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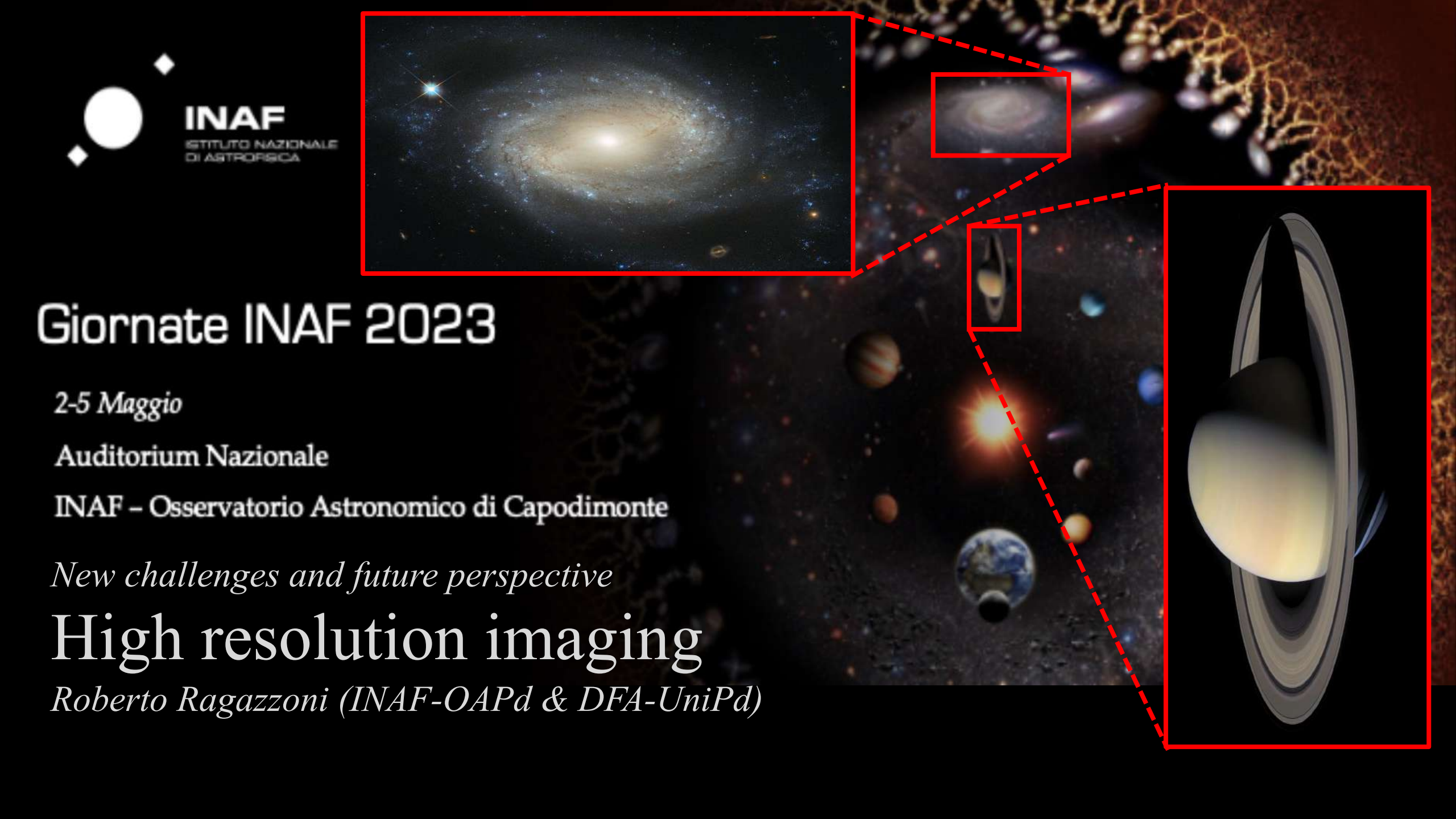
ISTITUTO NAZIONALE
DI ASTROFISICA

Giornate INAF 2023

2-5 Maggio

Auditorium Nazionale

INAF – Osservatorio Astronomico di Capodimonte



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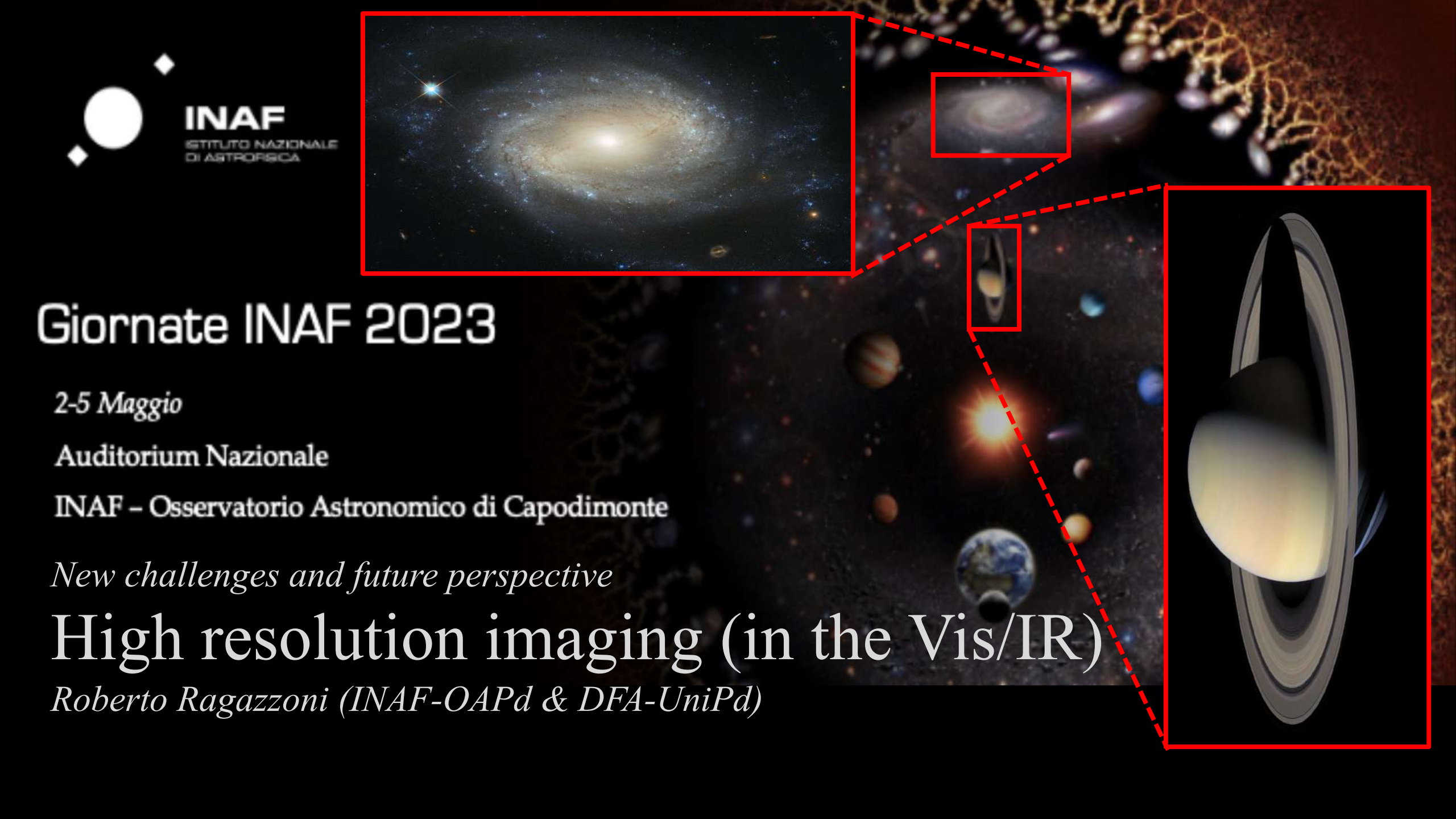
New challenges and future perspective

High resolution imaging

Roberto Ragazzoni (INAF-OAPd & DFA-UniPd)



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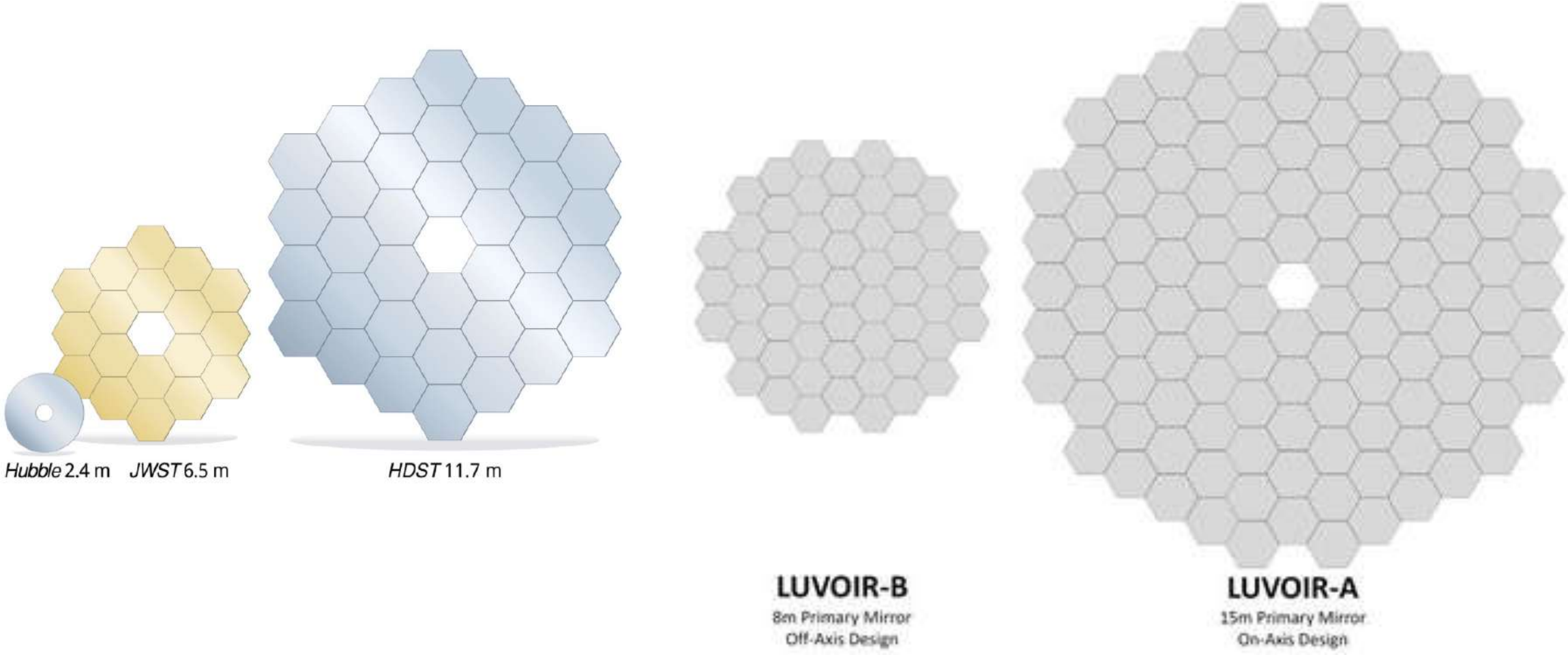
New challenges and future perspective

High resolution imaging (in the Vis/IR)

Roberto Ragazzoni (INAF-OAPd & DFA-UniPd)

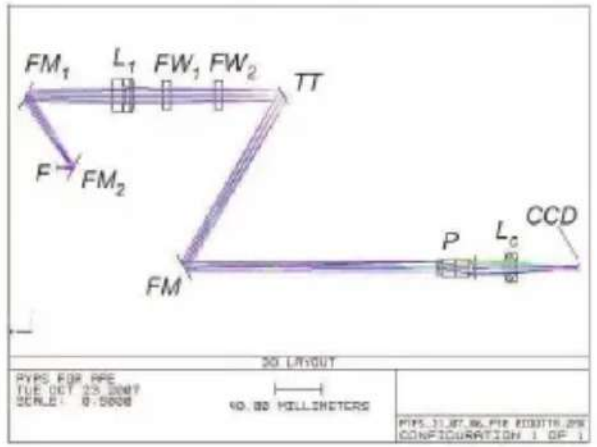
High angular resolution means…

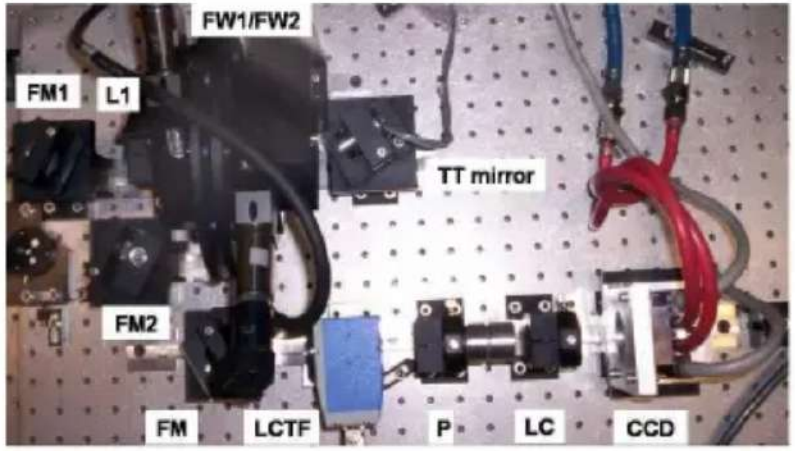
- Space Telescope of large aperture (HST, JWST, next generation…)



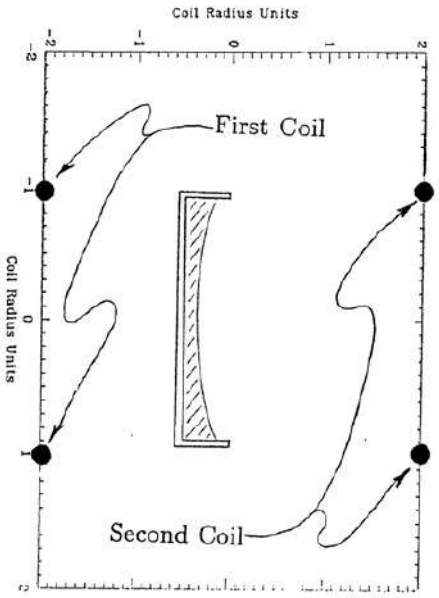
Capitalizing on existing or developing new concept…?

