Max-Planck-Institut
für Radioastronomie

A Global 86GHz VLBI Survey of Compact Radio Sources

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Introduction

A new global VLBI(Very Long Baseline Interferometry) survey of compact radio sources at 86 GHz has been started in October 2001. Its main aim was to increase the total number of objects accessible for future 3mm-VLBI imaging by a factor of 3~5. The participation of large and sensitive European antennas (like the 100m RT at Effelsberg, the 30m MRT at Pico Veleta, the 6x15m interferometer on Plateau de Bure) provides a single baseline sensitivity of up to ~ 0.1Jy, an image sensitivity of better than 10 mJy/beam, and a global uv-coverage for each source. In combination with European antennas (Onsala, Metsahovi) and the VLBA, the survey will be more sensitive and contain more sources than previous 3mm-surveys (i.e. Londsdale et al. 1998, Lobanov et al. 2000).

The survey was conducted in 3 observing session (October 2001, April 2002 and October 2002). A total of 127 compact radio sources, selected on the basis of their flux density and northern declination, was observed. Some of the objects were observed repeatedly. Among a total of 127 sources observed, only 5 sources (0710+439, 3C309.1, 1749+701, 2021+614, MWC 349) are not detected, and 13 sources are not able to be imaged due to insufficient uv-coverages. So, totally 109 sources are imaged with dynamic range of up to 100. For those 109 sources, the flux densities and sizes of core and jet components will be measured using Gaussian modelfitting(MODELFIT) within the DIFMAP program. The component sizes and flux densities lead to brightness temperature estimates for each structure component.

VLBI surveys at 86 GHz

Survey	Antennas	Observed	Detected	Imaged
1	3	45	12	...
2	2 – 5	79	14	...
3	6 – 9	67	16	12
4	3 – 5	28	26	17
Total of Unique		124	44	24
This Survey	12	127	122	***109***

Columns: 1 – Surveys; 2 – Number of participating stations; 3 – Number of objects observed; 4 – Number of objects detected; 5 – Number of objects imaged.
References : Survey 1 – Beasley et al. (1996); 2 – Lonsdale et al. (1998); 3 -Rantakyrö et al.; 4 – Lobanov et al. (2000)

