Diffuse Gamma Rays from External Galaxies

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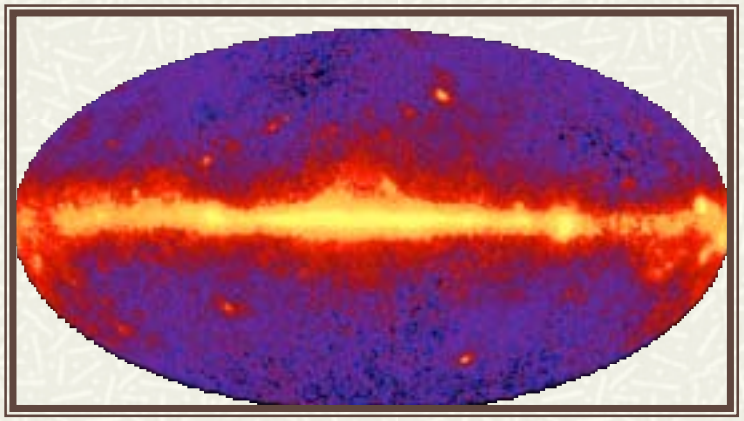
Outline/Motivation

- 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 → Assume ∝ supernova rate (normalize to Milky Way)
  - Number of targets → obtain from observed gas content
- Perform calculation for each LG galaxy…

Detectability of LG Galaxies

Galaxy	"Best Guess" Prediction (10^{-8} photons $cm^{-2}s^{-1}$)	EGRET Value/Limit (10^{-8} photons $cm^{-2}s^{-1}$)
LMC	11	14.2 ± 2.2 (Hartman et al 1999)
SMC	1.7	< 4 (Lin et al 1996)
M31	1.0	< 1.6 (Blom et al 1999)
M33	0.11	---

Pavlidou & Fields (2001)

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

GLAST expected sensitivity: 0.2×10^{-8} photons $cm^{-2}s^{-1}$
(for a 5σ detection after a 2-yr survey)

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 ⇒

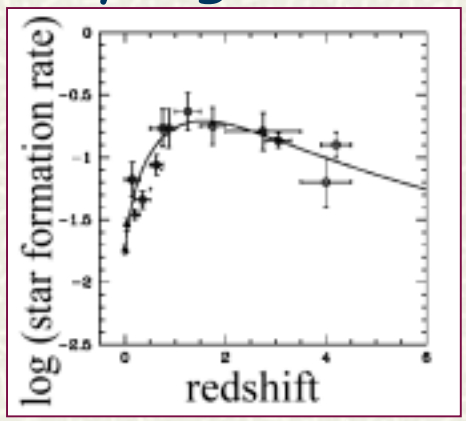
  guaranteed to make contribution to
  diffuse gamma-ray background

- 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



Cole et al 1991

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

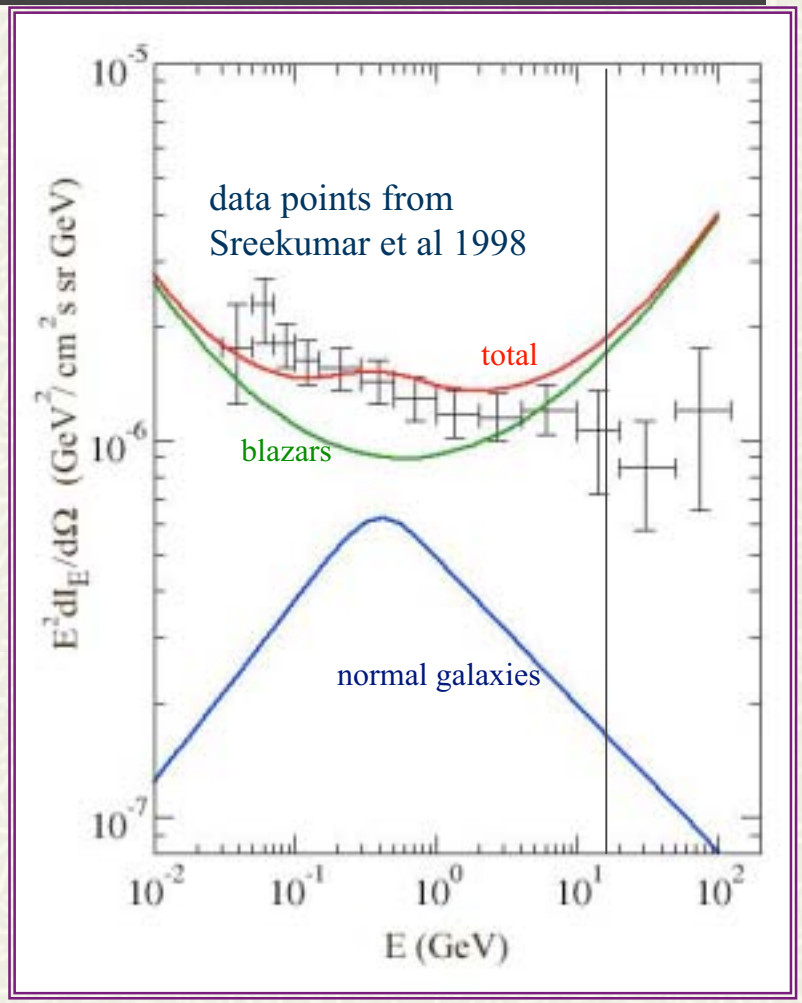
use *cosmic star formation rate* to calculate both effects.

