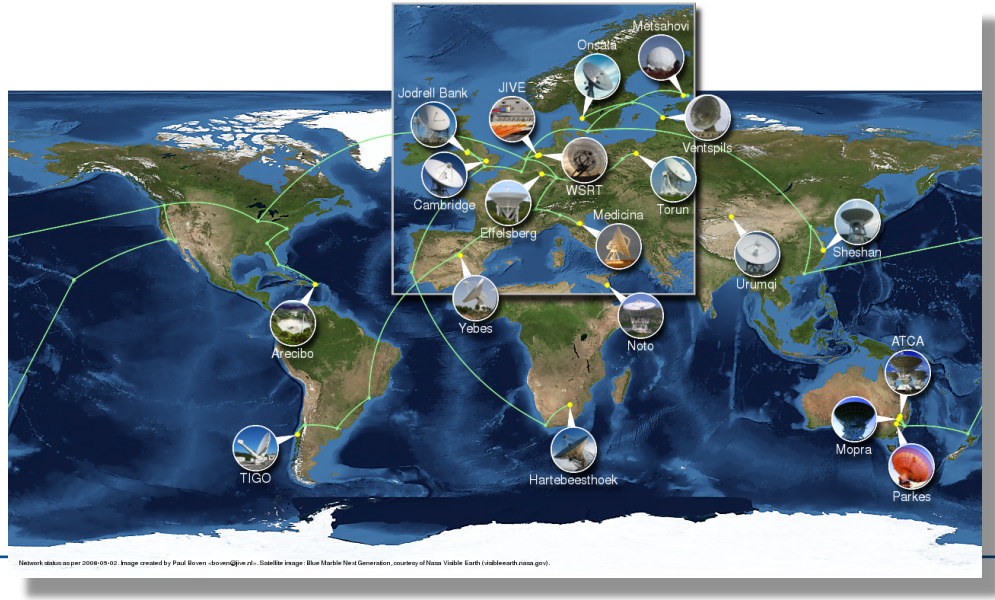
R&D at JIVE

Arpad Szomoru

JIVE - Joint Institute for VLBI ERIC -

- Promote and advance the use of VLBI for astronomy
  - Central correlation for European VLBI Network
  - Operational feedback to stations
  - User support
    - Preparation of observations
    - Data reduction
  - Improvement of VLBI technique in general
- Base budget from partners in 8 countries:
  - China, France, Germany, Italy, Spain, Sweden, United Kingdom, the Netherlands, South Africa
  - hosted by ASTRON



How the EVN stations view feedback from JIVE

R&D and Technical Operations Group

Technical Operations and R&D

Head

Arpad Szomoru

Hardware Support Engineer
Martin Leeuwinga 75%

Senior Software Engineer
Harro Verkouter

Software Project Scientist
Mark Kettenis

Network/Linux specialist
Paul Boven

Software Engineers
Des Small (ExBoX)

Bob Eldering

Digital Engineers

Jonathan Hargreaves
(RadioNet UniBoard)

BlackHoleCam Project Scientist
Ilse van Bemmel
(BlackHoleCam)

Scientific Programmer

Aard Keimpema
(NWO SCARIe)

Projects

No R&D budget

- R&D financed through EC and NWO projects

2006	**EXPReS**	**SA1**
		SA2
		JRA1
2008	**NWO-SCARIe**	
2009	**NWO-ExBox**	
	RadioNet FP7	**UniBoard**
		ALBiUS
2010	**NWO-ShAO collaboration**	
	NEXPReS	**SA1**
		SA2
		JRA1
		JRA2
2012	RadioNet3	**UniBoard^2**
		Hilado
2014	BlackHoleCam	WP1.1
		WP1.3
	NWO SKA-NL roadmap	SaDT: SAT architect
		SKA-VLBI
2015	H2020 ASTERICS	**Cleopatra**
		Obelix
	NWO KAT7-VLBI	

Not counting Space Science projects!

What do we do?

- Correlators
  - More capacity, new telescopes, development of AVN
  - New features, new science
- Data recording/playback/transport
  - Real time/near-real time
  - Higher bandwidths
- Automated operations
  - Get rid of disk shipping
  - Monitoring, automated fringe checking
  - Triggered observations
- SKA and mm VLBI
  - **User software**, VLBI with CASA
  - Simulations for BHC
  - Fringe checking
- Time and frequency transfer
  - For SKA
  - And on public networks

Out with the old…

- MkIV Correlator
  - Dead and gone!
  - Correlator boards sent to Hawaii

In with the new

- SFXC software correlator at JIVE:

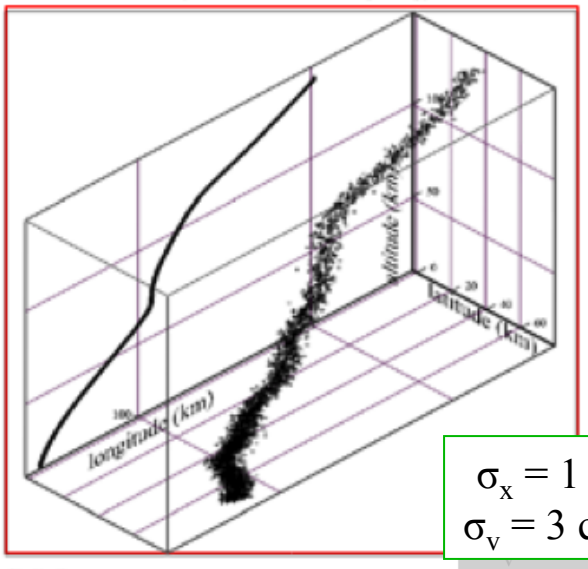
- 40 nodes; 384 cores
  (Intel Xeon 5500/5600/E5-2600)
- QDR Infiniband interconnect
  (32 Mbit/s)
- 8 nodes with 10 GbE
  (currently limited to 20 Gbit/s total)
- 13 stations @1Gbit/s real-time
  (with cross-polarisations)

- All recorded VLBI on SFXC since summer 2012
- First real-time e-VLBI in december 2012
- SFXC capabilities: talk by Aard Keimpema

