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A History of the EVN: 30 Years of Fringes

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At a meeting in Bonn on 5th March 1980, the directors of several European radio astronomy institutes agreed on setting up the European VLBI Network, to formalize joint European VLBI activities. A Program Committee was established and a Call for Proposals was issued with a deadline of 15 May. The committee met in Onsala on 4th June to review the proposals and the first official EVN observing session took place from 3–9 October, with a 4-telescope array (Effelsberg, Westerbork, Jodrell-MK II and Onsala-25m) at 5 GHz, recording with a 2 MHz bandwidth (4 Mbps). Thus we celebrate the 30th birthday of the EVN at this 10th EVN Symposium. Today the EVN comprises 15 institutes, which operate a total of 20 telescopes at 18 locations in 12 countries spanning 4 continents and a correlator dedicated to EVN observations. A 16-station array can now be used at 5 GHz and 11 stations regularly participate in e-VLBI observations with real-time correlation. The EVN observes using disk-based recording for 63 days a year, and an additional 10 days using e-VLBI; observations at 1 Gbps are routine in both. Here I describe some of the early history of European astronomical VLBI activities, the start of the EVN, and its growth in size and scope over the past three decades.

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1. The emergence of VLBI activities in Europe

Discussions on the feasibility of tape-recorded radio interferometry in Europe began as early as 1963, in the context of extending the baselines operated by the Jodrell Bank interferometry group beyond those possible with radio links - in particular to Crimea [1]–[3]. Construction of a system began at Jodrell around 1967, and "fringes" were eventually obtained to Arecibo at 610 MHz in November 1969 [1]. The first successful VLBI experiments, however, were in Canada and the USA in 1967, and the story of these developments has been described in a number of places [4]–[12]. The first VLBI observations at European observatories (Onsala in January 1968; Jodrell in June 1968; Simeiz in Sep/Oct 1969) were with baselines to US or Canadian telescopes. In 1971 the Jodrell system *did* produce the first VLBI fringes between 2 European telescopes - Jodrell MKI and Onsala [13][14] (Fig. 2 *left*). Despite some key astronomical results obtained from single-baseline VLBI experiments (e.g. the 1971 discovery of *superluminal* motion in quasars [15]), the benefits of using arrays of many telescopes were soon apparent [16]-[18]. The NRAO MK II recording system with 2 MHz bandwidth, introduced in 1971, became a universal standard for global astronomical VLBI, and remained a workhorse for two decades. In Europe several observatories continued observations with transatlantic partners [19][20]. A successful 1.7 GHz OH-line VLBI observation took place in 1975 between Effelsberg and Onsala [21]. In the USA a *Network Users Group* (NUG) was organized in 1975 [7], to coordinate proposal review and scheduling for a network of 7 telescopes. A regular series of 6 observing sessions per year, each 1 week long, began in March 1976. Two observing frequencies were observed in each, chosen from 22, 10.7, 5 and 1.6 GHz. Discussions on setting up a European VLBI Network started in the MPIfR cafeteria on 7 April 1975 [22] and led to a series of meetings (September 1975; March and October 1976). The author's VLBI initiation was at the 4th meeting at Jodrell Bank in September 1977 (Fig. 1).

Figure 1: 4th informal European VLBI Meeting, Jodrell Bank, 1st September 1977. From left to right: **Back:** Ponsonby, Matheson (Chilbolton), Matveenko, Rönnäng, Pearson, Winnberg, Robbins (Oxford), Pauliny-Toth, Davies, McLintock (Nottingham), Kellermann, Sykes (Nottingham), Porcas, Anderson, Wall (RGO), van Ardenne **Front:** Stannard, McSteele (NPL), Bååth, Preuss, Cohen, Booth, Barber (Chilbolton).

The first 3-station "Europe only" VLBI took place on 2nd October 1976 [23], with observations of the giant radio-galaxy 3C 236 at 1.6 GHz, using Effelsberg, Onsala and Dwingeloo (Fig. 2 *right*). These observations were processed at the NRAO MK II correlator in Charlottesville. European VLBI received a boost when construction of a MK II correlator at the MPIfR was completed at the end of 1977. A second, ambitious, European experiment took place from 6–9 January 1978. Named "JODE" (after the initial letters of the telescopes), this was an attempt to do *polarization* VLBI at 1.6 GHz, taking advantage of the sensitivity provided by the large collecting areas of Effelsberg and the Jodrell MK IA telescope (renamed "Lovell Telescope" in 1987), together with Onsala and Dwingeloo. Cross-hand correlation, using the single-channel MK II system, was achieved by switching between LHC and RHC polarizations every 1 minute at Effelsberg and every 2 minutes at Jodrell. This experiment was the first to use the MPIfR correlator. Although some preliminary polarization VLBI results were presented at the Heidelberg VLBI Symposium in August 1978 [24], only single polarization results were ultimately published [25][26]. March 1978 saw the first use of Westerbork (at 1.4 GHz) in phased-array mode [27] while 22 GHz observations were made in November 1977 and October 1978 at Ef, Onsala-20m, Simeiz and Haystack [28].

