ESO Facilities for the next decade

Marina Rejkuba
Nando Patat
Bruno Leibundgut

LSST Followup Observations, Garching, 23 January 2024

European Southern Observatory - Today

La Silla

Paranal

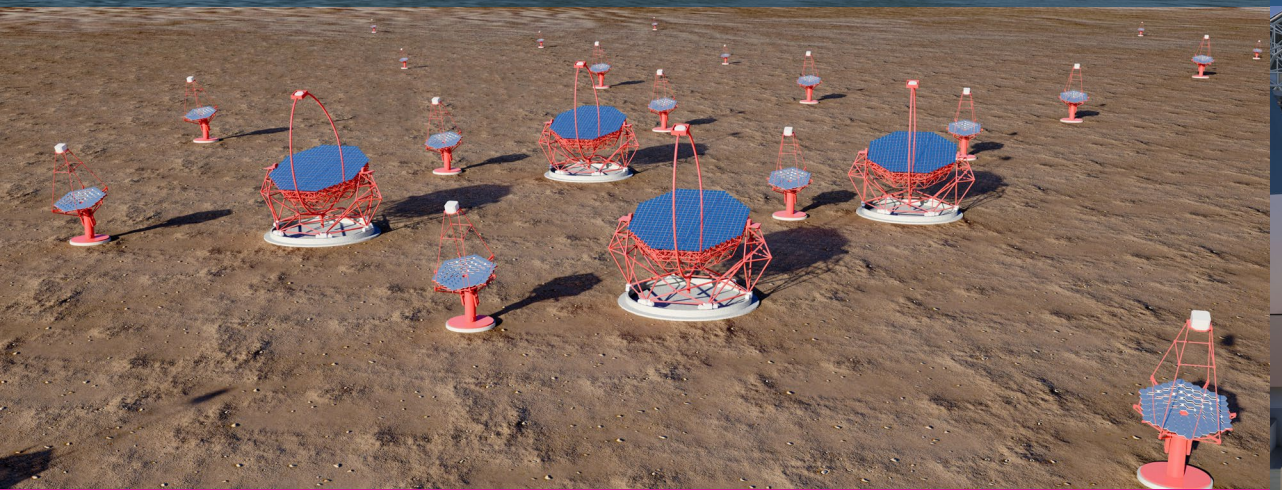
Chajnantor – Atacama Large Millimeter/submillimeter Array (ALMA)

European Southern Observatory – the coming years

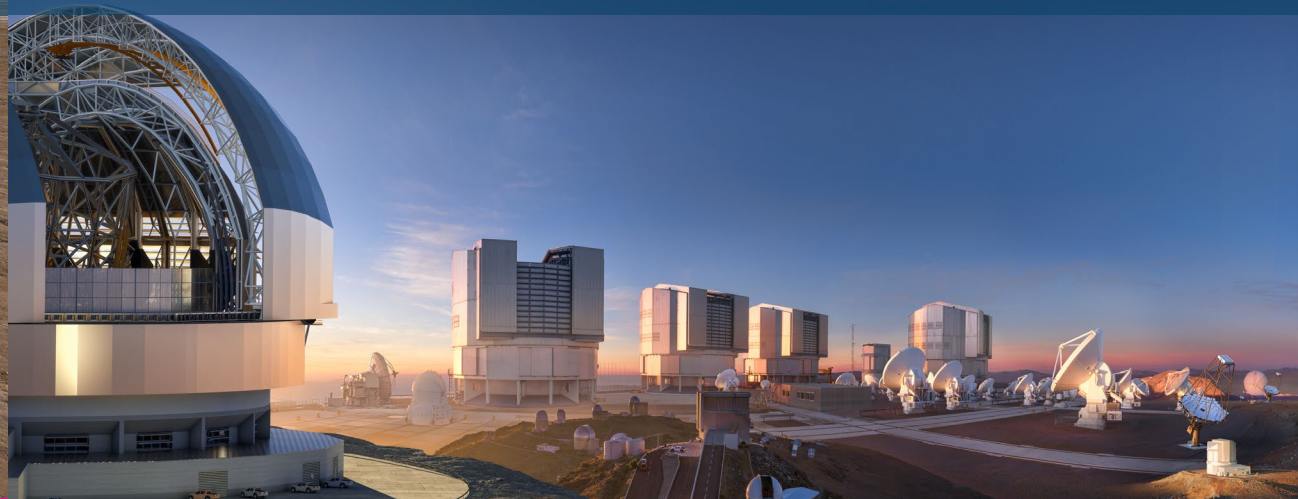
Cerro Armazones

The Extremely Large Telescope

Cherenkov Telescope Array



Multi-programme/-wavelength observatory



La Silla as a science platform – Hosted Telescopes

Swiss 1.2-metre Leonhard Euler telescope

ESO 1-metre Schmidt telescope

Danish 1.54-metre telescope

ESO 1-metre telescope

Rapid Eye Mount telescope

BlackGEM
hunting electromagnetic counterparts of gravitational wave events

MPG/ESO 2.2-metre telescope

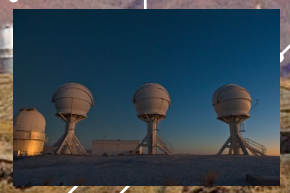
BlackGEM

TRAnsiting Planets and PlanetesImals Small Telescope – South

ExTrA

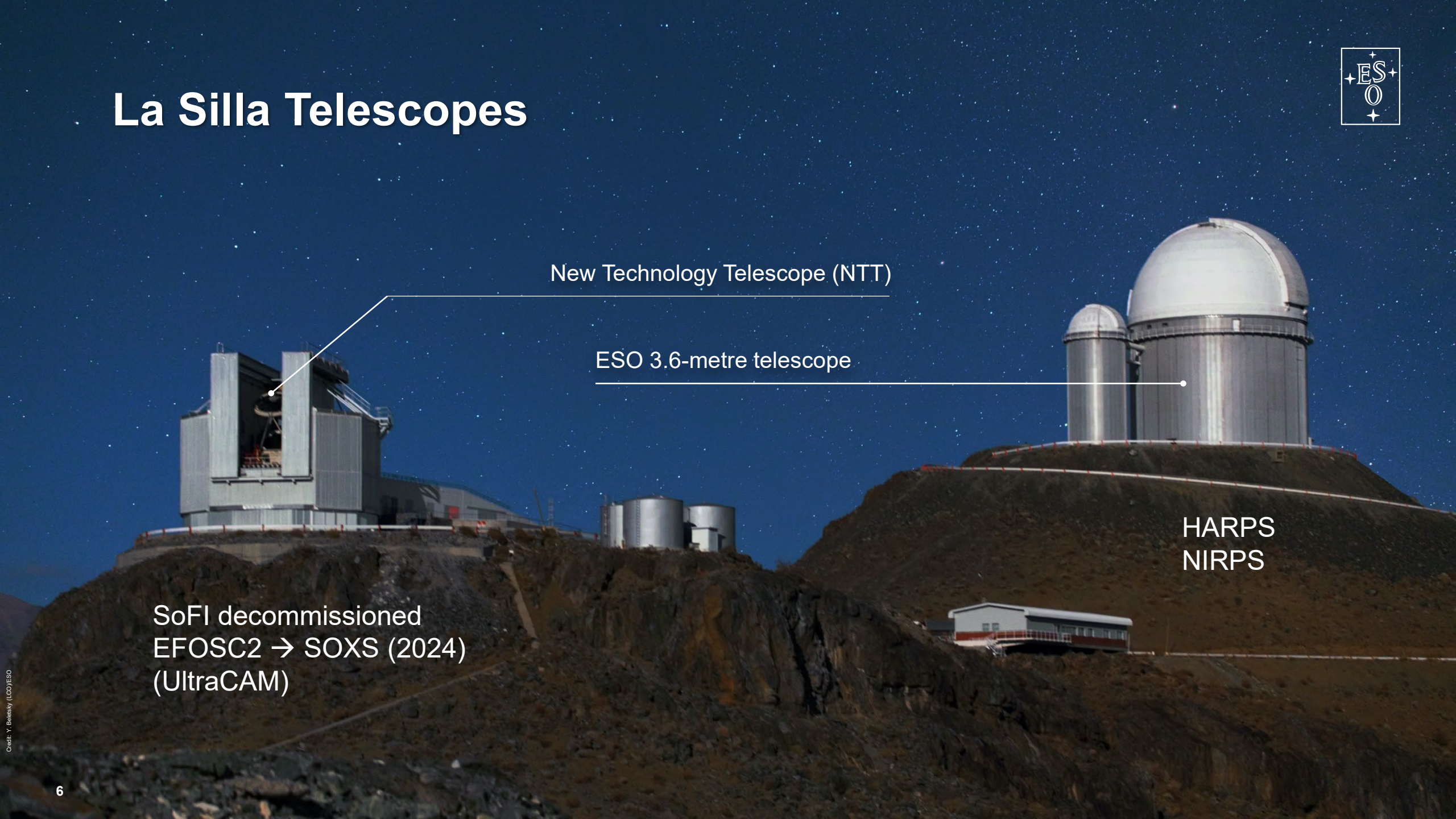
Télescope à Action Rapide pour les Objets Transitoires

Multi-site All-Sky CAmeRA



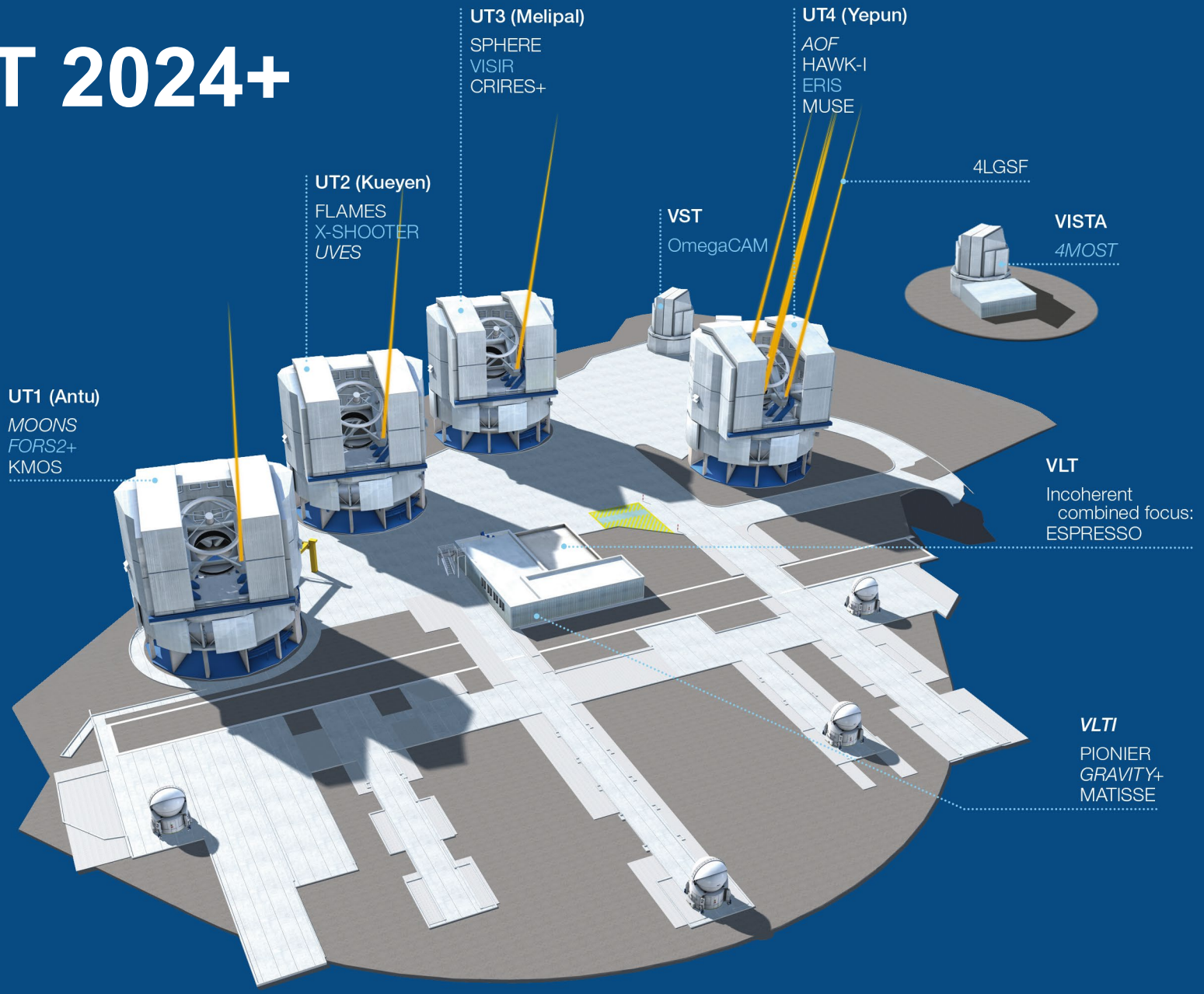
Credit: ENEL

La Silla Telescopes



Credit: Y. Beletsky (LCO)/ESO

The VLT 2024+



La Silla Paranal Facilities

VLT

- Instrumentation operating, in assembly and planned
  - Covers the available optical infrared wavelengths: 300nm to 20µm
  - Angular resolution from seeing limit to 50 µ-arcseconds
  - FORS2, UVES, FLAMES, VISIR, HAWK-I, X-Shooter, AOF, KMOS, MUSE, SPHERE, ESPRESSO, CRIRES, ERIS, MOONS, MAVIS, CUBES

