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A High-resolution Spectrograph at a Metre-class Telescope at Devasthal: What Can Be Gained?

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Abstract

The Indo-Belgian bilateral project titled "Belgo-Indian Network for Astronomy and Astrophysics (BINA)" is an excellent initiative to spark scientific collaboration between Belgian and Indian astronomers. The Belgian university, KU Leuven, owns and operates the semi-robotic Mercator telescope – a 1.2 m telescope stationed at the Roque de los Muchachos observatory on the island of La Palma. This telescope is equipped with the High-Efficiency and high-Resolution Mercator Echelle Spectrograph (HERMES). This contribution aims to discuss a long-standing idea – what would BINA, and by extension the entire Indian astronomical community, gain with the addition of a similar 1-m class telescope with a high-resolution spectrograph in Devasthal.

Keywords: techniques:spectroscopy ; telescopes ; instrumentation:spectrographs

1. Introduction

In the era of modern astronomy, large-scale observational facilities with multiple instruments are more and more commonplace. Such facilities are highly competitive since a plethora of science cases can be investigated through observations with these instruments. To complement the data collected with such facilities, the High-Efficiency and high-Resolution Mercator Echelle Spectrograph (HERMES, Raskin et al., 2011) mounted on the La Palma telescope at the Roque de los Muchachos observatory is uniquely suited. With a wavelength coverage of 380 to 900 nm and a resolution of $\sim 85,000$, it is supremely useful for stellar atmospheric abundance analyses and radial velocity monitoring of (candidate) binary systems. The HERMES spectrograph is operated by a consortium headed by KU Leuven, Belgium. The other members of the consortium are the Royal Observatory of Belgium, the Université Libre de Bruxelles, the Geneva Observatory (Switzerland) and the Tautenburg Observatory (Germany).

The Belgo-Indian Network for Astronomy and Astrophysics (BINA) is an initiative that emerged in the past two decades with the aim of fostering collaboration among Belgian and Indian astronomers from diverse backgrounds. This collaboration has yielded significant outcomes, including the installation of the 3.6-m Devasthal Optical Telescope (DOT) and the 4-m

International Liquid Mirror Telescope (ILMT). In addition to instrumental projects, the BINA collaboration has facilitated research visits for Indian scientists to Belgium and vice versa. Over the course of multiple BINA workshops, the collaboration has evolved beyond its original focus on instrumentation, embracing a broader scientific agenda. Many of the contributions presented in this workshop reflect this evolution.

The purpose of this contribution is to initiate a discussion regarding the potential installation of a facility akin to the Mercator telescope, i.e., a high-resolution spectrograph on a metre-class telescope, at the Devasthal observatory in India. This paper will delve into the scientific leverage, outreach opportunities, and benefits for students at astronomical institutes. It will also outline the requirements necessary to ensure the cost-effectiveness of such a facility. It is important to note that this contribution does not delve into the technical intricacies of the HERMES spectrograph; interested readers are directed to Raskin et al. (2011) for further information. Instead, this contribution will focus on the operation of the Mercator telescope, including its supporting software (Section 2), as well as the various science cases it enables (Section 3). The benefits for outreach and leverage for funding proposals are highlighted in Section 4. Finally, concluding remarks are provided in Section 5.

2. Operation of the Mercator Telescope

The Mercator telescope is maintained and operated by KU Leuven. It is operational for 360 days of the year and is closed for operations between Christmas and New Year. The weather conditions all year round account for a 30−40 % loss in observing time, either due to clouds or particulate dust (‘calima’) from the Sahara desert. This results in about 200–220 clear, spectroscopic nights on average every year. The average seeing at the observatory is around 1", which is slightly higher than that at the Devasthal observatory. The telescope is run solely in service mode. An astronomer and an engineer are stationed locally on the island of La Palma, who serve as support staff for telescope operators. Staff and PhD students from the Institute of Astronomy and Astrophysics at KU Leuven take 15-day observing runs with support from the local staff.

2.1. Observing cycles

The Mercator telescope operates on a semester-based observing cycles, starting in April and October every year. There is a call for proposals a few months prior to the start of the cycle. The time allocation committee (TAC) consists of astronomers from the HERMES consortium. Since the facility is located on a Spanish island, a few percent of observing time is set aside as guaranteed time for Spanish-led scientific programs every cycle. Additionally, 5 % of the total observing time is allocated for the “International Time Programme” (CCI-ITP). This programme is for all of the telescopes located at the Roque de los Muchachos observatory on La Palma.

