

# **WSRT and the EVN**

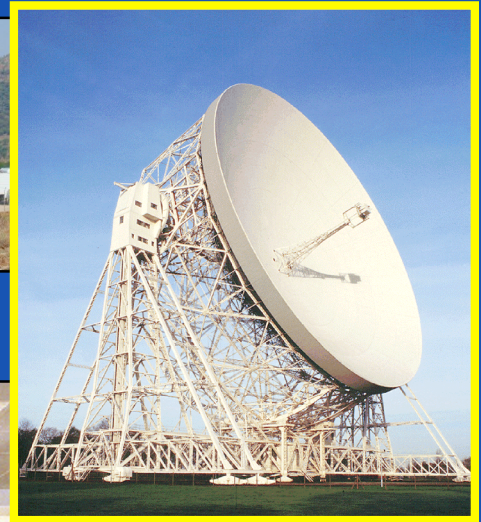


***Huib van Langevelde, JIVE director***

***WSRT Users meeting***

***Amersfoort, 4 June 2008***

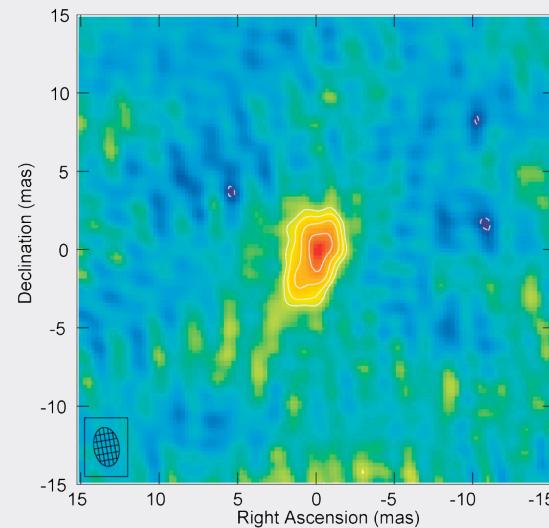
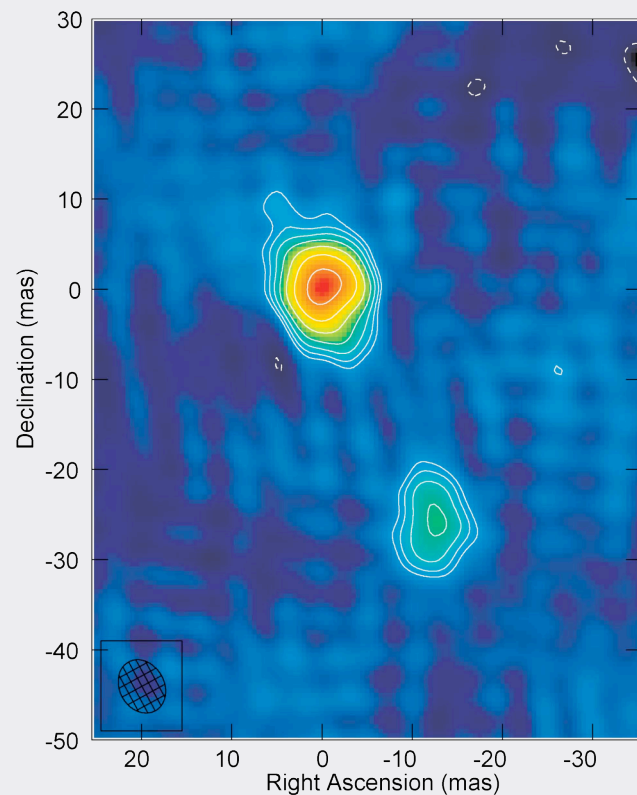
- **Role of WSRT in the European VLBI Network**
  - **Direction of development of the EVN**
    - e-VLBI happening now!
    - More bandwidth coming next
    - Developments for next decade
  - **How does the WSRT fit in?**
    - And the plans for the WSRT in the future
  
