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On going optical photometric monitoring of AGN TeV targets with the Watcher Robotic Telescope

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Abstract. Active Galactic Nuclei (AGN) show variability on various time scales and present complex correlations between these variations at different wavelengths. Simultaneous multi-wavelength observations can therefore be used to place constraints on the different emission models. In May 2015 we began optical photometric monitoring of a subset of the known TeV emitting AGN using the Watcher Robotic Telescopes (Boyden Observatory, South Africa) to obtain long term photometric monitoring of these sources. Currently 17 targets are included in this monitoring campaign. The sources are observed once per night in the V, R & i' bands, depending on observability and weather. The V, R and V-R light curves of four blazars are presented, all of which show variability which is consistent with previous studies. This demonstrates the feasibility of using the Watcher telescope to provide long term optical photometric monitoring of TeV blazars.

1. Introduction

The Watcher Robotic Telescope is a fully automated system located at the Boyden Observatory, South Africa. The system was initiated by the University College Dublin (UCD) Space Science Group, and is run in partnership with the Czech Technical University in Prague (ČVUT), the Institute for Astrophysics of Andalucia (IAA) and the University of the Free State (UFS). The primary science aim of the telescope is the rapid optical follow-up of gamma-ray burst triggers initiated by the Gamma-ray Coordination Network (see e.g. Murphy et al. 2015 & Martin-Carrillo et al. 2015a). Time that is not dedicated to GRB observations is used for observations of both galactic and extra-galactic sources. For example, Watcher has recently been used to follow the cataclysmic variable ASASSN-15ni (Martin-Carrillo et al. 2015b, 2015c).

To complement other multiwavelength observations we have begun, in May 2015, a long term monitoring programme of known TeV blazars, which have previously been detected with Imaging Atmospheric Cherenkov Telescopes, with the aim of providing long term multi-filter observations that can be used to place constraints in correlation studies.

The Spectral Energy Distributions (SEDs) of blazars are, in general, dominated by the non-thermal emission produced in relativistic jets, which is highly Doppler boosted since the direction of propagation lies close to our line of sight. The SEDs of the blazars show two distinct components at lower (radio to UV/X-

ray) and higher (X-ray to gamma-ray) energies. In the leptonic scenario, the lower energy component is produced through synchrotron radiation, while the higher energy component is produced through inverse Compton scattering of either the synchrotron produced photons, or external photons originating from, for example, the accretion disc, broad line region or dust torus. However, alternative hadronic models have been proposed (e.g. Böttcher et al. 2013).

If both the low and high energy components are produced through the same population of particles, there should be a correlation between the different components. However, observations have shown complicated behaviour with observed correlations, lags, anti-correlations and orphan flare events (e.g. Krawczynski et al. 2004, Blazejowski et al. 2005, Abdo et al. 2010, Fossati et al. 2008). In one recent example a search for correlation from PKS 2155-304 between TeV observations undertaken with H.E.S.S. (High Energy Stereoscopic System) and optical observations with the ATOM (Automatic Telescope for Optical Monitoring) telescope, found a complex relation which depends on the colour and gamma-ray state of the source (Abramowski et al. 2014).

Below we discuss the Watcher Robotic Telescope, the strategy of the monitoring campaign, preliminary results and the proposed future improvements.

2. The Watcher Robotic Telescope

The Watcher telescope is a 16 inch Cassegrain design (f/14.25) telescope, equipped with a Meade (f/6.3) focal reducer and is used with a Paramount ME equatorial mount. When a trigger is received from the Gamma-ray Coordination Network (GCN) the telescope automatically repoints and begins observations within, on average, 45 seconds after receiving the alert. An Andor iXon+ 888 CCD (1024x1024 pixels) is currently mounted, which records a 10'×10' field of view (with the focal reducer). V, R, g', r', i', Clear, and OIII filters are available. The telescope dome is fully automated with continuous monitoring of the atmospheric conditions with an on-site weather station, cloud meter and precipitation sensor.[1]

3. TeV blazar monitoring campaign

Currently 17 known TeV AGN targets, spread over a broad range in right ascension, are being observed as part of the long term monitoring campaign. Given the smaller size of the telescope, observations have been limited to sources brighter than 18th mag. All observations are controlled by the telescope's scheduler (with the highest priority given to observations of GRBs). Observations of the TeV AGN targets are scheduled to occur once per night, with each observation divided into 6 exposures of 60 seconds each, in the B, V and i' filters. The actual observation cadence depends on the observability of the source (airmass, weather, etc.) as well as if higher priority sources are being observed.