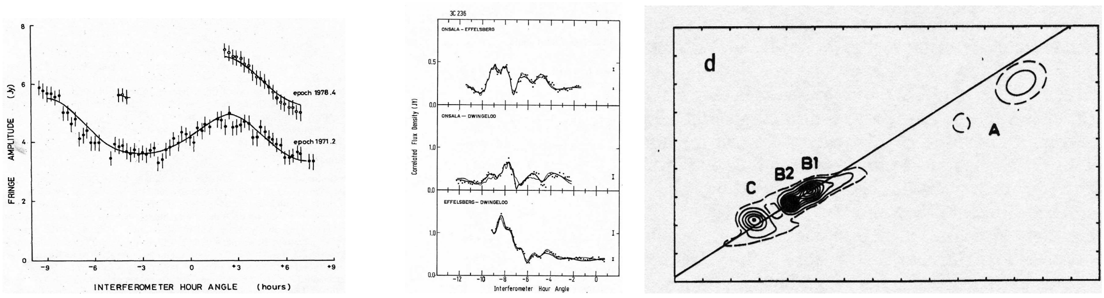

Figure 2: First all-European VLBI runs. *Left:* Jodrell–Onsala fringe visibility at 1.67 GHz on 3C 345 from 1971.2 [13][14]. *Right:* 3–station run, October 1976 – 3C 236 at 1.6 GHz [23]; tick spacing 100 mas.

In 1979 further *ad hoc* Europe-only VLBI sessions were organized in March (Eb, Wb & On at 5 GHz) and June (Eb, Jb & Dw at 1.6 GHz) and these *did* result in immediate publications on two of the "hottest" astronomical objects of the day, SS433 [29] and the newly discovered first gravitational lens 0957+561A,B [30]. At a VLBI Workshop held on 7-8th November in Bonn – with lunch at the author's favourite pub *Fronhof* – a plan to coordinate proposal review and scheduling in Europe was discussed. Europe-only sessions, still with *ad hoc* proposal review and scheduling, continued into the first half of 1980 (5 GHz in January and June [31][32], 1.6 GHz in February [33]), alongside the participation of some European telescopes in NUG sessions, notably Effelsberg, which had become an associate member in 1979. The first meeting of European Directors on 5th March 1980 finally led to the setting up of a program committee, and an agreement to have 6 EVN observing sessions per year. The EVN was thus established. Some results from the first session in October 1980 (see observing schedule in Fig. 3 *left*) are mentioned in [34] and [35]. Interestingly, both publications present series of European VLBI results from both before and after that session; to some extent the main immediate result from the founding of the EVN was a streamlined administration of an already-existing network operation.

This decade leading up to the formation of the EVN was a momentous one for radio interfer-

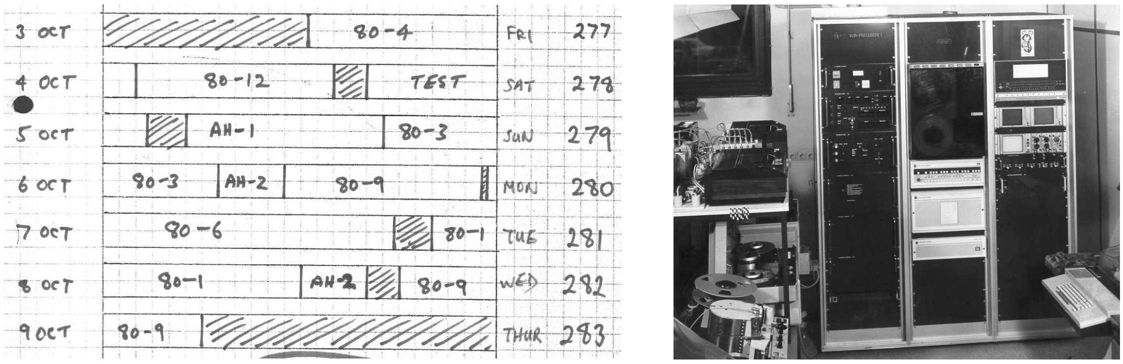

Figure 3: *Left:* First EVN Session schedule, October 1980. *Right:* Bonn MK II correlator, 1980. Note the 3 generations of MK II recorders (Ampex, IVC, VCR with 2", 1" & $\frac{1}{2}$" tapewidths, resp.) on the shelves.

ometry, with the construction of Westerbork (1970) and the Cambridge 5 km telescope (1971), and the start up of the US VLBI Network (1976), the VLA (1979) and MERLIN (1980). (The dedication of the VLA took place on the day after the first EVN session.) It saw the introduction of the CLEAN algorithm [36], closure-phase in the VLBI context [37] and its incorporation into synthesis imaging [38]. Prior to 1970, synthesis imaging was the exclusive tool of the Cambridge 1 mile telescope, and model-fitting visibilities (often amplitudes only) was the norm for other interferometers; by 1980 imaging had become the expected way of presenting interferometry results.

2. EVN – The First Ten Years 1980–1990

Proposals, Observing Sessions and Telescopes: From its beginning the EVN operated an "open skies" policy, accepting proposals from any qualified scientist. It provided *absentee observing* (observatory staff making service observations in the absence of a local collaborator), following the earlier introduction of this idea in 1979 on the US Network, thus facilitating VLBI for astronomers who were not part of a large VLBI collaboration. The EVN Program Committee (EVNPC) initially comprised 5 representatives from the committed observatories (Effelsberg, Westerbork, Jodrell, Onsala and Bologna - the Medicina telescope was to start operating 4 years later - and 3 "non-VLB" members. It met 3 times each year (it has ever since) following Calls for Proposals on 1st of February, June and October. The EVNPC not only reviewed proposals but also, via its observatory members, coordinated technical and operational aspects of the observing sessions. In 1982 the Effelsberg scheduler was appointed Scheduler, to coordinate the PC Chair's plans for the sessions with the NUG schedules. (The PC Chair and Scheduler roles were completely separated from 1990 on; see [39] for the author's account of a more recent Scheduler's year).

