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ENIGMAS OF CENTAURUS A

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ABSTRACT

Centaurus A (NGC5128) is the powerful radio source associated with the massive elliptical galaxy NGC5128. It is to a distance of about 3.8 ± 0.4 Mpc (Rejkuba, 2004) and is the closest active galaxy. Note that at this distance 1’ on the sky corresponds almost to 1 kpc. It is the largest extragalactic radio galaxy in the sky, with dimensions of about 5° × 9°. Centaurus A has strong emission at 1.4 GHz, about 215 Jy, from the central 30’of the radiosource. The morphology of NGC5128 is very complex and highly structured, it shows significant structure ranging over a factor of 10^8 in size from the largest scales down to less than a mili-arcsecond. Giant outer lobes are extending to about 250 kpc, the northern middle lobe extending to about 30 kpc, inner lobes and central jets extending to about 5.0 and 1.4 kpc. There is a jet which issues from the outer ridge of the northern inner lobe a further 7 kpc to a northern middle lobe. The northern middle lobe is strongly polarized on the ridge furthest from the outer jet which connects it to the inner lobe. The nature of the middle lobe remains unclear, but it is very likely that there is strong interaction between the radio source and the intergalactic medium. The inner jets and lobes have been studied in detail using VLBI and VLA. The proximity of Centaurus A means we have a better spatial resolution of the source, meaning we can see the more subtle interactions of the radio source with the intergalactic medium. The origin of the radio emission is relativistic plasma jets from the central black hole of NGC5128. Our scientific goal is to study the extent to which interactions with the intergalactic medium are shaping the morphology of Centaurus A (using the BDA, VLA, Chandra) and trying to associate approximately 26 knots observed by Chandra (0.85 keV to 2.5 keV) with possible features in BDA maps (1.2-1.7, 2.8 and 5.6 GHz). It will be possible (using X-rays and radio data) to extract spectra for a large number of jet regions. Another objective could be the study of the temporal behavior of Centaurus A at 22 and 43 GHz (Itapetinga antenna, Atibaia, Brazil), trying to associate the variability with the born of components in the jet. At 22 GHz we are observing parts of both internal lobes together with the central source, while at 43 GHz the northern lobe is well separated from the nucleus. But there is some contribution of the southern lobe. This inner jet at radio frequencies is also asymmetric, which the same sidedness as the middle lobe.

Key-words: galaxies: jets – galaxies: active – radio: galaxies: individual: NGC5128-CenA

INTRODUCTION

Centaurus A (J1950 α = 13h 22m 31.6 s δ = -42º 45’ 33”) is an active galactic nuclei (AGN) usually classified as a FR I type radio galaxy and as a Seyfert 2 object in the optical (Dermer and Gehrels, 1995). Centaurus A is sometimes called blazar at higher energies (Morganti et al., 1992). It contains an active galactic nucleus, having Marconi et al., 2001 estimated the mass of central black hole of about 10^8 M_π. Centaurus A possesses an inner jet close to the nucleus which is detected in the radio and X-ray regime. Centaurus A has a giant lobe with an extension of about 10° on the sky. It is detected from radio to MeV gamma-rays (Clay et al., 1994; Johnson et al., 1997; Israel, 1998). One characteristic of Cen A is its emission at gamma-rays, making it the only radio galaxy detected in MeV gamma-rays. All AGN detected at higher energies are blazars (Collmar et al., 1998). Blazars can be observed at several wavelenghts from radio to gamma-rays. Rapidly variable, blazar emit polarized nonthermal optical light and their total energy output is often dominated by their high-energy emission in X-rays and gamma-rays. Relativistic outflows are observed which and probably are powered by mass accretion onto black hole in the center. The jets are aligned almost parallel to the line-of-sight in blazars but we would like to point that there is other configuration to the jet in Centaurus A, perpendicular to the light-of-sight. This fact seems very controversial, but can be a representation of several active galaxies considered as normal, which are just too far away to be detected at gamma rays. The nucleus of Centaurus A is obscured by the dust lane. This core only can be visible at wavelengths longer than 0.8 µm (Marconi et al., 2000). Single telescope observations have not been able to resolve the nucleus at any wavelength. For example at 1 µm the maximum lengh that can be obtained is about 100 mas; radio interferometry (VLBI) reveals a central structure with 1 pc length (60 mas) at λ = 60 cm (500 MHz). Meisenheimer et al. (2007) carried out interferometric observations at mid-infrared (8.3 µm and 12.6 µm). The mid-infrared emission from the core of Centaurus A is dominated by an unresolved source with less than 10 mas. A counter jet also can be seen inside Centaurus A. At 43 GHz (with interferometric observations) an angular diameter about 0.5 mas or 0.01 pc can be observed. It is the remnant of catastrophic disturbance between two galaxies: a dusty spiral galaxy and a bright elliptical galaxy. In consequence of the interaction there are several outbursts inside this source.

