European Consortium for VLBI

Biennial Report 2003-2004

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Foreword by the Chairman of the Consortium

This Biennial Report presents the science activities of the users and the technical and operational activities of the member institutes of the European VLBI Network (EVN) over the period 2003 – 2004.

The EVN is a network of Radio Observatories extending well beyond Europe to include two Member telescopes in P.R.China and Associate Members at Arecibo Observatory on the island of Puerto Rico and Hartebeesthoek Radio Observatory in the Republic of South Africa. Up to 14 radio telescopes in 11 countries are operated as a single VLBI array during three yearly observing sessions of three to four weeks. The EVN regularly co-observes with the USA Very Long Baseline Array to form a global array and with stations of NASA's Deep Space Network as a network affiliate. EVN has also operated jointly with HALCA, the space-born component of the VLBI Space Observatory Programme (VSOP) in Japan, which extends the baselines to 30,000 km.

This Report provides a review of the wide range of science produced by the EVN and its member institutes of a two year period. It reflects the high level of data quality of the EVN as a cutting-edge VLBI network but also exemplifies the scope and the impact of this science on the rest of astronomy.

Significant technical advances have been made during the recent period. The disk-based Mk5 recording systems have been introduced at all network telescopes for routine EVN operations and have largely replaced tape-based recording. In the 2003-2004 period rapid developments were made by the EVN with respect to e-VLBI, the art of real-time transfer and processing of data from EVN telescopes. Real-time e-VLBI images were generated using a many as six EVN observatories using the GEANT research network. The generation of the first e-VLBI image represented an important milestone on the path towards using this new technique as an operational scientific tool.

The EVN member institutes and partners have successfully submitted the RadioNet intiative to the Sixth Framework Program of the European Union and have received substantial support from the Commission. The RadioNet program incorporates a Trans National Access program with a variety of activities to improve the service to the EVN user community and to widen this community, a number of Network Activities to further strengthen the cooperation among the Network partners in a number of operational and technical areas, and some forward looking research activities related to astronomical software and new generation radio telescopes such as the Atacama Large Millemeter Array in Chile and the Square Kilometer Array. The intense collaboration between European radio astronomy Insitutes has been recognized as a successful formula for operating state-of-the-art network research infrastructures.

Very Long Baseline Interferometry in Europe serves as an excellent example of an enduring successful trans-national collaboration between scientific partners at national observatories. The performance quality and the quality of the EVN data depend strongly on the innovative and skilled contributions of the staff at each of those Observatories and the incorporation of new technical advances and developments into the observing procedures.

The EVN family gratefully acknowledges the vitally important financial investments made at each of these observatories by the national funding agencies in support of VLBI in Europe.

Willem A. Baan, ASTRON Radio Observatory, The Netherlands
Chairman, EVN Consortium Board of Directors

1. The European Consortium for VLBI

The European VLBI Network (EVN) was formed in 1980 by a consortium of five of the major radio astronomy institutes in Europe (the European Consortium for VLBI). Since then, the EVN and the Consortium has grown to include 12 institutes with 16 telescopes in Spain, UK, the Netherlands, Germany, Sweden, Italy, Finland, Poland and China, a 16 station data processor at JIVE in Dwingeloo and a 9 station data processor at MPIfR in Bonn. In addition, the Hartebeesthoek Radio Astronomy Observatory in S. Africa and the NAIC Arecibo Observatory in Puerto Rico are active Associate Members of the EVN. Together, these individual centres form a large scale facility, a continent-wide radio telescope.

The EVN is linked on a regular basis to the 7-element Jodrell Bank MERLIN interferometer in the UK to create a very sensitive "regional network", and to the US NRAO Very Long Baseline Array and the NASA Deep Space Network to create a "Global Network". The EVN, in stand-alone or global mode, also observed together with the orbiting radio telescope HALCA launched in February 1997 by the Institute of Space and Astronautical Science (ISAS) in Japan as part of the first dedicated Space VLBI mission VSOP (VLBI Space Observatory Programme).

The member institutes of the Consortium are (in alphabetical order):

Radio Astronomy

1) ASTRON, The Netherlands Foundation for Research in Astronomy, Dwingeloo, The Netherlands
2) Hartebeesthoek Radio Astronomy Observatory (HartRAO), S. Africa (Associate Member)
3) Institute of Radio Astronomy (CNR IRA), Bologna, Italy
4) Jodrell Bank Observatory (JBO), University of Manchester, Jodrell Bank, UK
5) Joint Institute for VLBI in Europe (JIVE), Dwingeloo, the Netherlands
6) Max-Planck-Institute for Radio Astronomy (MPIfR), Bonn, Germany
7) Metsähovi Radio Observatory (MRO), Helsinki University of Technology, Espoo, Finland
8) National Astronomical Observatory (OAN), Alcala de Henares, Spain
9) National Astronomy and Ionosphere Center, Arecibo Observatory, Puerto Rico (Associate Member)
10) Onsala Space Observatory (OSO), Chalmers University of Technology, Onsala, Sweden
11) Shanghai Astronomical Observatory, National Astronomical Observatories, Shanghai, P.R. China
12) Toruń Centre for Astronomy, Nicolaus Copernicus University, Toruń, Poland
13) Urumqi Astronomical Observatory, National Astronomical Observatories, Urumqi, P.R. China

Geodesy

14) Bundesamt für Kartographie und Geodäsie (BKG), Wettzell, Germany

The EVN Consortium Board of Directors (CBD) is a body whose membership consists of the Directors of the member institutes of the EVN. It meets twice a year to discuss EVN policy, operational, technical and strategic issues. The CBD elects a Chairman and vice-Chairman from its ranks who serve for a period of 2 years.

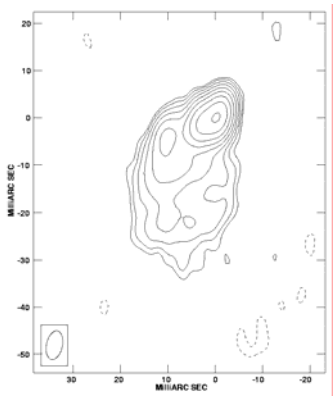
2. Reports on Scientific VLBI-related Research

The scientific research carried out by various groups using EVN facilities cover a wide range of topics, from the Solar System and nearby Universe to the very distant objects. Here we present a summary of some of these studies starting with the work on far away Active Galactic Nuclei and then moving as close as our Solar System.

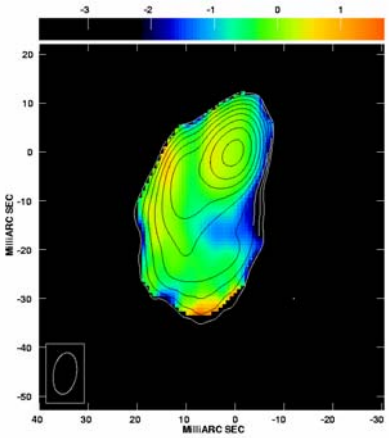
2.1 AGN phenomena on the parsec scale

A number of projects deal with the study of BL Lac objects and the relation between these extreme examples of AGN and edge-darkened (FR1) radio galaxies.

BL Lac objects are a class of extragalactic radio sources. They exhibit highly variable polarized radio emission and are distinguished from optically violently variable quasars by their weak optical line emission. The milliarcsecond (mas) and arcsecond scale jets of BL Lac objects are often misaligned. The arcsecond scale emission is typically more diffuse indicating that the jet has become decollimated between the milliarcsecond and arcsec scales. It has also been suggested that BL Lacs are the beamed counterparts to FR1 radio galaxies. The jets observed in FR1 radio galaxies have lengths of one to several kpc at which point they disrupt to form diffuse plumes. IF BL Lac objects are simply FR1 galaxies that make a small angle to the line of sight, then this transition from a well-collimated jet to a diffuse plume may take place on scales of just a few tens of mas. In order to investigate these changes of structure with scale, Reynolds (JIVE), Gabuzda (U. Cork), and Cawthorne (U. Central Lancashire) have carried out low frequency observations with the VLBA. At the lower frequencies, more diffuse jet emission becomes more dominant allowing tracing the development of the jet on larger scales.

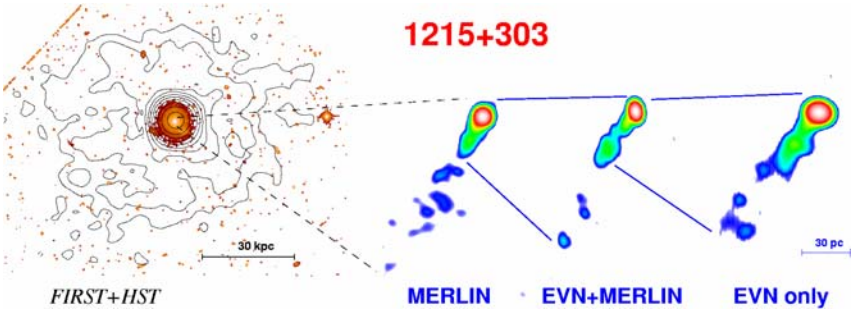


The Figure shows an image of the BL Lac object 1219+285 at 2.6GHz. This source has a known mas-scale jet that extends about 10 mas to the east of the core, but is essentially unresolved on arcsecond scales. The figure shows that the jet changes direction towards the south at about 10 mas from the core, after which the jet appears to become much more diffuse.

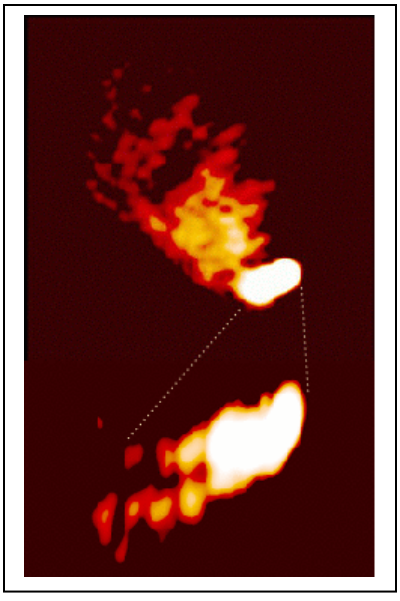


The Figure shows a spectral index map of the source produced using observations at 1.7 and 2.6 GHz. It is notable that the region where the jet changes direction shows enhanced brightness and this figure shows that the spectral index is also flatter in this region. This is indicative of an interaction between the jet and the surrounding medium which results in the jet changing direction. It also appears that the jet has become disrupted which explains why the object is unresolved on arcsecond scales. It is tempting to associate the diffuse emission seen in these images with the plumes seen at the end of the jets in FR1 radio galaxies, but it is also possible that what we are seeing is simply the end of an expanding jet which makes a small angle to the line of sight.

Giroletti and Bondi (both IRA) have carried out VLBI observations of low redshift BL Lac objects in order to study the morphological and polarisation properties of these sources in relation with the unified schemes. From the jet/counterjet ratio, core dominance, and synchrotron self-Compton model, the intrinsic orientation and velocity of the jets are estimated and found consistent with the FR 1 radio galaxies being the parent population. There is also a trend in the pc-scale polarization properties between BL Lac objects and radio galaxies.
The case of the BL Lac object 1215+303 is particularly interesting. The FIRST radio image shows a diffuse large scale halo centered on the HST optical nucleus. EVN and MERLIN images reveal an inner core-jet morphology, with the jet maintaining the same direction up to a (projected) distance of about 500 mas. The large jet/counterjet ratio and other arguments argue for a significant Doppler beaming. The jet axis is oriented at 15 +/- 5 deg to the line of sight, and it has a bulk Lorentz factor of about 3.8.

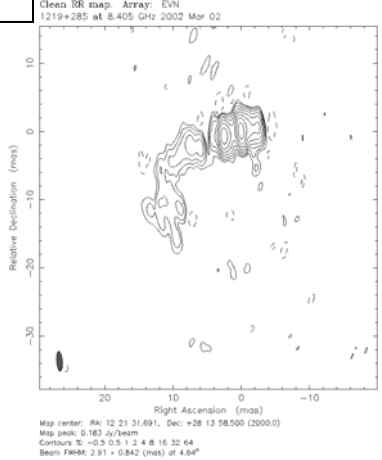


Montage showing the optical (HST) and radio structure of 1215+303 observed at increasing linear resolution, from VLA to EVN.



The image shows the pc-scale radio structure of the BL Lac Mrk 501. The lower image is a blow out of the inner jet region showing the transition to an edge-brightened jet.

EVN radio image at 8.4 GHz of the OVV BL Lac object ON 231

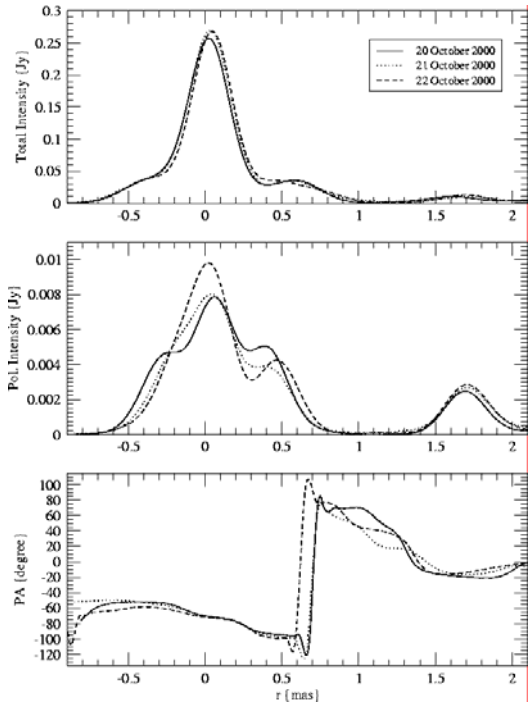


A high angular resolution study of the BL Lac object Markarian 501 in the radio band has been performed by Giroletti (IRA). This study is based on data taken at 14 epochs, including Space VLBI observations. These very high quality observations allowed to study the kinematics of the parsec-scale jet and to estimate its bulk velocity and orientation with respect to the line of sight. Limb-brightened structure in the jet is clearly visible in the data, and its possible origin in terms of velocity gradients in the jet is discussed.

VLBI observations of optically violent variable (OVV) BL Lac objects are an ongoing project carried out by Mantovani (IRA) in collaboration with Massaro (University of Rome). Recently, new EVN observations of ON 231 and OQ 530 have allowed to study the link between the optical variability and the nuclear radio structure. The possible scenarios for interpreting both the time evolution in the optical luminosity and the changes in the parsec scale structure are:

- the jet points very close to the observer direction, and undergoes strong instabilities and oscillations;
- a slowly precessing jet, which approached the observer line of sight during the past few decades.

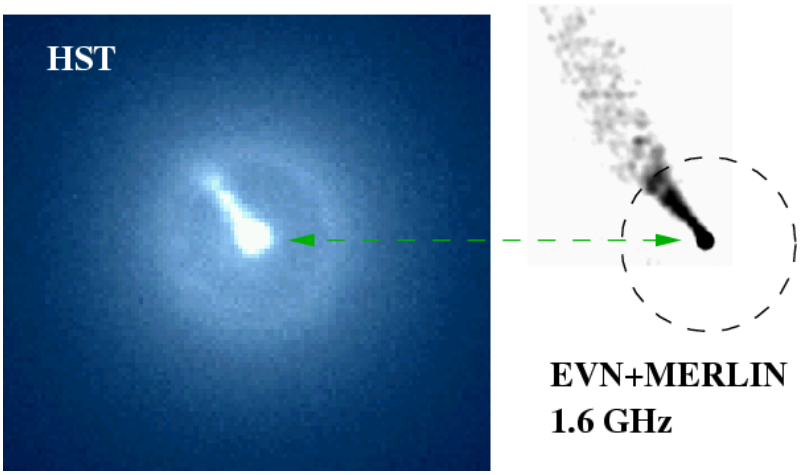
Bernhart and Krichbaum (MPIfR) have analyzed the sub-mas structure of the intraday variable (IDV) BL Lac Object 0954+658 which was observed with Space VLBI (including EB) at 5 GHz. Repetition of these observations within a few days allows to search for structural variability (in total and polarised intensity) in the sub-pc structures of IDV sources. This is a new aspect compared to the usual long-term VLBI observations, putting hard constraints to our present understanding of the still mysterious phenomenon of IDV. Within this short timerange (16, 20, 21, 22 October 2000) no change in total intensity occurred but a slight increase in polarised intensity in the core region from the third to the fourth epoch could be detected. The higher resolution of the space array compared to the ground array reveals that the inner core region consists of at least two components separated by roughly 0.5 mas. At present, it is under investigation whether the physical cause of the polarisation variability is due to refractive interstellar scintillation or jet/source intrinsic.



Profiles of total intensity (top panel), polarized intensity (middle panel) and EVPA (bottom panel) of the last three epochs of the 0954+658 observation.

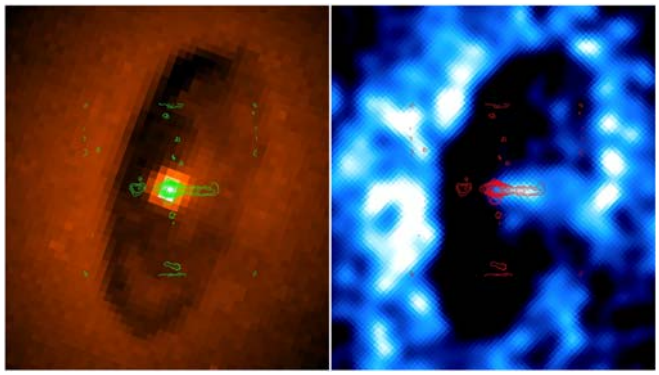
For the understanding of the central regions of Radio Galaxies and Quasars the high resolution provided by the VLBI is crucial and indeed these objects are the topic of many VLBI projects.

Broad band (radio and optical) observations of the nuclear region of nearby radio galaxies have proven very effective in investigating the jet morphology and energetics near the nucleus and containing the electron population responsible for the broad band synchrotron emission. Giovannini (IRA) and collaborators used EVN+MERLIN and VLA multi-frequency observations to study the jet in the radio galaxy 3C 264 from the pc to the kpc scale. These observations confirm the existence of regions with different properties. The most remarkable feature is the transition between a well-collimated jet to a conical-shaped wide jet at about 80 pc from the core. New pieces of information on the spectrum of the radio-optical jet in 3C264 are added. The brightness profile of the jet is consistent with a spine brightened jet in the inner 100 pc and with an edge-brightened jet beyond.



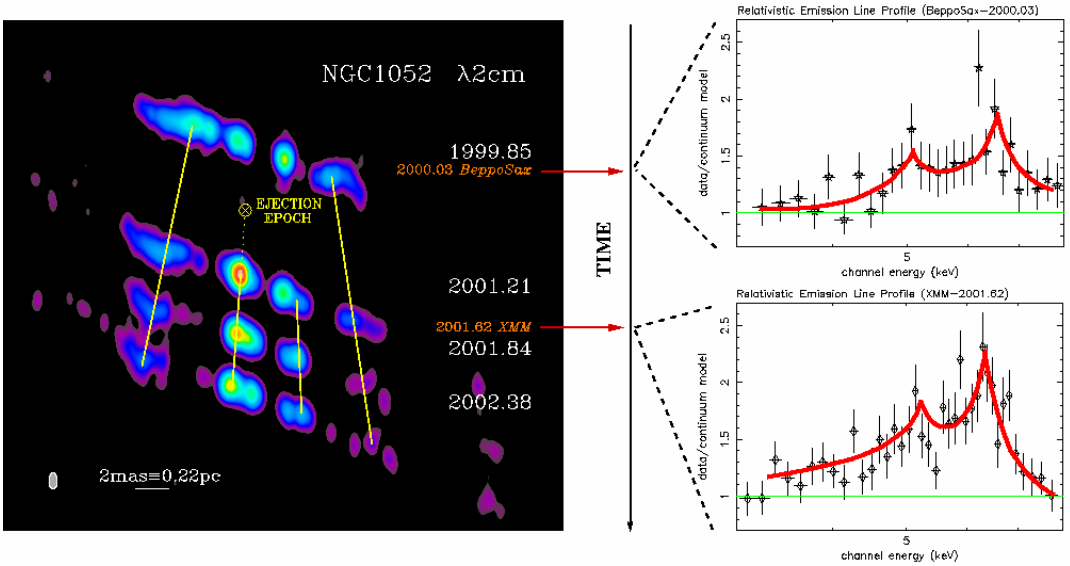
HST archive image of 3C 264 showing the circum-nuclear ring and the optical jet (Baum et al. 1997). Right: radio image of the jet at 1.6 GHz, with an angular resolution of 40 mas. The locus of the ring seen in the optical is plotted on the radio image for comparison.

Similarly, Chiaberge (IRA) and collaborators have used EVN+MERLIN observations to image the radio counterpart of the optical jet detected in 3C270 finding that the optical emission is consistent with a synchrotron spectrum from the radio to UV domain with a spectral index of about -0.7 ($S\nu \propto \nu$-α).



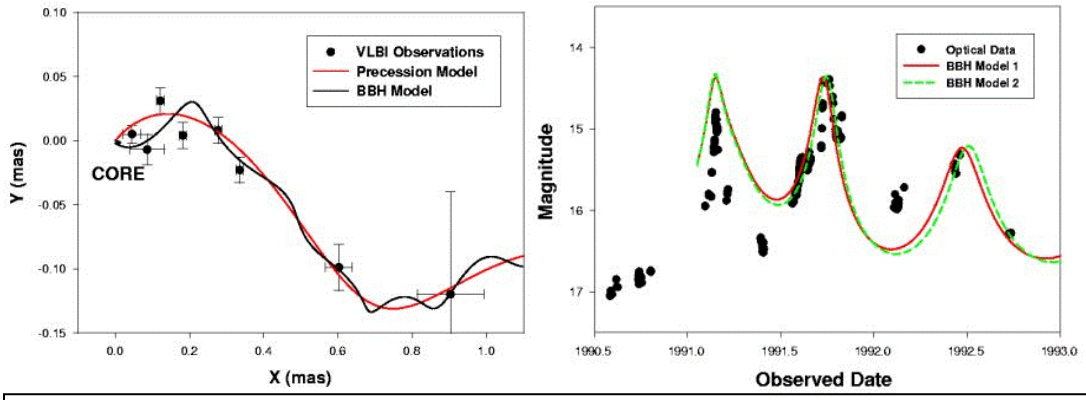
EVN+MERLIN contours at 18 cm with 30 mas resolution super-imposed to the HST optical (left) and UV (right) image of 3C 270.

A variable relativistic, broad iron line was found in the X-ray spectrum of the source NGC 1052 - based on the analysis of XMM-Newton and BeppoSax data – by M. Kadler, E. Ros (MPIfR), K. Weaver (LHEA, NASA/GSFC), J. Kerp (RAIUB), and J.A. Zensus (MPIfR). Together with an analysis of VLBA 2cm Survey monitoring data, an inter-relation between the accretion process and jet production was revealed. A violent injection of jet plasma into the jet of NGC1052 during this monitoring campaign occurred in 2000 and was accompanied by significant variability of the relativistic iron line between the two X-ray observations before and after this ejection event. The observational signature suggests that a part of the disk was fed into the black hole and a fraction of the material was ejected into the jet.



Before and after a violent plasma injection into the eastern VLBI jet of NGC1052, the source X-ray spectrum exhibits different profiles of the relativistic broad iron line, produced from the very inner regions of the accretion disk. This implies that a part of the disk was fed into the black hole and a fraction of the material was ejected into the jet.

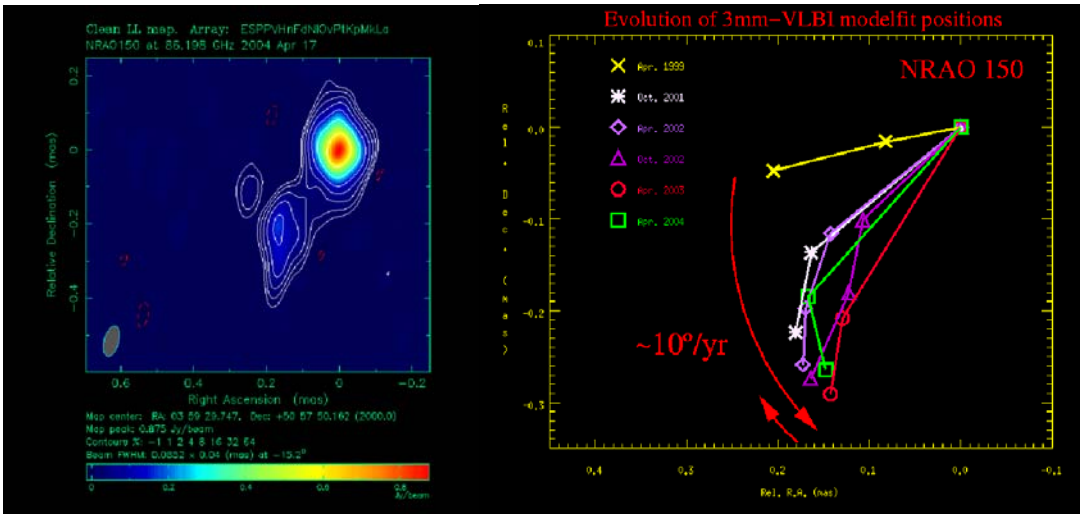
Lobanov (MPIfR) and Roland (IAP, Paris) developed a binary black hole model that describes optical variability and kinematics and emission from compact relativistic jets in powerful AGN. This model, applied to the quasar 3C345, explains the variations of radio and optical emission from the quasar, and reproduces the structural variations observed with the VLBI in the parsec-scale jet of this object (see Figure below). The binary system in 3C345 is described by two equal-mass black holes with masses of approximately 7.1 times 10^8 solar masses separated by approximately 0.33 pc and orbiting with a period ca. 480 yr. The orbital motion induces a precession of the accretion disk around the primary black hole, with a period of approximately 2570 yr. The jet plasma is described by a magnetized, relativistic electron-positron beam propagating inside a wider and slower electron-proton jet. The combination of Alfvén wave perturbations of the beam, the orbital motion of the binary system and the precession of the accretion disk reproduces the variability of the optical flux and evolution of the radio structure in 3C345.



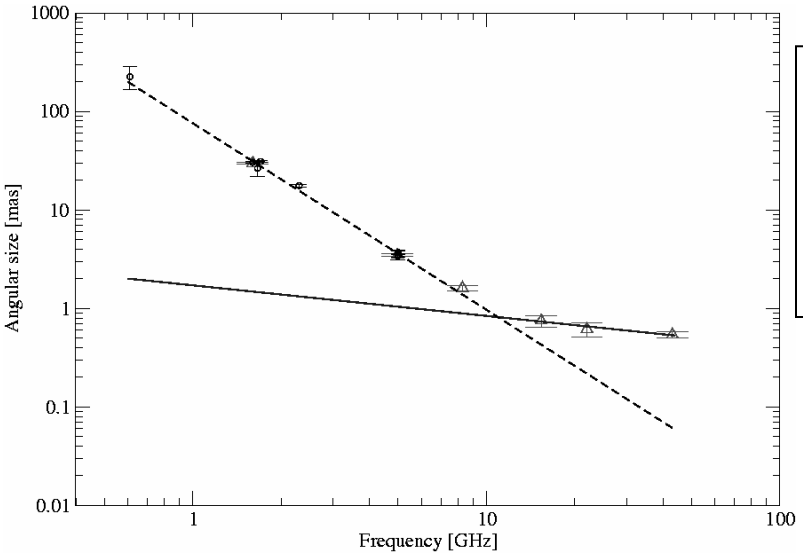
The binary black hole model applied to the quasar 3C345. **Left**: The two-dimensional path of the jet component C7 within 1 mas of the nucleus. The difference between the precession fit and the binary black hole model fit is due to the orbital motion of the black hole ejecting the jet. **Right**: Optical variability in 3C345 in 1990-93. Solid lines show the fits by the binary black hole model. Individual peaks result from the orbital motion in the binary system.

M. Kadler, J. A. Zensus, E. Ros (all MPIfR), together with the VLBA 2 cm Survey collaboration (see http://www.nrao.edu/2cmsurvey), continued VLBI observations of a sample of more than 200 active galactic nuclei. New observations were analyzed and the existing database of kinematic measurements in the jets of these active galaxies was extended. This project aims to better understand the complex kinematics of the relativistic jets and the magnetic fields. The distribution of the observed speeds is not compatible with the predictions of ballistic models. In many cases curved trajectories were observed, and accelerations in the motions of jet features were measured. A significant fraction of the jets show sub-relativistic motions.

Agudo, Krichbaum, Bach, Pagels, Alef, Graham, Witzel and Zensus (all MPIfR) together with Bremer and Grewing (IRAM) and Teräsranta (Metsahövi) have monitored the continuum radio- to mm-VLBI jet evolution in the radio loud quasar NRAO 150. The first results have revealed an unusual strong misalignment of ca. 120 deg. between the cm and mm jets (see Figures below). The new Global 3mm-VLBI Array and 7 mm VLBA images have shown that this extreme misalignment is produced by the fast counterclockwise rotation of the innermost 0.5 mas of the jet at an angular speed of ca. 10 deg./yr. (projected in the plane of the sky). The latest analyzed Global 3mm-VLBI Array image (taken on 2004 April) have revealed for the first time a change on the rotation sense of the jet. This result suggests a possible periodicity in the jet wobbling, and have allowed to make the first constraints on this period, P>8.3 yr. in the reference frame of the observer, and the wobbling amplitude, A>50 deg. projected in the plane of the sky.



K. Gabanyi, S. Britzen, T. Krichbaum, U. Bach, A. Kraus, A. Witzel and A. Zensus (MPIfR) have performed a multi-frequency VLBI study of the heavily scattered quasar B2005+403. Long wavelength EVN observations obtained at 1.6 GHz, 5 GHz, and 8 GHz show that the source image is dominated by angular broadening. The measured diameters of the major axis (between 0.67 GHz and 8 GHz) can be fitted by ϑ = 75.78 +/- 3.33 ν -(1.89 +/- 0.04) (ν in GHz). VLBI measurements performed at higher frequencies (15 GHz, 22 GHz, and 43 GHz) can not be fitted by this relation. At these frequencies, the imaged source structure is less affected by interstellar scattering. A power law fitted to the data (ϑ = 1.72 +/- 0.37 ν -(0.31 +/- 0.07)) gives an estimation of the intrinsic source size. Thus, at an arbitrary frequency of 1GHz, the scattering size can be estimated to be ϑ scat=(75.8+/-3.3) mas. The 15 GHz, 22 GHz, and 43 GHz maps reveal an east-west oriented core-jet structure with stationary and moving jet components. The derived value for the apparent superluminal motion is ~2c. An extended lobe-like feature is found south-east from the central part of the source.



