The METIS Laser Tomographic AO system

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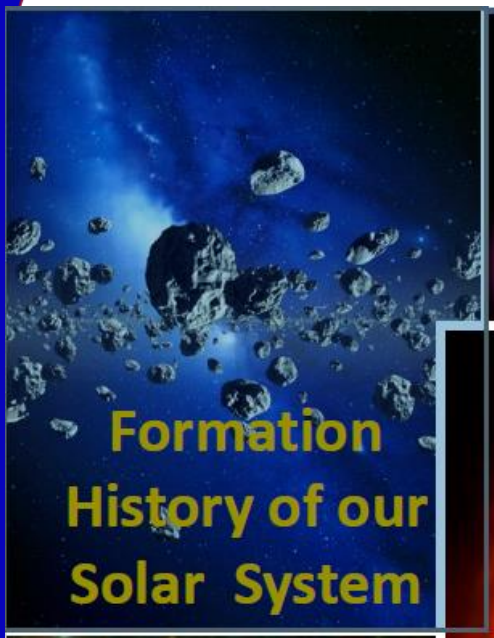
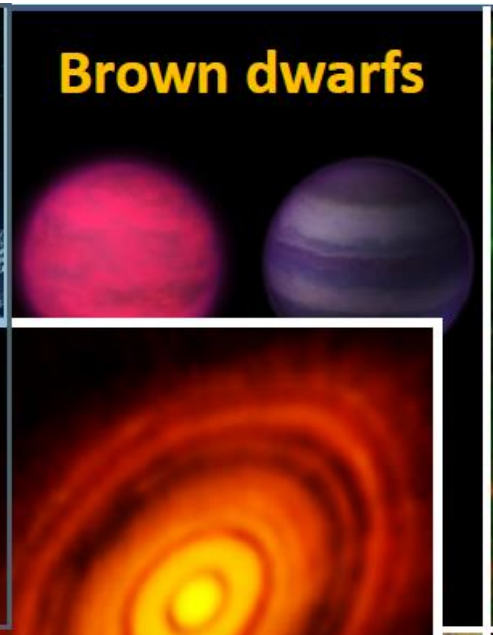
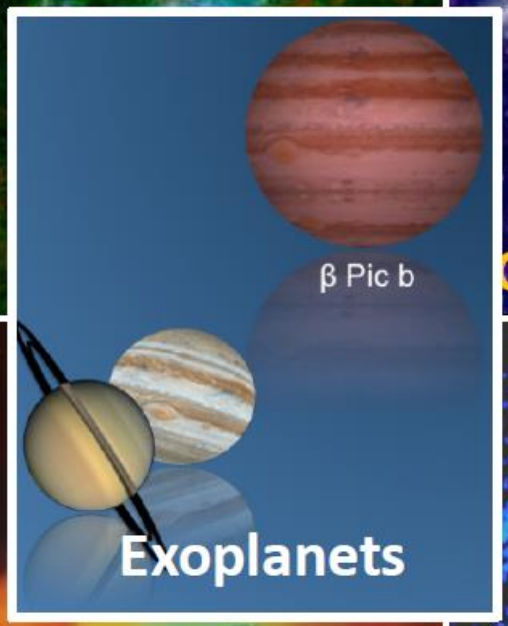

Formation
History of our
Solar System

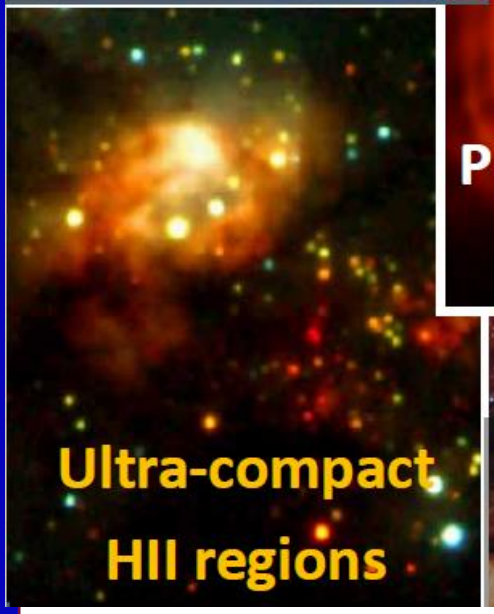

Brown dwarfs


Evolved stars


Galactic Center

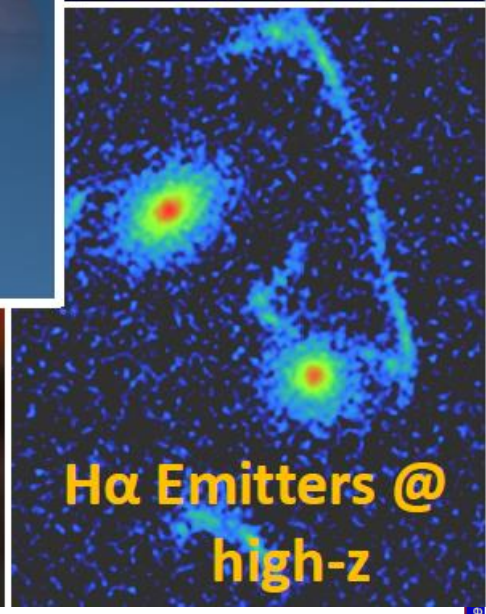

Proto-planetary
Disks


β Pic b
Exoplanets


Ultra-compact
HII regions

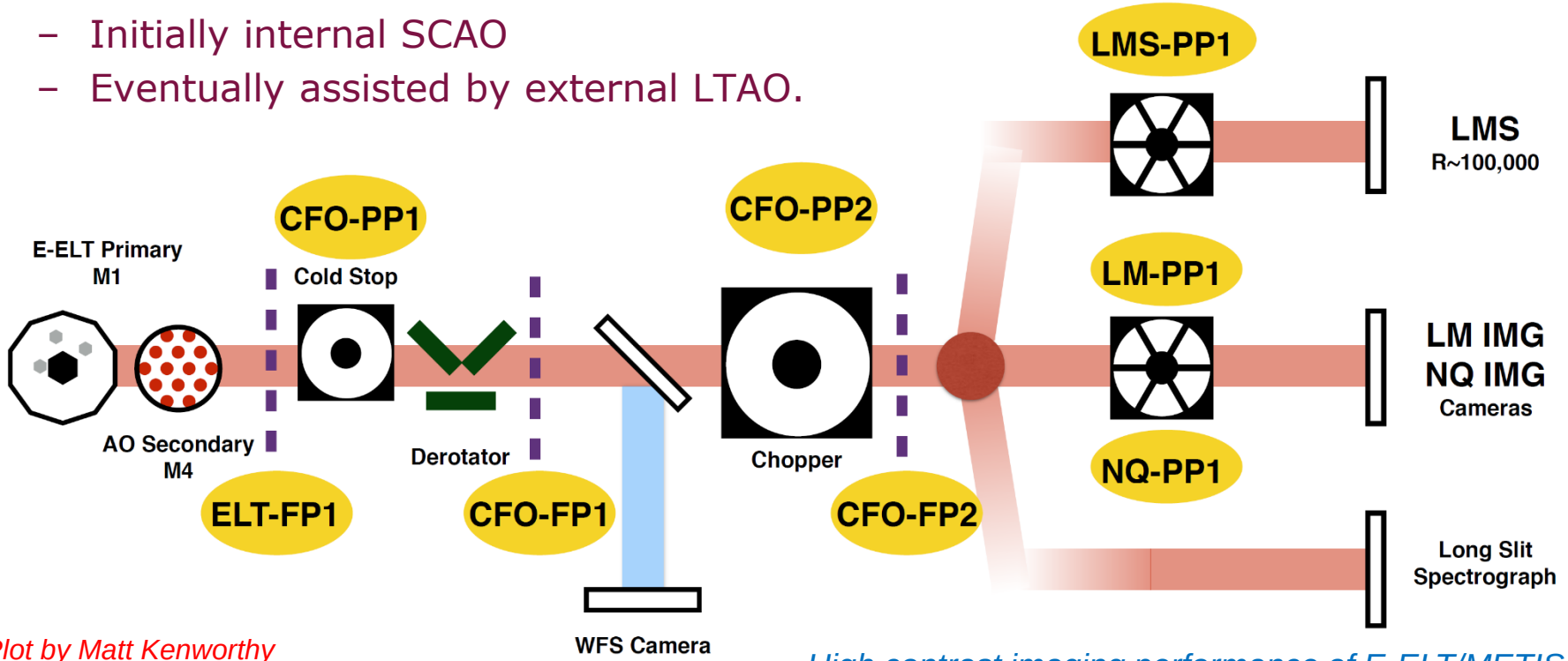

Super Star
Clusters


AGN & Seyferts


Hα Emitters @
high-z

METIS will include the following observing capabilities:

- Imaging at 3 – 19 μm
  - Includes low/medium resolution slit spectroscopy
  - Includes coronagraphy for high contrast imaging.
- High resolution (R ~100,000) IFU spectroscopy at 3 – 5 μm
  - Includes extended simultaneous wavelength coverage mode
  - Combined with coronagraphy
- All at diffraction limit
  - Initially internal SCAO
  - Eventually assisted by external LTAO.