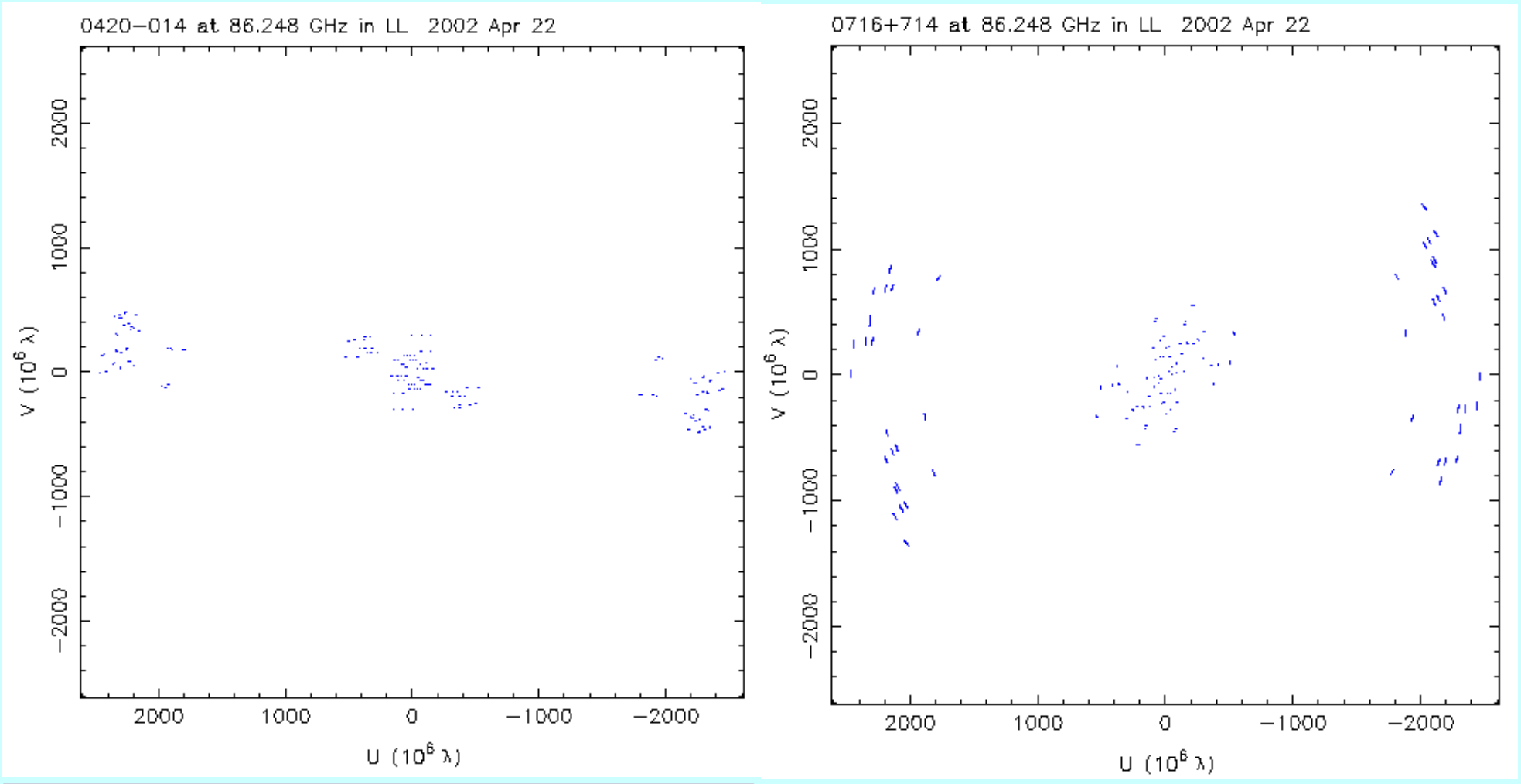
Survey Observation

Participating Telescopes

Station	Diameter (m)	Tsys (K)	Gain (K/Jy)	Eta (%)
Effelsberg	**100**	**130**	**0.14**	**7**
Haystack	**37**	**200**	**0.58**	**15**
Plateau de Bure	**31**	**120**	**0.18**	**65**
Pico Veleta	**30**	**120**	**0.14**	**55**
VLBA	**25**	**120**	**0.03**	**17**
Onsala	**20**	**250**	**0.05**	**45**
Metsähovi	**14**	**300**	**0.02**	**30**

The survey was conducted in three observing sessions of CMVA (The Coordinated mm-VLBI Array), which has been succeeded by GMVA (The Global mm-VLBI Array) since 2003.

