2nd Fermi Symposium, Poster P4 -139

Summary: Undetected sources make a contribution to the Galactic 'diffuse' emission at some level.
We describe a method to estimate or put limits on these, with illustrations using Fermi data.

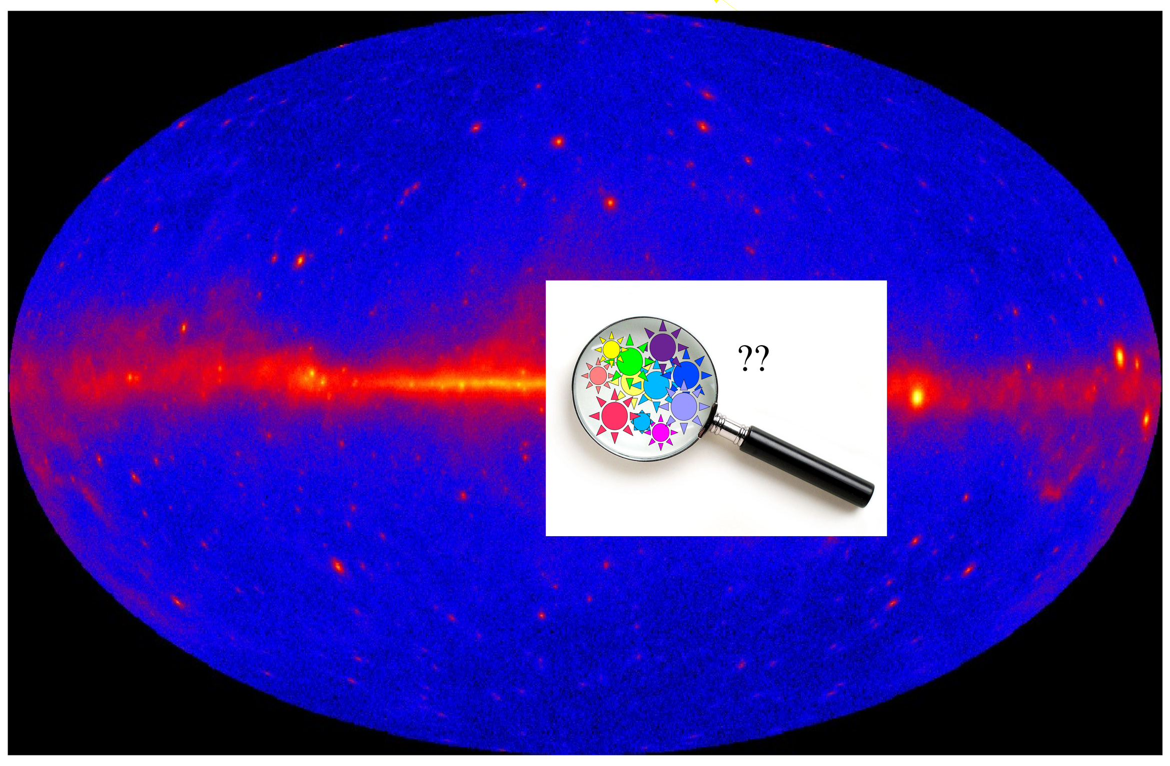
Fermi Gamma-ray Space Telescope

Contribution of source populations to the Galactic 'diffuse' emission

A. W. Strong, on behalf of the Fermi Large Area Telescope Collaboration

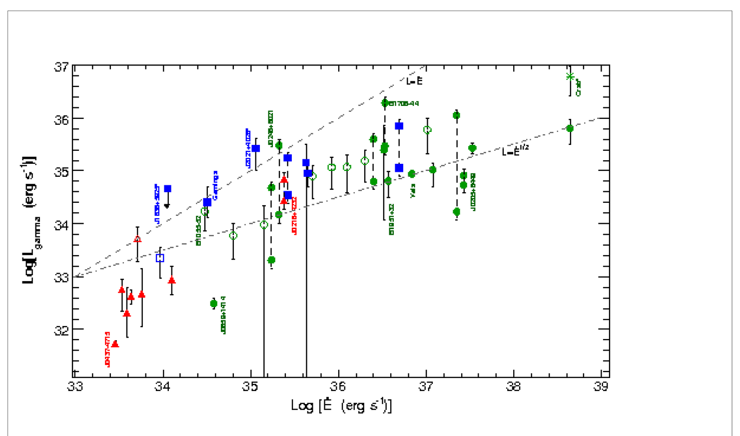
The gamma-ray emission from the Galaxy arises from both interstellar processes and compact sources. Only a small fraction of the sources in the Galaxy have been (or will be) detected by the Fermi Large Area Telescope: the most luminous and the nearest ones. At some level the interstellar and source emission become observationally indistinguishable, and explicit modelling is required. The analysis of Galactic 'diffuse' emission with Fermi naturally concentrates on the interstellar component associated with cosmic rays, gas and interstellar radiation fields, but estimates of the contribution from undetected source populations are still essential when comparing models with data.
We describe a simple population-synthesis approach which allows a general study to be made without invoking details of the nature of the sources. The model populations are required only to be consistent with constraints from current Fermi source lists, and from the 'diffuse' emission itself. Estimates of the contribution from undetected sources are then possible. Upper limits can be set on the luminosity function of dim source populations which could contribute to the diffuse emission while remaining undetected.

