NEW RESULTS FROM THE HRX BL LAC SAMPLE

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ABSTRACT We present results for the Hamburg BL Lac sample, based on data provided by the RASS-BSC. By fitting a single power law to the X-ray data we find, in a number of objects, an additional absorbing component to the galactic value of $N_H$, which might be attributed to intrinsic absorption. A more probable cause seems however to be a curvature in the X-ray spectra in the sense that they are more curved for steeper slopes. The known relation between the X-ray spectral slope and the ratio between optical and X-ray flux ($\alpha_{OX}$) also applies to this BL Lac sample, even though less significant than in previous works. We also find a dependence of X-ray luminosity on $\alpha_{OX}$.

KEYWORDS: galaxies: active – BL Lacertae objects: general – X-rays: galaxies

1. INTRODUCTION

BL Lac objects are rare AGN, which are thought to be oriented towards us with their jet, thus showing high polarisation, strong variability at all wavelengths and non-thermal featureless spectra. Still there are several open questions about the nature of the BL Lac objects, e.g. whether there are differences between the BL Lac objects which are selected due to their strong radio-emission (RBL) and those selected because of their X-ray brightness (XBL). The difference between those two classes might be mainly caused by different peak frequencies of the two components in the BL Lac spectrum: XBL have usually a higher peak frequency of the synchrotron branch than RBL and thus we have high-frequency (HBL) and low frequency (LBL) peaked BL Lac objects (see e.g. Fossati et al. 1998). Between those two classes one can find intermediate objects (IBL) whose properties show them to be the link between HBL and LBL. We study the X-ray spectra of IBL and HBL and fit them with a single-power law with absorption by neutral hydrogen to investigate any possible spectral differences between these two samples.

2. THE HAMBURG X-RAY BRIGHT BL LAC SAMPLE

This work is based on the bright sources from ROSAT All Sky Survey (Voges et al. 1996), which have an X-ray flux $f_X > 11 \cdot 10^{-13}$ erg cm$^{-2}$ sec$^{-1}$ in the hard PSPC energy band (0.5–2.0 keV). A first complete sample of 39 BL Lac objects (Bade et al.
FIGURE 1. The “intrinsic” absorption ($N_{H,\text{intrinsic}} = N_{H,\text{free-fitted}} - N_{H,\text{galactic}}$) versus X-ray spectral slope. The negative values are caused by large errors on the free-fitted $N_H$ so that they are consistent with $N_{H,\text{intrinsic}} = 0$. The linear regression takes the errors in $N_H$ and $\alpha_X$ into account.

1998) in an area of 2800 deg$^2$ is based on the Hamburg/RASS X-ray bright sample (HRX, Cordis et al. in preparation). A larger sample of candidates has been derived by cross-correlating the X-ray sources from RASS in a larger area (4500 deg$^2$) with radio catalogues (NVSS, FIRST: radio flux limit $\simeq 2.5$ mJy). These 262 sources, if not already classified, have been included in follow-up spectroscopy with the 3.5m telescope on Calar Alto. Up to now this statistically complete sample is 95% classified and contains 72 BL Lac objects, both of the HBL and the IBL type. For 61 of them we have already determined the redshift ($z < 0.9$; Beckmann 1999). We will use in the following this sample of 72 BL Lacs.

3. X-RAY SPECTRA

Since the only available spectral measures are the two hardness ratios given in the RASS-BSC, we can only assume a simple spectral shape and apply the method of Schartel et al. (1996) to determine its parameters. We therefore assume that the spectrum is in the form of a single-power law absorbed by two different contributions: the galactic absorption and an “intrinsic” absorption that is given by the difference between the best fit absorption and the Galactic one ($N_{H,\text{intrinsic}} = N_{H,\text{free-fitted}} - N_{H,\text{galactic}}$). The galactic values were taken from Dickey and Lockman (1990). We find a strong correlation of the “intrinsic” absorption with the spectral slope (Fig. 1) on a $> 99\%$ confidence level also when taking into account the large errors in $N_{H,\text{intrinsic}}$. The negative values of $N_{H,\text{intrinsic}}$ seem to be caused by large errors; if we just take into account objects with an error of $N_{H,\text{intrinsic}} < 0.3$, we do not have any “negative absorption” at all. Since we do not see any correlation to other observable parameters (such as flux or luminosity), we make the hypothesis that this is an effect of curvature in the X-ray spectra (see e.g. Urry et al. 1996).
FIGURE 2. The relation between X-ray dominance ($\alpha_{OX}$) and X-ray spectral slope ($\alpha_X$) for the whole BL Lac sample. X-ray dominant objects are on the left.

Thus the flat X-ray spectra are well described by a single power law with galactic low energy absorption ($N_{H,\text{intrinsic}} \simeq 0$), while for steep spectra the curvature is significant and an additional “absorption” is needed to fit the X-ray data to a single-power law. In this model, a large value of $N_{H,\text{intrinsic}}$ would be explained by a convex spectrum. Nevertheless, true intrinsic absorption can not be ruled out in principle.

4. $\alpha_{OX} - \alpha_X$ RELATION FOR HRX-BL LAC

A relation, which is found for BL Lac objects, is the dependence of the spectral slope $\alpha_X$ on $\alpha_{OX}$. This effect, which shows objects with a higher X-ray dominance having flatter X-ray spectra, was detected in several X-ray bright samples of BL Lac objects (e.g. Wolter et al. 1998, Padovani & Giommi 1995, Comastri et al. 1995). Based on the RASS data we determined this relation for the HRX-BL sample (Fig.2). The effect of spectral flattening in the X-ray region with decreasing $\alpha_{OX}$ is detectable, even though less significant than in previous works. An analysis, which takes into account the errors in $\alpha_{OX}$ and $\alpha_X$ gives a significance for correlation of both values on a $> 93\%$ level.

5. DEPENDENCE OF X-RAY LUMINOSITY ON $\alpha_{OX}$

Another physical parameter which seems to be correlated to the X-ray dominance is the X-ray luminosity of the BL Lac objects. Because we know the redshift and

we define $\alpha_{OX}$ as the power law index between 1 keV and 4400 Å with $f_{\nu} \propto \nu^{-\alpha_{OX}}$, that describes the X-ray dominance over the optical brightness.
FIGURE 3. The relation between X-ray dominance ($\alpha_{OX}$) and X-ray luminosity in the hard (0.5 – 2keV) ROSAT-PSPC band. There are no X-ray faint BL Lacs with low $\alpha_{OX}$.

thus the luminosity for more than 80% of our objects, it is possible to study this relation. Figure 3 shows the dependency of $\log L_X$ on $\alpha_{OX}$. There seem to be no objects, which are X-ray dominant (low $\alpha_{OX}$) and have a low X-ray luminosity. This result is solid, because we do not miss any redshift for objects with $\alpha_{OX} < 0.9$ (Beckmann 1999). This effect could be explained in the view of the unified schemes (e.g. Padovani & Giommi 1995). The HBL are more X-ray dominated (low $\alpha_{OX}$) and the X-ray luminosity is therefore high because the X-ray band is in the vicinity of the peak frequency. On the other hand, LBL (high $\alpha_{OX}$) have their maximum of the synchrotron emission in the optical region and are X-ray faint.

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