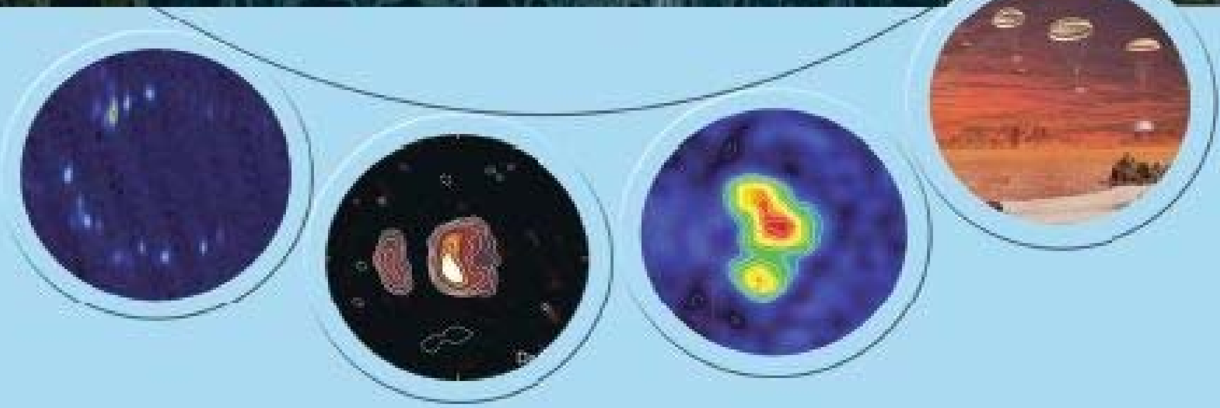
Joint Institute for VLBI in Europe

Biennial report 2005-2006



JIVE
JOINT INSTITUTE FOR VLBI IN EUROPE

The Joint Institute for VLBI in Europe (JIVE) was established as a scientific foundation in December 1993. JIVE's mandate is to support the operations of the European VLBI Network (EVN) in the widest sense.

JIVE's operations are supported via multi-national funds from the following organisations:

Netherlands Foundation for Research in Astronomy (ASTRON), the Netherlands;

National Geographical Institute (IGN), Spain;

Italian National Institute of Astrophysics (INAF), Italy;

Max Planck Institute for Radio Astronomy (MPIfR), Germany;

National Astronomical Observatory of China (NAOC), China;

Netherlands Organisation for Scientific Research (NWO), the Netherlands;

Onsala Space Observatory (OSO), Sweden;

Particle Physics and Astronomy Research Council (PPARC), UK.

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FOREWORD BY THE CHAIRMAN OF THE JIVE BOARD

The core task of the Joint Institute for VLBI in Europe is to support the operations of the European VLBI Network. Timely processing of the astronomic observations and delivering a flawless data product, ensures the optimal use of the scientific facility in which JIVE plays a central role. The transition to recording of disks has brought a major improvement of the efficiency, quality and astronomical capabilities of the EVN. During the 2005 – 2006 period the first user experiments with Giga-bit-per-second recordings were carried out, enhancing the sensitivity of the EVN even further. It also resulted in a substantial improvement of the reliability of the network. Moreover, the efficiency of correlation improved to such a degree that now typically all experiments are made available to the astronomers before the next session starts. Combined with continuous improvements in the data product, and their accessibility through the archive, these are important advances for the users of the EVN.

JIVE also successfully demonstrated a number of important innovations that will enhance the scientific impact of the EVN in the future. Starting from the earlier proof-of-concept project, the e-VLBI experiments were transformed into an operational scientific service, with up to 6 antennas, competitive data rates of 256 Mb/s and convincing operational robustness. This is demonstrated by the fact that the first scientific papers based on e-VLBI observations emerged towards the end of 2006. A crucial step to enable this was the successful EXPReS proposal. A considerable fraction of the upgrades that are necessary for e-VLBI are funded from this EC 6th framework project.

Another innovative use of VLBI was the tracking of the Huygens probe by radio telescopes during the descent of the Huygens spacecraft in January 2005 to the surface of Titan, the largest moon of Saturn. Within an ESA supported project, JIVE staff had taken the responsibility to monitor the direct signal from the lander in order to determine the trajectory through the Titan atmosphere with km accuracy. This in itself was indeed achieved after intensive and complex data processing. Another major result from this initiative was the direct detection of the Huygens signal by several larger radio-telescopes around the world, which caught the attention and imagination of a large audience.

For the partners in the EVN these innovations offer important starting points to expand the astronomical potential of the network. In this respect the introduction of the ParselTongue software should be highlighted, which is making a significant difference throughout the community, as it directly helps young scientists to process their data much more flexibly.

Through this wide range of activities, JIVE proves its great value for the European VLBI Network, assuring that there is a place where the focus is unambiguously on the advance of the collaborative long baseline technique. Indeed this is an asset for European radio-astronomy, now that the landscape is changing rapidly with the advent of SKA and its pathfinder instruments like LOFAR. The EVN will play a role in the shaping of the SKA program. I expect there to be a lot of opportunities for JIVE and the EVN to take advantage of the technological innovations that will be developed in this context.

There will also be a high demand for young radio-astronomers, in particular those who have an affinity for the technical details of our trade. In this respect it is very good to see that the JIVE staff now has increased their involvement in training PhD students through European collaborations. Being actively involved in the many aspects of VLBI science ensures that the JIVE focus is strongly on astronomical applications.

With all these new projects at JIVE the number of employees has grown rapidly reaching a total of 36 at the end of 2006. This implies that there is now more temporary than permanent staff, a sign of success, but at the same time a concern, as the pressure on management increases and more complex structures are required to support the organization and project management.

Finally, the end of this reporting period is coincident with the end of the directorship of Mike Garrett, who left JIVE in January 2007. He has been the architect of the growth of JIVE during the last 4 years. By seeing the opportunities for innovation, in particular in the area of e-VLBI, he has laid out a clear path for the development of the EVN. On behalf of our entire community I like to thank him for the dedication and energy with which he has played this important role for the EVN and JIVE.

Prof. Dr. Anton Zensus

Chairman of the JIVE Board

1. INSTITUTE

1.1 Introduction

During 2005 and 2006 JIVE successfully demonstrated a number of VLBI innovations. Most of these activities have now taken the form of externally funded projects. After the conclusion of a successful Proof-of-Concept project, the e-VLBI effort has now become a large-scale, EC-funded project, with high visibility in the radio-astronomical and networking communities. Another example is the success of the VLBI observations of the Huygens probe during its descent to the surface of Titan, one of the moons of Saturn. By tracking the probe with some of the largest radio telescopes around the world it was possible to calculate an extremely accurate trajectory of the Huygens spacecraft, and provide the mission with vital Doppler data. Within the context of RadioNet, ParselTongue was introduced as a new platform for data reduction. In the area of astronomical research JIVE was able to secure new projects and attract new talented people. In the midst of all these energetic activities, the focus on the JIVE core business was never lost and production of astronomical data sets actually progressed more efficiently than ever before. The strength of JIVE was reflected in the ESF formal review in early 2006 in which JIVE was assessed as outstanding and judged to be leading the world in VLBI innovations.

1.2. Core business

The operational capabilities of the disk-based Mark5 playback system continued to be improved, replacing the old tape-based playback system completely by 2006. Throughout the transition period, the Data Processor remained flexibly configurable to accommodate both tape- and disk-based recordings. The resulting improvement in efficiency has had a clear effect on the correlator metrics. Similarly the ERI, which is a measure of telescope performance compiled at JIVE, shows a steady improvement. This is not only the result of the introduction of the disk systems, but also due to very tight monitoring during so-called ftp tests. Data quality has improved noticeably as well, while Gbps recording has now become a standard mode. The PCInt hardware became operational in 2005 and played a crucial role in processing a number of experiments with extreme storage requirements. The data archive was further improved and direct access to the archive by users has now largely replaced the distribution of tapes. A large number of predominantly young visitors visited JIVE to process their data aided by JIVE staff. The European Radio-Interferometry School in Manchester (2005) and the EVN Symposium in Torun were important events in the interaction with the VLBI user community.

1.3. Projects

Until 2005 the e-VLBI effort was mainly sustained through a Proof-of-Concept project, based on internal EVN resources and collaborations with several National Research and Educational Networks (NRENs) and DANTE, the operator of the pan-European research network GÉANT. During that year a 6th framework proposal, EXPReS, was submitted to the EC, and rated first in the DG Information Society round of proposals. In March 2006 the EXPReS project, in which JIVE plays the role of coordinator, formally started. Its work packages deal with creating an operational e-VLBI service and establishing connectivity to the telescopes, in Europe and beyond. Networking activities ensure continued communication with the NRENs, as well as a platform to discuss the policy changes needed to ensure an optimal use of the new capabilities. A separate project is aimed at developing 10 Gbps VLBI and distributed correlation ("Future Arrays of Broadband Radio-telescopes on Internet Computing", FABRIC). At JIVE the technical development has focused on enhancing the correlator for e-VLBI, implying a major overhaul of the data processor software which was designed to handle data recorded weeks or months earlier. The impressive progress in connectivity and robustness has made it possible to offer e-VLBI science runs for time-critical observations to the astronomical community. After overcoming some growing pains these runs successfully deployed 5 or 6 telescopes, and in the first year of EXPReS two scientific papers resulting from these efforts were accepted for publication (e.g. Figure 1.1).

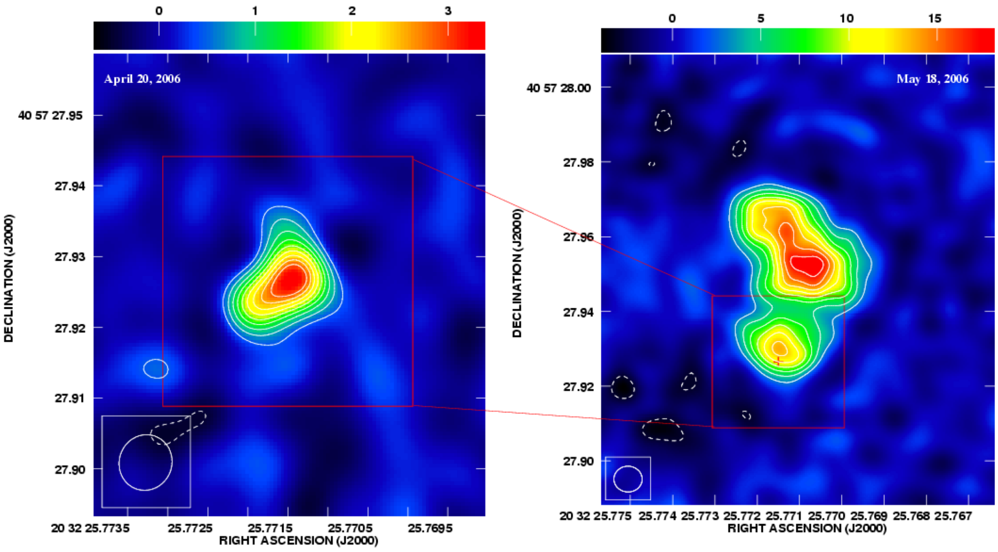


Figure 1.1: e-EVN total intensity maps of Cyg X-3 in quiet state (to the left, 2006 April 20) and 10 days after a huge outburst (to the right, 2006 May 18). The e-VLBI observations took place with Cm, Jb2, Mc, On, Tr and Wb14 at 128 Mbps (Tudose et a, to be published 2007, see also section 5)

Also in 2006 the SCARIe project (Software Correlator Architecture Research and Implementation for e-VLBI) was funded by NWO. This establishes a new collaboration with computer scientists at the University of Amsterdam and the Dutch National computer centre SARA. Its goals are largely complementary to JIVE's work-packages in the EXPReS "Joint Research Activity" FABRIC, and it aims to investigate some of the work-load distribution and balancing problems associated with the distributed correlation problem. This project will make extensive use of the Dutch Grid computing infrastructure.

JIVE continued to lead the ALBUS FP6 RadioNet software project. The first results of this software project reached the user community in the form of the so-called ParselTongue software. This allows users to combine well-established algorithms in a modern scripting environment. It has turned out to be very useful for processing large datasets and non-standard calibration schemes. As a result it is rapidly being picked up by young radio-astronomers across Europe. JIVE also has the lead in the

Astronomical and Data Simulations of the SKADS – the Square Kilometre Array (SKA) Design Study coordinated by ASTRON and funded by the EC, which started in 2005.

In 2005 and 2006 JIVE participated, with great success, in the Huygens mission, through a number of subsidies received from ESA. Originally the experiment was designed to perform VLBI tracking of the descent. JIVE scientists were not only responsible for the data analysis, but also for organising the world-wide observations of the spacecraft in January 2005. This generated an enormous amount of attention in the press when it became clear, very soon after the landing, that these observations provided the earliest sign that the Huygens probe had survived the landing (Figure 1.2). Moreover, the direct observations of the spacecraft carrier signal became the only source of Doppler tracking data, when the originally planned relay of Doppler data to the Cassini orbiter failed. The tracking of the Huygens descent proved a great success and led to a number of publications co-authored by JIVE staff members. Furthermore, it highlighted the potential for VLBI spacecraft navigation in the future.

Figure 1.2: Leonid Gurvits (left, on RTL editieNL) and Huib Jan van Langevelde (right, NOS journal) featured prominently on Dutch national TV after the press picked up that JIVE had secured vital radio measurements of the Huygens descent on Titan.

With respect to astronomical research, JIVE was already involved in the Marie-Curie project ANGLES. In collaboration with colleagues from the EVN a new initiative was taken for "Early-Stage TRaining site for European Long-wavelength Astronomy" (ESTRELA). This programme supports up to 3 PhD positions that JIVE will offer in collaboration with Dutch universities.

1.4. Other events

On 7 July 2005 JIVE hosted the EC astronomy press event with support from ASTRON. In several presentations, EC-funded astronomy projects explained their objectives to journalists from a large number of European countries. The press gathered in Westerbork the day before for a barbecue which allowed them to talk to the local astronomers. On the press event day itself, the European commissioner Janez Potočnik was present, as was the Dutch science and education minister Maria van der Hoeven. The EC-commissioner was introduced to the correlator and the e-VLBI effort. He officially ended the tape era for European VLBI by stopping the last tapes. In the press event itself various issues related to the European science policy were addressed (Fig 1.3).

Figure 1.3: EU commissioner Janez Potočnik and Maria van der Hoeven, Dutch Minister for Education Culture and Science, during the EC press event.

As mentioned, JIVE featured in many newspaper articles and even television programs covering the Huygens landing. In 2006, NASA awarded a group of scientists, including Ian Max Avruch, Leonid Gurvits and Sergei Pogrebenko with the "Group Achievement Award" for "greatly enhancing the Cassini-Huygens mission by detecting the probe's radio signal at Earth and determining the Doppler shift to measure the wind speed on Titan". The award was presented by Anton Zensus, chairman of the board, at the dinner following the JIVE board meeting in November 2006 (Figure1.4).

Figure 1.4: NASA Group Achievement Award for Leonid Gurvits and Sergei Pogrebenko (Max Avruch not shown on the picture).

JIVE staff also appeared in a Japanese documentary on the VSOP mission. In addition JIVE was mentioned in an article in the Dutch version of National Geographic about the activities at the Dwingeloo observatory on the occasion of 50 years Dwingeloo Radio Telescope. Of course JIVE was involved in the "open days", during which the general public can visit JIVE and ASTRON in Dwingeloo and Westerbork. In 2006 the event took place in Dwingeloo and attracted about 3000 visitors.

The International Academy of Astronautics (IAA) recognised the performance and achievement by the team of scientists, engineers and managers in the field of Astronautics by the VLBI Space Observatory Programme (VSOP). The Laurels for Team Achievement Award 2005 was given to an international group of astronomers on the VSOP project, amongst which Leonid Gurvits.

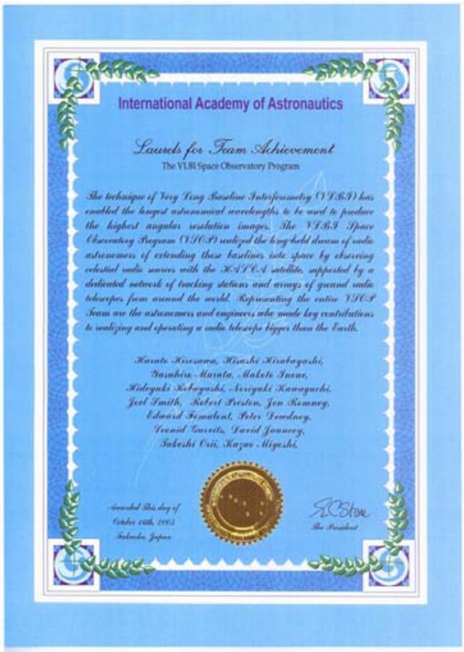


Figure 1.5: The group of IAA Laurels

The e-VLBI project also received a prestigious award for its progress in high speed data transfer at the Internet2 symposium held in April 2006. The winning team comprised Arpad Szomoru (JIVE), Alan Whitney (MIT Haystack Observatory), Yasuhiro Koyama (NICT) and Hisao Uose (NTT Laboratories GEMnet2/GALAXY Project) (Figure 1.6). The Internet2 IDEA Awards program encourages innovative advanced network applications that have had the most positive impact within the research and education community. The winning applications were judged to represent innovative applications of the internet at its best.

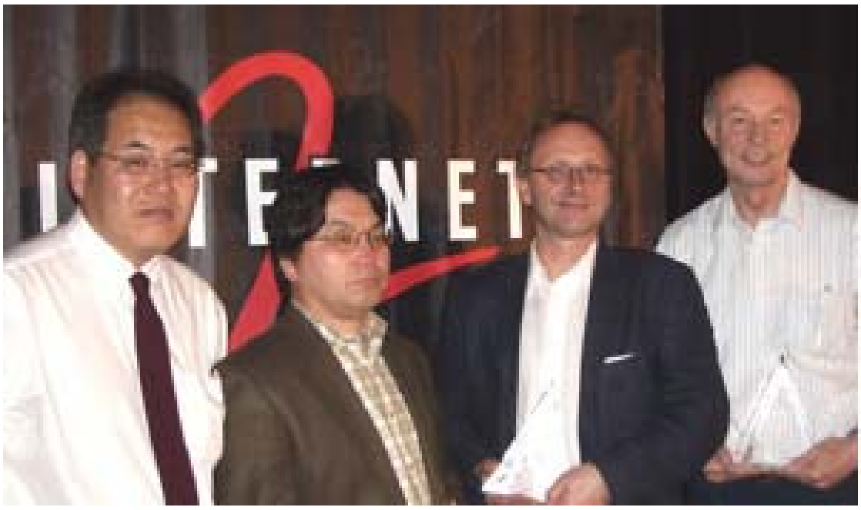


Figure 1.6: from left to right:, Masaki Hirabaru of NICT accepting on behalf of Yasuhiro Koyama, Hisao Uose of NTT Laboratories, Arpad Szomoru of JIVE and Alan Whitney of the MIT Haystack Observatory

In the summer of 2006, JIVE organised the Next Generation Correlator workshop. This 4-day event (26-29 June) was attended by 67 scientists. The discussions focused on the technical possibilities to implement large scale correlation for future radio-astronomy projects. Recent developments in software correlation and FPGA-based systems were discussed in the context of e-VLBI, LOFAR and other SKA pathfinders.

During the spring 2006 semester Huib Jan van Langevelde, together with Tom Oosterloo (ASTRON), organised the annual inter-academical master's course of the Dutch universities. This year's topic was interferometry and about 25 students from 6 locations over the entire country attended the course. Hayley Bignall assisted in setting up the practical data reduction sessions and among the guest lectures was one by Mike Garrett on the future of radio-astronomy.

1.5. Personnel changes

In 2005 Steve Parsley, who had been the head of technical R&D, left JIVE. At the start of 2006 Arpad Szomoru assumed the leadership over the technical aspects of the correlator; he also became responsible for the e-VLBI effort. Some changes had to be made to the organisational structure of the various groups within JIVE to accommodate this new division of labour.

During these two years a number of new people joined JIVE as support scientists. An equal number of good friends left to take the next step in their careers in different places. Overall, JIVE has grown substantially, especially in 2006, with two major EC projects in full swing (RadioNet and EXPReS). A number of new software and networking engineers work on the correlator and network-related issues, the EXPReS project office brought a number of new faces to JIVE as well and several PhD students are now on the JIVE payroll. This has resulted in a growth over two years from 26 to 36 JIVE staff members.

The success of EXPReS meant we had to find office space for a large number of new employees. Several of the upstairs rooms that until now held single occupants were converted to two-person rooms, and new offices were constructed in the basement for the operators and the EXPReS crew. At the same time, the capacity of the JIVE visitor's room was increased to accommodate 7 visitors at one time. Not counting the visitor's room, at the end of 2006 a total of 11 new working spaces had been created.

Figure 1.7: New offices in the JIVE basement

At the same time it became clear that the architect of EXPReS was going to leave JIVE, as Mike Garrett accepted the post of General Director of ASTRON. This annual report has been compiled under the responsibility of the new director, Huib Jan van Langevelde.

2. SCIENCE OPERATIONS AND SUPPORT

2.1. Production Correlation

2.1.1. Sessions and Their Experiments

Before session 1/2005, the observations of the Huygens probe descent onto Titan took place. From the correlator's perspective, this included our first ever correlations from Australian and Japanese telescopes (where most Australian telescopes recorded with PC-EVN and Kashima with K5, both subsequently translated to Mark 5), and continued our experience with VLBA observations recorded with Mark 5. The inhomogeneity of the array resulted in more than the usual amount of difficulty in preparing the control files and clock-searching, but eventually everything worked well.

Session 1/2005 itself had a total of ten user experiments. Among these was the first Gbps user experiment to be correlated and distributed. Three of the experiments were globals. However, only three VLBA telescopes provided their recordings on tape; the ones that participated in the Huygens observations sent disks. There was a great deal of problems with winter weather in Europe, with several telescopes having to abandon because of snow or high winds.

Session 2/2005 had twelve user experiments, including three more Gbps recordings. In one of these, Green Bank also participated at 512Mbps (by recording with one-bit sampling instead of the two-bit sampling used elsewhere -- the correlator "saw" Green Bank's data as being two-bit sampled, with the magnitude bit always set to "high"). There was one global, but it did not use all the VLBA telescopes. This session saw an unusually high number of equipment problems at the telescopes. Noto suffered an azimuth-drive casualty in the third user experiment, which sidelined it for the remainder of the session. Torun was without its H-maser, which was out for servicing, and substituted a Rb frequency standard with the consequent reduction in coherence time. Effelsberg suffered a Mk4-formatter casualty, which required them to shift to the VLBA formatter and tape recording for 1.5 experiments. These were the only tapes received from this otherwise all-disk session.

Session 3/2005 also had twelve user experiments, including four more Gbps recordings. Westerbork and Robledo had similar problems in their Mark 5 Gbps recordings, in which the data decodability would come and go on time-scales of several minutes. The net consequence was a loss of about 40% of the data from these telescopes in the Gbps experiments. The underlying cause proved to be interference from nearby video cables. This behaviour continued for a couple subsequent sessions at differing stations; eventually following discussions with the stations and at TOG meetings, this problem seems to be resolved. There were three globals in this session, with eight of the VLBA telescopes recording onto Mark 5. The azimuth-drive casualty at Noto continued to prevent their participation. Engineering work at the Lovell telescope meant that it missed the C-band session, where it was replaced by the Mark-2, but it was back in time for the L-band session, during which the Gbps experiments were scheduled.

Session 1/2006 had a total of fifteen user experiments correlated at JIVE. Among these were two Gbps experiments and three globals. Included in the global experiments were periods of full 16 disk-stations correlation, which was also a first. Spectral-line experiments at 5 cm (methanol or excited hydroxyl masers) formed more than half the total number. Typically, the PIs from these experiments wanted the maximum possible spectral resolution, which led to multiple-pass correlation (with either a continuum/line tactic or separate correlations per sub band or polarization). There were the usual problems with winter weather, with the continental telescopes northward of 50 degrees missing at least parts of some experiments because of snow.

Just days after the end of session 1/2006, there were two target-of-opportunity experiments devoted to the flaring in RS Oph (one each at L- and C-band), recorded on disk by 10-11 station arrays at 512 Mbps. As the star was already beyond the peak of its flare by the time of these observations, there was quite a premium on rapid correlation and distribution of the resulting FITS files. Following coordination with the PIs, JIVE fully correlated the C-band experiment prior to receipt of the Noto disks to provide the fastest results, then correlated the L-band experiment (by then the Noto disks had arrived), and finally re-correlated the C-band experiment with all stations. Table 2.1 summarizes the number of [calendar] days following observation until completion of correlation and distribution of the FITS files:

	Correlation completed	FITS files distributed
C-band (without Noto)	8	10
L-band (all stations)	11	14
C-band (all stations)	15	18

Table 2.1: days following the observation of the target-of-opportunity experiments on RS Oph to completion of correlation and distribution of the FITS files.

Prior to the start of session 2/2006, there was a follow-up target-of-opportunity observation of RS Oph, this time at 1 Gbps. A paper including these observations appeared in Nature in July. The period between sessions 1/2006 and 2/2006 also saw the first e-VLBI observations resulting from the new open calls for e-VLBI proposals.

Session 2/2006 also had fifteen user experiments, including three more Gbps recordings and five globals. This session was the first to be entirely tape-free: all stations sending data to JIVE for correlation recorded exclusively onto Mark 5 disk packs. UHF experiments were included for the first time in two years. Urumqi had to miss one of these because of conflicting Chinese lunar mission requirements.

Session 3/2006 was extraordinarily short, owing to engineering work at Effelsberg and Shanghai. There were only five user experiments, including one at Gbps recording and three globals. This was another disk-only session.

There were a total of eight separate e-VLBI user experiments observed during 2006 in five different e-VLBI "sessions", for which separate open calls-for-proposals were promulgated. All but the first one of these lasted a full 24hr, to provide the opportunity to observe any sidereal-time range.

Tables 2.2 and 2.3 summarize projects observed, correlated, distributed, and released in 2005 and 2006. They list the number of experiments as well as the network hours and correlator hours for both user and test/NME experiments. Here, correlator hours are the network hours multiplied by any multiple correlation passes required (e.g., because of continuum/line, separate correlation by subband/pol to maximize spectral resolution, etc.).

	User Experiments		
	N	Ntwk_hr	Corr_hr
Observed	36	495	634
Correlated	34	600	807
Distributed	46	624	870
Released	39	556	772
	Test & Network Monitoring		
	N	Ntwk_hr	Corr_hr
Observed	21	103	106
Correlated	20	101	104
Distributed	20	101	104
Released	24	110	113

Table 2.2: Summary of projects observed, correlated, distributed, and released in 2005.

	User Experiments		
	N	Ntwk_hr	Corr_hr
Observed	46	554	732
Correlated	48	603	797
Distributed	49	618	812
Released	57	713	963
	Test & Network Monitoring		
	N	Ntwk_hr	Corr_hr
Observed	23	139	163
Correlated	21	110	110
Distributed	19	101	101
Released	17	95	95

Table 2.3: Summary of projects observed, correlated, distributed, and released in 2006.

With the advent of disk-based recordings, the processing factor -- defined as the actual correlator time required to complete an experiment divided by the product of network hours times the number of passes required -- has decreased noticeably. However, there do seem to be some problems that affect Gbps recordings preferentially, notably interference into the flat cable from the formatter (from nearby video-cables), an increased sensitivity to slow disk(s) in a given Mk5 pack, and the diagonal weights that affect all 16MHz sub band playback through the station units. Efforts to recover the maximum amount of data possible increases the cumulative processing factor for Gbps experiments. For experiments from 2005-6, these cumulative processing factors are: 2.61 for Gbps experiments, 2.33 for experiments with one or more tape-station, and 1.89 for other disk-only experiments.

Figure 2.1 presents the work division among various correlator tasks (production, clock-searching, network/correlator tests) as a number of hours per week, over the past three years (2005-6 highlighted). A six-week running average is shown. Troughs in the production hours correspond to periods when the correlator queue ran out of possible experiments prior to the start of the next EVN session, during which time we can focus more on correlator testing (e-VLBI, recirculation, fine-tuning the disk-servoing algorithm, etc). Bursts of time spent on network tests (cyan) in and immediately following sessions are also apparent. Since 25 April 2005, we have been running with two operators while keeping the 1:3 night-shift rotation (thus a three-weekly cycle of 80-80-40 hr/wk), reducing the net hours-per-week to 66.67 over the 6-week smoothing used in the plot.

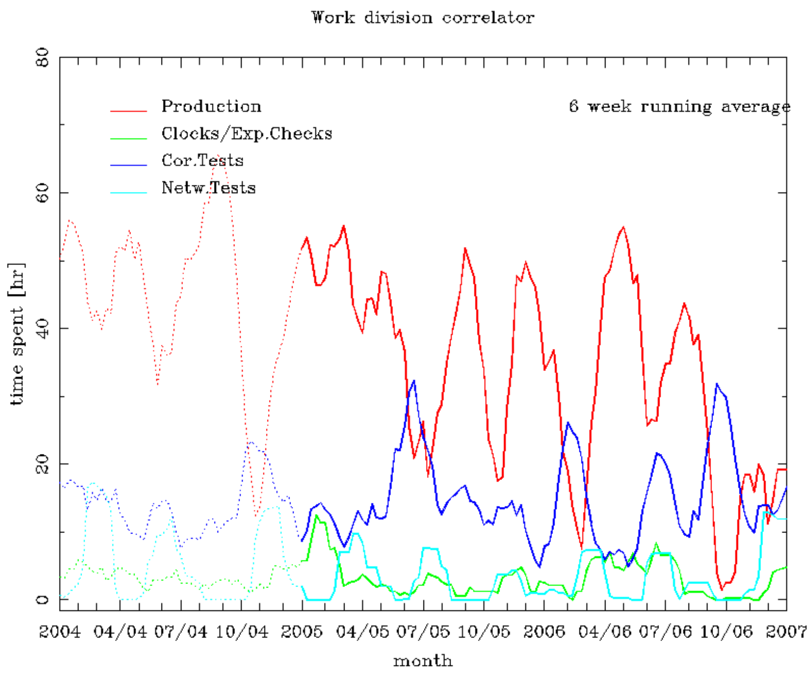


Figure 2.1: Work division among various correlator tasks, in hours per week.

Figure 2.2 presents various measures of correlator efficiency. The red line plots the completed correlator hours during time actively devoted to production correlation. The green line shows completed correlator hours over the total operating time of the correlator -- the red and green lines diverge more in periods when production takes up a smaller fraction of the total time available. The blue line shows completed network hours over total operating time -- the green and blue lines diverge because some experiments require multiple passes. A twelve-week running average is shown to smooth out spurious peaks caused by periods with no remaining production correlation.

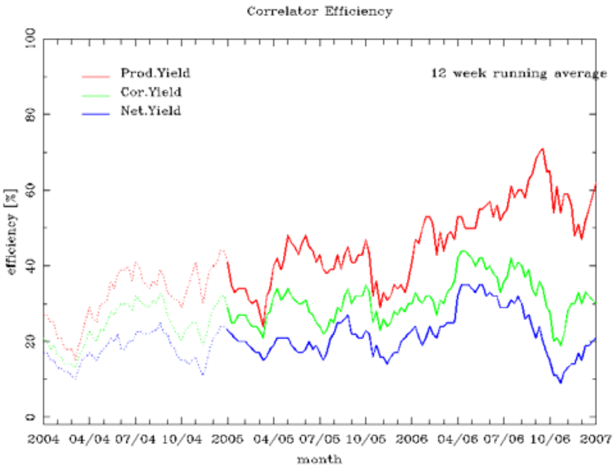


Figure 2.2: Various measures of correlator efficiency.

Figure 2.3 presents the size of the correlator queue at different stages in the processing cycle, showing a snapshot of the status at the end of each week. The red line plots the number of correlator hours that remain to be correlated. The green line plots the number of correlator hours whose data remain to be distributed to the PI. The blue line plots the number of correlator hours associated with recording media that have yet to be released back to the pool (in practice, release occurs prior to the following session, leading to a blocky pattern for the blue line).

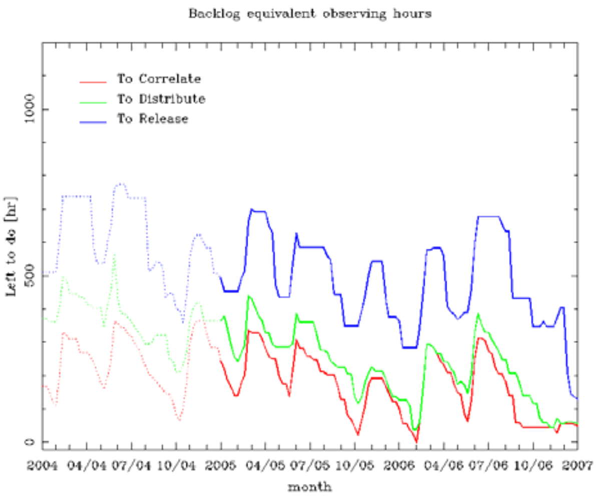


Figure 2.3: Size of various correlator queues, measured in correlator hours.

2.1.2 Logistics and Infrastructure

The data processor has 16 Mk5A units, all housed inside temperature-controlled cabinets. Ten working tape playback units remain in place, and can still be attached to SUs via a simple swap of input cables.

The disk-shipping requirements are derived from the recording capacity needed by a session (from the EVN scheduler) and the supply on-hand at the stations (from the TOG chairman). The EVN policy that stations should buy two sessions' worth of disks; hence the disk flux should balance over the same 2-session interval. A different rule pertains to NRAO stations, under which we pre-position disk packs to make up the anticipated difference between what NRAO stations will observe in globals to be correlated at JIVE and what EVN stations will observe in globals to be correlated in Socorro

Table 2.4 charts the net disk flux to support both EVN and VLBA stations (all entries in TB), with positive balance signifying flow away JIVE to stations or from EVN to NRAO.

IN		OUT		BALANCE	NET
3/2003	22.00	2/2004	30.52	+8.52	+8.52
1/2004	63.69	3/2004	86.31	+22.62	+31.14
2/2004	111.52	1/2005	69.89	-41.63	-10.49
3/2004	122.53	2/2005	100.67	-21.86	-32.35
1/2005	140.58	3/2005	142.31	+1.73	-30.62
2/2005	176.99	1/2006	152.93	-24.06	-54.68
3/2005	211.85	2/2006	303.37	+91.52	+36.84
1/2006	191.05	3/2006	133.36	-57.69	-20.85
2/2006	306.63	to recycle in 1/2007			
3/2006	103.68	to recycle in 2/2007			

Table 2.4: balance of disk receipts/shipments from/to EVN stations. The applicable guideline is to recycle disks in time for recording in the 2nd-following session, which is how the pairs are ordered per row, followed by the balance per receipt/shipment pair and the cumulative balance since the beginning of disk recording.

As more telescopes have made the transition to disk-recording, we have encountered instances in which we find the record pointer has been set near zero, preventing playback of the data on disk. There is a Mark 5 command that usually fixes this situation, with no adverse effect to the data itself.

However, for a handful of packs since session 2/2005, this Mark 5 command did not work, and we returned the packs to Conduant. They recovered these packs without charge, and upon their return we were able to play back of all the data recorded, but this extra step cost time and (shipping) money. Currently, this recovery at Conduant is largely manual, so it does not appear likely that we will have this capability in-house on the short term.

In the autumn 2005, largely motivated by the arrival of two new Support Scientists, we made major revisions to the Post-Correlation Review and Clock-Searching guides. These guides provide step-by-step procedures for carrying out fundamental operations at the correlator and for the process of generating FITS files for the users from correlated data. The new guides were placed into the internal wiki page that was created this year. By the end of 2006, the correlator operators had taken over much of the clock-searching responsibilities.

2.1.3 Astronomical Features

Towards the end of 2005, we began to include celestial pole offsets into the CALC8-based a priori correlator model. These amounted to about a 20-25 mas shift of direction of the celestial ephemeris pole added onto the IAU1980 nutation model used by CALC8. We made this shift before beginning a K-band water-maser experiment. In the early autumn of 2006, following careful testing, we shifted over to CALC10 for the a priori correlator model. The shift to the IERS conventions 2003 that moves away from the equinox-based to the non-rotating origin paradigm for conversion between terrestrial and celestial reference frames in itself makes essentially no net numerical difference compared to the previous correlator model. Rather, the practical advantages include a direct means to compute UVWs consistently to the delay/phase polynomials fed to the correlator, as well as the opportunity to incorporate surface meteorology into the calculation of tropospheric zenith dry/wet delays at some point in the future. Currently, the zenith delays are computed using pressure and temperature parameterized by only station height, regardless of season or local weather conditions; this would usually be the single most discrepant constituent of the a priori model, especially for phase-referencing at low elevations. The models for handling some effects have improved between the versions of CALC (pole tide, ocean loading, etc.), but these differences are generally of lesser relative magnitude. The shift to the new version of CALC came with shifting to a new CCC computer, and was timed to avoid having it fall in the middle of multi-epoch astrometric projects.

In session 2/2006, Jodrell Bank recorded data from both Cambridge and another MERLIN station (Darnhall) onto Cambridge's Mark 5 pack in an experiment for which the 16 MHz MERLIN bandwidth left "unused" channels in the recording. We copied the Cambridge pack onto an empty Mark 5 pack, and through straightforward VEX-file manipulation were able to correlate the data for both stations. Fringes were seen in the subbands which contained actual signals on all Cm-* and Da-* baselines. This scheme offers the possibility to record a third MERLIN station routinely in combined EVN+MERLIN experiments, providing a more robust for tying the two arrays together. There should be no additional proposing or scheduling burden on the PI, but at correlation the presence of another station may have consequences for the maximum number of frequency points, and we would need to have sufficient free disk-packs on-hand to which to copy the data.

In session 3/2006, there was a separate test experiment specifically using both Jb1 and Jb2 in order to provide data for developing a means to use Jb2 data to "steer" Jb1 phase-connection in light of Jb1's slower allowed slew rate that precludes it from reaching all source changes in a typical phase-reference schedule.

2.2. EVN Support

The EVN pipeline has been re-written in ParselTongue (see section 4.3). The new pipeline is considerably easier to use, more robust and has much greater scope for future development due to the improved coding environment. The pipeline scripts are available from the ParselTongue wiki (RadioNet) and should provide a good basis for other (semi-)automated VLBI reduction efforts.

The pipeline provides telescopes with feedback on gain corrections for all experiments correlated, both NMEs/fringe-tests and user experiments. These data can identify telescopes/frequency bands with particular problems. The support scientist also calculates the EVN Reliability Indicator (ERI) for each experiment during the pipelining. The ERI takes into account all failures that were detected while reviewing the data. In addition to routine network monitoring, NMEs also provide data for ftp fringe tests that run on JIVE's installation of the NICT software correlator. These ftp fringe tests continue to provide the opportunity to identify station problems early in the session (stations receive initial reports on the same day as the experiment is observed) and have contributed to an overall increase in the ERI in recent sessions. Figure 2.4 shows fringe plots generated automatically from a fringe test, which are available to the telescopes via the EVN web site.

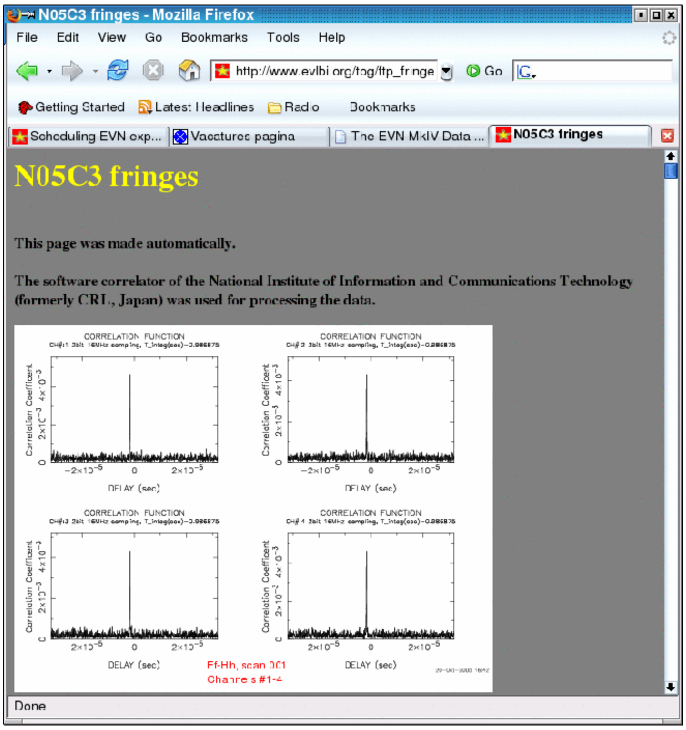


Figure 2.4: Fringes on the baseline Effelsberg - Hartebeesthoek from the session 3/2005 NME ftp fringe-test scan, as seen on the EVN web page.

