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# Space Science Applications of Near-field VLBI

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## Abstract

The core of the Planetary Radio Interferometry and Doppler Experiment (PRIDE) is the accurate estimation of the state-vector of a spacecraft using Very Long Baseline Interferometry (VLBI) tracking. We will describe a number of implementations of the PRIDE technique presenting past and current experiments, and discussing the involvement of PRIDE in future ESA's missions.

## PRIDE Science

The VLBI tracking of spacecraft has been successfully applied to a number of space missions. The PRIDE experiments estimate the state-vector of the spacecraft with high accuracy by performing VLBI observations of the spacecraft and natural celestial reference radio sources. This technique proved to be very efficient in the VLBI experiment with the Huygens probe carried out during its descent on the surface of Titan [1, 2].

Due to the ability to provide precise measurements of spacecraft lateral coordinates, radial velocity and its derivatives [3], PRIDE is a multi-disciplinary enhancement of the scientific suite of space missions.

In case of a planetary probe orbiting around planets or satellites, PRIDE can estimates of the mass and gravity field of the study objects. PRIDE can also address the following scientific areas:

- Ultra-precise celestial mechanics;
- Geodynamics, internal structure and composition of planet and moons;
- Shape and gravimetry;
- electric properties of icy satellite surfaces and their plasma environments;
- fundamental physics and general relativity.

VLBI tracking of the spacecraft in combination with routine observations of radio sources of the celestial reference frame allows us to firmly tie a planetary system into the reference frame. This would represent a major contribution to planetary geodesy and the definition of the Solar System reference system.

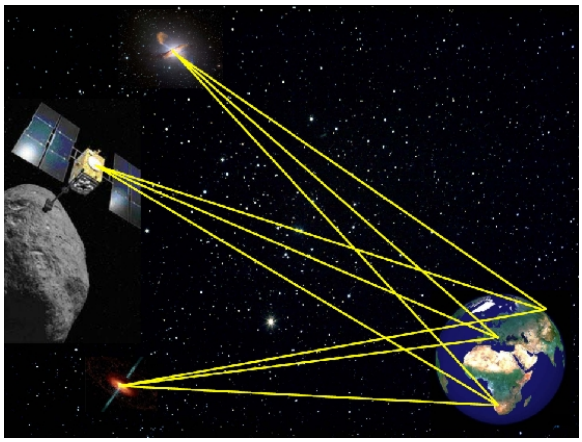

Figure 1: Artistic impression of a typical PRIDE setup.

## PRIDE and space missions

PRIDE offers a high degree of synergy with the typical on-board instrumentation and does not include components requiring mission-critical technology developments. The required on-board instrumentation (transmitters, ultrastable oscillators, antennas) are developed and used by space mission operations regardless of PRIDE.

Such flexibility and the many scientific outcomes for the minimal requirements have contributed to make PRIDE one of the selected experiments for the next ESA's L-class mission: JUICE (see L. Gurvits contribution to this conference).

This allows PRIDE to observe any spacecraft equipped with a transmitter. In the course of the past three years, Venus Express has been observed to perform tests to improve the PRIDE observations and post-processing pipeline. Scientific outcomes of such tests include solar wind scintillation and study of Venus atmosphere (see Bocanegra et al contribution to this conference). Another ESA's planetary mission observed with PRIDE has been Mars Express including observations during a Phobos fly-by. PRIDE observations are planned for the next Phobos fly-by in December.

Closer to our own planet, PRIDE has helped geophysical studies with a number of observations of the GLONASS satellites orbiting around the Earth. The ESA space telescope Herschel has also been a target of our VLBI measurements in preparation for the ESA's Gaia mission. Gaia is an ambitious astrometric mission to chart a three dimensional map of the Milk Way and, like Herschel, Gaia will be orbiting around L2. PRIDE observations are necessary to ensure the optimal orbit determination needed for the highly accurate Gaia measurements. Another project that currently benefits from PRIDE is the Russian-led space VLBI mission RadioAstron.

In addition to science topics, PRIDE will provide support to mission operations, in particular, mission navigation and trajectory determination as well as onboard systems and instrumentation diagnostics. A separate and potentially beneficial application of PRIDE is its ability to provide limited Direct-to-Earth delivery of data from spacecraft [4].

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# References

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