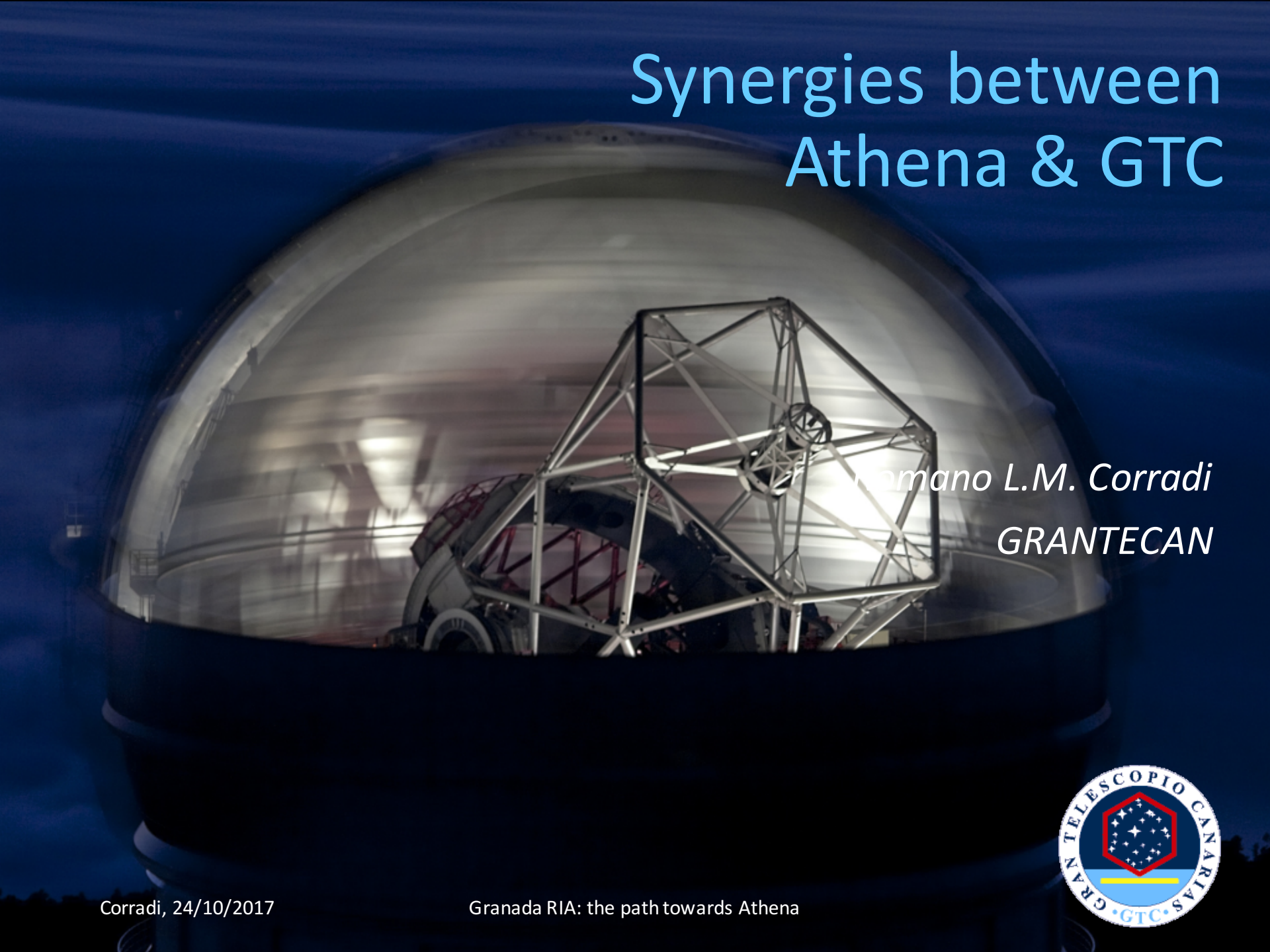
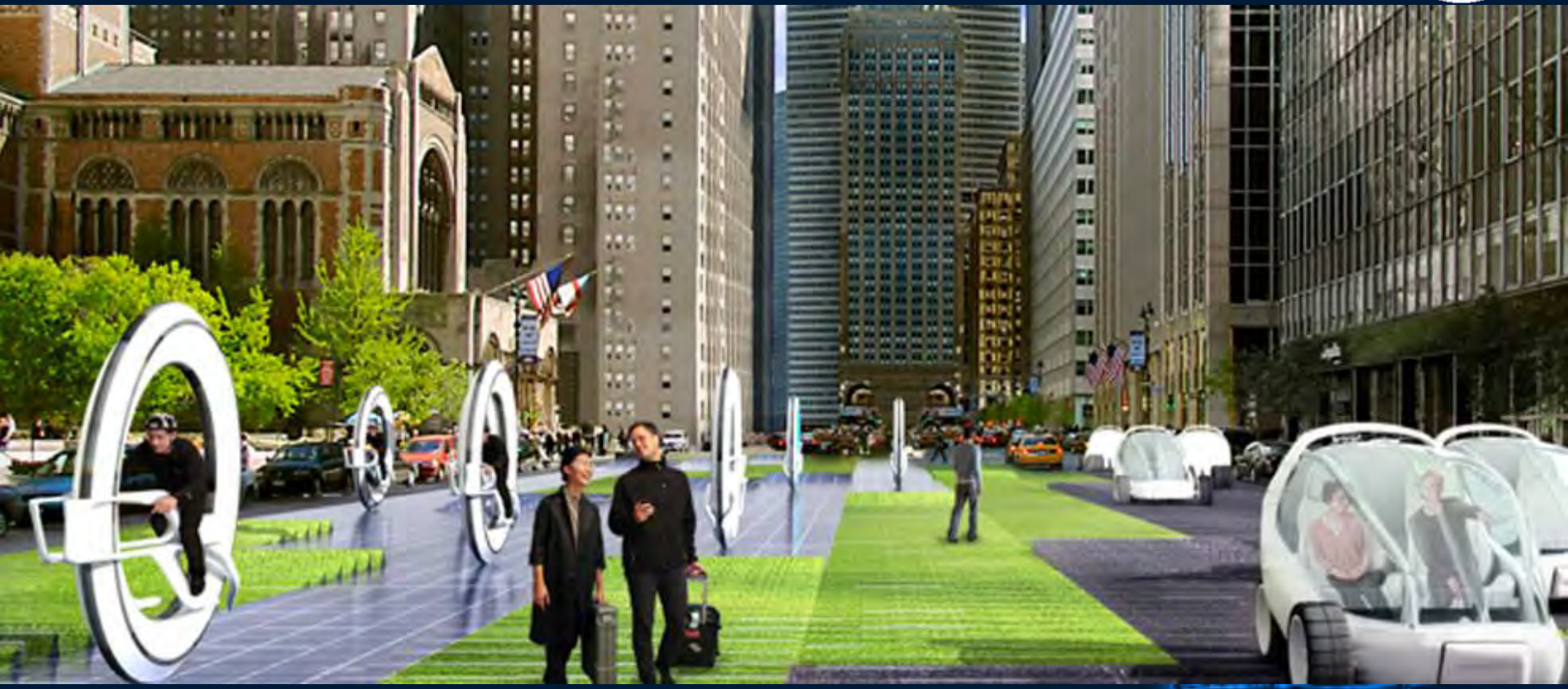
Synergies between Athena & GTC

[redacted]mano L.M. Corradi

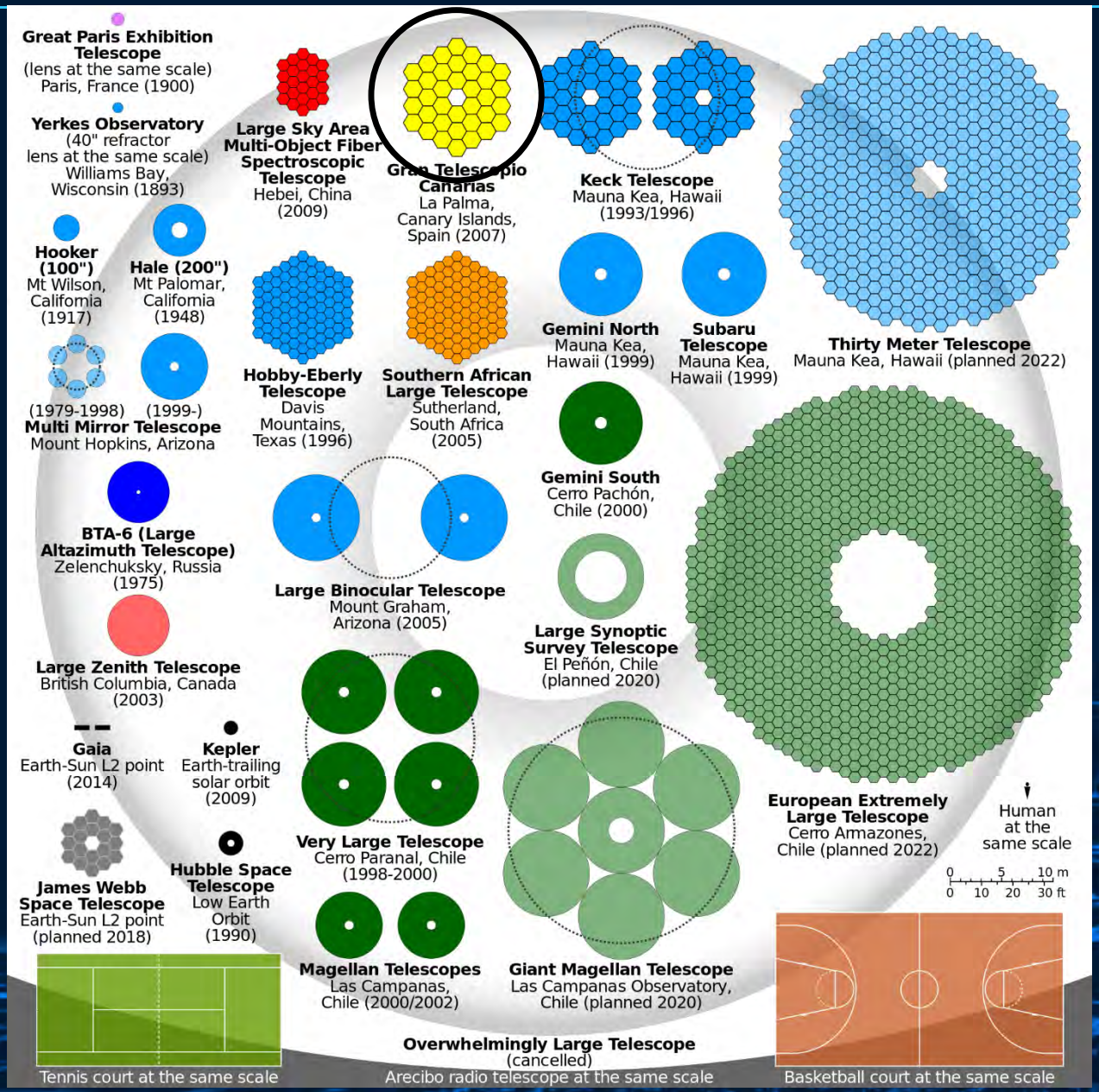
GRANTECAN



2030…



2030…


Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor lens at the same scale)
Williams Bay, Wisconsin (1893)
Hooker (100")
Mt Wilson, California (1917)
Hale (200")
Mt Palomar, California (1948)
(1979-1998) (1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia (1975)
Large Zenith Telescope
British Columbia, Canada (2003)
Gaia
Earth-Sun L2 point (2014)
Kepler
Earth-trailing solar orbit (2009)
James Webb Space Telescope
Earth-Sun L2 point (planned 2018)
Hubble Space Telescope
Low Earth Orbit (1990)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China (2009)
Gran Telescopio Canarias
La Palma, Canary Islands, Spain (2007)
Keck Telescope
Mauna Kea, Hawaii (1993/1996)
Hobby-Eberly Telescope
Davis Mountains, Texas (1996)
Southern African Large Telescope
Sutherland, South Africa (2005)
Gemini North
Mauna Kea, Hawaii (1999)
Subaru Telescope
Mauna Kea, Hawaii (1999)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
Large Binocular Telescope
Mount Graham, Arizona (2005)
Gemini South
Cerro Pachón, Chile (2000)
Large Synoptic Survey Telescope
El Peñón, Chile (planned 2020)
Very Large Telescope
Cerro Paranal, Chile (1998-2000)
Magellan Telescopes
Las Campanas, Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory, Chile (planned 2020)
European Extremely Large Telescope
Cerro Armazones, Chile (planned 2022)
Human at the same scale
0 5 10 m
0 10 20 30 ft
Overwhelmingly Large Telescope
(cancelled)
Arecibo radio telescope at the same scale
Tennis court at the same scale
Basketball court at the same scale

