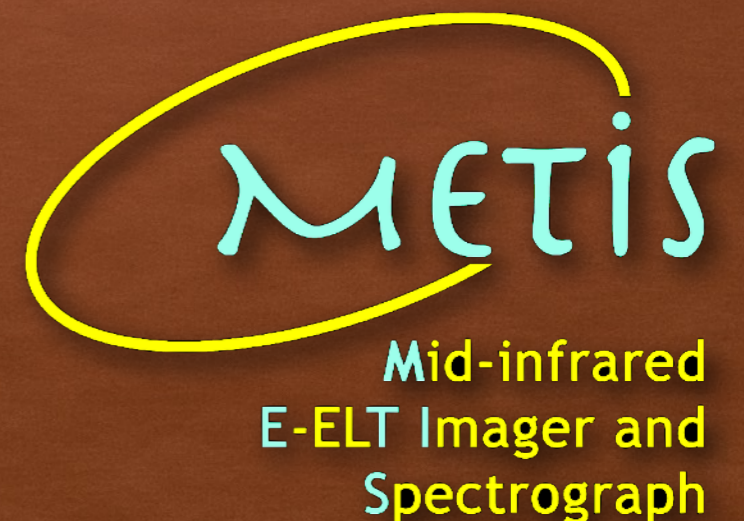


# HIGH-CONTRAST IMAGING WITH ELT/METIS

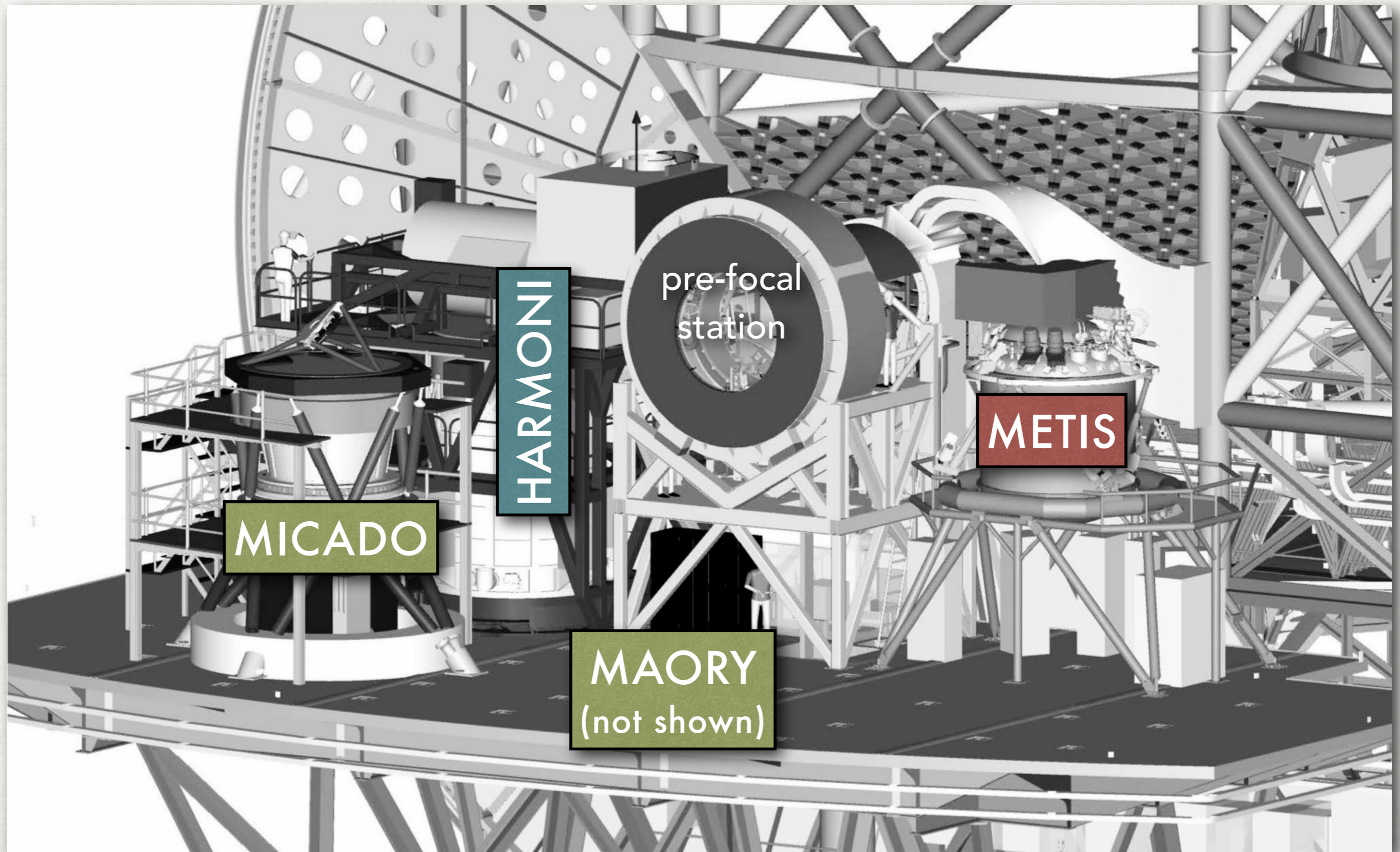
OLIVIER ABSIL

+ THE WHOLE METIS HCI TEAM

UNIVERSITY OF LIÈGE



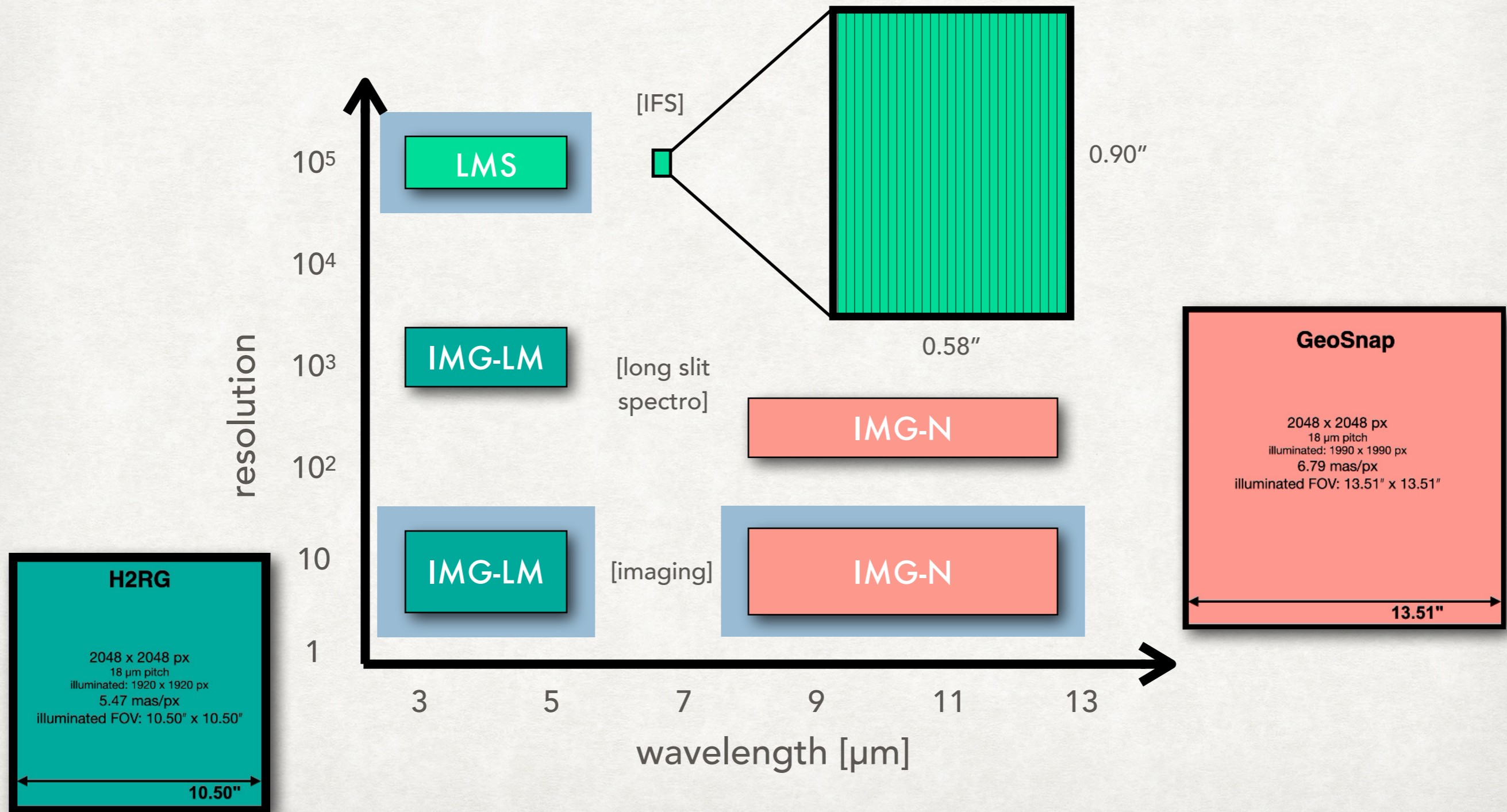
# FIRST GENERATION INSTRUMENTS @ ELT



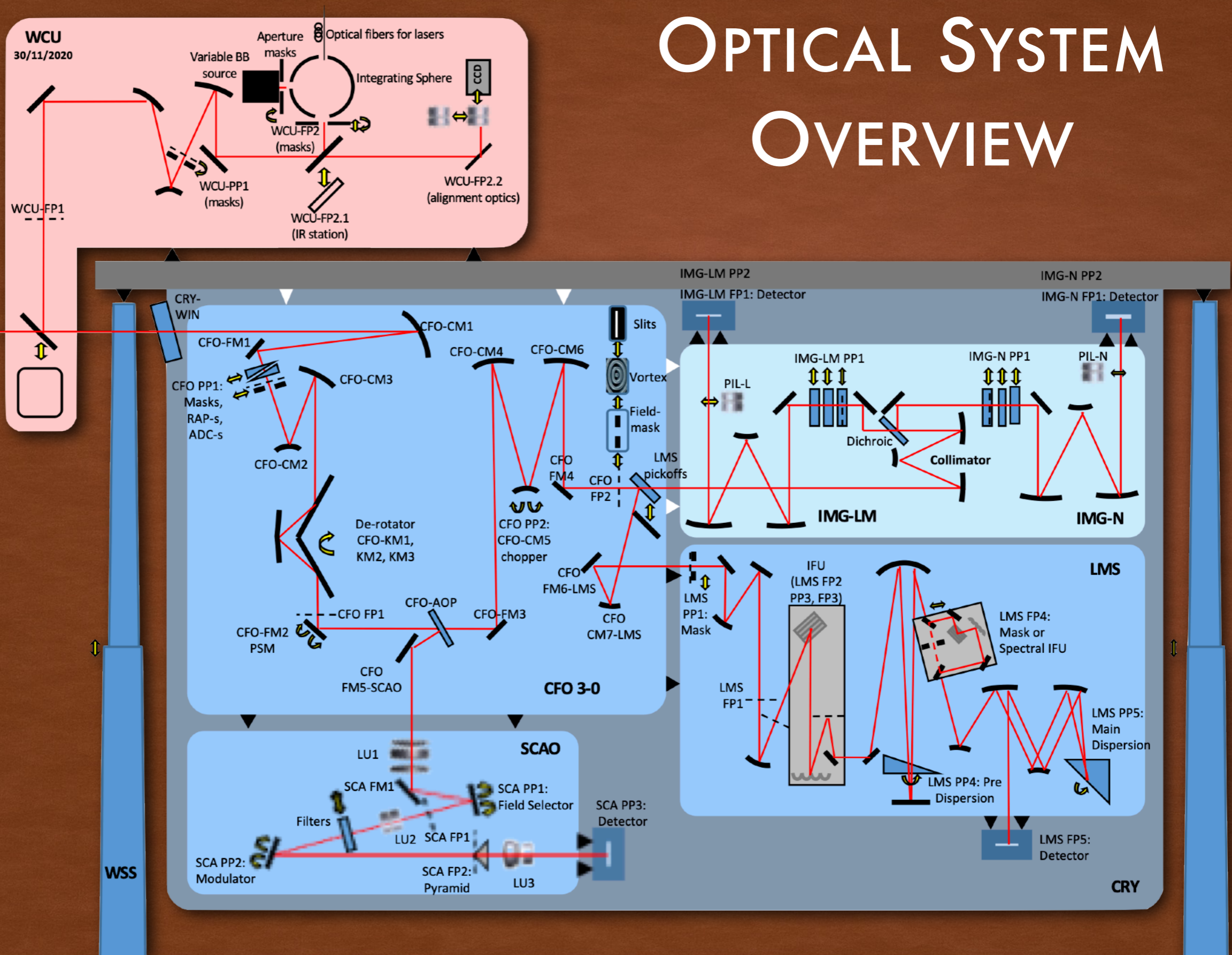
# METIS INSTRUMENT BASELINE

All modes work at diffraction limit of 38-m ELT using single-conjugate AO

 = coronagraphic capabilities



# OPTICAL SYSTEM OVERVIEW



1:1 scale model



