DM Flux

Wen-Hua Wu

December 2020

We can obtain the dark matter (DM) flux Φ_χ kicked by neutrinos emitted from a supernova (SN) with known positions, onto the earth by the following formula:

$$\Phi_\chi = L_\nu n_\chi c \sigma_{\nu-\chi}$$

n_χ and L_ν are number density of DM per volume on the line of sight from SN to earth and number density per area of neutrino, $\sigma_{\nu-\chi}$ is the cross section between DM and neutrino, which is about 10^{-30} 10^{-40}. c is light speed. We adopt the NFW model for DM distribution:

$$n_\chi = \frac{\rho_s}{m_\chi \frac{r}{r_s}(1+\frac{r}{r_s})^2}$$

$\rho_s = 0.184 \quad GeV/cm^3, r_s = 24.42 \quad kpc$ (M. Cirelli, G. Corcella, A. Hektor, G. Hutsi, M. Kadastik, et al., JCAP 1103, 051 (2011), 1012.4515.)

And L_ν is:

$$L_\nu = \frac{N_\nu}{4\pi R^2}$$

N_ν is the total number of neutrino in the shock (roughly 10^{58}), R is the distance between shock and SN. And if we want to calculate the actual flux observed on the earth, we must first figure out the relation between traveling time of neutrino t, and the receiving time of DM flux t'. Suppose the total traveling time of neutrino flux is T, and set $t = 0$ when neutrino flux begins from the SN, and $t' = 0$ when neutrino flux reaches the earth. And if we take the velocity of DM particle to be v, neutrino's velocity to be c, then it's easy to obtain that:

$$\begin{aligned} t' &= \frac{(c-v)(T-t)}{v} \\ \frac{dt}{dt'} &= \frac{-v}{c-v} \end{aligned} \tag{1}$$

Then the DM flux observed on the earth is:

$$\Phi'_\chi(t') = \Phi_\chi(t)\frac{dt}{dt'} = \frac{-v}{c-v}\frac{N_\nu}{4\pi R^2} n_\chi c \sigma_{\nu-\chi} \tag{2}$$

Where $n'_\chi(t') = n_\chi(t)$
If you notice the negative sign, that's because the nearer the DM particle is kicked the sooner it can reach the earth, thus the DM flux observed is sort of time reversal. Furthermore, we can see that the flux is actually proportional to the passed DM Halo density along LOS. Thus if we can observe some significant DM flux caused by a SN, we can use the observation to examine the density distribution of DM Halo along the LOS. And if we suppose $m_\chi = 10MeV$, the SN is on the line from Galactic center (GC) to the earth, and is $0.1kpc$ away from GC, while the earth is roughly $10kpc$ from GC, and the cross section is 10^{-28}. Then the total number of DM received on earth is 3×10^8 DM particles.