VLT & ELT

Elena Valenti

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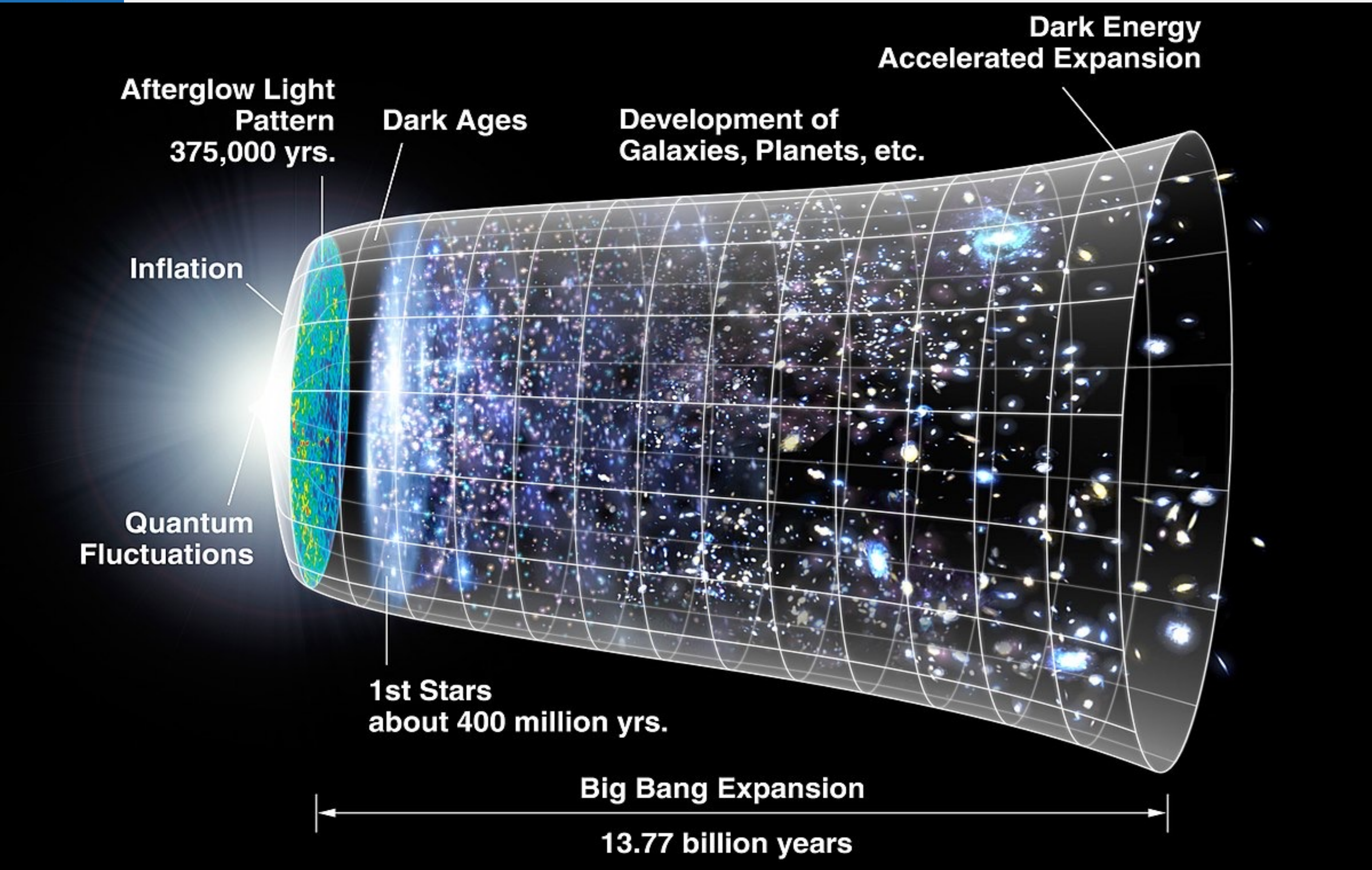
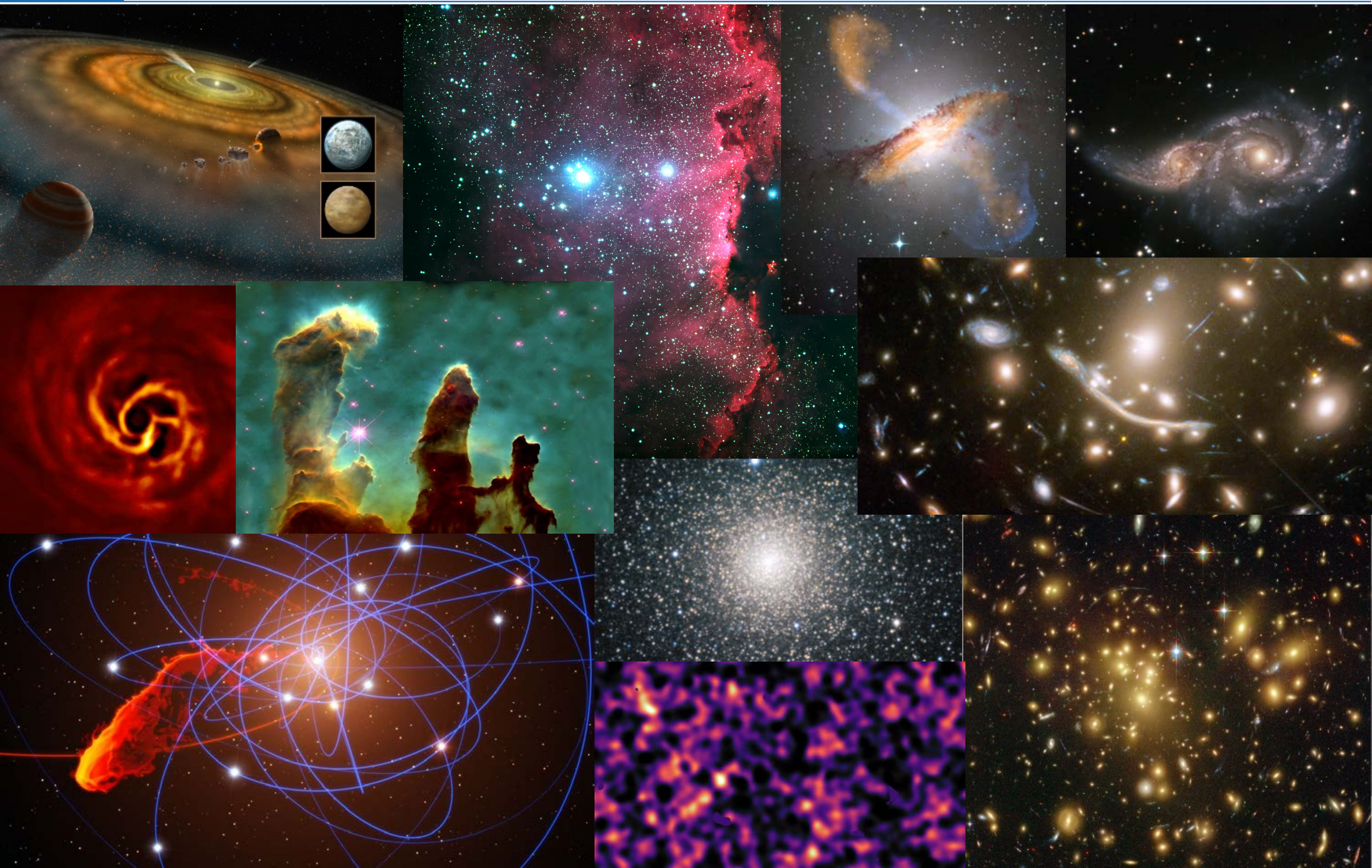
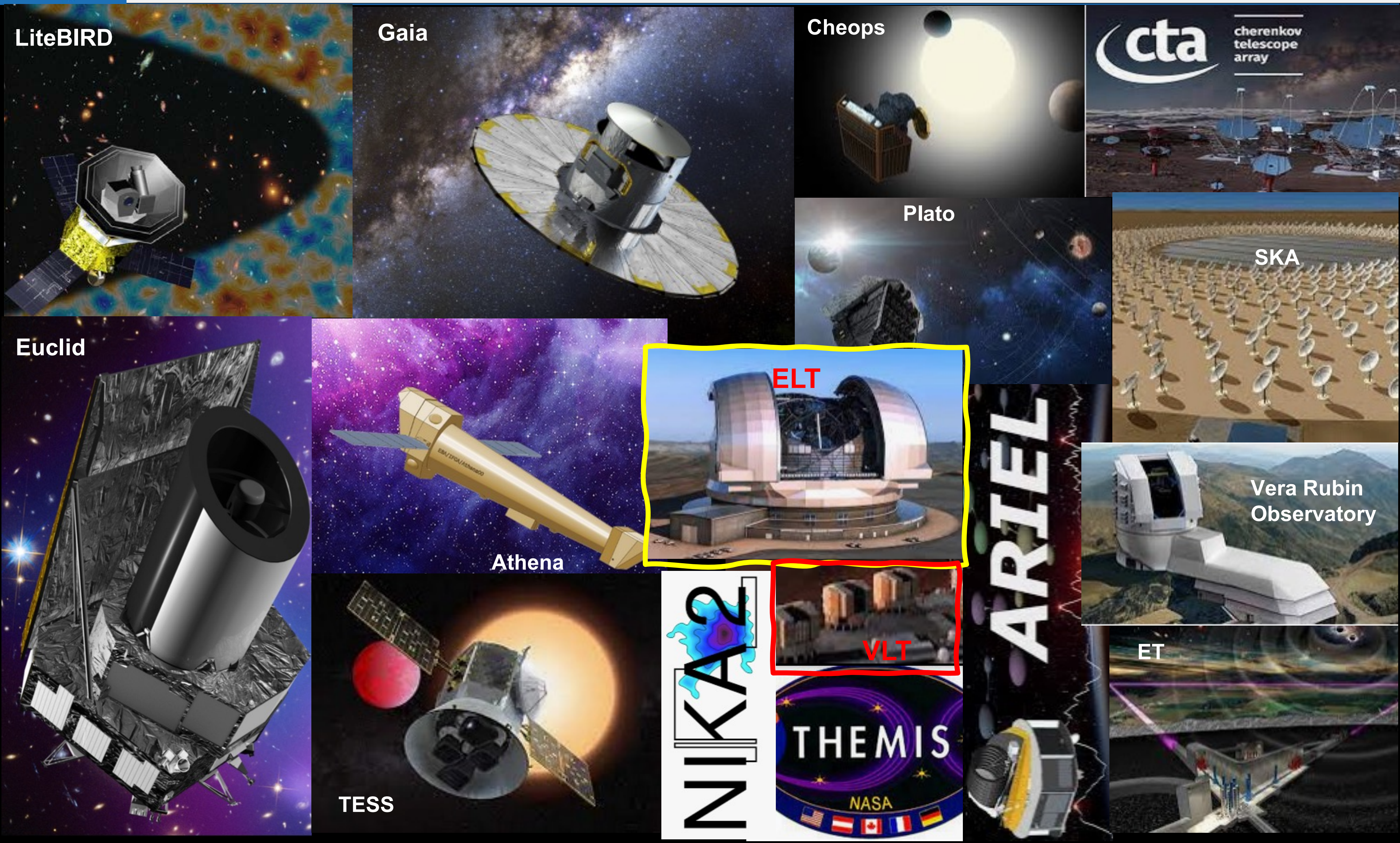
Exploring the Universe in space and time is what unites us!



Very diverse quests

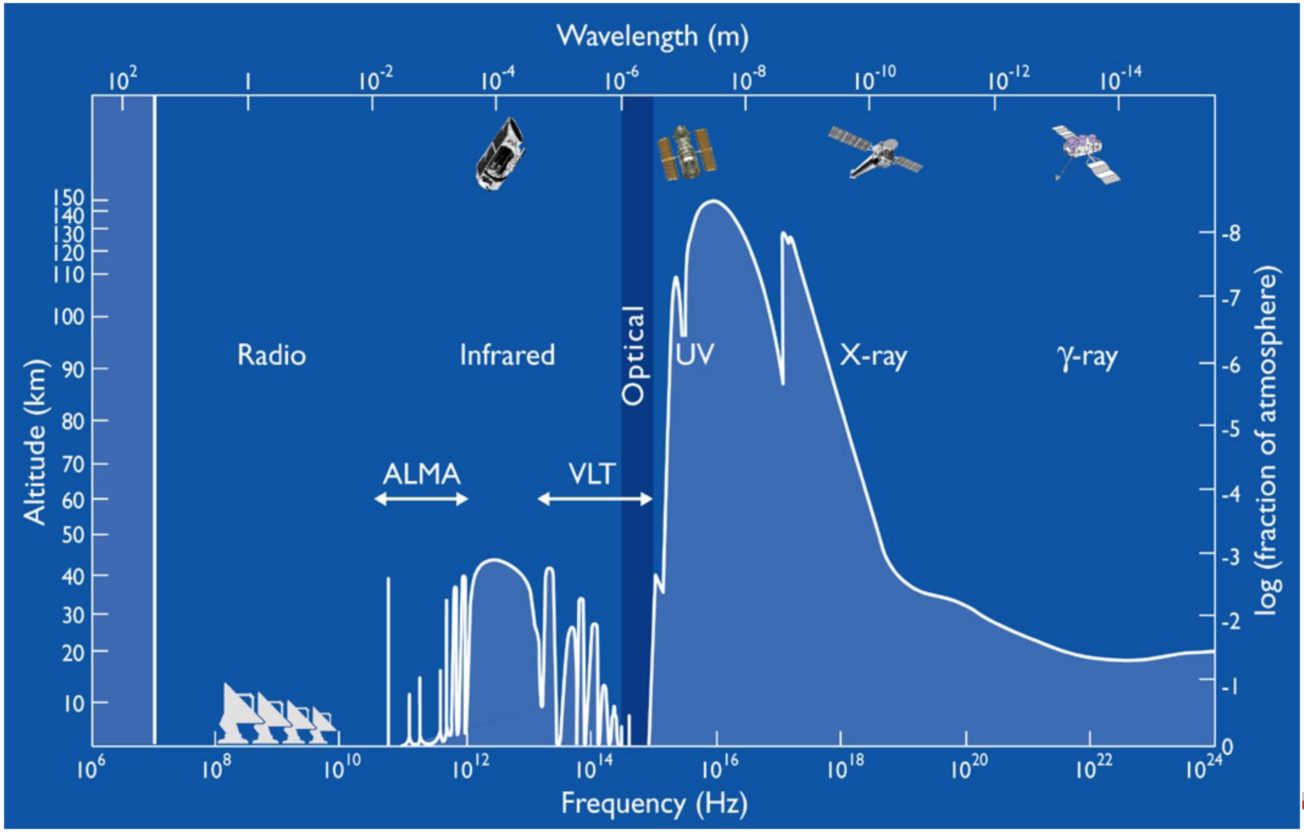


Your current & future observing tools to explore the Universe

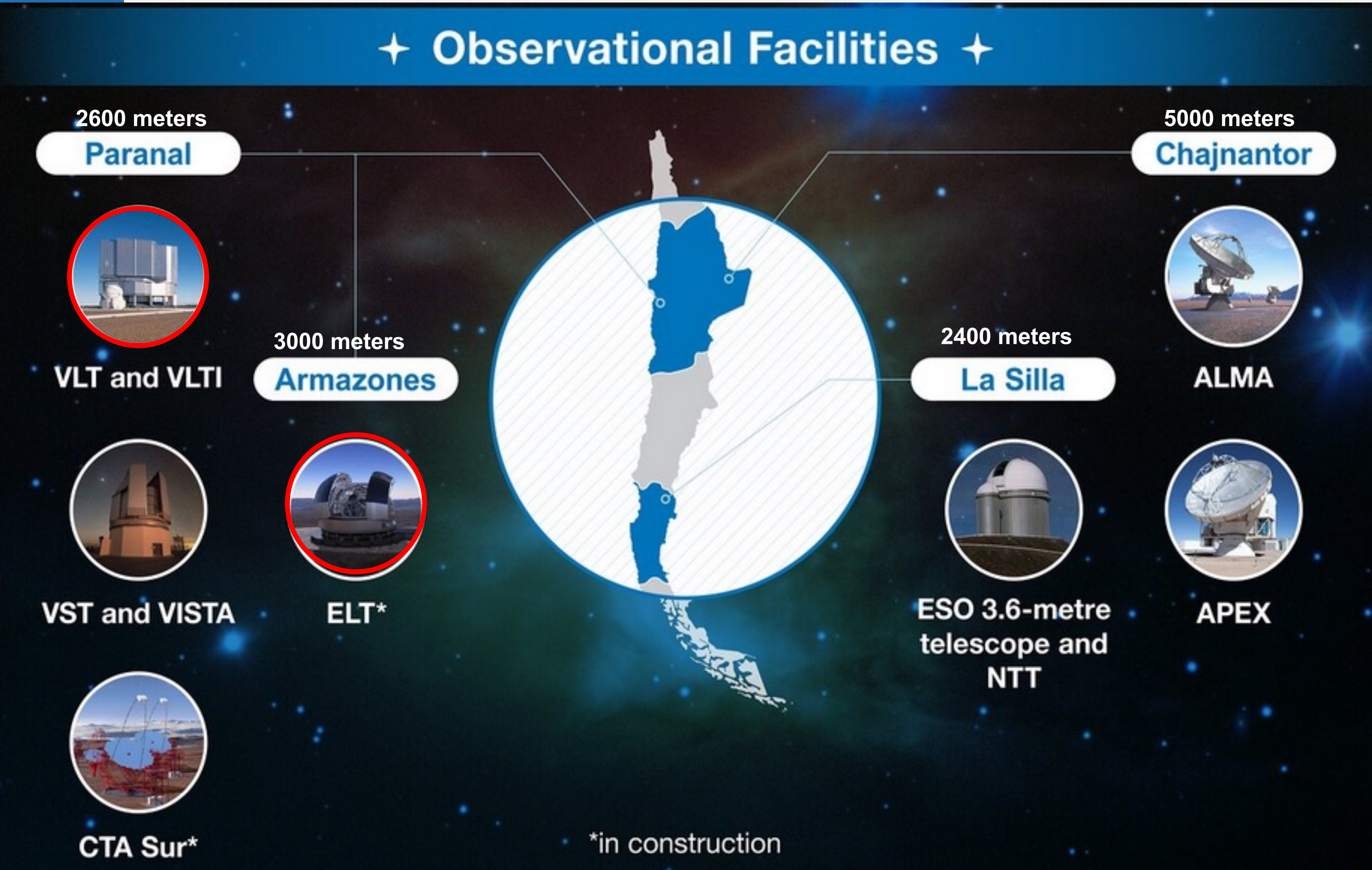


Astrophysics in the golden era

- Multi-Wavelength: full coverage of electro-magnetic spectrum
- Multi-technique approach
- Synergy and complementarity btw different observing facilities
- Access to gravitational waves!!!!

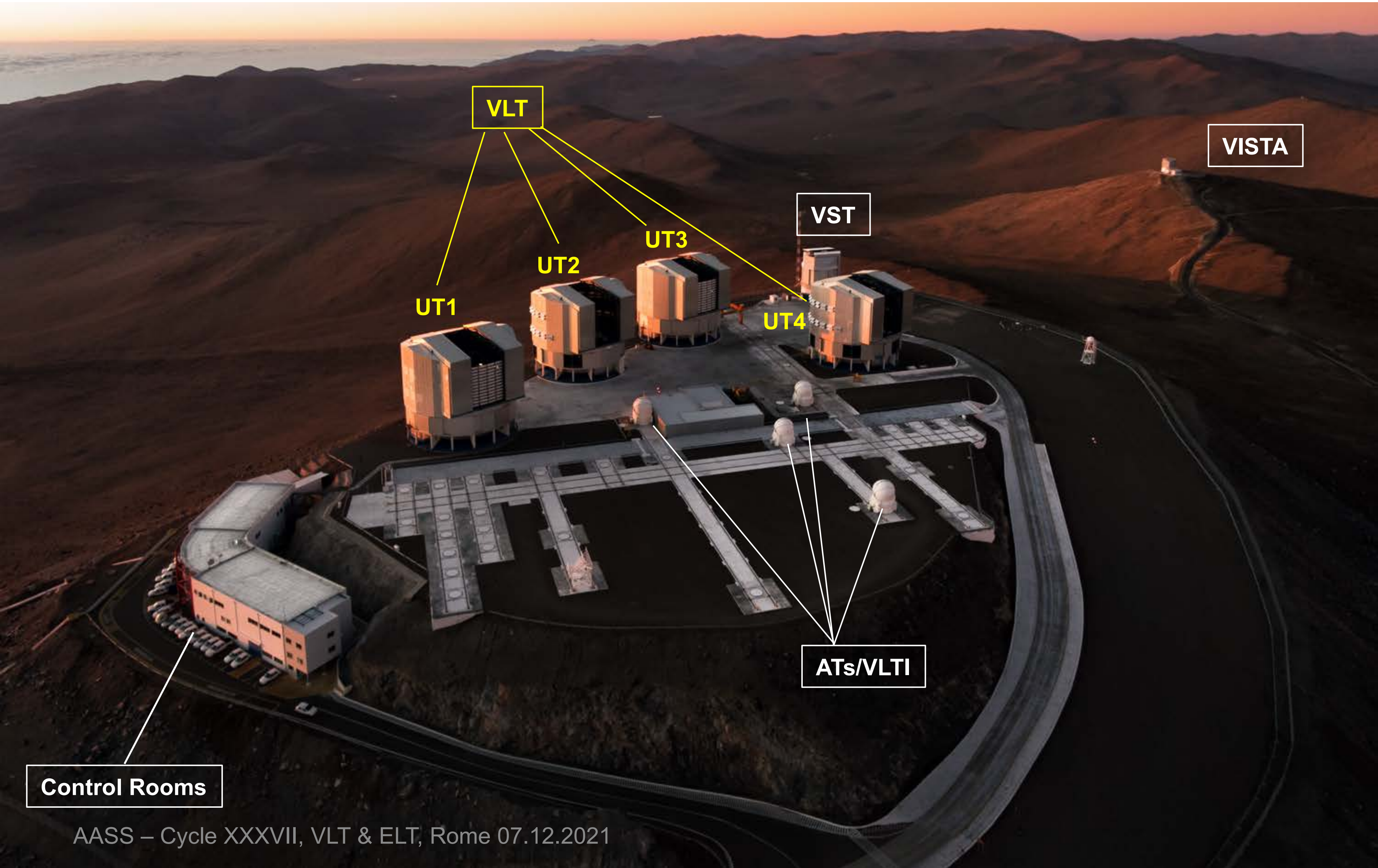


ABOUT ESO

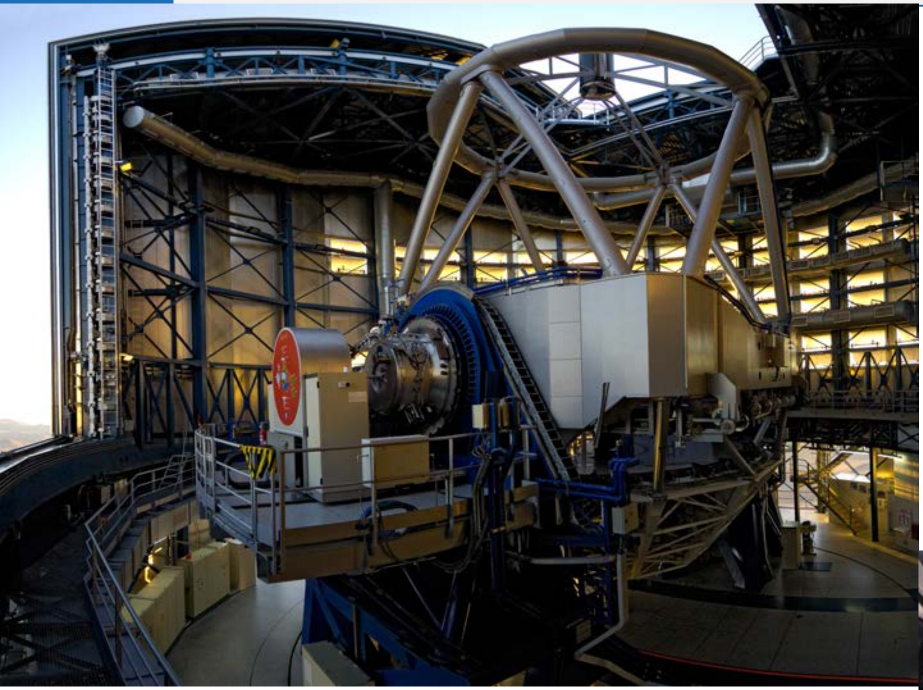


Observational Facilities
2600 meters
Paranal
VLT and VLTI
VST and VISTA
CTA Sur*
3000 meters
Armazones
ELT*
5000 meters
Chajnantor
ALMA
APEX
2400 meters
La Silla
ESO 3.6-metre telescope and NTT
*in construction

Paranal



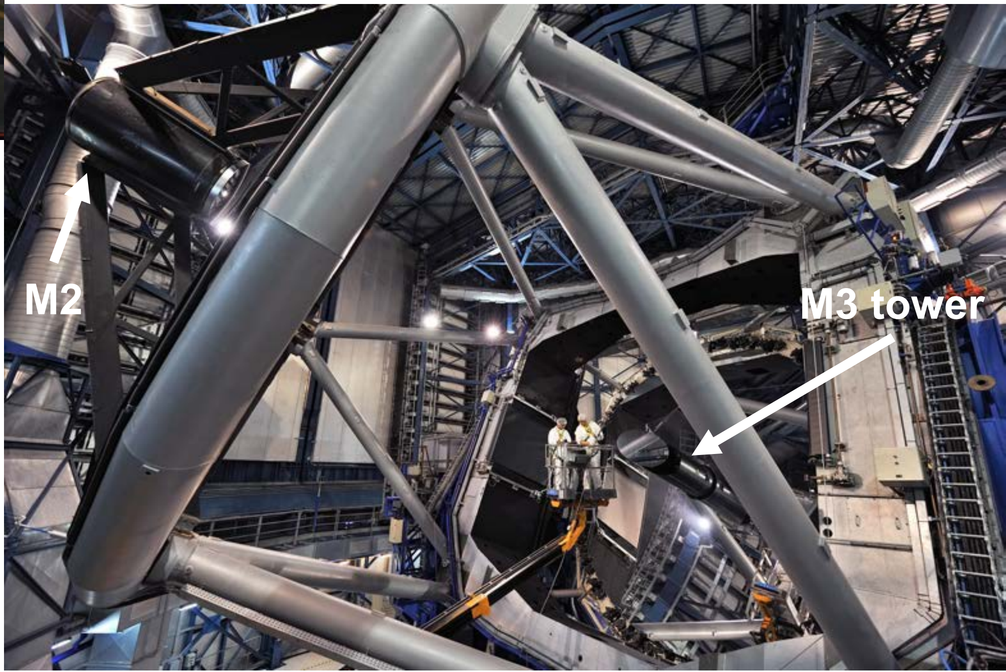
The Unit Telescope (UT)



