A sample of small size compact steep-spectrum radio sources. VLBI images and VLA polarization at 5 GHz

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ABSTRACT
Global VLBI observations at 5 GHz have been performed to study the source morphology in 10 compact steep-spectrum (CSS) sources selected from the Peacock & Wall catalogue with the aim of finding asymmetric structures produced by the interaction with the ambient medium. The combination of these data and earlier 1.7-GHz observations allows the study of the spectral index distribution across the source structure and the unambiguous determination of the nature of each component. In seven sources we detected the core component with a flat or inverted spectrum. In six sources the radio emission has a two-sided morphology and comes mainly from steep-spectrum extended structures, like lobes, jets, and hotspots. Only one source, 0319+121, has a one-sided core-jet structure. In three out of the six sources with a two-sided structure the flux density arising from the lobes is asymmetric, and the brightest lobe is the one closest to the core, suggesting that the jets are expanding in an inhomogeneous ambient medium which may influence the source growth. The interaction between the jet and the environment may slow down the source expansion and enhance the luminosity due to severe radiative losses, likely producing an excess of CSS radio sources in flux density limited samples. The lobes of the other three asymmetric sources have a brighter-when-farther behaviour, in agreement with what is expected by projection and relativistic effects. Simultaneous VLA observations carried out to investigate the polarization properties of the targets detected significant polarized emission ($\sim$5.5%) only from the quasar 0319+121.

Key words: galaxies: active – galaxies: jets – galaxies: nuclei – quasars: general – radio continuum: galaxies – radio continuum: general

1 INTRODUCTION

The evolutionary stage of a powerful extragalactic radio source is currently thought to be related to its linear size. Statistical studies of the population of radio sources in the first stages of their individual evolution are fundamental for a comprehensive understanding of the radio emission phenomenon and its duty-cycle. Compact steep-spectrum (CSS) and Gigahertz-peaked spectrum (GPS) radio sources are intrinsically small-sized (linear size, LS $\leq$ 15 - 20 kpc), powerful ($P_{1.4\text{GHz}} > 10^{25}$ W Hz$^{-1}$) extragalactic objects generally associated with distant (z>0.2) galaxies and quasars. Their main characteristic is the steep radio spectrum ($\alpha > 0.5$, $S \propto \nu^{-\alpha}$) in the optically thin regime, that flattens and turns over at low frequencies, between 1 GHz and 30 MHz (O'Dea 1998). The genuine youth of these objects was strongly supported by the determination of both the kinematic (e.g. Owsiianik & Conway 1998; Polatidis & Conway 2003; Polatidis 2009; Giroletti & Polatidis 2009; Orienti & Dallacasa 2010) and radiative (e.g. Murgia et al. 1999; Murgia 2003; Orienti et al. 2007) ages of a dozen of the most compact objects (LS $\leq$ 100 pc) which turned out to be about $10^3$–$10^5$ years. Given their young age and the intrinsically small size, CSS/GPS sources provide us with a unique opportunity to study how the radio emission evolves and which role the ambient medium plays on their growth during the first stages of their evolution. A dense, inhomogeneous environment may slow down the expansion of the radio source in the case one jet interacts with a dense cloud. Although the confinement may not last for the entire source lifetime, it may cause an underestimate of the source age.

The radio morphology of CSS/GPS radio sources closely...
resembles that of Fanaroff-Riley type-II radio galaxies (Fanaroff & Riley, 1974), but on much smaller scale. Their radio structure is usually termed symmetric in the sense that the radio emission is found on the two opposite sides of the core (when detected), giving rise to the classification of either compact symmetric objects (CSOs, Wilkinson et al. 1994), if they are smaller than 1 kpc, or medium-sized symmetric objects (MSO, Fanti et al. 1993), if they extend on scales up to 15-20 kpc. However, a large fraction of CSS and GPS sources have a very asymmetric two-sided morphology (e.g. Saikia et al. 2003) where one of the lobes is much brighter and closer to the core than the other. This kind of asymmetry cannot be explained in terms of beaming effects and path delay, suggesting that the two jets are piercing their way through an inhomogeneous medium (e.g. Orienti et al. 2007; Jeyakumar et al. 2005). A strong indication of asymmetries produced by a jet-cloud interaction comes from the detection of atomic hydrogen in absorption only against the brighter (and closer to core) lobe in the CSS objects 3C 49 and 3C 268.3 (Labiano et al. 2006), and in the restarted source 3C 236 (Conway 1999). Moreover, evidence that the ionized gas may be inhomogeneously distributed around the radio source was provided by the detection of asymmetric free-free absorption against the two lobes in one of the most compact radio galaxies (LS < 16 pc): J0428+3259, J1511+0518 (Orienti & Dallacasa 2008), and OQ 208 (Kameno et al. 2000). All these indications suggest that in a substantial fraction of small objects the radio source is not uniformly enshrouded by a homogeneous environment and the two jets may experience different conditions during their propagation through the interstellar medium. Although the gas is not dense enough to frustrate the jet expansion for the entire source lifetime (e.g. Siemiginowska et al. 2003; Fanti et al. 2004, 1993), it may slow down the source growth if a jet-cloud interaction takes place. The high fraction of asymmetric intrinsically-compact radio galaxies strongly supports this scenario.

In this paper we present results of global-VLBI and VLA observations at 5 GHz aimed at determining the radio morphology and the polarimetric properties of 10 out of the 16 sources of the CSS sample selected by Dallacasa et al. (1993) from the Peacock and Wall catalogue (Peacock & Wall 1981). Furthermore, the combination of these data with the 1.7 GHz images already published by Dallacasa et al. (1995) allows the analysis of the spectral index distribution across the source, which is crucial in order to unambiguously constrain the nature of each source component.

The paper is organized as follows: Section 2 describes the radio data and the data reduction; in Section 3 we report the results and a description of each radio source, while discussion and summary are presented in Sections 4 and 5, respectively. Throughout this paper, we assume $H_0 = 71 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_M = 0.27$, $\Omega_{\Lambda} = 0.73$, in a flat Universe. The spectral index is defined as $S(\nu) \propto \nu^{-\alpha}$.

## 2 OBSERVATIONS AND DATA REDUCTION

### 2.1 The VLBI data

Global VLBI observations at 5 GHz (6 cm) were carried out on September 16 and 17, 1991 for a total of 30 hours, using the Mark II recording system (Clark, 1973) with 1.8 MHz bandwidth in left circular polarization (LCP), at the stations reported in Table 1. The data were correlated with the JPL–Caltech VLBI Correlator at the California Institute of Technology in Pasadena.

