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CGCG 292-057: A Near-Distance Merger Galaxy with Double–Double Radio Lobes and X-shape Structure

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Abstract. J1159+5820 is an extended radio galaxy with a quite unusual morphology, featuring two pairs of radio lobes. Such sources, called double–double radio galaxies, constitute a very rare class of extragalactic radio sources. Furthermore, the extended radio structure of this source shows an X-shape form. According to a much likely scenario, such a morphology is due to interrupting nuclear activity in its central active galactic nucleus. Interestingly, the host of this source is a near-distance bright galaxy named CGCG 292-057, which is clearly disturbed, with tidal features and shells as plausible signs of a recent merger.

Key words. Galaxies: active—individual: CGCG 292-057.

1. Introduction

Galaxy mergers and interactions are main triggers for many of AGNs (e.g. Koss *et al.* 2010). The large number of powerful radio sources hosted by galaxies with peculiar optical morphologies (tails, shells, dust-lanes, etc.) can be taken as evidence for such a scenario. However, the nature of triggering events remains uncertain to date. For one, it is not clear at which stage of merging the onset of radio activity takes place. For obtaining more information on the AGN activity and the connection with a merger event, a comprehensive study of properties of radio structures is essential. A good candidate for such a study can be the galaxy CGCG 292-057. This object is clearly disturbed with tidal features and shells providing plausible evidence for a recent merger. CGCG 292-057 is a bright $R \sim 14$ mag near-distance galaxy located at a redshift of 0.054. We have discovered that it hosts a prominent extended double radio structure with a quite unusual radio morphology (see Fig. 1). According to a much likely scenario, such a structure is due to interrupting nuclear activity in its central AGN.

2. Basic radio properties

J1159+5820 has been mapped in recently performed northern-sky radio surveys, i.e. the Westerbork Northern Sky Survey (WENSS; 327 MHz; Rengelink *et al.* 1997),

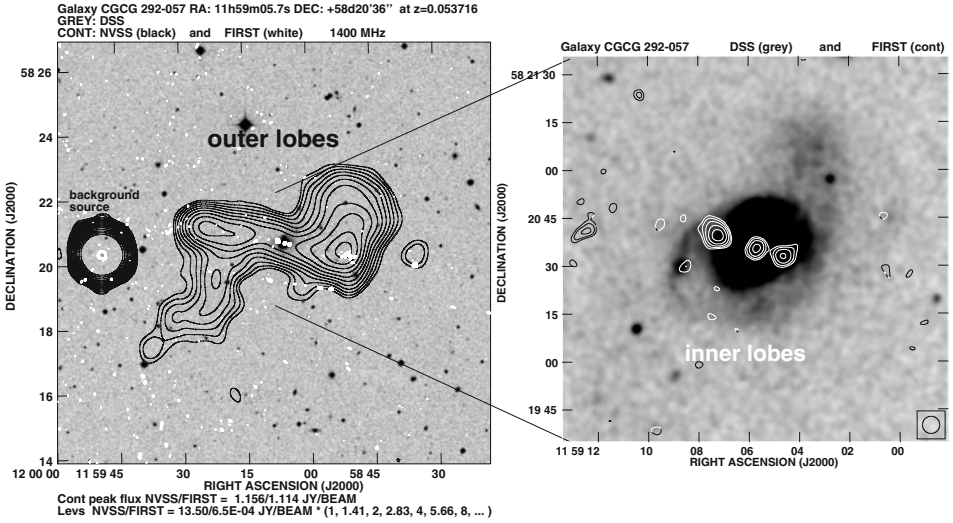

Figure 1. 1400 MHz VLA images of J1159+5820. *Left panel*: The contour maps of the entire source from the NVSS (black) and FIRST (white) surveys overlaid on the optical field from the DSS. *Right panel*: The contour map of the central part of the source from FIRST overlaid on DSS. The contour levels are spaced by a factor of $\sqrt{2}$, and the first contour is 1.35 and 0.65 mJy beam^{-1} for the NVSS and FIRST, respectively. The size of the FIRST beam is given as a circle in the bottom right corner of the image.

the NRAO VLA Sky Survey (NVSS; 1400 MHz; Condon *et al.* 1998), and the Faint Images of the Radio Sky at Twenty-Centimeters (FIRST; 1400 MHz; Becker *et al.* 1995). At first glance, the extended ($\sim 4\farcm3$, which corresponds to 270 kpc) radio morphology of J1159+5820 resembles an FRII-type (Fanaroff & Riley 1974) radio galaxy, though with some unusual features. It shows an X-shape structure, which is characterized by two low-surface-brightness lobes oriented at an angle to the high-surface-brightness radio lobes, giving the entire source its characteristic shape. The two pairs of lobes pass symmetrically through the position of the host galaxy. Several authors have attempted to account for the structure of X-shaped sources and there are a number of models explaining it as the result of backflow, buoyancy, conical precession, reorientation of the jet axis, or presence of some unresolved binary AGN system with two pairs of jets. The total integrated flux of the extended structure of the source is 851.3 ± 32.2 and 325.6 ± 10.1 mJy at 327 and 1400 MHz, respectively. This corresponds to the 1400 MHz luminosity of 24.33 W/Hz, which is below the FRI/FRII luminosity break. In the FIRST map, there are no hot-spots detected in the outer lobes. However, there appears an elongated diffuse shell-like structure in the western outer lobe at the position of a likely hot-spot.

