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Optical measurements by cooled CCD cameras for CANGAROO-III

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The CANGAROO-III consists of four telescopes (10m diameter, 8m focal length) installed at Woomera, in South Australia to observe celestial γ-ray sources by detecting Cherenkov light from air showers. Stereo observations have started since March 2004 with improved angular resolution and lower energy threshold, etc. In this paper, we present some preliminary results of the optical measurements by cooled CCD cameras.

1. Introduction

The measurements have been done in 2004 and here we describe the reflectivity of telescope reflectors, air transmittance and night sky background around our site. For all the measurements reported here, we used cooled CCD cameras (ST5C and ST7E , SBIG) which we attached to our telescope. To discuss the dependence on wavelength, Johnson-type filters were used together. The center wavelength of the filters is 533nm (V-filter), 434nm (B-filter), 362nm (U-filter).

2. Reflectivity of telescope reflectors

The reflector consists of 114 spherical mirror segments [1]. To measure the average reflectivity of the telescope reflector, we compared the light intensity of a star imaged at the camera plane with that of one seen through a camera lens. The measurements were done for three newer telescopes which we call T2,T3 and T4. The procedure was as follows: First, a telescope tracked a bright star so that the reflected star lights were focused on a white screen which was put in front of a PMT camera surface and the image was taken by a CCD camera with V filter described above. Second, the telescope was slightly moved so that the star came into a field-of-view of the CCD camera, and the star image was taken by the CCD camera. To minimize the effect of temporal change of atmosphere, the direct star image was taken after the reflected image as soon as possible, and typical time interval of two images was 2 minutes.

This procedure was repeated for all three telescopes, and we calculated the "relative reflectivity" of telescopes as the light intensity of the reflected star image obtained from a CCD image (in CCD counts per second) divided by that of the direct star image. The ratio of relative reflectivity between three telescopes is about $\mathrm{T2} : \mathrm{T3} : \mathrm{T4} = 0.85 : 0.92 : 1.0$.

To estimate the absolute reflectivity of the telescope reflector, the reflectivity of the screen was measured separately. Because the reflectivity of the screen depends on a incident angle of the light, it was measured by a CCD camera using a Laser beam which location was altered to change the incident angle to the screen. For the calibration of the absolute reflectivity, it was also measured by a spectrometer at one fixed incident angle which is equal to 24 degree. The final result obtained from above two measurements is shown in Fig. 1.

Thus we can estimate the absolute reflectivities of the telescope reflectors as $66{\pm}8\%$ (T2), $72{\pm}4\%$ (T3), and $78{\pm}5\%$ (T4) (preliminary, Fig. 2).

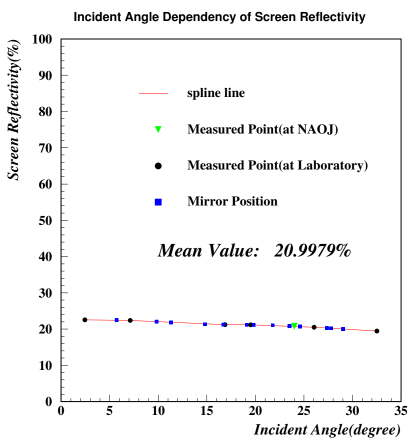

Figure 1. The measured screen reflectivity and the distribution of each mirror segment

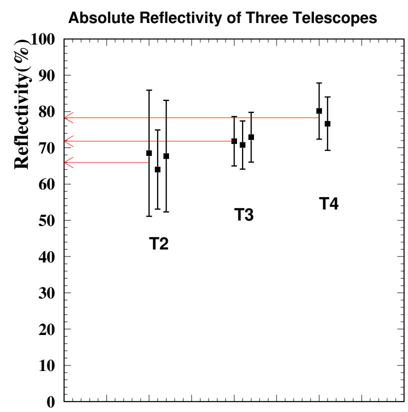

Figure 2. Reflectivity of three telescopes. From right side, T2, T3, T4.

3. Atmospheric transmittance

The atmospheric transmittance around our site is an important factor to estimate γ-ray flux and energy from observed Cherenkov light. There are several methods to measure the atmospheric environment such as using LIDAR. This time we used bright stars to see the variation of starlight extinction according to their zenith angle. We applied 3 optical filters (V, B, U) to compare the wavelength dependence of extinction. The measurements were carried out as follows. We selected a handful of bright stars at various zenith angles and took the picture one by one using a CCD camera with a lens.

