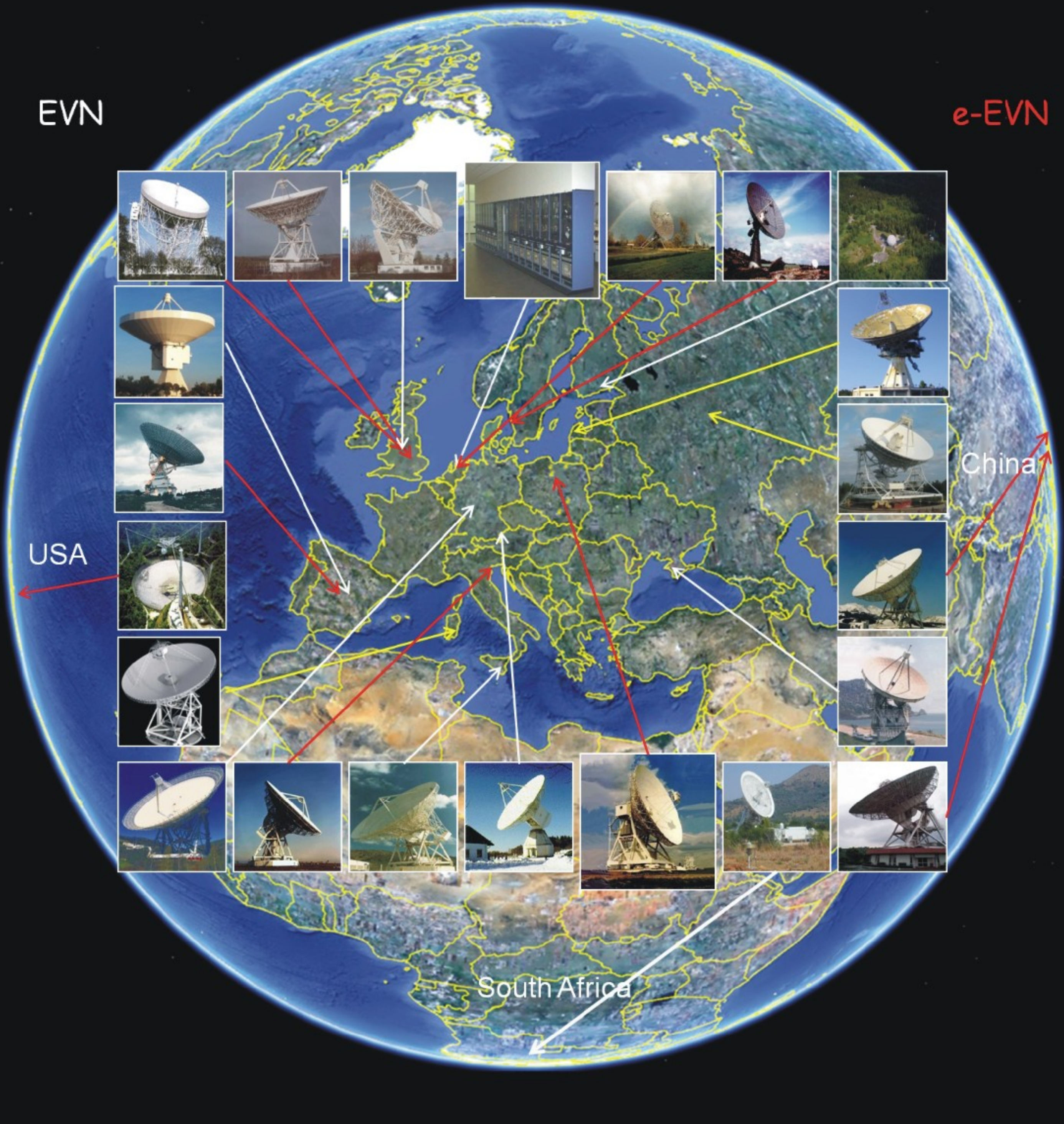
EUROPEAN vlbi NETWORK

Consortium for Very Long Baseline Interferometry in Europe

Biennial Report 2009-2010



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Foreword from the EVN CBD Chairman

The European VLBI Network achieved the age of 30 in 2010, the age of a mature, scientifically prosperous, leading international endeavour. The Consortium noted with great pleasure the impressive, broad range of results obtained with the Network. These cover major astrophysical areas of radio astronomy research, as well as showing the capability of EVN high resolution and high sensitivity research in areas untouched until now. This report presents updated information on biennial EVN organizational changes, technological progress and the most important of the outstanding scientific achievements. The information presented in this report reflects the joint activity of EVN institutes, meaning many people who make the EVN one of the best RA instruments in the world. Thanks to all who made the contributions.

The EVN offers long-term technical and scientific benefits to all member institutes and to the astronomers, who are actively studying a variety of astrophysically exciting objects within the radio domain. The technical progress made within the EVN, under the umbrella of the EC Framework Programs (in particular RadioNet), and with support from our own funding agencies, has been remarkable - extending from telescope operations and improved instrumentation, to the Network organization, science support and exchange of ideas. Thanks to many dedicated groups among the CBD with the TOG and the Program Committee playing a leading role, the e-EVN matured to an operational and successful, real time instrument. The future of EVN operation is being decided mostly by progress achieved in e-technology. The major strategic direction has been an expansion towards broad band - high sensitivity, real time, frequency agility, and extremely high angular resolution towards a world class, leading instrument.

Currently the European VLBI Network is growing fast in the number of available telescopes, enlarging the total collecting surface, and in numbers of broad band receivers, up-to-date back-ends, and high speed real time connectivity. Over the last few years the status of the EVN has risen significantly. New stations are aspiring towards EVN membership or cooperation. The new members and new telescopes coming into operation strengthen the EVN's role as the world's highest sensitivity, high resolution radio astronomy infrastructure located in the Northern Hemisphere.

Adding new European telescopes and those in Russia, China, Ukraine and Latvia would guide the EVN towards a unique future high angular resolution northern array competitive with the SKA. The EVN is, in fact, the SKA path finder and provides a major drive in pushing technology development, vitally important for new generation instruments.

During the reported period the Russian KVAZAR network was incorporated into the EVN (in November 2009) and since then it has provided a stream of high quality, extremely valuable data. The signing of the EVN accession document by the Director of the Institute of Applied Astronomy of the Russian Academy of Sciences marked a historic event. Russia formally become a new partner of the European VLBI Network Consortium, having a long standing history of VLBI experience. This strategic expansion to fill the eastern gap between European and Chinese telescopes by adding three 32m antennas of the KVAZAR Network, with the future potential to also

include the 70m at Ussuriisk, made the EVN network more powerful and truly a global endeavour.
There is another interesting aspect of this event. It happened during celebrations commemorating the fall of the Berlin Wall, which divided the people of Europe for 44 years. Despite the oppressive rule of communist governments, scientists from both sides maintained cooperation, and the VLBI was one of such very successful areas.

The current capabilities of the EVN in terms of sensitivity, frequency coverage and spectral resolution, wide-field mapping, and rapid-response have allowed European radio astronomers to produce significant advances in many areas of modern astronomy. The EVN has paved the way towards large-scale highly efficient cooperation in science, which is unprecedented in this part of the world, and helped to formulate new concepts of future international scientific collaboration.

Progress made on the Sardinia 64m Telescope is impressive. The 64m SRT is now nearly complete and will be able to start operations in 2012. Together with the coming SRT and the recent restart of the 26m at Hartebeesthoek Observatory the EVN will reinforce its research power.

The 32m Venspils antenna (Latvia) should finally start its long prepared service in VLBI. The Nobeyama Radio Observatory (Japan) is considering formal engagement with the EVN. There are new large Chinese antennas coming into operation soon, and the 70m Evpatoria telescope (the Ukrainian Academy of Sciences) is considering EVN participation.

The HartRAO (which now has full membership status), presented the Consortium detailed information about MeerKAT and a possible connection to the EVN. The new potentials of a proposed African VLBI Network based on existing communication antennas located on the continent has arisen. This ambitious project started with the HartRAO team supporting a project in Ghana to install VLBI instrumentation on a 32m antenna in Kuntunse near Accra.

Many EVN telescopes are already connected via fibre-optical dedicated cables, allowing more e-EVN experiments and science sessions with 1 Gbps transmission rates obtained routinely.

In conclusion, it is clear, that with Arecibo included, the EVN is truly a global network with a bright future. At the moment, the EVN is the most advanced and the largest radio astronomy instrument in the world. Its leading position in the Northern hemisphere will still remain strong after completion of the SKA. The high resolution images and high precision astrometry put the science based on EVN measurements at the forefront of astronomical research. For next decade the EVN will remain to be the major radio astronomy facility in the world, around which new ideas will continue to emerge.

The JIVE correlators are fully operational and cope with session data very efficiently. The coordination of e-EVN and fast data release to the PIs make JIVE a very strong and fundamentally important institute. Work to restructure the status to ERIC is in progress. This should help to secure EU funds to support present and future development. It is in the interest of all observatories in the EVN. Enhancement of the existing correlator, and development of a new generation correlator for JIVE and ultra fast fibre-optical links to all network telescopes are worthwhile activities that should be pursued.

The EC funded RadioNet program has been of great success for FP6 and continues to be so for FP7. Much support comes to the EVN from Trans National Access funds and Joint Research Activities. Significant development of new technologies within the program makes us stronger in tough global competition. Multi-beam radio cameras, advanced digital technologies, mm and sub-mm arrays developments pave the way towards future investments. The networking activities improve mobility, exchange of knowledge, and better use of human and material resources. One of the very important aspects of FP7 is organizing and financing international scientific meetings, especially to attract and support young researchers from European (and other) countries. We encourage young scientists and research students to explore new challenges. The FP7 RadioNet EU program is leading European radio astronomy along the European road map strategy.

Progress in e-EVN operation continues, and the activity of JIVE leads us to formal recognition of e-EVN as the SKA path finder, which could allow the EVN partners to access a new channel of European funds. The e-technologies being developed and implemented for e-EVN are of unique value for SKA project studies.

The EVN Consortium has elected a new Chairman – Prof. Simon Garrington (JBAC, Manchester) and Vice Chairman - Prof. Anton Zensus, (MPIfR, Bonn) for the period of 2011-2013. There are also changes in the chairpersons of the EVN Program Committee - the new Chairman is Dr. Tom Muxlow (JBAC), and the EVN Technical and Operations Group, with new Chairman Dr. Michael Lindqvist (OSO, Onsala). Special thanks and congratulations for the excellent work done for the EVN community are forwarded to Tiziana Venturi. She chaired the PC for many years and chaired the Science Working Group of EC RadioNet FP7, all for the benefits of EVN users and young scientists. Similar thanks are also directed to Walter Alef. He was the TOG Chair from January 2003 leading the technical development of the EVN from the tapes and MkIII era through MkIV and MKV with disk recording and implementation of DBBC and finally to the e-EVN. The TOG under his professional leadership helped us to go through very many important technical developments giving us a state-of-the-art interferometry network.

Finally, an important activity is the outreach of the EVN to the general public. Especially in 2009 - the Year of Astronomy, there was extensive outreach, which successfully grabbed international attention. Very impressive and politically important contributions from the EVN to enlighten the inauguration of the IYoA and other international, relevant activities, had great success. Congratulations to all involved, we wish many more spectacular events, which so well promote research conducted under the exceptionally effective and profitable international cooperation scheme of the VLBI.

On behalf of the EVN CBD Chair and EVN CBD Secretary, I would like to thank all of you for your fruitful cooperation and for your activities in the EVN community during our 2 year leadership.

Andrzej Kus, Toruń Centre for Astronomy (TCfA), Poland
Chairman, EVN Consortium Board of Directors

Magdalena Kunert-Bajraszewska, Toruń Centre for Astronomy (TCfA), Poland
Secretary, EVN Consortium Board of Directors

1. The European Consortium for VLBI

The European VLBI Network (EVN) is an interferometric array of radio telescopes spread throughout Europe (and beyond) that conducts unique, high resolution, radio astronomical observations of cosmic radio sources. It is the most sensitive VLBI array in the world, thanks to the collection of extremely large telescopes that contribute to the network.

The EVN and the body which administers it, the European Consortium for VLBI, has expanded rapidly since those early days, and now includes a total of 15 major institutes, including the Joint Institute for VLBI in Europe (JIVE). The overall policy of the EVN is set by the EVN Consortium Board of Directors (CBD). CBD is a body whose membership consists of the Directors of the member institutes of the EVN. It meets twice a year discuss EVN policy, operational, technical and strategic issues. The CBD elects a Chairman and vice-Chairman from its members who serve for a period of 2 years. Issues related to technical aspects of EVN operations are considered by the Technical and Operations Group (TOG).

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

1) ASTRON, The Netherlands Foundation for Research in Astronomy, Dwingeloo, The Netherlands
2) Bundesamt für Kartographie und Geodäsie (BKG), Wettzell, Germany
3) Hartebeesthoek Radio Astronomy Observatory (HartRAO), S. Africa (Associate Member)
4) Institute of Applied Astronomy (IAA), St. Petersburg, Russia
5) Institute of Radio Astronomy (INAF IRA), Bologna, Italy
6) Jodrell Bank Observatory (JBO), University of Manchester, Jodrell Bank, UK
7) Joint Institute for VLBI in Europe (JIVE), Dwingeloo, The Netherlands
8) Max-Planck-Institute for Radio Astronomy (MPIfR), Bonn, Germany
9) Metsähovi Radio Observatory (MRO), Helsinki University of Technology, Espoo, Finland
10) National Astronomical Observatory (OAN), Instituto Geográfico Nacional, Madrid, Spain
11) National Astronomy and Ionosphere Center, Arecibo Observatory, Puerto Rico (Associate Member)
12) Onsala Space Observatory (OSO), Chalmers University of Technology, Onsala, Sweden
13) Shanghai Astronomical Observatory, National Astronomical Observatories, Shanghai, P.R. China
14) Toruń Centre for Astronomy, Nicolaus Copernicus University, Toruń, Poland
15) Urumqi Astronomical Observatory, National Astronomical Observatories, Urumqi, P.R. China

2. Accession of the IAA as new member of the EVN Consortium

The Institute of Applied Astronomy, Russian Academy of Sciences, (St. Petersburg) joined the EVN in November 2009. The ACCESSION to the European VLBI Network Consortium Agreement was signed by the Prof. Dr. Andrey Finkelstein†, Director the Institute for Applied Astronomy and Prof. Dr. Andrzej Kus, Chairman of the EVN Consortium Board of Directors.

From left: S. Garrington, A. Kus, A. Finkelstein†, R. Bachiller, Behind: A. Zensus

Radio interferometric network KVAZAR designed and constructed by the Institute of Applied Astronomy (IAA) of the Russian Academy of Sciences (RAS) consists of three radio astronomical observatories: Svetloe (Sv), Zelenchukskaya (Zc) and Badary (Bd). The main element of each observatory is a fully steerable radio telescope with a homologous 32-meter main mirror.

From left: S. Garrington, A. Kus, A. Finkelstein†, R. Bachiller, Behind: A. Zensus

The radio telescopes of the KVAZAR network at Svetloe (Sv), Zelenchukskaya (Zc) and Badary (Bd) are now available for EVN observing sessions. Proposers may request these telescopes in EVN proposals for observations at 18cm, 6cm and 3.6/13cm.

A. Kus, A. Zensus, A. Finkelstein†, R. Bachiller

† A. Finkelstein has died suddenly on 18th Sep 2011.

3. Scientific highlights on EVN research

3.1 Galaxies and cosmology

Revealing compact cores in the faintest galactic nuclei with the EVN

The fact that radio quiet AGNs are not entirely radio silent has been known for a long time. However, the nature of the radio emission in these faint sources has not been understood yet. Thanks to its remarkable sensitivity, the EVN has been successful in detecting the nuclei of several Seyfert galaxies at or below the milliJansky level. Working at both 1.6 and 5 GHz, and exploiting the long and sensitive baselines provided by the inclusion of the Arecibo radio telescope, the EVN has provided relevant constraints on the emission mechanisms, showing that in some sources synchrotron is a viable explanation, while in other targets thermal processes are the only possible explanations (Giroletti & Panessa 2009, 2011; Bontempi et al. in prep.).

Figure: Combined optical and EVN images of Seyfert galaxies. Clockwise from top left: NGC 4051, NGC 4388, NGC 5033, and NGC 4501. Optical images from Sloan Digital Sky Survey, radio ones from EVN observations at 1.6 GHz (Giroletti & Panessa 2009, typical beam 10 × 5 mas).

EVN observations of the binary black-hole candidate SDSS J1536+0441

In October 2009 the EVN observed the candidate binary black-hole system SDSS J1536+0441 at 5 GHz, detecting two compact components separated by 0.97 arcsec (Bondi & Perez Torres 2010) and coincident with the VLA components (named A & B) imaged at 8.4 GHz (Wrobel & Laor 2009). The first VLBI detection of both components proves the presence of two compact AGNs with radio luminosity L_R~10^40 erg/s. The radio spectral index of A & B was derived using 1.4, 5, 8.5, and 22.5 GHz observations. Both sources have flat or inverted radio spectrum. In particular, source A has a rising spectrum up to ~30 GHz, rest frame. Given the moderate brightness temperature derived from the 5 GHz EVN observations, it is suggested that thermal free-free emission from an X-ray-heated disc may be powering the radio emission in source A (Bondi & Perez Torres 2010).

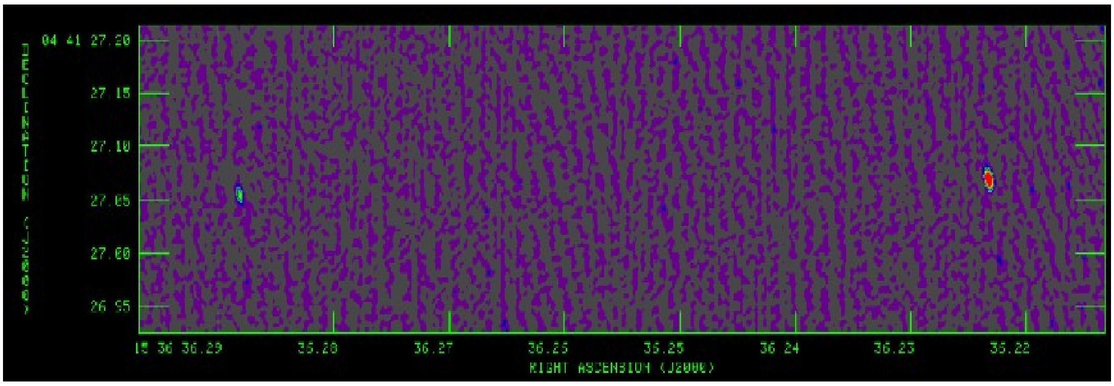
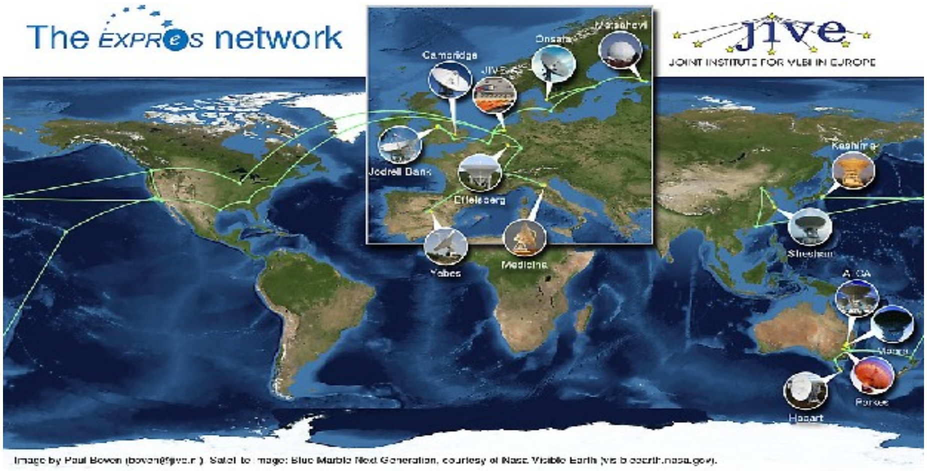


Figure: EVN image at 5 GHz of the SDSS J1536+0441 field. The resolution is 14x7 mas at position angle 16deg. The 1sigma r.m.s. noise is 15 microJy/beam. Source A, on the right, has a peak flux of 0.62 mJy/beam, source B, on the left, has a peak flux of 0.22 mJy/beam.

Global e-VLBI observations of the first gamma-ray Narrow Line Seyfert 1

The detection of gamma-ray emission by Fermi-LAT from the radio loud Narrow Line Seyfert 1 PMN J0948+0022 (Abdo et al. 2009, ApJ 699, 976) triggered a multi-wavelength campaign between March and July 2009. Given its high compactness (Doi et al. 2006, PASJ 58, 829), inverted spectrum, and 0deg declination, the source was an ideal target to observe at 22 GHz with a Global VLBI array extending from Europe to East Asia and Australia. In order to deliver prompt results to be analysed in combination with the other instruments participating in the campaign, the observations were carried out with real time VLBI, for the first time on a Global scale. Indeed, the source was revealed on baselines up to 12500 km, with fringes found for all telescopes. The observations have revealed the characteristic traits of relativistic beaming (high brightness temperature, variability, one-sided jet, linear polarization), contributing to the conclusion that radio loud NLS1 are similar to classical blazars. Exploiting the e-VLBI capabilities, the main results have been published just a few months after the campaign (Abdo et al. 2009, ApJ 707, 727), while a more detailed analysis has been presented in Giroletti et al. (2011, A&A 528L, 11).



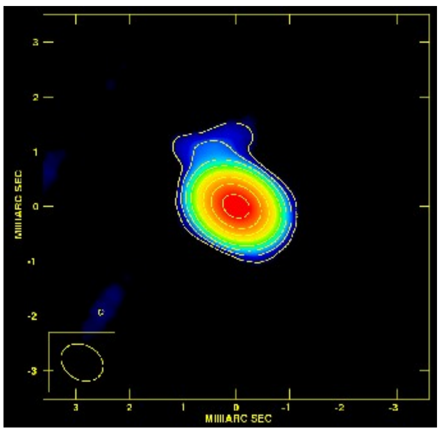


Figure: Left: the array of telescopes participating in the e-VLBI campaign on PMN J0948+0022, the first e-VLBI project on a global scale. Right: image of the source from the e-VLBI data taken on 2010 June 10.

A double-double radio source with a few kiloparsec-sized inner pair

According to a well-established paradigm, the activity of galaxies can be recurrent. The signature of a renewed activity is most convincing if a large, double-lobed relic structure straddles a pair of young lobes giving rise to the so-called double-double radio source (DDRS). Typically, the separation of the outer lobes in DDRSs is not greater than one order of magnitude that of the inner lobes. It may happen, though, that the inner part is too compact to be properly imaged in the maps encompassing the outer one and so, as a whole, the source does not appear as a DDRS but as a core-dominated triple (CDT), where the alleged core is actually a compact, luminous double source. Of course, not every CDT will turn out to be a DDRS when its core is magnified, but B0818+214 was a likely candidate for a DDRS. Fig. 1 shows its overall structure as seen in FIRST.

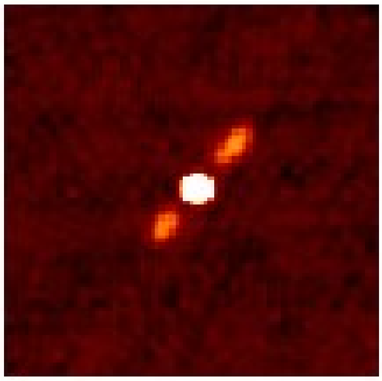


Figure 1: In the FIRST image, B0818+214 appears as a core-dominated triple. But what is the true nature of that bright "core"?

To reveal the nature of the "core" of B0818+214, we launched an 18-cm observation using the EVN combined with MERLIN. The resulting image is shown in Fig. 2. The "core" of B0818+214 is actually a double, well aligned with the outer double seen in the FIRST image. Can B0818+214 be labelled a DDRS then? To answer this question we measured the flux densities of all components in the most recent EVN+MERLIN L-band image and an earlier MERLIN-only C-band image, and calculated the spectral indices. They make it clear that the southeastern feature of the inner structure is an FRII lobe. The morphology and steep spectrum of the northwestern region leaves no doubt that it is a lobe as well. All in all, the inner double is a mini-FRII and B0818+214 as a whole, indeed, fulfils the criteria of a DDRS. However, given that the linear size of the inner pair is less than 5.7 kpc, the inner-to-outer size ratio amounts to only 1:100 - an order of magnitude less than in standard DDRSs.

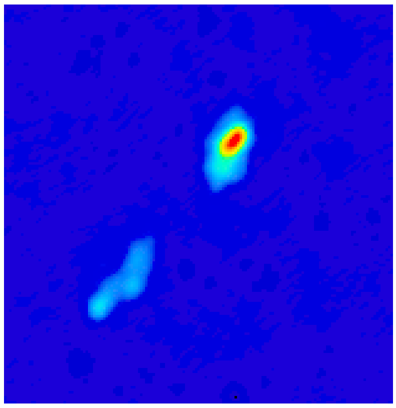


Figure 2: EVN+MERLIN L-band image of the central component of B0818+214. It turns out to be an FRII-like double, a hundred times more compact than the whole radio source.

This work is published in A. Marecki & M. Szablewski (2009, A&A 506, L33)

Compact source resolution and rapid variability in Arp220

Batejat, Conway (Onsala) and collaborators have continued making deep continuum monitoring observations of the compact radio sources in the nearby Ultra Luminous Infra Red (ULIRG) galaxy Arp220 (Batejat et al. 2010, astro.ph: 1011.4063v1).

A final 6 cm image of the Western nucleus of Arp220 made by combining three global VLBI epochs separated 4 months apart is shown in Fig 1. The rms sensitivity of the final image is only 8 mμJy/beam. This deep image gives 31 detected sources in the Western nucleus and 11 in the Eastern nucleus. Remarkably it is found that three of the sources in the Western nucleus appear to vary dramatically on times-scales of four months or less (see Fig 2). If ascribed to emission of components the changes correspond to superluminal velocities of 4c. It is possible that at least one of those sources is associated with a supermassive black hole (SMBH) in the Western nucleus of Arp220 (Downes, D., & Eckart, 2007, A&A, 468, L57) presented dynamical evidence for such a SMBH in Arp220's Western nucleus by analysing the position-velocity diagram from CO(2-1) observations and also found a hot dust feature that might be powered by a buried AGN. The positions of two of the variable sources are consistent with that of the hot dust emission (see Fig 1) making them possible AGN candidates. The fact that we have multiple variable objects is however difficult to reconcile with interpretation unless perhaps the two sources represent hotspots of a compact symmetric object and the variability is due to scintillation in the ionised galactic foreground. Other possible explanations for these enigmatic variable sources are that they represent beamed stellar-mass black holes or accreting intermediate mass black holes.

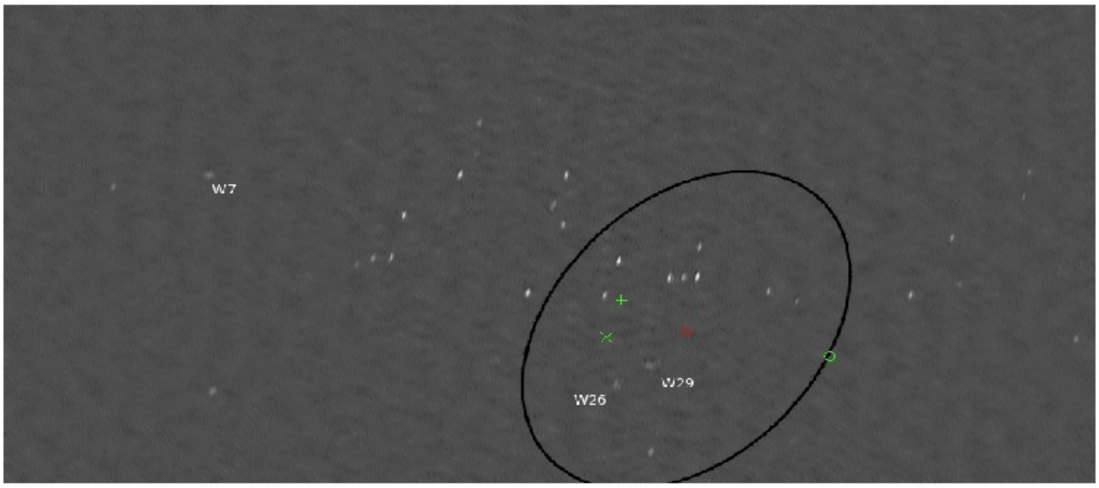


Figure 1: Greyscale shows the combined 6~cm global array natural weighted image of the Western nucleus of Arp220 from Batejat et al. (2010). The rms noise is 8~mmJy/beam, the image size is 512x256~mas. Labeled in white are the highly variable sources W7, W26 and W29. The green crosses give the 1.3 mm and 2.3 mm IRAM positions of the hot dust ``AGN" feature from Downes & Eckart (2007), the green circle is the position from the 0.8 mm observation of Sakamoto et al. 2008. Errors on these positions are estimated to be of order 50 - 100 mas. The black ellipse gives the orientation and size of the hot dust feature as fitted by Downes & Eckart (2007) centred at the centroid of the three mm interferometer positions.

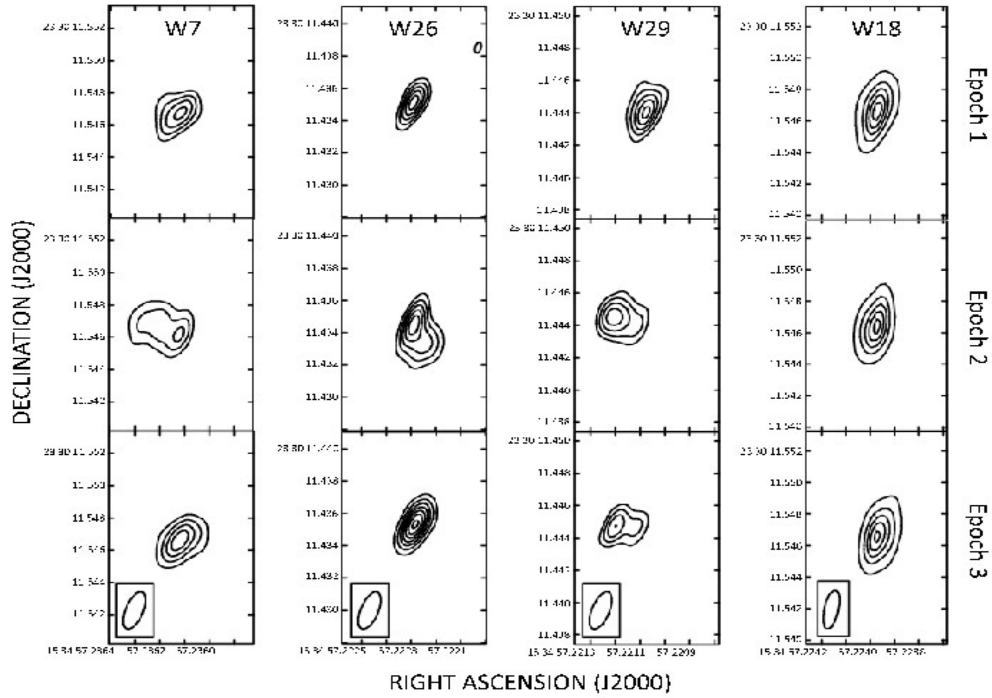


Figure 2: Variability of three compact sources in Arp220 at 6 cm wavelength taken from Batejat et al. (2010). The columns show in order the varying sources W7, W26 and W29 and finally as a control the non-varying resolved source W18 at epochs A to C (from top to bottom). The contours are at 4, 6, 8, ... times thermal noise for the variable sources and at 4, 12, 20,... times thermal noise for the control source.

Batejat, Conway et al. (2010) also presented a detailed analysis of the sizes of sources as observed in 3.6 cm wavelength global VLBI observations and 2 cm HSA observations. A total of seven sources were found to be resolved at both wavelengths, six of these have the characteristics of supernova remnants (SNRs; which are interacting with the ISM) and one that of a supernova (interacting with the projenitor stars' wind blown bubble). The resolved SNRs fit on the same luminosity (L) to diameter (D) relation as the SNRs in M82 and the LMC. Given the noise in the measurements the observed correlation is consistent with a $L \sim D^{-9/4}$ relation; such a relation is theoretically expected if the magnetic field energy in the SNR shell has a constant ratio to the shell ram pressure and this declines as the SNR evolves through its Sedov phase and decelerates. The values of the measured radio luminosities are consistent with 5% - 20% of the total explosion energy being injected into relativistic particles, the proposed ratio of 0.01 between field and ram pressure energy densities (Berezhko and Volk 2004, AA, 427, 525) and the expected ram pressure. Our observations therefore strongly argue in favour of models in which magnetic fields are internally generated in SNR shells rather than being due to compressed ISM fields.

Low luminosity AGN

Parra et al. (2010, ApJ 720,555) report EVN snapshot observations of a sample of 90 moderate luminosity Infra-Red luminous galaxies at 6~cm wavelength. In total 20 sources show detected fringes at (sub)millijansky levels; these detections are too luminous to be due to radio supernovae or supernova remnants and are argued instead to be due to embedded radio loud AGNs. Comparison with VLA observations shows that the VLBI detected sources lie almost exclusively within sources that are compact (<500 pc diameter) at VLA resolution, this latter component of radio emission fits the FIR-radio correlation and is likely powered by star-formation. Overall the results suggest that AGNs preferentially occur within compact starbursts, pointing toward an evolutionary relation in which compact starbursts can help feed a central black hole and produce AGN emission.

A VLBI study of dying and restarting radio sources

In some radio sources, the energy supply from the nucleus has been switched off, as can be deduced from the overall steep radio spectrum. EVN and MERLIN observations of four such radio sources have been obtained; of those two are probable restarting sources, while the other two are CSS, which are likely to be in a phase of inactivity and therefore dying. The structures found in the two CSS suggest that these sources are indeed dying: the flux remaining in the radio cores is very weak compared to the total extended flux (which is resolved out in the EVN observations), and, although not completely switched off, the cores are probably fading gradually (F. Mantovani, PoS(10th EVN Symposium)089, 2010).

