Distinguishing the DSNB and dark matter annihilation signals

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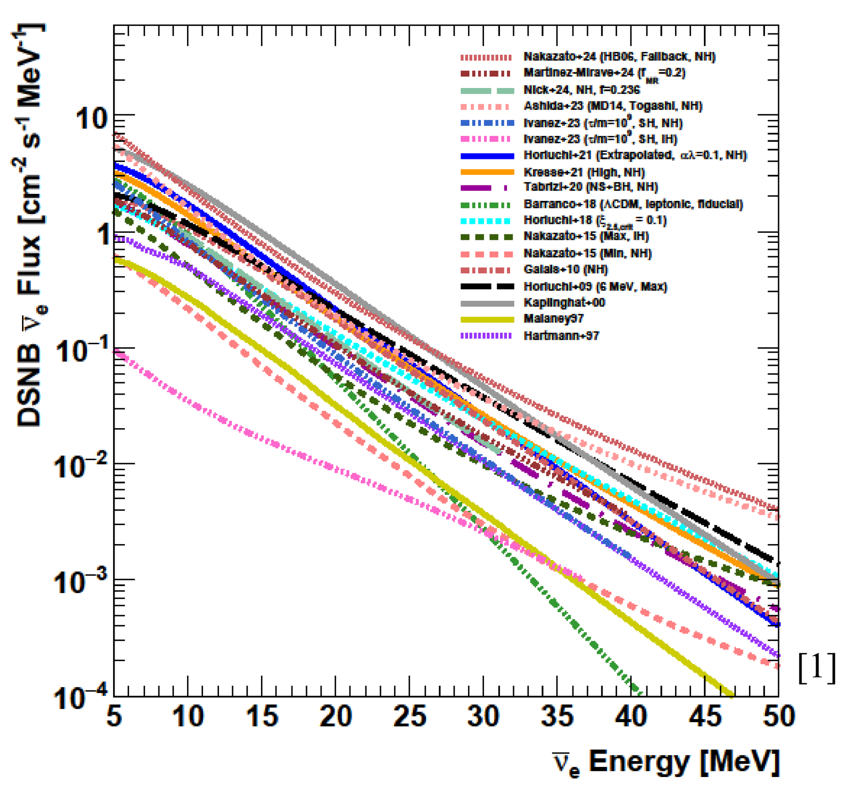
The ongoing Jiangmen Underground Neutrino Observatory (JUNO) and the upcoming Hyper-Kamiokande (HK) and Deep Underground Neutrino Experiment (DUNE) are expected to detect the neutrinos in the Diffuse Supernova Background (DSNB). However, the DSNB signal is similar to neutrinos from MeV dark matter annihilation. We study the neutrino flux from the annihilation of dark matter and the possible ways to distinguish the signals.

DSNB

The Diffuse Supernova Neutrino Background (DSNB) is the cumulative neutrino and anti-neutrino fluxes from all the past core-collapse supernovae in the universe.



Dark Matter

Dark matter and anti- dark matter can annihilate into neutrino and anti-neutrino pairs: $\chi\chi \rightarrow \nu\bar{\nu}$.

From the galactic plane [2]