The NMEs processed in a fully automated way, with minimal support scientist interaction, except in compiling the written reports sent to the stations (first reports were less than 2 hours after the start of the experiment). Web-pages now include autocorrelation spectra for each station, and the correlation vexfile. The 5cm band in session 1/2006 ftp tests failed because the software correlator could not handle the recording mode, which was repaired by the time of session 2/2006.

These ftp fringe tests continue to be very successful in identifying telescope problems and thus have helped to "save" user experiments by providing feedback quickly enough for the telescope staff to effect repairs:

* in the session 1/2005 K-band fringe test, there were no fringes to Effelsberg, and the problem was fixed prior to the actual beginning of the session.
* in the session 1/2005 C-band NME, a problem with BBC2 at Urumqi was noticed, and it was replaced before user experiments began prior to session 2/2005. BBC3 at Torun was seen to be dead, and a higher BBC was substituted via non-standard patching for experiments within the session, where possible (i.e., ones not using all BBCs).
* in the session 3/2005 C-band fringe test, there were no fringes in the upper BBCs (9-16) to Shanghai, which they discovered to be a formatter problem that they were able to fix before the next experiment. Finding this problem in the fringe test was a result of modifying the observing tactics to include all BBCs, prompted by Gbps recording becoming a more standard feature.
* in the session 2/2006, no fringes to Urumqi or Darnhall led them to find incorrect local oscillator settings.
* in the session 2/2006, a problem with BBC3 at Onsala was identified that did not show up in standard station tests -- the problem was only identified after the VC was removed from the rack and analysed in the lab.

The effect of more telescopes participating successfully can be seen in the net improvement of ERI values as a function of time, shown in figure 2.5 (after discounting uncontrollable losses due to weather). This plot shows the ERI for all user experiments over the past six years, and denotes e-VLBI experiments with solid squares. The median ERI for normal EVN/global experiments was never more than 75% in any session up through session 1/2004, but starting from session 2/2004 it has not been below 84%. (Note that for global experiments, the ERI is computed considering only the participating EVN stations.)

Timely delivery of amplitude calibration results can still sometimes be a problem, but the situation overall continues to improve. ANTAB generation at the telescopes seems to be going well. Results are similar to those reported previously, but some improvement is noticed especially at 6 GHz. Torun calibration has improved greatly in the last year (partially due to the repair of a software error in the ANTABFS script which affected VLBA racks).

C-band calibration is generally satisfactory. Jb-MkII developed a severe problem in 2005 which continued into session 1/2006. However, results of session 2/2006 were considerably better. The previous problems were probably due to a faulty determination of the gain curve. 6 GHz (used for Methanol and excited-OH line observations) has shown considerable improvement in the last year. X-band calibration seems to be good across the network. K-band is more problematic for all telescopes gain errors don't seem to be stable (limiting the transferability of NME results to user experiments). Further investigation into opacity effects, pointing errors, poor sensitivity, and other possible causes is an ongoing topic. Calibration at 18 cm is quite variable with occasional experiments having quite large errors. RFI is probably the major source of error. Calibration at Urumqi is frequently poor at this frequency.

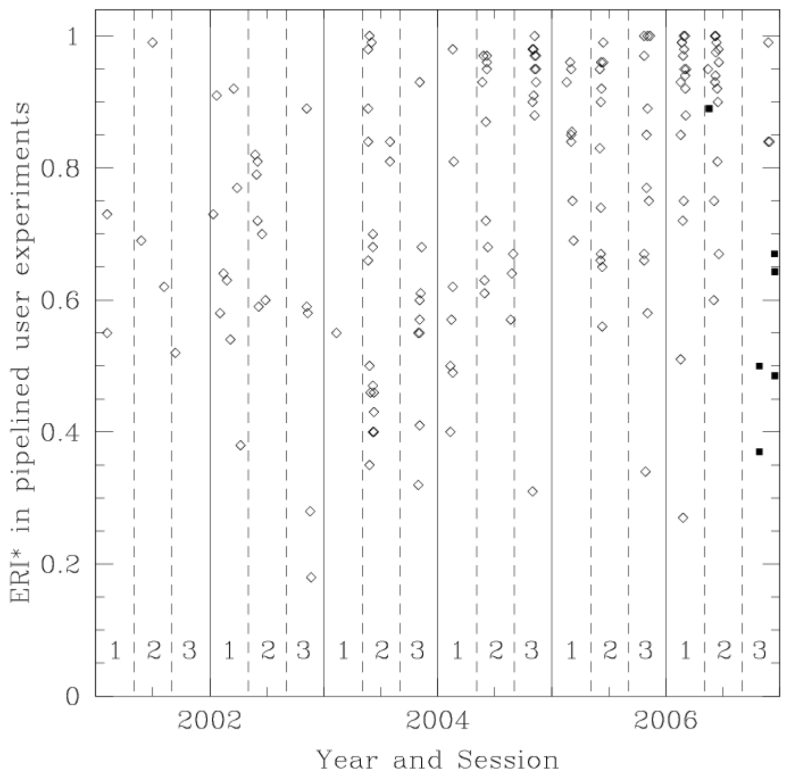


Figure 2.5: Plot of the EVN Reliability Indicator for user experiments up through session 3/2006.

However, most 18cm experiments give good results at most stations. At non-standard frequencies (red-shifted HI) where RFI is severe results are poorer. These experiments also used Arecibo which typically results in a lot of low-elevation observing for the European antennas. Problems at UHF are due to the extreme RFI in that band (some stations are unable to take any calibration at all).

Various enhancements to the field system and "sched" were included to facilitate scheduling natively disk-based experiments up to Gbps recording rates. The tactics for treating adaptive tape motion in disk experiments evolved over the year, because noticeable reductions in the disk-servoing time, especially for high recording rates, rendered this mode less advantageous at the correlator.

Following the decision by the EVN Consortium Board of Directors, Leonid Gurvits continued to coordinate EVN efforts to assist to the Ventspils International Radio Astronomy Centre (Latvia) and the Institute for Radio Astronomy of Ukraine to upgrade their the telescopes in Irbene (32 m) and Evpatoria (70 m), respectively, to a level that would allow participation in EVN observations. In

March 2005, Leonid Gurvits (together with Willem Baan and representatives of the European Space Agency) visited the Radio Astronomy of Ukraine (Kharkov), the National Academy of Sciences and the National Ukrainian Space Agency for in-situ assessment of the readiness of the 70-m radio telescope in Evpatoria for test VLBI observations with EVN. In the second half of 2005 JIVE began assisting IRAU in the upgrade process itself. In July 2005, Leonid Gurvits visited Latvia and gave a presentation at the Ventspils International Radio Astronomy Center and the Ventspils University College.

In the second half of 2006, there were initial fringe tests to these two aspiring EVN stations. Both tests used the DBBCs being developed in Noto, recorded onto PC-EVN, and were translated into Mk4 format on Mark 5 disk packs for correlation at JIVE. Each used a network of three stations, and observed about an hour per day over two consecutive days: 3-4 August for Evpatoria and 13-14 November for Irbene. Good fringes were seen in baselines to Evpatoria in the the expected subbands/polarizations (they recorded only LCP). The Irbene tests were observed at 12 GHz, which was the only receiver available at Irbene. This covers methanol maser emission, but is not a standard EVN observing band. The Irbene autocorrelation showed the correct trace in frequency and shape for the methanol maser emission in the band; separate receiver/observing problems at the other two participating stations precluded seeing fringes to a continuum source.

The results of these initial fringe tests are encouraging developments for the future participation of these stations in the EVN.

2.3. PI Support

The EVN Archive at JIVE is up and running. This provides web access to the station feedback, standard plots, pipeline results, and FITS files. More than half of the PIs use the Archive to access their distributed FITS files, rather than having a DAT or DVD sent to them. Public access to source-specific information is governed by the EVN Archive Policy – the complete raw FITS files and pipeline results for sources identified by the PI as "private" have a one-year proprietary period, starting from distribution of the last experiment resulting from a proposal. PIs can access proprietary data via a password they arrange with JIVE. PIs receive a one-month warning prior to the expiration of their proprietary period. We have also increased the storage available on the archive machine. The total size of the FITS files in the archive at the end of 2006 was about 3.08 TB; figure 2.6 shows the growth of the EVN archive size over time. Provisions have been made to store a copy of all the user data outside the main Dwingeloo building.

The science operations and support group continues to contact all PIs once the block schedule is made public to ensure they know how to obtain help with their scheduling, and to check over schedules posted to VLBEER prior to stations downloading them.

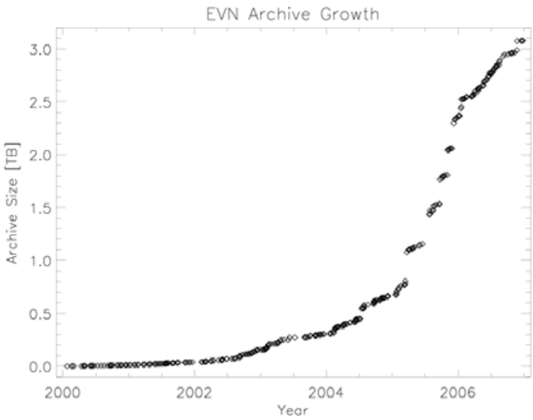


Figure 2.6: Size of FITS files in the EVN archive as a function of time.

Support for disk-only and Gbps schedules have made their way into the newer versions of SCHED. In the recent past sessions, there have been a handful of instances in which a station observed using a superseded version of an experiment's schedule, about evenly split between the fault laying mostly with the PI (schedules posted exceedingly late) and with the station (downloading schedules before our allocated checking period was over). New safety features have been incorporated into the pre-observation system that should help avoid some incarnations of this problem. Indeed, the first session following these new procedures passed without such incidents. The pre-observation communication also provides the opportunity to inform eligible PIs about the benefits of the RadioNet trans-national access programme, as well as the extra reporting they would eventually need to provide.

Significant work has gone into creating support for EVN/Global VLBI proposals in the NorthStar web-based proposal tool. SCHED catalogues have been updated so that all EVN stations, and more recently VLBA ones, have disks as their default recording medium. Roll-out of the proposal tool for use by users is planned for the first proposal deadline (1 Feb) of 2007.

JIVE hosted 27 data-reduction visits in 2005 and 20 in 2006. In addition, through the period of the report, there were five post-graduate students who were co-supervised by members of JIVE staff, and who visited frequently. In the beginning of 2006, we reorganized the layout of the visitors' room, making more efficient use of the available space to house more workplaces. There are now five dual-processor PCs running Linux, one sun workstation running Solaris and one windows-based PC. A small cluster of four interconnected top-end workstations, to accommodate processing of very large wide-field data sets was put in place in the second half of 2006. This occupies an additional two work places.

3. TECHNICAL OPERATIONS AND R&D

3.1 Data Processor Maintenance

3.1.1 Data Playback Units

As in previous years, capstan motors were the main cause of DPU failures. In 2005, some failed motors were sent to Metrum UK and fixed, although two of them were returned "no fault found". Metrum offered to upgrade the existing motors to a new and much improved design, at a price of £1695 per motor. Such an investment was found not to be justifiable in view of the rapidly decreasing use of tapes. Other problems, such as broken reel brakes and tape path readjustments, were handled in-house.

The use of the DPUs decreased further during 2006. While the February EVN session still saw a few experiments with one or two tapes, the June session was completely tape-free. With EVN operations about to become disk-only, some of the DPUs were offered for sale to Metrum.

3.1.2 Station Units

The process to clean TRM boards of corrosion continued. In all, a total of 30 TRMs were sent to Azteco where they were cleaned and coated with a protective material. This treatment seems to have halted the degradation, but whether the reliability of the boards has improved remains unclear.

3.1.3 Mark5 Units

Apart from one failed power supply, the Mark5A units performed reliably. Some minor hardware problems occurred, such as the failure of an onboard LAN interface and a power supply, but these were repaired in-house. One of the JIVE units was sent to Westerbork before the October EVN session because of intermittent recording problems with the Westerbork Mark5. However, subsequent tests at JIVE of this unit could not reproduce these problems. All 16 Mark5As are now mounted in cabinets, and at the end of 2006 the total number of operational DPUs had been reduced to 10.

3.2 Data Processor Developments and Upgrades

3.2.1 Mark5

A long-standing problem with 1 Gbps playback at the EVN correlator was finally solved in June of 2005. At 1 Gbps, servoing on the Mark5 units tends to be less effective than at lower data rates, which makes the initial placement of the read pointer in the data stream quite critical. When the placement is not exact, it can take many seconds before synchronization is achieved. In the case of short scans, this can cause a large amount of data to be lost.

While the correlators at Haystack, Bonn and JIVE seemingly used the same method of calculating start bytes, only the EVN correlator experienced problems with synchronization at 1 Gbps. Finally, Friso Olnon and Arpad Szomoru decided to visit the MPIfR in Bonn to investigate their synchronization method in detail. They soon realized that the only real difference was to be found in the number of ROT clock broadcasts; the Bonn correlator broadcasts the ROT clock once, while the EVN correlator continues broadcasting the ROT at regular intervals. After receiving one ROT, the Mark5 units will, using their system clock, count down until the start time of the scan, and start playback at the calculated start byte. The repeated ROT broadcast threw off this method and caused playback to start slightly late. Once identified, this problem was easily fixed by making the Mark5s ignore all but the first ROT broadcast.

3.2.2 Archive

Until 2005, the JIVE data archive was kept on a 1.9TB raid array. As this space was rapidly filling up two additional raid arrays were purchased at the end of 2004. The original plan was to locate one of these at JIVE and the other, as backup archive, at the headquarters of the WSRT. Instead of using one of the raid arrays as mirror, regular incremental tape backups are now made and sent to Westerbork for storage. Both new raid arrays were added to the archive machine in Dwingeloo, bringing the total capacity to 5.7TB. As not all slots are in use, this capacity still can be increased to 9TB. Replacing the 250MB disks now in use by 400GB disks would bring the total capacity to more than 13TB, which should be sufficient for at least a few years.

3.2.3 Re-circulation

Re-circulation, which enables one to optimize the use of a correlator through time-sharing its computing resources, was shown to work as a proof-of-concept. Some logistical issues still remain before turning this into a full operational capability of the EVN correlator.

3.2.4 Replacement of correlator control platform

Two heavy-duty Solaris servers were purchased to replace the ageing HP correlator control computer. These machines, equipped with redundant power supplies and dual AMD processors, are meant to be fully and instantly interchangeable, and provide powerful operational and code development platforms. Both local and third party software packages were successfully ported to Solaris, while taking the opportunity to fix and update existing code. This has led to considerable improvements and increased robustness of the control system.

3.2.5 Mark5A to B upgrade

The Station Units are currently the main cause of operational instability, which has been particularly problematic during e-VLBI operations. Spare parts are few, and replacements are unavailable. Upgrading the Mark5A units currently in use at JIVE to Mark5B will allow JIVE to phase out the Station Units. As a preparation for such an upgrade, Mark5B I/O cards, Correlator Interface Boards were purchased from Conduant and Haystack Observatory, and new serial links were manufactured by ASTRON and MPIfR. The upgrade, which is expected to take place in 2007, will also involve a sizeable software effort, as a large part of the control code will have to be re-written.

3.3 Technical R&D Projects

3.3.1 PCInt

3.3.1.1 Software

A large part of JCCS, the correlator control code, was ported to the Linux operating system. This development was started a year earlier and consequently had to be merged with developments in JCCS that had taken place during that year. This merged code then had to be verified for all three supported platforms. The main branch of the JCCS code was updated to include the byte-order safe correlator data format and solve some platform issues.

Early in the second half of 2005 the PCInt data path was validated at 1/8s integration time. During debugging Harro Verkouter found and solved a few bugs in his driver code for the high-speed serial-link DSPs which corrupted the data stream. Another necessary step before the architecture could be validated was 'sorting and normalizing'. Before the raw data from the correlator can be interpreted as correlation functions the data needs to be sorted. As the correlator chips only produce a limited number of lags, the data for a correlation function with more lags is computed in parts by different chips. After each integration, the data must be re-ordered to be contiguous in memory. This cpu-expensive operation is performed off-line. Using an implementation on the PCInt system, fringes could be extracted from the raw data. First fringes were detected. Work was started to integrate the PCInt code with the off-line AIPS++/CASA task, j2ms2, to enable it to read PCInt-generated data files into a measurement set.

3.3.1.2 PCInt Hardware

The InfiniBand problem, which made it impossible to use it ever since the purchase of the cluster, was finally solved. The problem turned out to be in the firmware of the switch. As the vendor could not fix this in-house the switch had to be sent to the manufacturer for a firmware upgrade. The switch was returned in the beginning of December but some performance issues remain.

3.3.2 Huygens Data Reduction, Software Correlator

Many developments took place within the Huygens project (covered extensively in section 6.1.1), in terms of software, hardware and networking efforts. In order to facilitate the conversion between different data formats and speed up data reduction itself, high speed connectivity was established between a number of Mark5 units, several general purpose computers and the PCInt cluster (see figure 3.1). Various software modules were written to convert data between different formats such as VSI-PCEVN, Mk5 and the internal software correlator format. This work was done in close collaboration with our colleagues Ari Mujunen and Youko Ritakari from Metsahovi Observatory. Building blocks were created for narrow band software correlation; these were also exercised using broad band data on continuum sources.

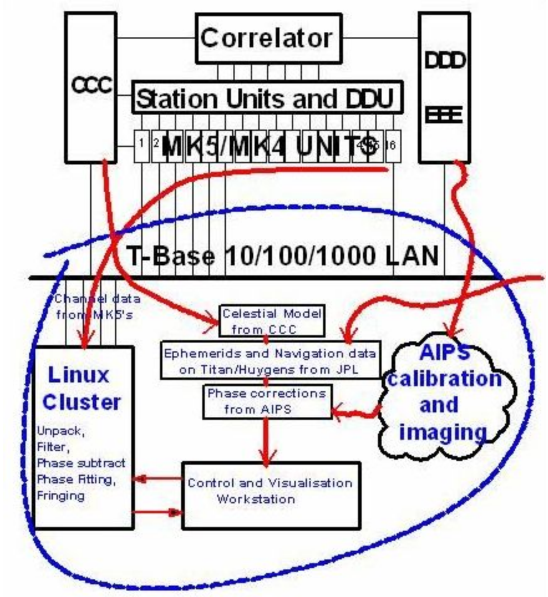


Figure 3.1: Huygens data reduction setup

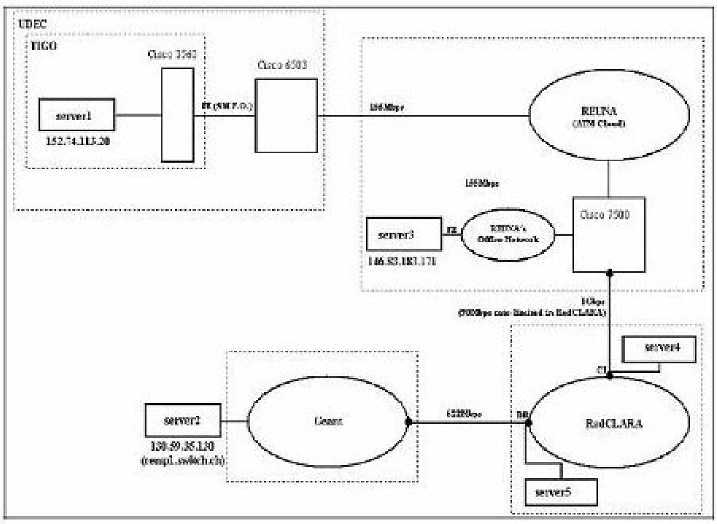
This effort has resulted in a software correlator which is now used as the basis for future software correlator developments at JIVE

Figure 3.2: Software correlator platform (top) and new correlator control computers

To support the EXPReS efforts at JIVE, a dual-core dual Opteron machine with a 5TB raid array was purchased. This machine has been used intensively for data transfer and protocol tests (from Metsahovi, Medicina, Bonn, Jodrell Bank and Sydney), as a development and operational platform for the JIVE software correlator and for software format conversion, for example during a geodetic K-band experiment with the Australian LBA. It was also used to support Smart-1 observations with EVN telescopes (Medicina, Metsahovi and Westerbork) and TIGO (Chile), as preparation of the actual observations during its planned crash on the lunar surface.

The controlled crash-landing of the European Space Agency's Smart-1 lunar probe in September of 2006 provided an opportunity to exercise connectivity to South America. A network of radio telescopes, led by a team of radio astronomers from JIVE, observed Smart-1 and recorded key data during its final moments and impact. Using e-VLBI, astronomers at JIVE received an important 10 seconds of data concerning the precise time and velocity at impact from Chile and Australia in a matter of seconds, and additional data were transferred and processed in a matter of hours.

In order to make this possible, extensive network tests were conducted by the PERT rapid response team of GÉANT, in which the entire network path from the TIGO radio telescope, located near Concepcion in Chile, and JIVE was investigated. This investigation has helped to identify the bottlenecks, determine the actual capacity of the link and suggest possible improvements. Local network improvements in Chile are planned and we expect to be able to include the TIGO radio telescope in a real-time e-VLBI experiment in the course of 2007.



Delays:
Server1 to server2: 292ms
Server3 to server2: 274ms
Server4 to server2: 273ms
Server5 to server2: 226ms

Figure 3.4: Network connection between TIGO and JIVE

3.4 e-VLBI

3.4.1 New personnel

On the first of March 2006 the EXPReS project formally got underway. For SA1, the service activity aimed at establishing a production e-VLBI facility, a total of five new staff positions were advertised. Although it proved harder than expected, eventually suitable candidates for all these positions were found. Zsolt Paragi, formerly one of the JIVE support scientists, started on the first of March as e-VLBI support scientist, while two scientific software engineers, Bob Eldering and Des Small, started in May and June, respectively. A network/Linux specialist, Paul Boven, started in December at JIVE, as did Jonathan Hargreaves, an electronics engineer, at Jodrell Bank.

3.4.2 Tests

e-VLBI testing, which until 2005 had been mostly ad-hoc, was set on a solid basis by scheduling tests at about six-weekly-intervals. Apart from these tests, which mostly were straightforward observations of bright sources, many tests were conducted as opportunities arose. Some only involved memory to memory data transfers from the stations to JIVE, others involved “real” formatter data (without any telescopes participating, but transferring data with valid time codes).

Tests during the first few months of 2005 either failed or were only partly successful. After some discussions with the Mark5 developers at Haystack Observatory it was found that these problems were caused by an incompatibility of a new version of the Mark5A control code with older versions of the Linux kernel. Most units at JIVE were subsequently upgraded to a new kernel. After this, a series of successful tests showed that a data rate of 128 Mbps from all European stations could usually be reached, and occasionally 256 Mbps. Connectivity to Arecibo remains limited, and although 64 Mbps has been reached occasionally, 32 Mbps failed several times as well.

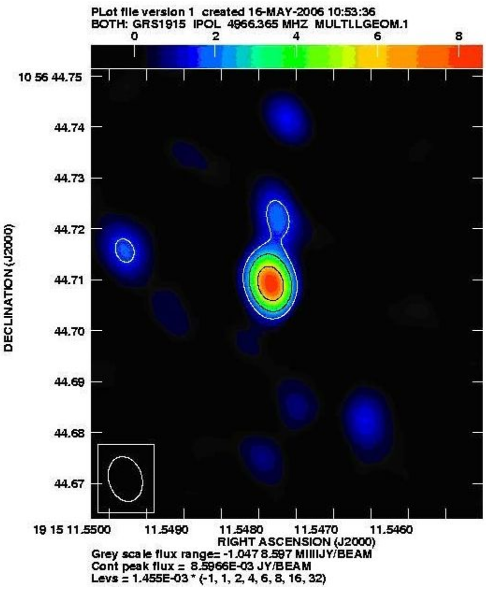


Figure 3.5: e-VLBI image of GRS1915 from the April observing run (20 April 2006)

With the start of the EXPReS project in March 2006, a full-scale real-time VLBI service had to be provided for the astronomical community. As a first step an open call for e-VLBI proposals was issued. Six science runs were conducted during 2006, one of which was granted time as a target-of-opportunity. Although the first 8 hour run was completely lost due to various software problems, the next runs went increasingly well. Operational developments continued throughout the year. The overall robustness increased greatly, and although some data still are lost during correlation job re-starts, a careful strategy of carrying these out during regularly scheduled fringe-finder scans minimized data loss on the targets. The production data-rate increased from 128 Mbps to 256 Mbps, and we were able to produce fringes at 512 Mbps from most telescopes. Turn-around time improved dramatically, and in some cases pipelined maps were produced within hours of the end of the observations.

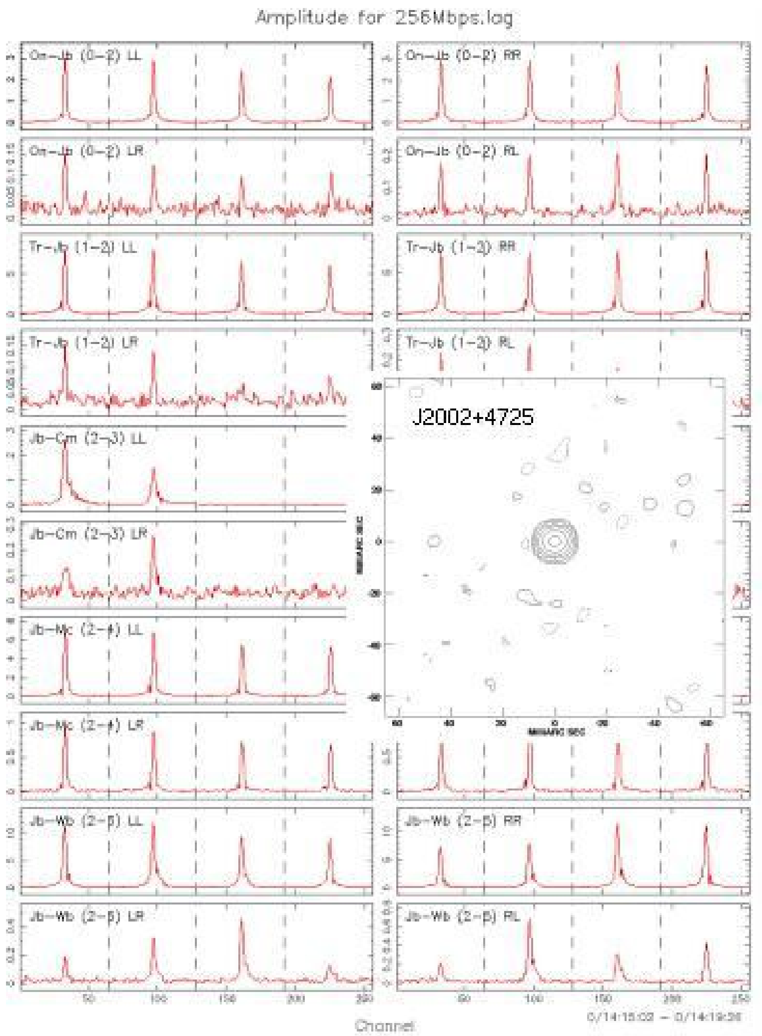


Figure 3.6: first 256 Mbps fringes to 6 European telescopes (18 May 2006)

The two main disadvantages of the current e-EVN, low sensitivity and low resolution, will disappear when Effelsberg, the most sensitive telescope of the EVN, and Shanghai, providing the longest baselines, are added in 2007; sensitivity will further increase when 512 Mbps becomes the operational data rate.

3.4.3 Demonstrations

Several high-profile demonstrations took place in 2005. At the EC PR event hosted by JIVE in July 2006 (described elsewhere in this report) fringes were obtained at 32 Mbps from all connected stations, including Arecibo. At the launch of GÉANT2 in Luxembourg, where e-VLBI was one of only three showcases, a demo was set up by Richard Hughes-Jones (University of Manchester) and Szomoru in which data were transferred from the Torun and Onsala Observatories and the GARR PoP in Bologna, to JIVE. This demo was very successful in attracting attention from the participants, many of whom were leading networking professionals.

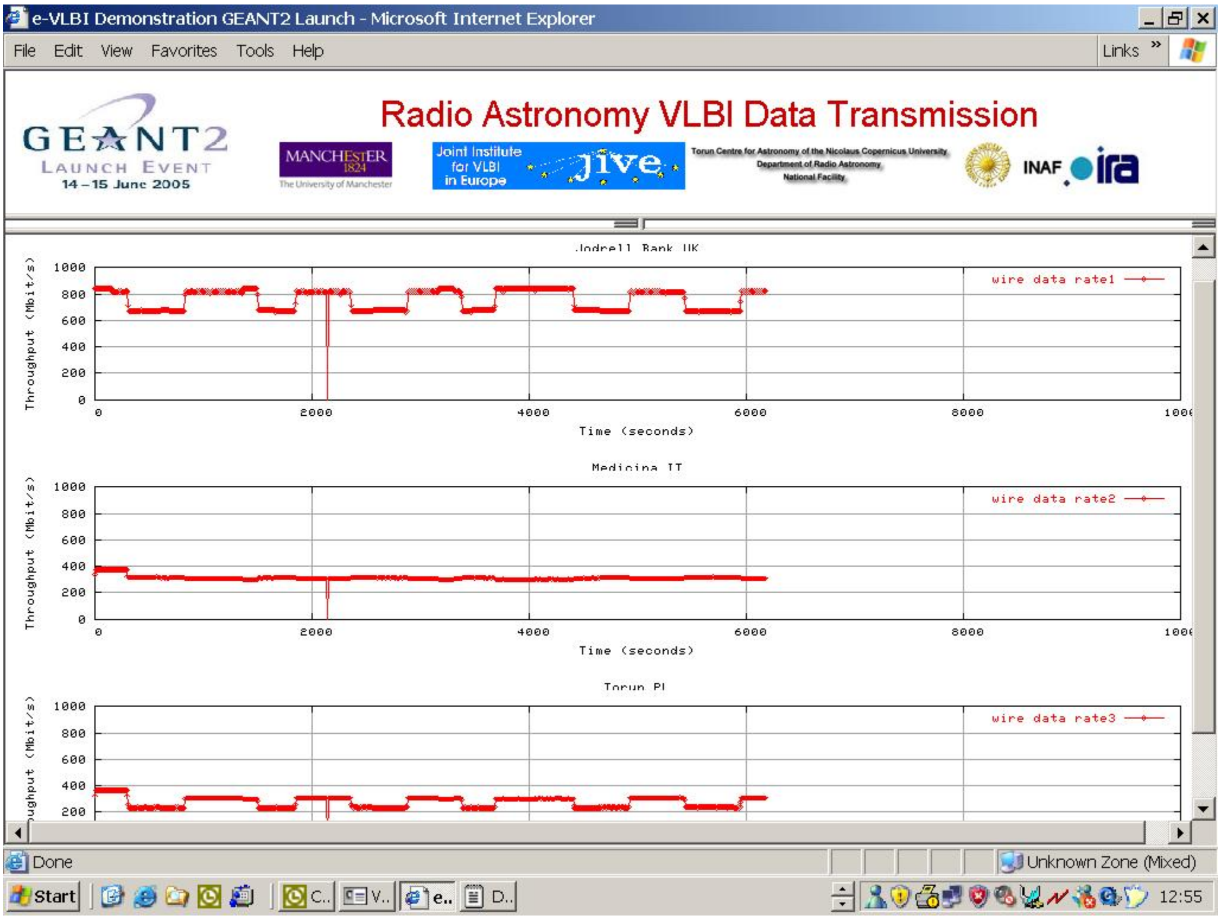


Figure 3.8: Demo display showing three data streams from stations to JIVE at GÉANT2 launch in Luxembourg

JIVE participated in two successful e-VLBI demonstrations at the iGRID2005 (September, San Diego) and Supercomputing 2005 (November, Seattle) conferences. These demonstrations, which were led by Haystack, involved many groups from the networking community and aimed at connecting telescopes in the USA, Japan and Europe in real-time through switched light paths. A light path connection was set up through the JIVE Gb network to the Westerbork Synthesis Radio Telescope, but unfortunately no fringes were obtained with the WSRT. Real-time e-VLBI was sustained for several hours with the Westford, Onsala and GGAO telescopes at 512 Mbps.

3.4.4 Development

3.4.4.1 Networks

Bwctl, a tool developed by Internet2 to test network throughput, was installed at JIVE and all stations. It was hoped that with additional bwctl boxes along the way it might be possible to quickly pinpoint bottlenecks. However, most NRENs could not grant access to equipment at their PoPs, and as a result the bwctl points are few and far apart. GÉANT did provide a very useful Internet weather map tool, which shows the usage and capacity of their network throughout Europe.

During 2005, modifications were made to the GÉANT network to allow the use of jumbo frames. The use of large packet sizes (larger than the standard MTU size of 1500 bytes) can greatly reduce the CPU load on the end systems, allowing higher data rates. At the end of that year, the connection to Torun supported an MTU of 8192, Westerbork 9000, Cambridge, Jodrell and Onsala 4470 (different limits imposed by different types of equipment). Both connections to Jodrell Bank were re-routed through UKLight, effectively establishing point-to-point light paths to JIVE.

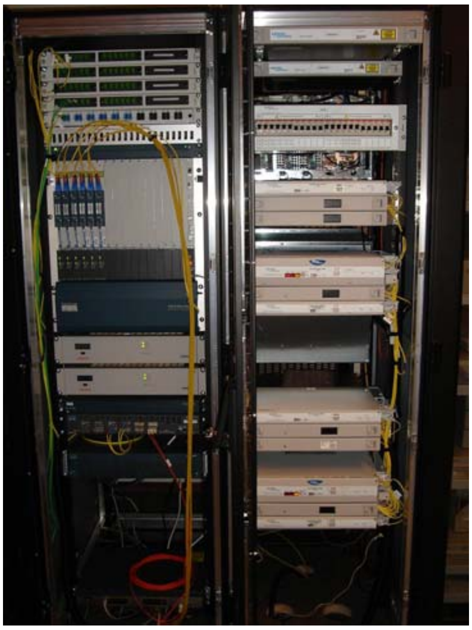


Figure 3.9: Old and new network equipment at JIVE: Cisco (left), Nortel/Avici (right)

The GÉANT2 and SURFNet6 networks came online in 2006. Both networks are fully hybrid, which means they provide IP-switched traffic as well as point-to-point lightpath connections, a feature which will become very important for e-VLBI. SURFNet6 consists of some 6000 km of dark fiber with Nortel/Avici equipment, the GÉANT2 network is largely based on leased dark fiber and Alcatel equipment.

3.4.4.2 Software

Many improvements and modifications were made to the correlator control code at JIVE. Running time-critical observations continuously for many hours puts quite new demands on the correlator, which after all has not been designed for real-time operations. Bugs had to be fixed that would never occur during normal operations. As a side effect of these fixes existing code was tightened, resulting in an increased robustness of the system.

Instead of having the operators at the stations start and stop transfers, set record modes and data rates, either by hand or through field system commands, all Mark5 commands are now sent to the stations by the correlator control computer. Further modifications were made to the control code to enable true real-time operations, and to make it possible to start observations at any point within a schedule, without needing to actually edit this schedule. These changes have improved the reliability and greatly simplified e-VLBI operations both at JIVE and at the stations.

Several stand-alone software modules were implemented and tested. A real operational improvement was achieved by enabling remote control of the Mark5A units at the stations. This ability is particularly important when doing 24 hour observations.

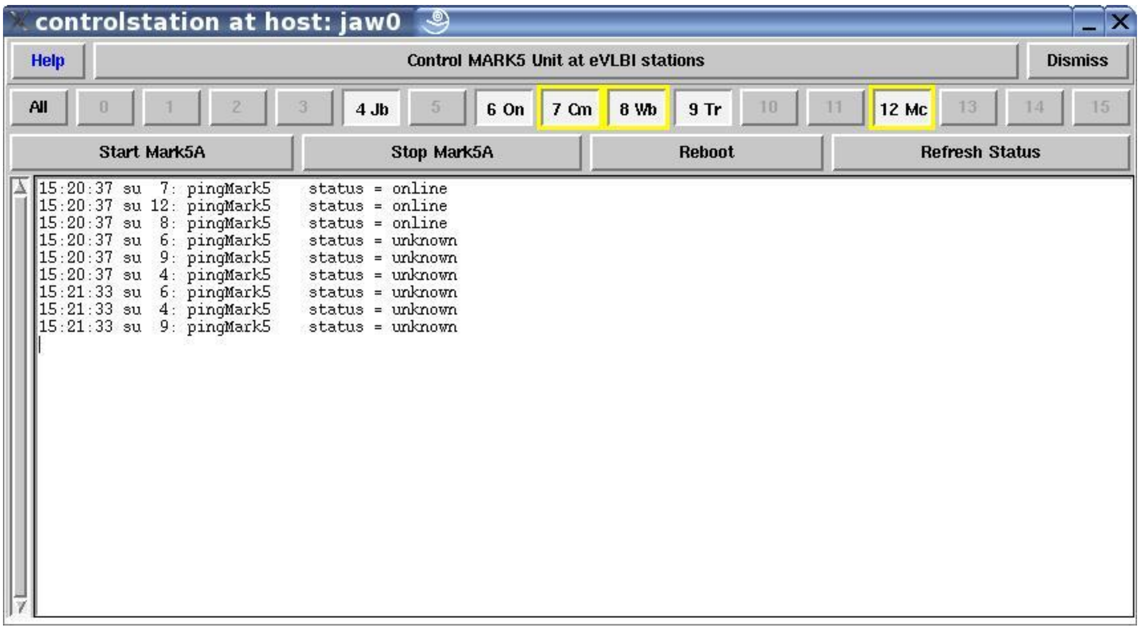


Figure 3.10: Graphical interface to Mark5A units at stations

Another very useful tool that became available were the integrating fringe display, enabling one to detect fringes of weak sources, essential during real-time and/or target-of-opportunity observations, and the data status monitor, providing an instant overview of the status of the correlation process. The output of these monitoring programs is also made available via a web page, providing feedback to the operators at the stations.

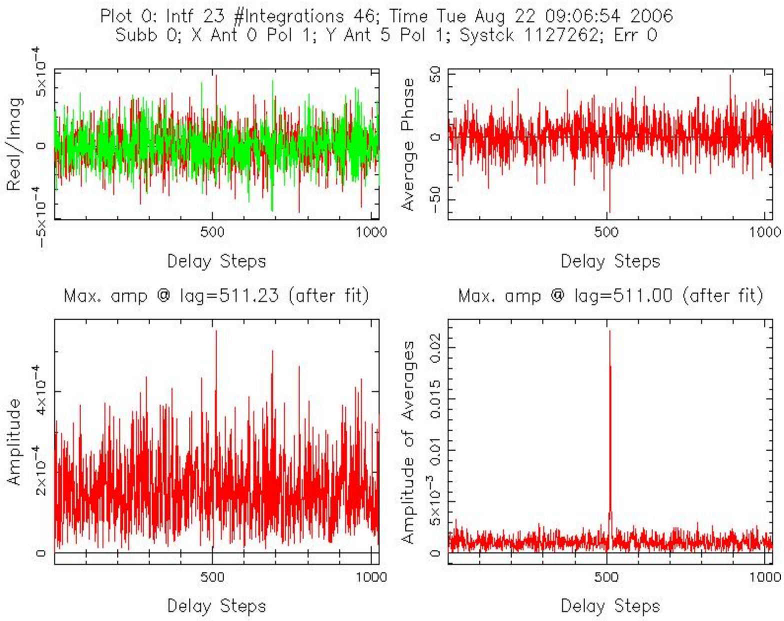


Figure 3.11: Fringe display of weak source: without (left) and with integration (right)

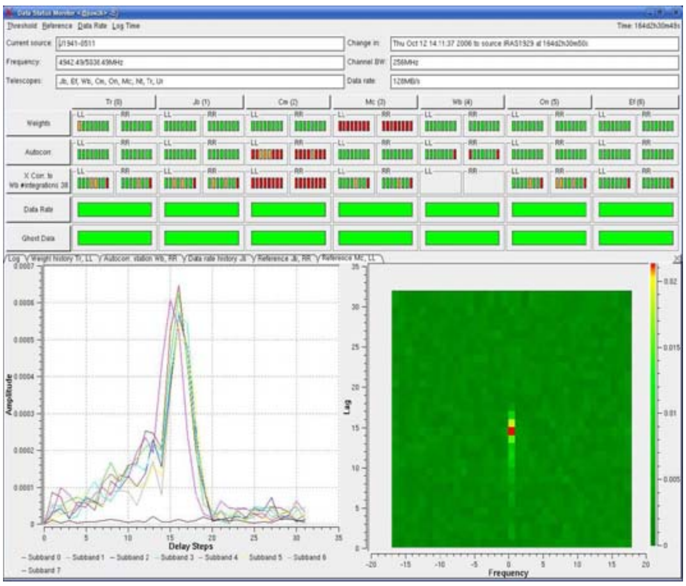


Figure 3.12: One of the views of the data status monitor

3.4.4.3 Hardware

Investigations by Richard Hughes-Jones and his students at the University of Manchester established that the older Mark5A units suffer from insufficient CPU power when transferring data over the internet at high rates. Burgess then upgraded the Mark5A units at Jodrell Bank by installing high-end dual CPU motherboards. This upgrade has proved very successful: since then 512 Mbps fringes to the Jodrell Bank and Cambridge telescopes have been regularly achieved.

