Centaurus A: The Nearest Blazar?

Zulema Abraham, Ulisses Barres de Almeida, Tânia P. Dominici, Anderson Caproni

Departamento de Astromia, Instituto de Astronomia, Geofísica e Ciências Espaciais, Universidade de São Paulo, Brazil

Abstract. Centaurus A (NGC5128), at a distance of 3.4 Mpc is the nearest Active Galaxy, classified as a low luminosity Fanaroff-Riley class I object. Although the central source is completely obscured at optical wavelengths, VLBI studies at radio frequencies show an unresolved core and an asymmetric jet at sub-parsec scales. Kinematical studies of the jet components show subluminal expansion velocities, which together with the jet-counterjet intensity ratio implies that the jet direction forms a large angle with the line of sight (50^o to 80^o). The nuclear emission is highly variable at all wavelengths, from radio to γ-rays. Single dish radio observations showed that the stronger, long duration outbursts (months to years) present a correlation at radio and X-rays, although it is not clear whether the emission mechanism is synchrotron radiation at both frequencies or if the inverse Compton process dominates at high energies. Moreover, no information is available about the correlation between the emission at these two frequencies at shorter timescales (days and hours), due to the lack of short term monitoring at radio frequencies. In this work we report 43 GHz monitoring of Cantaurus A at the Itapetinga Radio Observatory during the last year, with daily resolution during a three-month period. We found very large variations (factor of two) within a few days, which puts Centaurus A in the blazar category. These variations were superimposed to a continuous rise in flux density that lasted until the end of 2003, when it started a fast decline. No apparent correlation with the All Sky Monitor (ASM/RXTE) data was found at these short timescales.

INTRODUCTION

Centaurus A, at a distance of 3.4 Mpc [1], is the nearest radio galaxy, classified according to its luminosity and morphology as a Fanaroff and Riley type I object [2]. The host galaxy is elliptical, bisected by an obscuring dust lane that it is believed was formed during a recent merging event with a smaller spiral galaxy [3].

The radio structure is characterized by three pairs of lobes, oriented in the NE-SW direction, perpendicular to the dust lane. The outer lobes extend up to 250 kpc from the center of the galaxy; a single NE middle lobe is located at 30 kpc and the NE and SW inner lobes at 5 and 1.5 kpc from the core, respectively [4]. A well-collimated jet connects the compact core to the inner NE lobe, presenting several bright knots, some of them moving away from the core at subluminal velocities. Both the inner lobes and the jet are also seen at X-rays [5].

Flux variability from the nucleus of Centaurus A was detected at radio, infrared and X-rays along the years, which classifies Centaurus A as an Active Galactic Nuclei (AGN) [6], [7], [8].

CP745, *High Energy Gamma-Ray Astronomy,* edited by F. A. Aharonian, H. J. Völk, and D. Horns

Very Long Baseline Interferometry (VLBI) show a core-jet structure at parsec scales, with bright spots moving away from the core at subluminal velocities [10]. From these velocities and the ratio of jet-counterjet flux densities, the inclination of the jet, relative to the line of sight, was estimated to be between 60^o and 77^o [11].

The overall spectral energy distribution of the Centaurus A core resembles that of blazars, showing two peaks, one centered at the infrared, attributed to synchrotron emission, and the other at 0.1 MeV, produced by the inverse self-Compton process [12]. However, since the flux density at optical wavelengths is very uncertain, due to the high obscuration, the spectrum can be also fitted from radio to X-rays by a single power law, with a break at 150 keV; in this case, very high-energy inverse Compton photons are predicted [13].

In this work we report variability at 43 GHz within timescales of days, which seems to confirm the blazar nature of Centaurus A. However no correlation between radio and X-rays was found in this short timescales.

OBSERVATIONS

The 43 GHz observations were made with the radome-enclosed Itapetinga radiotelescope, between May 2003 and June 2004. The receiver was an ambient temperature K-band mixer with a 1 GHz double side band. The feed consisted of a rectangular horn, sensitive to the vertical component of the E-vector; the half-power beam width (HPBW) was 2.1 arc min at this frequency. Calibrations were made with a noise source and with an external load at room temperature, which corrected the data for gain fluctuations and atmospheric absorption. Absolute calibration was obtained from observations of Virgo A, which has similar right ascension, and a flux density of 10.7 Jy at 43 GHz.

