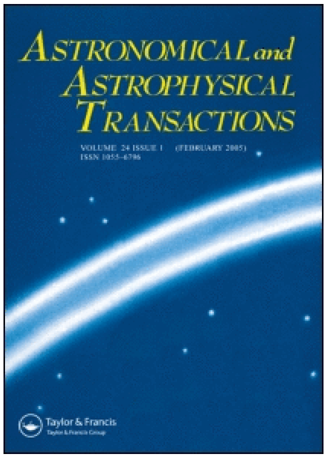

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

0836+710. High quality ground and VSOP images

A. Chuprikov [a]
[a] Astro Space Centre of P.N. Lebedev Physical Institute of Russian Academy of Sciences, Moscow, Russia

Online Publication Date: 01 August 2007
To cite this Article: Chuprikov, A. (2007) '0836+710. High quality ground and VSOP images', Astronomical & Astrophysical Transactions, 26:4, 371 - 378
To link to this article: DOI: 10.1080/10556790701592167
URL: http://dx.doi.org/10.1080/10556790701592167

Astronomical and Astrophysical Transactions
Vol. 26, Nos. 4–5, August–October 2007, 371–378

0836 + 710. High quality ground and VSOP images

A. CHUPRIKOV*

Astro Space Centre of P.N. Lebedev Physical Institute of Russian Academy of Sciences, Profsoyuznaya 84/32, 117997, Moscow, Russia

(Received 4 July 2007)

Some results from the processing of data of two Very Long Baseline Interferometry (VLBI) observations of well-known quasar 0836 + 710 are presented. This source demonstrates a big parsec-scale jet with reach structure in S (2300 MHz), C (4980 MHz), and X (8400 MHz) frequency bands and has been included into the Japanese mission titled VSOP (VLBI Space Orbital Program) as well as into the future Russian mission titled 'RADIOASTRON' source listing. The radio images presented here illustrate some interesting properties of radio structure of 0836 + 710. The processing of data has been carried out with the software 'Astro Space Locator' (ASL for Windows).

Keywords: SVLBI (space very long baseline interferometry); 'RADIOASTRON'; Astro Space Locator

1. Introduction

Observations of many astrophysical objects using the VLBI method could dramatically change our understanding of the nature of these objects. Most valuable are the VLBI observations on baselines whose length is about the size of the Earth. The Japanese program VSOP uses baselines with maximum baseline length. We present one result from the processing of data from Space VLBI observation of the quasar 0836 + 710 (J0841 + 7053). For comparison, another result from the processing of data of a Very Long Baseline Array (VLBA) observation is also presented in this paper.

2. Description of experiments

The VSOP observations were made on 7 October 1997 in C frequency range. Two bands covering the range between 4962 and 4994 MHz were recorded. 10 VLBA antennae were involved in this experiment. Two tracking stations (in Tidbinbilla, Australia, and in Madrid, Spain) were used to receive the signal from the satellite.

Observations of 0836 + 710 were made from 6 : 00 Universal Time (UT) until 17 : 00 UT. The data obtained were correlated at the National Radio Astronomy Observatory

*E-mail: achupr@asc.rssi.ru

Astronomical and Astrophysical Transactions
ISSN 1055-6796 print/ISSN 1476-3540 online © 2007 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/10556790701592167

Table 1. Nominal parameters of 0836 + 710.

Source names	Right ascension (2000)	Declination (2000)	2200 MHz Flux density [Jy]	4980 MHz Flux density [Jy]	8400 MHz Flux density [Jy]
0836 + 710 (J0841 + 7053, 4C + 71.07)	08:41:24.3652	+70:53:42.1730	3.25	2.45	2.00

(NRAO) VLBA correlator in Socorro New Mexico, USA. The final Flexible Image Transport System (FITS) file contained two frequency bands of 16 MHz width. All the observations were made in one polarization (LL). The Principle Investigator (PI) of this observation titled V041 was Dr. Andrew Lobanov (the Max Plank Institute for Radio Astronomy, Bonn, Germany). Later, this FITS-file was kindly passed to the author.

Table 1 contains coordinates and flux density values of source observed. 0836 + 710 (another name is 4C + 71.07) is known as a superluminal gamma-ray and X-ray loud quasar with core-dominated structure and high redshift ($z = 2.17$).

