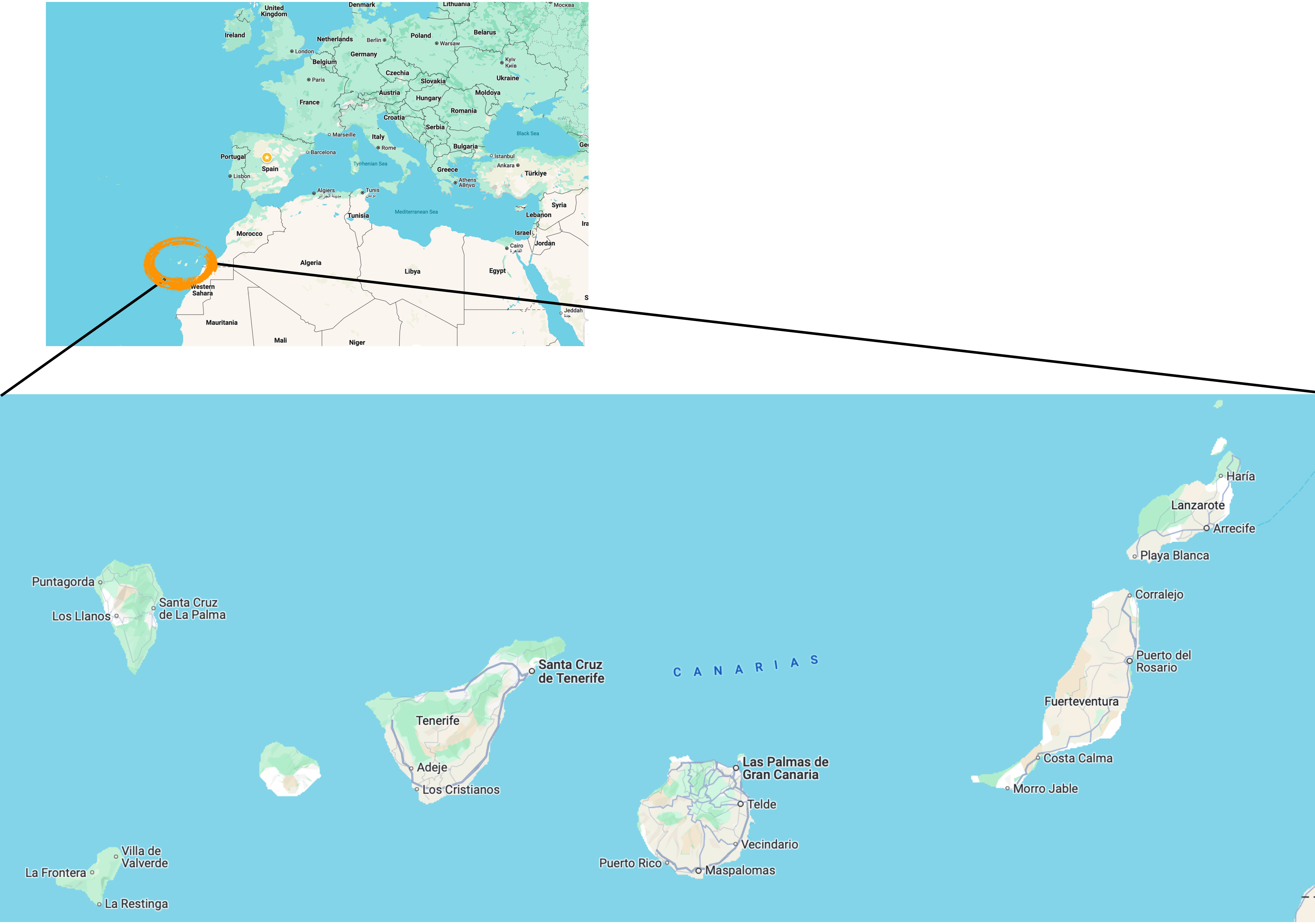
Gran Telescopio CANARIAS (GTC)

Josefa Becerra González
Instituto de Astrofísica de Canarias (Spain)
Thanks to Antonio Cabrera (GTC Head of Science Operations)


Canary Islands (Spain)
Denmark
Lithuania
Москва
United Kingdom
Ireland
Netherlands
Berlin
Poland
Warsaw
Belarus
London
Germany
Belgium
Kyiv
Київ
Czechia
Paris
Slovakia
Ukraine
Austria
Moldova
Hungary
France
Romania
Croatia
Serbia
Black Sea
Marseille
Italy
Rome
Bulgaria
Barcelona
Portugal
İstanbul
Tyrrhenian Sea
Ankara
Spain
Greece
Türkiye
Lisbon
Athens
Αθήνα
Algiers
مدينة الجزائر
Tunis
تونس
Syria
Tunisia
Mediterranean Sea
Lebanon
Morocco
Israel
Jordan
Cairo
القاهرة
Algeria
Libya
Egypt
Western Sahara
Jeddah
جدة
Mauritania
Mali
Niger



United Kingdom
Ireland
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Czechia
Slovakia
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Moldova
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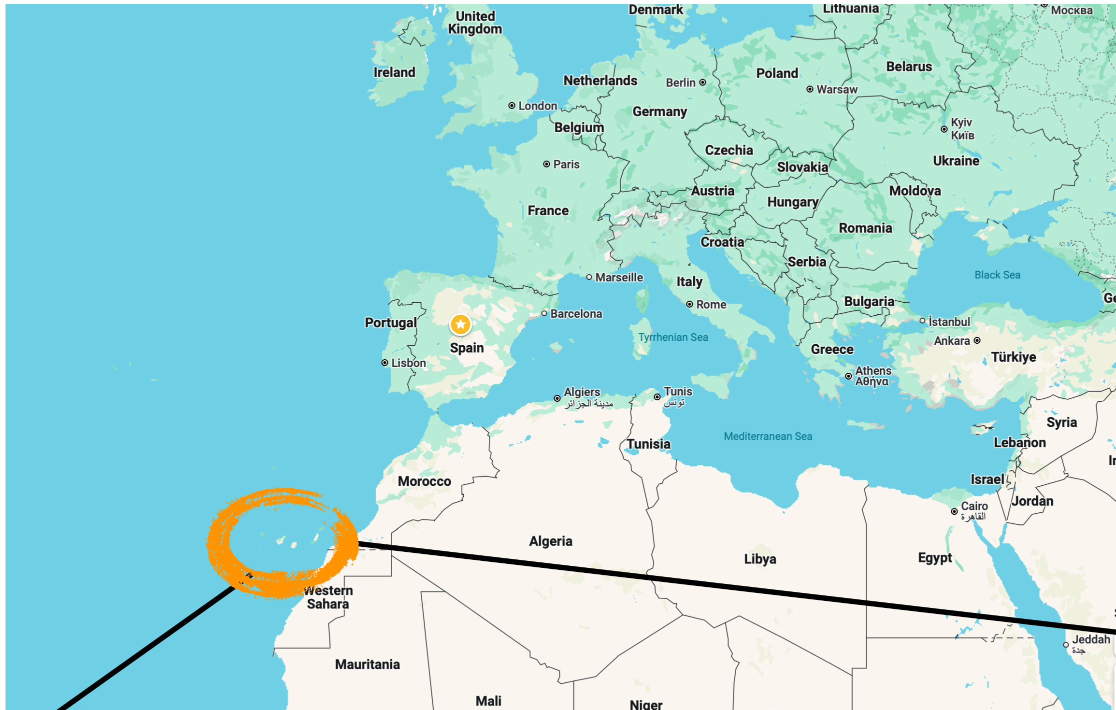
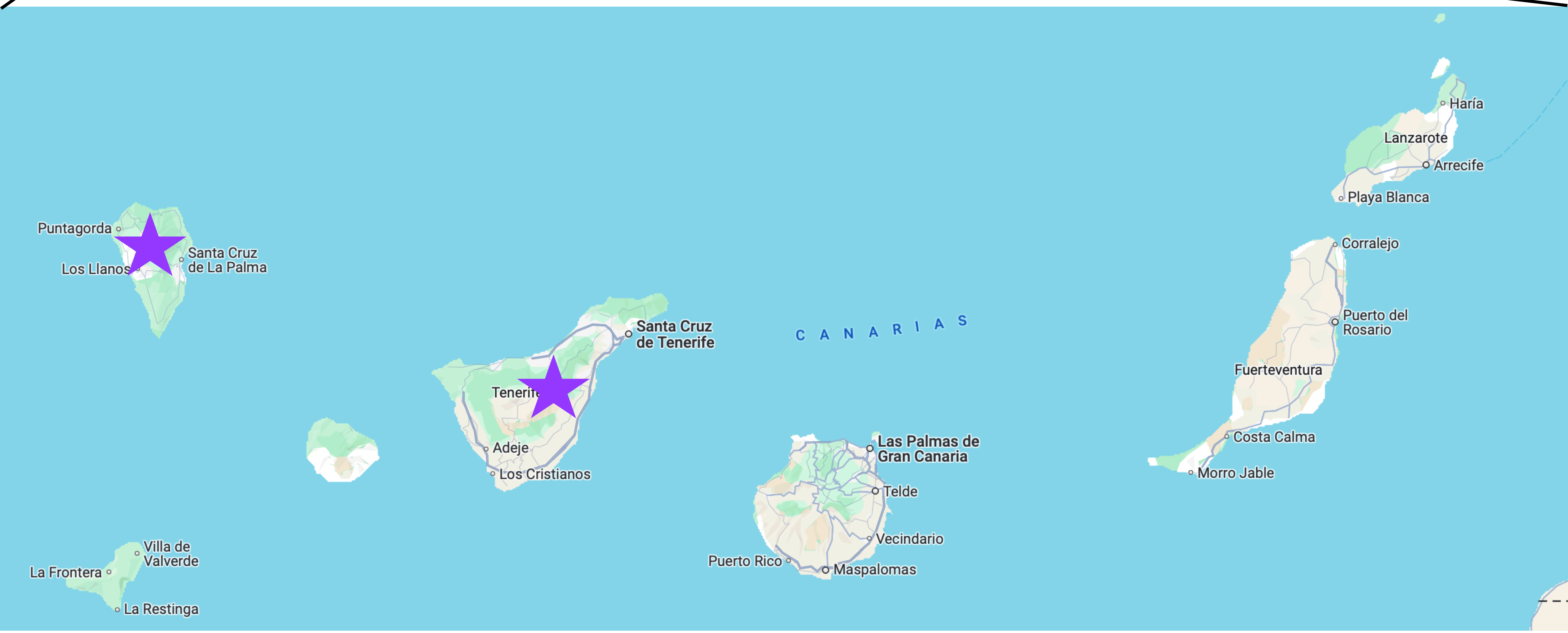
France
Romania
Croatia
Serbia
Black Sea
Marseille
Italy
Bulgaria
Portugal
Barcelona
Rome
Istanbul
Spain
Tyrrhenian Sea
Ankara
Lisbon
Greece
Türkiye
Athens
Algiers
Tunis
Tunisia
Mediterranean Sea
Syria
Lebanon
Morocco
Israel
Cairo
Jordan
Algeria
Libya
Egypt
Western Sahara
Jeddah
Mauritania
Mali
Niger
Haría
Lanzarote
Arrecife
Playa Blanca
Puntagorda
Santa Cruz de La Palma
Los Llanos
Corralejo
Santa Cruz de Tenerife
C A N A R I A S
Puerto del Rosario
Fuerteventura
Tenerife
Las Palmas de Gran Canaria
Costa Calma
Adeje
Morro Jable
Los Cristianos
Telde
Vecindario
Villa de Valverde
La Frontera
Puerto Rico
Maspalomas
La Restinga

Two observatories at **Canary Islands** (Spain):

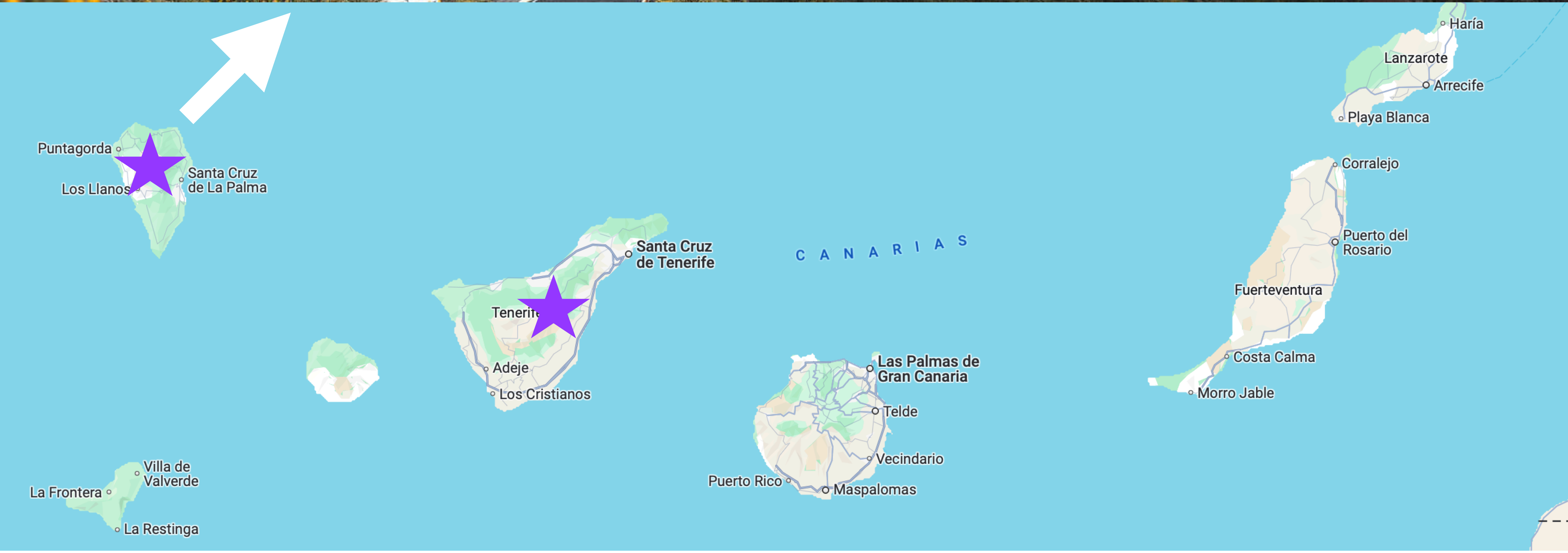
- **Teide Observatory** (Tenerife); 2390 m a.s.l.
- **Roque de Los Muchachos Observatory** (La Palma)

2396 m a.s.l.





Roque de los Muchachos Observatory (La Palma)



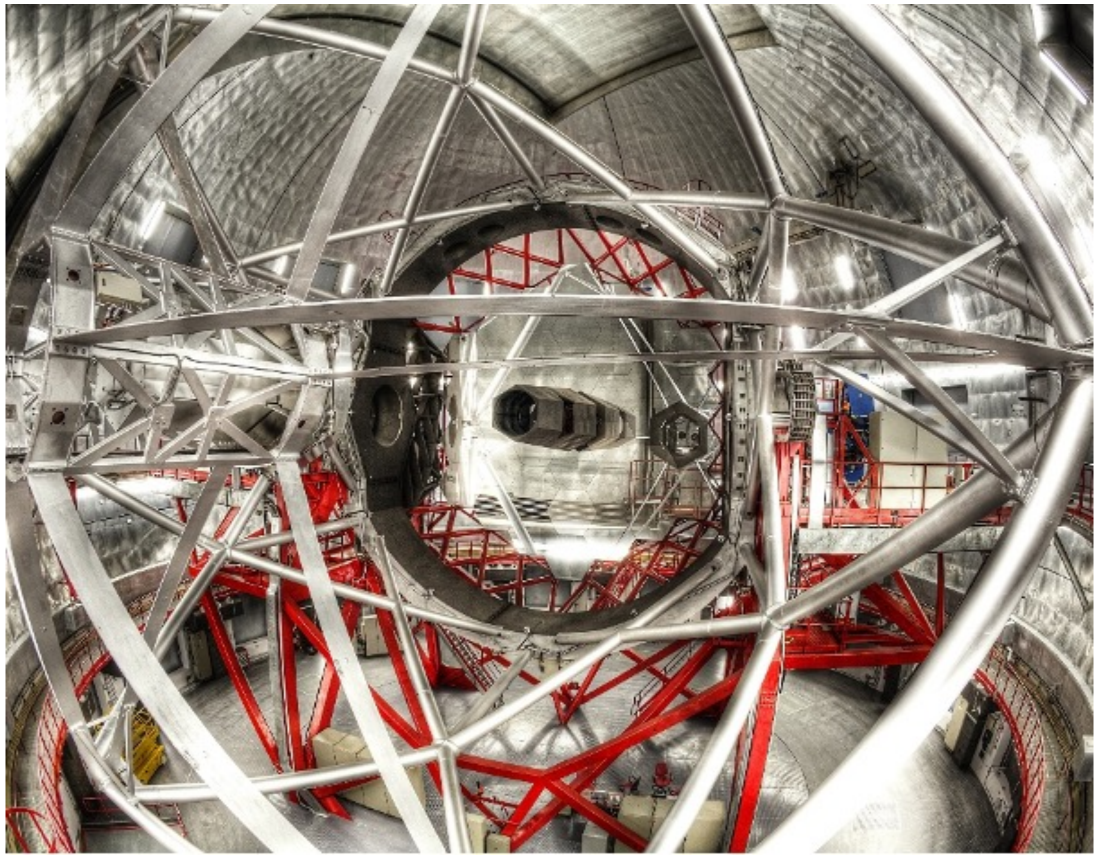
Gran Telescopio Canarias (GTC)

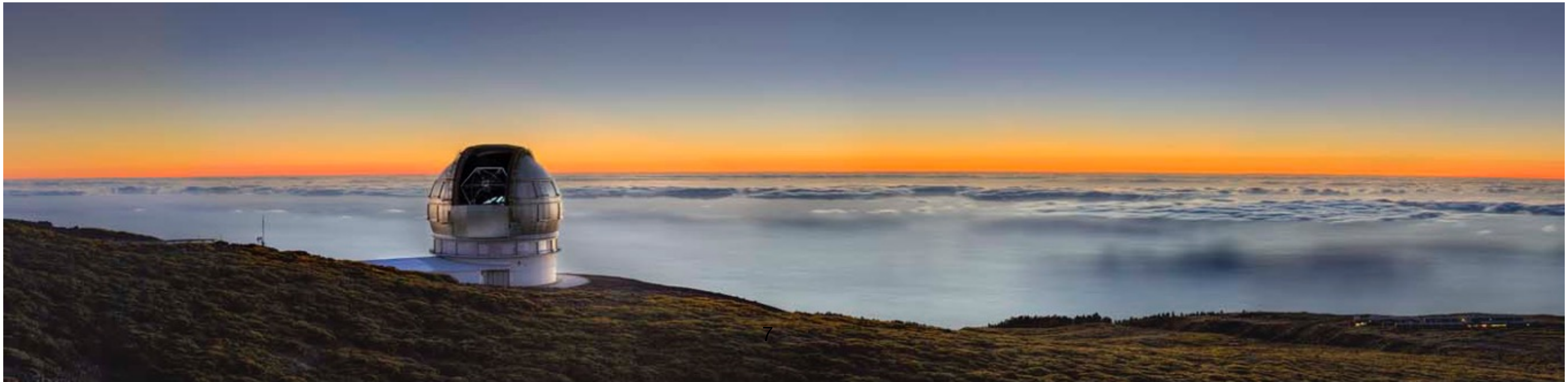
10.4 m Optical and Infrared telescope

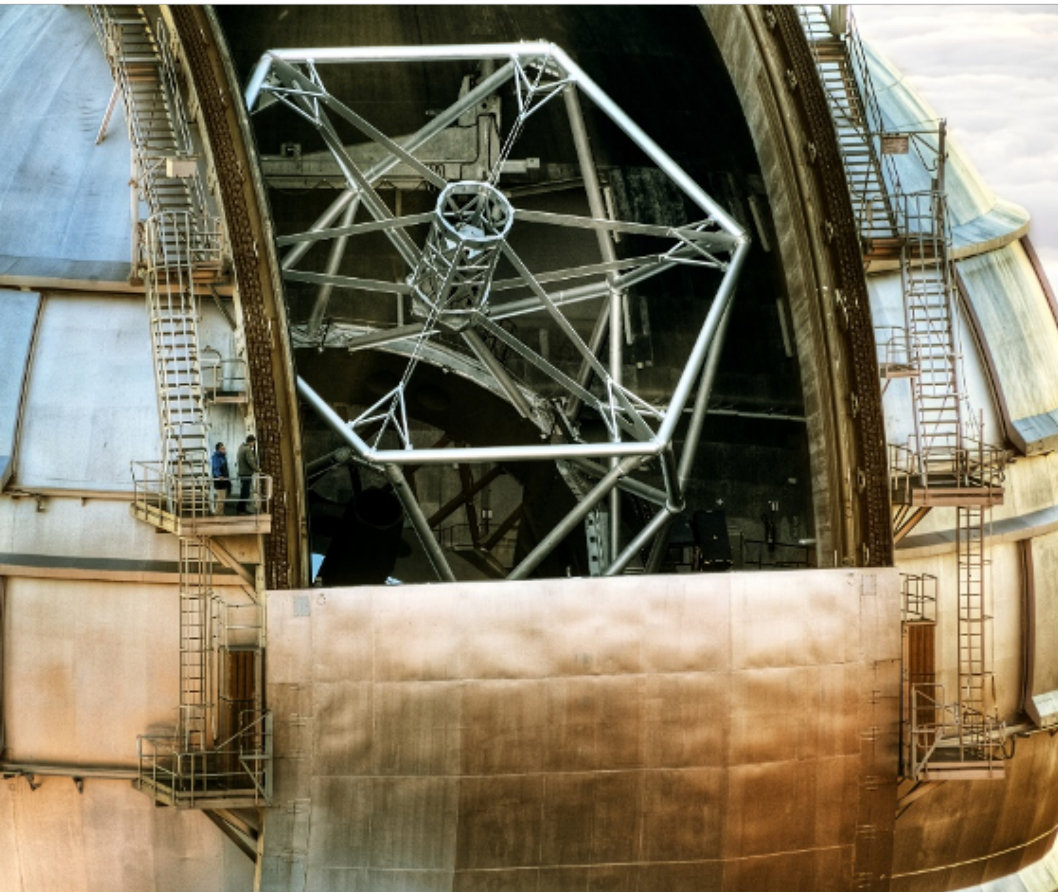
Gran Telescopio Canarias (GTC)

