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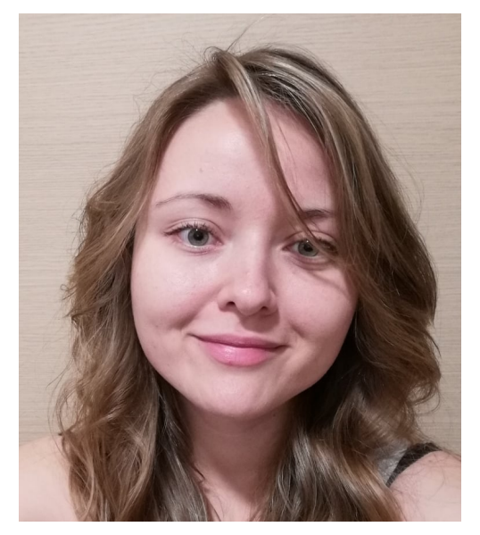

Lepto-hadronic radiation models for GRB afterglows and prospects for VHE detection

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Abstract

Gamma-Ray Bursts (GRBs) are intense and short flashes of gamma rays followed by a long lasting multiwavelength afterglow emission, detected along the whole electromagnetic spectrum. Recently Very High Energy (VHE) emision (>100 GeV) has been obtained during the afterglow of a couple of GRBs. In this preliminary work we numerically investigate the production of VHE photons in GRB afterglows. We adopt the Relativistic Blast Wave (RBW) model which is thought to describe the production of a GRB after the initial explosion and examine numerically the temporal and spectral evolution of the multi-wavelength emission of VHE detected afterglows. We use firstly a one zone leptonic model assuming that synchrotron and synchrotron self-Compton is the radiative mechanism that produces the VHE emission and, as a second step, involve a hadronic component to the problem.

Model

We assume that a RBW of an initial radius, mass load and bulk Lorentz factor $R_{\rm in}$, $M_{\rm in}$, $\Gamma_{\rm in}$ respectively, is sweeping up mass while propagating in the interstellar medium of constant density $\rho_{\rm ext}$. At the time the swept up mass reaches a critical value,the outflow starts decelerating. The bulk kinetic energy of the outflow is reconverted into internal energy and radiation. The evolution of $M(R)$ and $\Gamma(R)$ is given by [1]:

$$\frac{d\Gamma}{dR} = \frac{-4\pi R^2 \rho_{ext} \Gamma^2}{M} \tag{1}$$

$$\frac{dM}{dR} = 4\pi R^2 \rho_{ext} \Gamma \tag{2}$$

The downstream region of the shock is assumed as the radiation zone where particles (electrons) are injected, inside the volume of the RBW with a comoving width $r = R/\Gamma$. The energetic electrons pick up a fraction $\epsilon_{\rm e}$ of the accreted kinetic energy:

$$L_{\rm e} = \epsilon_{\rm e} \frac{dE}{dt} = \epsilon_{\rm e} 4\pi R^2 \rho_{ext} (\Gamma^2 - \Gamma) c^3. \tag{3}$$

We assume a mixed thermal/non thermal electron distribution injected. A fraction $(1-\eta)$ of the luminosity injected corresponds to a Maxwellian distribution, while the rest η to a power law with slope p [3]:

$$\frac{dN_{\rm e}}{d\gamma dt dV} = \frac{C}{2\Theta^3} \begin{cases} \gamma^2 e^{-\gamma/\Theta}, & \text{if } \gamma \le \gamma_{\rm nth} \\ \gamma_{\rm nth}^2 e^{-\gamma_{\rm nth}/\Theta} \left(\frac{\gamma}{\gamma_{\rm nth}}\right)^{-p}, & \text{if } \gamma > \gamma_{\rm nth} \end{cases} \tag{4}$$

where $\Theta \approx \epsilon_{\rm e}(1-\eta)(m_{\rm p}/m_{\rm e})(\Gamma/3)$, the temperature of the thermal component. The electrons emit synchrotron radiation [2] in a shock-generated magnetic field, written in the comoving frame as, $B = \Gamma\sqrt{32\pi\epsilon_{\rm B}\rho_{\rm ext}c^2}$. Here $\epsilon_{\rm B}$ is the ration of the magnetic energy density and the internal energy density. The same electrons also produce photons as a result of the Synchrotron-Self Compton process.

