Opportunities with EVN

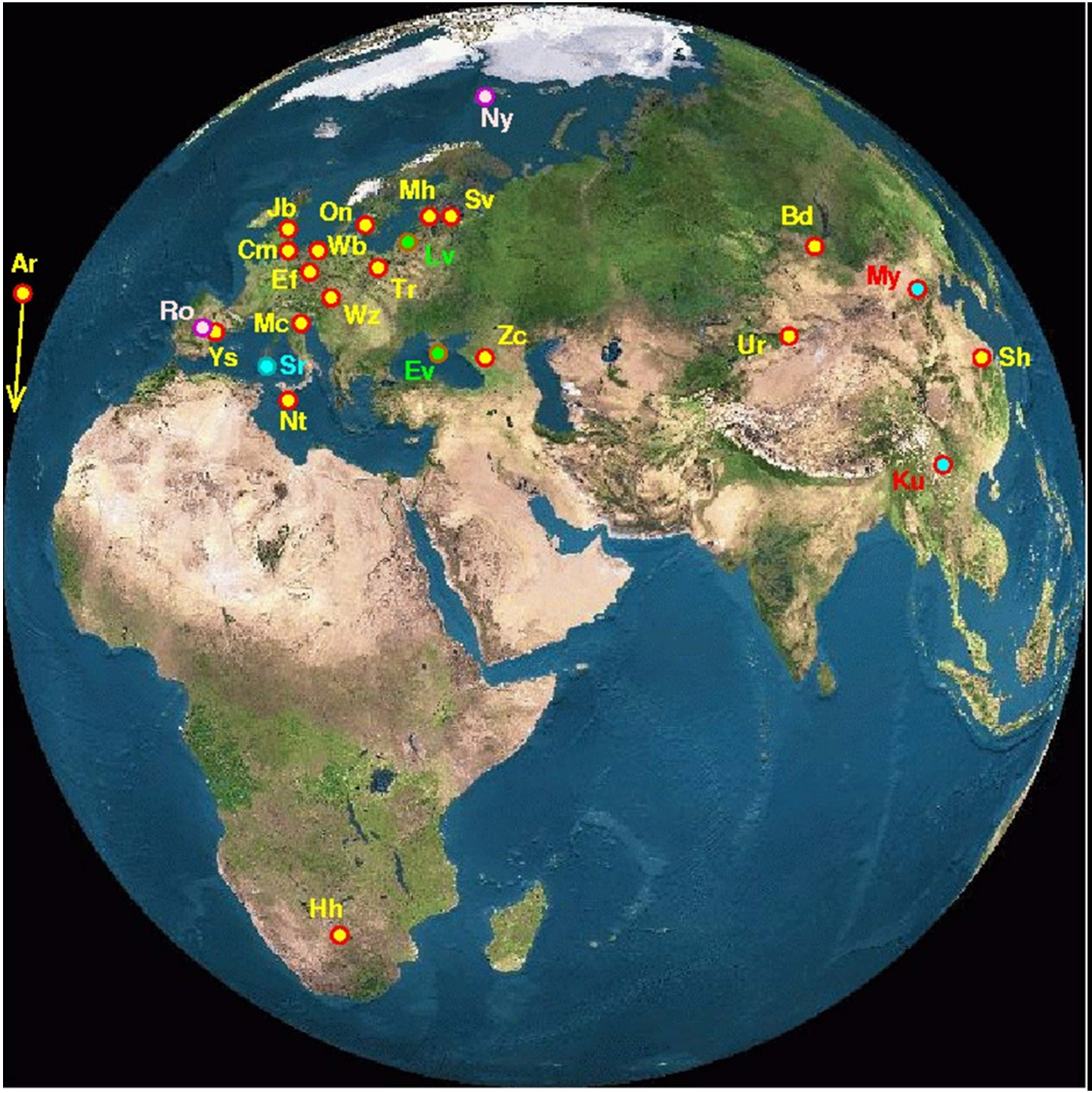
European VLBI Network

Andrzej Kus, Torun, Poland

VLBA Workshop, Charlottesville 27.01.2011

EUROPEAN VLBI NETWORK

http://www.evlbi.org



Yellow/Red: current operational EVN stations (18)

Cyan/Red: existing telescopes soon to be EVN stations (2)

Cyan/Blue: new EVN stations under construction (1)

Pink/Purple: non-EVN stations that have participated in EVN observations (2)

Green/Brown: non-EVN stations with whom initial EVN tests have been carried out (2)

Formation of the EVN (EVN Consortium)

The European VLBI Network (EVN) was formed in **1980** by five of the major radio astronomy institutes in Europe and Geodetic Dept of the University of Bonn. The founding radio astronomy institutes in red:

EVN institutes and stations :

MPIfR Effelsberg (Germany)
IRA Medicina (Italy)
Noto (Italy)
Robledo/DSN (Spain)
Torun (Poland)
ASTRON Westerbork (Netherlands)
OAN-Yebes (Spain)
Arecibo (Puerto Rico, USA)

Jodrell Bank & Cambridge (UK)
Metsähovi (Finland)
OSO Onsala (Sweden)
Shanghai (China)
Urumqi (China)
Wettzell (Germany)
Hartebeesthoek (South Africa)
IAA (Russia)

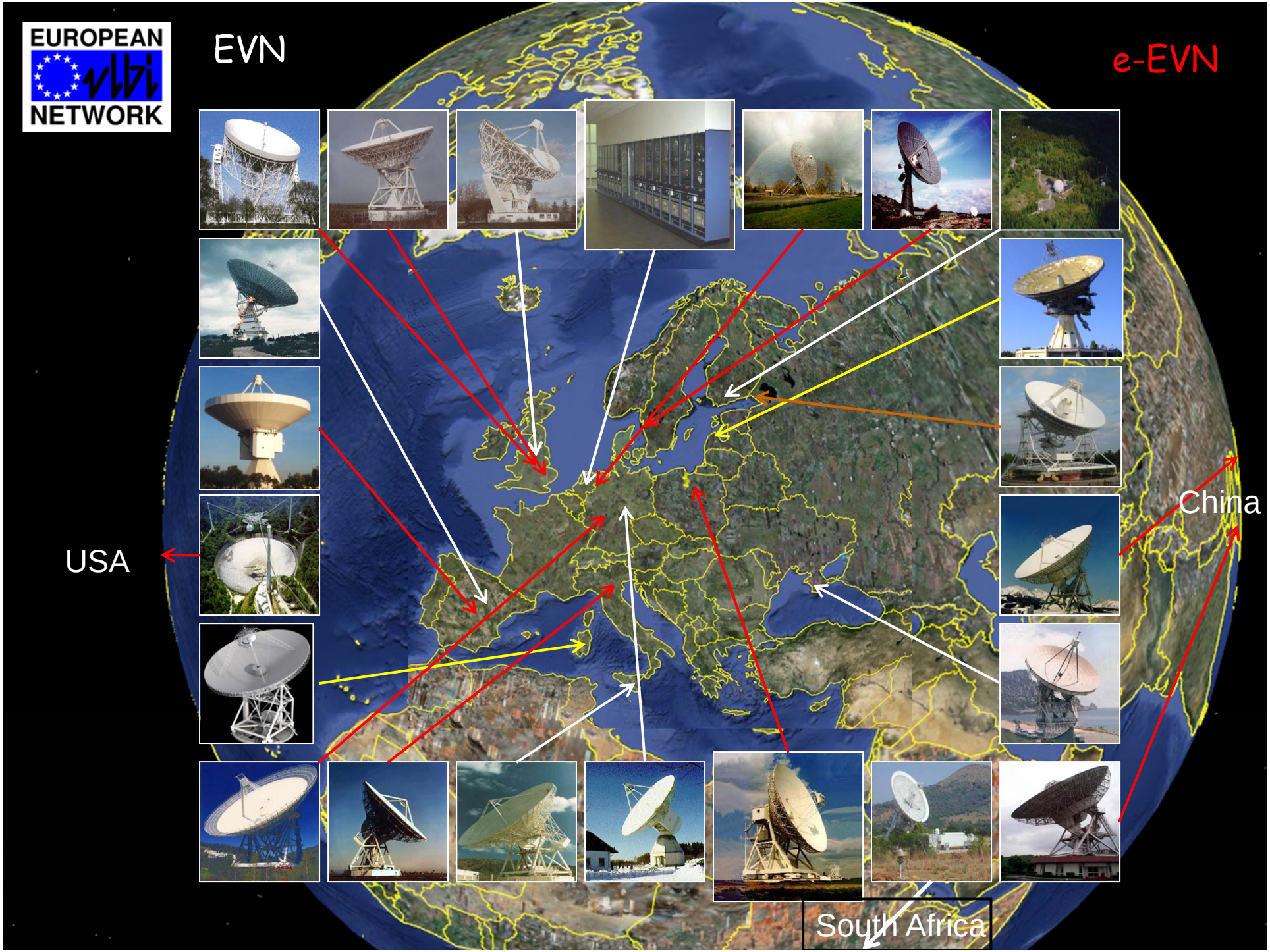
12 countries, 18 telescopes

Correlators for EVN observations

JIVE, Dwingeloo (Netherlands), MPIfR (Germany), NRAO (USA)

EVN Officers

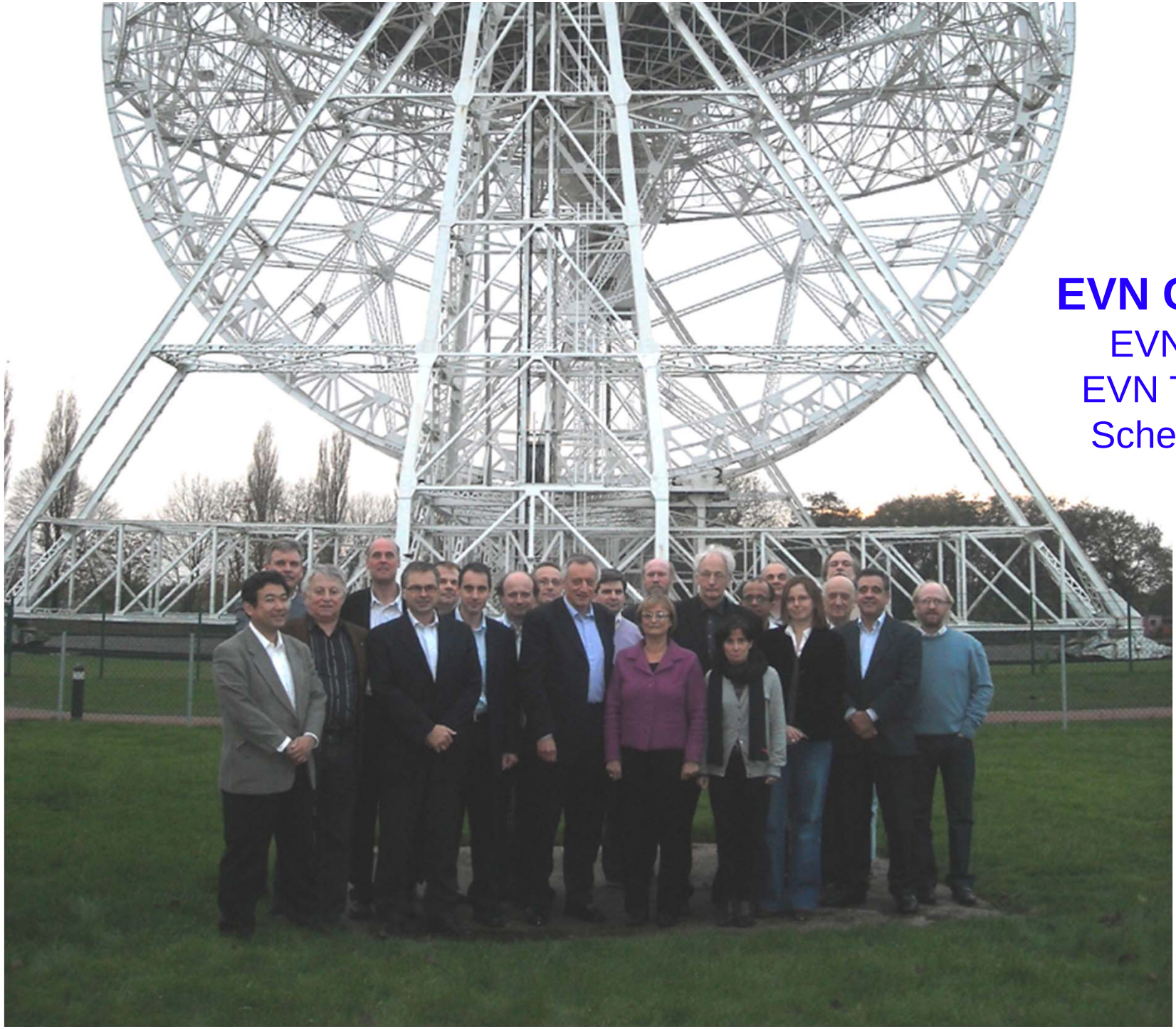
EVN Consortium Secretary:	Magdalena Kunert-Bajraszewska (tcfa)
EVN PC Chair:	Tiziana Venturi (t.venturi@ira.inaf.it)
EVN Scheduler:	Richard Porcas (porcas@mpifr-bonn.mpg.de)
EVN TOG Chair:	Walter Alef (alef@mpifr-bonn.mpg.de)


