Abstract  Neutrinos are the second most ubiquitous Standard Model particles in the universe. On the other hand, they are also the ones least likely to interact. Connecting these two points suggests that when a neutrino is detected, it can divulge unique pieces of information about its source. Among the known neutrino sources, core-collapse supernovae in the universe are the most abundant for MeV-energies. On average, a single collapse happens every second in the observable universe and produces $10^{58}$ neutrinos. The flux of neutrinos reaching the Earth from all the core-collapse supernovae in the universe is known as diffuse supernova neutrino background. In this Chapter, the basic prediction for the diffuse supernova neutrino background is presented. This includes a discussion of an average neutrino signal from a core-collapse supernova, variability of that signal due to the remnant formed in the process, and uncertainties connected to the other astrophysical parameters determining the diffuse flux, such as cosmological supernova rate. In addition, the current experimental limits and detection perspectives of diffuse supernova neutrino background are reported.

1 Introduction

The night sky has always been a subject of humans’ interest. Since the first observations through the naked eye centuries ago, humans have developed a myriad of telescopes that allowed us to witness photos from the whole range of the electromagnetic spectrum - these observations permitted us to decode pieces of information about multiple astrophysical objects. But only in the last century have new observation channels opened through cosmic rays (Hess, 1912) and neutrinos (Cleveland
et al, 1998). The latter ones are the second most abundant particles in the Universe. The Earth is submerged in a neutrino background spanning several orders of magnitude in energy (Koshiba, 1992; Haxton and Lin, 2000; Becker, 2008; Lunardini, 2010; Beacom, 2010; Spiering, 2012; Gaisser and Karle, 2017; Vitagliano et al, 2020). But neutrinos interact much more rarely than photons, they do not lose as much information on their way to the Earth as photons or charged particles. Consequently, they can provide insights beyond the ones that photons carry. A part of this ubiquitous neutrino background is comprised of neutrinos produced by the centers of all the past core-collapse supernovae in the Universe commonly named diffuse supernova neutrino background (DSNB) (Bisnovatyi-Kogan and Seidov, 1984; Krauss et al, 1984; Wilson et al, 1986; Ando and Sato, 2004); for more recent reviews see, e.g., (Beacom, 2010; Lunardini, 2010; Kresse et al, 2021; Horiuchi et al, 2021). This neutrino flux bears information of the entire core-collapse supernova population. The rest of this chapter is organized as follows; Section 2 outlines a short description of the DSNB calculation and discusses the uncertainty of the astrophysical parameters entering the calculation. Section 3 discusses the current experimental limits on the DSNB and the future sensitivities.

2 Diffuse supernova neutrino background

The most basic prediction of the DSNB involves an average neutrino emission per core-collapse supernovae and the rate of the collapses expected in the universe. The former is discussed in Section 2.1 and the latter in 2.2.

2.1 Average neutrino emission per core-collapse

Core-collapse supernovae (CCSNe) are one of the most efficient neutrino sources known so far (Alexeyev et al, 1988; Hirata et al, 1987; Bionta et al, 1987). In the centers of massive stars, the densities and temperatures are tremendously high, which permits the production of numerous amounts of neutrinos from electron capture on free protons and nuclei (Bethe et al, 1979; Fuller et al, 1982; Fuller, 1982; Bruenn, 1985; Martinez-Pinedo et al, 2012), deexcitation and thermal interactions of nuclei (Fuller and Meyer, 1991; Fischer et al, 2013; Martinez-Pinedo et al, 2012). These neutrinos carry almost the entire gravitational binding energy of the star within approximately tens of seconds (Burrows and Lattimer, 1986).

