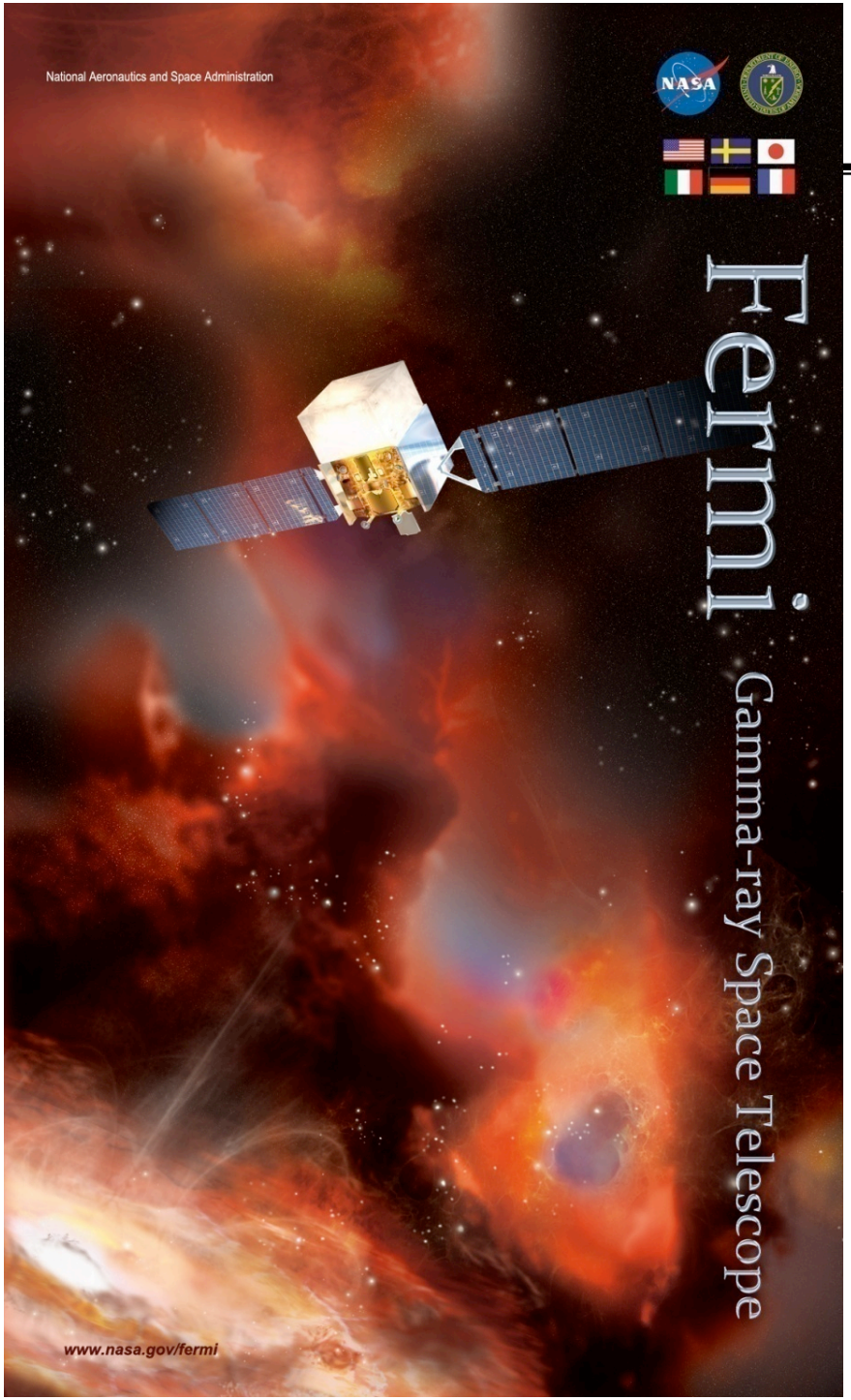


Fermi
Gamma-ray
Space Telescope

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

Seth Digel (KIPAC/SLAC) on behalf of the Fermi Large Area Telescope Collaboration

Outline

- 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

About the LAT & LAT Observations of the GC

- **Exposure, angular resolution, stability of response**
- **Never as much as you'd want, but a huge advance**

