Fermi Gamma-ray Space Telescope

Observations of the Large Magellanic Cloud and the Galactic Centre with Fermi

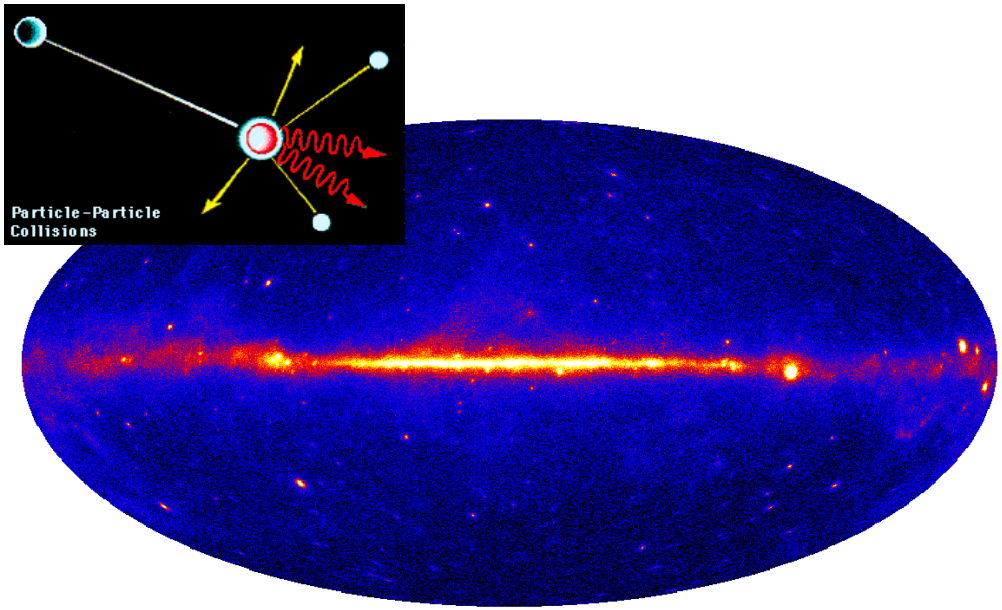
Jürgen Knödlseder

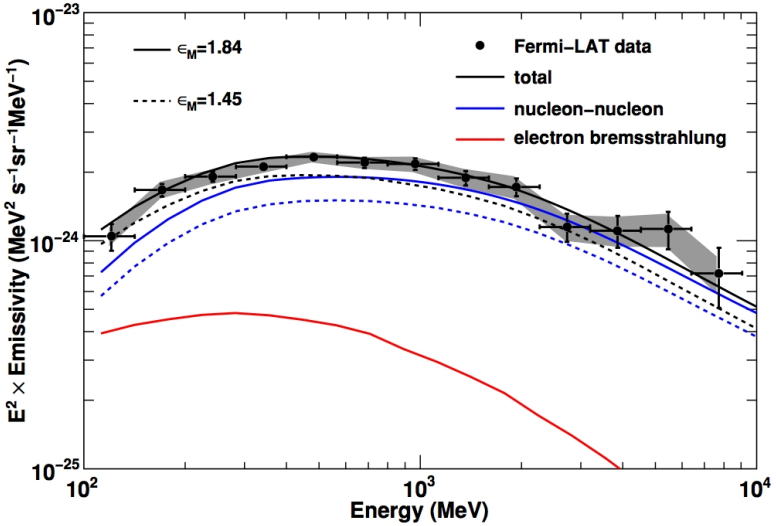
(Centre d'Etude Spatiale des Rayonnements)

On behalf of the Fermi/LAT collaboration

Emissions diffuses galactiques et extragalactiques
(2010/6/8-9)

