



Fermi
Gamma-ray Space Telescope

Workshop
“La Physique d'AMS”
LAPP Annecy
March 10th 2010

Cosmic rays and *Fermi* LAT measurements of interstellar gamma-ray emission

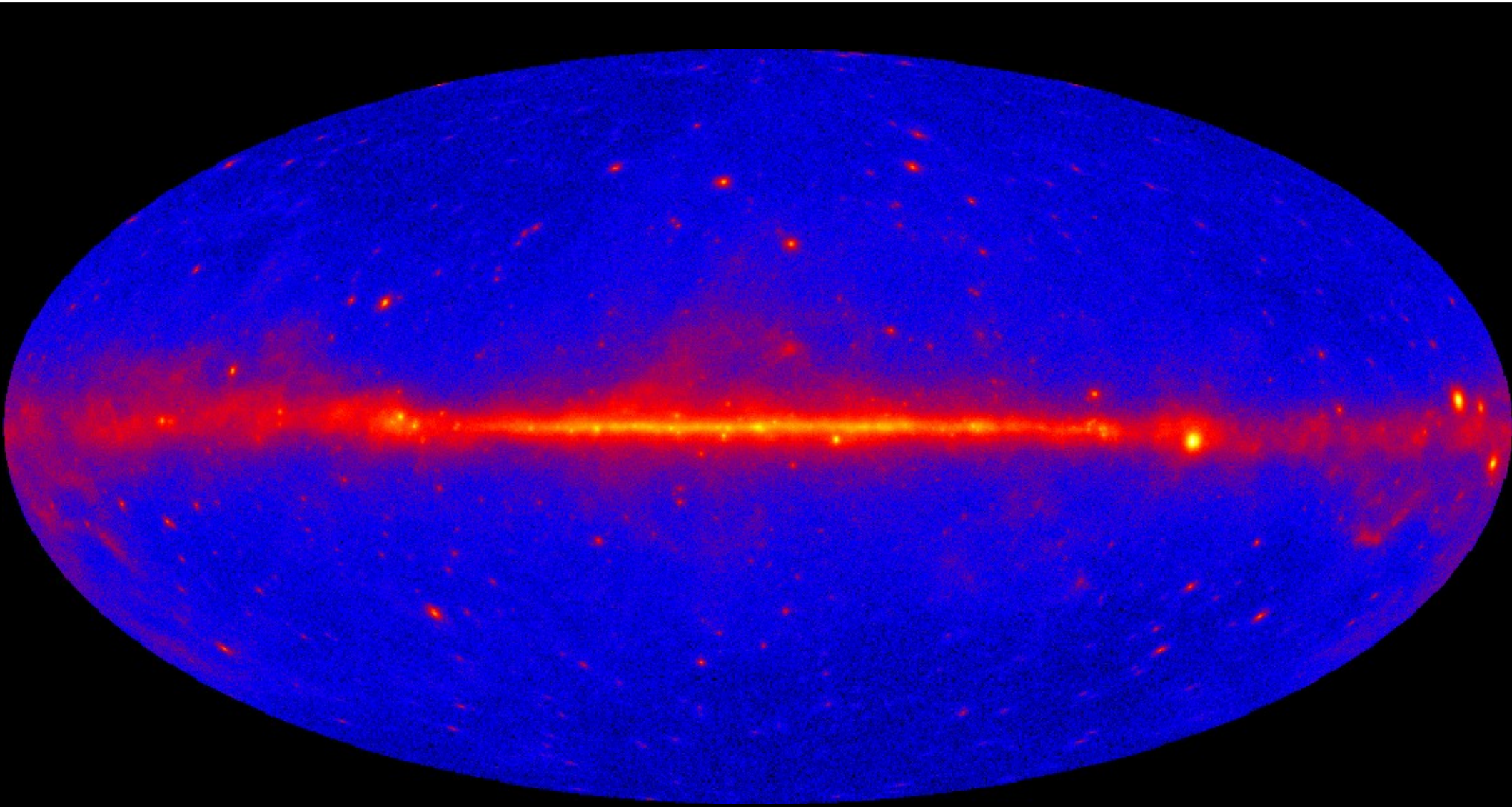
Luigi Tibaldo

luigi.tibaldo@pd.infn.it

Laboratoire AIM, Université Paris Diderot/SAp CEA Saclay
INFN – Sezione di Padova
Dip. di Fisica “G. Galilei”, Università di Padova

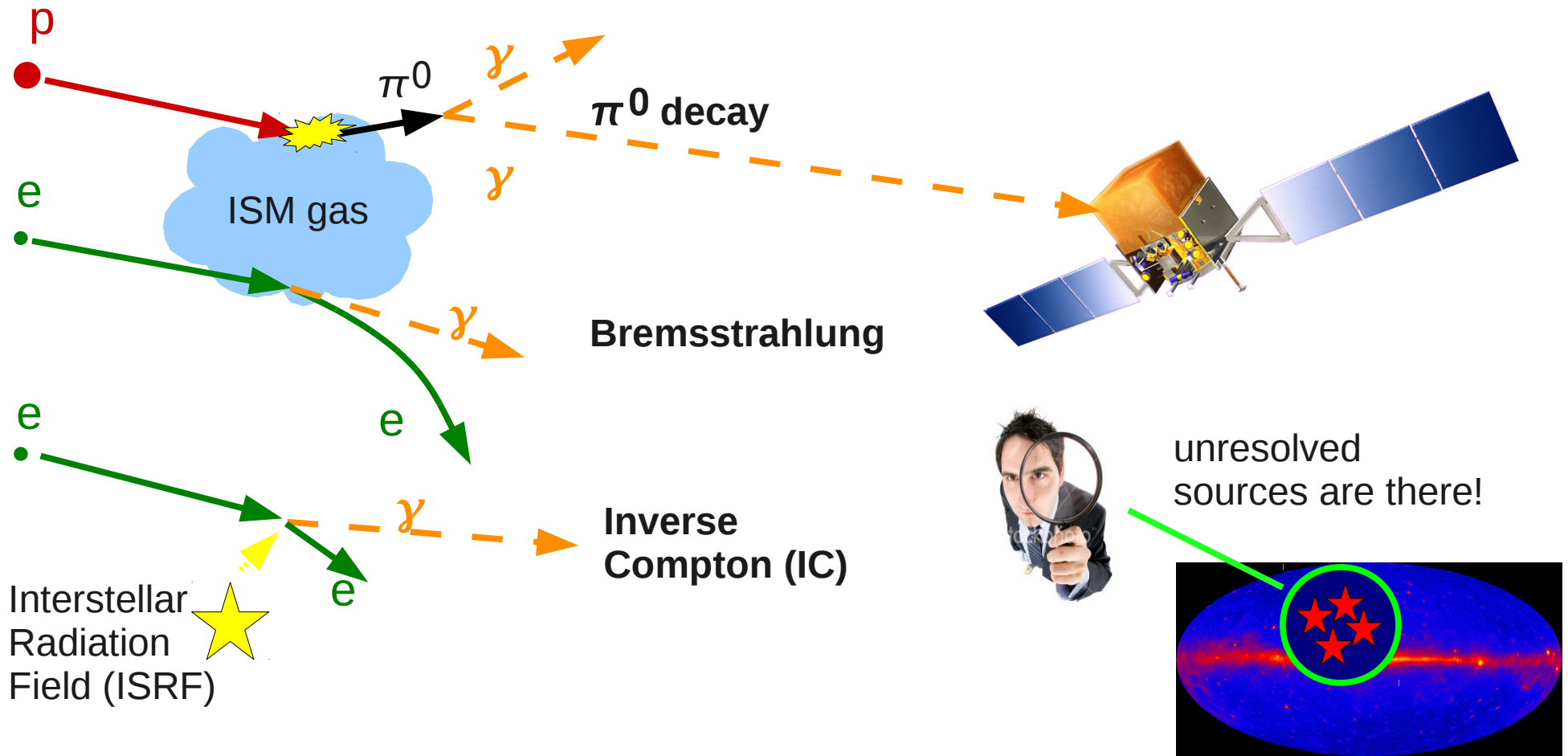
on behalf of the
Fermi LAT Collaboration

