Looking beyond Fermi. Thoughts for FIG SAG

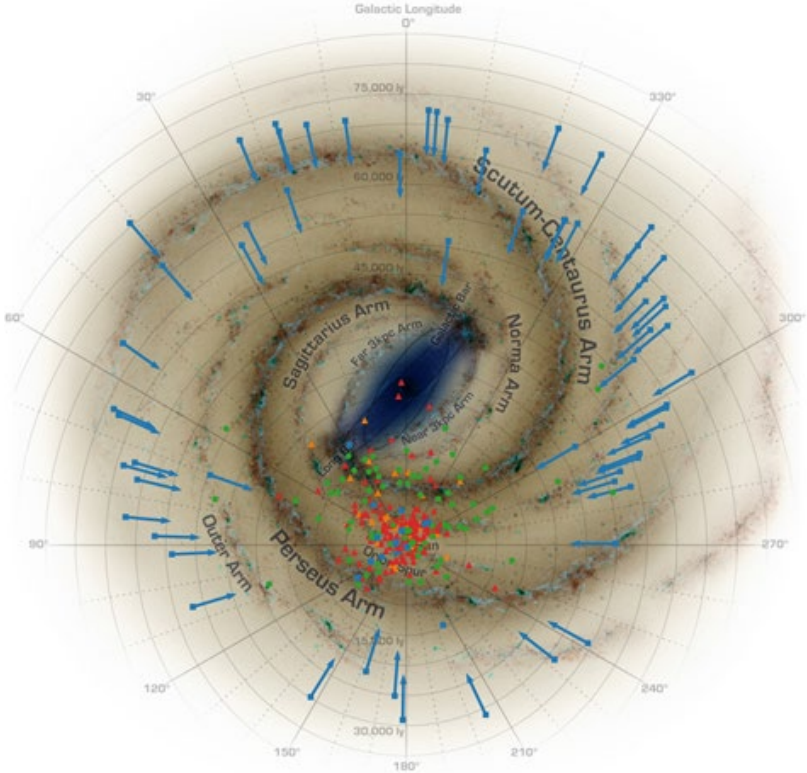
Liz Hays

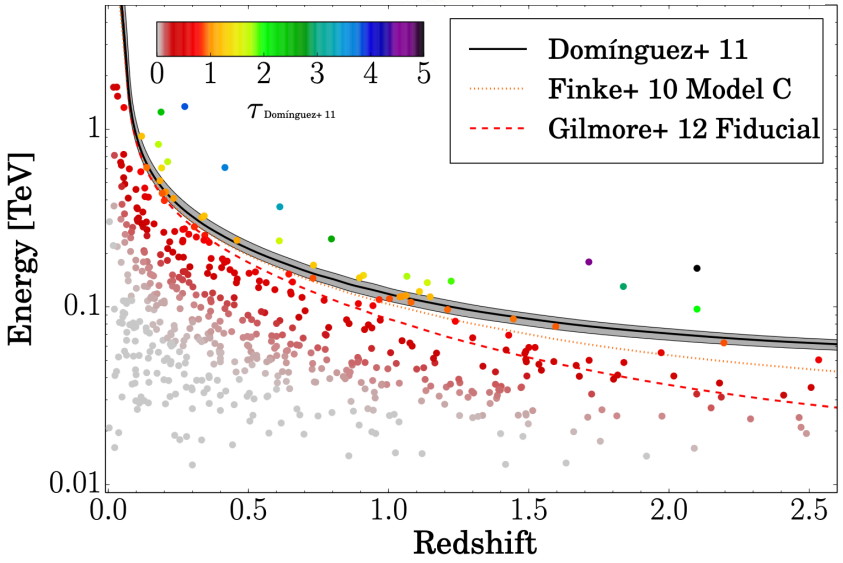
FIG SAG splinter meeting

September 2024, U. Maryland, College Park

Beyond Fermi: Sensitivity limitations

- In the Galaxy
  - Pulsars (294+) most within a few kpc
  - Novae (19) most within 4 kpc, 4 in Galactic bulge ~8 kpc
  - Source and diffuse studies limited by statistics above ~10 GeV
- Local Galaxies
  - LMC, SMC and M31 (extension resolved).
- Radio galaxies
  - Lobes of Cen A (3-5 Mpc), Fornax A (19 Mpc)
- Blazars
  - ~9 detected with redshifts from z = 3 - 4
- GRBs
  - On-axis out to z = 8 - 10