VLTI

- PIONIER, GRAVITY(+), MATISSE

VISTA

- 4MOST

NTT

- (EFOSC2), UltraCAM, SOXS

3.6m

- HARPS, NIRPS

VLT Instruments 2023

VLTI

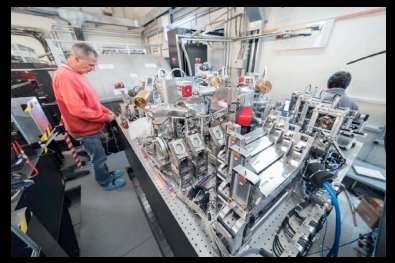
UT1

UT2

UT3

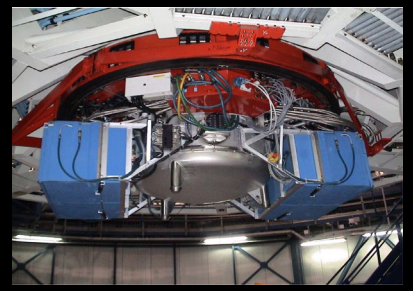
UT4

MATISSE

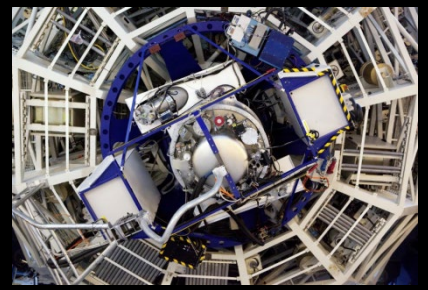


FORS2

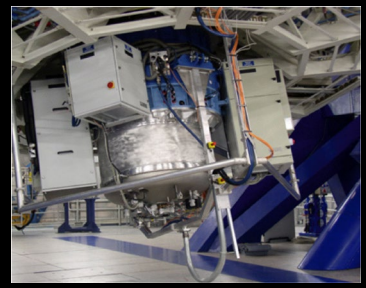
VISIR



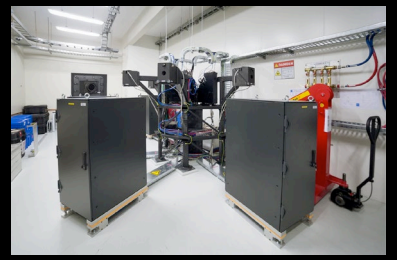
X-SHOOTER



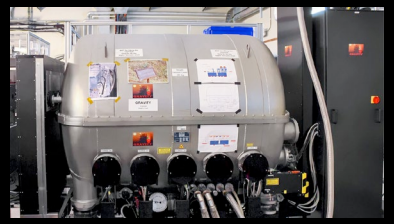
ERIS



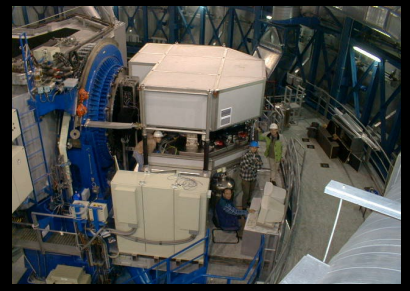
ESPRESSO



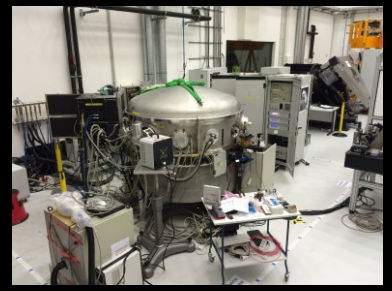
GRAVITY+



UVES

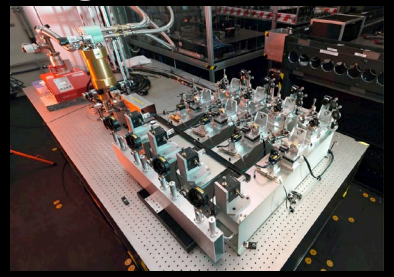


CRIRES

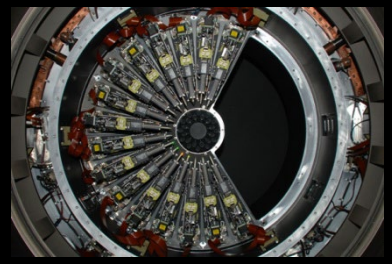


MUSE

PIONIER



KMOS

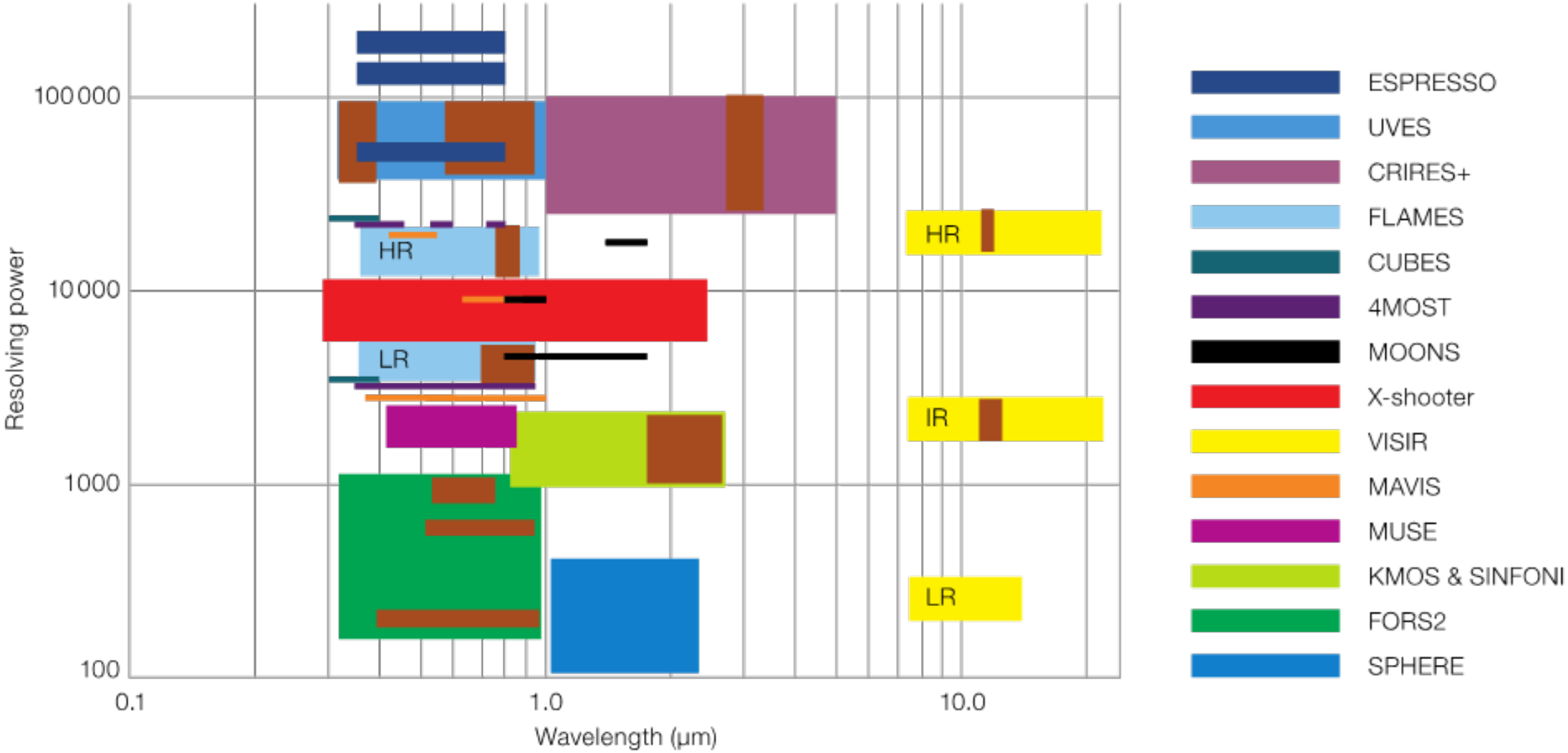


FLAMES

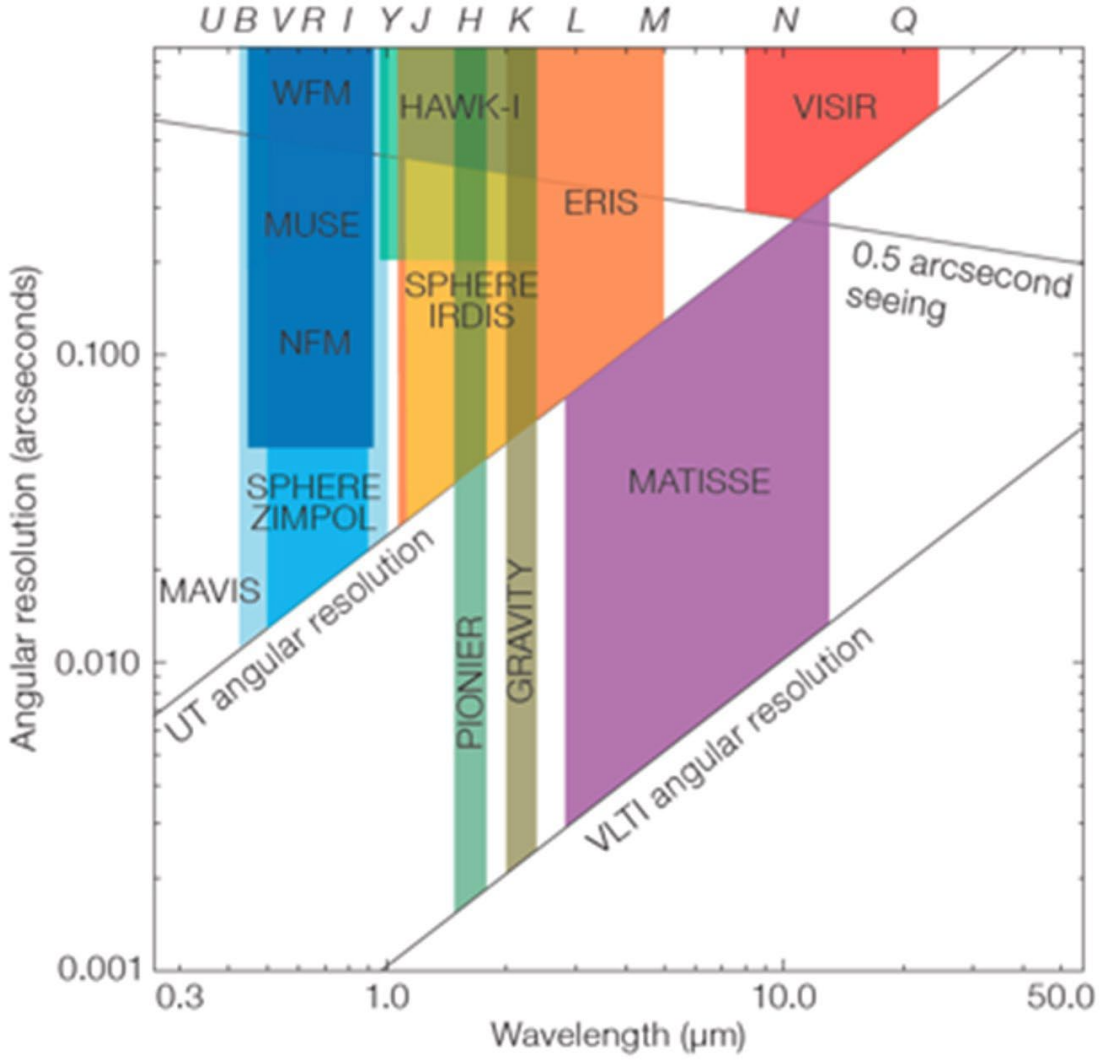
SPHERE

HAWK-I

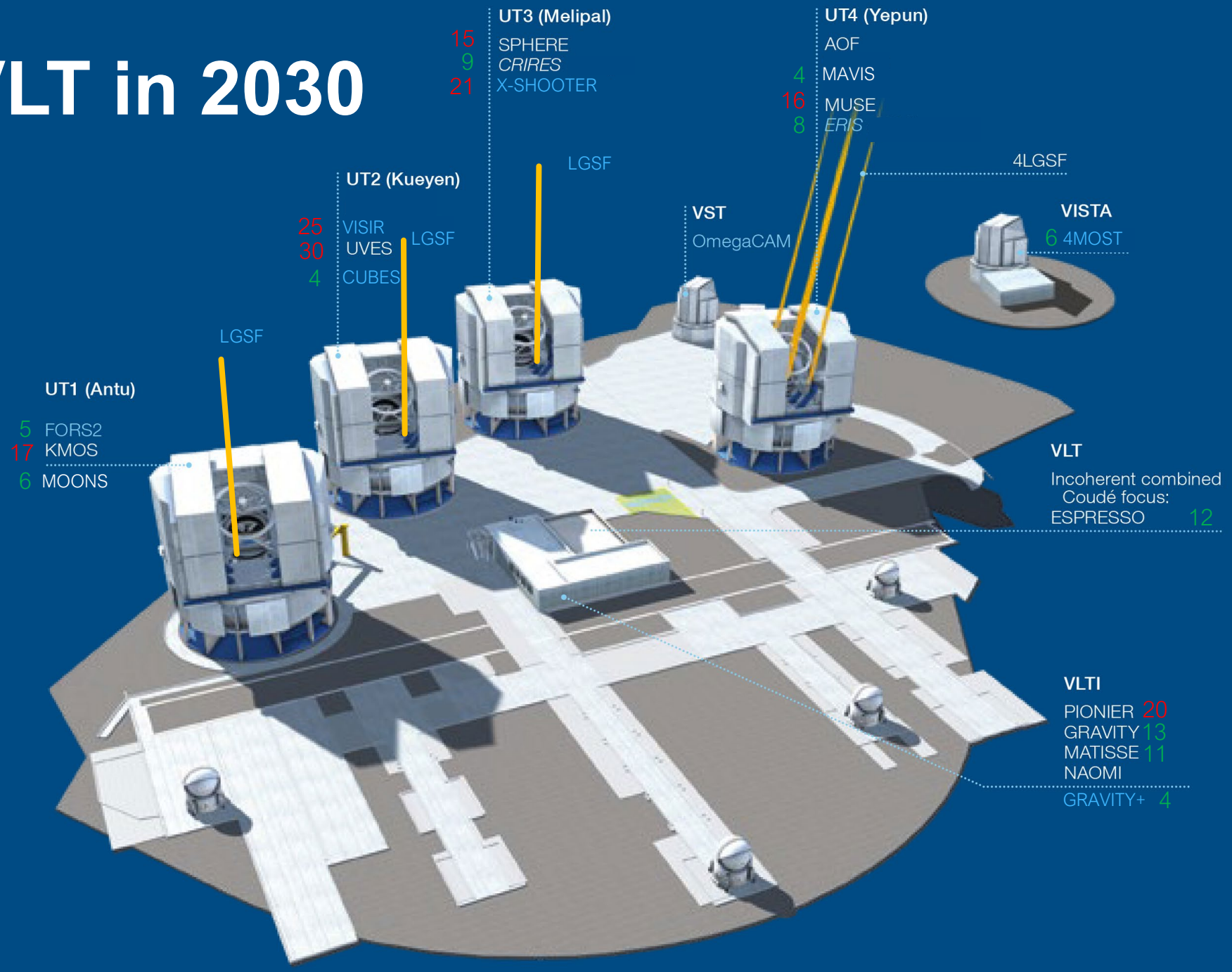
VLT Optical/Near-IR coverage



VLT Optical/Near-IR coverage



The VLT in 2030



ALMA

Observe the cold universe

- wavelengths from 300μm to 1.3mm (1 THz to 200 GHz)

