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Research Result Report
ICRR Inter-University Research Program 2025

Research Subject: Study of supernova neutrinos in Super-Kamiokande

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Summary of Research Result :

The purpose of this research is detection of the supernova neutrino in SK-Gd. There are two targets, one is neutrinos from nearby supernova explosion, the other is diffuse neutrinos from the past supernovae called 'Supernova Relic Neutrinos (SRN)'. The SK-Gd project is gadolinium (Gd) loading into Super-Kamiokande (SK) to increase inverse beta decay interactions of anti-electron neutrinos.

In 2020 summer, we've doped 13 tons of gadolinium sulfate into Super-Kamiokande, which is equivalent to 0.01% Gd mass concentration, and the SK-Gd experiment officially started. The neutron capture efficiency showed the expected performance, and the detector was operated stably. In 2022 summer, an additional 26 tons of gadolinium sulfate was introduced to the detection. (0.03% Gd mass concentration) The SK-Gd data taking is currently working well.

In 2024, we reported the first result of supernova relic neutrino in SK-Gd with 0.01% and 0.03% mass concentration gadolinium loaded water in SK-Gd. Though no significant signals were observed, the data showed about 2 sigma level of excess against the expected background events combined with all the SK phases. In FY2025, we published these results as a published paper. The three year's SK-Gd data demonstrated that it had similar sensitivity as the pure-water eight years SK data.

We also searched for neutrinos in Super-Kamiokande from the 'failed supernova candidate' that failed to explode due to the formation of a black hole after core-collapse, occurred in the Andromeda galaxy. No significant neutrino excess was observed, which provided the first experimental constraints on the supernova models.

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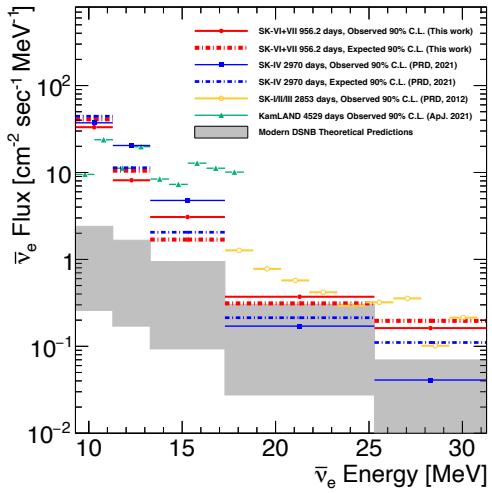
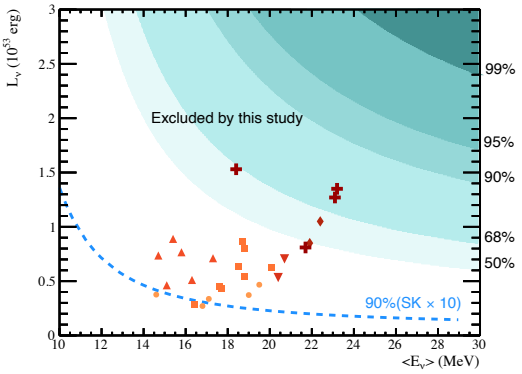


Upper limit of SRN flux [2]. Latest results in SK-Gd (red) and blue shows past results in SK (pure water, blue).



Total emitted electron antineutrino energy vs mean energy. The shaded bands indicate excluded region. Marks show the expectation of theoretical models [1].

Published paper

[1] Super-Kamiokande collaboration (K. Abe et. al.), Search for Diffuse Supernova Neutrino Background with 956.2 days of Super-Kamiokande Gadolinium Dataset, arXiv 2511.02222 (2025).

[2] Super-Kamiokande collaboration (F. Nakanishi et al.), First associated neutrino search for a failed supernova candidate with Super-Kamiokande, The Astrophysical Journal Letters. 997:L9 (2025).

Presentations

(1) M. Harada, Search for Diffuse Supernova Neutrino Background in Super-Kamiokande., ICRC2025, Geneve, Switzerland, June 16-22, 2025.
(2) Y. Koshio, Physics in Super-Kamiokande and Hyper-Kamiokande, 3rd International Workshop the Universe: from Quantum Mechnics to Quantum Gravity, Hanoi, Vietnam, November 26-28, 2025.
(3) F. Nakanishi, First Associated Neutrinos Search for a Failed Supernova Candidate with Super-Kamiokande, Seminar at APC, Paris, France, March 23, 2026.

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