EUROPEAN ORGANISATION FOR ASTRONOMICAL RESEARCH IN THE SOUTHERN HEMISPHERE

Scientific Technical Committee 98th Meeting 29 and 30 April 2021

For Recommendation

Science Evaluation of the Proposal to install a 2.5m Telescope on Cerro Murphy

This document is PUBLIC

Scientific Technical Committee is invited to issue a recommendation to the Director General.
1. Introduction

Proposals for Hosted Telescopes are evaluated for their science value by a panel selected by the ESO Directors for Science and Operations following the guidelines provided in STC-545. Panel members were Marcella Marconi (STC), Ross McLure (STC), Thomas Klein (ESO) and Bruno Leibundgut (ESO).

The proposal for the Hosting a 2.5m telescope on Cerro Murphy as a part of the ERC Synergy grant “Sub-percent calibration of the extragalactic distance scale in the era of big surveys – UniverScale” was submitted by a consortium of institutes in Poland, Chile, France and Germany by Grzegorz Pietrzyński. The new telescope should together with smaller, already existing, telescopes on Cerro Murphy observe eclipsing binaries and Cepheid stars to calibrate the local distance scale and perform reverberation mapping of active galactic nuclei at large redshifts to measure distances for a determination of the change of the Hubble parameter $H(z)$.

The panel finds:

The main scientific case (eclipsing binaries and Cepheid calibration) is extremely strong. This project is unique in sample size and the close temporal monitoring and promises a strong and tight calibration for an accurate determination of the Hubble constant. The second science case (reverberation mapping of distant AGN) appears weak and would not warrant a special telescope as requested here. It should be considered an add-on project at best.

There are several shortcomings in the proposal:

- Several existing, smaller telescopes shall be used in the project together with the new 2.5m telescope. The proposal does not describe how the observations of the different samples will be distributed between these telescopes. The instruments on the different telescopes are not described, in particular no spectrograph is mentioned.

- Spectroscopy is an important part of this project. However, no indication is given where the spectroscopy would be obtained. If the proposal depends on acquiring additional (ESO) time then this would need to be clarified.

- The proposal is planned for seven years but no scientific justification of this time span is provided.

- The addition of the proposed 2.5m telescope might change the current operations model for the Cerro Murphy telescopes significantly, e.g. in number of staff present at site, logistics support, power and water resources and safety aspects. The site is run under the ESO umbrella and impacts on ESO operations need to be clarified. A careful impact study should be done before acceptance by the Paranal Observatory. If the 2.5m telescope should be located at Cerro Murphy the existing agreement between ESO and the current partners (Nicolaus Copernicus Astronomical Center and the Ruhr University Bochum) will have to be negotiated.

- ESO has stated that La Silla is the preferred location of hosted telescopes. No consideration for operating the 2.5m telescope on La Silla has been provided in the proposal. At least an evaluation of a potential operation of the 2.5m telescope on La Silla should be done.

Recommendation:

The panel believes that the scientific prospects of this proposal are very good and could provide an important and unique addition to the distance ladder approach to measure the Hubble constant. The proposal lacks information on several aspects, which need to be resolved before implementation of the project. A clear description of the scientific planning
should be provided. The operational aspects need to be clarified with the Paranal Observatory, including an amendment of the existing agreement, before the project can be implemented.
2. **Sub-percent calibration of the extragalactic distance scale in the era of big surveys – proposal for a 2.5m telescope on Cerro Murphy**

2.1 Science Cases

There is some tension in the current cosmological model between local and early Universe measurements. Most prominently a discrepancy of about 4 to 5σ in the value of the Hubble constant, $H_0$, has emerged over recent years. This ‘Hubble tension’ has received significant attention and is the object of intensive studies. The most stringent determinations of $H_0$ come from the Planck satellite observations of the cosmic microwave background at $z \approx 1000$ and a combination of Cepheids and type Ia supernovae in the local Universe. Other ‘local’ determinations come from mega-masers, surface brightness fluctuations and time delays in gravitational lenses. The uncertainty in $H_0$ also imprints an uncertainty on the equation of state parameter, $w$, of dark energy. A small error in $H_0$ is critical to constrain $w$ and any potential deviation from $w = -1$, the value for the cosmological constant. The Large Magellanic Cloud has been traditionally a steppingstone for the extragalactic distance scale and a recent distance measurement based on eclipsing binaries by the proposing group has provided an accuracy of 1%. The extragalactic distance ladder contains currently two main rungs: Cepheids and/or the Tip of the Red Giant Branch (TRGB) to calibrate type Ia supernovae to reach the smooth cosmic expansion flow.

The proposers would like to use two independent geometric methods to calibrate the surface brightness vs. colour relation (SBCR) for eclipsing binaries and Cepheids. The goal is to observe 150 eclipsing binary systems in the Milky Way, to determine the stellar parameters (foremost diameter and colours) and obtain distances with an accuracy of about 0.5%. The SBCR could then be calibrated in the Milky Way with Gaia distances. This calibration would be applied to 30 eclipsing binaries in the LMC to achieve a distance with an accuracy below 1%.

A sample of 120 Cepheids in the Milky Way will be observed with optical and NIR photometry and spectroscopy to determine distances through the Baade-Wesselink method. Combining Gaia distances and the calibration of the SBCR from the eclipsing binaries the projection factor (p-factor) for the different phases of a Cepheid can be determined to about 1% and its debated dependence on the pulsation period can be quantified.

