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Expanding Radio Lobe associated with 3C 84

Keiichi Asada[1], Makoto Inoue[1], Hiroshi Nagai[2] and Seiji Kameno[2]

[1]Institute of Astronomy & Astrophysics, Academia Sinica, P.O. Box 23-141,
Taipei 10617, Taiwan
email: asada@asiaa.sinica.edu.tw

[2]National Astronomical Observatory of Japan, 2-21-1, Osawa, Tokyo, 181-8588, Japan

Abstract. Following the discovery of the expansion of a young radio lobe associated with the bright radio source 3C 84 in the Seyfert galaxy NGC 1275 using VSOP monitoring observation with duration of 3 years, we further investigated its evolution by utilizing VLBA monitoring data taken by MOJAVE project. As the results, we confirmed the expanding motion of both the southern and northern lobes, and detected side-way expanding motions for the first time. In meantime, the total flux density of the lobes are decreasing, while total flux density associated with the nuclei is significantly increasing. This cooling of the radio lobe can be well-explained with the energy loss through the adiabatic cooling.

Keywords. 3C 84, VLBI, radio lobe, CSO

1. Introduction

Compact Symmetric Objects (CSOs), categorized by Wilkinson *et al.* (1994) and Readhead *et al.* (1996), are compact radio sources with a double lobe structure. Their structures are extremely compact < 1 kpc, compared to $\sim$ Mpc, which is usual for Large Symmetric Objects (LSOs), but are similar to those of LSOs, such as Cyg A. The compact structure of CSOs has led to a hypothesis that they are in a young stage of their evolution into LSOs. Measurements of kinematic aging Polatidis & Conway (2003) and spectral aging Nagai *et al.* (2006) have confirmed the ages of some CSOs $<$ a few 1000 yrs.

The compact radio source 3C 84, hosted by the Seyfert galaxy NGC 1275, is one of the strongest radio sources and also a nearby (z =0.018) active galactic nucleus (AGN). Assuming that Hubble constant $H_0 = 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, 1 milli-arcsecond (mas) corresponds to 0.4 parsec (pc). Previous VLBI observations revealed that 3C 84 had a complicated radio structure on parsec scales, consisting of a bright core with a flat spectrum and radio lobe like southern and northern structures with a steep spectrum Walker *et al.* (2000). Multi epoch VSOP observations detected expanding motion of the southern radio lobe, and the age of radio lobe is estimated to be 45.7±8.9 years in 2001 by extrapolating the source size back to zero Asada *et al.* (2006). Interestingly, single dish observations of 3C 84 show that the outburst started at 1959 Nesterov *et al.* (1995), which is coincident well with the beginning of the expansion within the errors. In this paper, we report the results of our further investigation on the evolution of the radio lobe for much longer period by utilizing the archival data taken by VLBA through the MOJAVE project.

2. Data

We used data taken by VLBA observed at 15 GHz through MOJAVE project. Total number of the images were 45, those were taken during 1996 Nov. 21 to 2017 Aug. 25. Image were obtained by standard CLEAN method using Difmap.

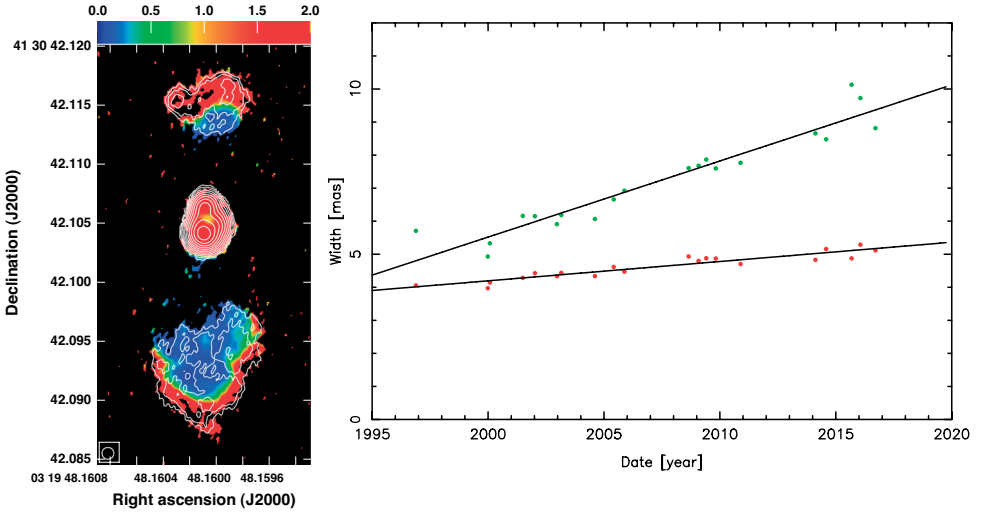

Figure 1. (left) Brightness ratio of the radio lobe at the epochs in 2000 and 2014. It is clearly shown that flux density increases at the edges of the radio lobes, while that at the inside of the radio lobe significantly decreased. Expansion towards side-way (i.e., towards east-west direction) is also clearly seen. (right) Deconvolved size of the southern radio lobe in both elongated (green) and side-way (red) directions as a function of time.

3. Results and Discussion

We show the brightness ration of the radio lobes between at the epochs in 2000 and 2014 in Fig. 1. Brightness at the nuclei region were significantly increased, while that at most of the region associated with the northern and southern radio lobes are decreased. However, the brightness at the edge of the radio lobes were clearly enhanced. It is an evidence that the radio lobe is expanding. We also show the size of the southern lobe as a function of the time Fig. 1. Southern radio lobe was expanded in both elongated and side-way directions, and its expanding speeds were estimated to be 0.3 and 0.08 c, respectively.

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