New era in VLBI astronomy:
e-VLBI

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The European VLBI Network

- Some of the world's greatest radio telescopes, e.g. Effelsberg 100m, Lovell 76m telescopes, Westerbork Synthesis Radio Telescope
- Outside Europe includes Hartebeesthoek (South Africa), Urumqi and Shanghai (China)
- Several telescopes are being built that will join the EVN: Yebes 40m (this year), telescopes in Sardinia, Latvia, Ireland and China
- Operating in three observing sessions per year, sometimes jointly with MERLIN (UK) and the VLBA (USA) – global VLBI
- Observing wavelength ranges from 92cm to 1.3cm
- The most sensitive standalone VLBI array (the so-called High Sensitivity Array formed occasionally by the VLBA, VLA, GBT and maybe Arecibo competes with it)
- The data are correlated in the EVN MkIV correlator at JIVE

http://www.evlbi.org/

http://www.jive.nl/
The end of the tape era

- Tape recording had limited performance (parity errors), and
- limited data rate (256 Mbps; 512 Mbps with two write heads).
- Tapes were expensive
- Tape playback units were not easy to maintain

- Disk based recording systems were developed at Haystack (Mark5A) and Metsahovi Radio Observatory (PC EVN)
- And it worked!
- The EVN is fully disk operational (Mark5A) since early 2004
- Cheaper, off the shelf technology, perfect recording; data rate up to 1 Gbps

http://www.haystack.edu/tech/vlbi/mark5/
A new era in VLBI astronomy: e-VLBI

Paragi et al. (in prep.)

MERLIN archive 1.6 GHz data, 1997
The reliability

- Disk recording is better quality, but it also provides a way to quickly check telescope performance: ftp tests
- 2-4s data at 256 Mbps ⇒ 64-128 MB files, may be transferred through the Internet!
- Data processed by a software correlator developed in NICT, Japan

- Since late 2004 there are regular ftp tests during EVN sessions.
- The software correlator runs on a PC cluster
- Feedback to telescopes used to take at least a week, now it is a matter of minutes
- OK, let us see what else can we improve…
 VLBI observations timeline

1-2 weeks  2-3 months  2-3 months

Select your source ⇒ Write an observing proposal ⇒ EVN PC makes a decision ⇒ EVN scheduler provides a date

... another 2-3 months  well, why would you hurry?

Observe with VLBI ⇒ Data correlation ⇒ Data processing ⇒ Publishing results

THIS MUST CHANGE!
Target of Opportunity projects

An example: the huge flare of SGR1806-20

- SGR1806-20 is a soft gamma-ray repeater a neutron star with very strong magnetic fields, a magnetar
- Produced the greatest explosion witnessed by humans in our Galaxy, on 27 December 2004
- Observations with various instruments, also VLBI (with the VLBA array)
- Could not image reliably because of lack of known calibrator in the vicinity of the target!

Is there a way to do these projects more efficiently? Is there a way to get the data and analyze them quickly???

Fender et al. (2005), MNRAS 367, L6
What is EXPReS?

- EXPReS = Express Production Real-time e-VLBI Service
- Three year project, started March 2006, funded by the European Commission (DG-INFSO), Sixth Framework Programme, Contract #026642
- Objective: to create a distributed, large-scale astronomical instrument of continental and inter-continental dimensions
- Means: high-speed communication networks operating in real-time and connecting some of the largest and most sensitive radio telescopes on the planet

http://www.expres-eu.org/
Jodrell Bank
UK

Medicina
Italy

Onsala
Sweden

Cambridge
UK

Westerbork
Netherlands

Soon available: Effelsberg, Yebes 40m, Shanghai …

Telescopes connections (early 2007)
The first e-VLBI science result (continuum)

• SN2001em was discovered on 15 September 2001 in UGC11794 galaxy (Pepenkova 2001).
• Redshift $z \approx 0.02$ corresponding to a distance of 80~Mpc.
• Filippenko and Chornok (2001) classified it as type Ib/c, most likely Ic.
• Exceptional radio and X-ray luminosities (off axis GRB, developing late radio emission due to jet break?),
• Not quite a 1 mJy radio source
• EVN observations: Cm, Jb2, On, Tr, Wb (128Mbps), +Arecibo 300m (64 Mbps) at 18cm, on 2005 Mar 11
• Tentative detection (4.5 $\sigma$) of the first real faint target with e-VLBI

