VLBI study of a sample of low-power compact symmetric objects

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INTRODUCTION: Compact symmetric objects (CSOs) are intrinsically compact extragalactic radio sources and represent the progenitors of classical radio galaxies. Several evolutionary models have been proposed to describe how the physical parameters (e.g. luminosity, expansion velocity, magnetic field) of high-power radio sources evolve as the relativistic jet propagates within the ISM of the host galaxy and beyond (e.g., Snellen et al. 2000, MNRAS, 319, 445). Weak jets are more prone to instabilities and seem to have a more individualised evolution scheme (Fig. 1; An & Baan 2012, ApJ, 760, 77). The interaction of relativistic plasma with clouds of gas, or the mass loading by stellar winds may be able to decelerate and/or disrupt the jet even in presence of continuous supply of relativistic particles (e.g., Perucho et al. 2014, MNRAS, 441, 1488). As a consequence, a large fraction of the energy of low-power jets is deposited in the host galaxy, and potentially impact the distribution and kinematics of the ISM of the host galaxy for longer time than high power jets. Increasing the number of confirmed low-power CSOs is crucial for improving our knowledge of the evolutionary path of radio emission and the influence of the jet on the host galaxy.

To date, samples of low-power CSOs are contaminated by core-jet objects, whose size is not intrinsically compact, but it is foreshortened by beaming effects. To circumvent this issue, we constructed a statistically complete sample of low-power CSOs by making use of archival mas-resolution observations at 1.4 GHz.

THE SAMPLE: We constructed a sample of candidate CSOs selecting sources with a pc-scale two-sided structure in VLBI images at 1.4 GHz from the mJIVE-20 project (Deller & Middelberg 2014, AJ, 147, 14). The selection criteria are:

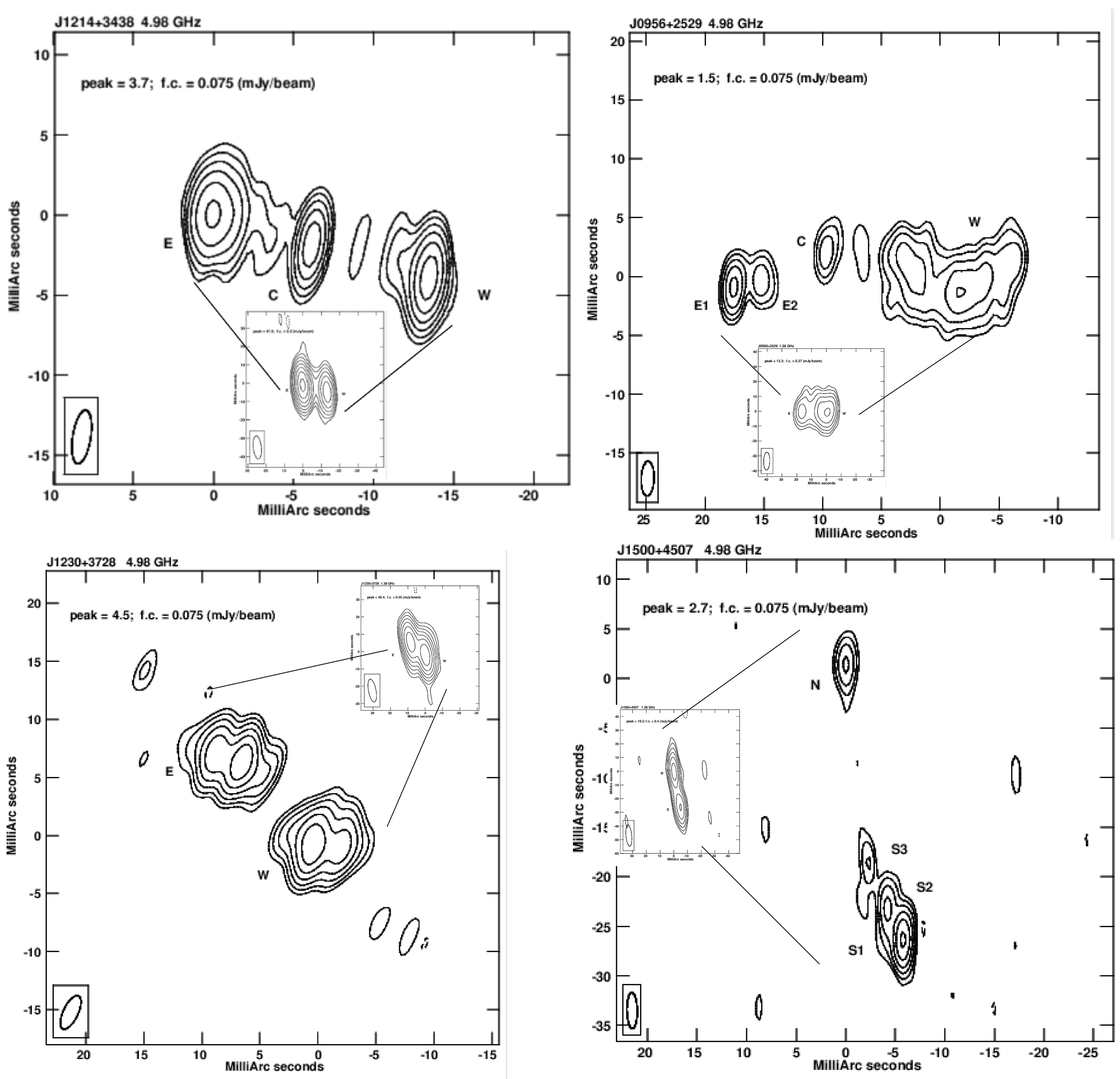
- Sources with a well-resolved double structure in VLBI images, but unresolved in FIRST;
- The VLBI total flux density is consistent with the flux density from the FIRST, indicating no emission on scales between those sampled by VLBI and the resolution of the FIRST;
- No flux density variability from the various epochs of the VLA Sky Survey (VLASS).