EUROPEAN
NETWORK
EVN
e-EVN
USA
China
South Africa

e-MERLIN

The key element of EVN

~ 50% EVN proposals request MERLIN



EVN CBD

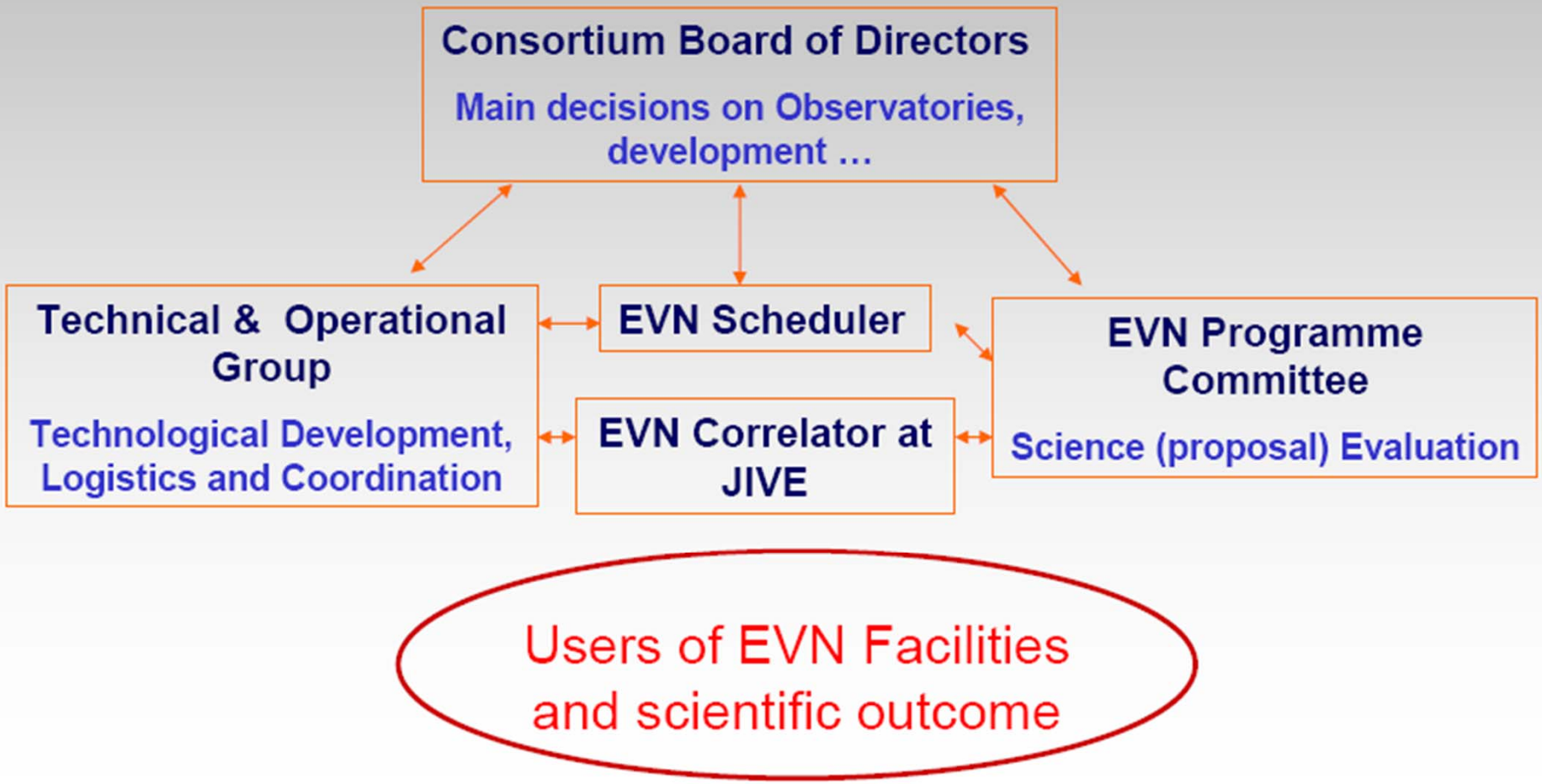
EVN PC

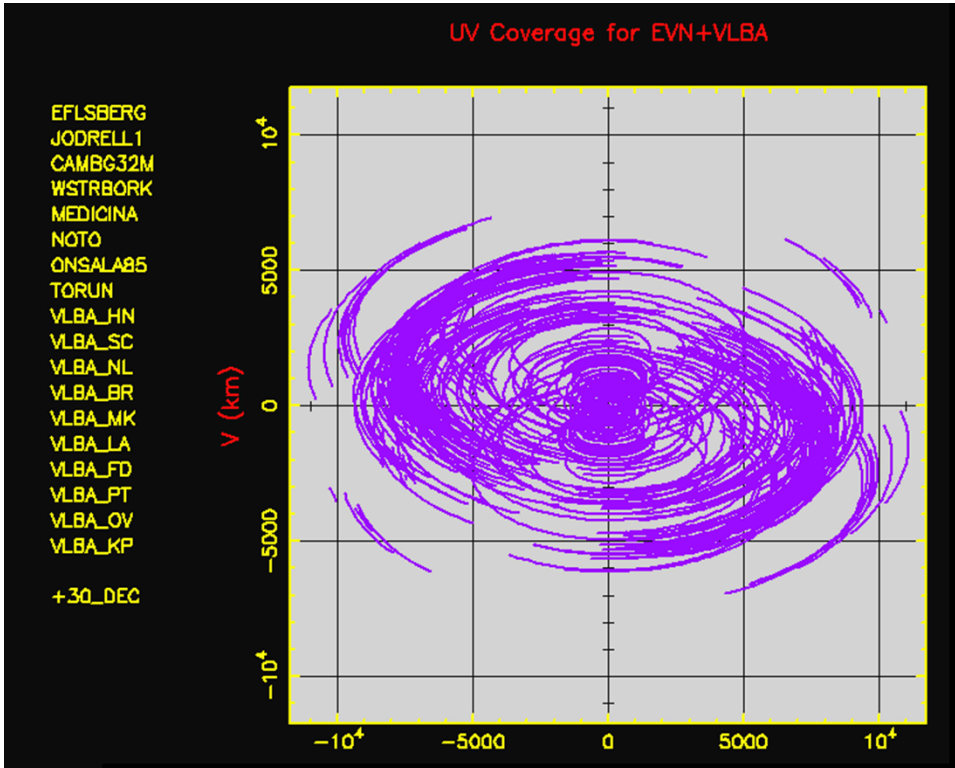
EVN TOG

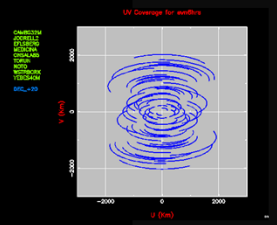
Scheduler

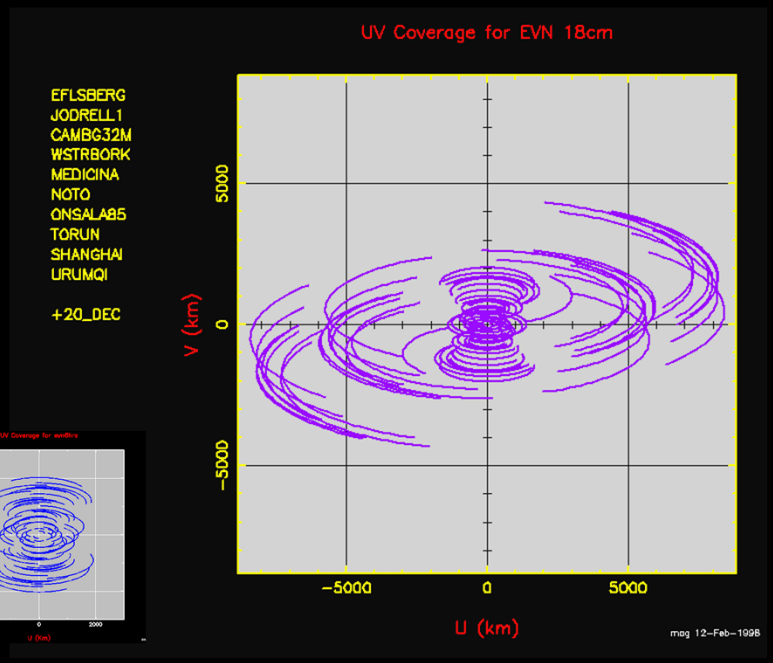
EVN Structure and Bodies

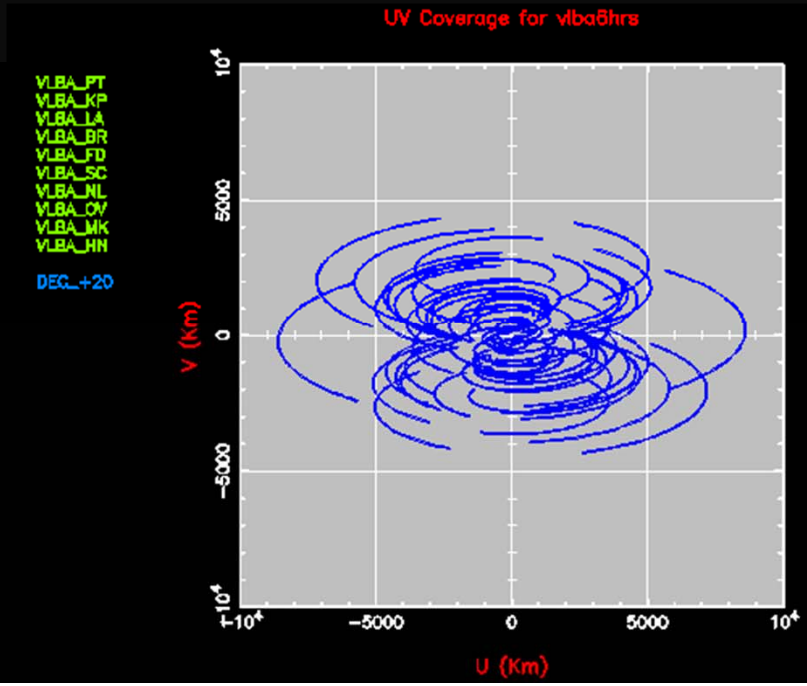
Consortium of individual Institutes and Observatories which share an overlapping plan of development and telescope observing time




UV Coverage for EVN+VLBA
EFLSBERG
JODRELL1
CAMBG32M
WSTRBORK
MEDICINA
NOTO
ONSALA85
TORUN
VLBA_HN
VLBA_SC
VLBA_NL
VLBA_BR
VLBA_MK
VLBA_LA
VLBA_FD
VLBA_PT
VLBA_OV
VLBA_KP
+30_DEC
V (km)
U (km)




UV Coverage for EVN 18cm
EFLSBERG
JODRELL1
CAMBG32M
WSTRBORK
MEDICINA
NOTO
ONSALA85
TORUN
SHANGHAI
URUMQI
+20_DEC
V (km)
U (km)


UV Coverage for vlba8hrs
VLBA_PT
VLBA_KP
VLBA_LA
VLBA_BR
VLBA_FD
VLBA_SC
VLBA_NL
VLBA_OV
VLBA_MK
VLBA_HN
DEC_+20
V (km)
U (Km)

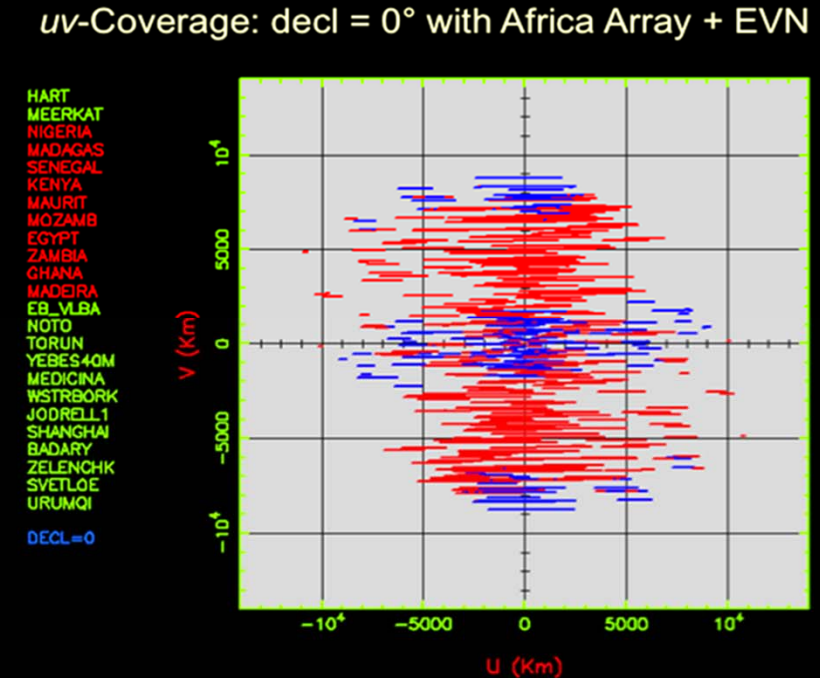

uv-Coverage: decl = 0° with Africa Array + EVN
HART
MEERKAT
NIGERIA
MADAGAS
SENEGAL
KENYA
MAURIT
MOZAMB
EGYPT
ZAMBIA
GHANA
MADEIRA
EB_VLBA
NOTO
TORUN
YEBES40M
MEDICINA
WSTRBORK
JODRELL1
SHANGHAI
BADARY
ZELENCHK
SVETLOE
URUMQI
DECL=0
V (Km)
U (Km)