The basic 4-telescope EVN operated at 1.4, 1.6 and 5.0 GHz (610 MHz was added in 1983), providing an array with high sensitivity, albeit moderate resolution, compared with the US Network. Other telescopes were frequently added to the array, notably Simeiz, Hartebeesthoek and the Torun-15m, organized separately by the proposers themselves. Many proposers saw the advantage of combining the EVN and the US Network for observations at their common frequencies; hence "Global" experiments were recognized if at least 2 telescopes from each network were proposed, and reviewed by both. A total of 6 single-frequency EVN sessions, each up to 1 week long, were organized in 1981, preceding or following the NUG session at that frequency; in 1982 this was reduced to 4 per year. In June 1984 a record-breaking 18 telescopes took part in 4 Global observations at 1.6 GHz [57][58], which saw the first VLBI use of one of the Cambridge 1mile telescopes and the MERLIN telescope at Defford. Simultaneous EVN+MERLIN observations, with VLBI recording at Defford and Cambridge, became a regular feature of EVN sessions from November 1988 (the new Cambridge 32m telescope replacing the 1-mile telescope after 1990). Other new telescopes built specifically for VLBI started full network operation, in particular Medicina in 1984 and Noto in 1989. Table 1 gives the dates of first fringes (or first traceable VLBI observations) at EVN and other European telescopes, and the year the corresponding institute joined the EVN Consortium.

Table 1: First VLBI Observations at EVN and other European Observatories

YEAR	DATE OF OBS.	TELESCOPE	BUILT	PARTNER TELESCOPE(S)	FREQUENCY	REFERENCES	EVN CONSORTIUM[1]
1967	Aug	ARECIBO	1963	Green Bank-140ft	610 MHz	[40]	2001 A
1968	Jan 27–Feb 3	ONSALA-26m	1964	Green Bank-140ft + Haystack	5 & 1.6 GHz	[41][42]	1984 F
1968	Jun 27–29	JODRELL MK I	1957	Algonquin + Penticton	408 MHz	[1][43]	1984 F
1969	Sep–Oct	SIMEIZ	1966	Green Bank-140ft	5 & 10.7 GHz	[2][12][44]	1985 (a) lapsed
1970	Nov 7	HARTEBEESTHOEK	1961	Island Lagoon (DSS41)	2.3 GHz	[45][46]	2001 A
1972	Nov	CHILBOLTON	1967	Algonquin	10.7 GHz	[47]	-
1973	Jun 18–21	EFFELSBERG	1971	Green Bank-140ft + DSS13	2.3 GHz	[22][48]	1984 F
1973	Nov 20	ROBLEDO-64m (DSS 63)	1973	Hartebeesthoek (DSS51)	2.3/8.4 GHz	[49]	1997 affiliate (as 70m)
1976	Oct 2	DWINGELOO	1956	Effelsberg + Onsala-26m	1.7 GHz	[23]	EVN->1983; (f) Wb [50]
1977	Sep 21–24	ONSALA-20m	1976	Green Bank-140ft + Haystack	8 GHz	[51]	1984 F
1978	Mar 31–Apr 2	WSRT-phased-array	1970	Effelsberg	1.4 GHz	[27]	1984 F
1978	May	JODRELL-MK II	1964	Onsala-26m	1.7 GHz	[52]	1984 F
1978	Nov	CAMBRIDGE-5km	1971	Effelsberg + others	5.0 GHz	[53]	-
1979	Mar	METSÄHOVI	1974	Effelsberg + others	5.0 GHz	[53]	1990 A
1980	Jun 1–2	KNOCKIN	1976	Effelsberg + Westerbork	5.0 GHz	[31]	M
1981	May 31	TORUN-15m	1976	Effelsberg	5.0 GHz	[54]	1985 (a)(f) Tr-32m
1981	Nov 12	SHANGHAI-6m	1981	Effelsberg	1.4 GHz	[55]	(f) Seshan
1983	Jul 27	WETTZELL	1983	Onsala-20m	8.4 GHz	Bonn-corr.	1985 A
1984	Mar	MEDICINA	1983	EVN	5.0 GHz	[56]	1984 F
1984	Jun 5	DEFFORD	1961	EVN	1.6 GHz	[57][58]	M
1984	Jun 5	CAMBRIDGE-1mile	1964	EVN	1.6 GHz	[57][58]	M
1984	Jun	NANÇAY	1965			[59][60]	1985 (a) lapsed
1987	June 9	SESHAN (Shanghai)	1987	Kashima + Gilcreek + Kauai	8.4 GHz	Qian Zhihan	1990 (a), 1994 F
1989	Mar	NOTO	1988	Effelsberg + Medicina	10.7 GHz	[61]	(F)
1990	May 24	MATERA	1990	Wettzell +	2.3/8.4 GHz	[62]	-
1990	Jun 25-26	YEBES-14m	1976	Effelsberg + Onsala-20m	43.0 GHz	[63]	1994 (a), 2000 (f) Ys-40m
1990	Nov 17	CAMBRIDGE-32m	1990	Jodrell-MK II	5.0 GHz	Bonn-corr.	(F)
1994	Mar 16	NANSHAN (Urumqi)	1994	Seshan + others	2.3/8.4 GHz	Qian Zhihan	1994 F
1994	Sep 14	NY-ÅLESUND	1994		2.3/8.4 GHz	[64]	-
1996	Apr 17	TORUN-32m	1995	Medicina	5.0 GHz	A. Kus et al.	1998 F
1999	Nov 16	TABLEY (Pickmere)	1980	Westerbork + VLA	1.6 GHz	[65]	M
2003	Mar 6	SVETLOE	1998	IVS	2.3/8.4 GHz	[66]	2009 F
2003		ZELENCHUKSKAYA	2000	Svetloe	2.3/8.4 GHz	M. Kharinov	2009 F
2004	Nov 4	DARNHALL	1980	EVN	6.7 GHz	[67]	M
2005		BADARY	2005	Svetloe + Zelenchukskaya	2.3/8.4 GHz	M. Kharinov	2009 F
2008	May 30	YEBES-40m	2007	EVN (data transfer via FTP)	22.0 GHz	[68]	(F)