Multi-frequency VLBI observations of GHz-Peaked-spectrum sources

Researchers in the former Urumqi Observatory have carried out VLBI observations by using the EVN, the targets are mainly the Gigahertz peaked spectrum (GPS) radio sources. GPS sources are compact extragalactic radio sources, assumed to be very young radio-loud active galactic nuclei and ideal objects for studying the early evolution of extragalactic radio sources. The VLBI observation is a vital tool for exploring the structure of these compact sources.

We defined a sub-sample of twelve GPS sources which have not been observed with the VLBI before, from the Parkes half-Jansky sample, and carried out VLBI observations at 1.6 GHz and 5 GHz with the EVN in 2006 and 2008, respectively, to classify the source structure and to find compact symmetric objects (CSOs). Additionally, we carried out the 4.85 GHz flux density observations for these sources with the Urumqi 25-m telescope between the years 2007 and 2009 to study whether there is any variability in the total flux density of the GPS sources or not. The results of the 5 GHz VLBI observations and total flux densities of these sources are presented in Cui et al (2010). From the VLBI morphologies, the spectral indices of components and the total flux variability of the twelve targets, we firmly classify three sources J0210+0419, J1135−0021, and J2058+0540 as CSOs (see Fig.1), and classify J1057+0012, J1203+0414, and J1600−0037 as core-jet sources. The others J0323+0534, J0433−0229, J0913+1454, J1109+1043, and J1352+0232 remain as CSO candidates need to be confirmed in future, and J1352+1107 has a complex feature. Apart from core-jet sources, the total flux densities of the CSOs and candidates are quite stable at 5 GHz both during a long-term of ~20 years relative to the PKS90 data and in a period between 2007 and 2009. The total flux densities are resolved-out by more than 20% in the 5 GHz VLBI images for 6 sources, probably because of diffuse emission in these sources. In addition, we estimated the jet viewing angles (Θ) for the confirmed CSOs by using the double-lobe flux ratio of the sources, the result being indicative of relatively large Θ for the CSOs.

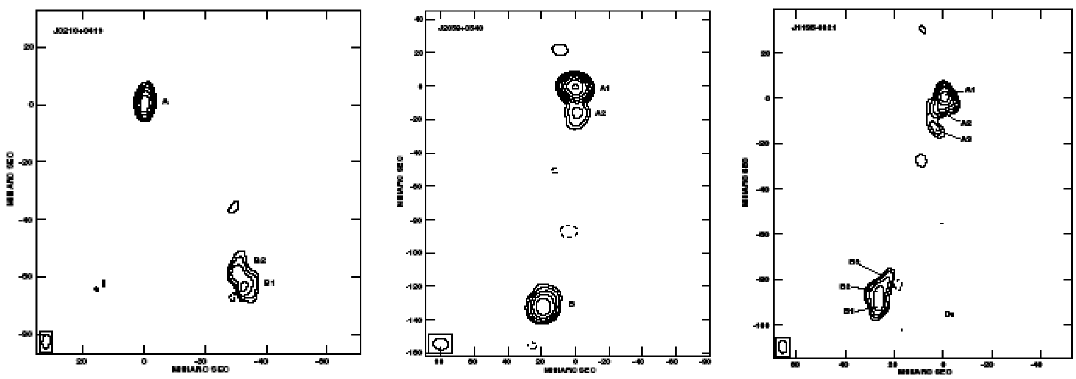


Figure 1: Three new CSOs at 5 GHz discovered by the EVN (J0210+0419 , J1135-0021, J2058+0540), from Cui et al. (2010).

We report the refined results of multi-frequency EVN observations of two GPS radio sources. The source B0914+114 is optically identified as an empty field. In the 1.6 GHz VLBI image, it shows a core component A, one-side jet B and two lobes C, E. Considering the source structure at 1.6 GHz, we have re-processed the data at 2.3, 5, 8.4 GHz with careful calibration in AIPS, the component E has been restored at 2.3, 5 GHz, and component C is restored at 8.4 GHz, as shown in the figures of Liu et al. (2009). The component spectra from the VLBI images at 1.6, 2.3, 5, and 8.4 GHz, show that the core A has a flatter spectrum than other components. Based on its structure and spectra, we classify this GPS source as a CSO. The second source PKS2121-014 is hosted by a galaxy at a redshift of 1.158. Using the VLBI results at 1.6, 2.3, 5, and 8.4 GHz we obtained the spectra for each component, the two lobes A and C show steep spectra, in which we have reprocessed the 8.4 GHz data with careful calibration in AIPS. The component B seen at 2.3 and 5 GHz was not detected in the 1.6 GHz observation, assuming an upper limit of 10 mJy set by 3σ in the image at 1.6 GHz, it exhibits an inverted spectrum which imply either a jet or probably an absorbed core. Based on the double lobe structure and the steep spectra of lobes, we classify this GPS source PKS2121-014 as a CSO.

Finally, we report the result of EVN observation of the giant radio galaxy J1313+696 (4C +69.15) at 2.3/8.4 GHz, only the core component of the giant radio galaxy was detected in the VLBI observation at the dual frequencies. The result shows a steep spectrum core with $\alpha = -0.82$ between 2.3 GHz and 8.4 GHz. The steep spectrum core may be a sign of renewed activity. Considering also the upper limit flux density of 2.0 mJy at 0.6 GHz from Konar et al. (2004), the core shows a GHz-peaked spectrum, implying that the core is very compact and absorbed. Further high resolution VLBI observations are needed to see whether the steep spectrum core consisting of a core with a steep spectrum jet or not (Liu & Liu 2009).

Origin of the complex radio structure in BALQSO 1045+352

Kunert-Bajraszewska et al. 2010 (ApJ, 718, 1345) new more sensitive high-resolution radio observations of a compact BAL quasar, 1045+352, made with the EVN+MERLIN at 5 GHz. They allowed us to trace the connection between the arcsecond structure and the radio core of the quasar. The radio morphology of 1045+352 is dominated by a knotty jet showing several bends (Fig.1). We discuss possible scenarios explaining such complex morphology: galaxy merger, accretion disc instability, precession of the jet and jet-cloud interactions. It is possible that we are witnessing in this source an ongoing jet precession due to internal instabilities within the jet flow, however, a dense environment detected in the submillimeter band and an outflowing material suggested by the X-ray absorption can strongly interact with the jet. It is difficult to establish the orientation between the jet axis and the observer in 1045+352 because of the complex structure. Nevertheless taking into account the most recent inner radio structure we conclude the radio jet is oriented close to the line of sight which can mean that the opening angle of the accretion disc wind can be large in this source. We also suggest that there is no direct correlation between jet-observer orientation and a possibility of observing BALs.

1045+352 is a CSS object and a HiBAL quasar at a medium redshift. Its linear size (~4 kpc) indicate it is a young object in the early phase of quasar evolution. The radio morphology of 1045+352 is dominated by the strong radio jet resolved into many sub-components and changing the orientation during propagation in the central regions of the host galaxy. As a consequence we observe at least three phases of jet activity indicate different directions of the jet outflow: components A_2-A_3 as the oldest one, structure A_1-B as the younger one, and the jet A as the current activity direction (Fig.1).

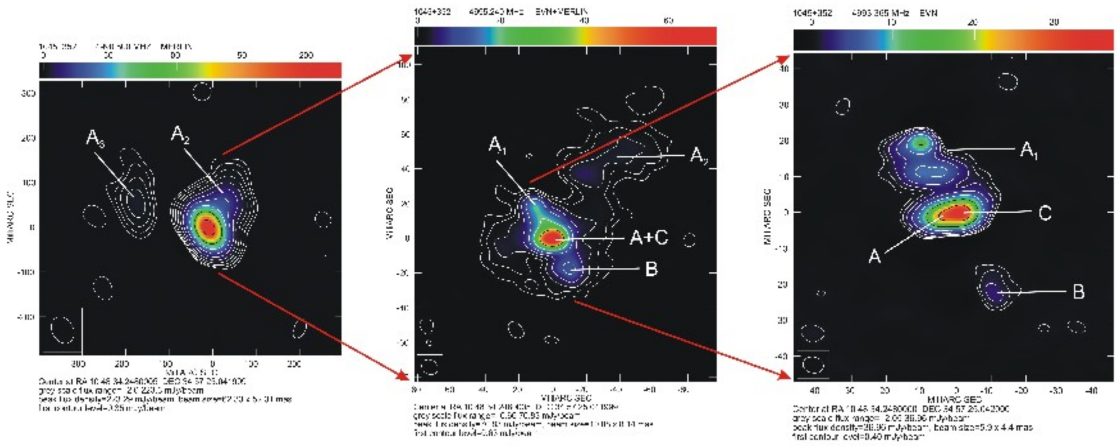


Figure 1: Radio images of 1045+352 at 5 GHz made with (from left): MERLIN, EVN+MERLIN, EVN. Contours increase by a factor 2 and the first contour level corresponds to ~3 sigma. Indications: C - radio core, A-A_3 - radio jet, B - probable counter-jet.

Morphology and orientation of radio-loud Broad Absorption Line quasars

BAL QSOs are still a not-well understood class of objects. In the UV spectra they show Broad Absorption Lines (BALs) in the blue wings of the UV resonance lines, due to ionized gas with outflow velocities up to 0.2 c. Two different models have been proposed to explain this phenomenon: in the orientation model BAL-producing outflows should be present in all QSOs, but seen only when they intercept the observer's line of sight. In the evolutionary model BAL QSOs are young sources still expelling their dust cocoon.

We performed VLBI observations with both the EVN (4.8 GHz) and VLBA (4.8 and 8.4 GHz) to map the pc-scale structure of the brightest radio-loud objects of our sample. A variety of morphologies and orientations have been found: 5 BAL QSOs in a total of 9 observed sources have a resolved structure, with a linear size < 1 kpc. In some cases the spectral index analysis of single components suggests a beamed emission toward the observer, in other cases a symmetric structure is evident from the map. From VLBI observations BAL QSOs do not seem to have a preferred orientation. Dimensions are typical of young GPS-CSS sources. This evidence could indicate an evolutionary scenario for the origin of this class of quasars.

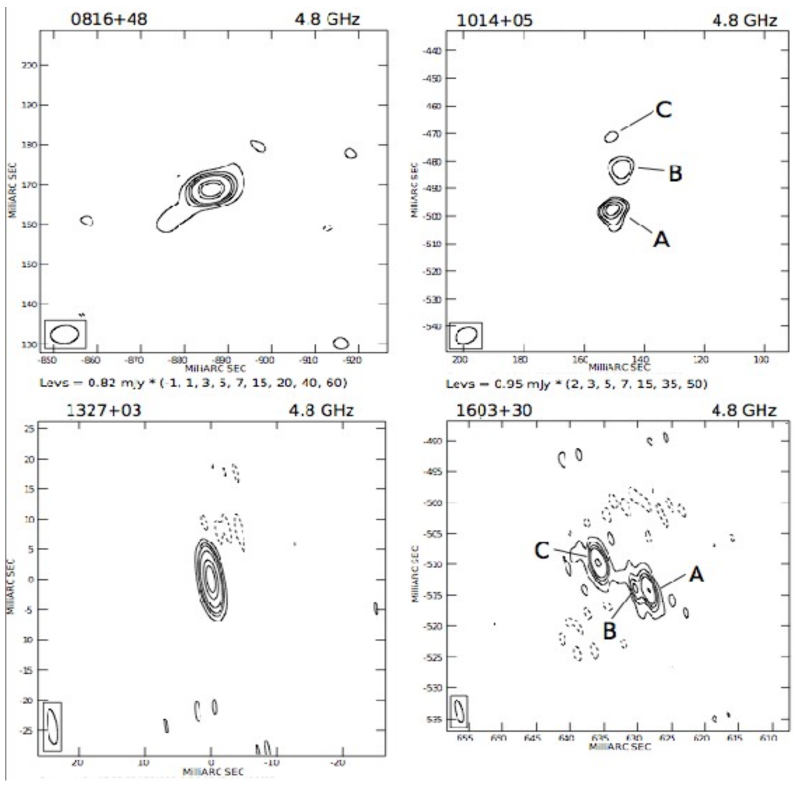


Figure: EVN maps at 4.8 GHz of four BAL QSOs.

High redshift sources, active galactic nuclei

Until recently there have been only seven quasars at redshifts greater than 4.5 observed with VLBI. This number was almost doubled in a mini-survey of the highest redshift quasars (4.5 < *z* < 5) with the European VLBI Network. Leonid Gurvits and Zsolt Paragi worked on this survey together with Sándor Frey (PI), Krisztina Gabányi (FOMI SGO, Penc, Hungary) and Dávid Cseh (Universite Paris Diderot, CEA Saclay). All five sources were detected at both 1.6 and 5 GHz, allowing for brightness temperature and spectral index measurements. In contrast to the brightest quasars at moderate redshifts, they had T_b~10^9 K and most of them had steep spectra, suggesting that they were not relativistically beamed sources. This indicates that they are likely to be young, evolving objects, resembling the gigahertz-peaked spectrum (GPS) and compact steep-spectrum (CSS) sources that populate the Universe at lower redshifts. The results were published by Frey et al. (2010), in Astronomy and Astrophysics.

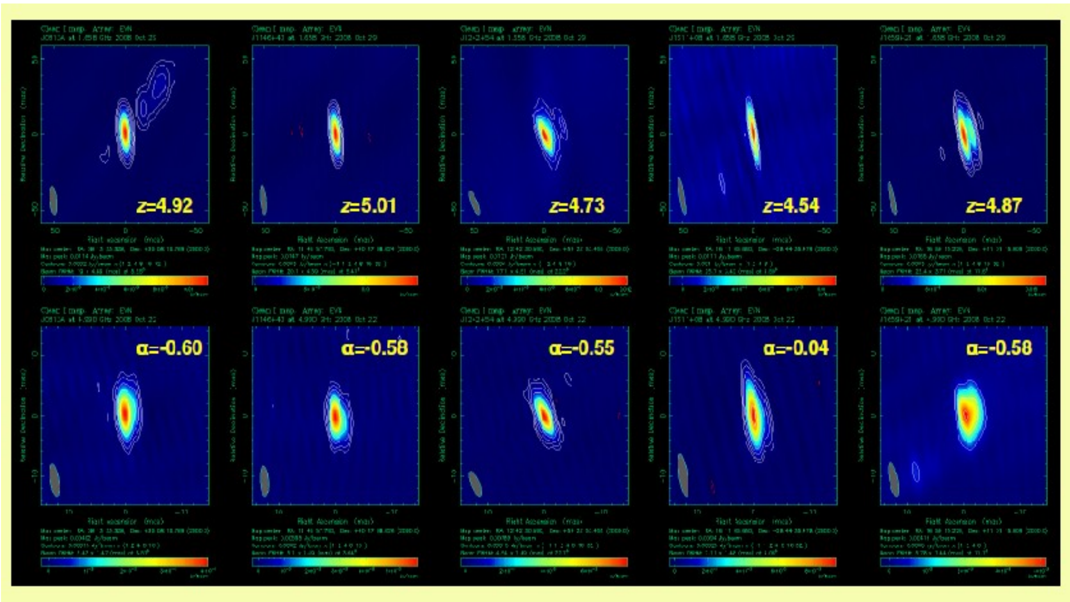


Figure 1: The 1.6 (above) and 5 GHz (below) EVN images of 5 very high redhsift quasars. These sources have significantly lower brightness temperatures than quasars at moderate redshifts, and tend to have steep spectra. They are probably young, evolving objects.

Recently Ryan et al. (2008, ApJ 688, 43) found and optical arc, which looks like a gravitationally lensed image of a galaxy. However, the foreground-lensing object apparently needed for producing such an arc is not seen in the deep optical and infrared images. It was proposed that most of the lensing mass may be in the form of dark matter, or the lensing galaxy is highly obscured. Together with Sándor Frey (PI, FÖMI SGO, Penc, Hungary) and Attila Moór (MTA Konkoly Observatory, Budapest), Bob Campbell and Zsolt Paragi carried out EVN e-VLBI observations of J1218+2953, a faint nearby radio source that was proposed to be part of this system. At 1.6 GHz, the tapered image of this source reveals a rich and complex structure in a nearly symmetrical "inverted S" shape, spanning almost 0.7". Its brightness distribution excludes the possibility that the radio source is a lensed counterpart of the optical arc, therefore both the arc and the radio source J1218+2953 cannot be gravitationally lensed images of the same background object. Instead, the observed radio structure may rather reside within a host galaxy providing the lensing potential to form the optical arc. It appears that J1218+2953 is probably a young, recently triggered and heavily obscured AGN. It is expanding in a dense interstellar medium which might cause the observed two-sided bent radio jet structure. This makes the "dark lens" interpretation unlikely (Frey et al. 2009, A&A 513, A18).

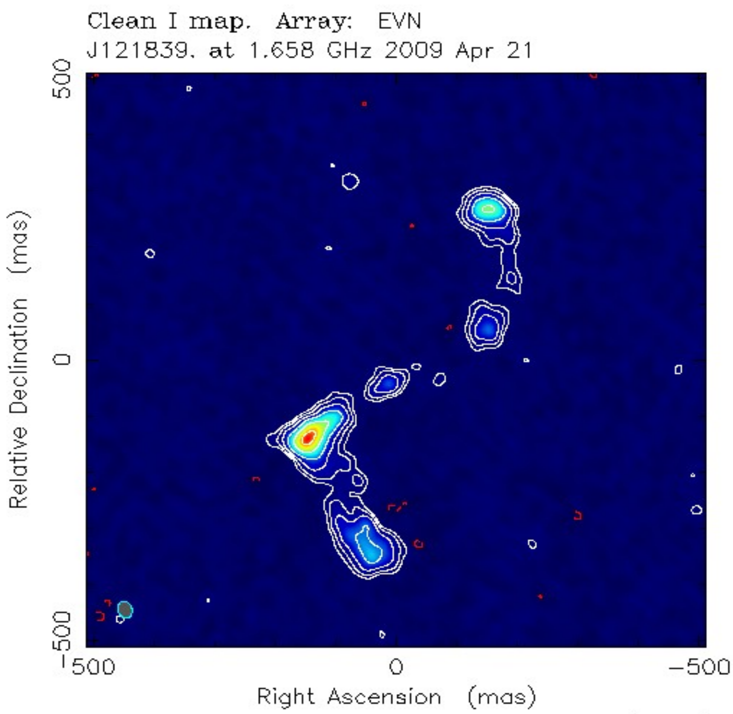


Figure 2: Naturally weighted L-band e-EVN image of J1218+2953, a candidate "dark matter" lens. The observations showed that instead the source is a heavily obscured, young AGN.

Ultra-steep spectrum radio sources

Mehreen Mahmud and Zsolt Paragi studied ultra-steep spectrum (USS) sources in collaboration with Huub Röttgering (Leiden Observatory, Universiteit Leiden), Hans-Rainer Klöckner (University of Oxford) and George Miley (Leiden Observatory, Universiteit Leiden). A small sample of 5 USS sources were observed with the e-EVN at L-band in June 2010 to look for compact emission in these peculiar objects. These exploratory observations resulted in two detections, 0722+291 and 1512+470 with total flux densities of 2 mJy and 42 mJy, respectively (note that only a fraction of the VLA flux density was recovered in both cases). While 0722+291 appeared very compact, 1512+470 showed a resolved structure on milliarcsecond scales. As was expected, it appears that USS sources are not from a homogeneous class of sources, since 3 sources did not possess compact structure, and the two detections were morphologically different on 10-mas scales (Mahmud, M., Paragi, Z., Rottgering, H. J. A., Kloeckner, H. R., & Miley, G. G. K, in Proceedings of the 10th EVN Symposium, Manchester, UK, 2010, ed. Rob Beswick). Further observations are planned at intermediate resolutions with e-Merlin for a bigger sample.

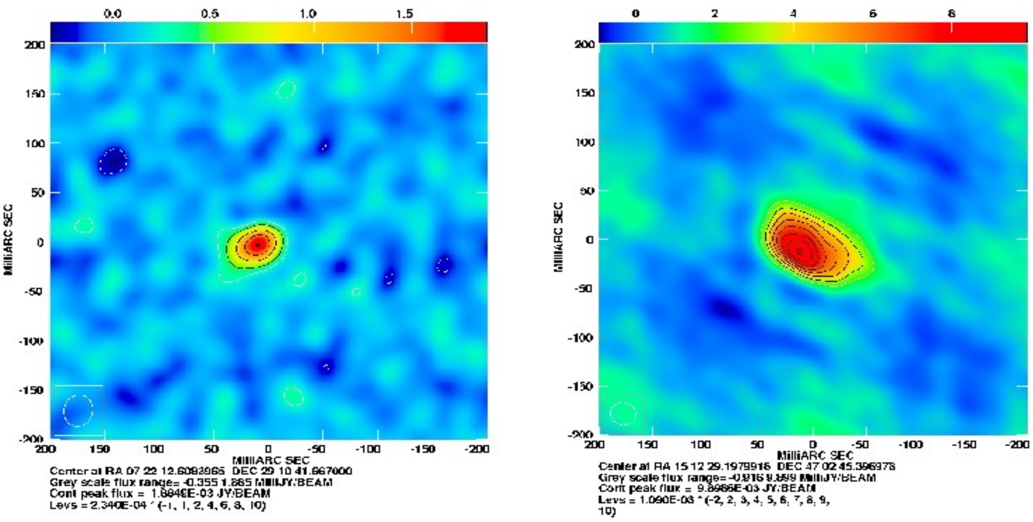


Figure 1: L-Band EVN total intensity maps of 0722+291 (left) and 1512+470 (right). For 1512+470, the peak brightness is 9.9 mJy/beam, the 1-sigma rms noise is 0.36 mJy/beam and the restoring beam is 23.88 x 22.31 mas at a position angle of 70.07 degrees. For 0722+291, the peak brightness is 1.88 mJy/beam, the rms noise is 0.085 mJy and the restoring beam is 32.15 x 26.43 mas at a position angle of -9.95 degrees.

Kinematics of the radio jet of 3C48

Compact-Steep-Spectrum (CSS) sources are important for two major reasons: (1) CSSs make up a significant fraction (~30%) of bright extragalactic radio sources detected at centimeter wavelengths, making them crucial for studies of dynamical evolution of powerful radio sources from CSOs to extended doubles (FR II galaxies); (2) because of the compactness and high brightness, CSSs are ideal probes of the physical environment of the host galaxy on scales of tens to hundreds of parsecs. 3C48 is a well-known optical quasar and also an archetypal CSS source. T. An (SHAO), X.-Y. Hong (SHAO), M.J.Hardcastle (University of Hertfordshire, University of Bristol), D.M.Worrall (University of Bristol), T. Venturi (INAF), T.J.Pearson (CalTech), Z.-Q. Shen, W. Zhao, W.-X. Feng (SHAO) observed this quasar with the EVN+MERLIN at 1.6 GHz in 2005 (project EA033) and with the VLBA in 2004 at multiple radio frequencies (project BH119).

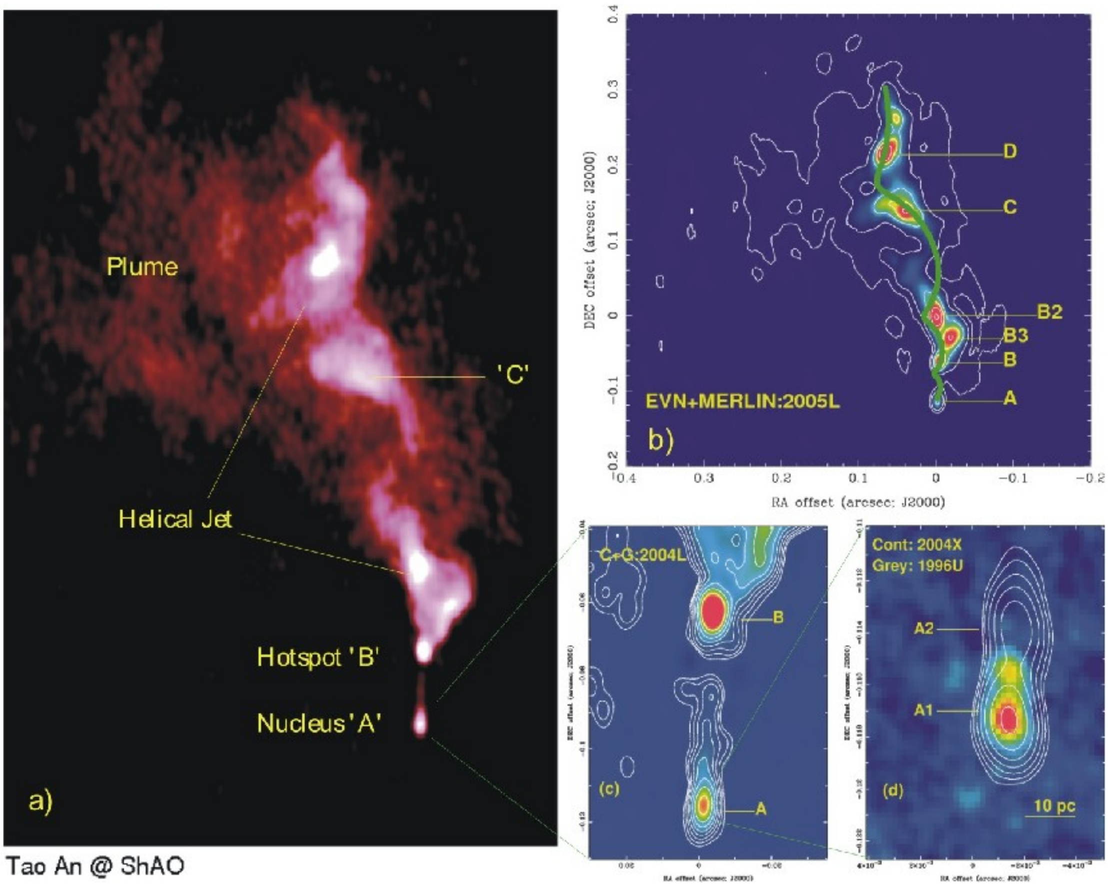


Figure 1: a) Radio jet of 3C48; b) helical jet model fit (green line) with K-H instability; c) highlight of the collimated inner jet; d) comparison of the 1996 15-GHz (color) and 2004 8.4-GHz (contour) image shows the jet knot *A2* moves to the north.

Figure 1 displays the 3C48 radio jet on various scales. The active nucleus *A* lies at the southern end of the jet. The hot spot *B* is the most brightest VLBI component at ~300 pc north of *A*. The most sensitive image (Fig.1c) first reveals a continuous collimated jet connecting between *A* and *B*. From *B* the jet flares and loses the collimation. The main body of the jet shows wiggling structure. The total extent of the VLBI jet is ~2 kpc, and the MERLIN image shows an extended cocoon structure embraces the compact VLBI jet and a weak counter lobe. The hot spot *B*, showing a high rotation measure and no signature of positional change, appears to host a stationary shock. Proper motion is only detected in the inner jet *A2* with β_{app}=3.7+/-0.4c. This is the first determination of apparent superluminal motion in this quasar, placing important constraint for the jet flow property and the geometry: a jet velocity >0.96c and the angle between the jet axis and the line of sight <20°. Outer knots beyond *B* are not detected proper motion, indicating an intrinsic deceleration process (An et al. 2010 MNRAS, 402, 87).

The kinematics and polarization of the jet as well as its wiggling structure are interpreted with a model involving with fluid instability. The radio jet emerges as laminar flow and forms a reconfinement shock at a certain distance where the jet reaches pressure equilibrium with its lobe. In the confinement shock, a significant fraction of the kinetic energy of the jet is dissipated to thermal energy and a bright hot spot (*B* in 3C48) is created. After passing through *B*, the laminar jet changes to turbulent flow. The jet turns disrupted before escaping the host galaxy, eventually 3C48 would develop into an FR I. It is a natural consequence of jet deceleration at the hot spot, more sensitive VLBI observations with a longer time span is under way to quantitatively estimate the flow speed of the outer jet and to study the dynamical evolution of the radio source of 3C48.

Monitoring the jet of M87 in coordination with high energy observations

The radio galaxy M87 is a privileged laboratory for a detailed study of the properties of extragalactic jets, owing to its proximity (D=16.7 Mpc, 1 mas = 0.080 pc), massive black hole (~ 6.0x10^9 solar masses) and conspicuous emission from radio wavelengths to very high energy (VHE, GeV/TeV domain). We started on November 2009 a monitoring program with the e-EVN at 5 GHz, coordinated with VHE and multi-wavelength (MWL) observations. Indeed, two episodes of VHE activity have been reported in February and April 2010 (M. Giroletti et al., Atel #2437, 2010).

Thanks to the EVN combined sensitivity and angular resolution, we have successfully revealed the complex structure of both the inner jet and the HST-1 complex 800 mas downstream. Thanks to a total of 12 epochs of observations, superluminal motion of individual components within HST-1 have been detected, shedding light on the observational properties of this region. The data have also been combined with MWL observations in order to understand the nature of the 2010 VHE event, which seems to be different from the ones in 2005 and 2008, opening new scenario for the radio-high energy connection (M. Giroletti et al., PoS(10th EVN Symposium)047, 2010).

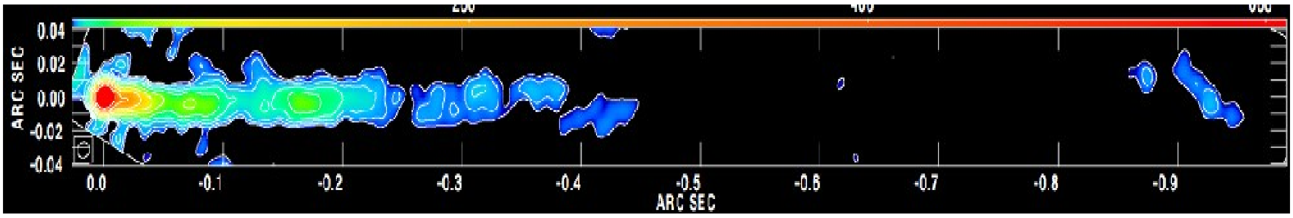


Figure: The jet of M87 from e-EVN observations at 5 GHz. The 400 mas long inner jet is revealed, as well as the HST-1 feature ~900 mas downstream, which is clearly resolved in complex substructures showing superluminal motions (image rotated by ~23 deg clockwise).

EVN observations of sources from the "Deep X-ray Radio Blazar Survey"

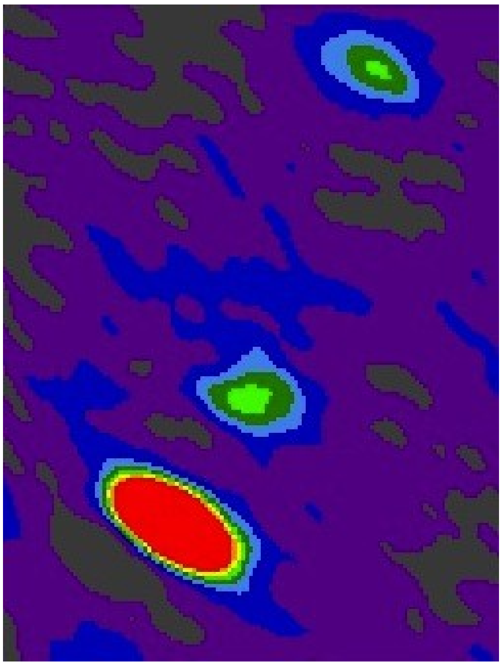


Figure: a color image of the z=1.478 quasar J1507.9+6241 made with a resolution of 4 x 2 mas at 60 deg. The peak flux density is 9.1 mJy. The total flux density about 11 mJy. The rms noise is 0.12 mJy/beam.

Blazars are an extreme class of Active Galactic Nuclei (AGN), characterized by a high luminosity, rapid variability, and high polarization. In the radio band, blazars are core-dominated objects with apparent superluminal speeds along relativistic jets pointed close to the observer's line of sight. Blazars have flat spectral indices and include flat-spectrum radio quasars (FSRQs) and BL Lacertae objects, the counterparts of high- and low-luminosity radio galaxies. A deep, large sample of blazars has been constructed by Perlman et al. (1998) and by Landt et al. (2001): the ``Deep X-ray Radio Blazar Survey" (DXRBS). The DXRBS sample is currently the faintest (down to 50 mJy at 5 GHz and power 10^{24} W/Hz) and largest blazar sample with nearly complete optical identifications. It is reasonable to expect that the objects in the DXRBS will be the counterparts of gamma-ray sources detected by the Fermi gamma-ray Observatory.

We are conducting the first milli-arcsecond resolution observations of a sample of faint blazars selected from the DXRBS with declination >-10 deg. The sample is formed by 87 target objects, 13% of which are BL Lacs and 87% FSRQs. 58 objects were already observed: 18 in Session 3, 2009 (project EM077A); 40 in Session 2, 2010 (projects EM077B, C). All the 18 sources observed within project EM077A have been detected and fringes were found at all baselines. Twelve sources are core dominated with a core-jet structure; the remaining sources are point like.

Seven out of 87 sources in our declination-limited complete sample of DXRBS sources have a possible detection by Fermi after 1 year of observing activity. Two of them exhibit a high degree of variability at 5 GHz. Moreover, in order to confirm the spectra of the DXRBS sources, simultaneous flux density measurements with the Effelsberg 100-m telescope at 11 cm, 6 cm, 3.6 cm, 2.8 cm have been obtained, and compared with the flux densities listed in the Green Bank catalogue built from observations performed in 1986-87. About 43% of the sources exibit significant flux density variability on a temporal scale of about 22 years. The observations will contribute to the ongoing efforts of quasi-simultaneous multifrequency observations of gamma-ray flaring candidates (F. Mantovani, et al., Proceeding of the workshop 'Fermi meets Jansky - AGN in Radio and Gamma Rays', Bonn, 2010, Eds. T. Savolainen, E. Ros, R. Porcas, J. A. Zensus).

From the expected discovery of a prolific supernova factory to the serendipitous discovery of the long-sought AGN in Arp 299-A

Within the constellation of Ursa Major, at a distance of 44 Mpc lies the luminous infrared galaxy Arp 299, which is the result of the merging of two galaxies, IC 694 (also known as Arp 299-A) and NGC 3690 (Arp 299-B1). Since Arp 299-A accounts for 40% of the total far-infrared luminosity of the system, this should result in about 0.9 SN/yr if standard relations hold.