A log-log plot of the measured angular size versus observing frequency. The dashed line represents ($75.78\ \nu^{-1.89}$) fit to the major axis sizes at the frequencies (0.61, 1.67, 2.28, 5 and 8 GHz). The solid line represents a ($1.72\ \nu^{-0.31}$) fit to the data points at frequencies of (15, 22, 43) GHz. Circles denote data from the literature, triangles data from this paper.

Hong, Jiang (Shanghai), Gurvits, Garrett (both JIVE) have obtained a number of high resolution radio observations of the AGN 1156+295. These include multi-epoch and multi-frequency VLBI, VSOP, MERLIN and VLA observations made over a period of 50 months. The 5 GHz MERLIN images trace a straight jet extending to ~ 2 arcsec at P.A. ~ -18 degrees.
Extended low brightness emission was detected in the MERLIN observation at 1.6 GHz and the VLA observation at 8.5 GHz with a bend of ~ 90 degrees at the end of the 2 arcsecond jet. A region of similar diffuse emission is also seen about 2 arcseconds south of the radio core. The VLBI images of the blazar reveal a core-jet structure with an oscillating jet on a milli-arcsecond (mas) scale which aligns with the arcsecond jet at a distance of several tens of milli-arcseconds from the core. This probably indicates that the orientation of the jet structure is close to the line of sight, with the northern jet being relativistically beamed toward us. In this scenario the diffuse emission to the north and south is not beamed and appears symmetrical. For the northern jet at the mas scale, proper motions of 13.7+/-3.5 , 10.6+/-2.8 and 11.8+/-2.8 c are measured in three distinct components of the jet (q0=0.5, H0=65 km /s /Mpc are used throughout this paper). Highly polarised emission is detected on VLBI scales in the region in which the jet bends sharply to the north-west. The spectral index distribution of the source shows that the strongest compact component has a flat spectrum, and the extended jet has a steep spectrum. A helical trajectory along the surface of a cone was proposed based on the conservation laws for kinetic energy and momentum to explain the observed phenomena, which is in a good agreement with the observed results on scales of 1 mas to 1 arcsec.

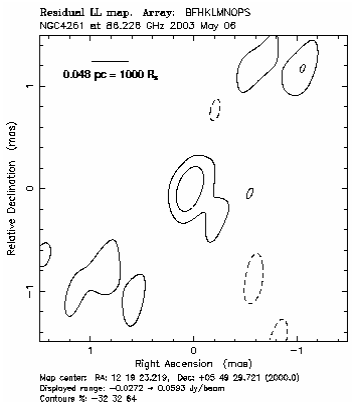
Hong, Zhao, An, Jiang, Wang, Feng, and Sun (Shanghai) have observed NRAO530 with the EVN at 5 GHz, the MERLIN at 1.6 and 5 GHz, and the VLA at 5 and 8 GHz showing the complex morphology on scales from pc to kpc. The VLBI image shows a core-jet structure indicating a somehow oscillation trajectory on a scale of 30 mas, north to the strongest compact component (core). The core-jet structure extended to several hundreds mas at about P.A. -50 degree and a distant component located 11 arcsec west to the core are detected in both the MERLIN and the VLA observations. An arched structure of significant emission between the core and the distant component is also revealed in both the MERLIN image at 1.6 cm and the VLA images at 8.4 and 5 GHz. The core component shows a flat spectrum with α~ 0.08 while α~1 for the distant component. The steep spectrum of the distant component and the detection of the arched emission suggest that the western distant component is a lobe or a hot-spot powered by the nucleus of NRAO530. A patch of diffuse emission, 12 arcsec nearly east (P.A. 70 degr) to the core component, is also observed with the VLA at 5 GHz, suggesting a presence of a counter lobe in the source.

An, Hong (Shanghai), Venturi (IRA), Jiang, and Wang have carried out a multi-frequency and multi-epoch study of PKS 1502+106 at radio frequencies. The analysis is based on an EVN dataset at 5 GHz and archive VLBA (Very Long Baseline Array) datasets at 2.3, 8.3, 24.4 and 43.1 GHz over a period of 8 years. The source is characterized by a multi-component one-sided jet at all epochs. The high-resolution images at 5, 8.3, 24.4 and 43.1 GHz show a curved-jet morphology in the source. The radio core brightness temperature approaches the equipartition limit. Superluminal motions of 37.3+/-9.3 c, 22.0+/-15.5 c, 10.5+/-2.6 c and 27.9+/-7.0 c are measured in four distinct components of the jet. The analysis supports the idea that the relativistic jet in PKS 1502+106 is characterised by extreme beaming and that its radio properties are similar to those of γ-ray loud sources.

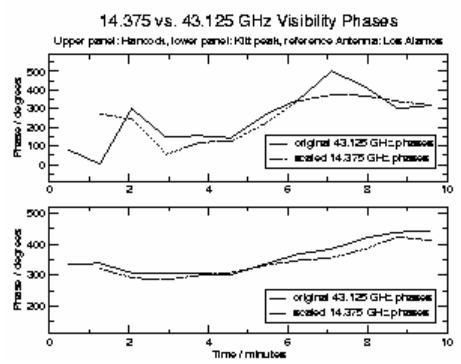
Jiang and Wang (Shanghai) have obtained EVN observations of 3 Broad Absorption Line quasars at 1.6 GHz. They are all compact with linear sizes less than 1 kpc. The flat spectral source, J1556+3517, is unresolved at about 20 mas resolution, indicating that the orientation of the radio jet in this source is probably near the line of sight. J1312+2319 shows asymmetric two-sided structure on a scale of several hundreds pc. This structure resembles that of Compact Symmetric Objects (CSO), however, it has a bright central component at the present resolution. The jet orientation of J1312+2319 may be far from the line of sight. J0957+2356 is also unresolved, but with a steep spectrum, therefore the jet orientation in this source is unclear. These results are not consistent with the unification of BAL and non-BAL quasars by orientation.

The most distant quasars discovered recently in the Sloan Digital Sky Survey have redshifts of z~6. Observations of these sources may be fundamental in understanding the early structure formation in the Universe. It appears that black holes with masses exceeding 10^9 Solar mass already existed at z=6. This estimate comes from the measurement of the optical luminosity of these systems. However, simulations show that up to 30% of these sources may be magnified by gravitational lensing and the corresponding black hole masses would be over-estimated.
One of these very high redshift sources, SDSS 0836+0054 (z=5.82) has detectable radio emission at cm wavelengths. Phase-referencing observations with the EVN at 18cm conducted by Frey & Mosoni (FOMI) and Paragi & Gurvits (JIVE) show that the radio structure of the source at 10 milliarcsecond angular resolution is somewhat resolved. The flux density detected with VLBI is equal to that measured earlier with the VLA. This suggests that the source is not multiply imaged.

The technique of fast frequency switching was demonstrated by Middelberg (MPIfR, ATNF), Roy (MPIfR) and Walker (NRAO) for phase calibrating high-frequency observations of sources too weak for self calibration. We interleaved 15 GHz scans, with which to derive phase solutions with selfcal, and 43 GHz or 86 GHz scans to be calibrated using scaled-up phases interpolated from the 15 GHz scans. The technique allowed detection of NGC 4261 with 60 mJy/beam peak at 86 GHz which is below the normal selfcal detection limit. The technique can, in principle, provide images that are phase referenced to the source itself at lower frequency, giving reliable measurement of frequency-dependent core shifts in AGNs and to test models of jet structure through opacity effects, though this was not demonstrated due to ionospheric effects at 15 GHz that we had not calibrated sufficiently accurately.



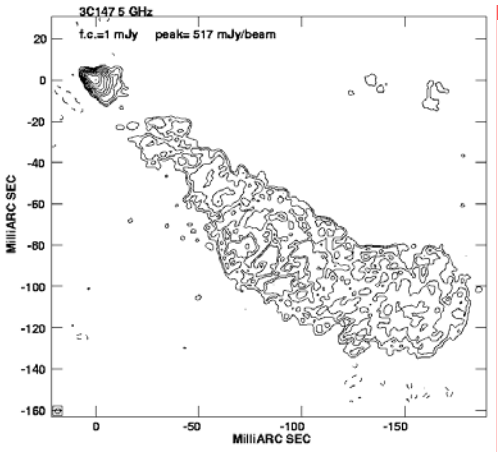
Naturally weighted, full-resolution image of NGC 4261 at 86 GHz, calibrated with scaled-up phase solutions from 15 GHz. Fringe-fitting has been used to solve for one residual phase and rate solution per 25 min scan before exporting the data to Difmap. No further self-calibration and no deconvolution have been applied. The image noise is 8.4 mJy/beam and the dynamic range is 7:1. The synthesized beam has a diameter of 0.35 x 0.54 mas in P.A. 11d and corresponds to a linear resolution of 0.048 pc or 1000 Rs. The bar in the upper left corner shows the size of the minor axis.



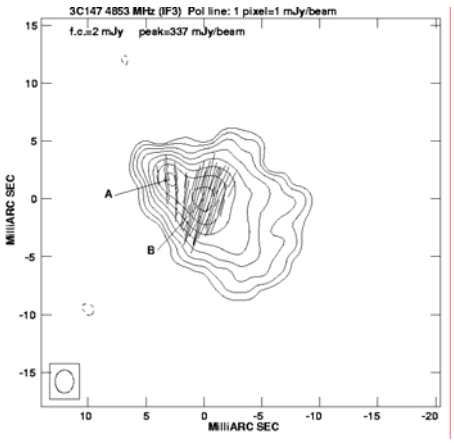
Demonstration of the scalability of phase solutions. 43 GHz fringe-fitted phase solutions (solid lines) on 3C 273 compared to 15 GHz fringe-fitted phase solutions multiplied by the frequency ratio (dashed lines) from the VLBA antennas at Hancock (upper panel) and Kitt Peak (lower panel) to the reference VLBA antenna at Los Alamos. The phases follow each other very well.

Young powerful extragalactic radio sources represent a particularly interesting class of AGN that can only be studied in detail using the high resolution of the VLBI.
The anticorrelation between the intrinsic peak frequency and the source size in Compact Steep Spectrum (CSS) and GigaHertz Peaked Spectrum (GPS) radio sources is generally interpreted in terms of synchrotron self-absorption. This implies that these objects are young, with ages in the range 10^2-10^4 years. A great deal of observations has been carried out in the last years to study this class of radio sources. In particular Orienti (IRA) and collaborators used multi-frequency observations of CSS in the B3-VLA sample allowing to study the local spectral curvature in order to derive the spectral break due to synchrotron losses, which is a strong indicator of the age of the relativistic electron population (Orienti et al. 2004). The ages derived in this way turned out to be in exceptionally good agreement with the kinematic ages derived from the outward motion of the mini-hotspots.
At high frequencies (> 8.4 GHz) the detection of the source core is rather common, although the total flux density accounted by the core itself remains well below 1%.

A VLBA polarimetric study of a sample of CSSs mainly associated with quasars has been carried on by Rossetti (IRA) and collaborators to investigate the polarization characteristics of their jets, lobes and cores, and possible jet-cloud interactions. They found that the cores are usually either unpolarized or show only weak polarization. Polarized emission is detected along the jets at projected distances greater than 15 pc, with emission blobs being up to 20-30% polarized. High RM values (up to 10^4 rad/m^2 are associated with bends in the radio jet. Some sources are completely unpolarised (e.g. 3C 99, 3C138, 3C343). New VLBI observations complete the sample of small double compact sources in the Peacock and Wall catalogue (Rossetti et al. 2005).



5 GHz image of the CSS 3C147



Zoom-in of the nuclear region of the CSS 3C147, with polarization vectors superimposed.

Polatidis (MPIfR) and Conway (Onsala) reviewed observations of the expansion of compact symmetric objects (CSOs). These objects have structures similar to classical double sources (such as Cygnus A) but are thousands of times smaller; they are thought to be a very young phase in radio loud AGN activity. It is important to study these objects to understand the triggering mechanism of AGN activity. To date source expansion has been reported in 10 CSOs and all these objects are very young (<3000 yrs). In a few sources ages have also been estimated from energy supply and spectral aging arguments and these estimates are comparable. This argues that these sources are close to equipartition and that standard spectral ageing models apply. Proper motion studies are now constraining hotspot accelerations, side-to-side motions, and differences in hotspot advance speeds between the two hotspots of a source. Although most CSOs are young sources their subsequent evolution is unclear. There is increasing evidence that in some objects the CSO structure represents a new phase of activity within a recurrent source.

Marecki (Torun) and his collaborators continue a large programme on sources described as Very Compact Symmetric Steep Spectrum (VCSSS). After several year observations the final analysis is on the way. Some papers were already published more are prepared for submission.Generally the CSS class of compact radio sources is characterized by sub-galactic linear dimensions but morphologically show similarities to large scale objects. According to Marecki and his co-workers CSS are inter-medium evolutionary stage between young GPS and large scale FRI and FRII AGNs. Thus some of the generally weaker CSS can end as large scale powerful FR source. A competitive hypothesis assumes that the CSS objects are old and their morphological structure is modeled by dense and turbulent intergalactic medium. In this respect it is also very important that the central engine remains active for sufficiently long time or often switch on into the active stage. The observations and results of newly defined sample of CSS sources can provide arguments to clarify which of the above schemes is the real one. The first early VLBI results from 2002 concluded that the observed CSS sources are not evolving towards large scale FRs. No compact FRIs were found, their evolution remains unclear. Similarly to other sources CSS are randomly oriented towards observer and therefore can also show beaming effects. Some CSS are similar to FRIIs but they do not show hot spots, what suggest lack of fresh electrons beamed by jets to lobes. The spectrum is very steep and remains so for long time supporting the idea that the activity of central engine ceased shortly after first initial burst. It is possible that AGNs can terminate their activity at any stage of their evolution. The papers by Marecki et al. concentrate on Medium Size Objects (MSO) by studying them with VLA, MERLIN and VLBI. The compactness can be interpreted by their age and the MSO can be precursors of larger/older objects - LSOs. It is argued that not all young sources will evolve towards the larger ones but some of MSO can be

short-lived phenomena due to lack of stable fuelling of the black hole. The evidence is presented that some of MSOs could be prematurely “dying” objects.
The idea of re-occurrence of activity in radio-loud AGNs is the current subject of VLBI studies by Marecki and his collaborators (2004). According to a well established paradigm, the compactness of CSS sources is a direct consequence of being young. Based up on the study, an important element can be added to this standard picture in that in a number of sources in our sample, the activity of their host galaxies has probably switched off quite recently. CSS sources, being at an intermediate stage of the evolution of radio sources, are believed eventually to become large-scale sources. However, an interrupted activity scenario implies that not all CSS sources attain large sizes, but instead can `die early'. The observed overabundance of compact sources can readily be explained in this way.

Further VLBI studies of bright CSS quasars (mostly 3C309.1) were continued as part of the Ph.D. thesis of M. Gawronski (Torun) that is being prepared for publication. Initial VLBI data were inforced by VSOP observation at 5 and 1.66 GHz. New observations at C-band (polarization) and X-band were added and the preliminary results were presented at YERAC and EVN conferences. The interesting result concerns physical properties of twisted helical jet. A mathematical modeling is helping to understand the process. M.Gawronski discovered 5 new objects of HYMORS class. The studies were curried out using data from the VLA but a new project to study cores of HYMORS using EVN is being prepared. The properties of their mass VLBI structure remain to be investigated.

Liu and Yang (Urumqui) have proposed that Thomson scattering could have observational effect in Compact Symmetric Objects (CSOs). They have developed a 'semi-transparent screen' method for accounting the re-scattering back photons by which they estimated that the Thomson scattering contributes a factor 1.75 to the lobe flux ratio of OQ208 and 2.5 to the component flux ratio of NGC4261.

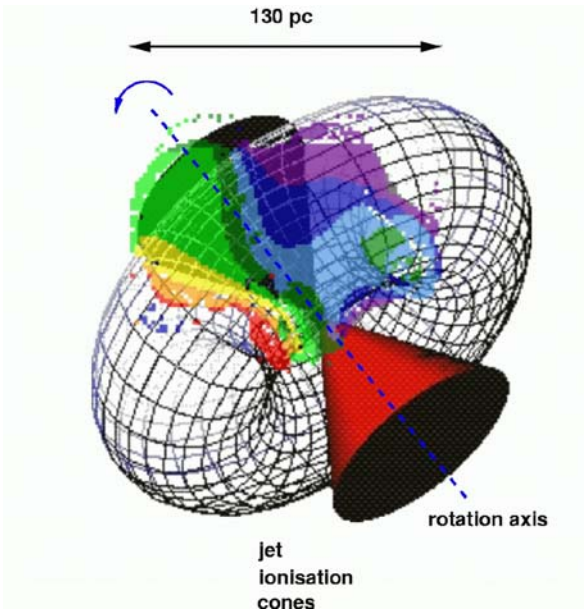
In addition (and complementary) to the study of the continuum, VLBI line observations are key in revealing the circum-nuclear environment of AGN.
The very luminous Active Galactic Nuclei found in distant galaxies mark distinct periods of intense activity in the lifetime of these systems. During such periods, the power source for the nuclear engine is generally assumed to be the accretion of matter onto a massive compact object. However, the great variety of nuclear signatures can only be explained with a non-isotropic spatial distribution of strongly obscuring material. The nature of this obscuring structure, its spatial distribution, and in particular, their relation to the nuclear engine are topics of great interest.

In recent EVN observations, Hans-Rainer Klöckner (Univ of Groningen), Willem Baan (ASTRON) and Michael Garrett (JIVE) have been able to image molecular emission of a prominent AGN called Markarian 231 and to infer the spatial distribution and dynamics of an obscuring torus or “donut”-like structure that surrounds and rotates about the nucleus.
While the physical processes governing the nuclear engines have been generally confirmed observationally, the direct imaging of the structural components of the nuclear region has not yet been possible, except in some very special cases. The new results uniquely probe the structure and dynamics of the obscuring material on scales of several tens to hundreds of light-years.
Markarian 231 is located 530 million light years away, and is the most luminous infrared galaxy in the local universe. The prominent tidal tails seen in optical images, together with its high dust content, conclusively demonstrate that it is undergoing a major merger (i.e. it is the product of the collision and interaction of two previously isolated galaxies). At the core of Markarian 231 lies an active nucleus with powerful jets of radio emission emanating from its centre.

The molecular emissions observed by Klöckner et al. in Markarian 231 are due to the OH molecule that through self-amplification (maser action) can become a million times more luminous than their Galactic counterparts. Such “megamaser” emissions have been observed in around 100 galaxies, which are also characterized by intense infrared emission. The OH emission revealed by the EVN observations suggests a spatial structure, which is best described as an

inclined rotating torus (donut-like) structure, surrounding the central engine with an (estimated) inner radius of 90 light years and a thickness of 200 light years. The total extent of this structure is modeled to be about 600 light years across, and it forms the inner part of a larger scale galactic disk also seen in the galaxy. Figure 1 shows the main details of the model.

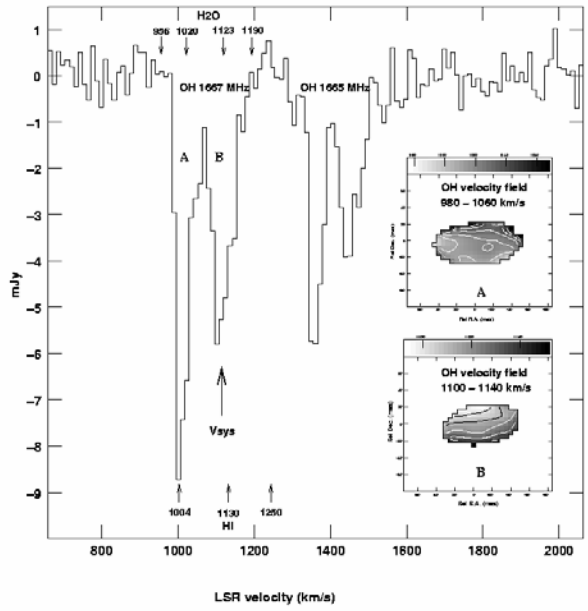
Although imaging of galactic nuclei has been performed in various other experiments, these data provide a first clear view of the dynamics of a nuclear component on such scales and the interpretation is consistent with the general understanding of Active Galactic Nuclei and the Unified Schemes that explain the variety of observed characteristics.



Inferred model of the nuclear torus in Markarian 231 is displayed as a wire diagram with symmetric cones, indicating the nuclear outflow (the ionization cones of the nuclear region). Superimposed is the velocity field of the OH 1667 MHz emission in pseudo coloor, where the bluish pattern indicates the emission coming towards the reader (as seen by the Doppler effect) and the redder part is moving from the reader into the paper. The symmetry axis of the torus has been inclined by 56 degrees, and rotated anti-clockwise by 35 degrees.

Desmurs (OAN) participates in a study with the EVN to map the 6 GHz OH distribution in Mrk 231 and Mrk 273 and determine column density and velocity fields in the absorbing clouds. The data are being analyzed. OH is expected to be found in regions of high TB, around the core for Mrk 273, and towards the lobes in the case of Mrk 231.

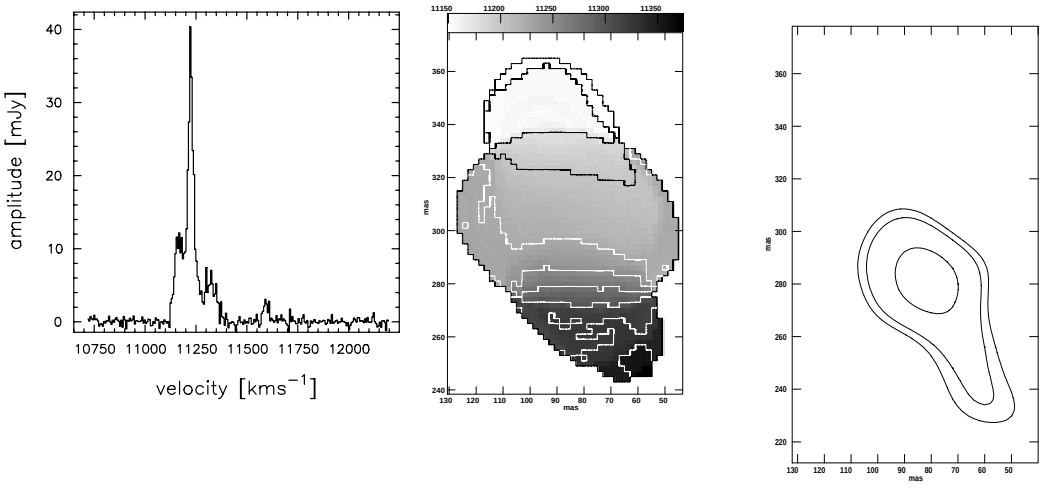
Broad hydroxyl (OH) absorption-lines in the 1667 MHz and 1665 MHz transition towards the central region of NGC 3079 have been observed by Y. Hagiwara (ASTRON), H.-R. Klöckner (Univ. Groningen), W.A. Baan (ASTRON) at high resolution with the European VLBI Network (EVN). The velocity fields of two OH absorption components against the unresolved nuclear radio continuum were resolved across the central ~10 parsecs. The velocity field of the OH absorption close to the systemic velocity shows a rotation in nearly the same sense as the edge-on galactic-scale molecular disk probed by CO(1-0) emission. The velocity field of the blue-shifted component displays a gradient in almost the opposite direction. This blue-shifted velocity field represents a non-rotational component, which may trace an outflow from the nucleus, or material on the receding side of an expanding shell shocked by the kiloparsec-scale superbubble. This OH absorption component traces a different structure that does not support a counter-rotating disk suggested on the basis of the neutral hydrogen absorption. The velocity gradients traced by the OH absorptions on scales of several parsecs are important to understand the nuclear structure of NGC 3079.



EVN and Westerbork observations have been carried out by Klöckner (Univ. Groningen) & Baan (ASTRON) to investigate the hydroxyl (OH) Megamaser emission in Mrk 273 at different spatial resolution. At EVN baselines the conti-

nuum observations display a number of distinct structural radio components in the central square arcsecond of the merging galaxy Mrk 273. The continuum emission of these components show both flat and steep spectral indexes, but provide no clear clues to the nature of the nuclear engine. Surprisingly the OH emission has only been detected toward a small fraction of one of the continuum components which provides an unexpected view of the molecular environment and the nuclear power plant.

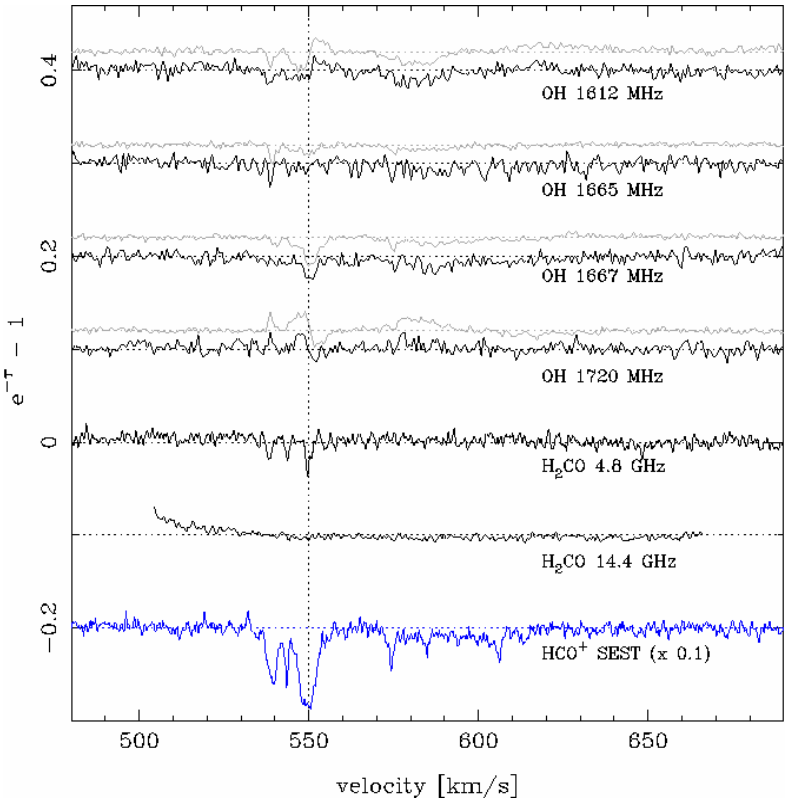
The OH emission detected by the EVN measurement accounts for only 12% of the total OH Megamaser emission in Mrk 273 as seen with the Westerbork array, but it shows the dominant triple emission line feature. The OH emission is tracing a 108 pc large structure partially superposed on the eastern radio component in the 500 pc times 300 pc large continuum emission region. The emission characteristics of both OH main lines (1667 and 1665 MHz) in combination with the associated near-infrared and radio-continuum emission suggest that the maser process is produced by an optically thin environment with a complex pumping scheme. The spatial structure, the velocity characteristics and the triple line emission feature of the hydroxyl emission reveal an organized motion of an edge-on disk/TORUS surrounding a central object of a binding mass of 1.4 10^9 Msun. The line observation determines the location of the nuclear power source and together with the radio continuum indicates the combination of a nuclear starburst coexisting with either a heavily obscured or weak nuclear power plant. These results are presented in a paper by Klöckner & Baan (2003).



Left: Integrated line emission spectrum of Mrk 273 observed with the EVN. The velocity scale corresponds to a heliocentric velocity of the 1667 MHz line with a spectral resolution of 5.6 km/s. The strong line features displayed here correspond to the 1667 MHz main-line emission and the weak emission line is related to the 1665 MHz main-line. The expected velocity difference between the OH main-line transitions in the velocity frame of the 1667 MHz line at the redshift of Mrk 273 is +365.6 km/s.

Middle and right: The velocity field of the 1667 MHz emission line and the continuum emission seen in a close-up of the northern nucleus in Mrk 273. The spatial resolution is 41 times 34 mas. The velocity field of the OH 1667 MHz emission is shown in grey colors covering a velocity range between 11150 to 11350 km/s and contours are separated by 25 km/s. A north-south velocity gradient of 1.62 km/s per mas is observed (2.19 km/s pc^{-1}), where the northwestern edge moves towards the observer. Only the OH lines located in the center and the southern edge of the disk are superposed on the observed continuum emission.

Centaurus A, the nearest AGN, shows molecular absorption in the millimeter and radio regime. By observing the absorption with VLBI, van Langevelde (JIVE) and collaborators try to constrain the distribution of the gas, in particular whether it resides in the circumnuclear region. Spectra taken with the VLBA show OH and formaldehyde absorption at high spatial resolution (see Figure), displaying absorption from a range of components known from previous studies.

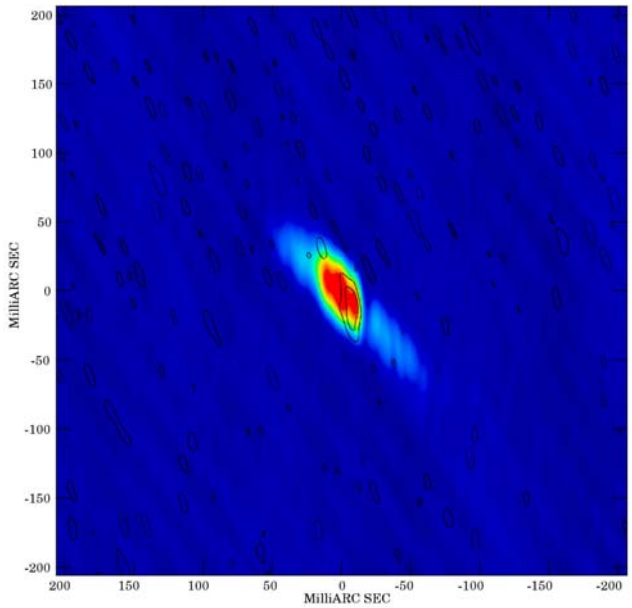


At first, this seems to indicate that the molecular absorption is smooth on scales larger than a few parsecs.

For the millimeter absorption, Eckart (MPIEP Garching), Wild (IRAM), and collaborators have proposed a particularly interesting model, in which the absorption takes place in a system of tilted molecular rings with co-rotating gas at high latitudes. The model predicts the structure to be much larger than the VLBI radio source. Indeed the OH absorption images show absorption that is consistent with this at all velocity components.

However, the formaldehyde absorption is less straightforward (see Figure).

Spectra for OH and H2CO from VLBA data, obtained in a sub-arcsecond beam. For comparison OH spectra obtained with the ATCA are shown as well in grey, slightly offset from the VLBA data. The bottom spectrum is HCO+ from the SEST (Israel et al., 1991, AA 245 L13).

