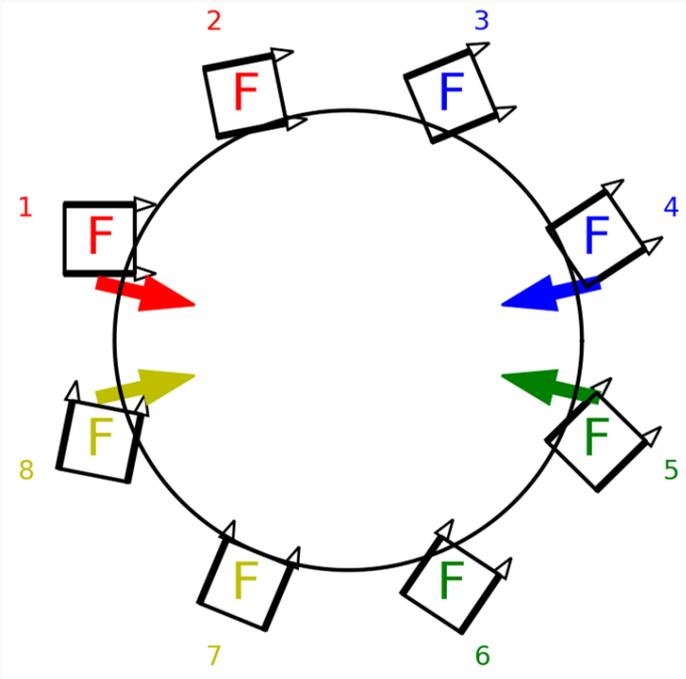Maximum rotational diversity 😁 -> difficult to do mechanically 🤬

Figure 5: Ideal **super-resolution** alignment.
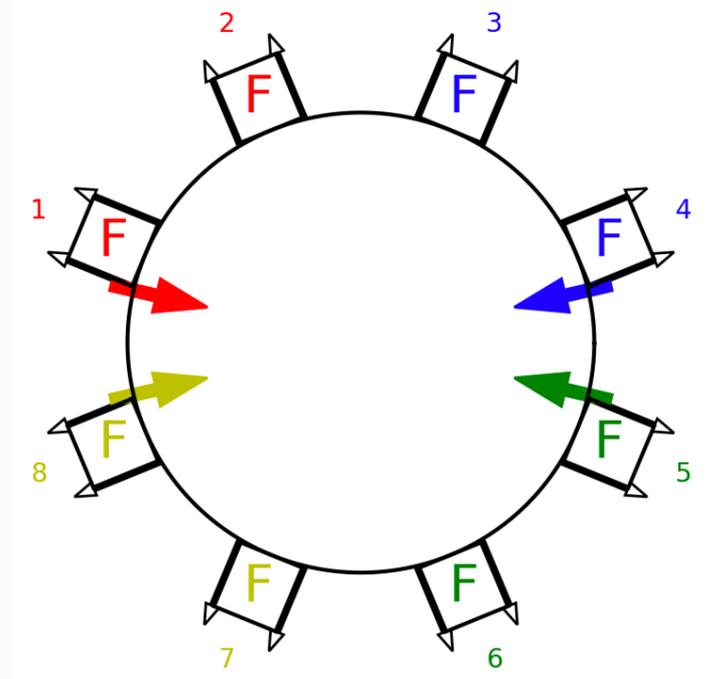Maximum rotational diversity (modulo pi/2)

Figure 6: Ideal **mechanical** alignment.
WFS cameras mounted radially, reduces volume
of enclosure and simplifies cable routing.

SUPER-RESOLUTION LGS WFSING

But wait, there's more!

