Open our eyes to wider fields in VLBI surveys

Kristóf Rozgonyi [1] and Sándor Frey [2]

[1]Department of Physics of Complex Systems, Eötvös Loránd University, H-1117, Pázmány Péter sétány 1/A, Budapest, Hungary; e-mail: rstofi@gmail.com

[2]FÖMI Satellite Geodetic Observatory, PO Box 585, H-1592 Budapest, Hungary; e-mail: sandor.frey@gmail.com

Abstract

The innermost pc-scale structure of radio-loud active galactic nuclei (AGN) can be directly studied with the technique of **very long baseline interferometry (VLBI)**. High-resolution VLBI imaging observations reveal the geometry and the physical properties of relativistic jets emanating from the vicinity of the accreting central supermassive black holes. **VLBI surveys** allow us to conduct statistical investigations of large source samples, and also to discover new phenomena or types of objects. High-quality VLBI imaging of hundreds or thousands of radio sources is an observationally and computationally intensive task. Moreover, the compact radio jet structure in AGN is usually **confined to the central region** of tens of milli-arcseconds (mas). The VLBI technique does not allow imaging with an undistorted field of view larger than typically a few arcseconds at cm wavelengths. However, for practical reasons, often a much **smaller fraction of the field**, the central region is imaged only. Here we introduce an automated imaging process and present its application to the publicly available calibrated visibility data of a prominent VLBI survey. We imaged the ~1.5-arcsec radius fields around more than 1000 radio sources, and found a variety of **radio structures that extend to ~100-mas scales** in a small subset of the sample. Some of them were missed in the original survey and are yet unknown in the literature. We also give possible interpretations of these structures.

Treasure-house of data: VIPS

We examined the **VLBA Imaging and Polarimetry Survey (VIPS)** [1]. It contains 1127 AGN observations (Figure 1) taken at 5 GHz with the Very Long Baseline Array (VLBA) interferometer. The calibrated VLBI visibility data sets can be downloaded from the VIPS data collection index page [2]. The **original field of view** of the interferometer was ~1.5 arcsec but the imaging was typically preformed only in the **central area** of 128 mas×128 mas. Even though large structures were reported in the original publication, we could find further objects in the full-field images with structures extending beyond the central area.

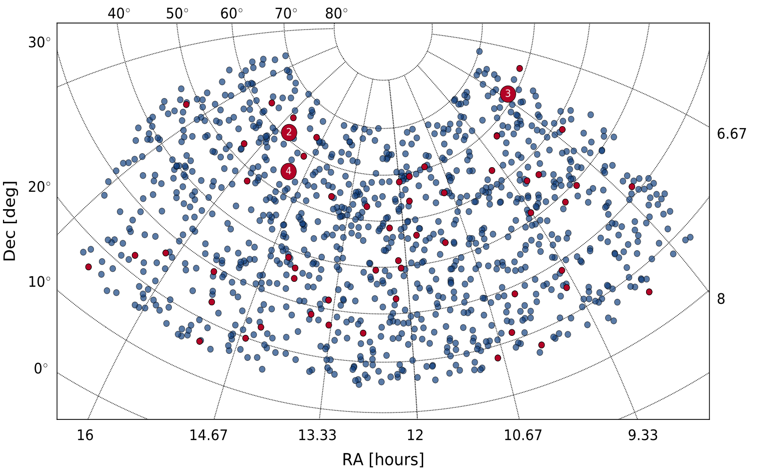

Figure 1: Stereographic projection of the 1127 VIPS source positions. The blue and red dots correspond to sources with no extended structure and candidates, respectively. The large red dots with the respective figure number correspond to the example images.

J15398+6113

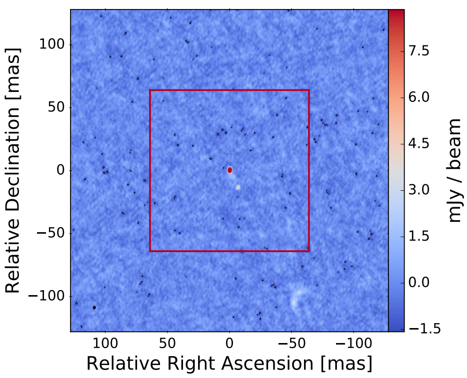

Figure 2: VLBI image of J15398+6113, a typical member of the sample of extended candidates. There is a faint diffuse emission region at ~120 mas distance from the core, in the same position angle as the inner jet structure. The red square indicates the area originally imaged in VIPS.

