e-VLBI with the SFXC software correlator

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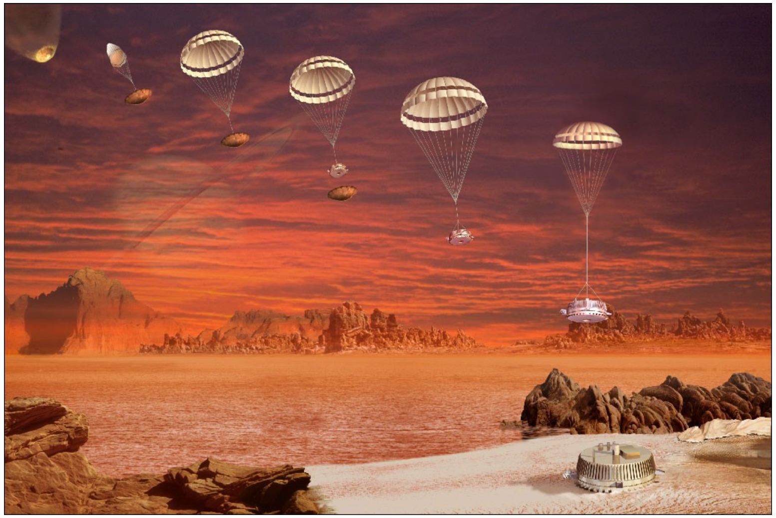
History

C++ implementation of the SFXC correlator used for the Huygens probe tracking.



Super FX Correlator algorithm developed by Sergei Pogrebenko.

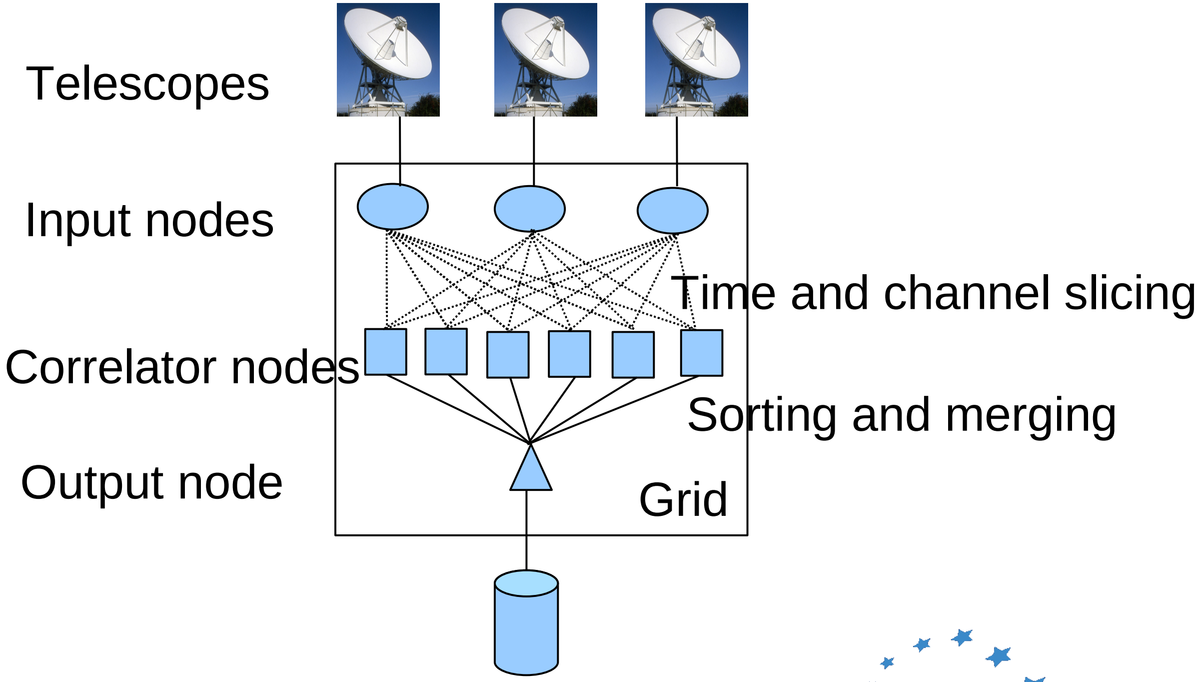
- FX correlator
- Narrow-band, high spectral resolution
- Fractional bit-shift before fringe rotation
- All baselines calculated on a single “node”

