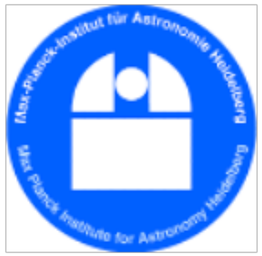
Getting ready for ELT/METIS high-contrast science

Olivier Absil
University of Liège

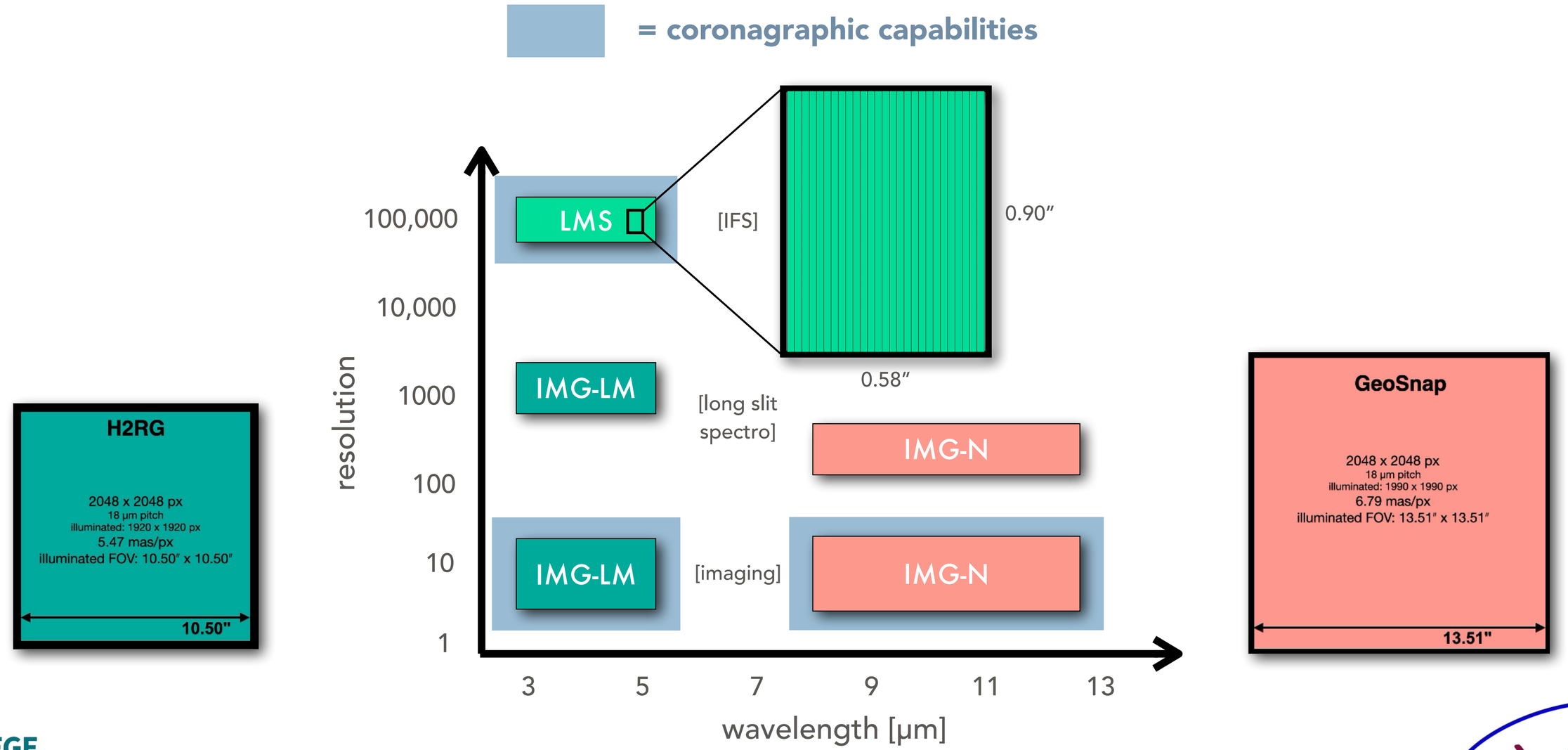
centra
center for astrophysics and gravitation



Science and
Technology
Facilities Council

UK Astronomy
Technology Centre

The METIS context



Mid Infrared E-ELT Imager and Spectrograph

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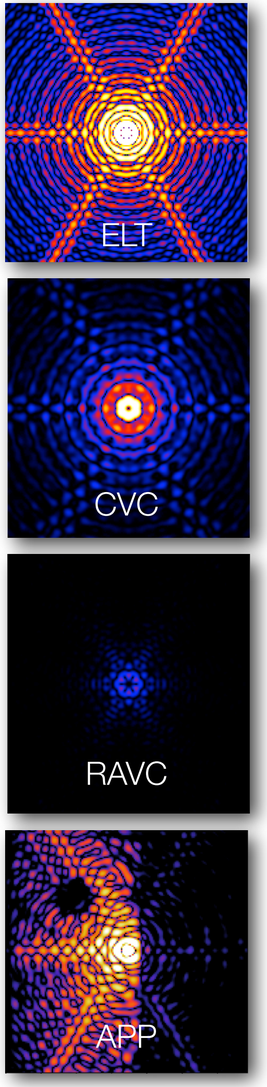
Baseline coronagraphic modes