Plot by Matt Kenworthy

High contrast imaging performance of E-ELT/METIS - Brunella Carlomagno [Yesterday, P1003]

SCAO

- Excellent on-axis
- Integrated in METIS: Minimal residual jitter/NCPA
- No-frills first light AO

BUT:

- Requires bright GS: Low sky coverage

- SR@3.7μm (L) > 60% (goal: >80%) [m_K=10,median]
- SR@10μm (N) > 93% (goal: > 95%) [m_K=10,median]
- Contrast >3x10^{-5}(goal 10^{-6}) @5λ/D (goal 2λ/D) [m_L<6]

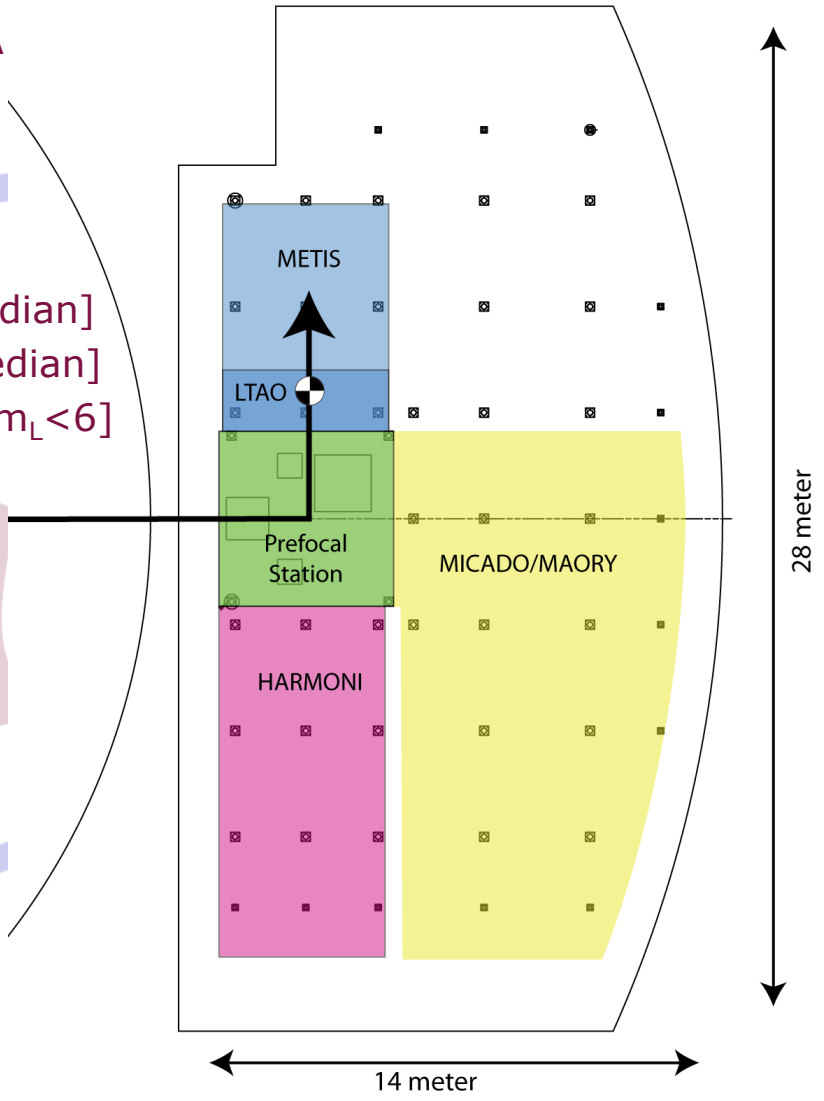
LTAO

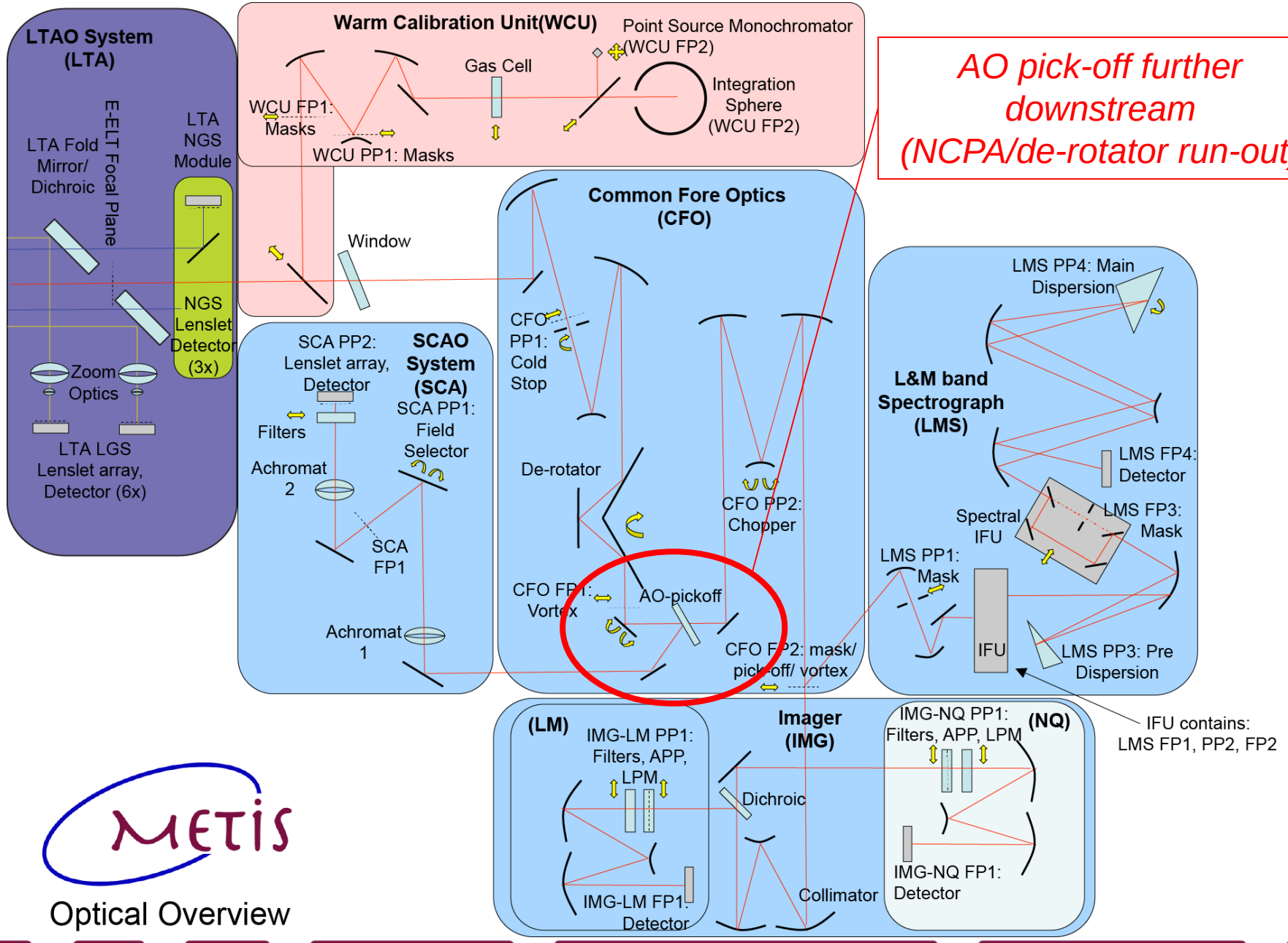
- Accepts fainter NGS(s): Increased sky coverage
- In METIS baseline

BUT:

