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Constraining the Cosmic Star Formation Rate with the MeV Background

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The Cosmic Gamma-ray Background (CGB) in the MeV regime has been measured with COMPTEL [12] and SMM [9]. The origin of the CGB in this energy regime is believed to be dominated by gamma-rays from Type Ia supernovae. We calculate the CGB spectrum within the framework of FRW cosmology as a function of the cosmic star formation rate, SFR(z) [10]. Several estimates of the SFR(z) have been reported since the pioneering work of Madau et al. [5]. Here we discuss observational constraints on SFR(z) derived from models of the CGB. In particular, we consider the SFR obtained from Gamma-Ray Burst observations [6], which increases dramatically with redshift beyond z $\sim$ 1 in contrast to most estimates which saturate or show a mild increase with redshift. Gamma-ray bursts may be the most powerful tracers of star formation in the early universe and thus provide signposts of the initial epoch of element synthesis. The star formation rate implied by GRB statistics results in a gamma-ray background that matches the observations more closely than that inferred from other tracers of star formation. This may provide some support for the GRB/SFR-paradigm, which in turn promises a powerful diagnostic of star formation, and thus cosmic chemical evolution, from the era of Population III stars to the present.

1. The MeV Background

The CGB in the MeV regime has been studied by HEAO-1 A4 [2],SMM [9], and COMPTEL [12]. Supernovae (mostly of type Ia) are the dominant contributors in this energy regime [10]. We previously demonstrated that SNII [10],GRBs, and Cen A-like (FRI) radio galaxies (without density evolution [11]) can account for a few percent of the observed flux. Below $\sim$ 300 keV the contribution from Seyfert galaxies dominates (e.g.,[13]), while blazars dominate above $\sim$ 100 MeV [8], but see Scharf & Mukherjee [7] for a discussion of alternatives. Based on the known gamma-ray spectra of these sources one may expect a CGB spectrum that displays significant changes in spectral index or even gaps. The data (Figure 1) do not show a gap, but the spectral profile does undergo a transition from the Seyfert regime to the blazar regime. The predicted gamma ray flux from SNIa fills the intermediate energy band at the approximately right level, but the detailed spectral shapes at the Seyfert-SNIa and SNIa-blazar interfaces are not fully explained by existing theoretical models.

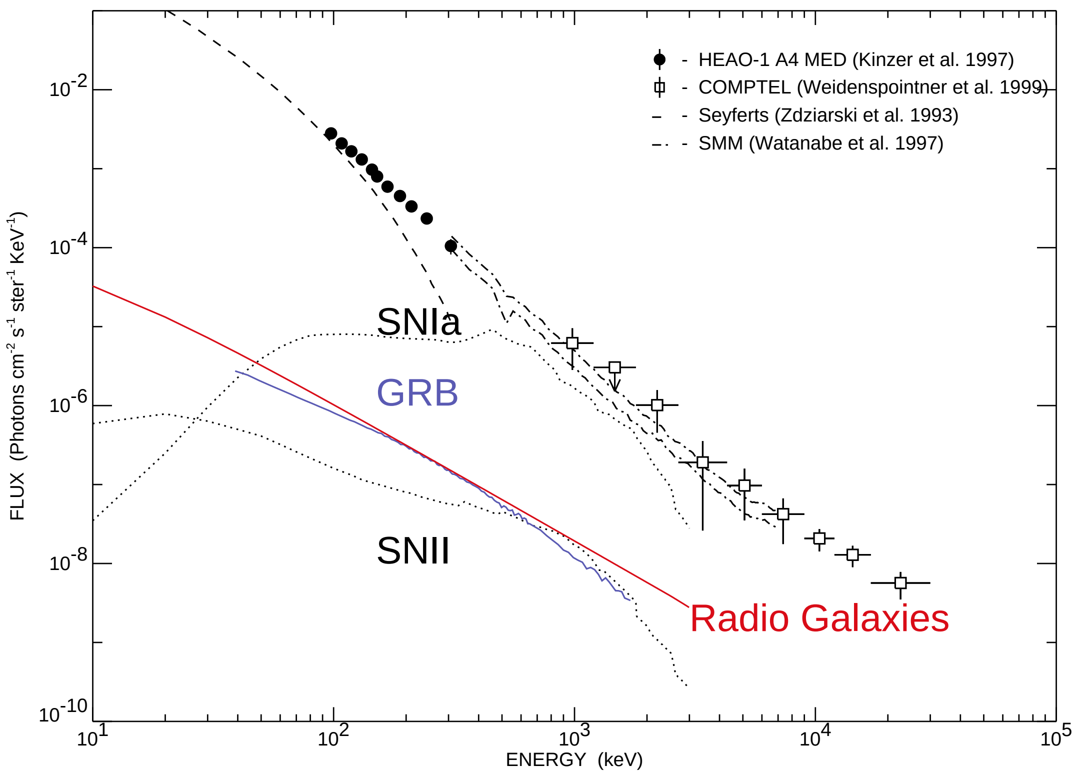

Figure 1. Observed MeV-CGB (HEAO-1 A4, SMM, COMPTEL). SNIa are the dominant contributors in this energy regime, while SNII, GRBs, and Radio galaxies contribute only a few % of the CGB flux (e.g., [11]).

