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Parsec scale jets in Brightest Cluster Galaxies

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Abstract. We present a statistically study of parsec scale properties of a complete sample of Brightest Cluster Galaxies (BCGs) in nearby Abell Clusters (distance class <3). Combined with data from the literature, we provide parsec scale information for 34 BCGs. We find a possible dichotomy between BCGs in cool-core clusters (two-sided parsec scale jets) and those in non-cool-core clusters predominantly one-sided parsec scale jets). We suggest that this difference is caused by the interplay between the jets and the surrounding medium. The one-sided structure in non-cool-core clusters may be due to Doppler boosting effects in relativistic, intrinsically symmetric jets whereas two-sided morphology in cool core clusters is probably related to the presence of heavy and mildly relativistic jets that have been decelerated on the parsec scale. Evidence of recurrent activity is also found in BCGs in cool-core clusters.

Key words. galaxies: jets— galaxies: clusters: individual — (galaxies:) cooling flows — radio continuum: galaxies

1. Introduction

Brightest Cluster Galaxies (BCGs) are a unique class of objects (Lin & Mohr 2004). These galaxies are the most luminous and massive galaxies in the Universe (Schombert 1986). Most BCGs are cD galaxies with extended envelopes but they can also be giant E and D galaxies. The optical morphology often shows evidence of past or recent galaxy mergers, such as multiple nuclei. They tend to lie very close to peaks of the cluster X-ray emission and to have velocities close to the cluster rest frame velocity. All these properties indicate that they might have experienced an unusual formation history compared to other E galaxies (Bernardi et al. 2006). In many cool core clusters BCGs often have blue excess light indicative of recent star formation (McNamara 2004).

In the radio band, it is well established that BCGs have peculiar properties. They are more likely to be radio-loud than other galaxies of the same mass (Best et al. 2006). Their radio morphology often also shows evidence of a strong interaction with the surrounding medium: some BCGs have a wide angle tail structure (WAT) that is either extended on the kiloparsec scale (e.g., 3C 465 in A2634,

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Sakelliou & Merrifield (1999)), or of small size (e.g. NGC4874 in Coma cluster, Feretti & Giovannini (1985)); others are diffuse and amorphous sources, either extended (3C 84 in Perseus, Pedlar et al. (1990)) or of small size (e.g., the BCG in A154, Feretti & Giovannini (1994)). These last two sources are rare in the general radio population, but frequently present in BCGs and in particular in BCGs located in cool core clusters of galaxies.

Radio-loud AGN in BCGs have been proposed as a potential solution to the cooling-flow problem. X-ray cavities in the emitting gas coincident with radio lobes demonstrate the interplay between the radio activity of BCGs and the slowing or arrest of cooling in cluster centers (Dunn et al. 2006). Despite these results, many important properties of BCGs are poorly known. Moreover, it is unclear if radio properties of BCGs in cooling flow clusters systematically differe from those of BCGs in merging clusters.

On the parsec scale, BCGs have been poorly studied as a class, data being available only for the mostly famous, bright radio galaxies.

2. The sample

To investigate the BCG properties on the parsec scale, we defined a sample of BCGs unbiased with respect to their radio and X-ray properties. We selected BCGs in nearby Abell clusters with the following constraints: 1) Distance Class ≤ 2, and 2) Declination $> 0°$. All clusters have been included without constraints on cluster conditions (e.g cooling) and no selection is present on the BCG radio power. In the complete sample, we have 27 BCGs, including cases like A400 (double BCG, 3C75) and clusters with a clear double structure (e.g. A1314) where we observed the BCG of both substructures.

We collected for all 27 sources of the complete sample VLBA observations at 5 GHz in phase referencing mode that allow typically resolution of 3×1.8 mas and noise level in our final maps of 0.1 mJy/beam. To improve our statistics, we performed a search in the literature and archive data looking for VLBI data of BCGs in Abell clusters with DC >2. We added to our complete sample the following clusters: A690, A780, A1795, A2052, A2390, A2597, and A3526 (expanded sample).

Among the sources of the extended sample, we analized in particular 4C 26.42, the BCG of A1795 (Fig. 1). In (Liuzzo et al. 2009a) we presented our results: the interaction with the surrounding medium seems to be fundamental in order to understand the peculiar radio morphology of this BCG.

Statistical results are presented in Table 1. In the expanded sample, we find a remarkable dominance of two-sided sources in relaxed clusters (70%), and of one-sided (56%) or non-detected (39%) sources in merging systems. No one-sided source is present in cool core clusters, and no two-sided source is present in non cool core clusters. We have to note that most of undetected sources in VLBA observations are in BCG that are radio quiet (or faint) also in VLA observations.