Figure 1: A view of the Mercator Telescope Control System taken from the Mercator Observing Cookbook.

2.2. Weather monitoring

In order to assist the observer with in-situ meteorological data, there is a dedicated weather station installed outside the Mercator telescope building. Additionally, sensors inside the telescope dome and on top of the building provide data on the humidity, temperature and pressure. This data is complemented by all-sky cameras and weather monitors from other telescopes on La Palma, providing the observer with a plethora of information with which decisions can be made. Moreover, there are hard-coded closure conditions in place so that a sudden, drastic change in weather conditions does not damage the primary mirror of the telescope.

2.3. Supporting software

Since the Mercator telescope is a semi-robotic telescope, user-friendly software has been developed by the Mercator team to facilitate efficient operating of the telescope. Amongst the different software, the Mercator Telescope Control System (MTCS) is a prominent one. Installed on a touch-screen in the control room, the MTCS allows the observer to open and close the dome and telescope cover at the touch of a few buttons. Additionally, the instrument can be set using the tertiary mirror, and telemetry data from within the dome can be accessed. In case of mechanical or electrical failures, troubleshooting is also possible with this software. This is accompanied by a schematic of the current direction and elevation of the telescope, which is extremely handy when trying to observe in windy conditions. A screenshot of this software can be seen in Fig. 1.

Another critical software is the Mercator Observatory Control System (MOCS). It is a graphical user interface that the observer can use to monitor the telescope, instruments and the

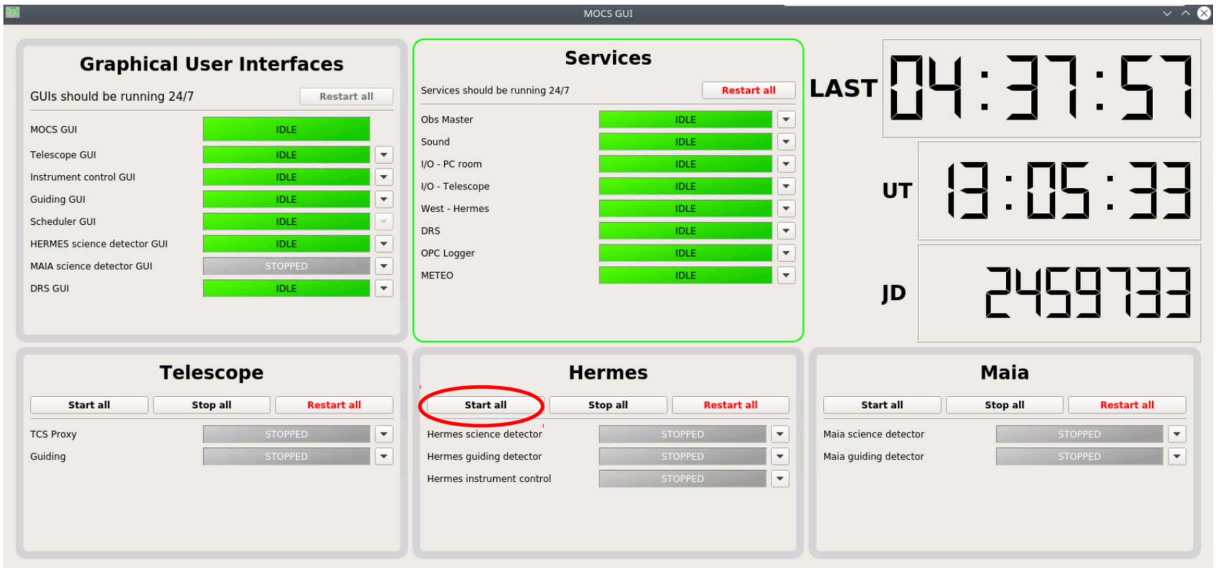

Figure 2: The graphical user interface of the Mercator Observatory Control System (MOCS) provides the operator with critical information about interfaces, services, and telescope controls.

services that are running in the building. In case of any malfunctions, it allows the telescope operator to quickly identify and restart the relevant service or interface. It also provides a log of the technical flow of control during the observations, allowing the operator to take note of any anomalies if present. The graphical user interface of MOCS can be seen in Fig. 2.

2.4. Observing on a night

On a typical night of telescope operations, the observer first takes flat field and wavelength calibrations for the instrument (HERMES, in this case) before the start of the night. Using the scheduler tool (Fig. 3), the observer creates the schedule for the night where the targets are pooled by priority, visibility, airmass, and if they are time-critical. The estimated observing time in the scheduler takes into account the pointing of the telescope. In theory, an observer needs to handle the scheduling only at the start of the night if the weather conditions remain stable.

