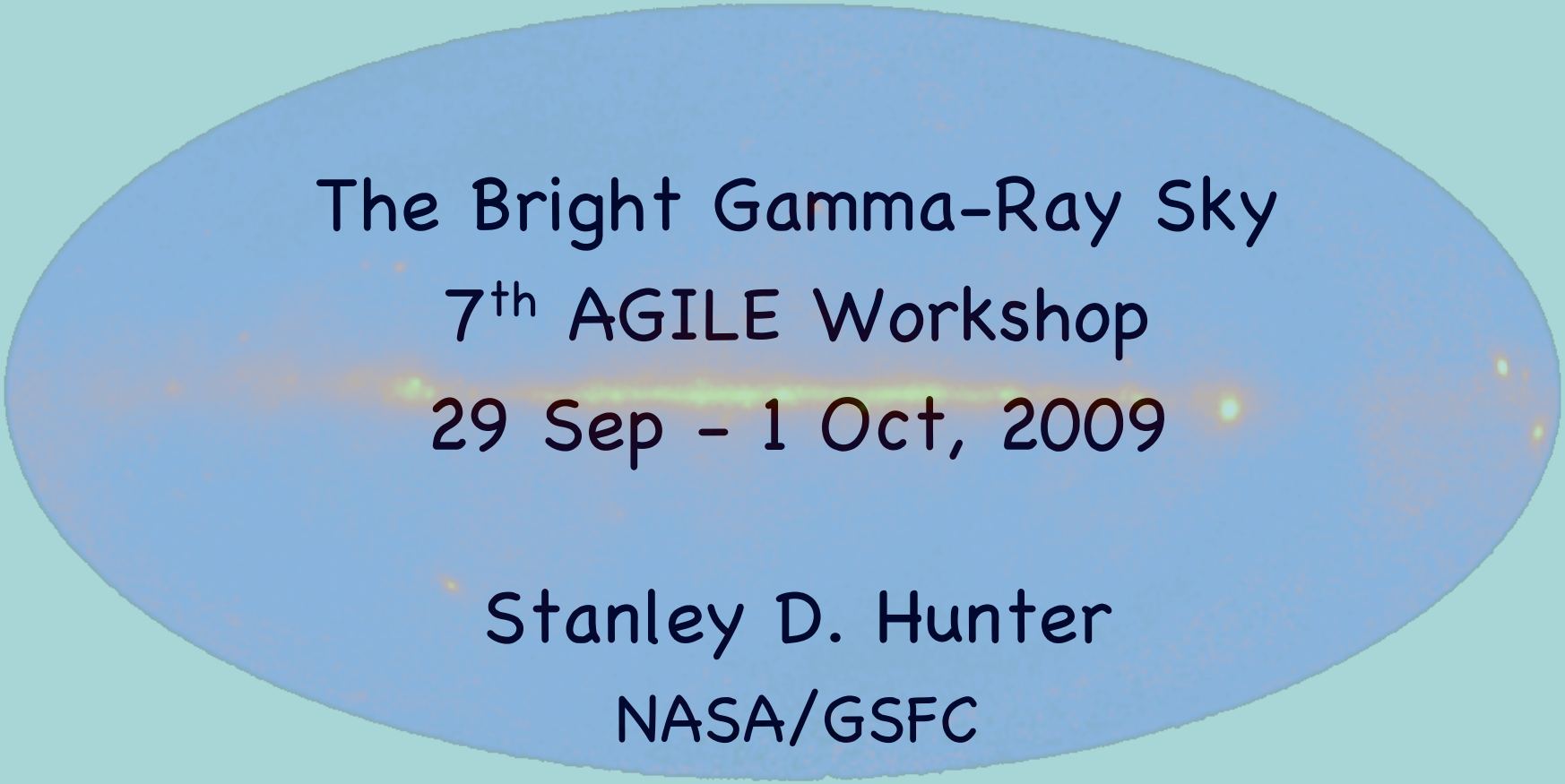
Galactic Diffuse Gamma-Ray Emission



The Bright Gamma-Ray Sky

7th AGILE Workshop

29 Sep - 1 Oct, 2009

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Galactic Diffuse Emission

The beginning:

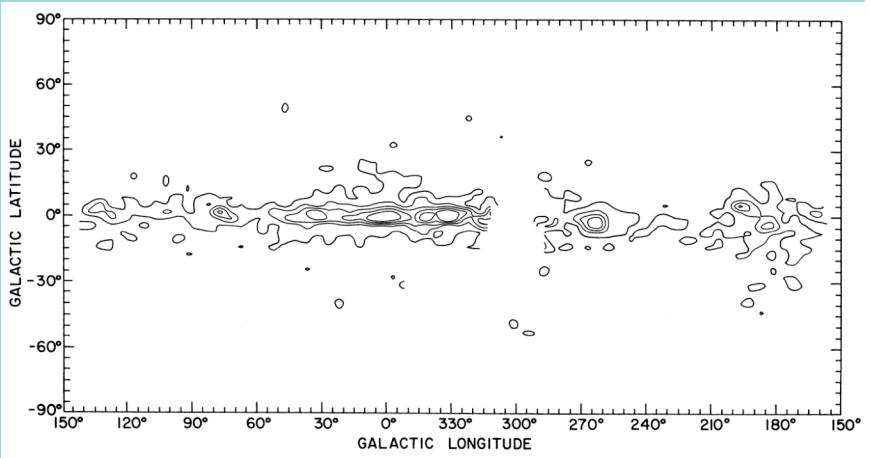
OSO 3, 8 Mar 1967 - 4 Apr 1982

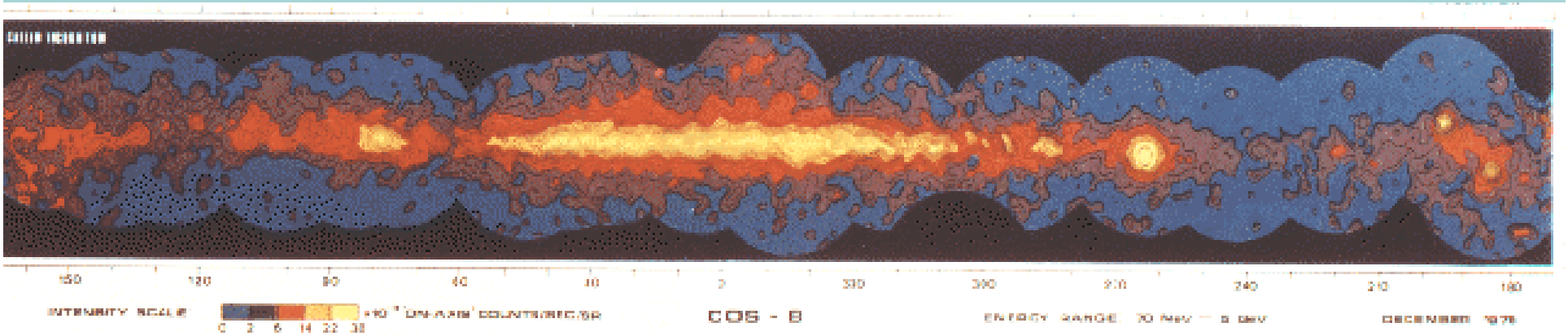
A complete sky survey showed that the celestial distribution of gamma-rays is highly anisotropic, being concentrated along the galactic equator.

First Generation:

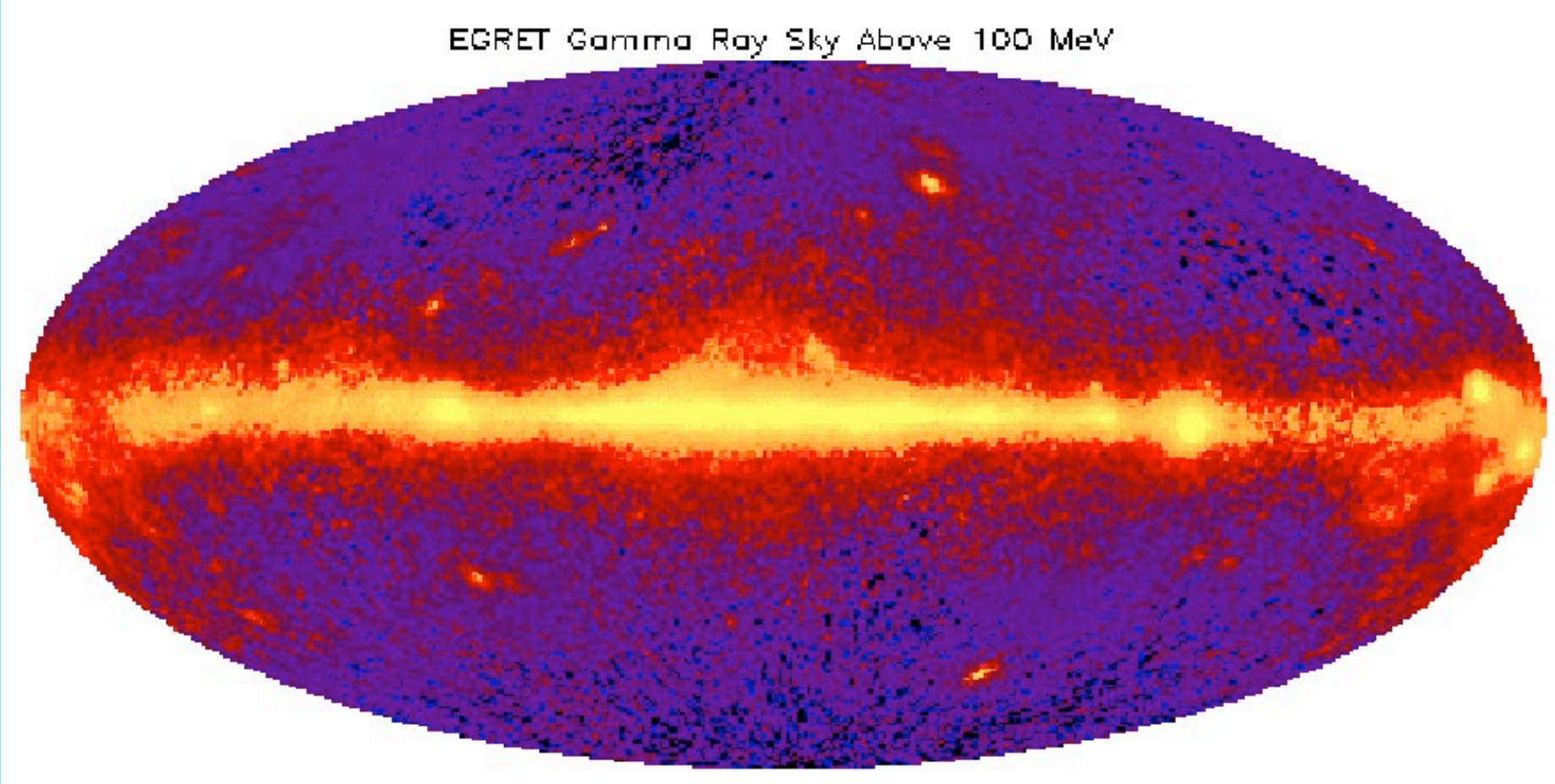
SAS 2, 19 Nov 1972 - 4 Jun 1973

COS B, 9 Aug 1975 - 25 Apr 1982

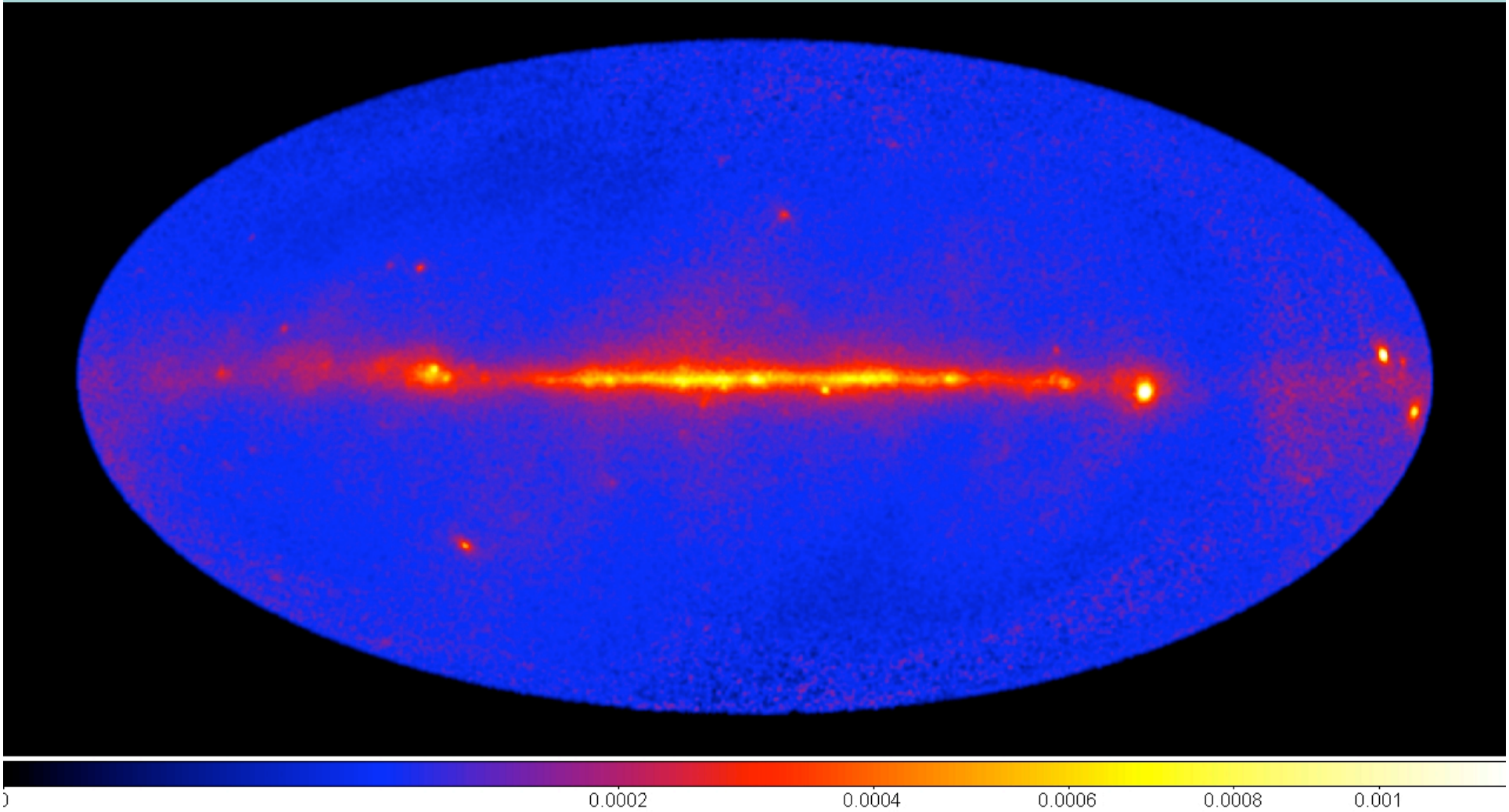




CGRO/EGRET, 5 Apr 1991 - 4 Jun 2000

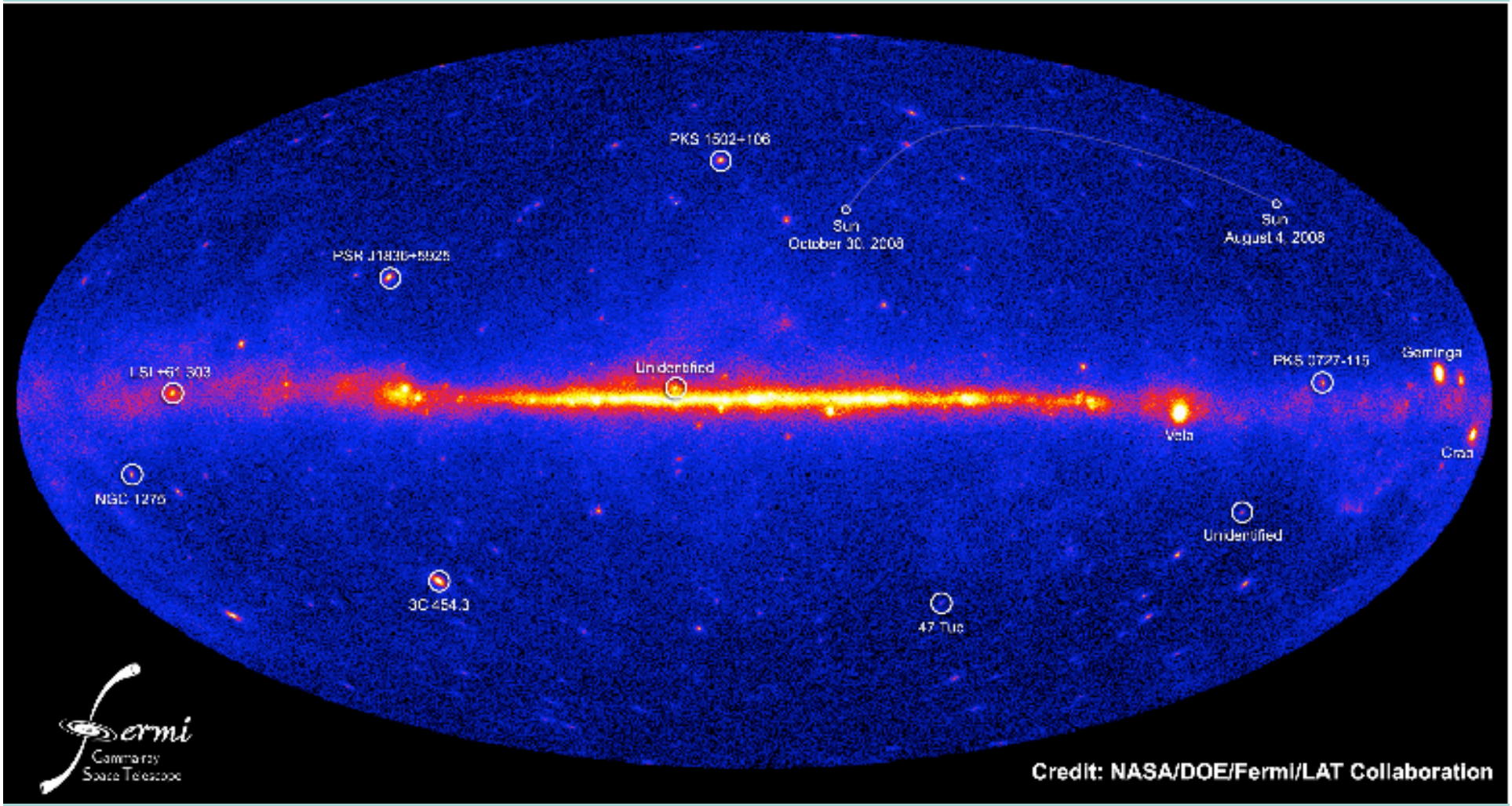


AGILE, Apr. 2007



Courtesy of M Tavani & the AGILE Team

FERMI/LAT, Mar. 2008



Studying the Diffuse Emission

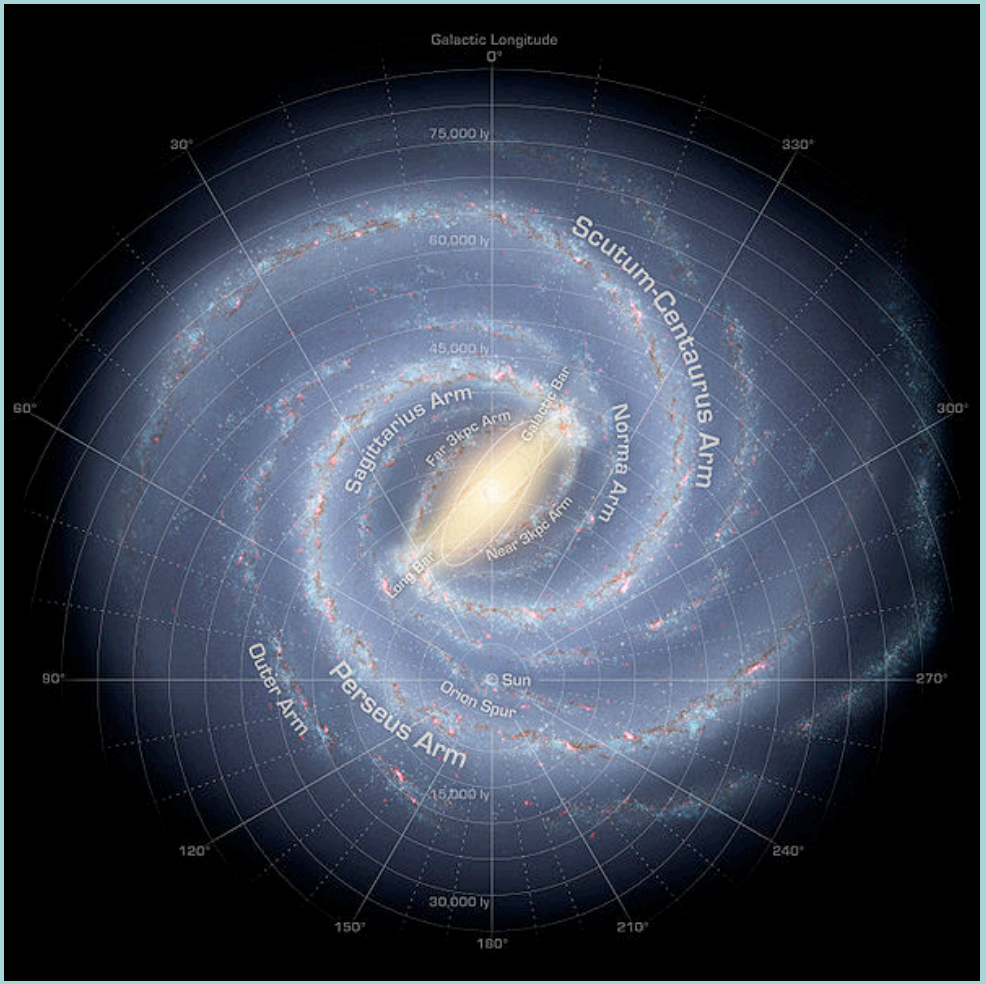
