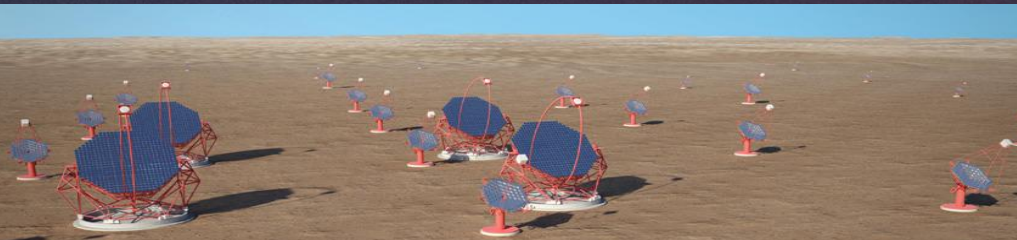




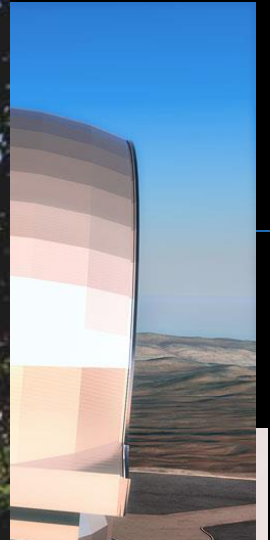
# Opportunities with ESO optical and infrared telescopes

Bruno Leibundgut and Antoine Mérand





Observa  
8 Tel  
APEX in



© Julien Girard 2019



# Overall strategy

- ALMA mm/sub-mm flagship facility
- ELT future O/IR flagship facility
  - faint, high-angular resolution, near-infrared
- VLT/I current O/IR flagship facility
  - multi-purpose instrumentation
  - focus on unique capabilities
    - optical/ultraviolet, versatility, flexibility, angular resolution
- 4m telescopes dedicated to specific topics
  - VISTA → surveys (VIRCAM → 4MOST)
  - 3.6m → radial velocity studies (HARPS, NIRPS)
  - NTT → transient spectroscopy (EFOSC2 → SOXS)

# VLT/ Opportunities

## ■ Four 8m telescopes

- flexibility
- scientific throughput
  - 1200 observing nights/year

## ■ Successful operational model

- expand existing model to allow new modes
  - high time resolution photometry and spectroscopy
  - faster turnaround (currently DDT)
  - closer interaction with user, e.g. remote observing

## ■ Telescope system

- spatial resolution from 1 degree to 2 mas
- wavelength coverage from 320nm to 20 $\mu$ m
- spectral resolutions from a few to 100000

# Multi-Wavelength Astrophysics

- ESO offers access to optical, infrared and sub-mm wavelength ranges
- VLT/I provides many resolution scales
- Operational model adapted to fast reactions/transient targets

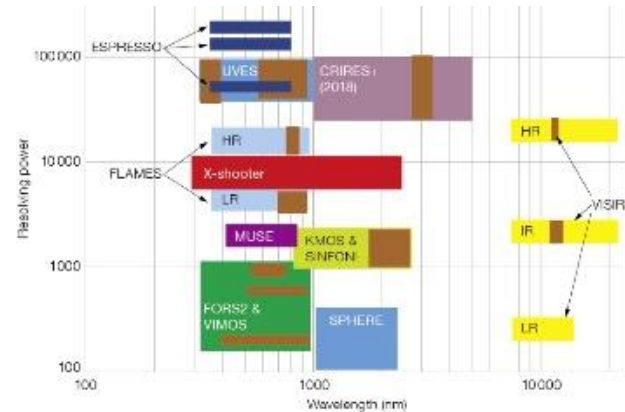


Figure 1: Wavelength-Spectral Resolving power diagram for the VLT instruments of 1<sup>st</sup> and 2<sup>nd</sup> generation.

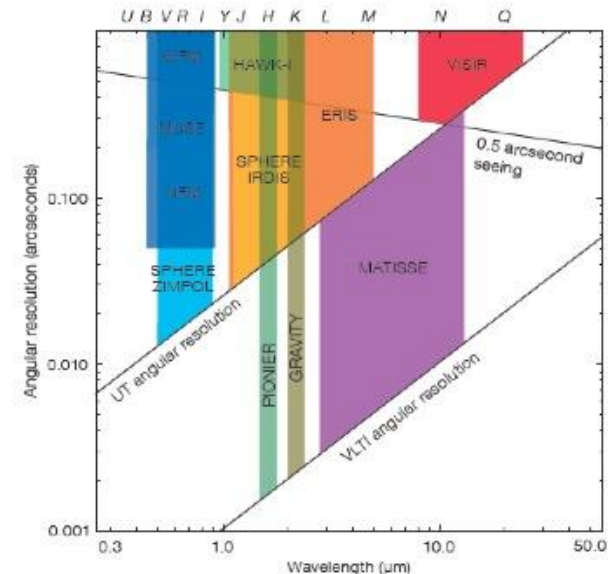


Figure 2: Wavelength-angular resolution diagram for the VLT/I instruments of 1<sup>st</sup> and 2<sup>nd</sup> generation.

# Current VLT instruments

## ■ Spectrographs:

- High: UVES, ESPRESSO, CRIRES
- Mid: XSHOOTER
- Low: FORS2, ERIS, VISIR

## ■ Imagers:

- Visible: FORS2
- Near IR: HAWK-I, ERIS
- Mid-IR: VISIR

## ■ MOS:

- FLAMES (fibers)
- FORS2 (slitlets)
- KMOS (mini-IFUs)

## ■ IFU:

- ERIS
- MUSE

## ■ Interferometric:

- PIONIER
- GRAVITY
- MATISSE

# Paranal Facilities

## ■ VLT

- Instrumentation **operating**, in assembly and planned
  - Covers the available optical infrared wavelengths 300nm to 20 $\mu$ m
  - Angular resolution from seeing limit to 50  $\mu$ -arcseconds
  - **FORS2, UVES, FLAMES, VISIR, HAWK-I, X-Shooter, laser guide star facility, KMOS, MUSE, SPHERE, Adaptive Optics Facility, ESPRESSO, CRIRES+, ERIS, MOONS, CUBES, MAVIS**