The GeV gamma-ray sky



first 12 months of LAT Science operations

Interstellar gamma-ray emission

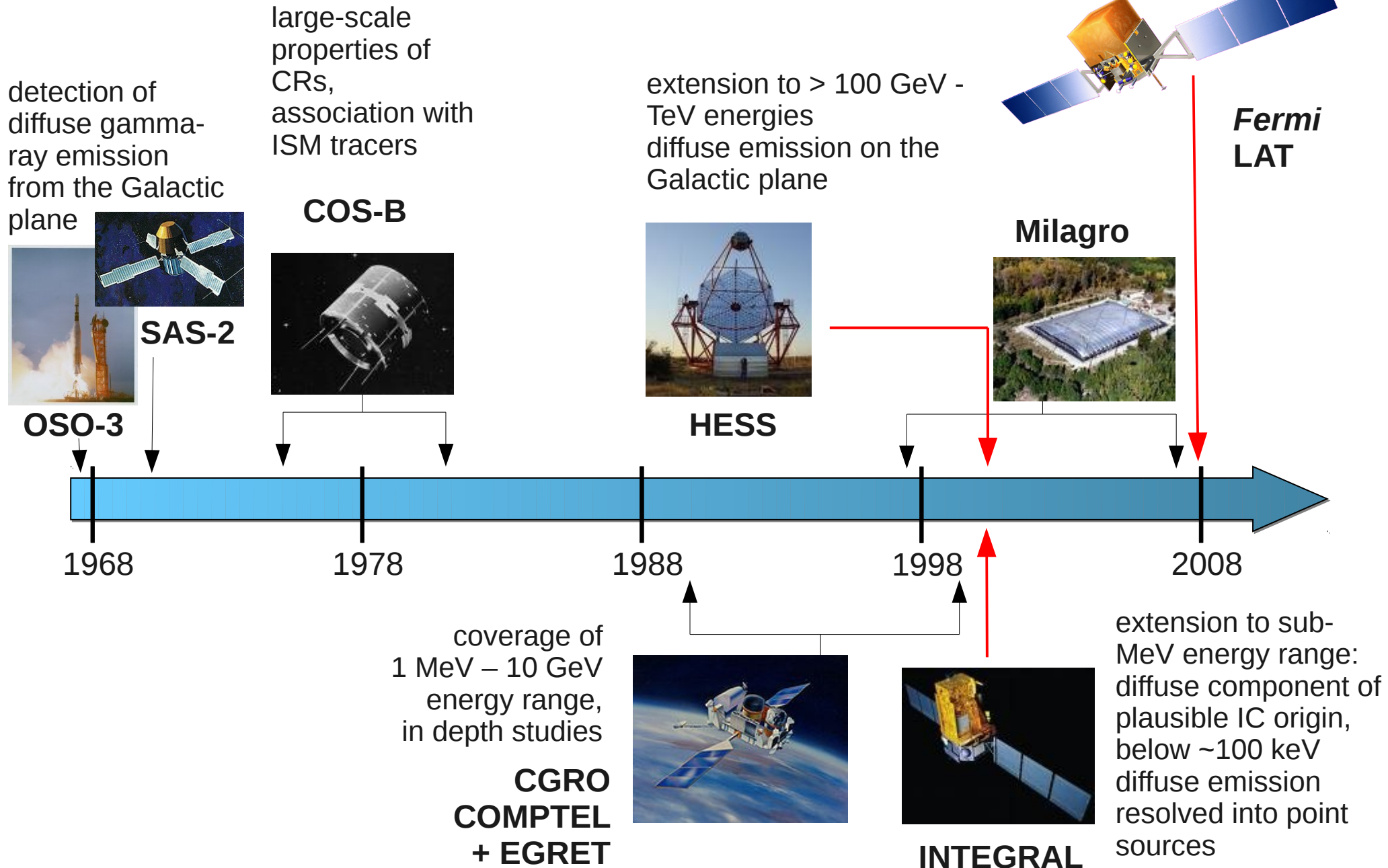


- cosmic-ray tracer
- distant locations not accessible by direct measurements



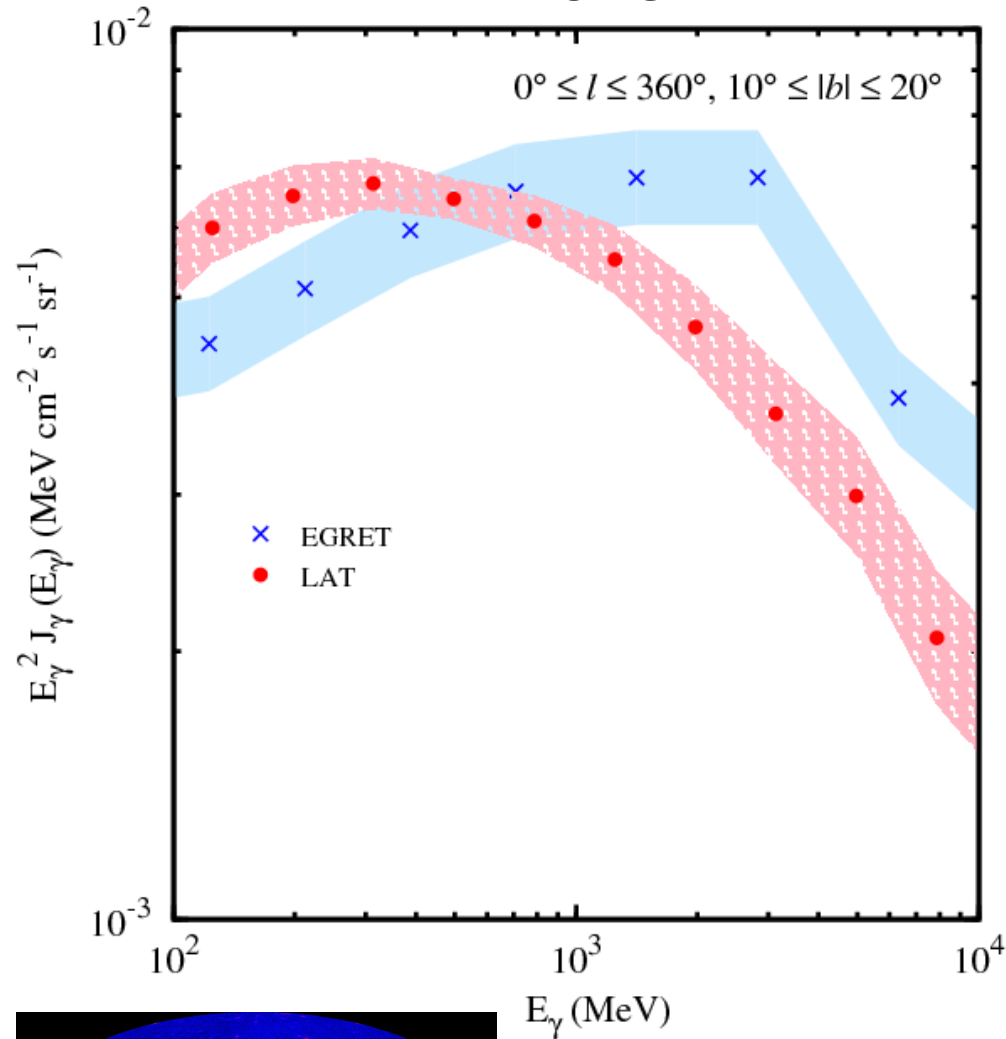
are there contributions from exotic processes???

