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Very High Energy Neutrinos from nearby long GRB Afterglows

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Very High Energy Neutrinos from nearby long GRB Afterglows

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Abstract. Long duration Gamma Ray Bursts (GRBs) are well-motivated sources of Ultra High Energy Cosmic Rays (UHECRs) and neutrinos. During the afterglow phase these particles can be produced as a result of acceleration and interaction there in. We have modeled afterglow spectra and light curves from synchrotron cooling of accelerated electrons. We have fitted data of 17 long GRBs detected within redshift 0.5 in case of the GRB blastwave evolving in a wind and constant density interstellar medium. The afterglow photons can interact with the shock accelerated protons to produce very high energy neutrinos. We have calculated the neutrino flux for photo-pion interactions for all these GRBs. As IceCube have been detecting very high energy neutrinos for the last four years and a larger future extension called Gen 2 is planned, this calculation will help in understanding more about GRB neutrino production. Calculation of flux and estimation of events for Northern Hemisphere GRBs are done for the upcoming neutrino observatory KM3NeT.

1. Introduction - Neutrinos from GRB afterglows

In Gamma Ray Bursts (GRBs) the afterglows followed by the prompt emission are produced by the synchrotron emission of relativistic electrons accelerated in the external shock. The Ultra High Energy Cosmic Rays (UHECRs) are expected to be produce in the GRBs afterglows and interact with synchrotron emitted photons to produce high energy neutrinos. We have modeled the afterglow synchrotron radiations, their spectral energy distribution (SED) for different time intervals and light curves for different frequencies in case of 17 GRBs within redshift 0.5. We have done the modeling for all these GRBs in the constant density interstellar medium (ISM) and in the wind environment. Using the parameters from the modeling, neutrino fluxes are calculated for individual GRBs for different time intervals in both wind type medium and ISM. The Neutrino observatories like IceCube have helped for the progress in the experimental neutrino astronomy. Neutrino fluence from individual GRBs and stacked fluence for the upcoming IceCube Gen-2 and KM3NeT in both ISM and wind environment is calculated. An upperlimit for the stacked fluence for the IceCube Gen-2 and KM3NeT observatory has also been calculated, in case of non-detection.

2. Synchrotron modeling of GRBs

The Fermi-LAT, *Swift* XRT/BAT, UVOT/optical and other optical data are used for the modeling. For the synchrotron spectrum modeling, the observed photon flux we have used in the slow cooling regime ($\nu_m < \nu_c$) as given in [1] is:

$$F_\nu = F_{\nu,max} \begin{cases} (\frac{\nu}{\nu_a})^2 (\frac{\nu_a}{\nu_m})^{\frac{1}{3}}; \ \nu < \nu_a, \\ (\frac{\nu}{\nu_m})^{\frac{1}{3}}; \ \nu_a < \nu < \nu_m, \\ (\frac{\nu}{\nu_m})^{\frac{-(p-1)}{2}}; \ \nu_m < \nu < \nu_c, \\ (\frac{\nu_c}{\nu_m})^{\frac{-(p-1)}{2}} (\frac{\nu}{\nu_c})^{\frac{-p}{2}}; \ \nu_c < \nu_s, \end{cases} \tag{1}$$

and for the fast cooling ($\nu_m > \nu_c$):

$$F_\nu = F_{\nu,max} \begin{cases} (\frac{\nu_a}{\nu_C})^{\frac{1}{3}}; \nu < \nu_a, \\ (\frac{\nu}{\nu_c})^{\frac{1}{3}}; \nu < \nu_c, \\ (\frac{\nu}{\nu_c})^{\frac{1}{2}}; \nu_c < \nu < \nu_m, \\ (\frac{\nu_m}{\nu_c})^{\frac{-1}{2}} (\frac{\nu}{\nu_m})^{\frac{-p}{2}}; \nu_m < \nu < \nu_s. \end{cases} \tag{2}$$

Here, ν_m, ν_c and ν_s are the synchrotron frequencies, correspond to the minimum energy, cooling energy and the saturation energy of the electrons respectively and ν_a is the self absorption frequency, for the detailed equations refer [2, 3, 4]. Using the model parameters neutrino flux and fluence from these GRBs are calculated as in the following sections.

3. Neutrino Flux from 17 Long Nearby GRBs.

The neutrino production from $p\gamma$ interaction via Δ^+ has been done for GRBs, [2, 5]: $p\gamma \rightarrow \Delta^+ \rightarrow n\pi^+, \pi^+ \rightarrow \mu^+ + \nu_\mu \rightarrow e^+ + \nu_e + \nu_\mu + \bar{\nu}_\mu$. The neutrino flux calculated in both ISM and wind environment are shown in fig.1 and fig.2, respectively. The accelerated proton spectrum and ν fluxes from $p\gamma$ interactions are calculated as in [2, 6].