- Largely unoptimized
- Correlator core only

Design Decisions

- Parallelisation in both subbands and time.
- All baselines for a single subband processed on a single cluser node.
- Further course grained parallelisation (in time only) to distribute over multiple clusters.

- Input node
  (one per station)
- Correlator node
  (as many as feasable)
- Output node
- Manager node



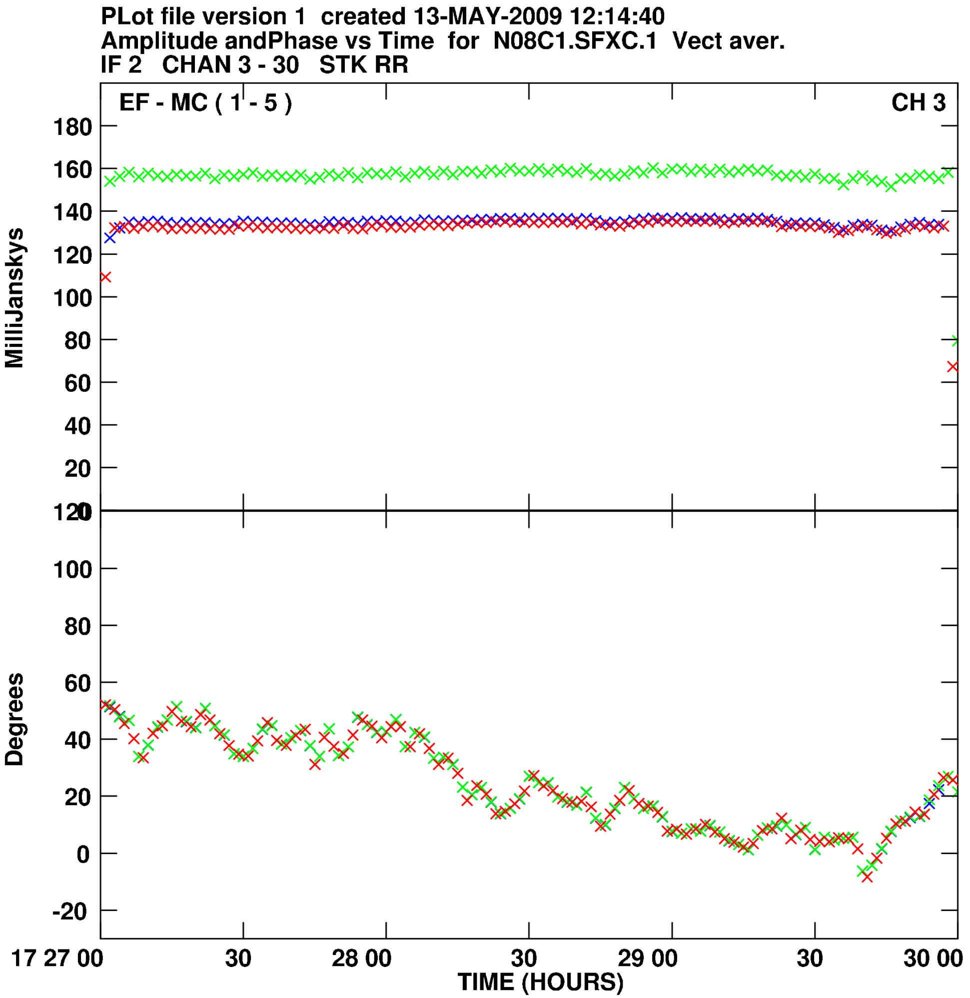
EXPReS

Current State

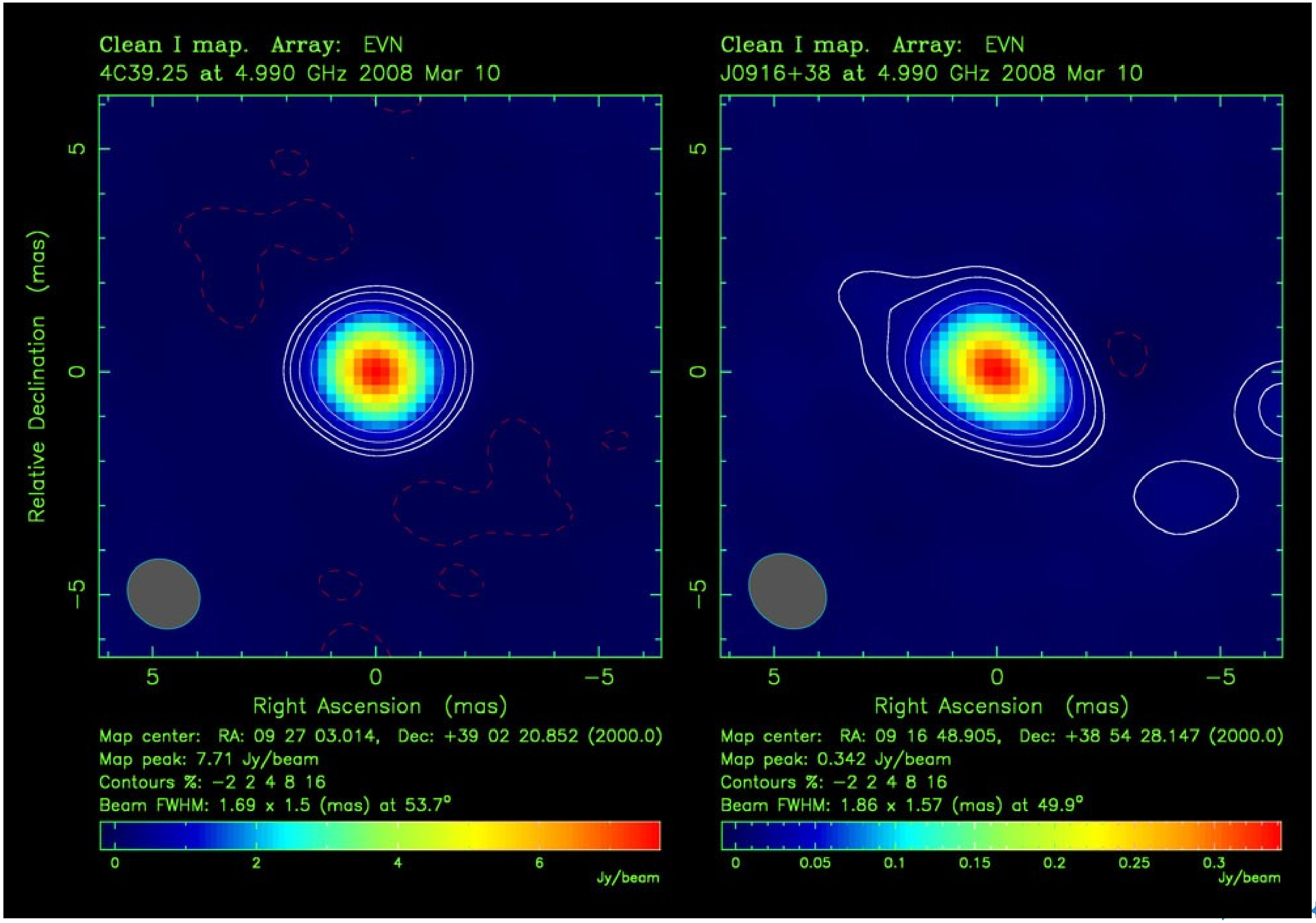
- VEX-driven, with small JSON-based control file specifying correlation parameters.
- Modular: input, correlation and output nodes.
- Parallelized using MPI; distributes subbands and time slices.
- Scales from SMP machines to largish clusters.
- Integrated delay model based on CALC 10.
- All subbands processed, both LSB and USB, cross-correlations.
- Takes Mark4/VLBA (Mark5A) and Mark5B input data.
- Output data can be converted into aips++/CASA MeasurementSet
- Supports both 1-bit and 2-bit samples (and combinations)
- MeasurementSet → FITS IDI using existing tools
- Huge performance increase over the last year!