## ■ VLTI

- **PIONIER, GRAVITY, MATISSE**

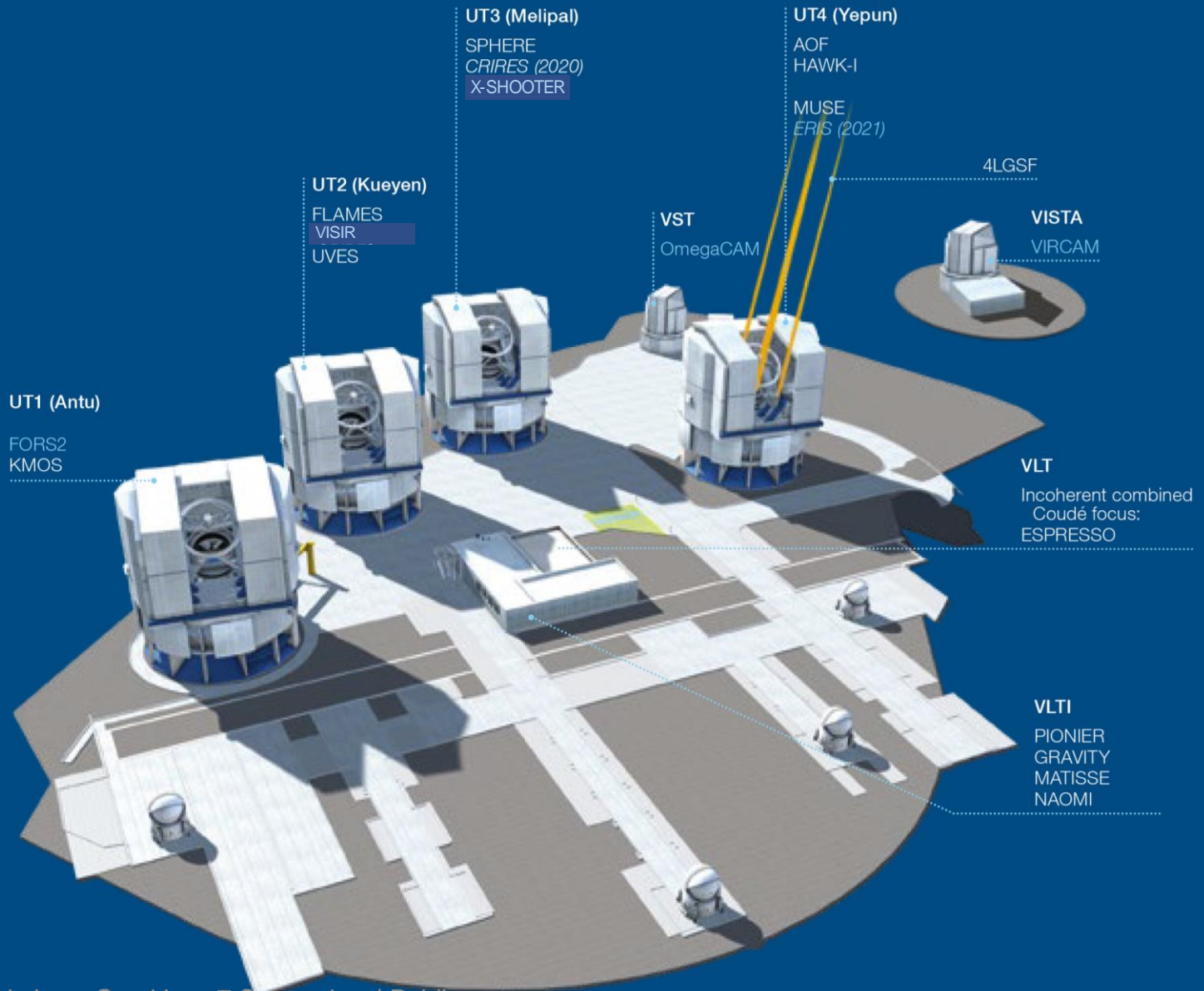
## ■ VISTA

- **VIRCAM, 4MOST**

## ■ VST

- **$\Omega$ Cam**

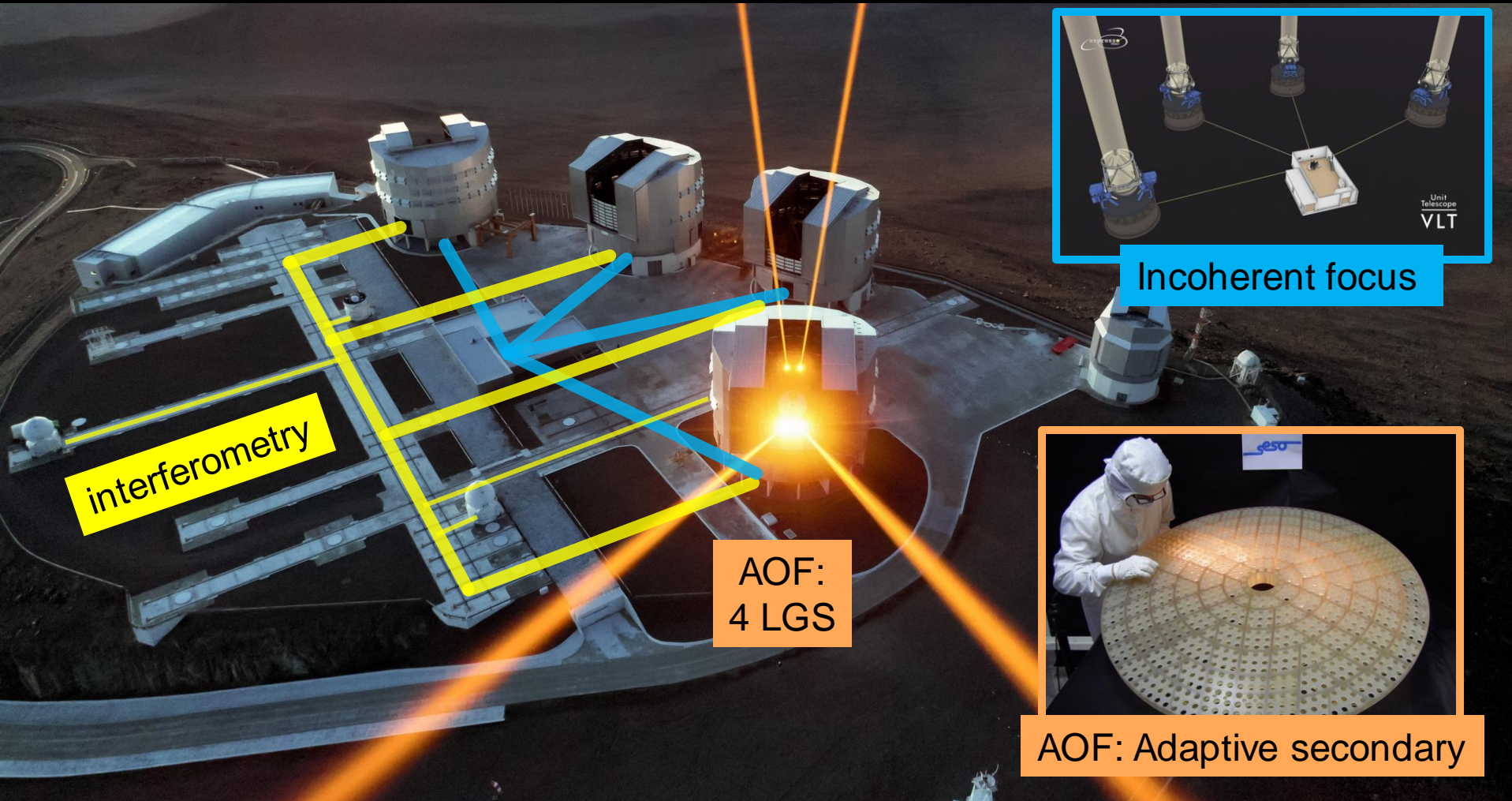
# Paranal 2020







# VLT unique capabilities





# Everything about instruments

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

European Southern Observatory

ESO — Reaching New Heights in Astronomy

Public Science User Portal Contact Site Map Search Go!

Science Users Information > Observing Facilities > Paranal Facilities > Paranal Instrumentation > SPHERE 04 Sep 2020

**Paranal Facilities**

- Emergency Procedures
- Procedimientos de Emergencia
- Call for Proposals
- Paranal News
- Contact Information
- Paranal Telescopes
- Paranal Instrumentation
- CRIRES
- ESPRESSO
- FLAMES
- FORS
- HAWK-I
- KMOS
- MUSE
- SPHERE**
  - Overview
  - News
  - Instrument Description
  - Manuals
  - Tools
  - Instrument Operation Team
  - Visitor Instructions
  - Science
  - beta Exposure Time Calculators

**SPHERE - Spectro-Polarimetric High-contrast Exoplanet REsearch**

**Summary**

SPHERE is the extreme adaptive optics system for imaging, low-resolution spectroscopic, and polarimetric observations in the visible and near-infrared wavelengths.

Publications based on data obtained with the SPHERE instrument include: [Beuzit et al., 2019 \(A&A 631, A155\)](#). They show the capabilities of the instrument and the data reduction pipeline that were used.

**Contact Information**

- Questions related to service mode observations: [Contact the SPHERE Support Department](#).
- Questions related to visitor mode observations: [Contact the SPHERE Support Department](#).
