Constraining the magnetic field in the parsec-scale jets of the brightest *Fermi* blazars with multifrequency VLBI observations

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We report on measurements of magnetic field strength in parsec-scale radio structures of selected bright *Fermi* blazars, based on synchrotron spectrum fitting to VLBA images made at seven frequencies in the 5-43 GHz range.

Introduction

We fit broad band radio spectra of selected bright *Fermi* blazars using 5-43 GHz VLBA observations made during the first year of *Fermi* operations. We use a homogeneous synchrotron source model (Pacholczyk, 1970) and reconstruct the magnetic field and particle energy distribution. In most cases, only an upper limit on the magnetic field strength could be placed, because spatial regions where the spectral turnover is detected usually remain unresolved.

Model reliability

Whenever feasible, the frequency-dependent core position (the "core shift" effect) was taken into account when aligning VLBI images at different frequencies. The physical parameters presented in Table 1 correspond to typical values for emitting electrons inside a large area of a few milliarcseconds in size. In smaller regions the parameters may be different if the electrons inside these regions do not contribute significantly to the total emission in the observed frequency range. The results are consistent with estimates obtained by a method based on model-fitting bright VLBI components with 2D Gaussian functions (see Fig. 2 and Savolainen et al., 2008). We note that the model-fitting based approach enables to put tighter limits on the magnetic field strength because it usually has higher angular resolution.

Electron energy spectrum

The spectra above the synchrotron turnover are nearly flat or slightly inverted in many observed sources. This may result from blending of a few emission components with different peak frequencies (an example may be seen in the core region of BL Lacertae, see the top right panel in Fig. 2). Alternatively, a nearly flat spectrum may imply hard energy spectrum of the emitting electrons (as may be the case for the component B1 in jet of BL Lacertae which spectrum is presented on the lower right panel in Fig. 2, see also Table 2). The hard electron spectrum is difficult to explain by conventional acceleration mechanisms.

Results

Since γ-ray emission in blazars is suggested to originate from regions spatially close to the VLBI core, the estimations of the magnetic field strength and electron energy distribution presented in Table 1 could be used to constrain SED models.

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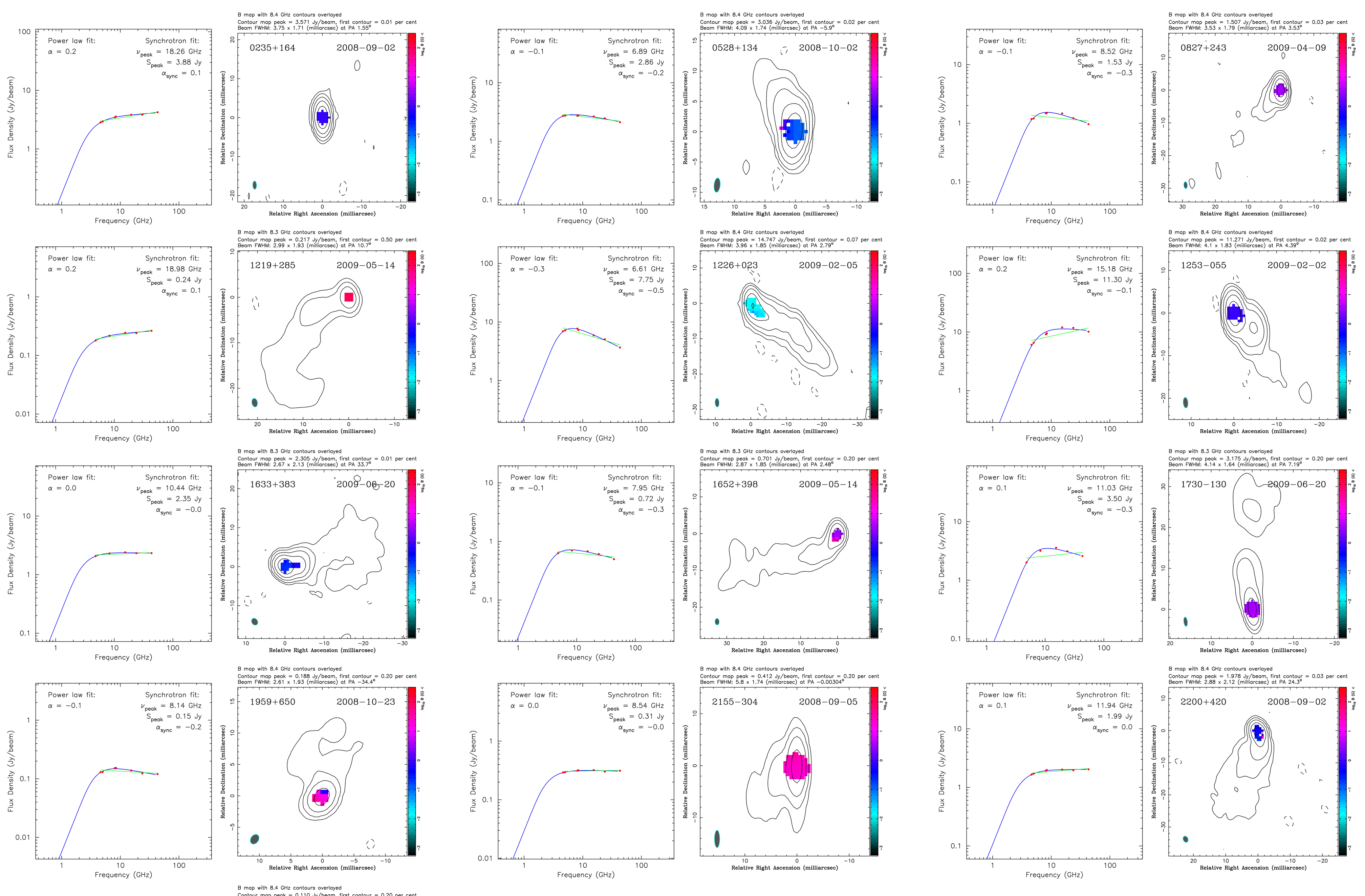