[1] MEMBERSHIP: F = Full; A = Associate; (F) = operating institute already F; (a) = no longer A; (f) = institute now F with different telescope; M = MERLIN telescope

A successful 327 MHz VLBI experiment with the Ooty (India) telescope took place in December 1983 [69][70], involving several EVN telescopes but outside the remit of the EVNPC. However, the category of Global was expanded in 1984 to include proposals at the NUG frequencies of 22 and 10.7 GHz and 327 MHz if at least 2 EVN telescopes were available (e.g. Onsala 20m and Effelsberg at 22 GHz). The new telescope in Medicina joined observations at 10.7 and 22 GHz, and, following a surface upgrade, the Jodrell MK II telescope began participating at 22 GHz in 1986. Thus EVN operations grew into multi-frequency sessions. In 1986 the US Network also dropped to 4 sessions per year, and gradually a Global VLBI array evolved, operating 4 sessions per year at up to 3 frequencies in each. The EVN adopted 8.4 GHz and the geodetic 2.3/8.4 GHz frequency pair as standards in 1987 and 1988 respectively. By the end of the decade over 75% of EVN proposals were Global (see Fig. 4 *left*).

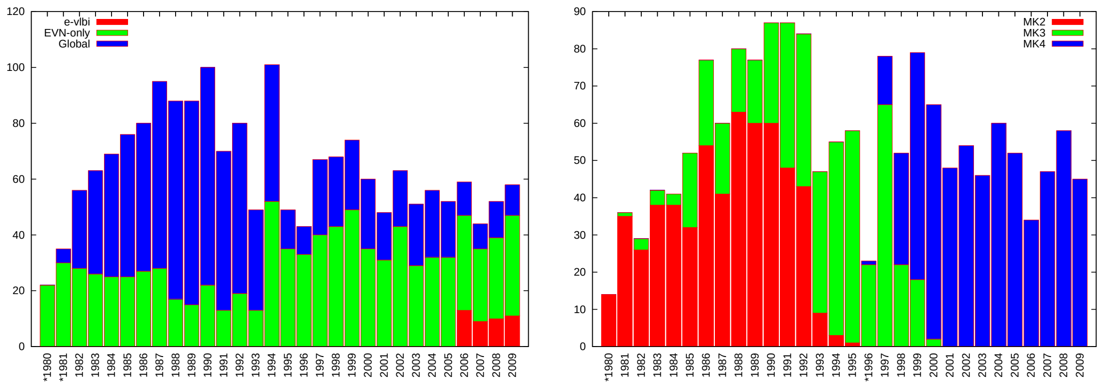

Figure 4: EVN Statistics 1980–2009: *Left:* Numbers of Proposals. (* only 2 deadlines in 1980; this number is also a lower limit. In 1981 some Globals may not be classified as such). *Right:* Recording systems used in observations, compiled from entries in the Bologna catalog of EVN observations, supplemented by the author's records. Numbers exclude *VSOP* projects observed 1997-2001. (* only 2 sessions in 1980; in 1996 observations were severely reduced due to replacement of the Effelsberg azimuth track.)

Recording and Correlating: Initially the common recording system for all EVN observatories was MK II, the 3-station Bonn correlator (Fig. 3 *right*) being the default processor for European investigators; multiple correlation passes were, of course, necessary for obtaining data from all baselines. "Absentee correlation" did not exist but assistance was given to visiting astronomers by MPI staff. However, Caltech operated a 5-station correlator ("Block 0") for continuum observations, and this was used for some experiments, especially Global projects involving US collaborators. By 1988 Caltech had finished construction of the 16-station "Block II" correlator [71]. This became the MK II correlator of choice for the increasing number of large Global continuum experiments, the Bonn correlator being reserved mainly for small, local or spectral-line projects.