COS-B >300 MeV

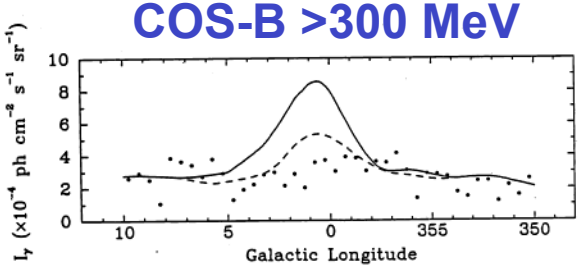
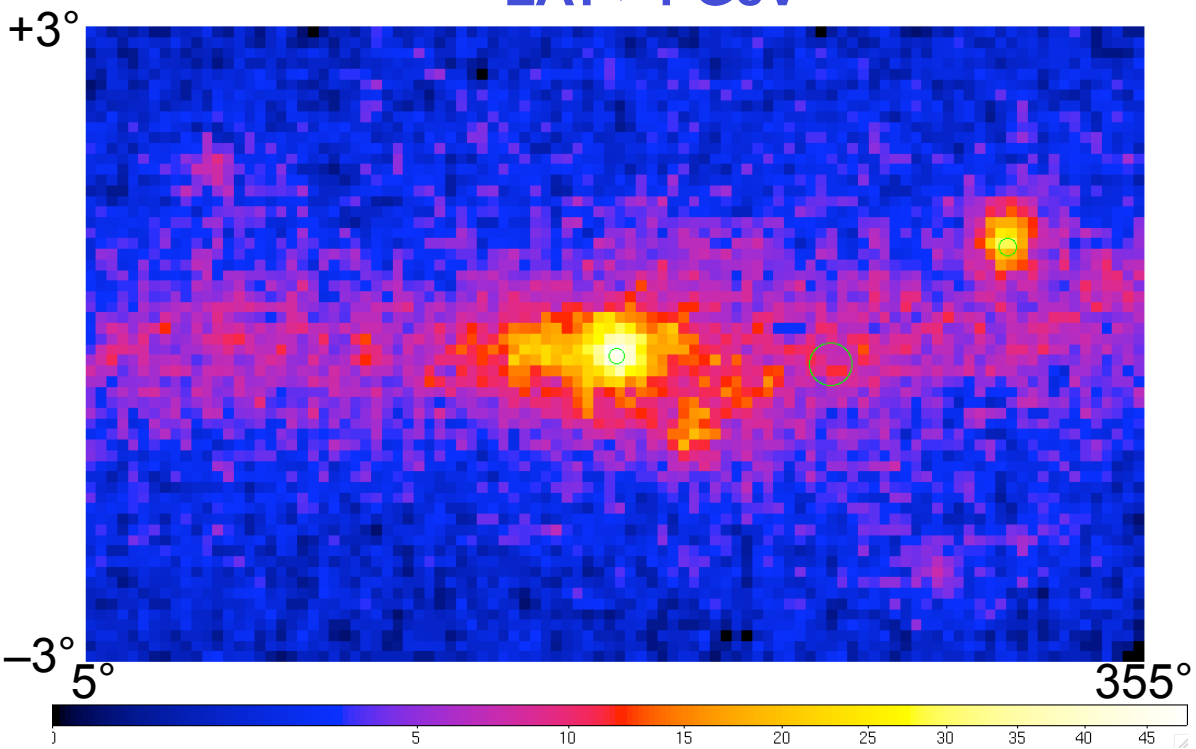


Figure 2. Profiles of observed and predicted γ-ray intensity in the Galactic center region, averaged over $|b| < 1°$. Points: observed COS-B γ-ray intensity (300–5000 MeV). Solid curve: predicted γ-ray intensity using the standard mass calibration ratio, N_{H_2}/W_{CO}, derived from Galactic disk observations. Dashed curve: predicted γ-ray intensity using the standard mass calibration ratio, but with the eight wide-line clouds indicated in Figure 1 removed from the analysis

Stacy, Dame, & Thaddeus (1987)

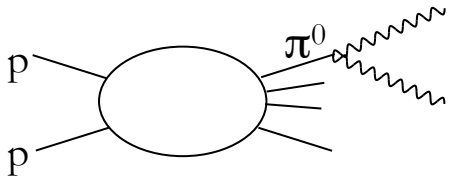
LAT >1 GeV

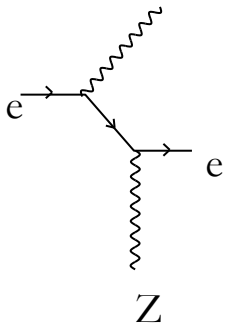


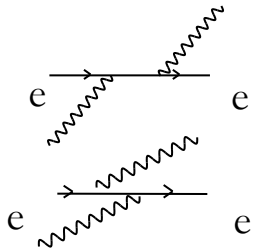
12-month data set, Diffuse class, **Front** only
smoothed with σ = 0.1°
BSL source location circles overlaid