- Please [send us your comments, suggestions and manuals](#).

**Content of these pages**

The following items are available on all the SPHERE instrument pages:

- Overview: a short description of the instrument.
- Calibrations: a summary of the night-time calibrations.
- News: list of changes affecting the instrument.
- Instrument Description: all the important parameters and characteristics.
- Manuals: links to all the documents related to the instrument.
- Tools: a collection of useful tools and information.
- Instrument Operations Team.
- Visitor Instructions: Instrument specific instructions for the instrument.
- Science: Science done with SPHERE, including during Science Verification.

**Tools and Tips**

**SPHERE-specific tools**

SPHERE does not require special preparation tools.

**SPHERE Data Reduction**

Information about the SPHERE data reduction software and the VLT data reduction in general can be found on the following pages:

- [SPHERE data reduction pipeline](#)
- [Quality Control and Data Flow Operations](#)

**Visualization of 3D Spectra in Image Cubes**

- [QFitsView](#)
- [Euro3D Visualization Tool](#)
- [CASA](#)

**Calibration of NIR Data (References to ISAAC Documents)**

- [Telluric \(Spectroscopic\) Standards and the Hipparcos Telluric Standard Finder](#)
- [Library of Stellar Spectra from Pickles 1998; PASP 110, p863](#)
- [Atlas of OH lines \(compressed postscript\) from Rousselot et al. 2000; A & A 354, p1134](#)

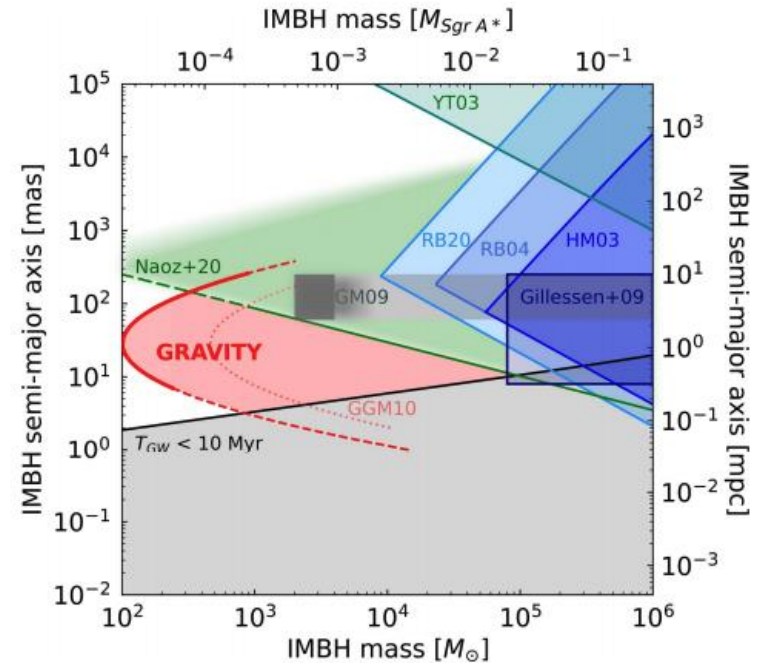
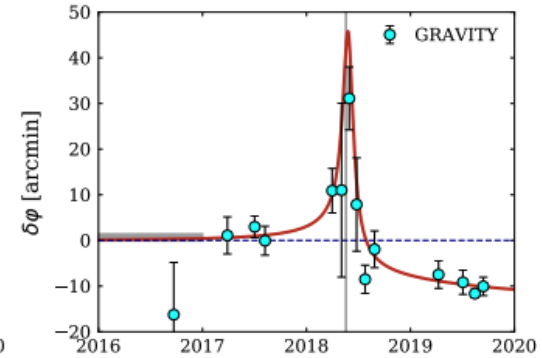
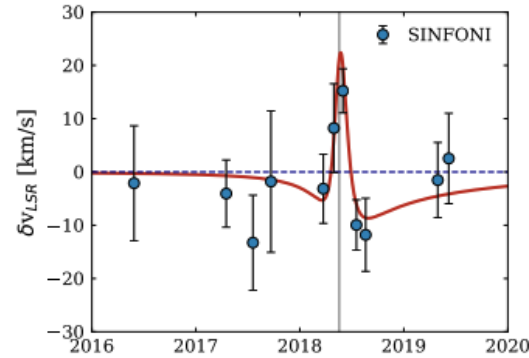
**Generic Tools and information**