We can also minimise **LGS spot truncation** by rotating:

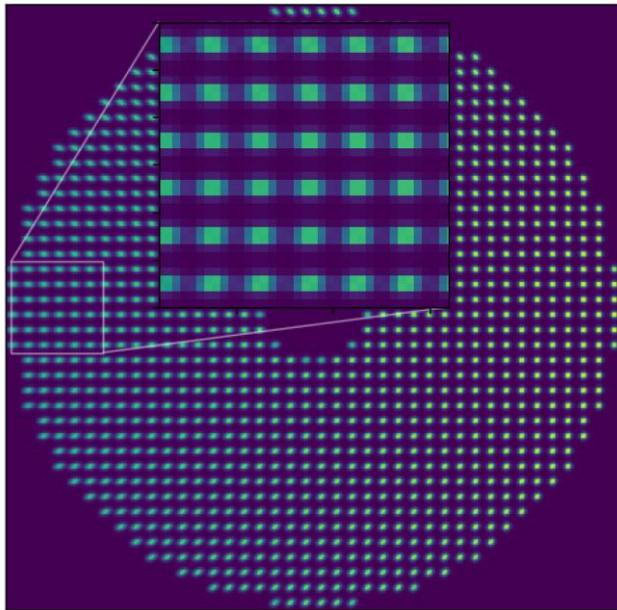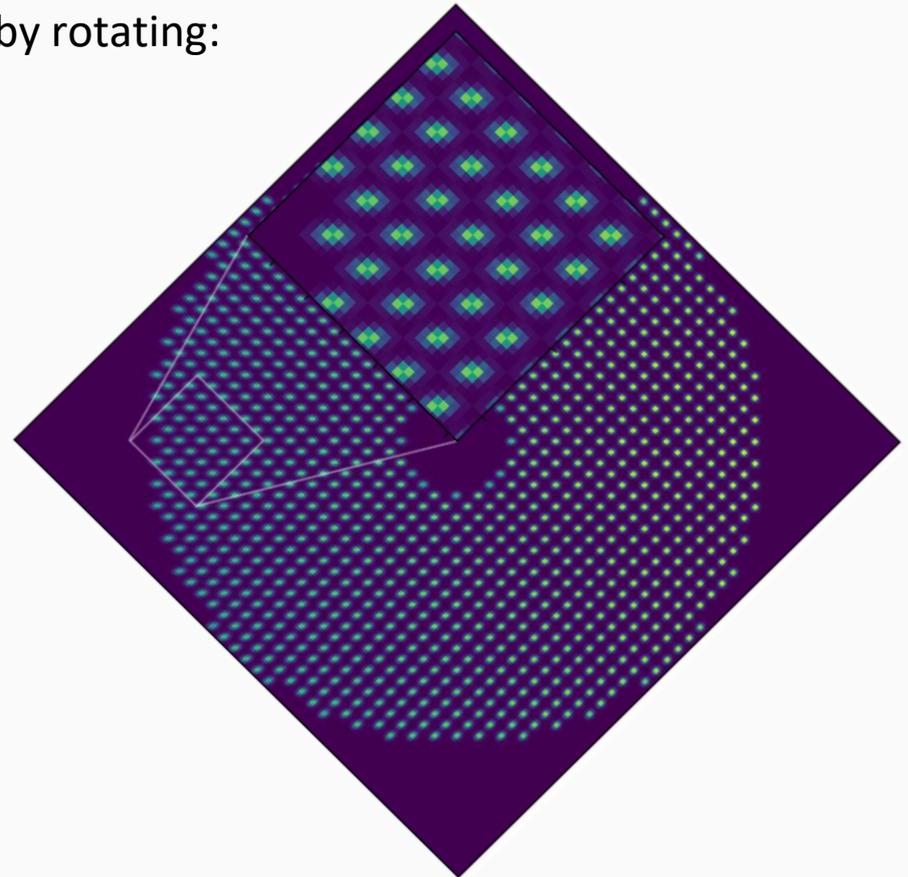Figure 7: LGS elongation axis aligned with **short-axis** of SH spot array

Figure 8: LGS elongation axis aligned with **long-axis** of SH spot array

Super-resolution LGS WFSing

So… we want to simultaneously optimise for:

- Maximum diversity,
- Simplest mechanical implementation,
- Minimal LGS spot truncation.

