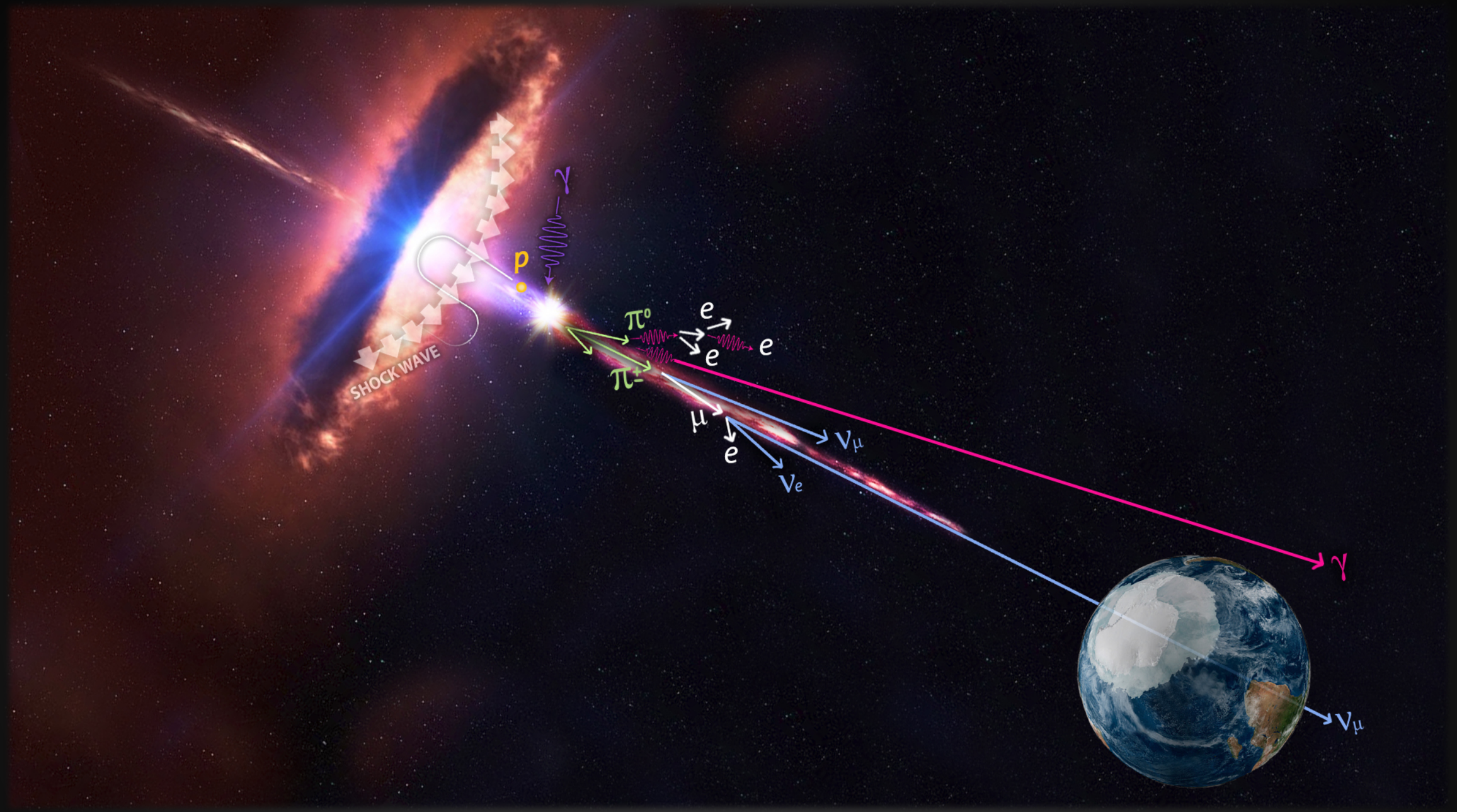

Understanding Relativistic Jets Via Multi-Messenger Observations

Marcos Santander (on behalf of Bindu Rani)

