All-Sky Search for Neutrinos Correlated with Gamma-Ray Bursts in Extended Time Windows Using Eight Years of IceCube Data

{ Elizabeth Friedman, IceCube Collaboration }   University of Maryland

Abstract

Since the discovery of a diffuse astrophysical neutrino flux by the IceCube Neutrino Observatory, many sources have been studied as possible progenitors of high-energy neutrinos. In particular, gamma-ray bursts (GRBs) have been considered as possible neutrino sources due to their extremely high energy output [1]. Several analyses with IceCube data have set strong limits on prompt neutrino emission from GRBs; however, the searches for neutrino emission beyond the prompt phase are more limited [2], [3]. This analysis searches multiple time windows for each GRB, ranging from ten seconds to fourteen days, to measure both prompt and possible extended neutrino emission. Data collected from eight years of exposure with the IceCube detector is used in this analysis, which is coincident with over two thousand GRBs.

Previous Measurements

Previous IceCube analyses have set strong limits on the prompt phase of the GRB:

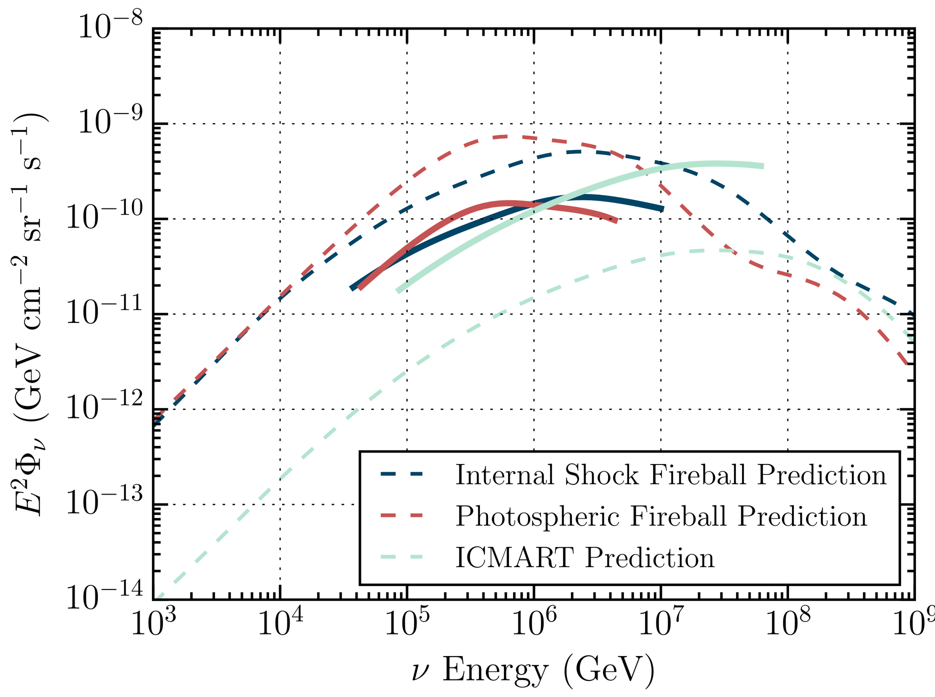

Figure 5: Current per-flavor upper limits (90% CL, solid lines) for prompt neutrino production models (dashed lines) for $f_p = 10$ and $\Gamma = 300$. See references contained in [2] for information on the models tested.

References

[1] K. Asano & K. Murase. Gamma-ray bursts as multienergy neutrino sources. *Advances in Astronomy*.

[2] The IceCube Collaboration. Extending the search for muon neutrinos coincident with gamma-ray bursts in icecube data. *The Astrophysical Journal*, 843(2):112, Jul 2017.

[3] The IceCube Collaboration. An absence of neutrinos associated with cosmic-ray acceleration in -ray bursts. *Nature*, 484(7394):351–354, Apr 2012.

[4] P. Coppin. Grb web 2.0, 2020.

GRB Catalog

Many satellites contribute to a single catalog of GRBs maintained on a public website [4].

Satellite	# GRBs	% Catalog
Fermi GBM	1236	59.1%
Swift	621	29.7%
IPN	146	7.0%
Fermi LAT	79	3.8%
Other	9	0.4%

Table 1: Table 1 shows the satellites that measure the position of a GRB.

2,091 GRBs are studied in eight years of IceCube data, and are divided into sub-populations by hemisphere and duration. "Short" GRBs are those lasting less than two seconds.

Northern Long GRBs:	969
Northern Short GRBs:	173
Southern Long GRBs:	825
Southern Short GRBs:	124

Future Work

This work will shortly be unblinded by the IceCube Collaboration and results published. The next step is to run this analysis in real-time and send alerts to the general community when a GRB presents a p-value less than 1%.