Validation

- Comparison with the Mk4 Hardware Correlator & DiFX

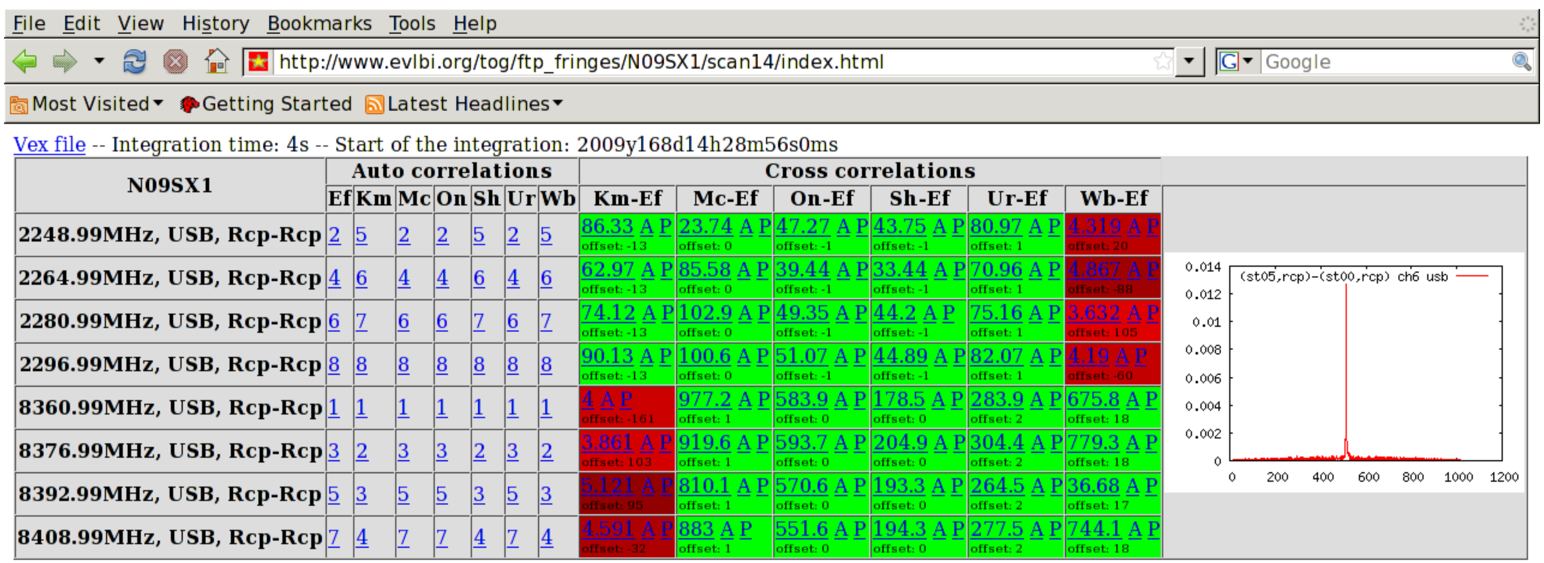


First Image


Clean I map. Array: EVN
4C39.25 at 4.990 GHz 2008 Mar 10
Relative Declination (mas)
Right Ascension (mas)
Map center: RA: 09 27 03.014, Dec: +39 02 20.852 (2000.0)
Map peak: 7.71 Jy/beam
Contours %: −2 2 4 8 16
Beam FWHM: 1.69 x 1.5 (mas) at 53.7°
Jy/beam
Clean I map. Array: EVN
J0916+38 at 4.990 GHz 2008 Mar 10
Right Ascension (mas)