*Paragi et al. (2005), MSAIt 76, 570*
e-VLBI activities in 2006

- There are regular e-VLBI test observations in every six week (on average)
- Normal operations at 256 Mbps (Cm, Jb2, Mc, On, Tr, Wb)
- Fringes to several telescopes at 512 Mbps, most recently to Mc
- 24h time is pre-allocated for science observation during each e-VLBI test
- Observing proposals may be submitted two weeks before the advertised date

Science projects observed in 2006:

- Cyg X-3, 20 Apr/18 May, 128 Mbps, Tudose et al.
- GRS1915, 20 Apr, 128 Mbps, Rushton et al.
- LSI +61.303, 256 Mbps, 26 Oct, Perez-Torres et al.
- Algol, 26 Oct/14 Dec, 256 Mbps, Paragi et al.
- Calibrators near M81, 14 Dec, 256 Mbps, Brunthaler et al.
- INTEGRAL microquasar candidates, 14 Dec, Pandey et al.
First refereed journal papers:


Tudose et al. (2007), *MNRAS* ... very soon

Cyg X-3
LSI 61+303 preliminary results:

Gamma-detected XRB candidate;

Recent VLBA observations (Mioduszewski et al.) suggest interacting pulsar wind…

e-EVN, MERLIN, CHANDRA
Observations on 26 October 2006

Perez-Torres et al. (in prep.)
Algol preliminary results:

26 October 2006

Csizmadia et al. (in prep.)
512 Mbps e-VLBI run

1/2 February 2007

(Cm), Jb2, On, Mc, Wb

And Ef, Sh, Yb … coming: We are almost there!!!
Westerbork – e-EVN as a unique instrument

- Westerbork Synthesis Array data may help in calibration (amplitude, linear and circular polarization)
- May help to confirm detection/non-detection of weak targets
- Could be used as a ‘built-in’ alert instrument for the e-EVN
- Wb can help improving coordinates of new transients… (note that there are cases when we cannot afford time to get this information from an external instrument, e.g. the VLA)
- …with adaptive scheduling, this could be immediately used for the VLBI array
- Not to mention the additional information on the very large-scale structure (which we normally waste when we do not reduce Wb data along with the EVN)
Back to Algol, 14 December 2006 run:

Clean I map. Array: EVN
ALGOL at 4.974 GHz 2006 Dec 14

Plot file version 2 created 19-APR-2007 15:23:48
Amplitude vs Time for ALGOL.TBAVG.1 Vect aver.
IF 1 CHAN 1 STK U
RT0 - RT1 (1 - 2)

TIME (HOURS)
Summary – is e-VLBI useful for science?

• First of all, it works! Significantly reduces science turnaround time.
• e-VLBI is easy and practical for users with little or no experience with VLBI. Data analysis pipeline does most of the work! Additional PI support is available at JIVE.
• Westerbork + e-EVN will be a unique instrument: calibration, WSRT alert for e-VLBI, position information on new transients
• Yes, these developments are mainly driven by technical/logistical considerations, but there is the possibility of doing new type of VLBI science ...
• …especially when adaptive scheduling is becoming a reality
• May contribute significantly to follow-up observations of GLAST Galactic transients and maybe GLAST GRBs.
Want to propose e-VLBI observations?

e-VLBI proposals must be submitted through a web proposal tool.

e-VLBI proposals are just like other EVN proposals, but you must take additional care to

• justify properly why urgency is needed (target of opportunity, e.g. known transient flares, or need to check calibrators quickly for another project, taking part in an observational campaign)

• give accurate coordinates (sub-arcsecond accuracy)

• specify all the details of the proposed observations – schedule will be made by JIVE staff

• contact Bob Campbell (campbell@jive.nl), to find out if preferred correlation mode is OK

• keep in mind the limited resolution (~6*8 mas at 6cm), uv-coverage and sensitivity at the moment

• When 512 Mbps is possible and Effelsberg joins the array, the sensitivity will improve greatly; with Shanghai joining during 2007, the resolution will be better as well

• Be ready to travel to JIVE for quick data processing

• Think creatively, find projects that make appropriate use of this unique service!