- Separate system: System-to-system jitter
- Increased complexity

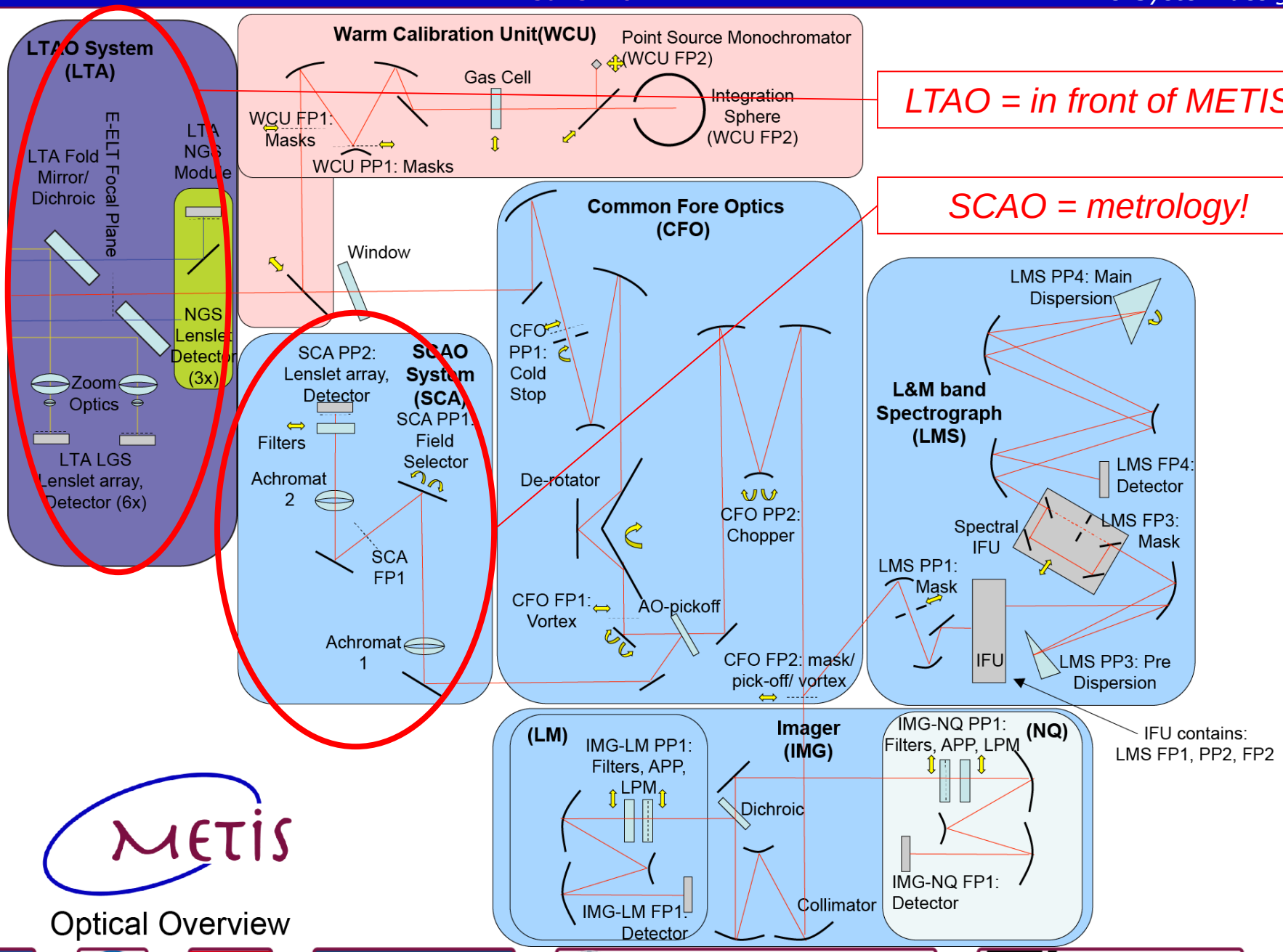
- SR@3.7μm (L) > **30%** (goal: >**50%**) [m_K@ 80% SC, median, >**45° Zenith Angle**]
- SR@10μm (N) > 85% (goal: > 90%) [m_K@ 80% SC, median, **>45° Zenith Angle**]
- Residual jitter < **10 mas** (goal: < 3 mas)
- Sky coverage >80% (goal: 100%)





METIS

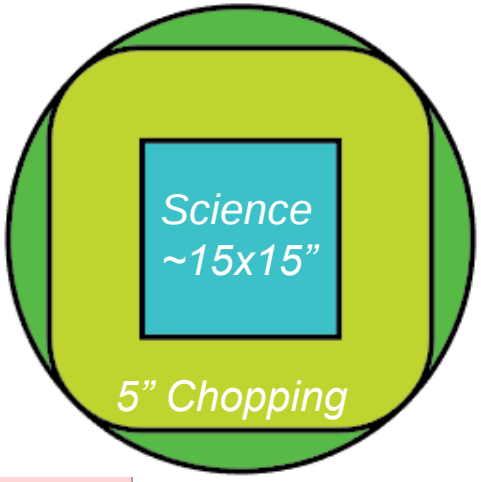
Optical Overview

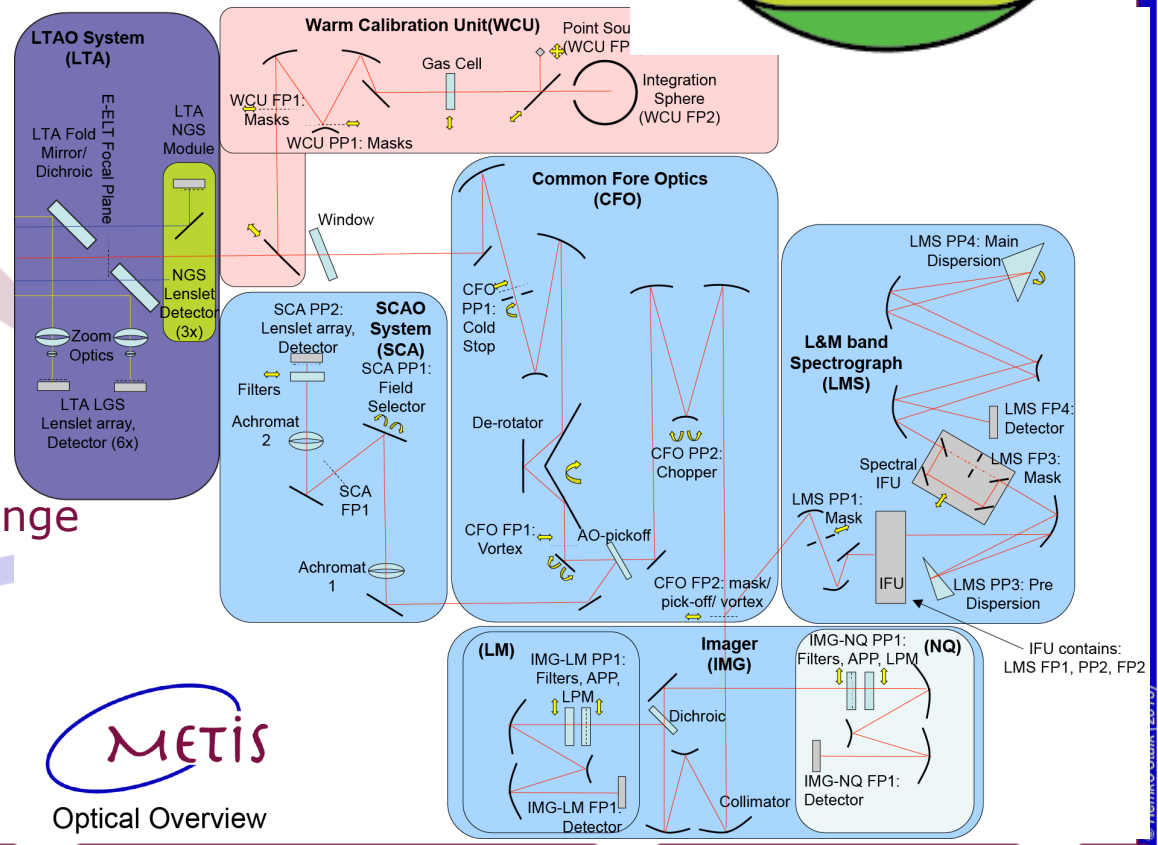


METIS

Optical Overview

- SCAO internal to METIS
  - Cold, low IR background
  - *Before* internal chopper
- AO Dichroic after de-rotator
  - Splits at ~2.9 micron
  - Full METIS field (15x15" + chopping = 33")
  - Allows for correction of de-rotator errors
  - Field tracking easier
- IR WFS
  - Embedded sources
  - Selex SAPHIRA
    - (VLT Gravity)
- Pyramid WFS vs SH
  - Extended sources
  - Impact of spiders
  - Cold modulator still challenge
  - SH as fallback (?)
- Pupil Stabilizer
  - Actuator vs sub-aperture
- Software de-rotation





METIS
Optical Overview

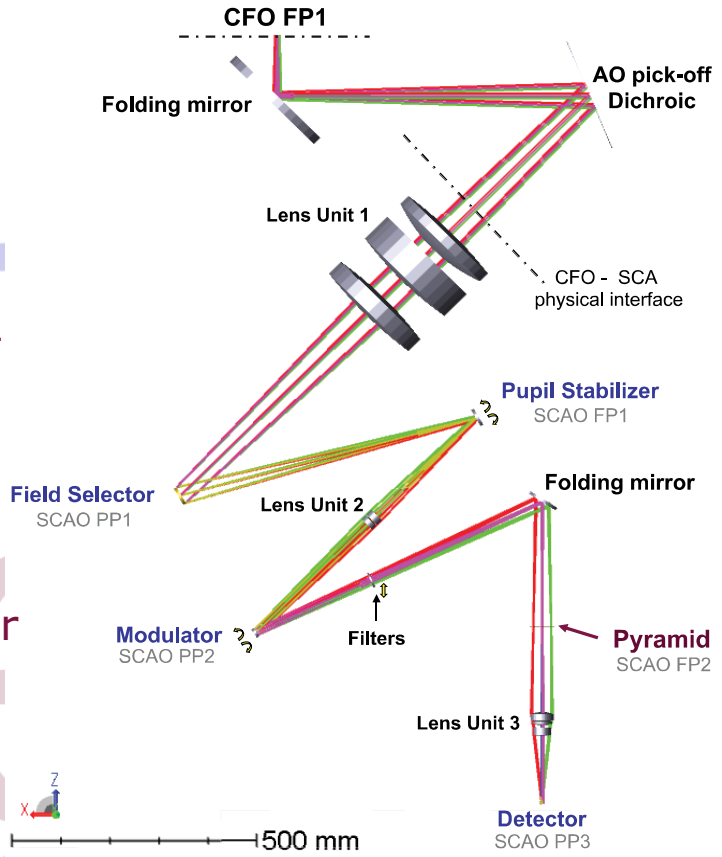
Status of the SCAO design of METIS and end-to-end simulation performances – Faustine Cantalloube [Yesterday, P1004],

