Observation of Geminga and Crab pulsars using HAGAR telescope systems

B. S. Acharya*, R. J. Britto*, V. R. Chitnis*, R. Cowsik†, N. Dorji*, S. K. Duhan*, K. S. Gothe*, P. U. Kamath†, M. K. Mahesh†, B. K. Nagesh*, A. Naidu*, N. K. Parmar*, T. P. Prabhu†, L. Saha‡ F. Saleem†, A. K. Saxena†, S. K. Rao*, S. K. Sharma*, A. Shukla†, B. B. Singh*, R. Srinivasan† G. Srinivasulu† P. V. Sudersanan* S. S. Upadhya* and P. R. Vishwanath†

*Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India
†Indian Institute of Astrophysics, Sarjapur Road, 2nd Block, Koramangala, Bangalore 560034, India
‡Saha Institute of Nuclear Physics, 1/AF, Bidhannagar, Kolkata 700 064, India

***Abstract*. We have observed Crab and Geminga pulsars using the recently commissioned high altitude telescope array, HAGAR, in the Himalayas. Data were analysed using the"Tempo" package. The known period of the pulsar was properly extrapolated as applicable to the epoch's of our observations. No significant evidence for the pulsed emission of gamma-rays were seen from both sources at a threshold energy of about 200 GeV in our preliminary analysis.**

***Keywords*: Gamma-ray Pulsars, VHE $\gamma-$ray astronomy, HAGAR, Crab, Geminga**

I. Introduction

The satellite based detectors have been successful in detecting pulsed emission of high energy γ-rays from pulsars [1], [2]. The recently launched Fermi-GLAST [3] satellite is expected to detect significant number of new gamma-ray pulsars and also provide improved light curve to aid the analysis of ground-based data.

The energy spectra of γ-rays from most pulsars [4] show dominant power at energies < 1 GeV. Many attempts were made to detect these pulsars at higher energies using the ground-based atmospheric Cherenkov technique so as to extend the energy spectrum or infer the cutoff energy. Recently, the MAGIC collaboration was successful in detecting pulsed emissions from the Crab pulsar at energies > 25 GeV [5].

We have observed Crab and Geminga pulsars using the recently commissioned high altitude telescope array, HAGAR, in the Himalayas. Our observations, data analysis methods and preliminary results are highlighted in this paper.

II. Data Collection and Analysis

The high altitude telescope array, HAGAR, consists of 7 non-imaging telescopes installed at Hanle in Ladak at an altitude of 4270 m amsl. The event arrival times were recorded with a resolution of 1 μs using a real time clock which was synchronized to GPS clock every second. The details of the array and the experimental setup are given in an accompanying paper [6]

The observations on Crab and Geminga pulsars were carried out during Sept-Dec 2008. The log of observation runs is shown in table I. The event trigger rate based on any 4 out of 7 telescopes was about 12 Hz and the corresponding primary gamma-ray threshold energy is about 200 GeV.

We have looked for the evidence of pulsed emission of gamma-rays using TEMPO package, contemporaneous pulsar elements and the known period of the pulsar as observed at lower frequencies. The details of the analysis procedure are discussed elsewhere [7]. Pulsar phasograms were constructed for each source. A minimum of 5 triggered telescopes were demanded for event selection during analysis (NDF $\geq$ 5).

TABLE I: Log of Observation data

Observation Period	Crab hrs	geminga hrs
Sep-Oct08	8.76	-
Oct-Nov08	23.50	11.4
Nov-Dec08	15.50	20.8

III. Conclusions

The light curves for crab pulsar is shown in figure 1 and for geminga pulsar in figure 2. The first 3 panels in figure 1 corresponds to 3 observations seasons and the fourth panel is the cumulative data. Similarly, in figure 2 the top 2 panels corresponds to data from Oct - Nov 08 and Nov - Dec 08 observing seasons, while the lower left panel is for the cumulative data. The positions of P1 p2 pulses are also marked in the phasogram. The ratio P1/P2 ratio is expected to reduce with increase in energy for the crab pulsar. Therefore at higher energies only P2 pulse may be present as it could have harder spectrum compared to P1 pulse.

No evidence for pulsed emission was seen in a subset of data. The analysis of remaining data as well as background data is going on. Preliminary result on the steady flux of gamma-rays from crab nebula is presented in an accompanying paper [8].