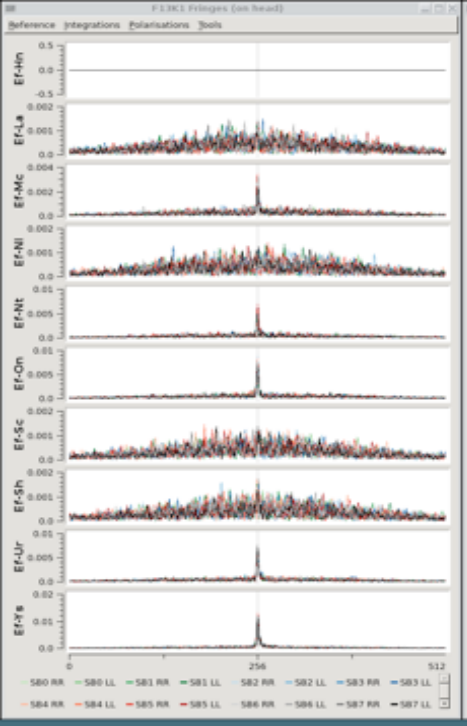
The birth of SFXC

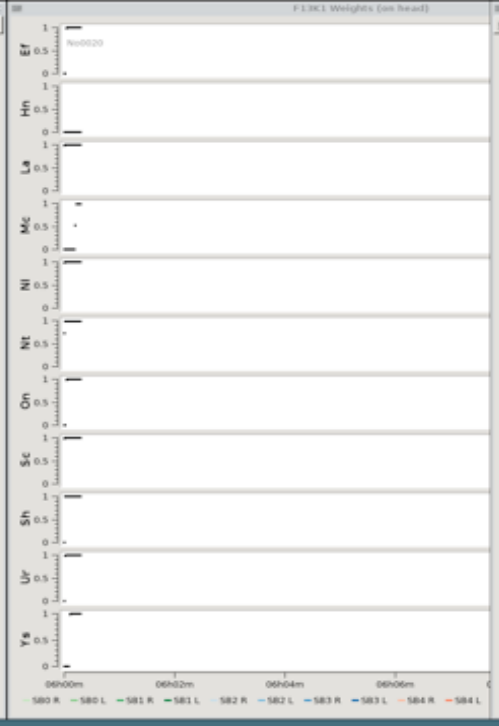
- Tracking of Huygens probe during descent to Titan
- Ad hoc use of the Huygens uplink carrier signal at 2040 MHz
- 17 radio telescopes around the world
- Salvage of Doppler experiment
  - *Special purpose, narrow band software correlator*

