The twin-jet system in 3C 452

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Abstract

The radio galaxy 3C 452 displays a unique combination of symmetric double-jet morphology, large black hole mass ($M_{BH} = 3.5 \times 10^8 M_\odot$, Marchesini et al. 2004), and vicinity ($z = 0.081$). It is a rare example of a two-sided Fanaroff-Riley II source which can be imaged at high radio frequencies through VLBI observations. Here we present the first VLBI images of this source on sub-parsec scales, which revealed a highly symmetric twin-jet system. We performed a pixel-by-pixel analysis of the innermost $\sim 10^3 - 10^4$ Schwarzschild radii to investigate the bulk speed profile, setting an upper limit of $\sim 80^\circ$ on the jet viewing angle. The jet orientation close to the plane of the sky makes 3C 452 a prime target to test the existence of a thick obscuring torus surrounding the supermassive black hole, as predicted by the standard model of active galactic nuclei. To this end, we performed an X-ray analysis using XMM-Newton data. The X-ray spectrum appears to be dominated by Compton reflection off cold matter, indicating a highly absorbed source with intrinsic hydrogen column density of $\sim 6 \times 10^{23}$ cm^{-2}. A VLBI spectral analysis hints at the presence of free-free absorption at the jet base.

First view from kilo-parsec to sub-parsec scales

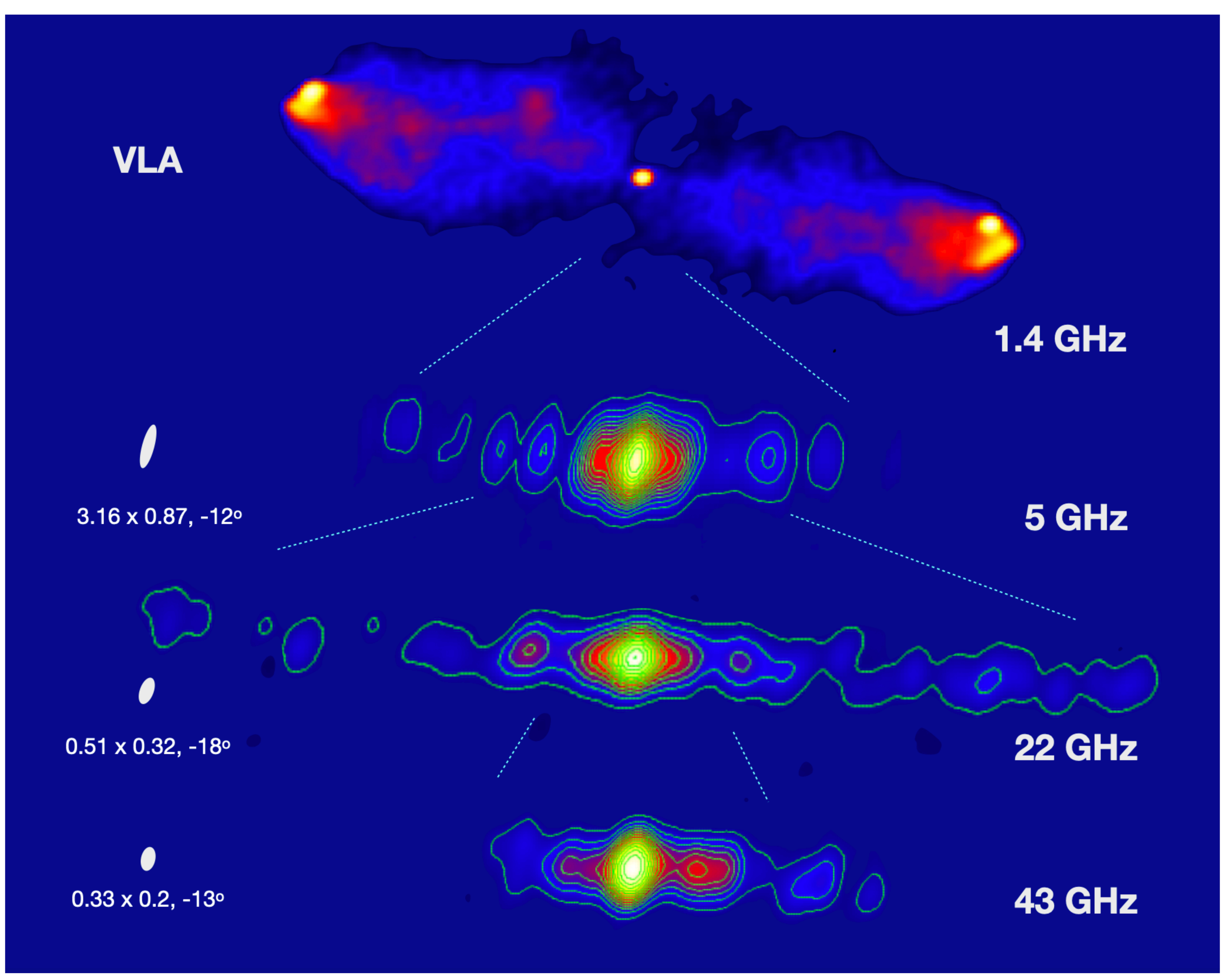

Fig.1. Twin-jet structure of 3C 452 from kilo-parsec to sub-parsec scales. The top image was obtained from VLA data at 1.4 GHz. The following maps show the VLBI structure at 5 GHz, 22 GHz, and 43 GHz. Due to the frequency dependent shift of the VLBI core ('core shift' effect), the location of the central black hole is uncertain. In addition, the distinction between the approaching and receding jet is not unequivocal.

VLBI Spectral analysis

We perform a spectral analysis using the simultaneous 22 GHz and 43 GHz data. The flux density S_ν is assumed to depend on the frequency as $S_\nu \propto \nu^a$.

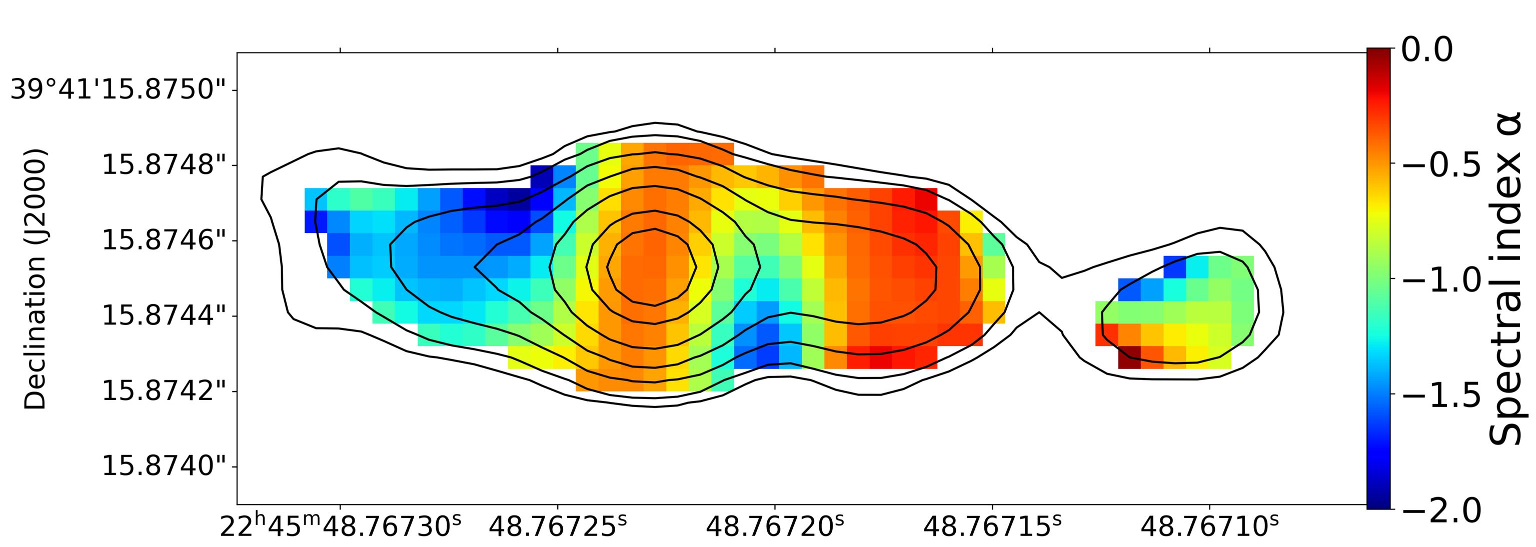

Fig.2. Spectral index map between 22 GHz and 43 GHz. The contours denote the 43 GHz continuum emission. We assume the core shift between the two frequencies to be negligible with respect to our resolution.