Each source was observed in snap shot mode for about 1.0–1.5 hour of global time plus 1.5–2 hour of each subnetwork (stations in Europe and US were observing two different sources). For about 24 hours the VLA (in A configuration) was used in phased-array mode as part of the network, greatly enhancing the sensitivity of the observations. This allowed us to have also simultaneous conventional interferometric data (see Section 2.2). In addition, the MERLIN array was jointly observing, but various failures allowed us to use small parts of the VLBI data taken at Cambridge and Knockin only.

The correlated VLBI data were read into the Astronomical Image Processing System (AIPS) package, developed at the National Radio Astronomy Observatory (NRAO) where fringe fitting, amplitude calibration, editing, self-calibration and imaging were performed. The flux density scale was calibrated following Cohen et al. (1975), using B0016+731, B0235+164 and B0851+202 (OJ287) as calibration sources, with adopted flux densities of 1.70, 1.74 and 3.37 Jy respectively, as derived from the VLA simultaneous observation (see Sect. 2.2).

Our earlier 1.7-GHz images (Dallacasa et al. 1993) were used as reference in order to solve for phase ambiguities and to constrain initial self-calibration. The standard techniques of editing, mapping and self-calibration were applied. Gain self-calibration was applied only once at the end of the process, adopting a solution interval longer than the scan length (30 min), in order to remove residual systematic errors and to fine tune the flux density scale. The gain corrections obtained from self-calibration were in general within 2%. The $1\sigma$ noise level on the images, measured far from the source, is in the range of $0.2 - 0.9$ mJy/beam, often not far from the thermal noise ($\sim 0.17$ mJy/beam for a typical observation). The dynamic range, defined as the peak–brightness over r.m.s noise level ($S_p/1\sigma$), varies from $\sim 200$ to $\sim 5000$. The resolution achieved is about 2 milliarcseconds.

### 2.2 The VLA A-configuration Data

During the VLBI observation, the VLA in A-configuration was observing in phased array mode for 24 hours at 5 GHz, allowing us to obtain also images with a resolution of about 0.4 arcsecond for all the sources. In this way we got accurate flux density measurements of each source and calibrators and we could search for extended radio emission with angular size up to 10 arcsec. Furthermore, we obtained VLA polarization information for all the sources. The calibration of the instrumental polarization could not be very accurate since no suitable D-terms calibration source was observed on
Figure 1. \( \mathbf{V} \)-\( \mathbf{U} \)-coverage of 1413+349 at 1.7 GHz (a) and at 5 GHz (b). The latter is restricted to the central region to match the area covered at 1.7 GHz. Sources at higher declination have better matches.

Figure 2. 0223+341: Global VLBI images at 5 GHz of the eastern component (a) and of the total source structure (b). The restoring beam is 2.5\( \times \)1.3 mas\(^2\) in p.a. \(-18^\circ\), and 20\( \times \)15 mas\(^2\) in p.a. \(-27^\circ\), respectively, and they are plotted in the bottom left corner of the image. In addition, on each image we provide the peak flux density in mJy/beam and the first contour intensity (f.c.) in mJy/beam, which corresponds to three times the off-source noise level. Contour levels increase by a factor of 2. The box on panel b represents the area shown with higher resolution in panel (a).

In this section we present the total intensity VLBI images at 5 GHz for the 10 sources discussed in this paper and listed in Table 2 together with spectral index images obtained by comparing these 5-GHz data with those at 1.7 GHz presented in Dallacasa et al. (1992). For each source...
Table 2. Radio properties of the 10 CSS sources from the catalogue presented in Peacock & Wall (1981) and discussed in this paper. Column 1: source name (B1950); Col. 2: optical identification; Col. 3: optical magnitude [inhomogeneous bands]; Col. 4: redshift; Col. 5: linear scale factor. For consistency with Dallacasa et al. (1995), a value of $z = 1$ has been assumed for the sources without redshift; Col. 6: maximum angular size from the 5-GHz VLBI image; Col. 7: maximum linear size; Col. 8: flux density at 5 GHz, as measured by the VLA during the VLBI observation; Col. 9: flux density at 5 GHz from the VLBI images; Col. 10: fractional polarization as measured by the VLA at 5 GHz; Col. 11: spectral index between 1.7 and 5 GHz computed using these VLA data and the 1.7-GHz VLA total flux density from Dallacasa et al. (1995); Col. 12: estimated turnover frequency (Dallacasa et al. 1995); Col. 13: references for the optical magnitude: 1: Peacock et al. (1981); 2: Labiano et al. (2007); 3: Stickel et al. (1994); 4: Sloan Digital Sky Survey Data Release 9 (SDSS DR9) (Ahn et al. 2012); 5: Stickel & Kühr (1996).

| Source | Opt. Id. | m | z  | θ_{max} | z | S_{VLA,6} | S_{VLBI,6} | p_{pol} | α_{thin} | ν_{m} | Ref. |
|--------|----------|---|----|---------|---|-----------|------------|--------|----------|-------|------|
| 0223+341 | Q | 21.3r | 2.910 | 7.898 | 0.56 | 4.42 | 1.75 | 1.63 | <0.6 | 0.38 | <100 | 1 |
| 0316+161 | G | 23.4V | 0.907 | 7.830 | 0.22 | 1.72 | 2.89 | 2.51 | <0.2 | 0.81 | 800 | 2 |
| 0319+121 | Q | 18.0V | 2.662 | 8.079 | 0.04 | 0.32 | 1.37 | 1.33 | 5.5 | 0.17 | <100 | 3 |
| 0404+788 | G | 22.0r | 0.598 | 6.662 | 0.13 | 0.87 | 2.95 | 2.64 | <0.6 | 0.48 | 350 | 1 |
| 0428+205 | G | 18.0r | 0.219 | 3.507 | 0.10 | 0.36 | 2.38 | 2.00 | <0.2 | 0.38 | 1150 | 4 |
| 1225+368 | Q | 21.4r | 1.973 | 8.486 | 0.06 | 0.51 | 0.76 | 0.73 | <0.5 | 0.88 | 1750 | 4 |
| 1358+624 | G | 19.8r | 0.431 | 5.500 | 0.05 | 0.28 | 1.77 | 1.67 | <0.5 | 0.70 | 550 | 4 |
| 1413+349 | EF | - | - | 8.041 | 0.03 | 0.24 | 0.92 | 0.87 | <0.4 | 0.53 | 850 | 4 |
| 1600+335 | G | 23.8R | - | 8.041 | 0.07 | 0.42 | 2.58 | 2.55 | <0.5 | 0.15 | 2400 | 5 |
| 2342+821 | Q | 20.2R | 0.735 | 7.285 | 0.18 | 1.31 | 1.31 | 1.29 | <0.7 | 0.83 | 500 | 5 |

