Bull. Astr. Soc. India (2000) **28**, 235-239

Gamma ray astronomy : New Indian initiatives

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Abstract. In this brief review, major new initiatives presently under implementation in India in the field of γ–ray astronomy are discussed in the backdrop of the just-concluded exploratory phase in the field.

Key words : gamma-ray astronomy, Atmospheric Cerenkov Telescopes, particle detector arrays, cosmic ray physics.

1. Introduction

Gamma-ray astronomy, which deals with the highest energy photons from the space (~ 100's keV - 100's TeV) gives a perspective of the non-thermal universe which complements the panaromic view coming from other spectral windows (Bhat, 1997; Ong, 1998). In recognition of this promise, experimental investigations in this spectral band were started in India, by the TIFR group at Ooty in South India, more or less concurrently with the corresponding effort made elsewhere in the world. They set up an array of tracking Cerenkov telescopes for detecting celestial γ–rays at TeV energies (Vishwanath, 1996 and references therein). Radiopulsars were made the main targets of these investigations and pulsed signals were reported from the Crab and Vela pulsars (Bhat et al, 1982). The Ooty system was subsequently shifted to Pachmarhi in order to avail of comparatively better sky conditions expected there. In the first phase of the Pachmarhi investigations, again, a number of interesting observations were made, and some possible detections reported (Bhat, 1996a).

In parallel with the atmospheric Cerenkov effort outlined above, the TIFR High Energy Cosmic Ray group also operated medium-size surface arrays of particle scintillation-detectors at Ooty and Kolar Gold Fields (KGF), for a number of years (Acharya, 1996). The highlight results from these experiments are the reported detection of episodic pulsed γ–ray signals from the X-ray binary systems, Cyg X-3 and Her X-1 (Gupta et al, 1990; Acharya, 1996 and references therein) and the Crab pulsar/Supernova remnant (Rao and Sreekantan, 1992) at Ultra High Energies (UHE). While the KGF experiment has since been closed down, the Ooty particle-array has been shifted to a different location in that place and is presently undergoing a major systems upgradation.

The BARC group started their explorations in the field of ground-based γ–ray astronomy in early seventies at Gulmarg in North India. A wide-angle, large-area photomultiplier detector system was set up for detecting optical fluorescence flashes induced in the terrestrial atmosphere by extremely short-duration γ–ray bursts in the keV-MeV photon energy range, predicted to accompany Supernova outbursts and primordial black-hole explosions (see Razdan and Bhat, 1997, for relevant references). The system could also detect single UHE γ–ray photons and cosmic-ray particle (> 0.5 PeV) through atmospheric Cerenkov detection mode. This was followed by setting up a first-generation multi-mirror Cerenkov telescope at Gulmarg for dedicated γ–ray astronomy work in the TeV photon energy range. For more details of this phase of the γ–ray astronomy within BARC, including the scientific results obtained, the reader is referred to Razdan and Bhat (1997).

In addition to the above-referred ground-based experimental activities in the field of γ–ray astronomy, wide-field γ–ray detectors ($E_\gamma \sim$ 20 keV - 3 MeV) have been flown on two Indian satellite platforms (SROSS-C) by the ISRO Satellite Centre for detection of cosmic γ–ray bursts (GRB). One of these experiments (Kasturirangan, 1999) is still on and has been detecting confirmed burst events at the rate of ~ 1 per month since its launch in May 1999.

2. New-generation experiments

In order to ensure that Indian astronomers contribute effectively to the global efforts aimed at fully realizing the promise held by the fields of ground-based γ–ray astronomy and cosmic-ray physics as efficient probes of the non-thermal universe, several major new facilities are being set up in the country. A key-feature of all these future-generation experiments is their substantially augmented event characterization capability, leading to better detection sensitivity and spectral measurements. We discuss here the key experimental features of these upcoming astronomy facilities in the country.

