Gamma-ray Emitting Young Radio Source Candidates

W. McConville (University of Maryland / NASA GSFC)
C. C. Cheung (NRL), & Ł. Stawarz (ISAS / JAXA)
on behalf of the Fermi Large Area Telescope Collaboration

Compact Symmetric Objects (CSO's) are widely considered to be the young versions of present-day FR1 and FR2 radio galaxies, with characteristic sizes of < 1kpc and ages on the order of a thousand years. Prior to the launch of Fermi, young radio sources were predicted to emerge as a possible new gamma-ray emitting population that would be detected after several years of all-sky exposure by Fermi's Large Area Telescope (LAT). With over 2 years of exposure accumulated by the LAT, the majority of CSO's remain undetected, while the question of young radio sources as a gamma-ray population still remains open. Here we examine the radio through gamma-ray properties of candidate CSO sources with corresponding gamma-ray associations and discuss the observational properties of each in the context of their possible CSO classifications.

4C +55.17

Radio Properties

- VLBA radio structure extended over 52 mas (~400 pc at z=0.896)
- Brightest 5 GHz VLBA component reaches a brightness temperature (T_b) less than 2 x 10^8 K [13].
- VLA-scale emission may be indication of previous jet activity
- No evidence of radio variability from archival radio to sub-mm monitoring observations [2][15][11][6].