TABLE I OBSERVATORIES, TELESCOPES AND AVAILABILITY

EVN OBSERVATORIES	TELESCOPE Code	Diameter(m)	AVAILABILITY (see also TABLE II)
Jodrell Bank (UK)	Jb-1 Lovell	76	Wavelengths >=6cm
	Jb-2 Mk2	25	Wavelengths < 18 cm
Cambridge (UK)	Cm	32	For EVN+MERLIN only - see(a)
Westerbork (NL)	Wb Array	Nx25	See note (b)
Effelsberg (D)	Eb/Ef	100	
Medicina (I)	Mc	32	
Noto (I)	Nt	32	
Onsala (S)	On-85	25	Wavelengths >= 5 cm
	On-60	20	Wavelengths < 5 cm, + 13 cm
Sheshan(Shanghai,CH)	Sh	25	
Nanshan(Urumqi,CH)	Ur	25	
Torun (PL)	Tr	32	
Metsaehovi (FI)	Mh	14	Wav. 1.3, 0.7 cm. 13,3.6
Yebes (E)	Ys	40	Wavel. 1.3, 3.6, 5, 13cm (e)
Arecibo (USA)	Ar	305	see note (c)
Hartebeesthoek (SA)	Hh	26	
Wettzell (D)	Wz	20	Limited; 13, 3.6 cm only
Svetloe	Sv	32	
Zelenchukskaya	Zc	32	
Badary	Bd	32	

OTHER OBSERVATORIES

Miyun	My		50	Limited; 13, 3.6, 30cm only
Kunming	Km		40	Limited; 13, 3.6cm only
Robledo (Madrid, E)	Rob70	DSS-63	70	Limited;
	Rob34	DSS-65	34	Limited; 13, 3.6 cm only
		DSS-54	34	Limited; 7mm only
Matera (I)	Ma		20	see note (d)
Ny-Alesund (NO)	Ny		20	see note (d)

TABLE III FREQUENCY (RECEIVER) AGILITY

SITE	SWITCH TIME	SCHED CONTR	WAVELENGTHS	COMMENTS
Eb	40s	yes	13, 6, 3.6, 2, 1.3, 0.7	sec. focus / high
Ef	40s	yes	2, 1.3, 0.7	single-box rx / lo
Eb	40s	yes	18,21	single rx; I.F. le
Ef	40s	yes	18,21	single rx; I.F. le
Wb	300s	no	92,49,30,21,18,13,6,3.6	prime focus
Mc	70s	yes	18/21, 13, 3.6, 1.3	prime focus
Mc	240s	yes	18/21, 13, 3.6, 1.3<=> 6	prime <=> secondar
Nt	70s	no	18, 13, 3.6, 1.3	
On85	0s	yes	18, 21	Changes in PRC fil
On85	0s	yes	6,5	Changes in PRC fil
On60	600s	no	1.3, 0.7, 0.3	
On60	60min	no	3.6/13 to <1.3	
Tr	30s	yes	18, 6, 5	SCHED switch betwe
Cm	180s	yes	18/21, 6, 1.3	Changes in PRC fil
Hh	30s	yes	13, 6, 5, 3.6	Manual IF-VC cabli
Sh	5min	no	13/3.6, 6, 1.3	
Ur	50min	no	1.3,3.6/13,6,18/21,30,49,92	no automatic cha
Ro70	300s	yes	Any band to 18	ifadjust
Ro70	300s	yes	Any band to 1.3	ifadjust
Ys				Pending new info

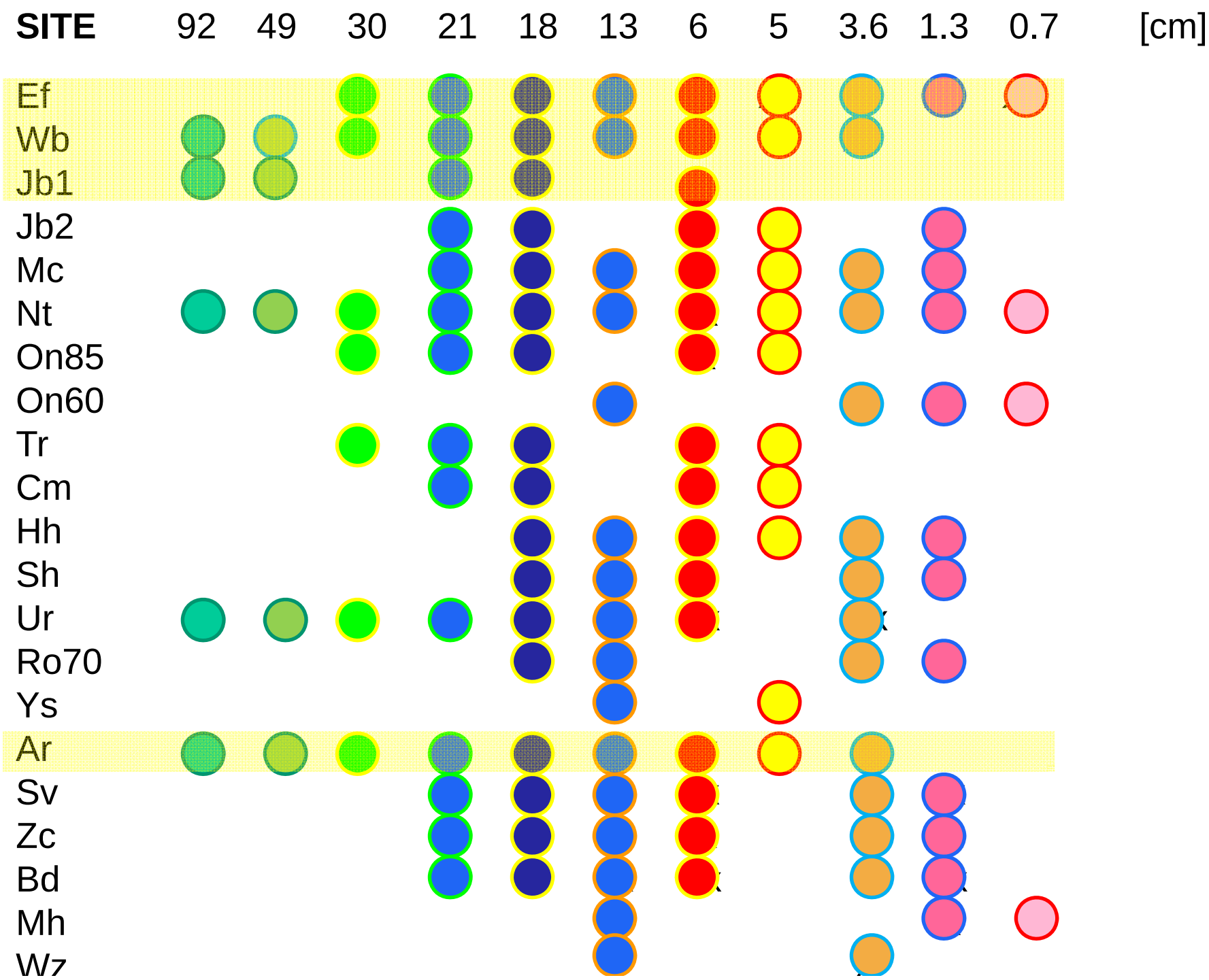
(#) TABLE IIIA 21/18cm FREQUENCY RANGE + AGILITY

SITE	SCHED CONTR	LOCAL CMDS	Frequency range	COMMENTS
Eb/Ef	yes	no*	1290-1430, 1590-1725	New system (2009)
Jb1/2	yes	yes*	1370-1430, 1550-1730	30s switch time
Cm	yes	yes	1370-1430, 1550-1730	30s switch time
Wb	no	yes	1150 - 1800	rephase after agility(5Min)
Mc	yes	yes	1350-1450, 1595-1715	21 and 18:different ptg model
Nt	yes	no	1400 - 1705	Continuous band (no delay)
On85	yes	yes*	1200-1450, 1594-1720	Changes in PRC file
Tr	yes	no	1350 - 1750	
Ur	yes	no*	1400 - 1735	mixed patch:VC1-4low,5-8hi
Ar	?	?	1150 - 1730	
Hh	-		1580-1750	
Sh	-		1600-1740	
Sv	-	-	1380 - 1720	
Zc	-	-	1380 - 1720	
Bd	-	-	1380 - 1720	

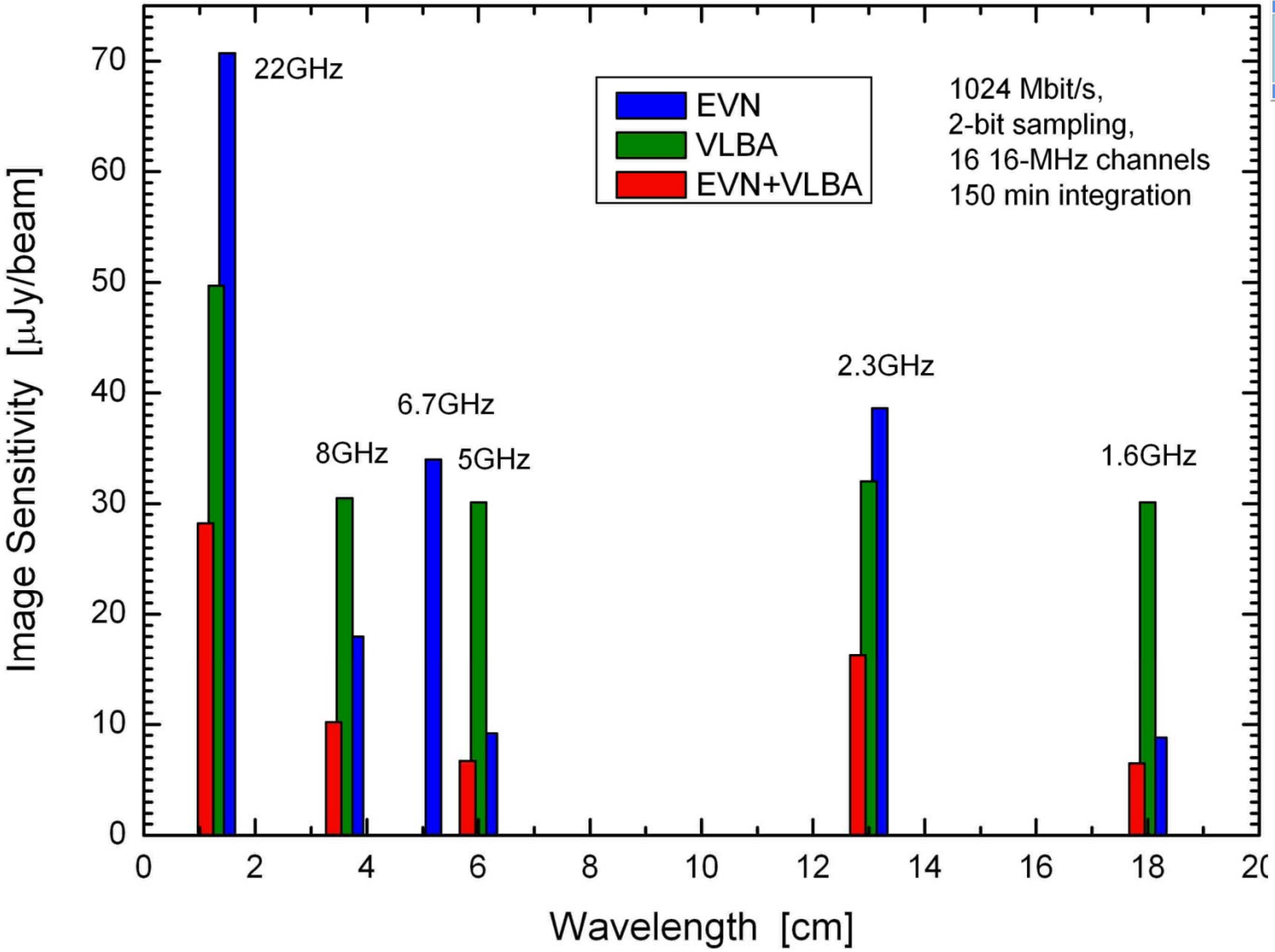
more telescopes/Institutes aspire (China, Ukraine, Japan, ...)

