IVS Newsletter

Issue 28, December 2010

IVS Live – Observing Sessions Come Alive...

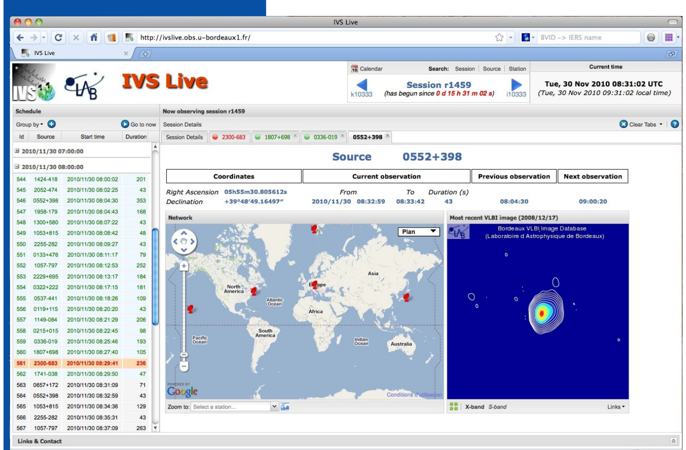
– Arnaud Collioud, Laboratoire d'Astrophysique de Bordeaux

Have you ever wondered: which IVS session is currently running, which stations are observing, or which source is being observed? And was finding the answers to these questions too complicated to satisfy your needs? Now there may be a tool that will be able to change that.

IVS Live author Arnaud Collioud.

Enter "*IVS Live*". *IVS Live* is a Web site, which has been developed and hosted by the Laboratoire d'Astrophysique de Bordeaux, based on the dynamic Web site created for the International Year of Astronomy 2009 (IYA) very large astrometric session. Direct your Web browser to http://ivslive.obs.u-bordeaux1.fr/ and find out more. Here some things that you will find:

Sessions in real-time and source images. Monitoring of IVS sessions is the main reason for the existence of the *IVS Live* Web site. Session schedules are routinely added to a dedicated database and then become accessible in *IVS Live*. The homepage automatically loads the currently observed IVS session (if there is any) or counts down to the session to come. All *IVS Live* functionalities are organized through a simple user interface, which is divided into several subpanels. One contains the schedule of the session, which may be sorted by time, source name, or scan duration. The main panel provides an introduction of the session: dates and type, source list, and a network map. While the session is running, *IVS Live* is automatically updated thanks to a synchronization procedure with a displayed master clock. For each source observation, a new tab is created in the main panel. This tab regroups information related to this specific observation: the latest VLBI images available for the source extracted from one of the VLBI image databases, the observing network (along with static station details, pictures and webcam links, if available), and some useful scheduling information about this observation and source. The source names within tab titles and schedule are color-coded according to the source observation status (completed, ongoing, or to come).



Snapshot of IVS Live during the observation of R1459.

Navigate through IVS sessions and master schedules. If you are interested in a session other than the one automatically loaded, you can easily change the active session in IVS Live. The previous and next sessions are directly selectable from the main interface. If you are looking for a more elaborate tool to look for specific IVS sessions, the "Calendar" is what you need. The Calendar provides a quick and convenient graphical visualization of all IVS master schedules (from 1979 to 2011 thus far). It provides daily to monthly to yearly views and gives basic information about each session like duration or observational network.

Search for specific sessions, sources, or stations. In addition to be an IVS session monitoring tool, *IVS Live* may also help you to retrieve specific information about a given session, source, or station. By using search forms, you may query the underlying *IVS Live* database using several search criteria. For example, a session may be queried by its code (e.g., rdv84, i10023), time span (01 through 30 November 2010), and/or type (Intensive, non-Intensive). Each such query leads to a response window with the result list. In the case of a session search, you will see the list of matching sessions along with the links for directly loading a session into *IVS Live*. Source and station queries result in a list of matching sources or stations with links to additional details (e.g., position, images, map location, webcam link, and list of sessions with the selected source or station).