Studying galaxies in gamma rays

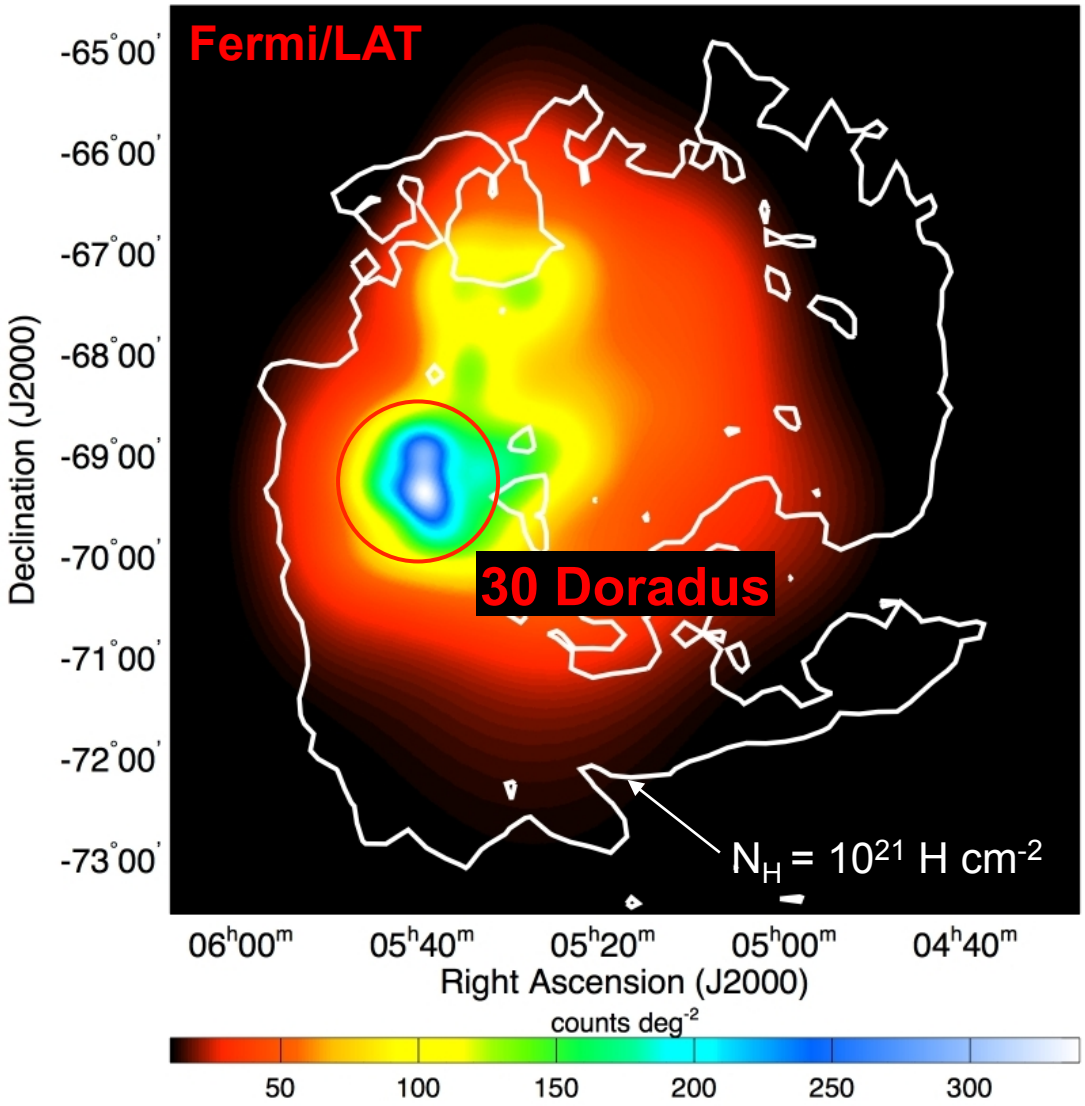


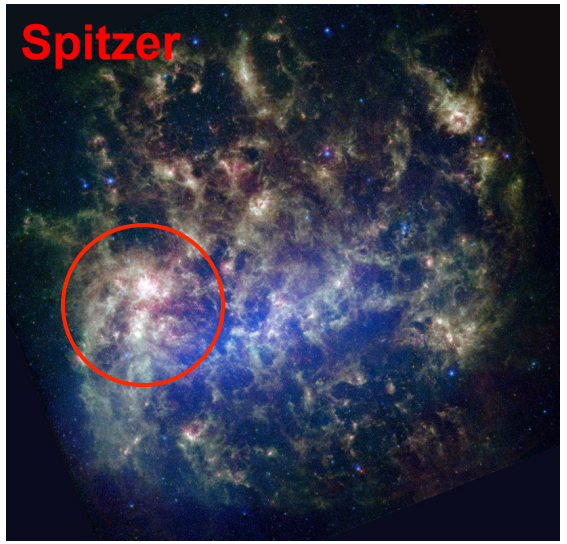


Abdo et al. (2009), ApJ, 703, 1249

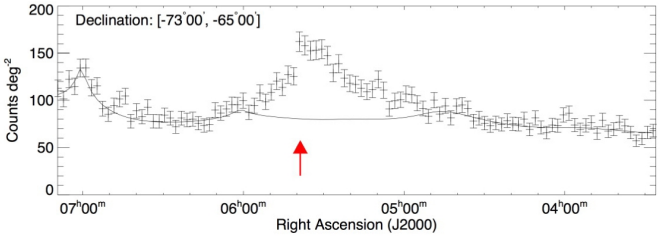
- **Galactic gamma rays trace cosmic-ray proton interactions (cosmic-ray acceleration sites & propagation)**
- **Observations of nearby galaxies provide an outside view**
- **LMC is prime target (D ≈ 50 kpc, i ≈ 20°-35°, diameter ≈ 8°)**
- **Initial detection by EGRET (no detailed spatial / spectral information)**

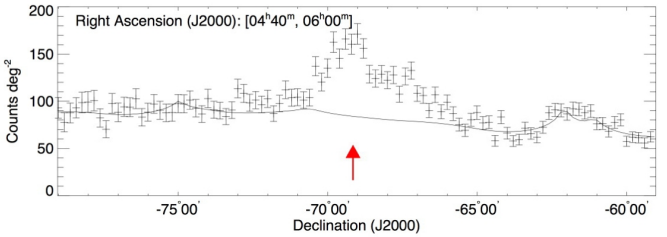
Resolving the LMC in gamma rays





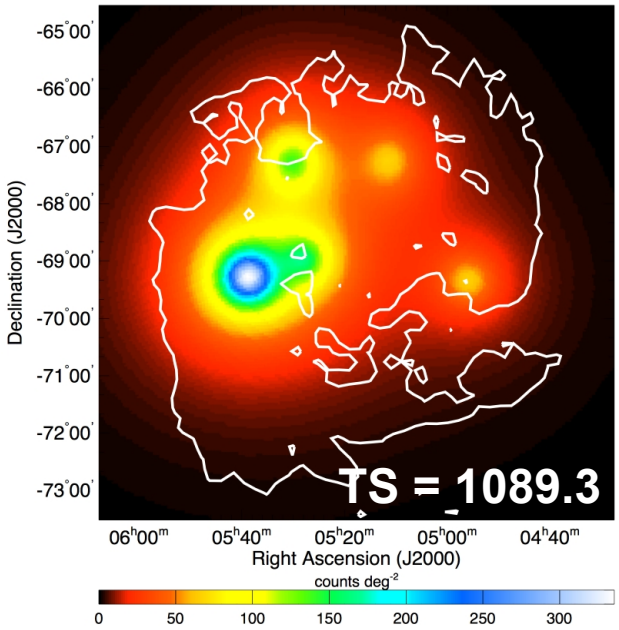
NASA/JPL-Caltech/M. Meixner (STScI)



