EVN Observations of Mars Landers - Enhancing Knowledge of the Martian Interior

Jasper Edwards[1], Guifré Molera Calvés[1], Dominic Dirkx[2], Vidhya Pallichadath[2], Giuseppe Cimò[3], Pradyumna Kummamuru[1], Sebastien Le Maistre[4] and Noor Masdiana Md Said[1]

[1]University of Tasmania, Hobart, Australia; [2]Delft University, Delft, The Netherlands; [3]Joint Institute for VLBI in Europe, Dwingeloo, The Netherlands; [4]Royal Observatory of Belgium, Brussels, Belgium.

Introduction

After more than 15 years of development and a number of successful demonstrations [1] on operational spacecraft (Huygens (2005), Smart-1 (2006), Venus Express (2008 - 2014) and Mars Express 2012 ->), the **Planetary Radio Interferometry and Doppler Experiment (PRIDE)** [2] is preparing for experiments on future missions, including the LaRa experiment on the ESA's ExoMars-2022 lander. The high precision of spatial positioning and multi-station Doppler data provided by PRIDE presents a unique opportunity to enhance the scientific return of interplanetary missions. Of particular interest, in current and near future missions to the Martian system, is improving our understanding of Mars' interior. The PRIDE Doppler data has evidenced the capability to reduce the estimated uncertainty of Mars orientation parameters, which are strongly linked to the behaviour of the Martian interior. We conducted observations of **NASA's InSight lander** to complement the mission's radio science experiment [4], as well as in preparation for observations **of ESA's ExoMars-2022 lander**.

Figure 1: UTAS 26m Antenna, Tasmania, Australia.