Table 1. Observational data. The diameters listed for the WSRT and the VLA (in brackets) are equivalent diameters, i.e. 3 antennas for WSRT and 27 antennas for the VLA. The sensitivities of the VLA refer to a single antenna (0.12) and to the whole array (2.3).

| Antenna | Diam.(m) | $T_{sys}$ (K) | Sens. (K/Jy) |
|---------|----------|---------------|--------------|
| WSRT (NL) | 43 | 25 | 38 | 0.12 |
| Jodrell Bank (UK) | 25 | 38 | 0.1 |
| Knockin (UK) | 25 | 38 | 0.1 |
| Cambridge (UK) | 32 | 38 | 0.23 |
| Onsala (S) | 26 | 30 | 0.06 |
| Effelsberg (D) | 100 | 75 | 1.45 |
| Noto (I) | 32 | 30 | 0.16 |
| Haystack (US) | 37 | 75 | 0.165 |
| Green Bank (US) | 43 | 30 | 1.93 |
| OVRO (US) | - | - | 0.21 |
| VLA (US) | 25 (130) | 35 | 0.12 (2.3) |
| VLBA_{NL} (US) | 25 | 40 | 0.12 |
| VLBA_{FD} (US) | 25 | 40 | 0.12 |
| VLBA_{PT} (US) | 25 | 40 | 0.12 |
| VLBA_{KP} (US) | 25 | 40 | 0.12 |
| VLBA_{LA} (US) | 25 | 40 | 0.12 |

we provide a description of the main characteristics.

3.1 Source images

In general, for each source we obtained images with a set of different restoring beams and samplings in order either to match the resolution of our 1.7-GHz images, or to get all the details of the structures.

The $uv$-coverages at 1.7 and 5 GHz for the source 1413+349 are shown in Fig. 1 as an example: the 5-GHz visibilities are restricted to the region covered by the 1.7-GHz data. Sources with higher declinations have a better match between the 1.7-GHz and 5-GHz $uv$-coverages. High resolution images at 5 GHz of each source are presented in Figs. 2 – 11. For the source 0316+161 we present also the high resolution image at 1.7 GHz with the

Figure 3. 0316+161: images of the northern and central components at 5 GHz (a) and at 1.7 GHz (b) restored with an elliptical Gaussian with FWHM = $6 \times 3$ mas$^2$ in p.a. $-16^\circ$, plotted in the bottom left part of the images. On each image we provide the peak flux density in mJy/beam, and the first contour (f.c.) intensity (mJy/beam), which is three times the off-source noise level. Contour levels increase by a factor of 2.
identification of the source core, which was not provided in the paper by Dallacasa et al. (1995). In the case of 0223+341, where one lobe is located at about 0.5 arcsec from the main component, and 1600+335, where the central component is surrounded by an extended low surface brightness feature, a lower resolution image is presented next to the high-resolution one.

Source parameters (total flux density and deconvolved size) have been generally measured by means of the AIPS task JMFIT for marginally resolved components. When a component could not be properly fitted with a Gaussian profile, TVSTAT was used to measure the flux density, while the angular size was measured from the lowest contours and it corresponds to 1.8 times the size of the full width at half maximum (FWHM) of a conventional Gaussian covering a similar area (Readhead 1994).

Sub-components are referred to as North (N), South (S), East (E), West (W), Central (Ce), Jet (J), and flat spectrum core (C) when detected, following the labelling used in Dallacasa et al. (1995). The parameters of the sub-components are given in Table 3.

To produce the spectral index distribution across each source, we created low-resolution images with the same resolution as the high-resolution images at 5 and 1.7 GHz. The formal error on both the total and local spectral index is about 0.1, and it has been calculated assuming the error propagation theory. However, we note that the use of the total flux density in computing the spectral index may cause an artificial steepening due to the absence of the shortest spacing at the higher frequency, implying that the formal errors associated to the extended components may be a lower limit. The total spectral index values are reported in Table 3.

3.2 Notes on individual sources

Here we provide a description of the radio morphology of the observed sources. In addition to the local spectral index derived on the spectral index images (Fig. 12), we computed the total spectral index integrated on the whole component by means of the total flux density measured on the high-resolution images at 5 and 1.7 GHz. The formal error on both the total and local spectral index is about 0.1, and it has been calculated assuming the error propagation theory. However, we note that the use of the total flux density in computing the spectral index may cause an artificial steepening due to the absence of the shortest spacing at the higher frequency, implying that the formal errors associated to the extended components may be a lower limit. The total spectral index values are reported in Table 3.

3.2.1 0223+341 \{ Q, m_r=21.3, z=2.91\}

The radio source 0223+341 (alias 4C 34.07) is optically identified with a quasar at redshift \( z = 2.91 \) (Willett et al. 1993). Our global VLBI image at 5 GHz (Fig. 2b) has enough resolution to reveal the substructure of the most compact region labelled East in the image published at 1.7 GHz (Dallacasa et al. 1995). This component has a very complex morphology dominated by two resolved bright knots separated by \( \sim 10 \) mas (79 pc), E1 and E2, located at the northern and eastern tips of the structure. In the SW direction the source is resolved in several blobs pointing towards the western lobe, visible in MERLIN images (Dallacasa et al. 1995). In our 5-GHz observations the western lobe, W, is detected at a few mJy level only (Fig. 2b), implying a steep spectrum, although the lack of short spacings may have prevented the detection of the large scale diffuse emission. The central compact component, Ce, accounts for 16 mJy, and is located \( \sim 68 \) mas (537 pc) from component E at a position angle (p.a.) of 43°. On the other hand, component W is at about 490 mas (3.8 kpc) from component Ce, with a position angle of -110°. Since the compact component Ce is completely resolved in the high-resolution image, its interpretation as the source core is unlikely.

