Diffuse Gamma Rays from External Galaxies

Vasiliki Pavlidou & Brian Fields
University of Illinois at Urbana-Champaign
Outline/Motivation

- **Which gamma rays?**
  \[ p_{CR} + p_{ISM} \rightarrow p + p + \pi^0 \]
  \[ \downarrow \]
  \[ \gamma + \gamma \]

EGRET all-sky map above 100 MeV
(EGRET team)

- **Local Group galaxies: Detection as point sources by EGRET / GLAST**

- **Collective contribution from all galaxies to the diffuse gamma-ray background**
Single Galaxy Calculation

- *Gamma-ray emissivity proportional to:*
  - Cosmic-ray flux
  - Number of targets

- Perform calculation for each LG galaxy...

  - Assume $\propto$ supernova rate (normalize to Milky Way)
  - Obtain from observed gas content
## Detectability of LG Galaxies

<table>
<thead>
<tr>
<th>Galaxy</th>
<th>“Best Guess” Prediction (10^{-8} \text{ photons cm}^{-2}\text{s}^{-1})</th>
<th>EGRET Value/Limit (10^{-8} \text{ photons cm}^{-2}\text{s}^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMC</td>
<td>11</td>
<td>14.2 ± 2.2 (Hartman et al 1999)</td>
</tr>
<tr>
<td>SMC</td>
<td>1.7</td>
<td>&lt; 4 (Lin et al 1996)</td>
</tr>
<tr>
<td>M31</td>
<td>1.0</td>
<td>&lt; 1.6 (Blom et al 1999)</td>
</tr>
<tr>
<td>M33</td>
<td>0.11</td>
<td>---</td>
</tr>
</tbody>
</table>

Associated uncertainty: ~ factor of 2
(dominate by uncertainty in MW SNR)

GLAST expected sensitivity: 0.2 \times 10^{-8} \text{ photons cm}^{-2}\text{s}^{-1}
(for a 5\sigma detection after a 2-yr survey)

Pavlidou & Fields (2001)
GLAST Prospects

- Once measured, gamma-ray fluxes of LG galaxies can give cosmic-ray fluxes -> CR observations in extragalactic environments

- Once multiple galaxy detections exist, can test assumptions of model w/o inference to MW

- Are energy spectra consistent w/ each other?
Guaranteed Background Sources

- Normal galaxies, Blazars: only identified extragalactic sources detected by EGRET

- More exist that are unresolved ⇒ guaranteed to make contribution to diffuse gamma-ray background

- All other proposed background sources constrained by (observed - guaranteed) background
Multiple Galaxy Calculation

gamma-ray flux of typical galaxy higher in the past because:

1. *Star formation rate higher*  
   ⇒ more supernovae  
   ⇒ larger cosmic ray flux

2. *Smaller fraction of baryons confined in stars*  
   ⇒ Larger gas fraction  
   ⇒ More targets available

use *cosmic star formation rate* to calculate both effects.

normalize gamma-ray luminosity *and spectrum* to (observational) MW data.

Cole et al 1991
Results/Comparison with EGRET

- “guaranteed” 2-component model for gamma-ray background: normal galaxy contribution + blazar contribution (Stecker & Salamon 1996)

- Relative normal galaxy contribution: highest at ~ 1GeV (about 1/3 of summed spectrum)

Pavlidou & Fields (2002)
GLAST Prospects

GLAST will test the 2-component model:
- will resolve many more blazars but very few new normal galaxies
  ⇒ relative blazar contribution reduced
  ⇒ will detect normal galaxy peak at ~ 1 GeV
Conclusions

- **GLAST will detect LMC, SMC, M31, maybe M33**
  - CR physics in extragalactic environments

- Normal galaxy contribution to extragalactic background: varies with energy, maximum at ~ 1GeV, ~ 1/3 of total

- **GLAST will test if EGRET-measured background is mostly due to (a) unresolved point sources (blazars) or (b) truly diffuse sources (e.g. structure formation shocks)**

- If (a) is true, **GLAST might detect feature due to normal galaxies at ~ 1GeV**