The VLBA observations of the same object were made on 15/16 April 1999 in S (2200 MHz) and X (8400 MHz) frequency ranges simultaneously. Eight frequency channels were recorded, each 8 MHz wide, with four at S band (centred at 2.22, 2.24, 2.33, and 2.36 GHz) at four at X band (centered at 8.41, 8.48, 8.80, and 8.90) for a total bandwidth of 8 MHz in each frequency band. This experiment was the survey observational session titled RDV14. 0836 + 710 was observed from 15 April 1999 15 : 20 UT until 16 April 1999 10 : 45 UT. Nine short-time observations 5–10 minutes each were made for this source during these 19.5 hours.

The same VLBA correlator has been used for RDV14 primary data processing. The FITS-file obtained after such correlation data processing has four frequency bands of 8 MHz width for S range as well as for X range. Again, all the observations were made in one polarization (RR).

All the data of RDV14 were preserved in archive and later kindly passed to the author by Dr Leonid Petrov (The Goddard Space Centre, USA).

3. Method of data processing

Similar schemes of data processing were used for both experiments. The scheme consists of the following stages:

1. Amplitude calibration of data with use of system temperatures and antennae effective area values measured during the observations.
2. Single band Fourier fringe search of all the data.
3. Single band least squares fringe fitting of all the data.
4. Self-calibration of all the data.
5. Averaging of all the data over frequency and time.
6. Editing of all the data.
7. Imaging.

The whole data processing cycle detailed above was performed with software titled ‘Astro Space Locator’ (ASL for Windows). This software is free and is available on the Internet. See [1] for details.

Amplitude calibration of data of RDV14 was made using two calibration tables (gain curve (GC) and system temperature (TY)) created with the VLBA correlator during the primary data processing.

The same procedure of data amplitude calibration for ground-space experiment V041 had some peculiarities. Unfortunately, there was neither GC nor TY calibration table in the

FITS-file created with the correlator. Thus, it was necessary to find all the calibration data in corresponding archives. Additionally, the following values of calibration parameters for the VSOP satellite antenna were obtained:

1. Effective area value for C frequency range is 17.11 square metres.
   In other words, degrees per flux unit value (DPFU) is equal to 0.0062.
2. System temperature values for C frequency range are the following:
   - 99.5–102.6 K for lower frequency band (4962–4978 MHz)
   - 103.7–105.9 K for upper frequency band (4978–4994 MHz)

The text calibration file that contains all the values above was written manually. This file has been used for the ASL amplitude calibration procedure similar to Astronomical Image Processing System (AIPS) task 'ANCAL'.

Phase calibration of all the data of both experiments was much more complex. First of all, it was necessary to perform the Fourier global fringe search to estimate the primary values of residual delay and fringe rate for each antenna, each frequency group, and each time interval. After this procedure, global fringe fitting was performed to obtain more precise solution for gains of each antenna and, simultaneously, to create the source model. After the application of gains obtained to initial visibility function, it is correct to average the visibility over time and frequency in order to increase the signal-to-noise ratio (SNR). After this, self-calibration was done to reconstruct the source structure. Finally, the technique of multi-frequency synthesis (MFS) was used to unify data from all frequency channels correctly and to reconstruct the source image. The MFS technique is more important for the VLBA experiment titled RDV14, because two widely separated frequency ranges had been used in these observations, as mentioned above.

4. Results of data processing

Results of processing of data from the RDV14 VLBA experiment are shown in figures 1–4. The MFS technique was used to unify the data of S and X frequency ranges.