- [ETC, Exposure Time Calculators](#)
- [Phase 1 Proposal Preparation and Submission](#)
- [Phase 2 Proposal Preparation for Service Mode observations](#)
- [Phase 2 p2pp](#)
- [Magnitude / Jansky Converter: ST-ECF NICMOS Tools](#)



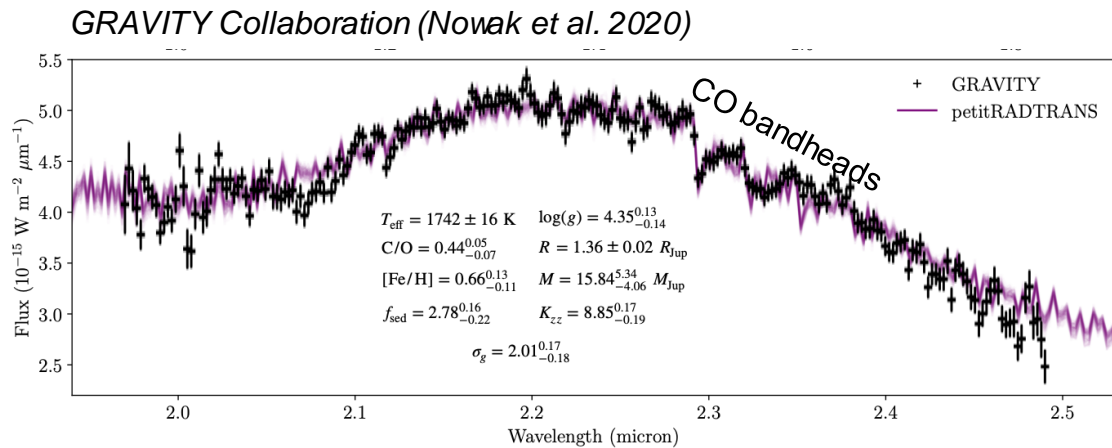
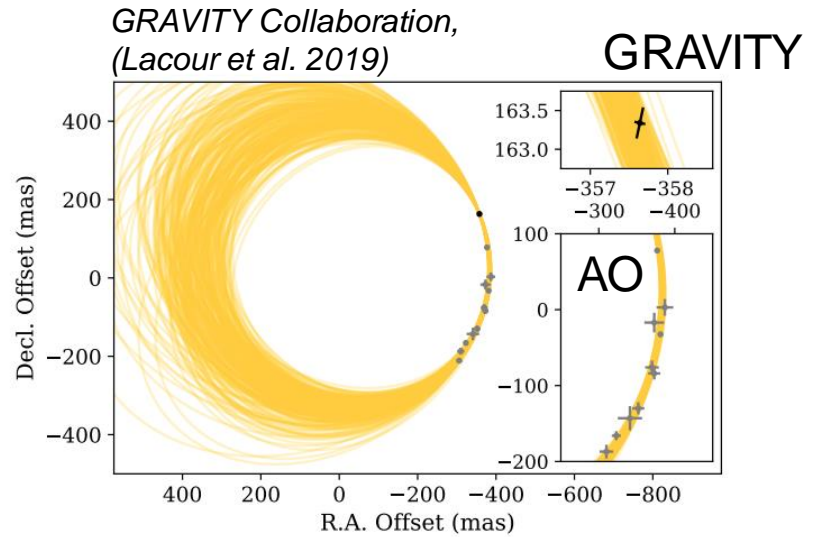
# Schwarzschild precession around Sgr A\*

- SINFONI and GRAVITY culminate 30 years of observation of star S2 using ESO facilities
- New S2 orbit nearly excludes all possible additional intermediate mass black hole around Sgr A\*



# VLT observes exoplanets

- GRAVITY astrometry of HR8799e (x10 better than AO) disproves co-planar hypothesis for HR8799b-e orbits.
- Carbon to oxygen ratio measurement for  $\beta$  Pic c favours core-accretion formation scenario

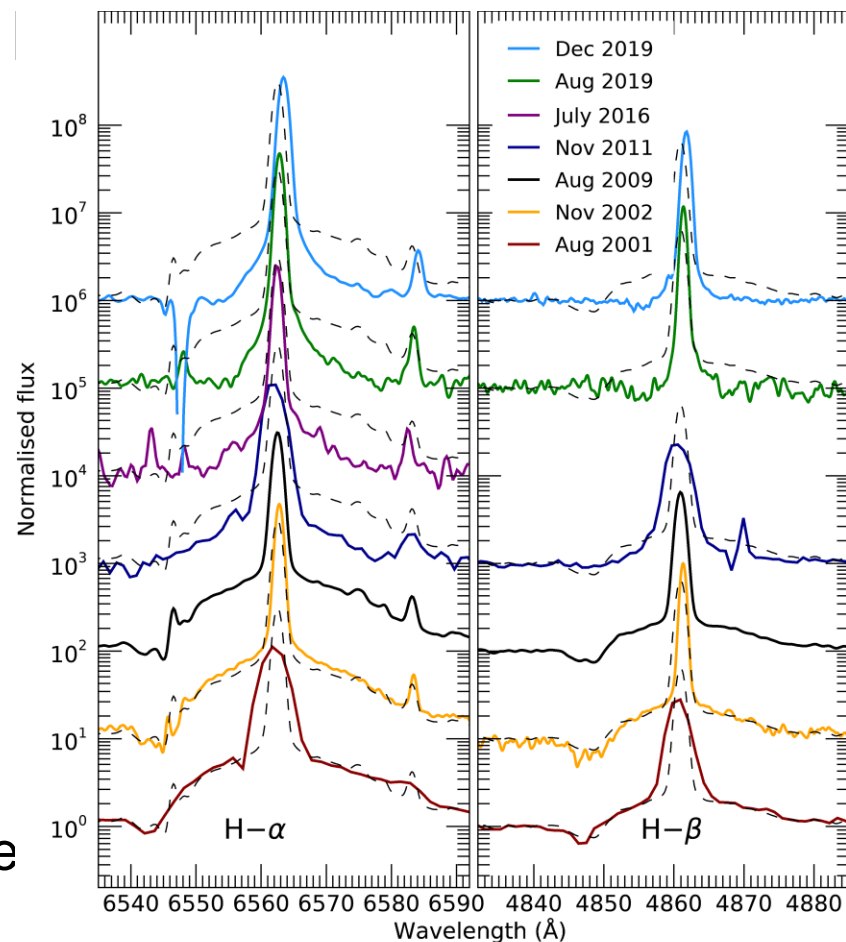


# Disappearance of a star

## ■ Long-term observations of an LBV in the dwarf galaxy

### PHL293B

- Combination of new and archival data from
  - ESPRESSO, X-shooter, UVES, HST/COS, INT/IDS, WHT/ISIS
- Disappearance of the broad wings in the H lines after 2009
  - LBV changed from active state
- Either star dropped in luminosity and increased temperature (plus some dust)
- Or LBV collapsed to a black hole without a supernova



