The background of the slide is a large, oval-shaped map of the sky in gamma rays. The map shows a prominent horizontal band of high intensity, representing the Galactic plane, with colors ranging from blue (low intensity) to red and yellow (high intensity). There are several bright, localized sources scattered across the sky, particularly in the upper and lower hemispheres. The map is overlaid with a thin yellow border.

*Diffuse Gamma Rays:
A Model-Independent Approach*

by

Tijana Prodanović

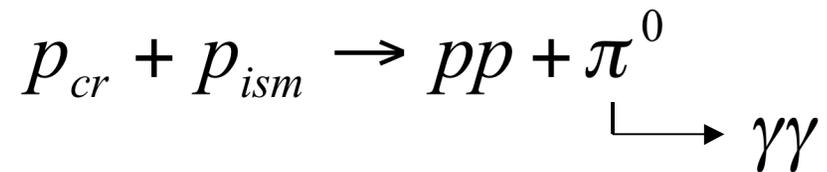
Brian D. Fields

University of Illinois at Urbana-Champaign

Outline

- Use model-independent ways of constraining both Galactic and extragalactic gamma-rays:
 - Shape of “pionic” gamma-ray spectrum
 - ${}^6\text{Li}$ -gamma-ray connection

‘Pionic’ Gamma Rays



- Distinctive spectrum – pion “bump”; peaks at $m_\pi/2$
(Stecker 1971; Dermer 1986)
- But no strong evidence for pion “bump”
- Can use the shape of the spectrum (Pfrommer & Enßlin 2003)
to find max “pionic” fraction

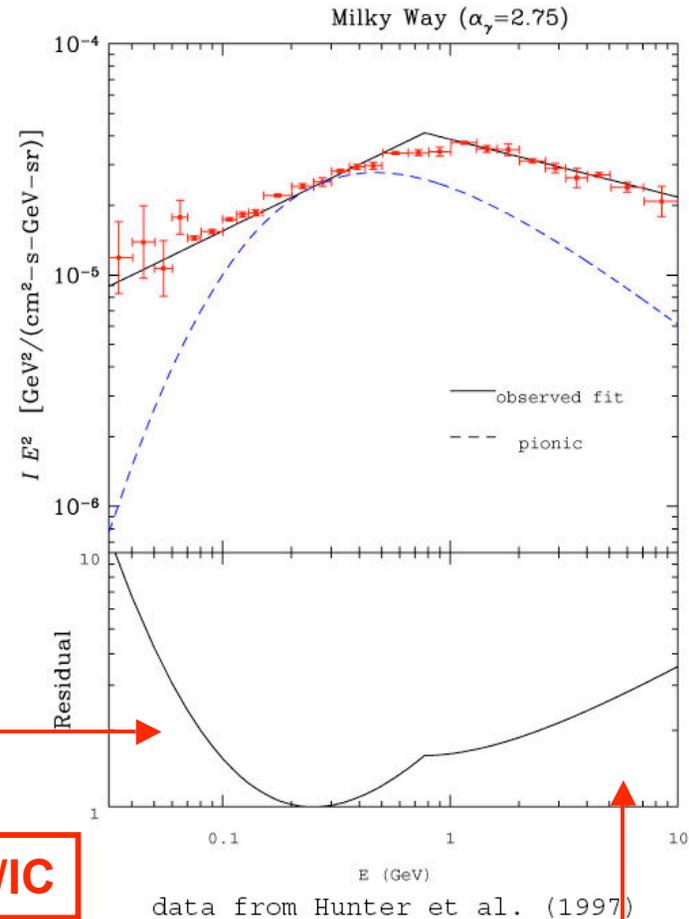
Galactic “Pionic” Gamma Rays

- Find max $I_{\gamma}^{(\pi)}$ so that “pion bump” stays below observed Galactic spectrum
- GCRs: $\phi_p^{\text{GCR}} \propto p^{-2.75}$
- Max “pionic” fraction

$$\Phi_{\gamma}^{(\pi)} / \Phi_{\gamma}^{\text{obs}} \sim 50\%$$

- But notice the residual!