Map center: RA: 09 16 48.905, Dec: +38 54 28.147 (2000.0)
Map peak: 0.342 Jy/beam
Contours %: −2 2 4 8 16
Beam FWHM: 1.86 x 1.57 (mas) at 49.9°
Jy/beam

FTP Fringe Tests

- SFXC used for EVN operation since May 2007
- Interactive web page
- Many changes based on station feedback

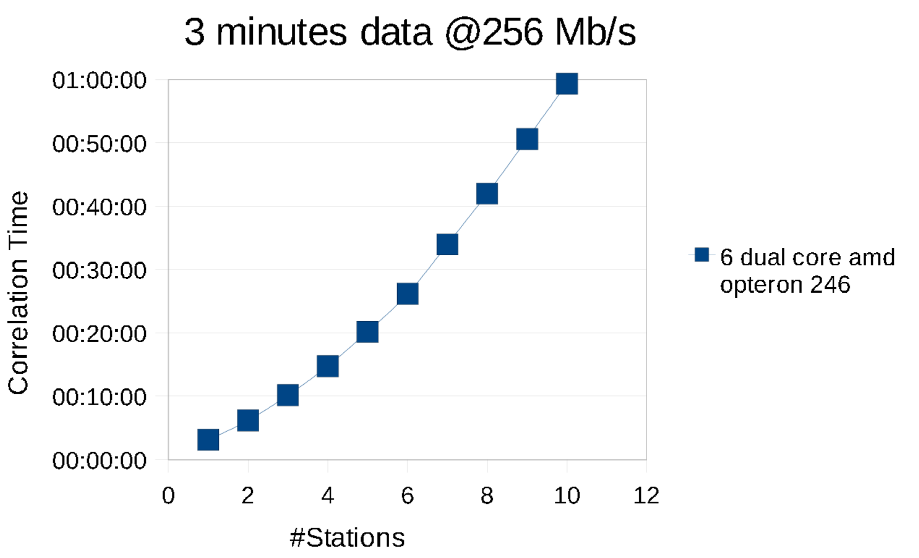


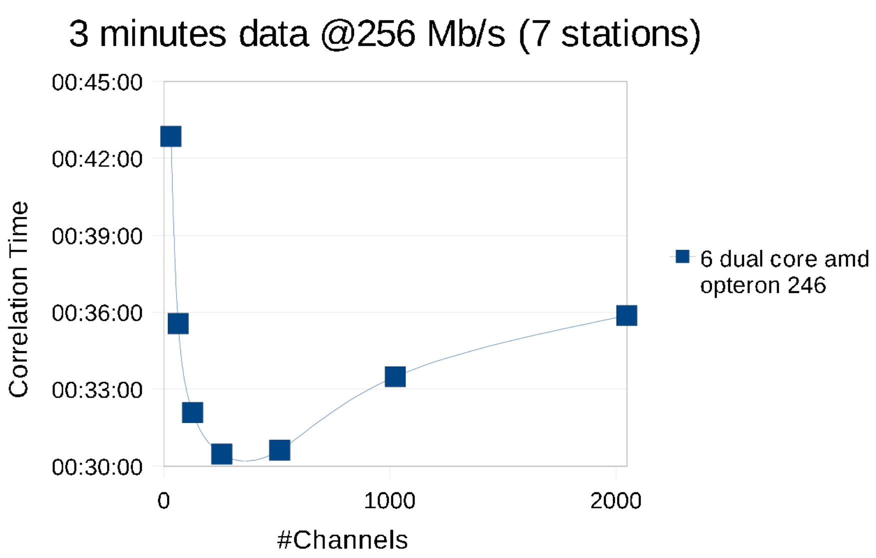
Vex file -- Integration time: 4s -- Start of the integration: 2009y168d14h28m56s0ms