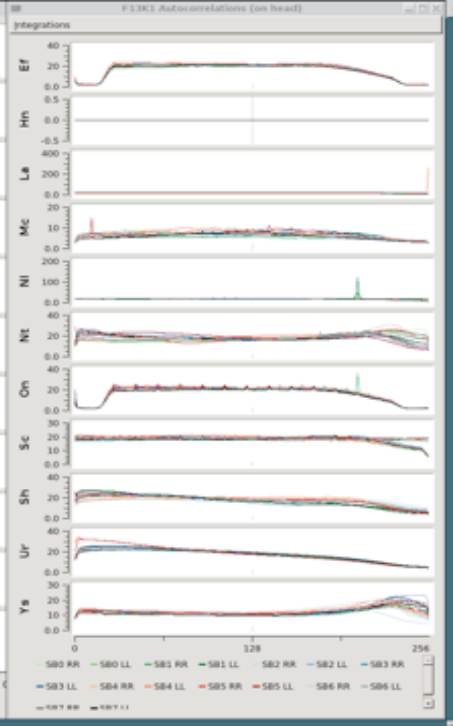
3D Huygens descent trajectory

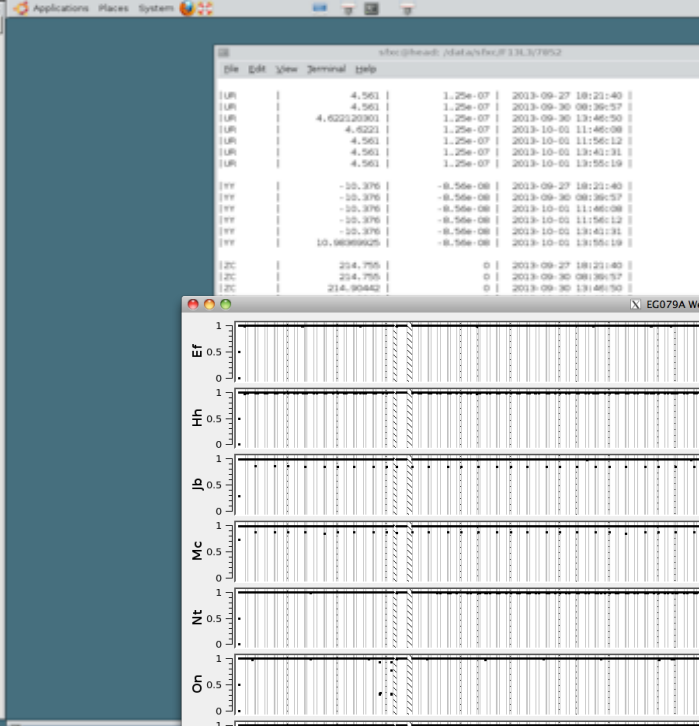


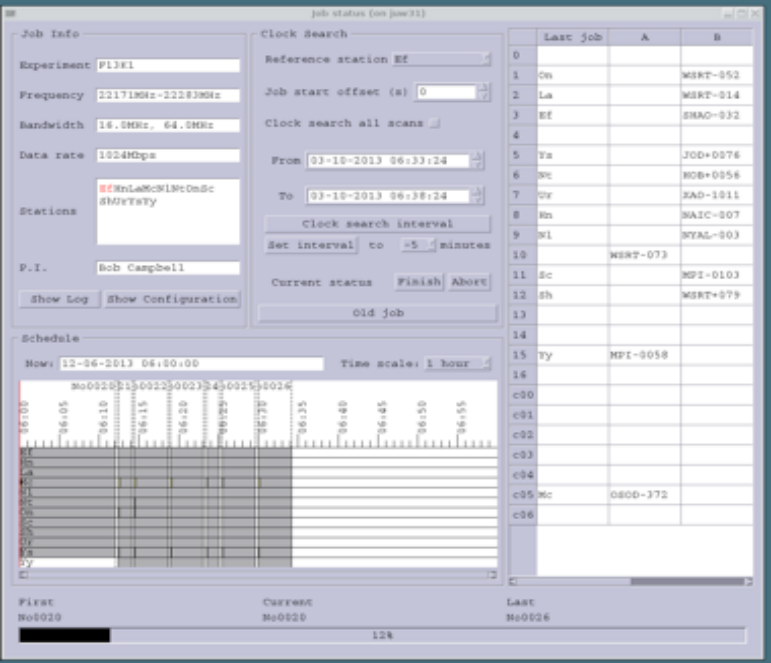
σ_x = 1 km
σ_v = 3 cm/s

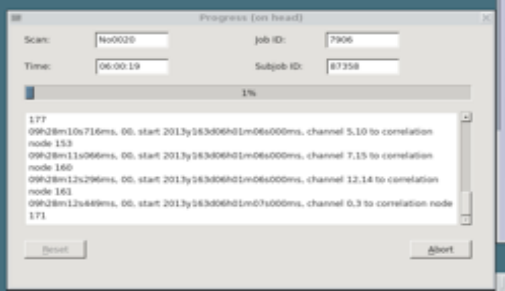

F13K1 Fringes (on head)
Reference Integrations Polarisations Tools
Ef-Hn
Ef-La
Ef-Mc
Ef-Nl
Ef-Nt
Ef-On
Ef-Sc
Ef-Sh
Ef-Ur
Ef-Ys
0
256
512

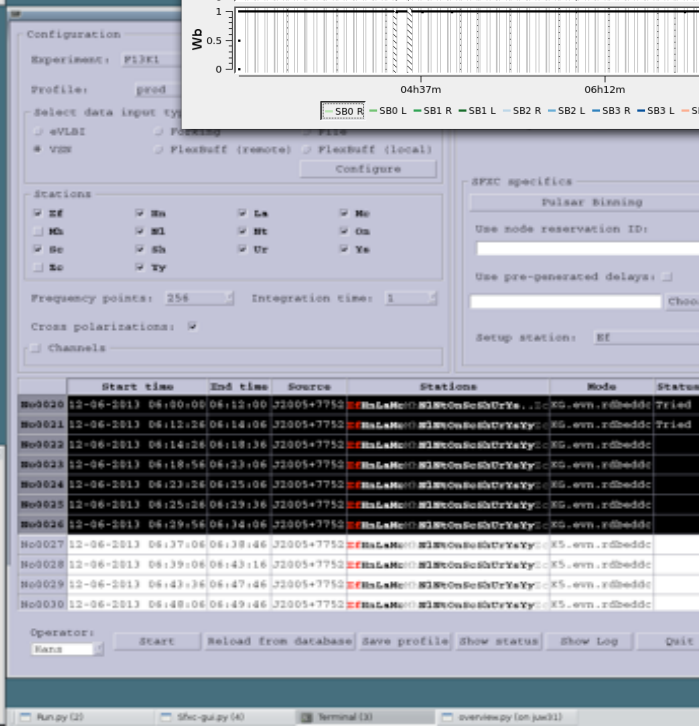

F13K1 Weights (on head)
No0020
Ef
Hn
La
Mc
Nl
Nt
On
Sc
Sh
Ur
Ys
06h00m
06h02m
06h04m
06h06m


F13K1 Autocorrelations (on head)
Integrations
Ef
Hn
La
Mc
Nl
Nt
On
Sc
Sh
Ur
Ys
0
128
256


Applications Places System
sfxc@head: /data/sfxc/F13L3/7952
File Edit View Terminal Help
EG079A W
Ef
Hh
Jb
Mc
Nt
On
Wb
04h37m
06h12m

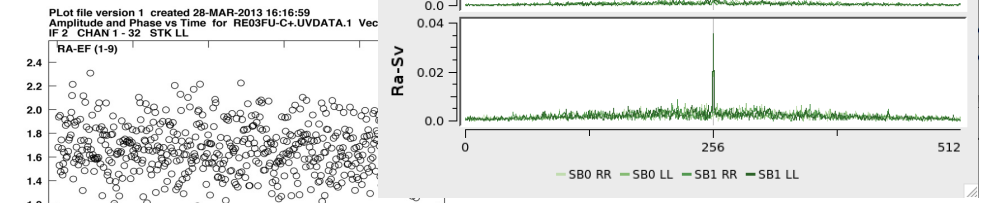

Job status (on jive31)
Job Info
Experiment P13K1
Frequency 2217.0MHz-2228.0MHz
Bandwidth 16.0MHz, 64.0MHz
Data rate 1024Mbps
Stations EfHnLaMcNlNtOnScShUrYsYy
P.I. Bob Campbell
Show Log
Show Configuration
Clock Search
Reference station Ef
Job start offset (s) 0
Clock search all scans
From 03-10-2013 06:33:24
To 03-10-2013 06:38:24
Clock search interval
Set interval to +5 minutes
Current status Finish Abort
Old job
Schedule
Now: 12-06-2013 06:00:00
Time scale: 1 hour
First No0020
Current No0020
Last No0026
12%

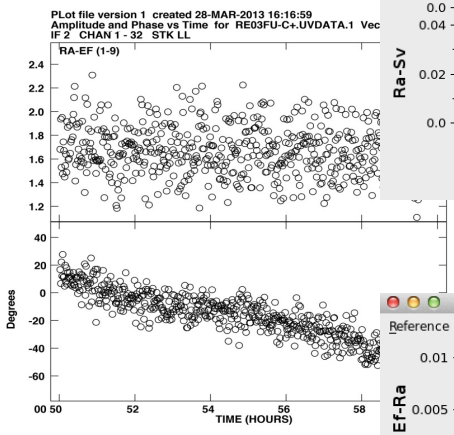

Progress (on head)
Scan: No0020
Job ID: 7906
Time: 06:00:19
Subjob ID: 87358
1%
Reset
Abort


