Fermi LAT Observations of Diffuse Gamma-Ray Emission in the Galactic Center

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• LAT and LAT observations of the Galactic Center region
• Origin of diffuse gamma-ray emission
• Modeling the diffuse gamma-ray emission
  – What’s wrong with doing it in the GC
• Approaches to updating gas and cosmic-ray distributions – refining the model
• Current status and next steps
• Exposure, angular resolution, stability of response
• Never as much as you’d want, but a huge advance
Origin of Diffuse Gamma-Ray Emission

- Production mechanisms are well understood
  - $\pi^0$ decay – secondaries from CR proton-nucleon collisions
  - Bremsstrahlung – scattering of CR electrons by protons/nuclei
  - Inverse Compton scattering of low-energy photons by CR electrons
  - The nuclei that matter are in interstellar gas – not stars
  - The photons are starlight, re-radiated starlight, and CMB

- Why model the diffuse emission? 1) because we have to; 2) to learn about the interstellar medium and cosmic rays
Radiative transfer is simple – the Milky Way is transparent to LAT gamma rays; corollary: GC diffuse emission comes from 25+ kpc path length to and through the Galactic center.

This region of the sky is perhaps the most difficult to model accurately, even if we understood the distribution of CR sources and cosmic-ray propagation (not that we don’t, GALPROP fans!)

- Of course, GIGO applies – gas distributions, ISRF, cosmic-ray sources & propagation.
Challenges: conditions and kinematics

- **H I in absorption against Sgr A**
- CO distribution in velocity and longitude

Leiden-Argentine-Bonn H I (Kalberla et al.)

- **We interpolate ‘rings’ across the GC (|l| < 12°) and use a Launhardt-like NB component in the innermost ring**
• H.E.S.S. survey of the Galactic plane revealed a TeV diffuse component (after source subtraction), photon spectral index ~2.3, considerably harder than 2.7 for Galactic CRs.
Refining the diffuse emission model is done in comparison with LAT data, which means it must be iterative with low-latitude point source detection and fitting.

We have 2 approaches within the LAT collaboration for large-scale modeling of diffuse emission: GALPROP-based and a kind of hybrid, fitting linear combinations of templates for gas and IC-related emission:

- **Spatially, the methods are similar**
- **Spectrally, the hybrid approach (with more d.o.f.) allows closer matching to the LAT data**

The hybrid approach is the basis for gll_iem_v02.fit*, the first public release.

* [http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html](http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html)
The all-sky Galactic diffuse emission model released by the LAT team (red curve) somewhat under-predicts the sky intensity in the GC region. Similar deviations are present in a GALPROP model calculation (blue) for the same region; Models are clearly in the right ballpark, although clearly deviations are greater than the systematic uncertainty. N.B.: No point sources are included.
• The diffuse gamma-ray intensity in the GC region is intense not dominated by the GC region
• Systematic uncertainties in the GC contribution remain large

Spatial Residuals

$>300 \text{ MeV, } \mid \theta \mid < 1.5 \text{ deg}$

*Preliminary*

$\text{gll\_iem\_v02.fit + iso.}$

$\text{GALPROP (54\_87exph7S) + iso.}$
The diffuse gamma-ray intensity in the GC region is intense & not dominated by the GC region. Systematic uncertainties in the GC contribution remain large, interstellar radiation and gas.
• Focus on the GC region for structure at low longitudes

• Alternative tracers for molecular gas: higher critical density or optically thin(ner) than CO

• Launhardt et al. (2002) & Ferriere, Gillard, & Jean (2007) studied gas in the inner Milky Way, but with parametrized distributions
• Understanding the diffuse emission toward the Galactic Center quantitatively (spatially and spectrally) relates to understanding the state of the gas, the interstellar radiation field, cosmic-ray sources, and propagation
• Standard all-sky models are only ~ok in the GC region
• Refinement goal: understanding of point sources + diffuse emission together