TABLE II ANTENNA+RECEIVER PERFORMANCE (SEFD = system noise in Jy)

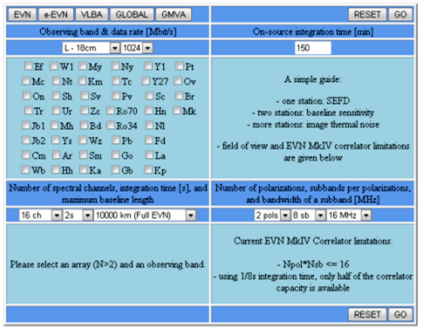
Wavel'th	92	49	30 %	21 #	18	13*	6	5 (g)	3.6*	1.3	0.7 cm
Jb-1 (e)	132	83		36=	44=		35				
Jb-2 (d)				350=	320=		320	300		910	
Cm (a)				220=	212=		136	410		720	
Wb (b)	150	90	120	30=	30=	60y	60	1600	120		
Eb/Ef			65	20=	19=	300r	20	25	20	90	200
Mc				490=	600=	400	170	840	320	700+	
Nt	980s	yes	1025	820=	784=	770r	260	1100	770r	800	900
On-85			900	320=	320=		600	1500			
On-60						1110r		(09)?	1000j	1380j	1310j
Sh					670	800r	720		800r	1700	
Ur	3020s	(f)	2400L	350=	270=	680r	200		480r	(f)	
Tr			2000	250=	230=		220	400		(08)	
Mh !						4500r			3200r	2608	4500
Ys (h)						yes	(09)	484	200	200	
Ar	12	12	3	3.5	3	3	5	5	6		
Wz						1250r			750r		
Hh					450	380	795	680	940	3000	
Sv				240	240	330	140		200	710	
Zc				240	240	330	140		200	710	
Bd				240	240	330	140		200	710	
My	(09)	(09)				(09)r			(09)r		
Km						350r			480r		
Rob70					35L	20-			18	83	
Rob34						150			106-		y
Ny						850r			1255r		


SITE
92
49
30
21
18
13
6
5
3.6
1.3
0.7
[cm]
Ef
Wb
Jb1
Jb2
Mc
Nt
On85
On60
Tr
Cm
Hh
Sh
Ur
Ro70
Ys
Ar
Sv
Zc
Bd
Mh
Wz

EVN + VLBA network sensitivity



EVN Calculator



256 MHz BW

Current Status

18 radio telescopes – not all available at all frequencies

(e)MERLIN joins at a number of observing frequencies

6 standard bands + 5 non standard

Continuum and spectral line observing

Disk Recording rate up to 1 Gbps EVN correlator at JIVE

Standard bands

Waveband	Default central frequency
18 cm	1664 MHz
13 cm	2268 MHz
6 cm	4992 MHz
5 cm	6668 MHz (Methanol), 6030 MHz (OH)
4 cm	8418 MHz
1 cm	22230 MHz

Non standard bands

Waveband	Default Central Frequency
90 cm	327 MHz
50 cm	610 MHz
21 cm	1416 MHz
2 cm	15362 MHz
7 mm	43214 MHz

Angular resolutions in milliarcsec

Array	90 cm	18cm	6cm	3.6 cm	1.3 cm	0.7cm
EVN	-	15	5	3	1	0.6
EVN (inc. Sh/Ur)	30	5	1.5	1	0.3	0.15
EVN+VLBA	19	3	1	0.7	0.25	0.13

Image sensitivity in μJy/b for 128 Mbps (Δv = 64 MHz) and 8 hr on source

Array	18cm	6cm	5cm	3.6 cm	1.3 cm
EVN Array (*)	28	35	148	96	238
+Ro-63	22	-	-	48	148

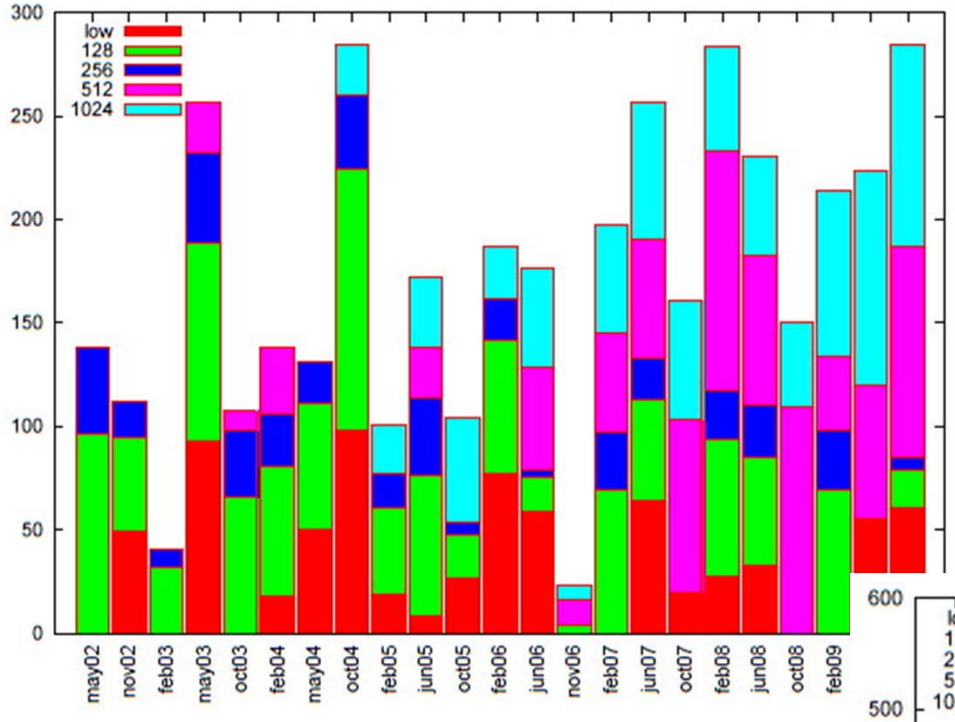


Figure 2: Total number of hours recorded for user observations in each ses

Total number of hours recorded
for user observations
in each session 2002-2009

Total number of bits recorded
for user observations
in each session 2002-2009

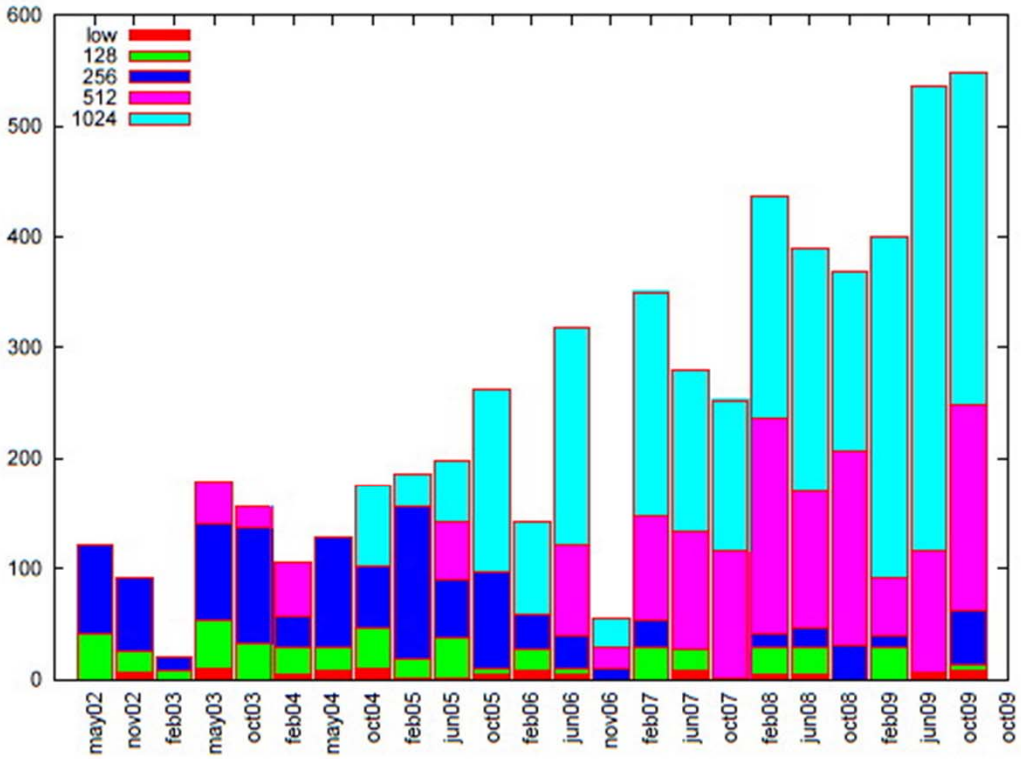
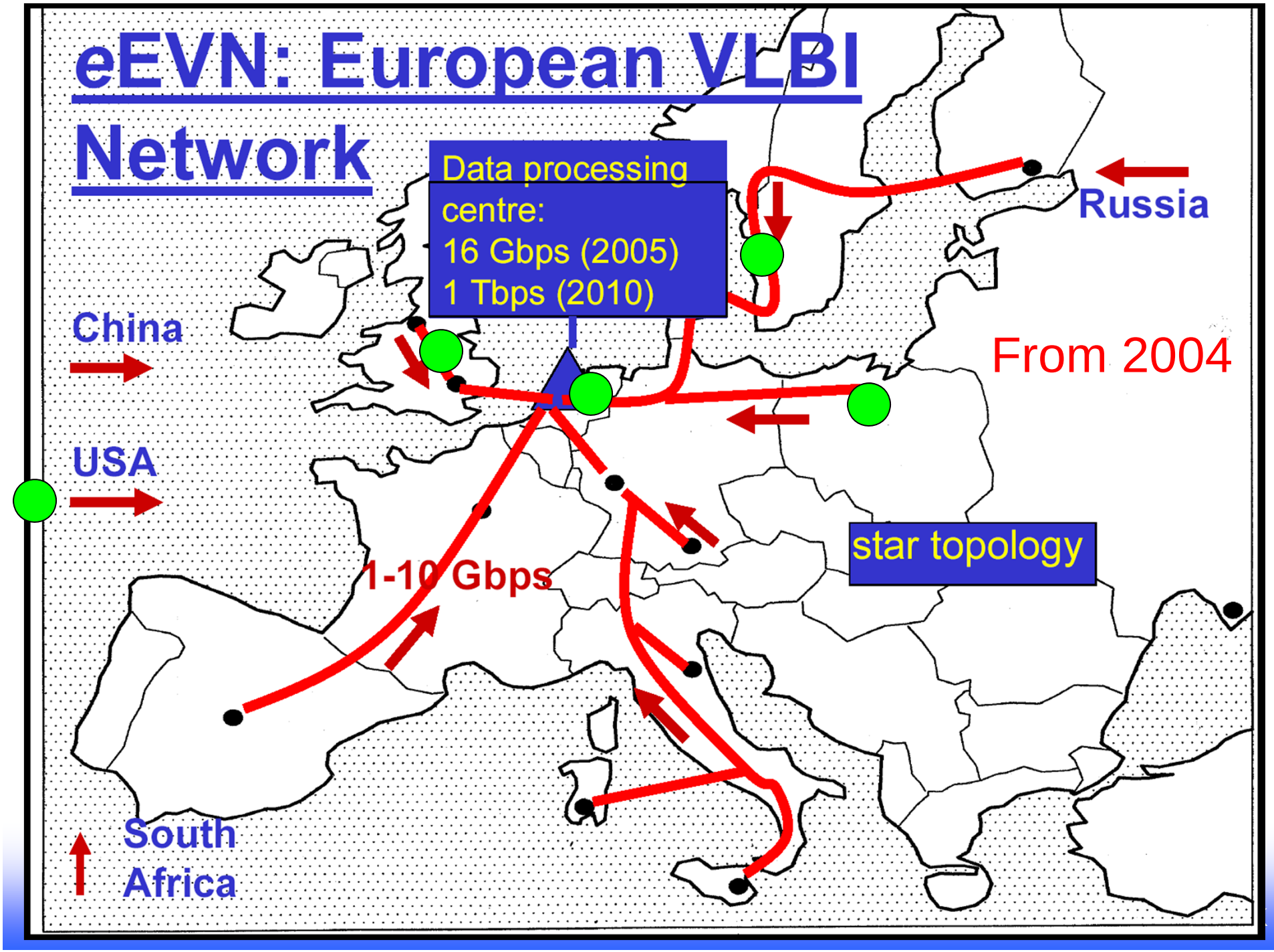


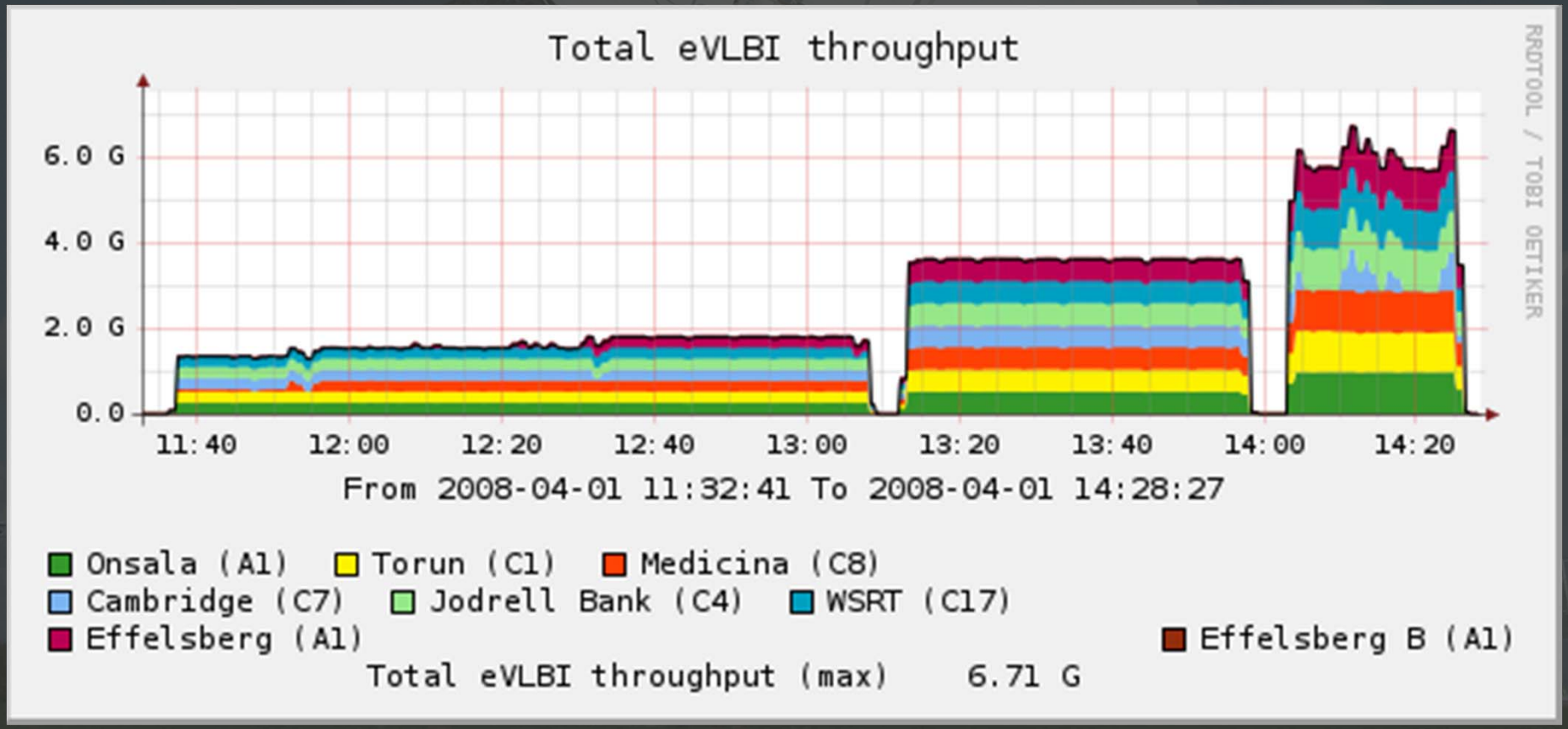
Figure 3: Total number of bits (TB) recorded for user observations in each session