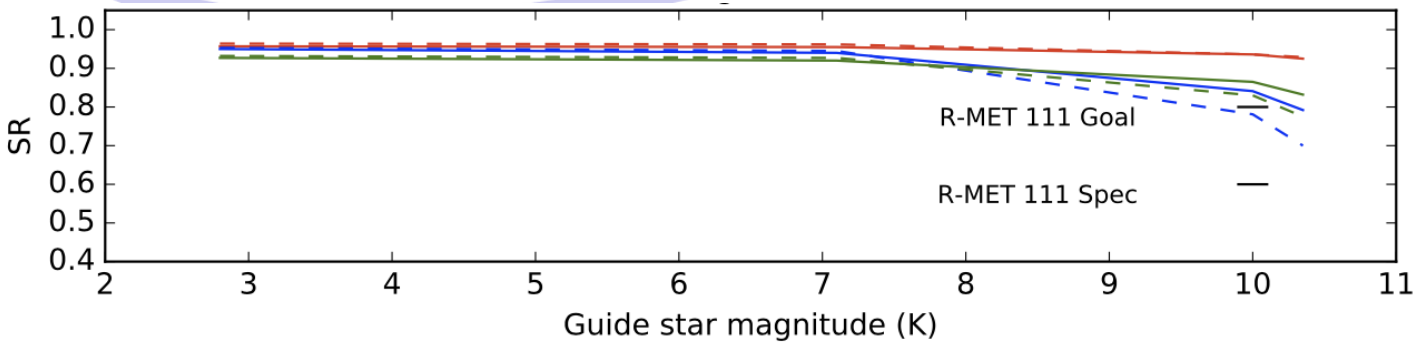
Drawback of Pyramid WFS:

- Requires modulator inside cryostat
- Limited linearity range, to work away from zero-WFE (NCPA)

Advantages of Pyramid WFS:

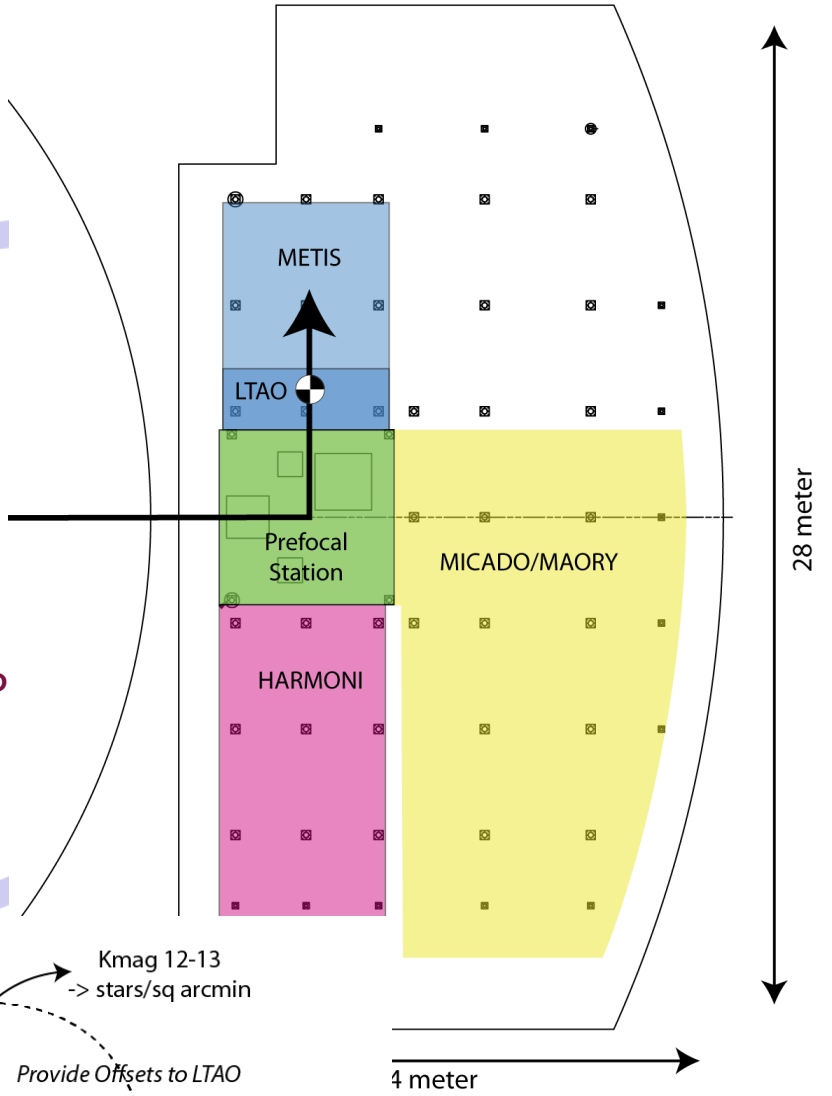
- Better performance (Strehl Ratio, SR) under all circumstances (with respect to SH-WFS)
- Lower residual tip-tilt (TT) motion as required for High Contrast Imaging (HCI)
- Differential piston is better controlled
  - *On the performance of reconstruction methods in the presence of spiders – Andreas Obereder [Talk Fri 15:10]*
- Use existing SAPHIRA detector (as used in CIAO)
- ***Easier re-use for metrology LTAO***