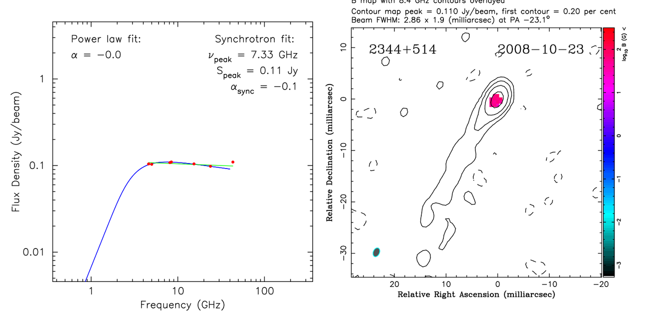

Figure 1. VLBI images and spectra of 13 sources for which the synchrotron self-absorption turnover frequency was measured. Shaded area on the images marks the region to which the upper limit on the magnetic field strength presented in the Table 1 correspond.

Table 1: Physical parameters estimation

Source	B1950	Epoch	$p^{a,b}$	$B_\perp^{b,c}$ (G)	Comments
AO 0235+16	0235+164	2008-09-02	0.8	≤ 0.89	
	0528+134	2008-10-02	1.4	≤ 0.12	
	0716+714	2009-02-05			inverted spectrum $\alpha = 0.4$, model N/A
OJ 248	0827+243	2009-04-09	1.6	≤ 3.4	
OJ 287	0851+202	2009-02-02			inverted spectrum $\alpha = 0.7$, model N/A
W Com	1219+285	2009-05-14	0.8	≤ 108	preliminary analysis
3C 273	1226+023	2009-02-05	2.0	≤ 0.016	
3C 279	1253−055	2009-02-02	1.4	≤ 0.89	
	1510−089	2009-04-09			inverted spectrum $\alpha = 0.2$, model N/A
4C 38.41	1633+383	2009-06-20	1.0	≤ 0.24	preliminary analysis
Mrk 501	1652+398	2009-05-14	1.6	≤ 3.5	preliminary analysis
	1730−130	2009-06-20	1.6	≤ 3.6	preliminary analysis
	1959+650	2008-10-23	1.4	≤ 17	
	2155−304	2008-09-05	1.0	≤ 26	
BL Lac	2200+420	2008-09-02	1.0	≤ 0.44	
3C 454.3	2251+158	2008-10-02			inverted spectrum $\alpha = 0.9$, model N/A
	2344+514	2008-10-23	1.2	≤ 57	43 GHz data not included in the fit

^{a} p is the power law index in the electron energy distribution $N(E) = N_0 E^{-p}$.
Note, that for the optically thin part of the synchrotron spectrum $p = 1 - 2\alpha$, where α is defined as $S_\nu \sim \nu^\alpha$.
^{b} The estimations correspond to the region of parsec–scale radio core.
^{c} The values are in the observer's frame.