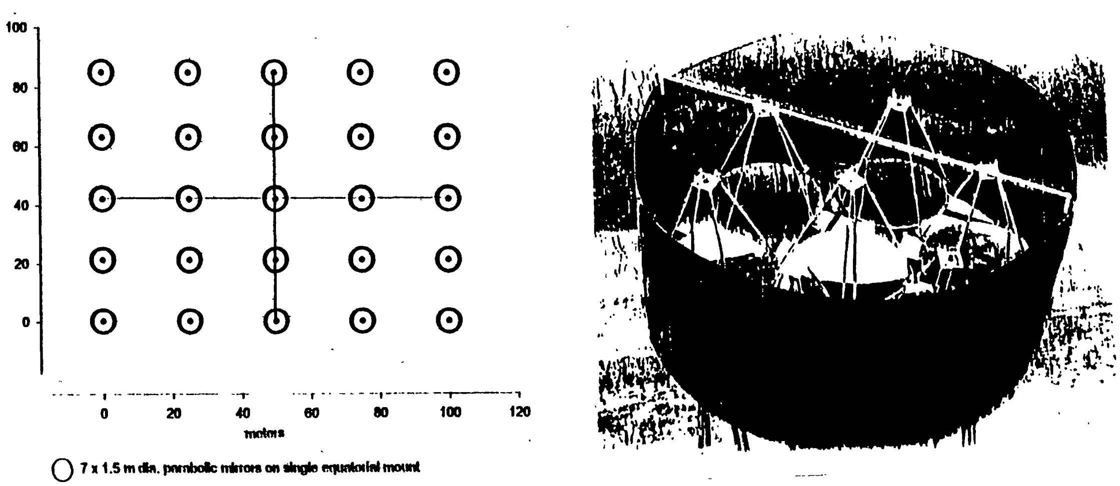

Figure 1. Schematic Layout of the PACT array at Pachamarhi and (b) a picture of one telescope unit of the array, comprising 7 x 1.5 m parabolic mirrors on a single equatorial mount.

2.1 GRAPES III array

This is a collaborative India-Japan experiment (Tonwar 1999) being set up at Ooty, primarily for studying the mass-composition of UHE cosmic-rays ($\geq 3 \times 10^{13} eV$). It consists of a surface array of 721 (presently 217) density / timing electron-detectors (plastic-scintillator sheets of 1 m^2 area), spread over a geographical area of ~ $10^4 m^2$ at Ooty. Its most distinctive feature would be the deployment of a 500 m^2-area muon detector ($E_\mu \geq 1$ GeV), the largest used so far internationally (Klages et al, 1997), This feature will, enable GRAPES III to carry out, both, cosmic ray mass-composition studies and UHE γ–ray astronomy investigations with a high resolution. The experiment is planned to be fully commissioned soon; for more details, refer to the accompanying paper by Tonwar (1999).

2.2 Pachmarhi array

The Pachmarhi Atmospheric Cerenkov Telescope (PACT) array (Fig. 1), comprises 25 individual Cerenkov telescopes, each consisting of 7 parabolic mirrors mounted symmetrically on single equatorial mount and making up a total reflector area of ~ $4.4 m^2$, which are spread over an area of 85 m x 100 m (Bhat, 1995). The event arrival direction is determined with an accuracy of (~ $0.2^\circ - 0.3^\circ$) by timing the onset of the Cerenkov wavefront at different light collectors with ≤ 1 ns time-resolution and is used to substantially reduce the isotropic cosmic-ray background while searching for γ–rays from a cosmic point-source. Further rejection of the residual background is being sought by using a series of promising new data-cuts, based on the lateral and arrival-time distributions of Cerenkov photons at the array elements. This approach for background rejection is orthogonal to the Cerenkov Imaging Technique employed by a majority of TeV γ–ray astronomy experiments at present. The γ–ray threshold energy of the PACT is estimated to be ~ 350 GeV. The flux sensitivity is expected to be ~ $3.8 \times 10^{-12} \gamma\ cm^{-2} s^{-1}$ at $E_\gamma > 1$ TeV in 50 hrs of on-source observations (Bhat et al, 1999).

2.3 GRACE facility

This new astronomy facility is being established at Mt. Abu for probing essentially the entire γ–ray spectral band (~ 100's keV - 100's TeV) from a single geographical location (Bhat et al, 1994). Four high-sensitivity experiments, TACTIC, MYSTIQUE, MACE and BEST (Fig.2) are being set up in a phased manner for this purpose. While the first 3 telescope systems will exploit the atmospheric Cerenkov detection technique for detecting single photons in the energy bracket ~ 10's GeV - 100's TeV, the BEST would search for cosmic γ–ray bursts (E_r ~ 100's keV - 100's MeV), using the atmospheric scintillation technique.