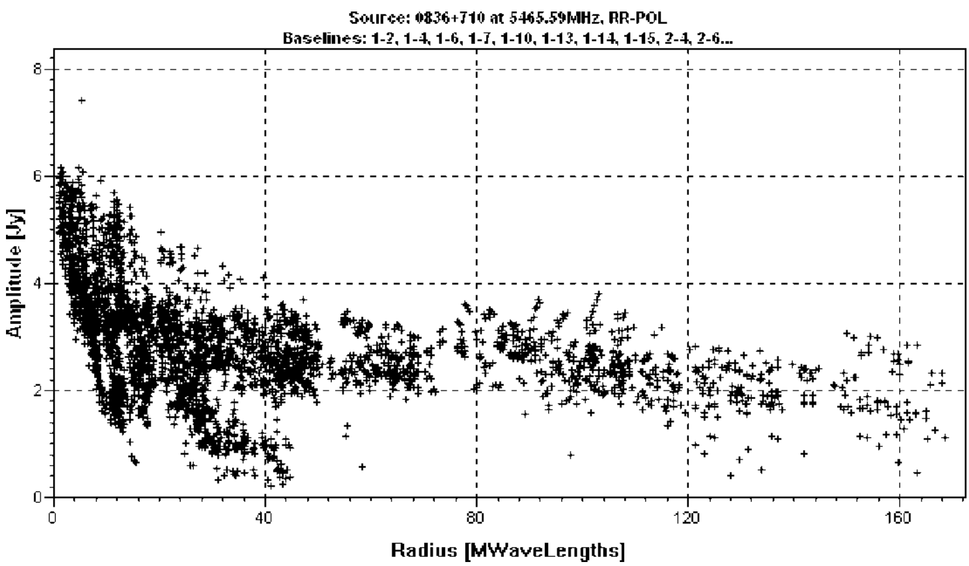

Figure 1. RDV14. Visibility amplitude as a function of (u, v)-radius.

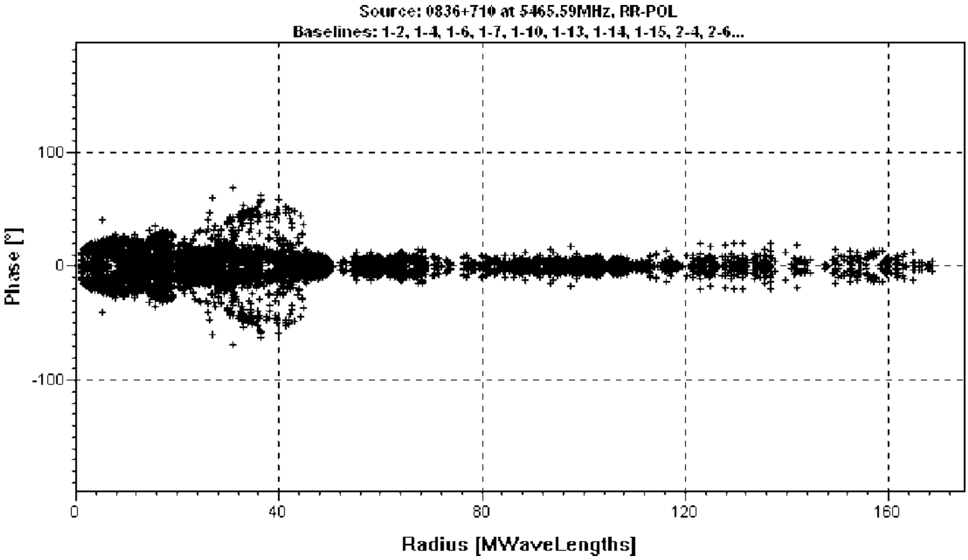

Figure 2. RDV14. Visibility phase as a function of (u, v)-radius.

