Search for Gamma-ray clusters of galaxies with the CANGAROO-II telescope

Takahiro HATTORI and Kyoshi NISHIJIMA
Department of Physics, Tokai University, Kita-Kaname 1117, Hiratsuka, Kanagawa 259-1207, Japan
Tomonori TOTANI
National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka Tokyo 181-8588, Japan
for the CANGAROO collaboration

Abstract

Merging clusters of galaxies are promising candidates for the origin of high Galactic latitude, steady, unidentified EGRET gamma-ray sources. 3EG J1234−1318 is one such object and may also be a detectable TeV gamma-ray source. We observed this target for ∼23hrs (on-source) and ∼24hr (off-source) between March 7^{th} and 14^{th}, 2002, with the CANGAROO-II telescope. Here we show the preliminary results of our observations.

1. Introduction

The detection of synchrotron emission from clusters of galaxies at radio, EUV and hard X-ray energies (*e.g.*, see [1] for a recent review, [2], [3]) indicates the presence of non-thermal particles in these objects. Large numerical simulations of merging clusters of galaxies have been carried out and the emission from non-thermal particles has been modelled. (*e.g.*, [4], [5], [6], [7], [8]).

On the other hand, as is well known, over half of all EGRET sources are unidentified. Totani and colleagues ([10], [11]) searched for associations between EGRET unidentified sources and the positions of some clusters of galaxies, and found that seven steady sources at high Galactic-latitude ($|b| > 45°$) chosen by Gehrels et al. [9] are statistically significantly correlated with close pairs of galaxy clusters. They estimated the number which EGRET should detect and claimed that a large fraction of the steady isotropic unidentified EGRET sources could be due to the radiation from dynamically merging clusters of galaxies.

In their model, if about 5% of the shock energy is transferred to non-thermal electrons, GeV gamma-ray emission may be explained by the inverse Compton scattering of the cosmic microwave background photons by those elec-

pp. 1–8

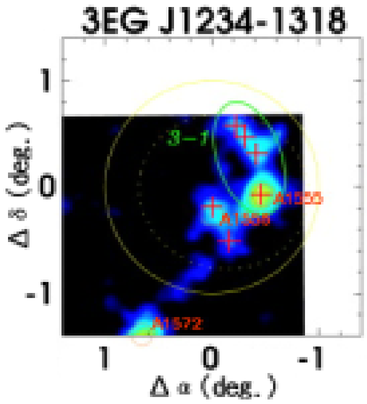

Fig. 1. Significance map of clusters of galaxies obtained from an optical all sky catalog.[11]

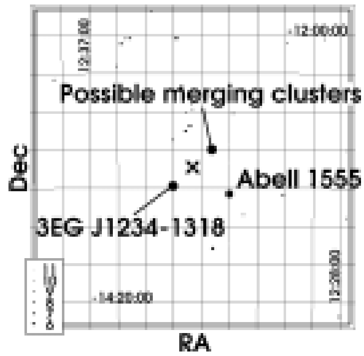

Fig. 2. Sky map of the 3EG J1234−1318 observation. The large square with thick line shows the FOV of the CANGAROO-II 10 m telescope. The center cross is a tracking position of this observation.

trons. They also pointed out the detectability of TeV gamma-rays. Assuming the magnetic field strength and shock velocity for typical clusters, the maximum gamma-ray energy is expected to exceed 1 TeV and the expected size of the emission region $\geq 1^\circ$.

2. 3EG J1234−1318

3EG J1234−1318, centered on $(\alpha, \delta) = (12^h 34^m 02^s.40, -13^\circ 18' 36'')$, is one of the seven steady EGRET unidentified sources at high Galactic latitude. Its spectral index is -2.09 ± 0.24 in the EGRET energy region. This source has a rich structure, revealed by the optical all sky catalog (Fig 1.) The region indicated by an ellipse contains three or four clusters which could be merging, including the Abell cluster A1555.

The estimated integrated flux above 1 TeV is $3.2 \times 10^{-12} cm^{-2} s^{-1}$. This flux is estimated from the extrapolation of EGRET spectrum and is $\sim 3\sigma$ above the sensitivity expected from ∼39 h observation for point sources with the CANGAROO-II telescope.

Table 1. Cut criteria for image parameters.

