The Quasar 3C 345
an archetypical active galactic nuclei

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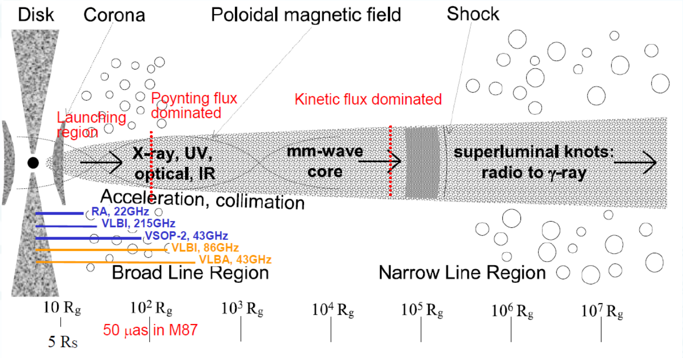
Introduction



Collimated outflows are formed close to central black holes.

The source: 3C 345

Classification: BLRG, highly variable/OVV blazar
(one of the best studied blazars)

Redshift: z=0.593 (Marziani et al., ApjS 1996)

Distance/Sizes: $D_L \approx$ 3.5 Gpc, 6.6 pc/mas, 1 $\frac{\text{mas}}{\text{year}} \rightarrow$ 34.5c
in concordance with H_0 = 71 km s^{-1} Mpc^{-1} and $\Omega_\Lambda = 0.72$

Properties (*from literature*):

- one sided superluminal jet with apparent speeds $\beta_{\text{app}} \leq$ 20c
- viewing angle to the line of sight: $\Theta =$ (2.6 - 6)$^\circ$
- Bulk Lorentz and Doppler factors: $\Gamma \approx 20$; $D \approx 8$
- Jet opening angle: $\alpha_{\text{app}} \approx 12.9^\circ$, $\alpha_{\text{int}} \approx 1.2^\circ$
- high variability across all wavelengths, from radio to X-rays with a long-term periodicity of 3.4-4 years

VLBA radio monitoring

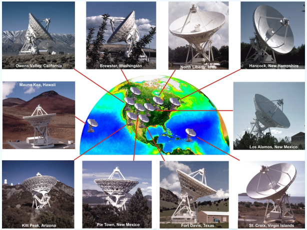
A new cycle of enhanced nuclear activity of 3C 345 began early 2008 observable at all wavelengths.

Followed-up by dedicated VLBA observations (2009 - 2010) and observations as part of the BU blazar sample (Marscher et al.) in approx. monthly intervals:

- Schinzel et al.: 12 epochs; 10 hours each; 15, 24, and **43 GHz**
- Marscher et al.: 14 epochs at **43 GHz**

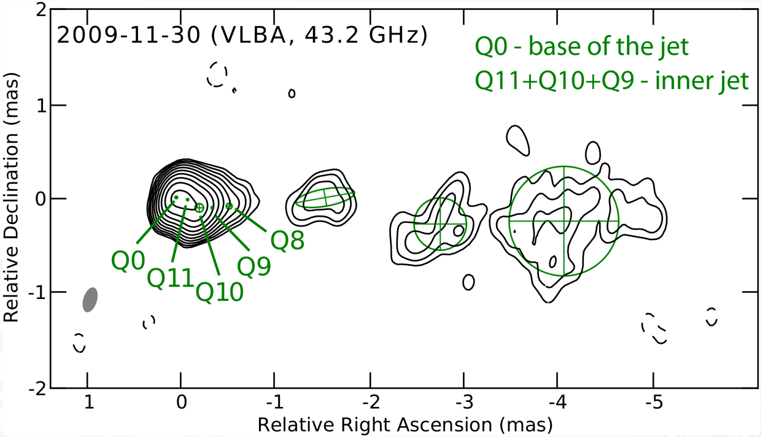
Data Reduction & Analysis:

- AIPS (Astronomical Image Processing System) – calibration
- Difmap – mapping and modelfitting



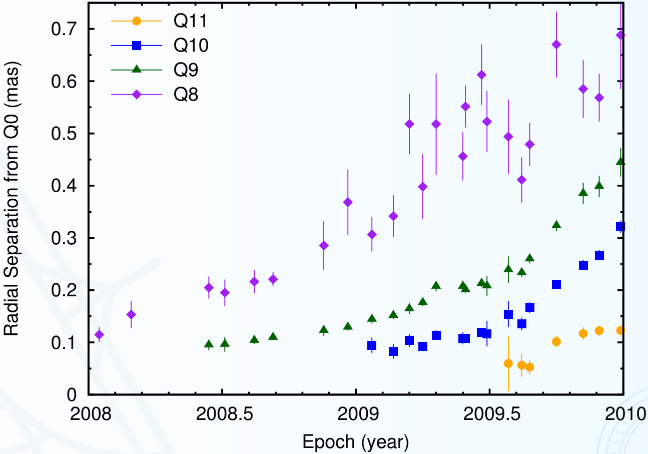
NRAO’s Very Long Baseline Array (VLBA)