- Required for point source analysis, especially near the Galactic plane

- Study the diffuse emission
  - Probe of matter and CR distribution
    - CR density gradient, propagation, and spectrum
  - Galaxy is transparent to gamma-rays
    - Superposition of sources & extended emission
      - Inner Galaxy and tangent points of the arms

Galactic Structure

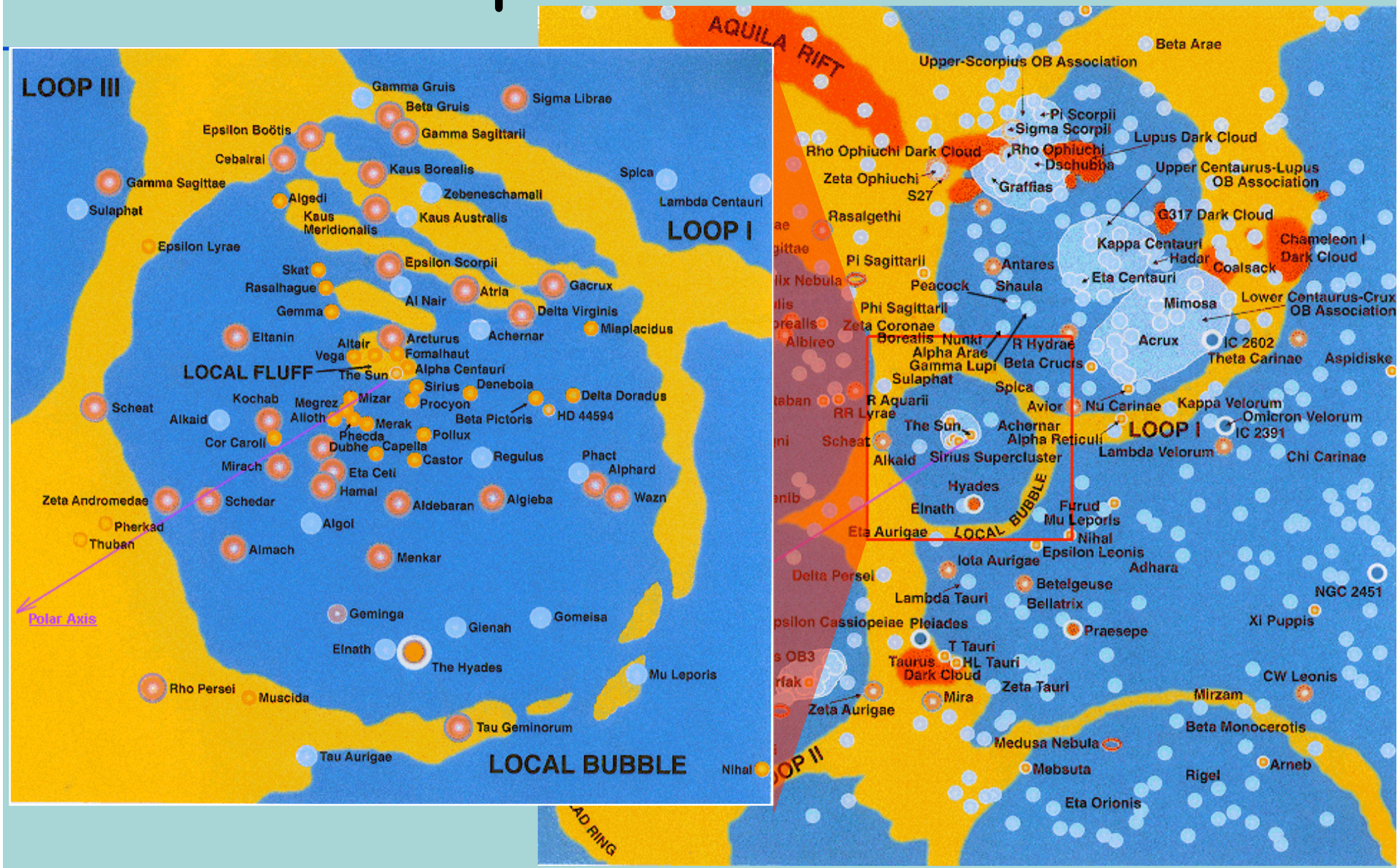
- Spitzer infrared data
  - Two major arms
  - Central bar