IVS Live is a tool that can be used to follow sessions in real-time, navigate through IVS sessions, or search and display specific information about sources (especially images) and stations. It will be regularly updated and extended in order to maintain and increase its value for the IVS community. Feel free to discover its capabilities and contact the author (collioud@obs.u-bordeaux1.fr) with any inquiries and/or suggestions.

Gravitational Deformations of VLBI Telescopes and Their Impact on Geodetic Results

– Pierguido Sarti and Claudio Abbondanza, IRA – INAF, Italy

VLBI telescopes are large structures that undergo gravitational deformations when their masses are steered to point to different directions in the sky. This was already known in the early days of geodetic VLBI, but the topic was not given enough emphasis in order to support effective investigations in the subsequent decades. The determination of the effects of gravitational flexures on the VLBI observable is far from being trivial and requires a lot of effort. Furthermore, the first study on the deformation of the Fairbanks antenna yielded a negligible effect on signal path variation (SPV). It was thus erroneously assumed that this result would be valid for a larger set of antennas.

Newer studies applied to the Medicina and Noto (Italy) telescopes, however, found that the SPV may not be zero and may not be neglected a priori, being dependent on the particular deformative pattern of the telescope despite its size. In this article we would like to draw the attention of the VLBI community to

- the importance of gravitational flexure of VLBI telescopes,
- the effects of deformations on the estimates of antenna positions,
- the modeling required to mitigate the biases due to gravitational flexure, and
- the actions required to ensure a higher level of accuracy of VLBI positioning.

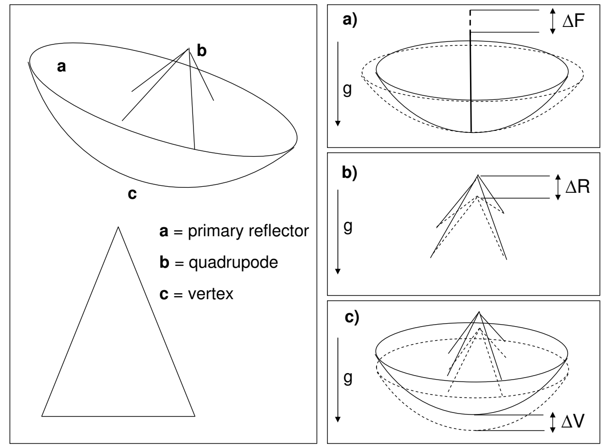
A bibliography list provides references to papers that elaborate in more detail this important topic.

The signal path variation can be modeled as the sum of three terms accounting for the deformations of the quadrupod, the primary reflector, and the sag of the dish. The SPV model for telescopes observing with a primary focus configuration (cf. Figure 1) is a simple, elevation-dependent linear combination of three terms:

$$\text{Prime focus telescope:} \quad \Delta L(e) = \alpha_F \Delta F(e) + \alpha_V \Delta V(e) + \alpha_R \Delta R(e)$$

where ΔF(e) is the variation of the focal length of the paraboloidal primary reflector, ΔV(e) is the displacement of the vertex of the primary reflector along the line of sight, and ΔR(e) is the displacement of the feed horn phase center along the same direction. The three terms of the combination are strictly connected to the action of gravity on the telescope structure. The latter term is straightforwardly related to the gravitational deformation of the quadrupod legs. The displacement of the vertex is related to the sag of the optical system under the effect of gravity. is caused by the folding of the primary reflector as the pointing elevation varies from zenith to horizon.

The Δ terms can be accurately estimated with terrestrial techniques or with finite element models (FEM) of the



The elevation angle dependent effects of gravitational deformations, here exemplified on an AZ-EL telescope in prime focus, are changes in focal length (a) as well as displacements of the receiver (b) and the vertex (c).

antenna under consideration. The authors have determined these terms for the two Italian antennas at Medicina and Noto. They determined the receiver displacement ΔR(e) in terrestrial trilateration and triangulation surveys. The vertex motion ΔV(e) was derived from an FEM modelling. The focal length variation ΔF(e) was determined from the point clouds of laser scanner surveys done for different pointing elevations. For more detail on the survey part, the interested reader is referred to the references in the bibliography list.