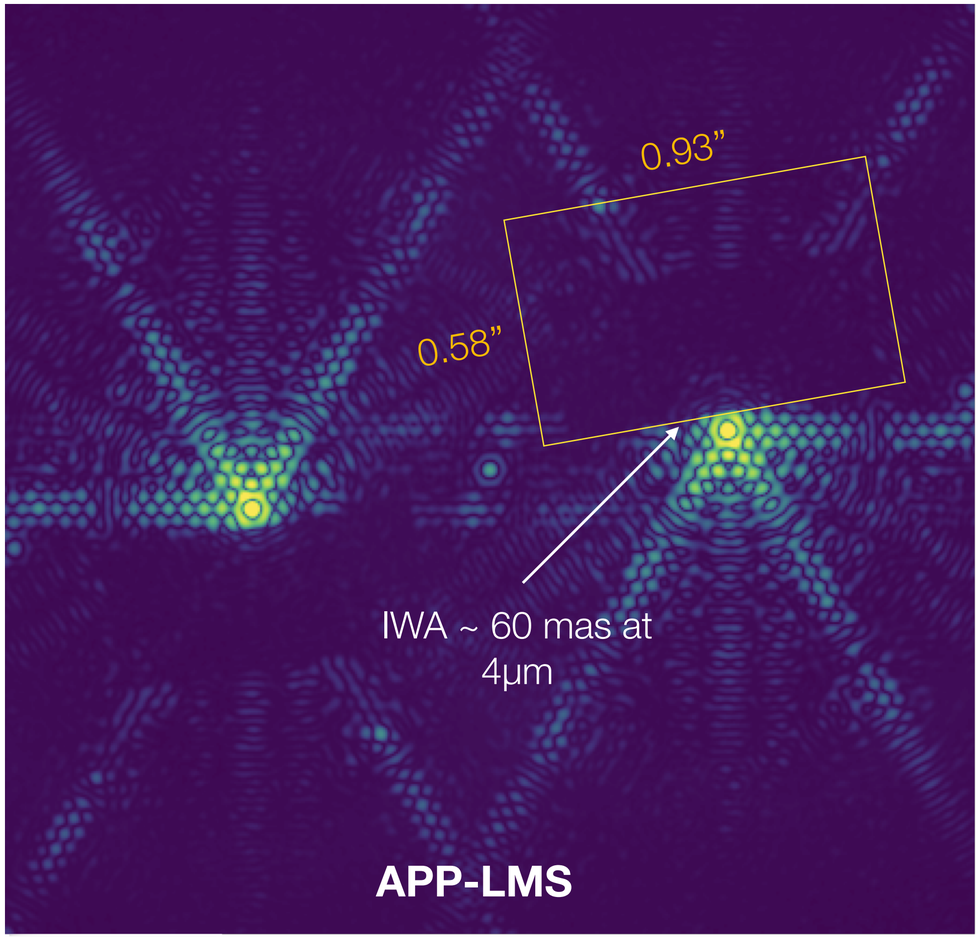
- Rationale
  - small IWA (compensate long wavelengths)
  - high throughput (compensate thermal background)
  - robust performance (cope with ELT uncertainties)
  - high TRL in the thermal infrared
- Two main coronagraphic modes
  - LMN-band (apodized) charge-2 **vector vortex** - small IWA + high throughput
  - LM-band **grating-vector APP** - small IWA + robustness

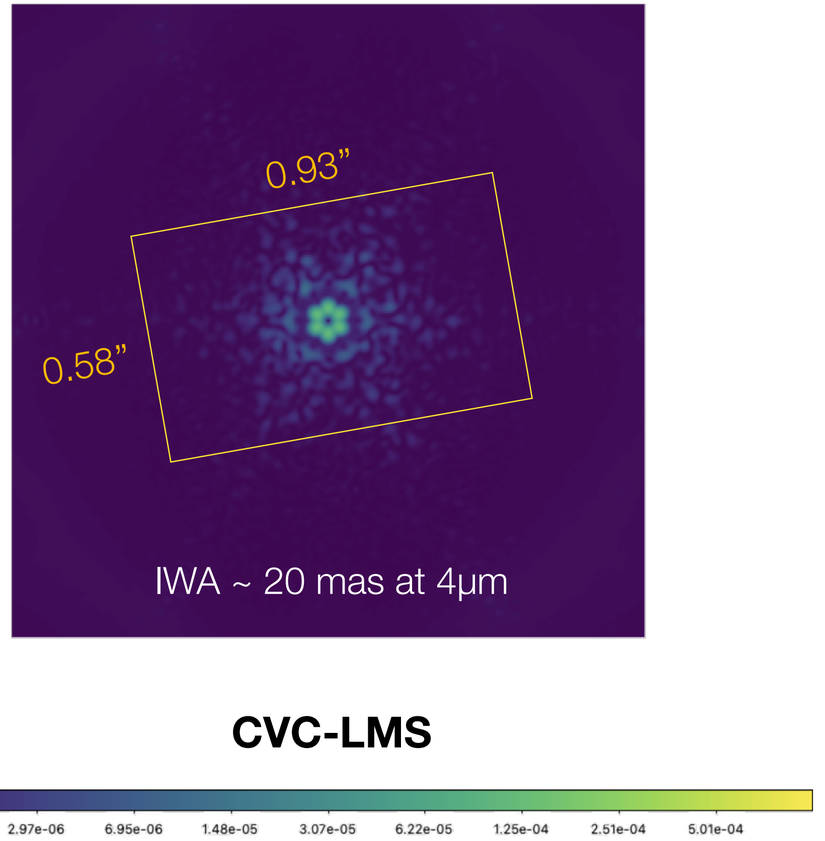


~% leakage

~‰ leakage

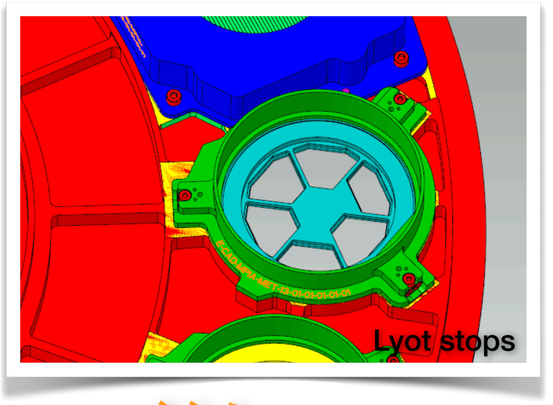
HCI + IFS modes (R = 100,000)

