A zoom into the jet launching region of the radio galaxy Cygnus A

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AGN Model

Observations, Results and Discussion

Global VLBI at 86 GHz/3 mm (GMVA)

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Simplified view of the stratified jet in Cyg A

Summary
About Cygnus A

- One of the first and strongest extra-galactic radio sources and a prototype for FRII radio galaxies
- Nearby, $z = 0.0561$ corresponding to 250 Mpc and a resolution of $1 \text{mas} \sim 1.1 \text{pc}$ and $0.1 \text{mas} \sim 400$ Schwarzschild radii ($R_s$)
- Prominent two sided jets on parsec scales.
- Large viewing angle $\sim 75^\circ$ $\rightarrow$ less relativistic effects
AGN Model

Peacock, Cosmological Physics (1991)

Type II

Cygnus A

Type I

BL Lac & Quasar

100 pc

0.1 pc

Peacock, Cosmological Physics (1991)

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- GMVA observations from May 2009, Oct 2009 and May 2010
- Beam of $\sim 0.1 \times 0.05 \text{ mas}$ → $\sim 200 R_s$
- Peak flux varies around $\sim 250 \text{ mJy/beam}$ noise level at $\sim 0.15 \text{ mJy/beam}$

Boccardi et al. 2016b
Global VLBI at 3mm (86 GHz)

Stacked image of Cyg A at 86 GHz combining all 3 GMVA observations from 2009-2010 restored with a circular beam of 0.1 mas.

- Recovers more of the limb-brightened jet
- Lower noise level of $\sim 0.1 \text{ mJy/beam}$

Boccardi et al. 2016b
Jet width vs. distance from the core

→ the jet is transversally resolved! $d_{\text{min}} = 51 \pm 22 \, \mu\text{sec} \sim 227 \pm 98 \, R_s$
Global VLBI at 7mm (43 GHz)

Jet kinematics from 7mm VLBI observations from Oct 2007 to Nov 2009

Oct 07

Oct 08

Mar 09

Nov 09

Distance $z$ [mas]

Time $t$ [years]

Boccardi et al. 2016a

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Jet kinematics

- Mildly relativistic
- Accelerating on parsec scales
- Stratified in Bulk speed

- Because of the large viewing angle, jet components will get fainter when they are faster.

Boccardi et al. 2016a
Stacked image of all 4 epochs

Jet width vs. distance from the core

→ limb brightened jet structure

→ parabolic shape with a mean opening angle, $\Theta \sim 5^\circ$
Simplified view of the stratified jet in Cyg A

- Parabolically expanding
- Accelerating on scales of $10^3 - 10^4 R_s$
- Spine-sheath structure
- Even faster flow might exist
- On larger scales, at 5 GHz, the jet appears cylindrical (e.g. Carilli et al 1991)

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Our VLBI studies indicate that the jet in Cygnus A is produced by a mildly relativistic and parabolically expanding disk wind. Acceleration and shape are consistent with expectations from a magnetically-driven jet. Stratified jet structure and limb brightening of the flow suggests coexistence with a faster narrow spine (BH-driven?)

To further constrain this picture:

- Proposed RadioAstron observations at 22 GHz, providing a beam of up to 60 μsec
- Proposed more sensitive GMVA (3 mm/7 mm) observations close in time to the RadioAstron dates
Thank you!