Radio-quiet AGN are a promising source for explaining astrophysical IceCube neutrino events.

# Ghost(-particle) stories: Connecting IceCube neutrinos to radio-quiet AGN

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**Introduction**

The last few years have seen exciting coincidences of high-energy neutrinos with radio-loud (jetted; IceCube-170922A and TXS 0506+056; IceCube 35 and PKS 2155−304) and radio-quiet active galactic nuclei (non-jetted; NGC 1068), as well as Tidal Disruption Events (IceCube-191001A and AT2019DSG). These coincidences have generally been at a $\sim 3\sigma$ confidence level.

While hadronic acceleration processes are required to generated significant neutrino fluxes in these sources, the physical conditions required for efficient neutrino production lead to a cascade of emissions, from $\gamma$-ray to X-ray energies, that is usefully constrained with X-ray observations. We report our results of multimessenger studies of IceCube-190331A and IceCube-200615A.

**Results for IceCube-190331A**

We have performed *Swift*/XRT, *Swift*/UVOT, *NuSTAR*, X-Shooter and ATCA follow-up observations of the IceCube neutrino alert IceCube-190331A. This event is important as it has a high likelihood of being astrophysical in origin (due to its high energy). We find two X-ray source in the tiled *Swift*/XRT mosaic observations. The brightest *Swift*/XRT source (#1) is consistent with 2MASS J22292559−20184. Due to its known optical counterpart and its X-ray brightness it seemed to be the most likely source of neutrinos. A high X-ray brightness is required to explain the expected electromagnetic emission from secondary cascades of hadronic particles. The source is not detected in ATCA with strong constraints on the radio flux, and it is not detected by *Fermi*/LAT. The X-Shooter spectrum confirms that it is a type 1 Seyfert galaxy. The neutrino localisation region was serendiptidously located near the highest sensitivity location of the field-of-view of Swift/BAT. This constrains and rules out a bright GRB at the time and location of the neutrino (FM et al. 2020).

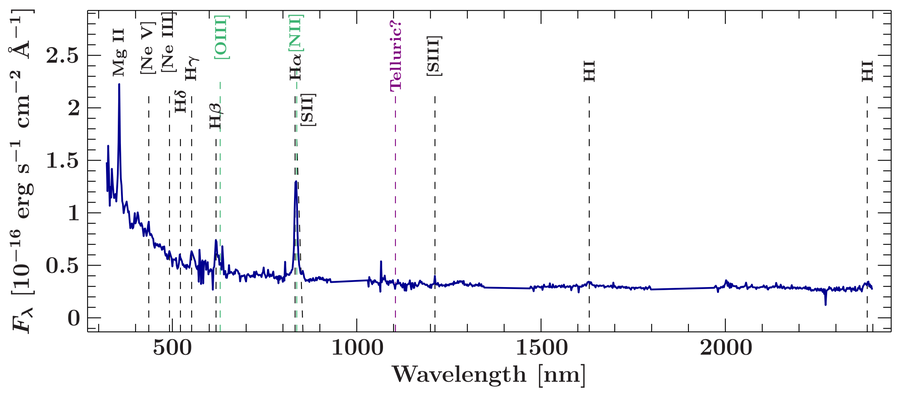


**Figure 1.** X-Shooter spectrum of 2MASS J22292559−20184 confirming it's radio-quiet nature. This is a possible counterpart to the neutrino event IceCube-190331A (FM et al. 2020).

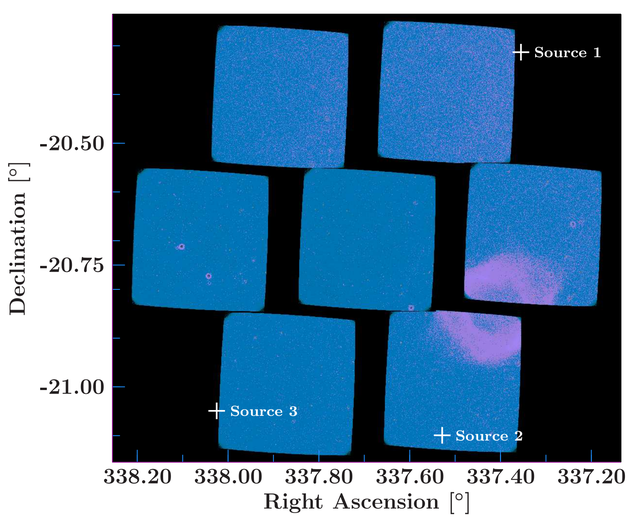


**Figure 2.** *Swift*/UVOT mosaic follow-up of the localisation region of IceCube-190331A. The Helix nebula, NGC 7293, is clearly visible in the west. It is not detected at X-ray energies and not considered a possible neutrino counterpart. Source 3 is below the X-ray detection threshold, and source 1 was unfortunately not in the field of view in the initial tiling observation (FM et al. 2020).

**Results for IceCube-200615A**

Follow-up for IceCube-200615A was limited as several ground-based telescopes were not available in 2020. VLA, *Swift*/XRT and *NuSTAR* observations were crucial in constraining the multiwavelength SED of the only potential counterpart found for this event: 1RXS J093117.6+033146. VLA was able to detect the source, but the ratio of the optical and the radio flux shows that this is a radio-quiet AGN, likely a Seyfert-type object (FM et al. in prep).

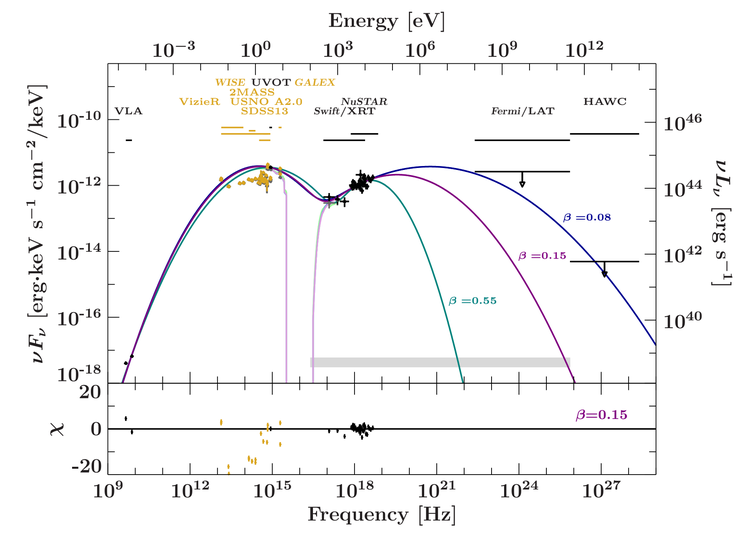


**Figure 3.** Multiwavelength SED of 1RXS J093117.6+033146 with potential models for the high-energy emission (FM et al., in prep).

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