The initial picture of the core-collapse explosions assumed that the bounce shock that ceases the rapid infall of the inner core was energetic enough to lead to an observable in photons explosion. However, detailed calculations together with numerical simulations have shown that the bounce shock loses a significant fraction of its energy to photodissociation of heavy nuclei and ram pressure of the still infalling core. Due to that loss, the shock stalls after traveling only tens to hundreds
of kilometers. (Colgate and White, 1966) and (Bethe and Wilson, 1985) postulated and explained how neutrinos streaming from the inner core could interact within the shock and reenergize it, leading to a supernova explosion. Initially, especially in spherically symmetric simulations, explosions were not achievable after including neutrino heating for massive progenitor stars. But the modern state-of-the-art 3D simulations (Burrows, 2000; Janka, 2012; Ott et al, 2013; Janka et al, 2016; Vartanyan et al, 2019; Burrows and Vartanyan, 2021) demonstrate that the delayed neutrino heating mechanism aided by the hydrodynamical instabilities and convection-driven turbulence can lead to successful explosions (Blondin et al, 2003; Tamborra et al, 2014; Couch and Ott, 2015).

The distribution of energies emitted by the core-collapse has been found to be representable by the fit (Keil, 2003; Keil et al, 2003; Tamborra et al, 2012) of the

$$\phi_{\nu_i}(E_{\nu_i}, t) = \delta_{\nu_i}(t) \left( \frac{E_{\nu_i}}{\langle E_{\nu_i}(t) \rangle} \right)^{\alpha_{\nu_i}(t)} \exp \left( - \left( \frac{\alpha_{\nu_i}(t) + 1}{E_{\nu_i}(t)} \right) \right), \quad (1)$$

where \(E_{\nu_i}\) is the neutrino energy, \(\langle E_i(t) \rangle\) is the average energy, and the normalization factor \(\delta_{\nu_i}(t) = \left( \int dE_{\nu_i} \phi_{\nu_i}(E_{\nu_i}, t) \right)^{-1}\). The pinching parameter \(\alpha_{\nu_i}(t)\) which tells how much the spectrum differs from a pure Fermi-Dirac distribution; which is recovered in this form when \(\alpha_{\nu_i}(t) \equiv \alpha = 2.3\) and the mean energy is connected to the temperature by \(\langle E_i(t) \rangle = 3.15 T_{\nu_i}(t)\). The differential flux of neutrinos \(\nu_i \in \{\nu_e, \bar{\nu}_e, \nu_\mu, \bar{\nu}_\mu, \nu_\tau, \bar{\nu}_\tau\}\) can be then expressed by the relation

$$f_{\nu_i}(E_{\nu_i}, t) = \frac{L_{\nu_i}(t)}{\langle E_{\nu_i}(t) \rangle} \frac{\phi_{\nu_i}(E_{\nu_i}, t)}{4\pi D^2} = \frac{F_{\nu_i}(E_{\nu_i}, t)}{4\pi D^2}, \quad (2)$$

where \(L_i(t)\) is the luminosity and \(D\) is the distance to the supernova.

The core collapse of a massive star can also lead to a direct black hole formation (Fryer, 1999; Sekiguchi and Shibata, 2004b,a; Zhang et al, 2008; Fischer et al, 2009; O’Connor and Ott, 2011a); plausibly without the observable electromagnetic radiation. In these cases, neutrinos may be the only detectable messengers from such an event. The directly black hole-forming progenitors are expected to produce more energetic neutrino spectra as the proto-neutron star masses are larger, leading to hotter and denser environments. In the case of neutron-star-forming core-collapse models, the mean energies of neutrinos tend to be between 10-18 MeV (Mirizzi et al, 2016), depending on the flavor. In the case of black-hole-forming models, the mean energies can grow to more than 20 MeV (Mirizzi et al, 2016).