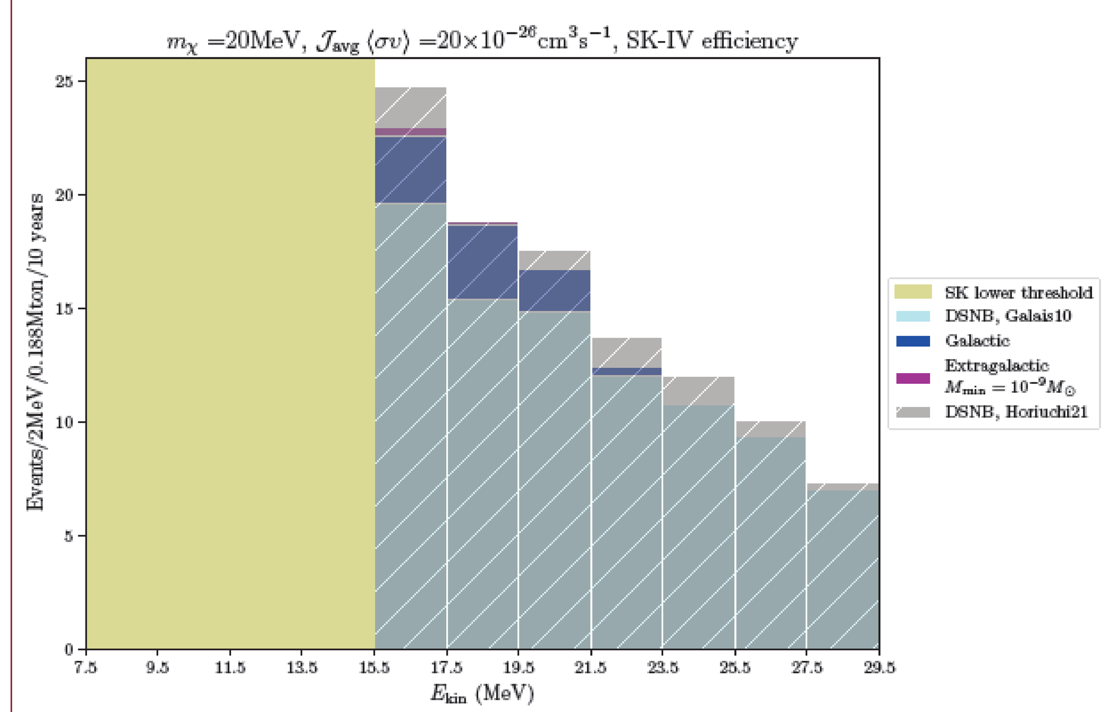
$$\frac{d\Phi_{\bar{\nu}}}{dE_{\bar{\nu}}} = \frac{<\sigma v>}{8\pi m_\chi^2} \mathrm{J} \frac{dN_{\bar{\nu}}}{dE_{\bar{\nu}}}$$

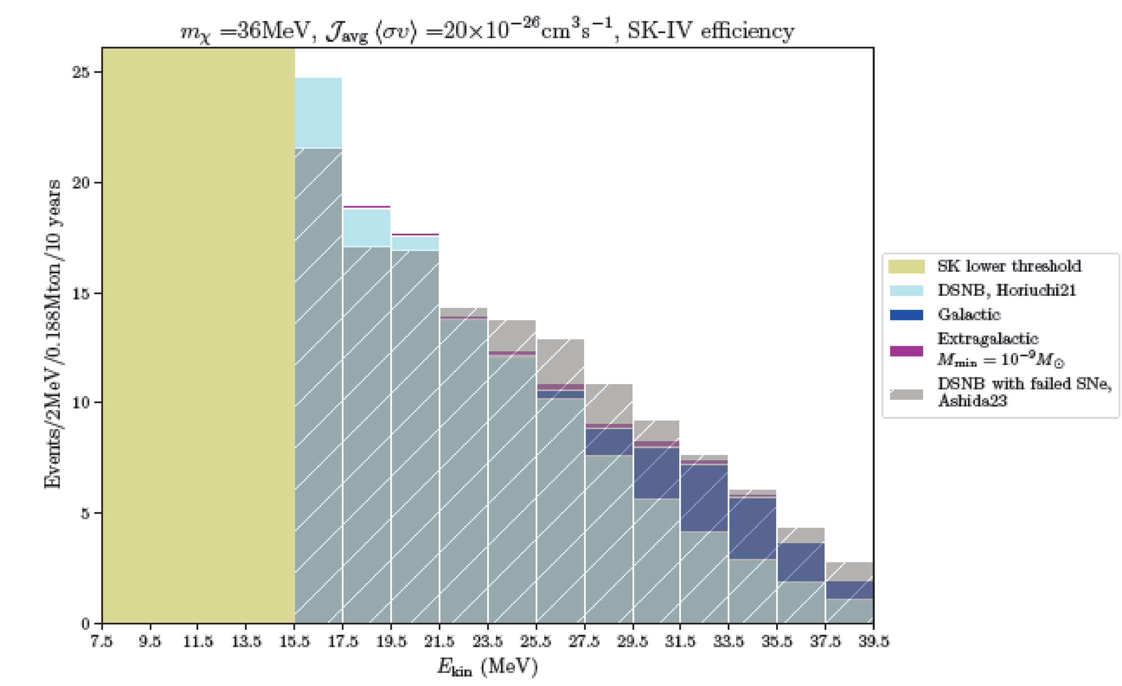
From extragalactic sources [3]

$$\frac{d\Phi_{\bar{\nu}}}{dE_{\bar{\nu}}} = \frac{<\sigma v>}{2} \frac{c}{4\pi H_0} \frac{\Omega_{\mathrm{DM},0}\rho_c^2}{m_\chi^2} \times \int_0^{z_{\mathrm{up}}} dz \frac{\Delta^2(z)}{h(z)} \frac{dN_{\bar{\nu}}}{dE_{\bar{\nu}}}$$

