USE OF MILLISECOND PULSARS TO TEST AND LINK PLANETARY EPHEMERIDE REFERENCE FRAMES TO ICRF

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ABSTRACT. We describe here the method used to test the links between INPOP and DE reference frames to ICRF in using radio timing and VLBI astrometry of millisecond pulsars. The obtained rotation matrices are consistent with estimations done previously for DE405 and DE200 and confirm the efficiency of such procedures in waiting for a densification of millisecond pulsars with a mas-level VLBI and radio-timing astrometry.

1. METHOD

Space missions need more and more accurate positions and velocities of solar system objects and especially the earth. It is then important to check the planetary ephemerides accuracy in using very accurate observations of objects close from the earth (in order to be sensitive to the earth orbit) but not used in the fit process of the ephemerides. If the same object is also directly connected to ICRF sources, we can also test the link between the planetary ephemeride frame and ICRF.

VLBI-derived positions of millisecond pulsars (MSP) can provide a tie between the extragalactic (earth-rotation based) reference frame in which VLBI "operates" and the dynamic (earth-orbit based) reference frame in which MSP timing positions are derived.

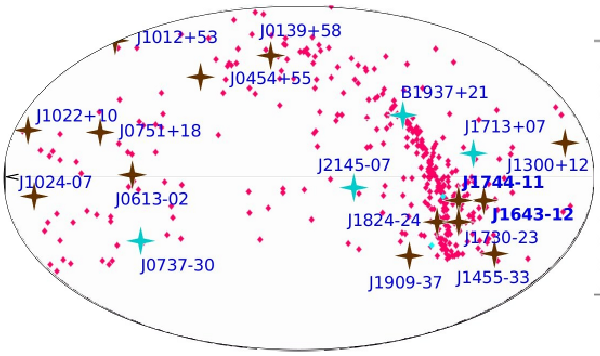
If (α_{PE1},δ_{PE1}) are positions of a MSP deduced from TOA in using Planetary Ephemerides 1 (PE1) and (α_{PE2},δ_{PE2}) are positions of the same MSP deduced either from VLBI observations and then in ICRF either from TOA in using Planetary Ephemerides 2, the differences(α_{PE1},δ_{PE1}) and (α_{PE2},δ_{PE2}) can be seen as residual rotations $R_x(\theta)$,$R_y(\eta)$ and $R_z(\zeta)$ about the x,y and z axis of PE1 reference frame such as $\alpha_{PE1} = R_x(\theta)R_y(\eta)R_z(\zeta)\alpha_{PE2}$ and $\delta_{PE1} = R_x(\theta)R_y(\eta)R_z(\zeta)\delta_{PE2}$. The angles θ, η and ζ can then be deduced by least square fitting.

2. MILLISECOND PULSARS USED FOR THIS STUDY

From the radio timing profiles obtained at the NRT (Desvignes 2010), we selected 18 MSPs with radio timing astrometry better than 10 mas. These 18 MSPs are used for the estimation of the rotation matrices between DE414, INPOP08, DE405 and DE200 presented in figure 1. For the second step, we collected in the literature positions and velocities of millisecond pulsars obtained by VLBI astrometry (Chatterjee et al. 2009, Deller et al. 2009) and observed by the NRT. 4 MSPs have a mas-level accuracy in both techniques, VLBI and radio timing, and are used to test the link between planetary frames and ICRF. The obtained rotation matrices are presented in this volume in (Fienga et al. 2010).

3. RESULTS

We have first estimate the impact of using different planetary ephemerides (with different set of planet masses) on the analysis of radio timing data. For the 18 MSP used for this study, no specific trend remains in the postfit residuals of the radio timing despite the change in planet masses and initial conditions brought by each different ephemerides. Among the parameters fitted during the radio timing data analysis, the positions and the proper motions of the pulsars are sightly modified. No other parameters related to the distance, the rotation or the orbit of the companion are affected by the change of planetary ephemerides.



	θ mas	η mas	ζ mas
18 MSPs with TOA $(\sigma_\alpha,\sigma_\delta) < 10$ mas			
DE405 → DE200	-0.4 ± 0.3	-13 ± 0.4	-13 ± 0.3
(Standish 1998)	-1 ± 2	-14 ± 3	-10 ± 3
DE414 → DE405	1.5 ± 0.3	-1.0 ± 0.4	-0.9 ± 0.3
INPOP08 → DE405	1.3 ± 0.3	-0.3 ± 0.4	-1.1 ± 0.3
INPOP10A → DE405	1.6 ± 0.3	-0.7 ± 0.4	-0.7 ± 0.3
Only 4 MSPs with TOA $(\sigma_\alpha,\sigma_\delta) < 10$ mas			
DE405 → DE200	-0.5 ± 0.2	-12 ± 0.3	-13 ± 0.18
INPOP08 → DE405	1.4 ± 0.03	-0.03 ± 0.05	-1.4 ± 0.03
INPOP10A → DE405	1.7 ± 0.01	-0.03 ± 0.02	-1.0 ± 0.01

Figure 1: On the left hand side, distribution in (α,δ) of MSPs on an Aitoff equatorial map centered on (0,0). The small stars are (Hobbs et al. 2004) PSR catalogue positions. The big stars are the MSP used in this study, the light gray ones are the one selected for the link between INPOP and DE reference frames to ICRF. On the right hand side, angles of rotation deduced from adjustment of rotation matrices defined in the text. The angles are given in mas and the uncertainties are the formal 1-sigma deduced from the least squares.

Based only on radio timing observations, the angles presented in figure 1 and obtained in using the 18 selected pulsars are quite compatible with previous determinations of rotation matrices between planetary frames. In (Fienga et al. 2010) are given the rotations obtained between planetary ephemerides frames and ICRF as deduced from pulsar timing and VLBI astrometry. None of these rotations are statistically significant except the one between DE200 and the ICRF. The obtained matrices are consistent with results obtained by (Folkner et al. 1994) and (Standish 1998). This is also consistent with the fact that DE200 was not directly linked to ICRF. VLBI tracking data of spacecraft were not used for the DE200 construction and only optical observations of planets with an accuracy of about 100 mas were used to link the planetary frame to the ICRF.

This study shows the efficiency of using radio timing and VLBI astrometry of millisecond pulsars to estimate the rotation matrices between the planetary frames and between the DE and INPOP frames with the ICRF. We checked that the procedures give similar angles as the one already deduced by other methods (Standish 1998, Folkner et al. 1994) and confirmed the mas level internal accuracy of the planetary ephemerides. More MSPs should be observed in VLBI in order to increase the sample to directly link planetary frames and ICRF.

4. REFERENCES

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