Once the telescope pointing is complete, the guiding camera attached to the telescope acquires a full field-of-view image. It suggests the brightest star at the center of the field as the target to be observed. This has to be cross-checked by the observer, as the auto-suggestions are problematic in the case of crowded fields. Once this has been selected, however, the software then moves to center the fibre on the program star and proceeds with the exposure. The guiding camera field-of-view can be seen on its graphical user interface in Fig. 4.

At the end of the night, calibrations for the instrument are performed and flat fields are acquired. All procedures for closing the telescope are handled by the MCTS, e.g., ensuring the telescope is parked in the correct procedure, closing the dome and the telescope cover, and ensuring that the hydraulics and other electrical connections are safely turned off. Once this has

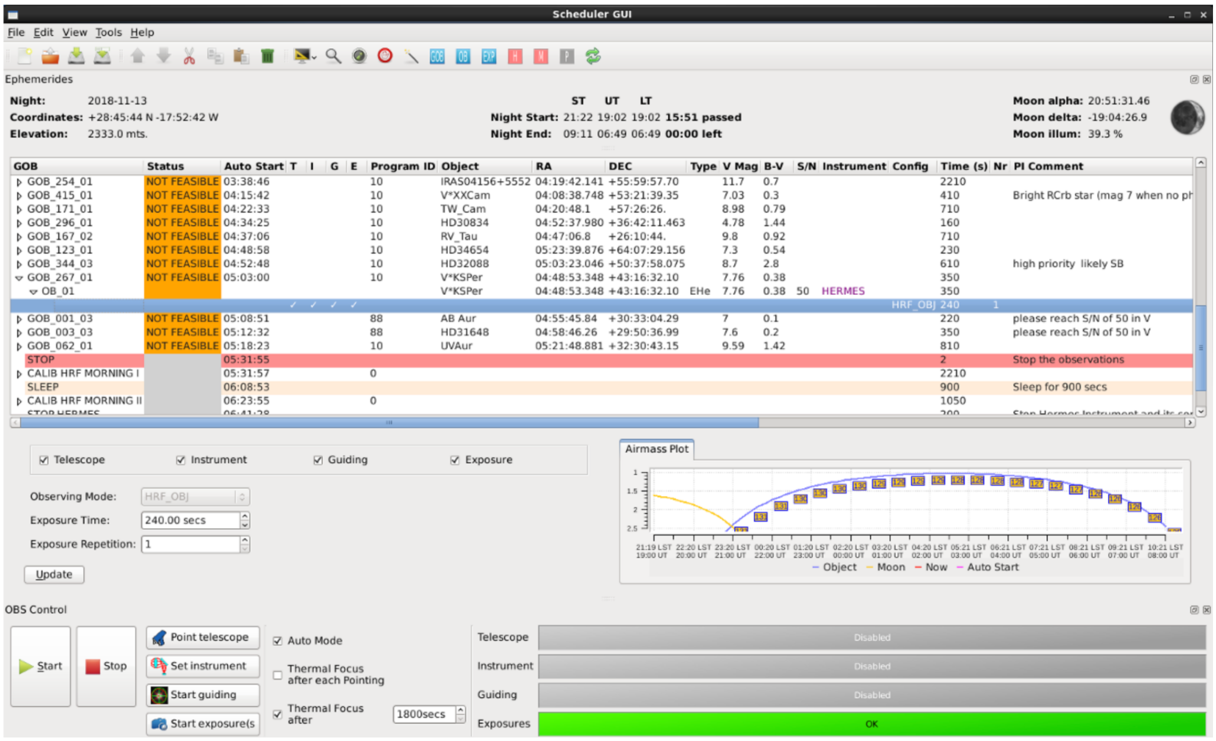

Figure 3: The Mercator scheduling tool. The observer can schedule targets based on visibility and time constraints, pooled by priority.