GTC today

- Funded by Spain (90%), México (5%), and the University of Florida (2.5-5%)
- Belongs to the set of Spanish *Unique Scientific & Technical Infrastructures*
- Construction started in 2000, first light in 2007, operations started in 2009
- Located at Observatorio del Roque de los Muchachos, La Palma
- 10.4 m alt-az , Ritchey-Chrétien configuration
- Effective collecting area 73 m^2
- Effective focal length 169.9 m → plate scale 1.21 arcsec mm^{-1}

Focus	Field of view Ø
Nasmyth	20 arcmin (1 m)
Cassegrain	15 arcmin
Folded Cass.	5 arcmin

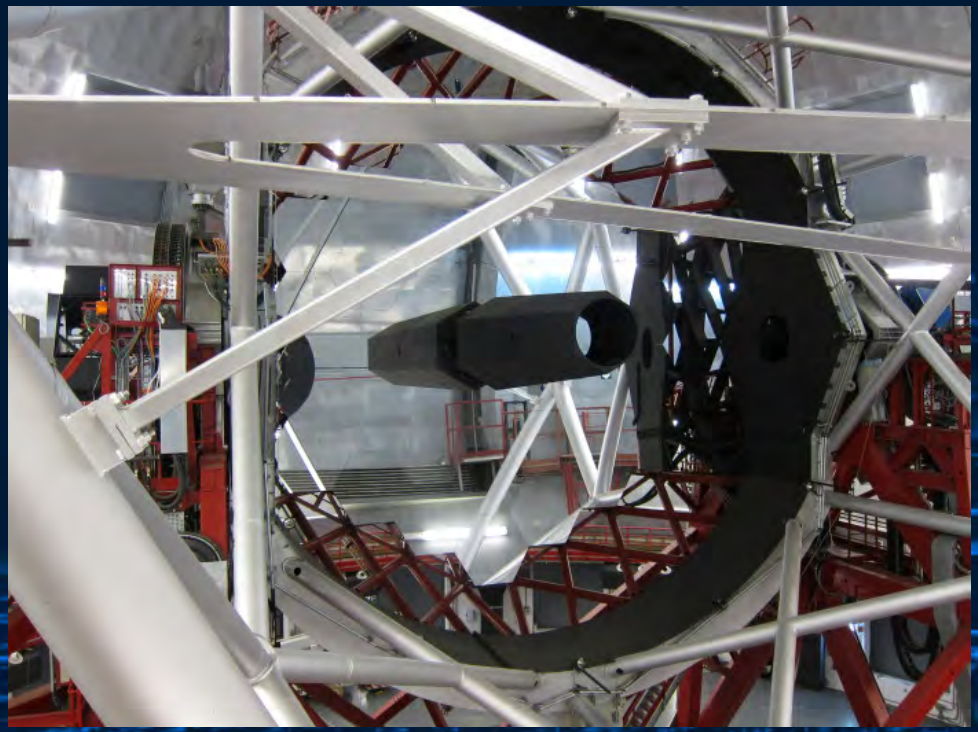
- Total tel. moving weight 400 t

M1

36(+6) hexagonal aluminium-coated Zerodur segments 1.9m wide, 8cm thick, of 6 different types

Total weight = 17 tonnes

Open/closed-loop active-optics control provided by 108 positioners (piston and tip-tilt), 216 moment actuators, and 168 position sensors (capacitive edge-sensors) → 324 active degrees of freedom (72 for stacking, 36 for phasing, and 216 for change of segment figure)



M2

Aluminium-coated beryllium, 118 cm wide, 13 cm thick, 35 kg weight.

M2 provides GTC aperture stop.

5 active degrees of freedom → alignment, chopping, tip-tilt correction

The focal stations

M3 (flat elliptical 1.5x 1.1 m) position select focal station in <5 min.

Available foci:

2 Nasmyth

1 Cassegrain

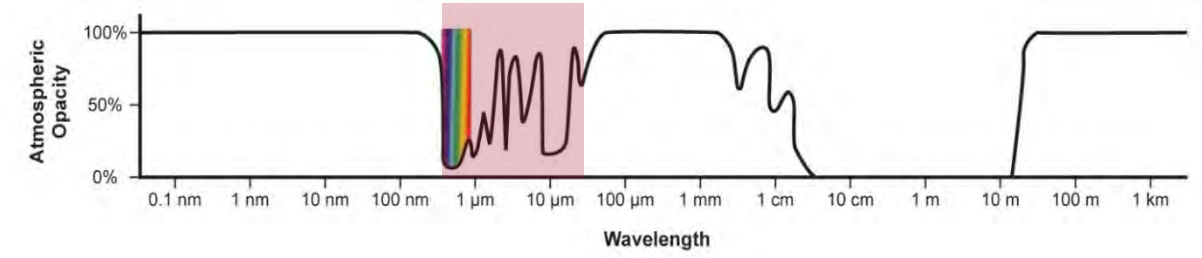
4 folded Cass.

[Coudé]

[prime]

GTC designed to serve the whole scientific community

- general-purpose instruments covering the whole atmospheric transmission window (0.3-25 microns)

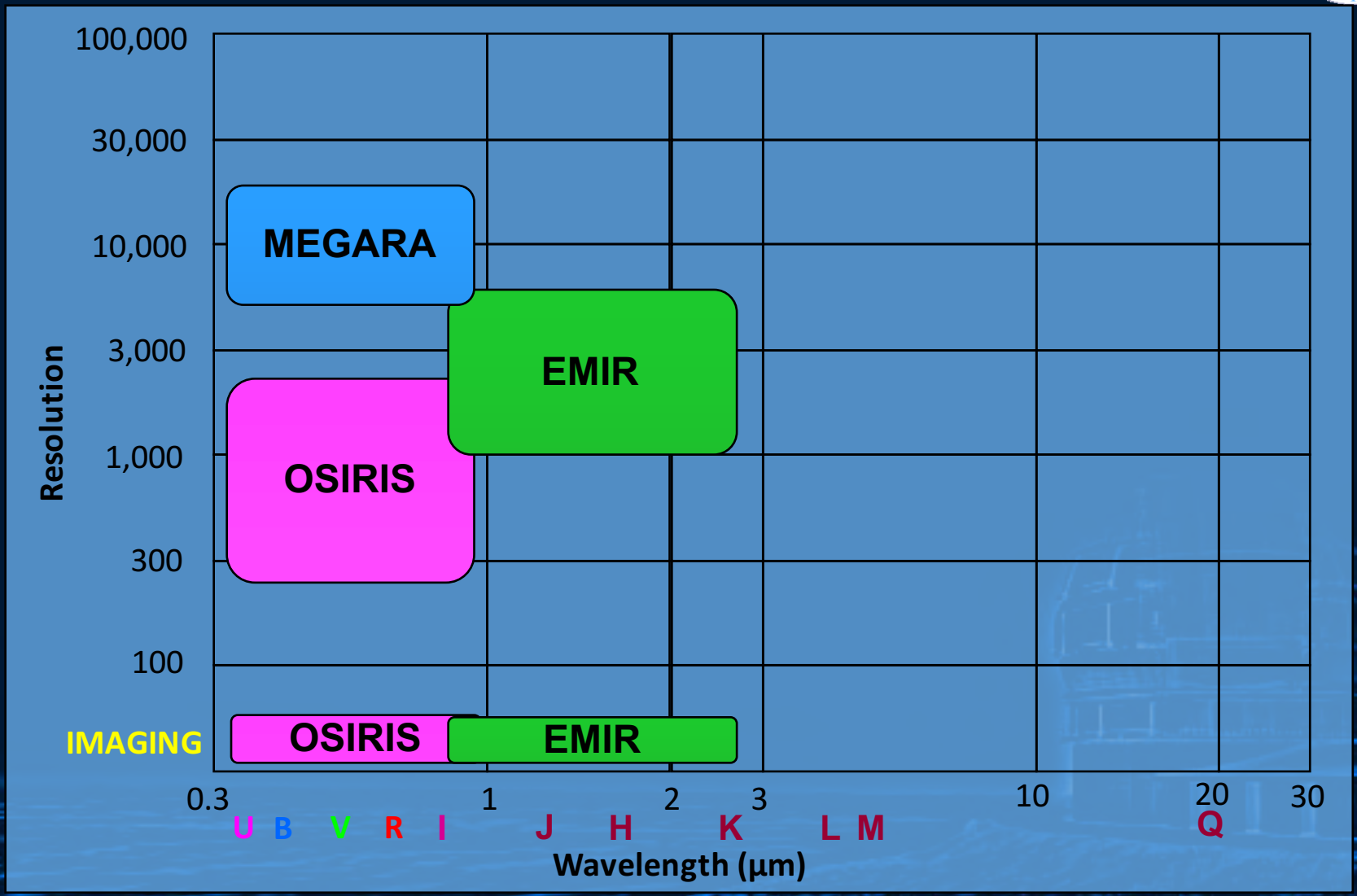


- + instruments with specific and unique capabilities.

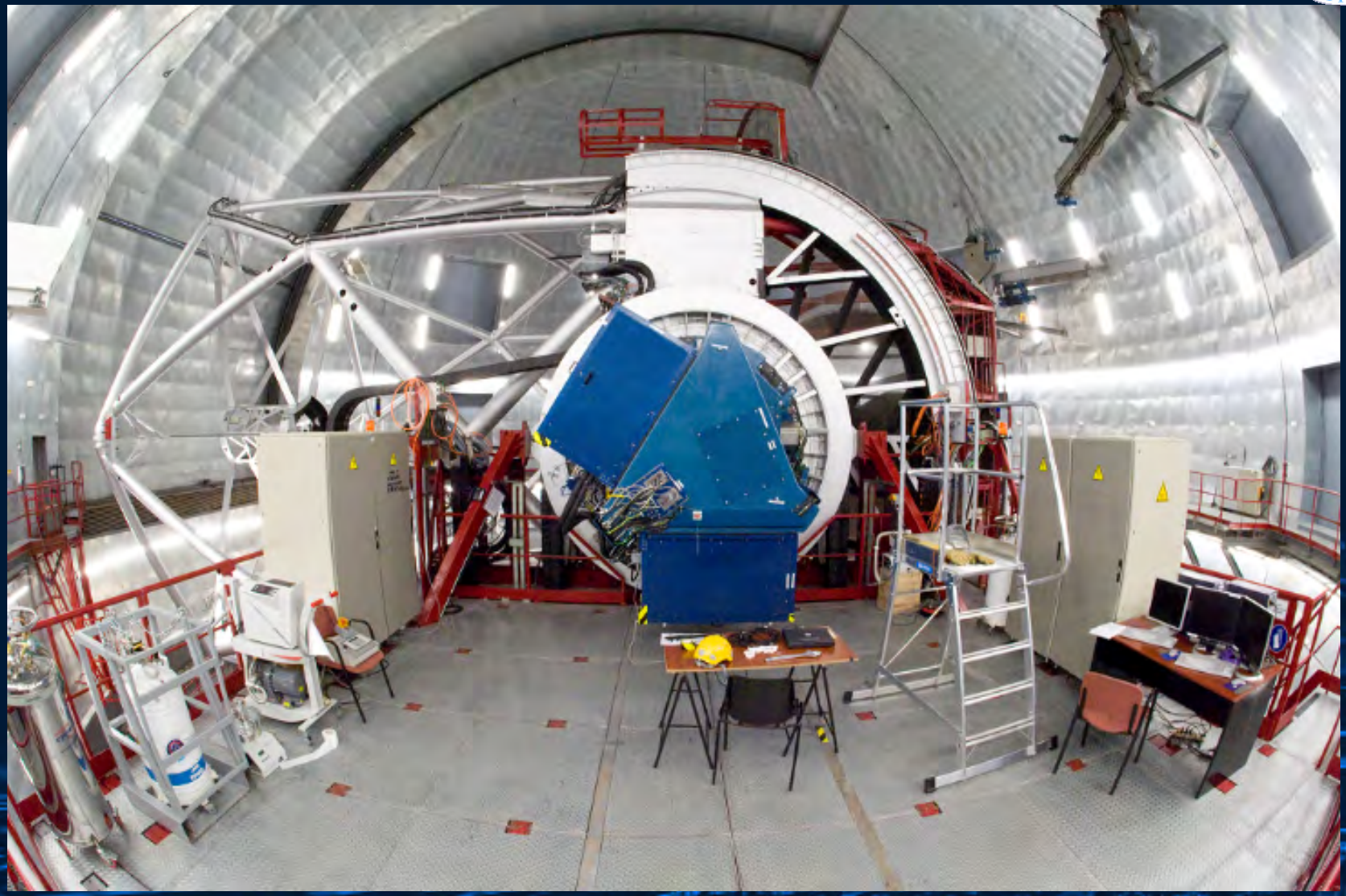
Distinguished features are:

