# Search for Very High Energy candidate sources using South African observatories

**Abstract.** The multi-wavelength South African observatories are ideally located to complement the very high energy (VHE) observations undertaken with the H.E.S.S. telescope located in Namibia. We are undertaking a long term multi-wavelength campaign and a literary search to identify potential VHE energy extra-galactic sources which may be observable with the H.E.S.S. telescope. The early stages of this project have focussed on identifying candidate sources and undertaking optical photometric observations with the UFS/Boyden 1.5-m and Watcher telescopes located at the Boyden observatory, and optical spectroscopy observations with the South African Large Telescope and the SAAO 1.9m telescope located at the South African Astronomical Observatory (SAAO). We present an overview of the proposed observational programme, the different possibilities available for multi-wavelength observations and initial results from this project.

## 1. Introduction

Astronomy is currently in a special position as we are able to observe the universe from radio up to gamma-ray energies. More and more, multi-wavelength astronomy is required to understand the physical processes occurring in a multitude of sources. This extends from, for example, gamma-ray pulsars which show both radio and gamma-ray pulsations [1], gamma-ray binary systems which show varying multi-wavelength behaviour [2], AGN which show variations over the entire spectrum of energies, including rapid $< 1$ d flaring in gamma-rays, for example 3C 454.3 [3] to gamma-ray bursts (GRBs) and their afterglows spanning from GeV energies to radio [4]. All these examples point towards the importance of multi-wavelength support to complement the gamma-ray observations at both GeV and TeV energies.

South Africa is in a good position to contribute towards multi-wavelength support of these observations. Given our similar geographical location to the H.E.S.S. gamma-ray telescope in Namibia and the possibility that CTA South may be placed in Namibia (currently the two candidate sites are Aar, Namibia and ESO, Chile), we would argue that South Africa should become more involved with the High Energy (HE) and Very High Energy (VHE) systems and, in particular, contribute and continue to contribute to multi-wavelength follow-ups and observations of HE/VHE systems.

Here we present a short overview of the proposed observational programme we are undertaking, primarily to classify systems within the Second LAT AGN Catalogue (2LAC) [5] for the eventual identification of potential VHE sources, the different possibilities available for multi-wavelength observations and initial results from this project.

## 2. Optical and Radio Telescope within South Africa

There are a number of telescopes available in South Africa and more detailed presentations are presented elsewhere at this meeting. Some of these telescopes have already been involved with multi-wavelength/TeV studies [6]. Here we only very briefly discuss the systems that we have used or are planning on using.

### *2.1. Optical telescopes: Boyden observatory and SAAO*

The Boyden Observatory is located approximately 25 km North-East of Bloemfontein, South Africa. The main instrument on site is the 1.5-m Boyden reflector. The telescope is in Cassegrain configuration with photometry capabilities. The system is equipped with a standard U, B, V, R, I filter wheel and an Apogee U55 Back-illuminated CCD camera. The second science telescope on-site is the 40-cm Watcher Robotic Telescope. This telescope is operated remotely and has the main science aim of observing GRB afterglows. However, non-alert time can be used for on-going monitoring of other systems, for example [8] reported on on-going blazar monitoring.

The SAAO is host to a number of optical/near-infrared telescopes run both by the NRF and external organizations. Here we mention only the Southern African Large Telescope (SALT) and the SAAO 1.9-m telescopes. Both systems are equipped for optical photometric and spectroscopic observations. The grating spectrograph on the SAAO 1.9-m telescope allows for low to medium resolution spectral resolution. SALT, on the overhand, is a 10-m class telescope, allowing low to medium resolution spectroscopy (R$\sim$5000-9000) with the RSS spectrograph and high resolution spectroscopy with the HRS which is currently under commissioning. In addition both systems are capable of very rapid photometry with the SHOC camera (SAAO 1.9-m) and the BVIT (SALT).

### *2.2. Radio telescopes: HartRAO, KAT7 and SKA*

The HartRAO radio telescope is a single-dish 26-m telescope located near Hartbeespoort, South Africa, operating between 1.67 to 23 GHz. The system has been involved with VLBA and regularly contributes to AGN monitoring, observations.

The expansion towards the development of SKA in South Africa (see e.g. [9]) has lead to the development of KAT-7 which is also regularly contributing towards the AGN monitoring.

