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A Unification of X-ray selected BL Lacs and FRI Radio Galaxies

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Abstract In this work, we revisit the unification scheme using the radio observations of X-ray selected BL Lacertae objects (XBLs) and FRI radio galaxies. The results are: 1) BL Lacertae objects and FRI radio galaxies show similar extended radio luminosity, and 2) In the luminosity and core-dominance plot, BL Lacertae objects and FRI radio galaxies are located in the same region, suggesting a unification of XBLs and FRI radio galaxies.

Key words: galaxies: BL Lacertae objects — general-galaxies: fundamental parameters — galaxies: jet

1 INTRODUCTION

BL Lacertae objects, which are an important subclass of blazars, show some peculiar observational properties, which can be explained by using the relativistic beaming model. These objects are identified as low-luminosity radio galaxies (FRI-type) and are classified as radio-selected (RBLs) and X-ray selected (XBLs) according to their provenance. They were later classified as low-frequency peaked (LBL) and high-frequency peaked (HBL) BL Lacertae objects according to their spectral energy distribution (SED) (e.g., Padovani & Giommi 1995). Generally, RBLs correspond to LBLs and XBLs to HBLs. They emit most of their synchrotron power at low (far-IR, optical) and high (UV-soft-X) frequencies, respectively.

Observations and studies show that those two subclasses have different properties and the differences can be explained using the relativistic beaming model (see Fan & Xie 1996; Fan et al. 1993, 1994, 1997; Fan 2005). Urry, Padovani, Stickel (UPS) (1991) proposed that BL Lacertae objects be unified with FRI radio galaxies. However, based on the Hubble diagram, Xie, Zhang, Fan, Liu (XZFL) (1993) argued that BLs, FRI radio galaxies and FRII (G) radio galaxies should be grouped into a single class, and the argument was supported by an infrared analysis (Fan et al. 1997). In any case, unification schemes are interesting for further studies of such properties as the innermost structure and the emission mechanism. We now have two samples of BL Lacertae objects and FRI radio galaxies available for an attempt in this connection.

2 SAMPLE AND RESULTS

From a paper by Kollgaard et al. (1996), we can get our sample of XBLs, while from a paper by Zirbel et al. (1995), we can get the FRI sample. See Table 1, in which Column 1, gives the name, Column 2, redshift, Column 3, core-luminosity at 5 GHz in units of W Hz^{-1}, Column 4, extended-luminosity at 5 GHz in units of W Hz^{-1}, Column 5, Core-dominance parameter, Column 6, total luminosity at 5 GHz in units of W Hz^{-1}.

In the two-component model, the observed power is the sum of the core and the extended components, $P^{\rm tot} = P^{\rm core} + P^{\rm ext}$. The data in the table give the following results:

For the averaged values, we have

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$\log P^{\rm core} = 23.37 \pm 0.85$,
$\log P^{\rm ext} = 24.48 \pm 0.97$,
$\log P^{\rm tot} = 24.56 \pm 0.96$, and
$\log R = -1.33 \pm 0.41$ for 46 FRI radio galaxies.
$\log P^{\rm core} = 24.63 \pm 0.34$,
$\log P^{\rm ext} = 24.23 \pm 0.61$,
$\log P^{\rm tot} = 24.81 \pm 0.32$, and
$\log R = 0.36 \pm 0.58$ for 24 XBLs.

We can discuss correlation between the luminosity and the core-dominance parameter with the data given in Table 1.