The brightness of stars declines exponentially with the thickness of atmosphere (the "air mass", which is normalized to 1 for a star at the zenith) and therefore the magnitude of brightness of starts which is propotional to logarithm of the brightness is a linear function of the air mass. In Fig 3,we plot the calculated instrumental magnitudes of stars (which we calculated as $-2.5\times\log(\mathrm{star},\mathrm{flux})$) versus air mass which is approximately equal to $1/\cos(\mathrm{zenith},\mathrm{angle})$. In Fig 3, fitting lines are also shown.

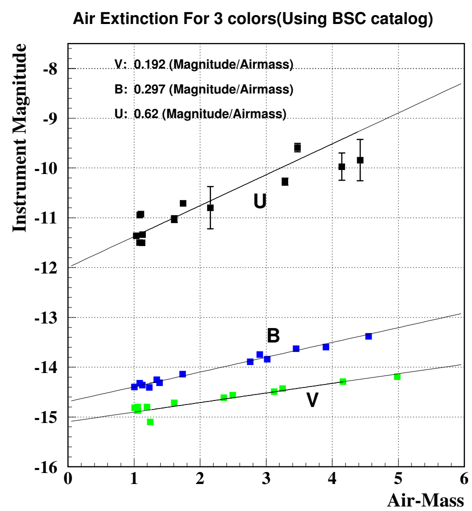

Figure 3. Air extinction measured in 3 color bands. The green points represent the star measured with V filter, and similarly blue and black points with B and U filter

4. Night sky background

Night Sky Background (hereafter NSB) is always a major noise for Cherenkov observation. Typically Jelley's estimated value

$$2.55\times10^{-11}\mathrm{J/cm^2/sec/str}(4300\sim5500\mathring{A}) \quad (1)$$

is used as a reference [2]. A CCD camera was attached at the center of telescope reflector (T4) and a B filter was applied. CCD images were taken during Cherenkov observations. The observation targets were the Crab nebula:(ℓ,b)=(184.558°, -5.784°) and NGC253:(ℓ,b)=(97.369°, -87.964°) on November 8th 2004. Since the Crab nebula locates near the Galactic plane and NGC253 locates far from the Galactic plane, we expected that there is a difference in NSB flux.

The procedure of data analysis is as follows. First, we calculated the mean CCD count/pixel/sec of the image except the star region. The results were about 15 ± 2count/pixel/sec for Crab and 10 ± 2count/pixel/sec for NGC253. Second, to convert the CCD counts to the photon fluxes, we compared the observed counts to the light fluxes of the stars taken from the literature [3]. Third, we made a assumption that the frequency dependence of NSB is constant over the wavelength range of the filter. To compare the NSB flux to Jelley's estimation, the NSB flux integrated over the range of $430\sim550$nm is calculated and the results are shown in Fig 4 together with Jelley's estimation (green line).

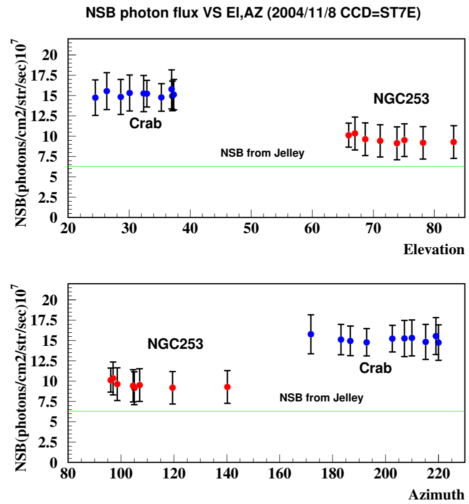

Figure 4. Calculated NSB flux estimated from CCD measurement

5. Summary

We have done measurements of optical properties of CANGAROO III telescopes by using star lights as well as estimating the night sky background lights in the Woomera site. Such calibration of the telescope is important to reduce TeV gamma-ray results from the observation data, and the procedure of analysis is now under way. The final conclusion will be reported in this conference.

References

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