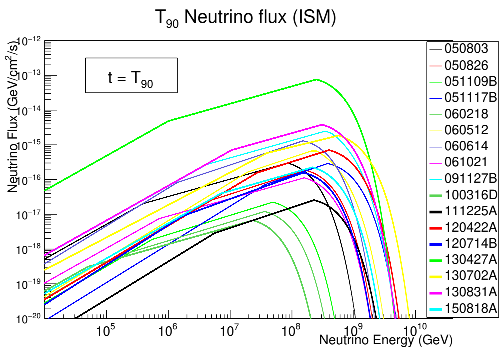

Figure 1. Neutrino flux for the GRBs calculated for the ISM

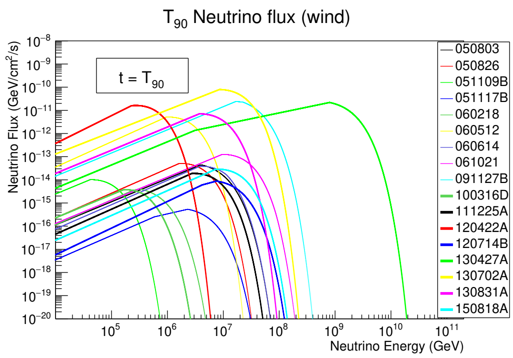

Figure 2. Neutrino flux for the GRBs calculated for the wind environment

4. Neutrino events and Fluence with upperlimit for the IceCube Gen-2 and KM3NeT

We have calculated the neutrino fluence from individual southern hemisphere GRBs and stacked fluence for the upcoming IceCube Gen-2. In case of northern hemisphere GRBs the neutrino fluence and stacked fluence are calculated for KM3NeT in both ISM and wind environment. We calculated the neutrino events as;

$$N_\nu = \int_{E_{\nu,min}}^{E_{\nu,max}} \int_{T_{90}}^{100T_{90}} dN_\nu/dE_\nu A_{eff} dE_\nu dt_{90}; \tag{3}$$

Here, A_{eff} is the effective area of neutrino observatory and T_{90} of the GRB is the time interval over which 90% of the total background-subtracted counts are observed. Fig. 3 and Fig. 4 shows the neutrino fluence plots of the southern hemisphere GRBs for the IceCube Gen-2 in ISM and wind environment, respectively. The Neutrino fluence plots of the northern hemisphere GRBs for the KM3NeT in ISM and wind environment are as in Fig. 5 and Fig. 6, respectively.

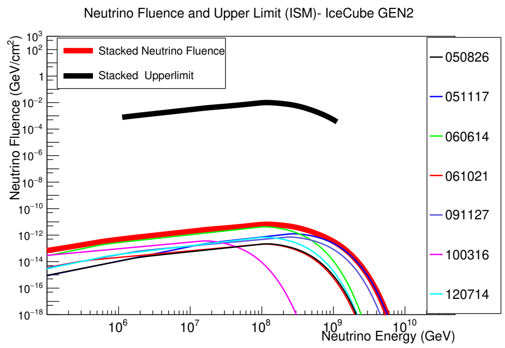

Figure 3. Neutrino fluence for the IceCube Gen-2 in the ISM.

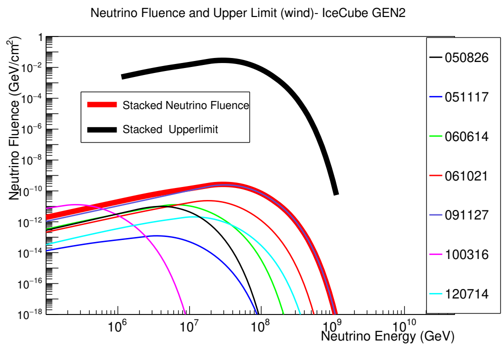

Figure 4. Neutrino fluence for the IceCube Gen-2 in the wind environment.

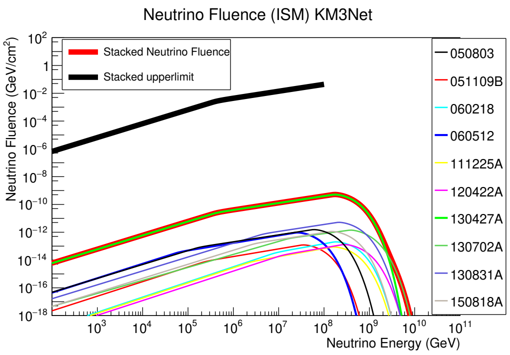

Figure 5. Neutrino fluence for the KM3NeT in the ISM.

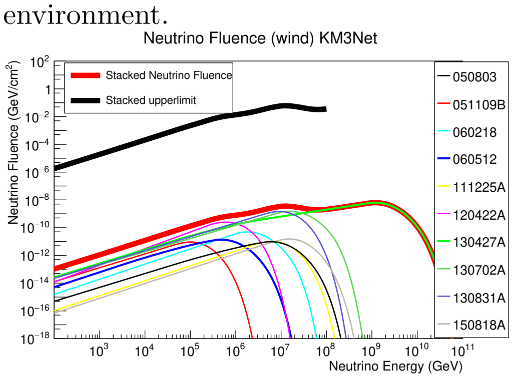

Figure 6. Neutrino fluence for the KM3NeT in the wind environment.

5. Discussion/Conclusion

We have calculated neutrino flux and fluence from 17 GRBs within redshift 0.5 using afterglow model parameters from the fitted electromagnetic data. Present and future neutrino telescopes can potentially detect these neutrinos from GRBs or constrain model from non-detection. Estimates of neutrino events from these GRBs are done for IceCube Gen-2 and KM3NeT. Also estimated the upper limit on stacked fluences for non-detection.

6. References

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