The TACTIC, comprising a compact array of 4 imaging γ–ray telescopes, has been built and installed, and is now in the final phase of commissioning at Mt. Abu (Bhat, 1996). Data collected by the Imaging Element of this instrument within a few days of its 'seeing the first light' in 1997, has produced evidence for a series of TeV γ–ray flares from the active galaxy, Mkn 501, a unique event so far, because of its almost synchronous detection by 5 other gamma-ray telescopes operating in different parts of the globe (Bhat et al, 1997; Protheroe et al, 1997). The Gurushikhar (Mt. Abu)-based 1.5m optical/infra-red telescope of the Physical Research

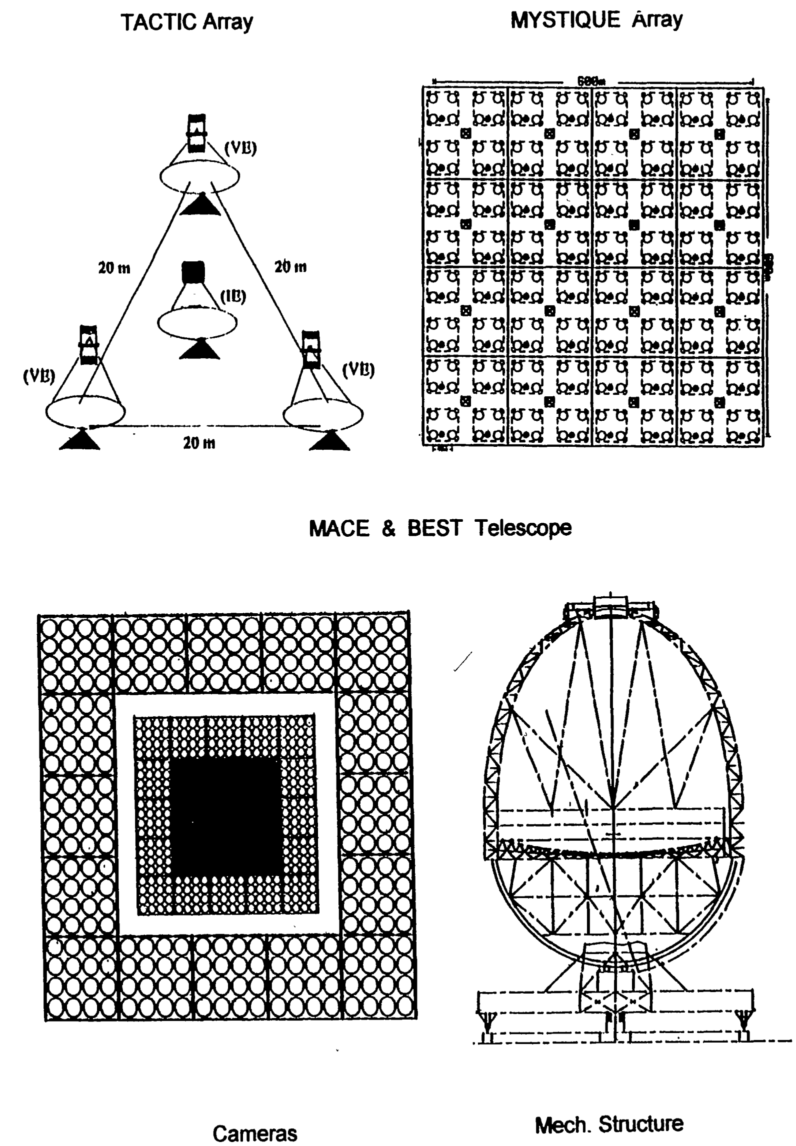

Fig.2 Schematic diagrams of GRACE experiments : (a) TACTIC array. The central element carries a 349 pixel Cerenkov light imaging camera while the three vertex elements carry duplex detector arrays in their focal plane. (b) The proposed layout of the MYSTIQUE wide-angle Cerenkov detector array. (c) Mechanical structure of the 25m aperture MACE light collector and (d) Camera configuration for the MACE and BEST telescope systems.