2. Star Formation Rates

The CGB flux from SNIa depends on the cosmic Star Formation Rate (SFR), which is a sensitive function of redshift. The first published SFR(z) for z = 0 to 5 [5], now referred to as the "Madau Curve", was based on the Hubble Deep Field - North (HDF-N). The data revealed a rapid increase from z=0 to $z \sim 1$ by a factor of 20 or so, then a decrease for higher z. SNIa between z = 0 and z=2 contribute the bulk of the observed flux [10].

Several new estimates of SFR(z) have been published since the pioneering work of Madau. Some studies suggest a flat SFR after z = 1, others argue for a continued increase beyond $z \sim 1$. A recent study [4] using the Hubble Deep Field - South (HDF-S) suggests that the original Madau estimate misses a dominant fraction of the ultraviolet luminosity density of the universe at high redshift, and that the Madau curve "at redshifts $z < 2$ must be reduced by a factor of ~ 2". Their new SFR(z) increases from z =0 to 2 by a factor of only 2, but more rapidly above z = 2 (Figure 2). We re-calculated the CGB using the Lanzetta-SFR, and find that the CGB flux is lower by a factor of 3 (at 1 MeV) than the flux derived from Madau's rate (Figure 3). Because other possible contributors to the CGB, as mentioned above, account for only a few % of the flux, we can not match

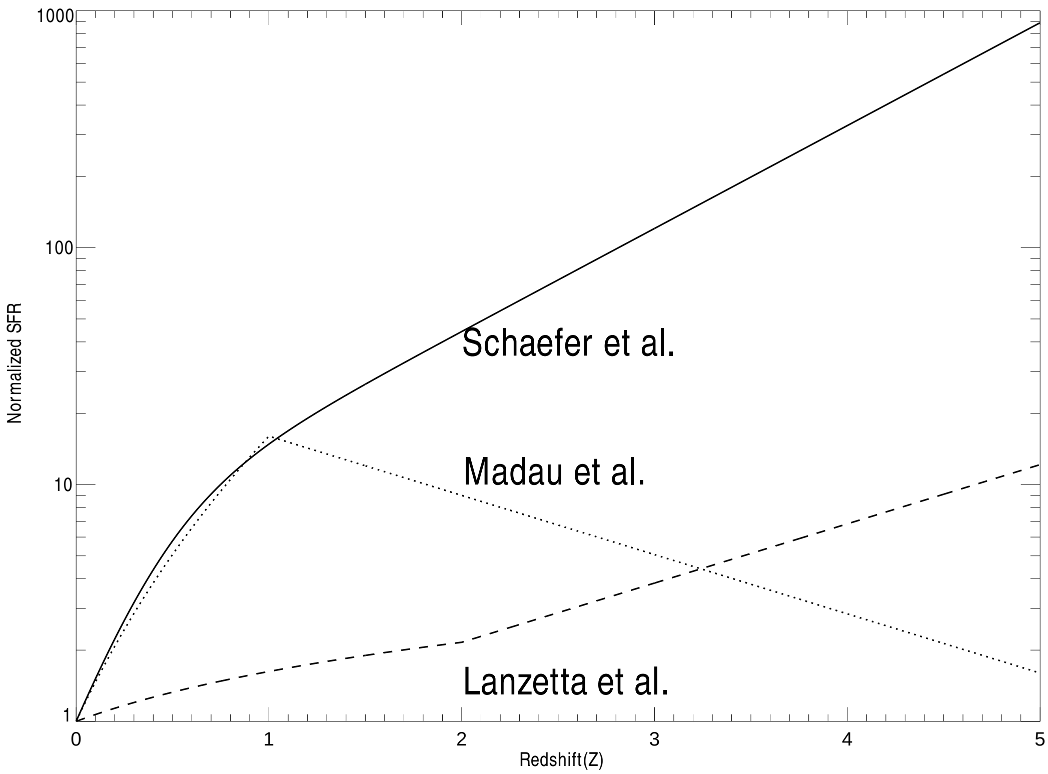

Figure 2. Cosmic star formation rate per comoving volume normalized to the present day rate density. The Madau-SFR(z) is contrasted with rates from Lanzetta *et al.*[4], and Schaefer *et al.*[6].The latter is derived from GRB observations.