Global Partnership

- Europe (ESO), North America (USA/NSF and Canada/NRC), East Asia (Japan/NINS, Taiwan/NSC/ASIAA, South Korea/KASI)

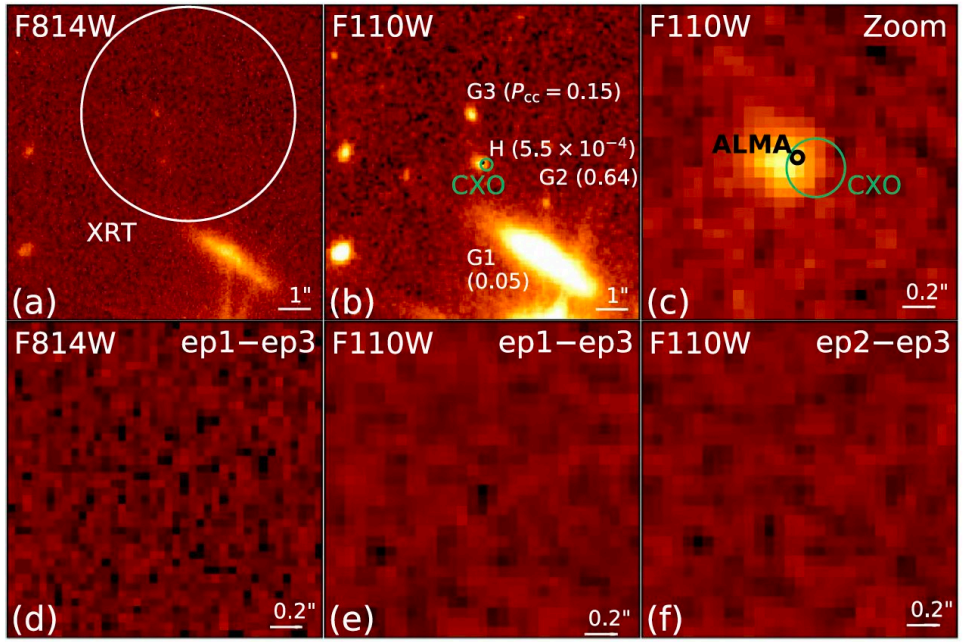
66 antennas located at 5000m altitude

50 12m antennas

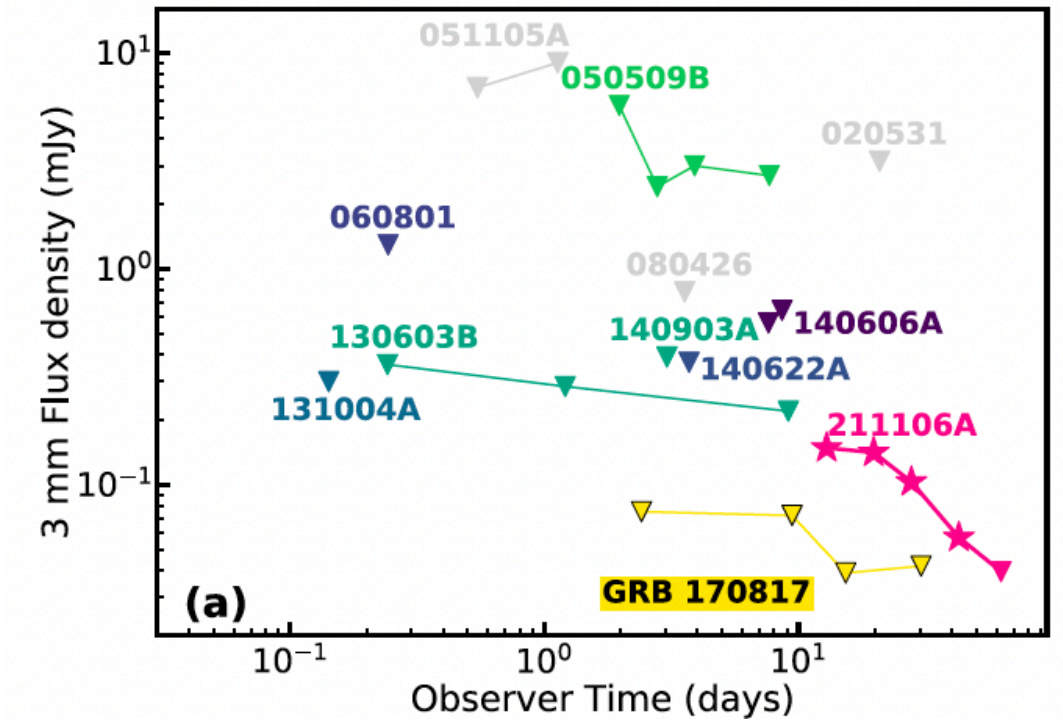
12 7m + 4 12m antennas (compact array)

Available for ToOs

Neutron star merger in mm light



Colour images: HST
White/green/black circles: Swift-XRT/Chandra/ALMA detections



Laskar et al. 2022

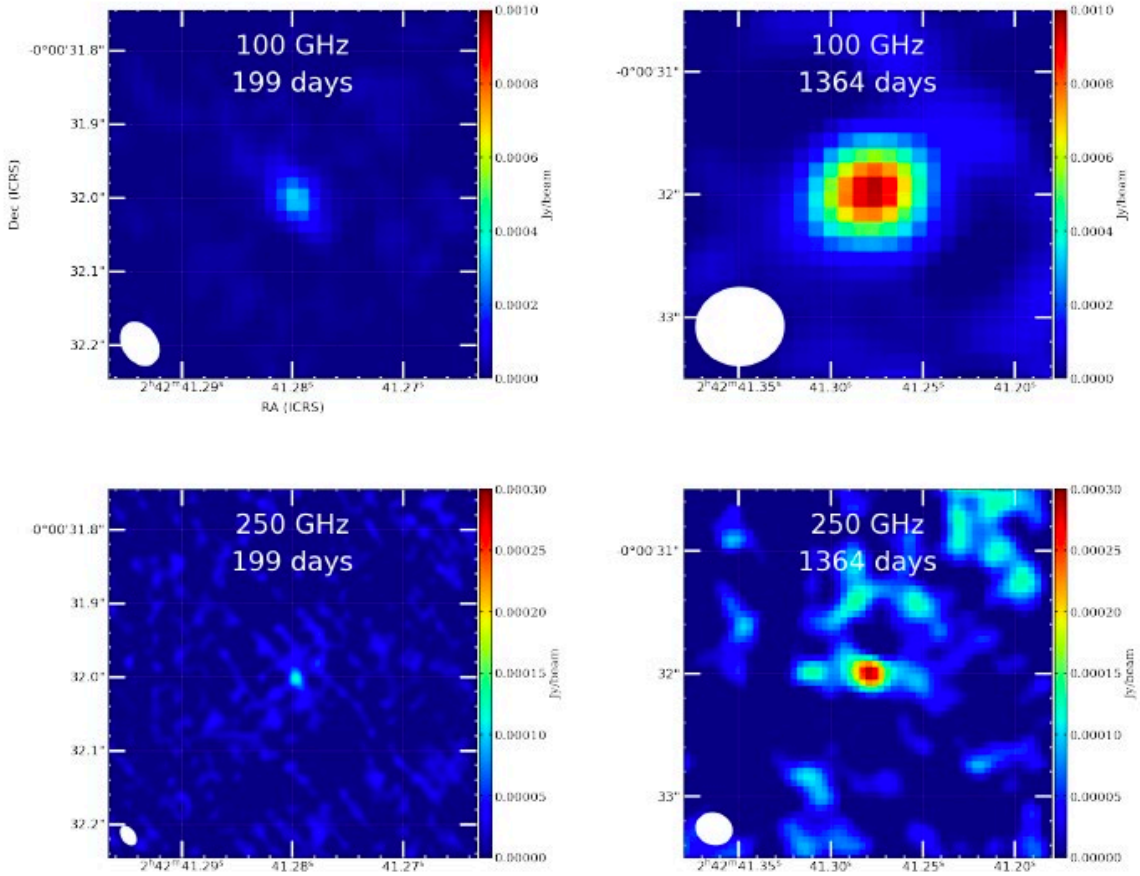
Stars: Short GRB 211106A
Triangles: upper limits of short GRBs including GRB 170817 (Gravitational Wave event, in yellow)

ALMA captures for the first time the afterglow of a neutron star merger in mm wavelengths, enabling accurate localisation and constraining the jet opening angle to < 16 degrees

Resurrection of type IIL SN 2018ivc (Maeda et al. 2023)

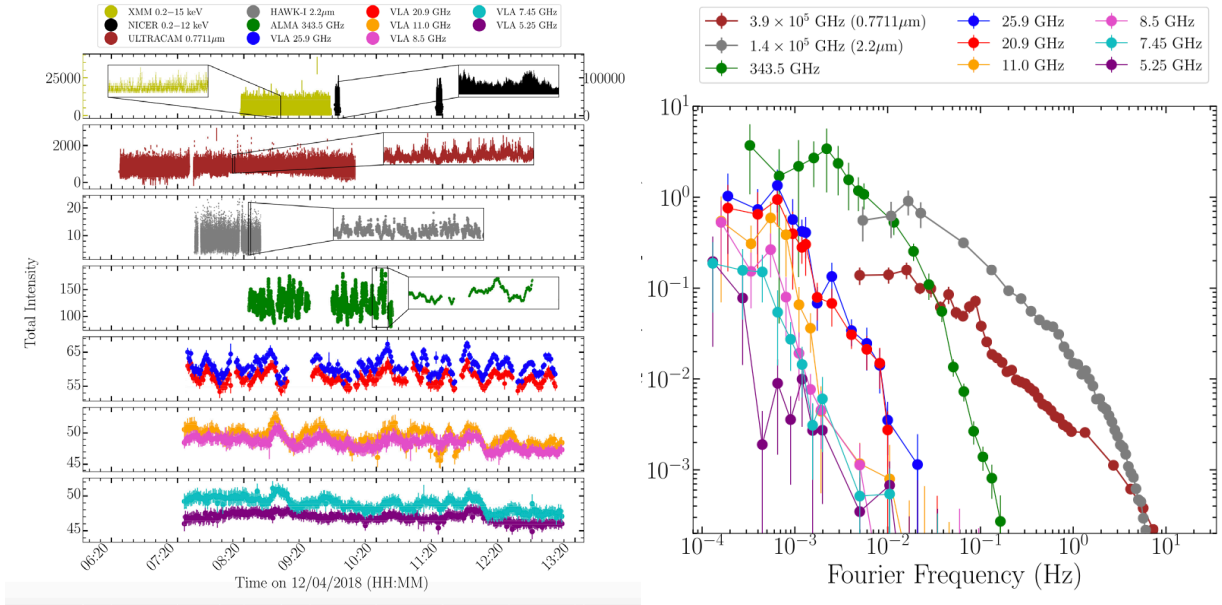
Long-term monitoring of SN 2018ivc with ALMA revealed unprecedented rebrightening starting more than one year after explosion.

This allows to reconstruct the distribution of circumstellar matter and thus the mass-loss history in the final > 1000 years.



And second life as neutron stars and black holes

Tetarenko et al. 2021



Jet propagation speed in a black hole X-ray binary:
highly relativistic and confined (0.45 degrees) jet carrying away 60% of the accretion power!