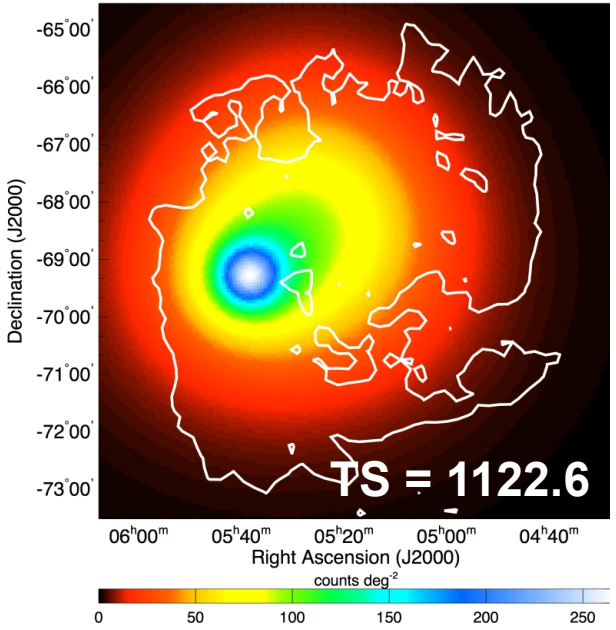


Modelling the spatial distribution - I

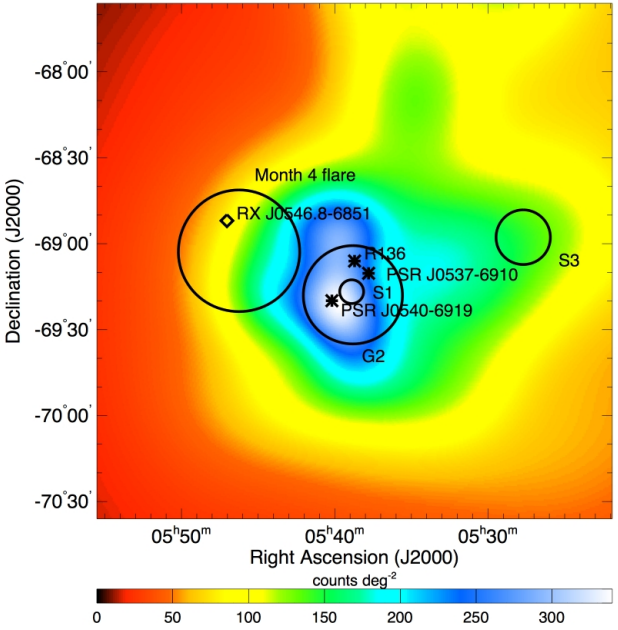
5 point sources



2 Gaussians

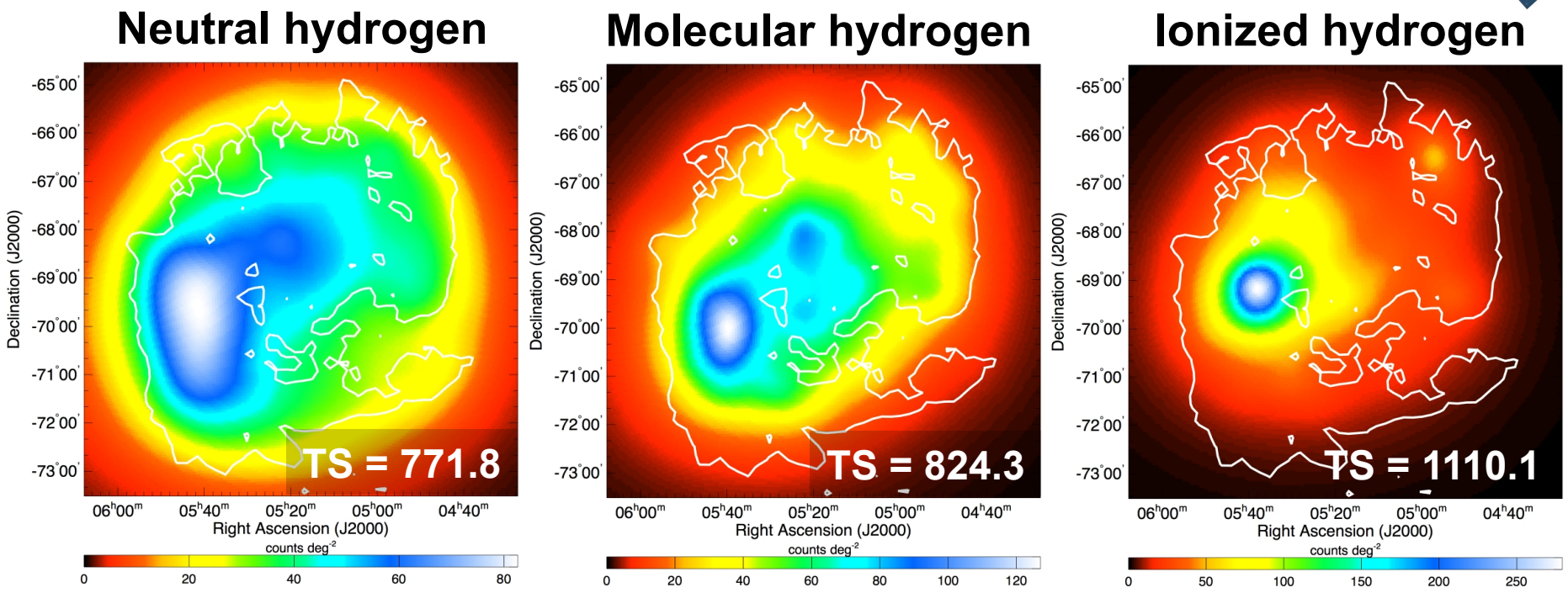


Zoom into 30 Doradus



- **2 Gaussians fit better than 5 point sources despite smaller number of parameters ⇒ emission is unresolved into point sources**
- **30 Doradus emission incompatible with point source emission from PSR J0537-6910, PSR J0540-6919 (no pulsations) and R136**