$sumADC < 6200$	$6200 < sumADC < 16900$	$16900 < sumADC$
$0.05 < Width < 0.10$	$0.05 < Width < 0.15$	$0.05 < Width < 0.15$
$0.05 < Length < 0.30$	$0.10 < Length < 0.25$	$0.10 < Width < 0.30$
$0.50 < Distance < 1.00$	$0.50 < Distance < 1.00$	$0.50 < Distance < 1.10$

3. Observation

We observed 3EG J1234−1318 with the CANGAROO-II telescope from March 4^{th} to 14^{th}, 2002. The total observation time is ∼23 hours and ∼24 hours for ON- and OFF-source data, respectively. The coordinate of the center of the merging clusters is $(\alpha, \delta) = (12^h32^m38^s.40, -12°59'24'')$, which is about 0.45° northwest of the position of 3EG J1234−1318. At present we cannot rule out the possibility that these objects are unrelated. Therefore, for the ON-source data, the telescope pointing was offset 0.23° to the northwest of 3EG J1234−1318, which is midway between the EGRET source and the center of the merging clusters. We, therefore, can analyze for both the EGRET source position and the merging center of clusters under the assumption they are gamma-ray sources. Fig 2. shows the sky maps of this observation. After removing data obtained in bad weather conditions, we used approximately 75% of the total data in the following analysis.

4. Analysis

We select pixels with more than 300 ADC counts, corresponding to a 3.3 photoelectron threshold, to remove noise and night sky background. Signals arriving within $\pm 30 nsec.$ from an average arrival time T_{ave} are used. We require more than five adjacent PMTs, which we call T5a cluster. The data from above 60° elevation are used in this analysis. Following the data reduction, a stable shower rate of ∼2 Hz was obtained through our observation period.

We analyze the remaining shower data using the Hillas parameters. Distributions of image parameters for simulated gamma-rays (shaded histogram) and for OFF-source showers being considered to be protons (open histogram) are shown in Fig. 3. In order to select gamma-ray like events effectively, we optimize the cut positions of each parameters for three ADC counts ranges, respectively, the results of which are summarized in Table 1.

After these reduction procedures, the detection efficiency of gamma-ray like events and the background rejection power are estimated to be 42.0% and 95.8%, respectively.

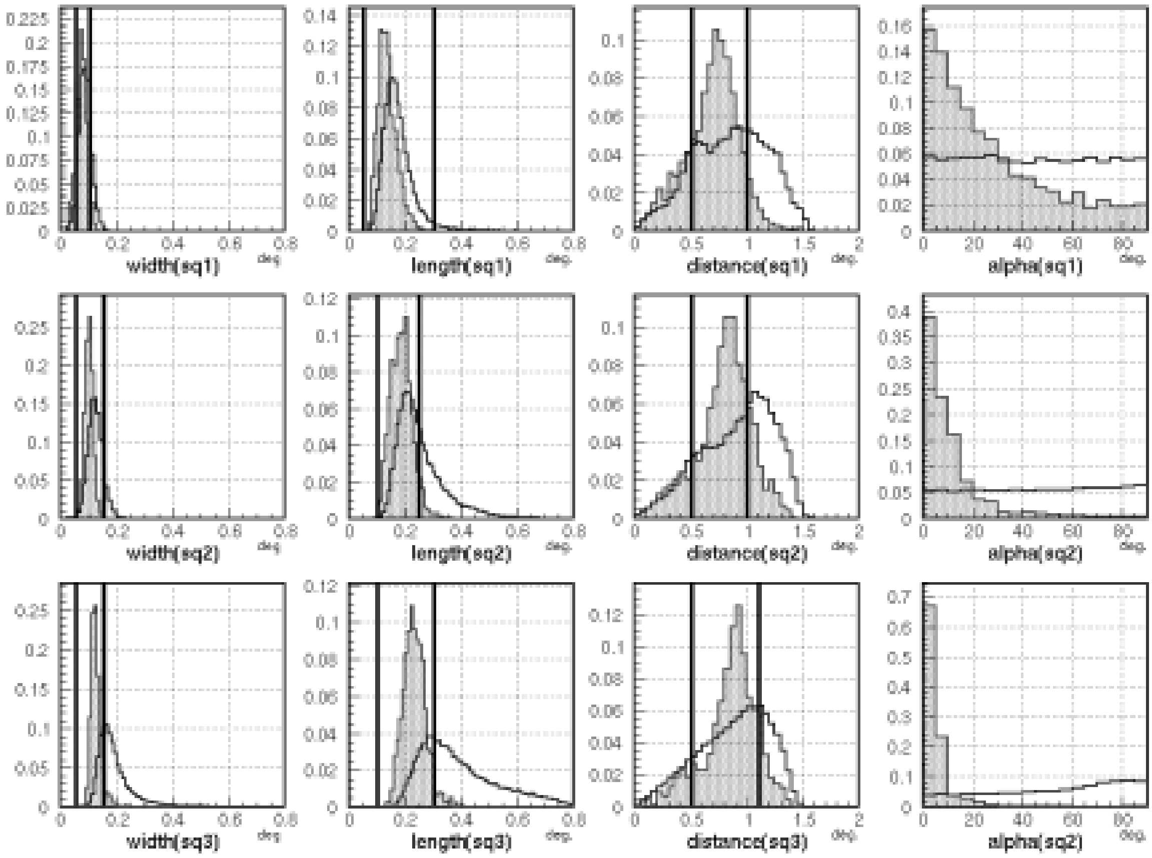

Fig. 3. Image parameter distributions. Image parameters for simulated gamma-ray (shaded histogram) and OFF-source (open histogram) are shown. The cut criteria (Table 1.) are shown with the thick lines in these figures. sq1, sq2 and sq3 mean the three sumADC regions, $sumADC < 6200$, $6200 < sumADC < 16900$ and $16900 < sumADC$, respectively.

