Search for Diffuse Fluxes of Extraterrestrial Muon-Neutrinos with the AMANDA Detectors

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Abstract

The AMANDA neutrino detector has been in operation since the start of the austral winter of 1997. The analysis of the initial year of data taking has produced a 90% confidence level upper limit on an E^{-2} flux of muon-neutrinos, at the earth, at a level $E^2\Phi(E) = 8.4 \times 10^{-7}$ cm^{-2} s^{-1} sr^{-1}GeV, for a predominant neutrino energy range 6-1000 TeV, which is the most restrictive bound placed by any neutrino detector. When specific models of neutrino emission are tested, it is found that some are excluded. Here we summarise the findings of this first year of data taking, and discuss the prospects for diffuse neutrino searches with the expanded AMANDA-II detector.

1. Introduction

High energy extraterrestrial neutrinos are believed to be produced in energetic accelerated environments through proton-proton or proton-photon interactions via pion production and decay. Such an accelerator might be the core of an active galaxy, powered by a supermassive black hole. In their pioneering work, Stecker, Done, Salamon and Sommers[19] calculated the expected diffuse flux of neutrinos from the sum of all active galaxies and found that such a flux could be observable deep underground in a large neutrino detector. Further predictions have followed (for a summary see for example the review of Learned and Mannheim[14]), and with the construction and operation of the first high energy neutrino detectors, the sensitivity has been reached to enable such predictions to be tested. Searches have been made and limits have been reported by the DUMAND [5], Frejus [17], Baikal(ν_e) [4,8], MACRO [3] and AMANDA(ν_e) [1] neutrino detectors. Here were discuss the results [2] and implications of the 1997 AMANDA-B10 search for a diffuse flux of extraterrestrial muon-neutrinos and examine the capabilities of the expanded AMANDA-II detector. A search for diffuse neutrinos of all flavours via a cascade event detection channel is described elsewhere [12].

2. Implications of the 1997 AMANDA-B10 ν_μ limits

The final diffuse analysis of the 1997 AMANDA-B10 data set has been described in detail in references [2,15] and references therein. The analysis was tailored to preferentially select high-energy upward moving muons from the background of lower energy atmospheric neutrinos. The optimised sensitivity of the detector[11] for the 130 days livetime was found to be at a level $E^2\bar{\Phi}_{90\%}(E) = 7.8\,(8.7) \times 10^{-7}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}\,\mathrm{GeV}$ excluding (including [6,7,9,10]) uncertainties. After applying these cuts to the data, we obtain limits at a level of $E^2\Phi_{90\%}(E) = 7.7\,(8.4) \times 10^{-7}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}\mathrm{GeV}$ excluding (including) uncertainties.

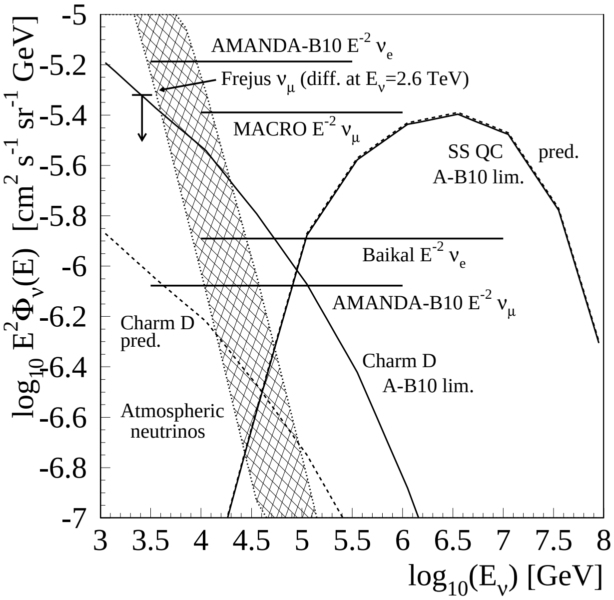

Fig. 1. Summary of experimental 90% classical confidence level flux limits from various detectors assuming an E^{-2} spectrum. From top: AMANDA-B10 (ν_e) [1], Frejus [17], MACRO [3], Baikal [8] and AMANDA-B10 (ν_μ)[2]. The background atmospheric neutrinos [13] are indicated by the hashed region representing the angular dependence of the flux. Also shown are the predicted fluxes (dashed), and AMANDA-B10 experimental flux limits (solid) for a diffuse AGN prediction (SSQC [18] – nearly overlapping dotted and dashed curves) and for one prediction of prompt charm neutrino production in the earth's atmosphere [22]. Since most events will originate from neutrinos near the peak of the detector sensitivity ($E_\nu \sim 10^5$ GeV), the limits at that point for different spectral shapes are similar.

After accounting for the loss of half the expected ν_μ flux due to neutrino oscillations on the way to earth, we find that the predictions of Szabo and Protheroe [20] are excluded. Both models of Stecker and Salamon [18] (quasar core and blazar jet) predict about half the number of events corresponding to the experimental upper limit and are therefore not excluded. The limit of the original Stecker, Done, Salamon and Sommers flux [19] (SDSS) is a factor of 4 above the prediction and therefore the prediction is not excluded. Figure 1 shows the summary of limits from various experiments and the results from the AMANDA-B10 search. Note that due to neutrino oscillations, the Stecker/Salamon quasar core curve prediction should be lower by a factor two compared to what is shown.

3. Limit setting potential of AMANDA-II

The AMANDA-II detector was completed over the austral summer of 1999/2000 with the addition of a surrounding ring of strings about the core of the B10 detector, taking the total number of modules from 302 (B10) to 677. Initial sensitivity calculations indicate that the one-year average limit for an E^{-2} flux is of order $E^2\bar{\Phi}_{90\%}(E) = 2\times10^{-7}\,cm^{-2}\,s^{-1}\,sr^{-1}\,GeV$, and the limit for the combined data set (1997-2002) should be less than $E^2\bar{\Phi}_{90\%}(E) = 10^{-7}\,cm^{-2}\,s^{-1}\,sr^{-1}\,GeV$. This sensitivity will further test model predictions and observations at this level may exceed theoretical upper bounds on the neutrino flux [16,21].

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