

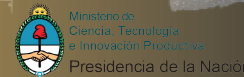


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GNAO - an MCAO system for the Gemini North telescope

Gaetano Sivo, Julia Scharwächter, GNAO team, GNAO science
team, Gemini AOWG



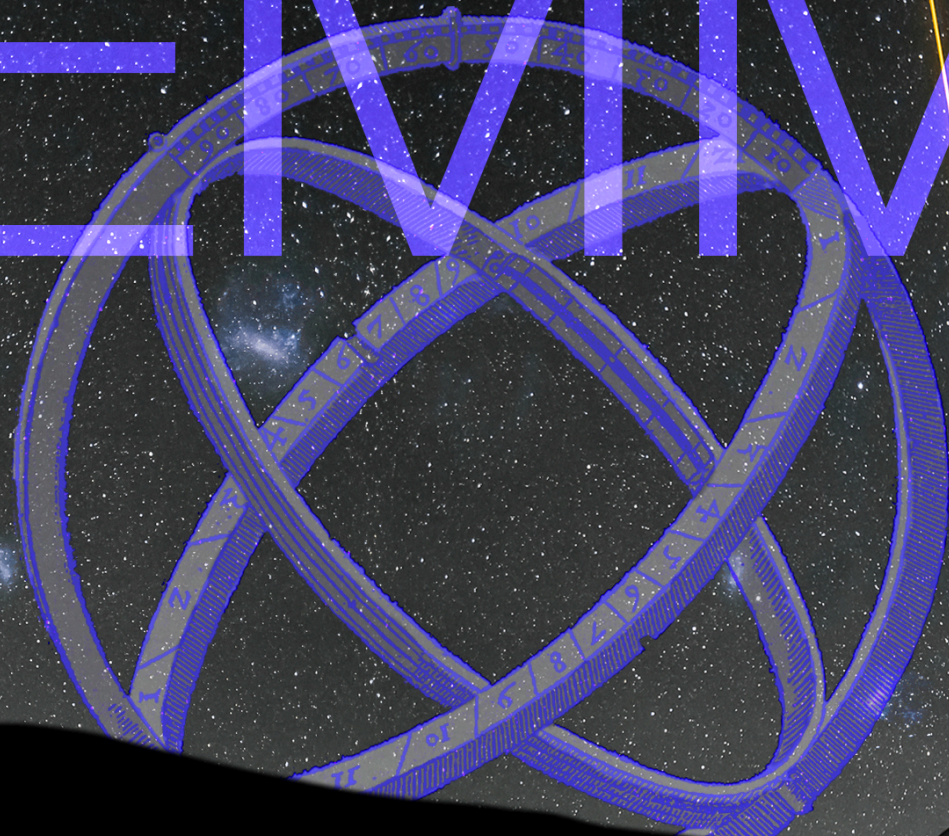


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GEMMA Program



GEMMA



Gemini in the Era of Multi-Messenger Astronomy





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GEMMA Program



Adaptive Optics



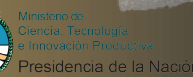
Time Domain



Outreach

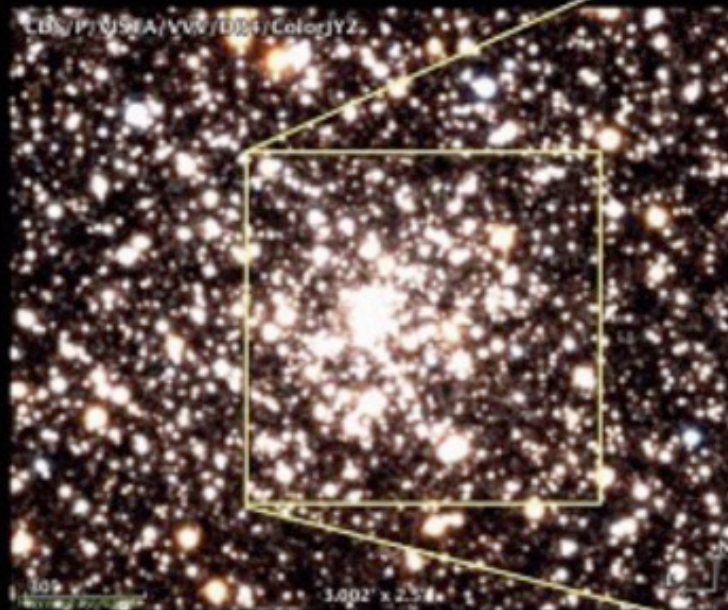
More info about general GEMMA

<https://www.gemini.edu/gemma/index.html>

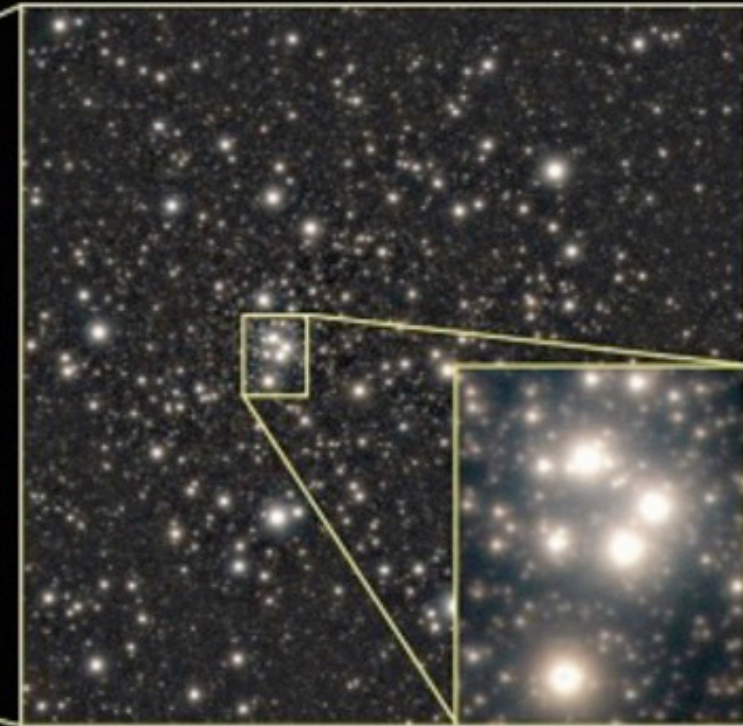


What is GeMS ?

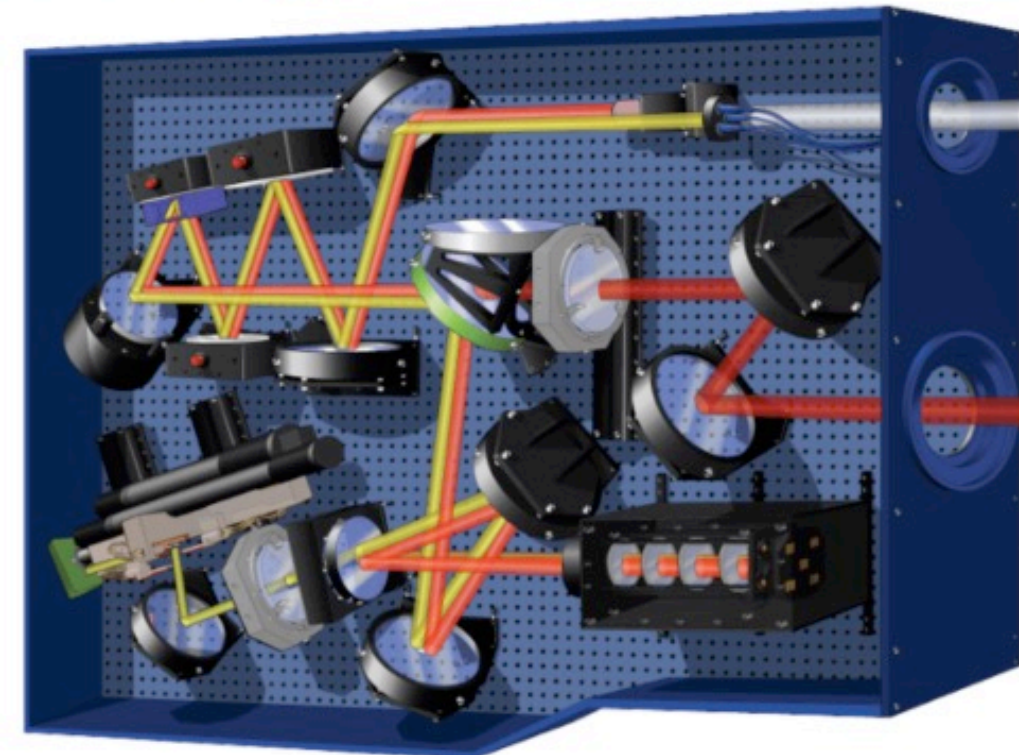
HP 1 - A Fossil Relic in the Galactic Bulge



