Vienna Correlation Center Annual Report 2017/2018

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Abstract In September 2018, Technische Universität Wien (TU Wien) was approved as an IVS Correlation Center. The main contribution to the IVS is with the correlation of sessions observed by the AUSTRAL network dedicated to southern hemisphere astrometry. For the correlation, we use the Vienna Scientific Cluster (VSC-3), which is a supercomputer located in Vienna. In this report, we provide details about our supercomputing infrastructure in terms of software and hardware. We highlight our main activities related to IVS VLBI correlation and other scientific developments. Furthermore, we report about our future plans and a new correlation infrastructure which is currently under development.

1 General Information

At TU Wien, we correlate VLBI sessions on the Vienna Scientific Cluster (VSC-3) which is a collaboration of several Austrian universities that provides supercomputer resources and corresponding services to their users. The VSC is located at the Arsenal building of TU Wien and is operated by the VSC Research Center and the Information Technology Solutions (TU.it) of TU Wien. Our main contribution to the IVS is by correlating sessions of the AUSTRAL VLBI network. These sessions are usually scheduled once per month and are part of southern hemisphere astrometry projects. One of these projects is the SOuthern Astrometry Program (SOAP). The scientific goal of SOAP is to improve positions of compact extragalactic sources with declinations $< -45°$. We take also part in distributed correlation experiments to evaluate a correlation strategy in the VGOS era.

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2 Correlation Capabilities of the VSC-3

One of the most important elements in the processing infrastructure of a VLBI correlation center is a High-Performance Computing (HPC) cluster. At TU Wien, we use the supercomputer infrastructure of the VSC-3 for this purpose (see Figure 1). The hardware

Fig. 1 Picture of the room where the 2020 nodes with liquid submersion cooling of the VSC-3 are stored. Picture was taken at VSC Arsenal TU Wien building ©Claudia Blaas-Schenner.

capabilities which are intended for processing a large amount of data and for intensive i/o workloads make the VSC-3 an appropriate multiprocessor computing environment for the correlation of the large amount of VLBI data. The VSC-3 consists in total of 2020 nodes, each equipped with two processors. A detailed description of the configuration of such a compute node and further relevant technical aspects can be found in Table 1. Usually, we request 10 nodes of this type to carry out our correlation tasks. The high-performance BeeGFS parallel filesystem intended for intensive i/o workloads provides our data storage facility on the VSC-3. For more information see [3]. A summary of the key values of the most important capabilities of the VSC-3 for both hardware and software can be found in Table 2. This table also shows the capabilities of the VSC-4, which will be a new member of the Vienna Scientific Cluster family. It will be used for VLBI correlation as soon as the installation is finished in 2019.

In terms of software we use the jive5ab software package[1] for data transfer tasks, the Distributed FX software correlator (DiFX [2]) for the actual correlation tasks, and the Haystack Observatory Post-processing Software (HOPS[2]) for fringe-fitting. To create the final VGOS database for submission to the IVS we use the vgosDbMake program of the nuSolve release.

Table 1 Configuration table of the compute nodes of the VSC-3.

Motherboard	Supermicro X9DRD-iF Intel Patsburg Chipset QuickPathInterconnect (QPI) 8.0GT/s Dual Xeon Sandybridge (E5 Series) Up to 256GB DDR3 1600/1333/1066/800MHz Slots: 1 (x16) PCI-E 3.0 and 4 (x8) PCI-E 3.0 Intel® 350 Dual-Port Gigabit Ethernet Controller 8x SATA2 and 2x SATA3 ports Integrated IPMI 2.0 with Dedicated LAN Supermicro RSC-RR1U-E8 1U PCI-E Riser Rad
Chassis	SNK-P0047P passive 1U heat sink X9 Generation Motherboard Indium Foil replaces heatsink paste 1U PowerSupply 350W
CPU	2 x Intel Xeon IvyBridge-EP E5-2650v2 2.60GHz 8 Core - 20MB Cache Intel HT Technology 95W TDP (Thermal Design Power)
Memory	8 x 8192MB DDRIII1866 ECC Registered

[1] http://www.jive.nl/~verkout/evlbi/

[2] https://www.haystack.mit.edu/tech/vlbi/hops.html

Table 2 Summary of the key values of the most important capabilities of the VSC-3/4.

	VSC-3	VSC-4
# cores	160 (on request)	480 (private)
disk space	230 TB	1 PB
e-transfer rate	several Gbps	
max. data throughput*	36 Gbps	to be verified
e-transfer software	jive5ab	
correlation software	DiFX	
fringe-fitting software	HOPS, PIMA	
geodetic analysis software	nuSolve, VieVS	

* max. data throughput during DiFX correlation (more description in [4])

3 Activities during the Past Two Years

The correlation activities at TU Wien go back to 2016 with the installation of correlation software at the VSC-3. In the last two years, we started correlating VLBI sessions on a more routine basis and implemented the full VLBI processing chain of data transfer, correlation, fringe-fitting, post-correlation processing, and geodetic parameter estimation in our working environment at TU Wien. We developed third-party tools to support the correlation procedure to enable a more automated correlation and fringe-fitting process. This proved to be very helpful, and it is becoming more economical with respect to operational tasks. For more efficient processing of the correlation tasks, we investigated the processing performance of the software packages within our supercomputing infrastructure on the VSC-3. We developed a tool to convert the fringe-fitting output of fourfit and PIMA into vgosDB. With this, it is possible to directly access the fringe-fitting output with our in-house software VieVS [1]. In 2018, we developed a digital simulator to generate VLBI baseband data which is designed and written in Matlab. This program contains also a VLBI Data Interchange Format (VDIF) formatter to pipe the simulated data into common correlation software packages and test their functionality.

