New RadioAstron observations of the radio galaxy 3C 84 at 22 GHz

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Due to its brightness, proximity and variable nature 3C 84 is one of the most well-studied radio sources on the sky. Our study is a follow-up of the high resolution RadioAstron observation from 2013 (Giovannini et al. 2018). The new 22 GHz measurements taken in 2016 reached a resolution of 45 μas, and reveal several changes in the structure of the inner parsec region as well as in the collimation profile of the re-started jet.

The main features of the source:

1) detection of the limb-brightened jet and counter-jet (Fig. 1)
2) flip in the hotspot's position to the leading edge of the jet due to interaction with the ISM, also observed by Kino et al. (2021); after the flip, the jet propagation halted between 2016.8 and 2018, until it broke out from the dense clumps of ISM
3) jet base has swinged to the East by 20° since 2013 → possible jet precession
4) brightness temperature of the hotspot is still high, $T_b \approx 6.7 \times 10^{11}$ K, which indicates a particle dominated region
5) collimation profile (Fig. 2) evolved from quasi-cylindrical to parabolic, which we can see on both the clean image, as well as on the one made using ehtim → the pressure of the surrounding cocoon, discovered by Savolainen et al. (2021) from 5 GHz RadioAstron observations, has possibly decreased between the observations leading to a less efficient jet collimation