3.4.4.4 Expansion of e-VLBI network

Several new telescopes were added to the expanding list of Gb-enabled sites. Although the physical labour of digging trenches and installing fibres was completed last year, Medicina was finally connected to GARR and GÉANT in 2006, and now participates in all e-VLBI sessions. Metsahovi was connected at 10 Gbps, but had not yet produced fringes by the end of 2006.

3.5 Meetings

3.5.1 EVN-NREN, e-VLBI workshops

During 2005 two EVN-NREN meetings were held, both at Schiphol Airport. While the first meeting (in the last week of January) was still somewhat modest in scope and concentrated on overall progress and ways to move forward, circumstances had changed considerably when the second meeting took place in October. EXPReS and GÉANT2 had been funded, which meant that e-VLBI was set to become a major development effort for JIVE and the EVN, and that DANTE would be able to provide the needed network resources. As a result the meeting focused on the developments needed for EXPReS and on the detailed plans for the new GÉANT2 and SURFNET6 networks (topologies, capabilities like light-path switching, bandwidth on demand).

The 4th e-VLBI Workshop was hosted in July of 2005 by the Australia Telescope National Facility in Sydney, with 60 participants. One day was reserved for a networks meeting in which the networking community presented their views and projections for e-VLBI. The overall opinion was that e-VLBI was developing at a rapid pace. In fact, during the meeting it became known that funding had been approved to connect three ATNF telescopes at 1 Gbps, opening the possibility to involve the ATNF in worldwide e-VLBI experiments.

In September 2007 the 5th e-VLBI workshop returned to its original venue, Haystack Observatory. The meeting featured workshops on networking by Internet2 experts and covered a broad range of topics. The meeting was well attended with again 60 participants, reflecting the high level of interest e-VLBI continues to generate.

3.5.2 Next Generation Correlators

JIVE hosted the 3rd RadioNet Engineering Forum Workshop "Next Generation Correlators for Radio Astronomy and Geodesy" in Groningen in June of 2006. The aim of the workshop was to review the current state-of-the-art in the field of correlator development, in an attempt to identify those technologies (including software, hardware and hybrid approaches) that might best address the requirements of future radio instruments, including the SKA and related SKA pathfinder projects.

The meeting brought together nearly 70 engineers and scientists from all over the world, and was generally regarded as very successful, with ample opportunity for discussions and informal exchanges of ideas.

Figure 3.14: Poster of the NGC meeting hosted by JIVE

4. SOFTWARE DEVELOPMENT

4.1. Correlator Software

4.1.1. FABRIC Software Correlator

In 2006 JIVE assumed the lead for FABRIC, the "Joint Research Activity" in EXPReS. For JIVE this mostly entails work on the software correlator, which started in March 2006 when Ruud Oerlemans was transferred from the Huygens Spacecraft tracking to the FABRIC project. Towards the end of 2006 Yurri Pidopryhora arrived at JIVE. The EC funded project FABRIC is complemented by the Dutch SCARIe project and halfway 2006 Nico Kruithof joined JIVE on this NWO funded effort, which is carried out in collaboration with UvA and SARA in Amsterdam.

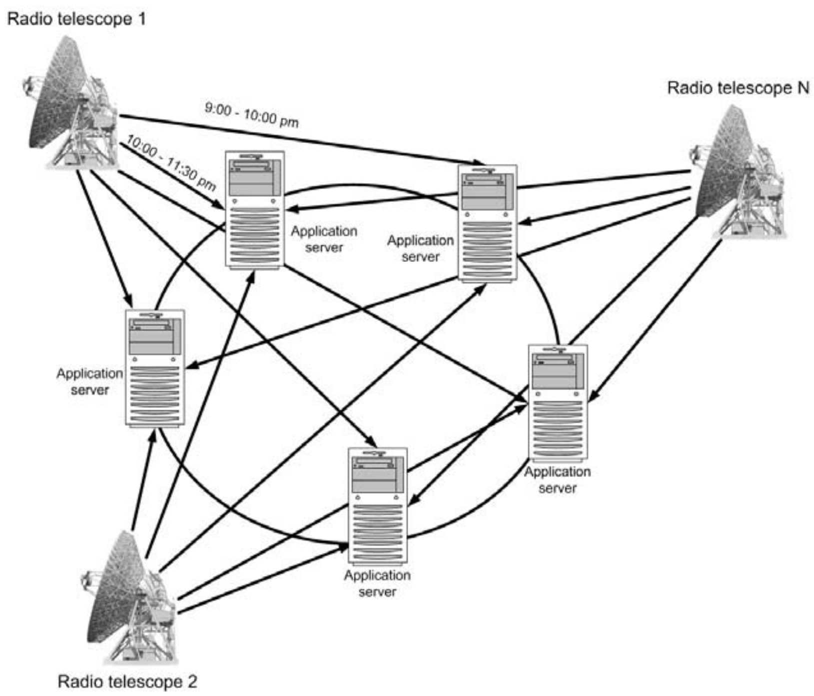


Figure 4.1: Possible topology for future distributed correlation. Note that the number of compute nodes would grow with the number of telescopes squared. In this naive sketch one node (which could be an entire Grid cluster computer) is assigned to one baseline, in reality the data may be sliced in time, frequency band or polarisation.

The overall project FABRIC (Future Arrays of Broadband Radio-telescopes on Internet Computing) contains two major work-packages, one on data acquisition and the other on distributed correlation. The latter is carried out in collaboration between JIVE and PSNC (Poznan). It is based on the software correlator that has been developed for tracking the Huygens landing on Titan. Maintaining the narrow-band capabilities, this algorithm can be deployed on standard computing to implement high precision wide-band correlation. If this application can be ported to Grid computing, it can be used for operational correlation in the future, especially for a limited range of special applications (e.g. pulsar gating). The work-packages aim at adopting the workflow management systems from Virtual Lab applications for this purpose (Figure 4.1). The challenge will be to set-up the routing to cluster computers in such a way that the network can keep up with the incoming data rates.

During the year various meetings were organised to converge on an overall design. Some of the early work concentrated on software to stream data from Mk5 systems to remote cluster nodes. At JIVE the team focused on providing the correlator core by porting the code from a very specialized Matlab implementation to more generally deployable compiled code. The team profited very much from a visit by Adam Deller (Swinburne University, Australia) linked to the Next Generation Correlator Workshop in Groningen. This led to an exchange of ideas on system architecture and parallelization, which is now being exercised in the SFXC (software FX correlator) code. In November 2006 the first version of the multi-process SFXC was issued. The whole correlation job is divided into as many time slices as there are processors available. Benchmarks have been run using this version of the software to determine the scalability of it.

4.2. Logistics Software

Various improvements were made to the software that makes the archive accessible to the users. In particular, new source selection tools were introduced, for example a connection was made that allows pipeline images to be overlaid directly on images from on-line optical databases such as available through Aladin (Figure 4.2).

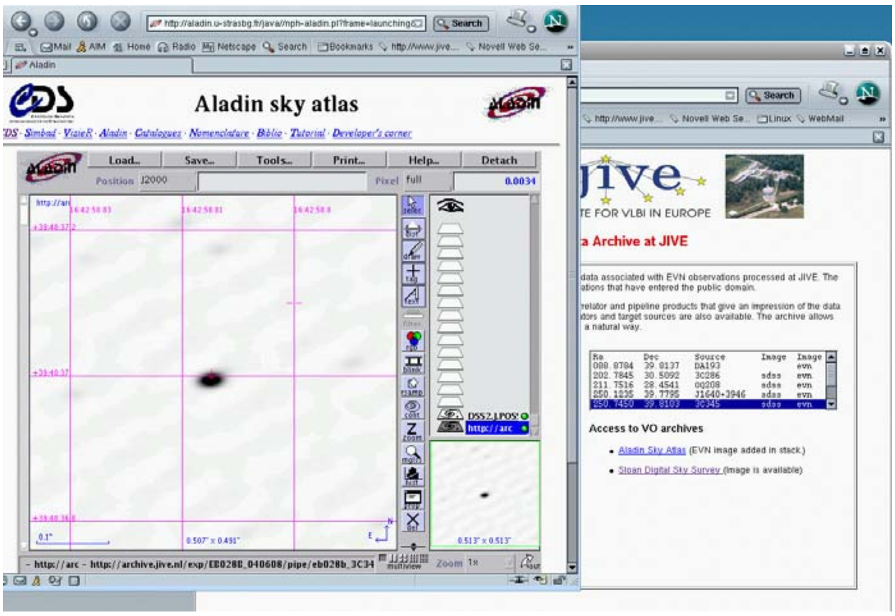


Figure 4.2: Screenshot of the archive tool that plots the pipeline image of 3C345 on POS plates through Aladin.

Much attention also went into being able to distinguish between public and restricted data access, now that some of the products in the archive have become public. Besides the implementation of password protection, tools were developed to monitor the access on project level. Enhancements were made to allow outside users to download large datasets efficiently. For export on DAT tapes a new tool was created to write these automatically. This ensures a uniform product and at the same time it produces professional labels. The local backup procedure was enhanced with software to make use of a newly acquired LTO system. The tapes are kept at the Westerbork site.

The EVN has worked towards adopting the Northstar proposal tool, which was developed at ASTRON in the context of RadioNet Synergy. JIVE has taken the responsibility to maintain the EVN specific part of Northstar. Work in this area progressed to a first demo version by the end of 2006 in collaboration with ASTRON.

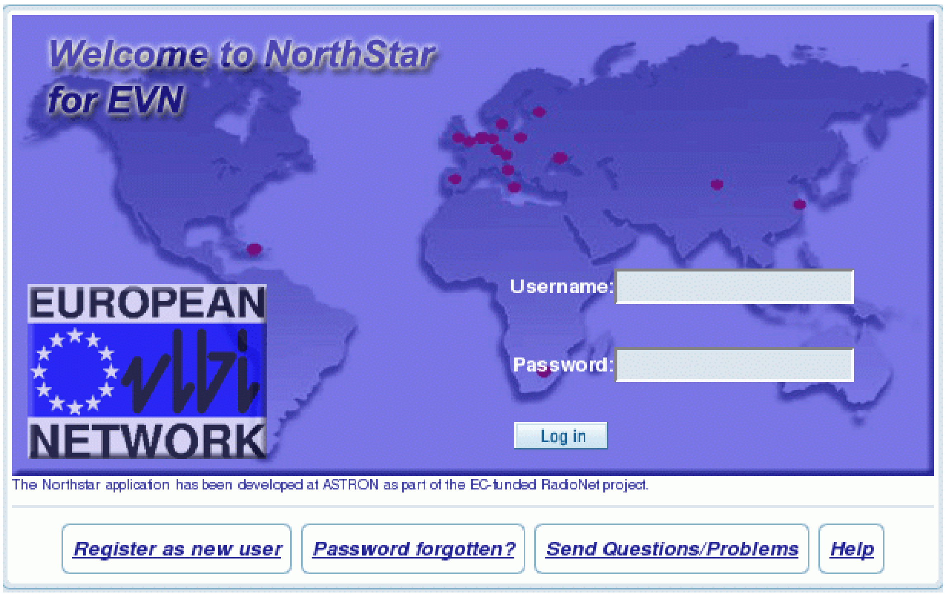


Figure 4.3: Login screen of the Northstar proposal tool for the EVN

4.3. ALBUS

ALBUS (Advanced Long Baseline User Software) is the Joint Research Activity in RadioNet that concentrates on making new algorithms available to the user community. In this project JIVE has the overall management responsibility and also carries out 4 of the original work packages. Moreover, JIVE has taken the lead on ParselTongue, which is now probably the most visible one amongst the ALBUS projects. The ALBUS work at JIVE encountered some delays in 2006 when Mark Kettenis, the original ParselTongue author, moved on to other responsibilities within JIVE.

Calibration transfer

The first part of this work package provided the direct transfer of system temperature calibration and off-source flagging information from the telescopes to the data product. The EVN pipeline (developed in ParselTongue) has been enhanced to allow it to use these calibration data and attaches them to the data product, meaning that the old-style external calibration files are no longer required for user processing. Further efforts need to concentrate on solving bottlenecks in the data provided from the telescopes to ensure better accuracy and correct formatting.

The correlator software has been upgraded to allow phase-cal measurements to take place continuously. The output from the measurements is attached to the data product and can now flow through all the stages of JIVE's internal data handling. The usefulness of the resulting product for phase calibration has been demonstrated using software written in ParselTongue. There is also a related effort to improve the accountability of the correlator model in the output data. This allows one to extract the component parts of the model which can then be replaced by, for example, external troposphere models.

Ionospheric calibration
Different strategies for calibration of the ionosphere are exercised in this project. The estimates of the ionospheric conditions include purely theoretical models, conventional GPS estimates, local GPS data and global empirical models. One hurdle was to develop methods to add these estimates to AIPS data sets. In 2005 some encouraging preliminary results were obtained. However, it remains difficult to identify a method that performs optimally in all conditions. In 2006 the focus was on the development of the three dimensional minimum ionosphere model (MIM). By modelling the ionosphere at many different altitudes, this model is able to reproduce ionospheric delay patterns for much longer baselines than can be achieved by the standard two-dimensional models. Anderson, who is responsible for this project, has also closely collaborated on the ionospheric calibration issues with LOFAR staff.

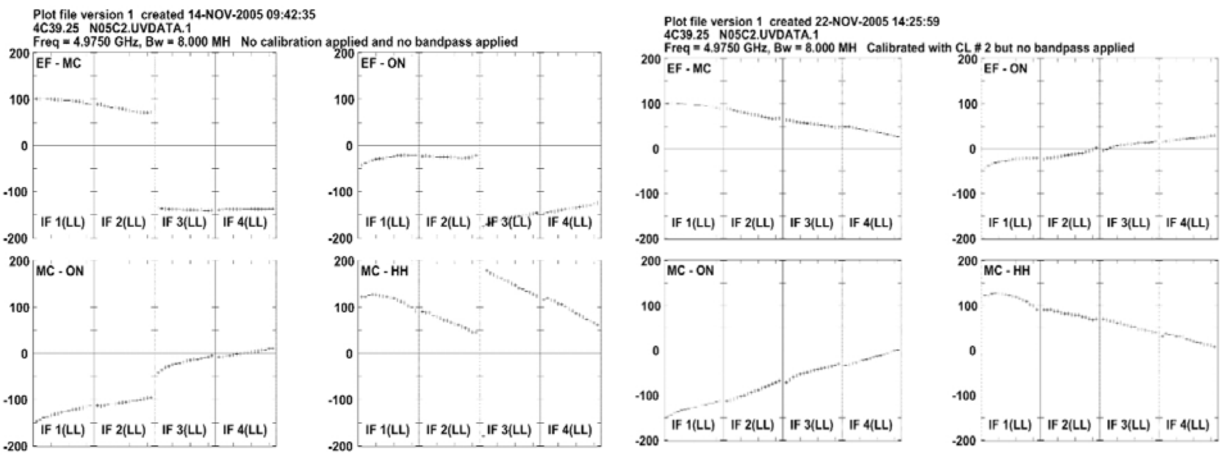


Figure 4.4: Phase response on several baselines before (left) and after (right) applying the phase tone detections made at the EVN Mrk4 data processor

In 2005 this worked focused on processing EVN test data taken in various conditions. But more recently the algorithms were deployed to assist in the reduction of a 320 MHz science project (figure 4.4). The goal of this project was to perform wide-field imaging at low frequencies. The ionospheric delay errors at these low frequencies are typically the largest sources of calibration errors and the ionosphere changes substantially over the field of view. ParselTongue software was developed to apply existing ALBUS ionospheric correction methods to radio data for arbitrary directions on the sky (instead of the phase reference centre of individual observations). This was quite successful, but the small isoplanatic patch size of the observations (on the order of a couple of tens of arcminutes) also hindered efforts to apply ionospheric phase corrections from individual sources in the field to other sources.

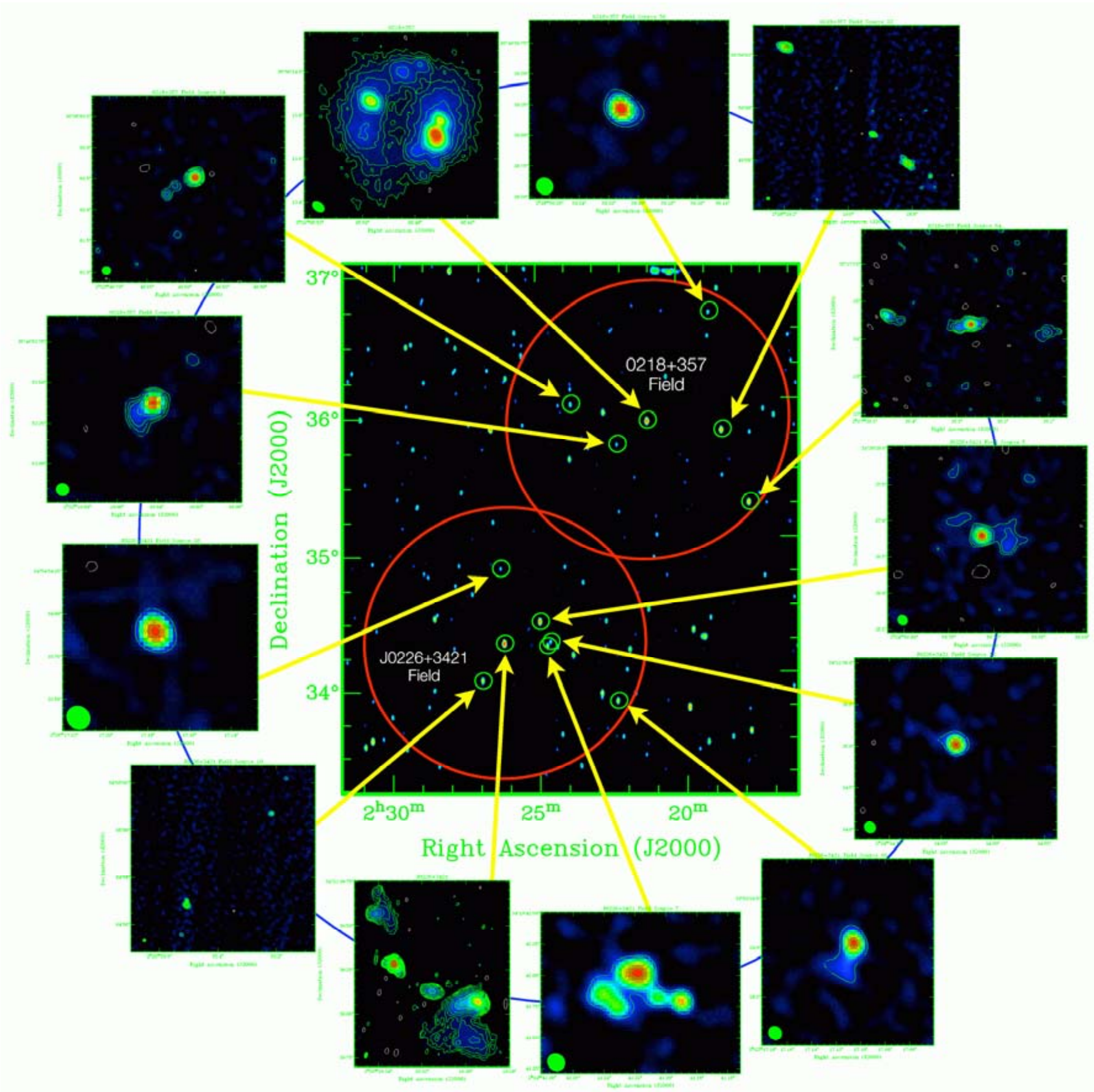


Figure 4.5: Thirteen sources detected using wide-field VLBI at 90 cm in 3.1 degree2 fields around the AGN J0226+3421 and the gravitational lens 0218+357. The central image is a low resolution WENSS image of the surveyed regions (Lenc et al., 2006).

Post-correlator processing

Preparatory work for the post-correlator processing entails the transformation of the high-resolution correlated data into JIVE's intermediate data format, the AIPS++ Measurement Set. The new approach is necessary because of the limitations in supported size and speed of the old format. This will allows re-processing of data (e.g. off-line integration, filtering and analysis). During most of the reporting period, this project was awaiting new manpower, similar to the Wide-field imaging project.

Wide-field Imaging

Some initial work on wide-field imaging for ALBUS started in 2006 and focused on software development to facilitate data reduction for a 320 MHz dataset (above). Software to simplify processing tasks was written in ParselTongue to automate many of the repeated AIPS tasks necessary to calibrate the observations for a particular direction in the sky and then shift the phase reference centre. Unfortunately, the processing steps necessary to perform this use routines which require that copies of the full dataset be written out to disk many times. This means that processing the data is extremely slow. A new routine to incorporate the same functionality into a single routine needs to be developed within AIPS to significantly speed up the processing.

Infrastructure Software: ParselTongue

In order to implement various ALBUS tasks it was decided to work on a software package for scripting AIPS tasks and accessing its data structures from Python. In two years amazing progress on this package, called ParselTongue, has been made. It builds on the Obit package developed by Cotton at NRAO, and the implementation was done by Mark Kettenis. Several internal JIVE projects were used to test and verify the use of ParselTongue (e.g. figure 5.20 in the science section).

The first public release of ParselTongue was made in January 2006. This marked the completion of the first two stages of the original ParselTongue project plan. Besides being used within ALBUS to implement and verify new algorithms it has been used to improve the EVN pipeline (Pypeline), which fills the archive with additional products, including preliminary images. At Jodrell Bank Observatory an imaging pipeline for the MERLIN data archive was implemented and integrated within Astrogrid, the British Virtual Observatory. By the end of 2006 ParselTongue had a considerable user base with researchers at several institutes across Europe, Australia and the United States. Among its users are a relatively large fraction of PhD students. Besides EVN and MERLIN data, it is also used for data from other telescopes like the GMRT and the VLA, including algorithm research for the LOFAR telescope.

Of course releasing the software to a wider audience uncovered bugs and brought in requests for additional features. Improvements were made available to the user community in five more releases throughout 2006. User documentation and release notes are available on the RadioNet wiki, where there is also a deposit for contributed code and examples (http://www.radionet-eu.org/rnwiki/ParselTongue). New effort focuses on the distribution mechanism and documentation.

5. SCIENTIFIC RESEARCH

Cosmology & Deep Fields

A team composed of Mike Garrett, Peter Barthel (Groningen) and Seungyoup Chi (Groningen) analyzed a wide-field, global VLBI data set, targeting a region of sky centered on the Hubble Deep Field (HDF-N). This huge data set comprises three 12-hour epochs of global VLBI data that included the participation of the 100-m Effelsberg (DE), Green bank (US), and 76-m Lovell (UK) telescopes. The data were correlated at JIVE (in wide-field mode) generating 675 GB of data. The recording rate was limited to 128 Mbps in order to obtain fine spectral resolution and each epoch was correlated in 2 passes in both right (R) and left (L) hand circular polarization. The data were calibrated by averaging the data set and then applying the corrections to the unaveraged data set.

A total of 92 radio sources of Muxlow et al. (2005) were surveyed over a total of 201 arcmin^2 divided into four annular fields with different angular resolutions and sensitivities. The images in the HDF-N reach thermal noise levels of ~7.3 microJy/beam with 4 milliarcseconds angular resolution. Above a 5σ threshold, 12 radio sources in HDF-N and HFF were clearly detected. Figure 5.1 shows four detections in HDF-N, including a new VLBI detection, and figure 5.2 presents the other 8 radio sources detected in HFF.

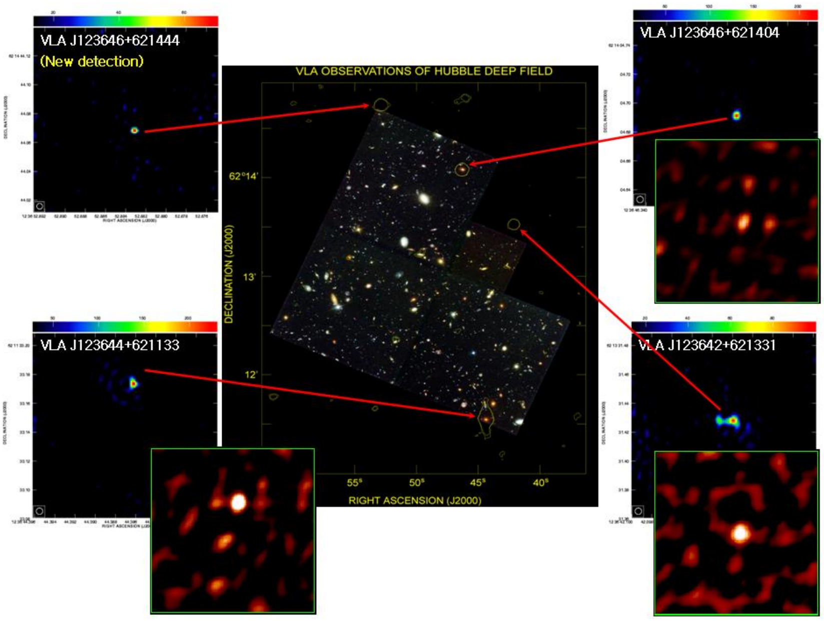


Figure 5.1: New global VLBI detections in the HDF-N (pseudo colours), together with sources that were previously detected by the EVN (flame colours). A VLA radio map (yellow contours, Richards et al. 1998) is superimposed on the deep HST image. The original VLBI images reach ~30 microJy/beam r.m.s. noise levels, and the new VLBI images reach ~7.3 microJy/beam

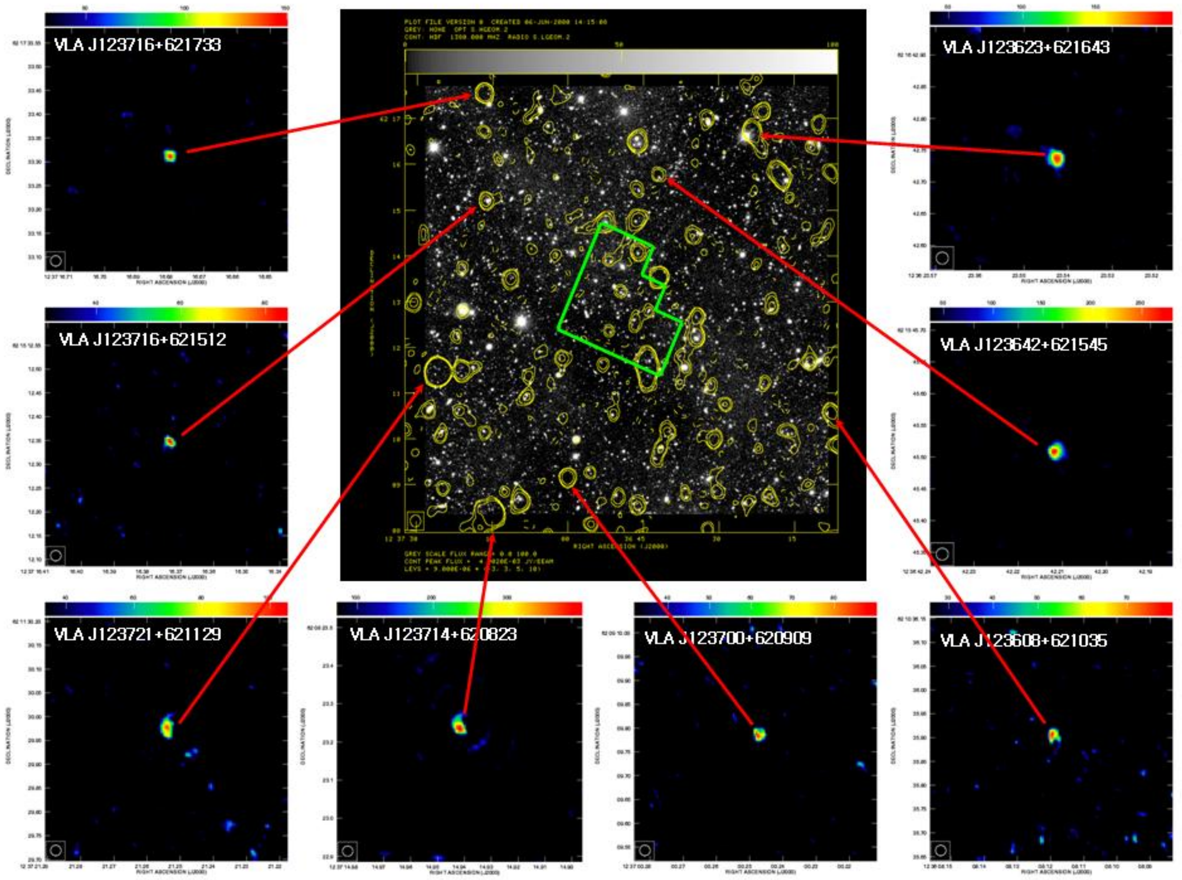


Figure 5.2: New global VLBI detections in the HFF (pseudo colours), together with WSRT radio map (yellow contours) superimposed on the CFHT I-band image (grey scale, Garrett et al. 2000). Both angular resolution and sensitivities of the images are degraded (tapered data)

A pilot project of the Deep Extragalactic VLBI-Optical Survey (DEVOS) has been conducted over the last three years by an international group including Leonid Gurvits and Mike Garrett. The ultimate goal is to get VLBI images of 10,000 of optically identified extragalactic radio sources. Going after VLBI detections in a FIRST-based sample of extragalactic sources, the yield was estimated to be 30%. This value will be verified by further DEVOS pilot observations and might become an important input for the SKA design study. A paper (Mosoni et al. AA, 2006, 445, 413) summarizes the results of the pilot phase of the project. The completion of this pilot also allows one to properly estimate observing resources needed for a full scale survey. Previously unknown sources for future in-depth studies were identified in the project (Figure 5.3).

In 2006 JIVE guest Emil Lenc (Swinburne University), assisted by Olaf Wucknitz and Mike Garrett, started analysing two wide-field correlator passes to conduct the first wide-field VLBI survey at 90cm wavelength and to study systematically the source population at this low frequency on VLBI scales. Twenty-six sources were successfully detected, although ionospheric effects make phase calibration difficult (see Figure 4.4 in ALBUS section?).

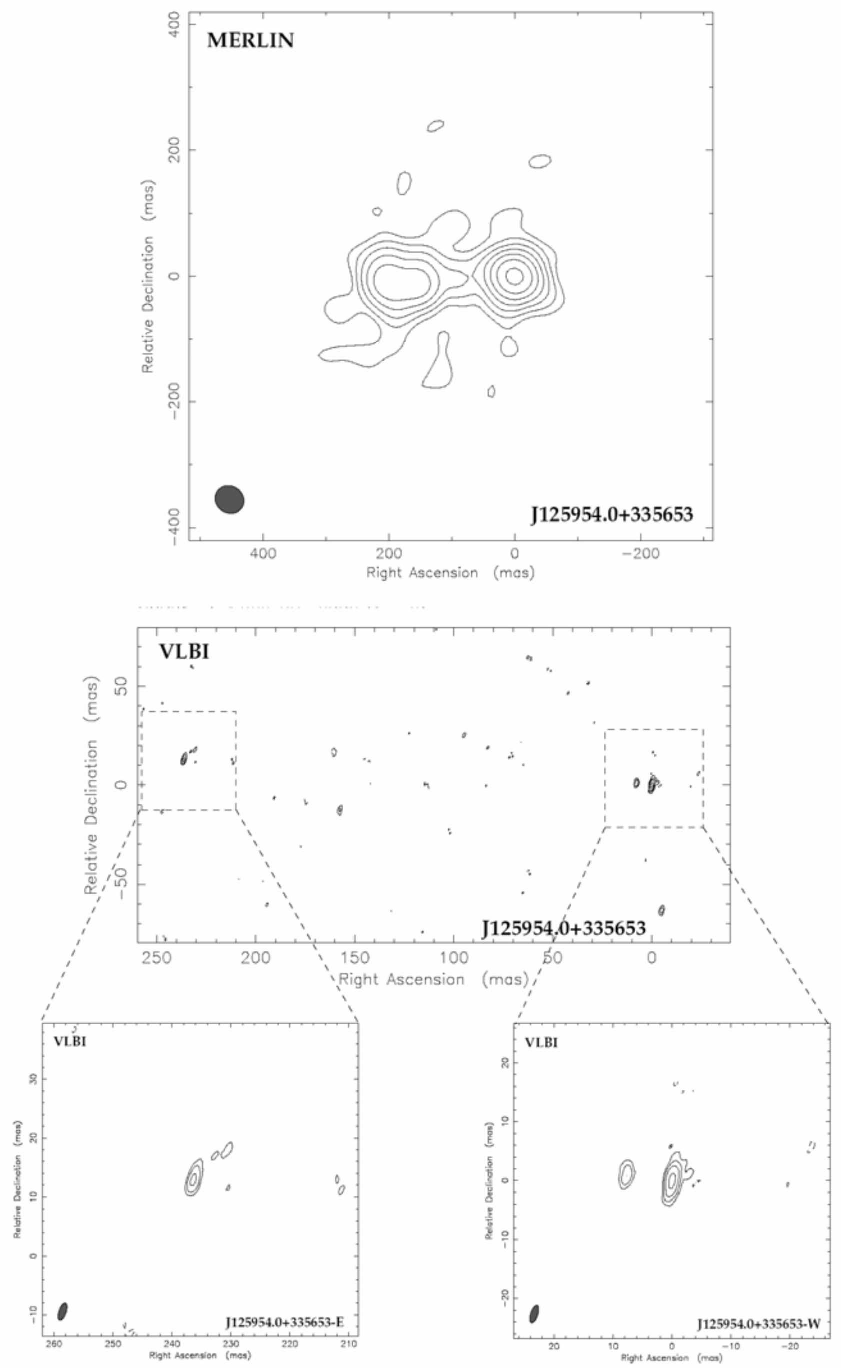


Figure 5.3: An example of a previously unknown compact structure in the radio galaxy J125954.0+335653 (Mosoni et al. 2006, AA 445, 413).

Hayley Bignall is involved in the MASIV (MicroArcsecond Scintillation-Induced Variability) VLA Survey for intraday variability at 5 GHz. Redshift data obtained from the literature and from recent observations with the NOT show a statistically significant decrease in interstellar scintillation (ISS) with redshift (see Figure 5.4). The decrease in ISS must be due to an increase in the apparent angular size of the radio sources in the high redshift universe (the same effect that suppresses the twinkling of planets seen in the night sky). The observed angular size of the quasar jets can depend on redshift due to the cosmology, due to intrinsic evolution of the jets or due to propagation through the turbulent, ionized intergalactic medium (IGM). The various effects are under investigation. It is important to obtain the redshifts for the remainder (approximately half) of the 482 MASIV sources in order to rule out selection effects and to make use of the MASIV Survey as a cosmological tool.

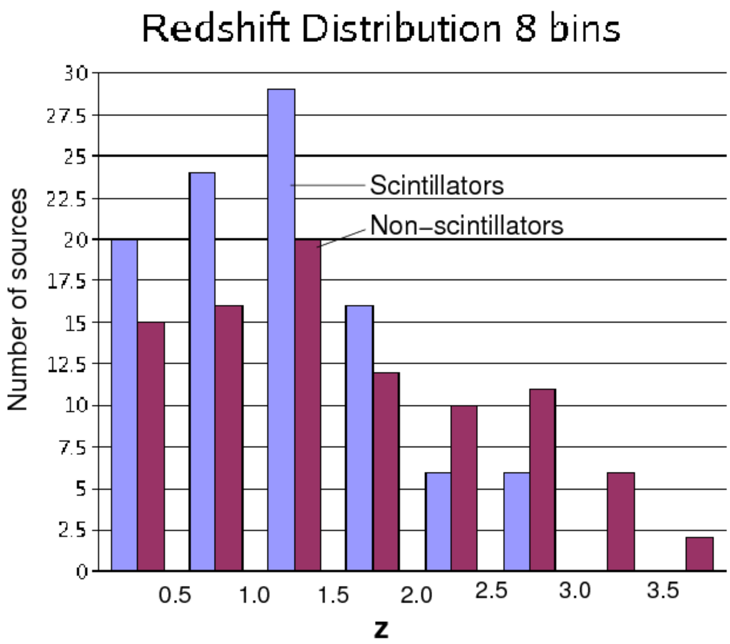


Figure 5.4(a): Redshift distribution of sources in the MASIV Survey. Sources observed to scintillate have a significantly different distribution than those in which no scintillation was detected, with fewer scintillating sources at high redshifts.

Alicia Berciano-Alba was involved in the concept design of a fictitious space mission to study Dark Matter and Dark Energy (DEMON), being the team leader of a group of 14 people that was formed during the Alpbach summer school 2005. Between May 24th-28th she attended the SPIE symposium 2006 (Space Telescopes and Instrumentation II: Ultraviolet to Gamma Ray) in Orlando to present a poster about DEMON, and was also invited to give a talk about the mission in a special session for young researchers. The paper with the details of the satellite was published in the SPIE conference proceedings 2006 (Vol. 6266 626633-1).

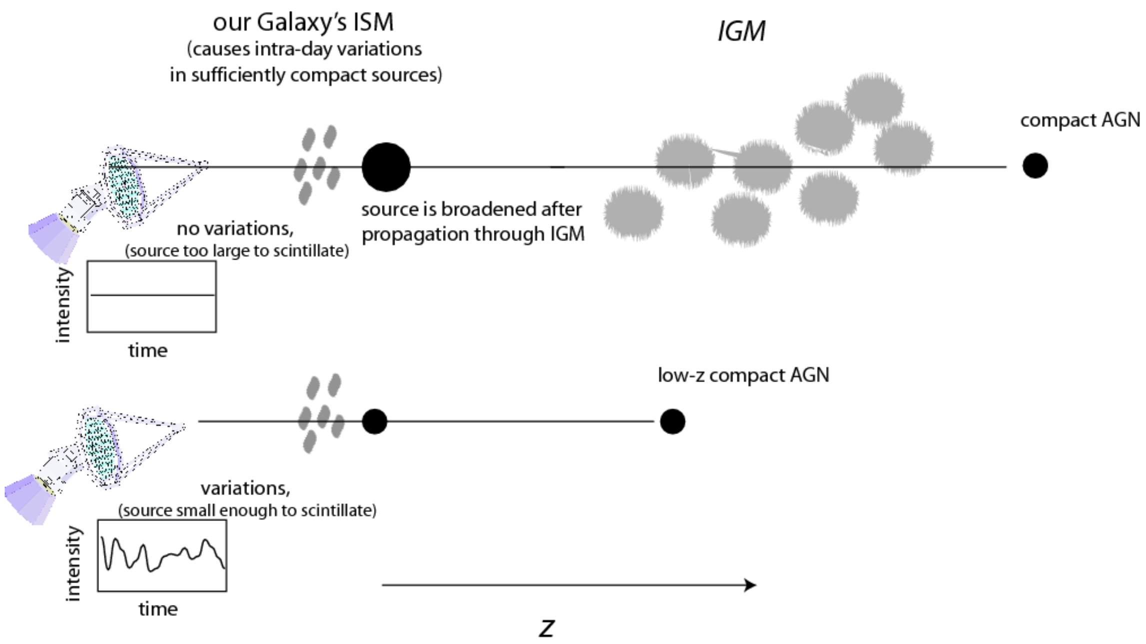


Figure 5.4(b): Cartoon illustrating the effect of suppression of interstellar scintillation due to scatter-broadening in the intergalactic medium.

Gravitational Lenses

The gravitational lens effect acting on extended background sources potentially provides a unique opportunity to determine the mass distribution of a lensing galaxy to great detail and very accurately, because each multiply imaged component contributes its own constraints. Since the true (unlensed) structure of the background source is not known a priori, sophisticated modelling techniques must be used that can fit for the mass distribution and the source structure simultaneously. For interferometric radio data, the currently most successful method is LensClean, invented by Kochanek & Narayan in 1992 and developed by Olaf Wucknitz. In order to interpret its results correctly and to develop further improvements, the noise and error properties of LensClean, which are partly inherited from Clean, have to be analyzed, see Figure 5.5). Olaf Wucknitz continued the work on new deconvolution methods for interferometric observations of lensed sources. Markov-chain Monte Carlo methods were used to study systematic effects of trial methods and to explore the full range of possible source structures instead of limiting the interest to maximum-likelihood fits. The goal is to introduce regularisation constraints into radio lens modelling algorithms in an optimal way.