The single-channel MK II recording system had only 2 MHz bandwidth and thus limited sensitivity for continuum observations. The 28-track MK III system, developed primarily for geodetic VLBI, had been introduced in 1979, and offered a dramatic improvement in bandwidth (56 MHz with 28 $\times$ 2 MHz channels), albeit with much greater costs of record terminals and tapes (see [72] for a review of VLBI instrumentation). Some early Global projects were observed using the MK III terminals at Effelsberg and Onsala, with correlation at Haystack. The situation changed with the completion of a MK III correlator in Bonn at the end of 1982, and the gradual acquisition of terminals at other EVN observatories. At this time an EVN Technical Working Group (TWG) - renamed Technical and Operations Group (TOG) in 1998 - was formed, with a first meeting in Bonn on 8-10 February 1983. The first EVN-only user projects using MK III recording took place in October 1983, with correlation in Bonn. However, the high cost (~$400) per tape and their short running time (13 mins at 56 MHz) initially prevented the use of MK III recording for all but the most worthy projects (Fig. 5). The situation was eased with the Track Density Upgrade project at the end of the decade, which provided a 12-fold increase in the number of tracks recorded on a tape. In 1990 a new MK III correlator was completed in Bonn, with double the capacity and 5 playback drives (see Fig. 7 *left*). These developments, known as "MK IIIa", resulted in a great increase in MK III observing time. By 1990 over a third of all EVN projects used MK III recording (see Fig. 4 *right*).

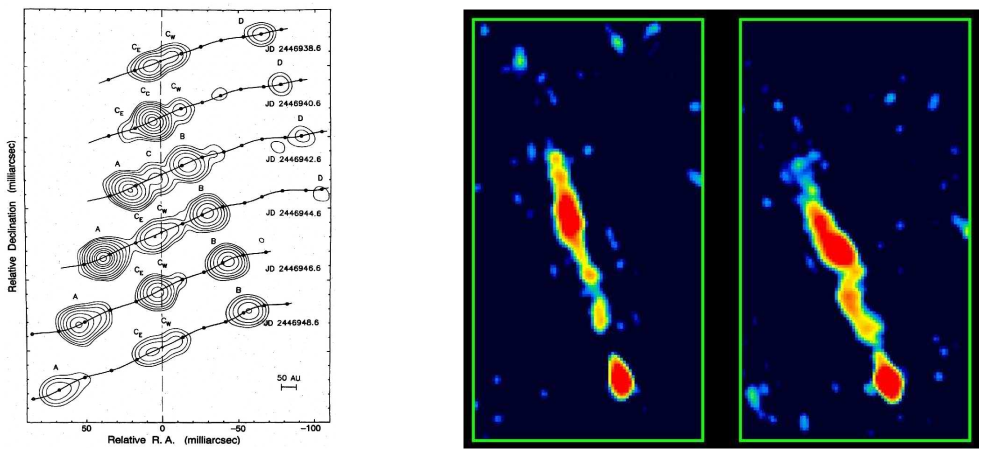

Figure 5: *Left:* EVN 5–station 5 GHz observations of SS433 [73] in May-June 1987; 6 epochs, spaced by 2 days and consuming most of the EVN MK III tape supply ! *Right:* Global 9–station 1.6 GHz observation of gravitational lens 0957+561 [74] in November 1989; image B on left, image A on right. Each panel is 60 × 120 mas. Note the opposite image parities.

The EVN Consortium and Search for European Funding: Like its US counterpart, the EVN had started as an admirable, astronomer-driven, "bottom-up" structure, with each member observatory providing manpower and equipment for the EVN operation from its own funds. Following their first meeting in 1980, the directors of the EVN institutes met annually (twice in 1983). One central theme of discussions became the funding of a large, wideband correlator with a capacity beyond that of any planned expansion of the Bonn MK III correlator, to match future growth of the EVN. In the USA similar plans had started as early as 1977 [75][76] leading eventually to the VLBA. At their meeting in Vienna on 16 June 1984 the EVN directors decided to formally establish the *Consortium of European Radio Astronomy Institutes for VLBI* which could be "referred to in approaches to outside bodies". The Consortium Agreement was signed in July 1984, and the first EVN Consortium meeting held on 12 February 1985 in Bonn (see Fig. 6). (Meetings were held subsequently twice per year.) Full Member institutes were Onsala, NFRA, MPIfR, Jodrell and IRA-Bologna (each committing at least 45 days observing per year), with Associate Membership for Torun, Simeiz, Nançay and the new geodesy telescope in Wettzell. An obvious "outside body" to approach was the European Economic Community (one of the "European Communities" (EC) and becoming the European Union (EU) in 1993). An earlier approach to *DGXII* of the EC's Commission in September 1983 had been unfruitful. In 1986 a large proposal to the EC for funding a 20-station *Advanced Data Processing Facility* was prepared, along with one for a "Twinning Grant" (submitted October 1986) for interim support. The latter was successful and was used to support an engineer in Bonn and travel associated with the MK IIIa upgrade. The main proposal proved to be too large for any identifiable EC budget – despite support from Nature editorials [77][78] – although in 1989 some money was granted to "highlight the importance and value of this project". This was used to fund development of a prototype MK III/VLBA recorder by a European company, Thorn-EMI (later Penny and Giles), and a 6th MK IIIa playback drive at the Bonn correlator with improved electronics.

Figure 6: First meeting of the EVN Consortium, Bonn, 12 February 1985. **Clockwise:** Schilizzi, van der Laan, Brouw, Seeger, Smith, Gorgolewski, Setti (Chair), Matveenko, Booth, Pauliny-Toth, Graham, Mezger, Wielebinski, Zinz, Porcas, Schwartz.