We observed Arp 299-A with the eEVN in 2008, and found indeed a large number of compact sources in its inner 150 pc, and most of them are likely young core-collapse supernovae (CCSNe) and supernova remnants (SNRs) (See left panels of Fig. 1 and Perez-Torres et al. 2009, A&A, 507, L17). We found evidence of at least three relatively young, slowly evolving, long-lasting radio supernovae (A0, A12, and A15 in the image) that appear to have unusual CCSN properties, suggesting that the conditions in the local circumstellar medium (CSM) play a significant role in determining the radio behaviour of expanding SNe. Their radio luminosities are typical of normal RSNe, which result from the explosion of type IIP/b and type IIL SNe. All of these results support an scenario where a recent star-forming burst (less than 10-15 Myr old) instantaneous starburst in the innermost regions of IC 694, and confirm that the inner regions of Arp 299-A are an extremely prolific supernova factory. We therefore requested further observations, this time using the full-EVN at 1.7 and 5.0 GHz, to characterize the nature of all these compact sources (See right panels of Fig. 1 and Perez-Torres et al. 2010, A&A, 519, L5). The top right panel shows the inner 150 pc region of Arp 299-A as imaged with the full EVN at 5.0 GHz, with all the white blobs being the compact sources we wanted to characterize. What caught our interest was the line of objects toward the top right of this image (A1-A5 region). This was not a chance alignment, but could either be a chain of supernovae and SNRs in a super star cluster approximately 500 years old, or a core and jet of a hidden AGN. The chances that the objects belong to such superstar cluster are less than 3 in a million, and therefore we can rule out this possibility. On the other hand, the morphology, radio luminosity, spectral index and ratio of radio-to-X-ray emission of the A1–A5 region is consistent with a low-luminosity AGN (LLAGN), and rules out the possibility that it is a chain of young radio supernovae (RSNe) and supernova remnants (SNRs). We can therefore conclude that A1–A5 is the long-sought AGN in Arp 299-A.

Interestingly, the object labelled A0 is not part of the AGN. Actually, it is a supernova discovered in 2004 by Neff and collaborators. At a mere projected distance of less than 2 pc from the AGN, it is one of the closest to a central supermassive black hole ever detected. We suggest that this vicinity of massive stars could be the reason why Arp 299-A AGN is so weak – nearby massive stars heating their surroundings and dispelling the material that it would otherwise accrete.

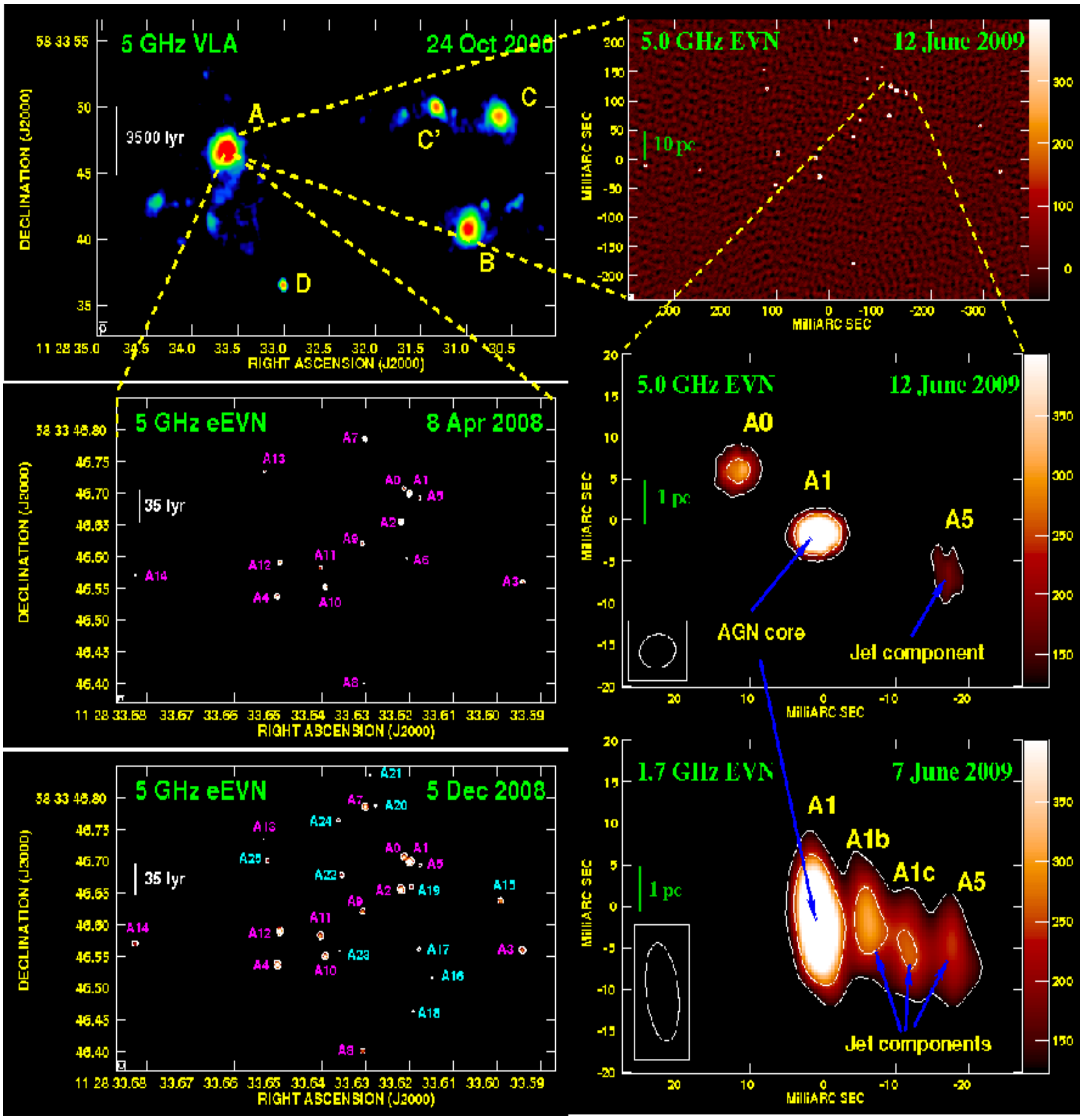


Figure 1: Left: 5 GHz observations of Arp 299 obtained with the VLA (top) and with the eEVN (middle and bottom). The relatively compact emission traced by the VLA in Arp 299-A is clearly resolved out in a number of very compact components, most of them being young core-collapse supernova and/or supernova remnants. Right: 1.7 and 5.0 GHz full-EVN quasi-simultaneous observations of Arp 299-A obtained in 2009 show that component A1 is the long-sought AGN in Arp 299A. A recent supernova (~6 yr old; labeled A0 in the image) is at a mere distance of 2 pc from the AGN, showing that both AGN and starburst activity coetaneous in this galaxy.

M82: a local SNR laboratory studied with long-term VLBI and MERLIN monitoring

M82 is the prototypical starburst galaxy, and because of its relative proximity (D=3.6Mpc) and northerly position is an ideal laboratory to study extragalactic star-formation and the evolution of individual radio supernovae (RSNe) and supernova remnants (SNRs). The central kpc of M82 is incredibly rich at radio wavelengths, containing many tens of individual compact radio sources. The majority (~2/3) of these sources are radio supernovae with ages ranging from a hundred to a few tens of years old, and luminous HII regions, however amongst these 'typical' star-formation related source there remains several enigmatic objects.

Over the last 30 years M82 has been subject to semi-regular high resolution observations with MERLIN and VLBI arrays. Over this time period 6 epochs of VLBI (Global VLBI, EVN-only or gVLBI+MERLIN) have been observed primarily at L-band but more recently also at C-band (see Figure 1). The long term monitoring of the brightest and most compact source in M82 has measured the expansion velocities of the most compact of these SNR sources to be between few and 20,000 km/s over the last 3 decades (Beswick et al 2006, Fenech et al 2008, 2010).

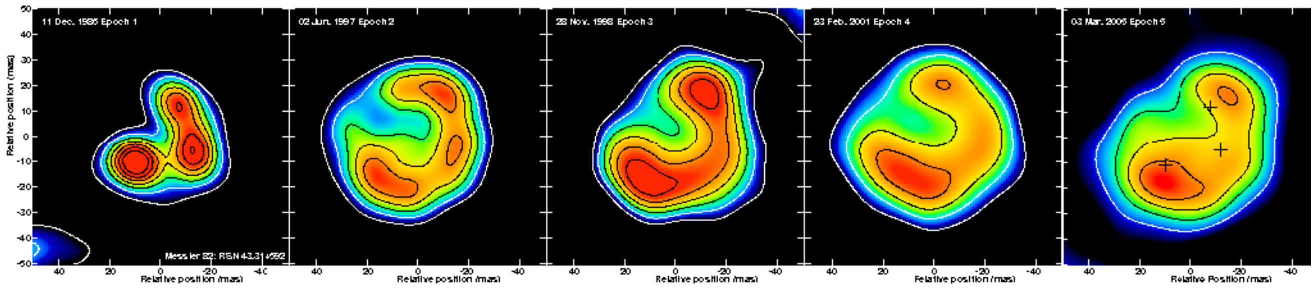


Figure 1: 5 epochs of VLBI imaging of the SNR 43.31 in M82 between 1986 and 2005

The most recent VLBI epochs (2005 and 2009) of this monitoring program (Fenech et al 2010, Fenech et al in prep) have combined global VLBI observations with simultaneous MERLIN observations. The inclusion of short-spacing MERLIN data has resulted in resolved VLBI imaging of 38 of sources, massively increasing the sample that can be imaged at VLBI resolutions, which was previously just 6. This is now a statistically useful sample of source for which directly imaged expansion velocities can be derived (Fenech et al in prep.), allowing the evolution of SNRs covering a wide range of ages (~30 to few hundred years old) and environments to be studied in a single galaxy.

In addition to the historical SNR and HII regions in M82, over the last 5 years, two new radio sources have been detected. In May 2008 a new, bright radio supernova, SN2008iz was discovered from VLA observations by Brunthaler et al (2009, A&A, 499, 17). This source has now been extensively monitored with VLBI (Brunthaler et al 2010, 516, 27) tracing its first few years of expansion. Following the initial announcement of the detection of this new source, extensive MERLIN flux density monitoring of the sources in M82 was undertaken (Gendre et al 2011 in prep) during which a second new transient (Fig. 2) was discovered (Muxlow et al 2010, MNRAS, 404, 109). This new transient source remains enigmatic and the subject of continued investigations. Its discovery was made in 1st May 2009 and it was not visible just 6 days prior to this, allowing its birth date to be precisely pinpointed. Plus unusually for an SNe initial measurements, just days after its birth, showed the source to have a steep, non-thermal radio spectral index.

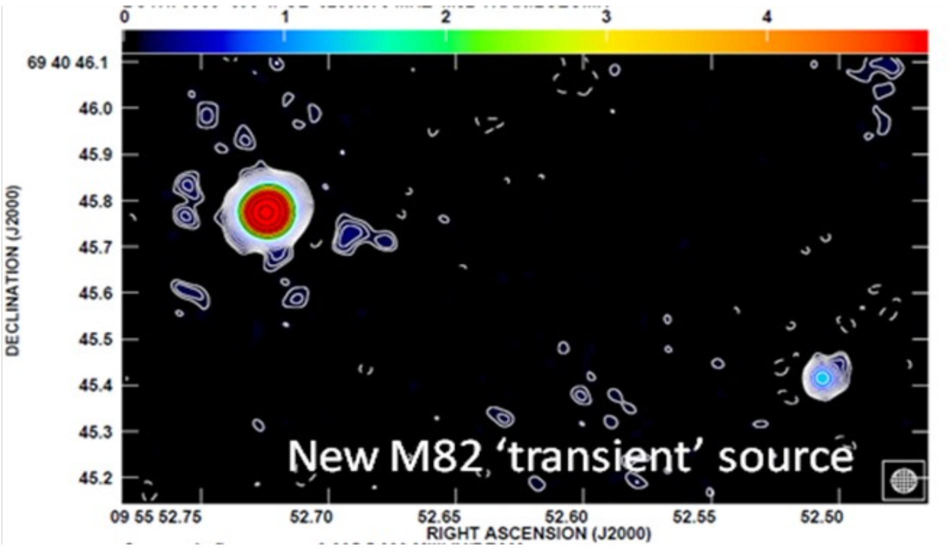


Figure 2: e-MERLIN image of the new transient source (bottom left source) and one of the historical SNRs in M82 from December 2010.

This compact source has subsequently shown only small variations in flux density, but early VLBI observations by Fenech et al, and Brunthaler et al, have resolved its structure showing an extended east-west orientation (see Fig 3.) and an angular size implying a expansion speed many times larger than is typical SNe sources. This early 'jet-like' structure along with its radio light curve, spectral index, and potential high proper-motion as seen astrometricly with MERLIN and e-MERLIN (Muxlow et al 2010) imply that this source may be related to an outburst from an accreting system rather than a new, albeit faint SNe. VLBI monitoring of the structural evolution of this unique source is still underway in order to constrain its nature.

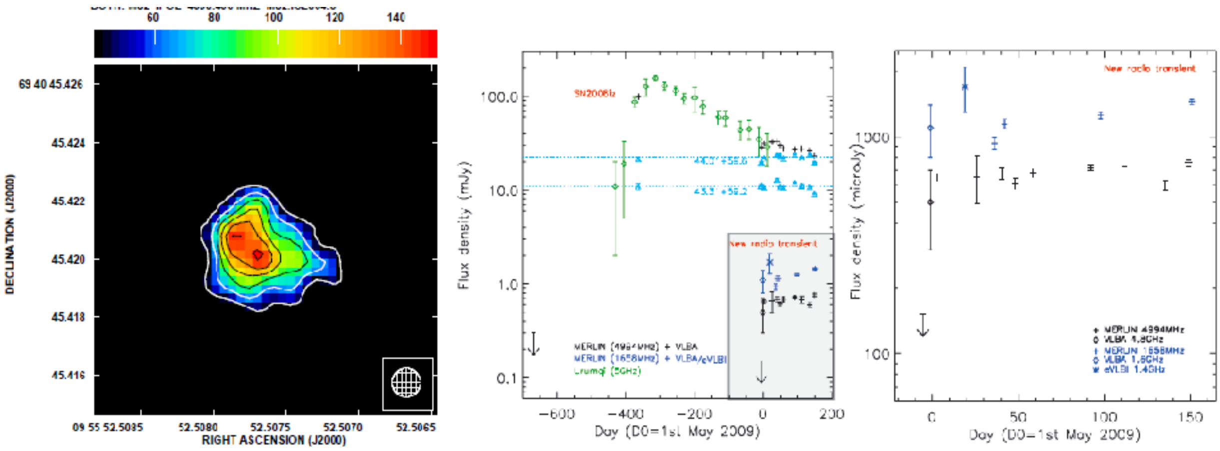


Figure 3: Left: New 5GHz Global VLBI image of the new 'Transient' source in M82. Observations were made 6months following the initial outburst of the source. Right: Radio light curves for SN2008iz and the new transient source derived from MERLIN and VLBI (Muxlow et al 2010).

3.2 Stellar evolution in the Galaxy

An accurate distance to the Cygnus X star forming complex

Cygnus X is one of the closest giant molecular cloud complexes and therefore an extensively studied region of ongoing high-mass star formation. The key difficulty in studies of such regions is the uncertainty in their distance; commonly, one finds distances between 1 and 2 kpc in the literature. Previously it has been demonstrated that one can use 6.7 GHz methanol masers for measuring trigonometric parallax; using the EVN, error bars as small as 22 arcseconds were obtained, with measured distances as far as 2.5 kpc with a 12% error bar (see Rygl et al. 2010, A&A 511, A2). Trigonometric parallaxes are the only unbiased, and therefore most trustworthy, method to measure distances.

The 6.7 GHz transition of methanol is exclusively associated with massive star forming regions; it is very strong, stable, and has small internal motions. Luckily, four star forming regions in the Cygnus X complex, W75N, DR20, DR21 and IRAS 20290+4052 (see Figure 1) host 6.7 GHz methanol masers. During 2009 and 2010 a team lead by Kazi Rygl (MPIfR, INAF-IFSI) performed 8 epochs of EVN observations (EB039) towards the 6.7 GHz methanol masers in these regions. In addition, one or two Japanese stations joined the EVN observations for several epochs to increase the angular resolution. A preliminary distance to W75N of 1.3~0.07 kpc (see Figure 1) has been found, based on 8 epochs (see Rygl et al. 2010, arXiv:1011.5042). This is significantly closer than the distances quoted in the literature for this source (1.7 - 2.0 kpc). To address the question whether Cygnus X is really one big complex of star forming regions or not, an accuracy of the order of 30 arcseconds is needed. With the third year (another 4 epochs) of additional EVN observations, currently ongoing, it is expected to finally resolve the distance issues of the Cygnus X region.

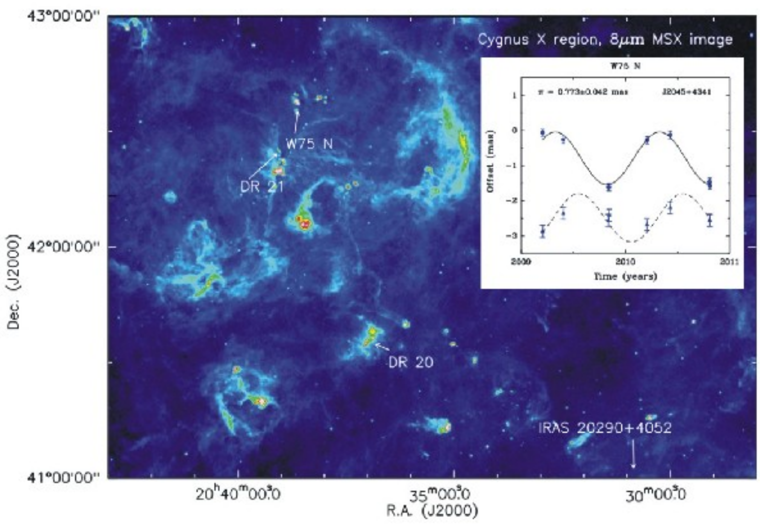


Figure 1. MSX 8 micron map of the Cygnus X region. Indicated are the star forming regions with methanol masers targeted in the EVN observations. Also shown is the 8 epoch parallax fit to W75N (using the quasar J2045+4341 as position reference); the solid line represents the fit in right ascension and the dashed line in declination.

Massive star forming regions

Kalle Torstensson and Huib van Langevelde continued their work on the nearby star forming region Cep A (Torstensson et al., arXiv:1010.4191). They measured an outflow in thermal methanol with the JCMT, which is roughly consistent with the orientation of the methanol masers on a much smaller scale as observed with the European VLBI Network. The methanol masers that straddle the waist of Cep A are interpreted to outline a large scale ring structure perpendicular to the outflow axis of the central source. Remarkably, the velocity field does not show a rotation signature, but seems to be dominated by a small radial motion. It could be hypothesized that the ring outlines an accretion shock, where in-falling gas hits the accretion disk. In a project led by Wouter Vlemmings the same Cep A methanol masers are observed with MERLIN to obtain measurements of the magnetic field direction (Vlemmings et al., 2010, MNRAS , 404,134). Although the interpretation of maser polarization can be quite complex, the measurements reveal a structured large scale magnetic field, which is perpendicular to the accretion disk in this high mass young stellar object. Combined with measurements of the field strength, this observation reveals that magnetic fields can be the dominant force in regulating the formation of high mass stars. This is an important clue that the formation mechanism of high mass stars may resemble that of less massive stars.

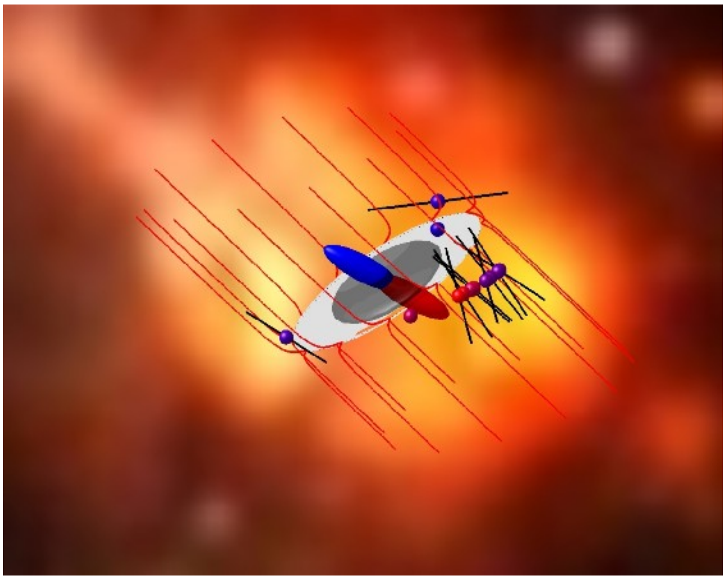


Figure 1: The magnetic field configuration around the young massive star Cepheus A HW2 and the location of the methanol regions from which the 3D structure was inferred. The figure shows that the magnetic field is almost perfectly perpendicular to the disk through which matter is transported onto the star

The diversity of methanol maser morphologies in HMSFRs

Anna Bartkiewicz (TCfA/Toruń) and Marian Szymczak (TCfA/Toruń) together with Huib van Langevelde (JIVE/Leiden), Anita Richards (JBO/Manchester), and Ylva Pihlstrom (Albuquerque/NRAO) used the EVN in a phase-referencing mode to observe high-mass star-forming regions (HMSFRs) using the 6.7 GHz methanol maser line. These targets were discovered in the Toruń unbiased survey (Szymczak et al. 2000, 2002) and observed earlier using MERLIN in order to find good positions. During seven EVN runs (74 hr in total), during which between four to nine antennas were used, data towards 31 objects were collected and in the end good quality images were obtained with signal-to-noise ratio above 1000 and an angular resolution of a few mas.

The main aims of this project were to study a number of methanol masers at milliarcsecond scale that are associated with massive proto- or young stars and to derive their absolute positions at mas accuracy. These both goals were achieved and several types of morphology could be identified: simple (1), linear (5), ring (9), arched (3), complex (9) and pair (1 source). Since there is no straighforward explanation of the origin of the methanol emission in HMSFRs a few existing models were considered: a circumstellar disc/torus, an outflow and a shock colliding with a rotating molecular cloud. Surprisingly, when fitting a simple model with a rotating and expanding thin disc for nine methanol rings we noticed that the expansion/infall dominated. This suggests the association of the masers with the interface between the disc/torus and outflow. A similar scenario was reported for the archetypical star forming region Cep A (Torstensson et al. 2011). These results showed that the VLBI survey that was more sensitive, with better spectral resolution and concentrated on weaker masers led us to discovery of a new class of objects and enabled us to study in details the close environment around newly born massive star.
These results were published in Bartkiewicz et al. 2009, A&A, 502, 155.

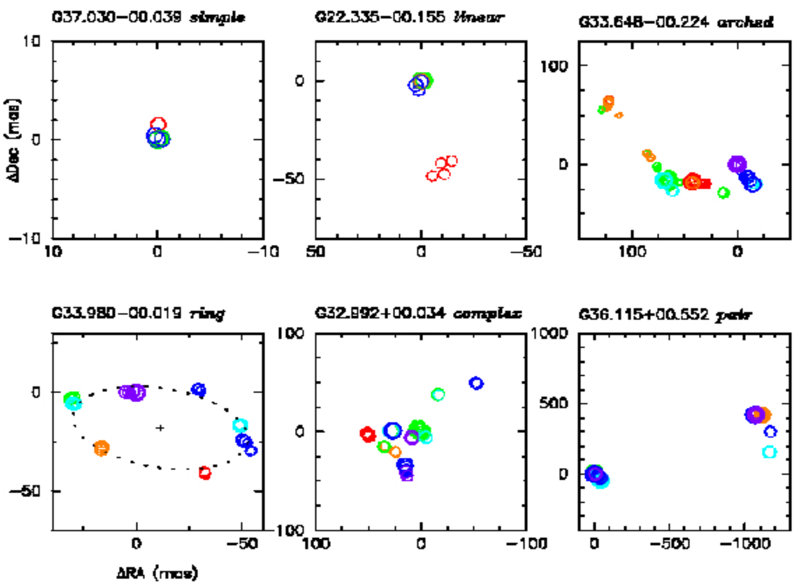


Figure: Images of different morphologies of 6.7 GHz methanol masers detected using EVN. The best-fitting ellipse and its centre are marked by dotted curve and a cross, respectively.

Full polarization observations with the EVN of 6.7-GHz methanol masers around massive star-forming regions

Magnetic fields are attributed an important role in star formation, in particular in halting the collapse, transferring angular momentum and powering the outflows. Gravitational collapse of molecular clouds proceeds preferentially along the magnetic field lines, giving rise to large rotating disk or torus structures orthogonal to the magnetic field (Matsumoto & Tomisaka 2004). Consequently, the molecular bipolar outflows, which originate from the protostar, are driven parallel to the magnetic field (e.g., Cohen 2005; McKee & Ostriker 2007). This picture, despite being largely accepted for low-mass star-formation ($M<8\ M_\odot$), is still under debate for the formation of high-mass stars ($M>8\ M_\odot$).

The best probes of the magnetic field at the smallest scales in the high-mass star-forming environment are maser lines. Their bright and narrow spectral line emission is ideal for detecting the Zeeman-splitting as well as the direction of the magnetic field. So far the most investigated sources are H2O and OH masers, revealing ordered structure in the magnetic field and field strengths between 10 and 600 mG (e.g., Vlemmings et al. 2006a) and few mG (e.g., Fish et al. 2005), respectively. Even though methanol (CH3OH) is the most abundant of the massive star-formation maser species (e.g. Pestalozzi 2007), the first 6.7-GHz (5 1→60 A+) methanol maser linear polarization observations have only recently been made (e.g., Vlemmings 2006b; Green et al. 2007; Dodson 2008). Like H2O, CH3OH is a non-paramagnetic molecule, and thus any linear polarization is of the order of few percent (~2-3%), while circular polarization is well below 1%. In order to understand the role of magnetic fields in the formation of massive stars it has been necessary to start to observe the linear and circular polarized emission of 6.7-GHz methanol masers at milliarcsecond resolution. The only instrument that is able to do it is the European VLBI Network (EVN).

In middle June 2008 a pilot observations were made with 8 of the EVN antennas (Surcis et al. 2009, A&A, 506, 757). This observations revealed for the first time the magnetic field morphology around one of the massive protostar (VLA1) of the massive star-forming region W75N. Linear polarization fractions and Zeeman-splittings up to 4.5% and 0.8 m/s were measured, respectively. Studying the linear polarization vectors Surcis et al. (2009) determined that the magnetic field is parallel to the molecular bipolar outflow. From the Zeeman-splitting measurements the authors were able to measure a magnetic field strength of about 15 mG, this strength value reveals that the magnetic field plays an important role in the dynamics of the protostar. The results are shown in Fig.1. Two follow-ups observations with the EVN have been requested after the pilot observations allowing the PIs to investigate the magnetic field around 10 massive star-forming regions.

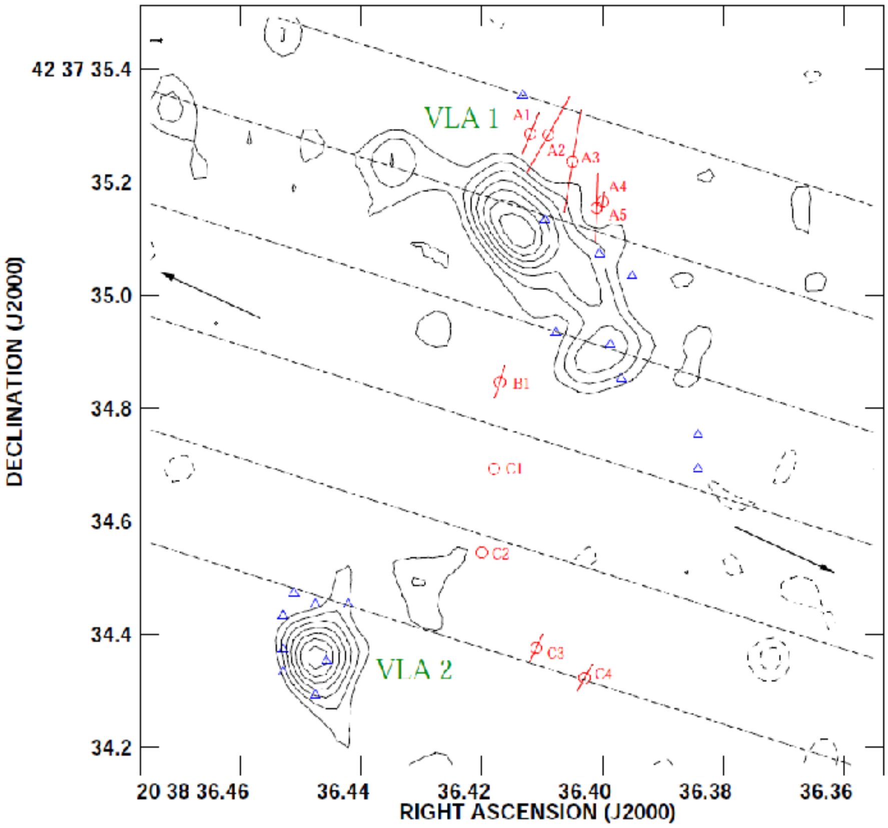


Figure 1: Positions of methanol and water masers superimposed on 1.3 cm continuum contour map of the VLA1 thermal jet and VLA2 (Torrelles et al. 1997). Contours are -3, -2, 2, 3, 4, 5, 6, 7, 8 x 0.16 mJy/beam. Blue triangles indicate the positions of the water masers as reported by Torrelles et al. (1997). Red circles indicate the position of the 10 methanol maser features with their linear polarization vectors (40 mas correspond to a linear polarization fraction of 1%). The two arrows indicate the direction of the bipolar outflow (66°) and the parallel dashed-lines the magnetic field lines (73°±10°) as derived from the linear polarization (Surcis et al. 2009, A&A, 506, 757) .

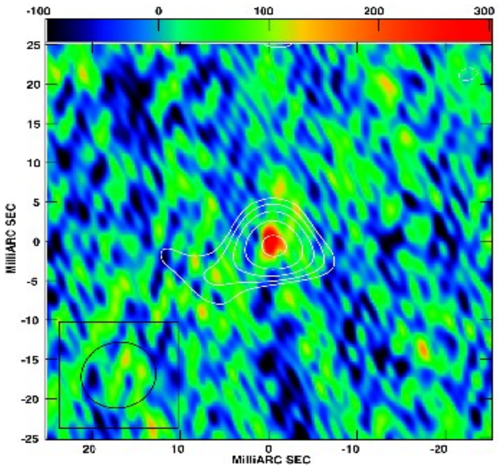
EVN observations of the gamma-ray nova V407 Cyg

On March 2010, the symbiotic Mira V407 Cyg went into outburst, brightening by 2.4 mag over its pre-outburst magnitude. Independent of the optical event, the Large Area Telescope onboard Fermi revealed a transient high-energy gamma-ray source positionally coincident with V407 Cyg. The Fermi-LAT detection of V407 Cyg has shown that novae can generate gamma-rays, probably as consequences of shock acceleration in a nova shell. The e-EVN has been used to obtain images of the source on time scales of a few days and a few weeks after the optical and gamma-ray events, which have revealed with increasing fidelity the details of the source, which appears clearly shell-like (M. Giroletti et al., ATel #2536, 2010). Interpretation of the EVN data is ongoing.

3.3 Galactic transients

e-VLBI observations of X-ray binary transients

The e-VLBI technique employed at the EVN is extremely important for the study of radio transient phenomena. Taking advantage of this real-time correlation mode we used the array to observe some X-ray binary (XRB) transients in outburst: Cyg X-3, Aql X-1, Cyg X-1. The quick data release capability of the EVN allowed us to report the preliminary results to the scientific community within days from the observational runs (Rushton et al., 2010, ATel, 2734; Tudose et al., 2009, ATel 2000, ATel 2317; 2010, ATel 2755, ATel 2911).



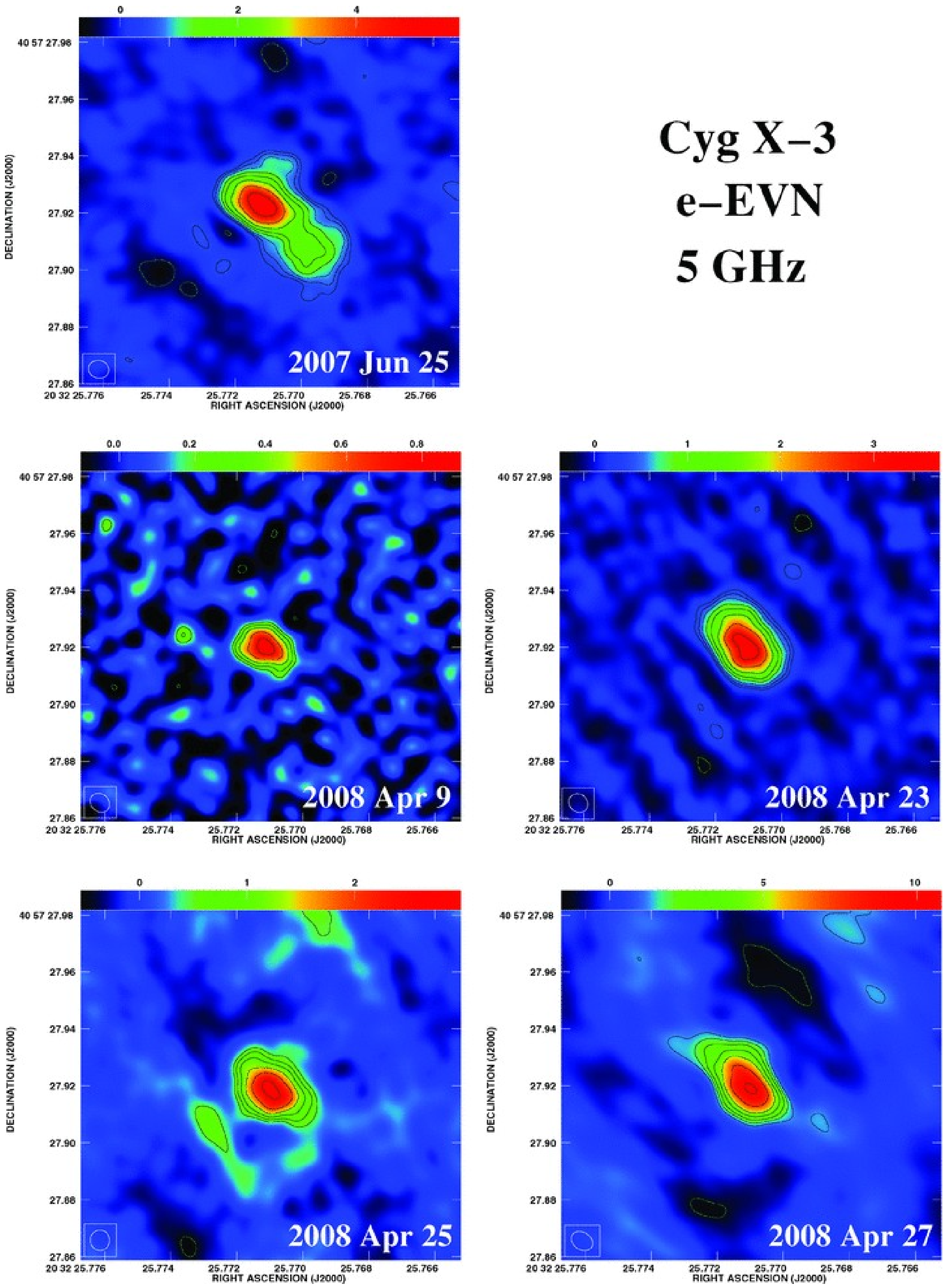
e-VLBI observation of Aquila X1

A series of EVN observations of Cyg X-3 at 5 GHz, together with archival VLBA data at 5 or 15 GHz and MERLIN data at 5 GHz, complemented with RXTE X-ray observations, were analyzed in Tudose et al., (2010, MNRAS, 401, 890) in the context of testing at mas scales a previously proposed classification of the radio/X-ray states of the object. We found that in active states the radio emission from the jet is dominating that from the core and the classification of the radio/X-ray states as defined at arcsec scales cannot be applied directly at mas scales. This shows, once again, the importance of high resolution observations in probing the behaviour of XRBs. Using the same radio data sets, Miller-Jones et al., 2009 determined for the first time the proper motion of Cyg X-3.

