Search for Short Transient Neutrino Emission with DeepCore-IceCube

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ABSTRACT

We present the results of a search for sources of transient neutrino emission using IceCube and DeepCore data acquired between May 15th 2012 and April 30th 2013. While the search methods employed in this analysis are similar to those used in previous IceCube point source searches, the data set being examined consists of a sample of predominantly sub-TeV muon neutrinos obtained through a novel event selection method. Thus, this search represents a first attempt at a point source analysis in this relatively unexplored energy range. The reconstructed direction and time of arrival of neutrino events is used to look for any significant self-correlation in the dataset; there is no comparison of the data set to a list of possible sources. This search encompasses the Northern sky ranging in declination from -5° to 90°. Examination of the data revealed no significant source of transient neutrino emission. This result has been used to construct limits on generic soft-spectra transients as well as a specific model of neutrino emission from soft jets in core-collapse supernovae.

Subject headings: neutrino astronomy, neutrinos, GRB, supernova, astroparticle physics

1. Introduction

The nascent field of neutrino astronomy exhibits great potential in its ability to answer several open questions in astrophysics. Specifically, the detection of astrophysical sources of neutrinos will help resolve one of the long-standing problems in astrophysics, the mechanisms behind the production and acceleration of cosmic rays. The hadronic nature of cosmic rays ensures that proton-proton collisions and photo-hadronic interactions are likely to occur at sites of cosmic ray acceleration therefore ensuring the production of pions and ultimately neutrinos. Unlike the charged nuclei that constitute cosmic rays, neutrinos lack charge and very rarely interact with intervening matter allowing these particles to provide directional information about their source. The detection of neutrino sources will therefore provide unequivocal identification of sources of cosmic rays.

Perhaps the most promising potential source for this analysis is a special class of core-collapse supernova referred to as a choked GRB.

Observations indicate that there is a correlation between long duration gamma-ray bursts (GRBs) and core-collapse supernovae (SNe). The leading model for GRB production assumes that relativistic jets are generated by the core-collapse within the progenitor star. Charged particles undergo Fermi-acceleration within internal shocks of these jets and subsequently give rise to gamma ray emission once the jets breach the surrounding stellar envelope. Very few SNe result in the occurrence of GRBs, however, it has been suggested that a significant fraction of core-collapse SNe manage to produce mildly relativistic jets. These jets are insufficiently energetic to break through the envelope and are effectively 'choked' resulting in a lack of observed gamma ray emission. In both the failed and successful GRB scenario, neutrino production can occur if protons are accelerated in the internal shocks of these jets. These neutrinos may be detectable by the IceCube neutrino observatory and its low energy extension DeepCore. This thesis presents the methods and

results of a dedicated search for temporal and spatial clustering of neutrino events during the IceCube 2012 data season. Examination of 22,040 neutrino event candidates acquired over a detector livetime of 330 days revealed no statistically significant transient source of neutrino emission. Limits on the rate of choked GRBs in the nearby universe for possible values of neutrino emission model parameters are presented.

(Ando & Beacom 2005)

2. Event Selection

The IceCube detector is primarily designed for the detection of high-energy ($E_\nu \geq 1$ TeV) muon neutrinos originating from the Northern sky.

2.1. DeepCore Filter

The selection process begins with the output of the DeepCore filter, a data filter designed to isolate low-energy events interacting within a defined volume about the central DeepCore portion of IceCube.

2.2. Boosted Decision Tree

3. Analysis Method

4. Results and Interpretations

REFERENCES

Ando, S., & Beacom, J. F. 2005, Physical Review Letters, 95, 061103

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