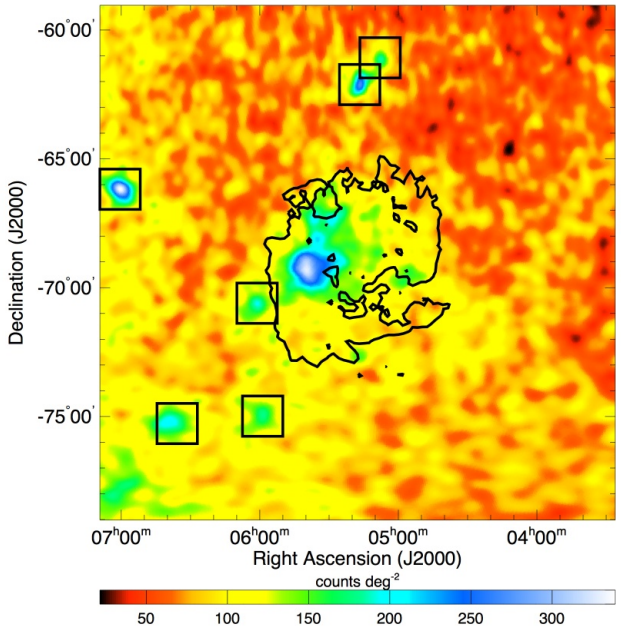
Modelling the spatial distribution - II



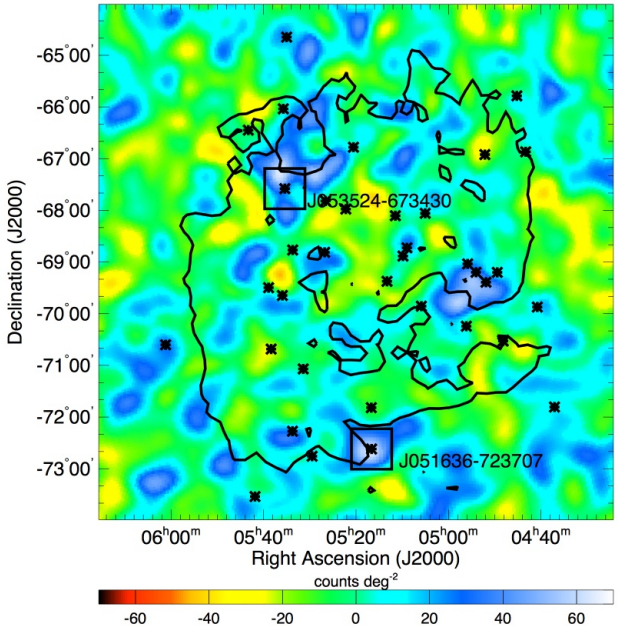
- **Neutral & molecular hydrogen templates poorly fit the data**
  ⇒ gamma-ray emission correlates little with gas
- **Ionized hydrogen template provides best fit**
  ⇒ gamma-ray emission correlates well with star forming regions
- **Exclusion of 30 Doradus from fit does not change these findings**

Background blazars

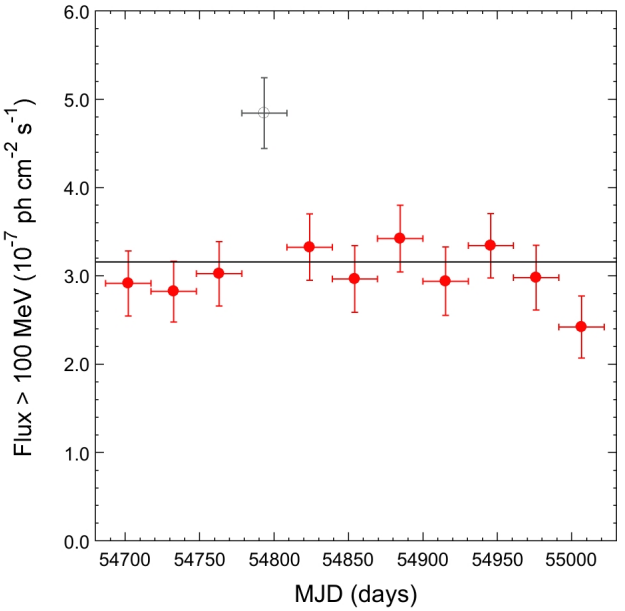
Total counts map



Residuals (2 Gaussians)