VVV - VISTA (4m)
FWHM-0.8", $K_{\text{lim}} \sim 17$



GSAOI+GeMS - Gemini-South (8m)
FWHM-0.1", $K_{\text{lim}} \sim 20$



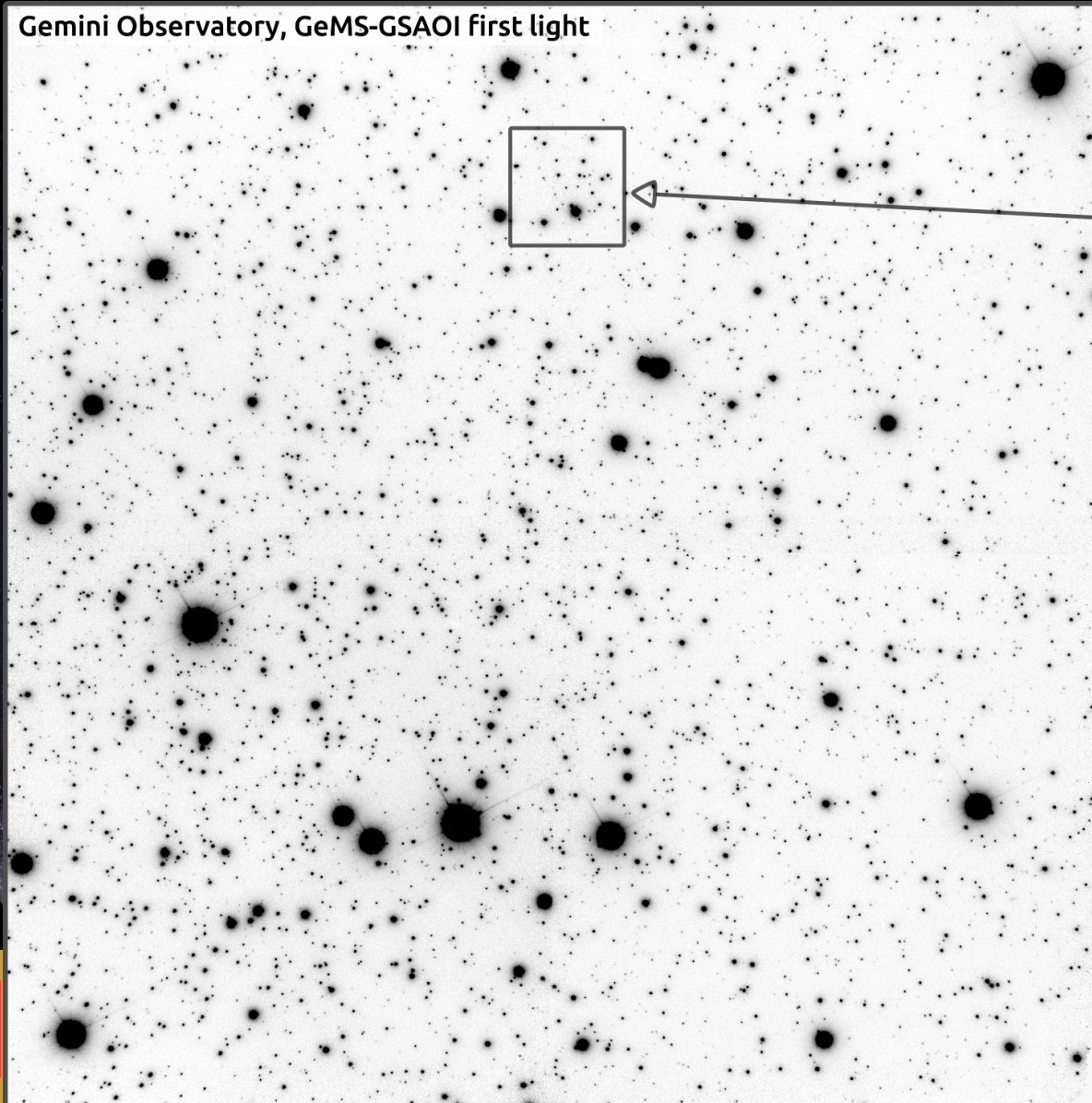


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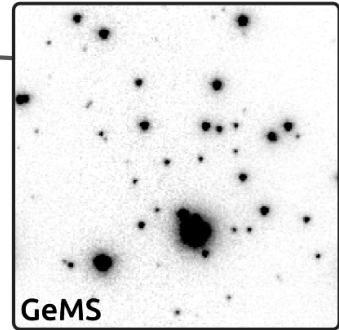
Why MCAO



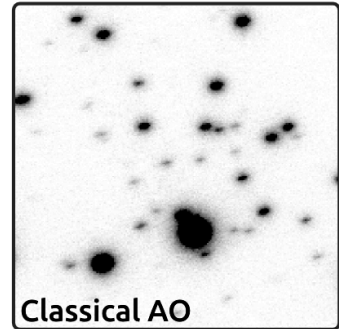
Gemini Observatory, GeMS-GSAOI first light



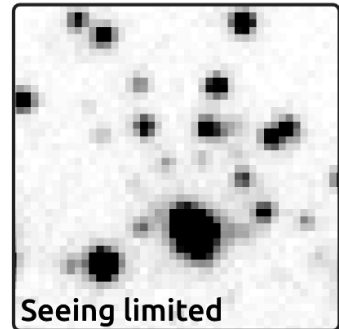
NGC288, H band
13mn exposure
Field of View 87"x87"
FWHM = 0.080"
FWHM rms = 0.002"



GeMS



Classical AO



Seeing limited

Rigaut et al., MNRAS 2014



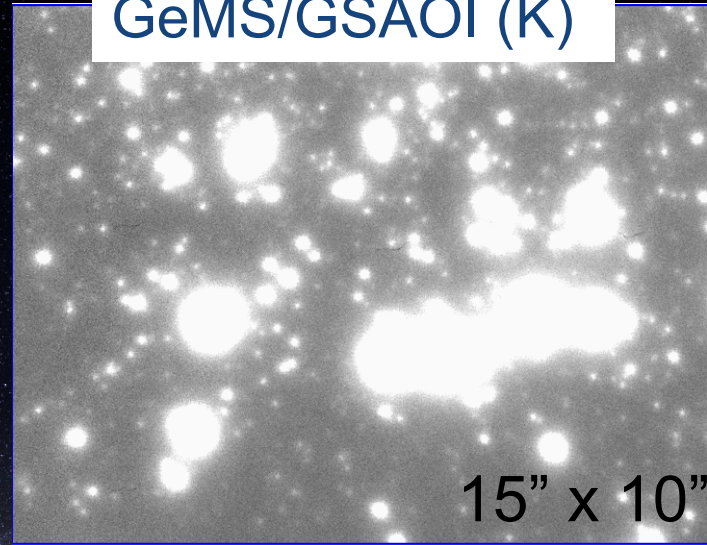
Why GNAO



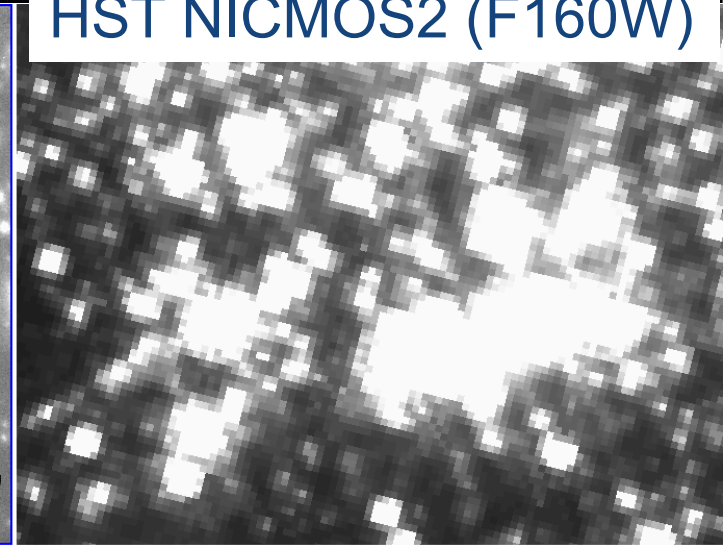
- Current Gemini-N single-conjugate AO (SCAO) system ALTAIR is aging
- SCAO limited to narrow field-of-view with AO-degradation off-axis
- Many science cases depend on wide-field AO compensation (e.g. photometry in crowded fields, accurate astrometry)

[Lawrence, Andersen et al., in prep.]

