The Extremely Large Telescope

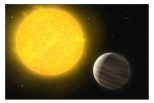
Science, operations and multi-messenger astrophysics

Michael Sterzik, European Southern Observatory

ELT Timeline

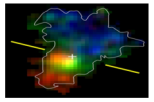
- Initial concepts: early 2000s
- ELT as Strategic Priority: December 2004
- Design phase: 2006+
- Site selection: April 2010
- Approval of the ELT Programme: June 2012
- Ground breaking ceremony: June 2014
- Green light for construction: December 2014
- Contract for Dome & Main Structure: May 2016
- First stone: May 2017
- Mirror casting: M2, M3 2017, first M1 segments 2018
- First light: 2025
  - Transition to Science Operations: 2026

Top Level Science Cases

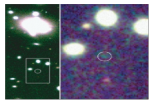


Extra-solar planets: discovery of Earth-like planets, direct imaging of larger planets and, possibly, their atmospheres

Resolved stellar populations: resolve a representative sample of galaxies in the nearby Universe into stars to reconstruct *directly* their formation and evolution history



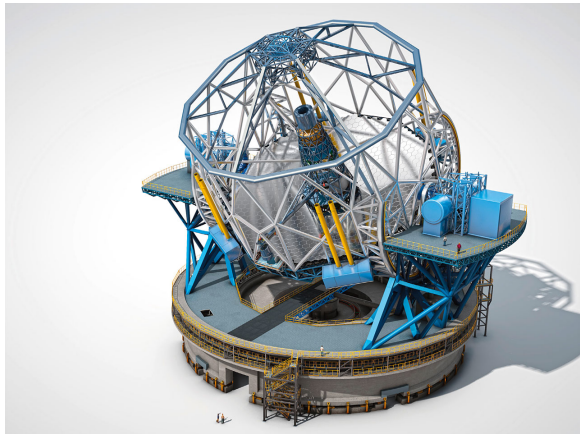
Physics of the high redshift universe: spatially resolved spectroscopy to the highest redshift galaxies to derive their stellar masses, ages, chemical compositions, star formation histories and dynamical states across cosmic time

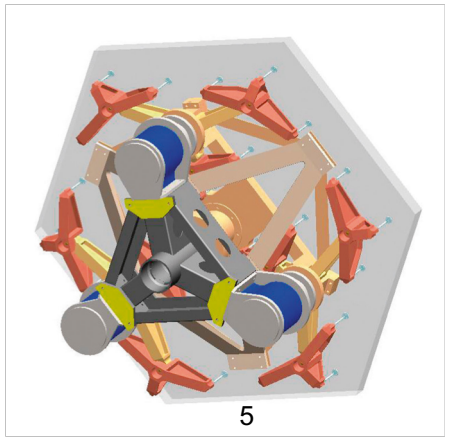


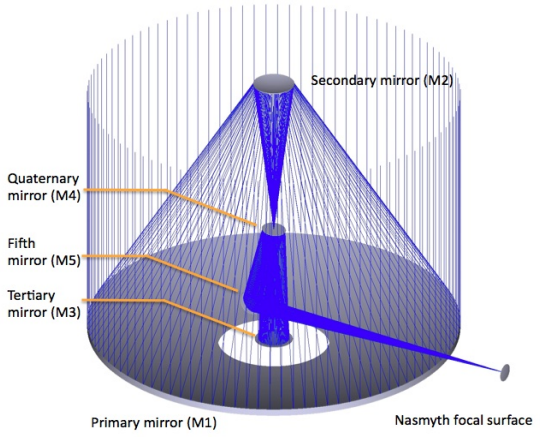
Cosmology and fundamental physics: *direct* observation and measurement of the expanding Universe; variations the of fundamental physical constants over cosmic time

The ELT in a Nutshell

- The next (giant) step in optical-infrared astronomy
  - Built and operated by ESO
  - Landmark ESFRI
- 39 meters in diameter, filled segmented aperture
  - 798 1.4-meter hexagonal segments
  - 5 mirror *adaptive optics design*: M4 with ~5000 actuators
  - 6 Laser Guide Stars
- Two Nasmyth platforms for the instruments
  - Possibility of a Coudé focus for ultra-stable instruments