Martellus, Henricus, Germanus; Florence, 1489



www.spitzer.caltech.edu/Media/releases/ssc2008-10/ssc2008-10b.shtml

Complex Structure

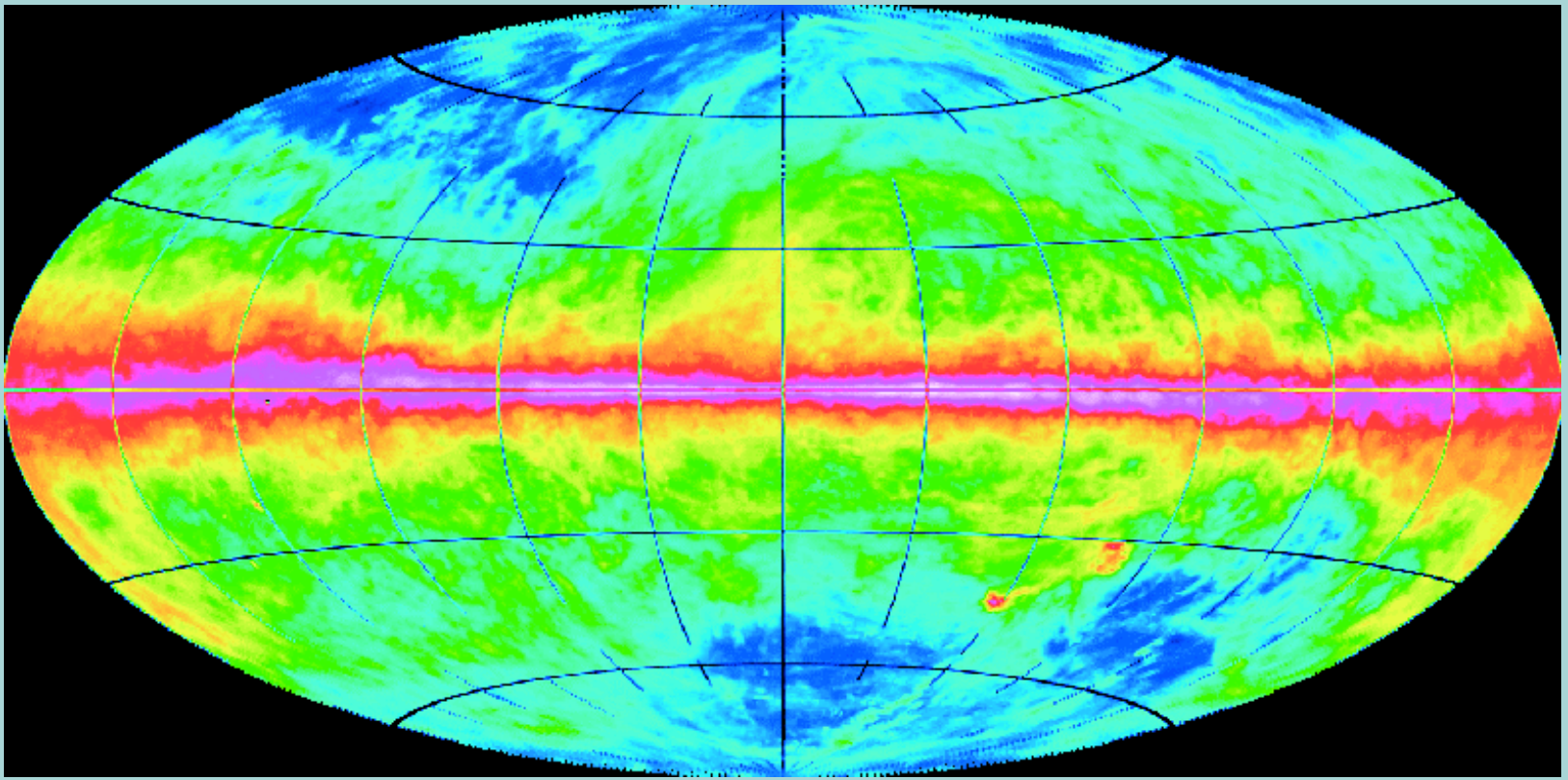


⇐ ~1/2 kpc ⇒

Modeling the Diffuse Emission

- CR interactions with matter & photons
  - ISM (H_I, H_2, and H_{II})
    - Nucleon-nucleon (π^0)
    - Bremsstrahlung
  - Inverse Compton on ISRF
- Distribution of matter
  - Galactic rotation curve
- CR density
- Extra-galactic diffuse

HI: Leiden/Argentine/Bonn Survey



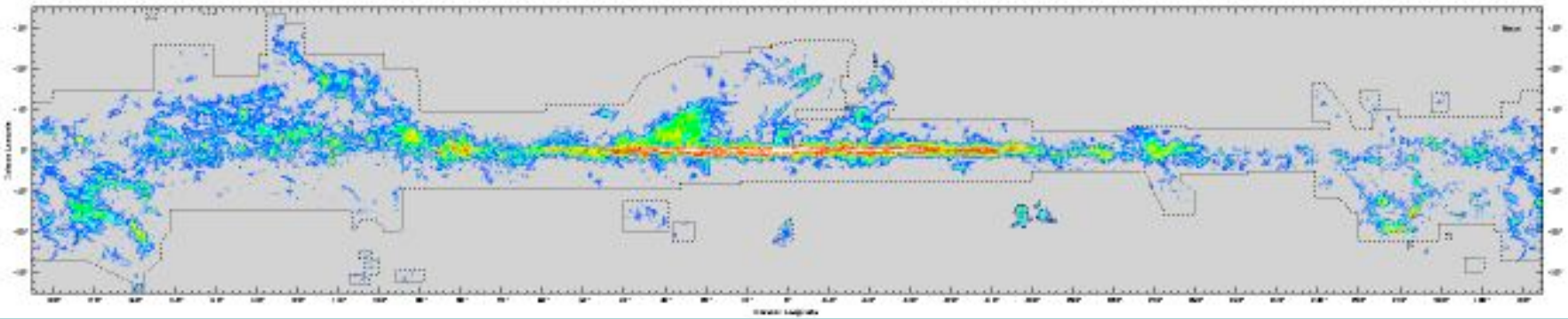
HI emission integrated over the velocity range $-400 < v < +400$ km s^{-1}