When geodetic observations are performed in secondary focus, the SPV model is expressed as:
where the deformation terms Δ are the same as in the prime

$$\text{Cassegrain telescope:} \quad \Delta L(e) = \beta_F \Delta F(e) + \beta_V \Delta V(e) + 2\beta_R \Delta R(e)$$

focus case, but the linear coefficients differ, as made obvious by the use of the different letter symbol.

The linear coefficients α and β are strictly telescope-dependent and their computation must be precisely performed. This is described in detail in Abbondanza and Sarti (2010). The coefficients need to be determined for every telescope individually and their computation requires the knowledge of certain telescope parameters. For the primary focus configuration, the required input parameters are:

- the diameter of the primary reflector,
- the focal length of the primary reflector, and
- the edge tapering of the illumination function.

For Cassegrain-type telescopes, the computation of the linear coefficients requires:

- the diameter of the secondary hyperbolic reflector,
- the focal length of the primary reflector,
- the distance between the subreflector and the Cassegrain focus, and
- the edge tapering of the illumination function.

These parameters are related to the optics of each telescope. The challenging part is the determination of the linear coefficients α_R and β_R which entails solving an integral equation. The other two linear coefficients can then easily be determined through simple linear relationships (see Table).

Linear coefficient for...	Prime focus telescope	Cassegrain telescope
...receiver displacement	$\alpha_R = \alpha_R(\text{tel. par.})$	$\beta_R = \beta_R(\text{tel. par.})$
...vertex displacement	$\alpha_V = -1 - \alpha_R$	$\beta_V = -1 - 2\beta_R$
...focal length change	$\alpha_F = 1 - \alpha_R$	$\beta_F = 2 - 2\beta_R$

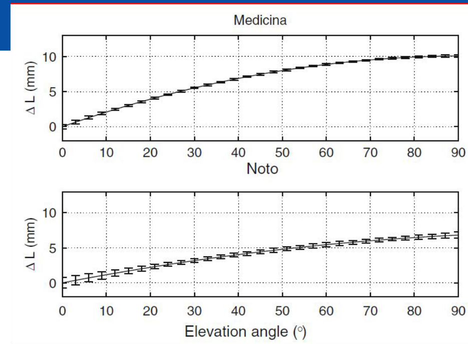
The values of the linear coefficients will have to be determined and collected for every IVS Network Station. The authors offer to assist in the computation of the coefficients and to prepare a database of all coefficients for general usage.

Gravitationally induced variations in the path of the radio signal, having a sinusoidal dependency on the pointing elevation, map into the local vertical component of the telescope reference point with an inverse proportional relation. These variations can be modeled in the data analysis providing external correction files which can be regarded as the equivalent of phase center variation files of the GNSS technique. This certainly represents a significant as well as mandatory step towards the mitigation of the biases which affect geodetic VLBI.

For the telescopes of Medicina and Noto, the SPV values increase from horizon to zenith from 0 to 10.1 mm and from 0 to 7.2 mm, respectively (see Figure 2). When the SPV model is introduced in the VLBI data analysis to correct the effect of the gravitational flexure on the observations, its impact on the height component of the telescope is 8.9 mm and 6.7 mm for Medicina and Noto, respectively. These corrections, under any circumstances, cannot be regarded as negligible.

The SPV model equations clearly express the signal path variation as an elevation-dependent linear combination of three terms. Therefore, its value can be computed only if the linear coefficients and the gravitational deformation patterns are known.