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

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)

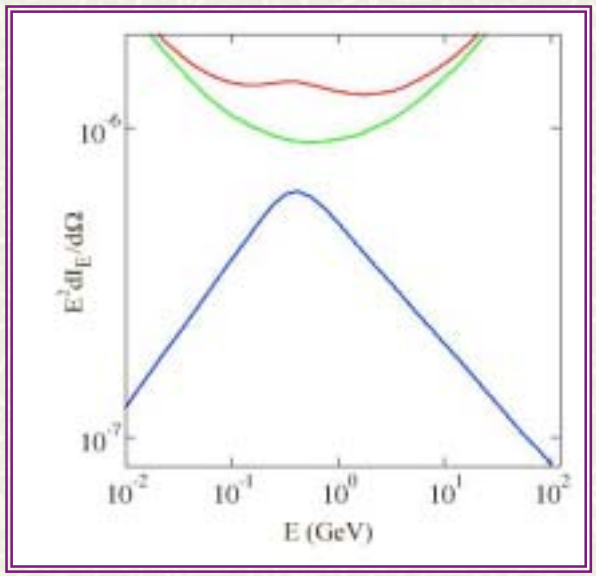
GLAST Prospects

GLAST will *test the 2-component model:*

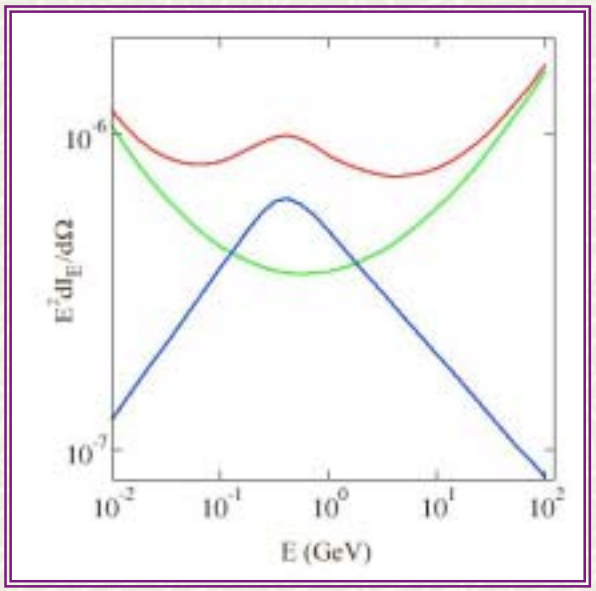
will resolve many more blazars but very few new normal galaxies

⇒ relative blazar contribution reduced

⇒ will detect normal galaxy peak at ~ 1 GeV



EGRET



GLAST

Conclusions

- GLAST will detect LMC, SMC, M31, maybe M33
  -> CR physics in extragalactic environments
- Normal galaxy contribution to extragalactic background: varies w/ 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