The central feature shows a mildly flat spectrum, while a strong asymmetry is observed between the jet and the counter-jet side. The west side shows a much flatter spectrum, possibly indicative of free-free absorption from the surrounding material.

Speed profile based on the jet/counter-jet ratio

Computing the ratio, *R*, between the jet and the counter-jet flux density at the same distance from the core, and assuming a spectral index $\alpha = -0.7$, we estimate the intrinsic speed β for different viewing angles θ. A lower limit of $\theta = 60^\circ$ was previously determined by Giovannini et al. 2001. We performed the analysis at the frequency of 22 GHz.

$$R = j/cj = \left(\frac{1+\beta cos\theta}{1-\beta cos\theta}\right)^{2-\alpha}$$

Since the intrinsic speed $\beta < c$, our analysis sets an upper limit of $\theta < 80^\circ$ on the viewing angle.

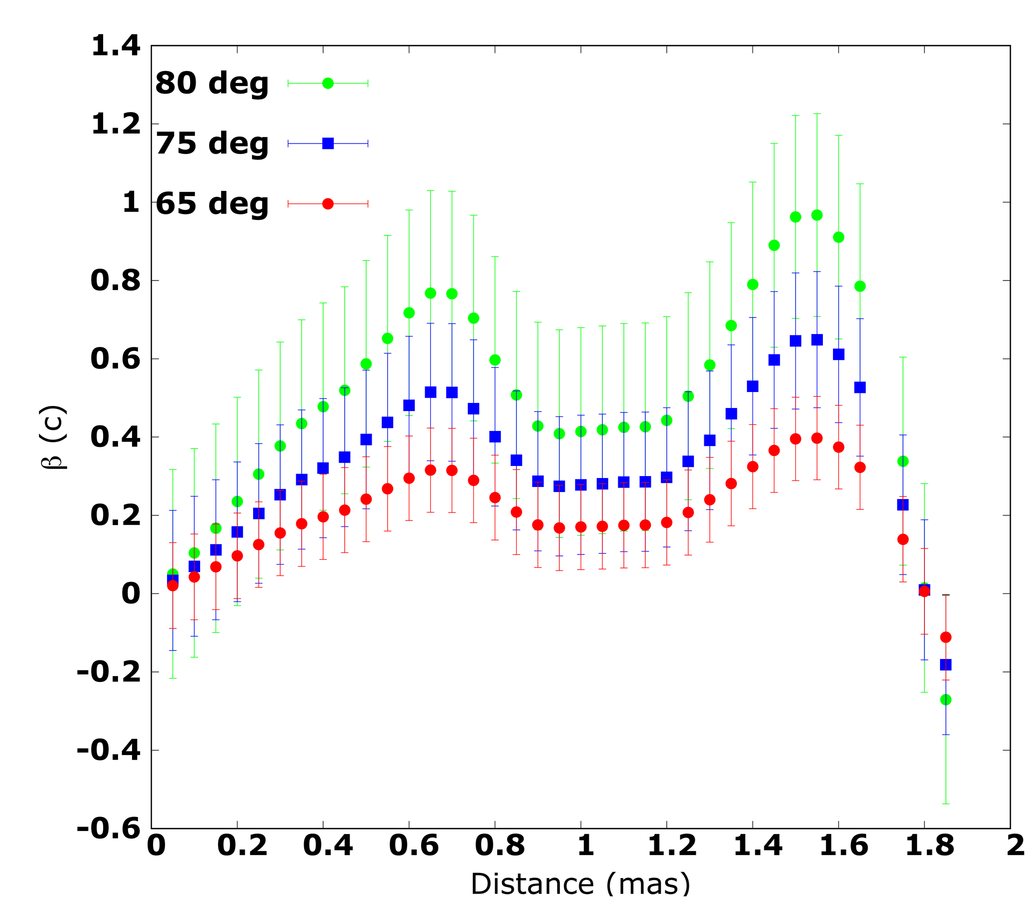

Fig.3. Intrinsic speed profile for three different viewing angles (65, 75, 80 deg) as a function of the distance from the 22 GHz core, derived based on the jet-to-counter-jet intensity ratio.

