Compact AGN at X-rays

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The evolution of extragalactic radio sources has been a fundamental question in the study of active galactic nuclei for many years. There are still open questions on the radio source initial phase concerning its impact on the host galaxy and the evolutionary path from compact to large radio structures. Recent X-ray observations not only provides new insight into these processes, but also can help to discover and explore new classes of objects.

1 Introduction

Gigahertz Peaked Spectrum (GPS) and Compact Steep Spectrum (CSS) radio sources are believed to be young radio sources, at the beginning of their evolution (Fanti et al. 1995, Snellen et al. 2000, Kunert-Bajraszewska et al. 2010, Kunert-Bajraszewska & Labiano 2010). They represent the early stages of the growth of AGN jets, which interact and heat the interstellar and then intergalactic medium (ISM and IGM, respectively). Studies of these interactions provides key information about the energy deposited into the surrounding medium by expanding radio sources. This is fundamental to our understanding of the feedback process, for example.

The number of GPS and CSS sources with X-ray observations has increased significantly over the last decade (Siemiginowska et al. 2008, Tengstrand et al. 2009). However, a complete sample is still unavailable and there is therefore no statistically solid and systematic study of the X-ray properties of such sample. Most of the high-energy investigations have been done using Chandra and XMM-Newton observations. However the entire radio structure is usually enclosed within angular scales that cannot be resolved by X-ray telescopes, so the X-ray morphology is usually not accessible (Siemiginowska 2009). Nevertheless the Chandra observations of GPS/CSS sources have brought already some surprising results: an X-ray cluster (Siemiginowska et al. 2005, 2010) and thermal diffuse X-ray emission (Massaro et al. 2009) associated with the radio-loud CSS sources.

Probably, both type of the X-ray emission, thermal and non-thermal, are present in young AGN. Thermal emission is emitted by the ISM of the host galaxy shock heated by the expanding radio structure (Begelman & Cioffi 1989, Heinz et al. 1998) or disk's hot corona. Non-thermal radiation is produced through inverse Compton scattering of the local thermal or synchrotron radiation fields of the lobe electron population (Stawarz et al. 2008).

Studies of the origin of the X-ray emission rely mainly on the analysis of X-ray spectral features and relation between radio and X-ray emission (Tengstrand et al. 2009). They have been biased towards high-luminosity objects so far. Our project extended these studies to the low luminosity regime ($< 10^{42}$ erg sec^{-1}) for the first time (Kunert-Bajraszewska et al. 2014).

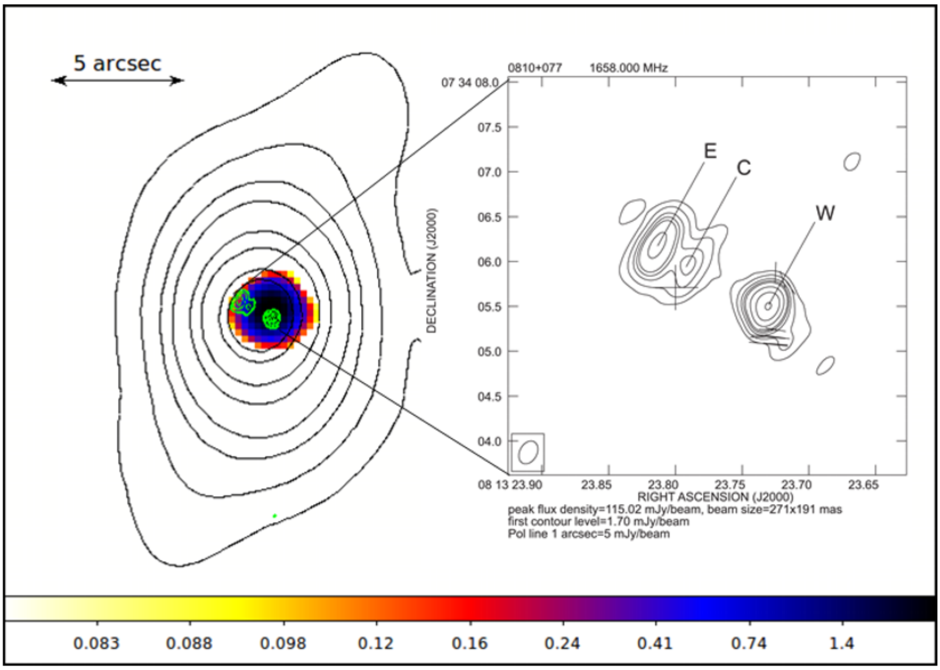

Fig. 1: SDSS optical (black contours), Chandra X-ray (color) and MERLIN 1.6 GHz (green contours) emission from 0810+077. Additionally the enlarged radio map is shown in the panel. We have used 0.15 pixel blocking for the X-ray images. The cross indicates the position of an optical counterpart taken from the SDSS, C is a radio core and E,W - radio lobes. The radio contours increase by factor of 2, the first contour level corresponds to $\approx 3\sigma$ and amounts 1.7 mJy/beam.

2 Our results

We have observed a *pilot sample* of seven low luminosity compact AGN with Chandra. Four of them have been detected, the other three have upper limit estimations for X-ray flux (Kunert-Bajraszewska et al. 2014). The Chandra ACIS-S image of one of the sources with the largest number of X-ray photons is shown in Figure 1 as an example. We also overlayed the SDSS optical and radio MERLIN 1.6 GHz contours on the X-ray emission to picture the scale of these emissions.

One of the objects, 1321+045, appeared to be associated with an X-ray cluster (Kunert-Bajraszewska et al. 2013). This is the second CSS source known to be associated with the large X-ray cluster. It has a different radio morphology than the already discovered 3C 186 (Siemiginowska et al. 2005, 2010) and it is much less luminous in radio. These two CSS sources probe different radio source properties but in a similar cluster environment.

We have used the new observations together with the observational data for known strong CSS and GPS objects and large scale FR Is and FR IIs to study the relation between morphology, X-ray properties and excitation modes in radio-loud AGN. We found that the low power objects fit well to the already established X-ray - radio luminosity correlation for AGN and occupy the space among, weaker in the X-rays, FR I objects. Theoretical models predict that the X-ray luminosity of young AGN can exceed the radio luminosity, and it is independent of the viewing angle (Stawarz et al. 2008). Indeed our observations show that the X-ray luminosity of CSS and GPS sources is, in general, comparable to or higher than their radio luminosity (Kunert-Bajraszewska et al. 2014).

Finally, we have tested also the AGN evolution models by comparing the radio/X-ray luminosity ratio with the size of the sources, and indirectly, with their age. This study also suggests that the division into two different X-ray emission modes (Sambruna et al. 2004, Evans et al. 2006) , viz. X-rays originating from the base of the relativistic jet (FR Is), and X-rays originating from the accretion disk (FR IIs), is already present among the younger compact AGN. The result of this study hints toward the fact that below some radio power level the compact GPS and CSS sources start to resemble the FR Is. However, further observations are necessary for confirming these trends and these will be done with XMM-Newton. The new analysis and results will be published soon.

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