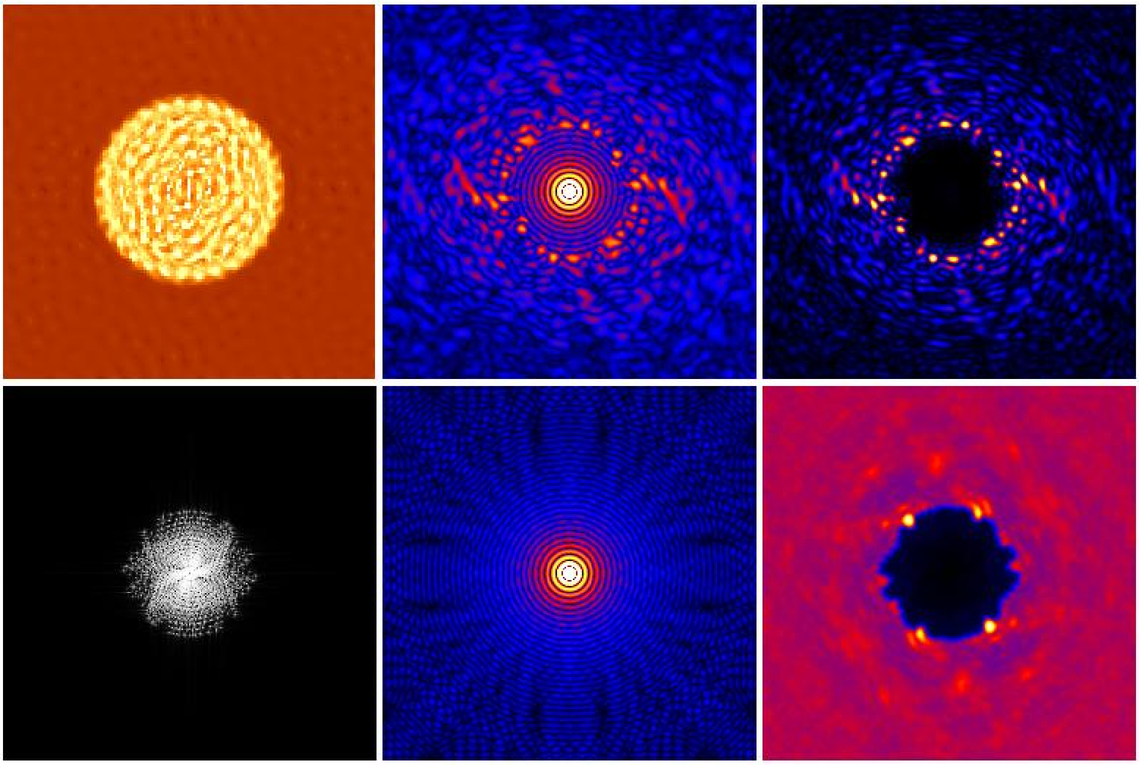


Figure 5.5: Illustration of Clean simulations to study the noise properties. The images show the mean Clean result (without Clean beam convolution) in (a) image and (b) uv space, (c) the systematic error in uv space, (d) the uv coverage, (e) the model in uv space, and (f) the mean statistical error in uv space. The model source was a uniform disc of constant surface brightness.

One of the most interesting applications for LensClean is the lens system B0218+357, which has been used to determine the Hubble constant from the time delays among its images. Global VLBI observations conducted at 90/50cm extend the study of the Einstein ring to higher resolutions and will allow the investigation of mass substructure and propagation effects. Preliminary maps of B0218+357 were presented at the Nederlandse Astronomenconferentie 2006 (see Figure 5.6). The ionosphere, although relatively well behaved during the observations, produced phase fluctuations which make phase referencing difficult. Together with Rupal Mittal (MPIfR, Bonn) the frequency dependence of the flux density ratio in B0218+357 was investigated further. It became clear that magnification gradients together with the frequency-dependent source structure cannot explain the observed effects. Free-free absorption in the ISM of the lensing galaxy, on the other hand, fits the observations very well.

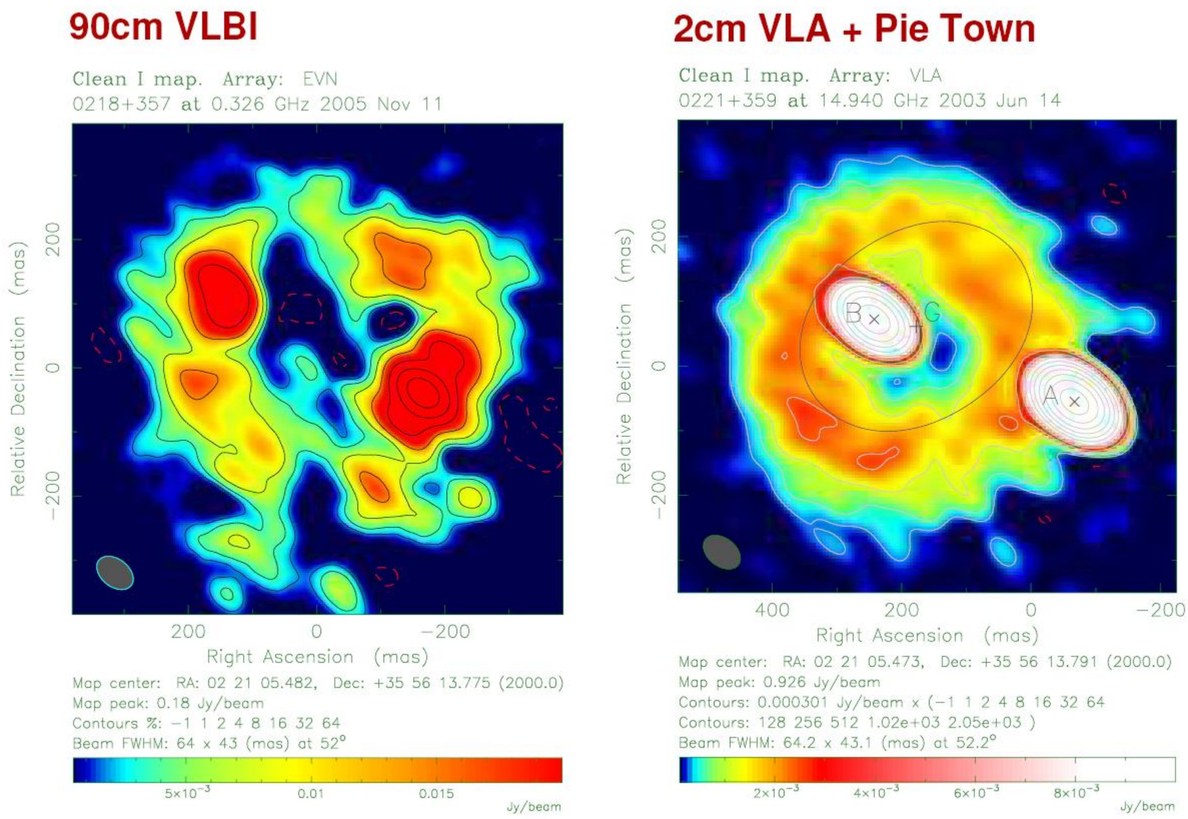


Figure 5.6: Left: Preliminary map of B0218+357 at 90cm observed with a VLBI array consisting of the VLBA, Jodrell Bank and the Westerbork phased array. Right: VLA+Pie Town map at 2cm for comparison. Even though the details in the 90cm map are still uncertain we can already see significant differences which are partly due to frequency-dependence of the source structure and partly due to propagation effects (scattering and free-free absorption)

With Oliver Czoske (University of Bonn), Olaf Wucknitz observed the colliding cluster of galaxies Cl0024+1654 with the VLA to detect a possible radio halo or relics and to help with the identification of multiply lensed background sources. This complements similar observations of A2218 and MS0451-0305. For the analysis of VLA continuum observations, it was necessary to develop a new method to correct the data for bandwidth smearing of strong interfering sources in the field. The algorithm fits for the unknown bandpass functions and removes confusing sources with full bandwidth smearing correction. The same cluster was observed with the VLA in A configuration to investigate the structure of a possible AGN jet/lobe in the centre. Such a source would provide additional non-thermal pressure which has to be taken into account when interpreting X-ray observations based on the hydrostatic equilibrium assumption. Calibration and mapping this data set comprised a main part of the project of 2006 summer student Filomena Volino (Bologna), supervised by Olaf Wucknitz and Mike Garrett. Main purpose of the project is to search for lensed background radio sources.

Together with Neal Jackson (Jodrell Bank Observatory) and Mike Garrett, Olaf Wucknitz started to develop strategies to use LOFAR for gravitational lens studies. A condensed version is published in the science case for an extended LOFAR. Lens searches will form part of a project for which Wucknitz successfully applied for funding from the German Science Foundation (DFG) in the Emmy-Noether-Programme to start a small research group in 2007.

Andy Biggs observed the six-image gravitational lens system B1359+154 with the High Sensitivity Array (HSA), consisting of the VLBA, GBT, phased-VLA, Arecibo and Effelsberg antennas. The goal of the observations was to try and detect the jet, currently only visible in the three brightest images. B1359+154 is of particular interest due to its six-image configuration; this results from the chance alignment of three galaxies (that form part of a larger group) along the line of sight to the background quasar. If the jet can be detected in all six images then it may be possible to constrain the mass distribution in the core of a group of galaxies.

The identification of highly magnified, multiply imaged radio sources by the foreground massive cluster Abell 2218 was published by Mike Garrett with Kirsten Knudsen & Paul van der Werf (both Leiden). The sources are also detected in the sub-mm (Knudsen et al. 2004) and at other wavelengths. Figure 5.7 shows the radio emission (WSRT 1.4 GHz) overlaid upon the Spitzer 24 micron emission.

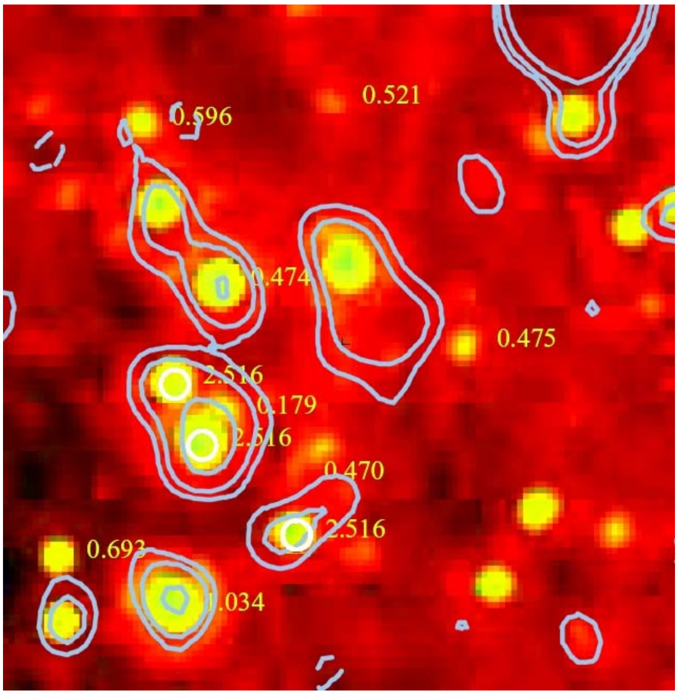


Figure 5.7: A deep 1.4 GHz WSRT map of the central region of Abell 2218 (light blue contours) is superimposed on a Spitzer Mid-IR image (Egami et al. 2006). Most of the Spitzer/WSRT sources are located at moderate redshift (values indicated on the image) with the exception of the gravitationally lensed sub-mm/radio source (indicated by white circles) that is both multiply imaged & highly magnified. This background source is located at z ~ 2.9.

Mike Garrett, Alicia Berciano-Alba, Leon Koopmans (RuG) and Olaf Wucknitz have also been involved in the detection of a second multiply imaged and highly magnified radio source, produced by massive cluster lensing. Like Abell 2218, the background radio source (z ~ 2.9) is also detected by SCUBA (Borys et al. 2004) and the similarity between the radio and sub-mm emission is striking, with the source stretching 1 arcminute across the sky.

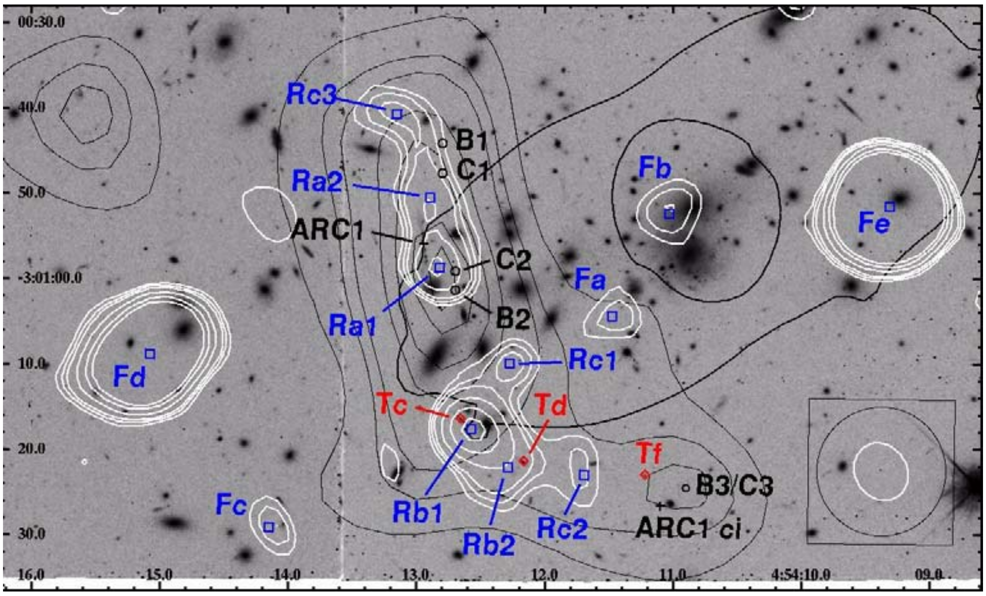


Figure 5.8 The VLA 1.36 GHz naturally weighted contour map (solid white) superimposed upon a inverted NIR image of the centre of the cluster MS0451.6-0305 and the SCUBA 850 – μm contour map (dashed black) from Borys et al. 2004. Contours of the radio map are drawn at -3,3,4 & 5 times the 1-σ noise level of 9 μJy / beam. Contours of the sub-mm map are drawn at 4,6,8 & 10 mJy. The white circle inside a box in the bottom-left corner is the beam-size of the radio map (6.99 x 6.03 arcsec in position angle PA = 32.59º)

Mike Garrett supported Sunita Nair (Raman Research Institute) in her development of a model of a helical jet in the gravitationally lensed radio source PKS1830-211, in which ballistically ejected plasmons from a precessing nozzle are able to fit previous structural changes in the source as seen in 43 GHz VLBA observations. An observed jet precession period of 1.08 yr is inferred from the model, translating to an intrinsic period of 30.8 yr for a source at redshift zs= 2.51 and an assumed jet bulk velocity beta of 0.99c. This fits well with the picture of the active galactic nucleus hosting a binary black hole system at its centre, where one member of the system emits the jet and the precession results from its orbital motion around its companion.

Gamma Ray Bursts and Supernovae

In March, Mike Garrett and Zsolt Paragi participated in the first e-VLBI continuum science demonstration observations. The target source of these observations was SN2001em, a supernova event that unexpectedly brightened in 2004, leading some to suggest that this source might be an example of a misaligned GRB and that the brightening was due to enhanced radio emission associated with the (now) non-relativistic jets. The e-VLBI observations of the source were dogged by various problems. By the time the software had been changed the source was setting for most of the e-VLBI antennas involved (Onsala, Westerbork, Arecibo and Torun; Jodrell Bank and Cambridge were shut down due to high winds earlier in the day). With all these problems only about 30 minutes of good data were obtained but it was still possible to detect the source on all baselines involving Arecibo. A tentative image of the SN2001em is presented in Figure 5.9.

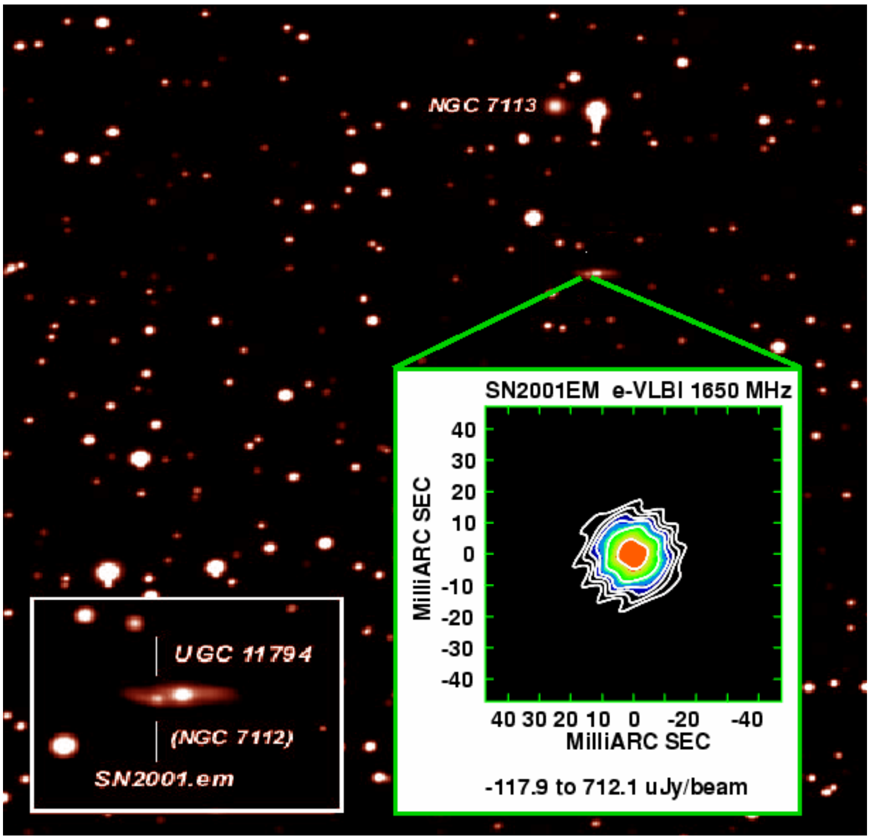


Figure 5.9 The tentative e-VLBI detection of SN2001em in NGC7112.

Scintillation and Propagation effects

Hayley Bignall worked in collaboration with Wouter Vlemmings (JBO) to interpret rapid variability in the 22 GHz water maser lines of NGC 3079, which was serendipitously discovered with the GBT (see Figure 5.10). The observed variability is best explained as weak interstellar scintillation of masers ~12 microarcseconds in angular size, consistent with models assuming a thick, clumpy accretion disk.

ATCA observations of the episodic fast scintillating quasar PKS 0405-385 in 2006, led by Lucyna Kedziora-Chudczer (University of Sydney) showed extremely rapid variability on timescales of minutes. Hayley Bignall was involved in simultaneous observations with the VLA and ATCA that allowed a very accurate measurement of the variability pattern arrival time delay between the two telescopes, 177.2 +/- 4.5 seconds. The time delay measurement will help determine the scattering screen velocity and anisotropy in the scintillation pattern, allowing detailed modelling of the microarcsecond-scale source structure.

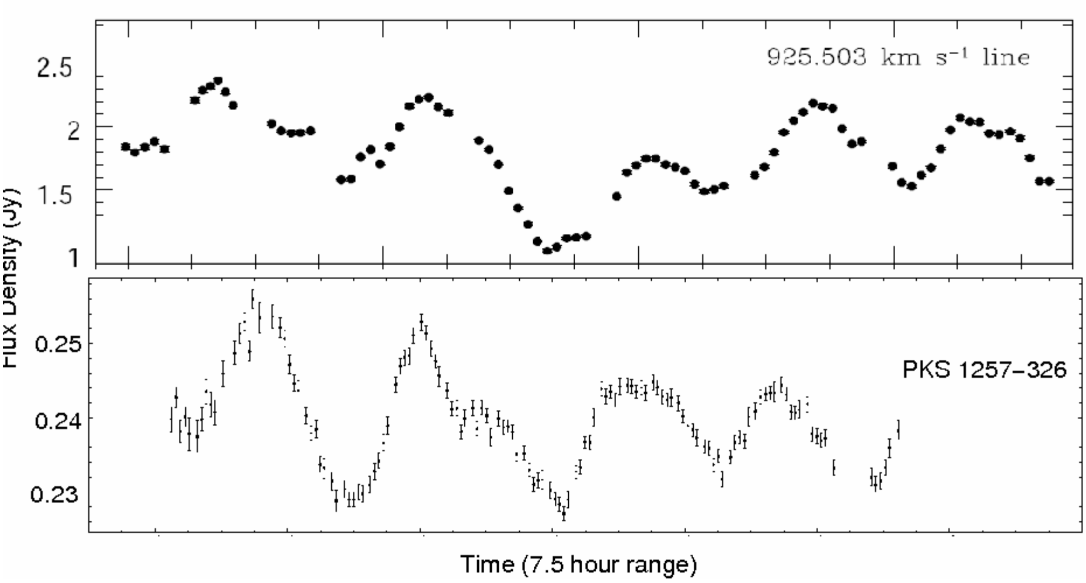


Figure 5.10: A comparison of the rapid variations seen in one of the water megamaser lines of NGC 3079 (top panel), observed at a wavelength of 13.5mm with the GBT in April 2006 (Vlemmings et al.), and the quasar PKS 1257-326 (lower panel) during 16mm continuum observations with the ATCA over the 2006 new year period. The same mechanism, namely scintillation due to weak scattering in nearby Galactic interstellar plasma, is proposed to explain the remarkably similar short-timescale intensity fluctuations seen in these completely different radio sources.

Multi-epoch ATCA data for the gamma-ray loud quasar PKS 1622-297 were analysed by Hayley Bignall in collaboration with Kiyoaki Wajima (Korea Astronomy and Space Science Institute) and Phil Edwards (ATNF). These indicated the presence of persistent intraday variability (IDV) consistent with refractive interstellar scintillation of the VLBI core component (see Figure 5.11). IDV has been found in an unusually large fraction of EGRET-detected AGN, suggesting a connection between the high-brightness radio and gamma-ray emission.

Giuseppe Cimò arrived in mid-September 2006, and has worked on the rapid variability of Active Galactic nuclei. He has been analysing VLBI data from the Australian VLBI network (LBA), combining these with time series from a single dish monitoring project (COSMIC) at the University of Tasmania, as well as Australia Telescope Compact Array observations that provide accurate spectral and polarimetric information. The aim is to describe both the innermost (sub-pc) regions of the compact radio objects and the interstellar medium responsible for the rapid scintillation. Giuseppe Cimò is also PI on an experiment using the VLBA and the Green Bank Radio telescope that aims to provide a measurement of the distance to the scattering material causing the rapid scintillation of several flat spectrum radio sources.

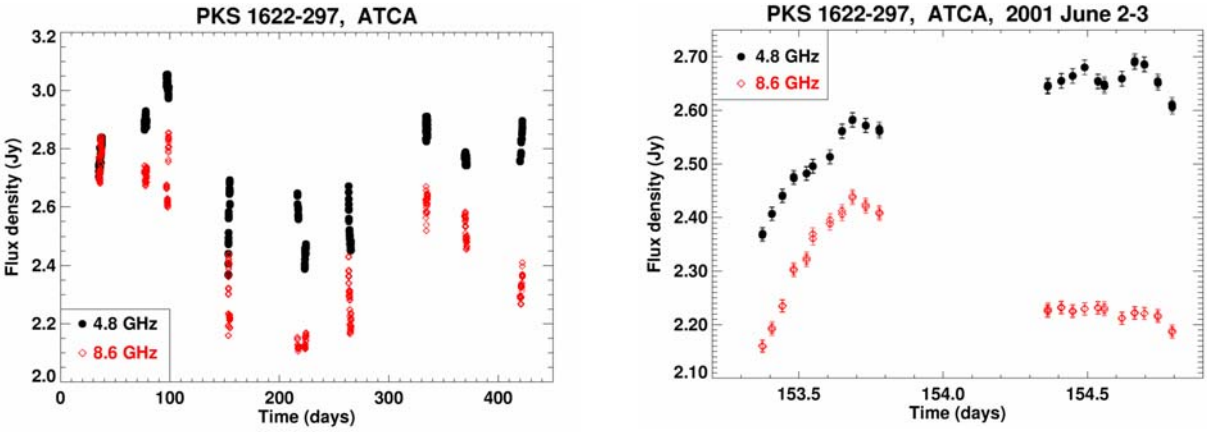


Figure 5.11 Left, Data from ATCA monitoring of the gamma-ray loud quasar PKS 1622-297 at 4.8 and 8.6 GHz. Horizontal axis shows time in days starting on 1 Jan, 2001. Right, Expanded view of the data from June 2001, when the largest amplitude intra-day variability (IDV) was observed. The observed IDV was shown to be consistent with what is expected from refractive interstellar scintillation of the VLBI core.

Cormac Reynolds and Hayley Bignall worked with summer student Juan Carlos Algaba (Valencia) in 2005 to analyse VLBA data on the fast scintillating quasar PKS 1257-326 at 5, 8 and 15 GHz. Although the observations were made in June when the scintillation is relatively slow, the effect of variability was evident in the data, and an algorithm and AIPS procedure were developed to remove the effect by subtraction of a variable point source model. PKS 1257-326 has a broad, steep-spectrum component on milliarcsecond scales, extended to the northwest in the same direction as the arcsecond-scale jet. The VLBA observations confirmed that PKS 1257-326 has more extended structure than typical scintillating sources (e.g. Ojha et al. 2004, ApJ, 614, 607), showing that it is unusual scattering in the nearby ISM, rather than unusual source properties, which is responsible for the extreme, intrahour variability observed for this particular source.

Active Galactic Nuclei

During 2005-2006 James Anderson completed his thesis work on emission mechanisms in low-luminosity AGN. A large component of this work involved developing an improved advection-dominated accretion flow model to compare with observed emission characteristics in a sample of 25 galaxies. The results showed that the standard advection-dominated accretion flow was unable to match simultaneously the observations in the radio, optical and X-ray regions of the spectrum. Many different ways of modifying the standard accretion model to match the observed emission characteristics were investigated. Figure 5.12 shows example spectra from these simulations.

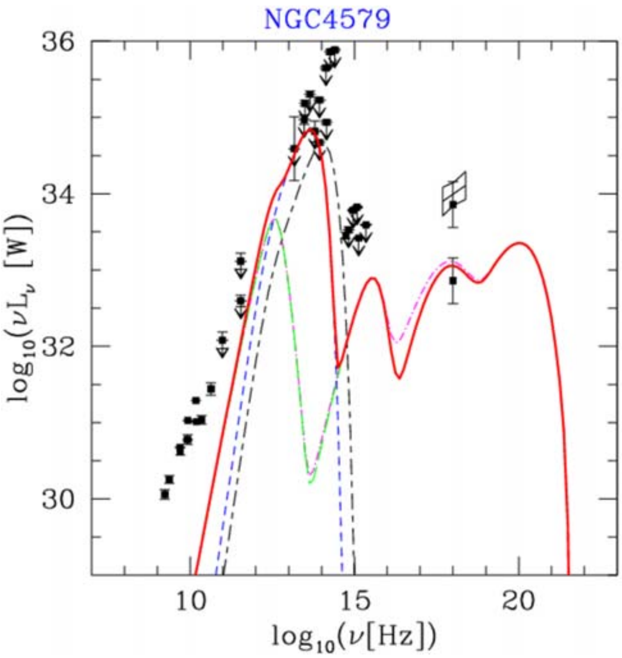


Figure 5.12: LLAGN model spectra. The left-hand plot shows a model spectrum for NGC 4579 (red line) composed of an ADAF component (green line) and an outer thin-disk component (blue line). The right-hand plot shows four different ADAF model spectra for the Milky Way LLAGN (Sgr A). The quiescent radio and X-ray measurements are reasonably well modeled by the ADAF model, but the infrared emission is poorly modeled. The high-state X-ray emission is difficult to match using the standard ADAF model (blue line) as it overpredicts the radio emission. However, variability in the critical point fluid flow predicts a better match to the overall spectrum (magenta line).*

It was found that either the accreting fluid must be unbound to the black hole, or the accreting plasma must have a significant number of non-thermal electrons. A jet-core model for the emission was shown to be also viable.

In the summer of 2006, James Anderson and Subhashis Roy (ASTRON) jointly supervised Dana Viças on a project investigating the possible polar-ring galaxy IC 51. GMRT observations of neutral hydrogen in the system indicate that the gas probably does not form a complete ring, but rather a large arc. Considerable effort was therefore needed to fit models to the data to estimate the gas density and inclination as a function of radius from the central nucleus.

Cormac Reynolds worked with Liu Xiang (UAO) on the analysis of EVN observations of a sample of GHz-Peaked-Spectrum (GPS) radio sources, which aimed to find Compact Symmetric Objects (CSOs). CSOs play a key role in understanding the very early stage evolution of radio galaxies. Three sources from a sample of eleven GPS sources observed at 2.3/8.4 GHz were confirmed as CSOs, with the remainder being a mixture of CSO candidates, core-jet or single component sources. Fourteen GPS sources were observed at 5 GHz to study the polarization. Of these, two core-jet sources, 1433-040 and DA193 exhibit integrated fractional polarizations of 3.6% and 1.0% respectively. The other twelve sources had no clear detection of pc-scale polarization, confirming that GPS sources generally have very low polarization at 5 GHz. In addition, a component in the jet of quasar DA193 was estimated to have superluminal motion of 3.3±0.6 h-1 c from observations over 5.5 years.

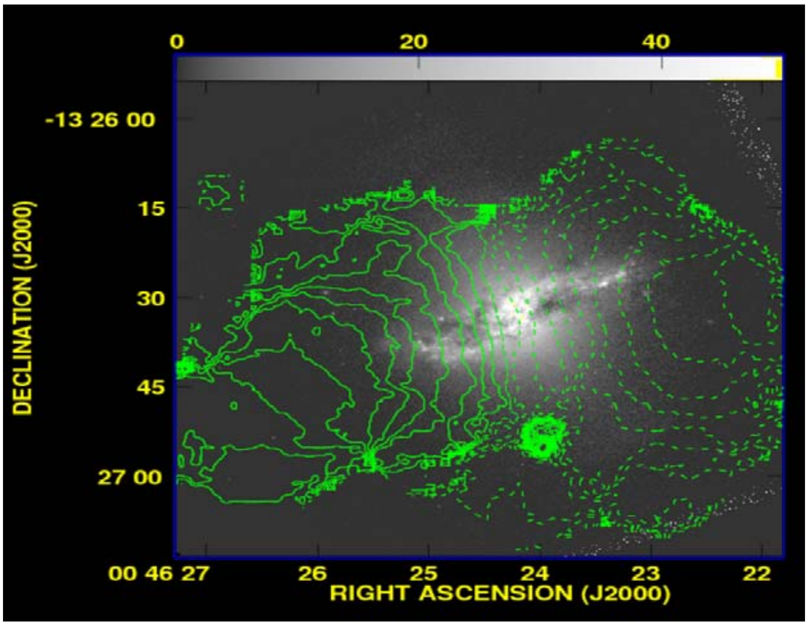


Figure 5.13: A Hubble optical image of IC 51 is overlaid with HI velocity contours from GMRT observations. Model fitting suggests that the gas only forms a partial ring, possibly indicating that this galaxy is in the process of forming a polar ring following a collision with another galaxy.

With Silke Britzen (MPIfR) and Rene Vermeulen (ASTRON), Bob Campbell worked on statistical studies of the jet-component kinematics of CJF sources. This project had three basic thrusts. First, obtaining consistent fits for the 3-4 epochs of snapshot observations of the 293 sources. He made a difmap variant that in addition to the elliptical Gaussian parameters describing source component structure also outputs the statistical uncertainties associated with these parameters and the correlation matrix resulting from the fit. Second, these results were used to estimate kinematic models for the components in 266 of the CJF sources, comprising 779 components (237 sources with redshifts, comprising 699 components). This large sample provides the basis for correlation analysis of apparent component velocity against other source properties (class, luminosity, etc.) as well as direct comparison with the VLBA 2cm survey. Intra-source statistics of acceleration and bending as a function of distance along the jet were also compiled. Third, the correlations between the radio and ROSAT soft X-ray properties of the sources were investigated: radio core-dominance and pc/kpc-scale misalignments versus ROSAT detections. Both inverse-Compton and equipartition Doppler factors were computed to investigate aspects of the beaming.

Separate work on 1803+784 by Silke Britzen, Thomas Krichbaum, Arnold Witzel (all MPIfR), Bob Campbell, and others including Richard Strom (ASTRON) combined VLBI and MERLIN observations to trace structure from the inner 10mas to 2". These were able to follow the morphology of the jet from the oscillatory mainly E-W path at VLBI scales within ~100mas (~0.7kpc) to a distinct 90 degree bend to the south at about 0.5" from the core leading to a southerly component about 2" away. Further Wb observations bridge this southerly ~14kpc component to a much more distant region of emission 45" to the south. Additionally, these people with others including Thomas Beckert (MPIfR) and James Campbell (U. Bonn) used 43 epochs of geodetic X-band observations to follow the evolution of the innermost region of 1803+784. Seven jet components were traced in the inner 3mas region, with a new jet component seen to be emitted about every 2 years. There was a relatively stationary component at 1.4mas from the core, which is also the brightest component. Components interior to this approach it at apparent speeds of 8-11c, and appear to be subsumed by it. A mechanism involving recombination shocks was put forward to explain the behaviour of the components in the inner 1.5mas region.

Hayley Bignall is working in collaboration with Phil Edwards (ATNF) on radio studies of the southern BL Lacertae object PKS 2005-489, which was detected in TeV gamma-rays by the H.E.S.S. group in 2005. PKS 2005-489 was one of a sample monitored with the ATCA and LBA as part of Hayley Bignall's PhD project. New LBA observations were made in May 2006, aiming to verify the subluminal component separation tentatively inferred from earlier VLBI data. Relatively slow component speeds are often seen in TeV-emitting AGN, compared with GeV-emitting (EGRET-detected) AGN, despite the evidence for high Doppler factors required to explain the TeV emission. Possible reasons for this could be jet deceleration between the TeV and VLBI scales, an underlying bulk speed much greater than the observed pattern speed, or different jet opening angles and/or viewing angles leading to slower apparent speeds.

Hayley Bignall is PI on an EVN+MERLIN project to study the BL Lac objects identified in the "Deep X-ray Radio Blazar Survey" (DXRBS) which had not previously been observed at high resolution. The newly identified BL Lacs tend to have properties spanning the range between "classical" X-ray and radio-selected BL Lac samples, and are expected to provide a more complete picture of BL Lacs in the context of unified models for radio-loud AGN. Sixteen target sources were observed over a 48-hour period in June 2005. Hayley Bignall worked with Hermine Landt (CfA), who visited JIVE in March 2006, and Cormac Reynolds on VLA and ATCA data for the entire DXRBS BL Lac sample of 44 objects. Many of the sources show complex extended structure and large misalignment angles of the jets between parsec and kilo-parsec scales.

Andreas Brunthaler analysed VLA and VLBA monitoring of a radio flare in the Seyfert I galaxy III Zw 2, allowing very detailed study of the spectral and spatial evolution of a synchrotron self-absorbed jet. The relative astrometry in the VLBA observations was precise on a level of a few micro-arcseconds. A phase of frustration of the jet was observed, where it showed no spectral or spatial evolution, before it broke free and started to expand with apparent superluminal motion. The results provide a good confirmation of synchrotron theory and equipartition for jets.

Nearby galaxies

In collaboration with Avi Loeb, Mark Reid (CfA) and Heino Falcke (ASTRON), Andreas Brunthaler used recent VLBA measurements of the proper motion of M33, a satellite of the Andromeda galaxy M31, to constrain the proper motion of Andromeda based on the survival of the disk of M33 in tidal interactions with M31 in the past. The unknown transverse velocity of Andromeda has been a major uncertainty in the dynamical history of the Local Group of galaxies (Figure 5.14).

Andreas Brunthaler reduced archival VLA data of the nucleus of the nearby galaxy M81 to search for circular polarization. The source shows strong variability in the circular polarization at all frequencies but the sign stays constant over almost one decade. The polarization properties are strikingly similar to the properties of Sgr A*, the central radio source in the Milky Way, supporting the hypothesis that M81* is a scaled up version of Sgr A*.

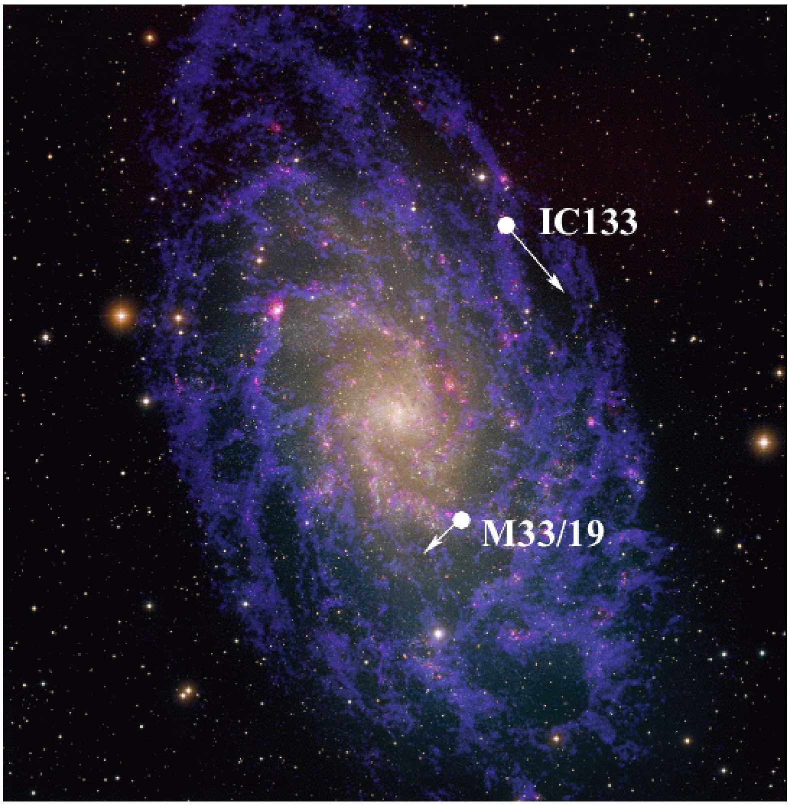


Figure 5.14: position of two regions of maser activity in M33. Also shown are motions due to rotation of the HI disk (shown in blue). The optical image of M33 was provided by Travis Rector (NRAO/AUI/NSF and NOAO/AURA/NSF), and the HI image by David Thilker (NRAO/AUI/NSF) and Robert Braun (ASTRON)

Zsolt Paragi, in collaboration with Mike Garrett and Andy Biggs, detected a radio source in the error box of the ultra-luminous X-ray source M82 X-1 with the EVN (Figure 5.15). The observations were carried out at 1.6 GHz using a data rate of 1 Gbps on 27 October 2005. From the VLBI-scale structure and especially from deep MERLIN observations (by Muxlow et al.), the association of this object to the ULX is unlikely. The non-detection of a radio counterpart indicates that the X-rays are not beamed relativistically in the source. Relativistic beaming was one of the scenarios to explain the highly super-Eddington luminosities in ULXs. Because of the huge luminosity, and the observed

X-ray quasi-periodic oscillations, it is now generally believed that M82 X-1 is powered by an intermediate-mass black hole. We used the recently established formula for the black hole activity plane that relates the X-ray luminosity, radio luminosity and compact object mass, to estimate an upper limit of ~ 500 solar masses to the mass of the black hole in the system. It follows that our data do not support an IMBH with more massive than 1000 solar mass, as inferred from the X-ray observations. It is possible that M82 X-1 may be powered by a less massive intermediate mass black hole, or an X-ray binary accreting at highly super-Eddington rates, like the famous Galactic source SS433.

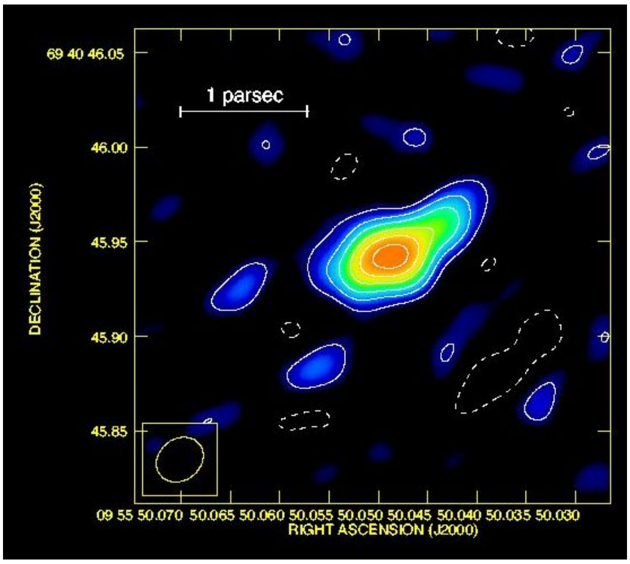


Figure 5.15: A radio source detected by the EVN in the position error box of the ultraluminous X-ray source M82 X-1. The experiment took place on 27 October 2005 at 1.6 GHz, using 1 Gbit/s data rate. From the radio structure and other considerations it follows that the source is not related to the ULX. We derive an upper limit of 67 microJansky to the ULX, from which we estimate an upper limit to its black hole mass of about 500 solar masses. These observations show that M82 X-1 is likely not powered by an intermediate mass black hole (IMBH) of ~1000 solar masses as was believed earlier. A less massive IMBH or a stellar mass XRB with geometrically beamed X-ray emission are the alternatives.

