Recent developments at JIVE

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JIVE
Joint Institute for VLBI
ERIC

EUROPEAN vlbi NETWORK

SFXC

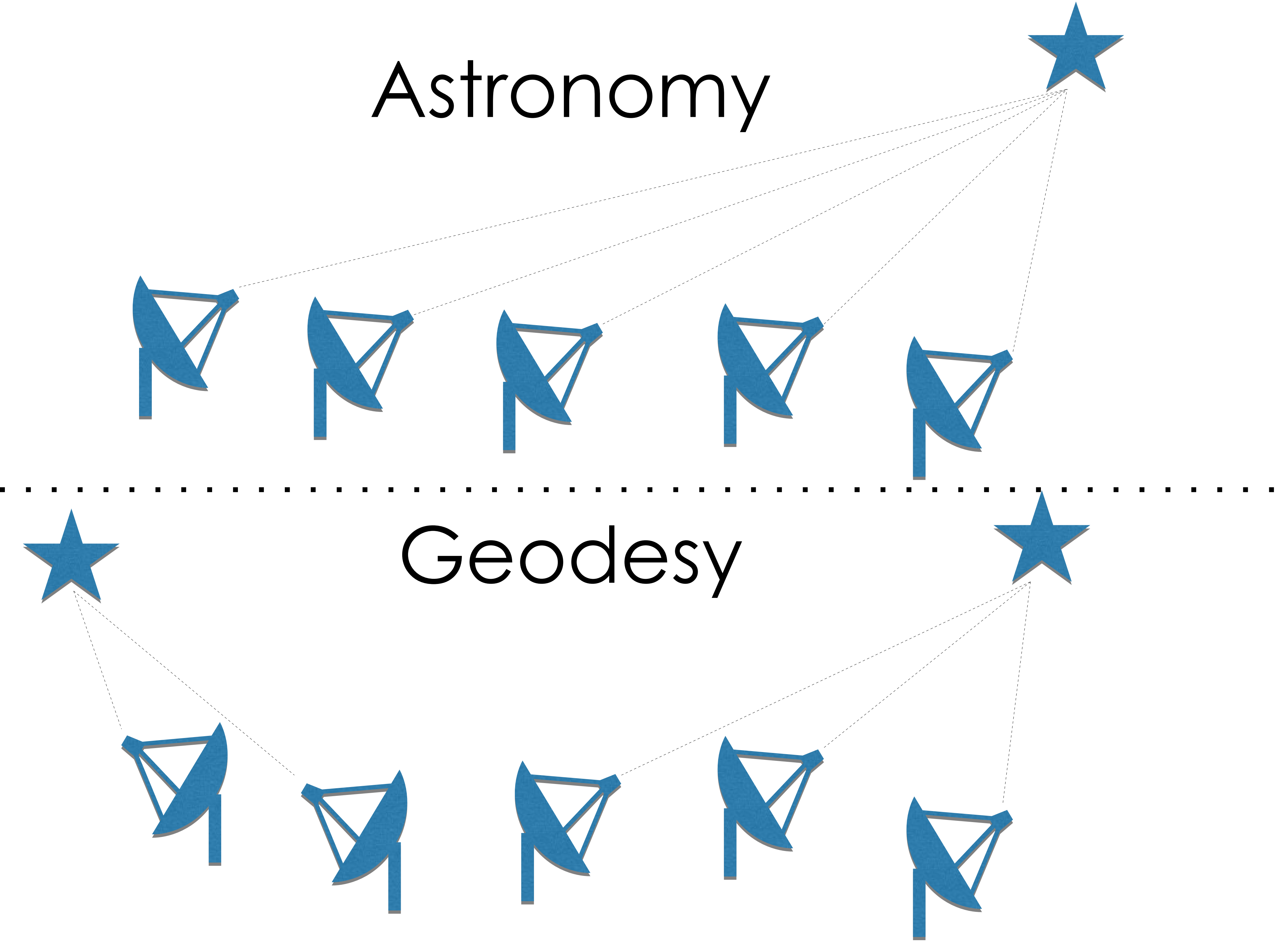
- MPI application written in C++
- EVN correlator since 2010, replaced MkIV completely in 2012
- Delay model: CALC10 or external
- Rich set of features
  - Multiple simultaneous phase centers
  - Pulsar binning + coherent dedispersion
  - Mixed-bandwidth correlation
  - New: Support for Geodetic VLBI
- Nightly mirror of development repo:

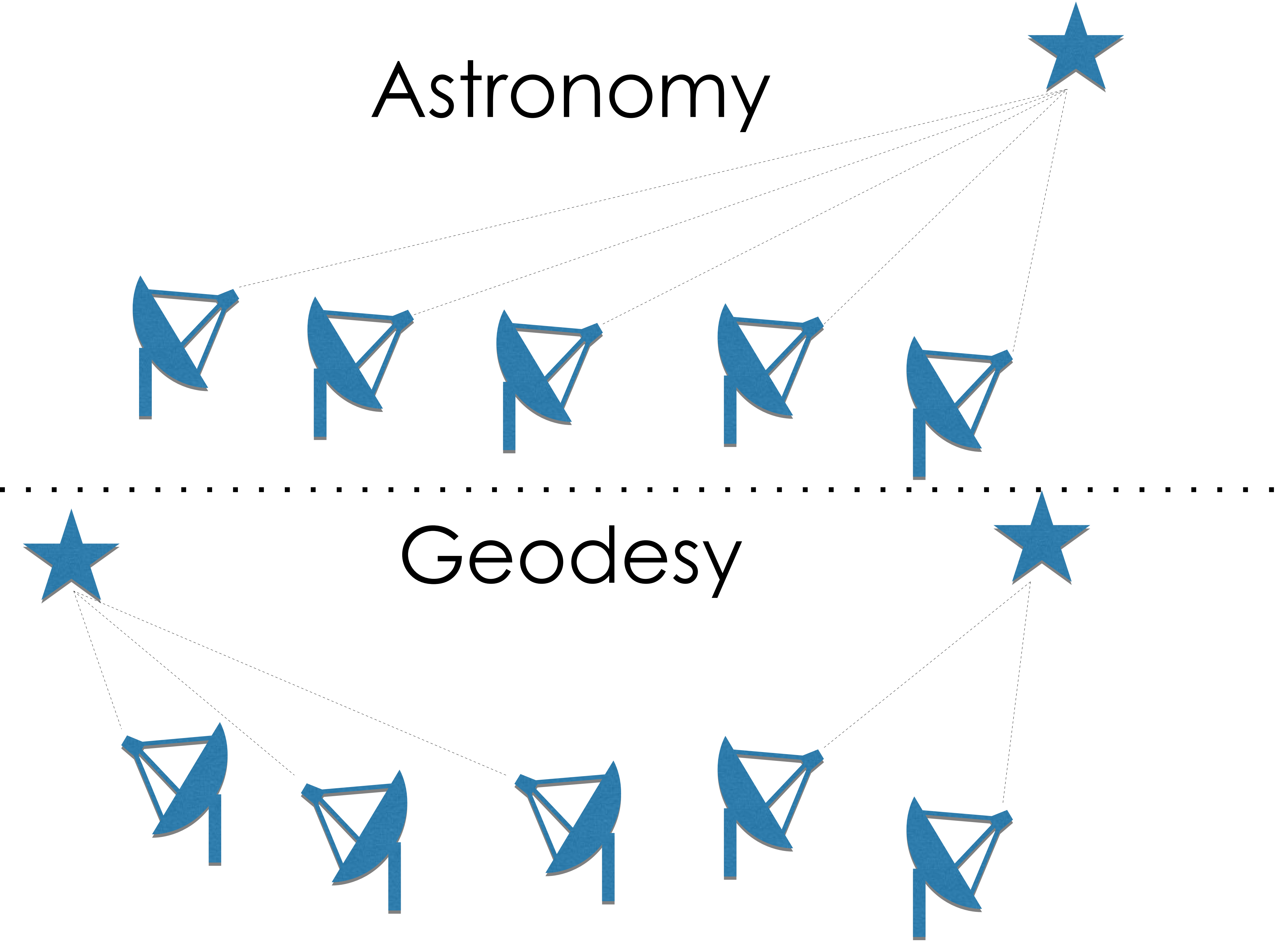
  Official: https://svn.astron.nl/sfxc Unofficial: https://github.com/aardk/sfxc
- Installation instructions:

  http://www.jive.nl/jivewiki/doku.php?id=sfxc

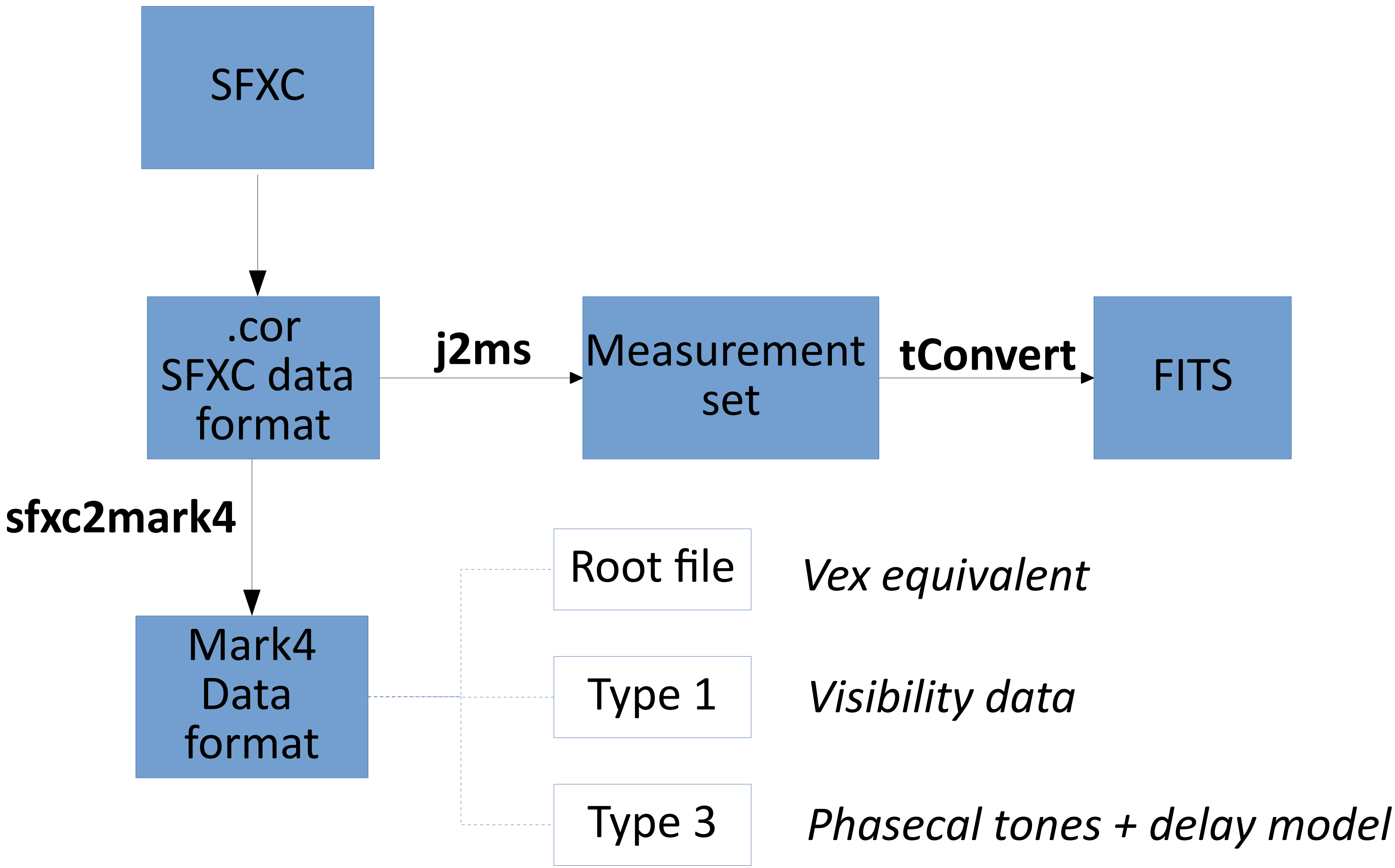
SFXC is Open Source software available under GPL version 2 or later

