A Three-decade X-band VLBI Study of 3CR Lobe-dominated Quasar Nuclei

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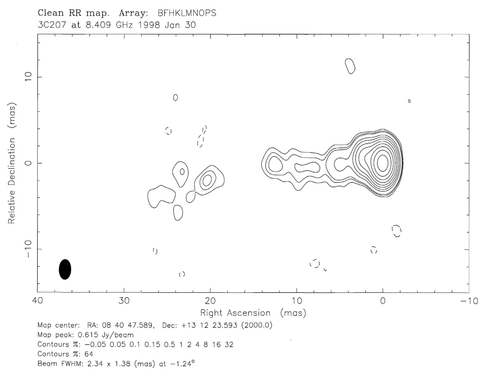
Abstract

We report X-band VLBI observations of several 3CR lobe-dominated quasar nuclei from 1981 to 2010, mostly obtained with the NRAO VLBA. The goal is to follow flux density outbursts and to fully determine the jet morphology and kinematics on 1-100 pc scales. In 3C207, the core region has flux outbursts at mean intervals of 7 yr; one of these is actually a double outburst from a stationary true core and a swinging component 0.5 mas apart. The position angle (PA) of the swinging component varies by 40°, while the PAs of the jet components span 25°. The jet extends to 25 mas. Average superluminal speeds are about 10*c*. One component shows apparent acceleration from 7*c* to 14*c* at 2-3 mas from the true core, in a jet recollimation zone that redirects the flow toward PA 90°. Individual jet components expand until reaching the recollimation zone. In 3C263 and other objects, some of the same phenomena are seen, including ejection of jet components over a range in PA, superluminal motion, and apparent acceleration, but to a lesser degree. Possible physical interpretations involving beaming, orientation, projection, precession, and magnetic effects will be discussed.

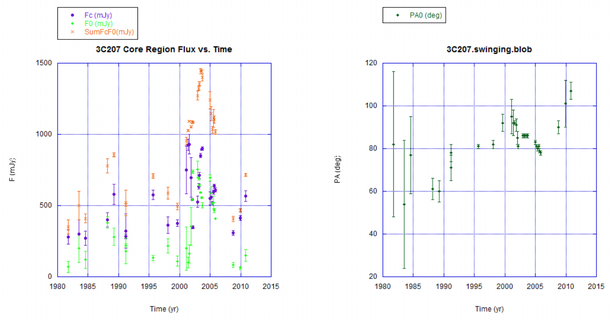
The Lobe-dominated Quasar Sample

- **Sample Selection:** Complete, flux-density-limited sample of 25 revised 3CR lobe-dominated quasars (LDQs). Selection by lobe emission minimizes orientation bias due beaming. Nuclei ~1 mJy to ~1 Jy. See Hough & Readhead (1989, AJ, 98, 1208).
- **Goals:** To advance our knowledge of flux outbursts and jet morphology & kinematics on ~1-100 pc scales in LDQ nuclei viewed over a wide range of orientations. When polarized emission detected, map core and jet magnetic field configurations.
- **Key Results from Previous VLBI Studies:** (1) All 25 detected; (2) 22 one-sided jets (3 just faint cores); (3) inner jets bend a few degrees; (4) jet speeds in 15 are ~0 to ~10*c*; (5) outer components faster than inner ones, but acceleration thus far seen in only 1 component; (6) 4 with significant core/inner jet rotation measure, 2 of these have long jets (~25-40 mas) with longitudinal magnetic fields. See Hough (2008, ASP Conf.Ser., 386, 274).
- **The Present Study:** Observations of 6 LDQs – 3C207, 3C208, 3C212, 3C249.1, 3C245, 3C263 – at 8.4/10.7 GHz, 1981-2010 for all but 3C208 (1988-2010). Frequent sampling with VLBA era essential to study core outbursts, jet trajectories, and jet accelerations.