Using EVN data at 5 GHz, VLA data at 5 and 8 GHz and VLBA data 8 GHz, Miller-Jones at al., (2010, ApJ, 716, L109) obtained the best radio coverage of an outburst of Aql X-1. This was also the first time that Aql X-1 was detected in radio at VLBI scales. An increase in the radio emission was detected not only on the transition from the hard to the soft X-ray state, as expected, but also on the reversed transition. Previous suggestions of radio quenching in the soft X-ray state were confirmed.

Cyg X-1 was observed with EVN at 5 GHz and VLBA at 2 and 8 GHz and the results were reported in Rushton et al., (2010, PoS, 061) In the soft X-ray state the radio emission was found to be still present which is at odds with what was observed in other similar objects.

Summaries of radio transient studies involving the EVN array were presented in Miller-Jones et al., (2010, IAUS275, 224) and Tudose et al., (2010, PoS,053).

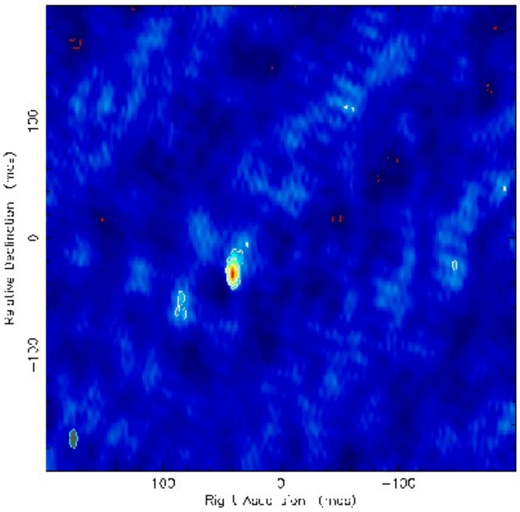


e-VLBI multiyear study of Cygnus X-3.

Galactic pulsars, variable and transient radio sources

Since 2009, Jun Yang started providing technical support for Ding Chen (National Time Service Centre, Chinese Academy of Sciences, P.R. China) to perform VLBI pulsar astrometry. The first interesting pulsar for the group is the millisecond pulsar PSR J0218+4232 (Fig. 1). The pulsar is one of brightest pulsars in X-rays and it is one of the candidate pulsars that could be used for deep space navigation of satellites carrying small X-ray detectors. The first VLBI observation of PSR J0218+4232 was done by the group with the EVN on 4 November 2010. The data were correlated on the new SFXC software correlator at JIVE via binning correlation to align pulse signal and to remove off-pulse data. A proposal for follow-up multi-epoch EVN observations was submitted to measure its proper motion and distance. VLBI astrometry will help to reduce the input covariances of the pulsar timing solutions. A possible application could be a network of X-ray pulsars with good astrometric and timing solutions serving as beacons for navigation of deep-space satellites.

Figure 1: The EVN detection of the millisecond pulsar PSR J0218+4232. The contours start from 3-sigma noise level in each image and increase by a factor of 2. The beam is shown in the bottom-left corner. The pulsar has a peak brightness ~0.7 mJy/beam (SNR ~20). The image origin reflects the position inferred from timing observations, including timing-derived proper motion, and the offset shows the residual error (~50 mas).



Jun Yang and Zsolt Paragi observed the new galactic black hole transient XTE J1752-223 with the e-EVN and the VLBA at four epochs in February 2010, in collaboration with Catherine Brocksopp (Mullard Space Science Laboratory, University College London), Stephane Corbel (Universite Paris) and others. A moving jet component was detected (Fig. 2). The proper motion analysis showed that it was significantly decelerating by the last epoch (0.34 mas per square day). The overall picture is consistent with a mildly relativistic jet interacting with the interstellar medium or with pre-existing material along the jet. Beside the decelerating ejecta, a new jet component was also detected at the fourth epoch (Yang et al. 2010, vol. 409. p. 64). There were further EVN observations carried out in March 2010 to follow-up on a new radio burst, and additional VLBA observations in April 2010 in order to identify the reactivating core in the system.

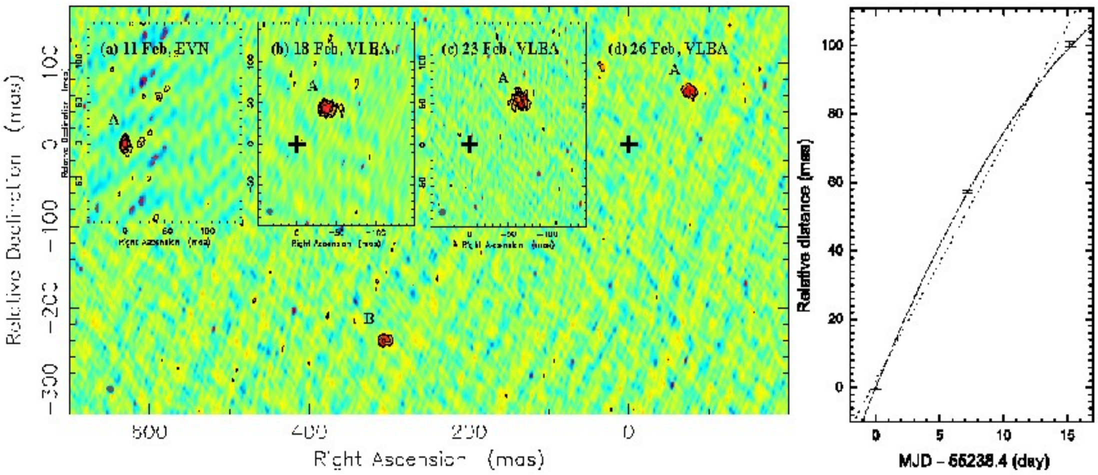


Figure 2: The decelerating jet in the Galactic black hole candidate XTE J1752-223. The cross shows the location of the first detection of component A. The contours start from 3-sigma noise level in each image and increase by a factor of 1.4. The right-hand panel plots the fitting results of the proper motion data of component A using the modes with (solid curve) and without deceleration rate (dotted line).

4. EVN Network Operations

4.1. EVN Program Committee (EVN PC)

The EVN PC is an independent body appointed by the EVN CBD, which carries out the scientific and technical assessment of all standard EVN, e-VLBI and Global VLBI requests for observing time. A Call for Proposals is distributed three times a year, with proposal deadlines on 1st February, 1st June and 1st October. The EVN PC usually meets one month after each deadline to evaluate the proposals received. All standard EVN, global VLBI and e-VLBI proposals are evaluated at the PC meetings, for observations during the standard and e-VLBI scheduled sessions.

Each EVN PC member provides a review and a pre-grade of the proposals before the meeting, then a thorough discussion on each proposal and the final evaluation are carried out during the meeting itself. Summary comments as well as the detailed comments of each PC member are sent to the PI afterwards.

Membership

The EVN PC now comprises 8 observatory members, including a representative from the EVN data processor at JIVE, whose particular responsibility is to assess the feasibility of the proposed observations from their observatory perspective. In addition, up to 4 at large members are part of the EVN PC, chosen from non-EVN institutes to complement the astronomical experience of the observatory members.

Proposals requesting the Arecibo Radio Telescope or the MERLIN array are sent to representatives at these institutes for an additional technical review. The EVN PC Scheduler is member of the EVN PC and participates in each EVN PC meeting, but he does not carry out a scientific evaluation of the proposals.

Tiziana Venturi from INAF-Istituto di Radioastronomia, has been Chairperson from 1st June 2008 throughout 2010. Elmar Koerding (Nijmegen University) was appointed as new member at large in June 2009, and three new members were appointed in January 2010: José Carlos Guirado (University of Valencia), Wouter Vlemmings (University of Bonn) and Alessandro Capetti (INAF, Osservatorio Astronomico di Torino). Capetti resigned after becoming head of his observatory and was promptly replaced by Nektarios Vlahakis (University of Athens) in June 2010. In 2009 Richard Strom was replaced by Antonios Polatidis as representative of ASTRON.
The EVN PC Membership as of 31 December 2010 is shown in the Table.

EVN PC Member	Institute
Tiziana Venturi (Chairperson)	INAF-IRA, Bologna
Bob Campbell	JIVE, Dwingeloo
Antonios Polatidis	ASTRON, Dwingeloo
Jean-Francois Desmurs	OAN, Madrid
Michael Lindqvist	Onsala Space Observatory
Andrei Lobanov	MPIfR, Bonn
Tom Muxlow	Jodrell Bank Observatory
Zhi-Qiang Shen	Shanghai Observatory
At large members:	
José Carlos Guirado	University of Valencia
Elmar Koerding	Nijmegen University
Nektarios Vlahakis	University of Athens
Wouter Vlemmings	University of Bonn
Richard Porcas (EVN Scheduler)	MPIfR, Bonn

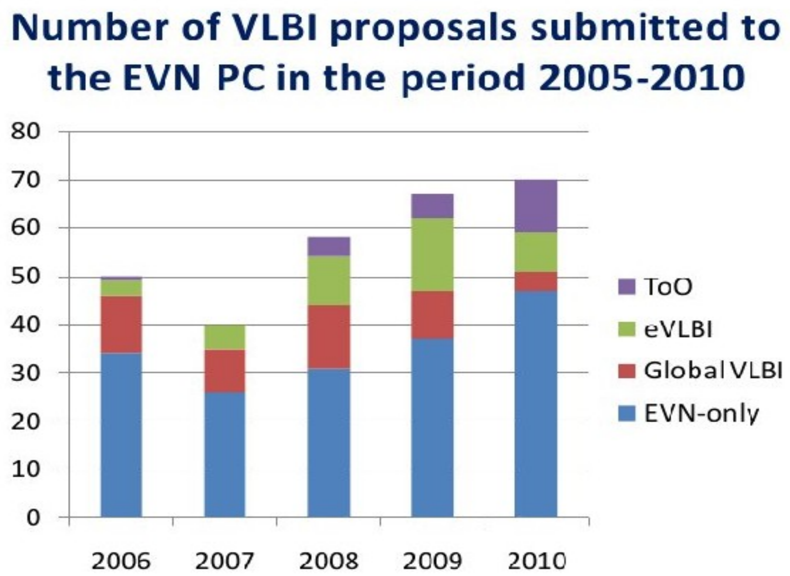
The composition of the EVN PC during 2009-2010

Meetings and proposal statistics

The six PC meetings in 2009 and 2010 were held in Bologna (3 March 2009), Madrid (24 June 2009), Cambridge (10 November 2009), Hamburg (11 March 2010), Dwingeloo (29 June 2010) and Valencia (9 November 2010). On the occasion of the EVN PC meeting in Hamburg, a mini-symposium was successfully organized by Andrei Lobanov. The meeting had an informal character and was intended as an opportunity for the community of the Astronomical Observatory (young postdocs and students in particular) to familiarize with Very Long-Baseline Interferometry and very high resolution radio astronomy. The PC members provided an introductory talk on the EVN facilities, and a number of presentations highlighted the broad range of scientific topics and questions the EVN may successfully address.

At the standard deadlines, in 2009 the EVN PC received 15 eVLBI, 37 EVN-only and 10 global VLBI proposals, and in 2010 8 e-VLBI, 47 EVN-only and 4 global VLBI proposals. A large number of Target of Opportunity proposals has also been received: 5 in 2009 and 14 in 2010. Most of them requested ad hoc e-VLBI time. The largest majority of ToO observations were successfully carried out, partly in the

scheduled e-VLBI runs and partly in e-VLBI in-sessions during the standard EVN sessions. Only in a few cases ad hoc runs were organized.
If we consider the total number and all types of proposals we received 65 in 2009 (~23% e-VLBI, ~53% standard EVN-only, ~15% globals, ~8% ToO) and 70 in 2010 (~11% e-VLBI, ~67% EVN-only, ~6% globals, ~16% ToO). A small fraction of the proposals (both standard and eVLBI) requests multi epoch observations.



Total number of proposals submitted to the EVN PC in the period 2006 - 2010, divided into EVN-only, Globals, eVLBI and ToO.

As always, 6cm and 18cm are the most requested observing bands, with 5 cm observations following in the priority list. 6cm and 18 cm are regularly scheduled during the eVLBI sessions.

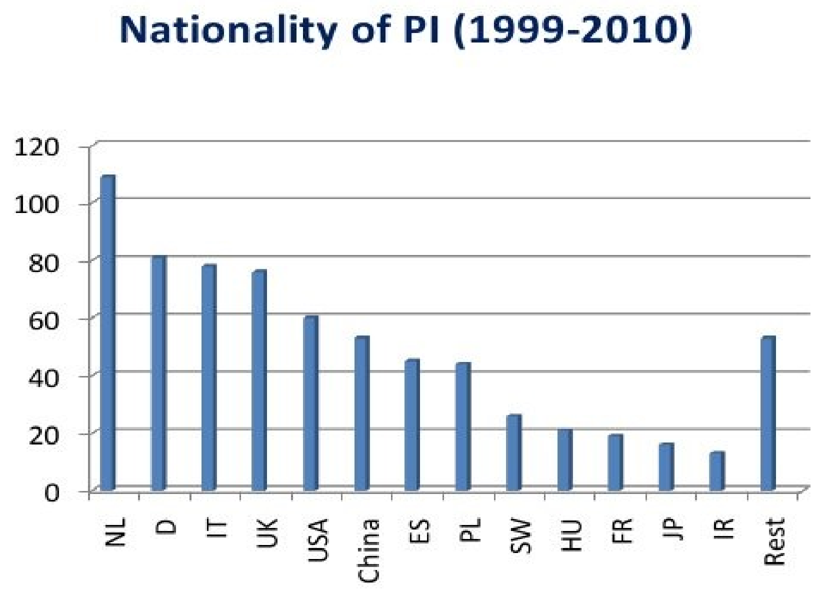
The EVN proposals received by the PC cover a wide range of scientific areas, and some of them are opening new fields for long baseline interferometry. The proposed studies address all stages in stellar evolution, from star formation to supernova remnants; weak and obscured AGN as well as "classical" studies of powerful radio galaxies and quasars; galactic and extra-galactic transients; galactic astrometry and reference frames. A large fraction of ToO proposals are part of multiband campaigns, triggered by flaring events in extragalactic AGNs or in galactic systems detected by high energy observatories. The flexibility of the e-VLBI allows the EVN to play a crucial role in the Fermi era.

The science carried out with the EVN was presented at the 10th EVN Symposium, held in Manchester in September 2010. It has been extremely rewarding to see that among the 70 oral presentations in the program, 27 were based on EVN observations (standard EVN, e-VLBI and global VLBI), 17 were based on VLBA-only data and one on VERA observations, while the remaining presentations were dedicated to new instruments and to technological developments. Most of the EVN observations presented were very recent, indicating a fast data delivery and analysis.

The EVN Users community

The PIs of EVN and Global proposals are drawn from a large international users community; the largest majority (of the order of 80%) of PIs comes from European institutes and universities, and the remaining mainly from US and China. The teams requesting eVLBI come mainly from Europe.

The EVN PC is also a useful channel of communication within the EVN users community. The Call for Proposal, circulated via email, and the Guidelines for Proposal Submission available as web page, provide important guidance on the proposal preparation. New and inexperienced users often contact the EVN PC, the EVN Scheduler and/or the JIVE support scientist for specific questions.
An EVN Users' Meeting was held in September 2010 during the 10th EVN Symposium, organised by the Jodrell Bank Observatory in Manchester. The agenda covered the whole process of VLBI, from proposal writing and schedule preparation, to correlation and data analysis. Some EVN users were asked to report on their recent experience with the EVN, and were encouraged to provide feedback on the whole system.



Distribution of PIs from EVN Institutes for all the proposals received in the period 1999-2010.

4.2 Scheduling and Operations

EVN and GLOBAL sessions scheduled in 2009-2010

2009 Session 1: 26 Feb - 19 March
Wavelengths: 6cm, 1.3 cm, 18cm, 5cm, 0.7cm

This was a full length session although, as often, days during the 5cm part were very unevenly filled since nearly all the methanol maser projects required the same GST range (Galactic Centre). There were only single user projects in the 1.3cm and 0.7cm part. There were 2 global projects, 3 observations involving Arecibo and 1 involving Robledo. MERLIN was used for some projects at both 6cm and 18cm. One project was correlated at the Bonn correlator and the rest at the EVN correlator at JIVE.
A total of 21 observations from 13 proposals was observed. Projects requiring MERLIN were given some scheduling priority as a number of MERLIN antennas will not be available in session II. Yebes took part for the first time in the 5cm part. The Yamaguchi (Japan) antenna was also added to one of the 5cm projects. The Onsala, Noto and Effelsberg observatories are thanked for permitting the scheduling of a 5th wavelength (7mm) in the session.

2009 Session 2: 28 May - 18 June
Wavelengths: 5 cm, 18 cm, 6 cm, 13/3.6 cm

This was another full length session, and the first for some time without any global projects (at least since June 2002 when the present scheduler came to office !). 4 observations involved Arecibo. 5 observations used an incomplete MERLIN array. There was only a single user project at 13/3.6 cm. One project was correlated at the Bonn correlator and the rest at the EVN correlator at JIVE.
A total of 25 observations from 11 proposals was scheduled. Yebes was scheduled for the first time at 6cm. The Yamaguchi (Japan) antenna was added to one of the 5cm projects.

2009 Session 3: 22 Oct - 12 Nov
Wavelengths: 6 cm, 1.3 cm, 5 cm, 18/21cm, 0.7 cm

This was again a full session lasting 21 days, with 5 different wavebands (thanks again to Effelsberg, Onsala and Noto for allowing the 5th (7mm) waveband). Arecibo was used for 1 observation, Robledo for 2 and MERLIN for 3. The Bonn (software) correlator was used for 3 observations and the rest used the EVN correlator at JIVE. There were 4 Global observations.

A total of 14 proposals were scheduled, comprising 20 observations as follows: 6cm (5), 1.3cm (2), 5cm (6), 18cm (6), 7mm (1). An observation at 21cm to test the pulsar gating mode of the JIVE software correlator was also scheduled.

2010 Session 1: 4 Mar - 19 Mar
Wavelengths: 18 cm, 5 cm, 6 cm, 13/3.6cm

This was again a full session lasting 21 days. Arecibo was scheduled for 4 observations but due to telescope structural failure could not take part. Robledo was scheduled for 6h for 1 observation. GBT was scheduled for 4 observations. VLBA was scheduled for 6 observations. The VLBA correlator was used for 3 observations, the Bonn (software) correlator for 2, and the EVN correlator at JIVE for the others. A UHF-band project planned for this session proved not to be technically feasible at Arecibo and was thus withdrawn.
A total of 19 proposals (including 1 ToO) were scheduled, comprising 27 observations as follows: 18cm (10), 5cm (7), 6cm (8), 3.6cm (1), 3.6/13cm (1). The KVAZAR network telescopes Zc and Bd took part for the first time as full EVN members in the network monitoring runs at 18, 6 and 3.6/13 cm. The Shanghai telescope took part for the first time at 5cm.

2010 Session 2: 27 May - 16 June
Wavelengths: 6 cm, 5 cm, 18 cm,

This was the first EVN session which included both disk recording and a number of e-VLBI observations, to make efficient use of the available time and disk resources. The first (disk) part contained 22 user observations: 6cm (8), 5cm (3) and 18cm (11). There were 3 global observations. Arecibo was scheduled for 1 observation and MERLIN for 5. The EVN correlator at JIVE was used for 15 observations, the VLBA (DiFX) software correlator for 1, the Bonn (DiFX) software correlator for 4 and the JIVE software correlator for 1. The 2 KVAZAR Network telescopes Zelenchukskaya and Badary were used for the first time for 5 user observations, following their successful participation in network monitoring observations in Session 1. The Noto telescope was unavailable, due to an azimuth bearing failure.
Following the last disk observation at 18cm, a switchover to e-VLBI (6 observations) took place on 9th June, starting with a 5.5h test run, followed by a ToO observation (V407 Cygni), an e-VLBI short observation and 2 normal e-VLBI observations. After the weekend the e-VLBI section continued at 6cm, with a second ToO observation of V407 Cygni, and a project proposed for disk observing but whose goals were judged (by the PC Chair, Scheduler and PI) to be achievable with e-VLBI. All e-VLBI observations were run at 1024 Mbps where possible.

2010 Session 3: 21 October - 11 November
Wavelengths: 5cm, 6cm, 1.3cm, 18cm, 13/3.6cm

The Chinese telescopes at Seshan (Sh) and Nanshan (Ur) were not able to participate in this session as they were required for observing a new Lunar space mission. This restricted the number of projects which could be scheduled, since the long E-W baselines of the EVN are in high demand. The Noto telescope was also not yet repaired and so unavailable for this session. However, the Hartebeesthoek telescope came back in operation and was scheduled for observations at 6 and 13/3.6 cm.
This session contained a total of 22 user observations: 5cm (3), 6cm (1), 1.3cm (4), 18cm (11) and 13/3.6cm (3). There were 4 global observations; the EVN correlator at JIVE was scheduled for 16 observations, the JIVE software correlator for 2, the Bonn software correlator for 1 and the VLBA software correlator for 3. Arecibo was scheduled for 1 observation and the DSN 70m at Robledo for 2. All 3 KVAZAR Network telescopes were scheduled for 1 observation at 6cm and 9 at 18cm; participation of these telescopes allowed a number of observations to be scheduled despite the lack of the Chinese telescopes.

STATISTICS OF EVN SESSIONS 2009-2010

Sess. Date	N_p	N_o	Hrs	TB	Dur.	Eff(%)	EVN	GL	TST	c	l	p
FEB09	13	33	243.0	428.0	21.3	47.6	19	2	12	11	10	0
JUN09	11	33	262.0	555.9	20.9	52.3	25	0	8	18	6	1
OCT09	14	34	344.0	508.3	21.0	68.3	16	4	14	13	7	0
MAR10	20	39	327.3	636.0	18.8	72.4	19	8	12	18	8	2
JUN10	20	37	281.2	520.6	19.7	59.5	22	3	12	24	5	2
OCT10	14	32	271.5	515.5	21.4	52.9	18	4	10	11	8	3

COLUMNS:
(1) session date, (2) number of different user projects scheduled, (3) number of observations scheduled , (4) total number of hours scheduled, (5) number of TB of disk recorded at EVN observatories, (6) duration of session in days, (7) scheduling efficiency (ratio 4 to 6), (8) number of EVN projects scheduled, (9) number of Global projects scheduled, (10) number of test observations (including calibration periods), (11) number of user observations observed in continuum, (12) number of user observations observed in spectral line, (13) number of user observations observed using pulsar gating

EVN e-VLBI RUNS 2009 - 2010

SESSION	DATE	λ	Hr	e-VLBI PROPOSAL TYPE				
				Normal	Short	Disk	ToO	Trigger
9e01	22JAN09	18cm	21h	2	1	-	-	-
9e02	10FEB09	18cm	17h	2	-	-	-	1
9e03	24MAR09	6cm	15h	1	-	-	-	1*
9e04	21APR09	18cm	24h	2	1	-	1	1
9e05	19MAY09	18cm	24h	2	-	-	1	1
9e06	27AUG09	6cm	0h	-	-	-	-	1
9e07	10SEP09	18cm	15h	2	-	-	-	-
9e08	29SEP09	18cm	10h	1	2	-	-	1
9e09	15OCT09	6cm	0h	-	-	-	-	1
9e10	19NOV09	6cm	21h	1	-	-	-	1*
9e11	01DEC09	6cm	0h	-	-	-	-	1
9e12	10DEC09	6cm	18h	2	-	1	-	1
10e01	27JAN10	6cm	18h	2	1	1	-	1
10e02	10FEB10	6cm	18h	2	-	-	2	1
10e03	30MAR10	6cm	19h	2	1	-	1	1
10e04	22APR10	18cm	18h	1	-	-	1	-
10e05	19MAY10	6cm	24h	-	1	-	2	1
10e06	08SEP10	6cm	12h	1	-	-	-	1
10e07	29SEP10	18cm	17h	1	1	-	-	-
10e08	04OCT10	6cm	10h	-	-	-	1	1*
10e09	23NOV10	6cm	23h	2	-	1	1	1
10e10	15DEC10	6cm	22h	1	1	1	-	1
1* = trigger observations actually triggered and observed								

Target of opportunity requests 2009-2010

There were 5 ToO requests received in 2009. Of these, 4 resulted in scheduling ad hoc time outside of disk or e-VLBI sessions:

Proposal	λ	SCHEDULED
RB002	6cm	e-VLBI 12/13 May
RG001	1.3cm	e-VLBI 23 May (+ later observations)
RR003	6cm	e-VLBI 2/3 July, 7/8 July (not observed)
RE001	18cm	disk 1 Feb 2010

In 2010 there were 14 ToO requests. Most could be accommodated in standard e-VLBI or disk sessions. 4 resulted in scheduling ad hoc time outside sessions:

Proposal	λ	SCHEDULED
RG002	6cm	e-VLBI 1 Mar 2010
RY002	6cm	e-VLBI 1 April (cancelled)
RR004	6cm	e-VLBI 8/9 Jul 2010
	6cm	e-VLBI 10/11 Jul 2010
RP016	6cm	e-VLBI, 29 September (extension of eVLBI run)

4.3 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 (vice-chair Michael Lindqvist of Onsala) and met three times during the period of this report: at the Centre for Astronomy, Nicolaus Copernicus University, Poland, on April 17, 2009, at Effelsberg Radio Telescope, Max Planck Institute for Radio Astronomy, Bonn, Germany, on December 4, 2009, and at the Metsähovi Radio Observatory, Helsinki University of Technology, Finland, June 21, 2010. All meetings were supported by Radionet (funded from the European Community's seventh Framework Programme under RadioNet-FP7). Reports from the meetings are available on the EVN web-site (www.evlbi.org).

The main emphasis of the TOG activities during the period of this report were maintaining the high level of performance achieved in the previous years, improving the reliability of the operation as a whole, and the quality of the network calibration. The development of the Digital Base-Band Converter (DBBC) continued in the reporting period albeit slower than planned due to a manpower bottleneck. Version 2 of the DBBC went into production in about summer of 2010. First units were installed in the field only toward the end of the reporting period. The first regular observations of a DBBC were planned for EVN session one in 2011. Due to the delay of the DBBC only very few Mark 5A units were upgraded to Mark 5B and increasing the recording bandwidth to 2 Gbit/s and 4 Gbit/s was postponed as well.

Significant achievements to be noted are:

- The disk pool for recording VLBI observations at the telescopes was increased further by the EVN member institutes. All observations can now be observed with the proposed bitrates of up to 1 Gbps.

- The calibration of the amplitude of the observed interference fringes could be improved further and only occasionally some stations show calibration errors of more than 10%.

- The process which was implemented to prevent observations with different versions of user schedules at different telescopes has been very successful.

- EVN and global pulsar observations can now be correlated due to the availability of the software correlators.

- The involvement of the TOG in the Technical Operations Workshop (TOW) at Haystack has increased and subjects which are important for astronomical VLBI observations are well covered.

- The three antennas of the KVAZAR network successfully joined the EVN network.

- E-VLBI observations are now also done inside the normal disk-based EVN sessions. This reduces the number of disks needed per session.

- The telescopes at Noto and Hartebeesthoek developed a major hardware failure. Both institutes were successful in raising funds for the repair. It is expected that both important EVN telescopes will be able to observe again in 2011 or 2012.

5. VLBI technical developments and EVN operations support at member institutes

5.1 ASTRON, Westerbork Synthesis Radio Telescope, The Netherlands

The Westerbork Synthesis Radio Telescope (WSRT) took part in all EVN sessions in 2009 and 2010 as well as in a large number of e-VLBI (planned and targets of opportunity) observations.


The Westerbork Synthesis Radio Telescope (WSRT) consists of 14 dish-shaped antennas

The digital Tied Array Distribution Unit (TADUmax) system, with the Mark5B recorder has been in use over the whole of this period for tied-array observations.

Until session 2009/1, for observations involving a single dish (5cm and wide field-of-view), the combination of the Mark IV DAS and a Mark5A recorded was used. Since Session 2009/2, single dish VLBI observations use also the combination of TADUmax and Mark5B.

The Mark IV rack was subsequently decommissioned at the end of 2009 and was donated to the Kunming station.

Following the move of the WSRT control room at the building in Dwingeloo in 2008, all e-VLBI sessions are performed from there. For normal, disc-recorded observations, operators are based at the WSRT site.

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

The 20-m radio telescope in Wettzell (RTW) is an essential component of the Geodetic Observatory Wettzell (Fundamentalstation Wettzell, FSW) and is jointly operated by Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie (FESG) of the Technical University Munich. It is collocated to the other geodetic space technique systems at Wettzell, like Laser Ranging System, Global Navigation Satellite System receivers, a large laser gyroscope and several complementary local measuring systems for meteorology, hydrology and seismic. The BKG also runs in cooperation with Chilean partners the Transportable Integrated Geodetic Observatory (TIGO) in Concepción/Chile and together with the German Space Center (DLR), the Institute for Antarctic Research Chile (INACH) and partly the FESG the German Antarctic Receiving Station (GARS) at O'Higgins base.

The 20-m RTW has supported the geodetic VLBI activities of the IVS and other partners, such as the EVN, for over 25 years. It is the most engaged geodetic VLBI network station within the IVS (in the years 2009 and 2010 with 196 24h and 663 1h geodetic-VLBI-sessions an 16 special program sessions as spacecraft observations in total 5383 operating hours). Because of a severe problem with the elevation bearing, the observation workload in 2010 had to be reduced to less than 50% of the normal from March to August. In consultation with the IVS Coordinating Center, the IVS 2010 Master Schedule was adjusted to optimize the combination of R1 and R4 with minimal influence on the time series. The main priority was to participate in all daily one-hour INTENSIVE sessions (INT) in order to determine UT1-UTC. For these sessions the complete data transfer is done with e-VLBI techniques. RTW routinely uses the increased Internet connection capacities of 1 Gbit/sec for the e-transfers to Bonn, Tsukuba, and Haystack. According to the implementation of a Field System extension for remote control, weekend INTENSIVEs were done in the new observation modes by remote attendance, remote control from students at the laser ranging system, or completely unattended (these new modes were suspended in the time of the bearing problems).

In addition to the standard sessions, RTW was also active for Digital Baseband Converter (DBBC) tests and for spacecraft tracking. Within these additional one-hour observations the ESA Venus Express and the Mars express spacecraft were observed at X-band with the Wettzell radio telescope, using a framework of the assessment study for possible contributions in the European VLBI network to the upcoming ESA deep space missions. The first goal of these observations was to develop and test the scheduling, data capture, transfer, processing, and analysis pipeline. The high dynamic range of the detections allowed achievement of a milliHz level of the spectral resolution accuracy and extraction of the phase of the spacecraft signal carrier line. Apart from other important results, the measured phase fluctuations of the carrier line at different time scales can be used to determine the influence of the Solar wind plasma density fluctuations on the accuracy of the astrometric VLBI observations.

Repair of the bearings of the 20-m radio telescope.

Within the maintenance work, the repair of the bearing was one of the big events of the year. The radio telescope team became aware of emerging elevation bearing problems about a year ago. In early spring the problem increased, when squeaking noises forced the operators to stop observing sessions. In March a special inspection done by the Wettzell group and a team from Vertex Antennentechnik GmbH brought to light that the elevation bearings were severely damaged. The right side of the elevation axis was lowered by 2 mm and the left side by 0.5 mm in comparison to the original state. In consultation with the Coordinating Center, Wettzell's observing load was reduced while technical solutions were investigated. In order to change the defective bearings, a disassembly of the antenna was unavoidable. Luckily a sufficient amount of money was put aside by FESG over the past several years so that the repair could be funded by the FESG. Then the repair itself was scheduled for September to November. A 400-ton crane lifted the 40-ton main reflector and the counterweights (each 35 tons) off the pedestal. After inspection the gear wheels and the new elevation bearings were installed a few days later. Following a couple of photogrammetric surveys the dish surface could be re-adjusted to 0.15 mm RMS. Almost as planned, the 20-m radio telescope went back into operation on 29 November 2010. Within the whole maintenance the RTW team, the administration of the TUM (especially FESG), and, of course, the whole team of Vertex Antennentechnik GmbH did an excellent job.

The new TWIN Telecope Wettzell (TTW) Project

The Twin Telescope Wettzell (TTW) project has been planned for the period 2008-2011. As the construction of the tower foundations was finished at the end of 2009, where the main driver was the high stability requirement of the reflector for several load scenarios (with snow, ice, and wind), the structures of the main reflectors were assembled from their single parts at the beginning of 2010. The elevation cabins (40-ton-per-piece steel construction) had to be trucked from Italy to Wettzell on a heavy load transport. As the 400-ton crane was already ordered for the repair of the 20-m telescope, it was cost-effective to also use it for the mounting of the "Twins". On 19

October 2010 the lift of the 13.2-m reflectors became a media event with television and reporter teams on location. The installation worked flawlessly and after the last of the 280 screws at each reflector was tightened, the silhouettes of the new instruments were visible for the first time.