Keimpema, Kettenis, Pogrebenko, et al., Experimental Astronomy, ***39****, 259 (2015)*
arXiv:1502.00467


Astronomy
Geodesy


Astronomy
Geodesy

sfxc2mark4

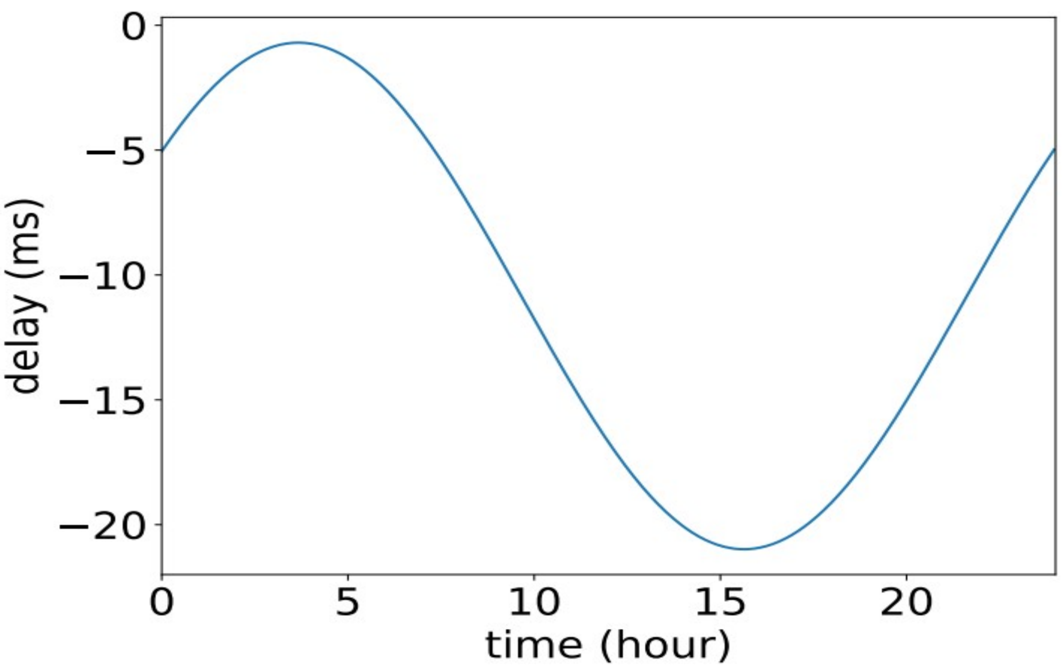

SFXC
.cor
SFXC data
format
j2ms
Measurement
set
tConvert
FITS
sfxc2mark4
Mark4
Data
format
Root file
Type 1
Type 3
Vex equivalent
Visibility data
Phasecal tones + delay model

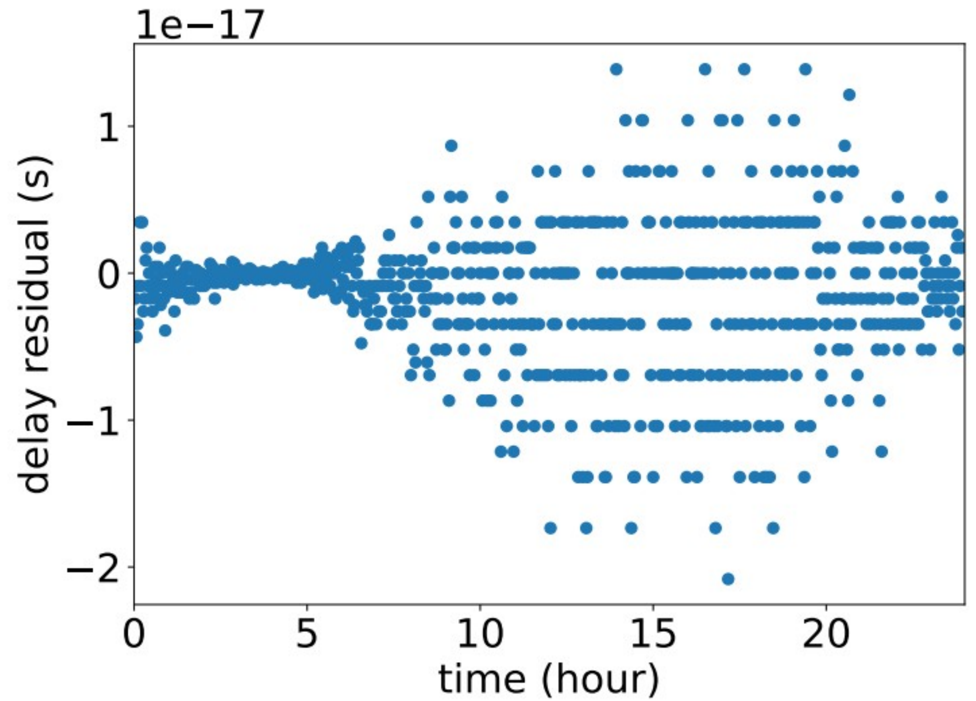
Correlator Model

SFXC	DifX/HOPS/AIPS
sampled every second	spanning a few minutes
interpolated using Akima spline	polynomial of (up to) degree 5

