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Science with GECCO, the Galactic Explorer with a Coded Aperture Mask Compton Telescope

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The Galactic Explorer with a Coded Aperture Mask Compton Telescope (GECCO) is a novel concept for a next-generation telescope covering hard X-ray and soft gamma-ray energies. We will present the potential and importance of this approach that bridges the observational gap between the keV and GeV energy range. With the unprecedented angular resolution of the coded-mask telescope combined with the sensitive Compton telescope, a mission such as GECCO can disentangle the discrete sources from the truly diffuse emission. This also allows to understand the gamma-ray Galactic center excess and the Fermi Bubbles, and to trace the low-energy cosmic rays, and their propagation in the Galaxy. Nuclear and annihilation lines are spatially and spectrally resolved from the continuum emission and from sources, addressing the role of low-energy cosmic rays in star formation and galaxy evolution, the origin of the 511 keV positron line, and fundamental physics. Such an instrument also detects explosive transient gamma-ray sources, which enable identifying and studying the astrophysical objects that produce gravitational waves and neutrinos in a multi-messenger context.

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1. Introduction

The Imaging Compton Telescope [COMPTEL; 1] on board the Compton Gamma Ray Observatory had been observing the MeV sky from 1991 to 2000. This has provided a comprehensive view of the sky with an instrument having and energy-dependent angular resolution of 1.7 – 4.4 degrees and a large field-of-view of ~1 sr. In Figure 1 we show a rather recent re-analysis by the authors of [2] called COMPTEL-Reloaded: it shows the all-sky image in the 9 – 30 MeV. While this is one of the most informative all-sky images at MeV energies to date, it becomes apparent that a more effective source detection is in need of a improved angular resolution and of the ability to tell the diffuse emission from point-sources apart.