IT'S GOT  
TO BE  
BIG!

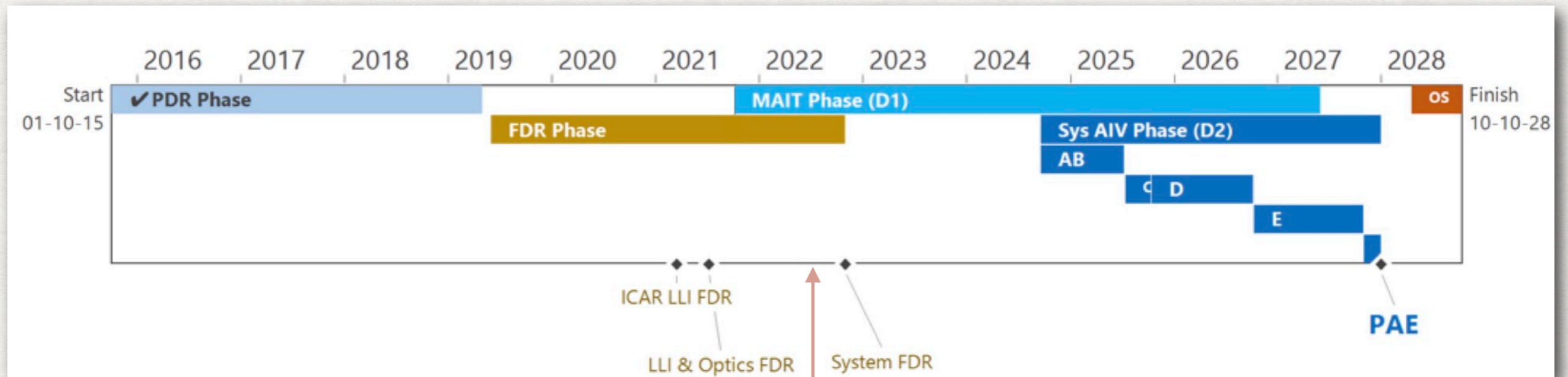
(and cold)

METIS PI

# METIS TIMELINE

~ 670 FTE & 20 M€ hardware budget over 13 yrs

first light: end of 2028

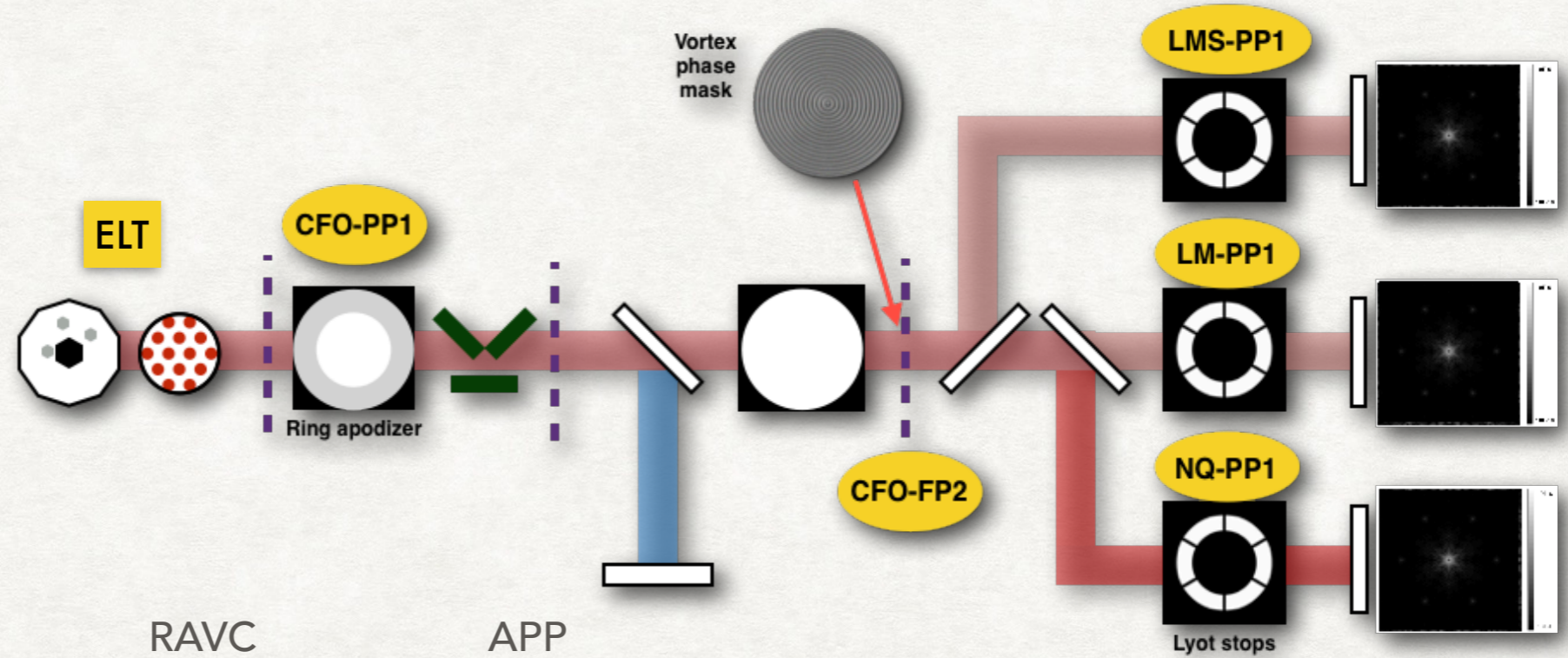


today

**FDR documentation deadline!**

# HIGH-CONTRAST IMAGING MODES

(Ring-Apodized)  
Vortex Coronagraph

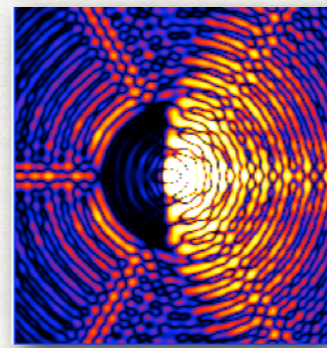
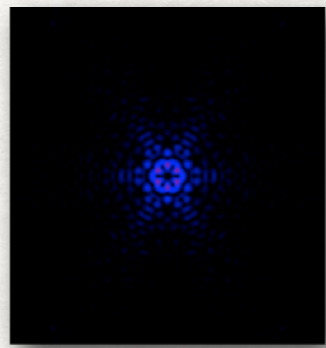
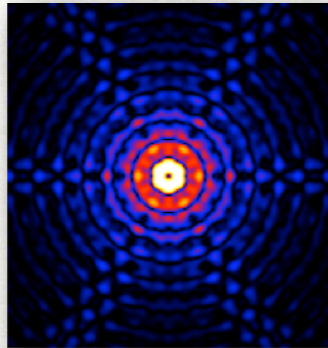
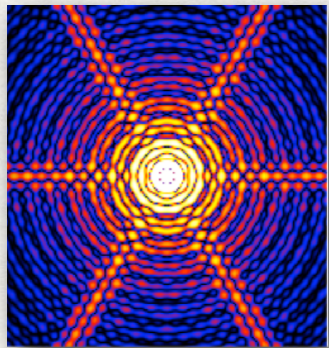