Although the total spectral index of component E is \( \alpha = 0.3 \) (Table 3), the analysis of the local spectral index distribution (Fig. 12a) indicates different values for E1 and E2: \( \alpha \sim 0.3 \), and \( \alpha \sim 0 \), respectively. This difference may be an effect of different physical sizes in presence of synchrotron self-absorption (SSA), which is more effective on the smaller component E2. A possible interpretation of the flat spectra and the complex structure, reminiscent of the hotspot 3C 20 East (Hardcastle et al. 1997), although on much smaller scales, is that knots E1 and E2 may be the primary and secondary components of a double hotspot. In this scenario the source core may be self-absorbed even at 5 GHz, and is located between component E and W. On the other hand, VLBI observations at 327 MHz (Lenc et al. 2008, Dallacasa et al., in preparation), pointed out the presence of a northern component located at about 0.24 arcsec (\( \sim 2.4 \) kpc) from component E, which was not detected in the MERLIN-VLBI images presented by Dallacasa et al. (1995). The presence of the northern
Table 3. Size and flux density of the components in the VLBI images. Columns 1 and 2: source name and component label; Cols. 3, 4, and 5: deconvolved major and minor axes, and the position angle of the major axis derived from the fit to the image. The values reported are the FWHM of the fitted Gaussian component; Col. 6: VLBI flux density at 5 GHz; Col. 7: spectral index computed from the full-resolution images at 1.7 and 5 GHz; Col. 8: the equipartition magnetic fields (see Section 4.3). For consistency with Dallacasa et al. (1995), when the redshift is not available we assume \( z = 1 \) in the determination of the magnetic field and the value is reported in italics.

| Source       | Comp. | \( \theta_1 \) | \( \theta_2 \) | \( \theta_a \) | S_5 | \( \alpha_{1.7} \) | \( H_{\text{eq}} \) |
|--------------|-------|----------------|----------------|-------------|-----|----------------|----------------|
| (1)          | (2)   | (3)            | (4)            | (5)         | (6) | (7)            | (8)            |
| 0223+341     | E1    | 2.2            | 0.8            | 24          | 872 | 0.5            | 66             |
|              | E2    | 1.1            | 0.6            | 117         | 239 | 0.0            | 66             |
|              | E^a   | 7.6            | 3.2            | 127         | 1545| 0.3            | 25             |
|              | W^a   | 21.4           | 5.7            | 48          | 20  | 2.5            | 4              |
| 0316+161     | N^b   | 48.5           | 24.6           | 165         | 2560| 0.8            | 4              |
|              | C     | 2.9            | 2.4            | 168         | 18  | 0.3            | 5              |
|              | S^a   | 37.6           | 9.5            | 131         | 33  | 2.4            | 1              |
| 0319+121     | C^e   | 1.3            | 0.2            | 173         | 824 | 0.2            | 121            |
|              | J^b   | 2.0            | 1.4            | 3           | 219 | 0.7            | 15             |
|              | J     | 38.5           | 4.3            | 170         | 508 | 0.7            | 15             |
| 0404+768     | W^b   | 7.8            | 5.7            | 147         | 1100| 1              | 7              |
|              | W^b   | 55.8           | 31.6           | 105         | 2304| 0.5            | 3              |
|              | C     | 4.1            | 0.9            | 7           | 182 | -0.5           | 14             |
|              | E^b   | 21.0           | 21.0           | -           | 157 | 0.9            | 2              |
| 0428+205     | C^e   | 1.0            | 0.2            | 156         | 29  | -0.4           | 25             |
|              | J     | 3.6            | 0.5            | 162         | 135 | 16             |
|              | S     | 2.3            | 1.6            | 129         | 538 | 14             |
|              | S^b   | 23.2           | 9.0            | 135         | 1777| 0.4            | 6              |
| 1225+368     | E1    | 2.9            | 1.3            | 142         | 457 | 0.8            | 28             |
|              | E2    | 1.5            | 0.9            | 64          | 91  | 1.0            | 27             |
|              | E3    | 2.1            | 1.7            | -           | 41  | 1.0            | 13             |
|              | C     | 2.2            | 2.2            | -           | 62  | 0.3            | 13             |
|              | W^b   | 4.5            | 4.5            | -           | 29  | 1.4            | 10             |
| 1358+624     | N^b   | 15.0           | 10.0           | 120         | 391 | 1.0            | 5              |
|              | C     | 2.3            | 1.1            | 116         | 38  | 0.3            | 9              |
|              | S^b   | 33.5           | 11.5           | 120         | 1250| 0.6            | 5              |
| 1413+349     | C     | 3.5            | 0.7            | 32          | 607 | 0.3            | 28             |
|              | E^b   | 23.3           | 7.0            | 40          | 227 | 0.7            | 5              |
| 1600+335     | C^e   | 1.6            | 0.4            | 17          | 1926| 0.0            | 67             |
|              | J     | 3.0            | 1.5            | 173         | 351 | 16             |
|              | E^a,b | 35.5           | 18.1           | 100         | 97  | 0.5            | 2              |
| 2342+821     | W^b   | 27.8           | 22.2           | 85          | 1181| 0.8            | 4              |
|              | C^e   | 16.7           | 5.5            | 130         | 59  | 1.0            | 5              |
|              | E^b   | 7.7            | 3.3            | -           | 25  | 1.0            | 5              |

a The component parameters have been derived on the low resolution map.
b The component angular size has been measured on the contour image, while the flux density has been derived by means of TV-STAT.
c The spectral index refers to the combination of components C and J (J1 in the case of 0319+121).

Component may indicate that component E is likely hosting the source core. The spectral index computed between 327 MHz and 1.7 GHz turns out to be flat \( \alpha \sim 0.2 \) supporting this interpretation. Almost 96% of the total flux density measured by the VLA is recovered by our global-VLBI observations. No significant polarized emission has been detected by the VLA at 5 GHz \( (p < 0.6\%) \).
3.2.4 0404+768  [G, $m_r=18.0$, $z=0.219$]

The radio source 0404+768 (alias 4C 76.03) is optically identified with a galaxy at $z = 0.5985$ (O'Dea et al. 1991). The image at 5 GHz (Fig. 5) confirms the morphological interpretation proposed in Dallacasa et al. (1995) (in both cases the image is rotated counterclockwise by 45°). The core region, C, hosting both the source core and the jet base, is located between the two lobes at the easternmost edge of the visible jet. The core flux density is 182 mJy, i.e. 6% of the total flux density measured by the VLA. The radio structure is very asymmetric: the core is located about 70 mas (465 pc) and 40 mas (265 pc) from components E and W, respectively. A one-sided jet connects the core with the western lobe. The radio emission is dominated by component W, that accounts for almost 80% of the total VLA flux density. The flux-density ratio between the western and the eastern structures is $R_6 \sim 9.5$ and 7 at 1.7 and 5 GHz, respectively, while the arm-length ratio is $R_R \sim 0.6$, implying a brighter-when-closer behaviour.

