CANGAROO-II and CANGAROO-III

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Abstract. Preliminary results from CANGAROO-II, a 10 m imaging Cherenkov telescope, in Woomera, South Australia are presented. They include the confirmation of detections of TeV gamma-ray sources we have reported using a 3.8 m telescope, CANGAROO-I. Also the status of the construction of an array of four 10 m telescopes, called CANGAROO-III, is reported. The first telescope of the array was upgraded from the 7 m telescope and the second one is being constructed in this year. The full array will be operating in 2004.

INTRODUCTION

CANGAROO is an acronym for the Collaboration of Australia and Nippon (Japan) for a GAmma Ray Observatory in the Outback. After successful operation of the 3.8m imaging Cherenkov telescope (CANGAROO-I) [1] for 7 years, which was the first of this kind in the southern hemisphere, we constructed a new telescope of 7m diameter (CANGAROO-II) in 1999 [2] next to the 3.8m telescope in Woomera, South Australia (136°47′E, 31°06′E, 160m a.s.l.). Then the construction of an array of four 10m telescope (CANGAROO-III) was approved and as a first step the 7m telescope was upgraded to 10m diameter, which is the first telescope of the CANGAROO-III array [3, 4, 5, 6, 7]. The major parameters of the CANGAROO telescopes are summarized in Table 1.

TABLE 1. Properties of the CANGAROO telescopes. (†: CFRP mirrors of 80cm in diameter)

	3.8m telescope	7m telescope	10m telescope
Focal length	3.8m	8m	8m
Number of mirrors	7 (11m^2)	60 (30m^2) †	114 (57m^2) †
Number of PMTs	256 (3/8")	512 (1/2")	552 (1/2")
Readout	TDC & ADC	TDC	TDC & ADC
Point image size (FWHM)	0.1°	0.15°	0.20°
Operation	1992–1998	May 1999–Feb 2000	Mar 2000–

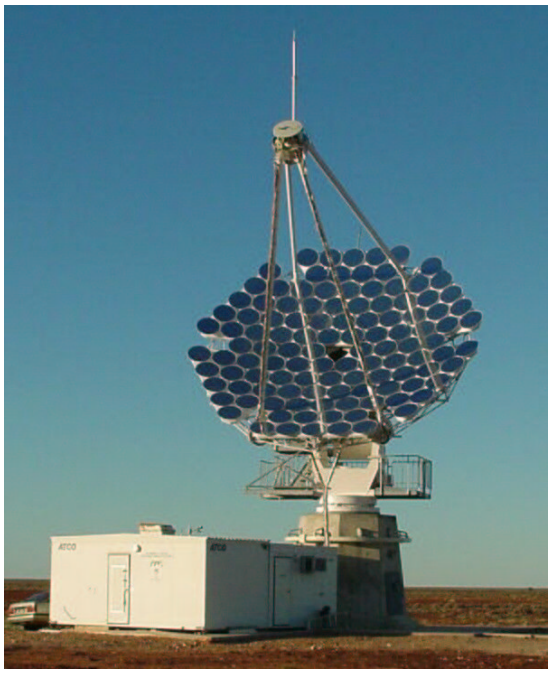

FIGURE 1. The 10m imaging Cherenkov telescope in Woomera, South Australia. The huts contain the electronics and the telescope power.

PRELIMINARY RESULTS FROM CANGAROO-II

Initial performance of the 7m telescope is reported in ref.[8]. Observations with the 7m and 10m telescope were carried out in 1999 and 2000, respectively. The target objects were selected from our list of TeV gamma-ray sources: Crab, PSR 1706-44, Vela, SN1006, RXJ 1713.7-3946, in order to confirm our previous detections with the 3.8m telescope. Also nearby X-ray selected BL Lacs were observed: PKS 2005-489, PKS 2155-304 and PKS 0548-322 along with multiwavelength campaigns. Here we give brief description of some preliminary results obtained so far.

Crab. As the standard candle in the TeV gamma-ray astronomy, we observed the Crab repeatedly, although it is visible only at large zenith angles ($53^\circ \sim 56^\circ$) and thus at higher threshold energies ($\sim$ 6 TeV for 1999 observations) compared with northern Cherenkov telescopes. The flux obtained from observation by the 7m telescope is consitent with our previous report by the 3.8m telescope [9] (Fig. 2).

RXJ 1713.7−3946 (G347.3−0.5). This is a supernova remnant detected with the 3.8m telescope [10]. Figure 3 shows the alpha distribution for the data taken in 2000 with the 10m telescope after the standard imaging analysis, showing we have confirmed the detection. The threshold energy is $\sim$ 400 GeV. The peak near alpha of zero is broader than that for point sources and may indicate the emission is extended. The details will be given elsewhere [11].

