CAB contribution to ELT-HARMONI

Last steps of the instrument design phase

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HARMONI is the optical and near-IR integral field spectrograph (IFS) selected as a first-light instrument for the Extremely Large Telescope (ELT). With four spatial scales (30, 20, 10 and 4 mas) and a wide range of spectral resolving powers (3500-1800), HARMONI will allow astronomers to address many of the ELT science cases. The Centro de Astrobiología (CAB CSIC/INTA) and the Instituto de Astrofísica de Canarias (IAC) form part of the international consortium developing HARMONI, participation that will constitute an unique scientific opportunity, allowing access to the ELT as soon as it becomes operative.

We describe here the current status of the CAB responsibilities: the Calibration Module (CM) and the low-order wavefront sensing sub-system (LOWFS), the Calibration Plan of the instrument and the HARMONI science simulator (HSIM). On the technical side, the calibration module will simulate the optical output of the telescope, and provide the functionality needed to obtain all the calibration data frames. The LOWFS hosts the NGS sensors of HARMONI, and supports most of its observation modes (no-AO, LTAO, and SCAO modes). LOWFS is key to measure and correct the incoming wavefront from the telescope, and to provide knowledge (relative or absolute) of the location of the science focal plane with an extremely challenging accuracy of a few microns over the whole technical field (~400mm).

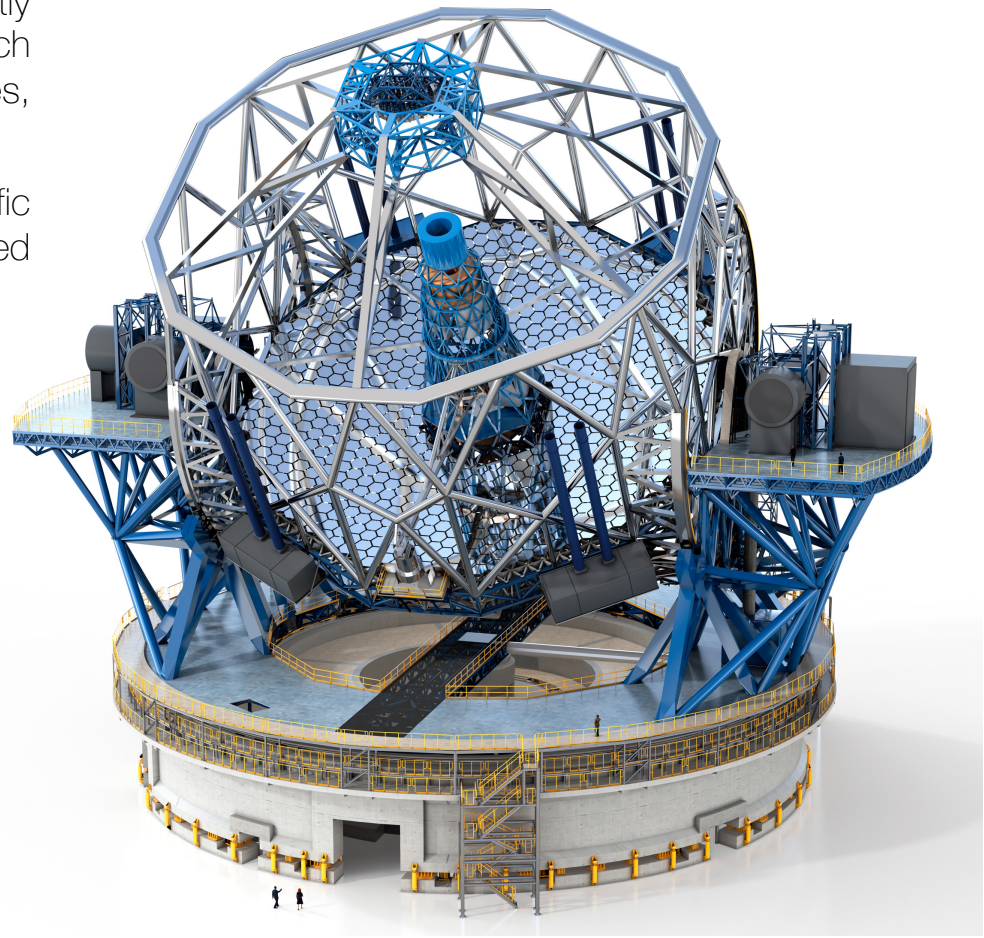
The new era of the Extremely Large Telescopes

Extremely large telescopes are considered worldwide to be a ground-breaking milestone in the development of ground-based astronomical facilities. They are meant to vastly expand our astrophysical knowledge, allowing detailed studies in almost all fields such planets around other stars, the first objects in the Universe, supermassive black holes, and the nature and distribution of the dark matter and dark energy.