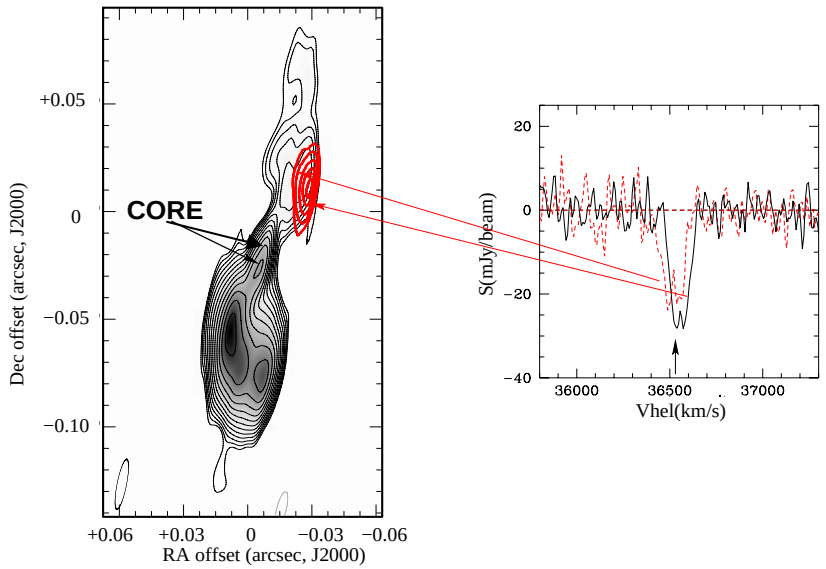


A map of the 4.8 GHz continuum of CenA, overlaid with the H2CO absorption in the 550 km/s feature. Clearly the feature does not cover the entire structure equally.

The data shows absorption against the core, but significantly little is seen against the jet. Naively, this seems to indicate that this structure is local to the nucleus. However, the scales are uncomfortably small. To get further constraints on the location of the molecular gas, models were evaluated that treat the excitation of the molecular species as a function of distance to the nucleus. For both OH and H2CO the influence of nuclear emission distance closer than 100pc is deemed to be important. OH main-line masers are expected when the mid-IR becomes strong, and formaldehyde masers may occur when the radio emission is very intense. From the excitation analysis and the modest line width, we conclude that the gas must be at 200pc - 2kpc from the nucleus,

consistent with the Eckart model. In this model the formaldehyde must be restricted to high density, small-scale structures in the mid-plane of the tilted rings, which also explains the absence of red-shifted components in the spectrum.

The radio source 4C12.50 has often been suggested to be a prime candidate for the link between ultra-luminous infrared galaxies and young radio galaxies. Morganti (ASTRON) and collaborators have carried out EVN+VLBA observations of the neutral hydrogen in the nuclear regions of this object showing that most of the gas detected close to the systemic velocity is associated with an off-nuclear cloud (~50 to 100 pc from the radio core) with a column density of ~ 1022(Tspin/100 K) cm^{-2} and an HI mass of a few times 10^5 to 10^6 Msun (see Figure and Morganti et al. 2004). A number of possibilities were considered to explain the results. This cloud could indicate the presence of a rich and clumpy interstellar medium in the centre, likely left over from the merger that triggered the activity and that this medium influences the growth of the radio source. The location of the cloud – at the edge of the northern radio jet/lobe -- suggests that the radio jet might be interacting with this gas cloud. This interaction could be responsible for bending the young radio jet. The velocity profile of the gas is relatively broad (~150 km/s) and this represents the kinematical evidence for interaction of the radio plasma with the cloud. The possibility that the cloud is part of a broader circumnuclear structure was also considered, but it appears to be more difficult to explain the observed characteristics. The VLBI study of the neutral hydrogen in 4C12.50 suggests that HI detected near the systemic velocity (as it is often the case in radio galaxies) may not necessarily be connected with a circum-nuclear disk or torus (as is very often assumed) but instead could be a tracer of the large-scale medium that surrounds the active nucleus and that may influence the growth of the young radio source.



Continuum image (black contours and grey scale of 4C12.50 with superimposed the total intensity of the HI absorption (red contours). The position of the radio core as derived by Stanghellini et al. (1997) and confirmed by Lister et al. (2003) is also indicated. The contour levels for the continuum image are: -5, 5 mJy/beam to 800 mJybeam in steps of factor 1.5. The contour levels for the total intensity of the \HI\ absorption are -2.5, -2.0, -1.5, -1.0, -0.5 Jy beam^{-1} \kms.

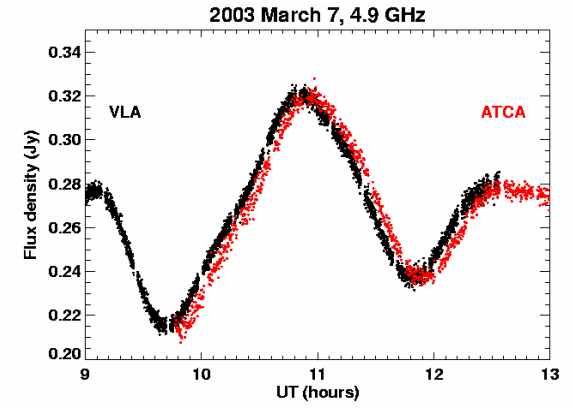
Tarchi & Moscadelli (INAF Cagliari), Henkel & Menten (MPIfR Bonn), Chiaberge (IRA/INAF Bologna), and Brunthaler (JIVE) conducted a VLBA+GBT+VLA experiment to detect water vapor maser emission in the nucleus of 3C403. This source is the first radio-loud quasar to have water vapor maser emission detected in the nucleus, and is the most distant water maser yet detected. Unfortunately, the source was too weak to be detected and the observation failed, although having only a relatively distant reference source at ~4deg separation may also have contributed

to the non-detection. An EVN observation at 6 cm of the same source was conducted in May 2004 in order to establish the pc-scale morphology of the AGN; this experiment was successful, and detected a small jet structure. Subsequently, a closer reference source (~1deg) has been found, and new 22GHz observations are planned.

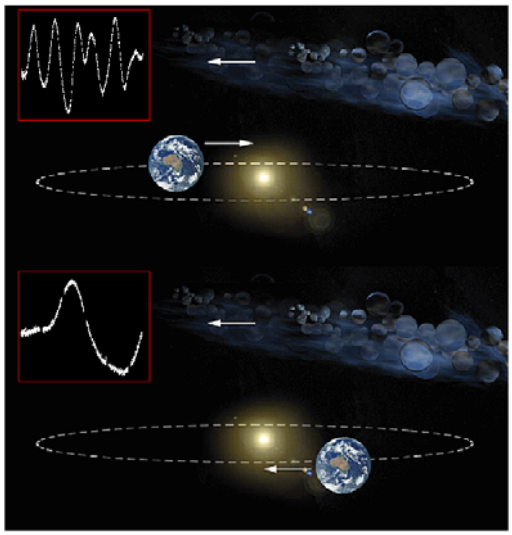
Variability and interstellar scintillation

Radio waves from distant quasars are scattered as they pass through the turbulent, ionized interstellar medium (ISM) of our Galaxy. If the quasar is very compact, this results in intensity fluctuations, known as interstellar scintillations (ISS) which can be observed with radio telescopes on Earth. Observations of ISS at cm wavelengths can be used to map source structure and evolution on micro-arcsecond scales. This gives clues as to how the radio jets in distant AGN form and evolve close to the central super-massive black hole. ISS is also a unique probe of turbulence in the local Galactic ISM.

In order to use ISS as a probe of source structure, we need to know the velocity and characteristic dimensions of the scintillation pattern, and the distance to the scattering material. Bignall (JIVE), Macquart (NRAO) and collaborators have recently derived these parameters for the quasar PKS 1257-326, using a novel technique combining observations of the variability pattern time delay between two widely separated telescopes, and of the change in scintillation timescale over the course of the year.



The Figure shows a simultaneous observation of PKS 1257-326 in March 2003, with the Very Large Array (VLA) and the Australia Telescope Compact Array (ATCA). The pattern of intensity fluctuations is clearly seen at the VLA a few minutes before arriving at the ATCA, as the scintillation pattern drifts across the Earth. Both the scintillation velocity and any anisotropy in the pattern influence the observed delay.



The Figure illustrates how the timescale of variability changes over the course of a year: when the Earth and ISM move in opposite directions, their relative velocity is large and the scintillation timescale short. Six months later, the Earth and ISM move in similar directions, their relative velocity is small, and the scintillation timescale is long. ATCA data from 12h observations in January and July 2003 are shown in the red boxes. [Background graphics courtesy of Renee Dillon.]

The variations observed in PKS 1257-326 are very rapid because the scattering occurs in an unusually nearby patch of ISM turbulence, only around 10 pc from the Sun. Interestingly, VLBI observations show a mas-scale jet aligned with the direction of anisotropy in the scintillation pattern, and also with the arcsecond-scale jet, which suggests that source structure plays a role in the observed scintillation of this source, with the VLBI "core" also having an elongated jet structure on sub-mas scales. Further work on the VLBI data and polarized source structure continues in collaboration with Reynolds (JIVE) and Ojha (ATNF).

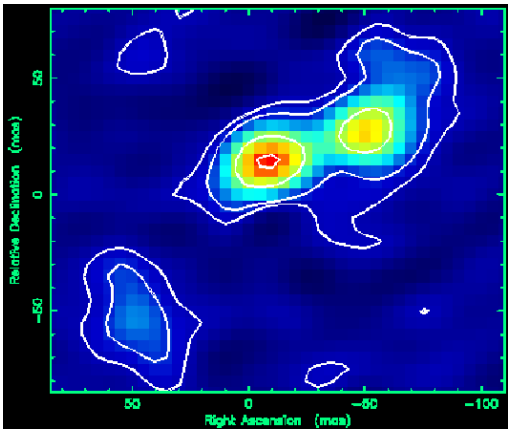
Lovell (ATNF), Jauncey (ATNF), Bignall (JIVE), and collaborators have recently undertaken a large survey with the VLA to investigate ISS in a sample of 700 compact quasars, and found that such rapid ISS is extremely rare. Most ISS occurs in more distant scattering screens, and therefore on longer timescales, requiring dedicated monitoring programs in order to derive micro-arcsecond-scale source properties in detail. Several projects are ongoing to follow up the MASIV Survey, in order to compare IDV behaviour with other source properties, for example VLBI structure, high energy emission, optical identification and redshift.

Systematic monitoring of total power flux for chosen blazers and Seyfert galaxies is continued in Torun with 32m at 5 GHz. In combination with data obtained from radio up to gamma rays a detailed physical model was constructed and verified. In 2003 a second paper was published (Katarzynski et al. 2003). The main effort concerns Mrk 421, the goal is to explain its spectrum from radio via IR, optical, UV, X to gamma range. Detailed calculations allowed to narrow range of physical parameters describing properties of jets and medium around central black hole. Detailed calculations took into account optical emission of host elliptical galaxy. The paper gives better insight into processes responsible for the observed light curves. The authors present self consistent model to explain observed flux variability. In this project several observational sessions were organized to make simultaneous fast sampled observations in optical and radio bands. Some of the above results used VLBI data and were finalized in form of Ph.D. thesis.

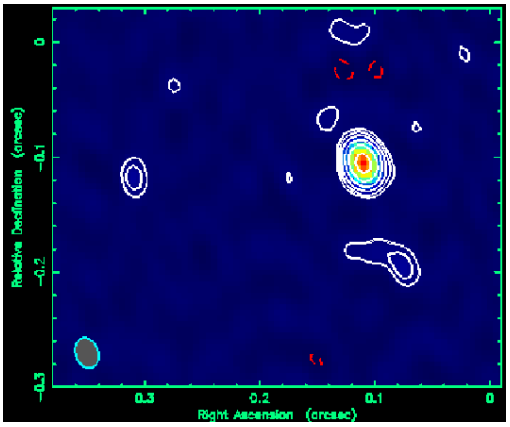
Liu (Urumqui) and collaborators have detected a possibly quasi-periodic, intra-hour variation in the blazar 3C273 by observing at both 6 and 3.6 cm with the Urumqi 25 meter radio telescope. They explain the variability as most likely due to shocked relativistic jet or instabilities of matter orbiting near the horizon of central black hole (see Liu, X., 2003).

2.2 Starburst galaxies and supernovae

A. Polatidis (MPIfR), in collaboration with J.E. Conway (OSO) and Y. Pihlstroem (NRAO) made combined 18cm continuum EVN and MERLIN observations of a sample of thirteen Ultraluminous Infrared Galaxies (ULIRGs), aiming to explore the connection between the AGN and the starburst phenomena. The images produced have the parsec and deci-parsec scale resolution necessary to distinguish between radio emission from supernovae or supernova remnants and an active nucleus at the centres of these galaxies.
Analysis of the five brighter galaxies showed that roughly 50%-70% of the total flux density is resolved at parsec-scale resolution. The parsec-scale structure consists of multiple components, with sizes of a few to tens of parsecs, and brightness temperatures ranging from 105 to 107 K. All components are too large to be single radio supernovae and in three of the galaxies their luminosities suggest that they may be clustered young radio supernovae or supernova remnants. In two of the galaxies (UGC 5101 and NGC 2623) the brightness temperatures and spectra of components are consistent with them being weak AGN, a fact corroborated by X-ray observations.

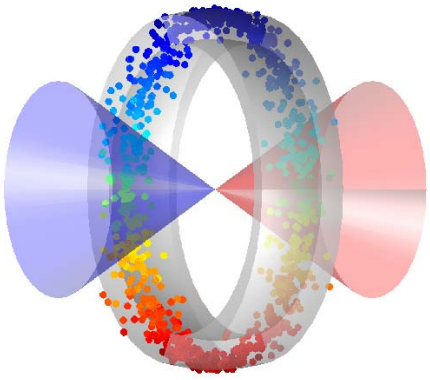


The EVN image of UGC 05101 restored with a beam of 22x17.4 mas. The peak is 17.5 mJy/bm and the contours are drawn at 1, 2, 4, 8, 16 x 1mJv/bm



The EVN image of NGC 2623 restored with a beam of 27 x 19 mas. The peak is 10.8 mJy/bm and the contours are drawn at 1, 2, 4, 8, 16 x 0.25 mJv/bm

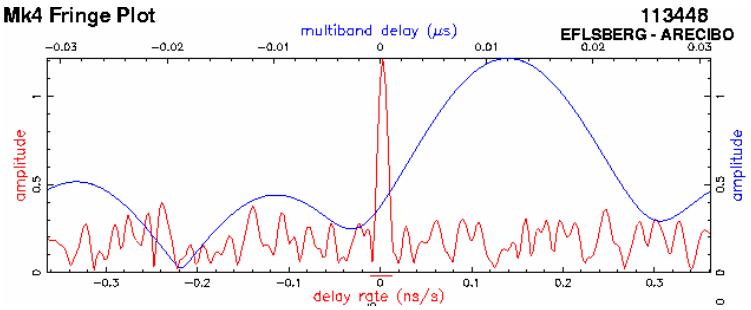
VLBI observations of extragalactic OH megamasers provide a unique means to study the dynamics and physical conditions of molecular gas in starbursts and composite starburst/AGN. Parra, Conway (OSO), Elitzur and Pihström (NRAO) have carried out detailed modeling of such maser emission toward the megamaser IIIZw35 (see Figure). This source has one of the most regular structures observed; occurring within a rotating ring of radius 22pc. The brightest emission occurs at the tangent points of this ring. The velocity gradient across the ring indicates an enclosed mass 7 x 106 solar masses. The OH maser emission in IIIZw35 as in other megamasers, apparently comes from two components; a diffuse component plus bright unresolved features. Parra et al have shown how this appearance can be explained if there is only one component of emission in dense clumps. The bright compact maser features seen at the ring tangents then arises from the chance overlap in space and velocity of multiple clumps.
In order to explain the source asymmetry the model also requires bicones of free-free absorption which form the basis a superwind.



Model of the clumpy OH megamaser emission in galaxy IIIZw35 from Parra et al 2004 which can explain both the apparently compact and diffuse maser components via a single phase medium of compact clouds. Individual OH maser clouds in a rotating circumnuclear ring (light grey) are shown colour coded according to their Doppler recession velocities. Also shown in blue and red are bicones of outflowing free-free absorbing gas. At the maser ring tangents multiple overlaps between clouds in both position and velocity are likely giving rise to high gains. These overlaps produce at the tangent regions bright maser spots via amplification of background continuum. In contrast at the front and back parts of the maser ring where cloud overlaps rare emission is only detected at low resolution when the interferometer beam contains a large number of low gain maser spots.

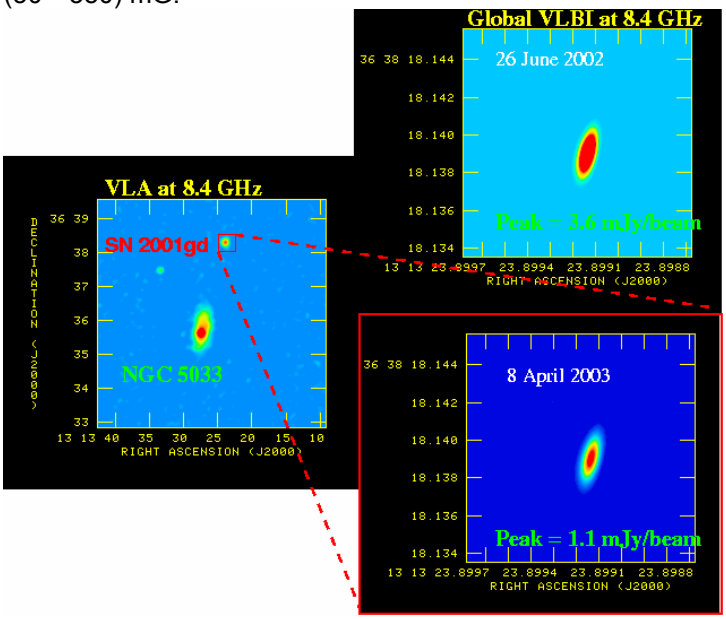
Porcas and Alef (MPIfR), together with Salter and Ghosh (Arecibo) and Garrington (Jodrell) have investigated the prevalence of compact structure in the faint radio source population. Some 992 sources from the NRAO FIRST Survey were observed in 4 6-hour periods between October 2003 and June 2004, using 1.4 GHz VLBI on the single baseline between Effelsberg and Arecibo. Each source was observed for just 1 minute; use of wideband (512 Mbps) recording permits any FIRST

source (above 1 mJy) with sufficiently compact structure to be detected on this ultra-sensitive baseline. The data were correlated at the Bonn Mk4 processor. An additional 400 sources could also be investigated by re-correlation at other FIRST source positions within the Arecibo primary beam (210 arcsec). Preliminary results from the subset of 252 target sources observed on 22 March, 2004 indicate that about a third of all FIRST sources have compact structure detectable at the ca. 6 mas resolution of this baseline. Surprisingly, this result appears to be independent of the FIRST Survey source flux density.



Fringe plot showing the detection of the 1.03 mJy FIRST source 113448 +284323 on the baseline Arecibo-Effelsberg. Integration time is 1min, bitrate is 256Mb/s (RHC only). The jagged plot is the residual fringerate spectrum; the smooth plot is the multiband delay function.

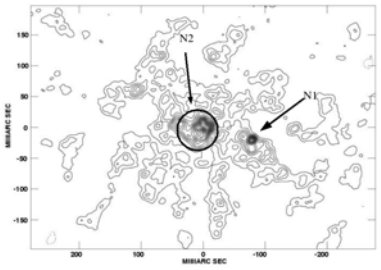
Global VLBI observations at 8.4-GHz SN2001gd in the spiral galaxy NGC 5033 (D = 13.1 Mpc) were carried out on 26 June 2002 and 8 April 2003 Pèrez-Torres (Granada) and collaborators (Stockdale et al. 2003). The supernova was found unresolved and model fitting was used to estimate the angular diameter of SN2001gd. The data nominally suggests a relatively strong deceleration for the expansion of SN2001gd, although the possibility of a free supernova expansion cannot be dismissed. From the VLBI observations on 8 April 2003, it is possible to infer a minimum total energy in relativistic particles and magnetic fields in the supernova shell of Emin=(0.3—14) x 1047 ergs, and a corresponding equipartition average magnetic field of Bmin= (50—350) mG.



Montage showing the position of SN~2001gd in NGC~5033 using a VLA image and the global VLBI images at 8.4 GHz.

The Ultra Luminous Infrared Galaxy Mrk 273 was observed at 5 GHz (EVN+MERLIN) and 1.7 GHz (EVN-only) by Bondi (IRA) and collaborators (Bondi et al. 2005). The main goals of these observations were to obtain the spectral index of the compact features and the extended halo of the northern component in Mrk 273. The main results of this analysis, based also on previous VLBA observations at 1.4 GHz obtained by Carilli & Taylor (2000) are:

- component N1 has a steep radio spectrum (α = -1.2 +/- 0.1; $S\nu \propto \nu$-α) and it is highly unlikely to be the radio counterpart of the AGN. It rather suggests that the compact non-thermal emission is produced by a very luminous radio supernova (RSN) or a combination of unresolved emission from several nested supernova remnants (SNR) and/or RSN.
- The morphology of component N2 is indicative of several compact features embedded in diffuse emission. The integrated spectral index of N2 is flat ((α = -0.5 +/- 0.1) and can be interpreted as due to the superposition of several unresolved components, e.g., RSNe, SNR, or both, whose radio emission peaks at different frequencies and is partially free-free absorbed. Is it also possible that one of the compact components in this region is the radio counterpart of the AGN. The radio spectral index and luminosity of the extended emission is consistent with being produced by relativistic electrons diffused away by supernova remnants.

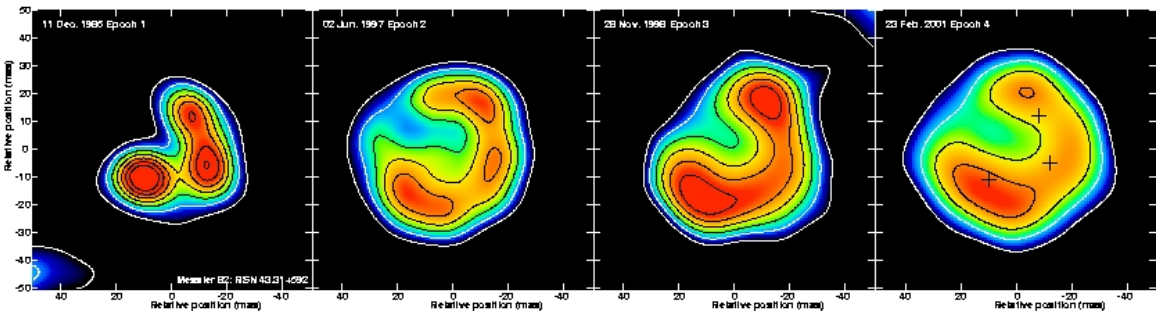


EVN+MERLIN image of the northern component in Mrk 273 at 5 GHz. The peak surface brightness in the image is 0.74 mJy/beam. The unresolved feature N1 and the region N2 are labeled on the map.

Radio studies of extragalactic supernova remnants (SNR) are currently limited by sensitivity and to some extent angular resolution. However such studies are essential as they provide unique insights into the early evolution of radio supernova and supernova remnants. Within starburst galaxies such studies have several distinct advantages, the first of which is the inherently high star formation rates. This allows a relatively large number of SNR to be studied at the same time. These sources tend to have ages that can be measured in decades rather than centuries which are more applicable to galactic remnants. Additionally, because the area over which the starburst occurs is typically a kiloparsec or so in extent, and as the distances to the nearest starburst galaxies are a few Mpc, the relative distances to each individual SNR will only vary by a fraction of a percent. Consequently radio interferometric studies of starburst galaxies offer an ideal opportunity to study samples of SNR at the same distance, with a constant linear resolution and surface luminosity limit.

Over the last 18 years R. Beswick (JBO) and collaborators have regularly used VLBI to observe the radio structure and expansion of the SNR within the nearby prototypical starburst M82. The last epoch of these observations was made in March 2004.
Within M82 ~50 compact radio sources have been observed, with roughly two thirds of these identified as SNR. However when observed with VLBI only a few of these sources are detected.
One of these sources is the compact shell-like remnant 43.31+592 (see Figure below). In the latest of this series of observations we demonstrate that the shell of RSNe 43.31+592 is freely expanding at a rate of 7350+/-2100 km/s. This is consistent with our previous epochs and contrary to the theoretically predicted expansion rates of ~500 km/s expected for RSNe in the high pressure environment of the M82 starburst region.

The next epoch of observations, scheduled for later this spring, will help to constrain further this expansion rate, as well as possibly allowing the detection of any deceleration.



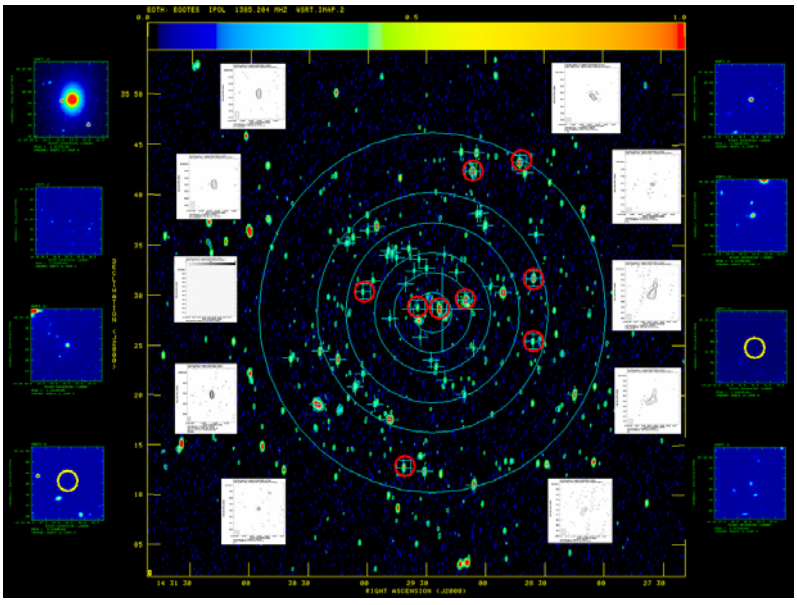
False-colour images of 4 epochs of VLBI observations of the RSNe 43.31+575. All images have been convolved with a circular 15mas beam in order to match the earliest 1986 EVN-only epoch. The crosses marked on epoch 4 represent the positions of the three compact knots observed in epoch 1.

Paragi and Garrett (JIVE) observed SN2004aw, in NGC3997, with the VLA, in a broad collaboration with theorists and X-ray astronomers. SN2004aw was an extremely bright type Ic supernova, which suggested that this source may have been related to a gamma-ray burst. However, no GRB was ever associated with this source. If this object was an off-axis GRB, one might expect to see radio emission from the decelerated radio jets some time after the explosion. SN2004aw was not detected with the VLA at the epoch of the observations.

2.3 VLBI surveys of extragalactic sources

Advances in VLBI recording technology, correlation output data rates and off-line analysis techniques now permit the detection of sub-mJy radio sources across a wide field of view, comparable to the FWHM of the primary beam response of individual VLBI antennas.

NOAO Bootes Field - Garrett (JIVE), Wrobel (NRAO), and Morganti (ASTRON) have conducted deep, wide-field 1.4 GHz VLBI observations of an area of sky located within the NOAO Bootes field, using the NRAO VLBA and 100-m Green Bank Telescope. Applying wide-field VLBI techniques, a total of 61 sources, selected from a WSRT image, were surveyed simultaneously with a range of different sensitivities and resolutions (see Figure).



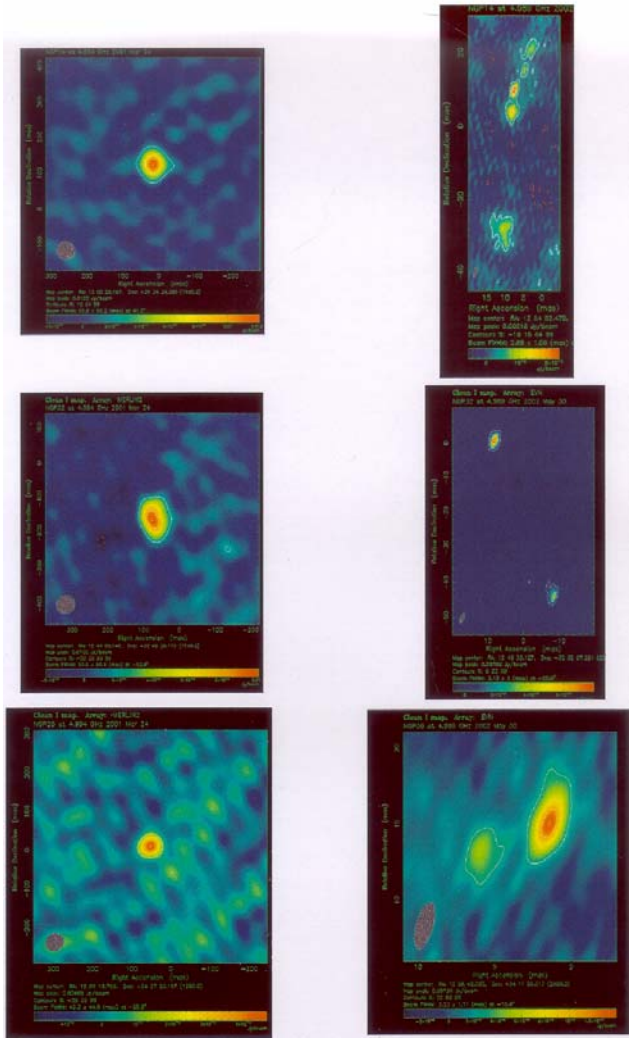
Deep GBT-VLBA 1.4 GHz observations of the NOAO Bootes Field. The rms noise level in the central region of the VLBI images (shown in black-white) is 9 microJy per beam. Optical identifications are shown at the edges of the figures.

The inner 0-2', of the field reached an unprecedented 1-sigma rms noise level ~9 microJy/beam and yielded 2 detections. These are the deepest VLBI images made to date. A further 7 sources were detected in the rest of the field. All of the sources have a brightness temperature in excess of 10^5

K; suggesting they are AGN. Optical identifications are available for 8 of the 9 VLBI detections - only VLBI J142906.6095 remains unidentified (I > 25.6m). Two sources are not detected in K-band (K > 18.5m) suggesting that some significant fraction of these compact radio sources may be located at z > 1. The VLBI detection rate for sub-mJy radio sources is 8%. The VLBI detection rate for mJy sources is higher, 29%. This trend is expected if the radio emission associated with fainter sub-mJy and microJy sources increasingly arises from extended regions of star formation. The 9 VLBI detections pin-point the precise location of AGN or candidate AGN, and their VLBI positions can help to anchor the NOAO Bootes field to the ICRF. The simultaneous detection of several sub-mJy and mJy radio sources, in a single observation, suggests that their combined response may be used to self-calibrate wide-field VLBI data. Future VLBI observations of faint sub-mJy and microJy radio sources can take full advantage of this "full-beam" calibration technique.