Numerical Approach

We develop a numerical code that solves a set of time dependent ergo-differential kinetic equations (eqs. 5, 6) and gives as a result the evolution of the electron and photon differential number densities inside an expanding spherical source volume.

$$\frac{\partial n_{\rm e}}{\partial t} + c\frac{3 n_{\rm e}}{r} = Q_{\rm e} + \mathcal{L}_{\rm e} \tag{5}$$

$$\frac{\partial n_\gamma}{\partial t} + c\frac{3 n_\gamma}{r} + \frac{n_\gamma}{t_{\gamma,esc}} = Q_\gamma + \mathcal{L}_\gamma \tag{6}$$

The rate of losses ($\mathcal{L}_{\rm e,\gamma}$) and injection ($Q_{\rm e,\gamma}$) include: synchrotron radiation, synchrotron self-absorption (ssa), IC scattering, photon-photon pair production ($\gamma\gamma$), and adiabatic losses. Simultaneously, the numerical code computes eqs. 1,2.

Numerical Results

We run the numerical code and investicate the role of the η parameter in the resulting photon spectra and light curves.

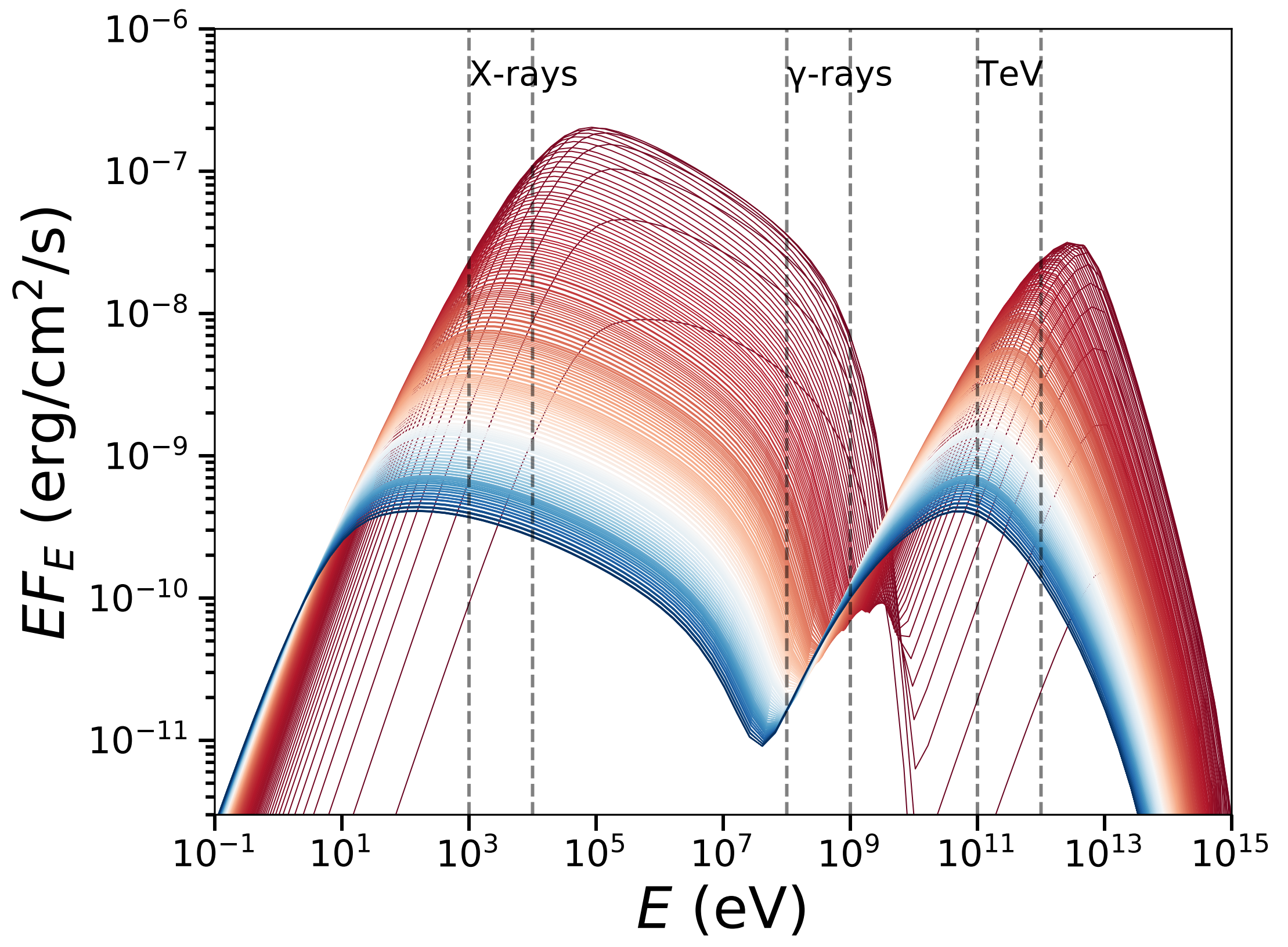

Figure 1:The photon broadband observed spectra, assuming a pure power law injection, $(\eta = 1)$. Here, $\Delta t_{\rm obs} = 1 : 10^5$ sec, shown in colour, $E_{kin} = 10^{53}$ erg, $\Gamma_{\rm in} = 400$, $\epsilon_{\rm e} = 0.3$, $\epsilon_{\rm B} = 3 \times 10^{-3}$, $p = 2.3$. These values are representative in GRB afterglow models. We assume also that $z = 0.4$.