Since the objective of this work was to study short timescale variability on a daily basis, special care had to be taken with the calibration, especially with atmospheric fluctuations. For that reason, the observations were made in a differential mode; scans of 30 arc min amplitude were made across Centaurus A, centered at the core and passing through the two inner lobes. The stronger NE lobe was used as a secondary calibrator and the core flux density normalized to its instantaneous value. Since the rectangular horn is sensitive to the vertical component of the E-vector and the scan position angle rotates as the source moves in the sky, the observations were always made at the same sidereal time, to guarantee that no polarization effects were introduced in the observations.

In Figure 1 we show the average of most of the observations. It was used to separate the NE and SW lobes, assumed to be Gaussian functions, from the core, also defined as a Gaussian with half power width equal to the telescope beam width. The flux density of the NE lobe resulted to be 8.2 Jy; the flux density of Centaurus A core will be always referred to this value.

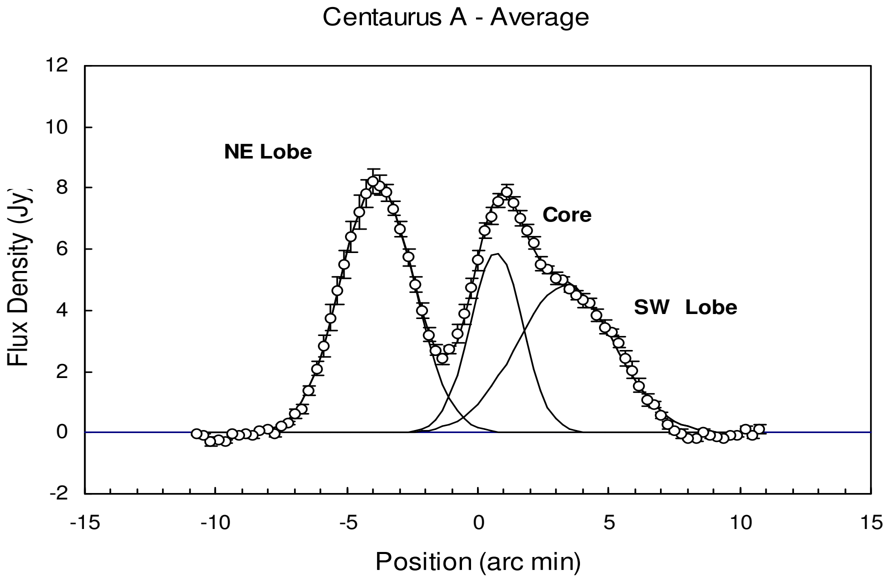

Figure 1. Average of all observations: scans across Centaurus A, centered at the core and passing through the centers of the NE and SW inner lobes.

RESULTS

For each observation, the contribution of the two normalized inner lobes was subtracted and the relative flux density of the remaining central component was determined by fitting a Gaussian of HPW equal to the telescope beam width. The flux density of the core of Centaurus A, relative to the flux density of the NE inner lobe, is shown in Figure 2 for the period May 2003-April 2004. The error bars are 5 times the rms, obtained from the subtraction of the two lobe models and the variable core model from the data. The observations were closely spaced (almost daily) during May-August 2003 after which they became monthly. We can see that there was a slow increase in the flux density up to October 2003; since then it started a continuous decay that lasted until March 2004, in which it attained a very low level.

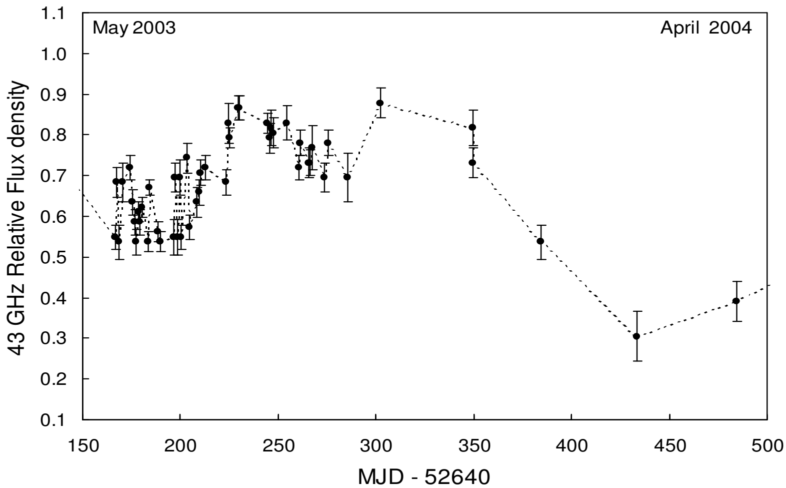

FIGURE 2. Relative flux density of the Centaurus A core relative to the flux density of the NE lobe for the interval May 2003 – April 2004.