Allan et al. 2020

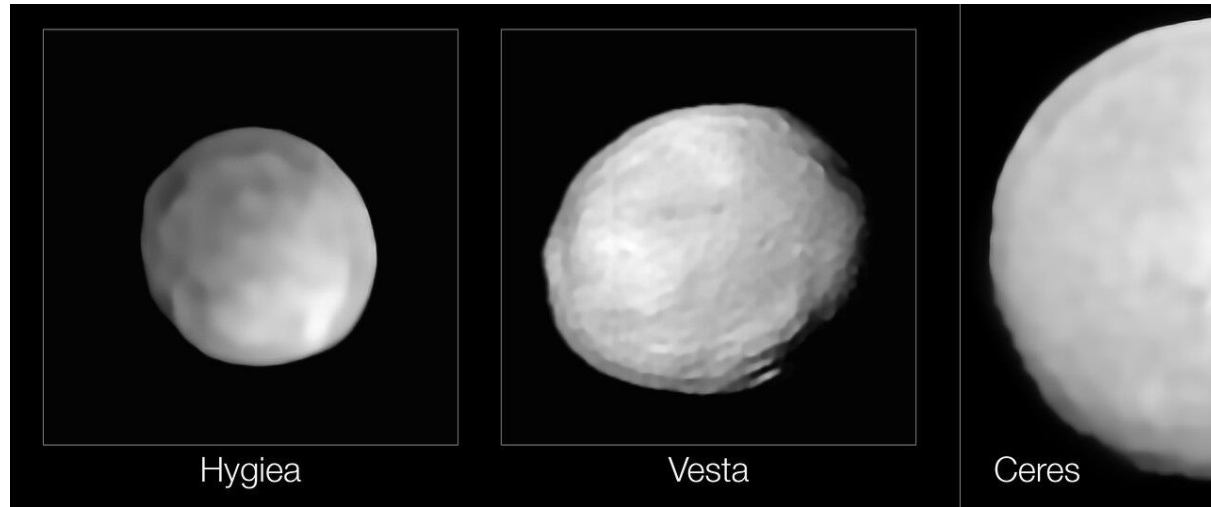
# Shapes of Asteroids

- Origin of asteroids → collisional debris?
- SPHERE observations of (10)Hygiea
- Shape nearly spherical and surface without major craters

- contrary to, e.g., (4)VESTA
- diameter 440km
- density 2000kg/m<sup>3</sup>

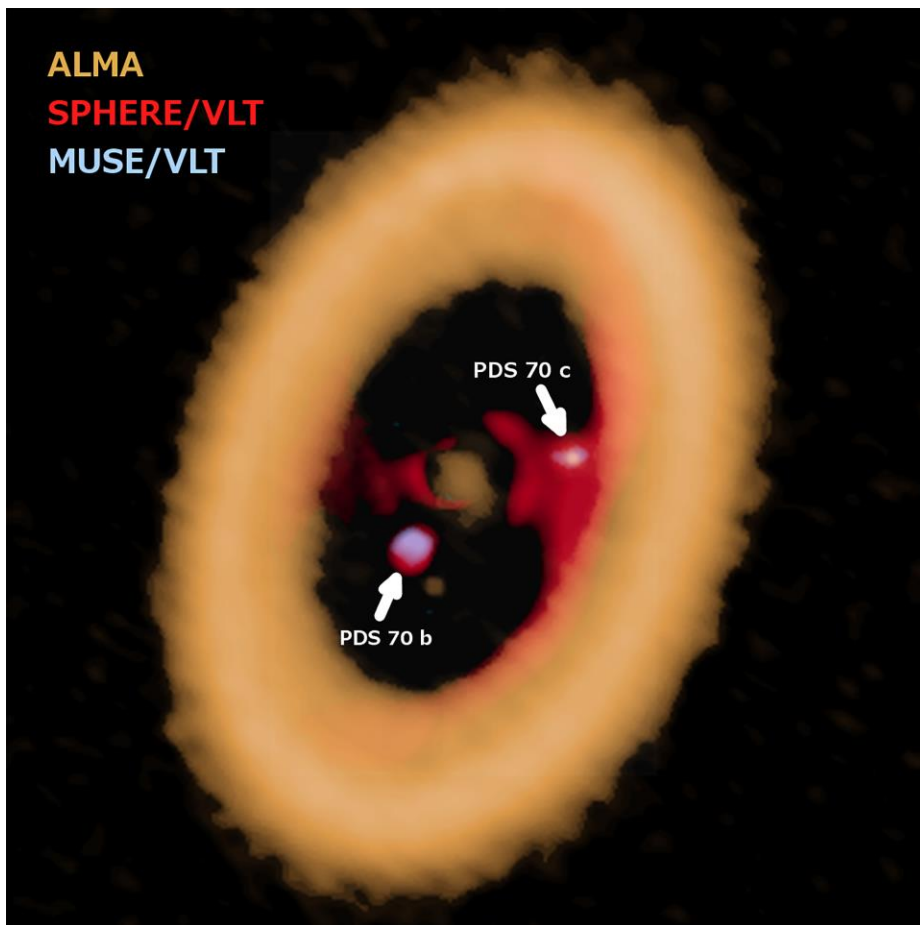
## ■ Formation

- possibly after a major impact
- reformed from the debris under self gravity
- signatures of a minor planet



