VLBI MONITORING OF BL LAC-OBJECTS +

Lars B. Bååth
Onsala Space Observatory, S-439 00 Onsala, Sweden

This is a report on an ongoing project designed to study structural variations on the milliarcsecond scale in four BL Lac-type objects. The observations are made at λ6 cm with a global VLBI network consisting of the combined US and European networks and with some additional antennae like one in South Africa and one in Finland. A typical experiment involves 7-9 stations and produces maps with a resolution (FWHM) of 1-1.5 m.a.s depending on the declination of the source.Seven experiments have been made since the start in 1978, resulting in hybrid maps at three epochs for each of the four main sources: AO 0235+164,0735+178,Mk 421, and 1749+701. The same restoring beam has been used for each source at all epochs. The epoch March 1979 is an exception though, the maps from then were restored with a larger beam corresponding to the resolution on the European baselines only. The results from the epochs 1978-1979 have already been published (Bååth et al. 1981), and papers describing the results from the later epochs are in preparation.

All the sources varied in flux density over the period 1978-1981.The most varying source was AO 0235+164;0735+178 decreased steadily in flux; Mk 421 and 1749+701 both had at least two outbursts. The four sources will be presented here in order of increasing right ascension, thus avoiding to group them together into any artificial subclasses.

AO 0235+164

AO 0235+164 has been previously discussed at this meeting by D.Jones and F.Briggs.The source is particularly interesting since its optical spectrum shows absorption lines corresponding to two redshift systems:z=0.52 and z=0.85. It is also one of the most violently varying extragalactic sources known with several large outbursts since the flux monitoring started in 1975 (G.Nicholson, private comm.). We observed the source with VLBI close to the peak of the two outbursts in March 1979 and October 1980, and also in December 1981 just at the beginning of the 1982 outburst (Fig. 1).The only component in each map which is intense enough to house the outburst is the core,and therefore the outer component should, in analogy with outbursts followed in other core-dominated radio sources like 3C 345 and 3C 273,be a remnant from a previous outburst.Doing this

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analogy we would identify the northeast extension in the first map as emanating from the 1975-outburst, in the second map from the 1979-outburst, and in the third map from the 1980-outburst.This results in an apparent speed of angular separation, consistent for all three events, of 1-1.5 m.a.s. per year or 45c ($z=0.85, H_0=55$ km sec^{-1} Mpc^{-1}, $q_0=0.05$). Caution must be taken though since each component is observed only once. There is some evidence in our data from the second epoch of a component that is either far away or too large to be more than marginally observed with our interferometer,a possible remnant from the previous epoch. The components must evolve faster than in other well studied varying VLBI sources,and it is therefore necessary to observe the source more often than once a year.The position angle of the jet is also different in the three maps.Blandford and Königl (1979) concluded from the change in polarization angle during the 1975-outburst that the new component should move northward from the core.Our map from 1979 does not show any extension in this direction, but the next epoch map, observed closer in time to the event, does. The first two epoch maps are therefore consistent with a scenario in which the new components move northward to start with and then turn towards east. The third map does not fit into this scenario. The position angle of the jet is around 45^{o} though the size is about the same as in the map at the previous epoch.Therefore the outburst probably started in a direction different from that of the previous ones.

0735+178

This radio source has been called "the cosmic conspiracy" because of the way a number of partly selfabsorbed radio components conspire to form a flat spectrum (Cotton et al. 1980;Marscher 1980). 0735+178 was observed at the same epochs as AO 0235+164, and the maps are shown in Fig. 2. The VLBI structure is dominated by two components.The northeast (NE) component decreased in flux and the position angle relative the stronger (core) component changed significantly between the first two epochs.This continued over the third epoch,the peak brightness of the NE component decreased whereas its southeast part increased in intensity.Gaussian fittings to the 1980 and 1981 maps show that a component had moved from the core-component towards the northeast with an apparent angular speed of 0.2 m.a.s. per year. The new component can be seen in the maps as an increasing extension of the core towards the northeast. It is also observed in the spectrum as an increase of the flux density at frequencies higher than 10 GHz during 1980 followed by a decrease during 1981.Also,a component with a high-frequency turnover had to be added to the radiospectrum of 1979 in order to fit this as the superposition of the components observed with VLBI (Cotton et al. 1980;Bååth 1980). The new component remains optically thick at 5 GHz during the period we observed it and is therefore not a strong feature in any of the maps.The only way to definitely observe the component is to increase the resolution, and therefore we observed the source with a global VLBI network at λ1.35 cm,resulting in a resolution of 200 microarcsec. The component was detected, and the apparent speed of angular separation, based on three epochs, was 0.18 m.a.s. per year, or 2.6c. 0735+178 is thus a member of the superluminal family of radio sources as has been predicted (Marscher 1980;Bååth et al. 1981).