Origin of Diffuse Gamma-Ray Emission

- **Production mechanisms are well understood**
  - **π^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**



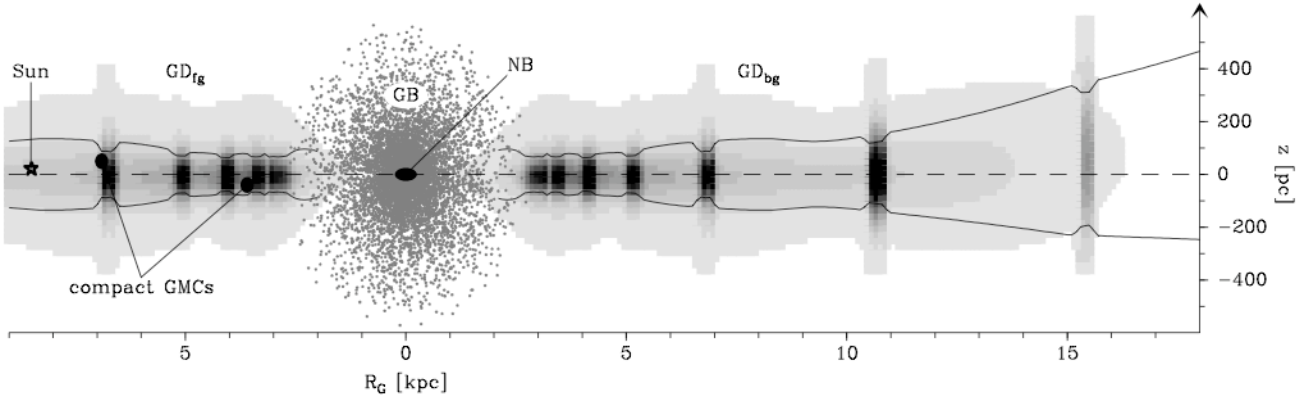




- **Why model the diffuse emission? 1) because we have to; 2) to learn about the interstellar medium and cosmic rays**

Modelling the Interstellar Diffuse Emission

- **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**



Schematic but it has the general features right

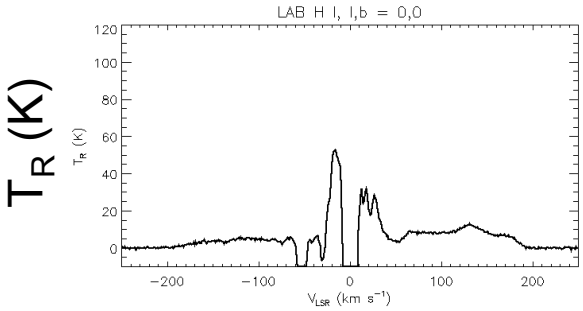
Launhardt et al. (2002)