- Segmented (and still we can provide a lot on cophasing…) Bonaglia et al. 2010

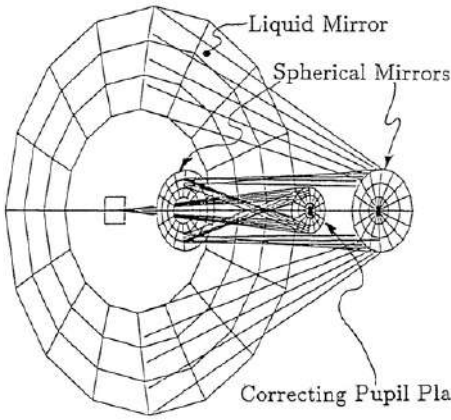




- Foldable mirrors (new materials, MPE)
- Liquid (with magnetic or ferromagnetic forces)



Ragazzoni et al. 1996



Adaptive Optics

- INAF master the field both in the WFS & DM area

Ragazzoni 1996

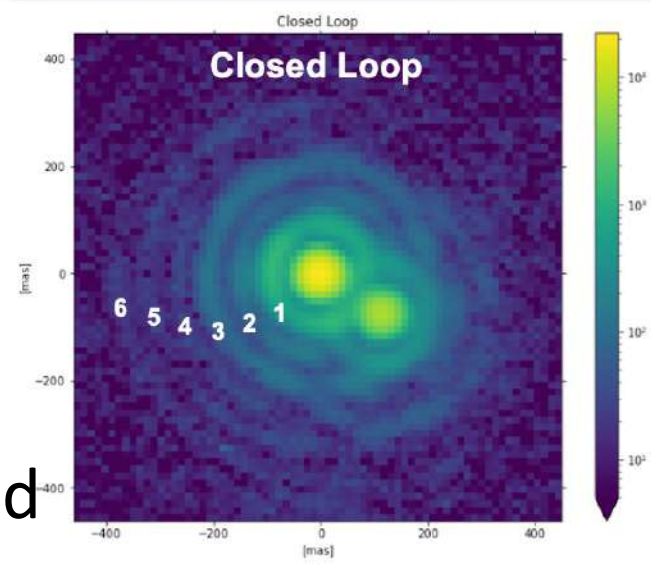
Salinari et al. 1996

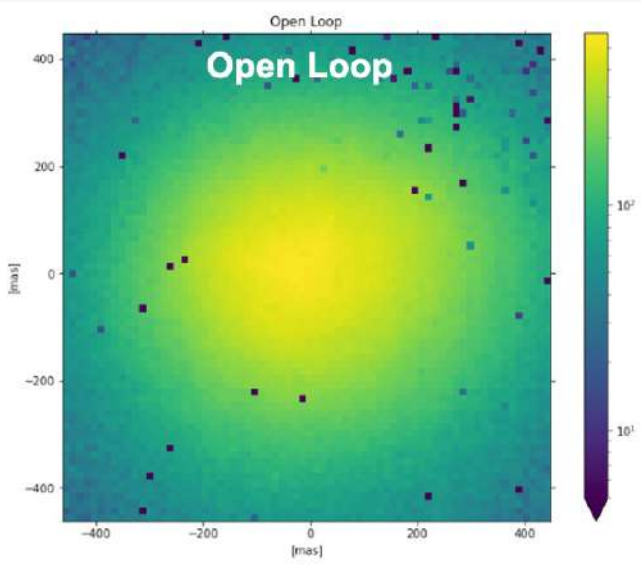
- Efforts to push the edges for:
  - Bluer
  - Higher Strehls
  - Higher contrast
  - Large(r) Field of Views
  - Feeding spectrographs

ERIS

Riccardi et al. 2023

On-Sky results: NGS-mode



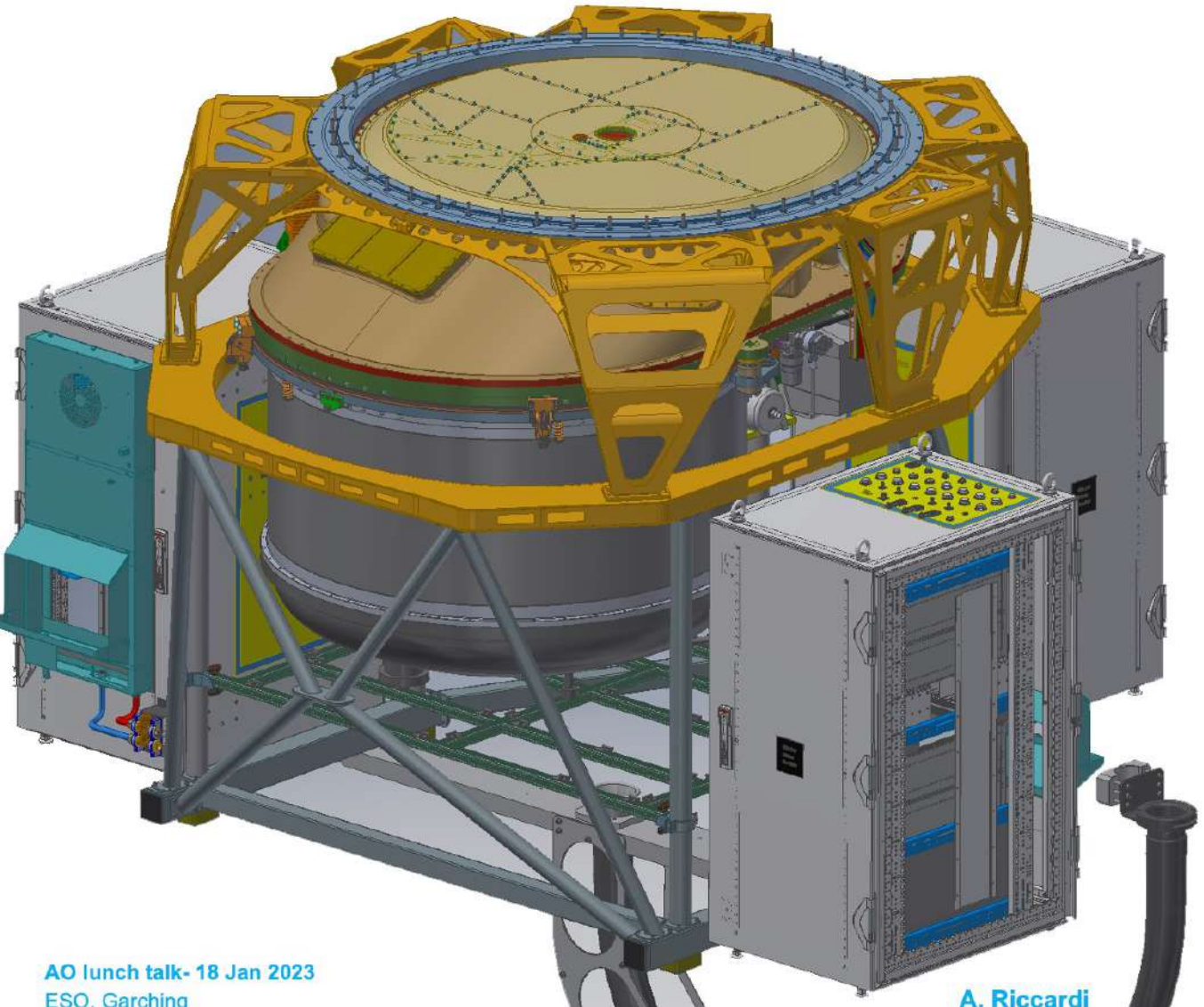


Comm1D NIGHT 02
17369-1757HDS2486, double star
magG$_{RP}$=8.6, NGS-mode
NIX: Br-g, 13 mas/pix

Log scale

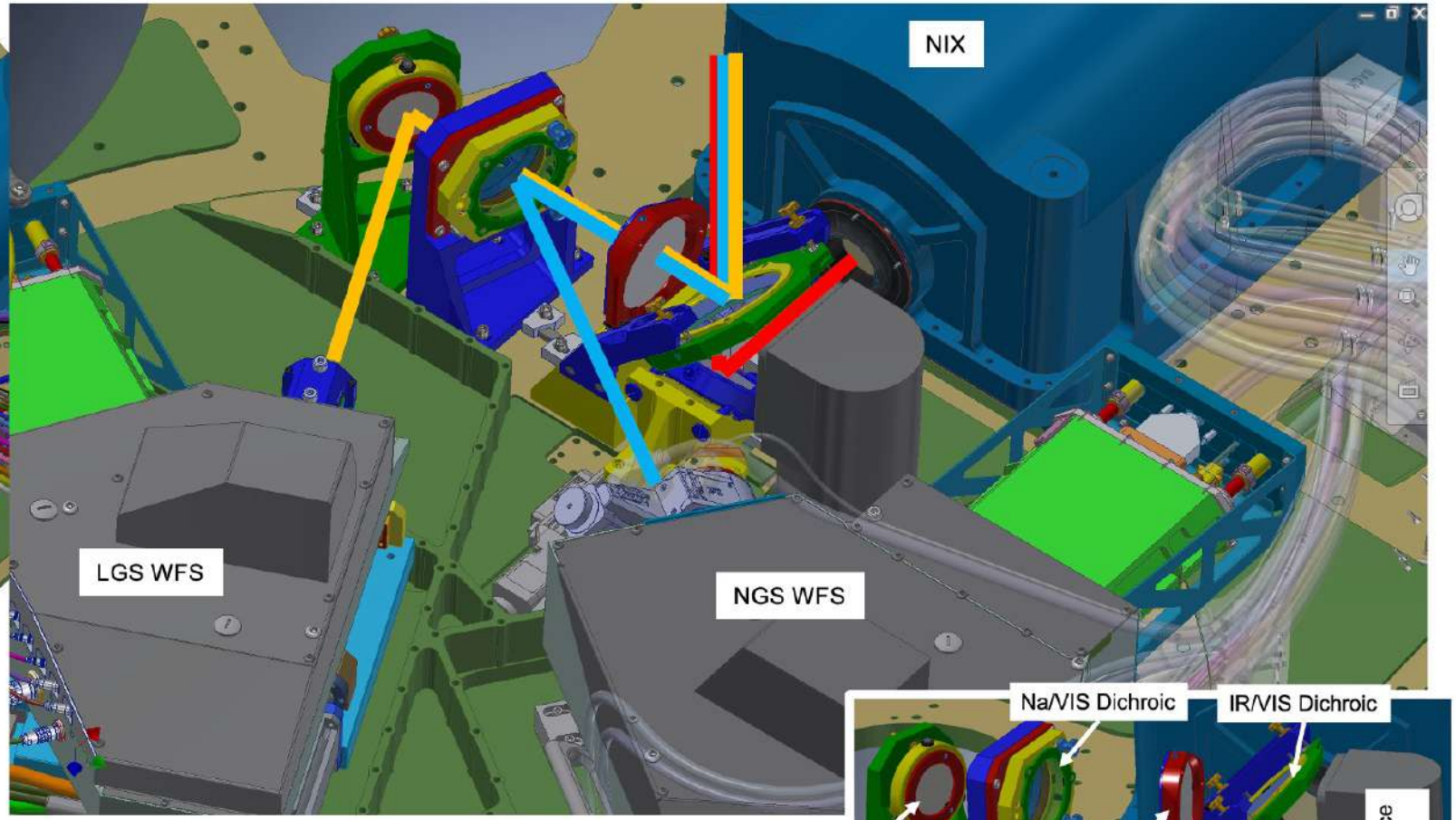
- Enhanced
- Resolution
- Imager and
- Spectrograph
- NIR & Cass focus of UT4 (8.2m) – PI Rick Davies (MPE)

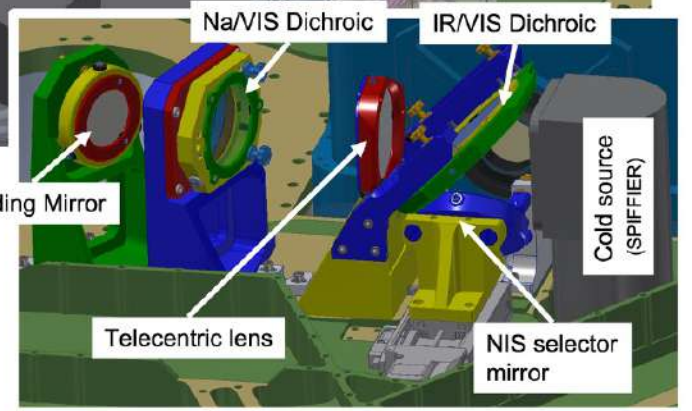
ERIS on Cass focus of UT4 (Feb 22)



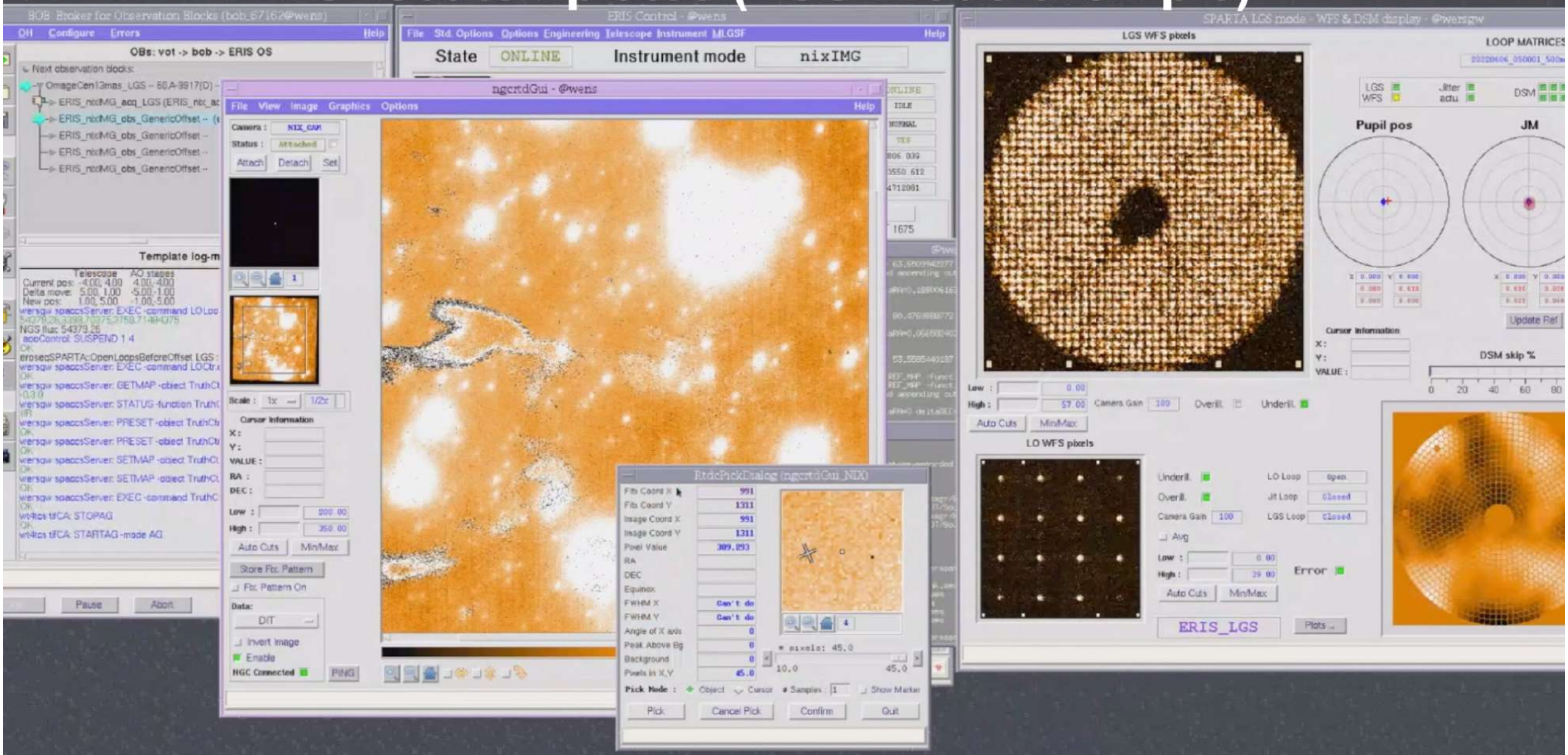
The ERIS AO module

Relay Optics
(a.k.a. warm optics)