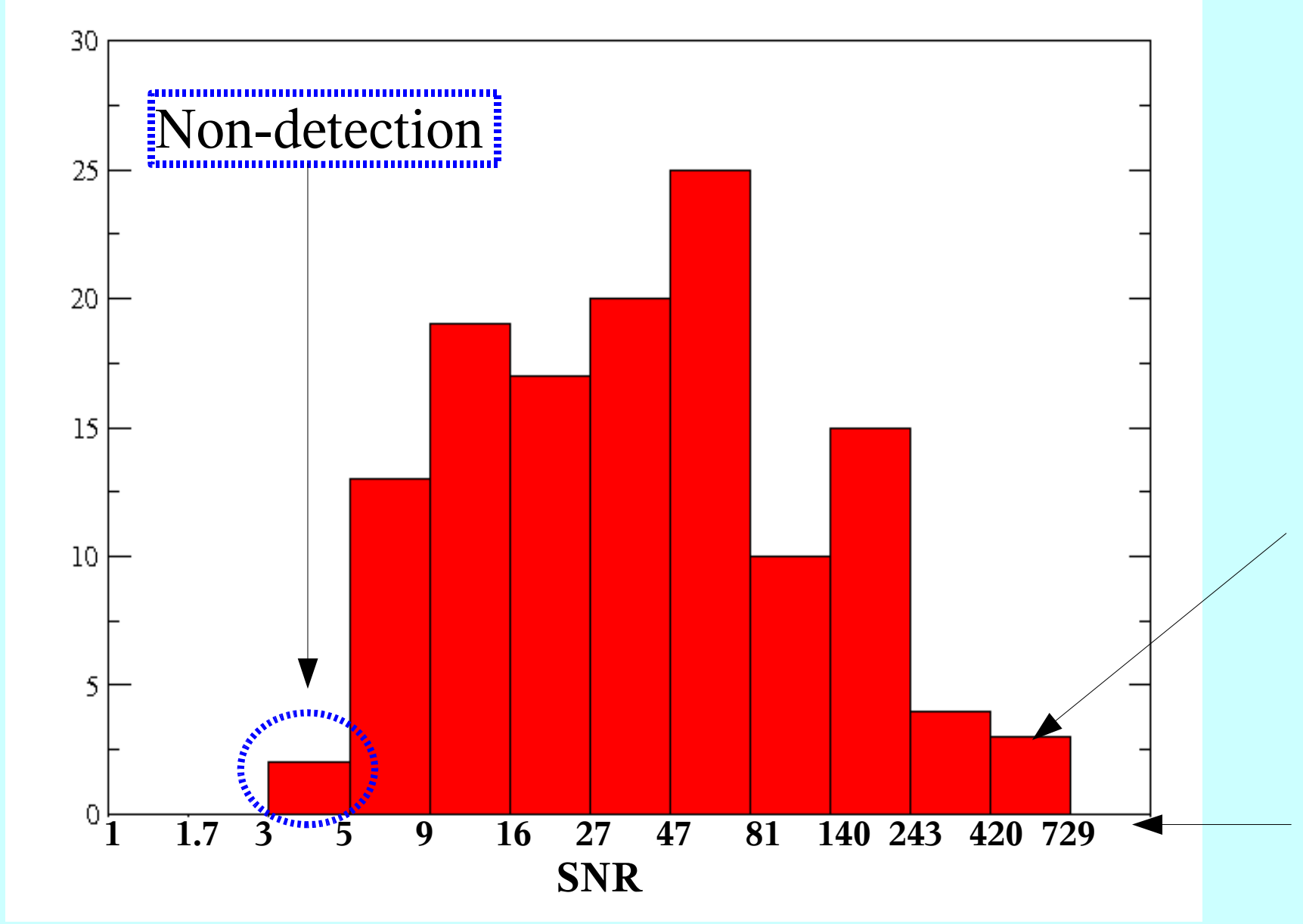
Typical UV-Coverages on Low/High Dec.



0420-014 : Dec = -01h 20m 33s

0716+714 : Dec = 71h 20m 36s

Almost every sources were observed with 3 ~ 4 scans(7min per each). Due to the larger number of the participated stations(> 12), we improved the baseline sensitivity and image sensitivity by a factor of 3 ~ 5 times, compared with the existing surveys.



Histogram of the fringe SNR distribution in the whole Survey data

In the Survey, 122 out of 127 sources observed have yielded fringe detections with SNR > 6.

The highest SNRs are 425 on the Pico Veleta – Plateau de Bure of 1741-038 and 425 on the Effelsberg – Pico Veleta of 1633+382

The X-axis is in logarithmic scale of √3. A few sources with SNR< 5 are non-detected.

