Vienna Correlation Center Biennial Report 2019/2020

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Abstract The Vienna Correlation Center is run by the Technische Universität Wien (TU Wien) and uses the hardware infrastructure of the Vienna Scientific Cluster (VSC-4). At the VSC-4 we have access to 480 processing cores and exclusive storage of 1 PByte. The VSC-4 is linked with a bandwidth of 10 Gbps into the global GEANT network. We use jive5ab and tsunami for data e-transfer and DiFX, HOPS, and PIMA for correlation and fringe-fitting. We use NuSolve for the creation of VGOS databases. In 2019 and 2020, we contributed to the IVS by correlating 20 AUSTRAL sessions, 15 short baseline sessions within HartRAO and Wettzell, 20 Intensive sessions with the network Hb-Ht-Yg, 5 EU-VGOS sessions, and took part in three VGOS correlator comparisons. In 2021, we plan to correlate 10 VGOS-O sessions and further EU-VGOS sessions. From a scientific point of view, our focus will be on source structure in the fringe-fitting process.

1 General Information

At the research unit Higher Geodesy of the Technische Universität Wien (TU Wien), we correlate IVS VLBI sessions on an operational basis and for specific scientific projects. VLBI correlation's software components are installed on the currently most powerful supercomputer ever installed in Austria. The supercomputer is called Vienna Scientific Cluster-4[1] (VSC-4) and is located 2.5 km next to our TU Wien offices (see Fig. 1). The VSC is a collaboration of several Austrian universities that provides supercomputer resources and corresponding services to their users. Hence, the VSC is used for a variety of scientific projects in a wide range of disciplines. In total, the VSC-4 consists of 790 nodes. At the research unit Higher Geodesy, we have exclusive access to 10 of these nodes, which are reserved for projects related to VLBI correlation and are accessible anytime for the members of our VLBI group. In addition, storage of 1 PByte has been purchased to complete the VLBI correlation's hardware system, also in view of the enormous data volumes in the VGOS era.

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[1] `https://vsc.ac.at/systems/vsc-4/`

2 Component Description

The capabilities of a VLBI correlator are frequently measured by three quantities: e-transfer rate, correlation data throughput, and storage size. These quantities and the software components are described in the following.

The VSC-4 consists of 10 so-called login nodes, which are servers that are linked to the GEANT network allowing a maximum data rate of 10 Gbps. This particular setup makes it possible to split up the data transfer over the 10 login nodes, and data can be transferred simultaneously on the login nodes. Currently, the e-transfer to the Vienna correlator is organized in such a way that each VLBI station is assigned to a specific login node. Up to 10 stations can thus transfer their data simultaneously to the VSC-4. However, it is essential to note that the 10 Gbps bandwidth is shared between the login nodes and other users of the VSC.

