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OBSERVATIONS WITH THE HIGH ALTITUDE GAMMA RAY (HAGAR) TELESCOPE ARRAY IN THE INDIAN HIMALAYAS

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Abstract. For several decades, it was thought that astrophysical sources emit high energy photons within the energy range of the gamma-ray region of the electromagnetic spectrum also. These photons originate from interactions of high energy particles from sources involving violent phenomena in the Universe (supernovae, pulsars, Active Galactic Nuclei, etc.) with gas and radiation fields. Since the first reliable detections of cosmic gamma rays in the 1970's, improvements in instrumentation have led gamma-ray astronomy to an established branch of modern Astrophysics, with a constant increase in the number of detected sources. But the 30-300 GeV energy range remained sparsely explored until the launch of the Fermi space telescope in June 2008. The ground-based gamma-ray telescope array HAGAR is the first array of atmospheric Cherenkov telescopes established at a so high altitude (4270 m a.s.l.), and was designed to reach a relatively low energy threshold with quite a low mirror area (31 m^2). It is located at Hanle in India, in the Ladakh region of the Himalayas. Regular source observations have begun with the complete setup of 7 telescopes on Sept. 2008. We report and discuss our estimation of the systematics through dark region studies, and present preliminary results from gamma-ray sources in this paper.

Keywords: gamma rays: atmospheric Cherenkov technique, methods: data analysis, telescopes: HAGAR

1 The HImalayan Gamma-Ray Observatory (HIGRO)

Located at 4270 m a.s.l. in the Ladakh region of the Himalayas, in North India (Latitude: 32°46'47" N, Longitude: 78°59'35"E), the HImalayan Gamma-Ray Observatory (HIGRO) is a collaboration between four Indian Institutes: Bhabha Atomic Research Centre (BARC) and Tata Institute of Fundamental Research (TIFR) in Mumbai (Bombay), Indian Institute of Astrophysics (IIA) in Bangalore, and Saha Institute of Nuclear Physics (SINP) in Kolkata (Calcutta). It consists of two experiments using the Atmospheric Cherenkov Technique (Koul et al (2005) & Fig. 1). Operating with the full array of telescopes since 2008, the HAGAR experiment is a sampling array of 7 telescopes built with 7 para-axially mounted 0.9 m diameter mirrors each one, giving a total reflective area of ~ 31 m^2 (Chitnis et al. 2009a). The phase 2 of HIGRO will be the installation of an imaging 21 m diameter telescope, MACE (Major Atmosperic Cherenkov Experiment), whose first light is expected in 2012 (Yadav et al. 2009). Other characteristics of this new instrument are a total reflective area of ~ 330 m^2 from 356 mirror pannels, f/1.2 m, FOV of $4° \times 4°$, 1088 pixels. In 2016, MACE should be completed by three additional similar telescopes. The location in longitude of HIGRO will allow uninterupted observations along with other major gamma-ray observatories of the Northern Hemisphere: MAGIC in Canary Islands and VERITAS in the USA. This is particurlary convenient to monitor sources such as AGNs, with flux variabilities in sub-hour time scales.

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Fig. 1. *Left and middle:* the HAGAR telescope array. *Right:* MACE design

HAGAR operates with a trigger logic designed to significantly reject random triggers due to night sky background light, as well as some of the cosmic ray events. Thus, a coincidence of any 4 telescope pulses above a preset threshold out of 7 telescope pulses, within a resolving time of 150 to 300 ns, is required to generate a trigger pulse. Preliminary simulations yield an estimation of the HAGAR energy threshold to be around 200 GeV before performing analysis cuts on data, for a total experimental trigger rate around 14 Hz. Investigations and tests are currently undergoing to approch the 100 GeV energy threshold.

2 Preliminary analysis of HAGAR data

In order to remove isotropic emission due to cosmic rays, source observation region (ON) is compared with OFF-source region at same local coordinates on the sky, but at a different time (before or after tracking the source region). The Crab nebula, standard candle of the γ-ray astronomy, is used to calibrate the instrument and optimize hadronic rejection. However, signal extraction can be confirmed if background fluctuation between ON and OFF-axis source is not dominant, so an important step in the validation of the analysis method is to observe and analyse data by comparing two sets of OFF-source regions (called dark regions), located at a similar declination of Crab nebula ($\simeq 22°$). A statistical significance less than 3 σ was obtained from 6.6 hours of dark region data (13 pairs) in our preliminary analysis, which is an indication that systematic effects due to sky and time differences during observations are not dominant in our data/analysis. The analysis of 9.1 hours of Crab nebula data (13 pairs) from the period Sept-Dec 2008 gives an excess from the source direction at 6.0 σ significance, corresponding to 4.1 ± 0.7 counts min^{-1} above ~ 250 GeV (Britto et al. 2009).

Several other sources are observed with HAGAR. We give in brackets the duration in hours of the ON-source observations up to September 2010: Galactic sources: Crab Nebula and pulsar (83), Geminga pulsar (59), X-ray binary LSI +61 303 (8), MGRO 2019+37 (13); and extragalactic sources (blazars): Markarian 421 (75) and 501 (49), 1es2344+514 (52), and 3C454.3 (13). Preliminary results from Mkn421 (Chitnis et al. 2009b) and pulsars (Acharya et al. 2009) were reported as upper limits on the fluxes of the gamma rays.

Further improvements in the On/Off pair selection, as well as development of hadronic rejection methods based on simulations and flash ADCs, are expected to improve these preliminary results (Britto et al. 2010). From 2012, MACE is expected to be operational, next to the HAGAR array. MACE was design to reach an energy threshold as low as $\sim$20 GeV, which is good for the studies of pulsars and high redshift AGNs where spectral energy distribution cutoffs are expected.

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