MASTER optical observations of the blazar TXS 0506+056 during the IC170922A

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Based on Lipunov et al. 2020 ApJL 896 L19
High-energy neutrino event IC170922A and the flaring blazar TXS 0506+056

Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A

The IceCube Collaboration, Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S., INTEGRAL, Kanata, Kiso, Kavli, Liverpool Telescope, Subaru, Swift/NuSTAR, VERITAS, and VLA/17B-403 teams††
Light curve resulting from the multimessenger observations

- Variations in high-energy photons after the event
- $3\sigma$ chance coincidence probability
MASTER Global Robotic Network and its telescopes

- 8 40-cm catadioptric pair telescopes with a $2^\circ$ FOV
- Able to automatically respond to an alert 1 minute after the notice
MASTER-Net follow-up optical observations

- Two telescopes (MASTER-Amur and MASTER-Tavrida) reacted to the event but only one (MASTER-Tavrida) was able to make proper frames
- Start of the observations 73s after the trigger, 3 frames in the first 15 minutes, 23 frames in the first 3 hours.
- Zenith distance 84° at the start
Light curve during the event

- A significant optical decay immediately after the event, followed by a rebrightening to the past level two hours later (amplitude $0.81 \pm 0.02$ mag)
MASTER optical history

- TXS 0506+056 didn’t decay to the absolute minimum ever observed during IC170922A
Causes of optical decay

- First, decay is connected to the blazar itself and therefore to the neutrino production
- Second, decay is due to the absorption in the atmosphere (zenith distance 84° right after the event) and so not connected to the neutrino production
- The only cause verifiable with our data is the second
Magnitude variations of check stars

- Optical decay can’t be explained by atmospheric absorption ($g-r=0.38$ for TXS 0506+056) if blazar’s spectrum doesn’t change extremely with no increase in overall luminosity
Decay connected to the blazar

- Could be explained if the optical emission is mostly produced in proton synchrotron emission

\[ p + \gamma \rightarrow \begin{cases} p + \pi^0 \rightarrow p + 2\gamma_{\text{Fermi}} \\ n + \pi^+ \rightarrow n + \mu^+ + \nu_\mu \end{cases} \]

Contradicts very high-energy gamma-ray data that hints towards lepto-hadronic emission models (see Ansoldi et al 2018 ApJL 863 L10, Gang Cao et al 2020 PASJ 72 2)

- Limitation on the neutrino production zone size: several light days for Lorentz factor of 5 (see Xiaofeng Li et al 2020 ApJ 896 63)

- Similar effect is seen in very high-energy gamma-ray data (see Ansoldi et al 2018 ApJL 863 L10)
Results

- TXS 0506+056 underwent a significant optical decay during IC170922A and rebrightened 2 hours later (amplitude $0.81 \pm 0.02$ mag)
- Can’t be explained by atmospheric absorption if spectrum doesn’t change extremely
- Similar effect on a different timescale is seen in very high-energy gamma-ray data
- Neutrino production zone doesn’t span for more than several light days