GeMS/GSAOI (K)



HST NICMOS2 (F160W)



Example:
Embedded massive star clusters:

R136 in 30 Doradus



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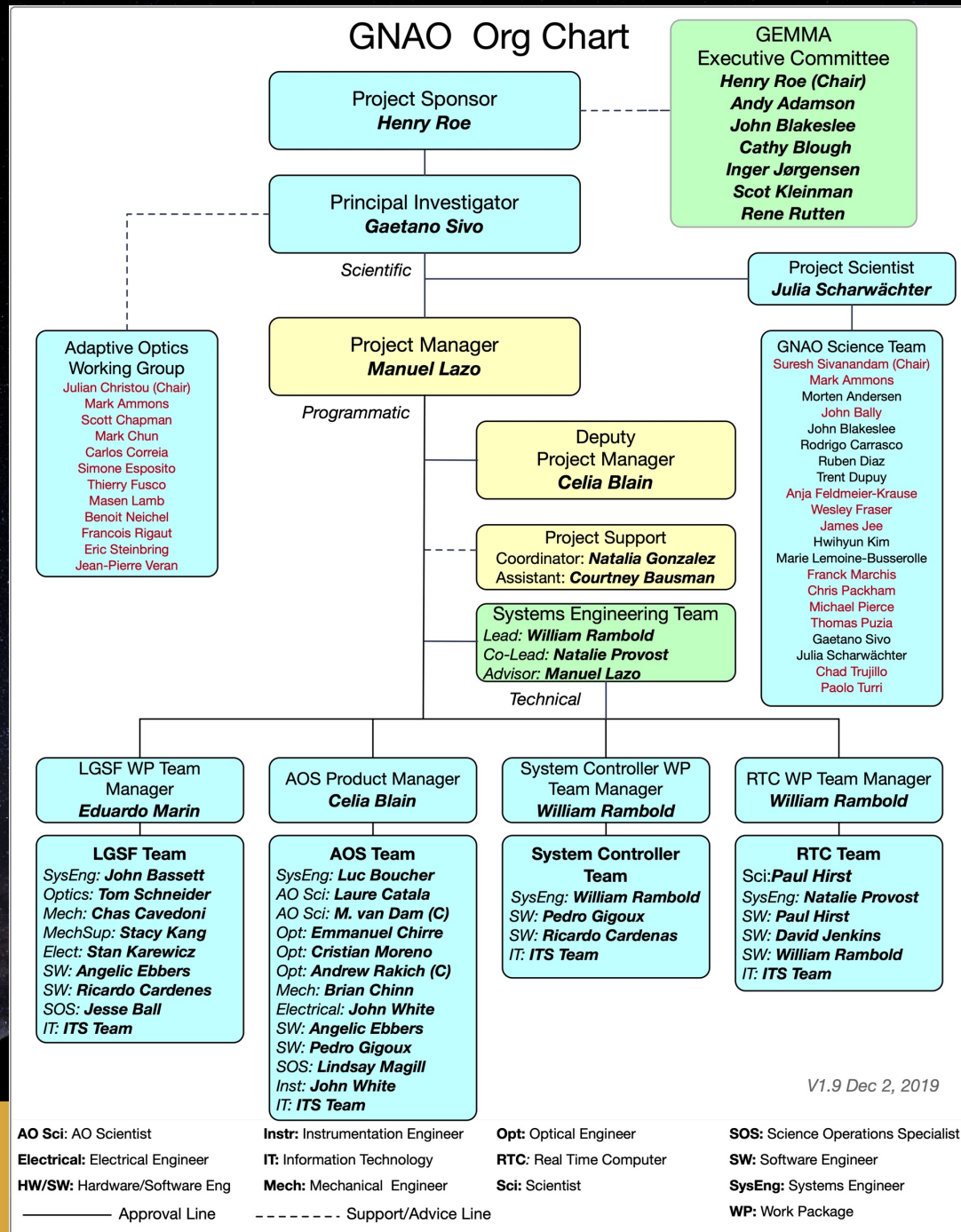
GNAO Overview



- MCAO @ Gemini North
- Designed to feed Imaging and Spectroscopic instrument
 - First light instrument GNAOI
 - Visiting instrument GIRMOS
- Needs to deliver uniform close to diffraction limit correction on 2' FoV in the NIR
- Keep open future upgrade
 - Laser GLAO using ASM



GNAO Org Chart



AO Sci: AO Scientist
Electrical: Electrical Engineer
HW/SW: Hardware/Software Eng
Instr: Instrumentation Engineer
IT: Information Technology
Mech: Mechanical Engineer
Opt: Optical Engineer
RTC: Real Time Computer
Sci: Scientist
SOS: Science Operations Specialist
SW: Software Engineer
SysEng: Systems Engineer
WP: Work Package



GNAO Main Requirements



Science field of view	2' diameter (performance spec. in 85"x85")
Wavelength	$0.830 \mu\text{m} \leq \lambda \leq 2.5 \mu\text{m}$
Zenith angle	50° (operational up to 60°)
K-band Strehl ratio H and J-band	≥ 0.3 (with <10% variation) in median conditions ≥ 0.14 and ≥ 0.05
Rel. photometric accuracy	$\leq 2\%$
Rel. astrometric accuracy (3 NGS, K-band)	$\leq 0.2 \text{ mas}$
PSF uniformity/temporal stability	10% or better (excellent conditions)
Optimized on-axis correction	Enhanced on-axis Strehl for narrow-field science
AO telemetry	Storage for post-processing by science user
Non-sidereal tracking	Rates of $\leq 450 \text{ "/hr}$
Operability	Nominal queue operations, 2-person night crew
Stability	Closed loop Ops up to 1.2" seeing @0.5 μm
Sky Coverage	20% with 3NGSs @ Galactic Pole 60% with 1NGS @ Galactic Pole