3. EVN 1991–2000

Impact of the VLBA and EVN expansion: The US Very Long Baseline Array (VLBA) came into being gradually [79]. When each new dish came on line (Pie Town was the first in 1987) it was added into US Network sessions. The first seven were equipped with MK II recorders; the resulting enlarged Global experiments could only be processed at the Block II correlator. (The Bonn MK II correlator was shut down on 15 June 1992.) This changed when, as a result of the US Transition Plan, the NSF ceased to fund VLBI at Caltech in January 1993. EVN and Global MK II operations ceased almost immediately except for a few monitoring programs; the last Global MK II project was observed in September 1994. Another casualty of the plan was the network frequency of 10.7 GHz (last Global session in 1991), as the original US Network telescopes were replaced by those of the VLBA, which had 15 GHz instead (never adopted by the EVN).

NRAO took over US Network operations from the US VLBI Consortium (as it had officially become in 1981) on 1 June 1992, and became the partner of the EVN for Global experiments. The VLBA recording system had much in common with MK IIIa, using the same basic tape transport, but employed new recording modes with wider and fewer "IF" channels. The 10 new telescopes could record some MK IIIa modes and the 20-station VLBA correlator could process them but, for operational reasons, the VLBA had to use new, double-length "thin" tapes. After the decline of MK II in 1993 the VLBA correlator was the only large correlator capable of processing Global observations with large numbers of telescopes although, with support from the German geodesy community, the original Bonn MK III correlator was revived and operated alongside the new, together with an additional 3 playback drives (10 in total including the Penny and Giles prototype). Thus EVN observatories embarked on a series of recording upgrades, the first being a modification of the MK IIIa recorders to permit use of thin tape (and hence access to the VLBA correlator). A further upgrade to MK IV (wideband channels compatible with VLBA modes and a formatter capable of recording up to 1 Gbps) was implemented by 1997, just in time for compatibility with the Japanese Space VLBI project, *VSOP*.

The loss of MK II and limited access to the VLBA correlator for MK III observations almost certainly contributed to the drop in numbers of Global proposals from 1994 on (see Fig. 4 *left*).

Remarkably, this drop was accompanied by a sharp increase in EVN-only proposals, perhaps because the EVN had expanded eastwards, with the Seshan (Shanghai) telescope joining in 1990 and Nanshan (Urumqi) in 1994. By 1996 the addition of the new Torun-32m telescope brought to 9 the number of telescopes operated by Full Member institutes, including truly intercontinental baselines. (Two more continents were added when Arecibo and Hartebeesthoek became Associate Members in 2001.) Between 1997 and 1999 a working agreement was also reached with JPL, whereby the DSN 70m dish at Robledo (and also that at Goldstone) would provide 16 h of observing time for each EVN session if recommended by the EVNPC. New frequencies were also added to the EVN repertoire, with a 43 GHz Global session together with the VLBA in February 1995 and an EVN–only 6 GHz session (for methanol and excited-OH lines) in May 1995.

The Founding of JIVE: The failure of the EC to provide the 17.8 M ECU (European currency unit, roughly 1.2 US $) to construct a large correlator resulted in a change of tactic in 1992. Stimulated by an award of 1 M ECU from the EC under its *Human Capital and Mobility* program for “Access to Large Scale Facilities”, a new EVN institute - the Joint Institute for VLBI in Europe (JIVE) - was established in Dwingeloo in 1993 (inaugurated 9th June), largely with 5.5 M ECU from the Dutch Ministry of Education and Science, but also with contributions from other sources. With its own Director and a governing Board composed of EVN observatory directors, JIVE’s main purposes were the construction and operation of a large correlator and provision of user support for the EVN. Operations costs were provided by a number of VLBI institutes (or, later, their funding agencies). Before the new correlator became operational, some funds were used to pay EVN Support Scientists, two of whom were stationed at the VLBA and Bonn correlators to oversee correlation of EVN projects; others were employed at some of the EVN telescopes. EC funds were also used to finance three “EVN Research Fellows” at EVN observatories.

The new 16-station EVN MK IV correlator at JIVE [80] was finally inaugurated on 22 October 1998 (see Fig. 7 *right*); first fringes had been obtained in July 1997 [81]. The first EVN observations destined for the EVN correlator at JIVE were observed in 1999; by 2000 it was processing all but a small fraction of EVN-only projects, and roughly half of all Global projects (shared with the VLBA correlator) shortly thereafter. The last EVN MK III project was observed in June 2000 and sent to

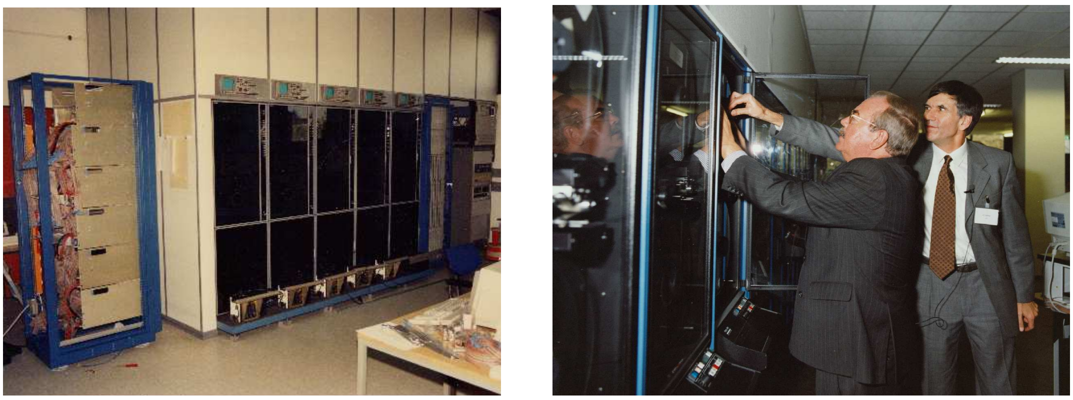

Figure 7: *Left:* Bonn MK III correlator upgrade 1990. *Right:* Inauguration of the EVN correlator at JIVE, October 1998. Mr. Relus ter Beek, the Queen’s Commissioner in the Province of Drenthe, loads a tape on one of the Penny and Giles playback drives, assisted by Richard Schilizzi, Director of JIVE.

the Bonn correlator for processing. Shortly afterwards this, too, was shut down and resurrected as a MK IV correlator, primarily for geodetic and 3 mm VLBI observations.