Configuration
Experiment: P13K1
Profile: prod
eVLBI
VSN
FlexBuff (remote)
FlexBuff (local)
Configure
Stations
Frequency points: 256
Integration time: 1
Cross polarizations:
Channels
SFXC specifics
Pulsar Binning
Use node reservation ID:
Use pre-generated delays:
Setup station: Ef
Start time
End time
Source
Stations
Mode
Status
Operator:
Start
Reload from database
Save profile
Show status
Show Log
Quit

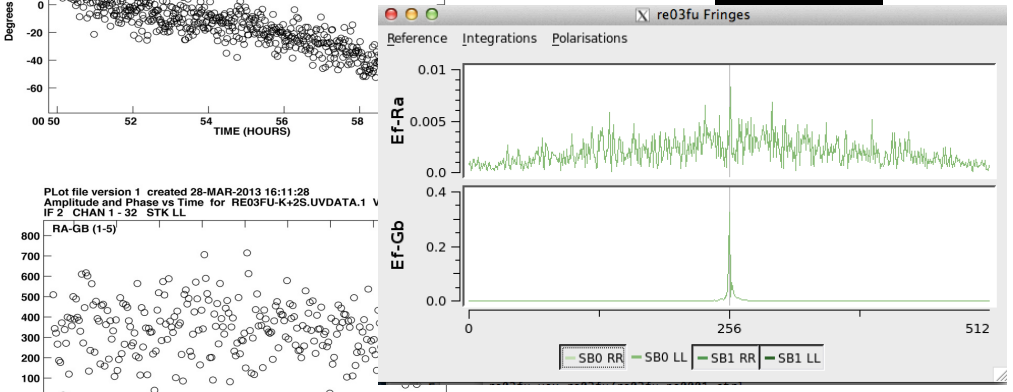
RadioAstron fringes on SFXC at JIVE

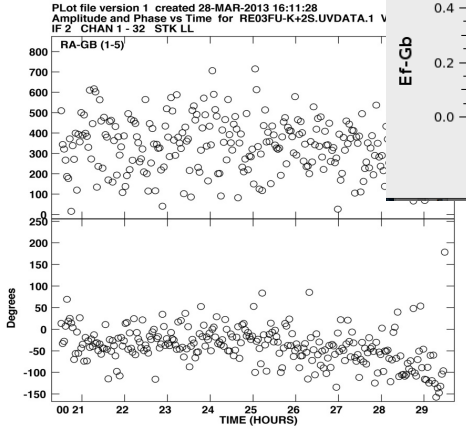
5 GHz





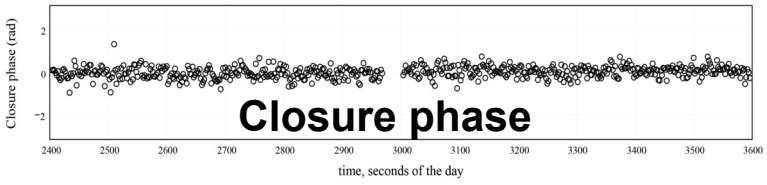
22 GHz



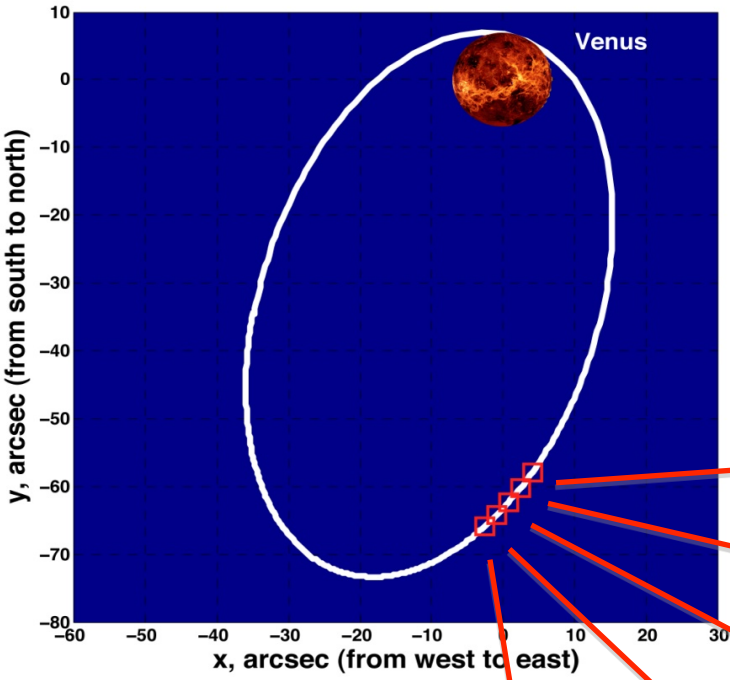


0716+714

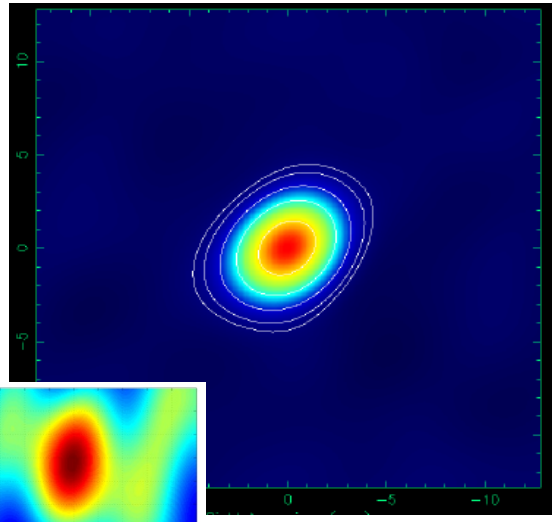
B ≈ 2.5 D_{Earth}



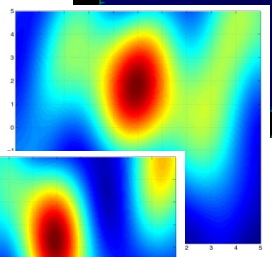
