Research-based activity

Search for neutrino sources with IceCube

Research goal

Students will reproduce a search for astrophysical sources of high-energy neutrinos using IceCube data.

Learning goals

Students should be able to:

List examples of potential sources of high-energy neutrinos.

Describe why we want to find sources.

Describe or illustrate what a source looks like in IceCube data.

Perform a search for a neutrino source using pre-generated sky maps and calculate a p-value.

Explain what the p-value means and how the analysis could be improved.

What's needed

A board and paper

Resources provided (link)

General description of the activity.

Example of talk to guide the analysis.

Randomized sky maps of the very high energy events detected in IceCube.

Activity proposal: Search for neutrino sources with IceCube

(please use the talk to guide the activity, comments on the slides explain concepts mentioned below, such as angular resolution or signal region)

Teachers will ask/remind to students why we are looking for a flux of very high energy neutrinos, i.e., that we want to find the sources of cosmic rays. What are some potential sources?

Activity designed by Jacob Feintzeig (WIPAC). May 2014
Contact learn@icecube.wisc.edu with your questions/suggestions or visit http://go.wisc.edu/a3qi7z to get access to specific educational resources.

Teachers will show two maps, one with positions of 28 random events and one with positions of events with a simulated source. This will be followed by a discussion of how a source appears in our data and the concept of angular resolution.

Next will be a discussion about what a signal is, what background is, and how to distinguish between the two qualitatively.

Teachers will describe a simple method of counting events inside a "signal region" and repeating the procedure on scrambled maps to estimate significance. We will choose as our region a circle around the galactic center with a 15-degree radius.

Concepts of p-values and random scrambling will be explained.

Students will break up into groups of two (or four, depending on total class size). Each group will be provided with 10-20 randomized sky maps and will be asked to count events in the signal region.

Groups will come up to the board to construct histograms of scrambled trials as a class.

Students will be shown the real sky map and asked to count the number of events in the signal region and use a histogram to estimate p-value.

The group will discuss: Is this significant?

Teachers will lead a discussion on obvious flaws of the analysis: What if an event falls right outside the bin? If there's a track inside the bin, shouldn't that be more significant? Wouldn't it be better to include detailed information on angular resolution for each event individually? What if we don't know where the source is going to be? This leads to a basic description of what the likelihood is and does, guided by the paper. A sky map indicating likelihood (colors) will be shown.

Teachers will explain how the p-values were calculated in the paper.

Finally, teachers will guide a discussion about future searches for cosmic ray sources in IceCube, including the importance of statistics and correlations with results from other experiments.