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GNAO subsystems

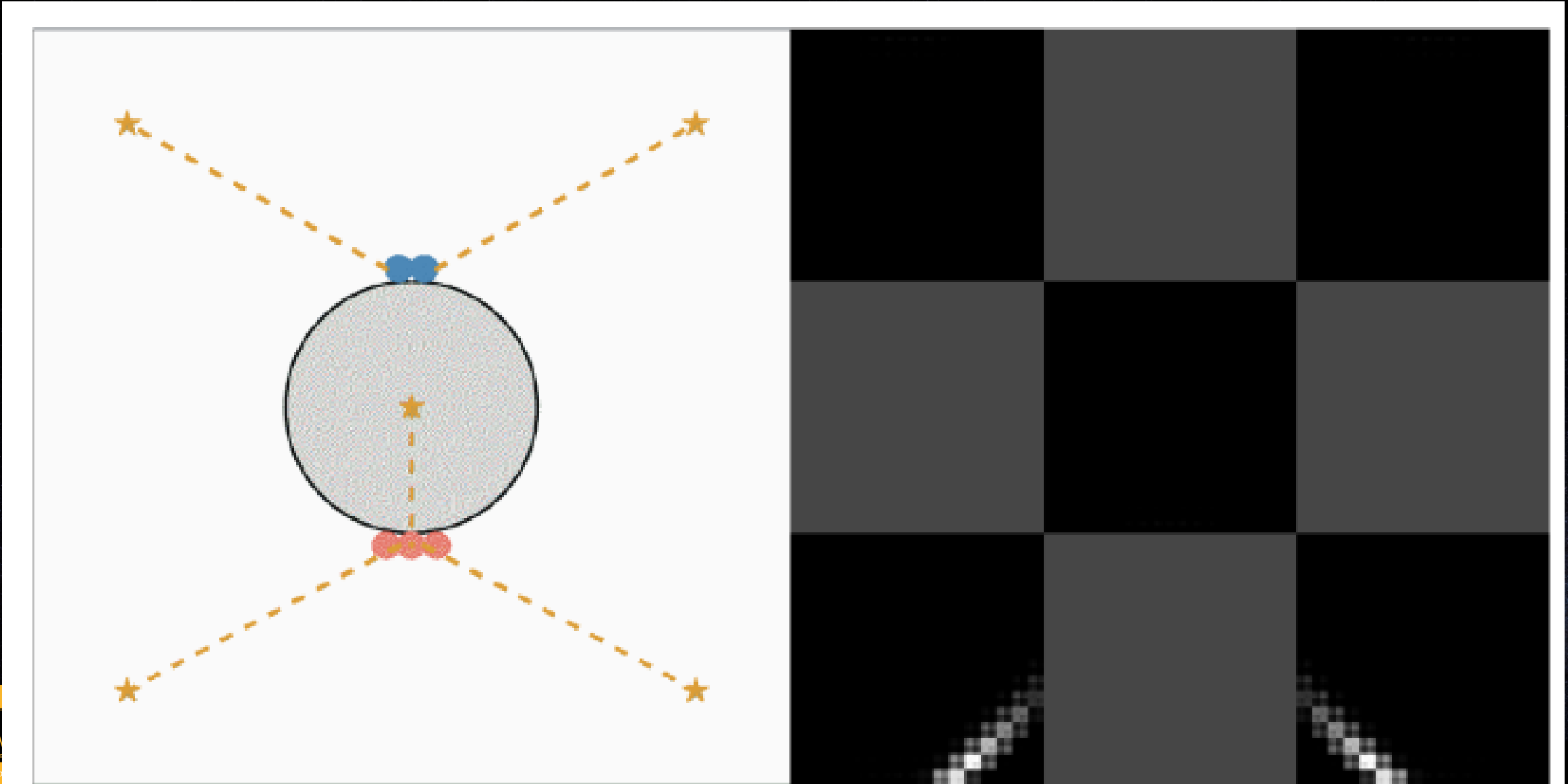


- Laser Guide Star Facility
- Adaptive Optics Subsystem
- Real Time Controller
- Control System



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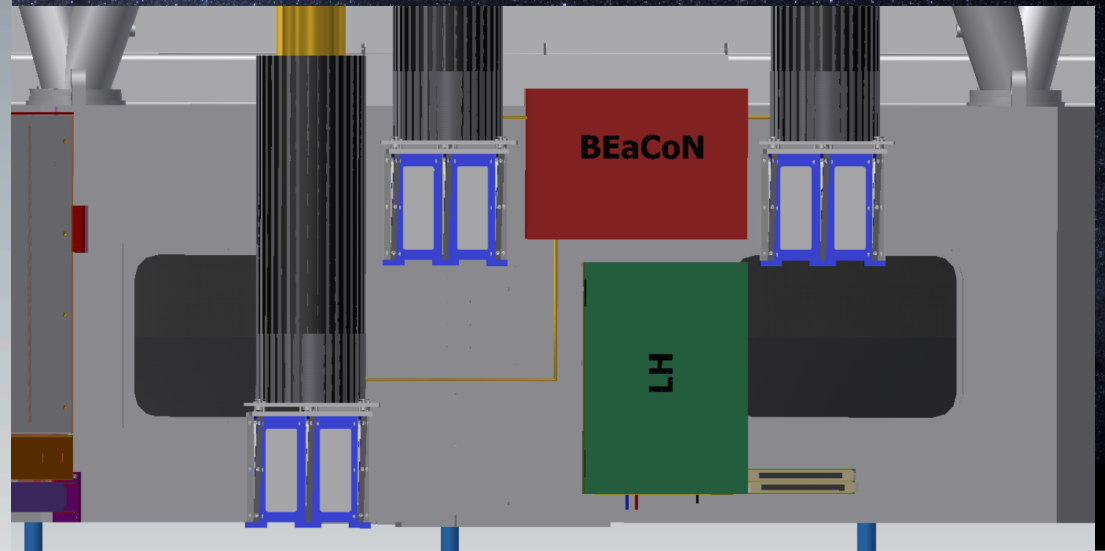
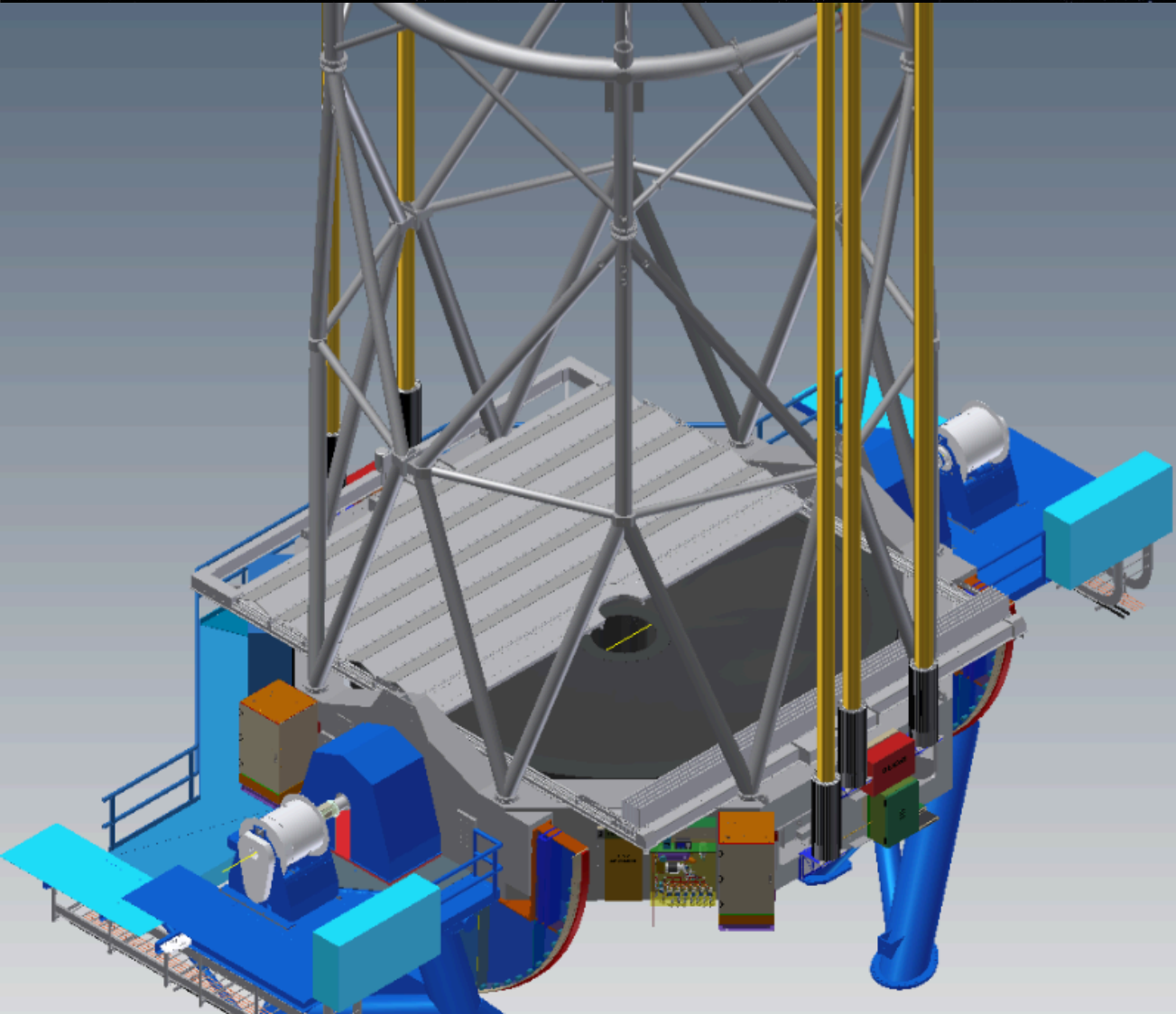
Laser Guide Star Facility





