TU WIEN VieVS

Vienna VLBI and Satellite Software

VLBI Correlation Activities at TU Wien

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Motivation for VLBI Correlation

Scheduling	Observing	Correlation	Fringe-Fitting	Post-Correlation Processing	Geodetic Parameter Estimation
TU WIEN VieVS Vienna VLBI and Satellite Software		DiFX	HOPS PIMA	TU WIEN VieVS Vienna VLBI and Satellite Software nuSolve	TU WIEN VieVS Vienna VLBI and Satellite Software

- Additional element in the VLBI processing chain in our group
- Correlation as a bottleneck for the increasing amount of data due to the VGOS observing plan
- We can contribute with a wider field of capabilities to the VLBI community

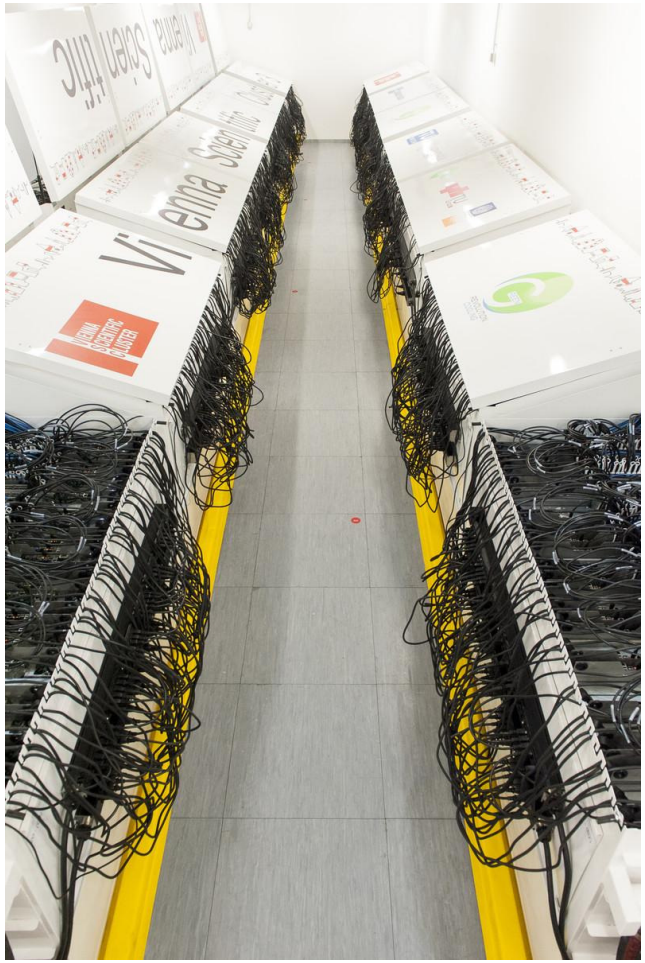
→ **Installation of DiFX on the Vienna Scientific Cluster (VSC-3)**

History of Correlation in Vienna

- 2014 Installation of the VSC-3
- 2016 Jun: Installation of DiFX and HOPS on the VSC-3 (J.McCallum)
- Jun: Correlation of first session AUG032
- Sep: Correlation of first satellite observation APOD2
- Nov: Correlation of McWz
- 2017 May: Correlation of ds317
- Sep: Correlation of first official IVS session AUA025 (J.Gruber, J.McCallum)
- Dec: Correlation of AUA026
- 2018 April: Correlation of European Intensive Session
- Correlation of CRDS94, verified by WACO
- Correlation of AUA028, AUA032, ...
- Correlation of SBL500

Hardware Capabilites of the VSC-3

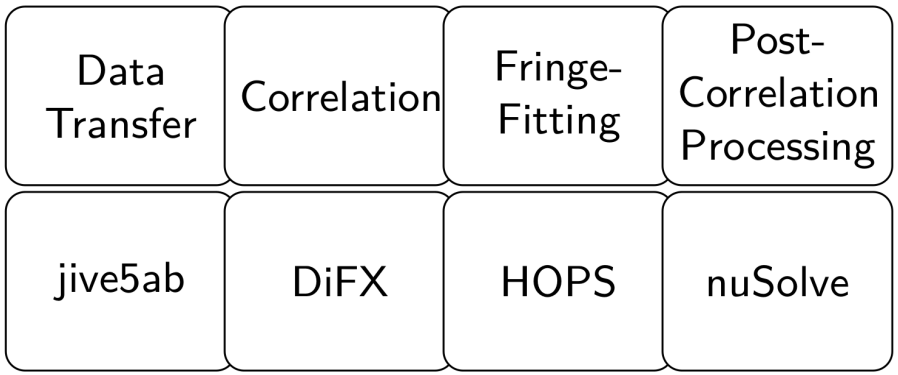
- **Hard facts:**
  - Installed by ClusterVision
  - Consists of 2020 nodes (each equipped with 2 processors), 2020 nodes equals to 32320 cores
  - Intel Xeon E5-2650v2 processors from the Ivy Bridge-EP family with 8x2.60 GHz and 20MB SmartCache
  - Intel QDR-80 dual-link high-speed InfiniBand fabric
  - BeeGFS parallel Filesystem
- **Suitable for VLBI correlation?**
  - BeeGFS parallel Filesystem developed for intensive i/o workloads makes the VSC-3 to an appropriate computing environment for the VLBI correlation