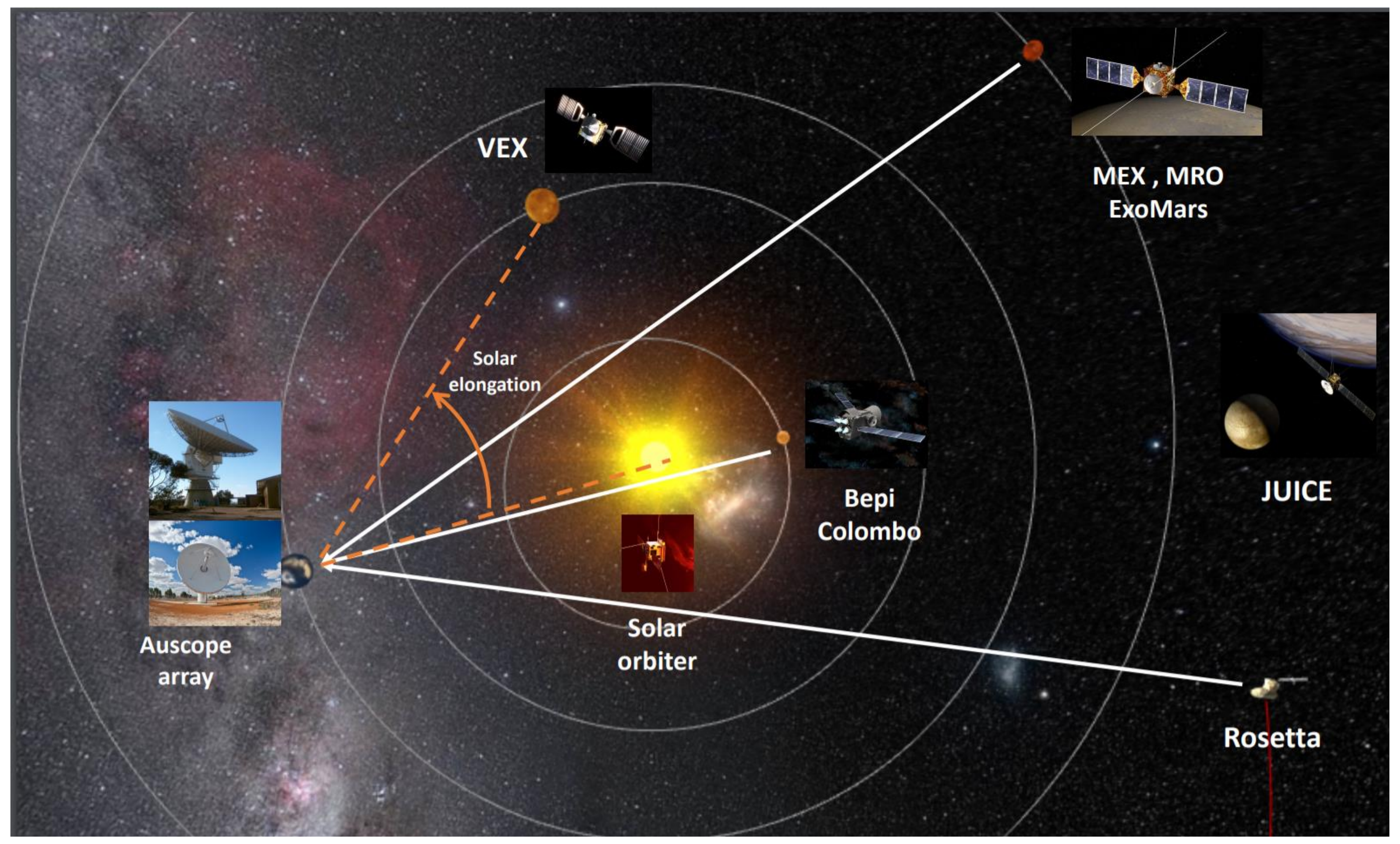

Figure 2: Current and future missions observed by UTAS.

Observations

In 2020, we organised observations of Mars Insight using radio telescopes from the European VLBI Network (EVN) and the University of Tasmania (UTAS) array. The experiment consisted of six sessions, divided into three blocks, with two observational epochs per block (22-23 February, 29-30 May, 21-22 October). The epochs had a duration ranging from 1 to 2 hours (depending on the craft transmission window). We used two approaches for the sessions: one with multiple long (19-minute) scans of the craft, the other with short (2-minute) scans alternating between the craft and an appropriate reference source with a small angular deviation from Mars (for phase-referencing) [3].

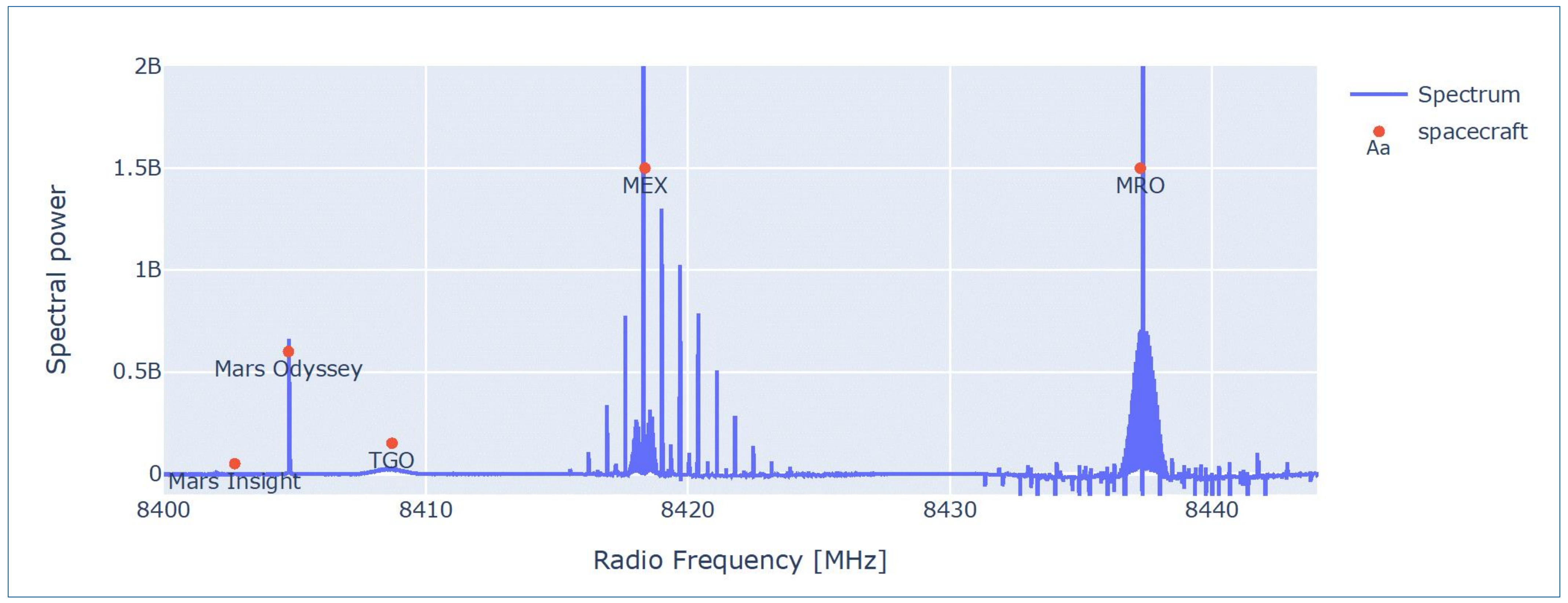

Figure 3: Spectral profile of Mars based space missions (X-band).