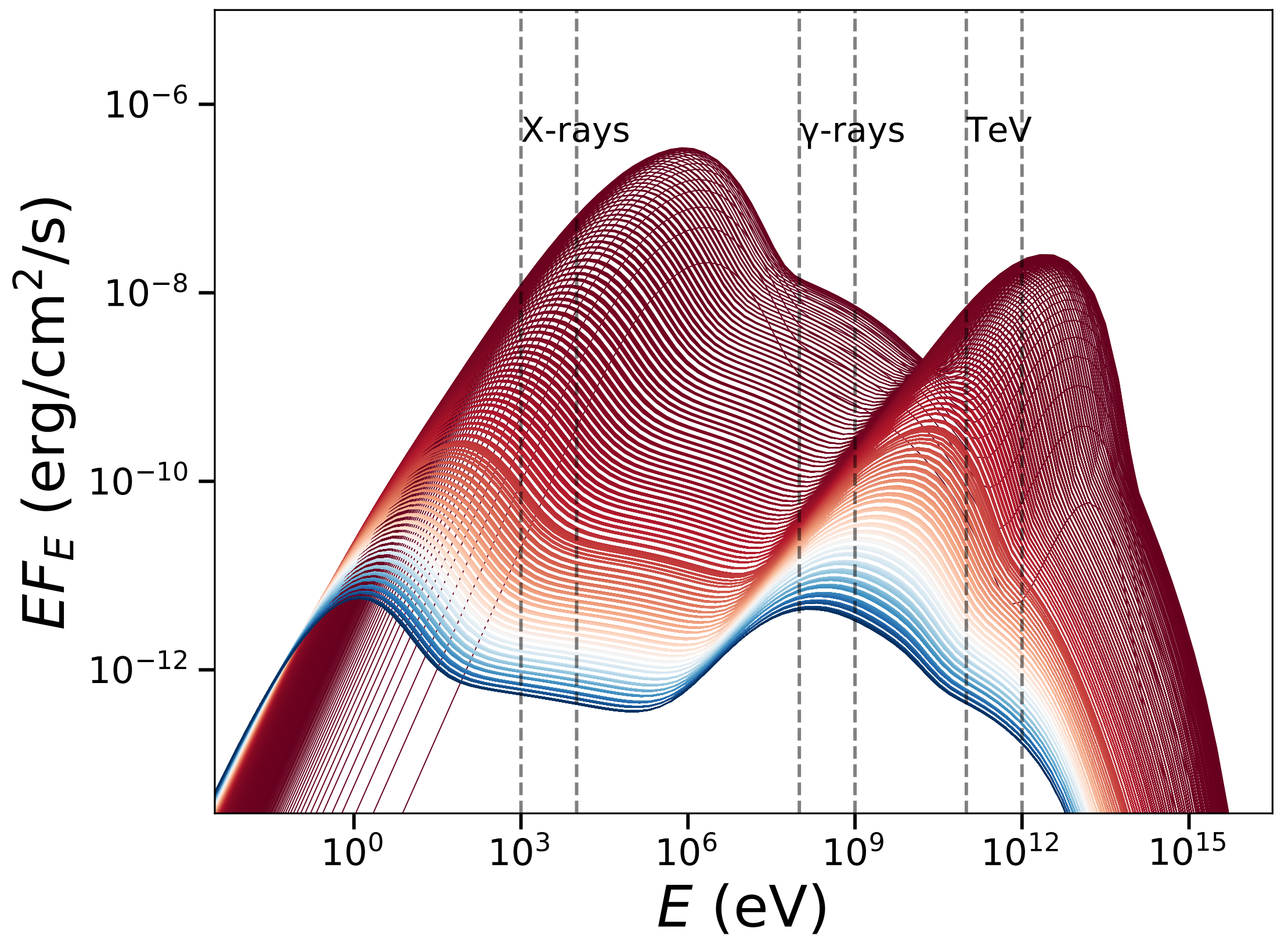

Figure 2:The evolution of photon broadband spectra for the same parameters as above, assuming however, that only a 10% of the electrons have a power law distribution $(\eta = 0.1)$.