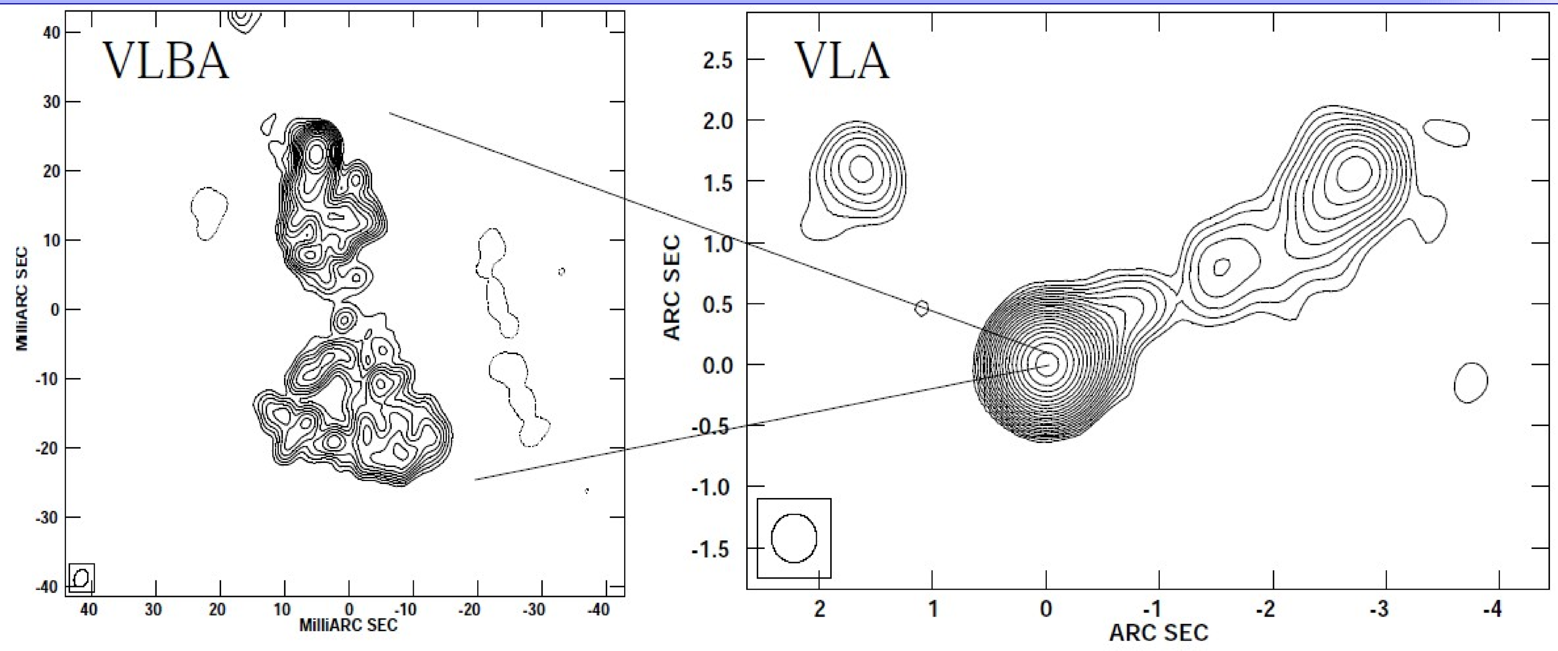

Figure 1: 5 GHz VLBA map (left) of the inner parsec-scale radio structure, reimaged using data from [5]. The beam size is 2.0 mas x 1.6 mas (position angle -29.6°), with contours increasing by √2 starting at 1 mJy/beam. The 5 GHz VLA map (right) shows the large scale radio structure (from [14]), using a beam size of 4" and the lowest contour starting at 2mJy/beam and increasing by factors of √2 .

