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Abstract. We present results on polarimetry on RGB BL Lacs. This sample has its roots in ROSAT and Green Bank catalogues. The broad band spectral energy distribution of RGB BL Lacs differs from the "traditional" BL Lacs, filling the gap between two extremes, HBLs and LBLs. We found that the polarization properties of the sample are also intermediate to HBLs and LBLs. The highest measured polarization was ~19% and ~60% of the objects had high polarization. Our results suggests that there is a connection between HBLs and LBLs and between the synchrotron peak frequency and the degree of polarization.

1. Introduction

BL Lac objects are a subclass of Active Galactic Nuclei (AGN) and are the most extreme and enigmatic objects of AGNs. BL Lacs are characterized by no or only weak emission lines ($W_\lambda < 5\AA$), rapid variability from radio regime up to TeVs and high with variable polarization. Before the new sky surveys (e.g. ROSAT All-Sky-Survey (RASS), NVSS, FIRST) the total number of BL Lac objects was ~250 (Padovani & Giommi 1995). The best studied BL Lac samples are the radio selected 1 Jy sample (Stickel et al. 1993) and the X-ray selected *Einstein* Extended Medium Sensitivity Survey (EMSS) (Stocke et al. 1991). These samples consist only the brightest objects from each survey. The largest complete samples have only ~ 30-50 objects. This may cause serious biases, which are hard to incorporate. As an example, comparing broad band spectral energy distributions (SED) of HBLs and LBLs (or XBLs and RBLs, respectively) it was found that there was no (or hardly any) overlapping in the S_x/S_r or α_{ro} vs. α_{ox} spectral index distribution (Figure 1). The new BL Lacs samples (e.g. RGB, Laurent-Muehleisen, 1998, DXRBS, Perlman et al. 1998) have filled the "gap" between LBLs and HBLs. It is still under debate what is the relationship between HBLs and LBLs and on the other hand AGNs and BL Lacs. Studies of these intermediate samples will help us to find out the fundamental parameters of activity, e.g. whether it is orientation, synchrotron peak frequency of the SED, luminosity etc.

The RGB sample was selected correlating RASS and 5 GHz Green Bank cata-

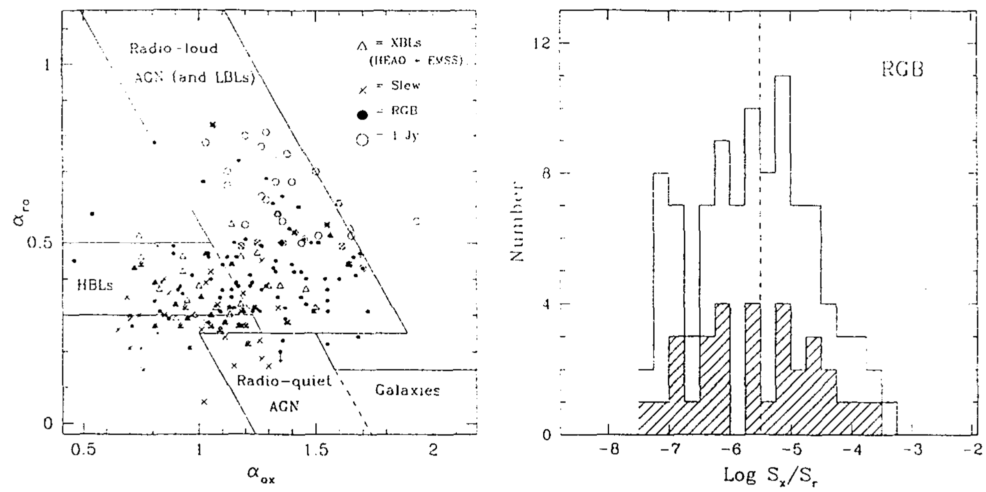

Figure 1. *The α_{ro} vs. α_{ox} spectral index distribution for the RGB and comparison samples (left). Intermediate BL Lacs Flux ratio log(S_x/S_r) distribution for the RGB sample. The dashed line corresponds (log(S_x/S_r)=-5.5) the "traditional" RBL vs. XBL division (right). RGB sample fills the gap between two extreme classes of BL Lacs and the flux ratio distribution shows no evidences of bimodality. The hatched area shows the RGB Complete sample.*