Galactic transients

Since early 2006, the e-EVN has carried out regular science observations with the array of Cambridge, Jodrell Bank (MkII), Medicina, Onsala, Torun and Westerbork (phased array) telescopes. Bob Campbell, Mike Garrett, Zsolt Paragi, Cormac Reynolds and Arpad Szomoru from JIVE took part in some of these science experiments. Observations of GRS1915+105 (led by Anthony Rushton, JBO) and Cyg X-3 (led by Valeriu Tudose, Univ. Amsterdam) were the first attempts to image microquasars in outburst with the e-VLBI technique. Unfortunately, both sources had faded significantly by the observations on 20-21 April 2006. Cyg X-3 soon produced another great outburst which was observed with the e-EVN on 18 May 2006. The VLBI image shows the expanding ejecta on 10 milliarcsecond scales. The extended structure showed significant linear polarization, indicative of relativistic shocks (see figure 5.16). All the above mentioned experiments were carried out at 128 Mbps. These were the first e-VLBI results that were published in refereed journal papers (Rushton et al. 2007, Tudose et al. 2007).

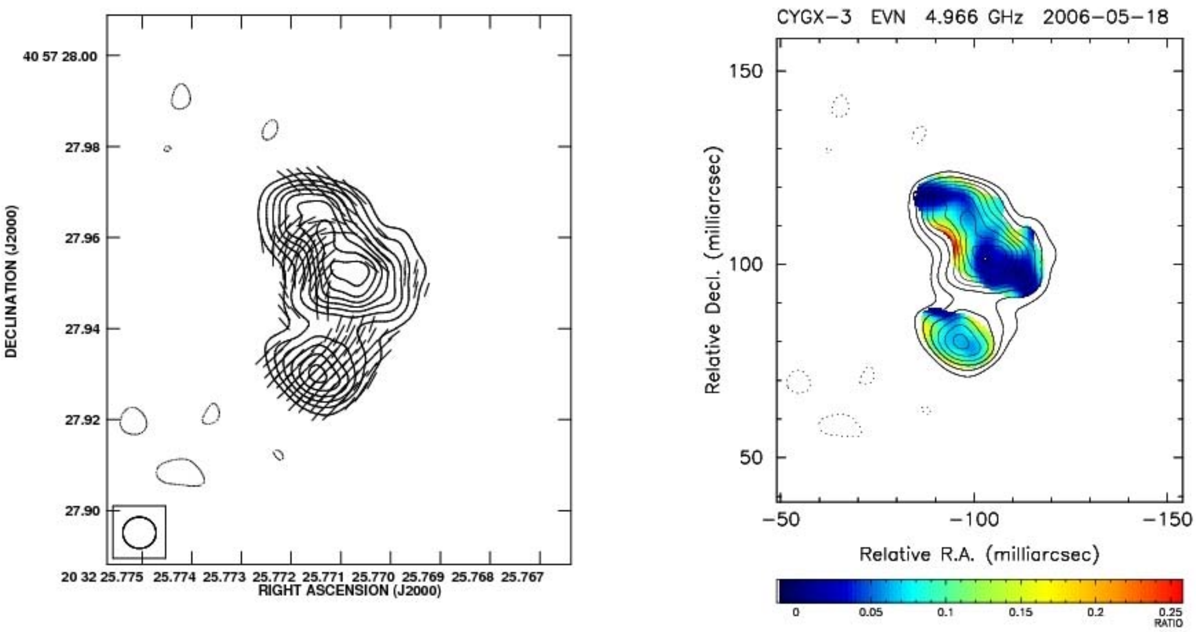


Figure 5.16: e-EVN linear polarization (left) and fractional polarization (right) maps of Cyg X-3 during outburst on 18 May 2006. The e-VLBI observations took place with Cm, Jb2, Mc, On, Tr and Wb14 at 128 Mbps. From these data we were able to produce the first ever VLBI-scale polarization map of a microquasar, which proved the existence of relativistic shocks in the ejecta.

On 27 December 2004, a giant flare was detected from the magnetar SGR 1806-20, only the third such event recorded. This burst of energy was detected by a variety of instruments and even caused an ionospheric disturbance in the Earth's upper atmosphere that was recorded around the globe. Mike Garrett and Zsolt Paragi were part of a team of astronomers (led by Chryssa Kouveliotou, NASA/GSFC) that detected and followed up the fading radio afterglow produced by this outburst, using a variety of radio telescopes, including the VLA, ATCA, MERLIN and the VLBA+GBT. Garrett led the VLBA campaign, proposing 3 epochs of rapid response science observations of the source, scheduling them on the 3, 5 and 10 January, Zsolt Paragi and Valeriu Tudose (Amsterdam) processed the data.

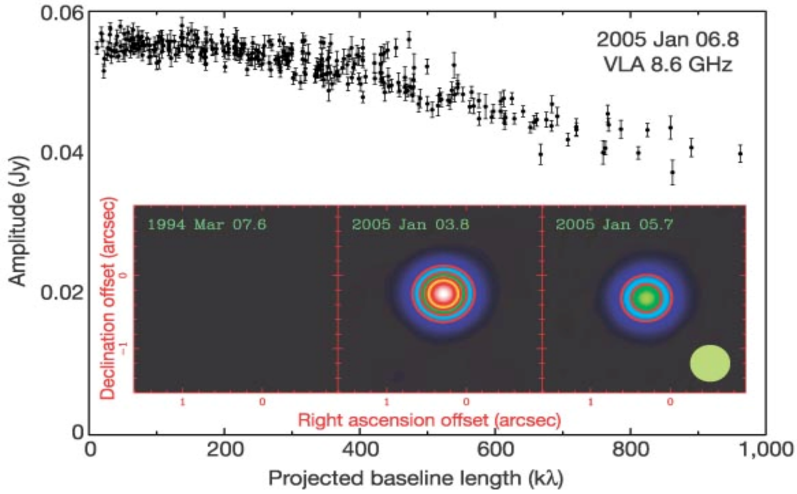


Figure 5.17: The main panel shows the visibility amplitude of SGR 1806-20 as a function of projected baseline length (in units of thousands of wavelengths; 100 kλ ~3.5 km) at epoch 2005 Jan 06.8 (9.9 days alter the giant flare), as seen by the VLA (Gaensler et al. 2005). The decrease in amplitude as a function of increasing baseline length clearly indicates that the source is resolved. The inset shows images of the source at three epochs (before the giant flare - left, and after the outburst – middle and right), smoothed to a uniform resolution of 0.5" (indicated by the green circle at lower right).

The VLA observations (Gaensler et al. 2005, Taylor et al. 2005 – see figure 5.17) and the MERLIN/VLBI+GBT (Fender, Muxlow, Garrett et al. 2006 – see figure 5.18) show a resolved, linearly polarised radio nebula, expanding at approximately a quarter of the speed of light. To create this nebula, at least 4.10^{43} ergs of energy must have been emitted by the giant flare in the form of magnetic fields and relativistic particles. The radio observations were published in various publications including Nature, the latter receiving significant public attention via various press releases.

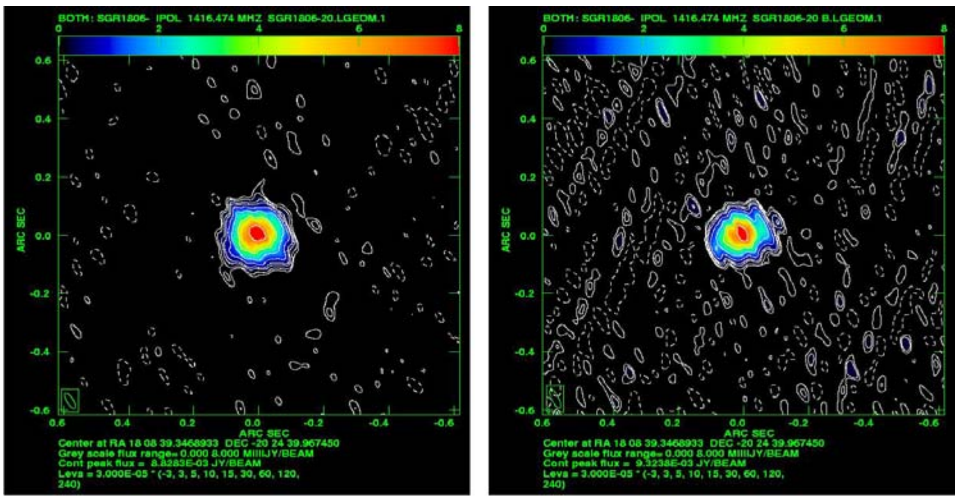


Figure 5.18: VLBA+GBT+VLA 1.4 GHz observations of SGR1806-20 after the giant flare. Structural changes in the radio source are clearly seen between the two epochs (Fender, Muxlow, Garrett et al. 2006).

Young stellar objects

Huib van Langevelde worked with Anna Bartkiewicz and Marian Szymczak (both Torun) on 5cm EVN data, following up methanol maser sources from the Torun blind survey. The data proved to be of excellent quality, allowing high fidelity imaging and astrometry. One of the sources, G23.657-0.127, shows a beautiful ring structure, reminiscent of the circumstellar SiO masers around evolved stars. Such a ring has not been observed in methanol masers before and it offers a unique perspective for the interpretation. There is no clear velocity structure around the ring, which one would expect if this was resulting from a circumstellar disk seen face-on. Instead an interpretation is preferred in which the ring delineates some sort of shock front running into the molecular material around the forming star. Most importantly, in this case there can be no doubt where the central young stellar object is located. After this discovery in 2005, various follow-up observations started in 2006. For example high frequency VLA observations at 22 and 43 GHz were taken in order to detect the central object, but these resulted in marginal detections leaving the status of a central ultra-compact HII region unclear. Together with Andreas Brunthaler (now MPIfR) 12 GHz observations were made to measure the expansion of the ring and initial results were obtained. These will also yield a distance from parallax measurements; the distance to this source can currently only be estimated from Galactic rotation, yielding a physical size of the ring of 1000 to 2000 AU.

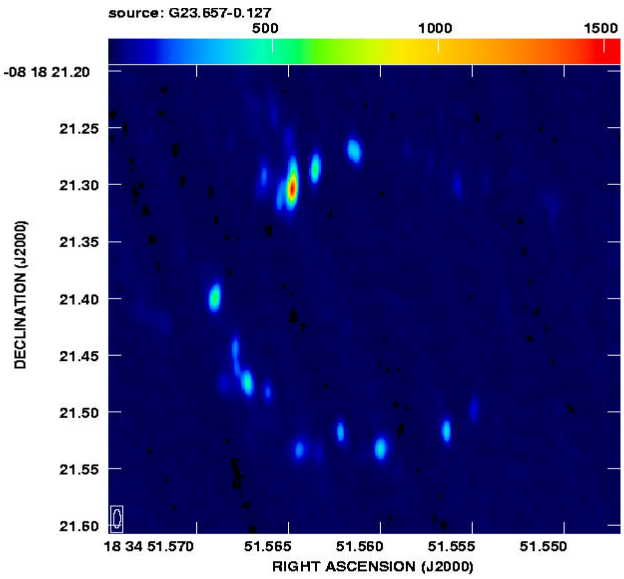


Figure 5.19: Zero moment map of the methanol maser G23.657-0.127.

In 2006, Kalle Torstensson started an ESTRELA PhD project with Huib van Langevelde based in Leiden. This work initially concentrates on a sample of nearby known methanol masers and is based on previous work with Chris Phillips (ATNF). EVN observations were done in wide field imaging and phase referencing mode. Preliminary results were obtained on the famous Cep A young stellar object. The HW2 source (Figure 5.20) is supposed to originate from the ionized outflow from a massive young star. Around this object numerous water masers are known, related to shocks between the outflow from the source and the ambient molecular cloud. The water masers were earlier used in work with Wouter Vlemmings (JBO) to measure the importance of the magnetic field in this same source. In one case it will be possible to make a direct link between the water and methanol masers. Earlier detailed analysis of the kinematics of the water maser sources has revealed that there exists more than a single origin for these shocks; on very small scales around Cep A, a number of high mass stars are forming. However, the 6.7 GHz masers seem to lie in the equatorial region of HW2, at an offset of 300 - 700 AU from the central source, forming a large-scale, single structure.

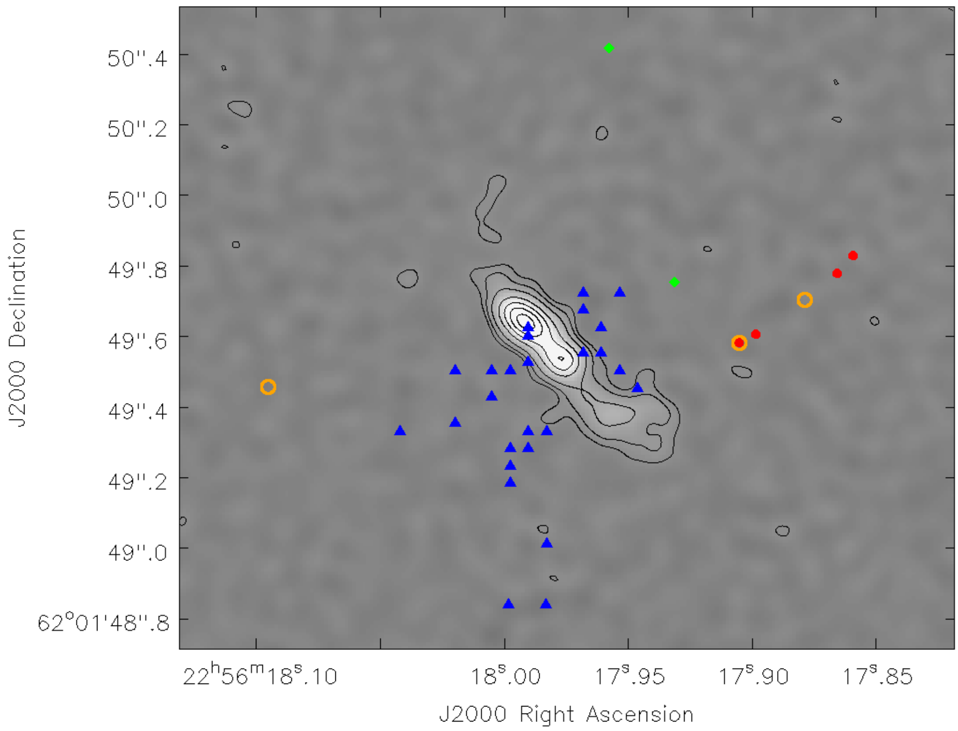


Figure 5.20: The source HW2 in the star forming region Cep A. The grey scales represent the 22 GHz continuum and the blue triangles the locations of H2O masers. The red dots indicate the 6.7 GHz methanol maser positions, the orange circles the 12 GHz methanol masers and the green dots the methanol maser emission at 107 GHz.

This result is the first outcome from an EVN campaign to map out methanol masers in astrometric and wide field imaging mode. To deal with the massive data volumes, we performed calibration in batch mode, exploiting the new capabilities of ParselTongue. Furthermore, a project to find masers over the extended region covered in wide field mode was started in collaboration with Stephen Bourke (Galway). The overall goal of the project is to characterize the radio and (sub)mm signature of the young massive star at the origin of the methanol maser. Characterizing the underlying stars with radio and mm observations is part of the project and ideally this should be performed at the highest possible spatial resolution, for example with the eSMA.

Lisa Harvey-Smith began working at JIVE in October 2005 and in November of that year successfully defended her Ph.D. thesis entitled "Studies of OH and methanol masers in regions of massive star-formation" from the University of Manchester's Jodrell Bank Observatory. In two publications the first linear polarization maps of 6.7-GHz methanol masers and the first detection of a large-scale, extended filaments of masing gas with systematic velocity gradients, which had been predicted for many years, were presented.

Harvey-Smith was the principle investigator in a successful joint EVN+MERLIN follow-up proposal to observe the possible circumstellar disc around the massive star-formation centre in W3(OH). She is also undertaking a project to search for methanol masers in nearby galaxies, a survey of methanol and excited OH masers near ultra-compact HII regions using MERLIN, high spectral-resolution maser mapping in possible maser 'disks' using data from the VLBA, the EVN and MERLIN, a multi-line survey of W49 using the eVLA, and methanol and OH maser polarimetry with MERLIN and the EVN.

Lisa Harvey-Smith together with Rebecca Soria-Ruiz co-supervised JIVE summer student Ana Cabral for a ten-week project in 2006, leading to the discovery of 6.7-GHz methanol masers in W75S and W75 main, detecting linear polarization.

In a large collaboration, Andreas Brunthaler used phase-referencing VLBA observations of water masers near the star-forming region W3(OH) to measure their parallax and absolute proper motions. The measured annual parallax was 0.489 +/- 0.017 mas, where the error is dominated by systematic tropospheric propagation. The corresponding distance of 2.04 +/- 0.07 kpc is consistent with photometric distances from previous observations and with the distance determined from methanol maser astrometry. It was also found that the source driving the H_2O outflow, the "TW-object", moves with a three-dimensional velocity of >7 km s^{-1} relative to the ultracompact HII region W3(OH).

With Tracey Hill (Leiden), who is employed on this project through NOVA funding, Huib van Langevelde did some initial work on millimetre projects to define the physical nature of pre-stellar cores of high mass star formation. With Dave Lommen (Leiden) Huib van Langevelde worked on ATCA data taken at 3mm of a sample of southern T Tauri stars. This resulted in new clues on the dust evolution in these objects. It turned out to be a considerable challenge to find consistency between the calibration of different datasets, but in the end work shifted to writing up the results on dust evolution.

Evolved stars

In collaboration with the VLBI group at the OAN (Spain), Rebeca Soria-Ruiz focused on the study of SiO circumstellar maser emission in long-period variable stars. SiO masers occur in the inner layers of the circumstellar envelopes of late-type stars, providing a unique probe to understand the physics and chemistry of these regions. The spatial distributions of several SiO maser transitions observed with the VLBA challenge current theoretical pumping mechanisms for SiO masers. Spectral line overlap in the pumping scheme was suggested to explain the results obtained.

Rebeca Soria-Ruiz also took part in the monitoring of the HCN emission in a sample of carbon-rich circumstellar envelopes, using the 30 meter Pico de Veleta radiotelescope (IRAM). The newly detected stars will also be observed with the VLBA.

In several projects with Wouter Vlemmings (JBO), Huib van Langevelde continued to work on circumstellar masers. This worked concentrated on the interpretation of high resolution H_2O masers at first. Later a start was made with the processing of new OH maser astrometry. The new measurements include an in-beam calibrator to allow more precise measurements. After it was established that this worked reliably, Huib van Langevelde worked with Daniele Biancu (summer student from Bologna) to implement the complex data-flow in ParselTongue scripts. This demonstrated the power of this interface to implement rather complex data reduction recipes. Progress was made in setting up the batch processing for the large astrometry project.

Solar System

Max Avruch has worked primarily on observation and analysis of the Huygens Probe VLBI Tracking Experiment. In the weeks leading up to impact on January 14^{th} 2005, he coordinated the observational setup of the 17 telescopes which took part. The control files include frequency settings and calibrator sources, required several iterations to achieve the proper setups for each station, due to the unusual conditions of the experiment.

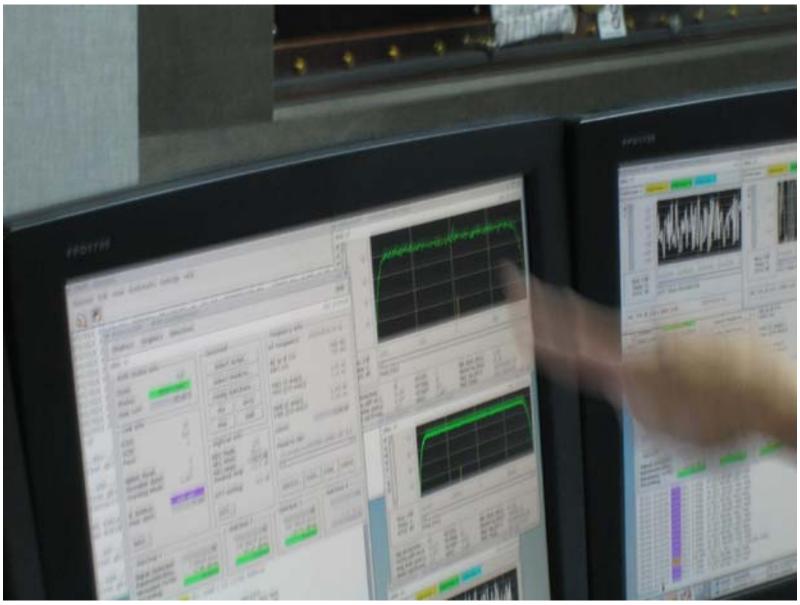


Figure 5.21: First Detection of the Huygens Probe at the Green Bank Telescope, by the JPL Radio Science Receiver.

For the observations, Max Avruch was part of the JIVE/ESA/JPL contingent at the Green Bank Telescope. The Huygens signal was detected by the JPL Radio Science Receiver at about 10:20 UTC, the first proof that the probe had survived entry. The probe was observed by the Parkes telescope to land at approximately 12:45 UTC. The probe's batteries far outlasted expectations, so that at 15:00 UTC when the VLBA was scheduled to end observing, the Mauna Kea telescope was reallocated and kept in the array. As Huygens set below the Parkes horizon at 16:00 UTC, and all telescopes performed a final calibration, Max Avruch quickly prepared an extended schedule for several telescopes in Europe that might possibly continue the observation. Some telescopes made an attempt, but unfortunately none detected the probe.

Max Avruch oversaw the processing of the Huygens experiment at the EVN Mark IV data processor at JIVE. Special handling was required due some unusual features of the observation, and a few bugs in correlator control software were uncovered. The data were processed in February and March, and post-processing with AIPS began in April 2005. He has also been involved in developing the software correlator for the Huygens tracking Experiment.

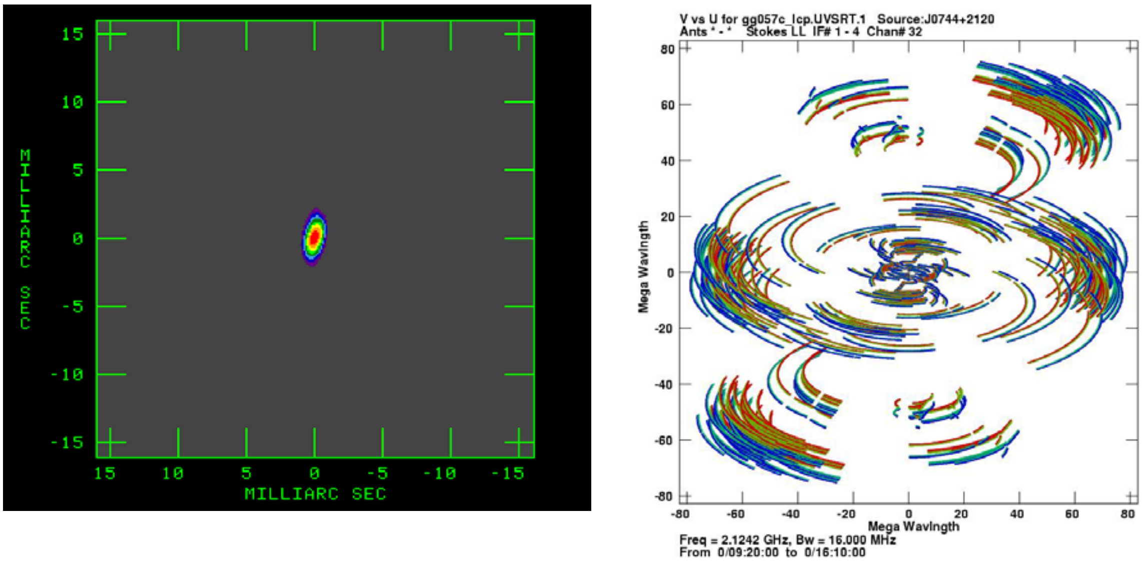


Figure 5.22: Left, Preliminary image of the phase reference source J0744+2120 in the Huygens Tracking experiment, and right (u,v)-coverage by the Huygens VLBI Tracking array on the phase reference source J0744+2120.

Shanmugha Sundaram is involved in Solar research at long radio wavelengths - metric & decametric - and the multi-wavelength complementary study of energetic solar radio events above the photosphere, such as flares, noise storms, coronal mass ejections, coronal holes and solar wind. Data for this research has been procured from a variety of ground- and space-based Solar-observation platforms. Installation and performance-validation of the allied data-reduction software was done concurrently.

Zsolt Paragi was PI of Westerbork observations of Comet 9P/Tempel 1 (with Mike Garrett, Hayley Bignall, Sergei Pogrebenko and others), around the time when the Deep Impact mission probe crashed into the object. The goal was to detect OH molecules that emerged from the comet after the event. Unfortunately, the level of OH emission was below the 3 sigma detection limit of about 15 mJy km^{-1} s^{-1}.

Ionosphere

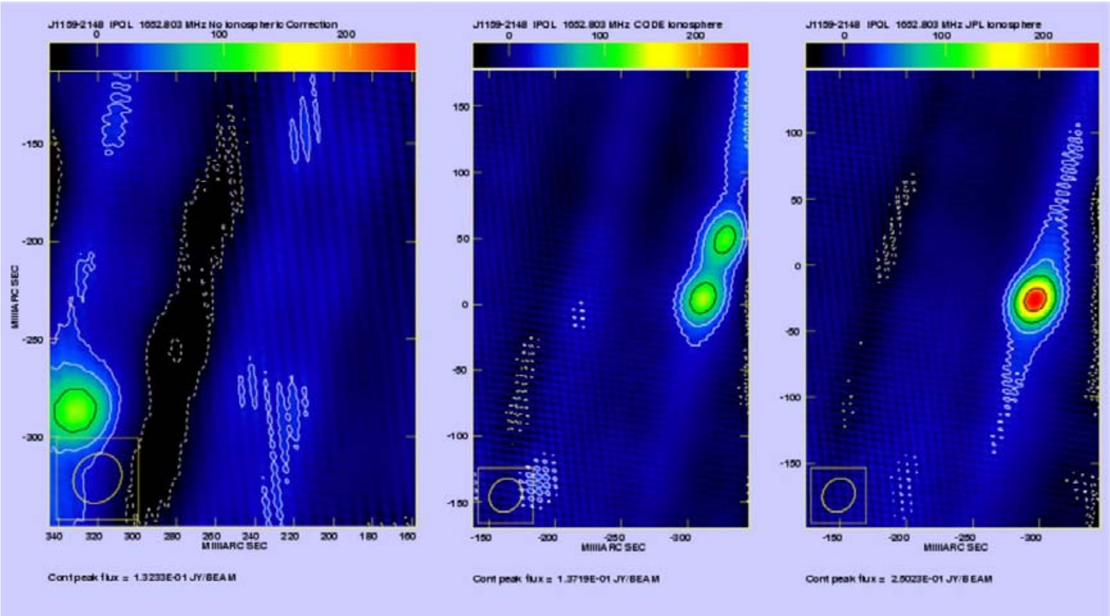


Figure 5.23: preliminary test results for different ionospheric calibration data sources for the EVN. All three images have the same colour flux scale from -0.036 mJy/beam to +0.250 mJy/beam, with contours indicated at factors of 2,4,8,... times 0.012 mJy/beam. The image on the left was produced with no ionospheric corrections applied. The central image was produced using ionospheric corrections from the CODE group. Finally, the right-hand image shows the results using ionospheric calibration data from the JPL group.

Within the ALBUS project, James Anderson researched the modelling of radio signals through the ionosphere. The three images in Figure 5.22 show preliminary test results using different ionospheric calibration methods for the EVN. The source J1159-2148 was observed at 1.6 GHz in phase-referencing mode on 2 June 2005. Progressive modelling of the ionosphere shows improvement, as the deep negatives have been eliminated and the results of fringe-fitting are better, but significant ionospheric distortions remain. These tests suggest that ionospheric corrections can significantly improve EVN observations at low frequencies.

Bob Campbell continued to provide ionospheric simulations to Dan Lebach (CfA) in support of VLBI astrometry related to the Gravity Probe-B guide-star program.

Other

In 2005 and 2006 Huib van Langevelde has been active in establishing the eSMA, in which the CSO and JCMT provide long baselines for the SMA interferometer on Mauna Kea. In 2005 first fringes were obtained to the JCMT with the SMA correlator during a visit by Mark Bentum (ASTRON). In October 2005, Huib van Langevelde participated in tests on Mauna Kea that yielded the first fringes to the CSO. He also led an international team that defined first science targets for the eSMA. During the 2006 JCMT shutdown the focus was on establishing a new receiver for the 345 GHz band on the JMCT. After the shutdown Huib van Langevelde and Kalle Torstensson travelled to Hawaii together with Sandrine Bottinelli (Leiden) in December 2006 to test the phase stability of the interferometer.

Huib van Langevelde is also involved the definition of the Dutch ALMA Regional Centre node.

Lisa Harvey-Smith has been involved in a number of public outreach activities: (i) producing web pages explaining the maser research undertaken at JIVE; (ii) writing a Royal Astronomical Society press release and speaking to the international media through radio, television and newspapers; (iii) writing and broadcasting reports about the activities of JIVE and the IAU for a popular Astronomy internet podcast "The Jodcast"; and (iv) compiling an exhibition on Women in Astronomy for the ASTRON/JIVE Open Day and Girls Day, using personal stories from female astronomers around the world, that aims to raise the public profile of female scientists.

Bob Campbell was involved in setting up the charter of the European VLBI Group for Geodesy and Astrometry (EVGA) on 23 April 2005 in Noto. This is a subgroup of the IVS, and comprises all European IVS associated members and is also open to any scientist affiliated with a European institute involved in geodetic and/or astrometric VLBI. Among other items, the EVGA fosters the use of European VLBI resources for deriving high quality reference frames, and promotes and represents European geodetic and astrometric VLBI within the broader international scientific communities.

6. SPACE SCIENCE PROJECTS

6.1. Huygens VLBI experiment

On 14 January 2005, the European planetary probe Huygens entered the atmosphere of Titan after a seven-year interplanetary trip. JIVE coordinated the radio astronomy segment of the mission, which included VLBI tracking and two independent direct Doppler measurements (the latter conducted by JPL). The effort provided crucial support to the mission and helped to achieve the goal of one of the mission experiments, the Doppler Wind Experiment (DWE). The quality and quantity of the data make it possible to achieve much more than the original scope of the project (e.g. to study the Titan astrometry, flight dynamics of the probe on the parachute descent trajectory).

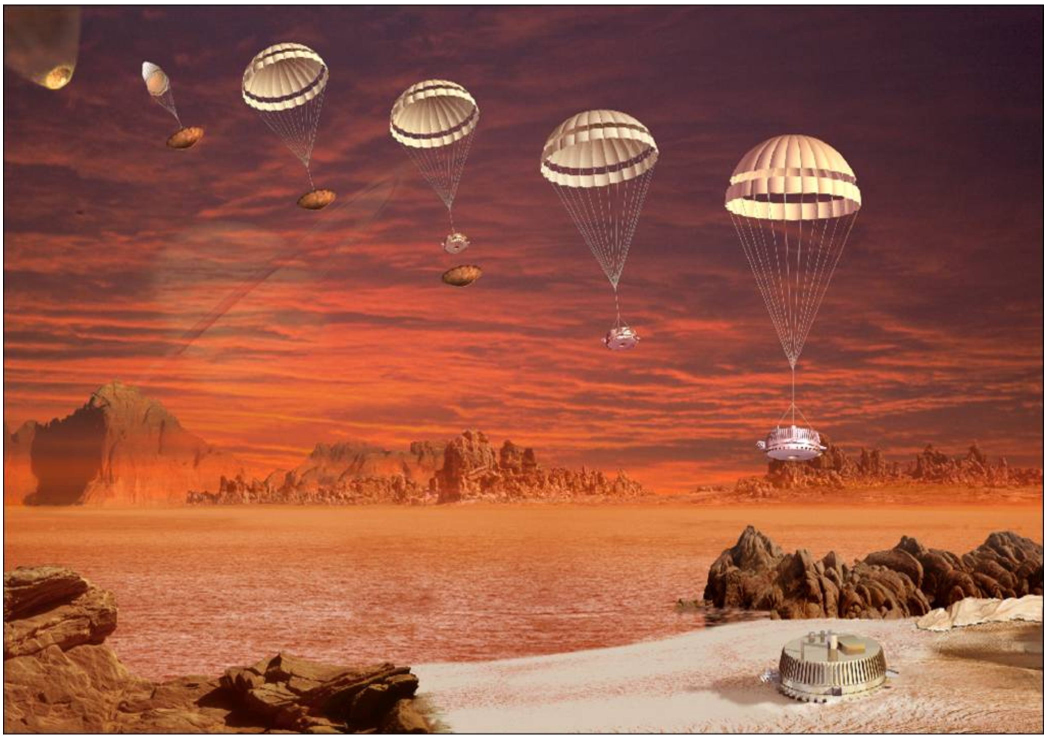


Figure 6.1: Artist's impression on the Huygens descent on Titan (courtesy of ESA)

Seventeen radio telescopes (Figure 6.2) took part in the observations of the Huygens Probe on 14 January 2005. Fifteen of them were capable of receiving the Huygens Channel A carrier signal at the frequency of 2040 MHz, two others were used as "anchors" for phasing-up the network using observations of background reference- sources. Data processing was conducted at JIVE. It involved both the "standard" Mark 4 EVN Data Processor and a special narrow-band Huygens software correlator.

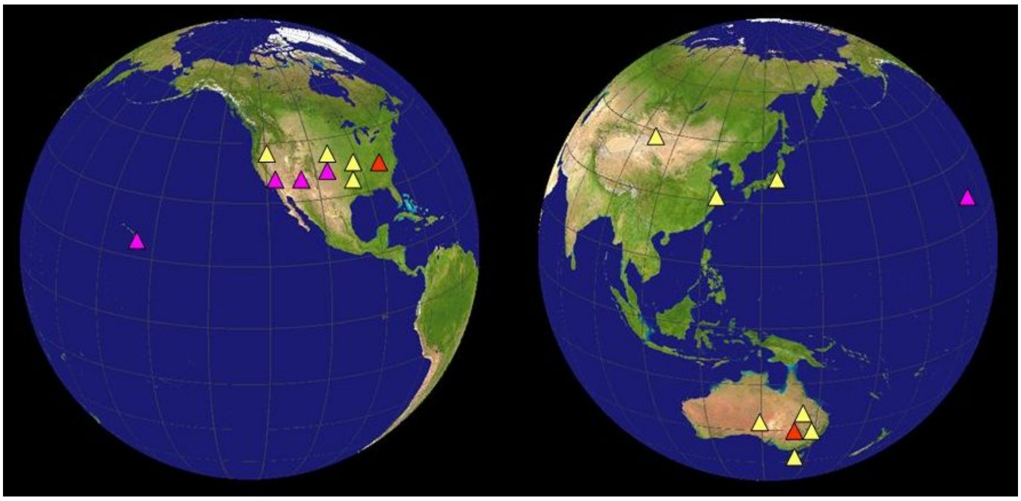


Figure 6.2: Configuration of radio telescopes involved in VLBI tracking of the Huygens Probe as seen from Titan in the beginning of tracking at 09:30 UTC (left panel) and at the end of the experiment at 16:00 UTC (right panel) on 14 January 2005. All seventeen telescopes participate in VLBI observations. Two telescopes shown in red (Green Bank and Parkes) participated in real-time detection of the Huygens Channel A carrier signal at 2040 MHz. The latter two plus four VLBA telescopes shown in purple participated in Doppler measurements.

Results of VLBI data processing indicate that the goal of the experiment – ultra-precise measurements of the Huygens Probe position in the atmosphere and on the surface of Titan – is achieved. The radio interferometric response from the Huygens carrier signal (so called "VLBI fringes") was detected on most of baselines. Radial velocity measurements (Figure 6.3), a by-product of VLBI data processing, will serve as an additional, "bonus" set of data for fine-time analysis of Huygens Probe motion.

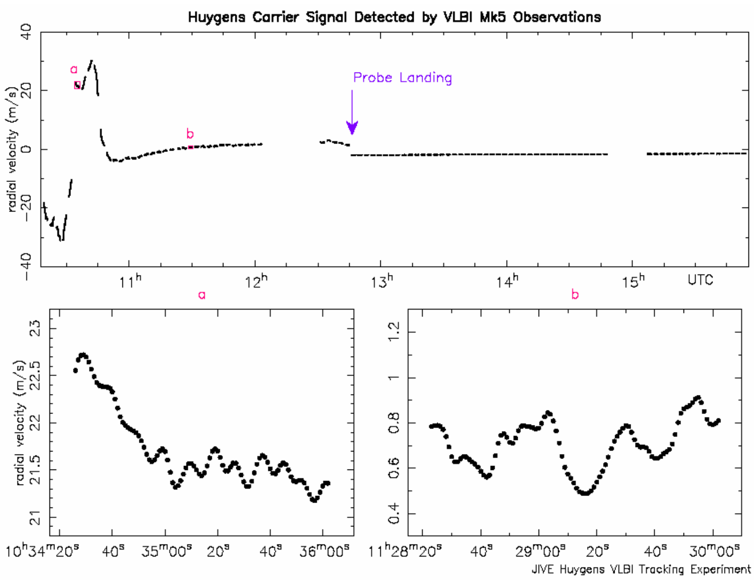


Figure 6.3: Radial velocity of the Huygens Probe obtained from VLBI Mk5 data recorded at the GBT and Parkes radio telescopes (upper panel). Two lower panel plots show high-time resolution "zooms" in the radial velocity data.

The Huygens VLBI tracking experiment shows an example of synergies between experimental techniques developed in fundamental astrophysics based on advanced technologies of radio physics, quantum electronics, digital signal processing, and planetary science, exploration of the Solar System by deep space probes. This synergy is the first step in future novel applications of VLBI for planetary missions of the coming decades.

Spin-off of the Huygens VLBI tracking project includes development of the prototype of a general-purpose high spectral resolution Software Correlator.

JIVE featured in more than 200 major national and international mass media (e.g. Nature, CNN, BBC, AWST, Discover, etc.).

Express-processing of the Huygens data – e-VLBI test with the Australian telescopes. The Huygens VLBI tracking experiment was augmented by "next-morning" processing of two 15-minute scans on a calibrator source obtained during the Huygens observing run at two CSIRO ATNF telescopes, Parkes and Mopra. The data were first recoded on PCEVN disks with the data rate of 512 Mbps that were transported within hours after the observation by a charter plane to the ATNF Headquarters in Epping, NSW, Australia (Figure 6.5).

Figure 6.5: transportation of the PCEVN disks

From there, the data were translated via fibre optic cables over Pacific, across North America and further on over Atlantic to the JIVE data processor in Dwingeloo (Figure 6.7).

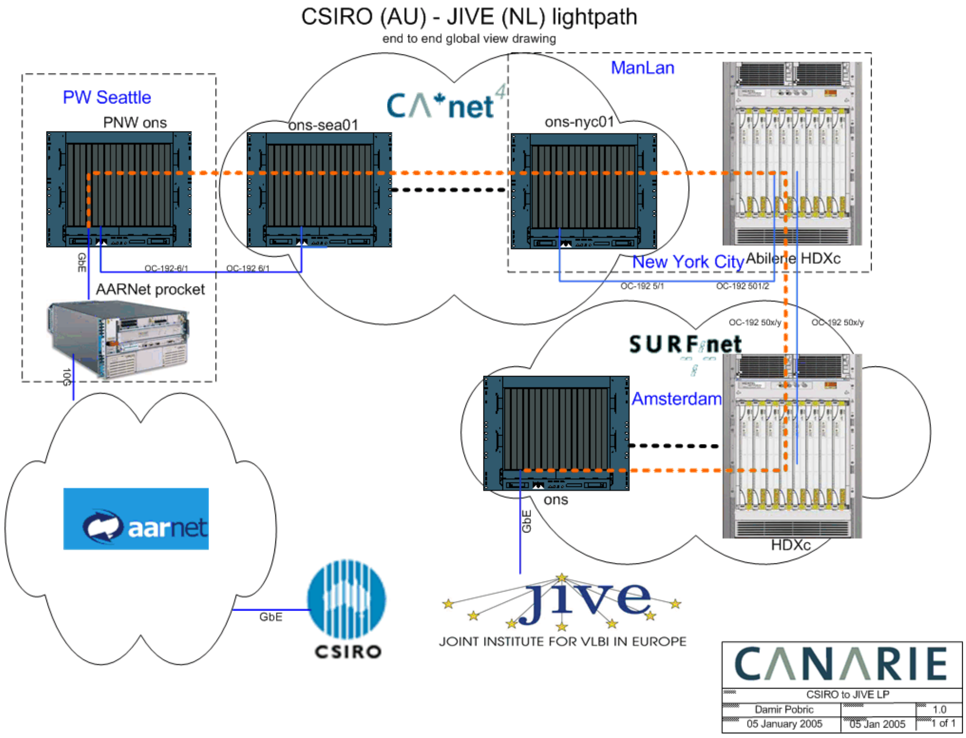


Figure 6.7: Huygens data path

It took several hours to translate about 900 Gbit of data total. At the next step, the data were reformatted remotely by the Metsahovi group at the Helsinki University of Technology from the “native” for ATNF telescopes PCEVN standard to the Mark 5A standard, suitable for correlation at JIVE. Another 1.5 hours were needed to detect the interferometric “fringes” (response) on the baseline Parkes – Mopra. This detection was achieved about 13 hours after completion of the observations of the Huygens Probe at Parkes and Mopra.