- Tunable/custom filters (OSIRIS)
- MOS/IFU at low and intermediate resolution (OSIRIS, EMIR, MEGARA, MIRADAS)
- IR polarimetry (CIRCE, CanariCam)
- High throughput (MEGARA, MIRADAS)

GTC instrumentation today



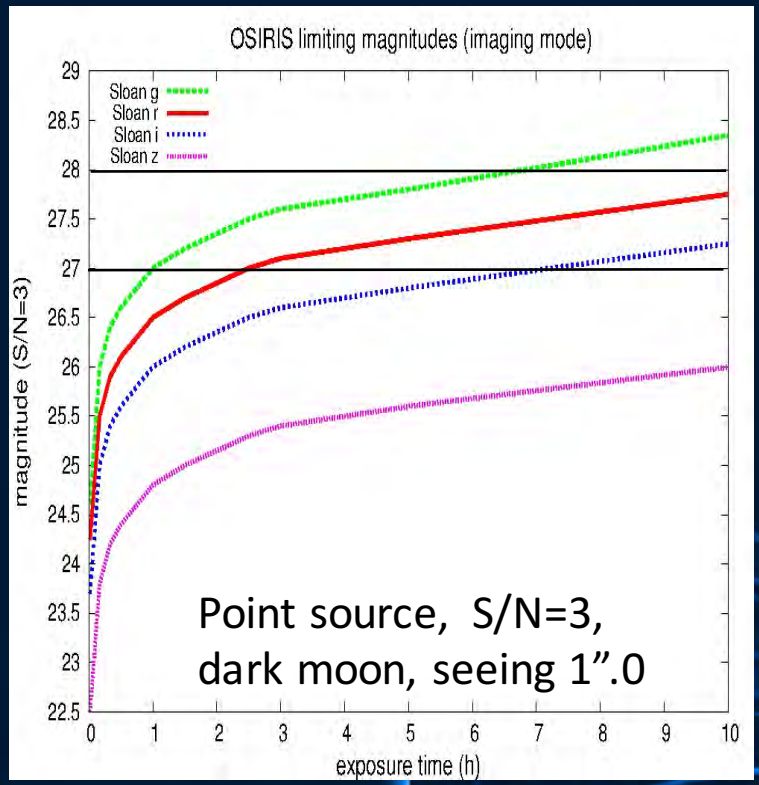
OSIRIS optical imager and spectrograph



OSIRIS imager and multi-object spectrograph

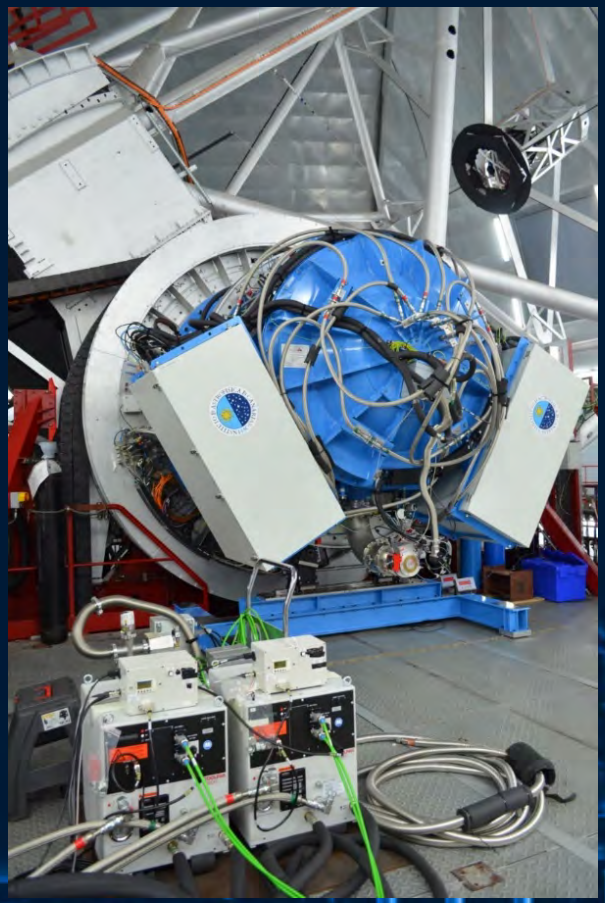
Common-user instrument since 2009. Developed at the IAC.

Spectral Range	0.36-1.00 µm
Detector	2 x Marconi 2k x 4k
Plate Scale	0.125 arcsec pix^{-1}
Field of view	7.8 x 7.8 $arcmin^2$
Imaging modes	broad/medium band, TFs, fast photometry
Spectroscopic modes	long-slit, mask MOS
Spectral resolution	300 to 2500



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.		$1.4x10^{-18}$ 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~22.8 in 1h, for S/N=5 & 0.6 arcsec aperture

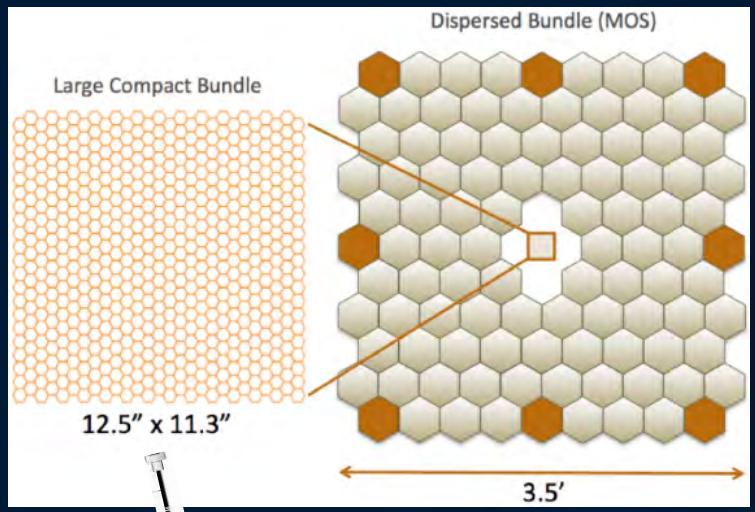


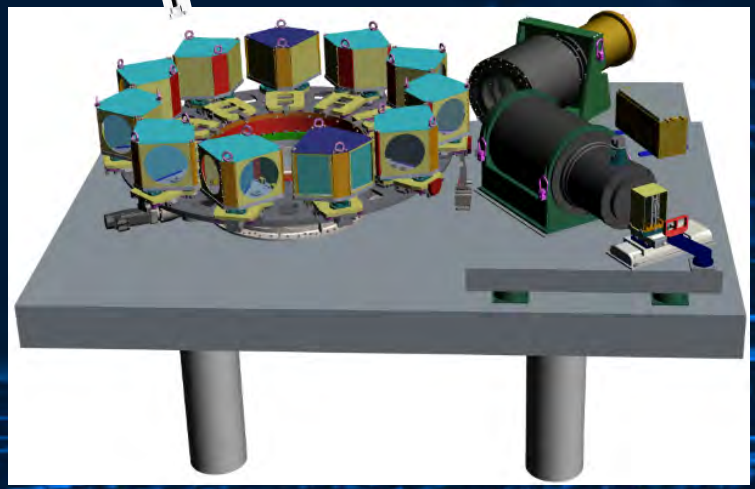
EMIR NIR imager and multi-object spectrograph

MEGARA optical medium-res multi-object spectrograph

Commissioned on summer 2017.

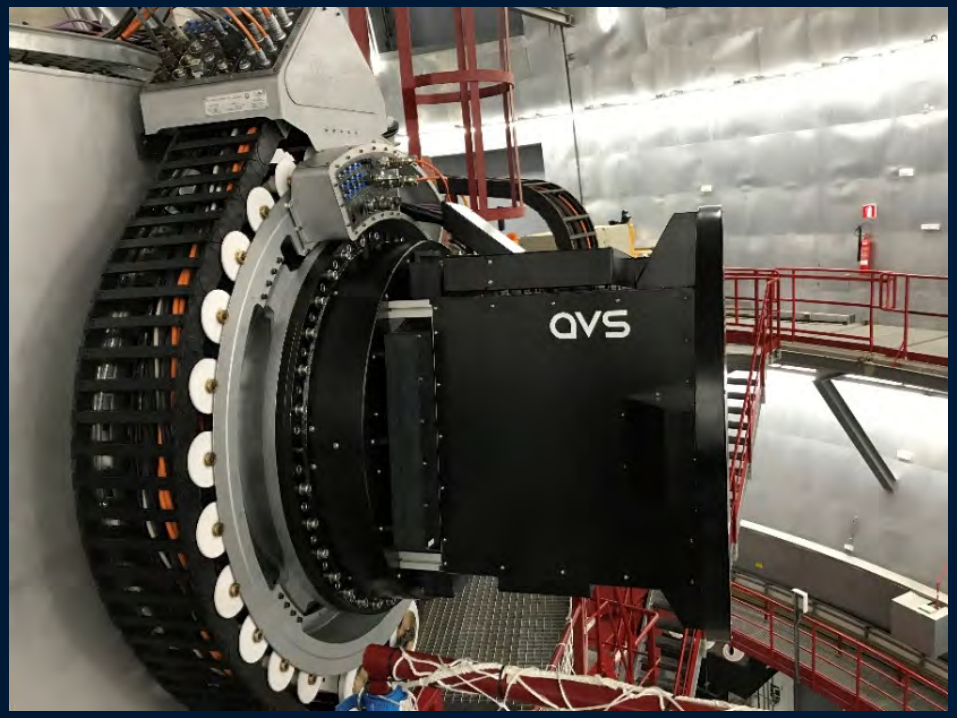
Spectral range	0.365-1.000 µm
Detector	E2V CCD231-84-1-E74
IFU field of view	12.5 x 11.3 arcsec^2
IFU spaxel size	0.62 arcsec
MOS	100 x 7-fibre mini-IFUs
MOS field of view	3.5 x 3.5 arcmin^2
Spectral resolution	6000 to 18700
# of spectra	650



