

Institute for Cosmic Ray Research, The University of Tokyo
Super-Kamiokande Collaboration

Super-Kamiokande Reports the First Indication of the Diffuse Supernova Neutrino Background

— A clue to the faint “whispers” imprinted across cosmic history —

The research results were presented on June 25, 2026, at **Neutrino 2026: XXXII International Conference on Neutrino Physics and Astrophysics**, held at the University of California, Irvine, USA.

Summary

The Super-Kamiokande Collaboration*¹ has, for the first time in the world, found an indication of the Diffuse Supernova Neutrino Background (DSNB)*² at a significance level of 2.6 sigma (99.5% confidence level). This result was obtained through a detailed analysis of approximately 5,000 days of observational data, combining the pure-water operation period (3,349 days between 2008 and 2020) and the gadolinium*³-loaded period (1,653 days from 2020 to the present). The DSNB is the integrated flux of neutrinos originating from all core-collapse supernovae*⁴ throughout cosmic history, and its direct detection has been a long-standing goal since the launch of the Super-Kamiokande (SK) project. This achievement provides an important clue for deepening our understanding of the history of cosmic star formation and nucleosynthesis.

Background

Core-collapse supernovae are explosive phenomena that occur at the final stage of massive star evolution, releasing enormous amounts of energy in the form of neutrinos. In addition to neutrinos, these explosions disperse elements synthesized in stellar interiors into space. They are thought to be the primary sources of the carbon, oxygen, silicon, iron, and other elements that constitute our own bodies and the world around us.

The DSNB is the accumulation of neutrinos emitted by all core-collapse supernovae throughout cosmic history, from the early universe to the present. However, neutrinos arriving from vast distances are diffuse, and their signals are extremely faint, making detection challenging.

Capturing the DSNB would provide a definitive observational means to quantitatively

unravel the history of nucleosynthesis and star formation in the universe, and to test theoretical models. Undertaking this observation is nothing other than straining to hear the "faint whispers" of supernova explosions engraved in cosmic history.

SK's predecessor detector, Kamiokande, succeeded in the direct observation of neutrinos from a single supernova (SN 1987A). However, detecting the DSNB — the accumulated signal from distant supernovae — has remained a long-standing challenge for Super-Kamiokande.

Observation Method and Results

Super-Kamiokande detects Cherenkov light produced when neutrinos interact with water, using a 50,000-ton tank of ultrapure water and approximately 13,000 photomultiplier tubes installed 1,000 meters underground in Kamioka, Hida City, Gifu Prefecture, Japan.

In this study, researchers analyzed approximately 5,000 days of data, combining the pure-water operation period (3,349 days between 2008 and 2020) and the gadolinium-loaded period (1,653 days from 2020 to the present). The introduction of gadolinium to SK's ultrapure water improved the accuracy of supernova neutrino signal identification via efficient identification of neutron captures, thereby greatly enhancing the detector's background rejection capabilities.

In this analysis, after effectively removing backgrounds — primarily atmospheric neutrino events and spallation events involving oxygen nuclei in water induced by cosmic rays — the team identified a statistically significant excess signal in the neutrino energy range from 13.3 to 81.3 MeV.

The significance of the excess signal is 2.6 sigma (99.5% confidence level). Although it cannot be explained as a random fluctuation, it does not yet meet the discovery threshold (5 sigma or higher) and is therefore currently described as an indication rather than a definitive detection. The estimated DSNB flux is $3.6 \pm 1.6 \text{ cm}^{-2} \text{ s}^{-1}$, consistent with the range predicted by several theoretical models (for example, the Horiuchi et al. 2009 6 MeV model, which predicts $2.1\text{--}3.9 \text{ cm}^{-2} \text{ s}^{-1}$).