ESO Facilities

ESO offers a wide spectrum of electromagnetic observational opportunities

- Optical and near-infrared facilities from 4m to 40m apertures and angular resolutions from μarcsec up to several arcminutes
- OIR and/or mm/sub-mm characterization of sources discovered at different wavelengths or by different messengers
- Operational modes for quick follow, multi-wavelength coverage, flexible scheduling
- Extensive archive of objects in the southern sky

ESO Operations: transient science follow-up

Proposals for Target of Opportunity & Transients follow-up

- Unpredictable: Director's Discretionary Time
- Predictable: Generic proposal for specific science case
- *Soft & Hard ToOs (>48h or <48h execution window)*
- *Rapid Response Mode (RRM) - interrupt ongoing observation*
- *Service Mode observations including time-links*

Phase 2:

- Target of Opportunity (ToO) or RRM generic OB as template for trigger
- Time-linked scheduling containers & possible nested concatenations

The ESO Transient Sky

Traditionally challenging for community observatories

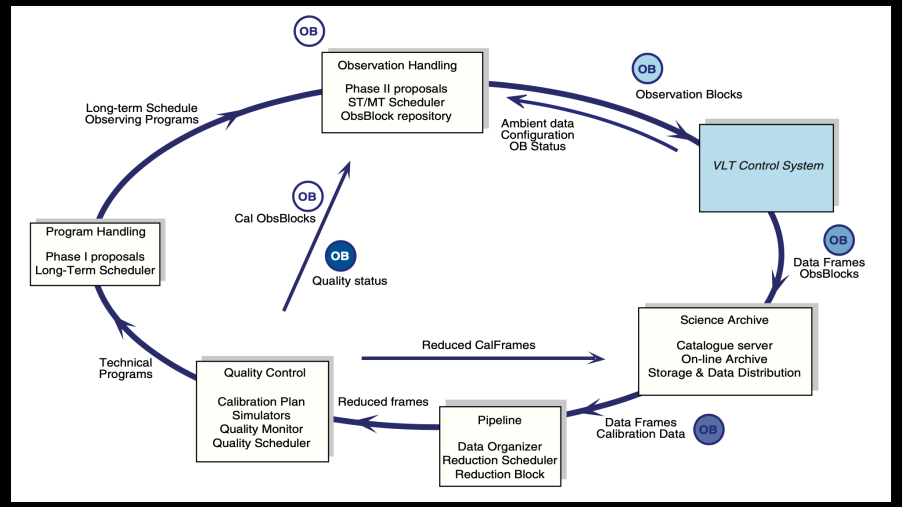
- operational modes
- flexible scheduling
- variable timescales
- large target of opportunity fraction
- rapid response mode

❾service mode operations

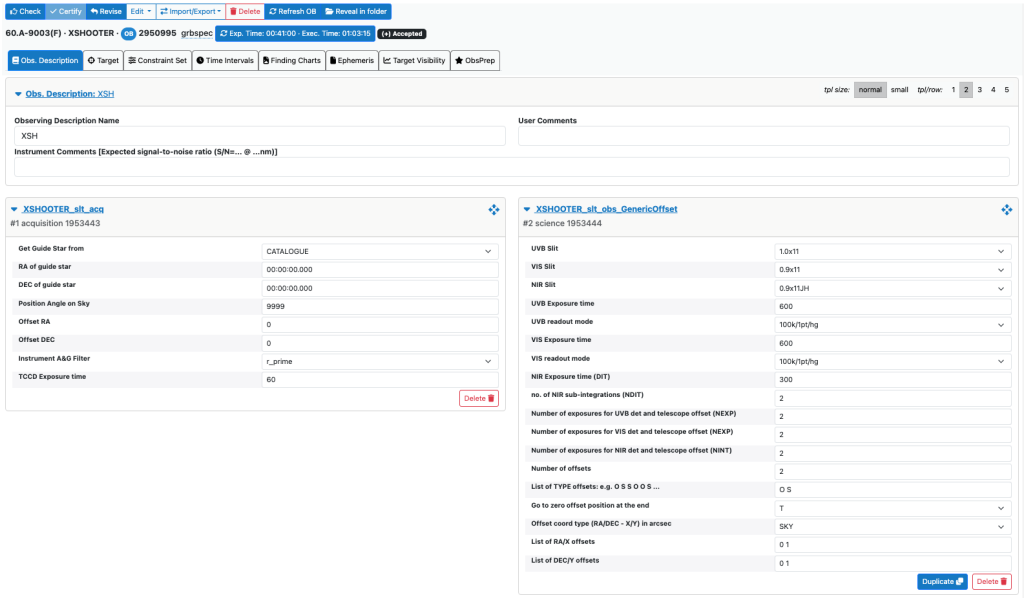
❾dedicated telescopes

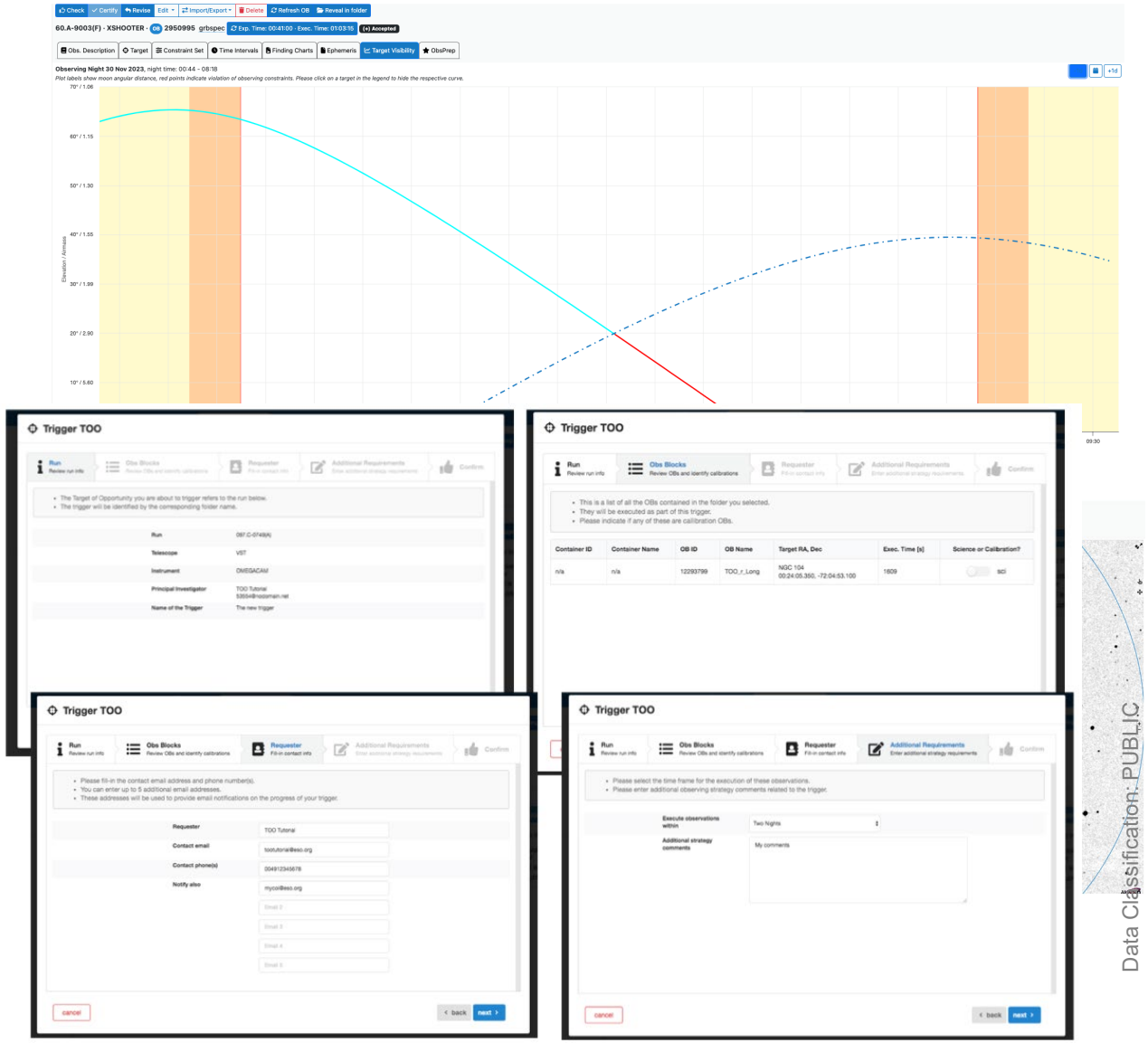
Systematic archiving

- time series



Triggering of ToOs





P2 + ObsPrep: visualisation, selection of blinc

Planning the observations

API: Programmatic preparation of the OBs

Night Log Tool: time accounting

Rapid Response Mode (RRM)

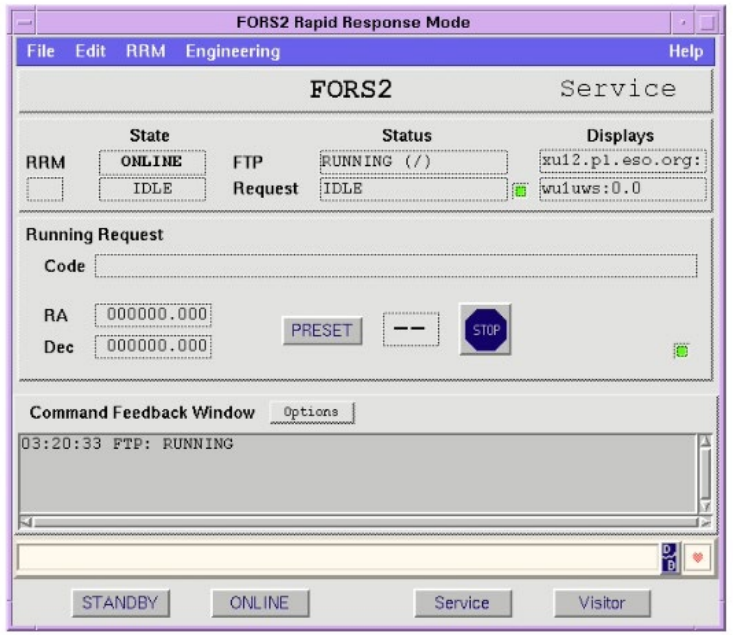
Immediate reaction offered for:

- FORS2, UVES, X-SHOOTER, SPHERE, HAWK-I, MUSE

Trigger sent via ASCII file to ftp server picked-up by the cron job → interrupts the ongoing SM/VM observation & loads the RRM OB

Telescope automatically checks if focus change is needed → preset to the ftp file coordinates → start acquisition

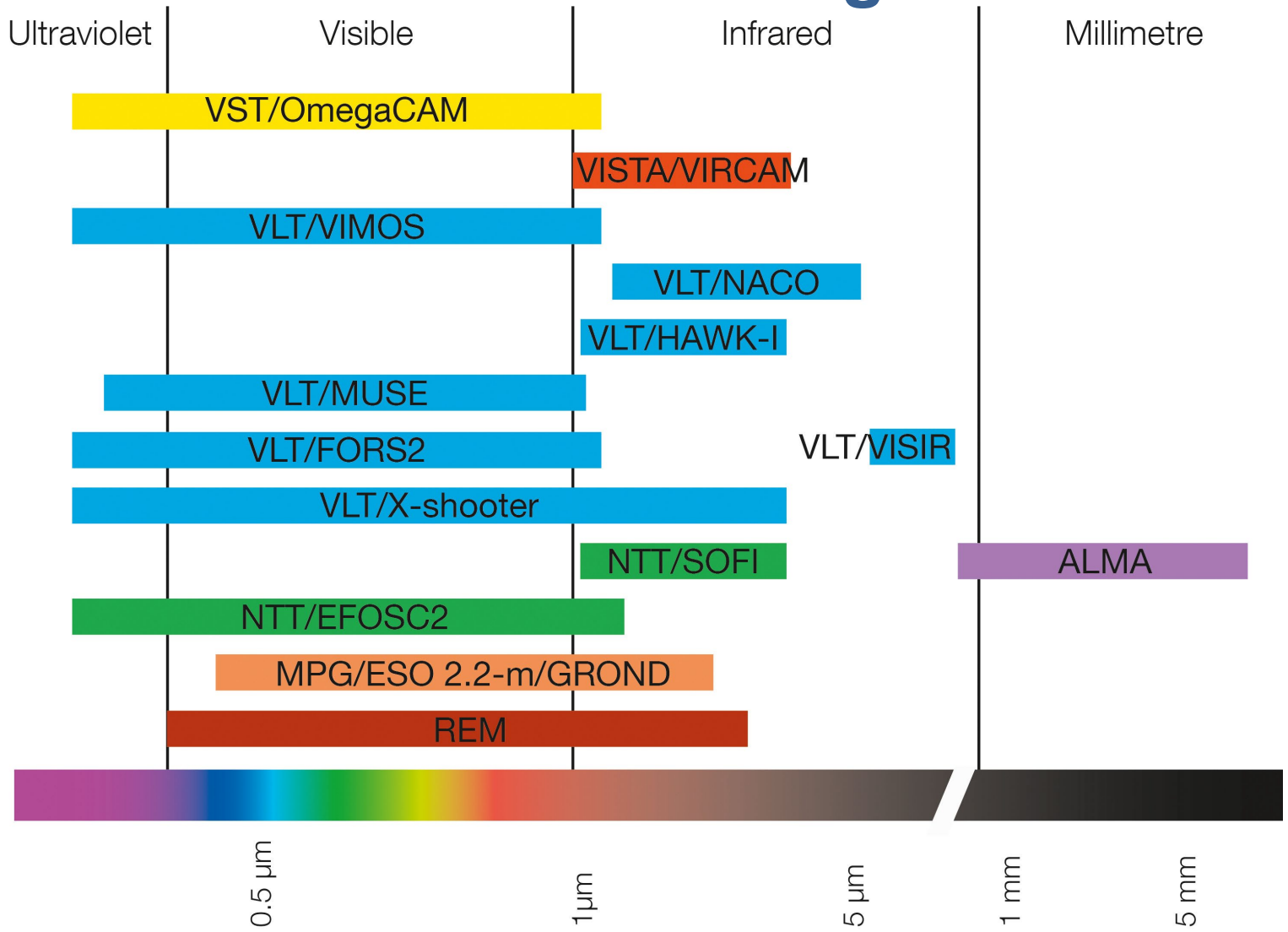
Further follow-up with ToOs & time-linked OBs



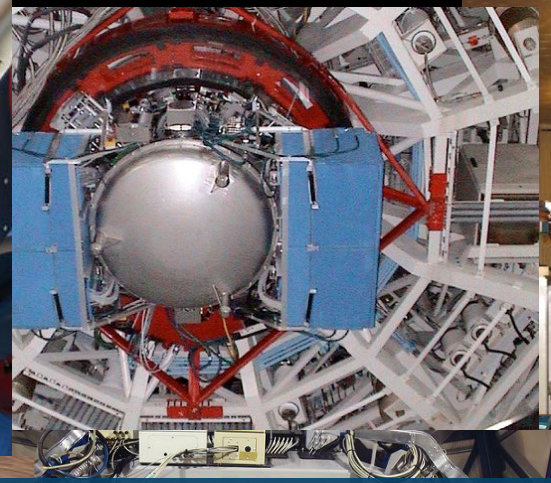
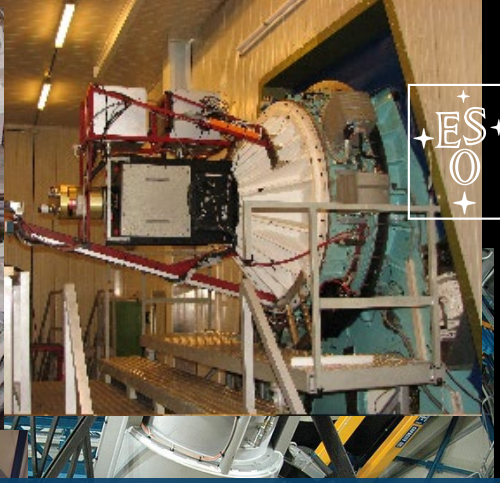
ESO's role in the observations of the optical counterpart of GW170817