- **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**

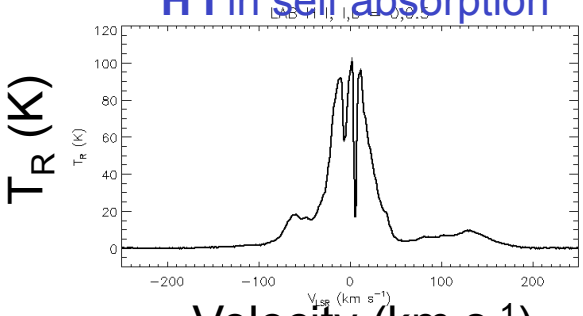
Diffuse Modeling: Interstellar gas

- **Challenges: conditions and kinematics**

H I in absorption against Sgr A*



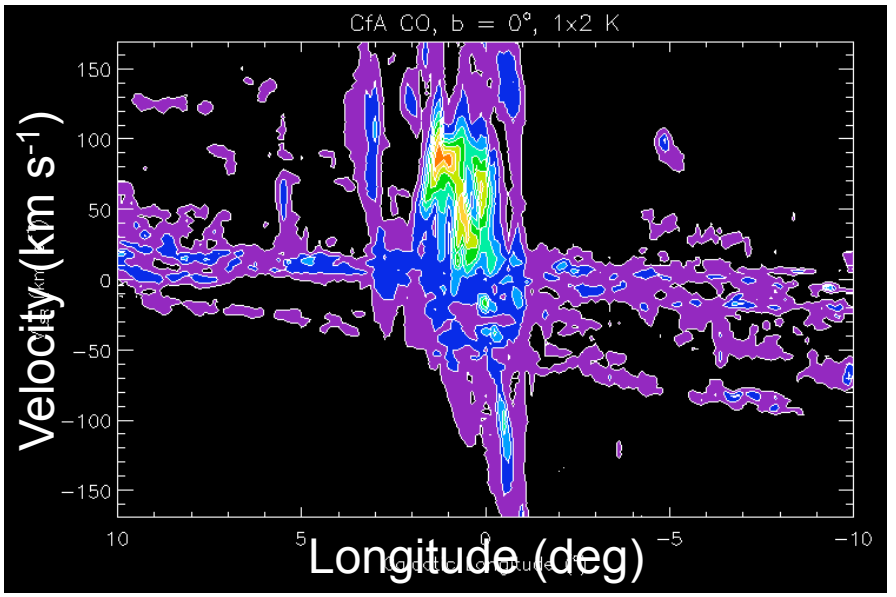
H I in self absorption



Velocity (km s^{-1})

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

CO distribution in velocity and longitude

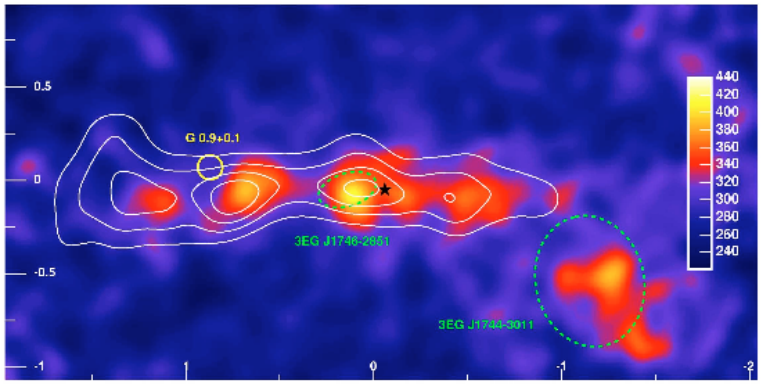


CfA CO (Dame et al.)

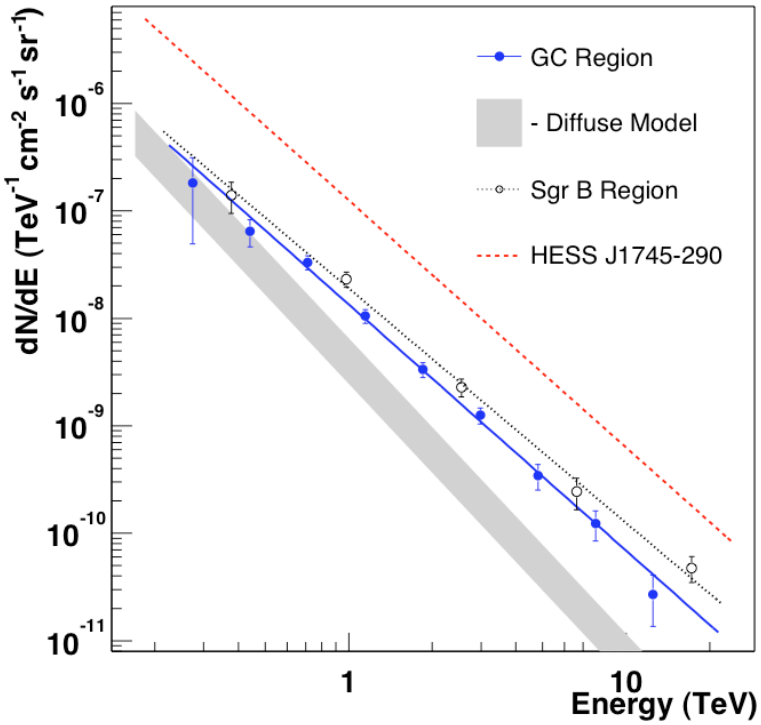
- **We interpolate 'rings' across the GC (|*l*| < 12°) and use a Launhardt-like NB component in the innermost ring**