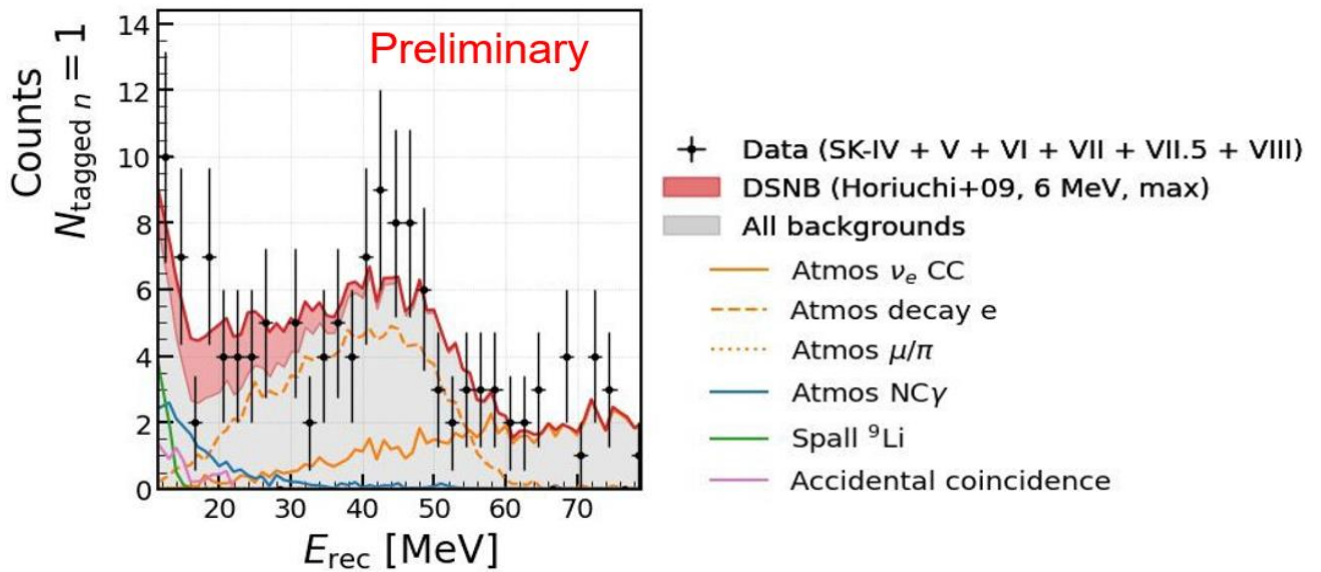
Significance and Future Prospects

. This first indication of the Diffuse Supernova Neutrino Background strongly suggests the signal's existence. However, with the current statistical significance at 2.6 sigma, additional data accumulation and further analysis improvements are necessary for a definitive detection. Ongoing observations at Super-Kamiokande, together with future collaboration with its successor detector, Hyper-Kamiokande, are expected to further improve sensitivity. This result is also expected to place strong constraints on models of cosmic star-formation

rates and nucleosynthesis. In particular, it is anticipated to contribute to a better understanding of the formation processes of neutron stars and black holes, as well as the chemical evolution of the universe.

Regarding this result, Hiroyuki Sekiya, Associate Professor at the Institute for Cosmic Ray Research, The University of Tokyo, and spokesperson for the Super-Kamiokande experiment, commented: “Observing the world's first indication of the Diffuse Supernova Neutrino Background is a deeply meaningful achievement and has been a long-cherished goal since the beginning of the Super-Kamiokande project. At the same time, the current statistical significance is 2.6 sigma, and additional data accumulation and further improvements in analysis are essential for definitive detection. We will continue observations at Super-Kamiokande and work toward a conclusive detection. We hope that this result will lead to a deeper understanding of the cosmic history of star formation and nucleosynthesis, as well as the formation processes of neutron stars and black holes.”

Observation Data and Analysis Results



Energy distribution of single-neutron events with Cherenkov angles close to 42 degrees, selected as candidates for the Diffuse Supernova Neutrino Background. The red region indicates the observed DSNB component.