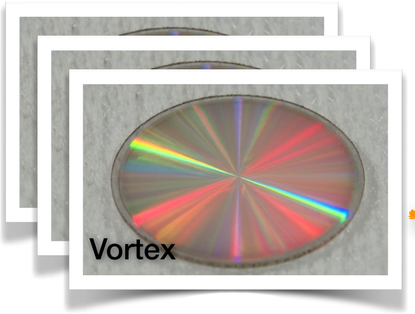


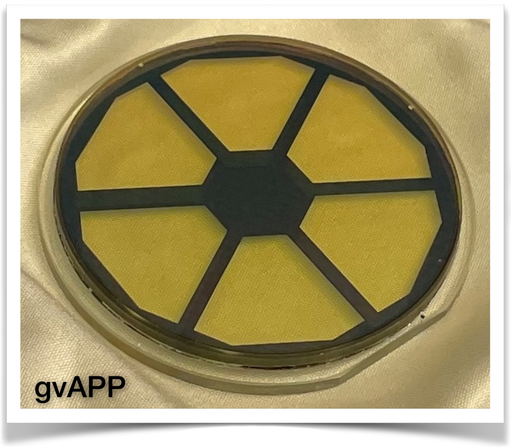


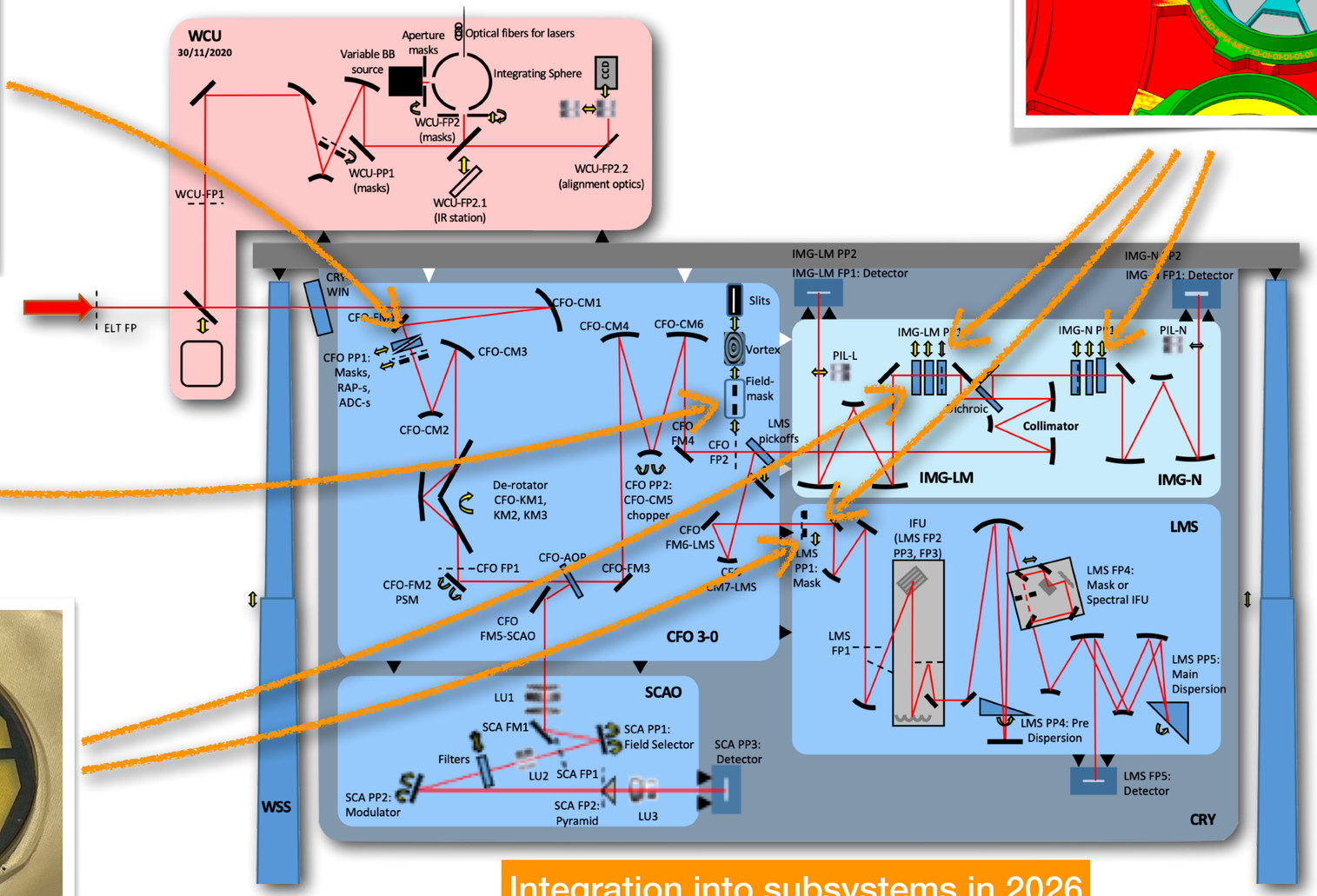
Expected raw contrast ranging from 10^{-3} to 10^{-5} inside the image slicer

MAIT status









Integration into subsystems in 2026

HCI system-level tests in 2028

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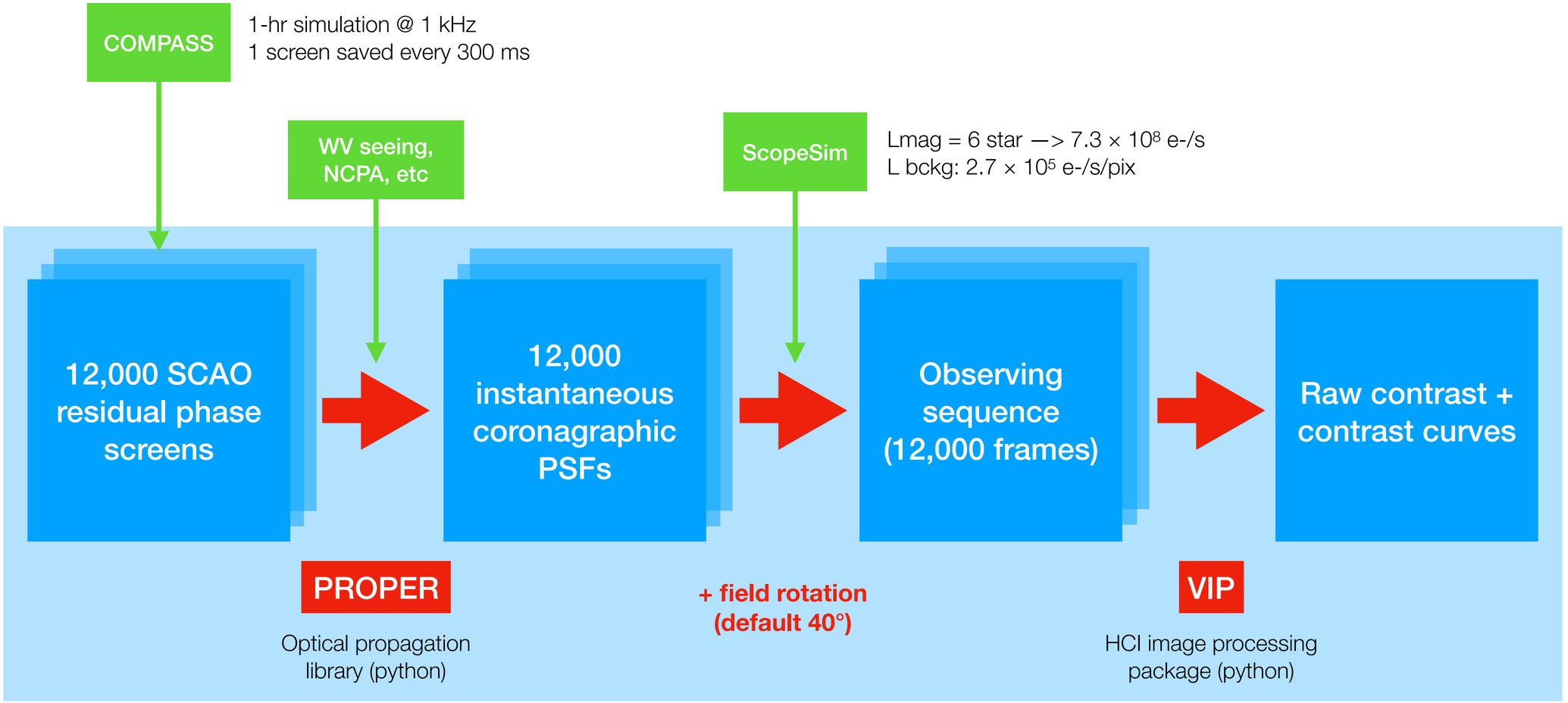
End-to-end simulations