Moreover we infer:

- **Mildly relativistic speeds.**
- **Possible evidence of bulk acceleration within the innermost 2 mas, corresponding to ~3 parsecs (projected).**

X-ray Spectral analysis

We also present an X-ray spectral analysis using data from the XMM-Newton satellite, in order to test the presence of a torus obscuring the nucleus. The spectrum was extracted within a radius of 0.44 arcmin, in the 2-10 keV energy band.

Best model $\longrightarrow$ **model=zphabs*(zpow+gauss)+phabs*apec**

- We obtain a relatively high X-ray luminosity $L_X = 8 \times 10^{43}$ erg/s.
- We model a prominent iron line, indicative of efficient accretion.
- We estimate a high hydrogen column density $N_H = (61.8 \pm 5.2) \times 10^{22}$ cm^{-2}

$\downarrow$

Strongly absorbed source

(In agreement with Fioretti et al. 2013)

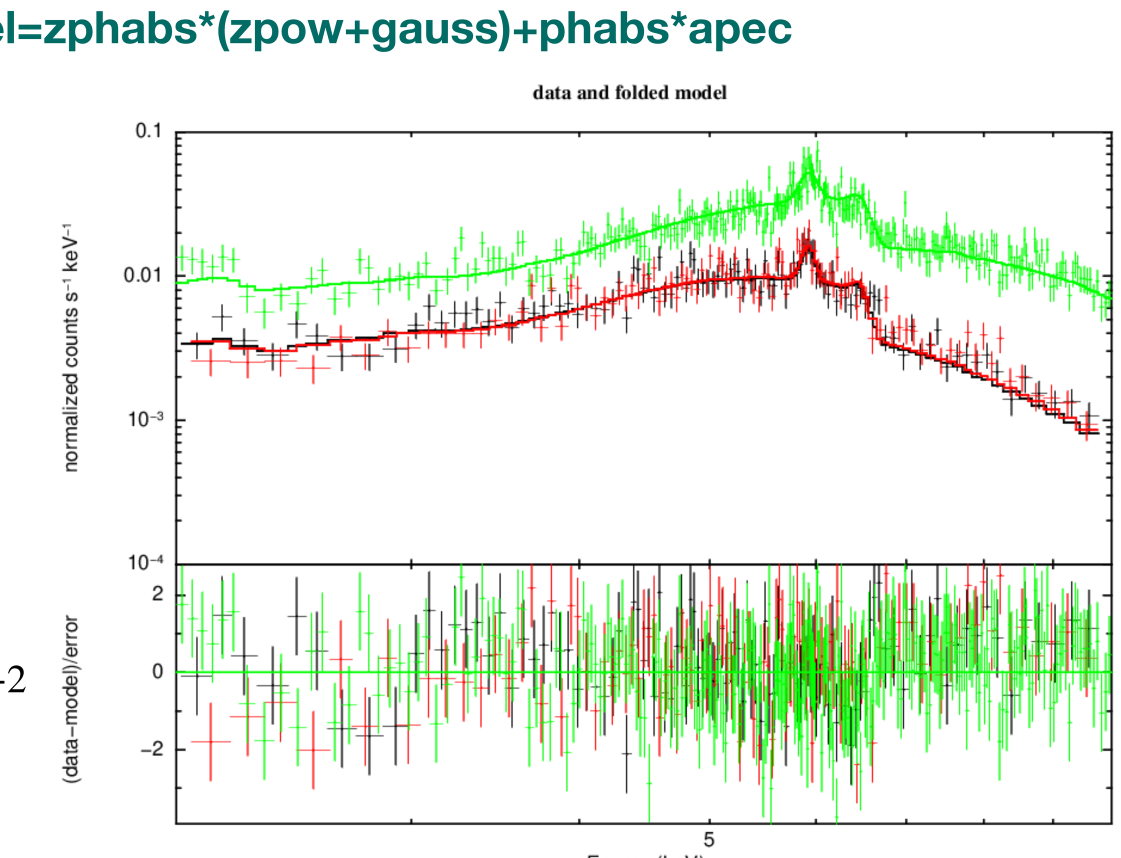

Fig.4. X-ray spectrum of 3C 452 in the 2-10 keV energy band, as observed by XMM-Newton.

References

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- Fioretti, V., Angelini, L., Mushotzky, R. F., Koss, M., & Malaguti, G. 2013, A&A, 555, A44
- Giovannini, G., Cotton, W. D., Feretti, L., Lara, L., & Venturi, T. 2001, ApJ, 552, 508