[1]More information is available on the Watcher Telescope at http://watchertelescope.ie/

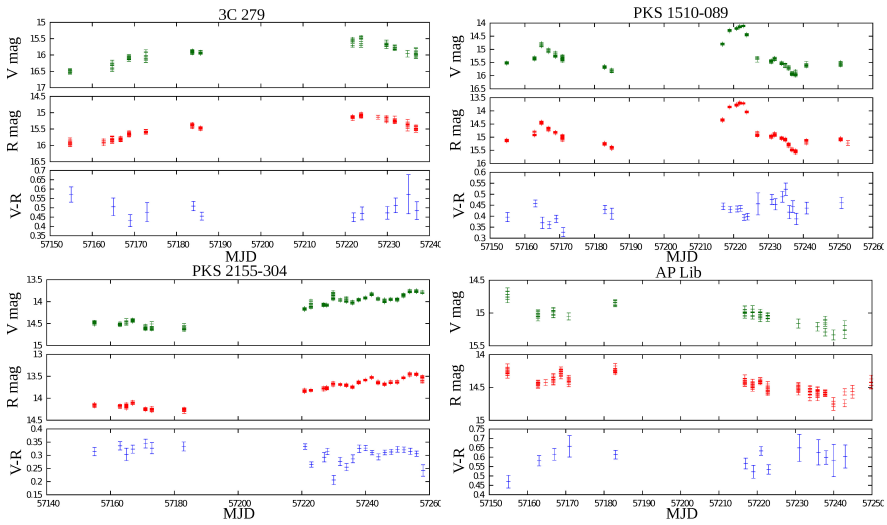

Figure 1. V, R and V-R light curves for 3C 279 (*top left*), PKS1510-089 (*top right*), PKS 2155-304 (*bottom left*) and AP Lib (*bottom right*).

4. Data reduction and analysis

All data frames are corrected for the bias offset and flat field using the standard IRAF/NOAO/CCDRED packages. The exposure times are short enough, and the camera cooling efficient enough, that dark current effects are assumed to be negligible. Photometry is performed using the NOAO/DAOPHOT packages, for multiple apertures, and aperture optimizations is performed using the NOAO/PHOTCAL packages.

Differential photometry is performed using a weighted average of a selection of comparison stars on the same field of view, following a method similar to that outlined in Everett & Howell (2001). Each star is weighted according to $\omega = \sigma_{\rm err}^{-2}$ where $\sigma_{\rm err}$ is the error given by the PHOT function. Where known apparent magnitudes are available for the comparison stars, the differential light curves are corrected for the offset between the average instrumental magnitudes of the companion stars and their known apparent magnitudes. The variability in the V-R colour is calculated from the daily binned magnitude in each filter.

5. Results

Figure 1 shows the results from the initial optical photometric monitoring of four prominent blazars (3C 279, PKS 1510-089, PKS 2155-304 & AP Lib). For each source, the V, R and V-R light curves are shown. As expected all four sources shown here exhibit the long term optical variability expected for AGN. Similar variability has been reported for these sources by, e.g. Abramowski et al. (2014), Sandrinelli et al. (2014), Wierzcholska et al. (2015).

In particular, PKS 1510-089 shows a large flaring event during the monitoring period. The first peak, around MJD 57165, occurs around the same period of

a reported increase at TeV energies by the MAGIC (Major Atmospheric Gamma Imaging Cherenkov Telescopes) telescope (Mirzoyan et al. 2015). All sources also show variations in the V-R colour as shown by the change in V-R with time and brightness.

6. Future Development

The preliminary results for the four sources demonstrate that long term monitoring is feasible using the Watcher Telescope. The planned future developments for this project are: the expansion of the number of monitored sources, the implementation of a fully automatic data reduction and analysis pipeline, providing public access to the data generated by the analysis pipeline, and, ideally, using the data to trigger alerts for other multi-wavelength observations.

7. Conclusions

The automated Watcher telescope, while designed for GRB follow-up observations, is well suited to long term monitoring of known and candidate TeV AGN sources. The optical observations obtained thus far demonstrate the feasibility of using the system to perform long term monitoring of blazar targets and the multi-filter observations can be used to place constraints on the multi-wavelength observations of known TeV AGN.

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References

Abdo A.A. et al. 2010, Nature, 463, 919
Abramowski A. et al. 2014, A&A, 571 A39
Blazejowski M. et al. 2005, ApJ, 630, 130
Böttcher M., Reimer A., Sweeney K., Prakash A. 2013, ApJ, 768, 54
Everett M.E. & Howell S.B. 2001, PASP, 113, 1428
Fossati G. et al. 2008, ApJ, 677, 906
Krawczynski H. et al. 2004, ApJ, 601, 151
Martin-Carrillo A. et al. 2015a, GCN Circular 18085
Martin-Carrillo A. et al. 2015b, ATel 7855
Martin-Carrillo A. et al. 2015c, ATel 7875
Mirzoyan R. et al. 2015, ATel 7542
Murphy D. et al. 2015, GCN Circular 17947
Sandrinelli A., Covino S., Treves A. 2014, A&A, 562, A79
Wierzcholska A. et al. 2015, A&A, 573, A69