Proceedings of the 6th European VLBI Network Symposium
Ros, E., Porcas, R.W., Lobanov, A.P., & Zensus, J.A. (eds.)
June 25th-28th 2002, Bonn, Germany

Space VLBI observations of the quasar 1351−018: tentative detection of apparent superluminal motion at z=3.707

S. Frey[1], L. I. Gurvits[2], A. P. Lobanov[3], R. T. Schilizzi[2,4], N. Kawaguchi[5], and K. Gabányi[1]

[1] FÖMI Satellite Geodetic Observatory, P.O. Box 546, H-1373 Budapest, Hungary
[2] Joint Institute for VLBI in Europe, P.O. Box 2, 7990 AA Dwingeloo, The Netherlands
[3] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[4] Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands
[5] National Astronomical Observatory, Mitaka, Tokyo 181-8588, Japan

Abstract. Sub-milliarcsecond resolution images of the extremely distant quasar 1351−018 ($z = 3.707$) were made using the VLBI Space Observatory Programme (VSOP) at two epochs. The high angular resolution of VSOP at 5 GHz allowed us to identify a jet component within 1 mas from the quasar radio core. The inner jet position angle is misaligned by 130° with respect to the 10-mas scale jet. The position of the innermost jet component has changed significantly over a period of less than 3 years, implying a proper motion of 0.18 mas/year which corresponds to an apparently superluminal speed. We present our imaging results and discuss the potential importance of the detection of superluminal motion in high redshift quasars.

1. Introduction

The radio-loud quasar 1351−018 (J1354−0206) is among the most distant objects observed with Space VLBI (SVLBI) in the VLBI Space Observatory Programme (VSOP, Hirabayashi et al. 1998). Its redshift is $z = 3.707$ (Osmer et al. 1994). The source is included in our sample of more than 20 extremely distant ($z > 3$) quasars imaged with VSOP at 1.6 and 5 GHz. The primary goal of this project is to study milliarcsecond (mas) and sub-mas structures of distant quasars at high emitted frequency (for $\nu_{\rm obs} = 5$ GHz and $z > 3$, $\nu_{\rm em} = (1+z)\nu_{\rm obs} > 20$ GHz), and to compare them with ground-based VLBI structures in low redshift sources. On the other hand, statistical investigation of mas scale structures in quasars as a "standard" object provides material for cosmological tests using the "apparent angular size–redshift" (e.g. Gurvits et al. 1999) and the "apparent proper motion–redshift" (e.g. Kellermann et al. 1999) relations. For these studies, extremely distant sources are of special importance since cosmological effects are better pronounced at high redshift. More details and other results of the on-going VSOP survey of $z > 3$ quasars are presented elsewhere (Hirabayashi et al. 1998; Gurvits et al. 2000; Frey et al. 2000; Lobanov et al. 2001).

2. Observations and results

The quasar 1351−018 was observed on 1998 Apr 12 with the array consisting of the orbiting radio telescope HALCA and four ground radio telescopes (the Australia Telescope Compact Array, Hartebeesthoek, Kashima and Sheshan). This source received particular attention because earlier ground-based Very Long Baseline Array (VLBA) observations at 5 GHz (Frey et al. 1997) showed a weak feature separated by 13 mas from the core at the position angle (PA) of −13°. On the other hand, our first-epoch VSOP image (Fig. 1) revealed an inner jet component within 1 mas from the core at PA=117°. This large misalignment between the 10 mas scale and sub-mas scale jet direction is qualitatively confirmed by ground-based VLBA images from the USNO Radio Reference Frame Image Database at 2.3, 8.4 and 15 GHz (Fey & Charlot 2000) as well. We proposed to observe the source again with VSOP, involving ten antennas of the VLBA as the co-observing ground array at 5 GHz, in order to look for possible changes in the inner jet structure and possibly to image the jet bending on intermediate scales. The second-epoch observations took place on 2001 Jan 23. The data calibration and imaging were performed using the NRAO AIPS package. The high resolution image made using optimally weighted data on space–ground baselines to enhance angular resolution (Fig. 2) proved the existence of the inner jet component. Moreover, the core–jet separation apparently increased over a period of 2.78 years while the PA remained the same. The 10-mas scale component could again be detected using effectively the ground data only, but the jet could not be directly observed on mas scale. The naturally weighted image is shown in Fig. 3.

