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VLBA Observations of Bright High Frequency Peakers

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Abstract: The anticorrelation between the turnover frequency in the radio spectrum and the projected linear size (indicative of the age in the currently favoured *youth model*) in powerful and intrinsically compact radio sources suggests that the youngest objects must have the highest turnover frequencies. We present preliminary results of new VLBA observations of a sample of sources peaking at frequencies higher than a few GHz, making them good candidates for being *newly born* sources. Our initial analysis deals with the morphological classification which allows us to study the contamination from beamed sources dominated by a single unresolved component.

Keywords: galaxies: active — quasars: general — radio continuum: galaxies

1 Scientific Background

The study of the population of powerful and intrinsically compact CSS/GPS (compact steep spectrum/gigahertz peaked spectrum) sources has led to the discovery of a correlation between the turnover frequency ($\nu_{\rm max}$) in the radio spectrum and the projected angular size (θ). This correlation is expected from the synchrotron self absorption (SSA) theory, where $\theta^2 \propto \nu_{\rm max}^{-5/2}$, and supports the hypothesis that the spectral peak is indeed caused by SSA (even if the free–free absorption, FFA, mechanism could play a role (Bicknell, Dopita, & O'Dea 1997; Mutoh et al. 2002)).

In the current favoured model (the youth scenario) the small linear size is related to the age of the source, implying that the youngest objects have the highest turnover frequencies.

We aim to find objects younger than the CSS/GPS radio sources by selecting them on the basis of their peaked spectrum. The available samples of CSS/GPS sources have a range in turnover frequencies from ~100 MHz to ~5 GHz. Objects with turnover frequencies above 5 GHz, which we call high frequency peakers (HFPs), would represent smaller/*younger* sources. One of the disadvantages of this approach is the contamination from beamed radio sources like blazars which possess radio spectra peaking above a few GHz as the result of self-absorbed synchrotron emission from the jet base. Complete and correct morphological and spectral information is a key element for the selection of very young objects.

2 The Bright HFP Sample

The selection of the bright complete sample of candidate HFPs ($S \geq 300$ mJy at 4.9 GHz) has been done in two steps (Dallacasa et al. 2000):

- cross-correlation of the 87GB catalogue (4.9 GHz) with the NVSS catalogue (1.4 GHz) and selection of the sources with inverted spectra and with slope steeper than -0.5 ($S \propto \nu^{-\alpha}$);
- removing from the sample variable flat spectrum sources by means of simultaneous multifrequency VLA observations (40 s on each source, at 1.365, 1.665, 4.535, 4.985, 8.085, 8.485, 14.96, and 22.46 GHz).

A selection criterion based only on two observations at different epochs does not guarantee us to be free from the contamination of variable flat spectrum sources, as in an outburst state their spectra could be inverted.

The final sample consists of 55 sources whose radio spectra peak at frequencies ranging from a few GHz to 22 GHz. We remark also that five objects have flux densities still rising at 22 GHz even if their spectral index is close to zero. About half of the sources were previously optically identified in the literature, mostly with high redshift quasars. The optical identification work is ongoing (Dallacasa, Falomo, & Stanghellini 2002) and it is confirming that among the hosts of HFP sources the fraction of galaxies, as opposed to quasars, is rather small (about 30% at most) compared to the CSS/GPS samples (Fanti et al. 1990; O'Dea 1998; Stanghellini et al. 1998).

Figure 1 shows the anticorrelation between linear size and turnover frequency in the rest frame for the Fanti et al. (1990) CSS sample and Stanghellini et al. (1998), Snellen et al. (1998) GPS samples. The line is the expected correlation between the linear size, LS, and ν_{max} in the case of SSA (R. Fanti 2002, personal communication). In the same plot the HFPs with known redshifts are shown. The

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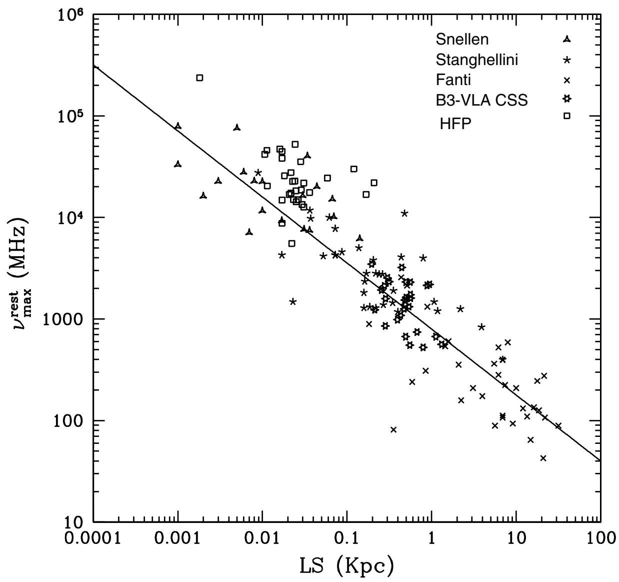

Figure 1 Rest frame turnover frequency vs linear size for CSS/GPS samples and for the HFP sample.

