GODDARD SPACE FLIGHT CENTER

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The Unresolved Star-forming Galaxy Component of the Extragalactic Gamma-ray Background*

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1. Introduction

As in the Milky Way, cosmic-ray interactions with interstellar gas in star-forming galaxies can result in the production of gamma-ray emission. As such, they could comprise a significant contribution to the extragalactic gamma-ray background (EGB) as measured by the *Fermi* Large Area Telescope (*Fermi*-LAT) and the Energetic Gamma-ray Experiment Telescope (EGRET). The question of the contribution of star-forming galaxies to the EGB is a matter of their star formation rate (SFR), their gas content, and how they evolve throughout cosmic history.

2. Objectives

To model the star-forming galaxy contribution to the EGB as measured by both *Fermi* and EGRET. Since the gamma-ray emission of a star-forming galaxy is mostly dominated by π^0-decay, its gamma-ray luminosity is largely determined by its SFR and gas mass. As such, we seek a relation between the gamma-ray luminosity of a galaxy at a given epoch and its SFR and neutral hydrogen (H_2 + HI) gas mass.

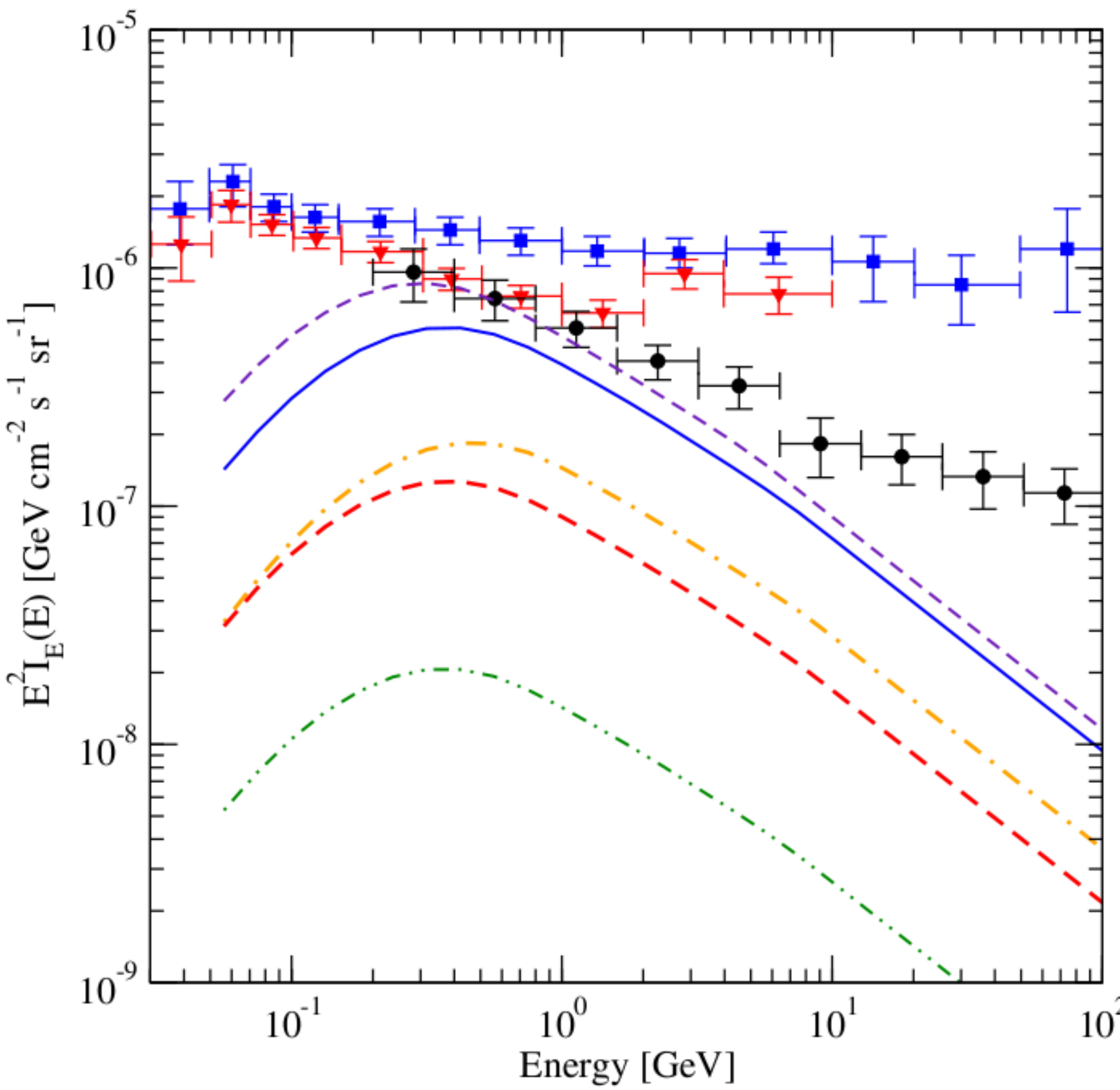
3. Method

The star-forming galaxy contribution to the EGB is given by

$$I_E(E_0) = \iint F_{ph}(E_0,z,L_\gamma)\, n(L_\gamma,z)\, dV_{com}/d\Omega\, dL_\gamma,$$

where $F_{ph}(E_0,z,L_\gamma)$ is the galaxy gamma-ray spectrum, which depends on its SFR and its neutral hydrogen gas mass, and $n(L_\gamma,z)$ is the comoving number density of star-forming galaxies.

