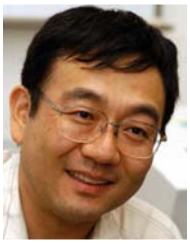
【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)



Title of Project : Search for Supernova Relic Neutrinos

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Research Area : Particle/Nuclear/Cosmic ray/Astro physics

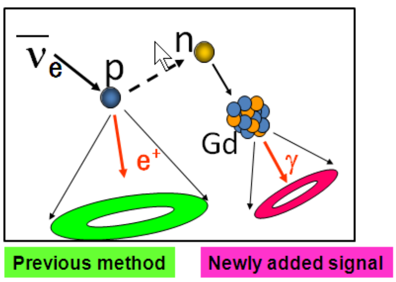
Keyword : Cosmic ray (experiment)

【Purpose and Background of the Research】

Massive stars more than 8 times the mass of our Sun finish their lives by explosions called supernovae. Supernovae are triggered by gravitational collapse of the iron core of these heavy stars. Since the density of matter is very high at the time of these explosions, neutrinos carry away 99% of the explosion energy because such dense matter is only transparent to neutrinos. There are approximately 10^{20} stars in the universe, and about 0.3% of them have masses more than 8 times the solar mass. So, about 10^{17} stars have become supernovae so far in the history of the universe. The neutrinos produced through the whole history of the universe are called supernova relic neutrinos (SRNs). The purpose of this research is to develop a method to detect SRNs.

【Research Methods】

The flux of SRNs is estimated to be about several tens of neutrinos per second and per square centimeters. It sounds like a strong flux, but it is much smaller than the flux of Boron-8 solar neutrinos; at the orbit of the Earth they have a flux of about 6 million neutrinos in the same units. Because neutrinos have very small cross section for interactions on matter, a large volume detector like Super-Kamiokande (SK) will be necessary to detect SRNs. In SK, we expect somewhere between 0.8 and 5 SRN signals per year, where the wide range of this event rate is due to prediction model uncertainties. However, in order to find SRN events among natural backgrounds induced by cosmic rays and solar neutrinos, a new method to identify the real signal is necessary. Supernovae produce all types of neutrinos. Electron-anti-neutrinos have the largest cross section on matter among them, and their interaction on free protons produce positrons and neutrons. So, if we can detect not only positrons but also neutrons, we can select pure SRN signals. For this purpose, we need to put 0.2% gadolinium compound into the SK water tank. Gadolinium has a large neutron capture cross section and emits high energy gamma rays which can be detected by the photomultipliers in the SK tank. SK is a multiple purpose detector, which at present is used for precise study of neutrino oscillations using solar, atmospheric, and man-made neutrinos. We therefore need to demonstrate that gadolinium will not cause any problems for other physics at SK before introducing it into the SK tank. In this research program, we will make a 100 ton-class test tank to mimic the SK detector and prove the principle.



【Expected Research Achievements and Scientific Significance】

If we can demonstrate gadolinium is OK using the test tank, we can convince our SK collaborators to introduce gadolinium. Then, SK will be able to cleanly detect about 4 – 20 SRN events with 5 years of data. This will be the first observation of SRN in the world. Since SRNs are accumulated neutrinos from the beginning of the universe, we will be able to study the star formation history. All chemical elements heavier than helium are produced by supernovae, so SRNs will tell us the origin of the materials surrounding and comprising us.

【Publications Relevant to the Project】

・Super-Kamiokande collaboration, "Search for supernova relic neutrinos at Super-Kamiokande", Phys. Rev. Lett. 90 (2003) 061101.
・J.F.Beacom and M.R.Vagins, "GADZOOKS! Anti-neutrino spectroscopy with large water Cherenkov detectors.", Phys. Rev. Lett. 93(2004)171101.
・Super-Kamiokande collaboration, "First Study of Neutron Tagging with a Water Cherenkov Detector", Astroparticle Physics 31 (2009) 320-328.

【Term of Project】 FY2009-2013

【Budget Allocation】 159,900 Thousand Yen

【Homepage Address and Other Contact Information】

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