3. Structural changes

The change in the apparent position of the innermost jet component between the two epochs is 0.5 mas. The uncertainty of this measurement is 0.2 mas, mainly due to the relatively poor (u, v) coverage of the first-epoch SVLBI observations. The corresponding proper motion is $\mu = 0.18 \pm 0.07$ mas/yr. Assuming a standard Friedmann cosmology with $q_0 = 0.5$ and $H_0 = 100h$ km s^{-1} Mpc^{-1},

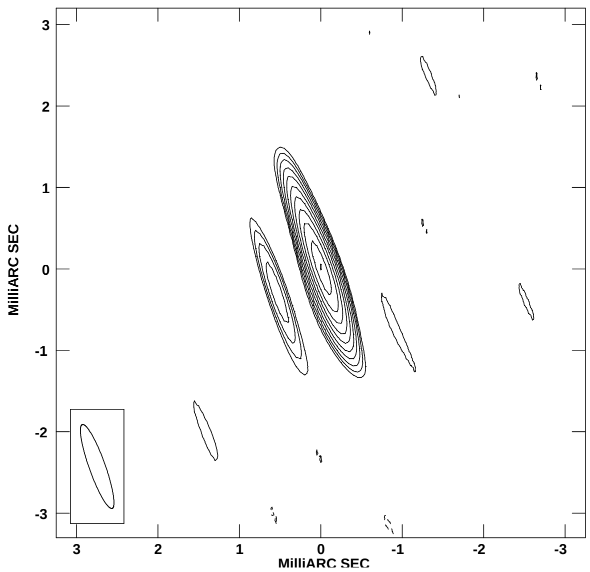

Fig. 1. 5-GHz SVLBI image of 1351−018 on 1998 Apr 12. Contours are at −3.5, 3.5, 5, 7, 10, 14, 20, 28, 40, 56, 80 and 99% of the peak brightness of 367 mJy/beam. Restoring beam is 1.09 mas × 0.20 mas at PA=20°.

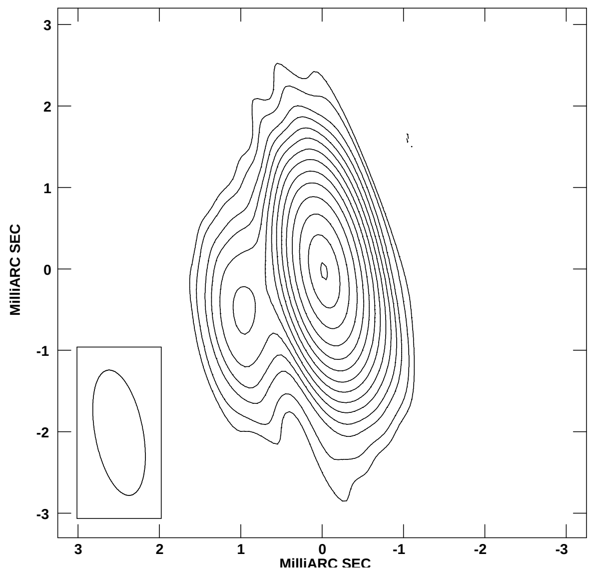

Fig. 2. 5-GHz SVLBI image of 1351−018 on 2001 Jan 23. Contours are at −1, 1, 1.5, 2.5, 3.5, 5, 7, 10, 14, 20, 28, 40, 56, 80 and 99% of the peak brightness of 547 mJy/beam. Restoring beam is 1.56 mas × 0.59 mas at PA=11°.

this translates to an apparent transverse speed of $\beta_{\rm app} = (9.2 \pm 3.7)/h$ (e.g. Porcas 1987).