Also, it is worth highlighting that no signal path variation can be inferred or predicted based on the stiffness and dimension of the antennas: these are not properties on which the computation can rely. Particularly, large and flexible telescopes may undergo large deformations (i.e., large Δ terms in the second term) whose combination, according to the SPV model equations, results in a small or negligible signal path variation. Conversely, compact and rigid telescopes may show small gravitational deformation that, combined according to the SPV model equations, may cause a significant and non-negligible signal path variation.



Signal path variations with error bars for the Medicina and Noto telescopes as a function of elevation angle.

As previously mentioned, elevation-dependent sinusoidal variations of the path of the incoming radio signal bias the height components of the telescope position. As a consequence, VLBI-derived height estimates may suffer systematic errors whose correction is currently impossible due to the non-availability of the Δ terms and the lack of the linear coefficients α and β for almost all of the telescopes that observe in the IVS observing program.

Therefore, in order to dominate the systematic errors and to mitigate their effects on the positions and the scale estimated with the VLBI technique, it is necessary to promote and coordinate a worldwide surveying project aimed at determining the three gravitational deformation terms Δ of the linear combinations of the SVP models for prime focus and Cassegrain telescopes for all IVS Network Stations.

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An "Old Lady" and Her Young "Twins"
«The Geodetic Observatory Wettzell repairs its 20-m radio telescope and continues construction of the Twin Telescope»

– Alexander Neidhardt, FESG/TU Munich, Geodetic Observatory Wettzell

The Geodetic Observatory Wettzell is well-known in the space geodesy and gravimetry communities as one of the few fundamental stations in the world. With its 20-m radio telescope (RTW), laser ranging systems, GNSS receiving systems, gravimeters, and ring laser, all co-located within less than a kilometer, it can be viewed as a pathfinder station for the Global Geodetic Observing System (GGOS). New projects like the VLBI2010-compliant Twin Telescope Wettzell (TTW) pave the way into the future. However, the maintenance and upkeep of the existing instruments is equally important (e.g., to further build the long-term time series). Hence, when the old 20-m radio telescope developed severe problems with the elevation bearings, a repair became highest priority. While the TTW project is funded by the German Government under the leadership of the *Federal Agency for Cartography and Geodesy (BKG)*, the RTW repair was financed by the *Research Facility for Satellite Geodesy (FESG)* of the *Technische Universität München (Technical University Munich, TUM)*. BKG and TUM run the observatory at Wettzell in a fruitful cooperation. The combination of geodetic infrastructure, science, and research ensures that the technical capabilities meet highest standards now as well as in the future.

Repair of RTW. The repair of the 20-m radio telescope was one of the big events of the year. The radio-telescope team became aware of emerging elevation bearing problems about a year ago. First tests pointed to the greasing system as the trouble maker. Introducing shorter maintenance intervals seemed to solve the problem. But in early spring the problem increased, when squeaking noises forced the operators to stop observing sessions. In March a special inspection done by the Wettzell group and a team from Vertex Antennentechnik GmbH brought to light the unpleasant truth: the elevation bearings were severely damaged. The right side of the elevation axis was lowered by 2 mm and the left side by 0.5 mm in comparison to the original state. It was immediately evident that the high observation load needed to be curtailed. In consultation with the Coordinating Center, Wettzell's observing load was reduced while technical solutions were investigated. In order to change the defective bearings, a disassembly of the antenna was unavoidable. Hence, funding had to be identified for this immense repair work—and this quickly (less than half a year) if larger damages to the telescope were to be avoided. Costs of at least €0.5 million were mentioned. This constituted an almost unsolvable problem considering the EU-wide bidding requirement and other administrative hurdles. Luckily a sufficient amount of money was put aside by FESG over the past several years anticipating the need for a major repair of this intensively used instrument despite its excellent maintenance. Led by FESG and its head Prof. Urs Hugentobler (and with a lot of help from TUM lawyers and the Bavarian Chamber of Commerce), a public and EU-wide tender procedure was executed. This made it possible to plan the repair work for the period September through November. Eventually, Vertex Antennentechnik GmbH was awarded the contract and they immediately started to manufacture the bearings and special lifting equipment (e.g., adapted spreaders and support constructions for the counterweights). According to plan RTW observed the last IVS session before the repair on 31 August 2010. This date marks the end of a 27-year period of uninterrupted participation in VLBI (and IVS) observing sessions. Quite a feat considering the expected lifetime of 20 years for the 20-m telescope!