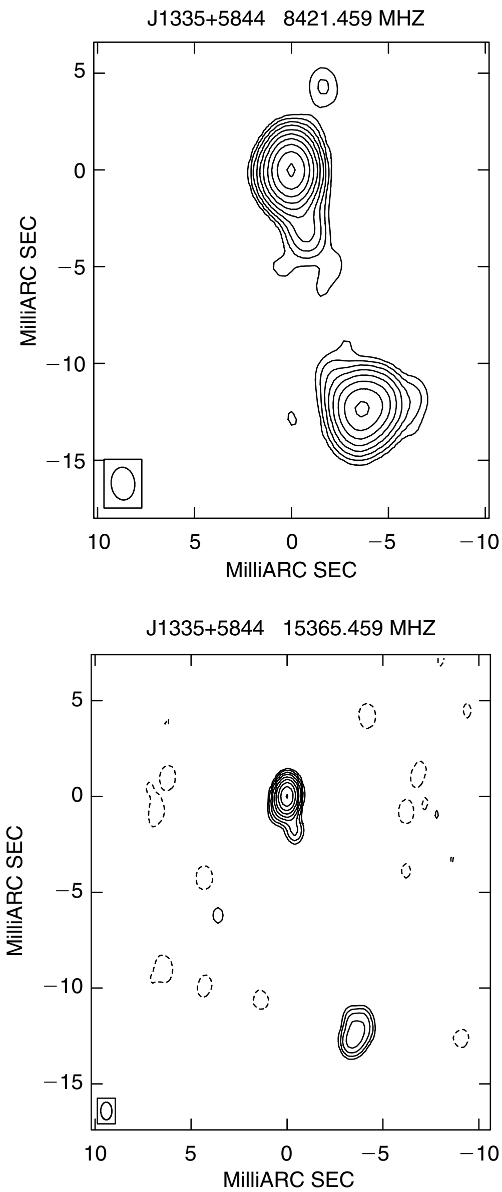

Figure 2 1335+5844: 8.4 GHz (top) and 15.4 GHz (bottom).

spectral peak is calculated by fitting the simultaneous radio spectra of the sources using the VLA data while the linear size is derived from observations of these candidates found in various databases: the VLBA Calibrator Survey (VCS), the Radio Reference Frame Image Database (RRFID), the Caltech–Jodrell Bank, VLBA 2 cm (Kellerman et al. 1998) and 6 cm (Fomalont et al. 2000) Database. The distribution of these sources across the ν–LS plane is consistent with being continuous.

3 New VLBA and VLA Observations

We plan to complete the identification of this sample using both high frequency VLBA and multifrequency VLA observations.

- **VLBA observations.** High resolution imaging together with spectral information is very important to correctly classify the radio sources. Fifty sources from the bright HFP sample were observed with the VLBA at two different frequencies well above the spectral peak, in the optically thin part of the spectrum. A few sources for which we already had satisfactory morphological information were not included in those observations. The morphology expected for intrinsically small and young objects is that of compact symmetric objects (CSOs), eventually asymmetric in flux density. On the other hand, core–jet radio structure is typical of blazar objects and they are also known to possess some degree of flux density and spectral variability. An example of a good CSO-like morphology candidate is J1335+5844 (no optical identification is available), shown in Figure 2. The overall angular size is ~18 mas, with two main regions of emission, the northern one brighter and smaller (but resolved) than the southern one. The results from these observations will allow us to determine the spectral index distribution which is very important in order to correctly classify the nature of the components, to possibly locate the core and to determine the radio morphology.
- **VLA observations.** New VLA observations in B configuration at 1.465, 1.665, 4.565, 4.935, 8.085, 8.465, 14.94 and 22.46 GHz have been approved. The proposed observations will address the following questions:
  - study the variability in both flux density and spectral shape: among the sources classified as genuine HFPs from the previous VLA observations flux density variability is not uncommon (see Dallacasa et al. 2000);
  - define the polarisation properties of these sources: absorption mechanism (SSA or FFA), physical conditions in and around the source, ordering and

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direction of the magnetic field may be investigated via polarisation studies (Cotton et al. 2003);
- determine if there is any extended emission by means of sensitive 1.4 GHz observations: extended emission associated with sources with convex spectra can be explained by recurrent nuclear activity, i.e. the young compact radio source is propagating out amidst the relic of the previous epoch of activity (Baum et al. 1990).

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