Prodanović and Fields (2004a)

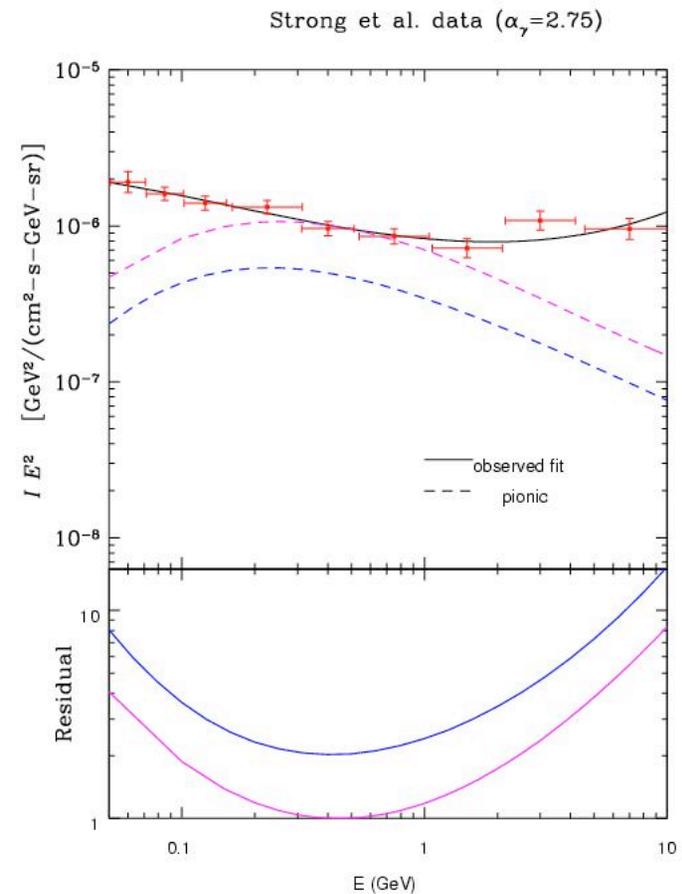


Brems/IC

July 15th ???

Estimating GCR “pionic” γ -rays from EGRB

- “Pion bump” not observed in EGRB data
- Maximize pionic spectrum so that it stays below the observed EGRB
- **GCRs** – accelerated in SNRs; use propagated spectrum $\phi_p(E) \propto (m_p + E)^{-2.75}$
- Integrate over the redshift history of **GCR** sources (cosmic star-formation rate)
- Max “pionic” fraction $\Phi_\gamma^{(\pi)} / \Phi_\gamma^{obs} \sim 75\%$



Fields and Prodanović (2005)

Estimating SFCR “pionic” γ -rays from EGRB

- **Structure Forming Cosmic Rays**

(A. Loeb talk; also see V. Pavlidou talk) — assume all come from strong shocks with spectrum (about the same source spectrum as for GCRs, but unlike GCRs it does not suffer propagation effects)

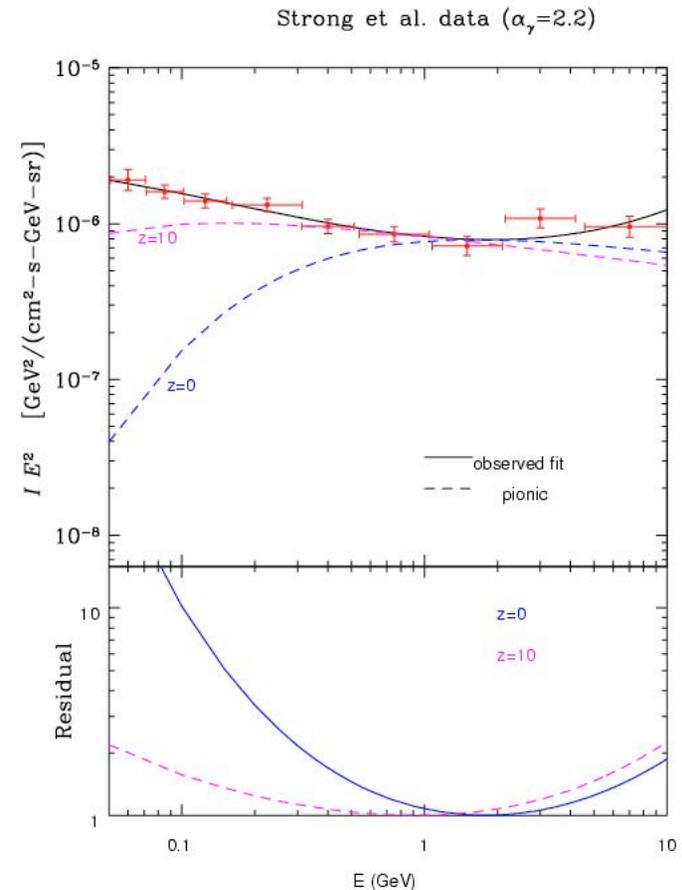
$$\phi_p(E) \propto p(E)^{-2.2}$$

- Assume all pionic γ -rays are from **SFCRs** and all come from single redshift (unlike for GCRs, history not known in this case)