Methods

An unbinned log likelihood analysis is used to analyze individual GRBs in ten time windows. These time windows are illustrated in Figure 1, and are centered on the T100 until the longest time window, which searches 1 day prior and 14 days after the GRB. In each time window, real data is compared to scrambled background data to determine a p-value. The best p-value from the ten time windows is chosen for each GRB.

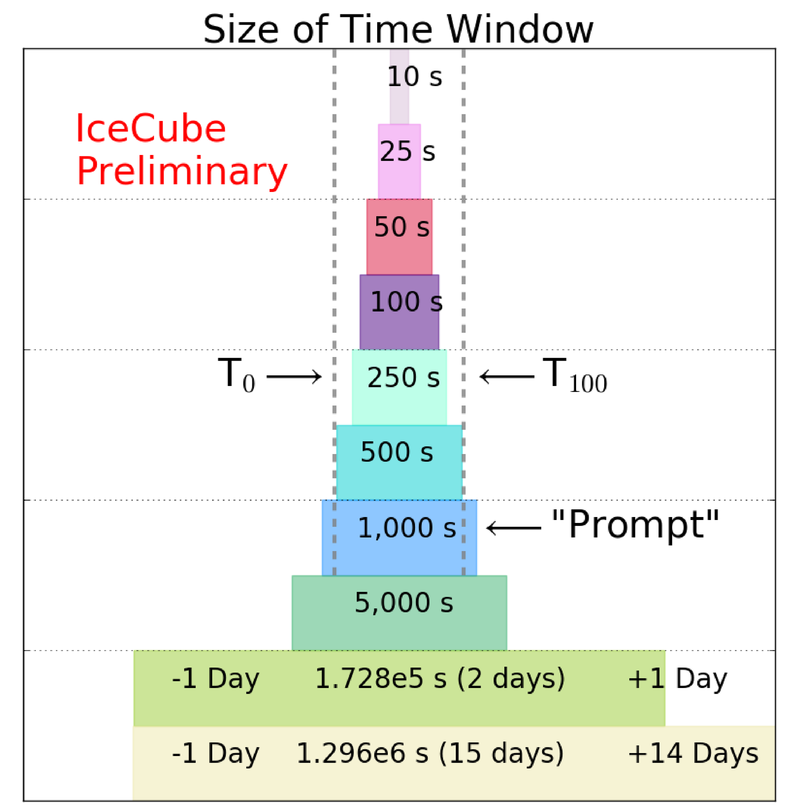

Figure 1: An illustration of the ten time windows considered in this analysis. The times are in reference to the center of the T_{100}.

The uncertainty in the source position is taken into account, particularly for GRBs detected by Fermi-GBM.

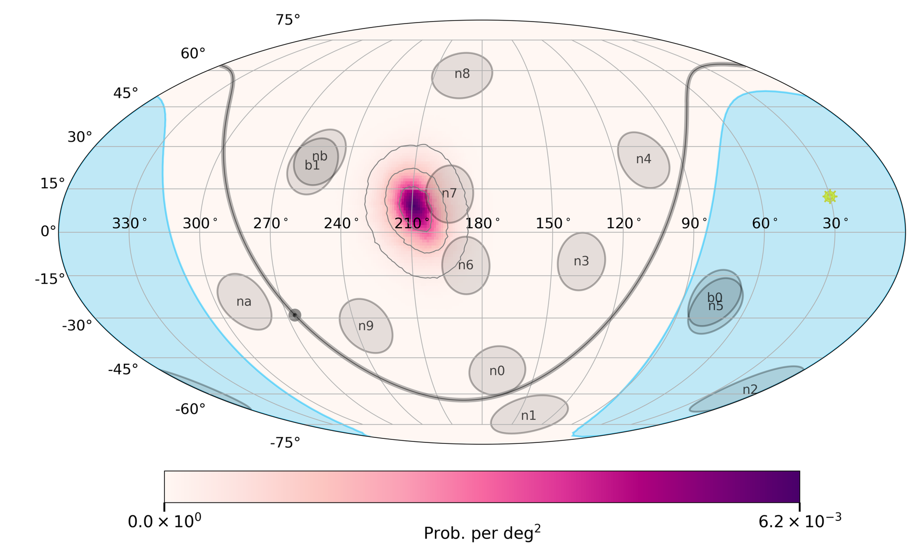

Figure 2: An example skymap for a GRB detected by Fermi-GBM. This map is treated as a spatial prior in the analysis likelihood.

Sensitivity

The sensitivity of this analysis is determined by injecting signal neutrinos into Monte Carlo simulated data until 90% of the resulting p-values are less than 0.5. For well-localized GRBs, this can be summarized in Figure 3.