VLBI Correlation at the VSC-3

- **Current resources at our institute:**
  - 230 TB private storage media
  - Cores available upon request, usually up to 160 cores
- **Characteristics:**
  - The VSC is maintained by IT experts
  - Support by VSC-3 IT experts when installing new software
  - Processing power (number of nodes) can be adjusted to the current correlation work load
  - Linked to a very high data rate connection (GÉANT)

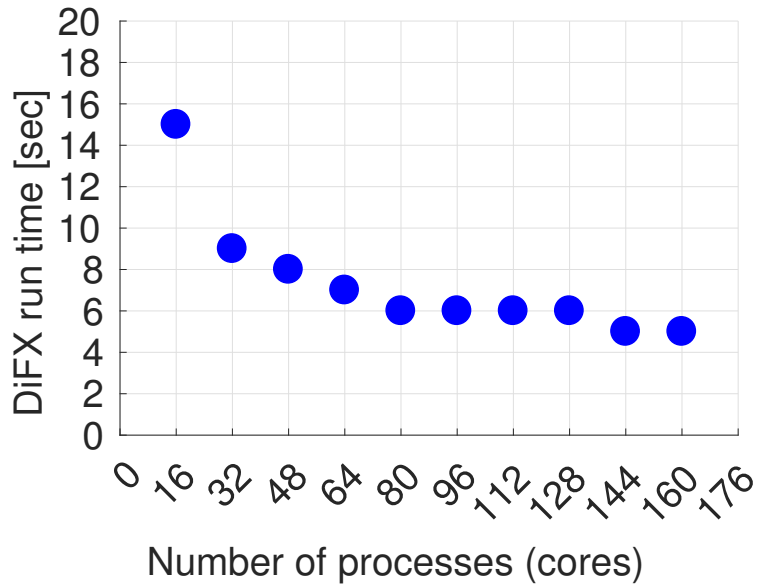
Software Capabilities of the VSC-3



- **jive5ab** for data transmission
- Distributed FX (**DiFX**) software correlator
- Haystack Observatory Postprocessing System (**HOPS**) with the program fourfit for fringe-fitting
- **nuSolve** is used for post-correlation processing and for geodetic parameter estimation to verify the correlation results
- **SLURM** for cluster management and job scheduling

Performance Tests per scan

- To evaluate the most efficient VSC-3 node configuration per scan
- Methodology: Rerun of the same scan with the same DiFX processing with changing number of cores:
  - Accumulation period 0.512 sec, spectral resolution 0.25 MHz
  - 1 to 10 nodes with 16 processes (cores)
  - session v012, scan 060-1500b, stations SA,WN
- Significant improvement until 80 cores



Performance Tests of a session

- Usage of parallel scan processing strategy to make efficient use of more cores.
- Can be realized with the **SLURM job array**
- For example: 320 cores are available. Split up the pool of cores into several DiFX jobs in parallel. Each scan takes 6 sec.

Serial scan processing

Total processing time 24 sec

scan 1	320 cores
scan 2	320 cores
scan 3	320 cores
scan 4	320 cores

Parallel scan processing

Total processing time 6 sec

80 cores	80 cores	80 cores	80 cores
scan 1	scan 2	scan 3	scan 4

Data Transfer from and to the VSC-3

- The VSC-3 can be accessed via five IP addresses
- On each of the IP addresses runs a jive5ab process
- There is one UDP/TCP port per login node
- Pushing data
- Pulling data
- White-listing is a two step process which takes some time

	whitelisted	**tested**
Bonn	~	x
Hartrao	✓	✓
INAF	✓	✓
Ny-Alesund	✓	✓
Onsala	✓	x
Japan	✓	✓
UTAS	✓	✓
Warkworth	✓	✓
Wettzell	✓	✓

Sessions correlated AUA sessions

- **Scientific background:** VLBI SOuthern Astrometry Project (SOAP) program
- **Stations:** AuScope Array with HOBART26, KATH12M, YARRA12M, HARTRAO, HART15M, WARK12M, WARK30M, DSS34
- **Antenna setup:** 1 Gbps recording rate and S/X-band
- **Results:**

Session Name	QCODE	% of Total scans
AUA025	5-9	54%
AUA026	5-9	58%
AUA028	5-9	71%
AUA032	5-9	70%

- **Characteristics:** Absence of FLUX information of sources, G-codes on local baselines HARTRAO-HART15M and WARK12M-WARK30M, X-band only for WARK30M