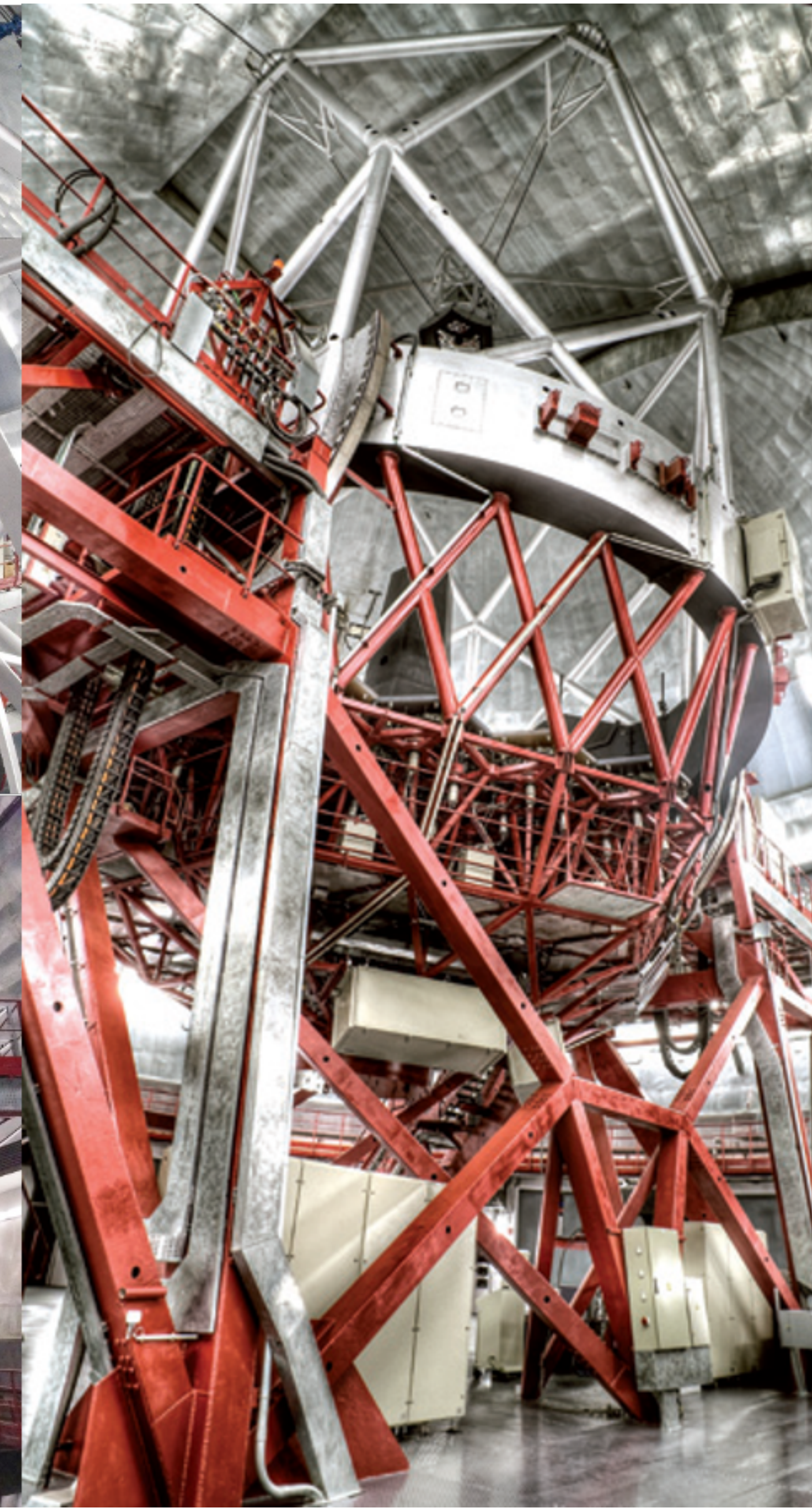
10.4 m Optical and Infrared telescope

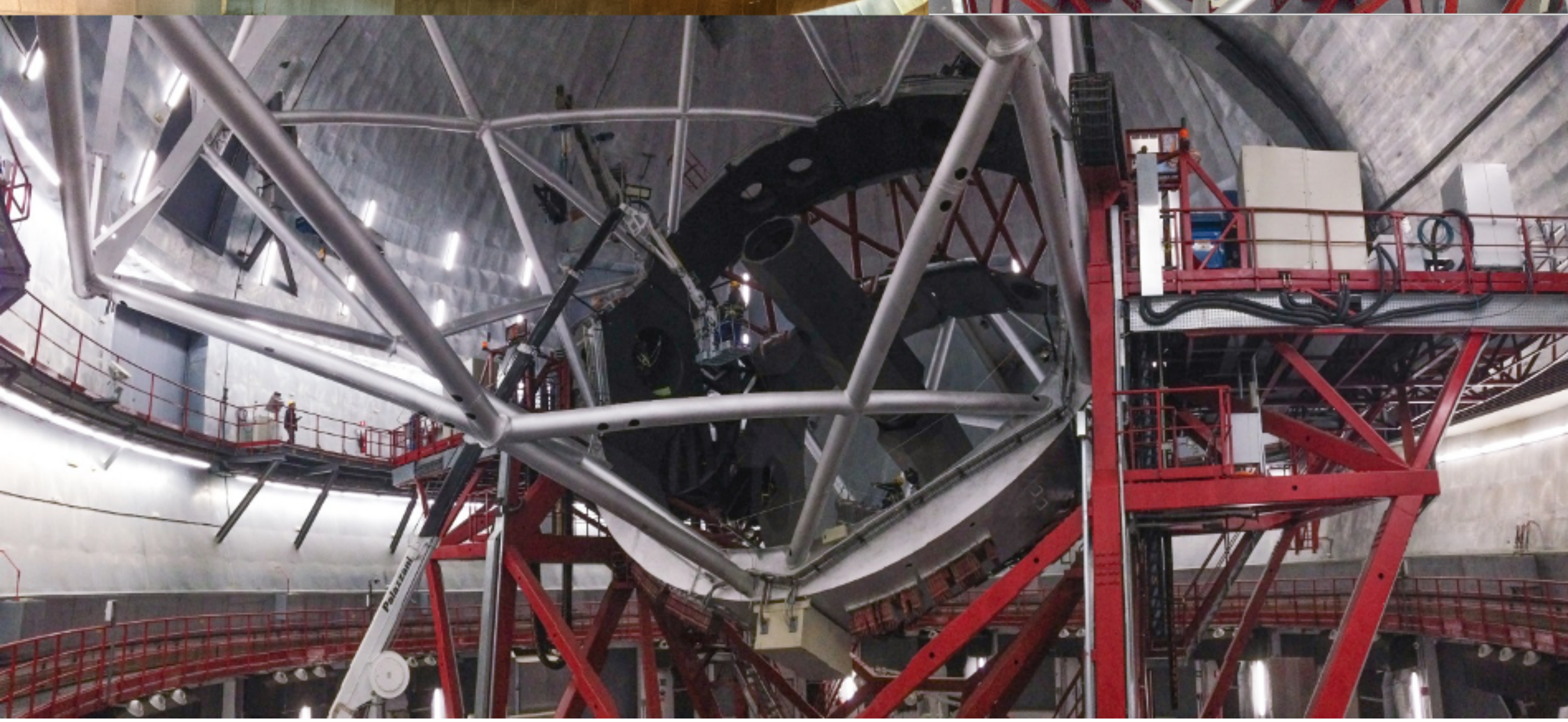
- Located at 2267 m a.s.l.
- GTC telescope is an initiative of the Instituto de Astrofísica de Canarias (IAC). Start of the operation in 2009
- Funded by Spain (90%), México (5%), and the University of Florida (2.5-5%)
- Effective collecting area 73 m^2. **Largest optical telescope in the world**
- Effective focal length 169.9 m —> plate scale 1.21 arcsec mm^{-1}



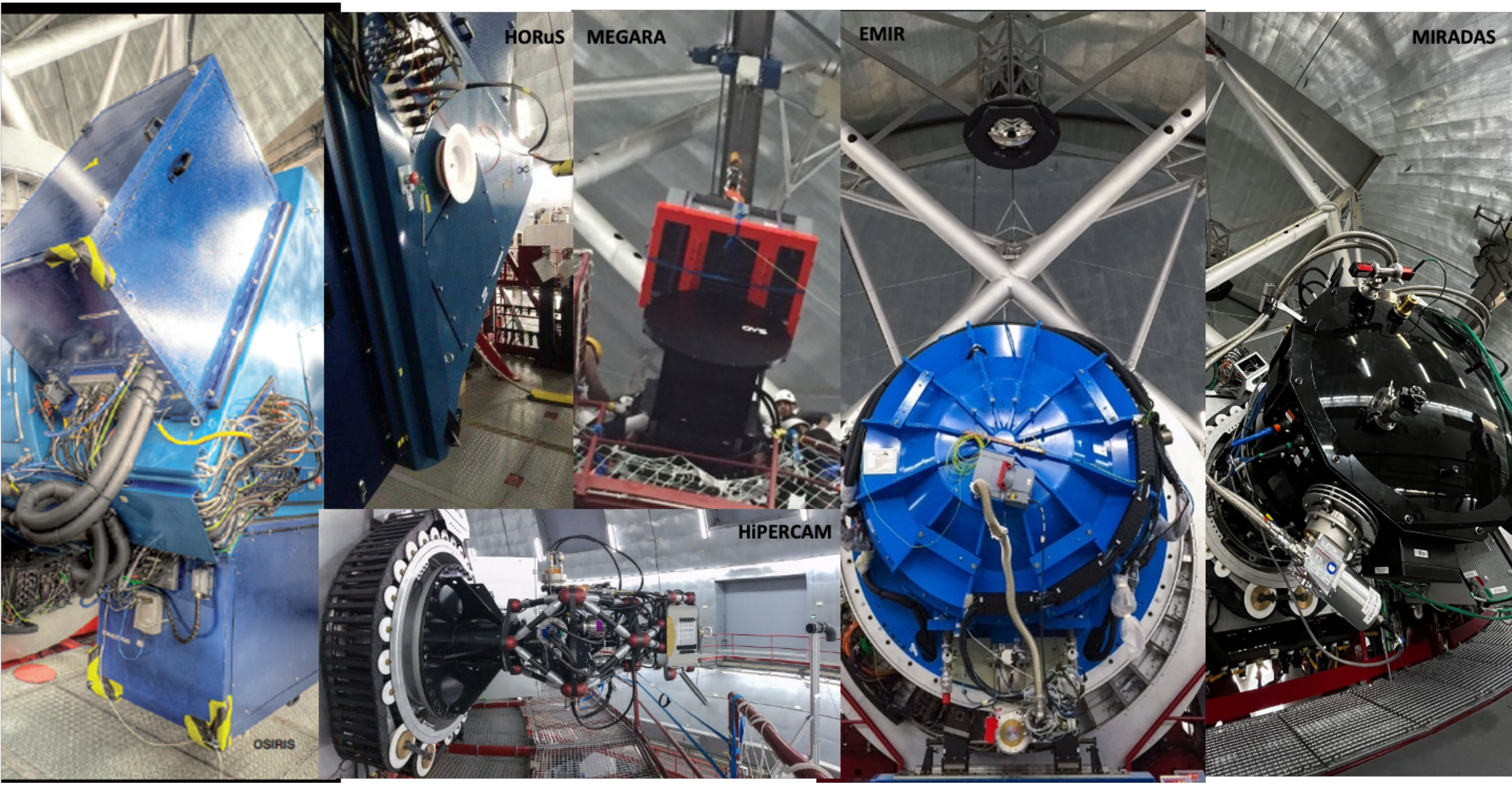




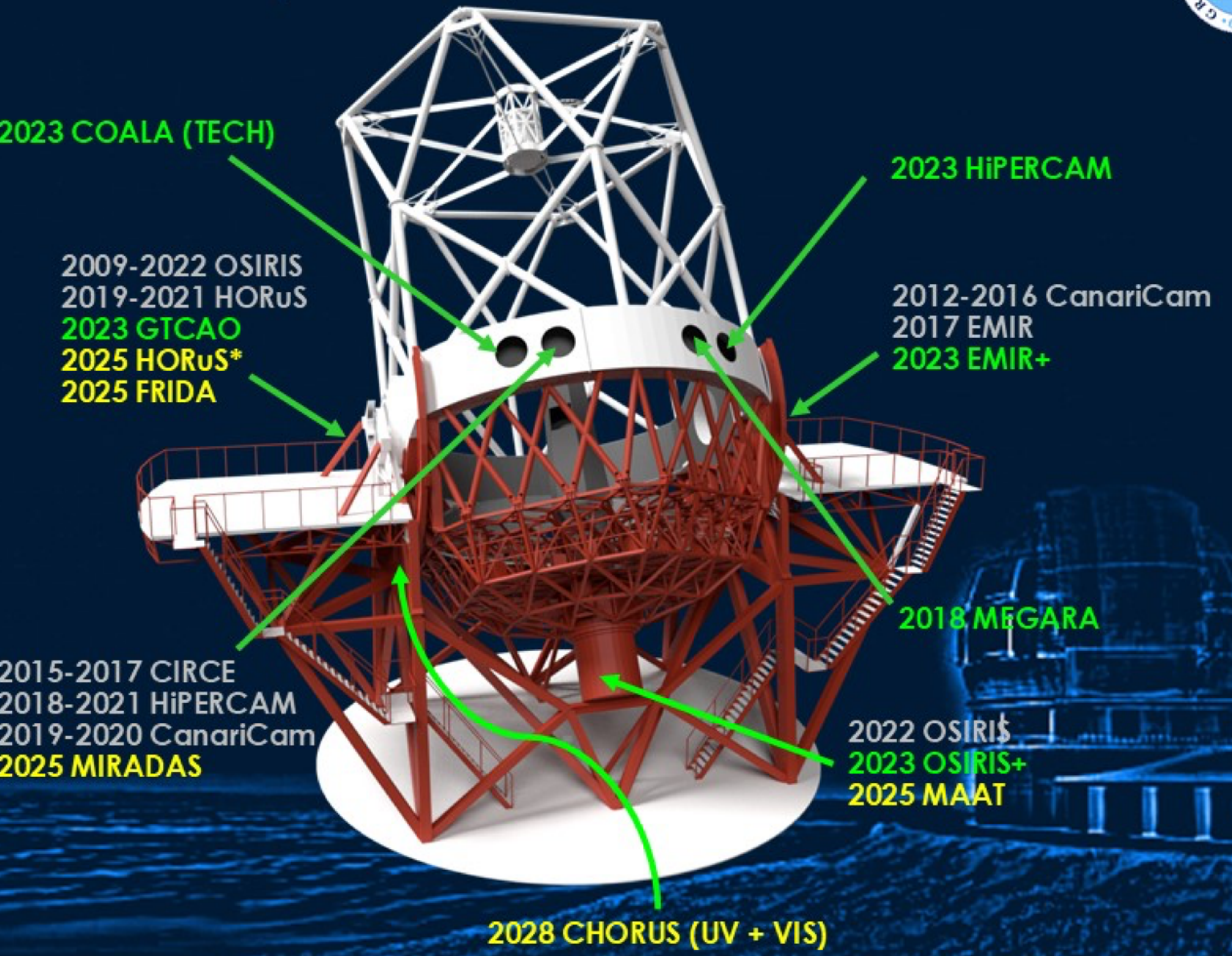


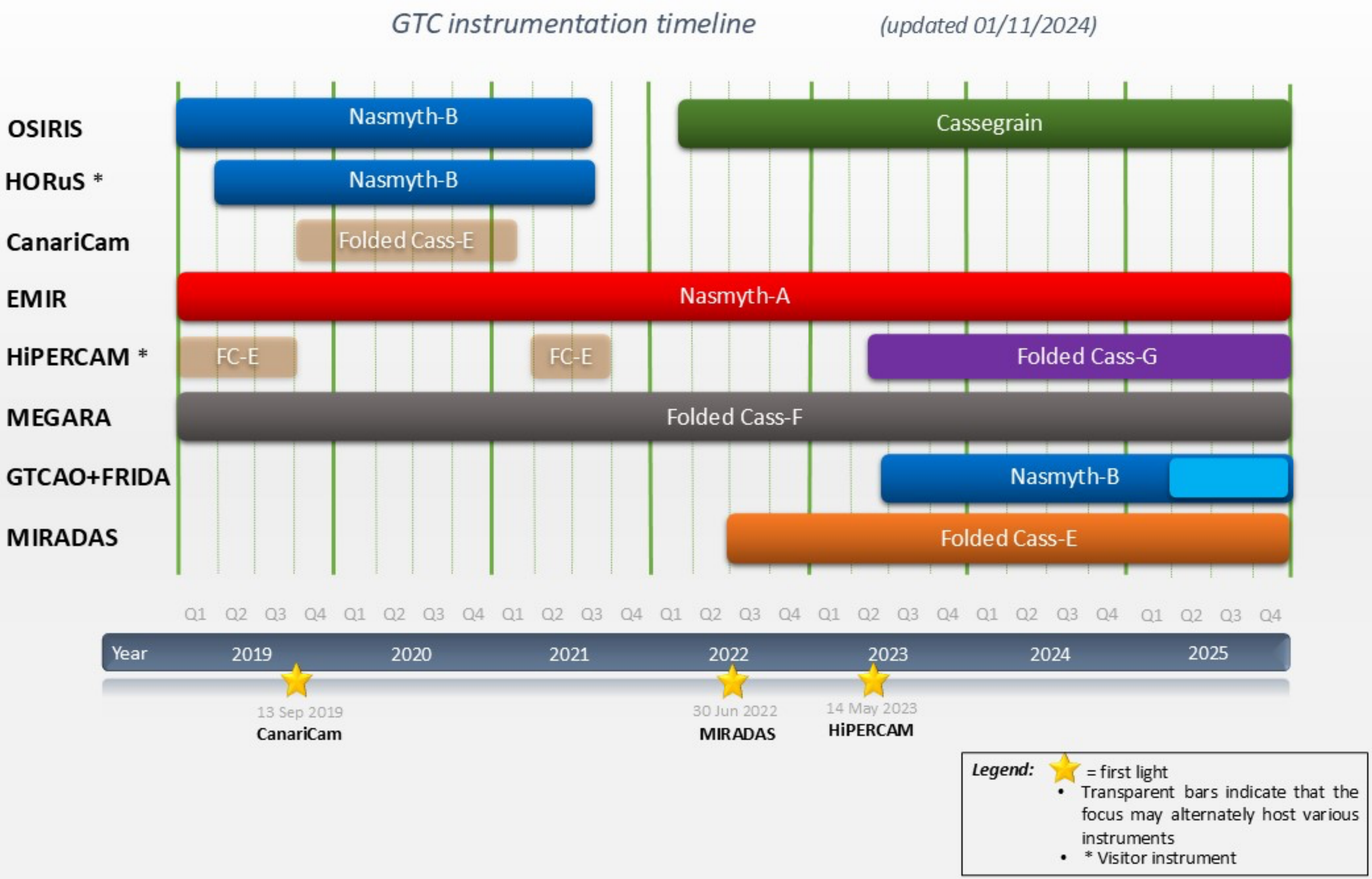



Ultravioleta
Infrarrojo
400 nm
450 nm
500 nm
550 nm
600 nm
650 nm
700 nm
750 nm


HORuS
MEGARA
EMIR
MIRADAS
HiPERCAM
OSIRIS

GTC instruments (2009-2028)