- **Phased array corner stone for high sensitivity EVN**
  - Main selling point of the EVN: BIG telescopes
  - Outperforming any other array in pure sensitivity



(c) E.P.B. 2006

# Reaching the $\mu\text{Jy}$ universe

- **WSRT in the EVN 69% of experiments in phased array**
  - **At 6cm and 18cm work-horse frequencies for the EVN**
    - **Not available at higher frequencies**
  - **29% Single dish at 5cm (Methanol)**
  - **2% wide-field imaging**

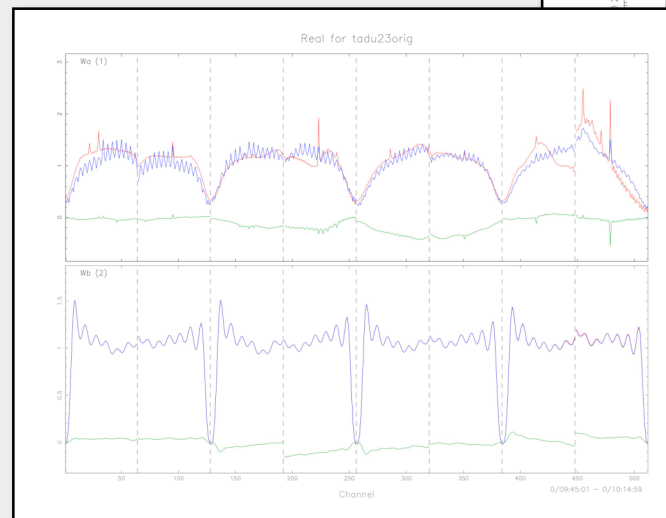
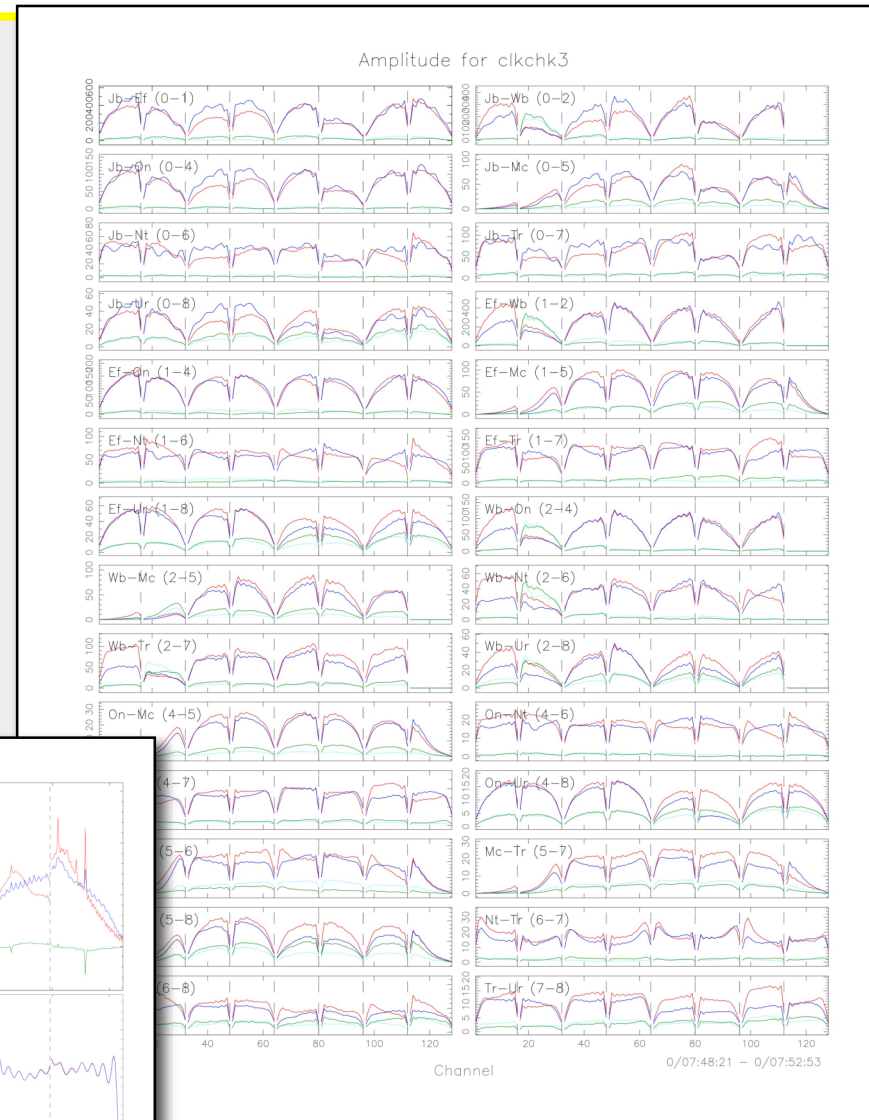