Spectral Aspects of the Diffuse Model

- **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**



Aharonian et al. (2006)



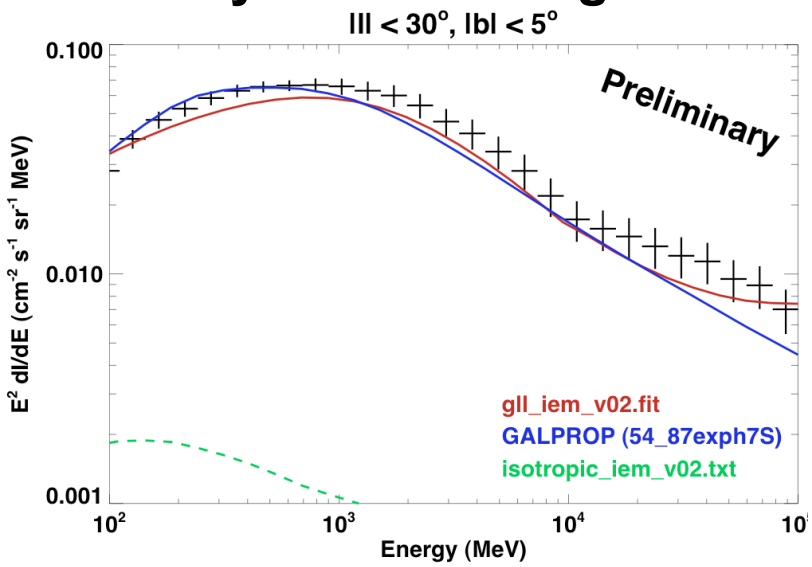
Refining Models for the Diffuse Emission

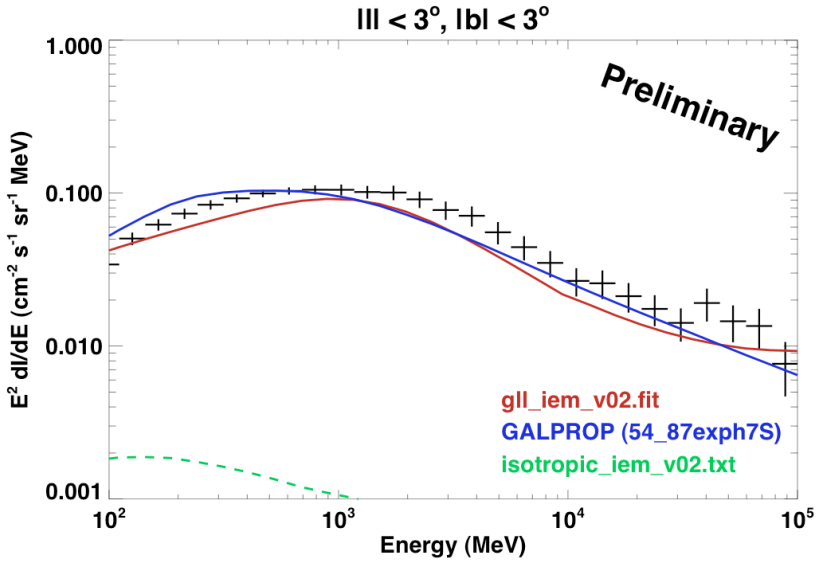
- **Refining the diffuse emission model is done in comparison with LAT data, which means it must be iterative with low-latitude point source detection and fitting**
- **We have 2 approaches within the LAT collaboration for large-scale modeling of diffuse emission: GALPROP-based and a kind of hybrid, 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

Spectral Residuals

- **The all-sky Galactic diffuse emission model released by the LAT team (red curve) somewhat under-predicts the sky intensity in the GC region**