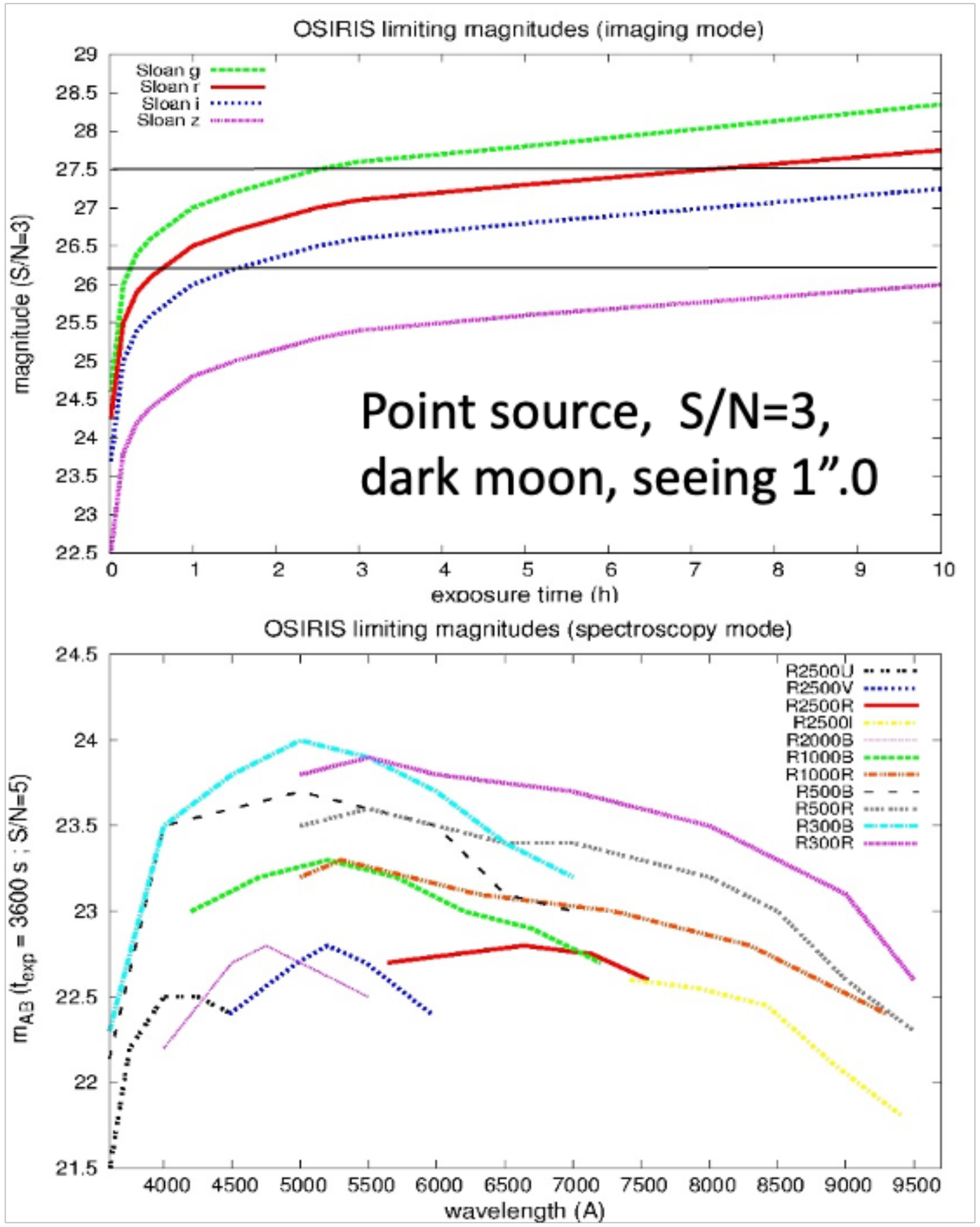


GTC instrumentation timeline
(updated 01/11/2024)
OSIRIS
HORuS *
CanariCam
EMIR
HiPERCAM *
MEGARA
GTCAO+FRIDA
MIRADAS
Nasmyth-B
Cassegrain
Nasmyth-B
Folded Cass-E
Nasmyth-A
FC-E
FC-E
Folded Cass-G
Folded Cass-F
Nasmyth-B
Folded Cass-E
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Year
2019
2020
2021
2022
2023
2024
2025
13 Sep 2019
CanariCam
30 Jun 2022
MIRADAS
14 May 2023
HiPERCAM
Legend:
= first light
Transparent bars indicate that the focus may alternately host various instruments
* Visitor instrument

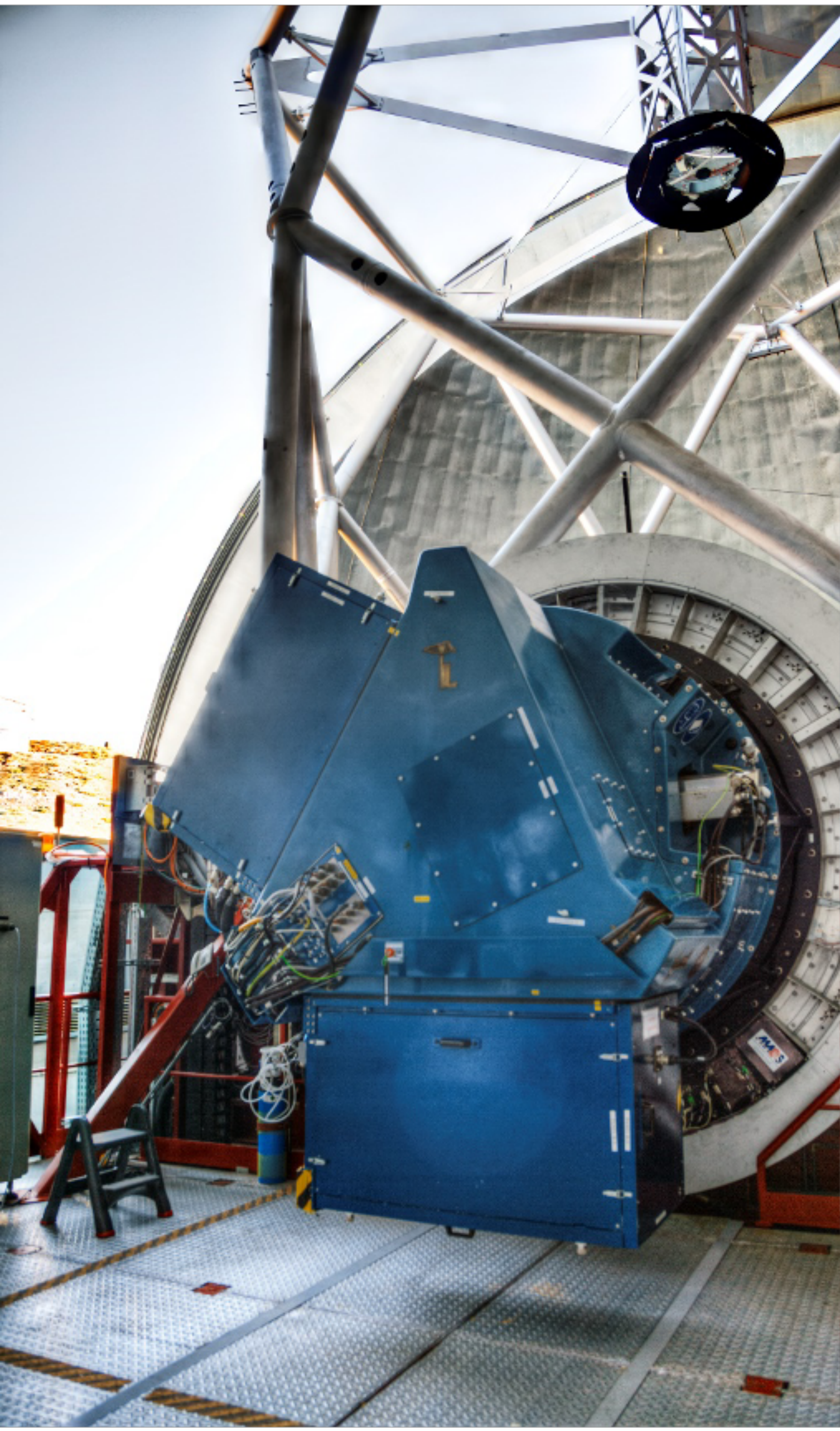
OSIRIS/OSIRIS+

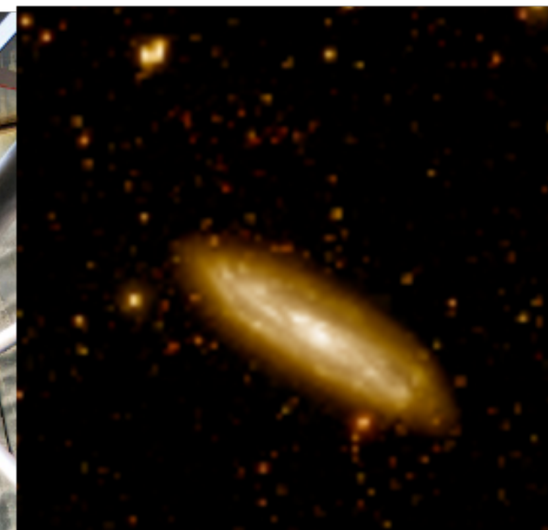
Common-user instrument since 2009 (Nasmyth B), moved to Cassegrain in 2022, upgraded to a new blue sensitive 4k x 4k monolithic CCD in December 2022 (**OSIRIS+**).

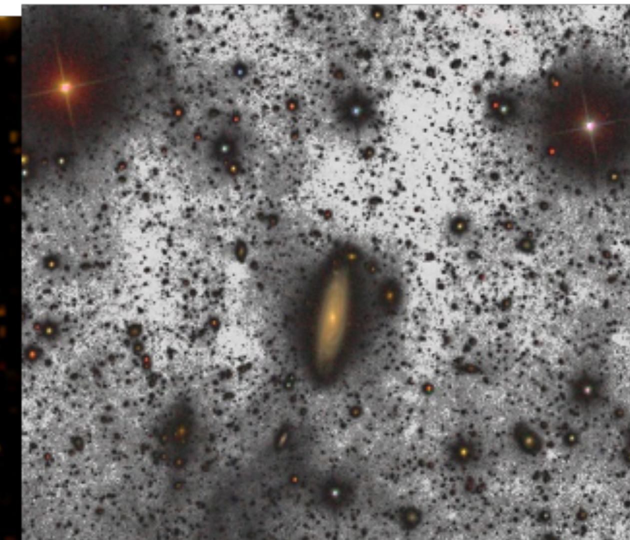
Spectral Range	0.36-1.00 µm
Detector	E2V CCD231-84-1-E74
Plate Scale	0.125 arcsec pix⁻¹
Field of view	7.8 x 7.8 arcmin²
Imaging modes	Broad-band Medium band Tunable Filters Fast photometry
Spectroscopic modes	long-slit mask MOS
Spectral resolution	300 to 2500

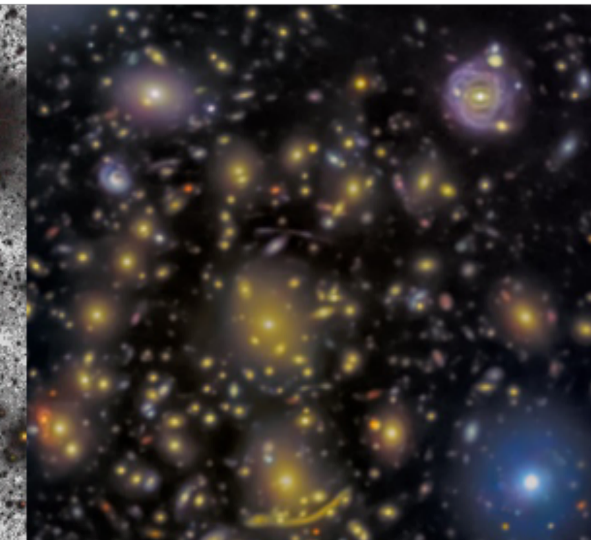


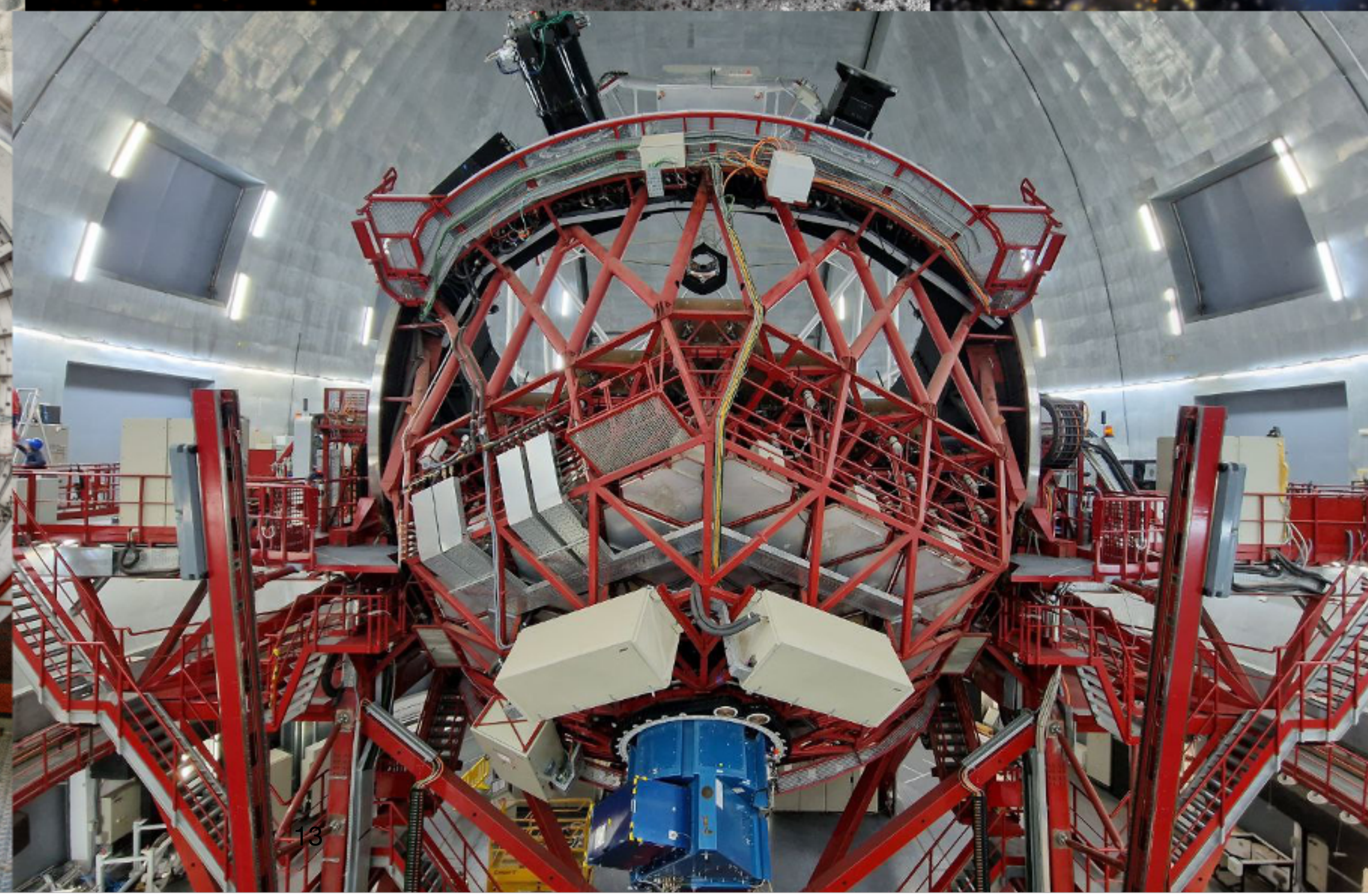
OSIRIS/OSIRIS+



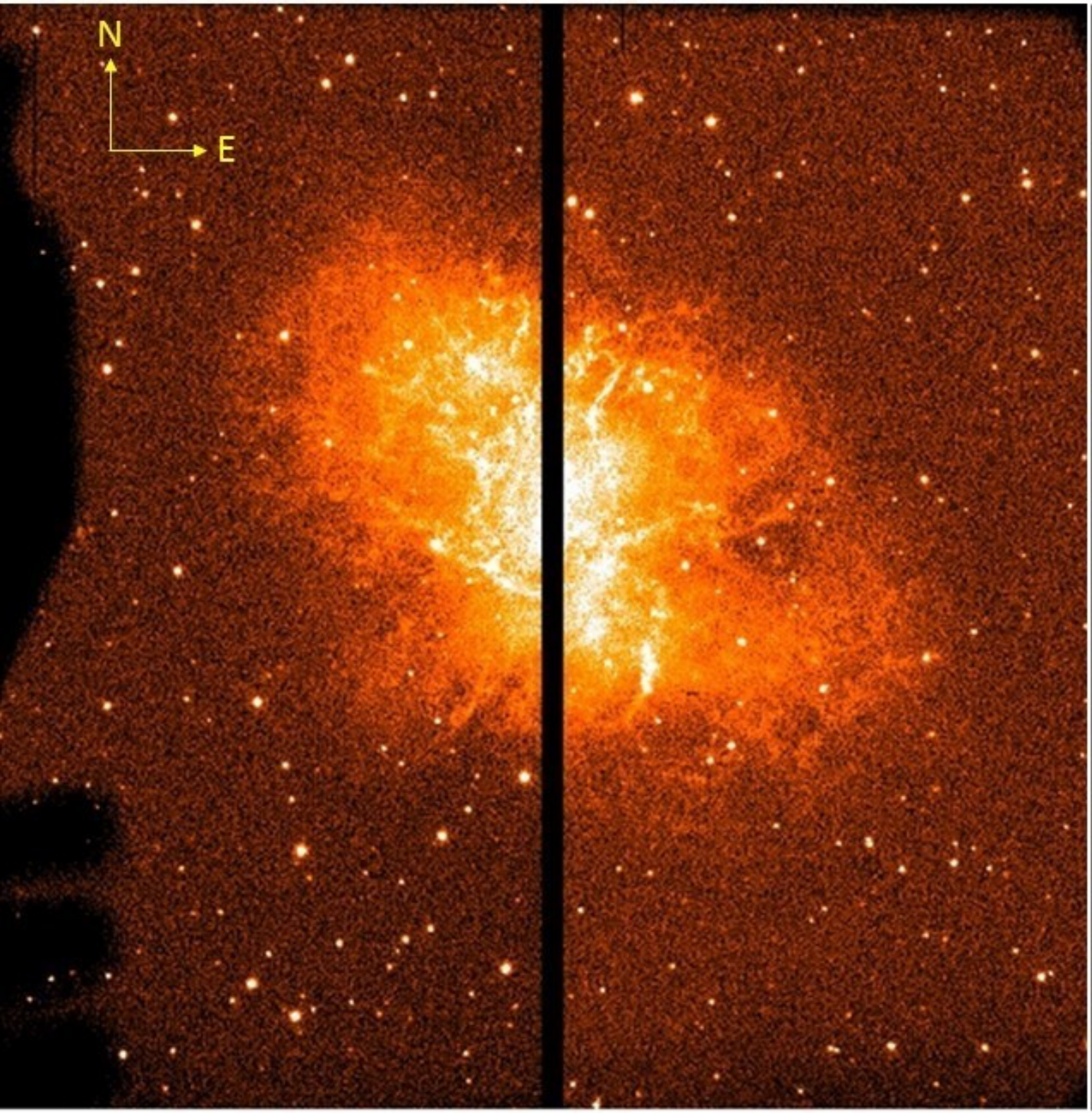


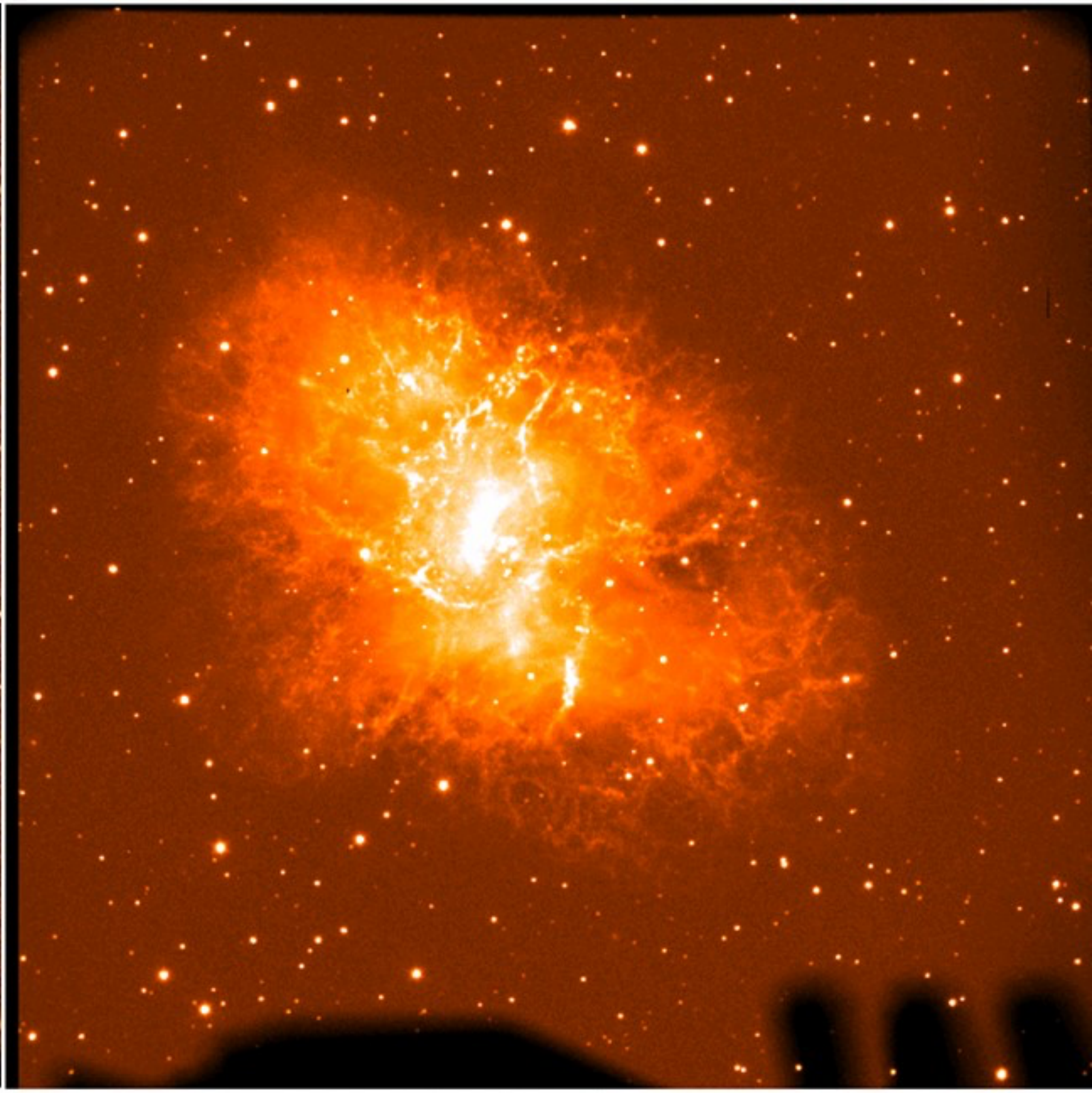






OSIRIS/OSIRIS+



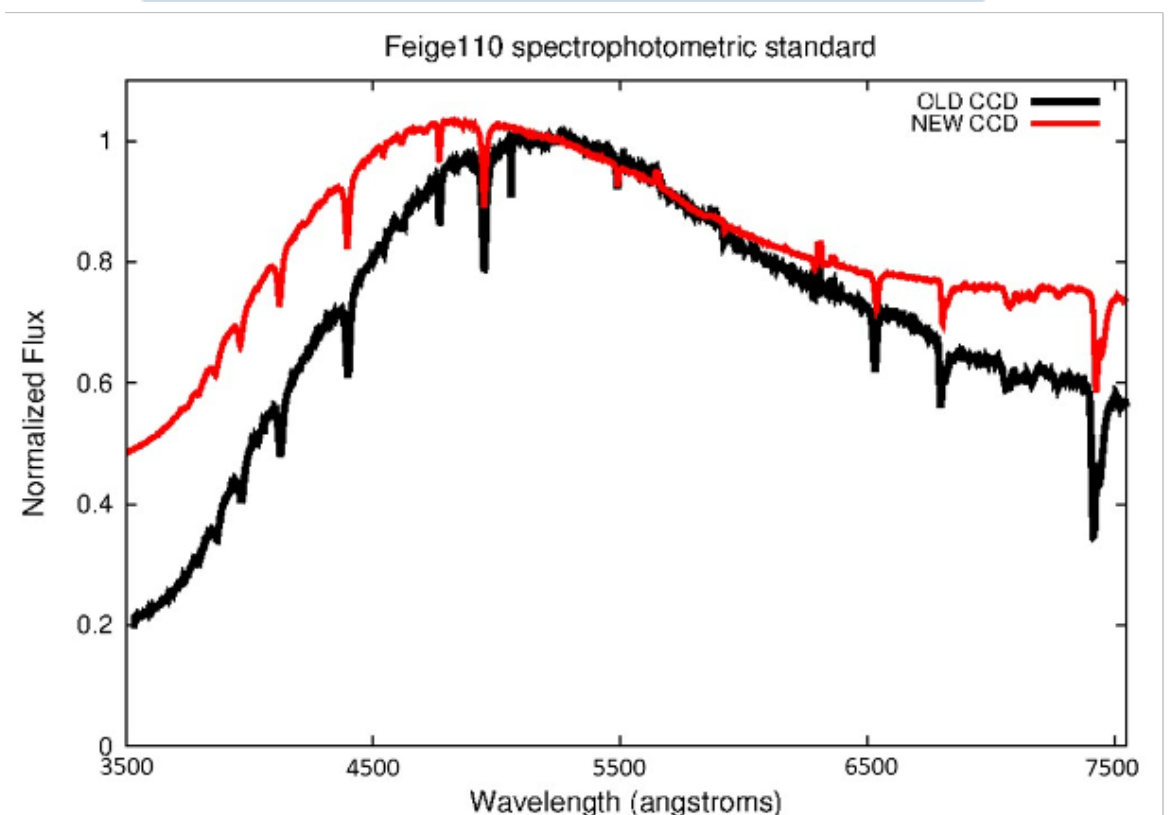


OSIRIS+ (new detector)

- **Notable sensitivity gain** at bluer wavelengths (0.5-1.2 mags) but also some improvement in the red.