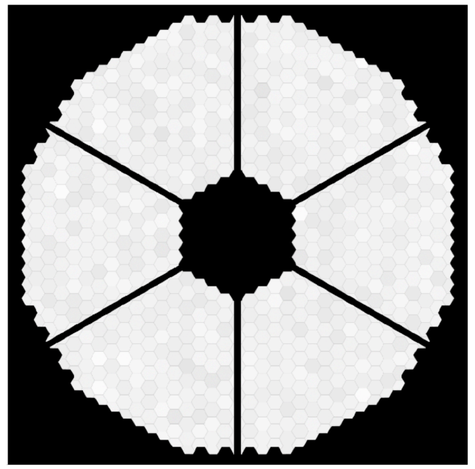


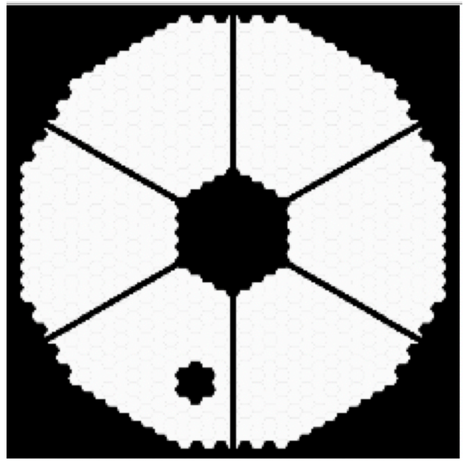
HEEPS

(https://github.com/vortex-exoplanet/HEEPS)

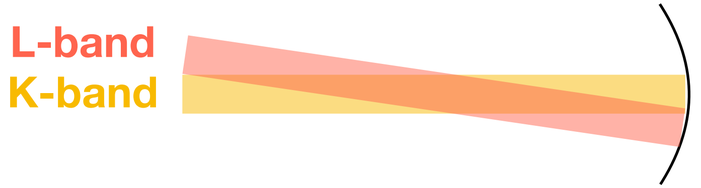
Main simulated effects

- SCAO residuals **Poster: Pourcelot**
  - COMPASS simulator (incl. wind-load pointing jitter, residual petal piston, …)
- Other atmospheric effects
  - atmospheric dispersion
  - water vapour seeing (see next slides)
- NCPA (see next slides)
- Pupil-related effects
  - ELT exit pupil stability, segment reflectivity, misaligned segments
- Miscellaneous
  - coronagraph imperfections, vortex center glow, finite stellar size, …



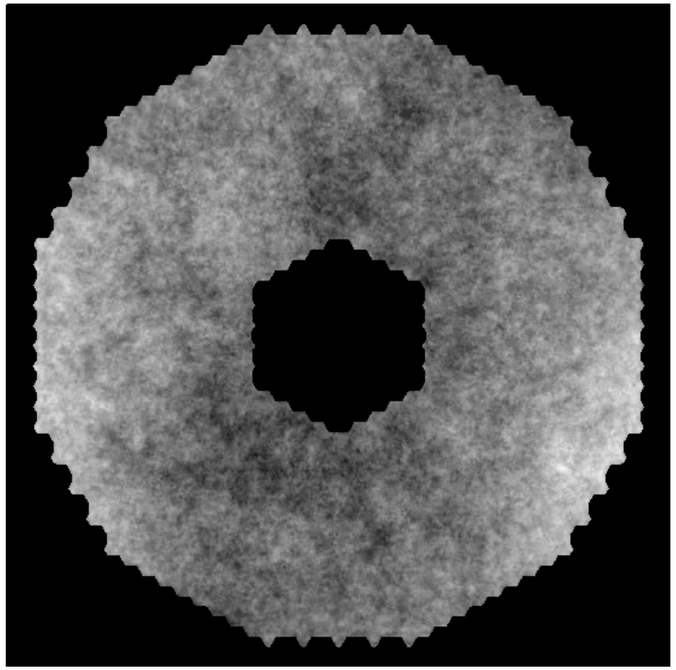


Non-common path aberrations



- Combination of static, quasi-static, and dynamic
- Phase aberrations
  - main quasi-static source: chromatic beam wander
  - main dynamic source: water vapour seeing (next slide)
- Amplitude aberrations
  - quasi-static Talbot effect from chromatic beam wander