- Efficient and flexible scheduling of observations: rapid follow-up of transients
- Complementary suite of telescopes and instruments
- Curated data archives

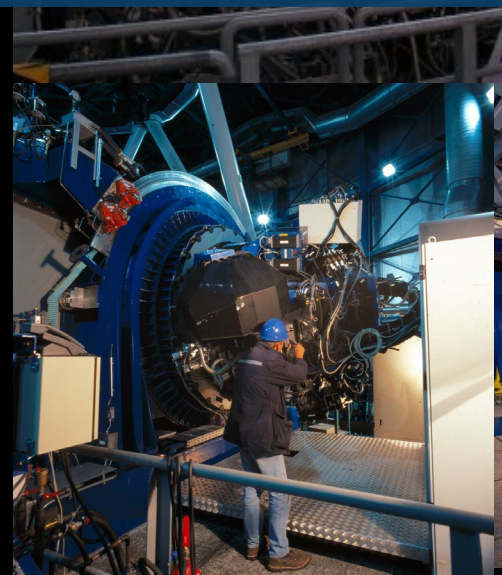
Simultaneous ESO observations of GW170817 at different wavelengths



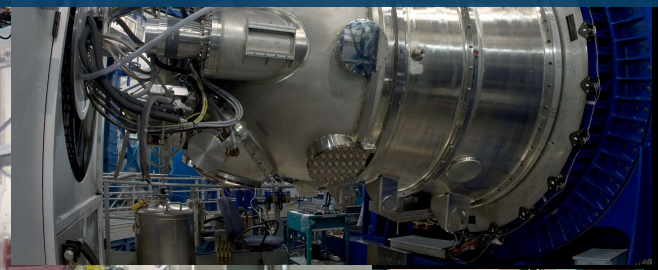


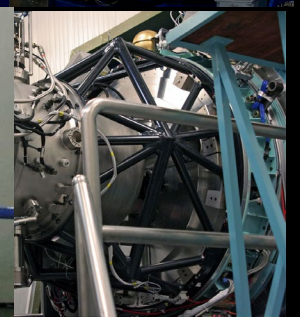



More than 5,000 scientific images and spectra
More than 115h of observations
14 instruments
7 telescopes

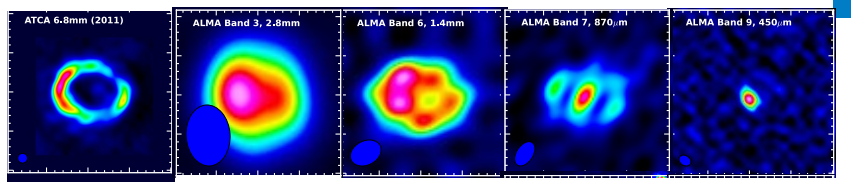








Long-Term Monitoring Programs



Indebetouw et al. 2014

SN 1987A

- ALMA and VLT observations since start of operations

QSO monitoring for H_0

LMC variables

- VISTA Magellanic Cloud Survey (VMC)

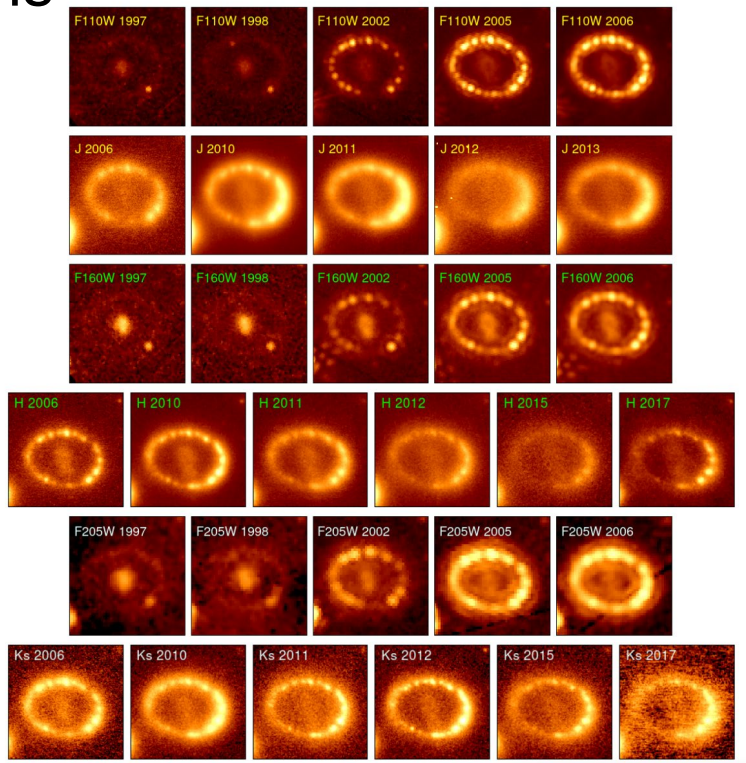
Araucaria project

VISTA Variables in the Via Lactea (VVV)

Galactic plane

Public Spectroscopic Surveys

- PESSTO, PESSTO+, ePESSTO+
  - 90 nights per year for spectroscopic SN follow-up
  - concentrate on peculiar and rare types of supernovae



Kangas et al. 2023

Data Curation/Archives

Increasing importance of data products

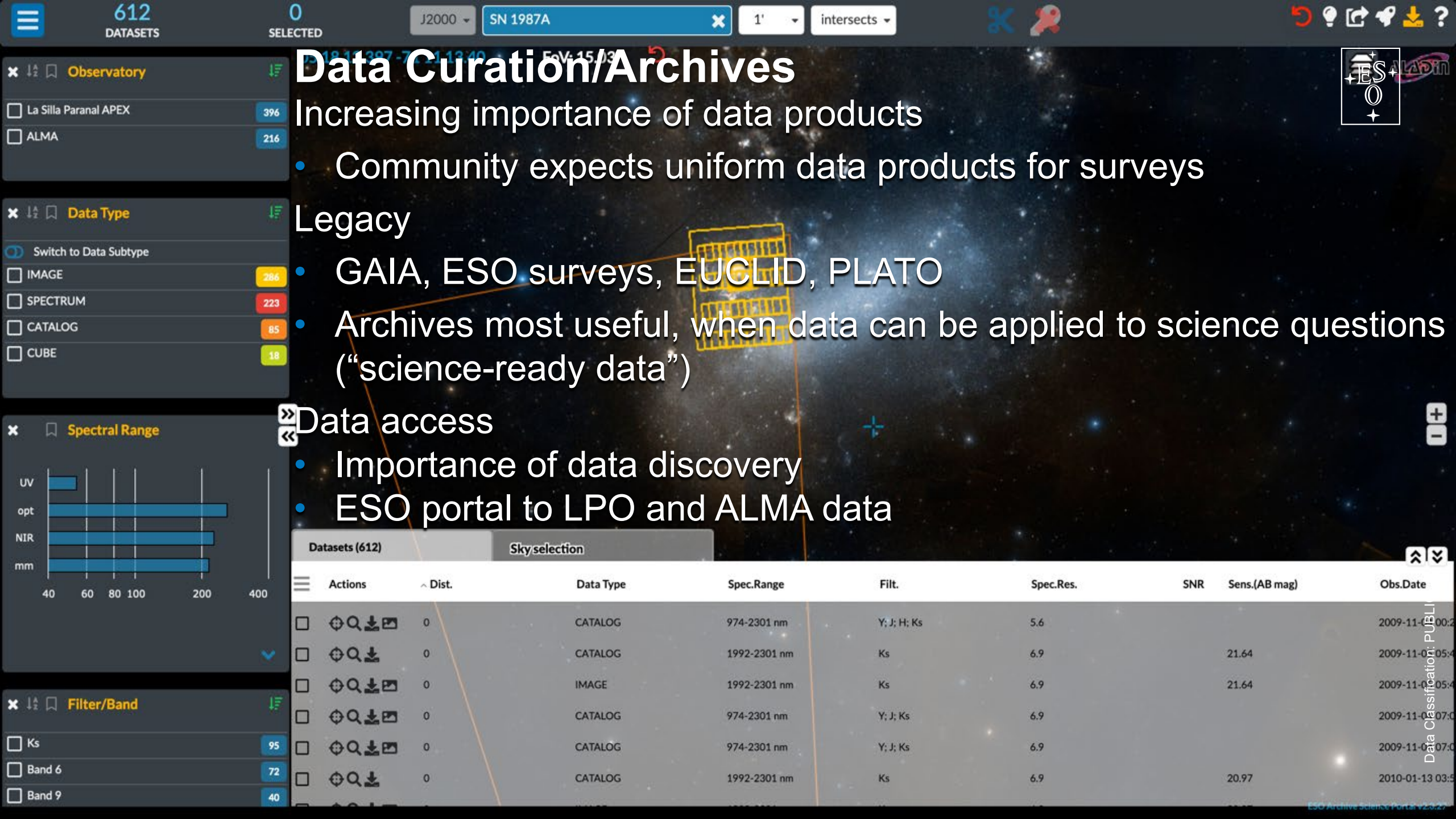
- Community expects uniform data products for surveys

Legacy

- GAIA, ESO surveys, EUCLID, PLATO
- Archives most useful, when data can be applied to science questions (“science-ready data”)

Data access

- Importance of data discovery
- ESO portal to LPO and ALMA data



Coordinated Observations

Example: gravitational wave events

- Coordinated observing run with the GW observatories science runs
- ESO community organisation
  - single VLT proposal → ENGRAVE

Example: transients/supernovae

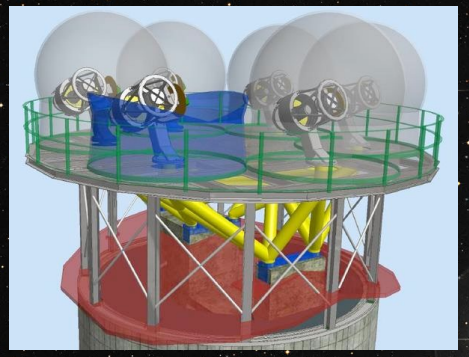
- Community organized itself
  - PESSTO → ePESSTO → PESSTO+ → ePESSTO+
  - Transient brokers → session tomorrow morning
  - Supernova Early Warning Systems (SNEWS) – neutrino detection follow-up
  - X-ray community – coordinated XMM+VLT/I proposals

Optical/Infrared Telescopes in the Multi-Messenger Era

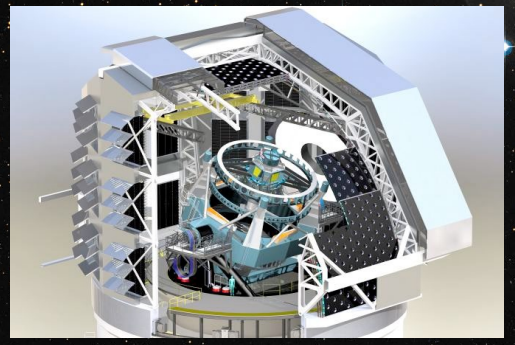
Alerts from many different sources: gravitational waves, neutrinos, electromagnetic searches