Interferometric fringes on the calibrator source obtained in the Huygens e-VLBI demonstration early in the morning of 15 January 2005 (Figure 6.8) coupled with the detection of the Huygens channel A carrier signal at GBT and Parkes using both RSR and VLBI data acquisition during and soon after the mission on 14 January provided a solid proof that the goal of the radio astronomy segment of the Huygens mission would be achieved.

The “next morning” result of the express processing of data from the radio astronomy segment of the Huygens mission was the first application of the e-VLBI technique for spacecraft tracking with the recording data rate of 512.Mbit/s and transmission rate of several hundred Mbit/s.

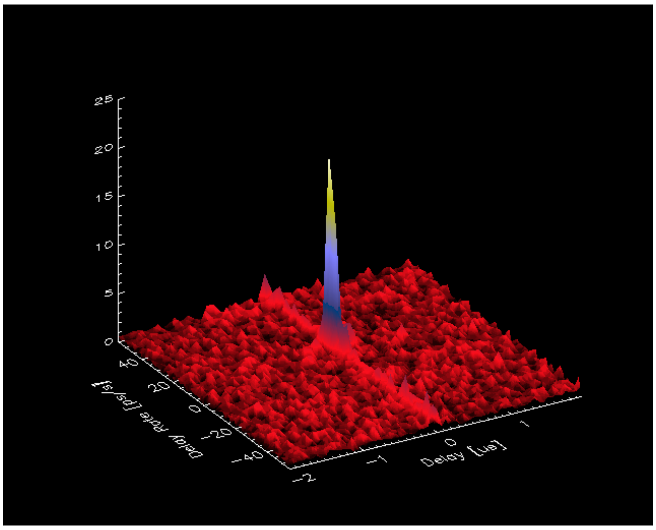


Figure 6.8: Morning fringes

The Huygens e-VLBI demonstration would have been impossible without the efforts of the networking community, who on very short notice provisioned a dedicated light path between Australia and JIVE. George McLaughlin, Steve Maddocks, Mark Prior and Alan Cowie (AARNet), Shaun Amy (CSIRO), Craig Russell (CeNTIE), Hervé Guy and Damir Pobric (Canarie), Bill Mar (Pacific Northwest GigaPoP), Geoff Lakeman (University of Washington), Caroline Carver (MANLAN) and Dennis Paus (SURFnet) provided crucial contribution to the effort. A fraction of the JIVE "home" e-VLBI Huygens team is shown on Figure 6.9.

Figure 6.9: JIVE e-VLBI Huygens team

6.2. Astro-G/VSOP-2

Following approval of the next generation Space VLBI project Astro-G/VSOP-2 by the Japanese Aerospace Exploration Agency (JAXA), the European VLBI community has begun organizing itself for active involvement in this exciting mission. The launch of Astro-G (Figure 6.10) is planned for 2012, leaving not that much time for intensive preparatory activities in Japan and elsewhere.

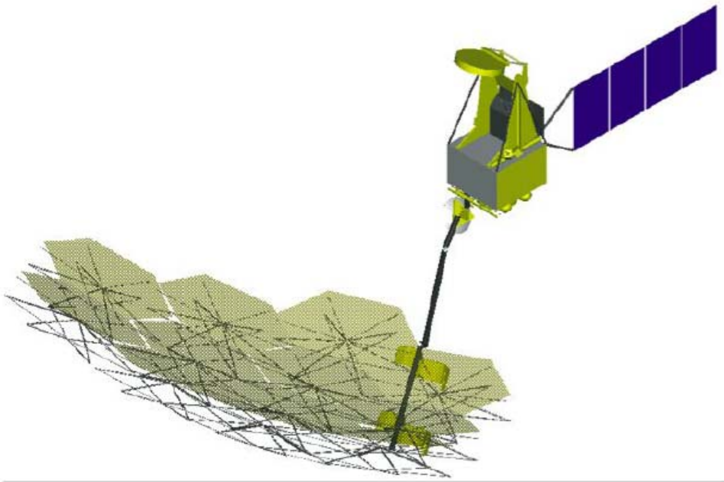


Figure 6.10: The schematic design of the Astro-G/VSOP-2 spacecraft. The effective aperture of the main reflector is 9 m (courtesy JAXA).

The European participation in Astro-G/VSOP-2 is seen as a natural continuation of the extensive involvement of the European radio astronomers in the Japan-led first dedicated Space VLBI mission, VSOP/HALCA. JIVE coordinates the European effort in support to the Astrp-G/VSOP-2. On 15 June 2006, JIVE hosted the European kick-off meeting of the Astro-G/VSOP-2 project. The meeting was attended by Prof. H. Hirabayashi (JAXA/ISAS) and more than 20 participants from a number of European institutes. The main task of the meeting was to work out the plan of actions toward establishing a European segment of the Astro-G/VSOP-2 mission and explore various funding opportunities.

6.3. LIFE

JIVE (Mike Garrett, Leonid Gurvits) participated in the initiative "Towards a European Infrastructure for Lunar Observatories" in collaboration with ASTRON, the EADS Space Transportation and other industrial and scientific organisations. The development resulted establishing the EADS project LIFE (Lunar Infrastructure For Exploration). The second working meeting of the initiative group was conducted at the EADS Space HQ in Bremen on 22-24 March 2005, and an international DGLR Symposium "To Moon and beyond" was held in Bremen 15-16 September 2005. At both meetings JIVE representatives gave presentations. A white paper resulted from this activity is expected to create a basis for much wider international initiative.

6.4. BepiColombo

Leonid Gurvits participated in the preparation of a series of experiments onboard the ESA BepiColombo mission. The mission is expected to be launched in 2013 for studies of Mercury and near-solar environment. The mission as a whole and its specific science packages were approved by the ESA Council at the end of 2005. The experiment with JIVE involvement includes nuclear physics and radio astronomy segments and is being supported by an international group of scientists from Belgium, France, Japan, Italy, the Netherlands, Russia and the USA.

6.5. Smart-1

The European Space Agency's Smart-1 spacecraft completed its almost three year mission on 3 September 2006 with a controlled impact with the surface of the Moon. A network of radio telescopes, led by JIVE recorded the final moments and impact of Smart-1.

The impact occurred when the Moon was below the horizon in Europe. The European telescopes were unfavourably located to observe the impact, but the INAF-IRA Medicina 32-m Radio Telescope paid the tribute to the mission recording the last transmission of Smart-1 over Europe about 11 hours before the impact. Later the radio astronomy monitoring continued at the ROEN (North-eastern Space Radio Observatory, Fortaleza, Brazil), Transportable Integrated Geodetic Observatory (TIGO, Concepcion, Chile), Mt. Pleasant Observatory (Hobart, Australia) and the CSIRO Australia Telescope Compact Array (Narrabri, NSW, Australia). All five radio telescopes operated in VLBI mode, the data were processed at JIVE using software developed and used for tracking of ESA's Huygens Probe during its descent through Titan's atmosphere in January 2005. VLBI observations of Smart-1 resulted in detection of the signal with extremely high spectral resolution and determination of the impact time with the accuracy of 10 us (corresponding to the displacement along the trajectory of only 2 cm, Figure 6.11).

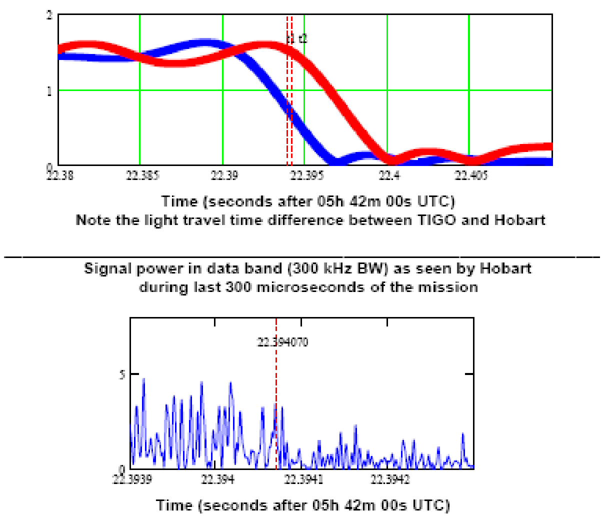


Figure 6.11. Upper panel: the power of Smart-1 radio carrier as detected by TIGO (red line) and Hobart (red line) during the last second of the mission. Bottom panel: narrow-band detection of the signal carrier at Hobart.

The Smart-1 mission was conceived by ESA as a pathfinder of new technologies, in particular, in the area of propulsion and "science reconnaissance". The VLBI experiment described here as the latest addition to the Smart-1 science programme is in full consistency with the sense of innovation. It paves the way for future applications of VLBI technique for prospective planetary probes. These applications will include experiments that require extremely high accuracy of time and coordinate measurements. They will also allow radio astronomers to detect very weak radio manifestations of physical properties of planets and other celestial bodies. These experiments will address such the diverse areas of science as comparative planetology and fundamental physics.

A portion of data from the TIGO telescope in Chile was sent to JIVE as part of the EXPReS project (Express Real-time e-VLBI Service) coordinated by JIVE (see also section 7.1). The observations of Smart-1 validate the use of VLBI for tracking of future lunar and planetary missions such as China's Chang'E-1 Lunar orbiter, scheduled to launch in 2007.

7. EC AND OTHER INTERNATIONAL PROJECTS

7.1. FP6 EXPReS Project

7.1.1. Introduction

JIVE is the coordinating partner for EXPReS, Express Production Real-time e-VLBI Service, an Integrated Infrastructure Initiative (I3) funded under the Sixth Framework Programme (FP6), contract number 026642, as a three year project. As coordinator, JIVE is responsible for distributing EC funds to partners, monitoring project progress and formal reporting to the EC.

EXPReS consists of 19 partner organizations. The partners include both astronomical institutes and national research and education networks (NRENs). Thirteen of the partners are EU members with the remaining located in Africa, Asia, Australia, North and South America.

* Joint Institute for VLBI in Europe (Coordinator), The Netherlands
* AARNet, Australia
* Arecibo Observatory, National Astronomy and Ionosphere Center, Cornell University, USA
* Australia Telescope National Facility, a Division of CSIRO, Australia
* DANTE, UK
* Hartebeesthoek Radio Astronomy Observatory, National Research Foundation, South Africa
* Institute of Radioastronomy, National Institute for Astrophysics (INAF), Italy
* Jodrell Bank Observatory, University of Manchester, UK
* Max Planck Institute for Radio Astronomy (MPIfR), Germany
* Metsähovi Radio Observatory, Helsinki University of Technology (TKK), Finland
* National Center of Geographical Information, National Geographic Institute, Spain
* Netherlands Foundation for Research in Astronomy (ASTRON), The Netherlands
* Onsala Space Observatory, Chalmers University of Technology, Sweden
* Poznan Supercomputing and Networking Center, Poland
* Shanghai Astronomical Observatory, Chinese Academy of Sciences, China
* SURFnet, The Netherlands
* Torun Centre for Astronomy, Nicolaus Copernicus University, Poland
* Transportable Integrated Geodetic Observatory (TIGO), Universidad de Concepción, Chile
* Ventspils International Radio Astronomy Center, Ventspils University College, Latvia

EXPReS is organized into three activities (network, service and joint research) split into seven sub-activities. Of the seven, four sub-activities are led by JIVE personnel:

Activity	Name	JIVE Activity Leader
NA1	Management of I3	T. Charles Yun
NA2	EVN-NREN Forum	
NA3	e-VLBI Science Forum	
NA4	Outreach and Dissemination	Kristine Yun
SA1	Production e-VLBI Service	Arpad Szomoru
SA2	Network Provisioning for a Global e-VLBI Array	
JRA1	FABRIC	Huib Jan van Langevelde

7.1.2. Accomplishments

EXPReS is charged with providing production services to the astronomical community and from the very first month, e-VLBI has been available. The diagram below shows selected highlights from 2006 (note that the project was launched in March 2006). Steady progress is evident over the first year. Milestones for increasing bandwidth and multiple telescopes appear quickly. Stable and operational support for science observations is established and integrated into the regular e-VLBI observation schedule.

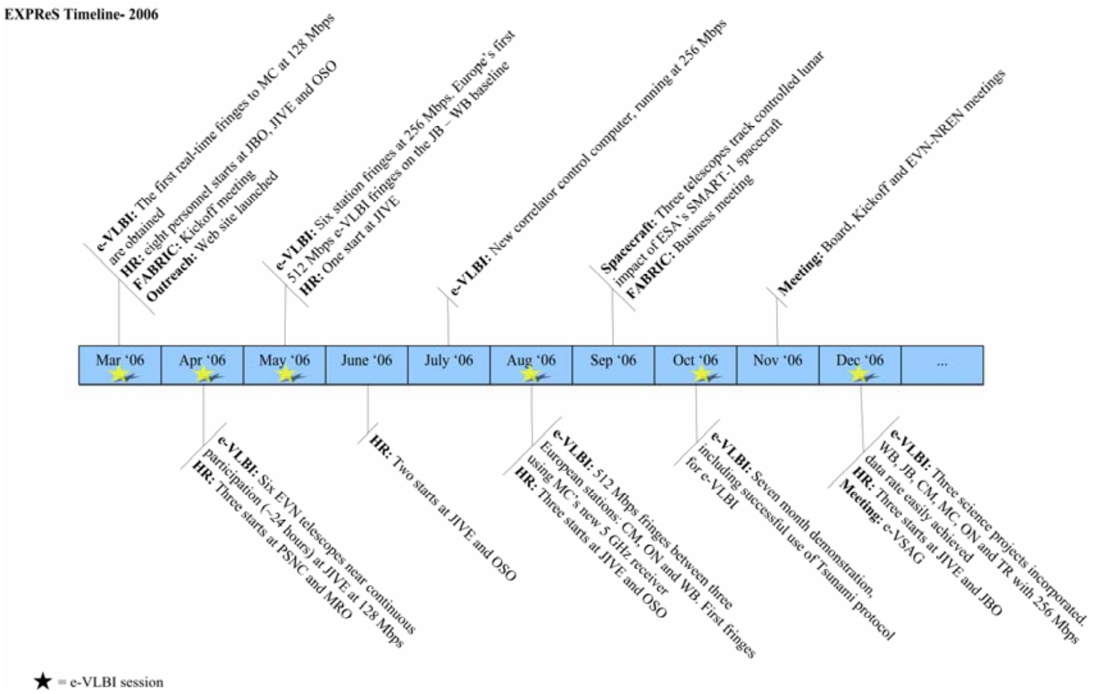


Figure 7.1: EXPReS Timeline (only 2006)

EXPReS is creating a service that is useful to the community and produces results as seen with the participation in the Smart-1 Lunar Landing (September 2006). EXPReS participants tracked the European spacecraft Smart-1's final mission, a controlled impact to the surface of the Moon. Astronomers monitored radio transmissions from Smart-1 using a network of radio telescopes located in South America and Australia. The observation allowed radio astronomers to pinpoint the exact time and location of the impact and investigate radio-physical effects of wave propagation in close vicinity to the lunar surface. The exercise provided EXPReS with valuable lessons that were used to improve the operational e-VLBI service.

In addition to spacecraft tracking, EXPReS is supporting fundamental science. e-VLBI observations have been conducted regularly since the beginning of the project. The preprints of the first two refereed publications to come from EVN e-VLBI operations appeared on the 'astro-ph' preprint server on Nov 2. These publications, Tudose et al. 2006 (http://arxiv.org/abs/astro-ph/0611054) and Rushton, et al., 2006 (http://arxiv.org/abs/astro-ph/0611049), have been accepted for publication in Monthly Notices of the Royal Astronomical Society (UK).

Mon. Not. R. Astron. Soc. 000, 1–4 (2006) Printed 3 November 2006 (MN LaTeX style file v2.2)

arXiv:astro-ph/0611049 v1 2 Nov 2006

First e-VLBI observations of GRS 1915+105

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Accepted 2006 October 25. Received 2006 October 25; in original form 2006 October 6

ABSTRACT

We present results from the first successful open call e-VLBI science run, observing the X-ray binary GRS 1915+105. e-VLBI science allows the rapid production of VLBI radio maps, within hours of an observation rather than weeks, facilitating a decision for follow-up observations. A total of 6 telescopes observing at 5 GHz across the European VLBI Network (EVN) were correlated in real time at the Joint Institute for VLBI in Europe (JIVE). Constant data rates of 128 Mbps were transferred from each telescope, giving 4 TB of raw sampled data over the 12 hours of the whole experiment. Throughout this, GRS 1915+105 was observed for a total of 5.5 hours, producing 2.8 GB of visibilities of correlated data. A weak flare occurred during our observations, and we detected a slightly resolved component of 2.7×1.2 milliarcsecond with a position angle of $140° \pm 2°$. The peak brightness was 10.2 mJy per beam, with a total integrated radio flux of 11.1 mJy.

Key words: ISM: jets and outflows - X-ray binaries: individual (GRS 1915+105).

1 INTRODUCTION

The use of the Internet for electronic very-long-baseline interferometry (e-VLBI) data transfer offers a number of advantages over conventional recorded VLBI, including improved reliability due to real time operation and the possibility of a rapid response to new and transient phenomena. Decisions on follow-up observations can be made immediately after the observation rather than delayed by potentially weeks due to problems in shipment of tapes/discs to the correlator. The first open call with a suitable GST range for observations of GRS 1915+105 using the e-EVN (electronic European VLBI Network)[1] gave us the opportunity to test e-VLBI under operational conditions. A number of recent test runs have shown that 128 Mbps data rates can be obtained reliably to the 6 European telescopes; Cambridge, Jodrell Mk2, Medicina, Onsala, Torun and Westerbork, currently connected via national and international research networks to the EVN correlator at Joint Institute for VLBI in Europe (JIVE). Steps are currently being taken to improve the reliability of 256 and 512 Mbps connections, and also develop 1 Gbps transmission as part of the EXPReS[2] project.

Microquasars are ideally suited for study by e-VLBI since they often have flares associated with the ejection of radio emitting clouds in the form of jets. Time-scales of this emission are in the range of hours to days at cm wavelengths, and decisions about subsequent observations, need to be taken quickly.

The X-ray binary GRS 1915+105 was first discovered in 1992 (Castro-Tirado et al. 1992) by the WATCH instrument on the GRANAT satellite. The system comprises a low mass, K-M III star (Greiner et al. 2001b) companion and a 14 ± 4 $M_\odot$ black hole (Greiner et al. 2001a). It was the first Galactic source observed to display superluminal motion, and is well known for its rapid variability and strong variable radio flux. It spends the majority of its time in relative radio-quiescence, with low radio and X-ray brightness, and with a characteristic low/hard state X-ray spectrum. In such a state

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[1] http://www.evlbi.org/evlbi
[2] see – http://www.expres-eu.org

Mon. Not. R. Astron. Soc. 000, 1–?? (2006) Printed 2 November 2006 (MN LaTeX style file v2.2)

arXiv:astro-ph/0611054 v1 2 Nov 2006

First e-VLBI observations of Cygnus X-3

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Accepted XXXXXX. Received XXXXXX; in original form XXXXXX

ABSTRACT

We report the results of the first two 5 GHz e-VLBI observations of the X-ray binary Cygnus X-3 using the European VLBI Network. Two successful observing sessions were held, on 2006 April 20, when the system was in a quasi-quiescent state several weeks after a major flare, and on 2006 May 18, a few days after another flare. At the first epoch we detected faint emission probably associated with a fading jet, spatially separated from the X-ray binary. The second epoch in contrast reveals a bright, curved, relativistic jet more than 40 milliarcseconds in extent. In the first, and probably also second epochs, the X-ray binary core is not detected, which may indicate a temporary suppression of jet production as seen in some black hole X-ray binaries in certain X-ray states. Spatially resolved polarisation maps at the second epoch provide evidence of interaction between the ejecta and the surrounding medium. These results clearly demonstrate the importance of rapid analysis of long-baseline observations of transients, such as facilitated by e-VLBI.

Key words: accretion, accretion discs – stars: individual: Cygnus X-3 – ISM: jets and outflows – radiation mechanisms: non-thermal – techniques: interferometric.

1 INTRODUCTION

The X-ray binary Cygnus X-3 was first detected in X-rays by Giacconi et al. (1967). The infrared (e.g. Becklin et al. 1972) and X-ray fluxes (e.g. Parsignault et al. 1972) show a periodicity of 4.8 hours which is interpreted as the orbital period of the system. The nature of the compact object is not known (Schmutz, Geballe & Schild 1996; Mitra 1998). As for the companion star, there is compelling evidence pointing toward a WN Wolf-Rayet star (van Kerkwijk et al. 1996; Fender, Hanson & Pooley 1999; Koch-Miramond et al. 2002).

Giant outbursts and large flares have been observed at radio wavelengths in Cygnus X-3 since 1972 (Gregory et al. 1972). In quiescence the soft X-ray emission is correlated with the radio emission, while the hard X-ray is anti-correlated with the radio; in a flare state, the situation is reversed: the hard X-ray correlates with the radio and the soft X-ray emission is anti-correlated (Watanabe et al. 1994; McCollough et al. 1999; Choudhury et al. 2002).

Radio observations made during such large flares at different resolutions with the Very Large Array (VLA), Multi-Element Radio Linked Interferometer Network (MERLIN), Very Long Baseline Array (VLBA), and European VLBI Network (EVN) (Geldzahler et al. 1983; Spencer et al. 1986; Molnar, Reid & Grindlay 1988; Schalinski et al. 1995, 1998; Mioduszewski et al. 2001; Martí et al. 2001; Miller-Jones et al. 2004) directly show or are consistent with two-sided relativistic jets (with the notable exception of the VLBA observations of a flare in February 1997, when the jet was apparently one-sided; Mioduszewski et al. (2001)).

2 OBSERVATIONS

One of the aims of e-VLBI is to enable mapping with long-baseline networks of radio telescopes in a manner which makes it possible to map transient phenomena, such as microquasars, in near real-time. This will provide the ability to make informed decisions about the optimum observing strategy to employ (frequency of observations, array compo-

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Figure 7.2: Lead page from the first e-VLBI pre-prints, from Rushton et al. (left) and Tudose et al. (right)

Operational support of e-VLBI requires connectivity to participating telescopes and providing assistance to obtain network connectivity is an important aspect of the project. The goal of the project is to have each telescope online and connected to JIVE. Progress is being made connecting telescopes, with dedicated lightpaths to several telescopes already in place. As you can see from the physical diagram below, the location of some telescopes will pose challenges above and beyond the traditional "last mile" problem.

Figure 7.3: Physical diagram indicating locations of participating telescopes.

7.1.3. EXPReS meetings

EXPReS organized meetings for the project as a whole, as well as specific project activities.

2006 March - FABRIC Kick-off
2006 September - FABRIC Business Meeting
2006 November - Board, Kick-off, e-VSAG and EVN-NREN meetings

The First EXPReS Board Meeting was held on 1 November 2006 in Zaandam, the Netherlands. Several important decisions were made at the meeting. First, the Board selected Ari Mujunen as the Board's chair and Tasso Tzioumis as vice-chair. Organizationally, the board chose to draft and accept several amendments to the project's Consortium Agreement. During the meeting, the approach for the project's annual review by the European Commission was discussed and planned. Along with the Board Meeting, the project co-located additional project meetings for the eVSAG and EVN-NREN.

Additional information about EXPReS is available on the project website at http://expres-eu.org/

Figure 7.4: EXPReS Board and Kick-off Meeting, November 2006

7.2. FP6 I3 RadioNet Project

JIVE continued its extensive involvement in the implementation of the EC FP6 I3 Project RadioNet. The contract commenced in January 2004. During the reporting period, the Institute is involved in the following RadioNet tasks:

* Bob Campbell coordinated the RadioNet Trans-National Activity "Access to the EVN";
* Leonid Gurvits was the RadioNet Project Scientist and member of the RadioNet Management and Executive teams and administered the RadioNet TNA and NA travel budget. James Anderson and Mark Kettenis are employed on this project and various people contribute to this project;
* Marjan Tibbe participated in secretarial tasks for the RadioNet Management and Executive teams and administered RadioNet documentation at JIVE including TNA and NA travel and subsistence claims;
* Huib van Langevelde was the leader of the RadioNet Joint Research Activity ALBUS (development of user data reduction software for radio astronomy – see section 3.3 of the present report) and a member of the RadioNet Executive team.
* The Institute also acted as the banker for the RadioNet travel budget.

The JIVE contingent of RadioNet officers was actively involved in the preparation and submission of the First and Second Annual RadioNet reports which were accepted by the European Commission in April 2005 and April 2006, respectively.

Four semi-annual RadioNet Board meetings were held during the reporting period: at the Paris Observatory, 29 March 2005: at MPIfR, 28 December 2005; in Volterra, Italy, 20 April 2006; and in Westerbork, the Netherlands, 28 November 2006. The latter meeting was co-hosted by JIVE and ASTRON. The Board meeting in Paris was augmented by a scientific mini-symposium co-organised by Leonid Gurvits and Nicolas Dubouloz (Paris Observatory). The Board meeting in Volterra was preceded by a special RadioNet FP7 planning meeting, for which JIVE prepared several proposals on the contents of an FP7 I3 proposal.

JIVE hosted the EC Press event on astronomy developments in Europe on 7 July 2005. In preparation for the event, JIVE together with its RadioNet and EVN partners, prepared a set of new PR materials (including a new JIVE booklet, produced in collaboration with Alastair Gunn, JBO) and new JIVE exhibition booth. See more on the event in section 1.

The FP6 RadioNet EVN Trans-National Access (TNA) programme provides funding to EVN telescopes to provide access to eligible projects, and supports travel by investigators from eligible projects to visit JIVE or another EVN institute. An eligible project is one in which the PI and at least 50% of the author list as a whole are associated with institutes in the EU member and associated states, excluding the Netherlands as the host country of JIVE. Table 7.1 summarizes various statistics from the past two years of EVN TNA activity.

	2005	*2006*
Number of experiments supported	19	32
comprising how many individual researchers	61	92
Number of different PhD students in supported groups	6	14
participating in how many supported experiments	10	12
Total number of access hours	253	365
Number of data reduction visits	4*	4
number of data reduction visits made to JIVE	4*	3
Number of publications from previous supported experiments	2	18
of which were in a refereed journal	2	7

*Table 7.1: Annual statistics for various aspects of the EVN TNA program over 2005-2006 (*visits in 2005 and 2006, projects could be earlier)*

The TNA programme also provides travel support for EVN Programme Committee EVN PC) members to attend EVN PC meetings and for the PC chair and the EVN scheduler to attend EVN CBD meetings and User meetings. The total travel support reimbursed in 2005 amounts to 23.179 Euro, and in 2006 to 21.765 Euro.

7.3. EuroPlanet

The EC FP6 Coordination Action EuroPlaNet commenced its activities in January 2005. JIVE is a member of EuroPlaNet The project reflects JIVE's involvement in the ESA/NASA mission Cassini/Huygens (see section 6.1) and other Space Science projects. In particular, JIVE participated in the coordination of the ground-based observations in support to the

Cassini/Huygens and preparatory activities for other ESA planetary missions. In 2006, JIVE coordinated radio astronomy campaign in support to the ESA's first Lunar mission Smart-1 (see section 6.4). In September 2006, JIVE presented results of these experiments at the First European Planetary Science Congress (EPSC-1) in Berlin, organised by EuroPlaNet.

7.4. FP6 SKA Design Study

JIVE is involved in EC FP6 SKA Design Study (SKADS) project. The institute's specific task deals primarily with Design Study 2 (DS2): "Science and Astronomical Data Simulations". Mike Garrett is the overall leader of DS2 which comprises two separate tasks, one of which (DS2-T2: "Astronomical Data Simulations") is led by Cormac Reynolds.

Representatives of the institute (Mike Garrett, Cormac Reynolds and Leonid Gurvits) participated in a number of preparatory meetings for this project and contributed to the Description of Work. The project has officially commenced in the second half of 2005, though work on DS2 did not begin in earnest until the second half of 2006.

In October 2006 Shanmugha Sundaram took up a position at JIVE as post-doctoral researcher on SKA simulations funded by SKADS. His project focuses on developing a software description of an Aperture Array in order to allow simulations of an SKA comprising such elements. Applying this simulator to simulations of the nanoJansky sky provided by SKADS collaborators will enable us to quantify the likely scientific performance of the proposed instrument. Shanmugha Sundaram attended the MeqTrees Workshop held at ASTRON in October 2006, and has since successfully applied this analysis package to simulate some simple aspects of an aperture array. Work continues to develop these early results into a complete aperture array simulator by the end of the SKADS program in 2009.

7.5. ESTRELA

ESTRELA (Early-Stage TRaining site for European Long-wavelength Astronomy) is an early stage training network coordinated by Neal Jackson at Jodrell Bank. In ESTRELA Bonn, Manchester, Bologna and Gothenburg collaborate with ASTRON and JIVE. It provides for a number of PhD students who will work in this network on research topics in radio-astronomy. In 2006 Kalle Torstensson was selected for a position at JIVE. He is based at Leiden University and works closely with Huib van Langevelde on methanol masers.

7.6. ANGLES

Similarly ANGLES (Astrophysics Network for Galaxy LEnsing Studies) is a network for research of gravitational lenses. Its coordinator is Ian Browne in Jodrell [check]. Mike Garrett is supervising Alicia Berciano-Alba who is working at the Kapteyn Institute in Groningen. Olaf Wucknitz has joined JIVE as a postdoc on this program.

7.7. KNAW-CAS

JIVE continued active participation in the collaboration with the radio astronomy groups in China under the KNAW-CAS contract. Leonid Gurvits coordinated this contract together with Richard

Strom (ASTRON). The new phase of the project began in January 2005 with the focus on VLBI support of the Chinese Lunar programme. JIVE is involved in preparation of the experiment, in particular exploiting know-how obtained in the Huygens VLBI tracking project. Two new VLBI radio telescopes are being under construction in China. JIVE is involved in training activities of the personnel of these two VLBI facilities (Figure 7.5).

Figure 7.5: Young visitors to JIVE from Chinese radio astronomy groups, left to right: Jun Yang (ShAO), Tao An (ShAO) and Longfei Hao (YAO), May 2006.

In December 2005, the collaboration with the Chinese radio astronomy community has reached an important milestone: the National Astronomy Observatories of China (NAOC) and JIVE have signed a Memorandum of Agreement (MoA) on participation of the NAOC in the JIVE Foundation for the period 2006 - 2008 (Figure 7.6). The MoA will facilitate further strengthening of the collaboration in VLBI science and technology, in particular, during the preparatory and in-orbit phase of the VLBI-supported first Chinese Lunar mission Chang'E-1.

Figure 7.6: Professor Hong Xiaoyu and Dr. Mike Garrett – handshake after signing the MoA on NAOC membership in the JIVE Foundation, Bonn

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(JIVE staff is marked bold).

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Appendices

Appendix 1

JIVE Board

Prof. P.J. Diamond	-	MERLIN/VLBI National Facility, Jodrell Bank Observatory, UK *Chairman*
Prof. Dr. J.A. Zensus	-	Max-Planck-Institute for Radioastronomy, Bonn, Germany *Vice-Chairman*
Prof. R.S. Booth	-	Onsala Space Observatory, Onsala, Sweden (until 1 Dec. 2005)
Prof. H. Olofsson	-	Onsala Space Observatory, Onsala Sweden (from 1 Dec. 2005)
Prof. H.R. Butcher	-	ASTRON, Dwingeloo, The Netherlands
Prof. Dr. J. Gomez-Gonzalez	-	National Geographical Institute, Madrid, Spain
Dr. F. Mantovani	-	Institute for Radioastronomy, Bologna, Italy
Dr. Xiaoyu Hong	-	Shanghai Astronomical Observatory, China

Appendix 2

JIVE Financial Report for 2005/2006

Balance
(amounts x €1000)

ASSETS	**2005**	**2006**
Fixed Assets		
Computer Equipment	165	120
Furniture	43	43
	208	**163**
Current Assets		
Work in Process	52	185
Receivables:		
Debtors	121	98
EU		518
Other	46	1
Cash at Bank	2193	2371
TOTAL	**2620**	**3336**

LIABILITIES		**2005**	**2006**
Capital			
General Reserve		1622	1879
Other Liabilities			
EXPRES			577
ASTRON		641	523
Creditors		97	68
Other			7
Received in advance:			
	FP6		
	RadioNet	132	15
	ALBUS	93	10
	SKADS		35
	EXPRES		110
	Huygens	35	44
	NWO-Scarie		68
	TOTAL	**2620**	**3336**

JIVE Financial Report for 2005/2006 (cont.)

JIVE - Profit and Loss statement 2006

(amounts x €1000)

Revenues			
Contributions		***2005***	***2006***
INAF	Italy	210	240
MPI	Germany	90	90
PPARC	United Kingdom	240	240
IGN	Spain	140	140
OSO	Sweden	140	140
NAO	China		20
NWO	Netherlands	454	454
ASTRON		400	400
		1674	**1724**
Projects			
FP6 RadioNet	EU	607	635
FP6 Angles	EU	70	
ALBUS	EU	114	83
ICN	EU	113	
EXPRES	EU		388
SKADS	EU		30
PCI	EVN	161	
Mark V	RINANU	21	
Huygens contracts	ESTEC	292	54
Cooperations NL-China	KNAW	38	
Scarie	NWO		13
Europlanet	CNRS		1
Other			
Other		1	
FP6 RadioNet - 2004	EU	234	
Education	NWO	42	25
Interest			
Interest		41	48
	TOTAL	**3408**	**3001**

Expenditures	***2005***	***2006***
Institute		
Salaries	1242	1156
Depreciation	104	99
Other	283	319
ASTRON - Overhead	400	400
	2029	**1974**
Projects		
FP6 RadioNet	243	265
FP6 Angles	70	
ALBUS	96	73
EXPRES		332
SKADS		30
Europlanet		1
Upgrade Projects	4	2
Scarie		13
Optical Fibre Dev.	11	
PCI	132	
Mark V	5	
Mark V - RINANU	19	
ICN	113	
Huygens contracts	147	54
Coop NL-China	35	
	875	**770**
TOTAL	**2904**	**2744**
Result	**504**	**257**

Appendix 3

JIVE Personnel

2005/2006

Dr. M.A. Garrett*	Director
Dr. J.M. Anderson	Postdoctoral Research Assistant
Dr. I.M. Avruch	Data Analysis Scientist
Ms. A. Berciano Alba	Early Stage Researcher
Dr. A. Biggs	Support Scientist (until 1 June 2005)
Dr. H. Bignall	Support Scientist
Mr. E.P. Boven	Network/Linux Specialist (since 1 December 2006)
Dr. A. Brunthaler	Support Scientist (until 1 August 2005)
Mr. J. Buiter	Tape Recorder Engineer
Dr. R.M. Campbell*	Head of Science Support and Operations
Dr. G. Cimo	Support Scientist (since 18 September 2006)
Ms. H.D. van Dijk	Secretary (since 1 January 2006)
Drs. B. Eldering	Sofware Engineer (since 1 May 2006)
Dr. L.I. Gurvits*	Programme Manager, Senior Scientist
Dr. L. Harvey-Smith	Support Scientist (since 1 October 2005)
Dr. Ir. M.M. Kettenis	Software Engineer
Mr. B. Kramer	Software Technician
Dr. N.G.H. Kruithof	Postdoctural Research Fellow (since 1 October 2006)
Dr. H.J. van Langevelde*	Head of Software Development
Mr. M. Leeuwinga	Operator
Mrs. S.K. Mellema	Secretary
Mr. M. Nijk	Operator (until 13 May 2005)
Ir. R.H.J. Oerlemans	Software Engineer (since 1 January 2005)
Dr. F. Olnon	Online Software Engineer
Dr. Z. Paragi	Support Scientist
Eur. Ing. S.M. Parsley*	Head of Technical Operations and R&D (until 1 August 2005)
Dr. Y. Pidopryhora	Software Engineer (since 1 December 2006)
Dr. S.V. Pogrebenko	Senior Development Engineer
Dr. C. Reynolds	Senior Support Scientist
Mr. N. Schonewille	Chief Operator
Ms. R. Soria Ruiz	Support Scientist (since 1 October 2005)
Dr. G.A.S. Sundaram	Postdoc (since 12 October 2006)
Dr. A. Szomoru*	Online Software Engineer (until 31 December 2005) Head Technical Operations and R&D (since 1 January 2006)
Mr. H. Tenkink	Operator
Ms. M. Tibbe	Office Manager (until 1 November 2006)
Mr. K.J.E. Torstensson	PhD Student (since 1 September 2006)
Drs. H. Verkouter	Offline Software Engineer

Dr. O. Wucknitz	Postdoc (since 1 May 2005)
Mr. T. Yun	Program Manager (since 1 August 2006)
Mrs. K.S. Yun	PR/Outreach (since 1 August 2006)

* member of JIVE Management Team

Appendix 4

Visitors to JIVE

2005

G. Aben	SURFnet, NL
W. Alef	Max Planck Institut für Radioastronomie, Bonn, Germany
J. C. Algaba	University of Valencia, Spain
G. Barnes	BBC Horizon, UK
A. Bartkiewicz	Torun Centre for Astronomy, Poland
A. Berciano Alba	Kapteyn Institute, Groningen, NL
D. Biancu	Istituto di Radioastronomia, Bologna, Italy
S. Bourke	University of Galway, Ireland
S. Britzen	Max Planck Institut für Radioastronomie, Bonn, Germany
S. Casey	Jodrell Bank Observatory, UK
S. Chi	Kapteyn Institute, Groningen, NL
B. Cotton	National Radio Astronomy Observatory, Charlottesville, USA
P. Couzin	Alcatel Alenia Space, France
R. Dodson	Observatorio Astronomico Nacional, Spain
R. Dutta-Roy	University of Bonn, Germany
P. Edwards	ISAS/JAXA, Japan
E. Fomalont	National Radio Astronomy Observatory, Charlottesville, USA
S. Garrington	Jodrell Bank Observatory, UK
N. Gizani	University of Lisbon, Portugal
A. Golden	National University of Ireland, Galway
A. Gunn	Jodrell Bank Observatory, UK
P. Hazel	Avonsoll Ltd. UK
M. Henseler	Max Planck Institut für Radioastronomie, Bonn, Germany
X. Hong	Shanghai Astronomical Observatory, China
A. Howard	AARNet, Australia
R. Hughes-Jones	Manchester University, UK
D. Jauncey	Australia Telescope National Facility/CSIRO, Australia
D. Jiang	Shanghai Astronomical Observatory, China
C. Jin	Beijing Astronomical Observatory, China
B. Kazeminjad	Institute of Space Research, Graz, Austria
C. van't Klooster	European Space Agency/ESTEC, NL
M. Kunert	Torun Centre for Astronomy, Poland
J-P. Lebreton	European Space Agency/ESTEC, NL
X. Liu	Urumqi National Obersvatory
M. Makiguchi	Image Science Inc., Japan
G. McLaughlin	AARNet, Australia
R. Mittal	Max Planck Institut für Radioastronomie, Bonn, Germany
U. More	Max Planck Institut für Radioastronomie, Bonn, Germany
P. Olding	BBC Horizon, UK

M. Perez Ayucar	European Space Agency/ESTEC, NL
A. Richards	Jodrell Bank Observatory, UK
H. Rottman	Max Planck Institut für Radioastronomie, Bonn, Germany
A. Roy	Max Planck Institut für Radioastronomie, Bonn, Germany
Y. Sakata	Image Science Inc., Japan
J. Sansa Otim	Kapteyn Institute, Groningen, NL
L. Sjouwerman	National Radio Astronomy Observatory, Socorro, USA
V. Tudose	University of Amsterdam, NL
T. Tzioumis	Australia Telescope National Facility, Australia
W. Vlemmings	Jodrell Bank Observatory, UK
G. Wang	Shanghai Astronomical Observatory, China
N. Watanabe	Image Science Inc., Japan
K. Wiik	Turku University, Finland