We can see that superimposed to the slow flux density variations, there are rapid daily fluctuations, sometimes with amplitude larger than 1 Jy, which is a considerable fraction of the total flux density at this frequency. Figure 3 presents an enlarged graph of these fluctuations, together with the ASM/RXTE[1] (5-12 keV) X-ray flux. No correlation was found between the two light curves, although it is always possible that pointed observations with higher spatial resolution would modify this result.

DISCUSSION

Based on the occurrence of rapid variability and its orientation with respect to the line of sight, Centaurus A could be considered a misaligned blazar. However, the lack of correlation between X-ray and radio variability, implies that different processes must produce them. Also, rapid variability at 43 GHz is not easy to understand. If the excess emission were due to the synchrotron process, very high magnetic fields or very fast expansion velocities had to be invoked to account for the fast decrease in flux density.
On the other hand, external processes acting in the interstellar medium are not efficient in producing variability at such high radio frequencies. More closely spaced observations, both at radio X- and γ-rays are needed to get a better picture of the processes involved in the observed variability.

1 See http://xte.mit.edu

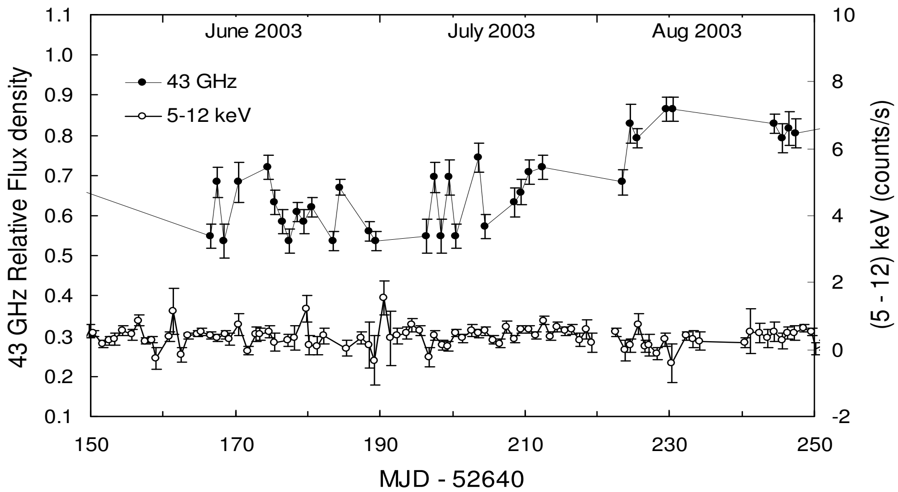

Figure 3. Extended view of the 43 GHz variability light curve, between May and August 2003, together with the RXTE (2-5 keV) data.

ACKNOWLEDGMENTS

This work was partially supported by the Brazilian Agencies CAPES, CNPq, FINEP and FAPESP.

REFERENCES

1. Israel, F. P., *Astron. Astrophys. Rev*. **8**, 237-278 (1998).
2. Fanaroff, B.L., Riley, J.M., *MNRAS* **167**, 31P-35P (1974).
3. Mirabel, I. F., Laurent, O., Sanders, D. B. et al., *A&A* **341**, 667-674 (1999).
4. Burns, J. O., Feigelson, E. D., Schreier, E. J., *ApJ* **273**, 128-153 (1983).
5. Hardcastle, M. J., Worrall, D. M., Kraft, R. P., et al. *ApJ* **593**, 169-183 (2003).
6. Botti, L.C.L., Abraham, Z., *MNRAS* **264**, 807-812 (1993).
7. Kellermann, K. I., Zensus, J. A., Cohen, M. H., *ApJ* **475**, L93-L96 (1997).
8. Beall, J. H., Rose, W. K., Graf, W., et al. *ApJ* **219**, 836-844 (1978).
9. Turner, T.J., George, I.M., Mushotzky, R. F., Nandra, K. *ApJ* **475**, 118-133 (1997).
10. Tingay, S. J., Preston, R. A., Jauncey, D. L., *AJ* **122**, 1697-1706 (2001)
11. Jones, D. L., Tingay, S. J., Murphy, D. W. et al. *ApJ* **466**, L63-L65 (1996).
12. Chiaberge, M., Capetti, A., Celotti, A., *MNRAS* **324**, L33-L37 (2001).
13. Bai, J.M., Lee, M.G., *ApJ* **549**, L173-L177 (2001).