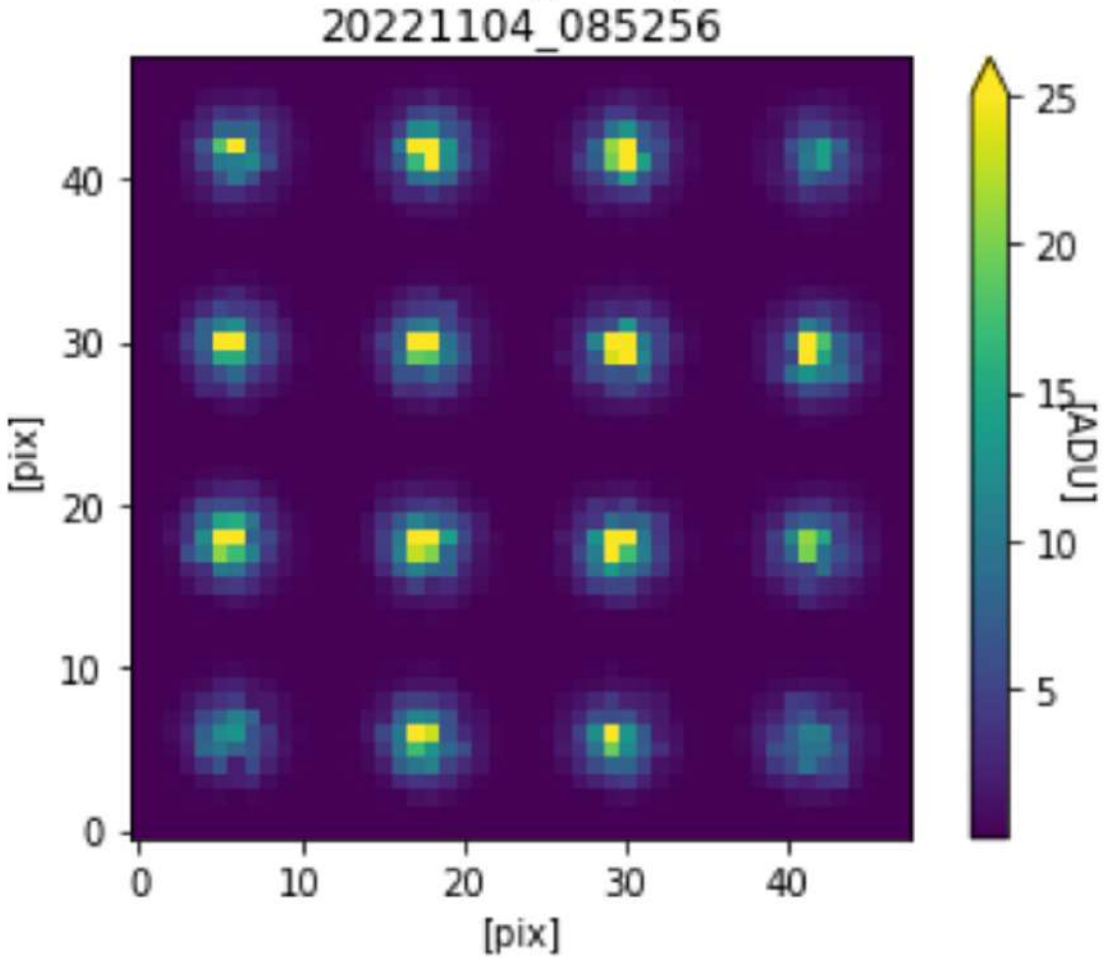


Offset templates (LGS-mode example)

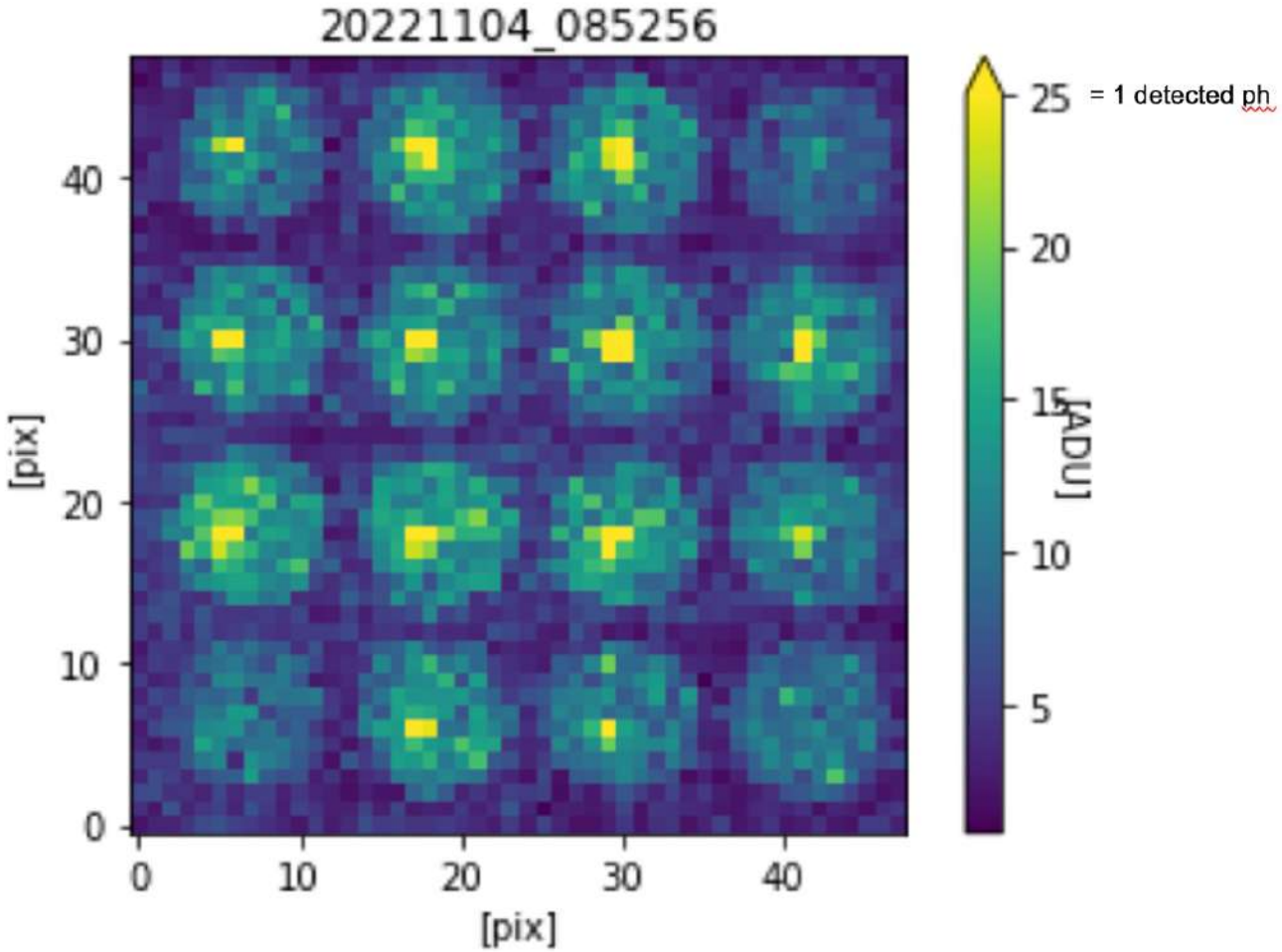


NGS LO sensor – mag19.1 100Hz

Average of 100 frames w Gaussian Weighting masks

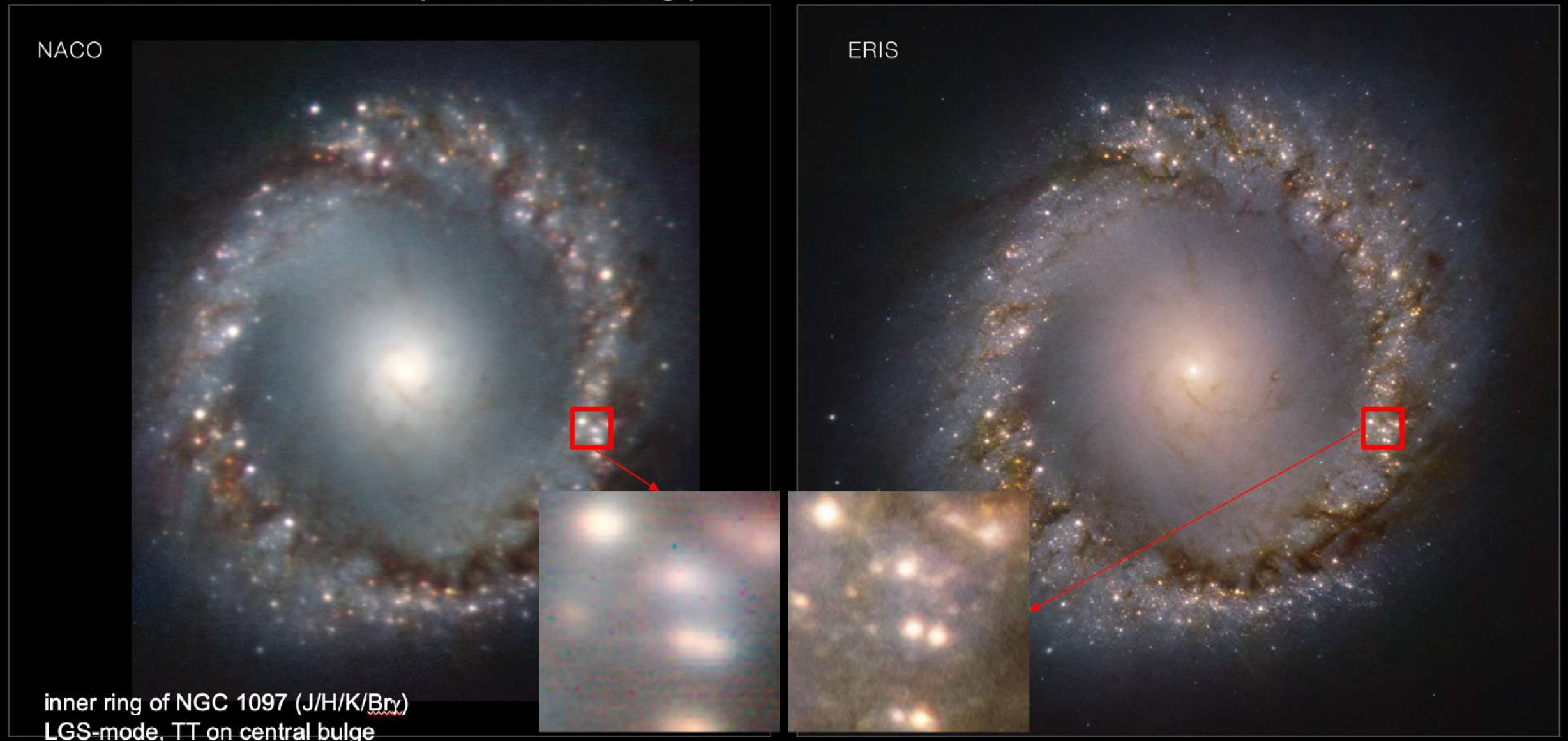


Average of 100 frames



Comm2: Handover to ESO

https://www.eso.org/public/announcements/ann22015/



inner ring of NGC 1097 (J/H/K/Brγ)
LGS-mode, TT on central bulge
FoV 23 x 23 as^2

SHARK-NIR

Marafatto et al. 2023

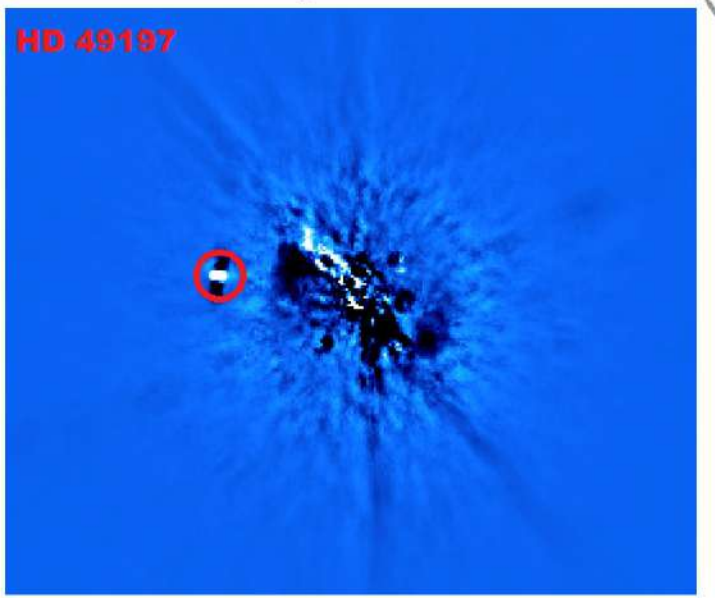
- System for coronography with
- High order
- Adaptive optics from
- R to
- K band (well, actually it is now limited to H…)
- NIR & Nasmith focus of LBT (8.4m) – PI: Jacopo Farinato INAF

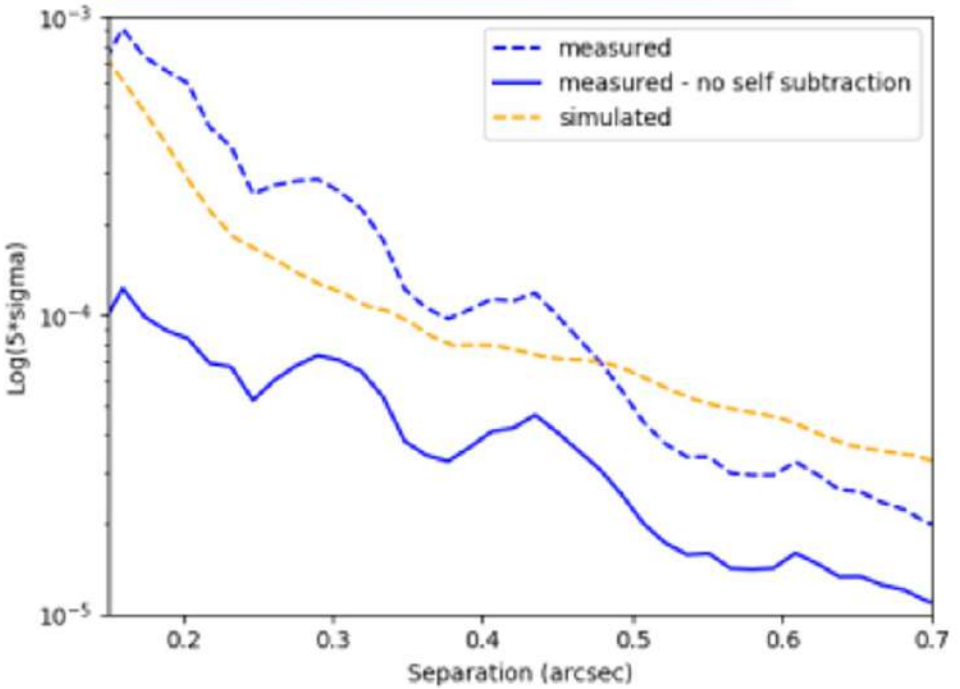
Com-run-1: Coronahraphic Test with Gaussian Lyot

First coronagraphic attempt on January 11th

- Quite famous and simple target: HD49197
- M_V: 7.8 M_H: 6.1
- Gaussian Lyot coronagraph
- Δmag. in H band between star and brown dwarf companion is 8mag., distance of 0.821”
- The result is obtained using the SHARK-NIR data reduction pipeline, applying the ADI technique, combining 73 images with an exposure time of 29.95s each, for a total exposure time of 36.4 minutes. The seeing was ranging from 1” to 1.2”.
- The total rotation of the FOV during the observation was 11.6 degrees.

