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

EVN and RATAN–600 study of AGN undergoing strong radio flares

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Abstract. Onsets of strong radio flares in several dozens of AGN were detected, and their evolution was studied using 1–22 GHz 6-frequency instantaneous spectra monitoring of compact extragalactic objects in 1997–2002 with RATAN–600. We observed six of these sources with the European VLBI Network (including HartRAO) at 5 GHz twice in 1999, February and September. The resolution of about 1–3 mas was achieved. Results of this VLBI project are reported and discussed. It is inferred that more than 80% of the total emission of these sources is coming from the mas scale. A typical behaviour of spectra evolution during strong radio outbursts in various objects is recognised suggesting a common physical nature of the variability. The flares started at the highest frequency and were moving to the lower frequency in a regular fashion. The behaviour of the flares is explained by a synchrotron emission of an evolving blob in a compact relativistic jet of an active galactic nucleus. Different physical models are discussed considering the single dish and the VLBI data.

1. Introduction

The physical processes causing the variability of AGN emission have long been of great interest. Much attention has been payed to sources with high amplitude of flares, especially if a flare occurs after a quiescent stage. In such a case subsequent flares do not overlap (as it frequently happens), and the observed flux is most likely the sum of a quiescent and an evolving powerful component emission. This situation is very suitable for comparison with predictions of theoretical models as there is no need to involve a large number of free parameters. We investigate the general properties of flares for different optical classes of AGN and analyse how strong are the distinctions between them.

2. Observations

Observations were made from 1997, March, to 2002, March (14 epochs), at 31, 13, 7.7, 3.9, 2.7, and 1.4 cm, simultaneously for all frequencies, with the RATAN–600 in the framework of a monitoring program. In 1997, March, we started a program for a sample of about 550 compact extragalactic sources with correlated flux density $F_c > 0.1$ Jy at 13 cm from the Preston et al. (1985) VLBI survey in the declination range from $-30°$ to $+43°$. Results of the observations made in December 1997, list of the sources included in the monitoring, method of observations and data processing are presented by Kovalev et al. (1999). Meridional observations and the horizontal localisation of the stationary antenna horns at the RATAN–600 provide the spectral responses during one–two minutes at all observed frequencies due to Earth rotation. Onsets of strong radio flares in several tens of AGN were detected in 1997–2002 (spectra variability for some of these sources, observed also with the EVN+, is presented in Figure 1).

In 1999, February and September, we observed the sources shown in Figure 1 with the European VLBI Network at 6 cm. The sources are as follows: quasars 0607–157 (z=0.32), 1958–179 (z=0.65), 2121+053 (z=1.94), BL Lacertae object 0235+164 (z=0.94), quasar or compact galaxy 0007+106 (III Zw 2, z=0.09), probably BL Lac object, rapidly variable 0524+034 (z is unknown). Observations were done with the EVN+ array of 9 antennas (Effelsberg 100 m, HartRAO 25 m, Jodrell Bank 26m, Medicina 32 m, Noto 32 m, Phased Westerbork, Shanghai 25 m, Torun 32 m, Urumqi 25 m). The resolution of about 1–3 mas was achieved for most images.

3. Discussion

From statistical and numerical model analysis we conclude that the spectra can be modelled as the sum of a synchrotron spectrum of an extended optically thin component (magnetised envelope/lobe, ‘spectrum 1’), dominating at lower frequencies, and a synchrotron spectrum of a compact component (relativistic jet, ‘spectrum 2’), dominating at higher frequencies. Spectrum 1 is generally constant or weakly variable, spectrum 2 can exhibit any degree of variability.

The observed flares started at the highest frequency and were moving to the lower frequency in a regular fashion. Considering non-stationary jets, a combination of two spectral components can account for the features of spectra with complex shapes. A variable emission of a jet can be produced by the non-stationary outflow of relativistic particles in the longitudinal magnetic field (see e.g. Kovalev et al. 2000) or by the propagation of relativistic shocks (see e.g. Marscher & Gear 1985). We have not found significant differences in the flare evolution for different groups of objects; observed quasars and BL Lacertae objects have similar fashion and rate of vari-

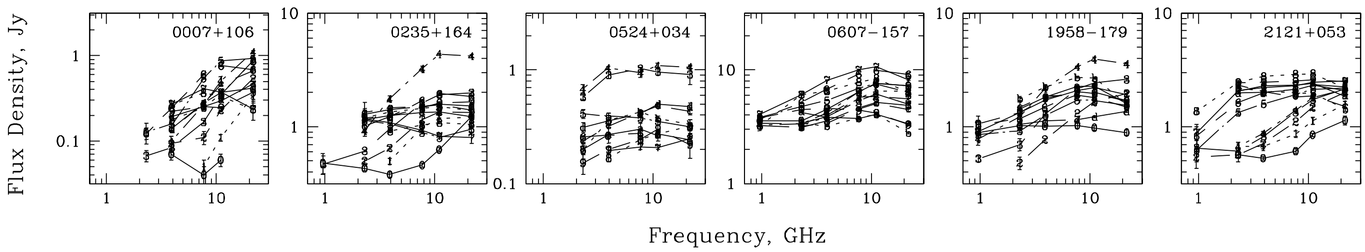

Fig. 1. Long-term variability of broad-band instantaneous spectra for six flaring objects from the EVN+ list. Shown are the 1–22 GHz spectra for 14 epochs in 1997–2002.