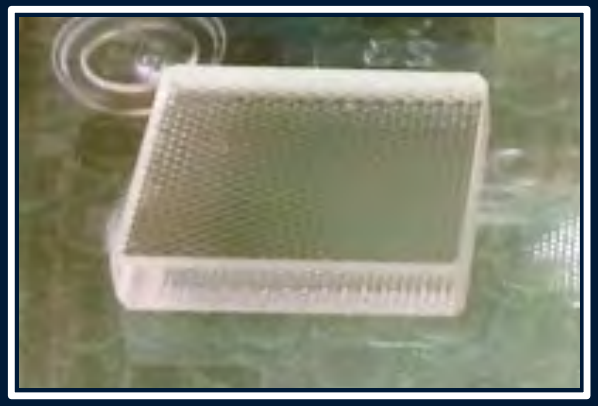


MEGARA

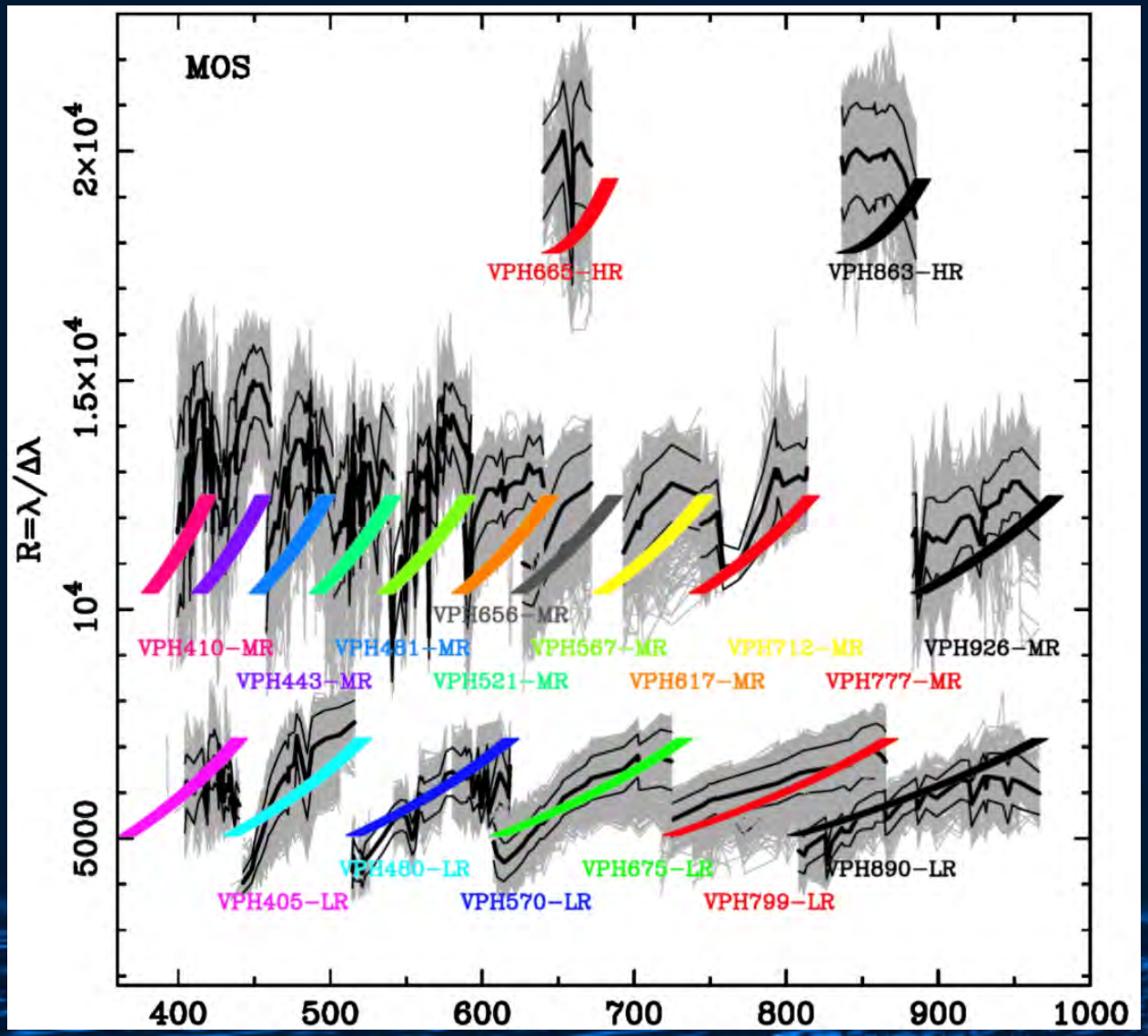
Commissioned on summer 2017.



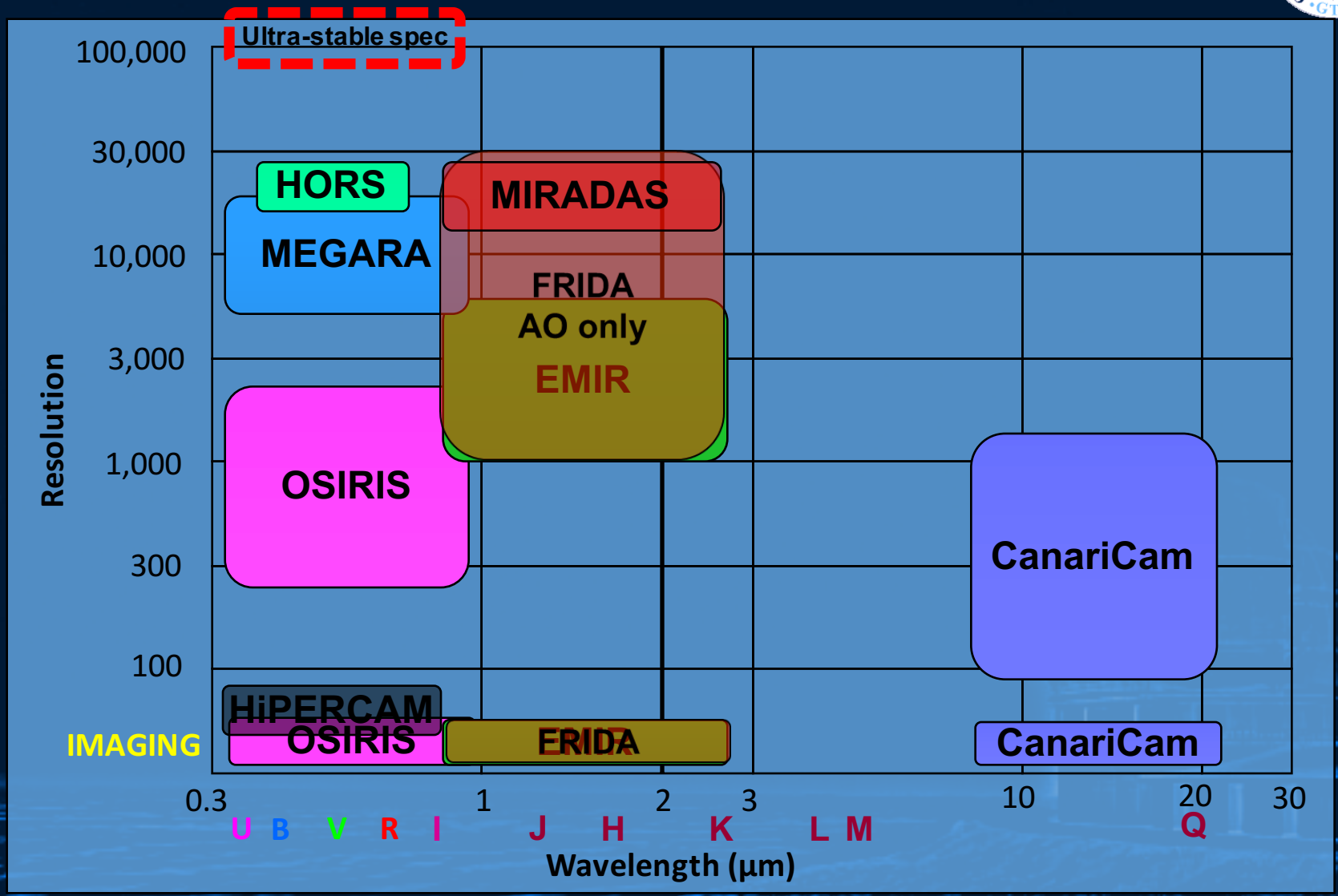
IFU microlens array → focal ratio from f/17 to f/3



MEGARA performance



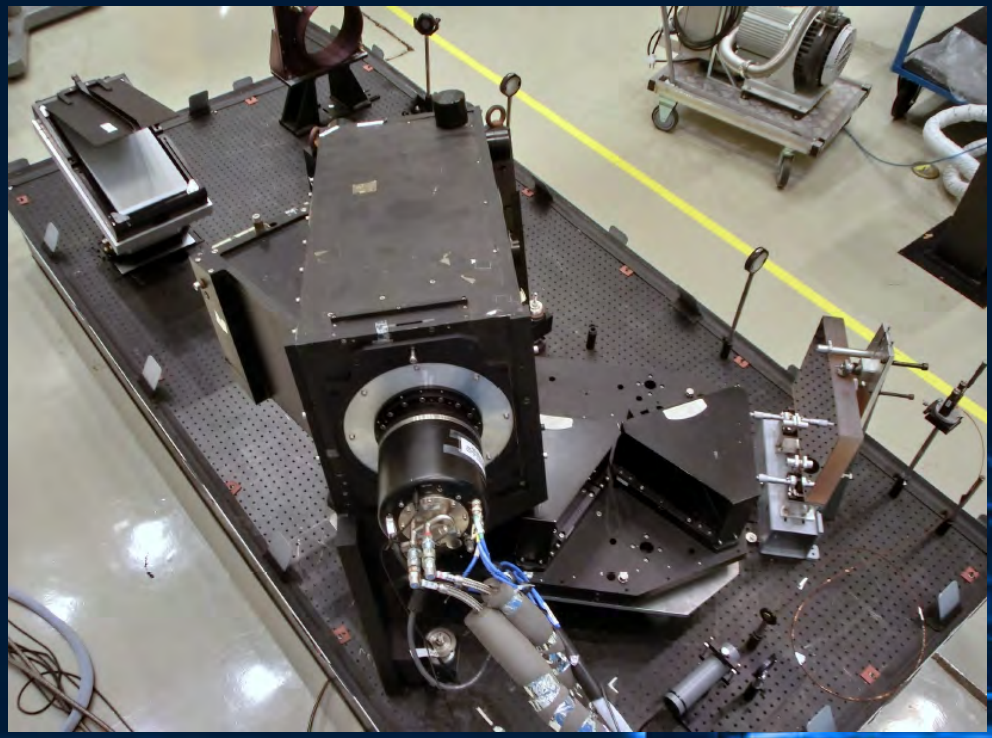
GTC instrumentation 2018-2021



HORS fiber-fed echelle spectrograph

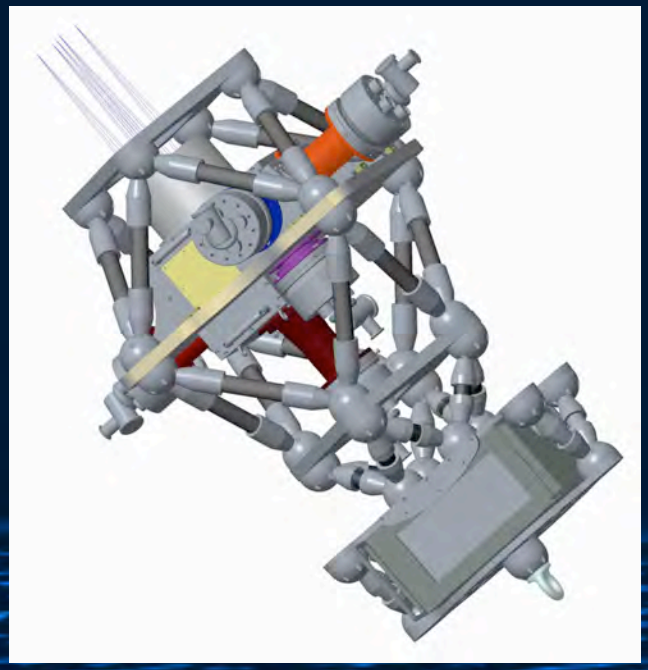
Being developed at the IAC, as an evolution of the UES spectrograph formerly used at the 4.2m WHT. Visitor instrument under commissioning, will share the Nasmyth focus with OSIRIS.

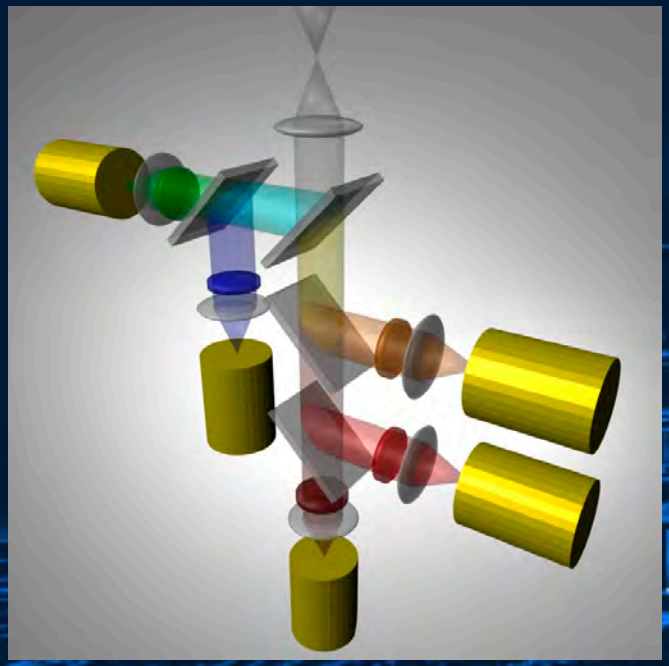
Spectral range	0.40-0.67 µm
Field of view	2.1 arcsec mini-IFU
Spectral resolution	25000