Source structure at 43 GHz



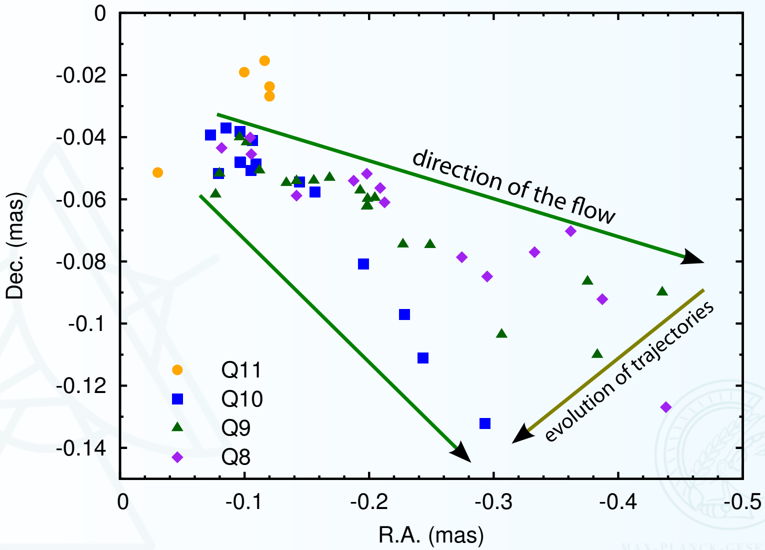
Best representation of the brightness distribution of the core region was determined through optimization of the minimum χ^2 statistics and degrees of freedom.

Radial separation of new features in the jet



Features apparently accelerate from 2-10c over a time period of 1.5 years and a distance of 0.3 mas (2 pc).

Trajectories of new features in the jet



γ-ray emission from AGN

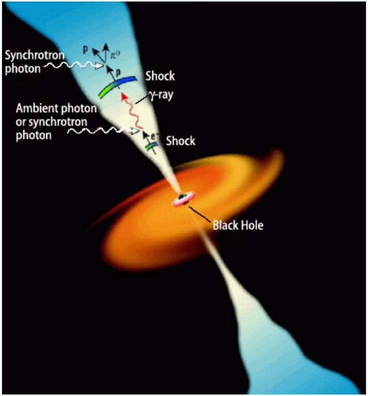
The number of detected γ-ray loud AGN has increased by a factor of 5 during the first year of Fermi/LAT observations!

Where and how are the observed γ-rays produced?

γ-rays are believed to be produced in a relativistic jet consisting of an e-p plasma.

Possible γ-ray emission mechanisms:

- Leptonic (Inverse Compton)
- Hadronic (i.e. proton-proton)
- Combination of Leptonic + Hadronic



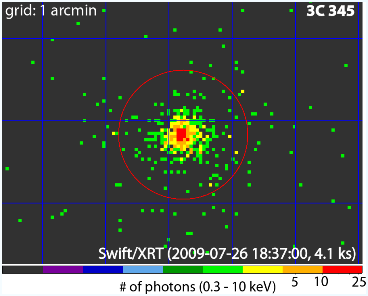
High energy emission

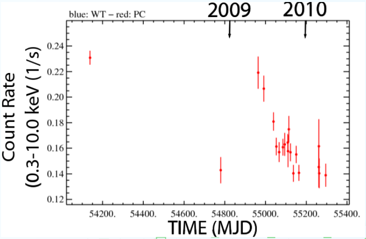
Known as prominent source up to X-ray energies, not in γ-rays (pre Fermi era).

X-ray emission dominated by the jet through inverse Compton has been concluded by Unwin et al. 1994, 1997.

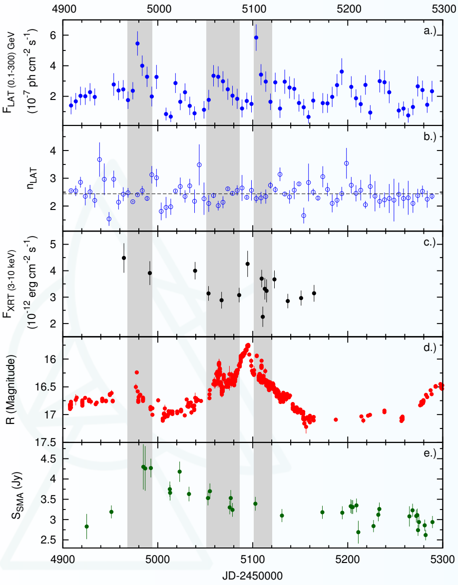
Typical X-ray flux (3-10 keV): $(3 - 5) \cdot 10^{-12}$ erg cm^{-2} s^{-1}

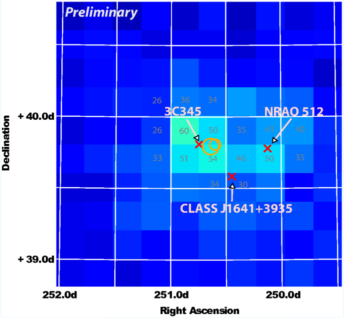
Note: During 2009 the nearby sources CLASS J1641+3935 and NRAO 512 were both a factor of 7-8 fainter at optical (18.5 Mag.) and X-ray wavelengths ($0.5 \cdot 10^{-12}\ \frac{\mathrm{erg}}{\mathrm{cm}^2\ \mathrm{s}}$) than 3C 345.