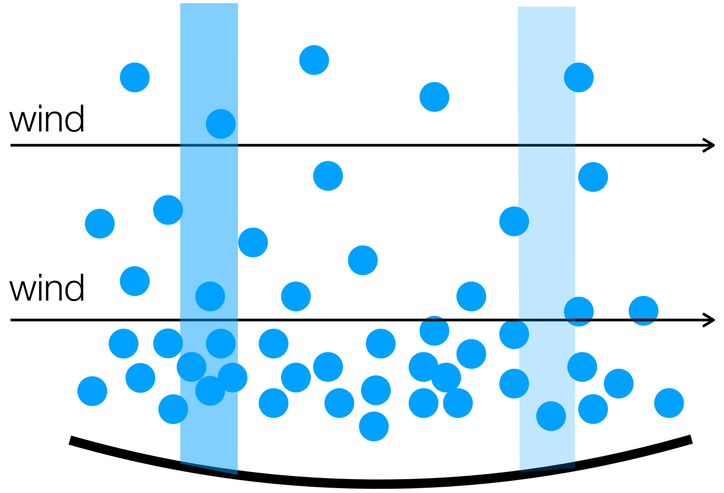
1h observing sequence around meridian

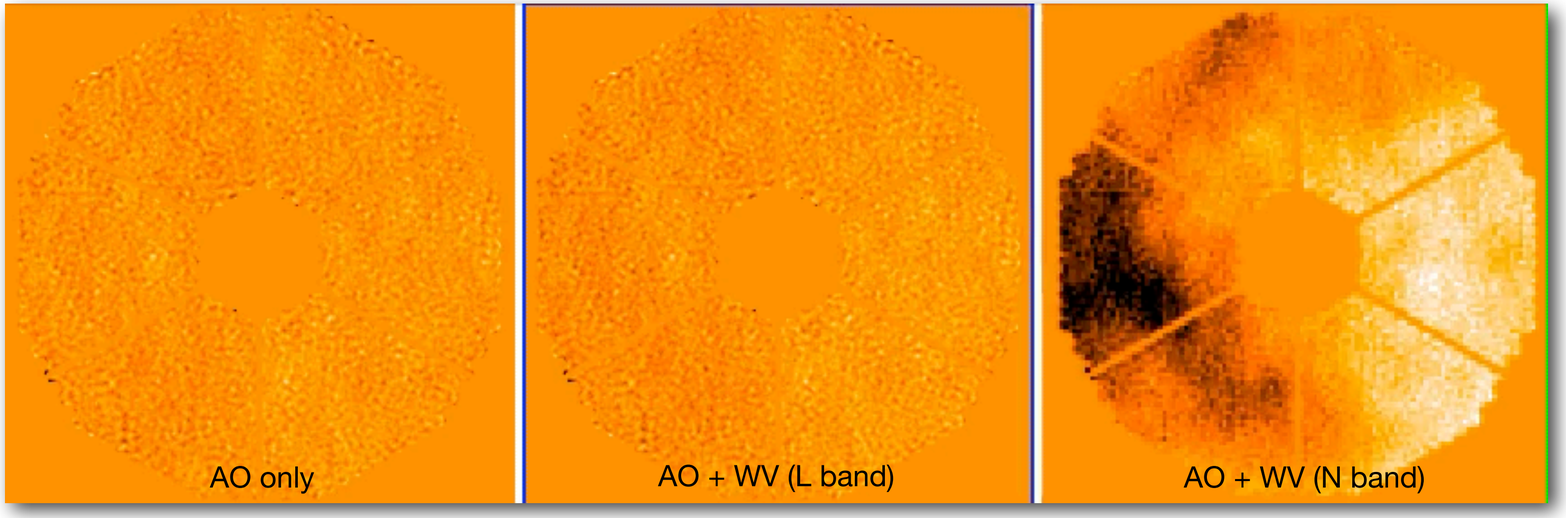


Median NCPA level ~ 100 nm
with ~ 30 nm variation due to CBW

Water vapour seeing

- Variable column density of water vapour
  - blown by wind —> WV seeing
- Highly chromatic in mid-IR
  - K-band SCAO not correcting LMN bands perfectly
  - up to 300nm rms additional WFE at N band





Asymmetric pupil WF sensing & control

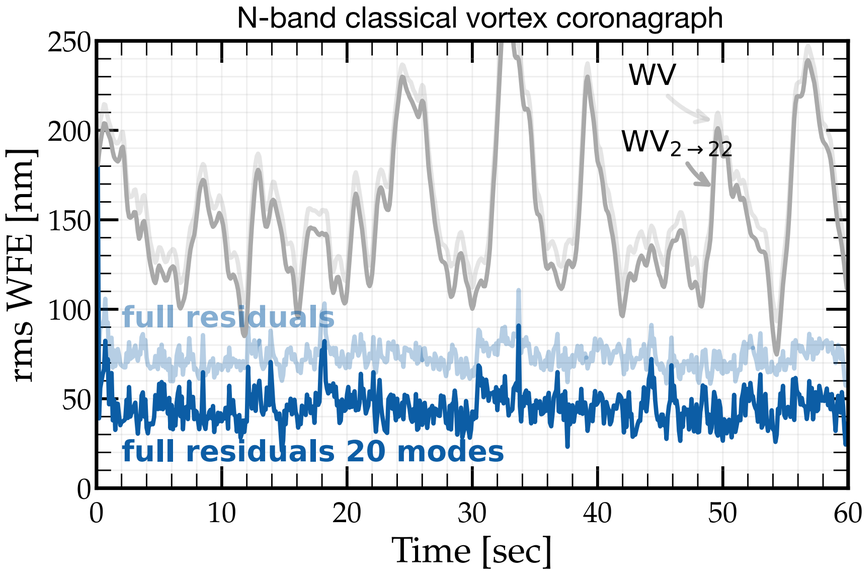
- FP wavefront sensing using IMG science camera