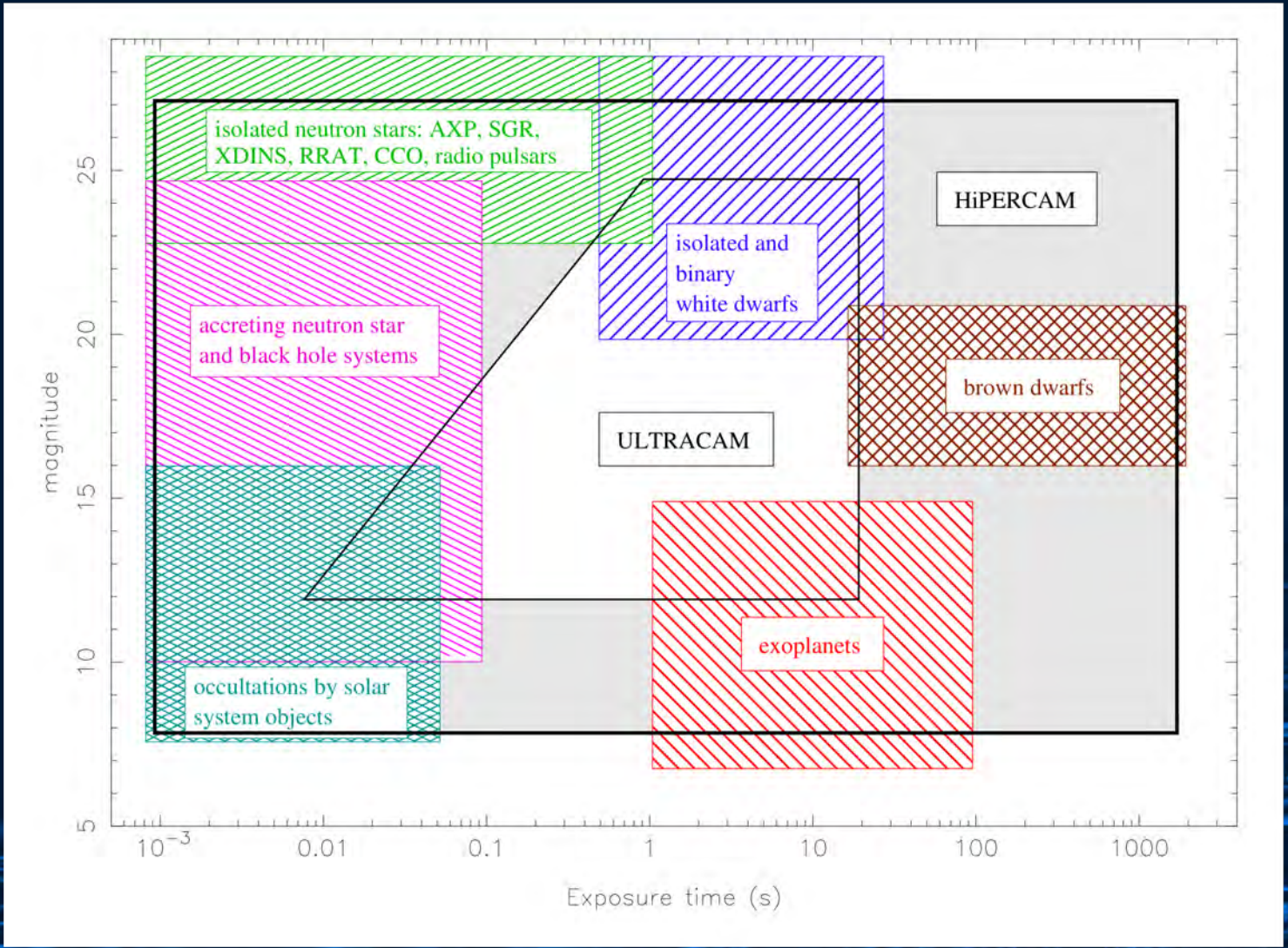
HiPERCAM (High PERformance CAMera)

- Is being commissioned on the 4.2m WHT now. Offered at the GTC starting from January 2018.
- 5 arms covering u g r i z → single-shot optical SED
- Fast photometry >1000 Hz frame rate (5 customed e2v CCD231-42 split frame-transfer detectors, Peltier cooled with deep depletion and fringe suppression)
- Scintillation correction

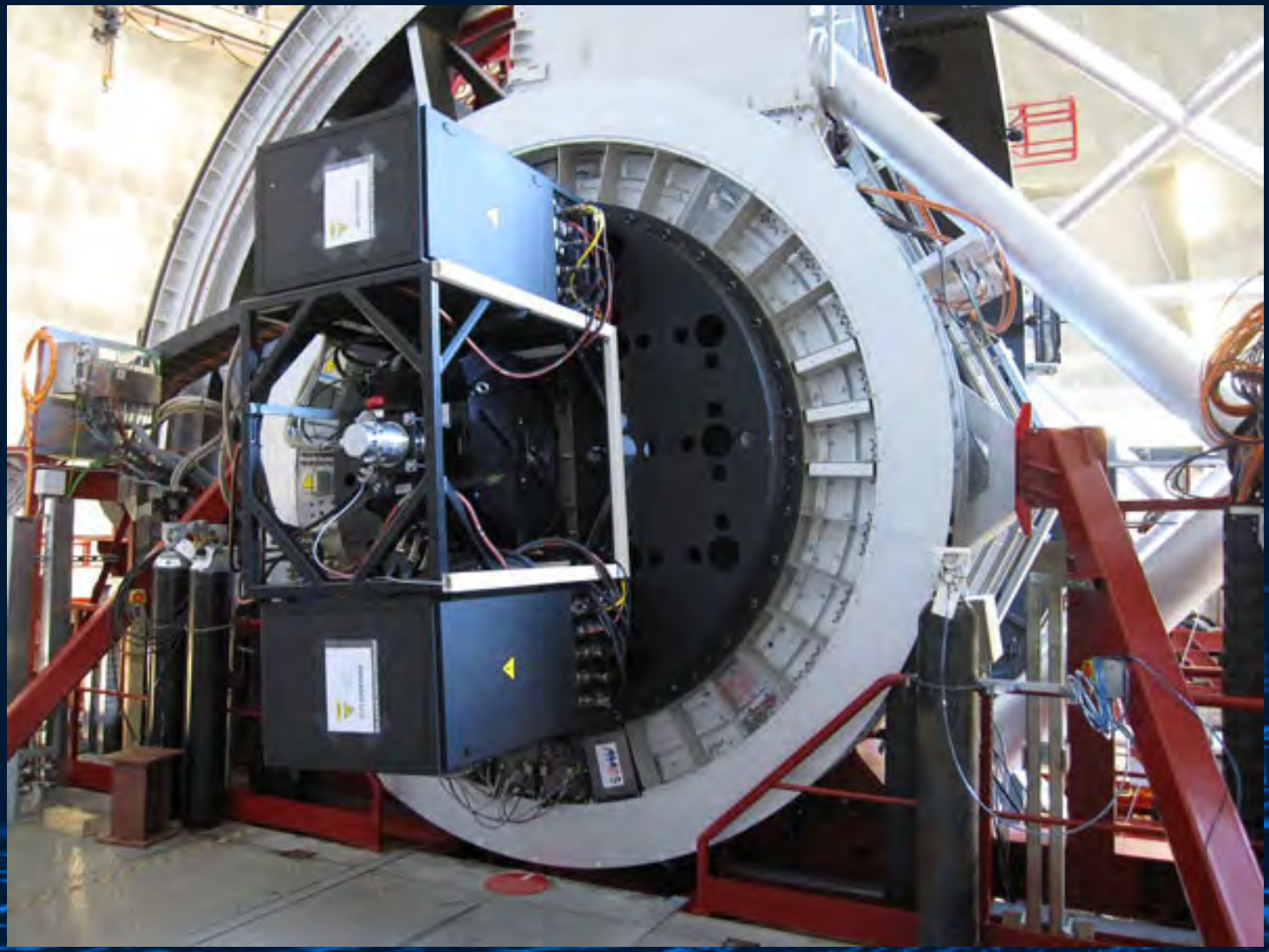




HiPERCAM parameter space



CanariCam mid-IR imager and spectrograph



CanariCam mid-IR imager and spectrograph

Common-user instrument since 2011. Developed by the University of Florida. Designed to reach GTC diffraction limit at 8 µm (0".2) ←→ Chop-nod (2 Hz) & fast guiding (50 Hz)

Spectral Range	7.5-25 µm
Detector	Raytheon 320x240 Si:As (cooled to 9K)
Plate Scale	0.08 arcsec pix^{-1}
Field of view	26 x 19 $arcsec^2$
Imaging modes	broad/narrow band, polarimetry
Spectroscopic modes	long-slit, polarimetry
Spectral resolution	175 to 1300

5σ detection for 30 min on-source			
Filter	FWHM (arcsec)	Sens. (mJy)	PWV (mm)
Si1-7.8	0.24	5.42	7.2
Si2-8.7	0.25	1.01	7.2
Si3-9.8	0.25	1.85	7.6
Si4-10.3	0.27	1.78	7.6
Si5-11.6	0.30	2.01	7.6
Si6-12.5	0.32	4.24	7.6
Q1-17.65	0.43	13.83	6.8
PAH-18.6	0.26	1.46	7.6
ArIII-8.99	0.26	3.51	6.6
SIV-10.5	0.29	3.57	6.6
PAH2-11.3	0.32	1.99	6.6
SiC-11.75	0.31	2.11	7.6
NeII-12.8	0.32	5.22	7.2
NeII_ref2-13.1	0.33	6.04	7.2
QH2-17.0	0.42	33.24	6.8
Q4-20.5	0.49	23.34	7.6
Q8-24.5	0.57	62.79	7.6

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 2018-2019.

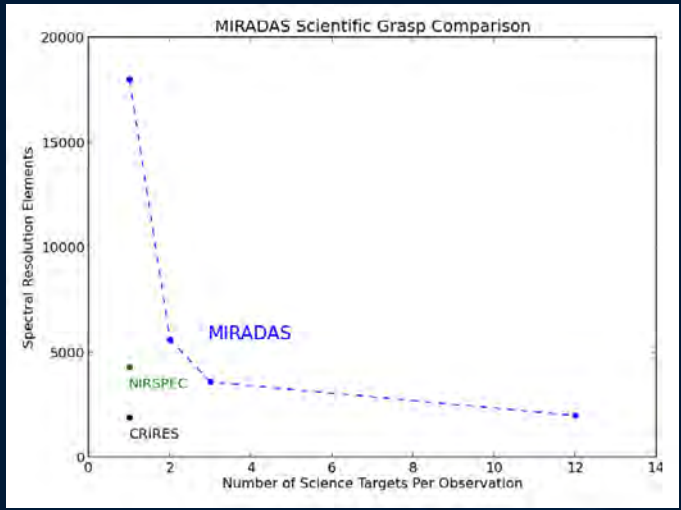
GTCAO	
Spectral range	0.9-2.5 µm
Correction	Shack-Hartmann wfs in visible light
Corrected fov	1.5 arcmin
On-axis SR	>0.65 at 2.2µm

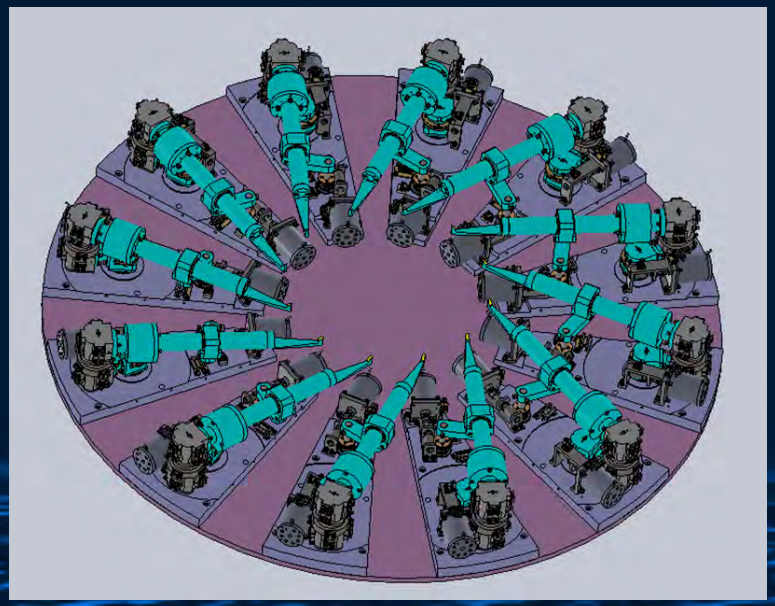
FRIDA		
Spectral range		0.9-2.5 µm
Detector		HAWAI2 2048^2
Imaging	mode	diffraction limited broad/narrow-band
	f.o.v + plate scale	20''x20'' (0.01 arcsec pix^{-1}) 40''x40'' (0.02 & 0.04 arcsec pix^{-1})
Spectroscopic mode		IFU 0.6x0.6, 1.2x1.2 & 2.4x2.4 $arcsec^2$
Spectral resolution		1000 (ZJ, HK), 4000 (Z,J,H,K), 30000 (H,K)

MIRADAS NIR medium-resolution multi-object spectrograph

Developed by the University of Florida. On the GTC in 2019.