ability. Therefore, the hypothesis of the different physical nature of the quasars and the BL Lacs was not supported in our study.

Comparison of the integrated flux, measured with the EVN+, and the results of RATAN–600 observations confidently gives that more than 80% of the total emission of the six observed sources is coming from the mas scale. In particular, this result confirms our previous assumption and interpretation of (1) the quiescent spectra by the emission of a jet in a quasi-stationary phase; (2) the spectra variability at frequencies higher than 1 GHz by the strongly variable spectrum of the compact relativistic jet. For the sources, a contribution of the weakly variable spectrum of extended components is negligible at frequencies higher than 1 GHz.

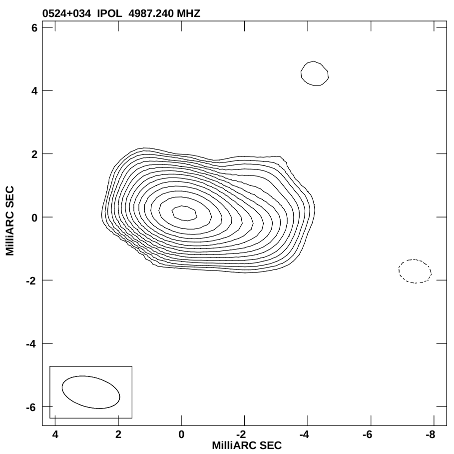

Fig. 2. The total intensity EVN+HartRAO map of 0524+034 observed at 6 cm in 1999. Contour levels are at −0.7, 0.7, 1.0, 1.4, 2.0, 2.8, 4.0, 5.6, 8.0, 11.3, 16.0, 22.6, 32.0, 45.2, 64.0, & 90.5 % of the peak brightness of 0.20 Jy/beam.

All the sources were resolved during the EVN+ two epoch experiment: the fringe visibility–baseline dependence cannot be modelled by a single δ-function component. At the same time we have not detected with confidence a jet in three of the sources: in III Zw 2, 0235+164 (it was detected close to a noise level a fast moving component separated from the VLBI core), and 1958–179. The other three sources, 0524+034, 0607–157, and 2121+053 show compact jets. To our knowledge, the high resolution sensitive 6 cm image for the object 0524+034 was first received in this experiment, so we put it in the present proceedings as an example of structures observed (see Figure 2). There are indications that the compact jet of 0524+034 is beginning to curve.

We have revealed very compact structure for almost all observed sources with strong radio flares. The exception is the quasar 0607–157. But it was expected from our spectral fitting, this source has the largest contribution of a low frequency slowly variable component to the total spectrum among all the sources observed with the EVN+. Observed structures can be interpreted in the context of the models discussed above, in accordance with numerical simulations which were done by us and other authors. The proper motion measurements and estimations of the Doppler boosting factor (made when possible) give usual values for such type of objects; we suggest that orientation of a jet for most sources is close to the line of sight.

4. Conclusions

We claim that the total spectra of AGN can be represented as the sum of two main broad-band spectral components. For different types of AGN the same behaviour of flares is revealed, suggesting a common physical nature of BL Lacs and quasars. Both the model with the longitudinal magnetic field and the shock-in-jet model explain satisfactorily the VLBI and filled aperture observational properties of the objects with strong radio flares under analysis.

Acknowledgements. The European VLBI Network is a joint facility of European, Chinese and other radio astronomy institutes funded by their national research councils. This research was partly supported by the Russian Foundation for Basic Research (projects 01–02–16812, 02–02–16305), and the Russian State Program "Astronomy".

References

Kovalev, Y. Y., Nizhelsky, N. A., Kovalev, Yu. A., Berlin, A. B., Zhekanis, G. V., Mingaliev, M. G. & Bogdantsov, A. V. 1999, A&AS, 139, 545

Kovalev, Yu. A., Kovalev, Y. Y. & Nizhelsky, N. A. 2000, PASJ, 52, 1027

Marscher, A. P. & Gear W. K. 1985, ApJ, 298, 114

Preston, R. A., Morabito, D. D., Williams, J. G., Faulkner, J., Jauncey, D. L. & Nicolson, G. D. 1985, AJ, 90, 1599