The new “skyline” of the observatory with the Twin telescopes in the background

The VLBI2010 concept suggests fast moving antennas (e.g. 12 degree in azimuth) with a broadband receiving system with a total bandwidth of 2 - 14 GHz, with the option to integrate the Ka-band (28 - 36 GHz). BKG has commissioned a tri-band feed that is able to work in the two geodetic frequency bands (S and X band), and also in the Ka band. But the Elevenfeed of Prof. Kildal (Chalmers University, Sweden) presently offers the best preconditions for the reception of a continuous frequency range of 2 to 14 GHz. Therefore for the second antenna an Elevenfeed is commissioned. Meanwhile the reviews of the mechanical and structural parts are successfully completed.

Participation at Novel EXplorations Pushing Robust e-VLBI Services (NEXPReS) project

In July the NEXPReS project started. The FESG Wettzell participates in Task 3 of Work Package 5 mainly together with MPIfR. The goal is to support the identification and repair of failures of the systems during e-VLBI correlations in near real-time. Therefore the software implementations for a remotely controllable extension to the NASA Field System (FS) will be continued. An appropriate authentication, a dedicated role management for different user types, different remote access states to shared telescopes, and sophisticated graphical user interfaces should be developed.

5.3 HartebeesthoekRadio Astronomy Observatory, South Africa


The 26 m radiotelescope in Hartebeesthoek Radio Astronomy Observatory

Following the failure of the south polar bearing of the 26m antenna in October 2008, the main technical activity of the observatory was to achieve the repair of the telescope and undertake extensive refurbishment of the receivers and other ancilliary equipment. Following the return to service of the 26m in July 2010, VLBI activities rapidly returned to an even higher level than before.

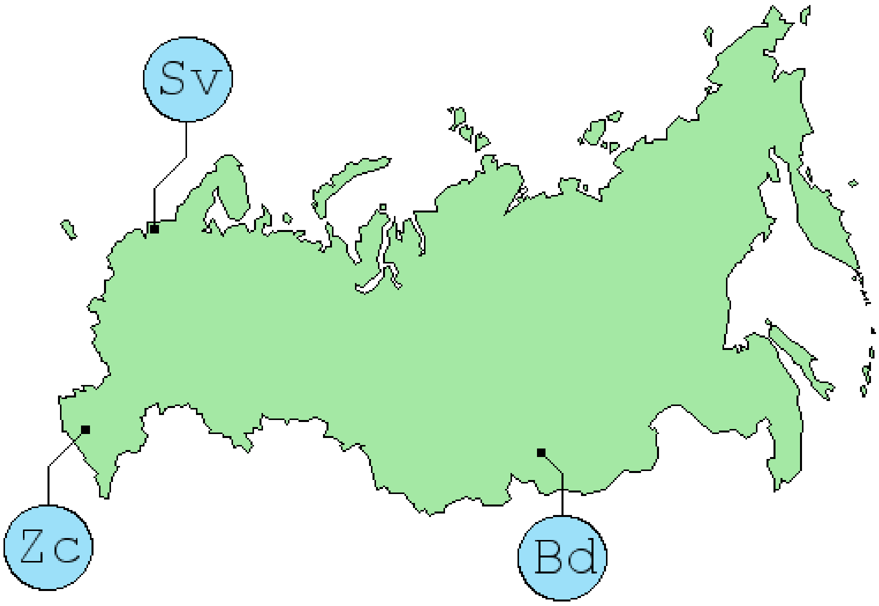
In the interim, the network connectivity of the observatory had improved to such an extent that the 26m telescope was immediately pressed into service as a new element of the e-EVN, ramping up to the full 1024Mbps data rate as envisaged by the EXPReS project in October 2010.

There was no significant receiver development on the 26m antenna over the period due in part to uncertainty over the future of this instrument, though there was extensive work on a new co-axial dual-band (s/X) dual-polarisation prime-focus cryogenic receiver for the 15m XDM prototype antenna which has now been ceded to the observatory as MeerKAT prototyping operations moved on to the Karoo. In particular we are still quantifying the 26m antenna performance at K-band before a possible upgrade to a cryogenic receiver would be considered.

Both the EFOS-28 hydrogen maser and the Mark4 VLBI terminal continue to perform well, though the latter is exhibiting more frequent component failures due to its significant age. In late 2010, extra-budgetary funds were secured to place an order for a replacement DBBC terminal, together with a second terminal and related Mark5B+ recorder to enable simultaneous VLBI operations on both 26m and 15m antennae at once. We were also able to secure funds for a second maser (for delivery late 2012) to replace the now defunct EFOS-8 and for 10 Gigabit networking equipment to support possible future e-VLBI requirements.

5.4 Institute of Applied Astronomy of the Russian Academy of Sciences, Russia

Radio interferometric network “Quasar” designed and constructed by the Institute of Applied Astronomy (IAA) of the Russian Academy of Sciences (RAS) consists of three radio astronomical observatories: Svetloe (Sv), Zelenchukskaya (Zc) and Badary (Bd).



Svetloe, Zelenchukskaya and Badary observatories on the map of Russia

The main element of each observatory is a fully steerable radio telescope with a homologous 32-meter main mirror and a 4-meter secondary mirror, equipped with five low-noise cooled receivers for wavelengths of 1.35, 3.5, 6.0, 13 and 18/21 cm, which allow to carry out observations in two orthogonal circular polarizations (Table 1).

Table 1. Present status of double-channels (LCP and RCP) cryogenic radiometers of the VLBI network “Quasar”

λ (cm)	Frequency range (GHz)	T_r (K)	T_{sys} (K)	SEFD (Jy)
21/18	1.38 — 1.72	8	43	240
13	2.15 — 2.50	10	48	330
6.2	4.60 — 5.10	8	27	140
3.5	8.18 — 9.08	11	34	200
1.35	22.02 — 22.52	20	80	710

The Sv, Zc and Bd radio telescopes usually participate in the observational programs of the International VLBI Service for Geodesy and Astrometry (IVS). In November 2009 the IAA RAS joined the EVN. Russian VLBI Network “Quasar” began fully participate in EVN sessions since 2010. The Institute also provides both VLBI and single-dish observational programs scheduled by the IAA Program Committee. Domestic VLBI observational programs were started in 2006 and the main goal of the programs is to determine Earth orientation parameters. There are two domestic programs: Ru-E — diurnal observations on 3-baselines interferometer for determining all Earth orientation parameters (polar motion, Universal Time and celestial pole coordinates) and Ru-U — observations of 8-hour duration for obtaining Universal Time. Observational activity of the VLBI Network “Quasar” observatories “Svetloe”, “Zelenchukskaya” and “Badary” in both international and domestic VLBI programs is presented in Table 2.

Table 2. Participation of “Quasar” stations in IVS, EVN and domestic observational sessions within the period 2009-2010.

Station	Number of EVN sessions (experiments)	Number of IVS sessions	Number of domestic Ru-E sessions	Number of domestic Ru-U sessions
Sv	1 (13)	73	44	22
Zc	3 (25)	95	44	79
Bd	3 (25)	97	44	78

In the period of 2009-2010 large-scale renovation was carried out in all observatories of the “Quasar”-network:
Digital Data Acquisition System (DAS) of new generation was put into operation in all observatories. This DAS was designed and constructed in the IAA RAS. All facilities of guiding and pointing systems were upgraded. H-masers of new generation were set into action in all observatories. All stations were equipped with the facilities for data transfer up to 10 Gbps rate.

In 2007 all “Quasar” stations were linked by optical fiber lines to provide e-VLBI mode. Currently Sv, Zc and Bd stations have an Internet connection with data transfer rates of at least 100 Mbps. To receive all three data flows from stations the 1 Gbit line is available in the IAA RAS Correlation processing center in St. Petersburg. In April 2009 the first e-VLBI session was successfully carried out with “Quasar” network. Since September 2009 the domestic VLBI project Ru-U has been routinely held in e-VLBI mode.

The 6-station correlator ARC was developed in the IAA RAS in the end of 2009. It provides processing data for 16 channels with 16 MHz bandwidth and two-byte sampling for each of 15 baselines. It regularly uses for processing data of domestic Ru-E and Ru-U experiments with Mark5B terminals.

Svetloe Observatory

Svetloe Radio Astronomical Observatory was the first station of “Quasar” VLBI network. Svetloe station is situated near St. Petersburg. Its coordinates are φ = 60°32′, λ = 29°47′, h = 86 m. The Mark5B disk recording system is used for all EVN observations. Present status of VLBI software: Linux 2.4.20, FS 9.10.3, Mark5B 2007y222d00h. In 2012 a revision of all elements and components of the antenna was performed; the rail was graded with the accuracy of about 0.5 mm (rms).

The 32 m radiotelescope in Svetloe.

The 32 m radiotelescope in Zelenchukskaya.

Zelenchukskaya Observatory

Zelenchukskaya station is situated in the North Caucasus (φ = 43°47′, λ = 41°34′, h = 1175 m). The Mark5B disk recording system is used for all EVN observations. Present status of VLBI software: Linux 2.4.20, FS 9.10.4, Mark5B 2007y222d00h. In 2009 the antenna surface adjustment was performed and after it the surface accuracy improved to 0.47 mm (rms).

Badary Observatory

Badary station is situated in the East Siberia about 130 km west of Baikal Lake (φ=51°46′, λ=102°14′, h=813 m). The Mark5B disk recording system is used for all EVN observations. Present status of VLBI software: Linux 2.4.20, FS 9.10.4, Mark5B 2007y222d00h. In 2009 the antenna surface was adjusted with the accuracy up to 0.48 mm (rms).

The 32 m radiotelescope in Badary.

5.5 Institute of Radio Astronomy - INAF, Italy

Medicina Station

During the period 2009-2010 the e-VLBI reached routinely a throughput of about 1Gb/s. It is also in progress the upgrade to 10Gb/s as well as the creation of a 10 Gb/s POP center in Bologna Headquarters.
The total capacity of MK5 disks is presently of 168TB.
Test of the multifeed receiver in the 18-26.5 GHz band and the monofeed in the 5.7-7.7 GHz have been concluded on the 32m in Medicina and delivered to SRT. In the VLBI bands they show respectively 20-25K and 7K of receiver temperature. The antenna gain measured on the 32m is like expected.

A dual feed system in the band 18-26.5 GHz is under construction as substitution of the SRT system.

These tests have also allowed the finalization of many aspects of the new observing software system. It is based on ACS (Alma Common Software) and the Field System will be part of it. This is the same system to be used on SRT.

It has been concluded the characterization of the fiber optic link to be used on the antennas. The installation phase of the cables and links will be concluded within 2011.

Money is now available to make heavy maintenance on the 32m antenna. We foresee to repair the elevation wheel, paint the antenna structure and change the subreflector drives. Also a substitution of the very old parts of the cryogenic helium pipelines will be done.

Sardinia Radio Telescope

Sardinia Radio Telescope (SRT), is a general purpose, fully steerable antenna of the National Institute for Astrophysics. SRT is funded by the Italian Ministry for Research, Sardinian Region and Italian Space Agency.

In 2010 the huge (500 tons) primary mirror back-up structure was installed on the antenna all in one go (Fig.1).

All parts were installed and at the time of the writing of this report (june 2011) the antenna is practically completed (Fig.2).

The beginning of the commissioning phase is foresee for late summer 2011.

Two of the three receivers are ready to be used while the third one, a dual frequency coaxial receiver in the bands 305-425 MHz and 1.3-1.8 GHz, is under assembling. Therefore SRT will start with five VLBI frequency bands (90cm, 21cm, 18cm, 5cm, 1.3cm).

Components for a multifeed receiver in the band 33-50 GHz are under development. One of these receiver chains can be used for VLBI in the 7mm band.

DBBC together with MK5C are available at the site.

Fig. 1 Installation of the primary mirror back-up structure

Fig. 2 SRT structure completed and moving

Noto Station

NOTO ANTENNA

Noto radiotelescope was the entire period stopped due to severe damage occurred on one of the azimuth wheels. This together with the structural problem on the azimuth track made evident as an important and expensive repairing action was necessary. The Italian Research Ministry after a long procedure allocated the funds for the repair: the operations will take a new improved track, new wheels and related accessories. The antenna should be able to restart the observations with a greater accuracy in pointing, particularly useful for the K and Q bands. A bid procedure will be issued and the repairing operations should probably start in summer 2011 in order to have again the antenna operative in the beginning 2012.

DBBC2

Over the last few years the EVN Digital Base Band Converter (fig. 3, 4) has been developed in a bilateral project lead by Gino Tuccari of IRA Noto and his collaborators and the VLBI group of the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn. The development has been conducted in a very strong, friendly and day by day collaborative environment. Indeed the VLBI laboratories in MPIfR have been the place where most of the prototypes have been built and tested .
People mainly collaborating to the development of the project are: G. Tuccari, W. Alef, A. Bertarini, S. Buttaccio, G. Comoretto, D. Graham, G. Nicotra, A. Roy, J. Wagner, M. Wunderlich.

The production of the DBBC2 backend has been realised by the (INAF) spin-off company HAT-Lab, which will successfully complete its second year of activity, with the fundamental support by the MPIfR. The continuous collaboration between the parts was and still is indeed a key element for the success of the system. At present about twenty units have been delivered or are under construction for the EVN, AUSCOPE and the Global Millimetre Network (GMVA).

In addition to the traditional standard observing modes, new possibility are present that allow to observe with a much increased data rate. Indeed it is possible by adopting the Polyphase Filter Bank (PFB) configuration to observe at 2 or 4 Gbps. It is planned to test the new capabilities in the beginning of 2011 at Effelsberg, Onsala and Yebes, later tests together with the VLBA are envisaged. It is hoped that all other EVN stations will join the high data rate modes by adding the appropriate capabilities at their telescopes.

Support for the MK5C and MK6 recording systems has been added to the DBBC with the FILA10G board (fig. 5), an interface able to deliver multiple 10Gbps data streams to standard 10 Gb Ethernet networks. Direct e-VLBI is also possible without any recorder from the backend to a correlator.

A kit has been developed and it is available for those stations who want to upgrade the standard DBBC2 system to the so-called DBBC2010, which is able to support the VLBI2010 observing modes. In this system eight IFs are available with eight PFB blocks to be recorded. A new project DBBC3 has been defined to greatly increase the IF bandwidth and sensitivity of the telescopes. The new features will be available also as upgrade of the existing terminal. It is planned for Effelsberg to observe the EVN May session 2011 entirely with the DBBC2 system as the main backend.

Fig. 3 A complete DBBC2 backend

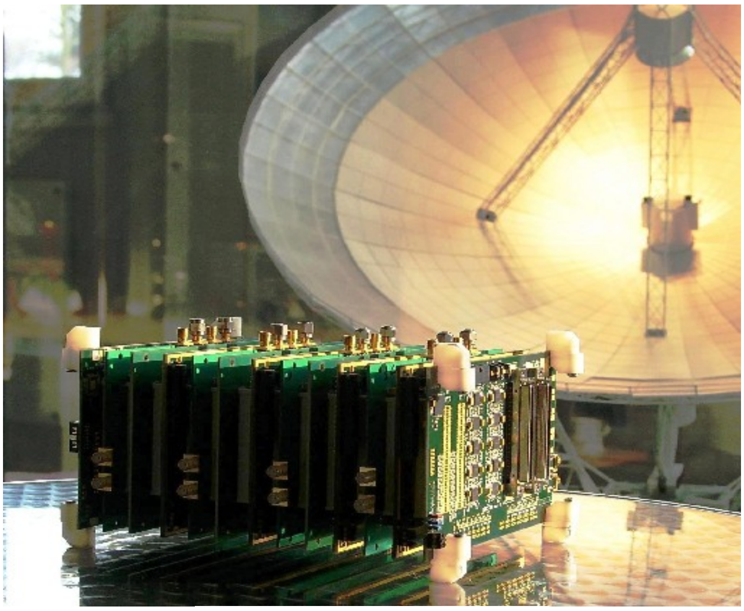


Fig.4 The DBBC2 board stack

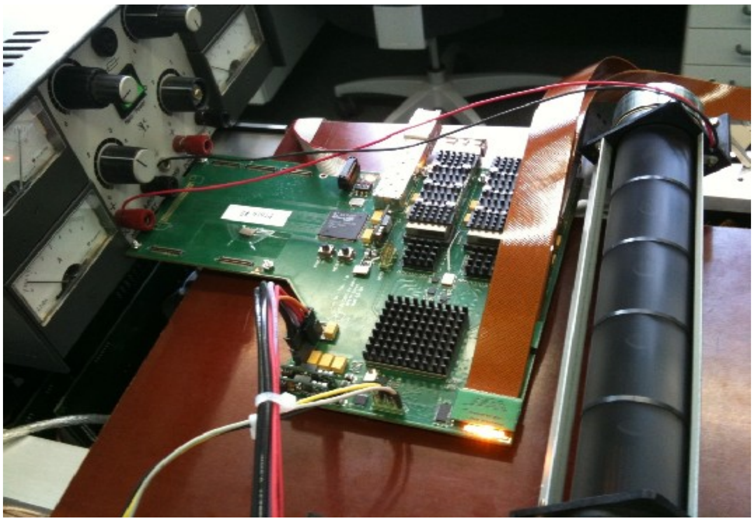


Fig.5 The FILA10G network card

5.6 Max-Planck-Institute for Radio Astronomy, Germany

MPIfR correlator

The Bonn VLBI correlator is jointly operated by the MPIfR, the German Federal Agency for Cartography and Geodesy (BKG), and the Institute for Geodesy and Geoinformation of Bonn University. It is used for the correlation of observations of the global mm-VLBI array (GMVA) which observes twice per year at 86 GHz with up to 13 antennas. In addition about 40% of the worldwide geodetic VLBI observations under the IVS umbrella are processed at Bonn. A few EVN experiments are correlated as well, either because they are MPIfR projects or because they need some of the features the Bonn correlator offers, like hands-on correlation, geodetic export path, availability of the correlator model in the exported data, or recently because of the new capability of pulsar gating.

In the time period between summer 2009 and end of 2010 the 10 year old MK IV hardware correlator was replaced by the DiFX software correlator (Deller et al, 2007). The development of DiFX is shared by a group of programmers at NRAO, MPIfR, CSIRO, ATNF, Curtin, Haystack. DiFX is executed on a small computer cluster with 60 nodes with nearly 500 compute cores (performace: ~4 TFlops in the Linpack benchmark). Input to the correlation process can be from up to 14 Mark 5 units and nearly 100 TB of disk space in RAID systems connected to the cluster. The capabilities of the DiFX correlator are summarized at http://www.mpifr-bonn.mpg.de/div/vlbicor/correlator_e.html

DiFX highlights are:

- Spectral resolution: DiFX currently supports powers-of-2 numbers of spectral points spanning each individual baseband channel, up to 4096 for routine DiFX processing, and up to 32,768 for very high spectral resolution.
- Spectral zooming: selection of a subset of correlated spectral channels from any or all basebands is possible. Only the selected channels are included in the output dataset.
- Multiple phase centers: the DiFX correlator implements multiple uv shifts inside the correlator, to generate as many phase centres (positions on the sky, within the antenna beam) as are necessary, in a single correlation pass. The output consists of one dataset of normal size for each phase centre. The correlation time is increased by a factor of about two to three.
- Pulsar gating: DiFX can bin pulsar visibilities into any number of bins, using incoherent dedispersion. As an option, after weighting each bin by the power contained in that bin, the bins can be summed up to yield the optimum SNR.
- Integration period: DiFX offers a continuous range of correlator integration periods over the range of practical interest from ms to seconds.
- Geodetic compatibility: In several investigations it was shown that the DiFX correlator performs at least as well as the MK IV correlator or the VLBA hardware correlator.
- Phase-cal extraction: All phase-cal tones in all sub-bands can be extracted at correlation time. The code was developed mostly at MPIfR.
- Output data formats: data from the DiFX correlator can be converted to FITS and/or MK IV format. Thus export paths to AIPS and CALC/SOLVE are available.

Work has been started at MPIfR to implement a database which will hold all information relevant for the correlation. In a further step this will be connected to an operator GUI which will be a modified version of NRAO's DiFX GUI.

Correlator Operation

Astronomical correlation was migrated to the DiFX correlator in autumn 2009. The additional requirements for converting geodetic correlation to DiFX –- phase-cal extraction and a converter to MK4 format –- became only available towards the end of 2010, which delayed the migration of geodetic correlation to December 2010. With DiFX the correlation proper is now always done in one pass even for very large observations, and in addition the correlation has become much faster. As Mark 5A and Mark 5B formats can be played back on all playback units at the DiFX correlator, logistics could be simplified.
The number of observations correlated stayed at a high level in 2009 and 2010. The total percentage of correlation time over total time was about 35% which is about the same as in previous years. About 40% of the correlation time was used for astronomical correlation, 60% for geodetic projects.
The 1 Gbit Internet line for eVLBI is being used extensively for transfers of VLBI data to the correlator. With the introduction of the DiFX correlator transferred data can be correlated directly from disk which is a major simplification.

mm-VLBI

During the two years of this reporting period MPIfR has been working to equip the APEX telescope (Chile, 5000m altitude) for VLBI observations with a recording bitrate of 2 Gbps and more. The following equipment was developed, built or purchased, and installed: VLBI downconverter, quarter-wave plate, test tone synthesizer, Digital Base Band Converter (DBBC), Mark 5C unit, pressure housing for two Mark 5Cs, H-Maser, environmental housing for the H-Maser, GPS receiver, media converter, several minor items and the necessary cabling. The first 1 mm VLBI observations are planned for spring 2011. The Pico Veleta telescope has been upgraded for 1mm VLBI with a DBBC and a Mark 5C unit to co-observe with APEX and US American mm-telescopes.

Global mm VLBI Array (GMVA)

MPIfR organises the Global mm VLBI Array (GMVA) which observes with a global array with 13 antennas twice a year for 5 days at 86 GHz bandwidth. This includes calls for proposals, proposal review, scheduling, correlation and calibration. Recently a project was started to streamline and simplify the data reduction for users by delivering a calibrated FITS file plus a cookbook to the observers.

Technical developments 100m-telescope

In August/September 2009 a new 18/21cm prime focus receiver was installed. Tsys is about 25 K. The receiver was successfully used during e-VLBI observations and in EVN Session 3/2009 and afterwards. It shares one prime focus box with three other receivers (1.0cm, 1.9cm, and a receiver for holography at 11.7 GHz). Although those are not used for VLBI it increases our flexibility to schedule different projects including VLBI observations.

During 2009/2010 preparations started to provide all the signals necessary (e.g. 1pps, 10 and 5 MHz, IF cables) to operate two new VLBI systems in the Faraday room at Effelsberg. The new systems are the DBBC for EVN and geodesy observations and the RDBE for observations with the VLBA. Placing this in the Faraday room will avoid interference to other observations, caused for example by 10GE network equipment for e-VLBI. At the end of 2010 a DBBC and Mark5B+ have been installed in the Faraday room and are working in parallel to the old MKIV and VLBA equipment. A NRAO RDBE and upgrade kits for two Mark5C units were bought as well as a 10GE switch to connect the two Mark5C to the DBBC and the RDBE.
The switch-over to a new control system based on Linux and VME machines -- started in July 2010 -- was completed. VLBI with the MKIV and the VLBA terminals both work fine, as do all the single dish observing modes of continuum, spectroscopy, and pulsars.


The 100-m radiotelescope in Effelsberg

A crack in the azimuth rail stopped observations for about 5 weeks in January 2009. The crack was welded and observations started again in the middle of February. The EVN Session in February/March was observed with reduced azimuth speed. Speed was back to normal for the May/June Session. Another crack happened in December 2009. To avoid a longer break in the winter season the crack was repaired using a diamond-shaped insert that helps to carry the load of the wheels from one end of the rail to the other. The hope is that this fix will also reduce the stress on the rail caused by temperature changes since it acts like an expansion gap. Although some wear down at the insert was observed new stabilization measures have solved the problems for now and no new crack appeared in the winter season 2010/2011.

DBBC developments
MPIfR and IRA Noto are partners in the development of the Digital Baseband Converters (DBBC), a project which is led by Tuccari of the Noto station. In 2010 the DBBC reached production stage which has been realized by HAT-Lab, a spin-off company of INAF.
MPIfR assembled, integrated and tested the prototypes. In the next step MPIfR handled much of the communication with the manufacturers and prepared the designs for the production process. It also supported HAT-Lab by providing lab space, as well as with integrating and testing of the DBBCs.
A board with two 10 Gbit optical Ethernet connectors and the required firmware was designed and realised. It has successfully been tested in the lab and the field. It can deliver 4 Gbps from the DBBC to e.g. a Mark 5C recorder. Bitrates of up to 8 Gbps are planned. It will enter production stage in 2011.

5.7 Metsähovi Radio Observatory, Finland

VLBI Observational Activities

Metsähovi performs both astronomical and geodetic VLBI observations in conjunction with three global networks of VLBI: the European VLBI network (EVN), the International VLBI Service (IVS; in collaboration with FGI), and the Global Millimeter VLBI Array (GMVA). Furthermore, Metsähovi has actively taken part in spacecraft VLBI tracking observations organized by Joint Institute for VLBI in Europe (JIVE) in cooperation with the European Space Agency (ESA) as well as real-time dUT1 experiments with Japan and Sweden (i.e., G. Molera et al., Tracking of Mars Express and Venus Express spacecraft with VLBI radio telescopes, American Geophysical Union, Fall Meeting 2010).

VLBI Sessions in 2009-2010
In 2009 to 2010 Metsähovi took part in six (2009) and seven (2010) geodetic off-line and real-time eVLBI sessions. The Global mm-VLBI Array (GMVA) observed two sessions, in May and October of 2010. Two regular 22 GHz and two 43 GHz EVN sessions were conducted at the station. In June and July 2010 two 22 GHz EVN ToO experiments were observed. The site also participated in two IYA sessions in 2009.

e-VLBI sessions in 2009-2010
In February 2009 Metsähovi participated in one e-VLBI experiment.

Technical activities

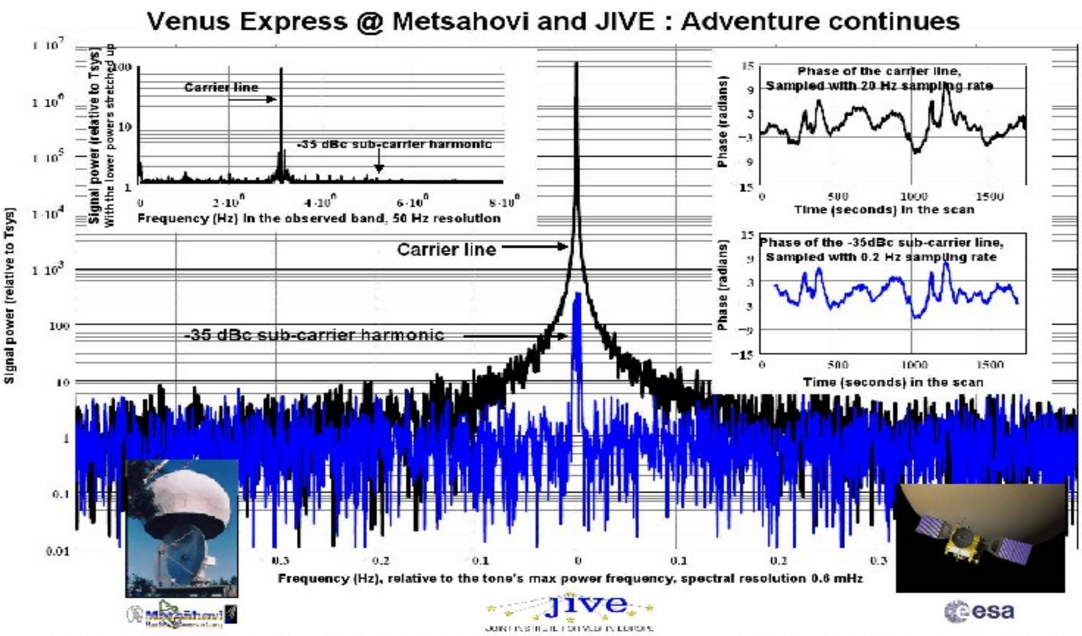
Receivers
The new 86 GHz receiver arrived in June 2009 to our laboratory. Unfortunately, we could not use it during any of the two mm-VLBI session organized in 2009. The receiver manufactured in Russia was still lacking major fixes in 2009. The 86 GHz receiver was used for the first time for the session c101a in May 2010. First we did preliminary tests for finding fringes with Onsala, Metsähovi and Yebes. Data was transferred electronically to Bonn and correlated with DiFX. Fringes were found. We are looking forward to get the results of the correlation from this session and to see the performance of the receiver.
The 43 GHz receiver has been out of order for the last years and it is still waiting to be repaired. The 22 GHz receiver is working fine. There have been some problems with the S-band of the geodetic S/X receiver since 2007. We changed the semi rigid coaxial cables of the receiver which were broken.

Status of BBC/dBBC
Status of our VLBI hardware remained the same as last time: a number of rack BBCs are broken and beyond worthwhile repair. Only 9 BBCs were being used in the experiments in 2010. We already have a quote and open order for one DBBC unit for geodetic purposes. Payment and escrow is an open issue. We hope to have a DBBC in late 2011. For the time being we will use an iBOB 1xVSI => 10G workaround design.

Metsähovi Data Processing Site
The observations of the ESA Venus Express spacecraft with the Mh radio telescope on X-band has continued during all the year 2009. Other stations, like Wz, Mc, Ma and Nt, have also joined the sessions. Data is analyzed with ultra-high accurate

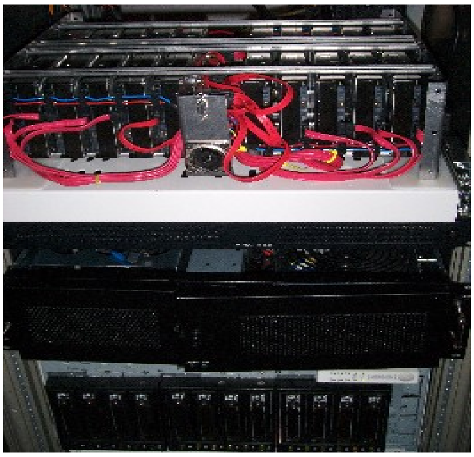
processing software for phase-locked satellite tracking based on the phase referencing method (J. Wagner et al, Presentation at RadioNet FP6 Workshop, Yebes, Spain, Nov 2008).
Internal storage capacity was upgraded by adding two new computers, the current capacity is up to 50 TB. Thus with new computers, lots of new RAID capacity, data archive, store and process multiple stations Metsähovi has capabilities to be a correlator center.

Four new Conduant disk pack empty SATA enclosures were bought in March 2009. These are the first SATA disks to be used at Metsähovi in Mark5.
Together with Sergei Pogrebenko et al., JIVE, software for Intel and Playstation3 was developed that can be used as a versatile classic spectrometer at real-time rates in 2009. We also created new sample processing software for phase-locked satellite tracking that is based on the phase referencing method (J. Wagner et al, Presentation at RadioNet FP6 Workshop, Yebes, Spain, Nov, 2008). JIVE developed the analysis tools. As an example, ESA Venus Express spacecraft was observed with Metsähovi radio telescope at X-band on June 11 2008 using multi-bit data sampling and capture instrumentation and high performance processing software, developed at Metsähovi. See figure below.



The ESA VEX S/C was observed with Metsahovi 14m antenna at X-band on July 11 2008. Data were processed and analyzed using the high-performance software developed at Metsahovi and analytical tools developed at JIVE. We made what we promised at the previous picture, issued 3 weeks ago, and even more: we got 0.6 mHz resolution, 10^6.7 dynamic range, and phase lock to the VEX as if it could be at 100 AU, in the Kuiper belt or even farer.

At the beginning of the year 2009 we got time to upgrade the hardware and operative system of the Field System. An unexpected power failure caused the original power supply to fail and it was relatively convenient to replace the motherboard together with the PSU earlier in summer 2008. New disks in Raid-1 mode were added now in January 2009. Finally, the latest stable OS version of Debian Etch 4.0 and fs-9.10.4 were installed. Major problem noticed during the installation was the failure of the communication between the serial port board and the formatter. Jan Wagner added few lines into the fs source code to fix the timing problem with serial port and Debian Etch and this patch was accepted by Ed Himwich to the upstream distribution of the FS. Also, the Debian community stopped



New VLBI rack with the 10 Gigabits internal switch, ibob, windows-ibob development pc, new host computer for the disk pack and the disk-pack itself.

the development of the package PGPLOT used by gnuplot, it needs to be compiled from source code.

Mark5A hardware was also upgraded. See notes related to the process in: http://www.metsahovi.fi/en/vlbi/vsib-docs/mark5_upgrade.shtml.

In 2010 we have continued the processing of VLBI data using programs developed by Jan Wagner.

We have also an opportunity to use two Finnish supercomputer clusters, one has 2100 cores and the other has 2880 cores. There are some differences in Unix versions and connectivity. The computers rank at roughly number 100 in the world top-500 supercomputer list.

This is rare opportunity to test the scalability of VLBI software correlators. So far the scalability tests have been done with maximum of 12 computers with four processor cores each, so moving to really powerful system is unknown territory. Scalability of high-speed data streams is also an interesting topic.

We have also been encouraged to apply for the computing grand challenge program in Finland and/or request resources in the world's top-5 supercomputer in Jülich, Germany. Because of lack of personnel resources, summer vacations and the migration to the new Aalto University we did not do these yet in 2010.

<u>Hardware and Mark5 emulation for 4 Gbps+</u>

We have developed a new data storage system (4G-EXPReS) after comprehensive testing of SATA equipment that is capable of 4-6 Gbits today and 8 Gbps in the near future. Google for “Backblaze” for the principle.

Based on COTS components and a standard 10G network card, a single “gamer” computer can store or send network data such as raw Ethernet frames or iBOB/dBBC/etc UDP packets at above 4 Gbps (G. Molera, European 4 Gbps VLBI and e-VLBI, EXPReS09, Madrid, Spain, June 2009).