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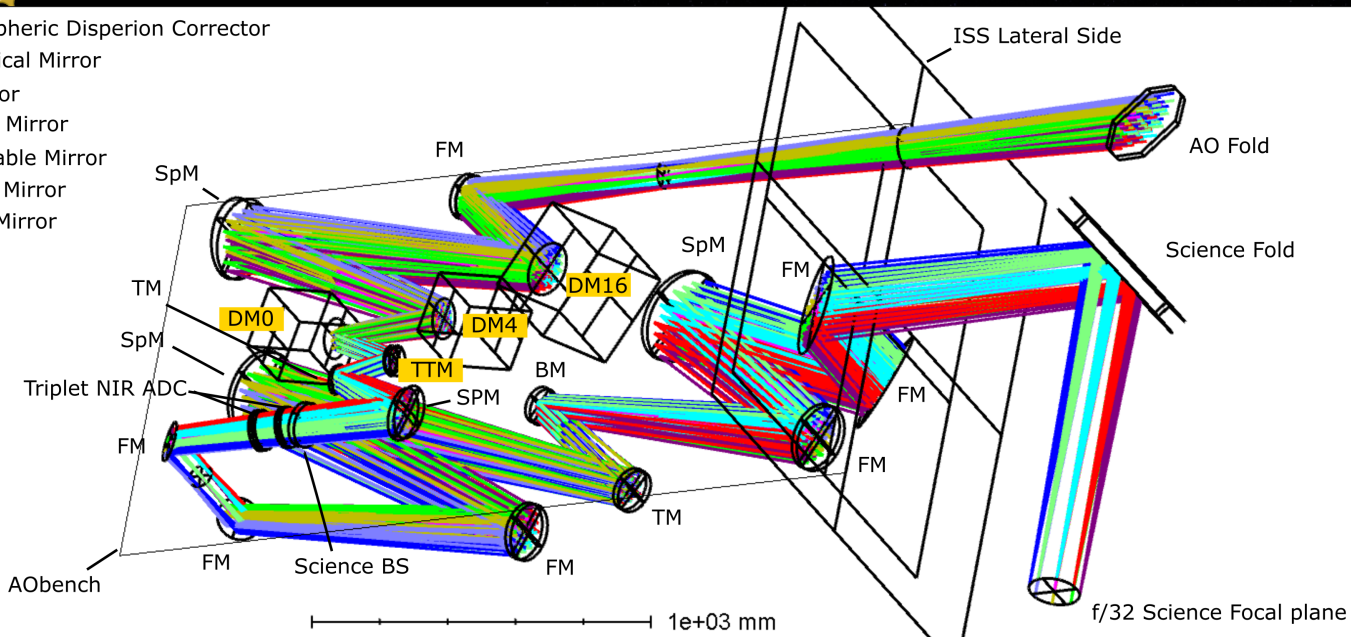
Laser Guide Star Facility





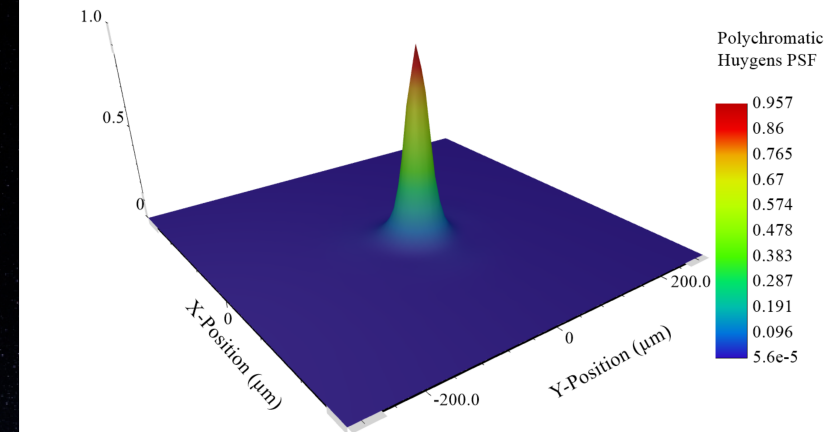
AO subsystems

ADC: Atmospheric Dispersion Corrector
 SpM : Spherical Mirror
 FM: Flat Mirror
 TTM: Tip-Tilt Mirror
 DM: Deformable Mirror
 TM: Toroidal Mirror
 BM: Biconic Mirror

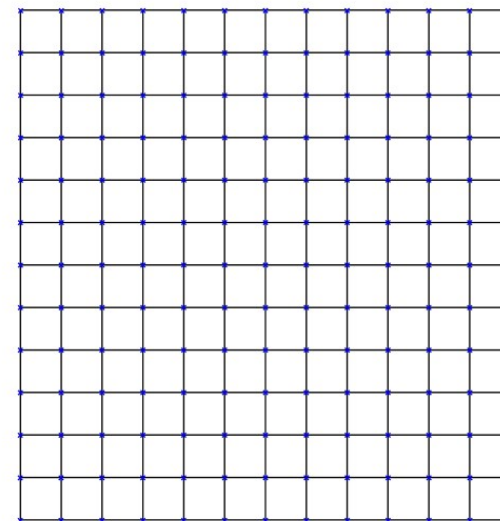


Science Path, 60-deg Zenith
 11/14/2019

GN MCAO bench Optical design
 Modified Offner Relay
 E. Chirre
 2019
 Configuration 4 of 12.



Polychromatic Huygens PSF	
Science Path, 60-deg Zenith 11/18/2019 0.8500 to 2.3000 μm at 0.0118, -0.0118 (deg). Image size is 594.23 μm square. Strehl ratio: 0.957 Center coordinates : 1.52210765E+01, -7.34082335E+01 Millimeters	GN MCAO bench Optical design Modified Offner Relay E. Chirre 2019 Configuration 4 of 12



Science Path, 60-deg Zenith

11/14/2019

Field: 0.0236 w 0.0236 h Degrees

Image: 102.57 w 106.66 h Millimeters

Maximum distortion: -0.1705% SMIA TV distortion: 0.0000%

Scale: 1.000X, Wavelength: 1.6000 μm

60-deg Zenith
 0.0236 h Degrees
 106.66 h Millimeters
 0.1705% SMIA TV distortion: 0.0000%
 Wavelength: 1.6000 μm

GN MCAO bench Optical design
 Modified Offner Relay
 E. Chirre
 2019
 Configuration 4 of 12



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End to End Simulations



- Monte-Carlo simulations run using **YAO**
- open-source, general purpose AO simulation tool developed by Francois Rigaut
- Used extensively on GeMS