- Sample Akima splines
- Fit polynomial of degree 5 over time intervals, default interval: 120 sec
- Implemented using NumPy / SciPy

Correlator model





More verification in Maria Eugenia Gomez's talk

Building up the cluster

Year	Nodes	CPUs	SIMD	Clockspeed (GHz)	Cores	Stations @1Gb/s
2010	16	Xeon E5520	SSE 4.2	2.3	128	?
2011	16	Xeon E5620	SSE 4.2	2.4	128	7
2012	8	Xeon E5-2670	AVX	2.6	128	13
2015	4	Xeon E5-2630v3	AVX2	2.4	64	16
2016	4	Xeon E5-2630v3	AVX2	2.4	64	19
2018	42	Xeon E5-2630v4	AVX2	2.2	840	12 x 4Gpbs
Total	90				1352	

Building up the cluster

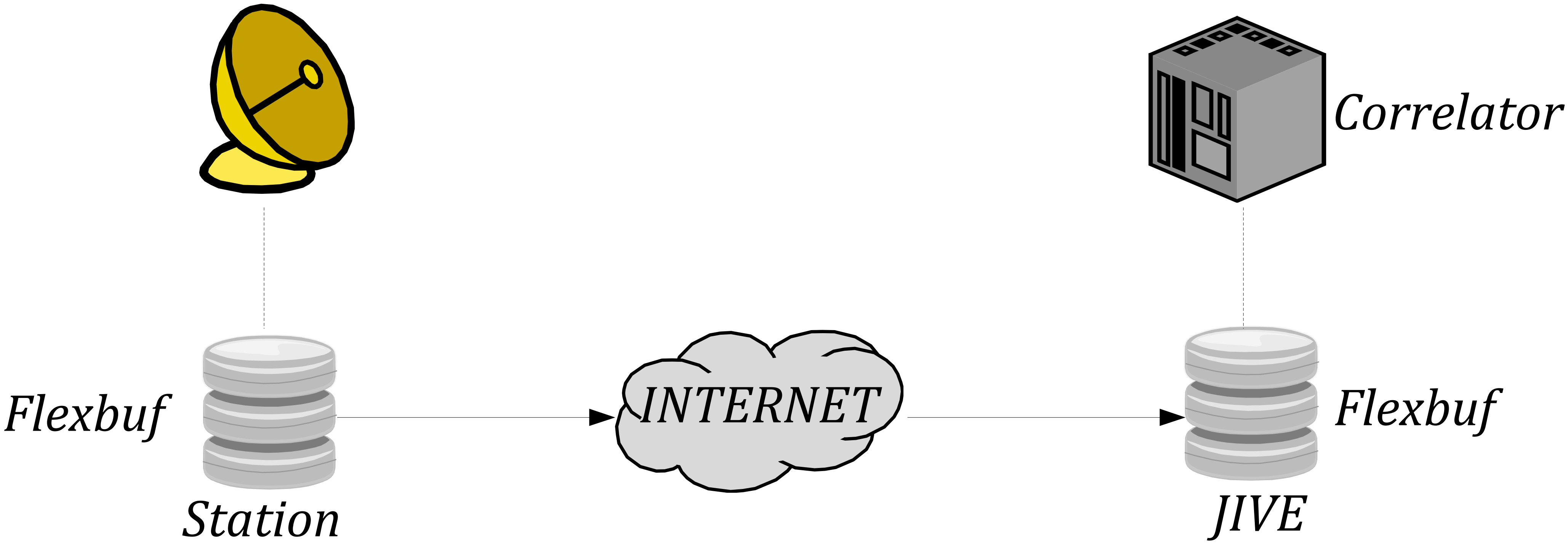
Year	Nodes	CPUs	SIMD	Clockspeed (GHz)	Cores	Stations @1Gb/s
2010	~~16~~ 10	Xeon E5520	SSE 4.2	2.3	~~128~~ 80	?
2011	16	Xeon E5620	SSE 4.2	2.4	128	7
2012	8	Xeon E5-2670	AVX	2.6	128	13
2015	4	Xeon E5-2630v3	AVX2	2.4	64	16
2016	4	Xeon E5-2630v3	AVX2	2.4	64	19
2018	42	Xeon E5-2630v4	AVX2	2.2	840	11 x 4 Gbps
Total	84				1304	


Flexbufs
Old compute nodes (512 cores)
4x Melanox SN2100
HP5412ZL Switch
Flexbufs
New compute nodes (840 cores)

Storage

- 17 Mark5A/B units
- 6 Mark5C units
- 2 Mark6; 2 x (master + slave)
- 14 Flexbuf units
  - almost 3 PB RAID-Z storage
  - e-shipping from most EVN stations
  - Wb records directly to Flexbuf @JIVE