Fig. 1. Total intensity map

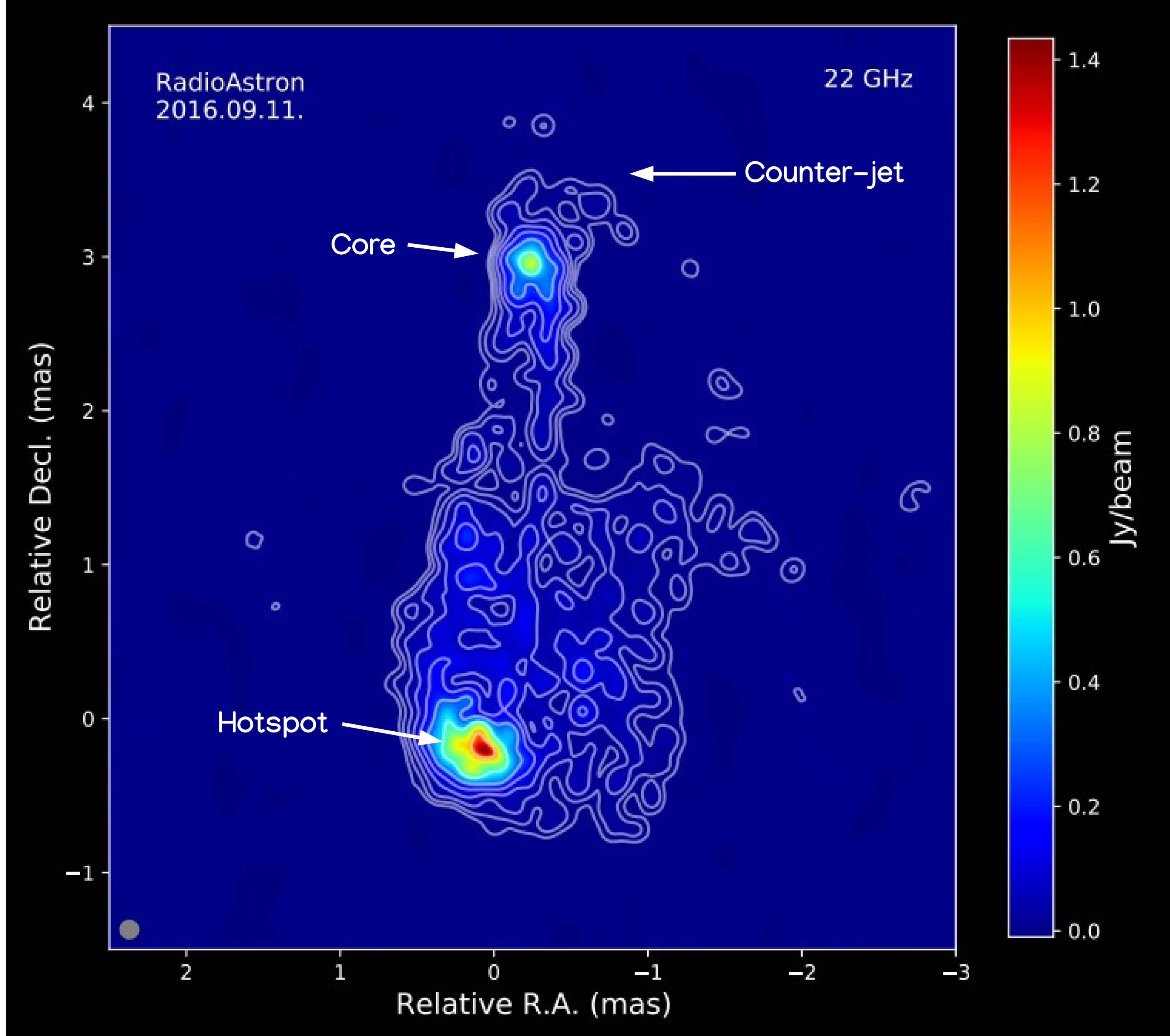
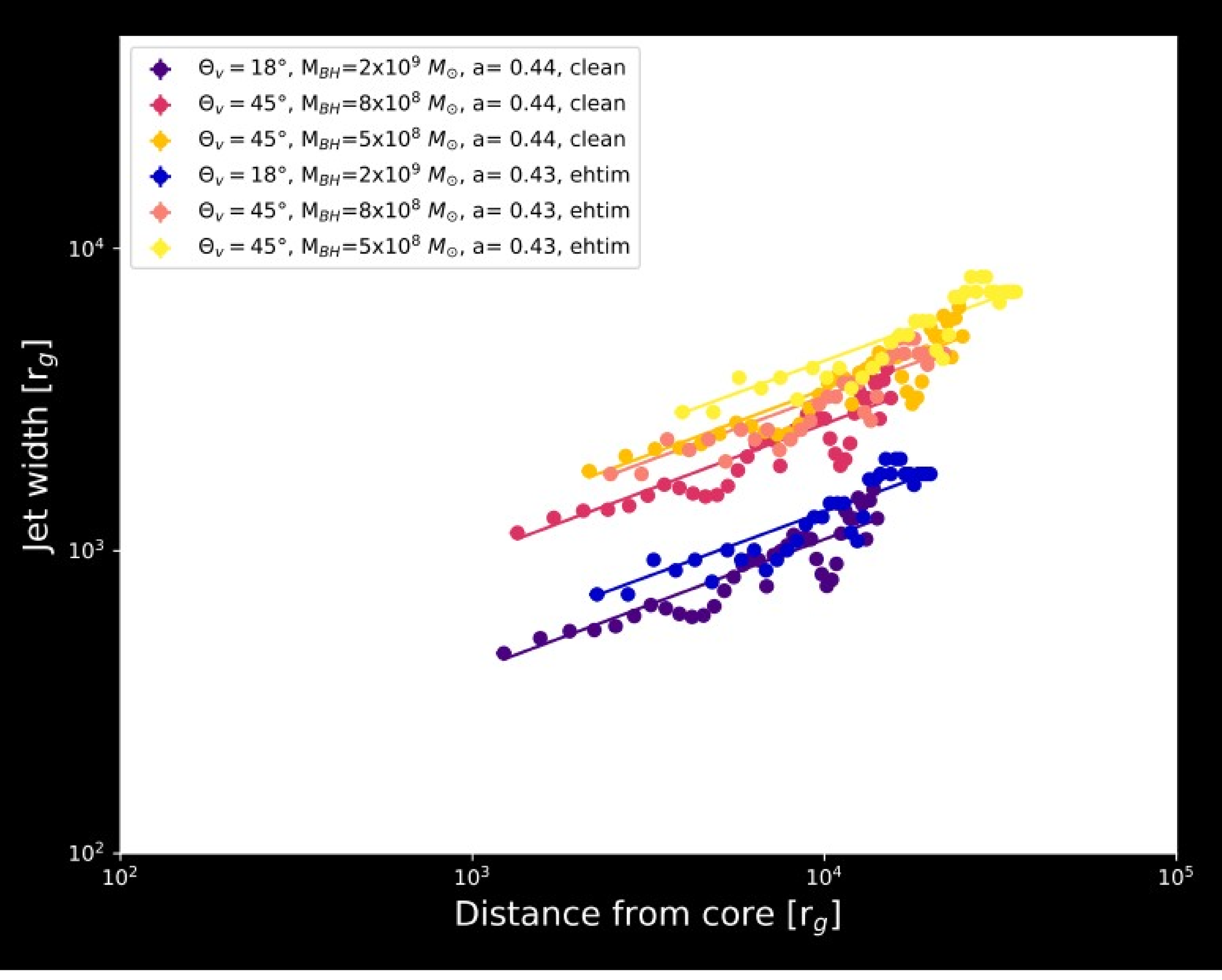


Fig. 2. Collimation profile measurement



Using quasi-simultaneous observations with the VLBA and Effelsberg at 4.8, 8, 15 and 43 GHz, with Medicina participating in the 4.8 GHz observations, we were able to construct spectral index maps (Fig. 5) and perform coreshift measurement. The inverted spectrum of the counter-jet and the northern part of the core is probably due to free-free absorption (Walker et al., 2000; Fujita&Nagai, 2017). The spectral index of the hotspot between 22 and 43 GHz is flat, while the jet has a slightly steeper spectral index. We also measure the frequency-dependent shift of the core position and calculate the distance of the jet apex from the location of the 43 GHz core. Our preliminary coreshift measurement (Fig. 3 and 4) yields a value of 98+/-2 μas, which is consistent with measurement of Paraschos et al. (2021). However, this coreshift is significantly larger than the one measured from the 2013 RadioAstron observations by Giovannini et al. (2018), who constrained the distance of the jet apex to be 30 μas based on the detection of the limb-brightened counterjet. This may indicate that the limb-brightened structure north of the 22 GHz core is not a counter-jet, but part of the stratified forward jet.

