The CJF survey: first results on superluminal motion

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Abstract. We present first results from a systematic analysis of the kinematics of the sources in the Caltech-Jodrell Bank flat-spectrum sample (hereafter CJF), which is based on global VLBI and VLBA observations performed at 5 GHz. One of the major goals of CJF is to make a statistical study of the apparent speeds of the sources, in order to investigate superluminal motion statistics with cosmic epoch and to place constraints on $q_{\circ}$ and $H_{\circ}$. We have investigated 245 out of 293 sources so far and we could determine jet velocities for 189 sources. We discuss correlations of superluminal motion statistics with respect to source classifications.

1. Introduction

The CJF sample is a complete flux-density limited sample of 293 flat-spectrum sources stronger than 0.35 Jy (Taylor et al. 1996). It integrates existing VLBI survey observations (Pearson & Readhead 1988; Polatidis et al. 1995; Taylor et al. 1994) into a large, homogeneous database for statistical studies of a broad range of astrophysical and cosmological issues. Optical identifications have been made for 97% of the CJF sample, and redshifts obtained for 92% of the objects (e.g., Stickel & Kühr 1994; Stickel et al. 1994; Xu et al. 1994; Vermeulen & Taylor 1995; Vermeulen et al. 1996). An overview summarizing existing investigations and references is given in Pearson et al. 1998.

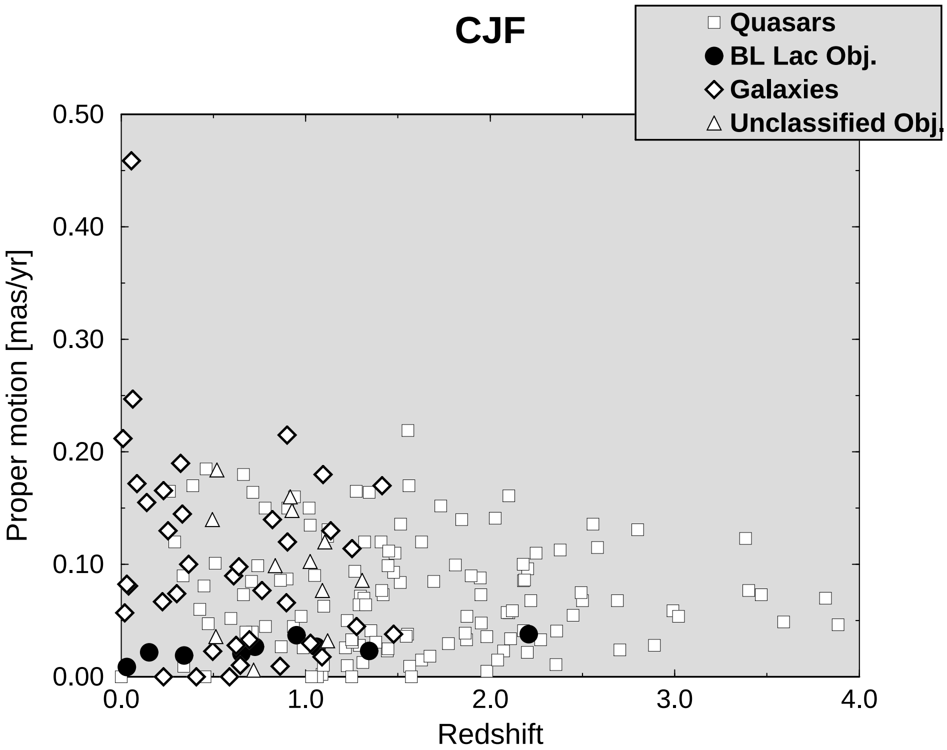

Figure 1. Internal proper motion-redshift diagram for 189 CJF sources: 130 quasars, 9 BL Lac objects, 38 galaxies and 12 objects not yet classified.

2. Observations and Results

We perform continuing VLBI monitoring with a typical separation between observations of about two years in order to measure internal proper motions in the parsec-scale radio sources. Our most recent observations (February 1998) comprise the second or third epoch for a sample of 120 sources; currently 245 sources have three epochs of observations and 48 sources have two observations. All observations were carried out with the VLBA in snapshot mode. Previous papers (Vermeulen 1995; 1996) investigated a subsample of the CJF, presented an analysis of apparent velocities, and discussed cosmological implications.
In order to create a homogeneous, statistically valid database, we started a systematic reanalysis of all epochs for all sources obtained in the 1990s. Here we present first results on the superluminal motion statistics as correlated with different source-identification classes for about two thirds of the CJF objects. We calculated jet component velocities for the component closest to the core, whose identification in all epochs was reliable. In some ambiguous cases, we calculated the average value over the velocity of several components. Source-specific peculiarities complicated our analysis: accelerations and decelerations along the jet, different velocities in the jet/counterjet, strongly bent sources, faint jets, etc. We analyzed those sources, which had been observed at least twice by February 1998 (245 sources). For 23 of those, redshifts are not known, 16 objects reveal very complex jet structures which have to be analyzed in detail again, and 17 sources show point like structures. Thus, jet velocities could be determined for 189 sources. Fig.1 displays the absolute value of the internal proper motions as a function of redshift for those objects.