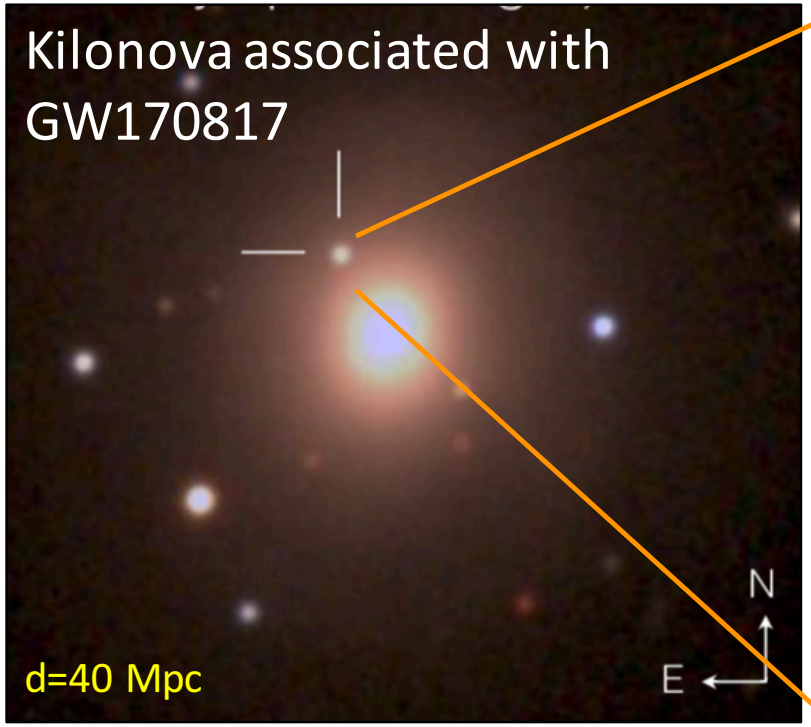


ELT Instrumentation

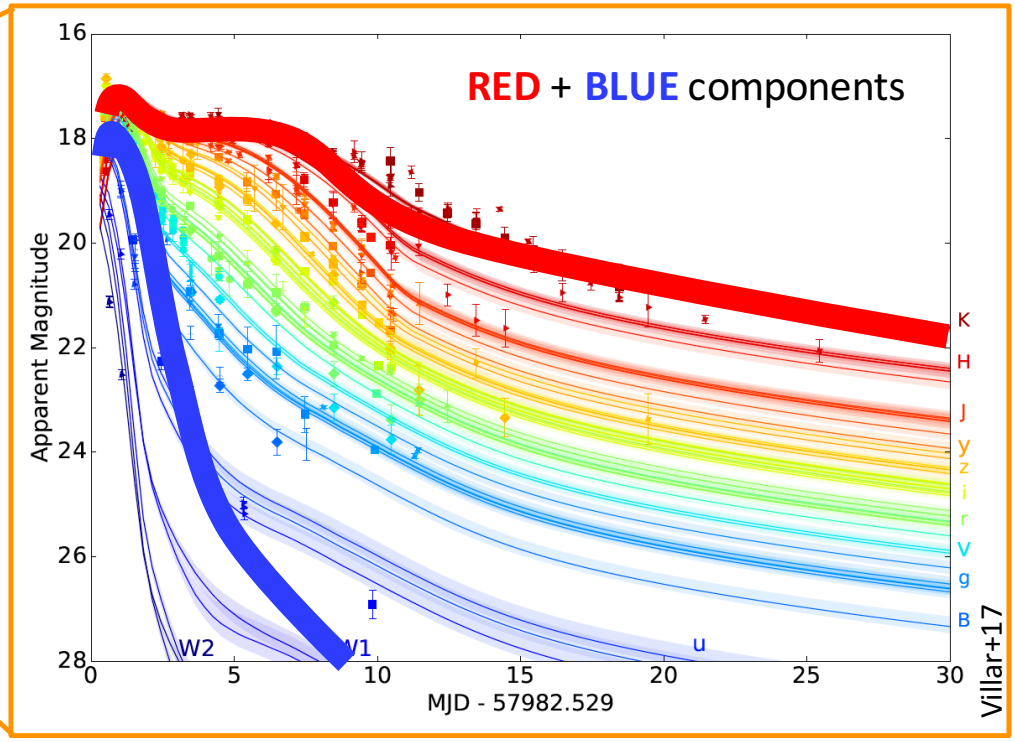
- Comprehensive instrumentation programme to exploit the capabilities of the ELT itself
- First generation instruments
  - Part of telescope construction
  - adaptive optics module (MAORY)
  - Optical/NIR Imager and Spectrograph (MICADO)
  - Single Field Integral-field Spectrograph (HARMONY)
  - Mid-IR Imager and Spectrograph (METIS)
- Instruments 4 & 5 (Phase A)
  - Multi-object spectrograph (MOSAIC)
  - High-resolution spectrograph (HIRES)

Potential for MM astrophysics

- The physics of Binary Neutron Star mergers
  - case of GW170817



DECam image from Soares-Santos+17; Cowperthwaite+17

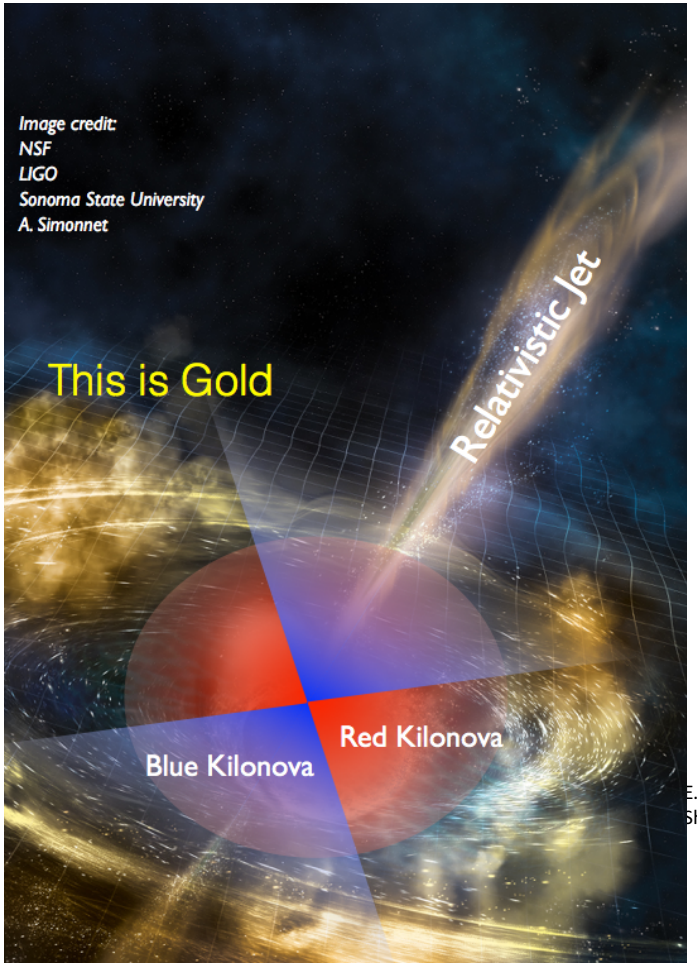


Photometry from ~70 telescopes worldwide

See AAS#233, Seattle, Jan 2019, US-ELT program session on discovery frontiers in time-domain astrophysics, Rafaella Margutti (NWU)

