Chin. J. Astron. Astrophys. Vol. 6 (2006), **Suppl. 2**, 349–352
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

Polarization and Beaming for Blazars

Jun-Hui Fan[1,2 ⋆], Yong-Xiang Wang[3], Tong-Xu Hua[1] and Y. Zheng[1]

[1] Center for Astrophysics, Guangzhou University, Guangzhou, China
[2] CAS-PKU Joint Beijing Astrophysical Center, Beijing, China
[3] College of Science and Trade, Guangzhou University, Guangzhou 511442, China

Abstract Based on the beaming model, a relation between the observed polarization and Doppler factor was obtained for BL Lacertae objects–BLs. If the flat spectral radio quasars—FSRQs fit a similar polarization-Doppler factor relation as BL Lacs, then we can find that the ratio, f, of the de-beamed jet luminosity to the unbeamed luminosity in the source frame in BLs is greater than that in FSRQs. In addition, in a revised polarization and core-dominance parameter plot, they obey to differently linear correlation suggesting that they have some differently intrinsic properties. The difference in f, found here, is consistent with the result by Fan (2003), which perhaps account for the emission line difference between BLs and FSRQs. We proposed that there is no evolution between BLs and FSRQs and their emission line difference is from the difference in their ratio f.

Key words: galaxies: blazars — galaxies: jets — polarization

1 INTRODUCTION

Observations indicate that there is a class of objects showing some special properties, namely, rapid variability, variable and high polarization, high luminosity, and superluminal motion etc. Those objects are called blazars, which have two subclasses, namely BL Lacertae objects (BLs) and flat spectrum radio quasars (FSRQs). Those two subclasses show quite similar observational properties except for the emission line property. There are strong emission lines in FSRQs but there are no or very weak emission lines in BLs. In addition, one can find that the optical polarization in FSRQs is lower than that in BLs on average. From the multiwavelength continuum properties, we obtained that BLs and FSRQs are a single class (Fan 1997). However, their difference in emission lines can not be ignored. In this work, we propose that the f difference to be responsible for the emission line difference. The paper is arranged as follows, in section 2, we present results, in section 3, we give some discussions and in section 4 we give a brief conclusion.

2 RESULTS

2.1 Result from Polarization

In a two-component beaming model, the observed total flux, $S^{\rm ob}$, is the sum of the unbeamed, $S_{\rm unb}$ and beamed, $S_j^{\rm ob}$ emissions. $S^{\rm ob} = S_{\rm unb} + S_j^{\rm ob} = (1 + f\delta^p)S_{\rm unb}$. Here f is a ratio of the intrinsic flux in the jet to the unbeamed flux. If one assumes that the emissions in the co-moving jet are also composed of polarized and unpolarized emissions, one can then derive a relation between the observed polarization and the Doppler factor (Fan et al. 1997; Fan et al. 2001),

$$P^{\rm ob} = \frac{(1+f)\delta_{\rm o}^p}{1+f\delta_{\rm o}^p}P^{\rm in}, \qquad (1)$$

⋆ E-mail: `fjh@gzhu.edu.cn`

where $P^{\rm in} = \frac{f}{1+f}\frac{\eta}{1+\eta}$ is the intrinsic polarization. $\delta_{\rm o}$ is the optical Doppler factor, and η the ratio of the polarized to the unpolarized luminosity in the jets. $p = 3 + \alpha(\text{or } 2 + \alpha)$ depending on the shape of the emitted spectrum and the detailed physics of the jet, and α is the spectral index.

Polarimetry observations have recently been done by many authors (see Wills et al. 1992; Efimov et al. 2002; Fan 2005 and reference therein). In our discussion, we used the observed highest polarization vs the radio Doppler factors (See Fan 2002).

For BLs and FSRQs, we can estimate their ratios, f and η by minimizing $\sum[P^{\rm ob} - \frac{(1+f)\delta_{\rm o}^{p}}{1+f\delta_{\rm o}^{p}}P^{\rm in}]^2$. The results are f = 1.501 and η = 0.431 for BL Lacertae objects; and f = 0.102 and η = 0.164 for FSRQs. Therefore, we can obtain the intrinsic polarization, $P^{\rm in} = \frac{f}{1+f}\frac{\eta}{1+\eta} = 1.3\%$, for FSRQs and $P^{\rm in} = 18.1\%$ for BL Lac objects. The best fitting results are shown in Figure 1. In this sense, BL Lacertae objects have both higher f values and higher intrinsic polarization than FSRQs, namely, $f_{\rm BL} \sim 15 f_{\rm FSRQs}$, and $P^{\rm in}_{\rm BL} \sim 14 P^{\rm in}_{\rm FSRQs}$.