Spitzer First Look Survey Field - Morganti (ASTRON), Garrett (JIVE), and collaborators prepared a paper presenting deep WSRT observations of the Spitzer First Look Survey. Wrobel (NRAO), Garrett (JIVE) conducted VLBA observations of bright mJy sources in the same field; these will be used as in-beam calibrators in planned Global VLBI Deep Field observations. Frayer (Spitzer SciCtr, Caltech), Garrett (JIVE), Morganti (ASTRON) and collaborators studied the IR properties of radio-selected submillimeter galaxies in the Spitzer First Look Survey field. Garrett (JIVE) and Orienti (INAF Bologna) made a detailed comparison of the Spitzer Mid-IR and WSRT faint radio source populations in the Spitzer First Look Survey.

DEVOS (Deep Extragalactic VLBI-Optical Survey) Recent progress in VLBI techniques makes it possible to explore parsec-scale structures in complete wide-field samples of tens of thousands of faint radio sources. In combination with state-of-the-art optical surveys such as the Sloan Digital Sky Survey (SDSS) this permits a census of the small-scale radio structures of faint active and starburst galaxies. In 2003 Gurvits & Garrett (JIVE), S.Frey & L.Mosoni (Satellite Geodetic Observatory, Hungary), Garrington (JBO) and Z. Tsvetanov (Johns Hopkins) began a pilot project called DEVOS (Deep Extragalactic VLBI-Optical Survey) aimed at working out observing methodology and data processing algorithms for massive VLBI surveys of optically identified extragalactic radio sources.



Extragalactic VLBI targets are distributed over a broad range of redshift reaching z~6. In order to achieve conclusive results on the intrinsic properties of sources as well as possible imprints of cosmological models, one has to match in luminosity sources detected and imaged with VLBI at low redshift (e.g., z=0.1) with those at high redshift (z=1). This requires VLBI study of high-redshift sources with luminosities as low as 10^23 - 10^25 W/Hz, which correspond to mJy-level flux densities. With the present-day VLBI instrumentation, such the level of sensitivity can be studied by using the phase-referencing technique.

MERLIN (left column) and VLBI (right column) images at 5 GHz of the sources NGP14, NGP32 and NGP36. Peak brightness of the VLBI image of NGP36 (bottom left image) is 1.4 mJy/beam, the lowest detected in the pilot DEVOS project. Note a striking difference between MERLIN-scale and VLBI-scale morphologies of the sources.

In the DEVOS pilot observations conducted in 2001, a demonstration sample of 47 radio sources from the VLA FIRST survey were chosen in the North Galactic Pole region within 2 degrees from the strong compact source J1257+3229. The latter was used as a reference calibrator. The sample sources were denominated NGP01 through NGP47 in the order of decreasing FIRST flux density. The weakest sources in the sample, NGP47 has the FIRST flux density of 30 mJy. In the first step of the project, all 47 sources were observed with the MERLIN at 6 cm. These observations resulted in filtering out those sources which are resolved at the angular scale of tens milliarcseconds. The remaining 37 sources were observed with the Global VLBI array at 5 GHz in one observing run of ~21 hours. The phase-referencing cycle included 2 min pointing on the calibrator and two scans on two weak targets. Each weak target was observed in 6-7 cycles providing up to 14 minutes of integration per source. The off-source image noise in these observations was ~200 microJy/beam. Twenty of the observed 37 sources turned to be below the detection limit of the experiment. The remaining 17 sources (about 1/3 of the original sample of 47 sources) turned to be bright enough for VLBI imaging. Examples of some of the images are shown in the Figure.

Based on the DEVOS pilot project one can estimate that a sample containing of order 104 faint radio sources in the luminosity range 1023 - 1025 W/Hz can now be surveyed at cm wavelengths with the milliarcsecond angular resolution. Such a high resolution radio survey, in conjunction with optical photometric and spectroscopic data from the SDSS, will provide a new ground for extragalactic studies. By increasing the number of VLBI-imaged sources by ~2 orders of magnitude, a new quality of astrophysical and cosmological applications is likely to emerge.

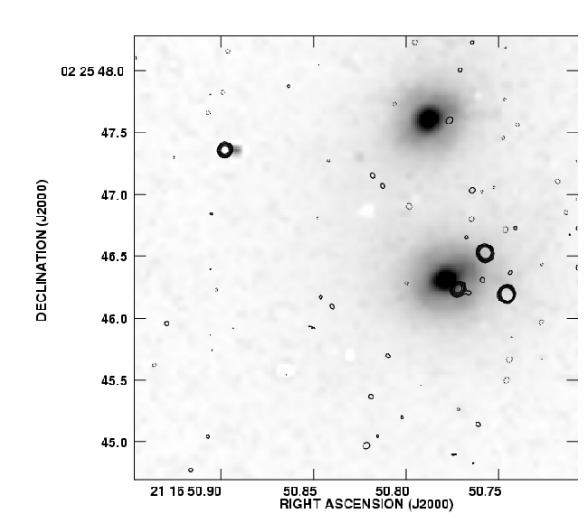
VSOP - Gurvits (JIVE) continued to participate in the VSOP Survey data analysis. He investigated the overlap between the VSOP and other (radio and optical) surveys of extragalactic radio sources and began a study of the sub-mas-scale distribution of spectral indices in the sample of extragalactic sources using VSOP Survey at 5 GHz and VLBA/VSOP Survey at 15 GHz. Gurvits & Paragi (JIVE), Frey (SGO), Lobanov (MPIfR Bonn), and collaborators continued to study milliarcsecond-scale radio properties of quasars at z>4 using data from VSOP and other facilities. A paper is in preparation.

CJF - The CJF is a complete flux-limited sample of 293 bright (S >= 350mJy at 6cm), flat-spectrum (spectral index > -0.5 between 6 and 20cm) radio sources in the northern sky (Dec >= 35) and away from the galactic plane (|b| >= 10). Quasars comprise 66.9% of the CJF, radio galaxies 18.4%, BL Lac objects 11.3%, and yet unclassified objects 3.4%. Britzen (MPIfR Bonn, U.Heidelberg), Vermeulen (ASTRON), Campbell (JIVE) and collaborators have made multi-epoch observations of the full CJF, to form the basis of a statistical study of the kinematics of the sources' jet components. The accumulated motion statistics can be used to investigate correlations with redshift or source type, both bearing on unification scenarios.

VLBI observations of CJF sources have been conducted since 1990, accumulating 3-4 epochs on each source. A variant of difmap was used to fit a circular- Gaussian component model for each source at each epoch, including output of statistical uncertainties for the model parameters and the correlation matrix of the fit. A comparison of the resulting uncertainties for selected sources with those more rigorously determined via difwrap, confirmed that the automated procedure did not introduce noticeable biases. Including the uncertainties and correlation matrices as input co-variances in the subsequent kinematic modelling, retains more information -- or perhaps better, more of the lack of information -- from the original observations following the fitting of simple circular Gaussian components. The kinematic model comprised, for each jet component, a

position at the mean epoch and a single (Cartesian) proper motion, again with uncertainties in the model parameters and the correlation matrix of the fit. Radial and azimuthal components of the proper motions follow directly from the above results.

2.4 Gravitational lenses

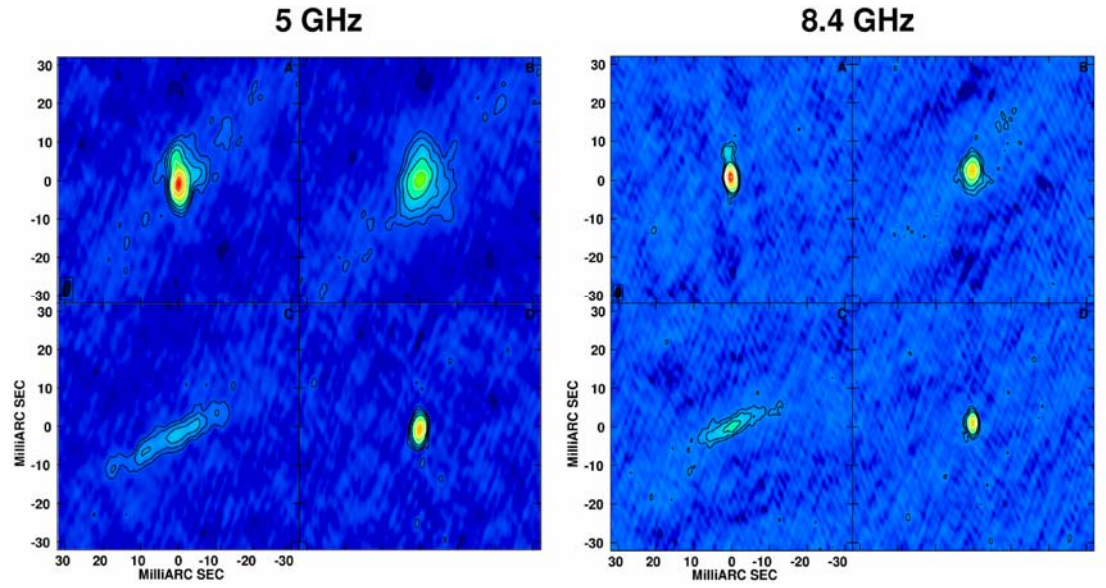


The gravitational lens survey, CLASS, discovered 22 lens systems in total, 6 of these coming from the bright subset JVAS. One of these is B2114+022, a system that has proved difficult to fully explain. It consists of four components, unresolved with MERLIN, three of these fitting into a 0.5 arcsec box plus a fourth located about 2.5 arcseconds away.

MERLIN 5-GHz map of JVAS B2114+022 (contours) overlaid on an HST NICMOS exposure (greyscale)].

The arrangement of the components is extremely characteristic of gravitational lensing, but there is considerable doubt about whether all four components are lensed images of the same source. While models can be found which fit the positions and flux density ratios of all four components, VLBI observations have shown that the components have very different structures, two being core dominated (A and D) and the other two extended with no sign of any compact structure (B and C).

In order to better understand the structure of the extended components and to locate a jet seen in the brighter of the two compact components in the fainter, Biggs (JIVE), Browne (JBO) and Augusto (Univ. Madeira) have obtained further time with the VLBA, a full long-track at both 5 and 8.4 GHz.

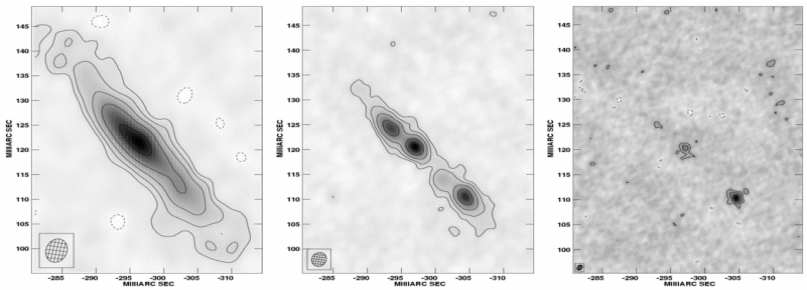


VLBA maps of components A, B, C and D of JVAS B2114+022 at 5 GHz (left) and 8.4 GHz (right).

A map of each component at both frequencies is shown in Figure. The compact structure of A and D is evident, as is the northward-pointing jet in A. Very close inspection of the contours of image D suggests that it is slightly extended to the east. This may be the counter-part to the jet in A, D being three times fainter (and therefore smaller) than A. As for B and C, each looks very different to A and D, but in different ways. At 8.4 GHz B is fairly featureless, but does show signs of structure. By 5 GHz it has become much more resolved and has a rather striking shape, that of an upward pointing arrowhead. C, on the other hand, is very resolved at both frequencies and very elongated. It too becomes significantly larger at the lower frequency.

Explaining these component structures is not easy. What seems clear is that A and D are true lensed images of a background radio source, their morphologies being perfectly consistent with the lens hypothesis. B and C are most likely associated with the primary lensing galaxy (there are two lensing galaxies at different redshifts). The available astrometry places C close to the center of this galaxy and at 8.4 GHz image C is centrally peaked, resembling a weak radio core with symmetric jets. In this scenario, B is a lobe associated with one side of this jet. The problem with this interpretation is that there is no detection of a corresponding lobe to the east. Lower frequency VLBA and Global VLBI data are still in the process of being analysed and may help to explain this intriguing lens system.

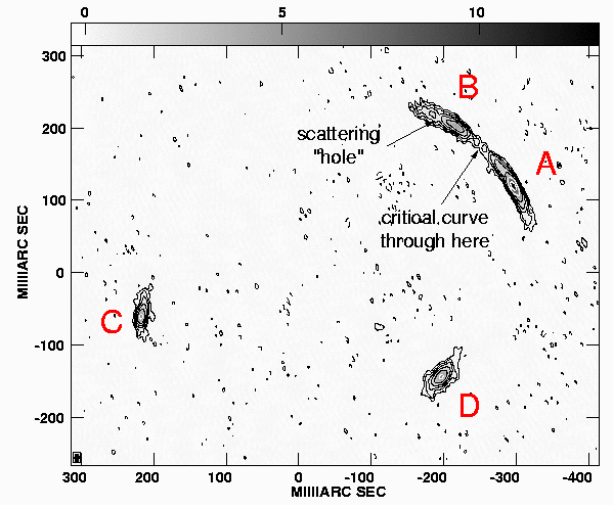
Biggs (JIVE) and members of the CLASS consortium carried out multi-frequency VLBI, optical and infrared observations of the quad lens system B0128+437, an intriguing source that lead us to believe that one of the images in this system is heavily scatter-broadened by ionised gas in the lensing galaxy. A search for HI absorption in the lens galaxy of this system with the WSRT proved negative although not all possibilities for the unknown lens redshift could be investigated due to RFI.



VLBA maps of image A of B0128+437 at 2.3 GHz (left), 5 GHz (middle) and 8.4 GHz (right).

New EVN and HST NICMOS data were acquired. The new EVN data were observed at a wavelength of 21cm, the longest to date for this system (13, 6 and 3.4cm having already been observed) and where the source is brightest and the postulated scatter broadening greater. The most striking aspect of maps made from these data is the continued increase in size of the images towards longer wavelengths.

One result of this is that the two merging images are now actually seen to merge, with a pair of components marking the probable location of the critical curve.

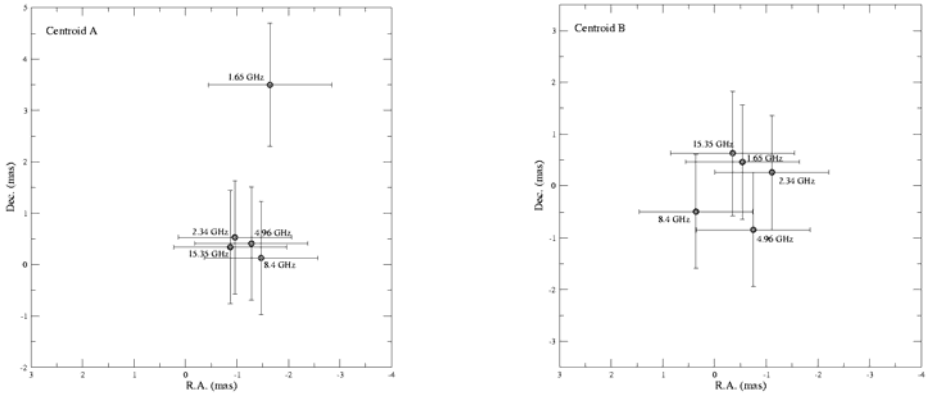


This will lead to better mass models. The scattering region is clearly visible as a pronounced "hole" in image B. Preliminary analysis of the HST data is underway and shows that image B is completely extinct, presumably due to dust associated with the gas responsible for the scattering.

EVN 1.4 GHz map of B0128+437. The area of scattering in image B is marked as is the position of the critical curve that passes between images A and B.

Biggs (JIVE), Browne (JBO), de Bruyn (ASTRON) and Koopmans (Univ. Groningen) completed of WSRT monitoring, at 5 GHz, of the gravitational lens system CLASS B2045+265. Twenty epochs of data collected over a period of ~ 4 months showed that the total flux density of the images (WSRT cannot resolve the individual images) was varying on timescales of days, with variations typically at the few per cent level and a maximum change of 5 per cent between consecutive epochs. This monitoring campaign was initiated as a means of confirming the variability of the individual lensed images that had previously been seen with MERLIN; WSRT, unlike MERLIN, has a proven track record of gravitational lens monitoring. Examination of archival VLA data (8 epochs at 8.4 GHz) also provided evidence for significant variability. Due to the low Galactic latitude of B2045+265 and its close proximity to the turbulent Cygnus region of the sky, the variability is probably a consequence of interstellar scintillation.

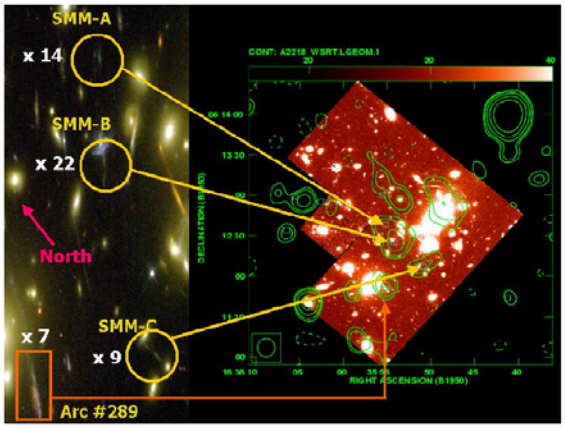
Mittal and Porcas (MPIfR), together with Browne (Jodrell), Biggs (JIVE) and Wucknitz (U. Potsdam), have continued their multi-frequency VLBI study of the gravitational lens B0218+357. The technique of "inverse phase-referencing" has been used to register the maps of B0218+357 at 1.7, 2.3, 5, 8.4 and 15 GHz, using the reference source 0215+354. The goal of these observations is to investigate to what extent any frequency-dependence of the position and structure of the background (lensed) source, when combined with realistic macro-models of the gradient of image relative-magnification across the field, could explain the anomalous frequency-dependent image flux density ratio observed in this system. An initial result is that the position of the centroid in the brightness distribution of A changes by ca. 5 mas between 15 and 1.7 GHz but in the direction along which the image relative magnification remains roughly a constant. In image B, there is no registered shift in the position of the centroid.



Relative positions of the centroids of B0218+357 images A and Bat five frequencies, derived from phase-referenced observations.

Garrett (JIVE) and Knudsen & van der Werf (Leiden) analysed 8.2 GHz VLA archive data of the rich cluster Abell 2218, detecting the first example of cluster lensing -- specifically lensed radio emission from the multiply imaged, z=2.516 submillimetre selected galaxy, SMM J16359+6612. Follow up WSRT observations detected all three images with the radio positions found to be coincident with the SCUBA sources.

The WSRT contour map (right) overlayed upon an HST image of the central regions of Abell 2218. Details of the optical morphology of the multiply lensed sub-mm galaxy are shown in the left-hand panels.



This is the widest separation lens system to be detected in the radio so far (see Figure), and the first time that multiply imaged lensed radio emission has been detected from a star forming galaxy, all previous multiply-lensed radio systems being associated with radio-loud AGN. Taking into account the total magnification of ~45, the WSRT 1.4 GHz observations suggest a star formation rate of 500 solar mass per year. The source has a steep radio spectrum and an intrinsic flux density of only 3 microJy at 8.2 GHz. Three other SCUBA sources in the field are also detected by the WSRT, including SMM J16359+66118, a singly imaged (and magnified) arclet at z=1.034. Higher resolution radio observations of SMM J16359+6612 (and other highly magnified star forming galaxies) will provide a unique opportunity to study the general properties and radio morphology of intrinsically faint, distant and obscured star forming galaxies. They can also help to constrain the technical specification of next generation radio telescopes, such as the Square Kilometre Array.

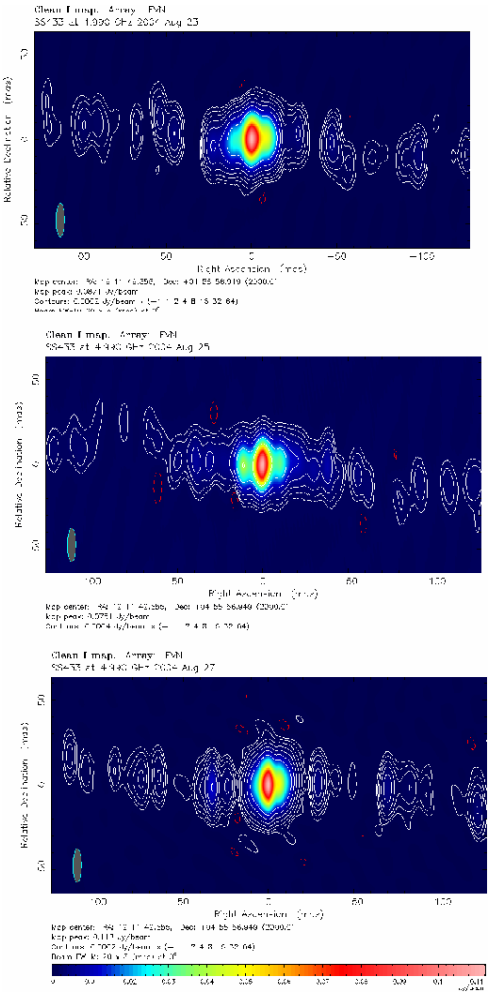
2.5 Galactic astronomy

Solar-system astronomy

JIVE has entered into collaboration with ESA to provide VLBI tracking of the Huygens probe as it descends through the atmosphere of Titan on 14 January 2005. The descent will be under parachute control, and last about 2.5 hours. The probe may then remain 'alive' subsequently on the surface of Titan until its batteries are depleted. VLBI tracking during the descent would provide information about dynamics of Titan's atmosphere. The observations will require a wide-band component in order to establish phase-referencing, plus also a very narrow-band component, as the Huygens S-band signal (2.04 GHz) occupies <1Hz in spectral width and is very weak (never being intended for tracking from Earth). An additional complication ensues from the 'footprint' of the descent falls entirely over the Pacific Ocean.

Much time was therefore spent in preparation for the actual observations. First, we arranged participation from the various stations in the Pacific region in the U.S., Eastern Asia, and Australia who could usefully observe the descent. The non-standard frequency of the Huygens signal and the coordination of different recording systems were principal issues. All participating stations had to be equipped with appropriate disk-based recording, and the capability to translate non-Mk4/VLBA formats onto Mk5 disks developed. A series of 'reconnaissance' observations of the area of the sky surrounding the Titan position of 14 January 2005 were carried out at several frequencies with the WSRT, ATCA, MERLIN, the VLA, and the EVN. A suitable phase-reference source (J0744+2120, 40mJy) was detected 30' from the future Titan position. Two 'dress rehearsal' VLBI observations were made on other spacecraft (Cassini, Mars Explorer) from the participating stations, which allowed the full data path from disk recording to processing through the (standard) wide-band correlation and the special-purpose narrow-band software correlation.

Smith et al. 2003 reported global VLBI observations of the T Tauri system at 8.4 GHz. A compact source was detected offset approximately 40 mas from the best infrared position of the T Tau Sb component. This source was unresolved, and constrained to be less than 0.5 mas in size, or 0.07 AU or 15 Rsun at a distance of 140 pc. The other system components (T Tau Sa, T Tau N) were not detected in the VLBI data. The compact source showed rapid variability which together with its circular polarization indicated that the observed flux arises from a magnetically-dominated region. Brightness temperatures in the Mega Kelvin range point to gyro-synchrotron as the emission mechanism for the steady component. The rapid variations are accompanied by dramatic changes in polarization and at times 100% circularly polarized emission was detected. This observation strongly suggests a coherent emission process, most probably an electron cyclotron maser. Based on this assumption the strength of the local magnetic field was estimated to be 1.5-3 kilogauss.



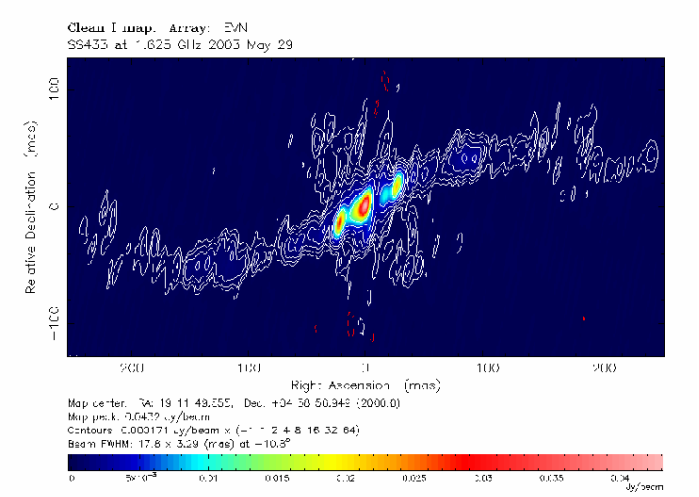
X-ray binaries and micro-quasars

Paragi (JIVE) conducted circular-polarization VLBI observations of the Galactic radio-jet source SS433 (see Figure).

Images of the micro-quasar SS433 from EVN observations, each taken two days apart (23, 25, 27 August 2004).

The Figure shows images from the EVN observations, each taken two days apart. The goal of this project is to observe SS433 in special companion star-accretion disk geometries, which may help to understand the relation between the accretion flow and structural changes in the radio jets. The preliminary results are in broad agreement with the ejection of the jet material occurring in bullets from a non-Keplerian disk, as predicted by magnetized two-component advective flow models.

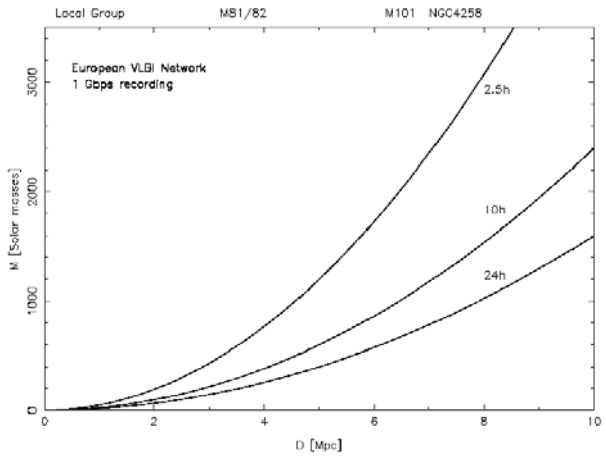
This work was carried out in a big collaboration with many researchers involved from various institutes. They detect neither linear nor circular polarization in the source on milliarcsecond scales, with a 3 sigma upper limit of 300 microJy/beam. Further analysis of the WSRT data showed that indeed the source was not circularly polarized at this epoch.



Global VLBI image of the precessing jets and the equatorial emission region of SS433. The observations were carried out at 1.6 GHz with the EVN, VLBA, the Green Bank Telescope, and a single dish of the VLA. There was no circular polarization detected in SS433 at this epoch. Linear polarization is also undetected in the inner ~100 mas region, which suggests that the source is depolarized by thermal plasma.

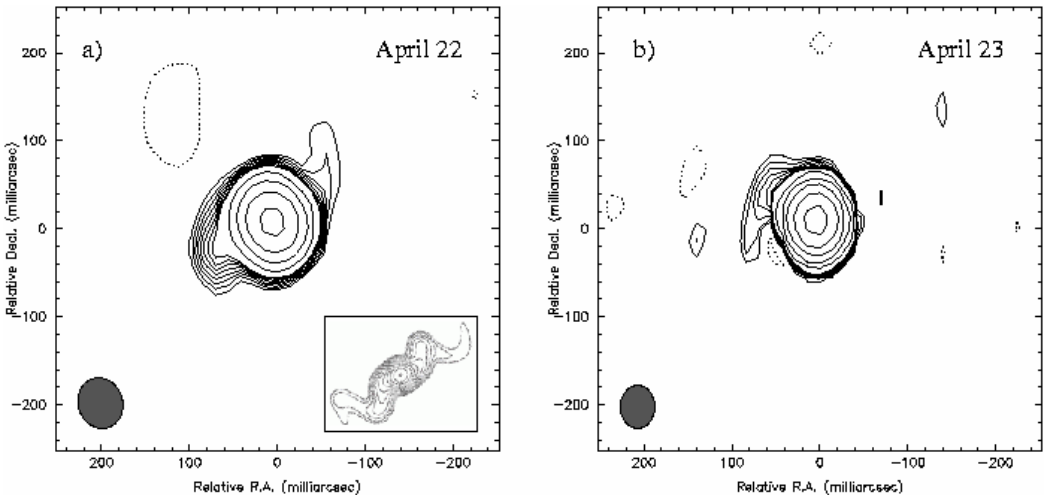
In August 2004 Paragi (JIVE) organised ad-hoc EVN observations of SS433, to support a multi-wavelength observing campaign initiated by S.K. Chakrabarti (SNBNCBS, Kolkata, India). The source was monitored for a week in the radio regime with the EVN and the GMRT, and in the X-rays with the RXTE satellite.

Paragi showed that intermediate-mass black holes (IMBH), if they exist, might be detected in nearby galaxies. If these systems produce radio jets analogous to micro-quasars and active galactic nuclei, we can estimate their radio flux. The EVN has the sensitivity to detect an IMBH with masses of several 100s to 1000s Solar masses (see Figure).



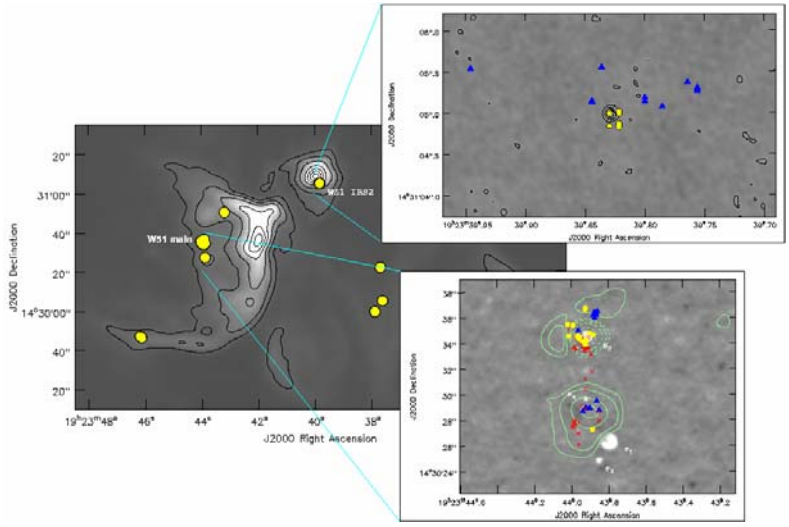
The minimum detectable mass of an intermediate-mass black hole in nearby galaxies with the EVN (1.6 GHz, 1 Gbps recording rate). The minimum black hole mass is given for distances up to 10 megaparsec, for on-source integration times 2.5 hours, 10 hours, and 24 hours.