In this poster we just illustrate the method on Fermi data without giving detailed conclusions



Method: Strong 2007, *Ap. Sp. Sc.* 309, 35, there applied to EGRET with predictions for Fermi

Ingredients of source population synthesis
Luminosity function – power law L^{-s} e.g. s = 1.5, between limits
eg 10^{36}-10^{39} γ s^{-1} >100 MeV high luminosity population, pulsar, PWN, SNR-like
(Fermi pulsars: 10^{32}-10^{36} erg s^{-1}= 6 10^{35}-6 10^{39} γ s^{-1})
10^{31}-10^{35} γ s^{-1} low luminosity populations, unknown types
Space density e.g. n = 50 – 10^6 kpc^{-3}
Spectrum - e.g. pulsar-like. Here use simple power-law $E^{-\alpha}$ for illustration.
Galactic distribution – e.g. from pulsars, SNR
Method : Monte Carlo simulation with oversampling to suppress fluctuations.
Construct (differential) source counts N(S) and spectra of sky regions

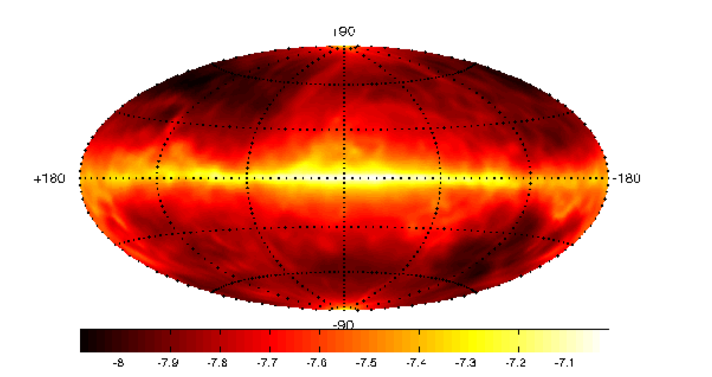


1st Fermi Pulsar Catalogue: Abdo etal 2009

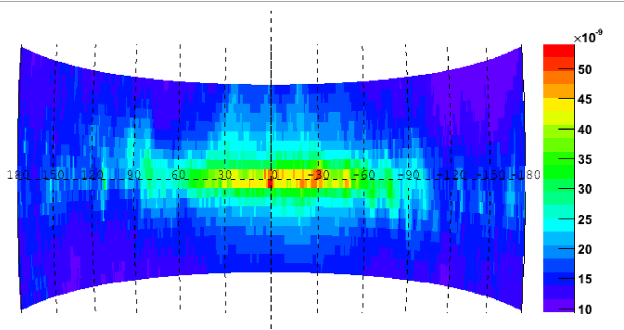
Observational constraints
Fermi 1st year catalogue (Fermi-LAT Collaboration, in preparation)
luminous sources : aim to reproduce N(S)
low-luminosity sources : just don't overshoot N(S), anywhere on the sky !
Spectra and maps of 'diffuse' emission constrain the parameters of populations

Large numbers of weak sources can hide, but are limited at low luminosities by isotropic populations which would be detected.
(cf Milky Way visual appearance vs naked-eye stars).
Typical estimate for γs : source populations ->10% of diffuse but very uncertain
..... how many *could* be lurking there ?
Reminder: the Galactic 'diffuse' 10-50 keV X-ray emission is made up of millions of stellar-type sources (Revnivtsev et al. 2009, Nature 458, 1142)

We do not attempt detailed physical modelling such as that for pulsars by Gonthier etal (2008, AIPC 968,112) or Faucher-Giguere & Loeb(2009, arXiv:0904.3102).
The approach is more generic, allowing for unknown populations, while being guided by known populations for plausible parameters.