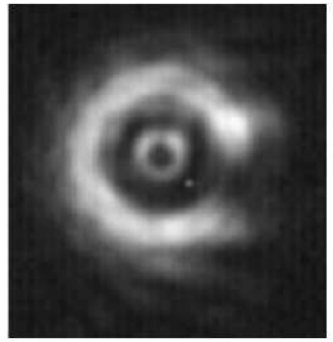
Results are in line with simulations performed accounting for similar observation parameters





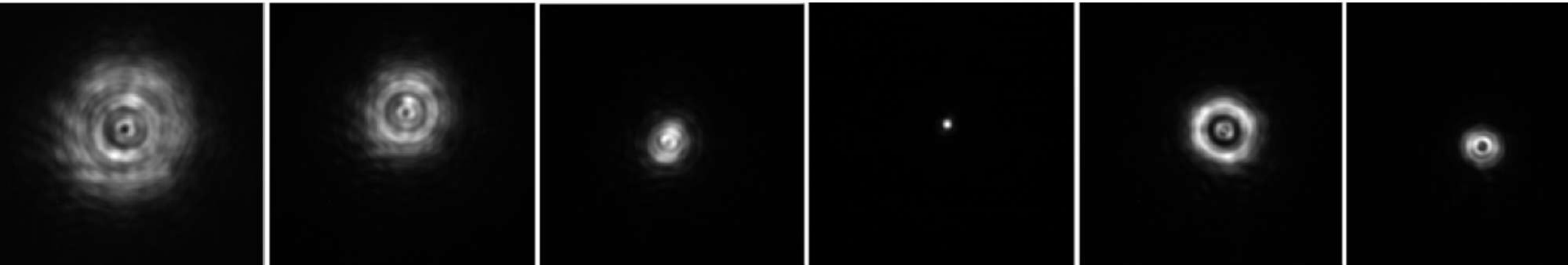
Com-run-1: Phase Diversity Test

The Phase Diversity (PD) algorithm, used to characterize the NCPA of the instrument, has been working on sky, which is a big achievement!
Residual WFE after PD correction is <30nm, although this can be further improved.
Unfortunately, we also experienced what we have called “the pacman effect”, a feature that appears in the defocused images, in certain observing conditions, in correspondence of the swing arm position. An investigation on the origin of such effect is ongoing, also with the help of the AO team (Enrico, Guido); it looks somehow similar to what already experienced in other instruments/telescopes (SPHERE@VLT, SCExAO@SUBARU), called “the low wind effect”, a phenomenon that occurs when the wind speed inside a telescope dome drops below 3-4m/s creating a temperature gradient near the telescope spider. NO EFFECT (OR ALMOST NEGLIGIBLE) on the AO PERFORMANCE!
As a matter of fact, when this feature is present, PD cannot converge. More investigation TBD.



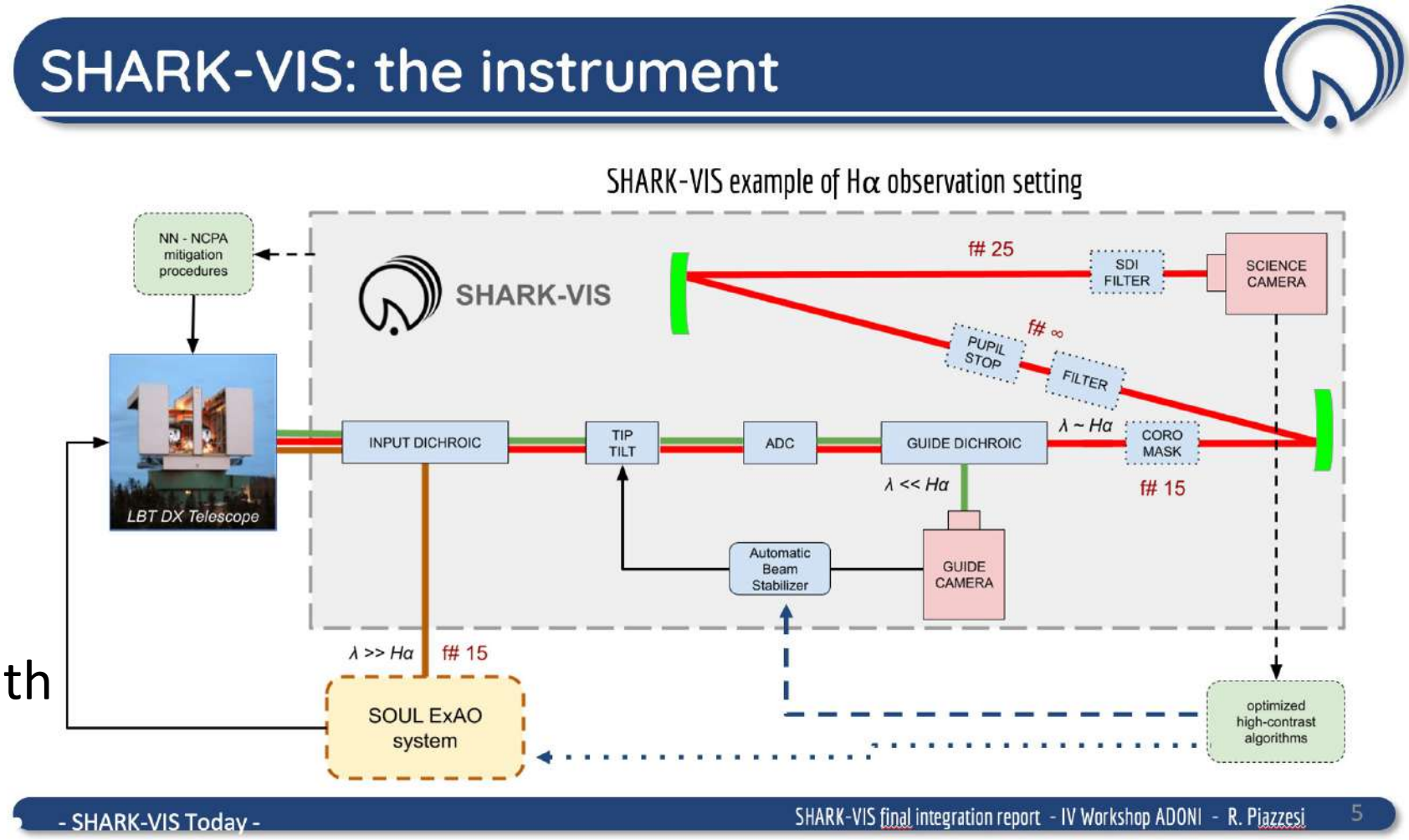
PACMAN effect

-3λ *-2λ* *-1λ* *focus* *+1λ* *+2λ*



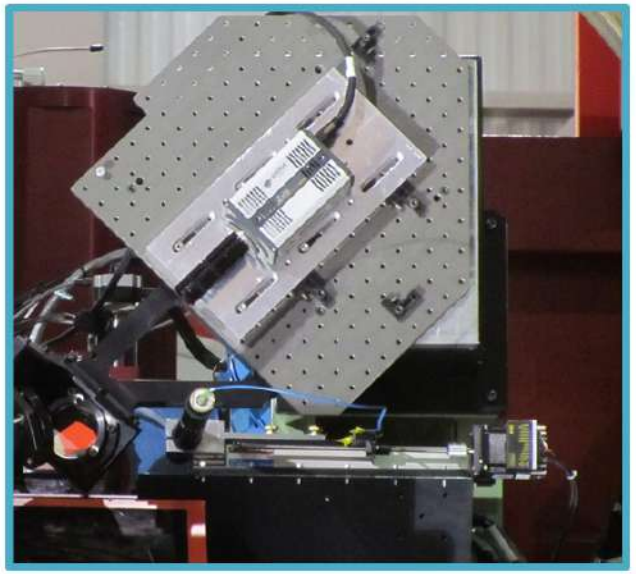
SHARK-VIS

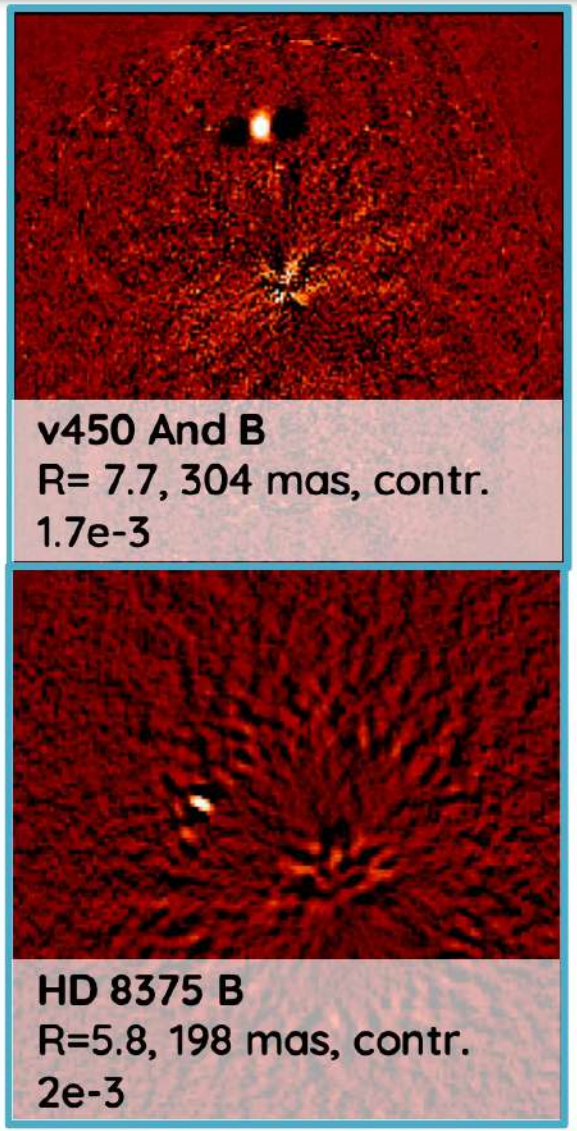
Plazzesi et al. 2022

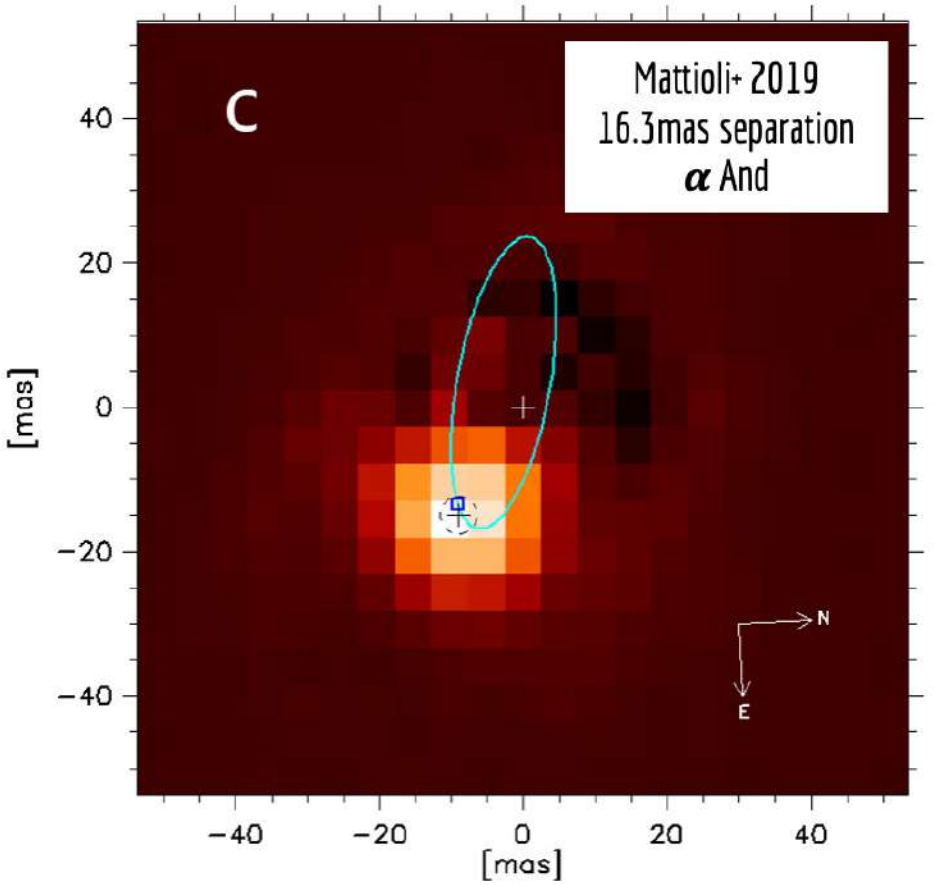


- System for coronography with
- High order
- Adaptive optics from
- R to
- K band (well, actually it is now limited to H…)
- VisR & Nasmith focus of LBT (8.4m) – PI: Fernando Pedichini INAF