Steady γ-ray Emission

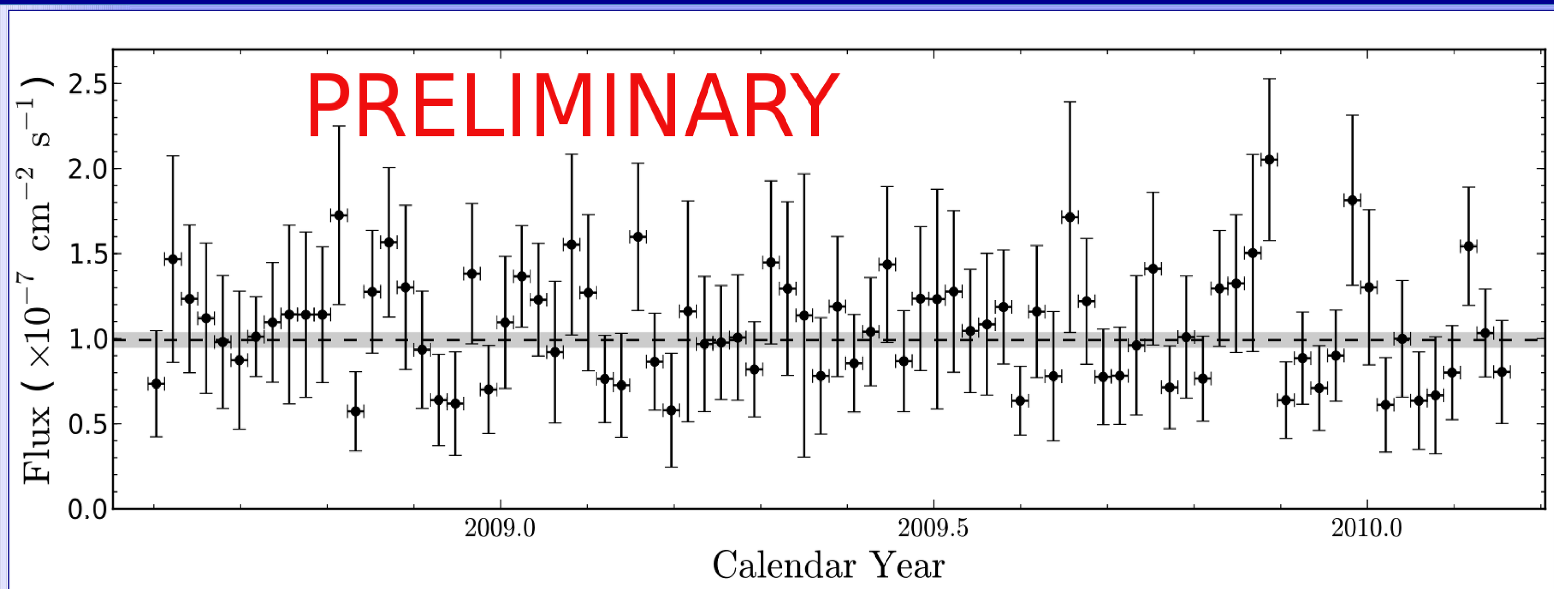

Figure 2: *Fermi* / LAT γ-ray light curve using 19 months of all-sky survey data, divided into 7 day bins. All points represent >3σ detections and are plotted along with their statistical errors. The dashed horizontal line and gray region represent the weighted average and corresponding error.