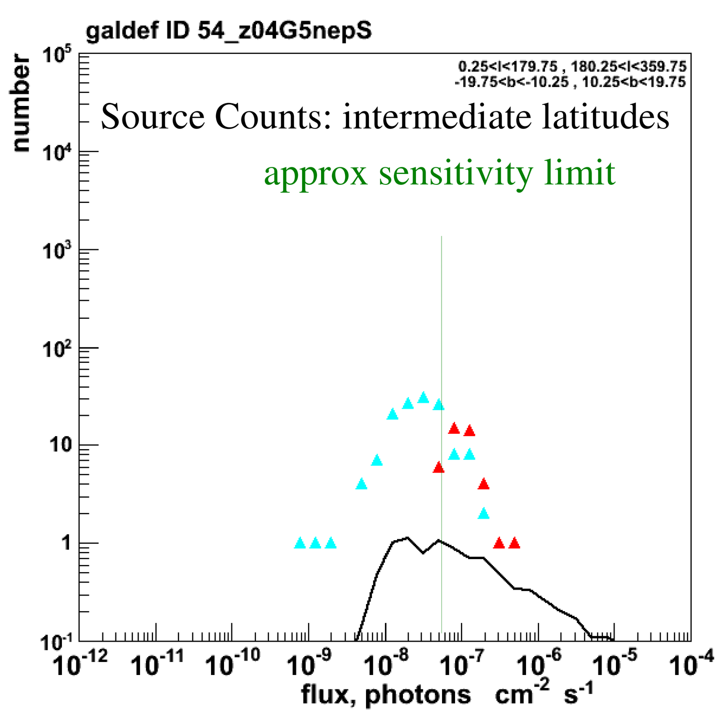
6 month pulsar sensitivity limit (>100 MeV)
Dimmest =8 10^{-8} cm^{-2} s^{-1} (gamma selected),
(cf 1.4 10^{-8} radio selected)
1st Fermi Pulsar Catalogue, Abdo et al 2009