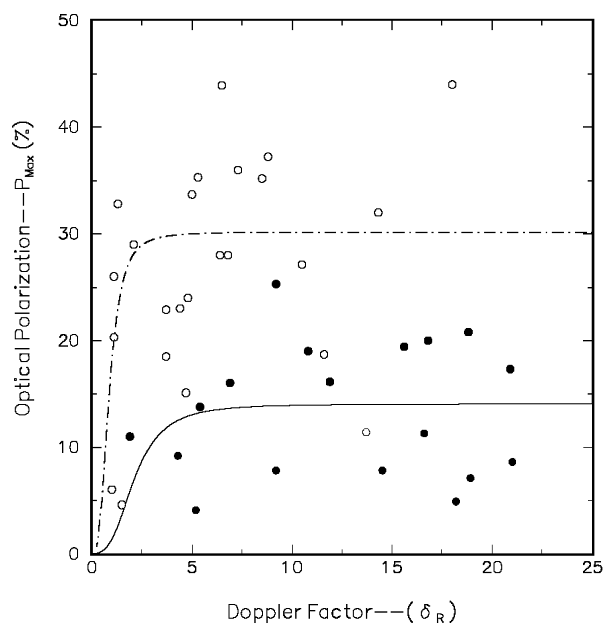

Fig. 1 Relation of polarization against the Doppler factor for BLs (open circle) and FSRQs (filled points). The curves are best fitting results.

2.2 Result from Superluminal Sources

For the flat jet spectra, one can define a core-dominance parameter $R = 1/2R_T[(1-\beta\cos\theta)^{-3} + (1+\beta\cos\theta)^{-3}]$ for a moving sphere. It was later expressed by Urry & Padovani (1995) as $R = f\{[\Gamma(1-\beta\cos\theta)]^{-3} + [\Gamma(1+\beta\cos\theta)]^{-3}\}$. So given Γ and R_T, $f = \frac{1}{2}R_T\Gamma^3$ can be obtained easily. Fortunately, from the beaming model, the Doppler factor and the superluminal velocity can be expressed as $\delta = [\Gamma(1-\beta\cos\theta)]^{-1}, \beta_{\rm app} = \frac{\beta\sin\theta}{1-\beta\cos\theta}$ which suggest that the Lorentz factor (Γ) and the viewing angle (θ) can be expressed in the forms $\Gamma = \frac{\beta^2_{\rm app}+\delta^2+1}{2\delta}$, $\tan\theta = \frac{2\beta_{\rm app}}{\beta^2_{\rm app}+\delta^2-1}$ So, the ratio f can be obtained for sources with known Doppler factor (δ), superluminal velocity ($\beta_{\rm app}$), and the core-dominance (R) (Fan 2003; Fan et al. 2004). The results indicate that log$f = 0.11 \pm 0.49$ for BLs and log$f = -1.59 \pm 0.19$ for FSRQs. The averaged value difference in log$f$ between BLs and FSRQs is Δ (log$f$) = 1.68±0.52. The difference given in a paper of Fan (2002) is in this range.

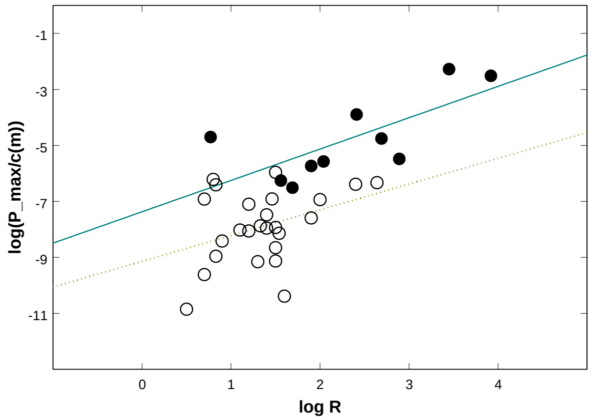

Fig. 2 Relation of revised polarization against the core-dominated parameter for BLs (filled points) and FSRQs (open circle). The lines are best fitting results (see Fan et al. 2004).

