A Search for VHE Emission from AE Aquarii

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Abstract

The DQ Her type cataclysmic variable AE Aquarii was observed with the first Cerenkov imaging telescope of the projected HEGRA five telescope array in August and September 1994. A naive analysis using the false source method yielded no evidence of an un-pulsed VHE γ-ray flux or of large scale flare activity. The results of a test for periodicity in the 34 s to 16 s region will be available in due course.

1 Introduction

AE Aquarii is a short period (9.88 hr) binary system at a distance of 100 pc, consisting of a white dwarf accreting material via a thin disc from its K dwarf companion [1][2]. A spindown of the white dwarf's 33.08 s rotation may power particle acceleration [3]. The Compton EGRET Survey gave an upper limit to the DC flux from AE Aquarii at 1 GeV of 10^{-10} cm^{-2}s^{-1} [4]. If particle acceleration requires magnetic reconnection or a potential drop across a vacuum gap [5] it is to be expected that γ-ray emission will be episodic (restricted to periods of low mass transfer rate) and have a hard spectrum; poor conditions for a satellite detection. During four years of atmospheric Cerenkov observations, the University of Potchefstroom group accumulated evidence of emission above $\approx$ 2.4 TeV at the white dwarf spin frequency and of red shifted QPOs [6] which were simultaneously present in later optical and VHE data with a 10% duty cycle. They also recorded two 1-3 minute bursts of γ-rays (one $\approx$200% above the cosmic ray background) [7]. The University of Durham group observed a similar 60 s flare of 75% over the background count rate above $\approx$300 GeV [8] and periodicity at the second harmonic of the spin frequency.

2 Observations

AE Aquarii was observed from La Palma (28.75°N, 17.89°W, 2200 m a.s.l.) between 2/8/95 and 11/9/95, with the first of five 8 m^2 telescopes to be added to the HEGRA Experiment. 45 hours of data were collected at zenith angles ranging from 28° to 53°. The HEGRA complex at the Observatorio del Roque de Los Muchachos and the telescope itself have been described in detail elsewhere [9].

The telescope, which is intended to carry a 271 pixel camera, is currently fitted with a smaller 61 pixel prototype. Each pixel consists of a 1" diameter photomultiplier fitted with a plexiglas light concentrator having a hexagonal front face. When closely packed, the 61 pixels, each of diameter 0.43° in the focal plane form a hexagonal camera 3.9° in diameter. The point spread function of a star and the accuracy of tracking are less than one fifth of the pixel size.

Consecutive 25 to 60 minute ON source observations were made since the intention is finally to concentrate on periodicity analysis and a search for sporadic emission; the loss of 50% of the possible observation time to OFF source measurements might halve the chances of detection. Owing to an error in the sign of the target declination, the "ON source" position was offset from the true source by $\approx 1.78°$ on the sky throughout. Thus AE Aquarii lay at the edge of the camera, and it was necessary to turn to the False Source method described by Fomin et al. [10]. This had the advantage that although the effective collection area was reduced for the true source, events centred on one or more false source positions around the camera could be considered as simultaneously aquired OFF source data. Any camera inhomogeneities were at least partially compensated for as the telescope has an alt-azimuth mount and the source positions therefore rotate about the centre of the camera co-ordinate system.

3 Analysis

After quality selection, including a requirement that the atmospheric extinction be < 0.2 (measured by the Carlsberg A. M. C.), 35 hours of raw data remained. These were corrected for pedestal offsets and gain differences between the 61 channels. The standard deviation (σ) of the pedestal of each channel was used in image preparation as follows: pixels which contained a signal in excess of 4.25σ were considered part of the image core, and their neighbours were accepted into the image if their signals were $> 2.25\sigma$. All other pixels were set to zero.

The Hillas image parameters were calculated as per usual [11] for the 262999 events having an image core of between 2 and 25 pixels, except that the origin of the image co-ordinate system was not taken as the centre of the camera; the calculation was performed once with the R.A. and Dec. of AE Aquarii as the origin (source A) and then repeated for two "OFF source" control positions, B and C, each at the same angular distance from the camera centre, at polar angles of 120° and 240° with respect to A.

3.1 Test for a DC excess

Shifting the source position to the edge of the field of view (the "recommended" shift would rather be $\approx 1^\circ$ - 1.2°) resulted in spurious small Azwidth events (potential γ-ray candidates) where the true image centroid lay outside the camera. Therefore, only events for which the angle between the radial vector from the source position to the camera centre and the vector from the source position to the image centroid was smaller than 30° were accepted. To ensure well-reconstructed images, a minimum value of the Distance parameter of 0.4° was required, whilst a maximum allowed Distance of 1.78° reduced the overlap of the three data sub-sets. In first order, these cuts restricted the sensitive area for each assumed source to a "wedge" of one sixth of the camera. No significant small Azwidth excess was observed from the true source (A) either in the dataset as a whole or in a single observation (a typical 40 minute run contained 1000 events per wedge, 30 of Azwidth < 0.2).

3.2 Test for flare activity

To test for ≈ 1 minute flares, as detected by other groups without the benefit of the imaging technique, it was necessary to remove the wedge restriction in order to increase the counting statistics. For each assumed source position, events of Azwidth < 0.2 were assigned to one minute bins on a run by run basis. A Li & Ma type significance [12] was calculated for each bin according to its contents as compared to the mean for the run excluding it and its nearest neighbours. The distribution of these significance values plotted for the entire dataset (2107 bins) was well approximated by a Gaussian for each position (see, for example, Figure 1). The test was repeated with the bin edges shifted by 30 s and with alternative bin widths of 2, 3 and 5 minutes. Allowing for the number of trials, no bin lay above expectation. No one minute excess above 8% of the background rate of $\approx 1\times10^{-8}$ cm^{-2} s^{-1} was observed.

Figure 1: *Gaussian fit to the count rate significance distribution for one minute samples of < 0.2 Azwidth events given source position A (AE Aquarii).*

4 Discussion

Employing γ/hadron separation via a 0.2 Azwidth cut, a 3 sigma limit to the DC flux above $\approx$ 1 TeV of the order of 5×10^{-11} cm^{-2} s^{-1} is estimated. This analysis is now to be refined by Monte Carlo simulation. In the months preceding the Rome Conference a periodicity search will also have a high priority.

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