Kalberla et al. 2005, A&A, 440, 775-782

Total column density, N_{HI}, 2×10^{22} cm^{-2} HPBW = 0.6°

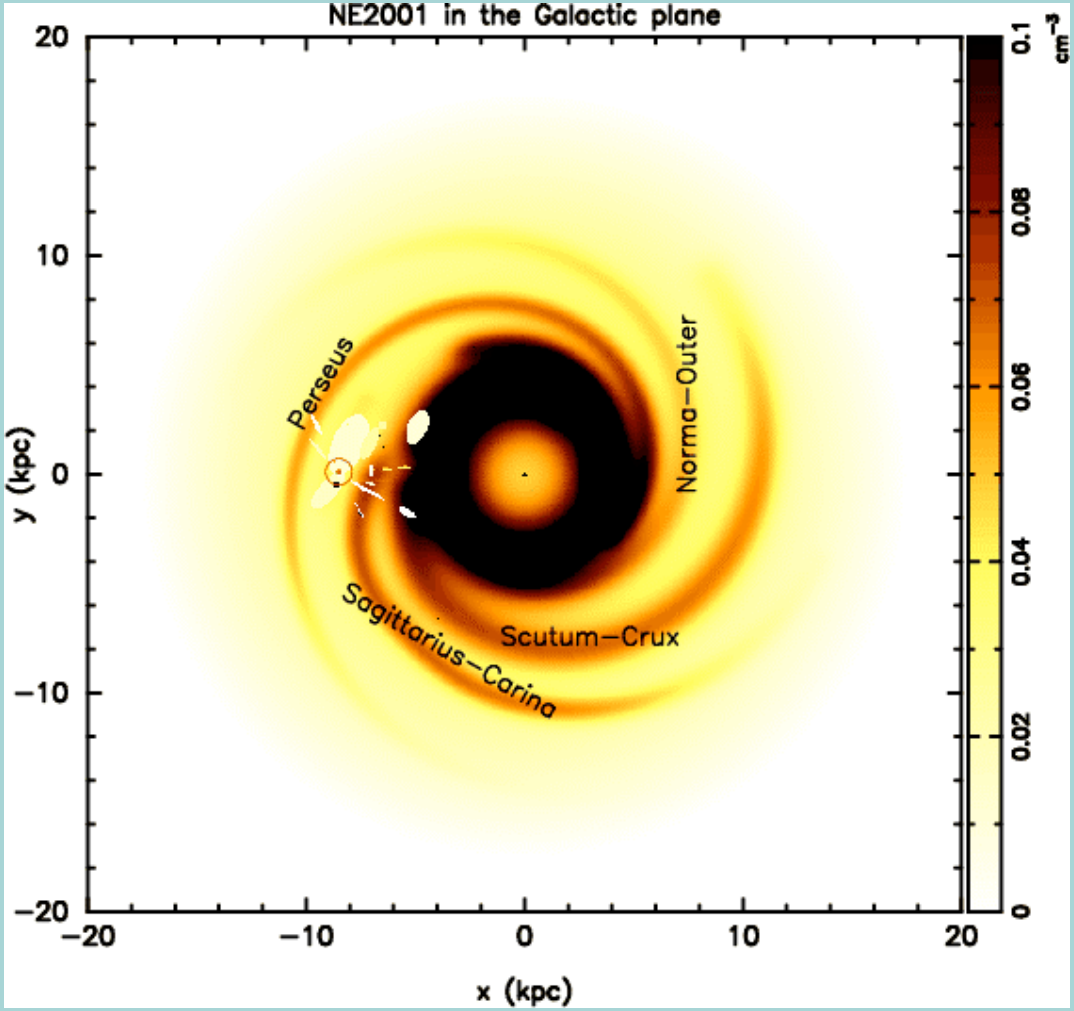
CO: CfA Compilation

- Dame et al. 2001 ApJ, 547, 792
- Complete coverage |b| < 32°, clouds > 1° effective angular resolution of 1/8°
- 0.1 - 3×10^{20} cm^{-2} , assumption of X-ratio
- Several isolated, high latitude clouds

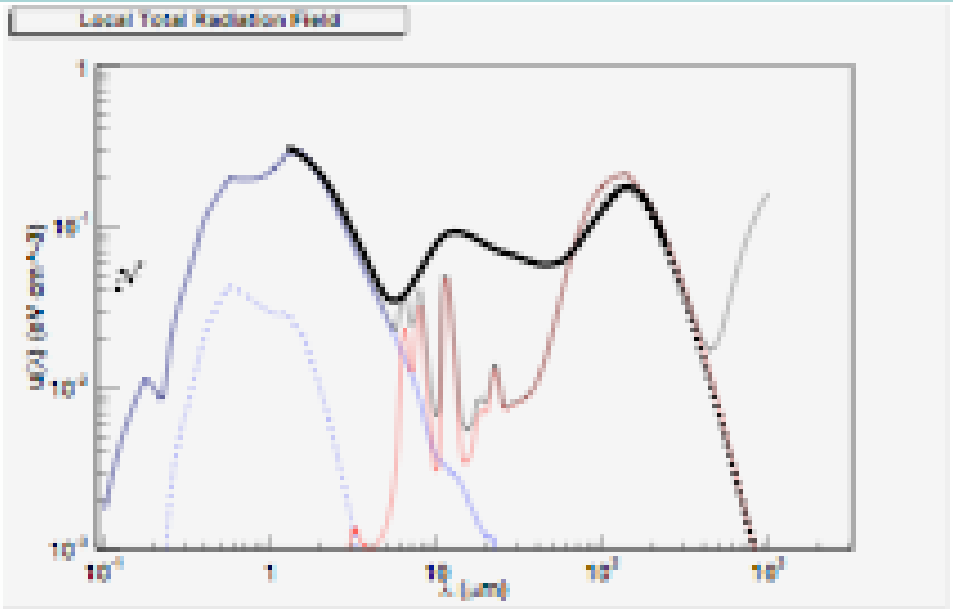


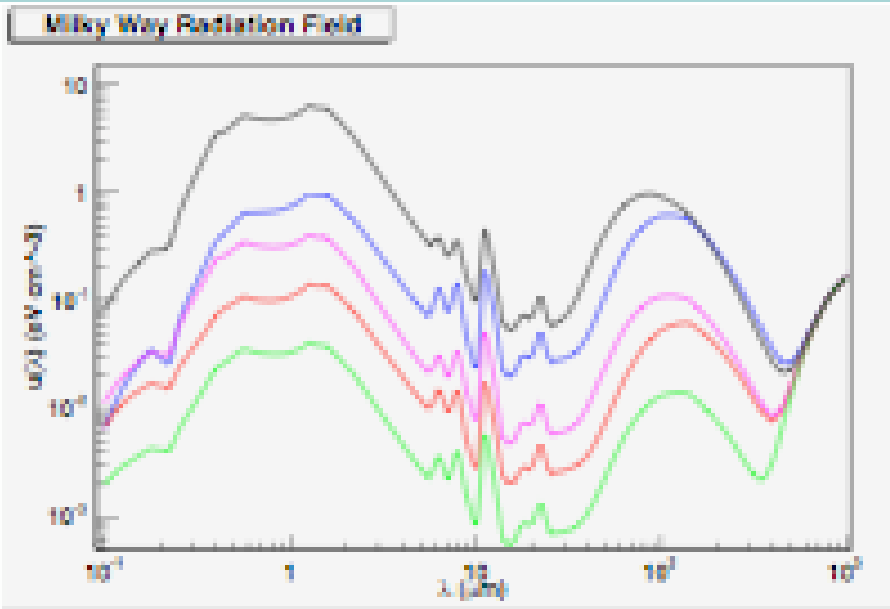
HII: NE2001

- Cordes & Lazio, 2002, 2003 from pulsar DM



Interstellar Radiation Field





Porter and Strong, 39th ICRC

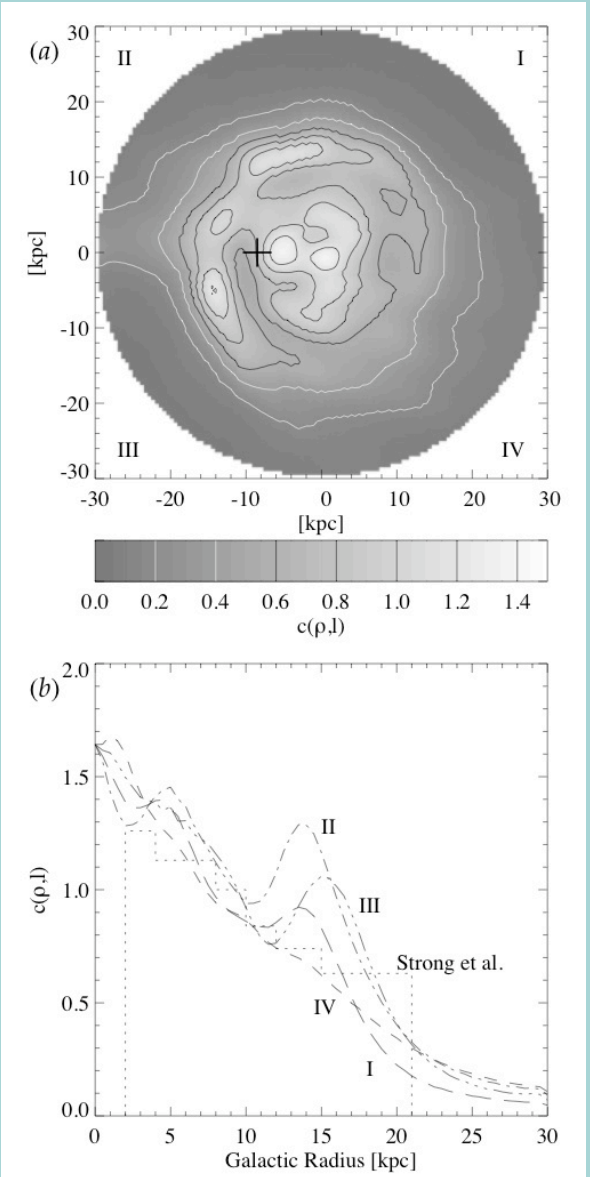
Black line: total radiation field, including CMBR.
Blue solid line: total optical. Blue dashed line: total scattered light.
Red line: total infra-red. Data: thick dot-dashed line, Apollo; thick solid line, DIRBE; thick dashed line, FIRAS.

Dark Gas, A Missing Component?

- Grenier, Casandjian & Terrier, 2005, Science, 307, 1292
- Not accounted for by HI and CO surveys
- Found at interfaces between atomic and molecular clouds in solar neighborhood
- Traced by E(B-V)
- Comparable mass to CO mass

CR Distribution

- Only measurement is in Solar neighborhood
  - Complicared by Solar modulation
- Two approaches:
  - 1) Model the CR propagation, constrained by composition, GALPROP, Strong et al.
  - 2) Assume local CR spectrum throughout Galaxy, density proportional to matter density, Hunter et al.