SUPER-RESOLUTION LGS WFSING

So we want to simultaneously optimise for:

- Maximum diversity, ☑
- Simplest mechanical implementation, ☑
- Minimal LGS spot truncation. ☑

Feeding these into a numerical optimiser gives:

**Wide field LE SR jumps from
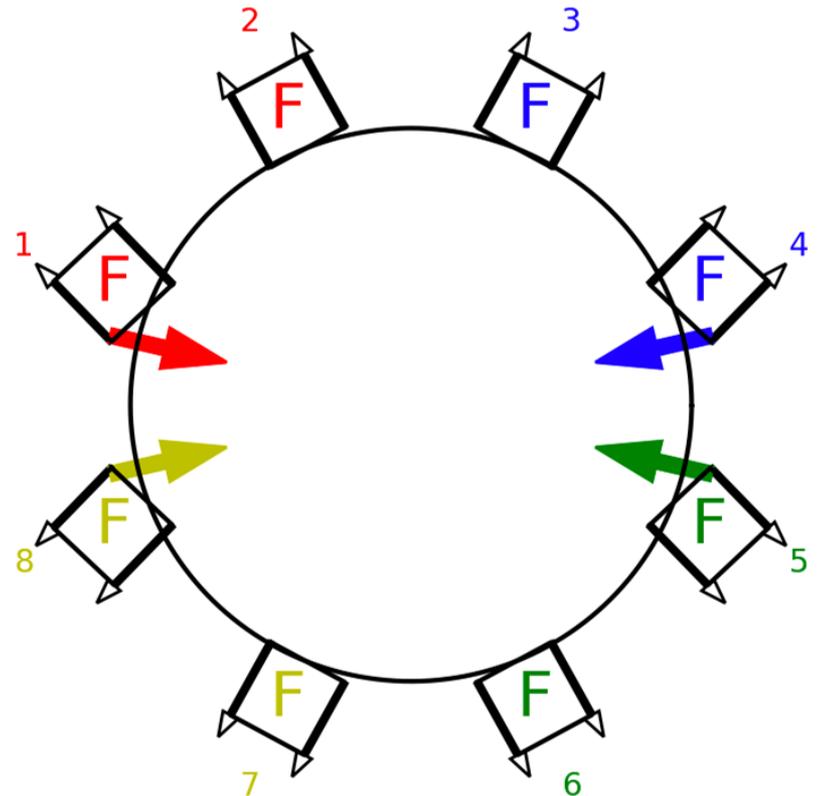24.7% -> 27.2% in V-band
(equiv: -27 nm RSS)**

Figure 9: Final selection of LGS clocking angles
to optimise all 3 criterion.
Coloured arrows indicate LGS elongation axes.

NCPAs in MAVIS

- Wide-field instrument + many surfaces -> field-varying static NCPAs
- Field-varying NCPAs + tight error budget -> tomographic phase diversity
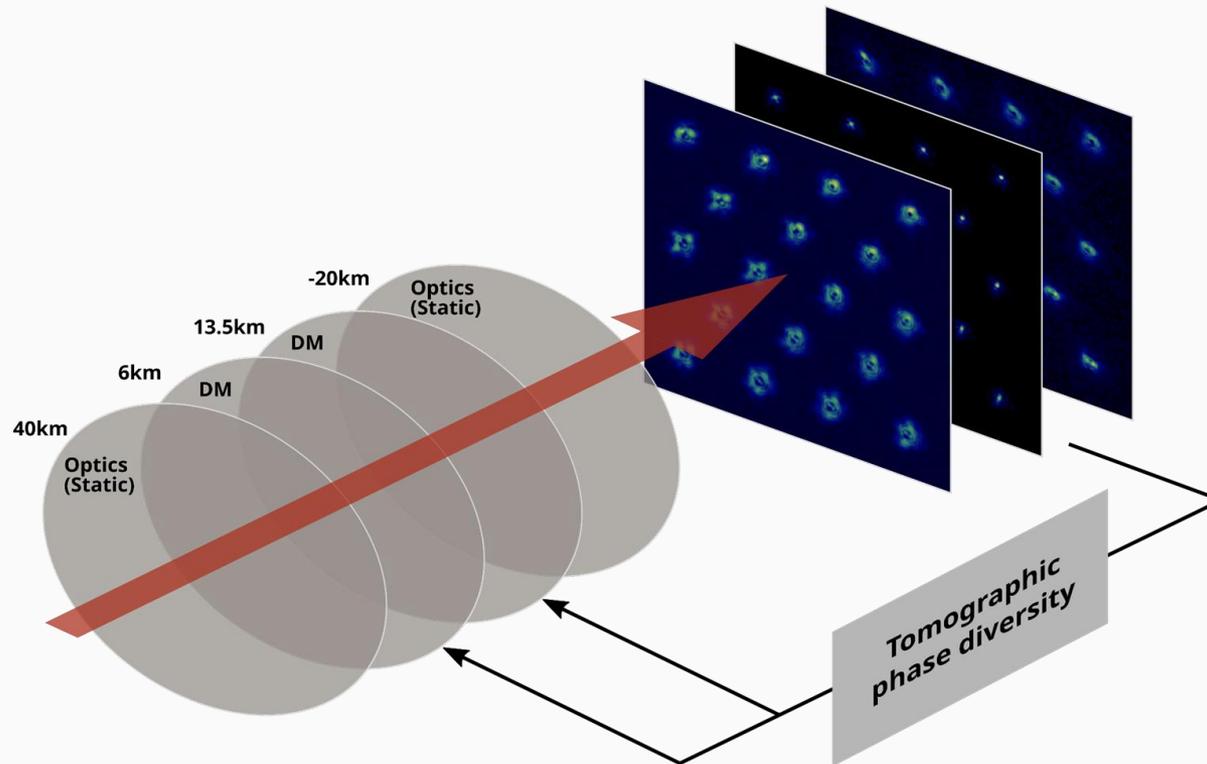- Method based on PRAy - Gratadour et al (2011)