Component W has a total spectral index of $\alpha = 0.5$ (Table 3), indicating that the radio emission is dominated by the hotspot. The core has an inverted spectrum ($\alpha \sim -0.5$, Table 3). The spectral index of component E is artificially steeper likely due to the emission of the extended structure that cannot be detected by our 5-GHz VLBI observations (Fig. 12). About 90% of the total VLA flux density could be recovered by our global-VLBI observations. No significant polarized emission has been detected by the VLA at 5 GHz ($p < 0.6\%$). Deeper VLBA observations in L and C bands will be presented in a forthcoming paper which will focus on an accurate spectral analysis of this source.

3.2.5 0428+205  [G, $m_r=22.0$, $z=0.5985$]

The radio source 0428+205 (alias DA 138) is optically identified with a galaxy at redshift $z = 0.219$ (Stickel et al. 1994). Its radio emission at 5 GHz is dominated by the southern and central components (Fig. 6), consistent with what was previously found by Fomalont et al. (2000). The northern lobe, located about 175 mas (~615 pc) from the core, is not detected by our 5-GHz VLBI observations. The high-resolution image could resolve the core region into two main components. From the spectral analysis (Fig. 12), we suggest that the core, C, is the northern component, that accounts for 29 mJy (i.e. 1.2% of the total VLA flux density), while the elongated component J is likely the main jet. The southern lobe, S is dominated by a
flux density is 60 mJy at 5 GHz (i.e. 8% of the total VLA flux density at this frequency). The radio emission is dominated by the eastern part of the source, while the western component, W, represents only 4% of the total flux density. The brightest component E1, likely a hotspot, is located at 32 mas (270 pc) from the core, and shows a local spectral index \( \alpha \sim 0.8 \) (Fig. 12f). The radio spectrum steepens going backward along the jet components (\( \alpha = 1.0 \)), indicating that components E2 and E3, located between the hotspot and the core, are likely knots in the jet. Component W is located at 23 mas (200 pc) from the core, and has a very steep spectrum (\( \alpha \sim 1.4 \)) without any evidence of compact regions. The hint of the jet visible in the 1.7-GHz image has disappeared at this higher frequency. The flux density ratio computed between the eastern and western structures is \( R_S \sim 12.8 \) and 20.3 at 1.7 and 5 GHz, respectively, while their arm-length ratio is \( R_R \sim 1.4 \), providing a brighter-when-farther behaviour. The total flux density recovered by our global-VLBI observations is in agreement with the value found with the VLA, excluding the presence of significant emission on scales larger than those represented in our VLBI image. No significant polarized emission has been detected by the VLA at 5 GHz (\( p < 0.2\% \)).
accounts for 22% of the total flux density. The core region is hosted in component C, which is characterized by an inverted spectrum ($\alpha \sim -0.3$). The core flux density is 38 mJy at 5 GHz, i.e. about 2% of total flux density. The total spectral index of component N is $\alpha = 1.0$, while some local flattening can be seen in its NE edge ($\alpha \sim 0.6$, Fig. 9), at about 15 mas (~84 pc) from the core, where a hotspot may be present. The southern jet has a spectral index $\alpha \sim 0.6$. Its structure is well collimated in the initial part, and broadens farther out ending in a diffuse, steep-spectrum emission. The flux-density ratio between the southern and northern structure is $R_S \sim 84$ pc) from the core, where a hotspot may be present. The southern jet has a spectral index $\alpha \sim 0.6$.

The radio emission is dominated by the brightest compact component, labelled C in Fig. 9, that accounts for 607 mJy (i.e. 66% of the total VLA flux density) and likely harbours the source core. The well-collimated jet, labelled S in Fig. 9 and a hint of the counter-jet emerge from the core component. The jet is about 54 mas in size and is resolved in several compact sub-components. It shows a peak at the outer NE edge of the structure, where a hotspot is likely present. The flux-density ratio between the eastern and western components is estimated from the 1.7-GHz data and is $R_S \sim 6.2$, while the arm-length ratio is $R_R \sim 3$, indicating a brighter-when-farther behaviour, as expected if the eastern and western components are the jet and counter-jet, respectively.

The total spectral index of the core region is rather flat with $\alpha \sim 0.3$, while the jet has a steeper spectrum with $\alpha \sim 0.7$ (Fig. 9).

Our 5-GHz global-VLBI observations could recover only 93% of the total flux density measured by the VLA at this frequency. The missing flux density is likely due to the western component which could not be accounted for by these observations.

No significant polarized emission has been detected by the VLA at 5 GHz ($p < 0.5\%$). However single-dish measurements at 15 GHz (Aller et al. 1985) find significant fractional polarization ($p \sim 5\%$) suggesting that this object may be highly depolarized at lower frequencies.

3.2.8 1413+349 [EF, $m=..., z=...$]

The radio source 1413+349 (alias OQ 323) lacks an optical identification. At 5 GHz the radio source displays a core-jet structure. The counter-jet, visible in the 1.7-GHz image (component West in Dallacasa et al. 1995), is completely resolved out at this frequency. The morphology presented in Fig. 9 is in good agreement with VLBA observations at the same frequency performed by Helmboldt et al. (2007).

3.2.9 1600+335 [G, $m_R=23.0$, $z=...$]

The radio source 1600+335 (alias 4C 33.38) is optically identified with a faint galaxy, but no spectroscopic redshift is available so far (Stickel & Kuhl 1996). The redshift $z = 1.1$ reported in Snellen et al. (2000) was estimated on the basis of optical magnitudes, but no detail on this approach was presented. For this reason we do not provide...
any value for the redshift of this source. The morphology of the radio emission is rather complex: the main region, labelled C in Fig. 10, is resolved into a sort of core-jet structure elongated in the NS direction, surrounded by blobs of the extended low-surface brightness emission visible at 1.7 GHz and almost completely resolved out by these observations. Hints of component E are detected in the low-resolution image only (Fig. 11b). The tapered image with the spectral index information (Fig. 12) reveals an extension to the South of the main region that bends towards the diffuse component located 40 mas to the East. Since both the extended components detected in Dallacasa et al. (1995) are severely resolved in these 5-GHz observations, a reliable determination of the spectral index could be done on the main component only, where it turned out to be flat ($\alpha \sim 0.0$), supporting the idea that it hosts the source core and the jet base, as suggested by its morphology.

