

Report for 2013 from the Bordeaux IVS Analysis Center

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Abstract This report summarizes the activities of the Bordeaux IVS Analysis Center during the year 2013. The work focused on (i) regular analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package, also extending our present solution back to 2002; (ii) systematic VLBI imaging of the RDV sessions and calculation of the corresponding source structure index and compactness values; (iii) investigation of the correlation between astrometric position instabilities and source structure variations; (iv) continuation of our VLBI observational program to identify optically-bright radio sources suitable as transfer sources to align the International Celestial Reference Frame (ICRF) and the future Gaia frame; and (v) assessment of the current IVS observing scheme for those Gaia transfer sources comprised in ICRF2. Also to be mentioned is the organization of a joint workshop with the Korean Space Science Institute and participation in meetings of the Working Group on the next ICRF realization.

1 General Information

The *Laboratoire d'Astrophysique de Bordeaux (LAB)*, formerly Bordeaux Observatory, is located in Floirac, near Bordeaux, in the southwest of France. It is funded by the University of Bordeaux and the *Centre National de la Recherche Scientifique (CNRS)*. VLBI activities are primarily developed within the *Métrologie de l'espace, Astrodynamique, Astrophysique (M2A)* team.

Laboratoire d'Astrophysique de Bordeaux

Bordeaux Analysis Center

IVS 2013 Annual Report

The contribution of the Bordeaux group to the IVS has been mostly concerned with the maintenance, extension, and improvement of the International Celestial Reference Frame (ICRF). This includes regular imaging of the ICRF sources and evaluation of their astrometric suitability, as well as developing specific VLBI observing programs for enhancing the celestial frame.

In addition, the group is in charge of the VLBI component in the multi-technique GINS software package [1] as part of a collaborative effort within the French *Groupe de Recherches de Géodésie Spatiale (GRGS)* to combine VLBI and space geodetic data (SLR, GPS, and DORIS) at the observation level. This effort also involves institutes in Toulouse, Nice, and Paris.

2 Description of Analysis Center

The Bordeaux IVS group routinely analyzes the weekly IVS-R1 and IVS-R4 sessions with the GINS software package. During the past year, weekly normal equations for all such sessions in 2013 (with six-hour EOP resolution) have been produced and integrated in the multi-technique solutions derived by the GRGS. We also worked at extending our solution to the past, analyzing all IVS-R1 and IVS-R4 sessions back to 2002. This extension was motivated by the goal of producing test solutions combining all space geodetic data at the observation level for the upcoming ITRF2013.

The group is also focused on imaging the ICRF sources on a regular basis by systematic analysis of the data from the RDV sessions which are conducted six times a year. This analysis is carried out with the AIPS

and DIFMAP software packages. The aim of such regular imaging is to characterize the astrometric suitability of the sources based on the so-called “structure index” and to compare source structural evolution and positional instabilities. Such studies are essential for identifying sources of high astrometric quality, which is required, i.e., for the future Gaia link.

3 Scientific Staff

During the past year, there were no changes in the IVS staff. In all, six individuals contributed to one or more of our IVS analysis and research activities during 2013. A description of what each person worked on, along with the time spent on it, is given below.

- Patrick Charlot (20%): person with overall responsibility for Analysis Center work and data processing. His research interests include the ICRF densification, extension, and link to the Gaia frame, studies of radio source structure effects in astrometric VLBI data, and astrophysical interpretation.
- Antoine Bellanger (100%): engineer with a background in statistics and computer science. He is tasked to process VLBI data with GINS and to develop procedures and analysis tools to automate such processing. He is also the M2A Web master.
- Romuald Bouffet (30%): Ph. D. student from University of Bordeaux whose thesis is focused on the study of the relationship between radio source structure and position instabilities. He is using astrometric data and VLBI images from IVS sessions.
- Géraldine Bourda (50%): astronomer in charge of developing the VLBI part of GINS and responsible for the analysis results derived from GINS. She is also leading a VLBI observational program for linking the ICRF and the future Gaia optical frame.
- Arnaud Collioud (100%): engineer with a background in astronomy and interferometry. His tasks are to image the sources in the RDV sessions using AIPS and DIFMAP, to develop the Bordeaux VLBI Image Database and *IVS Live* tool, and to conduct simulations for the next generation VLBI system.
- Alain Baudry (10%): radioastronomy expert with specific interest in radio source imaging and astrometric VLBI. He is a Professor Emeritus and has a part-time ESO contract to work on the ALMA

phasing for ultra-high resolution millimeter VLBI science.

4 Analysis and Research Activities in 2013

As noted above, a major part of our activity consists of imaging the sources observed during the RDV sessions on a systematic basis. During 2013, two such sessions were processed (RDV90 and RDV92), resulting in 347 VLBI images at either X- or S-band for 161 different sources. The imaging work load has been shared with USNO since 2007 (starting with RDV61); the USNO group processes the odd-numbered RDV sessions while the Bordeaux group processes the even-numbered ones. The VLBI images are used in a second stage to derive structure correction maps, and visibility maps along with values for structure indices and source compactness (see [2, 3] for a definition of these quantities) in order to assess astrometric source quality. All such information is made available through the Bordeaux VLBI Image Database (BVID)¹. At present, the BVID comprises a total of 3,691 VLBI images for 1,126 different sources (with links to an additional 7,851 VLBI images from the Radio Reference Frame Image Database of USNO) along with 11,542 structure correction maps and as many visibility maps.

