The Metrewavelength Sky
ASI Conference Series, 2014, Vol. 13, pp 131 – 134
Edited by J. N. Chengalur & Y. Gupta

Giant Metrewave Radio Telescope Observations of Abell 736: Discovery of a radio "Bubble" engulfing the radio source

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Abstract. Outbursts of radio active galactic nuclei (AGN) have significant impact on structure formation and evolution. It has been suggested that a cool core is always required for strong radio AGN of bright cluster galaxy (BCG, Sun 2009). We have observed a complete sample of groups with strong central radio AGN using *C*handra and Giant Metrewave Radio telescope (GMRT). From this study, we present first results for the BCG in the Abell 736 group using GMRT. We have discovered synchrotron radio "bubble" emission in which the 'Z'-shaped radio galaxy resides.

Keywords : clusters: individual (Abell 736) – galaxies: active – groups: radio

1. Introduction

Most of the baryons in galaxies, groups and clusters are visible either at optical wavelengths, in the form of stars, or in the X-ray wavelengths, where emission arises from the large quantities of high temperature ($16^6 - 10^8$K) gas mostly heated by compression and shocks during collapse and virialization. However, small but energetically important fractions can only be seen in other wavelengths; e.g., relativistic plasma interacting with strong magnetic fields are most visible in the radio regime through

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synchrotron radiation. Therefore an approach for collating observations in multiple wavelengths is required to study the physics that regulates the heating and cooling of intragroup medium (IGM) and intracluster medium (ICM) gas.

The mutual interaction between radio active galactic nuclei (AGN) and the ICM has significant impacts on both of them. Radio AGN may need an enhanced X-ray atmosphere to fuel them (e.g., Hardcastle et al. 2007; Sun 2009). The enormous jet power of AGN can not only quench cooling in cluster cool cores, but also drive the ICM properties away from those defined by simple self-similar relations involving only gravity (summarized in Voit 2005). The radio AGN outbursts generate cavities and shocks in the ICM, which serve as calorimeters for the total energy outputs of AGN. This allows us to understand AGN feedback and super-massive black hole (SMBH) growth (McNamara & Nulsen 2007). Moreover, measuring the ICM pressure is important for understanding the bending, deceleration and flaring of radio jets.

However, it is not only in clusters that these phenomena are seen. O'Sullivan et al. (2011), Cavagnolo et al. (2010), Dunn et al. (2010), etc. using extensive observations, both in radio and in X-ray, of numerous galaxy groups have demonstrated an important result: the AGN-driven feedback phenomenon is also visible in numerous X-ray bright groups. In groups as in clusters, examination of radio images at several frequencies is important because the higher energy particles have shorter radiative lifetimes than the lower energy ones. This causes the radio spectral index to steepen, so that evidence of older AGN-driven activity may be reflected only at low radio frequencies. Hence, high resolution low-frequency radio data are more reliable than those used by previous studies (e.g., Bîrzan et al. 2008) to study these phenomena, giving better constraints on the total luminosity and source morphology. Here, we present our first results for the bright cluster galaxy (BCG) in the Abell 736 (SDSS−C4 3289) group.

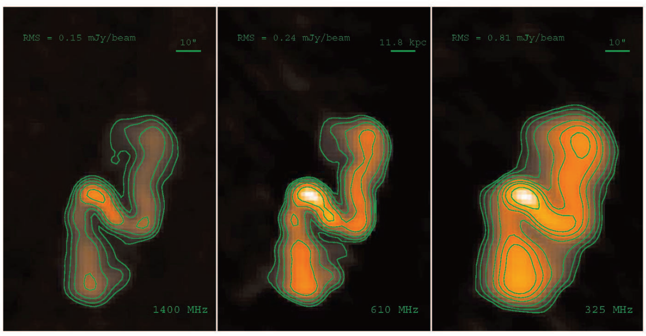

Figure 1. VLA FIRST survey image and full synthesis GMRT maps of BCG in the Abell 736 (SDSS−C4 3289) group at 1400 MHz (left panel), 610 MHz (middle-panel) and 325 MHz (right-panel). The contour levels in the maps start at 3 × rms noise levels and are spaced by a factor of two. The dashed lines give a scale of 10 arcsec = 11.8 kpc for the redshift of the source.