M1: 8.2m diameter (175mm thick), actively controlled by 150 actuators

M2: 0.94m diameter

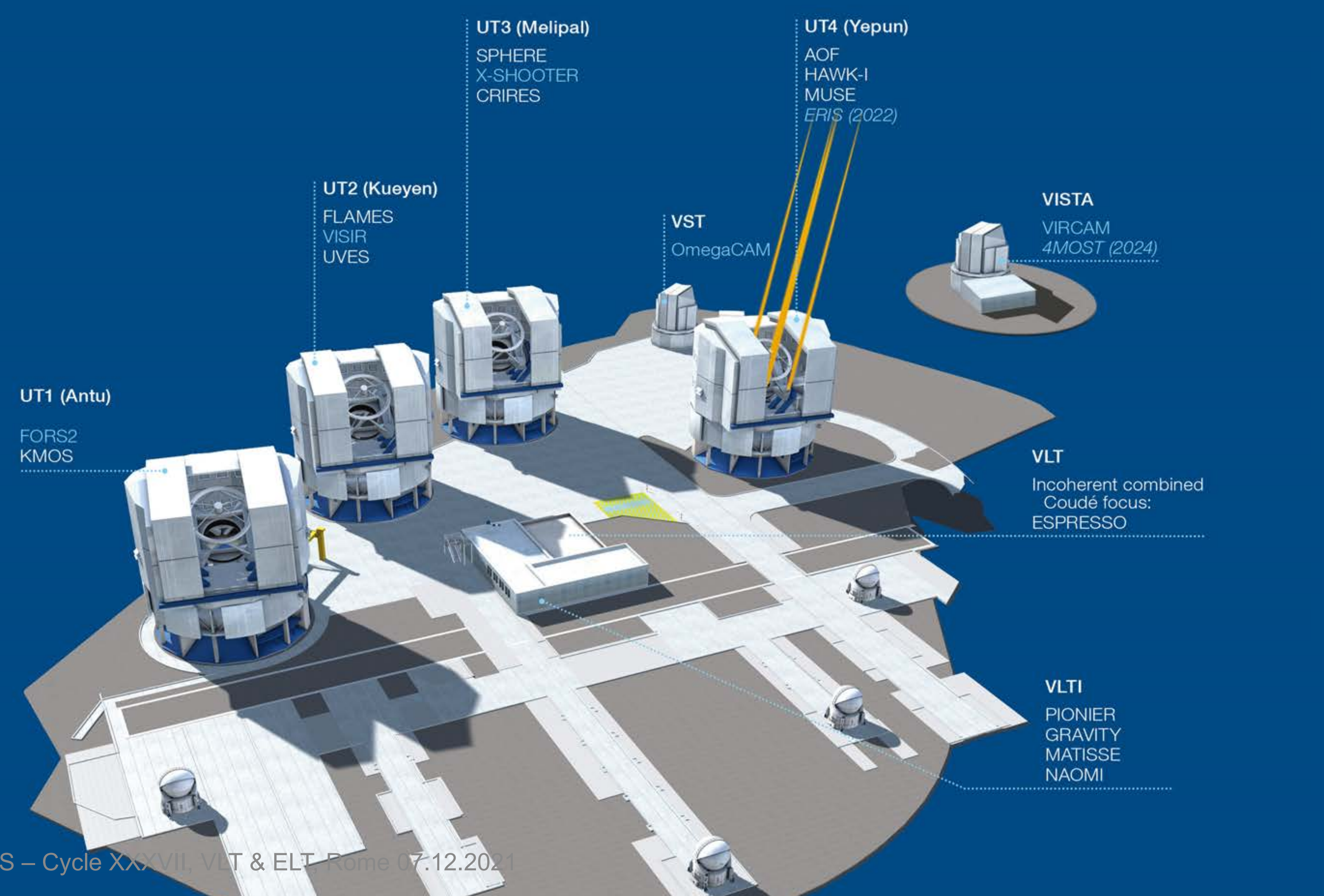
M3: 1.2x0.86m (elliptical flat)



The 3 modes of the VLT

Incoherent combined focus	Coherent combined focus (Interferometry)	Individual use of UTs
ESPRESSO	**MATISSE GRAVITY**	**FORS,KMOS XSHOOTER,MUSE SPHERE,HAWKI…**

The VLT in 2021

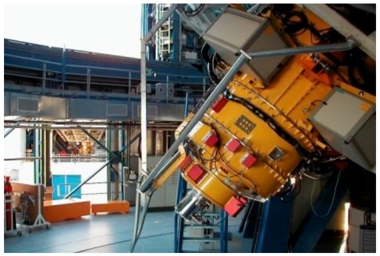


The VLT instruments in 2021

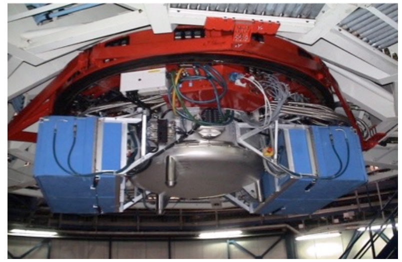
UT1 | UT2 | UT3 | UT4

Cassegrain focus

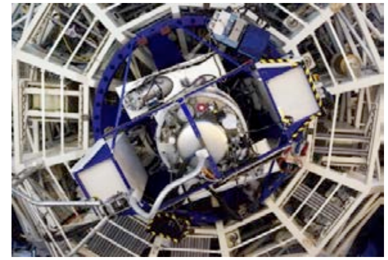
FORS2



VISIR



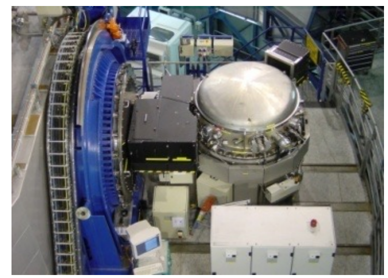
XSHOOTER



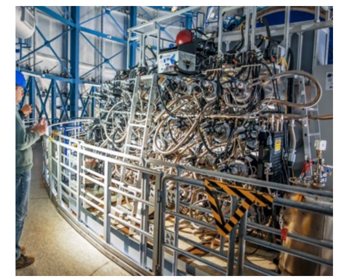
Nasmyth foci

UVES

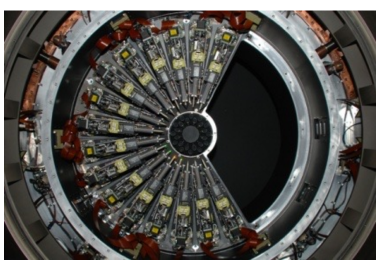
CRIRES+



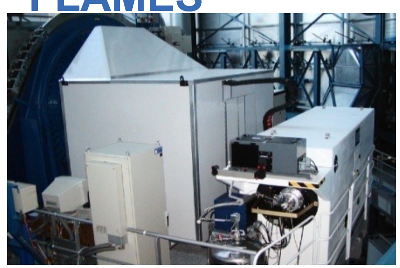
MUSE



KMOS



FLAMES



SPHERE

HAWKI

Incoherent Combined Coude focus

espresso

Coherent combined focus

Coming next .....

FORS upgrade

ERIS

MOONS
Multi Object Optical and
Near-infrared Spectrograph

MA
VIS

GRAVITY+

CUBES

BLUE muse
multi unit spectroscopic explorer

Coming next …..

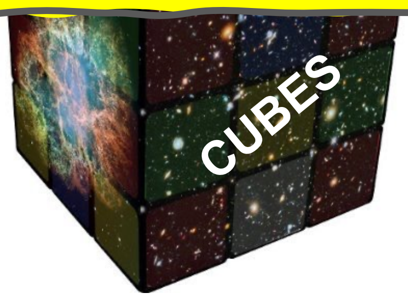
12+7 VLT instruments !!

Several working wavelength range!!

Tenths of different modes !!

Seeing and/or diffraction limited

- Imaging
- Coronagraphy (HCI, ADI)
- Single-object slit spectroscopy
- Multi-object spectroscopy
- IFU
- Polarimetry (Ima & Spec)

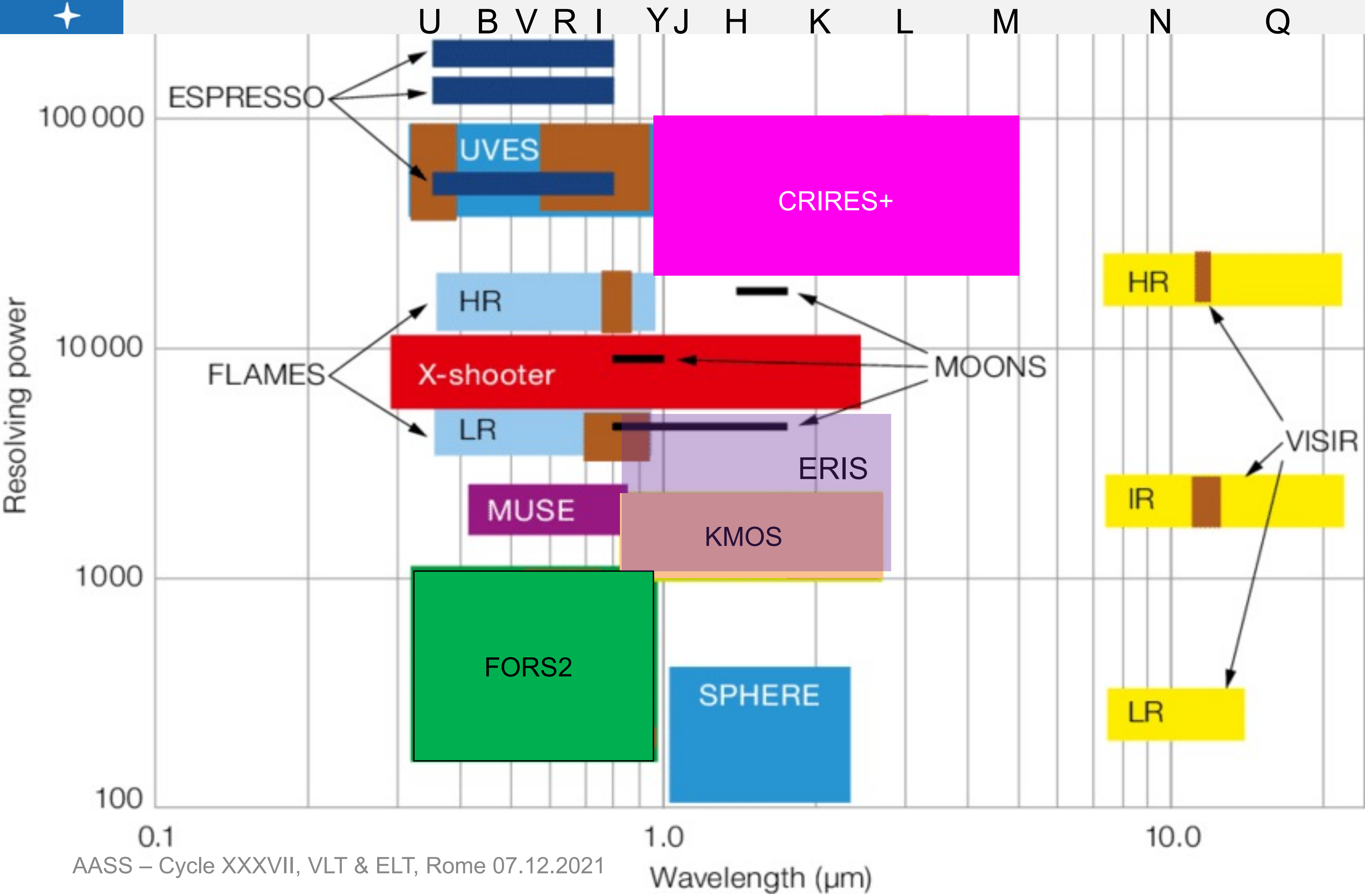


How to proceed??😱 😱 😱 😱 😱

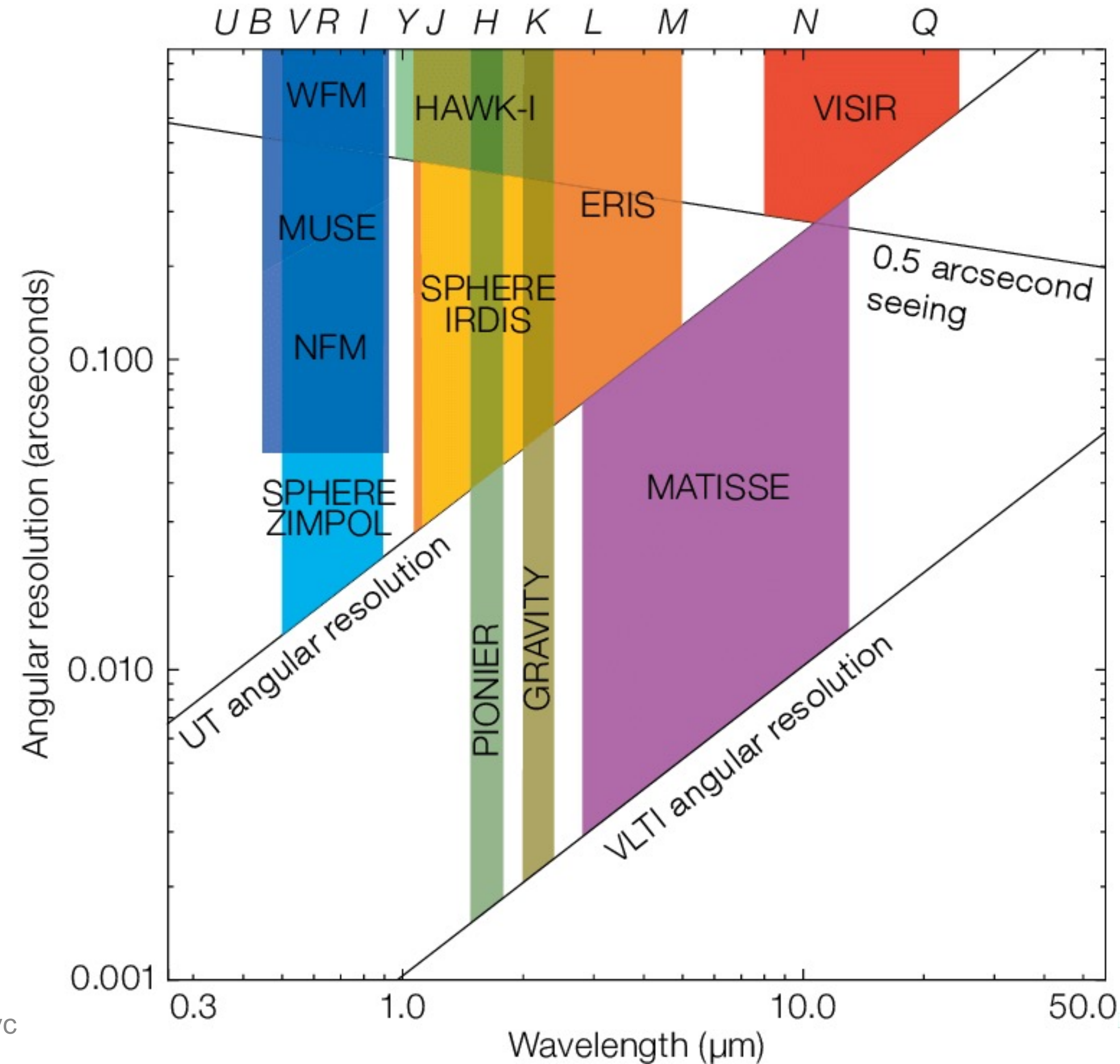
What's the best way for me to tell you about the VLT such as you can get a comprehensive view of all capabilities you have at your disposal, and at the same time, I don't loose your attention for 2 hours straight??

- General overview
- Some guidelines on how to select the VLT instrument(s) that best suits your science goal
- Where to find quickly detailed information
- Selecting only few (current and future) instruments:
  - Technical specifications
  - Science cases

VLT instruments in a nutshell



VLT instruments in a nutshell



How to select your VLT instrument(s)?

Trade-off between:

- FoV vs angular resolution
- Multiplexing vs single-object capability
- Wavelength coverage vs spectral resolution

INST	FORS2	KMOS	VISIR	SPHERE	HAWKI	MUSE	ERIS
FoV	6.8'x6.8' 4.3"x4.3"	2.8"x2.8"	1'x1' 38"x38"	11"x11" 1.7"x1.7" 3.5"x3.5"	7.5'x7.5'	1'x1' 7.5" x 7.5"	1'x1' 30"x30" 8"x8" 3.2x3.2" 0.8"x0.8"

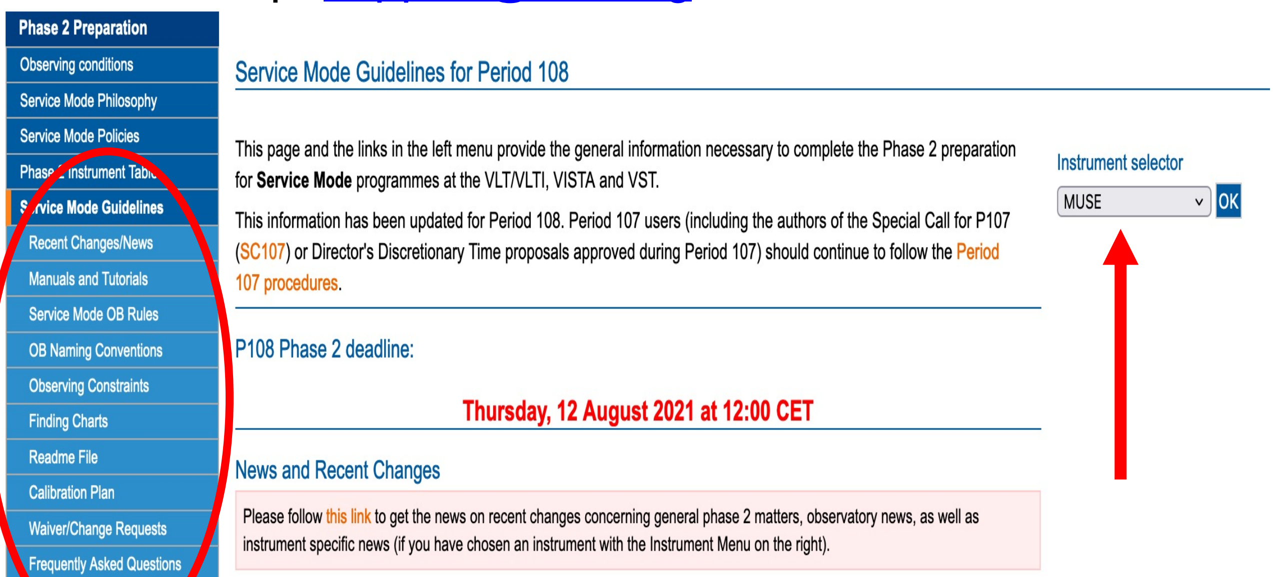
INSTRUMENT	FORS2	KMOS	FLAMES	MOONS
Multiplexing	19 [MOS] ~470 [MXU]	24	8+130	1000

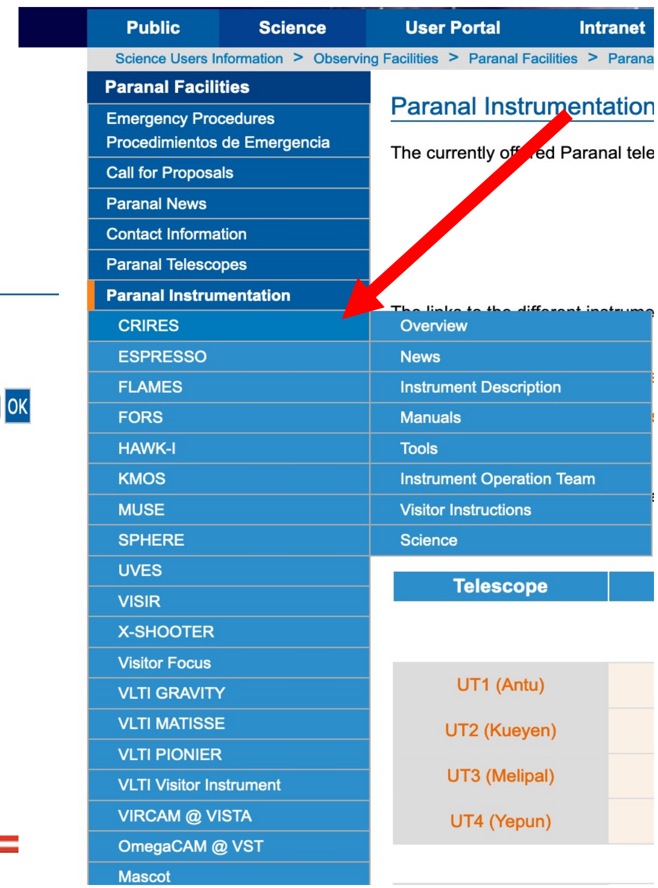
How to quickly get info

Paranal: Instruments Summary Table:
https://www.eso.org/sci/facilities/paranal/cfp/cfp109/instrument_summary.html

Paranal Instrumentation:
https://www.eso.org/sci/facilities/paranal/instruments.html

Service Mode guidelines:
https://www.eso.org/sci/observing/phase2/SMGuidelines.html
Ask for help: support@eso.org





The ESO Science Archive

- Remember that every photon collected with ESO facilities is stored in the Science Archive
- Upon the proprietary period expiration, access to the data is free to anyone!
- Check the archive before applying for VLT time

http://archive.eso.org/cms.html

Welcome to the ESO Science Archive Facility

The ESO Science Archive Facility contains data from ESO telescopes at La Silla Paranal Observatory, including the APEX submillimeter telescope on Llano de Chajnantor. All raw data from the La Silla Paranal Observatory are stored together with the corresponding calibrations, as well as selected products both contributed by the community or generated at ESO. In addition, the raw UKIDSS/WFCAM data obtained at the UK Infrared Telescope facility in Hawaii are available.

The Principal Investigators of successful proposals for time on ESO telescopes have exclusive access to their scientific data for the duration of a proprietary period, normally of one year, after which the data becomes available to the community at large. Please read the ESO Data Access Policy statement for more information, along with the relevant FAQs.

Browsing the archive does not require authentication. Please acknowledge the use of archive data in any publication.

There are three main ways to access the archive, varying for content and presentation/interface: the usual Raw Data query form, the innovative Science Portal to browse and access the processed data, and the novel Programmatic and Tools access which permits direct database access to both raw and processed data, and to the ambient condition measurements, also in a scriptable and VO manner. Other query forms are available in the table at the bottom of this page.

Raw Data

Science Portal
Processed Data

Catalogue Facility
Catalogue Data

Programmatic
Raw, Processed, Catalogue, and Ambient Data

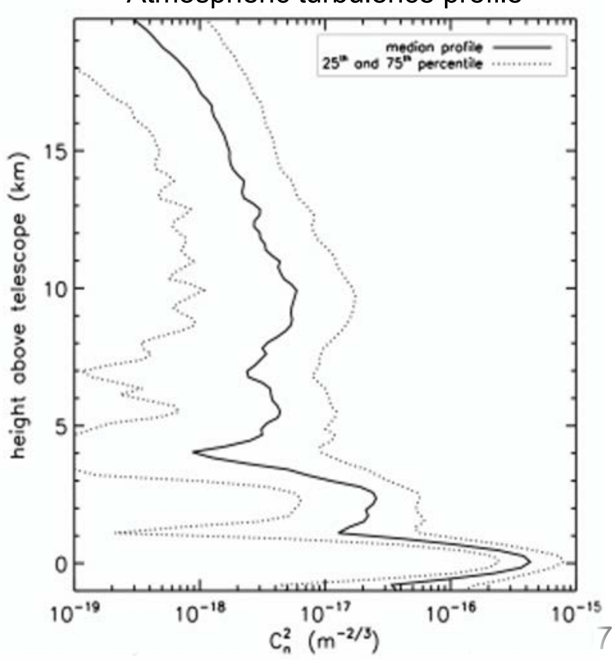
Community Forum
Share ideas, ask questions, send feedback

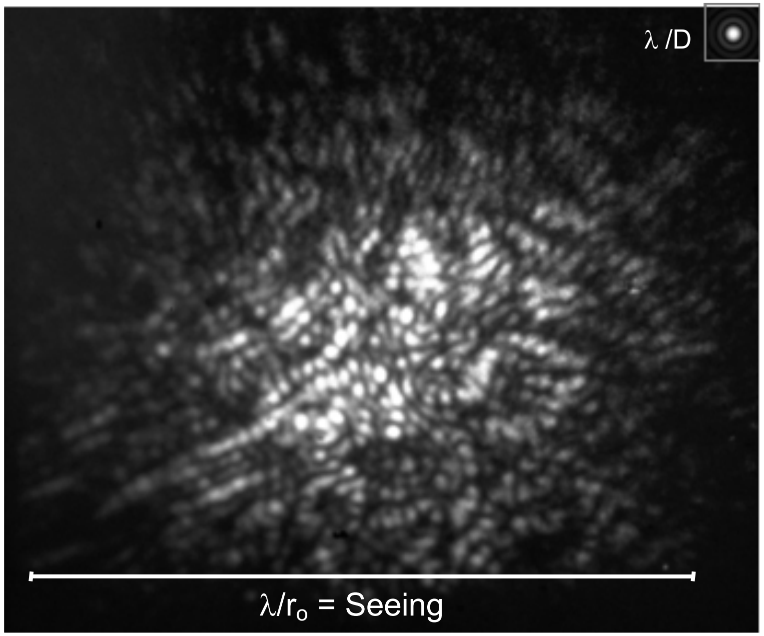
AO: basic principles

The atmosphere is turbulent!