Massi (MPIfR) together with Ribó, Paredes, Garrington (JBO), Peracaula and Martí have performed two consecutive MERLIN observations of the X-ray binary LSI+61o303. The first observation (see Figure below) shows a double-sided jet extending up to about 200 AU on both sides of a central source. The jet shows a bent S-shaped structure similar to the one displayed by the well-known precessing jet of SS433. The precession suggested in the first MERLIN image becomes evident in the second one (Fig 1 b), showing a one-sided bent jet significantly rotated with respect to the jet of the day before. Massi and collaborators conclude that the derived precession of the relativistic (beta=0.6) jet explains puzzling previous VLBI results. Moreover, the fact that the precession is fast could be the explanation of the never understood short term (days) variability of the associated gamma-ray source 2CG~135+01.



Masers in star-forming regions, proto-stars and HII regions

Methanol masers are often associated with ultra-compact HII regions and a fraction of these sources show linear velocity structures. In some cases it is reasonable to argue that these structures are the front-side of a rotating structure around a proto-star, but in general such velocity gradients could also arise in outflows. Moreover, approximately 2/3 of the methanol masers are not directly associated with an ultra-compact HII region, some are not in a known star-formation region and few actually show a clear linear gradient when mapped. This is demonstrated clearly in the EVN map of the well-known W51 region obtained by Phillips (ATNF) & van Langevelde (JIVE), exploiting the wide-field imaging capabilities at JIVE. Over an area of 4 arcminutes methanol masers were found in 8 distinct sites; three of these are very rich in other masers and clearly associated with sites of activity. The morphology of these methanol masers and their location with respect to the ultra-compact HII regions seems to argue for an out flow or shock origin of the masers (see Figure).

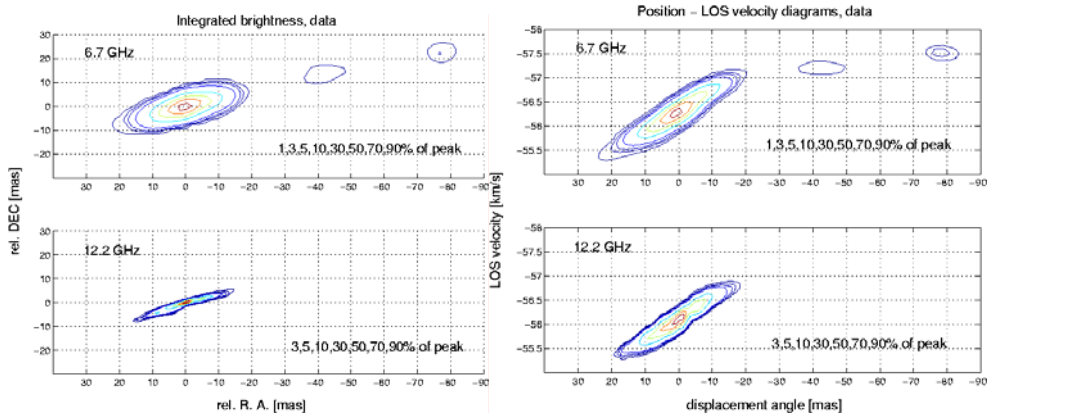


However, the same figure also shows 5 methanol masers without a clear association in other tracers. But from excitation and chemical arguments it is clear that something must be brewing at these sites as well. Methanol is thought to be formed on the icy grain mantles and can only be abundant in the gas phase if these grains have been evaporated recently.

Circles show the positions of methanol masers towards W51A, overlaid on 4.8 GHz continuum observed with the VLA. The inset shows details of the W51 main region and the IRS2 region with various other molecular tracers and high-resolution continuum. At a distance of 7 kpc, 1" corresponds to 7000 AU.

Imai (JIVE) and collaborators made VLBI observations to determine the linear polarization of water masers in the massive-star forming region W3 IRS5. Imai and van Langevelde (JIVE) began a project to study water masers in the star-forming region L1287.

Pestalozzi, Elitzur, Conway and Booth (OSO), 2004 presented modeling of 6.7GHz EVN and 12 GHz methanol maser observations toward the massive star-forming region NGC7538-IRS1 (see Figure below). It was shown that the maser in the main spectral feature almost certainly arises in an edge-on rotating circumstellar disk. Although such a disk origin has been suspected for a while this is the first strong proof in any methanol maser. The position-velocity diagram (see Figure below) shows a distinctive curvature which can be fitted assuming the methanol maser emission occurs in a range of radii in a disk with differential rotation. There is sufficient data that all the main parameters of the maser model are well constrained. The methanol maser occurs from radii of 350AU to 1000AU around a 30 solar mass central object. As well as being a first for methanol masers this result provides one of the few convincing pieces of evidence in any waveband for circumstellar disks around massive (> 8 solar mass) stars. This result strengthens the conviction that despite the theoretical difficulties massive stars form in the same way as low mass stars, i.e. via disk accretion.

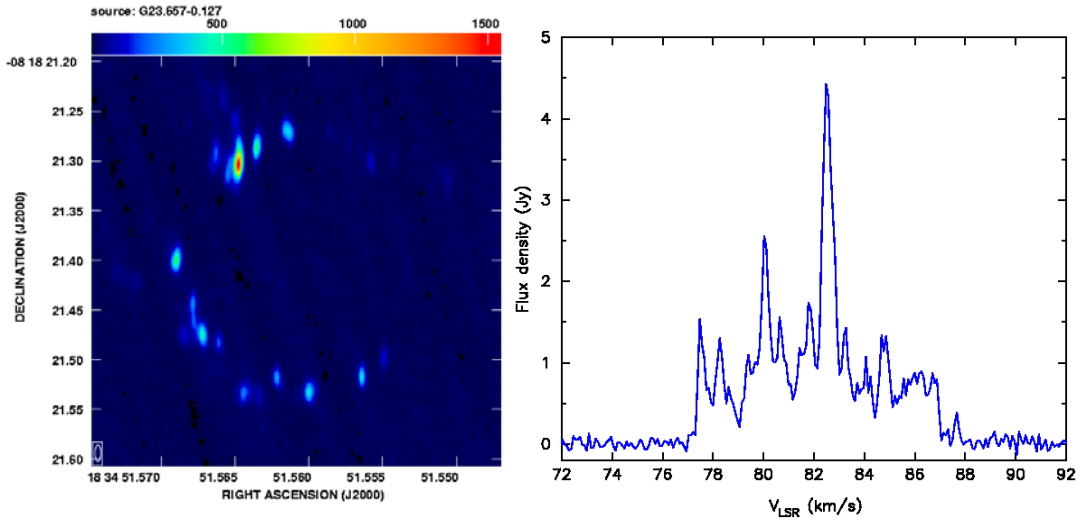


Methanol maser observations of NGC7538-IRS1 taken from Pestalozzi et al (2004). Left: Velocity integrated emission maps of the 6.7GHz (EVN) and 12GHz (VLBA) methanol masers in the main spectral feature of NGC7538-IRS1. Right: Position-Velocity diagram for the two masers where the emission have been integrated over the direction perpendicular to the source major axis.

MERLIN observations of the OH masers in K 3-35 were performed by Desmurs (OAN) and collaborators, with the goal of obtaining an accurate measurement of the position of this maser respectively to the 18cm OH maser.

M. Szymczak (Torun) and his co-workers continued studies of star formation regions in the Galaxy using methanol 5cm line as the probe of physical properties. Initial 32m survey resulted in several successful EVN proposals. The data are currently being processed; the first results were presented at conferences. The methanol line is known to be a good indicator of proto-stellar disks at intensive star formation regions. There were several EVN (+MERLIN) projects to study selected methanol sources. The main aims of the projects were to determine the special structure of methanol maser sources. The targets are selected from the Torun unbiased survey of the 6.7GHz methanol line in the galactic plane. The current models of methanol source geometry, mechanisms of molecule production in environments of massive (proto-)stars and the relationships of methanol emission with other tracers of star-forming activity were investigated.In the first group of observed sources, linear and arc like structures were detected. There were considerable numbers of maser clusters with internal velocity gradients roughly perpendicular to the major axis. These geometrical structures can arise in outflows and behind shock fronts. A spectacular result provided the observation of the candidate high-mass protostar G23.657-0.127. The 6.7GHz masers originate in a nearly circular ring of 127 mas radius and 12 mas width. The ring structure points at a central exciting object of which characteristics are typical for a young

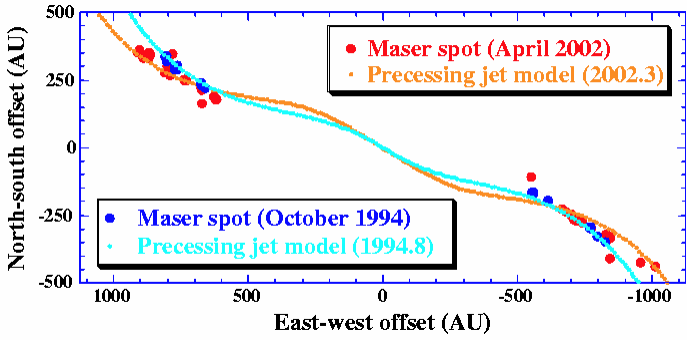
massive star; its bolometric luminosity is estimated to be ≤ 3.2x104 solar luminosity (Lo) and ≤1.2x105 Lo for near (5.1 kpc) and far (10.5 kpc) kinematics distances, respectively. This structure readily offers constraints on the origin of methanol masers by directly determining the separation of the excited region and the young star. Two scenarios are proposed, in which the methanol masers originate in a spherical bubble or in a rotating disc seen nearly face-on. This discovery was possible thanks to the superior image quality which allowed the detection of many weak features. The observations were among the first EVN 5 cm results with 8 antennas. The resulting rms noise level in line-free channels was 3.7 mJy/beam.



Masers in main-sequence stars, evolved stars and HII regions

Water vapor maser emission is a good tracer of dramatic transition phases in stellar evolution, formation of proto-stars and hyper-compact HII regions and rapid release of stellar mass at the time of a star s death. High velocity molecular flows traced by the maser emission from evolved stars are interesting objects for understanding morphological/dynamical change of mass loss of evolved stars and the shaping mechanism of planetary nebulae. In such stellar objects, there are only three water vapor maser sources (W43A, IRAS16342-3814, IRAS 19134+2131) which have very high velocity (> 100 km/s) flows at the final stage of stellar evolution.

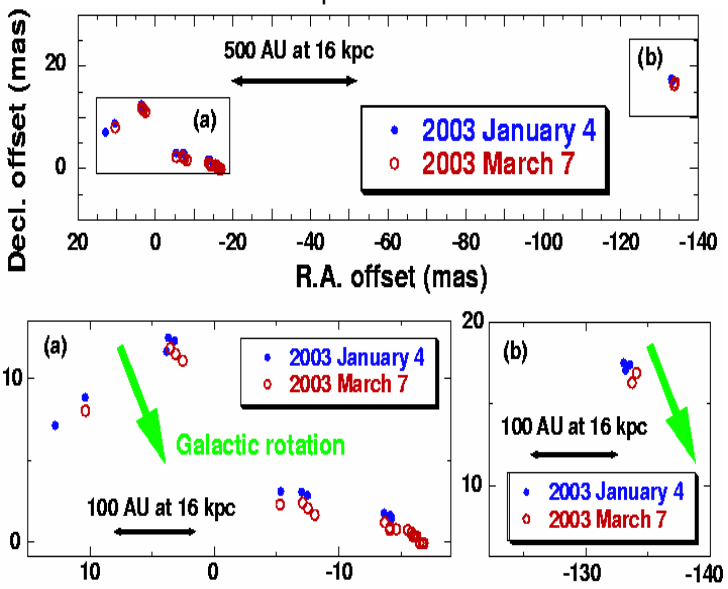
Imai (JIVE), Diamond (JBO), and collaborators have studied the morphology and kinematics of water vapor masers in W43A with VLBA observations. The water masers exhibit an extremely-collimated precessing jet of molecular gas. A dynamical age of the jet was only about 35 years.



The Figure shows the time variation of distributions of water maser features in W43A during 1994 -2002. The dynamical age estimated from maser proper motions for a short time scale (< 1 year) is almost equal to the true jets age, which is estimated from an extension length of maser feature distribution per 8 years. The maser distribution is well fit by a precessing jet model.

Proper motion of water maser features in W43A during 1994-2002.

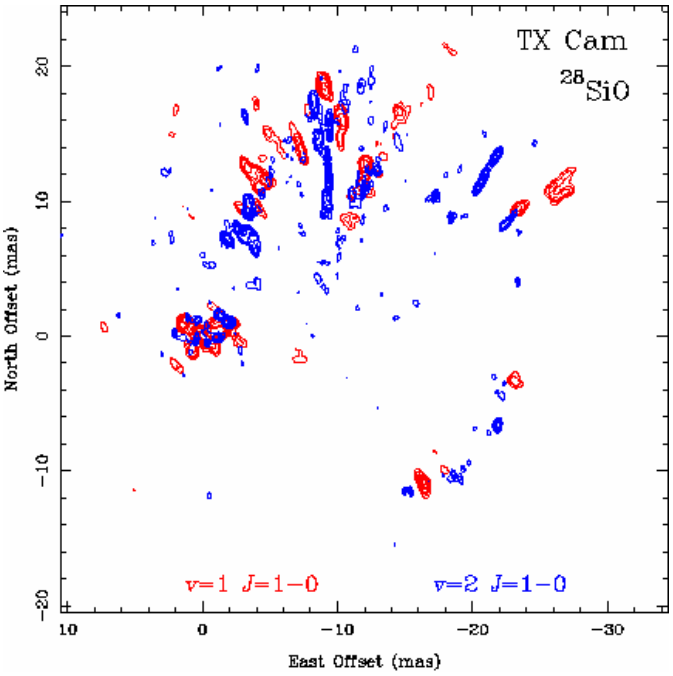
Imai (JIVE) and collaborators also used VLA and VLBA observations to study the morphology and kinematics of water vapor masers in IRAS19134+2131. In the case of this maser source, as shown in Figure, proper motions of the water vapor maser features show an expansion (approximately 120 km/s), blended with an orbital motion along the Galactic plane (around 200 km/s). A dynamical age of the expanding flow is about 50 years, which is roughly equal to that of the W43A jet. However, the jet collimation seems to have been already relaxed, which implies that the IRAS19134+2131 flow is more evolved than that in the W43A jet.



Water vapor maser proper motions in IRAS19134+2131.

Taking into account morphology and kinematics of these two water vapor maser sources and those of IRAS16342-3814, it is expected that such rare water fountains are seen for a very short period (< 100 years). Before or during that stage, an evolved star (OH/infrared-star) becomes a central object of a proto-planetary nebula, which photo-dissociates water vapor molecules in a circumstellar envelope. A collimated jet from an evolved star is also created in the same period. However, the jet formation mechanism is still unclear. Jet ejection from a binary system or from a single star by stellar dynamo action will be directly revealed by future observations.

Several projects to study SiO masers in the circumstellar envelopes of late-type stars are being developed by Soria-Ruiz (OAN), Alcolea, Colomer, Bujarrabal, Desmurs, Marvel (AAS), and Diamond (JBO). A second epoch of observations of 28SiO J=1-0 and J=2-1 (around 43 and 86 GHz respectively, or 7 and 3mm wavelength) v=1 and v=2, and 29SiO J=1-0 v=0 was performed in several AGB stars using the VLBA (see Figure on TX Cam).



SiO J=1-0, v=1 (in red) and v=2 (in blue) masers at 43 GHz towards TX Cam.

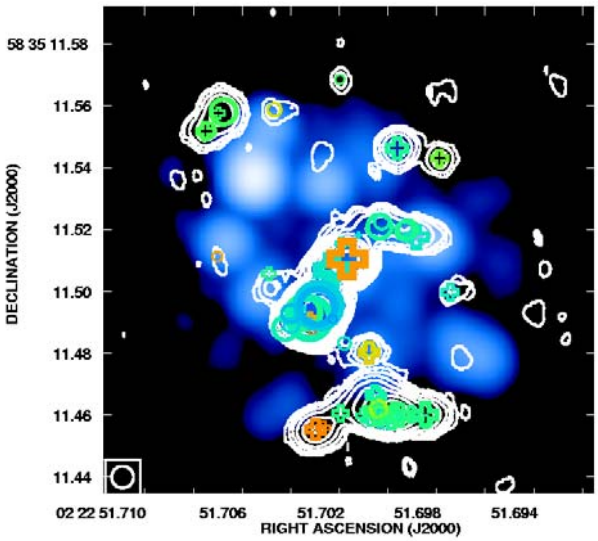
The new results on IRC +10011 (for the first time) and χCyg are published in Soria-Ruiz et al. (2004), The emission at 7mm and 3mm cannot be reproduced by current theoretical pumping models, either radiative or collisional. In particular, for IRC +10011, the v=1 J=1-0 and J=2-1 28SiO lines have different spatial distributions and emitting region sizes, the J=2-1 emission being located in an outer region of the envelope. For

χCyg, the distributions also differ, but the sizes of the masing regions are comparable. The line overlaps between ro-vibrational transitions of two abundant molecular species, H2O and 28SiO, are a possible explanation for the discrepancies found between the observations and the theoretical predictions. This overlapping process has been introduced in the calculations of the excitation of the SiO molecule. The conclusion is that the line overlaps can strongly affect the excitation of SiO and may reproduce the unexpected observational results for the two sources studied.

New studies of the 3mm SiO masers are being conducted with the new Global Millimeter VLBI Array (GMVA). An observational campaign in October 2004 by Colomer, Soria-Ruiz, Bujarrabal, Alcolea, and Desmurs (OAN) is being analyzed.

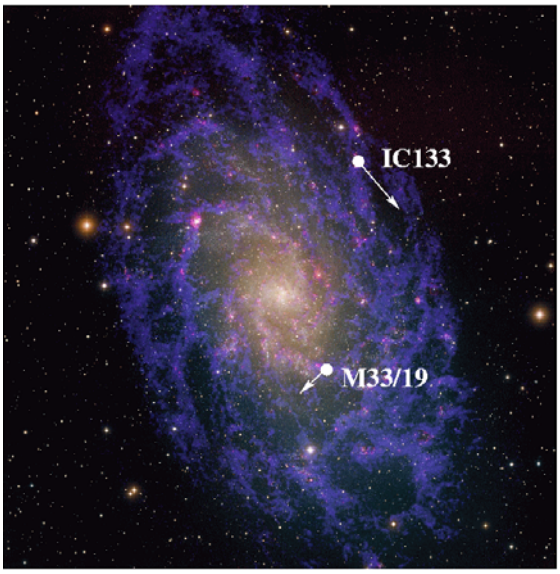
The SiO maser emission v=1 J=2-1 (3 mm) in the bipolar post-AGB nebula OH 231.8+4.2 has been studied by Desmurs, Sanchez-Contreras (Caltech), Bujarrabal, Alcolea, and Colomer. Milliarsecond-resolution maps obtained with the VLBA are compared with previous observations of the v=2 J=1-0 line (7 mm). These observations show that the SiO masers arise in several bright spots forming a structure elongated in a direction perpendicular to the symmetry axis of the nebula. This, and the complex velocity gradient observed, is consistent with the presence of an equatorial torus in rotation and with an infall of material towards the star.

Red supergiant stars and Miras play a significant role in enriching the ISM with dust and light elements like carbon or oxygen. High-resolution interferometry shows that their stellar winds are clumpy; it is not yet clear if this originates from uneven nucleosynthesis in the star itself or differentiation as the wind cools. The winds appear to go from near-spherical as solitary stars enter the red giant stage, to highly bipolar PNe and post-RSG ejecta. EVN and global VLBI observations of S Per (from Richards (JBO), Masheder and collaborators) show that OH masers at 1665 and 1667 MHz are found ~100-200 AU (8-16 stellar radii) from the star, in discrete filaments of average size 15-25 AU with a velocity span of 0.5-2 km/s. The Figure shows that the OH maser clumps are similar in location and size to the water maser clouds, but appear to interleave the water masers and have a more elongated distribution. This has persisted for centuries as it is also seen on a much larger scale in 1612 MHz masers. The Figure also shows that there is significant circular polarization, implying a magnetic field strength ~3 mG. MERLIN data (at lower resolution but in full polarization) give a similar value. This is only a few percent of the average field strength measured from water masers using the VLBA (Vlemmings, Diamond et al.). This surprising discrepancy is similar to the ~1:50 density ratio between the OH and water clumps implied by models for the respective masers. These results show that the stellar wind just outside the dust formation zone is differentiated by density and molecular composition on small scales comparable to the size of the star, that the lower density regions are more elongated, similar to biconical wind components seen in PPNe and explained by the colliding winds model for low-mass stars, and that the magnetic field is probably frozen in to the clumps so that its strength scales with density.



The white contours show the EVN-global VLBI integrated OH mainline maser emission around S Per. The + and o symbols indicate positive and negative Stokes V from regions with >30% circular polarization, shaded according to the maser velocity. The background image shows integrated water maser emission imaged by MERLIN.

2.6 VLBI ASTROMETRY

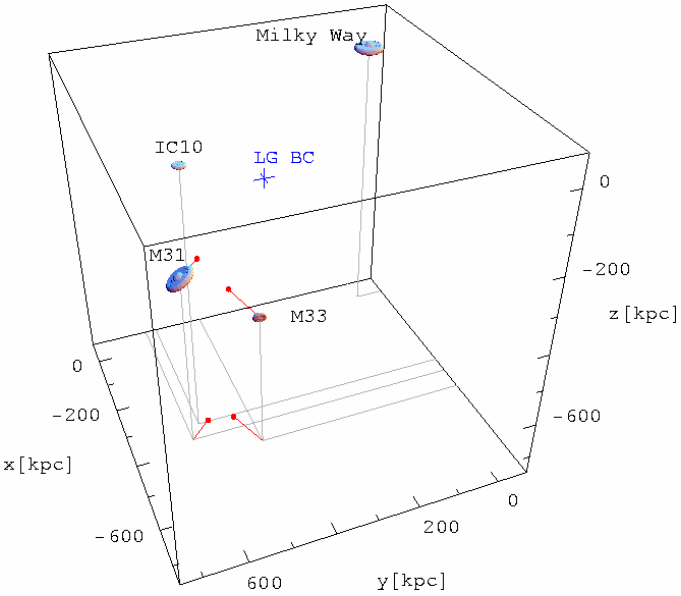


Brunthaler (JIVE), Falcke (ASTRON), Henkel (MPIfR), and collaborators at CfA determined the proper motion of water masers in M33, a small satellite galaxy of M31. Motion of ~30 micro-as/yr with respect to the background quasars were detected, with uncertainties in the order 5 micro-as/yr. Because of the separation of the water maser clumps in M33 (see Figure), translation of the galaxy as a whole could be decoupled from rotation of the galaxy. The VLBI rotational rate, together with the inclination and rotational speed from neutral-hydrogen spectroscopy of M33's gas disk, yields a geometric distance to M33 of 730kpc, with an uncertainty of 135kpc due to uncertainties in the derived M33 rotation and 100kpc due to observational uncertainties in the VLBI proper motions.

The positions of two regions of maser activity and their proper motion relative to the nucleus of M33 as measured by the VLBA. The image of M33 is courtesy of Rector, Thilker (NRAO), and Braun (ASTRON).

The translational motion of M33 is directed towards M31, at a speed of 190km/s relative to the Milky Way (see Figure below).

Searching for additional water maser sources in M33 has continued with the VLA, resulting in detection of an additional source that will be followed up with VLBA observations.



M33's motion in the local group, relative to M31 and to the Milky Way.

Rioja (OAN) participates in the implementation of high precision astrometric capability in observations with VERA (VLBI Exploration of Radio Astrometry), the new Japanese interferometer dedicated to differential VLBI. It consists of 4 20m-diameter telescopes equipped with fully-steerable dual beam configuration which allows observations of two adjacent sources simultaneously. In particular the calibration across the beams was successfully transferred in simultaneous observations of 3C345 and NRAO512 at 22 GHz. The team performed observations of continuum sources (1038+528AB) and YSO line sources.

2.7 Workshops

European Workshop on Astronomical Molecules 2004

From the 17th to 20th February 2004, a meeting on “Dense Molecular Gas around Protostars and in Galactic Nuclei” was held in the town of Zwolle in the Netherlands with the financial support from the RadioNet Consortium. About 50 astronomers from a dozen countries attended the meeting. Most of them were from European Institutes, but some came from Australia, South Africa, and USA. The Workshop program only had oral sessions with 41 talks and ample time for public and scientific discussion.

The objective of the Workshop was to explore molecular research in terms of the diagnostic tools it provides for stellar environments and for galactic nuclei. The meeting provided a platform for a meeting of theory and interpretation, and observations. The atmosphere of the workshop was very congenial and the meeting was full of young scientists that were eager to enter into discussions with the more 'established' participants.
Beside the scientific sessions, the LOC hosted a Workshop Dinner at a historical site just outside Zwolle. LOC members N. Csonka (ASTRON) and M. Tibbe (JIVE) did an outstanding job for the organization of the Workshop. Photos of the workshop as well as links to presentation files can be found at the web page of the meeting (http://www.jive.nl/molecules2004). The symposium proceedings have been edited by Y. Hagiwara, W.A. Baan and H.J. van Langevelde and have been published by Springer.

OAN organized the 7th European VLBI Network Symposium on New Developments in VLBI Science and Technology and EVN Users Meeting

The Observatorio Astronomico Nacional (OAN) of Spain, on behalf of the European VLBI Consortium, hosted the 7th European VLBI Network Symposium on New Developments in VLBI Science and Technology and EVN Users Meeting on October 12-15 2004 in Toledo, Spain.
A total of 97 scientists from all around the world attended the conference, mainly from Europe, but with a large representation of colleagues from Japan, China, Korea and Australia. The scientific program was organized in sessions devoted to:

- Galaxies: AGN and their environment, variability, gravitational lenses, megamasers.
- Stars: circumstellar AGB envelopes, star-forming regions, masers, supernovae, microquasars.
- Instrumentation: VLBI software and hardware, telescopes, new data transport infrastructures (e-VLBI).
- Techniques: Geodetic VLBI, astrometry and phase-referencing, wide-field mapping, mm-VLBI.

We enjoyed 64 oral contributions, including 7 review talks and 12 invited talks, and 28 posters. Many authors have made available their talks on the symposium website:
http://www.oan.es/evn2004/WebPage/proceedings.html
The symposium proceedings have been edited by Rafael Bachiller, Francisco Colomer, Jean-Francois Desmurs, and Pablo de-Vicente (OAN), and were distributed during the conference. The online version of the proceedings book is available at the symposium website, and also on astro-ph. The participants could visit the Yebes observatory (where the Users meeting was held) and check the status of construction of the new 40-m radio telescope, where a group picture was taken.

2.8 Bundesamt für Kartographie und Geodäsie (BKG) – Wettzell, Germany

The Radiotelescope Wettzell (RTW) is jointly operated by the Bundesamt fuer Kartographie und Geodäsie (BKG) and the Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (FESG) within the framework of the Forschungsgruppe Satellitengeodasie (FGS).

At the Fundamentalstation Wettzell (FSW) the 20m Radiotelescope (RTW) for VLBI is collocated with 3 more geodetic space techniques systems:as

- the WLRS (Wettzell Laser Ranging System) designed for SLR and LLR,
- several GPS receivers, integrated in the global IGS-, the European GPS-, and in the national GPS-network, and for time transfer,
- item a DORIS station on loan from CNES/France.

At the Wettzell observatory, the first ringlaser, “G" dedicated to the monitoring of the variations in Earth rotation has been developed in close cooperation with the University of Canterbury New Zealand. The system was established in 1998 to 2001 and is operating since fall 2001. “G" is sensitive to monitoring daily variations better than 10exp-8 relative accuracy.

Additional in situ observations were carried out:

- gravity observations, employing a super conducting gravity meter
- earth quake observations with a seismometer
- meteorological observations to monitor pressure, temperature and humidity, rain fall, wind speed, wind direction and also
- water vapour observations with a radiometer.

A Time and Frequency system (T&F) is established for the generation of time scales (UTC(IfAG)) and for the provision of very precise frequencies needed for VLBI, SLR/LLR and GPS observations, employing Cs-clocks and H-Masers and GPS time receivers. The time scale UTC(IfAG) is published in the monthly Bulletin T of the BIPM.

3. EVN Network Operations

3.1 EVN Program Committee (EVNPC)

The EVN PC is an independent body appointed by the EVN CBD which carries out scientific and technical assessments of all EVN and Global VLBI requests for observing time. A *Call for proposals* is distributed three times a year with proposal deadlines of 1st February, 1st June and 1st October. The EVN PC meets roughly one month after these deadlines to evaluate the proposals. EVN PC members provide reviews of each proposal in advance of the meeting, which are discussed and a final recommendation is formulated to the EVN Scheduler. Summary comments and the detailed comments of each PC member are sent to the PI (with copies to all co-Is) afterwards.

Membership

The EVN PC comprises 7 *observatory* members (including a representative from the EVN data processor at JIVE) which have particular responsibility for assessing the technical feasibility of proposed observations from their observatory's perspective. In addition, there are 5 *at large* members, chosen from non-EVN institutes, to complement the astronomical experience of the observatory members. Proposals requesting the Bonn correlator or the Arecibo telescope or the MERLIN array are also sent to representatives at these institutes for additional review. The EVN Scheduler is a member of the EVN PC, but he does not carry out a scientific evaluation of the proposals.

The start of 2003 saw a new Chairman for the EVN PC, Patrick Charlot from Bordeaux Observatory, to replace the outgoing Chairman, Simon Garrington, who finished his 3-year term at the end of 2002. At the beginning of 2004, three new members (from Florence, Cork and Jaén) were appointed to replace outgoing at large members. During the period covered by this report, the EVN PC membership was as given below:

PC member	Institute
Patrick Charlot (Chair)	Bordeaux Observatory
Javier Alcolea	OAN – Madrid
Marco Bondi	IRA - Bologna
John Conway	Onsala Space Observatory
Simon Garrington	Jodrell Bank Observatory
Dong Rong Jiang	Shanghai Observatory
Andrei Lobanov	MPIfR – Bonn
Richard Strom	ASTRON – Dwingeloo
Huib Jan van Langevelde	JIVE – Dwingeloo
Until 2003:	
Andreas Eckart	University of Köln
Arto Heikkilä	Halmstad
Luca Moscadelli	Cagliari Observatory
Since 2004:	
Claudio Codella	IRA – Florence
Denise Gabuzda	University College Cork
Josep Martí	University of Jaén
Richard Porcas (Scheduler)	MPIfR – Bonn

3.2 Proposal, Observing and Publication Statistics

In 2003 and 2004, six meetings were held, in Madrid (7 March 2003), Gothenburg (3 July 2003), Bologna (21 November 2003), Bordeaux (18 March 2004), Cork (9 July 2004), and Jaén (10 November 2004).