The new "skyline" of the Geodetic Observatory Wettzell with the 20-m radio telescope in the front and the new Twin telescopes in the back.

It was a boon to have the repair of the RTW and the construction of the TTW occurring in parallel, as it was possible to share heavy equipment between the two. Other cost-saving measures included that the telescope team did most of the preparation work: pulling cables, demounting the receiving system, and preparing the photogrammetric survey. Then came 15 September 2010, the day the entire station had been looking forward to: a 400-ton crane lifted the 40-ton main reflector off the pedestal. Everything worked well and on time despite some bad weather with high winds. In the following days, the counterweights (each weighing roughly 35 tons), the defective bearings, and the gear wheels were removed one after the other. After inspection the gear wheels and the new elevation bearings were installed a few days later. The bearings fitted well. Another four weeks later, Vertex reinstalled the counterweights and the main reflector, which slowly found its original place again. Following a couple of photogrammetric surveys the dish surface could be re-adjusted to 0.15 mm RMS. Then the telescope team could reinstall the VLBI equipment. Almost as planned, the 20-m radio telescope went back into operation on 29 November 2010 and will hopefully be so for many years to come.

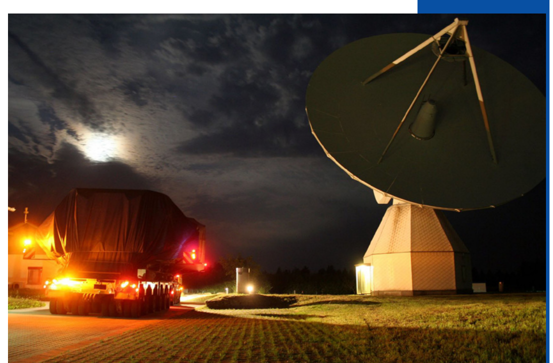
News...

Status of TTW. The Twin Telescope Wettzell project has been planned for the period of 2008–2011. The design of the TTW is fully compliant with the VLBI2010 vision of continuously operating and fast slewing antennas. After passing the critical design review at the end of 2008, construction work could begin. A thorough soil analysis with 12 drillings was done in order to determine the exact locations for the towers of the new radio telescopes. The construction of the tower foundations was started in fall 2009. Altogether 300 m3 of concrete (and reinforcement steel) was necessary to create a stable slab even though the ground was mostly bedrock. The main driver was the high stability requirement of the reflector for several load scenarios with snow, ice, and wind. The work was finished before winter set in, and the concrete towers were given time to settle. Also the construction of the operational building, which will host numerous operations rooms, a server room, and a workshop, had reached its basic shape.

The main work started in early spring 2010. The structures of the main reflectors were assembled from their single parts; for the first time, the ring focus design became visible. The advantage of the ring focus is that rays from the outer region of the main dish are reflected towards the center of the sub-reflector resulting in a better illumination of the feed horn. This design is very well suited for broadband feed horns, which require a wider opening angle. Then, the arrival of the first heavy load transport with the elevation cabins was imminent. The 40-ton-per-piece steel construction had to be trucked from Italy to Wettzell as a very wide load (6 m). The transports arrived at Wettzell on 23 August 2010. As the 400-ton crane was already ordered for the repair of the 20-m telescope, it was cost-effective to also use it for the mounting of the "Twins". Merely the arrival of the crane with its additional trucks for its counterweights of about 100 ton was spectacular. On 19 October 2010 the lift of the reflectors became a media event with television and reporter teams on location. With TTW being telescopes dedicated to geodetic applications, it is essential to achieve extremely low deviations in path lengths between the main reflector, the phase center of the feed horn, and the axes intersection of the telescope (the specified path length error is 0.3 mm!). The installation worked flawlessly and after the last of the 280 screws at each reflector was tightened, the silhouettes of the new instruments were visible for the first time. There is a new and impressive skyline at Wettzell now! First functionality tests of the new radio telescopes are scheduled for 2011.

