Astro2020 Science White Paper

The MeV Background

Thematic Areas: ☐ Planetary Systems ☐ Star and Planet Formation
☐ Formation and Evolution of Compact Objects ☑ Cosmology and Fundamental Physics
☐ Stars and Stellar Evolution ☐ Resolved Stellar Populations and their Environments
☐ Galaxy Evolution ☐ Multi-Messenger Astronomy and Astrophysics

Principal Authors:
Name: Marco Ajello
Institution: Clemson University, USA
Email: majello@g.clemson.edu

Name: Yoshiyuki Inoue
Institution: iTHEMS, RIKEN, Japan & Kavli IPMU, Japan
Email: yoshiyuki.inoue@riken.jp

Co-authors: P. Bloser (Los Alamos National Laboratory, USA), W.T. Vestrand (Los Alamos National Laboratory, USA), D. Hartmann (Clemson University), J. Finke (Navy Research Laboratory), Z. Wadiasingh (NASA/GSFC), C. Prescod-Weinstein (Chanda Prescod-Weinstein), U. Oberlack (Johannes Gutenberg University Mainz, Germany), F. Longo (University of Trieste and INFN Trieste), C. Shrader (NASA/GSFC, USA), V. Beckmann (CNRS / IN2P3, France), I. Agudo (IAA-CSIC, Spain), M. Petropoulou (Princeton University, USA), L. The (Clemson University), A. Strong (MPE, Germany), E. Bottacini (Dipartimento di Fisica e Astronomia, Università di Padova, Italy), J. W. Hewitt (University of North Florida, USA), A. Moiseev (CRESST/NASA/GSFC and University of Maryland, College Park), S. Griffin (NASA GSFC / University of Maryland College Park), D. Gasparrini (SSDC and INFN Roma Tor Vergata), J. A. Tomsick (UC Berkeley/SSL, USA)

Abstract: The emission of our Universe is well characterized at most wavelengths, but a gap remains at MeV energies. This is an energy range where nuclear decays type Ia supernovae (SNIa), emission from radio-loud and radio-quiet AGN and potentially dark matter interaction can each contribute to the MeV background. An all-sky MeV mission will allow us to measure the intensity and the angular fluctuations of the MeV background. This will allow us to constrain models of SNIa formation, the evolution of radio-loud and radio-quiet AGN, the growth of the most massive black holes and to constrain the cross-section for dark matter interaction.

1 Science Background

The origin of the MeV background, in the $\sim$0.2-100 MeV gap region, remains a long-standing issue in astrophysics. The first measurements by the APOLLO 15/16 missions (18) displayed an intriguing ‘MeV bump’ that was not later confirmed by HEAO-4 , SMM and COMPTEL (8; 20; 21). These latter missions characterized the MeV background spectrum as a power-law extension of the cosmic X-ray background (up to $\sim$3 MeV) (2). Up to this day there is no clear understanding of which source population, or emission mechanism, may account for the intensity of the MeV background. This is also due to the fact that the background itself remains also not well measured. Indeed, in the MeV energy range the extragalactic background is measured by the SMM and COMPTEL. Both instruments had several shortcomings with respect to performing an accurate measurement of the MeV background. SMM stared at the Sun and thus was limited to observations along the ecliptic plane, thus biasing the observations of the extragalactic diffuse emission. COMPTEL on the other hand was background dominated below 4 MeV (mostly due to activation) and its diffuse background measurement is affected by strong systematics (21).

2 Importance of gamma-ray observations

Dark matter annihilation (4), non-thermal emission from Seyfert galaxies (9), nuclear decays from Type Ia supernovae (6; 16), and emission from blazars (3) and radio-galaxies (10; 15) are among the candidates that were put forth to explain part or the totality of the MeV background. Blazars, radio-galaxies, and type Ia supernovae have been detected at MeV energies and as such their contribution to the MeV background is guaranteed. On the other hand the contribution from a putative dark matter interaction or the non-thermal emission of Seyfert galaxies is less secure. The latter is however worth of attention because by invoking the presence of non-thermal electrons in AGN coronae, it makes radio-quiet AGN a population able to account for both the X-ray and MeV backgrounds, justifying at the same time the power-law shape of the low-energy part of the MeV background. Moreover, recent ALMA observations have revealed an existence of non-thermal coronal synchrotron emission from nearby Seyferts (13). This secures that non-thermal electrons also exist in AGN coronae together with the thermal population. On the other hand, part of the < 3 MeV background spectrum can be accounted for by the emission of extremely powerful blazars, which are easily detected in the hard X-ray range and display very hard power-law spectra (3). The most interesting aspect is that in order to connect the X-ray and the γ-ray (i.e. GeV) background, the spectrum of the MeV background must harden at around 1-2 MeV and become softer at 40-60 MeV (see Fig. 1). This implies that either there are at least two source classes contributing to the MeV background or that another source class that exhibits a spectral bump needs to be considered. Star-forming galaxies, whose MeV to GeV emission is powered by cosmic rays, may be this additional population (14).