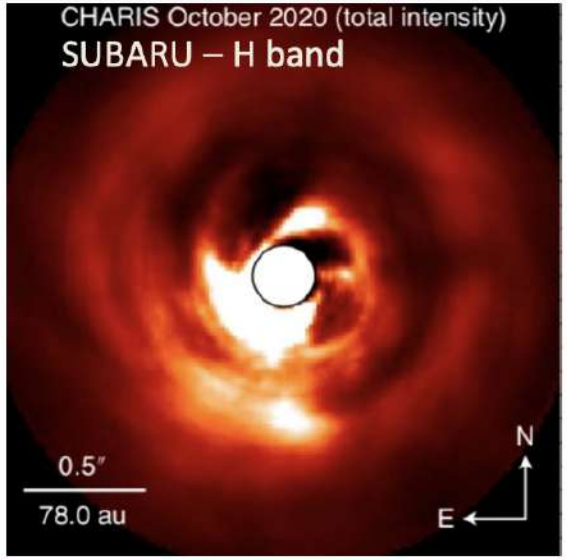
SHARK-VIS FORERUNNER: up and running

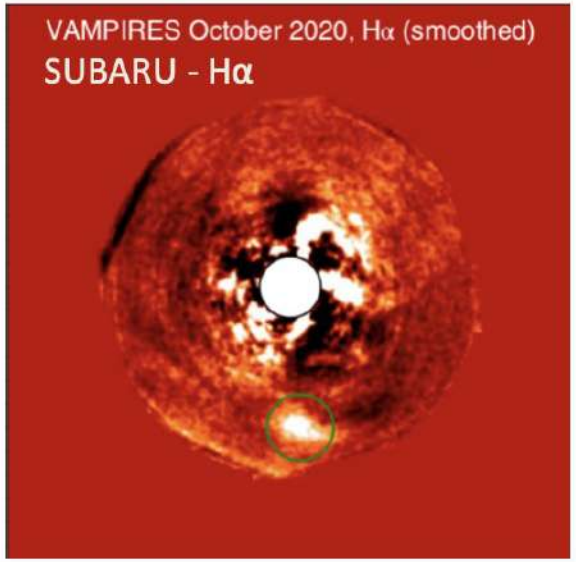


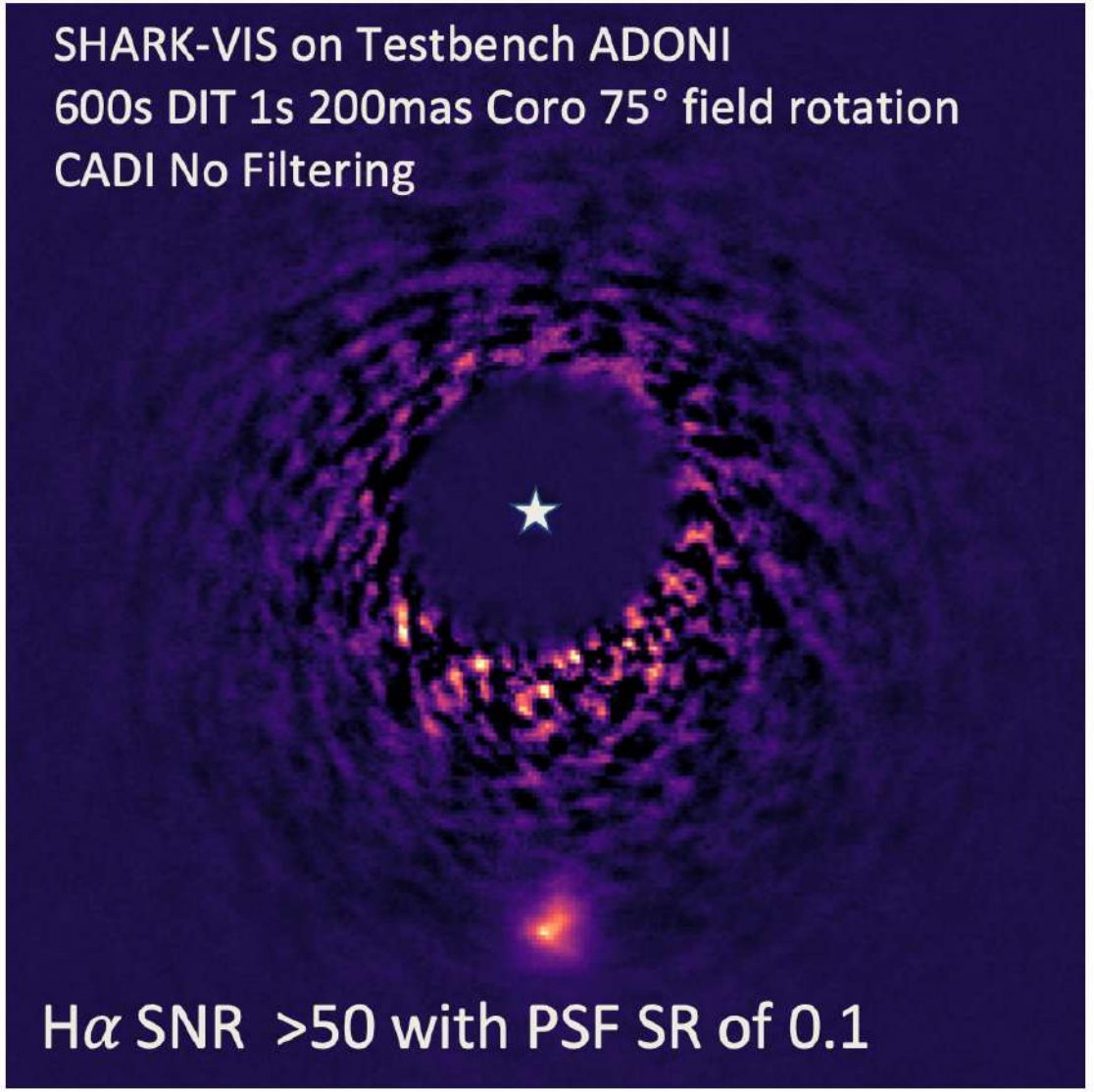




AB Aur R 7.0 b planet @ 590mas 2.0e-4

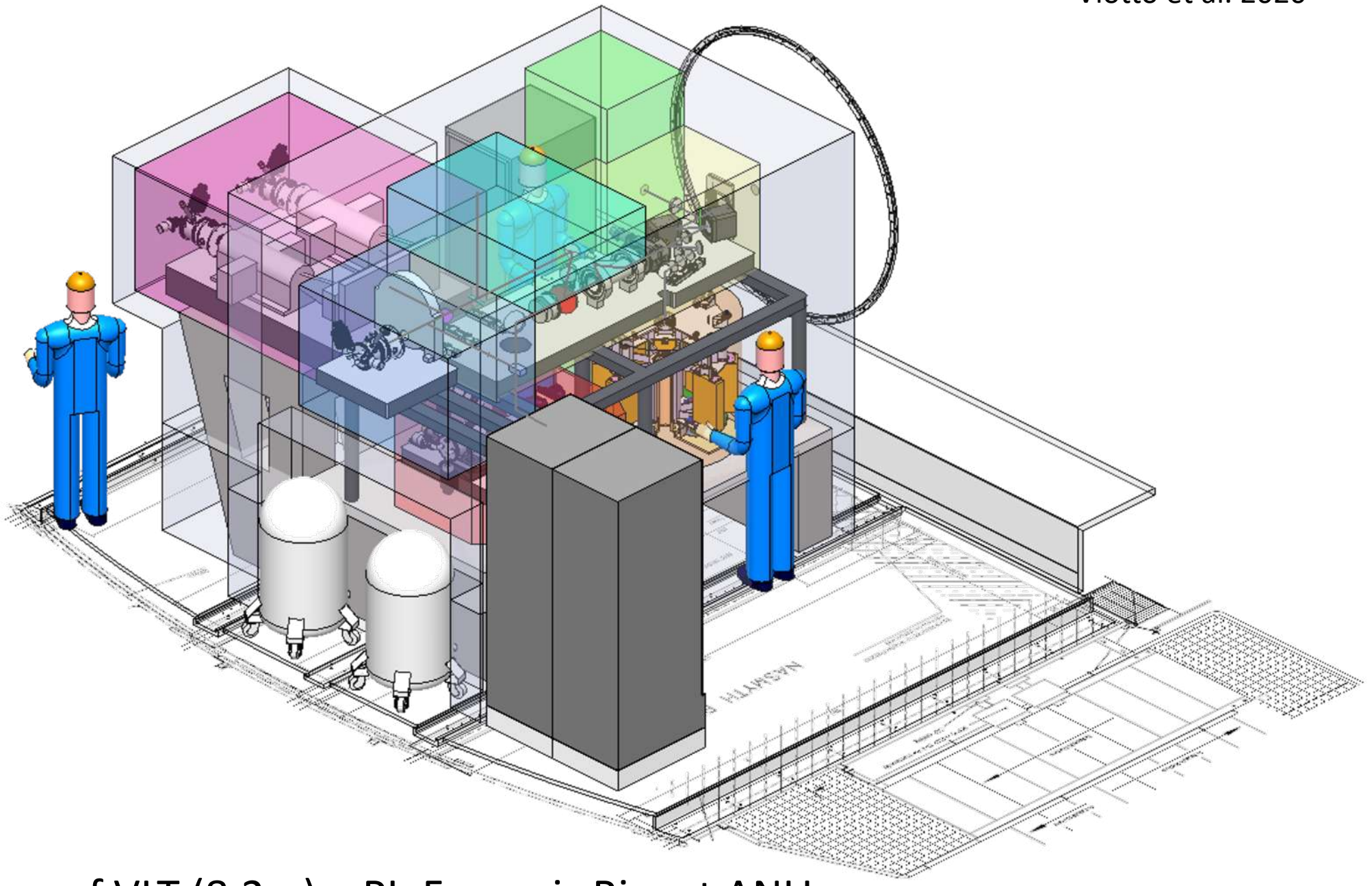






MAVIS

Viotto et al. 2020



- MCAO
- Assisted
- Visible
- Imager and
- Spectrograph
- Vis & Nasmith focus of VLT (8.2m) – PI: Francois Rigaut ANU

WHAT IS MAVIS?

MCAO

ASSISTED

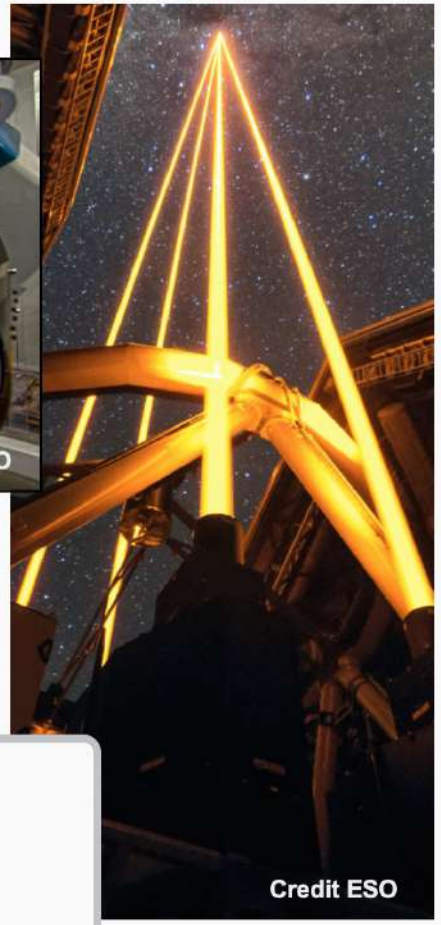
VISIBLE

IMAGER &

SPECTROGRAPH

Uses VLT UT4 AO Facility

- Existing deformable secondary
- Existing laser guide star facility



AO Module

- **Visible** (VRI, UB goal)
- **30"** Ø field of view corrected
- FWHM ≈ **20mas** (V band)
- Strehl ratio > **10%** (V band)
- Sky coverage > **50%** @ Gal. pole

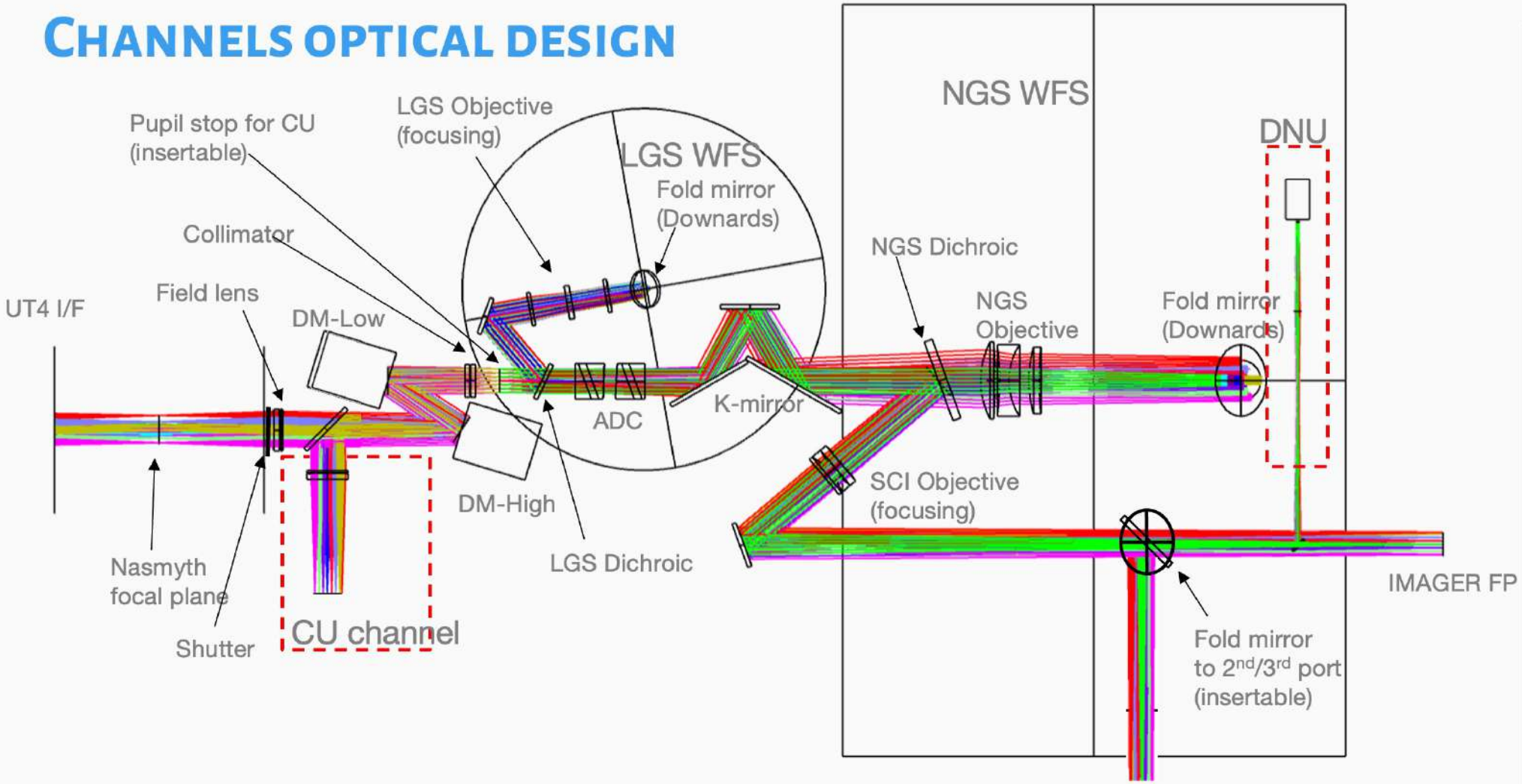
IFU Spectrograph

- **25 mas and 50 mas spaxels**
  - 3"x3" and 6"x6" FoV respectively
- **~5000 and ~12000** spectral resln modes
- 4 interchangeable VPH gratings

Imager

- 30"x30" FoV
- 7mas/pixel
- Wide + narrow band filters

CHANNELS OPTICAL DESIGN



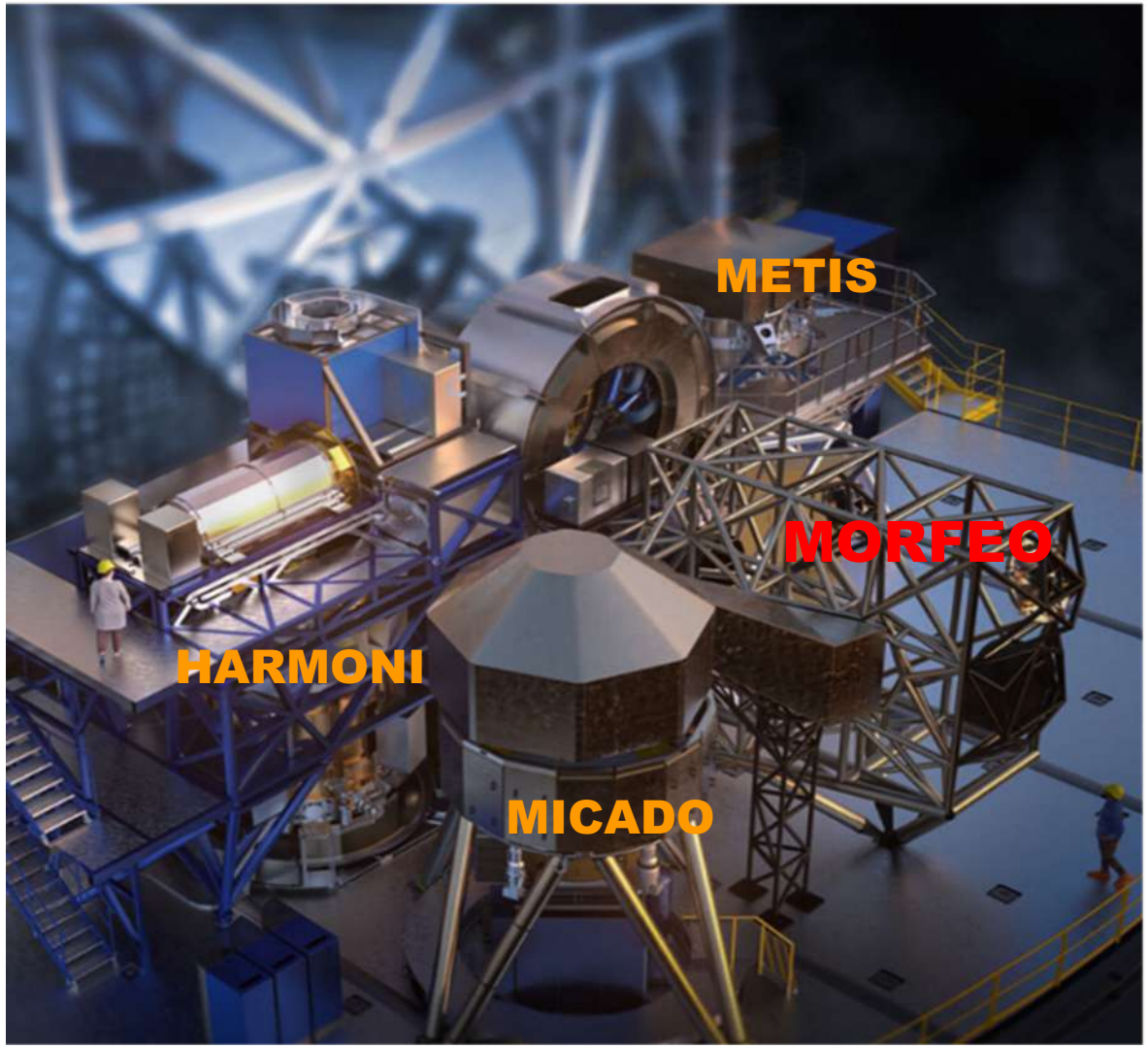
Things to consider while implementing AO:

- Define AO concept parameters
- LGS/NGS/SCI FoV derotation scheme
- LGS focusing mechanism
- Minimize # of optical elements
- Channels splitting (transmission)
- Wavebands selection
- NGS WFS FoV (trade-off with sim. perform. results)
- NCPA minimization
- Stability
- Calibrations

MORFEO (former MAORY)