ELT

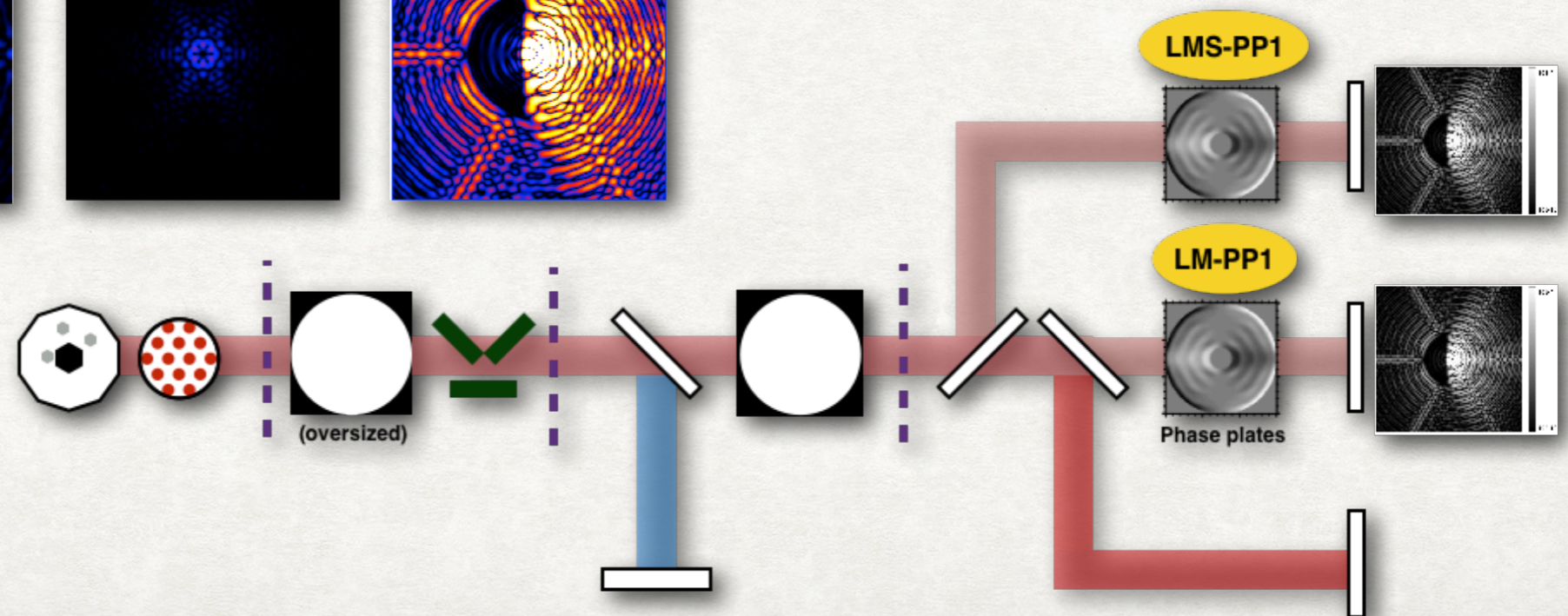
VC

RAVC

APP



Apodizing  
Phase Plate



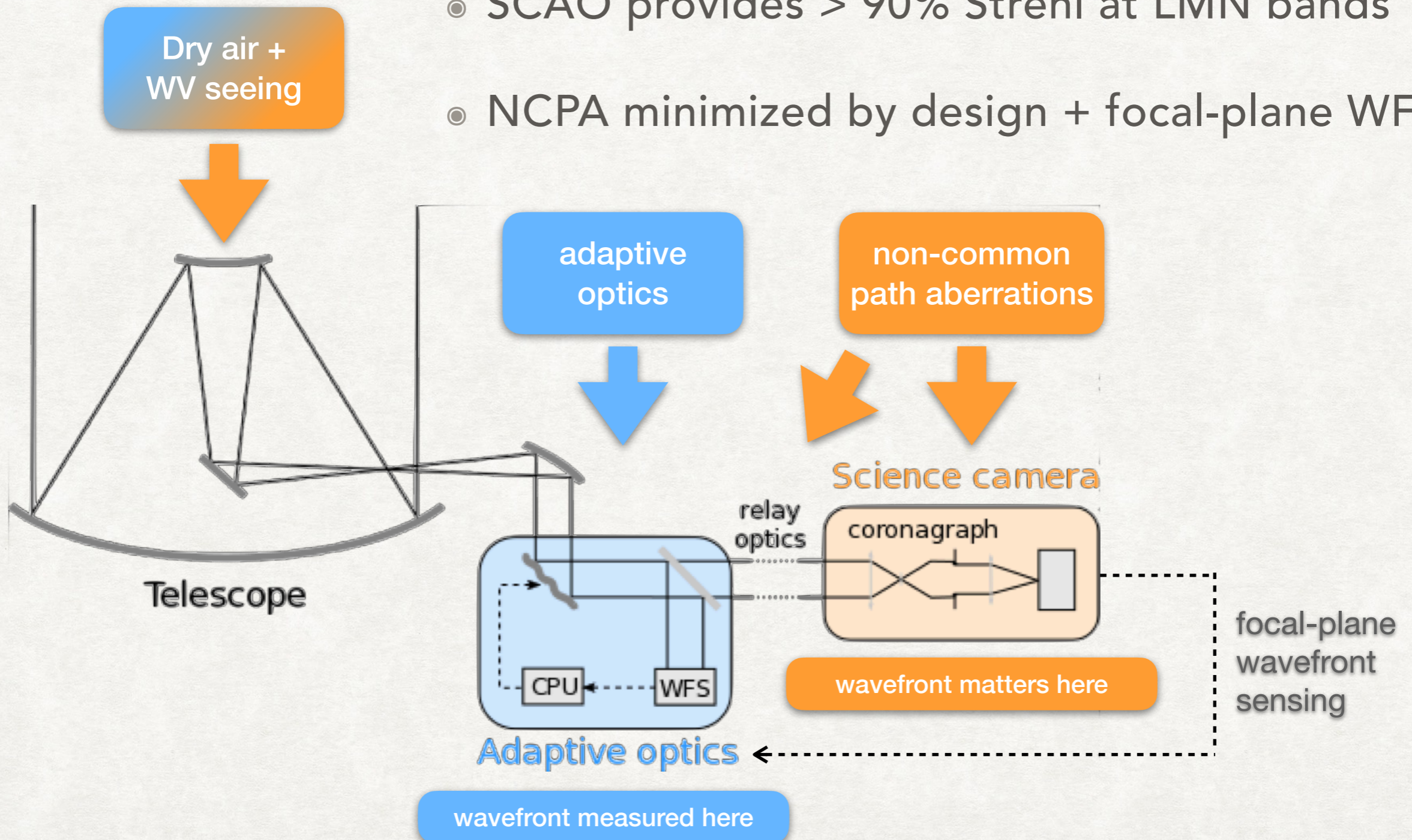
LMS-PP1

LM-PP1

Phase plates

# WAVEFRONT CONTROL STRATEGY

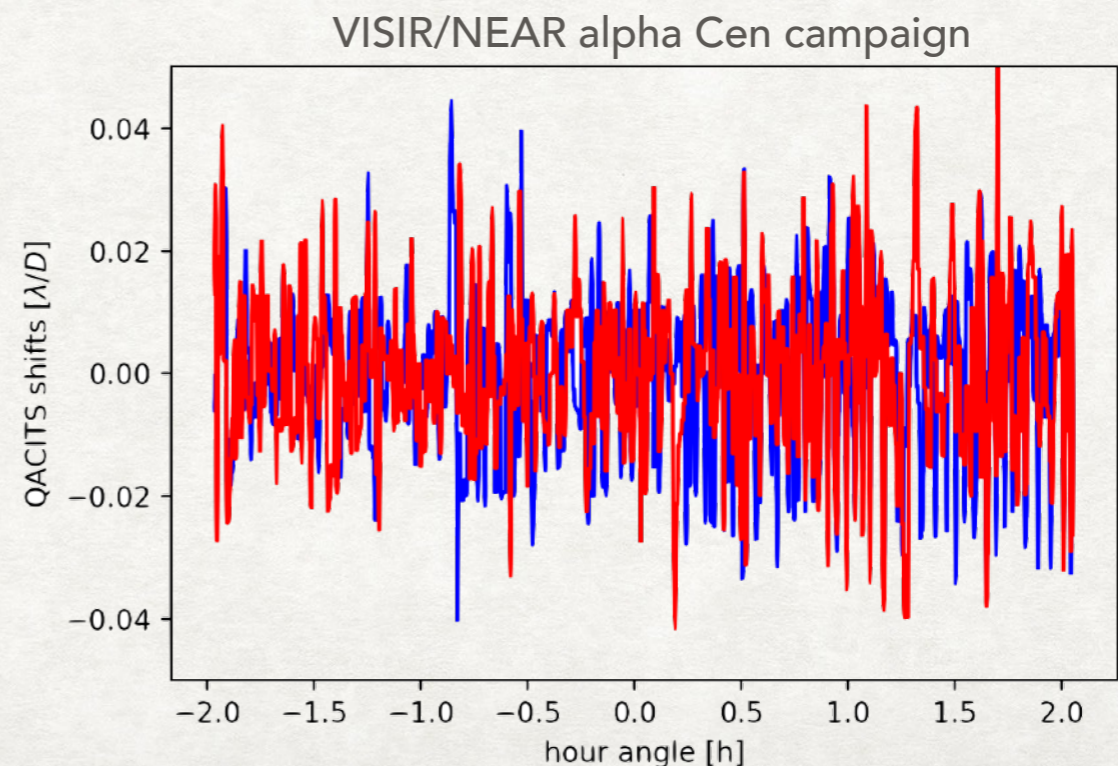
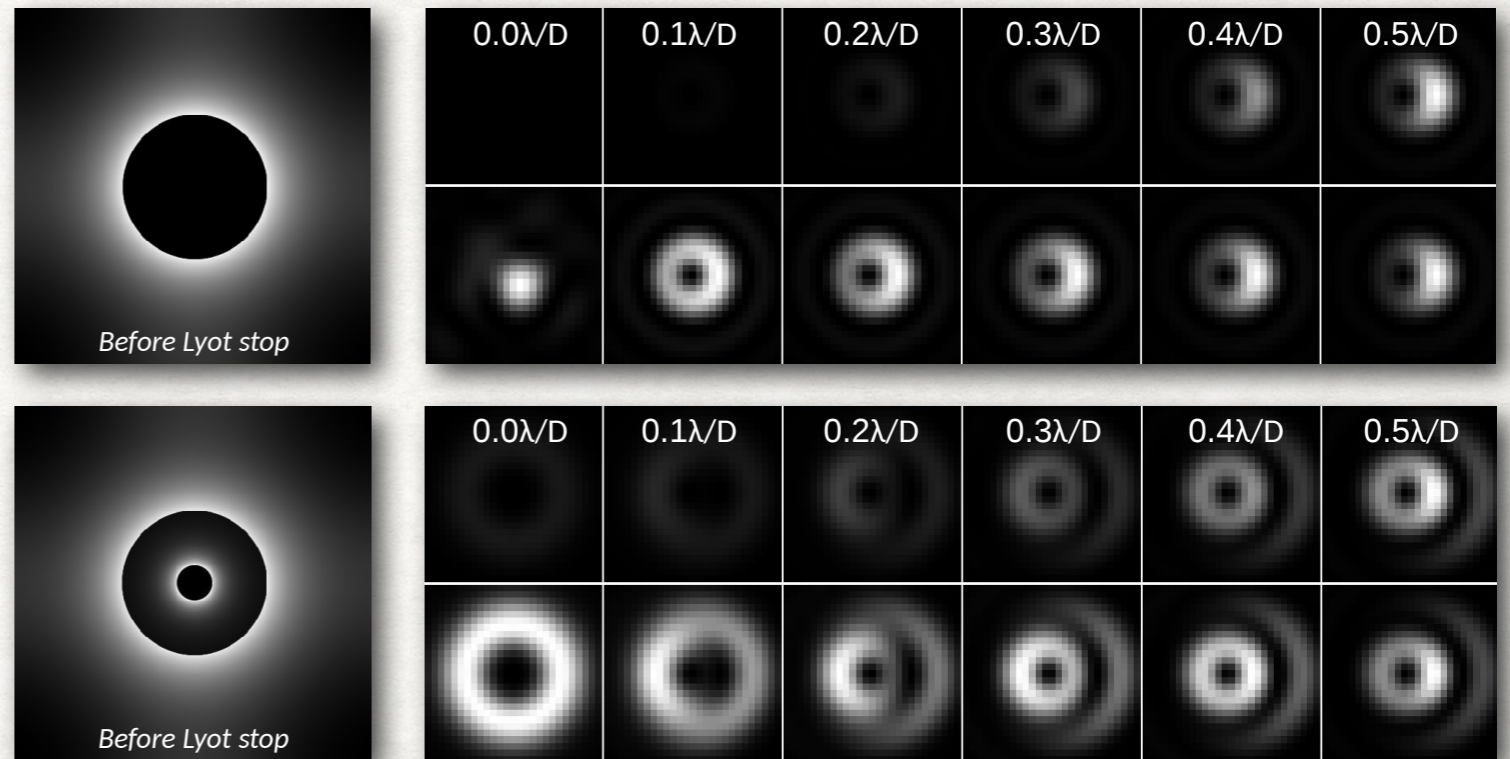
- SCAO provides  $> 90\%$  Strehl at LMN bands
- NCPA minimized by design + focal-plane WFS