40 years of interstellar gamma rays

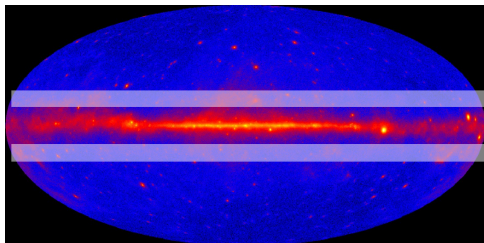
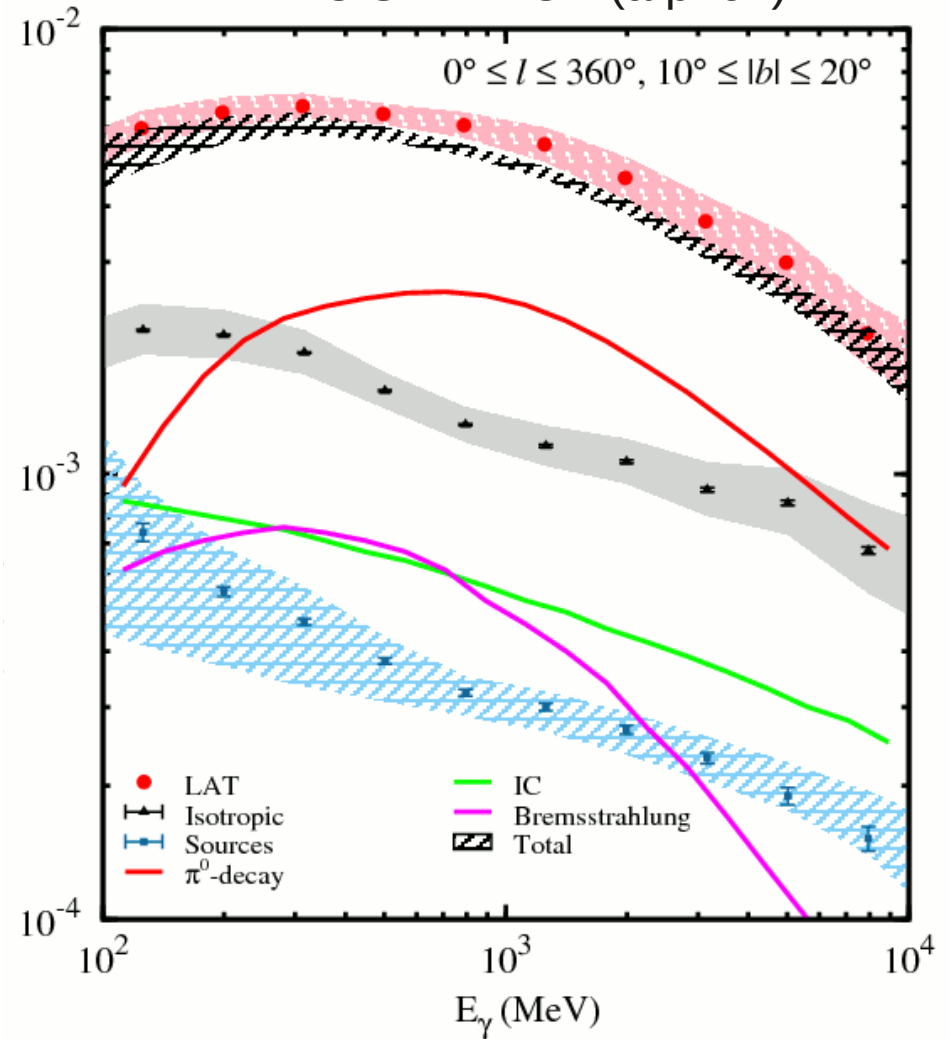


Inconsistency with EGRET GeV excess

LAT vs EGRET

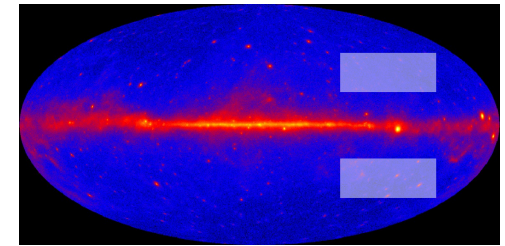
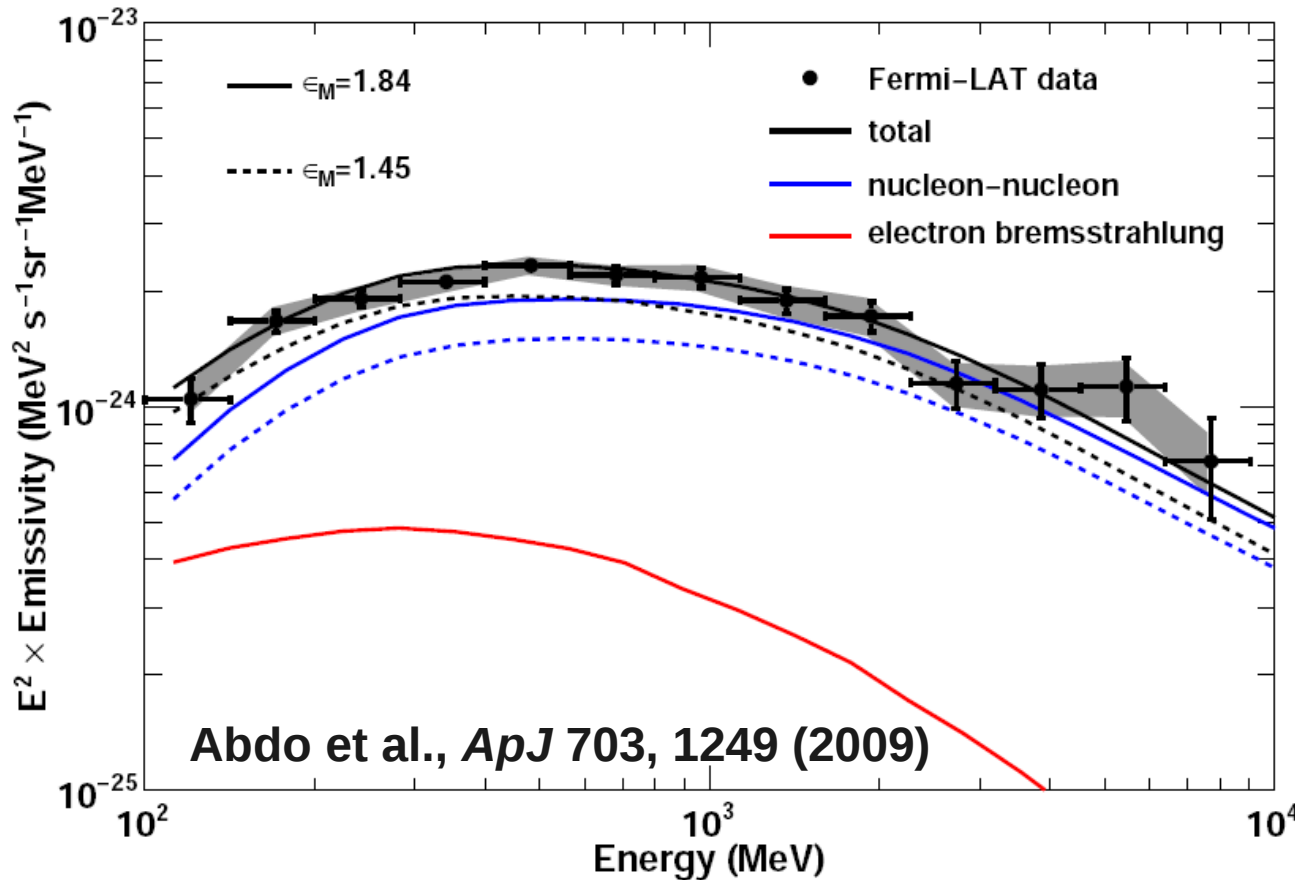


LAT vs GALPROP (a priori)



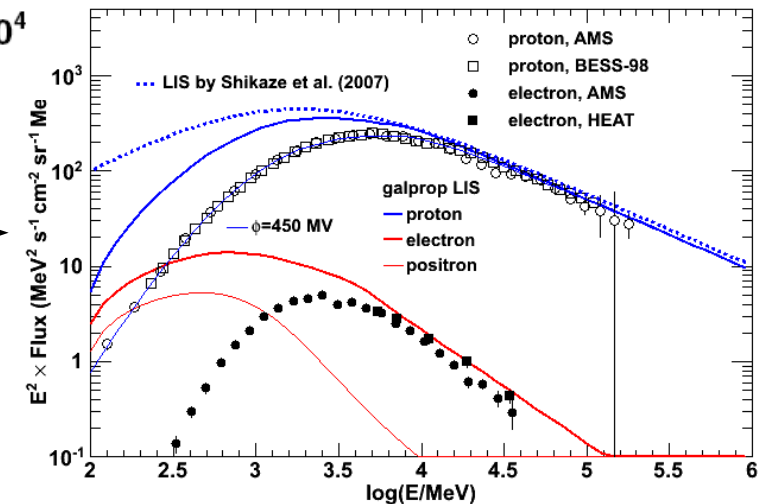
Abdo et al., *Phys. Rev. Lett.* 103, 251101 (2009)

