The GECCO Mission at keV and MeV energies

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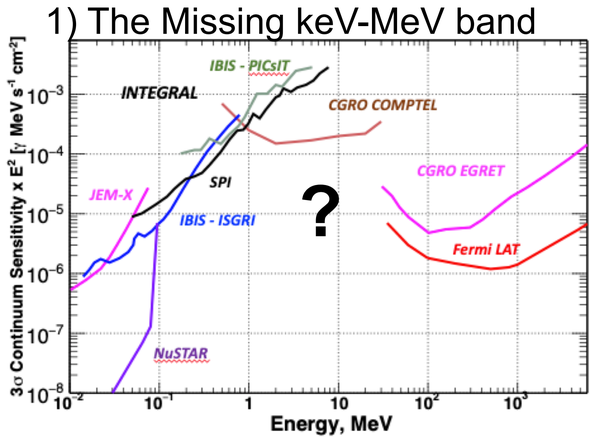
We present an innovative mission concept that builds upon the heritage of past and current missions improving the sensitivity and, very importantly, the angular resolution. This consists in combining a Compton telescope and a coded-mask telescope. The Galactic Explorer with a Coded Aperture Mask Compton Telescope (GECCO) is a novel concept for a next-generation telescope covering hard X-ray and soft gamma-ray energies. 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.

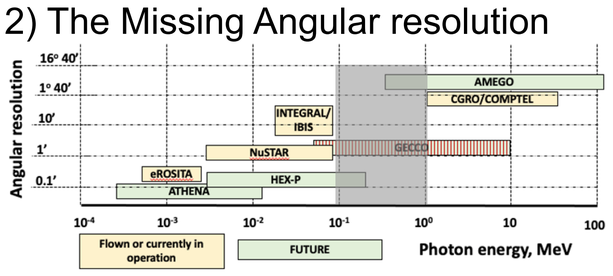
We present the GECCO mission and its science as recently published in JCAP07(2022)036..

THE PROBLEMS

1) The Missing keV-MeV band



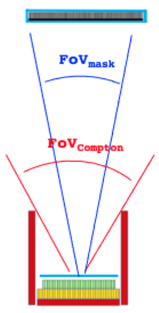
2) The Missing Angular resolution



OUR SOLUTION

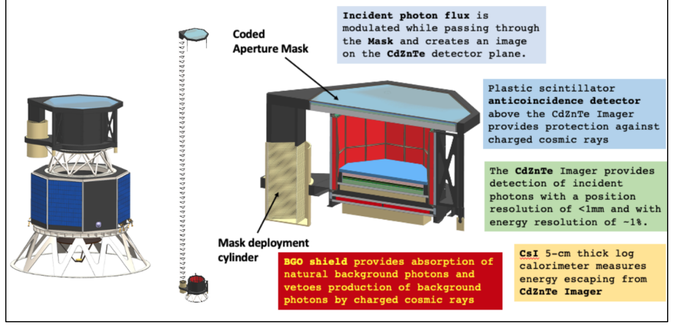
GECCO: Compton Telescope + Coded Aperture Mask Telescope

(see Moiseev's talk this conference)



Energy Range: 50 keV – 10 MeV
Energy resolution: < 1% at 0.5 – 5 MeV
Angular resolution:
~1 arcmin in the Mask mode with 3°- 4° FoV;
3° - 5° in the Compton mode with a 60° FoV (~ 1 sr)
Sensitivity: 10^{-4} - 10^{-6} MeV cm^{-2} s^{-1} over the entire energy range

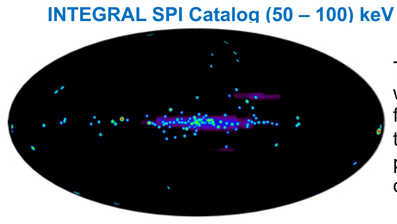
GECCO can be operated in either scanning or pointed mode, to be optimized according to the science objective



DETECTING SOURCES: The INTEGRAL/SPI & COMPTEL Heritage

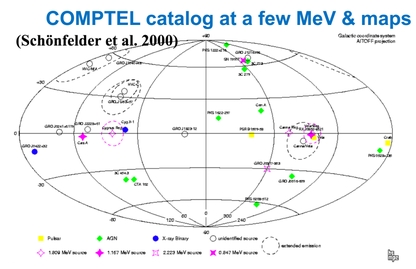
- **Disentangling and resolving sources**
- **Distinguishing sources from the truly diffuse emission**

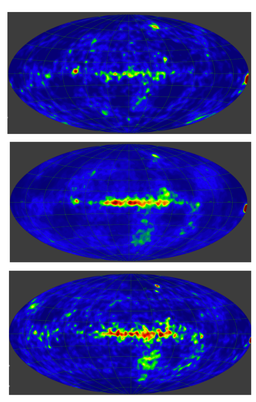
INTEGRAL SPI Catalog (50 – 100) keV



ESA/INTEGRAL/SPI
The left image shows the entire sky, as observed with the Spectrometer on board INTEGRAL (SPI) for six years of data. The two main contributions to the emission at these energies are clearly visible: point sources, galactic and extragalactic alike, and diffuse emission.