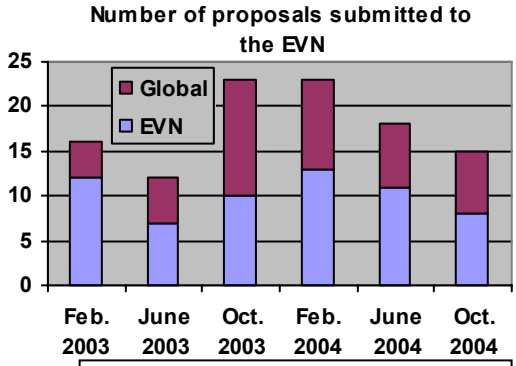


Figure 1: Number of EVN and global VLBI proposals received per deadline during 2003 and 2004.

The number of proposals reviewed at each meeting varied from 12 to 23, with an average of 18 proposals per deadline. This load is comparable to that seen in previous years. The chart in Fig. 1 indicates more specifically the number of EVN and Global VLBI observing requests for each deadline. There were 57% of EVN-only proposals and 43% of Global VLBI proposals for each of the two years. The portion of proposals requesting the MERLIN array, the Arecibo telescope, and DSN antennas over the period covered by this report were 20%, 15%, and 15%, respectively. As usual, the bulk of the proposals requested the prime wavelengths of 6 cm and 18/21 cm where EVN sensitivity is greatest. Each of these two wavelengths contributes to about one-third of all proposals while the other wavelengths contribute each to less than 10% (Fig. 2). Overall, there were 70% continuum projects and 30% spectral line projects.

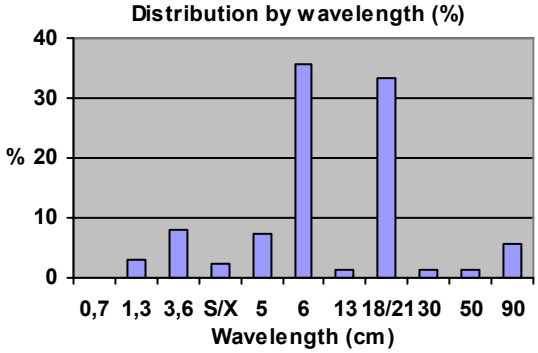


Figure 2: Distribution by wavelength of EVN and global VLBI proposals received during 2003 and 2004.

The range of EVN proposals received covers a wide variety of areas, reflecting the growing applications of VLBI as sensitivity increases. These included studies of masers in star forming regions, individual stars and X-ray binaries, pulsars and interstellar scattering, supernovae remnants in nearby galaxies, weak Seyfert nuclei, environment of active galaxies through OH and HI absorption lines and megamasers, the "classical" studies of AGN jets, and extragalactic and galactic astrometry.

EVN user community

The PIs of EVN and Global VLBI proposals are drawn from a large international user community. During 2003 and 2004, the 107 proposals received originated from PIs affiliated with research institutes located in 19 different countries, about 70% of which are in Europe and 30% in the rest of the world (Fig. 3). Roughly 60% of the proposals had PIs from non-EVN institutes and half of these do not include EVN collaborators either, reflecting the growing of a user community external to the consortium institutes.

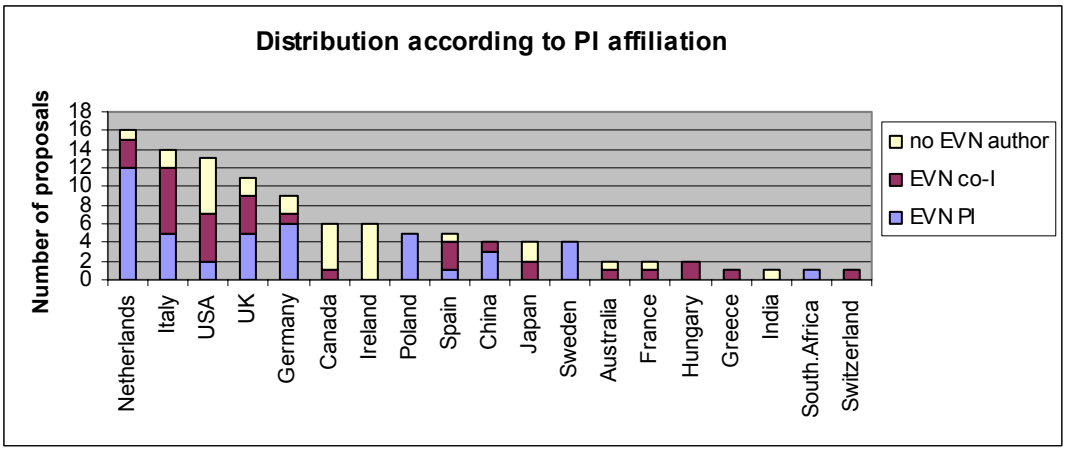


Figure 3: Distribution of EVN and global VLBI proposals received during 2003 and 2004 according to PI national affiliation. A distinction is made depending on whether the PI is affiliated with an EVN institute and when that is not the case whether the proposal includes EVN co-authors.

The EVN PC is also a useful channel of communication with the EVN user community. The Call for Proposals, available as a web page, provides important guidance on preparing proposals. New users often contact the EVN PC Chairman or EVN scheduler for specific questions. An EVN users meeting was held in October 2004 during the EVN Symposium in Toledo. The agenda covered the whole process of doing VLBI from proposal preparation to scheduling, correlation, and data analysis, providing an overview of the way the EVN works in practice and permitting fruitful exchanges with the user community. During the meeting, there was also a presentation about the future of the EVN, drawing prospects for 2010 and inciting users to express their views as regard to possible future capabilities and evolutions.

3.3 Scheduling & Operations

This report contains a summary of the 6 EVN observing sessions held during the 2-year period 2003-2004. Statistical data is given in the form of Tables 3.1 through 3.5, and this is followed by brief reports for each of the sessions. During this period 8 projects approved for observation (2 EVN-only and 6 Globals) became ineligible for scheduling, having failed to be scheduled in at least 2 suitable sessions due to lack of resources.

Qualifying Parameters used in the tables

N-OBS The number of scheduled observations. A single proposal may result in several observations if it requires multiple epochs, frequencies or sources.

HOURS Total number of observing hours scheduled using the EVN.

DAYS Total number of observing days scheduled using the EVN.

T-BYTES Total number of TBytes scheduled at EVN telescopes (including Robledo), assuming 90% recording during the scheduled periods. This number also assumes a full track at all participating telescopes, and hence is an overestimate for projects involving Seshan, Urumqi, Hartebeesthoek and especially Arecibo.

TB/TEL Total number of TBytes scheduled at a single telescope taking part in all the observations.

N-TEL Average number of EVN telescopes (including Robledo) taking part in the observations.

LENGTH Length of session between beginning of first project and end of last project (in days).

Table 3.1 The number of observations for all 6 sessions, giving TOTAL numbers, and subdivisions by experiment type (EVN-only, GLOBAL and Tests), whether Continuum or Spectral Line and by Correlator (Bonn, EVN-JIVE and VLBA).

Feb. 03 – Oct. 04	N-OBS	HOURS	DAYS	T-BYTES	TB/TEL	N-TEL
TOTAL	136	1407.2	58.6	891.8	117.6	7.3
EVN-only	62	810.2	33.8	553.7	66.4	8.2
GLOBAL	40	473.0	19.7	207.6	35.2	5.3
Tests etc.	34	124.0	5.2	130.5	16.0	8.0
Continuum	98	933.0	38.9	742.7	96.7	7.4
Spec. Line	38	474.2	19.8	149.1	20.9	7.2
Bonn-Corr.	8	127.5	5.3	139.8	17.4	7.6
EVN-Corr.	107	1057.2	44.0	664.8	83.8	7.8
VLBA-Corr.	21	222.5	9.3	87.2	16.5	4.6

Table 3.2 The TOTAL numbers for each of the 6 EVN observing sessions.

TOTAL	N-OBS	HOURS	DAYS	T-BYTES	TB/TEL	N-TEL
Feb. 03	6	58.5	2.4	27.7	4.8	5.5
May 03	31	338.5	14.1	196.0	24.9	7.7
Oct. 03	22	223.5	9.7	187.1	23.1	8.0
Feb. 04	21	160.5	6.7	131.7	16.3	8.0
May 04	23	251.7	10.5	153.8	19.3	7.7
Oct 04	33	364.5	15.2	195.5	29.3	6.2

Table 3.3 The TOTAL numbers for each observatory. Observations at Arecibo are assumed to be no longer than 3 hours. Observations at Cm are assumed to be at a bit rate no greater than 256 Mb/s

TOTAL	N-OBS	HOURS	DAYS	T-BYTES	TB/TEL	N-TEL
Eb	115	1248.2	52.0		107.2	7.8
Wb	109	1142.7	47.6		97.5	7.5
Jb	116	1211.2	50.5		102.4	7.6
Cm	56	563.2	23.5		35.9	8.7
On	115	1243.7	51.8		106.1	7.9
Mc	114	1219.7	50.8		106.9	8.0
Nt	109	1147.2	47.8		105.6	7.9
Tr	84	930.7	38.8		71.8	8.4
Ur	48	481.5	20.1		43.6	8.9
Sh	41	420.0	17.5		42.0	9.8
Hh	43	350.5	14.6		29.7	9.2
Ar	16	44.5	1.9		3.2	5.9
Yb	2	27.0	1.1		1.4	7.0
Mh	12	125.0	5.2		11.5	8.1
Wz	0	0.0	0.0		0.0	0.0
Ro	13	128.0	5.3		14.0	9.0

Table 3.4 Scheduling efficiency statistics; CAL includes scheduled amplitude calibration periods.

SESSION	LENGTH (days)	SCHEDULED (days) VLBI + CAL	EFFICIENCY	REASONS FOR LOW EFFICIENCY
Feb. 03	17	2.4 + 0.3	16 %	Effelsberg broken azimuth track
May 03	21	14.1 + 0.6	59 %	
Oct. 03	18	9.7 + 0.9		External scheduling constraints
Feb. 04	16	6.7 + 0.6	46 %	Short session, lack of GBT
May 04	21	10.5 + 0.5	52 %	GST bunching
Oct. 04	22	15.2 + 0.9	73 %	
TOTAL	115	58.6 + 3.9	54 %	
(TOTAL	98	56.2 + 3.6	61 %	excluding feb03)

Table 3.5 The TOTAL numbers for each wavelength and for EVN+MERLIN observations for User Projects only (i.e. excluding tests).

TOTAL	N-OBS	HOURS	DAYS	T-BYTES	TB/TEL	N-TEL
1.3 cm	8	119.0	5.0	79.1	10.0	7.6
5 cm	16	181.0	7.5	26.1	4.4	7.2
6 cm	29	384.5	16.0	319.1	41.8	7.7
3.6 + S/X	7	93.5	3.9	51.0	8.4	5.4
18/21 cm	30	385.2	16.1	270.1	32.3	8.1
30 cm (UHF)	3	35.5	1.5	5.6	0.9	6.0
90 cm	10	88.5	3.7	13.6	4.6	2.9
EVN + MERLIN	16	229.5	9.6	154.5	17.2	9.2
5 cm	6	91.0	3.8	16.8	2.0	8.3
6 cm	2	26.0	1.1	33.0	3.9	8.5
18 cm	8	112.5	4.7	104.7	11.3	10.0

Reports on individual EVN sessions

2003 Session 1: Feb 06 - Feb 27
Wavelengths: 1.3cm; 3.6/13cm; 18/21cm

This was largely cancelled due to the withdrawal of Effelsberg, where a crack in the azimuth track was discovered just before the session. Two global projects (GP034 at 1.3cm, GC023A at 3.6 cm) were observed since Effelsberg was not deemed to be critical for them. One EVN-only user project was observed (EI005A at 1.3 cm). This was the first of 2 planned, closely-spaced epochs, and the 70m DSS63 antenna at Robledo could be scheduled at the last minute to replace Effelsberg (courtesy of Pam Wolken at JPL). Other test observations were observed without Effelsberg.

2003 Session 2: May 22 - June 12
Wavelengths: 18/21 cm; 6 (+3.6) cm; 5 cm; 1.3 cm +MERLIN

This session was extra long (21 days), and large in consumption (370 thin tapes and 18 MK5A disk-packs), to make up for the decimation of Session 1 following the failure of Effelsberg due to the azimuth track problem. This was also the first session where 4 different wavelength sections

were scheduled, following approval of this at the previous CBD meeting. A fifth wavelength, 3.6 cm, was also inserted in the 6cm part for frequency-agile antennas. This capability is extremely useful for reducing waiting time between proposal submission and observation. Projects were scheduled strictly, only those with grades better than 1.5 getting on. Since this was the last session with EVN+MERLIN at 18/21cm until 2005, there were a number of projects with grades > 1.5 which remained for many sessions afterwards in the queue.

2003 Session 3: Oct 23 - Nov 10
Wavelengths: 3.6/13 cm; 6 cm; 18/21 cm

This session was of more normal length (18 days) and consumption (295 tapes). It contained two projects with external scheduling constraints (one together with the CHANDRA X-ray satellite and one using geodetic VLBI stations) which led to a rather large inefficiency in the use of time in the 3.6/13cm section. An "ad hoc" target of opportunity project at 3.6 cm ("Afterglow of GRB 030329") could be accommodated in the 6 cm part of the session. This session also marked the first use of the Jodrell Lovell Telescope for VLBI at 6 cm; uncertainties led to some disarray in guidance to PIs making schedules for 6 cm projects. Effelsberg recorded using Mk5A disk-packs for all projects to be correlated at the EVN and Bonn correlators, in order to gain experience of MK5 operations.

At the beginning of the session a questionnaire was sent out to the PIs of all the projects, requesting feedback on any problems they experienced making their schedules and suggestions for improvements in the process. They were asked to comment especially on the clarity or otherwise of the block schedule, usefulness of the PI Instructions document, the SCHED program and depositing schedules on vlbeer in Bologna. 7 out of 14 PIs replied, with generally positive comments, and some individual suggestions for improvements.

2004 Session 1: Feb 10 - Feb 26
Wavelengths: 1.3cm; 3.6cm; 6cm; 18/21cm; (+ tests at 5cm and 30cm); +MERLIN

This was a relatively short session, mainly due to a lack of "schedulable" projects. This was partly because most of the backlog at the session frequencies had already been worked off and partly because NRAO decided to severely ration GBT time to ca. 30h per session. All but 1 of the global projects had requested the GBT; in the end 36h were scheduled for a single proposal, GG053 A, B, C. The EVN had originally advertised 5cm and 30cm for this session but both were delayed until later sessions. A further unwelcome constraint (announced 8 December) was that the GBT was already heavily booked from Feb 5-20 for some critical GST ranges; this forced our highest rated project requiring the GBT (at 21 cm) to be scheduled at the end of the session. One project, denied use of the GBT (GM052A), was scheduled instead with the DSN 70m antennas at Goldstone and Madrid (at 3.6 cm) to avoid delaying it until later in the year. Although these antennas were not requested in the original proposal, the DSN scheduler was happy to accommodate such additional projects if considered worthy by the EVNPC.

A total of 249 "notional" tapes was scheduled, although Effelsberg recorded exclusively on MK5A disks for projects being correlated at JIVE or Bonn. In preparation for future 1 Gb/s observing, the NME experiments at all 4 wavelengths were observed at 512 Mb/s using a 1-bit sampling mode, to test the capabilities of the observatories to observe a wide-enough band for 1 Gb/s (2-bit sampling) recording. The original session "window" was to start on Thursday 5 Feb, but the actual start was on Tuesday 10 Feb, with a fringe test-tape scheduled 6 days before on Wednesday 4 Feb (at 1.3cm) giving a relatively long time for tape shipment to JIVE. An additional FTP fringe-test was scheduled at 6cm one day before the start of the 6cm session. The final user projects finished on Monday 23 Feb (i.e.14 day session). The remainder of the session window was used for making fringe tests with the new receivers at 5cm (Wb, Nt, together with Mc and Hh) and 30cm (Ur, Nt, together with Tr, On and Wb).

2004 Session 2: May 20 - June 10
Wavelengths: 6cm; 30cm (UHF); 18/21cm + MERLIN

The EVN had advertised the delayed 5cm for this session but, in the event, the MERLIN upgrade to 5cm was not ready in time, so this wavelength was postponed again (to October/November 2004). The Ur and Nt telescopes were scheduled for the first time at 30cm (UHF) this session. There was also another "first"; GM051 observed at 1238 and 1285 MHz using the 18/21cm receiver boxes at Wb, On, VLBA and GBT, and the 30cm (UHF) box at Eb. There were, in fact, a number of projects requiring non-standard set-ups in this session. Following concerns raised in the April TOG meeting about late and faulty schedules, selected PIs (those judged to have difficult schedules to make) were given advanced warning that their project was about to be scheduled, and encouraged to seek immediate assistance from the JIVE user support group. This session was scheduled throughout the entire advertised window although, alas, somewhat inefficiently due to a number of external constraints and, more importantly, because of a rather extreme "bunching" of required GST ranges for the proposed sources. Of 25 eligible projects, 22 days would have been needed in the range 16h-17h, and only 5 in the range 07h-08h; in the end, 17 projects using 17 days in the 1st range and 4 in the 2nd were scheduled, priority (as usual) being given to the highest-rated projects, but subject to other constraints. In this session, again, the GBT was not available for some of the time, due to prior commitments in May and "Maintenance weekday daytimes" mode. Arecibo also had few available times slots. Again, it proved possible to negotiate the addition of the Robledo 70m antenna (at 18cm) for one project (EB028B) which had not requested it in the proposal.

A problem with the JBO Lovell Telescope was announced during the lead up to the session (April 23rd) resulting in an increased restriction on the frequency of telescope moves. (This resulted in a phase-reference cycle time of no less than 10 minutes, which is probably inadequate, at least for 6cm observation.) The Jodrell MK2 telescope was offered as an alternative for such observations. A new 6cm receiver for Urumqi was not available on time so it could not take part in this session. A total of 249 "notional tapes" was scheduled although some observatories recorded using MK5A disk-packs instead. A test 1Gb/s observation was also scheduled. No user projects using 1Gb/s could be scheduled since the disk-recording capacity at some observatories could not be guaranteed. Both the eligible 1Gb/s projects (at 6cm) required the Lovell Telescope using phase-referencing, so in any case it would not have been sensible to schedule them.

2004 Session 3: Oct 21 - Nov 12
Wavelengths: 90cm; 6cm; 1.3cm; 5cm (+MERLIN)

This was quite a long session, and it was possible to work off a major part of the backlog of projects. It included a 90cm part, the first time this wavelength had been scheduled since MK4 recording was introduced. All eligible 90cm projects were scheduled, including a number of pulsar VLBI observations. Noto was unable to participate in these because correlation was at the VLBA (which has a working pulsar gate) and Noto could no longer record using tape. All eligible 5cm projects were scheduled, some together with MERLIN, or at least that part currently functioning with 5cm receivers. This was the first official EVN+MERLIN session at 5cm. One project which needed only Effelsberg and Onsala (because other antennas cannot reach red-shifted excited OH) was scheduled at the end of the session beyond the advertised session end window, so technically "outside the session". At 6cm the session included the first user 1Gbps projects. At 1.3cm a geodetic project was scheduled, designed to improve station locations for antennas which are not part of the regular geodetic network. (Unfortunately, one of these - JB Mark II - was not available on the day due to technical problems.)

3.4 Technical Developments and Operations

The Technical and Operations Group (TOG) is made up of the personnel at the EVN stations who provide the technical and operational expertise for operating the EVN as a VLBI array. They are also responsible for advising the EVN Consortium Board of Directors on all aspects of technical

and operational issues relevant to the reliability and performance of the network. The TOG is also the body which implements technical and operational upgrades across the network.

The TOG was chaired by Walter Alef of MPIfR and met three times during the period of this report: at the DSN Complex near Madrid on 30 June 2003, at the Fundamental Station Wettzell, Germany on 1 April 2004, and at Jodrell Bank Observatory on 22 November 2004. Reports from the meetings are available on the EVN web-site (www.evlbi.org). The meeting at Wettzell was combined with a one day training workshop. Subjects covered were Mark 5 system checkout, disk-module assembly and maintenance, Field System, single dish and amplitude calibration.

The major goal of the TOG is to improve and maintain the quality of service of the EVN towards the observers. Of high importance for achieving this goal are an E-mail discussion group and the regular meetings of the TOG which also serve as a forum for information exchange, teaching and planning.

The main emphasis of the TOG activities during the period of this report were the changeover from tape to disk-based recording, reliability of the telescopes, and the quality of the network calibration. Significant achievements to be noted are:

- The disk-based Mark 5 recording system developed by Haystack Observatory with support from BKG, EVN, KVN, MPIfR, NASA, NRAO and USNO was introduced at all network stations. At the end of 2004 all observations to be correlated at the EVN correlator at JIVE or at Bonn were recorded exclusively on disks. Due to the efforts of the TOG the phasing-in of the Mark 5 system was smooth with relatively few teething troubles. Its reliability and ease-of-use soon surpassed that of the tape-based system.

- Projects with bit-rates of 512 Mbit/s using the two heads of the MK IV tape drives were observed at the EVN in 2002/2003.

- The maximum recording bit-rate of the Mark 5 recorders of 1 Gbit/s was tested at the network stations and after solving some initial problems the first user projects at that bit-rate were observed in late 2003.

- To increase the reliability of the network and detect problems like missing interference fringes as early as possible regular so-called ftp fringe checks were introduced. Short scans recorded with the Mark 5 system are ftp-ed to JIVE where they are quickly correlated with the KSRC/NICT VLBI software correlator.

- New software for single dish calibration was written with strong support from the EVN and implemented in the Field System in collaboration with Ed Himwich of NVI. Improved single dish calibration helped to enhance the amplitude calibration of EVN observations.

As an Associate Member of the EVN, HartRAO participated in all of the EVN sessions during 2003 and 2004. HartRAO is available for all EVN sessions subject to the following criteria:

- The target sources are South of 30 degrees North
- For survey experiments with a number of sources, the HartRAO telescope should be scheduled for at least 50% of the experiment.

HartRAO can now support dual polarization at 18, 13, 6, 5/4.5, 3.5 and 2.5 cm as well as simultaneous 13/3.5 cm (S/X-band) wavelengths with Mark IV, Mark V and S2 recording systems.

4. Joint Institute for VLBI in Europe

4.1 Institute Organisation & Management Structure

In 2003, the Joint Institute for VLBI in Europe (JIVE) celebrated its tenth anniversary. This year was a pivotal one for the institute; in particular Prof. Richard Schilizzi resigned as director of JIVE at the end of 2002, in order to take up his new position as SKA International Project Director. Richard Schilizzi's contribution to JIVE (and the European VLBI Network in general) has been immense and the entire EVN wishes him well in his new position. At the end of 2002, the JIVE Board thus began an intensive international search to find a new director of JIVE. In May 2003, Dr. Michael Garrett was appointed Director JIVE, having served as interim director for the first half of the year. In the second half of the year, several changes were made to the organisational structure of JIVE and many of the staff's responsibilities and duties changed. This has had a beneficial effect on the efficiency of the institute, especially in terms of production VLBI correlation and network support.
During the period of this report the new Memorandum of Understanding (MoU) between the various JIVE Foundation funding partners was finally completed - this secures base funding for JIVE over the next 5 years (2003-2007 inclusive). The JIVE funding partners now include: NWO (NL), ASTRON (NL), PPARC (UK), CNR (IT), IGN (ES), OSO (SE) and MPIfR (DE). Associated with the introduction of a new MoU, a revised set of Statues were considered by the board and were formally accepted by all parties by the end of 2004. In December 2004 the director of JIVE (Dr. Mike Garrett), Dr. Leonid Gurvits and Prof. Philip Diamond (chairman of the JIVE Board) were invited to visit Shanghai and Beijing Observatories. The team was able to present the activities of JIVE to the Chinese Academy of Science in Beijing. The collaboration between JIVE and the various Chinese radio astronomy groups is already strong and there are ambitious plans to formalise and expand the range of joint activities – including both astronomical research and engineering programmes.
The financial position of JIVE in 2003-2004 was boosted by changes to the annual funding profile and the success of the FP6 RadioNet proposal – an Integrated Infrastructure Initiative (I3) of the European Commission involving the major radio astronomy institutes in Europe, coordinated by Prof. Philip Diamond (University of Manchester's Jodrell Bank Observatory). RadioNet FP6 builds upon the successful FP5 RadioNet projects, coordinated by JIVE. During 2003-2004 the RadioNet FP5 programme focused its attention on improving the reliability of the EVN – it established several new initiatives in this area including the introduction of Network Monitoring Experiments and the use of the Experiment Reliability Indicator (ERI). Within RadioNet FP6, JIVE is responsible for the EVN Transnational Access programme and also provides the overall project scientist. In addition, JIVE also leads the RadioNet ALBUS (Advanced Long baseline User Software) project that is expected to enhance the analysis of VLBI data in various areas such as calibration, wide-field & wide-band imaging, data parallelization etc.)

Over the course of the last two years JIVE has also been involved in pushing forward the application of the VLBI technique to other areas of research, in particular space science. JIVE has been in receipt of various awards from the European Space Agency, mostly aimed at supporting the ESA Huygens mission (see below). JIVE was also involved in other initiatives such as the FP6 SKA Design Study and EuroPlanet projects. By the end of 2004, work had already started in preparation of the submission of a large proposal to the EC Research Infrastructure Grid programme. The proposal called “EXPReS” (Express Production Real-time e-VLBI Service), seeks to make e-VLBI a production grade astronomical instrument. The proposal will also address the “last-mile” connection problem of some of the European telescopes. A key feature of the proposal is to ensure that e-MERLIN and e-VLBI can operate as a single instrument – the transparent combination of the two arrays would represent an unbeatable combination boasting an angular resolution ranging from arcsecond to milliarcsecond scales, and sub-microJy noise levels. The outcome of the proposal should be known in the summer of 2005.

4.2 EVN Data Processor: Developments & Enhancements

Upgrade of the correlator to Mk5 recording systems

2003-2004 was the period in which PC-based Mk5 disk recorders (as developed by the MIT Haystack Observatory, USA) began to replace magnetic tape units. This has led to an immediate improvement in the quality of EVN data and permitted the first transfer of VLBI data over high-speed networks - e-VLBI. The EVN Board of Directors decided that each institute should buy 2 Mk5 units - one for the telescope and one for the EVN correlator at JIVE (see Figure J1). Further support for the procurement of Mk5 systems was obtained as part of the ESA-JIVE Huygens VLBI project. By the end of 2004, the correlator was operating transparently with 16 Mk 5 systems – the largest Mk5 capable VLBI correlator in the world.

Figure 4.1: Anton Zensus and Walter Alef present JIVE with a Mk5 unit for the EVN correlator during the now traditional Bonn-Dwingeloo Neighbourhood VLBI meeting.

Figure 4.2: The PCInt Single Board Computers (top left) integrated with the Correlator output cards.

Post-correlator Integrator Project (PCInt)

Significant progress was made in enhancing the output data rate of the correlator. The Post-correlator Integrator (PCInt) project should permit data to be extracted from the correlator at data rates of up to 160 Mbytes per second and is essential in order to deal with the high temporal and frequency resolution required by various EVN and Global VLBI astronomical projects – in particular those that require (deep) wide-field imaging and high resolution spectral line capabilities. Most of the PCInt hardware was procured during 2003-4 and integrated with the rest of the offline data distribution and export system. The PCInt uses single board computers to capture data from the correlator (see Figure J2), storing and processing the data on a PC-Cluster that employs a high-speed InfiniBand network. Verification tests (including the use of astronomical data) are encouraging and the PCInt system is expected to handle EVN user data from EVN session 1/2005.

e-VLBI developments (real-time correlation at JIVE)

In 2003-2004, rapid developments were made by the EVN and JIVE with respect to e-VLBI. The first real-time VLBI data transfer and correlation between the EVN telescopes and the correlator at JIVE was demonstrated during this period and in April 2004 the first real-time e-VLBI image was generated (see Figure J3). All these tests were supported by the e-VLBI Proof-of-Concept project – a collaboration involving the major EVN observatories and European Research Networks, coordinated by JIVE and DANTE (operators of the pan-European Optical Fibre Research network – GEANT). The generation of the first e-VLBI image represented an important milestone on the path towards using this new technique as an operational scientific tool.

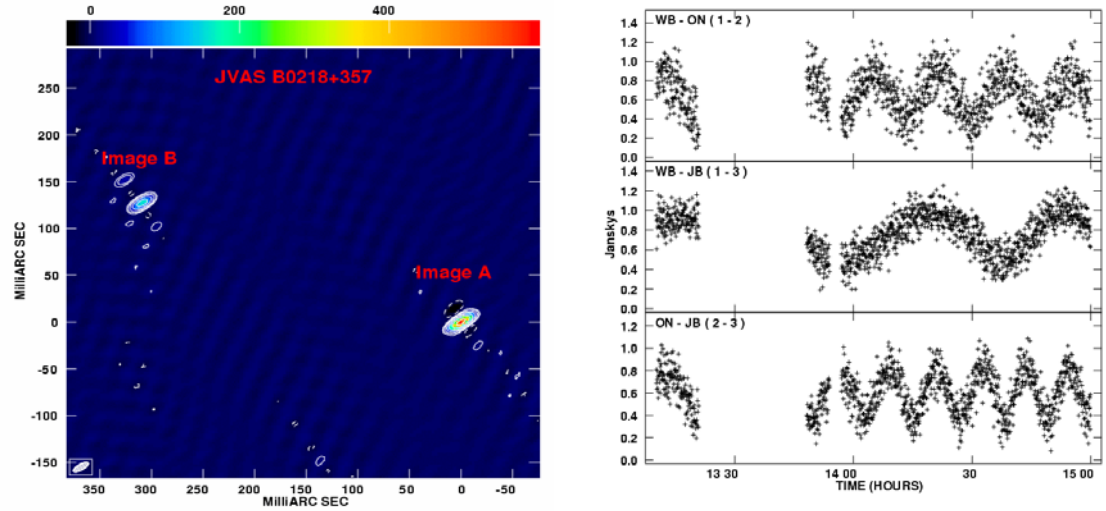


Figure 4.3: First e-VLBI real-time image (left) and data (right) of the gravitational lens system, 0218+375. The data were observed by a three telescope array (Westerbork, Onsala and Jodrell Bank) and correlated at JIVE in real-time.

Major changes were required to be made to the online EVN correlator control software, in an attempt to convince the data processor to operate in a real-time environment – a scenario not envisaged when the software was originally written. By the end of 2004, enhancements to the correlator were still being made in order to improve the poor reliability of the system during e-VLBI observations. In addition, the capabilities of the Mk5 systems were continually evolving and improving during 2003-2004, under the MIT Haystack Observatory e-VLBI development programme.