Ciliegi et al. 2022

Multiconjugate adaptive Optics Relay For ELT Observations



- NIR & ELT (39m) – PI: Paolo Ciliegi INAF

MCAO operational concept

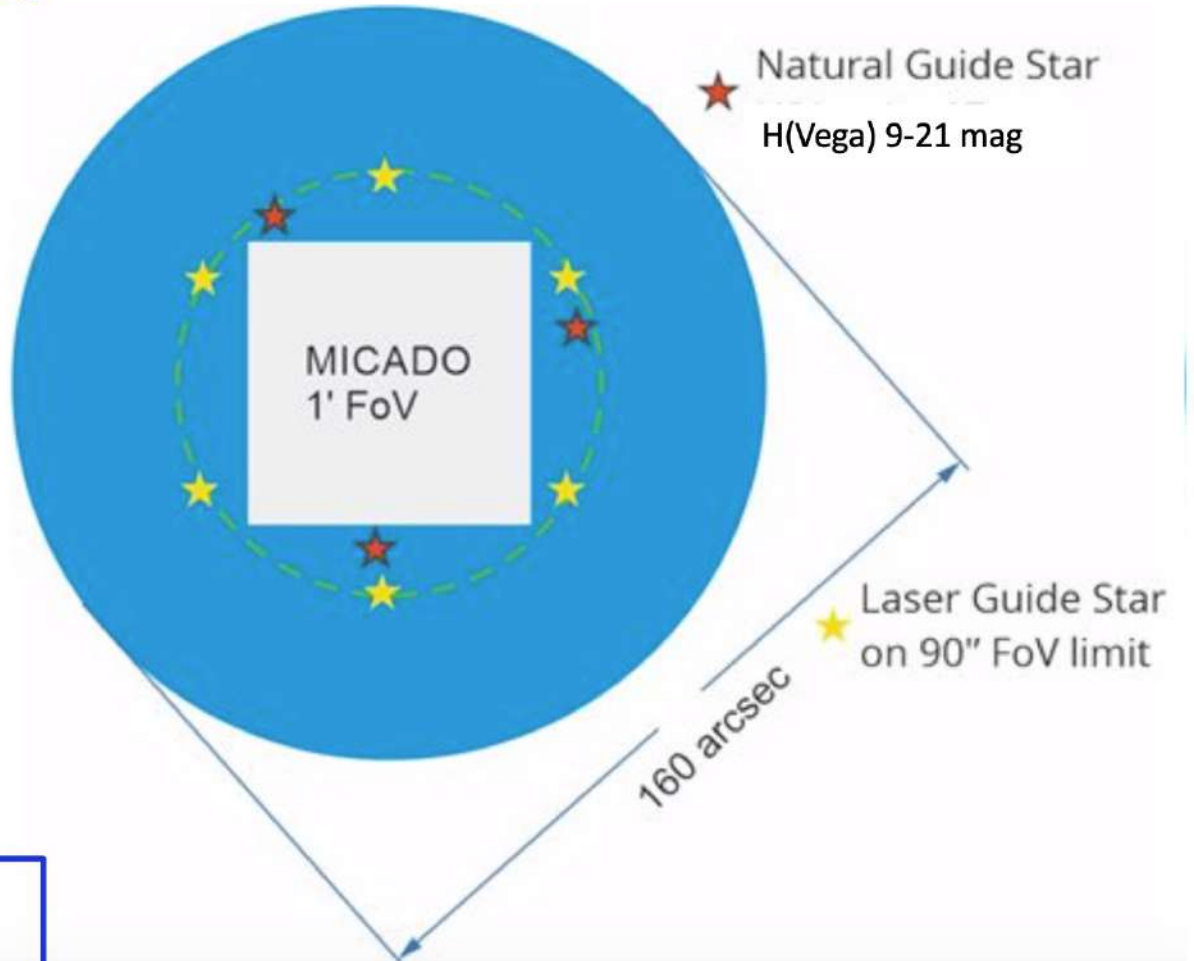
- Three natural guide stars (NGS; R<24, H<21)
- Up to six laser guide stars (LGS)

MCAO

- For comparison, **SCAO** requires 1 NGS with R<16

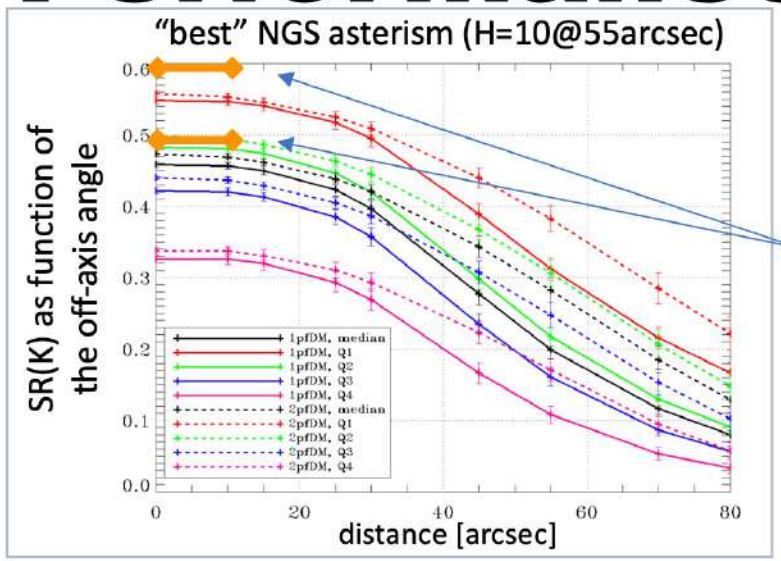
MCAO provides much larger **sky coverage**
(≳ 50%, MAORY requirements)

selection of targets based primarily on astrophysical rather than on technical criteria

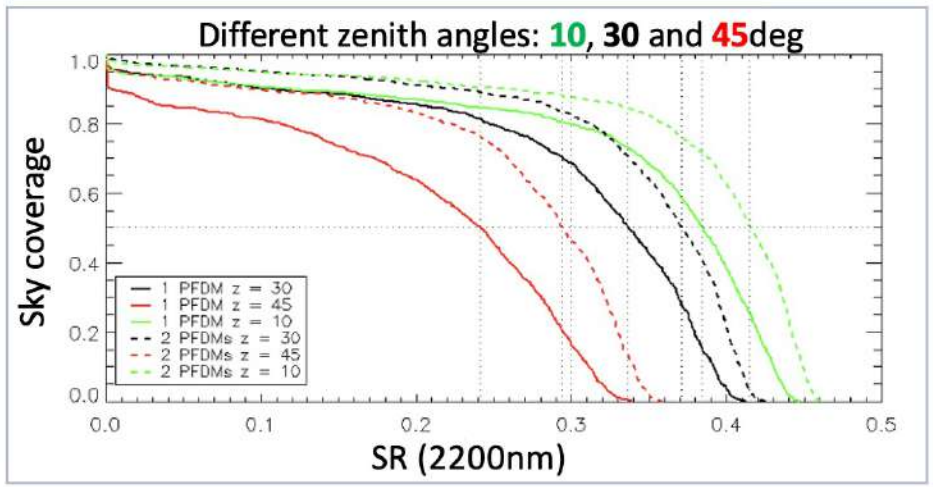


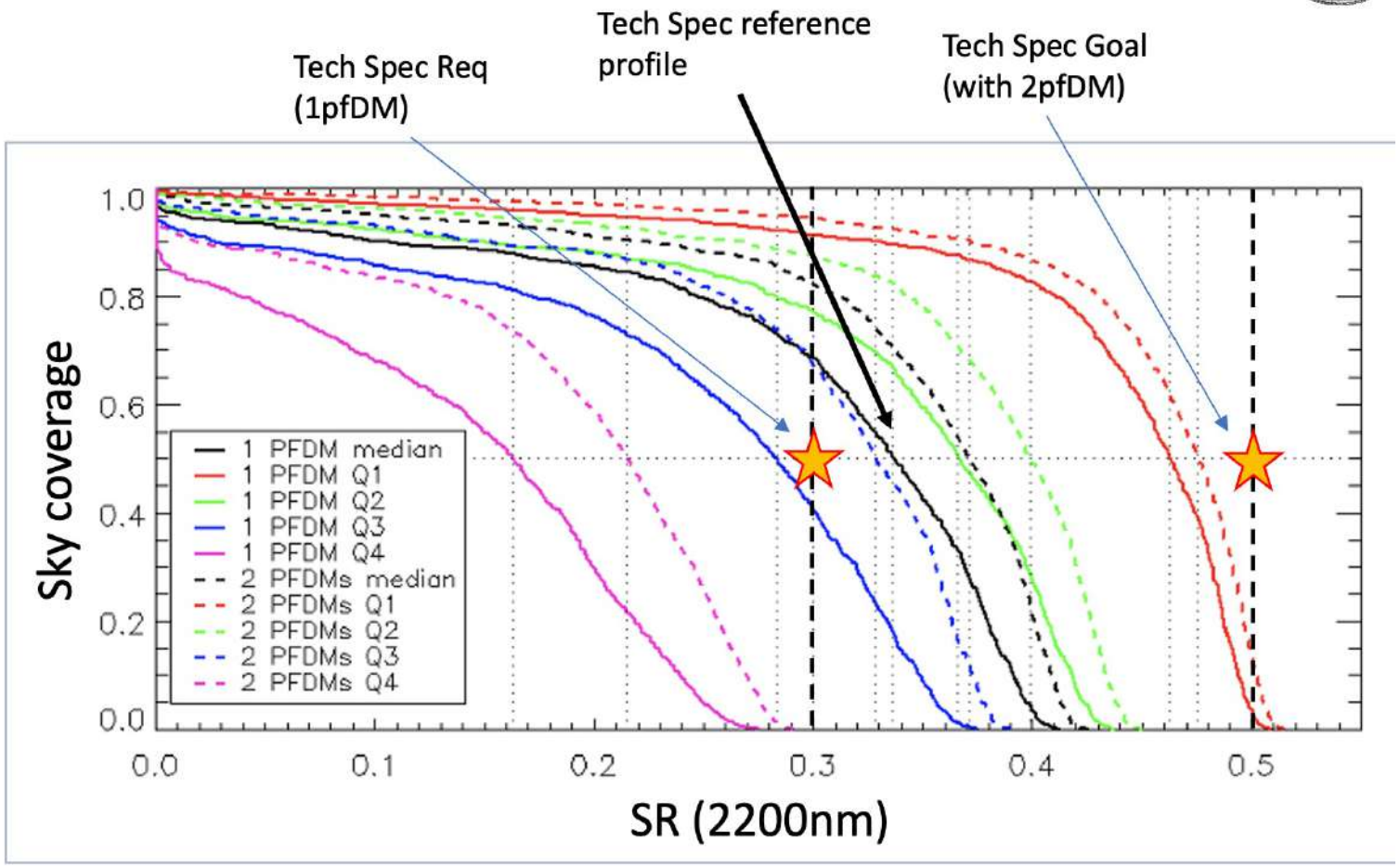
Performance

The SR measures the intensity profile reached at the peak of the PSF and it is directly proportional to the energy concentration within the diffraction limited core



Q1 Tech Spec Req and Goal





A system with a single DM is capable of delivering a SR well above 30% at 50% of sky coverage, while the presence of the second post focal DM (dashed lines) is fundamental to push the system toward maximal performance and higher robustness to varying atmospheric and observing conditions.

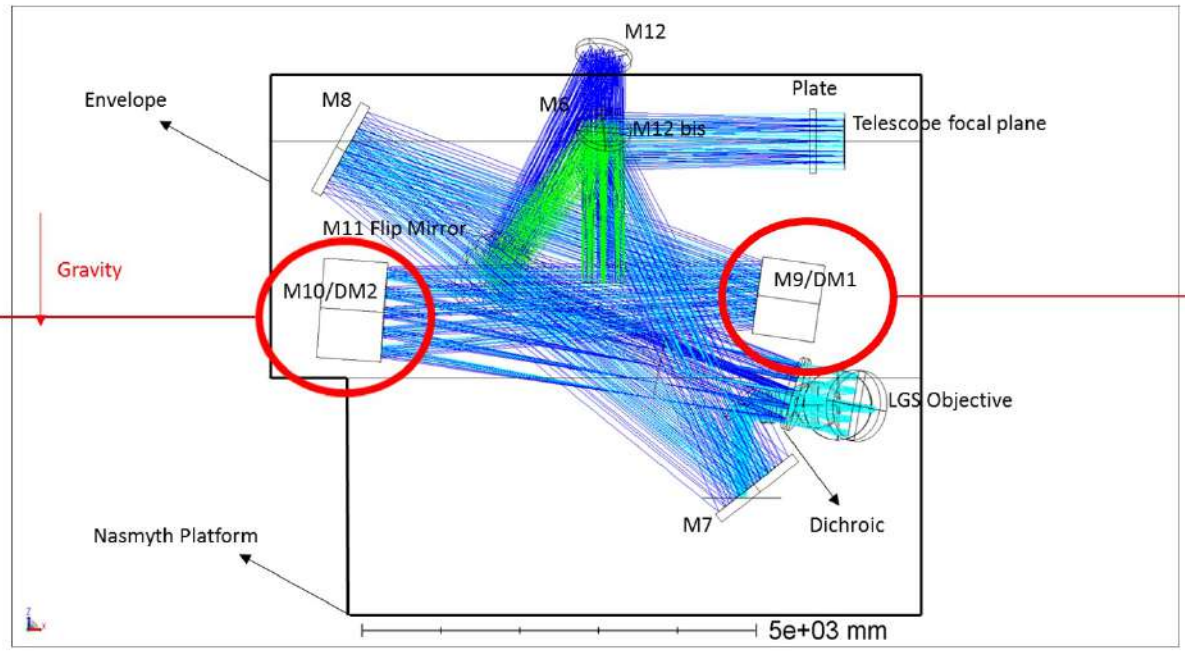
MAORY OPTICAL BASELINE

SECOND DM
Concave Spherical mirror
Diameter 1225 mm
Actuators : 1147 VCM
Conjugate at 6.5 KM

Not present in the baseline and not included in the original budget.