The 4G-EXPReS can be command compatible to the proposed Mark5C and allows to use better file formats. We used the 4G-EXPReS successfully to record low-speed water maser and spacecraft observations, have performed up to 7 Gbps Tsunami-UDP file transfers and have captured 2x2048 Gbps VLBI observations from iBOB UDP VDIF streams.

All the possible information about which hardware to buy, how to install the equipment or how to set up all the scripts are available in our web page documentation: http://www.metsahovi.fi/en/vlbi/ibob/4gexpres

We used the computing and storage hardware including older PC-EVNs during 2009 for real-time transfer and recording of astro/geo e-VLBI sessions, processing for single dish spectroscopy in the Solar system using VLBI equipment, phase-locked spacecraft tracking experiments as well as 512MHz wide-band cosmic lensing detection.

EVN Eight Gigabit Experiment (2 * 4 Gbps)

Under the EVN n09k3 in October 2009, Onsala, Jodrell Bank and Metsähovi performed the first 4 Gbps experiment in the EVN. It was a partial success. The Onsala 4G-EXPReS setup worked flawlessly at 4 Gbps through the experiment. The Metsähovi 4G-EXPReS worked perfectly too, but lack of disk capacity and not using Skype unfortunately led to the end that Onsala and Metsähovi did not have any common scans recorded. We hope to repeat the exercise at the next opportunity with all three stations and then finally be able to use JIVE software correlator capacity to process this 12 Gbps observation.

Hardware Photos

First version of the diskpack fully assembled and as used in several experiments. The Backblaze system http://blog.backblaze.com/ uses the same approach as the diskpack but is a rack-mount model.

We are planning to buy at least one for our VLBI data storage needs (backplanes are cheap $45 and the enclosure is available from Protocase at sub-$800).
It could be a very interesting high-capacity RAID storage solution for software correlator sites.

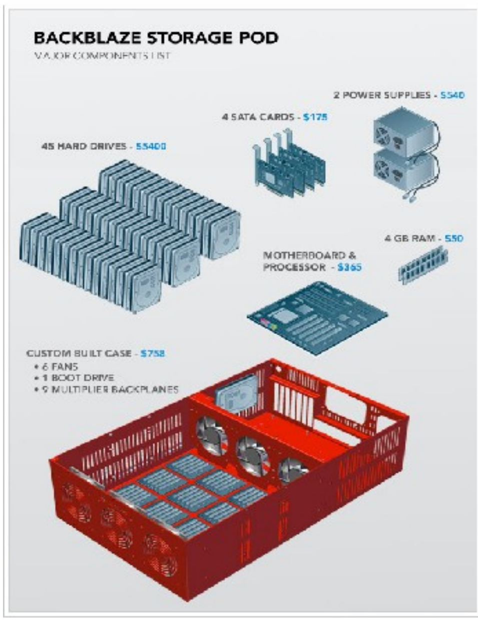


Image courtesy of Backplaze, 2009, http://blog.backblaze.com/2009/09/01/petabytes-on-a-budget-how-to-build-cheap-cloud-storage/

5.8 National Geographic Institute (IGN) / National Astronomical Observatory (OAN) & Yebes Observatory, Spain

The National Geographical Institute (IGN, Ministry of Development in Spain) is the host institution for the National Astronomical Observatory (OAN) and the Yebes Observatory (CAY), and operates the recently constructed 40 meter radio telescope and these facilities.

The telescope has participated regularly in all EVN sessions at X/S (8 & 2 GHz), C (5 and 6 GHz), and K (22 GHz) bands. Important technical upgrades are the setup of a dedicated 1 Gbps data link by fiber that allow to send VLBI data in real time to the correlator and JIVE, the purchase and setup of a DBBC, and the purchase of new 56 Tb of MK5 disks for the EVN pool (for a total of 119 Tb contributed).

First e-VLBI fringes of the IGN 40-m radio telescope in Yebes (Spain)

In the framework of the EC funded project "EXPReS" (http://www.expres-eu.org/), the Observatory was connected to GEANT at 1 Gbps in 2009. First e-VLBI fringes were obtained at C-band with the e-EVN during the campaign "100 hrs of Astronomy", on April 3rd 2009. This is an important milestone for the whole team involved in the commissioning of the telescope, in particular because of the successful operation of the antenna, receivers, VLBI and network equipment.

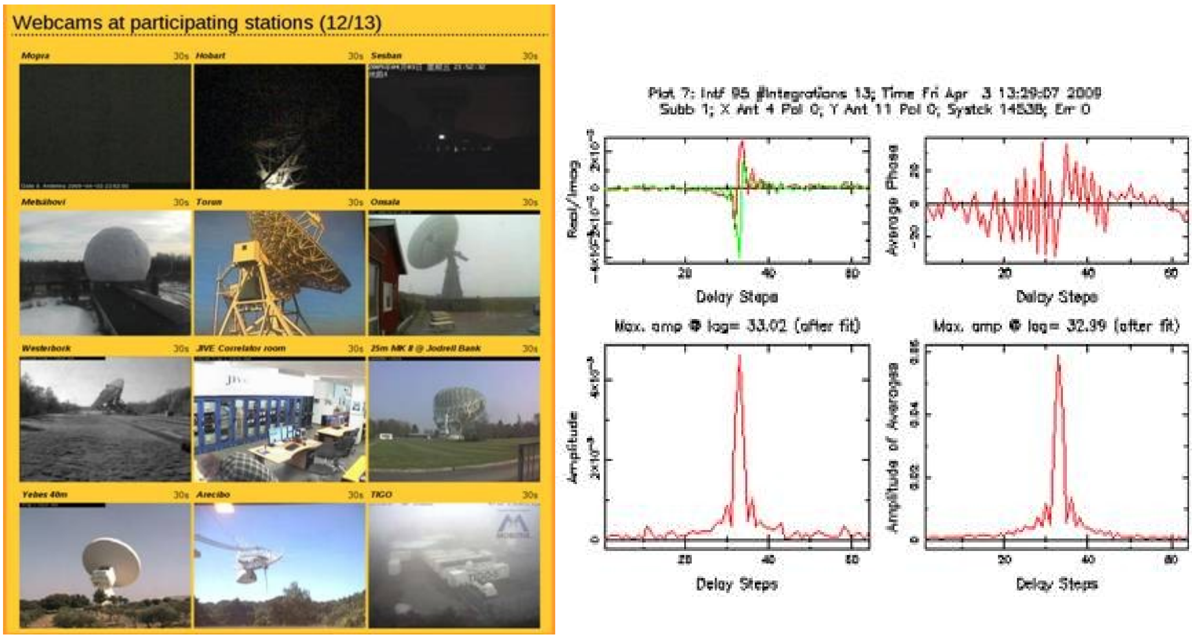


Figure: Participating telescopes, and example of real time fringes between Yebes and WSRT.

First results with the 3 mm receiver at the Yebes 40m telescope - fringes with Onsala and Metsähovi

Two important results were achieved at Yebes Observatory in the second half of April 2010, both related to the new 3 mm receiver installed at the 40m radio telescope installed at the beginning of December 2009. The frontend was previously used at Plateu de Bure and belonged to IRAM. Its receiver temperature is approximately 70 K and its system temperature 200 K. It has got two linear polarized channels: at 1 and 3 mm. Circular polarization is achieved by inserting a teflon plate in front of the horn. The plate can easily be rotated 90 degrees. The 3 mm receiver IF and the control and monitor system were built at Yebes. The receiver uses a cold/hot load scheme to calibrate in amplitude. Switching between hot/cold and sky is done in less than 2 seconds by moving mirrors. The cold load is done by using a mirror which looks into the cryostat.

On April 21st 2010, Yebes 40 m radio telescope took part for the first time in a 2 hour fringe test at 86 GHz together with Onsala 20 m and Metsähovi 14 m telescopes. Data were recorded on the 3 telescopes in disk packs and later transferred to Bonn correlator. The data were extracted using fuseMark5, which allows mounting the disk packs as an external disk, and transferred later using tsunami. Fringes were found in the three baselines with SNRs from 50 to 110. Metsähovi recorded the data on two polarizations, while Yebes and Onsala only used one circular polarization. Since polarization sense was unknown at Yebes, 6 scans were recorded with the plate in front of the horn in a given position and 2 were recorded after the plate was rotated 90 degrees.

The week after the successful VLBI fringe test, the SiO 2-1 V1 line towards evolved star IK Tau and R Cas was detected using an autocorrelator of 2048 channels and a bandwidth of 256 MHz. The line was checked with a similar observation at Pico de Veleta. The next goal is to improve the efficiency of the antenna by adjusting the panels of the main reflector and by replacing the current membrane at the receiver cabin vertex. We expect that the efficiency may increase 4 times after these works.

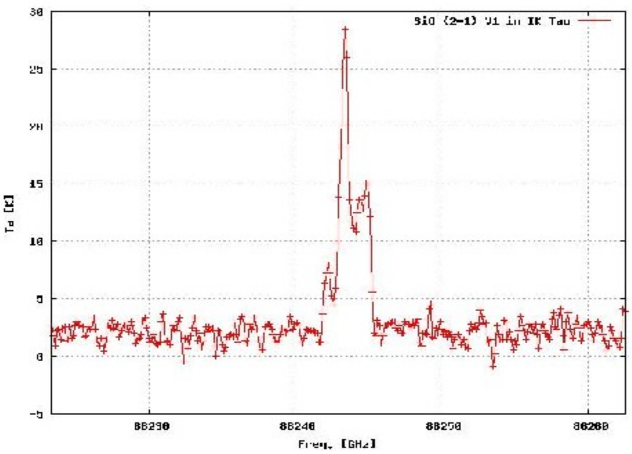


Figure: 3 mm receiver at the 40m cabin, showing the cryostat, mirror system (with the hot load) and the IF below the supporting structure; example of spectra of the SiO 2-1 V1 line obtained towards IK Tau.

Improvements in the Yebes 40m radio telescope

In 2010 the behavior of the subreflector as a function of elevation and its impact on pointing and gain was studied. A new model was applied that improved the telescope operation.
The surface of the 40m was adjusted by touching the screws that support the panels. The improvement of the gain was almost negligible at frequencies below 22 GHz. Further measurements and adjustments will be performed in 2011.

Receivers and backends

A new C Band receiver was installed at the telescope in 2010. The polarizer is cooled and it is connected to the horn via a waveguide that uses a window which isolates the cryostat from outside. The noise temperature is 35 K approximately.
Two new backends are being used since summer 2010 in single dish observations: an 8 channel continuum detector, and an 8 module FFT spectrometer.
The continuum detector is a PocketBackend on loan from MPIfR that uses the analog signal from the 4 wideband IF detectors of the VLBA terminal.
The FFT can be loaded with 4 different configurations. Currently we have two modules with a bandwidth of 100 MHz, two with a bandwidth of 500 MHz, two with a bandwidth of 750 MHz and two with a bandwidth of 1000 MHz. The three first couples use 16384 channels and the latter 8192 channels. Both backends are remotely controlled and monitored using Ethernet and have been integrated in the control system of the 40m telescope.

Maser

The old KVARZ maser had a severe problem in June 2009 and a new maser from T4 Science (Neuchâtel) was rented. This maser is operational since September 2009.

DBBC

A DBBC was received in 2009. Some tests were done between 2009 and 2010. No definitive software setup has been performed and it is not been used in regular observations yet.

Geo VLBI

The 40 m IGN radio telescope in Yebes participates actively in geodetic VLBI campaigns for the International VLBI Service for Geodesy and Astrometry (IVS). A total of 27 observation runs were performed in 2009-2010 (of the R4, RD, T2, and EUROPE campaigns).

As an activity for the International Year of Astronomy (IYA2009), Yebes 40 m radio telescope participated –together with other EVN telescopes such as Effelsberg, Onsala, etc, or the VLBA– in the IVS special astrometric session with the goal to observe as many of the 295 ICRF2 defining sources in a single 24-hour session as possible (the southern sky not being fully covered) avoiding possible systematic effects of patchwise observing. The session was accompanied by outreach activities at the stations and other sites. Bordeaux Observatory hosted a dynamic Web page at http://iya09-ivs.obs.u-bordeaux1.fr/ while the special session was described at http://ivscc.gsfc.nasa.gov/program/iya09/

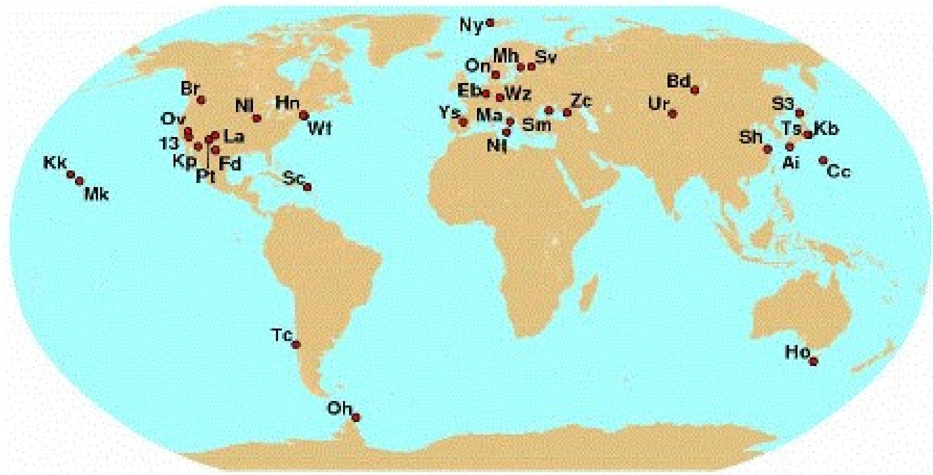


Figure: Map of the radio telescopes participating in the IYA09 special astrometric session.

IGN is also developing project RAEGE (for an *Atlantic Network of Geodynamical and Space Stations*, Web: http://www.raege.net/), setting up a Spanish-Portuguese network of four Geodetic Fundamental Stations, two in Spain (in Yebes and Canary Islands), and two in Azores Islands, as part of the deployments needed for the IVS VLBI2010 scenario. It is envisaged that each Geodetic Fundamental Station will be equipped with one radio telescope of VLBI2010 specifications (13.2-m diameter, able to operate up to 90 GHz, fast slewing speed), one gravimeter, one permanent GNSS station and, at least at the Yebes site, one SLR facility. IGN has experience in VLBI (being member of the EVN since 1993, and founder institute of JIVE), and it is participating in geodetic VLBI campaigns with its 14-m radio telescope in Yebes since 1995. The new 40-m radio telescope also participates actively in IVS campaigns. Construction of the first antennas has started. An agreement between IGN and the Autonomous Regional Government of the Azores ensure that the RAEGE project can become a reality by 2012.

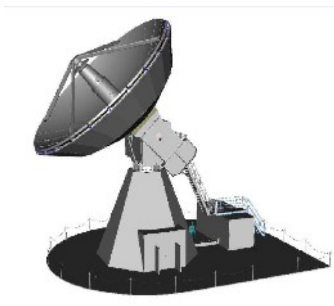


Figure: location and engineering model of the RAEGE antennas.

Outreach

The installation of a new instrument at Yebes, SPIDER *("Small Parabolic Instrument for Demonstration, Education, and Research")*, enhances the outreach activities developed by IGN and OAN. Built by the Swedish company Are Elektronik following the principles of the SALSA instrument developed by Onsala Space Observatory, SPIDER is a fully operational 2.3 meter radio telescope equipped with an L-band (21cm - 1420MHz) receiver and a spectrograph (352 channel correlator, 2.4MHz total bandwidth). The beam width is 7 degrees. A low noise preamplifier is mounted in the antenna focus and a coax cable feeds the signal to a cabinet which contains the receiver, power supplies and a modem. In the antenna vertex a small dipole antenna is installed for calibration purposes. This radio telescope is ideal for observing hydrogen in our galaxy, the Milky Way. The main aim is to map the spiral arms of the Galaxy. The Qradio software developed at the Onsala Space Observatory is used for controlling the radio telescope. This software communicates with "kstars".

The goal of SPIDER is to provide the opportunity to operate a real radio telescope to students and visitors, in the environment of the Yebes observatory, where the big 40 meter dish is close by but not accessible to them. The instrument may be operated remotely via internet from other centers (e.g. Madrid or University of Alcalá), and soon even directly from schools. Applications are being designed, in coordination with other EVN observatories which are part of the network of Visitor Centers sponsored by the EC FP7 project "RadioNet".

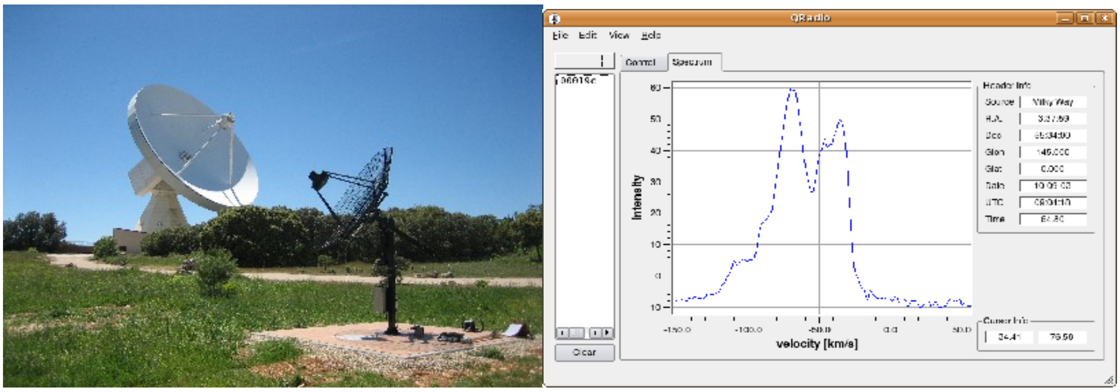


Figure: SPIDER installed next to the Yebes 40m radio telescope, and example of data.

5.9 National Astronomy and Ionosphere Centre, Arecibo Observatory, Puerto Rico

For much of the Program Year 2010, radio astronomy operations at Arecibo were heavily impacted by a structural problem discovered in early February 2010. Indeed, the zenith angle coverage of the telescope was limited to observations within 3.5° < Zenith Angle < 12° for about 9 months. Nevertheless, a full astronomical program was maintained, including VLBI observations, although this has had to be tailored to fit the available declination coverage and tracking time. Full telescope motions were restored in February 2011.

Within the time period from 2009 to 2010, Arecibo participated in a considerable number of VLBI experiments, including about 30 EVN-related runs and tests, covering EVN and Global Network disk-recording, and EVN eVLBI experiments. These operations involved observations at L-, C-, and X-band. Between the hours of midnight and 6 a.m. AST (= UT – 4 hr), during which extra internet bandwidth is made available under an agreement with the University of Puerto Rico (Rio Piedras Campus), the eVLBI operations used a data transfer rate of 512 Mbps between Arecibo and JIVE. During the other 18 hours of the day, a guaranteed maximum rate of 128 Mbps is available, although 256 Mbps is usually sustainable.

Arecibo VLBI operations during this period have been led by Dr. Tapasi Ghosh, assisted by Dr. Chris Salter. In respect of technical expertise, they have been ably supported by Dr. Arun Venkataraman, Head of the Arecibo Computer Department, and Mr. R. Ganesan, Head of the Arecibo Electronics Department), plus engineers Messrs. Dana Whitlow and Luis Quintero.

Two recent examples of VLBI science for which Arecibo's enormous sensitivity made an essential contribution are the following;

(1) EVN observations of parsec-scale radio cores in Seyfert galaxies were made at 1.6 and 5 GHz by a team led by Dr. Marcello Giroletti. Although these galaxies are considered to be radio quiet, the presence of compact radio cores seems to be essentially ubiquitous when the sources are observed with high sensitivity. Arecibo's presence was essential for this goal, and also provided the long baselines needed to obtain the highest angular resolution.

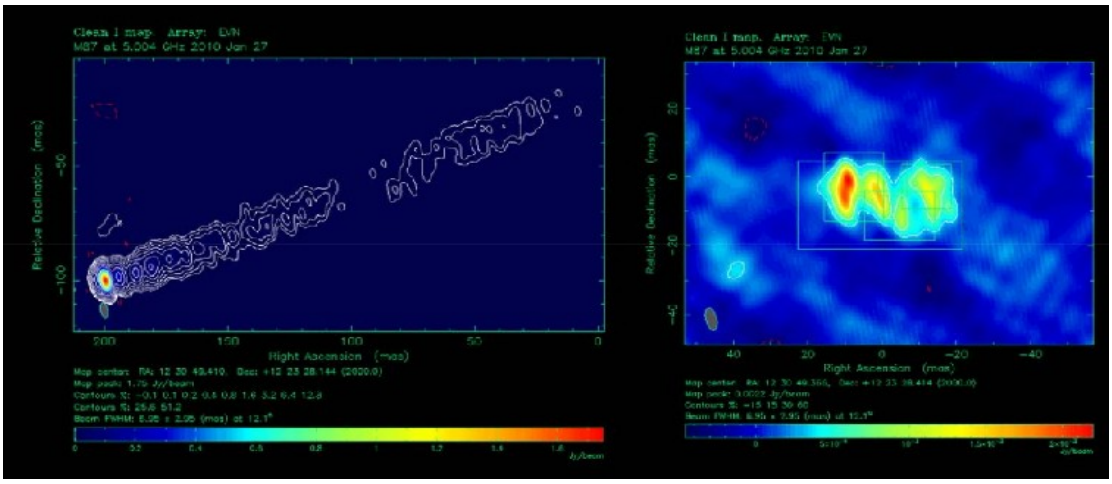


Figure 1: (left) Virgo-A jet at C-Band; (right) the HST-1 complex (courtesy: Marcello Giroletti).

(2) The well-known jet of the galaxy, M87, has been (and continues to be) regularly monitored with EVN eVLBI, including Arecibo. These observations have been made simultaneously with very high energy observations by VERITAS and other facilities. In particular, the source has shown some activity in the TeV band, and by great good fortune an EVN radio image (Figure 1) was obtained simultaneous with a high energy flare (Giroletti et al., Astronomer's Telegram, 2437). Here again, Arecibo is very important, providing both the high resolution needed to resolve the inner jet component and the sensitivity required to reveal the weaker complex named HST-1 far down the jet (about 800 mas from the core). Remarkably, apparent superluminal motion is found to be occurring in HST-1.

Arecibo made major moves towards the complete upgrade of its VLBI capabilities during PY 2010. Most apparent when visiting the Observatory is the acquisition from Patriot Corporation of a 12-m diameter antenna sited on a hill-top within the observatory grounds. The new antenna was assembled in the second half of 2010, following extensive ground-works that included the cutting and surfacing of a new paved road to the hill top (Figures 2 & 3). Commissioning of the antenna began late in the year, (and acceptance tests were successfully completed early in 2011). The 12-m antenna will act as a phase-reference telescope for Arecibo VLBI observations, plus serving in a number of other roles that contribute towards scientific operations, education and public outreach. The development of the techniques needed for the transfer of VLBI phase from the reference antenna to data from the 305-m dish will be a major area of development over the next couple of years.

In addition, a pair of RDBE digital back-ends for VLBI were ordered from NRAO, with delivery of the first unit coming in late 2010. These will soon replace the existing analog VLBA4 data acquisition rack and Mark-5A recorder presently used for VLBI recording. Completing the VLBI upgrade, a pair of Mark-5C VLBI recorders were ordered from, and delivered by, Conduant Corporation. At the end of 2010, these recorders were being equipped with updated software at the Haystack Observatory. Following on from earlier experience of 4-Gbps data recording using borrowed RDBEs and a pair of Mk5B+ recorders, initial tests with Arecibo's new systems are anticipated in mid-2011. (The first test of such recording at 2 Gbps rate was, in fact, made in June 2011.) This matched pair of VLBI digital backends can be used independently on the 12-m and 305-m antennas for phase referencing, or be employed together on either of these two antennas to enable recording at double the data rate.

Arecibo hosted the autumn-2011 meeting of the EVN Technical & Operations Group (TOG), August 29 and 30, 2011.

Fig. 2: Access Road (then nearing completion).

Fig. 3: The Arecibo 12-m Patriot Antenna.

5.10 Onsala Space Observatory, Sweden

The Onsala Space Observatory (OSO) telescopes continued during 2009 and 2010 to play a full role within the global observing program for astronomical VLBI. In total 10 astronomical VLBI-sessions (6 EVN sessions and 4 global mm-VLBI sessions) were conducted. OSO is also regularly involved in e-VLBI sessions within the EVN. In addition, the Onsala 20m telescope has been used for 24 and 27 geodesy VLBI experiments in 2009 and 2010, respectively, as part of the observing program of the International VLBI Service for Geodesy and Astrometry (IVS).
For most of the geodesy experiments the data were additionally recorded in parallel on the PC-EVN-computer that is daisy-chained to the Mark 5 unit. These data were transferred electronically using the Tsunami-protocol, and no Mark~5 modules were actually sent to the Bonn correlator. Only for the few experiments to be correlated at Haystack Mark~5 modules needed to be shipped.
Since 2009 the geodesy group at OSO performs almost all standard 24~h IVS-sessions where both Onsala and Tsukuba (Japan) are involved as so-called *24-hour ultra-rapid dUT1 experiments*.

The observational data from Onsala are real-time transferred to the VLBI correlator operated by the Geospatial Information Authority (GSI) at Tsukuba (Japan) where the data are converted and correlated with the Tsukuba data. Once 35 scans are correlated, an automated data analysis is performed and the earth rotation angle dUT1 is determined from the observations on the long west-east oriented baseline Onsala-Tsukuba. The data are analyzed in a "sliding-window-approach", i.e. when a new scan comes in the oldest is left out and a new analysis is performed. Thus, a time series of dUT1 is produced during the ongoing 24~hour long IVS-session. The results are available with very low latency and the progress of the analysis can be monitored on the webpage *http://www.spacegeodesy.go.jp/vlbi/dUT1/*.

Since February 2009 Rudiger Haas is the Technology Development Centers Representative in the Directing Board of the IVS. Since 2009 Rudiger Haas is also IVS delegate in the directing board of the International Earth Rotation and Reference Frame Service (IERS). Rudiger Haas is the chair of the VLBI Task Force of the Nordic Geodetic Commission (NKG) since 2006. Michael Lindqvist is the OSO representative on the EVN Program Committee and attended its meetings. Michael Lindqvist is vice-chairman of the EVN Technical and Operations Group (TOG) since the end of 2007.

VLBI technical activities at member institutes

Onsala Space Observatory

Onsala Space Observatory (OSO) have replaced the old coaxial IF-cable from the 25m telescope to the control room with an analogue fiber. This will enable us to participate in future 4 Gbps observations. A successful e-VLBI fringe test with the fiber was done on May 18, 2010. We also purchased a DBBC and a Mark5C and they have been installed in parallel to the production system. OSO routinely use the 10 Gbps light path for e-VLBI. OSO participates in NEXPReS.

5.11 Shanghai Astronomical Observatory, Sheshan Station, National Astronomical Observatory (NAOC, CAS). P.R. China

Observations

During the period 2009-2010,Shanghai 25meter radio telescope (also known as 'SESHAN25' in geodetic community) participated in five EVN sessions at 18, 13, 6, 5, 3.6 and 1.3 cm bands. All systems worked well in these observations. Shanghai 25meter telescope was absent in the November 2010 session because of its participation in VLBI tracking mission of Chinese Chang'E-2 satellite. Shanghai radio telescope also participated in fifty-four e-VLBI observations and formatter tests. From 2009 to the first half of year 2010, more than fifty testing experiments have been done with our Digital Base Band Converter (DBBC). We used the Chinese VLBI Data Acquisition System (CDAS) developed by SHAO for the tracking of Chinese Change'E-2 satellite in the middle of 2010. Before the launch of the Chinese Chang'E-2 satellite, SESHAN25 carried out a lot of test experiments. The satellite was launched on October 1st, 2010, in the following couple months, Shanghai and other three Chinese radio telescopes (Miyun 50 meter, Kunming 40 meter, and Urumqi 25 meter) conducted real-time VLBI tracking. Since December 2010, the tracking mission was changed to a regular long-term mode with a frequency of two or three days per week. In February 2011, Shanghai recovered the EVN sessions.

Update and Current status of equipments

A new 6.7GHz receiver with dual circular polarizations is available since 2010 Spring. And we got fringe in the EVN February session. Soon it witnessed the first methanol spectral lines from a massive star forming region observed with the new receiver. Methanol maser line studies were started both in single-dish and in VLBI modes since then.

One azimuth bearing was broken on September 11th, 2009. Then the broken bearing and three other old ones were replaced. The repair work and subsequent pointing tests took 40 days. We also performed routine maintenance of our antenna in the middle of 2010.

At the present, three VLBI terminals are working at the Shanghai VLBI Station, VLBA4, VLBA, and CDAS. The VLBA terminal includes a VLBA sampler, a VSI-C card together with a Mark 5B recorder. The CDAS terminal consists of an DBBC and a Mark 5B+ recorder, specially designed and used for the Chinese Chang'E-2 project. We have upgraded the MarK 5A Firmware Version to 12.06 (API 10.07, SDK 8.2), in order to be compatible with the SATA module. A problem in network transfer for Mark 5B was fixed; since then, recording with Mark 5B runs normally.

Personnel Changes of Sheshan VLBI Station

Dr. Qinghui Liu is awarded as the 'One Hundred Talents Programme Professorship of the Chinese Academy of Sciences' in 2009. He works in the VLBI group of SHAO and focuses on the application of same-beam VLBI technique in space explore mission and other VLBI-related technique developments. He is the chief of the technique group of the in-built 65-meter radio telescope. Linfeng Yu and Yongbin Jiang joined the VLBI group in 2007 and mainly answered for routine operation. Dr. Li Fu started her job in VLBI group since 2009, concentrating on the antenna panel issue of the 65-meter radio telescope. Weiye Zhong joined the receiver team of the new 65-meter radio telescope in 2009. Bo Xia replaced Dr. Tao An as the VLBI friend since January 1st, 2010.

e-VLBI

The Sheshan radio telescope participated in 512 Mbps e-VLBI observations organized by the EVN. On January 15-16 2009 the Sheshan radio telescope participated in the 33-hour continuous “marathon” e-VLBI observation demonstrated live in the opening ceremony of the International Year of Astronomy 2009 in Paris. On April 3-5 2009, the Sheshan radio telescope participated in e-VLBI observations as a part of the ``100 Hours of Astronomy".

Prospects

A new radio telescope with a diameter of 65 meter is in construction at a site about ~6 kilometer west of the current 25 meter radio telescope. The construction of the telescope progresses smoothly. The central pintle bearing combination was installed on October 29th, 2010. The space truss structure of the primary reflector and the alidade were completed as well. The primary reflector has been assembled on the ground and will be installed on the antenna mount in late this year or early next year. It is scheduled to be in operation at C(6 cm), S(13 cm), L(18&21 cm), X(3.6 cm) bands in mid of 2012.

Figure 1: Shanghai 65-Meter Radio Telescope. (top): The mount of the telescope has been completed. (bottom): The assembly of the primary reflector structure has been finished on the ground and will be installed on the alidade of the telescope late this year or early next year.

5.12 Toruń Centre for Astronomy, Nicolaus Copernicus University, Toruń, Poland

The 32-m radio telescope in Toruń

EVN Disk Sessions

The Torun Station (Tr) with its 32-metre radio telescope and Mark5A recorder has participated in all the 6 regular EVN sessions at wavelengths of 21, 18, 6 and 5 cm during the period - 152 experiments in all.

e-VLBI

Tr took part in all the e-VLBI scheduled experiments, plus occasional test observations outside the schedules.

Personnel Update

A young technician, Mr Michał Skiwski, joined our staff in July 2010. His duty is to develope software programming and building of electronic devices.

Hardware

The telescope receiver cabin has been reorganized during summer 2009. Now the central 1mx1m area is occupied by the OCRA-f array (4x4 feeds). All the other receivers are placed off-axis, including the OCRA-p system. In May 2009 a new L-band filter was mounted. It rejects frequencies (with strong RFI) above about 1680 MHz.

New 28-bit angle encoders (with absolute resolution of 0.0001 deg) for both the 32-m telescope drives have been acquired as replacement of the present 19-bit ones. Purchased were also optical fibres to replace copper cabling in control room and to the telescope.

Steps were taken to purchase DBBC in place of our considerably aged and worn out analogue BBCs.

SATA Disk-Packs

In February 2010 Tr added 64 TB of disk-pack capacity (8 SATA packs, 8 TB each) to the EVN pool, reaching total of 153 TB (this fulfilled the EVN agreed contribution expected of an active station). After recording them news came from JIVE that some of these large-capacity packs do not perform well in playback. Subsequently three of 1 TB disks (all are Barracuda 72000.12, Model ST31000528AS) had to be replaced (two at JIVE and one at Toruń, all under warranty).

Software

Telescope control system has been rewritten. It now runs under real time Linux and is in use since summer 2010. In all the six sessions Mark5A OS has been Debian "Etch" version 4.0 with the package mark5a_1.0.2-i386.deb. The Mark5A application code has been Mark5A2007y.225d. Field System version 9.9.2 has been used.

Meetings

The TCfA hosted the TOG Meeting on April 17th, 2009. Twenty seven participants from member institutions of the EVN attended.

5.13 Urumqi Astronomical Observatory, National Astronomical Observatory (NAOC, CAS). P.R. China

Figure: The Urumqi/Nanshan 25m radio telescope

Urumqi is the capital city of the province—Xinjiang Uygur Autonomous Region of China, our radio telescope is located at the 'Nanshan' mountain of Urumqi County which belongs to Urumqi city, so the telescope site is still in the area of Urumqi. The telescope has two names 'Urumqi' and 'Nanshan' historically, 'Urumqi' as a bigger name is more often used by the VLBI community. The distance between the Nanshan and the Urumqi downtown is about 60 km.

The observatory was founded in 1957, as just a part of the Chinese Academy of Sciences, in 2001 renamed as 'Urumqi Observatory, National Astronomical Observatories, CAS' and affiliated to the NAOC. We have formally no connection to universities, but there is a joint research center on astrophysics founded between Xinjiang University and the NAOC in 2009. Now (from 2011) our unit is again renamed as "Xinjiang Astronomical Observatory, Chinese Academy of Sciences".

We conduct about 10 VLBI experiments per year for the international VLBI service for geodesy and astrometry (IVS), and about 30 experiments per year for the EVN, and a few domestic VLBI experiments per year. During the Chinese lunar mission, we usually have about 2 day VLBI experiments per week, this kind of observations have the highest priority to be scheduled. Besides, we have single dish observations on pulsars, AGN, and astronomical lines, etc.