References

[1] Helmboldt J. F. et al. (2007), *Astrophysical Journal*, **658**, 203

[2] http://www.phys.unm.edu/~gbtaylor/VIPS/vipscat/vipsncapindx.shtml

[3] Shepherd M.C. et al. (1994), *Bulletin of the American Astronomical Society*, **26**, 987

Imaging of the extended field

The large sample size and the extended fields motivated us to image the sources and analyse the data in an **automated way**. The imaging and model fitting were performed through standard procedures using Difmap [3]. We modeled the visibility data with a central elliptical **Gaussian component**. In addition, extended structures were fitted with circular Gaussians. The number of these components was determined by the signal-to-noise ratio (SNR) in the residual map. We applied a 6-σ threshold for fitting a new component, as done in [1]. Thereafter, we calculated the separation of the circular components from the central elliptical Gaussian. We marked the sources with at least one fitted component **farther away than 50 mas** from the centre as candidates for having large-scale structure within the full VLBA field of view.

J07521+6112

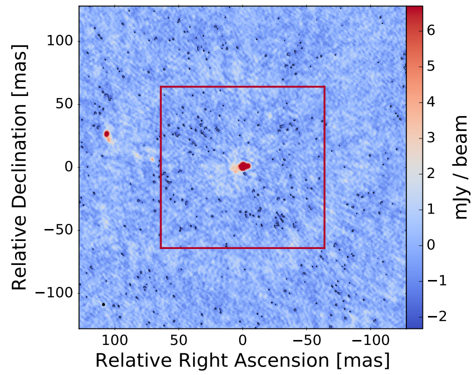

Figure 3: VLBI image of the distant source J07521+6112, with a jet structure extending up to ~100 mas from the central component, towards the east.

J15048+5438

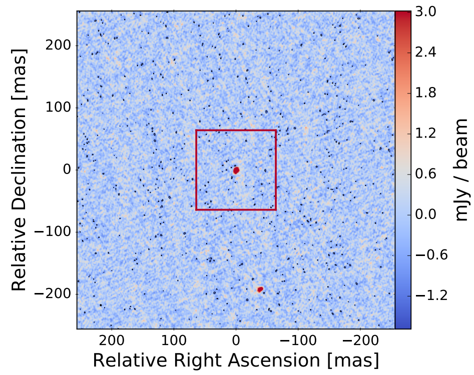

Figure 4: VLBI image of J15048+5438. A compact component is seen ~150 mas south of the central component. Follow-up multi-frequency observations could be useful to decide if this is a kpc-separation dual radio AGN, a gravitationally lensed background source with two images, or an AGN core plus a hot spot embedded in an extended lobe that is resolved out with the VLBA.

Results and plans for the future

We found **60 sources as candidates** with extended structure among the 1127 VIPS sources. To check the quality of the candidate sample, we visually inspected all the wide-field images. We found that in a few cases the distant components are unreliable because of the low flux density of the fitted components. An increased SNR threshold in the automated model-fitting procedure would eliminate these questionable cases. Certainly further quantitative classification of the sample is needed (and planned). Published information from the literature, analysis of archival data, and eventually new targeted observations would be necessary to reveal the true nature of these objects, on a case-by-case basis. These sources show **great diversity in morphology and brightness**. The large, typically ~0.1–1 kpc-scale structures could most probably be **extended jet structures**. However, the possibility of **dual radio AGN or gravitationally lensed radio sources** should also be investigated. As an illustration, here we present **three representative examples** (Figures 2–4) from the candidate sample. For these objects, the extended morphology seen in the images made from the reprocessed VIPS data with a field of view larger than the original one is yet unknown in the literature. We plan to perform the same automated procedure with other publicly available survey data, in a hope to find further objects with VLBI structure extended **beyond what is already known**.