By Richard Porcas


eEVN: European VLBI Network
Data processing centre:
16 Gbps (2005)
1 Tbps (2010)
Russia
China
From 2004
USA
star topology
1-10 Gbps
South Africa

e-EVN since 2004

(here Apr. 2008 performance)



MIĘDZYNARODOWY ROK ASTRONOMII 2009

Public outreach at the EVN observatories

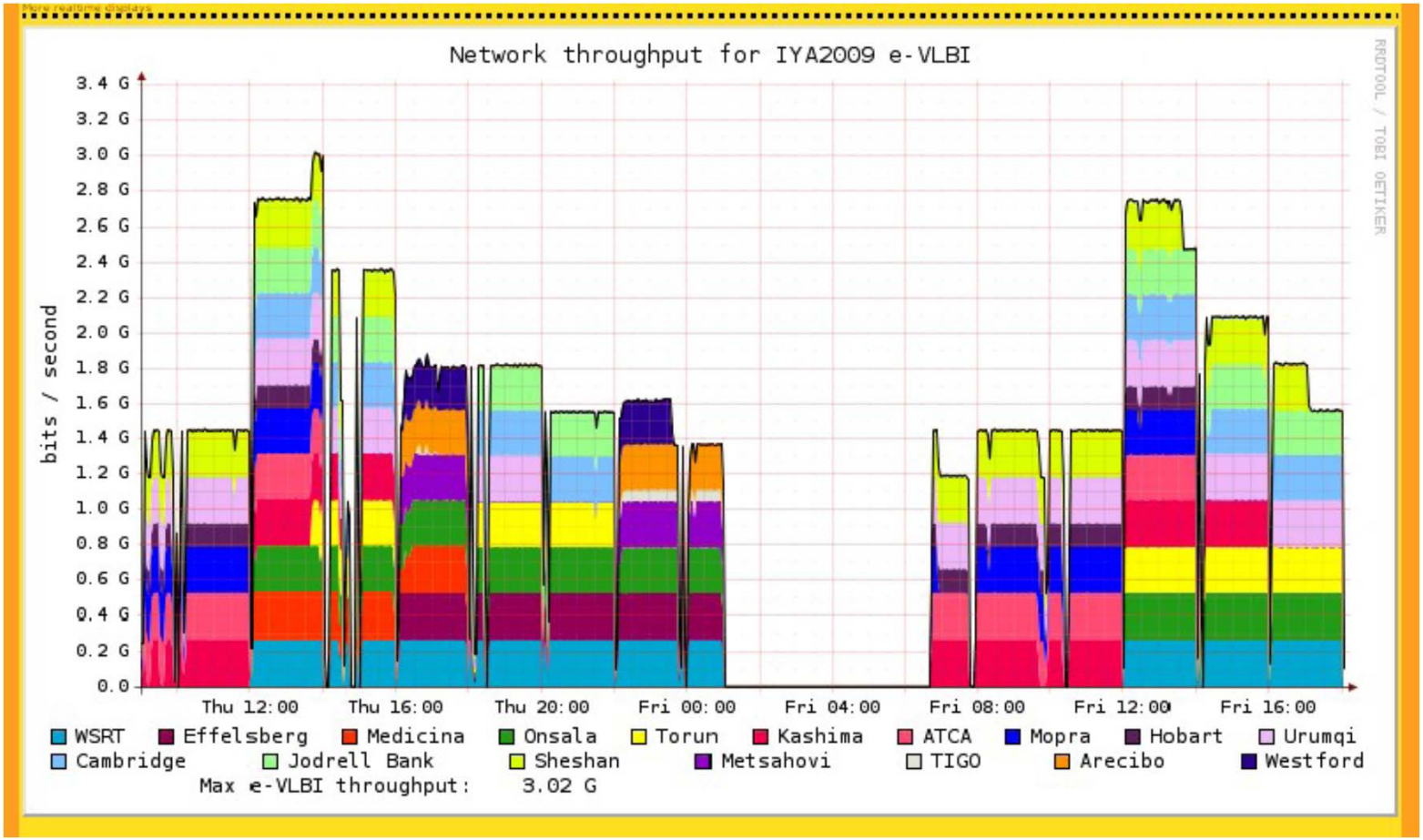
ODKRYJ WSZECHŚWIAT W TORUNIU

POLAND NATIONAL NODE

e-vlbi

15-16 January 2009

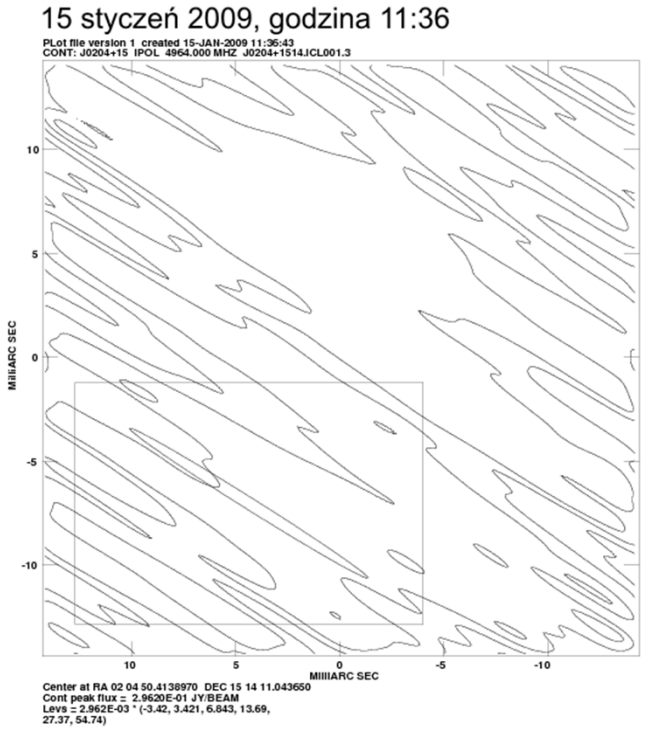
Inauguration of International Year of Astronomy

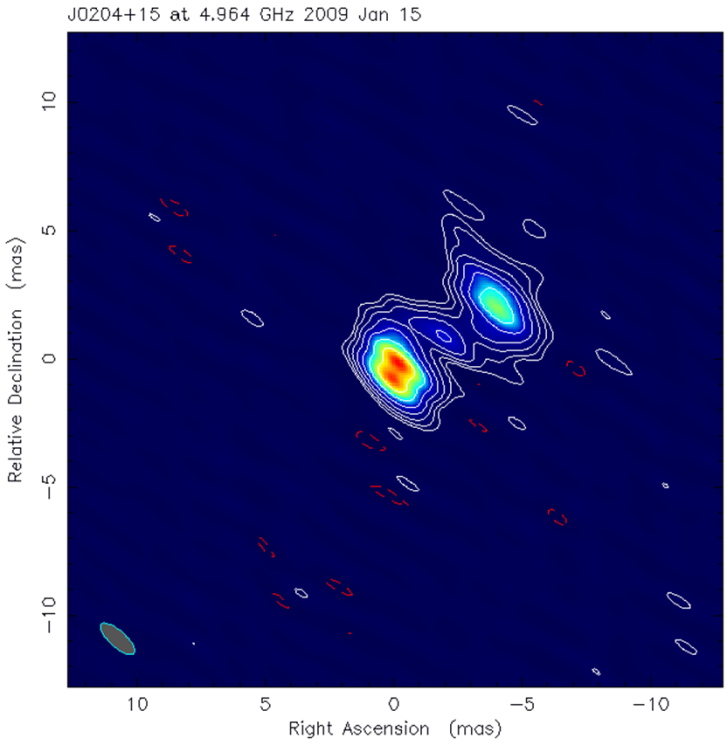


e-vlbi

15-16 January 2009

IYA





The EVN sites operating in e-EVN mode

e-EVN the SKA Pathfinder

The programme funded by the participating institutes and external sources,
EC FP6/FP7 projects **EXPReS** (2006-2009) and **NEXPReS** (2010-2013).
The development of user software supported through the
FP6 and FP7 **RadioNet** (JRA ALBUS and ALBBiUS).
Development of correlator software EXPReS (JRA FABRIC),
Development of the UniBoard is also funded by FP7 RadioNet as JRA.

e-EVN stations remotely controlled by JIVE :

WSRT, JBO, Cambridge, OSO, Torun,
Medicina, Arecibo, Yebes, Effelsberg,
Shanghai, Urumqi, KVAZAR,
Hartebeesthoek,

e-EVN sessions 2 days / month

e-EVN status table

Advertised frequencies and array configurations

Frequency band	e-EVN array
1.6-1.4 GHz (18-21cm)	Ar, Cm, Ef, Hh, Jb, Mc, On85, Sh (1.6 GHz), Tr, Wb14
5 GHz (6cm)	Ar, Cm, Ef, Hh, Jb, Mc, On85, Sh, Tr, Ys, Wb14
6 GHz (5cm)	Ar, Cm, Ef, Hh, Jb, Mc, On85, Tr, Ys, Wb1
22 GHz (1.3cm)	Cm, Ef, Hh, Jb, Mc, Mh, On60, Sh, Ys

The expected aggregate bitrate is 1024 Mbps with the following limitations. Arecibo is limited to 512 Mbps, and further limited to 256 Mbps outside UT range 4-10. Shanghai is temporarily limited to 256 Mbps. Medicina and Yebes are limited to 896 Mbps; in the 1024 Mbps mode (usually) the highest subbands are dropped. The effective data rate to the MERLIN telescopes (except for Jb1/Jb2) is 128 Mbps due to analog bandwidth restrictions. Availability of MERLIN outstations and Jb2 will be limited in 2010/2011 due to the e-MERLIN upgrade. Hartebeesthoek is now available for e-VLBI science and it will operate at full 1024 Mbps starting from the 23 November 2010 e-EVN run.

Upcoming e-EVN runs

23 November 2010, 13:00 UTC	17:10 GST	24 November 2010, 13:00 UTC	17:14 GST
15 December 2010, 13:00 UTC	18:36 GST	16 December 2010, 13:00 UTC	18:40 GST
25 January 2011, 13:00 UTC	21:18 GST	26 January 2011, 13:00 UTC	21:22 GST
15 February 2010, 13:00 UTC	22:41 GST	16 February 2010, 13:00 UTC	22:45 GST
22 March 2011*, 13:00			

Current operation - numbers of proposals

~ 20 proposals received every call (3/year) (70% success rate)

21/18	6	5	3.6	1.3	cm	wavelength
50%	20%	10%	10%	10%		(2008-2010)