Space Science: tracking of VEX

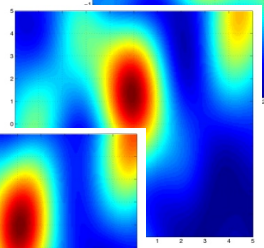


8.4 GHz
2011.03.28

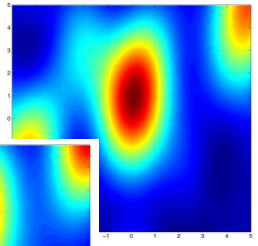


09^h05^m TDB

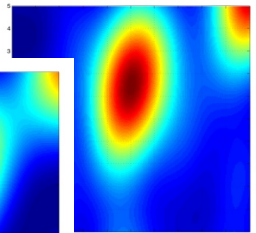




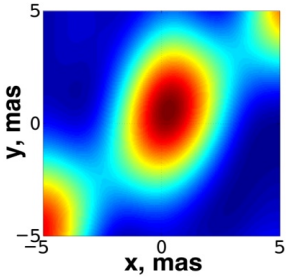
09^h30^m TDB



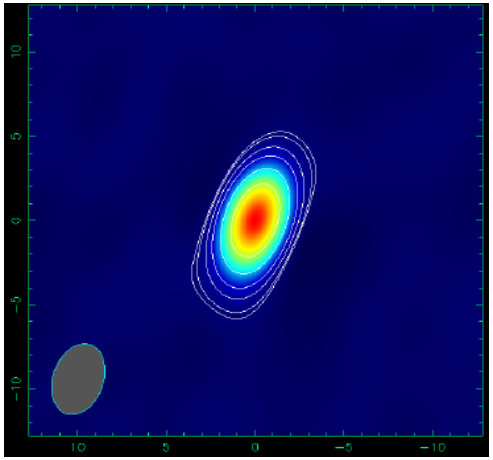
09^h55^m TDB



10^h20^m TDB



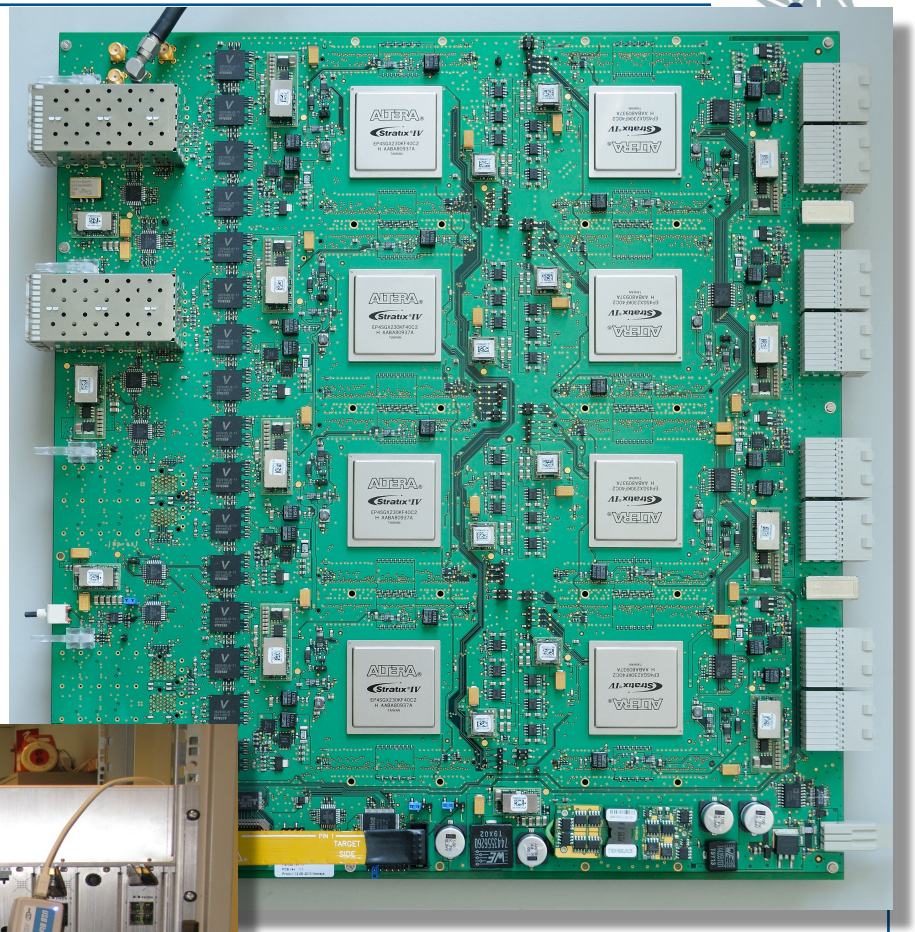
10^h45^m TDB



EM081c: On, Wz, Mc, Ma, Ys, Mh, Sv, Zc

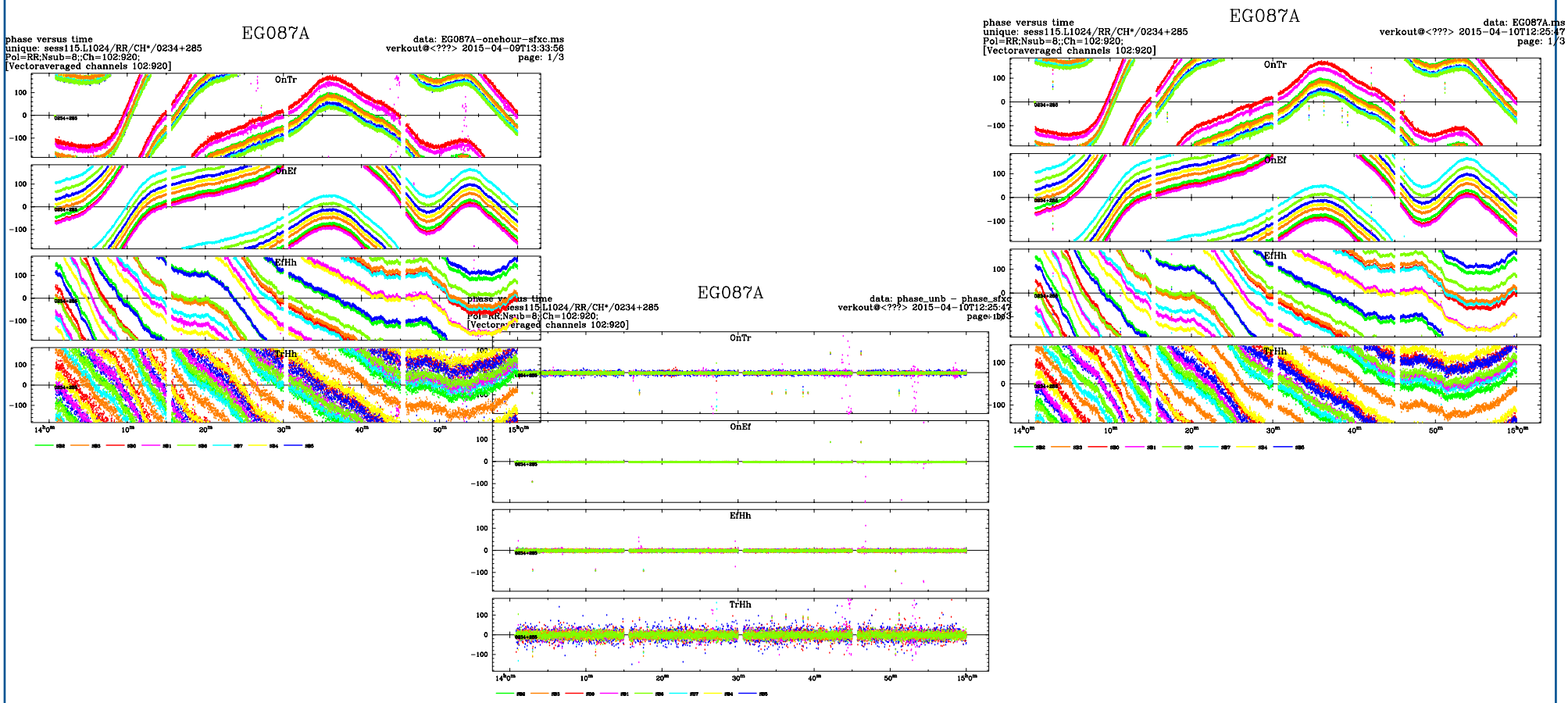
JUC (JIVE UniBoard Correlator)

- UniBoard: EC-funded, led by JIVE
  - JRA in RadioNet FP7 (also in RadioNet3)
  - Create generic, high performance computing platform for radio astronomy
  - ASTRON in charge of hardware development, various partners developing different personalities of board