### 2.2 Core-collapse frequency in the Universe

Core-collapse occurs for relatively massive stars \((8 \ M_\odot \lesssim M \lesssim 125 \ M_\odot)\) (Heger et al, 2003) which are characterized by short lifetimes (approximately \(10^6\) yr) on a cosmic scale. Due to this, the frequency of core-collapse events can be calculated directly using the star formation rate (SFR, \(\rho_*\)) and initial mass function (IMF, \(\xi\)).
These two parameters tell respectively about the speed of the formation of stars per co-moving volume and the distribution of stars’ masses at their births. Using them, the core-collapse supernova rate (CCSNR, \( R_{CC} \)) can be calculated as

\[
R_{CC}(z, M) = \frac{\dot{\rho}_*\(z\) \xi}{\int_{1.25}^{125} \frac{dM}{M_{\odot}} dM \xi}.
\] (3)

Employing this method means that any uncertainties impacting the measurements of the SFR and IMF will propagate to the CCSNR, and consequently DSNB; see, e.g., (Horiuchi et al, 2009; Lunardini and Tamborra, 2012; Mathews et al, 2014; Horiuchi et al, 2011; Møller et al, 2018; Singh and Rentala, 2021; Suliga et al, 2022; Ziegler et al, 2022).

Another way of determining the core-collapse rate is by identifying the frequency of the supernova events using electromagnetic observations (Mattila et al, 2012; Dahlen et al, 2012; Strolger et al, 2015; Petrushevskaya et al, 2016). This method also has its challenges. One of them is the fact that these are low-frequency events at small redshifts (Beacom, 2010). Moreover, the observations can underestimate the rate if not all core-collapse lead to an observable explosion, for example, when the star instead evolves directly into a black hole or a significant dust obscuration prevents clean observation (Mattila et al, 2012).

The percentage of progenitors evolving into black holes found by theoretical calculations and numerical simulations varies between a few to tens of percent (O’Connor and Ott, 2011b; Sukhbold et al, 2016; Sukhbold and Woosley, 2014; Ertl et al, 2016). There is also an effort to identify these stars by astronomical observations. Until now, two candidates have been found, among 27 nearby galaxies, which set the black hole-forming fraction to between approximately 4-40\% (Kooleank et al, 2008; Lien et al, 2010; Gerke et al, 2015; Adams et al, 2017b,a; Davies and Beasor, 2020; Neustadt et al, 2021).

On a separate note, (Horiuchi et al, 2011) identified a tension by a factor of two between the supernova rate calculated using the IMF and SFR and the one obtained directly from the observations of core-collapse explosions. This uncertainty propagates into DSNB modeling as well.

Looking from the other side, the DSNB measurement is an independent indirect probe of the SNR and fraction of back-hole-forming progenitors (Lunardini, 2009; Keehn and Lunardini, 2012; Horiuchi et al, 2011; Nakazato, 2013; Nakazato et al, 2015; Priya and Lunardini, 2017; Horiuchi et al, 2018; Møller et al, 2018; Kresse et al, 2021; Singh and Rentala, 2021; Horiuchi et al, 2021; Libanov and Sharofeev, 2022; Ekanger et al, 2022).

Observational evidence points out that most stars reside in binary systems (Sana et al, 2012; Zapartas et al, 2021), which opens up the possibility of binary interactions and introduces additional uncertainty in the DSNB. The binary interactions of massive stars can lead to redistribution of masses in the supernova population due to the mass transfer or changes in the number of stars undergoing core collapses by mergers. If two progenitors that were not expected to undergo supernovae form a star massive enough to undergo core collapse, the number of CCSN increases. On
the other hand, if both stars before the merger were expected to undergo CCSN, the mergers decreased the number of CCSN. Convolving these arguments with the IMF leads to the conclusion that the number of CCSN after including binary interactions increases. The effect of binary interactions on the DSNB can lead to a 0-75% increase in the flux (Horiuchi et al, 2021). The exact details depend on the modeling of the common envelope, in particular, how easy it is to unbind it and whether rotation effects are taken into account. The latter can lead to the development of more massive cores, which result in a larger neutrino flux (Horiuchi et al, 2021).