FoV: 10-30°

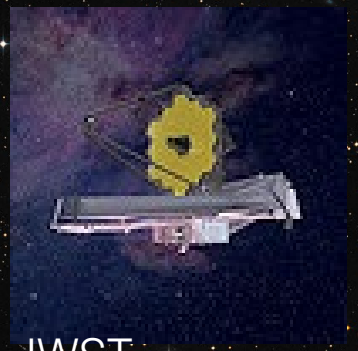
BlackGEM



LSST



JWST



Relatively Bright Objects

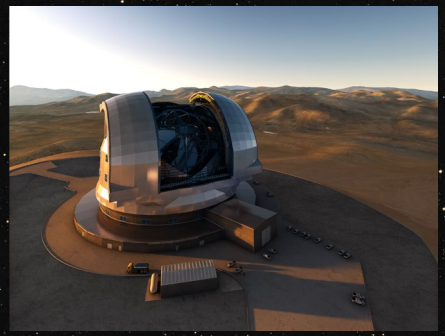
NTT

Faint objects

VLT

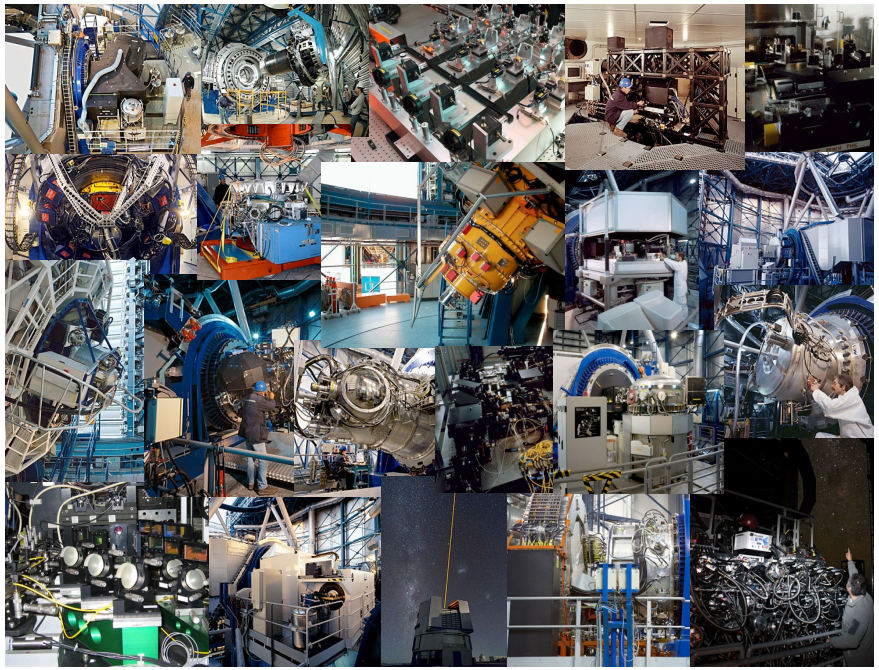
Very faint objects

ELT



Based on ideas by Steven Smartt

ESO Opportunities



Flexibility

- large instrumentation complement

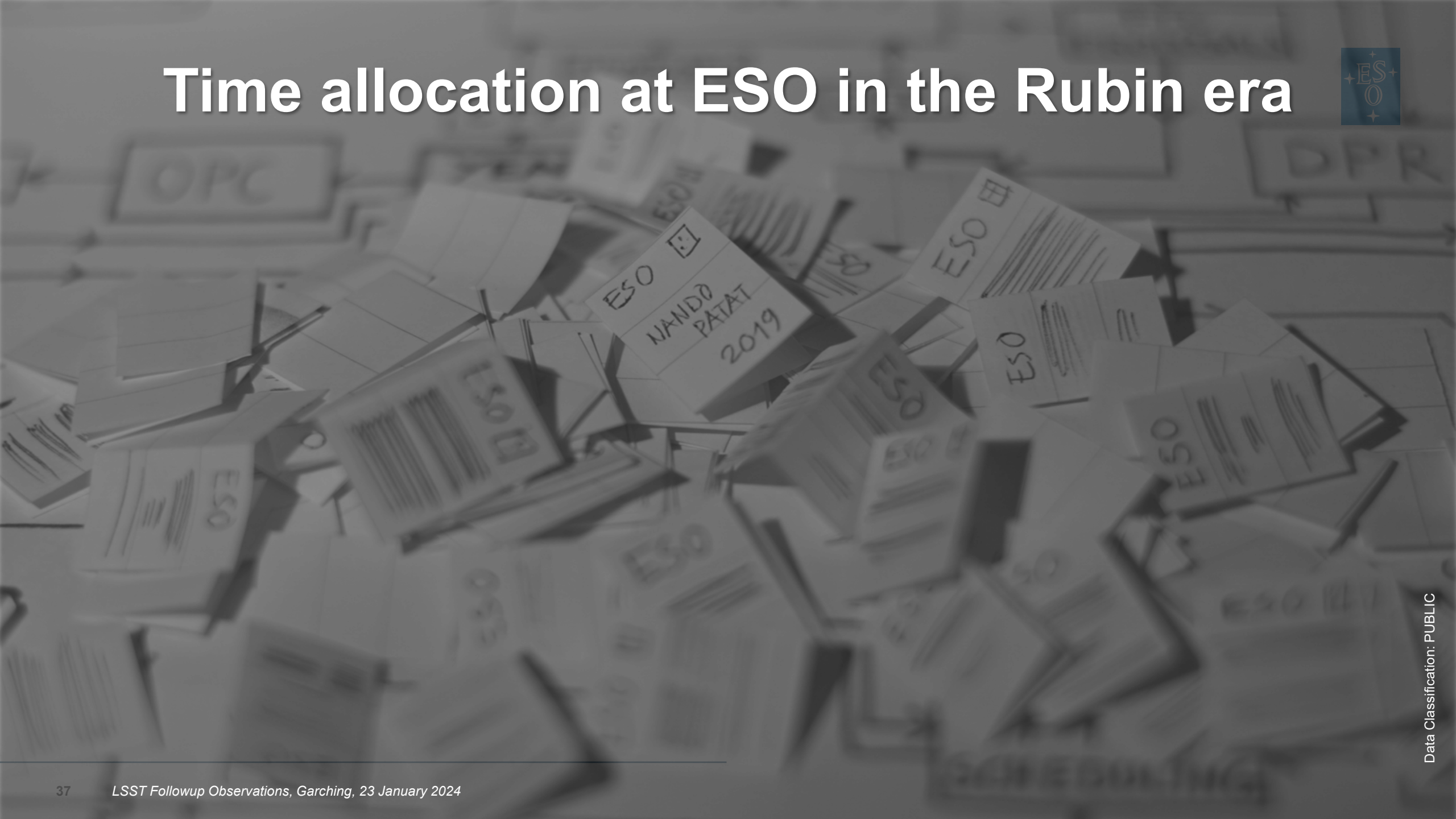
Uniqueness

- explore special features of our observatories
  - e.g. interferometry (VLTI)
- provide unique capabilities for simultaneous coverage of large wavelength ranges
  - e.g. observations of Comet Shoemaker-Levy 9 or Hale-Bopp, AT2019gfo/GW170817

Complementarity

- spectral follow-up of imaging surveys
- monitoring of special objects

Time allocation at ESO in the Rubin era

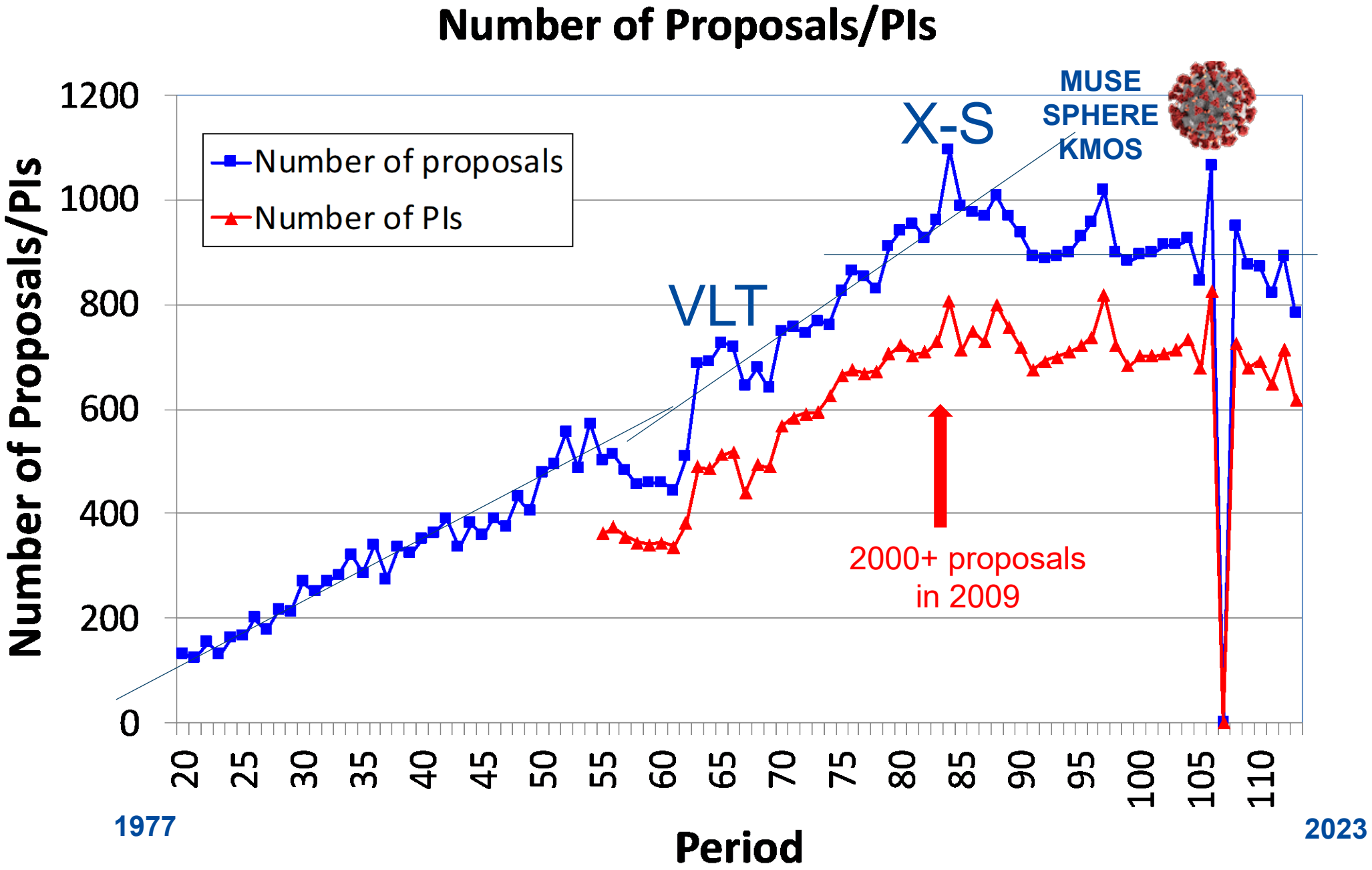


Call for Proposals and Proposal Review

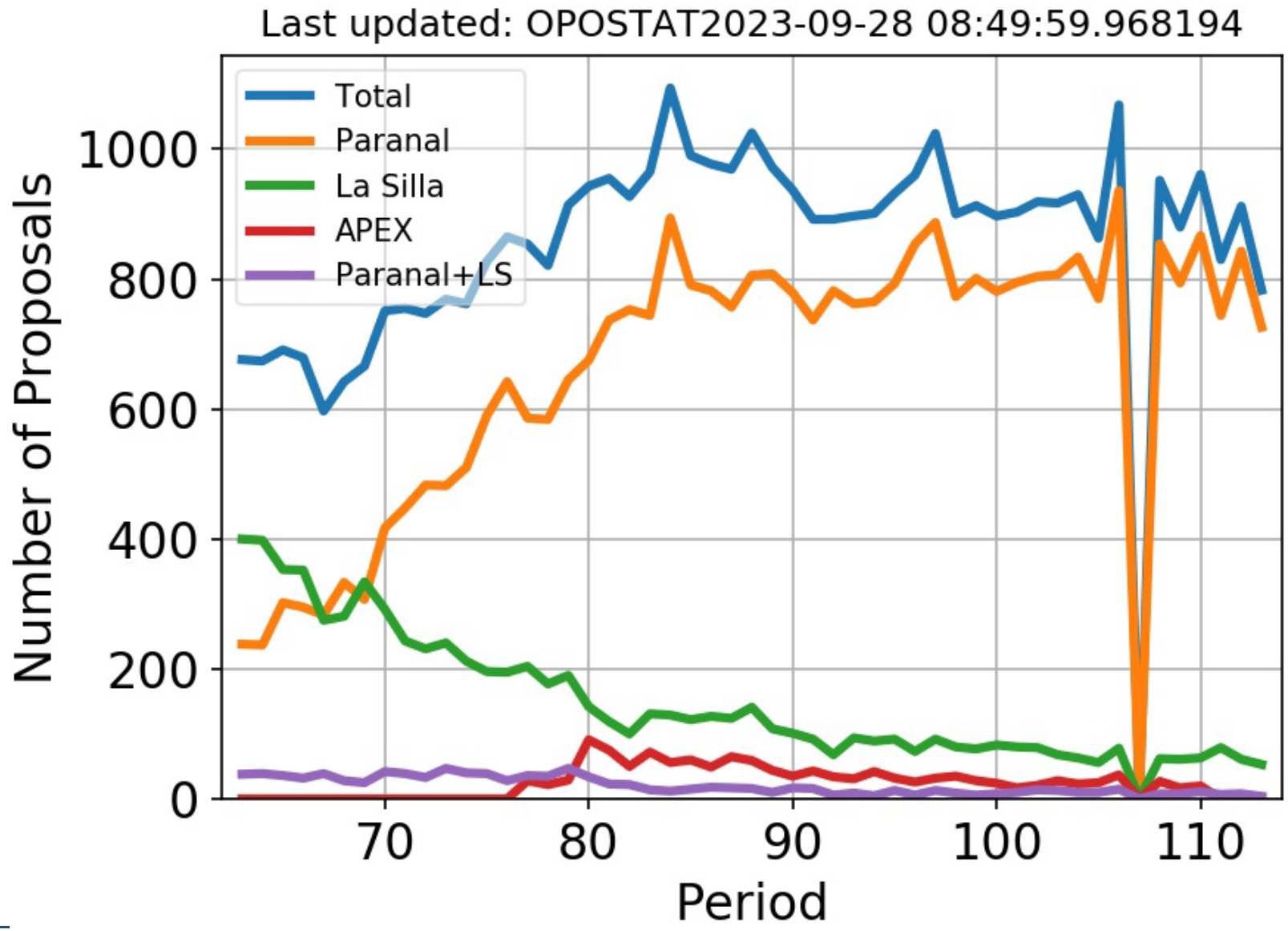
- ESO currently calls twice per year, in March and in September
- We receive and process ~1800 proposal per year (VLT/VLTI/3p6/NTT)
- As of P110 we have two review channels:
  - **Panels** for requested time > 16 hours (plus ToO, Joint and other special cases)
  - **Distributed Peer Review** (DPR) for requested time ≤ 16 hours
- The current fractions are 50/50 (number of proposals) and 85/15 (requested time)
- The fraction may change in future years, also depending on the evolution which will follow the start of ELT operations

