The Astronomical Journal, 133:1947–1953, 2007 May

37 GHz OBSERVATIONS OF A LARGE SAMPLE OF BL LACERTAE OBJECTS

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Received 2006 June 21; accepted 2007 January 5

ABSTRACT

We present 37 GHz data obtained at Metsähovi Radio Observatory from 2001 December to 2005 April for a large sample of BL Lacertae objects. We also report the mean variability indices and radio spectral indices in frequency intervals 5–37 and 37–90 GHz. Approximately 34% of the sample was detected at 37 GHz, 136 BL Lacertae objects in all. A large majority of the detected sources were low-energy BL Lac objects. The variability index values of the sample were diverse, the mean fractional variability of the sample being $\Delta S_2 = 0.31$. The spectral indices also varied widely, but the average radio spectrum of the sample sources is flat. Our observations show that many of the high-energy BL Lac objects, which are usually considered radio-quiet, can at times be detected at 37 GHz.

Key words: BL Lacertae objects: general — galaxies: active — radio continuum: galaxies

Online material: machine-readable tables

1. INTRODUCTION

BL Lacertae objects (BLOs) demonstrate the most violent behavior known among active galactic nuclei (AGNs). Their basic properties include high optical polarization, rapid and strong variability, and a near-featureless spectrum (Stein et al. 1976; Kollgaard 1994; Jannuzi et al. 1994; for an extensive review on AGNs, see Urry & Padovani 1995). The selection criteria in many surveys also include a flat radio spectrum ($S \propto \nu^{-\alpha}$, $\alpha \leq 0.5$; Padovani & Giommi 1995a and references therein).

The spectral energy distributions (SEDs) of BLOs are thought to consist of two components: a synchrotron component at lower frequencies and an inverse Compton component at higher frequencies. The locations of the components in the log ν-log νF_ν plane vary greatly, and this has been used as a classification basis for BLOs (Padovani & Giommi 1995b; Giommi et al. 1995; Sambruna et al. 1996; Nieppola et al. 2006, hereafter Paper I). For low-energy peaked BL Lac objects (LBLs) the peak frequency of the synchrotron component is at radio and IR frequencies, for intermediate BL Lac objects (IBLs), in the optical and UV frequencies, and for high-energy peaked BL Lac objects (HBLs), in the X-ray band. To further explore the physics behind this spectral sequence, it is important to know what the properties are that set LBLs and HBLs apart.

Radio monitoring provides insight into the variability characteristics and long-term behavior of AGNs. Metsähovi is one of the few observatories that target the high radio frequencies, and the only one observing at 37 GHz. BLOs have been observed by Metsähovi as part of the ongoing Metsähovi-Tuorla Observatory collaboration project. There are currently 398 BLOs in the Metsähovi AGN sample. We wanted to study this large sample of BLOs at 37 GHz because many of them had not previously been studied at high radio frequencies. Our aim was to measure the flux densities of the various subsamples of BLOs in order to get a full understanding of the high radio frequency behavior of these objects, all the way from the radio-selected BL Lac objects (RBLs) to the X-ray-selected BL Lac objects (XBLs). HBLs and XBLs have not been actively studied in the high radio frequency domain. Even though XBLs seem to be significantly weaker at radio wavelengths than RBLs, there is little evidence of radio-silent BLOs. Stocke et al. (1990) suggested that they do not exist, and even though there have been some recent studies on possibly completely radio-silent BLO candidates (Londish et al. 2002, 2004), the number of such BLOs is probably low. Because the only high radio frequency study on XBLs is a very small sample studied by Gear (1993), and only the low-frequency radio flux densities of these sources are known in general, it is possible that some of the rarely studied BLOs exhibit surprising spectral shapes in the high radio frequency domain, such as the extreme inverted-spectrum sources (Tornikoski et al. 2000, 2001; Torniainen et al. 2005).

Our studies also support the work of the Extragalactic Foreground Sources working group of the *Planck* satellite,[4] particularly that of the Low Frequency Instrument Consortium. In preparation for the *Planck* mission, one of our tasks is to estimate the number of extragalactic sources detectable at the *Planck* frequencies. The existence of unforeseen bright sources could seriously affect the primary task of *Planck*, i.e., the mapping of the cosmic microwave background (CMB). The theoretical aspects of blazar contamination in CMB maps have been thoroughly studied by Giommi & Colafrancesco (2004), Giommi et al. (2006), and Toffolatti et al. (1998). Because of the lack of actual measurements at high radio frequencies, many of the source statistics have been based on extrapolated low-frequency data. Therefore, we find it important to investigate in practice whether there will be source populations or subpopulations that are brighter in the high radio frequencies than earlier assumed, especially populations that exhibit significant variability and can, at times, make a significant contribution to the contamination of the CMB maps. It is vital to understand the high radio frequency behavior of the various BLOs to see how many of them, at least some of the time, can also be detected by *Planck*.

The main objective of this paper is to publish the data we have collected for almost 3 and a half years. We have also calculated

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[4] See http://www.rssd.esa.int/Planck.