- When turbulence occurs in a layer with temperature gradient it mixes air at different temperatures at the same altitude, thus producing fluctuations of temperature
- Fluctuations in temperature → fluctuations in density → fluctuation in the refractive index → wavefronts travelling at different velocities → **perturbations!**
- Turbulence varies spatially (refractive index fluctuations) and temporally (layers shifted by winds, boiling)

Atmospheric turbulence profile





AO: basic principles

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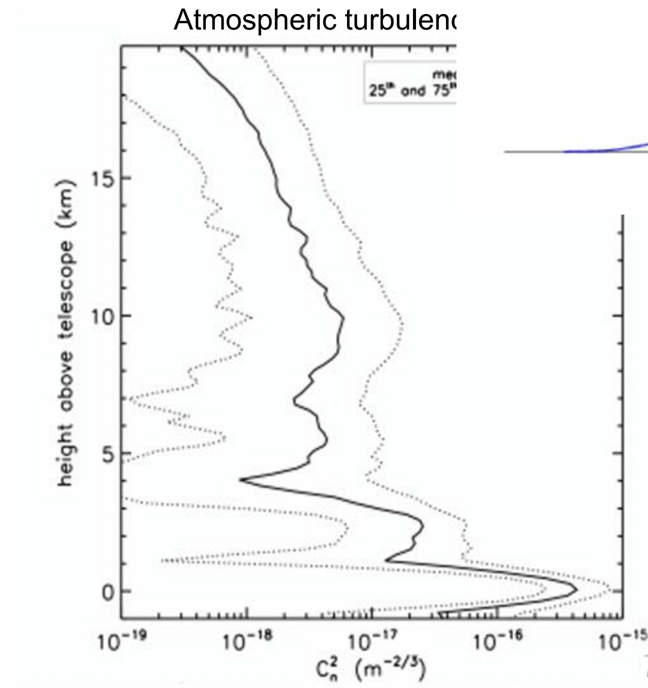
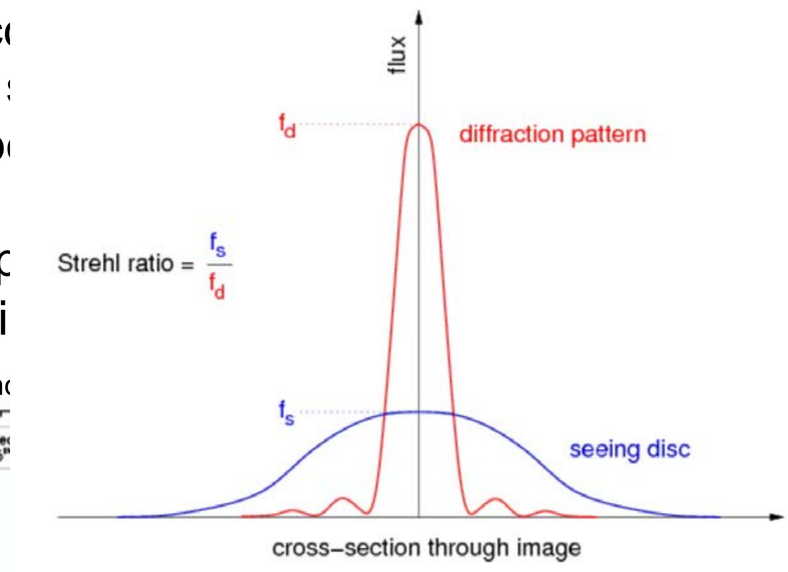
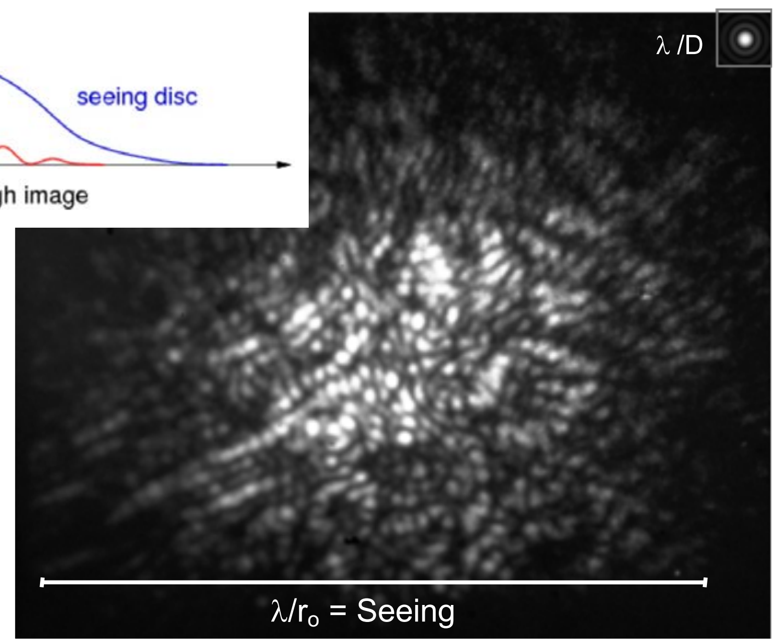
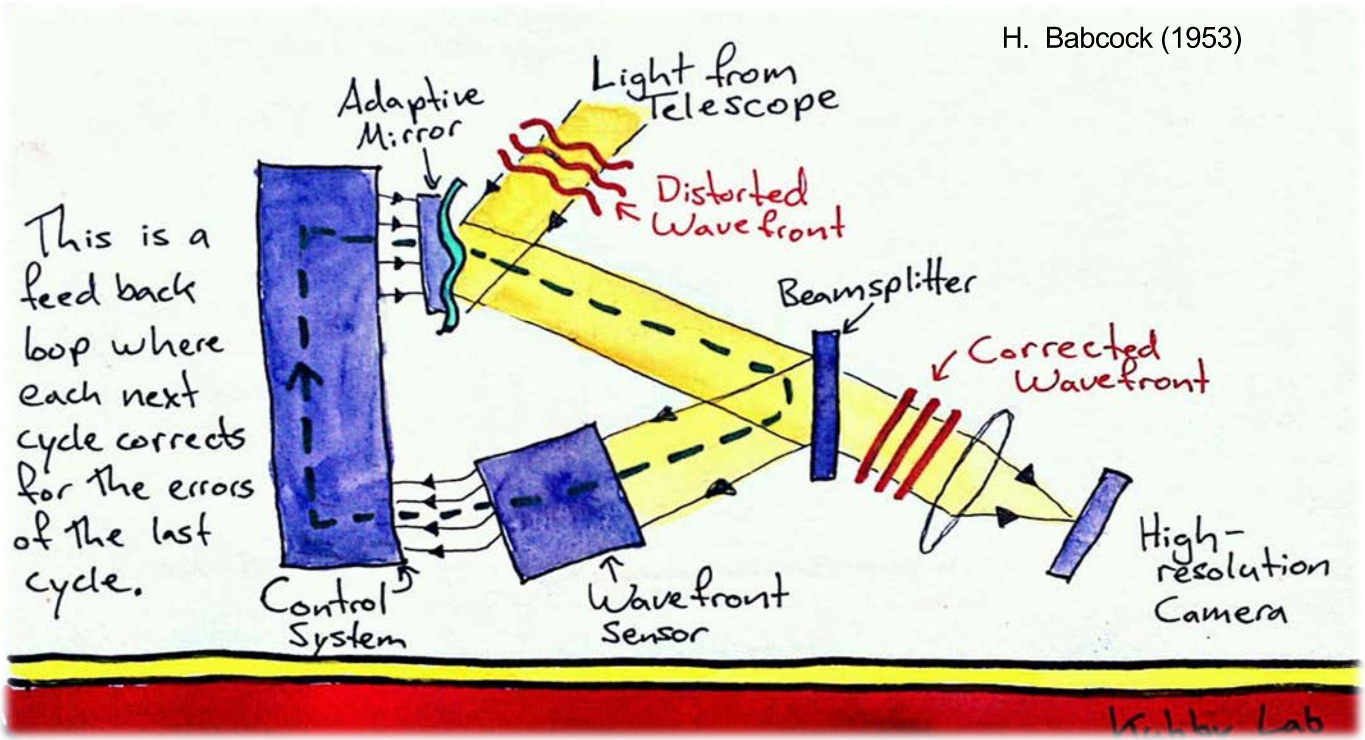






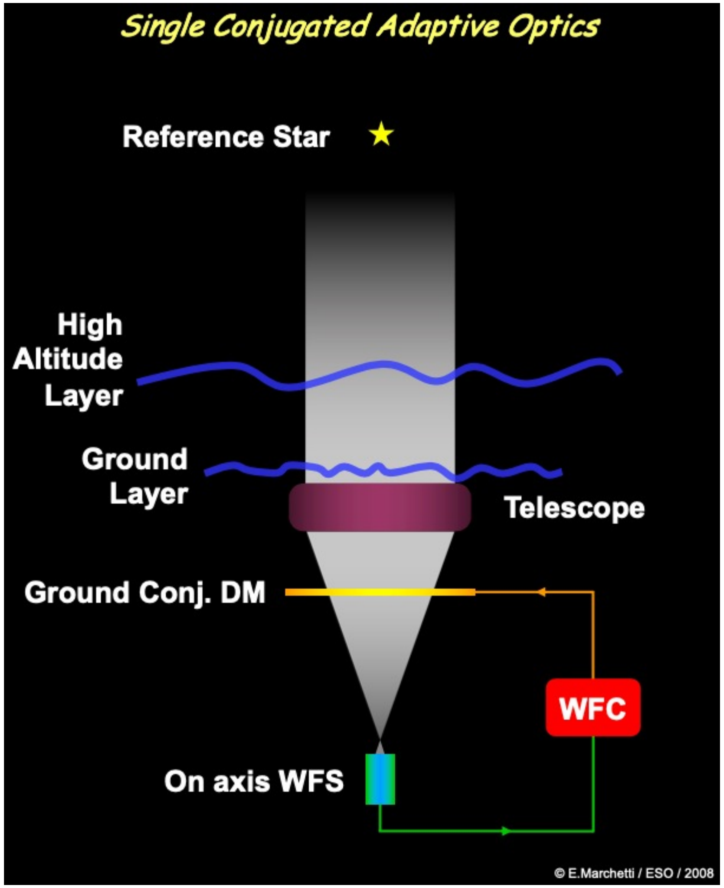
AO: basic principles

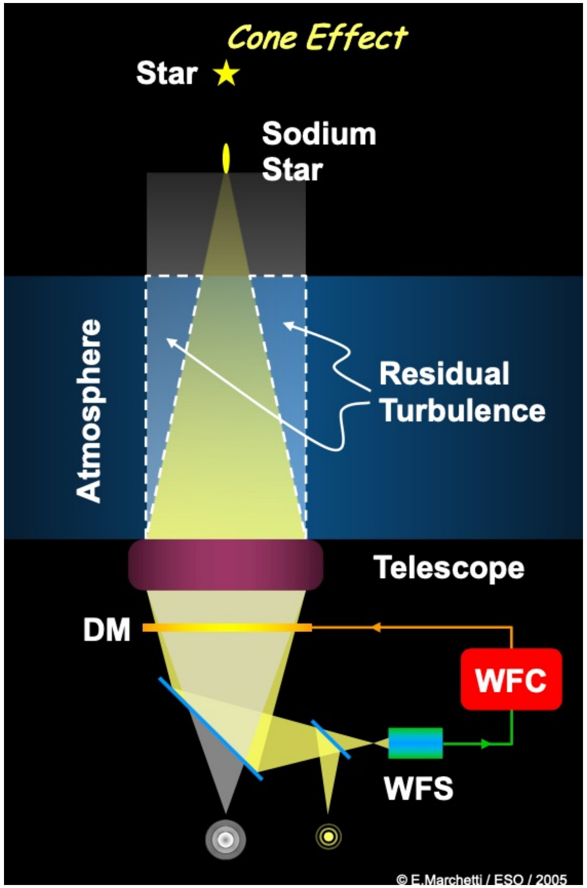
- Measuring the distortion of the incoming optical beam (WFS)
- Computing the compensation (RTC)
- Applying the compensation (DM)
- Do it all over again when phase distortion changes (close loop)

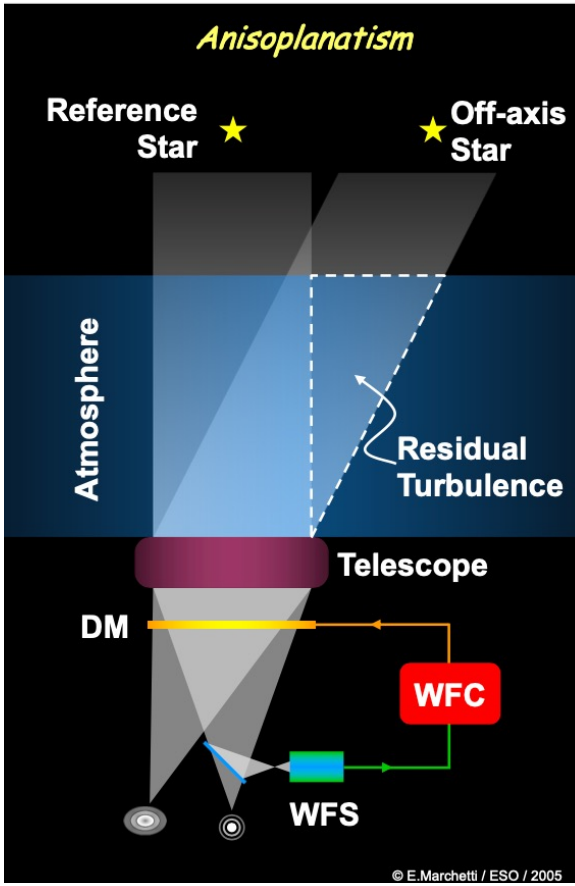


Different AO flavors

SCAO







Different AO flavors

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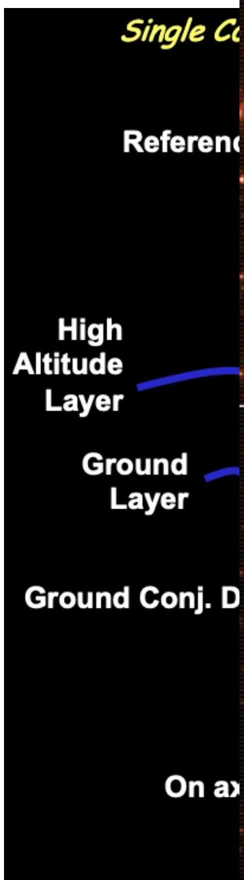
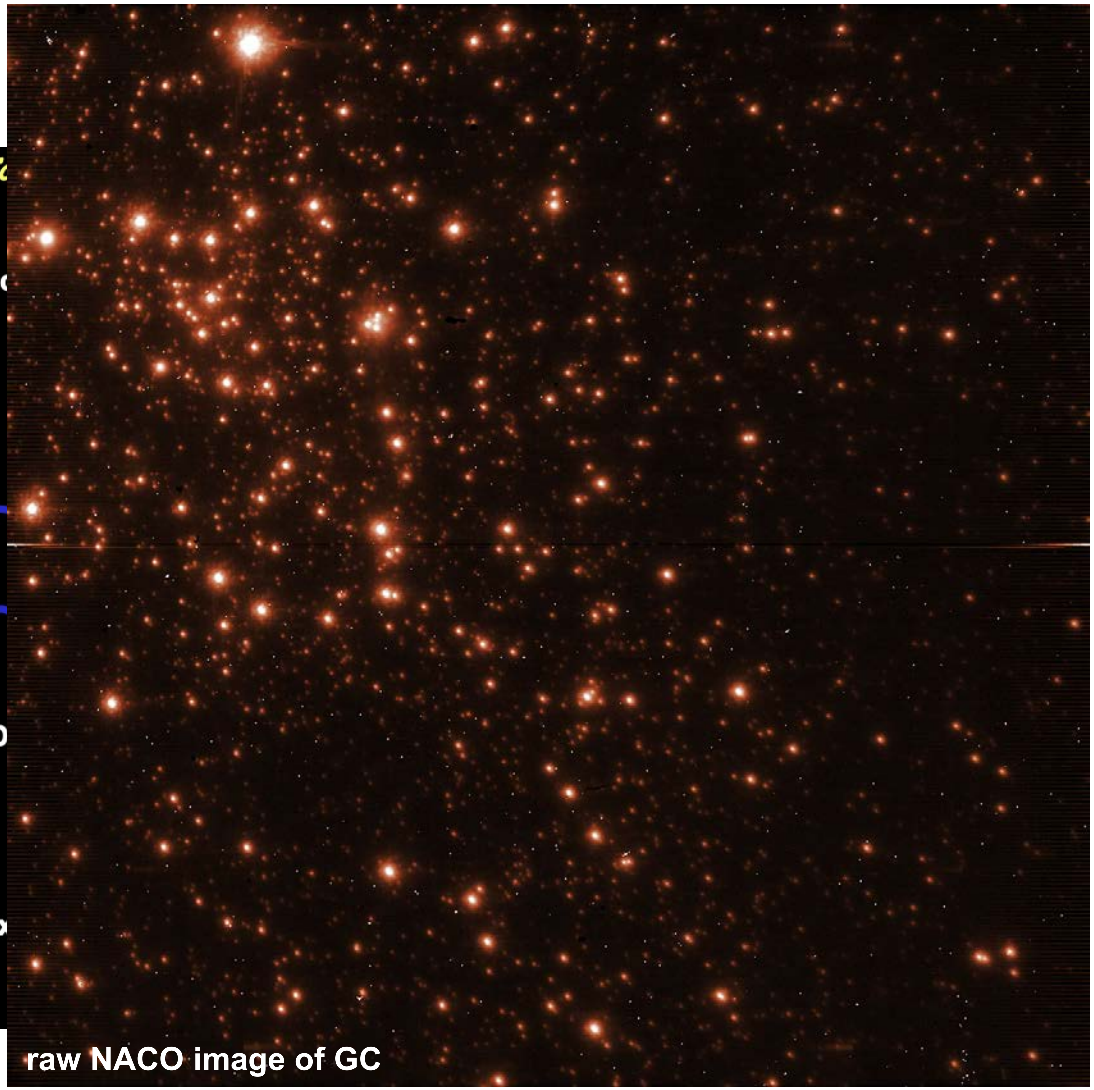
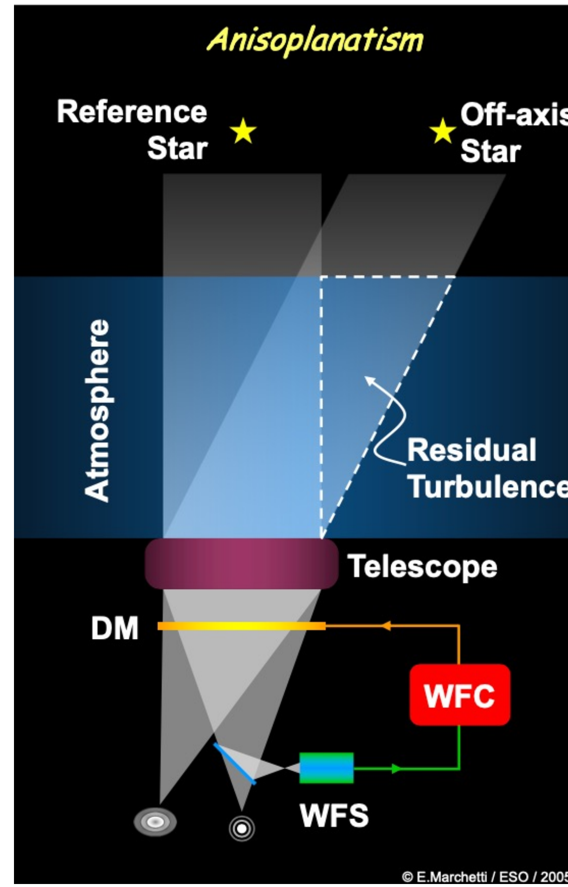


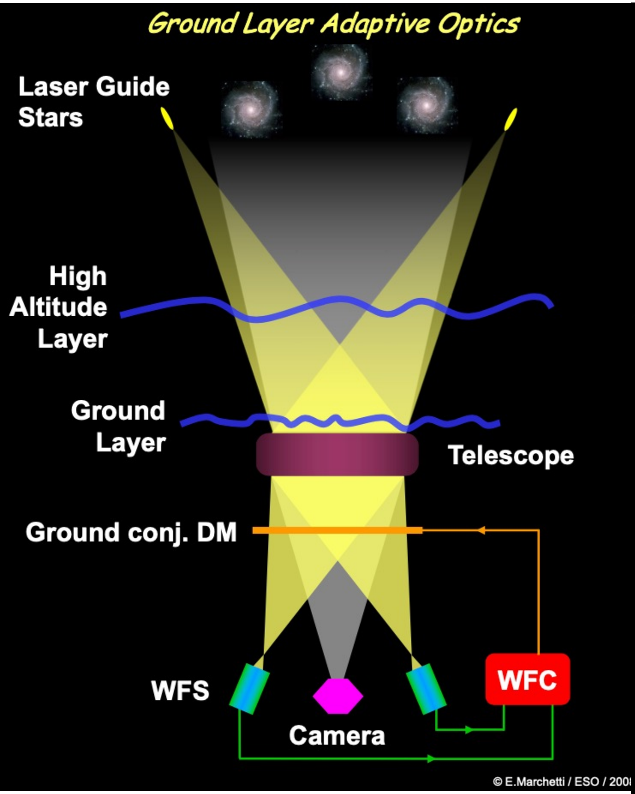


raw NACO image of GC

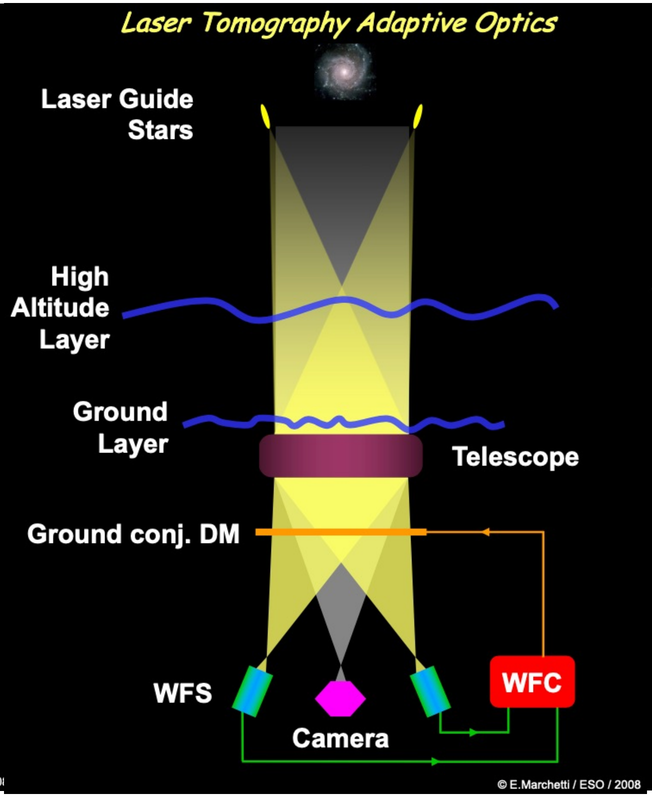


Different AO flavors

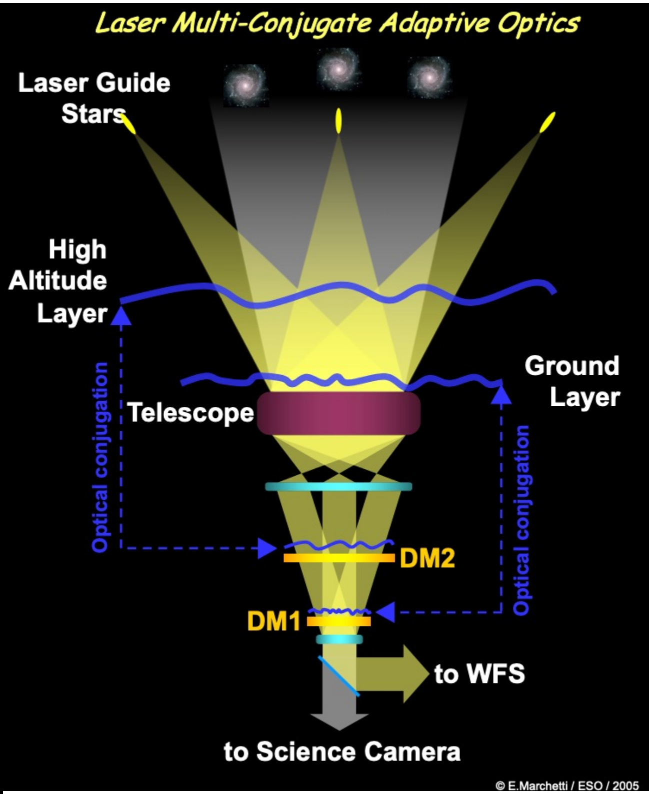
GLAO



LTAO



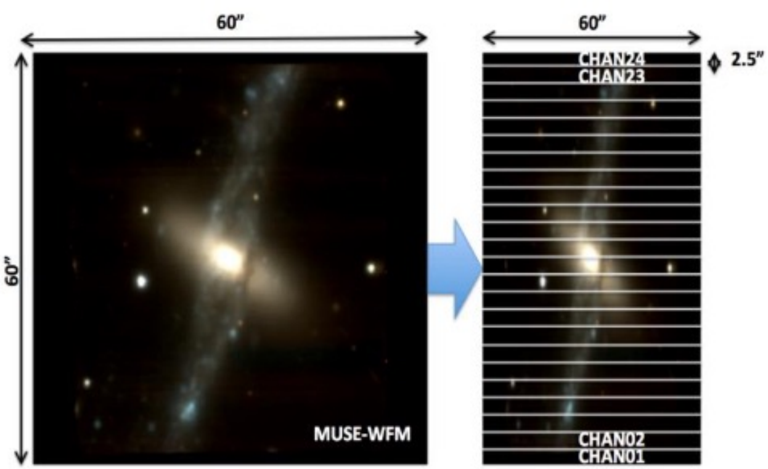
MCAO

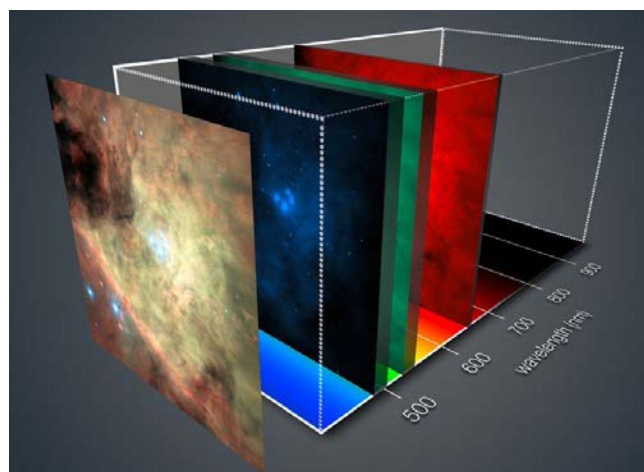


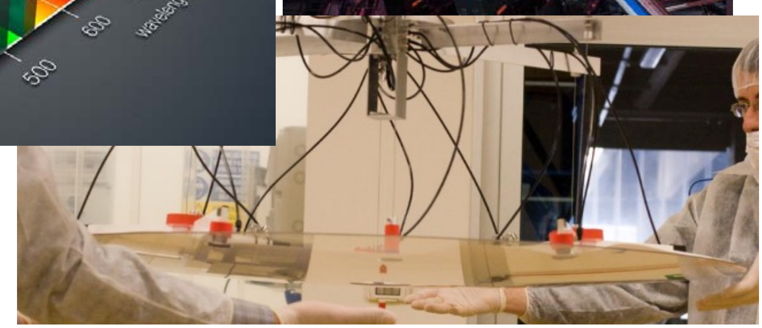
muse @VLT/UT4

multi unit spectroscopic explorer

- 24 IFUs
- Wavelength coverage: 480nm - 930nm (N), 465nm – 930 (E)
- Spectral sampling: 0.125 nm/px (<R> ~3000)
- FoV: 59.9” x 60.0” (WFM), 7.42” x 7.42” (NFM)
- Spatial pixel scale: 0.2”/px (WFM), 25mas/px (NFM)
- AOF (4LGSF & DSM) + GALACSI: GLAO (WFM) & LTAO (NFM)