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

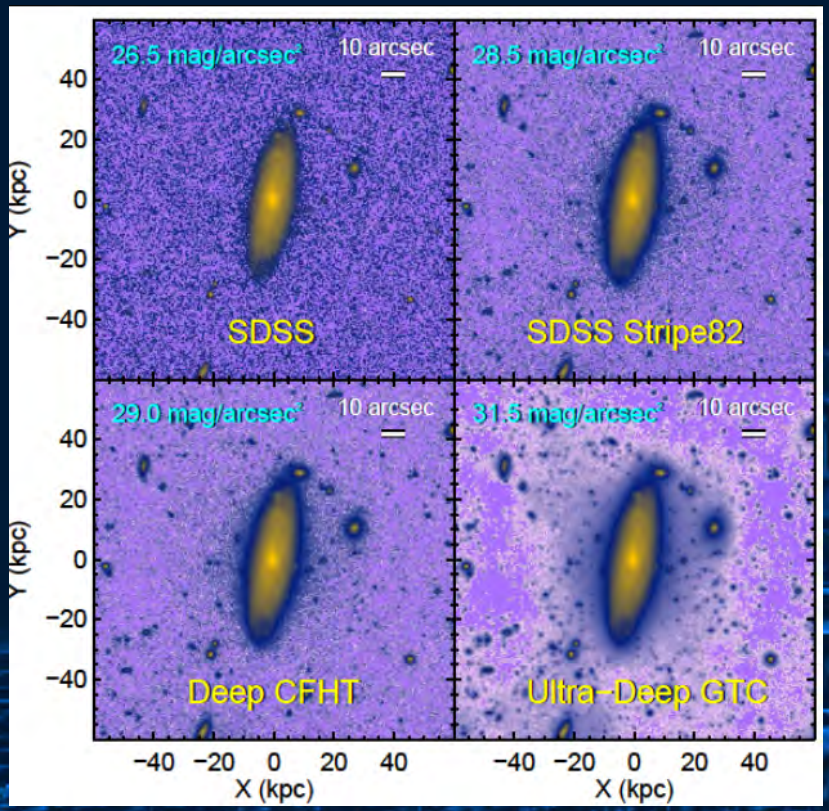




Scientific highlights

- Exoplanet atmospheres (transit differential spectroscopy)
- Compact binaries: black holes, microquasars, SN Ia progenitors
- Low-surface brightness galaxy components
- Spectro-photometric surveys of distant galaxies (Large Programme)
- GRBs

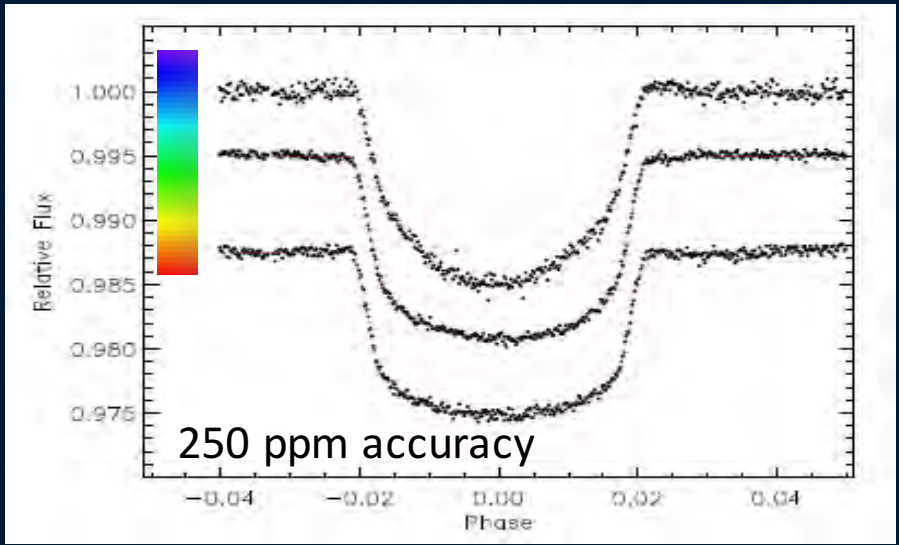
60 “X-rays” programmes

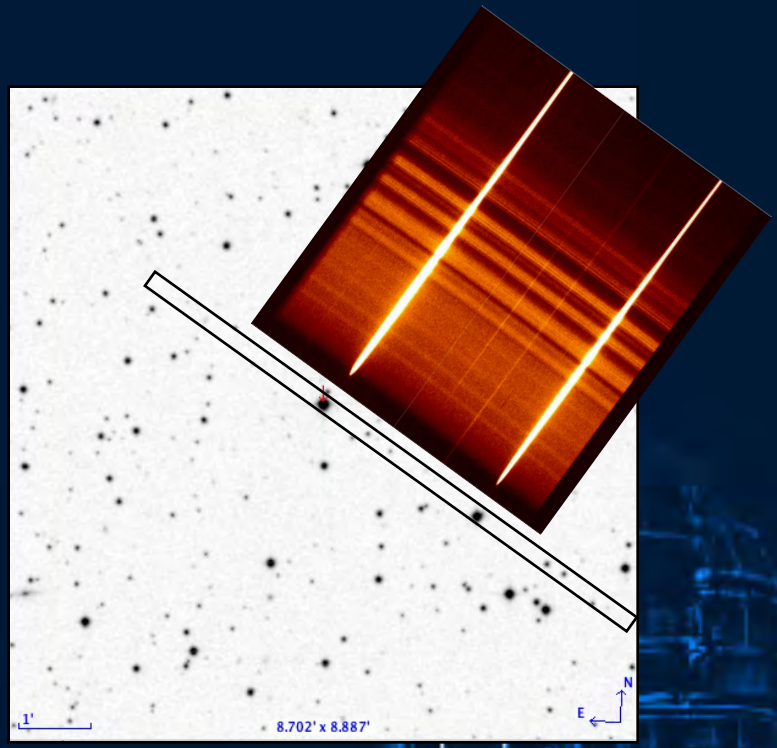


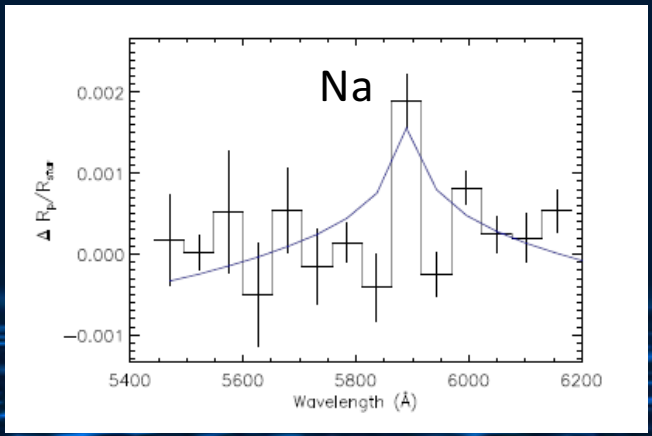
Scientific highlights (I)

GTC OSIRIS transiting exoplanet atmospheric survey: detection of sodium in XO-2b from differential long-slit spectroscopy

Sing et al. 2012 MNRAS, 426, 1663



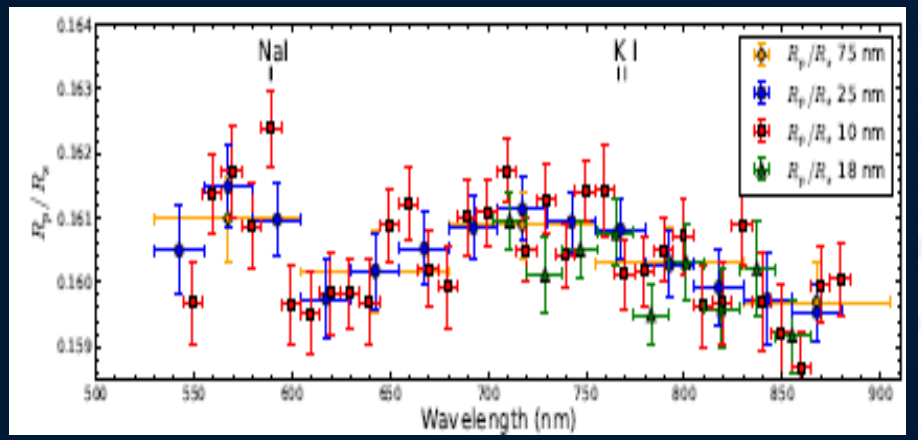


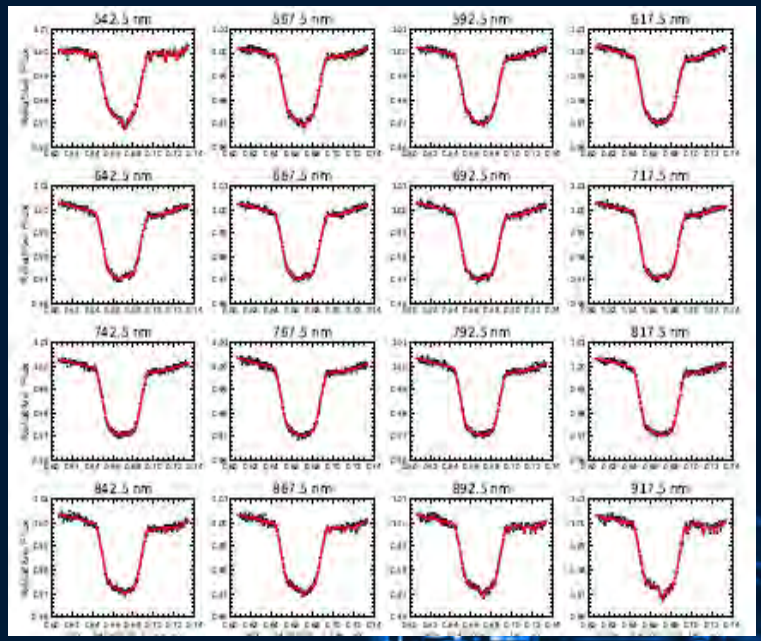


Scientific highlights (I)

The GTC exoplanet transit spectroscopy survey. I. OSIRIS transmission spectroscopy of the short period planet WASP-43b

Murgas et al. 2014 A&A 563, 41

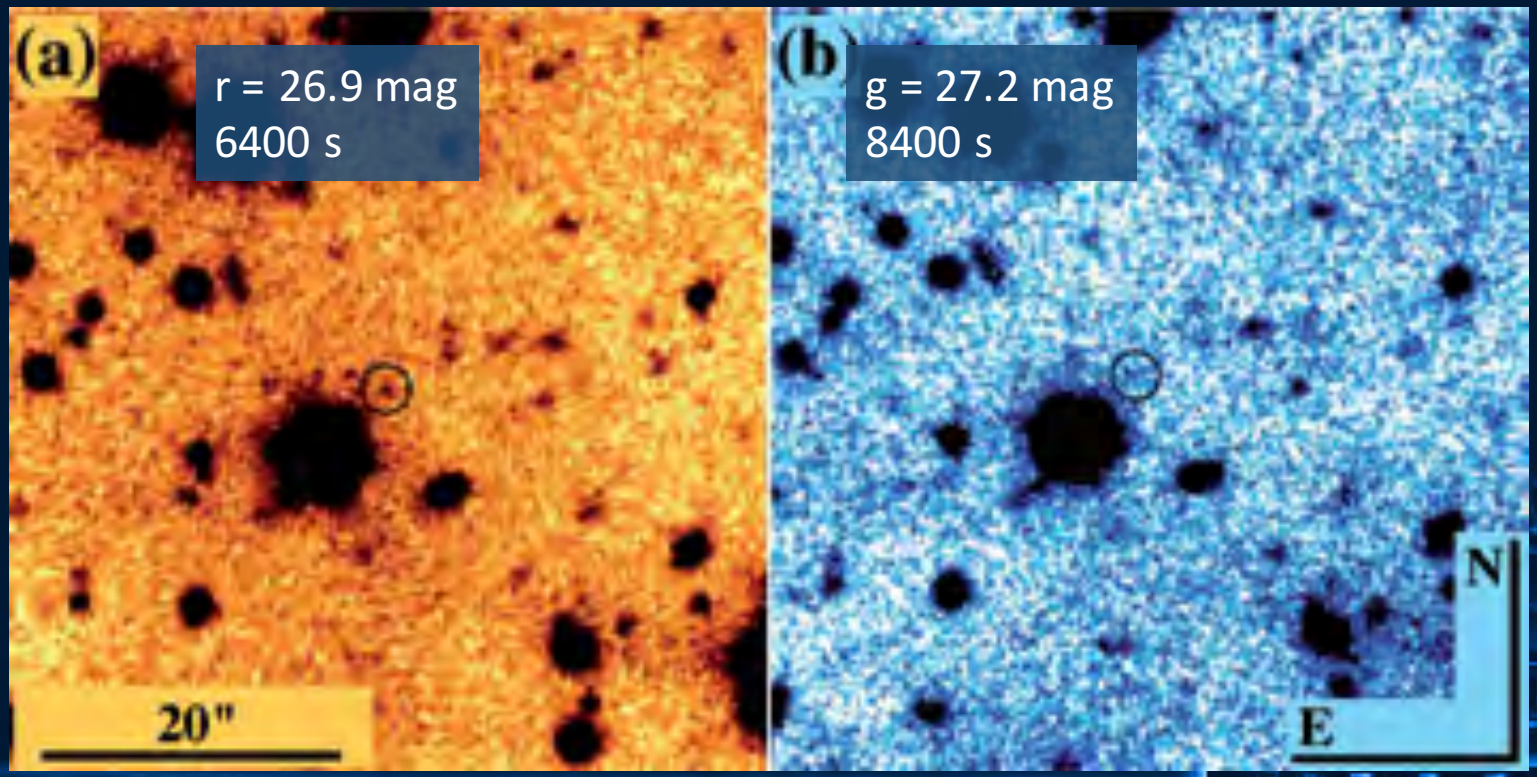




Scientific highlights (II)