TABLE 1
THE METSÄHOVI BL LAC SAMPLE

Source Name	R.A. (J2000.0)	Decl. (J2000.0)	Class[a]
NRAO 5	00 06 13.9	−06 23 36	LBL
RX J0007.9+4711	00 07 59.9	+47 12 07	IBL
MS 0011.7+0837	00 14 19.7	+08 54 04	HBL
RXS J0018.4+2947	00 18 27.8	+29 47 32	...
PKS 0017+200	00 19 37.9	+20 21 46	LBL

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Table 1 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

[a] As determined in Paper I.

some descriptive parameters for the sample. In § 2 we introduce the sample and describe the observations, and in § 3 we state the detection rates by class. In §§ 4 and 5 we report the values of the variability indices and spectral indices we found for the sample, and in § 6 we say a few words about the variability timescales. We finish with a discussion and conclusions in §§ 7 and 8. All statistical tests have been performed with the Unistat software, version 5.0.

2. THE SAMPLE AND OBSERVATIONS

The Metsähovi BLO sample consists of 398 objects, of which 382 are from the Véron-Cetty & Véron BLO catalog (Véron-Cetty & Véron 2000) and 17 are from the literature. Véron-Cetty & Véron (2000) consists of sources from several different surveys with a wide range of selection criteria. The Metsähovi sample is one of the largest BLO samples ever studied and offers a relatively unrestricted view of this group of AGNs. The declination range covered by the Metsähovi BLOs is from -11° to 86°.

Most of the sample sources were classified as LBL/IBL/HBL in Paper I based on their synchrotron peak frequencies, $\nu_{\rm peak}$, calculated from a parabolic fit to their SEDs. The class boundaries were $\log \nu_{\rm peak} \leq 14.5$ for LBLs, $14.5 < \log \nu_{\rm peak} \leq 16.5$ for IBLs, and $\log \nu_{\rm peak} > 16.5$ for HBLs. There are 98 LBLs, 96 IBLs, and 110 HBLs in the sample; 94 sources remained unclassified on account of poor spectral fits. The full source sample is listed in Table 1. For most sources, we use the object naming convention adopted from Véron-Cetty & Véron (2000). The subclass of each source is also listed.

The Metsähovi radio telescope is a radome-enclosed antenna with a diameter of 13.7 m. It is situated in Kirkkonummi, Finland, at 60 m above sea level. It has been used for AGN variability studies at 22, 37, and 87 GHz. The observations for this project were carried out using the 37 GHz receiver, which is a dual-horn, Dicke-switched receiver with an HEMT preamplifier operated at room temperature. The observations are ON-ON observations, alternating between the source and the sky in each feed horn. A typical integration time for one flux density data point is 1200–1600 s, and the detection limit under optimal weather conditions is approximately 0.2 Jy. As a primary flux calibrator we use DR 21, and as secondary calibrators 3C 84 and 3C 274. The error values include the contribution from the measurement rms and the uncertainty of the absolute calibration. For more details about the Metsähovi observing system and data reduction see Teräsranta et al. (1998).

The observations reported in this paper were performed between years 2001.95 and 2005.27. All flux densities and upper limits are listed in Table 2. The number of observations, $N_{\rm obs}$, for each source varies greatly. The most observed sources include BL Lac, OJ 287, Mrk 421, AO 0235+164, and S5 0716+714. They all have more than 100 data points, S5 0716+714 topping the list with 355 measurements. Such a high number of measurements is exceptional because an overwhelming majority of the sample (96%) have $N_{\rm obs} < 10$. The source S5 0716+714 was the target of an intensive multifrequency campaign in 2003 November (Ostorero et al. 2006). Before the start of the actual campaign it exhibited extremely active behavior in the radio domain and was monitored very frequently, especially in late 2003 and 2004.

The observation interval for each source also varies; for sources with $N_{\rm obs} > 5$ the average interval is 0.34 yr, or approximately 124 days. For objects observed five times or less, the average interval is on the order of 13 months.

Some of the best-known, radio-bright sources in the sample were also observed at Metsähovi prior to 2001 as part of the extragalactic sources monitoring project (Teräsranta et al. 1992, 1998, 2004, 2005). Many of them have frequently sampled flux curves dating back to the beginning of the 1980s. If these data are included, 21 sources in all have more than 100 measurements. We will discuss the flux curves and variability timescales of this limited BLO sample using the full data set in a forthcoming paper (E. Nieppola et al. 2007, in preparation).

3. DETECTION RATES

Table 3 lists the detection rates for the whole sample and the BLO classes separately. The detection limit is a signal-to-noise ratio (S/N) >4, typically ranging from 0.2 to 0.6 Jy depending on weather conditions. Approximately one-third of the sample has been detected at S/N > 4 at 37 GHz, although all of them have been measured at least once. Most of the detected sources are LBLs, and only 1/10 are HBLs. This is due to the larger average radio luminosities of LBLs compared to HBLs. Luminosity correlations of BLO classes are discussed in detail in Paper I. The detected HBLs include objects that were at first deemed unlikely to be detected. Typically, there are a few nondetections and one detection. This suggests that there is variability in these sources as well, but normally we cannot detect it due to the faintness of