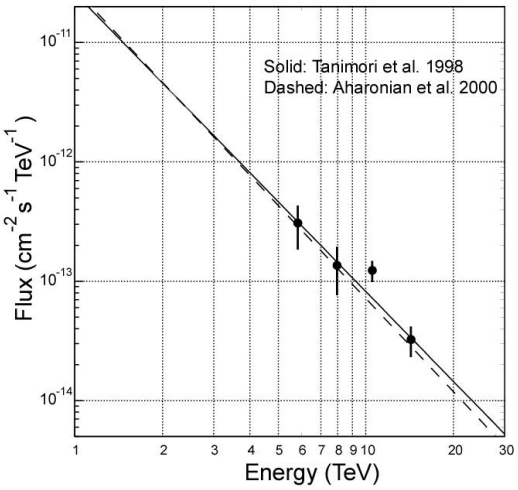

FIGURE 2. The flux of the Crab obtained from observation with the 7m telescope based on 43 hours of on- and 40 hours of off-source data. (Preliminary)

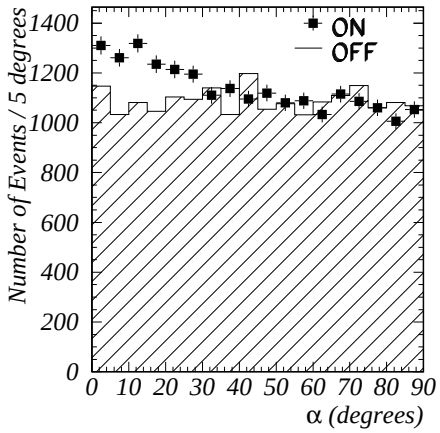

FIGURE 3. The alpha plot of RXJ1713.7−3946 data in 2000. Plots are for on-source data and histograms are for off-source data (11 hours each). The excess events near alpha of zero indicate a gamma-ray signal. (Preliminary)

PKS 2005−489 and PKS 2155−304. Although we spent a lot of time observing these southern nearby BL Lac objects, we could only set upper limits for these sources. From observations in 2000 Jul/Aug/Sep, they are 6.4×10^{-12} cm^{-2}s^{-1} above 450 GeV and 1.2×10^{-11} cm^{-2}s^{-1} above 400 GeV, respectively (2σ level, preliminary). The details will be given elsewhere [12].

Mrk 421. Following the alert of TeV flaring activities by the HEGRA group, we started observation of Mrk 421 at large zenith angles ($69 \sim 72^{\circ}$) in Feb/Mar 2001. Although the observation time is limited, preliminary analysis shows a gamma-ray

signal at 5σ level above 9 TeV. A detailed analysis is continuing [13].

Other sources. Results on SN1006 and PSR 1706-44 will be presented elsewhere [14, 15].

STATUS OF CANGAROO-III

We will start the construction of the second 10m telescope at the end of 2001. The full array of four telescopes, set at the corners of a diamond with sides of about 100m, will be operational in 2004. The performance as a system of telescopes will be described elsewhere [7]. With experience from the construction and operation of the CANGAROO-II telescope, we are making following efforts to improve the sensitivity of the telescopes [5].

Reflector. The reflector design is the same as the first 10m telescope. The mirrors, made of CFRP [16], are light and have proven to be durable, but they are under further improvement, especially to obtain better optical quality by refining the production process. The mirror attitude adjustment system has been redesigned to match our needs and save cost.

Telescope control. Each alt-azimuth telescope is controlled by a PC running Linux with a realtime extention (KURT). A master PC issue directives to each control PC via network and tracking modes can be flexibly changed. Clocks are synchronized by NTP software to a GPS receiver.

Camera. The new design of an imaging camera at the prime focus is hexagonal shape to minimize the dead space between PMTs. The total field-of-view is about 4 degrees covered with 427 PMTs of 3/4" diameter [7]. The light guides have been redesigned to maximize photon collection for the new hexagonal arrangement. High volages are supplied to PMTs individually. Each PMT base is included a preamplifier and signals are transmitted via twisted cables to the electronics which will be installed at the verandah of the telescope.

Electronics. The new electronics are all based on the VME specification. The front-tend module amplifies signal and feeds to an ADC, discriminates it and feeds to a TDC, an internal scaler and a trigger circuit. The ADC is an improved version of the module used in the first 10m telescope and includes an internal delay of 150ns which eliminates a long external delay cable. A pattern trigger circuit using a Programmable Logic Device is under developement to decrease accidental triggers due to night-sky background photons. Details will be given elsewhere [17].

Monitor. Cloud monitors detect infrared radiation from clouds making use of a thermopile module and supply useful information on data quality [18]. Weather monitors can record temperature, humidity and wind speed. These data are read out via serial line connection and stored for offline analysis.

SUMMARY

The CANGAROO-II 7/10m telescope has been in operation since 1999 and we have begun to produce preliminary results which confirm detections made with the CANGAROO-I 3.8m telescope. This is the first telescope of an array of four telescopes, called CANGAROO-III, which will be in operation in 2004. The final goal will be an energy threshold of 100 GeV and an angular resolution of less than 0.1 degee.

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