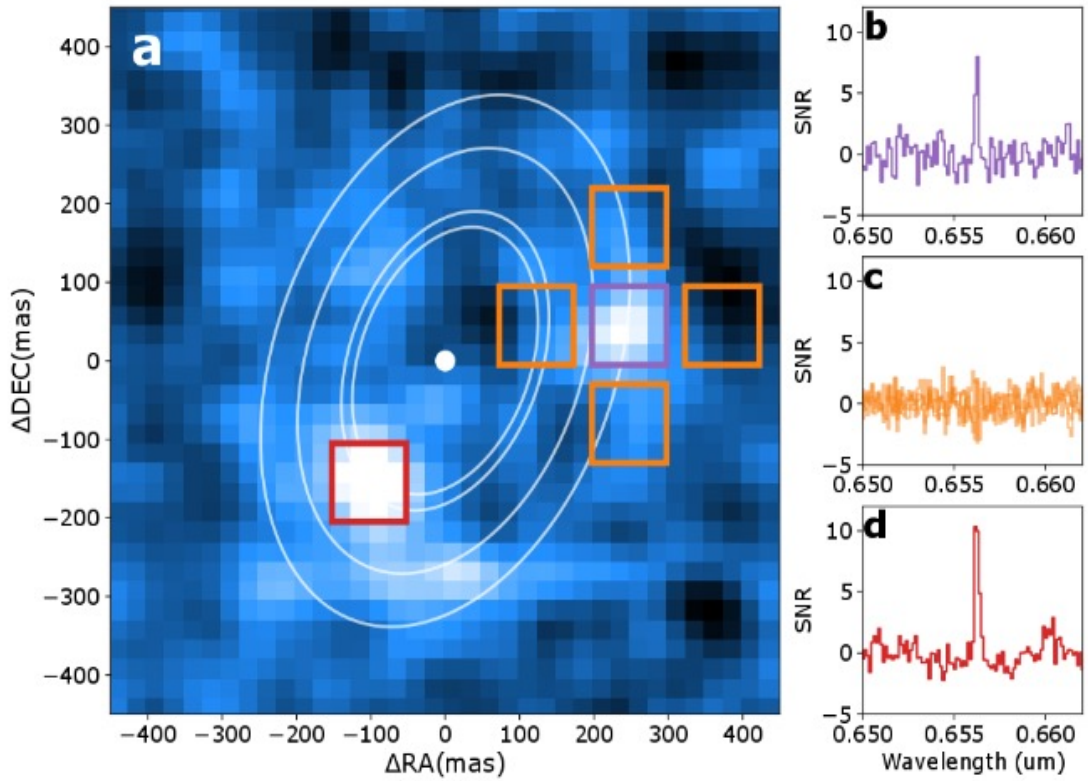


Science with MUSE: Planet formation

- Tracing ongoing planet formation in transitional disks at different stages of their evolution via accretion signature

The case of the young (5.4Myr) T-Tauri star PDS70 (d=113.4pc)

Hα map from MUSE/NFM



Haffert et al. 2019

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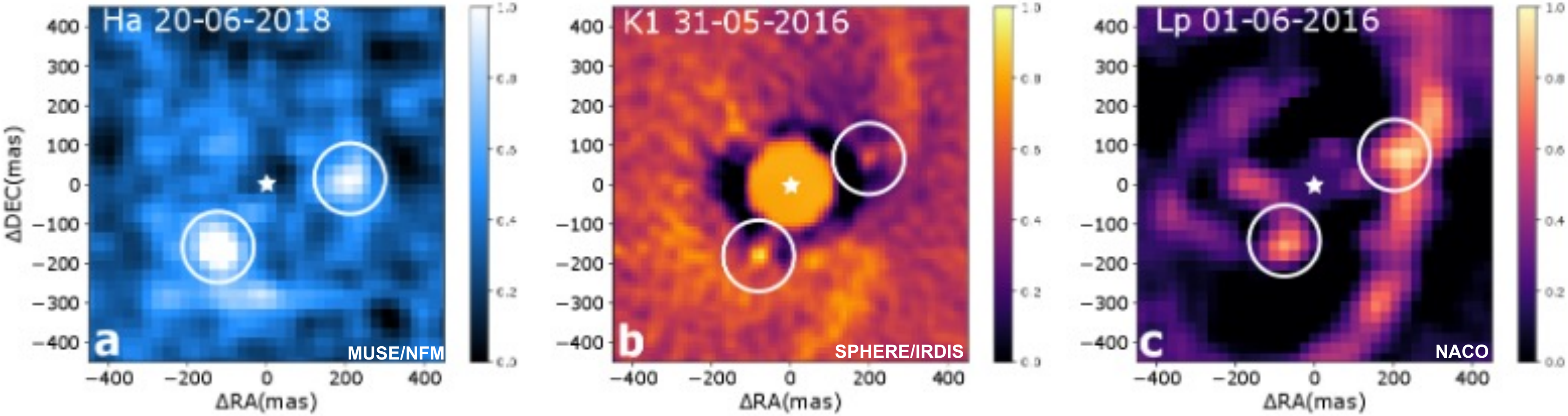
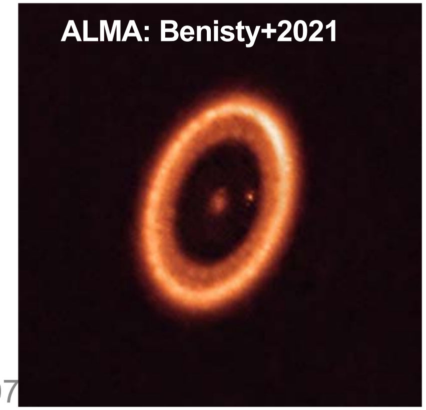


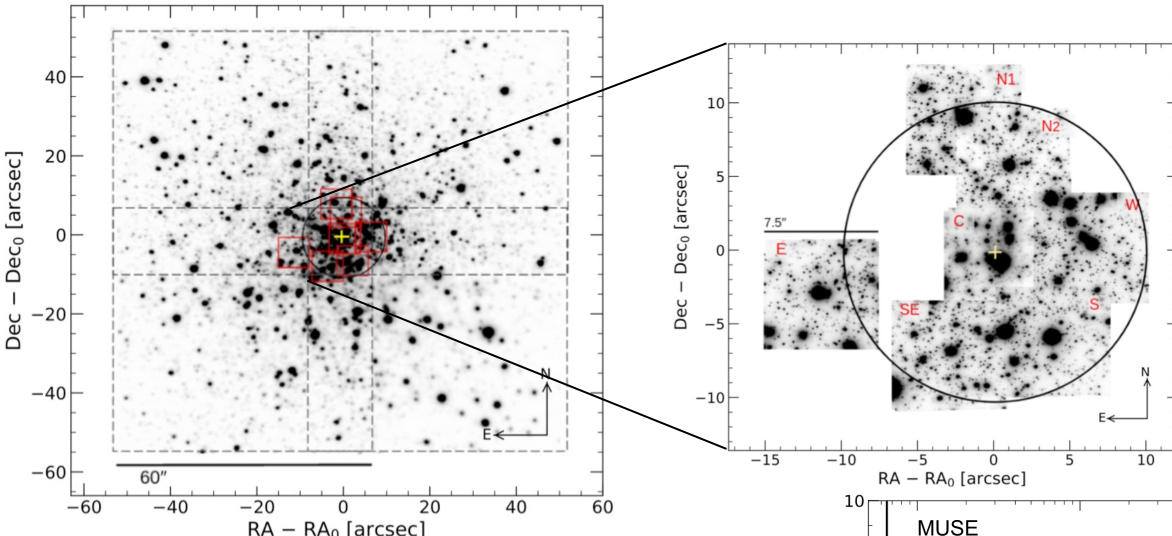


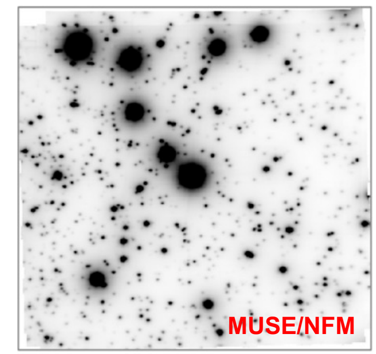
Haffert et al. 2019

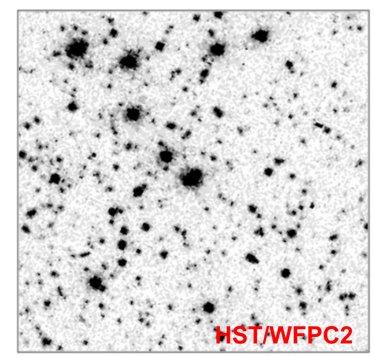
Science with MUSE: Resolved SPs

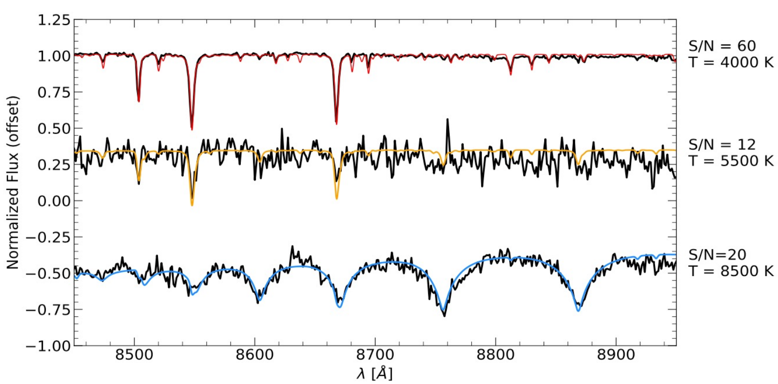
- Kinematics and internal dynamics of Globular Clusters

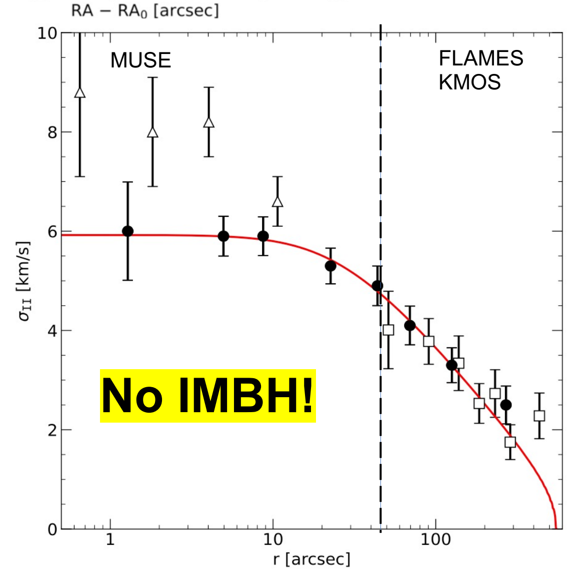
Spectra for more than 1700 individually resolved stars from MUSE+FLAMES+KMOS









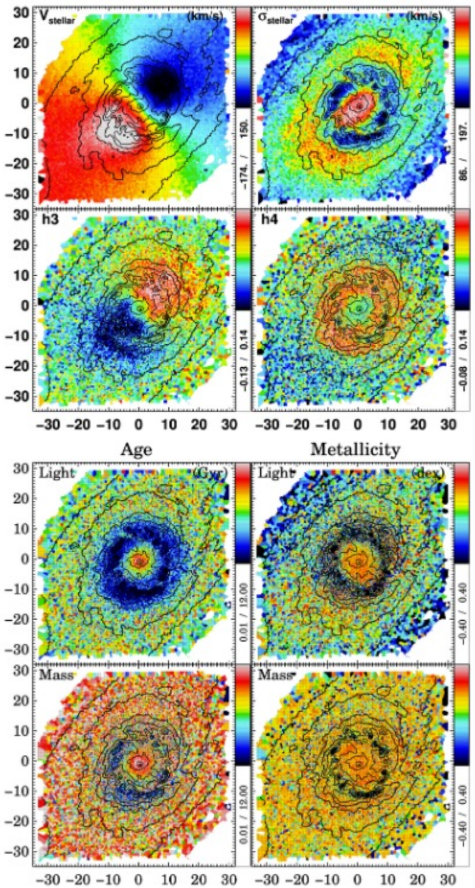


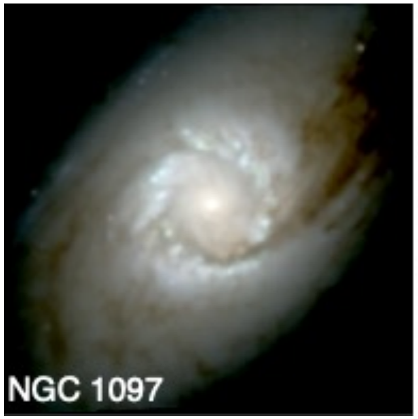
Leanza et al. 2021, sub.

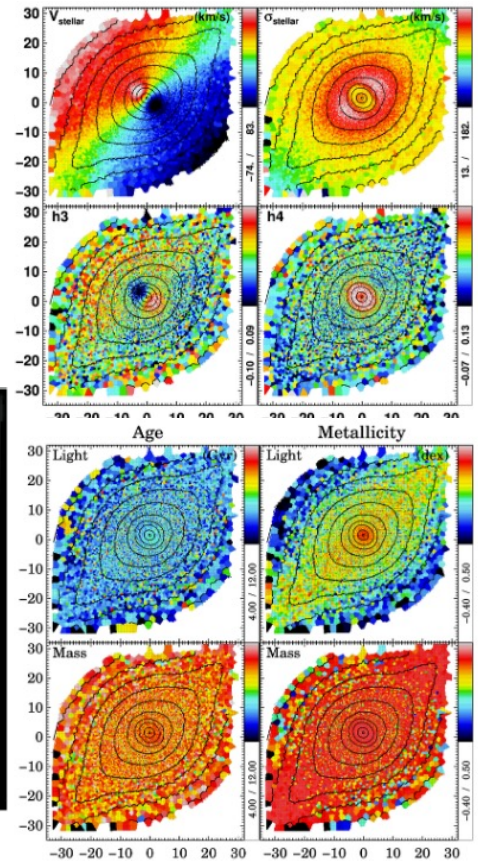
Science with MUSE: Galaxy evolution

- TIMER Survey: cosmic epoch of disk and bar formation

24 nearby barred galaxies with prominent central structure (i.e., nuclear rings and disk)





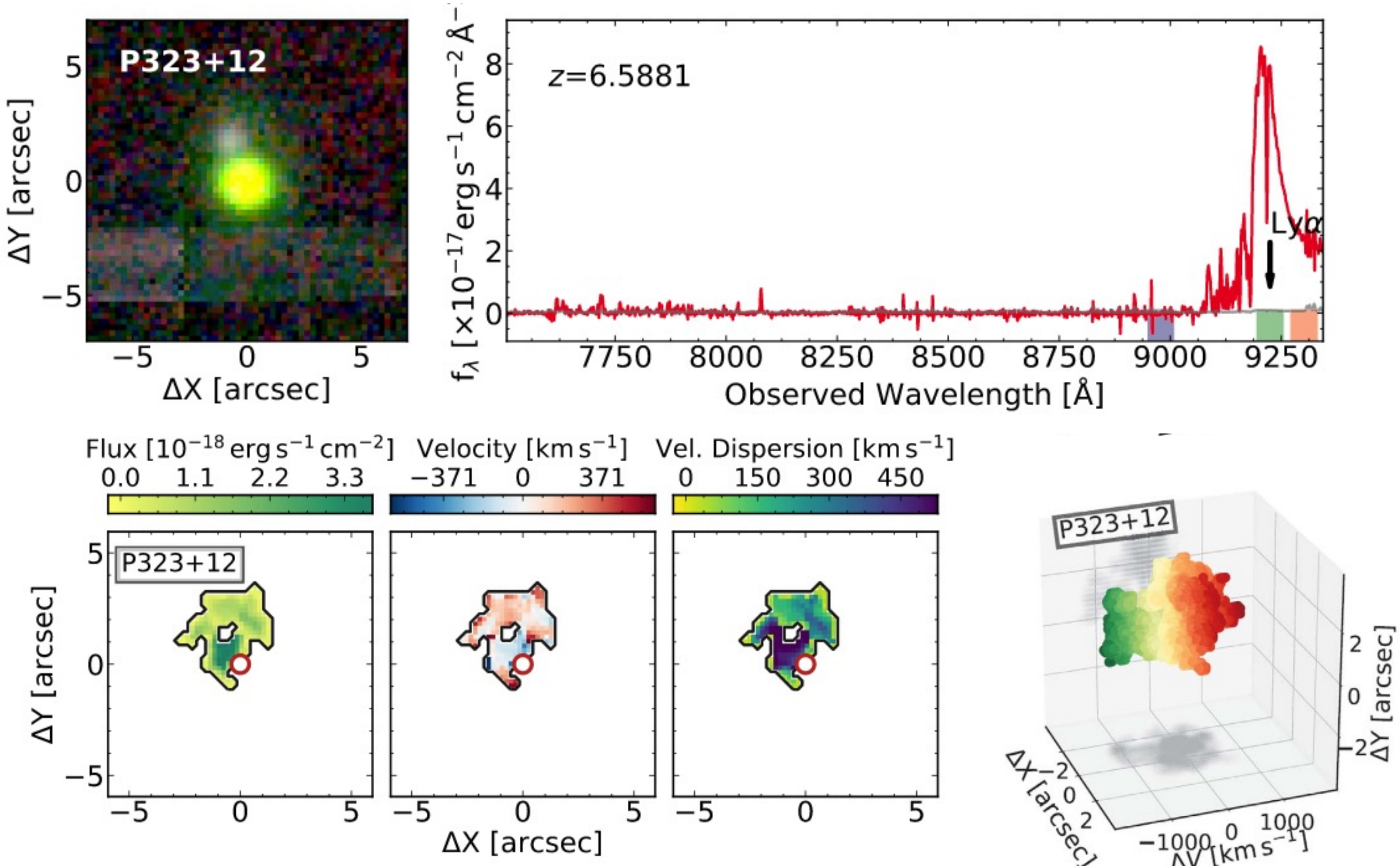


Gadotti et al. 2018

Science with MUSE: high-z Universe

- Extended Lyα emission around high-z quasars

REQUIEM MUSE Survey around 31 z>5.7 quasars



Farina et al. 2019

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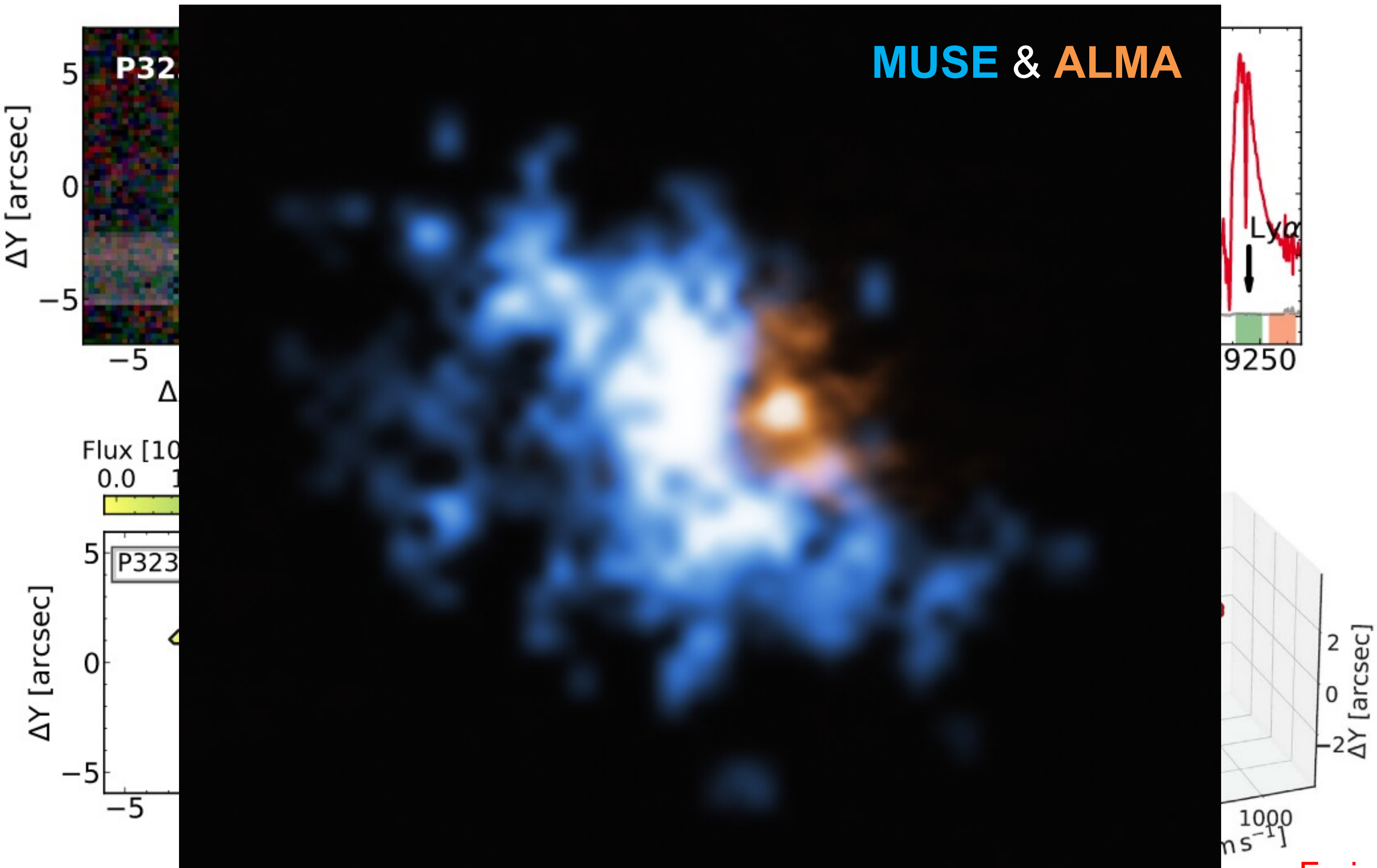
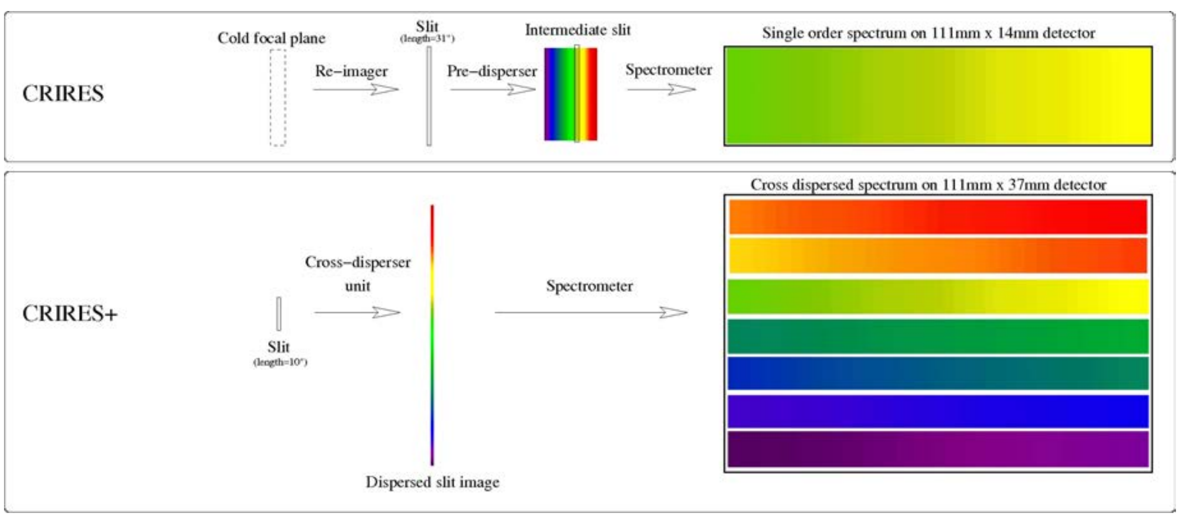


Farina et al. 2019

CRIRES+ @VLT/UT3

GOAL: Increasing the observing efficiency while maintaining the same spectral resolution and wavelength coverage

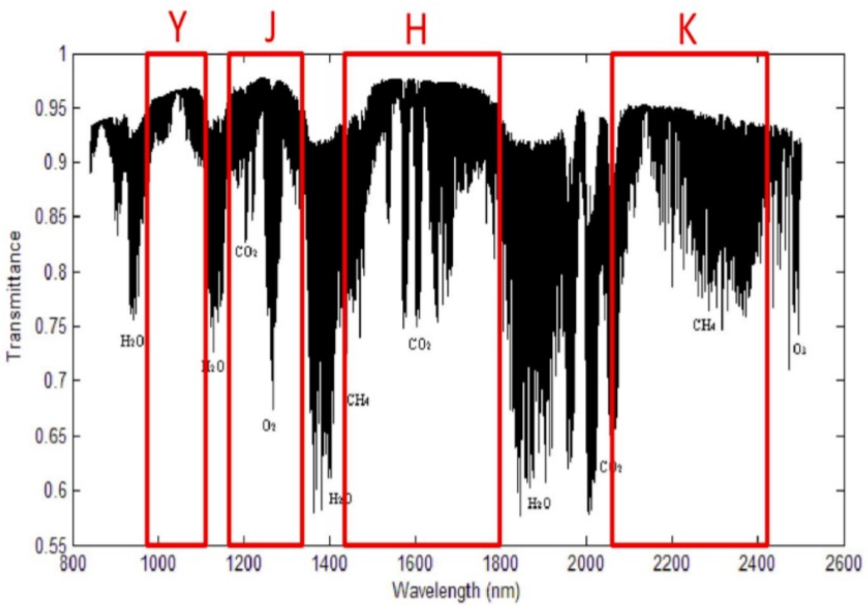
- Cross-disperser unit
- Larger FPA (3 Hawaii 2RG detector with 5.3µm cut-off wavelength)
- New gas cells and etalon system
- Metrology system
- Spectro-polarimetric unit (circular and linear polarization)

