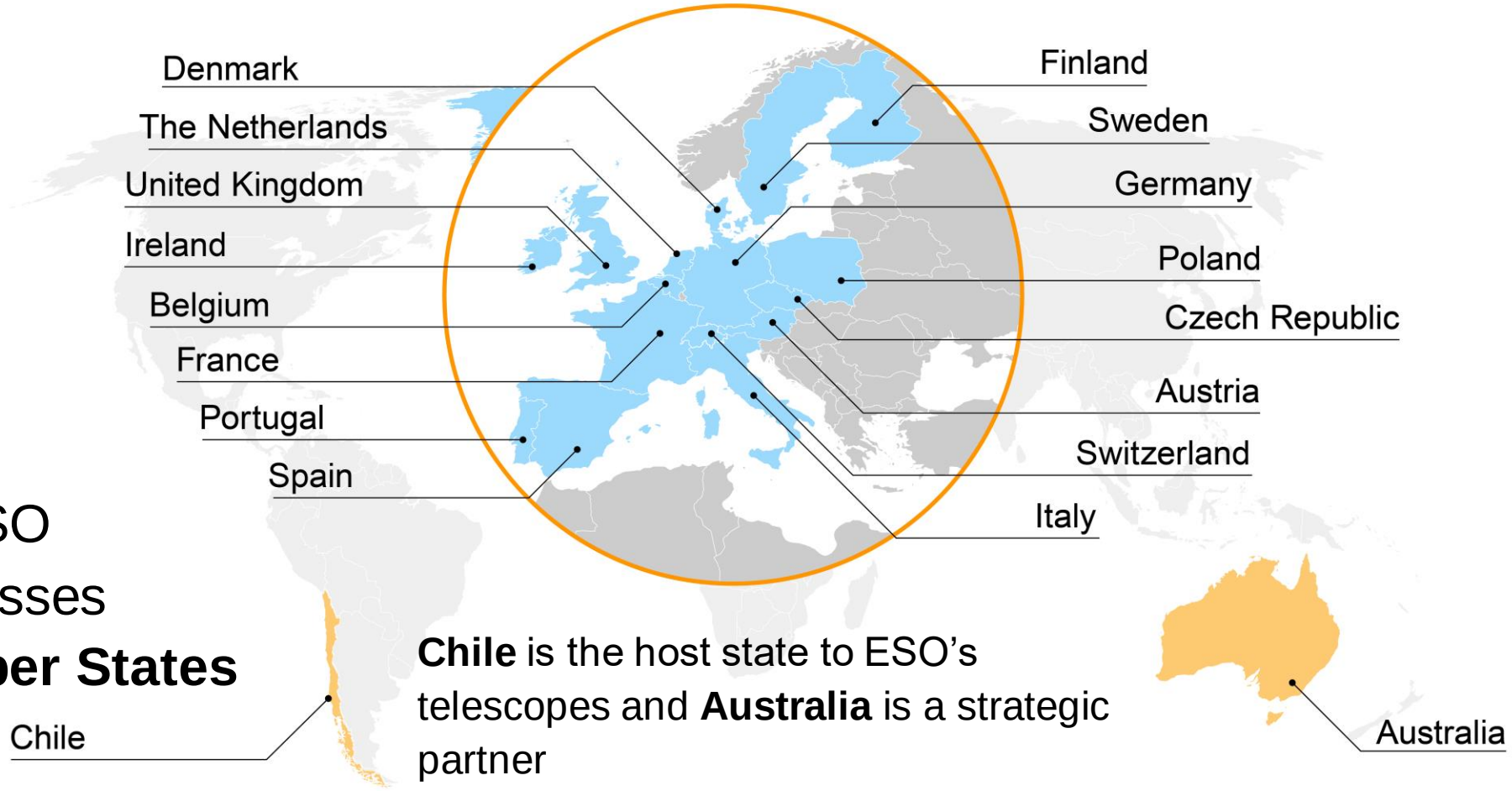
ESO's Present,

New & Upcoming Instrumentation

Eric Emsellem / Antoine Mérand

Member States and Partners



Today ESO encompasses
16 Member States

Chile is the host state to ESO's telescopes and **Australia** is a strategic partner

ESO telescopes

La Silla

ESO operated:

NTT 3.58 m

3.6-metre telescope

Hosted telescopes currently in operation: **11**

Paranal

ESO operated:

VLT and VLTI

4 x 8.2 m, 4 x 1.8 m

VISTA 4.1 m

Hosted telescopes currently in operation:

VST, NGTS, SPECULOOS

Armazones

Under construction:

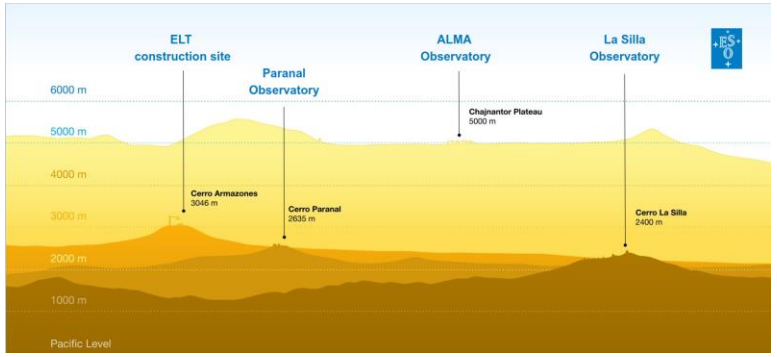
ELT 39.3 m

Chajnantor

ALMA

54 x 12 m and 12 x 7 m antennas

ESO telescopes



Paranal

VLT
VLTI

VISTA

CTA
South*

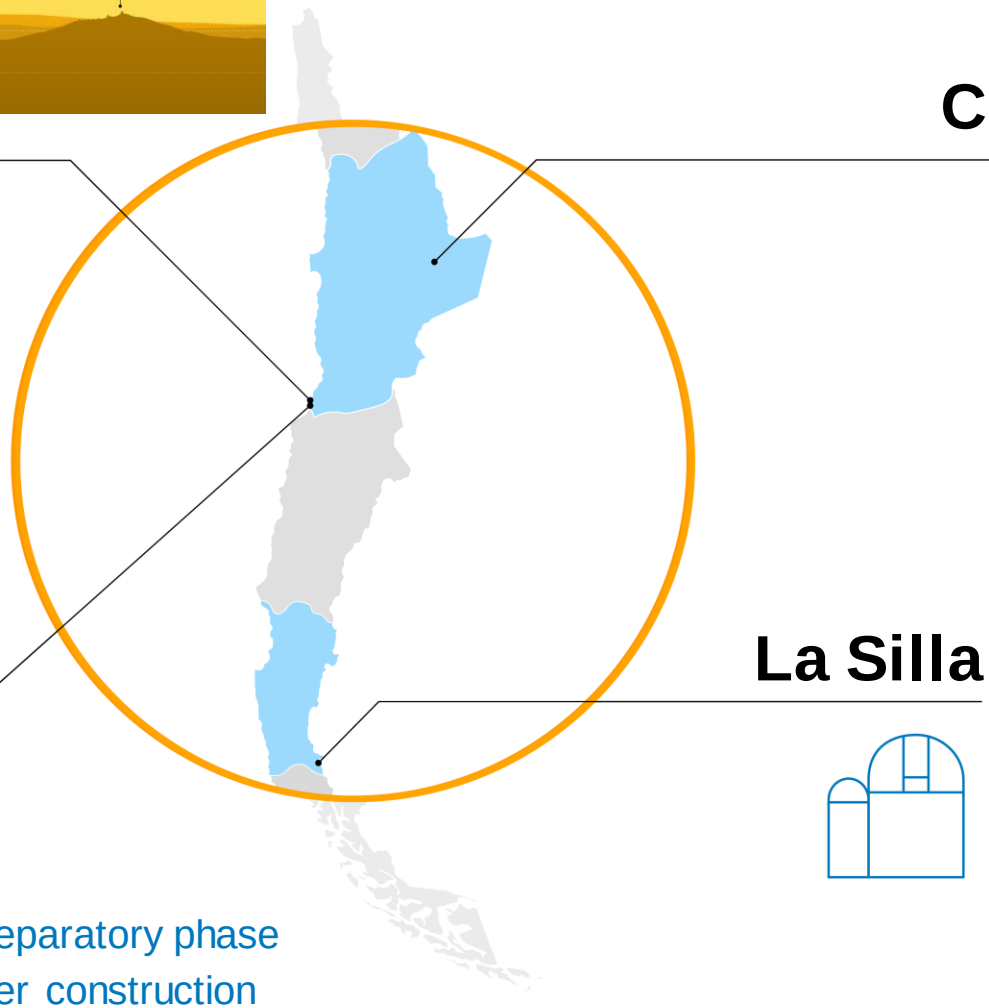
Chajnantor

ALMA

Armazones

ELT**

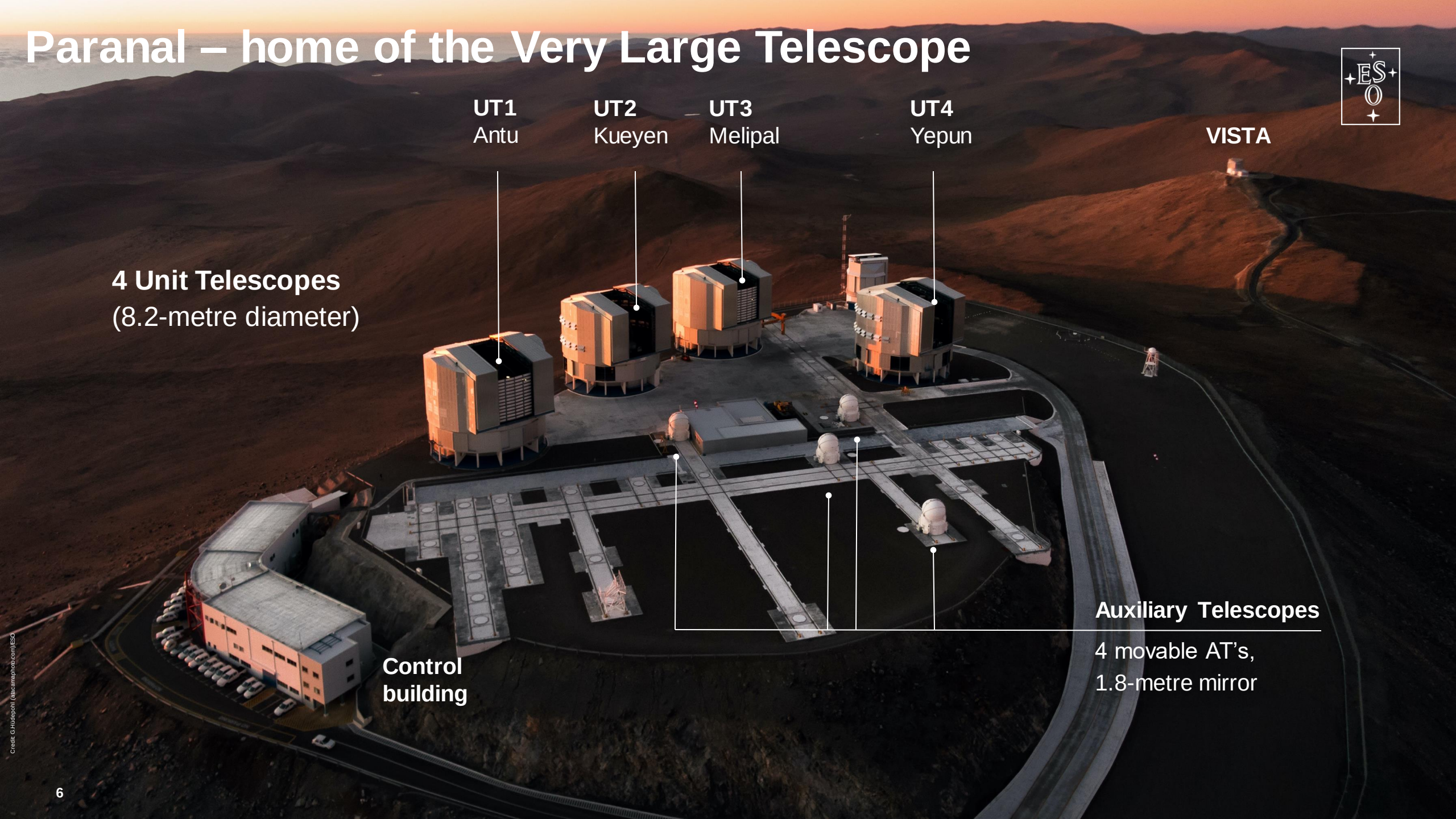
La Silla



* in preparatory phase
** under construction

Telescopes currently operated by ESO in La Silla

Paranal – home of the Very Large Telescope



Credit: G.Hüdepohl (atacamaphoto.com)/ESO

The **European Southern Observatory (ESO)** invites proposals for observations at ESO telescopes during Period 114 (**1 October 2024 – 31 March 2025**). The following instruments are offered in this Period:

La Silla

EFOSC2 (ESO Faint Object SpeCtrograph 2)
HARPS (High Accuracy Radial velocity Planetary Searcher)
NIRPS (Near Infra Red Planet Searcher)
ULTRACAM (High speed, three channel CCD camera)

Paranal

CRIRES (Cryogenic high-resolution IR Échelle Spectrograph)
ESPRESSO (Échelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations)
ERIS (Enhanced Resolution Imager and Spectrograph)
FLAMES (Fibre Large Array Multi Element Spectrograph)
FORS2 (FOcal Reducer/low dispersion Spectrograph 2)
GRAVITY (K-band instrument for precision narrow-angle astrometry and interferometric imaging)
HAWK-I (High Acuity Wide field K-band Imager)
KMOS (K-band Multi-Object Spectrograph)
MATISSE (Multi-AperTure mid-Infrared SpectroScopic Experiment)
MUSE (Multi Unit Spectroscopic Explorer)
PIONIER (Precision Integrated-Optics Near-infrared Imaging ExpeRiment)
SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch)
UVES (UV–Visual Échelle Spectrograph)
VISIR (VLT Imager and Spectrometer for mid-InfraRed)
X-SHOOTER (UV–Visual–NIR medium resolution échelle spectrograph)

A rich palette of instruments

Imagers

- Visible: FORS→FORSup, MAVIS
- Near-IR: HAWK-I, SPHERE, ERIS
- Mid-IR: VISIR

Spectrographs (300 nm – 20 µm)

- High: UVES, ESPRESSO, CRIRES+, HARPS, NIRPS, CUBES
- Mid: X-Shooter, SOXS
- Low: FORS→FORSup, SPHERE, VISIR

Interferometric

- Near-IR: PIONIER, GRAVITY(+)
- Mid-IR: MATISSE

Multi Objects Spectrographs:

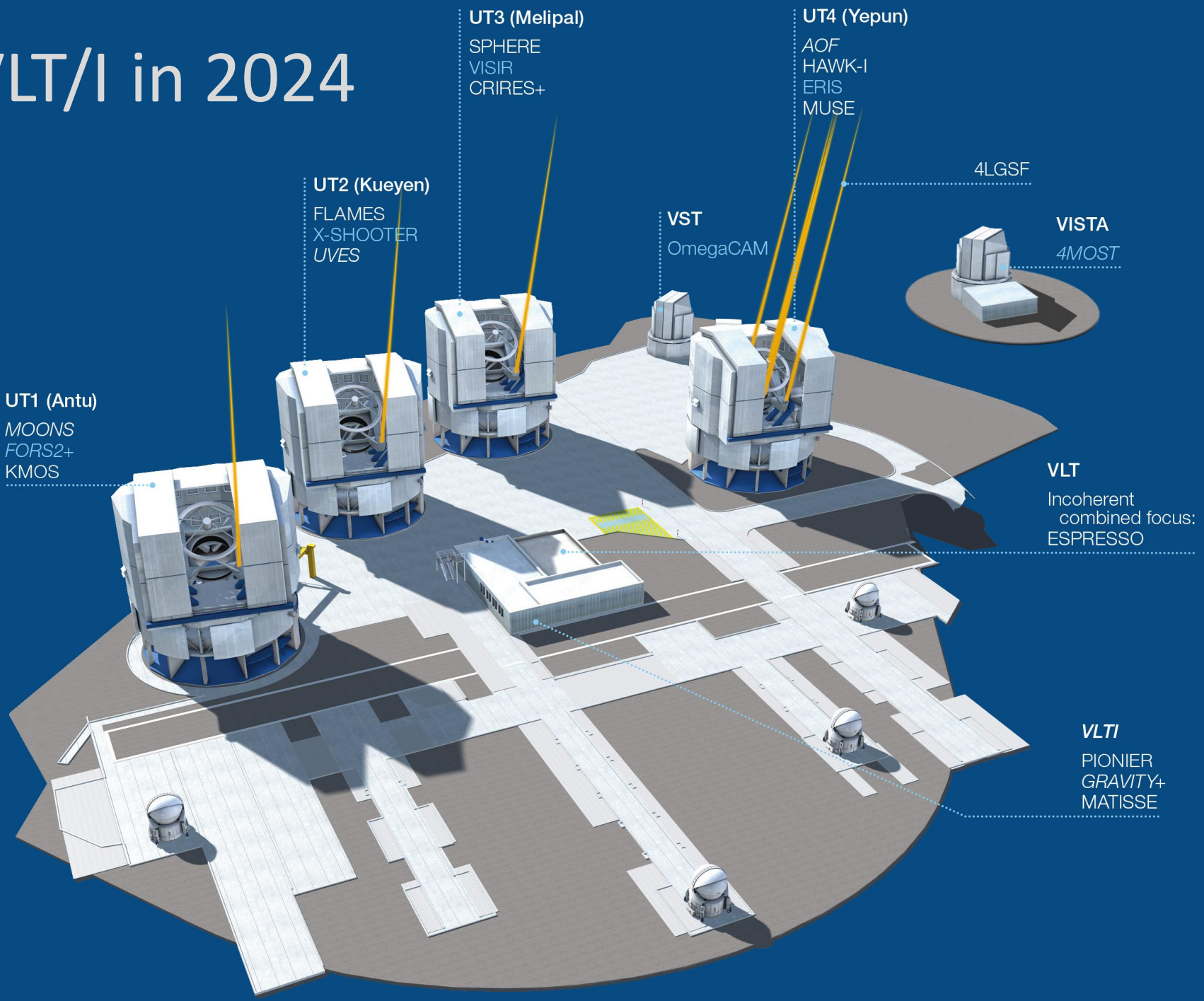
- Visible: FLAMES (fibres), FORS (slitlets), *4MOST* (fibres)
- Visible+Near-IR: MOONS (fibres)

Integral Field Units:

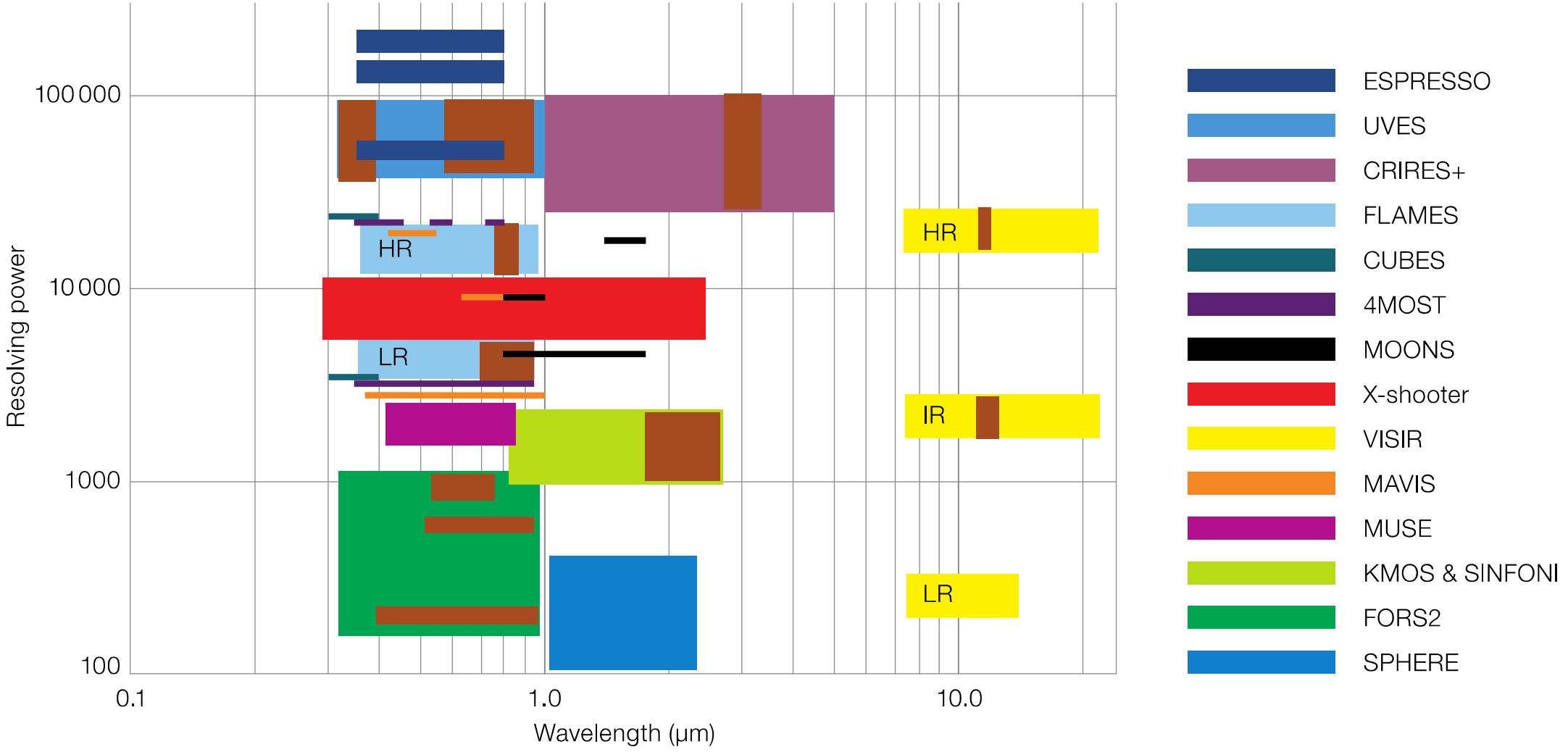
- Visible: MUSE, MAVIS, BlueMUSE
- Near-IR: KMOS (multi), SPHERE, ERIS

AO assisted
On 4m class
In dev.