Our global VLBI image accounts for 92% of the total flux density measured by the VLA.

No significant polarized emission has been detected by the VLA at 5 GHz ($p < 0.5\%$).

3.2.10 2342+821 \( [Q, m_R=20.2, z=0.735]\)

The radio source 2342+821 is optically identified with a quasar at redshift $z = 0.735$ (Stickel & Kühr 1996). In our 5-GHz global-VLBI image (Fig. 11), the source shows an aligned triple structure of about 160 mas (1.16 kpc) in size and position angle $\sim 110^\circ$, in agreement with the morphology found at 1.7 GHz (Dallacasa et al. 1995). The radio emission is dominated by the western component, W, that accounts for 1144 mJy that is 97% of the total VLA flux density. These observations could resolve the structure of components Ce and E. In particular, component Ce is elongated in the same direction of the whole source. The spectral index image (Fig. 12) does not reveal any region with a flat/inverted spectrum, leaving the core identification an open question. Component W has a spectral index $\alpha \sim 0.8$, while components Ce and E have steeper spectra. Almost 98% of the total flux density measured by the VLA is recovered by our global VLBI observations.

No significant polarized emission has been detected by the VLA at 5 GHz ($p < 0.7\%$).
Figure 12. Grey-scale spectral index images between 5.0 and 1.7 GHz of the sources studied in this paper, superimposed on the low-resolution 5-GHz contours convolved with the 1.7-GHz beam. (a): 0223+341; (b): 0316+161; (c): 0319+121; (d): 0404+768; (e): 0428+205; (f): 1225+368; (g): 1358+624. On each image we report the source name, the peak flux density in mJy/beam; the first contour (f.c.) intensity in mJy/beam, the increment contour factor, and the restoring beam plotted on the bottom left corner. The grey scale is shown by the wedge at the top of each spectral-index image.
4 DISCUSSION

4.1 Radio morphology

The high spatial resolution images provided by our global VLBI observations, complemented with the spectral index information, allow us to properly describe the morphology of the CSS sources studied in this paper. Among the 10 target sources, eight (3 quasars 0223+341, 1225+368, and 2342+821; 4 galaxies 0316+161, 0404+768, 0428+205, and 1358+624; 1 empty field 1413+349) have a two-sided structure, one source (the quasar 0319+121) has a one-sided core-jet morphology, while the galaxy 1600+335 shows a complex structure.

In seven sources (0316+161, 0319+121, 0404+768, 0428+205, 1225+368, 1358+624, and 1413+349) the core region is unambiguously detected, while in 0223+341 high-resolution observations at 327 MHz suggest that the source core is hosted in the eastern component. In general the radio emission is dominated either by lobes or by jets, while the core, when detected, usually accounts for about 1% of the source flux density, with the exception of a few cases.

Table 4. Morphology information.

|                | Q | G | EF | Tot |
|----------------|---|---|----|-----|
| Two-sided      | 3 | 4 | 1  | 8   |
| Core-jet       | 1 | 0 | 0  | 1   |
| Complex        | 0 | 1 | 0  | 1   |
| Core\(^a\)     | 4 | 2 | 1  | 7   |
| Core-dominated\(^a\) | 1 | 0 | 1  | 2   |
| Lobe-dominated | 1 | 3 | 0  | 4   |
| Jet-dominated  | 1 | 1 | 0  | 2   |
| Brighter-closer| 0 | 3 | 0  | 3   |
| Brighter-farther| 1 | 1 | 1  | 3   |

\(^a\)Sources with an unambiguous core identification.
Interestingly, among the asymmetric radio sources presented here, HI absorption has been found in all the four radio galaxies: 0316+161, 0404+768, 0428+205, and 1358+624 (Salter et al. 2010; Vermeulen et al. 2003). However, the lack of high spatial resolution observations does not allow us to locate the position of the HI and thus no conclusive results on a possible jet-medium interaction can be drawn. No observations searching for HI absorption in 1225+368 and 1413+349 are available.

In Fig. 13 we plot the flux-density ratio versus the arm-length ratio for the six double sources with unambiguous core detection discussed in this paper (filled circles), and for the CSS sources from Rossetti et al. (2006) (crosses), and Orienti et al. 2004 (triangles). When the flux density ratio could be derived at both 1.7 and 5 GHz, both values are plotted, and they are connected by a solid line. The vertical dotted line corresponds to an arm-length ratio of unity.

### Table 5. Luminosity and asymmetry parameters of the two-sided sources with an unambiguous core detection. Column 1: source name; Cols. 2, 3: flux density ratio at 1.7 and 5 GHz, respectively; Col. 4: arm-length ratio; Cols. 5, 6: Source total luminosity and core luminosity, respectively.

| Source          | \( R_{S,L} \) | \( R_{S,C} \) | \( R_{H} \) | \( \log L_{\text{tot}} \) | \( \log L_{\text{core}} \) |
|-----------------|---------------|---------------|-------------|-----------------|-----------------|
| 0316+161        | 14.0          | -             | 0.6         | 28.51           | 25.87           |
| 0404+768        | 9.5           | 7.0           | 0.6         | 28.08           | 26.43           |
| 0428+205        | 6.0           | -             | 0.3         | 26.60           | 24.60           |
| 1225+368        | 12.8          | 20.3          | 1.4         | 28.46           | 27.23           |
| 1358+624        | 2.2           | 3.2           | 1.9         | 27.65           | 25.39           |
| 1413+349        | 6.2           | -             | 3.0         | 27.92           | 27.50           |

Here, the HI absorption has been found across the entire radio galaxies: 0316+161, 0404+768, 0428+205, and 1358+624 (Salter et al. 2010; Vermeulen et al. 2003). However, the lack of high spatial resolution observations does not allow us to locate the position of the HI and thus no conclusive results on a possible jet-medium interaction can be drawn. No observations searching for HI absorption in 1225+368 and 1413+349 are available.