COMPTEL catalog at a few MeV & maps
(Schönfelder et al. 2000)



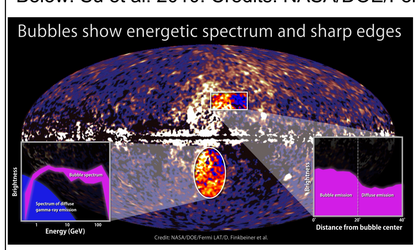


Right maps: Preliminary COMPTEL all-sky images using the new maximum-entropy method. Top to bottom: (0.9-1.7) MeV, (1.7-4.3) MeV, 4.3-9 MeV (Strong & Collmar (2019) Memorie della Societa Astronomica Italiana, 90,297)

THE FERMI BUBBLES & THE X-RAY BUBBLES

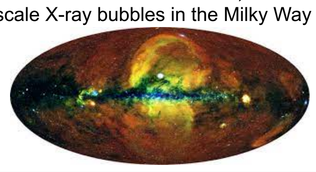
Investigating the origin of the Bubbles

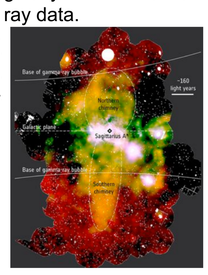
Below: Su et al. 2010. Credits: NASA/DOE/Fermi LAT /Finkbeiner et al.



Bottom:
Credits: Ponti/MPE/INAF and Morris/UCLA.
The galactic chimneys (yellow - orange areas extending vertically) are centered on the supermassive black hole at the center of our galaxy. XMM Newton x-ray data.

Below: Predehl et al. Nature 588, 227 (2020). The SRG/eROSITA all-sky map as a false color image (red for energies 0.3-0.6 keV, green for 0.6-1.0 keV, blue for 1.0-2.3 keV). Detection of large-scale X-ray bubbles in the Milky Way halo.

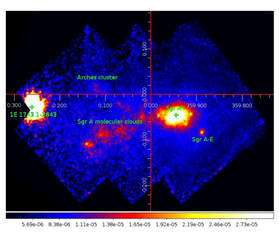




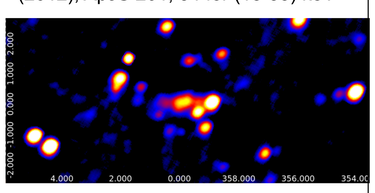
THE GALACTIC CENTER

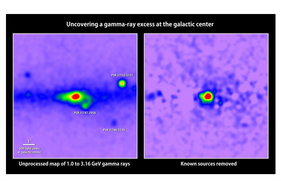
Understanding the nature of the central supermassive black hole; understanding the FERMI-LAT Galactic Center excess

NuSTAR (10-79) keV exposure - corrected smoothed image of the GC in Galactic coordinates (Mori et al. 2015)



Combined image of Swift/BAT INTEGRAL/IBIS of the GC obtained with the method in Bottacini et al. (2012), ApJS 201, 34 for (18-55) keV



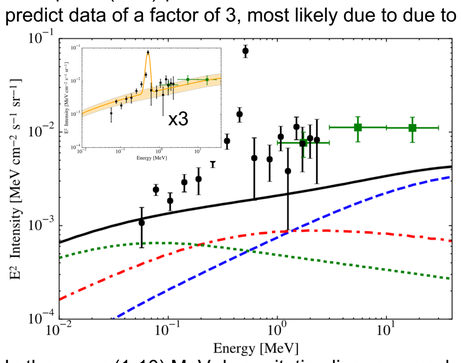


Left: (Credit: T. Linden, Univ. of Chicago) map from Fermi LAT at (1 - 3.16) GeV of the galactic center. Prominent pulsars are labeled. Removing all known gamma-ray sources reveals excess emission (right) that may be due to unresolved sources, truly diffuse emission or dark matter annihilations.

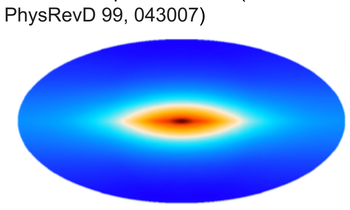
INTERSTELLAR EMISSION & COSMIC RAYS

Understanding low-energy Cosmic Rays, their propagation, their sources, and their role on the Galaxy evolution and star formation (Continuum emission and de-excitation nuclear lines)

Below (Orlando 2018, MNRAS 475, 2724): Models of the diffuse interstellar emission in the Inner Galaxy compared with INTEGRAL/SPI data (Bouchet et al 2011, ApJ, 739, 29) and COMPTEL data (Strong et al. 1999). This diffuse emission between tens of keV to tens of MeV is produced by inverse Compton scattering of CR electrons and positrons on the CMB (green), infrared (red), and optical (blue) photons. Insert: the best models constrained by multi-messenger data under predict data of a factor of 3, most likely due to due to many unresolved sources.