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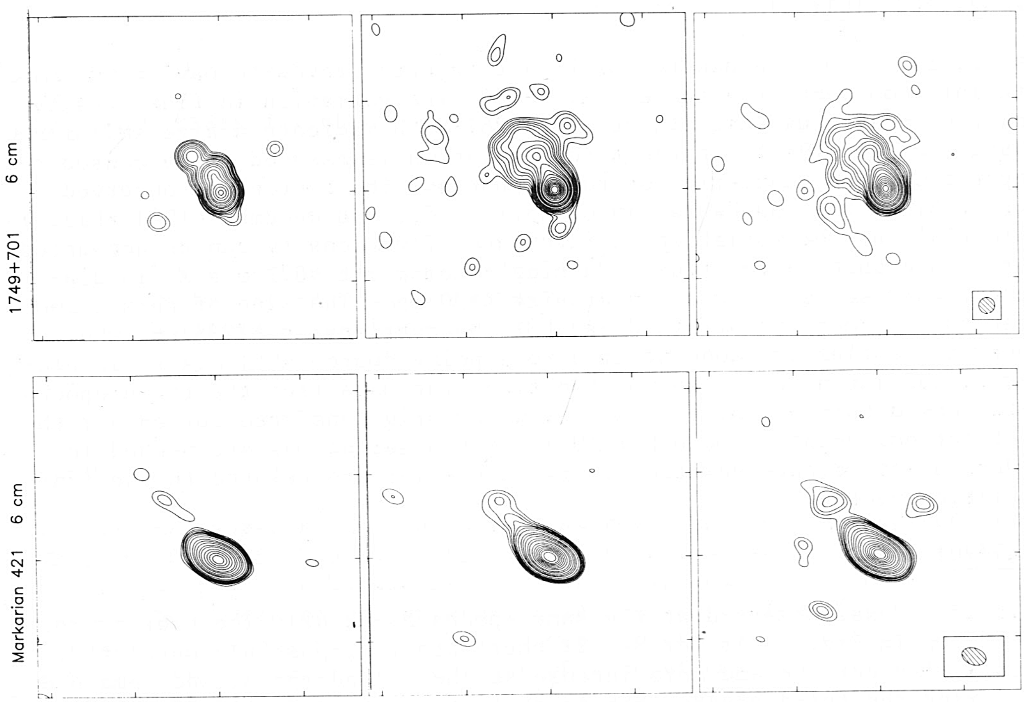

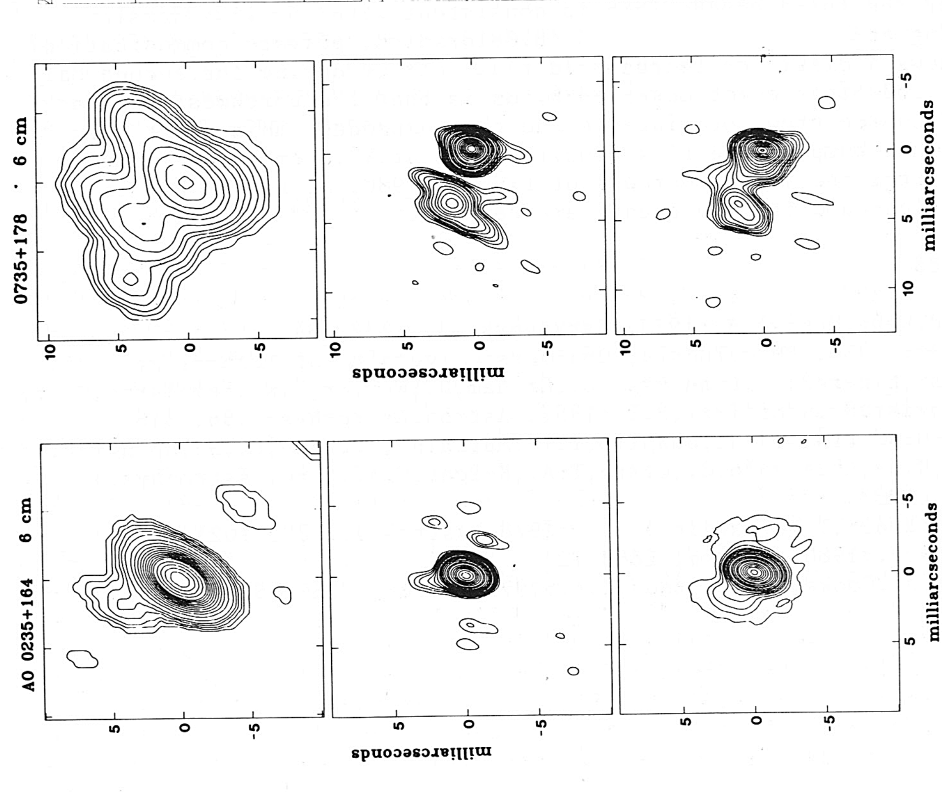

Fig. 1-4, from left to right, with the first epoch at the top in each figure. Tic marks are at every 5 milliarcsecond.

Mk 421(=B2 1101+38)

Mk 421 is one of the handful of BL Lac-objects proven to have underlying stellar components (Margon et al. 1978). The variation in flux density and the X-ray flux (Rickets et al. 1976) both indicate a size <0.1 m.a.s. (Margon et al. 1978), if the X-ray radiation is assumed to be caused by inverse Compton scattering of radio photons. The source was observed with VLBI at the epochs May 1980, April 1981, and December 1981 (Fig.3). Almost all of the variation in integrated flux density can be accounted for by a change in the flux of a single component <0.2 m.a.s. in diameter, corresponding to a linear size <150 mpc. The size of this component is even more constrained by VLBI observations at λ1.35 cm, where most of the flux was concentrated to a point source <0.1 m.a.s. in diameter, consistent with the Compton size. The maps from the three epochs also show a thin 5 m.a.s. long jet, which brightened and formed a rather distinct component in December 1981. More observations are needed in order to investigate how the events in the jet are related to the flux variation of the core.

1749+701

This source was observed at the same epochs as Mk 421. The hybrid maps are shown in Fig. 4. As for Mk 421 there are two, possibly unrelated, events. The core became more intense at the second epoch, and remained so during the third epoch. This is consistent with the flux density monitoring at λ3.8 cm done at NRL (B.Geldzahler, private communication) which shows a distincts increase in flux density during the second half of 1980. The other event observed by us is that the northwest part of the VLBI source grew more intense and then expanded. This event coincides with a bump in the flux density curve at λ3.8 cm which occurred shortly after the large increase of flux in 1980. As for Mk 421 it is not yet clear how the two events are related.

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