In Fig. 13 we plot the flux-density ratio versus the arm-length ratio for the six double sources with unambiguous core detection discussed in this paper (filled circles), and for the CSS sources from Rossetti et al. (2006) (crosses), and Orienti et al. 2004 (triangles). When the flux density ratio could be derived at both 1.7 and 5 GHz, both values are plotted, and they are connected by a solid line. The vertical dotted line corresponds to an arm-length ratio of unity.

### Table 5. Luminosity and asymmetry parameters of the two-sided sources with an unambiguous core detection. Column 1: source name; Cols. 2, 3: flux density ratio at 1.7 and 5 GHz, respectively; Col. 4: arm-length ratio; Cols. 5, 6: Source total luminosity and core luminosity, respectively.

| Source          | \( R_{S,L} \) | \( R_{S,C} \) | \( R_{H} \) | \( \log L_{\text{tot}} \) | \( \log L_{\text{core}} \) |
|-----------------|---------------|---------------|-------------|-----------------|-----------------|
| 0316+161        | 14.0          | -             | 0.6         | 28.51           | 25.87           |
| 0404+768        | 9.5           | 7.0           | 0.6         | 28.08           | 26.43           |
| 0428+205        | 6.0           | -             | 0.3         | 26.60           | 24.60           |
| 1225+368        | 12.8          | 20.3          | 1.4         | 28.46           | 27.23           |
| 1358+624        | 2.2           | 3.2           | 1.9         | 27.65           | 25.39           |
| 1413+349        | 6.2           | -             | 3.0         | 27.92           | 27.50           |

4.2 Asymmetries

The radio structure of the six two-sided sources with a secure core detection is not perfectly symmetric, and the majority of the radio emission arises from one of the jets/lobes. The flux density ratio \( R_S \) between the two sides of the source ranges from 2.2 in 1358+624 to 20.3 in the most asymmetric source 1225+368. In three sources, 1225+368, 1358+624 and 1413+349, we found a brighter-when-farther behaviour in which the brightest lobe/jet is the farthest from the core, as expected from projection and relativistic effects. In the case of the three galaxies 0316+161, 0404+768 and 0428+205 the core region is closer to the brighter lobe, which is opposite to what is expected in the above assumptions. In Table 5 the arm-length ratio and the flux density ratio are reported for the six two-sided sources with an unambiguous core detection.

Interestingly, among the asymmetric radio sources presented here, HI absorption has been found in all the four radio galaxies: 0316+161, 0404+768, 0428+205, and 1358+624 (Salter et al. 2010; Vermeulen et al. 2003). However, the lack of high spatial resolution observations does not allow us to locate the position of the HI and thus no conclusive results on a possible jet-medium interaction can be drawn. No observations searching for HI absorption in 1225+368 and 1413+349 are available.

In Fig. 13 we plot the flux-density ratio versus the arm-length ratio for the six double sources with unambiguous core detection discussed in this paper (filled circles), and for the CSS sources from Rossetti et al. (2006) (crosses), and Orienti et al. 2004 (triangles). When the flux density ratio could be derived at both 1.7 and 5 GHz, both values are plotted, and they are connected by a solid line. The vertical dotted line corresponds to an arm-length ratio of unity.
Among the sources with the brighter-when-farther behaviour, we investigate the advance speed and the jet orientation assuming that both jets are thrust by the same jet power and are expanding within a homogeneous medium. In this context, we assume a simple beaming model in which the asymmetries are produced by boosting effects. The flux density ratio is:

\[ R_S = \left( \frac{1 + \beta \cos \theta}{1 - \beta \cos \theta} \right)^{3+\alpha} \]  

(1)

where \( \beta \) is the source advance speed and \( \theta \) is the jet orientation angle to our line of sight. We note that the comparison of flux densities may not be appropriate due to relativistic time dilation that causes different evolution between the approaching and receding structures. However, this effect should not be relevant in these sources because the lobes/hotspots are oriented at larger angles than jets in blazars, and the evolution should be smothered, as supported by the lack of flux density variability in these sources.

By means of Eq. (1) we can derive the possible combinations of \( \beta \) and \( \theta \) which reproduce the observed flux density asymmetries. Fig. (1) shows the flux density ratio versus the jet orientation as a function of the advance speed. In this case we conservatively assumed \( \alpha = 0.7 \). It is clear that a source oriented at large angles to our line of sight, \( \theta \geq 80^\circ \), cannot produce large asymmetries even in the case the jet is advancing with \( \beta = 1 \). On the other hand, large asymmetries, i.e. \( R_S > 10 \), can be produced only assuming \( \beta > 0.3 \).

Among the sources studied in this paper, the object with the highest flux density ratio is 1225+368 with \( R_S = 20.3 \) and 12.8 at 5 and 1.7 GHz, respectively. Such high values can be explained assuming an advancing velocity of \( \beta \geq 0.4 \) and \( \theta \geq 30^\circ \). These are reasonable values in the case of 1225+368, which is optically associated with a quasar.

The other source showing a high flux density ratio (\( R_S \sim 19 \)) is the source B3 0039+398 (alias 4C 39.03) from Rossetti et al. (2006). Although no information on the optical counterpart is available, the high flux density ratio suggests that this source is likely associated with a quasar rather than a galaxy. According to the unified models, radio galaxies should be oriented at \( \theta > 45^\circ \), with the average value of \( \theta = 70^\circ \) (Barthel 1989). In a galaxy, such a strong asymmetry can be obtained only if the radio galaxy is expanding with \( \beta > 0.5 \). However, kinematic studies of young radio galaxies indicate that the mean expansion velocity is \( \sim 0.1c \) (Polatidis & Conway 2003; Giroletti & Polatidis 2004), implying that high asymmetries in galaxies are unlikely, because other \textit{ad hoc} ingredients should be invoked in addition to projection and relativistic effects.

**4.3 Physical parameters**

For the seven sources with a clear detection of the core component we investigate the contribution of the core luminosity to the source total luminosity and we compare the values with what was found for other classes of objects. In Fig. 15 we plot the luminosity of the core at 5 GHz versus the source total luminosity at 408 MHz for a sample of FRI and FRII from Zirbel & Baum (1995), and for CSS/GPS objects with a secure detection of the core from the samples by Fanti et al. (2001, 1990), Peck & Taylor (2000), Stanghellini et al. (1998); Dallacasa et al. (2000). For all the sources lacking observations at 408 MHz, the flux density at such frequency was extrapolated from the optically thin part of the spectrum. The same approach was used to derive the flux density at 408 MHz for those CSS/GPS objects whose spectrum was already self-absorbed at this frequency. In the case the flux density of the core at 5 GHz was not available, the 5-GHz flux density was extrapolated assuming a flat spectrum (\( \alpha = 0 \)).