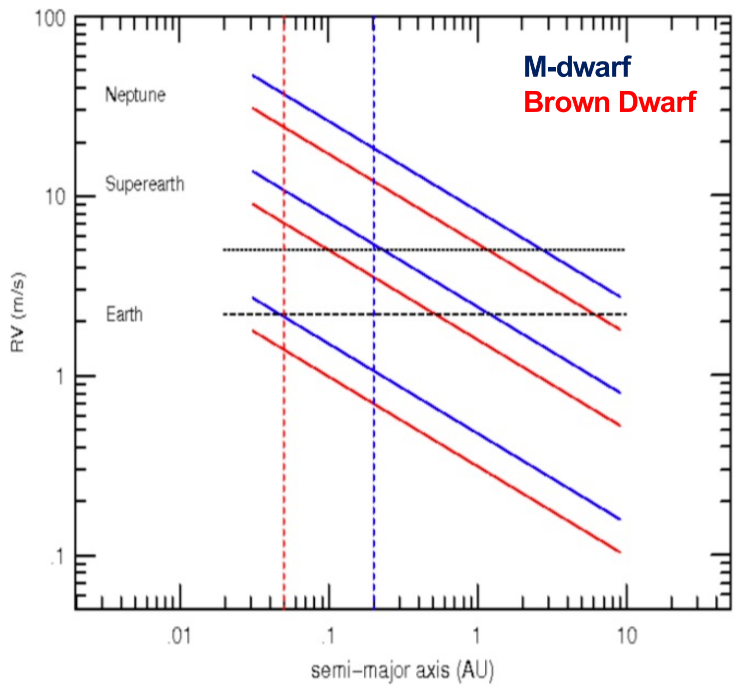


Spec Res: 50K, 100K
Silt width: 0.2”, 0.4”
Slit length: 10”
Wavelength: 0.95 - 5.3 µm
XDGW: 6 gratings (YJHKLM)
AO: curvature sensor MACAO
Pol: linear + circular (YJHK)
Gas cells: SGC, N_2O

Science with CRIRES+

- Search for super-Earth mass planet in the habitable zone of M-dwarfs



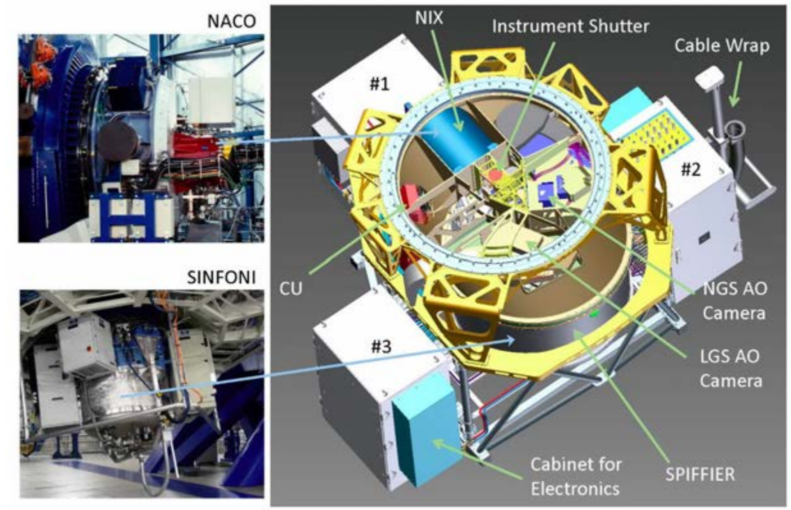


- Atmospheric characterization of exoplanets (i.e., in-transit spec)
- Origin and evolution of stellar magnetic fields (in M and brown dwarfs)
- Accurate stellar abundances and abundance patterns

ERIS @VLT/UT4

- PI: R. Davies (MPE-Garching), INAF (Arcetri), UKATC, NOVA, ETH-Zürich plus ESO

- NIX (imager) + SPIFFIER (IFU) + AO
- Wavelength coverage: 1-5 μm (NIX), 1-2.5 μm (SPIFFIER)
- AO system uses the AOF (i.e., DSM, 4LGSF), optical WFS, SCAO (NGS and LGS).
- AO performance: SR_K>68% (on-axis, NGS, M_R=8), and SR_K>54% (on-axis, LGS, M_R=12)
- Several modes:
  - Standard imaging
  - Coronagraphy
  - Slit spectroscopy (L, M)
  - IFU (J,H,K)

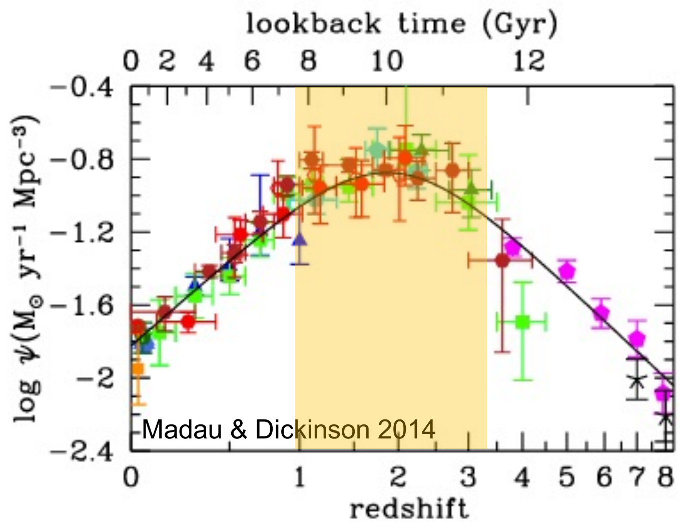


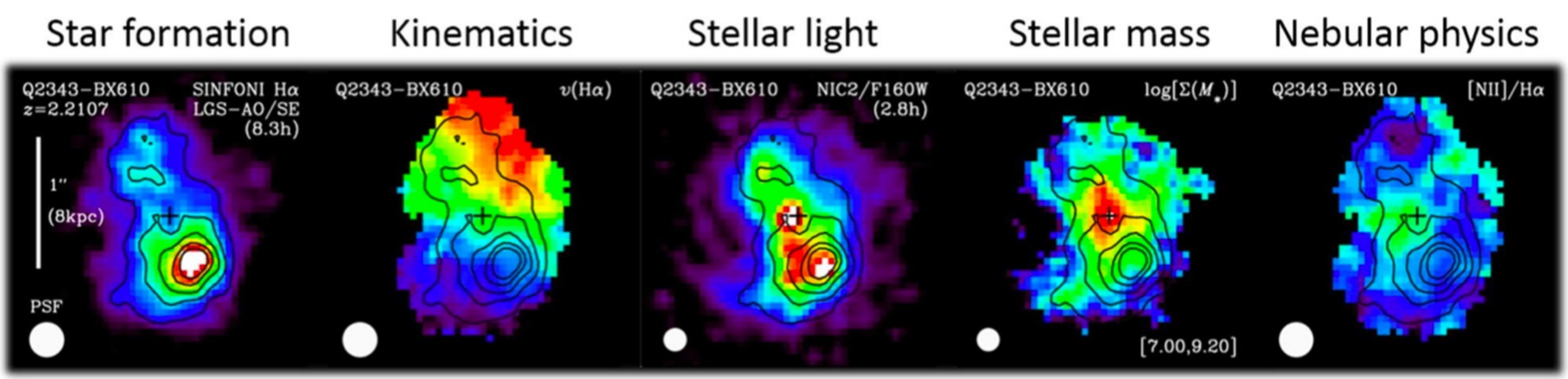
Module	FoV	Pixel scale	Spectral Resolution
NIX	27”x27” 54”x54”	13 mas/px 27 mas/px	~ 450 [= 12” x 86mas]
SPIFFIER	8”x8” 3.2”x3.2” 0.8”x0.8”	125 mas/spxl 100 mas/spxl 25 mas/spxl	~3000 ~8000

Science with ERIS

- Galaxy Evolution at the peak of cosmic SF rate (z~1-3)
  - growth of bulges
  - inflows in disks
  - SF in and between clumps
  - feedback and quenching from SF and AGN

→ **Signatures are imprinted on galaxies kinematics occurring on scale < 1kpc and a few 10 km/sec**

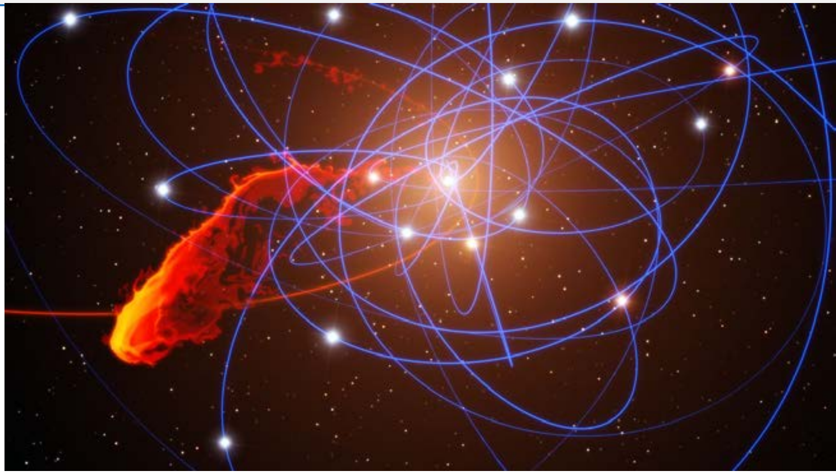


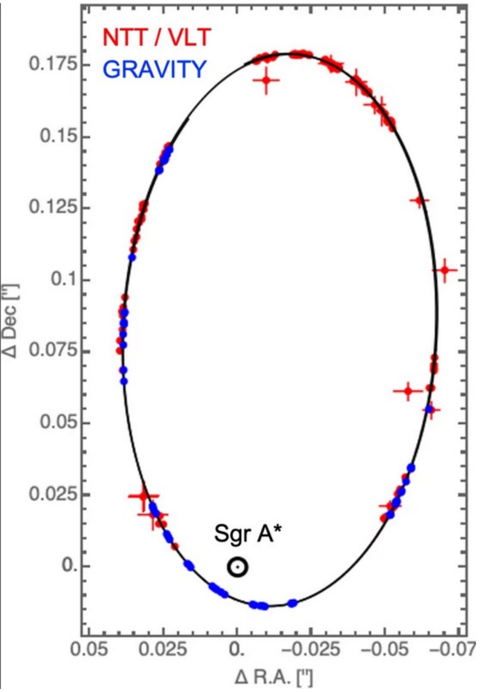


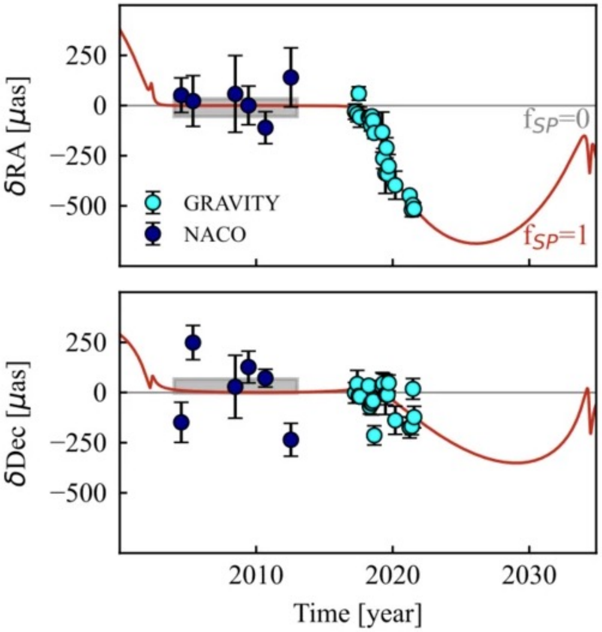
Credit: ERIS Consortium

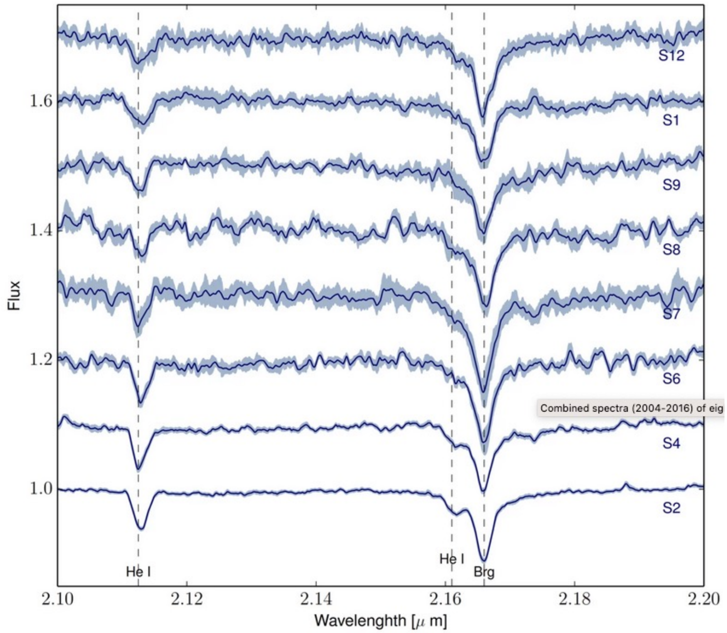
Science with ERIS

- The Galactic Center
  - Dynamics of various stellar populations
  - radiative behavior of SgrA*
  - Flares and gas streamers
  - Astrometric monitoring of fainter and closer stars around SgrA*







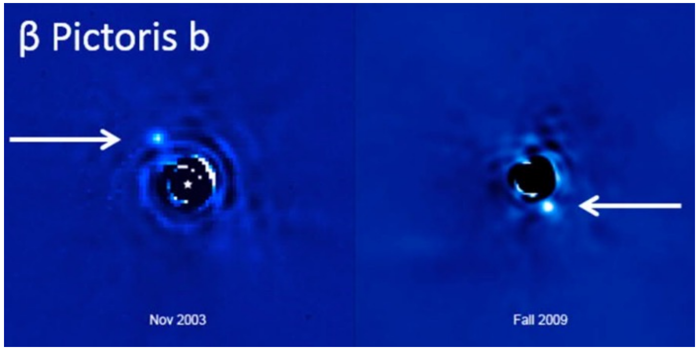


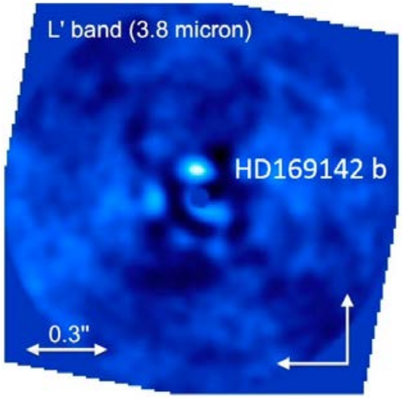
Credit: ERIS Consortium and MPE-Garching GC group

Science with ERIS

- Resolved clusters and field SPs (bulge, disks, halo)
  - Clusters accurate age (via CMDs)
  - Clusters internal dynamics (R_V, σ, PM)
  - Abundance patterns of key chemical elements (Fe, alphas, C, N, O)
  - Variables census in highly obscured region

- Direct imaging of exoplanets
  - old and young (access to L and M bands is crucial)
  - unique probe of atmosphere of gas giant planets (combined with SPHERE it proves much longer baseline → improving the atmospheric fitting model)

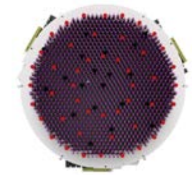




Credit: ERIS Consortium

MOONS@VLT/UT1

- PI: M. Cirasuolo (ESO)
- Multiplex: 1000 fibers, with the possibility to deploy them in pair
- FoV: 500 sq.arcmin
- Fibers: Aperture on sky=1.2”, Close pair=10”, max 7 fibers within 2’
- Wavelength coverage: 0.64 – 1.63 μm
- Medium and high spectral resolution

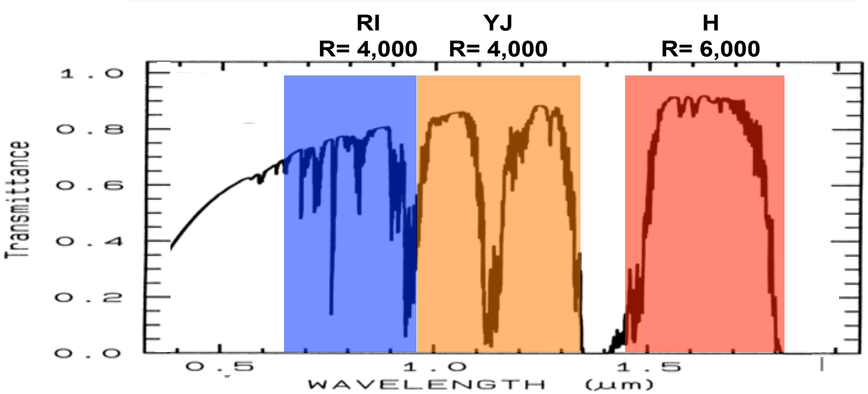


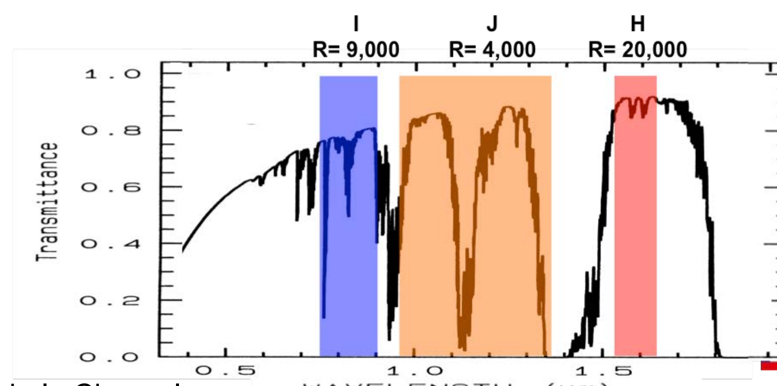
Medium resolution:

Simultaneously 0.64μm-1.8μm
- 0.64-0.95μm at R=4,000
- 0.95-1.35μm at R=4,000
- 1.42-1.81μm at R=6,600

High resolution:

Simultaneously 3 bands:
- 0.76-0.90μm at R = 9,000
- 0.95-1.35μm at R=4,000
- 1.52-1.63μm at R=20,000





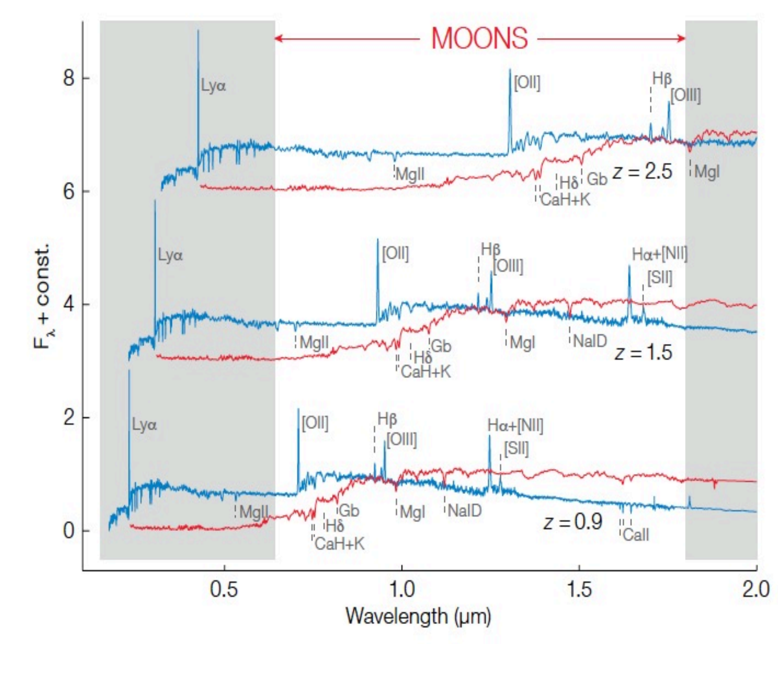
Credit: Michele Cirasuolo

Science with MOONS

- Galactic Archeology
  - Accurate (<0.1dex) chemical abundances of key elements (Fe, O, Na, Ca, Mg, Ti, Si, C, N)
  - Kinematics

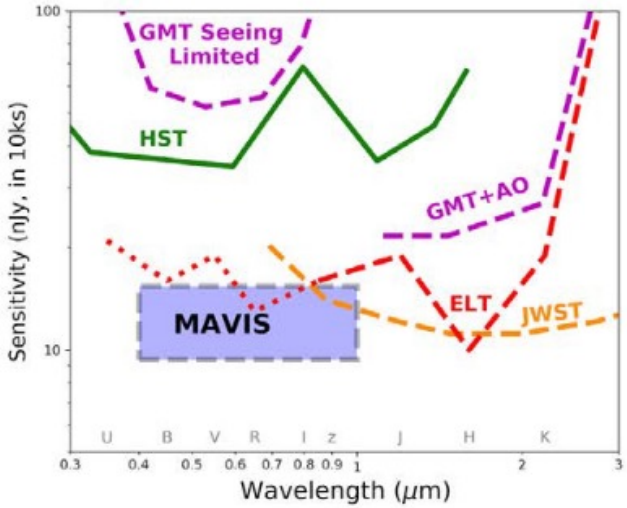
Strong synergy and complementarity with 4MOST, WAVE, Gaia

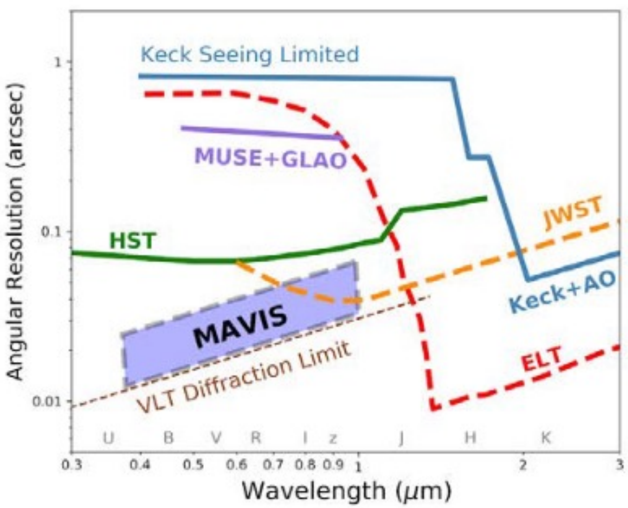
- Galaxy evolution through the peak of mass assembly to the epoch of reionization
  - Plenty of diagnostics for passive and SF galaxies
  - Physics of interstellar medium
  - Search for popIII sources (i.e., strong HeII)
  - Role of environment (groups, mergers, filaments, clusters, proto-cluster
  - AGNs



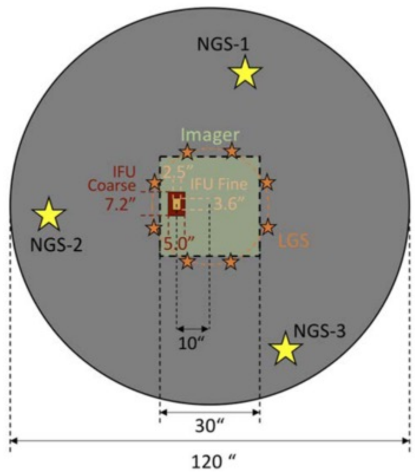
MAVIS@VLT/UT4

- PI: **F. Rigaut** (Macquarie Univ.)
- Imager + IFUs + MCAO
- Wavelength coverage: 370 – 1000 nm



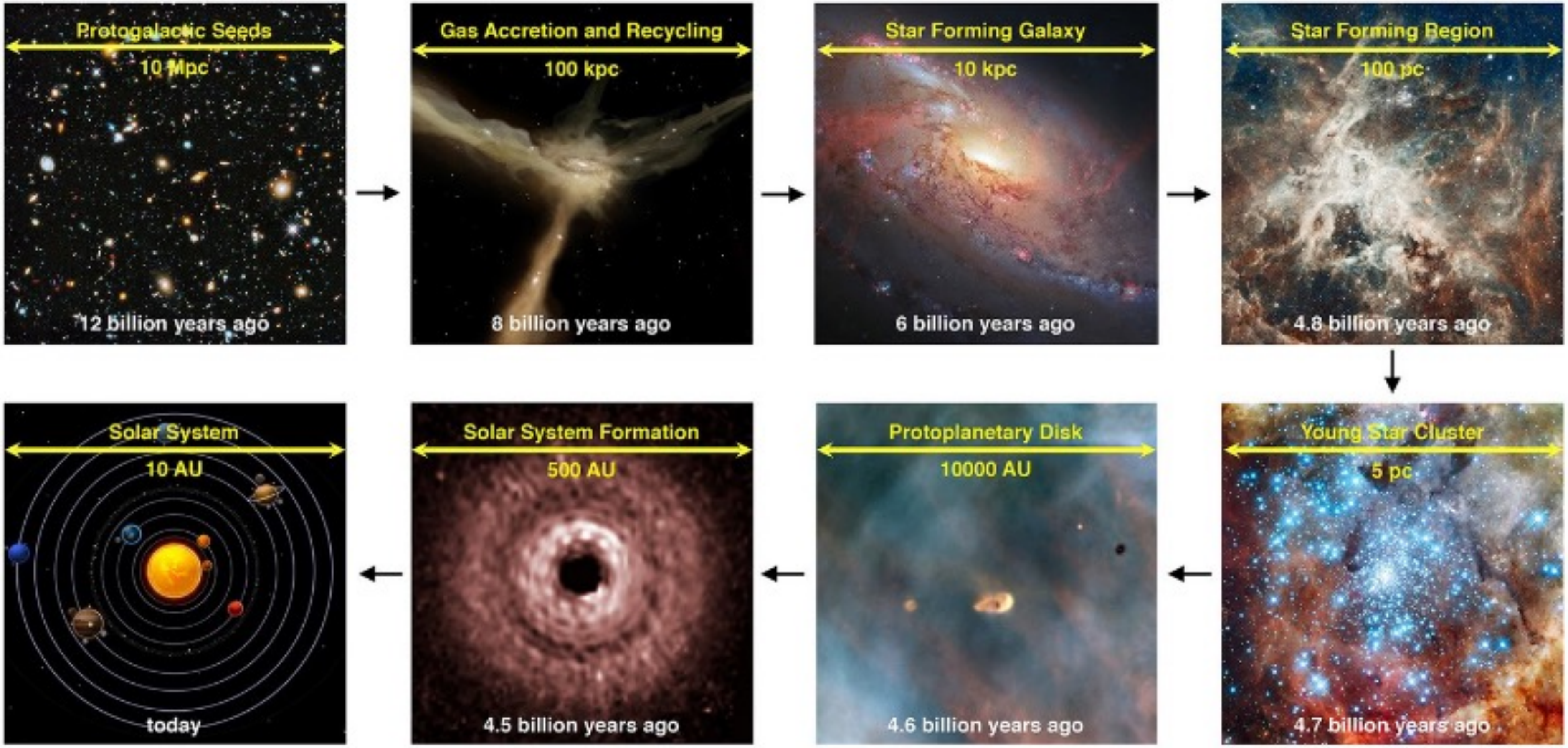


General Properties + AO Module		Imager	
Focus	Nasmyth A VLT-AOF (UT4)	Field of View	30" x 30"
NGS Field of View	120" diameter disk	Pixel Scale	7.36 mas/pix
Number of NGS	≤ 3	Sensitivity	V > 29mag (5σ) in 1hr
Limit. magnitude	Hmag ≥ 18.5	Filters	BVRI, ugriz, various narrow bands
LGS beacons	8 on a circle of 17.5" ⌀	**Spectrograph**	
Sky coverage	≥50% at the South Galactic Pole	IFU Spaxel and FoV, fine	20-25mas spaxels, 2.5"x3.6" FoV
Ensquared Energy	> 15% within 50mas at 550nm	IFU Spaxel and FoV, coarse	40-50mas spaxels, 5"x7.2" FoV
Strehl	> 10% (15% goal) in V-band	LR-Blue Spectral Config.	5,900 λ/Δλ, 370-720nm, 21@550nm
		LR-Red Spectral Config.	5,900 λ/Δλ, 510-1000nm, 21.5@750nm
		HR-Blue Spectral Config.	14,700 λ/Δλ, 425-550nm, 19.6@475nm
		HR-Red Spectral Config.	11,500 λ/Δλ, 630-880nm, 20.7@725nm