2.3 Diffuse supernova neutrino background estimates

The diffuse supernova background for sum of all neutrino flavors can be calculated with the expression

\[ \Phi(E_\nu) = \frac{c}{H_0} \int_0^{\zeta_{\text{max}}} \frac{1}{\sqrt{\Omega_\text{M}(1+z)^3 + \Omega_\Lambda}} \int_{8 M_\odot}^{125 M_\odot} dM F'_\nu(E'_\nu, M) R_{\text{CC}}(z, M), \]

where \( c \) is the speed of light, \( H_0 \) is the Hubble constant, \( z \) is the cosmological redshift, \( E'_\nu = E_\nu(1+z) \), \( \Omega_\text{M} \) and \( \Omega_\Lambda \) are respectively the fractions of the energy density in matter and dark energy, and \( F'_\nu(E'_\nu, M) \) is the time-integrated flux from a single core-collapse supernova in all flavors.

Figure 1 shows the DSNB estimated using (Salpeter, 1955) IMF, nominal SFR taken from (Horiuchi et al, 2011), and assuming that all the CCSNe emit the Fermi-Dirac neutrino spectrum characterized by the temperature \( T_\nu \) and total energy emitted by all flavors is \( 3 \times 10^{53} \) erg. The figure highlights how one of the uncertainties - the shape of the neutrino spectrum emitted from CCSN - modifies the DSNB. It also points out that higher fraction-of-black-hole forming stars in the entire CCSN population increases the high energy tail of the DSNB (Lunardini, 2009), as these stars are expected to produce hotter spectra. The shaded bands labeled Reactor, Solar, and Atmospheric indicate in which energy regions these irreducible neutrino backgrounds affect the DSNB measurement (see Section 3).

While propagating through the supernova medium, neutrinos undergo flavor conversions due to their self-interactions and coherent forward scattering of the medium particles. The neutrino conversions may affect the DSNB flavor content. The solution to the neutrino flavor evolution inside the core-collapse supernova is yet to be found. The main difficulty, compared to neutrino flavor evolution in the Sun, is the possibility of the neutrino self-interactions which may lead to highly non-linear flavor evolution (Duan et al, 2010; Balantekin and Pehlivan, 2007; Chakraborty et al, 2016; Tamborra and Shalgar, 2020). Thus, detecting the DSNB in all flavors is vital to disentangle the astrophysical uncertainties from the effect of neutrino flavor conversions.
Fig. 1 The DSNB for sum of all flavors assuming the Fermi-Dirac spectrum described by the temperature \( T_\nu \) and the total energy emitted in all flavors \( 3 \times 10^{53}\) erg. Different \( T_\nu \) reflect how one source of uncertainty - the spectrum emitted from CCSN - can modify the DSNB. The shaded bands labeled by the Reactor, Solar, and Atmospheric mark the regions where these three nonreducible backgrounds affect the DSNB measurement.

3 Detection of the diffuse supernova neutrino background

The weak interaction nature of neutrinos is simultaneously a blessing and a curse. On the one hand, neutrinos can travel large distances undisturbed, but on the other hand, it is incredibly challenging to detect them. A way of mitigating the difficulty of observing astrophysical neutrinos is building large detectors with many targets and shielding these detectors from large fluxes of particles interacting strongly and electromagnetically. Here we describe some of the neutrino detectors sensitive to MeV energies, suitable for diffuse supernova neutrino background measurement in various neutrino flavors.

3.1 Detection of the electron antineutrino component

The diffuse supernova neutrino background has not been observed so far. But Super-Kamiokande (SK), one of the existing large-scale water Cherenkov detectors, is the leader in setting the upper limits on the \( \bar{\nu}_e \) component of the DSNB. The latest results, from the DSNB search at SK, indicate that \( \Phi_{\bar{\nu}_e} < 2.7 \text{ cm}^{-2} \text{ s}^{-1} \), for \( \bar{\nu}_e \) energies larger than 17.3 MeV (Bays et al, 2012; Zhang et al, 2015; Abe et al,
Fig. 2 Limits on the $\bar{\nu}_e$ component of the DSNB from SK (Bays et al, 2012; Zhang et al, 2015; Abe et al, 2021) and KamLAND (Abe et al, 2022) (colored markers) together with theoretical predictions grey lines). Figure extracted from Ref. (Abe et al, 2021).