- No evidence of γ-ray variability over observed history by the LAT
- Weighted average flux (>100 MeV) of (9.5 ± 0.4) x 10^{-8} ph cm⁻² sec⁻¹ consistent with previous EGRET measurement of (9.1 ± 1.6) x 10^{-8} ph cm⁻² Sec⁻¹ [4].
- Although formally classified as a flat spectrum radio quasar, the steady γ-ray emission is uncharacteristic of this class of sources.

Broadband Modeling

- We apply the dynamic model of CSO's by [12].
- Models the γ-ray emission through inverse-Compton scattering of UV disk photons by the population of relativistic electrons in the young lobes.
- Model parameters are consistent with those of X-ray detected CSO's modeled by [10] using the same model.

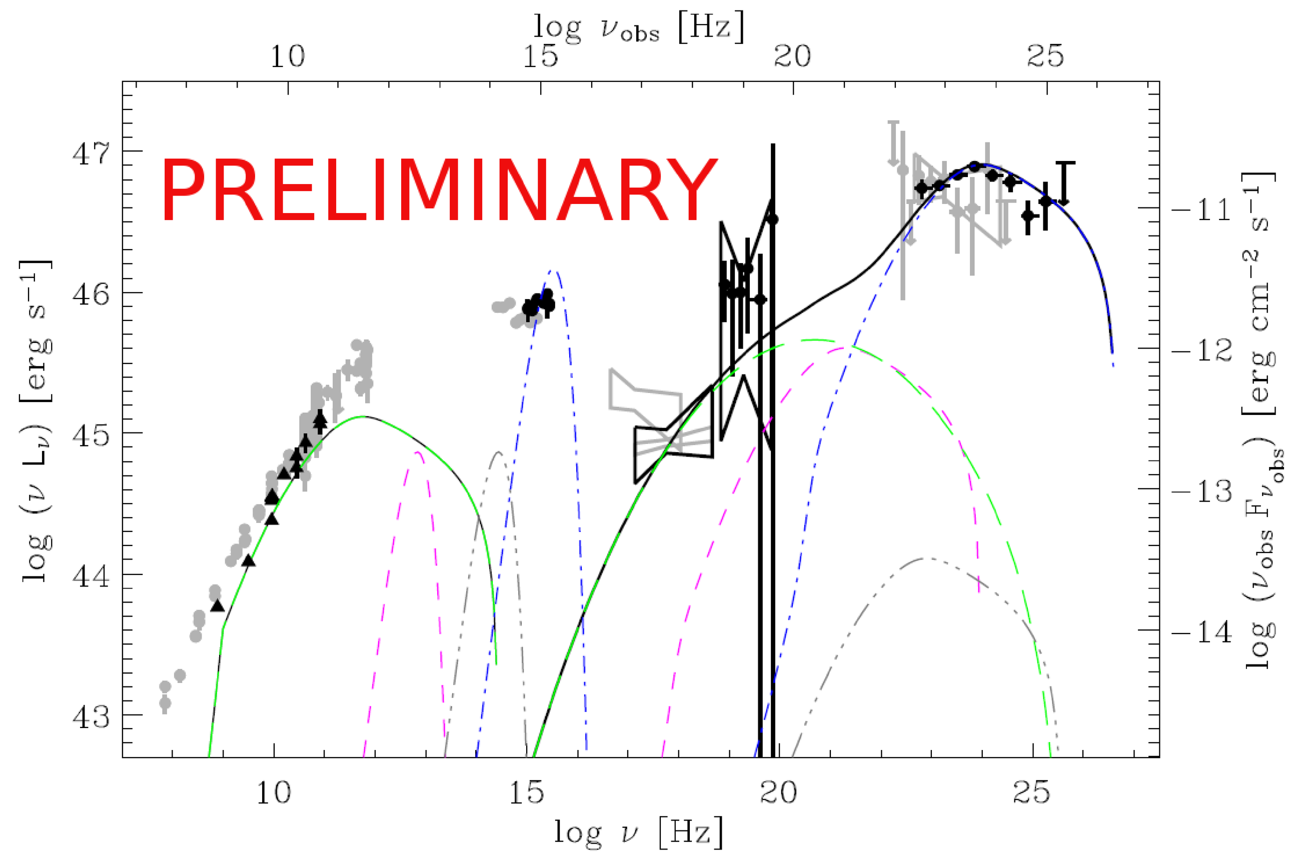

Figure 3: CSO model of 4C +55.17 using the dynamic model for broad-band emission of CSOs by [12]. The new LAT spectrum, along with contemporaneous data from *Swift* XRT, BAT, and UVOT are shown in black. In gray, archival data from EGRET, ROSAT, Chandra, SDSS, 2MASS, 5-year integrated WMAP, and historic radio data are included, as well as archival VLA measurements of the inner ~400 pc-scale structure (black triangles). The black curve indicates the total non-thermal emission of the lobes. The contributions from synchrotron and synchrotron self-Compton are indicated in green. The pink, gray, and blue blackbody type curves represent the dusty torus, starlight, and UV disk components, respectively, along with their corresponding inverse-Compton components as required by the model.

Discussion

The case for 4C+55.17 as a CSO is compelling. The asymmetric double radio morphology, which is a primary signature of young sources, coupled with the steady emission in both the γ-ray and radio wavelengths, are strong evidence in favor of 4C +55.17 as a CSO. The alternative blazar classification of the source is on the other hand difficult to reconcile with its observed properties, as blazars are characterized by compact, highly variable radio cores that are often unresolved, and demonstrate 5 GHz brightness temperatures in the range of 10^{10}-10^{14} K [13]. The dynamic model for CSO's by [12] successfully reproduces the observed broadband emission of the source without resorting to relativistic beaming effects, for which 4C +55.17 demonstrates no observable evidence.