the observed CGB with Lanzetta's SFR. Unless there is a class of not yet recognized contributors to the MeV background, the Lanzetta-SFR appears inconsistent with the observed CGB. However, the SFR derived by Lanzetta et al. is only a lower limit. To make the predicted flux agree with the observed CGB the cosmic stellar production rate must be significantly larger than implied by Lanzetta et al..

3. New SFR with CGB

We also investigate the SFR obtained from Gamma-Ray Burst observations [6], which increases dramatically with redshift beyond z > 1 (in contrast to most SFR estimates, which either saturate or decline for z > 1, see Figure 2). The CGB flux with the Schaefer-SFR not only matches the observed CGB flux in the MeV regime, but also reduces the apparent Seyferts-SNIa gap in the few 100 keV regime (Figure 3).

The number of gamma-ray bursts with measured redshifts is still too small to consider the GRB-SFR to be the most reliable method of determining the cosmic star formation rate. However, the fact that the CGB flux based on Schaefer's rate improves the match with the data does provide some additional support for the idea that GRBs trace the

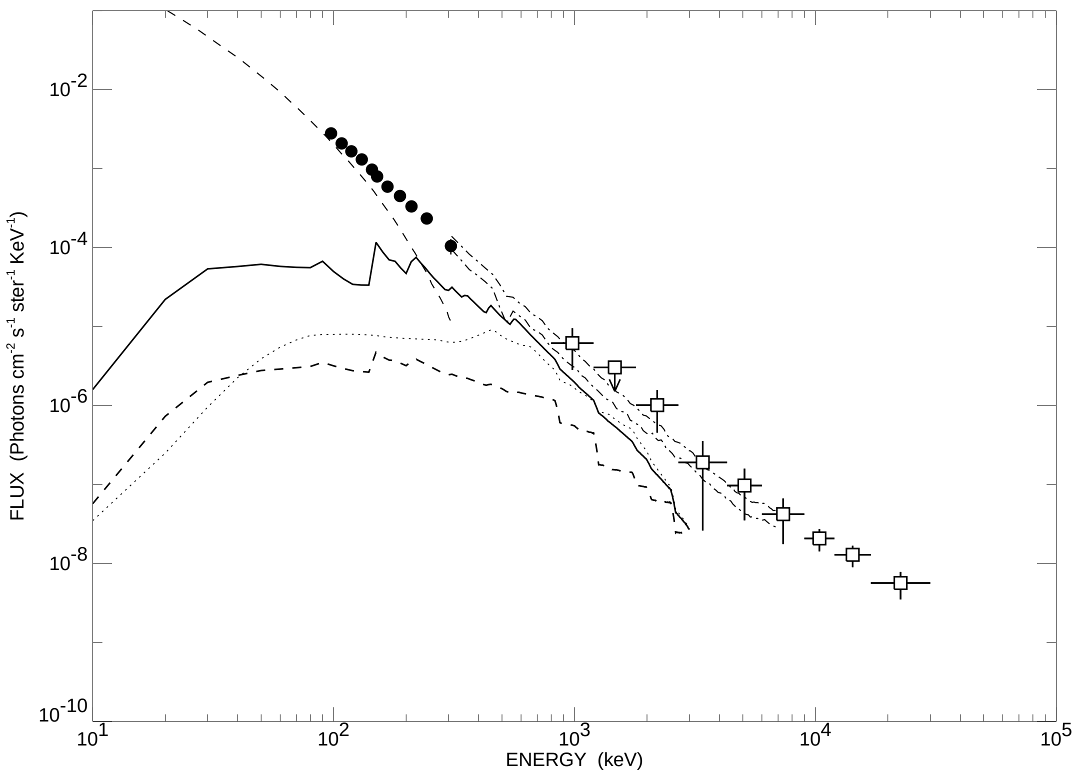

Figure 3. The CGB obtained with the Schaefer-SFR(z) based on GRB observations (solid line). Dotted/dashed lines are the CGB obtained with the Madau-SFR and Lanzetta-SFR, respectively. Data are the same as shown in Figure 1.The Schaefer-SFR produces a better match to the observed CGB.

formation of massive stars (e.g.,Heger et al. [1]) and thus provide a unique probe of the very high redshift universe (Lamb & Reichart [3]).

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