

# TeV observations of Centaurus A

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## Abstract

We have searched for TeV gamma-rays from Centaurus A and surrounding region out to  $\pm 1.0^\circ$  using the CANGAROO 3.8m telescope. No evidence for TeV gamma-ray emission was observed from the search region, which includes a number of interesting features located away from the tracking centre of our data. The  $3\sigma$  upper limit to the flux of gamma-rays above 1.5 TeV from an extended source of radius  $14'$  centred on Centaurus A is  $1.28 \times 10^{-11}$  photons  $\text{cm}^{-2} \text{s}^{-1}$ .

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## 1 Introduction

Centaurus A (NGC 5128) is the closest known radio galaxy ( $\sim 3.5$  Mpc), and is considered a misaligned AGN with a jet orientation angle of  $\sim 70^\circ$  [14]. Variability in X-ray and low energy gamma-ray flux of up to an order of magnitude on time scales of days to years has been observed [3]. The EGRET source 2EGJ1326-43, is considered to be associated with Centaurus A [11,12]. A number of upper limits and marginal claims for detection at TeV and PeV energies have also been reported. See [1] and references therein.

We used the CANGAROO 3.8m telescope [6] in observations of Centaurus A taken from March to April 1995. A total of 45 hours of ON and OFF source data were considered for analysis. An earlier analysis [13] assumed a single point source at the tracking centre. However, the spatial extent and number of interesting features of the Centaurus A region warranted an extended source analysis, out to  $\pm 1^\circ$ .

## 2 Analysis

We have based our analysis on the method of [4] in which location cuts, recalculated at every grid position of the search, are combined with shape cuts to form a skymap of the ON–OFF significance. We find that due to camera edge effects, some adjustment of image cuts as a function of source location is necessary to optimise the cosmic-ray background rejection over the search region. Location cuts used are *asymmetry* and the normalised distance between the assumed and calculated source position of the Čerenkov image. Shape cuts are the image *width* and *length*. This method will be described in more detail in a later paper. The actual values of each cut were selected *a priori* using Monte Carlo simulations. We found that the total cut combination provides a gamma ray acceptance of  $\sim 40\%$  and cosmic ray acceptance of  $\sim 1\%$  for point sources within  $\pm 1^\circ$  of the camera centre.

Three sites were considered as potential gamma-ray sources within the search: the tracking centre of these data based on the radio VLBI core position [7], the unidentified EGRET source, and the Northern Middle Lobe (NML) [10]. The tracking centre and EGRET source were considered as both point-like and extended sources while the NML was considered as a point-like source only as it is close to the search boundary. For an extended source, the ON and OFF source counts were obtained by summing the events passing cuts using a suitably high number of assumed source positions within the region of interest, taking care not to count an event more than once.

Table 1

Summary of ON–OFF excesses and  $3\sigma$  upper limits for the Centaurus A region. Where appropriate, the source/search radius is indicated.

Feature	ON–OFF( $\sigma$ )	Flux( $\geq 1.5$ TeV) $\text{ph cm}^{-2} \text{s}^{-1}$
Tracking <sup>a</sup> (point)	+1.6	$< 5.45 \times 10^{-12}$
Tracking <sup>b</sup> (extended, $0.23^\circ$ )	+1.5	$< 1.28 \times 10^{-11}$
EGRET <sup>c</sup> (point)	+2.8	$< 1.14 \times 10^{-11}$
EGRET <sup>d</sup> (extended, $0.5^\circ$ )	+1.4	$< 1.95 \times 10^{-11}$
NML <sup>e</sup> (point)	−0.7	$< 4.47 \times 10^{-12}$

a: Radio VLBI core position [7]. RA (J2000)  $13^{\text{h}}25^{\text{m}}29^{\text{s}}$  Dec  $-43^\circ01^{\text{m}}12^{\text{s}}$

b: Radius  $14'(0.23^\circ)$  covering ROSAT PSPC emission [15].

c: Highest significance within the error circle ( $0.68^\circ$  [9]). RA  $13^{\text{h}}23^{\text{m}}15^{\text{s}}$  Dec  $-43^\circ31^{\text{m}}12^{\text{s}}$ .

d: Source radius limited by  $\pm 1^\circ$  search. RA  $13^{\text{h}}26^{\text{m}}02^{\text{s}}$  Dec  $-43^\circ31^{\text{m}}12^{\text{s}}$ .

e: Northern Middle Lobe. Point source at max radio position [8]. RA  $13^{\text{h}}26^{\text{m}}08^{\text{s}}$  Dec  $-42^\circ15^{\text{m}}35^{\text{s}}$

### 3 Results and Discussion

No significant excesses were found within our search region and  $3\sigma$  upper limits were derived (table 1) for the features discussed earlier. The upper limits from this work are not in conflict with previous measurements, and lie at least an order of magnitude above the extrapolated EGRET flux (integral spectral index  $-1.5$ , [9]) at 1.5 TeV. We therefore cannot place constraints on gamma ray emission models concerning Centaurus A with this dataset. The upper limit from the point source within the EGRET error circle must be considered with a statistical penalty of  $\sim 100$  due to the non *a priori* nature of the search. We note that our observations were likely taken during a low state of X-ray emission, and might expect a greater chance of detectable TeV emission during a high state. The detection of TeV gamma rays by [5] was achieved during the historically highest state of X-ray emission. Clearly, observations are required with more sensitive telescopes at energies below 1 TeV, for example, by CANGAROO II [16] and HESS [2], covering all states of emission.

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