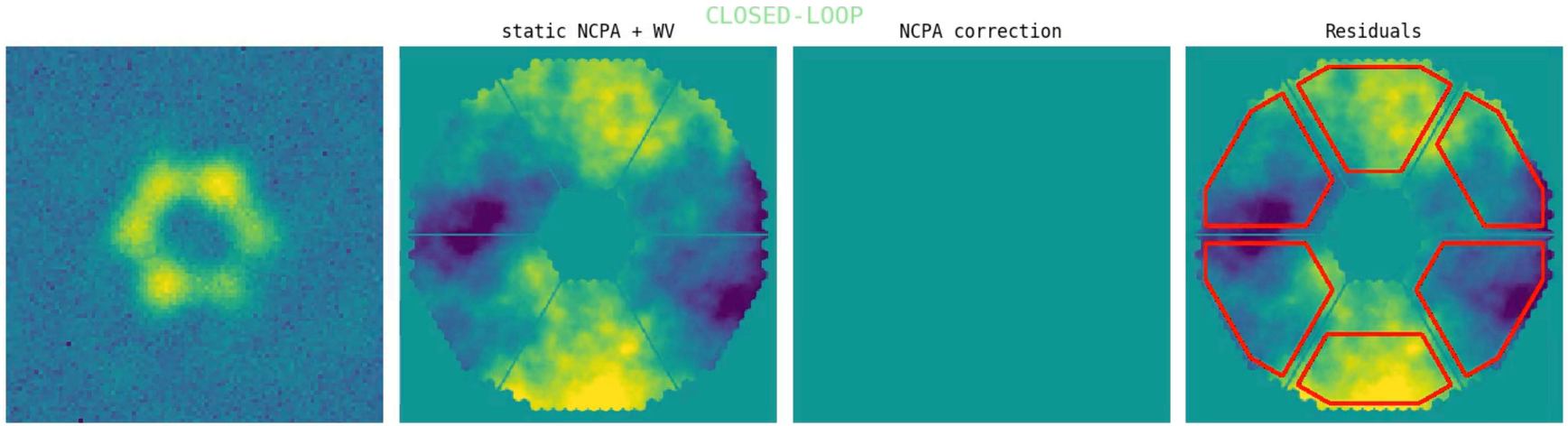
Poster: Orban de Xivry

- Lift phase retrieval ambiguity with asymmetric pupil mask —> ‘instantaneous’ retrieval

Poster: Taskin

- Control baseline = leaky integrator, but also exploring reinforcement learning





(Nmag = 0, 10 Hz closed-loop, 20 modes)

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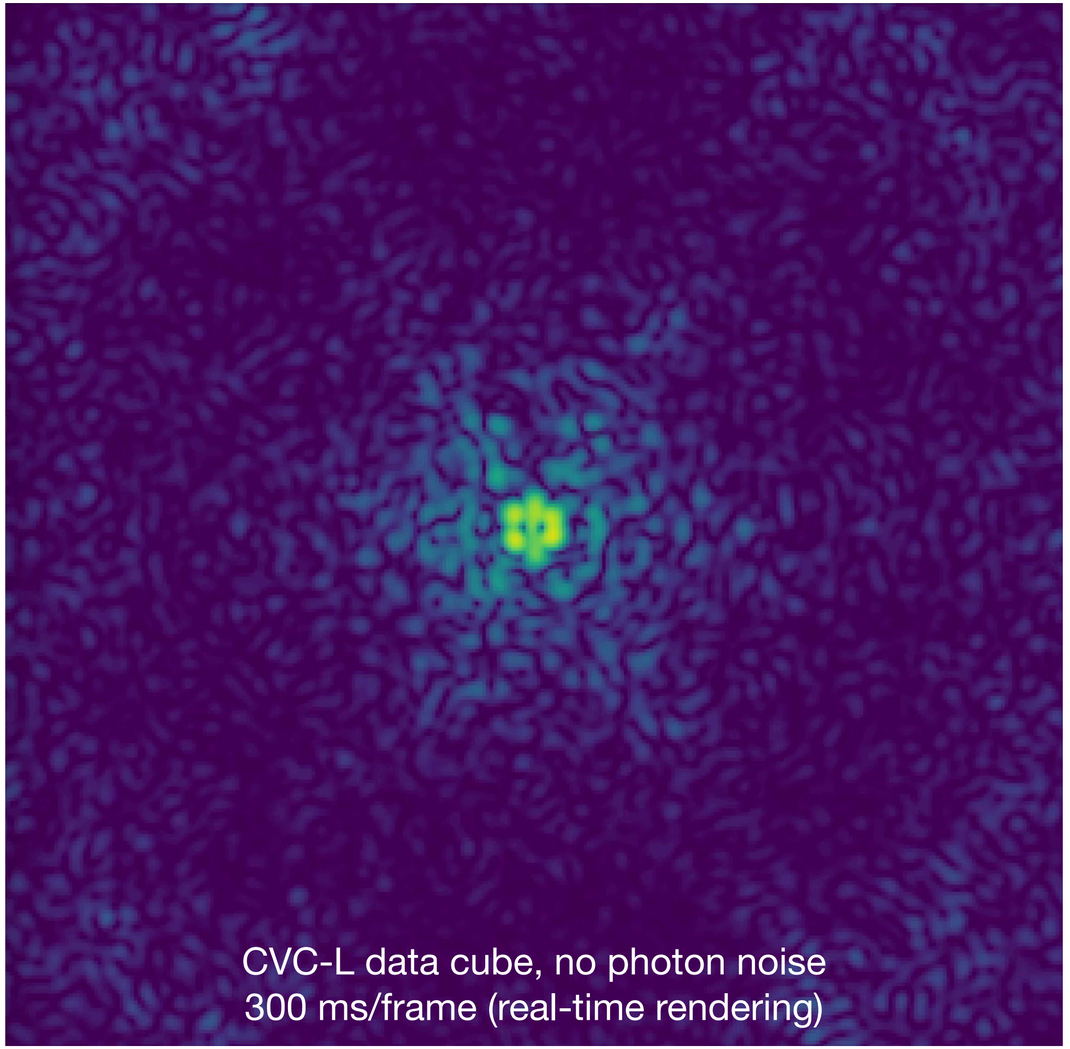
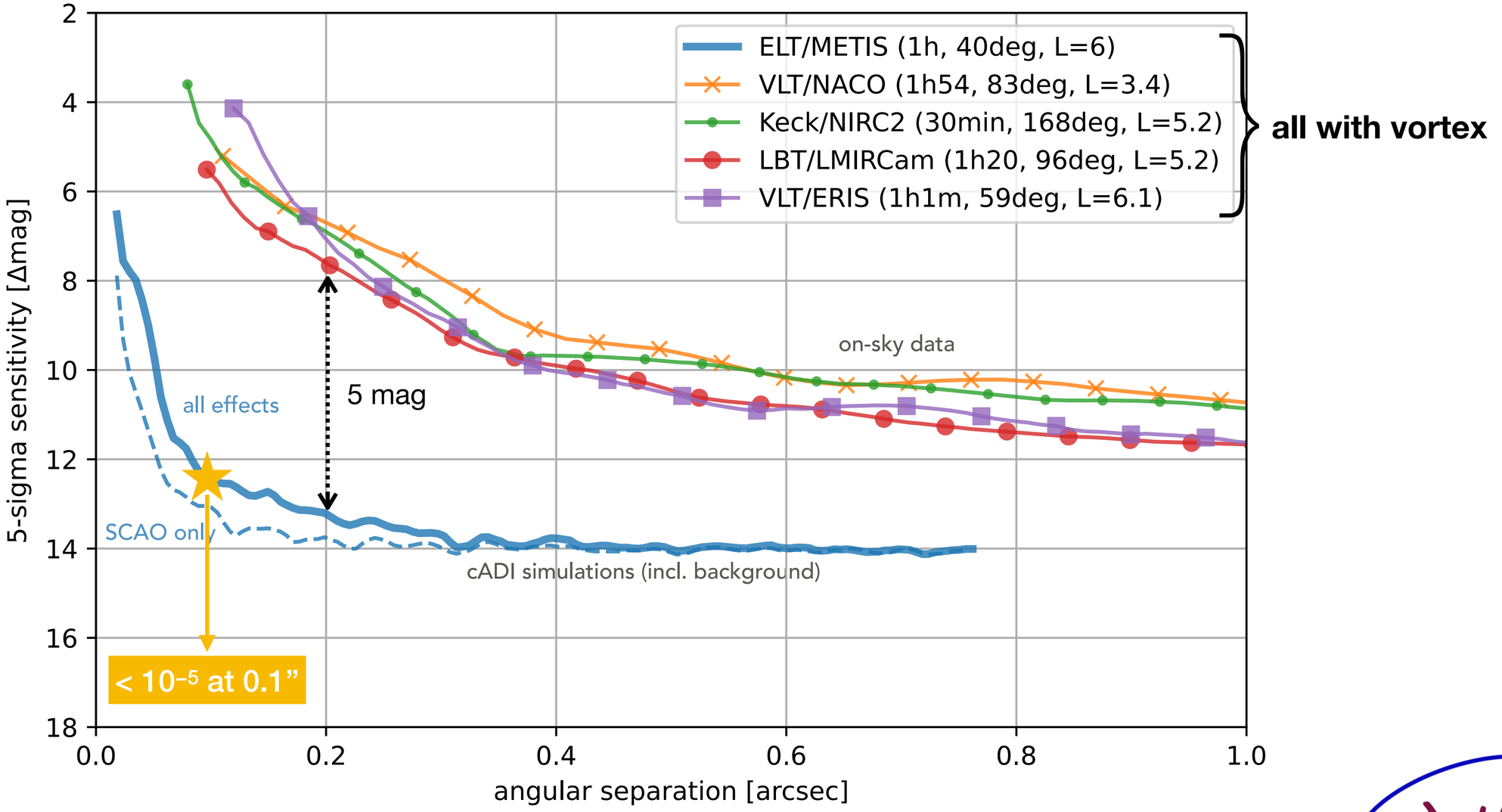
Mock data cubes