Figure 10: Tomographic phase diversity principle

NCPAs in MAVIS

- Requires many small sources over the science FoV (100 holes, each 5 um ø),

- Test masks produced by Optofab in Sydney provide sufficient accuracy and throughput tested at Stromlo.
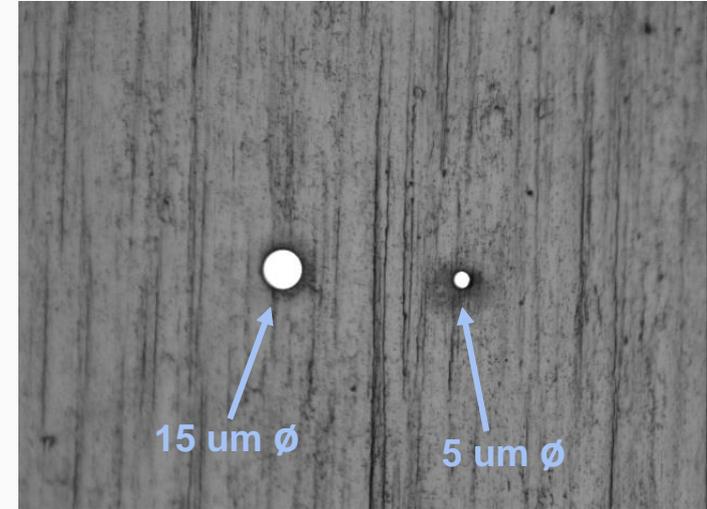