The final sample consists of 61 sources. The upper panel of Fig. 1 shows the radio power vs linear size plot for extragalactic radio sources. The selected sources fall in the yellow region. Although optical photometry is available for many sources, information on the redshift (either spectroscopic or photometric) is known only for a bunch of them. For the sources without redshift information we computed the physical parameters assuming z = 0.5 and z = 2.0 (bottom panel of Fig. 1).

NEW VLBI OBSERVATIONS: We performed deep VLBA observations at 5 GHz of 20 of the brightest sources (peak > 10 mJy/beam) in the sample to:

- determine the spectral index distribution and discriminate between steep-spectrum CSOs and core-jet blazars;
- Pick up faint components like extended lobes, undetected due to sensitivity limitation in earlier data, or core regions that are self-absorbed at 1.4 GHz.

CSO **Core-jet**



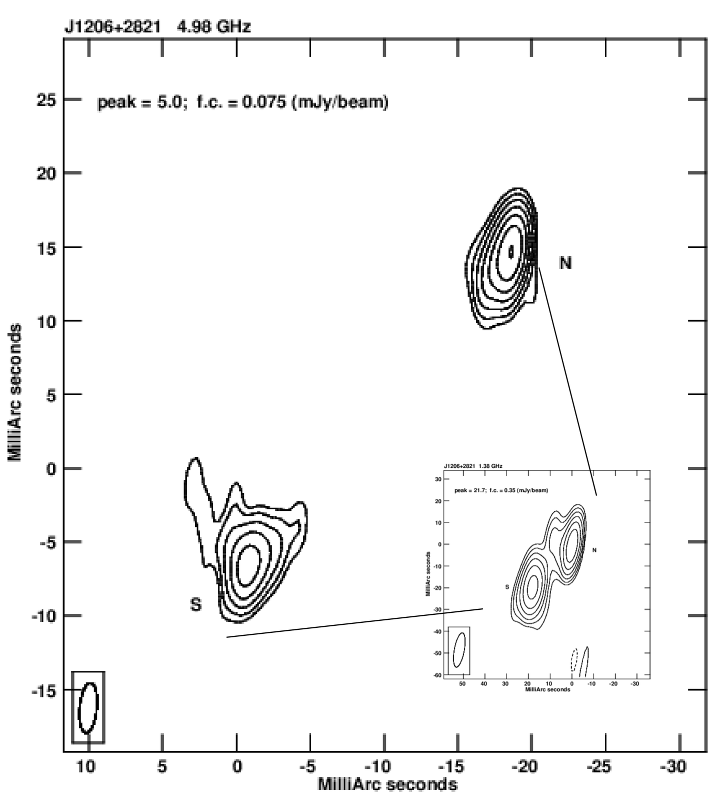
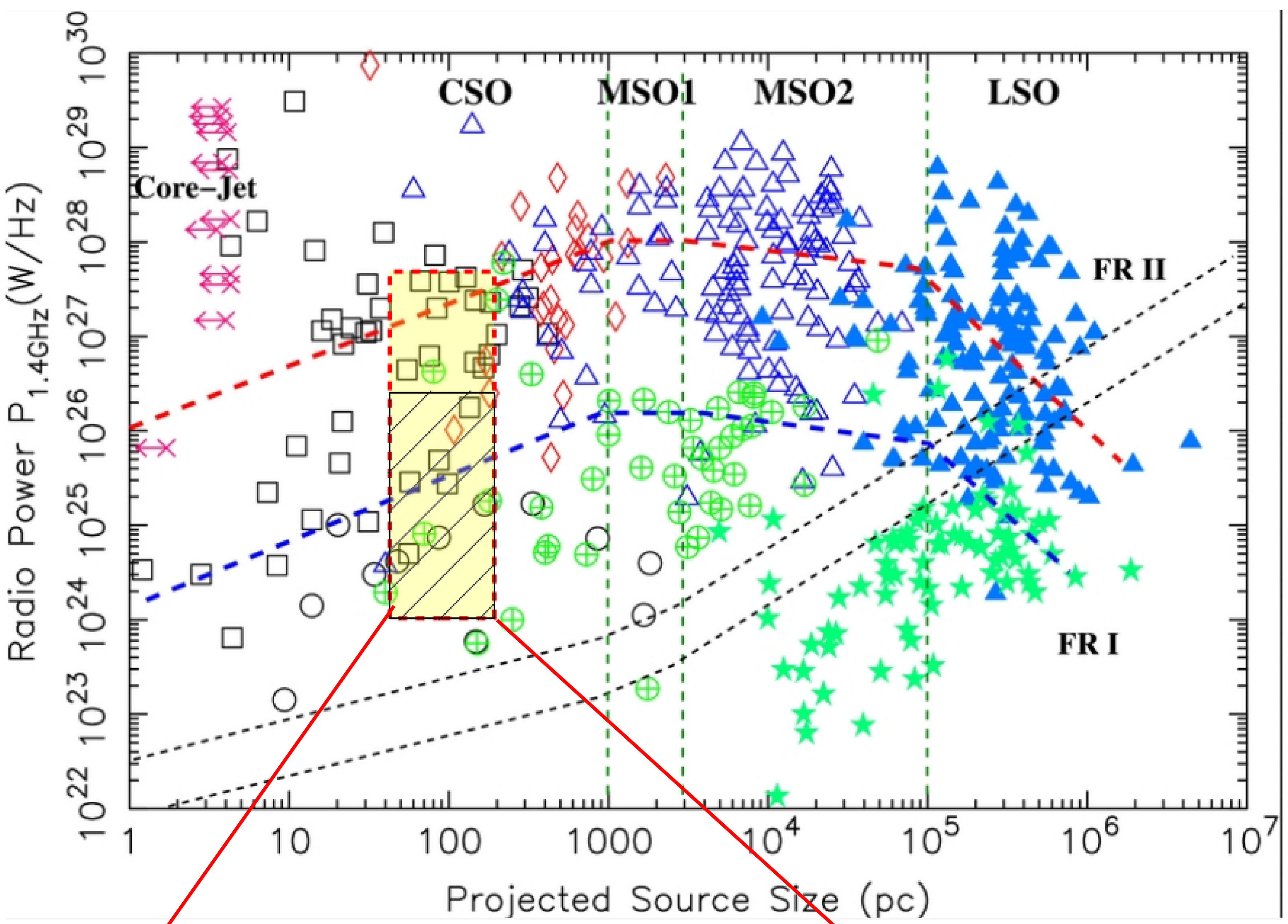


Figure 2. Examples of VLBA images at 5 GHz of CSOs (left column) and core-jet blazars (right column). The inset shows the VLBA image at 1.4 GHz from the mJIVE-20 project (Deller & Middelberg 2014).