Bottom: an example of the interstellar inverse Compton emission (Orlando 2019 PhysRevD 99, 043007)

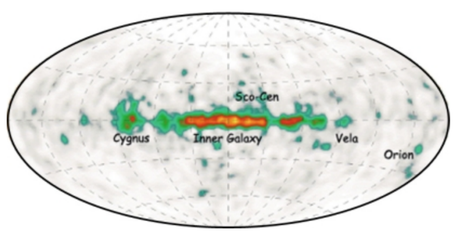


In the range (1-10) MeV de-excitation lines are produced by nuclear collisions of CR with interstellar matter (e.g. Bykov 2014, Astron. Astrophys. Rev. 22, 77)

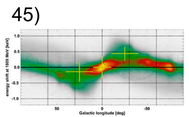
NUCLEOSYNTHESIS LINES

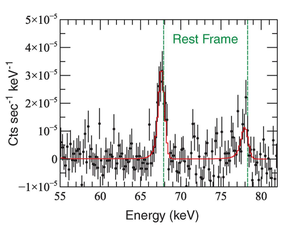
Resolving Galactic chemical evolution and sites of nucleosynthesis of elements

Plüschke et al, 2001: Al line at 1.9 MeV. The all-sky map shows the gamma-ray emission produced by the radioactive decay of ^{26}Al, tracing regions with massive young stars throughout the Milky Way. The image at the bottom left was produced using data by the COMPTEL from 1991-2000.



Bottom: Doppler shifts in gamma rays caused by galactic rotation (Diehl et al. 2006, Nature 439, 45)



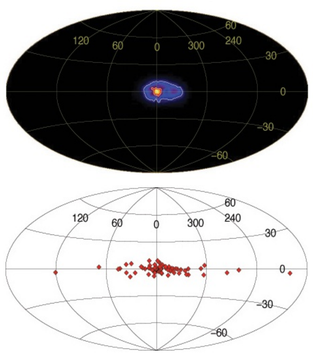


Left: Nustar result. 44Ti gamma-ray emission lines from SN1987A reveal an asymmetric explosion (Boggs et al. (2015) Science 348, 6235)

Other nucleosynthesis lines in the GECCO's energy range: 56Ni, 57Co, 60Fe

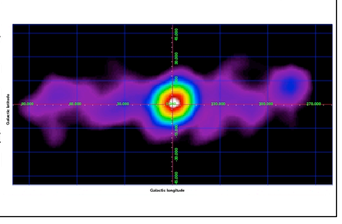
THE 511 KEV LINE

Localizing and clarifying the origin of the 511 keV electron-positron annihilation line



Left: Credits: ESA/Integral/MPE (Weidenspointner et al. 2008) The upper panel shows the glow of 511 keV gamma-rays as observed by the spectrometer SPI of INTEGRAL. The 511 keV emission coming from the annihilation of electrons by their antimatter counterparts, the positrons. The emission can be seen extending towards the right-hand side of the map. The lower panel shows the distribution of low mass X-ray binary stars with a hard X-ray spectrum. This stellar population has a distribution that may match the extent of the 511 keV map.

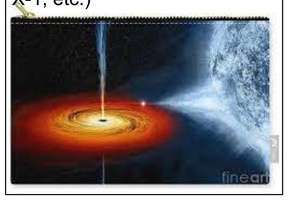
Right: INTEGRAL/SPI 511 keV. Credits: ESA/Bouchet et al. Spatial distribution of the 511 keV gamma-ray line from the positron annihilation in the central region of the Milky Way. The main emission is roughly circular, but weak emission is also detected along the Galactic plane.



ADDITIONAL SCIENCE TOPICS

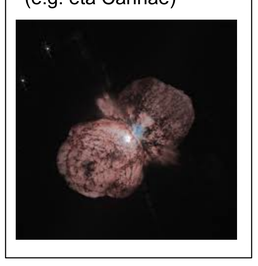
More specific Galactic and extragalactic science of classes of objects

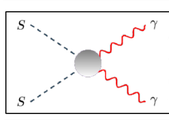
X-ray binaries (Cyg X-1, Vela X-1, etc.)



Rotation-powered pulsars and magnetars

Colliding Wind Binaries (e.g. eta Carinae)

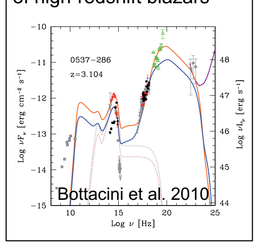




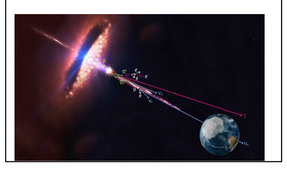
Annihilating and Decaying Sub-GeV Dark Matter (Profumo's contribution this conference)

Also extragalactic science

Detection and identification of high-redshift blazars



Identification and precisely localization of the sources of neutrino events



Identification and precise localization of the sources of gravitational wave events