EVN Users Meetings, Symposia and Schools: The first EVN Users Meetings took place on the occasions of the international VLBI conferences held in Bologna in June 1983 and Manchester in July 1992. Discussions in the Consortium Meeting in April 1993 on user feedback led to the suggestion of a 1–day "EVN/JIVE Mini-Symposium and Users Meeting" to be held at Jodrell on the occasion of the next Consortium meeting in October 1993. Thus the first "EVN Symposium" was held on 22 October. The second followed on 21st October 1994 in Torun, and they have been held every 2 years since (with increasing length), accompanied by users meetings. (Proceedings for all but the first can be found at: http://www.evlbi.org/meetings/meetings.html)

The first VLBI School was organized by the EVNPC and was held in Castel S. Pietro Terme (near Bologna) from 12–23 September 1988 [82]. In September 1995 the staff of JIVE organized a 3–day VLBI School in Dwingeloo, which included both lectures and practical demonstrations of data analysis. Similar schools were held in October 1997 and November 1999. A further school was held from 17–29 September 2001, again in Castel S. Pietro Terme, reviewing VLBI "in the light of the most advanced astronomical observations" [83].

VSOP: The idea of performing VLBI together with a radio telescope orbiting the Earth is almost as old as VLBI itself [3][84]. European astronomers were heavily involved in two proposed space-VLBI projects, *QUASAT* (1982–88)[85] and *IVS* (1990)[86], but neither came to fruition. A Japanese space-VLBI project was proposed in 1987 - the *VLBI Space Observatory Programme (VSOP)*. The satellite, renamed *HALCA* following its successful launch on 12 February 1997, deployed an 8 m dish, and orbited with an apogee height of 21,000 km and a perigee height of 560 km [87]. The EVN was at the forefront in arranging committments of ground telescope time for this mission via the Global VLBI Working Group; the EVN committed 30% of its observing time to *VSOP*. The EVNPC reviewed all proposals for open-time with *VSOP*; there was a special meeting to review the first 150 proposals on 27 January 1996. (It took place in the *De Trafford Arms* in Alderley Edge since the planned venue of Jodrell Bank was snow-bound !) EVNPC ratings were communicated to the mission via its Chairman's membership of the *VSOP* Scientific Review Committee. The number of EVN sessions per year had dropped to 3 in 1993 but, to accommodate *VSOP* observations, the EVN increased this to 4 during the operational phase of the mission (1997–2001), with the functioning *VSOP* frequencies of 1.6 and 5 GHz being run in each session (22 GHz did not survive the launch). All EVN *VSOP* observations were run in MK IV recording mode "128-2-2" and correlated at the VLBA correlator.

4. EVN 2001–present

The last EVN observation with *VSOP* took place on 20 November 2001 and from that year on the number of sessions per year reverted to three, each of 21 days, with up to 3 observing frequencies. From May 2003 this was increased to 4 frequencies to decrease the time between proposal submission and observation for less-used frequencies. Welcome increases in EVN collecting area came in this decade with a resurfaced, 5 GHz-capable Lovell Telescope (2003), the completion of the new Yebes 40m telescope and the accession of the IAA St. Petersburg, increasing the availability of the three 32m telescopes of the KVAZAR geodetic VLBI network for astronomy.

Higher bit-rates, Disk Recording and e–VLBI: Despite many technical advances in the first 20 years of EVN operation, one critical parameter – the maximum recordable bit rate – had hardly changed. From 1980 MK III was regularly used to record 112 Mbps in “Mode A” (224 Mbps was possible with double tape speed but only very rarely used on the EVN); in 2001 using MK IV the EVN was still limited to 256 Mbps, and the VLBA to 128 Mbps for sustained operation. A move to higher bit-rates began by using the second record head of MK IV recorders, 512 Mbps being achieved for an EVN user observation for the first time in May 2003. However, 512 Mbps operation with tapes proved unreliable and the gradual replacement of tape drives with MK V disk recording was the key to making higher bit-rates possible. It also permitted an increase to 1024 Mbps, with a first EVN user observation in October 2004. By June 2005 all EVN observatories were using MK V, with only occasional use of tapes for projects going to the VLBA correlator. Shortly afterwards tapes were abandoned (see Fig. 8 *left*).