Laboratory, Ahmedabad has also detected this event in the form of enhanced polarized optical light, indicating that very high energy γ–ray signals from BL-Lac objects like Mkn 501 result from leptonic rather than nuclear progenitor particles (Joshi et al., 1999).

The other three experiments, MYSTIQUE, MACE and BEST are presently in the design and development stage and are likely to be installed at Gurushikhar in Mt. Abu in the next 6-7 years. The MACE is planned to deploy a steerable light reflector of 25 m diameter and two types of focal-plane instrumentations — a high-definition central Cerenkov imaging camera comprising 600 fast photomultiplier tubes (Field of View ~ 6^0 x 6^0 with graded-pixel resolutions of 0.15° and 0.25°) and an off-centre guard-ring of 480 photon detectors for detecting the isotropic fluorescent photons produced in the terrestrial atmosphere (N_2^+ emissions) following the incidence of a cosmic γ–ray burst. On one hand, this instrument will enable us to do high-sensitivity γ–ray astronomy in the promising albeit still-unexplored γ–ray window above tens of GeV, making EGRET-detected sources the main focus of its attention (Dingus, 1995). On the other, it will attempt to detect and localize the arrival directions of γ–ray bursts to < 1° accuracy and also search for correlated hard photon emissions from them. The MYSTIQUE is planned to be an array of Large-Area, Wide-Angle Cerenkov detectors (FoV: 45° half-angle) with an unusually low photon threshold energy of ~ 5 TeV and an angular resolution of ≤ 0.2°. When fully commissioned, it will be the highest-sensitivity wide-field instrument available for γ–ray sky survey work in the VHE band.

3. Outlook

With such a concentrated effort directed towards future γ–ray astronomy and cosmic ray activities in the country, the prospects for making world-class contributioons by the Indian astronomer community in these promising fields in the coming decades are quite bright.

References

Acharya B.S., 1996, Proc. Int. Symp. "Perspectives of High Energy Astronomy and Astrophysics", Mumbai, 227.

Bhat C.L. et al., 1994, Proc. Towards a Major Atmospheric Cerenkov Detector-III, Tokyo, 347.

Bhat C.L., 1996, Proc. Int. Symp. on "Perspectives of High Energy Astronomy and Astrophysics", Mumbai, 394.

Bhat C.L., 1997, Bull. ASI, 25, 461.

Bhat C.L., 1997, Towards Major Atmospheric Cerenkov Detector-V, Kruger, 398.

Bhat C.L., et al., 1997, Towards Major Atmospheric Cerenkov Detector-V, Kruger, 196.

Bhat P.N. et al., 1982, Proc. Very High Energy Gamma Ray Astronomy, Ooty, India.

Bhat P.N. et al., 1995, Proc. Towards a Major Cerenkov Detector-IV, Padova, 194.

Bhat P.N. et al., 1996a, Proc. Int. Symp. on "Perspectives of High Energy Astronomy and Astrophysics", Mumbai, 370.

Bhat, P.N. et al, 1999, This proceedings.

Chitnis, V.R. and Bhat, P.N., 1999, Astroparticle Physics (in press).

Dingus, B.L., 1995, Proc. "Towards a Major Atmospheric Cerenkov Detector-IV, Padova, 61.

Gupta, S.K. et al, 1990, ApJ, 354, L13.

Joshi, U.C. et al, 1999, This proceedings.

Kasturirangan, K., 1999, Bull. ASI, 27.

Klages, H.O. et al, 1997, Proc. 25th ICRC (Highlight Session), Durban, 8, 297.

Ong, R.A., 1998, Phys. Repts., 305, 93.

Protheroe, R.J. et al, 1997, Proc. 25th Int. Cosmic Ray Conf., 8, 317.

Rao, M.V.S., Sreekantan, B.V., 1992, Current Science, 62, 617.

Razdan, H., Bhat, C.L., 1997, Bull. ASI, 25, 429.

Tonwar, S.C., 1999, This proceedings.

Vishwanath, P.R., 1996, Proc. Int. Symp. on "Perspectives of High Energy Astronomy and Astrophysics, Mumbai, 204.

Weekes, T.C., 1998, Phys. Rept., 160.