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PRIDE: Ground-based VLBI observations for the JUICE mission

G. Cimò (1,2), D. Dirkx (3), D. A. Duev (4), G. Molera Calvés (5), T. M. Bocanegra Bahamon (1,3) and L. I. Gurvits (1,3)

(1) Joint Institute for VLBI ERIC, JIVE, The Netherlands (cimo@jive.eu), (2) Netherlands Institute for Radio Astronomy, ASTRON, The Netherlands, (3) Delft University of Technology, The Netherlands, (4) California Institute of Technology, USA, (5) Finnish Geospatial Research Institute, Finland

Abstract

Precise determination of the lateral position of spacecraft on the celestial sphere is the main deliverable of the Planetary Radio Interferometry and Doppler Experiment (PRIDE). Using the radio astronomical technique of phase referencing (near-field) VLBI, PRIDE provides ultra-precise estimates of the spacecraft state vectors. As a selected experiment of the ESA's flagship mission Jupiter Icy Moons Explorer (JUICE), PRIDE will provide JUICE's lateral position in the International Celestial Reference Frame. These measurements, in synergy with the onboard radio science and optical astrometry instruments, will help to improve the current values of the ephemerides of the Galilean moons.

PRIDE and JUICE

PRIDE near-field VLBI observations of spacecraft can be used for a variety of scientific applications, including improvement of ephemerides, ultra-precise celestial mechanics of planetary systems, gravimetry, spacecraft orbit determination, and fundamental physics. These scientific applications are based on two observable quantities: the radial range rate (Doppler shift of the service communication system carrier signal) and the lateral (transverse) celestial position of the spacecraft with respect to the International Celestial Reference Frame (ICRF). The measurements of the spacecraft differential lateral position relative to ICRF are performed by VLBI observations of spacecraft and background extragalactic radio sources with accuracy of tens of μas (1-σ RMS) over integration time of $60 - 1000\,$s[3]. The geometry of a typical PRIDE measurement is shown in Figure 1. This technique is complementary to radio science experiments and addresses those areas of spacecraft mission science objectives that require accurate estimation of spacecraft state vector.

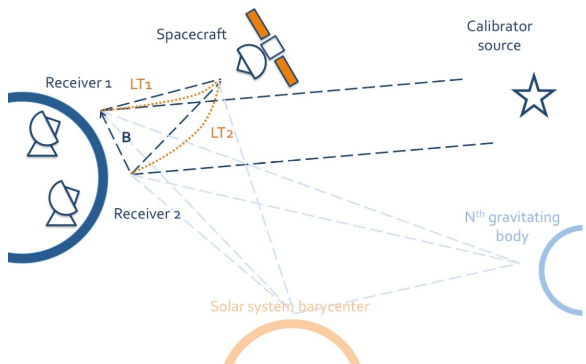

Figure 1: Geometry of a PRIDE experiment.

In the course of its orbits around the Galilean moons, the JUICE mission will perform detailed studies of the dynamics of the Jupiter system. The synergy of the onboard instrumentation and Earth-based observations will allow us to measure with unprecedented accuracy the dynamics of the Galilean moons. This will provide crucial input to the determination of the ephemerides and physical properties of the Jupiter system.

In this contribution, we introduce a covariance analysis of the relative quantitative influence of the JUICE-PRIDE observables to the determination of the ephemerides of the Jovian system and the associated physical parameters [2]. Furthermore, we present the experiments our team carried out to develop and improve VLBI and Doppler measurements of spacecraft and to study their scientific applications. The amount of data collected during PRIDE tests have also had a number of scientific outcomes: ESA's Venus Express (VEX) and Mars Express (MEX) has been extensively targeted by PRIDE for studying the solar wind by observing the effects of intervening ionized plasmas on the spacecraft signal [5]. Radio occultation experiments of both Venus Express and Mars Express have performed to derive vertical density, pressure and temperature profiles of planetary atmospheres [1]. In the case of MEX, a number of observations were carried out during the Phobos flyby on December 2013 [4].

PRIDE is a versatile experiment with zero impact on the science payload mass, and it offers a high degree of synergy with the typical on-board instrumentation. Near field VLBI can complement the scientific suite of any future missions with transmitting orbiters and/or landers.

References

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