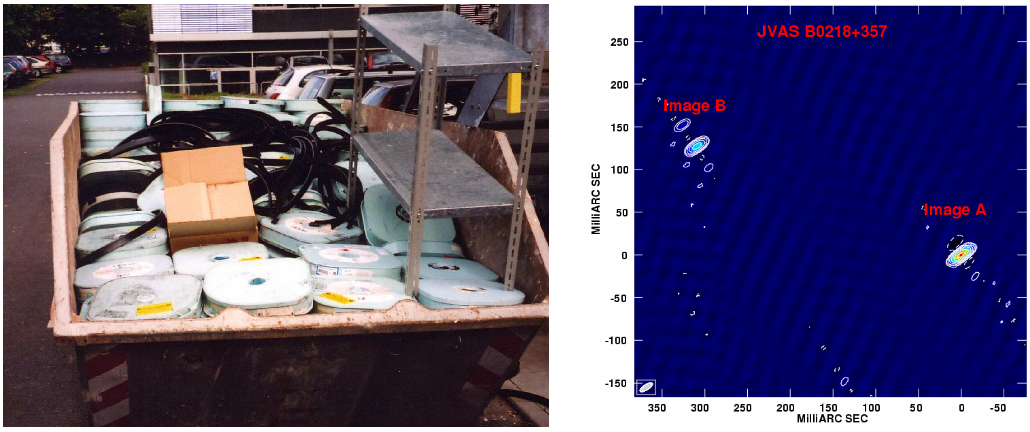

Figure 8: *Left:* Disposal of old tapes, Bonn 2008 *Right:* First EVN e-VLBI image, 28 April 2004

Another very significant development in this decade has been *e–VLBI*, the transfer of VLBI data from telescope to correlator over optical fibre links; its use for real-time correlation eliminates the need for recording. *Real-time VLBI* was first demonstrated in 1976 between Green Bank and Algonquin using the *Hermes* satellite for data transfer [88]. However, a very early European study of satellite-linked VLBI [89] in the late 1970’s, based on ESA’s *L-SAT* mission, showed it would be far too costly. The first EVN e–VLBI image, using the On, Jb and Wb telescopes and the MK IV correlator at JIVE, was obtained on 28 April 2004, at 5.0 GHz and using 32 Mbps transmission (Fig. 8 *right*). After 2 further demonstration runs [90][91], a first e–VLBI Call for Proposals was announced, with deadline 1 March 2006 and first 24-hour run on 16–17 March with 6 telescopes at 128 Mbps. There were 9 special e–VLBI deadlines, with observing runs 2 or 3 weeks later, before e–VLBI deadlines were incorporated with those for the main sessions in June 2007. By the time the Effelsberg telescope was connected in May 2008 the standard bitrate was 512 Mbps; by January 2010 this had risen to 1024 Mbps at most of the 10 telescopes taking part.

Concluding Remarks – Computers, Internet and VLBI: Today, computers, digital electronics and the internet pervade our lives so I conclude with a little nostalgia for earlier VLBI times when this was not so. Of course, VLBI would not be possible without computers but organizing and controlling observations, particular MK II, was largely done using telex and pieces of paper. Local scheduling and analysis programs grew around the correlators at Bonn, Caltech, NRAO and Haystack. Table 2 records the author's personal selection of some of the memorable steps forward.

Table 2: The Advance of Computers and the Internet in the VLBI Process

YEAR	HOW THINGS WERE DONE THEN
1978	Input parameters and output data for Bonn MK II correlator via 9-track magnetic "preptapes"
1979	Computer-readable punch cards sent through post for Green Bank 140ft MK II schedules
1980	Computer-generated schedules on floppy-disk sent through post for MK III observations
1982	EVN120 data transfer format defined by EVN software group
1983	Global fringe search algorithm introduced into AIPS [92]
1986	Simple antenna-based fringe-fitting algorithm introduced at Bonn correlators [93]
1988	MK II SCHED program re-vamped to schedule VLBA observations
1989	User-friendly PC-SCHED program available for scheduling MK III observations
1992	Machine-readable schedules deposited via FTP on central ASTBO1 server in Bologna
1993	MK3IN provides robust route from Bonn MK III correlator into AIPS
1994	First email submission of EVN proposals ("test – at own risk"), with Tex/Latex cover-sheet
2004	Web access to archive of FITS files of visibility data from EVN correlator at JIVE
2006	First EVN e–VLBI observing run
2007	First use of the NorthStar EVN web proposal submission tool

Optical fibre connections have now made realtime VLBI a reality, but for 40 years the term VLBI has been synonymous with radio interferometry using recorded signals, regardless of baseline length. What can we now say are its defining characteristics ? A definition based on the use of "independent clocks" can easily get bogged down in subtleties; are the long baselines of LOFAR VLBI ? Certainly the phase-locked Jodrell to Cambridge baseline is *not* VLBI on this definition, even if correlated at JIVE. Perhaps simply reverting to a definition where the baselines are very long is most fitting; it is, after all, the fact that they heavily resolve all the good amplitude calibration sources which is responsible for one of VLBI's most enduring and problematic characteristics.

The term "Moore's Law" is widely used to express the exponential growth of digital electronics and computing power with time. The doubling time is ill-defined but a value of 18 months gives a growth factor over 10^6 in the lifetime of the EVN. This has now made possible the development of completely digital backends, using digital down-conversion and filtering, and they will soon replace their analog equivalents at EVN telescopes, some of which date back 30 years. Computer speeds are now such that hardware correlators are being replaced with software running on computer clusters; EVN pulsar observations have recently been processed with software correlators at both Bonn and JIVE. But this is not new – the 360 kHz MK I system [10] used for the first transatlantic VLBI experiment to Onsala was also correlated in software ! What *is* curious is that VLBI imaging today is still based on algorithms developed when computers were a million times slower.

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