2021). This limit is still a factor of approximately 2-3 above the values obtained in most current theoretical estimates, as illustrated by Figure 2.

### 3.1.1 Water Cherenkov detectors

Water Cherenkov detectors operate utilizing the fact that charged particles that move at speeds higher than the speed of light of the detector medium emanate Cherenkov radiation. The detector then registers this light by photomultiplier tubes and detects the moving particle. But since neutrinos do not have an electric charge, to register their presence in the detector, they need to interact with the detector targets either by the momentum transfer or creation of a charged particle. In water, for neutrinos with energies close to $\mathcal{O}(10)$ MeV, $\bar{\nu}_e$ have the largest probability of interaction with free protons through the Inverse Beta Decay (IBD)

$$\bar{\nu}_e + p \rightarrow n + e^+.$$  \hspace{1cm} (5)

Ultimately, because the number of the hydrogen (proton) targets surpasses twice the number of the oxygen targets, the threshold for IBD reaction is low ($E_{th} = 1.806$ MeV), and both products of the reaction can be identified IBD is the primary DSNB observation channel in water Cherenkov detectors.

To reduce the backgrounds preventing the DNSB detection, SK has been adding gadolinium sulfate (GdCl$_3$) (Beacom and Vagins, 2004) to the water in the tank since 2020. To understand how the addition of GdCl$_3$ will help the background...
Fig. 3 Schematic of tagging the inverse beta decay in water with dissolved gadolinium sulfate (Figure based on the one from Ref. (Beacom and Vagins, 2004)).

suppression, let us take a closer look at how SK identifies the IBD events. In an IBD reaction, two products are made: a neutron and a positron. The positron emits Cherenkov radiation by which it can be identified. Unfortunately, in the DSNB energy window, several backgrounds emit Cherenkov radiation, e.g., decay electrons from invisible (with energies below the Cherenkov threshold) atmospheric muons. To distinguish the signal from background events, coincident detection of neutron and positron is required.

A way of doing so is looking for Cherenkov radiation followed up shortly by $\gamma$ cascades, which come from excited by neutrons nuclei. This neutron-tagging procedure demands a target element that is both efficient neutron capturer and deexcites by emission of well-measured and observable $\gamma$ cascade. So far this has been done using free protons. But it turns out that gadolinium has a cross section for thermal neutron capture,

$$n + \text{Gd} \rightarrow \text{Gd}^* \rightarrow \text{Gd} + \gamma,$$

$\approx 4.9 \cdot 10^4$ barn (Wolfram Research, 2022) (it is $10^5$ times higher than thermal capture on free protons) and deexcites fast by a $\gamma$ cascade with the total energy of 8 MeV which is much easier to observe in SK than 2.2 MeV deexcitation from protons. Addition of 0.1% GdCl$_3$ to the water in SK should reduce the invisible muon background by almost a factor of 5 and leave only single spallation product ($^9\text{Li}$) as background for the DSNB search (Beacom and Vagins, 2004; Abe et al, 2021). SK enriched with Gd might provide $3\sigma$ detection for the DSNB detection already after 5-10 years (Beacom and Vagins, 2004).
3.1.2 Liquid scintillator detectors

Another class of detectors which may measure the $\bar{\nu}_e$ component of the DSNB are the liquid scintillator detectors. This type of detectors can identify the IBD interaction by detecting both the prompt scintillation light coming from positron annihilation and its kinetic energy with coincidence by the delayed $\gamma$ rays from the neutron capture on proton.

