1 Derivation of the neutrino event rate from Cygnus OB2

I assume pp interaction for the case of Cygnus OB2, which seems likely according to the wind model of Torres et al. Assuming pp interaction and the observed gamma rays being hadronic, we have:

$$\int_{E_{\gamma,\text{min}}}^{E_{\gamma,\text{max}}} \frac{dN_{\gamma}}{dE_{\gamma}} E_{\gamma} dE = \int_{E_{\nu,\text{min}}}^{E_{\nu,\text{max}}} \frac{dN_{\nu}}{dE_{\nu}} E_{\nu} dE$$  \hspace{1cm} (1)

From Arahonian, et al we have the observed gamma ray flux being $\frac{dN}{dE_{\gamma}} = 6.2 \times 10^{-13} E^{-1.9}$. This is in units of particles/cm$^2$/s/TeV. We have the neutrino flux being $\frac{dN_{\nu}}{dE_{\nu}} = A(E/1\text{TeV})^{-1.9}$. The minimum photon energy is 1 TeV from the experiment. Maximum photon energy is about 100 TeV from figure 3 of Arahonian, et al. Minimum neutrino energy is about 1/2 TeV since the minimum photon energy is $E_{\gamma,\text{min}}/6$ and the minimum neutrino energy is $E_{\nu,\text{min}}/12$. What do we take for the maximum neutrino energy? We take the maximum proton energy and divide it by 12. Here, we need to make an assumption. We assume that the cosmic ray protons in Cygnus OB2 come from the nearby cosmic accelerator, Cygnus X-3. The maximum proton energy from Cygnus X-3 varies by model, I will use the result of Mitra, 1991. In his paper he states the maximum proton energy is about 5 PeV. The maximum neutrino energy is therefore about 417 TeV. Carrying out the integration, we get $A = 2.68 \times 10^{-13}$ which is in units of particles/cm$^2$/s/TeV.$\text{In GeV, it is } A = 2.68 \times 10^{-10}$ particles/cm$^2$/s/GeV.

Finally, our final neutrino spectrum is: $\frac{dN_{\nu}}{dE_{\nu}} = 2.68 \times 10^{-10} (E/1\text{GeV})^{-1.9}$.

To get an event rate, you take your neutrino spectrum and integrate it over effective area:

$$\int_A \frac{dN}{dE} \times A_{eff} dE$$ \hspace{1cm} (2)

I used ROOT’s TSPLINE3 class to interpolate the points of the effective area plot. With interpolation, you have a function you can numerically integrate over the result spectrum with. Doing this, I get a final event rate of 0.016 neutrinos per year. This is assuming an effective area for AMANDA II, however. This expected rate should go up by at least an order of magnitude. The minimum neutrino energy I assumed was also quite high, following the wind model of Torres et al. It is not out of the realm of possibility to expect an event or two per year from this source. This is definitely a candidate galactic source.