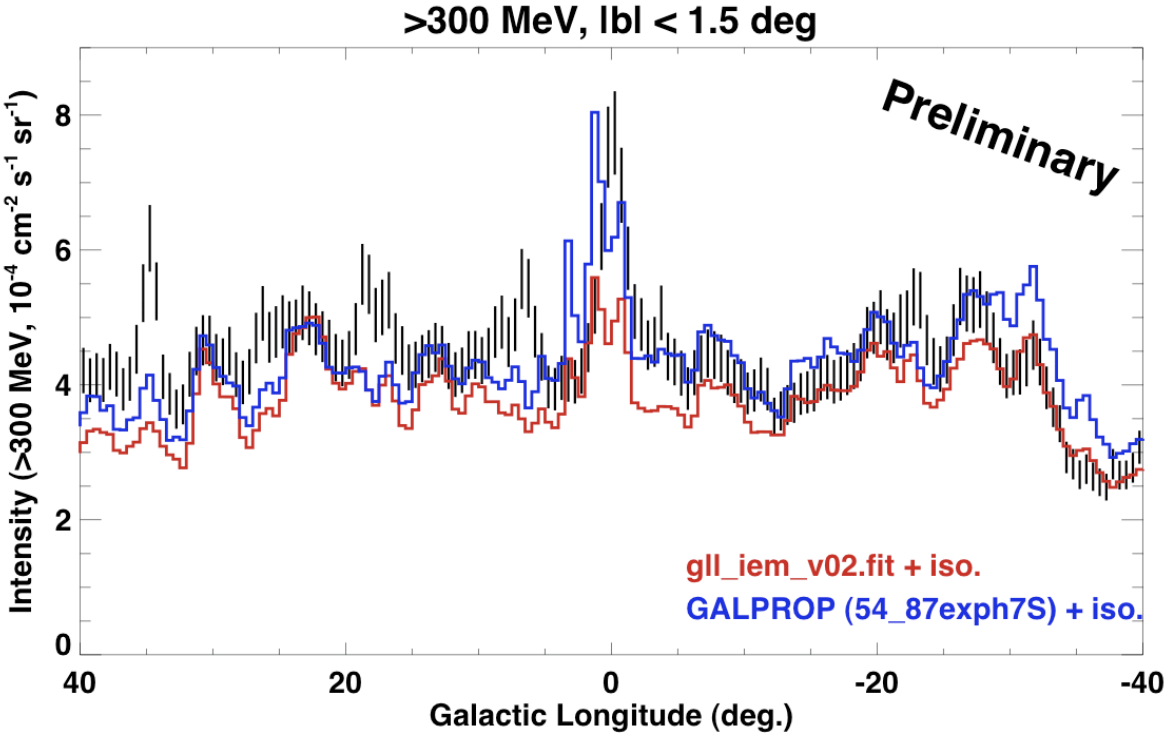




- **Similar deviations are present in a GALPROP model calculation (blue) for the same region;**
- **Models are clearly in the right ballpark, although clearly deviations are greater than the systematic uncertainty**
- **N.B.: No point sources are included**

Spatial Residuals

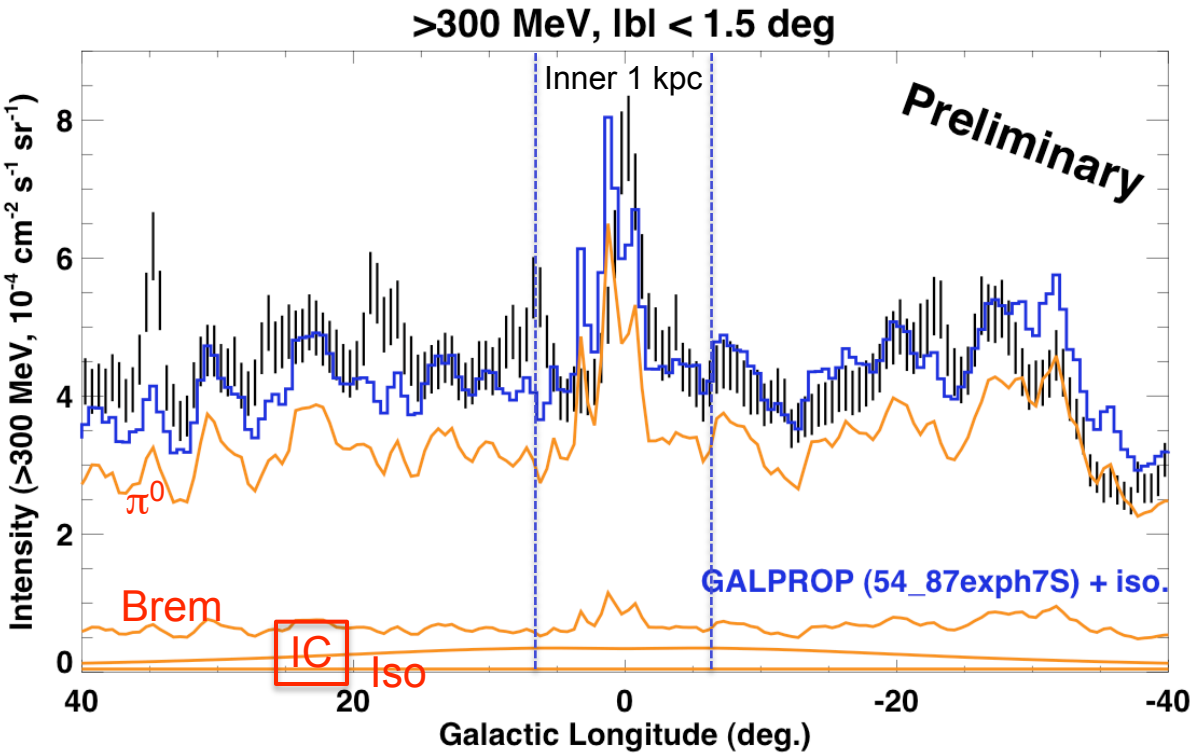
- **The diffuse gamma-ray intensity in the GC region is intense not dominated by the GC region**
- **Systematic uncertainties in the GC contribution remain large**