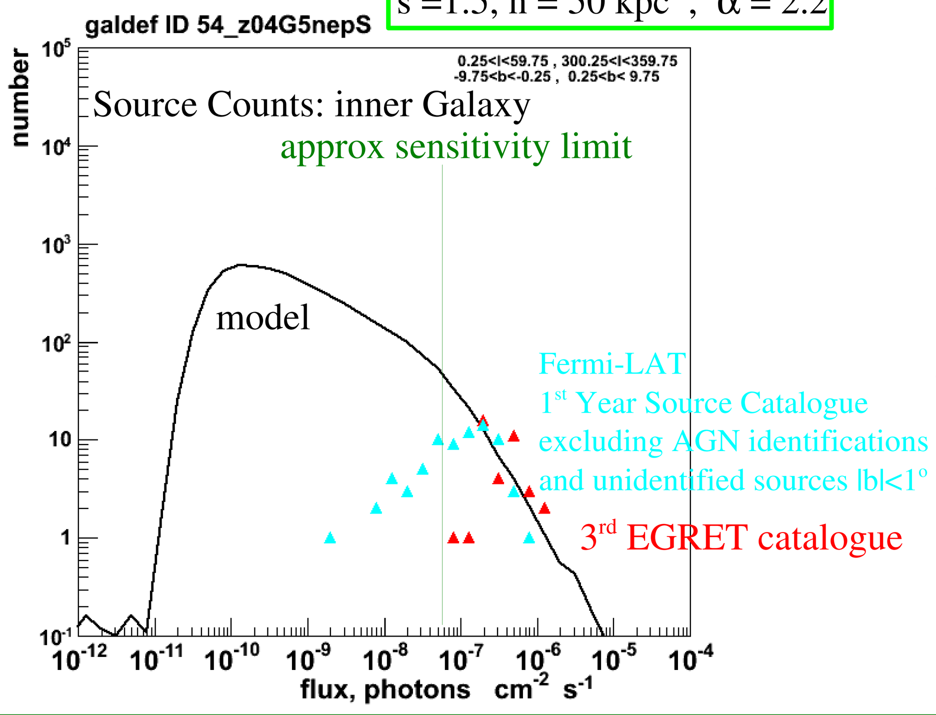


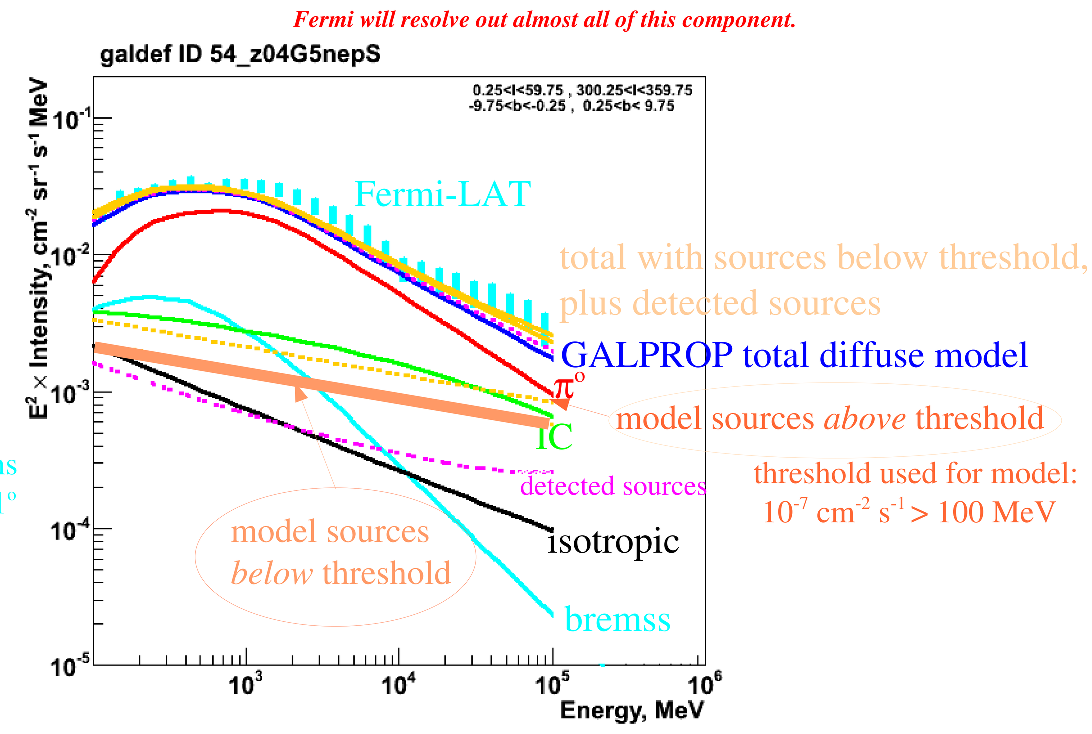
Fermi 1st year catalogue sensitivity limits (> 100 MeV) (approximate). Benoit Lott PRELIMINARY

10^{36}-10^{39} γ s^{-1} >100 MeV
s =1.5, n = 50 kpc^{-3}, α = 2.2

1. A luminous 'pulsar-like' population giving 5% of diffuse emission from sources below threshold
Fermi will resolve out almost all of this component.