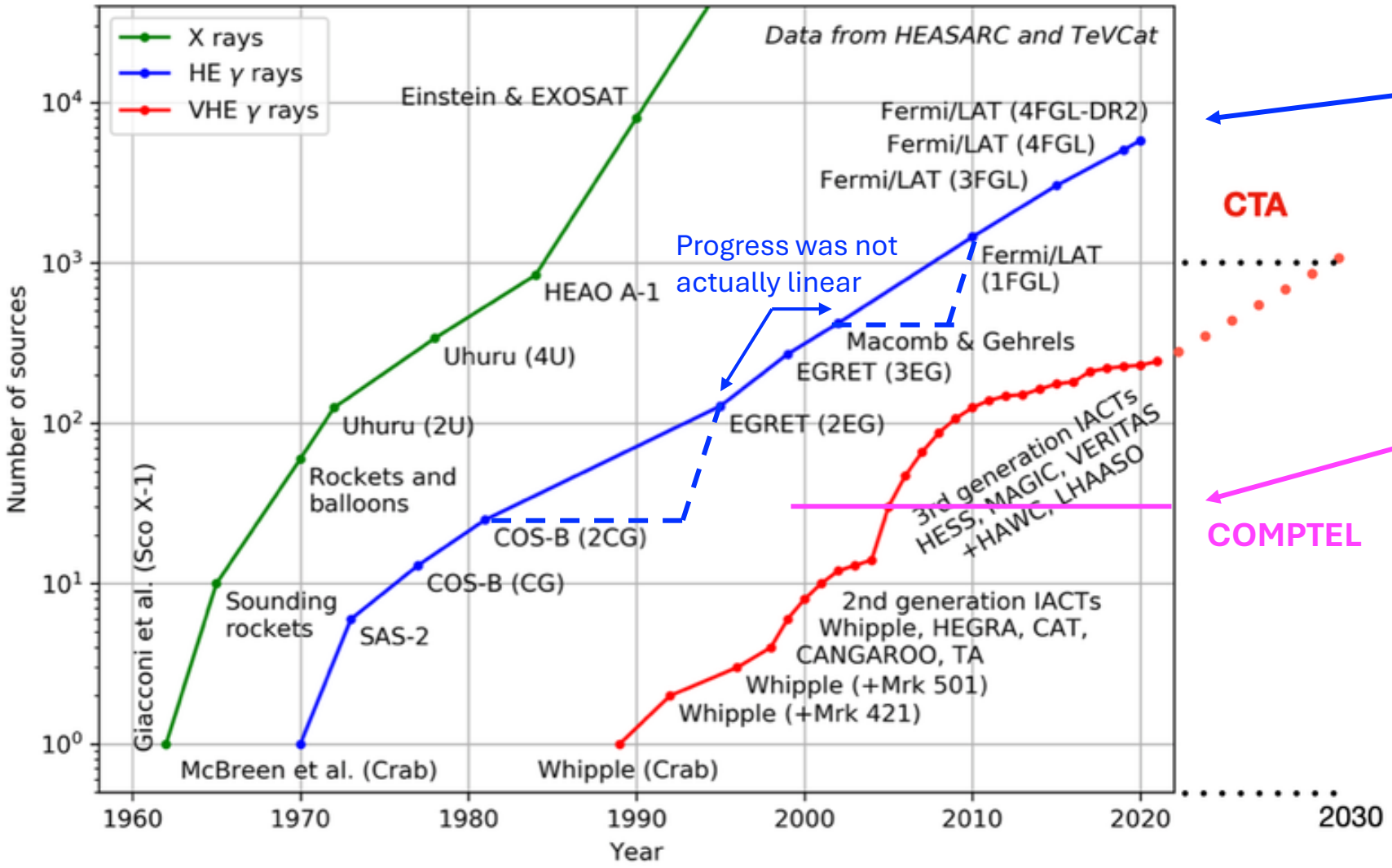


Beyond Fermi: Confusion Limitations

- Confusion
  - Galactic center
    - Evidence for a population of unresolved sources
    - Limits sensitivity to sources
    - Limits tests of dark matter
  - Parts of the Galaxy below ~few GeV
    - Diffuse impacts on sensitivity for source structure and spectral components
  - Complex Galactic sources and regions
    - Sources with overlapping or near-overlapping emission components at LAT angular resolution
    - Many SNR and PWN spectral and morphology studies done above a few GeV and limited to best resolution photons

From 2016 1FIG catalog of the inner Galaxy

Gamma-ray Source Growth



GeV persistent sources >7000

1000s of keV - MeV transients not shown.

32 persistent sources from COMPTEL in 1990s. (31 GRBs not shown) Still in Gen 1. Fermi can't help with this.

Figure from https://github.com/sfegan/kifune-plot

A gamma ray is a gamma ray is a gamma ray

0.1 MeV ≠ 1 MeV ≠ 10 MeV ≠ 100 MeV ≠ 1 GeV ≠ 10 GeV ≠ 100 GeV

Dominant sources and science changes dramatically across >6 orders of magnitude in energy and over time scales from usec to years.

Big challenge for this report and big opportunity for astrophysics.

Selected things to do in space beyond Fermi

- MeV imaging: Conduct a sensitive survey from ~100 keV – 100 MeV
  - Bring MeV source census to second generation – missing science!
  - pulsars – different population from GeV-peaked; probe synchrotron emission component
  - blazars – lower-energy peaked population, higher redshift and heavier black holes. Neutrino connections?
  - gamma-ray bursts – next stage in understanding origins and mechanisms. Maximize overlap with future GW observations to more distant horizon
- MeV spectrometry to map cosmic-ray acceleration sites in the Galaxy