Setting the stage

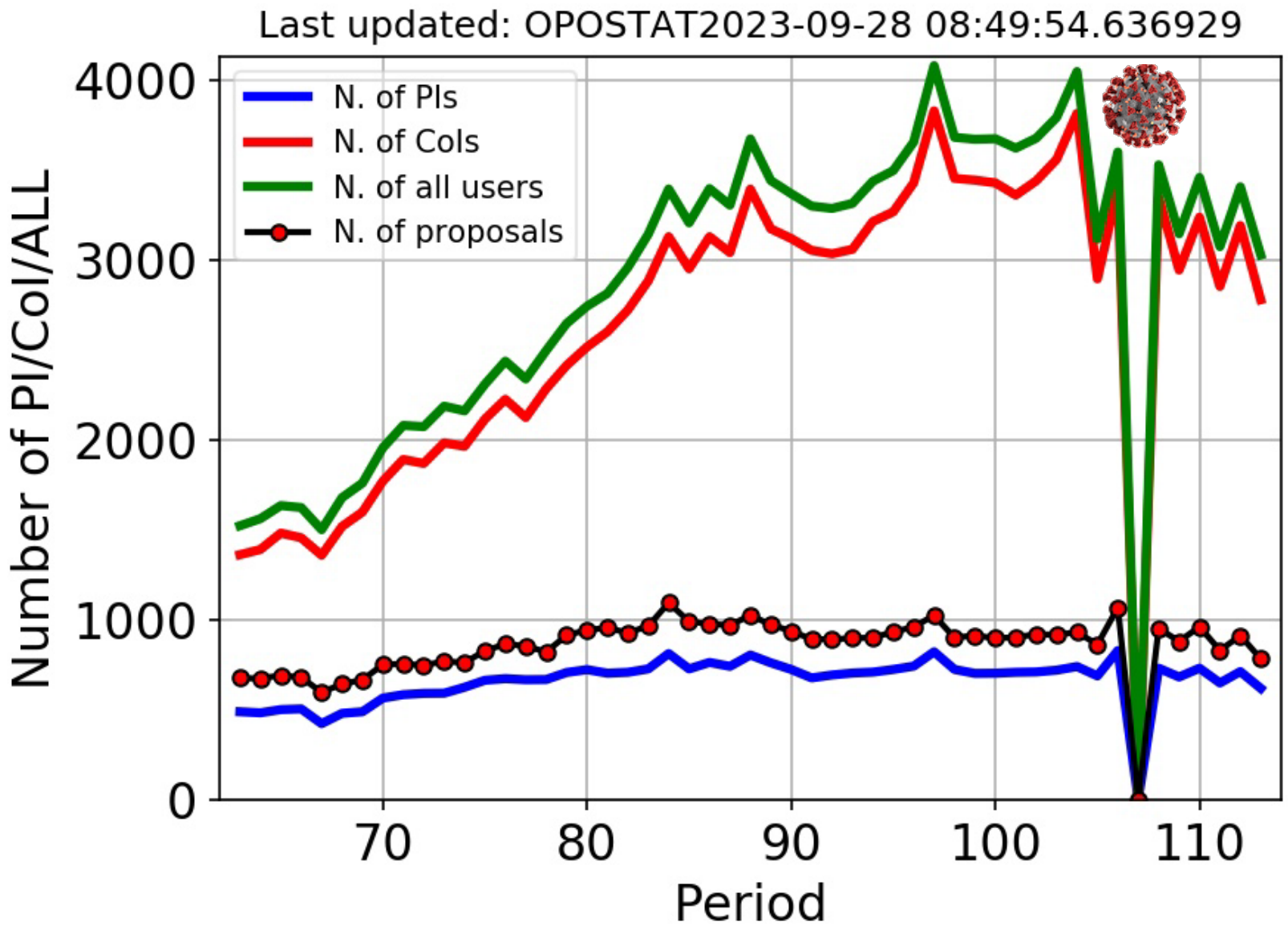
- ESO receives ~900 proposals/period
- ~700 distinct PIs
- ~3500 distinct co-Is from ~50 countries (IAU members ~10,000)
- The request is ~3200 nights/semester
- The available science time is ~1070 nights/semester
- A fraction (up to 15%) goes to **G**uaranteed **T**ime **O**bservations (GTO)

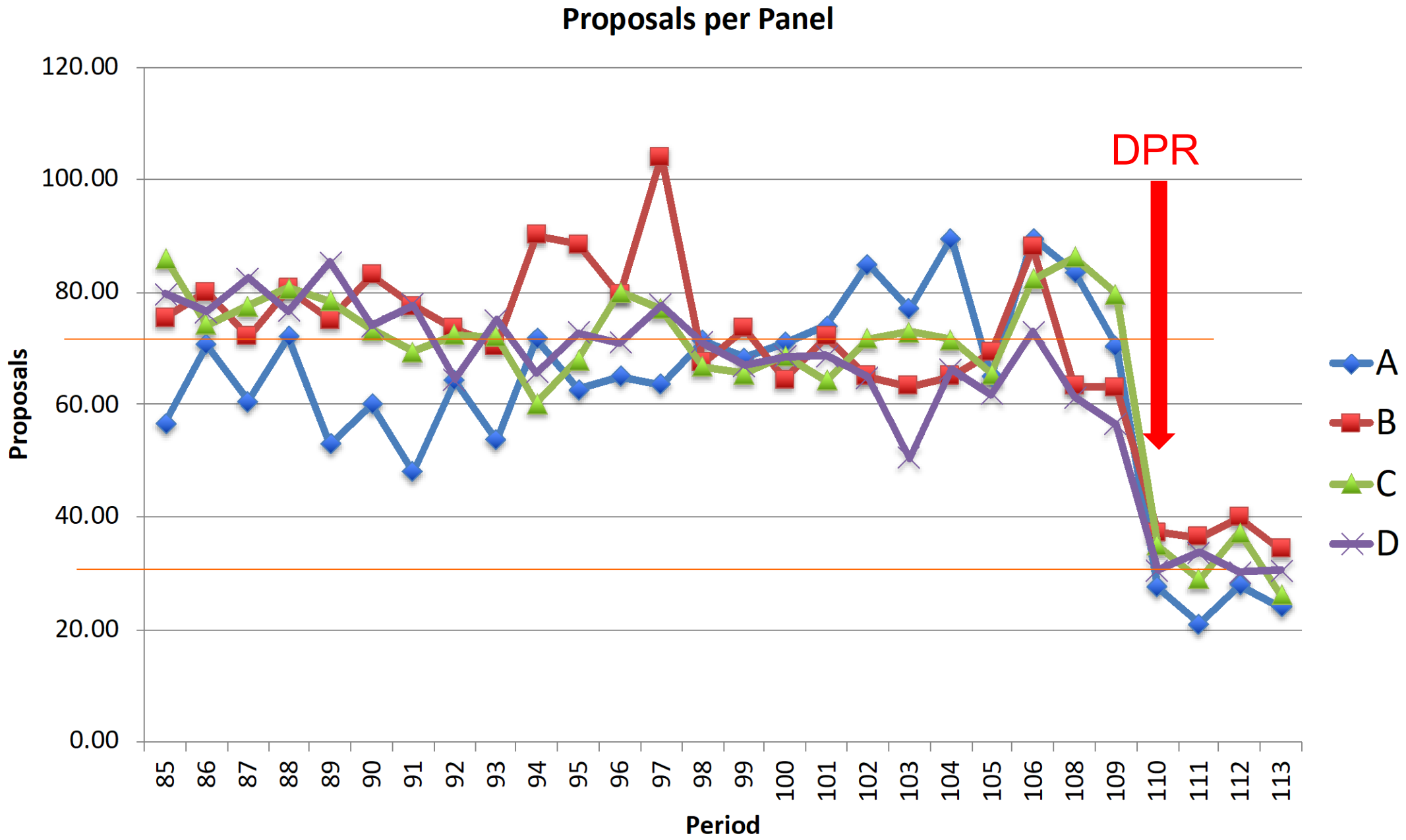


Number of proposals per site



Number of distinct PI/CoI/ALL





Programme Types

- **Normal programmes** (one semester, up to 100 hours)
- **Monitoring programmes** (up to 4 semesters, up to 100 hours)
- **Joint programmes XMM, ALMA** (one semester, with total time limitations)
- **Large programmes** (up to 4 semesters, more than 100 hours)
- **Director General Discretionary Time (DDT):** continuous submission
- All these programme types can include **Target of Opportunity** (ToO Hard/Soft) or **Rapid Response Mode** (RRM) runs
- **Surveys** (irregular calls, large allocations, running for up to 5 years). More below.
- Calibration programmes

Target of Opportunity flavours

- **ToO-Soft**: manual trigger, >48 hours before execution, ±1 day flexibility
- **ToO-Hard**: manual trigger, asap and <48 hours before execution or at specific times
- **Rapid Response Mode**: automated trigger, <4 hours before execution
- In the past there was a maximum 5% limit for ToO allocation. This limit has been removed in the current VLT/I Science Policy document.
- In practice, this limit was never reached. The typical ToO allocation at the VLT is ~3%, of which 30-50% is eventually triggered, bringing down the effective fraction of executed ToO to ~1%.
- ToO is scheduled at the VLT only if it qualifies for the A-rank class.
- In the Rubin-era this triggering fraction is expected to grow significantly.

Upcoming changes

- Move to **Yearly Calls** (YC) – probably in 2025
- Introduction of the **Fast Track Channel** (FTC) to compensate increase in the duty-cycle
  - Staggered deadlines (bimonthly?)
  - DPR-reviewed
  - Duty-cycle: 4/6 weeks
  - To cover new/important cases
- Redefinition of the DDT (transients only)

The extraordinary meeting of the Space Advisory Council was brief and stormy. Even in the twenty-second century, no way had yet been discovered of keeping elderly and conservative scientists from occupying crucial administrative positions. Indeed, it was doubted if the problem ever would be solved.

To make matters worse, the current Chairman of the

The extraordinary meeting of the Space Advisory Council was brief and stormy. Even in the twenty-second century, no way had yet been discovered of keeping elderly and conservative scientists from occupying crucial administrative positions. Indeed, it was doubted if the problem ever would be solved.

To make matters worse, the current Chairman

launched to prove one of his pet theories had done precisely the opposite.

Future changes

Recommendation 8 – Introduction of a high-risk channel for the submission of high-risk/high-gain projects requiring significant amounts of time.

ESO should consider introducing a high-risk channel (HRC), for the submission of very un-orthodox projects requiring significant amounts of time that no TAC would ever approve. The HRC should be allocated by a special, external committee (not necessarily composed by astronomers only) reporting directly to the DG, but should be kept separated from the DDT Committee. Only requests of large amounts of time for very risky, potentially highly rewarding proposals should be considered for this channel.

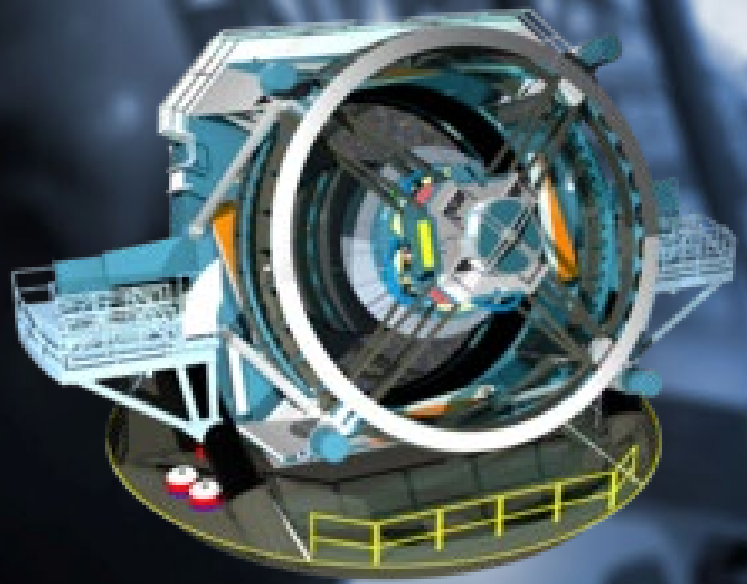
Public Surveys

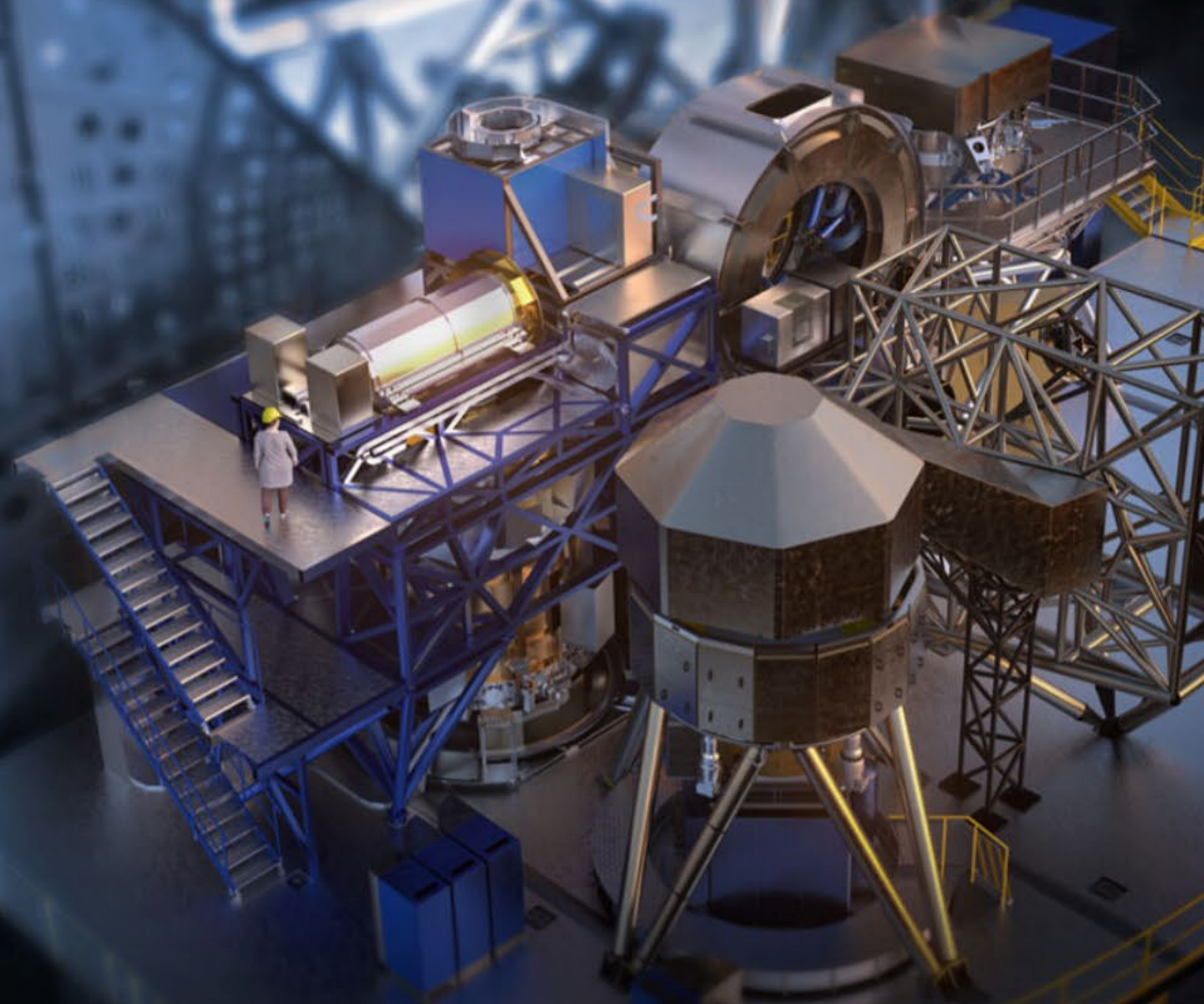
- Rare, called for [very] specific cases
- ESO issues a Call for Letters of Intent (LOIs)
- The community responds with the LOIs
- ESO contacts the potential PIs and calls for Survey Proposals
- The proposal are reviewed by the Public Surveys Panel (PSP)
- The PSP makes a recommendation to the Observing Programmes Committee
- A final recommendation is submitted to the Director General
- The successful surveys are asked to prepare a Survey Management Plan
- More details here.