In 2017 and 2018, we correlated twelve IVS sessions in total. One of these sessions, called CRDS94, was used to compare our correlation results against the Washington Correlator (WACO) to become an official IVS correlation center. The other sessions are dedicated to SOAP. The milestones reached with respect to correlation at TU Wien are listed in Table 3, including the period 2017/18.

Table 3 Milestones reached at the TU Wien correlation center, including the period of 2017 and 2018.

2014	Installation of the VSC-3
2016	Installation of DiFX and HOPS on the VSC-3 Correlation of first session AUG032 Correlation of first satellite observation APOD2 Correlation of McWz
2017	Correlation of ds317 Correlation of first official IVS session AUA025
2018	Correlation of European Intensive Session Correlation of CRDS94, verified by WACO Correlation of AUA028, AUA032, ... Correlation of SBL500 Approval as IVS correlation center

3.1 Automated Correlation of IVS Sessions

At TU Wien, we aim for a more automated correlation of VLBI sessions to reduce the manual interactions. This is helpful overall for IVS sessions dedicated to certain projects because within these projects the observing modes and correlation configuration usually stay the same for several sessions. We developed a program which takes over supporting correlation calculations and deals with exception handling and quality control. This program connects routines from DiFX, HOPS, and nuSolve in a processing chain to decrease manual interactions. These algorithms have been trained with the AUSTRAL network and SOAP schedules and make heavy use of the cluster management language SLURM, which is installed on the VSC-3. A log file parser has also been developed to obtain antenna status information more automatically.

3.2 Performance Tests and Correlation Efficiency on the VSC-3

Performance tests within high-performance computing systems play an important role in evaluating the most efficient processing configuration for correlation of raw VLBI data. We evaluated the scalability of DiFX and verified the user workload on the VSC-3. Furthermore, we applied a parallel scan processing strategy, realized with the SLURM job array. With this, an increased total data throughput up to 36 Gbps can be achieved.

3.3 Post-correlation Processing Toolbox in VieVS

We developed a software package which converts the fringe-fitting output of fourfit and PIMA into the vgosDb format. The software is written mainly in Matlab and can read fourfit Mark4 files (type-1,2,3,4) and also PIMA ASCII fringe-fitting output files. It consists also of a tool to parse station log files to extract cable delay and meteorological data and store them in the vgosDB files. With this, we can directly access and analyze the correlation results with our in-house software VieVS. Besides analyzing group delays, VieVS is also capable of processing single band and multiband delays.

3.4 Digital Baseband Data Simulator

A digital baseband data simulator has been developed in the period of 2017 until 2018. It is a software program to generate synthetic VLBI baseband data. The simulator is implemented in Matlab and contains a telescope model which is based on the parametrization of real antenna key characteristics. Moreover, source characteristics such as the signal structure of satellites and spatial velocities of source and receiver are taken into account in the model creation. Advanced digital signal processing (DSP) algorithms of Matlab are applied to model the antenna system. The software consists also of a VDIF formatter, which makes it possible to pipe the simulated raw VLBI data into common correlation software (e.g., DiFX) and test the simulated observations in the real VLBI process chain.

3.5 Correlation of Other Sessions

Besides official IVS sessions, we are also correlating other sessions with various scientific backgrounds.

One project is dedicated to an ESA project, "Independent Generation of Earth Orientation Parameters", which uses the Wettzell antennas and the new antenna in Santa Maria. Furthermore, we are correlating short baseline sessions at HartRAO and K-band observations. In the past two years, we also successfully correlated VLBI observations to the APOD satellite.

4 Staff

Three persons are involved in the work at the TU Wien IVS VLBI correlator center. Their names and most important responsibilities are listed here:

- Jakob Gruber (jakob.franz.gruber@tuwien.ac.at):
  - Ph.D. student in the field of VLBI raw data processing
  - maintenance of data transfer
  - correlation, fringe-fitting of AUSTRAL sessions and database submission to IVS
  - development of third party software to support correlation and fringe-fitting and correlation of various other special VLBI sessions
- Johannes Böhm (johannes.boehm@geo.tuwien.ac.at):
  - head of the VLBI group at TU Wien
  - backup for Jakob Gruber for data transfer, correlation, fringe-fitting of AUSTRAL sessions
- Jamie McCallum (jamie.mccallum@utas.edu.au):
  - station array manager of the AuScope VLBI array
  - supporting role for VLBI correlation activities at TU Wien

5 Current Status and Future Plans

As in the past two years, there will be an ongoing correlation of AUSTRAL sessions in 2019. In total there are twelve IVS sessions scheduled for 2019, one per month, with Vienna as the responsible correlator. In parallel with the correlation of IVS sessions, we will keep on correlating various other special VLBI sessions and improve and refine a more automated correlation pipeline. The new supercomputer VSC-4 is currently under development and should be ready to work in 2019. Once the installation is finished, we will move our complete VLBI correlation software repository to the VSC-4, and it will represent our new correlation working environment. We will gain access to 1-PB disk storage and 480 private processing cores on the VSC-4. In view of the increased data volume produced by telescopes in the VGOS era, this will be very useful to take up some of the correlation load. Finally, we are in the process of spreading all the correlation knowledge to more members of the TU Wien VLBI group.

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