1413+135

LAT γ-ray Discovery

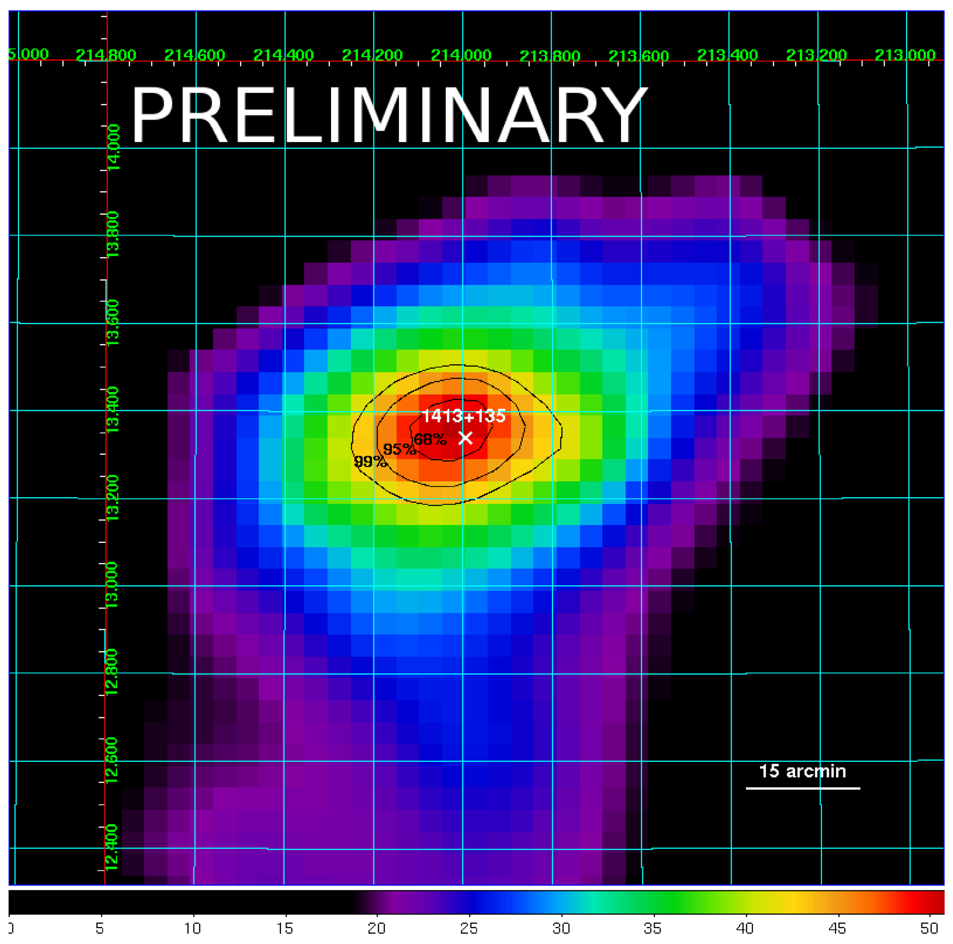

Figure 4: 30-month γ-ray point source localization, along with the radio position of 1413+135 (white "x"). Pixel values represent the test statistic (TS) [8] of a point source with a power law spectrum at each location using a maximum likelihood statistical fit. Black contours represent the 68%, 95%, and 99% confidence regions for a point source localization as derived from decrements of 2.3, 6.0, and 9.1 from the maximum TS of 50.8 (≈ 7.1σ).

Radio Properties

- Classified as a CSO by [3] based off of VLBA measurements of proper motions of the jet and counter-jet moving away from the central core.
- Total source extent is ~30 mas (~115 pc at z=0.247), which would formally place the source among CSO's.
- Variable radio core, seen at 820 mJy / beam in the 15 GHz MOJAVE image below (Epoch: 2009-03-25), constitutes a large fraction of the total emission

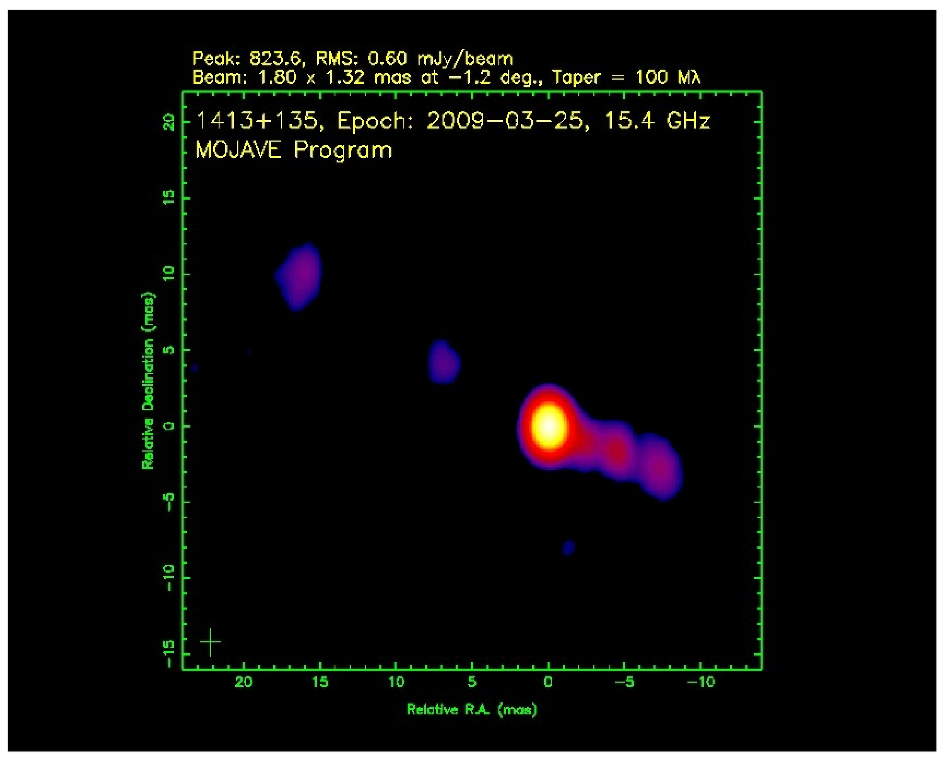

Figure 5: 15 GHz VLBA map of 1413+135 obtained from the MOJAVE monitoring program database [7], and contemporaneous with the low-state LAT observing period.