3. Results

The presence of a clear dichotomy between relaxed and non relaxed clusters is evident (Table 1). On mas scale, one-sided structures are only in BCGs in non cool core clusters, two-sided morphologies are only found in BCGs inside cool core clusters.

We use as a comparison sample the Bologna Complete Sample (BCS) (Giovannini et al. 2001, 2005) that is composed by 95 FRI radio galaxies spanning the same radio power range as our BCG sample and that is free from selection effects due to jet velocity and orientation. Among the results from the BCS study, Giovannini et al. (2005) and Liuzzo et al. (2009) found that the one-sided jet morphology is the predominant structure, in agreement with expectations based on a random orientation for sources with relativistic jets. Based on these conclusions, we suggest that all FRIs outside cool cores have similar parsec scale properties regardless of their host galaxy classification (BCG or non BCG). One-sided structures in non cool core clusters are produce by to Doppler boosting effects in relativistic, intrinsically symmetric jets.

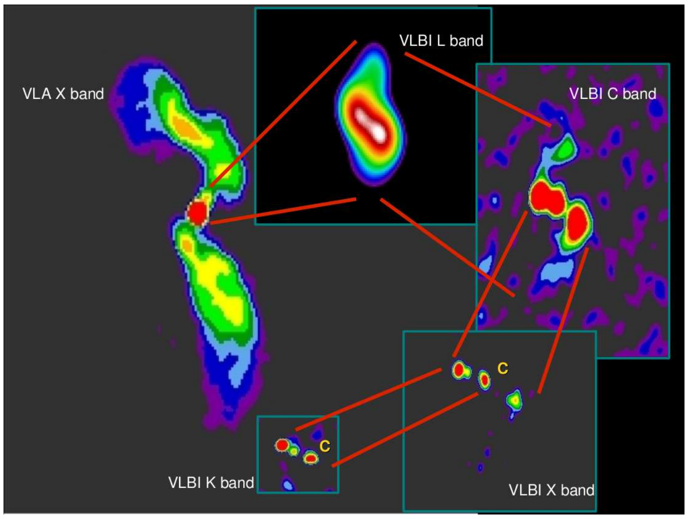

Fig. 1. Clockwise from left to right, zooming from kiloparsec to mas scale radiostructure of 4C 26.42 (Liuzzo et al. 2009a): color maps of VLA X band, VLBI L band, VLBI C band, VLBI X band and VLBI K band data. (C) indicates the core component.

Therefore, from the high fraction of two-sided pc scale morphology, we conclude that BCGs in cool core clusters have on mas scale mildly relativistic jets.

3.1. Mildly relativistic jets

Rossi et al. (2008) discussed the interaction between relativistic jets and the surrounding ISM. They showed that a jet perturbation grows because of Kelvin-Helmotz instability and produces a strong interaction between the jet and the external medium with a consequent mixing and deceleration. The deceleration becomes more efficient as the density ratio of the ambient medium to the jet increases.

Because of the dense ISM of BCGs in cool core clusters (Salomé & Combes 2003), we suggest that within BCGs in cool core clusters the jet interaction with the ISM is already relevant on the parsec scale. We note also that two-sided jets are present only in BCGs at the center of clusters with a central mass accretion rate $> 90\ M_{\odot}$/yr (Liuzzo et al. 2009b). In this scenario, as for sources in non cool core clusters, the jet begin relativistic (and thus one-sided at its base) but a large value of the density ratio can produce a sub-relativistic (and therefore two-sided) heavy jet at a much shorter distance from the central engine compared to "normal" FR I radio galaxies. This suggestion is supported by literature data on Hydra A and 3C 84 (Liuzzo et al. 2009b), BCGs of two cool core clusters (A780 and A426 respectively).

Moreover, in a few objects, episodic jet activity from the central engine of AGN are found . Recurrent activity of radio source in cool core clusters is of great interest to the study of AGN feedback in clusters (see also (Liuzzo et al. 2009b)).

More data are necessary to better understand and test the nature of the difference that we note between BCGs in cool and non cool clusters. We would also like to understand the properties of the restarted emission in BCGs. To improve the statistics of our analysis, observations of a larger sample of BCGs in cooling and relaxed clusters with the VLBA will be planned.

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Table 1. BCG counts in the complete (nearby) sample and expanded one. We report the number of BCG according to the cluster morphology and pc scale morphology.

Sample	Cluster morphology	Number	two-sided	one-sided	point	N.D.
Complete	cool core	5	2 (40%)	–	1	2
	non cool core	22	–	12 (55%)	1	9
Expanded	cool core	10	7 (70%)	–	1	2
	non cool core	24	–	14 (58%)	1	9

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