UNCOVERING THE HIGH-ENERGY EMISSION OF JETTED AGN AT COSMIC DAWN

High-redshift blazars (z>3) detected at gamma-ray energies enable us to study the accretion processes and black hole growth in the early Universe. However, their detection is difficult, and only about a dozen have been seen with the *Fermi*-LAT. We can utilize blazar flares as unique opportunities to detect and characterize the gamma-ray emission from high-z blazars and to gather contemporaneous multiwavelength observations to interpret their spectral energy distribution & physical parameters. In addition, the combination of gamma-ray and VLBI observations is a unique tool to study the location and physical mechanisms of the high-energy emission in blazar jets.

For these reasons, we designed a program to find flares in high-z blazars in real time, which is suitable to trigger observations across the electromagnetic spectrum, by using public *Fermi*-LAT data. Here, we present our findings for two blazars with z > 4.

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HIGH-Z BLAZAR MONITORING

- Our monitoring campaign covers 83 blazars that are listed in the BZCAT *[1]* with a redshift of z > 3
- Using public Fermi-LAT data to detect flares by high-z blazars in real time

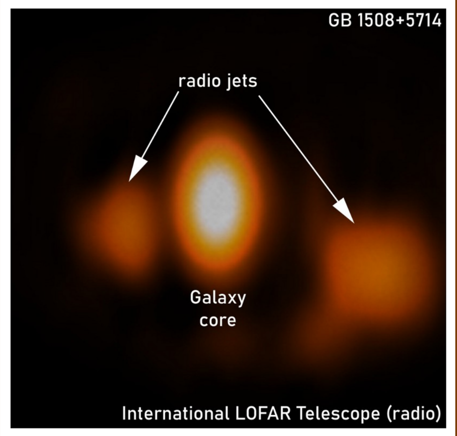
Fermi-LAT
Credit: NASA

- Trigger threshold for follow-up observations: TS value of 25 (~5σ) for time range of 30 days (based on strategy for a posteriori detections by Kreter et al. *[2]*)

GAMMA-RAY BLAZARS WITH REDSHIFT > 4

TXS 1508+572

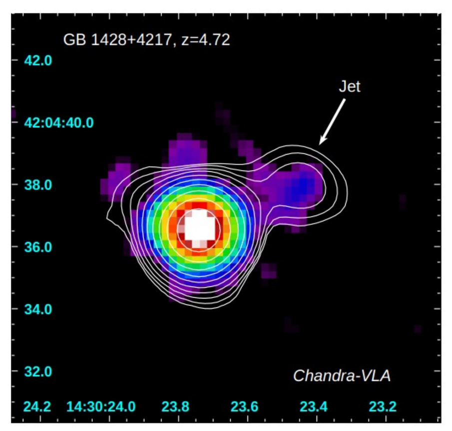
- First report of redshift z = 4.3 in 1995 *[3]*
- Source shows extended radio and X-ray emission
- Included in Fermi-LAT catalog (4FGL)
- Flare detection by our pipeline on 4 February 2022 *[4]*
- Paper → accepted in ApJ



