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Kinematics of parsec-scale structures in AGN: the 2cm VLBA Survey

E. Ros[1], K. I. Kellermann[2], M. L. Lister[2], J. A. Zensus[1], M. H. Cohen[3], R. C. Vermeulen[4], M. Kadler[1], and D. C. Homan[2]

[1] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[2] National Radio Astronomy Observatory, 520 Edgemont Rd., Charlottesville, VA 22903, US
[3] California Institute of Technology, Department of Astronomy, MS 105-24, Pasadena, CA 91125, US
[4] Netherlands Foundation for Research in Astronomy, Postbus 2, 7990 AA Dwingeloo, The Netherlands

Abstract. We are investigating the kinematics of jets in active galactic nuclei on parsec scales by studying a representative population of sources. This study is being carried out using the Very Long Baseline Array at 15 GHz, with more than 800 images taken since 1994. In this contribution we present an overview of the diversity of kinematics for a complete sample of sources.

Since 1995, we have been performing a monitoring program on a sample of over 170 Active Galactic Nuclei (AGN) using the VLBA[1] at 15 GHz to study the jet bending, pattern motions, accelerations or changes in the component strength, morphology and Lorentz factors.

In 1994, we began by observing a sample of 132 compact AGN approximately every 6 months with the VLBA at 15 GHz (Kellermann et al. 1998, herafter K98). In 1997 we added 42 sources to our sample (Zensus et al. 2002, hereafter Z02). Approximately 40 observing sessions have been carried out since August 1994 with the VLBA[2], giving one observation every 6–18 months for each source.

To make a robust statistical analysis of the kinematics and source properties, we need to define a "complete" sample. The initial criteria we followed were: a flat spectrum above 500 MHz and a 15 GHz flux density over 1.5 Jy for objects above the celestial equator and over 2 Jy for objects with declination between 0° and $-20°$. The catalogue from Stickel et al. (1994), from which the sources were initially chosen, is complete only at 5 GHz, so we needed to identify all the sources with the suitable flux density level from the available flux density surveys[3]. From the 174 available sources (see K98 and Z02) we discarded the weak VLBI cores and selected the sources with at least 4 VLBA epochs in our survey. We rejected the sources with final CLEANed or UMRAO flux densities below the 1.5/2 Jy level. That gives a total of 74 sources which represent a "complete" subsample of our survey sources.

After imaging the radio sources (see K98 and Z02) we measured the positions of the absolute and relative peaks of brightness in the images using the $\mathcal{AIPS}$ task IMFIT. For some sources with very close components or other problems, we performed a model fitting of the data using the task MODELFIT in DIFMAP. We cross-identified the same components at different epochs by using several criteria: flux density evolution, similar relative positions with respect to the main component (the "core"), etc. So far, we have reasonably well-determined motions for about 100 of the 174 sources in our sample extending over a time baseline of 4 to 6 years.

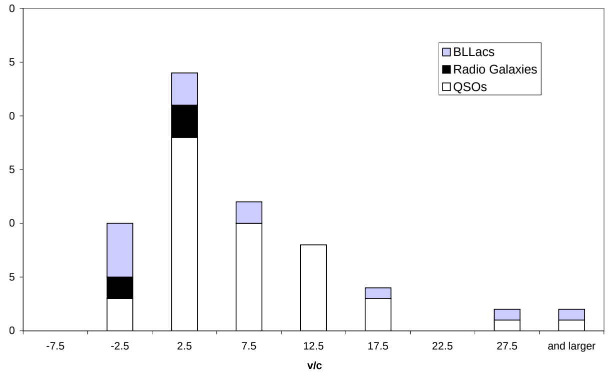

Fig. 1. Distribution of $\beta_{\rm app}$ for the different object classes of the "complete" subsample of sources (see text).

From the 74 "complete" sources, we do have kinematical data for 63 of these sources (14 BL Lac objects, 5 radio galaxies, and 44 QSOs). In Fig. 1, we present the distribution of apparent speeds[4] for their brightest components.

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[1] The Very Long Baseline Array of the U.S. National Radio Astronomy Observatory is operated by Associated Universities, Inc., under cooperative agreement with the U.S. National Science Foundation.

[2] Programs BZ4, BZ14, BK37, BZ22, BK52, BK68 and BK77. The next observations, will have the code BL111, corresponding to a large proposal named MOJAVE (Monitoring of Jets in AGN with VLBA Experiments).

[3] For instance, the University of Michigan Radio Observatory (UMRAO) survey, Aller et al. in preparation; the RATAN-600, Kovalev et al. 1999; or Metsähovi, Terästranta et al. (2001).

[4] For $H_0 = 65\,{\rm km\,Mpc^{-1}\,s^{-1}}$ $\Omega_m = 0.3$, and Ω_Λ=0.7.

Table 1. Component speeds in the sources shown in Fig. 2 and 3, ordered by the component proximity to the core.