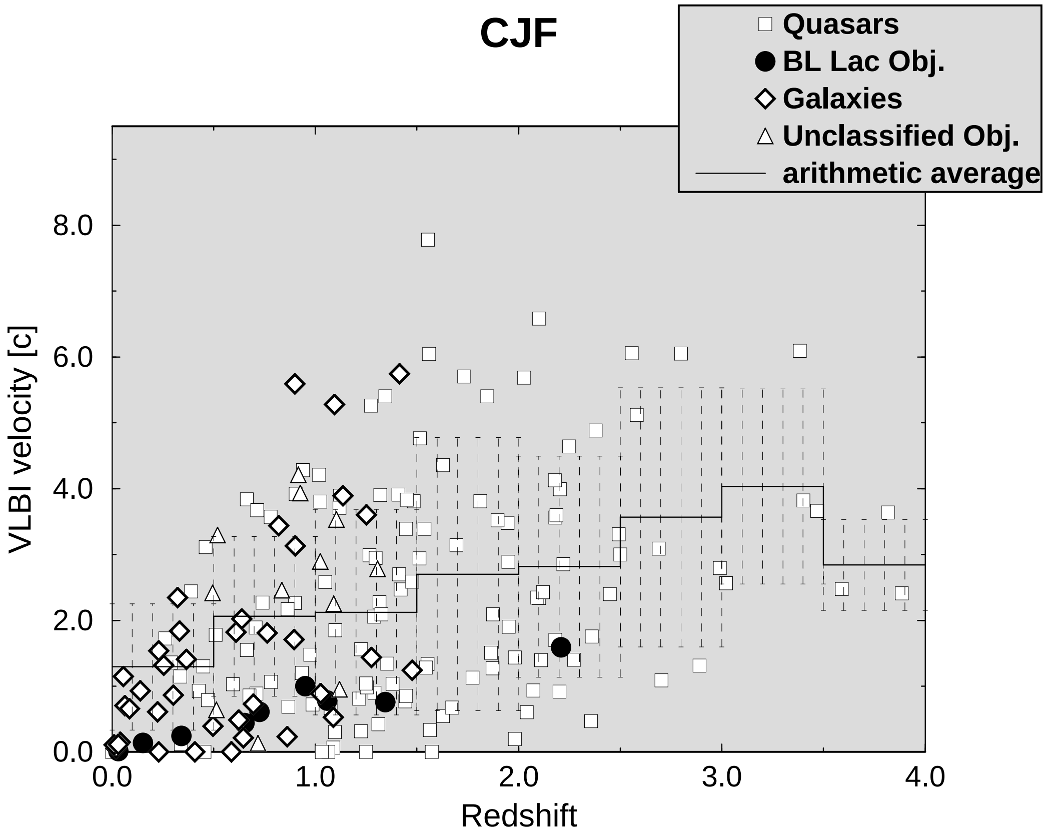

Figure 2. β_{app}-z diagram (bottom) for 189 CJF sources, assuming $H_\circ = 100$ km s^{-1} Mpc^{-1} and $q_\circ$=0.5. Superimposed is the arithmetic average and standard deviation calculated for the quasars in redshift intervals of 0.5.

Fig.2 shows the corresponding β_{app}-z diagram with the apparent velocities, using $H_\circ = 100$ km s^{-1} Mpc^{-1} and $q_\circ$=0.5. Different source classifications are shown with different symbols. Although we have not yet completed a careful error analysis taking all sources of uncertainties into account, we expect a realistic estimate for the error on the motions is less than 10-20%.

3. Discussion

From inspection of Fig.1, we see that the internal proper motions decrease with redshift, as expected in Friedmann cosmology (e.g. Cohen et al. 1988). Quasars and galaxies show a similar β_{app}-z distribution, although galaxies only contribute at lower redshifts. In Fig.2, we superimpose the arithmetic averages (solid line) and the standard deviation (dashed error bars) for the quasar population within CJF, calculated for redshift intervals of 0.5. It appears that the apparent velocities observed for quasars show a slight increase with redshift. The BL Lac objects, on the basis of velocities for 9 sources, show slower motions (average value: 0.62±0.49 c) as opposed to the quasars (average value: 2.43±1.70 c; 130 objects) but a similar increase with redshift. The broad β_{app}-distribution for the galaxies is reflected by an average value of 1.53±1.58 c (38 objects). A final evaluation and discussion of the results has to wait until we have completed our analysis of the CJF data.

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