It will be replaced with a monolithic mirror

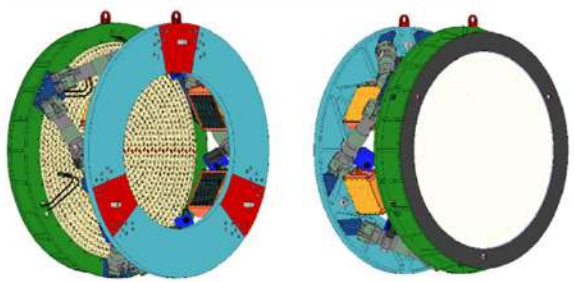
Available as an upgrade path

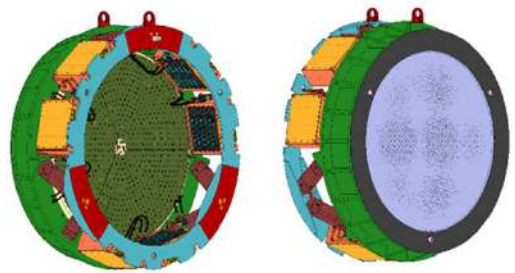


FRONT VIEW

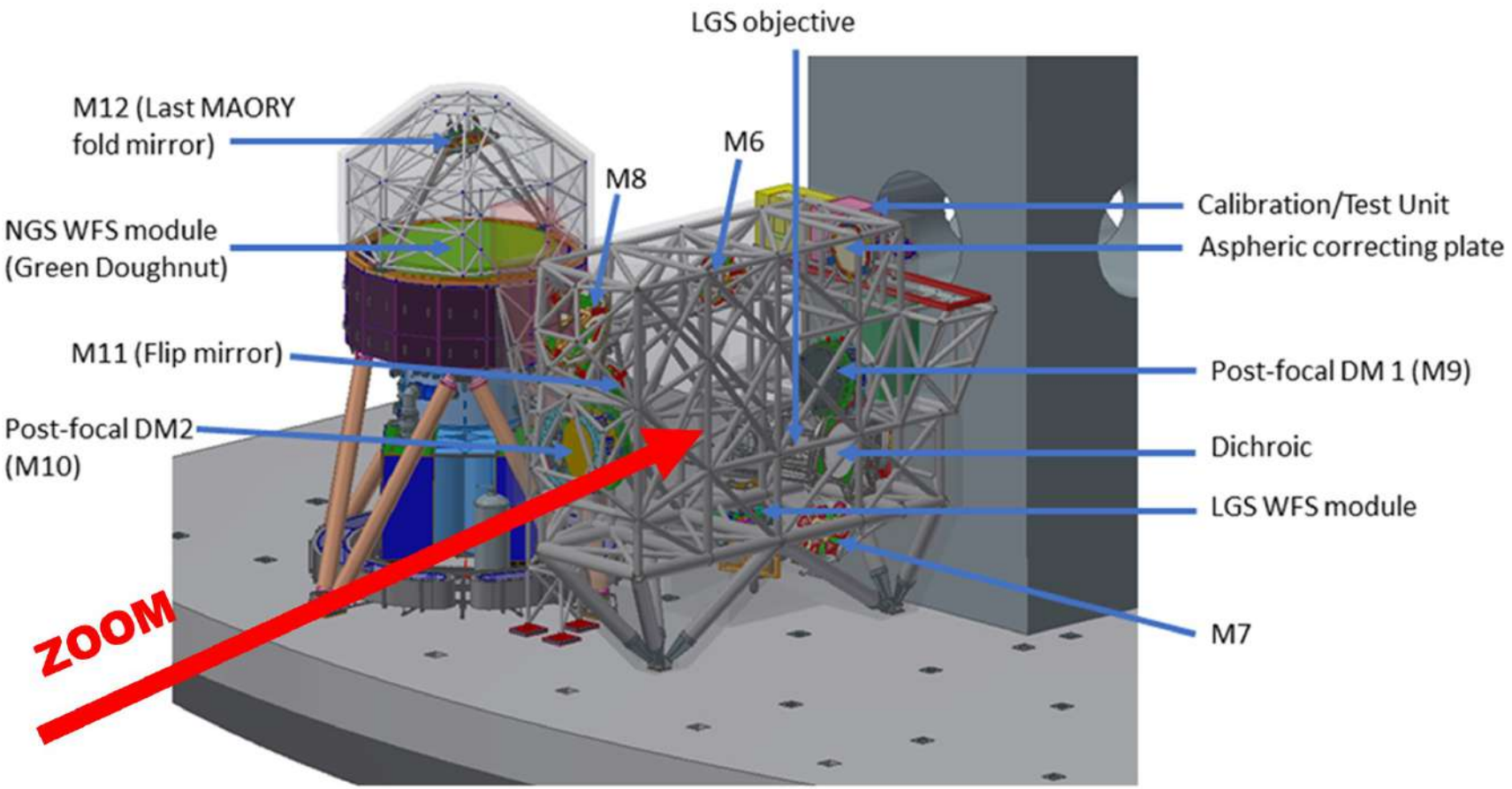
FIRST DM
Convex spherical mirror
Diameter 928 mm
Actuators : 1026 VCM
Conjugated at 17.5 Km

Present in the baseline





Come è fatto ?



MORFEO userà 9 stelle di guida (3 stelle reali, 6 laser), sensori di fronte d'onda di ultima generazione e 3 specchi deformabili per misurare e correggere la turbolenza a 3 differenti altezze nell'atmosfera

La distorsione della luce causata dalla turbolenza atmosferica verrà misurata usando nuovi sensori capaci di fare osservazioni centinaio di volte al secondo

MORFEO usa 7 grandi specchi (di cui 2 DM) per trasportare la luce dal piano focale del telescopio a quello di MICADO (o altro strumento). I sensori di fronte d'onda NGS sono fisicamente attaccati a MICADO per massimizzare le performance scientifiche.

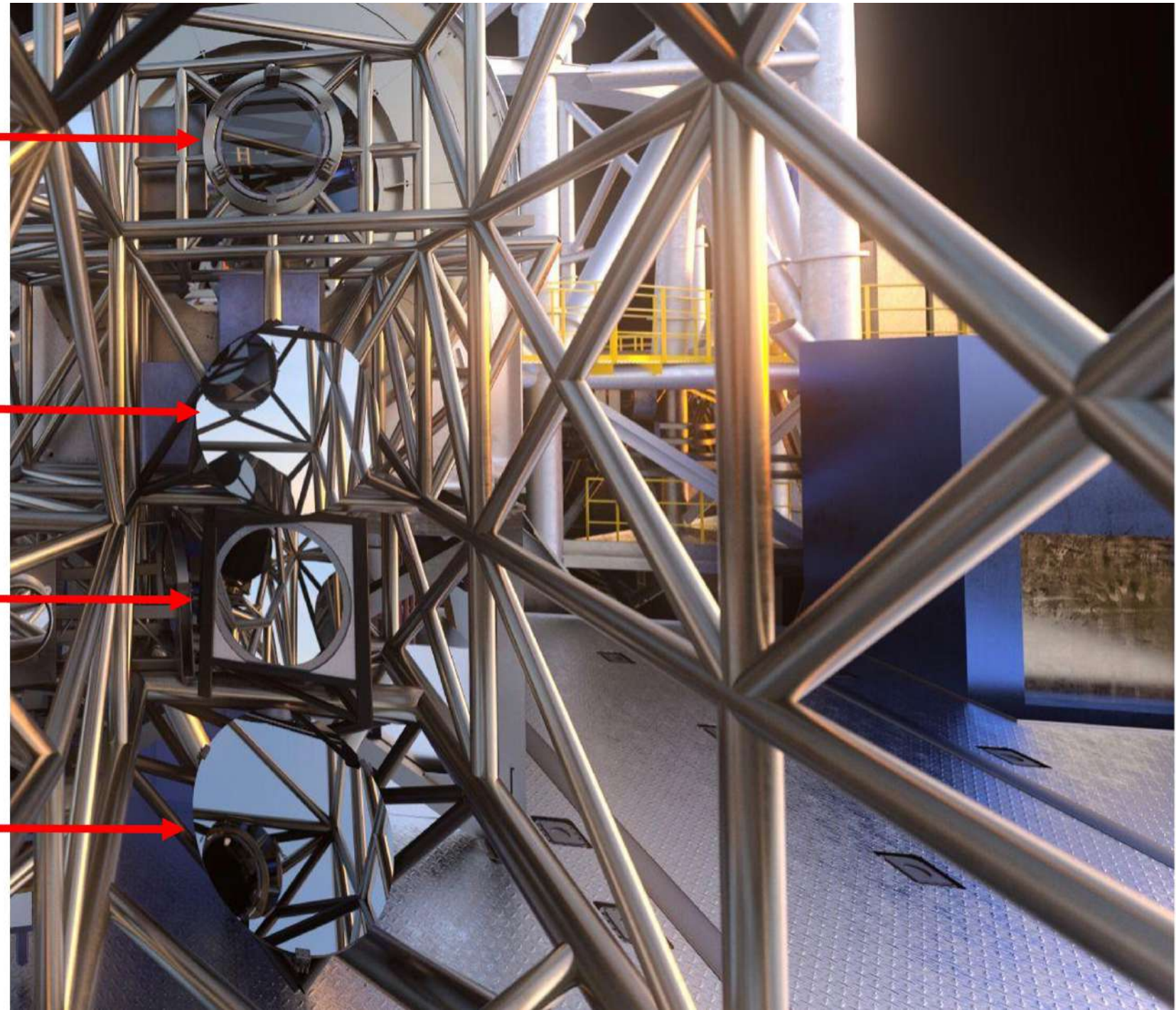
Un dicroico nel cammino ottico separa la luce dei laser inviandola al modulo LGS WFS mentre la luce ottica - infrarossa viene mandata agli strumenti scientifici e al sensore di stelle naturali

Aspheric
Correcting Plate

Primo SPECCHIO DEFORMABILE

DICROICO

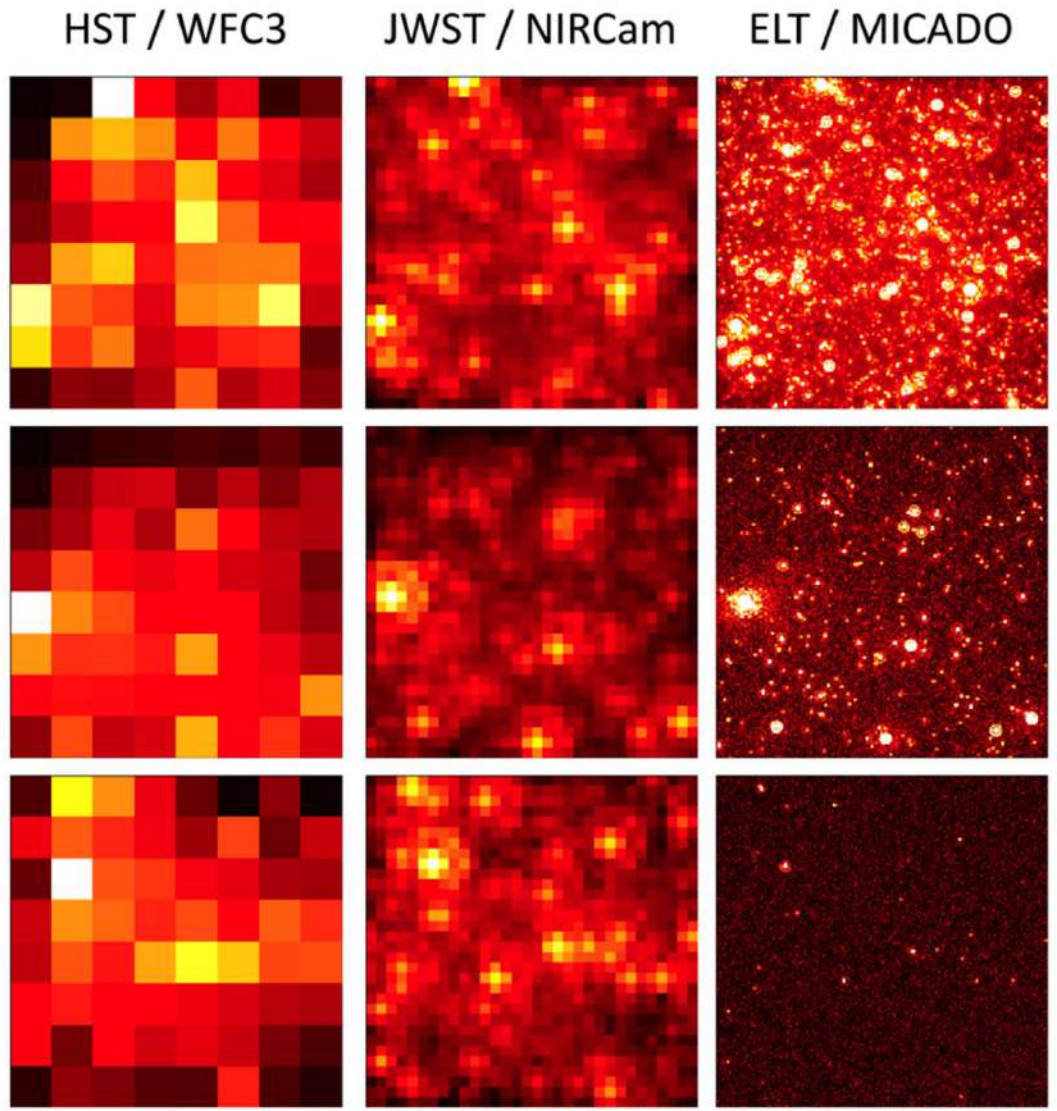
SPECCHIO M7



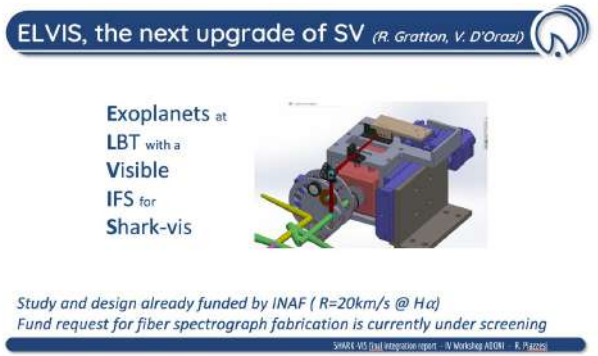
MORFEO - MICADO : CASI SCIENTIFICI

WHITE BOOK preparato dalla Science Team

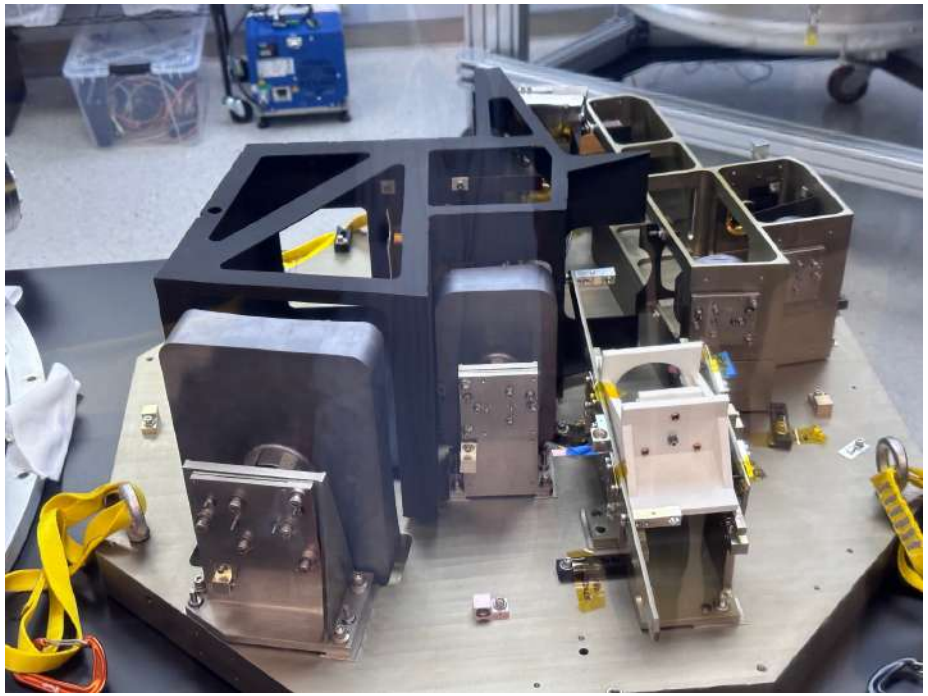
Verrà aggiornato in 2-3 anni per tener conto delle osservazioni e scoperte di James Webb



…when images are diffraction limited, spectrograph (and fiber-fed ones especially) do not necessarily scale with the diameter of the aperture….

