The Advanced Gamma-ray Imaging System (AGIS) – Science Drivers for Galactic Astrophysics –

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Abstract

The Advanced Gamma-ray Imaging System (AGIS), a concept for a next-generation atmospheric Cherenkov telescope array, would provide unprecedented sensitivity and resolution in the energy range >50 GeV, allowing great advances in the understanding of the populations and physics of sources of high-energy gamma rays in the Milky Way. Extrapolation based on the known source classes and the performance parameters for AGIS indicates that a survey of the Galactic plane with AGIS will reveal hundreds of TeV sources in exquisite detail, for population studies of a variety of source classes, and detailed studies of individual sources. AGIS will be able to study propagation effects on the cosmic rays produced by Galactic sources by detecting the diffuse glow from their interactions in dense interstellar gas. AGIS will complement results now being obtained in the GeV range with the Fermi mission, by providing superior angular resolution and sensitivity to variability on short time scales, and of course by probing energies that Fermi cannot reach.

AGIS Concept and Performance

The performance requirements for AGIS include >10x improvement in sensitivity relative to current-generation imaging atmospheric Cherenkov telescopes (IACTs, Fig. 1). Consideration of tradeoffs led to the adoption of a concept with 36 Schwarzschild-Couder 10-m class telescopes. The Schwarzschild-Couder design provides a large field of view (8°) and ~10k pixel cameras will provide angular resolution as good as 0.03° per photon. The array spacing will be sufficient to achieve >1 km^2 effective area over a broad energy range. Stereoscopic techniques employed in the trigger and filtering the background rejection will be substantially improved over current-generation instruments [1].

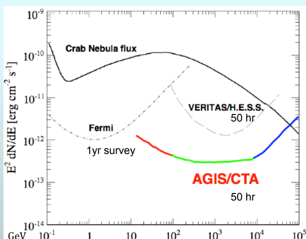

Fig 1. Sensitivity reach of AGIS and the Cherenkov Telescope Array (CTA) concepts relative to current ground and space missions

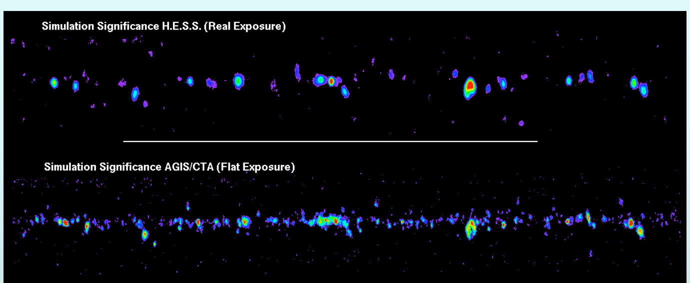

Fig 2. Comparison of simulated surveys of the Galactic plane with AGIS and a H.E.S.S.-like instrument. The sources here are only SNRs, with spatial and luminosity distributions as defined in [4]

AGIS Survey of the Galactic Plane

The initial H.E.S.S. survey of the Galactic plane [2] revealed 14 newly-detected TeV sources, most of which were identified as supernova remnants (SNRs), pulsar wind nebulae (PWNs), or compact-object binaries; 3 of the newly-found sources remain unidentified and further observations have since found other so-called 'dark accelerators'. Colliding-wind systems of massive stars have also been established as Galactic TeV sources (e.g., [3]).

The combination of unprecedentedly-large field of view and effective area together with finer angular resolution and improved background rejection relative to current and near-future generation Atmospheric Cherenkov telescopes give AGIS great potential for discovering and studying TeV accelerators in the Milky Way. For a comparable exposure as the H.E.S.S. survey of the Galactic plane, the AGIS survey speed will be >10 times faster and for a given level of exposure the AGIS survey will be ~3x more sensitive. This opens the possibility of **monitoring the inner radian for TeV transients or periodic sources**. In an AGIS sky survey, hundreds of sources will be detected and spatially resolved (Fig. 2).

TeV Galactic Diffuse Emission

The excellent sensitivity and resolution of AGIS will allow imaging of Galactic diffuse emission over much of the Milky Way and in regions of cosmic-ray acceleration will provide direct evidence of propagation effects on the spectra and densities of cosmic rays.

In Fig. 3 we show simulated photon detection probability contours for two energy ranges in a region surrounding the Galactic center, where for the purposes of the study cosmic rays were assumed to have been injected from the Galactic center region. The 'target' distribution of interstellar gas is the same in both energy ranges. The difference in appearance between the images is primarily due to energy-dependent diffusion.

In most regions of the Galactic plane the spectrum of the Galactic diffuse emission is soft relative to potential TeV emitters among the Galactic source populations, and even if it were not softer the excellent angular resolution will provide relative immunity to source confusion.

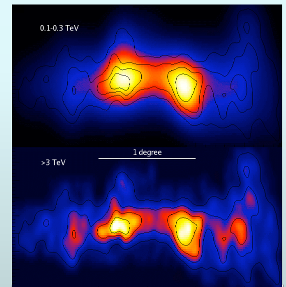

Fig 3. Simulated (and idealized noise-free) observations of the Galactic Center region, modeling a cosmic-ray source at the center [4]. Propagation effects can be studied from the energy dependence of the distribution of emission.

Cosmic Particle Acceleration

The fine angular resolution of AGIS will allow details of the shock acceleration in supernovas to be studied. Fig. 4 shows schematically that the resolution will be comparable with the angular scales of filaments detected in X-ray observations. When combined with observations at other wavebands, these constrain the physical conditions in the acceleration region including: the magnetic field strength, the energy densities of particles and radiation, and particle diffusion coefficients. Cosmic-ray production involves the complex physics of colliding magnetized plasmas with coupled turbulence and energetic particles. These processes probably also drive local magnetic field growth, as fields greatly exceeding the shock-compressed value seem needed to reach the observed high energies. Observations with AGIS will be particularly revealing, as they trace the most energetic particles, which for nearby sources will be localized with respect to the shock front

In some Galactic sources, TeV observations at energies beyond the Klein-Nishina limit will uniquely probe the proton component at the acceleration sites.

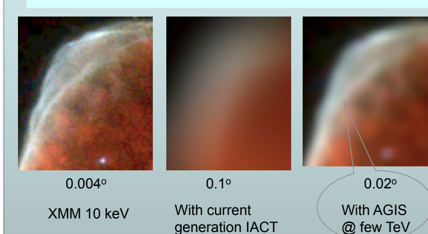

Fig 4. XMM observation of a portion of the shell of IC 443, showing via smoothing the relative resolving power of AGIS for details on the scale of an SNR.

Summary

The depth and speed of observations with AGIS will reveal many times more very high-energy gamma-ray sources than are currently known, allowing new Galactic populations to be found, characterized, and monitored. With the resolution of AGIS, particle acceleration sites in the Milky Way will be well resolved and subject to detailed study. AGIS will complement and extend the results from the Fermi Large Area Telescope.

References

[1] Maier, G. et al. 2009, Proc. 31st ICRC (arXiv:0907.5118)
[2] Aharonian, F., et al. 2006, Phys Rev Lett, 97, 1102
[3] Aharonian, F. et al. 2007, A&A, 467, 1075
[4] Funk S. 2009, Proc. Heidelberg International Symposium on High Energy Gamma-Ray Astronomy (AIP: in press, arXiv:0901.1885)