TABLE 2
37 GHz FLUX DENSITIES FOR THE METSÄHOVI BL LAC SAMPLE

Source Name	Obs. Year	Obs. Month	Obs. Day	Obs. Time (UT)	Julian Date	Flux Density (Jy)
NRAO 5	2002	5	24	06:40	2,452,418.778	1.71 ± 0.17
NRAO 5	2003	3	30	09:20	2,452,728.889	2.94 ± 0.25
NRAO 5	2005	2	9	13:10	2,453,411.049	2.69 ± 0.16
RX J0007.9+4711	2002	3	17	06:28	2,452,350.769	<0.36
RX J0007.9+4711	2003	3	16	05:56	2,452,714.747	<0.2

NOTES.—The error is listed for S/N > 4 detections only; for nondetections we have calculated S/N > 4 upper limits. Table 2 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

TABLE 3
Detection Rates for the Metsähovi Sample

Class	Number of Detected Sources	Percent of Class Detected	Percent of All Detected Sources	Number of Undetected Sources	Percent of Class Undetected	Percent of All Undetected Sources
All sources	136	34.2	100	262	65.8	100
LBL	75	76.5	55.1	23	23.5	8.8
IBL	35	36.5	25.7	61	63.5	23.3
HBL.....	16	14.6	11.8	94	85.5	35.9

Notes.—The detection limit is S/N > 4. All detected sources have at least one S/N > 4 measurement. For all sources, $N_{obs} \geq 1$.

the source. Figure 1 depicts the distribution of the average fluxes of the sample. It emphasizes the difficulties of detecting the sources; roughly half of the detected sources have average fluxes under 0.5 Jy.

4. VARIABILITY AMPLITUDES

To examine the variability amplitude of the sample we calculated three variability indices:

$$\Delta S_1 = (S_{max} - S_{min})/S_{min}, \quad (1)$$

$$\Delta S_2 = (S_{max} - S_{min})/(S_{max} + S_{min}), \quad (2)$$

$$\Delta S_3 = S_{max} - S_{min}. \quad (3)$$

The first two describe the fractional variability, whereas the third is simply the absolute variability of the source; ΔS_1 explicitly gives the proportion of the flux change to the minimum flux. Thus, $\Delta S_1 = 1$ means that the source has increased its flux level to twice its minimum flux density during our observing period.

Only S/N > 4 detections were used in calculating the indices. The bare minimum of two detections needed to estimate the 37 GHz variability were available for 87 sources in total, of which 6 were HBLs, 17 IBLs, 58 LBLs, and 6 unclassified. Figure 2 shows the distributions of the indices. The average and median variabilities for the whole sample and BLO classes separately are listed in Table 4.

In the distributions of ΔS_1 and ΔS_2 (Fig. 2, *top and middle*) most of the objects can be found in the lower end of the range, followed by a high-variability tail. A clear exception from the general distribution is S5 0716+714, whose ΔS_1 is anomalously high, 17.47, and $\Delta S_2 = 0.9$. For this object an unprecedented radio outburst was recorded during our observing period (see

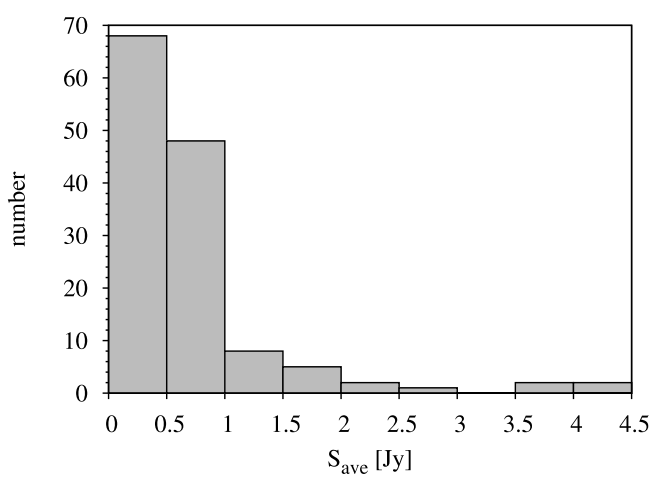

Fig. 1.—Distribution of the average fluxes of the sample sources.

