Unification of BL Lac objects and FR I and FR II(G) radio galaxies, and Doppler factor estimation for BL Lac objects

Xuhong Ye*, Junhui Fan*

* Center for Astrophysics, Guangzhou University, Guangzhou 510006, China
Email: fjh@gzhu.edu.cn

In this work, we collected a sample of 297 BL Lacs, 87 FR I and 41 FR II(G) radio galaxies with available core and extended emissions from published works to discuss the unified schemes and estimate the Doppler factor for BL Lacs. Wilcoxon rank-sum test (WRS) and Kolmogorov-Smirnov test (K-S) both suggest that the probabilities for the distribution of the extended luminosity of BL Lacs and that of FR I and FR II(G) radio galaxies to be from the same parent distribution are p_{WRS}=0.779 and p_{K-S}=0.326, suggesting they are unified. Based on the unification of BL Lacs and FR I and FR II(G)s, we propose a method to estimate the Doppler factors of BL Lacs: the correlation between intrinsic core luminosity and extended luminosity of BL Lac should be consistent with that of FR Is and FR II(G)s, and the observed core luminosity of BL Lacs is enhanced by Doppler factor, so we can derive a formula to estimate the Doppler factor for BL Lacs. Comparing our Doppler factor with those for the common sources in the literatures, we found a good linear correlation for common sources (Fig 1), supporting this unification method to estimate Doppler factor is reliable.
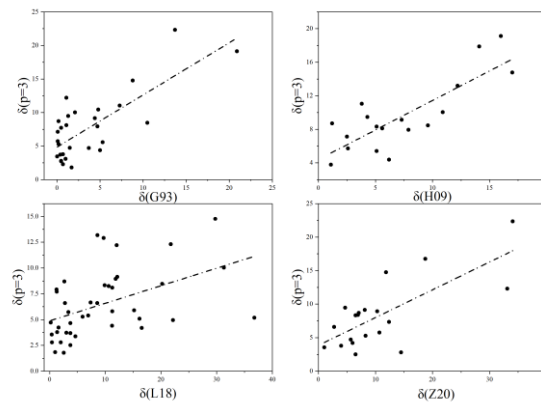
Fig 1. Plot of the correlation for common sources between our Doppler factor [δ(p=3)] and those from Ghisellini et al. (1993), [δ(G93)]; Hovatta et al. (2009), [δ(H09)]; Liodakis et al. (2018), [δ(L18)]; and Zhang et al. (2020), [δ(Z20)].