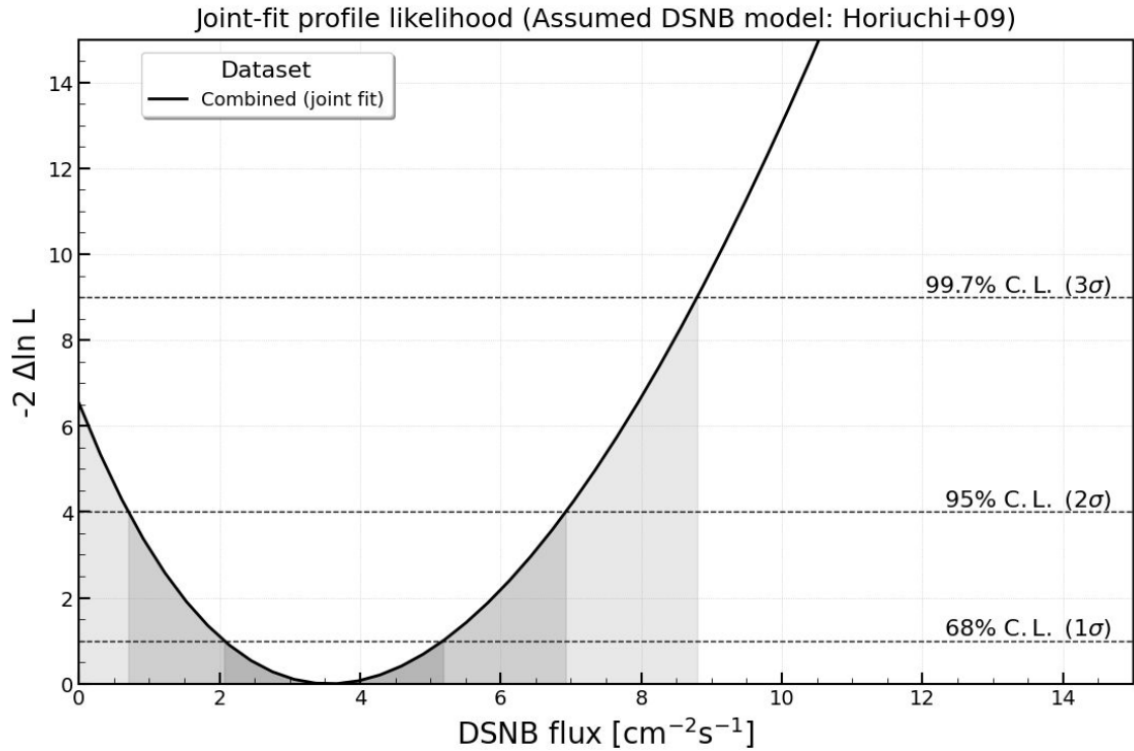


Figure showing the statistical interpretation of the observation results. The present result excludes the no-flux hypothesis at the 99.5% level and is best explained by a DSNB flux of $3.6 \text{ cm}^{-2} \text{ s}^{-1}$.

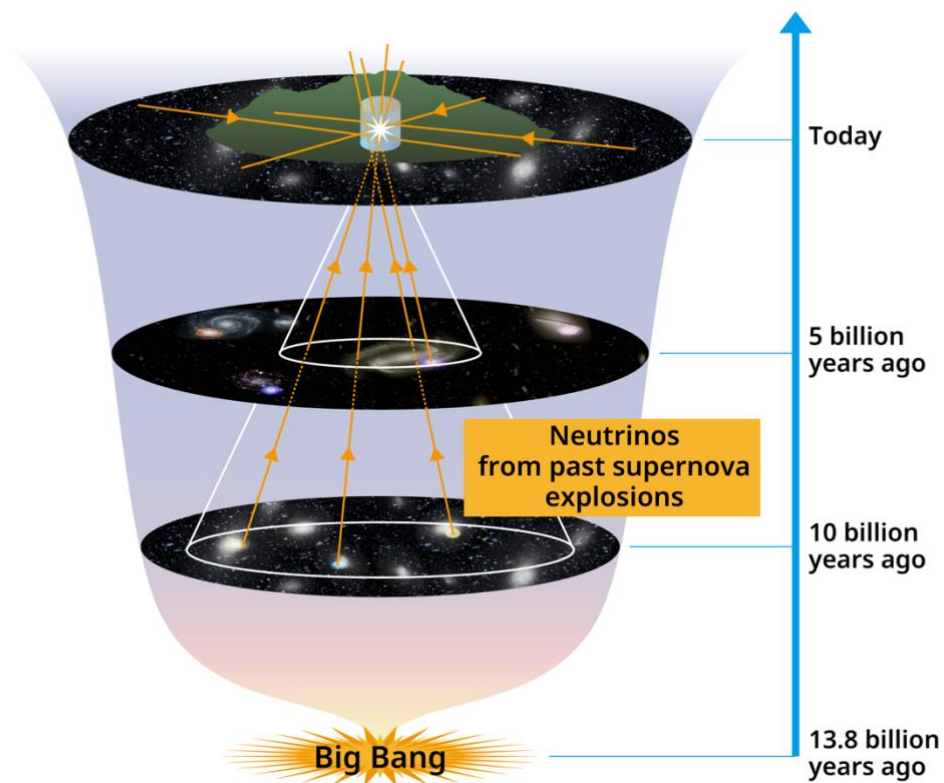
Glossary

*1 Super-Kamiokande

Super-Kamiokande is the world's largest underground neutrino observatory and began operation in April 1996. Located 1,000 meters underground in Kamioka, Hida City, Gifu Prefecture, Japan, it conducts neutrino observations and searches for proton decay. It is an international collaboration involving approximately 250 researchers from 60 universities and research institutions in Japan, the United States, Korea, China, Poland, Spain, Canada, the United Kingdom, Italy, France, and Vietnam, with the Institute for Cosmic Ray Research, The University of Tokyo serving as the lead institution.