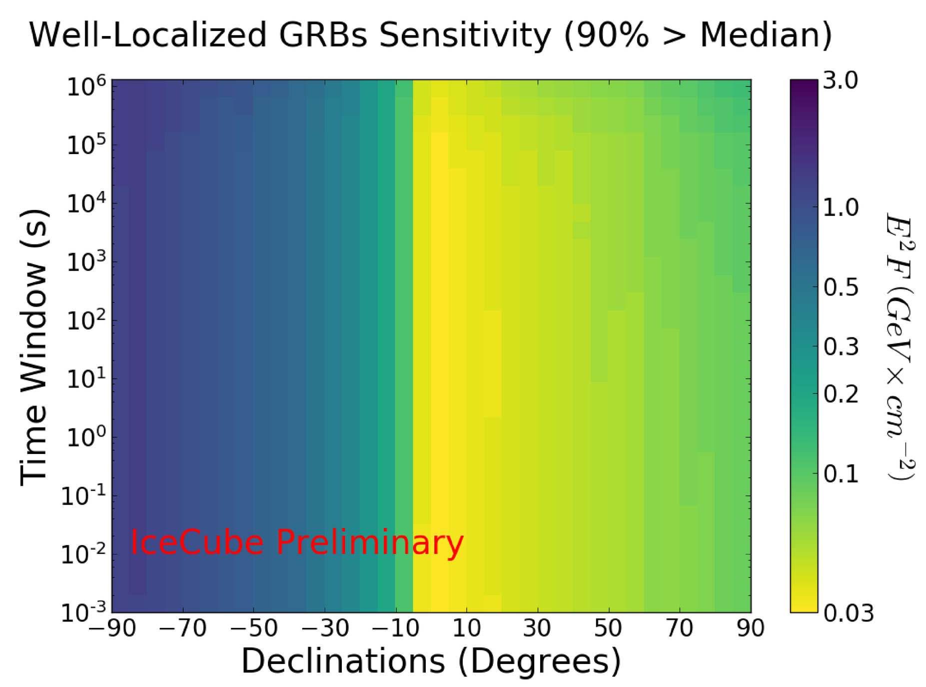

Figure 3: Neutrino time-integrated flux sensitivity for well-localized GRBs in this analysis

Over 50% of this sample's GRBs have a position uncertainly larger than 1° (see Figure 2).

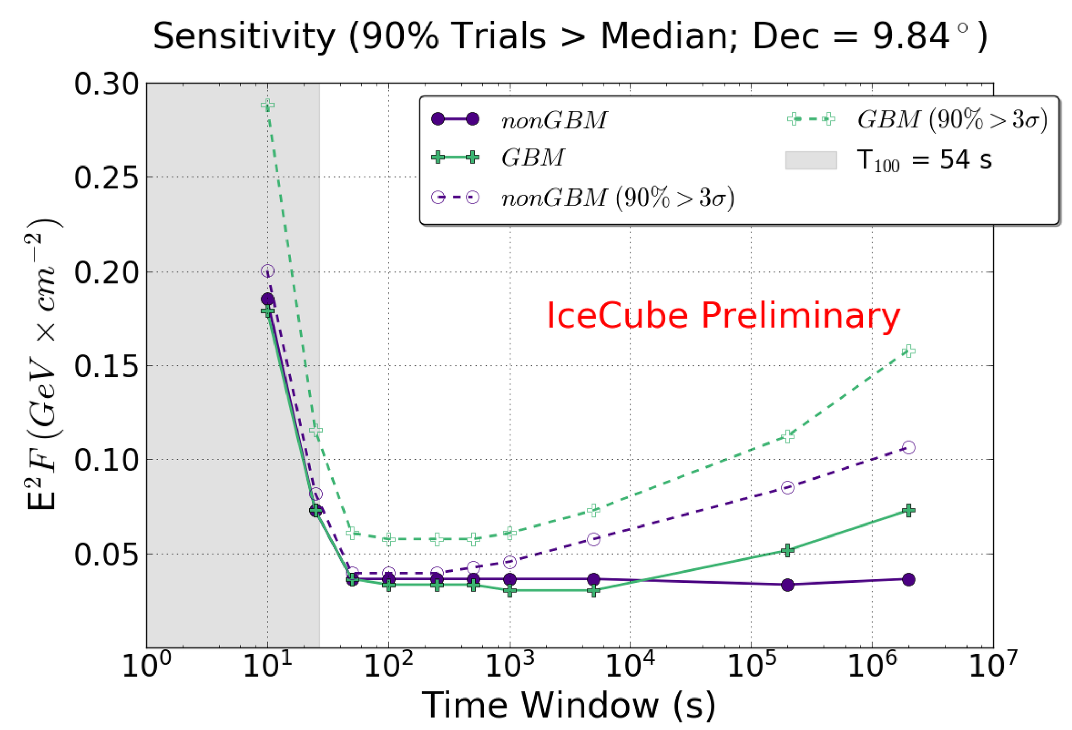

Figure 4: Neutrino time-integrated flux sensitivity and discovery potential for an example GRB that is poorly-localized (GRB180423A) compared to a simulated well-localized GRB centered at the same declination (9.84°)