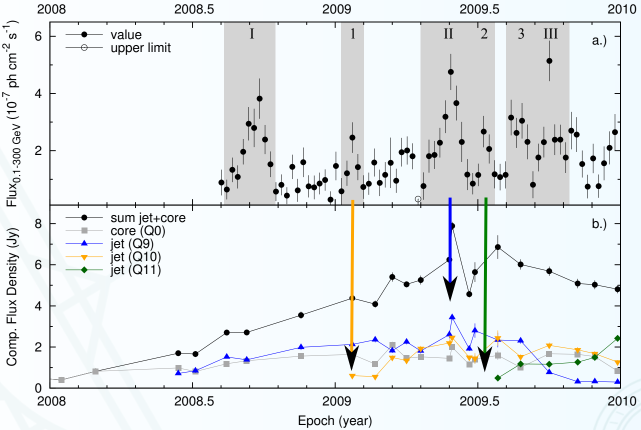
γ-ray detection and multi-wavelength identification





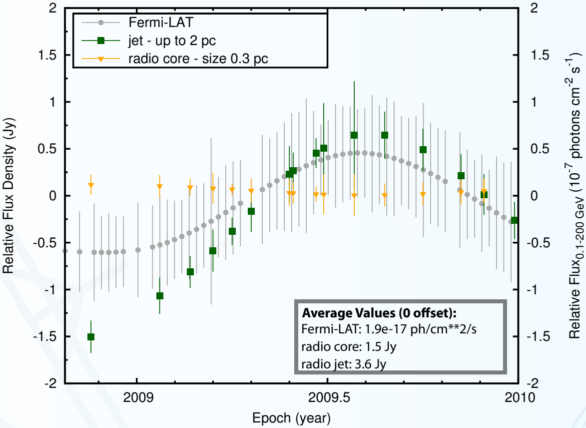
Raw Fermi/LAT counts map integrated over 20 months with radio positions of candidate sources and LAT error circles (large circle 11 months, smaller circle 20 months).

γ-ray flux vs VLBA flux densities



1. γ-ray events aligned with appearance of jet components (1,2).
2. Radio flare in the jet has γ-ray counterpart (flare II).

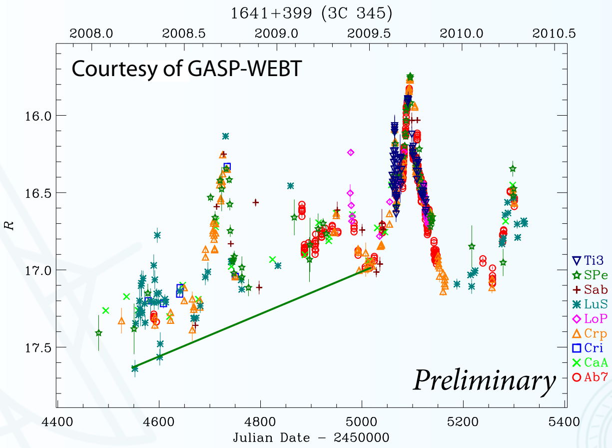
Trends



Long-term trends obtained by fitting cubic splines to the light curves of γ-rays, jet and core, rescaled to their respective mean flux values.

Core shows constant flux density, radio jet and γ-ray trends match.

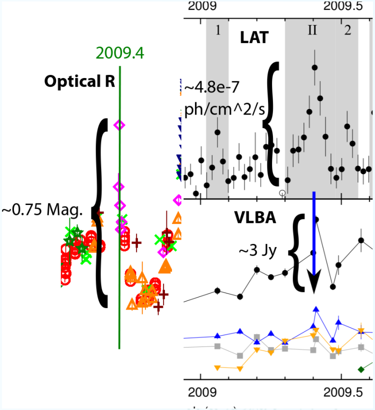
Trend in optical



Similar trend seen in the optical, which implies that baseline optical emission is dominated by the jet.

γ-ray flare II - a jet flare

- The radio observations was only one day before the peak of the γ-ray flare (JD 2454980; May 28, 2009).
- A peak in the optical R-band light curve (GASP) was observed two days before the peak of the γ-ray event.
- The region around the jet feature Q9 is most likely the origin of this flare. With a distance of 0.20±0.01 mas (1.3 pc) from the base of the jet.



Summary

- 3C 345 is detected as γ-ray loud source by Fermi/LAT.
- Observation of two new superluminal features producing γ-ray outbursts while passing through the 43 GHz VLBI core.
- Brightening of the inner radio jet at 43 GHz, at a distance of up to 40 pc from the VLBI core, is associated with a strong simultaneous γ-ray flare & fast optical flare.
- Evidence for a **direct correlation between radio and γ-ray emission, similar trends are observed in radio, optical and γ-rays.** Thus, not a single emission region can be responsible for the observed γ-ray emission.
- Sparse sampling of the radio data makes it difficult to obtain firm localizations of individual events in the radio jet.