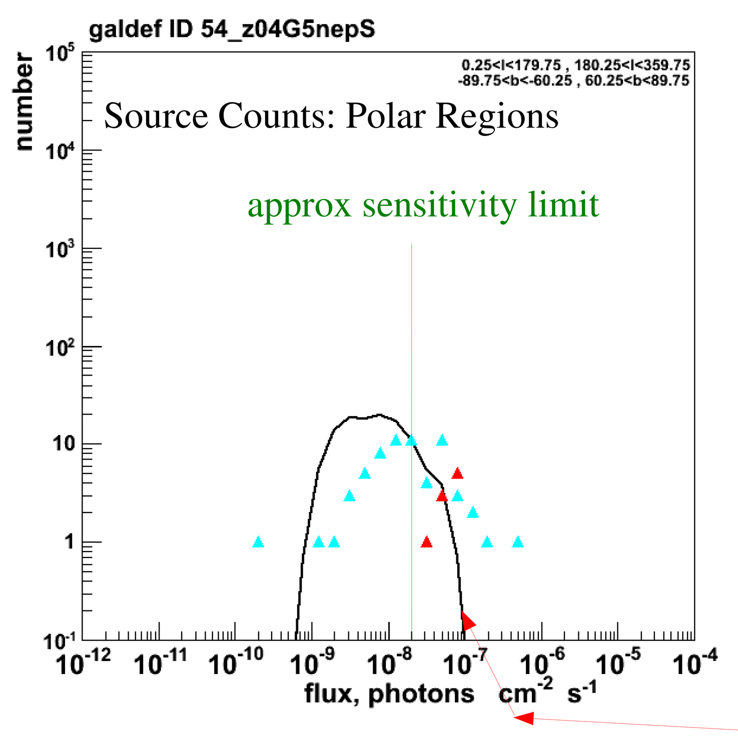


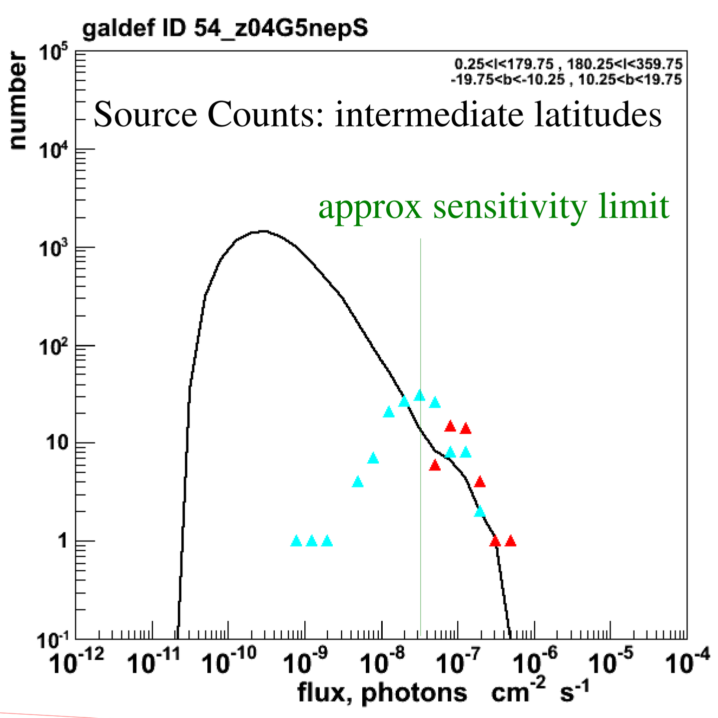


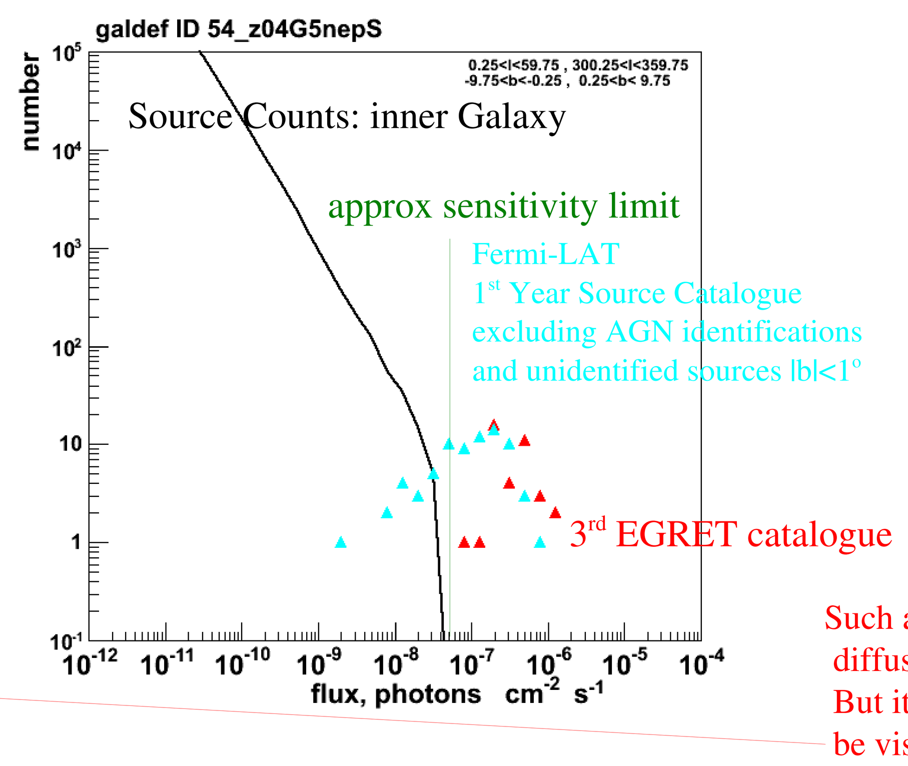
N(S) = number of sources in (logarithmic) bin of S