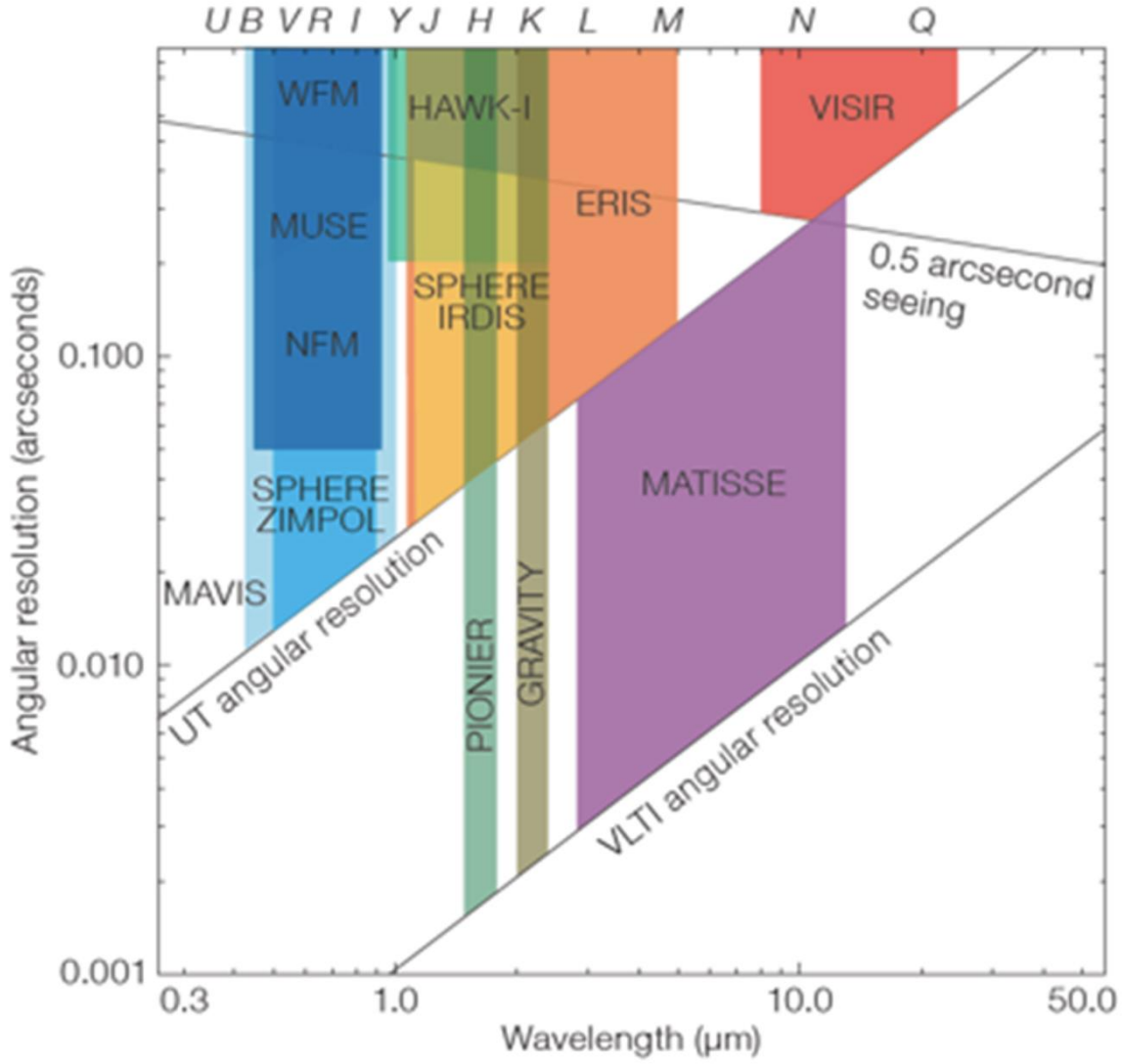
VLT/I in 2024


UT3 (Melipal)
SPHERE
VISIR
CRIRES+
UT4 (Yepun)
AOF
HAWK-I
ERIS
MUSE
4LGSF
UT2 (Kueyen)
FLAMES
X-SHOOTER
UVES
VST
OmegaCAM
VISTA
4MOST
UT1 (Antu)
MOONS
FORS2+
KMOS
VLT
Incoherent
combined focus:
ESPRESSO
VLTI
PIONIER
GRAVITY+
MATISSE

VLT Optical/Near-IR coverage



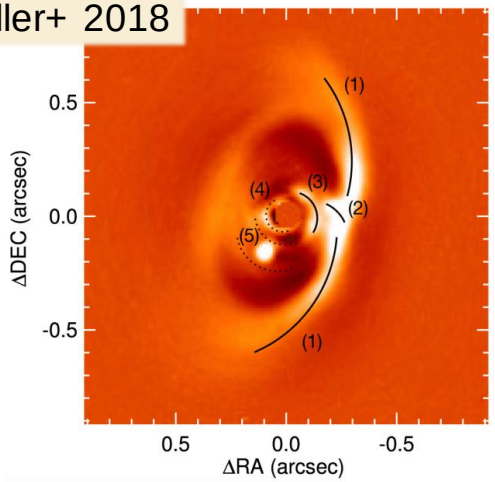
VLT Optical/Near-IR angular resolution



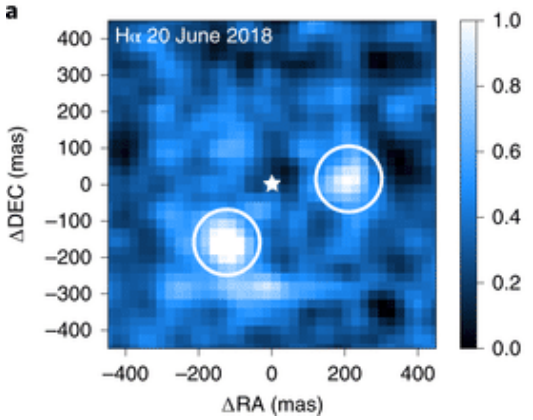
Observational Synergies: PDS 70 [T Tauri, ~5 Myr old]

Discovery by Müller+ 2018

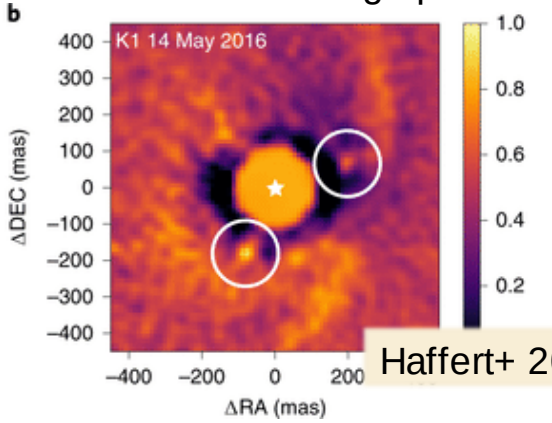
SPHERE: xAO



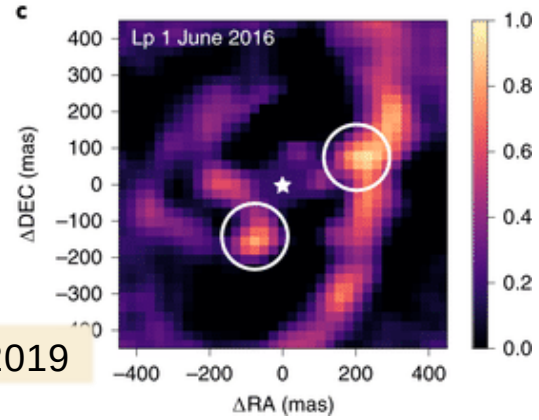
MUSE: AO visible IFU



SPHERE: coronagraph



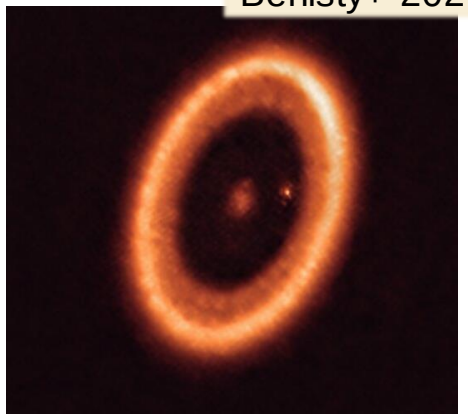
NACO: AO mid-IR

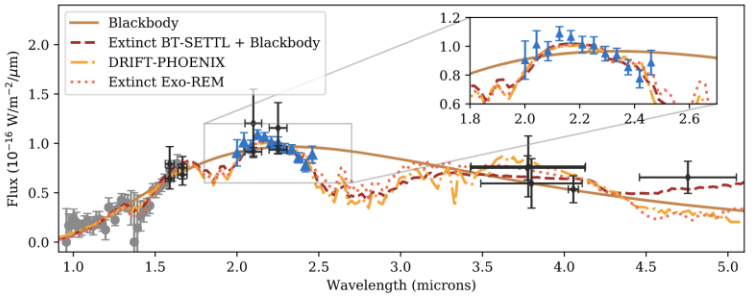


Haffert+ 2019

ALMA

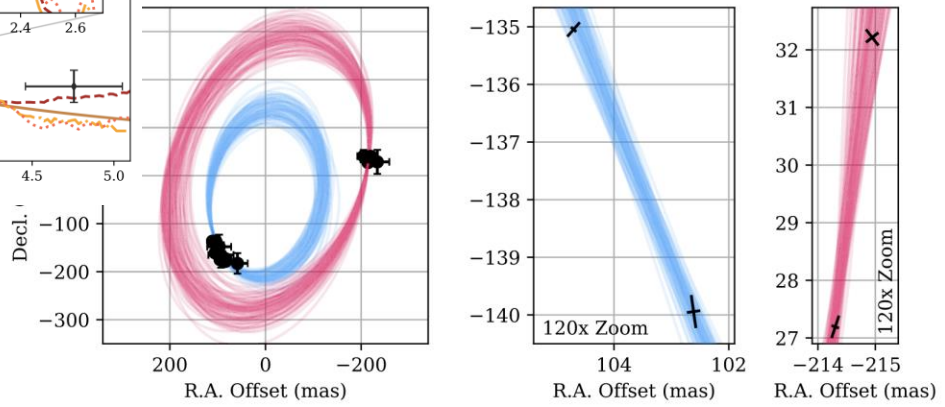
Benisty+ 2021





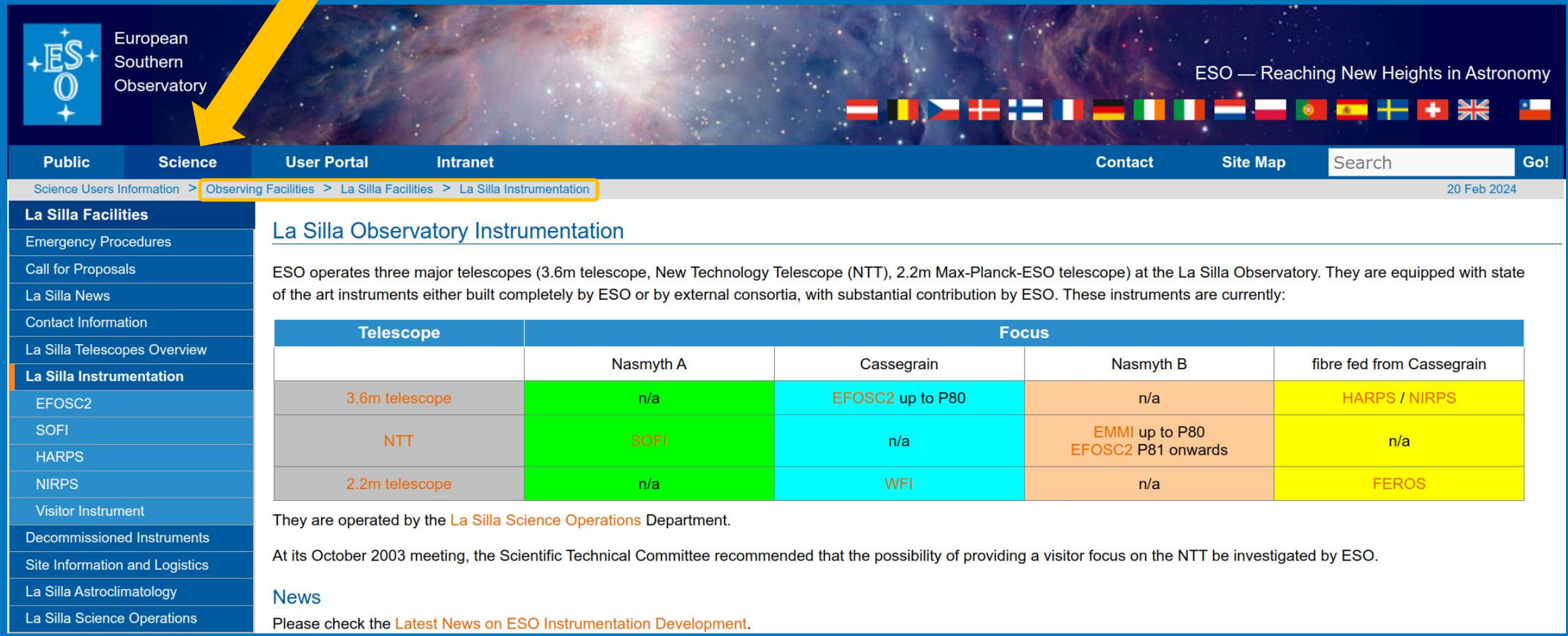
GRAVITY: sub-mas astrometry and spectroscopy