Potential for MM astrophysics

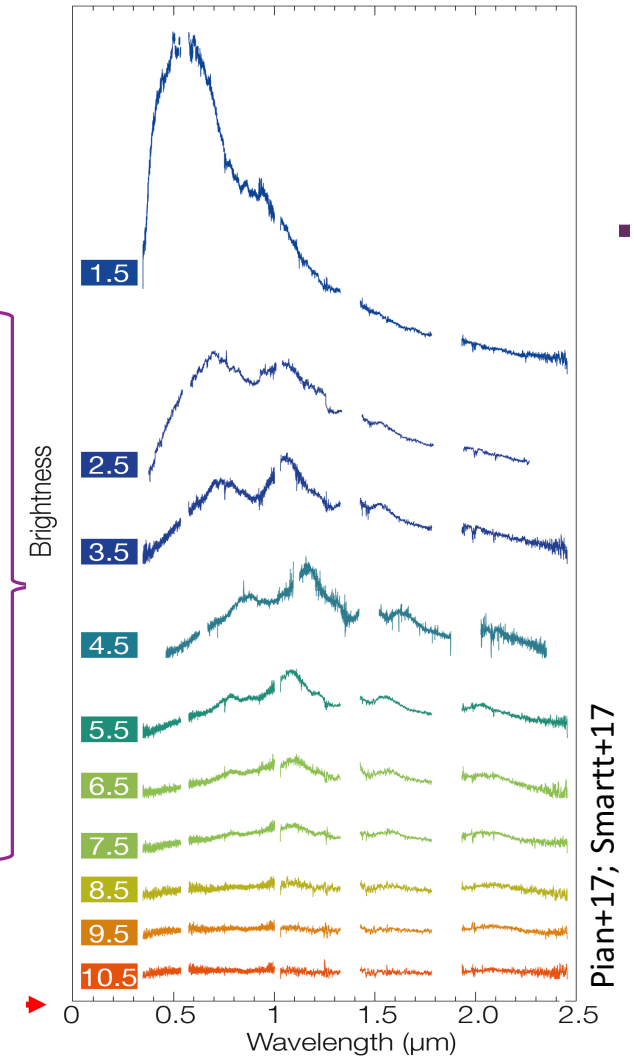
- The physics of Binary Neutron Star mergers
  - case of GW170817 w/ ESO/VLT



Constraints on the nature of the two colliding compact objects.

Nature of their remnant.

E.g. Chornock+17; Nicholl+17; Pian+17; Smartt+17; Valenti+17; Shappee+17;



Potential for MM astrophysics

- Why ELTs?
  - Todays VLT: local universe GW

z=0.024

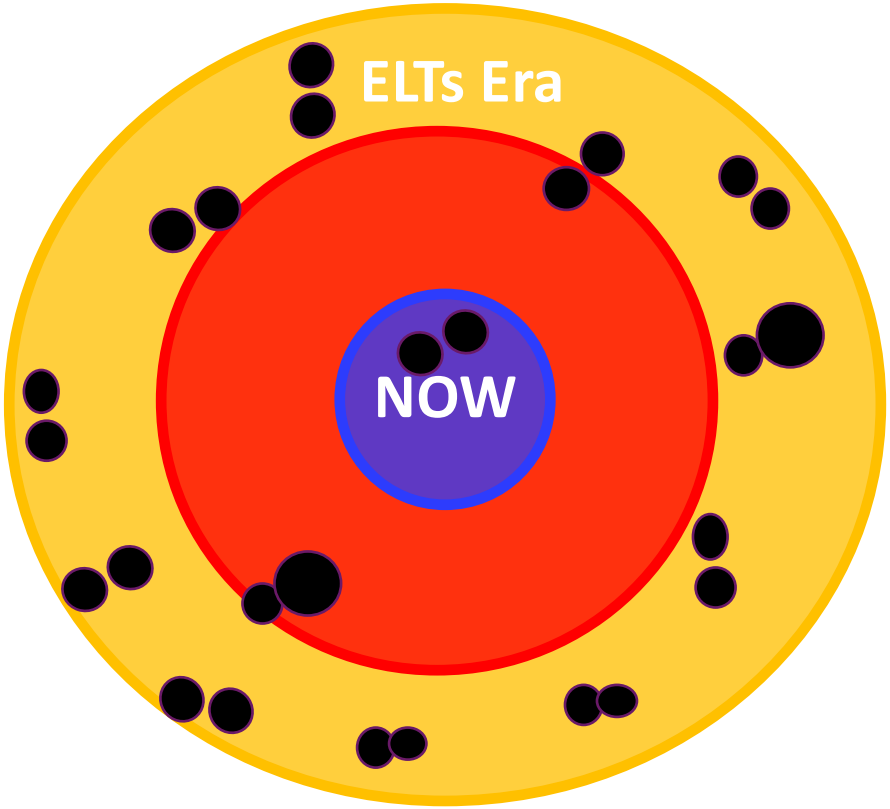
Potential for MM astrophysics

- Why ELTs?
  - ELT will map more distant mergers discovered by GW
    - future A+LIGO, LIGO Voyager/Cosmic Explorer (NSF) increase z

