Neutrino predictions from choked Gamma-Ray Bursts and comparison with the observed cosmic diffuse neutrino flux

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Abstract. The strong constraints from the Fermi-LAT data on the isotropic gamma-ray background suggest that the neutrinos observed by IceCube might possibly come from sources that are hidden to gamma-ray observations. A possibility emerged in recent years is that neutrinos may come from jets of collapsing massive stars which fail to break out of the stellar envelope, and for this reason they are known as choked jets, or choked Gamma-Ray Bursts (GRBs). We here show our predictions of neutrino flux and spectrum expected from these sources, focusing on Type II SNe, through detailed calculations of pγ interactions and accounting for all the neutrino production channels and scattering angles. We provide predictions of expected event rates for ANTARES, IceCube, and the next generation neutrino telescope KM3NeT. We also compute the contribution of the choked GRB population to the diffuse astrophysical neutrino flux, thus providing constraints on the local rate of this source population as to reproduce the observed neutrino flux.

1 Introduction

Supernovae (SNe) explosions originated from core collapse of massive stars can be accompanied by a Gamma-Ray Burst (GRB)-like outflow that could be unable to break through the stellar envelope [1]. In such a situation, we talk about a *choked GRB*, with gamma-rays hidden to observations. Despite the lack of gamma-ray emission, choked GRBs are potentially emitters of high-energy neutrinos. For this reason, these sources have attracted much attention in the last years because of the possibility of explaining the all-flavor cosmic neutrino flux observed by IceCube [2] without incurring into inconsistencies with the isotropic diffuse gamma-ray emission from neutrino sources detected by the Fermi satellite [3].

2 Predicted neutrino fluxes from choked GRBs

In this contribution, we summarize the results of our work [4], that readers are invited to refer for details. We performed Monte Carlo simulations of pγ interactions taking place in a choked jet, from which neutrinos arise, accounting for all the neutrino production channels

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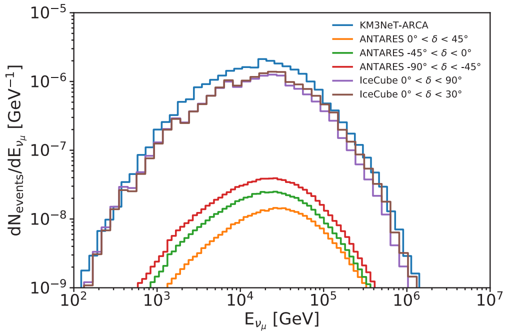

Figure 1: Number of events per energy bin induced in neutrino telescopes by ν_μ from an individual choked GRB.

Detector	Declination δ	N_{events}
ANTARES	$0° < \delta < 45°$	2×10^{-3}
	$-45° < \delta < 0°$	3×10^{-3}
	$-90° < \delta < -45°$	5×10^{-3}
KM3NeT/ARCA	Mean δ	2×10^{-1}
IceCube	$0° < \delta < 90°$	1×10^{-1}
IceCube	$0° < \delta < 30°$	2×10^{-1}

Table 1: Expected total number of events induced in neutrino telescopes by ν_μ from an individual choked GRB. The numbers in the table are obtained by integrating the curves in Fig. 1.

and scattering angles. Specifically, we computed the all-flavor time-integrated neutrino flux on Earth from type II SNe, by adopting the following benchmark values characterizing the jet features: Lorentz factor $\Gamma = 100$, jet lifetime $t_{\text{jet}} = 10^3$ s, and isotropic luminosity $L_{\text{iso}} = 10^{50}$ erg/s.

Our predictions of the number of ν_μ events expected from an individual choked GRB and detectable by ANTARES, IceCube, and the next generation neutrino telescope KM3NeT are reported in Fig. 1 and Tab. 1. We also computed the contribution of the choked GRB population to the diffuse astrophysical neutrino flux, providing constraints to the local rate of this source population as to reproduce the observed neutrino flux [5, 6]. We find that for GRB energies channeled into protons $E_{\text{p,jet}}$ between $10^{51} - 10^{53}$ erg, choked GRBs may contribute to the observed astrophysical neutrino flux, if their local rate is $R_0 = 80 - 1$ Gpc^{-3} yr^{-1}, respectively. If $E_{\text{p,jet}}$ is decreased, the local rate of choked GRBs has to increase in order to reproduce the IceCube data.

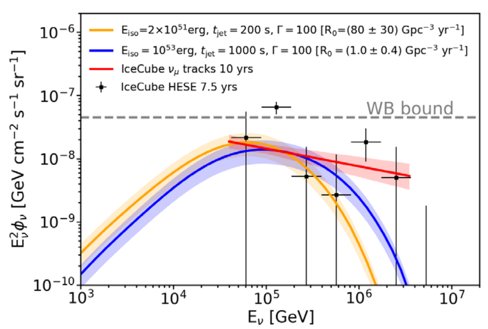

Figure 2: Diffuse neutrino spectra from choked GRBs expected on Earth, as compared with the IceCube results. The blue line refers to our benchmark simulation in better agreement with IceCube data as a function of the local rate of choked GRBs. The yellow line refers to a simulation for a less luminous GRB. The dashed grey line shows the Waxmann & Bahcall upper bound [7].

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