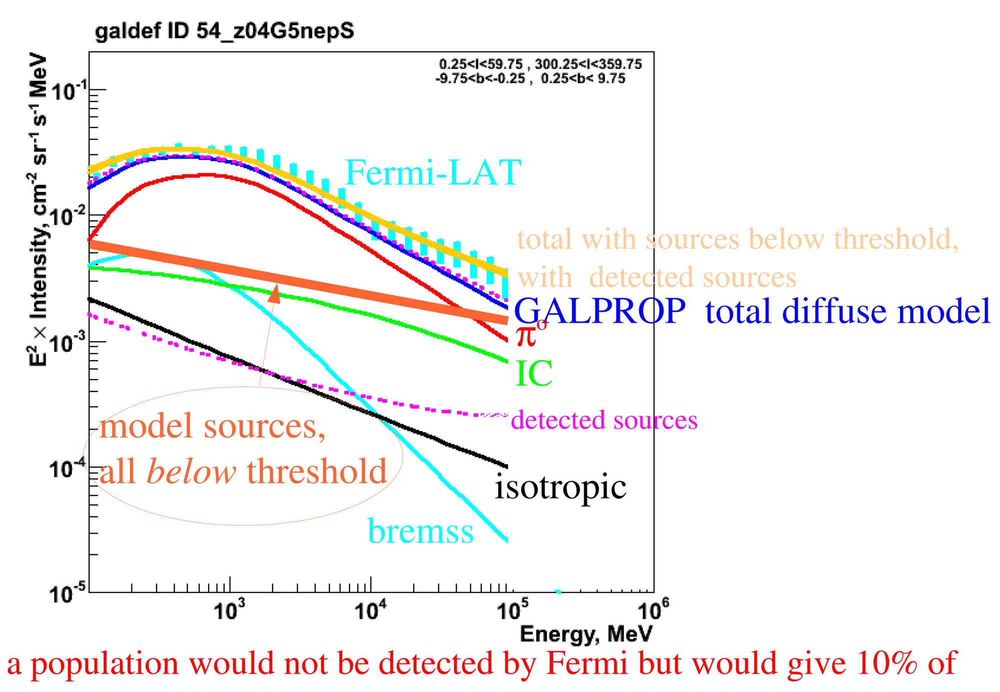
10^{34}-10^{35} γ s^{-1} >100 MeV
s = 1.5, n = 5 10^4 kpc^{-3}, α = 2.2

2. An 'invisible' population of dim sources all below detection threshold









Such a population would not be detected by Fermi but would give 10% of diffuse emission due to the large space density of sources.
But it could NOT be much larger than this since then then it would be visible as an isotropic source population at high latitudes.

General considerations.

By simple geometrical arguments (Strong 2007) it follows that the flux S_{max} of the brightest (= closest) source on the sky in a population of sources each with luminosity L producing a given total flux at the observer, scales roughly as S_{max} α $L^{1/3}$. This is illustrated by the *order-of-magnitude* estimates in the Table on the right.

Weak populations making 'diffuse' emission are difficult to 'hide' since their proximity compensates their small luminosity quite effectively, and the flux of the brightest source decreases only slowly with L.
Therefore source counts can give good constraints on the possible populations present in the 'diffuse' emission. Too many of them will fill the sky with detectable sources !

The calculation also shows that solar-type stars (inverse Compton) make a negligible contribution as a source population.

Order-of-magnitude estimates of properties of source populations, for illustration.

Type	Luminosity γs^{-1} >100 MeV	Space density kpc^{-3}	Emissivity cm^{-3} sr^{-1}	Nearest source distance pc	Nearest source flux >100 MeV cm^{-2} s^{-1}
pulsars	10^{37}	10^{2}	10^{-26}	200	2 10^{-6}
unknown	10^{34}	10^{4}	10^{-27}	50	2 10^{-7}
unknown	10^{31}	10^{6}	10^{-28}	10	10^{-8}
MS Stars	10^{21}	10^{8}	10^{-35}	2	10^{-18} (based on Sun)
Sun	3 10^{21}			1 AU	10^{-6} inverse Compton
Interstellar			10^{-26} (H atom)$^{-1}$		Fermi, CR+ISM models

Facit:
With the sensitivity of Fermi is will be possible to determine the contribution of luminous populations, and with a low threshold only a few percent of their contribution will remain unresolved.
It will also be possible place strict limits on the contribution of low-luminosity populations.
This type of modelling is essential for interpreting the diffuse interstellar emission since sources certainly contribute at some level and we have to be prepared to account for them. When the diffuse model departs from the observations it is necessary to address whether this is a defect in the model or the emission from such sources.

ALL RESULTS / PLOTS
PRELIMINARY