2.3 Polarization and Core-Dominance Parameter

Fan (2002) obtained that there is a relation, $P^{\rm ob} = c(m)R$, which suggests that there is a linear correlation between $\frac{P^{\rm ob}}{c(m)}$ and R, here $c(m)$ is a parameter associated with the optical magnitude (m). Based on the optical magnitude and the known ratio f (Fan 2003), we can get a statistically linear correlation between $\frac{P^{\rm ob}}{c(m)}$ and R, namely $\log\frac{P^{\rm ob}}{c(m)} = (1.89 \pm 0.08)\log R - 10.2 \pm 0.21$. It is different from the expected result $\log\frac{P^{\rm ob}}{c(m)} = \log R + {\rm const}$. However, when we consider BLs and FSRQs separately, we can get that

$$\log\frac{P^{\rm ob}}{c(m)} = (1.12 \pm 0.08)\log R - 7.37 \pm 1.5$$

for BLs, and

$$\log\frac{P^{\rm ob}}{c(m)} = (0.92 \pm 0.10)\log R - 9.14 \pm 2.3$$

for FSRQs. The results are shown in Figure 2.

3 DISCUSSION

There are many similarities between BLs and FSRQs: large and rapid variability, high and variable polarization, superluminal motions, and strong gamma-ray emissions. They both share the same relations in the effective spectral index and the optical color–color index plots (Fan 1997). Comastri et al. (1997) found that the X-ray and γ-ray indices of BL Lac objects and FSRQs show an anti-correlation. Nevertheless, the differences in their emission-line strength prevent one from classifying them as a single class. Do they belong to a single class or two different classes? If they are a single class, then how to explain their difference in emission lines? Their common properties should be from the beaming effect. Then the polarization should be explained using the beaming model since the polarization is the indicator of a beaming effect (Fan et al. 1997).

Someone proposed that there is an evolution process between BLs and FSRQs with the strong emission line FSRQs evolving into non-emission line BLs. If this is the real case, then one can expect that the central black hole masses in BLs should be more massive than those in FSRQs. However, from the central black hole masses, there is no statistical mass difference for FSRQs and BLs. Fan (2005) found that the average masses are $\log M = 8.06 \pm 0.54$ for FSRQs, and $\log M = 8.13 \pm 0.46$ for BLs. In this case, we can say that there is no evolution process between FSRQs and BLs, or if there is really evolution process between them, then the central black home mass is not an important factor in the evolution process. Anyway, this is a case that needs investigated further.

In the present work, we proposed that BLs and FSRQs are perhaps the same class with (1) the ratio of the de-beamed to unbeamed luminosities in BL Lac objects being higher than that in FSRQs, in this case, the beamed emissions dominate the line emissions in BL Lacertae objects, and (2) the intrinsic polarization in FSRQs is lower than that in BL Lacertae objects.

4 CONCLUSIONS

From the analysis mentioned above, we have the following results: The polarization mechanism in FSRQs is similar to that in BL Lac objects and the polarization is associated with the beaming model. That BL Lac objects show weaker emission lines than FSRQs is consistent with the fact that the f in BL Lac objects is greater than that in FSRQs. There is no evolution between BLs and FSRQs or the central black hole mass does not play an important role in the evolution process in AGNs.

Acknowledgements This work is partially supported by the National 973 project (NKBRSF G19990754), the National Science Fund for Distinguished Young Scholars (10125313), the National Natural Science Foundation of China (10573005), and the Fund for Top Scholars of Guangdong Province (Q02114). We also thank the financial support from the Guangzhou Education Bureau and Guangzhou Science and Technology Bureau.

References

Comastri A. et al., 1997, ApJ, 480, 534
Efimov Yu. S. et al., 2002, A&A, 381, 408
Fan J. H., 1997, ApL&C, 36, 55
Fan J. H., 2002, PASJ, 54, L55
Fan J. H., 2003, ApJL, 585, L23
Fan J. H. et al., 2004, ChJAA, 4, 533
Fan J. H., 2005, A&A, 436, 799
Fan J. H., Cheng K. S., Zhang L., 1997, A&A, 327, 947
Fan J. H., Cheng K. S., Zhang L., 2001, PASJ, 53, 207
Urry C. M., Padovani P., 1995, PASP, 107, 803
Wills B. J. et al., 1992, ApJ,398, 454