Local H I emissivity



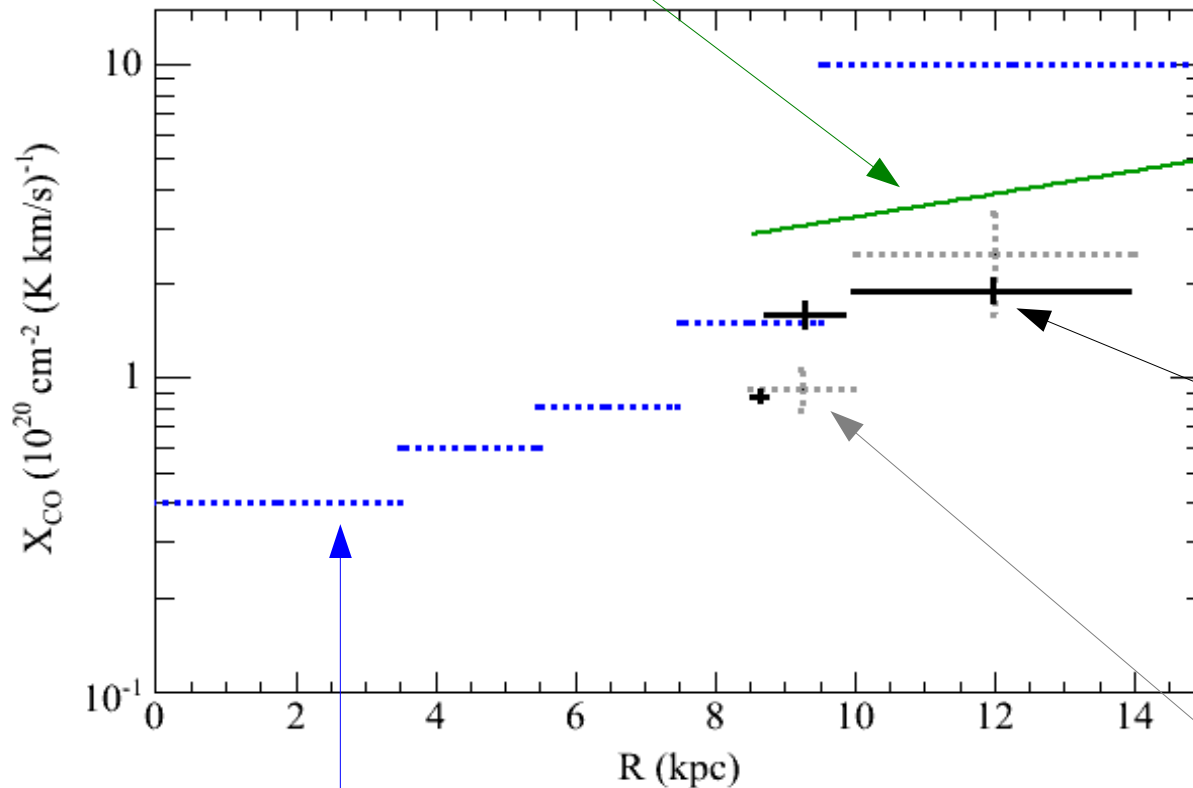
emissivity =
gamma-ray emission rate
per H atom

consistent with directly measured CR spectra



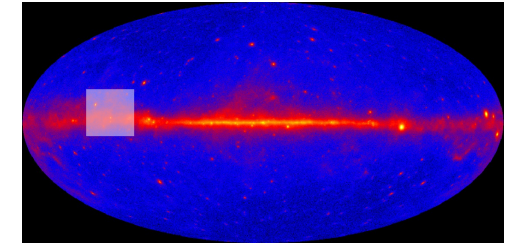
X_{co} gradient in the outer Galaxy

Nakanishi & Sofue
(2006), virial masses



Strong et al. (2004), combined model

Digel et al. (1996), gamma rays (EGRET)



$$X_{\text{co}} = \frac{N(H_2)}{W_{\text{co}}}$$

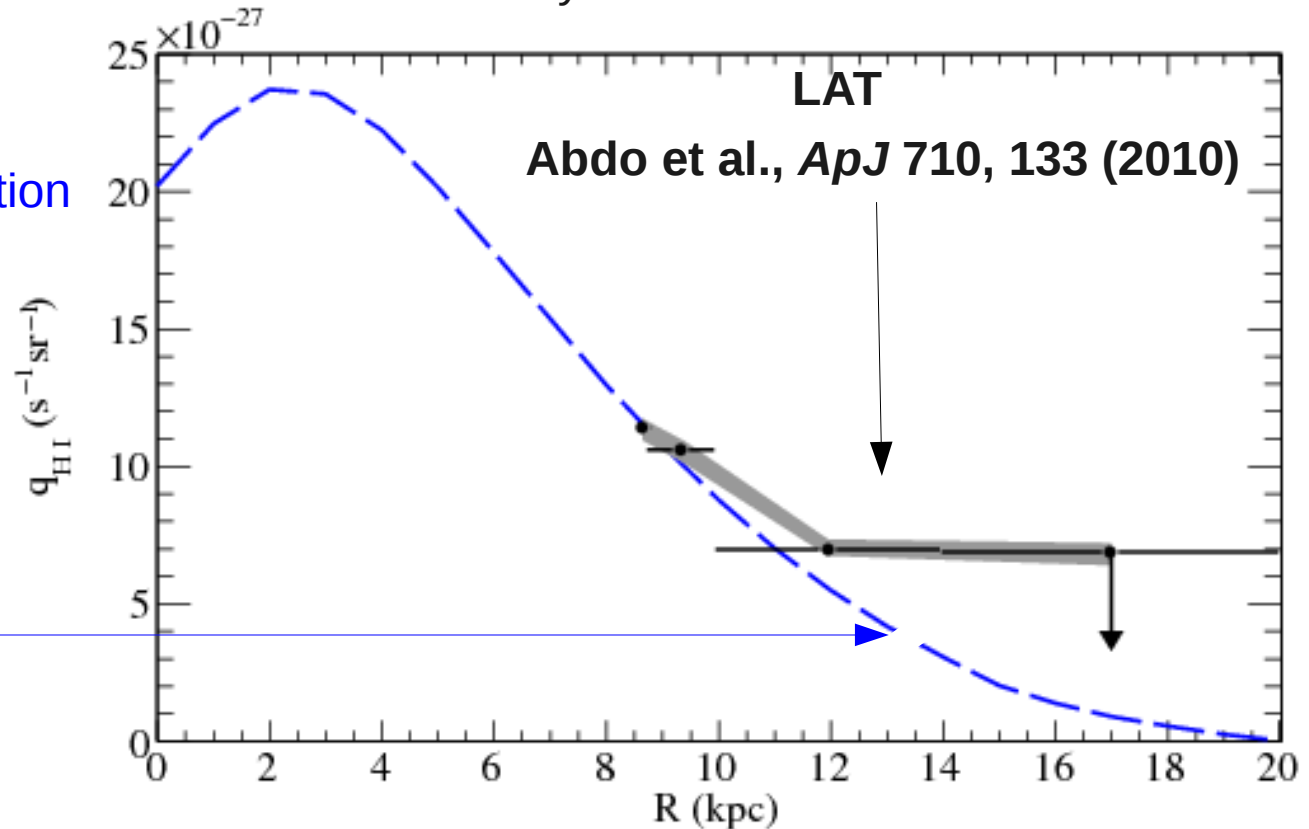
LAT

Abdo et al., *ApJ* 710, 133 (2010)

