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Published version information:

Citation: Bernhard R. Brandl et al., Final design and status of the Mid-IR ELT Imager and Spectrograph, METIS, Proceedings Volume 13096, Ground-based and Airborne Instrumentation for Astronomy X; 1309612 (2024)

DOI: https://doi.org/10.1117/12.3018975

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Final Design and Status of the Mid-IR ELT Imager and Spectrograph, METIS

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ABSTRACT

The Mid-Infrared ELT Imager and Spectrograph (METIS) will be one of only three 1st-generation science instruments on the 39m Extremely Large Telescope (ELT). METIS will provide diffraction-limited imaging and medium resolution slit-spectroscopy from 3–13 microns (L, M, and N bands), as well as high resolution (R≈100,000) integral field spectroscopy from 2.9–5.3 microns. Both imaging and IFU spectroscopy can be combined with coronagraphic techniques.

After the final design reviews of the optics (2021) and the entire system (2022), most hardware procurements have started. In this paper we present an overview of the status of the various ongoing activities. Many hardware components are already in hand, and the manufacturing is in full swing in order to start the assembly and testing of the subsystems in 2024 toward first light at the telescope in 2028/29. This rather brief paper only provides an overview of the project status. For more information, we refer to the detailed instrument paper which will be published soon.

Keywords: METIS, ELT, mid-infrared, final design, high-contrast imaging, high-resolution spectroscopy, hardware procurements, AIT

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Ground-based and Airborne Instrumentation for Astronomy X, edited by Julia J. Bryant,
Kentaro Motohara, Joël R. D. Vernet, Proc. of SPIE Vol. 13096, 1309612

© 2024 SPIE · 0277-786X · doi: 10.1117/12.3018975

1. INTRODUCTION TO METIS

METIS is the Mid-Infrared ELT Imager and Spectrograph, one of only three first-generation science instruments on the Nasmyth platform of ESO's Extremely Large Telescope (ELT). METIS is being built by a consortium of 12 partner institutes a from 10 different countries – NOVA, MPIA, UK-ATC, CEA Saclay, ETH Zürich, A*, ASIAA, Centra, the University of Cologne, KU Leuven, U Liège, and the University of Michigan – in close partnership with ESO.

All observing modes of METIS work at the diffraction limit of the 39m ELT (≈ 0."023 at 3.5μm) by means of a single conjugate adaptive optics system, and offer:

- Imaging over a field of view of 10.5" × 10.5" (at 3 – 5 μm) and 13.5" × 13.5" (at 8 – 13 μm). The imager subsystem also provides medium resolution, long-slit spectroscopy (R ≈ 1400 at 3 – 5 μm, and R ≈ 400 at 8 – 13 μm), as well as various modes of coronagraphy for high contrast imaging.
- Integral-field spectroscopy at high spectral resolution (R ≈ 100,000) at 3 – 5 μm, over a field of view of ~ 0.9" × 0.6". The IFS includes a mode with extended instantaneous spectral coverage $\Delta\lambda_{instant}$ ≈ 300 nm, as well as coronagraphy for high contrast IFU spectroscopy.

The (evolving) conceptional design of METIS has been reported at several previous SPIE symposia [1], [2], [3], [4], [5]. A conceptional overview of the instrument is shown in Figure 1. For the time being, a brief overview of the instrument concept and its expected performance can also be found in the ESO Messenger [6]. A short METIS introduction video can be viewed on YouTube [9].