## 3. Initial results

### *3.1. Classification of AGU within the 2LAC catalogue*

The Fermi/2LAC catalogue contains 886 identified sources in the "clean sample" classified as extragalactic due to location above $|b| > 10^\circ$ of which 157 had no clear classification ("AGU" sources) [5]. Follow-up observations reported by, for example [10], have classified a number of these systems, but a fair number remain unclassified. We have begun a processes to identify sources we wish to follow-up with South African telescopes from this sample. This is an extension of previous work undertaken to identify the unknown sources included within the 3rd EGRET catalogue by [11, 12], where 13 candidate sources where investigated. The main aim is to search for systems which could be TeV emitters. Eight main candidate sources were identified from the 2LAC unclassified sample, selecting sources which are visible from southern Africa and are within the observational limits of the SAAO 1.9-m telescope. Further, only (in general) bright radio sources ($>$ 100 mJy) were selected to allow us to undertake radio observations with the

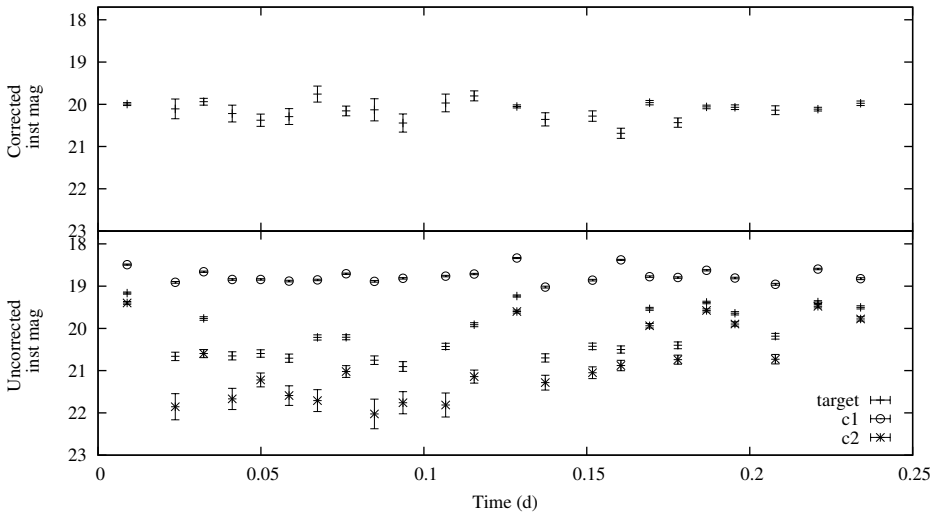


**Figure 1.** Preliminary analysis of Watcher observations of 1ES 0229+200 during the night of 2013 October 2. This is a short term integration time, intended to demonstrate the output of the photometric pipeline. Multiple stacking of the data is required to produce an accurate long term light curve for the source.

HartRAO 26-m. Follow-up optical spectroscopic observations were undertaken with the SAAO 1.9-m telescopes for two weeks during during the end of May 2014. Preliminary analysis shows, mainly featureless spectra as expected from blazars. This is an ongoing analysis and higher SNR observations will be proposed for SALT. Please see [13] for a detailed discussion.

Further multi-wavelength observations and literary searchers are planned to attempt to identify new potential VHE emitters. This will include the compilation of multi-wavelength data to construct the Spectral Energy Distributions (SEDs) for the target sources. This will be accompanied by additional optical monitoring of some of the sources to allow for variability studies.

*3.2. Optical monitoring of 1ES 0229+200*

Optical monitoring of the BL Lac 1ES 0229+200 was undertaken with the Watcher Robotic Telescope during October 2013 as part of a multi-wavelength campaign which coincided with NuSTAR and H.E.S.S. observations. Further observations were undertaken with the Boyden 1.5-m telescope, but the low altitude of the source made observations difficult as the telescope was very near its visibility limits. A new pipeline is being developed for the Watcher telescope to allow for a "quick look" at the data. A preliminary one night light curve is shown in Figure 1, for 1ES 0229+200, showing the uncorrected (lower) and corrected (upper) light curve. This data are stacking over short time periods (∼minute time scales) and therefore the target and fainter comparison star lie close to the noise regime. The light curve is presented as a demonstration of the output of the telescope. A more detailed analysis to obtain the long term (two week) light curve of the source is on-going.

*3.3. Galactic sources*

In addition to the extragalactic observations, we have also undertaken optical spectroscopic observations of the gamma-ray binary system PSR B1259-63 during April-June with SALT and the SAAO 1.9-m telescope around the time the system went through periastron. This binary star system consists of a Be star and 48 ms radio pulsar and has been detected at TeV energies

during previous periastron passages by H.E.S.S. (see e.g. [14]). The optical results may have important consequences for non-thermal production as the structure of the circumstellar disc, which will influence the shape of the shock front, may vary around periastron, as was previously reported by [15].

## 4. Conclusion

South Africa is well placed to offer multi-wavelength support to complement TeV observations, in particular the H.E.S.S. gamma-ray telescope located in Namibia and potentially CTA. Such multi-wavelength observations have already been undertaken. Here we briefly presented our on-going project to identify potential TeV emitting sources among the Fermi/2LAC catalogue as well as ongoing observations focussed on optical observations of TeV sources.

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