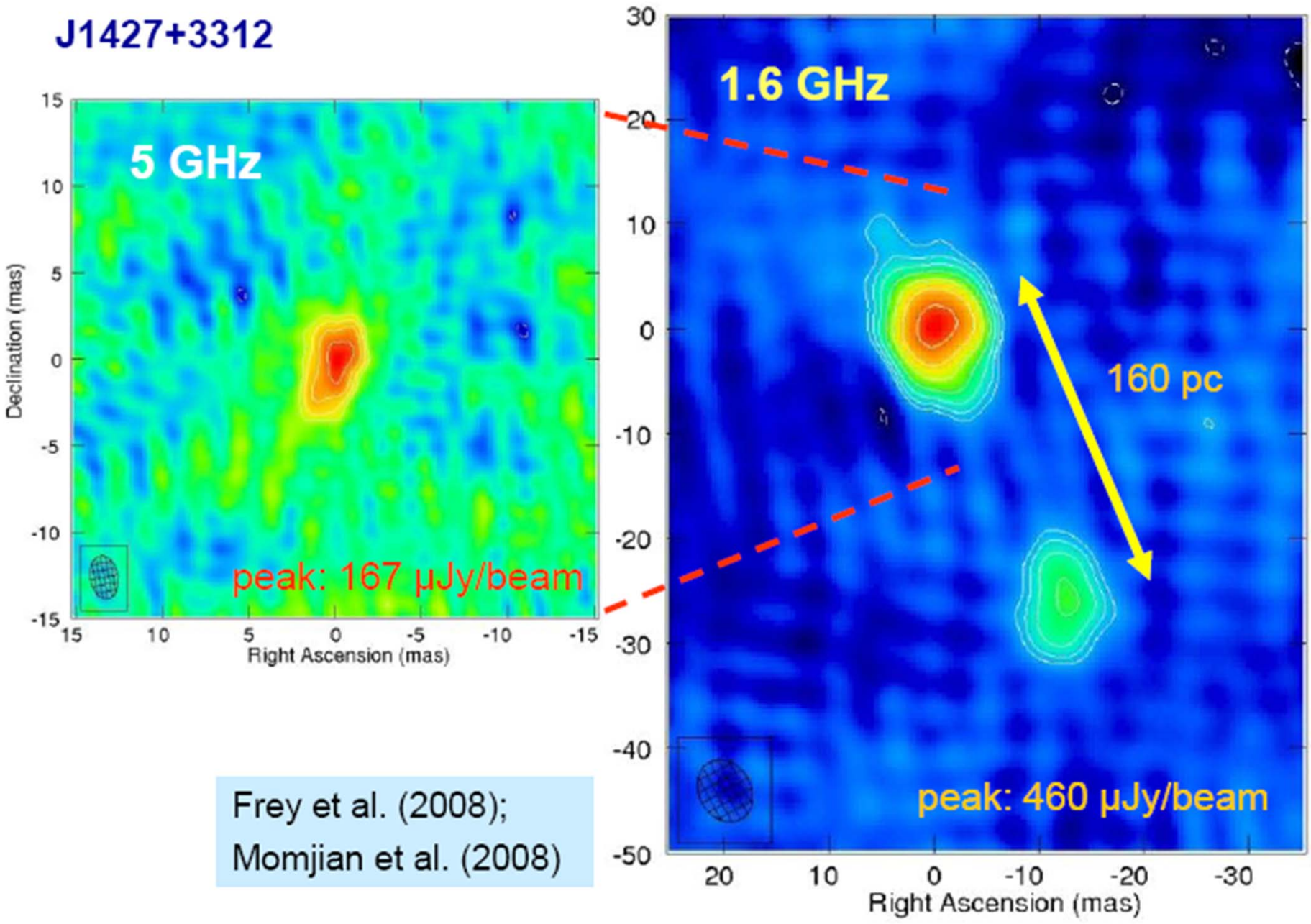
95% EVN (~50 % MERLIN) 5% global

High z QSO	~40%	AGNs , Galaxies	~30%
Masers	~20%	Stellar	~5%
Others	~5%		

ToO ~8 proposals / year other (short obs. Requests) ~4/y

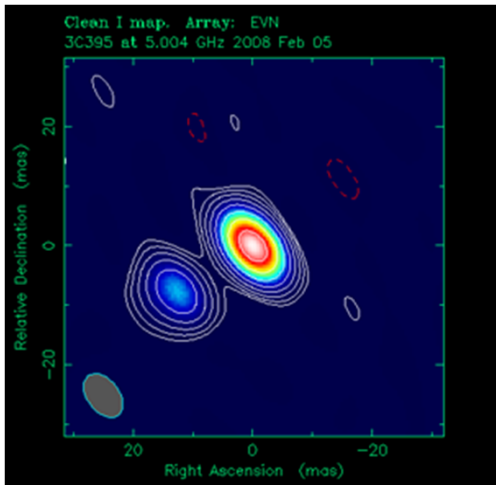
-TeV flare in M87
- Gamma-ray Nova V407 Cyg
- Cyg-X transition state
- X-ray transient J1659-152

- high z dusty quasars
- ultra steep spectrum RG



Frey et al. (2008);
Momjian et al. (2008)

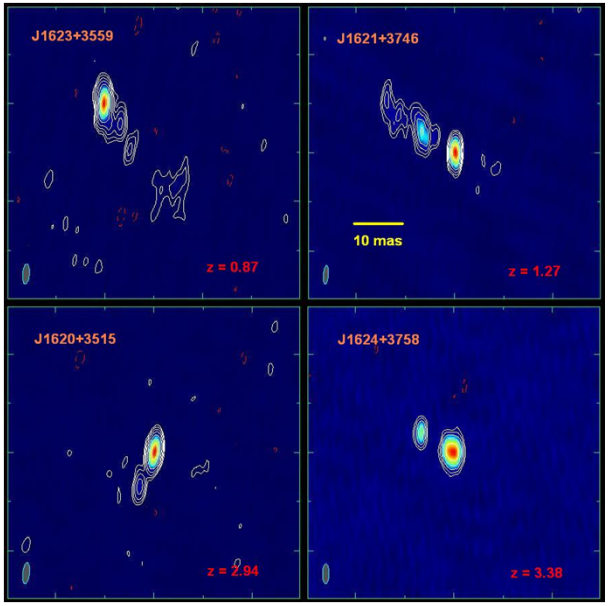
Some of EVN and Global VLBI results and images



EVN Image Gallery

and

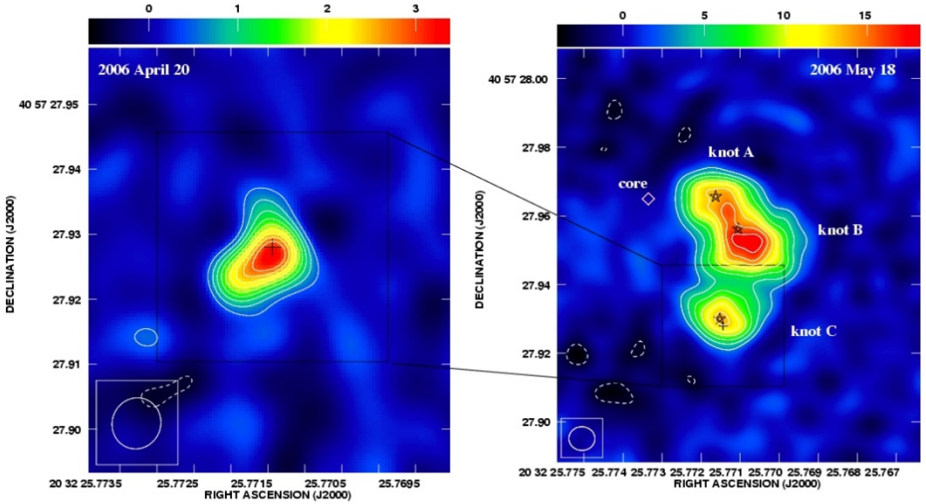
Bienial Reports



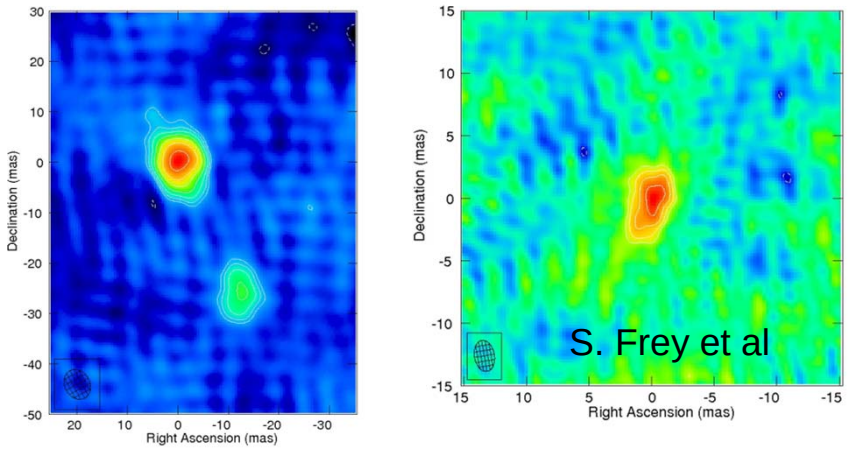
e-VLBI observation of 3C395 @ 1 Gbps

Sources from the Deep Extragalactic VLBI-Optical Survey (DEVOS) S.Frey, S.Garrington et al.

e-VLBI observations of Cygnus X-3



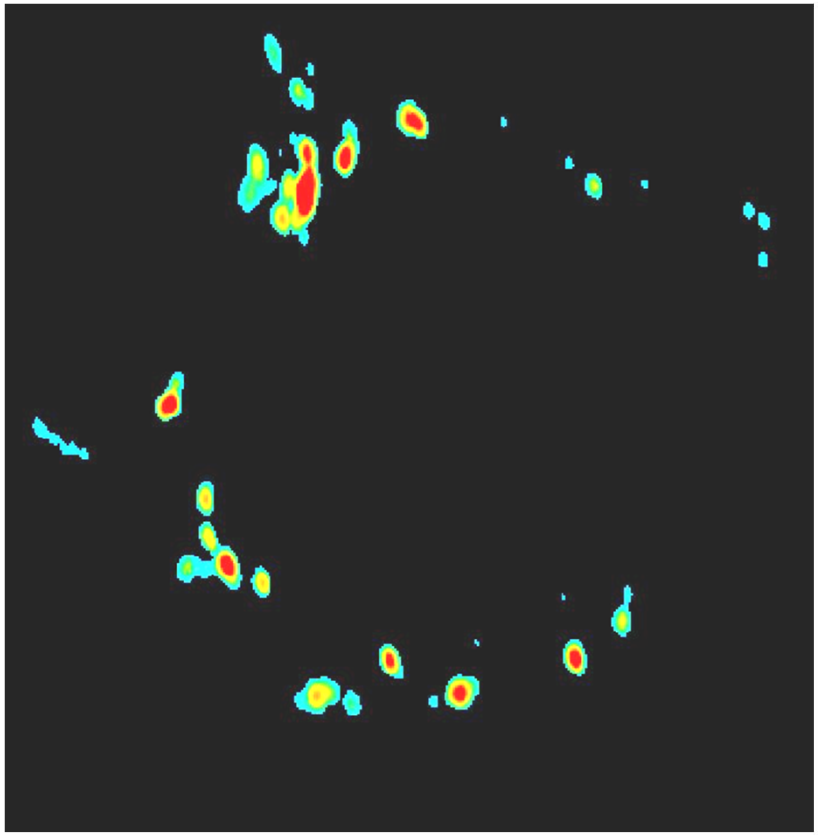
Tudose et al. (2007)



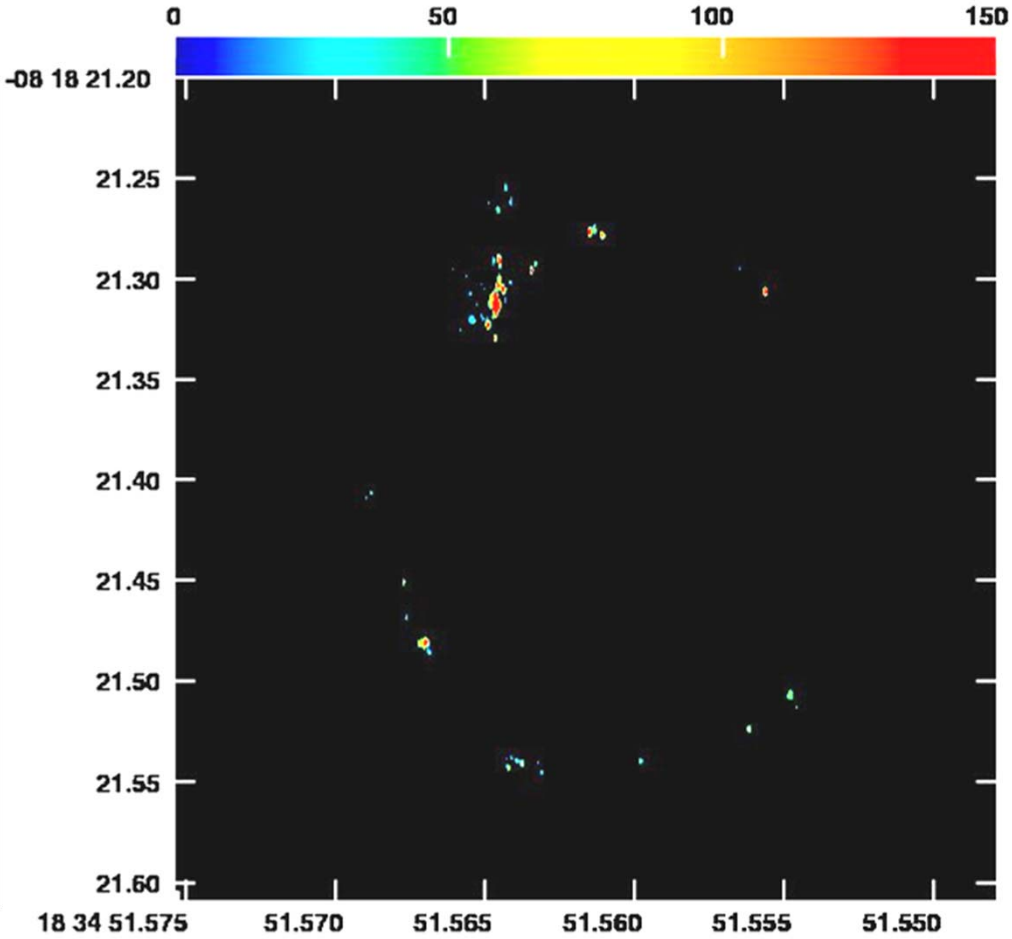
A compact symmetric object at z=6.12 ?