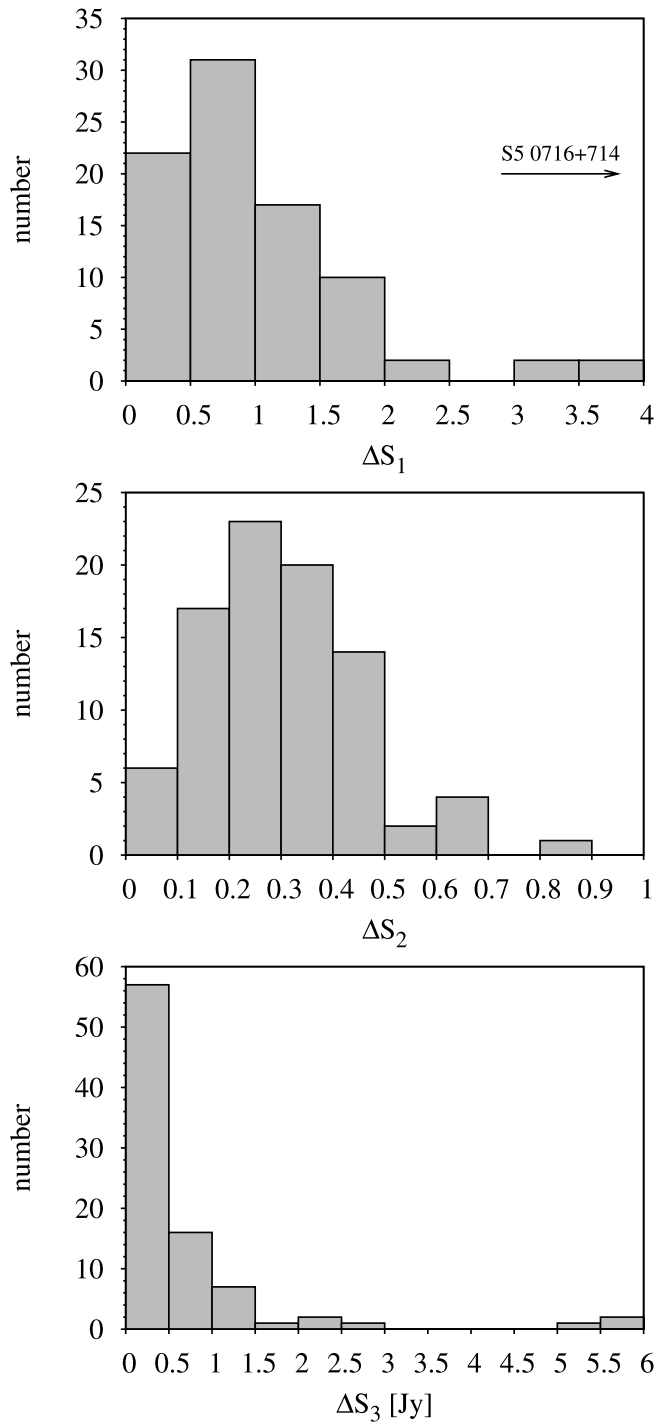

Fig. 2.—Distributions of the variability indices ΔS_1, ΔS_2, and ΔS_3. The object S5 0716+714 ($\Delta S_1 = 17.47$) has been omitted from the top panel for the sake of clarity.

TABLE 4

Variability Indices for the Whole Metsähovi Sample and BL Lac Classes Separately

Class	ΔS_1 Average	ΔS_2 Average	ΔS_3 Average	ΔS_1 Median	ΔS_2 Median	ΔS_3 Median	$N_{\rm det}$ Average	$N_{\rm det}$ Median
				All Data				
All sources	1.19	0.31	0.69	0.84	0.30	0.39	18.05	5.00
LBL	1.36	0.33	0.87	0.93	0.32	0.41	21.22	6.00
IBL	0.84	0.26	0.32	0.50	0.20	0.24	10.00	4.00
HBL	0.78	0.26	0.32	0.83	0.30	0.34	20.67	3.00
				$N_{\rm det} < 9$				
All sources	0.85	0.27	0.55	0.72	0.26	0.38	5.41	5.00
LBL	0.93	0.29	0.68	0.83	0.29	0.39	5.74	6.00
IBL	0.70	0.23	0.28	0.50	0.20	0.20	4.88	4.00
HBL	0.52	0.20	0.24	0.50	0.20	0.27	4.67	3.00

Notes.—Indices are as described in § 4, and $N_{\rm det}$ is the number of S/N > 4 detections for one source. In the top half all data are included, while in the bottom half data are limited to $N_{\rm det} < 9$. See text for details.

also § 6). The peaks of the distributions are $\Delta S_1 = 0.5$–1.0 and $\Delta S_2 = 0.2$–0.3. Looking at Figure 2 (*bottom*), it is clear that although the fractional variability of the sample sources is relatively high, their absolute variability is not. Even out of the detected sources, a large majority are very faint, and the flux levels increase less than 0.5 Jy. Noteworthy are the three sources at the far end of the scale, exhibiting flux changes of more than 5 Jy. These objects are S5 0716+714, OJ 287, and BL Lac.

As we see from the average results in Table 4, LBLs seem to exhibit slightly stronger variability than HBLs. The variability of IBLs is approximately the same as that of HBLs. However, there is a significant correlation between the number of detections, $N_{\rm det}$, and variability (Fig. 3), according to the Spearman rank correlation test. Radio-bright LBLs are observed more often, and therefore, they get a larger $N_{\rm det}$. The more measurements there are of a source, the more probable it is that it is observed during both a quiet and a flaring state, thus increasing its detected variability. To eliminate this selection effect, we calculated revised variability parameters for a sample in which $N_{\rm det} < 9$ for all sources. For those 30 sources that had nine detections or more, eight representative points were selected, with time intervals as regular as possible. We chose $N_{\rm det} = 8$ as the limit of the number of data points because below that point the correlation between $N_{\rm det}$ and ΔS_2 in Figure 3 disappears. The results for the $N_{\rm det}$-limited sample are also listed in Table 4.