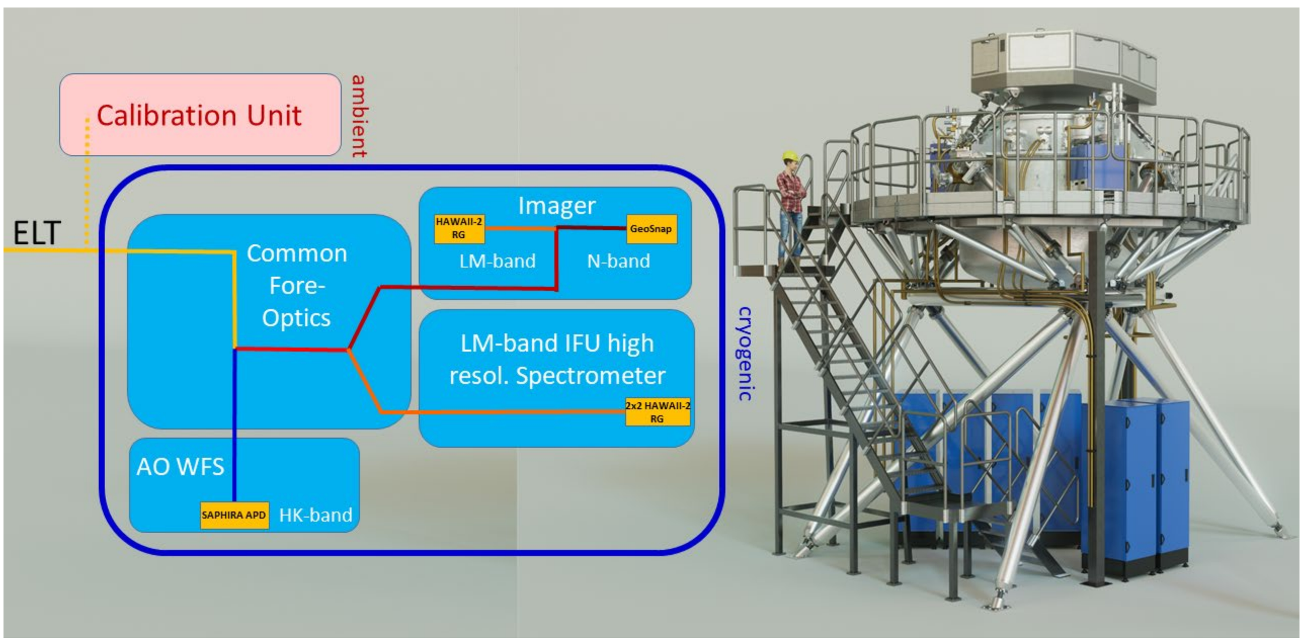

Figure 1 *Left*: schematic overview of the instrument concept: the beam from the ELT enters the cryostat through a window from the right and will be "pre-conditioned" within the so-called Common Fore-Optics, which provides image and pupil derotation, chopping, pupil alignment, atmospheric dispersion correction, as well as numerous filters and masks in the intermediate pupils and image planes. Here the beam gets split between the cryogenic AO wavefront sensor module (H & K-band) and the science modules (L, M, N-band). The science modules include the 2-channel Imager and the IFU high resolution spectrometer. The warm calibration unit can be used for initial testing during MAIT as well as for routine recalibrations during day time. *Right*: a rendered image of how METIS will look on the Nasmyth platform.

The main aim of this brief conference paper is fourfold: (1) remind the reader of what METIS is (this section), (2) summarize the current status of METIS (section 2), provide a complete list of all specific METIS presentations at this symposium (section 3), and (4) and outlook toward the next steps (section 4).

2. CURRENT STATUS OF METIS

The METIS project started with the 'Phase-A study' (May 2008 – Dec 2009), followed by an 'Interim Study' (Oct 2014 – Jul 2015), and was formally defined in the Agreement with ESO (Oct 2015). This led to the preliminary design review (PDR, May 2019). The Final Design Review (FDR) has been split into reviews for the long-lead items (Mar & Jul 2021), the main system FDR (Nov 2022), and the data pipeline review (Nov 2023). The formal acceptance of the final design by ESO was granted and announced in May 2024 [7].

METIS is now in full swing manufacturing, assembling, and testing components and subsystems. Thanks to the early reviews of long-lead items, many components have already been procured. Figure 2 shows a selection of hardware items that already exist.

3. METIS PRESENTATIONS AT THIS SPIE SYMPOSIUM

Altogether, a series of 34 papers on specific topics relevant to METIS have been at this SPIE Symposium, providing a detailed, in-depth description of METIS. The listing below is first subdivided by topic and then sorted by paper number.

<u>Optics</u>

- Paper 13096-192 by Ch. Delacroix: "*METIS high-contrast imaging: from final design to manufacturing and testing*"
- Paper 13097-290 by G. Orban de Xivry: "*ALF: an asymmetric Lyot wavefront sensor for the ELT/METIS vortex coronagraph*"
- Paper 13099-2 by D. Dolkens: "*The impact of micro-vibrations on the METIS instrument*"
- Paper 13100-100 by Ch. Delacroix: "*The ELT/METIS annular groove phase masks*"
- Paper 13100-257 by D.S. Doelman: "*Infrared vector-apodizing phase plates: prototyping for ELT/ METIS/ MICADO*"
- Paper 13100-258 by L. König: "*Design, manufacturing and prototype testing of the METIS ring apodizer*"

