

Status of the GAMMA-400 project

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Available online 8 February 2012

Abstract

The preliminary design of the new space gamma-ray telescope GAMMA-400 for the energy range 100 MeV–3 TeV is presented. The angular resolution of the instrument, 1–2° at $E_\gamma \sim 100$ MeV and $\sim 0.01^\circ$ at $E_\gamma > 100$ GeV, its energy resolution $\sim 1\%$ at $E_\gamma > 100$ GeV, and the proton rejection factor $\sim 10^6$ are optimized to address a broad range of science topics, such as search for signatures of dark matter, studies of Galactic and extragalactic gamma-ray sources, Galactic and extragalactic diffuse emission, gamma-ray bursts, as well as high-precision measurements of spectra of cosmic-ray electrons, positrons, and nuclei.

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Keywords: Cosmic rays; Gamma rays; Electrons; Positrons; Nuclei

1. Introduction

One hundred years after Hess’ discovery of the radiation coming from space, the main questions about the origin of

cosmic rays (CRs), their acceleration, and propagation in the Galaxy and intergalactic space remain open. Energetic CR particles when interacting with matter and radiation fields produce gamma-ray emission and, therefore, studies of gamma-ray sources and diffuse emission provide important clues to the origin and propagation of cosmic rays. A large number of outstanding problems in physics and

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astrophysics are connected with studies of CRs and associated gamma-ray emission. Among the most pressing issues are the nature of the dark matter, particle acceleration in Galactic and cosmological shocks, the origin of extragalactic diffuse emission, CRs in other galaxies and the role they play in galactic evolution, studies of the Galactic Center and local Galactic environment, CR propagation in the heliosphere, as well as many others.

The last years were rich in new breakthroughs and discoveries thanks to the combined efforts of many very successful space missions, such as PAMELA (Picozza et al., 2007), AGILE (Tavani et al., 2009), and Fermi-LAT (Atwood et al., 2009); balloon-borne missions, such as ATIC (Guzik et al., 2004), CREAM (Seo et al., 2004), and BESS (Yamamoto et al., 2007); as well as ground-based gamma-ray telescopes, such as MILAGRO (Atkins et al., 2004), H.E.S.S. (Aharonian et al., 2004), VERITAS (Weekes et al., 2010), and MAGIC (Aleksić et al., 2010). Among them are the new measurements of CR electrons-positrons by PAMELA (Adriani et al., 2009), Fermi-LAT (Abdo et al., 2009a), H.E.S.S. (Aharonian et al., 2009), and ATIC (Chang et al., 2008); antiprotons by BESS (Mitchell et al., 2005) and PAMELA (Adriani et al., 2011a); and a discovery of the break in the spectra of CR nuclei by ATIC (Panov et al., 2009), CREAM (Yoon et al., 2011), and PAMELA (Adriani et al., 2011b). In gamma rays – spectra of diffuse Galactic and extragalactic emission by EGRET (Hunter et al., 1997; Sreekumar et al., 1998) and Fermi-LAT (Abdo et al., 2009b); 270 Galactic and extragalactic gamma-ray sources with energies up to 20 GeV by EGRET (Hartman et al., 1999), approximately 50 sources up to 50 GeV by AGILE (Pittori et al., 2009), and nearly 1850 sources up to 100 GeV by Fermi-LAT (Abdo et al., 2011); about a hundred sources of TeV photons by H.E.S.S. (Tibolla et al., 2009), VERITAS (Holder et al., 2011), MAGIC (Cortina et al., 2011), and MILAGRO (Smith et al., 2010). These exciting recent developments show that we have just touched the tip of the iceberg and even more exciting discoveries are still awaiting us.

