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A search for astrophysical burst signals at the Sudbury Neutrino Observatory

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ABSTRACT

The Sudbury Neutrino Observatory (SNO) has confirmed the standard solar model and neutrino oscillations through the observation of neutrinos from the solar core. In this paper we present a search for neutrinos associated with sources other than the solar core, such as gamma-ray bursts and solar flares. We present a new method for looking for temporal coincidences between neutrino events and astrophysical bursts of widely varying intensity. No correlations were found between neutrinos detected in SNO and such astrophysical sources.

1. Introduction

The Sudbury Neutrino Observatory (SNO) collaboration has looked for time-dependent anomalies due to both periodic variations [1,2] in neutrino flux and short bursts of neutrinos [3]. In the present study, we are specifically searching for neutrino events that are correlated to other known astrophysical events. There is a wide variety of potential astrophysical sources of neutrinos. In this paper we consider "burst" events, which include γ-ray bursts (GRB's), solar flares, magnetars, and an intense burst observed in the Parkes radio telescope. These astrophysical burst events are short-lived and occur at random. It is expected that any related neutrino signal in the energy range of this search would be undetectable [4,5] and the present experimental constraints provide only limits [6–10].

Similar searches for neutrinos temporally correlated with astrophysical events have treated all bursts (regardless of their intensity) equally in terms of their potential for ν production [9], and/or examined only the highest-intensity burst(s) [10]. We used a maximum likelihood burst analysis, which features some advantages over previous analysis techniques when searching data from neutrino detectors for temporal correlations with astrophysical burst events. Such an analysis provides the versatility to deal with bursts whose intensities vary over many orders of magnitude, and to accommodate correlations between γ intensity and ν emission. This allows us to use the integrated intensity over a large number of bursts instead of only the most intense burst. The results from the analysis can therefore be employed to test a variety of models in a straightforward manner and, as with previous analysis techniques, can be employed to set limits on the number of neutrino events correlated with the bursts – and hence indirectly set limits on the fluences.

We begin with a discussion of the SNO detector before discussing two types of astrophysical events, GRB's and solar flares, on which we have chosen to focus. In Section 4, we present the analysis method and motivation. Next, we examine solar flare and GRB observations in conjunction with the SNO neutrino data set, and give limits for the associated parameter for neutrino fluences from the burst events. We also show how this can be related to the neutrino fluence limits that have been typically presented in the literature. In the final section, we search for signals in the SNO data associated with two unusual isolated astrophysical events: the Parkes radio burst [11] and the SGR 1806-20 magnetar eruption [12]. In all cases, no significant correlations are seen between the SNO data and the astrophysical sources. However, limits on neutrino fluences from solar flares and GRB's are improved in the low-energy ν regime compared to previous analyses in the literature.

2. The SNO detector

The SNO detector [13], shown schematically in Fig. 1, consisted of an inner volume containing 10^6 kg of 99.92% isotopically pure heavy water (^2H_2O, hereafter referred to as D_2O) within a 12 m diameter transparent acrylic vessel (AV). Over 7×10^6 kg of H_2O between the rock and the AV shielded the D_2O from external radioactive backgrounds. An array of 9456 inward-facing 20 cm Hamamatsu R1408 photomultiplier tubes (PMTs), installed on an 17.8 m diameter stainless steel geodesic structure (PSUP), detected Cherenkov radiation produced in both the D_2O and H_2O. The PMT thresholds were set to 1/4 of the charge from a single photoelectron. The inner 1.7×10^6 kg of H_2O between the AV and the PSUP shielded the D_2O against radioactive backgrounds from the PSUP and PMTs.

The detector was located in Vale's Creighton mine (46°28′30″ N latitude, 81°12′04″ W longitude) near Sudbury, Ontario, Canada, with the center of the detector at a depth of 2092 m (5890 ± 94 meters water equivalent). At this depth, the rate of cosmic-ray muons entering the detector was approximately three per hour. Ninety-one outward-facing PMTs attached to the PSUP detected

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