UniBoard Correlator

- One board roughly equivalent to MarkIV hardware correlator
  - At 250 Watt power consumption…
- Commissioning ongoing



16 stations at 4 Gbps?

- ~13 stations on current SFXC cluster at 1 Gbps
- 16 stations at 4 Gbps: factor of ~5 more hardware needed

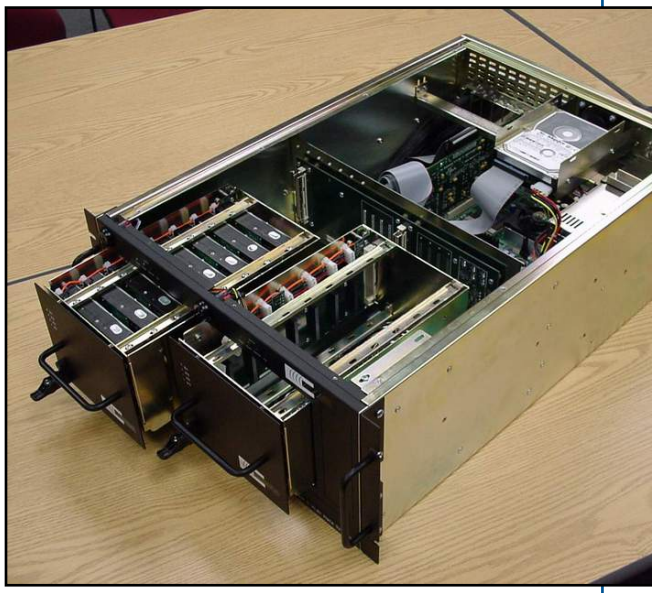
- 16 stations on 2 available UniBoards at 2 Gbps
- 4 Gbps: factor 2

platform	power consumption (kW)	investment (keuro)
SFXC	30	550
UniBoard	1	30

- Somewhat incomplete comparison
  - Software: fantastically flexible, easy to modify, HW getting cheaper as we go along
  - Firmware: very power efficient, once it goes, it goes, but not nearly as flexible, ideal for “simple” things