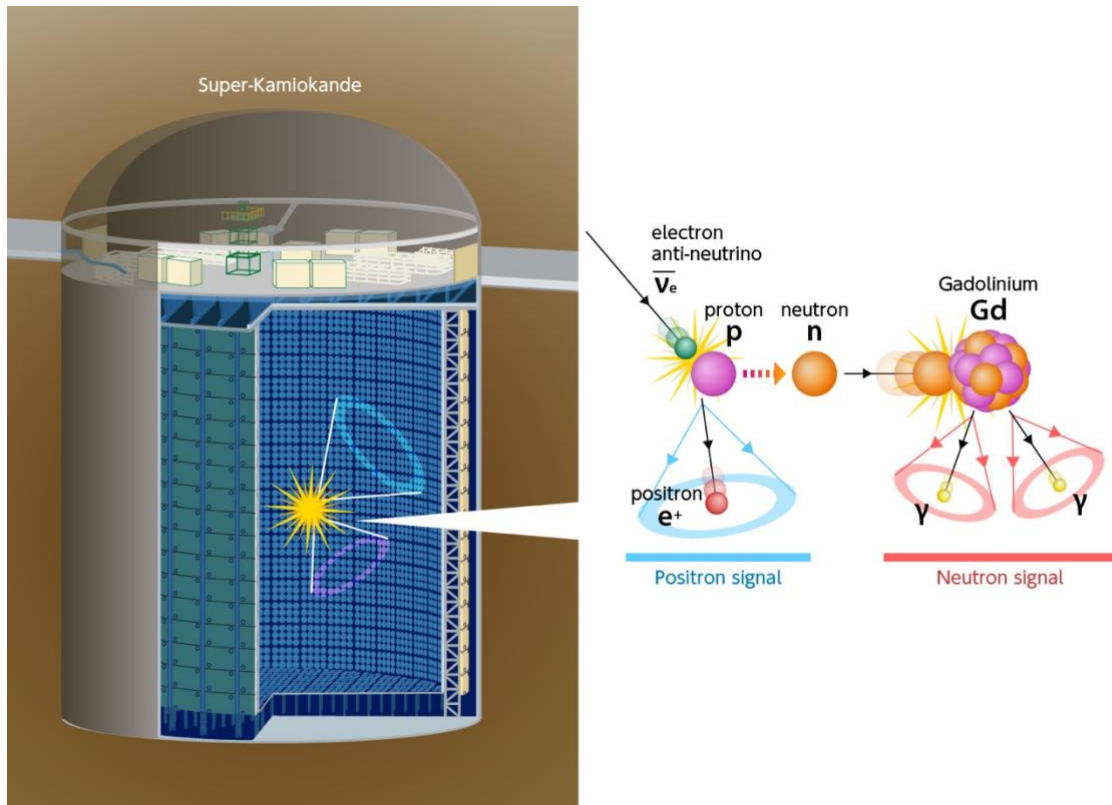
*2 Diffuse Supernova Neutrino Background (DSNB)

Across the universe, supernova explosions occur several times per second. Since the birth of the universe, neutrinos emitted by these supernovae have diffused through space and accumulated over cosmic time. This integrated neutrino flux is called the Diffuse Supernova Neutrino Background, also known as Supernova Relic Neutrinos (SRN).



*3 Gadolinium

Gadolinium (Gd), atomic number 64, is a rare-earth element with an exceptionally high ability to capture neutrons. When added to the water in Super-Kamiokande, gadolinium captures neutrons produced when electron antineutrinos from supernova explosions interact with water, creating an additional signal that helps distinguish those events from other background noise. Gadolinium was added to the Super-Kamiokande detector water in 2020 and again in 2022, and data taking has continued since then.



The addition of gadolinium enables signals from electron antineutrinos to be distinguished and detected more effectively.

*4 Core-collapse supernova

A core-collapse supernova is a gigantic explosion that occurs at the end of the life of a star more than about eight times as massive as the Sun. When nuclear fusion ceases, gravity causes the stellar core to collapse rapidly, leading to the formation of an ultradense neutron star or black hole. In the rebound, the outer layers are blown away, releasing vast amounts of matter and energy into space. This process also creates heavy elements and plays a crucial role in the evolution of the universe.