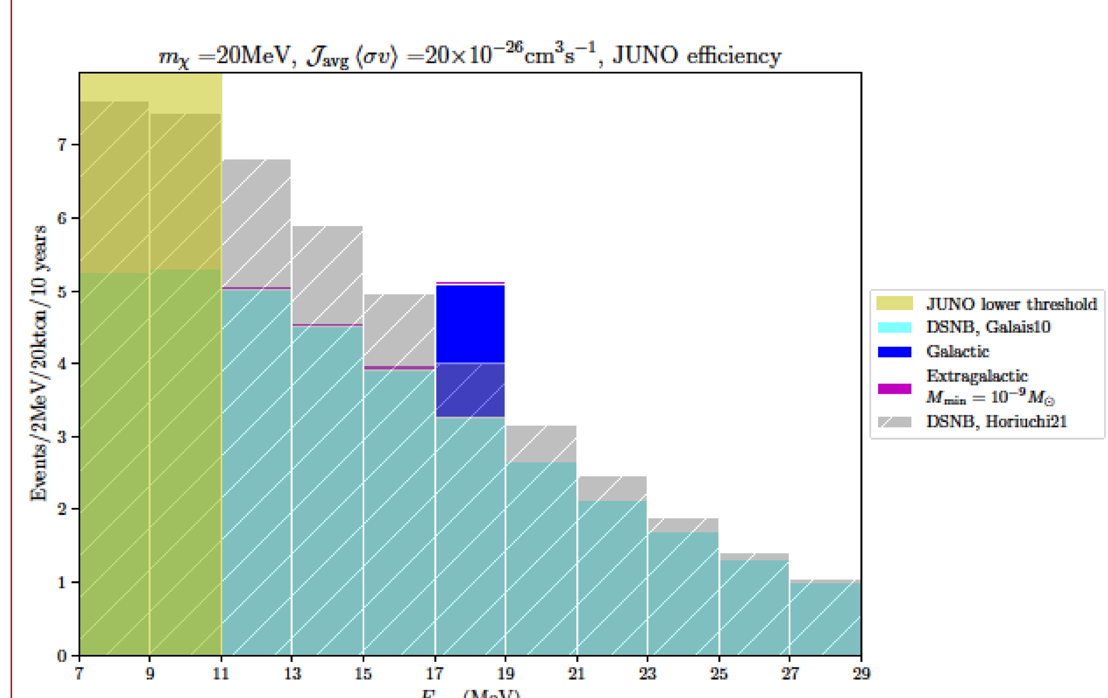
Here, $< \sigma v >$ is the annihilation cross-section times relative velocity, thermally averaged over the present DM velocity distribution. The J-factor is the line-of-sight integral of the square of the local DM density. $\frac{dN_{\bar{\nu}}}{dE_{\bar{\nu}}} = \frac{1}{3}\delta(m_\chi - E_{\bar{\nu}})$.
And $\Delta^2(z)$ is the factor that accounts for the enhancement to the annihilation rate due to the DM clustering in halos.