Wang+ 2021



Available instruments for the La Silla / Paranal Observatory

https://www.eso.org/sci/facilities/lasilla/instruments.html



European Southern Observatory

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20 Feb 2024

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- La Silla Instrumentation
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  - SOFI
  - HARPS
  - NIRPS
  - Visitor Instrument
- Decommissioned Instruments
- Site Information and Logistics
- La Silla Astroclimatology
- La Silla Science Operations

La Silla Observatory Instrumentation

ESO operates three major telescopes (3.6m telescope, New Technology Telescope (NTT), 2.2m Max-Planck-ESO telescope) at the La Silla Observatory. They are equipped with state of the art instruments either built completely by ESO or by external consortia, with substantial contribution by ESO. These instruments are currently:

Telescope	Focus			
	Nasmyth A	Cassegrain	Nasmyth B	fibre fed from Cassegrain
3.6m telescope	n/a	EFOSC2 up to P80	n/a	HARPS / NIRPS
NTT	SOFI	n/a	EMMI up to P80 EFOSC2 P81 onwards	n/a
2.2m telescope	n/a	WFI	n/a	FEROS

They are operated by the La Silla Science Operations Department.

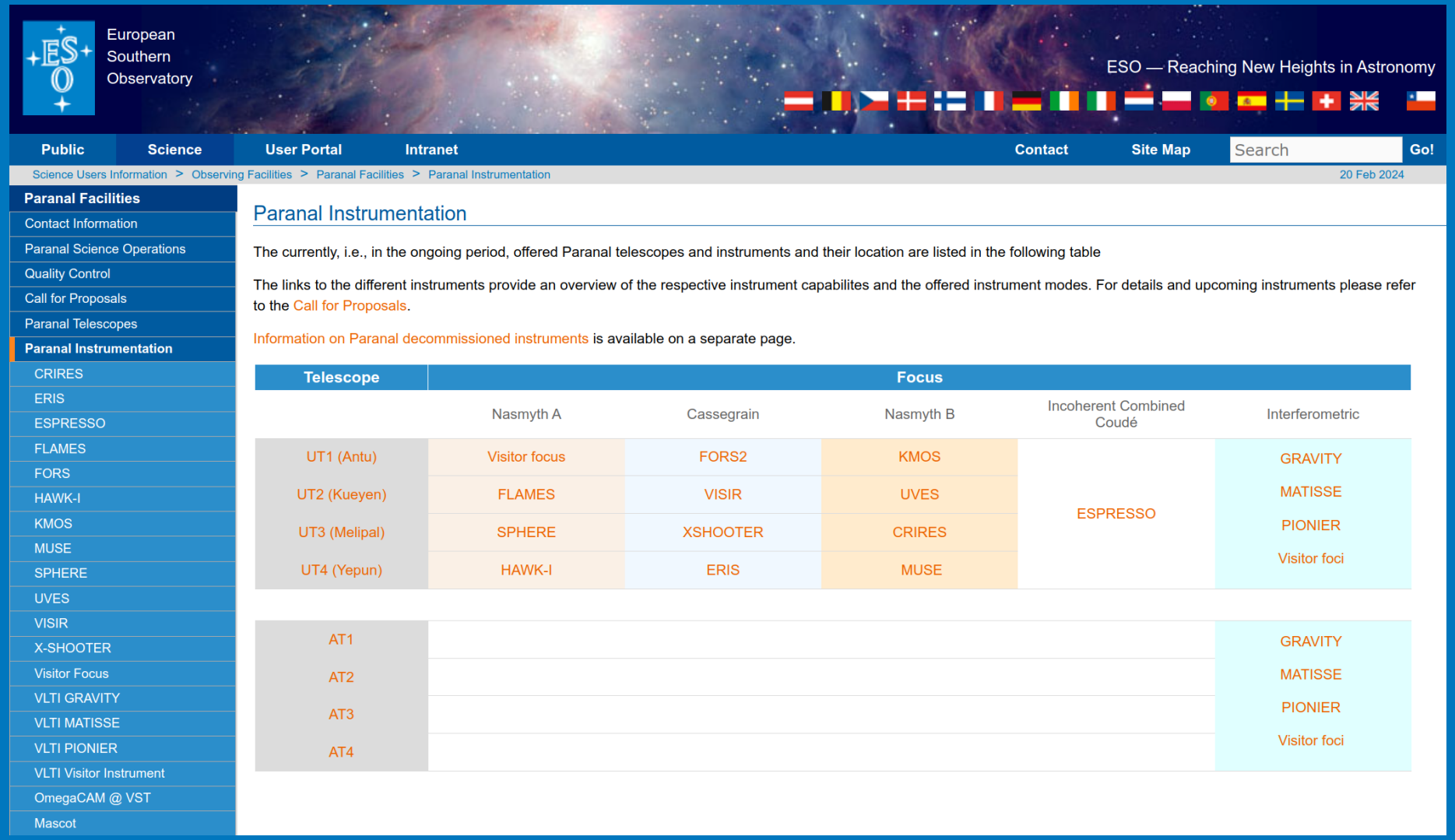
At its October 2003 meeting, the Scientific Technical Committee recommended that the possibility of providing a visitor focus on the NTT be investigated by ESO.

News

Please check the Latest News on ESO Instrumentation Development.

Available instruments for the Paranal Observatory

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



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Paranal Facilities

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  - FORS
  - HAWK-I
  - KMOS
  - MUSE
  - SPHERE
  - UVES
  - VISIR
  - X-SHOOTER
  - Visitor Focus
  - VLTI GRAVITY
  - VLTI MATISSE
  - VLTI PIONIER
  - VLTI Visitor Instrument
  - OmegaCAM @ VST
  - Mascot

Paranal Instrumentation

The currently, i.e., in the ongoing period, offered Paranal telescopes and instruments and their location are listed in the following table

The links to the different instruments provide an overview of the respective instrument capabilites and the offered instrument modes. For details and upcoming instruments please refer to the Call for Proposals.

Information on Paranal decommissioned instruments is available on a separate page.

Telescope	Focus				
	Nasmyth A	Cassegrain	Nasmyth B	Incoherent Combined Coudé	Interferometric
UT1 (Antu)	Visitor focus	FORS2	KMOS	ESPRESSO	GRAVITY
UT2 (Kueyen)	FLAMES	VISIR	UVES		MATISSE
UT3 (Melipal)	SPHERE	XSHOOTER	CRIRES		PIONIER
UT4 (Yepun)	HAWK-I	ERIS	MUSE		Visitor foci
AT1					GRAVITY
AT2					MATISSE
AT3					PIONIER
AT4					Visitor foci

Let's use a demo case

We want to study the detailed properties of a recurrent novae: T Pyx

- We would like some imaging to understand the overall distribution
- We would like some spectroscopy to trace the kinematics of the ionised species
- We expect a few 100 km/s velocity gradients in emission lines (ejecta)
- A field of a few arcseconds to ½ arcmin would be great!

Let's use a demo case

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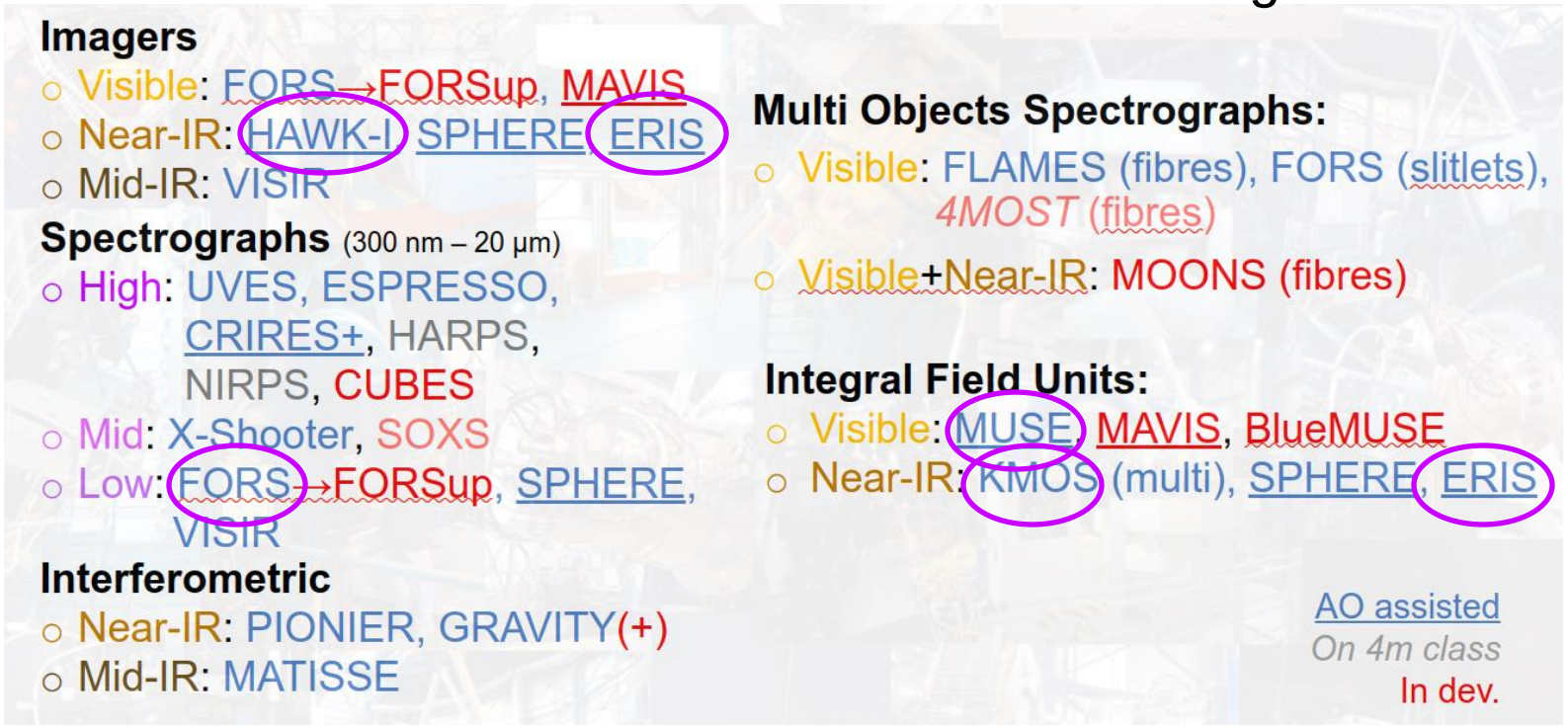