Besides the outer lobes described above, there is a second pair of coaxial lobes, well visible in the FIRST map. The outer lobes are believed to be formed in a previous cycle of jet activity, and the inner ones, are probably due to some later (present) nuclear activity. Such sources, called double–double radio galaxies (DDRGs; Schoenmakers *et al.* 2002), constitute a very rare ($\sim$15 objects in total; for references see e.g. Saikia & Jamrozy 2009) class of extragalactic radio sources. The

total flux density of three compact sources visible in the FIRST map is 8.61 mJy. The central radio component coincides well with the centre of the optical galaxy and the two side compact sources are located within the optical boundaries of the parent galaxy (see Fig. 1, left panel). The arm-length ratio of the FIRST central lobes is about 1.54 and its peak-flux ratio is 1.50. This corresponds to an inclination angle of the radio structure to the line-of-sign of about 80 degrees. It seems however from the optical image of the host that it is almost a face-on galaxy.

Both the known X-shaped and double–double radio galaxies are low-luminosity FRII or FRI/FRII transitional radio sources. It was suggested by Chen & Liu (2007) that there is a kind of evolutionary relationship between them. They proposed that X-shaped radio galaxies may form as a result of interaction of active supermassive binary black holes (SMBBHs) and some accretion disk, while DDRGs emerge due to the removal of inner disk region and the coalescence of SMBBHs.

In constructing a spectral index map of J1159+5820 we used the NVSS and WENSS images. The final gray-scale map of spectral index is shown in Fig. 2. There is a distinct steepening of the index from the presumed hot-spot regions towards the radio core. The spectral index near the position of the host galaxy is $\alpha_{1400}^{327} \approx 0.9$ and near the presumed hot-spot is $\alpha_{1400}^{327} \approx 0.6$ (S$\sim \nu^{-\alpha}$). The mean spectral index over the whole structure is about 0.76 and the mean spectral index over the east-southern and west-northern low-surface-brightness wings is about 0.85 and 0.79, respectively.

By combining the NVSS Stokes Q and U maps, we obtained linearly-polarized intensity and fractional polarization images. The whole structure, except for the east-southern wing, is strongly polarized. The integrated polarized total flux intensity of

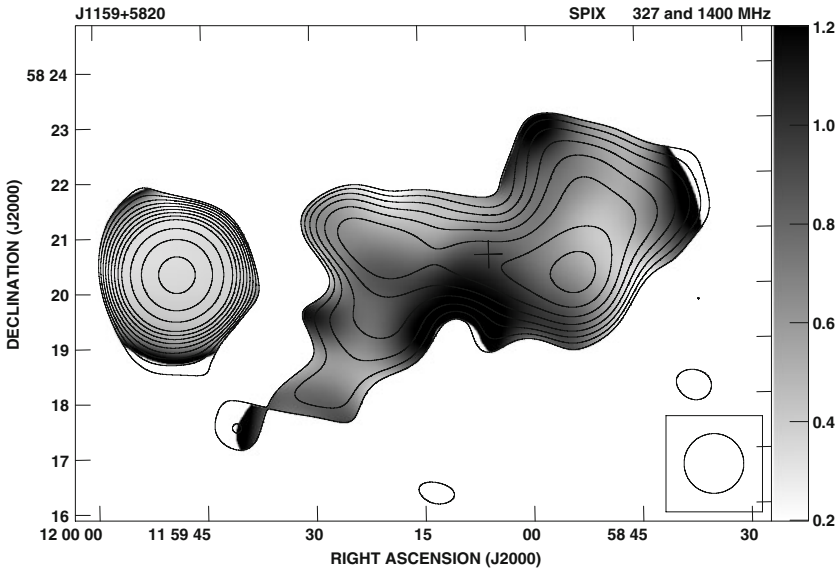

Figure 2. The map of spectral index α_{1400}^{327} across the radio galaxy. The WENSS contour levels are spaced by a factor of $\sqrt{2}$, and the first contour is 12 mJy beam^{-1}. A '+' sign denotes the position of the optical host galaxy, while the size of the beam is shown as a circle in the bottom right corner of the image.

the source is 61 mJy, which gives ∼19% for the mean fractional polarization. Such a high value of fractional polarization is typical of X-shaped sources (Dennett-Thorpe *et al.* 2002). The E-vectors are nearly parallel to the west-east direction in the central part of this source and in the vicinity of the presumed hot-spots changes the angle just a little. The west-northern wing of the source shows a distinct orientation of the E-vectors, nearly orthogonal to the source's major axis.

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