*Vernazza et al. 2019*

# An exomoon in formation



- Synergy between ALMA and VLT
- PDS 70: T Tauri star with a VLT/SPHERE-discovered companion PDS 70 b (Müller et al. 2018)
- H $\alpha$  emission (VLT/MUSE) at location of two planets indicates accretion onto these planets (Haffert et al. 2019)
- Initial analysis of ALMA data show a highly structured disk (Keppler et al. 2019), with an upper limit of circumplanetary material around PDS 70 b of  $0.01 M_{\text{Earth}}$
- Further analysis of the ALMA continuum emission at the location of PDS 70 c constrains this to the presence of  $2-4 \times 10^{-3} M_{\text{Earth}}$  in the form of dust, enough to form an exomoon (Isella et al. 2019), assuming typical dust-to-gas ratios

# The ESO exo-planet machinery

- HARPS at 3.6m telescope (in the future also NIRPS)
  - best radial velocity machine at a 4m telescope
  - extremely stable spectrograph
  - ESPRESSO at VLT
- SPHERE
  - adaptive optics supported imaging and spectroscopy
- VLT/GRAVITY
  - highest spatial resolution for follow-up observations of known systems
- FORS2/ERIS
  - transit measurements, atmospheres of exo-planets
- CRIRES+
  - spectroscopy of atmospheres



# Science with Paranal/La Silla telescopes

- Contributions to nearly all of astrophysics
  - Solar system
    - Trans-Neptunian Objects, asteroids, comets
  - Exo-planets
    - direct imaging, temperate planets, planetary systems
  - Stellar physics
    - metal-poor stars, supernovae, neutron star mergers
  - Milky Way structure
    - galactic centre, distances
  - Galaxy evolution
    - redshift surveys, rotation curves, absorption studies
  - Cosmology
    - accelerating universe, background temperature, chemical evolution

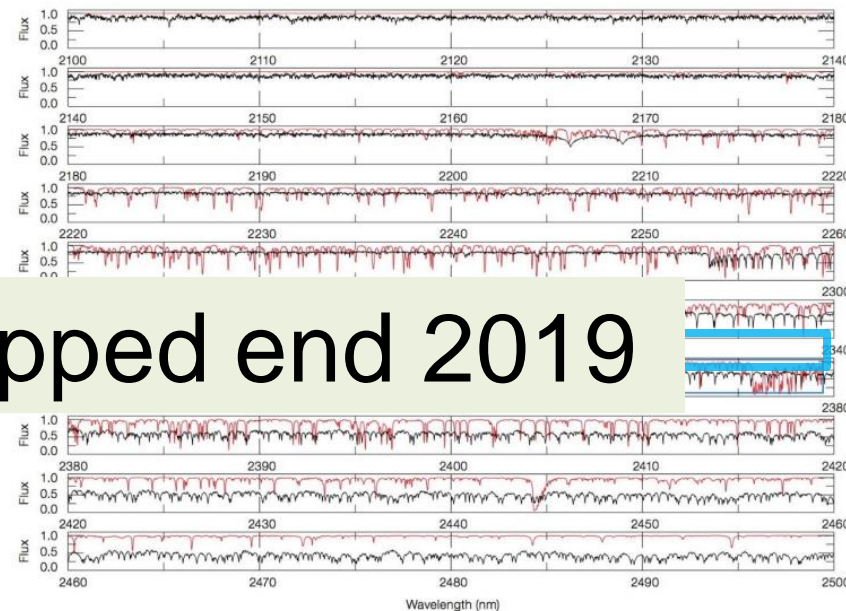
# Current Status of VLT/ instrumentation development

- GRAVITY for MATISSE commissioned and offered
- CRIRES mounted on UT3
  - Commissioning pending
- ERIS nearly completely integrated
  - PAE expected towards the end of 2020
- MOONS integration progressing
- 4MOST in construction phase
- FORS Upgrade project started
- MAVIS Phase A finished
- CUBES Phase A started
- NIRPS/3.6m and SOXS/NTT in integration phase



# CRyogenic InfraRed Echelle Spectrograph

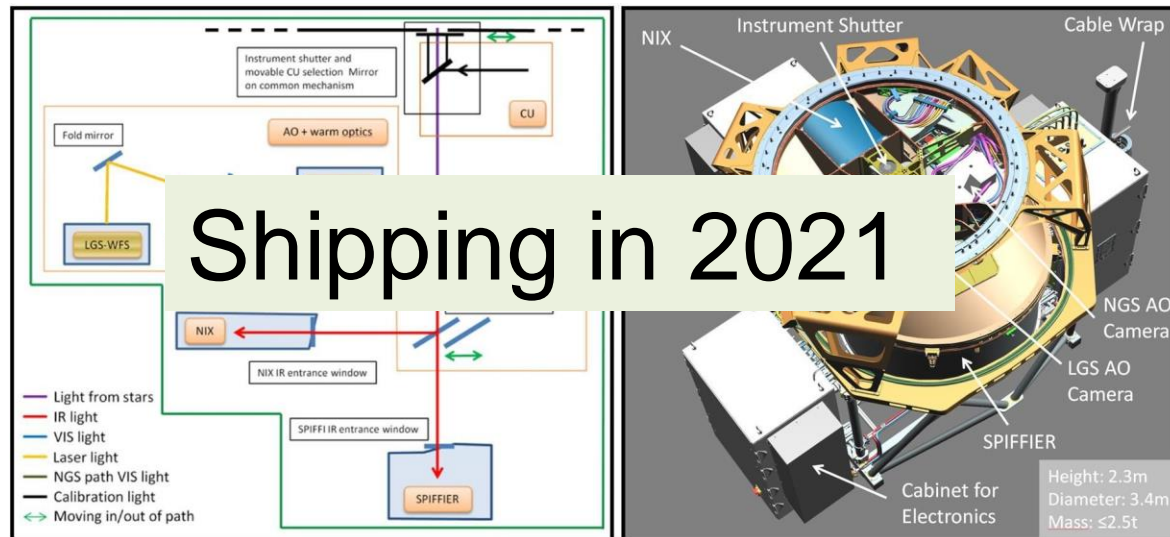
- Upgrade of existing AO-assisted high resolution spectrograph at 1-5 $\mu\text{m}$  ( $R=100,000$ )
- Use Hawaii 2RG up to 5 $\mu\text{m}$ : wavelength coverage x10
  - exoplanets velocimetry and atmosphere
- Polarimetry
  - Stellar magnetism



<https://www.eso.org/sci/facilities/paranal/instruments/crises/overview.html>

# Enhanced Resolution Imager and Spectrograph

- Near IR 1-5  $\mu\text{m}$  with 4LGS and adaptive secondary
- Replaces NACO and SINFONI
- Imager, coronagraph, sparse mask, IFU 1-2.5 $\mu\text{m}$ , LSS 3-5 $\mu\text{m}$
- Exoplanets, GC, resolved stellar pops, high-z, ...