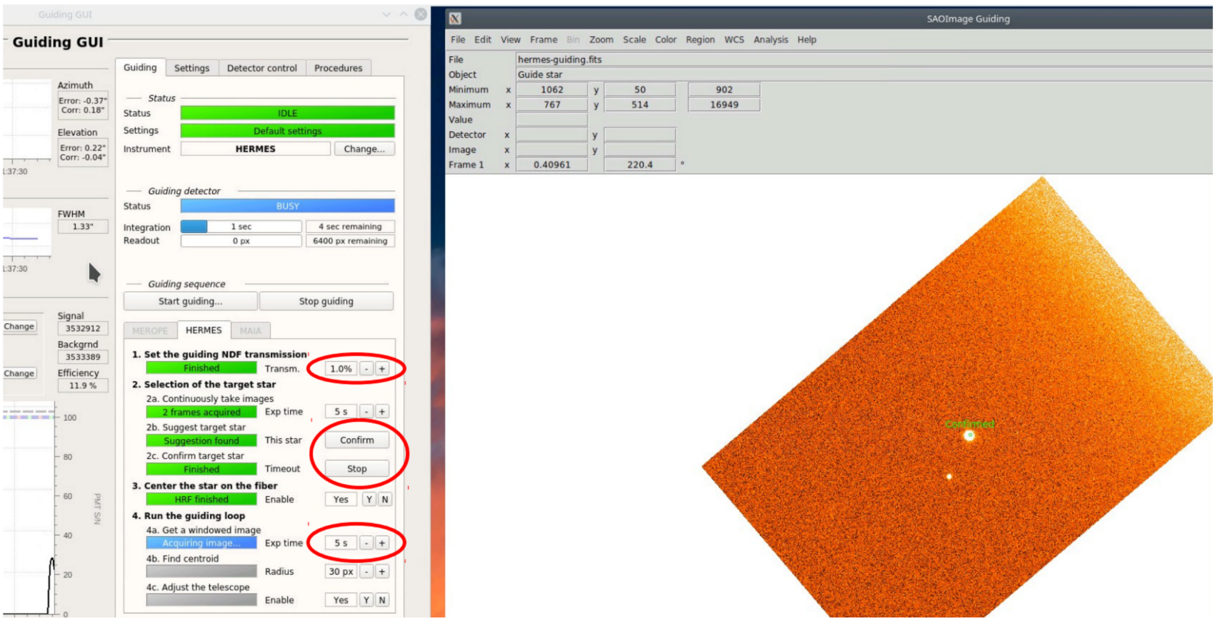

Figure 4: The guiding graphical user interface. The field of view image can be seen with the suggested target marked with a green box.

been verified by the observer, they write an end-of-night report for the Mercator team to review during the day. This report contains brief comments about the scientific programmes observed, if there were any technical issues, reports on the weather, and if operations ran smoothly. This allows the Mercator team to follow up on any problems encountered as soon as possible in order to maximise the available observing time.

3. Scientific Opportunities

The Mercator telescope, equipped with the HERMES spectrograph, has been utilized for a wide range of scientific investigations. This section highlights the scientific potential of a similar facility at the Devasthal observatory using examples from its existing counterpart. While the following section highlights several science cases addressed by the HERMES spectrograph, it is important to note that the examples provided are not exhaustive, and interested readers are encouraged to refer to the Mercator website for further information.

Since its launch in 2009, the HERMES spectrograph has gathered nearly 130,000 spectra across approximately 110 science programs, leading to approximately 380 peer-reviewed citations. Additionally, the MAIA imager installed on the Mercator telescope has played a crucial role in conducting photometric follow-ups of pulsating stars and supernovae candidates (e.g., Blanco-Cuaresma et al., 2016).

Given the Mercator telescope's guiding camera's limitations in detecting objects fainter than a magnitude of 12 in the V-band, the primary focus of scientific exploration has been in the field of stellar astronomy. However, studies have also utilized HERMES data to investigate Galactic extinction laws with diffuse interstellar bands (e.g., Maíz Apellániz et al., 2021), and star formation history (e.g., Miret-Roig et al., 2022).

Asteroseismology, in conjunction with space missions like Kepler, K2, TESS, and Gaia, has benefited from the HERMES data (e.g., De Cat et al., 2009; Beck et al., 2017; Baran et al., 2018; Bowman and Kurtz, 2018; Brogaard et al., 2018; Sekaran et al., 2020; Merc et al., 2021; Karjalainen et al., 2022; Van Reeth et al., 2022). Notably, combining spectral line profile variations with asteroseismic forward modeling techniques has propelled advancements in the field (e.g., Pedersen et al., 2021).