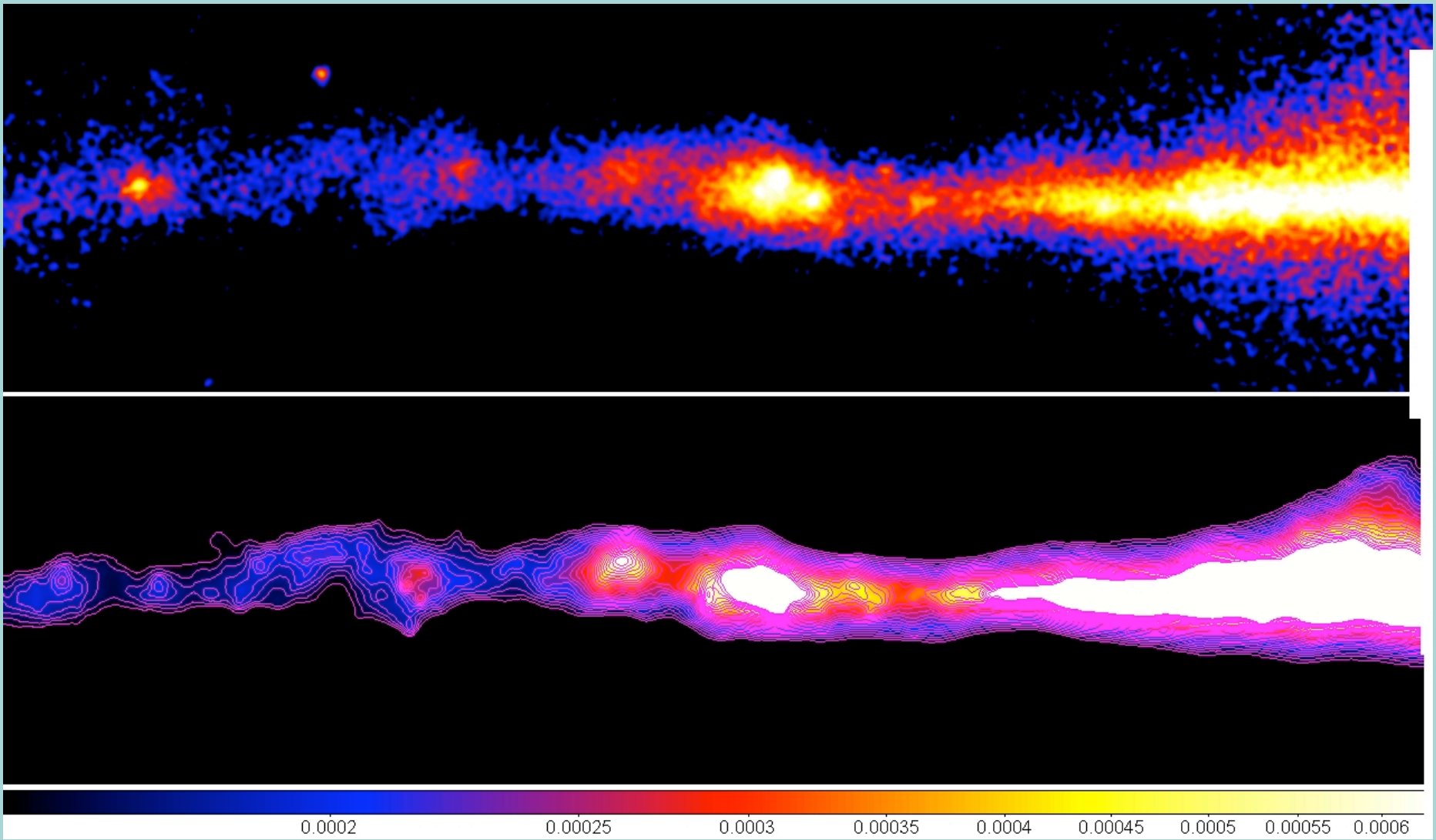


Model Inputs

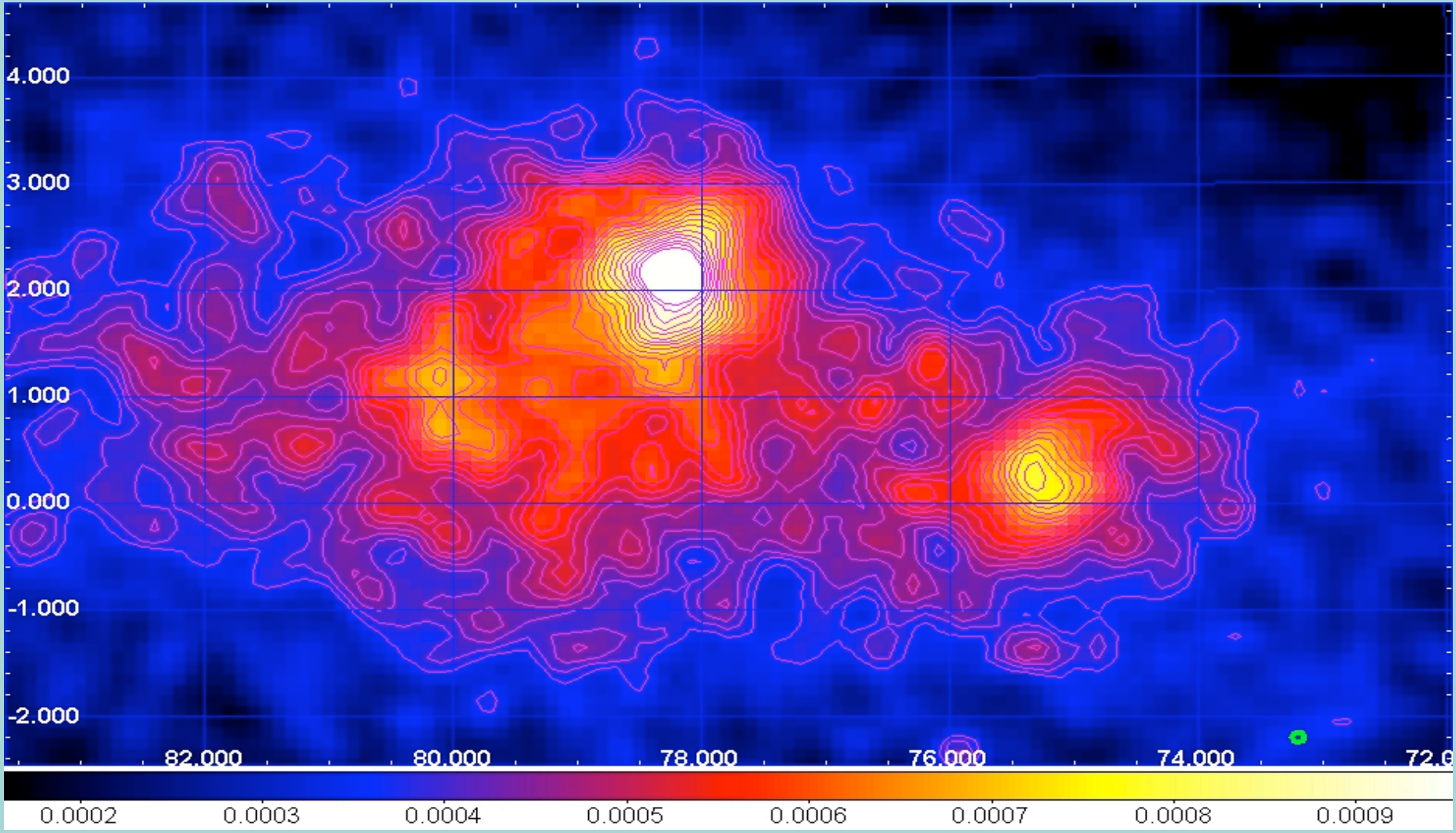
- ISM composition, H, He, …
- HI spin temperature, 125 K
- X-ratio = N_{H2}/W_{CO}
- Emissivity
  - Constant? Radial dependence?