Evolution of brightness temperature in the jets

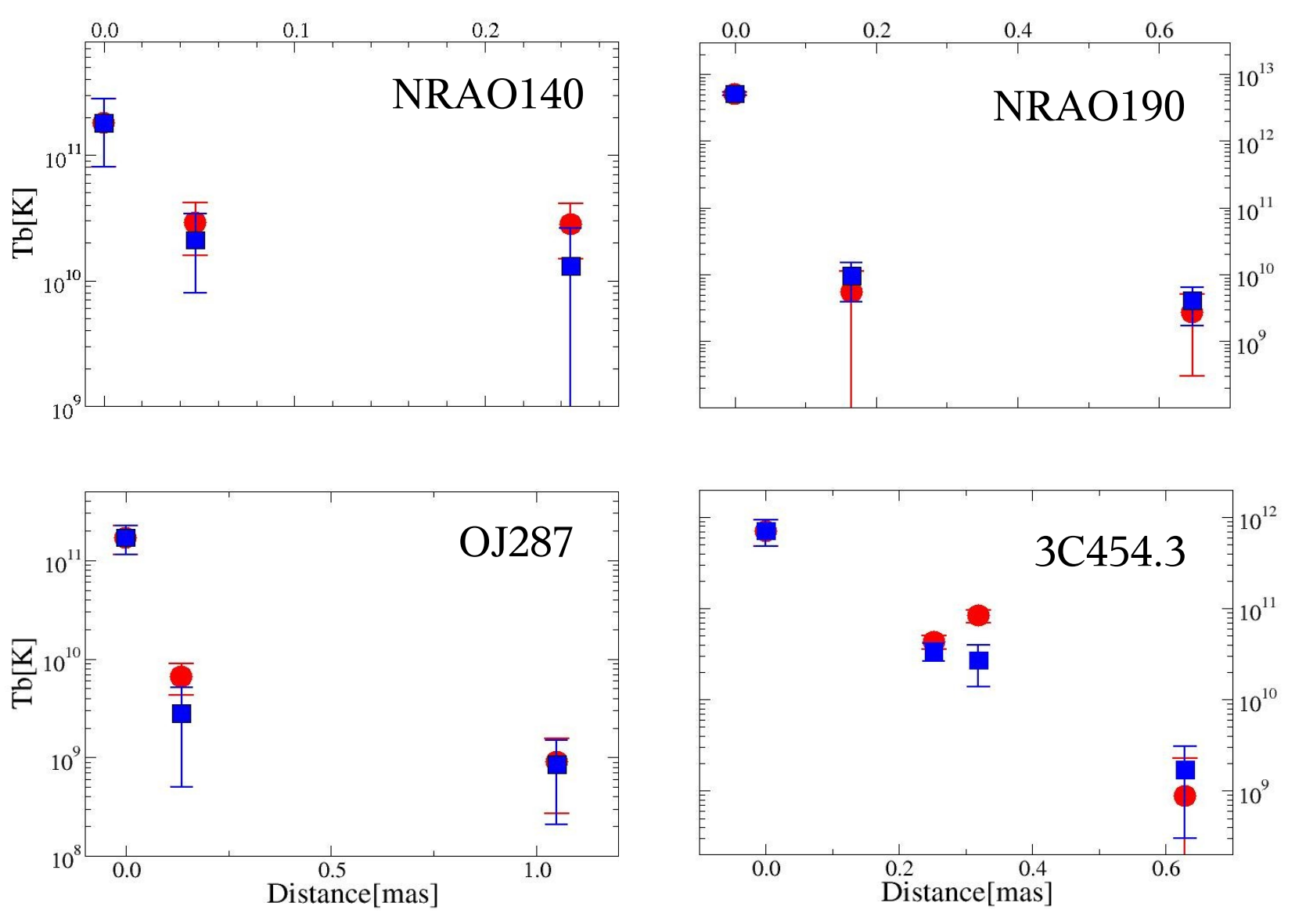


Fig. 1. Changes of the brightness temperature along the jets of several sources. Blue squares are the measured values. Red circles are the predicted brightness temperatures in shocks with adiabatic losses dominating the ratio emission. The initial brightness temperature in each jet is assumed to be equal to that measured in the VLBI core of that jet(see the context).

As mentioned by Lobanov et al.(2000), the difference of the derived intrinsic brightness temperatures of the core and jets, implies that the jet emission should evolve substantially already on the sub-milliarcsecond scales.

By our observations, we investigated the evolution of brightness temperature in the jets, using the postulation that each of the jet components is an independent relativistic shock with adiabatic energy losses dominating the emission (see Marscher 1990) and the assumptions from Lobanov et al.(2000).