Anna Bartkiewicz (Torun, UMK),
Andreas Brunthaler (MPIfR)
Marian Szymczak (Torun, UMK)
Huib van Langevelde (JIVE),
Mark Reid (H-SCfA)

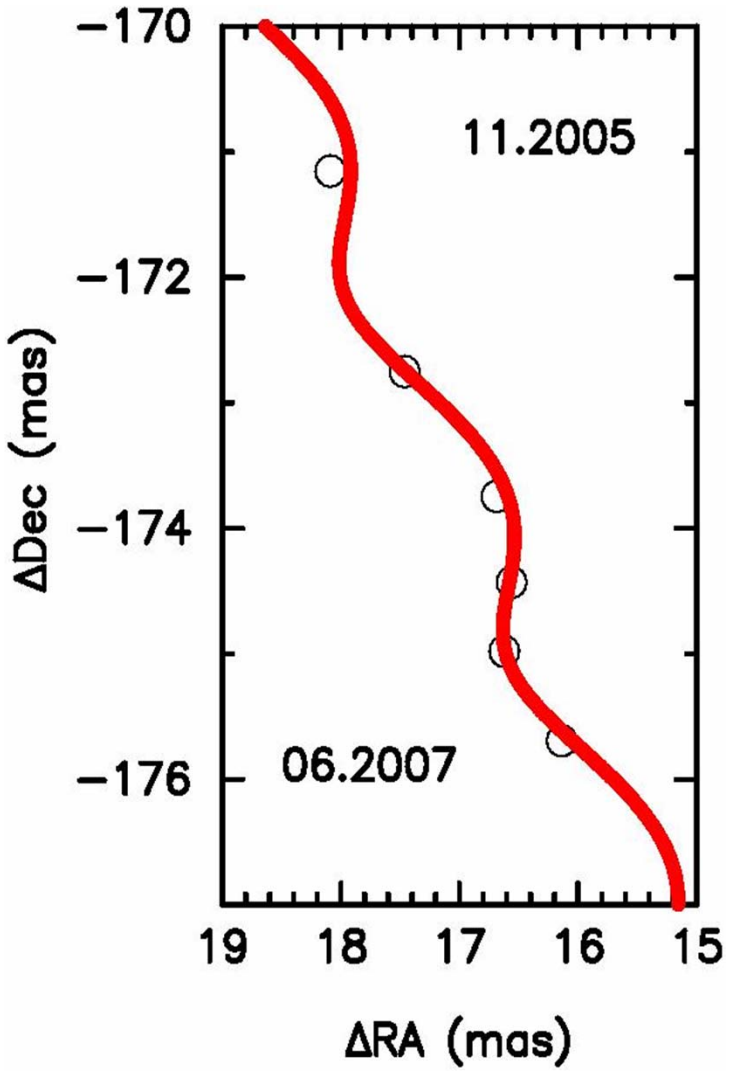
Parallax measurements to the methanol maser ring G23.657-0.127



Discovery of the ring-like structure of 6.7 GHz methanol maser using EVN (Bartkiewicz et al. 2005).



Detection of 12.2 GHz methanol maser towards the ring using VLBA.

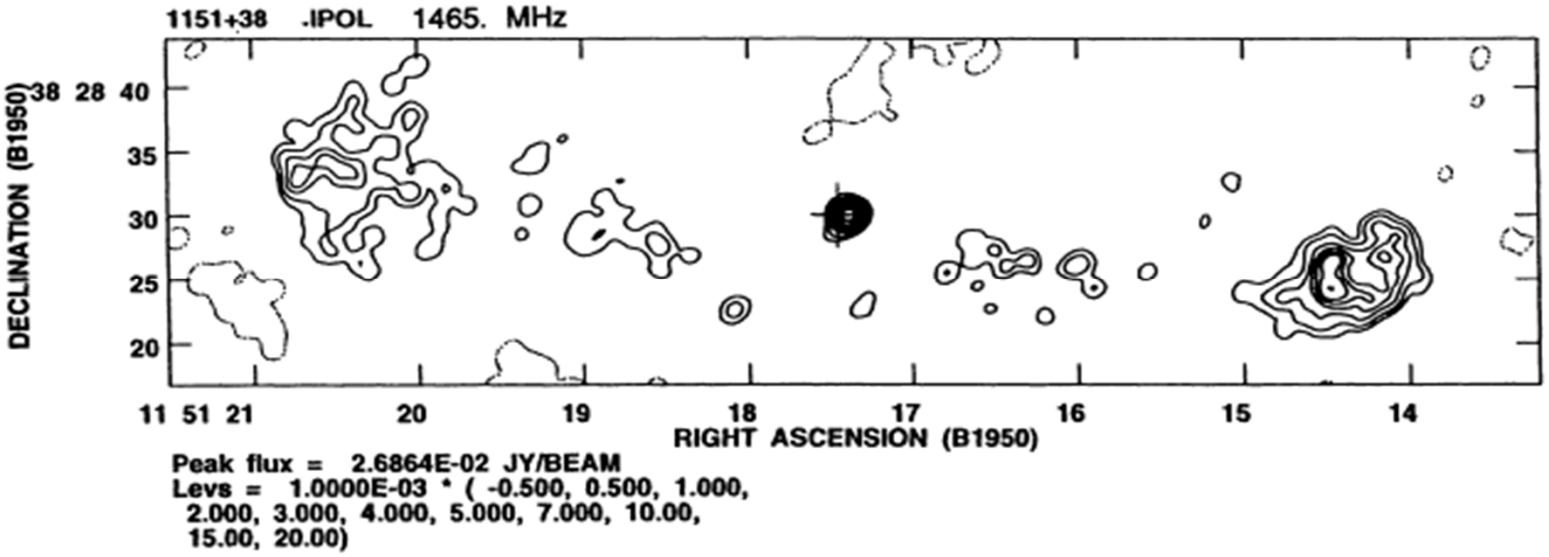


Observations of the ring in six epochs in 2006-07 lead to determination of the trigonometric parallax: 0.313 (+/- 0.039) mas and the distance of 3.19 (+0.46/-0.35) kpc (Bartkiewicz et al. 2008).

The size of the ring is estimated to be 405 au.
The distance is 30 percent closer than it was esimated from the near kinematic distance (5 kpc).

Bondi et al. (1993) *A&AS 101, 431*

1151+384 (VLA A-config.)

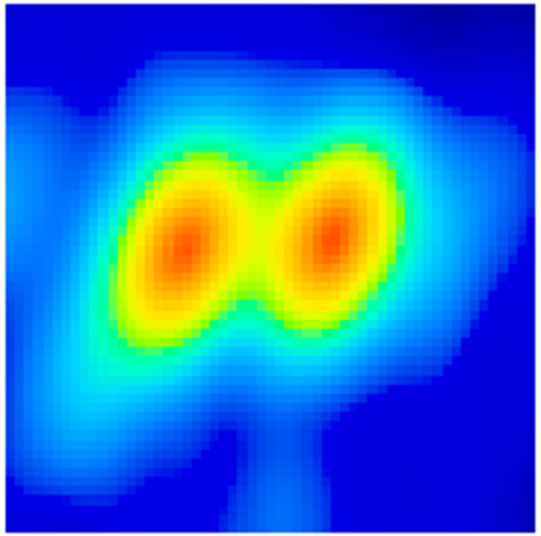


15 GHz VLBA proposal by A.Marecki

"1151+384 – the most compact and most puzzling double-double„

1151+384 is an extreme case of a DDRS

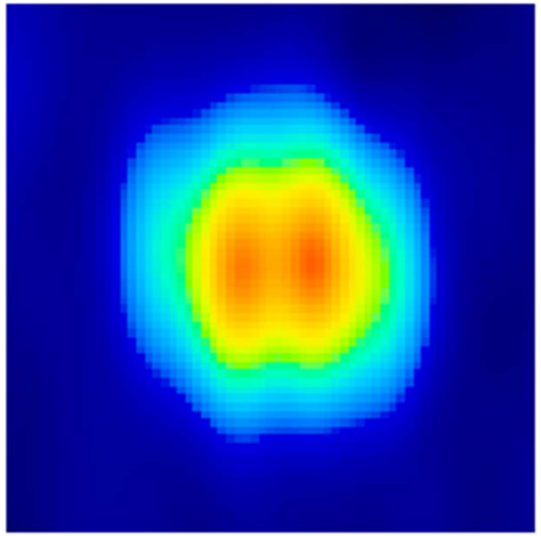
1151+384: z=0.198232 -> D_A=669.3 Mpc -> 3.245 pc/mas



17-Oct-2003, VLBA, 15 GHz

Beam size = 0.87 x 0.52 mas
Position angle=-20.55 deg

Separation =0.75 mas (2.44 pc)



17-May-2009, VLBA, 15 GHz

Beam size = 1.13 x 0.45 mas
Position angle= 0.13 deg

Separation =0.39 mas (1.27 pc)

Shrinking rate: 0.176 pc/year=0.57c (!)

?

Third epoch – VLBA - completed Dec. 2010

Andrzej Marecki, Torun, UMK.

e-EVN goals (future of the EVN) *(PD 2004)*

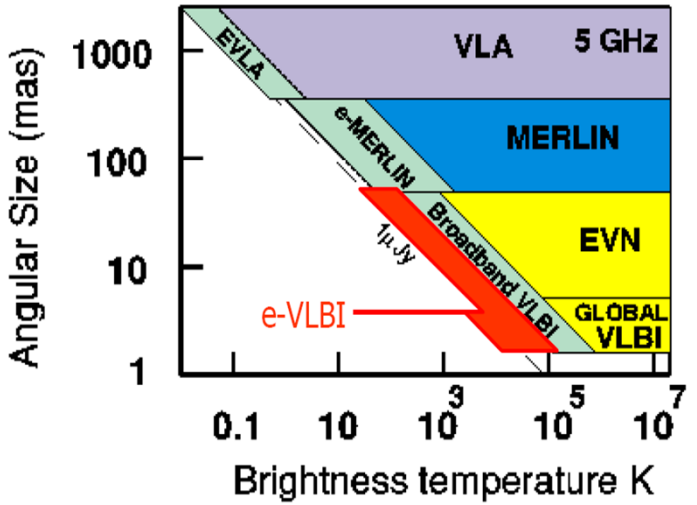
Technical

sub-microJy noise level
full uv-covarage via Multi-Frequency Synthesis
frequency flexibility and broad band covarage
0.3 – 1 GHz, 1-3 GHz, 4-8 GHz, 4-8 GHz, 15,22,43 GHz

Milliarcsec resolution and sub-mas astrometry
Wide-field imaging as standard
Simultaneous continuum and spectroscopy observations
New generation Software Correlator
Dynamic, central schedulling and control over the network

Astronomical

Ultra –sensitive High-resolution Imaging, astrophysics, cosmology, astrometry



Current activities of the EVN

(Except the observations & technology development)

EVN Symposia, Workshops, student's training (EC FP, M-C)

EVN NewsLetter

EVN Biennial Reports

EVN / JIVE web pages

EVN Public outreach

+ individual activities at each EVN Partner Institute

	Strong points	Weak points
EVN	EC support FP	PC (12 referees)
	Sensitivity	3 obs. sessions/year
	e-EVN / technology development	No 12 GHz
	new antennas (SRT,Yebes ....)	High frequency coverage
	u-v covarage	Calibration
	Open access - Number of users grow	only 24 days/year e-EVN
	Strong National Institutes/Facilities	Individually built equipment
	Students	
	European co-operation	
	EVN Symposium/Workshops (most recent results ~40% EVN)	
	JIVE	
VLBA	Range of frequencies	Are there any ?
	4 referees	e-VLBA ?
	Open access	4=>2 calls for proposals/year
	Quick allocation	
	Fast data processing	
	Reliability	
	100% VLBI dedicated	

Goals for the EVN (2010-2015)

- e-EVN as the standard operation
- More time for observations 30% => 50%
- More telescopes (a new once and „an old" N-S; E)
- More bandwidth (2 GHz)
- Reliable calibration system
- New generation correlator
- High frequency operation f>12 GHz
- RFI mitigation
- JIVE new legal identity as the ERIC
- Closer co-operation with VLBA
- Co-operation with SKA (e-EVN as SKA Pathfinder)

New telecopes for the EVN (SRT, Yebes, China)

New project for Torun

extremely low cost 90m RT

RT90 - the 90m radio telescope - parameters

1. **Diameter ~90 m** (symmetric paraboloid)
2. Cassegrain optics (f/D i D/d as for RT32)
3. Motion: Elevation < 25-90>; Az. <+/- 180>
4. Frequency range **0.1 - 22 GHz**
5. Bandwidth 16 GHz (in ~4-8 sub-bands)
6. Multi beam system <**50 – 100 beams**> (APRICOT FP7)
7. Digital back-ends (UNIBOARD FP7)
8. Fibre optical connection, 10-40 Gb/s (PIONIER)
9. **Remote operation**
10. Minimum cost of investment / operation
11. Estimated cost of the investment~ **40 MEuro (~ 120 M PLN)**

12. **Science** => surveys, sky monitoring, VLBI

13. Low level of RFI, radio protected zone
14. Proposed location 100 km N of Torun – (National Forest)

The Antenna

D <80-120m>
d = D/10
surface 0.5 mm RMS

Mount system :

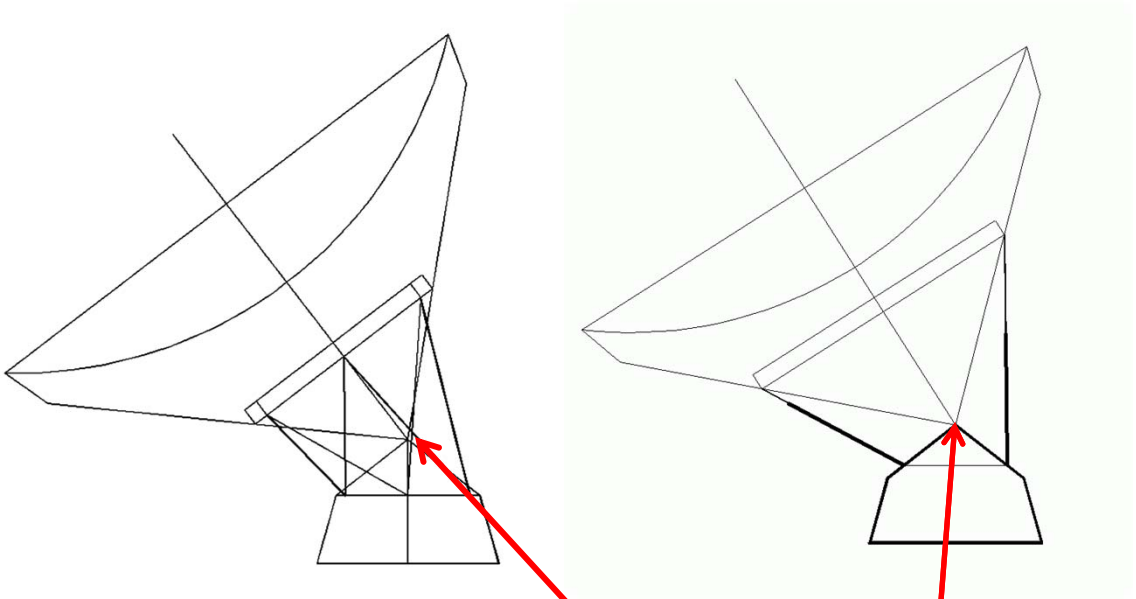
a) Classical Alt-Az mount
weight ~6,000 ton.