BDA OBSERVATIONS

BDA phase I: five antennas with 4 meter-diameter parabolic dishes were operated using alt-azimuthal mount and operating frequency range between 1.2-1.7 GHz. The 5 antennas had been laid out over a distance of 216 meters in the west-east direction for a spatial resolution approximately 3’ at 1.5 GHz. During this phase was impossible to map this radio source. BDA phase 2: it was planned to laid out 21 antennas over the distance of 400 meters in the east-west direction and another 10 antennas over a distance of 200 meters in the north-south direction forming a T-shaped array. The operating frequencies will include higher values: 1.2-1.7, 2.8 and 5.6 GHz. The spatial resolution will be 0.9’ with a sensitivity of about 5 Jy (1.2-1.7 and 2.8 GHz). BDA phase 3: four antennas will be added in the east-west direction and two more antennas in the north-south direction. The baselines will be increased in both directions to 2.5 km and 1.25 km, respectively, to increase the spatial resolution of the array up to approximately 4.5 arc seconds at 5.6 GHz. BDA appears as a highly competitive instrument because it can detect low flux density radio sources (< 60 mJy). With this final array will be possible to map the complex structures of Centaurus A.

ASSOCIATED FEATURES IN CENTAURUS A

The whole radio source has been mapped with single-dish telescopes at linear resolutions no better than 4 kpc. The radio-bright inner lobes have been mapped with aperture synthesis telescopes at higher resolutions of about 40 pc and the inner jets and core have been mapped at (sub)parsec resolutions in VLBI experiments. Centaurus A possesses an inner jet close to the nucleus with a large inclination of about 70º (Tingay et al., 1998). In Figure 1 several structures can be observed in this peculiar galaxy: the outer lobes, the middle lobe, the inner lobes and the jet. A pair of inner jets each extend almost 1.4 kpc (80”) from the nucleus, a pair of radio lobes which each extend out 6 kpc (6'). The northern middle lobe has a scale size of about 14' (14 kpc).