  - Follow-up for expected COSI measurements of e-e+ annihilation (sources?) and nuclear lines. Beyond enhanced ^{26}Al maps of star-forming regions, may have first imaging of ^{60}Fe from core-collapse SN.
- Explore jets down to lower energy (blazars, TDEs, microquasars); possibly apply polarization measurements to distinguish hadronic emission and magnetic organization

Warning: exemplary and not complete!

Selected things to do in space beyond Fermi

- Increase GeV sensitivity depth from ~100MeV - 100GeV
  - Expand horizon for GeV-peaked pulsars and deepen data for phase and spectral studies, and searches for glitches and variability, next-generation gamma-ray PTA – learn about neutrons stars, NS magnetospheres, stellar evolution, SMBH mergers
  - Expand horizon for novae, supernova remnants and pulsar system emission – define role of shocks in broad classes of stellar explosions and energetic outflows
  - Expand emerging gamma-ray classes, e.g. star-forming regions, CSO, microquasars
  - Are there must-have science needs for overlap from 10-100 GeV as ground-based techniques increase sensitivity below 100 GeV?
- Energy-tuned imaging?
  - Some technical approaches (Laue lens, Fresnel lens, glancing incidence) aim to achieve high angular resolution within a narrow energy range.
  - Maximize angular resolution for point sources with a tuned coded-aperture mask for Compton scattering (~200 keV - <10 MeV)

Warning: exemplary and not complete!

Summary

- Fermi limitations point to new opportunities
  - What requirements are most important? How do we get there?
- Many obvious things to do in sections of the gamma-ray band that have been limited
  - 1 MeV ≠ 1 GeV ≠ 1 TeV – these are very different bands!
- Lots to do! New capabilities = new science
  - Let’s describe compelling science drivers and enable discovery