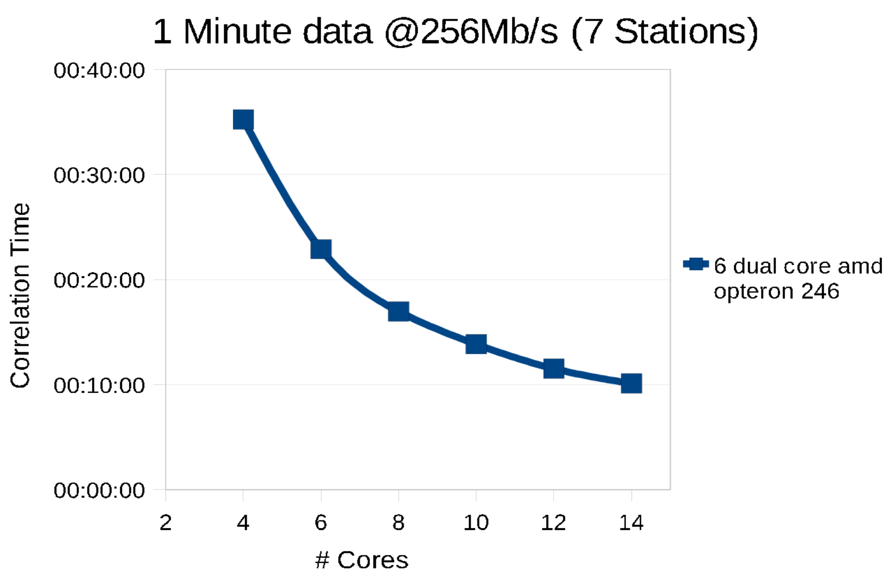
N09SX1	Auto correlations							Cross correlations					
	Ef	Km	Mc	On	Sh	Ur	Wb	Km-Ef	Mc-Ef	On-Ef	Sh-Ef	Ur-Ef	Wb-Ef
2248.99MHz, USB, Rcp-Rcp	2	5	2	2	5	2	5	86.33 A P offset: -13	23.74 A P offset: 0	47.27 A P offset: -1	43.75 A P offset: -1	80.97 A P offset: 1	4.319 A P offset: 20
2264.99MHz, USB, Rcp-Rcp	4	6	4	4	6	4	6	62.97 A P offset: -13	85.58 A P offset: 0	39.44 A P offset: -1	33.44 A P offset: -1	70.96 A P offset: 1	4.867 A P offset: -88
2280.99MHz, USB, Rcp-Rcp	6	7	6	6	7	6	7	74.12 A P offset: -13	102.9 A P offset: 0	49.35 A P offset: -1	44.2 A P offset: -1	75.16 A P offset: 1	3.632 A P offset: 105
2296.99MHz, USB, Rcp-Rcp	8	8	8	8	8	8	8	90.13 A P offset: -13	100.6 A P offset: 0	51.07 A P offset: -1	44.89 A P offset: -1	82.07 A P offset: 1	4.19 A P offset: -60
8360.99MHz, USB, Rcp-Rcp	1	1	1	1	1	1	1	4 A P offset: -161	977.2 A P offset: 1	583.9 A P offset: 0	178.5 A P offset: 0	283.9 A P offset: 2	675.8 A P offset: 18
8376.99MHz, USB, Rcp-Rcp	3	2	3	3	2	3	2	3.861 A P offset: 103	919.6 A P offset: 1	593.7 A P offset: 0	204.9 A P offset: 0	304.4 A P offset: 2	779.3 A P offset: 18
8392.99MHz, USB, Rcp-Rcp	5	3	5	5	3	5	3	5.121 A P offset: 95	810.1 A P offset: 1	570.6 A P offset: 0	193.3 A P offset: 0	264.5 A P offset: 2	36.68 A P offset: 17
8408.99MHz, USB, Rcp-Rcp	7	4	7	7	4	7	4	4.591 A P offset: -32	883 A P offset: 1	551.6 A P offset: 0	194.3 A P offset: 0	277.5 A P offset: 2	744.1 A P offset: 18