The ELT is a project led by ESO since 2005, and will constitute an unique scientific opportunity for the national astronomical community to access this new ground-based observatories.

The ESO ELT in numbers

- The world's biggest eye on the sky: 40m-class VIS-IR adaptive telescope, the largest optical telescope ever built
- M1 39 m (798 hexagonal 1.4 m mirror segments)
- Five-mirror design: three-mirror on-axis anastigmat + two fold mirrors used for adaptive optics
- 2.60 m adaptive M4 using 6 Laser Guide Stars
- Major technological and engineering challenge: diffraction-limited 40m telescope ~10 mas PSF core
- Approved by 2012, first-light targeted for 2026
- Operations planned for 2026 – 2056+



Credit: ESO

HARMONI: the first-light spectrograph for the ELT

HARMONI is one of the first-light instruments to be installed on the ELT as soon as it begins operations. It will function as a workhorse instrument for integral field spectroscopy in the wavelength range 0.47–2.45 μm, and its versatility will allow the community to address almost all the science programs of the ELT.

It will offer a set of spatial scales to optimise observations for a wide range of science programmes and observing conditions, and it is specifically design to exploit the best image quality delivered from the laser tomographic adaptive optics module of the telescope.

The international consortium developing HARMONI is led by the University of Oxford and the UK-ATC in Edinburgh, and is also conformed by the University of Durham, CRAL-Lyon, LAM, IAC-Tenerife, CAB-Madrid, and the University of Michigan.

HARMONI in a nutshell

- Optical and near-IR IFS (~32000 spectra)
  - Wavelength range: 0.47 - 2.45 μm
  - Spectral resolution: ~3500, 7000, 18000
  - Pixel scales: 30 mas, 20 mas, 10 mas and 4 mas
  - FoV: ~9”x6”, 4”x3”, 2”x1.5”, 0.8”x0.6”
- LTAO, SCAO, HCAO and No-AO (seeing-limited) observations
- Sensitivity: up to H_{AB}~27.4 mag (5σ, 5h, S/N~5, LTAO, point source)

