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Estimate of 1-100 TeV neutrino flux from X-ray flux measured in a sample of AGN blazars

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Abstract. We estimated the detectable fluxes of 1-100 TeV neutrinos from selected AGN blazars in correlation with their X-ray fluxes measured during Ginga experiment. From these results the number of events per year detectable by a km^3 neutrino telescope (NEMO project) ranges from 10 to 100.

Key words. elementary particles – galaxies: active – X-rays: general

1. Introduction

It has been suggested that high energy neutrinos ($> 10^{12}$ eV) could be generated also in AGN by hadronic mechanisms Halzen & Zas (1997). More precisely, protons in AGN core or jets could be accelerated to relativistic energies by the first-order Fermi mechanism Fermi (1951) and they would cool interacting with photons according to p$\gamma \rightarrow \Delta^+ \rightarrow \pi^+ n$ (Stecker et al. 1992). Thus neutrinos would be emitted by leptonic decay of charged pions generated in the proton-induced cascades: $\pi^+ \rightarrow \mu^+ \nu_\mu$, followed by $\mu^+ \rightarrow e^+ \overline{\nu}_\mu \nu_e$. The mechanism of detection of high energy muon-neutrinos consists in observing Cherenkov light emitted by long-range muons, produced in charged current neutrino-nucleon interactions in the matter (ice or water) surrounding the detector. Up to now no one succeeded in detecting these high energy neutrinos. In order to estimate high energy neutrino fluxes, Protheroe et al. (1992) have proposed a connection between the 1-100 TeV neutrino fluxes (F_ν) and the 2-10 keV fluxes (F_x) by:

$$F_\nu(E_\nu) \simeq 0.25\, F_x\, e^{-(20E_\nu/E_p)} E_\nu{}^{-2} \qquad (1)$$

(in cm^{-2} s^{-1} TeV^{-1}), where E_ν is the neutrino energy and E_p is the proton energy. In this context we have used the data at 2-10 keV, provided by the Ginga mission and Eq. 1, to estimate neutrino fluxes coming from a sample of blazars.

2. Data analysis

We have selected a sample of sources, observed both in the γ-ray and in the X-ray band. At first, we have chosen the sample of AGN blazars observed during the mission of the Compton Gamma Ray Observatory (CGRO, Mukherjee et al. 1997). So we have searched among the γ-ray sources only the ones with 2-10 keV fluxes. This second selection has been made utilizing gingalac (Ginga archive), included in LEDAS

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(LEicester Database and Archive Service, see `http://ledas-www.star.le.ac.uk`). After this selection only 6 objects result suitable for our aim (in Table 1, two examples of six selected sources). In order to determine the flux of neutrinos with energy range from 1 to 100 TeV, we have integrated Eq. 1 between $E_{min} = 1$ TeV and $E_{max} = 100$ TeV. The value of the maximum proton energy E_p has been found considering that the maximum reachable energy for a particle, accelerated by first-order Fermi mechanism (Halzen & Zas 1997), is $E \sim ZeBRc$, where Ze is the charge of the particle, B is the ambient magnetic field, R is the size of the region of acceleration and c is the velocity of electromagnetic waves in vacuum. Using $B \sim 5\ G$ and $R \sim 10^{-2}$ pc by Halzen & Zas (1997), the maximum energy for protons results $\sim 5 \times 10^{19}$ eV. The calculated neutrino fluxes (ϕ_ν) for two selected AGN of the sample and for every determination of the X-ray flux (F_x), obtained in different viewing periods, are listed in Table 1.

Name	${F_x}^a$	${\phi_\nu}^b$	${N_{ev}}^c$
Mrk 421	39.922	$7.354\ 10^{-11}$	100.77
	78.478	$1.445\ 10^{-10}$	198.08
	93.779	$1.727\ 10^{-10}$	233.70
3C 273	59.881	$1.103\ 10^{-10}$	151.16
	130.388	$2.402\ 10^{-10}$	329.22
	100.731	$1.885\ 10^{-10}$	254.26
	108.445	$1.997\ 10^{-10}$	273.73
	100.458	$1.996\ 10^{-10}$	269.46
	106.761	$1.850\ 10^{-10}$	253.58

Table 1. ^{a}Flux in $2 - 10$ keV range in 10^{-12} erg cm^{-2} s^{-1}; ^{b}1-100 TeV neutrino fluxes in erg cm^{-2} s^{-1}; ^{c}Event rates in km^{-2} yr^{-1}.

3. Discussion

In order to be detected, a muon-neutrino has to interact with matter (ice or water) surrounding the detector, according to: $\nu_\mu(\overline{\nu}_\mu) + N \rightarrow \mu^-(\mu^+) + X$, where N is a nucleon and X is any set of hadrons allowed by conservation laws. Considering that the neutrino has to interact within a distance of the detector which is shorter than the range of the muon it produces, the detection probability P (Halzen 1998) is expressed by $P = R_\mu/\lambda_i = AE_\nu^n$, where R_μ is the muon range, λ_i the neutrino interaction length, A a constant and E_ν the neutrino energy. For energy above TeV, n=*4/5* and $A = 10^{-6}$ with the energy in TeV units. So the observed event rate in a detector is: $N_{ev} = \Phi P$, where Φ is the muon neutrino flux. We estimated the event rate in a km^2 detector by: $N_{ev} = \int_{E_{min}}^{E_{max}} (2/3)\phi_\nu (P/E_\nu) dE$, where $P = 10^{-6} E_\nu^{4/5}$ is the detection probability for produced muons, ϕ_ν is the flux of 1-100 TeV neutrinos in km^{-2} yr^{-1} units. The factor 2/3 arises from the impossibility for the detectors to discriminate between μ^- and μ^+, produced by ν_μ and $\overline{\nu}_\mu$ respectively, and considering that ν_e cannot be detected. The final expression is: $N_{ev} = (5/6) 10^{-6} \phi_\nu (E_{max}^{4/5} - E_{min}^{4/5})$. The obtained values are listed in Table 1. From the estimated values a detector having an effective area of about 1 km^2 (a volume of 1 km^3) is able to detect an average number of 10^2 events yr^{-1} if a source having a neutrino flux ranging from $\sim 10^{-12}$ to 10^{-10} erg cm^{-2} s^{-1} exists. Besides, detectors with an area lower by one order of magnitude than 1 km^2 would have statistics of events of ~ 10 in a year!

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