- **J1427+3312, the most distant known radio loud QSO ( $z=6.12$ ),**
- **Observed with 10-telescope EVN configuration in 2007, incl WSRT**
- **1.6 and 5 GHz 1.4 and 0.8 mJy at L- and C-band, respectively**
- **Noise level at  $\approx 17\mu\text{Jy}$  for both frequencies**
- **WSRT provided crucial total flux density measurements**

**Frey, Gurvits, Paragi, Gabanyi, 2008, A&A (issue of 5 June 2008), arXiv:0805.0474**

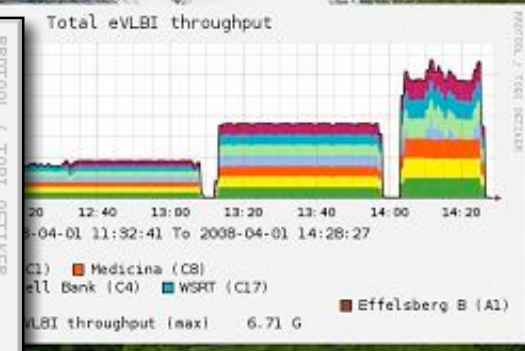
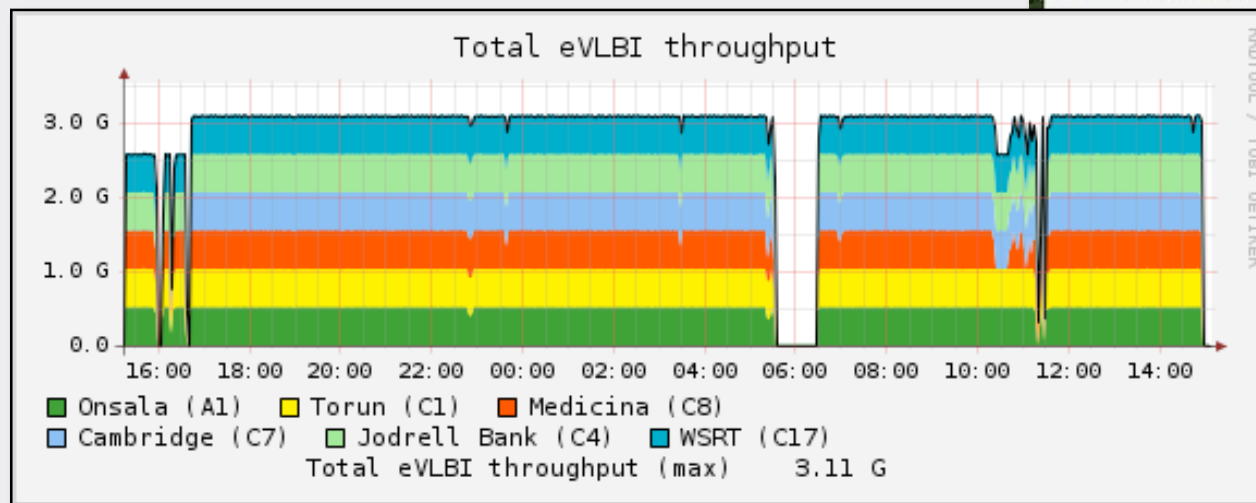
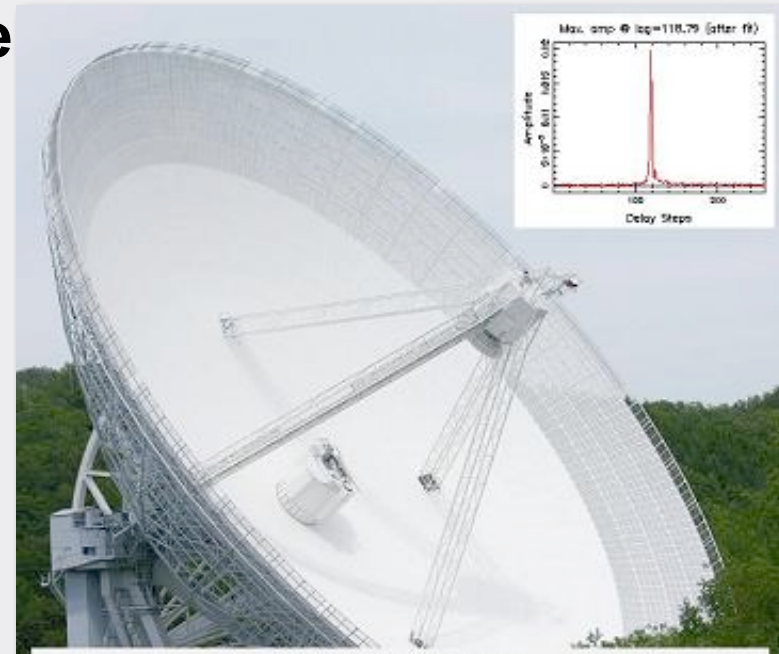
# Current bandwidth

