

# Report for 2009 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 2009. The work was focused on (i) regular analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package; (ii) systematic VLBI imaging of the RDV sessions and calculation of the corresponding structure index and compactness values; (iii) analysis of all available structure indices to identify potential defining sources for the ICRF2; (iv) continuation of our observational program to identify suitable radio sources for the link with the future Gaia frame; (v) development of a pipeline to model-fit VLBI structures in an automatic way; and (vi) simulations to assess the imaging capabilities of the VLBI2010 system and the accuracy of the corresponding structure corrections. Also to be mentioned is the enhancement of the Bordeaux VLBI Image Database and the construction of a dynamic web site for the IVS specific session dedicated to the International Year of Astronomy 2009. The IVS 10th Anniversary celebration held in Bordeaux on 25 March 2009 will remain as the highlight of the past year.

## 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 CNRS (“Centre National de la Recherche Scientifique”). VLBI activities are primarily developed within the M2A team (“Métrologie de l’espace, Astrodynamique, Astrophysique”).

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 celestial frame applications.

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, DORIS) at the observation level. This effort also involves space geodesy groups in Toulouse, Grasse, and Paris.

## 2. Description of Analysis Center

The Bordeaux VLBI group routinely analyzes the weekly IVS-R1 and IVS-R4 sessions with the GINS software package. During the past year, specific test solutions for the CONT08 sessions have also been derived as a contribution to the multi-technique solutions produced by the GRGS within the framework of the “Combination at the Observation Level” (COL) Working Group. Further work was dedicated to software improvement and the implementation of operational procedures, e.g. to download automatically the newly-available data from the IVS web site on a regular basis.

Another activity is focused on producing VLBI maps of the ICRF sources by analysis of data from the RDV sessions. This analysis is conducted with the AIPS and DIFMAP calibration and imaging 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 a number of applications, e.g. for selecting sources of high astrometric quality for the realization of the ICRF2 or the Gaia link.

### 3. Scientific Staff

The IVS group in Bordeaux comprises the following six individuals who are involved either part-time or full-time in VLBI analysis and research activities, as described below:

- Patrick Charlot (20%): 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 source structure effects in astrometric VLBI data, and astrophysical interpretation.
- Antoine Bellanger (80%): engineer with background in statistics and computer science. His main role is to conduct initial VLBI data processing and to develop analysis tools as needed. He is also the web master for the M2A group.
- Géraldine Bourda (40%): post-doc fellow funded by the GRGS and the LAB. She is in charge of the VLBI analysis with GINS for combining space geodesy data at the observation level. She also leads a VLBI observational program for linking the ICRF and the future Gaia frame.
- Arnaud Collioud (100%): engineer with background in astronomy and interferometry. His tasks are to process the RDV sessions with AIPS and DIFMAP to image the sources, to maintain the Bordeaux VLBI Image Database (BVID), and to develop VLBI2010 simulations.
- Ming Zhang (50%): post-doc fellow funded by the CNRS. His work is targeted towards finding automatic ways to model-fit VLBI structures and extract physical information with the aim of studying the evolution of the sources from the BVID.
- Alain Baudry (10%): radioastronomy expert with specific interest in radio source imaging and astrometric VLBI.

### 4. Analysis and Research Activities during 2009

As noted above, a significant portion of our activity consists in imaging the sources observed during the RDV sessions on a systematic basis. During the past year, two such sessions were processed (RDV72 and RDV74), resulting in 365 VLBI images at either X or S band for 172 different sources. The imaging work load has been shared between the USNO and Bordeaux groups 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)<sup>1</sup>. At present, the BVID comprises a total of 1898 VLBI images (with links to an additional 6984 VLBI images from the Radio Reference Frame Image Database of the USNO at either S, X, K or Q band) along with 8882 structure correction maps and as many visibility maps. Apart from being regularly updated, the BVID has also been recently enhanced with new functionalities (quick source query from browser tool bar, image slide show, RSS feed,...).

Additional work aimed at studying the evolution of these structures over time is also pursued to exploit the BVID for astrophysics. For this purpose, a pipeline that automatically fit Gaussian components to the observed VLBI structures has been developed. Its results are repeatable,

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<sup>1</sup>The BVID may be accessed at <http://www.obs.u-bordeaux1.fr/BVID>