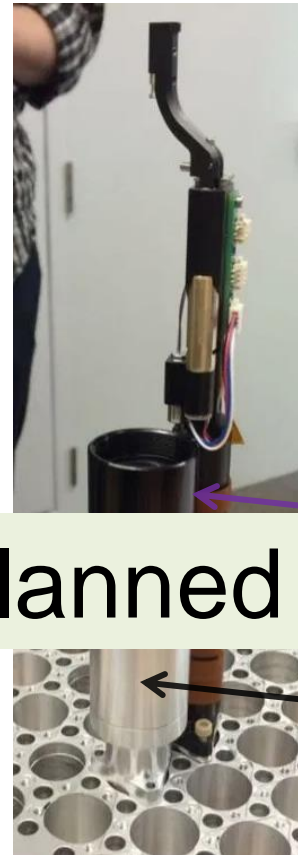


<http://www.eso.org/sci/facilities/develop/instruments/eris.html>

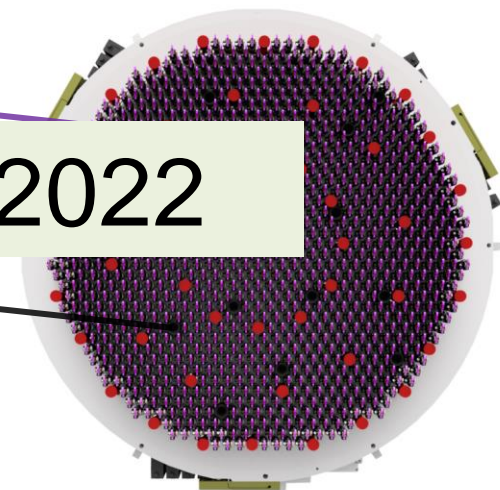


# Multi Object Optical and Near-infrared Spectrograph

- 1001 fibres over 500 arcmin<sup>2</sup>
- 0.65-1.8 $\mu$ m at R=4000-18000
- Science cases:
  - Galactic archeology
  - Growth of galaxies: million objects at  $z>1$
  - First Galaxies ( $z>7$ )



Planned 2022



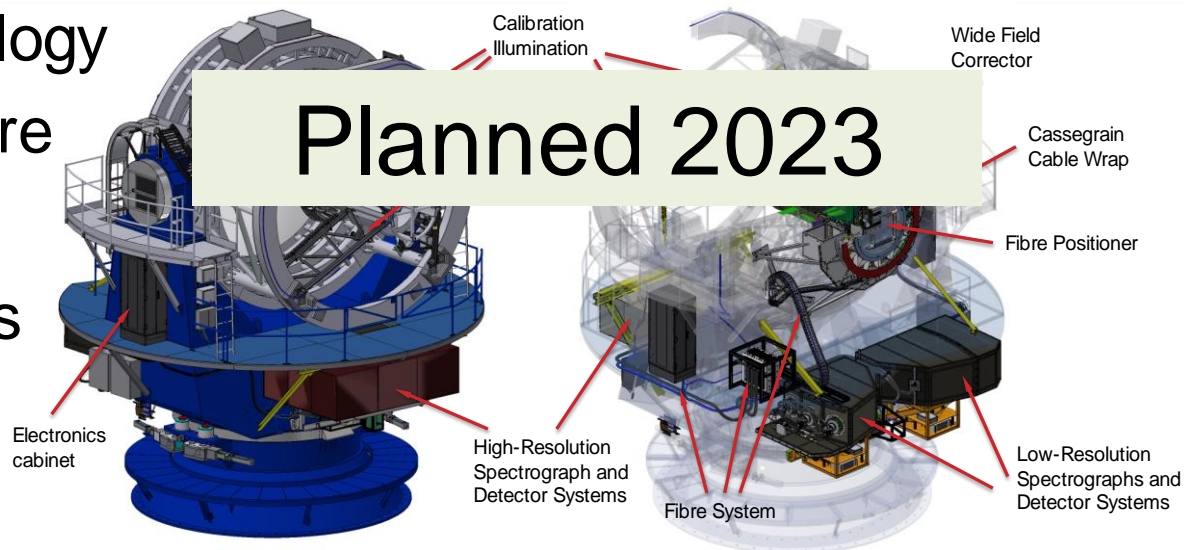
<https://www.eso.org/sci/facilities/develop/instruments/MOONS.html>

## Wide-field MOS on VISTA

- FoV  $\sim 4.1 \text{ deg}^2$
- 2436 fibres observed simultaneously
  - 812 fibres with  $R \sim 20000$ ;  $400 \text{ nm} < \lambda < 680 \text{ nm}$  (three settings)
  - 1624 fibres with  $R \sim 5000$ ;  $370 \text{ nm} < \lambda < 950 \text{ nm}$