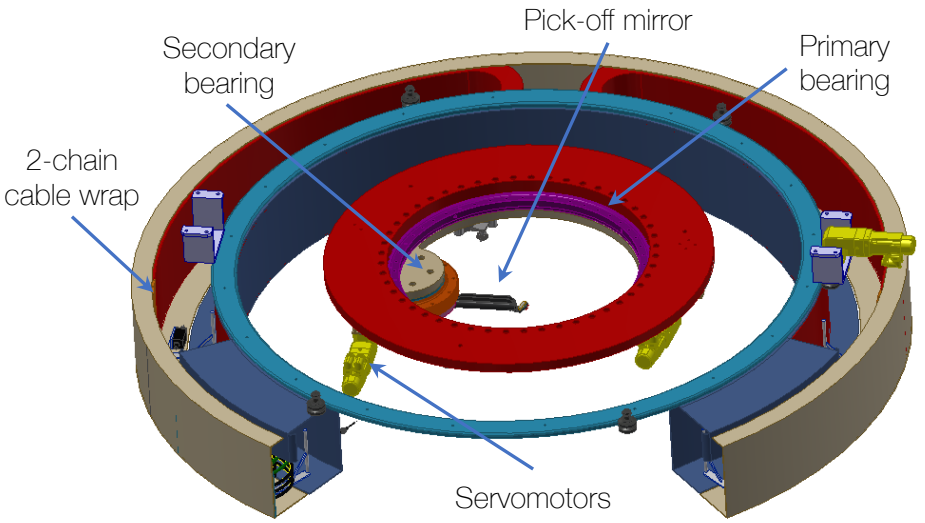
CAB contribution to ELT-HARMONI

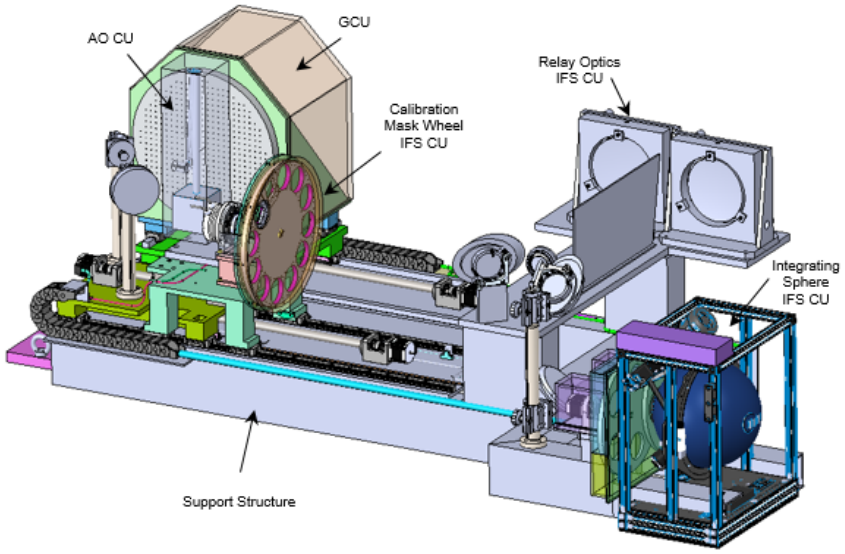
LOWFS - Low-order Wavefront Sensing Sub-system

- Pick-off arm (POA)
  - Pick-off mirror that can be positioned around the entire technical and scientific field of view of the instrument
  - Holds the wavefront sensing cameras on a mechanical stage (LOB)
  - Challenging positioning accuracy of ~10μm over the whole 400mm technical field
- Low-order optical bench (LOB, developed by U. Durham)
  - LTAO NGS sensors
  - Secondary Guiding Module (SGM)

CM - Calibration Module

- The CM includes all functions necessary to remove the instrumental signature from the observed science data:
  - Provide uniform (continuum and arcs) illumination at the ELT focal plane
  - Provide well-known spatial and spectral patterns
  - Monitor the health and stability of the instrument
- Three units to provide different sets of calibration data:
  - IFS unit: science calibrations
  - AO unit: SCAO and LNGS calibrations
  - GCU: geometrical calibration unit to calibrate the POA and SCAO





CAB contribution to ELT-HARMONI

Instrument Calibration Plan

- CAB hosts the Calibration Scientist of HARMONI, responsible of the development of the Calibration Plan of the instrument.
- The Calibration Plan describes all the tasks and procedures to perform the calibration of the science data from the instrument, and to perform the AO and monitoring calibrations.
- We also study, establish and refine the patterns to equip the CM with all the needed elements (lamps, masks, etc.) to perform the instrument calibration