Further observations with improved angular and energy resolutions in high-energy gamma-ray range are necessary to address the following issues: study unidentified sources which are one third of discovered gamma-ray sources (Abdo et al., 2011), including detailed investigation of the Galactic center, study sources for the energies more than several tens GeV, where the energy ranges of Fermi and ground-based gamma-ray telescopes do not overlap (Abdo et al., 2009c), study variability of many sources, study diffuse gamma-ray emission for energies more than several tens GeV, search for high-energy emission from gamma-ray bursts and transient gamma-ray sources. The largely unexplored energy range of several tens MeV – few hundred MeV with only handful of observed sources has an enormous discovery potential.

The diffuse gamma-ray emission above 100 GeV remains unexplored and may provide some clues to the origin of the dark matter (Abazajian and Harding, 2011;

Beischer et al., 2009). A search for a fine structure in the spectra of high-energy CR electrons-positrons and nuclei is another important direction to pursue.

2. The GAMMA-400 gamma-ray telescope

2.1. The GAMMA-400 performance

GAMMA-400 is designed to address scientific challenges and will detect gamma rays in the energy range 100 MeV–3 TeV with an angular resolution of 1–2° at $E_\gamma \sim 100$ MeV and $\sim 0.01^\circ$ at $E_\gamma > 100$ GeV, an energy resolution of $\sim 1\%$ at $E_\gamma > 100$ GeV, and an effective area of ~ 4000 cm² at $E_\gamma = 100$ GeV. The instrument will also be used to detect electrons (positrons) in the energy range 1–3000 GeV with a proton rejection factor $\sim 10^6$ and nuclei in the energy range 250 GeV/nucleon to 10^{15} eV/nucleon. The total mass of the instrument is 2600 kg with power consumption of ~ 2000 W and a telemetry downlink capability of 100 Gbyte/day. Together with GAMMA-400, the space observatory will include the KONUS-FG gamma-ray burst monitor (Aptekar et al., 2009) and a star sensor for determining the GAMMA-400 axes with accuracy of approximately 5".

The GAMMA-400 physical scheme is shown in Fig. 1. The basic idea of the instrument was outlined in earlier publications (Dogiel et al., 1988; Ginzburg et al., 2007, 2009a,b), but the design is being improved (Galper et al., 2011a,b,c) using the results of the current space missions Fermi-LAT and AGILE. Gamma-400 consists of scintillation anticoincidence top and lateral detectors (AC), converter-tracker (C) with approximately 25 layers of double (x, y) silicon strip coordinate detectors (pitch 0.1 mm)

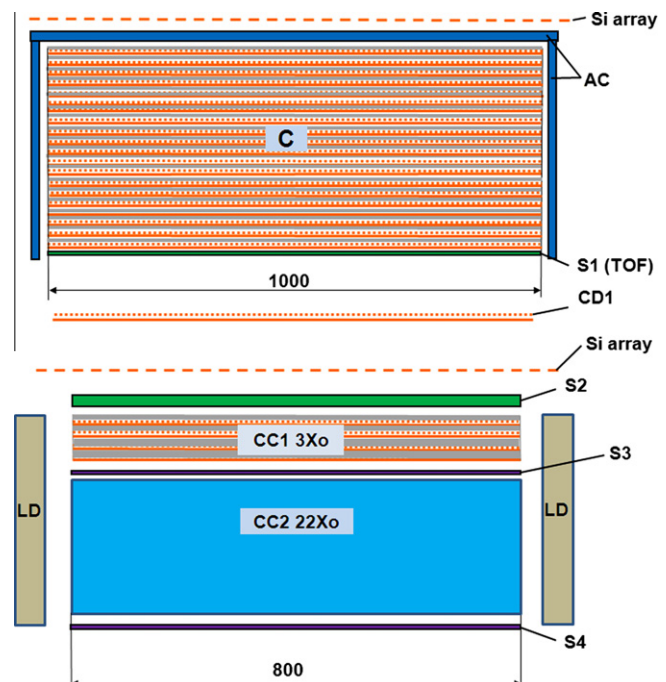


Fig. 1. The GAMMA-400 physical scheme.

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