As a comparison, we included also the blazars from the 3-month Fermi-LAT bright \( \gamma \)-ray source list (LBAS, Abdo et al. 2009). We note that the total flux density for the blazar population should be considered a lower limit since it refers to observations at 0.8 or 1.4 GHz (Giroletti et al. 2010) where the contribution of extended structures is less effective than at 408 MHz.

From Fig. 15 we found that CSS/GPS sources are the high-luminosity tail of the FRII population. Among seven sources of our sample with the core detected, five share the same region as FRII and CSS/GPS, while two objects, 0319+121 and 1413+349 fall in the area occupied by the blazars. These outliers are objects whose radio emission is dominated by the core/jets, and this suggests that boosting effects may play a dominant role in their radio emission. To derive a relation between the core and the total luminosity, we performed a linear regression fit of \( \log L_{\text{core}} \) versus \( \log L_{\text{tot}} \):

\[
\log L_{\text{core}} = a + b \times \log L_{\text{tot}}
\]

considering CSS/GPS objects. As a comparison, we performed two additional linear regression fits considering FRI/FRII and blazars, separately. Fit parameters obtained minimizing the chi-square error statistic are reported in Table 6.
for each component of the radio sources. We computed the magnetic energy, we derive the physical properties of minimum energy conditions (particle energy is equal to the magnetic field). On the basis of the observed parameters, and assuming point processes, we inferred the contribution from extended structures (pointed out by Giroletti et al. (2010).)

We presented the results from global-VLBI observations at 5 GHz of a sample of 10 out of 16 CSS sources from the LBAS, the slope is close to 1, indicating that the contribution from extended structures is negligible and the core dominates the source emission due to Doppler beaming effects, as it was already pointed out by Giroletti et al. (2010).

On the basis of the observed parameters, and assuming minimum energy conditions (particle energy is equal to the magnetic energy), we derive the physical properties for each component of the radio sources. We computed the equipartition magnetic field \(B_{eq}\), the minimum energy density \(u_{min}\), and the minimum internal pressure \(p_{min}\) using standard formulae (Pacholczyk 1970). We assumed that the source components have an ellipsoidal volume with a filling factor of unity, and an equal distribution between proton and electron energies. An average optically-thin spectral index of 0.7 has been adopted. We found that the minimum energy density \(u_{min}\) is between \(10^{-4}\) and \(10^{-6}\) erg cm\(^{-3}\), the minimum internal pressure \(p_{min}\) ranges between \(10^{-4}\) and \(10^{-7}\) dyne cm\(^{-2}\), while the equipartition magnetic field accounts for a few mG up to about 120 mG (Table 3). The latter value has been found in the compact core of the core-jet radio source 0319+121, which is also at very high redshift. The higher values are found in compact components and are similar to those found in the hotspots and core region of other CSS sources (Fanti et al. 1994; Dallacasa et al. 2002; Orienti et al. 2004), whereas in extended components, like lobes and jets, we found lower values.

### 4.4 Polarization properties

Several studies of the polarization properties of CSS sources (e.g. Cotton et al. 2003; Fanti et al. 2004) have shown that sources smaller than a few kpc have very low values of polarized emission at frequencies below 8.4 GHz. This result has been interpreted by assuming that compact sources are highly depolarized by the dense interstellar medium that enshrouds the radio emission and acts as a Faraday screen. Support to this idea is the detection of some level of polarized emission as we consider higher frequencies, while the sources are completely unpolarized at the lower frequencies.

From our VLA observations, we found that 9 out of the 10 sources studied here are unpolarized at 5 GHz, in good agreement with the expectation. The radio source 1358+624, unpolarized in our 5 GHz observations, turned out to be polarized at 15 GHz (Aller et al. 1985), suggesting that strong depolarization is taking place in this source. Only the quasar 0319+121 turned out to be significantly polarized, with a fractional polarization of about 5.5%. Since polarimetric observations are available at one frequency only, we cannot determine the rotation measure (RM). However, if we assume a low RM, we obtain that the magnetic field is parallel to the VLBI jet axis, as it is observed in quasars. The presence of significant percentage of polarized emission, together with the core-jet structure, suggests that this source may be oriented at a small angle with respect to the line of sight and its linear size may be foreshortened by projection effects.

### 5 SUMMARY

We presented the results from global-VLBI observations at 5 GHz of a sample of 10 out of 16 CSS sources from the sample presented by Dallacasa et al. (1995). The majority of the targets have a two-sided structure and the radio emission is dominated by lobes, jets, and hotspots. One sources, 0319+121, has a core-jet morphology and the radio emission comes mainly from the core component. This object is the
only one with significant polarized emission. High polariza-
tion level is uncommon in CSS sources, where the interstel-
lar medium enshrouding the radio source acts as a Faraday
screen causing severe depolarization of the radio emission.
The determination of the nature of the source components
has been provided by the availability of two-frequency ob-
servations which allowed the study of the spectral index dis-
tribution across the whole source. The core has been un-
ambiguously identified in 7 sources. Among them, the six
sources with a two-sided structure have large flux density
and/or arm-length asymmetries. In three cases the bright-
est lobe is the farthest from the core, in agreement with what
is expected in case of projection effects. The evidence that
the ambient medium may play a decisive role in producing
asymmetric objects is supported by the galaxies 0316+161,
0404+768 and 0428+205, where the brightest lobe is also the
closest to the core. The interaction with a dense medium
may slow down the jet growth, lowering adiabatic losses
and enhancing radiative losses. As a consequence the syn-
chrotron emission from the interacting jet is enhanced. If the
jet-environment interaction is not a sporadic phenomenon in
the lifetime of CSS radio sources, it may provide a possible
explanation of the high fraction of CSS objects in flux den-
sity limited sample.
The influence of the ambient medium on the source ex-
pansion has been proved on a few individual objects only
and no statistical study has been performed so far. Multi-
frequency VLBA observations of a sample of the most com-
 pact CSS/GPS objects (with linear size of a few parsecs)
have been already performed in order to investigate the role
played by environment during the very first stage of the source
growth. The results will be used to draw a complete and
reliable picture of the radio source evolution.

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