Flexbuf transition



- During observation data is recorded on local flexbuff at the station
- Data is transferred to flexbuff at JIVE for correlation
- For each station there is a corresponding flexbuff at JIVE
- Raw data is kept for one additional session after correlation
- Currently 14 flexbuffs at JIVE

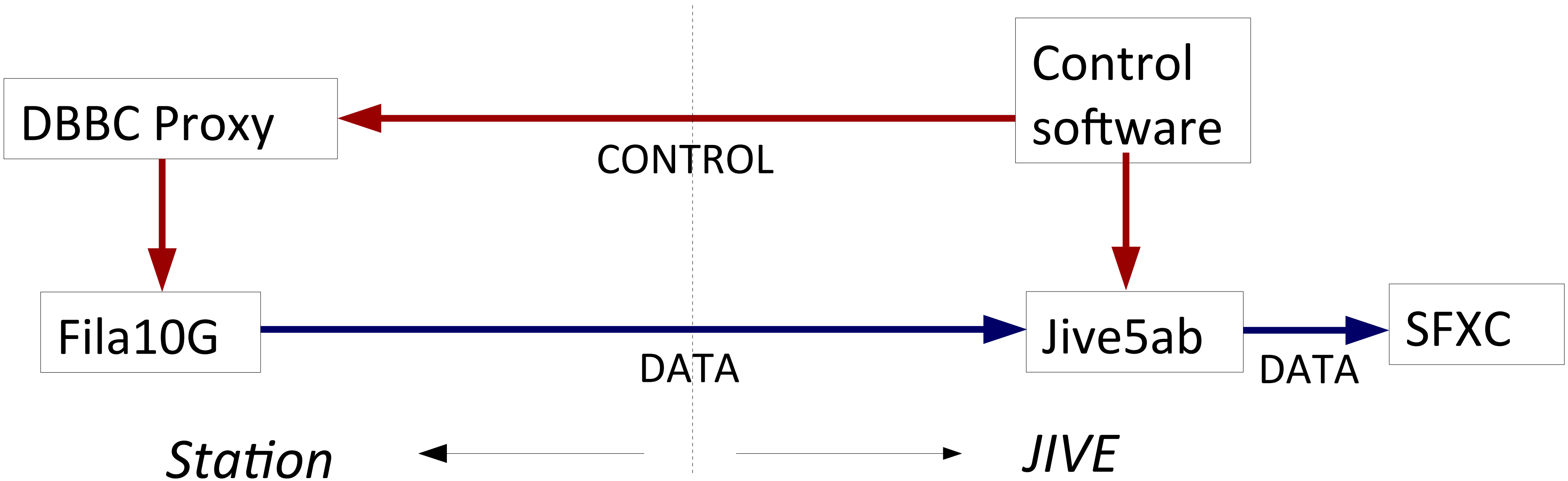
Realtime eVLBI at JIVE

- About 23-30% of EVN observing time
- Advantages of eVLBI
  - Reliability, online monitoring
  - Low latency from observation to distribution to PI
  - Rapid response
    - (Automatic) triggered observations
    - Target of opportunity
- Typical observation size is 10-11 stations
- EVN now defaults to 2 Gbps eVLBI (C band and higher), 4 Gbps after network upgrade (30 Gbps → 100 Gbps)
- Simultaneous correlation and recording on Flexbuff

e-EVN

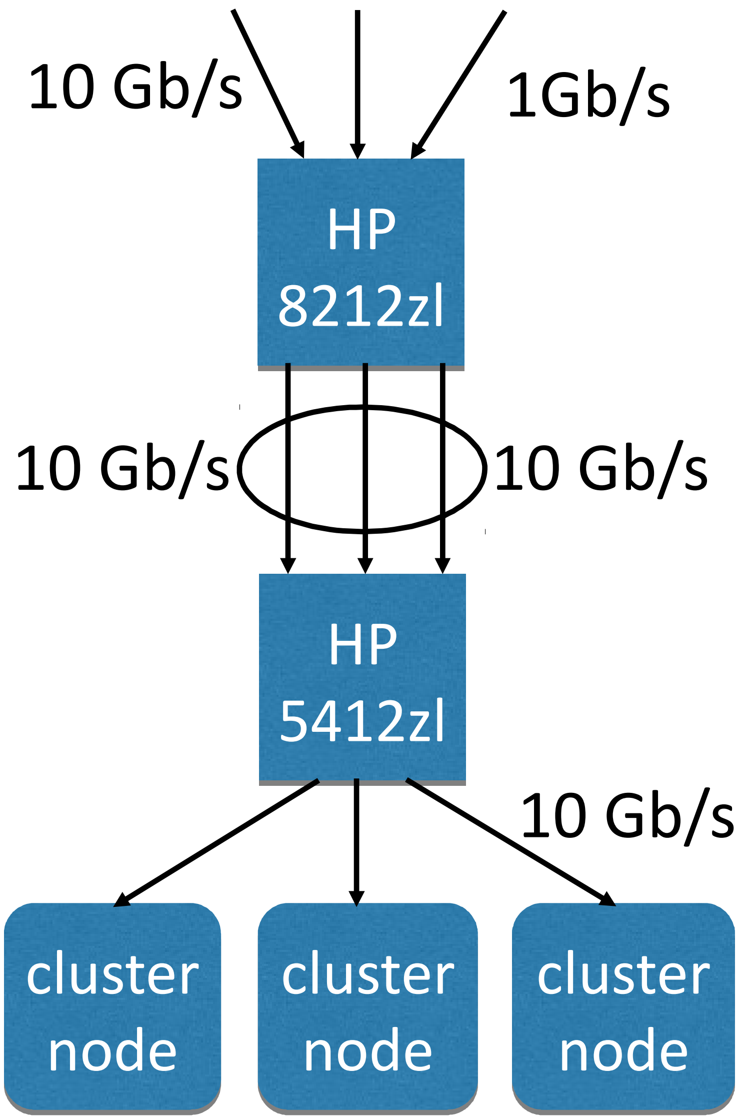
Station	Bandwidth	Type	Fila10G
Arecibo	512 Mbps	Routed	No
Effelsberg	4 Gbps	Lightpath	Yes
HartRAO	2 Gbps	Lightpath	Yes
Irbene	4 Gbps	Lightpath	Yes
Jodrell Bank	4 Gbps	Dedicated	Yes
Metsahovi	4 Gbps	Routed	Yes (?)
Medicina	4 Gbps	Routed	Yes
Noto	4 Gbps	Routed	Yes
Onsala	4 Gbps	Lightpath	Yes
Shanghai / Tianma65	1 Gbps	Routed	Yes
Torun	1 Gbps	Routed	No
Westerbork	2 Gbps	Dedicated	Yes
Yebes	4 Gbps	Routed	Yes