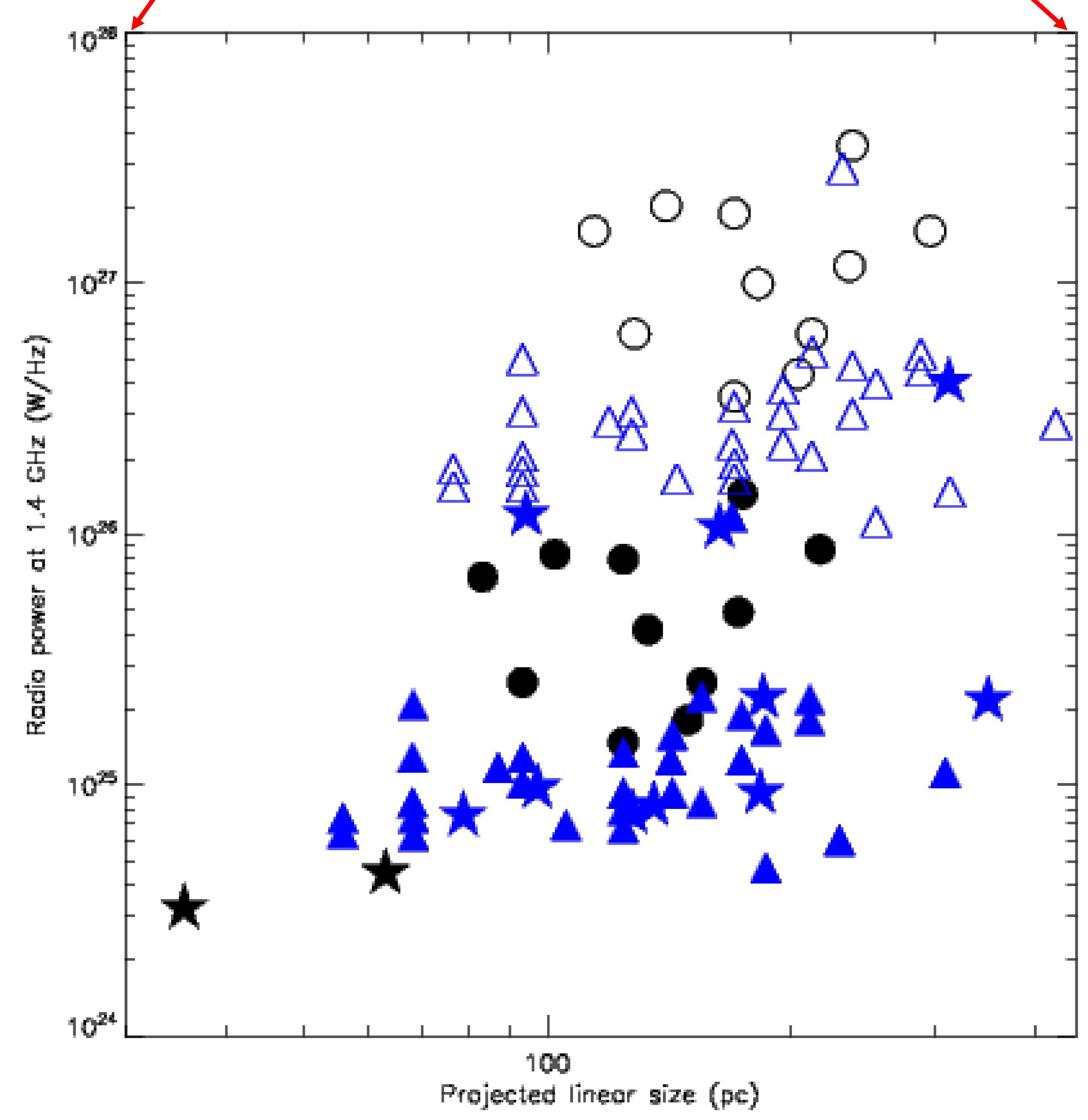


*Figure 1. **Top**: Radio power vs linear size for extragalactic radio sources (adapted from An & Baan 2012). The yellow area shows the locus of the selected sources.*

***Bottom:** The power-size plot for the candidate CSOs from our sample. Black circles/stars are the sources already observed at 5 GHz with VLBA (core-jet blazars have been removed), while the blue triangles/stars are the remaining objects. Filled and empty symbols refer to values computed assuming redshift 0.5 and 2, respectively. Stars indicate objects with known redshift.*

PRELIMINARY RESULTS

- We found 12 CSOs with two-sided steep-spectrum components, and 8 blazars with a steep-spectrum one-sided jet emerging from a flat-spectrum compact core (Fig. 2).
- In 3 CSOs we could detect the flat-spectrum core between the lobes, and 4 CSOs show significant flux-density asymmetry (flux ratio > 2).
- The radio power at 1.4 GHz and the linear size of the observed sources are in the range (3.2 – 87) $\times 10^{24}$ W/Hz (or up to 3.5×10^{27} W/Hz at z=2.0), and 35 – 215 pc (or up to 300 pc at z=2.0).

FUTURE PLANS

- **RADIO:** we plan to perform VLBI observations at 5 GHz of the remaining sources of the sample in order to populate the region of power-size plane which is still highly unknown. Observations of further 9 sources with peak > 6 mJy/beam have already been requested.

- **OPTICAL:** we will request optical observations of the sources that turn out to be CSOs and for which no counterpart is detected in SDSS or Pan-STARRS images. Unveiling the host galaxy and its redshift is pivotal for computing physical parameters, like luminosity, size, and estimate the advance velocity and magnetic field.

Results will be compared with the outcome of dedicated MHD simulations of low-power decelerating jets (e.g., Rossi et al. 2020, A&A, 642, 69). This will allow us to study various evolutionary paths for low-power CSOs and investigate the importance of jet deceleration and jet-ISM interaction.