logues. Palomar Sky Survey was used for object identification and the final classification was made with optical spectroscopy (Laurent-Muehleisen et al. 1998). The total number of the RGB BL Lacs is 125 and 38 of these are "new" identifications. In the α_{ro} vs. α_{ox} plane (Figure 1) intermediate BL Lacs (IBLs) occupy the are $\alpha_{ox} \gtrsim 1.1$ and $\alpha_{ro} \lesssim 0.45$.

2. Observations

We present our polarimetric observations from Nordic Optical Telescope (NOT) and Steward 1.5 and 2.3 m telescopes. We had three observing runs at NOT (Dec. 96, July 97 and Sept. 98) and one at Steward observatory (Jan. 98). At NOT we used ALFOSC with a calcite plate and R-band filter. The Steward observations were made in white light using "Two-Holer" (see Smith et al. 1992). For NOT data the reductions were done with "normal" IRAF routines. The flux of each double image was measured using aperture photometry and Stokes parameters were calculated for each object. The statistical bias of the polarization was corrected using the formula suggested by Wardle & Kronberg (1975).

For statistical studies we merged Steward "white-light" (40 objects) and NOT R-band (77 objects) observations together. Some objects have been observed more than once hence there are 96 observed RGB BLLacs all together. All the statistic studies are made using the first measured value. The effective wavelengths are slightly different, λ_W=5700 Å compared to λ_R=6380 Å. We believe that the difference is not significant because of a Kolmogorov-Smirnov (KS) probability that the two distributions are different of $P_{KS} << 95\%$ (the median P_R=4.39%, P_W=4.45%), the wavelength dependence of polarization from V- to R-band is small (e.g. Takalo

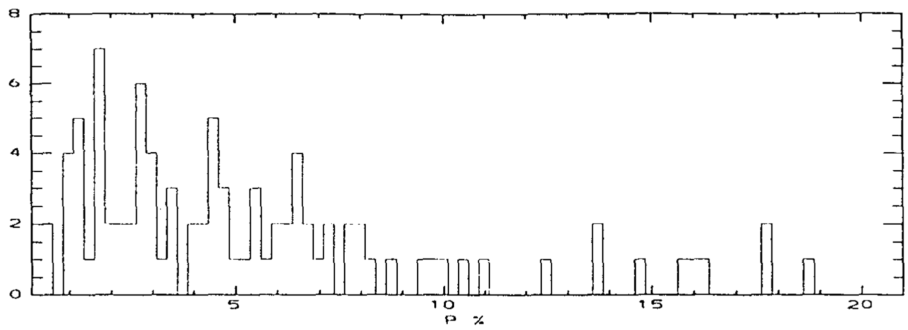

Figure 2. *Histogram of measured linear polarizations for the RGB sample. All the values are from the first epoch measurements.*

1991) and the difference between quasi simultaneous observations with "white-light" and R-band are small (see e.g. Smith et al. 1992). The used value might not be a representative value for an individual object, but a reasonable estimate for a group.

Table 1. *Polarization of the RGB subsamples.*

Sample	n	P_{max}	P_{med}	$n_{P>3\%}$
HBL	39	12.5	2.84	18
IBL	35	15.9	4.50	24
LBL	22	18.6	5.87	18

3. Discussion

In Figure 2 we show the histogram of polarization of RGB BL Lacs. We found that $\sim$ 60% of the RGB objects shows high ($P > 3\%$) polarization. This is about the same fraction as Kühr & Schmidt (1990) found for LBLs, but more than Jannuzi et al. (1994) found for HBLs. On the other hand the maximum polarization was less than 20%, which is about the same as has been found for HBLs but less than LBLs. Qualitatively the distribution looks like that there is a concentration of low polarized objects, a long tail towards high polarizations and very high polarizations are quite rare. This is what we expect if the polarization depends on the orientation of the relativistic jet to the observer.