The brightness temperature, Tb,J, of each jet component can be related to the brightness temperature of the core, Tb,C, through the following proportionality:

$$T_{b,J} = T_{b,C}(d_J/d_C)^{-\xi} ,$$

where $$\xi = [2(2s+1)+3a(s+1)]/6$$

and $$s=2.0(\alpha=-0.5) , \qquad a=1 .$$

Comparison of Brightness Temperatures of the VLBI cores with their jet speed

We compared the brightness temperatures(Tb) of VLBI cores, measured from our survey, with the apparent speed, βapp, of jets taken from 15 GHz observation (Kellermann el al. 2004). In Fig. 2, the apparent speeds for 86 sources, whose apparent speeds are available, out of 109 sources imaged, are compared with the brightness temperature. Adopting the assumptions from Homan et al. (2006), βapp is represented by a simple function of Tb, $\beta_{app} \approx T_{obs}/T_o$.

Three values of intrinsic brightness temperatures are used to get an insight of the comparison. Due to incorrectness of the assumptions that we took, the scatter in the plot is expected. We could not determine, from such comparison, the value of the intrinsic brightness temperature at 86 GHz, since we adopted βapp at 15 Ghz. If, however, we assume that the apparent speed of the jet component at 86 GHz is similar to that at 15 GHz, then the range of possible intrinsic brightness temperature is $1\times10^{9} \sim 1\times10^{11}$. Such a wide range of To should be narrowed by modeling the population of brightness temperature (Lobanov et al. 2000).