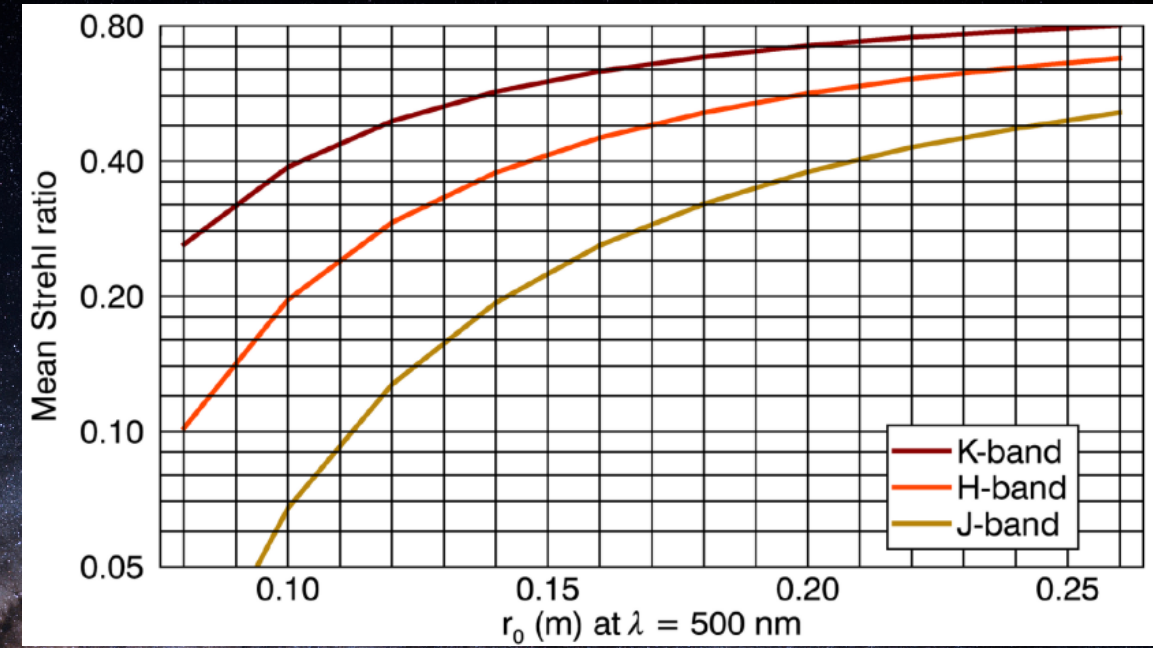
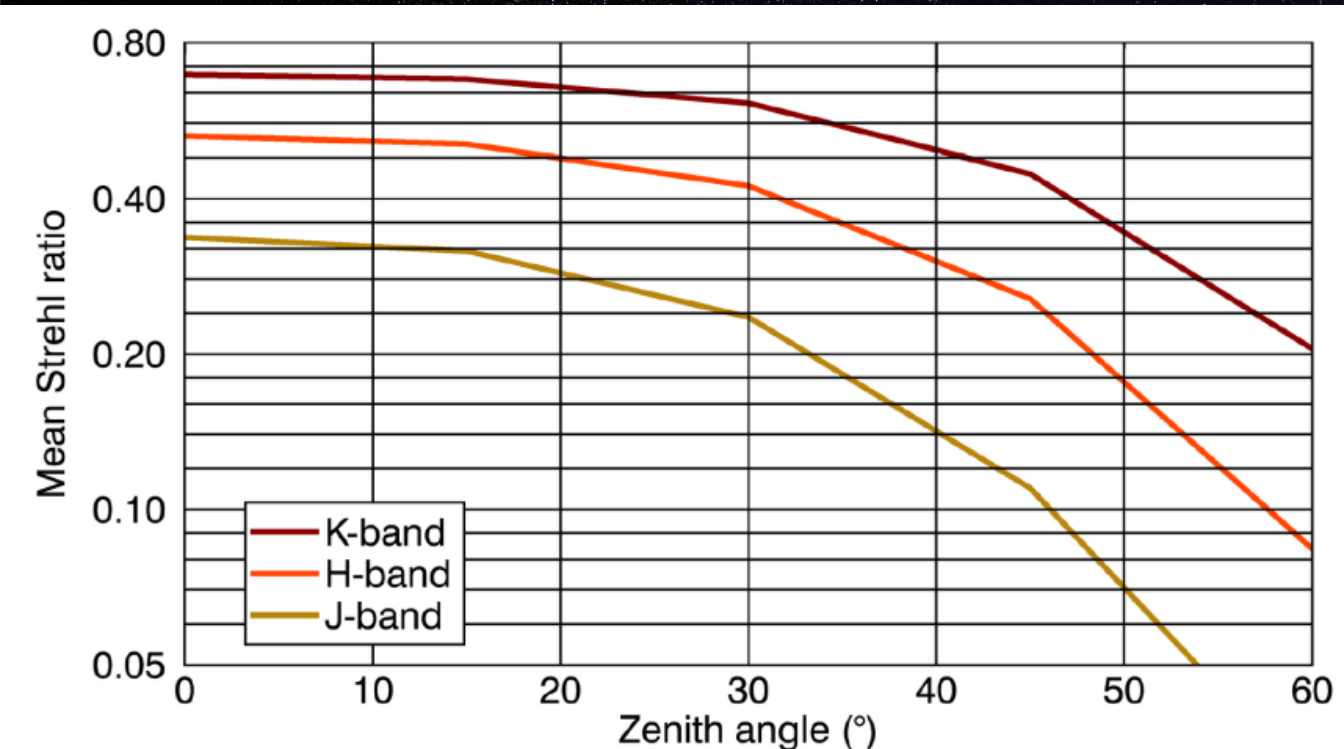
Big Bang Theory, Season 4 Episode 9



