

Astronomy Developments and Site Testing in East Africa

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Abstract. Two astronomical site testing initiatives are beginning in both Kenya and Ethiopia, with the aim of selecting suitable locations in those countries for initially modest sized (1-2m) optical telescopes. The first project, in Kenya, has to date involved a study of existing meteorological satellite data, from which potential sites have been selected for further studies (see paper by Graham et al. in these proceedings). A similar program of astronomical site testing, including using DIMMs, will begin later in 2014 in the Lalibela region of northern Ethiopia, at three potential sites ranging in altitude from ~3600 to 4500 m. In parallel to this, the Entoto Observatory and Research Centre (EO), comprising twin 1-m alt-az telescopes, has been established at Mt. Entoto, on the outskirts of Addis Ababa, and science operations are due to begin in early 2015.

1. Introduction

South Africa has been supporting astronomy developments in Africa for a number of years through a variety of initiatives. Students from other African countries have been trained through the South African National Astrophysics and Space Science Program (NASSP), a 4th year Honours undergraduate program designed to prepare students for postgraduate studies. Although priority has been given to students from countries which will host the final extended of the Square Kilometre Array (SKA Phase 3) and/or the proposed African VLBI Network (AVN), students from other African countries (e.g. Ethiopia) continue to participate in the NASSP.

A number of astronomy capacity building workshops in Africa have also been supported by South African (and other) astronomers, some with IAU sponsorship. Over the past ~5 years, workshops have been held in Kenya (2010), Ethiopia (2011), Uganda (2012) and Rwanda (2014). In addition, the East African Astronomical Society (EAAS) has been established, where there has been significant developments in establishing university courses, and most recently the Mt. Entoto Observatory and Research Centre, which will support teaching and research initiatives in the region.

2. Entoto Observatory (EO) and Research Centre

This centre was established by the Ethiopian Space Science Society (ESSS) in 2012 and is supported by both public and private universities in Ethiopia. Currently EO is financed by the member universities, ESSS and the Ethiopian government.

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Situated on the ~3100m Mt. Entoto, on the outskirts of Addis Ababa, the observatory was established as a multi-purpose facility to support teaching, research training, science research in astronomy and space science, and for public outreach. It consists of a facility including a visitor's centre with accommodation for students, lecturers and researchers, lecture rooms, IT and technical services and two recently installed twin 1.0m telescopes.

The ESSS vision for EO is to make Ethiopia an effective and extensive user of space science and technology, especially satellite science and technology applications, supporting all aspects of development within the country and to become a global contributor to the development of astronomy, space science and related sciences within ten years. This is to be achieved through developing the necessary capacity and research training and to build regional, continental and international networks to foster research and development in space science, astronomy and related technologies. In addition the promotion of space science, astronomy and related technologies will be achieved through establishing outreach programs.

The current status of EO is the all building construction has been completed, including the two domes for the 1.0-m telescopes, which were installed by early-2014 and first light subsequently obtained on both. Fully internet connectivity has been established to EO. In addition, the science instruments have been delivered, including two sets of site testing equipment. Final commissioning is in progress and is expected to be completed by early-2015.



Figure 1. The two domes for the twin 1-m telescopes at Entoto Observatory following completion of the construction in 2013. The trees have subsequently been trimmed!

3. The EO Telescopes and Instruments

The two EO telescopes are 1-m alt-az Ritchey-Chretien telescope, supplied by the German company, *ASTELCO*. The telescopes are compact, fast slewing f/8 systems, with two Nasmyth foci and two-element correctors giving a 45 arcmin field and a platescale of 25.8 arcsec/mm. Image de-rotators are installed on one foci, to support imaging CCD cameras, while the second focus can support high speed cameras, a fibre feed or visual eyepieces (for public viewing). The telescopes feature active control of the thin primary mirrors using a Shack-Hartman wavefront camera, to provide optimal alignment of the mirrors.