Science with MAVIS

By providing high angular resolution, sensitivity and spectral resolving power across most of the sky, MAVIS will enable discoveries across the cosmic history of the Universe



VLT: summary

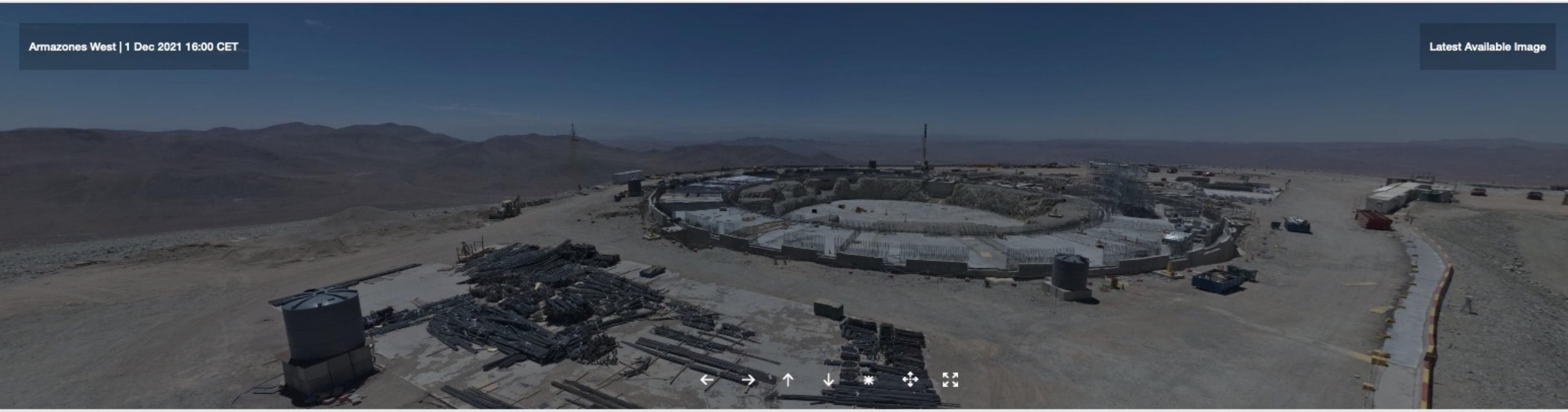
- VLT provides imaging, spectroscopic, coronagraphy and polarimetry across the whole optical and IR regime
- Different angular resolution and FoV
- Single-object and multiplexing spec capabilities
- Different spec resolving power (few 1K - 100K)
- Complementarity among ESO instruments and beyond

- VLT operation model (i.e., ToO, DDT, MP, LP) enables you to study the transient sky (e.g., rapid follow up of GRB, GW, variabilities, planet transits)

The ELT

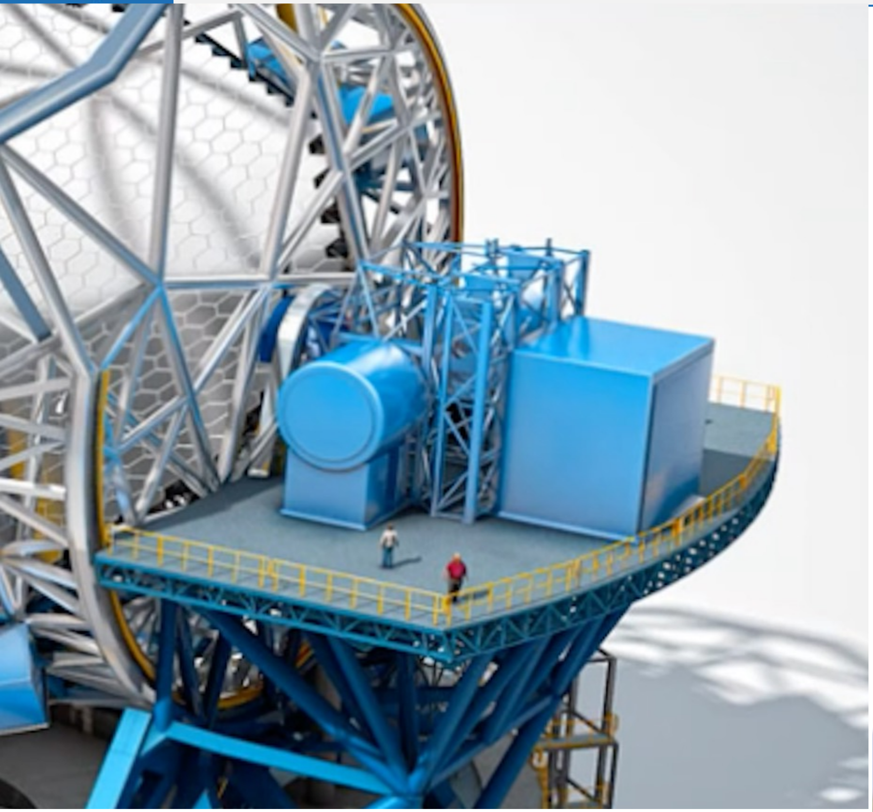
A real time look at the ELT

https://elt.eso.org/about/webcams



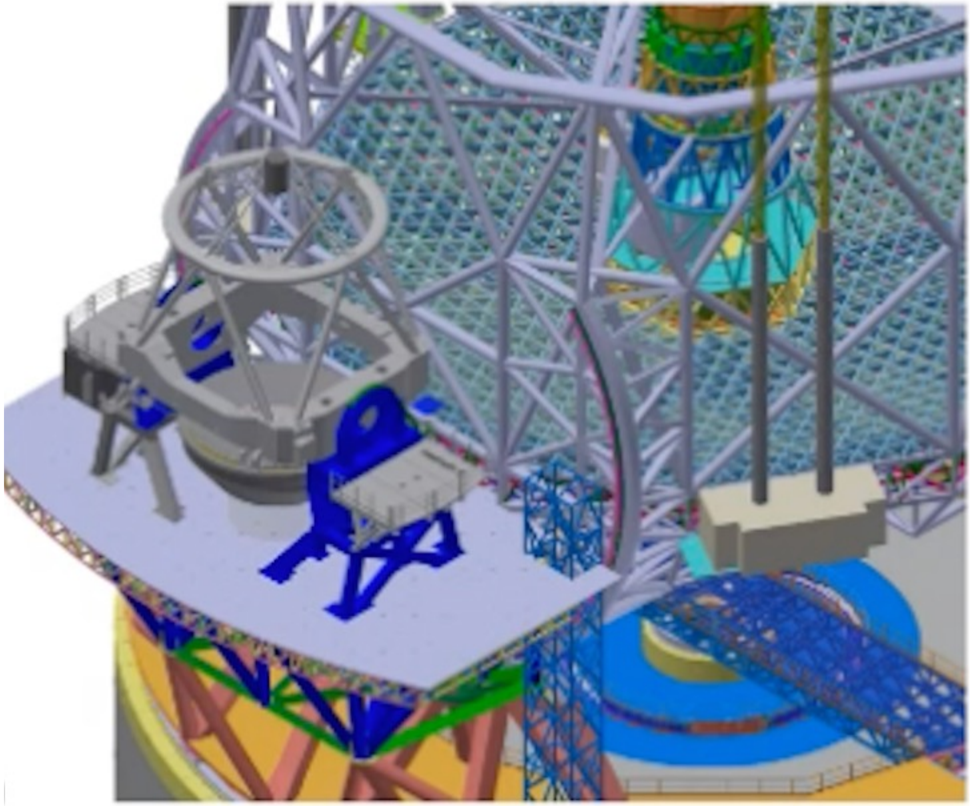
The ELT

The ELT Nasmyth platform

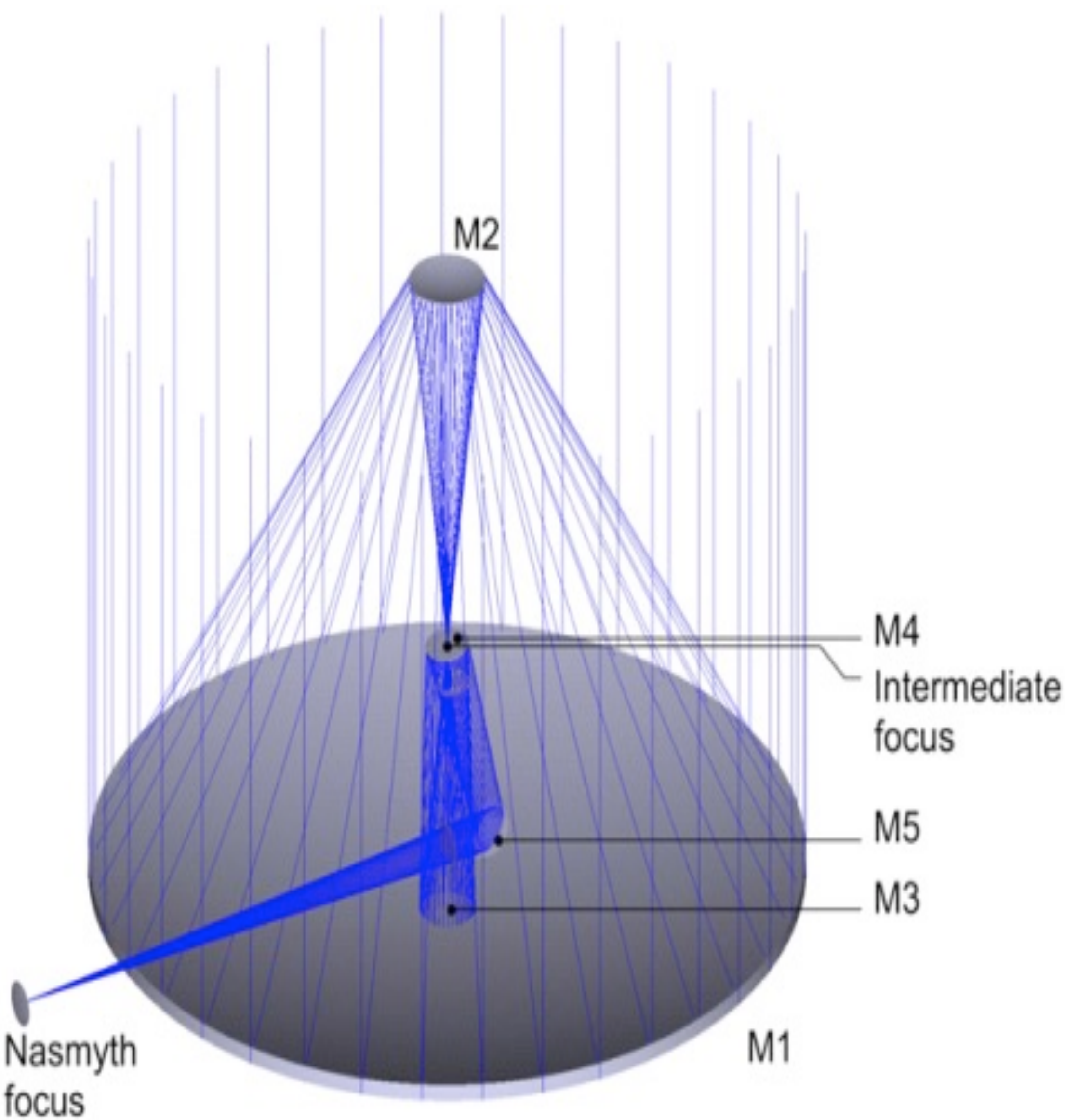


A VLT/UT on the ELT Nasmyth platform

Credit: ESO/R. Ridings



The ELT opto-mechanics



M1 Unit
39-m
Concave – Aspheric f/0.9
Segmented (798 Segments)
Active + Segment shape Control

M2 Unit
4-m
Convex Aspheric f/1.1
Passive + Position Control

M3 Unit
4-m – Concave – Aspheric f/2.6
Active + Position Control

M4 Unit
2.4-m
Flat
Segmented (6 petals)
Adaptive + Position Control

M5 Unit
2.7x2.1-m
Flat
Passive + Fast Tip/Tilt

LGSU
(Laser Guide Star Units)
Laser Sources + Laser Beacons
shaping and emitting

Credit: S. Ramsay

ELT instruments

Planets & Stars

Multi-AO **I**maging **C**amera for **D**eep **O**bservations

Multi-conjugate **A**daptive **O**ptics **R**ela**Y**

High **A**ngular **R**esolution **M**onolithic **O**ptical and **N**ear-infrared **I**ntegral field spectroscopy

Mid-infrared **ELT** **I**mager and **S**pectrograph

Galaxies & Cosmology

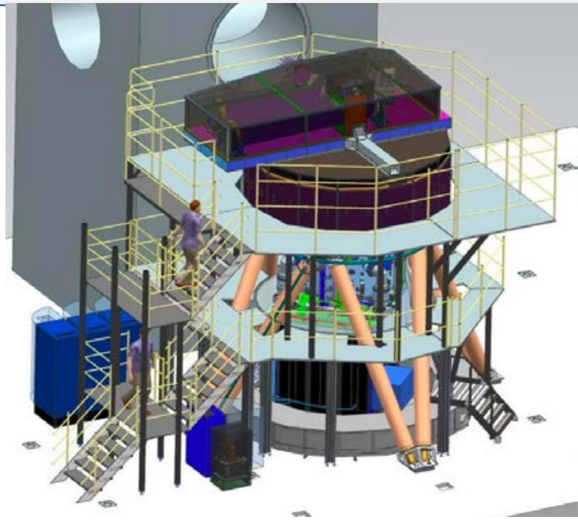
HIgh **RE**solution **S**pectrograph

MOSAIC: multi-object **S**pectrograph

MICADO@ELT

- **PI R. Davies** (MPE), MPIA, USM, IAG, NOVA, INAF, LESIA, A*, FINCA plus contribution from ESO

- Wavelength coverage: NIR (0.8 -2.4 µm)
- SCAO and MAORY MCAO systems
- SCAO as joint development between MAORY and MICADO
- Sensitivity similar to JWST but x6 better resolution
- Four observing modes



Standard Imaging

- 0.8-2.4 µm with > 30 BB/NB filter
- 1.5 & 4 mas pixel scale for FoV 19”x19” and 51”x51”

Astrometric Imaging

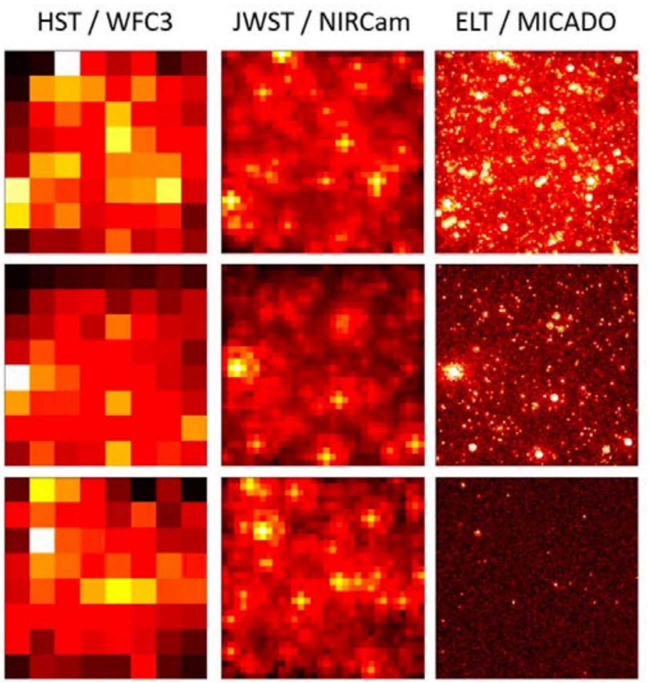
- 10-50 µas precision anywhere in the field
- 10 µas/yr = 5km/s at 100 Kpc after only few years (i.e., detecting PM of objects, too faint for Gaia, within the Galactic Halo)

High Contrast Imaging

- Coronagraphy, ADI
- small working angle

Slit Spectroscopy

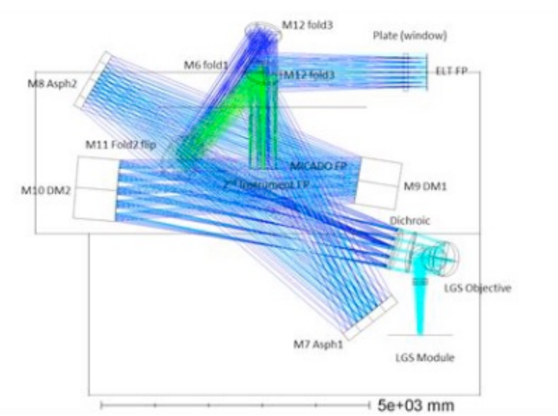
- fixed config. for 0.82-1.55 µm & 1.49-2.45 µm
- R~20K for point source (R~10K across slit)

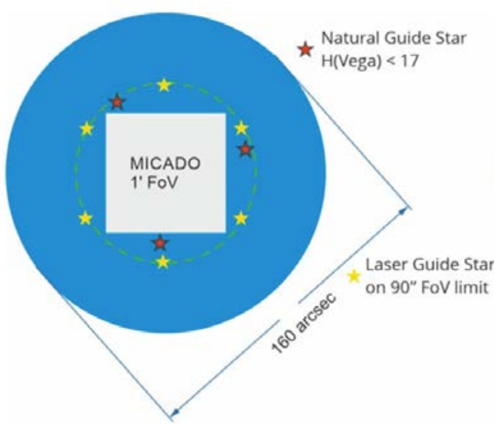


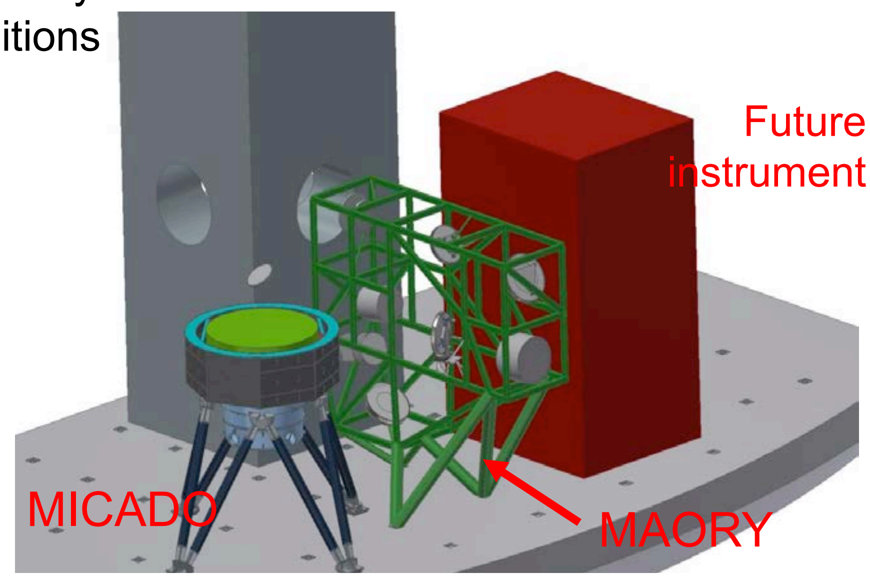
MAORY@ELT

- **PI P. Ciliegi** (INAF-OA Bologna), INAF (OA Arcetri, OA brera, OA Capodimonte, OA Padova, OA Teramo), INSU/CNRS-IPAG, NUIG

- MCAO system using up to 6 LGS and 3 NGS
- 1 or 2 post-focal DMs in addition to ELT-M4 to correct for atmospheric turbulence
- SCAO as joint development between MAORY and MICADO
- Optical beam can feed MICADO or second instrument port
- Performance goal: SR_K~ 60% with excellent uniformity over 2” FoV in best conditions; SR_K~ 30% in median conditions
- Sky coverage: 50% at South Galactic Pole

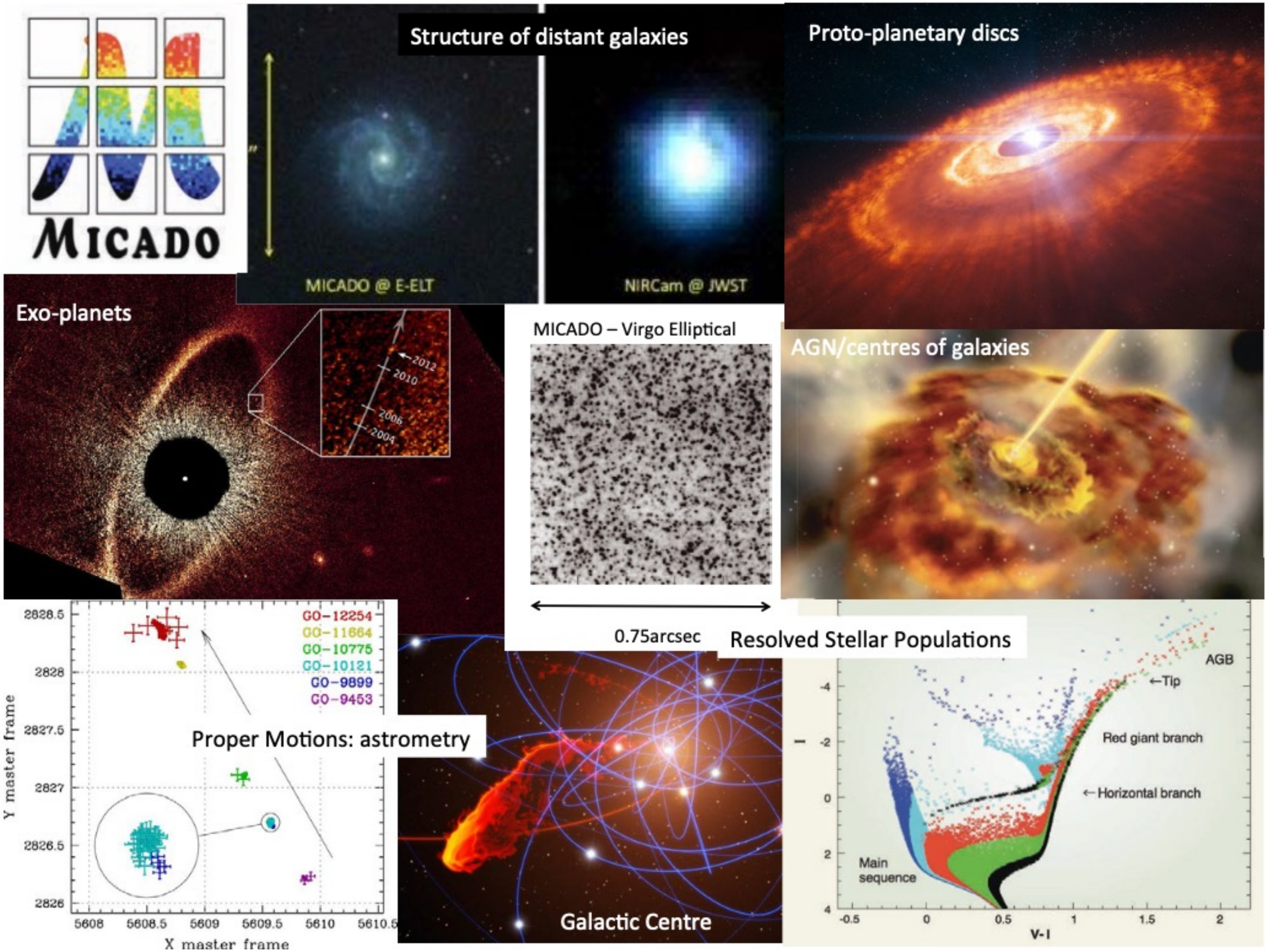






Credit: S. Ramsay and MAORY Consortium

Science with MICADO

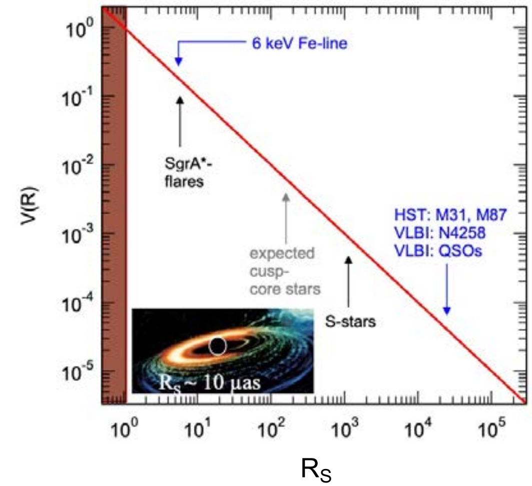


Credit: MICADO Consortium

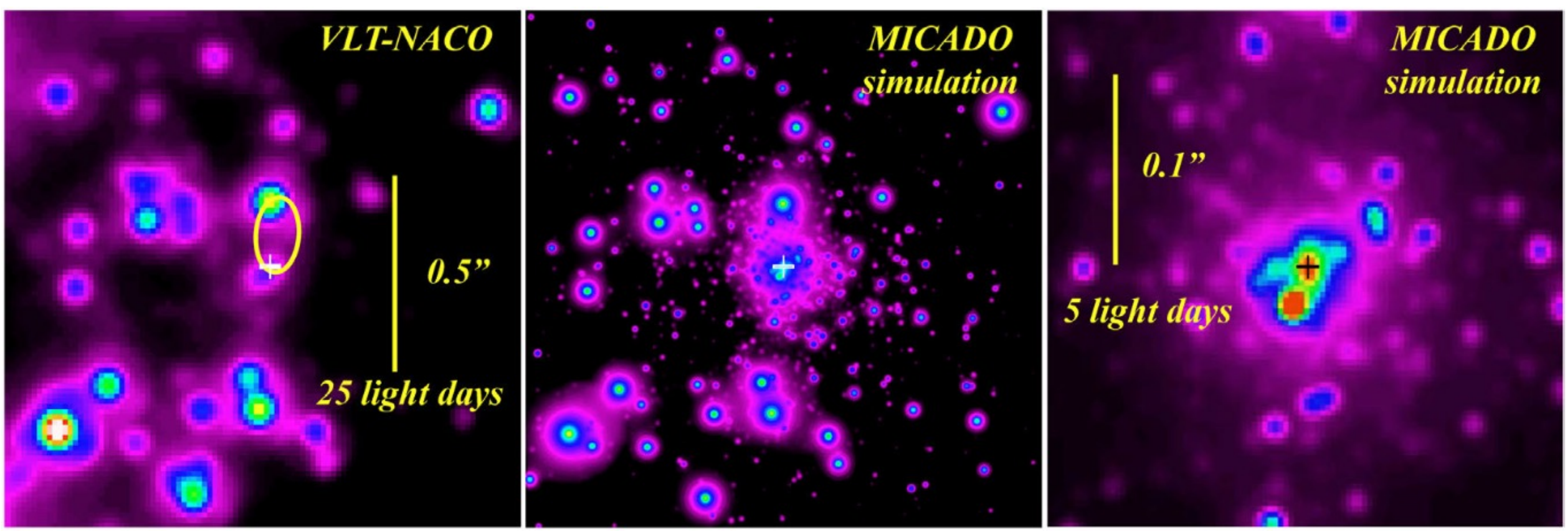
A

The Center of the MW

- **Testing the General Relativity in the strong-field regime**
  - Dynamical measurement of Gravitational Potential even closer to the event horizon where GR effects are stronger
    - <u>R_S:10^3-10^2 regime</u>: motion of faint (K~20-12) MS stars that will have orbital velocity of 0.1c → orbital period of few years → routine detection of SR and GR on the orbits
    - <u>Few R_S regime</u>: probed through flares