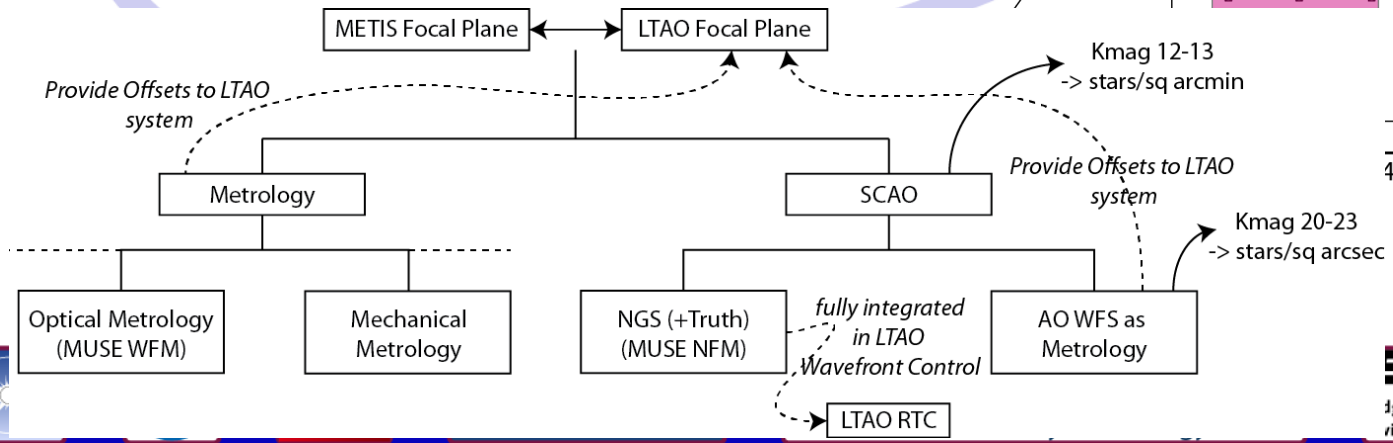


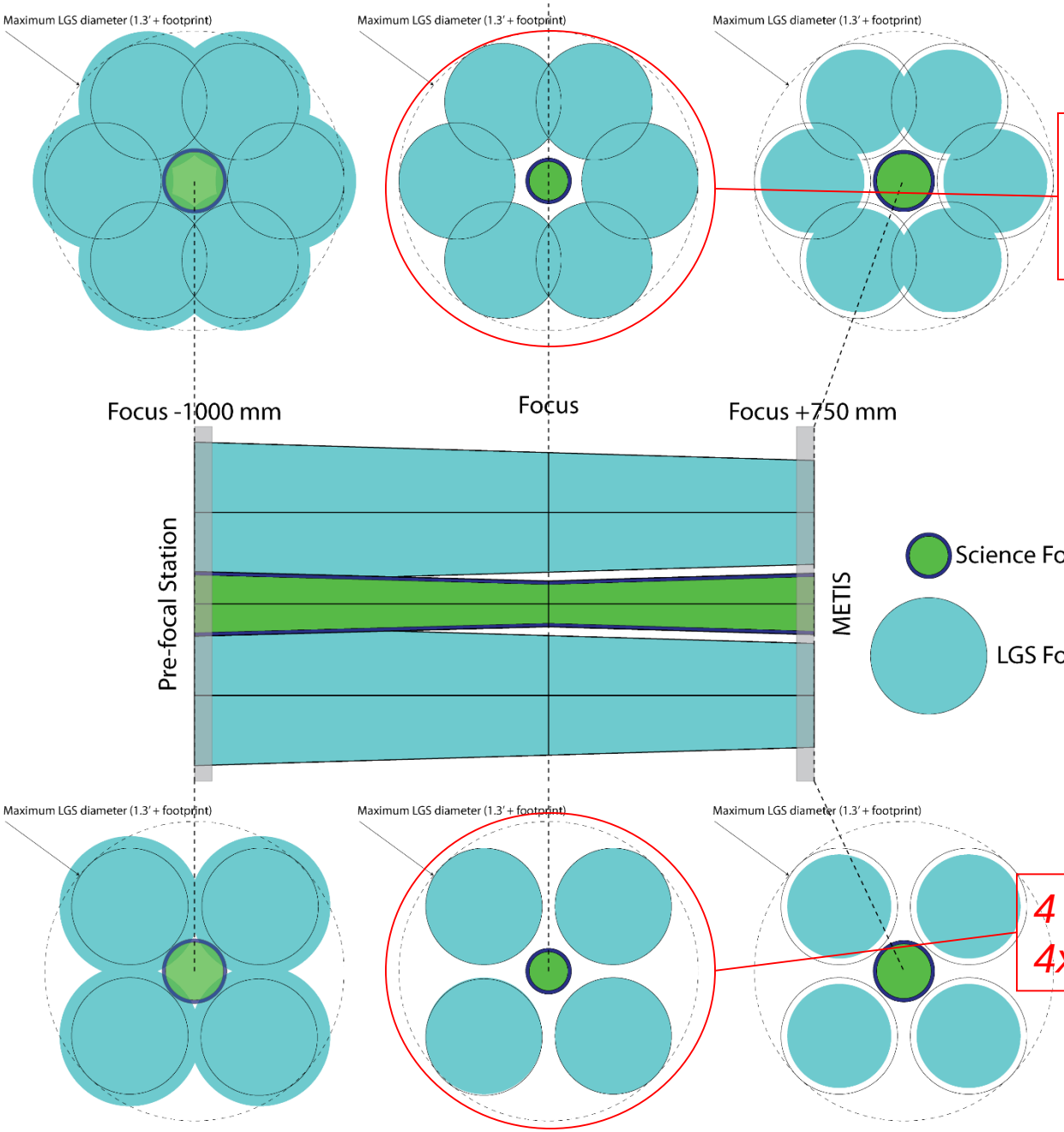


Constraints on LTAO

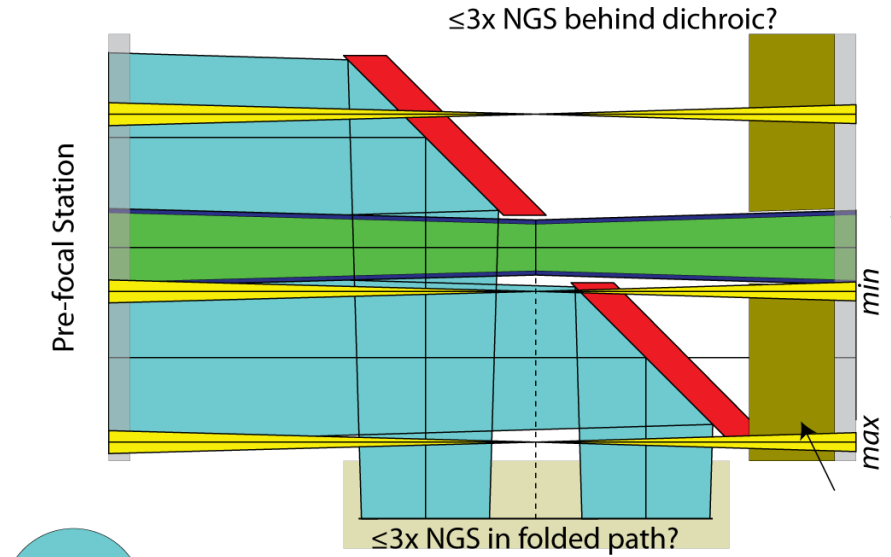
- Available space envelope
  - ~focus -1,+0.6 meter, 4.5 meter diameter
- Clear Science field
  - ~16.5" radius, including chopping
- Maximum LGS field 1.3' (Pre-focal station)
- Minimize LGS separation
  - Strong drop-off for larger asterism
- Maximize sky coverage
  - >80% (Goal: 100%)
- Minimize complexity
  - System stability & NGS configurations
- Stabilization between LTAO FP and science FP (dynamic NCPA)
  - Correction using internal SCAO WFS
  - Simplified significantly by Pyramid SCAO!

