Studying a Black Hole System That Is a Possible Neutrino Emitter With Newly Obtained NuSTAR X-ray Data

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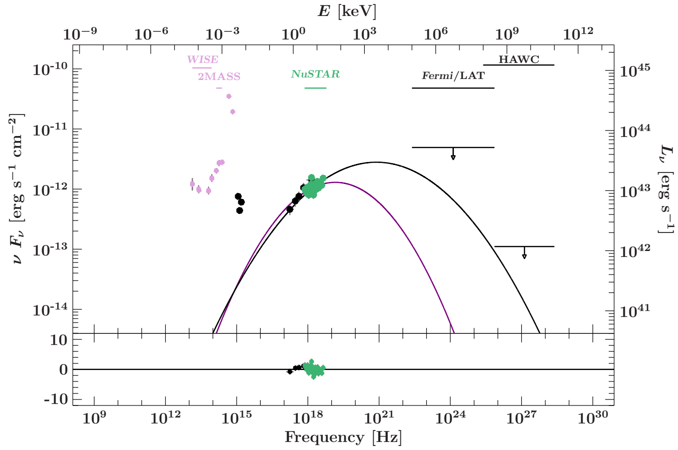
For over one hundred years, scientists have been detecting cosmic rays—high-energy particles that move through space at speeds approaching that of light—with no certain knowledge of all their sources. How far could they have traveled, and what phenomena could consistently accelerate particles to such energies?

One possibility is active galactic nuclei (AGN). These superluminous regions at the centers of most galaxies are believed to contain supermassive black holes (SMBHs), regions of space where gravity is so strong not even light can escape. We believe these high-energy processes produce neutrinos, particles which, much like cosmic rays, have myriads of sources.[1,2,3] Neutrinos are so numerous, tiny, and extraordinarily low in mass that hundreds of trillions harmlessly pass through us at all times! Being uncharged, neutrinos produced near their origins are promising tracers of cosmic rays since they are not deflected by magnetic fields. So how do we detect neutrinos and determine their sources?

The IceCube observatory in the Antarctic can detect neutrinos at energies higher than those produced in the Earth's atmosphere or by the sun. We have found that these are more likely to be astrophysical in origin. Astrophysicists have examined regions of the sky where they believe these neutrinos came from and sometimes found active galactic nuclei. This work examines whether a particular high-energy neutrino (IceCube-220303A) originated from a positionally associated active galactic nucleus (WISEA J175051.31+105645.3) with promising statistical significance. IC220303A's energy was estimated at 398.2 TeV, corresponding to a likelihood of being astrophysical of 76.42%.[4] Doing this may help us to better understand active galactic nuclei and, perhaps, the kinds of processes that can accelerate more massive particles like cosmic rays to such incredible energies.

Determining where a neutrino originates from begins with reconstructing its trajectory. To do that we look in the direction it came from where we can search for all possible sources within the uncertainty area. Once an adequate source has been determined, in this case an AGN, we determine whether it is a neutrino emitter. To do that, we require X-ray data from the source.

Raw X-ray data is obtained by the NuSTAR space telescope. We use this data to predict the number of neutrinos this AGN produced. We begin by plotting our X-ray data into a spectral energy distribution (SED), a log-log plot of photon energy flux versus photon energy. Data is plotted and fitted with the Interactive Spectral Interpretation System (ISIS) using a logarithmic parabola. This process ends with a neutrino number, which tells us the number of neutrinos we should expect from the source over the period IceCube has been active. Applying Poisson statistics to the neutrino number tells us the likelihood the neutrino came from the source.



Multiwavelength SED of WISEA J175051.31+105645.3

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[1] Eichler D., 1979, ApJ 232, 106

[2] Berezinskii V.S., Ginzburg V.L., 1981, MNRAS 194, 3

[3] Begelman M.C., Rudak B., Sikora M., 1990, ApJ 362, 38

[4] IceCube Collaboration 2022, GRB Coordinates Network 31670, 1