The science instruments for the EO telescopes consist of the following:

- A Finger Lakes FLI-PL4301E-1 camera ($2048 \times 2048 \times 24\mu\text{m}$) with a 21 arcmin square field and 0.62 arcsec/pixel.
- A Finger Lakes FLI-PL230-42 camera ($2048 \times 2048 \times 15\mu\text{m}$) with a 13 arcmin square field and 0.39 arcsec/pixel, although this camera serves as the detector for the fibre-fed FLECHAS échelle spectrograph
- An SBIG STXL-11002 active tip/tilt correcting camera ($4008 \times 2762 \times 9\mu\text{m}$) with a 15×10 arcmin field and 0.23 arcsec/pixel.
- An SBIG STL-6303E camera ($3060 \times 2040 \times 9\mu\text{m}$) with a 12×8 arcmin field and 0.23 arcsec/pixel.
- An Andor iXon EM+ 888 high speed camera with an Electron Multiplication CCD (E2V CCD97, $1024 \times 1024 \times 13\mu\text{m}$) with a 5.7 arcmin field and 0.34 arcsec/pixel.
- A fibre-fed $R=40,000$ échelle spectrograph, FLECHAS, covering the range 390 – 670nm in one exposure on the FLI-PL230-42 camera. A $50\mu\text{m}$ optical fibre with image slicer is utilized to provide two slices.

These instruments are designed to support both training of student in observational astronomy, but will also provide significant research capability. Although the EO is close to a city, with consequent issues of light pollution, the skies are not so bright as for a similar city in other parts of the world. No seeing measurements have yet been made for the site, although anecdotal evidence indicates only modest seeing (1-2 arcsec). Despite these constraints, it is anticipated that EO's facilities will allow significant science research to be undertaken.



Figure 2. The author with the first of the EO 1-m *ASTELCO* telescopes, during factory acceptance testing in Feb 2013.

4. Potential Science at Entoto Observatory

In 2011 the author was asked by ESSS to develop a draft list of science drivers to support the establishment of the EO.

While the trend in astronomy is to build *bigger* telescope to study fainter objects, there is still compelling forefront research that can – and indeed is being – conducted on modest sized (1-m class) telescopes. Current examples of science drivers associated with such telescopes include:

- Rapid follow-up observations of Novae, Supernovae and Gamma Ray Bursters (GRB)
- Observations of extra-solar planet transits
- Detection of extra-solar planets by precision radial velocimetry
- Detection of extra-solar planets by gravitational microlensing observations
- Target of Opportunity multi-wavelength observations (e.g. X-ray binaries)
- Synoptic monitoring of eruptive variable stars (e.g. recurrent novae, novae, symbiotic stars)
- Time series photometry of pulsating variable stars (e.g. Cepheids, white dwarfs, roAp stars)
- High time speed photometry of binary stars (e.g. cataclysmic variables, LMXBs, contact binaries)
- Search for Kuiper belt objects in the Solar System
- Observations of Near Earth Objects
- Active Galactic Nuclei variability studies

The list is not meant to be exhaustive, but rather illustrative of the various current topics for which astronomers with frequent access to a 1-m class telescope could make a substantial research contribution. They are focussed on stellar astronomy, since the 1-m aperture is not really sufficient to do competitive extra-galactic research, although there are some areas that could be considered (e.g. AGN).

Worldwide, there are plenty of examples of observatories with modest sized telescopes whose research output is significant and important. Indeed new observatories with 1-m class telescopes continue to be built. The tendency for modern telescopes design is to automate them as much as possible, something which is readily achievable with modern computing technology. This can lead to a better operational efficiency and has led to “roboticizing” telescopes: turning them into remote – or robotically – operated telescopes. A network of such telescopes can be used in “campaign mode” where several are used to undertake observations of the same objects, but at different times. This can maximize scientific productivity, sometimes giving results which are more than simply the “sum of the whole”. Examples include multi-longitude observations of variable stars, where the daily aliasing problems of single sites can be reduced. The Mt Entoto Observatory could be an important node in such multi-longitude observing campaigns.

5. The Future

With the establishment of the Entoto Observatory and Research Centre in Ethiopia, currently consisting of twin, well-instrumented, 1m telescopes, observational optical astronomy has been enabled. This will clearly benefit Ethiopian astronomers and those in the East African region. Continuing support will be needed to assist in the development of research programs and training of student, and this is already happening though the appointment of astronomers from outside the country with the required experience and background. It is hoped that visiting astronomers (e.g. for ~ a month or longer timescales) will also play a role in assisting in the development of competitive research programs and new collaborations.

Finally, a site testing initiative to select a potential new observatory site in the north of Ethiopia, in the Lalibela region, is soon to begin. Two sites (at 3600 and 4500m) have been set up with the requisite equipment (DIMMs, automatic weather stations, all sky cameras, sky brightness monitors) and infrastructure support (roads, housing) has been established. Over the period of several years, this site

testing will be undertaken by students from EO member universities. Eventually a new telescope is planned to be established at this site.