Over the past few decades, it has become evident that stars often exist in binary or multiple systems, particularly among massive stars (Mason et al., 2009; Sana et al., 2012, 2014, etc.). Understanding the impact of binarity on stellar evolution remains a topic of significant interest. With HERMES, binary stars across different mass regimes have been monitored extensively, allowing for the determination of their orbits, analysis of their chemical composition, investigation of their immediate surroundings, and comprehension of their evolutionary processes (e.g., Carneiro et al., 2018; Abdul-Masih et al., 2021; Bollen et al., 2021; Vega et al., 2021; Karjalainen et al., 2022; Molina et al., 2022). Systematic surveys of star populations at different stages of evolution also contribute empirical constraints for population synthesis codes (e.g., Dsilva et al., 2022; Kobzar et al., 2022; Mahy et al., 2022; Escorza and De Rosa, 2023).

Since the advent of gravitational wave astronomy, the hunt for black holes with stellar companions has become widespread. The HERMES spectrograph facilitates rapid follow-up observations of multiple candidates (e.g., Corral-Santana et al., 2018; Abdul-Masih et al., 2020; Bodensteiner et al., 2020; Shenar et al., 2020) and offers the possibility of long-term monitoring programs. Such campaigns not only enable significant scientific breakthroughs but also enhance the visibility of research within the broader astronomical community.

In summary, the use of the HERMES spectrograph in scientific investigations provides insights into both microscopic and macroscopic phenomena in the field of stellar astrophysics, encompassing various timescales. Implementing a similar instrument at the Devasthal facility would greatly enhance the existing range of science cases and complement the ILMT and the DOT effectively.

4. Outreach Opportunities and Funding

The addition of a facility described above to a prestigious observatory at Devasthal brings forth a multitude of opportunities that extend far beyond the realm of astronomical research. Firstly, having access to a telescope offers a significant advantage when it comes to funding applications. Potential benefactors, such as government agencies and private organizations, recognize the value of easy access to telescope time which is usually highly competitive and/or expensive. As a result, they are more likely to provide financial support to applications with access to such observatories equipped with these powerful instruments.

Secondly, the presence of an additional telescope opens up avenues for outreach initiatives, particularly at the high school level, where the wonders of astronomy can be shared with young minds. By organizing workshops, observing sessions, and educational programs, such a facility can generate greater interest in astronomy among students, potentially inspiring the next generation of scientists and astronomers.

Additionally, the inclusion of an instrument similar to HERMES at the Devasthal observatory provides an excellent opportunity for advanced education at the Masters and PhD levels. Students pursuing higher degrees can benefit from hands-on training in writing observing proposals, acquiring data, performing rigorous analysis, and producing comprehensive research reports. This practical experience, coupled with proper expert feedback, enables aspiring students to hone their proposal-writing skills to a competitive level on the international stage. With time and practice, they develop the expertise needed to craft compelling proposals that stand out among their global peers. This not only enhances the reputation of Indian astronomers but also promotes collaboration and recognition in the international scientific community.

5. Concluding Remarks

This contribution highlights the operational scheme and scientific capabilities of the HERMES spectrograph on the Mercator telescope. Taking these steps would ensure that a similar facility installed at the Devasthal observatory would run smoothly with minimal maintenance costs and delays. By operating the telescope via service mode, with observations pooled based on time constraints, visibility, and priority, the efficient running of the facility and the reduction of observing time loss can be achieved. Additionally, the supporting software described here aims to simplify the observer's experience and further enhance the operational efficiency of the facility.

Furthermore, this paper proposes various opportunities for outreach, education, and funding proposals, which would greatly benefit the Indian astronomical community on both local and international scales. These opportunities encompass a wide range of activities, including targeted outreach programs aimed at engaging the local Indian community, such as schools and educational institutions. These programs would aim to spark interest in astronomy and inspire young minds to explore the wonders of the universe.

Moreover, educational initiatives would be established to provide middle school and high school students with hands-on experiences and exposure to the world of astronomy. By participating in workshops, observing sessions, and data analysis activities, these students would have the opportunity to deepen their understanding of astronomical concepts and develop their scientific skills.

Additionally, specialized training programs would be designed to support PhD students in various aspects of their research journey. This includes guidance on writing research proposals, acquiring and analysing data, and effectively communicating their findings through research papers. By providing comprehensive training, the aim is to equip these students with the necessary tools and skills to excel in their research endeavors and contribute to the broader field of astronomy.

In summary, the integration of a similar facility at the Devasthal observatory not only holds promise for scientific advancements but also presents a unique opportunity to engage and inspire the local community. Through targeted outreach, educational initiatives for school students, and specialized training for PhD students, the potential for knowledge dissemination and the cultivation of future astronomers is vast.

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Further Information

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Conflicts of interest

The author declares no conflict of interest.

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