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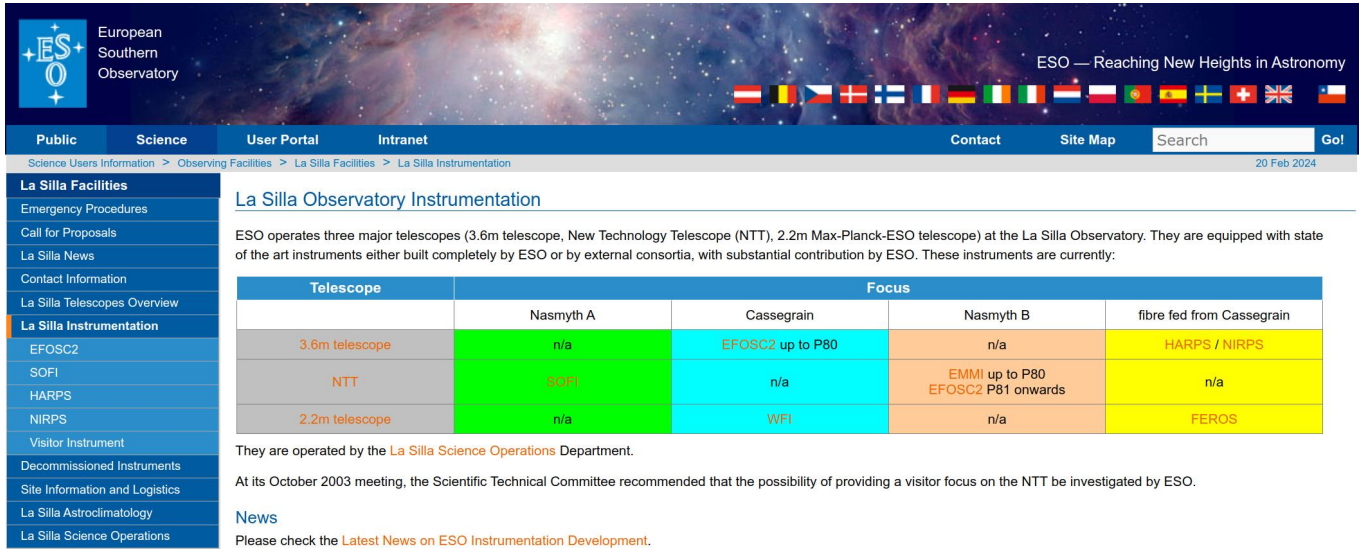

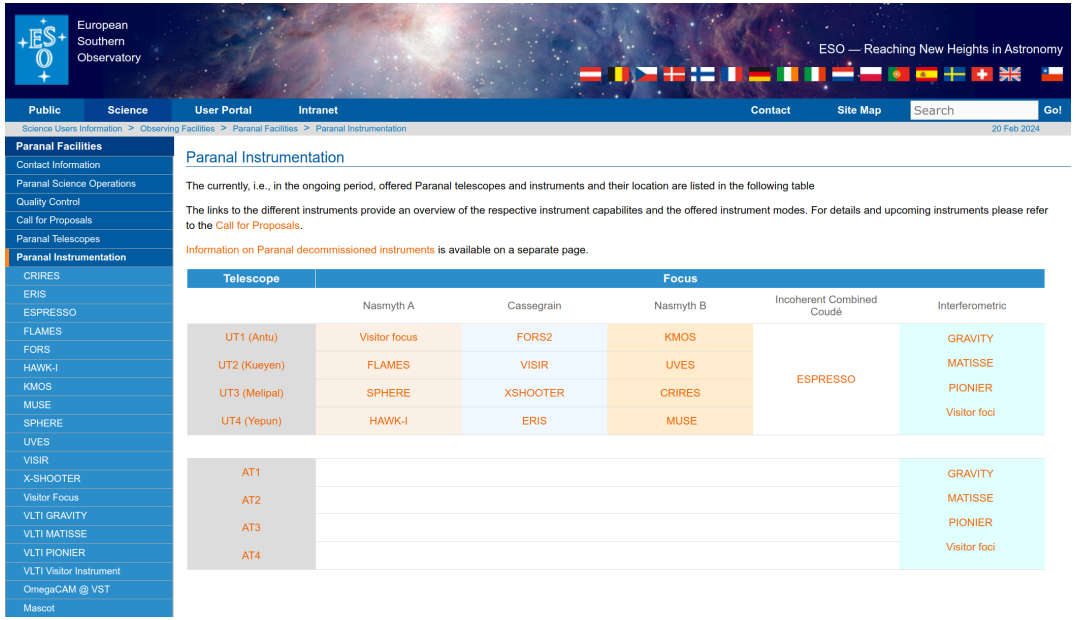

Let's use a demo case

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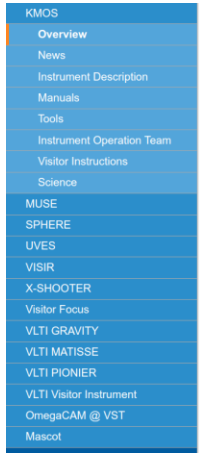

combined H+K band.

KMOS main specifications are summarized in the following table:

KMOS

Wavelength coverage	0.8 mum to 2.5 mum
Spectral bands	IZ, YJ, H, K, H+K
Spectral resolving power	R = 3400, 3600, 4000, 4200, 2000 (IZ, YJ, H, K, H+K)
Number of IFUs	24
Extent of each IFU	2.8" x 2.8"
Spatial sampling	0.2" x 0.2"
Patrol field	7.2 arcmin diameter circle
Close packing of IFUs	>= 3 within 1 sq. arcmin
Closest approach of IFUs	>= 2 pairs of IFU separated by 6 arcsec

MUSE

MUSE in a nutshell

The table below gives the basic parameters of the instrument.

Number of IFU modules	24
Wavelength range	480-930 nm (nominal) 465-930 nm (extended)
Detectors	24 x 4k x 4k MIT/LL CCD
AO type	noAO, Ground layer AO, and LTAO, 4x22 W lasers
Throughput WFM	14 % (480 nm) 35 % (750 nm) 14 % (930 nm)
Throughput NFM	13 % (480 nm) 26 % (750 nm) 11 % (930 nm)

Wide Field Mode (Currently offered)

Field of view	59.9"x 60.0"
Spatial Sampling	0.2" /pixel
Spatial resolution (FWHM)	0.4" @ 700nm
Resolving power	1770 (480 nm) -- 3590 (930 nm)
Limiting magnitude (1 hr, airmass=1.0, seeing 0.8"@V)	V_{AB} = 22.64 mag (550 nm) R_{AB} = 22.70 mag (650 nm) I_{AB}= 22.28 mag (784.9 nm)

Narrow Field Mode (Currently offered)

Field of view	7.42" x 7.43"
Spatial Sampling	0.025" / pixel
Spatial resolution(FWHM)	55 mas - 80 mas
Resolving power	1740 (480 nm) -- 3450 (930 nm)
Ensquared Energy (25 mas)	10% - 1%
Predicted limiting flux in 1 hr	$2.3x10^{-18}$ erg s^{-1} cm^{-2}
Predicted limiting magnitude in 1 hr	R_{AB} = 22.3 mag
Predicted limiting surface brightness in 1 hr	R_{AB} = 17.3 mag $arcsec^{-2}$

ERIS

Grating configurations

Band	λc (um)	λ range (um)	Resolution
J_low	1.25	1.09--1.42	~5000
H_low	1.66	1.45--1.87	~5200
K_low	2.21	1.93--2.48	~5600
J_short	1.18	1.10--1.27	~10000
J_middle	1.26	1.18--1.35	~10000
J_long	1.34	1.26--1.43	~10000
H_short	1.56	1.46--1.67	~10400
H_middle	1.67	1.56--1.77	~10400
H_long	1.76	1.66--1.87	~10400
K_short	2.07	1.93--2.22	~11200
K_middle	2.20	2.06--2.34	~11200
K_long	2.33	2.19--2.47	~11200

Plate scale options

Tag	Spaxel size	Field of view
25mas	12.5 x 25 mas	0.8" x 0.8"
100mas	50 x 100 mas	3.2" x 3.2"
250mas	125 x 250 mas	8.0" x 8.0"

Let's use a demo case

We want to study the detailed properties of a recurrent novae: T Pyx

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    - Manuals
    - Tools
    - Instrument Operation Team
    - Visitor Instructions
    - Science

MUSE - Multi-Unit Spectroscopic Explorer

*Work based on **MUSE** observations should cite the paper Bacon et al., SPIE 7735, 7 (2010).*

Work using the **Adaptive Optics Facility (AOF)** should cite the papers: Strobele et al. (2012), **and** Arsenault et al. (2008).

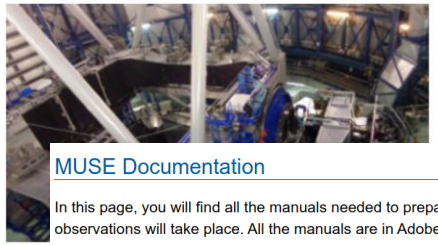
Summary

The following items are available on all the MUSE pages, using the bar on the left.

- Overview: a short description of the instrument
- News: list of changes affecting the instrument and/or its pages.
- Instrument Description: all the important parameters of the instrument.
- Manuals: links to all the documents related to MUSE.
- Tools: a collection of useful tools and informations for preparing and analyzing the MUSE observations.
- Instrument Operations Team
- Visitor Instructions: Instrument specific instructions for Visiting Astronomers
- Science: Science done with MUSE, incl. during Science Verification

Contact Information

- **Questions related to proposal preparation, service mode, and visitor mode observations** should be adc
- Please, send us your general feedback, comments, suggestions, or report errors and inaccurate statements i



MUSE Documentation

In this page, you will find all the manuals needed to prepare and analyze your observations with MUSE. Please be su observations will take place. All the manuals are in Adobe's Acrobat format.

Reference paper for MUSE: *Bacon et al., SPIE 7735, 7 (2010).*

Papers using AO data please reference: Strobele et al. (2012), and Arsenault et al. (2008).

Reference papers for MUSE deep-fields: *Bacon et al., A&A 608, 1 (2017).*

Reference paper for MUSE pipeline: *Weilbacher et al. arXiv:2006.08638*

MUSE User Manuals

All the information about the instrument itself, its modes and their characteristics:

- Period 113 Phase 2 (March 2024 - Oct 2024)
- Period 112 Phase 1 (Oct 2023 - March 2024) change on IROLS NGS limiting magnitude.
- Period 110 Phase 1 and 2 (Oct 2022 - March 2023 - no change in P111)
- Period 109 Phase 1 and 2 (April 2022 - Sep 2022)
- Period 108 Phase 1 and 2 (Oct 2021 - March 2022)
- Period 107 Phase 1 and 2
- Period 106, Phase 1 and 2
- Period 105, Phase 1 and 2
- Manuals for older periods

MUSE Pipeline Manual

- Last version can be found at the muse pipeline page.

MUSE User Manual

Doc. Number: ESO-261650
Doc. Version: 12.2
Released on:
Page: 1 of 121

Programme: VLT

Project/WP: Science Operations

MUSE User Manual

Document Number: ESO-261650

Document Version: 12.1

Document Type: Manual (MAN)

Released On:

Document Classification: Public

Prepared by:

Validated by:

Approved by:

Name

Let's use a demo case

We want to study the detailed properties of a recurrent novae: T Pyx!!