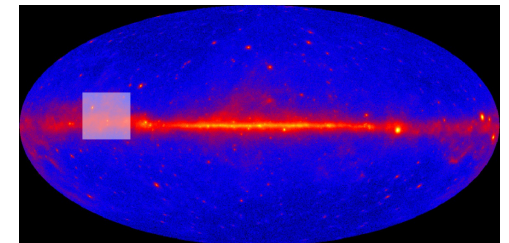
The CR gradient problem

H I emissivity as a function of Galactocentric radius

GALPROP
based on PSR distribution

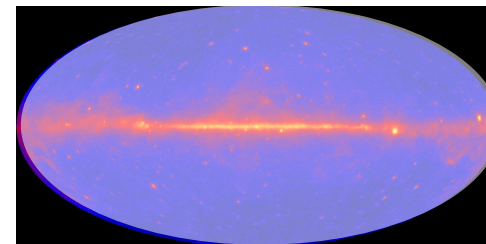
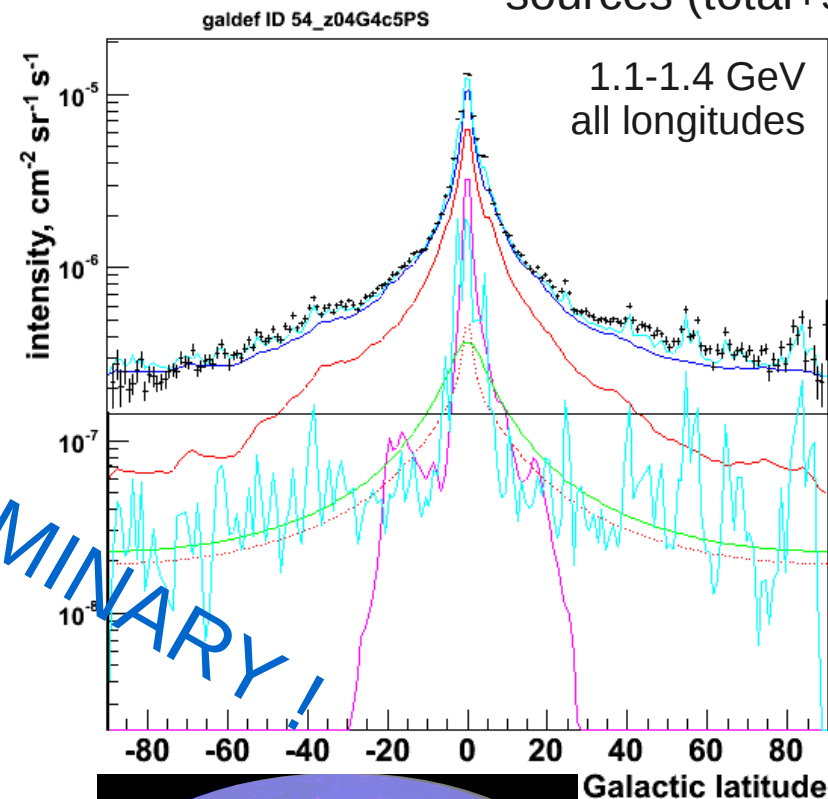
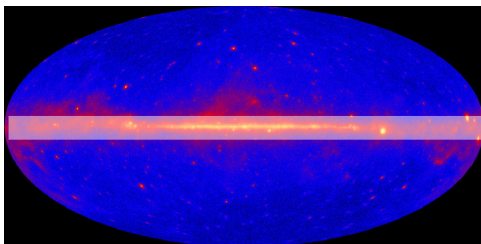
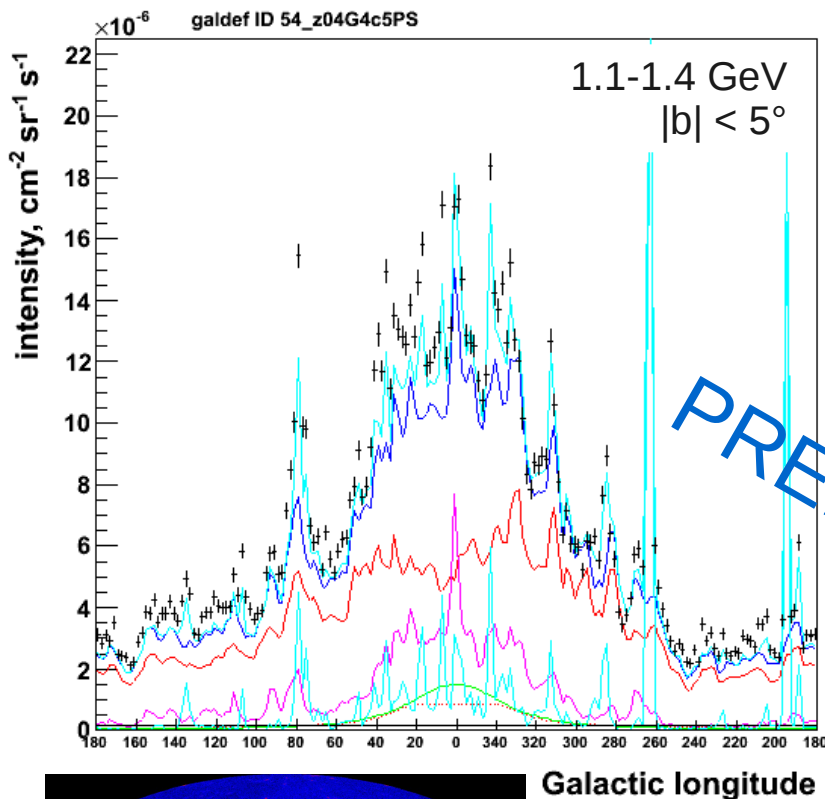
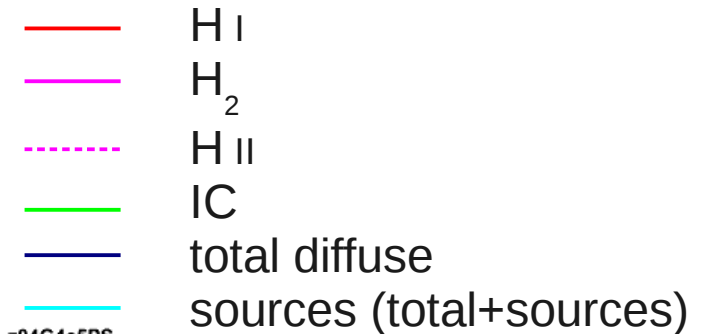


- missing gas?
- unresolved sources?
- CR sources in the outer Galaxy?
- CR propagation?



Toward a large-scale model ...

