Elusive Particles Shed Light on Origin of Cosmic Rays

July 16, 2018

A recent press conference, given by the IceCube, FermiLAT and MAGIC collaborations, has generated interest within both the astrophysics and high-energy particle physics communities [1, 2]. Using vastly different technologies, these three experiments have made coincident detections of very high-energy gamma-rays and neutrinos coming from a particular type of astrophysical object known as a blazar. Supermassive black holes, with masses typically exceeding one million times that of the Sun, are known to reside at the center of galaxies; when mass is being actively accreted onto these supermassive black holes, they become known as activate galactic nuclei, or AGNs. A majority of the accreted mass collapses to form a thin disk, however due to instabilities, some of the matter is ejected in thin beam, known as a jet, in the direction perpendicular to the disk. Simply put, blazars are AGNs that have their jets pointed in the direction of Earth (see Fig. 1 for an artist's depiction of a blazar); note that this distinction was made because the energy injected along the beam axis is significantly higher than in any other direction, making these objects astrophysically distinct.

The detection by IceCube (see Fig. 2), i.e. the detection of a high-energy neutrino arriving from a direction that coincides with a known blazar, solves an outstanding problem in astronomy that has puzzled scientists for nearly a century; namely, what is the origin of cosmic rays and ultra high-energy neutrinos. This observations also demarcates an important step in astronomy, as this is the second major discovery achieved by exploiting the benefits of multi-messenger observations (i.e. simultaneous detections by two experiments searching for different signatures of a singular event), with the first being the observation of merging neutron stars that occurred just last year.

References

[1] IceCube collaboration, *Neutrino emission from the direction of the blazar TXS 0506+056 prior to the IceCube-170922A alert*, Science **361** (2018) 147–151.

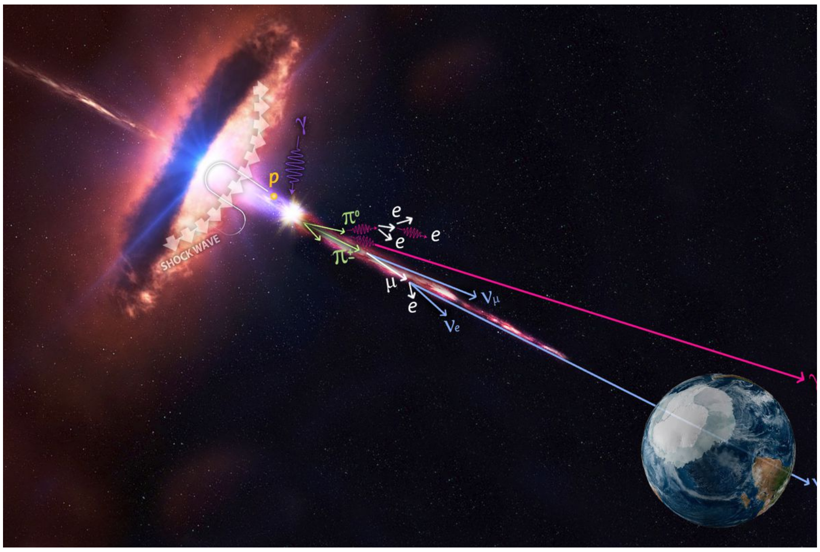

Figure 1: Artist's depiction of blazar emission and detection. As shown, shock waves accelerate protons near the AGN which subsequently interact with the medium, producing high energy gamma-rays and neutrinos. These secondary particles travel directly from the source to Earth unimpeded, allowing scientists to trace the origin of detected high-energy particles.

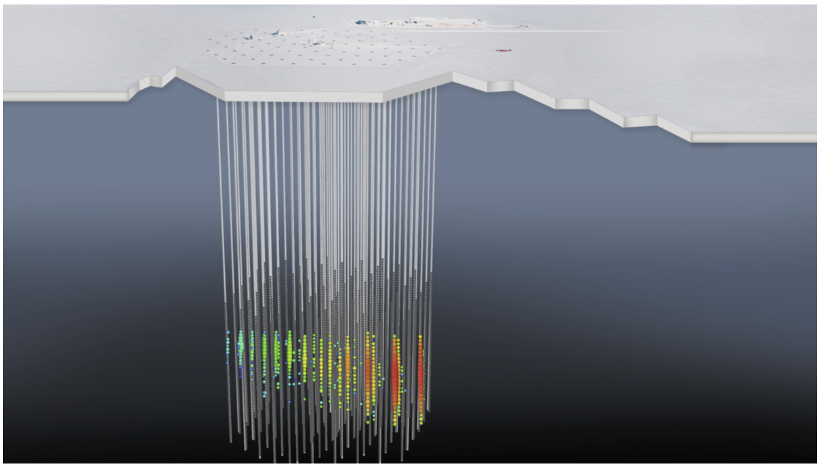

Figure 2: Depiction of IceCube detector, located in Antarctica. The IceCube collaboration has buried more than 5000 detectors in 1 km^3 of ice. A particle traversing through the ice may deposit some of its energy, which can subsequently be observed by the surrounding photomultiplier tubes. An example of such an event is depicted in the figure above, where the color denotes the relative time evolution of the event, and the size/density of colored pixels reflects the amount of energy deposited at each point.

[2] Liverpool Telescope, Swift/NuSTAR, MAGIC, H.E.S.S., AGILE, Kiso, VLA/17B-403, INTEGRAL, Kapteyn, Subaru, HAWC, Fermi-LAT, ASAS-SN, VERITAS, Kanata, IceCube collaboration, *Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A*, *Science* **361** (2018) eaat1378.