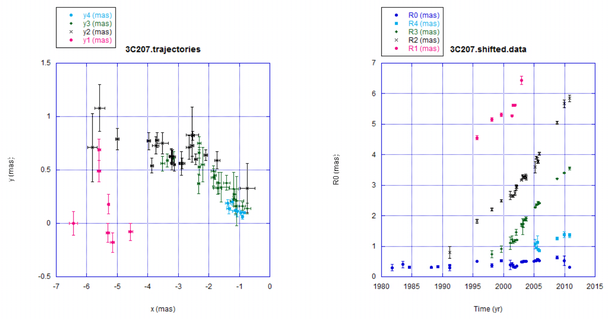
3C207: VLBA at 8.4 GHz



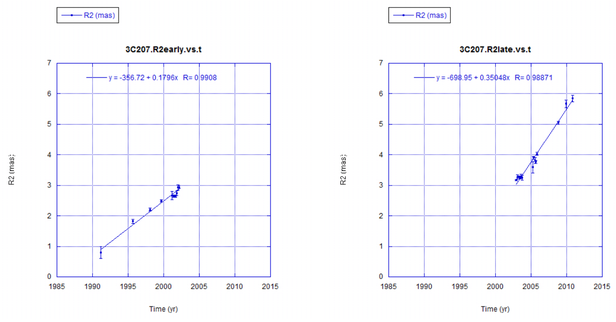
3C207 Core Region: Flux & Swinging Component PA vs. Time



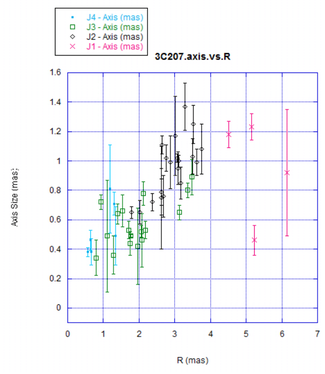
3C207 Jet Components: Trajectories & Core Distance vs. Time



3C207: Core Distance R2 vs. t, "early" and "late" times



3C207: Component Diameter vs. Core Distance



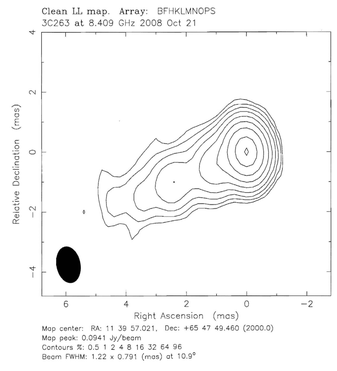
3C207 Results – 1

- Quasi-periodic flux outbursts (~7 yr)
- At least one is actually hidden *double* outburst when model region with "true core" and 0.5 mas "swinging component"
  → binary black hole?
- Numerous jet components out to ~25 mas (~175 pc projected distance)

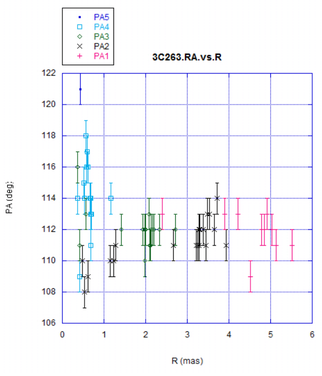
3C207 Results –2

- Swinging component has PA change ~40°, with jet blobs ejected thus far over range of ~25°
  → Precession of jet axis by 3-4°? Magnetic helix?
- Superluminal speeds ~10*c* on average, so γ_{min} ~10
- Best-studied blob accelerates from ~7*c* to ~14*c*
  → may be abrupt at ~20 pc projected distance in "recollimation" zone , flow then at PA~90°
- Jet blobs expand until reach recollimation zone
  → expansion adiabatic? then confined?
  → confinement: gas pressure or magnetic?

3C263: VLBA at 8.4 GHz



3C263: Position Angle vs. Core Distance



3C263 Results

- "Accelerated" superluminal motion, from 3*c* to 7*c* (Polito & Hough 2010, BAAS, 42, 377)
- PA of new component ejection shows signs of increasing over time, but all components are guided into PA=112° path further out
- So similar phenomena to 3C207, but *milder* due to orientation, projection, and beaming effects

Other Lobe-dominated Quasar Results

- 3C208, 3C212, and 3C249.1: slow (<1*c*) inner components and moderate (~2-4*c*) outer components
- 3C245: appears to have alternating slow/fast components (range ~4-11*c*)
- Search for variations in component ejection direction and component acceleration in progress

The Future

- Exhaustive X-band study of 3C207 done, so now pursue for other 5 LDQ nuclei
- Conduct similar analyses to follow outbursts, search for changes in ejection direction, extract Lorentz factors, measure accelerations, find opening angles, locate "recollimation" zone
- Constraints on precessing and helical jet models

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