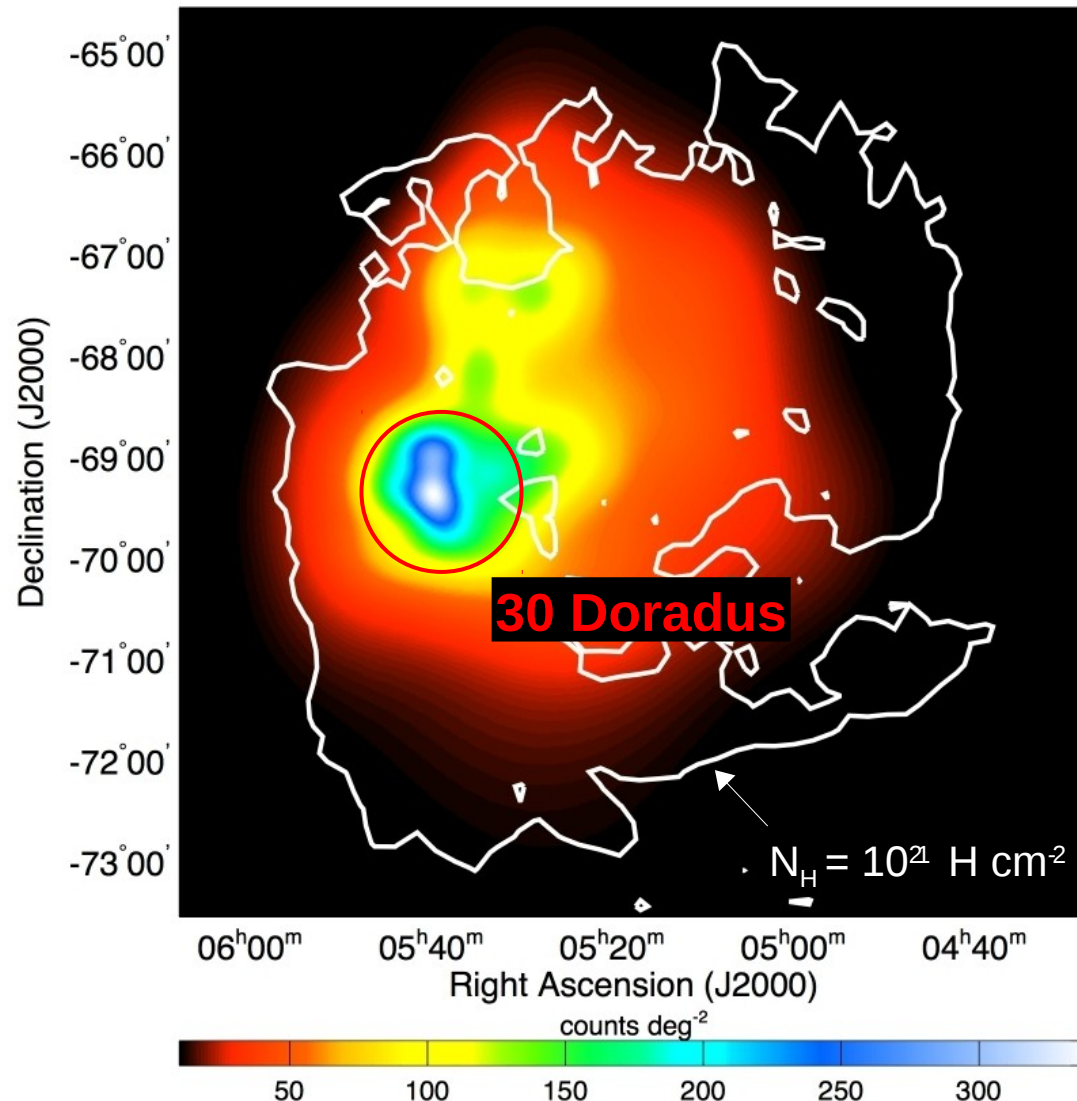
- putting together what we have learned ...
- still ongoing work!



from A. Strong's talk
at Gamma-ray
diffuse emission in
Zurich 2009

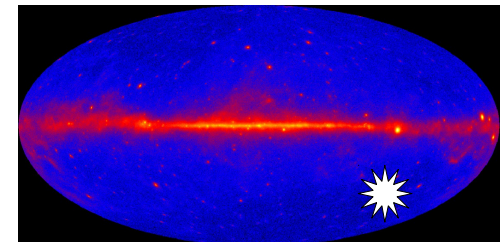
Our neighbor, the LMC

from J. Knödlseider's talk
at 2009 Fermi Symposium



- dist 50 kpc, incl 20° - 35° , diameter 8°
- view from outside!
- **FIRST** extragalactic object ever resolved in HE gamma rays!

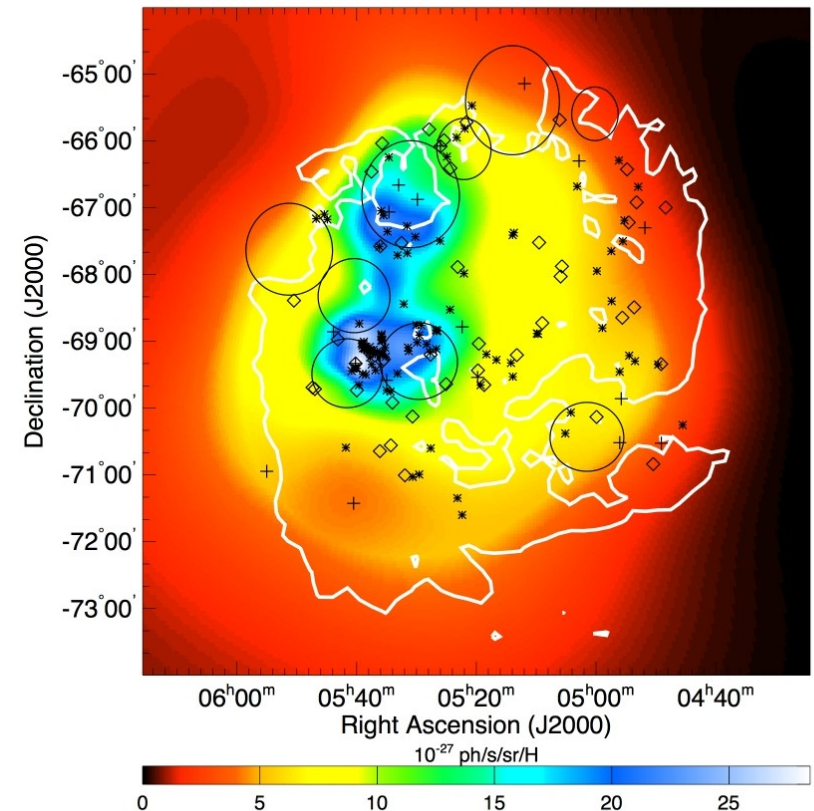
Abdo et al., A&A in press (2010)
arXiv: 1001.3298



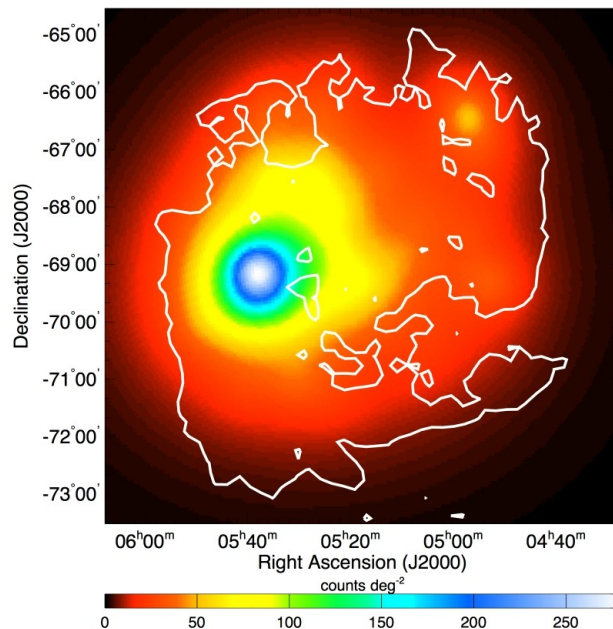
LAT counts (background subtracted, adaptively smoothed)

Mapping CR acceleration in LMC

- 30 Doradus bright in gamma rays, powerful CR accelerator
- gamma rays trace star formation ($H\alpha$) rather than interstellar mass ($H\text{ I}$, >90%)
- average CR densities $\sim 0.2\text{-}0.3$ local Milky Way
- small CR diffusion length!