15 um ø   **5 um ø**

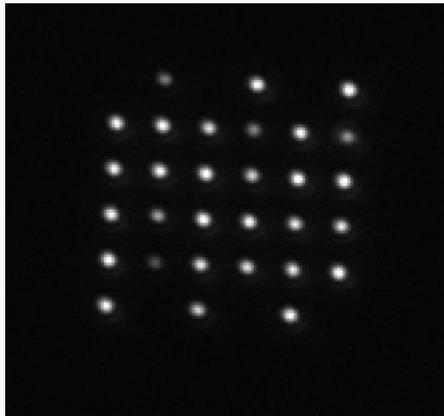Figure 12: Pinholes under microscope

Figure 11: Image taken of 5 um pinhole grid on the bench, pinholes are 40 um apart.
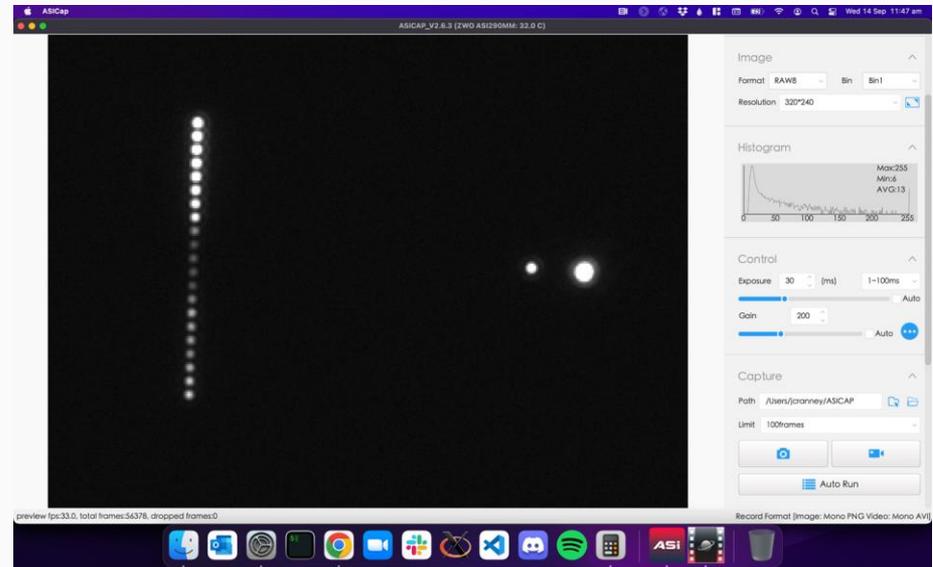

Figure 13: Imaged pinholes on the bench.
(left) varying focus of cutting laser,
(right) 5 um and 15 um pinholes.

NCPAs in MAVIS

- Simulations show we can converge on NCPA calibration with 64 sources simultaneously in less than 1 second on GPU,
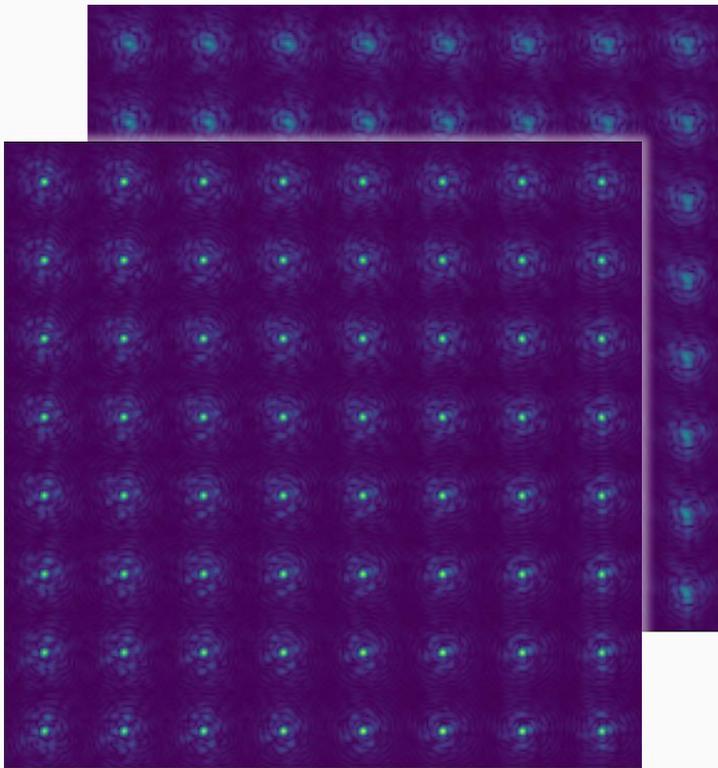- Prototyping in the lab for MAVIS commencing Q1 2023.
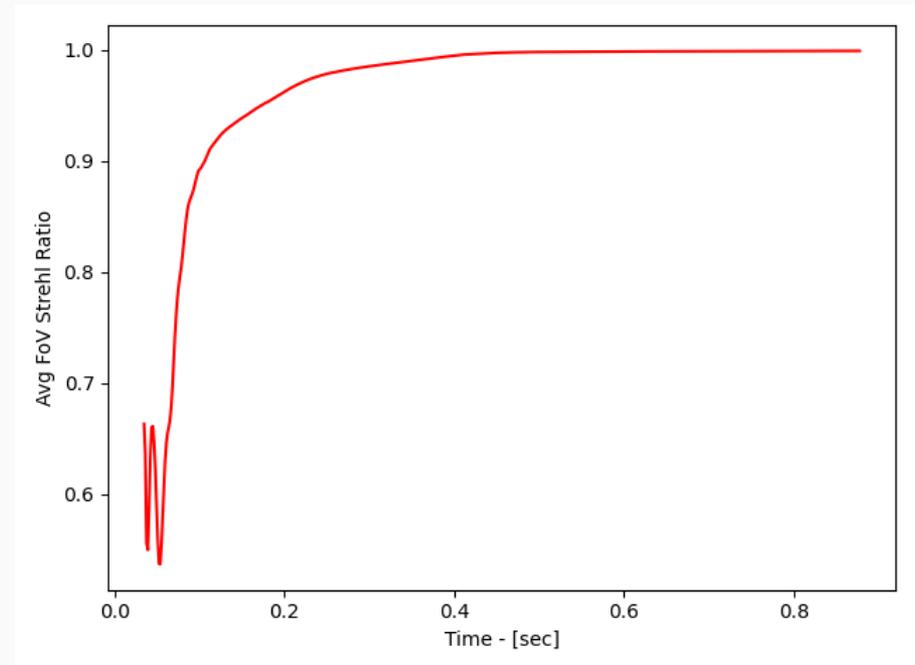