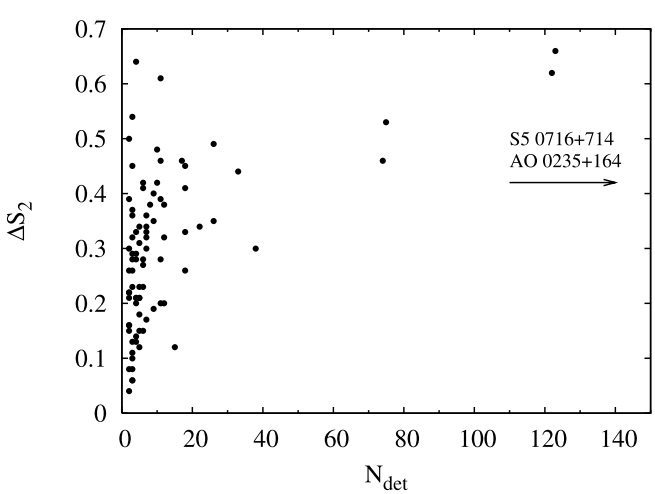

Fig. 3.—Variability ΔS_2 plotted against the number of detections $N_{\rm det}$. Data points for S5 0716+714 ($N_{\rm det} = 353$, $\Delta S_2 = 0.9$) and AO 0235+164 ($N_{\rm det} = 205$, $\Delta S_2 = 0.44$) have been excluded from the figure for the sake of clarity.

Limiting the value of $N_{\rm det}$ affected the two extremes (LBLs and HBLs) the most, while the variability parameters of IBLs remained almost the same (Table 4). This is because there are several LBLs with extremely high $N_{\rm det}$, and therefore very high variability, the most extreme object being S5 0716+714, for which $N_{\rm det} = 353$. Two examples of the six HBLs in the sample are the radio-luminous Mrk 421 and Mrk 501 ($N_{\rm det} = 74$ and 38, respectively). Because of the small number of HBLs, limiting the $N_{\rm det}$ values of these two objects had a big impact on the average variability index of the sample.

We looked for a possible correlation between ΔS_2 (Fig. 4) and the synchrotron peak frequency $\nu_{\rm peak}$ (as calculated in Paper I) using the Spearman rank correlation test. There was no significant correlation ($P = 0.25$). The lack of correlation between ΔS_2 and the synchrotron peak frequency also holds for the $N_{\rm det}$ -limited sample. This further emphasizes the continuity and uniformity of the BLO population found in Paper I. Usually RBLs are said to be more variable than XBLs, but our results so far give no sign of such a distinction.

5. SPECTRAL INDICES

We calculated spectral indices for frequency intervals 5–37 and 37–90 GHz to investigate the spectral behavior of BLOs

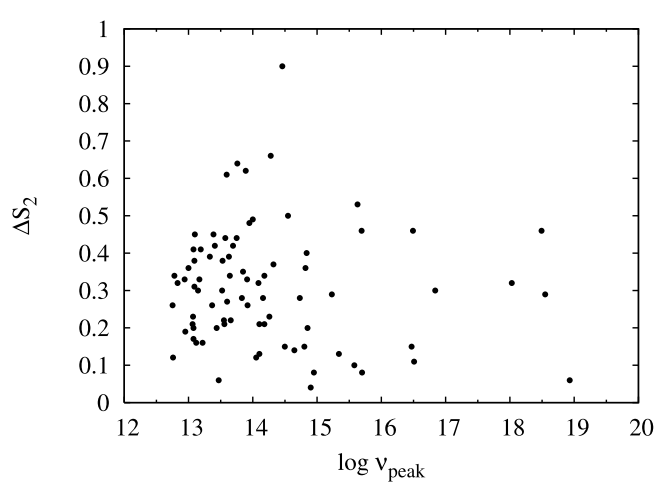

Fig. 4.—Variability ΔS_2 plotted against the synchrotron peak frequency $\nu_{\rm peak}$.

TABLE 5

Spectral Indices by Class for Frequency Intervals 5–37 and 37–90 GHz

Class	$\alpha_{\rm quiet}$ Average	$\alpha_{\rm flare}$ Average	$\alpha_{\rm ave}$ Average	$\alpha_{\rm quiet}$ Median	$\alpha_{\rm flare}$ Median	$\alpha_{\rm ave}$ Median
			5–37 GHz			
All sources	0.33	0.17	0.25	0.16	0.00	0.05
LBL	0.30	0.15	0.23	0.15	−0.02	0.01
IBL	0.28	0.07	0.16	0.13	−0.02	0.02
HBL	0.67	0.51	0.60	0.68	0.55	0.51
			37–90 GHz			
All sources	−0.10	0.15	0.00	−0.12	0.22	−0.02
LBL	−0.13	0.21	0.01	−0.10	0.36	−0.01
IBL	−0.03	0.23	0.09	−0.18	0.22	0.13

Notes.— The indices have been calculated with nonsimultaneous archival data. The 37–90 GHz indices of HBLs are omitted due to small sample size.

below and above 37 GHz. The spectral index is defined as $S_\nu \propto \nu^\alpha$. Only S/N > 4 detections were used. The results by class are shown in Table 5. The 37–90 GHz results for HBLs are omitted because there were only two HBLs with both 37 and 90 GHz data. The distributions of the indices can be found in Figure 5. The 5 GHz data are taken from the Astrophysical Catalogues Support System (CATS; Verkhodanov et al. 1997)[5] maintained by the Special Astrophysical Observatory, Russia. The 90 GHz data are taken both from CATS and from our observations with the Swedish-ESO Submillimetre Telescope (SEST) between 1987 and 2003.