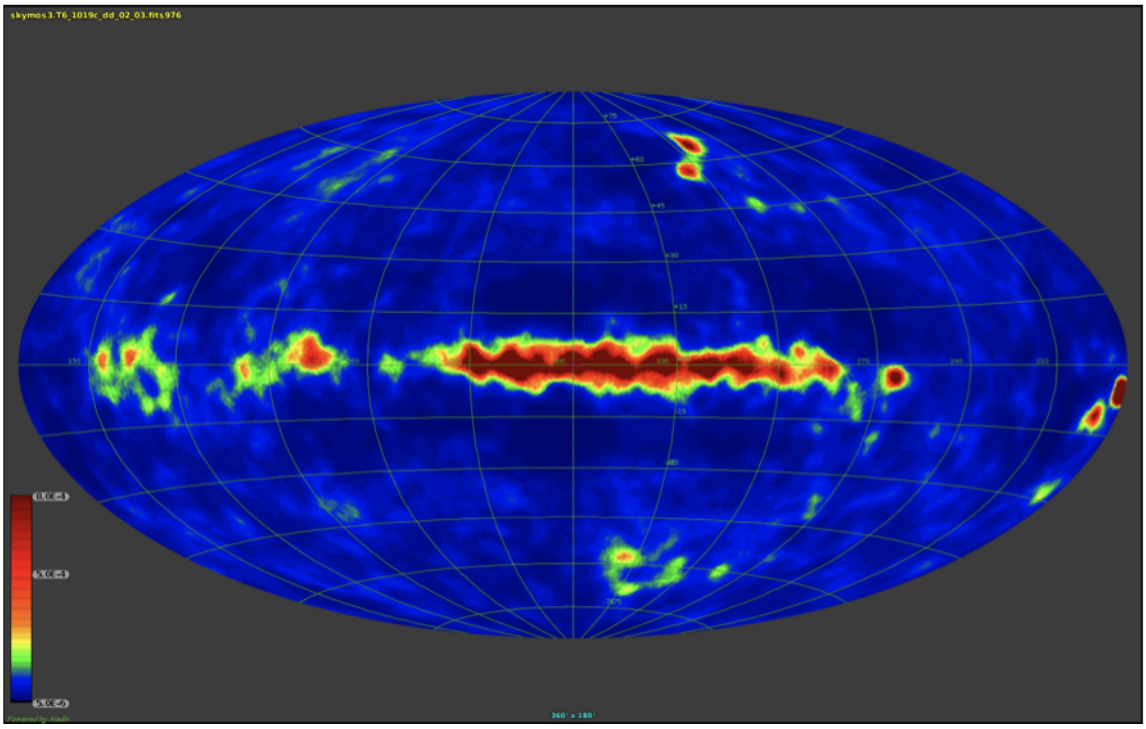

Figure 1: COMPTEL skymap in the 9 – 30 MeV band adapted from a recent re-analysis [2] called COMPTEL-Reloaded. The figure shows the rather large diffuse structure (red area) on the Galactic plane.

A mission like the Galactic Explorer with a Coded Aperture Mask Compton Telescope [GECCO; 3] features a coded-mask telescope and a Compton telescope. The position sensitive detector used for the coded-mask telescope acts also as a Compton telescope. The latter is able to detect and analyse the diffuse emission, while the former is able to precisely position the point-sources on the sky with an angular resolution better than 1 arcmin. For the most updated hardware development for GECCO see these proceedings [4]. In the following we will discuss the science topics that can be addressed by a mission with such properties.

2. Science with GECCO

Current theoretical studies of the Galactic diffuse emission [5] using most updated cosmic-ray propagation models suggest that the actual diffuse emission measurements by COMPTEL and by SPI on board the INTEGRAL mission exceeds the modeled diffuse emission up to a factor of three depending on the energy. This hints at the presence of point-like astrophysical sources that contribute to the measured diffuse emission and that cannot be detected and/or resolved. With its angular resolution and the ability to measure the diffuse emission, GECCO can contribute to solve this issue.

Very specifically, due to its ability of observing the inverse-Compton emission component after removing the source contamination, GECCO can provide the distribution across the Galaxy of cosmic-ray electrons and hadrons. In addition, GECCO can perform the first nuclear spectroscopic observation of low-energy cosmic-rays, which in turn allows for studying their spectra, composition, and distribution in the Galaxy. The center of the Galaxy observed by the Fermi-LAT reveals an excess emission compared to the diffuse emission models. The most interesting interpretations of this feature are the contribution due to dark matter annihilation and the abundance of unresolved sources in the inner Galaxy. To address this question the high-resolution observations by GECCO allow for resolving point-like sources. Indeed, the technology used by the Fermi-LAT has rather limited capabilities below ~500 MeV, while current X-ray telescope operate at lower energies that do not provide relevant information. Also, it seems that the Galactic center emanates the Fermi Bubbles that are each 10 kpc across to the North and to the South of the Galactic plane. MeV-counterparts of the Fermi Bubbles would favor the leptonic origin of these large structures, in which low-energy cosmic-ray electrons produce photons below ~10 MeV due to inverse-Compton scattering on the interstellar radiation field. Yet, the absence of such a counterpart would hit at hadronic processes that produce the Fermi Bubbles in a pion-decay scenario. Furthermore, the ability to resolve point-like sources on the Galactic plane can help in disentangling their emission from the Fermi Bubble, providing useful insights about the origin of these large-scale features. Similarly, it will be possible to differentiate between a genuinely diffuse origin (dark matter annibilation origin) of the 511 keV emssion in the inner Galaxy and point-like sources. Very specifically source classes that have been considered include microquasars, low-mass X-ray binaries, SNe Ia, and Wolf-Rayet stars.

Also extragalactic source populations can be observed by GECCO. Very precisely, high-redshift blazars shift their high-energy (inverse-Compton) peak emission component into the MeV band. With its angular resolution the mission can detect and precisely locate these sources for their identification, while the spectral measurement can discriminate between emission scenarios [e.g. 6]. The BGO shielding of GECCO, used for the background rejection, will result in the ability to detect and locate the prompt emission of GRB, similarly to the INTEGRAL [7] mission, which results in multimessenger capabilities of the mission.

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3. GECCO Team

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