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Cryogenic Challenges in Infrared Astronomy: The METIS Experience

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The Mid-infrared ELT Imager and Spectrograph (METIS) is one of the first-generation instruments being developed for the Extremely Large Telescope (ELT). It will observe in the 3–13 μm wavelength range, which is key for studying faint thermal emission from astronomical sources like exoplanets and distant galaxies. To detect such faint signals, METIS needs a cryogenic environment that reduces thermal background and ensures reliable performance of infrared detectors, which operate most efficiently at very low temperatures, typically between 35 K and 70 K.
METIS is being developed by a consortium of international institutes, with NOVA (the Netherlands Research School for Astronomy) acting as the Principal Investigator (PI) institute. In addition to its coordinating role, NOVA is also responsible for the Core Fore Optics (CFO), which is the front-end cryogenic optical METIS subsystem. The CFO includes several optical components and mechanisms - such as filter wheels, fold mirrors, and alignment stages - which direct the beam towards either the imager or the spectrograph, and allow for various observation modes. These mechanisms operate in a cryogenic environment and must maintain high precision and reliability under low-temperature conditions.
The large cryostat that houses the cryogenic system is designed and built by ETH Zurich. It provides the required vacuum environment for the cold subsystems, contributes to the mechanical stiffness and alignment of the instrument, and supplies the necessary cooling to the optics and detectors. The cryostat is designed for partial access to the internal components, which is important for integration and maintenance.
The overall thermal design of the cryogenic system of METIS uses a staged approach. First, a liquid nitrogen (LN_2) system is used for pre-cooling during cooldown. This is followed by active cooling with several pulse tube cryocoolers (PTCs), which bring the system down to its final operating temperature and maintain it during steady-state operation. The design aims to minimize thermal loads and temperature fluctuations to ensure stable performance.
In this talk, we will focus on the cryogenic aspects of METIS. We will present the main features of the cryostat, describe the thermal design and cooling strategy, and show examples of internal mechanisms operating at cryogenic temperatures. The aim is to provide an overview of the cryogenic system and highlight some of the technical challenges involved in developing and operating a mid-infrared instrument like METIS.

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