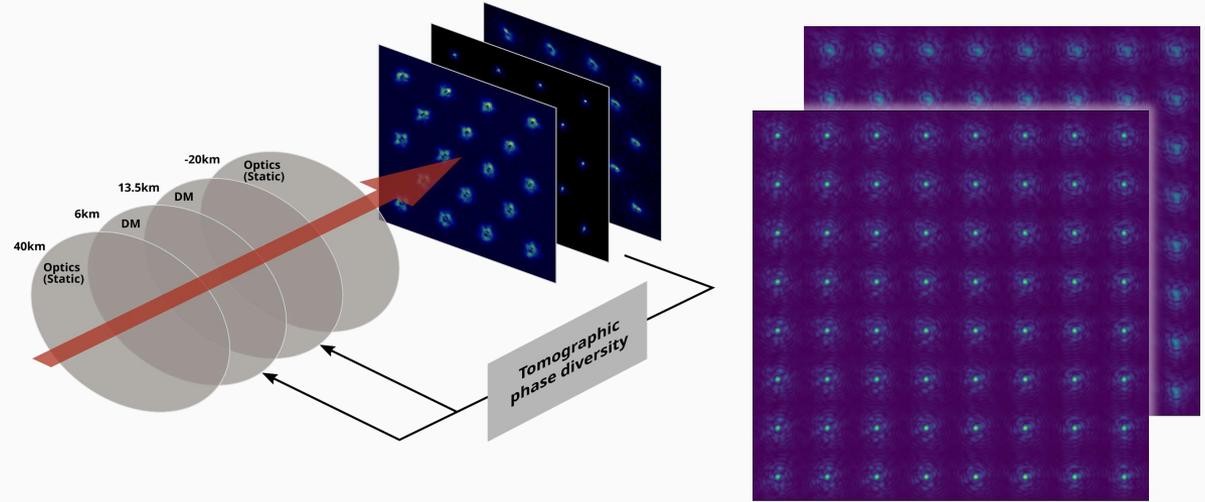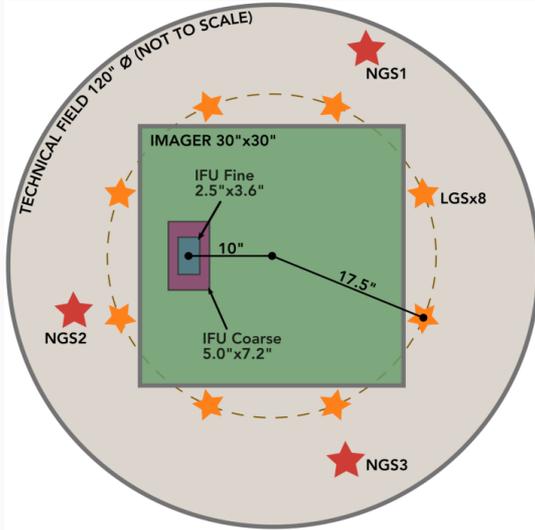Figure 14: Simulated NCPA pinhole images

Figure 15: Tomographic phase diversity convergence vs time.

THANKS!

Questions?