2006

T. An	Shanghai Astronomical Observatory, China
T. Antonova	Armagh Observatory, UK
A. Bartkiewicz	Torun Center for Astronomy, Poland
S. Bottinelli	Sterrewacht Leiden, NL
S. Bourke	National University of Ireland, Galway, Ireland
C. de Breuck	European Southern Observatory, Germany
A. Brunthaler	Max Planck Institute for Radio Astronomy, Bonn, Germany
A. Cabral	University of Porto, Portugal
W. Cannon	York University, Canada
S. Casey	Jodrell Bank Observatory, UK
M. Cunningham	University of New South Wales, Australia
A. Deller	Swinburne University of Technology, Australia
R. Dodson	Observatorio Astronomico Nacional, Spain
S. Frey	FOMI Satellite Geodetic Observatory, Budapest, Hungary
K. Gabanyi	Max Planck Institute for Radio Astronomy, Bonn, Germany
A. Gunn	Jodrell Bank Observatory, UK
Y. Hagiwara	National Astronomical Observatory, Japan
T. Hill	Sterrewacht Leiden, NL
X. Hong	Shanghai Astronomical Observatory, China
C. Jin	Beijing Astronomical Observatory, China
Y. Jun	Shanghai Astronomical Observatory, China
A. Kamble	Raman Research Institute, Bangalore, India
P. Kemper	University of Groningen. NL
H.-R. Kloeckner	Oxford University, UK
H. Landt	Harvard-Smithsonian Center for Astrophysics, Cambridge, US
C. Law	Jodrell Bank Observatory, UK
E. Lenc	Swinburne University of Technology, Australia
D. Lommen	Sterrewacht Leiden, NL

S. Longmore	Australia Telescope National Facility, Australia
M. Micholowski	Niels Bohr Institute, Copenhagen, Denmark
M. Okon	Poznan Supercomputing Center, Poland
M. Perez-Torres	Instituto de Astrofisica de Andalucia, Spain
L. Petrov	Goddard Space Flight Center/NVI, Greenbelt, US
C. Phillips	Australian Telescope National Facility, Sydney, Australia
J. Ping	Shanghai Astronomical Observatory, China
A. Rushton	Jodrell Bank Observatory, UK
D. Stoklosa	Poznan Supercomputing Center, Poland
M. Strong	Jodrell Bank Observatory, UK
R. Tilanus	Joint Astronomy Center, Hawaii, US
S. Tingay	Swinburne University of Technology, Australia
K. Torstensson	Onsala Space Observatory, Sweden
G. Tuccari	Institute for Radio Astronomy, Noto, Itlay
V. Tudose	University of Amsterdam, NL
W. Vlemmings	Jodrell Band Observatory, UK
F. Volino	Institute for Radio Astronomy, Bologna, Italy
C. Walker	National Radio Astronomy Observatory, Socorro, US
W. Na	Urumqi Astronomical Observatory, China
R. Weiss	Weiss Computer Systeme, Germering, Germany
T. Willis	National Research Council, Canada
F. Xie	Shanghai Astronomical Observatory, China

Appendix 5

Presentations 2005/2006

James Anderson

"Ionospheric calibration for the EVN", The First RadioNet Software Forum Meeting on Advanced Interferometry Software, Jodrell Bank, UK, 1-3 March 2005

"Radio Emission in Low-Luminosity Active Galactic Nuclei", ASTRON/JIVE Colloquia, 27 May 2005

"Ionospheric calibration for the EVN", The Square Kilometre Array hosted workshop "wide-field imaging techniques for radio synthesis arrays", Dwingeloo, NL, 22-24 June 2005

"Radio Emission in Low-Luminosity Active Galactic nuclei", Bonn-Dwingeloo Meeting, Bonn, 22 September 2005

"Ionospheric Calibration", ParselTongue Workshop, Dwingeloo, 13 October 2005

"Evaluation of Ionospheric Correction Methods for the European VLBI Network", URSI General Assembly, Delhi, India, October 2005

"The Ionosphere after URSI", ASTRON/JIVE lunch talk, Dwingeloo, 23 November 2005

"Variability in the Emission Spectrum of Sgr A*: ADAF Model Predictions", YEARAC 2006, Dalfsen, Netherlands, September 15 2006

"Wide-field VLBI Imaging and Calibration Using ParselTongue", Astronomical Data Analysis Software & Systems XVI, Tucson, United States, 15-17 October 2006

"MIM", Young LOFAR Day, Leiden, Netherlands, 30 October 2006

"Ionospheric Calibration for Long-Baseline, Low-Frequency Interferometry", Bonn, 7 December 2006

Max Avruch

"Status of the Huygens VLBI experiment", 3rd International Planetary Probe Workshop, Anavysoos, Greece, 28 June 2005

Hayley Bignall

"Extragalactic Radio Variability", lecture to summer students, Dwingeloo, 5 July 2005

"The rapid interstellar scintillation of PKS 1257-326", New Techniques and Results in Low Frequency Astronomy, Hobart, Australia, 9 December 2005

"The Scintillating Case of Quasar PKS B1257-326" (poster, awarded 2nd prize), NAC, Ameland, NL, 10-12 May 2006

"What is the scattering screen in front of quasar PKS B1257-326?", Small Ionized and Neutral Structures in the Diffuse Interstellar Medium, Socorro, NM, USA, 23 May 2006

"Observations of Intra-Hour Variable Quasars", International Colloquium on Scattering and Scintillation in Radio Astronomy, Pushchino, Russia, 21 June 2006

"Interstellar Scintillation of Extragalactic Radio Sources", lecture to summer students, Dwingeloo, 4 July 2006

"EVN & MERLIN studies of a new sample of BL Lac objects", 8th EVN Symposium, Torun, Poland, 27 September 2006

"A Tentative Detection of Angular Broadening by the Intergalactic Medium", ASTRON/JIVE Astro-

Lunch, Dwingeloo, 22 November 2006

Andreas Brunthaler

"Und sie bewegt sich doch... die Entfernung und Bewegung von M33", public Talk in Trebur, 15 April 2005
"The Geometric Distance and Proper motion of M33" Colloquium in Potsdam, 19 April 2005
"The Geometric Distance and Proper motion of M33" Colloquium in Amsterdam, 29 April 2005
"The Geometric Distance and Proper motion of M33" Talk at NAC in Blankenberge, 18 April 2005

Bob Campbell

"Climatological Ionospheric Prediction & GPS/ionosonde Constraint", Ionospheric Effects on Radio Imaging/Polarimetry, Dwingeloo, NL 24 February 2005
"Recent Results from the EVN Mk4 Data Processor at JIVE", 17th Working Meeting on European VLBI for Geodesy and Astrometry, Noto, IT 22 April 2005
"Geodetic Applications of VLBI", lecture to summer students, 9 August 2005
Phone-interview with "Natuurwetenschap & Techniek" (Edda Heinsman) about leap seconds that would be added at the end of the year, 26 October 2005
"The EVN MkIV Data Processor at JIVE: Correlator Operations and Capabilities", ESF Review Panel, Dwingeloo, NL, 22 January 2006
"JIVE, the EVN, and the Progess towards e-VLBI", Dwingeloo, NL, 9 February 2006 for the Connect International business meeting hosted by ASTRON]
"Corelator Model Changes: Celesital Pole Offsets & EOP Interpolation", Dwingeloo, NL, 16 February 2006
"Geodetic Applications of VLBI", lecture to summer students, 21 July 2006 "Developments at the EVN MkIV Correlator at JIVE", Torun, PL, 28 September 2006
"The EVN MkIV Data Processor", Dwingeloo, NL, 29 November 2006 (EVN CBD Meeting)

Mike Garrett

"21st Century VLBI" Colloquium, Utrecht, NL, 12 January 2005
"21st Century VLBI", Colloquium, Sterrenwacht Leiden, NL, 13 January 2005
"21st Century VLBI", Colloquium, Kapteyn Institute, Groningen, NL, 31 January 2005
"The EVN + SKA", EADS, Bremen, Germany, 23 March 2005
"Multiple Imaging of intrinsically faint radio sources by the massive cluster A2218", ANGLES workshop, Crete, 7 April 2005
"EXPReS", EC evaluation hearing, Brussels, 17 May 2005
"Deep Field Studies", ASTRON evaluation, Dwingeloo, NL, 7 June 2005
"Wide-field VLBI Imaging", SKA wide-field workshop, Dwingeloo, NL, 23 June 2005
"EXPReS e-VLBI project", Various presentations at EVN and JIVE Board mtg, Hartebeesthoek, South Africa, 23-24 May 2005

Leonid Gurvits

"Huygens Probe as seen by radio astronomers", ESOC, Germany, 12 January 2005
"Huygens VLBI tracking – press briefing", ESOC, Germany, 14 January 2005

“Express results of Huygens radio astronomy segment”, ESOC, Germany, 15 January 2005
“Mid-term status report on Huygens VLBI tracking”, Dwingeloo, 11 February 2005
“Multidisciplinary segment of the MGNS experiment”, MGNS kick-off meeting, Moscow, IKI, 15 February 2005
“First results of Huygens VLBI tracking”, HSWT mtg, Florence, 28 February 2005
“Radio astronomy segment of the Huygens mission”, EuroPlanet NA3 kick-off meeting, Graz, 9 March 2005
“Huygens mission and radio astronomy”, Lunar and Planetary Soc. Conference, Houston, USA, 16 March 2005
“VLBI in Space: exploration context”, EADS, Bremen, 23 March 2005
“Radio astronomy at the edge of the Universe and in the Solar System”, Space Research Institute, Moscow, 14 April 2005
“Progress report on the Huygens VLBI tracking project”, ESTEC, DTWG, 22 April 2005
“VLBI tracking of the Huygens Probe”, EuropLanet kick-off meeting, Vienna, 24 April 2005
“Christiaan Huygens, Huygens the Probe and radio astronomy”, Paris Observatory, 28 April 2005
“Report on RadioNet networking activities”, RadioNet Board, Paris, 29 April 2005
“Aspiring new telescopes”, EVN Board, Hartebeesthoek, 23 May 2005
“Precise VLBI tracking of the Huygens Probe”, Titan Conference, Heraklion, Greece, 1 June 2005
“Measurement of zonal winds on Titan – the Huygens Doppler Wind Experiment”, (poster), Titan Conference, Heraklion, Greece, 1 June 2005
“Radio Astronomy: adventure in the invisible Universe”, Amsterdam, NEMO, 14 June 2005
“Navigation in Space: from Christiaan Huygens to Huygens the Planetary Probe”, Scheepvaartmuseum Amsterdam, public lectures 18 and 19 June 2005
“Radio Astronomy and Huygens the Planetary Probe”, VeA, Ventspils, Latvia, 2 July 2005
“Huygens the Pkanetary Probe under aVLBI Magnifier”, EC Press Conference, Dwingeloo, 7 July 2005
“Radio Astronomy Segment of the Huygesn Mission (the story of “Channel C”)”, ESTEC, Noordwijk, 8 July 2005
“Status of the Huygens VLBI tracking project”, DTWG meeting, Dwingeloo, 12 July 2005
“Huygens VLBI tracking results”, (TWG-HSWT, IC, London, 29 August 2005
“LIFE in the context of space-based radio astronomy”, EADS-DGLR Symposium, Bremen, Germany, 15 September 2005
“BepiColombo and VLBI”, BepiColombo SWG meeting No. 2, ESTEC, Noordwijk, 21 September 2005
“VLBI tracking of the Huygens Probe”, ISAS Sci colloquium, Sagamihara, Japan, 11 October 2005
“BepiColombo MGNS status report”, BepiColombo SWT meeting No. 1, Kyoto, Japan, 14 October 2005
“First results of the Huygens VLBI tracking experiment”, Congress of the International Astronautical Federation, Fukuoka, Japan, 17 October 2005
“VSOP-2: view from Europe”, URSI GA Commission J meeting, Delhi, India, 26 October 2005
“EVN and JIVE status reports”, URSI GA Commission J meeting, Delhi, India, 28 October 2005
“Planetary science news in radio astronomy context”, SKA Science WG meeting, Pune, India, 1 November 2005

"SKADS and Space VLBI", SKADS kick-off meeting, Limelette, Belgium, 17 November 2005
"RadioNet Project Scientist report", RadioNet Board meeting, Bonn, 28 November 2005
"Aspiring new EVN partner telescopes in Latvia, Ukraine and India", EVN CBD meeting, Bonn, 29 November 2005
"RadioNet and radio astronomy news from Europe", National Astronomical Observatories of China, Beijing, 8 December 2005
"VLBI: and advanced tool for studying the Universe", Miyun Astronomical Observatory, Kunming, China, 14 December 2005
"European VLBI news", Shanghai Astronomical Observatory, Shanghai, China, 16 December 2005
"Status report on Huygens VLBI tracking project", ESA-JIVE project review meeting, Dwingeloo, 12 January 2006
"Space horizons as seen from JIVE", ESF Review, JIVE, Dwingeloo, 22 January.2006
"Compact extragalactic sources in the SKA sky: liabilities or assets", Cosmology, Galaxy Formation and Astroparticle Physics on the pathway to SKA, Oxford., UK, 12 April 2006
"QASP Networking Activity in FPO7 RadioNet", RadioNet FP7 planning meeting, Volterra, Italy, 20 April 2006
"Advanced VLBI applications as JRA of FP7 RadioNet", RadioNet FP7 planning meeting, Volterra, Italy, 20 April 2006
"Status of Huygens VLBI data processing", HUYGENS DAW, Noordwijk, The Netherlands, 15 May 2006
"Status of RT-70 in Evpatoria", EVN CBD meeting, Florence, Italy, 18 May 2006
"RadioNet – advanced radio astronomy in Europe", OPTICON FP7 Strategy meeting, Edinburgh, UK, 23 June 2006
"RadioNet: talking to the public", EuroPlaNet Education and Public Outreach meeting, Toulouse, France, 6 March 2006
"RadioNet Project Scientist Report", 5th RadioNet Board meeting, Volterra, Italy, 21 April 2006
"RadioNet Networking Activities", 5th RadioNet Board meeting, Volterra, Italy, 21 April 2006
"SKA(DS) and VSOP-2 through a common simulation prism", SKADS DS2-T1 kick-off meeting, Oxford, UK, 7 June 2006
"Outlook for European role in the VSOP-2 mission", European VSOP-2 kick-off meeting, Dwingeloo, 15 June 2006
"European VSOP-2 Contact Group:, Dwingeloo, 16 June 2006
"VLBI in Space: the next step", Lunch Presentation, Dwingeloo, 16 June 2006
"VLBI tracking of planetary missions as a mission tool and scientific experiment", IPPW-4, Pasadena, CA, USA, 27 June 2006
"Huygens the planetary probe under VLBI magnifier", University of Guanajuato, Mexico, 3 July 2006
"Radio surveys of compact structures in AGN: getting deeper, getting sharper", University of Guanajuato, Mexico, 3 July 2006
"Science and technology of VLBI in Space", University of Guanajuato, Mexico, 4 July 2006
"Square Kilometre Array: the next big step", University of Guanajuato, Mexico, 4 July 2006
"VSOP-2 as seen in Europe", COSPAR General Assembly, Beijing, China, 18 July 2006
"Ultra-precise VLBI tracking of the Huygens Probe in the atmosphere and on the surface of Titan",

COSPAR GA, Beijing, China, 19 July 2006

"Very Long Wavelength Universe: a view from the Moon", 36th COSPAR GA, Beijing, China, 22 July 2006

"Very Long Wavelength Astronomy from the Moon", ILEWG-8, Beijing, China, 25 July 2006

"RadioNet – an outlook of radio astronomy in Europe", XXVI IAU General Assembly, Prague, Czech Republic, 21 August 2006

"Smart-1 update", XXVI IAU GA, Prague, Czech Republic, 23 August 2006

"Radio astronomy view at and from the Moon", XXVI IAU GA, Prague, Czech Republic, 23 August 2006

"Status of VSOP-2 developments in Europe", XXVI IAU GA, Prague, Czech Republic, 24 August 2006

"Earth-based segment for a prospective ESA mission to Europa and Jupiter", DLR, Berlin, Germany, 26 August 2006

"Smart-1 and radio astronomy", Press-briefing at ESOC, Darmstadt, Germany, 2 September 2006

"Express-results on Smart-1 radio astronomy campaign", ESOC, Darmstadt, Germany, 4 September 2006

"Smart-1 VLBI campaign", SKADS meeting, Paris Observatory, Paris, France, 5 September 2006

"VLBI as a tool for planetary science missions", EPSC-1, Berlin, 19 September 2006

"Smart-1 and radio astronomy", EPSC-1, Berlin, Germany, 22 September 2006

"MGNS development status", BepiColombo Science Working Team, ESTEC, The Netherlands, 26 September 2006

"Back to the Moon: news from various quarters", Dwingeloo Friday lunch presentation, Dwingeloo, 6 October 2006

"European VSOP-2 news", JPL, Pasadena, USA, 31 October 2006

"VLBI tracking of the Huygens Probe: status of processing and results", Huygens DAW, Tucson, AZ, USA, 6 November 2006

"VLBI: an advanced tool for studying the Universe", Moscow State University, Moscow, Russia, 16 November 2006

"Radio Universe – by the eyes of a graduate of the School No. 2", Moscow Special Phisics and Mathematics School No. 2, Moscow, Russia, 19 November 2006

"News from ILEWG", LIFE workshop, Bremen, Germany, 23 November 2006

"Smart-1 review", LIFE workshop, Bremen, Germany, 24 November 2006

"LIFE and radio astronomy", LIFE workshop, Bremen, Germany, 24 November 2006

"RadioNet Project Scientist Report", 6th RadioNet Board meeting, Westerbork, The Netherlands, 28 November 2006

"RadioNet Networking Activities", 6th RadioNet Board meeting, Westerbork, The Netherlands, 28 November 2006

"VSOP-2 status and European news", EVN CBD meeting, Westerbork, 29 November 2006

"VLBI and future planetary missions", Astro-lunch, Dwingeloo, 7 December 2006

"Space horizons of VLBI: from Solar System to extragalactic Universe", Leiden University, Leiden, 13 December 2006

Lisa Harvey-Smith

"Methanol maser polarization in W3(OH)". European VLBI Network Symposium. Torun, Poland, 2006.

"Astrophysical masers" ASTRON/JIVE Summer Student Lecture series, Dwingeloo, July 2006.

"Finding the missing methanol masers in W3(OH)" Nederlandse Astronomenconferentie 2006. Ameland, 10th-12th May 2006.

"First methanol maps with the upgraded MERLIN". Invited contribution at the Royal Astronomical Society's National Astronomy Meeting. University of Leicester, April 2006.

Mark Kettenis

Kettenis, Mark; Szomoru, Arpad, Pluggable TCP Congestion Avoidance Modules for eVLBI, MIT Haystack Observatory, Westford, US, 19 September 2006

Mark Kettenis, ParselTongue demo, Astrogrid/RadioNet workshop for radio data providers, Oxford, UK, December 2006

Mark Kettenis, ParselTongue & the EVN Pypeline, presented at the Astrogrid/RadioNet workshop for radio data providers, Oxford UK, December 7 2006

Friso Olnon

"EVN Data Archive at JIVE", RadioNet Software Forum Meeting, Jodrell Bank, UK, 1-3 March 2005

Zsolt Paragi

"Triggering SS433 jets - as seen by the EVN, GMRT and RXTE", Triggering Relativistic Jets, Cozumel, Mexico, 28 March - 1 April 2005

"e-VLBI observations of SN2001em - an off-axis GRB candidate", Stellar End Products, Granada, Spain, 13-15 April 2005

"The first continuum e-VLBI science observations at the EVN", National Astronomical Observatory of Japan, Mitaka, 12 October 2005

"EVN Reliability and Performance", TOG-meeting, JIVE, 24 March 2006

"EVN observations of M82 X-1", astro-lunch presentation, ASTRON/JIVE, 15 March 2006

"Constraining IMBH black hole masses with VLBI", The 8th European VLBI Network Symposium on New Developments in VLBI Science and Technology, 26-29 September 2006, Torun, Poland

"Constraining the black hole mass in M82 X-1 with VLBI", The multicoloured landscape of compact objects and their explosive origins, 11-24 June 2006, Cefalu, Sicily

"Observing ULXs with VLBI", VI Microquasar Workshop: Microquasars and Beyond, 18-22 September 2006, Como, Italy

Steve Parsley

"e-VLBI Progress Review", 3rd EVN-NREN meeting, Schiphol, Amsterdam, 28 January 2005

Sergei Pogrebenko

"First VLBI fun with Smart-1", Astro-lunch, Dwingeloo, 7 June 2006

"Search for 22 GHz water vapour emission from Saturnian system", Cassini PSG meeting, Nantes, France, 21 June 2006

“Demo EVN observations of Smart-1”, Cassini PSG meeting, Nantes, France, 21 June 2006
“Ultra-precise VLBI tracking of future probes to Europa and Jupiter system”, Lindau, Germany, 26 October 2006

Cormac Reynolds
"Amplitude Calibration", TOG meeting, Onsala, Sweden, 30 June 2005
"Developments in SCHED", TOG Meeting, Onsala, Sweden, 30 June 2005
"Calibration Transfer at the EVN Correlator", Software Forum meeting, Jodrell Bank, UK, 1-3 March 2005
"Archives and Pipelines", European Radio Interferometry School, Manchester, UK, 8 September 2005
"Calibration Transfer on the EVN correlator at JIVE", ALBUS meeting, Dwingeloo, 13 October 2005
"SKA Science and Astronomical Data Simulations", SKADS Kick-off meeting, Brussels, Belgium, 16 November 2005
"Overview of Array Simulation Activities", SKADS DS2-T2 kick off meeting, Bonn, Germany, 10 Feb 2006
"Interaction Between Science and Technical Simulations in SKADS", SKADS meeting, Jodrell Bank, UK, 16 March 2006
"Exchange of Expertise", RadioNET Synergy meeting, Bologna, Italy, 11 April 2006
"Overview of Array Simulation Activities", SKADS DS3-T5 meeting, Oxford, UK, 6 June 2006
"Interaction Between Science and Technical Simulations in SKADS", SKADS DS2-T1 meeting, Oxford, UK, 7 June 2006
"DS2-T2 - Astronomical Data Simulations", SKA and SKADS meeting, Paris, France, 4 September 2006
"The EVN Archive", EVN Symposium, Torun, Poland, 29 September 2006
"Polarized Radio Sources", Leiden University, 1 October 2006
"SKADS Data Simulations and Meqtrees", SKADS DS2-T1 meeting, Oxford, UK, 12 December 2006

Rebeca Soria-Riuz
"Circumstellar masers in long-period variable stars", EVN SYposium, Torun
"SiO maser emission in oxygen-rich EGB stars", ALMA Meeting, Madrid

Arpad Szomoru
“Recent e-VLBI developments at JIVE”, EVN-NREN meeting, Schiphol, 28 January 2005
“Recent e-VLBI developments at JIVE”, RadioNet Software Forum meeting, Jodrell Bank, UK, 1-3 March 2005
“e-VLBI status at JIVE”, TOG, Onsala, Sweden, 1 July 2005
“Network issues associated with EXPReS”, 4th e-VLBI workshop, Sydney, Australia, 12-14 July 2005
“Current status and future of European e-VLBI”, 4th e-VLBI workshop, Sydney, Australia, 12-14 July 2005
“EXPReS”, 4th EVN-NREN meeting, Schiphol, 12 October 2005
“e-VLBI Status @ JIVE”, TOG Meeting, Dwingeloo, The Netherlands, 24 March 2006

"VLBI in Transition", SPIE Conference Ground-based and Airborne Telescopes, Orlando, USA , 24-31 May 2006
"New Use of an Old Correlator", Next Generation Correlators for Radio Astronomy and Geodesy, Groningen, The Netherlands, 27-29 June 2006
"Status of e-VLBI @ JIVE", Bits & Bytes Meeting, Jodrell Bank Observatory, Jodrell Bank, United Kingdom, 31 August 2006
"e-VLBI Developments at JIVE", 5th International e-VLBI Workshop 2006, MIT Haystack Observatory, USA, 17-20 September
"Recent e-EVN Developments", 8th EVN Symposium, Torun, Poland, 26-29 September 2006
"VLBI, een telescoop zo groot als de wereld", Open Day, Dwingeloo, the Netherlands, 22 October 2006
"e-EVN developments in 2006", 5th EVN-NREN Meeting, Zaandam, the Netherlands, 31 October 2006
"SA1: overview, first results", EXPReS Kick-off Meeting, Zaandam, the Netherlands, 31 October 2006
"Smart-1: using e-VLBI to track satellites", SURFNet Gigaport Seminar, Utrecht, the Netherlands, 2 November 2006
"Recent e-EVN Developments", Shanghai Observatory, Shanghai, China, 10 November 2006
"EVN and e-VLBI", China Science and Technology Network (CSTNET), Beijing, China,13 November 2006
"e-EVN: practical considerations", e-VLBI Science Advisory Committee Meeting, Westerbork, the Netherlands, 28 November 2006
"e-EVN: practical considerations", EVN Board Meeting, Dwingeloo, the Netherlands, 29 November 2006
"e-EVN: practical considerations", TOG Meeting, Noto, Italy, 4 December 2006
"e-EVN: practical considerations", Bits & Bytes Meeting, Manchester, United Kingdom, 7 December 2006

Kalle Torstensson

NOVA Fall School, Talk: "Methanol masers- Tracers of high-mass star-formation", Dwingeloo, 9 - 13 October 2006

Huib Van Langevelde

"Wide field and high dynamic range imaging" Dutch ALMA-RC meeting, Dwingeloo, 13 January 2005
"Interview on Huygens descent", TV Drenthe, Dwingeloo, 14 January 2005
"Interview on Huygens descent", Radio 1, Dwingeloo, 14 January 2005
"Interview on Huygens descent", RTL TV, EditieNL, Dwingeloo, 18 January 2005
"Interview on Huygens descent", Business News Radio, Dwingeloo, 18 January 2005
"Interview on Huygens descent", NOS Journal, Dwingeloo, 21 January 2005
"VLBI in beweging", NVWS Twente, Enschede, 8 February 2005
"A new era of Methanol maser observations", lunch talk, Dwingeloo, 16 February 2005
"VLBI in beweging", rondleiding gemeente Westerveld, Dwingeloo, 21 February 2005

"ALBUS objectives", Software forum, Jodrell Bank, March 1 2005
"Wide Field imaging", Software Forum Jodrell Bank, March 2 2005
"e-VLBI: a real-time radio telescope as big as Europe (at least)", national URSI day, Eindhoven, 27 April 2005
"ALBUS report", RadioNet board, Paris, 29 April 2005
"What is brewing at the sites of methanol masers", poster at IAU227, Catania, 16-20 May 2005
"Discovery of a ring structure in methanol maser emission from a protostar", poster at IAU227, Catania, 16-20 May 2005
"A biased view on IAU 227", lunch talk Dwingeloo, 31 May 2005
"Distributed Computing at JIVE", astro- informatics meeting, Utrecht, 21 June 2005
"New data reduction tools for the EVN", SKA wide field imaging workshop, Dwingeloo 23 June 2005
"JIVE correlator report", EVN PC, Bonn, 27 June 2005
"What is brewing at the sites of methanol masers", poster at Astronomical Society of Australia Annual meeting, Sydney, 4-7 July 2005
"Masers", Lecture to the summer students, Dwingeloo, 26 July 2005
"Spectral Line Science", Lecture at the European Radio Interferometry School, Manchester, UK, 6 September 2005
"Where Methanol masers spring…", talk at the national ISM/CSM meeting, Leiden, 12 September 2005
"VLBI in beweging", presentation for the Leiden Observatory Alumni (VOS), Dwingeloo, 17 September 2005
"JIVE & ASTRON", presentation for amateur astronomy group Enschede, Dwingeloo, 27 September 2005
"Transforming the way VLBI is done", ADASS XV, El Escorial, Spain, 5 October 2005
"ParselTongue: AIPS Talking Python", discussion session of the ADASS XV, El Escorial, Spain, 5 October 2005
"Why ParselTongue", ParselTongue workshop, Dwingeloo, 13 October 2005
"ParselTongue for calibration", ParselTongue workshop, Dwingeloo, 13 October 2005
"Wide Field Imaging", ParselTongue workshop, Dwingeloo 14 October 2005
"VLBI in beweging", presentation to amateur astronomy group southwest Drenthe, Hoogeveen, 18 November 2005
"VLBI in beweging", presentation to amateur astronomy group north Drenthe, Assen, 16 December 2005
"Scientific Software; data products & user access", ESF review of JIVE, Dwingeloo, 22 January 2006
"Instrumentation & Calibration" IAC'06 2nd lecture, Utrecht, 22 February 2006
"Sensitivity & Polarization" 4th lecture, Utrecht, 15 March 2006
"FABRIC kickoff", FABRIC kickoff meeting, Dwingeloo, 22 March 2006
"Spectroscopy" IAC'06 5th lecture, Utrecht, 29 March 2006
"Proposals for JRA's on algorithm and software development", RadioNet FP7 brainstorm, Volterra, Italy, 20 April 2006
"ALBUS status", RadioNet board meeting, Volterra, Italy, 21 April 2006
"VLBI" IAC'06 7th lecture, Utrecht, 26 April 2006

"SCARIe kickoff", SARA Amsterdam, 10 May 2006
"Astronomy", National Research Initiative on Computing brainstorm, Utrecht, 28 June 2006
"FABRIC, a pilot study of distributed correlation" NGC workshop, Groningen, 29 June 2006
"FABRIC Management report" FABRIC project meeting, Poznan, Poland, 25 September 2006
"Data processing software for Radio Astronomy", EVN Symposium, Torun Poland, 27 September 2006
"ParselTongue Demo" EVN Users meeting, Torun, Poland, 29 September 2006
"Report from the VLTI subpanel", ESO STC, Garching bei München, 24 October 2006
"What is FABRIC?", EXPReS kick off meeting, Zaandam, 31 October 2006
"FABRIC management", EXPReS board meeting, Zaandam, 1 November 2006
"SCARIe FABRIC; a pilot study of distributed correlation", SURF GiGaPort event, Utrecht, 2 November 2006
"ALBUS status report", RadioNet board, Westerbork, 28 November 2006
"FABRIC", EVN board, Dwingeloo, 29 November 2006
"Spectral Line VLBI", Radio Interferometry course, Leiden, 24 November 2006
"JIVE Correlator Tour", visit of C. de Visser, NWO general director, Dwingeloo, 23 November 2006

Olaf Wucknitz

"Can gravity lens gravity?", ANGLES workshop, Crete, Greece, 5 April 2005
"Gravitational lenses", summer students lecture, at JIVE/ASTRON 19 July 2005
"Noise in Clean maps",Bonn-Dwingeloo meeting, Bonn, 22 September 2005
"Lensing, data analysis and relativity", ANGLES ESR+ER mtg, Äkäslompolo/Ylläs, Finland, 6-9 February 2005
"Low-frequency VLBI observations of the gravitational lens 0218+357", Nederlandse Astronomen Conferentie, Ameland, NL, 10 May 2005
"How to remove bandwidth-smeared interfering sources", JIVE / ASTRON astro lunch, 22 March 2005
"Gravitational lenses", Lecture for summer students at JIVE/ASTRON, Dwingeloo, 20 June 2005
"Gravitational Lensing", invited review talk at 8th EVN symposium, Torun, Poland, 27 September 2006
"Living Life on the edge", E. Lenc, M. Garrett, O. Wucknitz, J. Anderson, S. Tingay poster at 8th EVN symposium, Torun, Poland, 26-29 September 2006
"How can B0218+357 be isothermal?", poster at conference "Applications Of Gravitational Lensing" at KITP, Santa Barbara, USA, 3-6 October 2006
"Image coherence of gravitational lenses", talk at ANGLES workshop 2006 at DARK, Copenhagen, Denmark, 14 November 2006
"Phases referencing and faint radio sources", Gravitational lenses two lectures for MSc course Radio Astronomy, Leiden, 6 December 2006
"Nutzung der neuen Generation von Radioteleskopen für die Gravitationslinsenforschung", presentation for the DFG (German Science Foundation) to support a funding proposal, Frankfurt/Main, Germany, 17 November 2006

Charles Yun

"Production services over network",5th International e-VLBI Workshop, Haystack, September 2006
"EXPReS, project management introduction", FABRIC Working Meeting, PSNC, September 2006
" Introduction to EXPReS", SURFnet GigaPort seminar for astronomers, 2 November 2006
" Introduction to EXPReS", EXPReS Board Meeting, 21 November 2006
"Beyond production e-VLBI services", IST 2007, Helsinki, November 2006

Appendix 6

Membership of international Boards and committees 2005/2006

Mr. J. Buiter

1992-	EVN Technical and Operations Group

Dr. R.M. Campbell

2003-	EVN Technical and Operations Group
2005-	European VLBI Group for Geodesy and Astrometry (EVGA)
2006-	EVN Programme Committee (EVN PC)
2006-	IAU Div. I working group on 2nd realization of the ICRF

Dr. M.A. Garrett

2003-	IAU Division X Organizing Committee
2003-	SKA International Science Advisory Committee
2003-	EVN Consortium Board of Directors
2004-	RadioNet Board of Directors

Dr. L.I. Gurvits

1993-	Global VLBI Working Group (GVWG)
2003-	IAU Division XI Organizing Committee
2004-	RadioNet Management Team
2004-	ESA-BepiColombo Science Working Group
2004-	ESA-Huygens Science Working Group
2006-	SOC of the International Symposium "Approaching Micro-Arcsecond Resolution with VSOP-2: Astrophysics and Technology", Sagamihara, Japan 3-7 Dec 2006

Dr. L. Harvey-Smith

2006-	ASTRON/JIVE Diversity Committee

Dr. H.J. van Langevelde

1998- 2005	NOVA education committee
1999-2006	EVN Programme Committee (EVNPC)
2004-	RadioNet Executive Committee
2005-	LOFAR DCLA review committee
2006-	ESTRELA project management board
2006-	LOFAR DCLA review committee
2006-	Member ESO STC
2006-	Member Dutch ESO contactraad
2006-	NOVA ISC
2006-	LOFAR calibration review committee

Eur. Ing. S.M. Parsley

1998-	EVN Technical and Operations Group

Dr. Z. Paragi

2002-2006	EVN Technical and Operations Group
2006-	e-VLBI Science Advisory Group

Dr. C. Reynolds

2006-	SKA Simulations Working Group

Dr. A. Szomoru

2006-	e-VLBI Science Advisory Committee
2006-	EVN Technical and Operations Group

Appendix 7

Membership of professional associations and societies 2005/2006

Dr. I.M. Avruch

1993-	Sigma Xi

Dr. H.E. Bignall

1997-	Australian Institute of Physics
1998-	Astronomical Society of Australia
2006-	Nederlandse Astronomen Club

Dr. A. Brunthaler

1995-	Deutsche Physikalische Gesellschaft

Dr. R.M. Campbell

1983-	Sigma Xi
1993-	American Astronomical Society
1996-	American Geophysical Union
2000-	International Astronomical Union
2002-	URSI

Dr. M.A. Garrett

1997-	International Astronomical Union

Dr. L.I. Gurvits

1992-	American Astronomical Society
1994-	Nederlandse Astronomen Club
1997-	International Astronomical Union
1998-	COSPAR Associate
1999-	URSI

Dr. L. Harvey-Smith

2003-	Fellow of the Royal Astronomical Society
2005	Member of the Nederlandse Astronomen Club

Dr. H.J. van Langevelde

1985-	Nederlandse Astronomen Club
1997-	International Astronomical Union
1999-	URSI

Dr. F. Olnon

1972-	Nederlandse Astronomen Club
1987-	International Astronomical Union

Dr. Z. Paragi

2001-	Roland Eotvos Physical Society
2001-	Hungarian Astronautical Society
2006-	Nederlandse Atronomenclub

Eur. Ing. S.M. Parsley

1983-	Institution of Electrical Engineers
1995-	Federation of European Engineering Institutions

Dr. S.V. Pogrebenko

2000-	International Astronomical Union

R. Soria Ruiz

2000	Sociedad Espanola de Astronomia (2000-)
2005	Nederlandse Astronomen Club (2005-)

Dr. A. Szomoru

2003-	URSI
2006-	Nederlandse Astronomen Club

O. Wucknitz

2005-	Nederlandse Astronomenclub

Appendix 8

Meetings attended 2005/2006

1. Scientific conferences attended by JIVE staff members

James Anderson
"Bonn/Dwingeloo Science Day", Bonn, Germany, 22 September 2005
XXVIIIth URSI General Assembly, 23-29 October 2005
YEARAC 2006, Dalfsen, Netherlands, 12-15 September 2006
Astronomical Data Analysis Software & Systems XVI, Tucson, United States, 15-18 September 2006
Young LOFAR Day, Leiden, Netherlands, 30 October 2006

Max Avruch
3rd International Planetary Probe Workshop, Anavyssos, Greece, 26 June – 1 July 2005

Hayley Bignall
The Grote Reber Memorial Conference: "New Techniques and Results in Low Frequency Radio Astronomy", Hobart, Australia, 6-10 December 2005
Nederlandse Astronomen Conferentie, Ameland, NL, 10-12 May 2006
"Small Ionized and Neutral Structures in the Diffuse Interstellar Medium", Socorro, NM, USA, 21-24 May 2006
International Colloquium on "Scattering and Scintillation in Radioastronomy", Pushchino, Russia, 19-23 June 2006
8th EVN Symposium, Torun, Poland, 26-29 September 2006.

Andreas Brunthaler
Nederlandse Astronomen Conferentie, Blankenberge, Belgium, 18 - 20 May 2005

Bob Campbell
6th IVS Analysis Workshop, Noto, Italy, 21-22 April 2005
17th Working Meeting on European VLBI for Geodesy and Astrometry, Noto, Italy, 22-23 April 2005
"Bonn/Dwingeloo Science Day", Bonn, Germany, 22 September 2005
"Ionospheric Effects on Radio Imaging/Polarimetry", Dwingeloo, 24 February 2005
"Next Generation Correlators for Radio Astronomy and Geodesy", Groningen, 27-29 June 2006
"8th EVN Symposium", Torun, PL, 26-29 September 2006

Mike Garrett
FP6 ANGLES workshop, Chersonissos, Crete, Greece, 3-8 April 2005

Leonid Gurvits
36th Lunar and Planetary Society Conference, Houston, TX, USA, 14-19 March 2005

Titan Conference, Heraklion, Crete, Greece, 30 May – 5 June 2005
To Moon and beyond, EADS and DGLR Symposium, Bremen, Germany, 15-16 September 2005
Annual Meeting of the International Academy of Astronautics, Fukuoka, Japan, 16-17 October 2005
URSI General Assembly, New Delhi, India, 23-28 October 2005
SKA Conference, Pune, India, 30 October - 3 November 2005
Cosmology, Galaxy Formation and Astroparticle Physics on the pathway to SKA, Oxford., UK, 10-12 April 2006
4th International Planetary Probe Workshop, Pasadena, CA, USA, 26-30 June 2006
36th COSPAR General Assembly, Beijing, China, 16-23 July 2006
International Lunar Exploration Working Group meeting, Beijing, China, 24-27 July 2006
XXVI IAU General Assembly, Prague, Czech Republic, 14-26 August 2006
First European Planetary Science Congress, Berlin, 18-23 September 2006

Lisa Harvey-Smith
IAU General Assembly, Prague, Czech Republic, 14th-25th August 2006
European VLBI Network Symposium. Torun, Poland, 2006
Nederlandse Astronomenconferentie 2006. Ameland, 10th-12th May 2006.
Royal Astronomical Society's National Astronomy Meeting. University of Leicester, April 2006.