2. Data

The data was acquired using Giant Metrewave Radio Telescope (GMRT) at 325 MHz and at 610 MHz on 2012-10-27 and 2012-10-22, respectively (project code 23_055) in the spectral line mode containing 256 channels. The nominal bandwidth for the observations was 16 MHz, whereas the effective bandwidth was 12.625 MHz and 13.125 MHz, respectively at 325 and 610 MHz. The data was reduced in a standard manner using AIPS, as explained in detail by Lal & Rao (2007), which provided us with radio images at resolutions of ~9.7 arcsec and ~4.8 arcsec, 1-σ RMS sensitivities of 0.5 mJy beam^{-1} and 0.3 mJy beam^{-1}, and dynamic ranges in the maps of ~390 and ~430, respectively at 325 and 610 MHz.

3. Radio Morphology of BCG in the Abell 736

Inspection of high resolution Very Large Array (VLA) FIRST survey image of BCG (Fig. 1) shows the presence of ridge lines of the two extended secondary lobes, which are not aligned with each other. The lobes are clearly offset from each other laterally by amounts approximately equal to their widths, and the inner edges of the secondary lobes are aligned with each other with respect to the galactic nucleus. Thus, instead of extending in opposite directions from the nucleus, the secondary lobes exhibit an approximately Z-shaped symmetry about the nucleus. Krishna et al. (2003) noted this Z-shaped symmetry in several radio galaxies, *e.g.*, NGC 326.

Possible formation scenario Krishna et al. (2003) proposed a model for sources showing Z-shape symmetry, which essentially takes into account the dynamical effect on the jets of the large-scale rotational field. The latter is naturally set up in the ambient medium as the nearby galaxy is captured as a process of minor merger by the parent galaxy hosting SMBH. The captured galaxy spirals in towards the core of the parent radio galaxy causing gas motions, which can bend the original jets into a Z-symmetric shape.

4. Preliminary Results and Future Plans

Fig. 1 shows the (nearly) similar radio morphology of BCG in the Abell 736 at 1400 MHz and at 610 MHz, whereas the radio morphology at 325 MHz suggests an excess of low-surface brightness radio emission surrounding the radio source. The left panel of Fig. 2 also suggests the presence of excess radio emission at this frequency. The significance of the excess emission lies in the presence of a radio “bubble” in which the radio galaxy resides. This is depicted in the low-resolution image at 325 MHz made after subtracting the source integrated flux density extrapolated from the measurements of integrated flux density at 1400 MHz and 610 MHz.

We have presented our first results from the sensitive GMRT observations of BCG

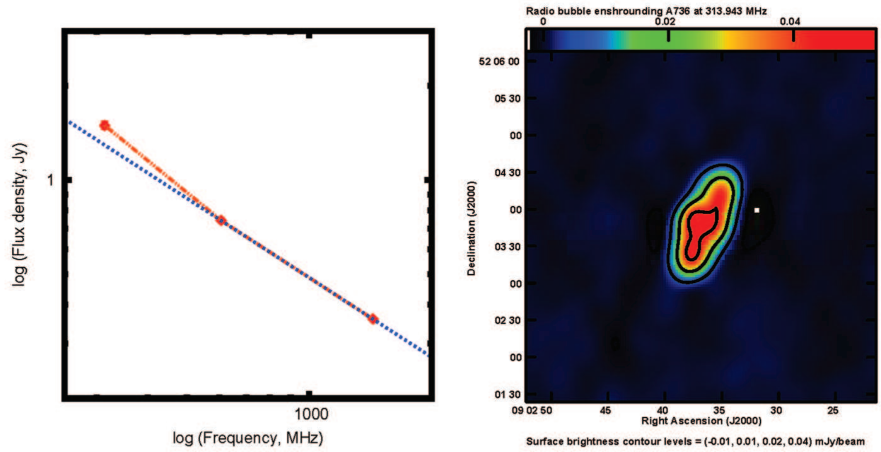

Figure 2. Integrated flux density (spectra) for BCG in the Abell 736 (SDSS−C4 3289) group (red). Measurements come from the images shown in Fig. 1. The error bars are smaller than the size of the symbol. The blue line is an extrapolation of the expected flux density at 325 MHz, and clearly shows the excess emission detected in 325 MHz GMRT image. This is due to the presence of the synchrotron radio "bubble" in which the radio galaxy resides.

in the Abell 736 (SDSS−C4-3289) group. The analysis of the data reveals a clear presence of "bubble" emission, engulfing the radio source. Further investigation on these data along with the high resolution *C*handra data will list more exciting results for this source and rest of the sample sources.

Acknowledgements

We thank the staff of the GMRT that made these observations possible. GMRT is run by the National Centre for Radio Astrophysics of the Tata Institute of Fundamental Research.

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