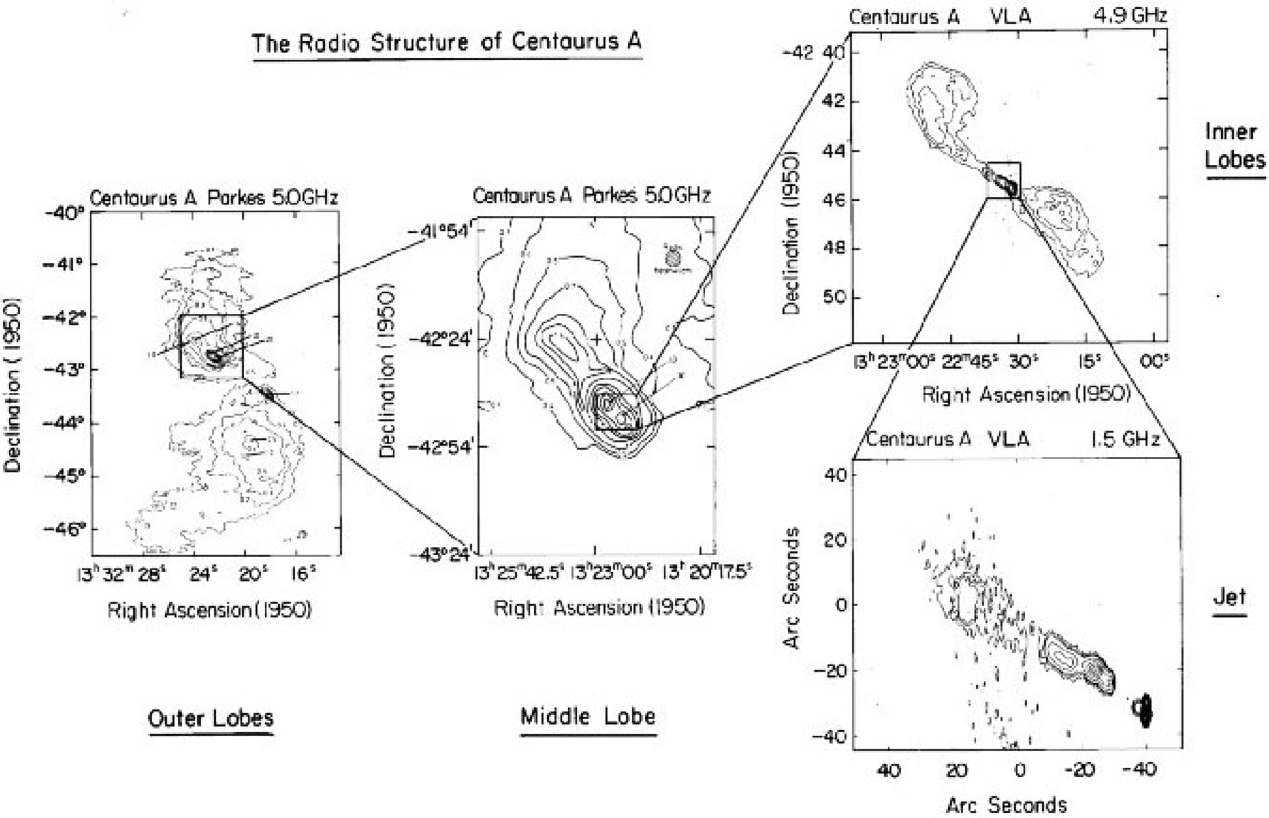

Fig. 1 - Components of the radio source CenA (Burns et al., 1983).

The nature of the middle lobe remains unclear. Maybe can be the interaction between radiosource and the intergalactic medium. The middle lobe is strongly polorised, with magnetic fields vectors almost orthogonal to the field lines of the connecting jets and inner lobes. This radiosource has been observed by Shain (1958), Sheridan (1958), Cooper et al. (1965), Haslam et al. (1981), Combi and Romero (1997), Junkes et al. (1993), Haynes et al. (1983), with angular resolution between 4.1’ and 48' and flux density between 28000Jy at 20 MHz and 681 Jy at 4.8 GHz. The internal lobes and core have been observed by Slee et al. (1983), Christiansen et al. (1977), Clarke et al. (1992), Tateyama and Strauss (1992), with angular resolution between 4.2” and 258” and flux density between 31 Jy at 43 GHz and 734 Jy at 324 MHz. The nuclear jet has been observed by Slee et al. (1983), Schreier et al. (1981), Clark et al. (1992), Jones et al. (1994), Schreier et al. (1981), Botti and Abraham (1993), Fogarty and Schuch (1975), Kellerman (1974), Tateyama and Strauss (1992), with angular resolution between 0.1” and 252” and flux density between 2 Jy at 327 MHz and 18 Jy at 89 GHz.

In the figure 2 we can see the interaction between the several features of this galaxy and the ambient intergalactic medium (IGM) at 5 GHz. Centaurus A is to a distance of about 3.7 Mpc and is the closest active galaxy. The proximity of this radio galaxy make Centaurus A the ideal source to study the influence this galaxy in the IGM. Centaurus A shows a wide range of complex structures with two jets emerging from its nucleus which bend as they interact with the intergalactic medium (Figure 2).