Several other galaxies in the Local Group can be reached by both methods (SMC, M31, M33, NGC 6822, IC1613, WLM and NGC 300) with VLT and the Magellan telescopes (Las Campanas Observatory). These distances can then be used to check for the Cepheid period-luminosity relation in different chemical environments.

The method can eventually be extended with extremely large telescopes (ELT and GMT) to directly calibrate host galaxies of type Ia supernovae.

Reverberation mapping of active galactic nuclei (AGN) uses the time delay between emission in the central accretion disk to establish the contamination to the broad-line continuum emission and the time delays. Detailed radiative transfer calculations will need to be performed to model the emission from the broad line region. Photometric monitoring of AGN samples out to redshifts of about 3, with excellent time delays measured in 14 narrow-band filters would yield individual distances and map the evolution of the expansion parameter $H(z)$.

2.1.1 Overlap with other projects

Most of the work on eclipsing binaries (e.g. the 1% distance determination to the LMC by proposers; Pietrzynski et al. 2019, Nature 567, 200) has used ESO telescopes. There is no other project of this scale operating or planned.
2.2 Implementation and Operations

All proposed science cases require high-cadence monitoring of the objects to establish photometry and spectroscopy. Cerro Murphy already hosts several telescopes operated the Nicolaus Copernicus Astronomical Center (NCAC) and the Ruhr University Bochum (RUB). The operations are regulated by an existing agreement between NCAC, RUB and ESO.

Currently operating are a robotic twin refractor telescope using BVRI imaging, a 40cm Newton telescope and an 80cm infrared telescope. The Polish Ministry of Science has funded an 80cm and a 1.5m telescope to be located at Cerro Murphy in 2022. The new 2.5m telescope – proposed here – for optical and infrared imaging has been funded through an ERC grant and is planned to be located at Cerro Murphy. All telescopes have optical or NIR cameras and will be dedicated to the monitoring of the eclipsing binaries, Cepheids and AGNs for the above projects.

The installation of a 2.5 m telescope at the existing site appears to be a significant extension of the observatory on Cerro Murphy, and associated with this, the required infrastructure and services. The proposal does not provide sufficient information for an assessment of the implications such a change has on ESO operations. The Cerro Murphy operations currently depend on the continuous presence of an observing team on site. This is an exception for a hosted project on Paranal premises with logistical and safety/security impact on Paranal operations. It is not clear to which extend the project has evaluated La Silla, as the ESO preferred site for hosted projects (ESO/STC-545), as suitable for the proposed OCA as a hosted telescope of significant size.

Funding for seven years has been secured. Future operations beyond this period shall be supported by the Polish Ministry of Science. No further specifications on this funding are provided.

10% of the observing time on all telescopes will be offered to the Chilean community as per the existing agreement between NCAC, RUB and ESO.

All services provided by ESO (e.g. water, fuel, liquid nitrogen) are reimbursed by NCAC and RUB.

2.3 Panel Comments

The science case for the eclipsing binaries and the Cepheids is very strong, unique and timely. The proposed project is certainly very ambitious. There are no other projects that would obtain comparable data for the calibration of the second step in the distance ladder. The method has been demonstrated by the accurate distance derived to the LMC and promises to offer a fundamental calibration of Cepheids. The calibration of the luminosity of type Ia supernovae will be further improved and a corresponding tightening of the value of the Hubble constant can be expected with further consequences for the equation of state parameter of dark energy.

The proposed use of the reverberation method to map the changes in the Hubble parameter is less convincing and appears currently not to be competitive with other methods, e.g. BAO, lensing delays or other reverb mapping studies, i.e. OzDES, LSST. It clearly should be considered as a secondary project and would not be sufficient to support the installation of a new telescope.

The proposal leaves several issues open:
- The required photometric accuracy for the project is not provided. Precise colours will be critical to obtain good reddening corrections, which are important for the derivation of accurate surface-brightness versus colour relations. Moreover, even if the adopted Period-Wesenheit relations for Cepheids are reddening free by definition, they rely on an assumed extinction law that might vary with the environment. A discussion would have been helpful to assess the photometric requirements and possible additional error contributions.
- The spectroscopy will also be needed for potential metallicity corrections of the Cepheid period-luminosity relations.
- Monitoring spectroscopy is required for the determination of the physical parameters of the eclipsing binaries, but the proposal does not describe where the spectroscopy would be obtained.
- There is no detailed description of the proposed 2.5m telescope and the instrumentation is only indicated as ‘optical and IR cameras’ to ‘complement spectroscopic observations’. The proposal does not specify from where the spectroscopic observations would come from.
- The different roles of the various telescopes for the projects are not described. A description of how the samples will be distributed across the telescopes and how the data will be combined, if needed, is missing. A simple description of magnitude ranges and the corresponding sample sizes would help.
- The ambitious goal of the project also relies on time applications for future large telescopes. The proponents claim this part of the project is risky but do not discuss what could be the impact on final results if this observing time were not allocated.
- The expected duration until completion of the various projects is not given. No description of additional time required at other telescope to perform the experiment is provided and it is not possible to assess how dependent the experiment is on obtaining spectroscopy at other telescopes.