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A new model for the cosmic evolution of the IR-to-UV Background

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Abstract. High energy gamma ray photons propagating in the intergalactic medium are absorbed by UV/optical and IR background radiation (EBL) via pair production. Because of this phenomenon, blazars spectra should be (partially) absorbed at TeV energies. An accurate model of EBL could in principle give fundamental information on the intrinsic blazar emission mechanism. We present new calculations of the EBL from UV to FIR as a function of redshifts. Our semi-empirical model accounts for the light emitted by galaxies and AGNs and includes dust reprocessing. The emissivity of galaxies is modeled convolving the SEDs obtained by synthesis population models with reliable star formation rate estimates. Absorption by dust follows a wavelength dependent law. Our EBL model reproduces existing data at z=0.

Key words. Cosmology: cosmic background radiation

1. Introduction

The new generation of γ-ray telescopes (AGILE and Fermi) and ground based Cherenkov telescopes (MAGIC, VERITAS and H.E.S.S.), are casting new light on the γ-ray sky. A γ-ray with energy $E = h\nu/m_e c^2$ interacts with a photon with energy $\epsilon \sim 1/E$ via pair production. Photons with energies in the 10 GeV-10 TeV band, as detected from γ-ray extragalactic sources, interact with photons of the UV to FIR background, the so-called Extragalactic Background Light (EBL). In particular blazars show absorption features in their spectra due to pair production. The knowledge of EBL at different redshift allows to model such features, and asses the intrinsic emission mechanism of blazars.

EBL models can be divided into two broad categories, according to the technique employed. A first class of models makes use of semianalityc galaxy evolution recipes (based on cosmological merger tree algorithm) to compute the star-formation rate along the cosmic history (e.g., Gilmore et al. 2009). A second class of EBL models directly uses observational data, such as galaxy luminosity functions, SED's, metallicity measures, etc (e.g., Kneiske et al 2002; Franceschini et al. 2008; Finke et al. 2010). Our model belongs to this class.

In the following we will adopt H_0=72 km/sec/Mpc, Ω_M=0.30 and Ω_Λ=0.70.

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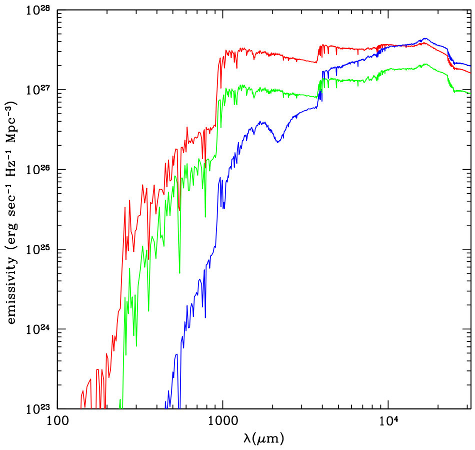

Fig. 1. Comoving specific (unabsorbed) emissivity at different redshifts: z=0.5 (green), z=1.5 (blue), and the z=3 (red).

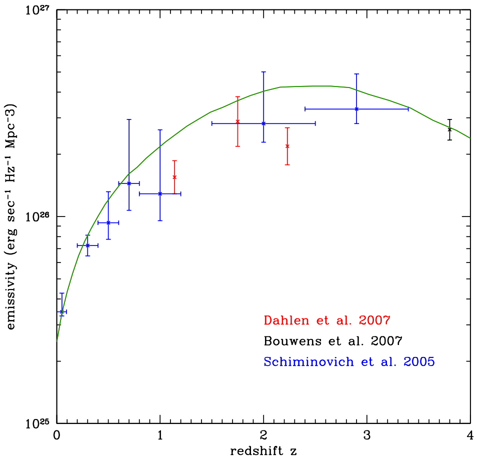

Fig. 2. Comoving emissivity at $\lambda = 1500$Å as a function of redshift. The emissivity is compared with available data.