Performance

- Benchmarks done on 6-node cluster
- Dual Opteron 246 machines (2 GHz)
- Performance comparable with DiFX







EXPReS

Correlation on GPUs?

- Initial attempt: offload FFTs on GPU:
  Improvement less than a factor of 2.

  Too much data transfer between main memory and GPU?

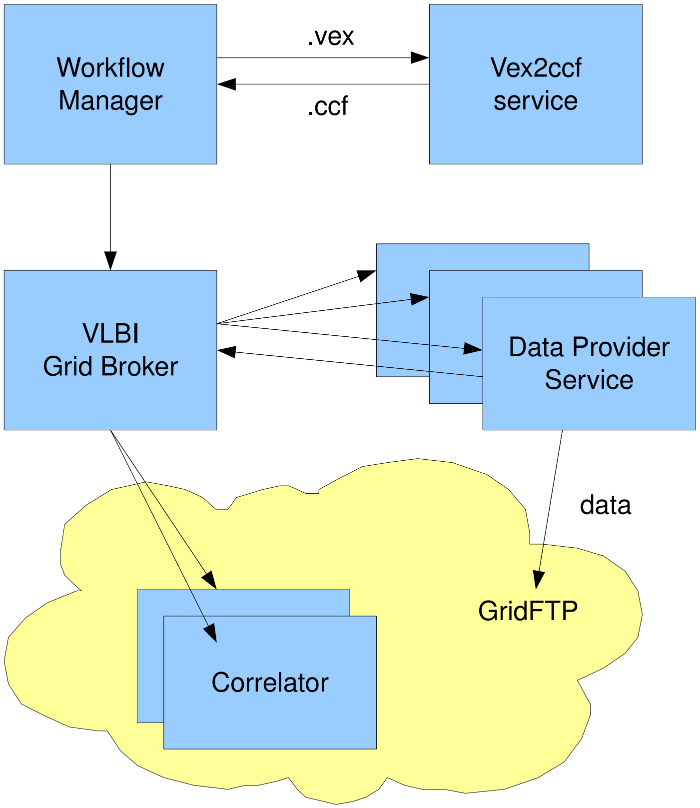
- Second attempt:implement full delay compensation and correlation on GPU:
  Using CUDA, work in progress.

- NVIDIA Tesla C870 with 1.5GB of memory

Distributed Correlation

Running a single correlation on multiple clusters

- Workflow Manager (PSNC)
- VLBI Grid broker (PSNC)
- Web Services (SOAP)
  - vex2ccf: Creates control file template from VEX
  - Data providers: Provides chunks of data and transfers them to GridFTP servers.



Implies staged correlation (uncorrelated data hits disk)

Distributed Correlation

Distributed correlation works:

- Succesful correlation done on two clusters in Poznan
- Third cluster @JIVE being added

But:

- Grid certificates don’t fit our community; use ssh instead.
- Existing HPC clusters are not necessarily suitable:
    - NFS performance problems.
    - Job scheduling seems to favour small jobs.
    - Libraries not always present.
    - Infiniband MPI implementations can be quirky.