ZPs	OSIRIS	OSIRIS+*
u'	25.7	26.9
g'	28.85	29.3
r'	29.3	29.4
i'	28.85	29.0
z'	28.15	28.3

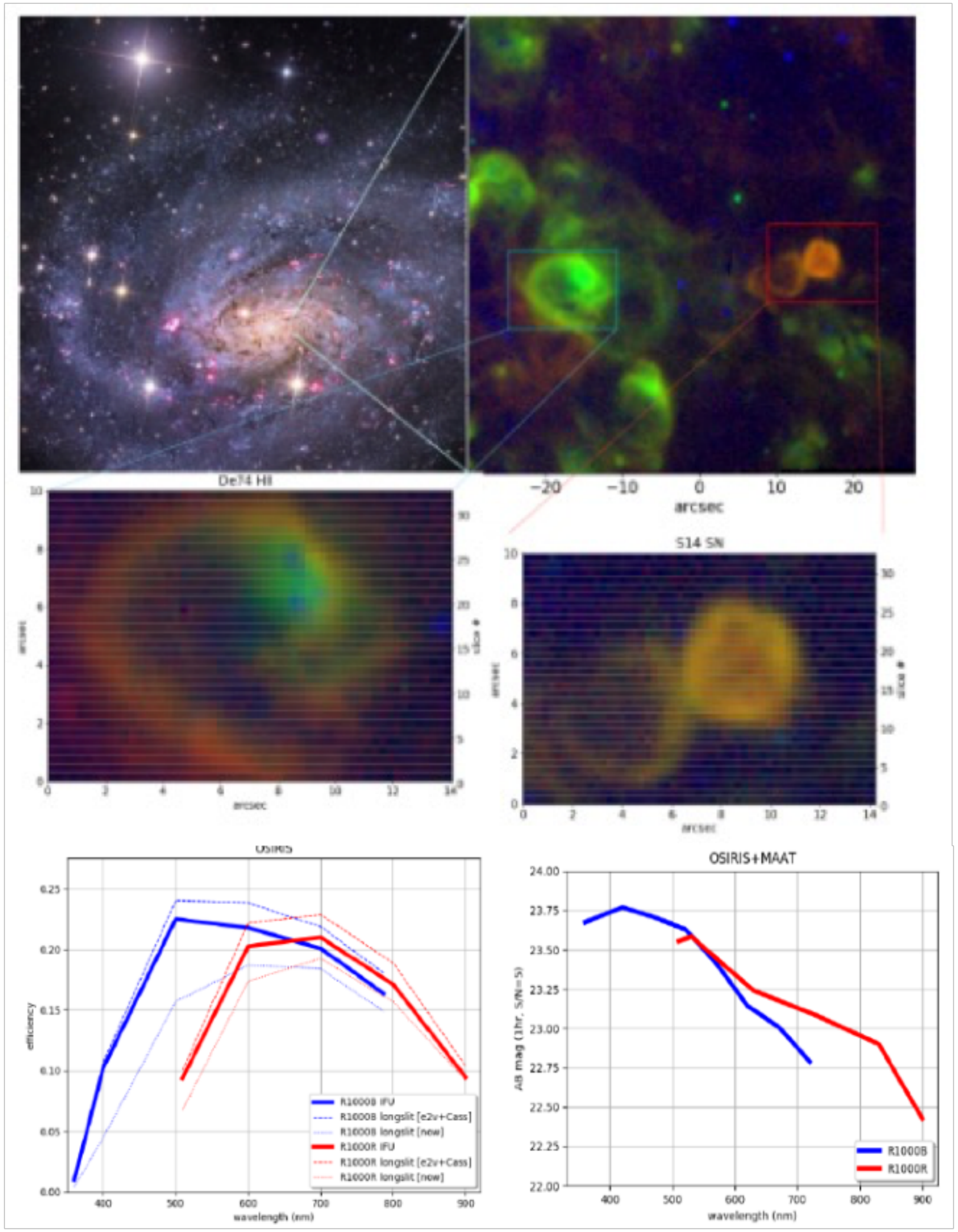
Filter	Surface mag limits (3sigma; 10"x10" boxes) mag/arsec2 (1.5 h on source)	Limiting magnitude (5sigma; r=1") mag (1.5 h on source)
Sloan u	30.3	26.0
Sloan g	31.5	27.3
Sloan r	31.0	26.6



MAAT @ OSIRIS

Integral-Field Unit (IFU) based on image slicers to be integrated in OSIRIS (mid-2025).

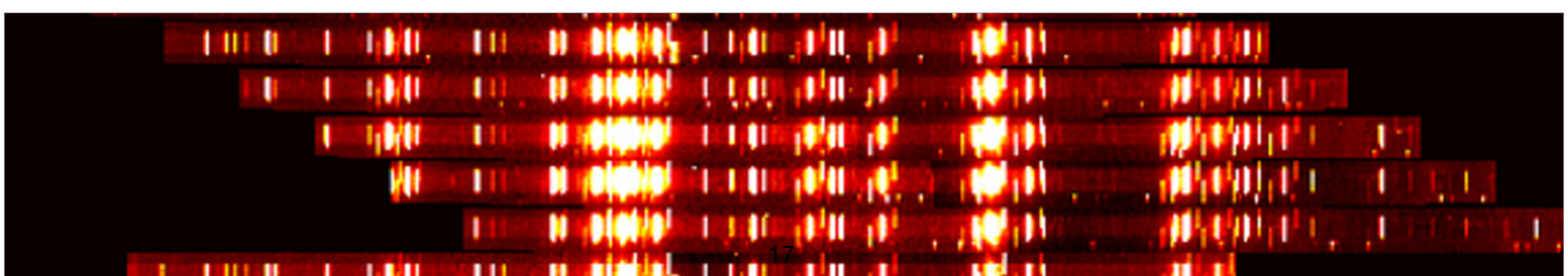
Spectral Range	0.36-1.00 µm
Detector	E2V 4k x 4k
Plate Scale	0.127 arcsec pix^{-1}
Field of view	12” x 8.5”
Module	Integral Field Unit
Spatial Sampling	0.303” x 0.127”
Spectral resolution	600 to 4100



EMIR

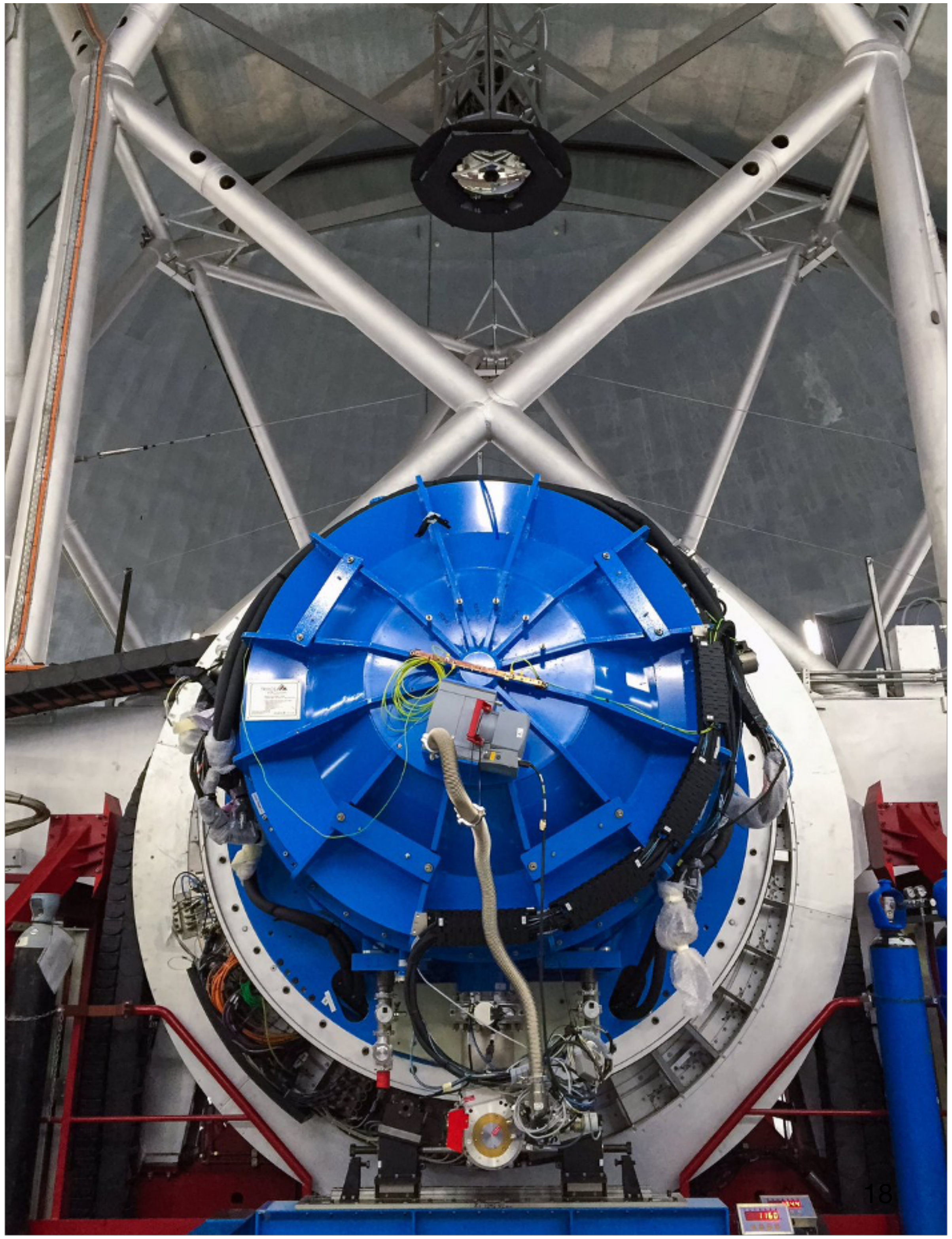
NIR imager and multi-object spectrograph

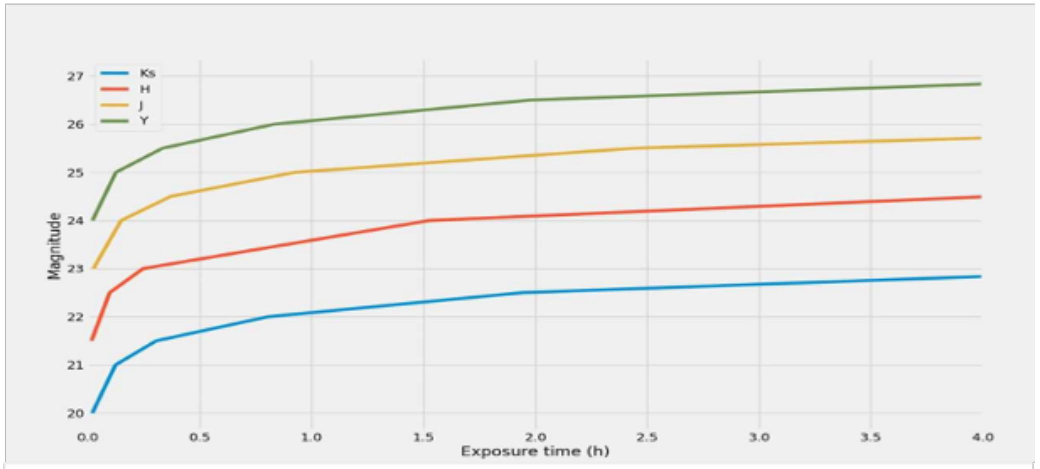
Spectral Range	0.9-2.5µm[1.1-2.5µm]	*MOS mode*	
Detector	HAWAI2 2048^2	*F.O.V.*	6.7 x 4 $arcmin^2$ (55 slitlets)
Spectral resolution	1000 (YJ, HK) 5000,4250,4000 (JHK)	*Sensitivity*	**K~20.1 in 2h @ S/N=5 (continuum)**
Spectral coverage	1 single window/exp.		1.4×10^{-18} erg/s/cm^2/Å @ S/N=6 (line)
Imaging modes	Broad/narrow band	*Imaging mode*	
Plate Scale	0.2 arcsec pix^{-1}	*F.O.V.*	6.7 x 6.7 $arcmin^2$
Image quality	θ_{80} < 0.3 arcsec	Sensitivity	**K~22.0 in 1h, for S/N=3 & 0.6 arcsec aperture**

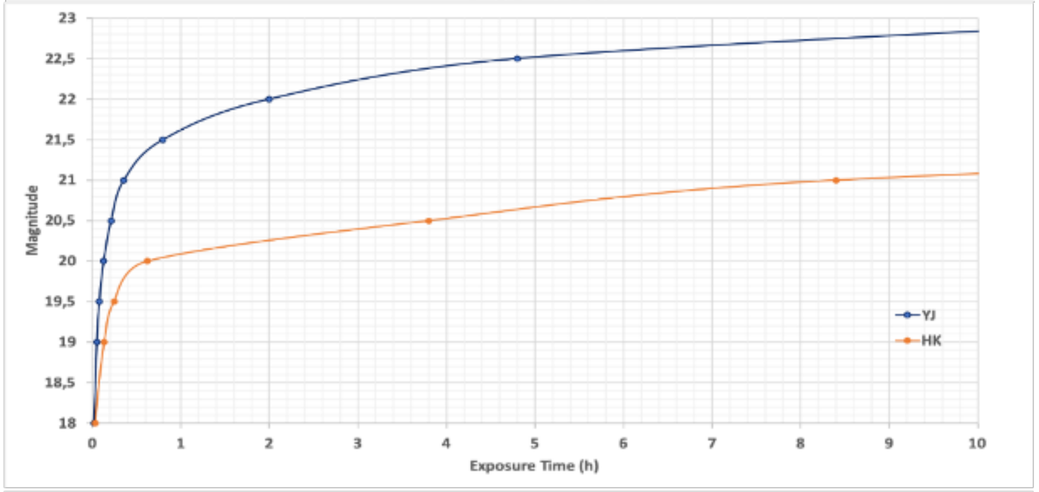


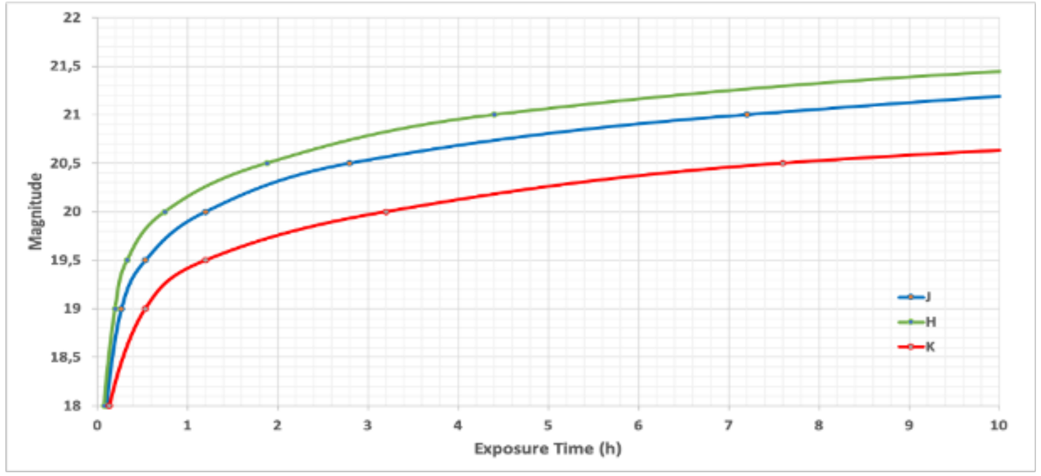
EMIR (detector upgrade 2023)

NIR imager and multi-object spectrograph







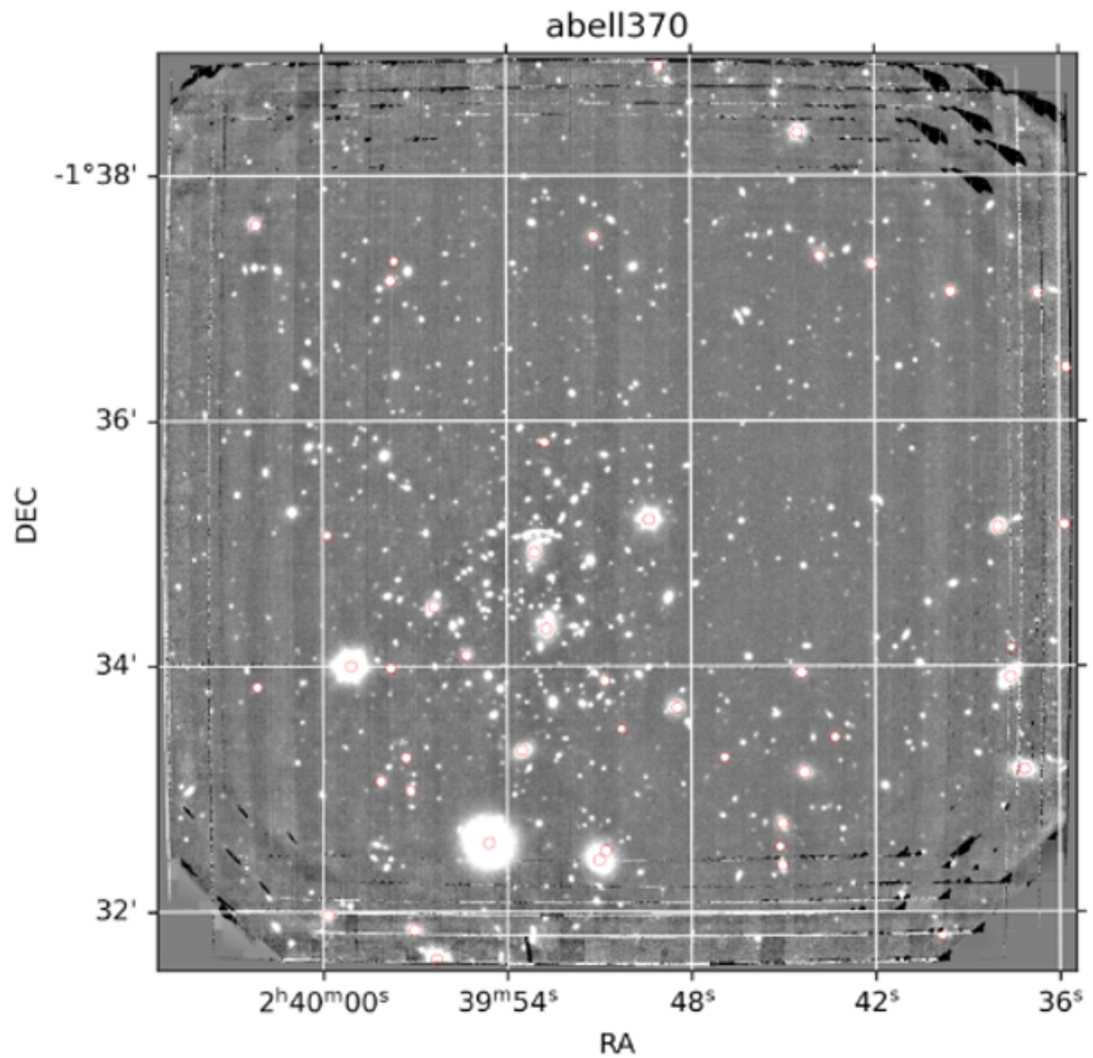


EMIR (detector upgrade 2023)