<u>Adaptive optics</u>

- Paper 13097-80 by Th. Bertram: "*How to make METIS SCAO work*"
- Paper 13097-116 by M. Feldt: "*Evolving the METIS soft real-time control system out of the simulation environment*"
- Paper 13097-137 by D.J. Mortimer: "*Building an ELT simulator in the lab for subsystem testing of METIS/SCAO*"
- Paper 13097-177 by C. M. Correia: "*Handing over from the ELT: online METIS mis-registration calibration with crazy fast control matrix updates*"
- Paper 13097-258 by B. Stadler: "*On how to gain 60nm RMS (for the instrument METIS) in AO control*"
- Paper 13097-304 by P. Pathak: "*Characterizing water vapour seeing for METIS HCI*"
- Paper 13101-145 by M. Kulas: "*METIS AOCS at the beginning of MAIT*"
- Paper 13101-146 by H. Coppejans: "*METIS RTC as a computationally heavy system*"

Figure 2 (a) Imager backbone structure, (b) focal plane wheel for 16 filters and masks (c) SCAO modulator, (d) SCAO test cryostat at MPIA, (e) derotator drive mechanism, (f) assembly support frame, (g) cryostat radiation shields at ETH, (h) K-mirror housing, (i) grating rotator mechanism, (k) cryostat vessel at the manufacturer, (l) SCAO pyramid for wavefront sensor, (m) SCAO field selector, (n) AIT integration facility at Leiden University (under construction) (o) Canon N-band grism, (p) ruling of the N-band grism, (q) IFU slicer, (r) IFU pupil mirror, (s) Canon Germanium immersed grating, (t) JPE beam chopper, (u) ICS GUI, (v) ICS test rack for testing and operation.

(Opto-)Mechanics

- Paper 13096-193 by M.C. Cárdenas Vázquez: "*The METIS imager: final opto-mechanics design and manufacturing*"
- Paper 13096-194 by Shiang-Yu Wang: "*The design and performance of the wheel systems in the common foreoptics of the ELT METIS*"
- Paper 13096-198 by M. Filho: "*Challenges to the manufacturing of the warm support structure for the METIS instrument at the ESO/ELT telescope*"
- Paper 13096-199 by P. Bizenberger: "*METIS: the imager: from design to verification*"
- Paper 13099-89 by D. Dolkens: "*Opto-mechanical analysis framework for the tolerancing of the METIS CFO*"
- Paper 13100-9 by E. Dijkstra: "*Manufacturing requirements and challenges of the fully integrated monolithic aluminium cryogenic tip-tilt mirror for the METIS instrument*"
- Paper 13100-110 by J. Lynn: "*Development of a monolithic flexure based tip/tilt cryo-mechanism to stabilize the pupil of METIS*"
- Paper 13100-111 by J.-Ch. Barrière: "*Design and performances of the ELT-METIS cryogenic derotator drive*"

Testing and AIT

- Paper 13096-195 by Y. Dallilar: "*Progress of the Warm Calibration Unit (WCU) subsystem of METIS towards the full subsystem integration: an overview of the post-FDR status*"
- Paper13096-196 by Y. Dallilar: "*Final optical design of relay optics and alignment optics of the Warm Calibration Unit in METIS/ELT: analysis, performances, and the procurement of the optics*"
- Paper 13096-197 by Y-C. Huang: "*AIT support equipment design for METIS*"
- Paper 13096-200 by R. Stuik: "*Counting down towards system level AIT for METIS*"
- Paper 13099-64 by M. Filho: "*Overcoming obstacles to the assembly, integration, and testing of the WSS/METIS*"

Software

- Paper 13101-31 by M. Baláž: "*Implementation plans for the data reduction pipeline for METIS at the ELT*"
- Paper 13101-80 by M. Baláž: "*Data reduction pipeline for the METIS integral field spectrograph*"
- Paper 13101-147 by W. Pessemier: "*The METIS instrument control system*"
- Paper 13101-152 by M. Salman: "*METIS cryostat and vacuum control*"

Miscellaneous

- Paper 13094-113 by A.M. Glauser: "*The as-manufactured design of the cryostat for ELT/METIS*"
- Paper 13099-6 by F. Bettonvil: "*Management of the METIS project*"
- Paper 13103-105 by B. Serra: "*METIS first light imager and spectrograph for the ELT: overview of the near and mid-infrared detector subsystems*"

4. MORE INFORMATION ABOUT METIS

METIS, being one of only three scientific 1st-generation ELT-instruments, receives a lot of interest from the astronomical community. With the final design being approved and hardware being manufactured, but first-light still about five years ahead, now would be the right time for one comprehensive description of the instrument. We therefore aim at a detailed, refereed journal paper in the near future [8].

ACKNOWLEDGEMENTS

The METIS project status presented in this paper is the result of the hard work of a dedicated team of more than 80 engineers, and more than 50 scientists. Their contributions will be recognized via co-authorship on the upcoming instrument paper [8].

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