Supporting European Very Long Baseline Interferometry
Introduction to JIVE

The Joint Institute for VLBI in Europe (JIVE) has been established as a scientific foundation since December 1993. JIVE’s mandate is to support the operations of the European VLBI Network (EVN) in the widest sense. The major activity has been the development, construction and successful operation of the EVN Data Processor, a powerful supercomputer that combines the signals from radio telescopes located across the planet, creating one huge telescope of inter-continental dimensions. Using this technique of Very Long Baseline Interferometry (VLBI), astronomers can make detailed images of cosmic radio sources, providing astronomers with their clearest, highest resolution view of some of the most distant and energetic objects in the Universe. JIVE provides comprehensive support to astronomers who may not be familiar with the VLBI technique, and develops new technologies and advanced concepts for VLBI. JIVE staff are also at the forefront of exploiting the VLBI technique in order to produce new and exciting scientific results in the fields of astrophysics, astrometry and space science.

VLBI is a technically challenging technique. Each of the individual telescopes, often separated by whole continents, must observe the same object at the same time and at exactly the same wavelength. Their station clocks (usually a hydrogen maser atomic clock) must all agree to within a few millionths of a second. JIVE has the crucial task of precisely aligning and combining these telescope data streams and automatically pipelining and exporting the processed data to the online EVN data archive system.

VLBI, and radio astronomy in general, is an important tool of the modern astronomer. During its short history, radio astronomy has revealed the structure of our Galaxy, probed the inner workings of stellar nurseries, discovered ravenous black holes devouring the cores of galaxies and detected the fading echo of the birth of the Universe. Not only that, radio astronomy has achieved the greatest resolution in any astronomical image and has detected the faintest objects ever seen.

The host organization for JIVE is ASTRON (the Netherlands Foundation for Research in Astronomy) located in Dwingeloo, the Netherlands. JIVE is a member of the European Consortium for VLBI and its operations are supported via multi-national funds from the Netherlands Organisation for Scientific Research (NWO) in the Netherlands, the Particle Physics and Astronomy Research Council (PPARC) in the UK, the Italian National Institute of Astrophysics (INAF) in Italy, Onsala Space Observatory (OSO) in Sweden, the National Geographical Institute (IGN) in Spain, the Max Planck Institute for Radio Astronomy (MPIfR) in Germany, and the Netherlands Foundation for Research in Astronomy (ASTRON) in the Netherlands.

A major part of the funding required to construct the VLBI data processor was initially obtained through a separate grant from the Dutch government worth over €5 million. JIVE has also been successful in procuring grants from the European Commission since an embryonic start via FP3, and is now a prominent member of the RadioNet Consortium, an Integrated Infrastructure Initiative (I3) project funded under FP6.
The EVN is managed by a Consortium of institutes which operate telescopes in Europe, the USA and Asia. Since its formation in 1980, the EVN has grown to include 12 active institutes with 16 radio telescopes in 11 different countries. Part of JIVE's mandate is to support and coordinate European network operations from a central location. In particular, JIVE Support Scientists are actively involved in monitoring the telescope network's performance - providing quick feedback to telescope staff if problems are detected.

The EVN telescopes conduct simultaneous observations for up to 15 weeks per year. The EVN is also regularly linked both to the 7-element MERLIN interferometer in the UK to create a very sensitive 'regional' network and to the US VLBA to create a 'global' VLBI network. In general, the more telescopes in the VLBI network the better the image quality, and the larger the distance between telescopes, the greater the resolving power. A substantial improvement in the sensitivity of the EVN and its overall performance has recently been achieved with the introduction of the new Mk5 recording system (developed by MIT Haystack Observatory, USA), capable of acquiring data from each telescope at rates of up to 1 Gigabit per second.
JIVE provides comprehensive on-site support to astronomers who wish to use the EVN, particularly new users with little or no experience of the VLBI technique. JIVE Support Scientists in Dwingeloo are available to help astronomers in the planning, scheduling and analysis of the observations. The EVN (through RadioNet) also organises biennial symposia and radio interferometry schools at which EVN users can present new scientific results and are trained in the practical aspects of VLBI data analysis. JIVE staff are also active in ongoing initiatives designed to improve the quality and reliability of network operations, and are actively involved in supporting emerging radio telescope projects that aspire to become members of the EVN. Over the last decade, JIVE has been involved in a fruitful scientific and technical collaboration with Chinese radio astronomy observatories, sponsored by the Royal Dutch and Chinese Academies of Sciences.