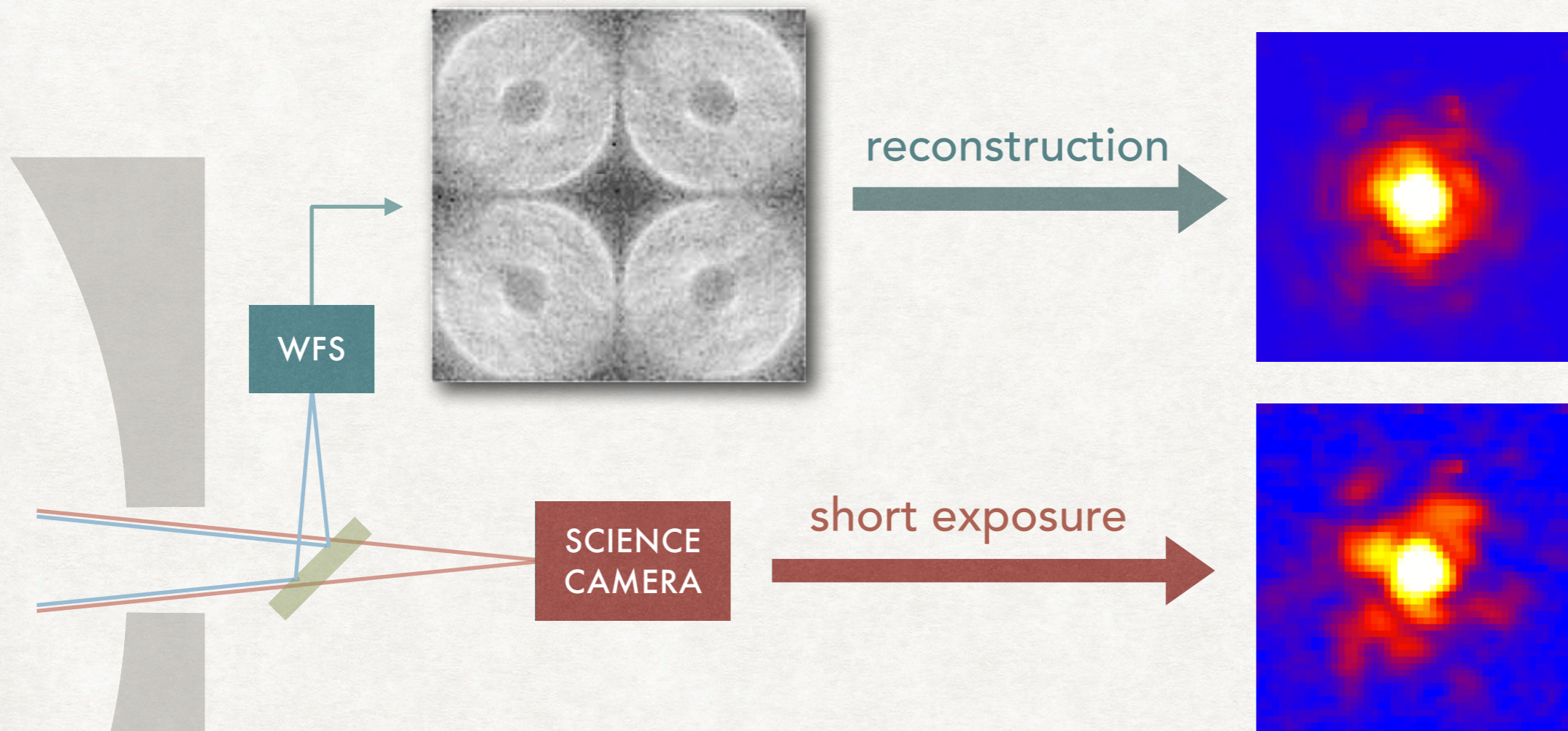


# POINTING CONTROL WITH QACITS

- Tailored to vortex coronagraph
- Measure asymmetry in coronagraphic PSF
- Reconstruct pointing error with nonlinear model
- Demonstrated accuracy  $\sim 0.01 \lambda/D$

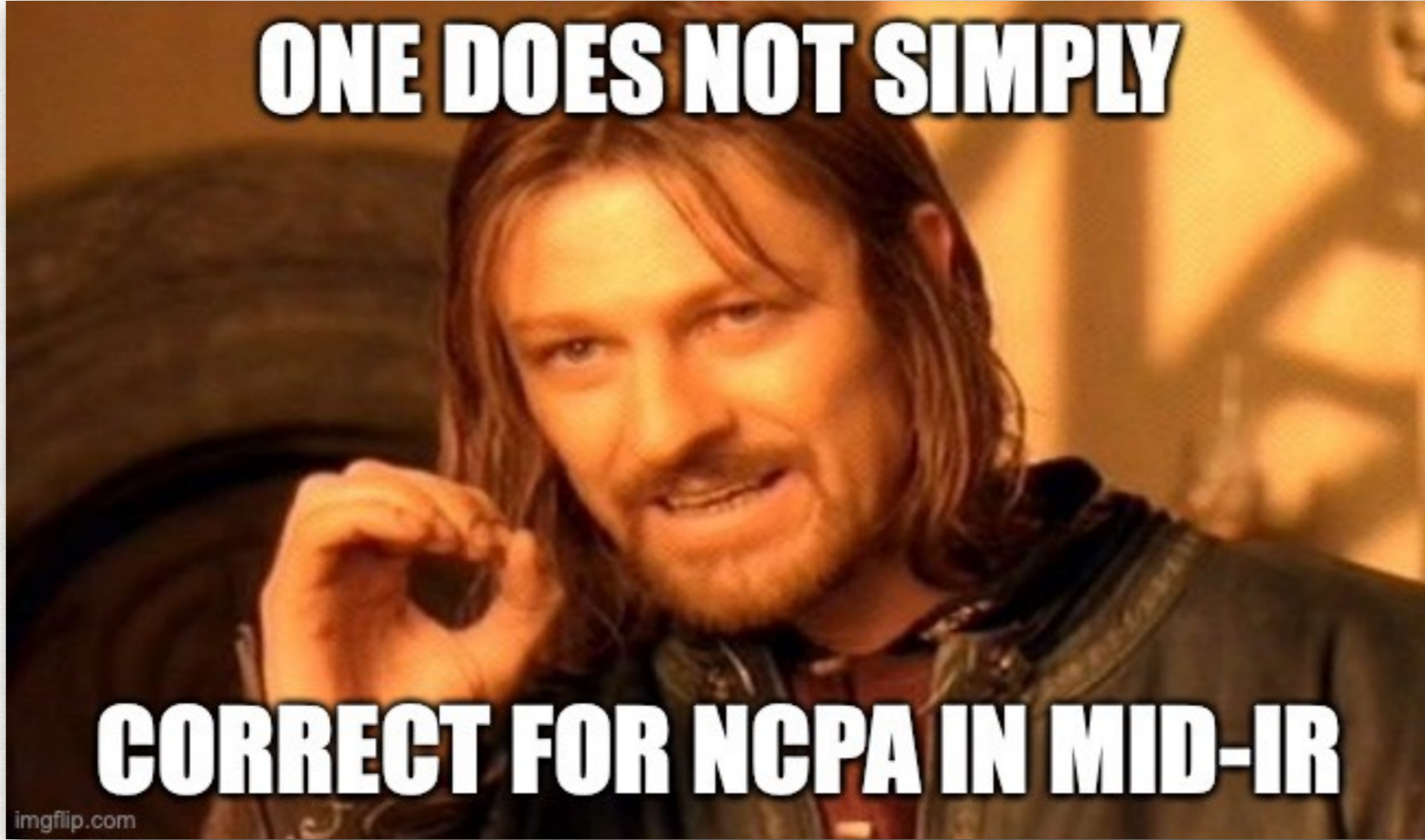


# NCPA CONTROL WITH PSI



- Reconstructed PSF  $\neq$  measured PSF due to NCPA
- Use SCAO residuals as source of diversity to infer pixel-wise amplitude and phase of NCPA

**ONE DOES NOT SIMPLY**

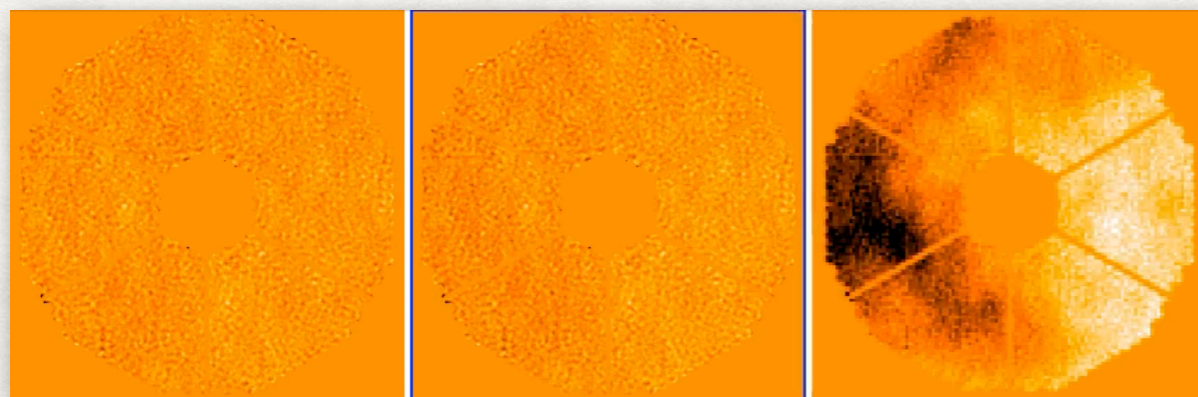
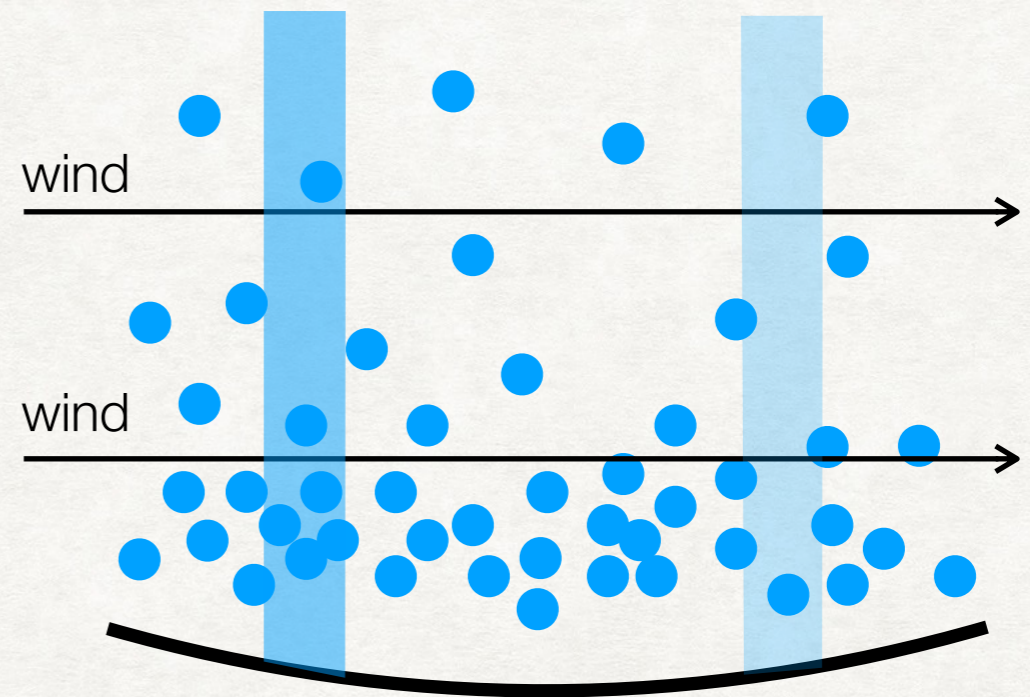