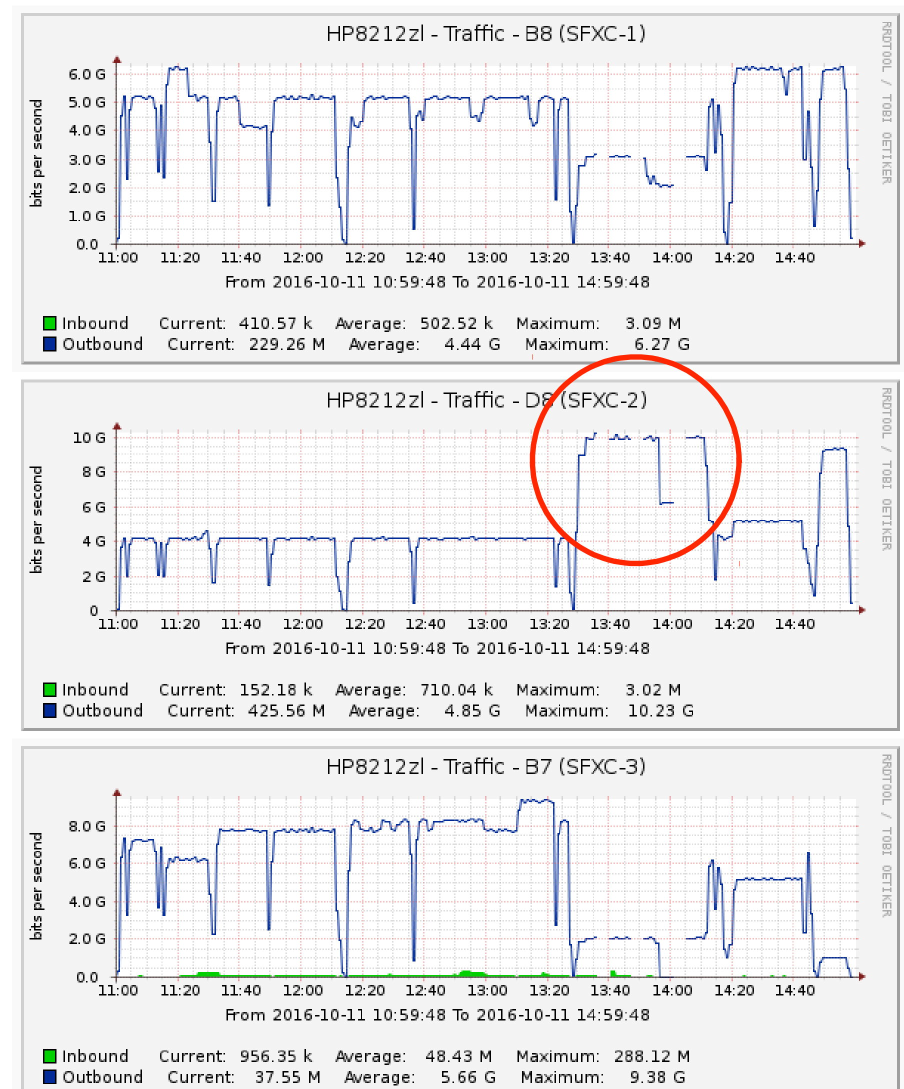
eVLBI data flow



- DBBC proxy APU allows communication with Fila10G
- Fila10G sends UDP data stream (typical 8032 byte packet size)
- One UDP packet = one VDIF frame
- Jive5ab detaches the data stream from the correlation, correlation continues if data stream stops
- **4 Gbps maximum data rate**

Internal Network Bottleneck





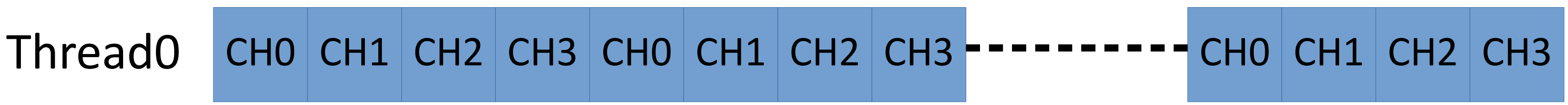
Scalability DBBC3 (32 Gbps)

- EVN personality: 2 x 4 GHz IF (=2 x 16 Gbps)
- How to divide data?

More is better!