Astronomy & Astrophysics manuscript no. aa
December 8, 2023

The physical properties of T Pyx as measured by MUSE

I. The geometrical distribution of the ejecta and the distance to the remnant

L. Izzo[1,2], L. Pasquini[3], E. Aydi[4], M. Della Valle[1], R. Gilmozzi[3], E. A. Harvey[5], P. Molaro[6,7]
M. Otulakowska-Hypka[8], P. Selvelli[6], C. C. Thöne[9], R. Williams[10,11]

[1] INAF, Osservatorio Astronomico di Capodimonte, Salita Moiariello 16, I-80131 Napoli, Italy
e-mail: luca.izzo@inaf.it
[2] DARK, Niels Bohr Institute, University of Copenhagen, Jagtvej 128, 2200 Copenhagen, Denmark
[3] European Southern Observatory, Karl Schwarzschild-Str. 2, 85748 Garching, Germany
[4] Center for Data Intensive and Time Domain Astronomy, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
[5] UK Astronomy Technology Centre, Royal Observatory Edinburgh, EH9 3HJ, Edinburgh, UK
[6] INAF-Osservatorio Astronomico di Trieste, Via G.B. Tiepolo 11, I-34143 Trieste, Italy
[7] Institute of Fundamental Physics of the Universe, Via Beirut 2, Miramare, I-34151 Trieste, Italy
[8] Astronomical Observatory Institute, Faculty of Physics, Adam Mickiewicz University, Słoneczna 36, 60-286 Poznań, Poland
[9] Astronomical Institute, Czech Academy of Sciences, Fričova 298, Ondřejov, Czech Republic
[10] Department of Astronomy and Astrophysics, University of California, Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, USA
[11] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

ABSTRACT

Context. T Pyx is one of the most enigmatic recurrent novae, and it has been proposed as a potential Galactic type-Ia supernova progenitor.
Aims. Using spatially-resolved data obtained with MUSE, we characterized the geometrical distribution of the material expelled in previous outbursts surrounding the white dwarf progenitor.
Methods. We used a 3D model for the ejecta to determine the geometric distribution of the extended remnant. We have also calculated the nebular parallax distance ($d = 3.55 \pm 0.77$ kpc) based on the measured velocity and spatial shift of the 2011 bipolar ejecta. These findings confirm previous results, including data from the GAIA mission.
Results. The remnant of T Pyx can be described by a two-component model, consisting of a tilted ring at $i = 63.7$ relative to its normal vector and by fast bipolar ejecta perpendicular to the plane of the equatorial ring.
Conclusions. We find an upper limit for the bipolar outflow ejected mass in 2011 of the bipolar outflow of $M_{ej,b} < (3.0 \pm 1.0) \times 10^{-6}$ $M_\odot$, which is lower than previous estimates given in the literature. However, only a detailed physical study of the equatorial component could provide an accurate estimate of the total ejecta of the last outburst, a fundamental step to understand if T Pyx will end its life as a type-Ia supernova.

Key words. editorials, notices – miscellaneous

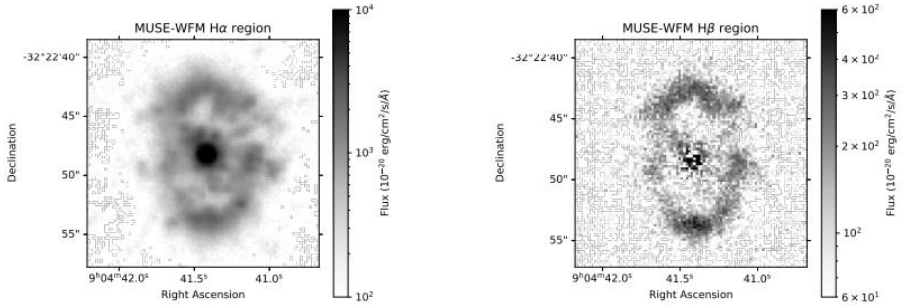


Fig. 2. The reconstructed Hα image of the remnant (left panel) and the corresponding Hβ image (right panel), both obtained from the MUSE-WFM data as described in the main text.

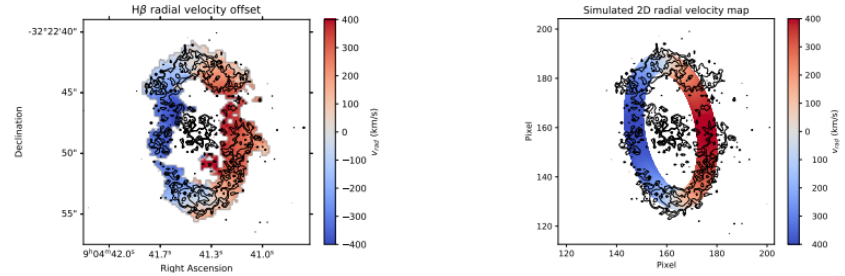
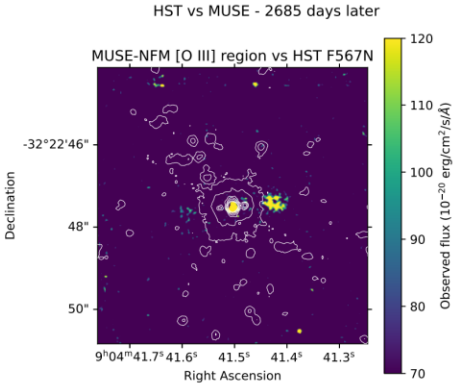
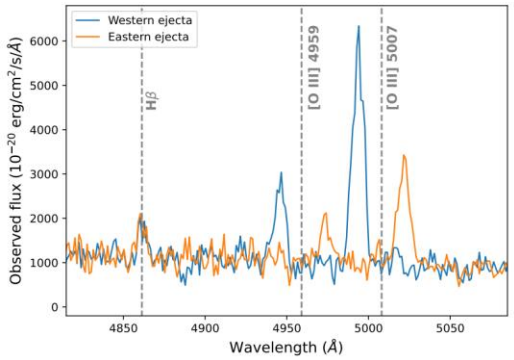


Fig. 4. (Left panel) The Hβ radial velocity map, obtained with the prescriptions given in the main text. The black curve represents the contour regions from the Hβ intensity flux map of Fig. 3. (Right panel) The simulated 2D radial velocity map of the ring remnant was obtained from the best-fit parameters and the procedure delineated in the main text.

MUSE WFM





MUSE NFM

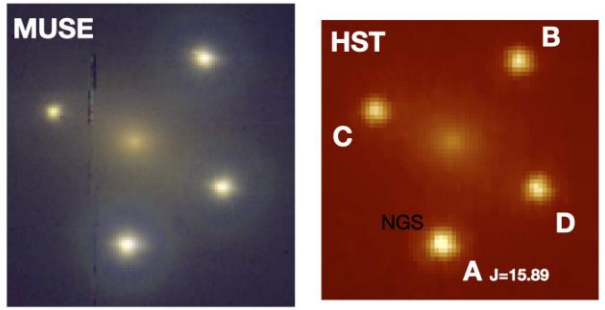
New and upcoming instruments for the La Silla / Paranal Observatory

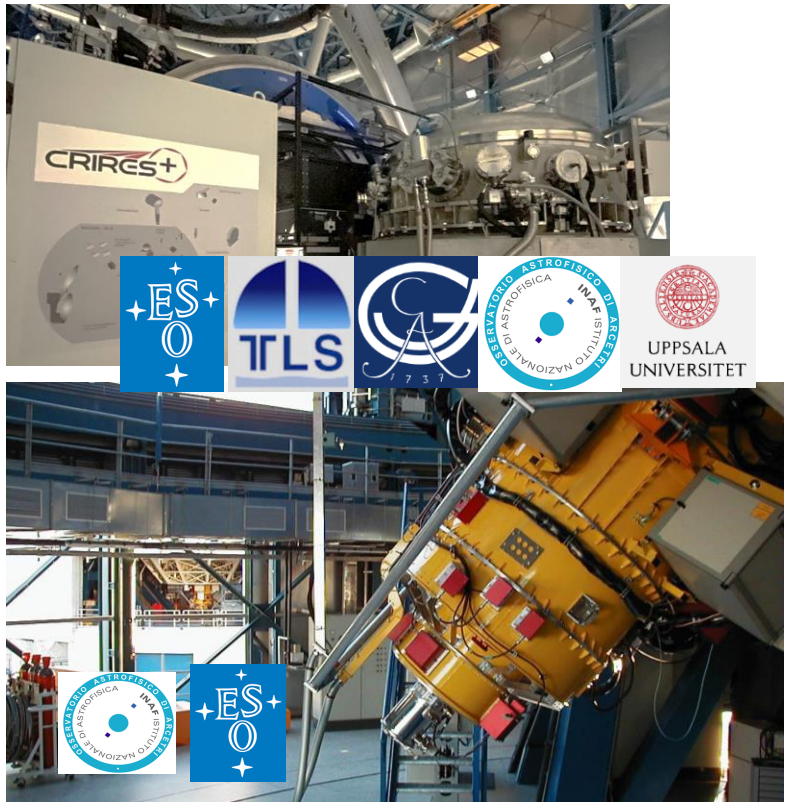
https://www.eso.org/sci/facilities/develop.html

Design Phase	Manufacture, Assembly Integration and Testing	Commissioning
FORS Upgrade (VLT)	4MOST (VISTA)	
CUBES (VLT)	SoXS (NTT)	NIRPS (La Silla 3.6m)
MAVIS (VLT)	MOONS (VLT)	
	GRAVITY+ (VLTI)	

Continuous Improvements

- **IRLOS for MUSE**: tip/tilt using SAPHIRA eAPDS offered
  - From 7<Jmag<15 to the upgrade 0.5<Jmag<19
- **CRIRES+**: AO-assisted high-res spectrograph at 1-5μm (R=100,000) offered
  - 1.5x more sensitive, x10 spectral coverage, polarimetry, 3m/s radial velocities
- **FORS up**
  - New 4k x 4k detector
  - Upgrade with ELT standards for 15 years life extension
  - In final design

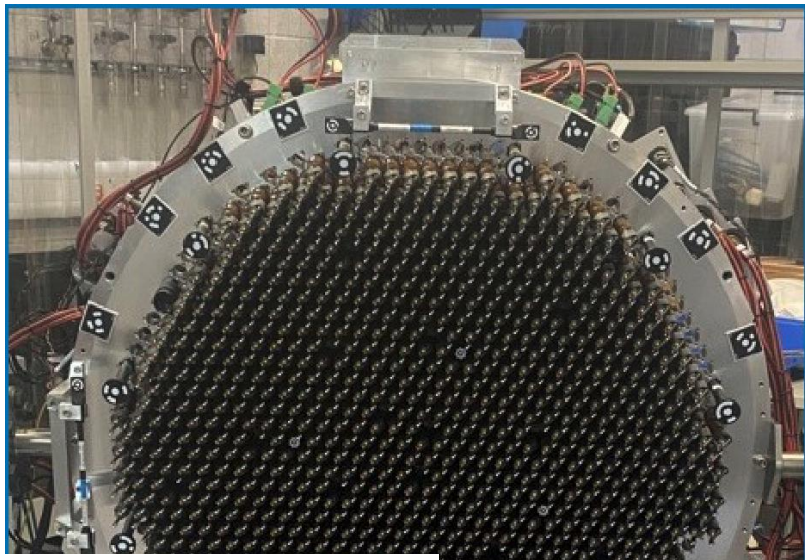


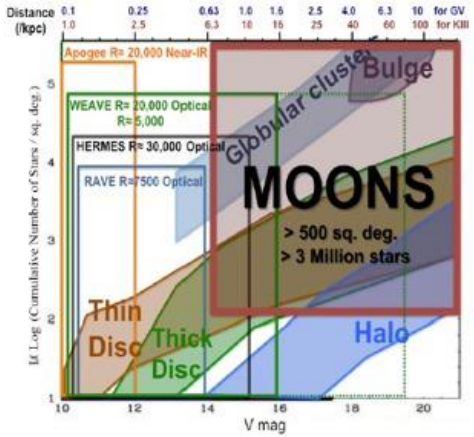


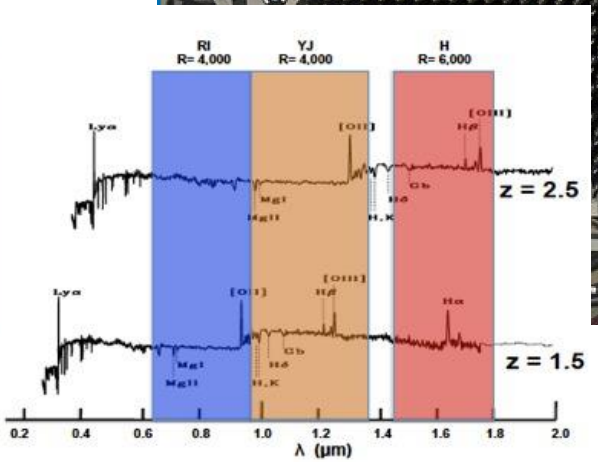
https://www.eso.org/sci/facilities/paranal/instruments/fors/forsup.html