Together with the existing 20-m antenna, the Twin Telescope offers many new possibilities for satisfying future geodetic needs. While the "Twins" are geared towards the future, the "old lady" is poised to continue its reliable work, extending the existing time series from 1983 and taking on new challenges on the way.

Personal acknowledgement: I would like to thank very much the radio telescope team for their excellent work, the administration of the TUM (especially FESG), and, of course, the whole team of Vertex Antennentechnik GmbH for their outstanding work!



(top): The arrival of the TTW elevation cabins with their 40 tons and as a very wide load transport at 3:00 am in the morning on August 23. In spite of this early time, villagers from nearby Wettzell joined the ride of the cabins to the observatory.

(top) Lifting of the 20-m reflector with the over-40-m-arm of the 400-ton crane was the highlight of the repair.

(top) Two cranes were necessary to mount and rotate the TTW elevation cabins into their upright position.

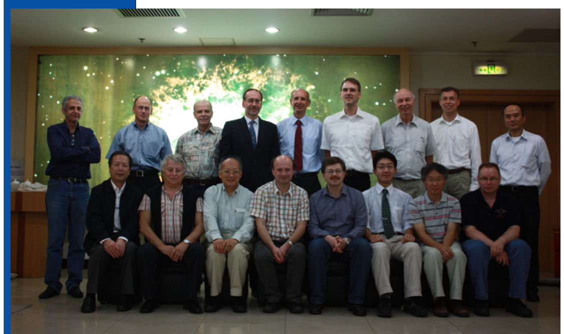
(left): Over 2000 reflection targets had to be installed by the Wettzell team following the instructions of Vertex engineers to get a quality photogrammetric survey of the reflector, the sub-reflector, and single panels.

News...

EXPOsed in Shanghai – The Directing Board Meets in China

– Dirk Behrend, NVI Inc./GSFC

While typhoon Megi made landfall in southern China, the IVS Directing Board made landfall in Shanghai and gathered for its 24th meeting in this megalopolis on the Yangtze River Delta in eastern China. Despite the rainy days caused by the outer bands of Megi, the Shanghai meeting turned out to be very successful. A big share of this success is due to the perfect organization done by the local hosts of the Shanghai Astronomical Observatory (SHAO) under the leadership of Xiuzhong Zhang. Many thanks to Xiuzhong!



Directing Board and guests at the Board meeting at SHAO.

The Analysis Coordinator Axel Nothnagel reported that the special issue on CONT08 in the Journal of Geodesy was well underway. The submitted papers had gone through the first review stage and were then with the authors for revision. It is anticipated that the special issue can be published in the March/April 2011 time frame. The CONT08 issue constitutes an excellent means to show that the measurements taken at the stations are the basis of scientifically relevant investigations. We would like to thank Axel and his co-editors Urs Hugentobler and David Salstein for making this happen.

Host Xiuzhong Zhang discusses with Technology Coordinator Alan Whitney the building of the new 65-m antenna at Sheshan.

The Observing Program Committee chair Dirk Behrend reported that another continuous VLBI campaign, CONT11, is planned for the time period 15–29 September 2011. With 16 stations having agreed to participate at the time of the meeting, CONT11 is poised to be the largest of the CONT campaigns thus far. As there will be a stronger southern hemisphere representation (seven stations), the network geometry will also be stronger than the previous CONTs. Simulation studies and existing constraints (e.g., media pool limitations, e-transfer bottlenecks) will determine the observing rate and frequency sequence to be used. Beyond the CONT11 campaign, the observing plan for 2011 will have larger networks in general (e.g., T2 with 19 stations) and the regional AUSTRAL sessions. This positive development is largely due to the coming online of the AuScope and New Zealand antennas as well as the repair of Hartebeesthoek and Fortaleza (which is scheduled for observing again in February 2011).