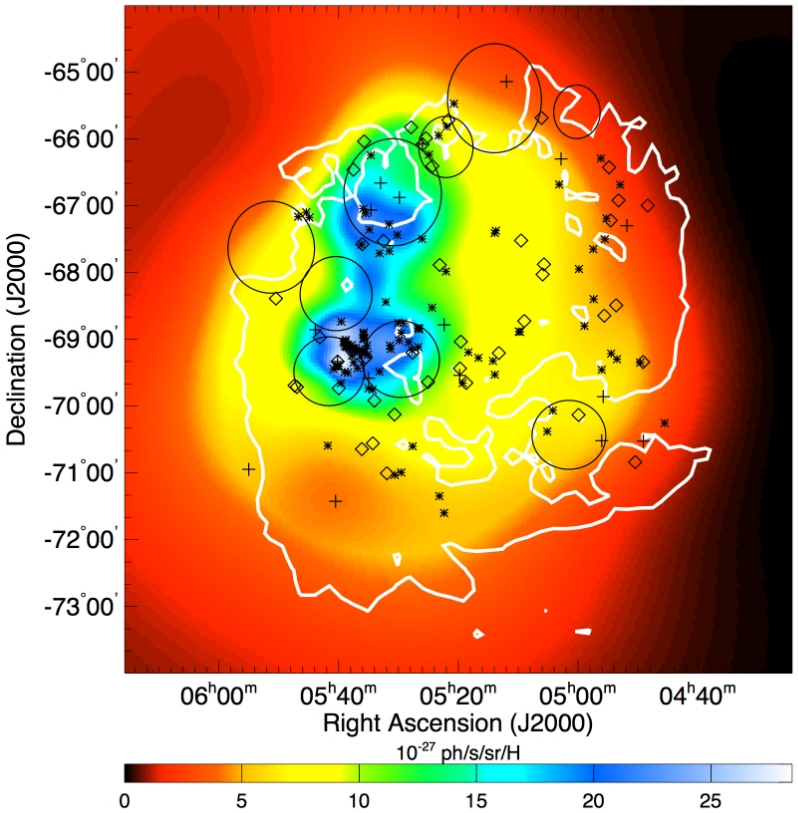
Monthly lightcurve



- About 10 background blazars expected in 20° x 20° field
- 6 CRATES sources associated with LAT sources outside LMC
- 1 CRATES source associated within LMC boundaries
- 1 flaring source near 30 Doradus during month 4 (RX J0546.8-6851?)

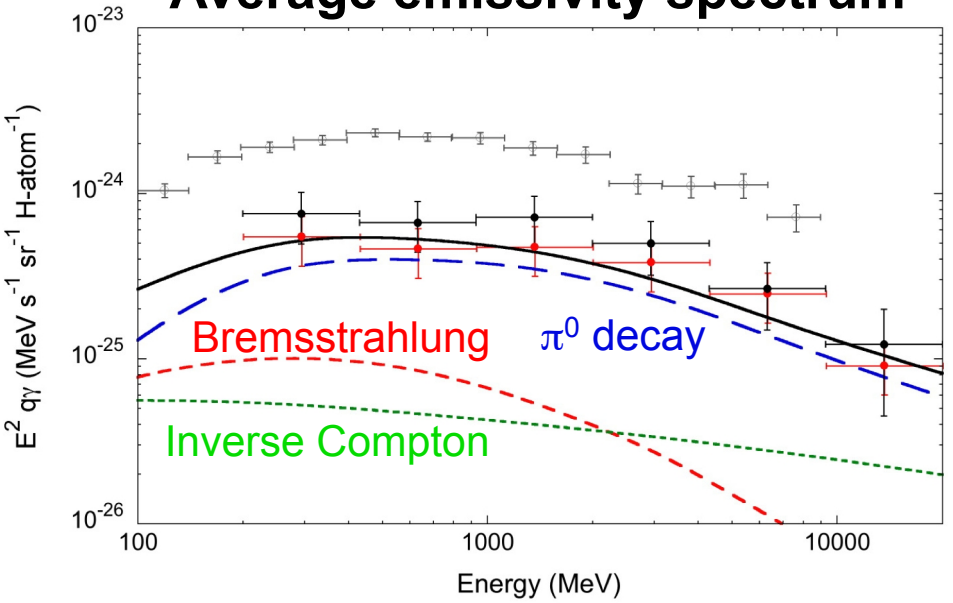
Cosmic-ray density

LMC emissivity map



- **Considerable cosmic-ray density variations**
- **Small GeV proton diffusion length**