- Dynamical study of young star clusters in the central 50pc (e.g. Arches, Quintuplet): presence of IMBH??
- Detection of the theoretically predicted dark cusp
- Central accretion zone surrounding SgrA* (e.g., outflows/jets)



Credit: MICADO Consortium

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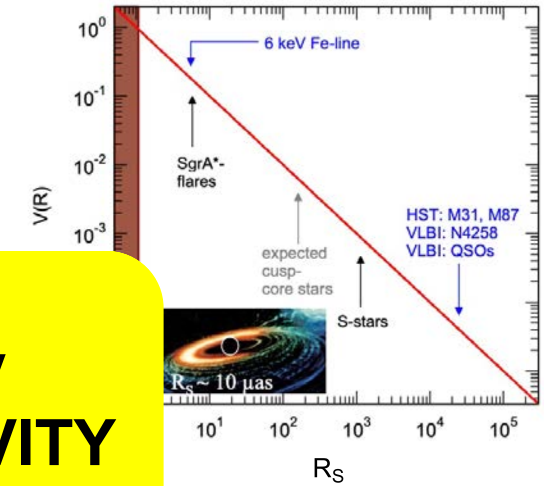
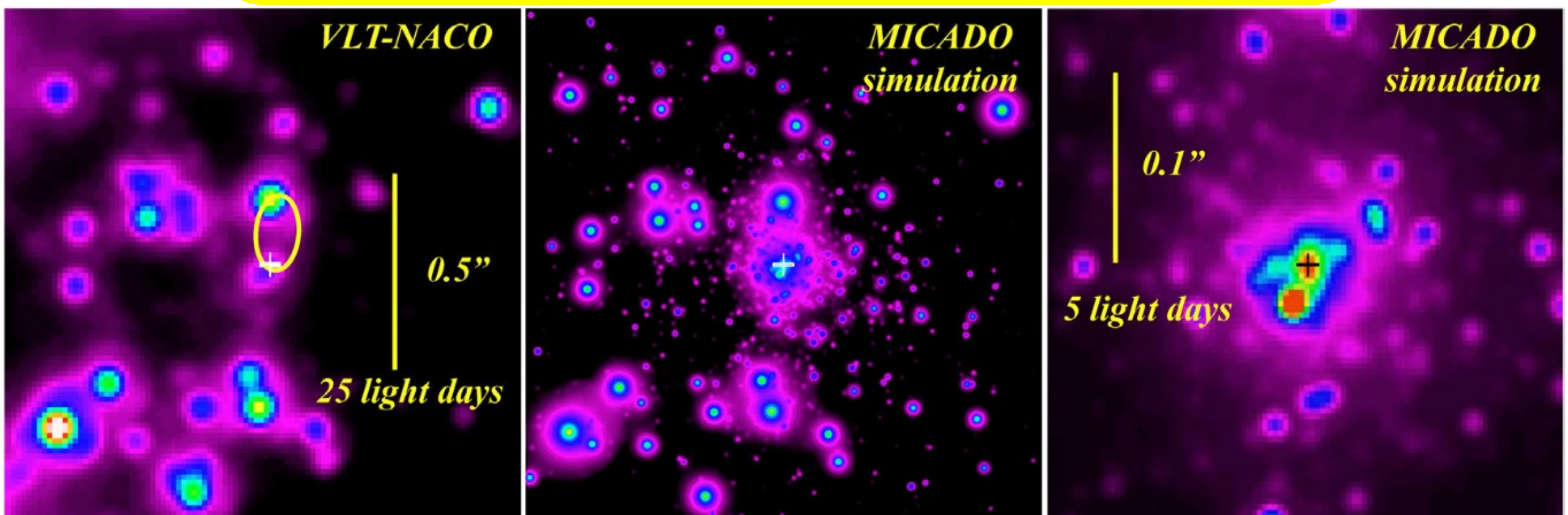
    - ...



- Dynamical ...
  Arches, Q...
- Detection ...
- Central ac...

MICADO is THE unique facility
Strong synergy with ERIS & GRAVITY

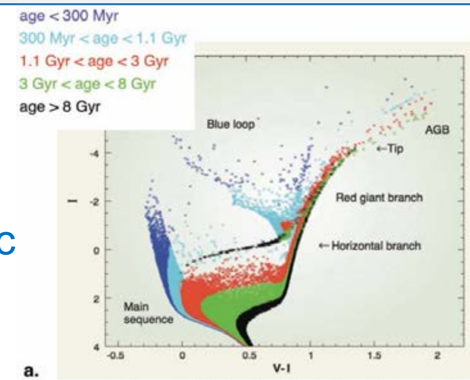


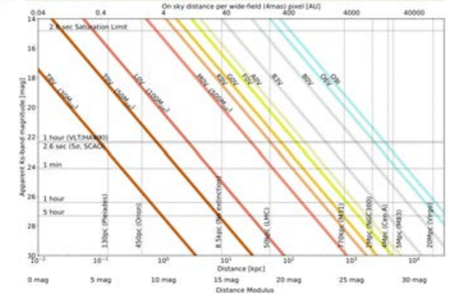
Credit: MICADO Consortium

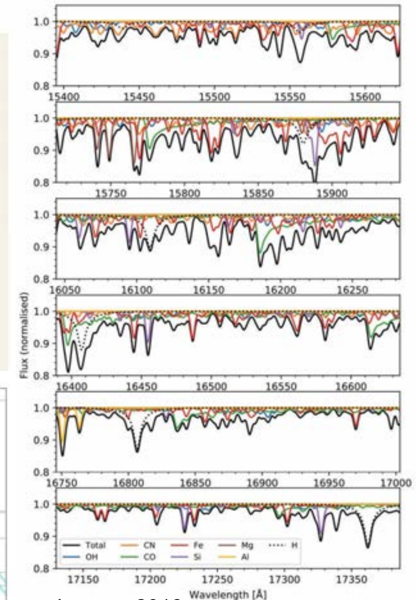
Resolved SPs

- Star formation and SFH in different environments
  - MS-TO at 2Mpc
  - HB at 10Mpc
  - TRGB to > 100Mpc
- Chepheid Period-Luminosity relation out to 100Mpc (H_0)
- Stellar spectroscopy beyond Local Group

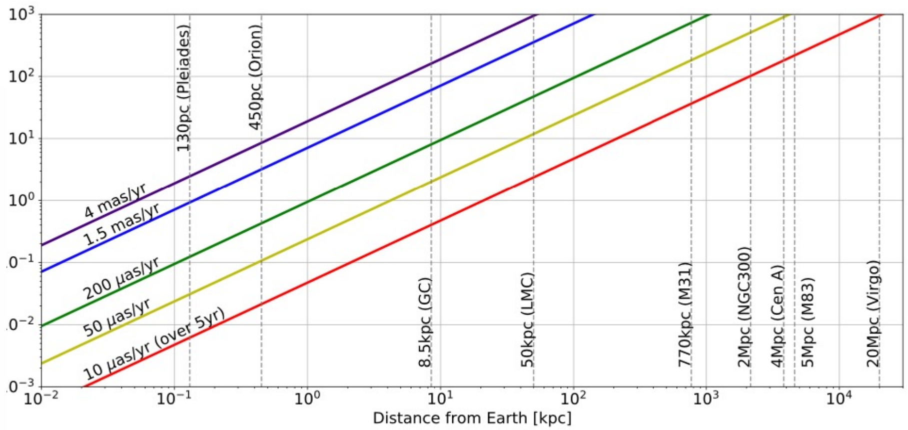
- Dynamics of dense stellar systems as probes of DM distribution in the MW and LG galaxies
  - proper motions of individual stars
  - Absolute motions of LG galaxies
  - high accuracy & stability
  - x10 better than HST

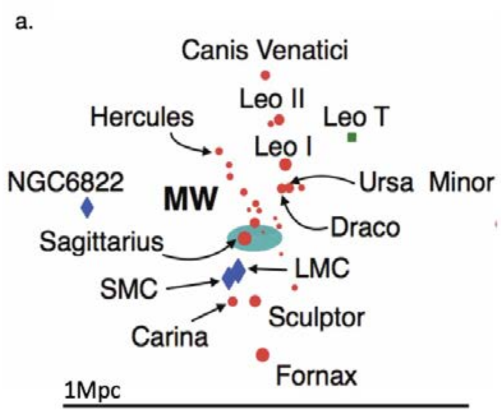


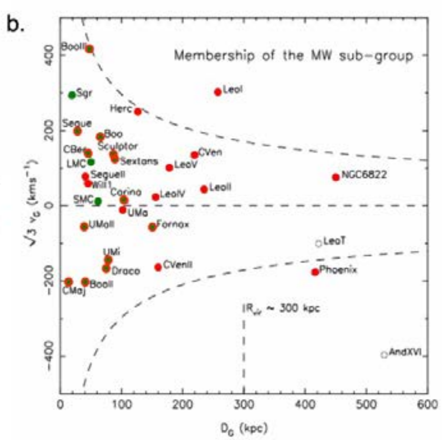




Larsen+2018







Credit: MICADO Consortium

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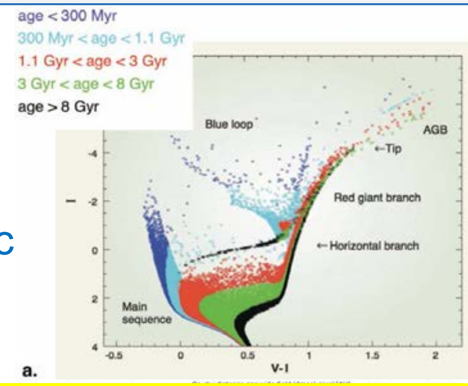
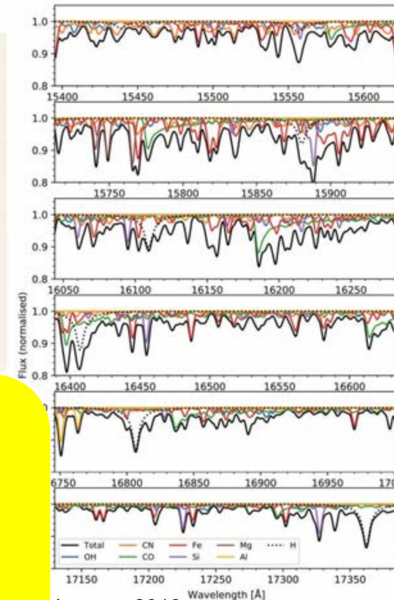


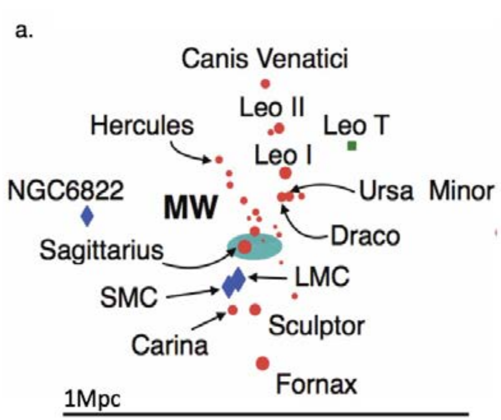


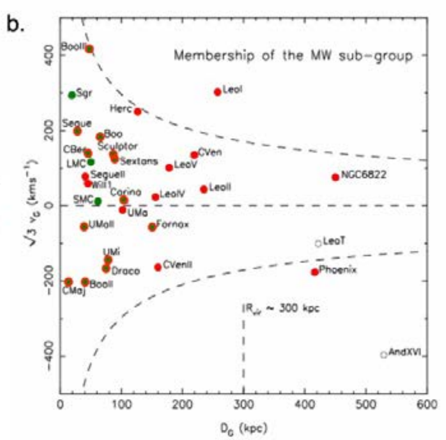
Larsen+2018

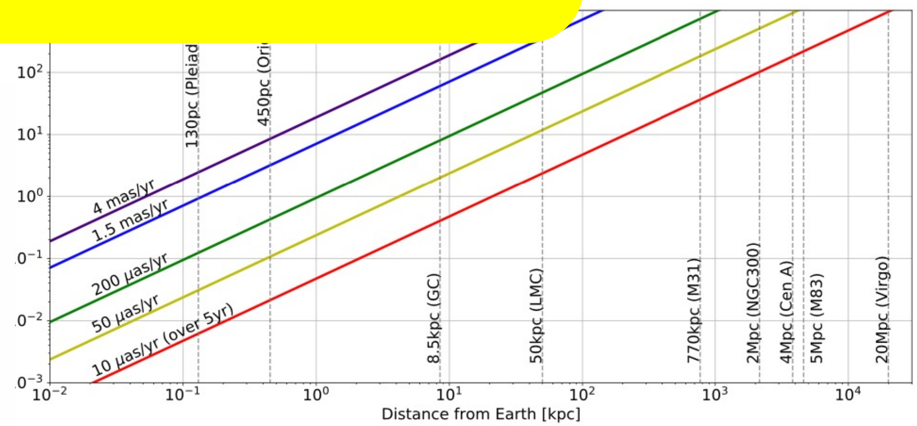
- Dynamics of … DM distributi…
  - proper m…
  - Absolute…
  - high accu…
  - x10 better than HST

Strong synergy with Gaia, ERIS, MUSE, MAVIS and HARMONI

(see also G. Bono's lecture)







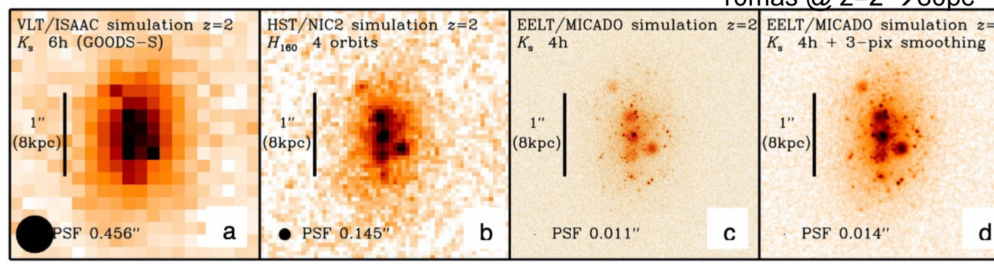
Credit: MICADO Consortium

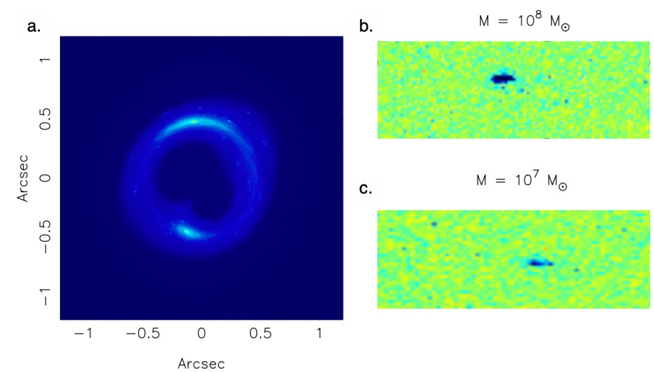
Science with MICADO

Galaxy Evolution: Detailed properties of distant galaxies

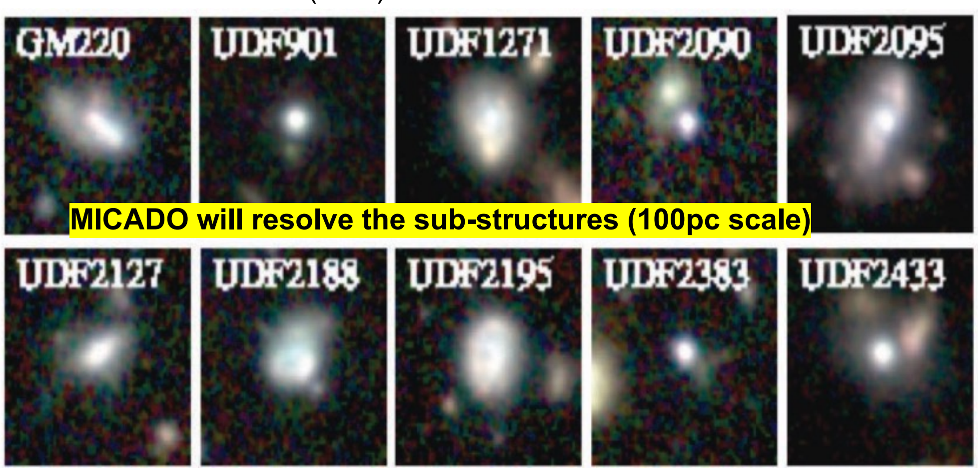
- Resolving disks at high-z
- bulges formation
- GCs formation
- Resolving compact galaxies at z>2
- Progenitor of ETG in densest environments
- Quasar host galaxy properties
- Structure of strongly lensed galaxies and DM halo substructure

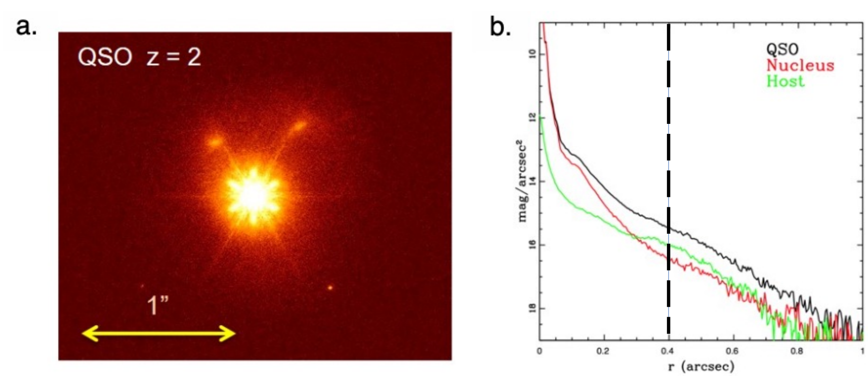
10mas @ z=2 → 80pc





Galaxies in cluster z~2 (HST) Mei+2015

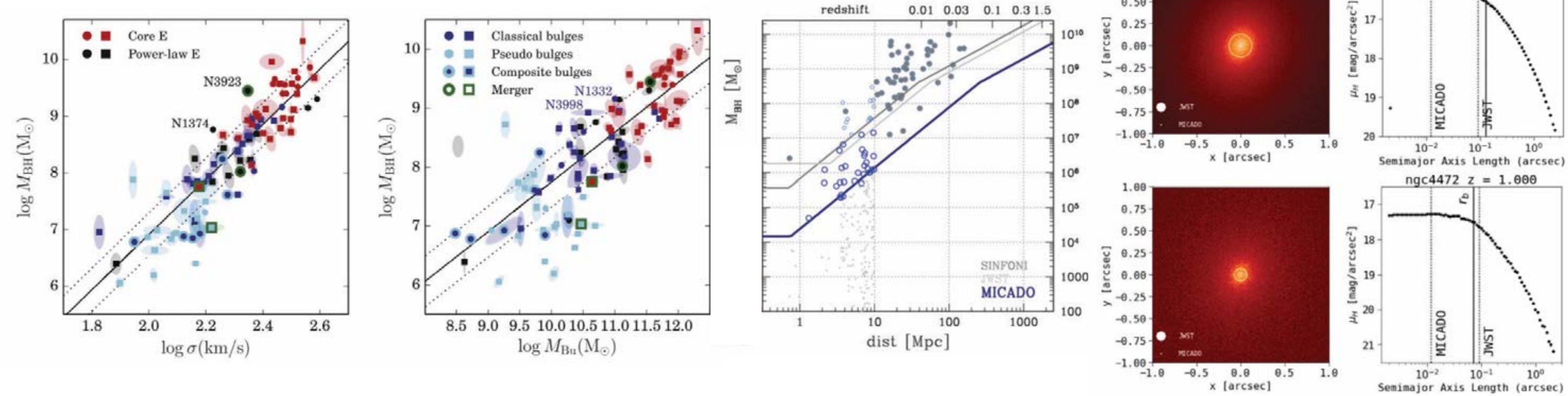




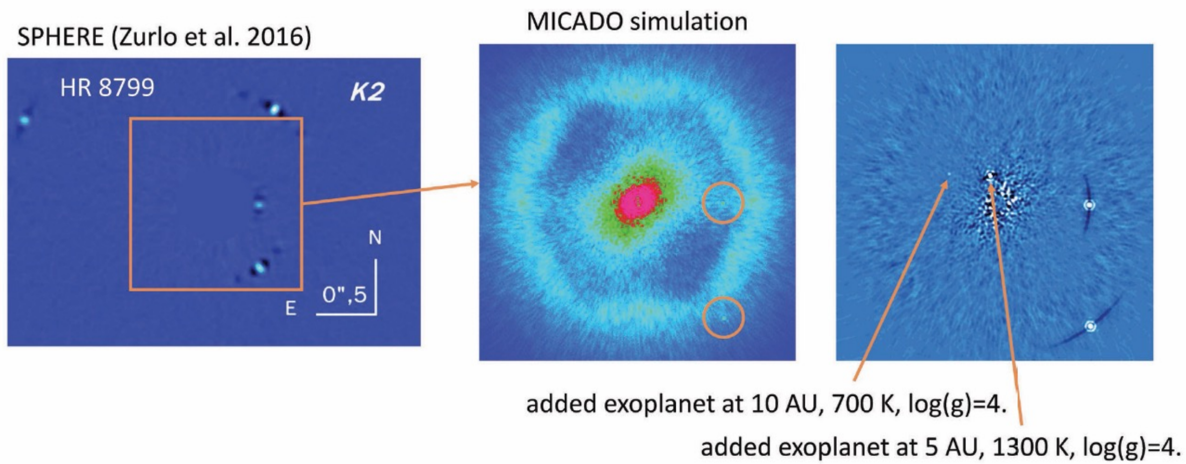
Credit: MICADO Consortium

Science with MICADO

Black holes in Galaxies



Planets: formation and evolution

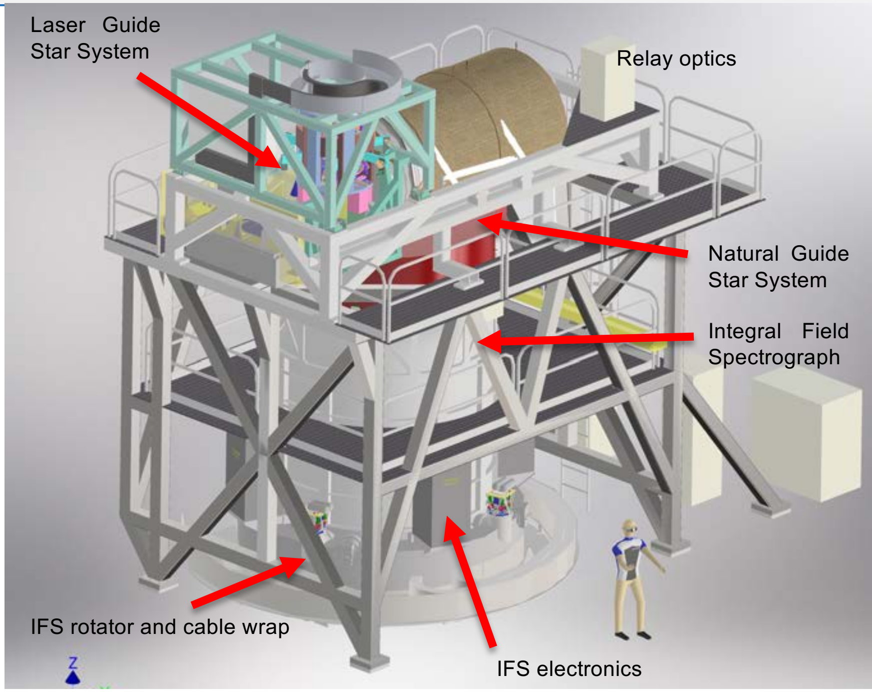


Credit: MICADO Consortium

HARMONI@ELT

- **PI N.Thatte** (Univ Oxford), UK ATC, IAC, CSIC-CAB, CRAL, LAM, IPAG, Durham Univ., Michigan Univ., ONERA, , IRAP, and ESO as associate partner

- 3D spectrograph (IFU) covering optical (0.47µm) to NIR (2.45µm)
- Resolving power: R = 3500 - 20000
- Seeing and diffraction (SCAO, LTAO) limited
- Four spaxel scales / FoV



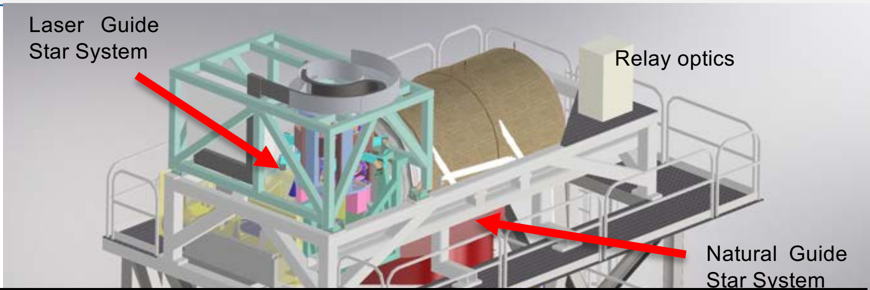
Spaxel scale [mas]	FoV [arcsec]	AO mode
60 x 30	5.5 x 9.1	NoAO
20 x 20	4.3 x 4.3	LTAO faint sources
10 x 10	2.1 x 1.5	LTAO bright sources
4 x 4	0.8 x 0.6	SCAO