Patrick Charlot gave a presentation of the dynamic Web site "IVS Live" that Arnaud Collioud had developed at the Laboratoire d'Astrophysique de Bordeaux (see lead article on page 1). The Board fully approved the site and thanked Arnaud for the excellent job. The "IVS Live" site has been linked in from the Observing Program pages of the IVS Web site; it can be accessed directly at http://ivslive.obs.u-bordeaux1.fr.

The day after the meeting proper the Directing Board toured the IVS Network Station at Sheshan (a one-hour bus trip from SHAO headquarters) and the construction site of a new 65-m VLBI antenna located about 5 km away from the old site. Then SHAO invited the Board members to visit the WORLD EXPO 2010. The 5.3 km^2 Expo ground was very impressive. With the Expo coming to an end at the end of October, it was a very popular destination and there were about 0.8 million visitors that day. Several pavilions had very long queues; the German pavilion had an official waiting time of six hours. However, there was so much to see and take in that this did not really matter. Overall a very good conclusion of the Shanghai days.

Chopo Ma checking out the lunch table.

Upcoming Meetings...

AGU Fall Meeting
San Francisco, USA
December 13-17, 2010

20th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting
Bonn, Germany
March 29-31, 2011

12th IVS Analysis Workshop
Bonn, Germany
March 31, 2011

EGU General Assembly
Vienna, Austria
April 3-8, 2011

Sixth IVS TOW Workshop
Haystack Observatory, Westford, MA, USA
May 9-13, 2011

IUGG General Assembly
Melbourne, Australia
June 28 - 7 July , 2011

http://ivscc.gsfc.nasa.gov/meetings

Experiencing the First VieVS User Workshop

– Minttu Uunila, Aalto University Metsähovi Radio Observatory and Nataliya Zubko, Finnish Geodetic Institute

From 7−9 September 2010, the first Vienna VLBI Software (*VieVS*) User Workshop was held at the Vienna University of Technology. The *VieVS* developers, seven external users, and local students participated in the workshop. The Vienna group had prepared presentations (held in the mornings) about different *VieVS* applications and about how we can use them to analyze geodetic VLBI data. *VieVS* consists of several parts, which can be used either together or separately depending on the task at hand. We found that *VieVS* is attractive for users, because it has a user-friendly interface and it is flexible to users' needs. In the afternoons we had practical training. This was helpful for the *VieVS* users, because many additional questions came up during data analysis. Although we had used *VieVS* before the workshop, we had no idea how many parts it included and how many applications it had.

In the introductory part, Johannes Böhm told to us how and why the development of the *VieVS* software was started and also about the developers group. Tobias Nilsson gave a general overview of the *VieVS* structure and provided installation advice. Then the basic parts of *VieVS* were presented: reading NGS files and other auxiliary files with *Vie_init* (Tobias Nilsson), theoretical delay modeling in *Vie_mod* (Lucia Plank and Hana Spicakova), and least squares adjustment in *Vie_lsm* (Kamil Teke). We had tested these basic parts before the workshop. However, the presentations were useful for a better understanding of the processes and adjustment procedures of *VieVS*.

Also new *VieVS* modules (*Vie_sim*, *Vie_glob*, *Vie_sched*) were presented at the workshop. With *Vie_sim* (Andrea Pany) it is possible to generate artificial delay observables. *Vie_glob* (Hana Spicakova) is useful for combining solutions of different sessions. And *Vie_sched* (Jing Sun) can be used to create optimal schedules for the observations. In addition, Emine Tanir from Karadeniz Technical University in Turkey presented analysis results she had obtained with the *VieVS* software.