2. Comoving Emissivity

The first step is the computation of the comoving emissivity. The specific comoving emissivity ϵ_ν (erg sec^{-1} Hz^{-1} Mpc^{-3}) is

$$\epsilon_\nu(z) = \int_z^\infty L_\nu(t(z) - t(z'))\rho(z')|\frac{dt}{dz'}|dz' \qquad (1)$$

The emissivity depends upon the normalized SED L_ν and the star formation rate ρ.

We computed the emissivity (Fig.1), convolving the SED of galaxies generated with the STARBURST99 code (Leitherer et al. 1999) with the the star-formation history given by Hopkins et al. (2006). In generating the SEDs we adopted instantaneous star formation, i.e., stars are formed in a single burst with Salpeter IMF, and their eventual evolution is described following the Padova evolutionary tracks.

The SEDs are computed for different fixed absolute metallicity Z (i.e. Z=0.04, Z=0.02, Z=0.008, Z=0.004, Z=0.001). The SEDs were then convolved with the redshift dependent star formation rate, adopting the redshift-metallicity law proposed by Kobilnicky & Kewley (2004).

The radiation emitted by the galaxy is absorbed and re-emitted by dust in the interstellar medium. We used a Calzetti law for absorption and we modeled the re-emission by dust as the sum of three black-bodies with at different temperatures (Kneiske et al. 2002).

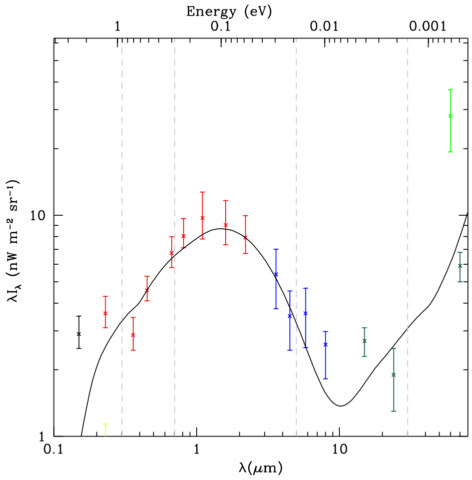

Fig. 3. Our model of EBL compared with local (z = 0) data.

3. CUBA

The comoving emissivity is integrated over the redshift to obtain the specific intensity J_ν:

$$J_\nu(z_0) = \frac{(1+z_0)^3}{4\pi}\int_{z_0}^{\infty}\epsilon_{\nu'}(z)e^{-\tau}\frac{dl}{dz}dz, \qquad (2)$$

where $\nu' = \nu(1+z)/(1+z_0)$, and τ is the effective optical depth due to absorption in the clumpy IGM. We performed this computation with the code CUBA (Haardt & Madau 1996), a radiative transfer code that follows the propagation of Lyman-continuum (LyC) photons through a partially ionized inhomogeneous IGM. CUBA outputs have been extensively used to model the Lyα forest in large cosmological simulations (e.g. Tytler et al. 2004; Theuns et al. 1998; Davé et al. 1997; Zhang et al. 1997). In Madau, Haardt, & Rees (1999) the focus was on the candidate sources of photoionization at early times and on the history of the transition from a neutral IGM to one that is almost fully ionized. The inclusion of updated ionizing and IR emissivity due to galaxies is in the new version of the code (Haardt & Madau, in prep.).

4. Results and conclusions

As Fig. 2 and Fig. 3 show, our model reproduces fairly well existing data. Differences with other existing models are in the UV band and NIR band, due to our improved modeling of galaxy and AGN emission. The main uncertaininties concern on the modeling of dust absorption of optical-UV radiation, and reemission in the IR.

Our next step is to use our redshift dependent EBL model to compute an up-to-date two-dimensional γ-ray opacity law as a function of the observed energy and of the source redshift, and to provide useful analytical fits to it. Moreover, we will computing via Montecarlo simulations the electromagnetic cascade due to the interaction ofγ-ray with the EBL. The cascade emission coming could in principle modify the spectrum of blazars, as suggested by Tavecchio et al. (2010), and hence it is a fundamental ingredient in interpreting blazar data.

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