Jiangmen Underground Neutrino Observatory (JUNO) (JUN, 2022), under construction, and THEIA (Askins et al, 2020), proposed, are the large-scale detectors which aim to measure the $\bar{\nu}_e$ component of DSNB within the next decades. Using the pulse shape discrimination techniques (Möllenberg et al, 2015; Dunger and Biller, 2019), these detectors are expected to suppress large neutral current atmospheric neutrino backgrounds and leave only the reactor and low energy atmospheric $\bar{\nu}_e$ fluxes as the backgrounds sources in the DSNB search window. JUNO is expecting to provide $3\sigma$ evidence for the DSNB detection after approximately 10 years of running (JUN, 2022) and THEIA after 1 year thanks to its large volume (Askins et al, 2020). THEIA would use a novel water-based liquid scintillator to get both scintillation and Cherenkov light, aiming to be the best of both worlds.

3.2 Detection of the electron neutrino component

Water Cherenkov and scintillator detectors cannot detect the $\nu_e$ component of the DSNB due to lower cross sections and high backgrounds present in the relevant energy range. Currently, the best upper limit on the $\nu_e$ component of the DSNB comes from the Sudbury Neutrino Observatory (SNO), which employed heavy water. The upper limit placed by SNO is $\Phi_{\nu_e} < 19 \text{ cm}^{-2} \text{s}^{-1}$, for $\nu_e$ energies between 22.9 MeV and 36.9 MeV (Aharmim et al, 2020), which is approximately a factor of 20 above the majority of the theoretical predictions. There are multiple challenges that made the measurement nonfeasible, including the large solar neutrino rate and decaying muon background.

3.2.1 Time projection chamber - Deep Underground Neutrino Experiment

The Deep Underground Neutrino Experiment (DUNE) is a planned neutrino experiment that will include a large-scale Liquid Argon Time Projection Chamber (40 ktons fiducial volume) (Abed Abud et al, 2021). In this type of detector the main detection channel of the DSNB neutrinos is the charge-current interaction of $\nu_e$ with argon targets ($\nu_e + {^{40}\text{Ar}} \rightarrow e^- + {^{40}\text{K}^+}$). The large sensitivity to electron neutrinos is a feature that distinguishes DUNE from the water Cherenkov and liquid scintillator detectors; it introduces a new channel of observation for the DSNB.

The $\nu_e$ is identified by its interaction products, in a similar manner as $\bar{\nu}_e$ in water Cherenkov and scintillator detectors. The detector registers the ionization track and
the scintillation light coming from the electron together with the $\gamma$ cascade from the deexcitation of potassium nuclei. If the spallation backgrounds can be efficiently reduced (Zhu et al, 2019) and DUNE operates on tens of years timescale, there is a possibility of detecting DSNB. In optimistic scenarios, $3\sigma$ could be achieved after 10 years of running (Møller et al, 2018).

### 3.3 Detection of the non-electron neutrino component

While the prospects for detecting the $\nu_e$ and $\bar{\nu}_e$ components of the DSNB seem optimistic, to fully capture all the physics and astrophysics involved with the DSNB the measurement of the non-electron flavors ($\nu_\mu, \bar{\nu}_\mu, \nu_\tau, \bar{\nu}_\tau$ - that are commonly described as $\nu_x$ in supernova due to their similarity) is also necessary. From the perspective of bare fluxes, the situation seems similar to $\nu_e$ and $\bar{\nu}_e$; the fluxes are comparable, and the detection window is nearly the same. Detecting MeV-scale non-electron neutrinos, however, is challenging because they cannot produce a charged lepton in their interactions as the lowest thresholds for the charged-current reactions are at least as high as the charged lepton masses. Due to this, the detection of the $\nu_x$ component of DSNB requires neutral-current channels.

A potential detection channel could be the elastic scattering of neutrinos on electrons, but it is not feasible since the signal cannot be distinguished from the ample backgrounds without the possibility to tag both products of the reactions in the detectors described in previous sections. The existing upper limit on the $\nu_x$ component of the DSNB is a thousand times worse than most of the theoretical models (Lunardini and Peres, 2008).