5. Preliminary Results

The preliminary result of the alpha distributions after all other cut had been applied, assuming the proposed merging cluster position as a source position, are shown in Fig. 4. We find no excess of events at values of alpha less than 20°. Fig. 5. also shows the alpha distributions assuming that 3EG J1234−1318 is the source position. Again, no excess is detected from the direction of this EGRET source.

Here we have considered the gamma-ray source to be a point source. However since the model of Totani et al. predicts an extended source, we need to consider this possibility in future analyses.

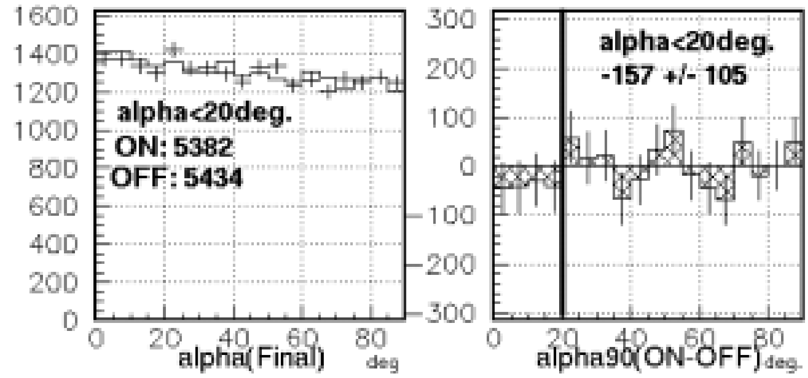

Fig. 4. Preliminary result of the alpha distribution after the cut of other parameters assuming the proposed merging cluster position as a source position.

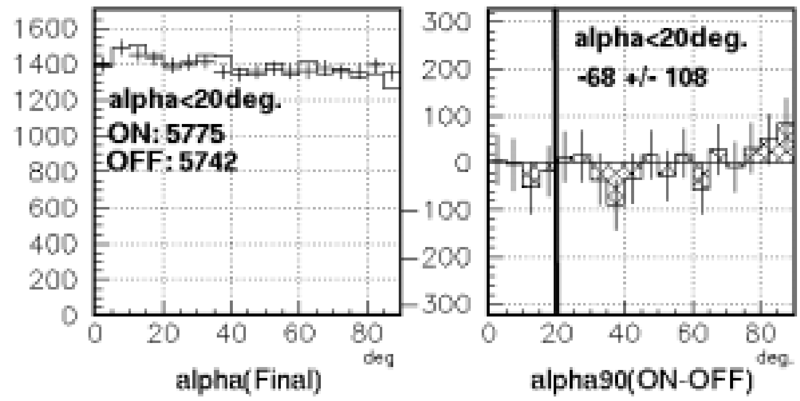

Fig. 5. Preliminary result of the alpha distribution after the cut of other parameters assuming the 3EG J1234−1318 position as a source position

6. Summary

Our preliminary results show there are no significant excess signals from the direction of 3EG J1234−1318 or the position corresponding to possible merging cluster. Our observation time is insufficient to constrain the model in [10]. Further observations with stereoscopic telescope arrays are required.

References

[1] Feretti, L., et al., in IAP 2000 meeting, Constructing the Universe with Clusters of Galaxies, ed. F. Durret and D. Gerbal

[2] Lieu, R., et al., 1996, ApJ 458, L5

[3] Fusco-Femiano, R., et al., 1999, ApJ 513, L21

[4] Colafrancesco, S., and Blasi, P., 1998, Astropart. Phys. 9, 227

[5] Sarazin, C. L., 2001, to appear in Merging Processes in Clusters of Galaxies, ed. L. Feretti, I. M. Gioia, and G. Giovannini (Dordrecht: Kluwer)

[6] Miniati, F., et al., 2001, ApJ 562, 233

[7] Berrington, R. C., and Dermer, C. D., 2002, astro-ph/0209436, submitted to ApJ

[8] Fujita, Y., et al., 2002, astro-ph/0210320, Submitted to ApJ

[9] Gehrels, N., et al., 2000, Nature 404, 363

[10] Totani, T., and Kitayama, T., 2000, ApJ 545, 572

[11] Kawasaki, W., and Totani, T., 2002, ApJ 576, 679