Simulations Results



bright guide stars, zenith, median seeing



No M2 print-through
No tip-tilt vibrations



Simulations Results

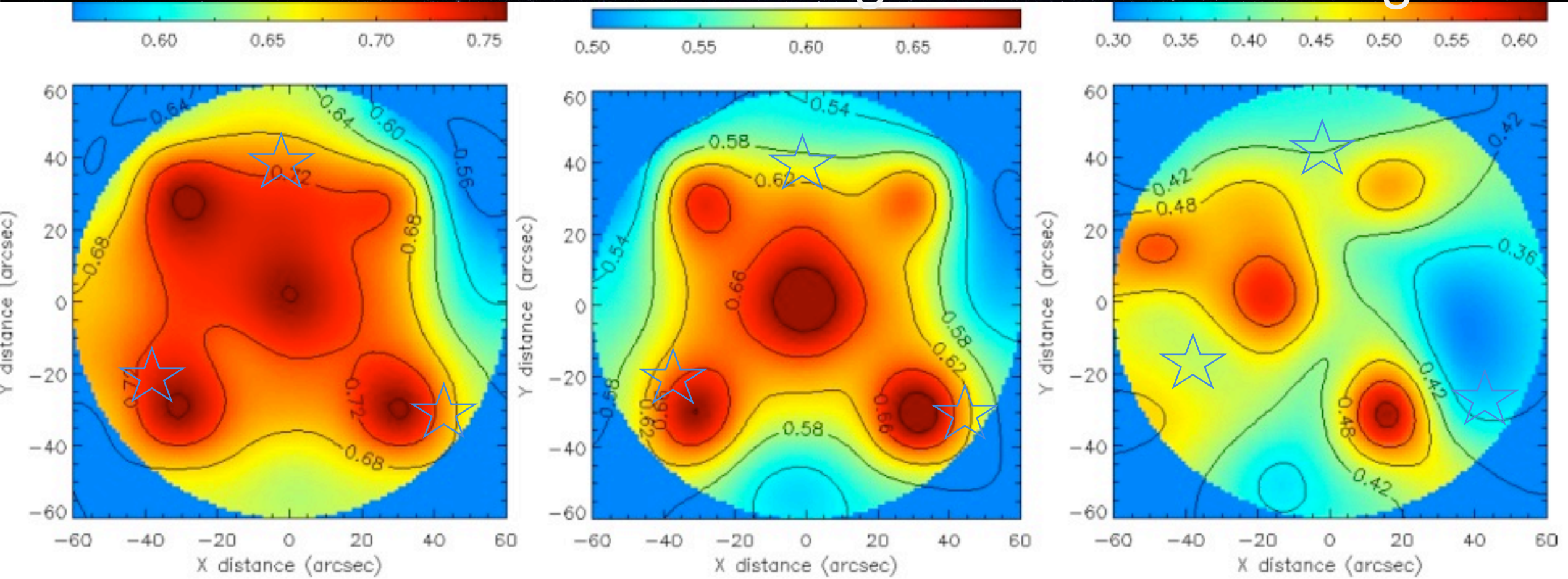


bright guide stars, median seeing

Zenith

30deg

45deg





Simulations Results

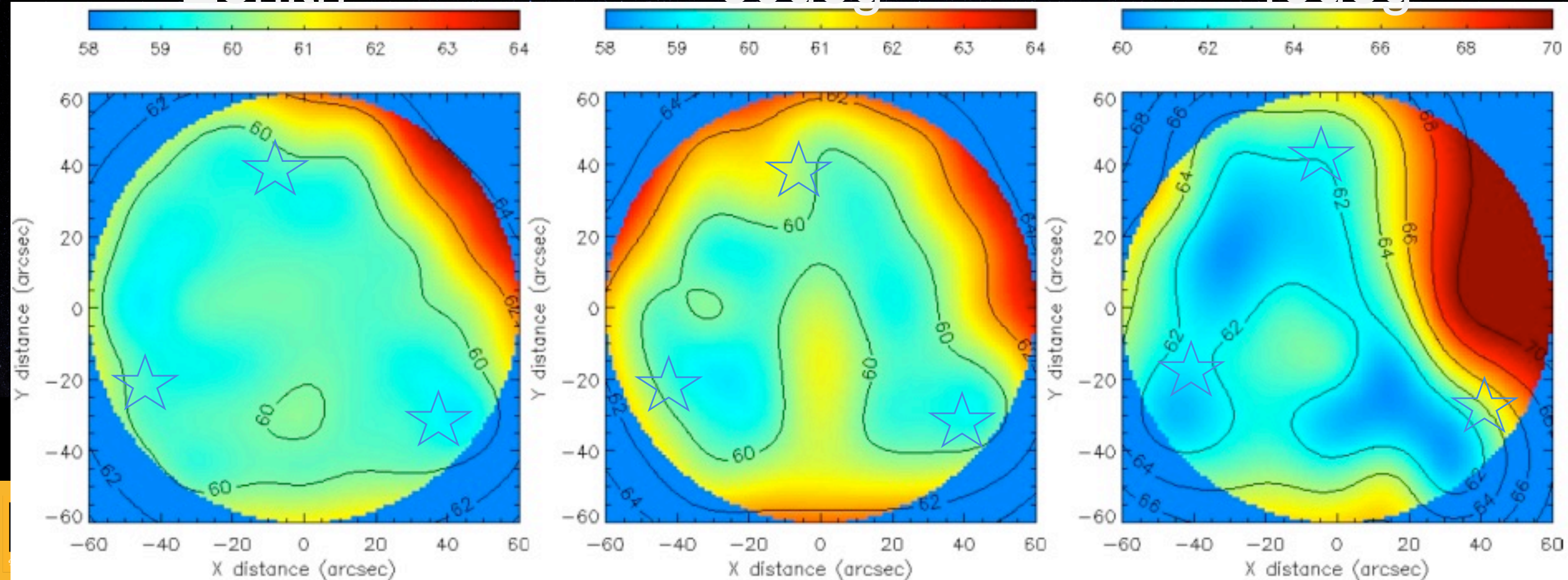


bright guide stars, median seeing

Zenith

30deg

45deg

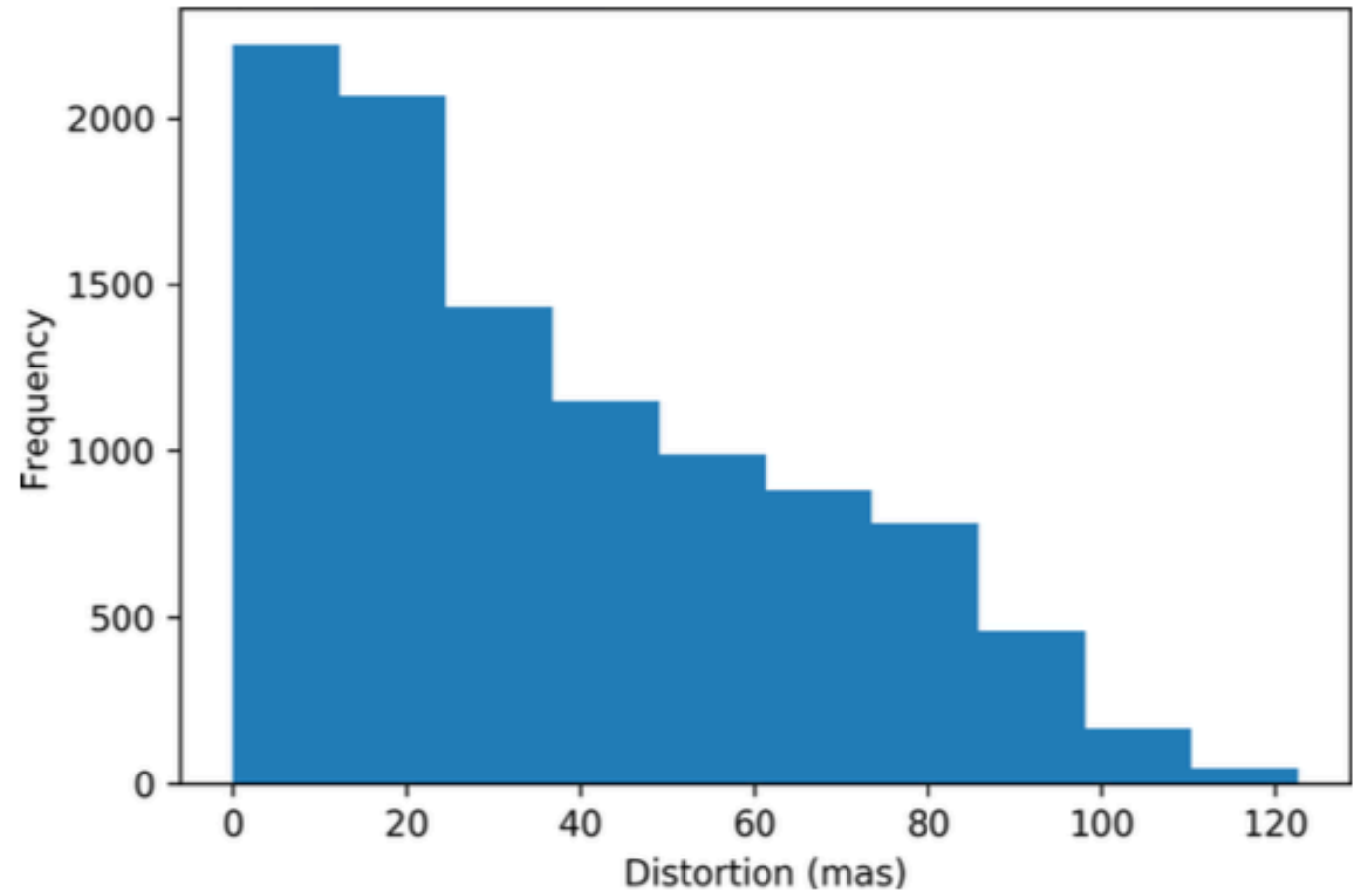
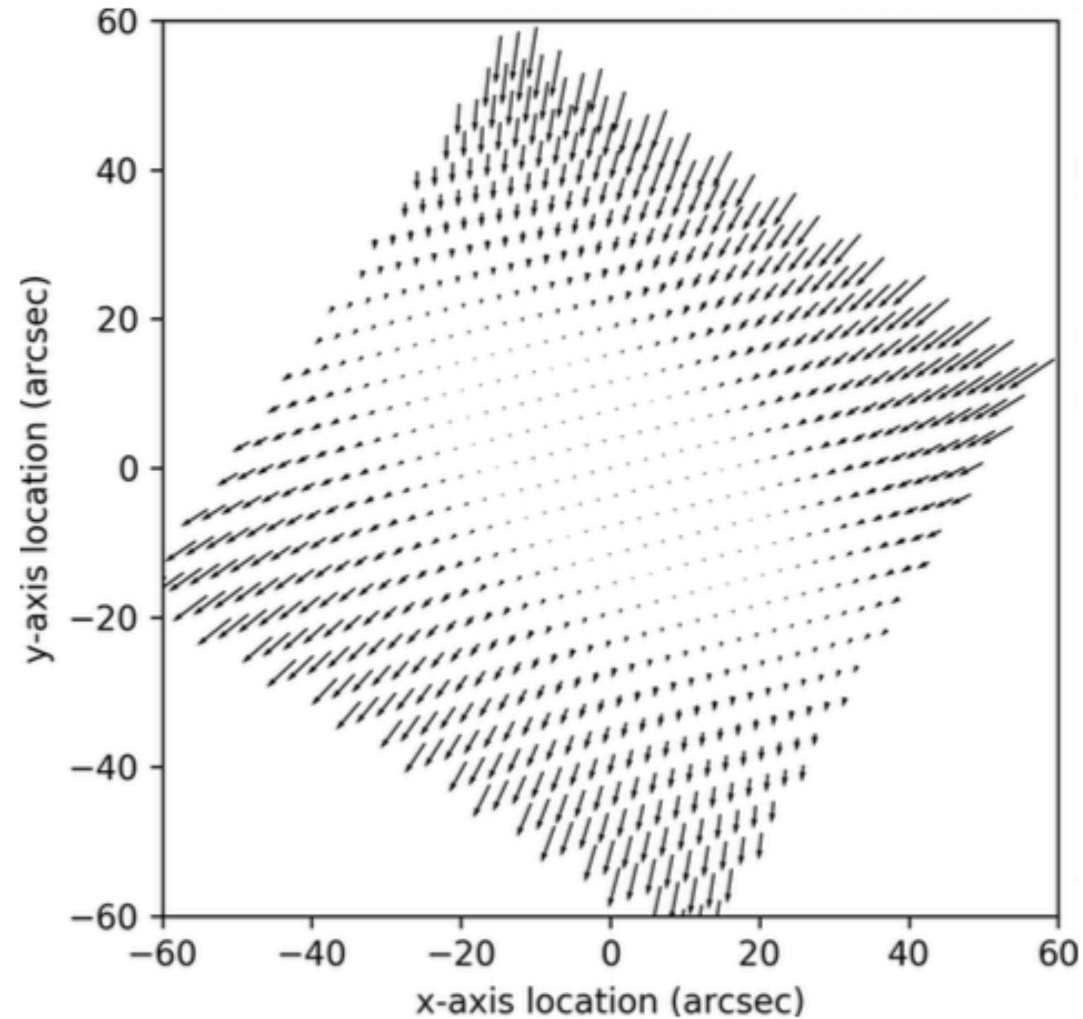




