Astrophysical Phenomena Revealed by Space VLBI
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A VSOP Observation of 3C 84

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Abstract

We present 5 GHz VSOP and 15 GHz global VLBI images of 3C 84. Our VSOP observation reveals a double-ridgeline structure in the southern component for the first time at this low frequency. We conclude that a jet and its back flow form this double-ridgeline structure. An inverted spectrum in the northern component indicates free-free absorption. This result is consistent with previous observations.

1 Introduction

The compact radio source 3C 84 in the Seyfert galaxy NGC 1275 is one of the strongest radio sources and a near-by (z=0.018) active galactic nucleus (AGN). It has been a prime target of Very Long Baseline Interferometry (VLBI) observations. Previous VLBI observations revealed a very complicated structure of 3C 84. It has a jet to the south and counter-jet to the north and a bright, flat-spectrum core. The counterjet shows a strong low-frequency cut off, while the main jet shows no low-frequency cut off. The asymmetric distribution of this cut off seems to be due to free-free absorption in a volume that surrounds the core and lies in front of the counterjet but is behind the main jet (Vermeulen and Readhead 1994; Romney et al. 1995). From previous VLBA observations at 15 GHz, it has been reported that the southern jet has a double-ridgeline structure in the east-west direction (Venturi et al. 1993).

2 Observations and Data Reduction

On 1996 November 21, we observed this source for 10 hrs with a global VLBI network at 15 GHz. We used the VLBA, the phased-VLA, and

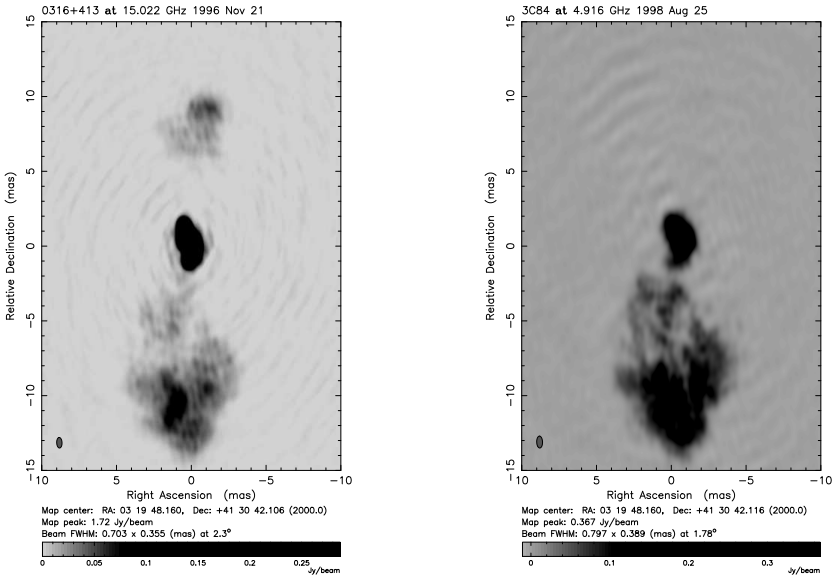

Figure 1: Clean images of 3C 84 at observing epochs 1996.89 with global VLBI at 15 GHz (left) and 1998.65 with VSOP at 5 GHz (right)

Effelsberg 100-m antenna. On 1998 August 25, we observed again for 14 hrs with the VLBI Space Observatory Programme (VSOP) at 5 GHz. At this time we used the VLBA, the phased-VLA, and the Space VLBI satellite HALCA. Amplitude calibration for each antenna and fringe fitting were performed with AIPS. Imaging, deconvolution, and self-calibration were performed using Difmap.

3 Results and Discussion

3.1 The Southern Jet

Images of both of our global VLBI and VSOP observations are shown in Fig. 1. Our VSOP observation at 5 GHz reveals a transversal structure of the southern jet in the east-west direction (see Fig 1). A double-ridgeline structure is shown clearly which has been already observed at a higher frequency. A spectral index distribution which is obtained by a comparison between 15 and 5 GHz is shown in Fig 2. The spectral index along the central ridgeline decreases from the north to the south,

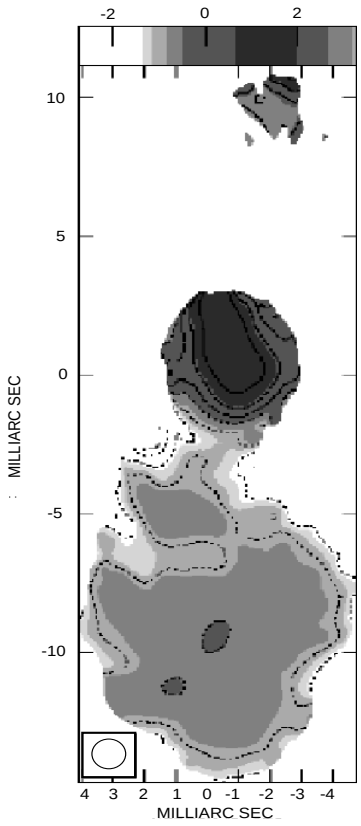

Figure 2: Spectral index distribution which is obtained by comparison between the 15 GHz global VLBI image and the 5 GHz VSOP image.

while that along the eastern ridgeline decreases from the south to the north. It is widely accepted that decay of spectral indices is caused by a energy loss in relativistic plasma. Hence the decay can be an indicator of a plasma age. A jetstream to the south forms the central ridgeline, while a back flow froms the southern hot spot form the eastern ridgeline. In the image taken by the VSOP at 5 GHz, there is another ridgeline parallel to the central and the eastern ridgeline in the southern jet. This western ridgeline can be a part of back flow, too.

The southern jet has a wiggled structure in the image taken by VSOP at 5 GHz (see Fig 1). Generally, there are many possibilities which is cause of the apparent wiggled jet structure such as the Kelvin-Helmholtz instability, or so on. Our spectral index map suggests that

the central ridgeline is the jet, while the eastern and western ridgeline is the back flow. Therefore, the wiggled structure in the main jet might be due to the Kelvin-Helmholtz instability between the jet and the back flow.

3.2 The Northern Jet

In the northern counterjet, there is a component which shows a spectral index $\alpha > 2.5$. It indicates that free-free absorption (FFA) is preferred as a reason of the low-frequency cutoff rather than synchrotron self-absorption (SSA). Furthermore, the spectral index increases from the counterjet to the core. This spectral index gradient is explained by a torus-like FFA absorber surrounding the core and lying in front of the counterjet but is behind the main jet. This idea is consistent with results of the previous observations.

4 Summary

We present the results of VSOP and global VLBI observations of 3C 84. From these observations, we produced a spectral index map to discuss the plasma age, and the absorption feature. A double-ridgeline structure is found in the southern jet in the image of the 5 GHz VSOP observation. Our spectral index map suggests a jet forms the central ridgeline, a back flow forms the eastern and western ridgelines, and the wiggled structure might be caused by Kelvin-Helmholtz instability between the jet and the back flow. Our spectral index map shows an inverted spectrum with its spectral index $\alpha > 2.5$ in the counterjet. This result is consistent with the previous idea which the core is surrounded by a torus like FFA absorber.

References

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