z=0.024

z=0.1

z=0.2

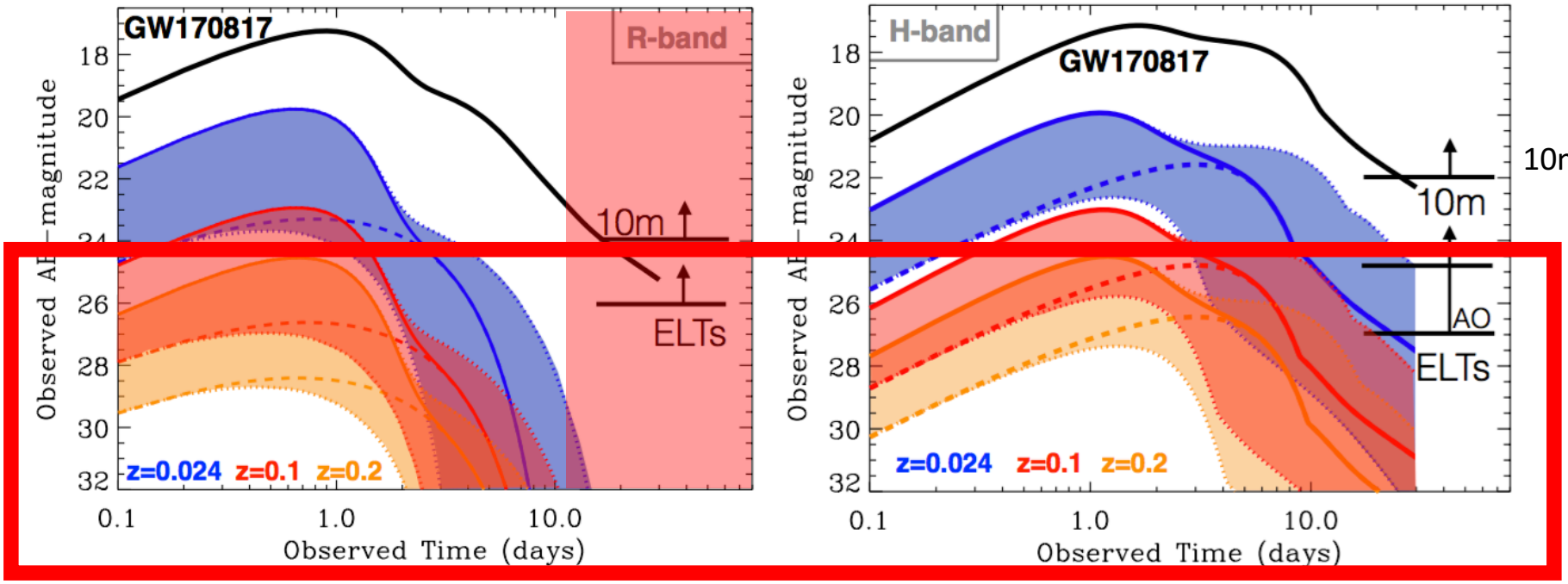


Potential for MM astrophysics

- Why ELTs?
  - ELT will map distant mergers discovered by GW

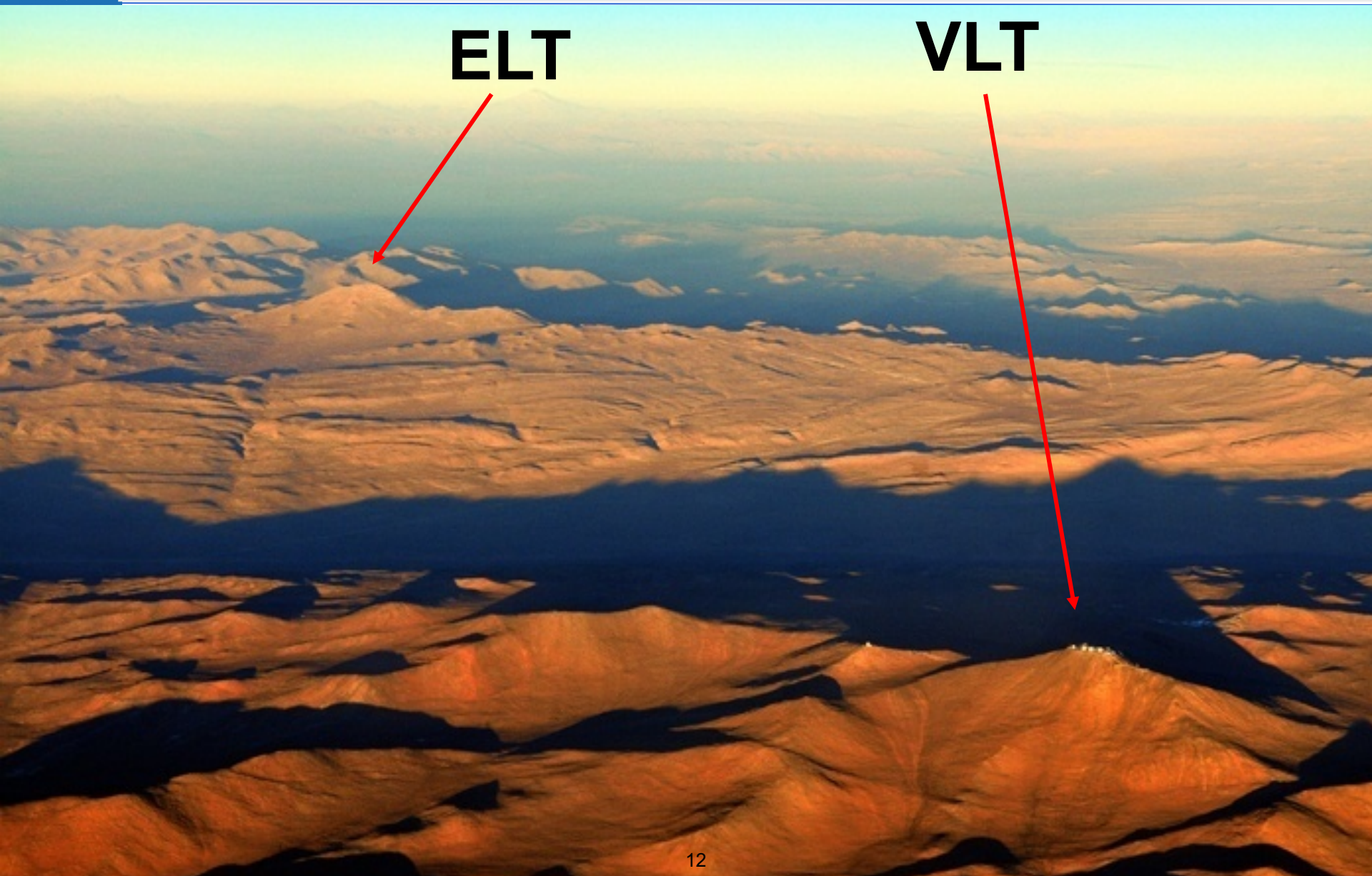
Chornock et al., 2020 white paper: MMA w/ ELTs