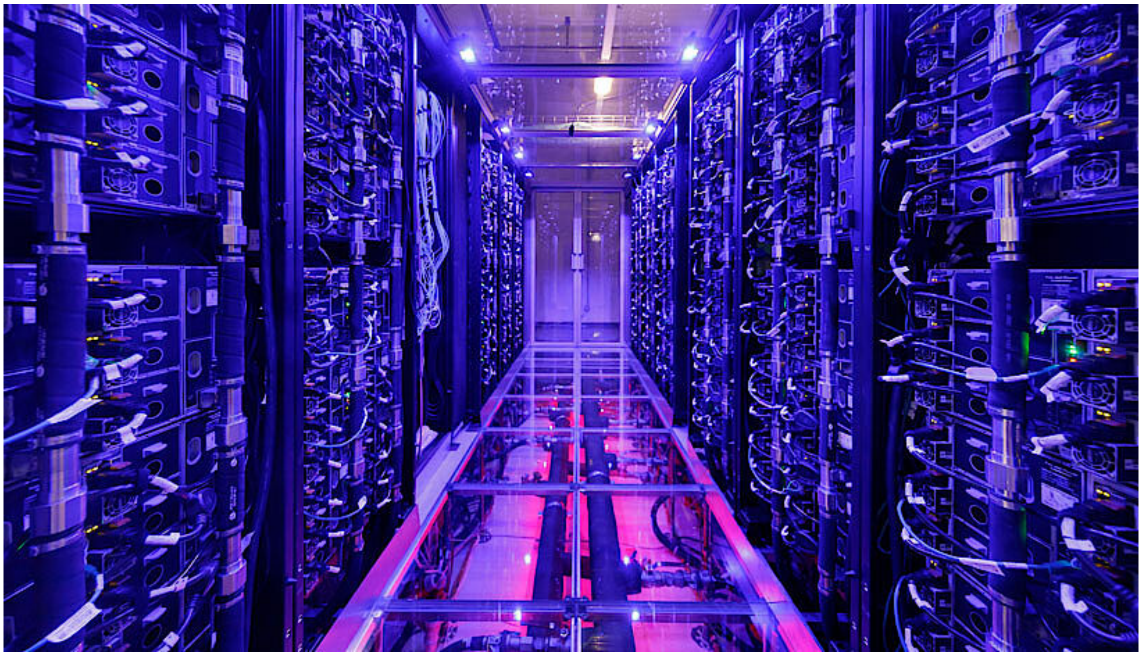

Fig. 1 VSC-4 – most powerful supercomputer in Austria. 10 nodes and 1 PByte are reserved for VLBI correlation. Linked with 10 Gbps to the global research network GEANT. (©http://derknopfdruecker.com/)

Two independent test methods were applied to test the net data rate. On the one hand, the maximum possible net data rate was tested with the iperf3 tool, which actively measures the maximum achievable bandwidth on IP networks. On the other hand, the VLBI specific data e-transfer software jive5ab developed by H. Verkouter was used to test the maximum possible transfer rates between the Joint Institute for VLBI (Jive) and the VSC-4. With iperf3 1.41 Gbps were achieved per stream, and 8.60 Gbps for 10 streams in parallel. Using jive5ab, 2.9 Gbps were possible on a single login node. Parallel data streams were not tested with jive5ab. For operational purposes, we use jive5ab and tsunami for data transfer.

The VSC-4 consists of 790 water-cooled nodes (Lenovo SD650), each with two Intel Skylake Platinum 8173 processors with 24 cores, interconnected with 100 Gbits/s OmniPath. For VLBI correlation, 10 of these high-performance nodes reaching 2.7 PFlops/s are reserved. This means that up to 240 cores (24 cores per node) can be utilized for VLBI correlation simultaneously. The Distributed FX style correlation software (DiFX, [4]) is installed to realize level-0 processing of the raw VLBI telescope data. While we continuously keep our DiFX installation up to date with the latest official releases, we also keep several older versions of DiFX to allow the processing of VGOS and legacy S/X observations. The Slurm[2] workload management and job scheduling software is used to efficiently process the VLBI raw data by DiFX and reach a high parallelization level. A single session can be parallelized, but also several sessions can be processed in parallel. The assignment of the processing cores for single and multi-session correlation with DiFX is handled by Slurm. A brief investigation of the data throughput by DiFX on the VSC-4 showed an excellent scaling with increasing the number of processing cores. The maximum data throughput which could be achieved by using 480 cores was 320 Gbps.

For data storage, a General Parallel File-System (GPFS) with 1 PByte size is mounted to the VSC-4. This data volume is dedicated to VLBI correlation only within the VSC-4.

Besides DiFX, the Haystack Postprocessing System (HOPS), PIMA, and nuSolve are installed at the VSC-4 to complete the entire raw data VLBI process-

[2] https://slurm.schedmd.com/documentation.html

ing chain. Consequently, it is possible to process raw VLBI data and provide vgosDb files to the IVS community.

3 Staff

Two persons are involved in the work at the TU Wien IVS VLBI correlator center. Their names and most important responsibilities are listed below. Additionally, Johannes Böhm is involved as responsible contact point to the VSC-4 team, and Axel Nothnagel acts as consultant concerning correlation/fringe-fitting and raw data simulation.

- Jakob Gruber
  - Ph.D. student in the field of VLBI raw data processing
  - maintenance of data transfer
  - AUSTRAL, short baseline, VGOS correlation
  - raw data simulation
  - development of third party software to support correlation and fringe-fitting and correlation of various other special VLBI sessions
- Frédéric Jaron
  - Postdoc Researcher
  - maintenance of data transfer
  - VGOS correlation
  - EU-VGOS correlation and organization
  - special interest in source structure for VGOS
  - development of third party software to support correlation and fringe-fitting and correlation of various other special VLBI sessions

4 Current Status and Activities

4.1 AUA Sessions 2019 and 2020

In 2019 and 2020, 20 Austral (AUA) sessions were correlated, about one session per month. The network consists of the telescopes: Ht, Hh, Hb, Ho, Yg, Ke, Ww, and Wa. In 2019 the sessions were dedicated to the SOuthern Astrometry Program (SOAP)[3]. The scientific goal of SOAP is to improve positions of compact extragalactic sources with declinations below -45 degrees. In 2020, the sessions were dedicated to mixed mode observations, where Hb was the only station observing with a VGOS receiver.