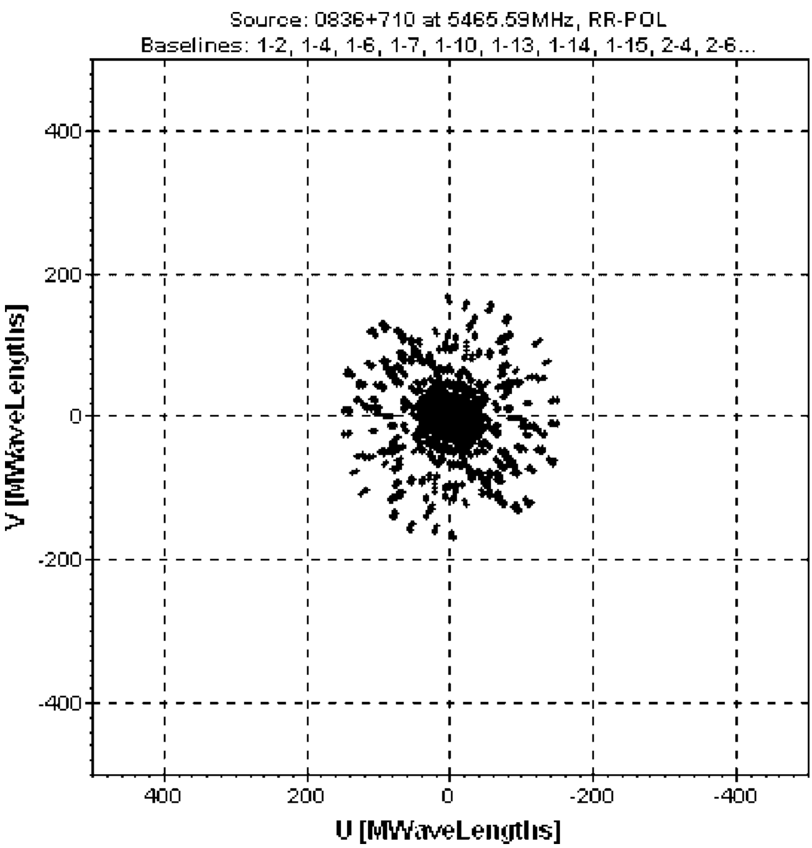

Figure 3. RDV14. (u, v)-plane coverage.

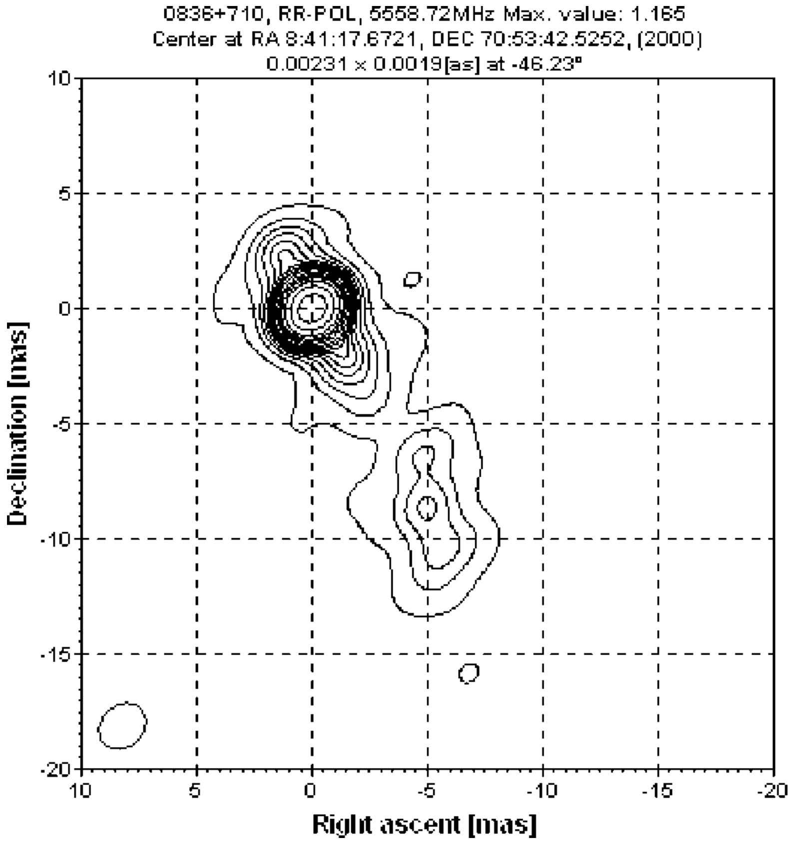

Figure 4. RDV14. Reconstructed VLBA two-frequency image of 0836 + 710.