https://arxiv.org/abs/1903.04629



Two sites, one Observatory

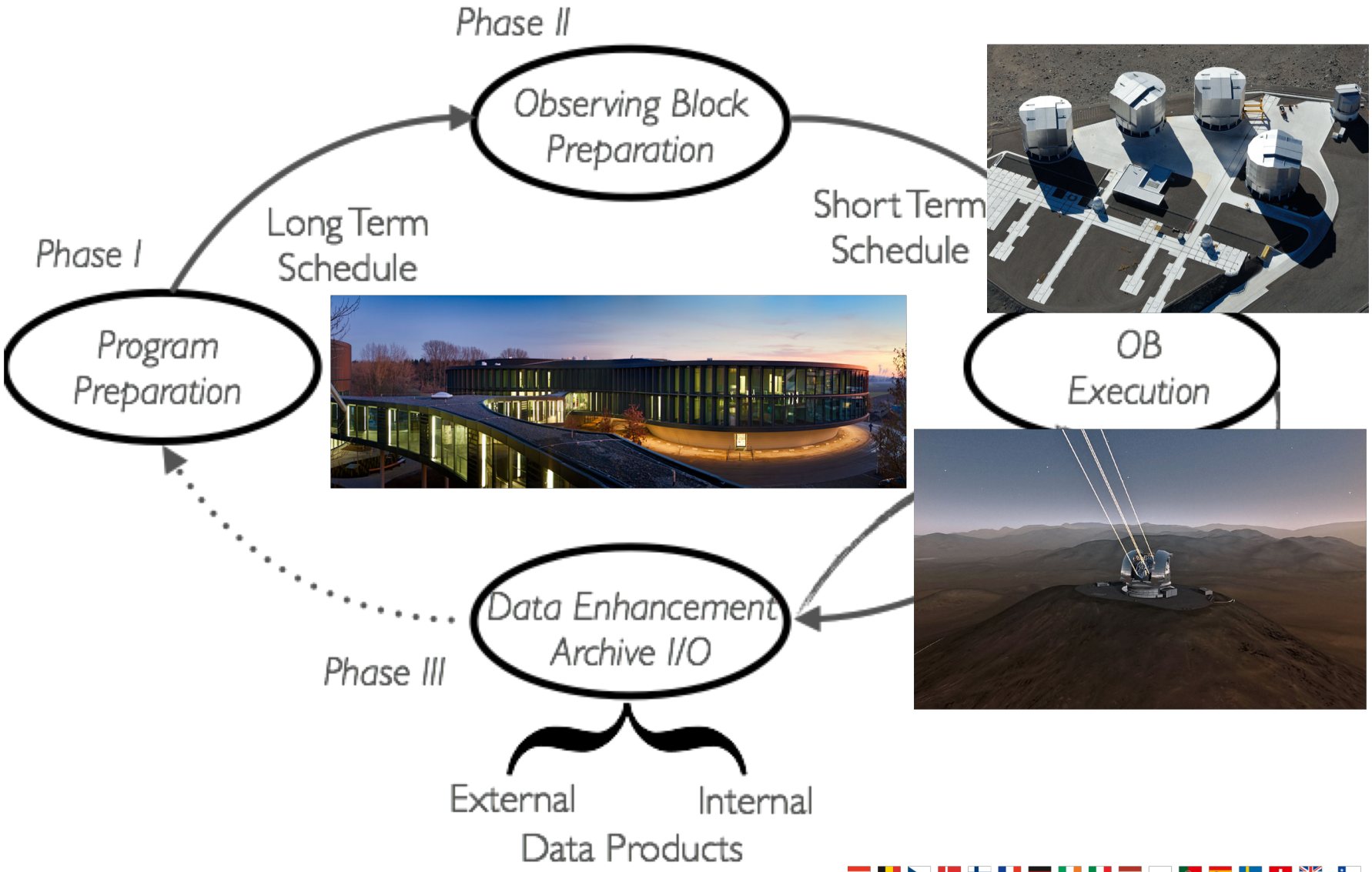
Armazones Paranal



Integrated Science Operations

- The ELT will be fully integrated in the existing La Silla Paranal Observatory
- Operational model derived from the VLT
  - Competitive access to observing time
  - Mix of different observing modes and programme types to optimize efficiency and science return
  - Science archive: raw data, data products
    - Cooperation with other data centers
- Builds on 25+ years of experience with VLT
- Data transferred online for near-real time quality control and transient science

Integrated Science Operations



VLT Rapid-Response Mode

- Ultra-fast response to transient science
  - GRB afterglows (SWIFT triggers)
  - Since 2004 (!) at the VLT
  - Response time <5min: abort, preset, acquire, observe
  - triggered through the Target of Opportunity channel
  - RRM/ToO will be available for ELT
  - http://www.eso.org/sci/php/sciops/RRM/rrmLog_WebStatus