The unusual γ-ray burst GRB 101225A from a helium star/neutron star merger at redshift 0.33

Thöne et al. 2011, Nature 480, 72



Scientific highlights (III)

SHARDS: An Optical spectro-photometric Survey of Distant Galaxies

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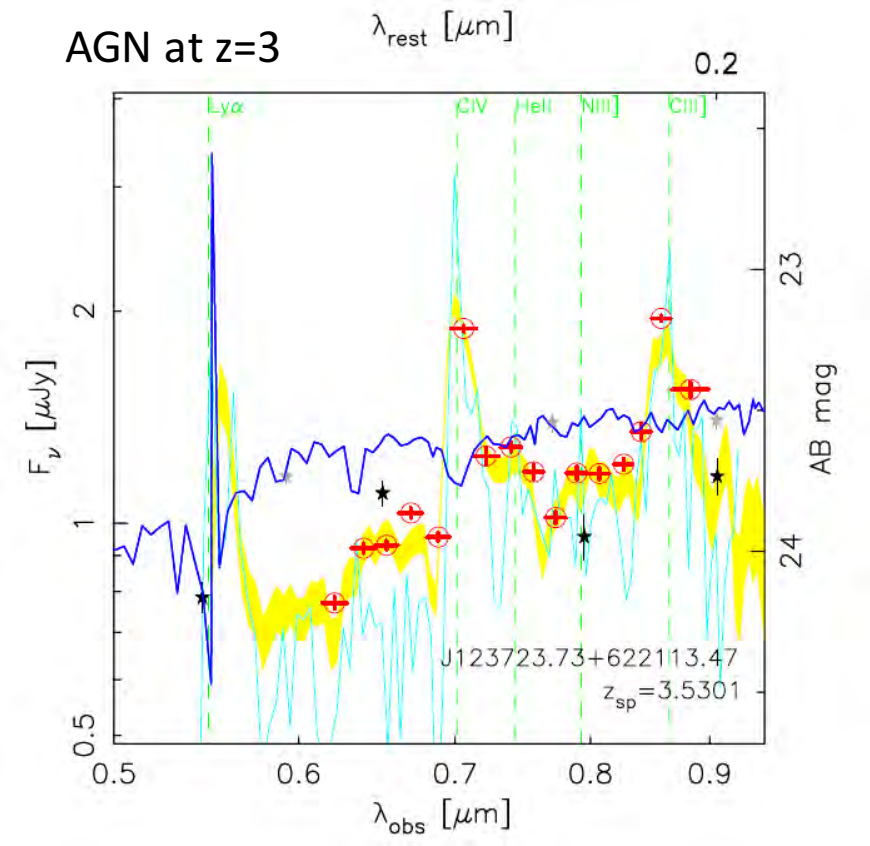
Pérez-Gonzalez et al. 2013, ApJ 762, 46

GOODSN images in 24 medium-band (R=50) customed filters down to mag 26.5

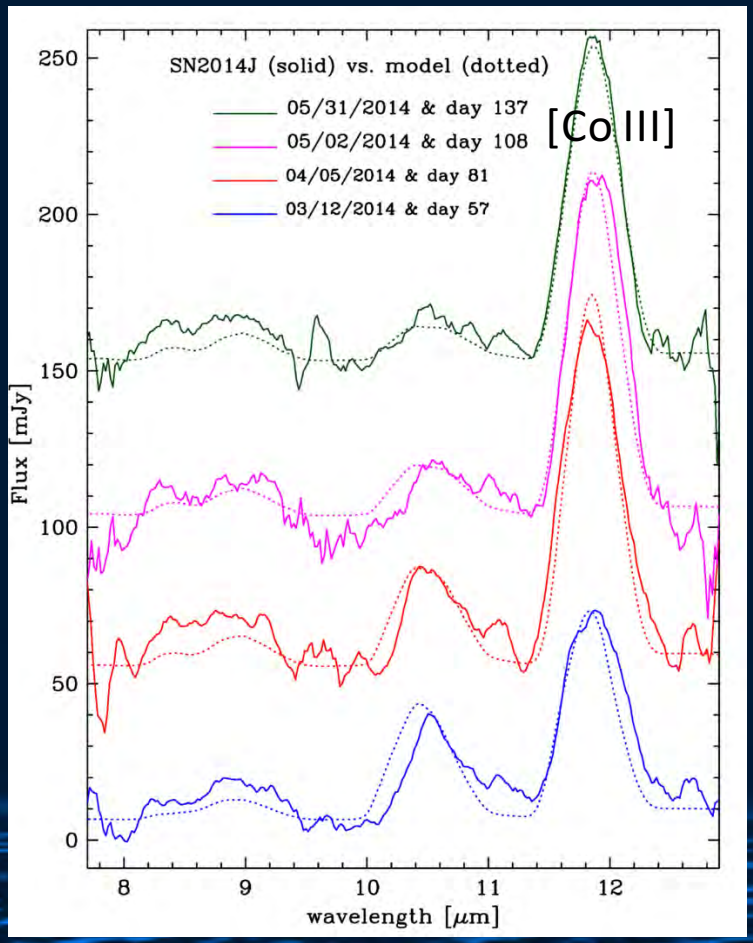


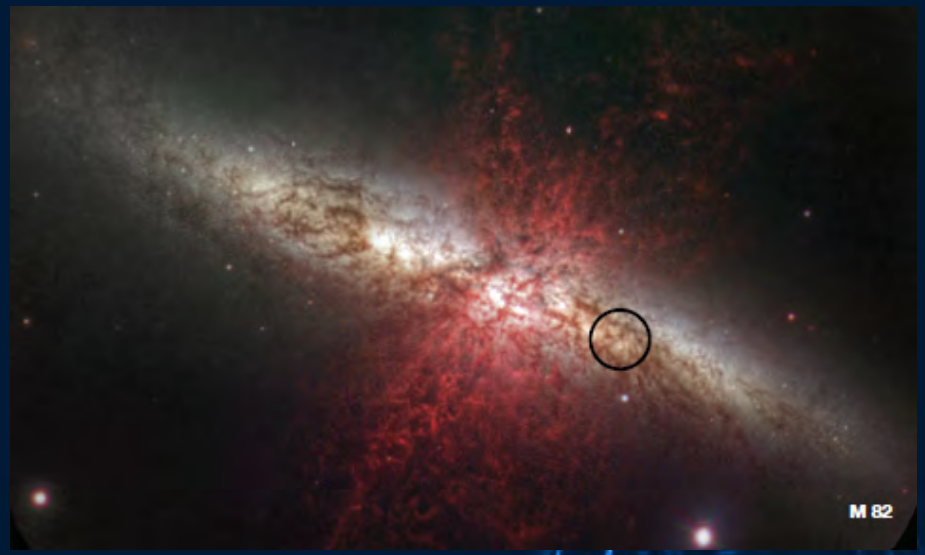
ground-based spectrum
HST spectrum
SHARDS
model

Scientific highlights (IV)

Mid-IR spectra of Type Ia SN 2014J in M82 spanning the first four months

Telesco et al. 2015, ApJ 798, 93



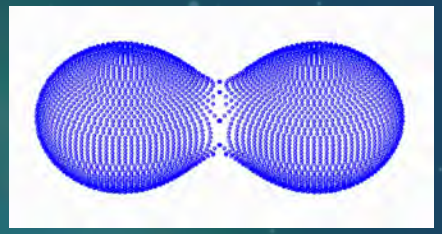


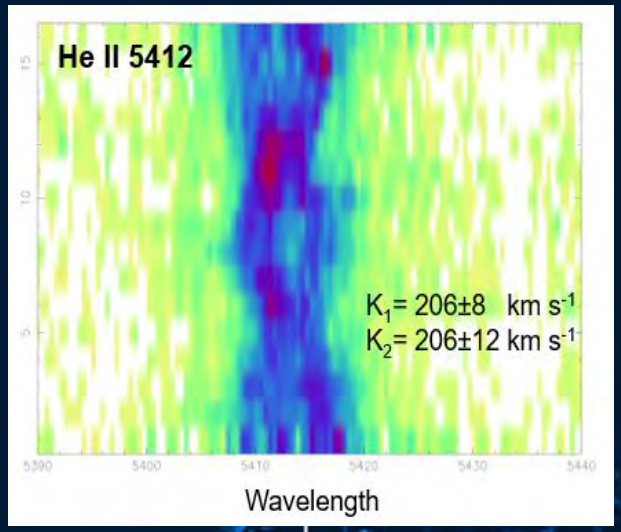
Scientific highlights

The double-degenerate, super-Chandrasekhar nucleus of the planetary nebula Henize 2-428

Santander-García et al 2015, Nature, 519, 63

P_{orb} = 4.2 hours
Mass ratio q~1
Orbital separation a = 1.6 R_{SUN}
Inclination i = 64.7 deg
M_1 = 0.88 ± 0.13 M_{SUN}
T_1 = 32400 K
R_1 = 0.68 ± 0.04 R_{SUN}
M_2 = 0.88 ± 0.13 M_{SUN}
T_2 = 30900 K
R_2 = 0.68 ± 0.04 R_{SUN}



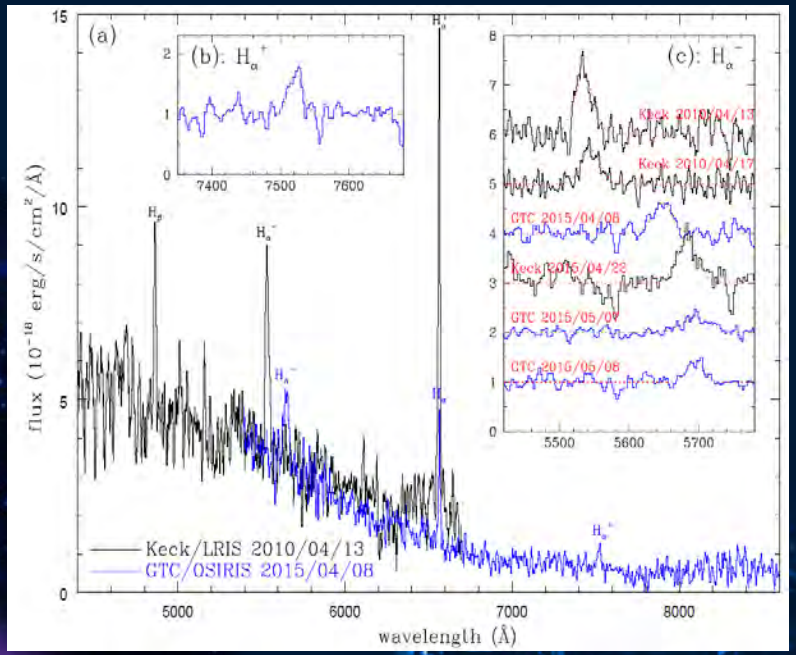


Double-degenerate M_1+M_2 super-Chandrasekhar
Will merge in < 700 million yr exploding as a SNIa