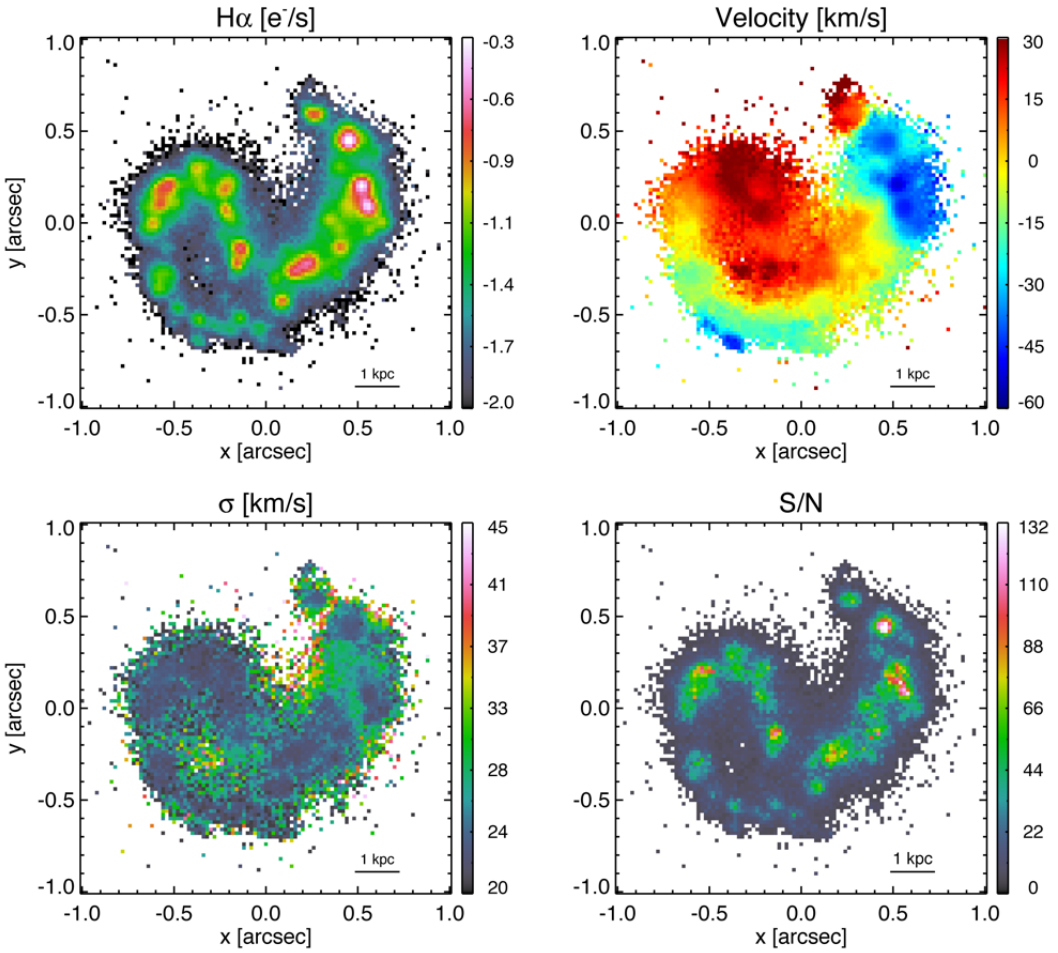
HSIM - HARMONI Science Simulator

- HSIM is an open-source (https://github.com/HARMONI-ELT/HSIM) parallel processing code to simulate HARMONI observations based on the user inputs
- This is an essential tool for the future HARMONI users to optimize the ELT observing time

HARMONI Science Team

- CAB also hosts the HARMONI Project Scientist, who is responsible of the coordination of the science team effort.
- We also participate on the definition and development of the science cases for the HARMONI scientific exploitation

HSIM simulation of a z~2 ULIRG

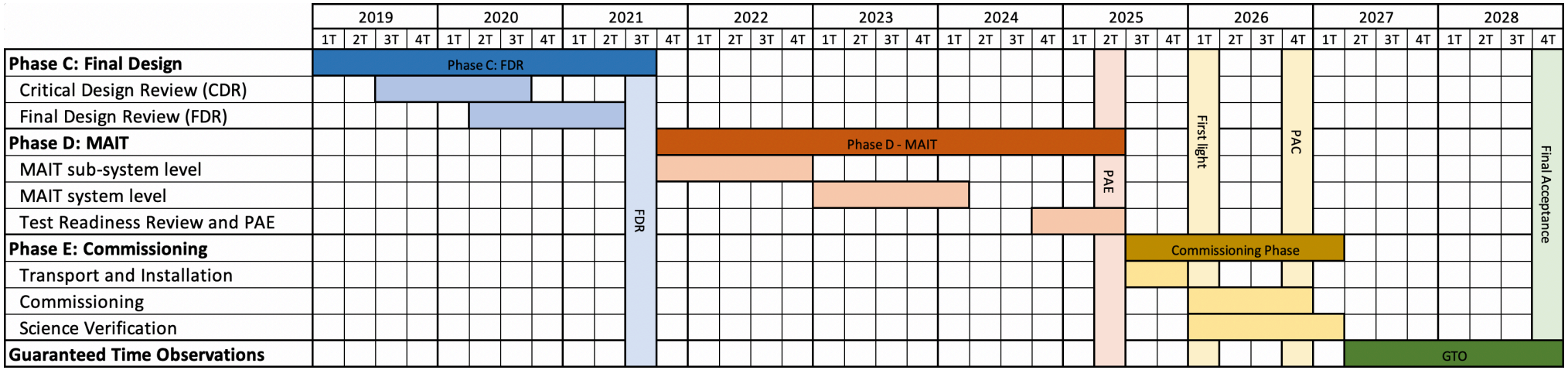


The road towards ELT-HARMONI first-light

HARMONI is currently ending its Final Design phase (Phase C), that started at the beginning of 2018. During the last months, the different HARMONI systems and sub-systems have undergone a series of Critical Design Review (CDR) processes, that will continue for the next year. The different reviews are key to assess that the current instrument design will meet all its technical specifications. In particular, the CM and LOWFS sub-systems passed their CDR reviews in October 2019 and February 2020.

In parallel, in the next few weeks, the instrument will start its Final Design Review (FDR) process. The design of the instrument will be carefully reviewed by ESO in a sequence of five review meetings, starting in July 2020, and ending by November 2021. The end of its Phase C is the last milestone of the design phase of the instrument, and marks the starting point for the manufacturing of the instrument.

The MAIT phase of the instrument is expected to spawn along 2022 until mid-2025, ending with the Preliminary Acceptance in Europe (PAE) of the instrument, last step before shipping to Chile. The first light of the instrument is expected by early 2026.



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