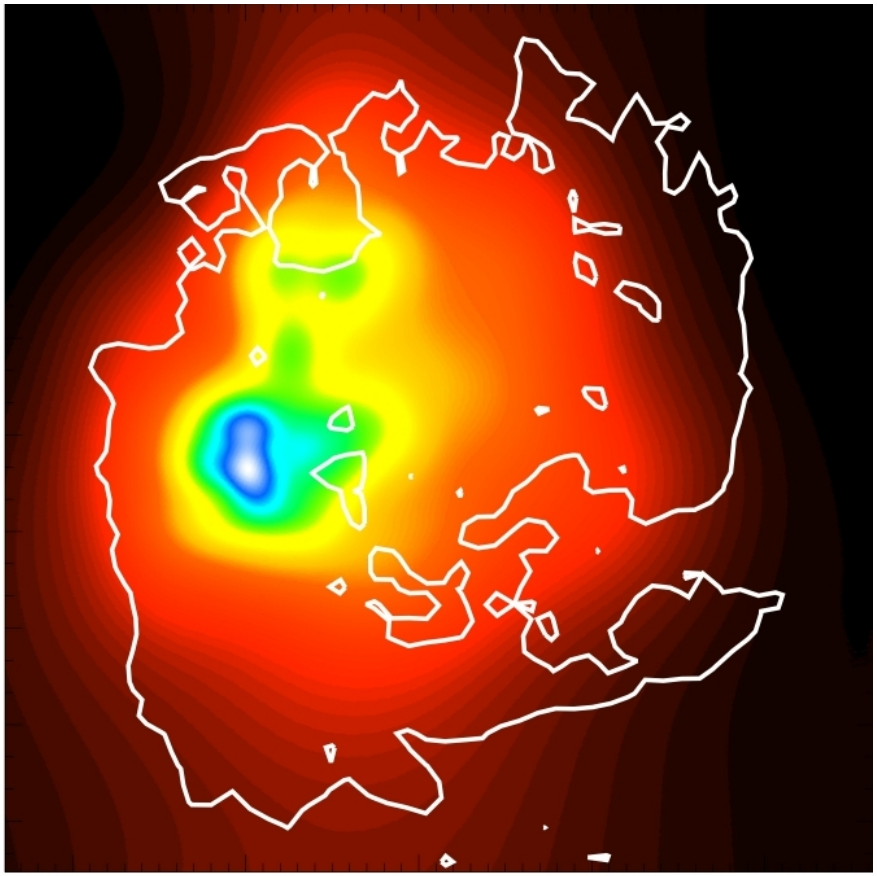
Average emissivity spectrum



- **Spectrum consistent with expectations from π^0 decay**
  (using local galactic p, e^-, e^+ spectral shapes)
- **Average cosmic-ray density about 0.2-0.3 times that in solar vicinity (consistent with difference between galactic and LMC SN rate)**

LMC Summary

- LMC for the first time resolved in gamma rays
- 30 Doradus star forming region is a bright source of gamma rays and very likely a powerful cosmic-ray accelerator
- No significant point source contribution (no pulsations from PSRs J0540-6919 and J0537-6910)
- Gamma-ray emission correlates well with massive star forming regions and little with the gas distribution
- Compactness of emission regions suggests little CR diffusion
- Average CR density ≈ 0.2–0.3 that in solar vicinity