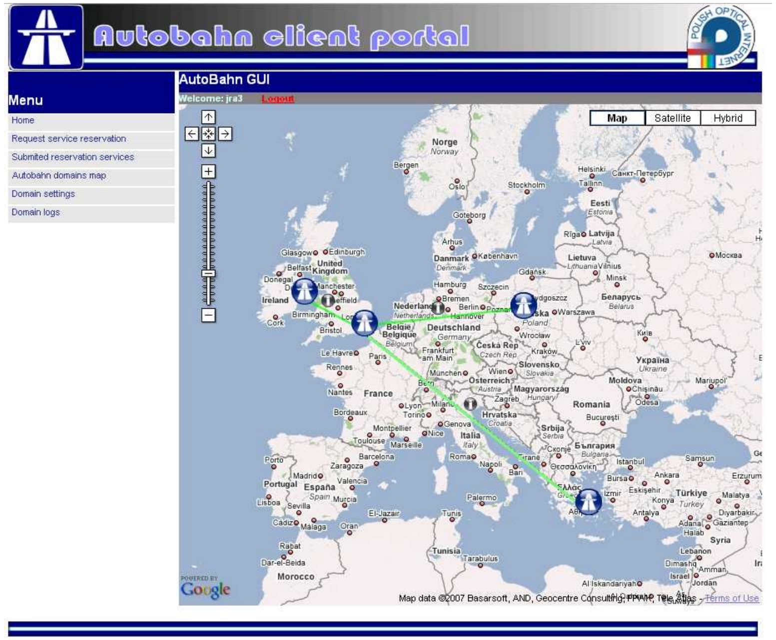
AutoBAHN

- JRA within GEANT2 developing a bandwidth-on-demand facility across domains

- Implemented by NRENs of Greece, Ireland, Poland and Croatia, using the GEANT2 testbed
- More NRENs working on deployment (but not SURFNet?)

- Interfaces to other BoD-systems being developed (Internet2).

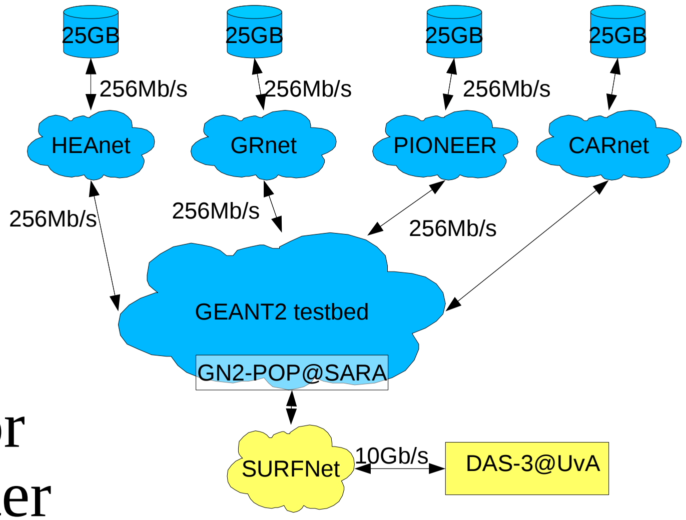
- Two ways of making reservations:
  - Interactive through web interface
  - Using a webservice



Using AutoBAHN for eVLBI

Interesting for several reasons:

- Many arrays don't observe 24/7
- Correlators in different locations
- Reduce cost?



Successfully demonstrated at SC08:

- Circuits configured directly by correlator
- Data streamed directly into DAS-3 cluster
- Also included data from Boston through Internet2 DCN

Future Development

- Pulsar Binning
- Finish GPU evaluation
- Add VDIF support
- Add jive5a support

Conclusions

- SFXC is ready to do real science.
- AutoBAHN is a promising technology.
- Can't run on just any cluster.
- Offloading FFTs on GPU is not worth it.

Thanks

- The GEANT2 AutoBAHN team
- Dominik Stoklosa, Marcin Okon and everybody else involved in FABRIC at PSNC