Meeting 1: Gamma-ray Science Priorities

Document Structure:

- General Information & Resources
- Science Topics Summaries:
    - Nature of Dark Matter/Dark Energy
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General Information & Resources

Date & Time: February 29, 2026, 1 PM GMT-5, Zoom.
Presentation Slides: Gamma-ray Science Priorities
Video recording: Meeting1_Zoom_recording.mp4
Timeline of the Video recording:
4:30 – 11:50: Welcome & Introduction to FIG SAG
11:50 – 32:00: General Group Discussion
32:00 – 53:40: Breakout session 1 (Only DM & Dark Energy Breakout Room recorded)
53:40 – 1:20:00: General Group Discussion
1:20:00 – 1:44:00: Breakout session 2 (Only DM & Dark Energy Breakout Room recorded)
1:44:00 – end: Concluding remarks

Science Topics Summaries

Nature of Dark Matter/Dark Energy

Link to the notes: Nature of Dark Matter/Dark Energy

Summary: We discuss the future of Dark Matter and Dark Energy searches, focusing on the potential contributions of gamma-ray observations and the synergies between various types of astronomical objects. We discuss the construction of telescopes with better spectral resolutions, such as ~50 eV, that would be able to pin down the 511 eV line and search the substructure of emission lines to identify DM candidates. We also discuss the importance of building a compelling case for gamma-ray research in identifying DM candidates, referencing Fermi's role, and the potential for future observatories about reaching the thermal relic line. We also highlight the importance of integrating the gamma-ray searches within the already-existing and future optical and radio observatories infrastructure to gain a better understanding of DM. We discuss

issues like the limitations of the current Galactic Center Excess measurements due to diffuse emission models and the non-optimal angular resolution of Fermi. We transition to DE research, emphasizing that we need to consult with theorists to pin down the questions that a space-based gamma-ray mission can accomplish (standard sirens from BNS mergers were mentioned, as well as PBH evaporation).

The second breakout session focused on identifying the kinds of gamma-ray data necessary to address the big questions in physics, including transient and extended source analyses. Improvements in PSF, energy resolutions – and the consideration between “wide” or “deep” (or both) were discussed. The feasibility of GeV polarization to help identify ALPs or distinguish between different candidates. Observing other galaxies to help us understand the 511 eV line and the GCE.

Formation and Merging of Supermassive Black Holes

Link to the notes: Formation and Merging of Supermassive Black Holes

Summary: To be added promptly.

Origins of Heavy Elements in our Galaxy

Link to the notes: Origins of Heavy Elements in our Galaxy

Summary: The discussion focused on the role and origins of the heavy elements in our galaxy, talking about stellar evolution, r-process and s-process nucleosynthesis, and cosmic ray spallation. We talked about whether the origins of r-process elements–either from supernovae or neutron star mergers–would still be a topic of discussion in 2030/the 40s, with a consensus leaning towards a continued exploration due to the complex nature of nuclear physics and the anticipated completion of nuclear line datasets. We emphasized the importance of gamma-ray spectroscopy to map the nuclear lines in the Galaxy, which could provide definitive answers on the sites of the heavy element formation, particularly the Thallium 208 line at 2.6 MeV. We touch upon COSI’s anticipated role and the technologies based on Compton scattering below 10 MeV as crucial in detecting certain nuclear lines. We acknowledge the challenges in isolating specific nuclear lines due to technology and competing against the diffuse background in MeV/GeV and the benefits of increased angular resolution. Different physical scenarios were discussed; such as the fission chain reactions that may trigger a supernova explosion and post-merger oscillations and their role in heavy-element production. We also talked about the maximum mass of neutron stars and the implications it may have on the heavy element outflow. The potential to extend observations to other galaxies to better understand the heavy elements would also be a point of interest, complemented by the BNS mergers to track heavy element formation across the Universe. We need a better angular resolution.

Sources of Cosmic Ray Accelerations

Link to the notes: Sources of Cosmic Ray Accelerations

Summary: We focused on understanding how protons are accelerated, and how they transport, and interact with the surroundings. We discuss the importance of combining gamma-ray observations with neutrinos to distinguish between hadronic and leptonic sources of cosmic rays and the exploration of the largely unexplored MeV gap. We highlight the need for improved energy and imaging resolution, polarization, and high-precision timing capabilities. Also, we emphasize the importance of dedicated software development for multi-mission analyses. We talk about the importance of tracing molecular gas and cosmic electrons within our Galaxy to directly probe gas structures and spiral arms with high angular resolution. Polarization was discussed to probe acceleration mechanisms, and magnetic field structure, particularly in the context of the AGN corona emission and TeV halos around pulsars. We consider the importance of long-term monitoring with a day-scale cadence to understand fluid dynamics and evolution in time domain parts of cosmic ray sources, as well as enough statistics to track orbital and super-orbital spectral properties in X-ray binaries. We require high angular and spatial resolution to distinguish between different radiation mechanisms (e.g., pion decay and bremsstrahlung), as well as large effective areas and continuous monitoring. Expected the unexpected 🙂 — similarly to the transition from CGRO to Fermi (Fermi bubbles), we may have an opportunity to discover things we have not yet seen.

Existence of Life in Our Galaxy

Link to the notes: Existence of Life in our Galaxy

Summary: The discussion about life in our Galaxy touched upon many aspects, including the search for techno signatures, biological signatures, habitability, and planetary defense. We discussed the potential of detecting gamma rays from nuclear weapon activity used by other civilizations, requiring a narrow-field telescope would be needed in detecting such signatures beyond our Solar System. Also, we discussed the use of anti-matter/matter reactors and spaceships using advanced technologies such as PBHs as forms of techno signatures. We discuss other wavelengths (X-rays) to search for similar signatures (free electron lasers). We noted that the gamma-ray activity of the host star makes a planet less habitable. It would also allow us to study our own Sun and characterize it to search for similar host stars in our Galaxy. We also talked about the effect of gamma-ray bursts and other gamma-ray sources on life (papers already written) and thought about how many exoplanets may be found nearby. We briefly mentioned the planetary defense but had no time to go into further detail.

Questions not Included Above

Link to the notes: Questions not Included Above

Summary: The discussion focused on topics not covered in other breakout groups, particularly focusing on MMA, diffuse emission, and the plasma physics of relativistic jets. There was interest in the potential crossover between gamma-ray spectroscopy and laboratory plasma spectra, tracing secondary reactions, and passive detection methods such as Compton scattering in foil. We also emphasize the urgency for new instruments as current missions like Swift and Fermi are nearing their end. We talk about the need to bridge the MeV gap; as well as an instrument to help us understand the prompt emission from gamma-ray bursts, which have strong implications for particle accelerations and VHE emission and pion production.