We have receivers right now available at 1.6 GHz, 2.3/8.4 GHz, 5 GHz, and 22 GHz (under construction). The VLBI recorders are MK5 (A, B, B+), actually the MK5B is used right now for most VLBI experiments. A DBBC device from Shanghai was equipped at the station, which used in the domestic and lunar VLBI experiments. We participated in the eVLBI experiments with 512Mbps successfully conducted by the EVN in the astronomy year 2009 for just a demo, and we stopped after that because of the high cost of the wideband internet. The S/X band feed horn was replaced by a new one (with wider bandwidth of S: 2.15-4.15 GHz, X: 8.1-9.0 GHz) in 2009. A new 22 GHz dual polarization receiver is completed, and will be put on the secondary focus in 2011. A picture of the 25m radio telescope at Urumqi/Nanshan is shown in Figure.

6. Joint Institute for VLBI in Europe (JIVE).

6.1 Science Operations and Support

Production Correlation

Tables 1 and 2 summarize projects observed, correlated, distributed, and released in 2009 and 2010, covering experiments correlated at JIVE. They list the number of experiments as well as the network hours and correlator hours for both user and test/NME experiments. In this usage, correlator hours are the network hours multiplied by any multiple correlation passes required (e.g., because of continuum/line, separate correlation by subband/pol to maximize spectral resolution, etc.).

	User Experiments			Test & Network Monitoring		
	N	Ntwk_hr	Corr_hr	N	Ntwk_hr	Corr_hr
Observed	91	859	1148	35	176	181
Correlated	83	772	983	32	162	172
Distributed	88	824	1065	32	161	166
Released	91	854	1085	34	170	175
e-EVN experiments	29	224	224			
e-EVN ToOs	6	68	68			

Table 1: Summary of projects observed, correlated, distributed, and released in 2009.

	User Experiments			Test & Network Monitoring		
	N	Ntwk_hr	Corr_hr	N	Ntwk_hr	Corr_hr
Observed	98	778	1041	16	51	51
Correlated	109	917	1236	19	67	67
Distributed	105	883	1183	20	73	73
Released	98	833	1155	16	61	61
e-EVN experiments	40	296	296			
e-EVN ToOs	15	138	138			

Table 2: Summary of projects observed, correlated, distributed, and released in 2010.

The experiments in 2009-10 reflected the customary mix of continuum and spectral-line observations, with Gbps continuing as the most popular continuum recording rate, and separate continuum/line passes for phase-referenced spectral-line experiments remaining the norrn. During this biennium, some new developments established themselves as recurring and standard features. Experiments needing very short baselines could include MERLIN out-stations as separate antennas in the EVN correlation—also providing a more robust combination for the EVN and MERLIN correlations. With more than eight stations regularly available for spectral-line observations, recirculation provides the means to maintain the desired spectral resolution in addition to the increased number of baelines. Multiple correlator passes handle separate correlation phase centers within a single pointing, or by sub-band provide wider bandwidth-smearing fields of view for more general wide-field mapping. The number of Target of Opportunity (ToO) observations grew explosively as a consequence of the maturation of e-EVN capabilities.

6. Joint Institute for VLBI in Europe (JIVE).

The e-EVN continued making huge strides in this biennium. For the two years, there were 29 and 40 user experiments (comprising 224 and 296 hours), including 6 and 15 ToOs (68 and 138 hours). Early in 2009, an e-VLBI demo for the International Year of Astronomy saw the largest number of stations correlating at once in real-time (12). On 24-25 March 2009, we had our first successful Gbps e-EVN user experiment, and Gbps has since become the standard mode for continuum e-EVN observations. Included among the ToOs was a 3-epoch experiment at 512 Mbps including Kashima and four Australian stations (Kashima translated their K5-format data to Mark5B prior to transmission; this was successful by the third epoch). Figures 1 and 2 illustrate the growth of e-EVN observations, both absolutely and as a constituent of total EVN observing. The categories listed in figure 2 include ToOs, triggered observations (see the Astronomical Features section), short (<= 2hr) exploratory observations, experiments proposed for disk recording but conducted in e-VLBI, and the standard e-EVN observations in regularly scheduled sessions.

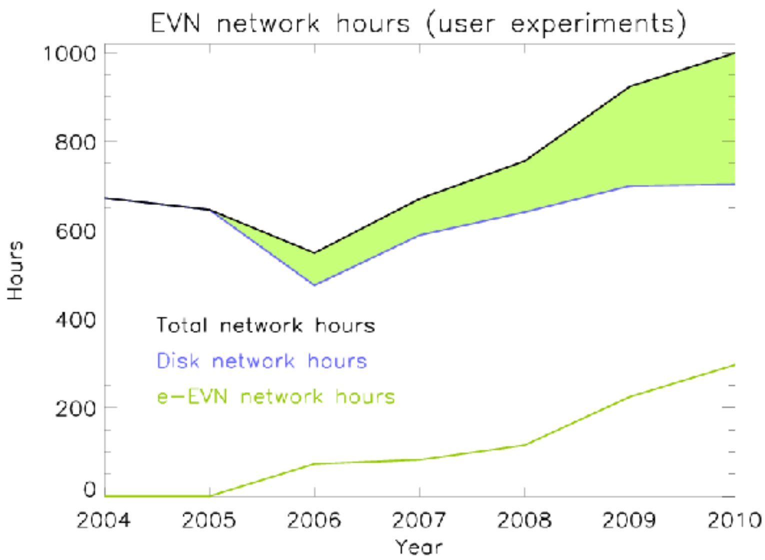


Figure 1: Annual EVN network hours, with the contribution by e-EVN observations shown by the shaded area.

There were plenty of "firsts" as seen by the correlator:

- Yebes 40m observations at 5 and 6 cm.
- Shanghai, Yamaguchi 32m, and VERA_Mizusawa observations at 5cm (the Japanese stations recording onto VERA tapes, and translating into Mark5B on disk-packs prior to shipping).
- Chinese stations at Kunming and Miyun participation in an EVN user experiment (3.6 cm).
- The KVAZAR stations (Svetloe, Zelenchukskaya, and Badary) participation as full EVN stations.
- Australian (Hobart, Mopra, Parkes, and ATCA) and Japanese (Kashima) stations participation in an e-EVN user experiment (1.3 cm).
- e-EVN observations scheduled within a conventional EVN disk session.

6. Joint Institute for VLBI in Europe (JIVE).

- Operational use of recirculation on the MarkIV correlator (see Astronomical Features below).
- Use of native Mark5B playback during correlation (as opposed to playing back a Mark5B recording via the Mark5A+ firmware on a Mark5A unit).
- Operational use of the SFXC correlator for user experiments — those requiring pulsar gating.

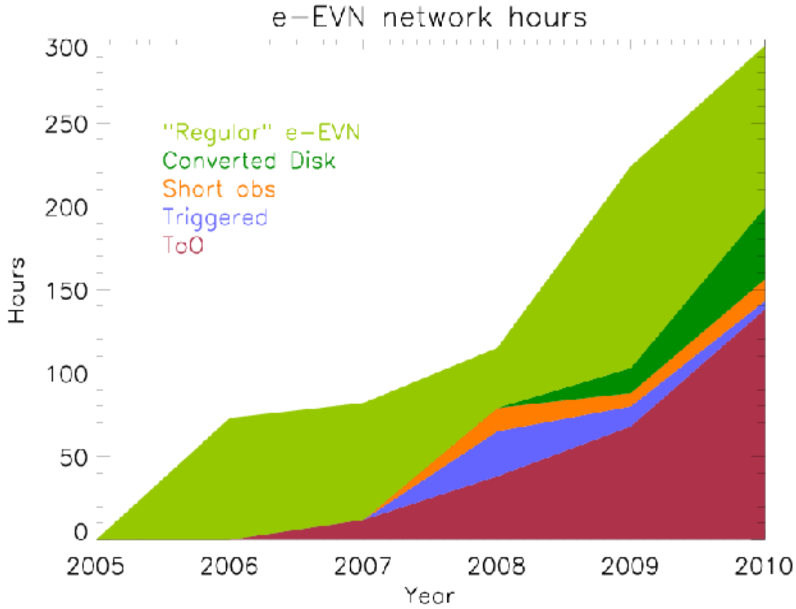


Figure 2: Division of annual e-EVN network hours into categories of proposals/experiments.

Logistics and Infrastructure

The disk-shipping requirements are derived from the recording capacity needed by a session and the supply on-hand at the stations (from the TOG chairman). The EVN and VLBA stations follow different sets of guidelines. The EVN policy states that stations should buy two sessions' worth of disks, hence the disk flux should balance over the same 2-session interval. Following distribution to the stations for session 3/2010, we had "over distributed" a net cumulative 47.2 TB of disk-pack capacity. The VLBA's need for sub-session turn-around, which essentially requires pre-positioning the difference between what NRAO stations will observe in globals to be correlated at JIVE and what EVN stations will observe in globals to be correlated in Socorro. Following the shipments in both directions for session 3/2010, we had "over distributed" a net cumulative 213.12 TB of disk-pack capacity.

Especially in 2010 sessions, experiments have been going to three different correlators (JIVE, Bonn, Socorro). This added some complexity to the pre-session disk-distribution planning. The principal goal is to avoid individual packs containing data for more than one correlator. Thus in the disk-distribution plan, the load for each target correlator for each station is computed separately. Packs on-hand at a station are applied to one of these individual-correlator loads prior to calculating what replenishment is required from JIVE. We try to use preferentially the largest-available packs for the farthest stations (to cut down on shipping), but consistent with minimizing unused capacity.

By the end of 2010 the play-back line-up is 14 Mark5As, 2 Mark5Bs, 1 Mark5B+, and 7 Mark5Cs. Among the standard EVN stations, Westerbork, Yebes, Urumqi, Badary, Zelechukskaya, and Svetloe currently provide Mark5B recordings (as do typically the Japanese stations and Kunming among the non-EVN stations correlated in this biennium). We can play back via a Mark5B unit (bypassing the station units) or via a Mark5A unit using the capabilities of the 5A+ firmware. Because Mark5B units cannot play back Mark5A recordings, we do need to retain enough 5A units to handle the maximum expected number of Mark5A stations, to minimize the conversions between Mark5 "flavours" of the individual units.

Astronomical Features

The impact of e-VLBI on expanding the kinds of astronomy that can be successfully pursued with the EVN was truly felt in 2009-10. Target-of-opportunity (ToO) experiments form the greatest advance. There have been 19 ToO proposals submitted in this two-year period (including one global and 2 disk-based ones), considerably more than in the previous decade — illustrating the change in mind-set with which astronomers view the EVN as an instrument that can respond rapidly to outbursting sources or provide the means to coordinate the EVN with observations at other wavelengths — typically high-energy satellite observations. In 2010, a full 38% of the observed EVN network hours correlated at JIVE were e-EVN observations, and 47% of these were ToOs. Triggered observations provide another means to approach transient behaviour of a pre-selected set of sources, enabling e-EVN observations of one of them when its behaviour prior to an e-EVN session shows that it has entered an interesting state. Once such a triggered proposal has been accepted, the group only needs to submit a short trigger request up to 24hr before the start of an e-EVN session, showing that the triggering criteria are met, to be considered for observation in that session. Short observations have always been possible with the EVN, requiring only a request letter to the PC chair in lieu of a full proposal. For e-EVN, short observations are considered to be up to two hours, and need to be requested up to three week before the desired e-EVN observing day.

Recirculation is a means of time-sharing MarkIV correlator resources for experiments that don't use the maximum sampling rate (32Mb/s, 16MHz Nyquist-sampled subbands), in order to increase the apparent spectral capacity in experiments that would otherwise have had spectral resolution limited by the number of stations or polarizations. The downside of recirculation is that the minimum integration time also scales with R, which may affect narrow-band spectral-line observations wanting a wide field of view. We also learned that the combination of recirculation on oversampled data does not work together. So users wanting 1024 or 2048 frequency points across 0.5 MHz sub-bands, would need to choose oversampling instead of recirculation, with the possible array-size limit of 8 stations. Recirculation has been on by default starting from session 2/2009 (we turn it off explicitly for short integration-time or oversampled experiments).

The possibilities for including additional MERLIN out-stations in the EVN correlation continue to expand. One additional dual-pol or three additional single-pol stations could already be “fit” into the Cambridge recording (one station/pol per each of the VLBA recorder's four IFs). The extra out-station data can be placed into "unused" subbands — ones in the observing set-up not needed for the 128 Mbps data per out-station transmitted over the MERLIN micro-wave link. We can now use multi-casting techniques developed for e-VLBI to access all stations' data from the single Cm disk-pack directly. The benefit is avoiding having to copy the Cm pack, the cost is use of an additional two Mark5 units during correlation to simulate the e-VLBI transfer into the switch/router. In 2010, two dual-pol out-stations were able to “fit” into the Cambridge data, by putting the 16 MHz signals from two station/pols into a single 500MHz IF by up-converting one of them when mixing into the IF and down-converting again when mixing into the BBCs.

SFXC provides the capability to use pulsar-gating/binning during correlation at JIVE; three such user experiments have been observed in the last two sessions of 2010. A number of independent bins can be placed within a single gate that has a start/stop phase with respect to the pulsar period. Each bin would produce a separate FITS file. Traditional gating (in the MarkIII sense) corresponds to 1 bin. Figure 3 shows an example of a correlation with 100 bins spread over a gate of a tenth of the period for PSR 0329+54 at 1.4 GHz. Figure 4 shows the Effelsberg single-dish pulse profile, illustrating that the SFXC pulse profile, built up from the independent bins within the gate, reproduces the pulse profile well. Other types of experiments that immediately benefit from SFXC include those with more than 16 stations and spectral-line experiments wanting more than 2048 frequency points per subband/pol.

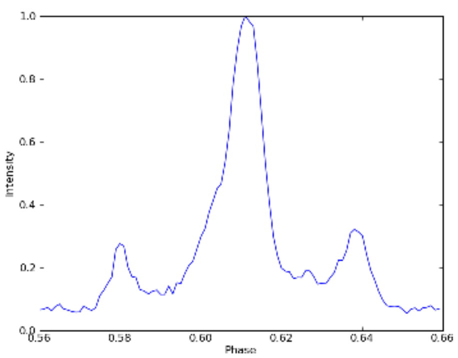


Figure 3: Pulse profile for PSR 0329+54 built up from 100 separate bins within a gate of one-tenth of the pulsar's period, from a test observation at 1.4 GHz.

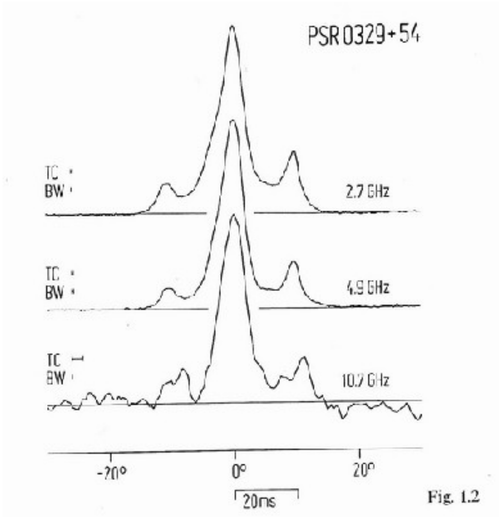


Figure 4: Effelsberg single-dish pulse profile from Sieber et al. (1975, A&A, 38, 169).

EVN Support

Automatic-ftp fringe tests are included in all network monitoring experiments (NMEs) or separate fringe-tests at the beginning of each new frequency sub-session within EVN sessions. Under the control of sched and the field system, a specified portion of a scan is sent directly to a computer at JIVE accessible by SFXC. These ftp fringe-tests are generally placed hourly, providing the opportunity to iterate on any identified problem. Use of ftp transfer and near-real-time correlation permits stations that don't have a full e-VLBI connection to participate. A Skype chat session during the ftp fringe-test observations provides even more immediate feedback between the station friends and the JIVE support scientists. Correlation of the ftp fringe tests takes place on the SFXC, and correlation results go to a web page available to all the stations, showing baseline amplitude and phase across the band as well as autocorrelations. The web-based results from the first and probably the second ftp transfer would be available to the stations before the end of the NME. These ftp fringe tests continue to be very successful in identifying telescope problems and helping to safeguard user experiments by allowing the station friends to take care of any such problems before the actual astronomical observations begin.

The EVN pipeline runs under ParselTongue. The pipeline scripts are available from the ParselTongue wiki and should provide a good basis for other (semi-) automated VLBI reduction efforts. We continue to pipeline all experiments correlated at JIVE, including NMEs, with results being posted to the EVN archive. The pipeline provides stations with feedback on their general performance and in particular on their gain corrections, and identifies stations/frequency bands with particular problems. Timely delivery of ANTAB amplitude calibration results from the telescopes seems to be improving, but remains an issue in e-VLBI experiments due to the shorter time-scales involved.

JIVE staff helped Onsala investigate the performance of their new optical-fiber system for getting the RF down from the 25m antenna. We determined improved SEFDs for Jodrell Bank Mark2 and Cambridge from a series of NMEs. Torun appeared to be missing fringes in only some 5cm experiments — it was discovered to be a LO change between EVN and single-dish observations that isn't under field-system control. Once this was realized, we were able to correlate with the appropriate LO offset (1 MHz) and regain the “missing” fringes. Session 1/2010 saw the first time Mark5B EVN data went to Socorro for correlation; we passed along the appropriate bit-stream/channel layouts for these stations in the various experiments.

There have been quite a few new stations participating in astronomical observations. The three KVAZAR stations have joined the EVN as members, and strengthen the array's capability to provide long baselines. We conferred with the station friends at IAA to understand how to provide set-up information in the user schedule files to work best with their data acquisition systems. Stations in Japan (Yamaguchi 32m, VERA_Mizusawa) have participated in some methanol-maser astrometric observations. These are not under field-system control, and provide Mark5B-format disk-packs they generate by translating from their natural K5 format and/or VERA recording tapes. Two new stations in China participated for the first time in EVN observations late in 2009: Kunming in the Phoenix mountains in southwest China and Miyun, about 140 km northeast of Beijing. Jun Yang helped organize the shipment of Westerbork's Mark4 data acquisition system to Kunming (superfluous at Westerbork since the establishment of their new fully digital TADUmax back-end, cf. section 2.2

of the JIVE biennial report 2007-2008). This Mark4 equipment would enable Kunming to record at a full Gbps, up from their previous 128 Mbps limit.

PI Support

The science operations and support group continues to contact all PIs once the block schedule appears, to pass along any information that would help them with their scheduling. For the new KVAZAR stations, this included setini sections appropriate for their non-standard back-ends. There were 14 first-time EVN PIs in 2009 and another 13 in 2010. We also check the PIs' schedules for problems prior to stations downloading them, with safeguards in place to minimize the chance that different stations use different versions of an experiment's schedule. In session 3/2010, after the PIs had deposited their schedules we learned that the Lovell telescope would not be able to observe. Behind the scenes, we restored Jodrell Bank Mark2 to schedules that had used the Lovell, including reinserting scans it may have missed in fast cycle-time phase-referencing observations. The pre-observation communication also provides the opportunity to inform eligible PIs about the benefits of the RadioNet trans-national access programme, as well as the extra reporting they would eventually need to provide.

The EVN Archive at JIVE provides web access to the station feedback, standard plots, pipeline results, and FITS files for experiments correlated at JIVE. Public access to the FITS files themselves and derived source-specific pipeline results is governed by the EVN Archive Policy: the complete raw FITS files and pipeline results for sources identified by the PI as "private" have a one-year proprietary period, starting from distribution of the last experiment resulting from a proposal. PIs can access proprietary data via a password they arrange with JIVE. PIs receive a one-month warning prior to the expiration of their proprietary period. The archive machine has 12.8 TB of dedicated disk space, with a buffer of another 1.8 TB that also houses the pipeline work area. The total size of the FITS files in the archive at the end of 2010 was 9.43 TB; figure 5 shows the growth of the FITS-file size in the EVN archive size over time.

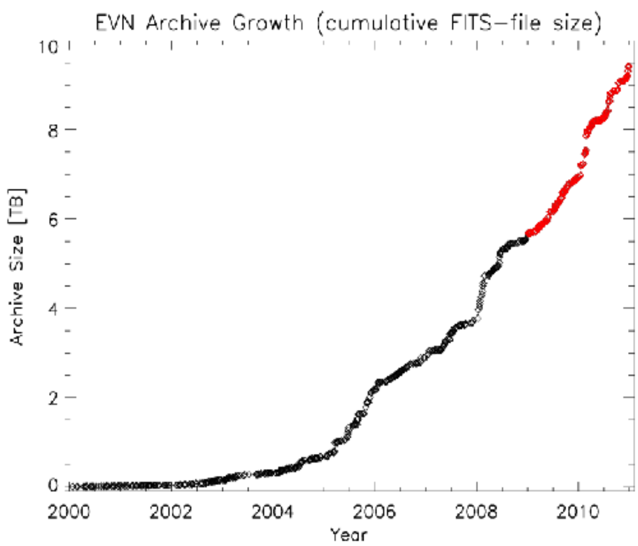


Figure 5: Growth in the size of FITS files in the EVN archive. Experiments archived in this biennial period are plotted in red.

We have begun to post two new types of FITS data on the archive: (i) FITS files from the Westerbork-array data obtained during the course of EVN observations, and (ii) the pipeline-calibrated UV-FITS files for individual sources. The Wb FITS files aren't directly available to users as such from the station; we take care of the data transformation from the Wb-archive Measurement Sets and place the resulting FITS files on the archive along with the FITS files from the EVN correlation. In some cases (e.g., narrow-field continuum mapping), the Wb FITS data can be several times the size of the EVN FITS data, so this extra processing is currently driven by PI request. The pipeline-calibrated UV-FITS data for individual sources contains the cumulative effects of all steps of calibration within the EVN pipeline. These pipeline-calibrated FITS files associated with "private" sources are protected by the same one-year proprietary period as are the plots/images of these sources and the full set of raw IDI FITS files.

JIVE hosted 8 data-reduction visits in each of 2009 and 2010. In addition, there were six post-graduate students who were co-supervised by members of JIVE staff during all or part of this period, and who visited frequently. The visitors' room has five dual-processor PCs running Linux, a MAC-mini, and a windows-based PC. Three of the Linux PCs have been replaced with more powerful machines this period, and these are also dual-boot Linux/windows.

Operations Throughput Plots

Figure 6 presents the size of the correlator queue at different stages in the processing cycle, showing a snapshot of the status at the end of each week. The red line plots the number of correlator hours that remain to be correlated. The blue line plots the number of correlator hours whose data remain to be distributed to the PI. The green line plots the number of correlator hours associated with recording media that have yet to be released back to the pool (in practice, release occurs prior to the following session).

Figure 7 shows the number of user experiments correlated at JIVE, along with the associated number of network and correlator hours, since 2003. The number of network hours correlated at JIVE, especially when considering both user experiments and NME/test observations, shows a steadily increasing trend. The growth in the number of user experiments has accelerated in recent years thanks to the new e-VLBI observations (more than tripling from 2005 to 2010). Both the increasing correlator hours and surging number of experiments keep the Science Operations and Support group busy, with PI interaction scaling more closely with numbers of experiments rather than their duration.

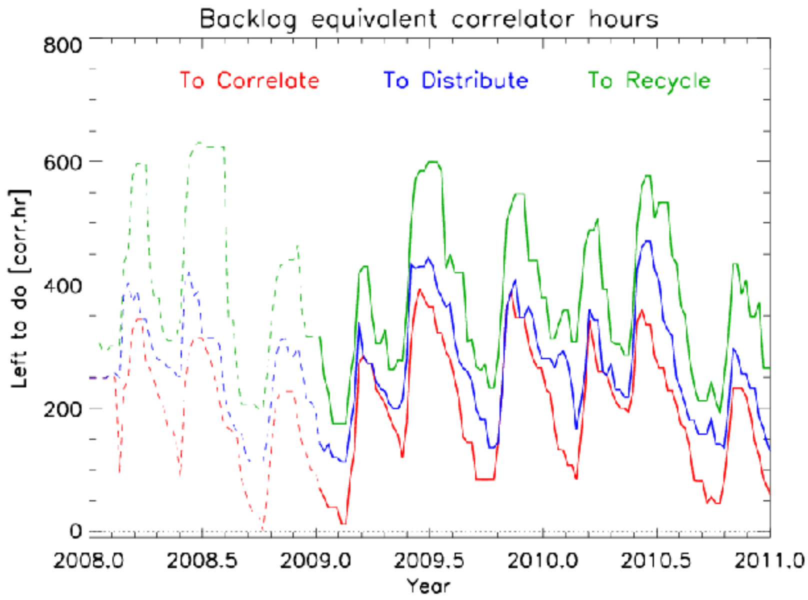


Figure 6: Size of various correlator queues, measured in correlator hours.

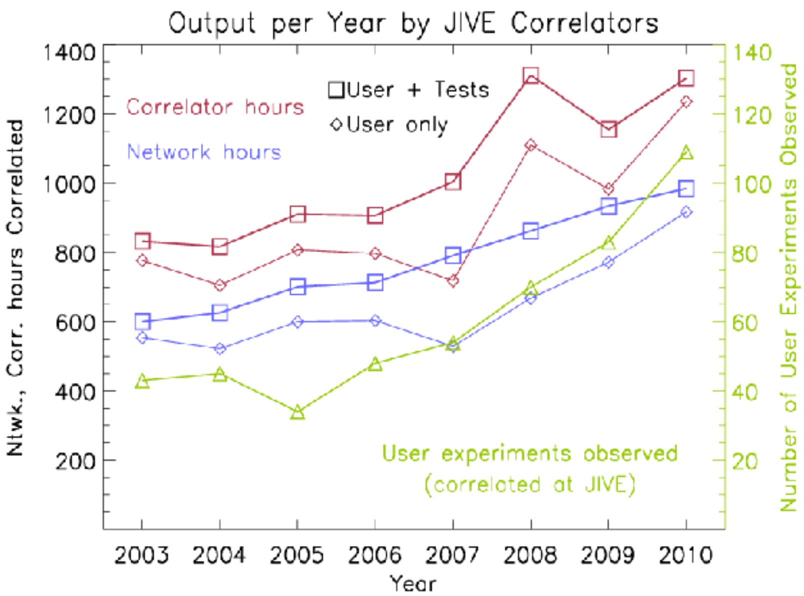


Figure 7: Amount of correlator and network hours plus the number of user experiments correlated in each year.

6.2 Correlator developments

During the period 2009-2010 the staff members of the Technical Operations and R&D group were involved in a large number of nationally and internationally funded projects. The EC-funded EXPReS project was extended to September 2009, followed by NEXPReS, which kicked off in July 2010. Work on the NWO-funded SCARIe project continued throughout the period, furthering the ambitions of JIVE in the field of distributed software correlation. JIVE also returned to digital engineering, with the start of the RadioNet FP7 UniBoard project, an international collaboration aimed at creating a generic FPGA-based high-performance computing platform along with several demanding radio-astronomical applications. This was accompanied by a number of related NWO-funded projects, such as ExBoX which aims at creating larger computing systems for correlation and beamforming, using the UniBoard as a building block, and the ShAO-NWO collaborative agreement, which stimulates the collaboration between Shanghai Observatory and JIVE through the exchange of scientists and students working in the fields of FPGA-based correlation and space science applications of VLBI.

As a consequence, several of the members of this group had to take on extra responsibilities in the form of the management of internationally distributed work packages. The new projects also posed new engineering challenges, which were met with enthusiasm and creativity. Staff members also fulfilled many other tasks in international context, liaising with research networks, the EVN partners and VLBI institutes in general, and participating in committees dealing with issues like the standardisation of VLBI formats and the modification of VEX standards.

The maintenance and improvement of the hard- and software infrastructure of JIVE remains one of the key tasks of this group. It is clear that the emphasis of this task will shift more and more towards enabling the large-scale use of the locally developed SFXC software correlator, and the implementation of a next-generation high-bandwidth FPGA-based correlator. While these will eventually completely replace the current EVN MarkIV hardware correlator and its custom-made peripherals, considerations of operational efficiency will determine the exact moment.

Figure 1: first e-VLBI test involving Badary during a cooling machine failure

The success of the NEXPReS proposal also meant that key personnel could be kept, preserving (in)valuable expertise for JIVE. Throughout this period only one person left the institute, when Friso Olnon, one of JIVE's most experienced software engineers, reached retirement age. In the period between EXPReS and the start of NEXPReS, one software engineer was seconded to NRAO, to work on the ALMA correlator development and gain international working experience.

Data Processor Maintenance

Running a complex piece of machinery like a correlator on a nearly continuous schedule involves the maintenance of a large number of supporting systems. Cooling system, paternoster, fire alarm and extinguishing systems are just a few of the systems that need regular maintenance and occasional repairs. A serious failure of the Dwingeloo main cooling machine in October 2009, right before the first e-VLBI test involving Badary (one of the new EVN stations) forced JIVE and ASTRON staff to take unconventional measures. Emergency rental cooling units were installed in the correlator room and fans throughout the building were commandeered to keep the equipment going (Figure 1). Eventually, the test turned out to be a great success. Finally, to accommodate the future expansion of hardware in the JIVE cellar, a new electricity distribution board with its own high-capacity connection to the central mains was designed, to be installed in 2011.

6.3 Data Processor Developments and Upgrades

Mark5

All Mark5 units were equipped with 10G Ethernet cards, one unit was converted to B+ for e-VLBI testing. As part of the NEXPReS project, seven Mark5C units were purchased from Conduant, two of which are already rack-mounted and operational. All units were upgraded to identical OS and Sdk versions through the central management server (Debian Etch and Sdk 8.2), and recommendations were made to the stations to follow suit, especially those who regularly participate in e-VLBI observations.

During the EXPReS project, a considerable amount of effort was put into re-writing the Mark5 control code, primarily in order to enable high-bandwidth UDP-based e-VLBI. Several new features were added, such as packet and channel dropping, to make better use of available bandwidth, and simultaneous recording/transmitting at the stations.

In NEXPReS this development continued, with an extensive overhaul of the code base, providing a much more efficient usage of available CPU cores through multithreading. B+ support was implemented and tested (in collaboration with colleagues in Australia and New Zealand). At the end of 2010 the code was nominally stable but not quite sufficiently tested yet.

Archive

At the end of 2010 the usage of the JIVE data archive reached about 12 TB, more than 75% of the total available capacity of 15 TB. To deal with the expected increase of data output (among others because of the increased use of the software correlator) a new solution to the archive storage will have to be found in 2011.

In 2010 an archive backup machine was purchased, together with the astronomy support group of ASTRON, and installed at the ASTRON Westerbork location. It is located in one of the Faraday cages at the WSRT and connected via the regular ASTRON network between the WSRT and Dwingeloo. Through this connection a daily updated mirror of the JIVE archive is maintained.

Mark5A to B upgrade

The upgrade of the Mark5A units currently in use at JIVE to Mark5B has been a long-standing and high-priority issue, as this would allow us to phase out the failure-prone SUs. However, although some of the stations do produce B-data, the need remains to keep a nearly full complement of operational Mark5A/SU combinations at JIVE. With the increasing use of the SFXC software correlator, the ongoing roll-out of dBBCs to the EVN stations and the full upgrade of the VLBA nearing its completion, this situation is fortunately bound to improve.

PCInt

The heavily used PCInt cluster, serving as the institute's common data processing platform, has reached an age where reliability issues start to dominate its operation. In order to find a replacement, a careful assessment was made of user demands and the expected size of future data products. By the end of 2010, a platform combining fast disk access, large storage and high performance had been selected and ordered. Likewise, an inventory had been made of user software that will have to be transferred, and various options (re-compilation, binary copies) had been evaluated.

SFXC Software Correlator

In the past two years the locally developed SFXC has grown into a fully operational system. Pulsar gating/binning functionality was implemented, including incoherent de-dispersion across each subband. This was successfully tested using both simulated data and data from a test observation. The first user experiment was observed in session 2 of 2010, and the data was correlated and distributed after extensive comparisons of the non-gated scans with results from the MarkIV correlator.

The software correlator now also provides sampler statistics (on a per-integration basis). Restrictions on the maximum number of spectral channels were removed, and the SFXC software correlator should now be capable of handling any spectral resolution that can be reasonably asked for by PIs. Support for the new VDIF standard was implemented and tested.

In early 2010, a modest-sized cluster was acquired to run the software correlator, consisting of 16 compute nodes, each with two quad-core CPUs and a head node with a single quad-core CPU for a total of 132 cores (Figure 1). The machines are connected to the Mark5 playback units through a dedicated Gbps network. The cluster nodes themselves are interconnected with a 40 Gbps Infiniband network. Considerable effort was spent on fine tuning and adjusting of the software to achieve the best possible performance. As a result it is now possible to correlate 9 stations @ 512 Mbps with 1024 spectral points faster than real time. Based on the performance and operational success of the EVN software correlator, the decision was taken to expand the available hardware by at least a factor of two, something that will take place in 2011.

In the course of NEXPReS, a new interface will be needed for the operators to run different correlators simultaneously, and to enable error handling and remote and (semi) automated operations. A first prototype of this interface has been implemented, currently only incorporating support for the SFXC software correlator. It makes use of the VEX – MySQL database conversion developed for the UniBoard project, and allows the specification of correlation parameters and the selection of specific scans, while providing feedback in the form of weight plots and rudimentary fringe plots.

Initially the fuseMark5 file system was used for reading data from disk packs, but to streamline operations direct reading from Mark5 diskpacks was implemented. Finally, in a development that will be of great importance for wide-field VLBI, support for correlating multiple phase centres was implemented and is now in the process of being tested.

Next-generation FPGA-based Correlator

With the MarkIV hardware correlator nearing the end of its useful life, and software correlators just about getting close to being able to take over the current correlator functionality and load, the need for a 100-fold more powerful true next-generation EVN correlator remains. Over the past years, JIVE and its partners have sought ways to set this in motion, and have been successful in raising funds to start the development of a fully FPGA-based correlator. As mentioned previously, three projects currently support this effort, the EC-funded UniBoard project, the NWO ExBoX project (in collaboration with ASTRON) and the ShAO-NWO collaborative agreement.

Figure 1: the SFXC cluster, consisting of four Transtec Calleo 642 servers. Each server contains four nodes, each node is equipped with two quadcore Intel Xeon 2.26 GHz E5520, giving a total of 128 cpu cores.