Scientific highlights

Relativistic baryonic jets from an ultraluminous supersoft X-ray source

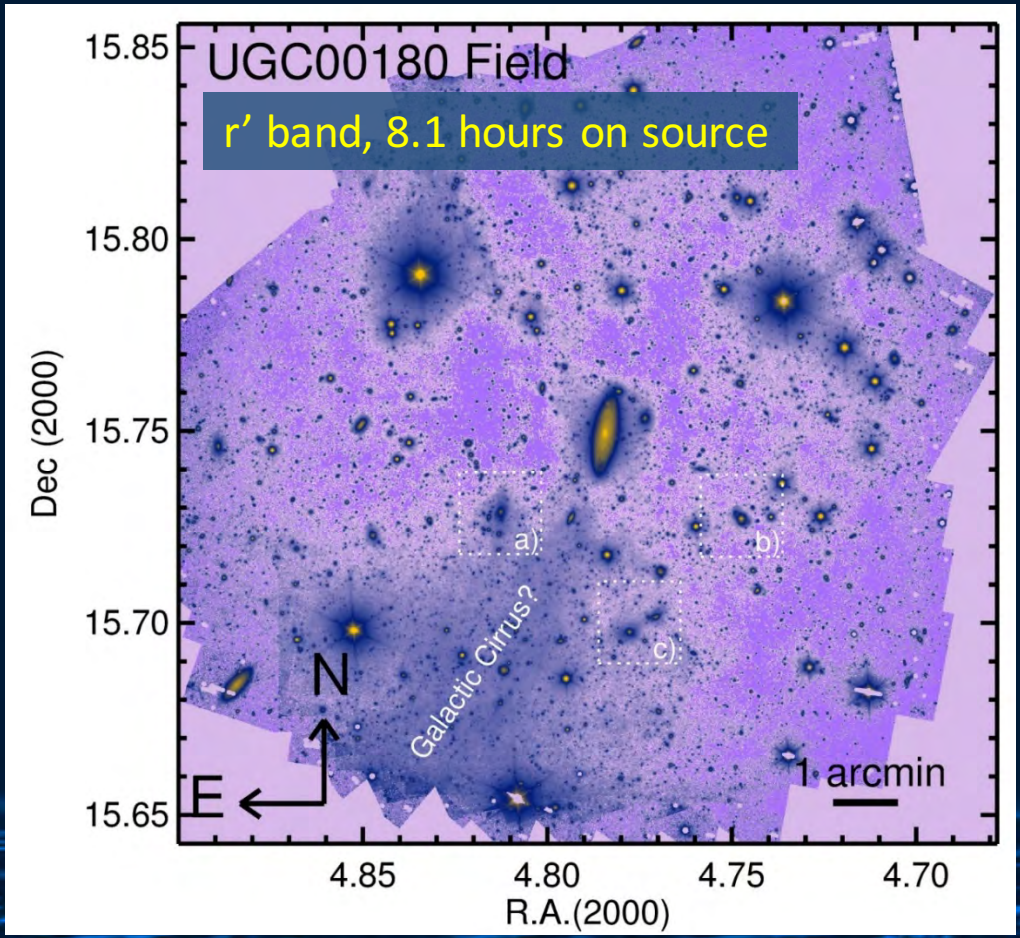
Liu et al, 2015, Nature 528, 108

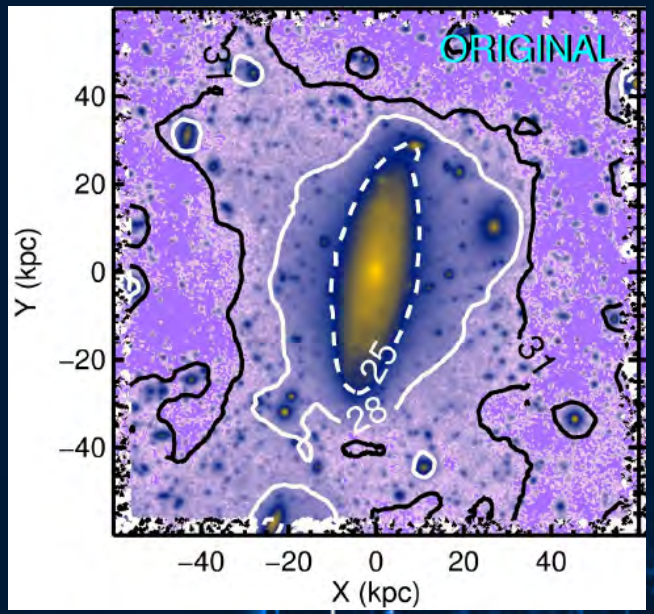


Scientific highlights (VII)

Beyond 31 mag arcsec^{-2}: the low surface brightness frontier with the largest optical telescopes

Trujillo & Liri 2016, ApJ, in press





Scientific highlights (VII)

Beyond 31 mag arcsec^{-2}: the low surface brightness frontier with the largest optical telescopes

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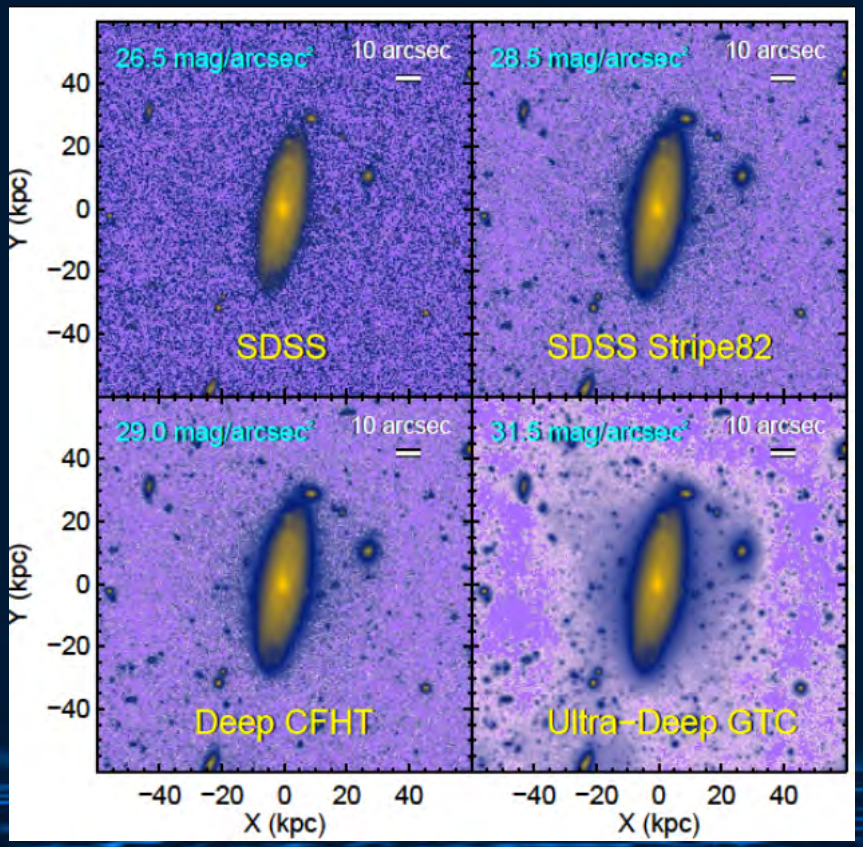
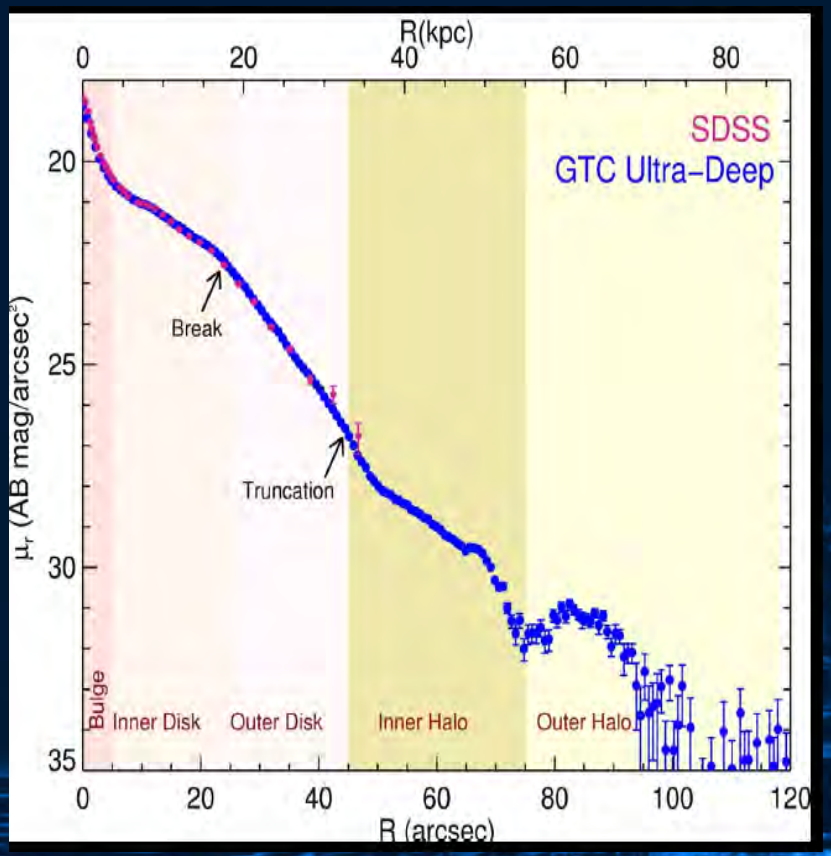
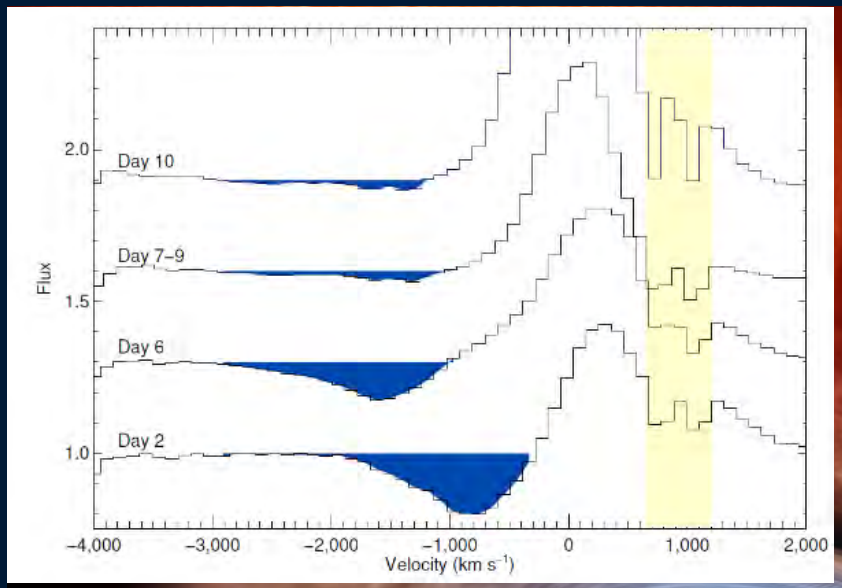


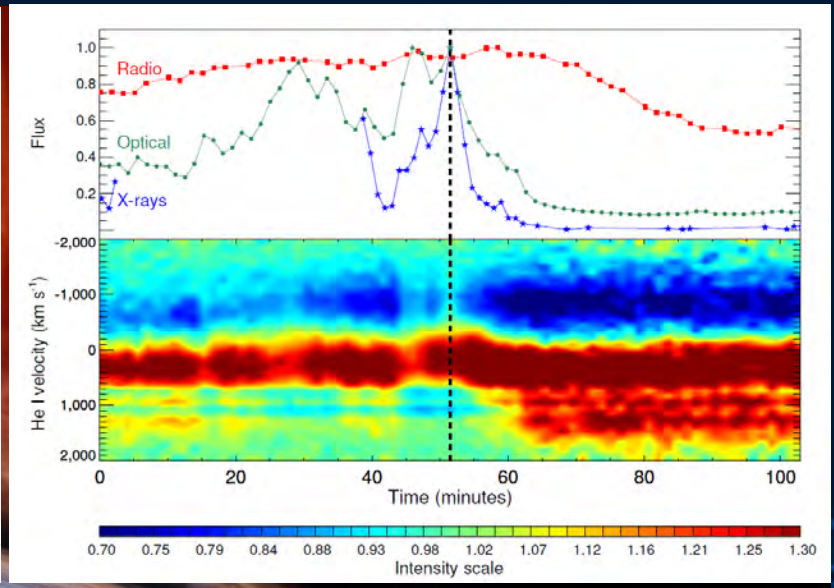


Scientific highlights

Regulation of black-hole accretion by a disk wind during a violent outburst of V404 Cygni

Muñoz-Darias et al. 2016, Nature, 534, 75





545 ~1 min GTC spectra obtained between 17 June 17 & 1 July 2015

GTC in the Athena era

ELTs will pose new challenges for the GTC →

Formal open discussion for instrumentation plan from 2020-on will start soon.

This is an opportunity and is your responsibility to decide what the GTC will be.

Present strengths: collecting area, flexibility, versatility, large amount of time for a single nations

Future:

Which of the above strengths do you want to retain?

Versatility or specialisation?

A near-UV opportunity?

Before or after Athena is operational?

Do you need the ELTs?

Coordinates observational effort (optical, IR, radio, …)?

The future of the GTC is in your hands

Science with the GTC, Valencia, 10-14 December 2018

CIRCE NIR camera and spectrograph

Developed by the University of Florida. Offered from 2015B as visitor instrument.

Spectral Range	0.9-2.5 µm
Detector	2Kx2K HgCdTe (Rockwell)
Plate Scale	0.1 arcsec pix^{-1}
Field of view	3'.4 x 3'.4
Imaging modes	Broad/narrow-band, polarimetry, fast photometry
Spectroscopic mode	Long-slit
Spectral resolution	450 (0".6 slit)
Spectral coverage	JH, HK