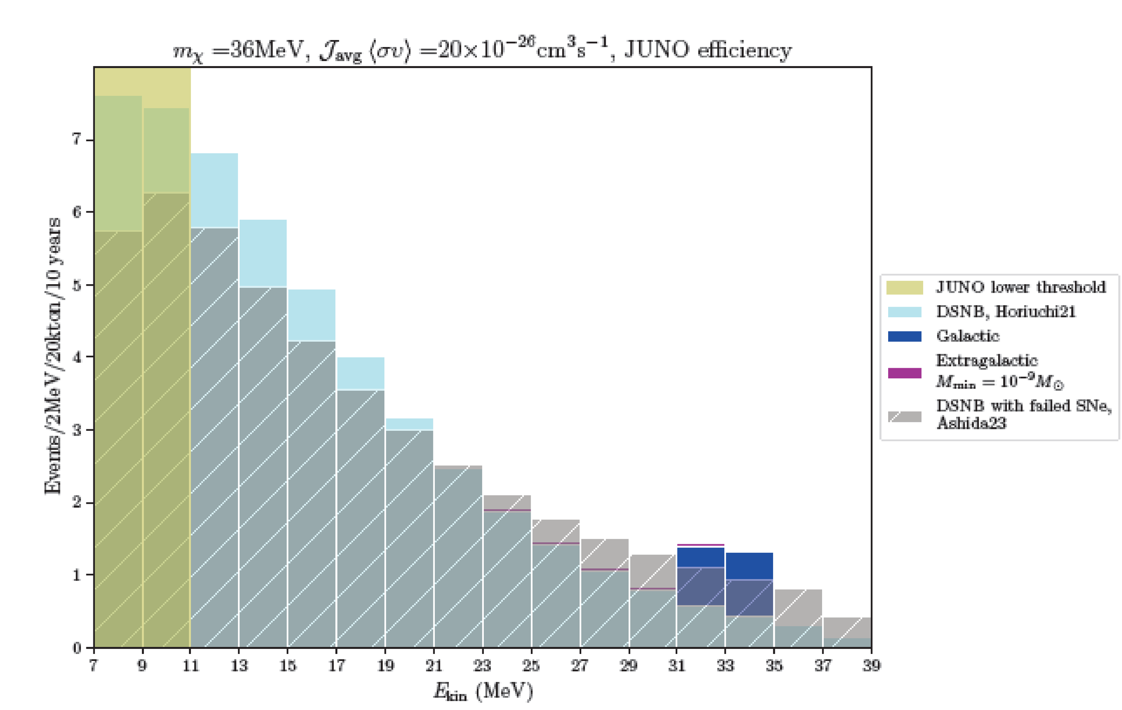
Signals Confusion





In Hyper-Kamiokande (HK), with the large number of theoretical DSNB models, it is possible to have a detection that could be interpreted it either as a DSNB + DM signal or a pure DSNB signal from a more optimistic model.
Dark matter with higher masses could imitate the effect of failed supernovae in DSNB models.
Here, we are assuming that HK has the same DSNB signal efficiency as the Super-Kamiokande phase IV observations.

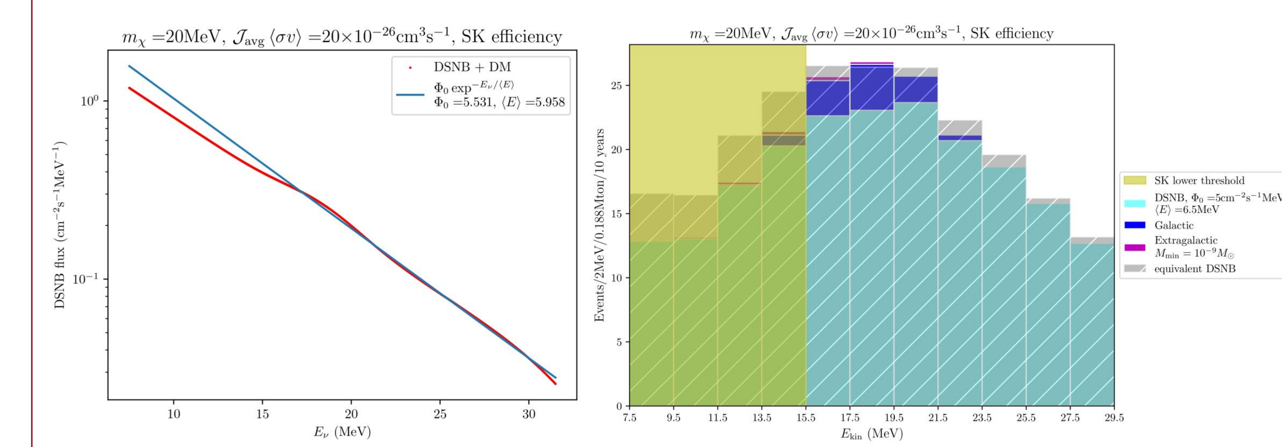




The Jiangmen Underground Neutrino Observatory (JUNO) has better energy resolution. In the ideal case, it would be easier to determine the contribution of dark matter. However, due to JUNO's smaller size, over the same observation period, the statistics can be low.

On-going Work

General exponential fit for the DSNB models $\Phi_e = \Phi_0 e^{-E/<E>}$ [4].



Including the effects of backgrounds such as atmospheric neutrinos.

Including the case where the dark matter particles annihilate into a pair of scalars ϕ, each promptly decaying into $\nu\bar{\nu}$ [3].

Statistical tests to distinguish the models: the profile likelihood method [5] and/or the χ^2_{pull} method [6]

Combining multiple detectors: JUNO's high resolution can be used as a guide for detectors that have higher volume/mass/operation time.

References

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