- **EVN operates at 1 Gbps**
  - Mk5A disk recording
  - Mk5B soon
    - Aiming at 4 Gbps
  - Requires 2 x 128 MHz @ 2 bits
- **WSRT phased array**
  - Dual pol 128 MHz bandwidth
  - With TADU system
    - Limited by WSRT IF system
  - TADU-Max will be fully digital



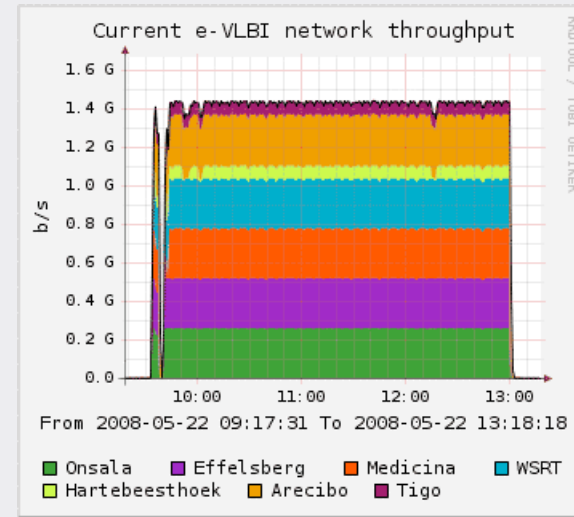
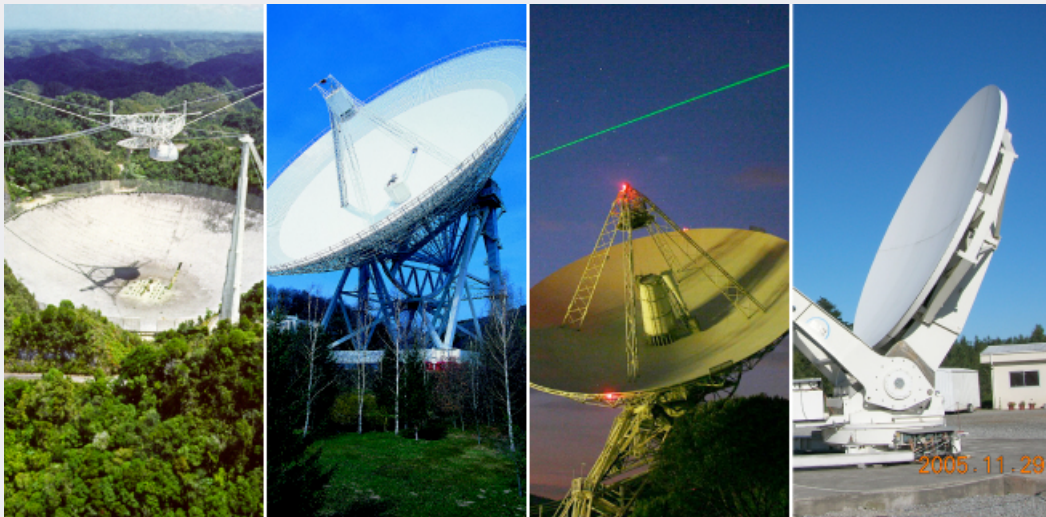
# Revolutionizing VLBI:

- e-VLBI now operational, reliable and with full sensitivity
  - Effelsberg on-line on 1/4/08
    - Extremely important for science
    - Boosts the sensitivity
- Routinely running 6 (7) telescopes at 512 Mbps



# World-wide e-VLBI

- EC project EXPReS has partners in 6 continents
  - All gave real-time fringes
  - As of last week
- Shows that e-VLBI is feasible on Global scale



# Why is e-VLBI exciting for astronomy?

- **Rapid response for rapid variability**
  - Fast response to requests
  - Immediate analysis of data, adapt observing parameters
  - Coordination with current and future observatories
- **Immediate feedback**
  - More robust data
- **Fewer consumables, logistics**
  - Constantly available VLBI network
    - Monitoring: for example astrometry
    - Spacecraft tracking
- **Growth path for more bandwidth**
  - More sensitive astronomy





# e-VLBI policy

- **Required a cultural change**
  - Peer review process is careful
  - The EVN is a distributed facility
  - The telescopes are involved in other programmes as well
- **Policy changes adopted in Nov 2007**
- **Now e-VLBI is booming in 2008!**
  - Had several e-VLBI runs this year
  - Some use trigger conditions
  - Also 3 epoch ToO observation
  - And big telescopes available

European VLBI Network  
**e-VLBI Observing Opportunities in 2008**  
Call for Proposals

**Special features in 2008 include:**

- Frequent 24-hour e-VLBI slots for:
  - classes of triggered transients
  - regular source monitoring
  - any normal continuum or spectral line observations
  - short pilot experiments
- Improvements to facilitate Target of Opportunity observations
- User support for e-VLBI observations, including scheduling and rapid analysis pipeline
- Real-time correlation with data rates up to 512 Mbps

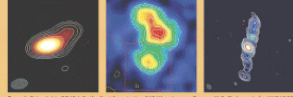
**Proposal deadlines**  
1 February  
1 June  
1 October

For details, consult the call for proposals posted three weeks before each deadline:  
[www.evlbi.org/evlbi/call\\_evlbi.html](http://www.evlbi.org/evlbi/call_evlbi.html)

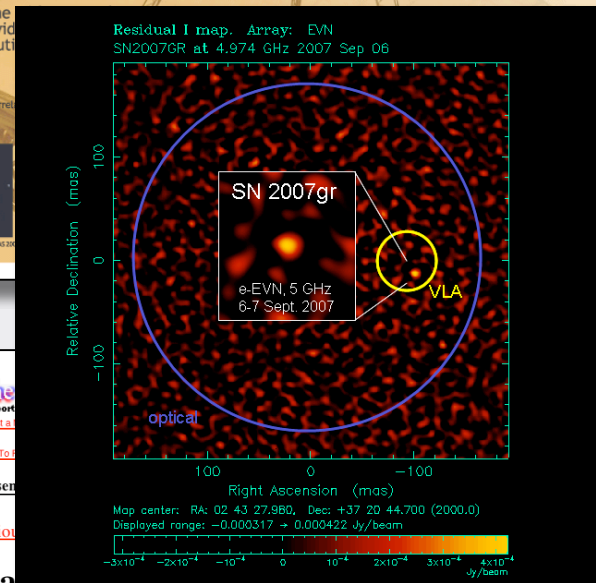
Participation of six stations in real-time expected to come online in 2008, providing enhancements of sensitivity and resolution.