University of Alabama

MMA SAG Session - HEAD 2019, Monterey, CA

AGN white papers

https://arxiv.org/abs/1903.04504

Astro2020 Science White Paper

Multi-Physics of AGN Jets in the Multi-Messenger Era

Thematic Areas: ☑ Multi-Messenger Astronomy and Astrophysics

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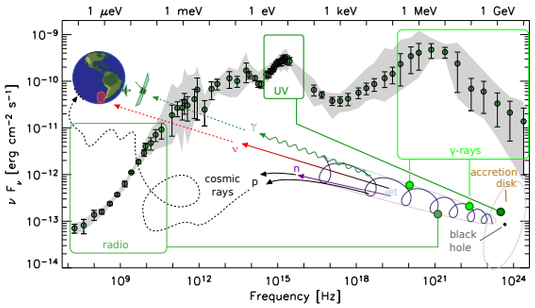

Figure 1: AGN jets, powered by accretion onto a central supermassive black hole, are the most powerful and long-lived particle accelerators in the Universe. Non-thermal processes operating in jets are responsible for multi-messenger emissions, such as broadband electromagnetic radiation and high-energy neutrinos. Background spectral energy distribution is adapted from [116].

1

Multi-Physics of AGN Jets in the Multi-Messenger Era

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https://arxiv.org/abs/1903.04447

Astro2020 White Paper

A Unique Messenger to Probe Active Galactic Nuclei: High-Energy Neutrinos

Authors: Sara Buson, University of Würzburg, University of Maryland Baltimore County ; **Ke Fang**, Stanford University; **Azadeh Keivani**, Columbia University; **Thomas Maccarone**, Texas Tech University; **Kohta Murase**, Pennsylvania State University; **Maria Petropoulou**, Princeton University; **Marcos Santander*** University of Alabama, **Ignacio Taboada**, Georgia Institute of Technology; **Nathan Whitehorn**, University of California - Los Angeles.

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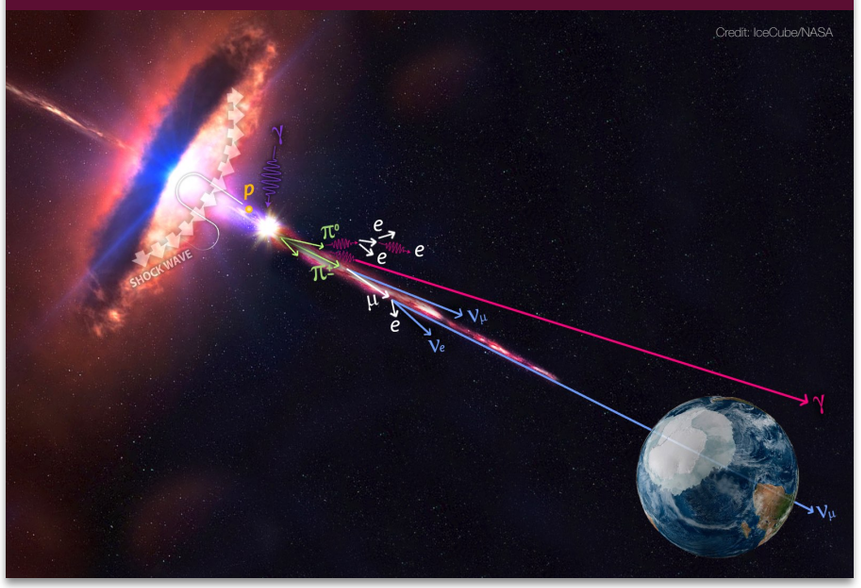
Multi-messenger Astronomy and Astrophysics



A Unique Messenger to Probe Active Galactic Nuclei: High-Energy Neutrinos

Principal author: M. Santander
Co-authors: S. Buson, K. Fang, A. Keivani, T. Maccarone, K. Murase, M. Petropoulou, I. Taboada, N. Whitehorn.
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Multi-Physics of AGN Jets in the Multi-Messenger Era