NIR imager and multi-object spectrograph

ABELL 370

J: 6 iter x 7 dith x 10 exp x 10s = 4200s

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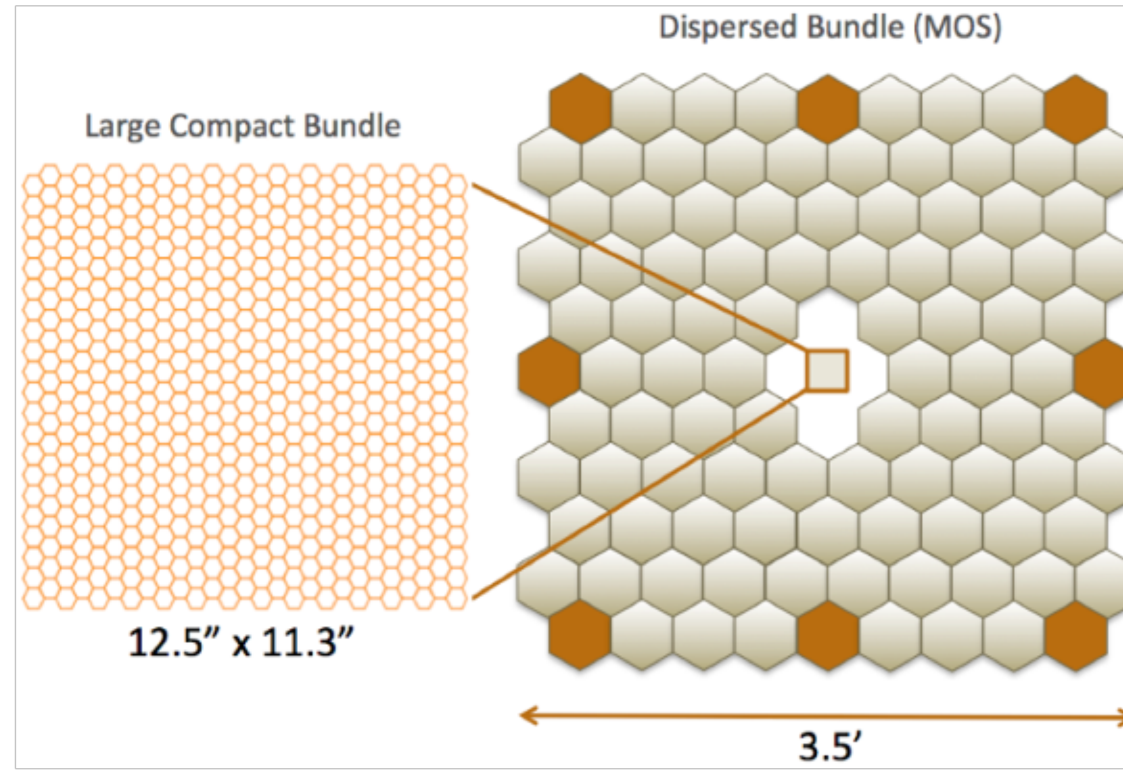
****Img nimgs, texp, mean, median, std : 420 10.0 0.049 0.000 0.267
***mlim(3sig): 25.038 mlim(5sig): 24.484
***Bckg_1img mean, median, std
          5.478 5.478 0.000
***mlim(3sig) mean, median, std
          25.038 25.038 0.000
***mlim(5sig) mean, median, std
          24.484 24.484 0.000
```

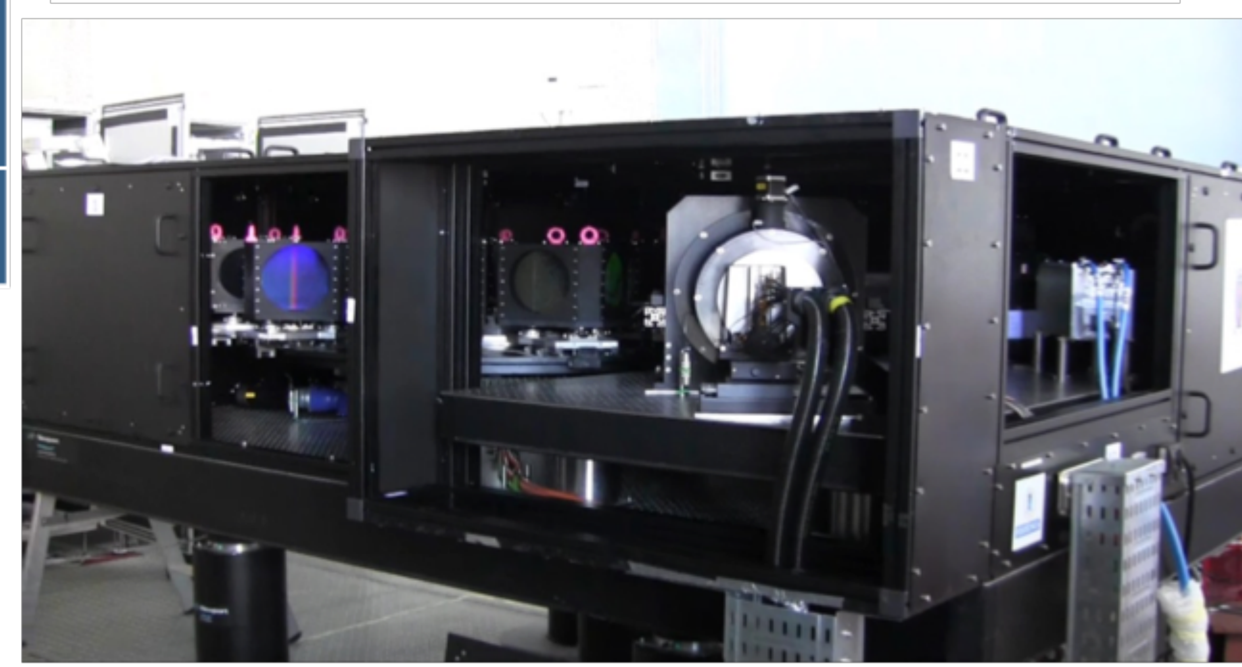
J = 25 mag

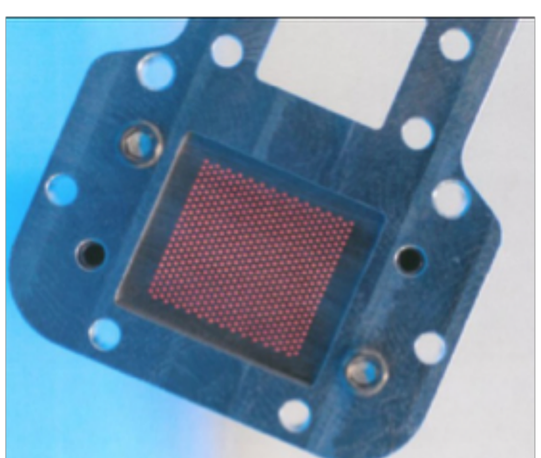
MEGARA
Optical medium-res multi-object spectrograph

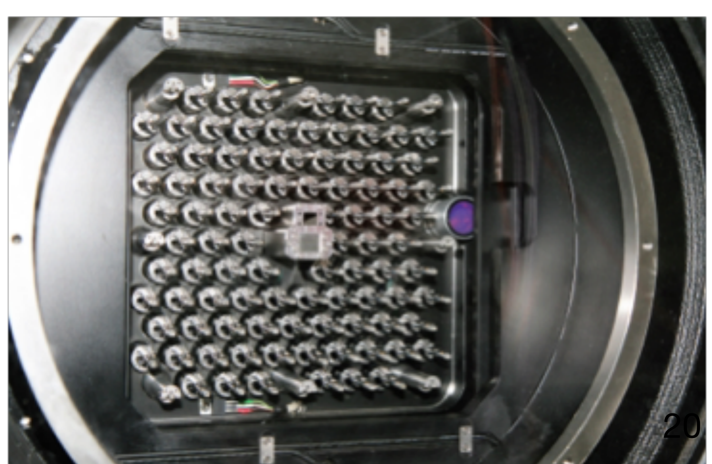
Common-user instrument since 2018 (FCass-F).

Spectral range	0.365-1.000 μm
Detector	E2V CCD231-84-1-E74
IFU field of view	12.5 x 11.3 arcsec^2
IFU spaxel size	0.62 arcsec
MOS	92 x 7-fiber mini-IFUs*
MOS field of view	3.5 x 3.5 arcmin^2
Spectral resolution	6000 to 20000
# of spectra	650





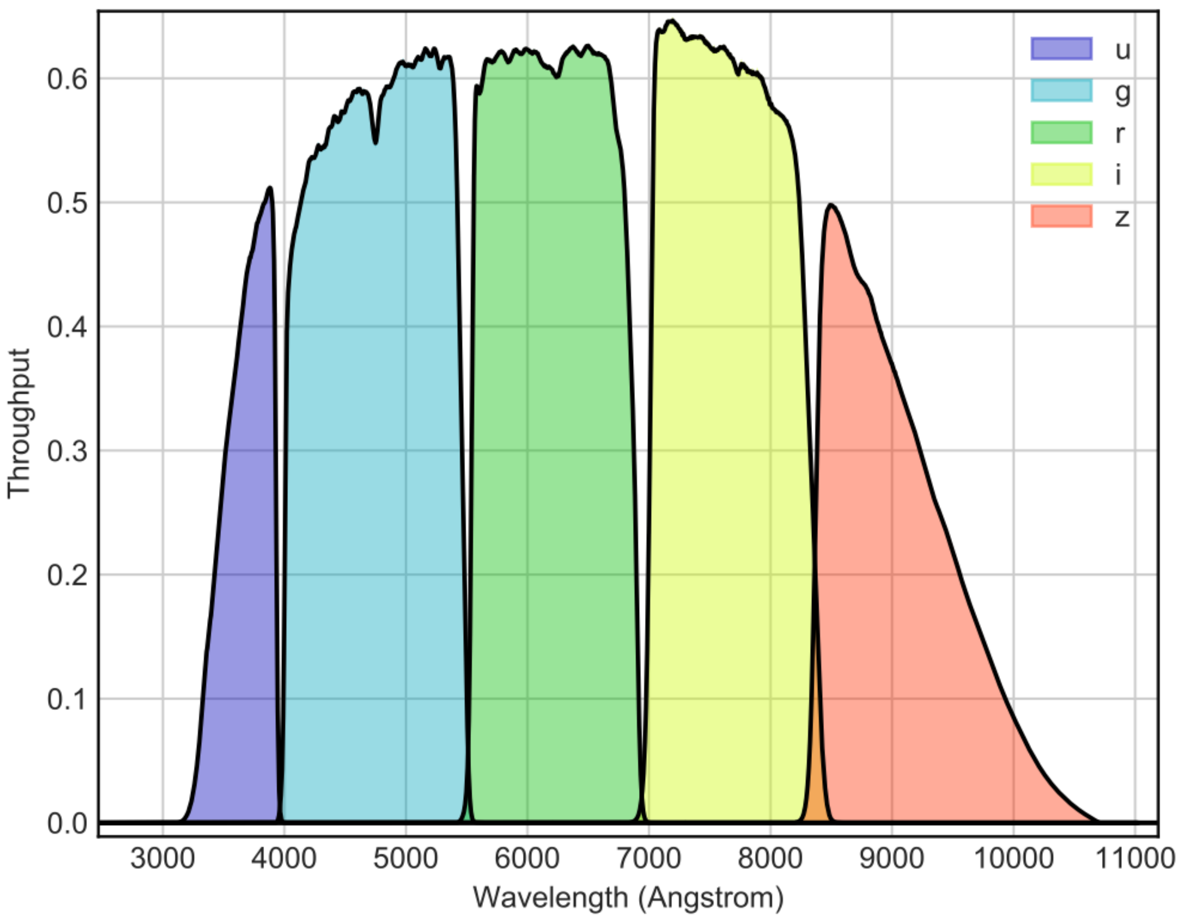




HiPERCAM
High Speed, Multi-band imager

First light at GTC in Feb 2018, installed (not permanently) at FCass E until Sep 2019.
Installed permanently at Fcass G from April 2023.

Spectral Range	0.36-1.00 μm
Detector	5 x E2V 47-20 frame-transfer devices
Plate Scale	0.081 arcsec pix^{-1}
Field of view	2.8 x 1.4 $arcmin^2$
Imaging modes	Fast photometry with broad band filters u'g'r'I'z' (simultaneous)



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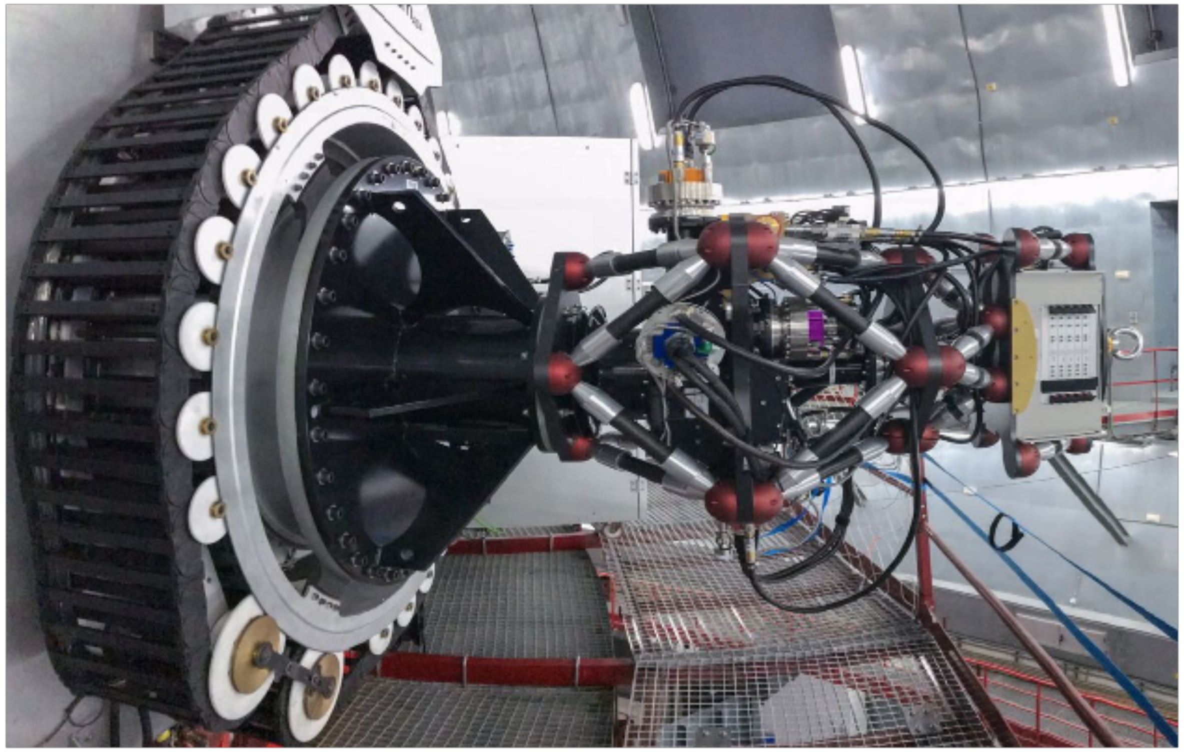

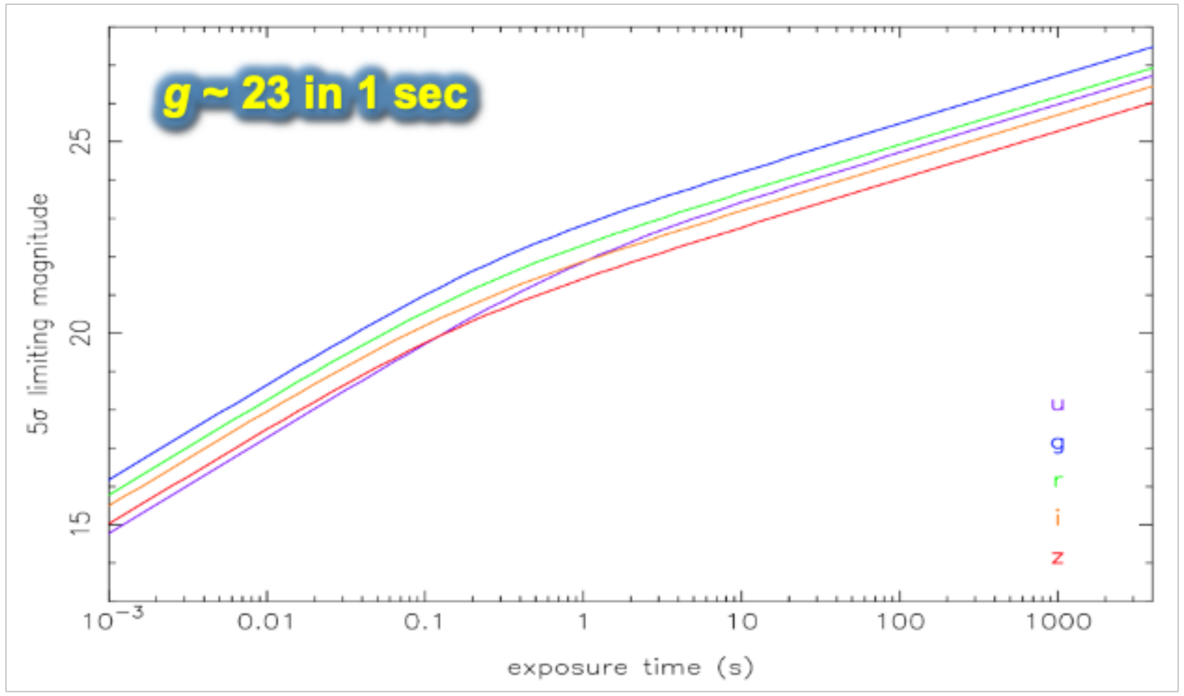

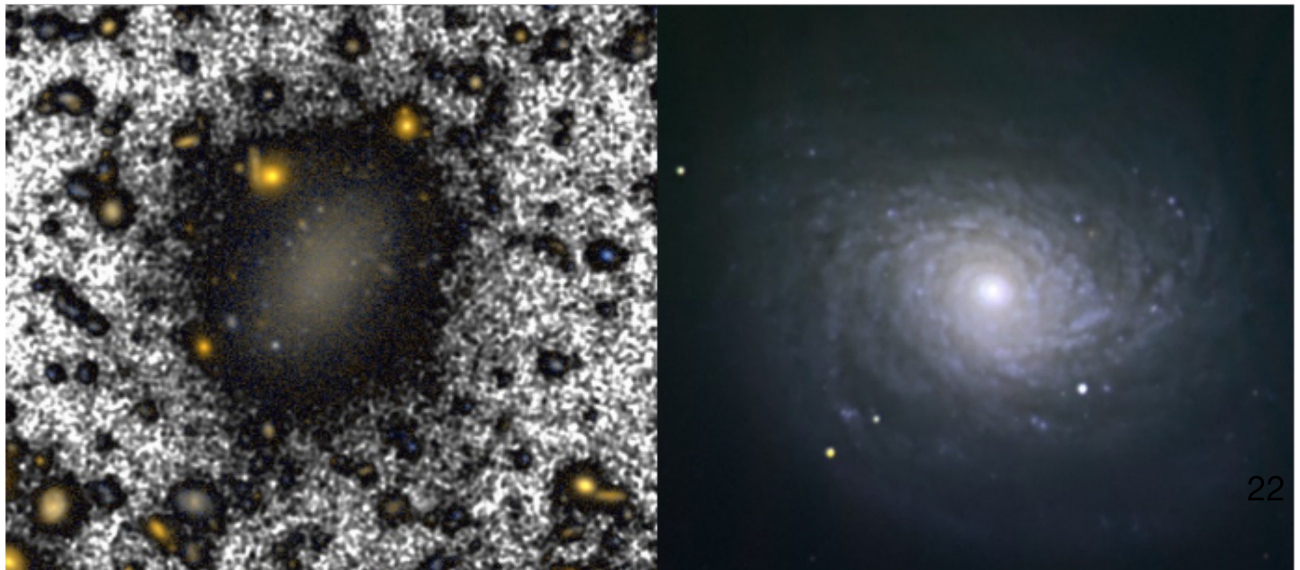

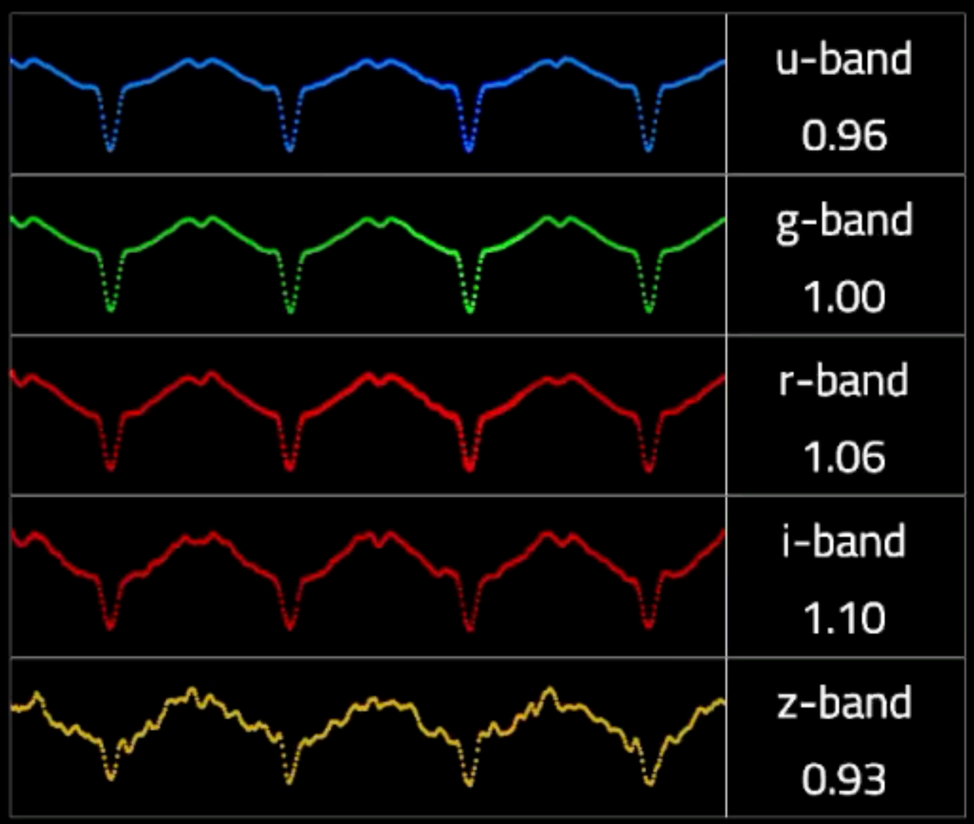
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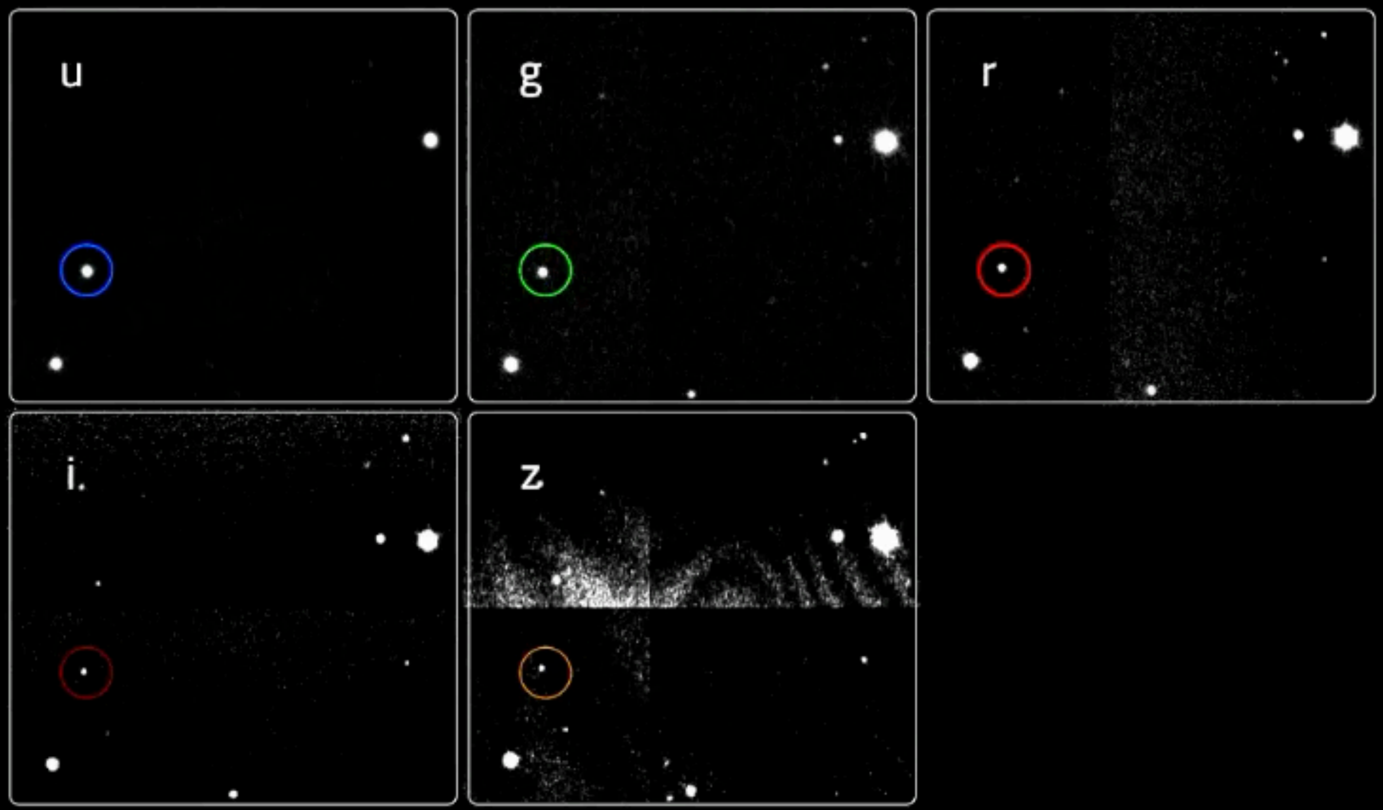
0.96
g-band
1.00
r-band
1.06
i-band
1.10
z-band
0.93


u
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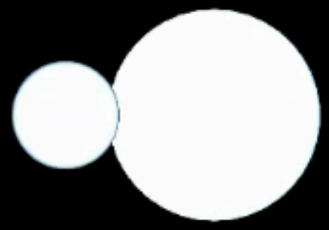
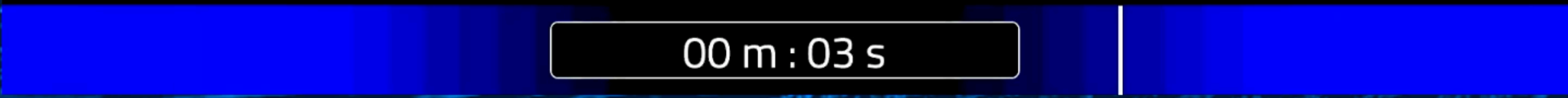
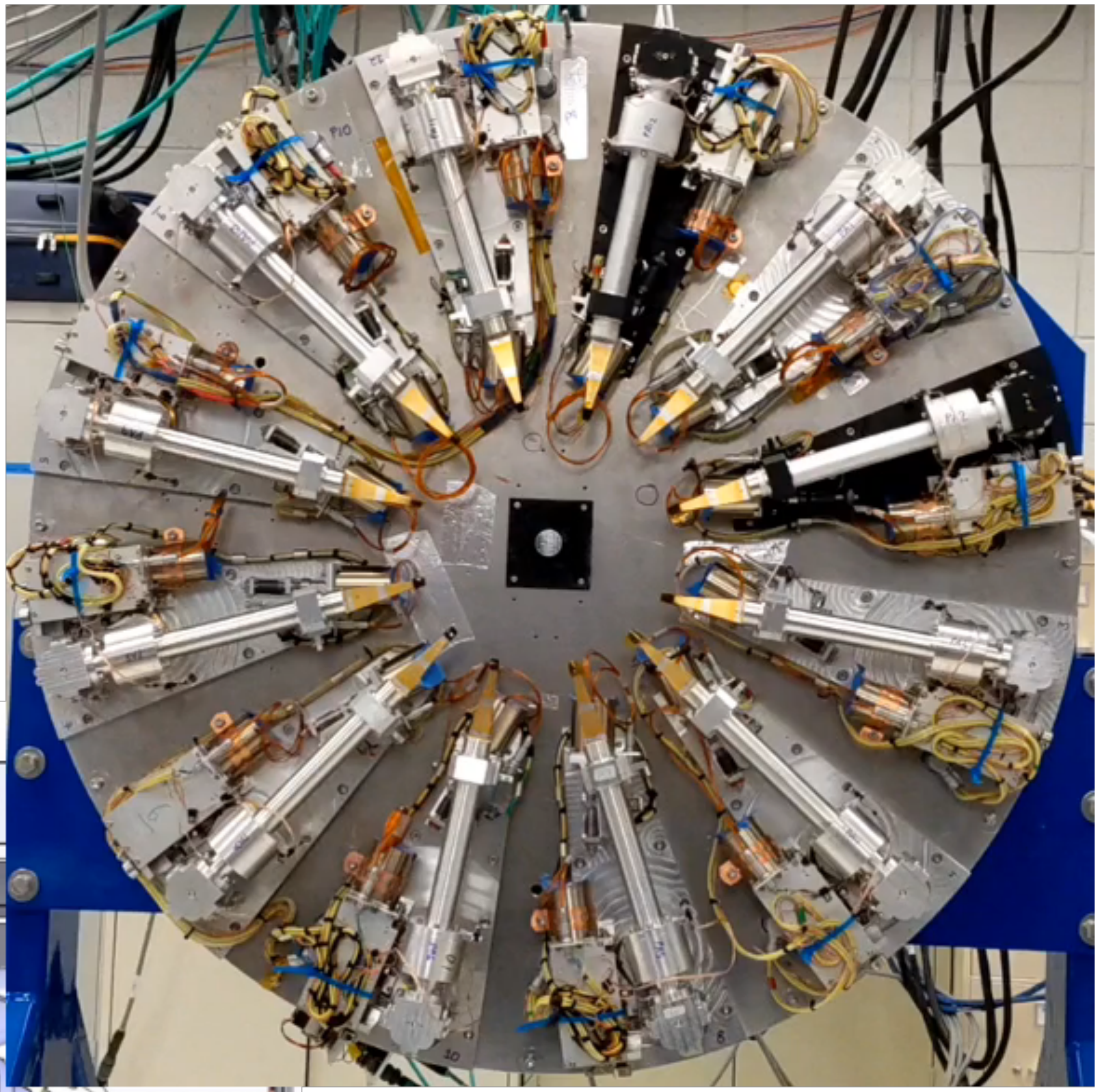
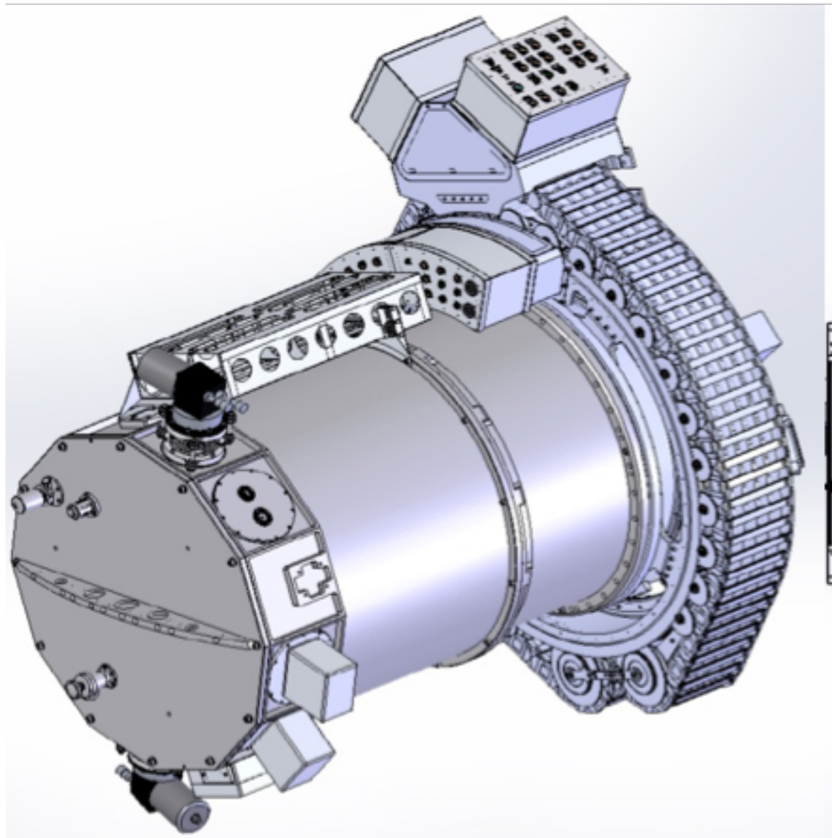


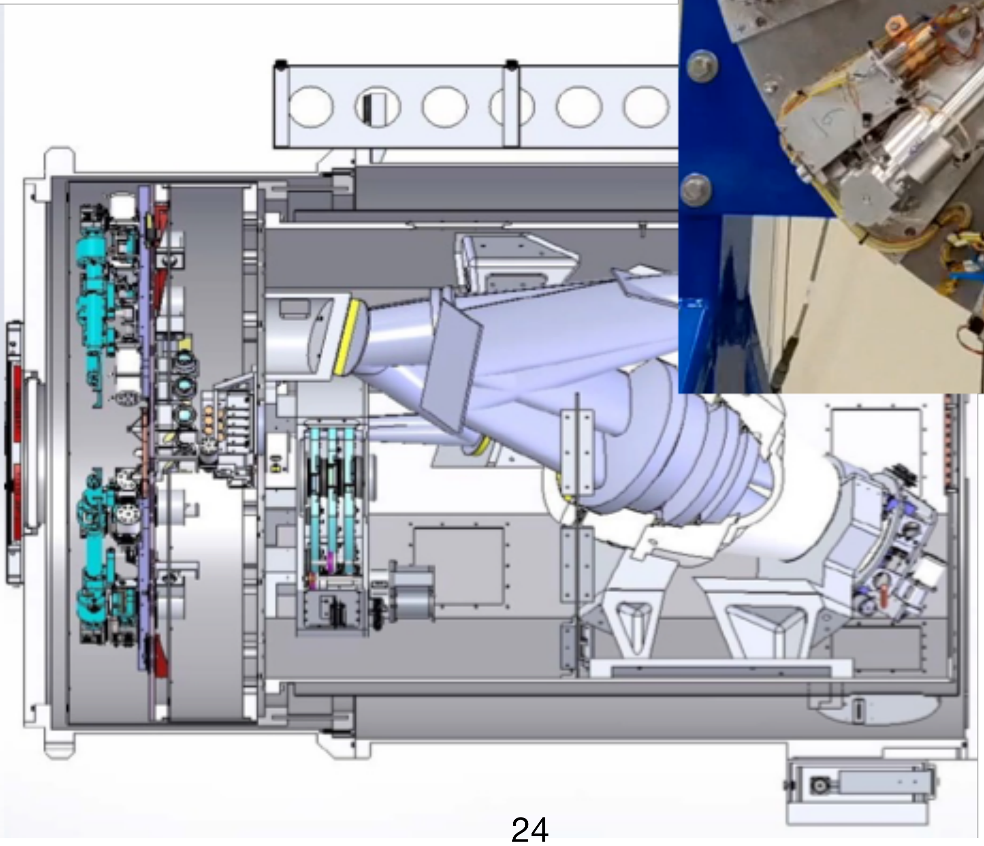

00 m : 03 s

MIRADAS
NIR medium-res multi-object spectrograph

Spectral Range	1-2.5 µm
Field of view	5’ x 5’
Spectroscopic mode	MOS up to 12 probe arms
Spectropolarimetry	WP in single-object mode
Spectral resolution	20000







GTC-AO + FRIDA
NIR imager and IFU spectrograph

Natural guide-star **Adaptive Optics is being developed at the IAC** in collaboration with GTC. In a second stage, a laser guide star will be added.