**CORRECT FOR NCPA IN MID-IR**

imgflip.com

# WATER VAPOR SEEING

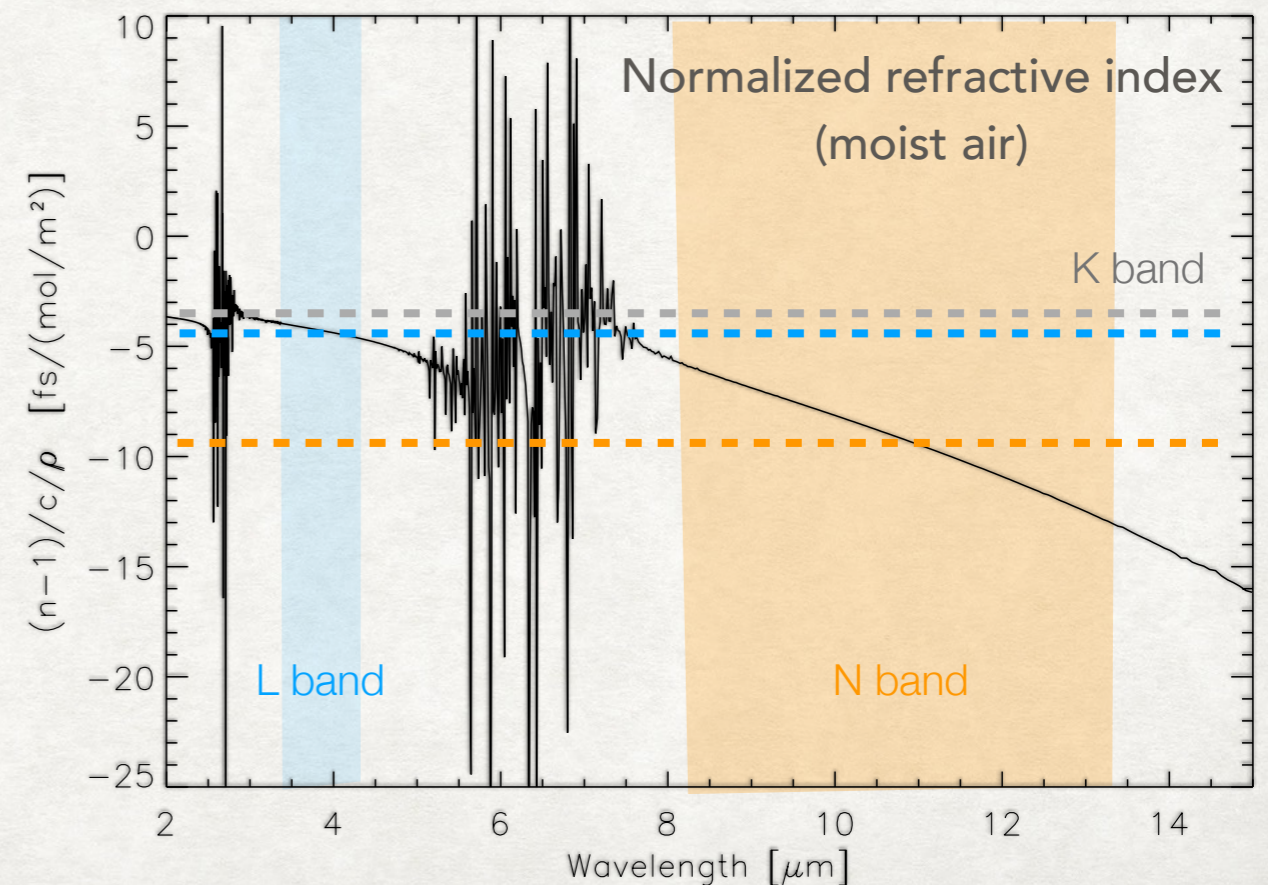
- Variable column density of water vapor above telescope
- Blown by wind  $\rightarrow$  water vapor seeing
- Highly chromatic in mid-IR  $\rightarrow$  SCAO correction not good at LMN bands
- QACITS + PSI need to run at 1 Hz



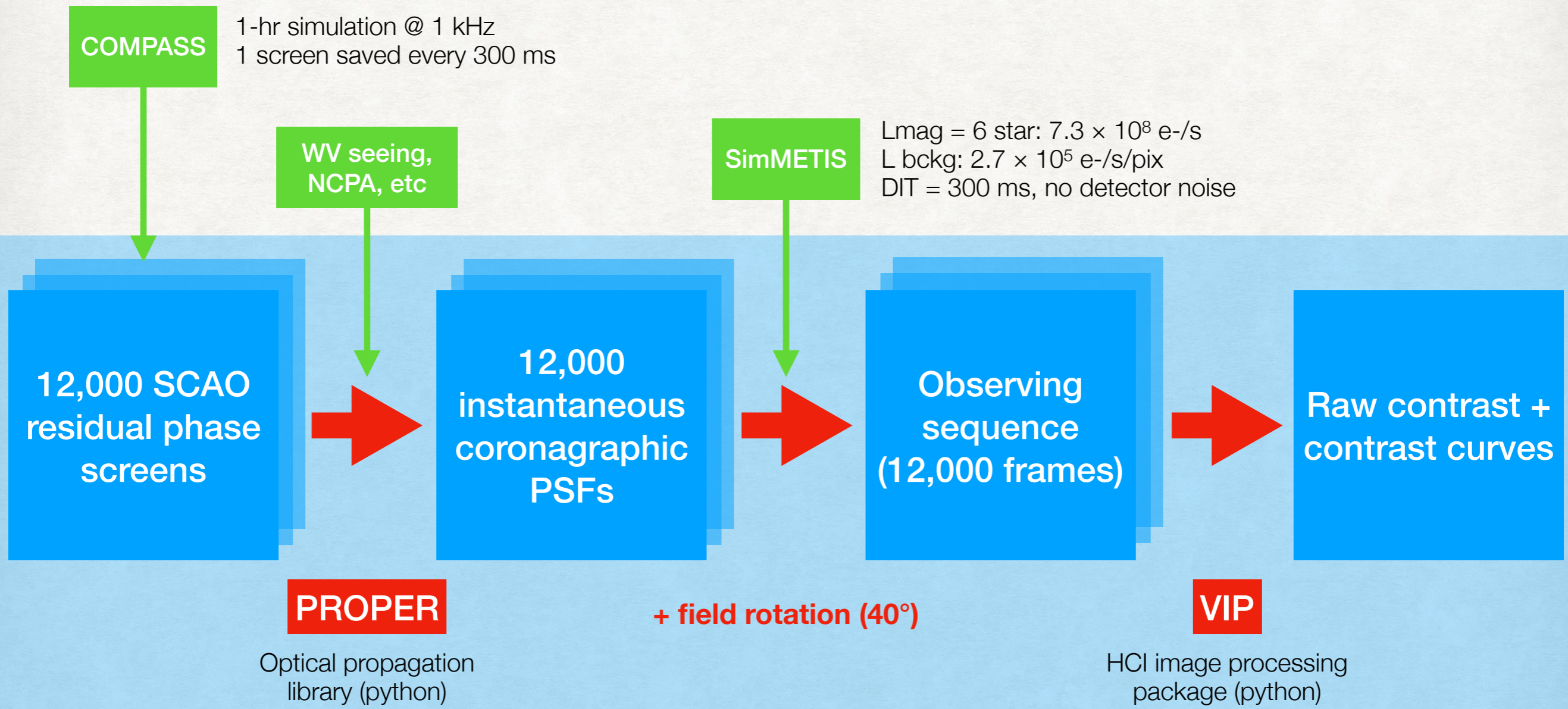
AO only

AO + WV (L band)

AO + WV (N band)



