A Search for VHE Gamma Rays from AGNs Visible from the Southern Hemisphere

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ABSTRACT

Observations have been made, using the University of Durham Mark 6 gamma ray telescope, of the very high energy gamma ray emission from a number of active galactic nuclei visible from the Southern hemisphere. Limits are presented to the VHE gamma ray emission from 1ES 0323+022, PKS 0829+046, 1ES 1101–232, Cen A, PKS 1514–24, RXJ 10578–275, and 1ES 2316–423, both for steady long-term emission and for outbursts of emission on timescales of 1 day.

Subject headings: BL Lacertae objects: individual (PKS 1514–24, PKS 0829+046, 1ES 1011–232, 1ES 2316–423, 1ES 0323+022, RXJ 10578–275) galaxies: individual (Cen A) — galaxies: active — gamma rays: observations

1. Introduction

One of the most unexpected results in high energy astrophysics in the last decade has been the discovery of high energy and very high energy (VHE) emission from active galactic nuclei (AGNs). The EGRET detector on board the Compton Gamma Ray Observatory established that BL Lacs (predominantly radio selected) and flat-spectrum radio sources are strong high energy gamma ray emitters, while X-ray selected BL Lacs have been identified as a source of VHE gamma rays.

The first AGN to be identified as a VHE source was Mrk 421 (Punch et al. 1992, Macomb et al. 1995, Petry et al. 1999). Since then, Mrk 501 (Quinn et al. 1996, Aharonian et al. 1997), 1ES 2344+514 (Catanese et al. 1998) and PKS 2155–304 (Chadwick et al. 1999a) have been identified as VHE sources. Some of these objects have shown periods of intense flaring activity on timescales as short as 15 minutes (Gaídos et al. 1996, Aharonian et al. 1999).

Previous surveys of VHE emission from AGNs (Kerrick et al. 1993, Roberts et al. 1998, Roberts et al. 1999, Rowell et al. 1999) have indicated that only close X-ray selected BL Lacs are observable at TeV energies. This is in accord both with theoretical models of gamma ray...
emission from AGNs (for a recent review see Ulrich, Maraschi, & Urry 1997) and absorption of VHE gamma rays on the cosmic infra-red background (Stecker, de Jager, & Salamon 1992, Stecker et al. 1996, Stecker & de Jager 1998). Recent progress in the understanding of blazars has shown that the distinction between radio-selected (RBL) and X-ray selected (XBL) BL Lacs is not exact and that there is a whole continuum between these two extremes (Ghisellini et al. 1998).

The Durham AGN dataset consists of observations of 10 AGNs made with the Mark 6 telescope from 1996 to 1998. The discovery of VHE gamma rays from PKS 2155–304 has already been reported; this is the most distant BL Lac yet detected at these energies (Chadwick et al. 1999a). Results from the two close X-ray selected BL Lacs PKS 0548–322 and PKS 2005–489 will be reported elsewhere (Chadwick et al. 1999b). Here we describe observations of 1ES 0323+022, PKS 0829+046, RXJ 10578–275, 1ES 1101–232, Cen A, PKS 1514–24, and 1ES 2316–423, covering a range of classes of AGN. The typical energy threshold for these observations is ∼ 300 to 400 GeV. This is ∼ 5 times lower than the typical threshold of the CANGAROO telescope, which is ∼ 2 TeV, which has also been used to observe Southern hemisphere AGNs (Roberts et al. 1999).

2. The Mark 6 Telescope

The University of Durham Mark 6 atmospheric Čerenkov telescope has been in operation at Narrabri, NSW, Australia since July 1995. The telescope is described in detail elsewhere (Armstrong et al. 1999). It uses the imaging technique to separate VHE gamma rays from the cosmic ray background, combined with a robust noise-free trigger based on the signals from three parabolic flux detectors of 7 m diameter and aperture f/1.0 mounted on a single alt-azimuth platform. A 109-element imaging camera (91 × 0.25° and 18 × 0.5° pixel size) is mounted at the focus of the central flux detector, with low resolution cameras each consisting of 19 pixels (0.5° pixel size) mounted at the focus of the outer (left and right) flux collectors. The telescope is triggered by demanding a simultaneous temporal (10 ns gate) and spatial (0.5° aperture) coincidence of the Čerenkov light detected in the three cameras. This multiple-dish triggering system is stable against variations in performance due to accidental coincidences, and enables the telescope to detect low energy gamma rays with high immunity from triggering by local muons. Initial work suggests that our system has a detection probability for 100 GeV gamma rays of about 1% with the probability of detection rising slowly to about 40% for 250 GeV gamma rays.