MOONS: Highly multiplexed spectrograph

- 1000 fibres over 500 arcmin^2
  - 0.65-1.8μm at R=4000-18000
- Main Science Cases:
  - Galactic archaeology
  - growth of galaxies
  - first galaxies (z>7)
  - Spectroscopic follow up of current and future VIS/near-IR surveys
- Installation (UT1) later in 2024



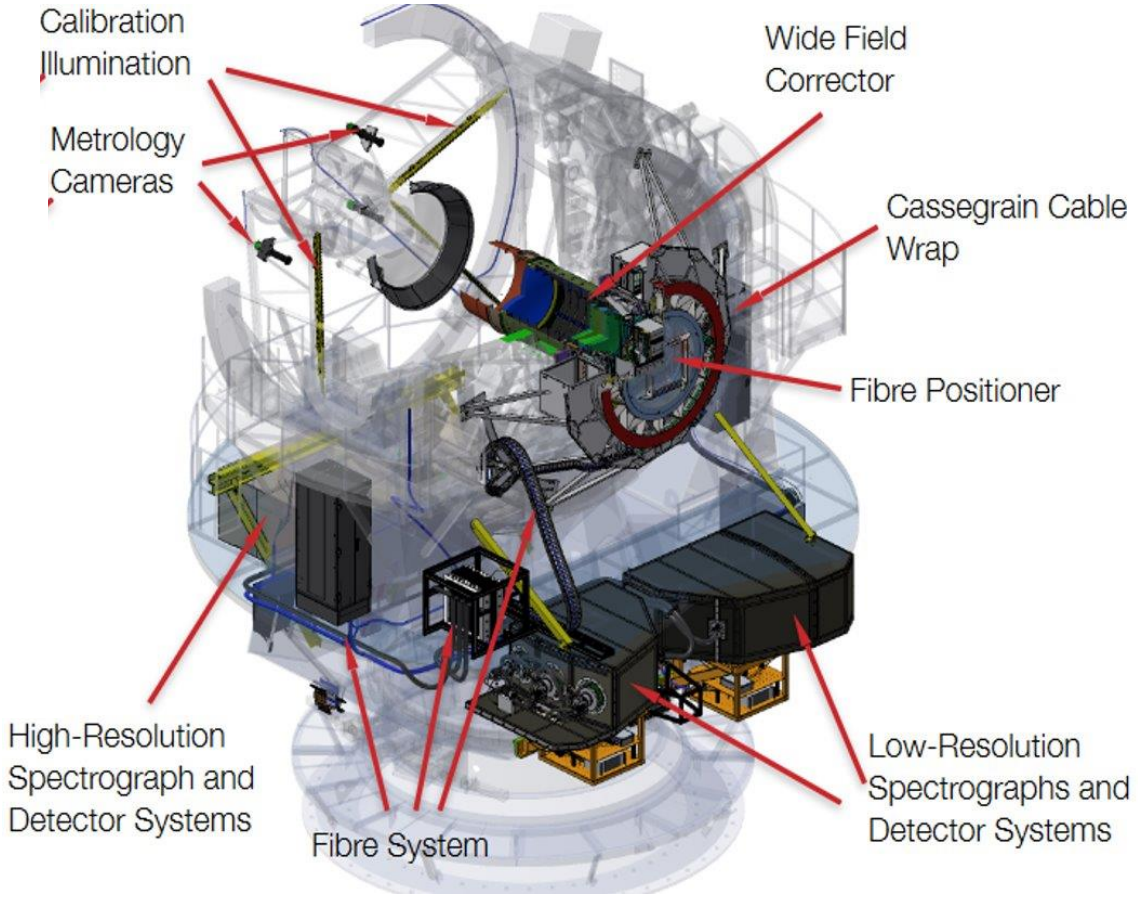




https://www.eso.org/sci/facilities/develop/instruments/MOONS.html

VISTA / 4MOST: a spectroscopic survey machine

- Telescope upgrade + new instruments
- 4.1 deg^2 and 2400 fibres:
  - 1600 @ R= 5000 390-950 nm
  - 800 @ R=18000 392-437, 516-573, 608-677 nm
- 15 surveys: galactic and extragalactic science case
- Operated by consortium
- Installation later in 2024



https://www.eso.org/sci/facilities/develop/instruments/4MOST.html

SoXS: time domain spectroscopic follow-up

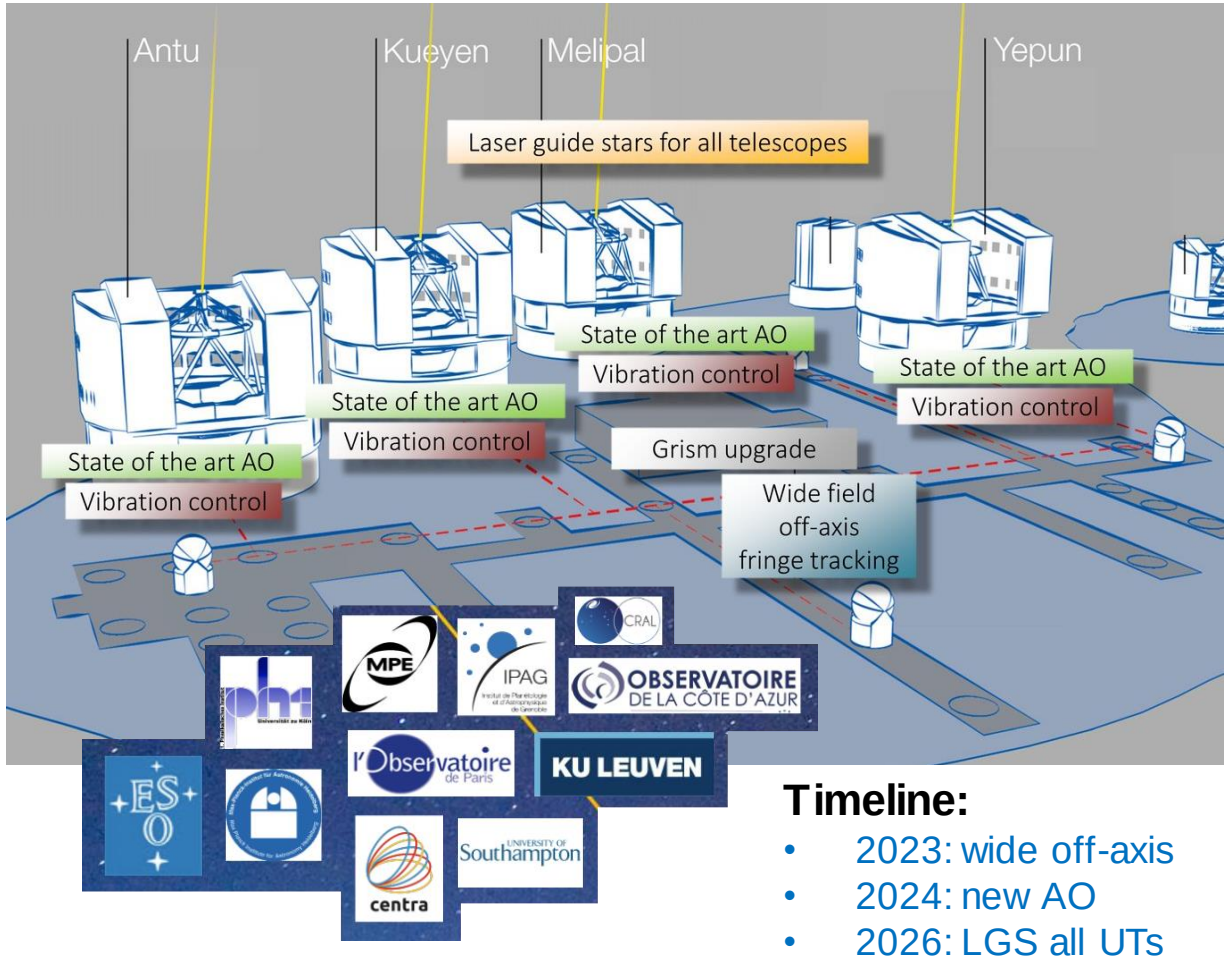
- Inspired by the success of XSHOOTER
  - Mid-resolution
  - Vis to near IR + slit imager
- To be installed at refurbished NTT
- Outsourced operations to consortium (with open time)
- Installation later in 2024

	UV-VIS	NIR
Spectral range	350-850 nm	800-2000 nm
Resolution (1" slit)	>3600 (≈4500 avg)	5000
Slit widths	0.5 - 1 - 1.5 - 5 arcsec	0.5 - 1 - 1.5 - 5 arcsec
Slit height	12 arcsec	12 arcsec
Detector	e2V CCD44-82 2Kx4K	Teledyne H2RG 2Kx2K
Pixel Size	15 µm	18 µm
Detector Scale	0.28"/pixel	0.25"/pixel

	Camera
Spectral range	360-970 nm
Detector	Andor iKon M-934 1Kx1K
Field of View	3.5'x3.5'
Pixel Size	13 µm
Detector Scale	0.205"/pixel

https://www.eso.org/sci/facilities/develop/instruments/4MOST.html

GRAVITY+: consolidate uniqueness of VLTI



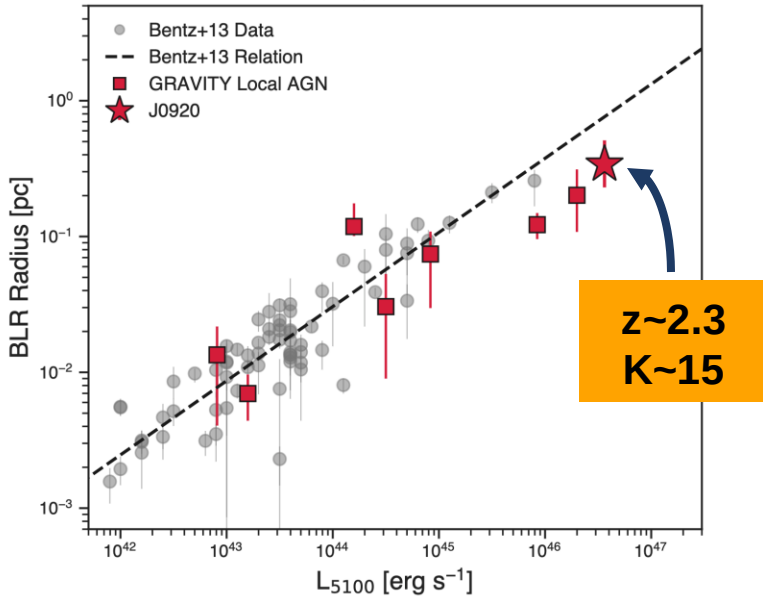
Timeline:

- 2023: wide off-axis
- 2024: new AO
- 2026: LGS all UTs

https://www.eso.org/sci/facilities/develop/instruments/gravity_up.html

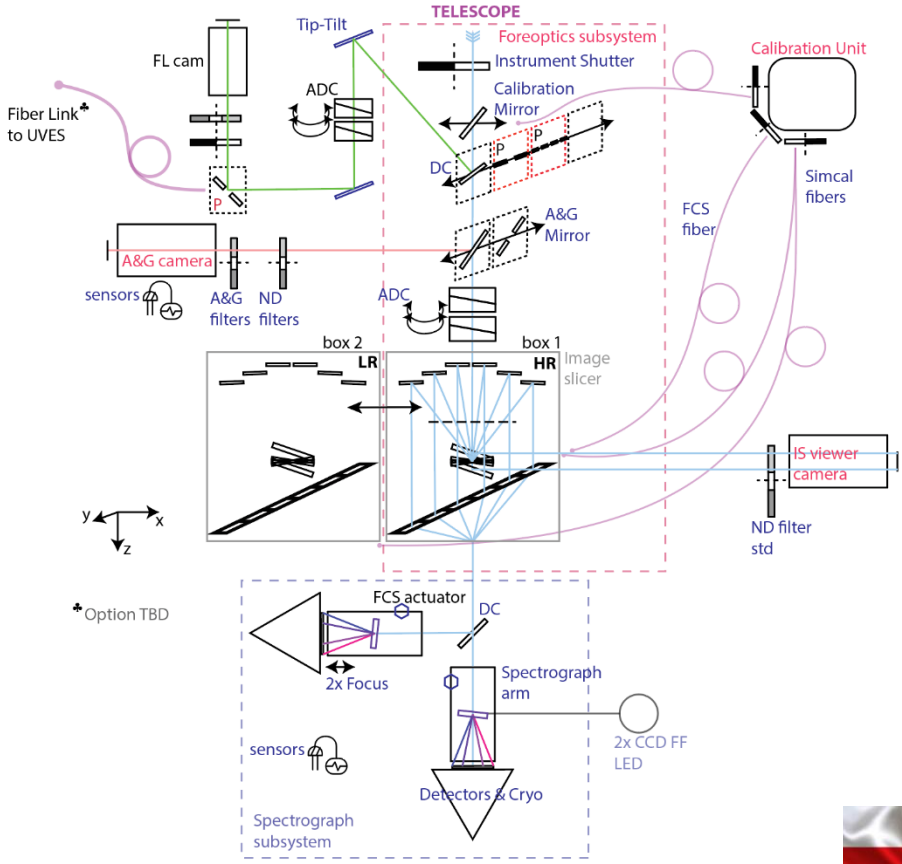
- One of two "VLT2030" project selected in 2019
- K~22 and better sky coverage
- Main science Cases:
  - The Galactic Centre
  - AGN SMBH masses up to z~2.5
  - Characterization of exoplanets
  - Young suns and their planet-forming disks

Abuter+ 2024, ESO/ann24002



CUBES: unique wavelength window of near-UV

- Exploit wavelength below ELT cutoff
- 305 to 400nm; R>20000; Slit 10”
  - Image slicer 6 x 0.25”
  - High efficiency: >40% goal 45% (5x UVES)
- Main Science Cases:
  - Asteroid and comets
  - Accretion
  - Low metallicity stars
  - Stellar nucleosynthesis
  - Missing baryonic mass
- Still in design phase (on sky ~2029)

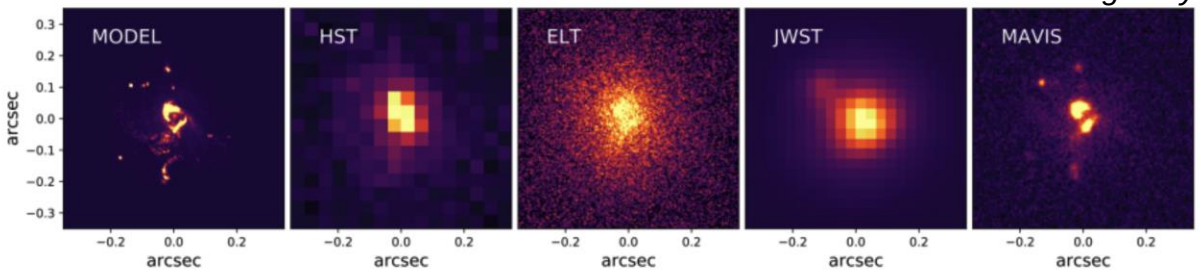


https://www.eso.org/sci/facilities/develop/instruments/cubes.html

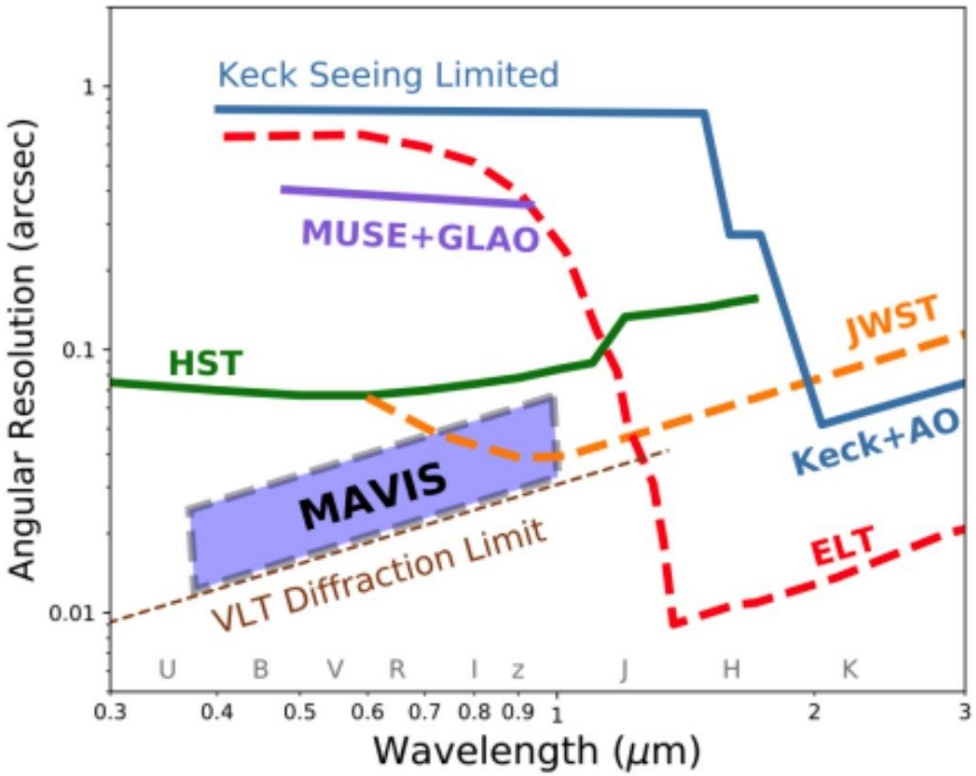
MAVIS: ELT-resolution in the visible

- **Diffraction limited in V-band**
  - **8 Laser Guide Star (split of 4LGSF); Near IR WFS**
  - **deformable secondary mirror (AOF/UT4)**
- Optical camera: 30” diam FoV
- IFU Spectroscopy 3”x3“ R~5000
- Main Science cases:
  - Solar system planets and moons
  - stellar evolution
  - star formation
  - mid-redshift galaxies
- Still in design phase (on sky in~2030)

Simulated 1h observation of z=5 galaxy



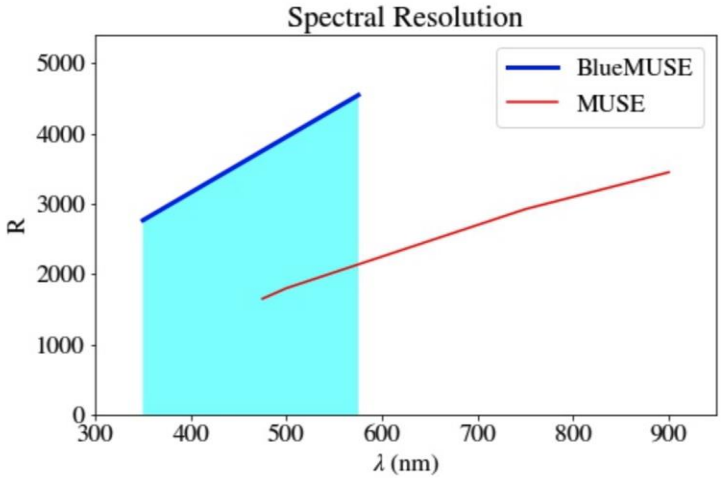
https://www.eso.org/sci/facilities/develop/instruments/MAVIS.html

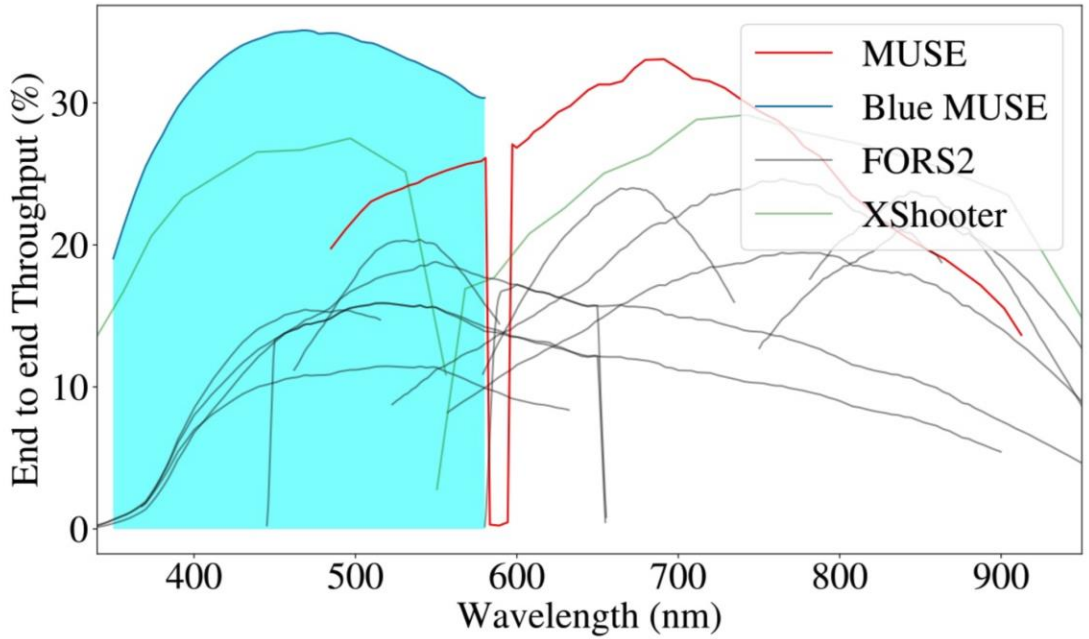


BlueMUSE: Seeing-limited, blue optimized IFU

- Second “VLT2030” project selected in 2019
  - 1’x1’ FoV
  - R~4000 from 350nm to 580nm
  - Single mode -> high throughput (30%)
- Main Science Cases
  - Massive stars clusters
  - Comets
  - Ionised Nebulae
  - Galaxies: starburst, low surface brightness, Lyman continuum emission
  - IGM gas flows
- Phase A to start in 2024

https://bluemuse.univ-lyon1.fr/





VLT2030 phase 2: Paranal Instrumentation for 2030+

Principles: Identify and consolidate strengths

- Very flexible Operation model
- Variety of instruments: workhorses and specialized
- Uniqueness of the VLT facility (incl. VLTI)
- Complement the ELT in the blue and in the visible
- Existing expertise in ESO and community

Phase1 ran in 2019:

- GRAVITY+ and BlueMUSE Selected

Phase2 to run in 2024/2025:

- Call for ideas for instruments and/or operation model

http://www.eso.org/sci/publications/messenger/archive/no.177-sep19/messenger-no177-67-69.pdf

Get involved early!

Science Verification[1] (right after commissioning, announced in the Science Newsletter[2])

- For observations of few hours
- Data are immediately public, and reduced by consortium/ESO

Instruments are usable from the first semester they are offered

- Some of the commissioning data are available
- User and template manuals
- Phase 1 and Phase 2 (including ETC)
- Pipelines and cookbooks with test data
- User Support team at ESO

Consortia get Guaranteed Time (GTO) for building the instrument, but

- Vast majority of observing time available as open time
- GTO has a limited scientific scope: many low hanging fruits!

[1] https://www.eso.org/sci/activities/vltsv.html
[2] https://www.eso.org/sci/publications/newsletter.html