- Max “pionic” fraction

$$z=0 \quad \Phi_{\gamma}^{(\pi)} / \Phi_{\gamma}^{obs} \sim 40\%$$

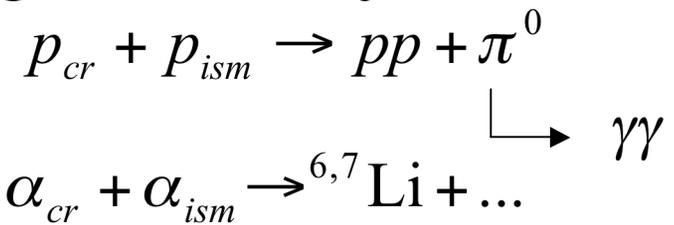
$$z=10 \quad \Phi_{\gamma}^{(\pi)} / \Phi_{\gamma}^{obs} \sim 80\%$$



Prodanović and Fields(2004a)

Li- γ -ray Connection

- Any cosmic-ray source produces both gamma-rays and lithium



- Connected essentially with ratio of reaction rates

$$\frac{\gamma}{\text{Li}} \propto \frac{1}{y_{\alpha,ism} y_{\alpha,cr}} \frac{\langle \sigma_{\gamma} \rangle}{\langle \sigma_{\alpha\alpha} \rangle} \quad (\text{Fields and Prodanović 2005})$$

- Li: local CR fluence
- γ : CR fluence across Universe
- Given one, constrain other

Results

- Use ${}^6\text{Li}$ since it is *only* made by cosmic rays
- Use ${}^6\text{Li}_{\text{Solar}}$, assume made by GCRs
 - $I_{\gamma,\pi}(> 0.1\text{GeV}) = 3.22 \times 10^{-5} \text{ cm}^{-2}\text{s}^{-1}\text{sr}^{-1}$
 - but *entire* observed EGRB (Strong et al. 2004)
 - $I_{\gamma}(> 0.1\text{GeV}) = 1.11 \times 10^{-5} \text{ cm}^{-2}\text{s}^{-1}\text{sr}^{-1}$
- What's going on?
 - MW flux higher than than average galaxy?
 - CR spectrum sensitivity (thresholds!; Li probes low E)
 - ${}^6\text{Li}$ not from GCRs?

Furthermore...

- Problem (?):
SFCR → pregalactic ${}^{6,7}\text{Li}$ → confused with Big Bang Li
- From observed EGRB estimate maximal pionic contribution, assign it to SFCRs → estimate Li_{SFCR} production

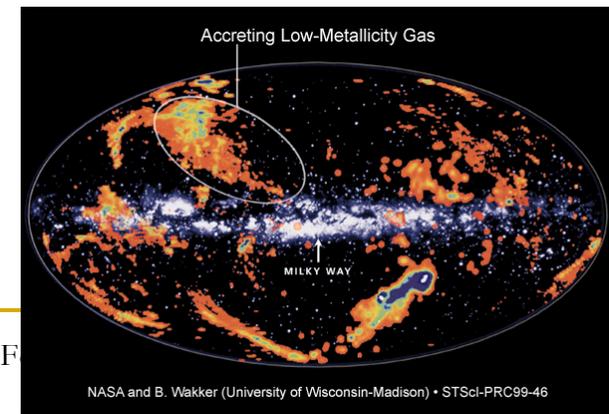
$$0.3 \leq \frac{\text{Li}_{\text{SFCR}}}{\text{Li}_{p,\text{BBN}}} \leq 4.0$$

(depending on the assumed redshift)

Testing The “Knee”

- Muraishi et al. (2005):
Extragalactic CRs (source spectrum $\sim E^{-3}$)
modulated by the galactic wind may produce the
“knee” (3×10^{15} eV) in CR spectrum
- But *any* source of CRs will affect ${}^6\text{Li}$!
- Thus one can use ${}^6\text{Li}$ (and in turn gamma rays) to
constrain contribution of any CR source to the
“knee”, or vice versa
- HVC Li : constrains LG SF CRs

Prodanović and Fields (2004b)



Conclusion

- Galactic GeV gamma-rays a mystery!
- No clear evidence to pionic component
- Model-independent way of testing gamma rays: ${}^6\text{Li}$ - γ connection
- GCR-made ${}^6\text{Li}$ requires too big EGRB: potential problem?
- ${}^6\text{Li}$ a powerful probe even at TeV energies
- Future: *GLAST*
 - *Better EGRB*
 - *Pion feature?*

Structure Formation Cosmic Rays

Miniati et al. 2000

- **Structure formation shocks** - cosmological shocks that arise from baryonic infall and merger events during the growth of large-scale structures
- Diffusive shock acceleration mechanism
 - => **structure formation cosmic rays**
- Mostly protons and α -particles