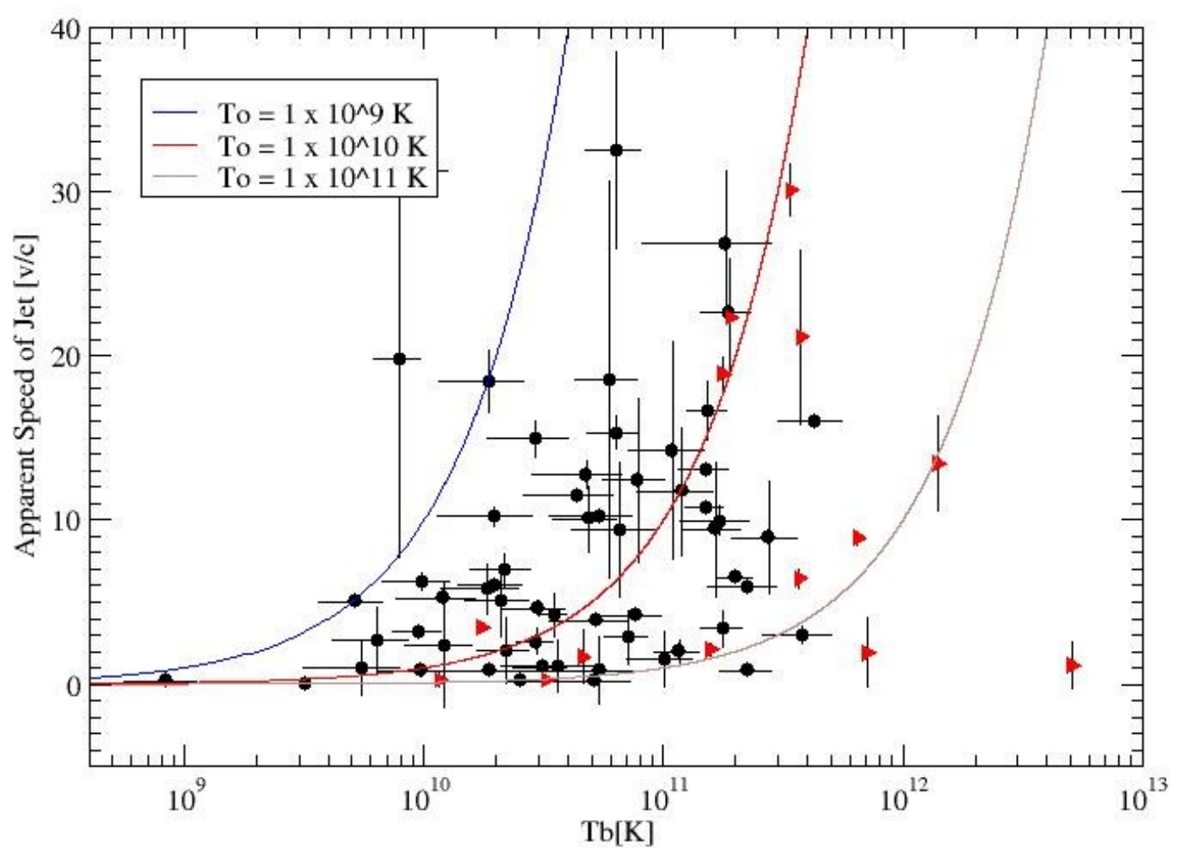


Fig. 2. Apparent speed of jet measured at 15 GHz (Kellermann et al. 2004) and observed brightness temperature(Tb) from our data. Lower limits of Tb are shown as red right triangle and solid circles represent measurements. Solid lines represent three groups of sources observed at the critical angle that have the intrinsic Tb; 1×10^{9} (blue), 1×10^{10} (red), and 1×10^{11}(brown)

The comparison of the brightness temperatures of core and secondary jet components from this survey, with similar estimates obtained from surveys at longer wavelengths, will be used further to study questions related to mechanisms of initial jet acceleration (*accelerating or decelerating sub-pc jets?*) and jet composition (*electron - positron, electron - proton plasma ?*).