During e-VLBI experiments, telescopes are connected to the correlator with almost immediate access to the data.

Images from e-VLBI observations in 2006 and 2007



From left to right: 3C484.2, the first five station 512 Mbps image; Cygnus X-3, Tudose et al., MNRAS 2007; the first six station 512 Mbps image; SN2007gr, Paragi et al., A&A #1215.



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## e-VLBI observations of Cyg X-3

ATel #1476: V. Tudose (UvA), Z. Paragi (JIVE), R. Fender (Soton), R. Spencer (JBO), M. Garrett (ASTRON), A. Rushton (JBO)  
on 15 Apr 2008; 10:04 UT  
Password Certification: Zsolt Paragi (zparagi@jive.nl)

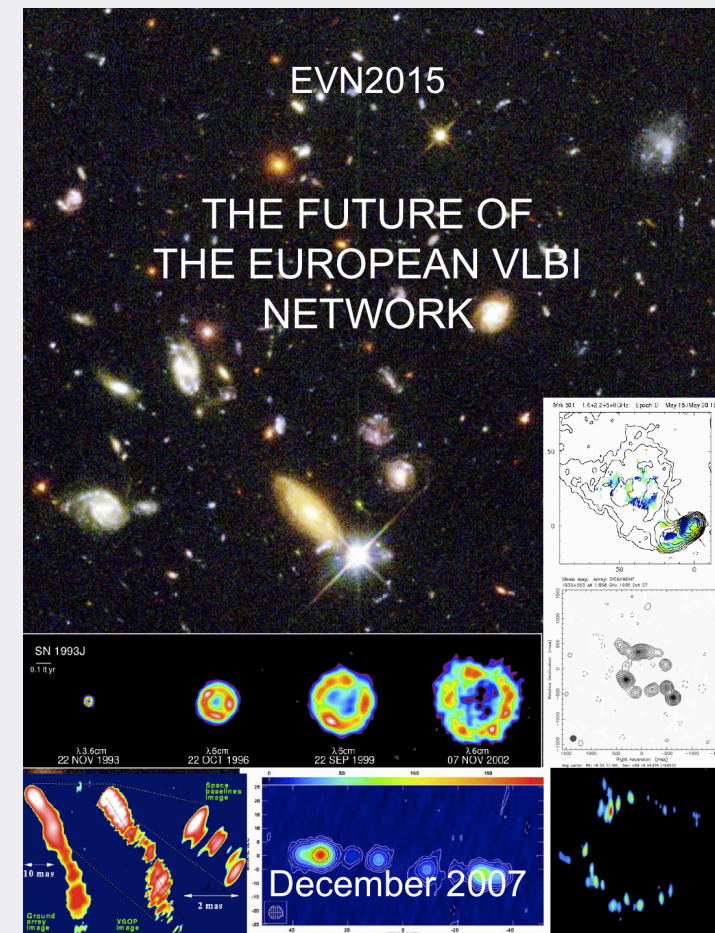
**Subjects: Radio, Binaries, Black Holes, Transients**  
**Referred to by ATel #: 1483**

We observed the X-ray binary Cyg X-3 on April 9th, 2008 for 9.5 hours, between 03:30-13:00 UT, at 5 GHz with the European VLBI Network (EVN) in e-VLBI mode (the data from the radio telescopes are sent over optical fibers in real-time to the correlator for processing). The radio telescopes participating in the experiment were: Cambridge, Medicina, Jodrell Bank MkII, Onsala (25 m), Torun and Westerbork (phased array).