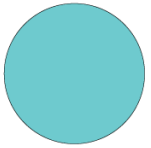


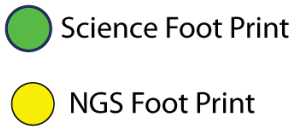


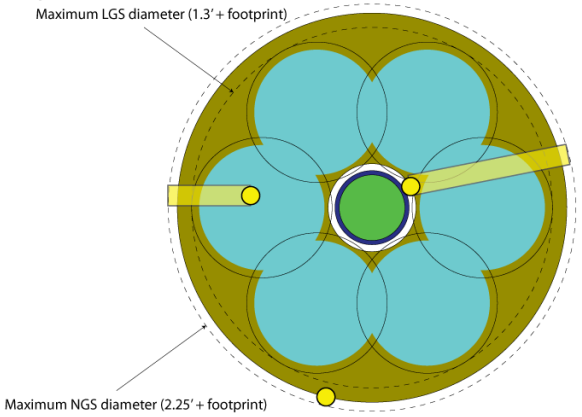


4-6x LGS

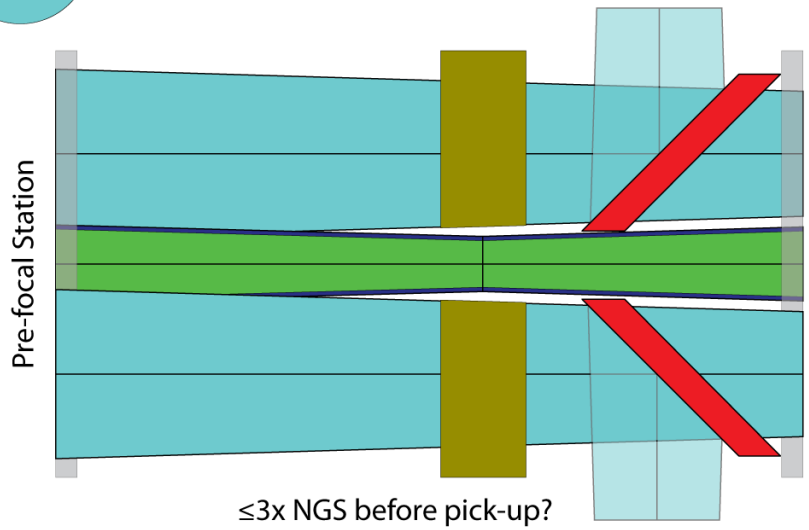




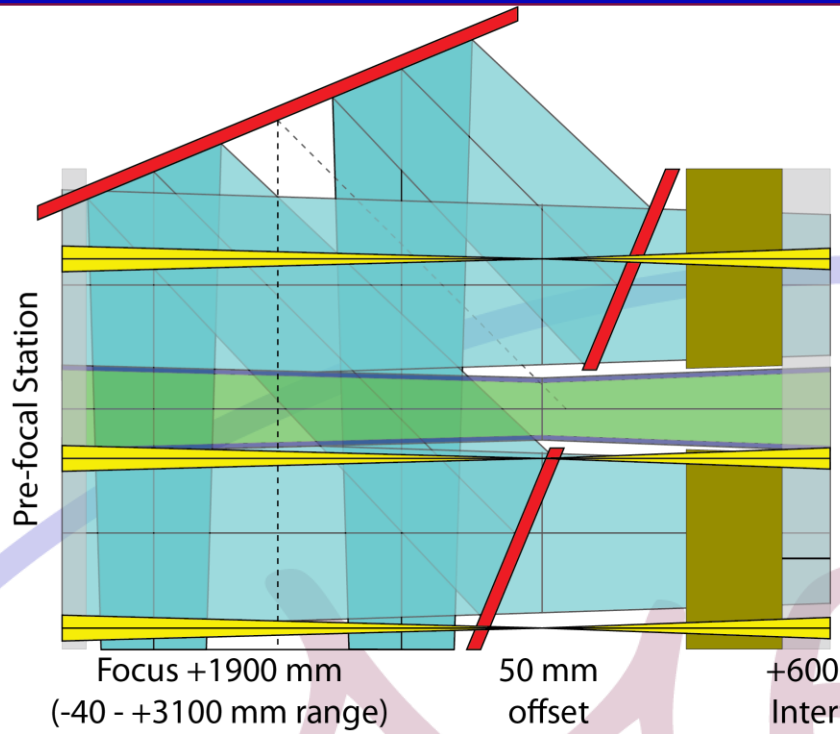


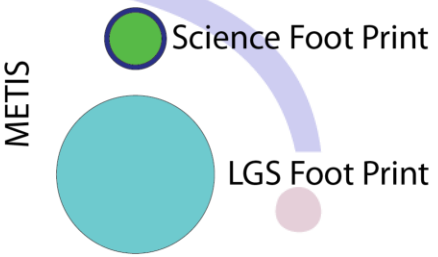


4x LGS



Double Fold





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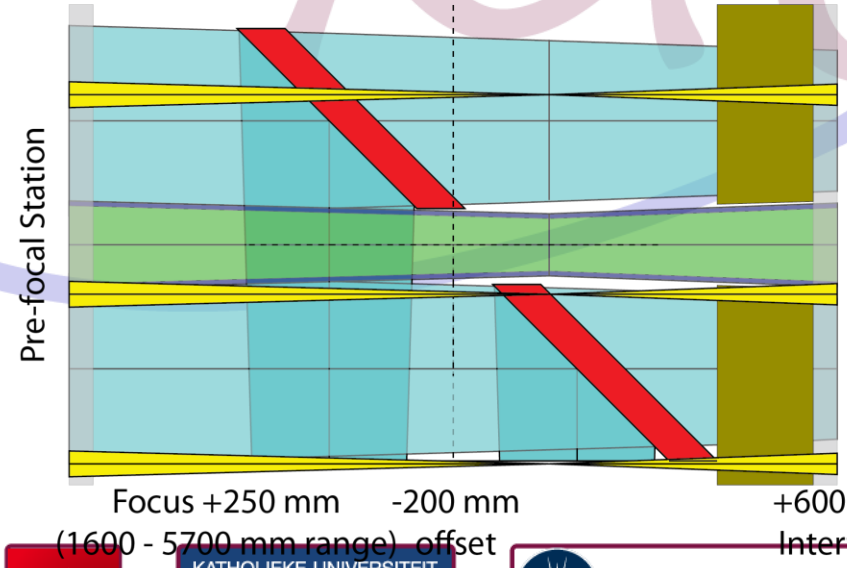
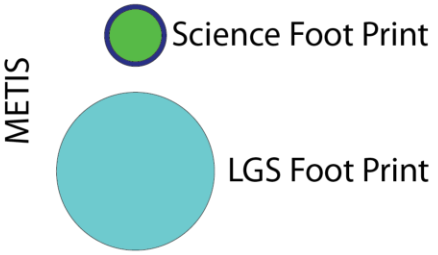
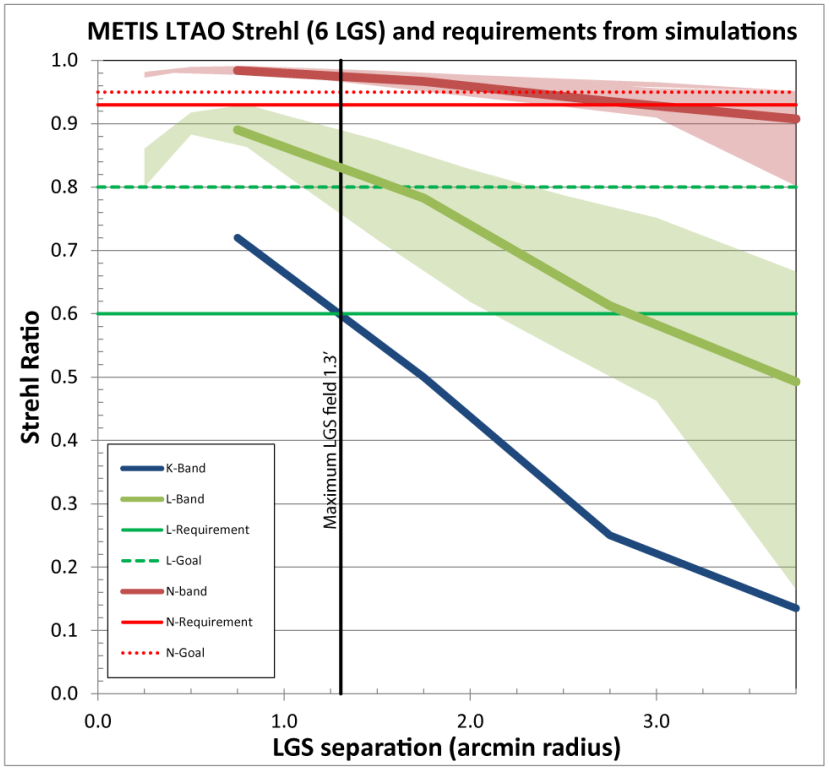
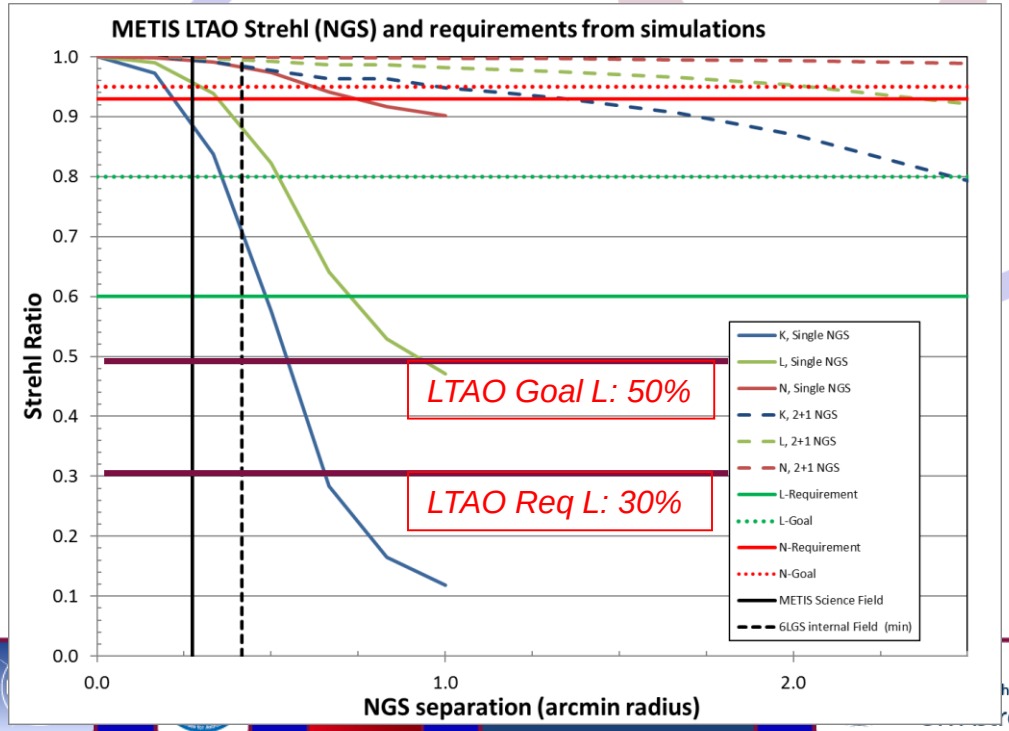