LOFAR radio image taken at 144 MHz
Credit: *[5]*

B3 1428+422

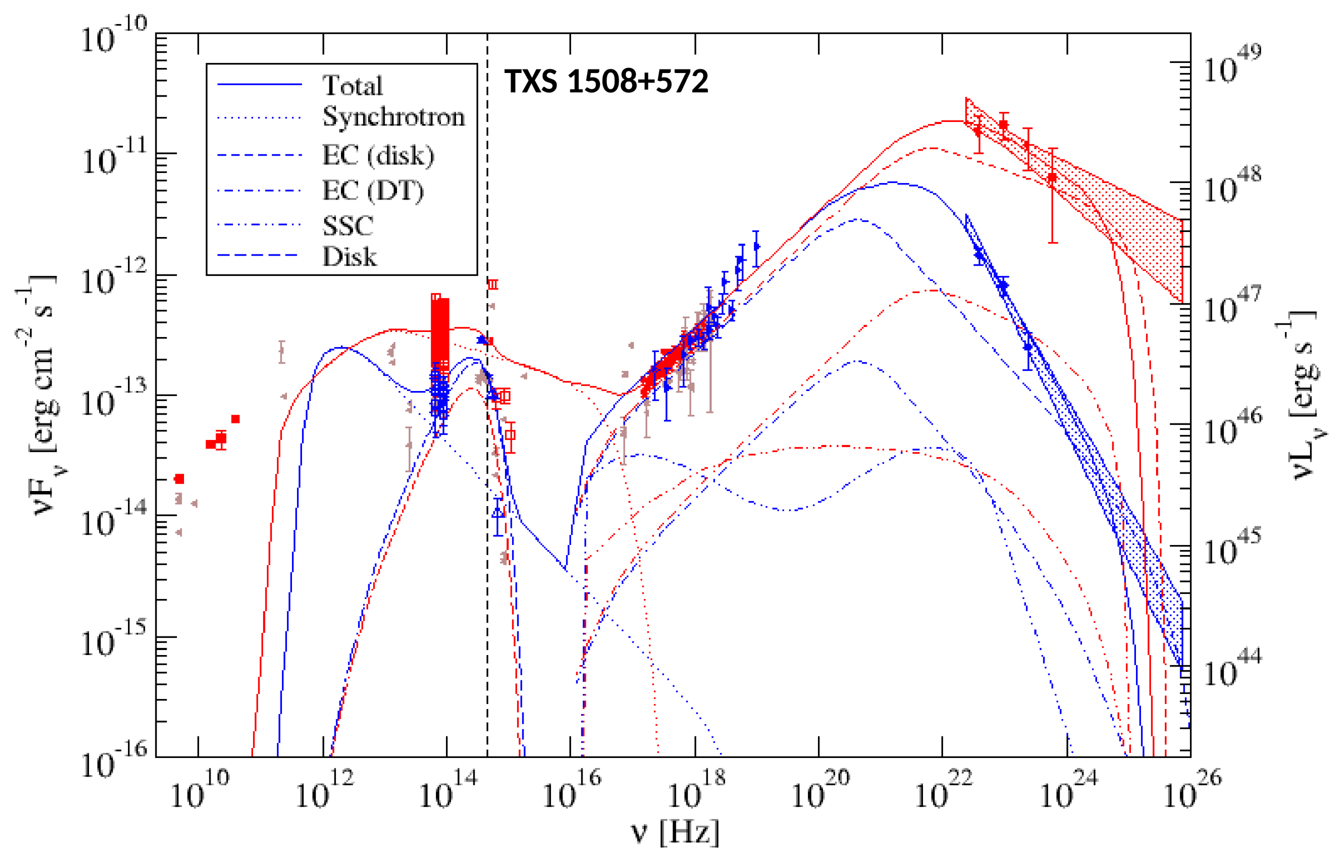
- First detection as high-redshift source (z=4.72) in 1998 *[6]*
- Also exhibits extended X-ray and radio emission
- Gamma-ray emission reported [8,2], but not a source of the 4FGL
- Flare detected in Dec 2023 → Paper in preparation



Chandra X-ray image with contours from a VLA radio observation.
Credit: *[6]*

MULTIWAVELENGTH CAMPAIGNS

- We analyzed additional data taken in
  - X-rays: XMM-Newton, Swift, and NuSTAR
  - Optical/IR: ZTF, NEOWISE, Sierra Nevada, Perkins Obs., Steward Obs.
  - Radio: Effelsberg, VLBA, and GBT
- Gamma-ray luminosity of TXS 1508+572 flare comparable to brightest blazar flares
- Very high black hole masses (> 10^9 $M_\odot$) needed to explain signatures from accretion disk and high-energy emission that is modeled with Inverse Compton emission