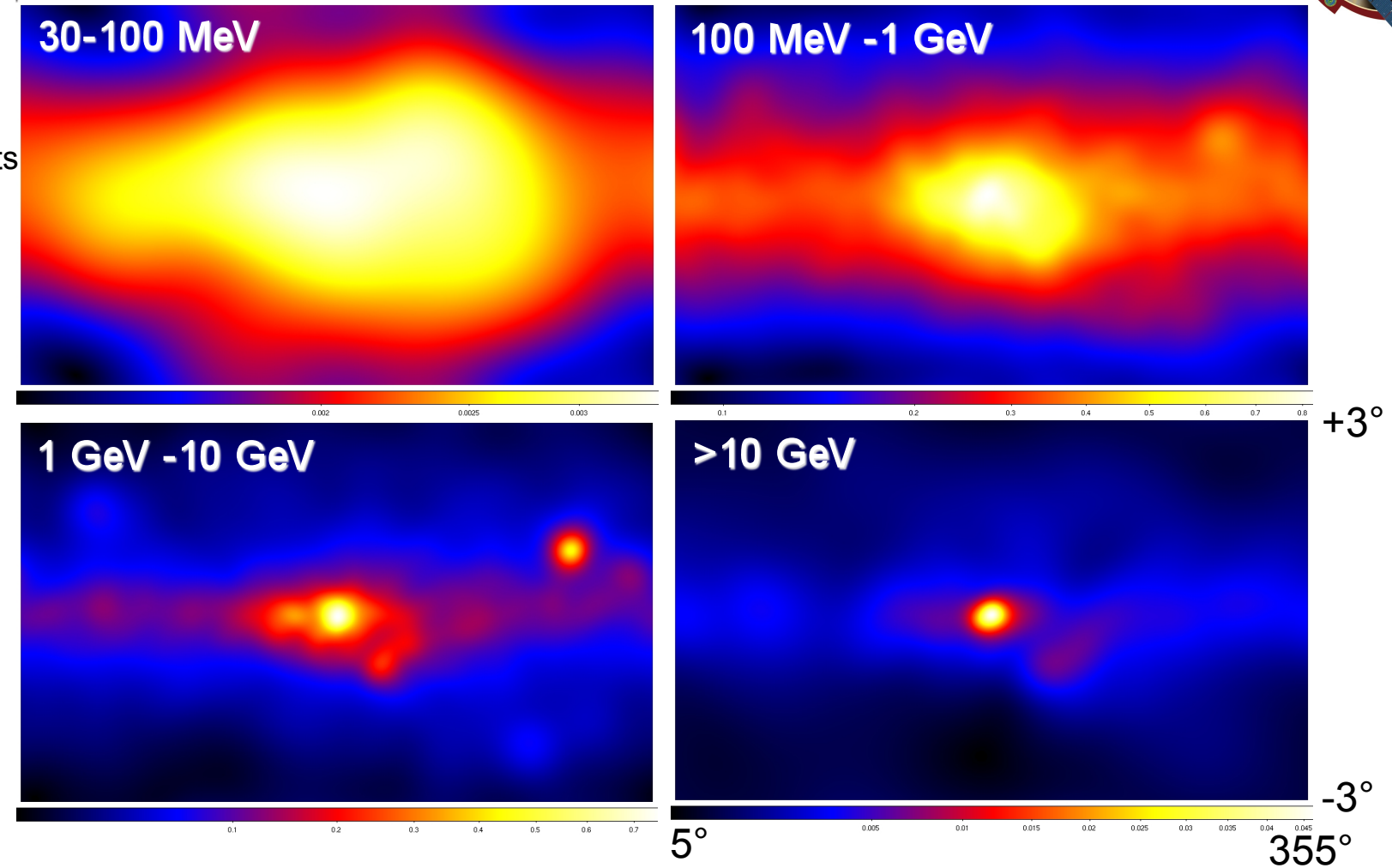
The Galactic Centre as seen by Fermi

21 months of data

front events only

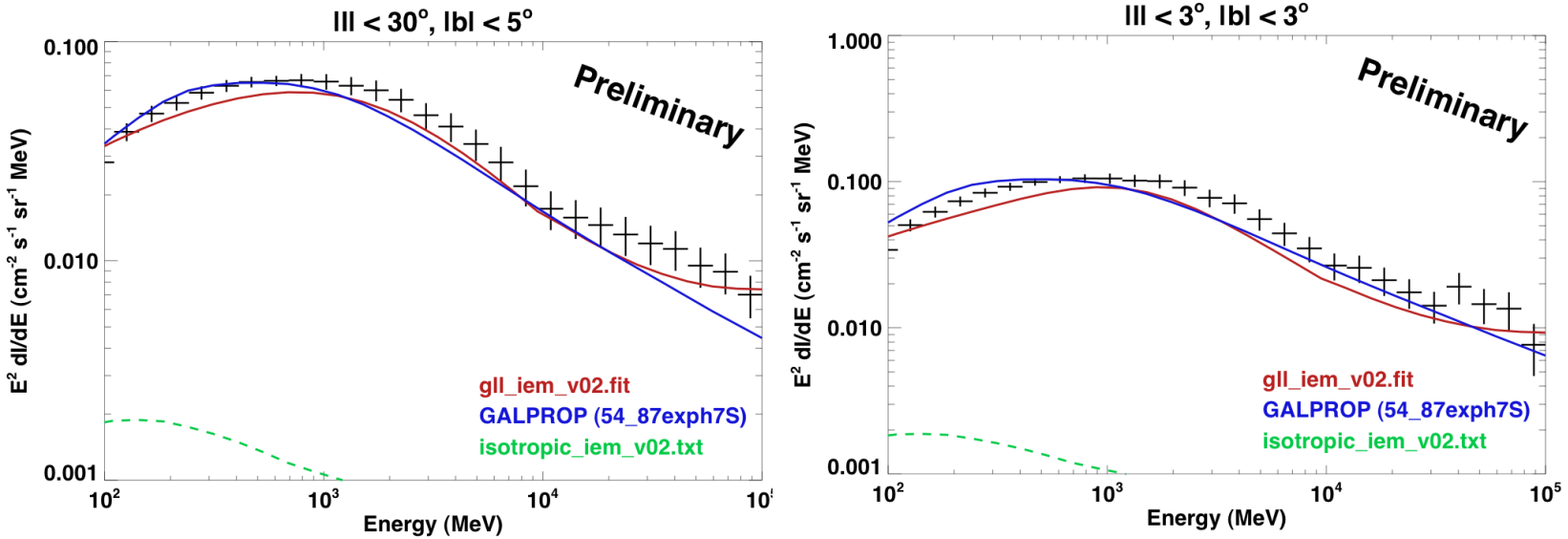
sqrt scaling

adaptively smoothed



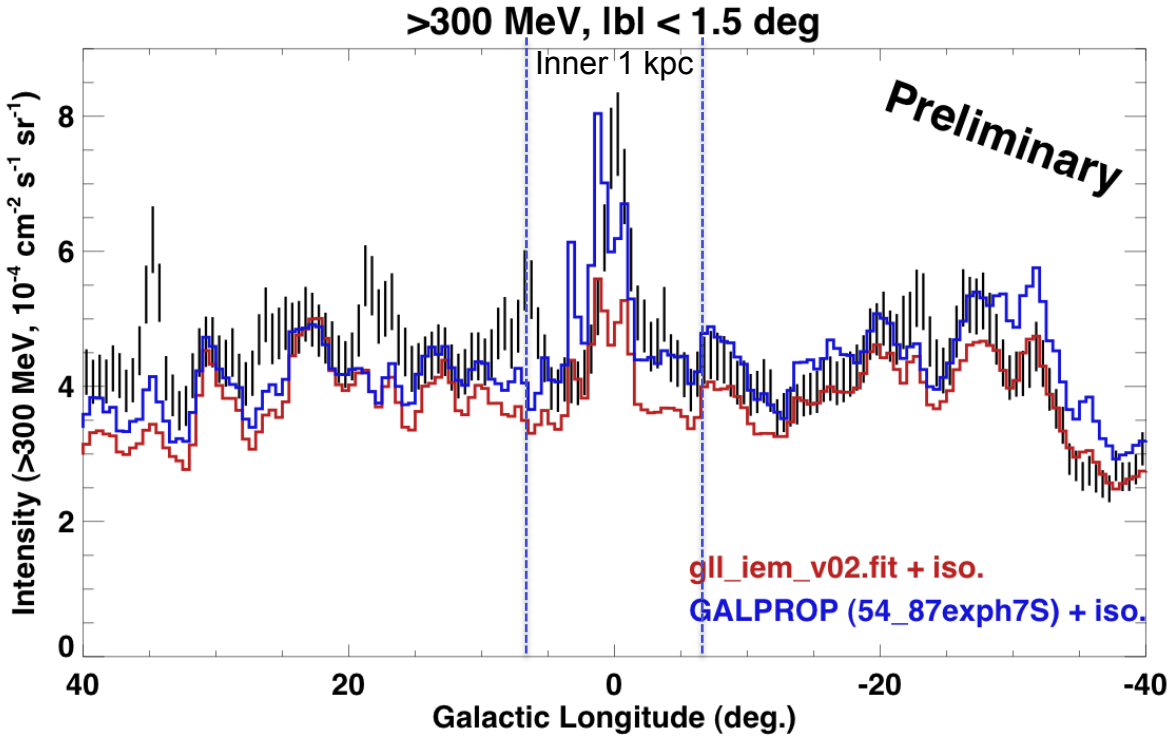
- **GC diffuse emission comes from 25 kpc path through the Galaxy**
- **Perhaps the most difficult region of the sky to model accurately**