In Table 5 and Figure 5 there are three different indices, $\alpha_{\rm quiet}$, $\alpha_{\rm flare}$, and $\alpha_{\rm ave}$. They are calculated from the minimum flux densities, maximum flux densities, and average flux densities, respectively. In both frequency intervals the range of indices was quite large. The maxima of the average indices were 2.23 and 1.09, and the minima were −0.56 and −1.47 in 5–37 and 37–90 GHz, respectively. As we see from Figure 5, the majority of the sources have flat ($\alpha > -0.5$) spectra in both intervals. The 5–37 GHz distribution has a tail toward the higher indices. There are 18 objects with $\alpha_{\rm ave} > 1$. Typically, these sources are X-ray-selected BLOs with little radio data. At 37 GHz in particular, 13 sources have only one S/N > 4 data point. It is plausible that these sources were in a flaring state at the time of the observation, which would result in an inverted spectrum. The 37–90 GHz distribution is less skewed but broader. S5 0716+714 has a conspicuously steep spectrum; its $\alpha_{\rm ave} = -1.47$. The steepness is exaggerated by the nonsimultaneity of the data; the 37 GHz average flux is strongly influenced by the high flux levels of the 2003 flare, whereas the 90 GHz data are from a quiescent state at an earlier epoch. For the whole sample, most of the data taken at 37 GHz were from observing epochs other than that for the 5 or 90 GHz data. Thus, we possess no information of the true shape of the continuum spectra during the various activity states. For a small subset of our sample we have managed to obtain truly simultaneous multifrequency spectra between 1 and 37 GHz. These results will be discussed in M. Tornikoski et al. (2007, in preparation). The nonsimultaneous spectral indices calculated in this paper only give us a crude estimate of the spectral behavior.

There are no major differences in the spectral indices between the BLO classes among the detected sources. For HBLs the 5–37 GHz indices are slightly more inverted than for LBLs and IBLs. The Spearman rank correlation test found no correlation between the spectral indices and the synchrotron peak frequency $\nu_{\rm peak}$, except for a marginal positive correlation for $\alpha_{\rm flare}$ and $\alpha_{\rm ave}$ at 5–37 GHz.

[5] Available at http://cats.sao.ru.

Generally, there is a correlation between spectral index and variability, steep-spectrum sources being on average less variable than flat-spectrum sources (Edelson 1987; Valtaoja et al. 1992). However, among the flat-spectrum sources, and especially among BLOs, no significant correlation has been detected. Our study is no exception: the 37 GHz variability depends on neither of the spectral indices according to the Spearman rank correlation test.

6. TIMESCALES AND FLUX CURVES

While all detected BLOs seem to exhibit some degree of variability, the timescales are diverse. We calculated the slopes of the flux density changes for each source. S5 0716+714 clearly has the fastest flux density variations. It has exhibited documented intraday variability (IDV) behavior and was also the subject of a very intensive monitoring campaign in 2003. Its flux density increased by 1.06 Jy in 40 minutes and 1.12 Jy in less than 2 hr, and decreased by 0.87 Jy in less than 2 hr during the 2003 flare. The multifrequency flare and the IDV during the campaign are discussed in detail in Ostorero et al. (2006).

AO 0235+164 has the second fastest variations: its flux density increased by approximately 0.4 Jy in less than an hour in 2004 August, after dropping from 2.38 to 1.76 Jy in 40 minutes 16 hr earlier. OJ 287 is also worth mentioning, with its flux density increase of 0.8 Jy in approximately 2 hr.

There were five sources that had a well-sampled flare during our observing period: AO 0235+164, S5 0716+714, OJ 287, 1308+326, and BL Lac, all of them LBLs. No two flares were alike; their type ranged from powerful and short (S5 0716+714, 2003 July to 2003 December, peak flux density 6.28 Jy) to broad and weak (1308+326, 2002 January to 2004 October, peak flux density 3.28 Jy). OJ 287 had two different outbursts. The later one, from 2003 August to 2005 April, reached the highest flux density value recorded in our observations, 7.8 Jy. The flare of BL Lac was still ongoing in 2005 April. The flux density had risen steadily since 2004 February and had reached 6.6 Jy in 2005 March. The mean duration of a flare is 17.6 months.