The Mark 6 telescope has been designed to provide stable operation which allows the observation of weak DC sources. All detector packages are thermally stabilised. The atmospheric clarity is continuously monitored both using a far infra-red radiometer (Buckley et al. 1999) and an axial optical CCD camera which allows the position and visual magnitude of guide stars to be monitored. The gain and noise performance of the PMTs, digitizer pedestals and associated electronics are continuously monitored by:
1. triggering the telescope at random times using a nitrogen laser / plastic scintillator / optical fibre light guide / opal diffuser system to simulate Čerenkov flashes and so enable flat-fielding, and

2. producing false triggers at random times to measure samples of the background noise.

3. Observations

Current VHE $\gamma$-ray observations of AGNs support the idea that it is the XBLs which are the most promising sources of VHE emission, as suggested by Stecker, de Jager, & Salamon (1996). The seven AGNs which are discussed in this paper comprise three XBLs, two RBLs, one intermediate class object and one close radio galaxy (Cen A) which has been detected previously as a VHE $\gamma$-ray source. While RBLs are thought to be less promising as VHE $\gamma$-ray sources than XBLs, observations in the VHE range will help to confirm the fundamental differences between the XBLs and RBLs. VHE $\gamma$-ray observations of BL Lacs have, in general, concentrated on the closest objects, but we have sought to extend the current redshift limit of $z = 0.117$ by observing more distant AGNs. With an energy threshold of $\sim 300$ GeV, the Mark 6 Telescope is well-suited to this task. In the case of one XBL, 1ES 1101–232, the VHE $\gamma$-ray observations were made contemporaneously with BeppoSAX observations.

Data were taken in 15-minute segments. Off-source observations were taken by alternately observing regions of sky which differ by $\pm 15$ minutes in right ascension from the position of the object to ensure that the on and off segments possess identical azimuth and zenith profiles. This off-source – on-source – on-source – off-source observing pattern is routinely used to eliminate any first order changes in count rate due to any residual secular changes in atmospheric clarity, temperature etc.

Data were accepted for analysis only if:

1. the sky was clear and stable, and

2. the gross counting rates in each on-off pair were consistent at the 2.5 $\sigma$ level.

A total of 54 hours of on-source observations under clear skies of 7 objects was completed, and an observing log is shown in Table I.

4. Data Analysis

Routine reduction and analysis of accepted data comprises the following steps:
1. calibration of the gains and pedestals of all 147 PMTs with their associated digitizer electronics within each 15 minute segment, using the embedded laser and false coincidence events,

2. software padding of the data to equalize the effects of on- and off-source sky noise on data selection (Cawley 1993, Fegan 1997),

3. identification of the location of the source in the camera’s field of view for each event, using the axial CCD camera,

4. a calculation of the spatial moments of each shower image relative to the source position, and

5. rejection of events containing an image which would be unlikely to be produced by gamma rays.

Events considered suitable for parameterization are those which are confined within the sensitive area of the camera (i.e. within 1.1° of the centre of the camera) and which contain sufficient information for reliable image analysis, i.e. which have \( \text{SIZE} > 500 \) digital counts, where there are \( \sim 3 \) digital counts per 1 photoelectron, and typically 200 digital counts are produced by a 125 GeV gamma ray.

The Čerenkov images recorded with the Mark 6 telescope are parameterized after Hillas 1985. These image parameters allow discrimination between the elliptical images, the major axes of which point towards the source direction, produced by a \( \gamma \)-ray shower and the broader, more irregular images produced by a hadronic shower. In addition, a measure of the difference between the positions of the centroids of the light recorded by the left and right flux collectors of the Mark 6 telescope provides a further discriminant, \( D_{\text{dist}} \) (Chadwick et al. 1998). Gamma rays are identified by selecting events on the basis of image shape and left/right fluctuation, and then plotting the number of events as a function of the pointing parameter \( \text{ALPHA} \); \( \gamma \)-ray events from a point source will appear as an excess of events at small values of \( \text{ALPHA} \). In this case, we define the \( \gamma \)-ray domain as \( \text{ALPHA} < 22.5^\circ \).