The UniBoard

The concept underlying the UniBoard, a single-board, all- station correlator, was originally proposed by Sergei Pogrebenko, system scientist at JIVE, in the late 90s. Such a board should have all the CPU power that could be fitted on, in the form of Field Programmable Gate Arrays (FPGA), and as much I/O capacity as possible. However, in those days FPGA technology was not far enough advanced to make this feasible. In 2007 however the situation had changed completely, with new generations of FPGAs combining massive computing power with ease of programming and fast development. The concept now became the basis for the UniBoard, one of the Joint Research Activities (JRA) in RadioNet FP7.

The aim of this project, which kicked off on January 1 2009, was the creation of a generic high-performance FPGA-based computing platform for radio astronomy, along with the implementation of several firmware personalities. The first partners and their original roles in the project were: JIVE (project lead, VLBI correlator), ASTRON (hardware and test firmware development), University of Manchester (pulsar binning machine), INAF (digital receiver), University of Bordeaux (digital receiver), University of Orléans (RFI mitigation), KASI (VLBI correlator), later joined by: Shanghai Observatory (VLBI correlator), University of Oxford (all-dipole LOFAR correlator). At this time concrete plans exist to use the UniBoard as the basis for the next-generation EVN correlator, the Apertif correlator and beam former system and at least one all-dipole LOFAR correlator, while several other applications are being considered.

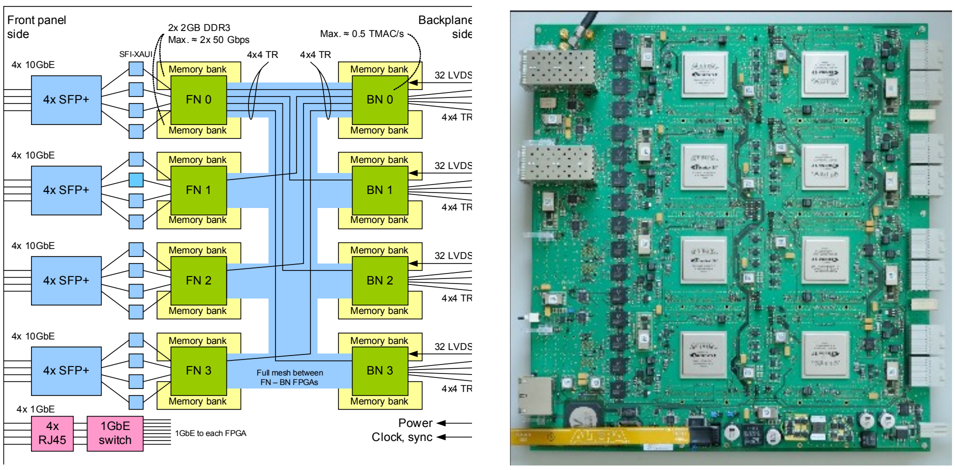


Figure 2: high level design (left) and prototype UniBoard, delivered May 17, 2010

The hardware

At the start of the project, an inventory was made of the hardware requirements posed by the different applications. Considerations of price, availability and pin lay-out led to the selection of the Altera Stratix IV EP4SGX230KF40C2 chip (40 nm, 1288 18x18 multipliers, 14.3 Mb internal block RAM, 24 + 12 transceivers). With 1288 multipliers at 400 MHz each of these chips could yield a maximum of about 0.5 TMAC/s.

A configuration of eight FPGAs per board was found to be optimal in terms of computing power, power consumption, density and complexity of the board (Figure 2). Each FPGA is connected to two DDR3 memory banks, mounted on the back side of the board. Four times four 10-GbE links connect to the front nodes (FN) via four SFP+ cages. A high speed mesh connects each FN to all back nodes (BN). The BNs in their turn connect via four times four 8-bits LVDS to a backplane connector. To make the board completely symmetrical, a 10G break-out board (the XGB) has been designed in the form of a mini-backplane, with a total of 16 CX4 connectors. For system management, each FPGA also has a 1Gb/s Ethernet connection to an onboard ethernet switch, which offers 4 x 1Gb/s connectivity on RJ-45 connectors. The central power supply of -48V is distributed on the board via DC/DC convertors and regulators, the PCB itself has 14 layers. Control and configuration are done via the embedded NIOS processor. The PCB production and board assembly were outsourced. The prototype was delivered May 17, 2010 (Figure 2). After a review of the modified design, a second production run has been initiated and the boards are expected April 2011.

Firm- and software

All documentation is posted on a project wiki, and all code is shared among the partners through a common repository. A large effort by JIVE and ASTRON engineers went into the construction of a general test design, combining tests of all interfaces and interconnections, which will be made available to the partners. The correlator design progressed well, with most of the individual components (filterbanks, correlator engine, delay) either in place or under development by the end of 2010.

The board control is being written at JIVE, as is the general correlator control system. After careful consideration and the evaluation of a number of test cases the decision was made to do this in Erlang. This high-level programming language, fairly unknown in astronomical software engineering, provides robustness and a very high level of completeness. Importantly, for a project with limited resources, it also enables a very short code development cycle.

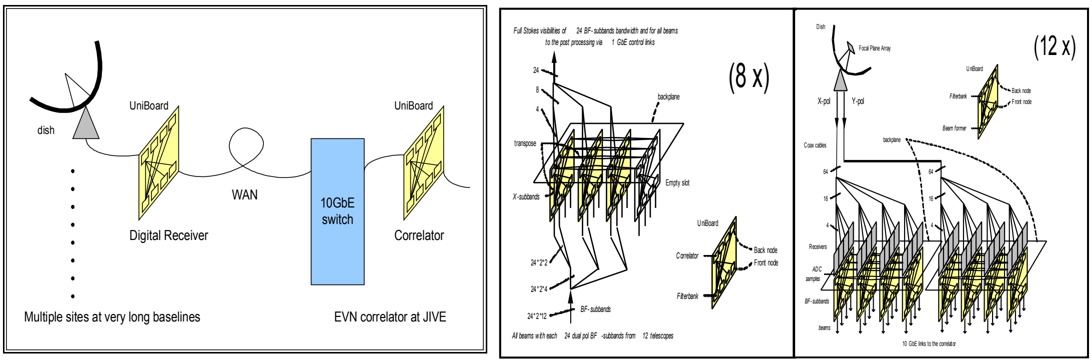


Figure 3: (left to right) UniBoard as VLBI correlator, Apertif correlator and beamformer

ExBoX

Several configurations for different applications are being considered, illustrated in Figure 3. This development is supported by ExBoX, which aims at combining UniBoards into much larger systems through custom-made back- or midplanes, suitable for example for Apertif. This also has a clear relevance for the even larger systems of the future, such as the phase 1 SKA correlator and beam former.

Software developments

ALBiUS

Software was developed to facilitate the combined use of AIPS and Casa. The work focused on two areas, a combined Python environment, and a calibration transfer mechanism. The combined environment utilises the ParselTongue interface to AIPS, developed at JIVE under the ALBUS project and further enhanced under the ALBiUS project. By modifying the Casa environment (which implements a Python use interface) the simultaneous use of Casa and AIPS is possible, with the latter being accessed via its ParselTongue interface.

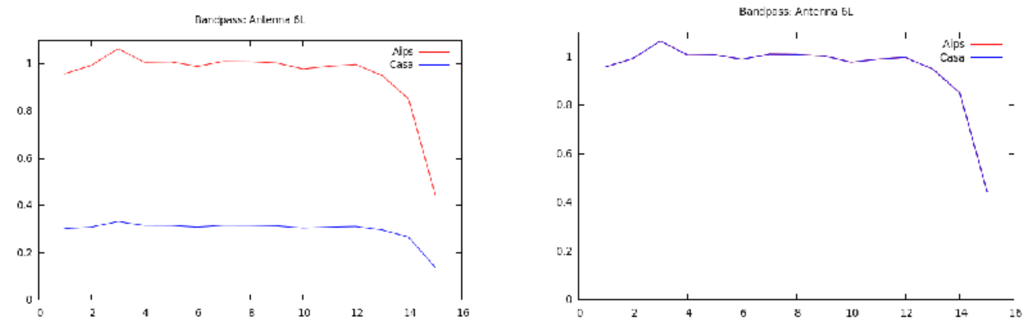


Figure 4: AIPS / Casa Calibration transfer. The first plot shows a bandpass produced in both Aips and Casa. The Casa bandpass was produced with a different normalisation. After transferring the Aips solutions to the MS, plot 2 shows the Aips and Casa tables to be equal.

As AIPS and Casa use different data formats, the FITS format can be used as a common denominator. The size of datasets, however, makes this an inconvenient strategy for most observations. A more acceptable approach is to maintain a copy of the data in each both AIPS and Casa's native formats and convert only the calibration tables, which are attached to the data throughout the data processing stages. The most common use case for such an approach is to use AIPS for the early calibration stages, such as amplitude calibration and fringe fitting, and then make use of Casa's plotting and imaging capabilities (Figure 4). To enable this, software was developed to convert Gain, Delay, Rate and Bandpass tables from AIPS into Casa.

ParselTongue

During the last two years, ParselTongue saw some major developments. An interesting new feature is the integration of AIPSLite, which makes it possible to run ParselTongue on computers without a pre-existing AIPS installation. Other improvements are the ability to have random access to visibility data, and the ability to change visibility data. This feature has resulted in the development of some clever alternative calibration strategies. ParselTongue 2.0 was made available to the user community in October 2010.

Obviously the user community extends well beyond the boundaries of the traditional group of "VLBI black-belt" users. There is a steady stream of new users that need help with installing ParselTongue on their systems, and there are the occasional bug reports as well. In many cases these requests/reports come from outside the EVN institutes. ParselTongue continues to be used for the EVN pipeline as well.

6.4 e-VLBI developments

In the period 2009 – 2010 the EVN was able to offer e-VLBI as a unique operational facility with capabilities comparable and even superior to traditional disk-based VLBI. With many of the largest and most remote telescopes connected at full bandwidth to the central processor at JIVE, the scientific and logistical benefits of real-time processing had finally become available to a network with competitive sensitivity and resolution. The fact that data can be ready for processing within hours after the observations, which in turn can be scheduled within days after the submission of a proposal, has not gone unnoticed by the user community. The growing popularity of e-VLBI has led the EVN to increase available observing time by more than 30%. While the bulk of EVN observations are still done in the traditional way, through the transport of magnetic media, immediate feedback has also greatly improved the reliability of disk-based VLBI. Data inspection during real-time observations has proven to be of great importance for studies of transient phenomena, but has also added back the excitement of doing live astronomical observations for VLBI users. With the conclusion that e-VLBI had grown into a robust, mature and fully operational mode of the EVN the EXPReS project ended in 2009.

The success of EXPReS clearly has had an impact on the plans for the future of VLBI. From the perspective of JIVE, the main ingredients for these are the further development of e-VLBI, the construction of a new correlator and the application of VLBI for space missions. During the years 2009 and 2010 important steps were taken in all three areas.

Even at the time of the successful conclusion of the EXPReS programme and the final review in November 2009, a new EC proposal called NEXPReS was being prepared. This proposal did very well and the project was awarded 3.5M€ in 2010, nearly the full amount that was originally requested. Its main objective is to make e-VLBI the operational mode for all VLBI observations in Europe. The work-programme includes a number of activities that aim to introduce transparent high-speed high-capacity storage into the e-VLBI processing chain. Together with (high) bandwidth-on-demand and distributed correlation facilities this will make the e-EVN far more sensitive, flexible and robust.

Although these plans rely to some degree on the large capacity and processing power of the EVN MkIV correlator, it is clear that the availability of a new correlator platform will be essential. The JIVE approach will be to deal with immediate requirements by deploying a software correlator alongside the current hardware correlator, while working towards a far more powerful correlator based on field-programmable gate arrays (FPGAs). The software correlator in use at JIVE is based on an implementation developed specifically for spacecraft detection, notably the tracking of the Huygens probe as it made its descent to the surface of Saturns' moon Titan. In late 2009 a medium size cluster was purchased. Towards the end of 2010 sufficient progress had been made in its commissioning to allow its first use in science observations. During this period JIVE also managed to raise considerable funds for the development of an FPGA-based next-generation correlator. UniBoard, a Joint Research Activity in the European RadioNet FP7 programme, got underway in 2009. This research activity was further strenghtened by an NWO-funded collaboration between JIVE and ASTRON called ExBoX and a collaborative agreement dealing with the joint development of FPGA-based VLBI correlators between NWO and Shanghai Observatory.

e-VLBI

In September 2009 the EXPReS project formally came to an end. By then, e-VLBI had become firmly established as a viable operational mode of the EVN. When Hartebeesthoek telescope returned on-line in 2010 after a major repair, at a full 1024 Mbps even, all important long baselines were available for real-time operations.

During 2009 several high-visibility e-VLBI demonstrations for the International Year of Astronomy took place (more on these demos in a next section). One demo featured a 33 hours (near-) continuous real-time tracking of several sources using telescopes from different arrays across the globe, something never done before in real time. The idea was subsequently picked up by a group of radio astronomers and used for a series of highly successful science observations.

Using various methods, data rates were optimised until most telescopes could transfer at a full 1024 Mbps. For those that still lack the connectivity, selective channel dropping allows a controlled cutting down of the data rate to maximise the use of available bandwidth.

As in the previous reporting period, each year some ten to twelve 24-hour e-VLBI sessions were scheduled throughout the year. In addition, the number of Target of Opportunity and triggered proposals kept on growing, resulting in an unprecedented number of Astronomers' Telegrams, quite apart from the wealth of regular scientific publications. The increased popularity and use of e-VLBI is illustrated in Figure 1, showing the aggregate data rate, averaged per year, flowing in real time into the correlator at JIVE.

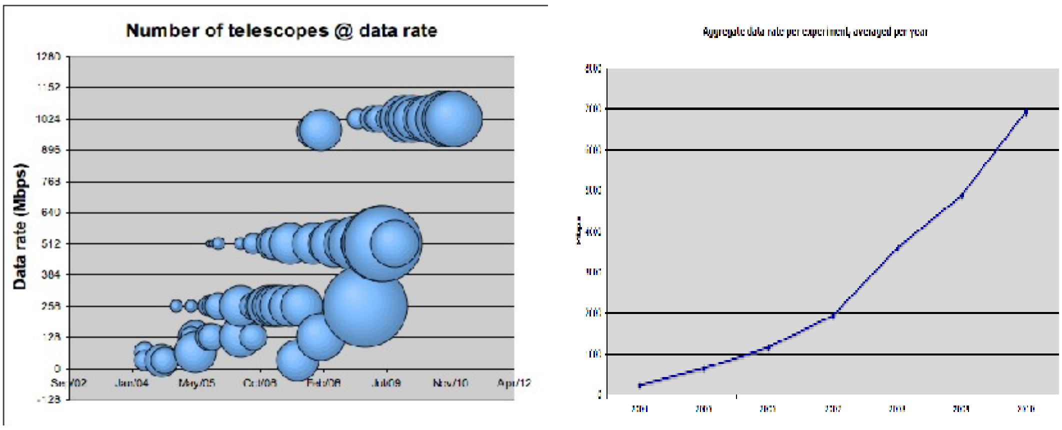


Figure 1: left: e-VLBI Bubble Plot. The size of the bubbles indicate the number of telescopes transferring data at a specific data rate. The smallest bubble is equivalent to one, the largest to twelve telescopes. Right: aggregate data rate streaming into EVN correlator per experiment, averaged per year.

Technical developments continued, resulting in the precise control of interpacket spacing, which further stabilised data transfers. Optimisation of both correlator and Mark5 control code and additions to and refinements of the control interfaces and feedback mechanisms led to a system that can actually be run for many hours, manned by a single operator. This led to some of the longest uninterrupted correlation jobs on record, as illustrated in Figure 2.

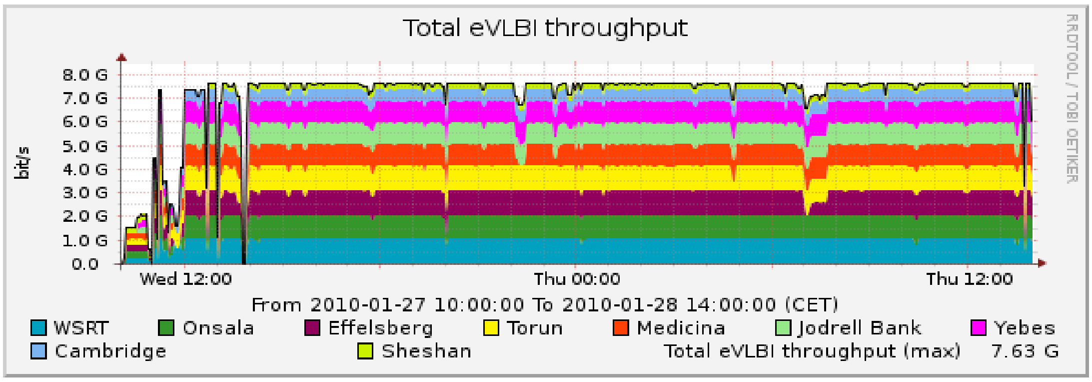


Figure 2: data throughput at JIVE during a >24 hour e-VLBI run in January 2010

The next step: NEXPReS

With EXPReS completed and global real-time 1Gbps e-VLBI a reality, a new look was taken at how the future of European VLBI might, or rather, should look. While the development of e-VLBI had been an outstanding technological success and had led to new and exciting science, it also was clear that some serious issues still needed to be resolved.

Connectivity of some telescopes remains an issue, and will remain so for the near future. At the same time, the current EVN rollout of new digital receivers and data acquisition systems will allow more sensitive observations at higher bandwidths, leading to data rates of 4 Gbps and more.

These considerations ultimately led to the successful submission to the EC of a follow-up project, called NEXPReS. The project itself is described in detail elsewhere in this biennial report.

NEXPReS kicked off in July 2010. In spite of difficulties hiring new staff for this project, work progressed well. The implementation of a new correlator control interface got underway, meant to allow simultaneous control of hard- and software correlators, and enable remote control and ultimately automated operations. The JIVE - developed Mark5 control software was completely overhauled, a MarkIV – VDIF on-the-fly convertor was created, as was a VEX – MySQL database translator. Finally, seven Mar5C units were purchased from Conduant, to be used for high-speed recording and data transfer.

7. Space Science in the context of EVN

Space science applications of radio astronomy methods, and especially the VLBI technique, are becoming a subject of growing demand among the new, large and active user community – planetary scientists and deep space mission specialists. A number of prospective planetary and deep space science missions will include in situ and remote experiments supported by Earth-based networks of radio telescopes. JIVE, with its EVN partners is developing Planetary Radio Interferometry and Doppler Tracking Experiment (PRIDE), a multidisciplinary enhancement of the scientific suite of planetary missions. PRIDE applications range from studies of the dynamics of extraterrestrial atmospheres to gravimetric diagnostics of the planetary interiors to fundamental physics. During the reporting period, the work focused on developments of the PRIDE methodology and data handling algorithms using operational planetary missions as observational targets. The PRIDE observations conducted in 2009-2011 addressed the methodology of spacecraft VLBI tracking and, as a valuable scientific by-product, provided input into the long-term diagnostics of the interplanetary medium at various Sun elongation angles (Molera et al., 2011, in preparation). Below, Venus Express (VEX) and Mars Express (MEX) PRIDE experiments are presented in more details.

PRIDE-VEX monitoring campaign

The ESA's Venus Express spacecraft has been observed with several EVN stations (Metsähovi, Medicina, Wettzell, Onsala, Matera and Noto) during the 2008-2011 campaign. The goal of the project was to develop and test the full PRIDE data handling pipeline, including scheduling of a near field object VLBI observation, data acquisition and transfer, processing of the spacecraft signals with the specially developed ultra-high resolution software spectrometer/correlator and analysis software based on the near-field delay prediction model.

The ultra-high spectral resolution spectrometer/correlator software was developed at the Metsähovi Observatory, while the analysis software – at JIVE. Several single-dish and multi-station experiments confirmed that high quality data could be acquired and a sub-milliHertz spectral resolution could be achieved. Figures 1 and 2 illustrate recent results of PRIDE observations of the VEX spacecraft with the EVN radio telescope.

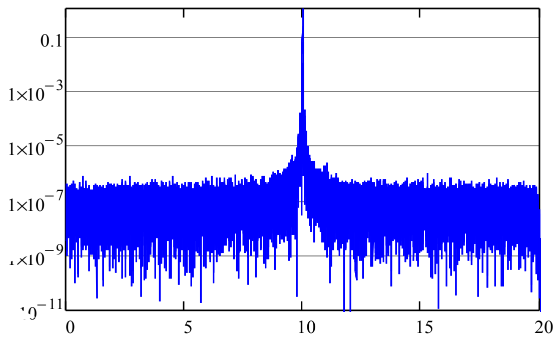


Figure 1: Ultra-high resolution spectrum of the VEX signal, obtained from the Wettzell date on 2010.03.31. The horizontal axis indicates the frequency within the tracking band, the vertical axis – the relative spectral power density. The spectral resolution achieved in this experiment is 0.9 mHz, the dynamic range is at the level of 10^7.

The observations have proven that the phase scintillation spectra have a near-Kolmogorov spectrum. The parameters of the scintillation patterns were measured with an accuracy that made these results very valuable in their own right. In particular, these data help to determine constraints imposed by the interplanetary plasma on the accuracy of astrometric and phase-referencing VLBI measurements and are of crucial importance for future ultra-precise PRIDE observations.

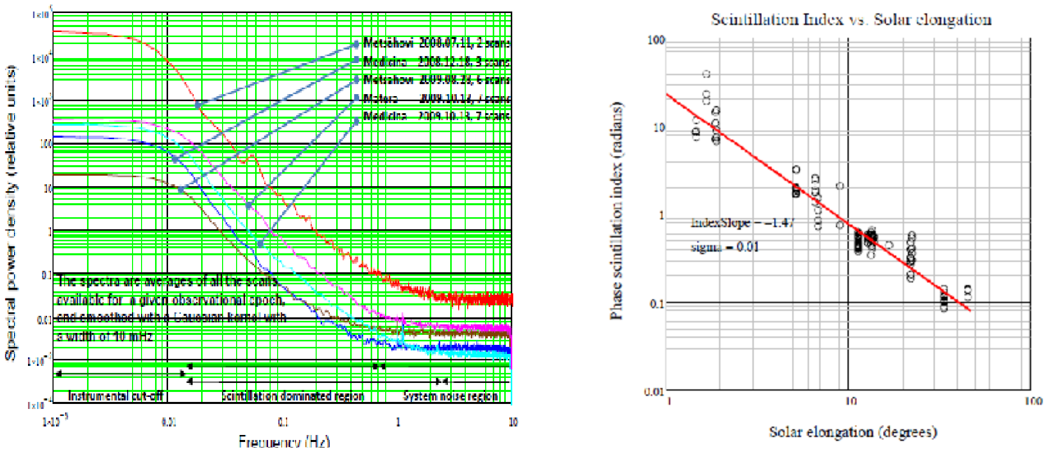


Figure 2: Left panel: examples of the phase scintillation spectra, detected by several EVN stations. Right panel: the dependence of the phase scintillation index on the solar elongation angle.

MEX-Phobos flyby observations with the EVN telescopes

The EVN stations Yebes, Wettzell and Metsähovi participated in the observations of the ESA'a Mars Express (MEX) spacecraft during its fly-by of the Martian moon Phobos on 3 March 2010. Using the ultra-high spectral resolution correlator, developed in at the Metsähovi Observatory, the PRIDE team detected the additional Doppler shift of the MEX spacecraft signal caused by the gravitational field of Phobos. The high quality of the Doppler detections (2-5 mHz or 1 mm/s in velocity terms) made improvements possible of the determination of the mass and mass distribution of Phobos. Figure 3 illustrates the detection and preliminary analysis results of this experiment.

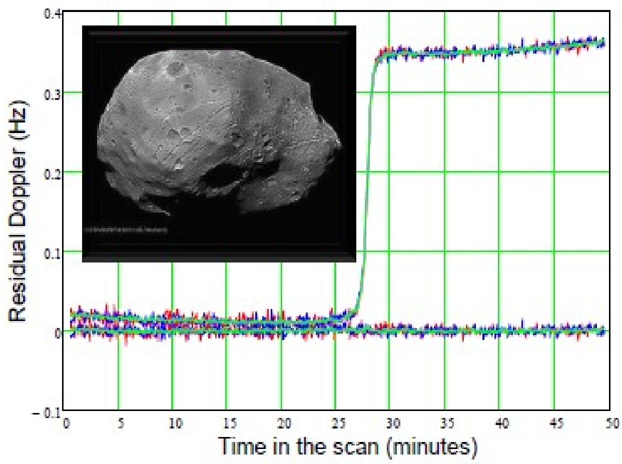


Figure 3: The residual Doppler shift of the MEX signal, as detected by the Yebes, Wettzell and Metsähovi stations. The upper traces indicate the case of the Phobos gravity (algorithmically) "switched off" in the spacecraft state vector predictions, the lower traces show the actual measured case in the presence of the Phobos gravity.

8. EVN Meetings

8.1 Science and Technology of Long Baseline Real-Time Interferometry: The 8th International e-VLBI Workshop (Madrid, June 22-26, 2009)

In recent years real-time, long-baseline, radio interferometry over optical networks has developed from a technical possibility to a mature technique. Scientifically, real-time operation is more important for long baselines, with their high spatial resolution, than for short baselines. However, until recently the required technology has not been readily available. Technical advances and the explosive increase of connection capacity have now radically changed the situation. Emerging radio interferometers (e-MERLIN, E-LOFAR, e-EVN and other e-VLBI arrays) do and will exploit mixed private/shared networks to achieve wide-bandwidth real-time operation. Mirroring developments in other wavebands of astronomy, these new real-time radio instruments are being optimized to study transient phenomena. Moving data transport to fiber also gives the prospect of rapidly expanding observing bandwidth and sensitivity as network capacity continues to increase. Technically and operationally today's e-VLBI instruments serve as precursors to the real-time Square Kilometer Array.

The National Geographical Institute (IGN) of Spain, in cooperation with the EXPReS project, hosted the conference at the premises of the National Astronomical Observatory in Madrid (Spain). One full day was spent at the Center for Technological Development in Yebes. People working on the science and technology of real-time, long-baseline radio interferometry met to discuss the state-of-the-art and future prospects.

Specific areas covered included:

- Scientific: Applications of real-time operation to astronomy, geodesy and other fields. Coordination of emerging e-VLBI arrays for best scientific return. Connections to transient monitoring in other wavebands.
- Technical: e-VLBI test experiments, use of new long distance links, development in techniques including selective packet dropping and novel protocols, the search for higher bandwidths, network status and monitoring, distributed processing, and future developments.
- Scientific/Technical: Technical possibilities of interest in planning future instruments. Desired technical requirements to fulfill scientific goals, science priorities for development.

The workshop web is available at http://www.oan.es/expres09/

The workshop gathered 84 participants working on both radio astronomy and network science in 19 countries around the world. Topics covering the status of e-VLBI, on-going projects in e-VLBI facilities around the world, latest scientific outcomes using high data rate and e-VLBI technology development were presented in 51 oral presentations and 11 posters. Because many experts were present, discussion panels on future organisation/multiwavelngth coordination to maximize science impact of e-VLBI (through the e-VLBI Scientific Advisory Group, eVSAG), network issues, and VDIF specifications, were organized. A meeting of the Internet

(academic) national providers (NREN) took place on Thursday, as part of the workshop regular agenda. Chaired by the DANTE representative, John Chevers, issues on coordination of the European GEANT high capacity data transport infrastructures with the NRENs, who provide connectivity to the VLBI radio telescopes, were discussed, as well as links to non-European partners such as Australia, of great impact to the scientific return of the e-VLBI network.

Participants had a chance to visit the historic site in Madrid, plus the 40-m radio telescope and all laboratories (in particular the LNA's one) in Yebes. A meeting of the EVN Program Committee was held in parallel to the conference, on June 24th 2009.

The proceedings of the EXPReS09 conference are available at: http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=82

Figure 1: Participants at the 8th International e-VLBI Workshop in Madrid

In October 2010 the workshop moved to Perth, Australia, where the topics dealing with e-VLBI were supplemented by reports on the exciting radio-astronomical developments in Australia. As always, this workshop was well attended, in this case by more than the usual suspects (Figure 2). A half-day meeting with the Australian NREN AARNET followed the 2-day workshop, and dealt with the many networking issues that have to be tackled to make ASKAP and, possibly, the SKA in Western Australia a reality.

Figure 2: International VLBI experts discussing the intricacies of certain scripting languages

8.2 40th Young European Radio astronomers Conference (YERAC)

It was held in Alcalá de Henares (Spain), from July 5th to 8th 2010, the fortieth edition of the European Radio astronomers Conference (YERAC). Annually since 1968, with only two exceptions, this conference has brought together young researchers from various research centers and universities in Europe, giving them the opportunity to present their work and establish links for future collaboration. In fact, many renowned scientists in the field of radio astronomy, including observatory directors, have participated in any edition of YERAC.

On this occasion, the Spanish National Astronomical Observatory (of the National Geographic Institute, Ministry of Development) and the University of Alcalá, through its General Foundation, have organized the event attended by fifty young talents. The conference was held at the School of Architecture and Geodesy, except a meeting held in the IGN Center for Technological Development in Yebes (Guadalajara, Spain), that the participants visited to learn about its advanced facilities.

The conference was funded by the European project FP7 RadioNET and the National Geographic Institute.

Website: http://www.oan.es/yerac2010/ [www.oan.es]

Figure 1: Participants at the 40th Young European Radio astronomers Conference (YERAC) in Alcala.

8.3 The 10th European VLBI Network Symposium and EVN Users Meeting: VLBI and the new generation of radio arrays (Manchester, 20-24 Sep 2010)

The 10th EVN Symposium was held in Manchester, in the week 20-24 September 2010. The meeting was a great success, both in terms of participation (almost 100 participants) and in terms of VLBI science. The programme covered a wide field of topics, from the nearby stars and star forming regions to the nuclear activity in the early Universe. Most of the talks were based on very recent results obtained with the European VLBI Network and e-VLBI networks. The superb sensitivity of the array and the real-time observing capabilities make the EVN is a key instrument for the hot science successfully presented at the meeting. The state of the art of the present VLBI and e-VLBI technology and the future perspectives were also presented. The EVN Users' Meeting was held in Jodrell Bank during the Symposium. The EVN users' community is active and demanding, and stimulated a lively discussion on the current performances of the array and on the future perspectives.

Figure 1: Participants of a football game, which takes place during each symposium.

Figure 2: Participants of the 10th European VLBI Network Symposium in Jodrell Bank Observatory.

9. International Year of Astronomy (IYA) 2009

Live demos played a large role throughout EXPReS, both for outreach purposes and as convenient focal points for the project. The undoubtedly most ambitious of these took place at the opening of the International Year of Astronomy (IYA) in January 2009, at the UNESCO headquarters in Paris.

The original proposal for this demo was to track one source in real-time continuously over a period of 24 hours. The VLBI community responded enthusiastically, and the participants included both EVN and non - EVN telescopes in Europe, China, Australia, Japan and North and South America (unfortunately Hartebeesthoek could not participate due to a mechanical failure). Because of the various limitations imposed by available receivers and geography, a total of three sources were observed at two frequencies, spread over a period of 33 hours.

In spite of a number of last-minute setbacks, which were all overcome through heroic efforts of the station staff members, and in spite of having to deal with 4 different data acquisition systems, and the fact that 4 of the 18 telescopes had never participated in e-VLBI with the EVN before, the demonstration went extremely well.

Extensive use was made at the venue of a large number of outreach tools, specifically created for the IYA demo. These included a special IYA VLBI website, an on-the-fly UV-plane/dirty beam plotter, an hourly updated Pypeline image of the sources, as well as an interactive VLBI demonstrator (Figure 1).

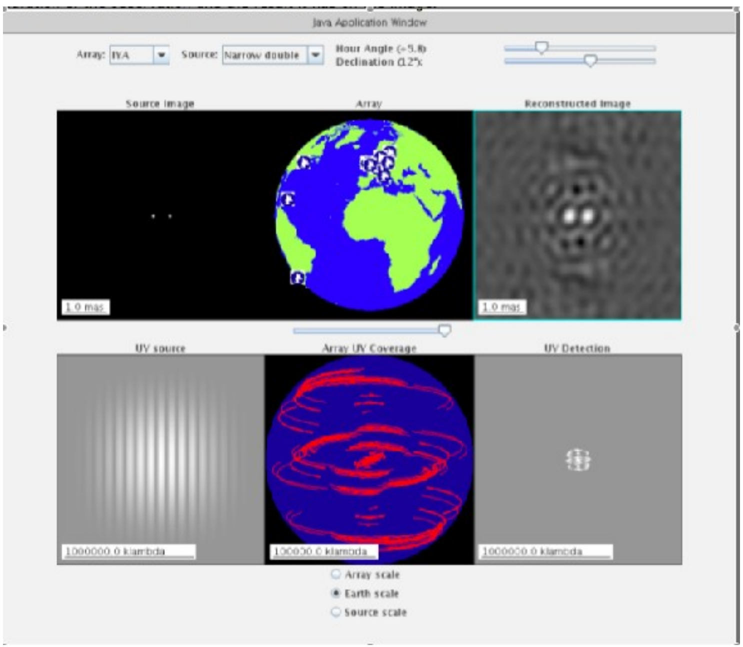


Figure 1: Interactive VLBI demonstrator

Figure 2: IYA VLBI pages, featuring live webcams of participating telescopes

Figure 3: JIVE staff in action at opening of the IYA in Paris, January 2009

This demo was followed by a somewhat scaled-down version, involving only EVN and Australian telescopes, during the so-called "Hundred hours of Astronomy". This IYA cornerstone event featured a 24-hour webcast, in which Huib van Langevelde represented the EVN, and displays of real-time results at the NEMO science museum in Amsterdam, at the open day at the Observatoire de Bordeaux and at Arecibo Observatory. In these observations the new Yebes 40m telescope joined the e-EVN for the first time.

A demonstration of software correlation was one of the main attractions at the booth of NWO at the Supercomputing 2010 conference in New Orleans. During that demonstration, which featured the pulsar binning capability of the SFXC correlator, pre-recorded data were streamed from Mark5's at JIVE into the DAS3 cluster at the University of Amsterdam. A pulse profile was displayed on the Exhibition Floor at SC10 showing the profile emerging from the noise floor as more and more data were being correlated.

10. EVN Publications in 2009-2010

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