Paranal Observatory Telescope Status

Current status of Paranal Telescopes at: Mon Mar 11 07:45:01 UTC 2019

Data sourced from: autrep@wvgvlti.pl.eso.org

Telescope	Status	Focus/Instrument
UT1/ANTU	Online/Idle Tracking	Cass/FORS2
UT2/KUEYEN	Online/Idle Tracking	NasA/FLAMES
UT3/MELIPAL	Online/Idle Tracking	NasA/SPHERE
UT4/YEPUN	Online/Idle Tracking	NasB/MUSE

SCIOPS 2019

19-22 Nov 2019
ESAC - Madrid

Cross Facilities Collaboration in the Multi Messenger Era

https://www.cosmos.esa.int/web/sciops-2019/

#sciops2019

Programme Organising Commitee

Christophe Arviset (ESA)
Michael Sterzik (ESO)
Bruno Leibundgut (ESO)
Peter Kretschmar (ESA)
Matthias Ehle (ESA)
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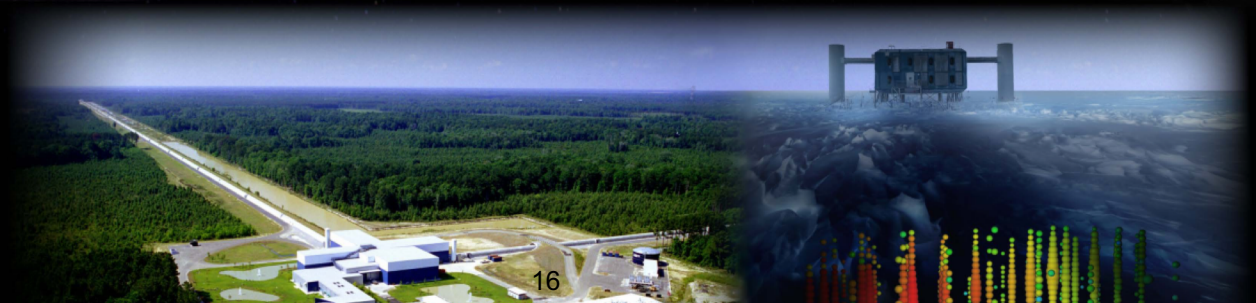

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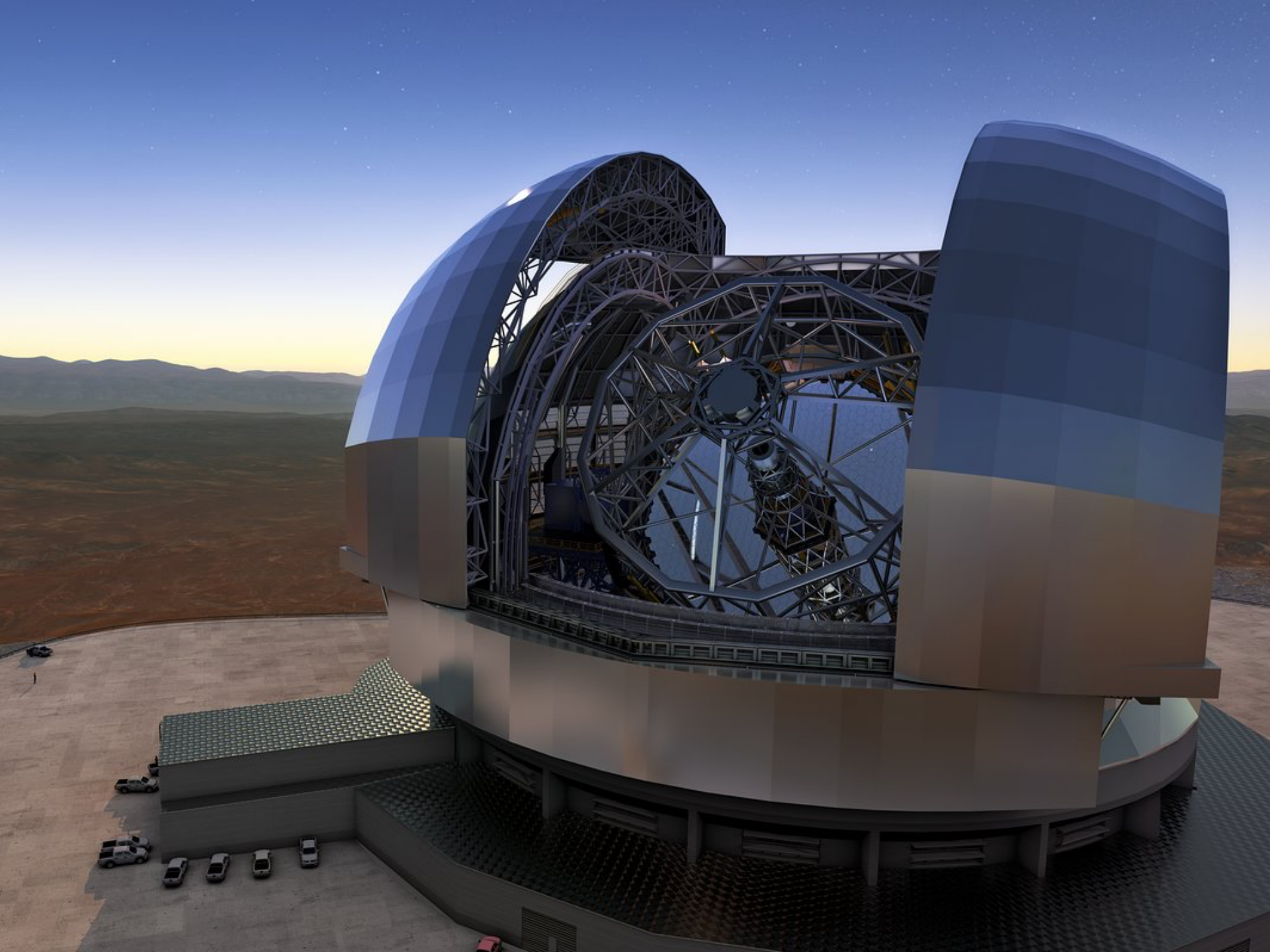
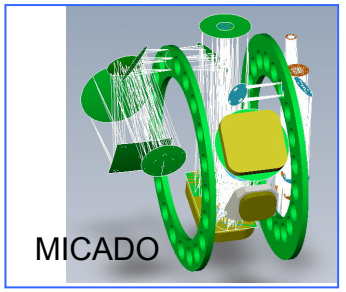
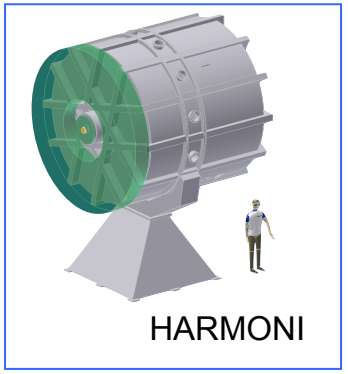