0.8”
(small part of the
full IMG FoV)



CVC-L data cube, no photon noise
300 ms/frame (real-time rendering)

L-band comparison with 10m-class telescopes



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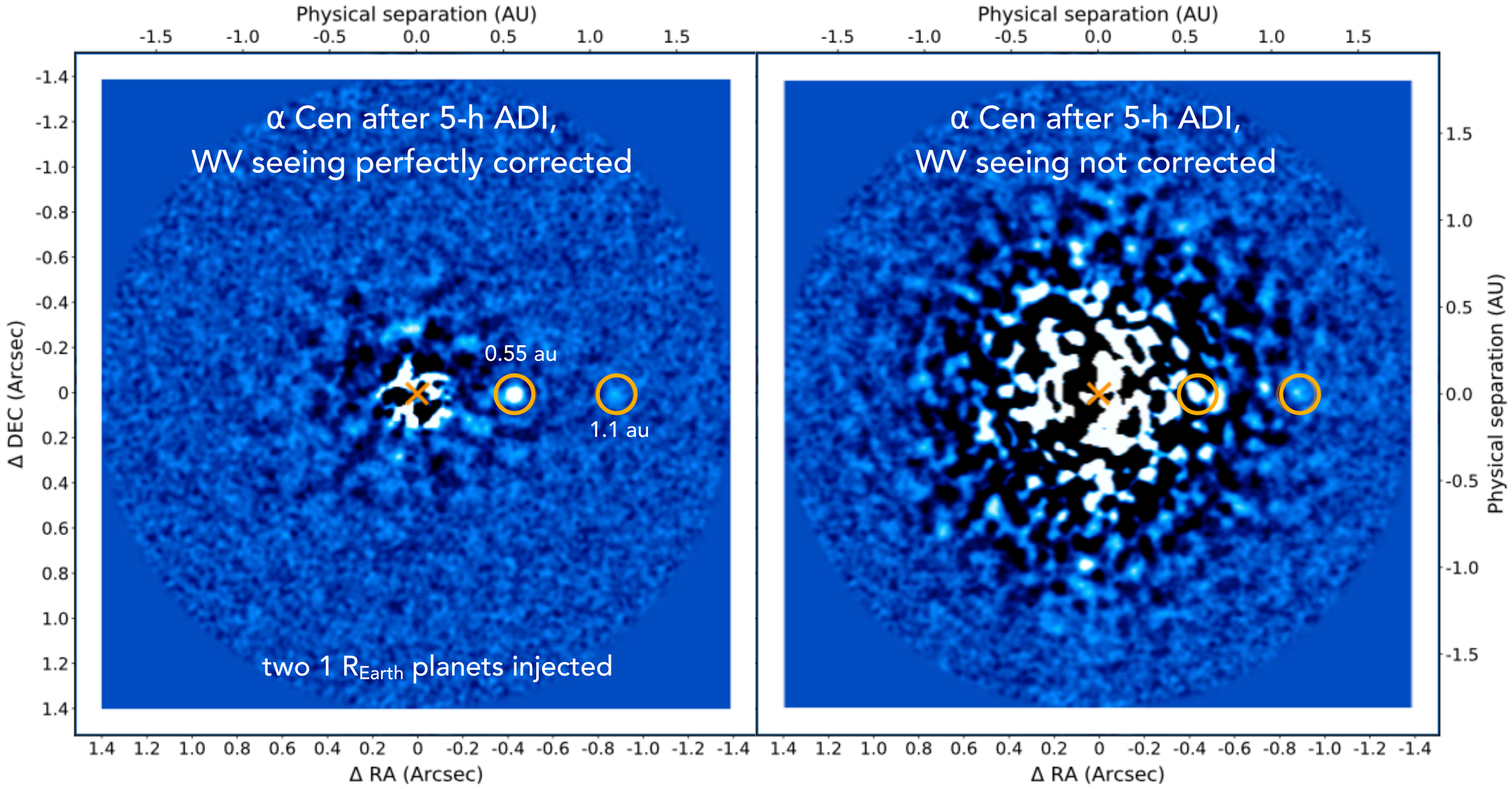
α Cen with N-band CVC