Distribution of Brightness Temperatures

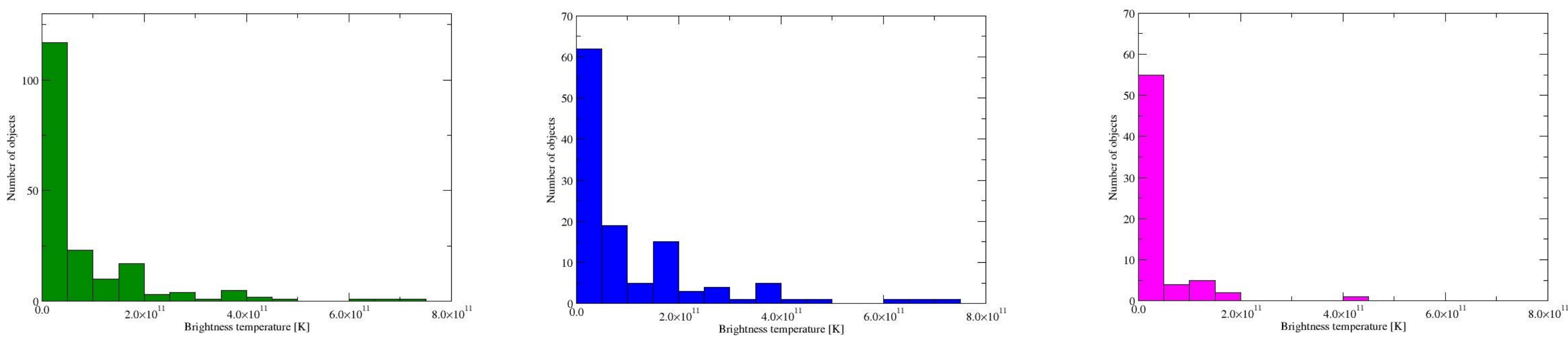
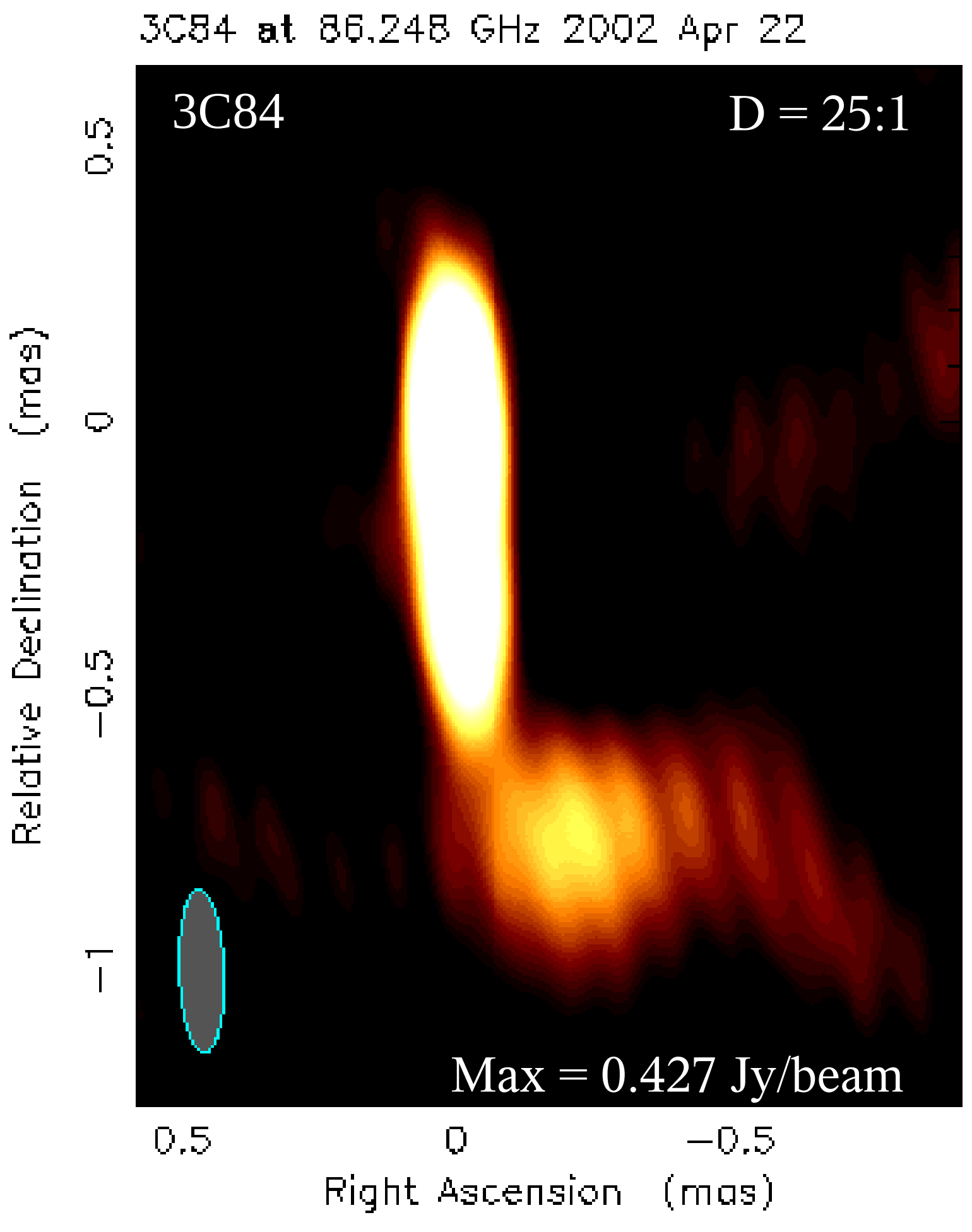
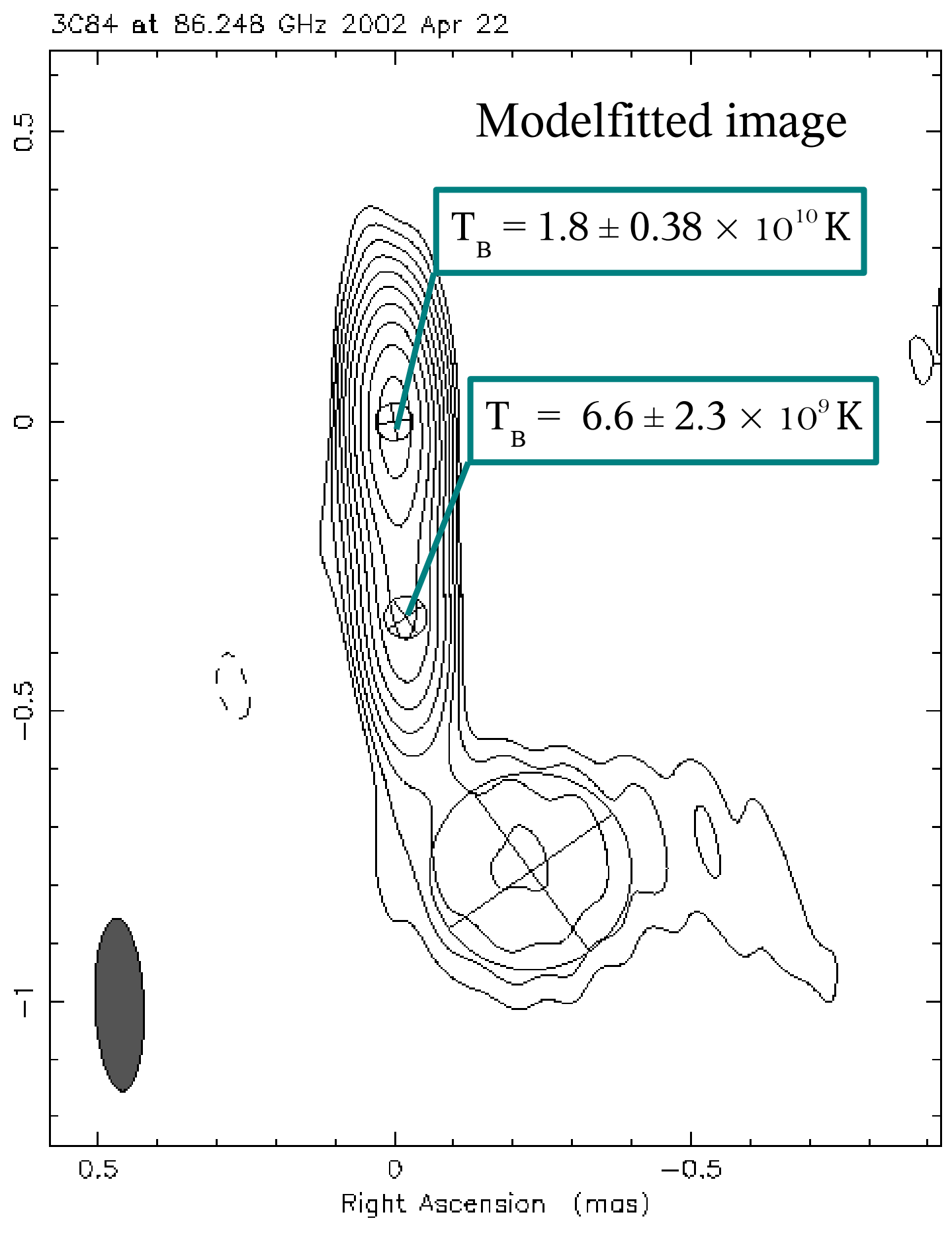