The selection criteria applied to these data are summarized in Table 2. They constitute a standard set of criteria developed from our successful observations of PKS 2155–304, and include allowance for the variation of image parameters with event size. They are routinely applied to data from all objects recorded at zenith angles less than 45°, which is the case for all the observations reported here.

5. Results

The dataset for each source has been tested for the presence of gamma ray signals. Typical results of the application of the cuts described above to one object (1ES 2316–423) are shown in
Table 3, and the corresponding ALPHA-plot is shown in Figure 1. The flux limits from the seven AGNs are summarised in Table 4. They are all $3\sigma$ flux limits, based on the maximum likelihood ratio test (Gibson et al. 1982, Li & Ma 1983). The threshold energy for the observations has been estimated on the basis of preliminary simulations, and is in the range 300 to 400 GeV for these objects, depending on the object’s elevation. The collecting areas which have been assumed, again from simulations, are $5.5 \times 10^8$ cm$^2$ at an energy threshold of 300 GeV and $1.0 \times 10^9$ cm$^2$ at an energy threshold of 400 GeV. These are subject to systematic errors estimated to be $\sim 50\%$. We have assumed that our current selection procedures retain $\sim 20\%$ of the $\gamma$-ray signal, which is subject to a systematic error of $\sim 60\%$.

![Graph](image)

Fig. 1.— (a) The ALPHA distributions ON and OFF source for 1ES 2316–423. The dotted line refers to the OFF source data. (b) The difference in the ALPHA distributions for ON and OFF source events.

We have also searched our dataset for $\gamma$-ray emission on timescales of $\sim 1$ day. The search for enhanced emission has been conducted by calculating the on-source excess after the application of our selection criteria for the pairs of on/off observations recorded during an individual night. A
typical observation comprising 6 on/off pairs of observations (1.5 hours of on-source observations) yields a flux limit of $\sim 1 \times 10^{-10}$ cm$^{-2}$ s$^{-1}$ at 300 GeV. Conversely, had any of the objects on which we report here produced a 15-minute flare similar to that seen from Mrk 421 with the Whipple telescope on 1996 May 7 (Gaidos et al. 1996), it would be detected with the Mark 6 telescope at a significance of around 7 $\sigma$. There is no evidence for any flaring activity.

5.1. Cen A

Centaurus A (NGC 5128) is the closest radio-loud active galaxy to Earth, at a distance of 5 Mpc ($z = 0.008$), and is often described as the prototype Fanaroff-Riley Class I low luminosity radio galaxy. It was identified as a TeV source in the early days of VHE gamma ray astronomy (Grindlay et al. 1975), with a flux of $4.4 \pm 1.0 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ at an energy threshold of 300 GeV when the object was in an X-ray high state. Observations of Cen A were also made with the University of Durham Mark 3 telescope which placed a $3\sigma$ flux limit of $7.8 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ at a similar energy threshold (Carraminana et al. 1990). The X-ray state of Cen A at the time of these observations was unknown. Observations of Cen A made in 1995 March/April with the CANGAROO telescope have resulted in a $3\sigma$ flux limit of $4.66 \times 10^{-12}$ cm$^{-2}$ s$^{-1}$ at $E > 1.5$ TeV for an extended source centred on Cen A (Rowell et al. 1999). There has also been a report at UHE energies of an excess in cosmic ray showers from the direction of Cen A (Clay, Gerhardy, & Liebing 1984). EGRET observations have recently been used to identify Cen A as a source of GeV gamma rays (Sreekumar et al. 1999), thus providing the first evidence for emission in the $30 - 10000$ MeV energy range from a source with a confirmed large-inclination jet.