Table 1 Data for XBLs and FRI Radio Galaxies

Name (1)	ID (2)	z (3)	$\log P_{\rm C}$ (4)	$\log P_{\rm E}$ (5)	$\log R$ (6)	$\log P_{\rm T}$ (7)	Name (1)	ID (2)	z (3)	$\log P_{\rm C}$ (4)	$\log P_{\rm E}$ (5)	$\log R$ (6)	$\log P_{\rm T}$ (7)
							0449–175	FRI	0.031	21.580	23.39	–1.99	23.397
0158.5+0019	XBL	0.299	24.5	24.1	0.230	24.531	0620–052	FRI	0.051	24.480	25.15	–0.80	25.216
0257.9+3429	XBL	0.245	24.5	23.1	1.305	24.426	0634–205	FRI	0.055	22.740	24.77	–2.21	24.775
0317.0+1834	XBL	0.19	24.2	23.4	0.716	24.192	0722+030	FRI	0.019	22.900	22.76	0.56	23.426
0323+022	XBL	0.147	24.7	23.8	0.845	24.703	0800+024	FRI	0.043	22.380	23.46	–1.24	23.483
0414+009	XBL	0.287	25.3	25.1	0.114	25.462	0915+032	FRI	0.062	23.120	23.93	–0.95	23.972
0548–322	XBL	0.069	24.2	24.9	–0.699	24.979	1040+031	FRI	0.036	23.480	24.01	–0.64	24.099
0607.9+7108	XBL	0.267	24.6	24.6	–0.076	24.865	1122+039	FRI	0.007	21.060	23.03	–2.15	23.036
0706+592	XBL	0.124	24.6	24.8	–0.222	25.004	1142+019	FRI	0.021	23.580	24.56	–1.13	24.589
0737.9+7441	XBL	0.315	25	23.6	1.265	24.888	1216+006	FRI	0.006	22.680	23.85	–1.34	23.869
1101+384	XBL	0.031	24	24.1	0.204	24.515	1222+013	FRI	0.004	21.920	22.85	–1.08	22.882
1101–232	XBL	0.186	24.8	25	–0.301	25.176	1228+012	FRI	0.004	23.370	24.70	–1.50	24.714
1133+704	XBL	0.046	24	24.3	–0.301	24.476	1251–012	FRI	0.014	22.870	24.17	–1.47	24.185
1221.8+2452	XBL	0.218	24.7	23.5	1.155	24.685	1318–043	FRI	0.011	23.480	24.05	–0.68	24.132
1229.2+6430	XBL	0.164	24.7	23.6	0.982	24.625	1322+036	FRI	0.018	23.290	23.36	0.01	23.670
1402.3+0416	XBL	0.2	24.5	24.3	0.204	24.715	1346+026	FRI	0.063	23.950	24.78	–0.97	24.820
1407.9+5954	XBL	0.495	25.1	25.2	–0.284	25.382	1414+011	FRI	0.024	23.270	24.41	–1.30	24.431
1443.5+6349	XBL	0.299	24.5	24.4	–0.022	24.690	1422+026	FRI	0.037	23.160	24.12	–1.11	24.150
1458.8+2249	XBL	0.235	24.8	23.8	0.919	24.768	1514+007	FRI	0.035	24.500	25.14	–0.77	25.211
1534.2+0148	XBL	0.312	25	25	–0.097	25.255	1525+029	FRI	0.065	22.660	23.94	–1.45	23.956
1552.1+2020	XBL	0.222	24.8	24.5	0.255	24.947	1553–228	FRI	0.065	23.780	24.10	–0.37	24.254
1652+398	XBL	0.034	24.8	23.6	1.255	24.879	1621+038	FRI	0.031	23.310	23.61	–0.34	23.772
1727+502	XBL	0.055	24.2	23.8	0.415	24.356	1626+039	FRI	0.030	23.610	24.92	–1.48	24.935
2143.4+0704	XBL	0.237	25	24.8	0.114	25.162	1648+005	FRI	0.154	24.080	27.31	–3.42	27.313
2356–309	XBL	0.165	24.7	24.1	0.544	24.753	1839–048	FRI	0.112	24.980	25.73	–0.89	25.787
0055–001	FRI	0.045	23.580	25.00	–1.59	25.012	1954–055	FRI	0.060	23.910	25.47	–1.74	25.480
0104+032	FRI	0.016	22.040	24.12	–2.26	24.125	2013–308	FRI	0.089	23.030	24.38	–1.52	24.394
0115–261	FRI	0.053	23.350	23.96	–0.73	24.035	2053–201	FRI	0.156	23.790	25.34	–1.73	25.350
0219+042	FRI	0.022	23.560	24.68	–1.28	24.701	2104–025	FRI	0.037	23.250	25.44	–2.37	25.445
0247–027	FRI	0.087	23.450	24.40	–1.10	24.431	2104–256	FRI	0.039	22.940	24.35	–1.58	24.362
0255+005	FRI	0.024	22.980	24.63	–1.83	24.638	2116+026	FRI	0.016	22.730	22.56	0.72	23.352
0300+016	FRI	0.032	22.660	24.50	–2.02	24.506	2152+069	FRI	0.027	24.110	25.43	–1.49	25.444
0305+003	FRI	0.029	24.480	24.70	–0.24	24.903	2153+037	FRI	0.291	24.670	27.09	–2.60	27.094
0320–037	FRI	0.005	21.450	24.51	–3.25	24.513	2229+039	FRI	0.017	22.720	23.98	–1.43	23.996
0331–001	FRI	0.139	24.530	25.99	–1.64	26.001	2322–123	FRI	0.082	23.310	24.94	–1.81	24.949

3 DISCUSSION AND CONCLUSIONS

BL Lacertae objects are an extreme subclass of AGNs and the relativistic beaming model has been successful in explaining their observed properties. The model was used to explain not only the particular observational properties but also some observed differences between RBLs and XBLs (see Xie et al. 1991; Fan et al. 1993; Fan & Xie 1996; Georganopoulos & Marscher 1999), although the viewing angle alone can not explain all the differences between the two subclasses (Sambruna et al. 1996). The interpretation is that BL Lacertae objects are those radio galaxies (FRI radio galaxies) with the jets aligned with the line of sight. We have, accordingly, collected the BL Lacertae objects and FRI radio galaxies for an investigation of their properties.

In our analysis, we found that in the plot of luminosity against the core-dominance parameter, XBLs and FRI radio galaxies show the same correlation. Moreover, the average extended luminosity is the same, within the errors, for the FRIs and the XBLs . This suggests a unification of these two subclasses.

On the other hand, when RBLs are considered, we find them to occupy a different region in the luminosity vs core-dominance plot. This suggests that if XBLs and RBLs are originally the same, then RBLs are more strongly beamed than XBLs.

We have compiled a sample of 24 XBLs and 46 FRI radio galaxies. Our analysis shows that a unification of XBLs and FRIs is valid, and that RBLs are more strongly beamed than XBLs.

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