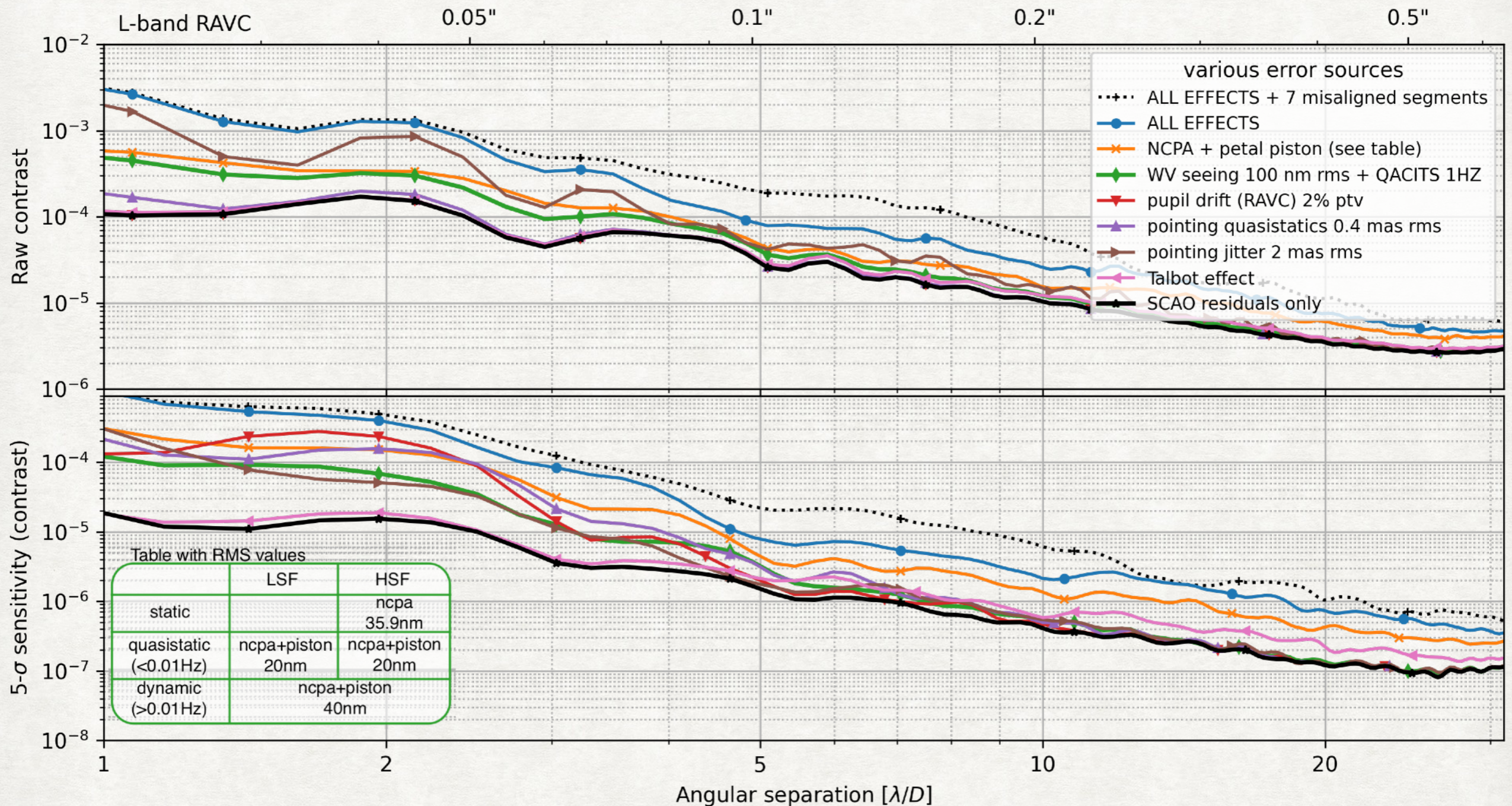
# END-TO-END HCI SIMULATIONS



## HEEPS

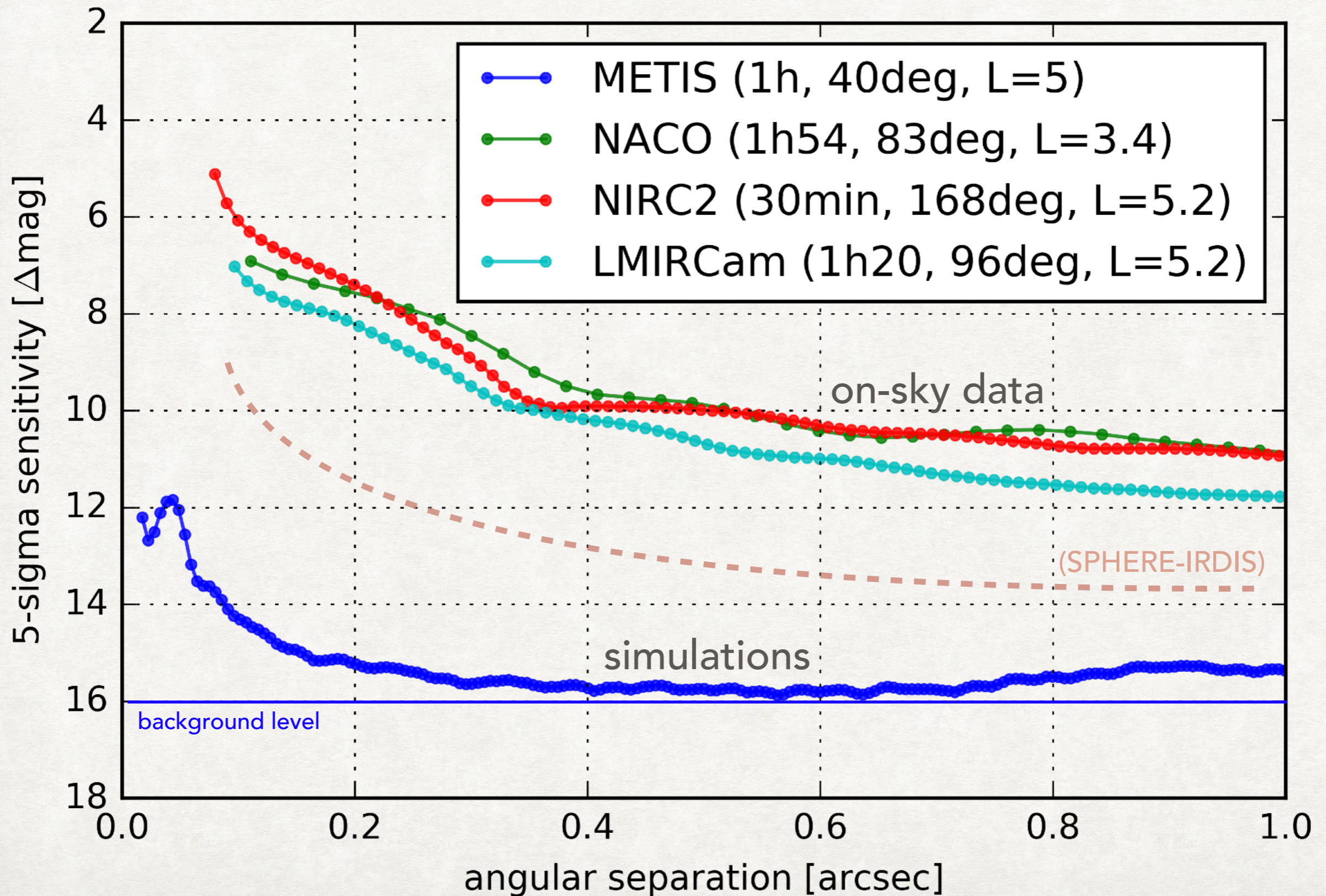
(<https://github.com/vortex-exoplanet/HEEPS>)

# EXPECTED PERFORMANCE (L BAND)



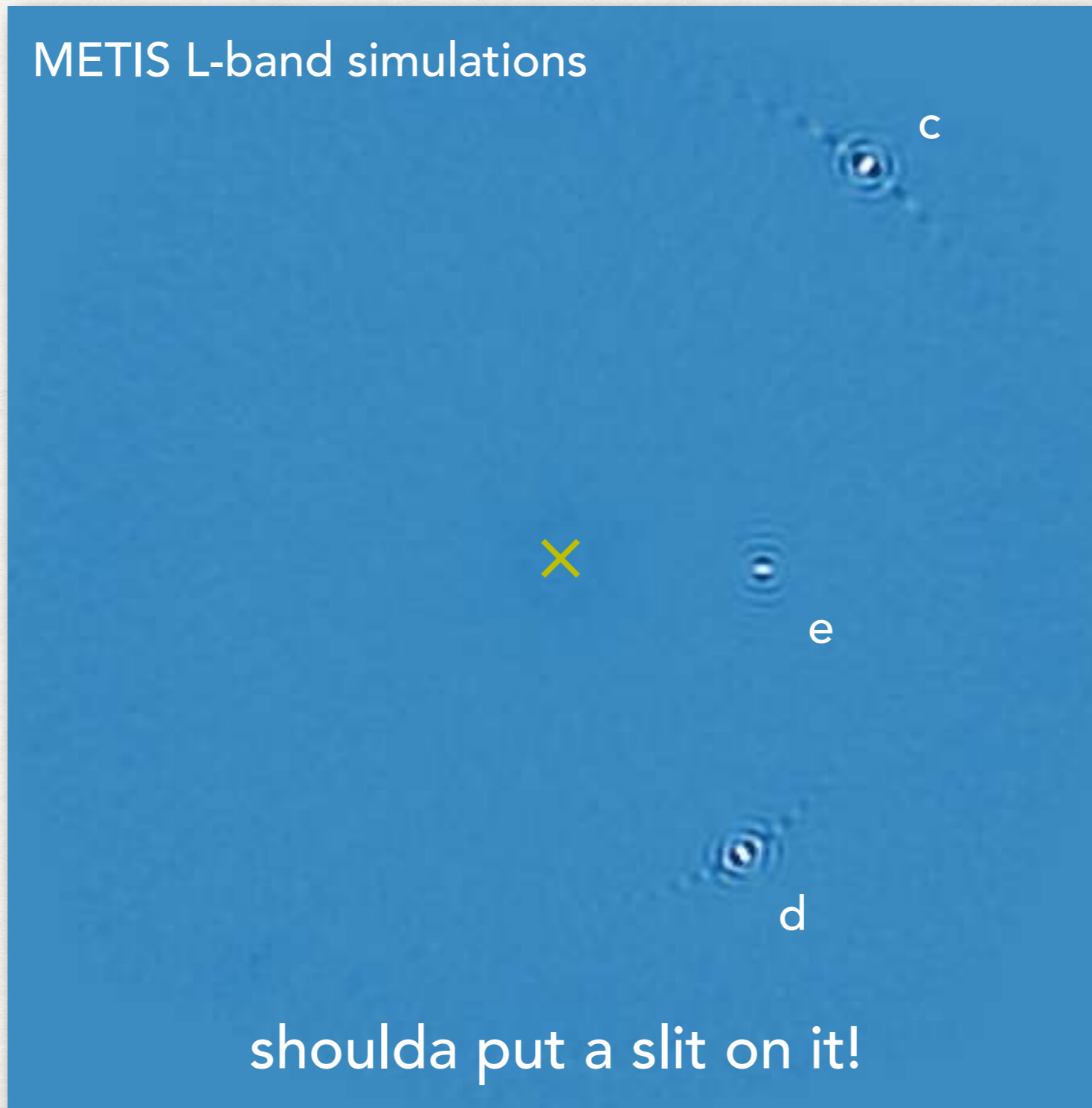
**METIS SHOULD REACH  $< 10^{-5}$  AT  $0.1''$**