The observations of Cen A made with the Mark 6 imaging telescope reported here provide a flux limit of $5.2 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$. *BeppoSAX* observations made in 1997 February, approximately two weeks before the commencement of our observations, show the source to have been in a low state, lower by at least a factor of $\sim 5$ than the outburst in 1974–5 (Grandi, Urry, & Maraschi 1999). *RXTE* observations taken contemporaneously with our data confirm that Cen A was in a low state in 1997 March.\(^1\) If, as seems to be the case in other AGNs, the X-ray and VHE $\gamma$-ray emission from Cen A are correlated, then it may not be surprising that we detected no VHE emission in 1997 March.

5.2. PKS 0829+046

PKS 0829+046, also known as OJ049, has a redshift of 0.18 (Palomo 1991). It was detected with both *HEAO-1* as an X-ray source (Della Ceca et al. 1990) and the EGRET instrument as a GeV $\gamma$-ray source (Fichtel et al. 1994, von Montigny et al. 1995, Mattox et al. 1997, Mukherjee et

\(^1\) Available on the web at http://space.mit.edu/XTE/asmlc/cena.html.
al. 1997). It has a large radio flux and is therefore classified as an RBL (Ciliegi, Bassani, & Caroli 1993); this suggests it is unlikely to be a detectable VHE $\gamma$-ray source. The present VHE limit is $4.7 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ for $E > 400$ GeV.

5.3. PKS 1514–24

Misidentified initially as AP Librae, PKS 1514–24 was one of the first radio-detected BL Lacs (Bolton, Clarke, & Ekers 1965). It has a redshift of 0.049, and although detected by EXOSAT (Schwartz & Ku 1983), its relatively small X-ray flux classifies it as an RBL (Ciliegi, Bassani, & Caroli 1993). Phase 1 observations with the EGRET detector on board CGRO resulted in an upper limit for the object of $7 \times 10^{-8}$ cm$^{-2}$ s$^{-1}$ at $E > 100$ MeV (Fichtel et al. 1994) nor does it appear in the 3rd EGRET catalog (Hartman et al. 1999). The VHE limit presented here is $3.7 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ for $E > 300$ GeV.

5.4. 1ES 2316–423

1ES 2316–423 ($z = 0.055$) was originally classified as a radio selected BL Lac (known as PKS 2316–423, see e.g. Stickel et al. 1991), but recently Perlman et al. 1998 have identified this object as an intermediate case whose high energy emission could be expected to extend up to VHE energies. The CANGAROO telescope has observed this object but detected no VHE emission, placing a 2$\sigma$ upper limit of $1.2 \times 10^{-12}$ cm$^{-2}$ s$^{-1}$ at a threshold energy of $\sim 2$ TeV in July 1996 (Roberts et al. 1998). The present measurement indicates a flux limit at the 3$\sigma$ level of $4.5 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ at $E > 300$ GeV. Assuming an integral spectral index of $\sim 1.5$ (c.f. Mrk 421 and Mrk 501), this corresponds to a 3$\sigma$ flux limit at $E > 2$ TeV of $\sim 2.6 \times 10^{-12}$ cm$^{-2}$ s$^{-1}$, comparable with the 2$\sigma$ flux limit from the CANGAROO experiment.

5.5. 1ES 1101–232

1ES 1101–232 is an XBL with a redshift of 0.186. It has been detected using both the HEAO-1 and Einstein satellites (Della Ceca et al. 1990, Perlman et al. 1996). Phase one EGRET observations resulted in an upper limit of $6 \times 10^{-8}$ cm$^{-2}$ s$^{-1}$ at $E > 100$ MeV (Fichtel et al. 1994). It was detected with the BeppoSAX satellite in 1997 (Wolter et al. 1998), and our observations of this XBL were made contemporaneously with a BeppoSAX campaign on the object. Indications are that the X-ray flux from 1ES 1101–232 was $\sim 30\%$ lower during our observations than in 1997 (Wolter, private communication). Our flux limit is $3.7 \times 10^{-11}$ cm$^{-2}$ s$^{-1}$ at $E > 300$ GeV.
5.6. RXJ 10578–275

The *Rosat* source RXJ 10578–275 was initially identified as a potential BL Lac from its optical characteristics ([Bade, Fink, & Engels 1994](#)). It has a redshift of 0.092 and is classified as an XBL. Our flux limit is \(8.2 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}\) at \(E > 300 \text{ GeV}\).