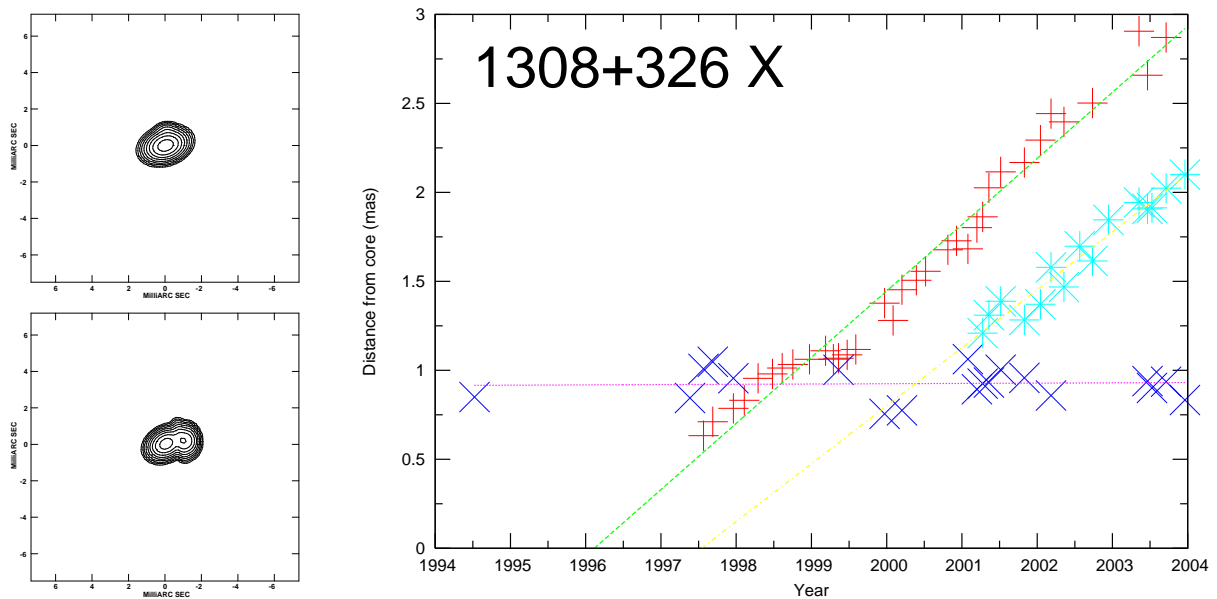


Figure 1. Structure models at X band for the ICRF source 1308+326 at epochs 1997.08 (upper left panel) and 1998.48 (lower left panel). The right panel shows the evolution with time of the component separation from the core. Three components are identified, with linear velocities of  $0.37 \pm 0.01$  mas/yr (green dashed line),  $0.33 \pm 0.02$  mas/yr (yellow dashed-dotted line), and  $0.00 \pm 0.01$  mas/yr (purple dotted line).

thereby providing objective comparisons between different data sets or reduction procedures, unlike traditional model-fitting which is usually user-dependent due to being accomplished manually. In a second step, the source models derived for all epochs are compared to estimate jet proper motions and flux density variability. This second pipeline calculates linear proper motion scatter to reduce the ambiguity in component sequencing and makes the most plausible component identification from epoch to epoch. Figure 1 illustrates our results for the ICRF source 1308+326. Comparison with results obtained manually are underway to assess the quality of this automatic reduction.

Another significant accomplishment of the past year is our contribution to the realization of the ICRF2. In this collaborative work, our task was focused on the selection of defining sources. The selection was made jointly with the Paris Observatory group based on (i) series of structure index, and (ii) arc source positions. This led to the identification of 295 defining sources with high astrometric quality and stable positions, which were adopted as a replacement for the ICRF at the XXVIIth IAU General Assembly held in Rio de Janeiro in August 2009 [4].

The work on the Gaia frame alignment [5] has made further progress, with calculation of structure indices for the 108 candidate sources imaged so far and preparation for the remaining observations. About half of the targets show point-like or quasi point-like structures. Assuming similar statistics for the remainder of the sample, we anticipate that a total of 200 new radio sources suitable for the Gaia alignment should be identified from this project ultimately.

Studies of the imaging capabilities of the VLBI2010 system continued during 2009 with focus on developing Monte Carlo simulations and calculating structure corrections from the simulated images in order to assess the accuracy of such structure corrections. The results of this work will be presented at the upcoming IVS General Meeting to be held in Hobart in February 2010.

## 5. Dissemination and Outreach

The Bordeaux VLBI group was involved in organizing two major IVS events during the past year: (i) the “VLBI 2009” series of meetings which were hosted in Bordeaux during the period 23–28 March 2009, and (ii) the International Year of Astronomy 2009 (IYA2009) specific IVS session which took place on 18 November 2009 and was meant both as an outreach and a scientific event.

The VLBI 2009 event comprised the 19th European VLBI for Geodesy and Astrometry Working Meeting, the 10th IVS Analysis Workshop, IVS Working Group meetings, and the 21st meeting of the IVS Directing Board. This event culminated with the celebration of the IVS 10th Anniversary on March 25 which was attended by 100 people, while being also streamed on the web in real-time.

The aim of the IYA09 session was to assemble the largest VLBI network ever and to observe as many ICRF2 defining sources as possible. A total of 34 stations was scheduled, while 243 of the 295 ICRF2 defining sources were observed. The contribution of the Bordeaux group consisted in making liaison with the official IYA2009 organization for outreach, preparing press releases, as well as building a dynamic web site displaying VLBI images of the observed sources in real time.

## 6. Outlook

Our plans for the coming year are focused on moving towards an operational analysis of the IVS-R1 and IVS-R4 sessions with the GINS software package. We will also continue imaging the RDV sessions in cooperation with USNO as well as evaluating the source astrometric suitability based on structure index and source compactness indicators. Additionally, we are planning to postprocess further the BVID data by using the pipeline that we have developed to automatically model-fit VLBI structures for astrophysical interpretation. Regarding the Gaia link, further imaging data should be acquired in the coming year, leading to the identification of additional suitable link sources. Simulations of the imaging capabilities of the VLBI2010 system will also continue with focus on the assessment of the accuracy of the structural corrections derived from these images. Finally, at the request of the IVS Directing Board, we are planning to extend the dynamic web site that was set up for the IYA2009 session in order to make it run for every IVS session.

## References

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