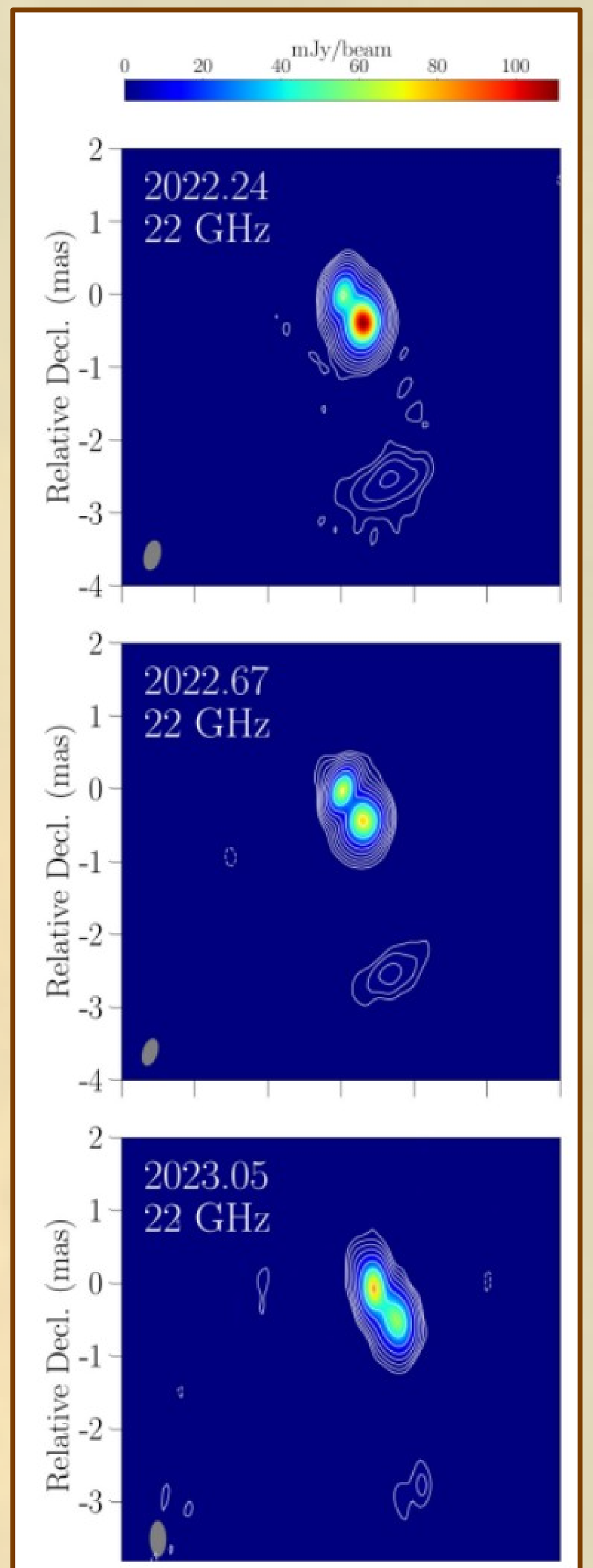
Modeling of the broadband SED of TXS 1508+572 during the quiet (blue) and flaring (red) state.
Credit: Gokus et al. *[9]*

SUMMARY & OUTLOOK

- Our pipeline enables contemporaneous MWL observations of high-redshift blazars during gamma-ray flares
- We conducted the first VLBI monitoring campaign for a flaring high-redshift gamma-ray blazar, see Benke et al. *[10]*
- Our full paper on the 2022 flare from TXS 1508+572 includes also an analysis of X-ray spectra and MWL variability, see Gokus et al. *[9]*
- MWL study of flare by B3 1428+422 ongoing

VLBI CAMPAIGN FOR TXS 1508+572

- First VLBI follow-up campaign of a flaring high-redshift blazar
- Four epochs cover 15, 22 & 43 GHz → source-intrinsic frequencies: 80, 117, and 228 GHz → probe regions closer to central supermassive black hole
- Morphological changes visible on monthly time scales
- Apparent speed of jet component (at 22 GHz): 0.13 ± 0.04 mas/yr
- Coreshift evolves as a new component travels through the core
- Origin of new component not connected to flare in 2022; must have been produced between 2016 and 2019



VLBI maps at22 GHz, taken with theVLBA and Effelsberg.
Credit: Benke et al. *[10]*

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