ELT first light: 2028

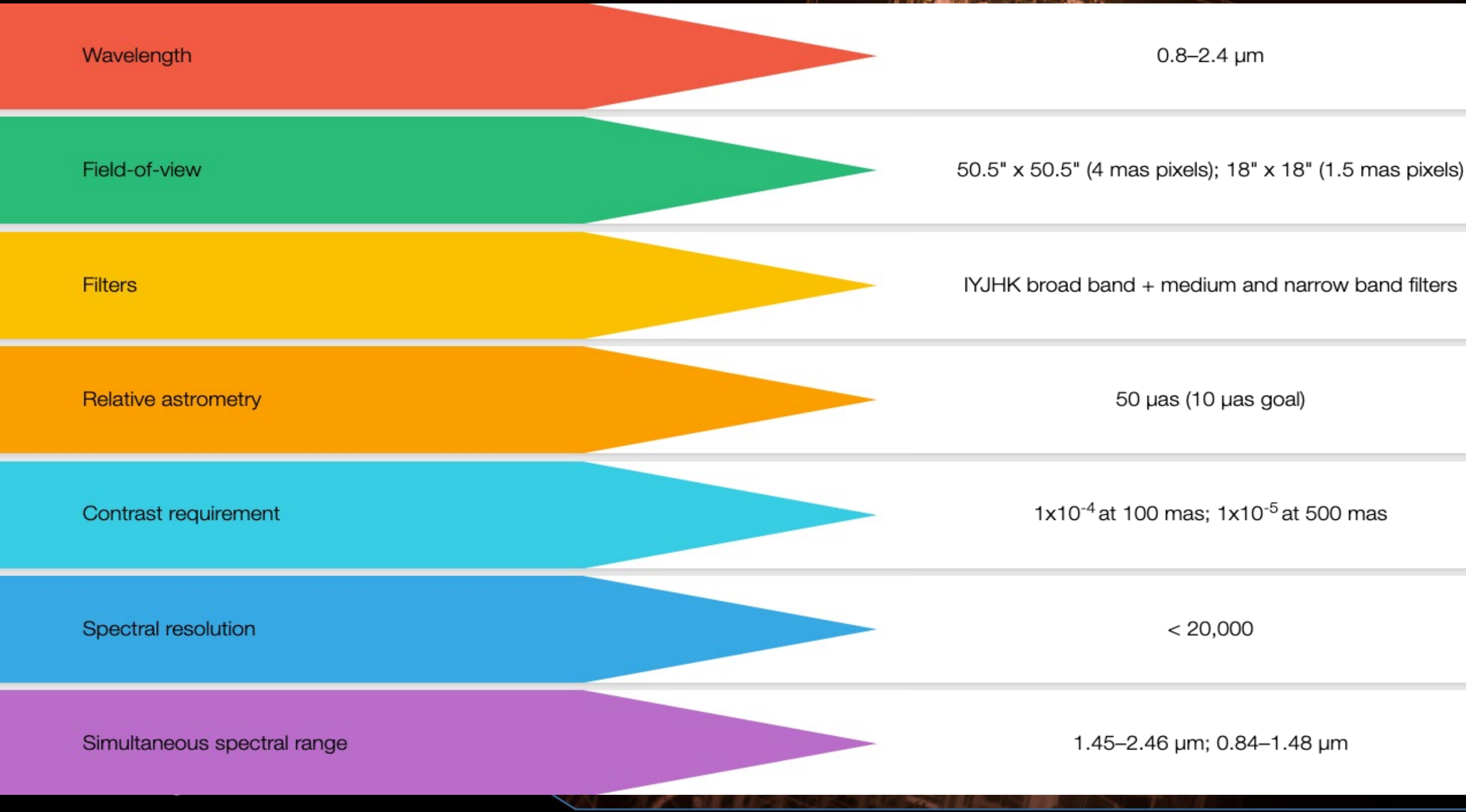
European Southern Observatory

The Extremely Large Telescope





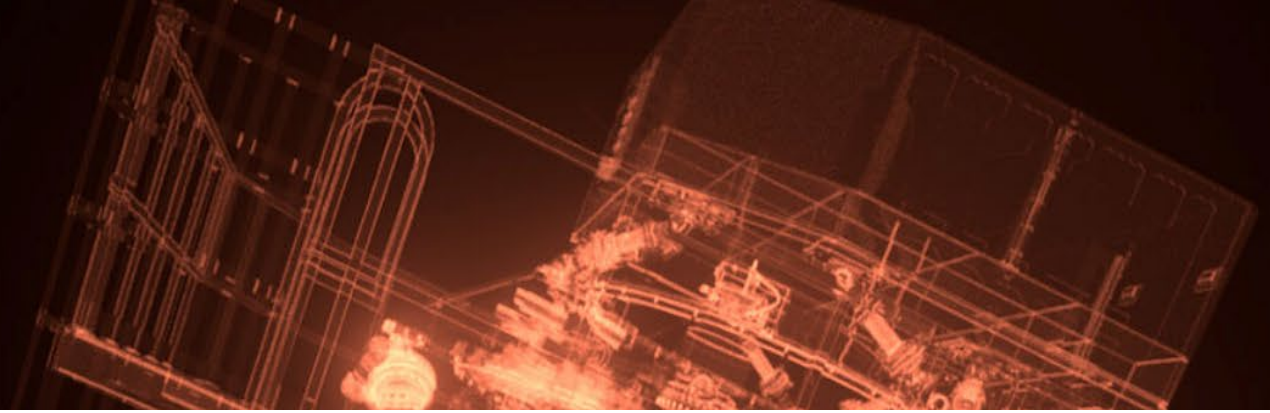
Instruments Overview


Wavelength
0.8–2.4 µm
Field-of-view
50.5" x 50.5" (4 mas pixels); 18" x 18" (1.5 mas pixels)
Filters
IYJHK broad band + medium and narrow band filters
Relative astrometry
50 µas (10 µas goal)
Contrast requirement
1x10-4 at 100 mas; 1x10-5 at 500 mas
Spectral resolution
< 20,000
Simultaneous spectral range
1.45–2.46 µm; 0.84–1.48 µm

Scale (mas)	Field of View	Comments
60x30	9.1”x6.1”	For non-AO visible observations
20x20	3.0”x4.1”	For optimal sensitivity (faint targets)
10x10	1.5”x2.1”	Best combination sensitivity/spatial resolution
4x4	0.6”x0.8”	Highest spatial resolution (diffraction limited)

Wavelength	0.47 – 1.80 μm (baseline)
Spectral resolution	5,000 – 20,000
Field-of-view	40 square arcmin
High Multiplex Mode	200 in VIS and 80+80 in NIR (baseline)
High Definition Mode	8 (baseline)

MOSAIC



Wavelength coverage	3 – 13 μm (imaging); the imager includes low-resolution slit spectroscopy and coronography 3 – 5 μm IFU spectroscopy
Spectral resolution	Low-resolution, long-slit R~400 (N-band), R~1500 (L-band), R~1900 (M-band) High-resolution, IFU R~100,000 (L,M bands)
Field-of-view	~10'' (imager), <1'' (high resolution IFU spectroscopy)
AO	all observing modes work at the diffraction limit with a single conjugate AO system

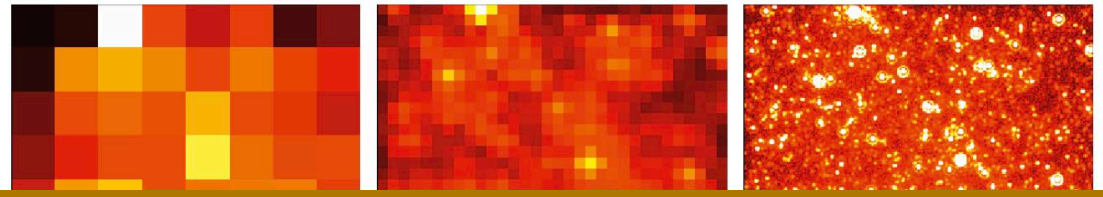
METIS

Instrument	Main specifications			Schedule				
	Field of view/slit length/ pixel scale	Spectral resolution	Wavelength coverage (μm)	Phase A	Project start	PDR	FDR	First light
MICADO	Imager (with coronagraph) 50.5″ × 50.5″ at 4 mas/pix 19″ × 19″ at 1.5 mas/pix	*I*, *Z*, *Y*, *J*, *H*, *K* + narrowbands	0.8–2.45	2010	2015	2019 2023	2028?	
	Single slit	*R* ~ 20 000						
MORFEO	AO Module SCAO – MCAO		0.8–2.45	2010	2015	2023		
HARMONI + LTAO	IFU 4 spaxel scales from: 0.8″ × 0.6″ at 4 mas/pix to 6.1″ × 9.1″ at 30 × 60 mas/pix (with coronagraph)	*R* ~ 3 200 *R* ~ 7 100 *R* ~ 17 000	0.47–2.45	2010	2015	2018		
METIS	Imager (with coronagraph) 10.5″ × 10.5″ at 5 mas/pix in *L*, *M* 13.5″ × 13.5″ at 7 mas/pix in *N*	*L*, *M*, *N* + narrowbands	3–13	2010	2015	2019		
	Single slit	*R* ~ 1400 in *L* *R* ~ 1900 in *M* *R* ~ 400 in *N*						
	IFU 0.6″ × 0.9″ at 8 mas/pix (with coronagraph)	*L*, *M* bands *R* ~ 100 000						
ANDES	Single object	*R* ~ 100 000	0.4–1.8 simultaneously	2018				
	IFU (SCAO)							
	Multi object (TBC)	*R* ~ 10 000						
MOSAIC	~ 7-arcminute FoV ~ 200 objects (TBC)	*R* ~ 5 000–20 000	0.45–1.8 (TBC)	2018				
	~ 8 IFUs (TBC)	*R* ~ 5 000–20 000	0.8–1.8 (TBC)					
PCS	Extreme AO camera and spectrograph	TBC	TBC					

1 milliarcsecond (mas) = 0.001″

Diffraction limit resolution: 4-12 mas

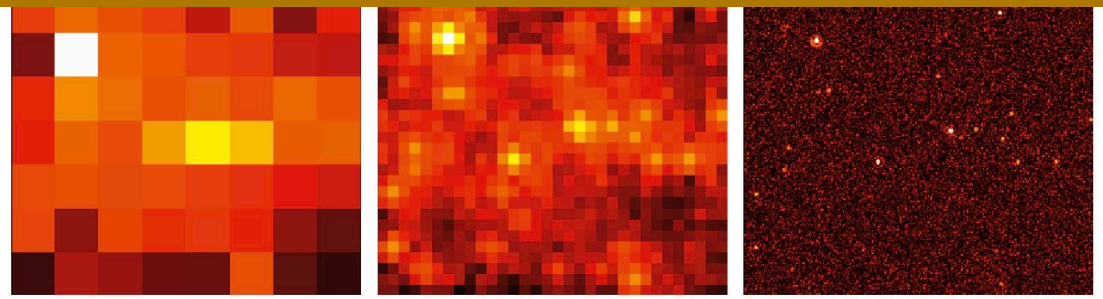
HST/WFC3 JWST/NIRCam ELT/MICADO



μ = 19.6

Imaging (MICADO + AO)	**R=3100** HARMONI+ AO 10mas spaxels	**R=7000** HARMONI + AO 10mas spaxels	**R= 17000** HARMONI + AO 10mas spaxels
$H_{AB} = 29.5$	$H_{AB} = 27.2$	$H_{AB} = 26.4$	$H_{AB} = 25.3$

5-sigma, 5 hours integration time



μ = 25.2

(10^4 stars arcsecond^{-2})

Davies et al (2021)

ELT (and ESO) Ready to respond

- Target of Opportunity and Rapid Reponse Mode planned
- 1-3 minutes telescope slew for the same instrument
- ~5 minutes for instruments within the same platform
- ~15 minutes for swapping platform
- Complexity added by the need for properly preparing the Observing Blocks (telescope guide star, AO star)

ESO – an integrated system

ALMA and ELT: flagship facilities

VLT: unique capabilities

- Interferometry → VLTI
- Large instrument complement, adaptive optics, flexibility, modern operations model

La Silla/4m telescopes: dedicated to

- Transients: NTT; SOXS
- Exo-planets: 3.6m; HARPS/NIRPS
- Multi-object spectroscopy: 4MOST@VISTA

Platform for smaller experiments: La Silla

ESO and ALMA Archives

- Rich resources of optical/NIR and sub-mm data
- Large coherent data sets from surveys
- Advanced data products

A true astronomy science park

Cerro Armazones
ELT

Cherenkov Telescope Array Site

Cerro Paranal
Very Large Telescope

Thank you!

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