Source	z	Id.	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}	$\dot{r}^{\,(a)}$	β_{app}
1928+738	0.300	Q	0.12	1.04	0.29	0.52	0.30	1.39								
3C 273	0.160	Q	0.23	2.56	0.55	6.23	1.26	14.24	1.05	11.80	1.36	15.36	0.82	9.20	0.79	8.94
4C 39.25	0.700	Q	0.075	3.19	0.006	0.26										
BL Lac	0.070	B	0.99	5.0	1.09	5.5	1.13	5.7	1.41	7.1						
3C 345	0.590	Q	0.36	13.4	0.37	13.7	0.49	18.2								
M87	0.004	G	0.07	0.02	0.19	0.05										

[a]: Given in mas yr^{-1}

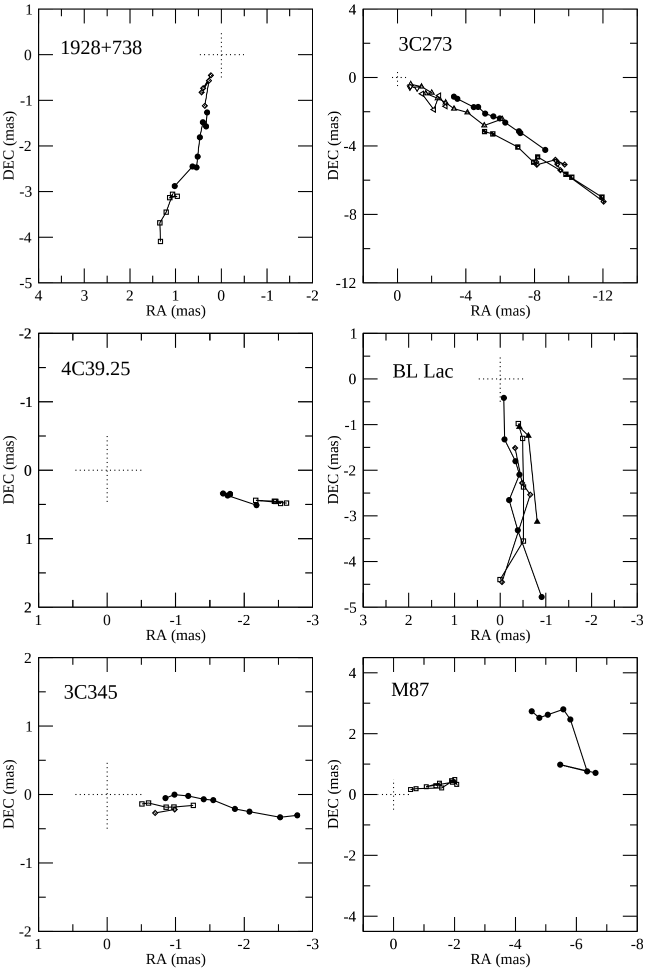

Fig. 2. Apparent sky trajectories of jet components in the AGN 1928+738, 3C 273, 4C 39.25, BL Lac, 3C 345, and M87. The crosses indicate the position of the VLBI cores.

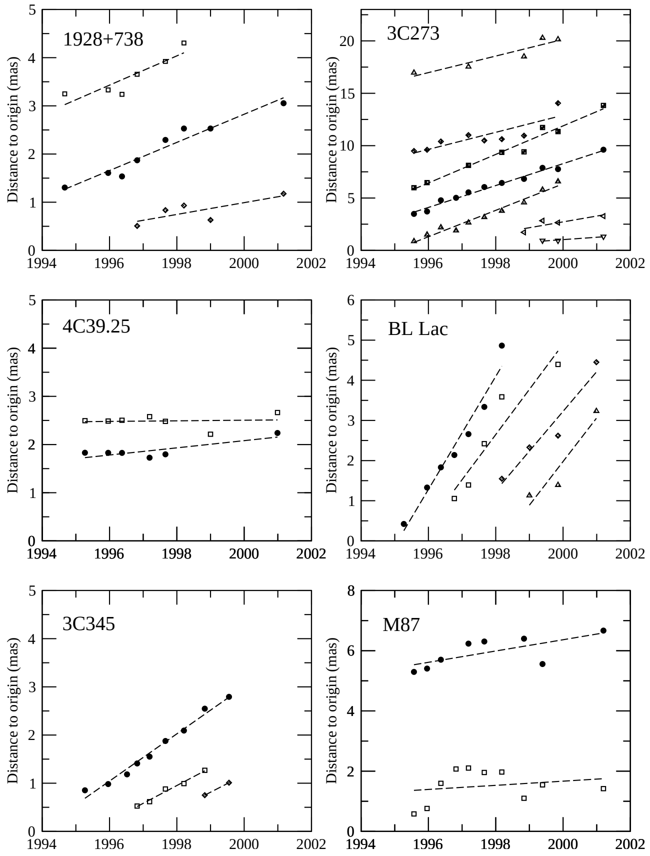

Fig. 3. Angular separation r versus time corresponding to the radio sources and components from Fig. 2.

The median of β_{app} for the different classes of objects is of 1.84, 0.02, and 5.23 (BL, G and QSOs, respectively).

As an example of our kinematical analysis, we show in Figs. 2 and 3 a selection of the component motions for six well-known AGN. Fig. 2 presents the sky trajectories of the components. The curved paths in 1928+738 and 3C 345 are remarkable. The components in M87 are extended and therefore their positions are not well-defined. BL Lac shows recurrent component trajectories. In Fig. 3 we show the time evolution of the component distance to the core. The slopes of the linear regression fits are the speeds given in Table 1 (their uncertainties, not given here, are below 5%).

A detailed description of the extensive kinematic analysis on the radio sources of the survey will be given in a forthcoming paper (Kellermann et al., in preparation).

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