Most of the sources in our sample have very few data points and thus no flux curve to speak of. As mentioned in § 3, for many of these faint sources, mainly HBLs and XBLs, our data consist of detections (S/N > 4) and nondetections (S/N < 4). This is partly due to the varying observing conditions, with the detection limit ranging from 0.2 to over 0.5 Jy, but it can also, at least partially, be caused by variability. There are examples of sources, expected to be faint and usually below the detection limit, suddenly measuring over 0.5 Jy, such as MS 0737.9+7441 and GB 1011+496. An especially good example of such behavior

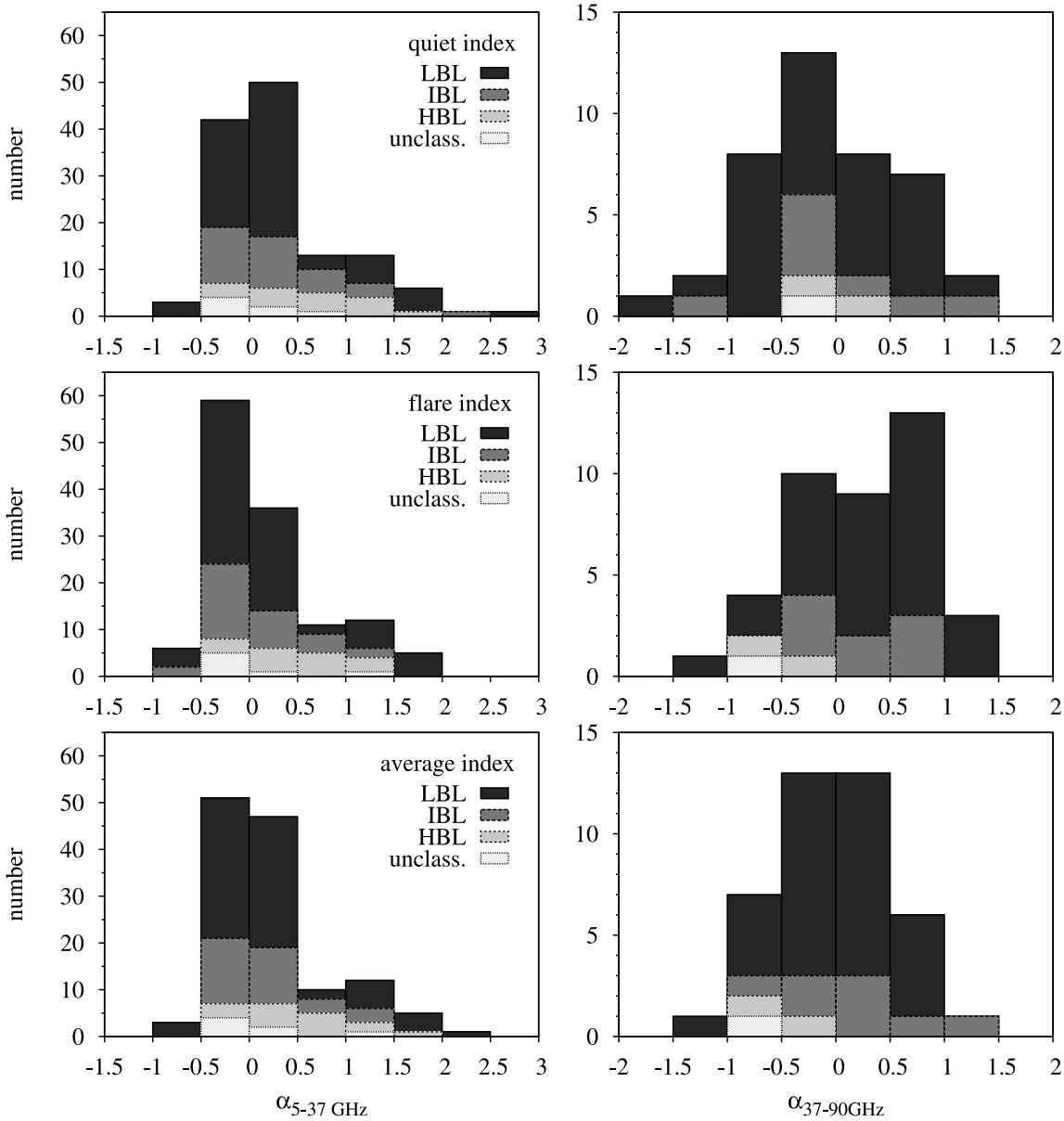

FIG. 5.—Distributions of the quiet, flare, and average spectral indices for the sample in the frequency intervals 5–37 and 37–90 GHz.

is RXS J1110.6+7133. It has one detection at 0.74 Jy and six nondetections.

7. DISCUSSION

In this paper we publish the data of the first 3.5 years of our ongoing BL Lacertae object observing project. We have also calculated some variability parameters and spectral indices for the sample.

The sample consists of 398 BLOs. During the 3.5 years of monitoring we made at least one significant (S/N > 4) detection of slightly more than one-third of the sources at 37 GHz, with the detection limit being on the order of 0.2–0.5 Jy. The largest subpopulation that was detected was LBLs (77%); 37% of IBLs and 15% of HBLs were detected. Even though the percentage of the detected BLOs is smaller in the high energy peaked population than in the low energy peaked one, it is interesting to see that also among them are a large number of objects that were detected at 37 GHz. This has a significant implication for the extragalactic foreground point-source modeling of the *Planck* satellite. Because the *Planck* detection limit will be comparable to that of the Metsähovi telescope, approximately one-third of the BLO population could also be detected by *Planck*. This should include at least some of the high energy peaked BLOs that are often excluded from both high-frequency radio observing campaigns and many of the models for CMB contribution by blazars. Giommi & Colafrancesco (2004) suggested that blazar flux variability at millimeter wavelengths may be a significant contributor to the CMB map contamination. Our findings of variability within the BLO sample, including clear signs of variability for sources in the HBL population, confirm this.