# METIS vs 10-M CLASS TELESCOPES



# RECOGNIZE ME?

METIS L-band simulations



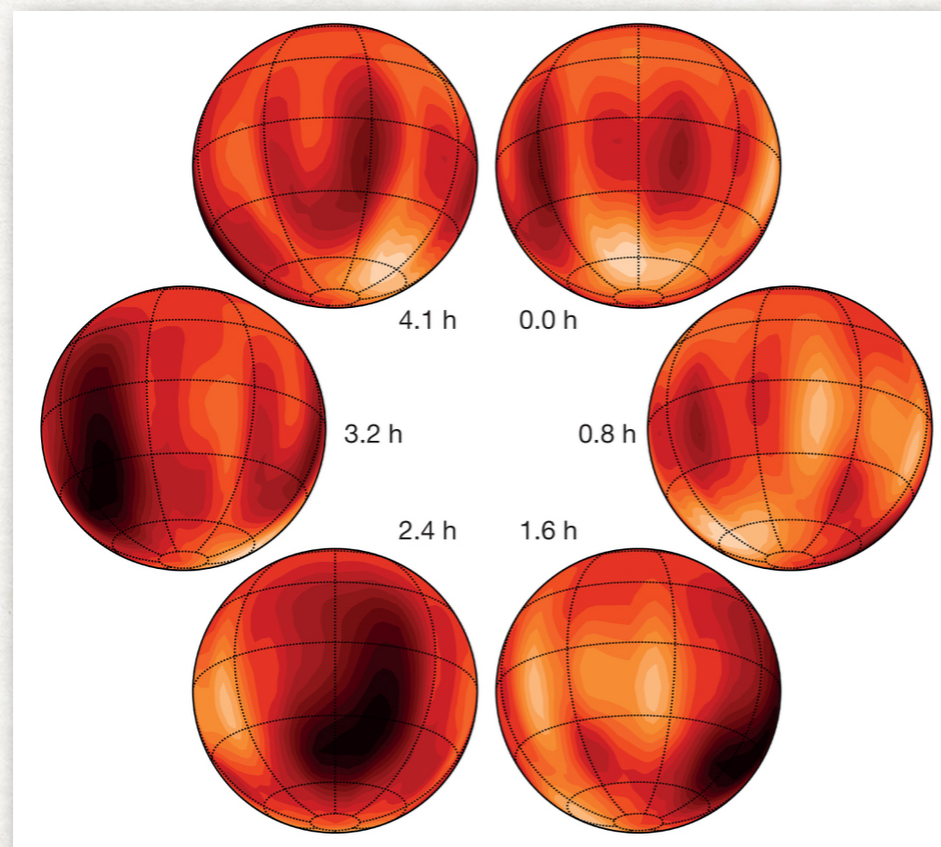
shoulda put a slit on it!



# 2D MAPS OF EXOPLANET ATMOSPHERES

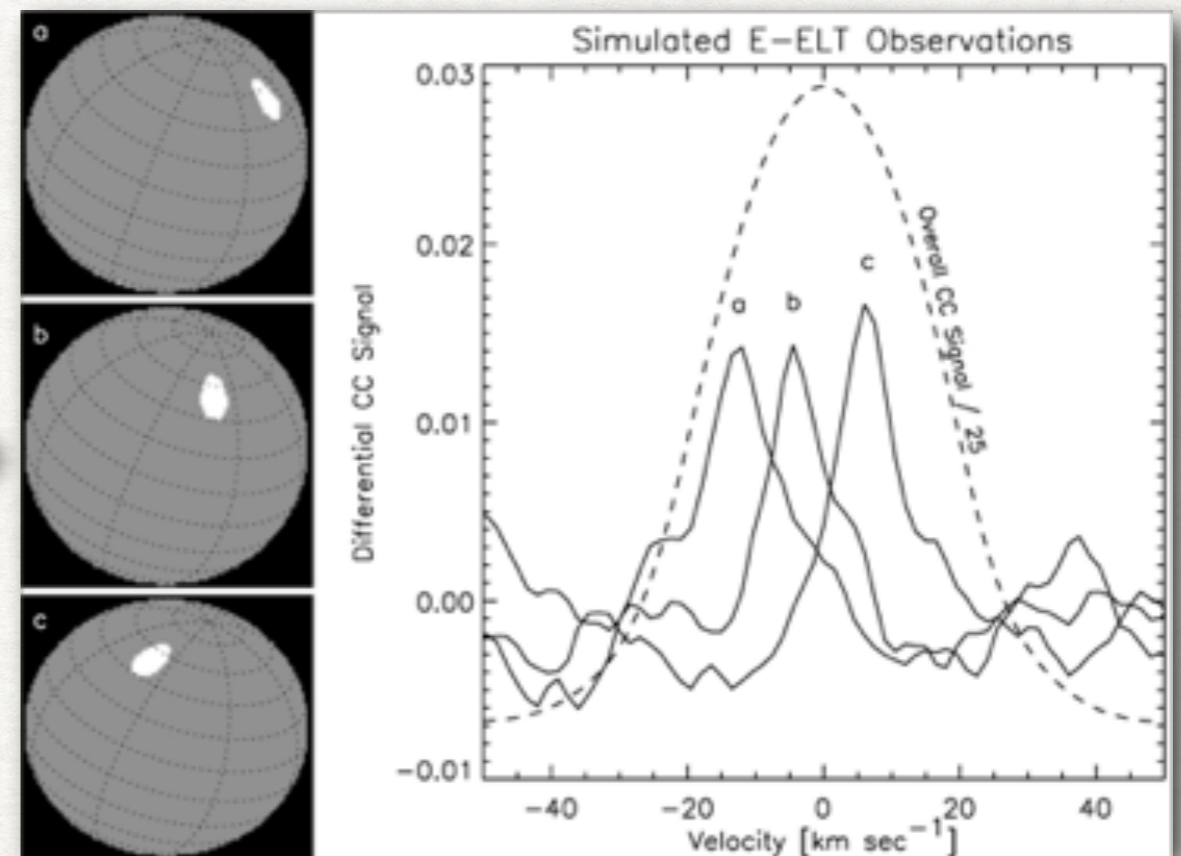
Even better: put an image slicer on it!  
( $R = 100,000$ )

From brown dwarf cloud maps...



Crossfield et al. 2014

to clouds in giant planets atmospheres!

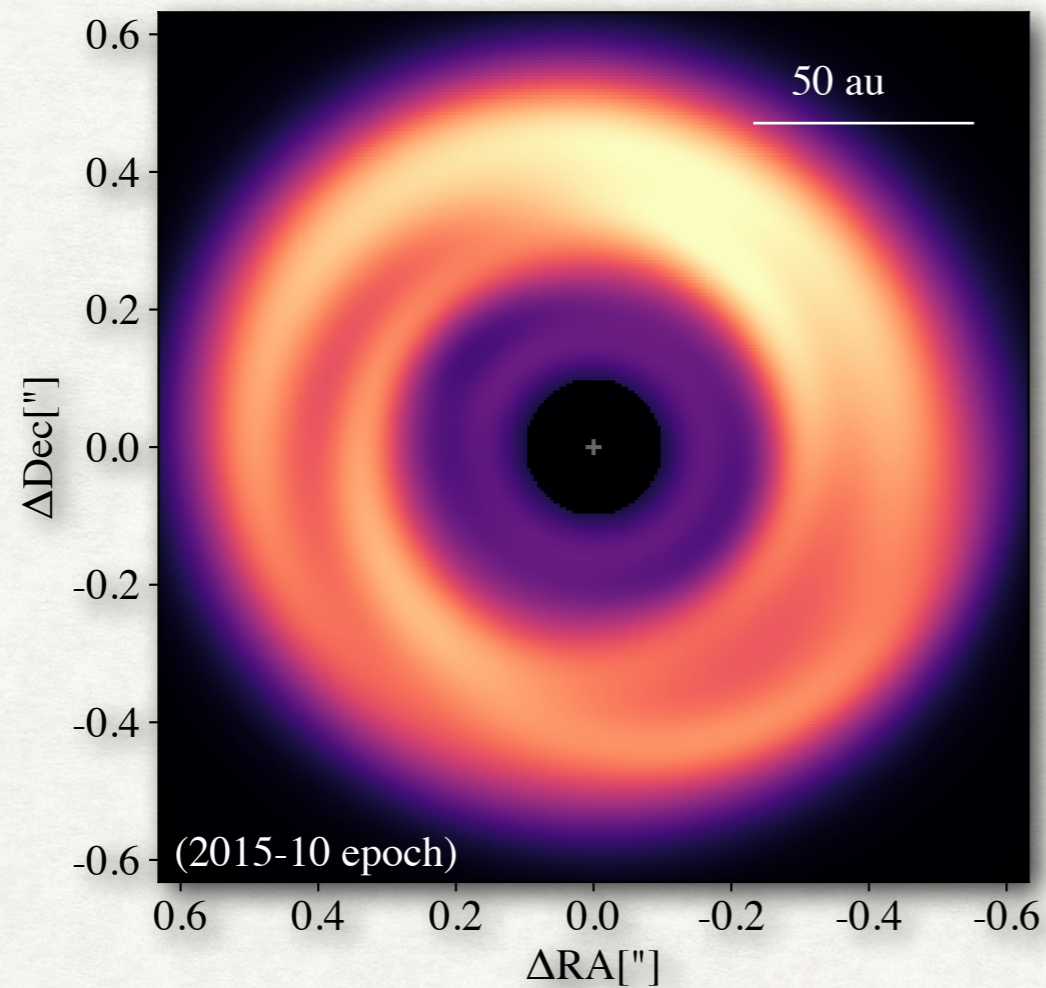


Snellen et al. 2014

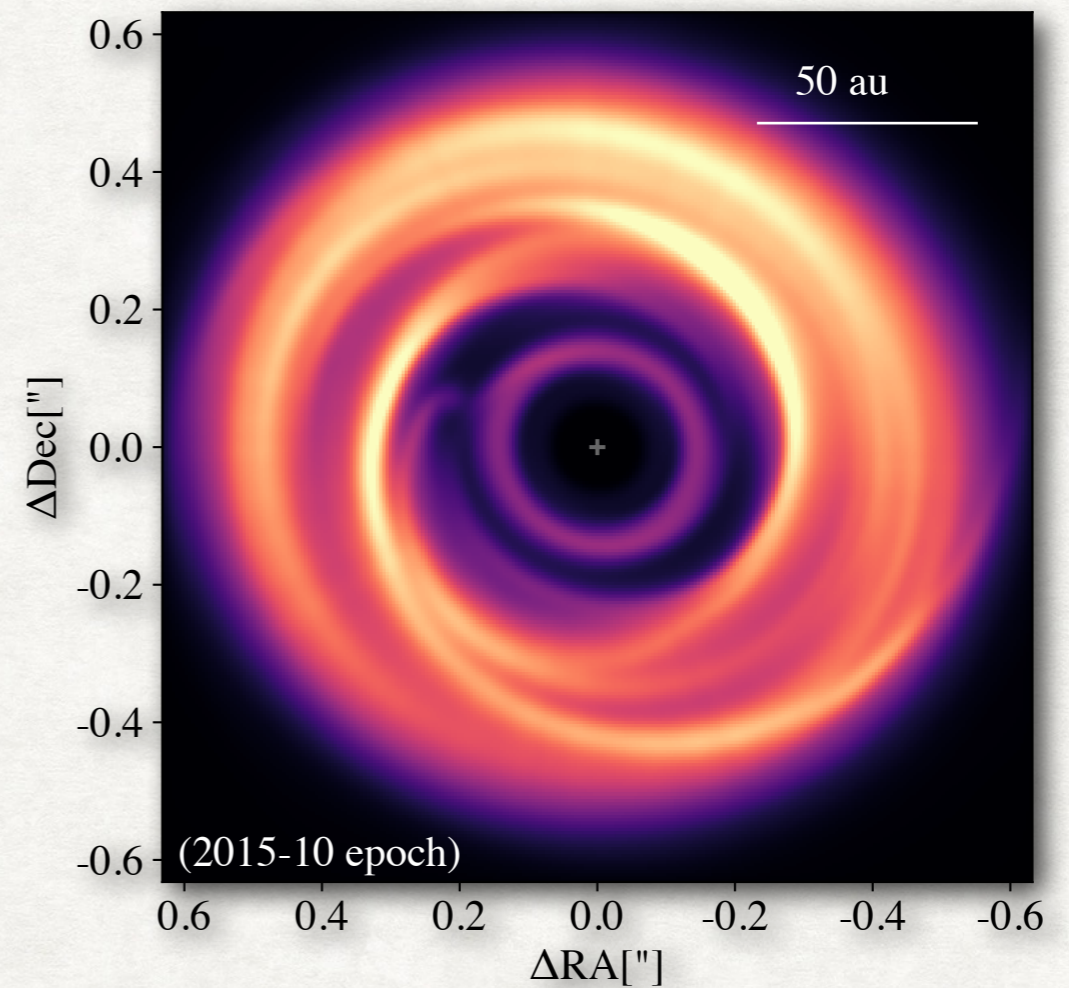
Your weather forecast for beta Pic b, starting 2029

