Mutual radio occultation experiment between ExoMars Trace Gas Orbiter and Mars Express: feasibility study and preparation for the data analysis

Bruno Nava\textsuperscript{1}, Anton Kashcheyev\textsuperscript{2}, Yenca Migoya-Orue\textsuperscript{1}, Sandro M. Radicella\textsuperscript{1}, Jacob Parrott\textsuperscript{3}, Beatriz Sánchez-Cano\textsuperscript{4}, Olivier Witasse\textsuperscript{3}, Håkan Svedhem\textsuperscript{3}, Dimitri Titov\textsuperscript{3}, and Chi O. Ao\textsuperscript{5}

\textsuperscript{1}The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
\textsuperscript{2}Department of Physics, University of New Brunswick, Fredericton, New Brunswick, Canada
\textsuperscript{3}European Space Agency, ESA/ESTEC, Directorate of Science, Noordwijk, Netherlands
\textsuperscript{4}School of Physics and Astronomy, University of Leicester, Leicester, UK
\textsuperscript{5}Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA

Radio Occultation is a very powerful technique to probe a planetary atmosphere, in providing vertical density profiles of the neutral atmosphere and ionosphere. The standard method uses a radio link at S and/or X band between a spacecraft and an Earth ground station. At Mars, such measurements are conducted since the 60s. The three most recent data sets are from MGS (1998-2006), Mars Express (since 2004) and MAVEN (since 2016). Taking advantage of two European spacecraft in orbit around Mars, the European Space Agency is currently preparing an experiment that consists of mutual radio occultations between Mars Express and the ExoMars Trace Gas Orbiter. Both spacecraft use UHF transceivers that are included primarily for communication between landers on the surface of Mars and the spacecraft, where the spacecraft act as relay orbiters to pass the data from the landers on to Earth. Therefore, these mutual occultations will be performed in the UHF range (centered around a frequency of 400 MHz). The feasibility of this technique on UHF was demonstrated between the NASA Mars Odyssey and Mars Reconnaissance Orbiters [Ao et al., 2015].

In this presentation, the advantages and challenges of this technique over the traditional spacecraft to Earth occultation measurements, the plans for conducting these experiments with Mars Express and the Trace Gas Orbiter, and the envisaged data processing technique will be briefly reviewed.

Before the data becomes available, and in order to prepare the data processing, a simulation-based strategy has been adopted to implement an algorithm able to retrieve vertical electron density profiles from Doppler shift measurements. More specifically, as a first step, simulated spacecraft orbits are calculated and a Chapman function is used to obtain the electron density of the Martian ionosphere. Subsequently, a numerical 3D ray-tracing algorithm [Kashcheyev et al., 2012] is applied to compute ray trajectories in the presence of the ionosphere and the relevant Doppler shift time series corresponding to the simulated radio occultation event. Then, assuming a spherical symmetry [Fjeldbo et al., 1971] for the ionosphere electron density, the (excess) Doppler data are converted to bending angles and impact parameters. Finally, the bending angle profile is inverted (through Abel integral) to a vertical refractivity profile, which, in turn, provides information about the ionospheric electron density.
For completeness, the simulation described above has been carried out with an exponential refractivity function defining the neutral atmosphere alone and with both the Chapman and the exponential refractivity functions to simulate the whole atmosphere of Mars.

The first results obtained by means of the mentioned approaches will be presented, with particular focus on the retrieval of the ionospheric electron density profiles.

**References**