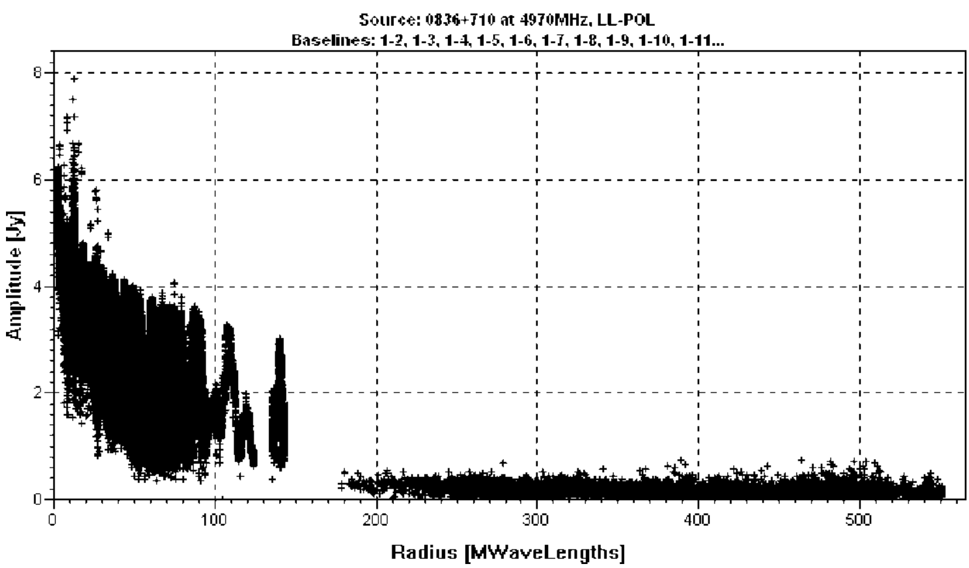

Figure 5. V041. Visibility amplitude as a function of (u, v)-radius.

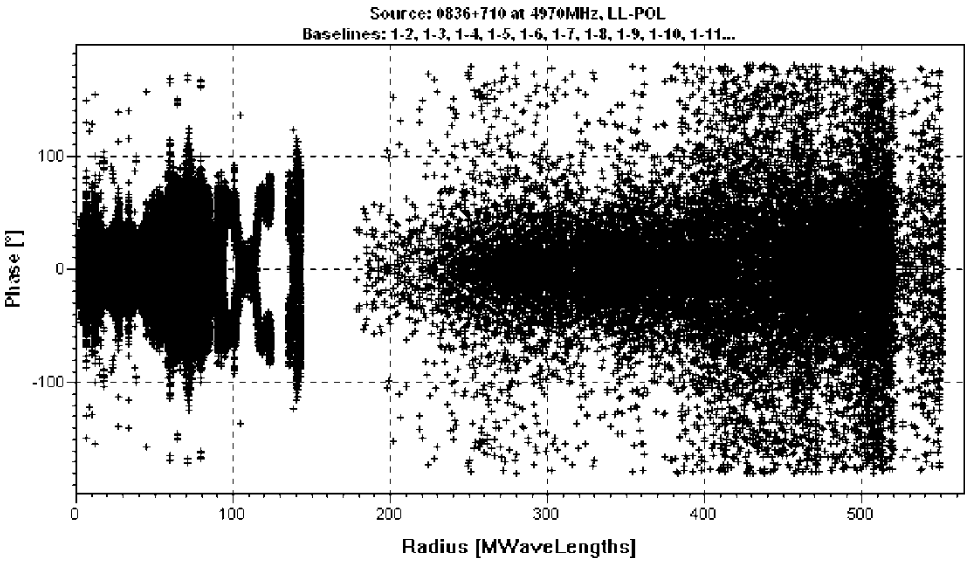

Figure 6. V041. Visibility phase as a function of (u, v)-radius.

Results from the processing of data from the V041 VLBA-VSOP experiment are shown in figures 5–8. The MFS technique was used to unify the data from the two frequency bands.

A simple analysis of the results above shows that:

- Using a satellite with semi-major axis of 17300 km, eccentricity of 0.6 and orbital period of 6.3 h allows very significant improvement of the (u, v)-plane coverage.

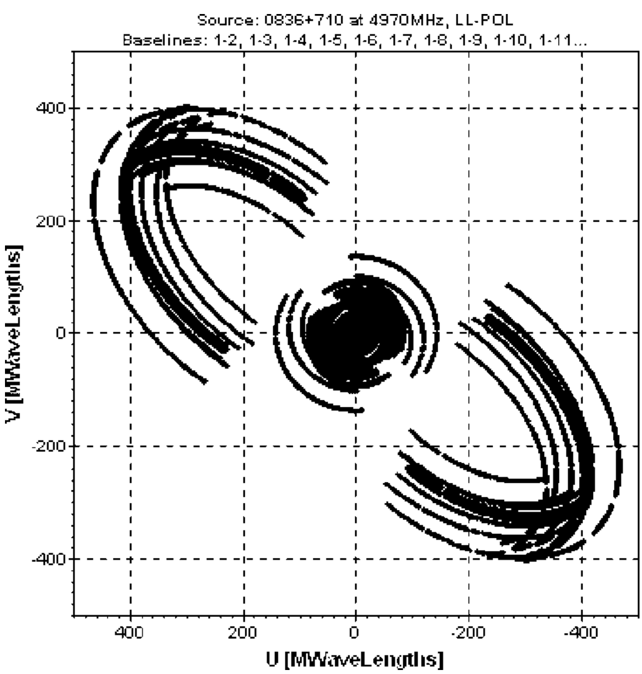

Figure 7. V041. (u, v)-plane coverage.