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 (same is true for GALPROP model)**
- **Models are clearly in the right ballpark, although clearly deviations are greater than the systematic uncertainties**
- **N.B.: No point sources are included**

Spatial Residuals



- **The diffuse gamma-ray intensity in the inner Galaxy is intense and not dominated by the GC region**
- **Systematic uncertainties in the GC contribution remain large**
- **Needs alternative gas tracers and possibly inclusion of CR inhomogeneities**

GC Summary

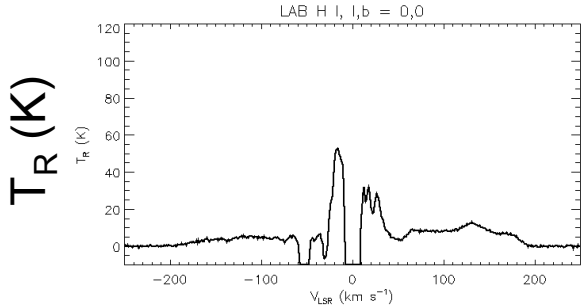
- **Understanding the diffuse emission toward the Galactic Center quantitatively (spatially and spectrally) relates to understanding the state of the gas, the interstellar radiation field, cosmic-ray sources, and propagation**
- **Standard all-sky models are only ~ok in the GC region**
- **Refinement goal: understanding of point sources + diffuse emission together**

Backup slides

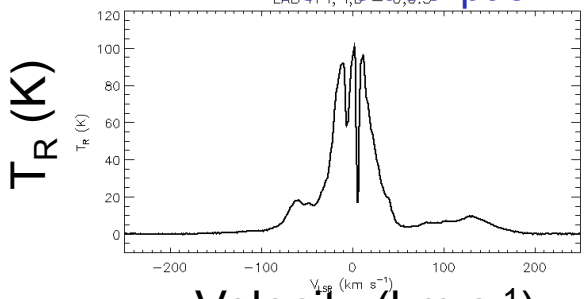
Diffuse Modeling: Interstellar gas

- **Challenges: conditions and kinematics**

H I in absorption against Sgr A*



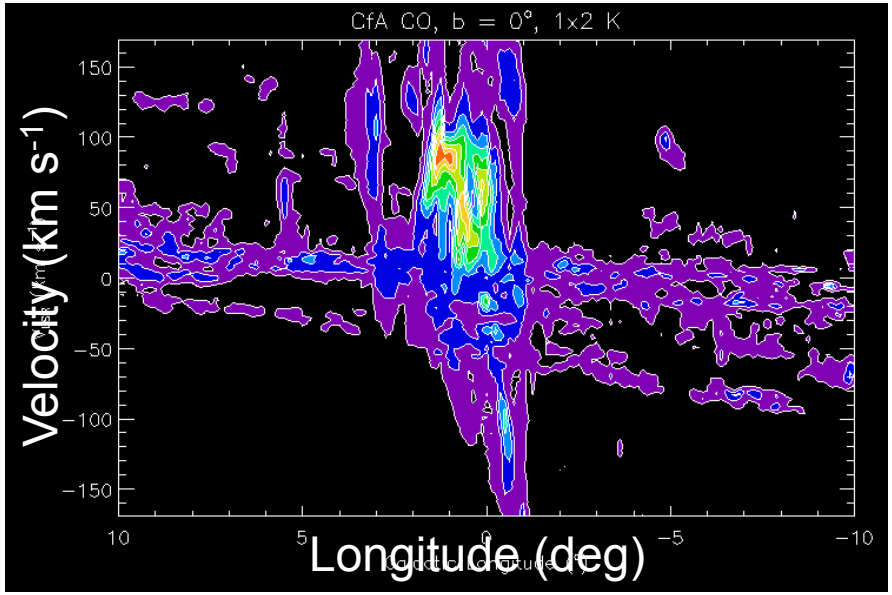
H I in self absorption



Velocity (km s^{-1})

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

CO distribution in velocity and longitude

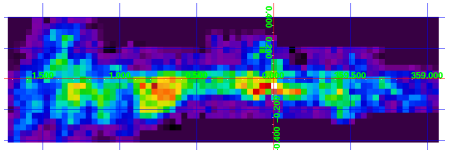


CfA CO (Dame et al.)

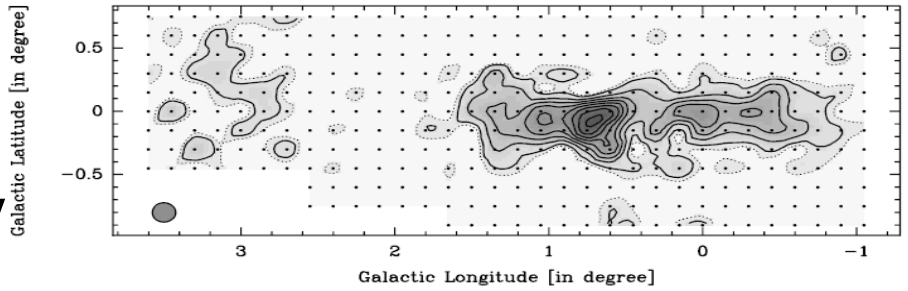
- **We interpolate 'rings' across the GC (|*l*| < 12°) and use a Launhardt-like NB component in the innermost ring**

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) and 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