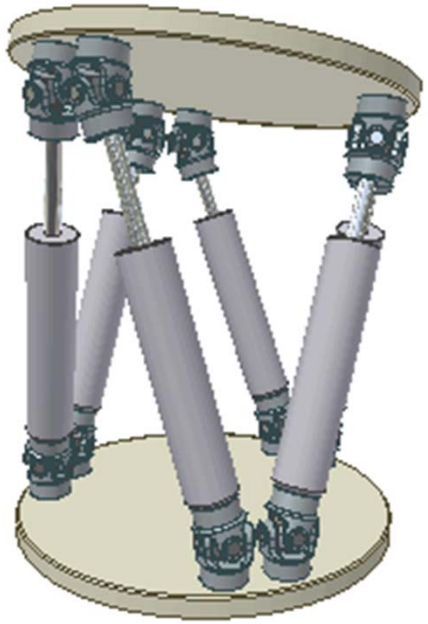
b) Simplified **– tilting only, hydraulic actuators**
weight ~1,200 ton.

Pointing 5 arcsec

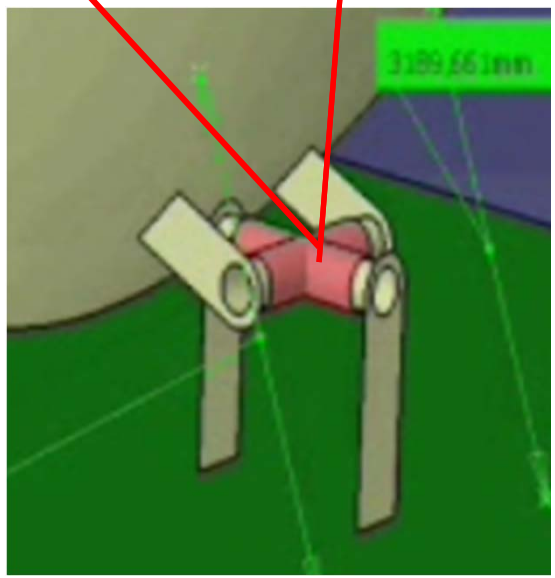
Tracking 2 arcsec

Slew 30 deg/min





Stewart platform



BIURO PROJEKTÓW
I REALIZACJI INWESTYCJI
SEPARATOR-ROBERTS & SCHAEFER
Sp. z o.o.
44-100 GLIWICE, ul. Bojkowska 37

Rewizja	Rodzaj zmiany	Data	Podpis

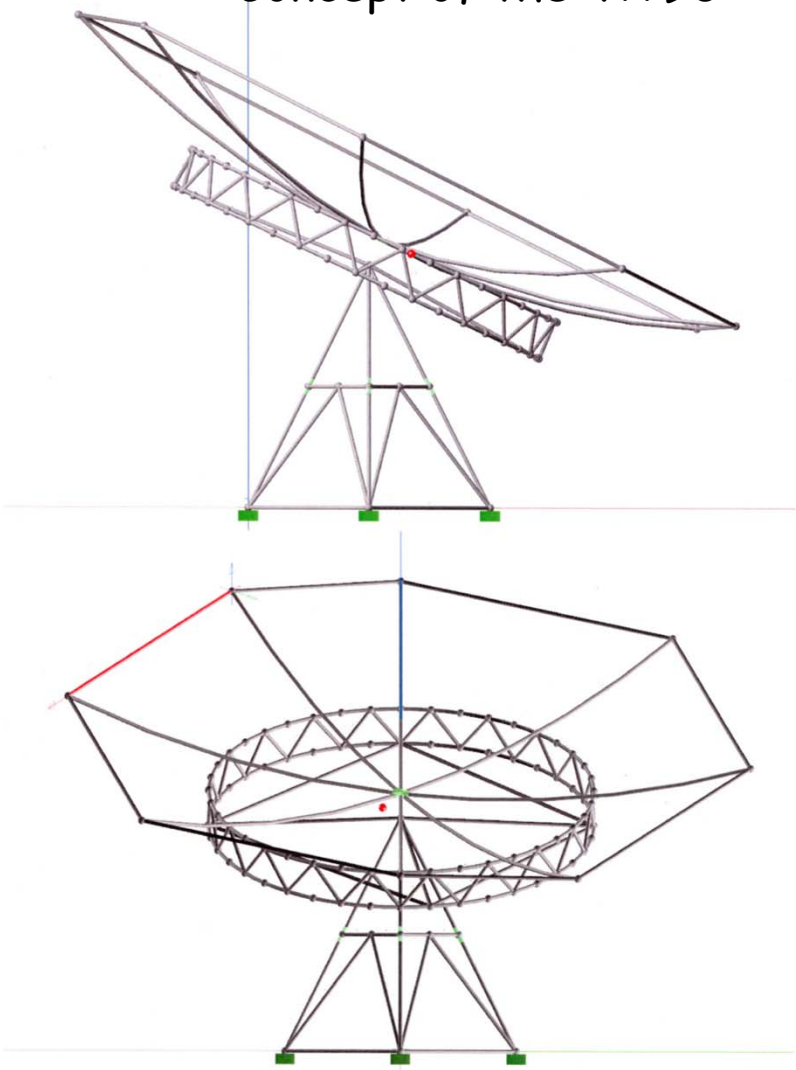
Klasa	Nr wykazu	Materiał	Masa kg	Podziałka

	Nazwisko	Podpis	Data
Projektant	mgr inż. J.Wilczak		01. 2010
Opracował	M. Raś		01. 2010

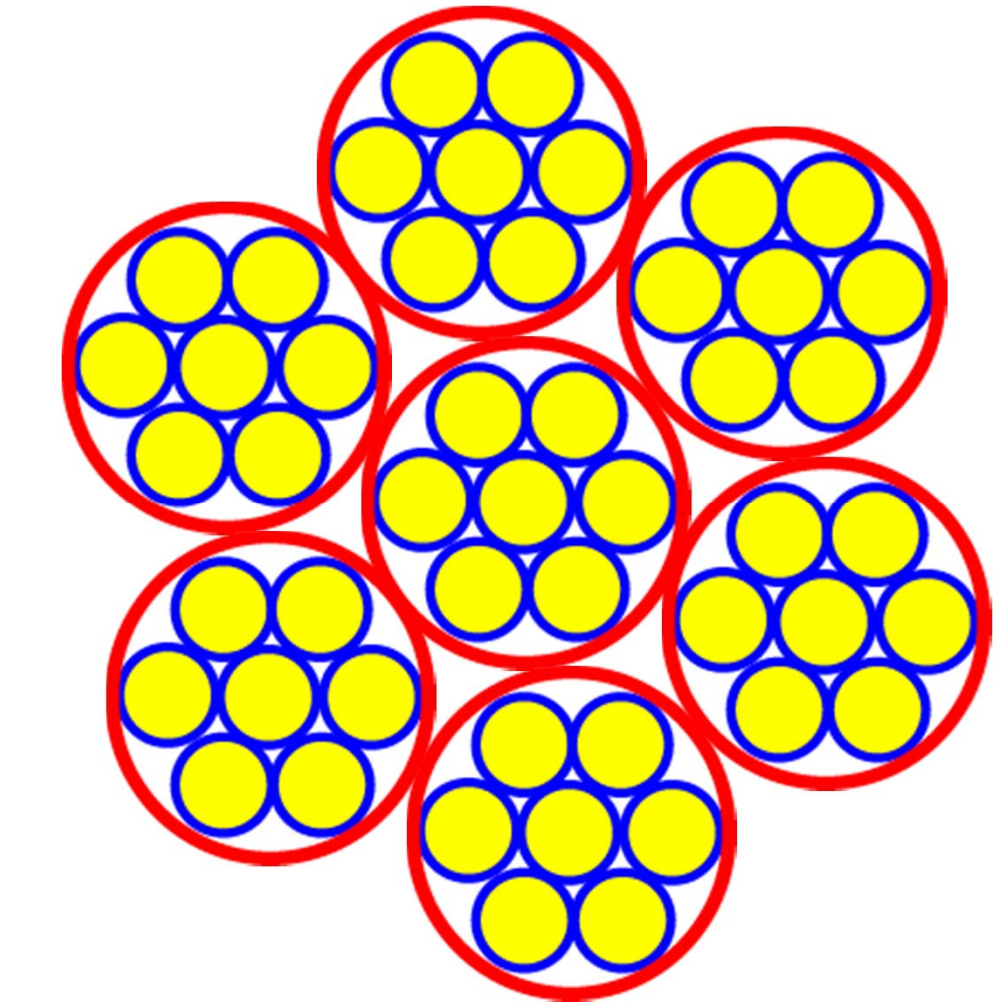
Nr arch. | Arkusz ilość ark. | Nr rys. SRS-T02

Koncepcja projektu
Radioteleskopu w Toruniu

Concept of the RT90



100m



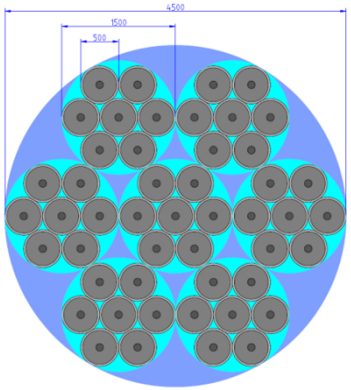
BW 5-21 GHz
POL LHC & RHC
Sub-Bands 2 GHz

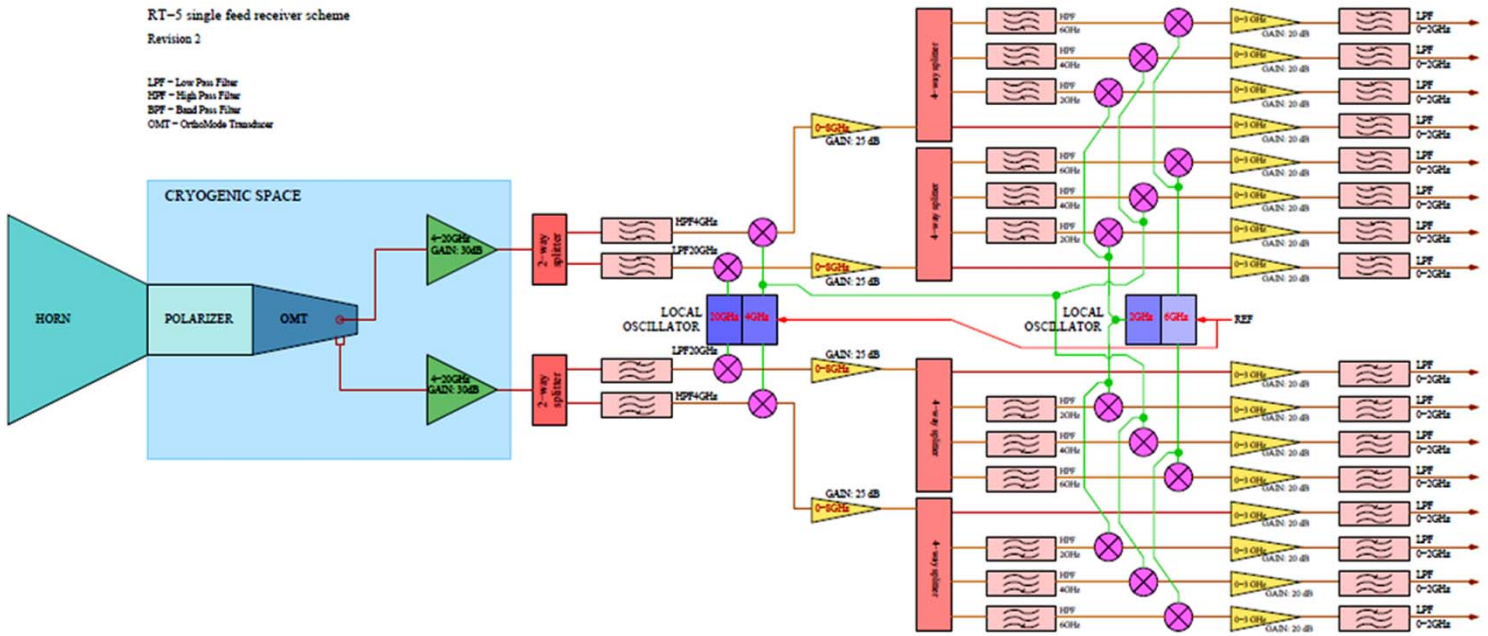
Digital Back-ends

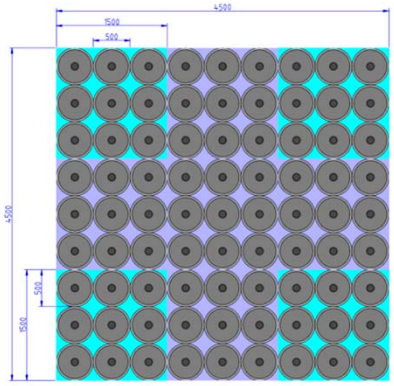
Radiometry
Polarimetry
Spectroscopy
PSRs
Transients

41 outputs x 2 pol x
16 sub-bands = 1312
out channels each
with ~1 kHz resolution

Receivers (MMIC ?) and digital back-ends based (FPGA technology)







Thank you

EUROPEAN VLBI NETWORK