#### 3.3.1 Direct dark matter detectors - coherent elastic neutrino-nucleus scattering detectors

Another possibility for observing non-electron neutrino component of the DSNB is the recently opened channel of neutrino detection – the coherent elastic neutrino-nucleus scattering (CEvNS) (Akimov et al, 2017). This process has nearly the same cross section for all neutrino flavors (Freedman, 1974), and the coherence condition is satisfied within the detection window of DSNB for most nuclei employed by the CEvNS experiments. The detectors solely focused on measuring the neutrinos from accelerators (Akimov et al, 2017), and nuclear reactors (Akimov et al, 2013; Agnolet et al, 2017; Strauss et al, 2017; Hakenmüller et al, 2019; Aguilar-Arevalo et al, 2019) are too small to register even a single DSNB event over tens of years. However, large-scale direct dark matter detectors such as XENON & LZ, DARWIN, PANDA (Aalbers et al, 2016; Aprile et al, 2017; Akerib et al, 2019; Aprile et al, 2018, 2020; Akerib et al, 2020; Meng et al, 2021) can. These detectors maintain extremely low background levels as their primary goal is to detect dark matter caused nuclear recoils. Because of it, it is not necessary to register both interaction
Fig. 4 The calculated sensitivity to the non-electron neutrino component of the DSNB in xenon-based CEvNS detectors. The y-axis ($E_{\nu_x}$) is the total energy emitted by one non-electron neutrino flavor, whereas the x-axis ($\langle E_{\nu_x} \rangle$) shows the average neutrino energy. In addition, the current SK limit on $\bar{\nu}_e$ (Abe et al, 2021) and the SNO limit on $\nu_e$ (Aharmim et al, 2020), the SN 1987A limit on $\nu_x$ (Suliga et al, 2022), and the average emission per collapse in nominal theoretical DSNB models (Møller et al, 2018) are shown.

products to register a neutrino interaction. While the completed detectors (Aprile et al, 2018) can only match the upper limits from neutrino electron elastic scattering, the currently running and planned detectors (Aalbers et al, 2016; Aprile et al, 2020; Akerib et al, 2020; Meng et al, 2021) can improve these limits approximately by two orders of magnitude (Strigari, 2009; Suliga et al, 2022); see Figure 4. In addition, depending on the exact exposure and the status of the uncertainty of the low energy atmospheric neutrino flux, this could potentially lead to detection.

Another potential channel for detecting the $\nu_x$ component of the DSNB is the elastic scattering of neutrinos on protons in liquid scintillator detectors such as JUNO (Tabrizi and Horiuchi, 2021). This detection channel, however, has considerable challenges, a vast number of background events originating from solar neutrinos, radioactive decays of detector material, and cosmogenic backgrounds (An et al, 2016).

Summary The diffuse supernova neutrino background is a guaranteed neutrino flux that encodes information about the entire core-collapse supernova population in the observable universe. Its detection can serve as an independent indirect measurement of the core-collapse supernova rate, the fraction of black-hole-forming
supernova progenitors, and the average neutrino flux per progenitor. Due to the unknowns connected to the neutrino flavor evolution in the dense environments and potential physics beyond the Standard Model in the neutrino sector, as well as uncertainties of the astrophysical parameters, to extract the most information, it is vital to detect diffuse supernova neutrino background in all flavors. The prospects for detecting the $\bar{\nu}_e$ and $\nu_e$ are optimistic. New strategies for detecting the non-electron flavor component are needed.

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Cross-References

Weak Interactions in Evolving Stars
Reaction Rate Uncertainties and Stellar Evolution
Neutrino charged and neutral current opacities in the decoupling region
Nuclear Physics Constraints on Neutrino Astrophysics
Neutrinos and Heavy element nucleosynthesis
Entanglement and Many-Body effects in core-collapse supernovae
Recent developments in neutrino collective oscillations in supernovae
Nuclear weak processes in astrophysical plasma
Explosive nucleosynthesis in core-collapse supernovae
Nucleosynthesis in neutrino-heated ejecta and neutrino-driven winds of core-collapse supernovae; neutrino-induced nucleosynthesis
Electron-capture rates for stars and supernovae

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