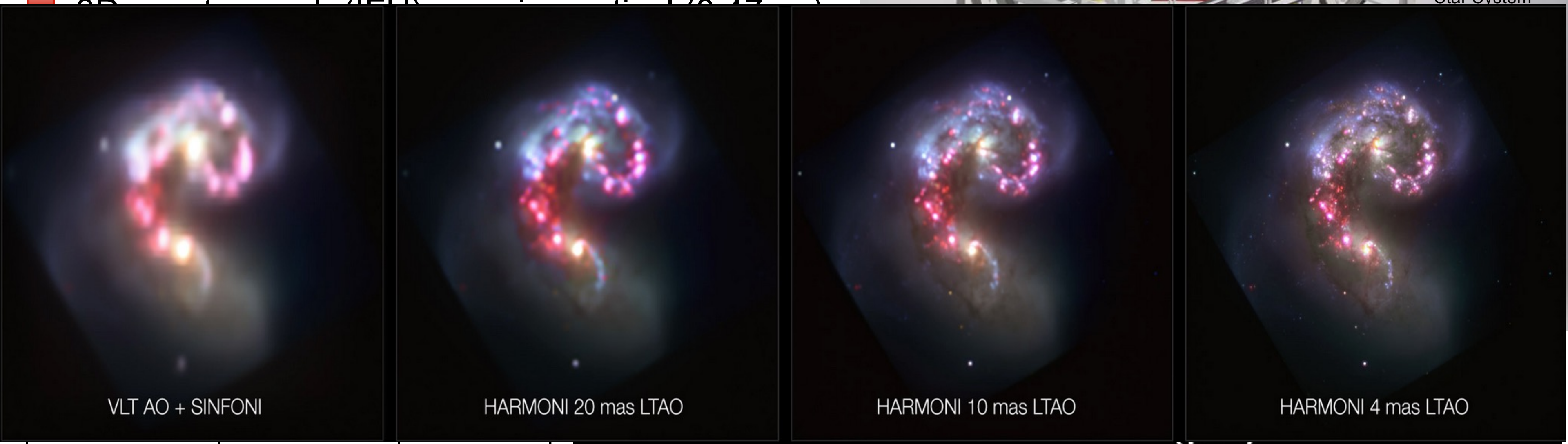
Bands	Wavelengths (µm)	R
"V+R" or "I+z+J" or "H+K"	0.45-0.8, 0.8-1.35, 1.45-2.45	~3000
"I+z" or "J" or "H" or "K"	0.8-1.0, 1.1-1.35, 1.45-1.85, 1.95-2.45	~7500
"Z" or "J_high" or "H_high" or "K_high"	0.9, 1.2, 1.65, 2.2 (TBD)	~20000

Credit: S. Ramsay and HARMONI Consortium

HARMONI@ELT

- **PI N.Thatte** (Univ Oxford), UK ATC, IAC, CSIC-CAB, CRAL, LAM, IPAG, Durham Univ., Michigan Univ., ONERA, , IRAP, and ESO as associate partner





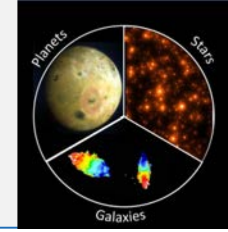
		faint sources
10 x 10	2.1 x 1.5	LTAO bright sources
4 x 4	0.8 x 0.6	SCAO

"V+R" or "I+z+J" or "H+K"	0.45-0.8, 0.8-1.35, 1.45-2.45	~3000
"I+z" or "J" or "H" or "K"	0.8-1.0, 1.1-1.35, 1.45-1.85, 1.95-2.45	~7500
"Z" or "J_high" or "H_high" or "K_high"	0.9, 1.2, 1.65, 2.2 (TBD)	~20000

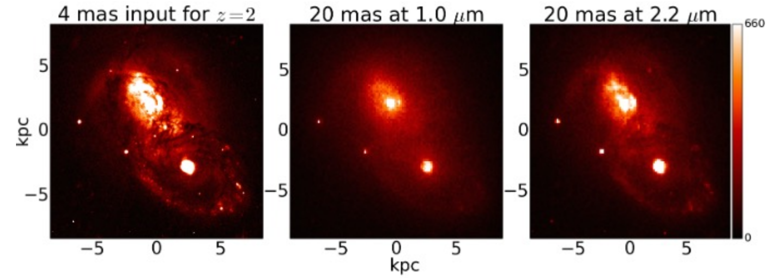
Credit: S. Ramsay and HARMONI Consortium

Science with HARMONI

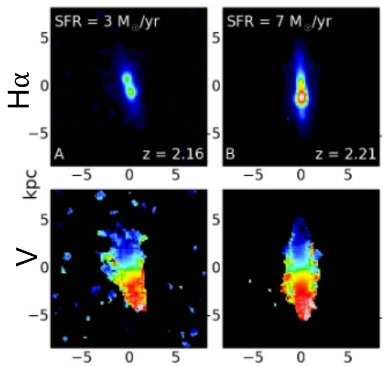
https://harmoni-elt.physics.ox.ac.uk/ForScience.html



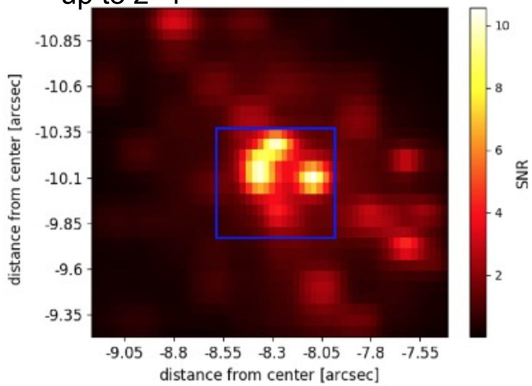
- Planetary science and exoplanets
- Resolved SPs: MW and nearby galaxies
- Galaxy evolution
- Cosmology and high-z Universe



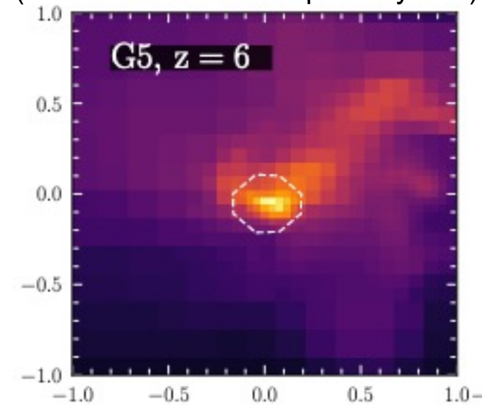
Emission line galaxies (z~2-3)

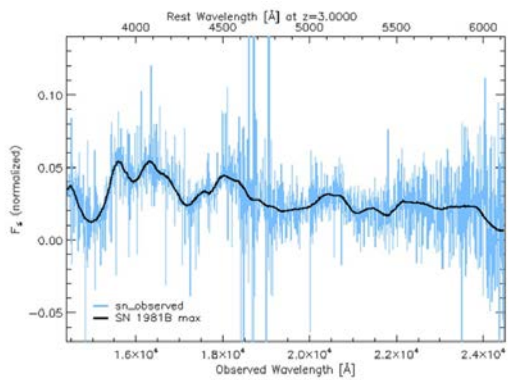


CGM traced by Lyα,Hα,C[IV],O[VI] up to z~4



Pop III traced by HeIIλ1640 emission (z~4 or even z~10 if top-heavy IMF)





Classifying SNIa at z~3
up to 80 days post max-light

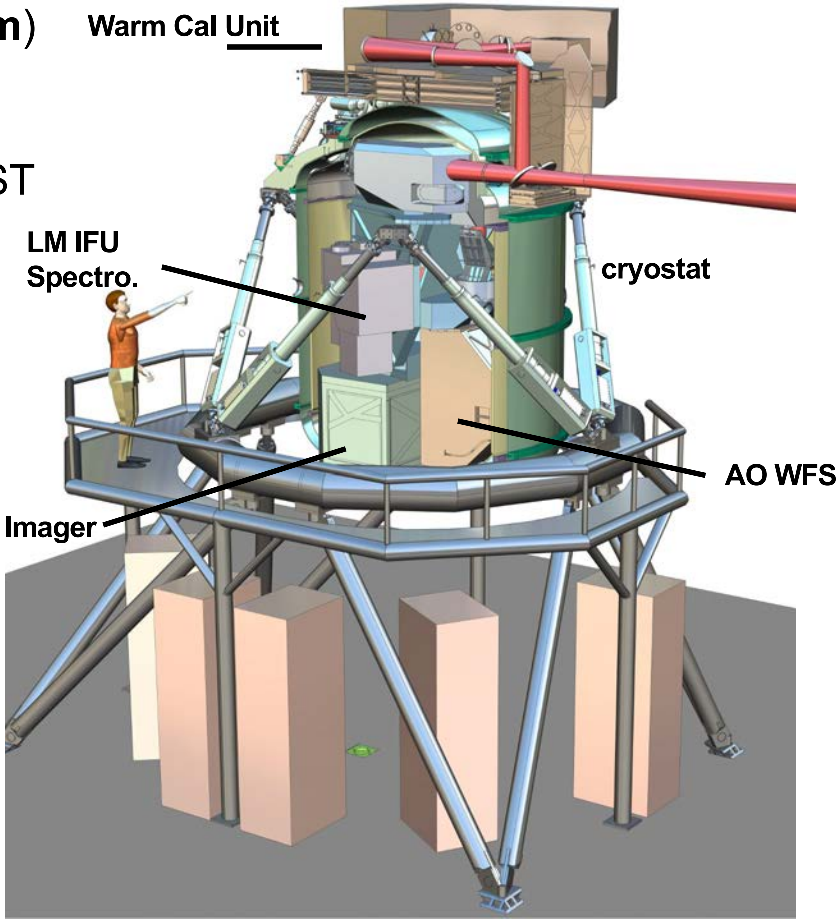
Credit: HARMONI Consortium

METIS@ELT

- **PI B.Brandl** (Univ. Leiden) Nova, MPIA-Heidelberg, Univ. Köln, UK-ATC, KU-Leuven, CEA-Saclay, CENTRA, ETH-Zürich, A*, Univ. Michigan, ASIAA, Univ. Liege plus ESO

- Wavelength coverage: thermal/mid-IR (**3µm to 13µm**)
- Angular resolution: x6 better than JWST
- Point source sensitivity ~Spitzer-IRAC
- Spectrally unresolved emission line sensitivity ~JWST
- Observing modes:
  - Imaging
  - Coronagraphy (HCI)
  - Slit Spectroscopy
  - IFU
- All modes work at diffraction limit (SCAO)

Mode	Imaging HCI	Slit Spectroscopy	IFU
λ coverage [µm]	3 – 5 7.5 - 13	3 – 5 7.5 – 13.5	3 - 5
Resolution	5.5mas/px 6.8mas/px	~1.5K – 1.9K ~400	100K
FoV	10.5”x10.5” 13.5”x13.5”	NA	~1”x1”



METIS@ELT

- **PI B.Brandl** (Univ. Leiden) Nova, MPIA-Heidelberg, Univ. Köln, UK-ATC, KU-Leuven, CEA-Saclay, CENTRA, ETH-Zürich, A*, Univ. Michigan, ASIAA, Univ. Liege plus ESO

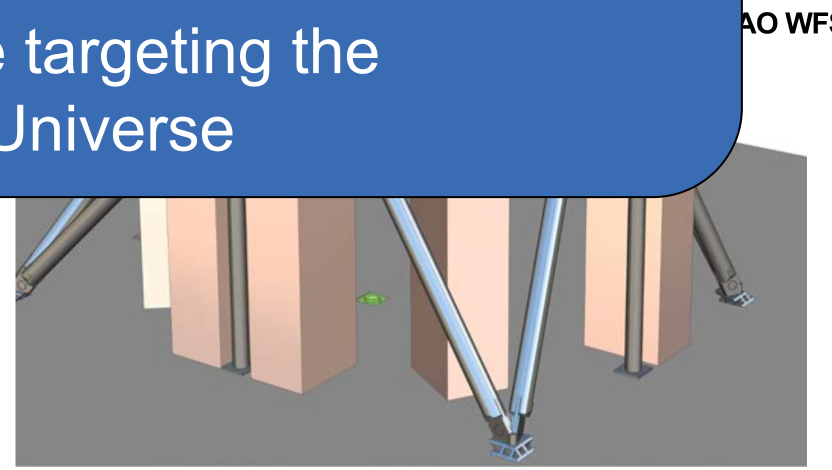
- Wavelength coverage: thermal/mid-IR (**3µm to 13µm**)
- Angular resolution: x6 better than JWST
- Poi
- S
- O

It combines **ERIS**, **CRIRES+** and **VISIR** capabilities but enhanced with
the spatial resolution and collecting area of the **ELT**

It's mid-IR workhorse targeting the cold and dusty Universe

- A

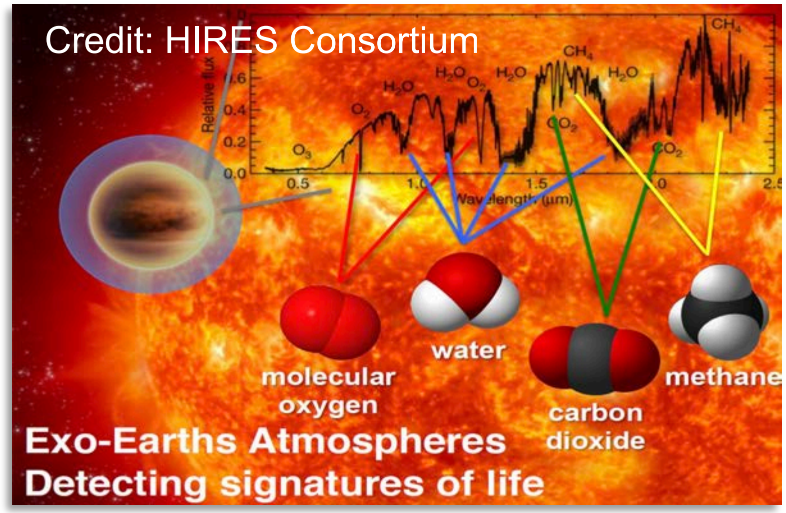
M			
λ coverage [µm]	3 – 5 7.5 - 13	3 – 5 7.5 – 13.5	3 - 5
Resolution	5.5mas/px 6.8mas/px	~1.5K – 1.9K ~400	100K
FoV	10.5"x10.5" 13.5"x13.5"	NA	~1"x1"



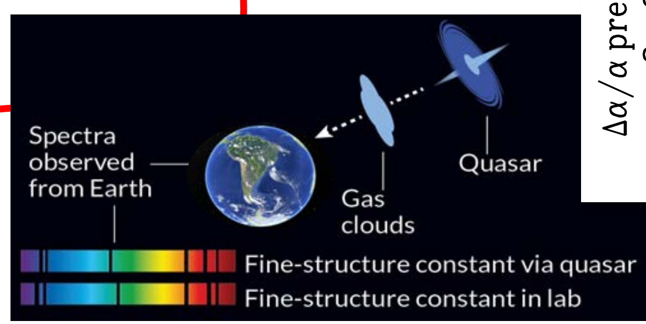
HIRES@ELT

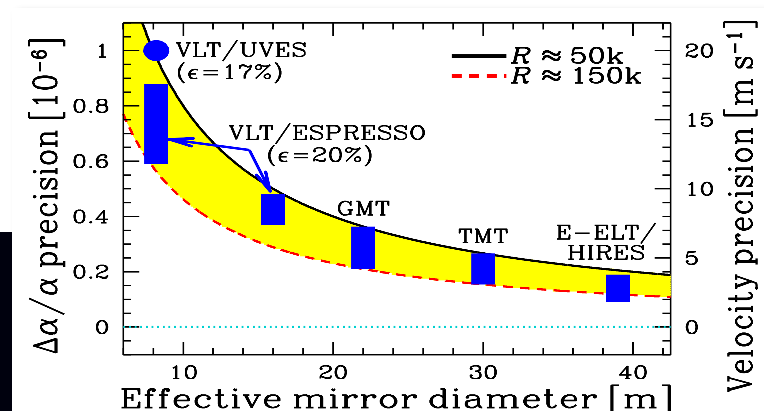
- **PI A. Marconi** (INAF), plus a very large Consortium

- Fiber-fed cross dispersed echelle spectrograph
- Single-object spec and IFU
- Wavelength coverage: simultaneous 0.45 -1.8 μm
- Resolving power: R = 100000
- Ultra-stable (~1 m/s)
- Seeing limited and SCAO+IFU



- **Exo-planets atmosphere**
- **Protoplanetary disks**
- **Stellar astrophysics**
- **Stellar Populations**
- **IGM**
- **Galaxy Evolution**
- **SMBH**
- **Fundamental Physics**



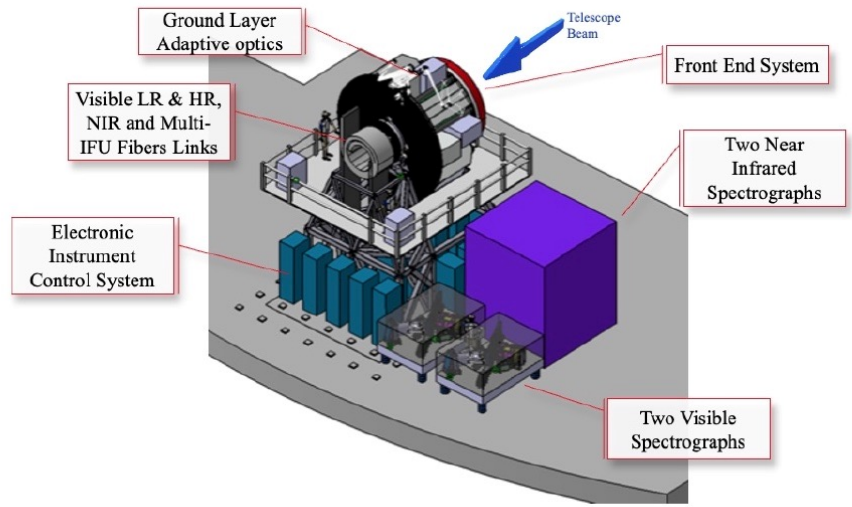


Community White Paper: Maiolino et al. 2013, ArXiV:1310.3163
ESO Messenger: Marconi et al. 2020, ArXiV: 2011.12317

MOSAIC@ELT

- **PI L. Tasca** (LAM), **Co PI M. Puech** plus a very large Consortium

- Multiplexing spectroscopy (fiber MOS and IFUs)
- Wavelength coverage: optical (0.45 μm) and NIR (1.8 μm)
- Seeing limited and GLAO
- Resolving power: R = 4000 - 18000



REQUIREMENTS

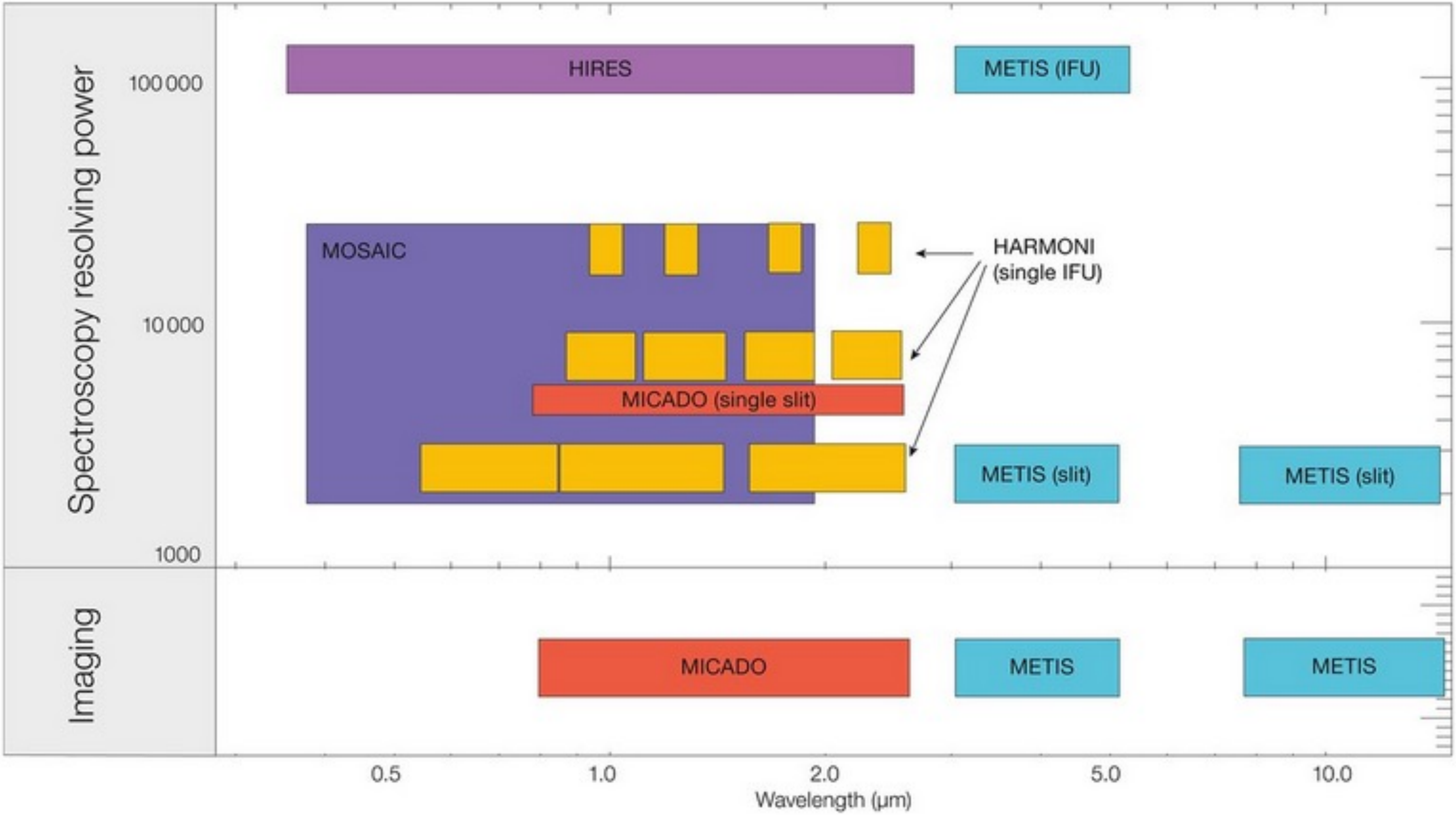
PARAMETER	MOS-VIS		MOS-NIR		mIFU	
	LR	HR	LR	HR	LR	HR
Multiplex	200	70	140	140	8	8
Wavelength coverage	0.45-0.77μm	0.51-0.57μm 0.61-0.67μm	0.77-1.80μm	0.77-0.89μm 1.52-1.62μm	0.77-1.80μm	0.77-0.89μm 1.52-1.62μm
Resolution	4000	18,000 18,000	4000	9000 18,000	4000	9000 18,000
Aperture	0.7″	0.7″	0.6″	0.6″	2.5″	2.5″
Spaxel	N/A	N/A	N/A	N/A	0.150″	0.150″

NOTE: In the VIS the full wavelength range is covered in 2 exposures (cf 1 exposure in the NIR).

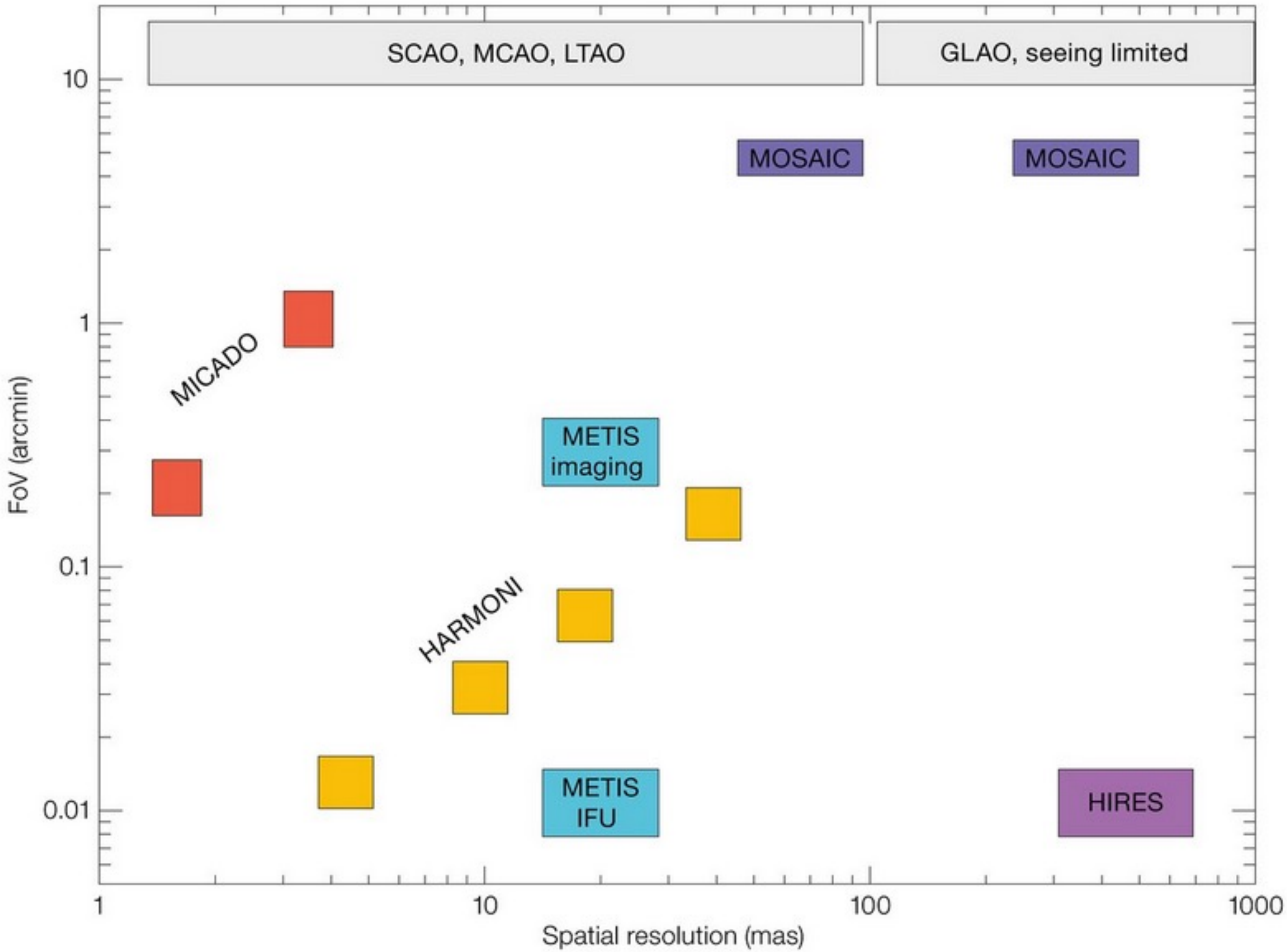
Science cases:
- SC1. First light galaxies
- SC2. Inventory of matter
- SC3. Mass assembly of galaxies
- SC4. Resolved stellar population beyond the local group
- SC5. Galaxy archaeology

Credit: V. Mainieri

The ELT in a nutshell



The ELT in a nutshell



The Universe is waiting for you to be explored
You have plenty of observing tools
Be open to use diverse and complementary approaches

Pick your astrophysics quest and be ready to pursue it with ELT by using its instruments simulator:

MICADO: https://simcado.readthedocs.io/en/latest/
HARMONI: https://github.com/HARMONI-ELT/HSIM
METIS: https://metis.strw.leidenuniv.nl/simmetis/

Don't be shy and THINK BIG!

THANKS