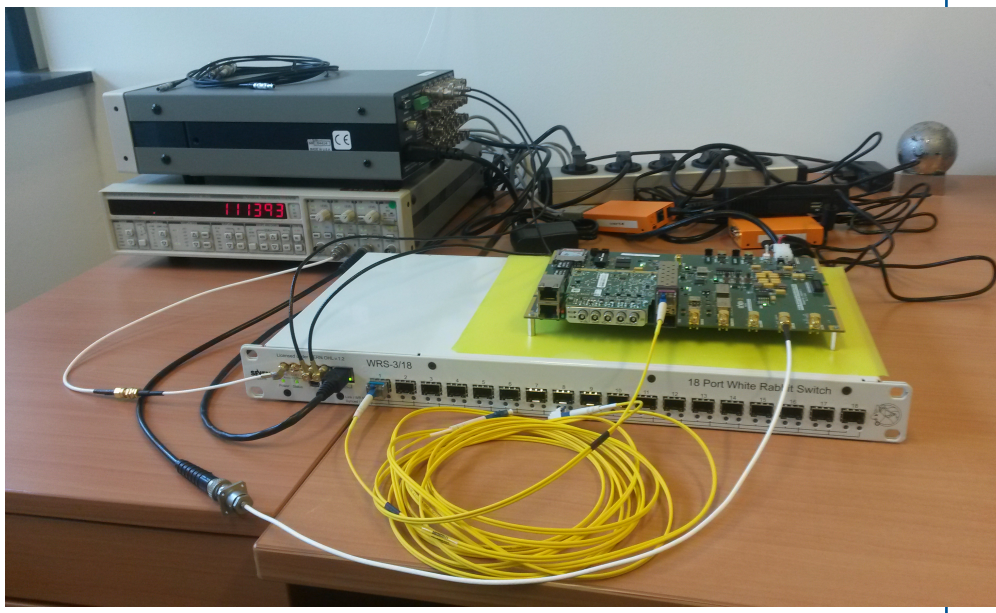
Data recording/transport: Jive5AB

- Original control code not adequate for needs of EVN
  - Full re-write of Mark5 control code
  - Used for all EVN operations, gaining traction in geo community as well
  - Incorporates full Mark5 command set, supports Mark5, Mark6, FlexBuff…
  - Many features; “Swiss army knife of (e)VLBI”
    - Channel dropping, on-the-fly corner turning, sending different chunks of data to different destinations, full VDIF support
  - Made e-VLBI possible at all
  - Enabled semi-automated fringe tests
  - M5Copy: transport any data from anything to anything
    - Choice between TCP, UDP, UDT
  - Essential for automated shipping
  - Future developments in ASTERICS
  - Talks by Rob Eldering and Harro Verkouter



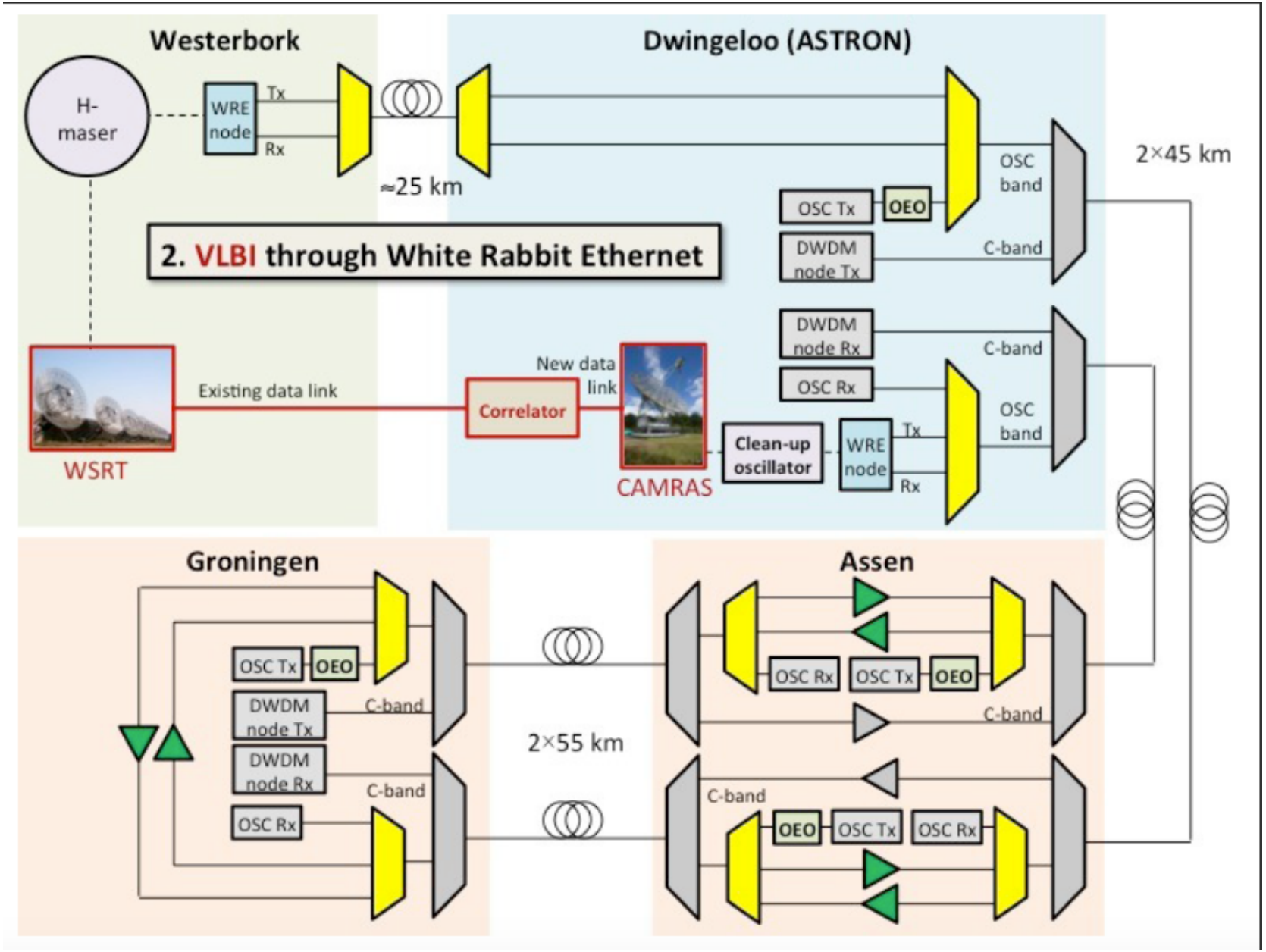
Time and frequency transport: White Rabbit

- SKA:
  - Measure timing performance with WR-ZEN board
  - Test with 10km fibre in climate chamber
  - Test on 24.4 km dark fibre Dwingeloo – WSRT
  - Test on e-Merlin fibre, eventually on Meerkat/ASKAP sites