Spatial Residuals

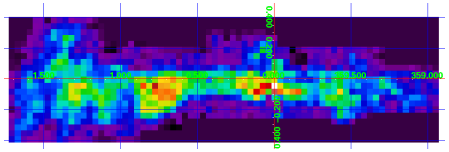
- **The diffuse gamma-ray intensity in the GC region is intense & not dominated by the GC region**
- **Systematic uncertainties in the GC contribution remain large, interstellar radiation and gas**

Components of this GALPROP model

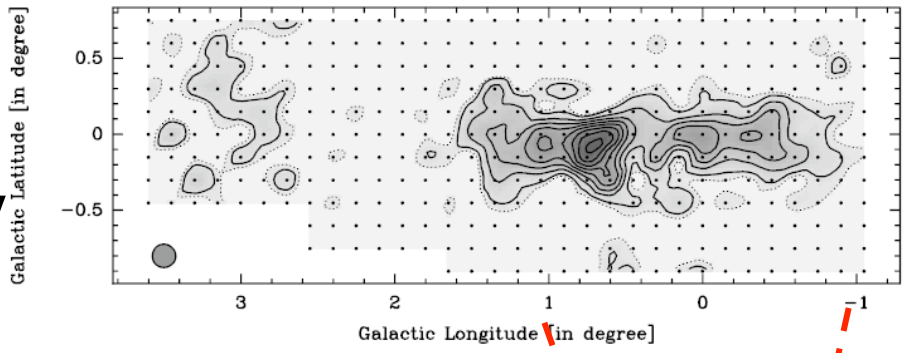


Spatial Modeling: Gas

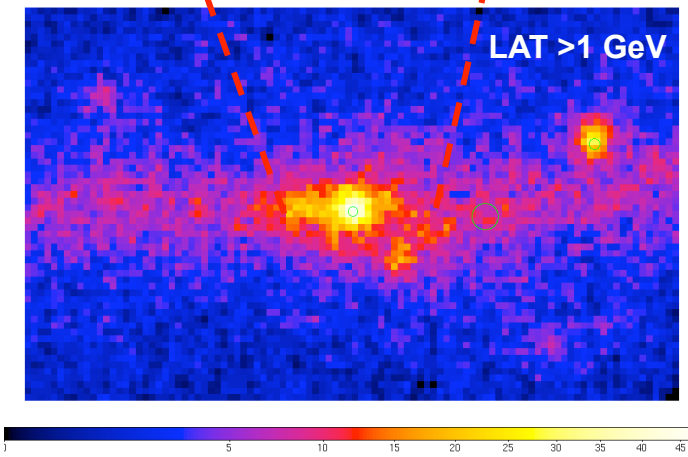
- **Focus on the GC region for structure at low longitudes**
- **Alternative tracers for molecular gas: higher critical density or optically thin(ner) than CO**
- **Launhardt et al. (2002) & Ferriere, Gillard, & Jean (2007) studied gas in the inner Milky Way, but with parametrized distributions**



CS (1-0) Tsuboi et al. (1999) NRO 45-m



$C^{18}O$ (1-0) Dahmen et al. (1997) Southern 1.2-m



Summary

- 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