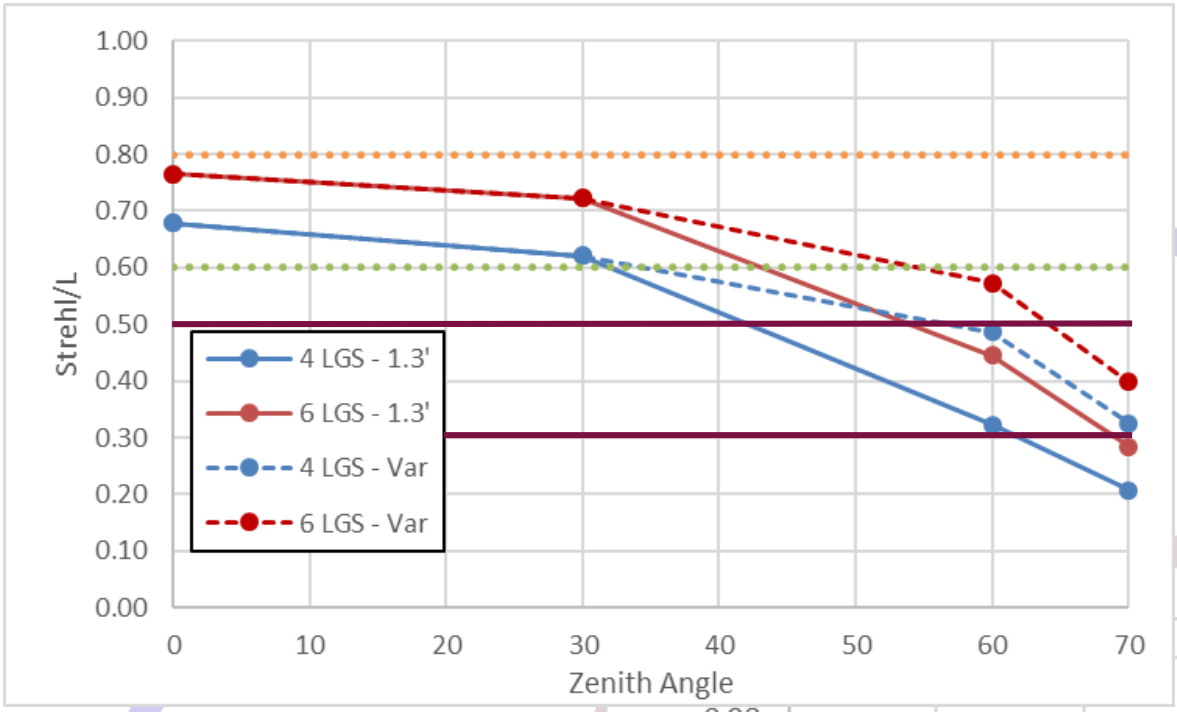
- LGS: Strong dependence on LGS asterism size
  - But strongly constrained by boundary conditions to 1.3’ radius
- NGS: Strong drop Single NGS
  - Ideally using SCAO WFS
    → impact on sky coverage
  - Large pick-up with Multi-NGS
    → System complexity





30 deg zenith
Median seeing
Bright LGS
Bright NGS

Miska Le Louarn
Daniela Saxenhuber

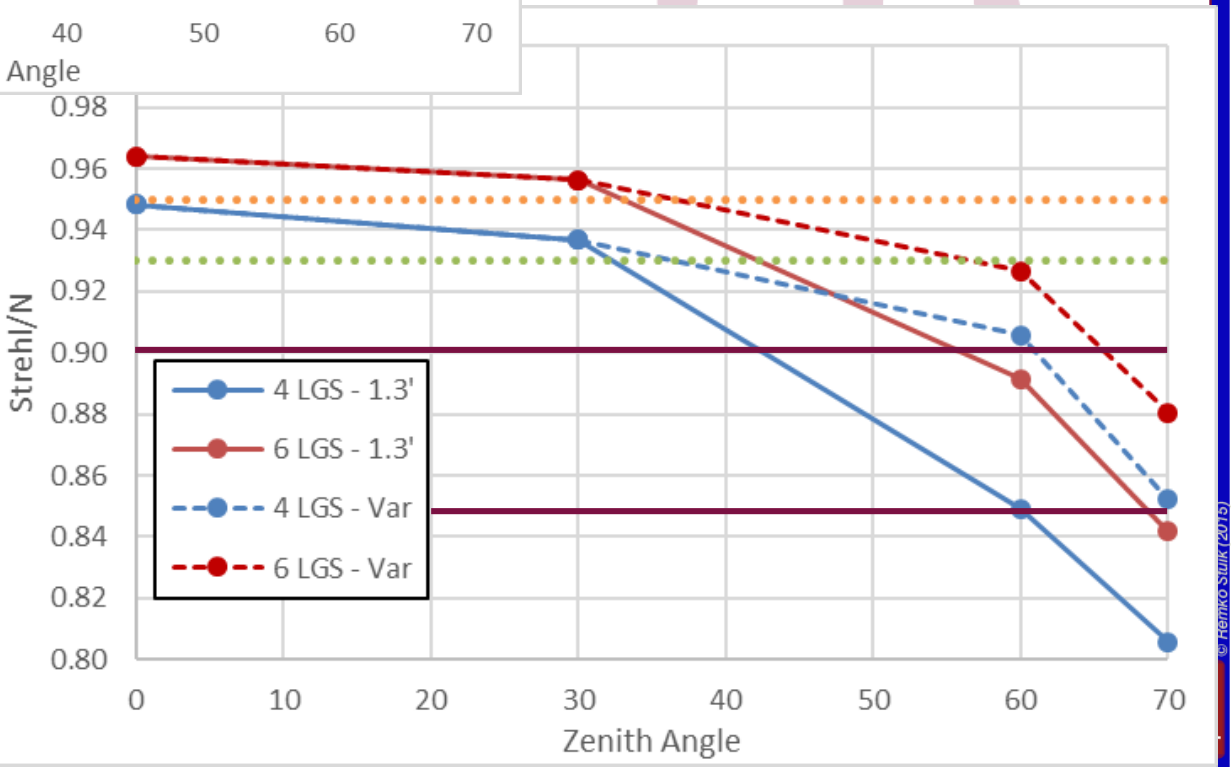


SCAO Goal:80%

SCAO Req: 60%

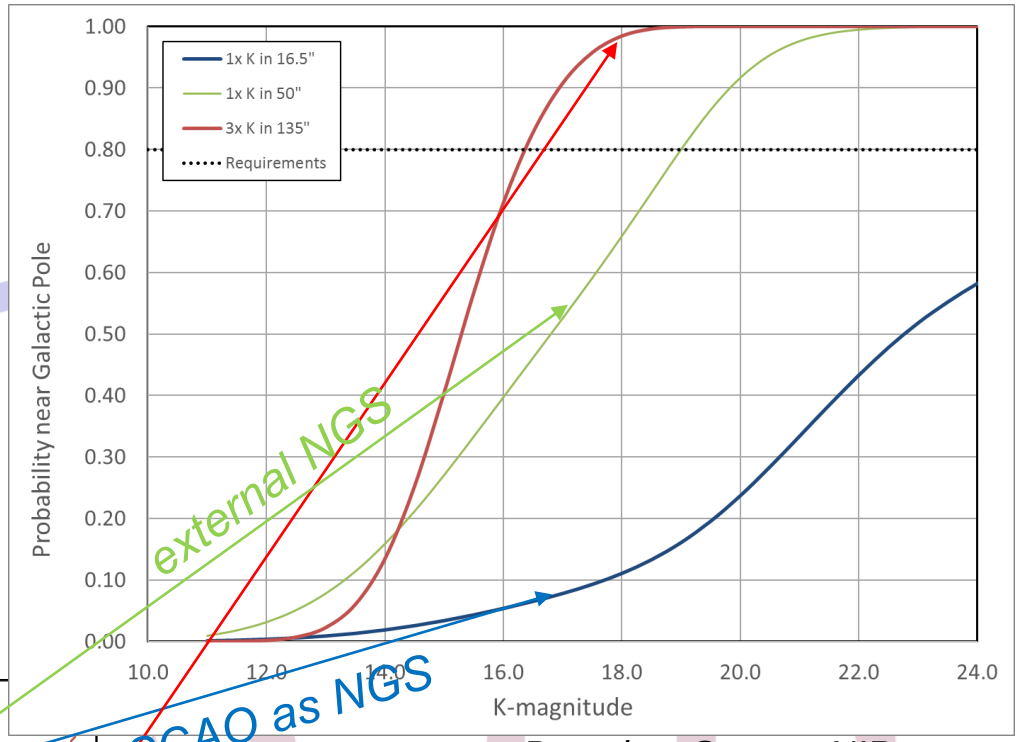
LTAO Goal: 50%

LTAO Req: 30%

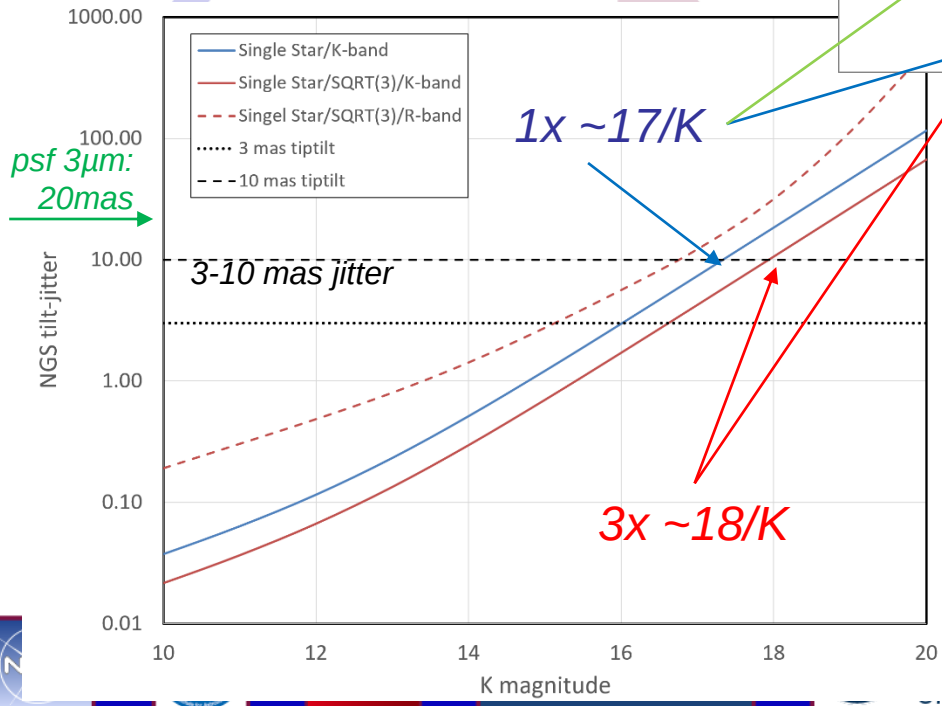


3 LTAO - NGS Configurations:

- ***1x NGS in science field***
  → Insufficient coverage, but science target!
- ***1x NGS in science field***
  → Nearly sufficient, 'easy' implementation.
- ***3x NGS in full field***
  → Meets requirements, but much more complex