By the end of 2004, six EVN radio telescope observatories were connected to JIVE via optical fibres, including Westerbork, Jodrell Bank, Cambridge, Onsala, Torun and Arecibo. With the success of producing the first e-VLBI image, the EVN CBD authorised the organization of several e-VLBI demos, the first being a spectral-line experiment operating at modest data rates (32 Mbps). This was extremely successful and the results were presented at the EVN Symposium at Toledo (Richards et al. 2004).

Although the first science results were obtained at relatively low data rates (32Mbps per telescope), other e-VLBI developments have focussed on stressing the GEANT network and telescope connections to the limit – our colleagues at Metsahovi were recently able to demonstrate data rates of up to 600 Mbps between Finland (Espoo) and JIVE. All these results have been widely reported (see Figure 4.4), especially in the specialised Research Network press.

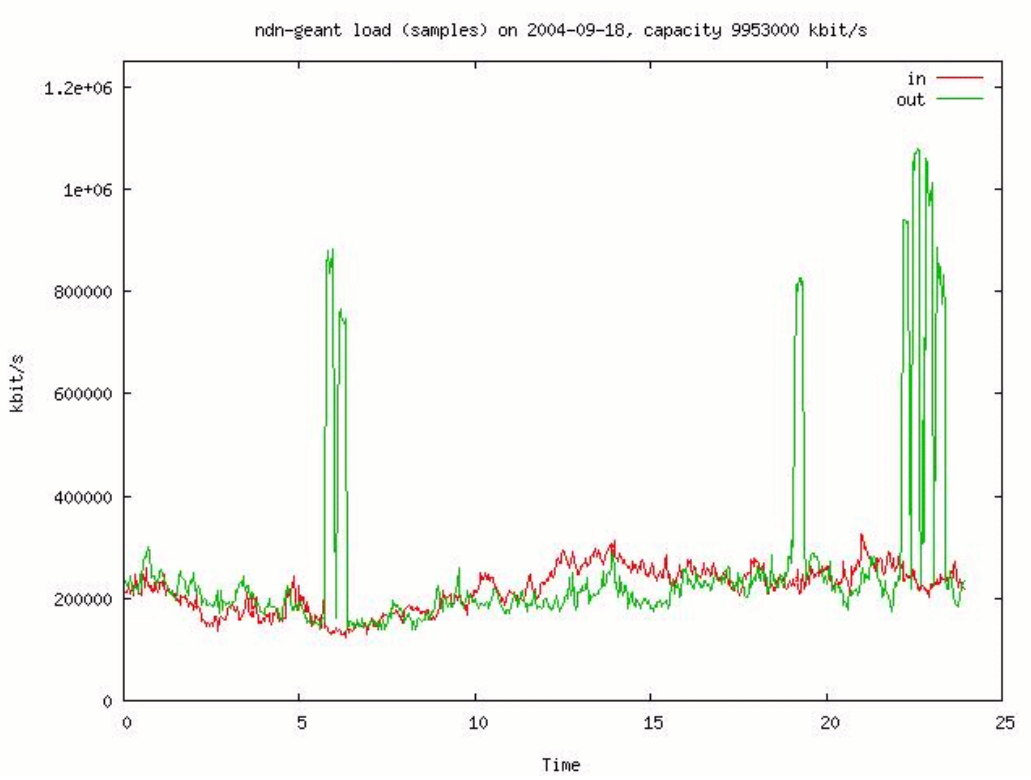


Figure 4.4: The effect of e-VLBI on the GEANT network was clearly visible during e-VLBI data transfer tests between Finland (Espoo) and JIVE, as conducted by staff from Metsahovi. The e-VLBI traffic dominates the network load, though it should be noted that even the e-VLBI load represents only 10 percent of the total capacity of the GEANT link.

4.3 Production Correlation at JIVE

Session 1/2003 session saw many experiments postponed or cancelled because of mechanical problems at key EVN telescopes. This conveniently minimized operational impact from the construction activities in the cellar during May. Session 2/2003 was quite large, owing to the many rescheduled experiments from previous cancelled sessions, requiring an estimated 447 correlator hours (taking into account multiple passes, job set-up time, etc., but not re-correlations or other problems that arose operationally). There were some "firsts" for the EVN data processor at JIVE: (i) the first user 512Mbps experiment, (ii) the first >16-station experiment (which required 3 correlator passes), (iii) the first experiment that used a sub-netted schedule and (iv) the first adhoc (non-session) target-of-opportunity experiments.

In session 3/2003, Effelsberg recorded exclusively on disk (except when scheduled as a VLBA antenna), which was our first operational use of Mk5 in normal user experiments. A notable milestone of the session 1/2004 EVN session was the first sub-second integration-time user experiments. Three stations were regularly recording onto Mk5 disks. In EVN session 2/2004, a UHF session was included for the first time since September 1999. There was a large fraction of global experiments (more than half of the non-UHF experiments). Up to eight EVN stations regularly recorded onto Mk5 disks, but there were no all-disk user experiments yet (a couple of experiments used 8 disks and 1 tape).

Before session 3/2004, seven ad-hoc user experiments were correlated at JIVE. These included three short EVN observations arranged to coincide with independent GMRT and X-ray observations of SS433, two global experiments in preparation for the Huygens-Titan encounter, and two real-time e-VLBI spectral-line experiments. In session 3/2004 we correlated our first 1

Gbps user experiments. This session also included a large 5cm session in which 8-9 stations participated successfully with all telescopes recording exclusively with Mk5A systems. These experiments provided us with our first taste of all-disk correlation. Also in these experiments, Darnhall (Da) replaced Jb2, producing good fringes throughout. This was Darnhall's first participation as an independent VLBI telescope correlated at JIVE. After the session, there was another ad-hoc user experiment -- the global 'dress-rehearsal' for the Huygens encounter.

Table 4.1 summarises projects observed, correlated, distributed, and released in 2003-4. The table lists 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., continuum/line, >16 station, 2 head stacks, different phase centres, etc.).

	User Experiments			Tests and NMEs		
	No.expts	Network hours	Correlator Hours	No, expts	Network hours	Correlator hours
Observed	85	1027	1453	69	148	166
Correlated	88	1076	1482	70	150	166
Distributed	89	1111	1478	71	153	172
Released	95	1237	1587	66	139	158

4.4 JIVE Network and PI Support

The continued success of automatically pipelining EVN and Global VLBI data has led to the creation of an impressive EVN Data Archive. The archive is now online and can be interrogated via a web-based interface. JIVE's support of the European VLBI Network continued a pace - in particular the introduction of ftp-VLBI tests in standard Network Monitoring Experiments was an important break through making an important contribution to the increased reliability of the network. JIVE support scientists were also heavily involved in assessing and improving the amplitude calibration data generated by the EVN telescopes.

Since May 2004, JIVE staff made a targeted effort to initiate PI (Principle Investigator) help with scheduling for EVN session 2/2004, in order to minimize the occurrence of "avoidable" problems arising from PIs making schedules that would be impossible to correlate or from the use of outdated versions of Sched .This was useful, especially in light of the experiments at unusual frequencies (UHF, highly red-shifted HI, OH) and the number of new users now using the EVN. In addition, post-schedule-deposit review caught a couple problems that could have compromised observations.

JIVE Support Scientitsts continued to support visiting astronomers in the analysis of VLBI data. Over the period of this report, 76 visits were made to JIVE. Many astronomers also made use of the scheduling support provided by JIVE.

4.5 ESA-JIVE Huygens VLBI Project

JIVE is leading an international effort to track the decent of the Huygens planetary probe onto the surface of Titan, supported via a contract with ESA. By employing the technique of VLBI, the aim is to be able to pin-point the location of Huygens probe to a ~ km precision throughout the period of its descent (expected to last 1.5 – 4 hours –see Figure 4.5). These data, together with Doppler measurements of the probe’s carrier signal will hopefully permit the 3-D trajectory of the probe to be calculated, and will help understand the wind dynamics of Titan in both the lower and upper atmosphere. The ESA-Huygens mission is undoubtedly one of the most ambitious space missions to date, and by the end of 2004 the excitement at JIVE was growing as the landing date approached (14 January 2005). The EVN has been involved in preparatory deep, wide-field imaging of the “Huygens” field. The contract with ESA has also had very important spin-off benefits for JIVE’s core activities, in particular a software correlator has been developed for the

Huygens observations that will form a basis on which to develop a general purpose software correlator for the EVN. The ESA contract also provided Mk5 units for both JIVE and NRAO.

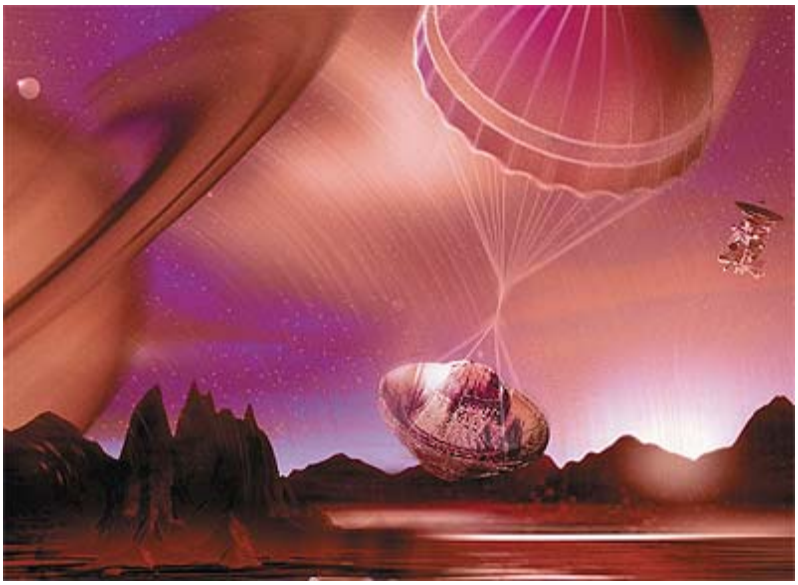


Figure 4.5: Artist's impression of Huygens descending onto the surface of Titan by parachute. JIVE will lead a global VLBI array of radio telescopes to track the probe as it descends through Titan's atmosphere.

4.6 Science Activities

Individual science results produced by JIVE scientific staff are presented elsewhere in this report. During 2003-2004 JIVE staff was involved in the publication of 79 papers in refereed journals or conference proceedings.

In 2003, the JIVE Board of directors decided that JIVE should co-sponsor PhD students studying in the Netherlands, and JIVE was successful in finding external support for PhD students and Post-doctoral research positions. In particular, JIVE was involved in the ANGLES RTN with a PhD student appointed in December 2004 to work on gravitational lensing at both JIVE and the Kapteyn Institute in Groningen. JIVE was also involved in the co-supervision of one student in the Anton Pannekoeck Institute (Amsterdam) and another in the Kapteyn Institute (Groningen) working on e-VLBI networking solutions. An additional PhD appointment (working in the area of VLBI Deep Fields) also to be located at the Kapteyn Institute was made at the end of the year.

JIVE was involved in co-sponsoring with ASTRON, two workshops during the period of this report – a European workshop entitled "Astronomical Molecules" held in Zwolle and an international Workshop on "Interstellar Scintillation of Extragalactic Radio Sources", held in Dwingeloo.

5. VLBI Operations support at member institutes

5.1 ASTRON, Westerbork Synthesis Radio Telescope, The Netherlands

Westerbork took part in European VLBI sessions during 2003 and 2004, and a small number of ad-hoc VLBI observations. This included for the first time at Westerbork single-dish observations of methanol masers at 5cm.

The majority of these observations were recorded on the Mark5A system. The Mark4 tape recorder continued to be used for projects to be correlated in Socorro, but this had problems with the recording heads becoming stuck and vacuum loss during recordings. There were also recurrent problems with the air-conditioning system which caused VLBI hardware problems.

The full 8 bands of the TADUmin tied array involved a new mixing scheme. This allows recording a full 1Gbit/s except for the highest 16MHz which are unavailable.

Since Westerbork observes using linear polarization, and the VLBI standard is to record circular polarization, we convert to circular polarization in the IF by adding the signals with a + or -90degree phase shift. New online software was introduced to determine the phase and delay difference between linear polarizations to allow this to be done more accurately. The observations of the phase and delay of the polarized autocorrelations and the noise source (which is positioned exactly half way between the linear polarization dipoles). For the lowest frequencies this measurement is impractical, as the autocorrelations are dominated by interference. However, there exists a system to switch the signals from X and Y dipoles in the frontends at these lower frequencies with only minor phase jumps and hence measure their phase and delay difference, but there was an online software problem when this was first tested in October 2004.

Since the Gbit connection we have regularly used ftp-eVLBI for fringe checks during and immediately before VLBI sessions. We have also been deeply involved in debugging testing and using eVLBI. Westerbork has taken part in the first science images produced by eVLBI, and continues in assisting JIVE in making 'streaming' real-time eVLBI into a production system.

5.2 Institute of Radio Astronomy, Italy

The Medicina and Noto 32-m dishes are part of the European VLBI Network and of the International VLBI Service for Astrometry and Geodesy. The Institute also offers single-dish observing time to external observers, on the basis of a scientific request, evaluated by an Committee.

A Network Server is maintained, which allows remote access to Principal Investigators, friends of VLBI at the VLBI stations and personnel at the correlator. Observing schedules and log files for all EVN/Global VLBI projects for all EVN stations are collected on this common area. The server can be accessed via web or anonymous ftp to vlbeer.ira.cnr.it for the network operational data.

Disks and MK5A disks modules were acquired increasing the number of experiments recorded on disk. On TOG request a dedicated software programme (Programme CHECKR) to check the recording tracks of the MK4/MK5 system has been prepared and made available to the EVN network stations.

The tape recorder in Noto, after the last failure, will not be repaired due to the fact that the heads have to be replaced. The Noto station became a disk-only recording station for the EVN. As a result of such a decision, all the experiments planned for correlation at the AOC in Socorro could not be observed.

The VLBI observations are run making use of the last release of the Field System. Programmes as CHECKR mentioned above can be activated via a command in the FS. A software engineer at Medicina is also working to an upgraded version of the programme GNPLT which is very useful to check the calibration data provided to the PIs by the network stations. Finally, in order to help the VLBI users in the observing schedule preparation, a graphic interface has been designed for the generally used programme SCHED in collaboration with NRAO.

5.3 Jodrell Bank Observatory, UK

During the period 2003-2004, the MERLIN/VLBI National Facility, based at Jodrell Bank Observatory, participated in all six EVN observing sessions. These involved the 25-m Mk2 telescope at 1.3, 5, 6 and 18/21 cm, the 76-m Lovell telescope at 6cm, 18/21 cm and 90cm, and the 32-m Cambridge telescope at 1.3, 5, 6 and 18/21 cm. In addition, the MERLIN telescope Darnhall performed VLBI observations at 5cm. National Facility telescopes were scheduled to observe 118 VLBI projects, for a total of 1653 telescope hours. 17 of these experiments were joint EVN+MERLIN observations, during which MERLIN provides short baselines allowing source structure to be mapped on scales from a few milliarcseconds to several arcseconds. During this two year period a total of about 241 telescope hours (14.5%) were lost due to technical problems at the time of observation, astronomer/operator error or weather. Most of this percentage was due to the transparent failure of a local synthesiser during the November 2003 session.

The first C-band observations using the Lovell telescope were performed during the November 2003 session. Although the VLBI equipment and the telescope itself performed excellently at this new frequency, a failure in a local synthesiser (that resulted in a 220 kHz frequency offset) compromised all the C-band observations on the Lovell. In contrast, the May 2004 session saw no time lost due to weather or technical difficulties. Part of the reason for the success rate in May 2004 was the reliability and ease-of-use of the Mk5 disk-based recording units. For the November 2004 session, the Mk2 telescope did not return from engineering work on the drive system in time for its allocated K and C-band observations. The K-band observations were cancelled, but for C-band (5cm) the MERLIN antenna at Darnhall was substituted for the Mk2. Since the 5cm observations were mostly narrow-band (2MHz channels), the limited MERLIN microwave link bandwidth was not a constraint and the astronomers were provided with the requested data. In fact, since Darnhall was equipped with a new e-MERLIN C-band receiver, its sensitivity was much better than would have been achieved with the Mk2 telescope.

5.4 Max-Planck-Institute for Radio Astronomy, Germany

The MPIfR correlator

The Bonn MK IV VLBI correlator is used for the correlation of observations of the newly formed global mm-VLBI array which observes twice per year with up to 13 antennas. In addition it supports a very significant fraction of the worldwide geodetic VLBI operation. A few EVN observations are correlated as well, either because they are MPIfR projects or as they need some of the features the Bonn correlator offers, like hands-on correlation, phase-cal extraction, geodetic export path, or availability of the correlator model in the exported data.

Correlator Improvements achieved in 2003-2004

After initial successful tests with two Mark 5p disk recorders, a total of 8 Mark 5A units have been installed at the correlator in 2003. The correlator can easily be reconfigured to operate with any combination of 9 tape drives and 8 Mark 5A disk playback units; for 2-head recordings a few cable connections have to be changed.

Improvements to the software which handles the Mark 5 recorders at the telescopes, the software of the Mark 5 units and the MK IV correlator software itself helped to increase the robustness of disk-based VLBI beyond what has been possible with tape-based systems. Important features are that the data is basically error-free and any scan can be accessed without wasting time in tape slewing or track finding before the correlation. Synchronization of the data streams from

different telescopes is virtually instantaneous. As a result the throughput of disk-only observations, correlated towards the end of 2004 was about twice that of tape-only VLBI observations. Re-correlation because of bad data is now seldom required.

About 100 disk-packs have been purchased, assembled and tested at Bonn with a total capacity of nearly 100 TB.

At the end of 2004 a project was initiated to upgrade the correlator to 12 stations and Mark 5B units, with completion expected in 2006. This includes a replacement of the failure-prone station units, upgrades of the existing Mark 5A units and a replacement of the correlator control computer.

MPIfR Correlator Operations

The number of observations correlated stayed at a high level in 2003 and 2004. The total percentage of correlation time over total time was about 50% which is a few percent higher than in 2001/2002. About 40% of the correlation time was used for astronomical correlation, 60% for geodetic projects. This corresponds to 15 resp. 35 astronomical projects in 2003 and 2004 and 45 resp. 51 geodetic experiments.

Observatory Activities

Alex Kraus acts as Friend of VLBI at the Effelsberg telescope and supervises absentee observing for EVN and other VLBI observations. Since late 2004 he was assisted by Axel Jessner. Where necessary, technical assistence for machine control of observing schedules is provided by Dave Graham.

Andrei Lobanov is the MPIfR representative on the EVN Program Committee and attended its meetings.

Richard Porcas is the EVN Scheduler and attended meetings of the EVN Program Committee and the EVN Consortium Board of Directors in this capacity. Assistence with EVN Proposal administration is provided by Ute Runkel, and Walter Alef takes care of the receipt of emailed proposals.

Walter Alef organises the distribution of tapes prior to observing sessions, in conjunction with the Scheduler, JIVE, the observatories and NRAO.

Walter Alef is Chairman of the EVN Technical and Operations Group (TOG). Dave Graham and Alex Kraus are also members. All 3 attend the TOG meetings.

Walter Alef is scientific supervisor of the MPIfR/BKG MK4 correlator in Bonn, and oversees the correlation of EVN experiments processed there. These include projects of an astrometric or geodetic nature (which can take advantage of the associated post-correlation software) and projects with "local" PIs (e.g. Bonn or Cologne) who wish to have a "hands on" approach to correlation.

Antonis Polatidis was responsible for the creation of schedules for the Fringe Test experiments run just before the start of each observing session.

Antonis Polatidis is responsible for maintaining the "EVN Status Tables" on the EVN Home Pages and Richard Porcas maintains the "Instructions for EVN Observers".

Walter Alef helped organise the VLBI "Technical and Operations Workshops".

Thomas Krichbaum, Dave Graham, Walter Alef and Richard Porcas jointly organise the European part of the Global 3mm VLBI Network. Richard Porcas is Scheduler, Thomas Krichbaum is

Schedule Coordinator and Walter Alef and Dave Graham coordinate the technical and correlation aspects.

5.5 Metsähovi Radio Observatory, Finland

Metsähovi Radio Observatory participated in four EVN sessions at 22 GHz in 2003--2004: Feb-2003, May-2003, Feb-2004, and Nov-2004. Geodetic test experiments for Finnish Geodetic Institute were performed in Mar-2004, May-2004, Sep-2004, and Nov-2004. Global mm-VLBI Array sessions were resumed with the new 3mm/2mm SIS receiver in Apr-2004 and Oct-2004.

At the moment MRO has two effectively part-time persons working in VLBI: Ari Mujunen, whose main occupation is laboratory engineer and Jouko Ritakari, who is working part-time at MRO. People from Finnish Geodetic Institute are helping in the geo sessions.

The S/X receiver built by TTI Norte, Santander, Spain, features standard geodetic RCP-only S and X bands (not wide-band X). The system temperature of this receiver is around 80 K when the LNAs are cooled to 15 K and the bulky feed system and polarizers are at room temperature. The receiver is owned and operated by Finnish Geodetic Institute and is thus not generally available for EVN observations by default. PIs wishing to use the receiver need to contact Metsähovi to initiate arrangements with FGI to get the permission to use their receiver.

The 22 GHz receiver is functioning as before.

The 43 GHz receiver is still being repaired for its broken RCP HEMT. A new pair of 43 GHz (LCP/RCP) HEMTs was purchased from the "YLINEN Electronics Ltd." in September 2003. The HEMTs have been installed but DC and bias wiring and testing is waiting for manpower and proposal pressure.

The new dual-feed 80-115/150 GHz SIS receiver from Institute of Applied Physics of the Russian Academy of Sciences (IAP RAS, Nizhny Novgorod) delivered fringes for the first time in April 2004 in a Global mm-VLBI Array session. The 3mm part features dual polarization and 2mm single LCP polarization. All swaps between 1.3cm, 0.7cm, 13/3.6cm, and 3mm/2mm are manual and require one workday (Mon-Fri 7--13 UT) plus the cool-down period.

At this moment Metsähovi uses two Russian Kvarz H-masers, with Kvarz-69 as the station frequency reference and Kvarz-70 as backup. They both have functioned very reliably throughout 2003--2004.

5.6 National Astronomical Observatory, Spain

The 14-m radio telescope of OAN at Yebes (CAY, Guadalajara, Spain) has participated in the EVN sessions at S/X frequencies in February and October 2003. Regular geodetic VLBI campaigns for measuring plate motions have also been performed (8 sessions in 2003).

The 14-m telescope control computer, and old HP1000, failed in December 2003. The lack of spare parts and technical support from the manufacturer has made its repair impossible. This telescope has therefore not participated in any VLBI observations in 2004. New observational campaigns will be possible once the 40-m radio telescope is completed by the end of 2005.

5.7 Onsala Space Observatory, Sweden

Onsala telescopes continued to play a full role in all of the EVN sessions in 2003 and 2004. In addition the Onsala 20m telescope has been used for some 18 geodesy (S/X-band) VLBI experiments in 2003 and 29 during 2004. In October 2003, the observatory signed a new MoU concerning observations at 3mm wavelength with the US National Radio Astronomy Observatory (for the VLBA), the Max-Planck-Institut für Radioastronomie, IRAM, Metsähovi Radio Observatory

and Instituto di Radioastronomia (for their NOTO antenna) and has participated in the two sessions organised for 2004.

In addition (see Chapter 5) Onsala was equipped with the MkVA in 2003 and was connected by a 1 Gb/s optical fibre link to the Swedish Internet backbone and participated in the first e-VLBI tests in January 2004 with Westerbork and Cambridge, and has taken part in all subsequent tests, including several tests to the USA (Haystack Observatory) organised by the geodesy network.

In December 2004 the Onsala group celebrated the 40th anniversary of the 25m telescope which was inaugurated on Nov 28, 1964. The antenna participated in the first transatlantic VLBI in 1968 and has now been involved in the first e-VLBI experiments both in Europe and across the Atlantic, showing that it continues to be in the forefront of astronomical research.

5.8 Shanghai Astronomical Observatory, P.R. China

Observations
Shanghai station, which is located at Seshan, 30 kilometres west of Shanghai, has taken on full role in all the EVN sessions in 2003 and 2004. In addition, Shanghai station has participated in 48 sessions of Geodetic VLBI observations, organized by the IVS.
Shanghai station will take part in the "Huygens project" in January 2005. Before that a series of rehearsals, together with other telescopes, have been performed in 2003 and 2004. Apart from international VLBI activities, Shanghai station also played an important role in domestic radio astronomy campaigns, e.g. Chinese VLBI Network (CVN).

Shanghai station has been successful in most EVN observations (52 out of 57) in 2003 and 2004. Three types of problems dominated in data loss and failures:

- most errors were related to problems of the antenna drive and control system;
- a number of errors took place when Mark V module or disk drivers did not work well.
- occasional problems resulted from receivers, e.g., LO unlock, RFI.

Activities have been taken to minimize above problem and to improve the performance:

- antenna panel has been adjusted in 2003, which greatly increased the sensitivities, especially at K band;
- a new set of antenna control system has being developed, and it is expected to replace the old one in the period of August-September of 2005, then problems due to antenna drive and control system should be levelled down; radio frequency interference inspect is being considered and will be performed soon.

In order to measure its sensitivity, a number of single-baseline experiments between Shanghai 25m (China) and Kashima 34m (Japan) telescopes were carried out at the end of 2004. Fringes were detected at each individual experiment, moreover the experiments were also used to measure the data transfer for the coming e-VLBI epoch. Shanghai station played the full role in the Huygens observation on Jan. 14, 2005.

5.9 Torun Centre for Astronomy, Poland

The Department of Radio Astronomy, Torun Centre for Astronomy is a division of Physics, Astronomy and Informatics Faculty at the Nicolaus Copernicus University in Torun. The personnel of the Centre consists of 22 research positions, 18 engineers and technicians and 20 supporting and administration staff. There are 15 Ph.D. students and above 60 undergraduates studying astronomy as a chosen subject. The Radio Astronomy Department with 31 employees operates two parabolic radio telescopes – 15m and 32m. The major instrument, the 32m precise antenna, is equipped with ultra low noise receivers covering bands from 40 cm down to 1 cm and with modern back ends used to process and record scientific data. Four basic units of the auxiliary equipment are in continuous use. The pulsar machine PSPM2, an autocorrelation spectrometer, broad band polarimeter and VLBI recording terminals (MkIV, MkVa, VLBA). In years 2003-2004

the 32m telescope was used for real observations in about 80% of the total time. The major programs in the above years are the VLBI studies of distant quasar, active galaxies as well as galactic compact objects carried out mainly within the European VLBI Network, the pulsar timing and studies of interstellar and stellar molecules. The fraction of time devoted to VLBI observations, tests and VLBI related maintenance approaches level of 1/3 of the total telescope time. VLBI is the most significant activity at Torun Centre for Astronomy. During the reported years Torun station observed in six EVN sessions and global experiments. Total number of the observing hours in VLBI mode in 2003 has reached 300 for 30 individual projects and in 2004 these were 546 hours for 63 projects in four bands (21, 18, 6 and 5 cm).
The activity to put up a high bandwidth fiber optic connection between Torun 32m telescope and JIVE correlator has been successfully completed. The real time and off line disk storage operation in EVN has been tested and implemented as a standard function from 2005. The 2004 delivery of our own MkVa disk recording terminal is plus real time operation have dramatically improved reliability of Torun in EVN, since the major reason for 2003 reduction in observing time were failures of DAQ tape recording unit.
The work made for EVN rewards the Observatory in reliability and high quality performance for all scientific activities.

5.10 Urumqi Astronomical Observatory, P.R. China

We regularly participated in the EVN observations (about 3 months each year), IVS observations (about 12 sessions each year). We also contributed to the Shanghai-Urumqi single-baseline satellite observations as test observations for Chinese lunar project. We did some Sino-Japan VLBI test and the Huygens international VLBI observations. Some VLBI experiments failed to give well fringes mainly due to a leak between the LCP and RCP in 18cm band, and LO problems in several bands. We had adjusted the hybrid of 18cm system and improved to give better result from afterward VLBI test experiment. We checked LOs, and planned to buy new LOs instead of using frequency synthesizers. We conducted a measurement of environmental radio interferences in different observing bands at the station. We planned to have the P-cal to be controlled by the FS in 2005. A new H-maser will be purchased in 2005.

5.11 Bundesamt für Kartographie und Geodäsie (BKG) – Wettzell, Germany

RTW has participated in various IVS-observing programs: R1, R4, T2, R&D, as well as VLBA and Europe. All these sessions run for 24 hours.

Additionally RTW participates in one-base-line-sessions to determine changes in rotational speed (UT1-UTC); these sessions are done once a day with 1 hour data recording; they are named INTENSIVES; this type of sessions is predestined to transfer recorded data by e-VLBI; the amount or recorded data is relative small (35 Gbytes), but the interest to get results immediately after the observations is very high. Currently there are two types of Intensives:

- INT1 is done by RT-Kokee and RTW from Monday including Friday.
- INT2 performed by RT-Tsukuba and RTW at Saturday and Sunday.

INT1 is performed since April 1984 continuously with radio telescopes in US (Westford, Greenbank and Kokee); presently INT1 is recorded in MK5-technique; data are recorded on a single fixed disk; starting with August 06, RTW has supported transfer of data via e-VLBI for 2 months. (Due to problems outside of Wettzell data transfer via e-VLBI has been stopped.)

INT2 is a second one-baseline interferometer between Tsukuba and RTW starting in 2003. Data are recorded with K4-DAT on cassettes and correlated in Japan. From January until August 04 the observation was performed at Saturday; starting with September 2004 observations are done also at Sunday; from that time 7 Sunday INT2 took place at Wettzell. Each last Sunday in the month data are transferred via e-VLBI to Japan (without sending a cassette or a fixed disk in parallel). It is highly desirable to transfer the data via internet from scientific point of view and cost of transportation.

6. VLBI technical Activities at member institutes

6.1 ASTRON, Westerbork Synthesis Radio Telescope, The Netherlands

Tied-Array Operation
At the start of 2003 Westerbork was using an interim solution for the tied-array hardware (called TADUmin). In 2004 this was upgraded from 4 bands to all 8 bands with 16MHz outputs and dual polarization (capable of producing 1Gbit/s when digitized at 2bits/sample). However this hardware is still an awkward mixture of analog and digital technologies.

At the end of 2003 it was decided that the optimal tied-array for the current IF section would be to go to a fully digital tied-array system (TADU) with VSI-H standard interfaces. Work continued in this period on the design and prototyping of this tied array hardware, and it is planned to interface this directly with a Mark5B recording system once these are available.