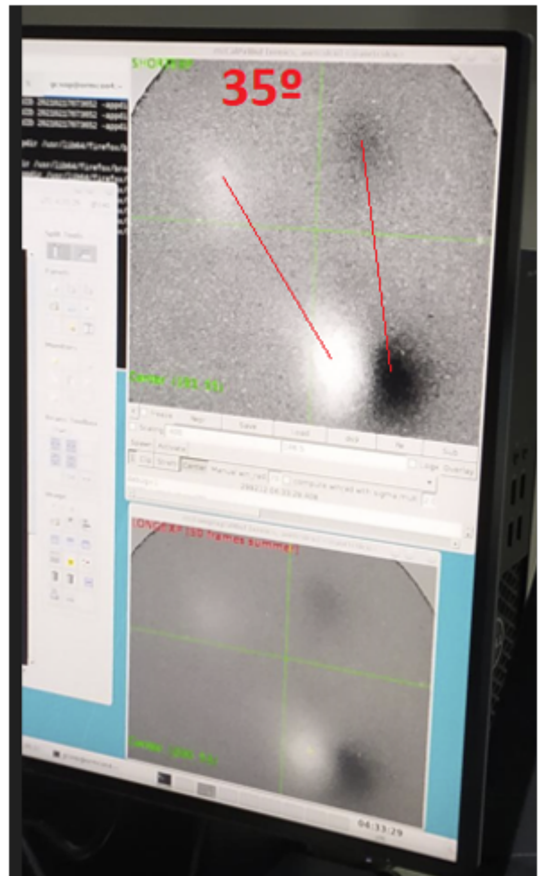
GTC-AO will feed **FRIDA** at Nasmyth. FRIDA is developed at UNAM (Mexico).

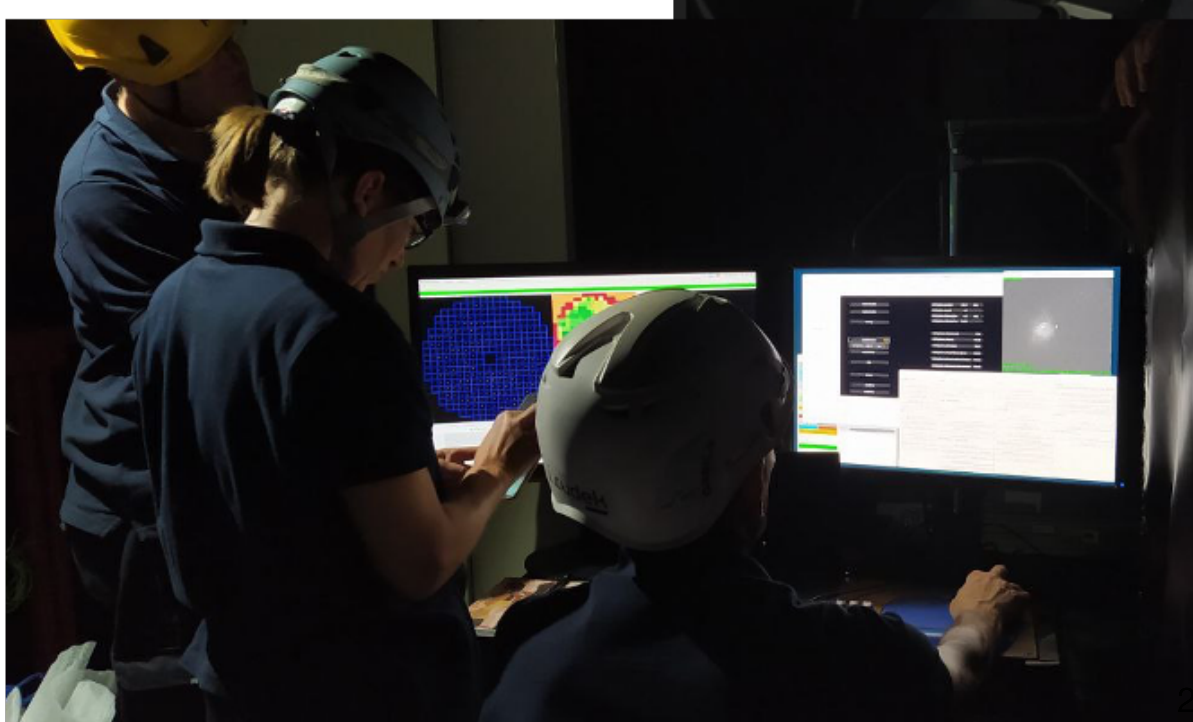
Both expected in 2024-2025.

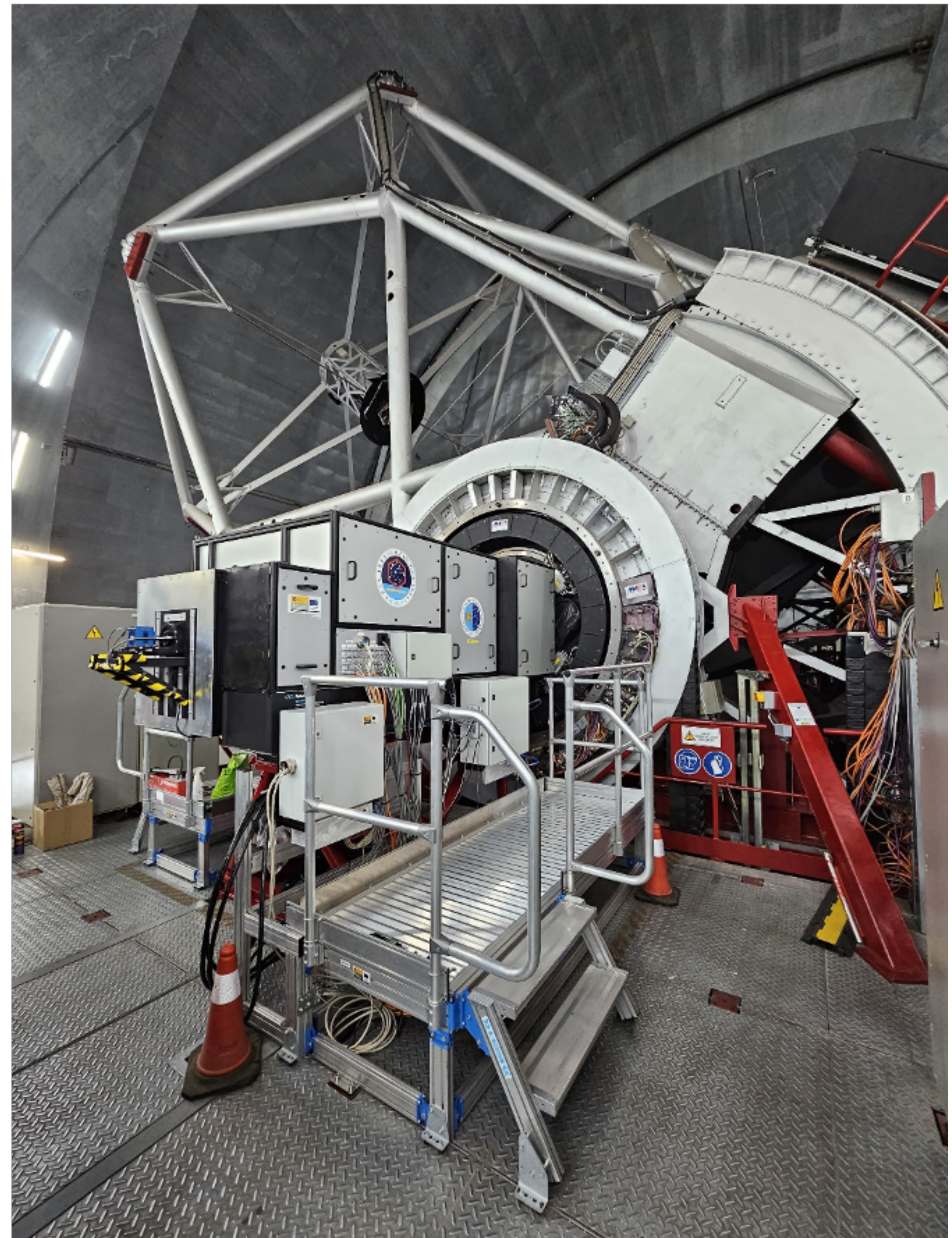
GTCAO	
Spectral range	0.9-2.5 μm
Correction	Shack-Hartmann wfs in visible light
Corrected fov	1.5 arcmin
On-axis SR	>0.65 at 2.2μm

FRIDA		
Spectral range		0.9-2.5 μm
Detector		HAWAII2RG 2048^2
Imaging	mode	diffraction limited broad/narrow-band
	f.o.v + plate scale	20''x20'' (0.01 arcsec pix^{-1}) 40''x40'' (0.02 & 0.04 arcsec pix^{-1})
Spectroscopic mode		IFU 0.6x0.6, 1.2x1.2 & 2.4x2.4 $arcsec^2$
Spectral resolution		1000 (ZJ, HK), 4000 (Z,J,H,K), 30000 (H,K)

GTC-AO + FRIDA
NIR imager and IFU spectrograph



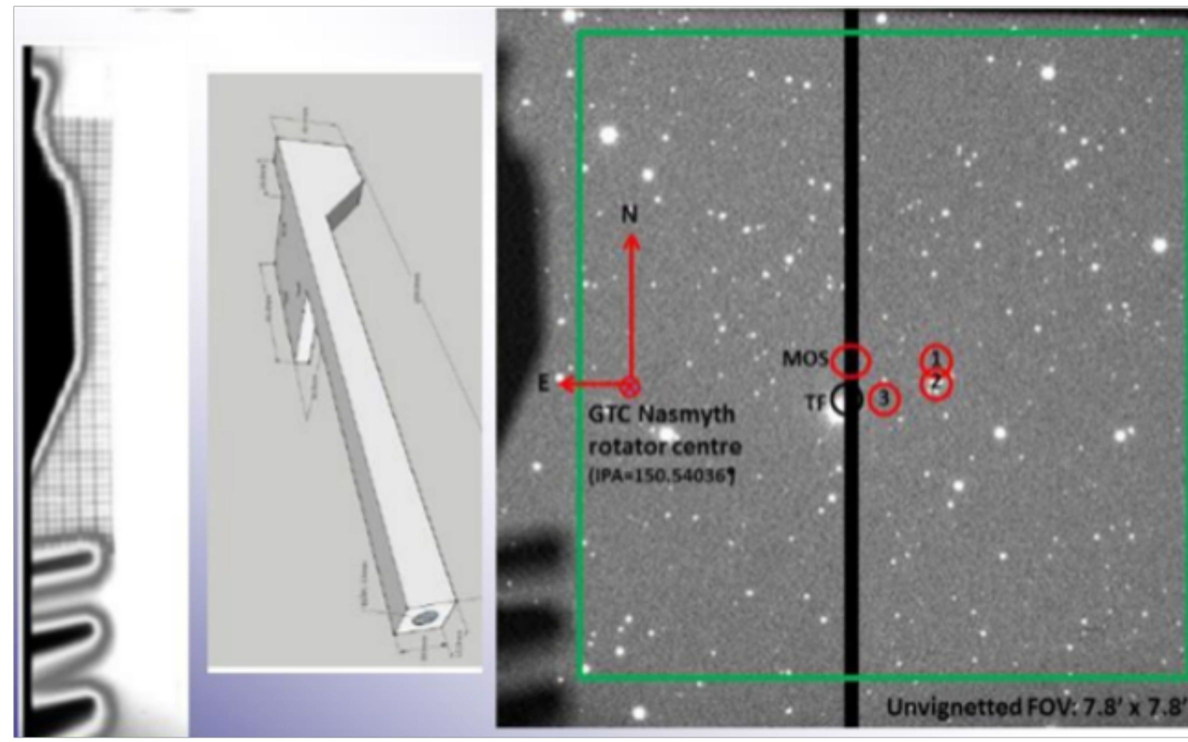


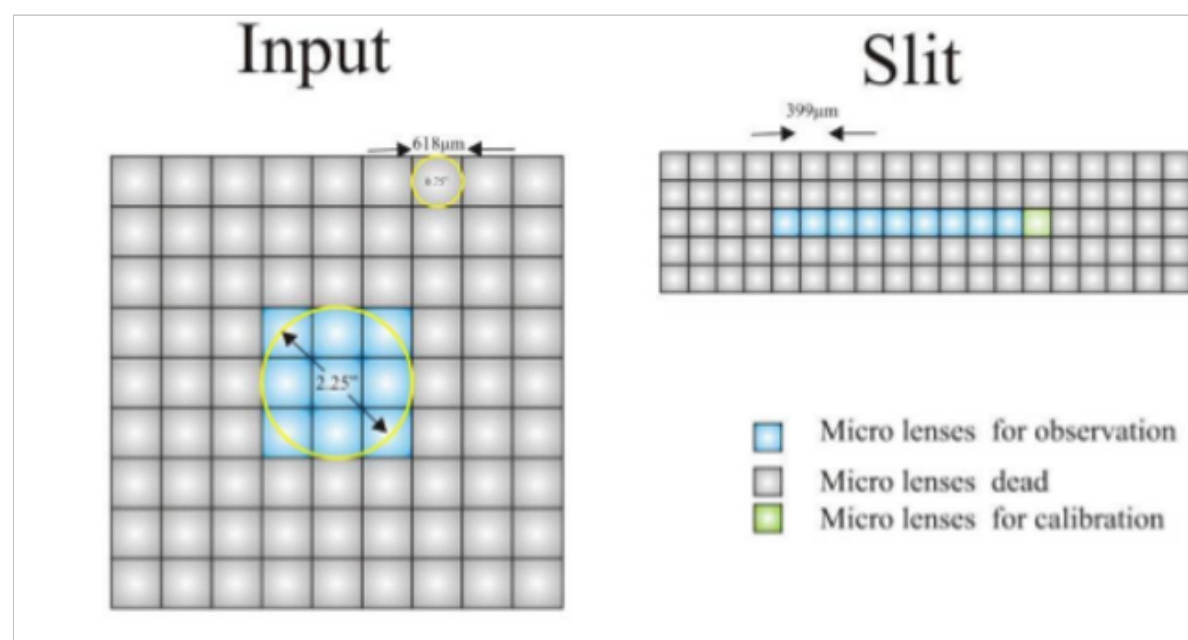


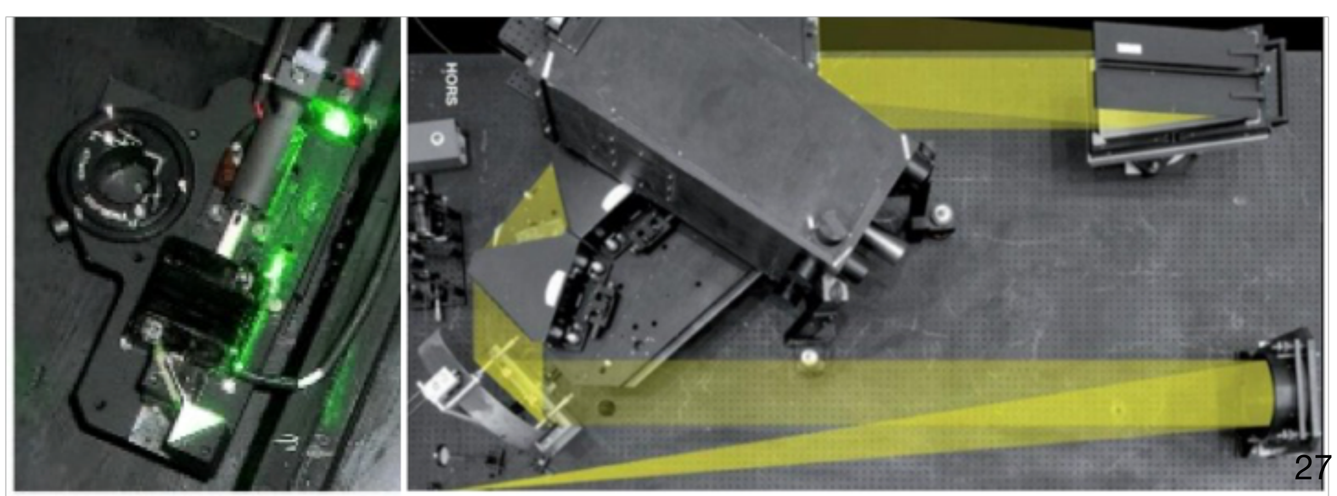
HORUS
High Optical Resolution Spectrograph

Accepted as visitor instrument (Nasmyth B, shared with OSIRIS), in operation from July 2019 to February 2021. Soon <u>vailable at Nasmyth B</u> after OSIRIS migration to Cassegrain, making use of the GTCAO optical bench, before the arrival of FRIDA.

Spectral Range	0.38-0.69 μm
Detector	4096 x 4096 Fairchild CCD486 BI
IFU Field of view	2.3 x 2.3 arcsec^2
Fiber size	0.75 arcsec
Spectral Resolution	25000







CHORUS
Canary Hybrid Optical High-Resolution Ultra-stable Spectrograph

Developed by National Observatories of Chinese Academy of Sciences (NAOC-NIAOT) within the framework of our 2016 Collaboration Agreement.

Subsystems	UV band Spectrograph (UVS)	Visible band Spectrograph (VIS)
Location	Below Nasmyth Platform B	Coudé room
Fiber configuration	Φ1.2" aperture on the sky SCI-C	Φ1.2" aperture on the sky SCI-A, SCI-B
Spectral resolution	R≥25,000	R≥110,000
Wavelength coverage	310-420nm	420-780nm
Wavelength calibration precision	—	~ 10cm/s with LFC
Calibration	Ordinary single fiber calibration	Sim.-Calibration, Sky subtraction
Instrument daily stability	—	Inside Instrument Vacuum Chamber at~16° C (±2° C) ±0.001° C /night Operation pressure in IVC ≤0.001 mbar
Instrument efficiency (from input fiber to detector front)	≥ 17% at peak, ≥ 5% at minimum	≥ 17% at peak, ≥ 8% at minimum

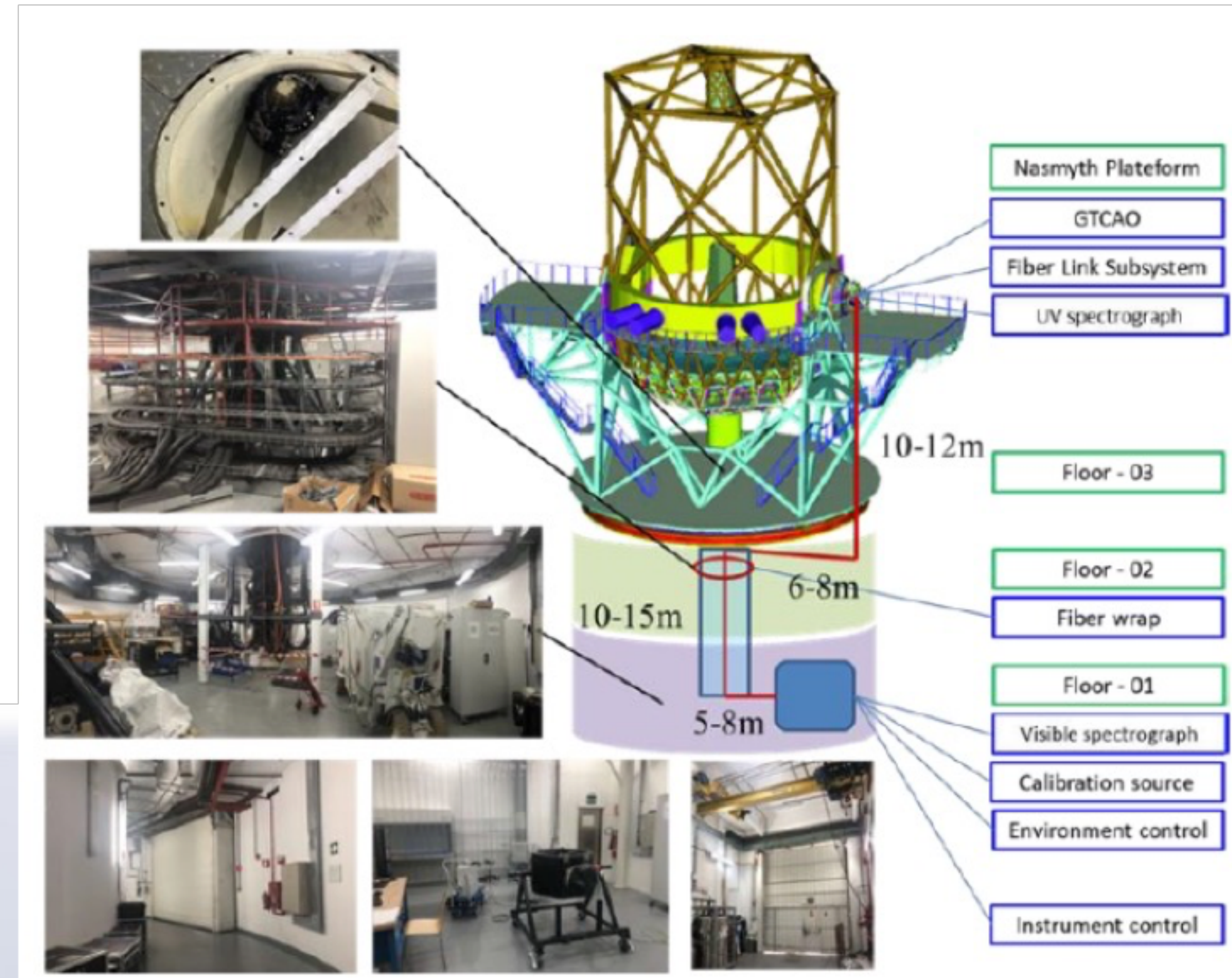
CHORUS
Canary Hybrid Optical High-Resolution Ultra-stable Spectrograph

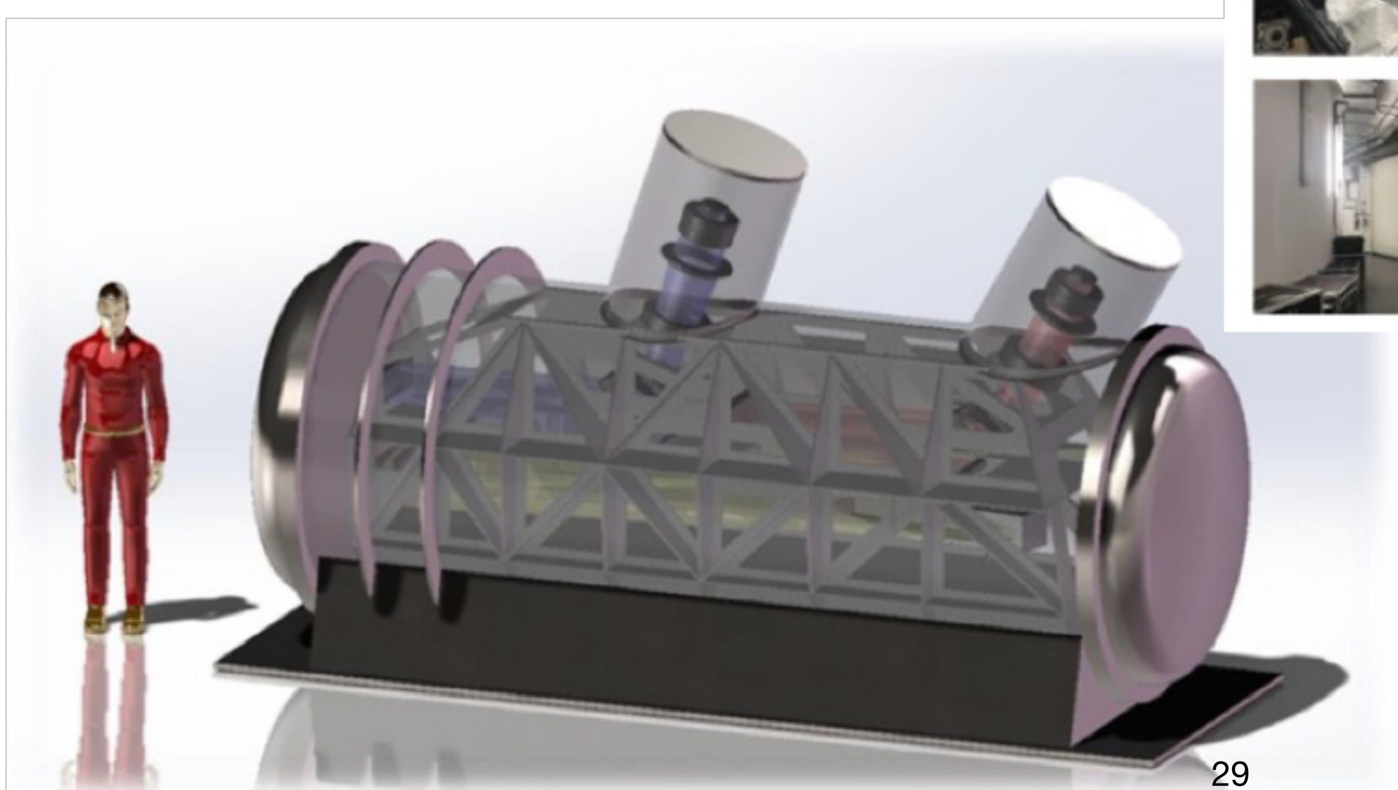
Two separated bands:

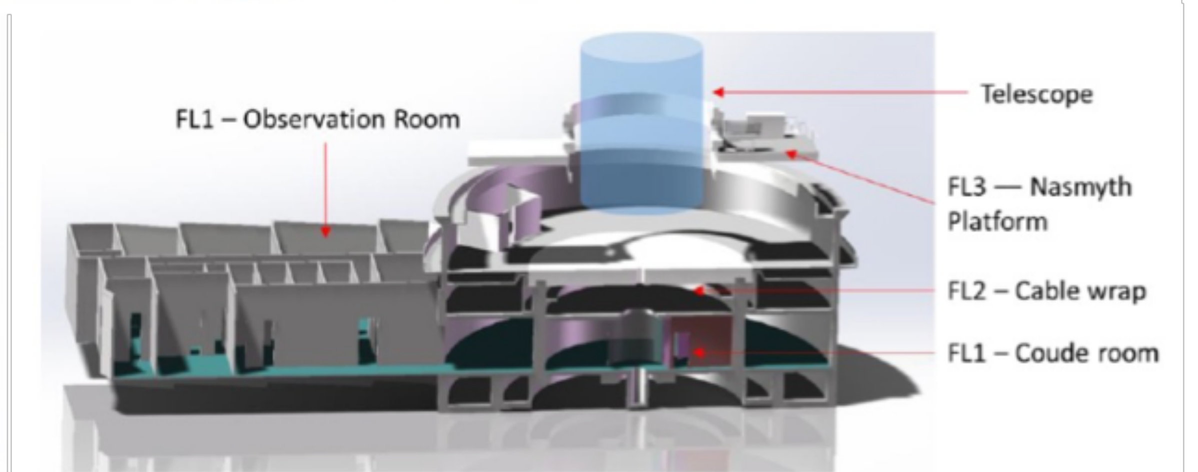
UV @ 310 – 420nm (R > 25000)
Visible @ 420 – 780nm (R>110000)