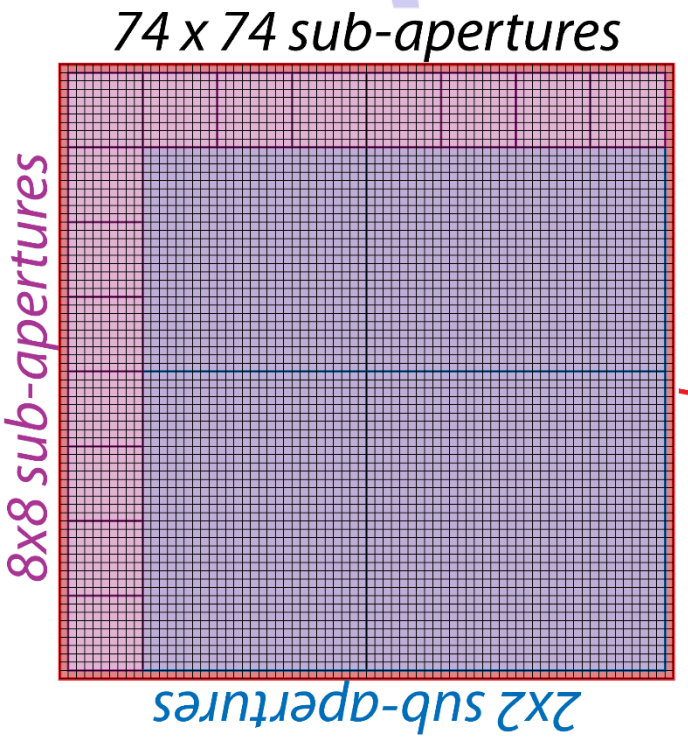
Based on Spagna NIR counts & USNO-B R-band counts

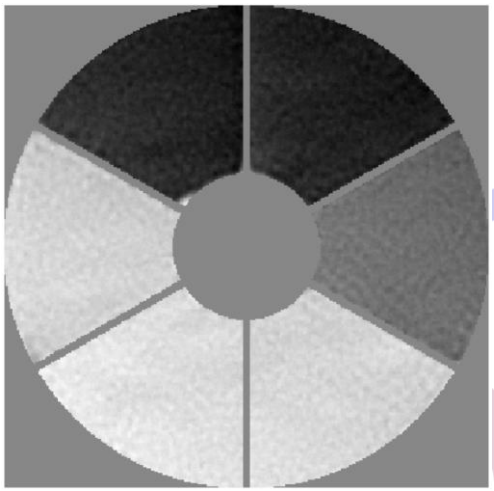


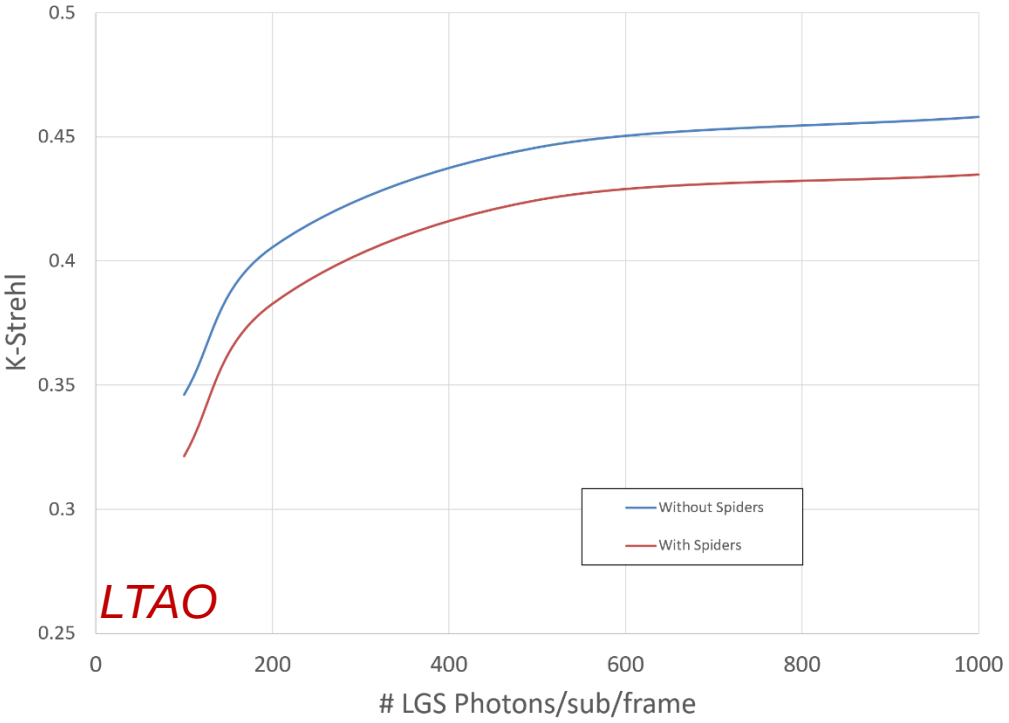
K-band sensing – limited by sky background

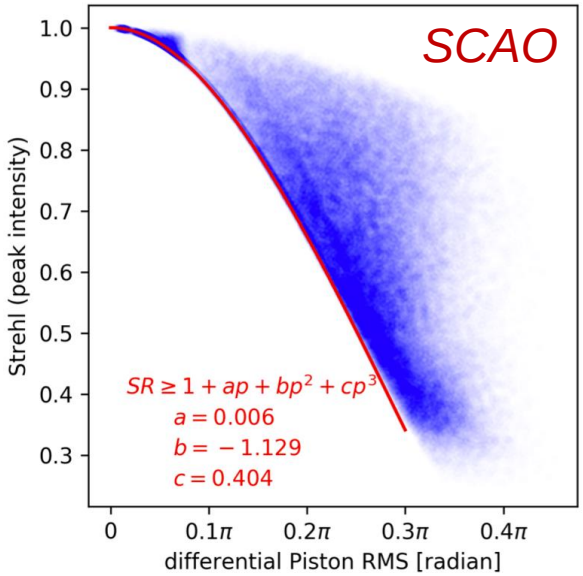
Re-using the SCAO WFS

- Low order WFS
  - Tip tilt → 1x1 WFS
    - Laser propagation (~Hz)
    - Vibrations (500 Hz)
    - Differential motion METIS ←→ LTAO (< ~Hz)
  - Focus → 2x2 WFS
    - Sodium Layer height (~Hz)
    - Differential motion METIS ←→ LTAO (< ~Hz)
  - High performance/low sky coverage!
- Metrology sensor
  - Tip tilt → 1x1 WFS
    - Laser propagation (~Hz)
    - Differential motion METIS ←→ LTAO (< ~Hz)
  - Focus → 2x2 WFS
    - Sodium Layer height (~Hz)
    - Differential motion METIS ←→ LTAO (< ~Hz)
- Truth Sensor → 8x8 WFS
  - ~0.1 Hz verification of LGS reconstructions
- Now with Pyramid WFS!
  - Binning pixels (no noise gain!) or binning slopes
    - Although interesting aliasing 74x → 8x
  - Full resolution of E-ELT









- LTAO with/without spiders
- Low flux case
- 6 LGS
- 1.3 arcmin asterism
- 1 center TTS, 10000 ph.
- 500 Hz

LTAO on ELTs with Spiders – Stefan Raffetseder [Thursday, P3056]

Summary

- METIS is the mid-IR instrument for the E-ELT
- METIS 2/3rd into its Preliminary Design Phase
  - PDR Expected May 2018
- METIS requires an AO system to meet its science requirements
  - Requires both SCAO and (eventually) LTAO
- SCAO system internal to METIS
  - Cold WFS pickup to minimize thermal background
  - Minimize NCPA and residual motions
  - Aiming for >60%@3.7 μm, >93%@10 μm
  - No-frills Pyramid SCAO system (but does not mean a simple task!)
- Delayed development of an external LTAO system
  - METIS Phase-B (2015-2018) – mainly definition of interfaces
  - Internal SCAO WFS for Metrology and truth sensing
  - External NGS for low-order sensing, probably 1 is enough
  - Constellation 6 LGS, shrinking with elevation