VieVS is developed in Matlab, and its GUIs make the usage nice and simple. *VieVS* uses NGS files as input. All IVS NGS files are already in the *VieVS* package, but every now and then you should download the newest files (and the other updates like atmosphere loading corrections) from the *VieVS* server. The output files are in Matlab format, but future output will be in SINEX format and the input format will change to that suggested by IVS WG4.

VieVS assists in simplifying routine work of the user. For example, if you need to analyze the same sessions many times, it is possible to make a process list of the sessions, so you do not have to select the sessions one by one each time. If you want to analyze, say, Intensive sessions, you can save the settings in a predefined parameter file and use it when analyzing those sessions. These two features make the use of the software easy. Other possibilities are, for instance, calculating your own Terrestrial Reference Frame (TRF) or drawing correlation matrices.

A comparison campaign with Calc/Solve, Occam, c5++, and SteelBreeze showed good agreement. Future *VieVS* versions will be equipped with additional tools like satellite tracking.

For us the workshop was a great experience—meeting other users and, of course, the developers of *VieVS*. The atmosphere of the workshop was open and warm, and there was room for specific questions and interesting discussions. The next *VieVS* User Workshop will be held in September 2011. More information about the software can be found at http://vievs1.hg.tuwien.ac.at.

Participants at the First VieVS User Workshop in Vienna.

The IVS Newsletter is published three times annually, in April, August, and December. Contributed articles, pictures, cartoons, and feedback are welcome at any time.

Please send contributions to ivs-news@ivscc.gsfc.nasa.gov.
The editors reserve the right to edit contributions. The deadline for contributions is one month before the publication date.

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The newsletter is published in color with live links on the IVS web site at

http://ivscc.gsfc.nasa.gov/.

NEWS...

Anne-Marie Gontier (1966-2010)

Our colleague and friend Anne-Marie died on 24 September 2010, aged only 44, after fiercely fighting with cancer. She was both a considerate and strong character, who chose to devote her skills to team work, especially service work for the IVS and the celestial reference frame at Paris Observatory (France).

Anne-Marie worked for 20 years with the astro-geodetic VLBI community. During her thesis work, she developed an original VLBI analysis software called GLORIA (GLObal Radio-Interferometry Analysis). This software is fit for research as well as for automatized applications. Being highly modular, its embedded models are easy to trace and test. Its modeling is fully consistent with that of the major software packages of the IVS. Anne-Marie also developed the first operational software implementing the concept of Non-Rotating-Origin (NRO) that had been proposed by Bernard Guinot as a replacement for the equinox for connecting positions in celestial and terrestrial reference frames. The NRO approach matches the extreme precision of VLBI observations in a more robust way than the old equinox approach.

Anne-Marie was the head of the IVS Analysis Center at Paris Observatory. With her colleagues, in coordination with the IERS, she investigated fine apparent radio source instabilities, thus contributing to the selection of the defining sources and the alignment of the recently adopted ICRF2. In her last publication (submitted), she participated in the first direct determination of the common aberration in proper motions of extragalactic radio sources due to the rotation of the Solar System barycenter around the Galactic center (5 microarcsecond/year), using VLBI observations from 1979−2010.

Her co-workers from her post-doc years at the Max-Planck-Institute for Radio Astronomy in Bonn (1993−1995) remember Anne-Marie with great affection. So do all her colleagues, to whom she always was friendly and supportive. She was the loving mother of two children. Anne-Marie practiced a number of sports: Tai Chi as well as team handball and rollerblading. She even participated in a 24-hour team inline skating race in Le Mans around 2005. In summer time she would ride her multi-colour motorbike to get to the observatory. And she played the saxophone.

During her first international meeting in Socorro (New Mexico) in October 1990, she once started a lonely walk along a never ending straight road into the desert...

– Martine Feissel-Vernier

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