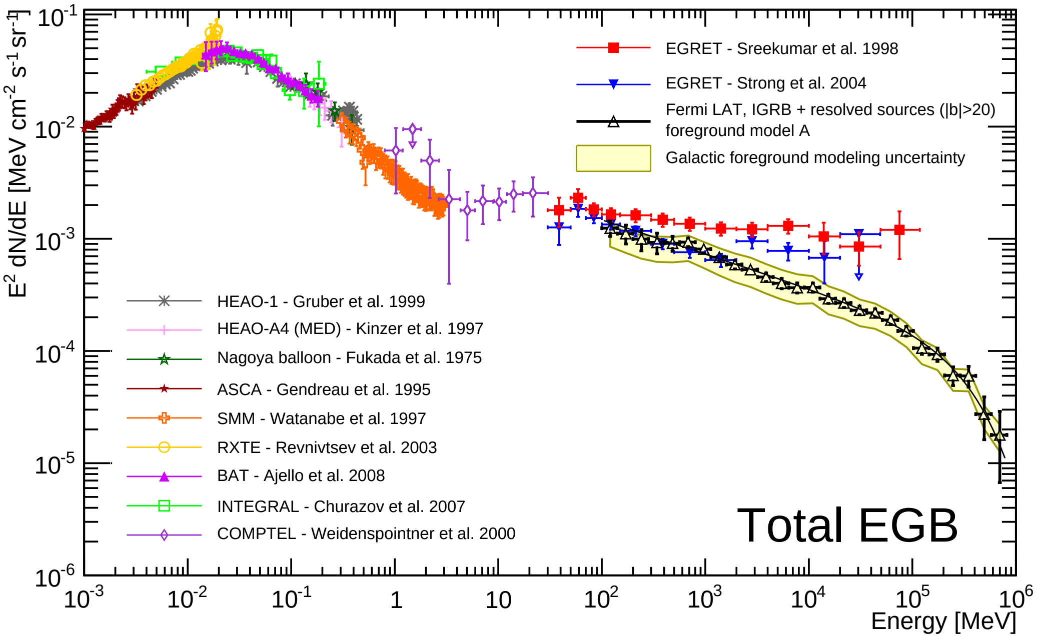

Figure 1: Spectrum of the high-energy background from X-ray to GeV γ-rays. Adapted from (1).

3 Expected results with an all-sky MeV mission

3.1 Intensity Measurement

An all-sky MeV mission will be able to perform a new, accurate, measurement of the MeV background at > 300 keV and up to a *few* hundred MeV providing good overlap with the X-ray and the γ-ray backgrounds. The measurement of the MeV background will require careful modeling of the Galactic diffuse emission and of the instrumental background. The former can be achieved using predictions of Galactic cosmic ray propagation models (17) tuned to fit the MeV telescope data, while the latter will require detailed Monte Carlo simulations and an event selection that minimizes non celestial signal. This new measurement may or may not confirm the spectral hardening and the softening at 40-60 MeV thus shedding light on the origins of the MeV background.

3.2 Angular Fluctuations

It is unlikely that the next generation MeV mission will be so sensitive to resolve enough (or a large fraction of) of the MeV background to unveil its origin. However, the angular fluctuations of the MeV sky will be used as a complementary tool to probe its origins (5; 11). Fig. 2 shows the Poisson term of the angular power spectra of Seyferts with non-thermal electrons in coronae (9) and FSRQs (3). For reference, we also plot Seyferts with simple thermal cutoff spectra (19), but note that those do not explain the MeV background. Since the contribution of the correlation term is negligible in this energy region (given the flux sensitivity of future instruments), the angular power spectrum is dominated by the Poisson term. As clearly seen in the Figure, the Poisson fluctuation measurement is a powerful tool to distinguish the origin of the MeV background. The difference of the C_l^p of Seyferts and FSRQs is more than an order of magnitude. This is due because Seyferts are fainter but more numerous than blazars. A new all-sky MeV mission will be able to unveil the origin of the MeV background through the measurement of the anisotropy of the sky.

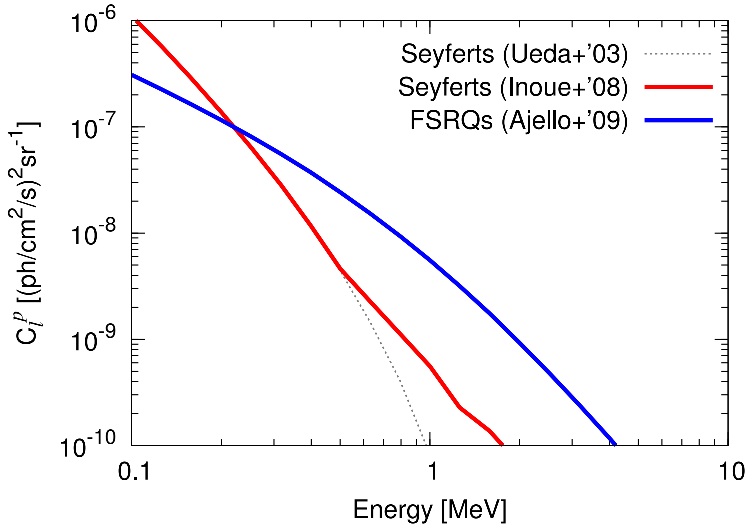

Figure 2: Expected Poisson term of the angular power spectrum of the cosmic MeV gamma-ray background at 200 keV–10 MeV. Red and blue curve corresponds to Seyferts with non-thermal electrons in coronae (9) and FSRQs (3), respectively, assuming the MeV background is explained by them. For reference, we also plot the model of Seyferts with thermal cutoff (19) by dotted curve which does not explain the MeV background radiation. Adapted from (11).

4 Summary

The emission of our Universe is well characterized at most wavelengths except at MeV energies. This is an energy range where nuclear decays from SNIa, emission from radio-loud and radio-quiet AGN and potentially dark matter interaction concur to create the MeV background. An all-sky MeV mission will allow us to measure the intensity and the angular fluctuations of the MeV background. Both will allow us to shed light on its origin. The MeV background provides crucial information to probe formation models of powerful blazars, the non-thermal content of AGN coronae, the rate of SNIa and dark matter interaction. Its characterization will open a new window on the study of the evolution of our Universe and should be done within the coming decade.

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