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# On the production of prompt neutrinos in gamma-ray bursts

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**Abstract:** We present preliminary results of a model with two zones in order to study the production of high energy neutrinos at the prompt phase of gamma-ray bursts (GRB). Protons and electrons are injected and accelerated in an acceleration zone limited by losses due to synchrotron, $p\gamma$, and $pp$ processes. The secondary pions and muons also undergo energy loss and gain within the acceleration zone, and the escaping ones are re-injected in a second zone where acceleration no longer operates. We compute the neutrino output expected from both of these zones for generic GRB parameters, and integrate over redshift to obtain a diffuse neutrino flux which differs from previous calculations.

## 1 Outline of the model and some results

We assume that the GRB duration is $t_{\rm grb} \sim 10$ s, and that there is a number of events of particle injection and acceleration (due for example to shell collisions leading to internal shocks) $\mathcal{N}_{\rm inj} = t_{\rm grb}/t_{\rm var}$, where $t_{\rm var} = 0.01$ s is the variability timescale. This timescale and the Lorentz factor are used to estimate the position of the emission region as [1] $r_{\rm inj} = 2c\Gamma^2 t_{\rm var}$ in the source frame, and a thickness $\Delta d' = r_{\rm inj}/(2\Gamma)$ in the comoving frame. As in Ref.[3], we take the comoving volume as $\Delta V' = 4\pi r_{\rm inj}^2 \Delta d'$, and we consider for simplicity that both the acceleration and the cooling zones have the same volume. Then it can be estimated that [3]: the comoving proton density is $n_{\rm cold} = E_{\rm grb}/(\mathcal{N}_{\rm inj}\Gamma\Delta V' m_p c^2)$ and the magnetic field $B = \sqrt{q_{\rm mag} 8\pi m_p c^2 n_{\rm cold}}$. We inject mono-energetic electrons and protons in the acceleration zone and obtain the particle distributions from the kinetic equation:

$$\frac{\partial N_{i,\rm acc}}{\partial t} + \frac{\partial \left[\dot{E}_i N_{i,\rm acc}\right]}{\partial E} + \frac{N_{i,\rm acc}}{t_{\rm esc}} = Q_i \delta(E_i - E_{\rm inj}) \quad (1)$$

where the energy change is $\dot{E}_i(E_i) = E_i \times \left[t_{\rm acc}^{-1}(E_i) - t_{i,\rm loss}^{-1}(E_i)\right]$ and the escape and acceleration rates are related through a free paramater $\xi_{\rm esc}$ as $t_{\rm esc}^{-1}(E_i) = \xi_{\rm esc} t_{\rm acc}^{-1}(E_i) = \xi_{\rm esc}\eta\ e\ B\ c/E_i$. The main cooling processes are synchrotron, inverse Compton (Synchrotron Self Compton), adiabatic, $p\gamma$ and $pp$ interactions. The target photon is considered to be the synchrotron emission of electrons, which for $\xi_{\rm esc} \lesssim 0.1$ becomes consistent with GRB observations. We also obtain the distribution of secondary pions and decaying muons using the same kinetic equation, but with an extra decay term, and with an appropriate injection term: pions from $p\gamma$ interactions are computed adopting a Delta function approximations of SOPHIA code[4], following Ref.[5]; the pion injection from $pp$ interaction is obained using analytic fits to results of the code SIBYLL [6], following Ref. [7], and the injection of muons and neutrinos is compited followin Ref. [8]. Particles escaping from the acceleration zone, are re-injected in the cooling zone, for which we solve a kinetic equation like Eq. (1), but with an injection term equal to $(N_{i,\rm acc} t_{esc}^{-1})$ for each particle type and without the escape term.

The total neutrino fluence is obtained by integrating in time the flux. Weigthing the fluence by the GRB redshift evolution $R_{\rm GRB3}(z)$ (e.g. Ref.[9]) we can integrate the neutrino background predicted by the present model. The result is shown in Fig 1 for the paramter sets of Table 1, while details of the calculation will be published elsewhere.

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Table 1: Parameters assumed and derived in the present model.

| Assumed parameters | values |
|---|---|
| $E_{\rm grb}$: GRB energy budget | $10^{53}$erg |
| $t_{\rm grb}$: total GRB duration | 10 s |
| $t_{\rm var}$: variability timescale | 0.01 s |
| $\gamma_{\rm inj}$: Lorentz factor of injection | 10 |
| $\eta_{\rm acc}$: efficiency of particle acceleration | $10^{-4}$ |
| $\xi_{\rm esc}$: $t_{\rm acc}^{-1}/t_{\rm esc}^{-1}$ | 0.1 |
| $q_{\rm mag}$: fraction of energy in $B$ | 0.1 |
| $\Gamma$: bulk Lorentz factor | 100, 300 |
| $q_e$: fraction of energy in electrons | $\sim 1.5 \times 10^{-7}$, $\sim 7 \times 10^{-8}$ |
| $q_p$: fraction of energy in protons | $6 \times 10^{-6}$, $7 \times 10^{-3}$ |
| **Derived parameters** | **values** |
| $r_{\rm inj}$: position of injection | $6 \times 10^{12}$ cm, $5.4 \times 10^{13}$ cm |
| $n_{\rm cold}$: comoving density | $4.9 \times 10^{13}$ cm$^{-3}$, $6.7 \times 10^{10}$ cm$^{-3}$ |
| $B$: magnetic field | $4.3 \times 10^{5}$ G, $1.6 \times 10^{4}$ G |

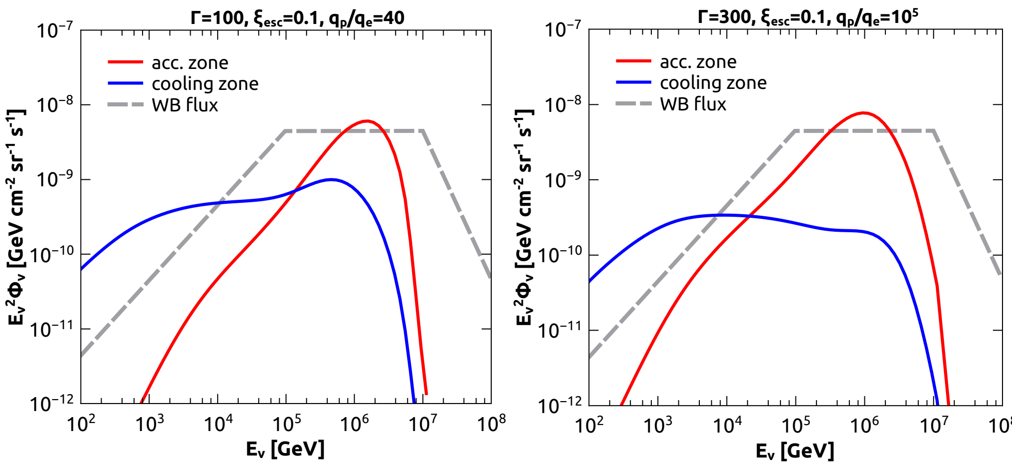


Figure 1: Neutrino diffuse background obtained for GRBs with typical Lorentz factors of $\Gamma = 100$ and $\Gamma = 300$. The well known Waxman-Bahcall flux is shown for comaparison.

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