Fig. 3. Distribution of the brightness temperatures measured in the ALL components(left), the VLBI core (left), and the jets(right). The bin size is 5e+10 K.

References
Beasley et al. 1996, In: Barvainis R., Phillips R.B. (eds.) MM-VLBI Science Workshop. Haystack Observatory, Cambridge, p.53
Homan, D.C., Kovalev, Y.Y., Lister, M.L. et al. 2006, ApJ 642L, 115
Kellerman, K.I., Lister, M.L., Homan, D.C., Vermeulen, R.C., Cohen, M.H., Ros, E. et al. 2004, ApJ 609, 549
Lobanov, A.P., Krichbaum, T.P., Graham, D.A., et al. 2000, ApJ 364, 391
Lonsdale, C.J., Doeleman, S.S., Phillips, R.B., 1998, AJ 116, 8
Rantakyrö, F.T., Baath, L.B., Backer, D.C., et al. 1998, A&AS 131, 451

The Source images at 86 GHz with the Global mm-VLBI





Among 122 sources detected, more than 109 sources are satisfactorily imaged. With those images the 86 GHz database will be expanded by a factor of 3 ~ 5.

With this survey observation, we are able to image and fit the secondary and tertiary jet components by simple Gaussion models and to measure the brightness temperatures of each core and jet components with obtained modelfit parameters.

Images on the top-left and top-right show the change of the direction of the jet components of 3C84 in a time scale of 6 month.