Key questions for AGN jets

- **What are the dissipation and particle acceleration processes?**
  - Multi-physics sims: study particle acceleration under different conditions, deliver temporal and spatial info on radiation and polarization.
  - High-res mm VLBI imaging and polarization from optical to X-ray / gamma.
- **What are the high-energy radiation mechanisms?**
  - Leptonic vs hadronic. Needs more than time-averaged SED predictions.
  - MM measurements: broadband, sensitive SED MWL coverage + HE neutrinos.
- **Where and how do jets produce high-energy emission and neutrinos?**
  - Large-scale MHD for jet launch and dissipation. Spectral and temporal obs. from 0.1 GeV to >TeV and high-res radio imaging.
- **Is gamma-ray emission related to jet structure?**
  - TeV Doppler factor crisis: Doppler factor derived from observations much lower than required to model the HE emission.
  - VLBI (< 100 grav radii) studies of jets vs ligh-of-sight angle, comparison of models with observations.

Multi-Physics of AGN Jets in the Multi-Messenger Era

How is the AGN jet energy converted to radiation?	**Where does the energy dissipation happen?**	**Do γ-rays have a leptonic or hadronic origin?**
• Multi-wavelength variability and polarimetry (LSST, IXPE, AMEGO) • High-resolution radio polarimetry (VLBI) • Neutrino production • Multi-physics (fluid, particle, radiation) numerical simulations	• High-angular & temporal resolution TeV telescopes (CTA, HAWC-South) • High-resolution radio imaging (VLBI) • Cosmic ray acceleration • Multi-scale simulations of fluid and particle dynamics	• High sensitivity TeV telescopes (CTA) • All-sky X-ray, MeV & TeV monitoring (STROBE-X, ISS-TAO, AMEGO, CTA, HAWC-South) • X-ray and γ-ray polarimeters (IXPE, AMEGO, AdEPT) • High sensitivity neutrino observatories (IceCube-Gen2, KM3Net)

Advocates for:

- Support to future instruments with large effective areas, excellent timing resolution, and wide fields of view that will be essential for advancing our understanding of jet physics in the next decade.

- Support to the development of multi-physics, multi-scale numerical simulations, and high-performance computing.

A Unique Messenger to Probe Active Galactic Nuclei: High-Energy Neutrinos

- Detecting neutrinos from AGN would help in our understanding of particle acceleration and origin of cosmic rays.

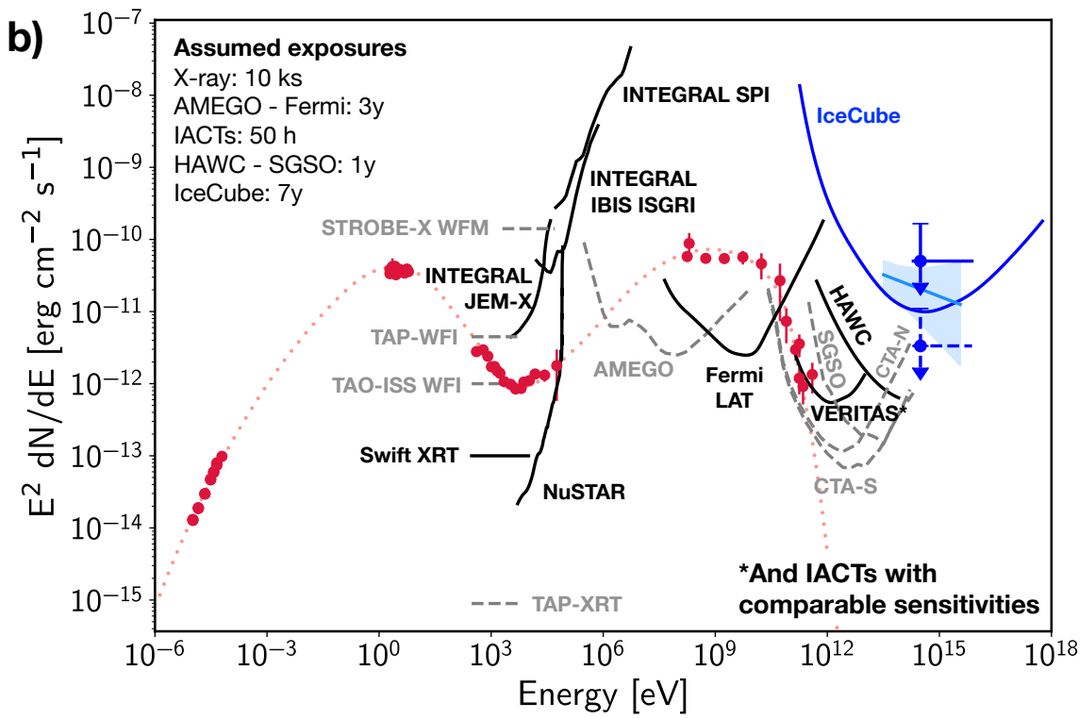
- The evidence for a correlation between high-energy neutrinos and a blazar (TXS 0506+056) has left many open questions for the coming decade:

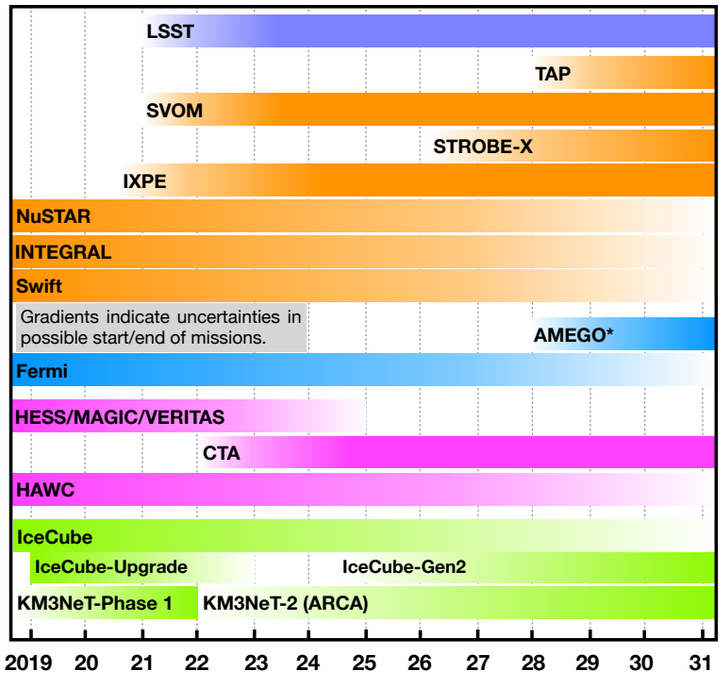
  - What makes the 2014-15 “neutrino flare” of TXS 0506+056 special?

  - Are there many neutrino emission sites?

  - What is the best strategy for finding new sources, specially if no correlation with GeV-TeV gammas exists?

A Unique Messenger to Probe Active Galactic Nuclei: High-Energy Neutrinos





- Advocate broadband, sensitive, wide-field coverage of a large number of AGN during the coming decade. Correlated studies with next-gen neutrino telescopes (specially IceCube-Gen2, KM3NeT, GVD)
- Low-energy (synchro peak of the SED) to monitor leptonic emission. **High-energy observations from soft X-rays to TeV.** Continuation of Swift and Fermi until new capabilities are identified. NuSTAR follow-ups and wide field X-ray instruments (e.g. TAP, STROBE-X WFM, TAO-ISS). AMEGO will be crucial at MeV + polarimetry (with IXPE + optical). VHE from CTA and wide field instruments (HAWC and others planned in the south).