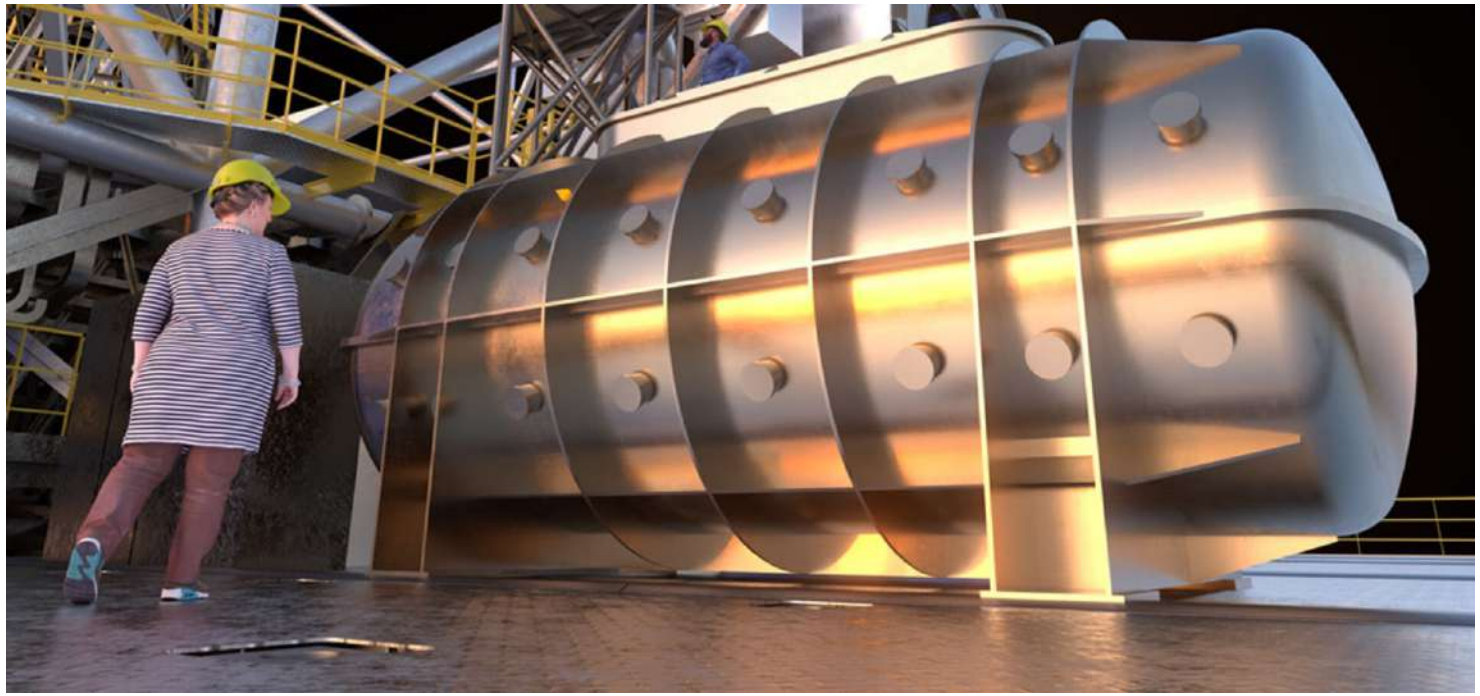


iLOCATER



- LBT 8.4m
- PI: Justin Crepp - UniND

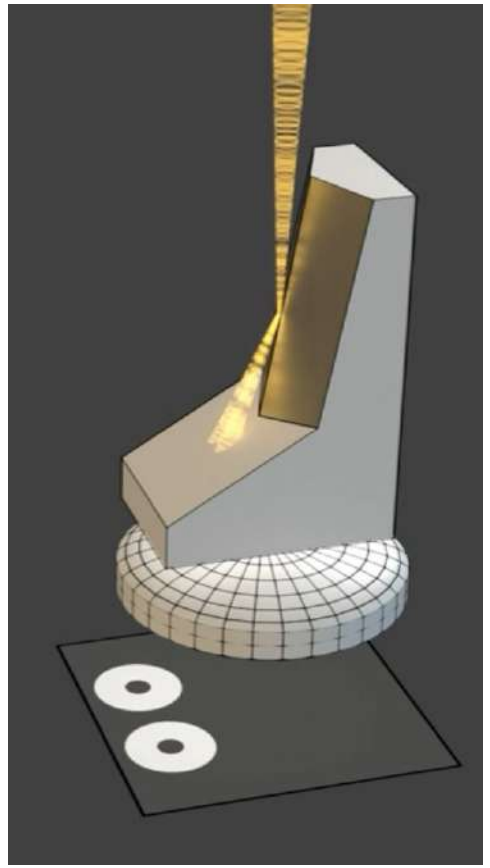
ANDES



- ELT 39m
- PI: Alessandro Marconi - UniFI

Adaptive Optics (what is next…???)

- Lacking (but working on it) a niche of intermediate pitch in DM's actuators
- Still missing "light-through" compensator
- WFS on LGS is "a new world"
  - Z-Invariant
  - Ingot-like
  - Dynamical refocusing
- Photon lanterns & integrated technologies
- CMOS technology is finally mature enough…!!!

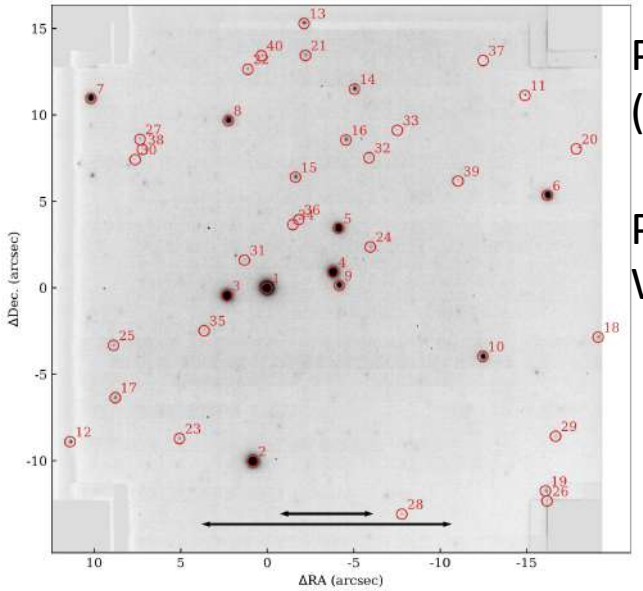


Interferometry

- Speckle
- Conventional
- Intensity
- Etherodyne

Interferometry

- Speckle



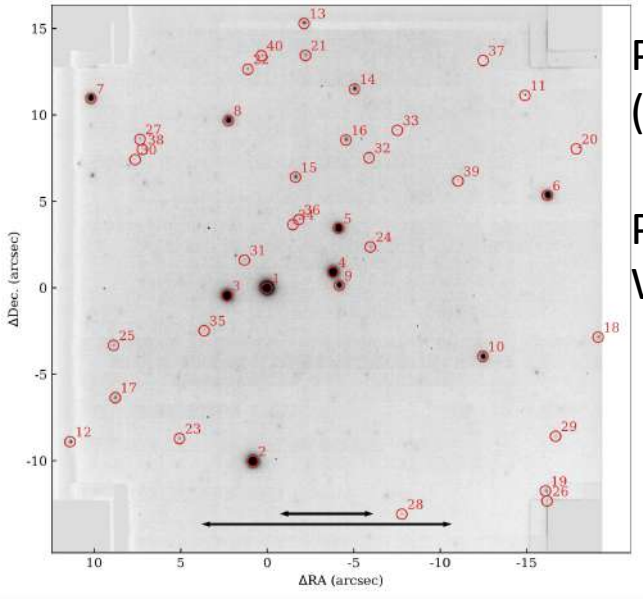
Post-AO speckle holography (visible and/or wide fields…??)

Possible follow-up on L-N@LBT Within the PNRR-STILES frame.

- Conventional
- Intensity
- Etherodyne

Interferometry

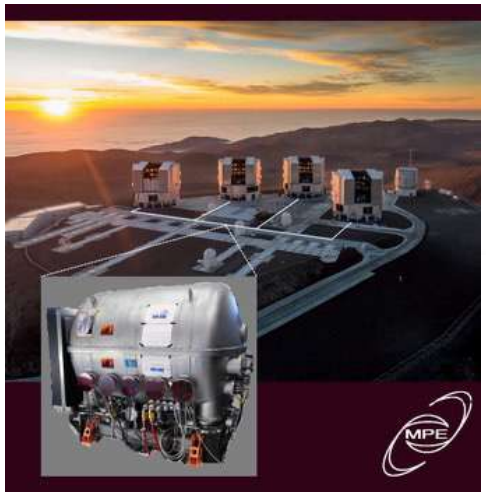
- Speckle



Post-AO speckle holography (visible and/or wide fields…??)

Possible follow-up on L-N@LBT Within the PNRR-STILES frame.

- Conventional



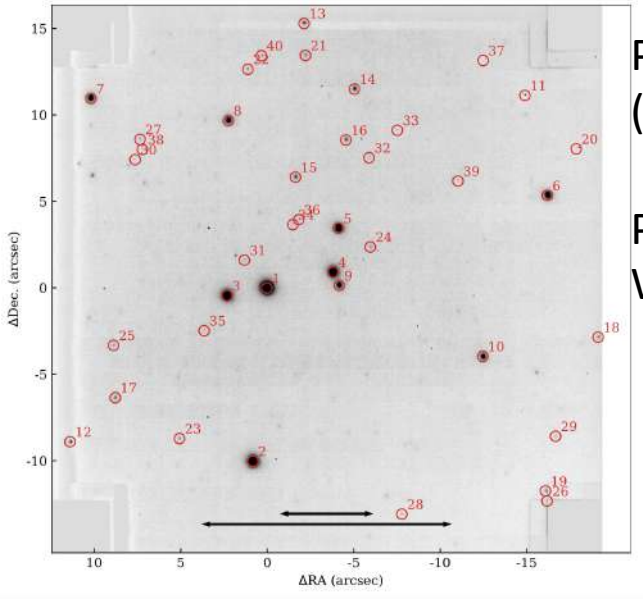
Gravity@VLTs

- Intensity

- Etherodyne

Interferometry

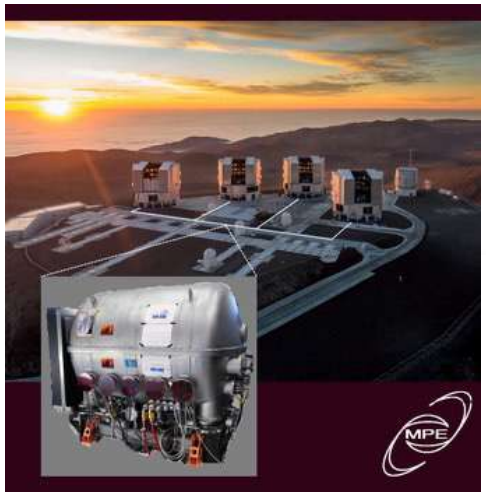
- Speckle



Post-AO speckle holography (visible and/or wide fields…??)

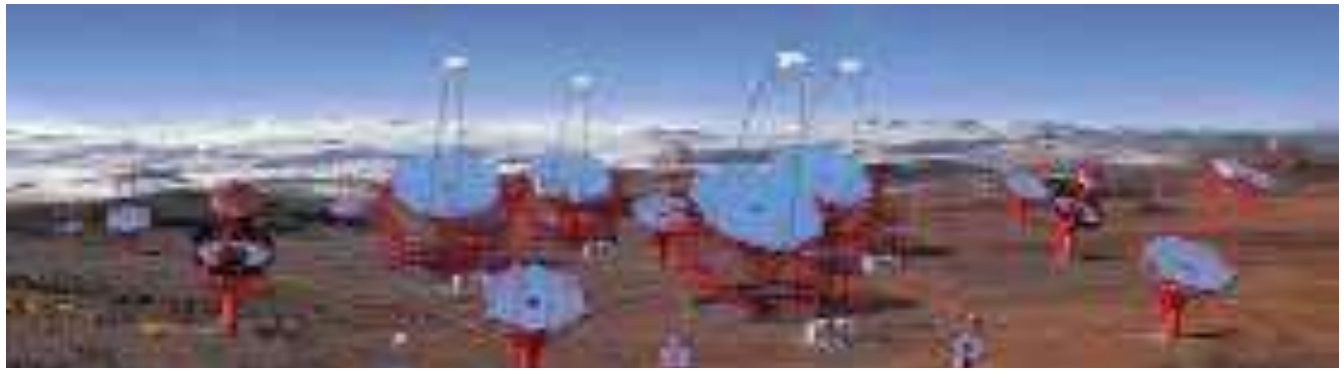
Possible follow-up on L-N@LBT
Within the PNRR-STILES frame.

- Conventional



Gravity@VLTs

- Intensity

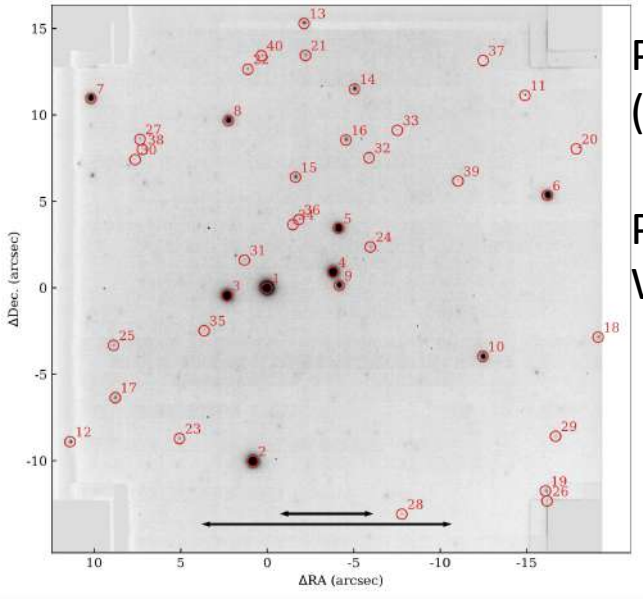


CTA

- Etherodyne

Interferometry

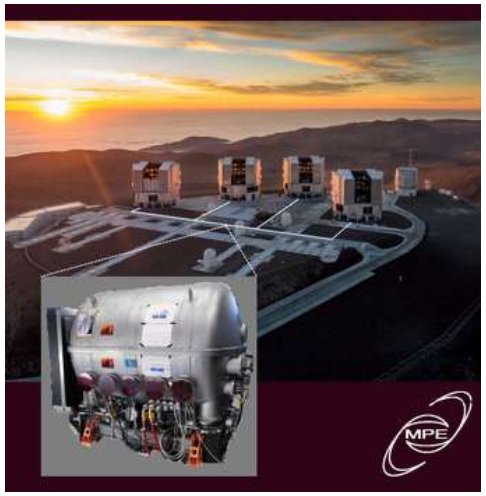
- Speckle



Post-AO speckle holography (visible and/or wide fields…??)

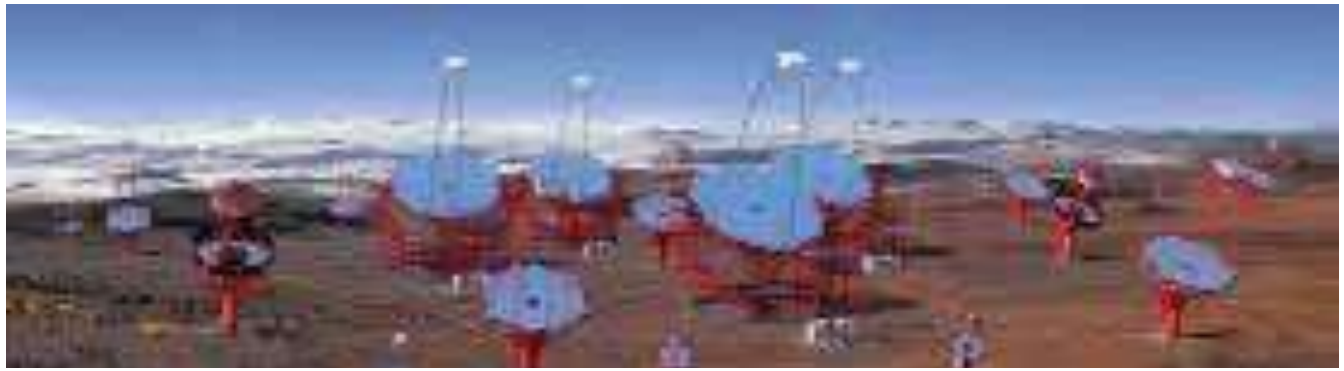
Possible follow-up on L-N@LBT Within the PNRR-STILES frame.

- Conventional



Gravity@VLTs

- Intensity



CTA

- Etherodyne

Thanks to the high-angular-resolution community

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And for the “image” thanks to my three stylists…:

O

V

S

..and to my personal armochromist…:

Leopoldo Benacchio