The key ingredients for determining the star-forming galaxy contribution to the EGB (namely the galaxy SFR and gas mass) are subject to a considerable degree of uncertainty. As such, rather than focusing on a particular model, we employ three different



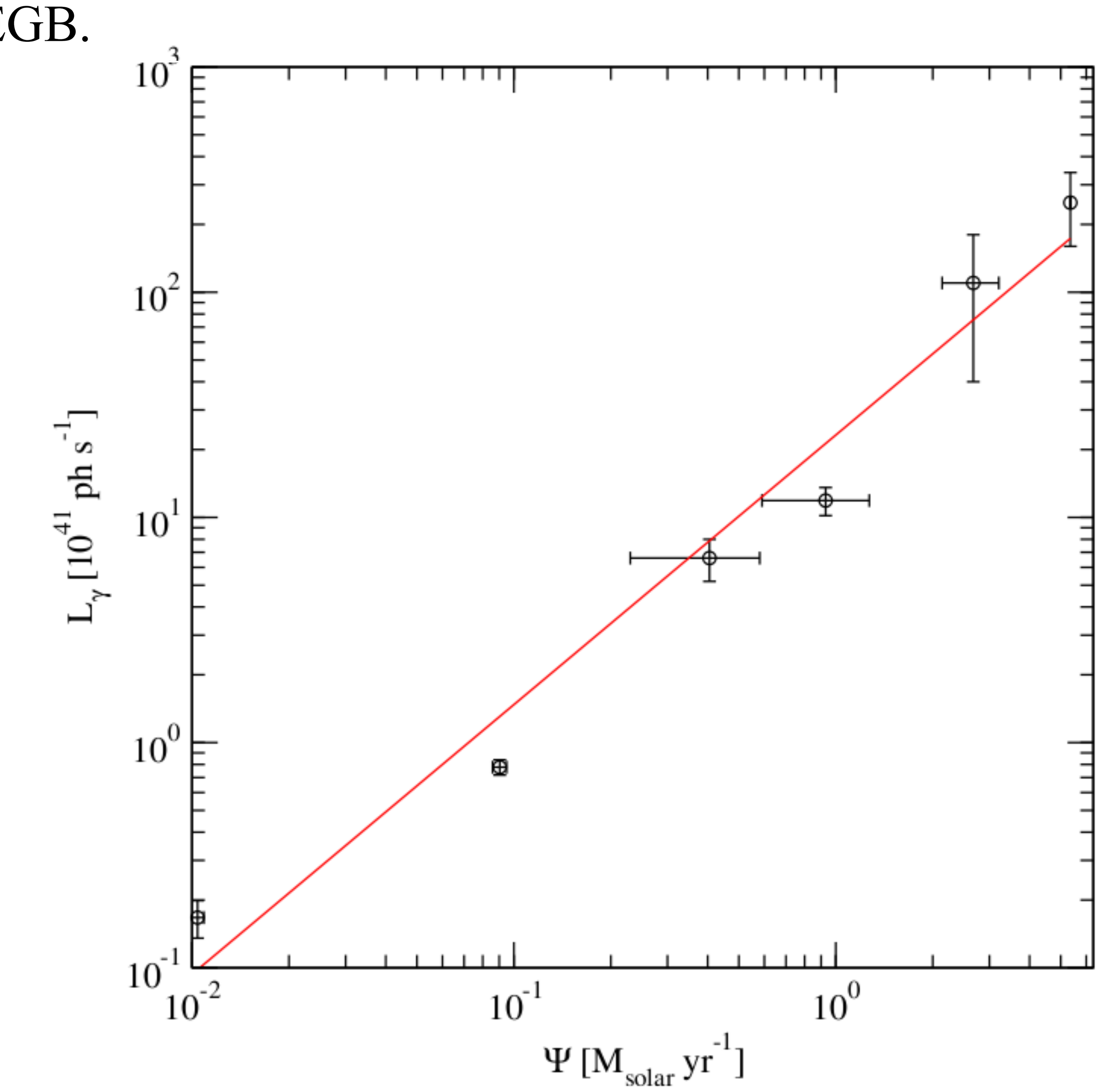
Star-forming Galaxy Contribution to the EGB

strategies to model the star-forming galaxy contribution to the EGB:

- **Relate the galaxy gas mass to its stellar mass assuming a gas fraction that evolves with redshift (red).** We employ the Schecter parameters of the stellar mass functions of Elsner et al. (2008) and the evolving gas fraction of Papovich et al. (2010).
- **Relate the galaxy gamma-ray luminosity to it SFR, which, in turn, is related to an observable for which there is a redshift distribution (star-forming - blue, yellow; starburst - green)**. We find a correlation between galaxy gamma-ray luminosity and SFR, which, in turn, is correlated with the IR luminosity. Thus, we can relate the galaxy gamma-ray luminosity to its IR luminosity (see also M. Ajello talk). We use the IR luminosity functions of Hopkins et al. (2010) for both star-forming and starburst galaxies.
- **Relate the cosmic density of gas in star-forming galaxies to the cosmic star formation rate. Relate the cosmic density of gas in star-forming galaxies to the cosmic star formation rate (purple).** Observations indicate that molecular hydrogen (H_2) traces the star formation in a galaxy. However, there is no direct correlation with atomic hydrogen (HI). Eventhough the giant molecular clouds that form stars must be created from the HI gas, the process of formation remains, as yet, unclear. Thus, for this approach, we emply the simple assumption that the amount of HI in star-forming galaxies is, *on average*, comparable to that of H_2 within the star-forming region.

4. Results

Depending on the model, star-forming galaxies can contribute substantially to the EGB. However, the spectrum of their contribution cannot explain the spectrum of the EGB as measured by *Fermi* and EGRET. Starburst galaxies contribute very little to the EGB.



Gamma-ray Luminosity vs. SFR for Fermi-detected Star-forming Galaxies

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