# ALSO A DISK & PROTOPLANET MACHINE

MWC758 with NIRC2 (simulation)

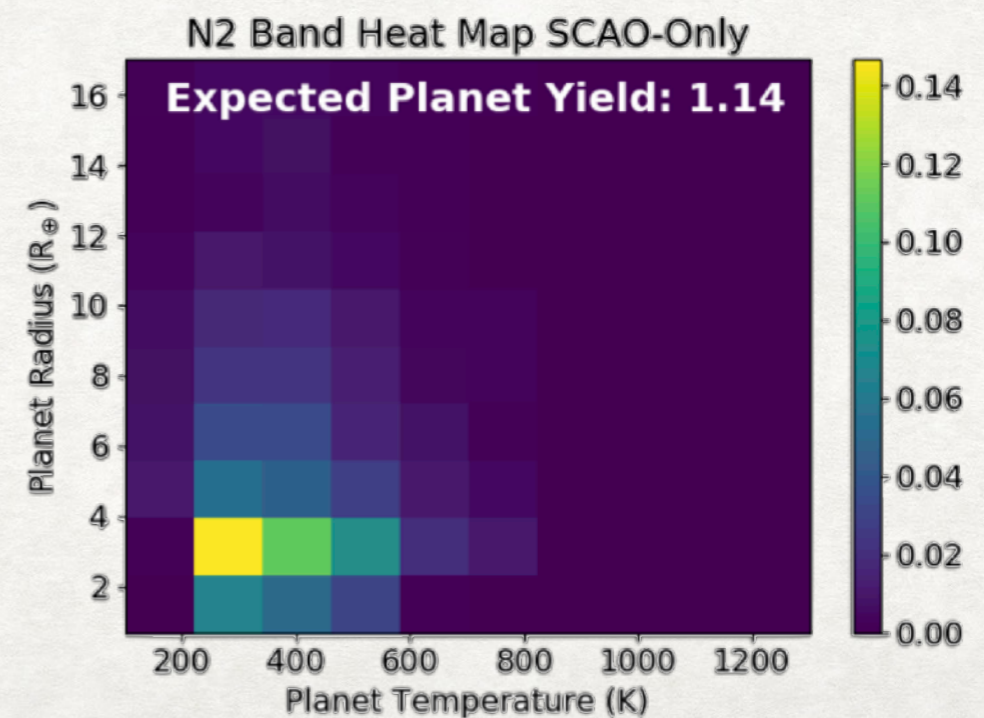
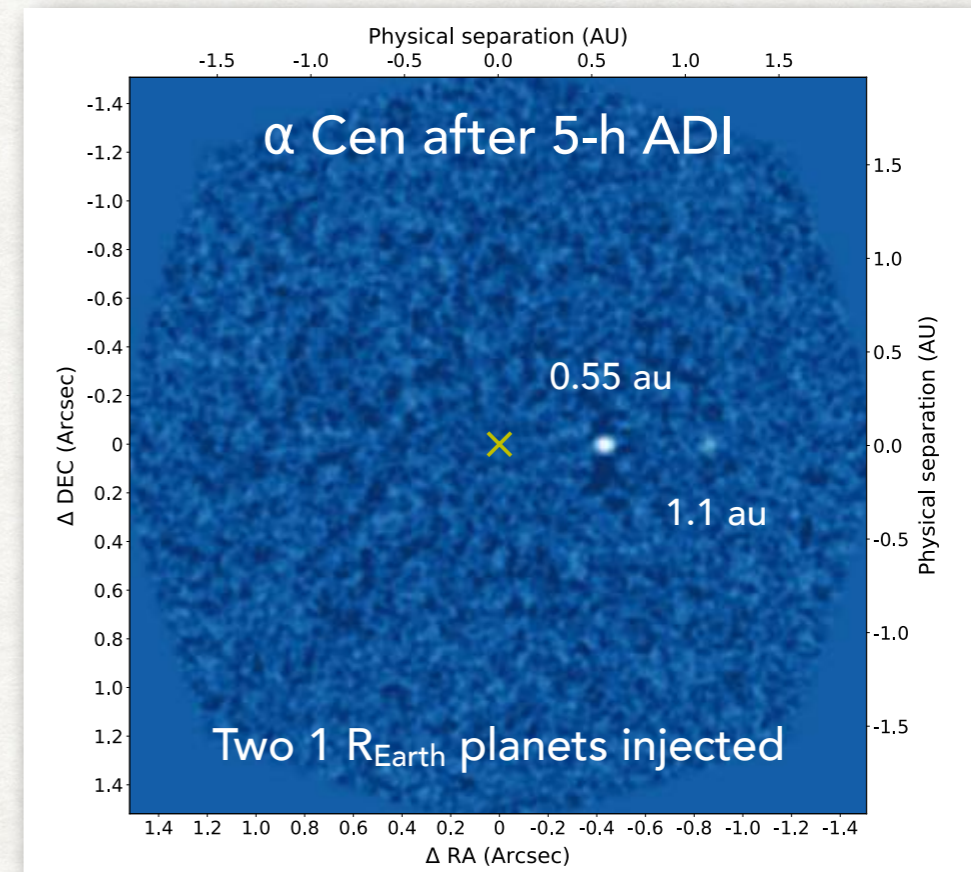


MWC758 with METIS (simulation)



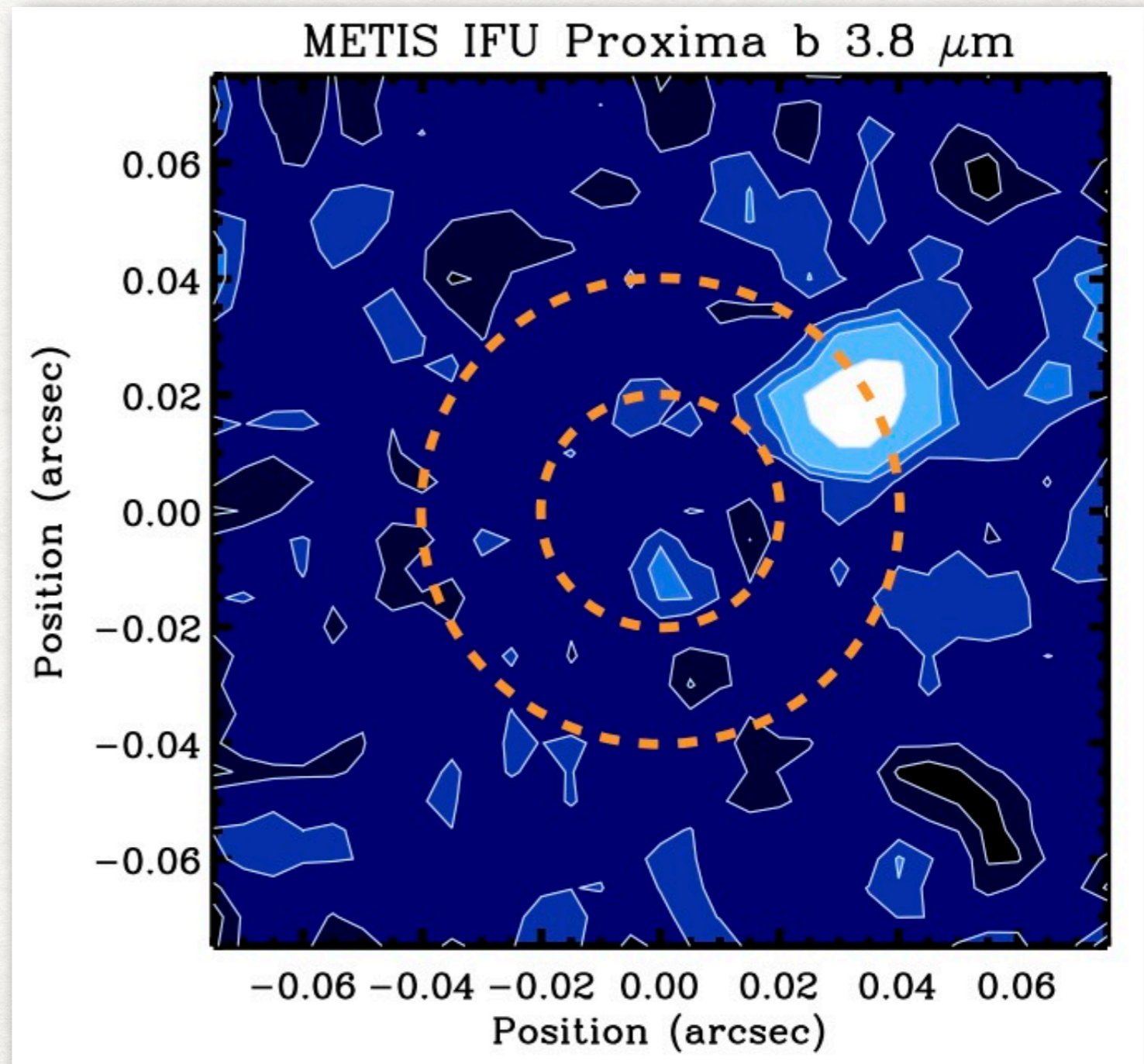
# A SHOT AT EARTH-LIKE PLANETS?

- N-band performance critical to reach temperate rocky planets
  - **control of WV seeing is key**
  - here assume SCAO-limited (still working on N-band PSI performance simulations)
  - Earth-like planet within reach around  $\alpha$  Cen in  $\sim 5$  hours
- Terrestrial regime potentially accessible around a handful of stars



# USING HCI+IFS ON PROXIMA CEN

- R = 100,000 IFS coupled with vortex and APP
- Proxima b:  $10^{-8}$  contrast at  $2 \lambda/D$ 
  - challenging, but within METIS background limit
  - gain of combining HCI+IFS not well known yet at such contrasts



# EXPECT THE UNEXPECTED!



(and let's keep our fingers crossed until then)