[3] http://astrogeo.org/soap/

4.2 Southern Intensive Sessions 2020

Besides the operational AUA sessions in 2020, Intensive experiments were carried out to estimate precise dUT1 values with the network Ht-Yg-Hb. As for the AUA 2020 sessions, Hb observed with the dual linear polarized VGOS feed, whereas Ht and Yg observed in legacy S/X mode. In total, 34 one-hour sessions were observed in 2020 and are being correlated in Vienna. The AUA 2020 and Southern Intensive data of 2020 can be used to determine the currently unknown peculiar offset for the Hb antenna, which can be of great interest to the VLBI correlation community.

4.3 Local Wettzell Sessions 2020

In 2020, three experiments with the local Wettzell network were processed to estimate precise local tie vectors. These are X-band only observations with Wn, Ws, and Wz, whereas Ws observed with a dual linear polarized VGOS feed.

4.4 Short Baseline HartRAO Sessions 2019 + 2020

Like the local Wettzell sessions, short baseline (SBL) sessions on the Hh-Ht baseline with a 6-hour duration were carried out and correlated in Vienna. They will be used to investigate the local ties in HartRAO ([3]). For correlation, a frequency offset is applied, which is also present in the observation, to decorrelate the phase cal tones on the local baseline. In total there are 12 SBL sessions.

4.5 VGOS Comparison Campaign

In 2019 and 2020, the Vienna correlator took part in three dedicated IVS VGOS correlator comparisons, led by MIT Haystack. Detailed comparisons between Haystack, Washington, Bonn, Shanghai, and Vienna were carried out. The first comparison was a so-called blind test for a VGOS Intensive session, which showed the great importance of a consistent clock model setup between correlators. The second comparison was a level-1 processing comparison of a 24-hour VGOS session, which showed an excellent agreement between the Haystack and the Vienna correlator. The third comparison was between the Washington and the Vienna correlator, and there was an excellent agreement in the group delays. However, the proxy-cable calibration delay results showed significant differences, which requires further investigations.

4.6 Simulation at the Raw Level (VieRDS)

Within the last couple of years, a novel simulation tool called VieRDS ([2]) has been developed to generate single dish VLBI raw data in the VDIF format. The simulated data can be processed by DiFX and can be used, e.g., to test new VLBI observation scenarios in a real correlation environment. The software is distributed within the umbrella of the Vienna VLBI and Satellite Software (VieVS, [1]) and can be downloaded from `https://github.com/TUW-VieVS/VieRDS`.

4.7 EU-VGOS

The EU-VGOS collaboration regularly carries out research and development sessions with a European network of VGOS antennas. The participating stations currently are: Oe, Ow, Ws, and Yb. In addition, from Japan Is joins the network. We are currently processing six EU-VGOS sessions, five of them have particularly short scan lengths. The PI for these sessions is Matthias Schartner, who scheduled these experiments while he was still a member of our working group in Vienna and who has moved to ETH Zürich now. We are testing the performance of the calibration algorithms released by MIT Haystack for VGOS sessions. And we are investigating the quality of geodetic observables obtained from these sessions.

5 Future Plans

In 2021 we plan to correlate 10 VGOS-O sessions, on which we will put a sharp focus. The session network will consist of 8 stations: Gs, K2, Mg, Oe, Ow, Wf, Ws, and Yj. We expect each station to record around 30 TByte, which sums up to 240 TByte per session. Hence, we should be fine with our current storage capacity of 1 PByte. Since K2 has been upgraded to e-transfer, we plan to set up the e-transfer link to K2 soon, which will be a significant simplification of the challenging VGOS transfer logistics. Besides the operational VGOS-O correlation, we plan to utilize VieRDS to carry out raw data simulations for VGOS observations. We will continue to process EU-VGOS sessions at the Vienna correlator center.

Acknowledgements

The authors are grateful to the Austrian Science Fund (FWF) for supporting this work with the project P31625 (VGOS Squared). The computational results presented have been achieved in part using the Vienna Scientific Cluster (VSC).

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