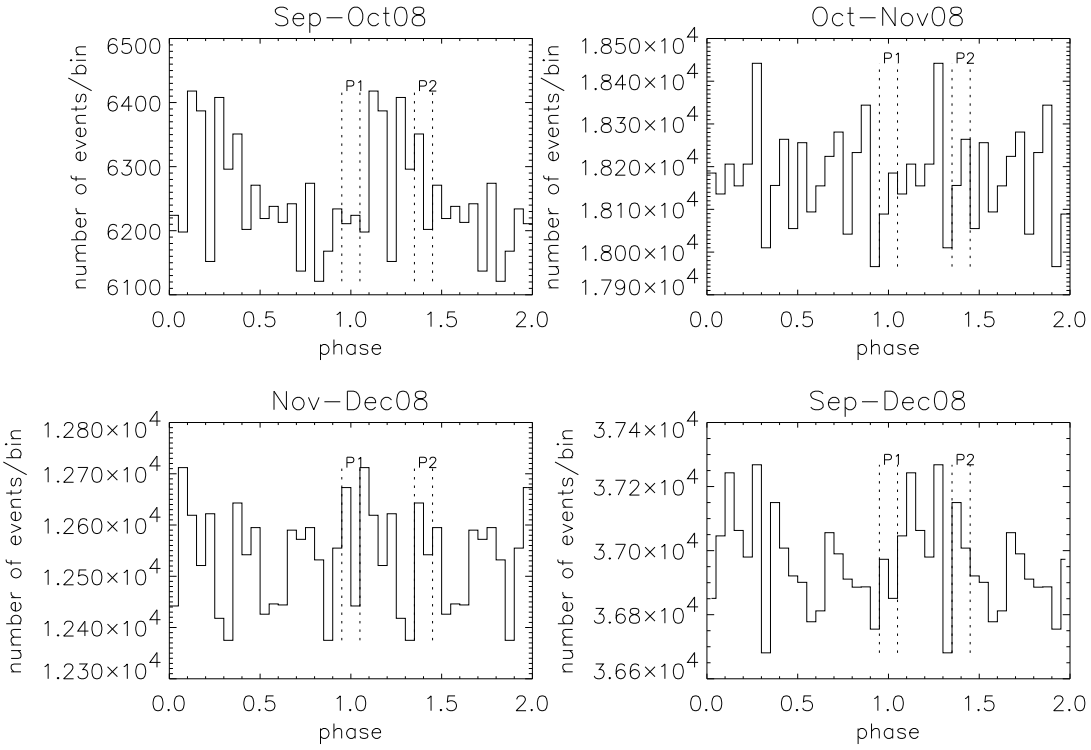

Fig. 1: Light curve of crab pulsar

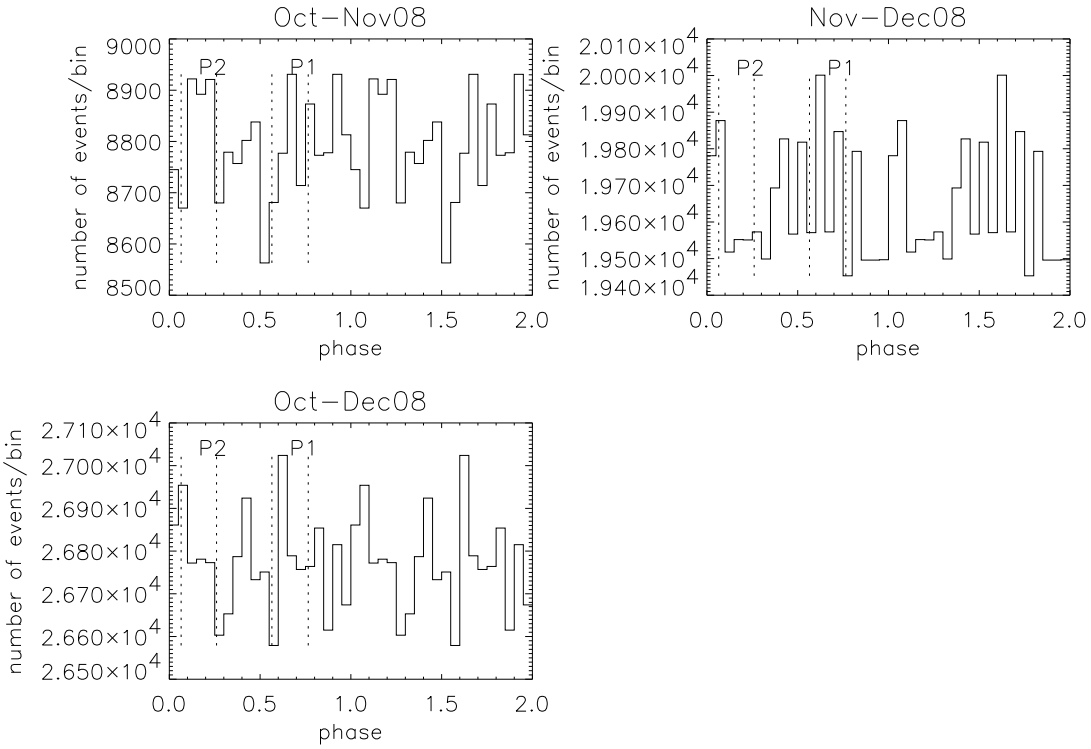

Fig. 2: Light curve of geminga pulsar

IV. ACKNOWLEDGEMENTS

Many persons from T.I.F.R. and I.I.A. have contributed to wards the design, fabrication, testing of HAGAR telescopes and data acquisition system, and helped during data collection. We thank them all. Also, we thank J.H.Taylor, R.N.Manchester, D.J.Nice,

J.M.Weisberg, A.Irwin, N. Wex, A.G.Lyne for the TEMPO code.

REFERENCES

[1] Thompson, D.J., in Astrophysics and Space Science Library, "Cosmic Gamma-ray sources" (Eds.: K.S. Cheng & G.E. Romero), **304**, 149 (2004)
[2] Pellizzoni, R.W. *et al.* , to appear in Ap J. 2008; Astro-ph:0810.1516v1
[3] Fermi-GLAST website: http://fermi.gsfc.nasa.gov
[4] Thompson, D.J., asXiv:astro-ph/01011039v1-3 (Jan 2001)
[5] Aliu, E. *et al.* , Science, **322**, 1221 (2008)
[6] V.R. Chitnis *et al.* , in these proceedings, **OG2.3** Paper ID# 0696 (2009)
[7] B.B. Singh *et al.* , Preprint, 2009
[8] R.J. Britto *et al.* , in these proceedings, **OG2.7**, Paper ID# 0958 (2009)