The $\mu = 0.18$ mas/yr value obtained is based on measurements at two epochs only, therefore it should be treated with caution. However, we point out that the extremely distant quasar 1351−018 is a good candidate for follow-up monitoring observations, either at a higher frequency (e.g. 15 GHz) with ground-based VLBI or with the next generation SVLBI. The apparent transverse speed derived is consistent with the high values measured for other active galactic nuclei (cf. Vermeulen & Cohen 1994; Kellermann et al. 1999). Detections of apparent superluminal motions at such a high redshift are relatively rare. Therefore this source would be an important addition to a data base that may eventually constrain the cosmological model using the “apparent proper motion–redshift” dependence (e.g. Vermeulen & Cohen 1994).

Acknowledgements. We gratefully acknowledge the VSOP Project, which is led by the Institute of Space and Astronautical Science (Japan) in cooperation with many organizations and radio telescopes around the world. We thank K.I. Kellermann and I.I.K. Pauliny-Toth for their crucial participation in the initial phase of the VSOP survey of high redshift quasars. SF acknowledges financial support received from the Netherlands Organization for Scientific Research and the Hungarian Scientific Research Fund (grant no. N31721 & T031723).

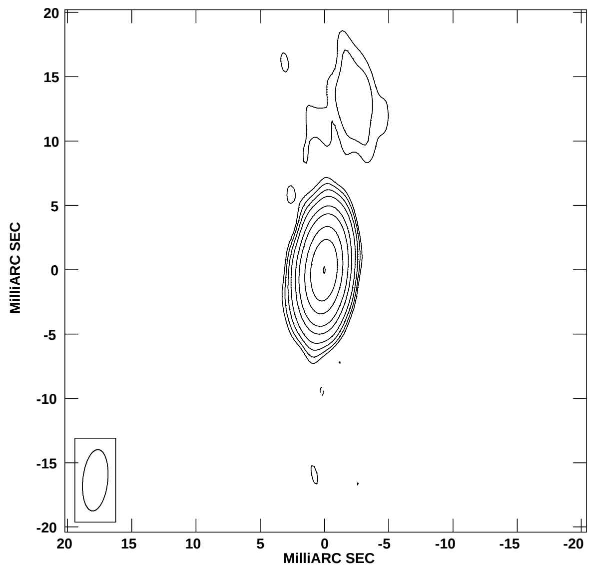

Fig. 3. Naturally weighted 5-GHz SVLBI (in fact ground-only) image of 1351−018 on 2001 Jan 23. Contours are at −0.25, 0.25, 1, 2, 5, 10, 25, 50 and 99% of the peak brightness of 643 mJy/beam. Restoring beam is 4.79 mas × 1.94 mas at PA=−6°.

References

Fey A.L., Charlot P. 2000, ApJS 128, 17
Frey S., Gurvits L.I., Kellermann K.I., et al. 1997, A&A 325, 511
Frey S., Gurvits L.I., Schilizzi R.T., et al. 2000, in: Proc. 5th EVN Symposium, eds. Conway J.E. et al., Onsala Space Observatory, 41
Gurvits L.I., Kellermann K.I., Frey S. 1999, A&A 342, 378
Gurvits L.I., Frey S., Schilizzi R.T., et al. 2000, AdSR 26, 719
Hirabayashi H., Hirosawa H., Kobayashi H., et al. 1998, Science 281, 1825
Kellermann K.I., Vermeulen R.C., Zensus J.A., et al. 1999, NewAR 43, 757
Lobanov A.P., Gurvits L.I., Frey S., et al. 2001, ApJ 547, 714
Osmer P.S., Porter A.C., Green R.F. 1994, ApJ 436, 678
Porcas R.W 1994, in: Superluminal Radio Sources, eds. Zensus J.A., Pearson T.J., Cambridge University Press, 12
Vermeulen R.C., Cohen M.H. 1994, ApJ 430, 467