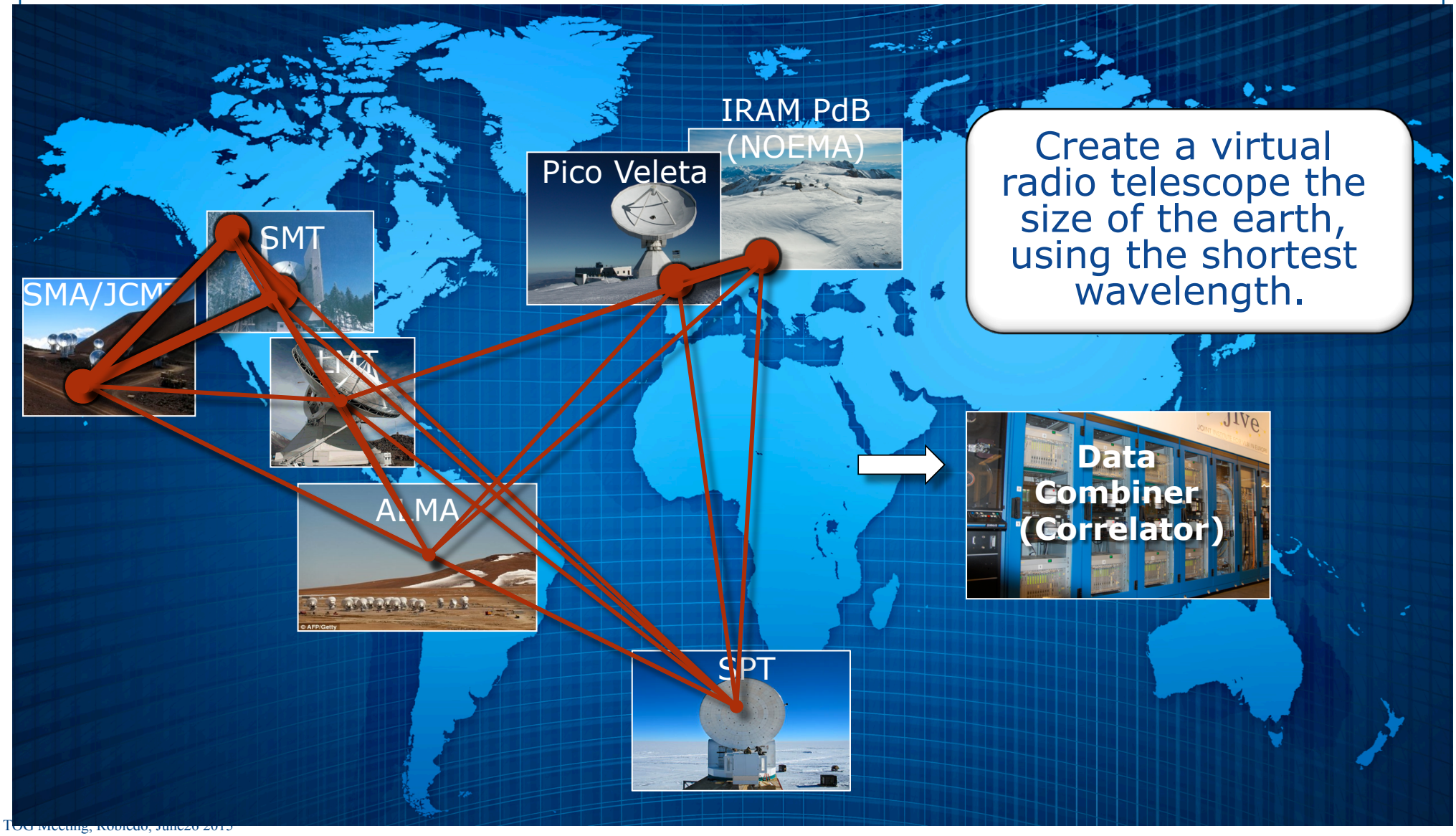


- CLEOPATRA:
  - Verify/demonstrate achieved 10^-13 stability (1s) and 1ns timing performance
    - by showing fringes between WSRT and Dwingeloo dish
  - Transfer of H-Maser signal from the WSRT to Dwingeloo

Frequency transfer demo in CLEOPATRA

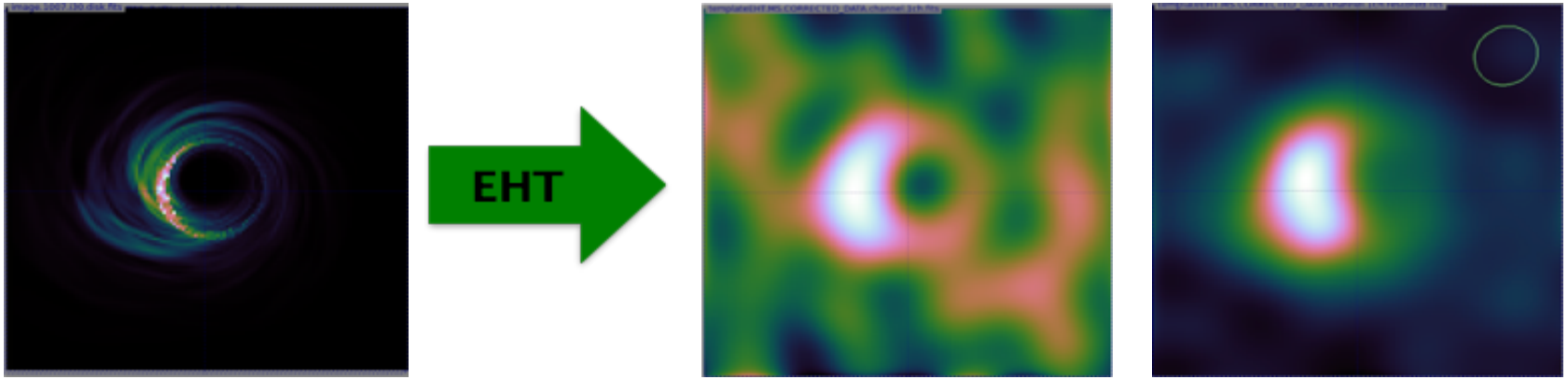


BlackHoleCam and the Event Horizon Telescope



JIVE involvement

- Software pipeline [JIVE]
  - CASA-based fringe-fitter for VLBI
- Array simulation [JIVE, Radboud, Rhodes]
- Robust turn-key VLBI operation [MPIfR, JIVE]



Courtesy: Monika Moscibrodzka, Roger Deane