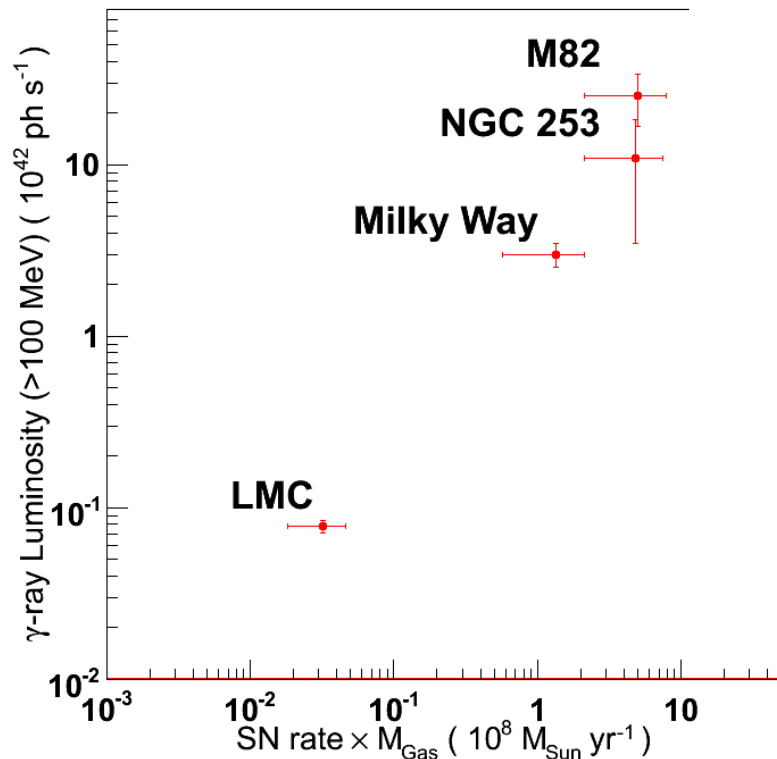
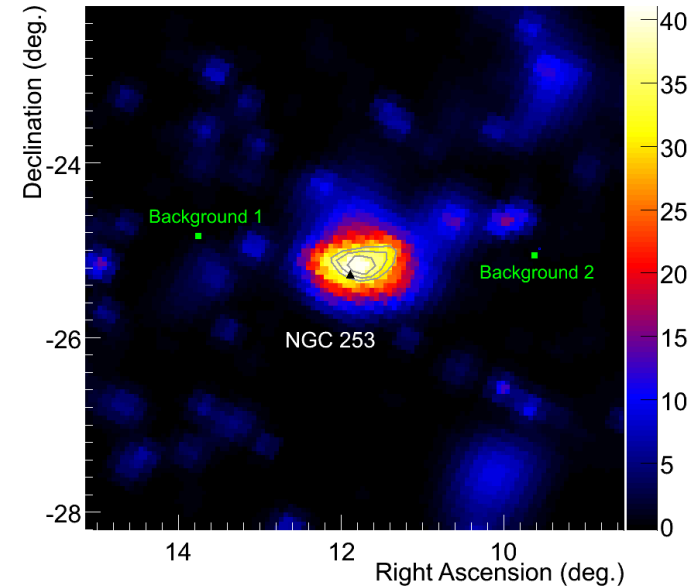
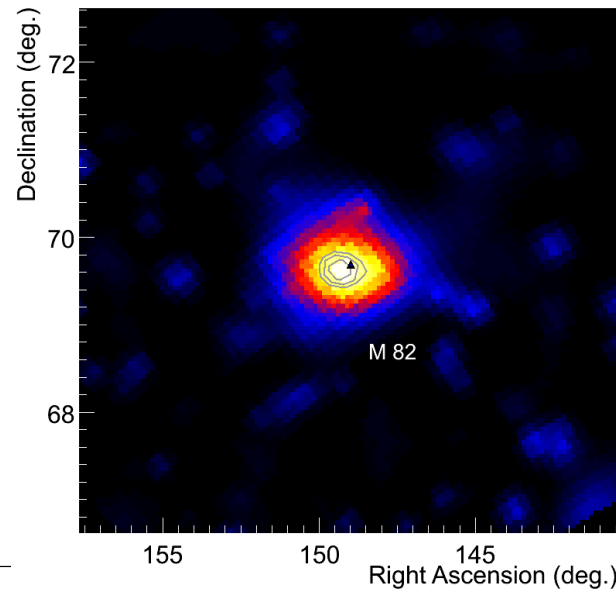
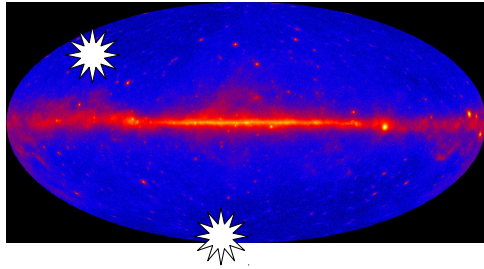
gamma-ray emissivity



$H\alpha$ template

Abdo et al., *A&A* in press (2010)
arXiv: 1001.3298

Starburst galaxies: M82 & NGC 253



LAT TS above 200 MeV

Abdo et al., *ApJ* 709, L152 (2010)

M82

- detected at 6.8σ
- detected at VHE by VERITAS

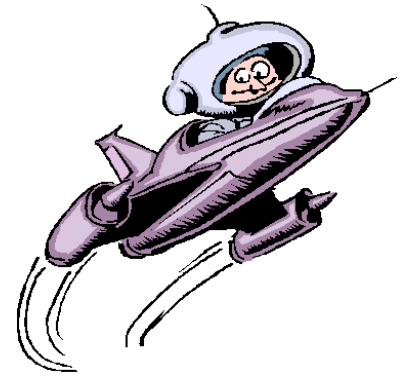
NGC 253

- detected at 4.8σ
- detected at VHE by HESS

Final remarks

Local emission compatible with CRs at Earth

- GeV excess not confirmed



Exploring the Milky Way ...

- characterizing interstellar emission with unprecedented sensitivity and resolution
- learning about CRs and the ISM

