Autonomous Spacecraft Navigation with X-ray Pulsars

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Abstract: Pulsars can be used as natural beacons for navigation, similar to the use of GPS satellites for navigation on Earth. In contrast to standard navigation methods, which rely on radio measurements by tracking stations on Earth, pulsar-based navigation can operate autonomously and is, therefore, independent from ground-based control and maintenance. This is particularly interesting for space missions that require a higher degree of autonomy, e.g. exploration of the outer solar system or manned missions to Mars, but could also be beneficial as augmentation of existing space technologies, such as GPS and Galileo satellite systems. Our research project aims at proposing telescope/detector configurations feasible for application in future pulsar-based navigation systems.

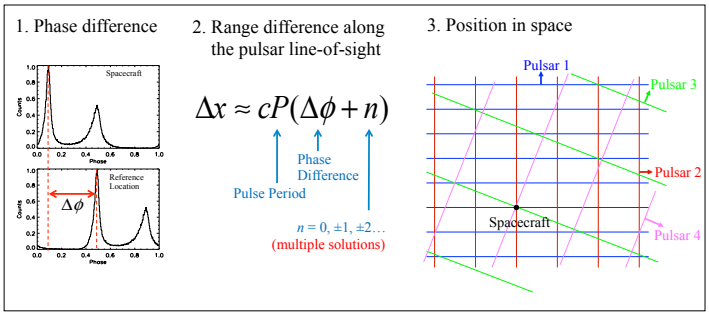

Figure 1: Principles of pulsar-based navigation. A spacecraft that carries the means to detect and analyse the periodic signals from pulsars can determine its position and velocity by comparing pulse profiles and pulse arrival times measured on-board with those predicted at a reference location and epoch.

As pulsars emit broadband electromagnetic radiation from radio to X- and γ-rays, a pulsar-based navigation system can be designed for any energy band that is optimal in terms of pulsar characteristics (luminosity, pulse shape, pulse period etc.), hardware specifications (type and collecting power of the antenna, temporal resolution of the detector etc.) as well as boundary conditions given by the spacecraft (size, weight, power consumption etc.). We have been analysing the performance of pulsar-based navigation systems as a function of these parameters by simulating pulse profiles as measured by an arbitrarily moving virtual observer. According to our studies, an implementation of this novel technology seems particularly promising in the light of new telescope and detector developments, such as low-mass X-ray mirrors and active pixel detectors. Currently, we are working on high-level designs of pulsar-based navigation systems for different mission requirements. The chart shown in Figure 2 illustrates the work logic of our current simulations.

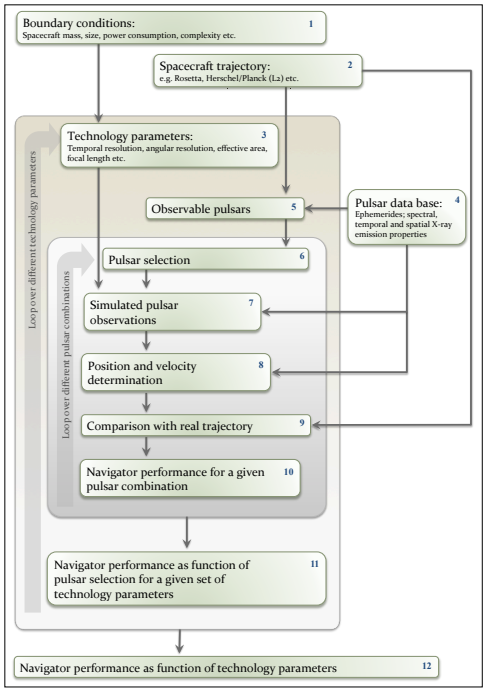

Figure 2: Work flow and logic of the simulations performed for a technology requirement study and demonstrator high-level design of a pulsar-based navigator.

References:

- W. Becker, M. G. Bernhardt, A. Jessner, 2013. Autonomous Spacecraft Navigation with Pulsars. In Proc. of *Relativistic Global Navigation Satellite Systems*. (In print.)
- M. G. Bernhardt, W. Becker, T. Prinz, F. M. Breithuth and U. Walter, 2011. Autonomous Spacecraft Navigation Based on Pulsar Timing Information. In Proc. of *2nd International Conference on Space Technology*.
- M. G. Bernhardt, T. Prinz, W. Becker and U. Walter, 2010. Timing X-ray Pulsars with Application to Spacecraft Navigation. In Proc. of *High Time Resolution Astrophysics IV*.

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