## Surveys only

- Galactic archeology
- Galactic structure
- Galaxy surveys
- Redshift surveys

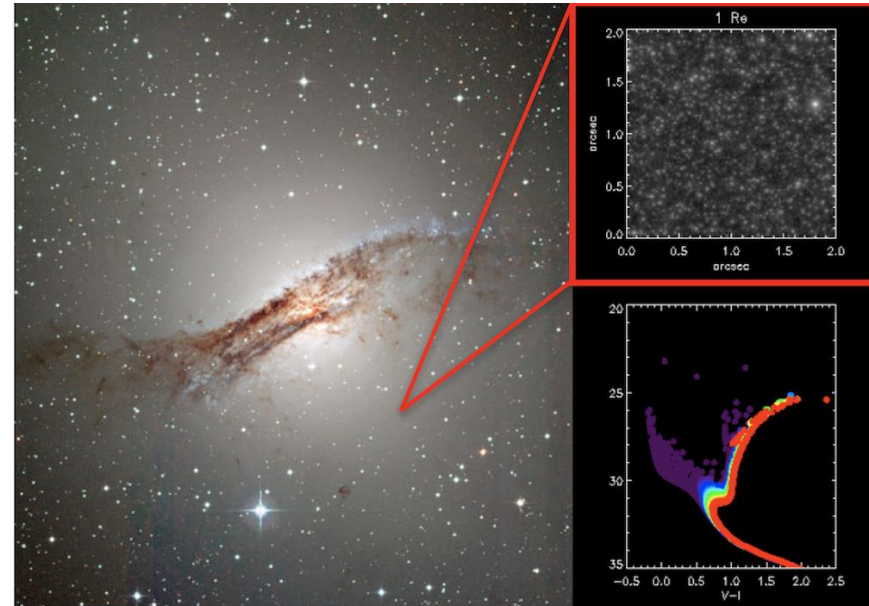


<https://www.4most.eu/>

# Instruments in development

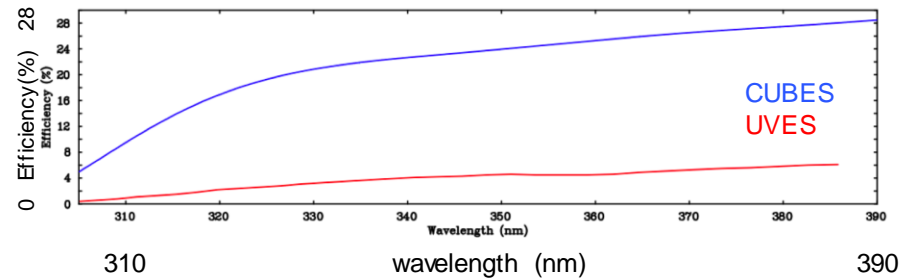
## ■ MAVIS:

- MCAO in the visible: imager and spectrograph
- Phase A finished
- <http://mavis-ao.org/mavis/>

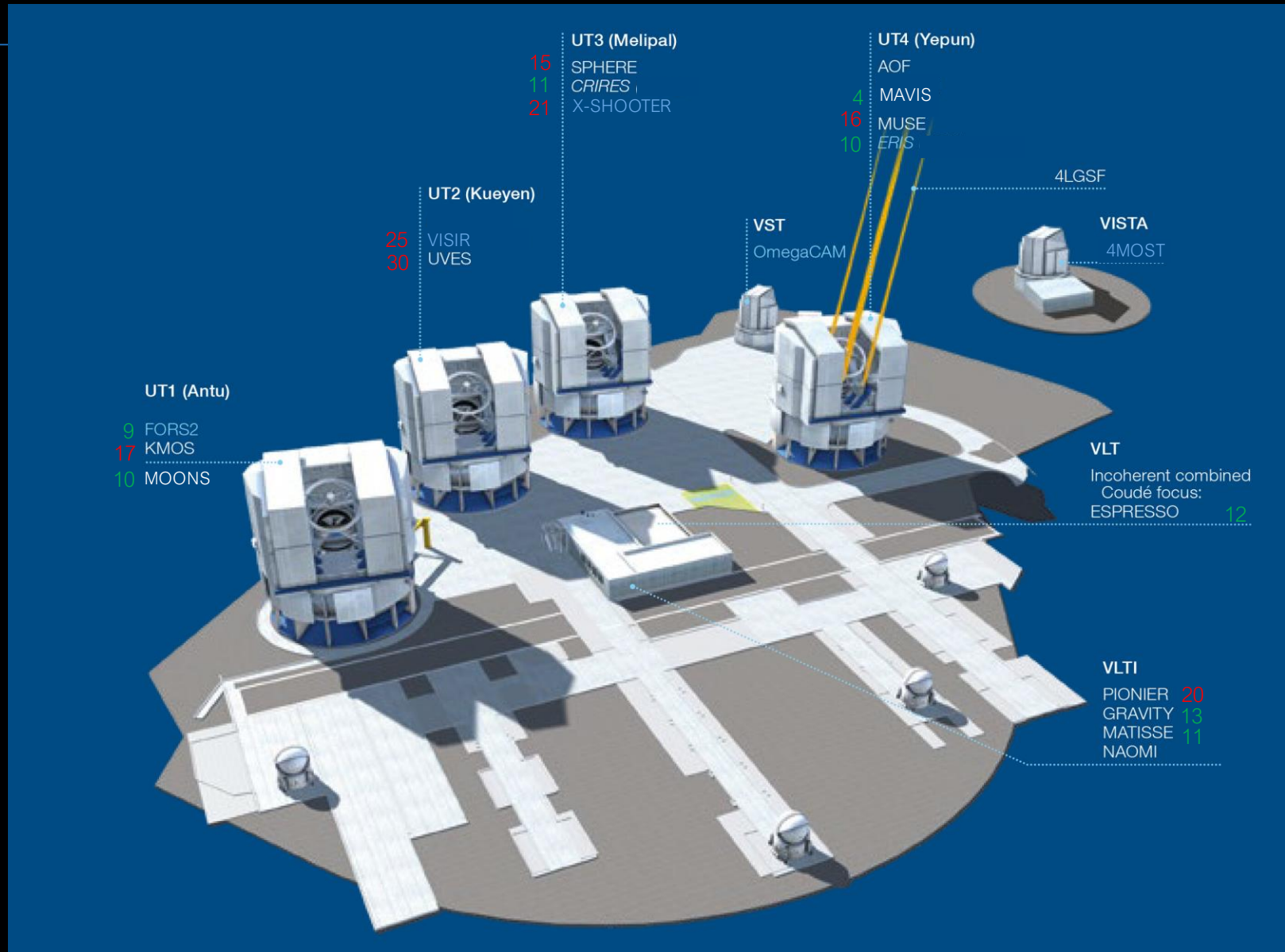


## ■ Near-UV high-resolution spectrograph

- New instrument (CUBES)
- Phase A started
- <https://cubes.inaf.it>



# VLT in 2030





# VLT/I in 2030

- Kicked-off at a Workshop in June 2019
  - Well attended, largely by instrument builders
- Science prioritization exercise explicitly polled the scientific community about science drive of the evolution of VLT/I, outcome injected into exercise
- White Papers delivered by 3 teams
- Reviewed at the 16-17 April 2020 STC meeting, clear priorities established:
  - GRAVITY+ <https://zenodo.org/record/3356274>
  - BlueMUSE <https://arxiv.org/abs/1906.01657>
- Teams informed in June
- Phase A planning started

# Stay involved

## ■ Student- and Fellowship programmes

- <https://www.eso.org/sci/activities/FeSt-overview/ESOstudentship.html>
- [https://www.eso.org/sci/activities/FeSt-overview/fellowship\\_programme.html](https://www.eso.org/sci/activities/FeSt-overview/fellowship_programme.html)

## ■ Visitor programme

## ■ Workshops and conferences

## ■ ESO Messenger

- <https://www.eso.org/sci/publications/messenger/>

## ■ Science Newsletter

- <https://www.eso.org/sci/publications/newsletter.html>

## ■ Web pages: [www.eso.org](http://www.eso.org)