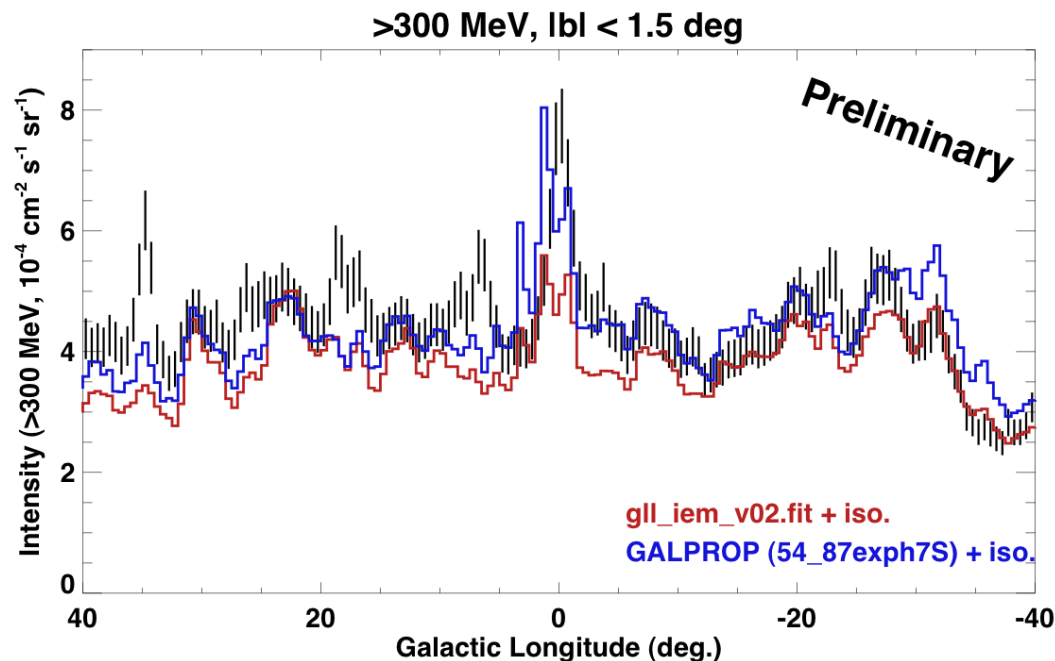
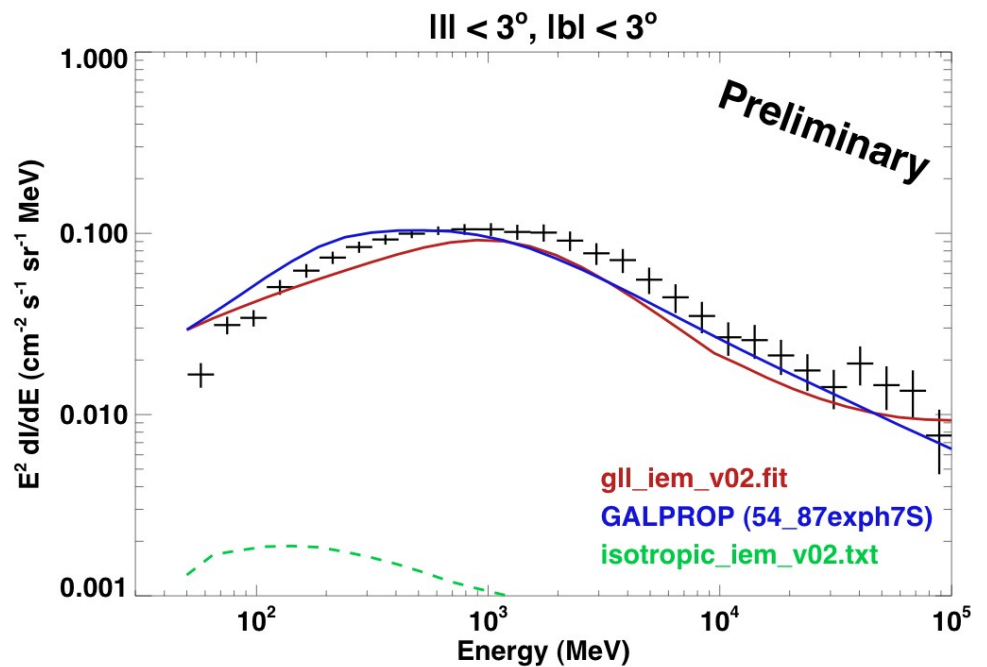
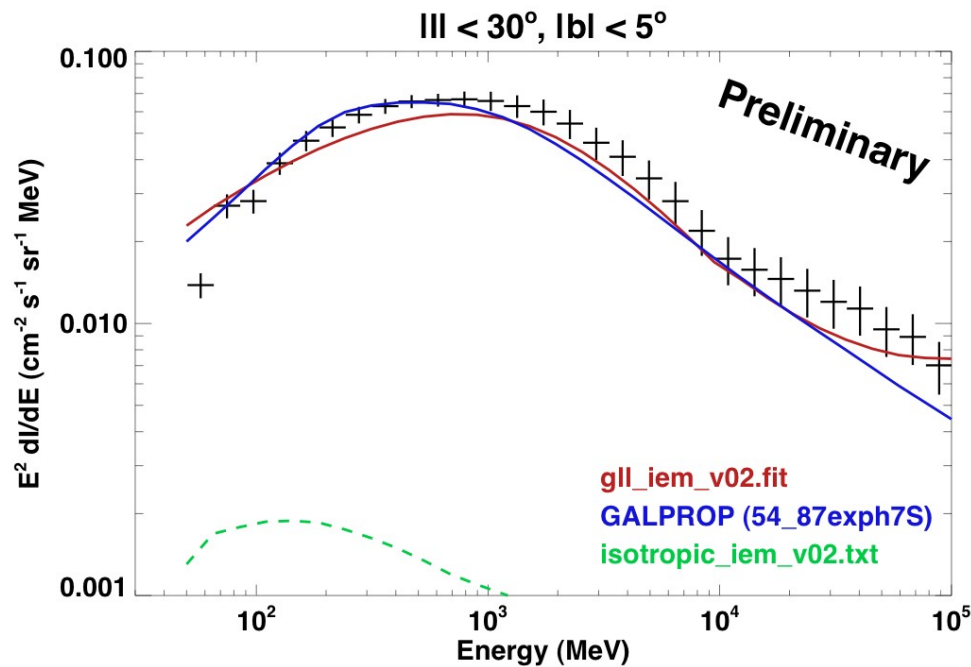


... and beyond

- universality of interstellar gamma-ray emission
- surprises: small CR diffusion length in LMC

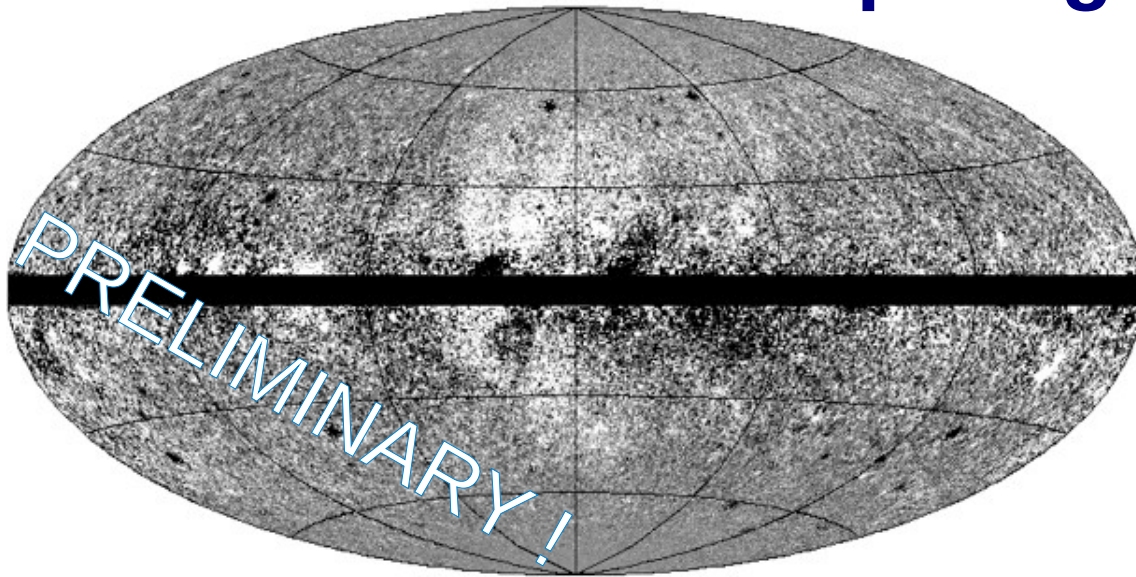
Backup slides

Diffuse emission from the GC region



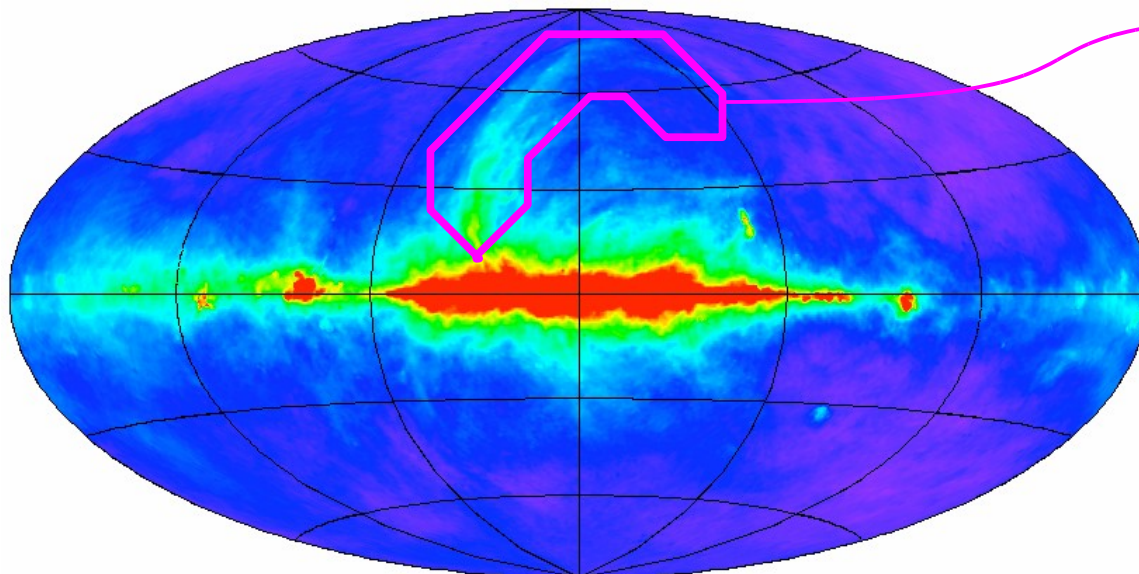
from S. Digel's talk
at 2009 Fermi Symposium

Loop I region



from J.-M. Casandjian's poster
at 2009 Fermi Symposium

gamma-ray residuals
LAT counts minus model ($E > 300$ MeV)



North Polar Spur

Casandjian & Grenier,
for the *Fermi* LAT collaboration
(2009)
arXiv:0912.3478

408 MHz map from Haslam et al., *A&A* 100, 209 (1981)