In addition to such regular imaging, studies aimed at characterizing correlations between astrometric position instabilities and source structural variations were pursued further. Moving from qualitative comparisons, we calculated correlation coefficients between time series of source positions and brightness centroid motions (as derived from the available VLBI images) for our previously selected set of 68 sources. Based on this calculation, an overall positive correlation coefficient was found, indicating that on average source position instabilities and structural variations are linked [4]. However, the comparison also revealed that a fraction of the sources show a negative correlation. Possible explanations for such discrepancies include misidentification of the core components over the epochs in the successive VLBI maps and effects of the S-band data which have not been considered in this work. Further investigations are continuing through a careful exami-

¹ The Bordeaux VLBI Image Database may be accessed at <http://www.obs.u-bordeaux1.fr/BVID>.

nation of every individual source and assessment of the significance of the calculated correlation coefficients.

Another major project carried within the group is the identification and characterization of appropriate radio sources to align the ICRF and the future Gaia optical frame. To this end, two complementary directions are followed: (i) the identification of such sources within ICRF2, and (ii) the search for additional sources (outside of ICRF2) to increase the pool of transfer sources. As noted in our 2012 IVS report, the examination of ICRF2 led to the identification of 195 transfer sources. These were further characterized as 89 sources which are sufficiently observed in current IVS programs (i.e., at least once a month), 62 sources which are not observed well enough in these programs (i.e., less than once a month), 20 sources which have a proper position accuracy but were only occasionally observed, and 24 sources which have a poor position accuracy, requiring further observations and improvement in accuracy to qualify as transfer sources. Following this analysis and previously proposed observations, the IVS has now begun to insert some of these sources into the regular IVS observing programs. The second direction (i.e. searching for new sources) has led to the identification of an additional 119 sources [5], all of which were observed during a dedicated 72-hour astrometric VLBI session conducted with the combined Very Long Baseline Array and European VLBI Network in May 2012. These data are now correlated and are awaiting analysis. Also to be mentioned in this framework is the extension of our work to the southern hemisphere with the submission of a proposal to the Australian Long Baseline Array (supplemented with additional VLBI stations) to characterize potential transfer sources in the south.

Most of this work (source imaging, assessment of structural effects, identification of Gaia transfer sources, etc.) naturally fits within the tasks of the newly formed IAU Working Group on the next ICRF realization which was set up at the 2012 IAU General Assembly. As such, we contributed to the first two meetings of this Working Group, held on 7 March 2013 in Espoo (Finland) and 18 September 2013 in Paris.

5 Dissemination and Outreach

A joint VLBI astrometry workshop was organized by the Bordeaux and KASI (Korean Astronomy and Space Science) VLBI groups as part of bilateral agreements between France and Korea. The workshop was held in Bordeaux on 24-25 October 2013. Sessions were devoted to radio interferometry techniques, high-resolution astrometry, radio sources and reference frames, as well as to time and frequency standards. Dissemination activities also included a talk given by P. Charlot at the *Bureau des Longitudes* in Paris on 6 November 2013, highlighting recent VLBI developments and the next generation VLBI system.

The *IVS Live* Web site [6], dedicated to monitoring IVS sessions and viewing VLBI images of the observed sources, was updated on a regular basis during 2013. It now includes 5,825 IVS sessions (with 68 stations participating) and 1,736 sources. Monitoring of the connections indicates that there were 866 visits from around the world (40 countries, 286 locations) during 2013, with 70% originating from different individuals. On the other hand, the Bordeaux VLBI Image Database was accessed from 85 different locations in 33 countries. In all, there were 547 connections, with one-third originating from different individuals.

6 Outlook

Our plans for the coming year are focused on moving towards operational analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package. Imaging of the RDV sessions and evaluation of the astrometric suitability of the sources will continue along the same lines. On the observational side, the immediate plan will be to analyze the astrometric data that we acquired on the 119 Gaia transfer sources identified from our program (see Section 4). We also expect the IVS to continue and expand observations of the 195 ICRF2 transfer sources now that Gaia has been launched and is soon to begin operations. In this respect, it would be desirable to schedule VLBI observations that are simultaneous with Gaia so that time series of radio and optical positions can be compared on a detailed basis. Depending on the outcome of our southern hemisphere proposal, observations in the south should also begin to develop. Finally, we expect to contribute to the work

towards the next realization of the ICRF in line with the plans that were set up during the initial meetings of the IAU Working Group in charge of this task.

Acknowledgements

We would like to thank the *Observatoire Aquitain des Sciences de l'Univers (OASU)* for supporting IVS activities in Bordeaux.

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