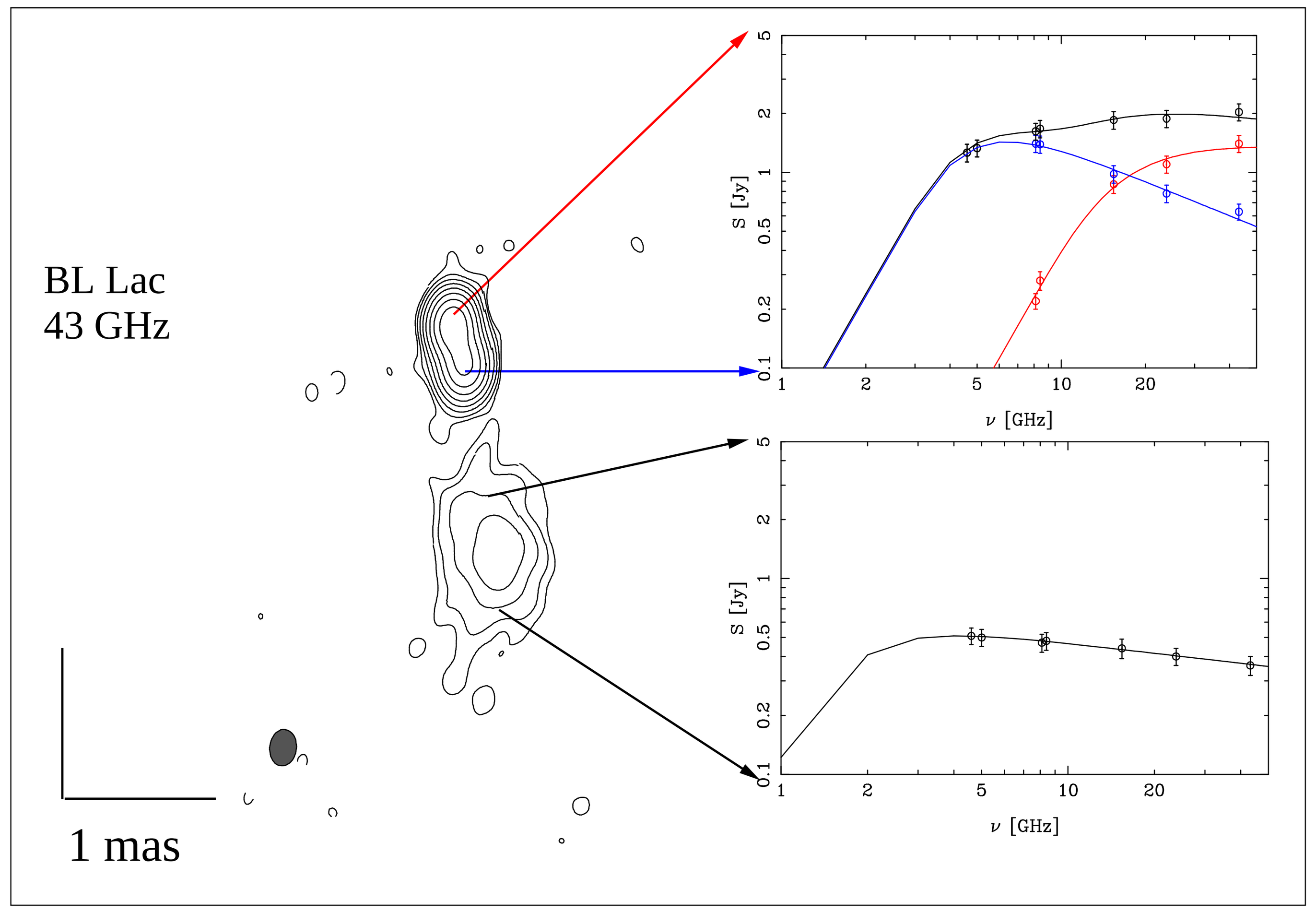

Figure 2. Results of the model-fitting based analysis of BL Lacertae. The source structure was approximated with Gaussian components (see Table 2). The fitting was conducted in the the uv plane. The two inner components are unresolved while the third component (B1) is resolved at 43 GHz. Unfortunately, the peak frequency for B1 is not well constrained, however, following Marscher (1983) we can put an upper limit on the magnetic field strength in this component B<0.06 G (observer's frame).

Table 2: BL Lacertae model component parameters

Component	Distance (mas)	ν_m (GHz)	S_m (Jy)	α
C1 (core)	0	> 43	> 1.02	$--$
C2	0.26	6.4	1.43	-0.58
B1	1.47	< 4.1	> 0.51	-0.17

ν_m — synchrotron self-absorption peak frequency.
S_m — synchrotron self-absorption peak flux.
α — spectral index in the optically thin part of the spectrum.

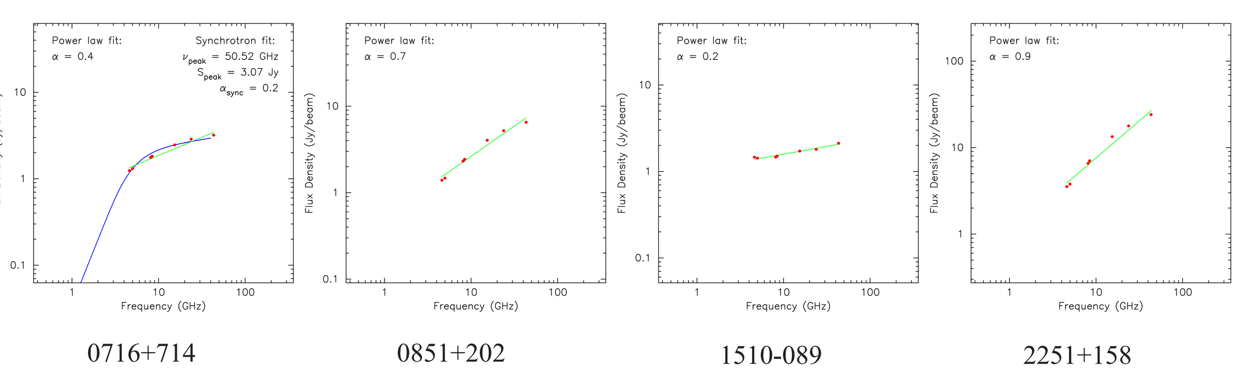

Figure 3. VLBA spectra of sources which spectra can not be adequately described by the simple homogeneous model.