- Galactic Rotation Curve
  - Kinematic deconvolution of line-of-sight column density

AGILE Diffuse Model

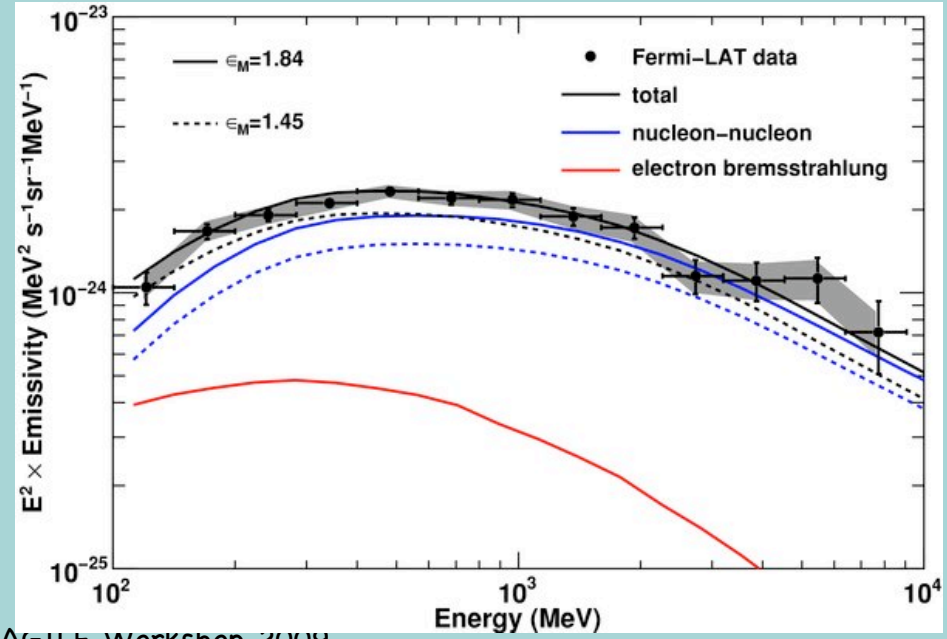


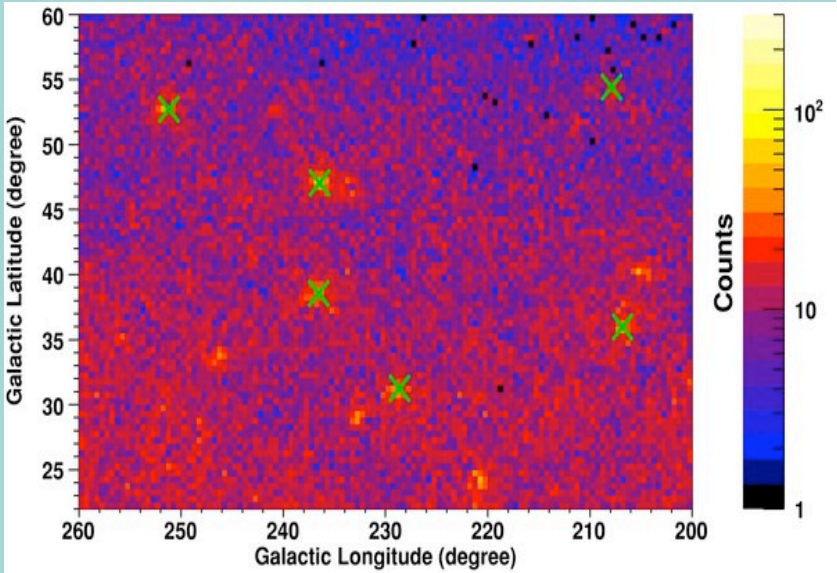
AGILE Obs., Cygnus Region

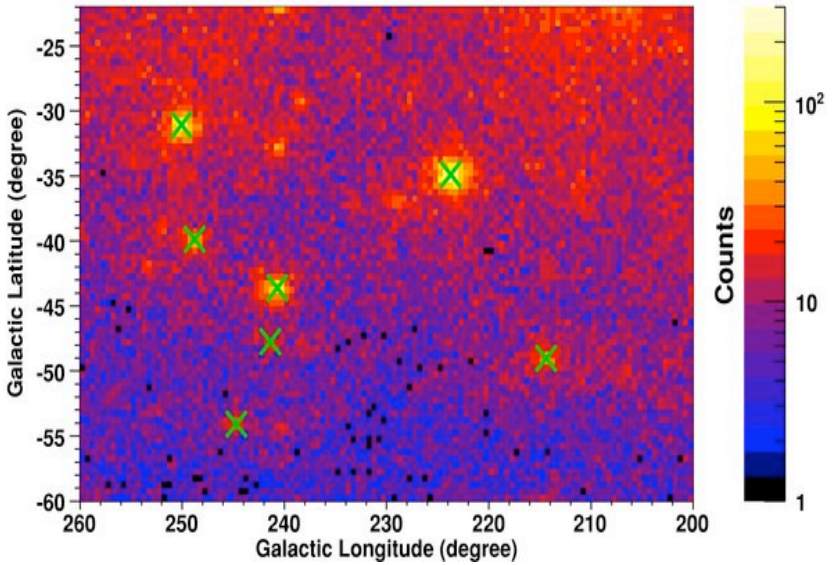


Fermi/LAT Observations

- FERMI LAT Observations of diffuse gamma rays produced through interactions between local interstellar matter and high-energy cosmic rays
  Abdo et al. 2009, ApJ, 703, 1249-1256

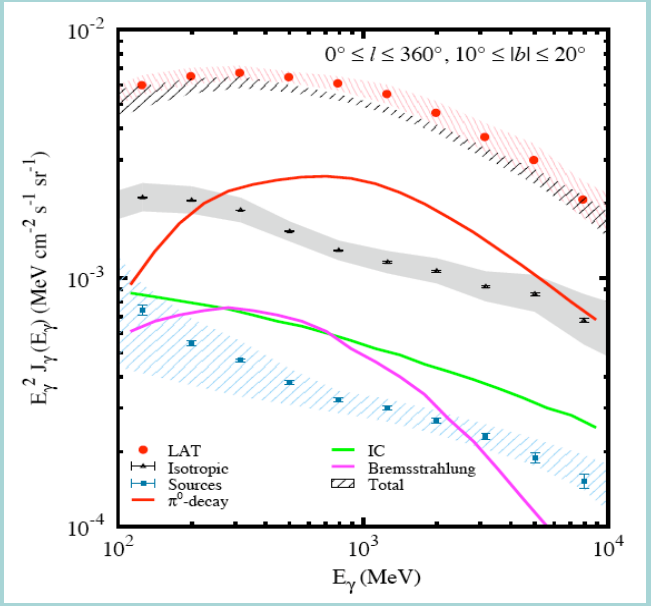


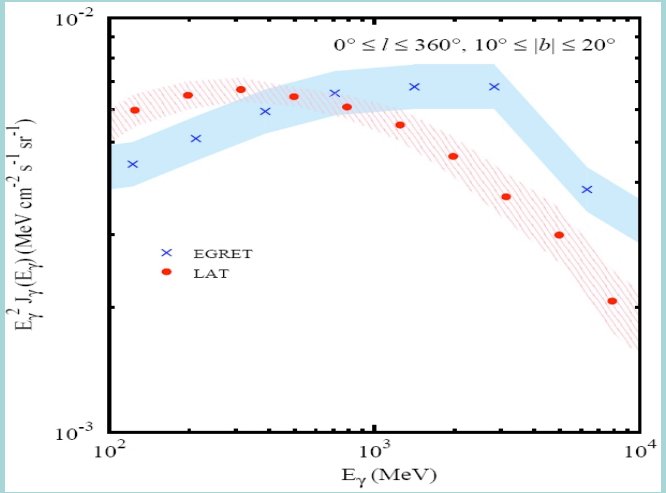




Medium Latitude Emission

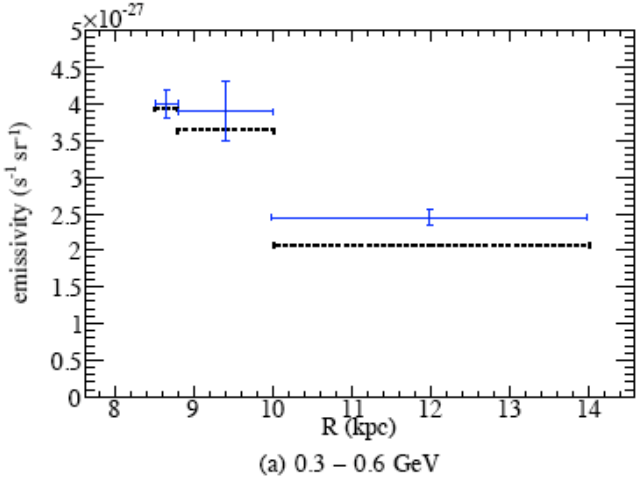
- $10^o < |b| < 20^o$
  - Local emission
    - Local CR density
  - Few sources
- Observed spectrum can be described by local CR density
  - Inconsistent with EGRET
    No "GeV excess"
  - Instrumental background