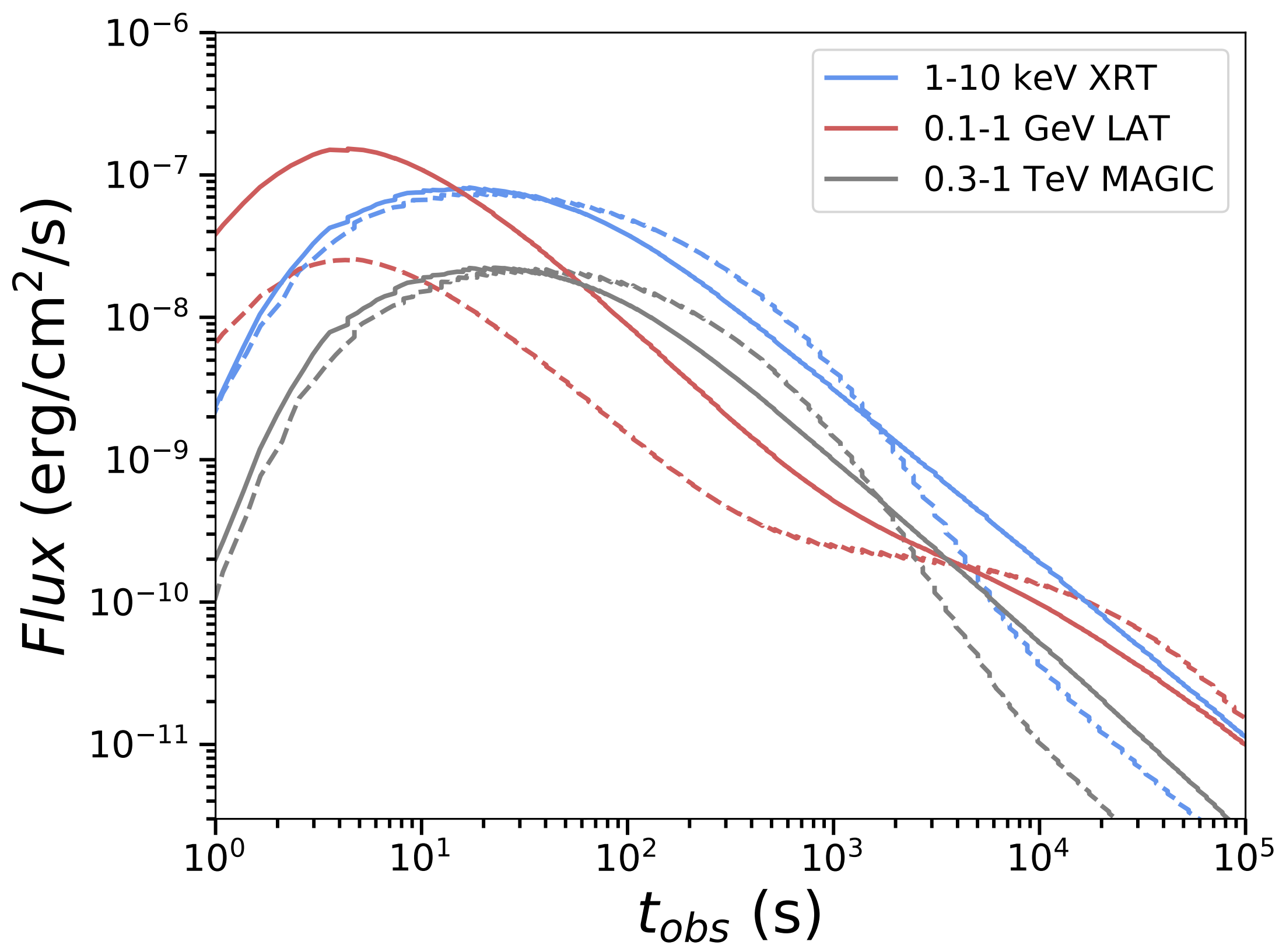

Figure 3:The X-ray, γ-ray and VHE light curves produced, for the parameters used in Fig. 1 (solid lines), where $\eta = 1$ and Fig. 2 (dashed lines), where $\eta = 0.1$.

Conclusions-Future Work

We conclude that the existence of the thermal electron component changes the temporal and spectral behaviour. In both cases we construct numerically the VHE photons detected in some afterglows. In the future we will:

- Fit an actual GRB afterglow with a VHE counterpart.
- Check how the results change in the case of a wind type medium.
- Include the hadronic component in the numerical code and investigate the role of relativistic protons in the overall spectrum.

References

[1] *R. D. Blandford and C. F. McKee Physics of Fluids Aug 1976*
[2] *R. Sari, T. Piran, and R. Narayan Apj Apr 1998*
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