5.7. 1ES 0323+022

1ES 0323+022 has been detected using both the *HEAO-1* and *Einstein* satellites ([Della Ceca et al. 1990](#), [Perlman et al. 1996](#)). It is an XBL with a redshift of 0.147, and has a spectrum which is very similar to the archetypal XBL PKS 2155–304 ([Giommi, Ansari, & Nicol 1995](#)). EGRET phase one observations resulted in an upper limit of \(6 \times 10^{-8} \text{ cm}^{-2} \text{ s}^{-1}\) ([Fichtel et al. 1994](#)). Stecker, de Jager, & Salamon 1996 predict a flux at \(E > 300 \text{ GeV}\) of \(4.0 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1}\). Our flux limit of \(3.7 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}\) at \(E > 300 \text{ GeV}\) is considerably higher than this prediction and so it is not in conflict.

6. Discussion

Whilst the interpretation of VHE upper limits from BL Lacs is complicated by the lack of a complete theory of VHE \(\gamma\)-ray emission from AGNs, Stecker, de Jager, & Salamon 1996 have predicted the TeV fluxes from a range of objects, one of which (1ES 0323+022), is included in the present work. The expected fluxes from the other XBLs included in this paper may be estimated on the basis of the work of Stecker, de Jager, & Salamon 1996 and Stecker 1998 using the simple relation \(\nu_x F_x \sim \nu_\gamma F_\gamma\) and the published X-ray fluxes. We estimate that the 300 GeV fluxes of 1ES 1101–232, 1ES 2316–423 and RXJ 10578–275 would be \(2.0 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1}\), \(1.5 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1}\), and \(3.3 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1}\) respectively, taking into account photon-photon absorption using the recent determination of \(\gamma\)-ray opacity by Stecker 1998. All these suggested fluxes are lower than the flux limits reported here. However, the lack of contemporaneous X-ray measurements in the case of most of our observations limits the usefulness of these predictions and emphasises the importance of simultaneous X-ray and \(\gamma\)-ray observations and multiwavelength campaigns. In the case of the RBLs, an extended observation of PKS 1514–24, a close RBL, lends support to the suggestion that RBLs are not strong VHE \(\gamma\)-ray emitters.

Our observations of Cen A were made when it was in an X-ray low state, in contrast to the earlier VHE detection of Cen A reported by Grindlay et al. 1975, which was made when Cen A was in X-ray outburst. Further VHE \(\gamma\)-ray observations during an X-ray high state would be desirable.
7. Conclusions

The Durham University Mark 6 Telescope has been used to make observations of 7 close AGNs: 1ES 0323+022 (XBL, \( z = 0.147 \)), PKS 0829+046 (RBL, \( z = 0.18 \)), RXJ 10578–275 (XBL, \( z = 0.092 \)) 1ES 1101–232 (XBL, \( z = 0.186 \)), Cen A (low luminosity radio galaxy, \( z = 0.0089 \)), PKS 1514–24 (RBL, \( z = 0.049 \)) and 1ES 2316–423 (transitional BL Lac, \( z = 0.055 \)). We find no evidence for either steady or flaring emission of \( \gamma \)-rays above 300 – 400 GeV. The flux limits are in excess of the fluxes predicted on the basis of the simple model of Stecker, de Jager, \& Salamon [1996]. The flux limit derived for 1ES 0323+022 (\( 3.7 \times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1} \)) is not in conflict with the specific prediction of Stecker, de Jager, \& Salamon [1996] (\( 4.0 \times 10^{-12} \text{ cm}^{-2} \text{ s}^{-1} \)).