First-generation Instruments (1)

- Two first-light instruments
  - MICADO: Optical near-infrared Imager and Spectrograph with Adaptive Optics
    - Spectral range: 0.8 – 2.5μm
    - Spectral resolution: 3000
    - Field of view: up to 53"

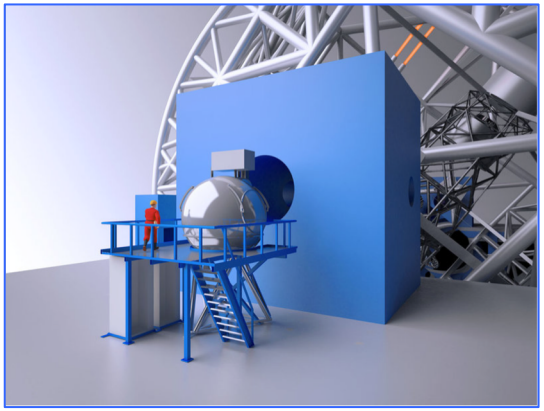

MICADO

  - HARMONI: Single Field Integral-field Spectrograph
    - Spectral range: 0.47 – 2.45μm
    - Spectral resolution 4000, 10 000, 20 000
    - Field of view: 10″x5″ or 1″x0.5″

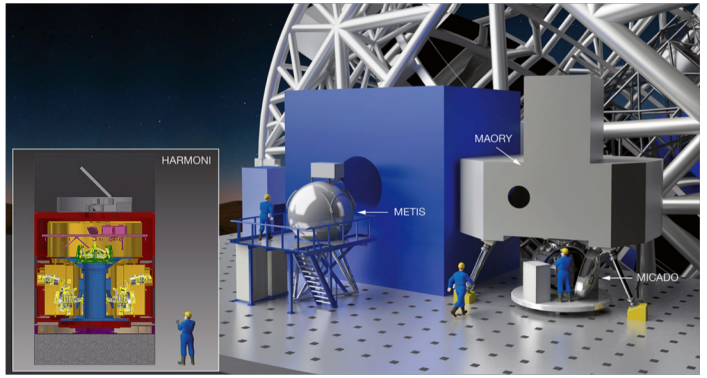

HARMONI

First-generation Instruments (2)

- METIS: Imager and Spectrograph
  - Spectral range: 3 – 20 μm
  - Spectral resolution: 1000 (L,M,N bands), 10,000 (N band), 100,000 (L,M bands)
  - Field of view: 11″x 11″



- MAORY: Adaptive Optics Module
  - Feeds MICADO and 2nd generation instrument
  - Multi-Conjugate Adaptive Optics
  - Field of view: 1’



Potential for MM astrophysics

- The physics of blazars as neutrino sources

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First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration*
on 4 Oct 2017; 17:17 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