CAS officially approved the funding for CHORUS. **<u>PDR at IAC held in Sept 2023.</u>**

Instrument delivery 2027.

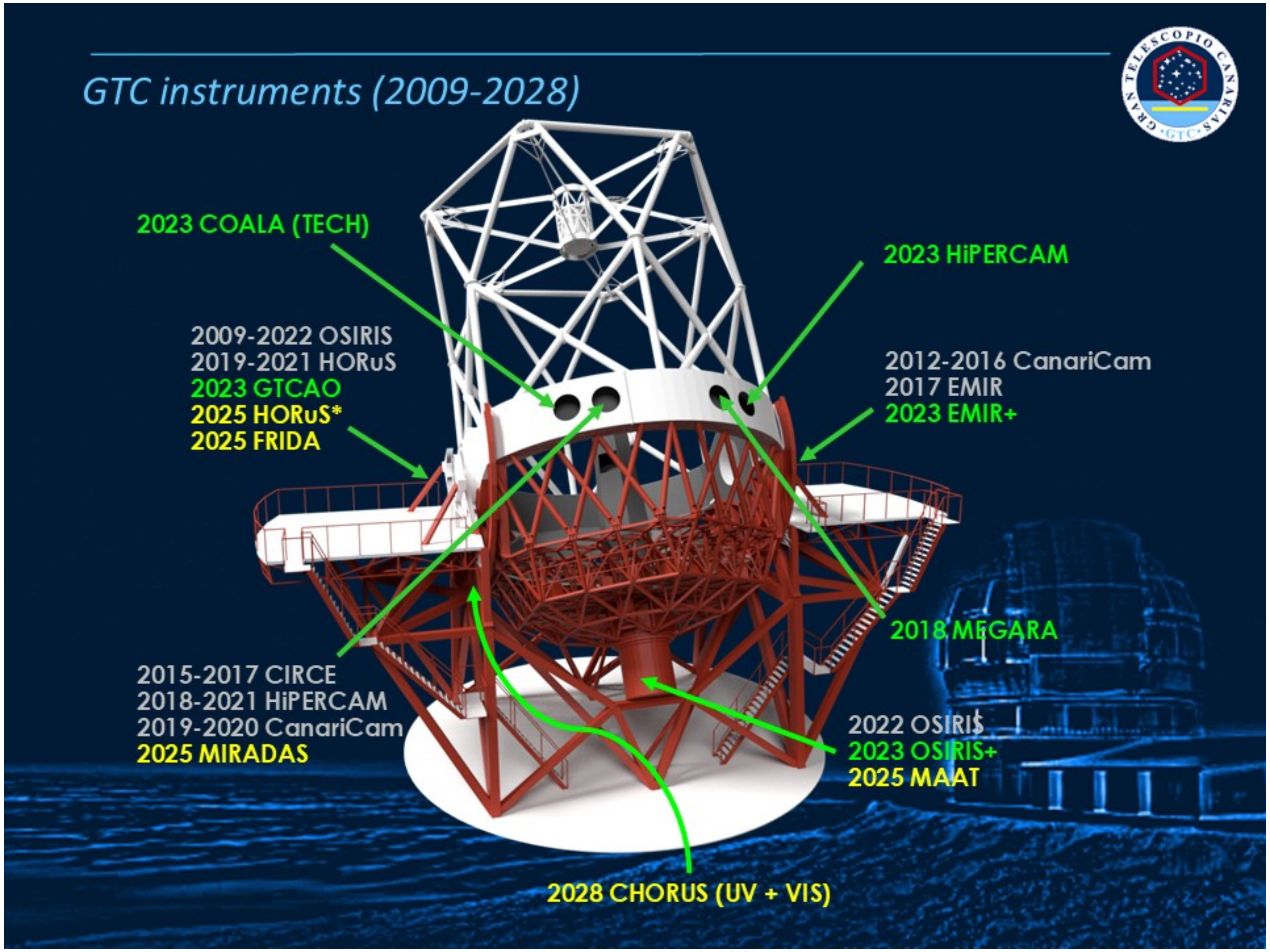






Call for a new instrument ongoing

2030+



GTC Proposals

- Proposal call are opened every semester for the **Spanish community;** Regular, Large Program (max. 100 h) and Filler
- As stakeholder institutions, Mexico and University of Florida have access to a fixed number of hours per semester
- Chinese community collaborative agreement
- Each institution handle its own proposals independently
- Director's Discretionary Time (DDT) can be submitted any time by members of the Spanish community, Mexico and University of Florida.
- International Time Program (ITP): 5% of the observation time of each telescope based at the Roque de los Muchachos Observatory, with the aim to provide an international collaborative framework. Proposal call opened yearly

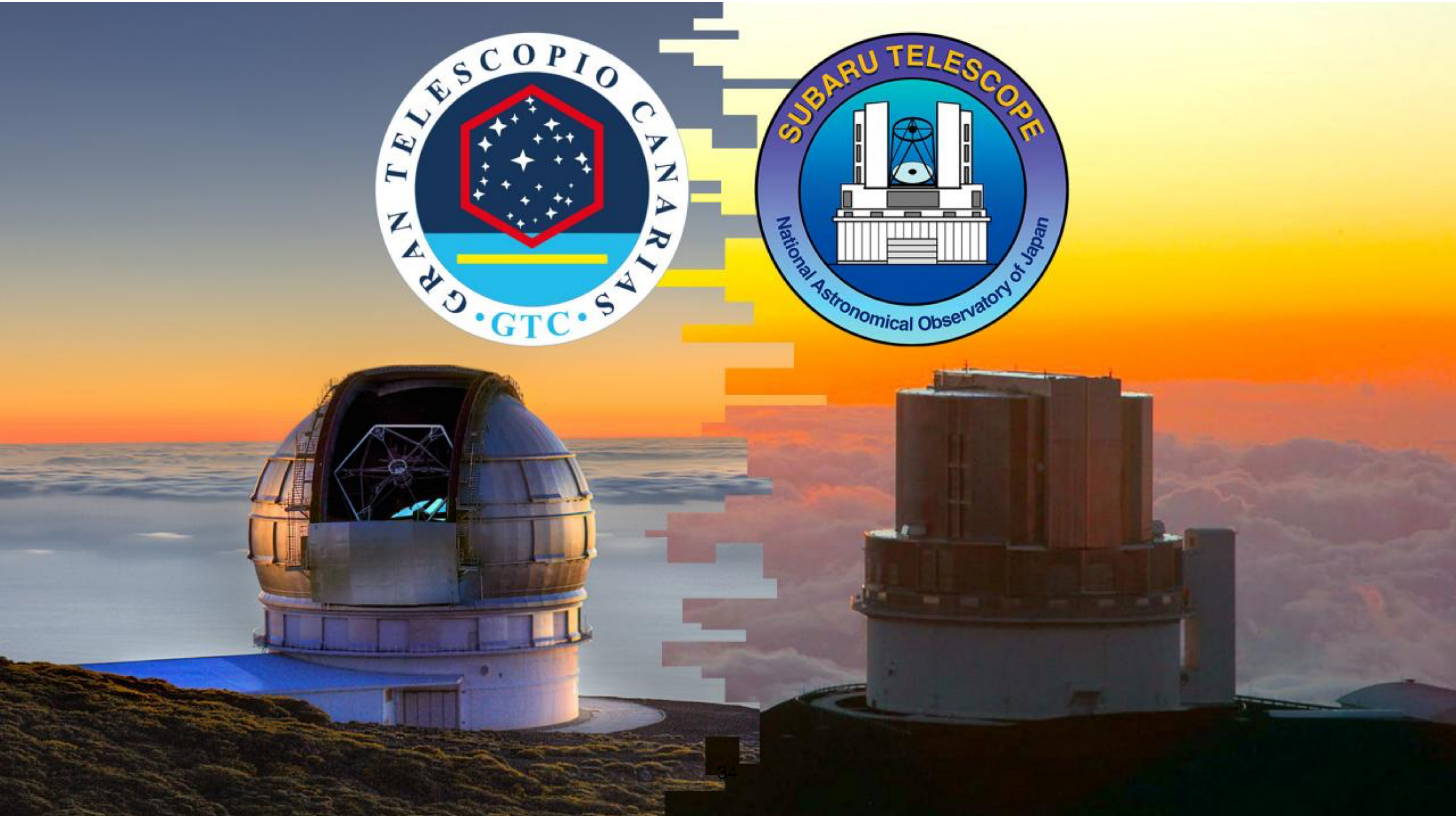
Observing with GTC

- The observations are typically carried out in queue mode in order to optimize the scheduling and adapt to weather requirements
- Visitor mode can be requested
- ToO observations can be triggered at any moment, even during the night
- No time restrictions for ToO duration, except the recommendations from the Time Allocation Committee
- Observation blocks are submitted and executed by the Support Astronomer on site

GTC-Subaru synergies

Capitalize the use of GTC & Subaru joint capabilities

GTC instrument versatility + Subaru Hyper Suprime Cam (HSC)
Collaboration from 2019



Does Light Emerge from a Black Hole Merger?: Subaru+GTC Collaboration to Target Gravitational Wave Events

April 12, 2023
Last updated: May 7, 2024

A research team led by researchers from the National Astronomical Observatory of Japan (NAOJ) and the Instituto de Astrofísica de Canarias (IAC) in Spain performed follow-up observations of a gravitational wave event using the Subaru Telescope and the Gran Telescopio CANARIAS (GTC) to search for electromagnetic emission from a binary black hole coalescence. The collaboration between the wide-field deep imaging capability of the Subaru Telescope and the observing flexibility of GTC played an important role in this study. The cooperative follow-up of a large number of gravitational wave events will elucidate the nature of these enigmatic phenomena.

zoom

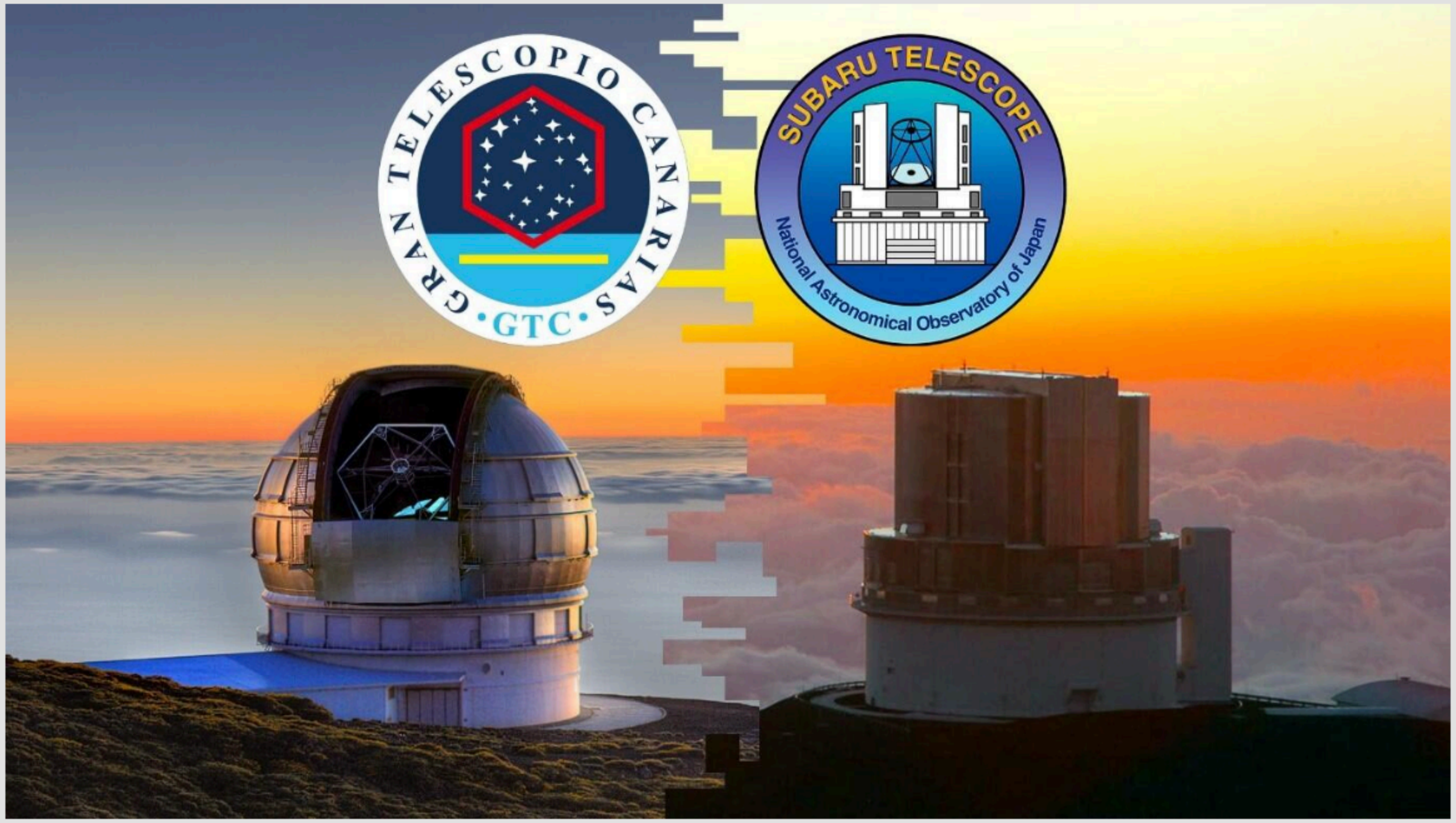