In Figure 3 (left) we show the $\log(S_x/S_r)$ vs. $\log(S_o/S_r)$ diagram for the sub sample from Laurent-Muehleisen et al. (1998). The distribution of the objects shows no bimodality. The average polarization shows smooth decrease from HBL-area to LBL-area. Figure 3 (right) shows the α_{ro} vs. α_{ox} spectral index distribution with measured polarization. The average polarization seems to increases from the lower left hand corner towards upper right hand corner, as expected. If we divide the sample in a three groups (HBLs, IBLs, LBLs) using figure 1, we find that the degree of polarization increases from HBLs to IBLs and from IBLs to LBLs (Table 1). Note that HBLs and IBLs have about the same α_{ro}, but α_{ox} steepens. It is expected that

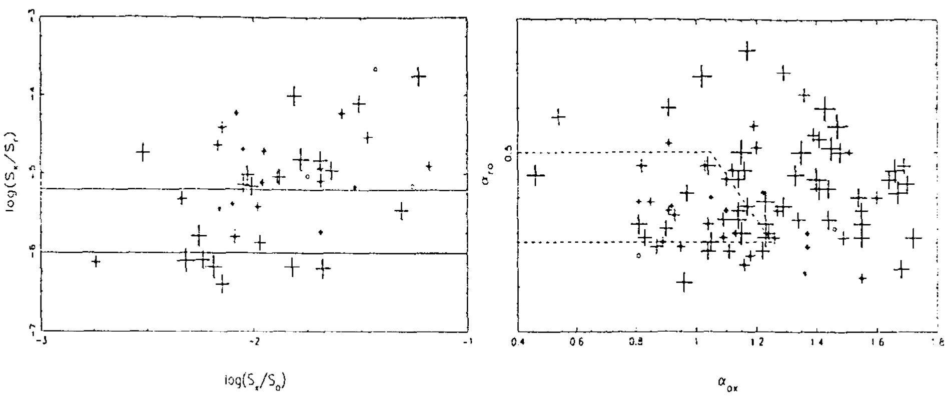

Figure 3. *Log(S_x/S_r) vs. log(S_o/S_r) for the BL Lacs from Laurent-Muehleisen et al. (1998). The size of the cross is proportional to the measured polarization and low polarized ($P < 3\%$) objects are marked with a circle. LBL-region is Log(S_x/S_r)<-6 and HBL-region Log(S_x/S_r)>-5.2. There is a smooth continuation from the RBL-like to XBL-like objects in any quantities. In the right hand panel we show the observed objects from Figure 1. Note the apparent increase of polarization to right from the marked (HBL) area from Figure 1.*

the α_{ox} steepens when the synchrotron peak frequency (ν_s) decreases. In this case our results suggests that (ν_s) and degree of polarization are related. To verify this infrared and high frequency radio data is needed to estimate more accurately the (ν_s).

Our results indicates that HBLs and LBLs belong to the same family. The difference of the classes might be synchrotron peak frequency of SED and possibly orientation. It should be noted that there remains many RGB "empty fields" from the POSS, which should be identified.

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References

Jannuzi B. T., et al. 1994, ApJ428, 130

Kühr, H., & Schmidt, G.D. 1990, AJ, 99, 1

Laurent-Muehleisen, S. A., et al. 1998, A&AS, 118, 127

Padovani, P., & Giommi, P. 1995, MNRAS, 277, 1477

Perlman, E. S. et al. 1998, AJ, 115, 1253

Smith, P. S. et al. 1992, ApJ, 400, 115

Stickel M. et al. 1993, A&AS, 98, 393

Stocke, J.T., et al. 1991, ApJS, 76, 813

Takalo, L. O. 1991, A&AS, 90, 161

Wardle, J.F.C. & Kronberg, P.P. 1975, ApJ, 194, 249