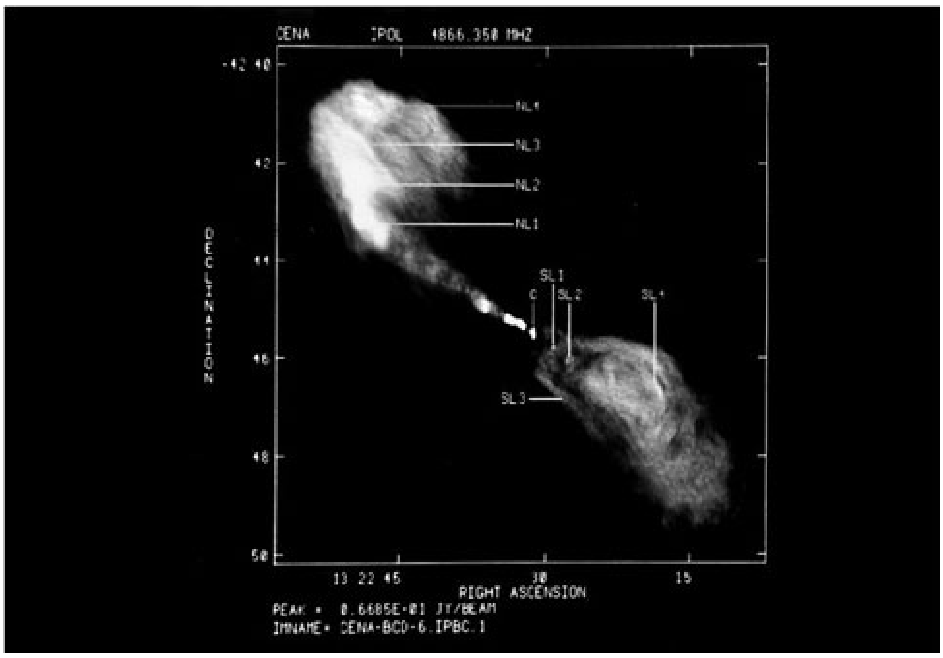

Fig. 2 - Inner lobes and jets at a resolution of 4.4 x 1.2 arcsec (Clarke et al., 1992).

The interstellar medium also can be very important in shaping the jets in Centaurus A (Graham, 1998). There is evidence that the galactic gas can be nice to the confinement of the jet in some Seyfert galaxies, in very distant quasars and in the knots of Centaurus A. It has been known for some time that shells of HI and molecular gas (CO), ionised optical filaments and young massive OB stars are all located well beyond the host galaxy and closely follow the inner and middle radio jets. These structures are the result of the interaction of existing intergalactic gas clouds shock-heated by the expanding jet-lobe. The shocks cause catastrophic cloud-collapse which eventually triggers star formation in northeast radio lobe (Graham, 1998).

VARIABILITY

Centaurus A is highly variable object in all wavelength bands (Kellermann et al., 1974; Davison et al., 1975; Winkler and White, 1975; Kaufmann et al., 1977; Lawrence et al., 1977; Mushotzky et al., 1978; Delvaille et al., 1978; Beall et al., 1978; Schreier et al., 1979; Baity et al., 1981; Feigelson et al, 1981; Botti, 1983; Gehrels et al., 1984; Cunningham et al., 1984; Lepine et al., 1984; Terrell, 1986; Botti, 1990; Turner et al., 1992; Botti and Abraham, 1993; Jourdain et al., 1993; Hawarden et al., 1993; Kinzer et al., 1995; Steinle et al., 1998; Bond et al., 1996; Romero et al., 1997; Kellermann et al.,1997; Turner et al., 1997; Gastaldi, 2007).

Botti (1990) found correlations between radio (22 and 43 GHz) and X-rays (3-12 keV). The large beams used (approximately 4' at 22 GHz and approximately 2' at 43 GHz) include significant non-nuclear emission, but the radio variability shows to be correlated with that at 3-12 keV which must be associated with the nucleus.

In the figure 3 is shown a continuous monitoring of Centaurus A in X-rays between 1991 and 2008 using the BATSE (Burst and Transient Source Experiment: 20–200 keV) instrument on board CGRO (Compton Gamma Ray Observatory) and RXTE (Rossi X-ray Timing Explorer: 2-10 keV).