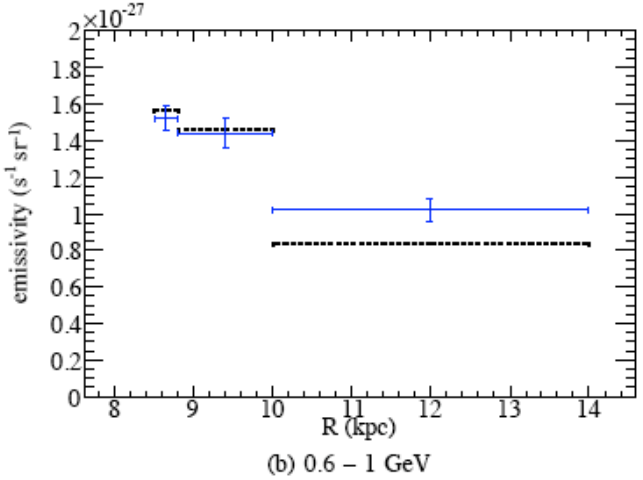


Porter et al. 39th ICRC, 2009

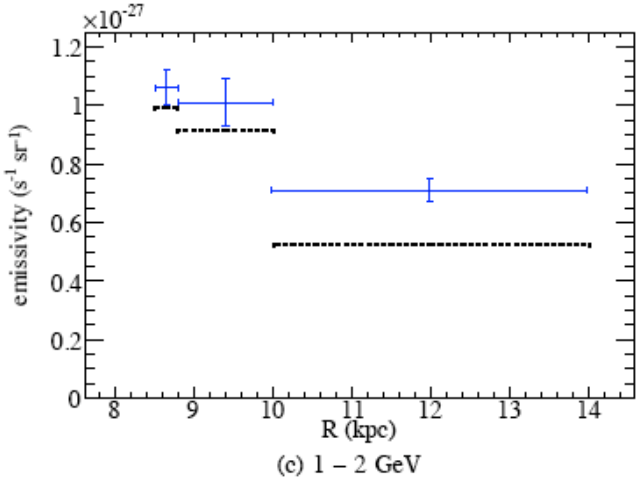
Emissivity vs. R_{Gal}



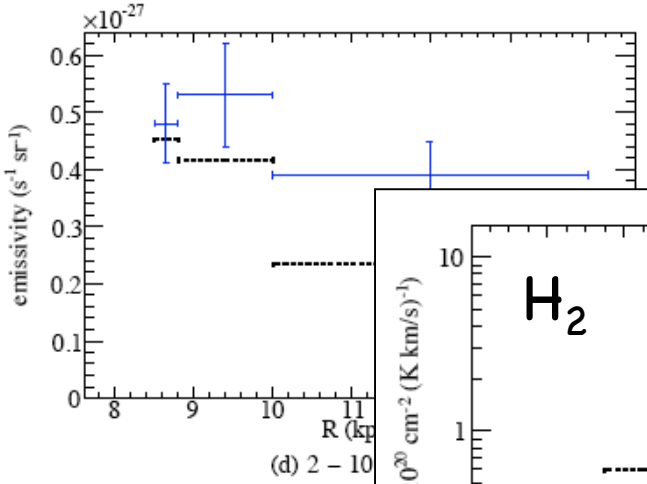
(a) 0.3 – 0.6 GeV



(b) 0.6 – 1 GeV

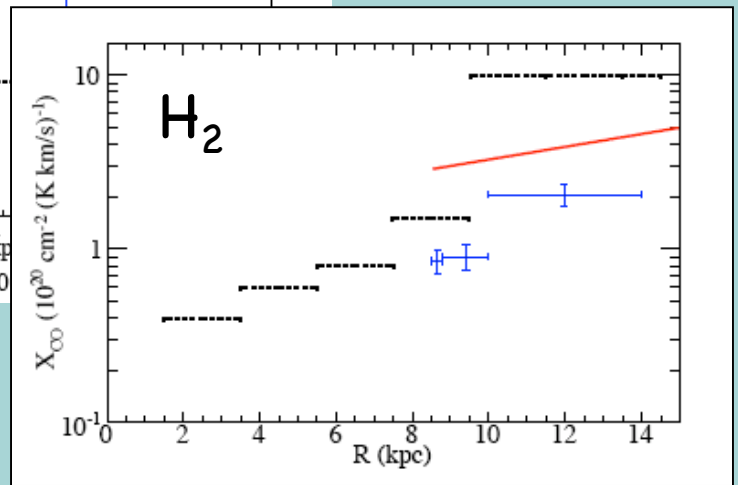


(c) 1 – 2 GeV



(d) 2 – 10

HI



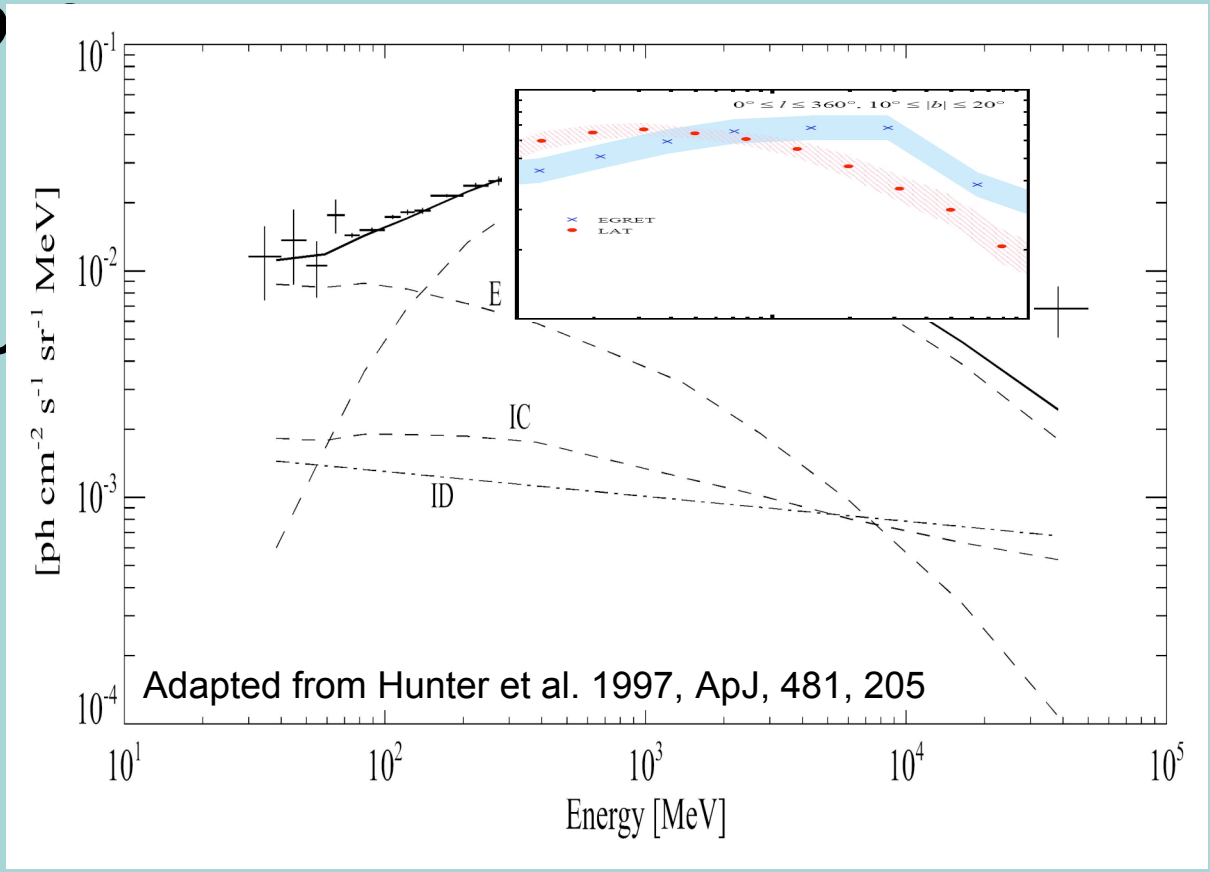
Tibaldo & Grenier, 2009 39th ICRC

Summary

- Diffuse Emission is
  Bright and Highly Structured
- Resolving the ISM?
  - Gamma-ray resolution is similar to HI and CO resolution
  - Small (nearby?) clumps of matter
    Look like point sources:
    if CR density is underestimated, or
    matter density is underestimated
- Entering a new phase of gamma-ray analysis

EGRET GeV Excess

- Origin: Comparison of EGRET data with diffuse model based on local CR spectra
- Many explanatio
  - Instrumental effect
  - Local CR spectru average
  - Dark Matter



Instrumental Effect

- Strong circumstantial evidence
  - Anomaly is seen over the entire sky
  - Anomaly above 1 GeV
    Back-splash correction above 1 GeV
  - Anomaly is power law in energy
    Simple 'correction' fixes Vela
    spectral discrepancy
- Counter Arguments
  - Calibration at 1, 4, and 10 GeV