Neutrinos and our Sun – Part 1

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The elusive neutrinos have periodically yielded their secrets to man and at each such juncture major advances have been achieved in our understanding of the sub-atomic phenomena. These particles also carry invaluable information about the centre of the Sun where energy is generated through nuclear fusion. In Part I of this article, history of the discovery of neutrinos is traced, their properties and types are described. Also, the Standard Model which forms the basis of the structure of matter and of which massless neutrinos are an integral part, is described.

The role of neutrinos in solar energy generation and the great ‘solar neutrino puzzle’ and its solution will be described later in the series.

1. Introduction

The neutrino is one of the elusive tiny particles created by nature. The hint of its existence came from radioactive beta-decay of nuclei. Although radioactivity was discovered at the very end of the nineteenth century (1896), it was only in 1931 that the neutrino was postulated by Pauli to save the principle of energy conservation in radioactive beta-decay. It took another twenty five years to detect neutrino interactions in the laboratory (1956).

Our sun, a dominant source of neutrinos, is powered by proton-proton fusion reactions in which 600 million tons of hydrogen are burned every second in the core. This nuclear fusion reaction, a process in which two light atomic nuclei merge to form a single heavier nucleus, produces not only heat and light but also a vast number
of neutrinos. Nearly seventy billion neutrinos from the sun pass through every square centimetre of our body (like our thumb nail) every second without any interaction. Photons or light produced in the deep interior of the sun undergo multiple interactions and take nearly ten million years to reach the surface of the sun and in this process of radiation transfer through the interior of the sun, the information of the core is lost. On the other hand, the neutrinos, because of their extremely weak interactions with matter, escape straightaway from the core without interacting and can thus be used to study the core of the sun, the seat of its energy generation. Neutrinos take only a few seconds to escape from the sun and they take another eight minutes to arrive on the earth.

A new role of neutrinos was realised on February 24, 1987, when astronomers observed a dazzling supernova in the Large Magellanic Cloud, which is a satellite galaxy to our own Milky Way, and is generally visible from the southern hemisphere. This supernova is named SN 1987A. It was bright enough to be seen by the naked eye. The parent star was about twenty times heavier than the sun. The most interesting part of SN 1987A is that two underground neutrino detectors, Kamiokande in Japan and IMB in USA, detected eight to twelve neutrinos from the supernova over a ten second interval. The detected neutrino signal strongly brought out the important role of neutrinos in the explosion of a massive star and its transformation into a tiny and incredibly dense object called a neutron star. Neutron stars are about twenty kilometres in diameter and extremely dense objects. They are as massive as or slightly more massive than the sun.

Only recently there is some evidence that neutrinos may possess a small mass (about a millionth the mass of an electron). What happens if neutrinos do possess some mass? As far as our day-to-day life is concerned, there