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| Object         | Date            | No. of ON source scans |
|---------------|-----------------|------------------------|
| Cen A         | 1997 March 08   | 5                      |
| Cen A         | 1997 March 10   | 5                      |
| Cen A         | 1997 March 11   | 6                      |
| Cen A         | 1997 March 12   | 6                      |
| Cen A         | 1997 March 13   | 5                      |
| PKS 0829+046  | 1996 March 15   | 3                      |
| PKS 0829+046  | 1996 March 17   | 6                      |
| PKS 0829+046  | 1996 March 18   | 7                      |
| PKS 1514–24   | 1996 April 14   | 2                      |
| PKS 1514–24   | 1996 April 15   | 6                      |
| PKS 1514–24   | 1996 April 17   | 6                      |
| PKS 1514–24   | 1996 April 18   | 7                      |
| PKS 1514–24   | 1996 April 19   | 10                     |
| PKS 1514–24   | 1996 April 20   | 6                      |
| PKS 1514–24   | 1996 April 21   | 6                      |
| PKS 1514–24   | 1996 April 22   | 8                      |
| 1ES 2316–423  | 1997 August 26  | 2                      |
| 1ES 2316–423  | 1997 August 27  | 2                      |
| 1ES 2316–423  | 1997 August 29  | 8                      |
| 1ES 2316–423  | 1997 August 30  | 13                     |
| 1ES 2316–423  | 1997 August 03  | 11                     |
| 1ES 2316–423  | 1997 September 06 | 4                     |
| 1ES 1101–232  | 1998 May 19     | 6                      |
| 1ES 1101–232  | 1998 May 20     | 3                      |
| 1ES 1101–232  | 1998 May 21     | 7                      |
| 1ES 1101–232  | 1998 May 22     | 6                      |
| 1ES 1101–232  | 1998 May 23     | 4                      |
| 1ES 1101–232  | 1998 May 24     | 4                      |
| 1ES 1101–232  | 1998 May 25     | 8                      |
| 1ES 1101–232  | 1998 May 26     | 8                      |
| 1ES 1101–232  | 1998 May 27     | 6                      |
| RXJ 10578–2753| 1996 March 20   | 7                      |
| RXJ 10578–2753| 1996 March 21   | 6                      |
| RXJ 10578–2753| 1996 March 22   | 2                      |
| 1ES 0323+022  | 1996 September 14 | 4                   |
| 1ES 0323+022  | 1996 September 15 | 4                  |
| 1ES 0323+022  | 1996 September 17 | 7                  |

Table 1: Observing log for observations of active galactic nuclei made with the University of Durham Mark 6 Telescope.
Parameter Ranges Ranges Ranges Ranges Ranges
SIZE (d.c.) 500 – 800 800 – 1200 1200 – 1500 1500 – 2000 2000 – 10000
DISTANCE 0.35° – 0.85° 0.35° – 0.85° 0.35° – 0.85° 0.35° – 0.85° 0.35° – 0.85°
ECCENTRICITY 0.35 – 0.85 0.35 – 0.85 0.35 – 0.85 0.35 – 0.85 0.35 – 0.85
WIDTH < 0.10° < 0.14° < 0.19° < 0.32° < 0.32°
CONCENTRATION < 0.80 < 0.70 < 0.70 < 0.35 < 0.25
\(D_{\text{dist}}\) < 0.18° < 0.18° < 0.12° < 0.12° < 0.10°

Table 2: The image parameter selections applied to the data.

| Parameter                        | ON      | OFF     | Difference | Significance |
|----------------------------------|---------|---------|------------|--------------|
| Number of events                 | 218541  | 220531  | -1990      | -3.0σ        |
| Number of size and distance selected events | 121334  | 121426  | -92        | -0.19σ       |
| Number of shape selected events  | 5454    | 5542    | -88        | -0.85σ       |
| Number of shape and \(ALPHA\) selected events | 1438    | 1508    | -70        | -1.29σ       |

Table 3: The result of the application of image parameter selections to the data from 1ES 2316–423.

| Object             | Estimated Threshold (GeV) | Flux Limit \((\times 10^{-11} \text{ cm}^{-2} \text{ s}^{-1})\) |
|--------------------|---------------------------|-------------------------------------------------|
| Cen A              | 300                       | 5.2                                             |
| PKS 0829+046       | 400                       | 4.7                                             |
| PKS 1514–24        | 300                       | 3.7                                             |
| 1ES 2316–423       | 300                       | 4.5                                             |
| 1ES 1101–232       | 300                       | 3.7                                             |
| RXJ 10578–275      | 300                       | 8.2                                             |
| 1ES 0323+022       | 400                       | 3.7                                             |

Table 4: Flux limits for observations of active galactic nuclei made with the University of Durham Mark 6 Telescope.