Distortions Performance



GNAO modified Offner relay design





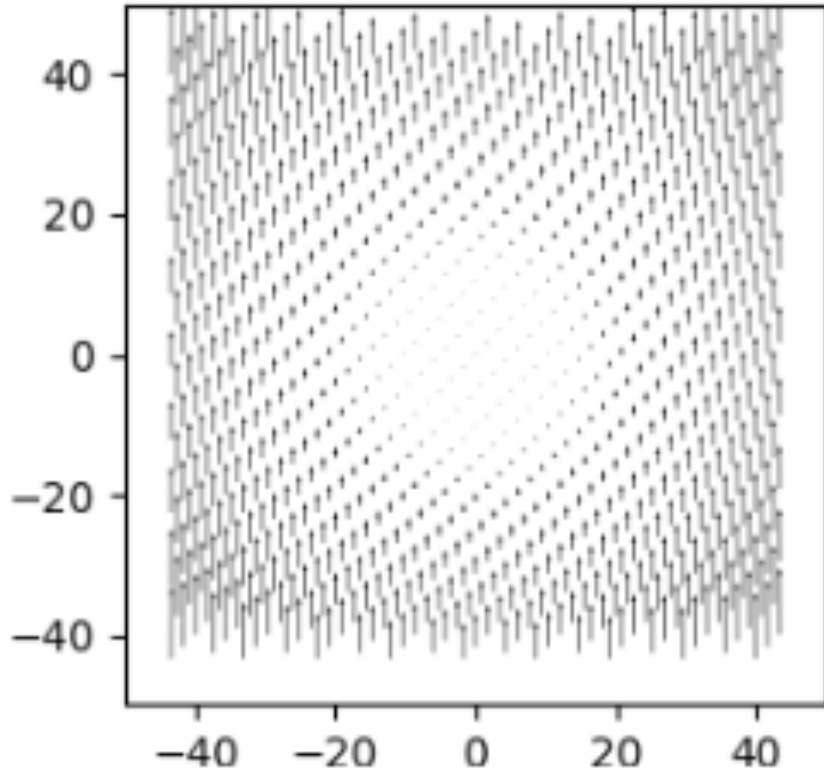
Comparison to GeMS



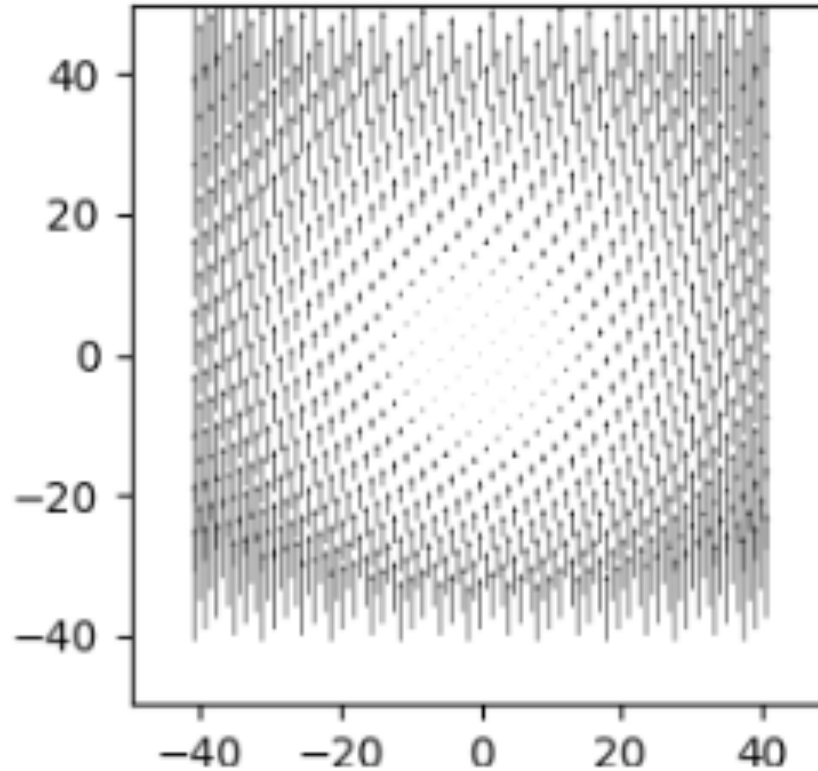
GNAO modified Offner relay design

→ 10 times better than GeMS

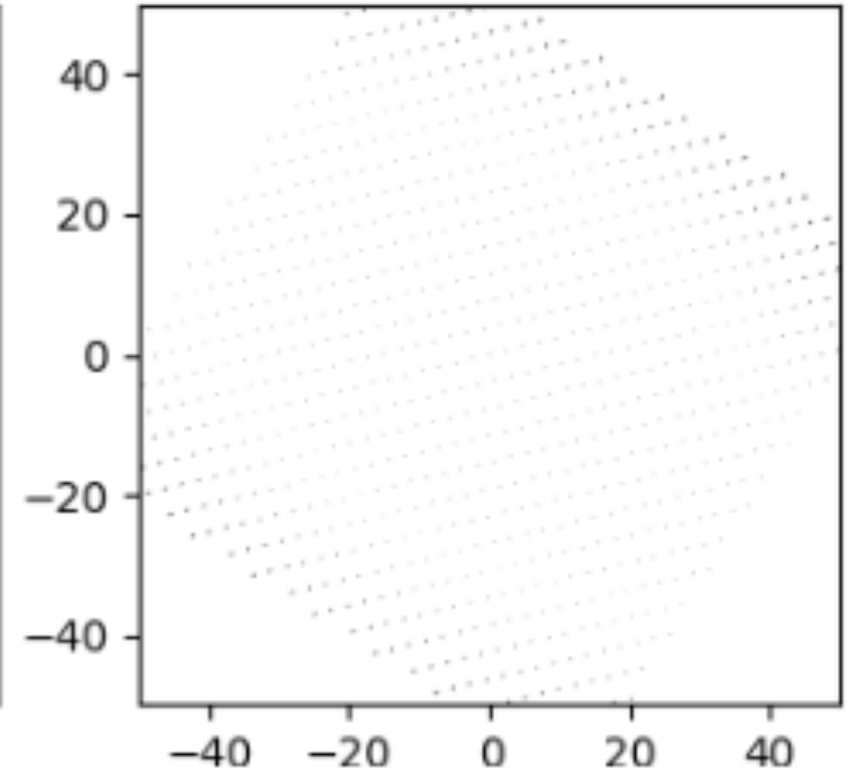
GeMS



4 OAPs



Offner





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GNAO next step



- RTC RFP out, review + selection process ongoing
- AOB RFP will be out VERY SOON, AoO already out
- GNAO passed CoDR in late September 2019
- GNAO first light for all subsystems by July 2024, full on-sky commissioning after