Bauke Kramer
Workshop on VO Standards and Systems for Data Centers and Large Projects, Garching, Germany, 26 June – 1 July 2005

Mark Kettenis
Bonn-Dwingeloo Symposium, Bonn, Germany, 22 September 2005
ADASS XV, San Lorenzo de El Escorial, Spain, 2-5 October 2005
Nederlandse Astronomenconferentie 2006, Ameland, The Netherlands, 10-12 May 2006
Astrogrid science workshop, Oxford UK, 4-5 December 2006

Friso Olnon
Workshop on VO Standards and Systems for Data Centers and Large Projects, Garching, Germany, 26 June – 1 July 2005
Bonn/Dwingeloo Science Day, Bonn, Germany, 22 September 2005
NAC Annual Meeting, Utrecht, NL, 13 January 2006
Nederlandse Astronomenconferentie, Ameland, NL, 10-12 May 2006

Zsolt Paragi
"Triggering Relativistic Jets", Cozumel, Mexico, 28 March - 1 April 2005
"Stellar End Products", Granada, Spain, 13-15 April 2005
"SKA Widefield Imaging Workshop", Dwingeloo, Netherlands, 22-24 June 2005
"Reionizing the Universe", Groningen, Netherlands, 27 June - 1 July 2005
"The Multicoloured Landscape of Compact Objects and their Explosive Origins: Theory vs. Observations", Cefalu, Sicily, Italy, 11-24 (14-22) June 2006

"Next Generation Correlator Workshop", Groningen, the Netherlands, 27-29 Jue 2006
"6th Microquasar Workshop", Como, Italy, 18-22 September 2006
"EVN Symposium", Torun, Poland, 26-29 September 2006

Cormac Reynolds
Bonn-Dwingeloo Symposium, Bonn, Germany, 22 September 2005
"European Radio Interferometry School", Manchester, UK, 5-9 September 2005
EVN Symposium, Torun, Poland, 26-29 September 2006
SKA Calibration and Imaging Workshop, Cape Town, South Africa, 4-8 December 2006

Rebeca Soria Ruiz
Nederlandse Astronomenconferentie 2006, Ameland, NL, 10-12 May 2006
8th EVN Symposium, Torun, Poland, 26-29 September 2006
Science with ALMA: a New Era for Astrophysics, Madrid, Spain, 13-16 November 2006

Arpad Szomoru
Bonn-Dwingeloo Science day, Bonn, Germany, 22 September 2005
8th EVN Symposium, Torun, Poland, 26-29 September 2006

Kalle Torstensson
10th Synthesis Imaging School, Albuquerque, New Mexico, USA, 13-20 June 2006
8th EVN Symposium, Toruń, Poland, 26-29 September 2006
eSMA Commissioning, Mauna Kea, Hawaii, USA, 12-13 December 2006

Huib van Langevelde
National URSI Meeting, Eindhoven, 27 April 2005
IAU 227 "Massive Star Birth: A Crossroads of Astrophysics", Acireale, Catania, 16-20 May 2005
ADASS XV, El Escorial, Spain, 3-5 October 2005
Next Generation Correlator workshop, Groningen, the Netherlands, 27-29 June 2006
The 8th European VLBI Network Symposium on New Developments in VLBI Science and Technology, Torun, Poland, 26 – 29 September 2006
Science with ALMA: a new era for Astrophysics, Madrid Spain, 13-15 November 2006

Harro Verkouter
ADASS XVI, Tucson AZ, USA, 15-18 October 2006
Nederlandse Astronomenconferentie 2006, Ameland, NL, 10-12 May 2006

Olaf Wucknitz
ANGLES workshop, Crete, Greece, 4-7 April 2005
SKA Wide Field Imaging Workshop, Dwingeloo, NL, 22-24 June 2005
ANGLES school, Manchester, UK, 2-3 September 2005
Bonn-Dwingeloo meeting, Bonn, Germany, 22 September 2005
ANGLES ESR+ER meeting, Äkäslompolo/Ylläs, Finland, 6-9 February 2006

Nederlandse Astronomenconferentie 2006, Ameland, NL, 10-12 May 2006
Extended LOFAR workshop, ASTRON, NL, 15-16 May 2006
8th EVN symposium 2006, Torun, Poland, 26-29 September 2006
Conference "Applications Of Gravitational Lensing: Unique Insights Into Galaxy Formation And Evolution" at KITP, Santa Barbara, USA, 3-6 October 2006
ANGLES workshop 2006 at DARK, Copenhagen, Denmark, 13-15 November 2006

Kristine Yun
EXPReS Kickoff Meeting, Zaandam, 31 October 2006
I3 Science and Society Workshop, London, 6 November 2006

2. Technical and business meetings attended by JIVE staff members

James Anderson
First Software Forum meeting, RadioNet, Manchester, UK, 28 February – 3 March 2005
ParselTonge Workshop, Dwingeloo, 13 October 2005
Instrumentation for Measuring Atmospheric Water Vapour, Wettzell, Germany, 9-11 October 2006
ALBUS telecon, 9 October 2006

Max Avruch
Huygens DTWG / JIVE VLBI Tracking Meeting, Dwingeloo, 12-13 June 2005

Hayley Bignall
EVN TOG meeting, Onsala Space Observatory, Sweden, 1 July 2005
TOG meeting, Dwingeloo, NL, 24 March 2006
EVN TOG meeting, Noto, Italy, 4 December 2006

Bob Campbell
“ESF Review Panel”, Dwingeloo, 21-23 January 2006
“EVN PC Meeting”, Yebes, 9-11 March 2006
“EVN TOG Meeting”, Westerbork/Dwingeloo, 23-24 March 2006
“European VSOP-2/Astro-G Kick-off Meeting”, Dwingeloo, 15 June 2006
“EVN PC Meeting”, Dwingeloo, 7 July 2006
“EVN CBD Meeting”, Dwingeloo, 29 November 2006
“EVN TOG Meeting”, Noto, IT, 4 December 2006
“EVN PC Meeting”, Noto, IT, 5 December 2006

Giuseppe Cimo
8th EVN symposium, Torun (Poland).
EVN TOG meeting, Noto (Italy).

Mike Garrett
EC Press Conference at RAL, Oxford, UK, 2-3 March 2005

Lunar exploration mtg, EADS, Bremen, 22-23 March2005
RadioNet meetings/ inauguration Yebes telescope, Madrid, Spain, 25-29 April 2005
EXPReS proposal evaluation, Brussels, Belgium, 16-17 May 2005
EVN and JIVE Board meetings, Hartebeesthoek, 23-25 May 2005
GEANT2 Launch, Luxembourg, 14-15 June 2005

Leonid Gurvits
BepiColombo Sci Working Group, ESTEC, Noordwijk, 24-25 January 2005
BepiColombo MGNS meeting, Space Res Inst, Moscow, 14-17 February 2005
Huygens Science Working Team, Florence, 28 February 2005
EuroPlanet NA3 kick-off mtg, Graz, 9 March 2005
Lunar exploration mtg, EADS, Bremen, 22-23 March 2005
Huygens Data Analysis mtg, ESTEC, Noordwijk, 22 April 2005
Huygens Attitude Determination and Reconstruction mtg, ESTEC, 23 April 2005
EuroPlanet Board meeting, Vienna, 24 April 2005
RadioNet Board meeting, Paris, 28-29 April 2005
VSOP Survey Working Group mtg, Dwingeloo, 9-14 April 2005
EVN and JIVE Board meetings, Hartebeesthoek, 23-25 May 2005
Huygens extended mission meeting, ESTEC, Noordwijk, 7 June 2005
VIRAC Advisory Council meeting, Ventspils, Latvia, 1-3 July 2005
Huygens Data Analysis meeting, Dwingeloo, 12-13 July 2005
Titan Working Group – Huygens Science Working Group meeting, Imperial College, London, UK, 28 August - 1 September 2005
Bonn-Dwingeloo Neighbourhood meeting, Bonn, Germany, 22 September 2005
BepiColombo Science Working Team meeting, Kyoto University, Japan, 14 October 2005
ESA-JIVE project review meeting, Dwingeloo, 12 January 2006
JIVE ESF Review, JIVE, Dwingeloo, 22 January.2006
RadioNet FP7 planning meeting, Volterra, Italy, 20 April 2006
Huygens DAW, Noordwijk, The Netherlands, 15 May 2006
EVN CBD meeting, Florence, Italy, 18 May 2006
OPTICON FP7 Strategy meeting, Edinburgh, UK, 23 June 2006
EuroPlaNet Education and Public Outreach meeting, Toulouse, France, 6 March 2006
5th RadioNet Board meeting, Volterra, Italy, 21 April 2006
SKADS DS2-T1 kick-off meeting, Oxford, UK, 7 June 2006
European VSOP-2 kick-off meeting, Dwingeloo, 15 June 2006
SKADS meeting, Paris Observatory, Paris, France, 5 September 2006
BepiColombo Science Working Team, ESTEC, The Netherlands, 26 September 2006
Huygens DAW, Tucson, AZ, USA, 6 November 2006
LIFE workshop, Bremen, Germany, 23 November 2006
6th RadioNet Board meeting, Westerbork, The Netherlands, 28 November 2006
EVN CBD meeting, Westerbork, 29 November 2006

Mark Kettenis
First Software Forum meeting, RadioNet, Manchester, UK, 28 February – 3 March 2005
ALBUS/Parseltongue meeting, Dwingeloo, The Netherlands, 13-14 October 2005
TOG meeting, Dwingeloo, The Netherlands, 24 March 2006
Next Generation Correlators for Radio Astronomy and Geodesy, Groningen, the Netherlands, 27-29 June 2006
5th International e-VLBI workshop, MIT Haystack Observatory, Westford, US, 17-20 September 2006
GigaPort Next Generation seminar for Astronomers, Utrecht, The Netherlands, 2 November 2006
Astrogrid/RadioNet workshop for radio data providers, Oxford, UK, 5-8 December 2006

Friso Olnon
First Software Forum meeting, RadioNet, Manchester, UK, 28 February – 3 March 2005
ParselTonge Workshop, Dwingeloo, 13 October 2005
ALBUS Progress Meeting, Dwingeloo, 14 October 2005
RadioNet press event, Dwingeloo, NL, 5-7 July 2005
FABRIC kick-off meeting, Dwingeloo, NL, 22 March 2006
TOG meeting, Dwingeloo, NL, 23-24 March 2006

Zsolt Paragi
VSOP Survey Workshop, ISAS, Sagamihara, Japan, 10-14 October 2005
TOG-meeting, JIVE, Dwingeloo, 24 March 2006
EXPReS kick-off meeting, Zandam, 31 October 2006

Steve Parsley
3rd EVN-NREN meeting, Schiphol, Amsterdam, 28 January 2005

Sergei Pogrebenko
EuroPlanet meeting, Vienna, 24 April 2005
Critical Design Review of the IR-led dBBC project, Bologna, Italy, 2-4 May 2005

Cormac Reynolds
RadioNet Synergy meeting, Granada, Spain, 19-22 January 2005
SKADS meeting, Zaandam, 24-25 February 2005
First Software Forum meeting, RadioNet, Manchester, UK, 28 February – 3 March 2005
ARTI meeting, Dublin, Ireland, 11-14 April 2005
Third IVS Technical Operations Workshop, Haystack, USA, 9-12 May 2005
SKADS meeting, Schiphol, 15 June 2005
EVN TOG meeting, Onsala Space Observatory, Sweden, 30 June 2005
Radionet Synergy meeting, Onsala, Sweden, 4-5 July 2005
"European Radio Interferometry School", Manchester, UK, 5-9 September 2005
ALBUS meeting, Dwingeloo, 13-14 October 2005
SKADS Kick-off meeting, Brussels, Belgium, 15-16 November 2005

e-Concertation Workshop, Bordeaux, France, 13-14 December 2005
RadioNet Synergy meeting, Granada, Spain, 19-22 January 2005
SKADS meeting, Zaandam, 24-25 February 2005
First Software Forum meeting, RadioNet, Manchester, UK, 28 February - 3 March 2005
ARTI meeting, Dublin, Ireland, 11-14 April 2005
Third IVS Technical Operations Workshop, Haystack, USA, 9-12 May 2005
SKADS meeting, Schiphol, 15 June 2005
EVN TOG meeting, Onsala Space Observatory, Sweden, 30 June 2005
Radionet Synergy meeting, Onsala, Sweden, 4-5 July 2005
ALBUS meeting, Dwingeloo, 13-14 October 2005
SKADS Kick-off meeting, Brussels, Belgium, 15-16 November 2005
e-Concertation Workshop, Bordeaux, France, 13-14 December 2005
SKADS DS2-T2 kick off meeting, Bonn, Germany, 10 Feb 2006
SKADS meeting, Jodrell Bank, UK, 15-16 March 2006
RadioNET Synergy meeting, Bologna, Italy, 10-11 April 2006
EARNEST meeting, Berlin, Germany, 23-24 May 2006
SKADS DS2-T1 and DS3-T2 meetings, Oxford, UK, 6-7 June 2006
SKA and SKADS meeting, Paris, France, 4-6 September 2006
e-VLBI workshop, Haystack, US, 18-21 September 2006
SKADS simulations and costing meetings, Cambridge, UK 15-16 November 2006
SKADS DS2-T1 meeting, Oxford, UK, 11-12 December 2006

Arpad Szomoru
EVN-NREN meeting, Schiphol, 28 January 2005
RadioNet Software Forum meeting, Jodrell Bank, United Kingdom, 1-3 March 2005
Geant2 Launch, Luxembourg, 14-15 June 2005
EXPReS proposal evaluation, Brussels, Belgium, 16-17 May 2005
TOG, Onsala, 1 July 2005
4th e-VLBI workshop, Sydney, Australia, 12-14 July 2005
4th EVN-NREN meeting, Schiphol, 12 October 2005
FABRIC Kick-off Meeting, Dwingeloo, The Netherlands, 22 March 2006
TOG Meeting, Dwingeloo, The Netherlands, 24 March 2006
SPIE Conference "Ground-based and Airborne Telescopes", Orlando, USA , 24-31 May 2006
Next Generation Correlators for Radio Astronomy and Geodesy, Groningen, The Netherlands, 27-29 June 2006
Bits & Bytes Meeting, Jodrell Bank Observatory, Jodrell Bank, United Kingdom, 31 August 2006
5th International e-VLBI Workshop 2006, MIT Haystack Observatory, USA, 17-20 September
FABRIC Meeting, Poznan, Poland, 25 September 2006
5th EVN-NREN Meeting, Zaandam, the Netherlands, 31 October 2006
EXPReS Kickoff Meeting, Zaandam, the Netherlands, 31 October 2006
SURFNet Gigaport Seminar, Utrecht, the Netherlands, 2 November 2006
Shanghai Observatory, Shanghai, China, 10 November 2006
China Science and Technology Network (CSTNET), Beijing, China,13 November 2006

e-VLBI Science Advisory Committee Meeting, Westerbork, the Netherlands, 28 November 2006
EVN Board Meeting, Dwingeloo, the Netherlands, 29 November 2006
TOG Meeting, Noto, Italy, 4 December 2006
Bits & Bytes Meeting, Manchester, United Kingdom, 7 December 2006

Hans Tenkink
Third IVS Technical Operations Workshop, Haystack, USA, 9-12 May 2005

Marjan Tibbe
RadioNet Board Meeting, Paris, France, 28-30 April 2005
RadioNet Financial Reporting Meeting, Brussels, 4-5 October 2005
RadioNet Financial Workshop, Manchester, UK, 11-12 October 2005
RadioNet Board Meeting, Manchester, UK, 27-29 November 2005

Huib van Langevelde
ALMA RC meeting, ESO Garching, 4 February 2005
RadioNet Software Forum, 1-3 March 2005
ALBUS project meeting, Jodrell Bank, 3 March 2005
LOFAR BlueGene dedication, Groningen, 26 April 2005
RadioNet board meeting, Paris, 28-29 May 2005
SKA software workshop, Dwingeloo, 22-24 June 20058
EVN-PC, Bonn, 27-28 June 2005
RadioNet press event, Dwingeloo/Westerbork, 6-7 July, 2005
European Radio Interferometry School, Manchester, 4-7 September 2005
NOVA ISC, Leiden, 22 September 2005
ParselTongue workshop, Dwingeloo, 13-14 October 2005
RadioNet board meeting, Bonn, 28 November 2005
LOFAR DCLA meeting, Dwingeloo, 23 November 2005
ASTRON, Nationale contactraad, Dwingeloo, 17 January 2006
ESTRELA coordination meeting, Bonn, 6-7 March 2006
NOVA Instrument Steering Committee, Leiden, 16 March 2006
FABRIC kick-off meeting, Dwingeloo, 22 March 2006
ESO Scientific & Technical Committee, Garching, 6-7 April 2006
RadioNet FP7 brainstorm, Volterra, Italy, 20 April 2006
RadioNet board meeting, Volterra, Italy, 21 April 2006
SCARIe kickoff meeting, Amsterdam, 10 May 2006
ESO Scientific & Technical Committee, Garching, 11 May 2006
LOFAR DCLA review, Dwingeloo, 23 May 2006
ESO contactgroep, Amsterdam, 1 June 2006
VSOP2 meeting, Dwingeloo, 15 June 2006
Next Generation Correlator workshop, Groningen, 27-29 June 2006
National Research Initiative on Computing brainstorm, Utrecht, 28 June 2006
NOVA Instrument Steering Committee, Utrecht, the Netherlands 18 September 2006

FABRIC Business meeting, Poznan Poland, 25 September 2006
EVN Users meeting, Torun Poland, 29 September 2006
InterStellar Matter/CircumStellar Matter NOVA meeting, Leiden, 10 October 2006
SIREN meeting on Dutch computing, Utrecht, 12 October 2006
ESO STC Garching, Germany 23- 24 October 2006
EC FP7 kick-off event, Brussels Belgium, 27 October 2006
EXPReS kick-off, Zaandam, the Netherlands, 31 October – 1 November 2006
SURF Astronomy event, Utrecht 2 November 2006
LOFAR calibration review, Groningen, the Netherlands, 6-8 November 2006
RadioNet board, Westerbork, the Netherlands, 28 November 2006
EVN board, Dwingeloo, the Netherlands, 29 November 2006
JIVE Board, Dwingeloo, the Netherlands, 30 November 2006

Harro Verkouter
First Software Forum meeting, RadioNet, Manchester, UK, 28 February – 3 March 2005

Olaf Wucknitz
ALBUS/Parseltongue meeting, JIVE/ASTRON 13-14 October 2005
Presentation for DFG, Frankfurt/Main, Germany, 17 November 2006, Leiden, 6 December 2006

3. Working visits and observing trips by JIVE staff members

James Anderson
NRAO Socorro, United States, 30 Jan - 21 Feb 2006
NRAO Socorro, United States, 16-17 October 2006
NRAO Socorro, United States, 24 Jan - 07 Feb 2006

Max Avruch
Huygens VLBI Tracking Observations, Green Bank, USA, 10-17 January 2005

Andy Biggs
MPIfR, Bonn, Germany, 18-22 April 2005

Hayley Bignall
Jodrell Bank Observatory, UK, 30 August - 3 September 2005

Andreas Brunthaler
Astrophysikalisches Institut Potsdam, 18 - 20 April 2005
Colloquium at Astronomical Institute Anton Pannekoek (speaker), Amsterdam, NL, 29 April 2005

Jan Buiter
Azteco, Zwijndrecht, 10 May 2005

Leonid Gurvits

Huygens mission operations, ESOC, Darmstadt, Germany, 11-15 January 2005
Evpatoria evaluation, Kharkov - Kiev, Ukraine, 2-5 March 2005
VSOP Survey Working Group, JAXA, Sagamihara, Japan, 8-23 October 2005
Beijing, Shanghai and Yunan Astronomical Observatories, China, 8-7 December 2005
University of Guanajuato, Mexico, 2-4 July 2006
DLR, Berlin, Germany, 26 August 2006
Smart-1 operations, ESA ESOC, Darmstadt, Germany, 1-3 September 2006
China, 28 November – 7 December 2006

Mark Kettenis

NRAO, Charlottesville, USA, 31 January – 25 February 2005

Friso Olnon

MPIfRA, Bonn, 2-3 June 2005

Steve Parsley

Avonsoll Ltd., Bristol, UK, 24 April 2005
Metrum Information Storage Ltd., Wells, UK, 25 April 2005
Metrum Information Storage Ltd., Wells, UK, 6 June 2005

Sergei Pogrebenko

Huygens VLBI Tracking Observations, Green Bank, USA, 10-17 January 2005

Cormac Reynolds

Lecture on "Polarization in Radio Astronomy", Leiden University, 1 October 2006

Arpad Szomoru

SURFnet study trip to Nortel and CANARIE, Ottawa, Canada, 26-29 April 2005
EXPReS EC Evaluation hearing, Brussels, Belgium, 17 May 2005
MPIfRA, Bonn, Germany, 2-3 June 2005
STARE meeting, Den Haag, The Netherlands, 21 June 2005

Kalle Torstensson

JCMT observing, Mauna Kea, Hawaii, USA, 15-19 December 2006

Huib van Langevelde

LOC/NOC, Utrecht, 19 January 2005
Leiden, 22 March 2005
Leiden, 7 June 2005
Hawaii, 26 October – 4 November 2005
Utrecht 9 November 2005
JCMT and eSMA visit, Hilo Hawaii 6 – 20 December 2006

Olaf Wucknitz
University of Potsdam, Germany, 22-24 May 2005
University of Potsdam, AIP, Germany, 19-20 April 2006
Bonn University and MPIfR, Bonn, Germany, 26-28 April 2006

Appendix 9

All projects having correlator activity in 2005/2006

Expt name	obs date	PI	type	correlated date	distibuted date	released date	Support Scientist
AAH01	180606	Angelakis	USER	140806	150806	111206	Campbell
D04C2	031204	Conway	TEST	(211204)	(221204)	070105	Bignall
EA033	070605	T.An	USER	(080905)	(111105)	030106	Bignall/Soria-Ruiz
EA035A	051105	Slysh	USER	(191205)	(231205)	040406	Campbell
EA035B	020306	Slysh	USER	150506	170506	030806	Campbell
EA035C	070606	Slysh	USER	160806	180806	111206	Campbell
EB030	030605	Bignall	USER	220905	031005	091205	Bignall
EB031A	220206	Bartkiewicz	USER	070406	210406	210806	Harvey-Smith
EB031B	230206	Bartkiewicz	USER	130406	210406	210806	Soria-Ruiz
EB032A	090606	Brunthaler	USER	211106	281106	181206	Campbell
EC021	051104	Conway	USER	110105	040205	250405	Bignall
EC023A	081104	Conway	USER	200105	140305	250405	Brunthaler
EC023B	091104	Conway	USER	270105	140305	250405	Brunthaler
ED026	180206	Doyle	USER	140406	270406	210806	Bignall
EF012	240206	Fish	USER	140606	170706	021006	Reynolds
EF015	110606	Fish	USER	300806	080906	111206	Bignall
EG029	041104	Goddi	USER	140105	100205	250405	Paragi
EG031	071104	Goedhart	USER	240105	180205	250405	Campbell
EG034	100605	Fender	USER	090805	110805	140905	Paragi
EH010	090305	Hagiwara	USER	060405	210405	130605	Paragi
EI006A	031104	Imai	USER	(151204)	190105	250405	Paragi
EI006B	180205	Imai	USER	250505	020605	220805	Brunthaler
EJ007A	070605	Jiang	USER	290705	021105	151205	Campbell
EJ007B	080605	Jiang	USER	070905	101105	151205	Campbell
EK010B	130200	Kloeckner	USER	(051001)	(070302)	150805	Avruch
EK012	151100	Kloeckner	USER	(090201)	(240402)	021006	van Langevelde
EK020A	050305	Kloeckner	ABAN	200405	200405	200405	Campbell
EK020B	020605	Kloeckner	USER	150705	250805	091205	Bignall
EK020C	080605	Kloeckner	USER	050905	141005	091205	Bignall
EK022A	291005	Kloeckner	USER	100206	160206	280406	Harvey-Smith
EK022B	301005	Kloeckner	USER	(121205)	(151205)	120406	Soria-Ruiz
EK022C	011105	Kloeckner	USER	(091205)	(151205)	120406	Campbell
EL032	061104	vanLangevele	USER	030205	230305	250405	Campbell
EL033A	231005	Lobanov	USER	030106	020206	120406	Harvey-Smith
EL033B	160206	Lobanov	USER	160506	310506	210806	Harvey-Smith

Expt name	obs date	PI	type	correlated date	distibuted date	released date	Support Scientist
EL033C	180606	Lobanov	USER	110906	101106	211206	Campbell/Cimo
EM048	070603	Minier	USER	(050903)	(220903)	240805	Biggs
EM058A	260206	Moscadelli	USER	310306	050406	210806	Campbell
EM059A	261005	Moscadelli	USER	020206	140206	120406	Bignall
EM061A	260206	Moscadelli	USER	190506	220606	210806	Soria-Ruiz
EM061B	270206	Moscadelli	USER	170506	240506	210806	Soria-Ruiz
EM061C	280206	Moscadelli	USER	140806	170806	111206	Campbell
EN003A	101104	Bartkiewicz	USER	(071204)	240105	120405	Campbell/Langevelde
EN003B	111104	Bartkiewicz	USER	(091204)	240105	120405	Campbell/Langevelde
EP049B	270205	Conway	USER	140405	200405	130605	Bignall
EP049C	130605	Conway	USER	250705	290705	150905	Bignall
EP051	271005	Paragi	USER	(071205)	(141205)	120106	Paragi
EP053	231005	Popovic	USER	020106	050106	120406	Campbell
EP054	240206	Pestalozzi	USER	060606	150606	210806	Bignall
EP055	150606	Parra	USER	110806	041006	111206	Campbell
EP056A	130606	Perez-Torres	USER	290606	020806	021006	Bignall
EP056B	140606	Perez-Torres	USER	250706	020806	021006	Bignall
ES049A	070305	Stanghellini	USER	300305	080405	020505	Biggs
ES049B	090305	Stanghellini	USER	040405	080405	020505	Biggs
ES051	271004	Sjouwerman	USER	300605	290705	140905	Brunthaler
ES053A	030305	Szymczak	USER	180405	280405	130605	Brunthaler
ES053B	050605	Szymczak	USER	300805	020905	091205	Paragi
ES054A	050605	Schilizzi	USER	280905	151105	141205	Paragi
ES054B	060605	Schilizzi	USER	051005	211005	141205	Bignall
ES055	021105	Cassaro	USER	(151205)	240106	120406	Paragi
ES056	080606	Szymczak	USER	110706	130706	111206	Soria-Ruiz
EV015	020606	Vermeulen	USER	050706	110706	021006	Soria-Ruiz
EX004	301004	Liu	USER	060105	090305	190405	Reynolds
EX006	030306	Xiang	USER	010506	300606	210806	Reynolds
EZ013	060305	Zhang	USER	(310505)	(170805)	200406	Campbell
F05C1	181005	Paragi	ABAN	311005	311005	311005	Paragi
F05K1	140205	Paragi	ABAN	070305	070305	070305	Paragi
F05L1	310505	Paragi	ABAN	060605	060605	060605	Paragi
F05P1	111105	Paragi	ABAN	131105	131105	131105	Paragi
F06C1	140206	Paragi	ABAN	170306	030406	170706	Paragi
F06C2	130606	Paragi	ABAN	210606	210606	210606	Paragi
F06L1	010306	Paragi	ABAN	260406	150506	170706	Bignall
F06L2	060606	Paragi	ABAN	120606	120606	120606	Paragi

Expt name	obs date	PI	type	correlated date	distibuted date	released date	Support Scientist
F06M1	210206	Paragi	ABAN	220206	220206	220206	Harvey-Smith
F06M2	090606	Paragi	ABAN	120606	120606	120606	Paragi
F06U1	010606	Paragi	ABAN	120606	120606	120606	Paragi
F06X1	170206	Paragi	ABAN	180206	180206	180206	Soria-Ruiz
FR006	030806	Reynolds	NME	240806	021006		Campbell
GA021	291004	Argo	USER	120105	240105	250405	Biggs
GB055A	211005	Bondi	USER	260106	300106	120406	Soria-Ruiz
GB055B	041105	Bondi	USER	080206	130206	120406	Campbell
GD018	040305	Diamond	USER	140605	170605	100805	Bignall
GD021A	060606	Diamond	USER	190706	171006	111206	Harvey-Smith
GD021B	170606	Diamond	USER	010906	231006	111206	Harvey-Smith
GG053A	200204	Garrett	USER	(111105)	(081205)	120106	Campbell
GG053B	210204	Garrett	USER	(290805)	(210905)	120106	Campbell
GG053C	220204	Garrett	USER	(141005)	(031105)	120106	Campbell
GG57A1	270804	Gurvits	USER	(071004)	(101104)	050105	Avruch/Campbell
GG057B	171104	Gurvits	USER	050105	050205		Avruch/Campbell
GG057C	140105	Gurvits	USER	280205	010405		Avruch
GG060	241004	Garrett	USER	100305	240705	140905	Campbell
GI001B	070604	Imai	USER	(050804)	(051204)	100105	all
GI001C	020305	Imai	USER	030505	300505	220805	Paragi
GK034	200206	Kharb	USER	240506	190606	070806	Soria-Ruiz
GM060	170206	McKean	USER	110506	060606	210806	Bignall
GM062A	020306	Orienti	USER	260406	030506	210806	Paragi
GM062B	050606	Orienti	USER	280806	130906	111206	Soria-Ruiz
GP042	030305	Pedlar	USER	110505	051005	091205	Campbell
GS023	291004	Smith	USER	180105	100305	250405	Bignall/Reynolds
GT006	120605	Pihlstrom	USER	110805	160805	140905	Campbell
GV018A	030606	Kanekar	USER	060706	280706	021006	Reynolds
GV018B	040606	Kanekar	USER	070706	280706	021006	Reynolds
GW017	111105	Wucknitz	USER	120106	300106	120406	Campbell
IG002A	110305	Garrett	TEST	110305	110305	200305	Paragi
IG002B	110305	Garrett	USER	110305	110305	200305	Paragi
IG002C	110305	Garrett	ABAN	110305	110305	110305	Paragi
N04C3	281004	Paragi	NME	(231104)	(061204)	170405	Paragi
N05C1	240205	Paragi	NME	210305	250405	090805	Biggs
N05C2	100605	Paragi	NME	(110705)	(101005)	200406	Paragi
N05C3	201005	Paragi	NME	141105	211105	161205	Paragi/Soria-Ruiz
N05K1	170205	Paragi	NME	030505	060505	210805	Brunthaler

Expt name	obs date	PI	type	correlated date	distibuted date	released date	Support Scientist
N05K2	261005	Paragi	NME	030106	060106	040406	Paragi/Soria-Ruiz
N05L1	010305	Paragi	NME	230305	040405	250405	Bignall
N05L2	020605	Anderson	NME	120705	190905	091205	Anderson/Paragi
N05L3	060605	Anderson	NME	270705	190905	091205	Anderson/Paragi
N05L4	080605	Anderson	NME	260705	190905	091205	Anderson/Paragi
N05L5	271005	Paragi	NME	181105	281105	161205	Bignall/Harvey-Smith
N06C1	160206	Paragi	NME	150306	030406		Paragi
N06C2	170606	Paragi	NME	300606	100706		Soria-Ruiz
N06C3	231106	Reynolds	NME	191206			Harvey-Smith
N06L1	020306	Paragi	NME	230306	030406	131206	Bignall
N06L2	070606	Reynolds	NME	030706	100706	131206	Soria-/Harvey-
N06M1	220206	Paragi	NME	240306	150506	170706	Harvey-Smith
N06M2	090606	Reynolds	NME	270606	280706		Harvey-Smith
N06U1	010606	Paragi	NME	030706	170706	280806	Bignall
N06X1	190206	Paragi	NME	230306	150506	170706	Soria-Ruiz
N06X2	271106	Soria-Ruiz	NME	181206	191206		Bignall
PC001	201006	Conway	TEST	071106			Paragi
RB001	151206	Brunthaler	USER	151206	151206	211206	Campbell
RF001	160306	Fender	USER	160306	160306	100406	Paragi
RF003	200406	Fender/Spencer	USER	210406	210406	070506	Reynolds/Campbell
RO001A	050306	OBrien	USER	160306	190306	230406	Campbell
RO001B	060306	OBrien	USER	210306	240306	171206	Campbell
RO002	150506	OBrien	USER	020606	110606	210806	Campbell
RP001	180506	Fender	USER	190506	240506	050606	Paragi
RP003	261006	Perez-Torres	USER	271006	291006	031106	Paragi
RP004	261006	Paragi	USER	271006	271006	031106	Paragi/Campbell
RP005	141206	Paragi	USER	151206	151206		Paragi
RP006	151206	Pandey	USER	151206	261206		Campbell
TE027A	261104	Reynolds	TEST	(261104)	(061204)	100105	Reynolds
TE028	201204	Reynolds	TEST	(201204)	(221204)	100105	Campbell
TE029	100205	Reynolds	TEST	100205	150205	070305	Reynolds
TE030	160205	Paragi	TEST	160205	210205	070305	Reynolds
TE031A	210405	Reynolds	TEST	210405	280405	010505	Reynolds
TE031B	210405	Reynolds	TEST	210405	280405	010505	Reynolds
TE032	260505	Reynolds	TEST	260505	300505	060605	Reynolds
TE033	280605	Reynolds	TEST	280605	110705	170705	Reynolds
TE034	070705	Paragi	TEST	070705	170705	010805	Reynolds

Expt name	obs date	PI	type	correlated date	distibuted date	released date	Support Scientist
TE035	080905	Bignall	TEST	080905	190905	041005	Bignall
TE036	061005	Reynolds	TEST	061005	101005	181005	Reynolds
TE037	241105	Reynolds	TEST	241105	051205	131205	Reynolds
TE038	230106	Reynolds	TEST	240106	130206	130206	Reynolds
TE039	160306	Reynolds	TEST	160306	030406	100406	Paragi
TE040	300306	Reynolds	TEST	300306	030406	100406	Reynolds
TE041	200406	Reynolds	TEST	200406	240406	070506	Reynolds
TE042	180506	Paragi	TEST	180506	290506	050606	Paragi
TE043	260606	Paragi	TEST	260606	110706	170706	Paragi
TE044	210806	Paragi	TEST	210806	280806	021006	Paragi
TE045	261006	Paragi	TEST	261006	271006	031106	Paragi
TH024	061004	Gurvits	TEST	(161204)	(231204)	050105	Avruch

Appendix 10

List of acronyms and definitions

AARNet	-	Australia's Academic and Research Network
AGN	-	Active Galactic Nuclei
AIPS	-	Astronomical Image Processing System
ALBUS	-	Advanced Long Baseline User Software
ANGLES	-	Astrophysics Network for Galaxy LEnsing Studies
ANTAB	-	File containing aprioiri station calibration information, used in AIPS
ANTABFS	-	"Raw" version of ANTAB
ASTRON	-	Netherlands Foundation for Research in Astronomy
ATCA	-	Australia Telescope Compact Array
ATNF	-	Australia Telescope National Facility
BBC	-	BaseBand Converter
BL-Lac	-	BL Lacertae
Bwctl	-	Bandwith Test Controller
CALC	-	Program to compute the apriori geometric delay-model
CAS	-	Chinese Academy of Sciences
CASA	-	Common Astronomy Software Applications
C-band	-	5 GHz observing band
CCC	-	Correlator Control Computer
CeNTIE	-	Centre for Networking Technologies for the Information Economy
CfA	-	Center for Astrophysics (Cambridge, MA, USA)
CJF	-	Caltech-Jodrell Flat spectrum Survey
Cm-* baseline	-	Cambridge-to-all-stations baseline
COSMIC	-	Continuous Single-disc Monitoring of Intra-day variability at Ceduna
CPU	-	Central Processor Unit
CSIRO	-	Commonwealth Scientific and Industrial Research Organisation
CSO	-	Compact Symmetric Object
Da-* baseline	-	Darnhall-to-all-stations baseline
DANTE	-	Delivery of Advanced Network Technology for Europe
DEMON	-	Dark Matter and Dark Energy
DEVOS	-	Deep Extragalactic VLBI-Optical Survey
DFG	-	German Science Foundation
DPU	-	Data Playback Unit
DXRBS	-	Deep X-ray Radio Blazar Survey
EADS	-	European Aeronautic Defence and Space Company
EADS LIFE	-	EADS Lunar Infrastructure For Exploration
EC	-	European Commission
EGRET	-	Energetic Gamma Ray Experiment Telescope
ERI	-	EVN Reliability Indicator
ESA	-	European Space Agency

eSMA	-	Extended SubMillimeter Array
ESTRELA	-	Early-Stage TRaining site for European Long-wavelength Astronomy
EU	-	European Union
e-VLBI	-	electronic VLBI
EVN	-	European VLBI Network
EXPReS	-	Express Production Real-Time e-VLBI Service
FABRIC	-	Future Arrays of Broadband Radio-telescopes on Internet Computing
FIRST	-	VLA Faint Images of the Radio Sky at Twenty-one Cm
FITS	-	Flexible Image Transport Systems
FP6	-	Framework Programme 6
FPGA	-	Field Programmable Gate Array ???
FTP	-	File Transfer Protocol
GARR	-	Gestione Ampliamento Rete Ricerca (Italian Academic and Research Network)
GB	-	Gigabyte
Gbps	-	Gigabit per second
GBT	-	Green Bank Telescope
GÉANT	-	Pan-European Gigabit Research and Education Network
GeV	-	Giga-electron-Volt
GMRT	-	Giant Metre-wave Radio Telescope
GPS	-	Global Positioning System
GPS	-	GHz-Peaked-Spectrum
GSFC	-	Goddard Space Flight Center
HDF-N	-	Hubble Deep Field - North
HFF	-	Hubble Flanking Field
HSA	-	High Sensitivity Array
I/O	-	Input/Output
IAA	-	International Academy of Astronautics
IDV	-	intra-day variability
IERS	-	International Earth Rotation Service
IGN	-	Instituto Geografico Nacional (Spain)
INAF	-	Istituto Nazionale di Astropisica (Italy)
IRA	-	Istituto di Radioastronomia (Italy)
IRAM	-	Institut de Radio Astronomie Milimetrique
ISM	-	Interstellar Medium
ISS	-	interstellar scintillation
IVS	-	International VLBI Service
Jb1+2	-	Jodrell Bank telescopes 1 + 2
JBO	-	Jodrell Bank Observatory (UK)
JCCS	-	JIVE Correlator Control Software
JCMT	-	James Clerk Maxwell Telescope (Hawaii, USA)
JIVE	-	Joint Institute for VLBI in Europe
JPL	-	Jet Propulsion Laboratory
K-band	-	22 GHz observing band

LAN	-	Local Area Network
LBA	-	Australian Long Baseline Array
L-band	-	1,6 GHz observing band
LOFAR	-	Low Frequency Array
LTO	-	Linear Tape Open (tape backup system)
Mk5	-	Mark 5 (PC based disk recording system)
MASIV	-	MicroArcsecond Scintillation-Induced Variability
MB	-	Megabyte
Mbps	-	Megabit per second
MERLIN	-	Multi-Element Radio Linked Interferometer Network
MHz	-	Mega Herz
MIM	-	minimum ionosphere model
MPIfR	-	Max Planck Institut für Radioastronomie (Germany)
MTU	-	Maximum Transmission Unit
NA	-	Networking Activity
NAOC	-	National Astronomical Observatory of China
NASA	-	National Aeronautics and Space Administration
NICT	-	National Institute of Information & Communications Technology (Japan)
NME	-	Network Monitoring Experiment
NOT	-	Nordic Optical Telescope
NRAO	-	National Radio Astronomy Observatory (USA)
NREN	-	National Research and Education Network
NWO	-	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
OAN	-	Observatorio Astronomico Nacional
OSO	-	Onsala Space Observatory (Sweden)
PC-EVN	-	disk-based recording format
PCInt	-	Post-Correlator Integrator
PERT	-	Performance Enhancement and Response Team
PI	-	Principal Investigator
PoP	-	Point of Presence
PPARC	-	Particle Physics and Astronomy Research Council (UK)
PSNC	-	Poznan Supercomputing and Networking Center
RFI	-	Radio Frequency Interference
ROEN	-	North-eastern Space Radio Observatory
ROSAT	-	Röntgen Satellite
ROT (clocks)	-	Reconstituted Observing Time
RuG	-	University of Groningen
SARA	-	Dutch National Computer Centre
SCARIe	-	Software Correlator Architecture Research and Implementation for e-VLBI
SCHED	-	VLBI Scheduling Software, developed by NRAO
SCUBA	-	Submillimetre Common-User Bolometer Array
SFXC	-	Software FX correlator
SHAO	-	Shanghai Astronomical Observatory (China)

SKA	-	Square Kilometer Array
SKADS	-	SKA Design Study
Smart-1	-	Small missions for Advanced Research in Technology
SPIE	-	International Society for Optical Engineering
SURFNet	-	Dutch Research Organisation
TB	-	Terabyte
TeV	-	Tera-electron-Volt
TIGO	-	Transportable Integrated Geodatic Observatory
TNA	-	Trans National Access
TRM	-	Track Recovery Module
UAO	-	Urumqi Astronomical Observatory (China)
ULX	-	Ultra-Luminous X-ray Sources
UTC	-	Coordinated Universal Time
UvA	-	University of Amsterdam
UVW	-	Coordinate system for the visibility data as measured by an interferometric arary
VC	-	Video Channel
VLA	-	Very Large Array
VLBA	-	Very Long Baseline Array
VLBEER	-	EVN schedule server
VLBI	-	Very Long Baseline Interferometry
VSOP	-	VLBI Space Observatory Programme
WSRT	-	Westerbork Synthesis Radio Telescope (Netherlands)

Appendix 11

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Cover design by Beabudai Design www.beabudai.nl

Image credits: Methanol maser ring in G23.657-0.127 (Bartkiewicz et al); Recurrent nova RS Ophiuchi (O'Brien et al.); Cyg X-3 in outburst, observed with e-VLBI (Tudose et al.); Huygens probe landing on Titan (courtesy of ESA)

ISBN: 978-90-805014-7-8

NWO PPARC INAF Max-Planck-Institut für Radioastronomie ASTRON NAOC