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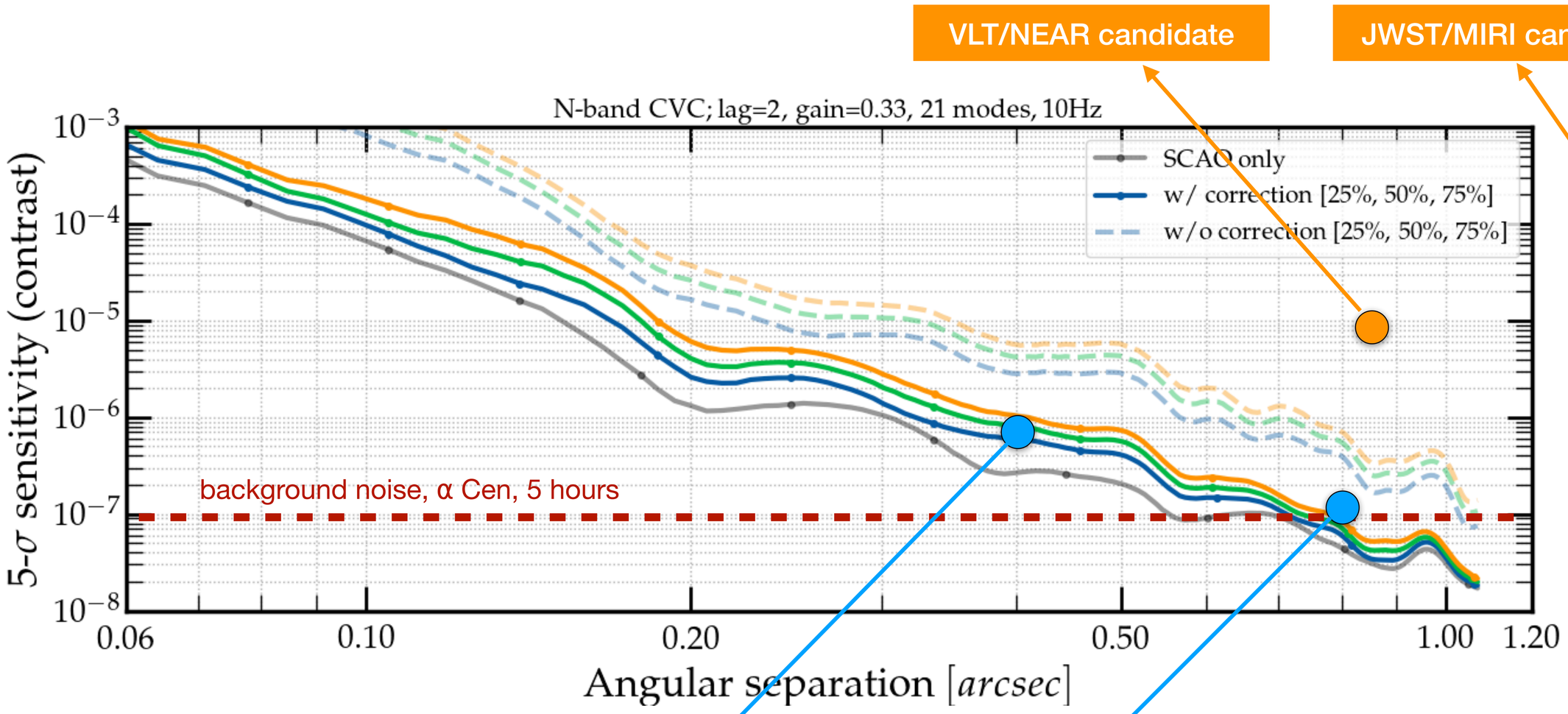
More science in posters (Chauvin & Hinkley)

α Cen at N band: detection limits



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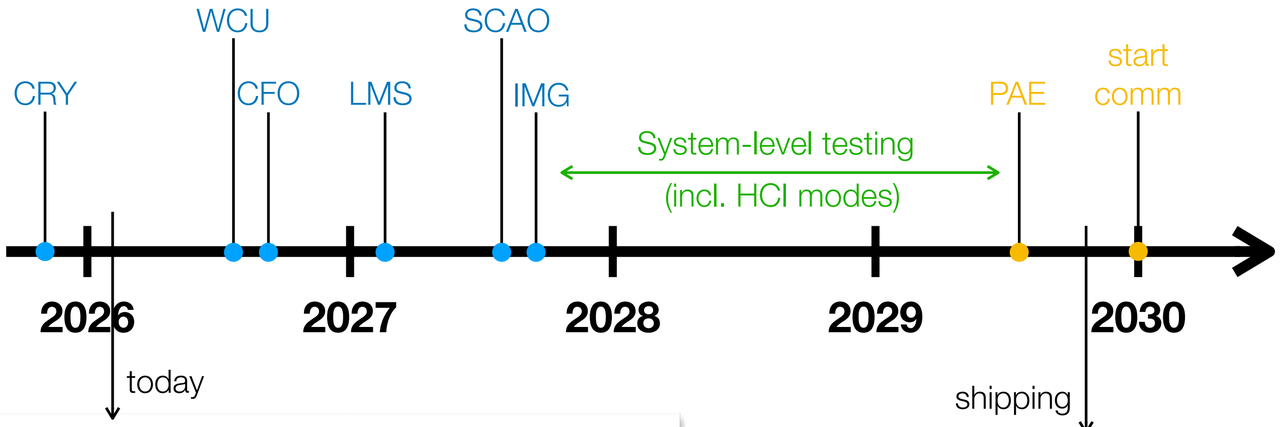
Only 4 years to go to first light!



ELT construction 70% completed

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