Sessions correlated

European intensive sessions

- **Scientific background:** ESA Project "Independent Generation of Earth Orientation Parameters"
- **Stations:** WETTZ13N, RAEGSMAR, WETTZELL
- **Antenna setup:** 1 Gbps (256 Mbps) recording rate and S/X-band
- **Results of v012:**
  - Detection of a few S-band fringes due to the lower recording rate observed than scheduled
  - Determination of a high number of X-band multi-band delay observations
  - SBD residuals scatter of ~20 ns due to a priori station coordinates of REAGSMAR
- **Status of EINT02,03,04,...,07:**
  - Detection in the S-band, no detections in the X-band
  - Further investigations are following

VieVS Post-Correlation Processing

- **Motivation:** To close the gap between the correlation/fringe-fitting output and VieVS
- **Components:**
  - Database conversion and update
  - Ambiguity correction
  - Ionospheric delay correction
  - Outliers flagging

VieVS Post-Correlation Processing status

- **Motivation:** To close the gap between the correlation/fringe-fitting output and VieVS
- **Components:**
  - Database conversion and update ✓
  - Ambiguity correction In work using closure conditions
  - Ionospheric delay correction On to-do list
  - Outliers flagging In work conversion of VieVS outlier file to vgosDb

VieVS Post-Correlation Processing

Database conversion and update

- Tool to convert the fringe-fitting output to vgosDb: createvgosdb.m
- **Realization:**
  - Library with matlab and bash scripts to read fringe-fitting output and station log files and create a vgosDb
  - Makes heavy use of NetCDF library, supports NetCDF version 4.3.3.1
- **Input:**
  - fourfit output files (type-1,2,3,4)
  - PIMA ASCII output
  - Station log files (configuration file for exception handling, e.g. sign of cable delay)
- **Verification:** Comparison with nuSolve tool vgosDbMake of correlated AUA sessions
- **Application:** Has been used for the European intensive session v012

Research Pipeline

Scheduling	Observing	Correlation	Fringe-Fitting	Post-Correlation Processing	Geodetic Parameter Estimation
TU WIEN VieVS Vienna VLBI and Satellite Software		DiFX	HOPS PIMA*	TU WIEN VieVS Vienna VLBI and Satellite Software	TU WIEN VieVS Vienna VLBI and Satellite Software

- Independent data flow in VieVS
- Analysis of impact of correlation/fringe-fitting models and configurations on geodetic parameter estimation
- *PIMA fringe-fitting is carried out by H.Krásná

Simulation of VLBI Baseband Data

- Software to generate simulated digitized VLBI baseband data
- **Input parameters:** Source strength, antenna sensitivity, ...
- **Output:** Digitized bit stream for each channel per station separately
- **Purpose:**
  - Knowledge gain, better understanding and insight of important parameters of the baseband data of a station
  - Can be used as input data for a correlation/fringe-fitting prototype
  - (Simulation) studies
- **Realization details:**
  - Written in Matlab
  - Bit stream is already split up in accumulation periods in the baseband data generation
  - FFT interpolation to make it possible to add delays with higher precision than recording rate

Simulation of VLBI Baseband Data

Input parameters

- Input parameters can be defined per channel and per accumulation block:
  - Sampling rate/bandwidth
  - Scan length
  - Integration time/spectral resolution
  - Source strength, antenna sensitivity
  - Phase cal repetition rate, pulse amplitude
  - Antenna velocity, source velocity
  - Sky frequency
  - Filter design
  - Cable delay
  - Channel phase delay
  - VLBI geometrical delay τ
  - Source structure, beam width
  - Bit depth
  - (Test signal for verification)

Simulation of VLBI Baseband Data

Input parameters

- Input parameters can be defined per channel and per accumulation block:
  - Sampling rate/bandwidth ✓
  - Scan length ✓
  - Integration time/spectral resolution ✓
  - Source strength, antenna sensitivity ✓
  - Phase cal repetition rate ✓ , pulse amplitude common value?
  - Antenna velocity, source velocity ✓
  - Center frequency ✓
  - Filter design type: ideal ✓ realistic amplitude shape, Chebyshev?
  - Cable delay ✓
  - Channel phase delay ✓
  - VLBI geometrical delay τ ✓
  - Source structure, beam width Not implemented yet!
  - Quantization bit depth Details about quantization? Cut off amplitude? Equidistant bit ranges?
  - (Test signal for verification) ✓

Outlook

- Further investigations of DiFX performance improvement on the VSC
- VSC-4 will be set up early 2019
  - We will gain access to dedicated storage 1 PB and 250 cores
- Ongoing correlation of AUA experiments
- Further development of post-correlation toolbox in VieVS
- Development of a correlation/fringe-fitting prototype in Matlab
- Spread the correlation knowledge to all members of the TU Wien VLBI group:
  - Johannes Böhm
  - Sigrid Böhm
  - Andreas Hellerschmied
  - David Mayer
  - Matthias Schartner

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