In the last few weeks Cyg X-3 has been passing through a clear transition towards softer states, as indicated by the ASM detector onboard the Rossi X-ray Timing Explorer (RXTE). This kind of behaviour has been associated in previous observations of Cyg X-3, as well as other X-ray binaries, with

# EVN2015 science case

- **Has been finalized and distributed**
  - Available on the web.  
<http://www.evlbi.org/publications/publications.html>
  - Wide range of science applications
- **Some highlights include**
  - Nature of starburst/AGN in cosmological fields
  - The fate of black holes/radio quiet AGN
  - Jet physics close to the event horizon (VSOP2)
  - Determining star burst activity, resolving SNR's
  - The nature of the ISM in active galaxies
  - Fundamental distances from astrometry
  - The accretion physics in transient radio sources
  - The detailed 3D kinematics of star formation
  - Pulsar astrometry
  - Monitoring spacecraft in the solar system



# Technology path EVN

- **Real-time connected VLBI**
  - No doubt here, only thing that sells, SKA pathfinder
  - Transient science, modern users are impatient
    - Buffer system will be required for robustness
- **Improved sensitivity by increased bandwidth**
  - Requires coordinated upgrade of IF systems
  - And many bit system for RFI robustness
- **Much better coverage at high frequency**
  - Where the sensitivity matters and can be obtained
  - And frequency flexible, of course
- **A different operational model, tighter control**
  - Faster, more robust, accurate calibration
- **High fidelity images require many telescopes**
  - Extend the EVN with new members and new antennas

# Technology path correlator

- **VLBI input changes**
  - Multiple data streams of 10 - 100 Gbps
  - 32 stations, or at least more than 16
  - Multiple bit representation
  - High bandwidth at higher frequency
- **Calls for a hundred fold more powerful correlator**
  - Compares to EVLA correlator
  - Similar size as some (other) SKA pathfinders
  - Probably needs FPGA based solution
    - Software correlators can be intermediate solution
  - Allowing for some specific applications
    - Spectral line, requires much better mixed bandwidth facilities
    - Pulsar gating
    - Atmospheric calibration
    - Multiple beam VLBI

# Future of radio-astronomy

- **Community is preparing to build the SKA**
  - And is constructing a number of SKA pathfinders
    - LOFAR will open up the transient radio-sky
    - e-MERLIN will probe new regime in sensitivity
  - Includes the e-EVN, exercising long-range connectivity
- **Changing priorities: a challenge and an opportunity**
  - **Must concentrate on very specific science case**
    - Long, Very Long Baselines, Northern hemisphere
  - **Take advantage of technology investments**
    - Correlators, connectivity, data acquisition
    - But possibly also receptors
- **Maintaining the distributed expertise is vital for SKA**
  - European radio-astronomy must develop a single roadmap
  - I think there will be a strong case for Europe based telescopes: LOFAR, VLBI
    - Training of future radio-astronomy users
    - Technology development, evaluation
    - Outreach: visit a telescope near you!

# Future WSRT in the future EVN

- **Current: Important collecting area at 18cm & 6cm**
  - **BUT: limited bandwidth to follow EVN upgrades**
    - Hard to beat sheer collecting area
    - In fact difficult at 18cm where bandwidth is limited anyway
  - Limited lifetime?
- **APERTIF: would lose 6cm phased array capability**
  - Assume a single MFFE antenna would remain for frequency coverage
  - **BUT: potentially gain 21cm bandwidth?**
    - Synergy with next generation correlator
    - Extend lifetime of the WSRT operations for VLBI?
    - Single antenna upgradeable to wider bandwidth?
  - **BUT APERTIF: would lose 6cm phased array capability (repeat)**
- **Long term future: coverage of higher frequencies**
  - For example: cluster of small high frequency antennas