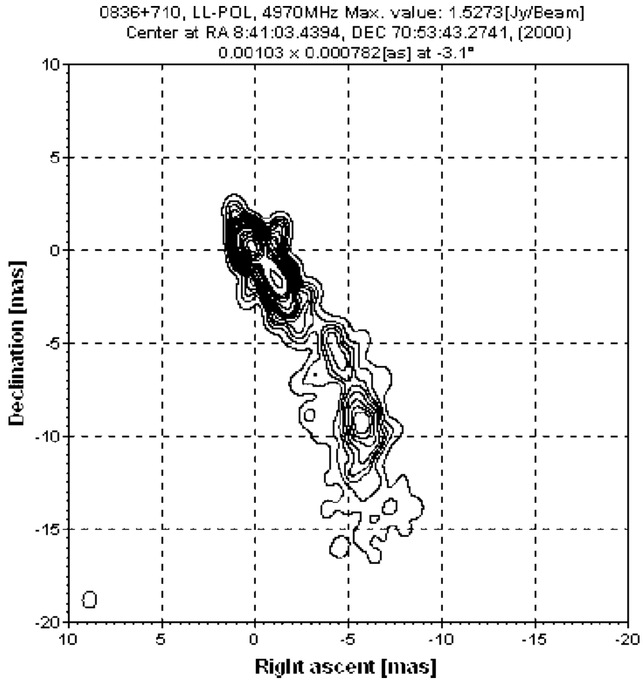

Figure 8. V041. Reconstructed VLBA-VSOP image of 0836 + 710.

- Diameter of the beam for Space VLBI observations is less than 1 milliarcsecond in the C frequency range.
- Diameter of the beam is more than 2 milliarcsecond for the same source VLBA observations and similar frequency range (S + X frequency range).
- The dynamic range value for the Space VLBI map reconstructed is approximately 940 (1.5 : 0.0016).
- The dynamic range value for the VLBA dual frequency map reconstructed is approximately 300 (0.9 : 0.003).

In other words, this example shows that VLBA co-observations with satellite that has short period and not any high orbit allows one to obtain results 2–3 times better than ordinary VLBA observation results.

It is necessary to remember that the 'RADIOASTRON' Space VLBI project includes the high orbit with semi-major axis of 189000 km and orbital period of 7–10 days. Moreover, evolution of the satellite orbit is also proposed. Thus, we could obtain, in principle, much finer results by processing the 'RADIOASTRON' data in comparison with the analogous VSOP data. On the other hand, it is clear that requirements for data calibration are much more stringent in this case.

5. Conclusions

The results above show that Space VLBI array data processing allows one to reconstruct radio images of astronomical objects with high resolution and high dynamic range. Often, this is necessary for investigation of extragalactic sources such as quasars and active galactic nuclei (AGN).

Such investigations are important because they could dramatically change our understanding of the nature of these objects. Methods of Space VLBI data calibration must be developed and improved. In particular, it is necessary for the future Space VLBI mission 'RADIOASTRON' because this project includes a high orbit satellite. Such investigations will be continued in the near future.

Acknowledgements

I thank Dr Leonid Petrov and Dr Andrew Lobanov for the original data. I also thank Dr Phil Edwards for calibration data and very useful discussions about the properties of SVLBI data processing. Moreover, I'd like to thank my colleagues Sergey Likhachev and Igor Guirin for assistance during the data processing.

References

[1] A.A. Chuprikov, An Imaging Software Project Astro Space Locator (ASL for Windows): New methods and software abilities, in *Proceedings Of the 6th European VLBI Network Symposium on new developments in VLBI Science and Technology, held at the Gustav-Stresemann-Institut, Bonn, Germany, on June 25–28, 27 2002.*