In order to have a reasonable estimate of how probable it is to observe the faint BLOs above the detection limit, we calculated the ratio of detections versus nondetections. For the HBLs for which there is at least one detection in our data, but excluding the two densely monitored and usually detected objects Mrk 421 and Mrk 501, the percentage of detections among all good-quality data points was 19%. If we add the X-ray-selected BLOs from the IBL and LBL subclasses, the percentage is 22%. Thus, the

probability to detect an HBL or XBL at a random observing epoch is on the order of 20%. This means either that their flux density remains on the verge of our weather-dependent detection limit or that they are variable, flaring sources.

Our earlier studies on southern flat-spectrum radio sources (Tornikoski et al. 2000) showed that many radio-bright AGNs spend much less time in an active state than in a quiescent or intermediate state. Our long-term monitoring project of radio-bright AGNs (Teräsranta et al. 2005; Hovatta et al. 2007) shows that 3.5 years of data is a rather short time to make any conclusive statements about such variability behavior as typical peak fluxes of flares or peak-to-peak timescales, because many of the dramatic changes in the flux density occur on long timescales. Thus it is important to consider the possible effects of long-term variability when interpreting results of a few years' monitoring campaign. While we can say that the BLOs detected during this campaign can be bright in the millimeter domain, we cannot rule out the possibility that the ones that now remained undetected could be much brighter if observed in a flaring state. This is an important issue when considering the contamination of CMB maps caused by extragalactic foreground sources; the data used for the modeling are historical data over one to a few epochs. We will discuss the long-term variability of a subsample of these BLOs in more detail in E. Nieppola et al. (2007, in preparation).

The variability indices ΔS_2 of our sample range from 0.04 to 0.9. The brightest sources are observed more often, whereas with the faint ones we make do with just a couple of measurements. This creates a selection effect and leads to biased variability behavior, as explained in § 4. For instance, in Ciaramella et al. (2004) the 37 GHz variability index for LBLs was $\Delta S_2 = 0.74 \pm 0.27$. Our average value was $\Delta S_2 = 0.33$. Our value is lower because it includes many rarely observed, faint LBLs. Therefore, it is very problematic to assign any variability value to a source, much less a source class, as it is always case-specific. Considering the differences in the results of the complete sample and the $N_{\rm det}$-limited one, we find that the variability index ΔS_2 changes little compared to ΔS_1 and ΔS_3. This is because as the difference between $S_{\rm max}$ and $S_{\rm min}$ increases ΔS_2 approaches unity. Meanwhile, ΔS_1 grows without limit and ΔS_3 approaches $S_{\rm max}$. Therefore ΔS_2 seems to be least sensitive to the effect of a varying number of measurements, and as such is probably the most convenient description of variability.

When we compare the variability characteristics of the BLO classes (LBLs, IBLs, and HBLs) no definite differences can be found. This is unexpected. RBLs are generally thought to be on average more variable than XBLs. Our results indicate that this is not necessarily true for LBLs and HBLs. However, we have to keep in mind that we can only study the radio-bright HBLs, whose properties one could expect to be similar to those of LBLs. Over 80% of HBLs still remain undetected at 37 GHz.

The 5–37 and 37–90 GHz spectral indices of the sample are diverse. In the lower frequency band the spectra are mostly flat, as expected, but in the higher band the distribution broadens to include both rising and falling spectra. This indicates that although BLOs are flat-spectrum sources at low frequencies, in the high radio frequencies their spectral behavior is not necessarily uniform.

The high-index tail of the 5–37 GHz spectral index distribution includes mostly XBLs with only one detection at 37 GHz. This could be thought of as further evidence of the flaring nature of the faint BLO population. If we assume that in quiescence, these XBLs have spectra similar to those of the vast majority of BLOs, their quiet flux level would be roughly on the order of 50 mJy or less. Thus, to be detected at Metsähovi, their flux densities must increase fourfold at the very least. We believe that active monitoring of the faint BLO population would result in more such detections. Also, using a more sensitive observing system to study a limited sample would be fruitful.

8. CONCLUSIONS

We have observed a sample of 398 BL Lacertae objects at the Metsähovi Radio Observatory from 2001 December to 2005 April. We obtained a $S/N > 4$ detection for 34% of the sources. The detected fraction of LBLs was 77%, of IBLs 37%, and of HBLs 15%. These figures are concordant with the typical radio-faintness of HBLs, as observed in Nieppola et al. (2006). However, we stress that HBLs cannot be considered radio-silent; this is verified by the serendipitous detections we obtained for some of them.

We gratefully acknowledge funding from the Academy of Finland for our Metsähovi and SEST observing projects (project numbers 205969, 46341, and 51436). We acknowledge European Commission funding under contract HPRN-CT-2002-00321 (ENIGMA). The authors made use of the CATS database (Verkhodanov et al. 1997) of the Special Astrophysical Observatory. The *Planck* satellite is a mission of the ESA. Our work has been carried out within its Low Frequency Instrument Consortium Working Group 6 (extragalactic foreground sources).

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