γ-ray Light Curve

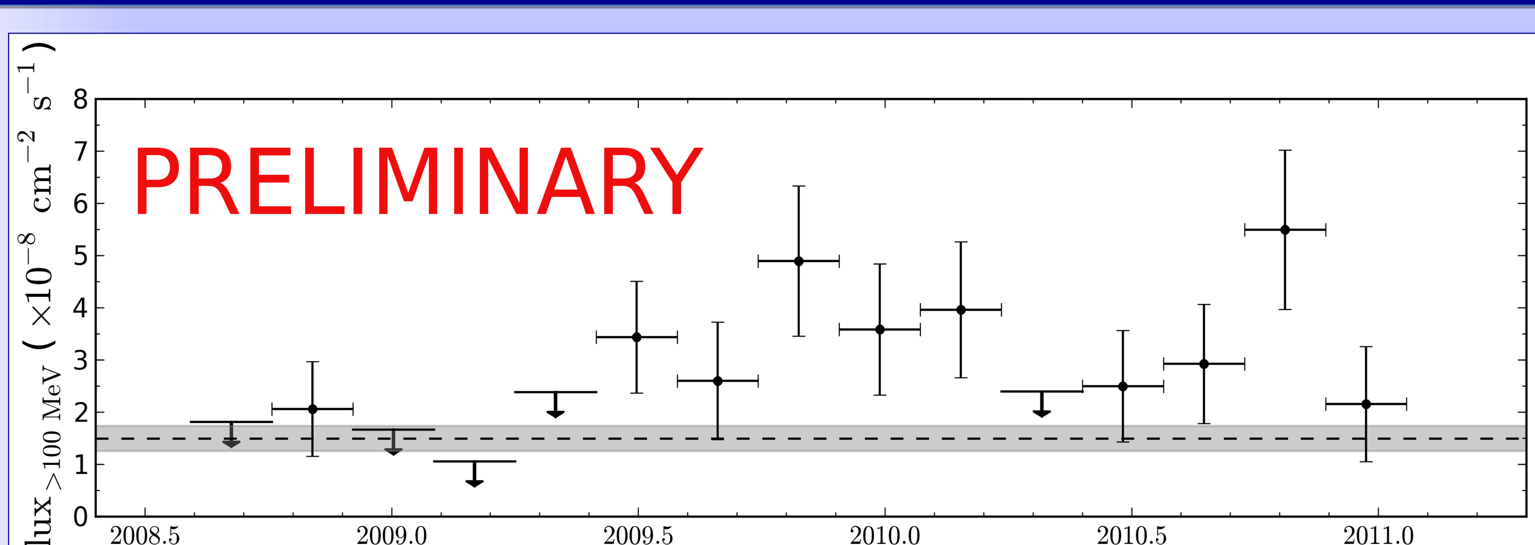

Figure 6: Fermi / LAT 30-month γ-ray light curve of 1413+135 divided into 60 day bins. Arrows represent 95% confidence upper limits. All points represent >2σ detections and are plotted along with their statistical errors. The dashed horizontal line and gray region represent the weighted average flux (>100 MeV) and corresponding error of (1.5 ± 0.2) x 10^{-8} ph cm⁻² sec⁻¹ (see [1] for a description of weighted average & variability calculation).

- A test of the γ-ray variability was performed by calculating the X^2 value of all points against the weighted average
- Resulting probability $P(X^2 > X^2_{obs}) = 0.0002$
- Variable nature of the source over the 30 month timespan restricts the bright γ-ray component to a sub-pc scale region.

Discussion

The VLBA radio morphology of 1413+135, which shows radio components extending from both sides of the central core, has a total extent of 230 parsecs, thus leading to the CSO classification of the source. On the other hand, the bright and variable radio core in the VLBA map is an unusual property of the young radio sources, with most having faint cores that are often undetected [9]. In the case of 1413+135, evidence of relativistic beaming from the core can also be found from superluminal motions that have been observed from the southeastern counterjet components [3][7]. Given the strong evidence of variability in the LAT light curve, the γ-ray emission must be confined to sub-pc scale distances. This restricts the possible emission sites to the unresolved core, milli-arcsecond-scale knots, or terminal shocks of the newborn jets. Further observations with the VLBA along with continued monitoring by the LAT may provide insights into the origin of the variable γ-ray emission from this unusual source.

Acknowledgements / References

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This research has made use of the MOJAVE database that is maintained by the MOJAVE team.

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