The production of high-resolution VLBI radio images requires the use of sophisticated computer algorithms running on high-performance, multi-processor computer clusters with access to Terabyte disk storage facilities. Astronomers are encouraged to visit the JIVE facility where Support Scientists are able to offer expert advice on all aspects of data calibration and VLBI imaging techniques. New software is also being developed at JIVE via the RadioNet ALBUS project, ensuring that radio astronomers have access to the very latest algorithms and processing methods. The EVN, together with JIVE, thus provide transparent, user-friendly operations with comprehensive support for external, non-expert users.

Currently, VLBI observations involve recording the radio signals locally at each telescope, using high-capacity magnetic tapes or (more recently) PC disk arrays such as the Mk5 system. The data are shipped to JIVE where they are replayed and combined together - often many weeks or months after the observations were made. For decades, radio astronomers have dreamt of the possibility of connecting VLBI telescopes in real-time, but until recently this was technically difficult given the high data rates involved. However, in recent years, huge progress has been made in the area of Information and Communication Technology. In particular, the creation of the pan-European research network, GÉANT, has permitted the first high-speed tests to be made - connecting radio telescopes in the UK, Sweden, Poland, Italy, the Netherlands and the USA to the EVN correlator at JIVE. In addition, the first real-time e-VLBI science results have been produced with the detection of the faint extragalactic supernova SN2001EM, and an expanding shell of dust and gas associated with an evolved star, IRC+10420. A new e-VLBI development programme, EXPReS (EXpress Production Real-time VLBI Service) has recently obtained significant funding support from the European Commission and other national funding sources. The aim is to create a reliable and flexible e-VLBI telescope distributed across Europe and beyond, particularly suited to the rapid follow-up of transient phenomena such as gamma-ray bursts.
Global VLBI observations provide astronomers with a resolution of less than 1 milliarcsecond (about 50 times better than the Hubble Space Telescope). This tremendous leap in resolution provides astronomers with a unique insight into the high-energy processes taking place in the centres of distant galaxies, close to the central, super-massive black holes that are thought to power them. Many of these objects eject enormous jets of subatomic particles accelerated to almost the speed of light. The fine detail available through VLBI allows the evolution of shocked regions of enhanced radio emission to be monitored as they travel along the jet. If the jet is orientated toward the observer, relativistic effects create the illusion of faster-than-light or ‘superluminal’ motion.

VLBI observations of very distant, high-redshift radio galaxies and quasars (including multiply imaged gravitational lens systems) also allow independent measurements of the expansion rate of the Universe and its deceleration, as well as constraining the amount and nature of ‘dark matter’ in the Universe.

Closer to home, global VLBI observations have been used to image supernova remnants located in nearby galaxies. Recent studies of a supernova in M81 reveal the development of an expanding shell-like structure within 1 year of the initial explosion. These observations, together with the optical expansion velocity, give the distance to the supernova and its parent galaxy.

VLBI can be used to measure positions, proper motions and parallaxes of radio emitting galactic objects (stars, pulsars, X-ray binary stars). The precision of VLBI astrometry has recently prompted astronomers to look for a ‘wobbling’ motion in nearby stars indicative of planetary companions. Masers in our own and external galaxies are also in constant motion. They are naturally-occurring microwave radio amplifiers found in areas where new stars are forming and old stars are dying. In NGC 4258, these motions allow the mass of the central black hole in this galaxy to be measured.

The maximum resolution of VLBI was previously limited by the largest distance between the telescopes on the Earth. However, in 1997, Japanese scientists at ISAS successfully deployed a radio telescope in Earth orbit. Observing simultaneously with ground-based telescopes (including the EVN), this satellite (called HALCA) triples the resolution achieved by global VLBI alone. JIVE supports Japanese plans to launch a much more sensitive VLBI telescope into space around 2010.

JIVE staff are active in almost all these areas of research and are also involved in applying the VLBI technique to fields outside of its traditional application. Astronomers at JIVE recently led and coordinated VLBI observations of the ESA Huygens spacecraft as it descended through the atmosphere of Titan, Saturn’s largest moon. In addition to detecting the first signals from the probe, the observations also revealed the probe’s trajectory as it descended via parachute on to the moon’s surface.