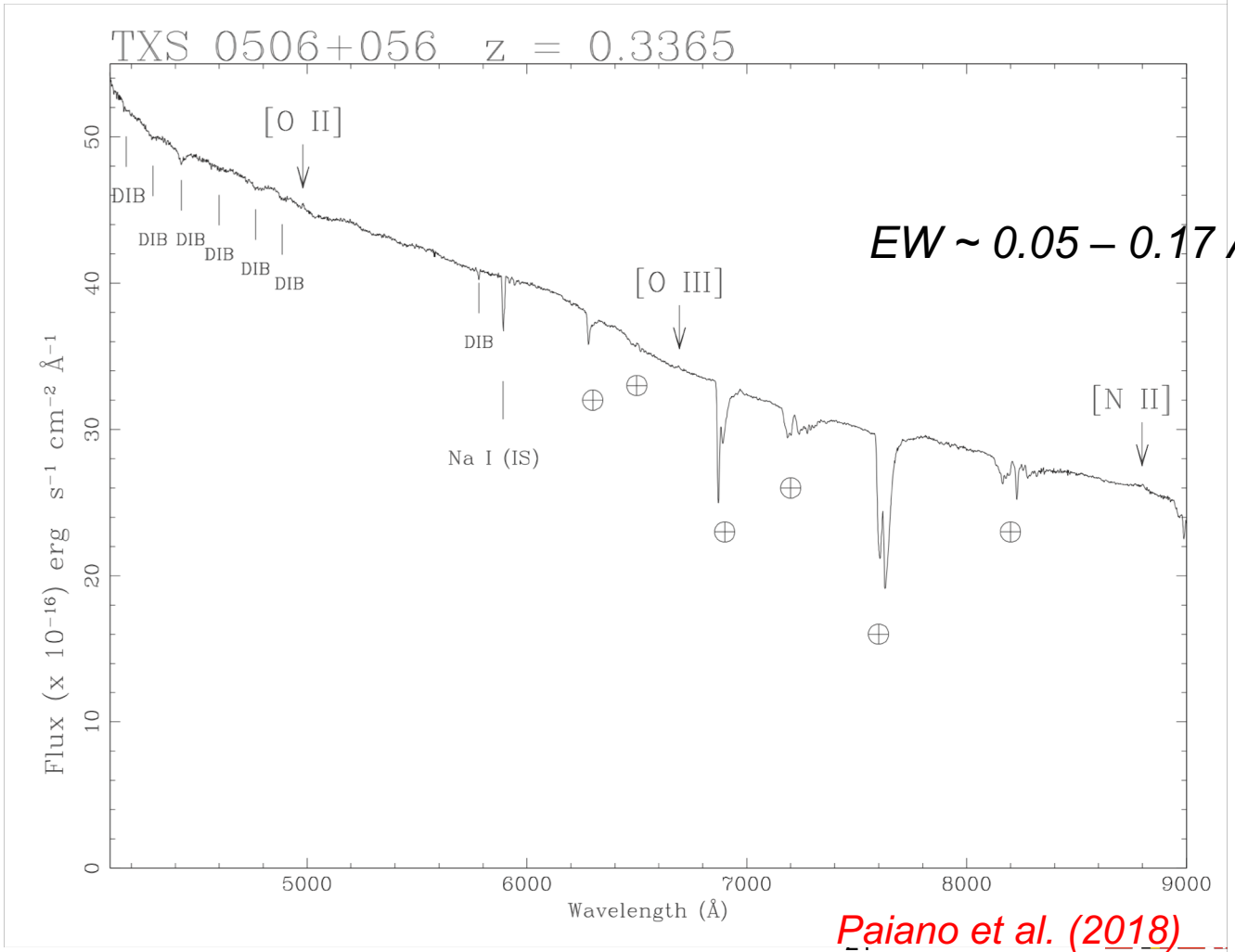
Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794,

Potential for MM astrophysics

- The physics of blazars as neutrino s
  - case of IceCube -170922A



EW ~ 0.05 – 0.17 Å

Paiano et al. (2018)

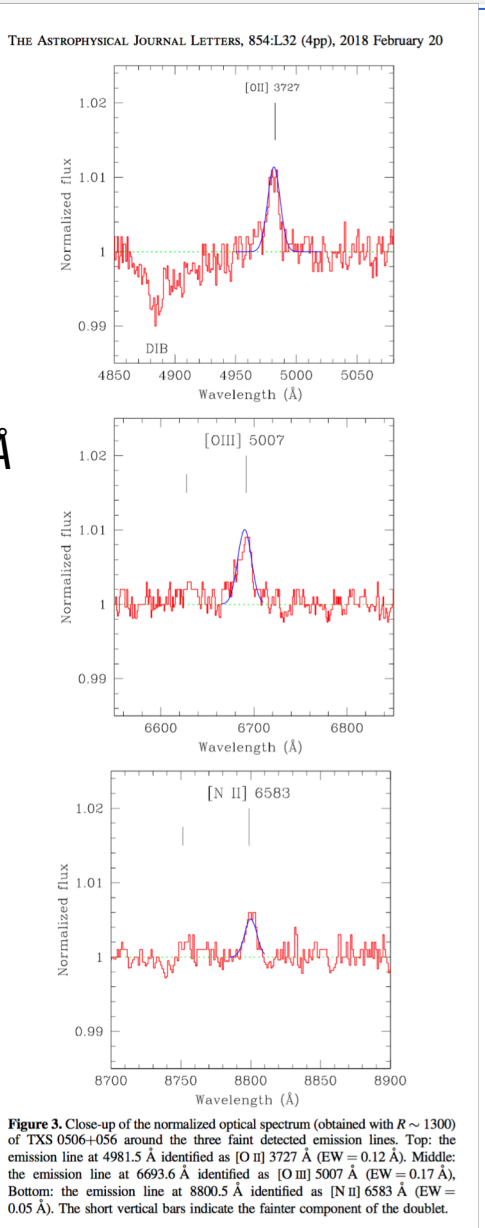


Figure 3. Close-up of the normalized optical spectrum (obtained with $R \sim 1300$) of TXS 0506+056 around the three faint detected emission lines. Top: the emission line at 4981.5 Å identified as [O II] 3727 Å (EW = 0.12 Å). Middle: the emission line at 6693.6 Å identified as [O III] 5007 Å (EW = 0.17 Å), Bottom: the emission line at 8800.5 Å identified as [N II] 6583 Å (EW = 0.05 Å). The short vertical bars indicate the fainter component of the doublet.

Potential for MM astrophysics

- Unveiling the physics of neutrino sources requires a stringent MM observational sequence
  - Detection by KM3NET
  - CTA γ-ray follow-up
  - SKA radio follow-up
  - X-ray when possible
  - VLT/ELT: non-thermal counterparts + redshifts
  - archival data + VO tools

Paiano et al. (2018)

ELT Data Management

- ELT data will be scarce and precious
  - There will be fewer 30-40 meter optical-infrared telescopes worldwide than 8 meters on Paranal alone
  - Wider context of big data
- Data rates and storage
  - Science data expected to be similar to the VLT: data volume not critical
  - Telescope/instrument telemetry: more challenging
- Data will be complex
  - Fully adaptive telescope
  - Telescope and instrument telemetry and atmosphere profile needed for science data processing
  - WIP

Data Transfer Infrastructure

Armazones (originally Bochum)

100km Optical Fiber

Paranal

GEANT2/DANTE

Trans-Atlantic link

GB-NREN

NL-NREN

DFN (D-NREN)

Queen Mary University of London