Fig. 3. Frequency dependent core position

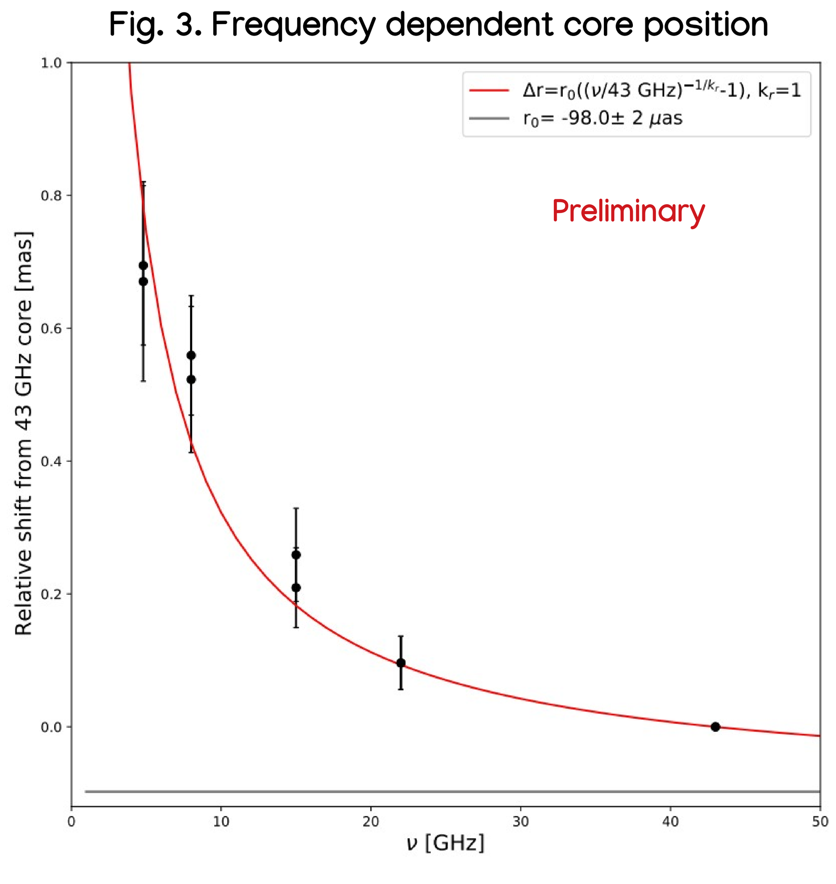


Fig. 4. Position of the apparent core at different frequencies

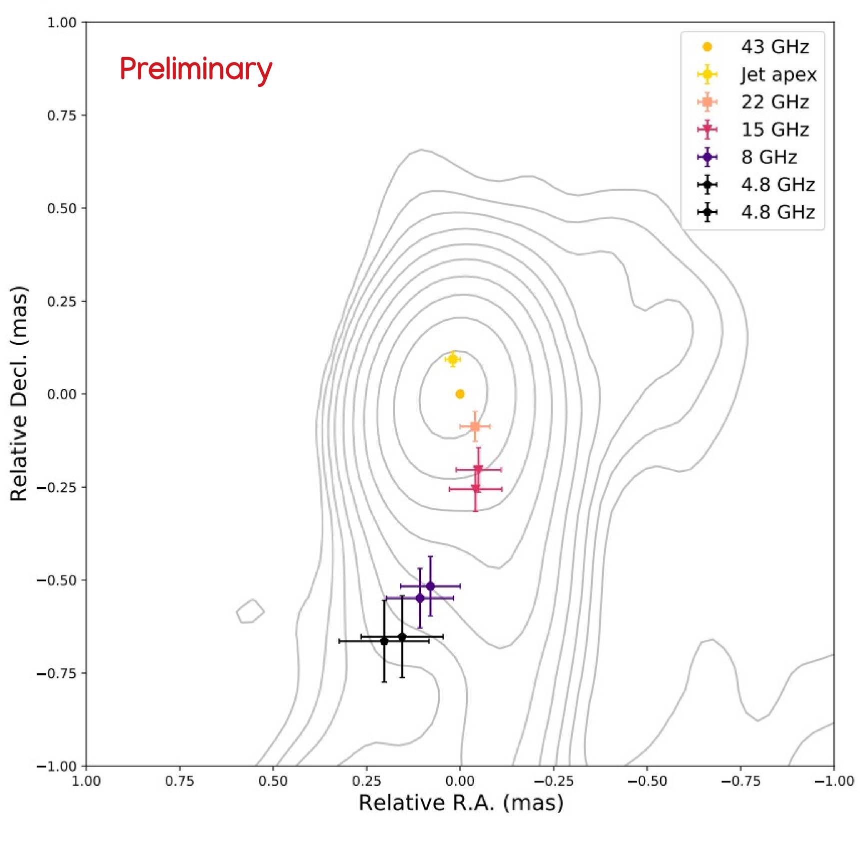
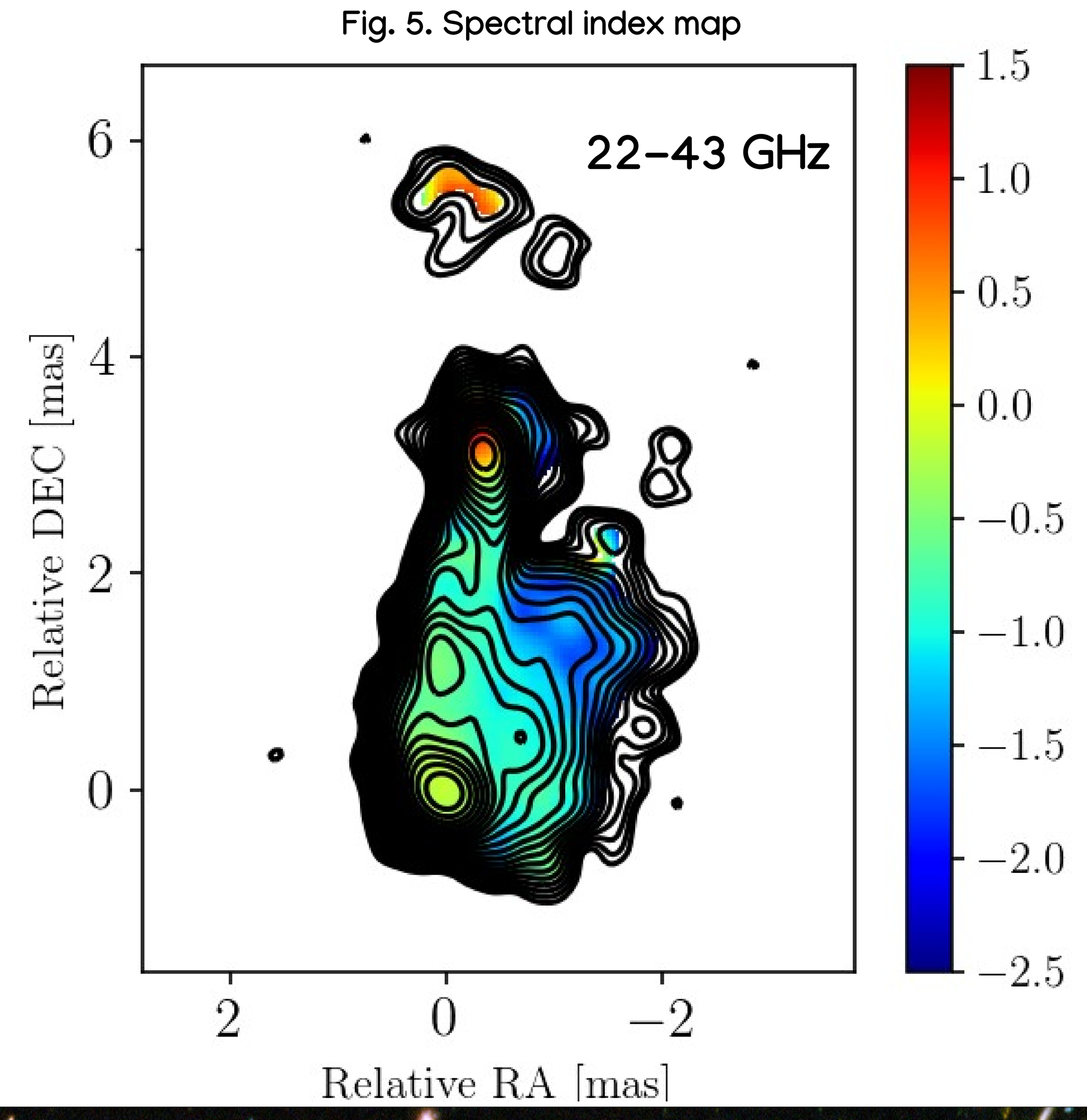


Fig. 5. Spectral index map



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