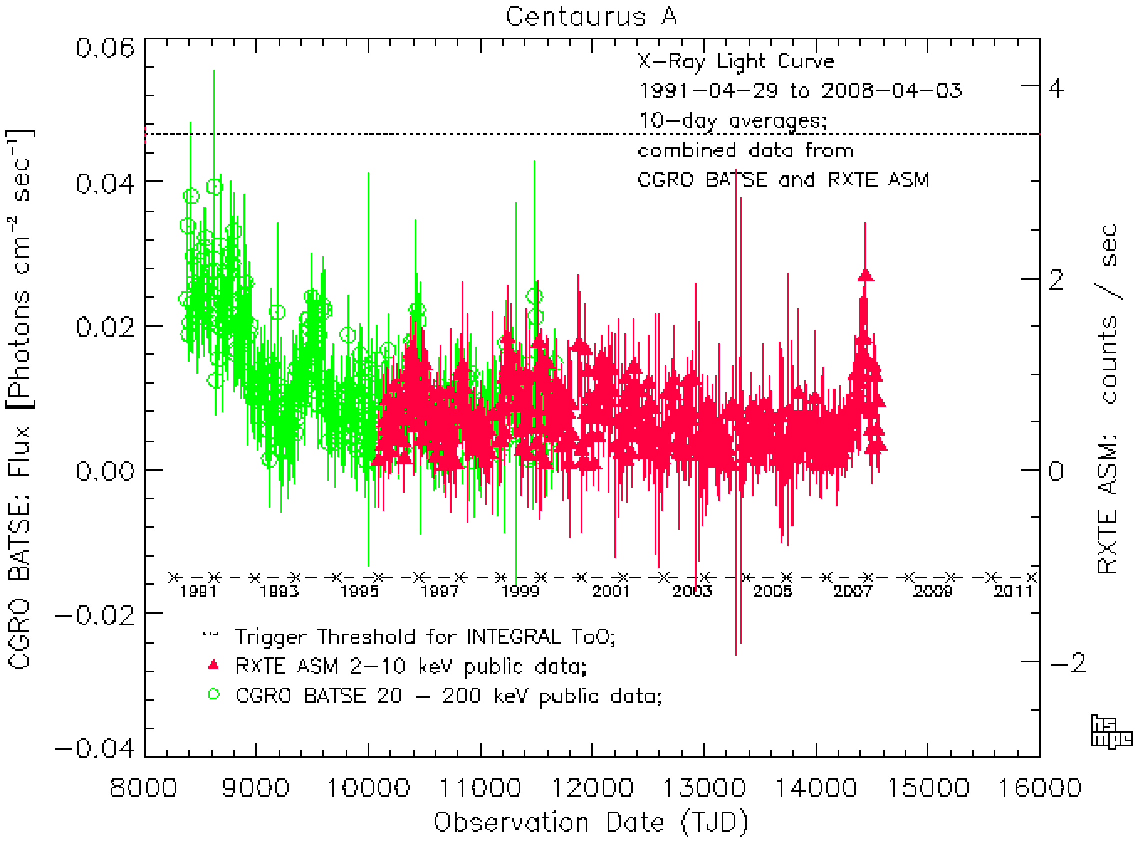

Fig. 3 - A continuous monitoring of Centaurus A (BATSE- Burst and Transient Source Experiment and RXTE-Rossi X-ray Timing Explorer).

DISCUSSION

There is evidence that an unknown distributed particle acceleration process operates in the jet of Centaurus A (Enigma 1). The inner part of the Cen A jet is dominated by shock-related knots. Farther from the nucleus there is more diffuse X-ray emission in the jet. The cause of particle acceleration in this part of the jet is unknown. Knot is any compact feature in the jet that is clearly distinguished in surface brightness from its surroundings.

The nature of the middle lobe remains unclear. The inner VLBI jet is also asymmetric, with the same sidedness as the middle lobe. The asymmetry of the inner jet can be due to Doppler Boosting but the same explanation is not correct in case of the asymmetry of the middle lobe (Enigma 2).The middle lobe is associated with soft x-rays-emission (Feigelson et al., 1981). Radio observations using high resolution still does not exist for this region of the source. BDA will be able to be used for this finality.

To make competitive extragalactic observations with BDA we need to work with good dynamic range. Australia Telescope Compact Array - ATCA is using a high dynamic range (100000). Image processing algorithms to deal with the high dynamical range and large field-of-view must be improved by BDA team. Will it be possible have high dynamic range in BDA system?

Explore feedback between the polarized radio jets and the environment of the Centaurus group of galaxies can be one of BDA goals. Will it be possible to exploit the strong polarized continuum of Centaurus A using BDA system?

Interaction between the non-thermal plasma ejected from the active nucleus and the interstellar medium of Centaurus A is responsible for a variety of phenomena such as ionisation of the gas and AGN driven outflows.

A high-energy outflow close to the black hole may be producing the X-rays by the same synchrotron process that explains the knots in the jet. The knots near the nuclear component are much brighter in X-rays than the farthest knots. The reason for this dimming is unknown (Enigma 3). It is likely to be related to the slowing of the jet. High–energy electrons spiralling around magnetic fields lines produce the X-ray emission from the jet. The electrons must be continually reaccelerated or the X-ray will fade out. Knot-like features detected by Chandra (Hardcastle et al., 2007) show where the acceleration of particles to high energies is currently occurring. The inner part of the X-ray jet close to the black-hole is dominated by these knots of X-ray emission. The radio emission is produced by the synchrotron process in which high-energy electrons radiate as they spiral around the magnetic field of the galaxy.

CONCLUSION

Centaurus A will be an ideal source to make non-solar observations with BDA system. No other radio galaxy allows its lobe structures to be studied in so specific detail. At declinations which range from - 47º to -38º, Centaurus A is perfectly located for the BDA.

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