Receiver Status
Westerbork tested and took into production a single 6GHz methanol line receiver. This is mounted on the frontend chassis used for prototyping and has no common frequencies with the other frontends in Westerbork. We can only use it for observations in single-dish modes and its SEFD is about 1600Jy.

At the end of 2004 Westerbork also took into production a low frequency (110-180MHz) receiver option. This is primarily intended for an overlap with the highest frequencies available to LOFAR, so that Westerbork can be used to calibrate the LOFAR response. In this frequency band interference is prevalent, so work also continues on RFI mitigation systems.

Recording Capabilities
During this period we rapidly switched from a majority of observations being done on tape (with a few tests being done with a prototype Mark5 recorder on loan from JIVE) to almost exclusively using Mark5A recordings. We bought 2 Mark5A recording units from Conduant (one to record in Westerbork and one to play back in JIVE) and 58Tbytes of disk packs. The Mark5A in Westerbork was upgraded with a Gbit/s glass-fiber ethernet card for eVLBI.

e-VLBI Operations
In 2003 we had a dedicated Gbit/s line for VLBI use installed in Westerbork. This fiber link joins us directly to JIVE with no routing over public networks. A separate Gbit connection is used for all other data.

Field System Status
In 2003 and 2004 the Field System software was upgraded several times to keep pace with recording system developments. The linux kernel was also upgraded to Debian Sarge 3.0 to allow for more modern hardware and to have a modern 'spare' computer ready to replace to FS PC in case of breakdowns. A newer Field system computer was ordered at the end of 2004.

6.2 Hartebeesthoek Radio Astronomy Observatory, South Africa

The new surface of the 26-metre telescope has now been installed. Most of the individual panels have an rms accuracy of better than 150 microns. Manual panel adjusters have been fitted at each mounting point and the initial setting of the surface has been done using a theodolite. This initial setting has resulted in a flat efficiency curve up to 12 GHz. The final adjustments will be made using satellite holography at 12 GHz and we are confident that the antenna will have good performance at 22 GHz. An ambient 22 GHz receiver is currently being developed to make test observations.

A new hydrogen maser, EFOS-28, has been successfully installed. This replaced EFOS-6 as the primary frequency and time standard at HartRAO. EFOS-6 will be retained as a backup system. EFOS-6 was in near-continuous operation since 1985.

A Mark V disk recording system has been installed at HartRAO, and this has been used successfully for both EVN and IVS sessions. Sufficient disc packs have been procured to meet the minimum requirements for HartRAO Mark V operations.

The new hydrogen maser, EFOS-28, on its arrival at HartRAO

Jonathan Quick assembling disk packs for the Mark V recording system at HartRAO

The last panel of the HartRAO 26-metre telescope being installed, signalling the completion of the major surface upgrade project

6.3 Institute of Radio Astronomy, Italy

The Institute of Radio Astronomy (IRA) operates the two radio observatories of Medicina and Noto, deeply involved in VLBI observations for astronomy and geodesy. The Institute is also in charge for the construction of a new 64-m dish located at San Basilio, near Cagliari, Sardinia Isle.

At the same time IRA contributes to the major radioastronomy projects carried out in international consortia. IRA covers almost entirely the area of technology research for radio astronomy instrumentation in Italy in a cooperation established with the University Departments of Electronics and Telecommunications in Florence, Rome and Messina, and with CNR Institutes in Bologna, Turin and Rome.

Medicina Radio Observatory

Upgrading of the antenna

The main upgrading done of the 32-m dish in the period 2003-2004 can be summarized as follows. There was a refurbishment of the antenna in term of a complete substitution of the old cables with the mounting of a new cable wrap and a new distribution of the cables network.
A new mechanical structure, which supports a new receiver configuration, has been mounted in the secondary focus cabin. At the same time, the automation and control via Field System of the subreflector/primary focus receivers movement has been completed. In this way the frequency agility of the radio telescope, i.e. a fast change of the observing frequency, can be fully performed avoiding any manual intervention as it was previously needed. New control hardware allows checking the housekeeping data coming from the receivers and also the switching among the secondary focus receivers. Moreover, the reliability of the antenna tracking has been improved with the mounting of a new servo-system. The pointing station software has been adapted to the new system.

Activities in micro-wave receivers and data acquisition

A new 5 GHz receiver with improved performance and wider bandwidth, with respect to the old receiver used until now for VLBI observations, as been installed and succesfully tested. The receiver is now in operation.

Development of new cryogenic Low Noise Amplifiers is in progress. 22GHz hybrid GaAs LNAs and InP MMIC chips were made available. The last ones have to be bonded and embedded in connectorized enclosures. The design of 28-40 GHz, 35-48 GHz and W band (around 90 GHz) LNAs are in progress by using the monolitic solution with InP technology. The expected delivery of the chips is foreseen for spring 2006. A 4.3-5.8 GHz hybrid LNA is under construction as well. These activities are the work packages assigned to IRA in the EC funded project FARADAY.

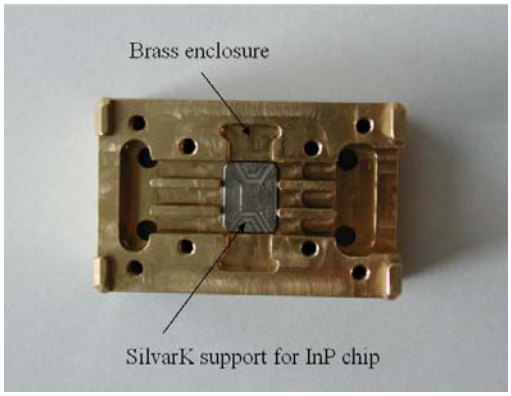


Fig. 1 - The new cryogenic 22GHz Low Noise Amplifier InP MMIC chip.

The polarimetric system has been upgraded. The software package for making raster scan observations is under test.

Data recording has been improved as well upgrading the MK5 recording system from prototype (MK5P) to MK5A. The performance of the MK5A system was tested. One of the tests implied the transfer of data from Bologna to the JIVE correlator in Dwingeloo by using high data rate GARR/GEANT network. The MK5A was found to work well.

Fibre Optics

A call for tender to carry out high speed optical fibre links in between Bologna and the Medicina observatory, and in between Noto and Catania was managed by GARR.IRA and the Emilia-Romagna Regional Government have signed an agreement under which the government will fund the fiber optic link at 1Gb/s between the Medicina station and the GARR backbone in Bologna.The link is foreseen to be completed in Spring 2005.

Noto Radio Observatory

Upgrading of the antenna

The active surface system and new panels have been successfully implemented at the Noto antenna. During 2002 the active surface system has been tested at 22 GHz and 32 GHz frequencies. The results confirm that it is possible to minimize the gravitational effects on the shape of the primary mirror. Measurements at 43 GHz were also performed more recently. The results achieved so far are really encouraging. The antenna efficiency is as good as 45%. The achieved Gain curve (Antenna Efficiency versus Elevation) is almost flat with Elevation.

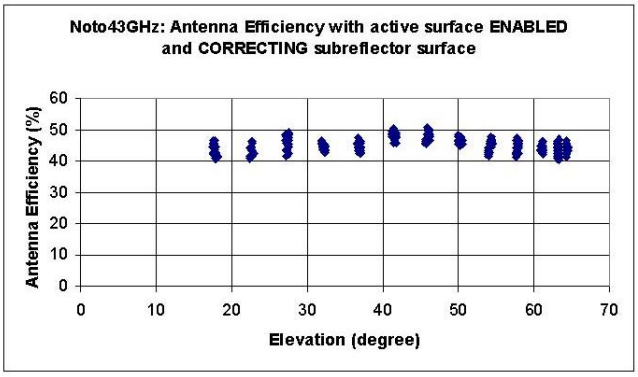


Fig. 2 - The Antenna Efficiency versus Elevation at 43 GHz of the Noto antenna with the active surface enabled.

To improve the antenna reliability a new driving system has been installed. It includes new brush-less motors, high accuracy encoders, Antenna Control Unit, drive amplifiers and everything is related to the movement control. From this renewal it is expected a more reliable system, with the goal to realise fully automatic observations in absentia of operators.

Receivers and Data Acquisition

A new 43 GHz has been designed in collaboration with IRA-Arcetri group and installed in the secondary focus of the antenna. The receiver has been used to test the performance of the active surface presented above. Further tests are planned at higer frequencies. For that purpose, a 86 GHz has been borrowed from Max Planck Institute fuer Radioastronomie and installed in the primary focus of the antenna. The receiver can tilt in z and y axis with the robotic equipment of the sub-reflector by a step motor with 0.01 mm resolution in order to control x axis. Software has been designed to control and optimize the focus position. The receiver is in the calibration phase.
CSELT has delivered the L and S/X band feeds, designed and built ad hoc for the Noto antenna. Laboratory measurements showed a good performance. The dewar has been designed and built with the collaboration of a workshop in Florence. Such system is responsible to cool both feeds and the entire set of front-end amplifiers. L band amplifiers, the same as those developed in Yebes, have been completely built in Noto, in collaboration with IRA-Arcetri group. Such job required to learn the complex techniques needed to operate with miniaturized chip components, and soldering methods as the ultrasonic bonding. The amplifiers show good performance at both ambient and cryogenic temperature. A new amplifier operating in S band has been fully designed in Noto and its realization in under the way.

A new low frequency receiver working in the frequency range 250 - 1000 MHz was made available for VLBI observations. It is a dual-polarization receiver. Both the UHF band (500-1000

MHz) and the VHF band (250-500 MHz) in single polarization (L or R) were successfully tested and fringes found at the correlator.

A cryogenic filter to mitigate the effects of a strong radar in the 21 cm band has been developed and is going to be realized. The filter was developed in collaboration with the Messina University.

The MK5A recording system has been successfully tested at 256, 512 and 1024 Mb/s.

Sardinia Radio Telescope
The construction of the Sardinia Radio Telescope (SRT) has started. The German firm MAN will be in charge for it. Images of the SRT site and of the progresses made in the construction can be found in the web page http://www.ira.cnr.it.

Fig. 3 - The Sardinia Radio Telescope foundation in October 2004.

As it can be seen from Fig. 3, the foundation construction is in the phase of casting the cement. The construction of steel antenna parts is going on in the MAN factory. Wheels and rail are ready, together with gears. Alidade parts are also almost completed. The active surface system is under construction as well together to the panels forming the primary mirror. The commissioning of the antenna servo system, the panels for the subreflector and the mirrors for the beam wave guide, will be soon under way. All the remaining servo systems construction, namely the primary focus receivers, subreflector, rotator drum and beamwaveguide rotating turret, are in progress.

6.4 Jodrell Bank Observatory, UK

By May 2004, a wear fracture was beginning to become apparent on the Lovell telescope wheel girder, and its use for phase referencing has since been restricted. Since this time, astronomers have been given the opportunity of switching to the Mk2 telescope instead as a temporary solution. As a longer term solution to including the Lovell telescope in phase referencing observations, a dedicated experiment was run in 2004 to assess whether the Mk2 telescope can adequately track Lovell phase corrections. It was found that delays could be easily tracked over a 10 minute cycle time (the current Lovell constraint) and further investigations are ensuing to allow this method to be generally available. Part of this investigation also includes the possibility of recording both Mk2 and Lovell data on a single Mk5 unit, allowing Cambridge to be included in the VLBI and/or MERLIN array.

Two major advances in the National Facility VLBI capabilities have been made during this period. Firstly, both MkIV and VLBA recorders now have Mk5 disk-based replacements. Both Mk5 systems are now in regular use for both FTP and real-time VLBI testing, as well as user experiments. In fact, only experiments to be correlated in Socorro are now recorded on tape. The other significant change is that the VLBI-dedicated Gigabit fibre Internet link to JIVE, to be used expressly for e-VLBI applications, was commissioned in December 2004, and has been performing well.

6.5 Max-Planck-Institute for Radio Astronomy, Germany

MPIfR staff play an active role in EVN technical developments. D. Graham, W. Alef, A. Kraus and M. Wunderlich are active members of the EVN TOG and attend their meetings.

In collaboration with IRAM Mark 5 units have been installed at both Plateau de Bure and Pico Veleta.

In collaboration with Haystack and IRAM a VLBI observation at 1 mm wavelength was made in 2003 with Mark 5 systems and a total recording bit-rate of 512 Mbit/s. Fringes were detected between Pico Veleta and Plateau de Bure. Weak fringes could even be found across the Atlantic between Pico Veleta and Kitt Peak. This corresponds to a resolution of 20 to 30 \mu as. (note: this should be micro_as, like mas)

In 2003 photogrammetric and holographic measurements of the sub-reflector of the Effelsberg telescope confirmed that the sub-reflector degrades the performance of the telescope for receivers in the secondary focus. A proposal for a replacement with an active surface was submitted to the Max-Planck Society and has been successful. In the last two years the planning for a new sub-reflector for the 100m antenna continued. In December 2004 a contract was placed in order to replace the existing system.

The improved sub-reflector will have a much higher accuracy (better than 100mu) and an active surface to correct for the incomplete homology of the prime reflector. In parallel, the worn focus drives will be replaced. Additionally, a mechanism for automatic receiver change in prime focus is to be installed, allowing for a change between prime and secondary focus or between three receivers in the prime focus. The latter will give the antenna more frequency agility in future.

The new sub-reflector is expected to be installed in the antenna in July 2006.

The tape drive of the MK IV terminal in Effelsberg was taken out of operation in 2003; from this point on all VLBI observations using the MK IV terminal have been recorded on disk with the Mark 5 system.

A water vapour radiometer has been constructed for tropospheric phase correction during high-frequency VLBI experiments, for improving phase-reference imaging performance and for atmospheric opacity correction. After system testing in Bonn and Effelsberg, the radiometer was installed on the focus cabin looking along boresight to maximize the beam overlap and is operating routinely. Data are logged into an SQL database and can be downloaded via a web interface developed under the RadioNet ALBUS joint research activity. Validation tests show opacity corrections consistent with those delivered by a standard sky-dip method using the 100 m telescope and validation of phase correction data applied to 3 mm VLBI data is ongoing. When tests are completed, the data will be advertised to EVN users.

Walter Alef and Alan Roy act for MPIfR in EVN's e-VLBI project. Since summer 2002 we have been actively investigating the financing of a 1 Gbit/s fibre connection between the telescope at Effelsberg, the institute in Bonn, the University of Bonn network, and the gateway of the German Research Network (DFN) to the European Geant backbone. A new attempt was started towards the end of 2004 with a proposal to the Max-Planck Society.

6.6 Metsähovi Radio Observatory, Finland

Metsähovi Radio Observatory (MRO) has continued using and developing the PCEVN data acquisition system, especially the eVLBI features. In the eVLBI data transfer test in Sep-2004, a 640 Mbit/s disk-to-disk speed record from the Otaniemi campus to JIVE was achieved with the PCEVN system. The experiment was extremely well received by the networking community and it

was published in the EU Information Society Technologies newsletter as an example of European networking success story, for details see http://www.cordis.lu/ist/rn/ri-cnd/news_oct_04.htm .

At the end of 2004 MRO has delivered a total of 29 PCEVN-based disk recorder systems, seventeen of them to Australia.

Since the termination of EVN-wide PCEVN project Metsähovi has continued the development of Metsähovi VSI Data System (MVDS). It is a simple and scalable multi-Gbps data acquisition system that adapts easily to the evolution of commodity PC technology.

Using standard microcomputers and Linux has proven to be a very successful strategy. The performance of the system keeps improving when the computer industry develops faster computers. As predicted, the latest-generation motherboards deliver sustained 512Mbps performance per PC in all directions (record, playback, disk-to-net, net-to-disk) with a 50--150Mbps safety margin.

6.7 National Astronomical Observatory, Spain

The 40m radio telescope

The construction of the new 40 meter radio telescope in Yebes is nearly completed (see figure 1). The telescope back structure and sub-reflector were lifted onto the concrete pedestal in December 2004. After the Nasmyth and other mirrors are installed, commissioning will start with a 12 GHz receiver for holographic measurements (in primary focus) and a cryogenic Ku-band (18-26 GHz) receiver with which we expect first light by the end of 2005.

More information can be found at the URL http://www.oan.es/ .

Figure: OAN-Yebes 40-m radio telescope erected in December 2004.

Software
The FS and the Mark5 software are regularly updated to the latest version.

Hardware
The 14-m telescope control computer, and old HP1000, failed in December 2003. The lack of spare parts and technical support from the manufacturer has made impossible its repair.

Nevertheless, the VLBI technical activities continued, in order to be ready when the new 40-m telescope is completed. A Mark5A system has been installed on a new rack, which also contains a transformer for the DAR, and connected to the 14-BBCs VLBA4 rack. Several disk packs (11 Tb) are available for VLBI observations with the new instrument.

Other equipment
The hydrogen source of the Kvartz CH1-75 maser has been replaced, which should allow optimum performance during the next two years.

The weather station has been replaced by a new one with better resolution and which also provides wind speed and wind direction. This station is 50m from the old one and in a better place since it is far from any building.

6.8 Onsala Space Observatory

During 2003 a number of maintenance and upgrade activities were performed at Onsala. In February, the Russian Kvarz maser was serviced and the dissociator unit was exchanged.
The VLBI system was upgraded to MkVA in August 2003 and in November the MkV unit was connected to the Swedish Internet backbone, with the help of SUNET, through which connection to the GEANT network was realised. The success of this operation was demonstrated in the first EVN e-VLBI test with Westerbork, Jodrell Bank and Onsala in January 2004. Data from all three telescopes was sent via their gigabit links to JIVE where a VLBI image of the observed source was produced the very next day. Further tests have shown that reliable measurements may be made with bit-rates up to 64 Mb/sec. In November, the observatory participated in a real-time demonstration at the 'SuperComputing 2004' conference and successful correlation of pre-recorded data from Onsala at the Haystack correlator was demonstrated at data rates higher than 200 Mb/s.

Technical problems with the 20m azimuth encoders first noticed in 2003 continued through 2004, despite the installation of new amplifiers for the encoders. This problem is still under investigation. The EFOS maser failed in June 2004 and was switched off since a repair was prohibitively expensive. The Kvarz maser continues to be the Observatory's frequency standard. Finally, interference due to UMTS mobile telephone signals has disturbed S-band observations during 2004. A new mast with line of sight to the telescope was erected earlier in the year in spite of protests from the observatory.

6.9 Shanghai Astronomical Observatory, P.R. China

Shanghai station is endeavouring to improve its observing performance in virtue of upgrades and developments in the telescope, receivers, recording system, hydrogen Maser.

Telescope
The control system of the telescope will be upgraded in the period of July to September of 2005.

Receivers
C band: The New C-Band cryogenic dual-circular-polarized front-end, which made with cooperation of ASTRON, works well after is being used since 2004.

S band: A new 13cm single polarization (RCP) receiver system is installed at the prima focus at Seshan. Its frequency coverage is 2000--2500 MHz. The receiver was specially built for the Huygens project.

L band: A new L band receiver with cryogenic dual-circular-polarized front-end will be available in the second half of 2005. Like as the C band receiver, the L band receiver was made with the great help of ASTRON. We wish it will be ready for the 3rd EVN session of 2005.

S/X band: Four new S/X receivers are being built in China for the Shanghai, Urumqi, Beijing, and Kunming telescopes. They will be available in the first half of 2006.

Recording system
Shanghai station is being upgrade to MK5 A. mini-DBBC systems are developing for Chinese VLBI Network.

Shanghai station keeps up with the paces of VLBI software developments (FS and Mark IV). A major update was done in September 2004, automatic data transfer are feasible in NME experiments. Fringes were detected from all ftp data in NME experiments.

H-maser
A new maser (MHM2010) has been used in routine VLBI experiments since May 2004, and it works well since then. We are evaluating its performance by comparing clock parameters before and after July 2004 in recent days. Initial quantitative data of clock offset from geodetic data analysis has shown that it is in good condition and much better than the old one.

Future plans
Shanghai station will take part in the China Lunar project. A set of mini DBBC system and a new S/X band receiver are being manufactured specially for the project.

The fibre link, which links Sheshan 25m telescope and host institute of Shanghai Astronomical Observatory, has been contacted and will be available by the end of 2005. Ftp data transfers would be speeded up.

6.10 Toruń Centre for Astronomy, Poland

The 32m Telescope
Several improvements of the telescope control, which lead to more reliable operation of the 32m antenna, were made in 2003 and 2004. Among them some had important aspects.
Occasionally the control system could loose orientation in which part of the sky (+/- 180 deg from the north) the telescope was pointing. The situation was been improved by replacement of motion direction detector units.
Tracking quality was also improved this time by implementing better software method of time synchronization between various units of the telescope control system.
During summer 2003 all electrical motors, used on both axes were serviced, some damaged parts were replaced including the main bearings, which were changed when necessary. A large fraction of relays used in hardware of telescope control system was replaced by new more robust units. Some other parts of hardware in the electrical cabin were also updated. A mechanical fault in one of gear boxes in azimuth was located and repaired leading effectively to smoother operation of mechanical parts.
A new 100 Mbps fiber network planned for the next generation control system and a data acquisition system was installed on the telescope. The local network works now much faster and many problems related to previously used narrowband LAN were overcome efficiently. This also resulted in improved operation in VLBI since the Field System can communicate with the telescope blocks quicker and thus more effective way.

By end of 2004 the 32-m telescope remains fully operational contributing into: VLBI, pulsar timing, spectral studies of methanol masers, polarization studies of the Galaxy and OCRA (30 GHz) project. During 2004 the surface panels of the telescope were reset. Holographic measurements at 12 GHz can be made now as a routine task at any moment. The current results show that dish surface accuracy is ~ 0.4 mm rms. As compared to the 1 mm rms before adjustments, this is the significant improvement of efficiency at 22-30 GHz bands. The estimate gives now ~35% aperture efficiency at 30 GHz. Further tuning will be done in next years. Pointing and tracking are almost satisfactory for 30 GHz operations (~ 10 arcsec rms).

Receivers

The 5 GHz system has been improved by added isolators between OMT and LNAs. This ensures polarization purity and stability. The system is now mostly used for polarization measurements of the Galactic background and VLBI. The UHF receiver is back into operation, it has been used in February 2004 session for test observations and in May/June session for EVN science projects.
CTI 1020R helium compressors were purchased and installed in 2003/4 and this gave Torun a comfort to be well prepared when a compressor unit fails. Currently the situation permits to keep the key receivers in the cooled phase permanently and select them in about 10-20 seconds according to the observing schedule. This is a very important for the network operation since often requested change of observing frequency will not result loss of data.
The receiver system improvements done over 2004 and 2005 have great impact on reliability and sustained operation of Torun telescope in EVN network as these allow fast change of the receiver and easy reliable automated operation. In effect the most common man made errors have been significantly reduced. Further tests aiming towards high frequency operation were performed at 12,5 GHz with single channel uncool receiver. The primary goal, complementary to VLBI activities project, was to do the antenna holography. In addition to major task, the 2.5 cm methanol line has been surveyed among known strong 5 cm maser sources. The holographic measurements are done using Eutelsat W2 satellite 11.7 GHz beacon. Two channel receivers use BBC units to convert beacon's signal to acoustic range. The correlation of both channels recorded on PC is done on line. Further data processing was done within AIPS. This work is very important development for planned extension of frequency operation range of the EVN. There are not so many telescopes in the network capable to observe with high efficiency at 22 GHz and higher frequency bands. Thus Torun 32m can add significant value.

One cm two beams cooled receiver for all sky survey (OCRA-p), constructed at Jodrell Bank Observatory, has been installed on the 32 m antenna. After the initial test observations we use this receiver for obtaining precise pointing table and for optimization of secondary - Cassegrain mirror positions. This work resulted in better pointing and antenna gain estimates at all EVN frequencies. It also provides information on the dish efficiency.

VLBI recorder

In October 2003 troubles begun with the P&G high speed magnetic tape recorder. The symptoms suggested a fault in the upper drive servo mechanism. Despite serious efforts (involving on-line help from JIVE), the recorder could not be repaired until early December. The problem was finally diagnosed by Torun's technicians and located in the tacho amplifier circuit within the capstan motor. Due to the above problem the November 2003 session was a serious failure at Torun.
In January-February 2004 further repairs of the P&G recorder took place (end tape sensor and second channel of servo electronics caused problems to smooth tape transportation). The dramatic improvements came with a change of recording technologies. In May 2004 the Mk5a recorder (plus 2 8-packs/DP) arrived (on loan from JIVE) and was used in few experiments (FTP-ing real test data and recording of an entire F04C3) during the session. Observations for all projects went without serious problems. First Torun FTP fringes ever made occurred for N04C2 in May the 20th.
In June 2004 the new Mk5a recorder for Torun arrived from the Conduant and the JIVE's Mk5a was returned to the owner. The first science (observations of SS433 disk-only experiment) with our own Mk5 was successfully recorded in August 23-27. The Mk5a and related software were easily handed by our staff with major contribution from VLBI Friends Gienek Pazderski and

Grzegorz Hrynek. From October/November 2004 session most of the experiments were recorded on disks using Mk5. Test FTP fringes to Tr were detected in both used bands. No any serious problems encountered.

Frequency standards
EFOS-15 H-maser started to develop symptoms of ageing in 2003. Since it regained lock three times on its own and so far works fine. In January 2004 the pressure of Hydrogen was increased and the maser worked fine for 2004. No obvious effect on stability was noticed, the overall performance had been acceptable. The extensive service, with major parts replacement was done at end of 2004 and beginning of 2005. The expected undisturbed operation of maser should continue for up to 2014.
A new rubidium frequency standard module purchased late 2003, had been put into operation as an emergency backup for the H-maser clock. The current situation permits us to rely on local frequency standards in all EVN observations with Torun. A back-up Rubidium frequency standard is synchronized to GPS, and provides an alternative source of stable frequency for lower end of observed bands.

e-EVN
Two 1 Gbps dedicated fiber connections between PIONEER node in Torun and TCfA (Piwnice) become fully operational in 2004. In September 8th the first e-VLBI fringes to Tr were obtained in test observations and then in September 10 the first 4-station (Tr, Cm, Wb, Ar) transatlantic real-time test experiment was successfully made. The baseline Ar-Tr set a new record in length of a real-time interferometer.September 22nd the first science e-VLBI experiments with Torun participation were made.

Improvements on service and management
A significant activity continued in 2003 and 2004 in respect to better management and organization. The local Friend of VLBI – Dr. K.Borkowski is involved into coordination of instrumental test measurements, organization of test and real EVN observations as well as into the analysis of station activity. He has been responsible for time measurements and H-maser maintenance. This is particularly important task since the atomic clock and the GPS based time service are basic for the high quality sustained EVN operation.
Further new organizational changes were introduced by Grzegorz Hrynek (Friend of VLBI terminals) and Gienek Pazderski (Technical Friend of VLBI). An improved log-book, with extensive check list, puts high demands on telescope operators. Regular, weekly meetings of the staff and monthly reviews of current problems and the progress are being held. In the effect the quality and reliability of Torun station improves from session to session. Also the state of the art measuring and testing equipment, essential for VLBI observations, is used much better way since new organizational scheme has been introduced.

6.11 Urumqi Astronomical Observatory, P.R. China

We successfully completed the Mark5A upgrade at the station in Feb. 2004, it was a hard work, and we should thank Dave Graham for email suggestions in that time. The FS was upgraded to the newest one and surprisingly the ON-OFF problem was resolved after that. Team China 3: Chopo Ma, Ed Himwich, Brian Corey and Richard Strand visited the station in May 2004. It was a fruitful visit in fixing problems and training. We together found and fixed e.g., 3 wrapped VCs etc., upgraded the Mark5 software, did sampler statistics and VC linearity measurement. But the cable measure was still failed, should be repaired.

In August 2004, a new 6cm dual polarization receiver system was installed at the station, which was made by MPIfR in Bonn and designed for VLBI and also for single dish the Galaxy survey with a sensitivity of about 2mK Tb/sec and SFED of 200Jy. It gives good fringes in afterward VLBI experiments.

We installed a new 30cm feed and receiver at the primary focus of the antenna, a test VLBI experiment gives fringes for Urumqi baseline. We are going to upgrade S/X system, 92/49cm system and the antenna control system in the future.

6.12 Bundesamt für Kartographie und Geodäsie (BKG) – Wettzell, Germany

The intensive use of RTW requires maintenance in particular to avoid failures during the observations. Some problems were caused by failures of the receiver cooling system during the hot summer period. The antenna control unit (ACU) fails randomly, the reasons were unknown. But end of 2004 the ACU was replaced by a new one.

The transition from the MK4 to the MK5A has been successfully completed. Two Mk5A system were integrated. One of the units is modified for the Intensive observations as Intensives only require one disk per experiment and not a complete 8 pack. The second unit is used as spare and also to test and to develop e-VLBI procedures. The tape drives still are available.

For e-VLBI a 34Mbps internet connection is installed. Due to the policy of German Telecom, the higher rate of 155Mbps or even more is still much to expensive. The link in Wettzell can be extended to 155Mbps, as soon as it is payable. The 34Mbps links allow the transmission of Intensive data to the correlator. Monthly it is used to send the Sunday INT2 observations to Kashima/Tsukuba. First test with Haystack and USNO, which has access to high speed internet via ISI Company, located in the neighbourhood of USNO in Washington, were conducted in order to ship the INT1 observations.

To improve the reliability the following actions were carried out:

- Two new PC's (one as back up) were implemented with the installation of the last version of the field system to replace the old PC's.
- The un-interruptible power supplies (UPS), which support all the components of the Data Acquisition System, including Mk4, Mk5 and K4 was completely renewed, as the previous system did not meet the growing requirements. A total survival period of more than one hour is realized now.
- The Dewar system has been improved through new vacuum valves and an automatic pumping station for better and faster maintenance.
- The old Antenna Control Unit (ACU), which employed a PC with an old MS DOS operating system and which caused several unexpected failures of the antenna, was replaced together with related hardware and interfaces. The new ACU is based on the real time operating system “VxWorks". The first experiences with the new ACU are promising, even though some minor points still need improvements.

7. EVN Publications including external PIs - 2003-2004

This list includes:
- publications based on results obtained with the EVN facilities;
- VLBI publications by authors affiliated with EVN institutes;
- other publications by JIVE staff;
- Publications based on results obtained with the EVN facilities
- VLBI publications by authors affiliated with EVN institutes

PhD theses

Wang W.H., 2003, "Radio observations and research of gamma-ray AGNs", PhD thesis, Shanghai Astronomical Observatory of NAOC, CAS

An T., 2004, "Radio observational studies of high luminosity AGNs and the dim Galactic center object Sgr A*", PhD thesis, Shanghai Astronomical Observatory of NAOC, CAS

Refereed journals: 2003

Argo et al (CLASS, many authors, including de Bruyn): "CLASS B0445+123: a new two-image gravitational lens system", MNRAS 338,957A

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