Scalability DBBC3 (32 Gbps)

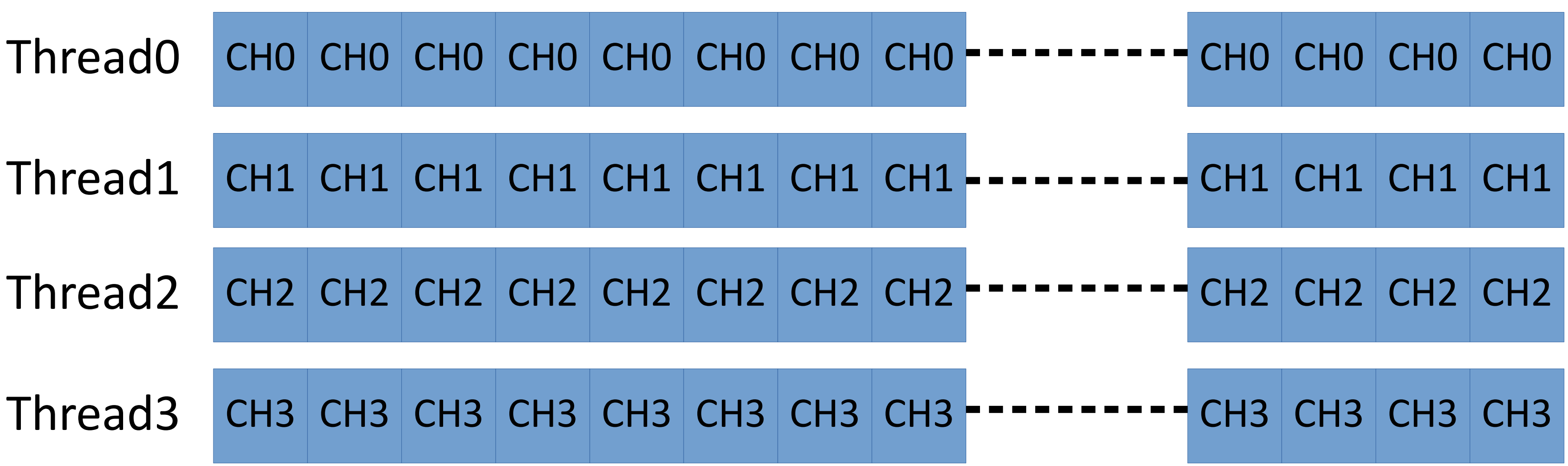
- Single threaded VDIF



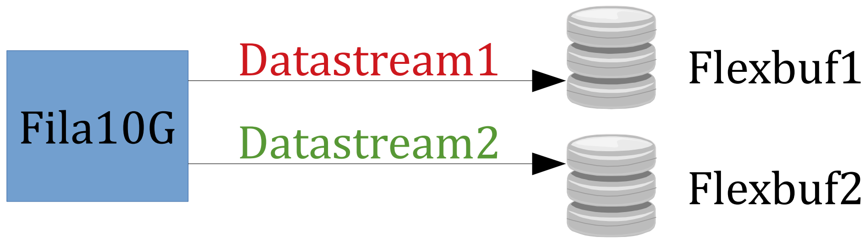
Requires expensive corner turning

VS

- Multi threaded VDIF



Multiple Data Streams



- To prevent networking / computation bottlenecks the data is split into multiple (typically 2 Gbps) datastreams
- Each data stream is handled by a seperate input node
- Supported in VEX2:

```
$DATASTREAMS;
*
def DVP;
  datastream = &DS1 : VDIF_legacy;
  thread = &DS1 : &THR1 : 0 : 32 : 8 Ms/sec : 2 : real : 8000;
  channel = &DS1 : &THR1 : &CH00 :  0;
  channel = &DS1 : &THR1 : &CH01 :  1;
  …
  channel = &DS1 : &THR1 : &CH15 : 15;
  datastream = &DS2 : VDIF_legacy;
  thread = &DS2 : &THR2 : 0 : 32 : 8 Ms/sec : 2 : real : 8000;
  channel = &DS2 : &THR2 : &CH16 : 16;
  channel = &DS2 : &THR2 : &CH17 : 17;
  …
  channel = &DS2 : &THR2 : &CH31 : 31;
enddef;
```

CASA transition

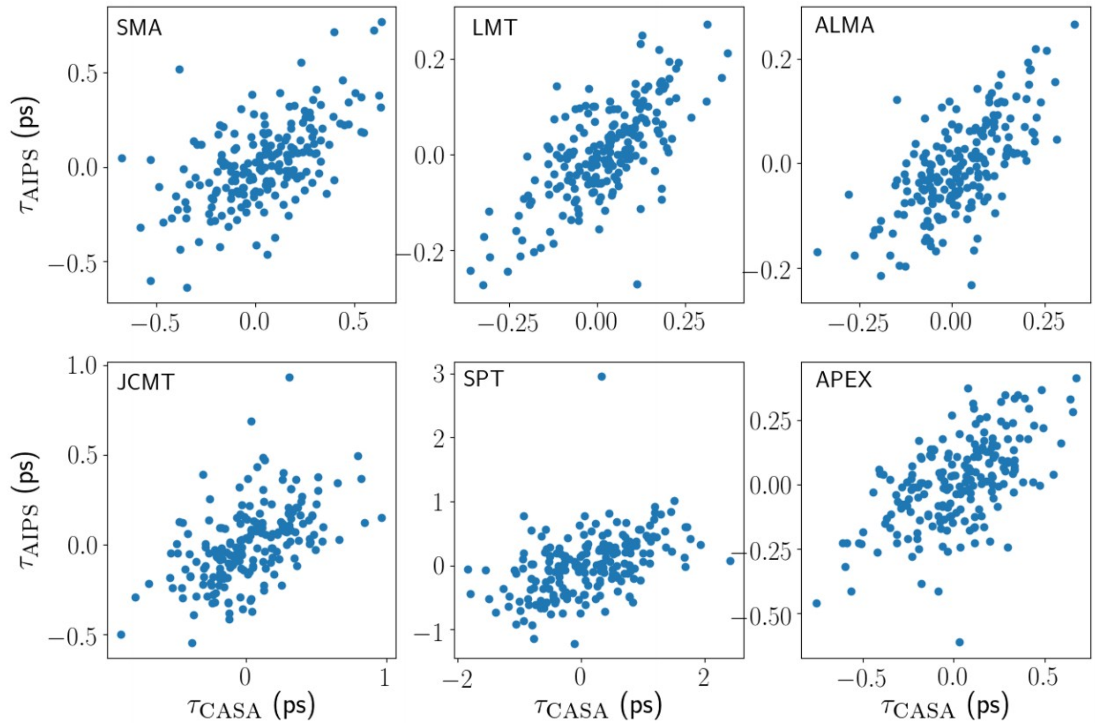
- AIPS is now legacy software
- CASA very widely used:

  VLA, ALMA, Meerkat, SKA
- ANTAB apriori amplitude calibration
- Fringe fitter for CASA
- Developed at JIVE by:

  Des Small, Mark Kettenis,

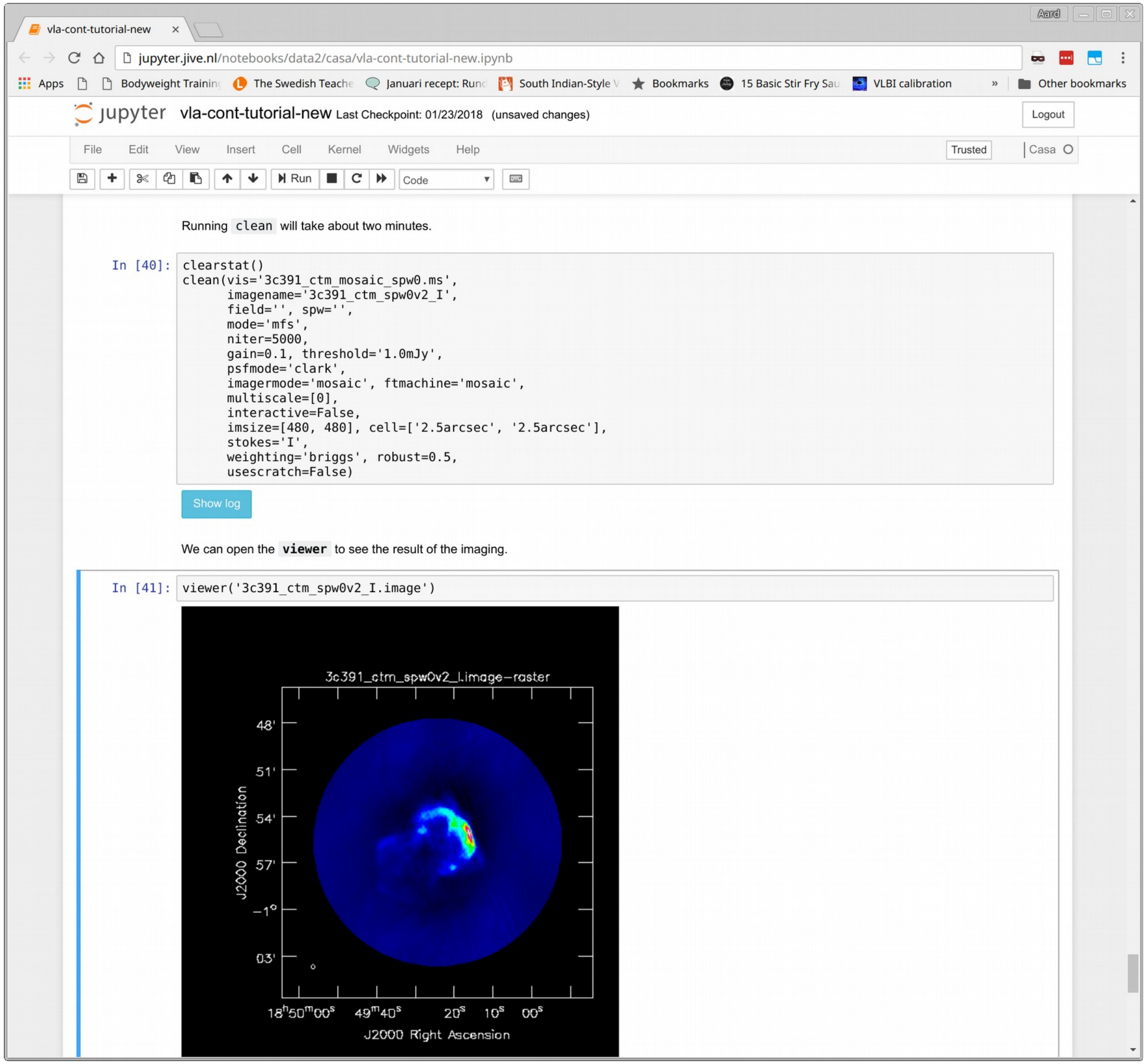
  and Ilse van Bemmel

Residual delay CASA vs AIPS for simulated EHT data



Iniyan Natarajan (Rhodes University), MNRAS (2019), in preparation

Remote pipelining using Jupyter and CASA



- Jupyter kernel for CASA
- Docker and Singularity containers
- Documentation and download https://github.com/aardk/jupyter-casa
- Live demo: http://jupyter.jive.nl

Architecture

Data are corner-turned, subbands are sent to different correlator nodes