Figure 1: The combination of the deep and wide field capability of the Subaru Telescope and the flexible spectroscopic follow-up by GTC plays a key role in revealing the nature of electromagnetic radiation related to gravitational wave events. (Credit: Gabriel Pérez, IAC)

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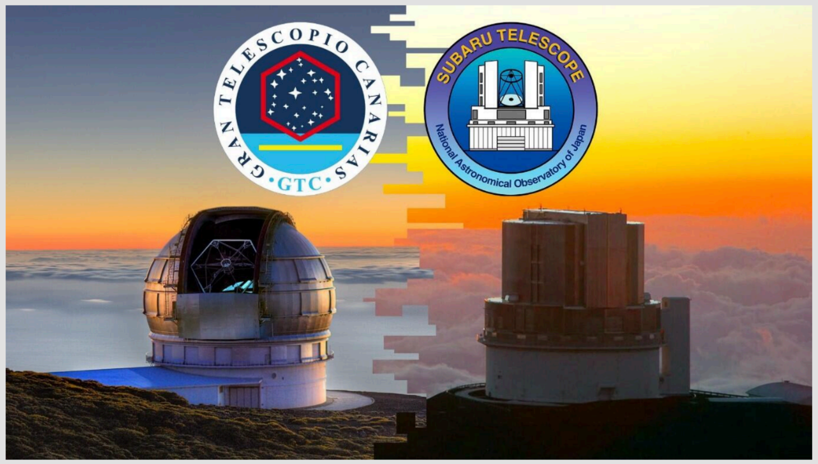

Figure 1: The combination of the deep and wide field capability of the Subaru Telescope and the flexible spectroscopic follow-up by GTC plays a key role in revealing the nature of electromagnetic radiation related to gravitational wave events. (Credit: Gabriel Pérez, IAC)

- LIGO/Virgo detection S200224ca, 50 deg2 error box @90% credible region
- Binary-black hole coalescence on 24 February 2020
- Subaru Hyper Suprime Camera survey covered 91% of the region
- Identification of 19 transient events during 3 different observation nights
- GTC spectroscopic follow up of possible host galaxies
- Work led by Ohgami & Tominaga

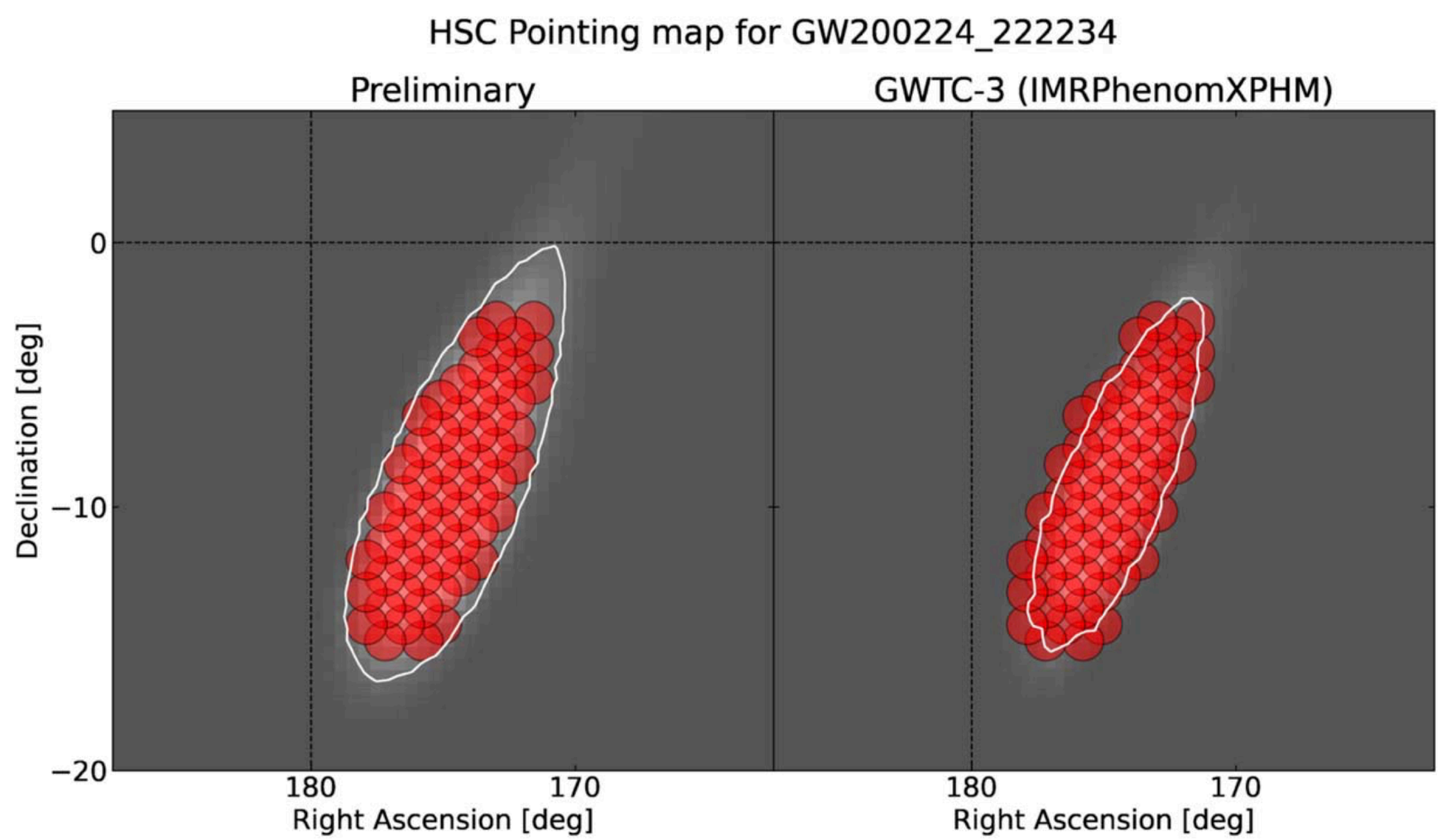

Figure 1. Observation pointings with the Subaru/HSC (filled red circles). The left and right panels are the preliminary localization skymap of GW200224_222234 (BAYESTAR; LIGO Scientific Collaboration & Virgo Collaboration 2020) and a refined version using the IMRPhenomXPHM model (GWTC-3 catalog; The LIGO Scientific Collaboration et al. 2021), respectively. The white contour lines indicate the 90% credible regions.

Ohgami et al. 2023

Optical spectroscopic follow up with GTC

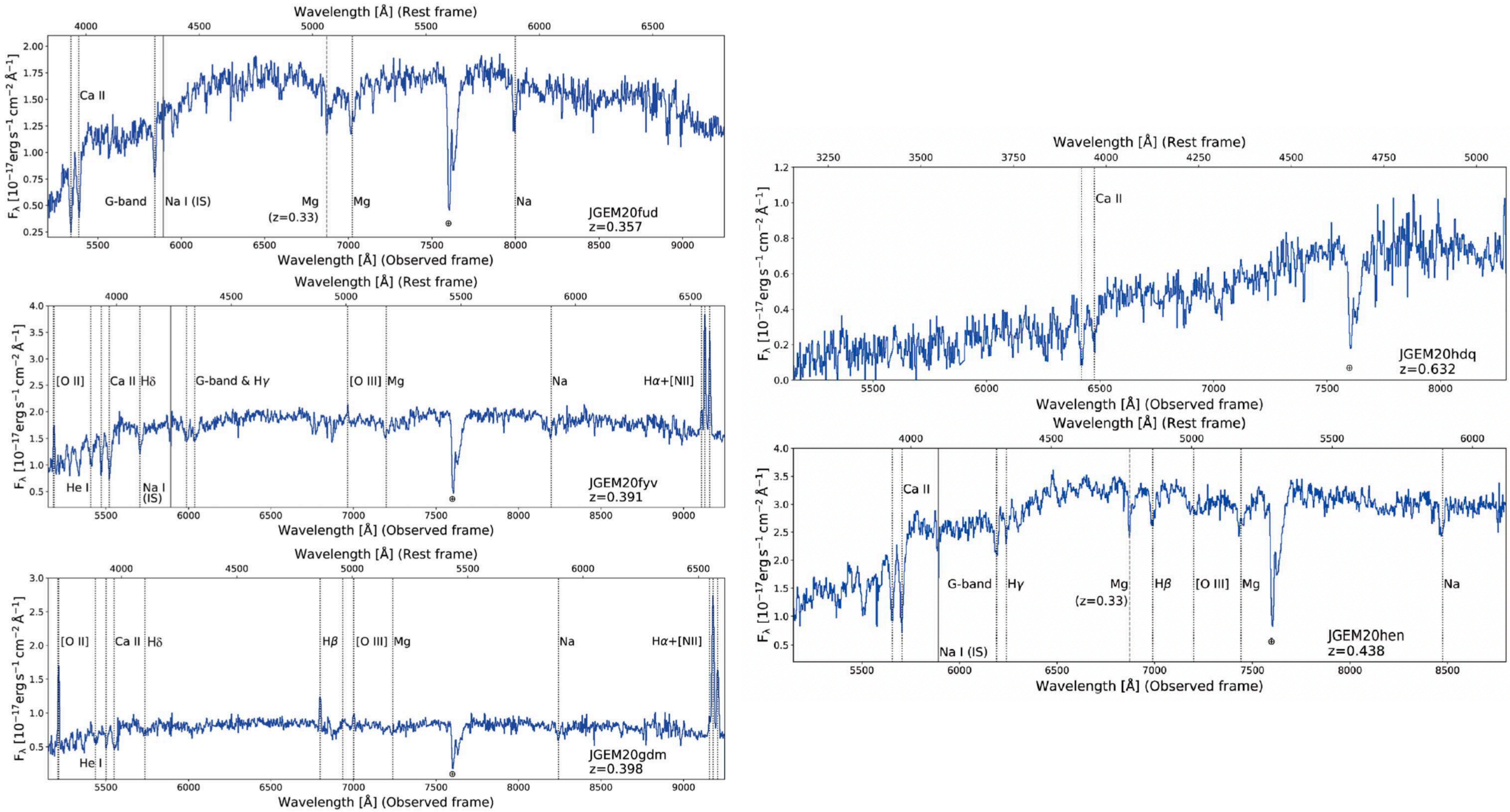

Figure 10. Optical spectra of candidates JGEM20fud, JGEM20fyv, JGEM20gdm, JGEM20hdq, and JGEM20hen observed with the GTC. The identified spectral features are marked by vertical dotted lines. The Na interstellar absorption feature is denoted by the solid vertical line. The emission lines identified as intervening systems are marked by dashed lines.

Ohgami et al. 2023

GTC-Subaru collaborative projects

- Research topics covered so far (see P29 by Tomoki Morokuma):
  - Gravitational wave counter electromagnetic counterpart searches*
  - Supernovae spectroscopic follow up
  - Fading quasar
- Open to explore some possible new topics
- **GTC Director Discretionary Time (DDT): 10 h*** (currently dedicated to GW electromagnetic counterpart searches)
- Large aperture telescopes synergies
- Subaru capabilities for large field of view observations
- GTC can use the different instruments during the same night
- High impact projects which maximize the joint scientific return from Subaru and GTC

Thank you!