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DENSIFICATION OF CELESTIAL REFERENCE FRAMES: TOWARDS NEW VLBI OBSERVING STRATEGIES

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Abstract. Building celestial reference frames such as the International Celestial Reference Frame (ICRF) from Very Long Baseline Interferometry (VLBI) observations is very important for geodesy, astrometry and astrophysics. We have started a project whose objective is to develop new VLBI analysis methods and observational strategies to densify such reference frames. Our strategy takes advantage of the phase referencing VLBI technique, which allows one to detect radio sources weaker than those traditionally observed with the standard wide-angle VLBI technique used to construct the ICRF. The combination of wide-angle and phase referencing VLBI observations should provide a denser and unified reference grid comprising both strong and weak radio sources. Actual data as well as simulated data will be used to test the method.

Keywords: astrometry, reference frames, VLBI, quasars

1 VLBI astrometric techniques

Celestial reference frames are aimed at measuring positions and motions of objects in the sky with the highest possible accuracy. They are essential for a number of astronomical and astrophysical studies such as Solar System dynamics, kinematics of the Galaxy or physics of distant active galaxies. Since the generation of the International Celestial Reference Frame (ICRF) and its subsequent adoption by the International Astronomical Union (IAU) in 1997 (Ma et al. 1998), the fundamental celestial frame has been defined based on extragalactic sources. The current IAU frame, the ICRF2, in use since 1 January 2010, comprises positions for 3414 sources (corresponding to an average of one source every $\sim 3^\circ$ on the sky), with a noise floor of 40 μas in the source coordinates (Fey et al. 2009). The ICRF2 was generated from nearly 30 years of Very Long Baseline Interferometry (VLBI) data (1979–2009) acquired with the standard wide-angle astrometric technique based on group delay measurements. Further densification of the frame with this technique requires sensitive instrumentation (large radiotelescopes, high recording rates,...) along with large amounts of observing time since weaker sources have to be observed.

Such weak sources may be observed more easily by using the differential phase-referencing VLBI technique (Lestrade et al. 1990; Beasley & Conway 1995). The principle of this technique is to calibrate the data of a (weak) target source from a bright angularly-close (a few degrees at most) calibrator, e.g. from the ICRF2 grid. Observations alternate between the target and the calibrator and the phase of the target is estimated relative to that of the calibrator after interpolation over successive calibrators scans. In this way, the data may be integrated over several hours, thereby permitting the detection of weak sources, unlike the standard VLBI technique which is limited to a few minutes integration time. The position of the target relative to that of the calibrator is then derived to an exquisite accuracy of a few tens of μas (Lestrade et al. 1990; Pradel et al. 2006).

2 New observing strategies

Our goal is to investigate the potential densification of the current reference grid by combining the two VLBI techniques described above (global astrometry and phase-referencing). With this scheme, we expect to bring many weak sources into the celestial frame and fill the interspace between the current grid of ICRF2 calibrators, as illustrated in Figure 1. More specifically, we aim at processing jointly VLBI group delay and phase data in

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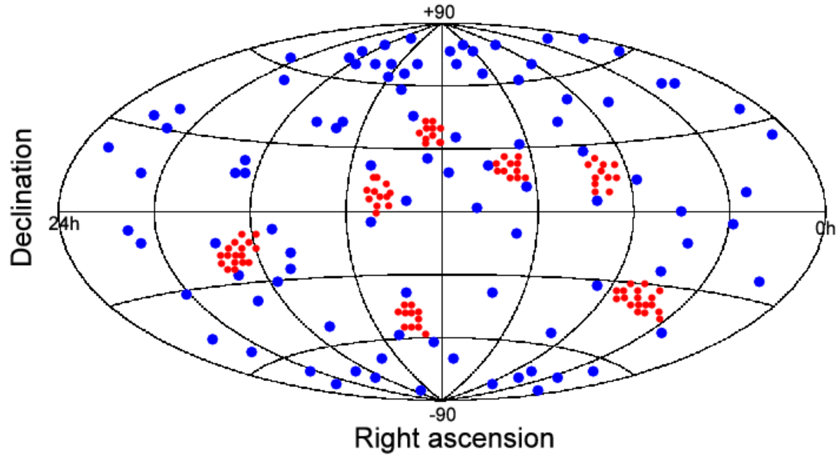

Fig. 1. Schematic representation of the anticipated densification of the current celestial reference frame (blue dots) by adding many weak radio sources observed by phase referencing VLBI (red dots).

Table 1. VLBI software packages used for global astrometry (GA) and phase referencing (PR)

GA	References	GA	References	PR	References
Calc/Solve	Ryan et al. (1993)	OCCAM	Titov et al. (2004)	AIPS	Greisen (2003)
GINS	Bourda et al. (2007)	QUASAR	Kurdubov (2007)	SPRINT	Lestrade et al. (1990)
MODEST	Sovers & Jacobs (1996)	SteelBreeze	Bolotin (2001)	UVPAP	Martí-Vidal et al. (2008)

a consistent and unified way. Table 1 lists the VLBI software packages used for global and phase-referencing VLBI astrometry. Among these, the JPL VLBI software package MODEST appears to be unique as it has the capability of processing both data types (group delays and phases) along with the potential for simulating artificial VLBI data sets. Simulations are likely to play a crucial role here for identifying the observing strategy that provides the highest astrometric accuracy and the most efficient VLBI scheduling. Actual data from the VLBA (Very Long Baseline Array) and EVN (European VLBI Network) archives will also be used for this work.

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