Analysis

Data acquired at each radio telescope were transferred to JIVE (the processing centre of the EVN) and to UTAS. Data processing was conducted using the dedicated Spacecraft Doppler tracking (SDtrack) software, developed to provide VLBI tracking support to interplanetary space missions [1]. Figure 3 shows the full wide-band spectra as observed on 2020.02.23 with the 30-metre radio telescope at Ceduna (Australia). At the time of the observations five spacecraft were transmitting simultaneously (Mars Insight, Mars Odyssey, Trace Gas Orbiter, Mars Express and the Mars Reconnaissance Orbiter). Each craft transmits with a unique carrier frequency and power, as indicated in the figure. The detection of Mars InSight showed weaker spectral power relative to the other craft. The lander is equipped with a low-gain antenna and heavy dust storms were present on Mars at the time of the observations, hence the lower spectral power. Figure 4 shows the topocentric frequency detections obtained on 2020.02.22 with 6 of the radio telescopes. Figure 5 shows the zoom (1 Hz) of the carrier signal transmitted by Mars Insight from the data collected at Effelsberg (100-m antenna, Germany).

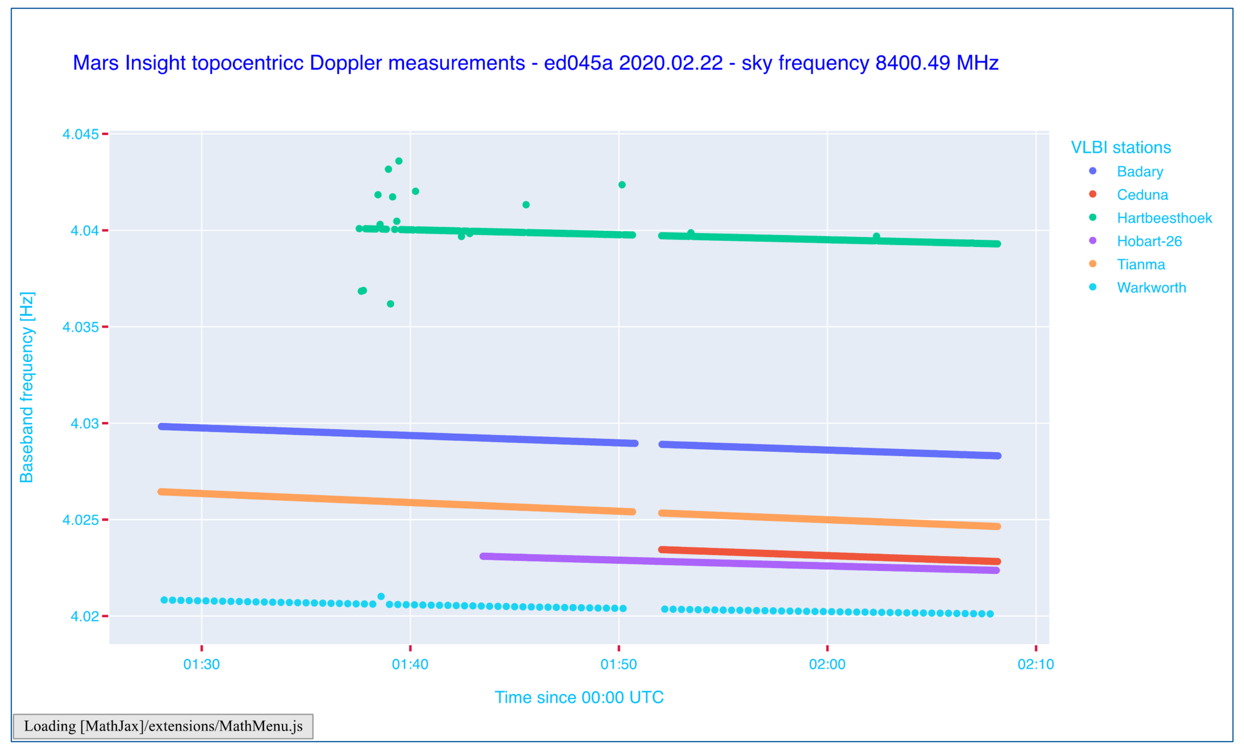

Figure 4: Topocentric frequency detections by station.

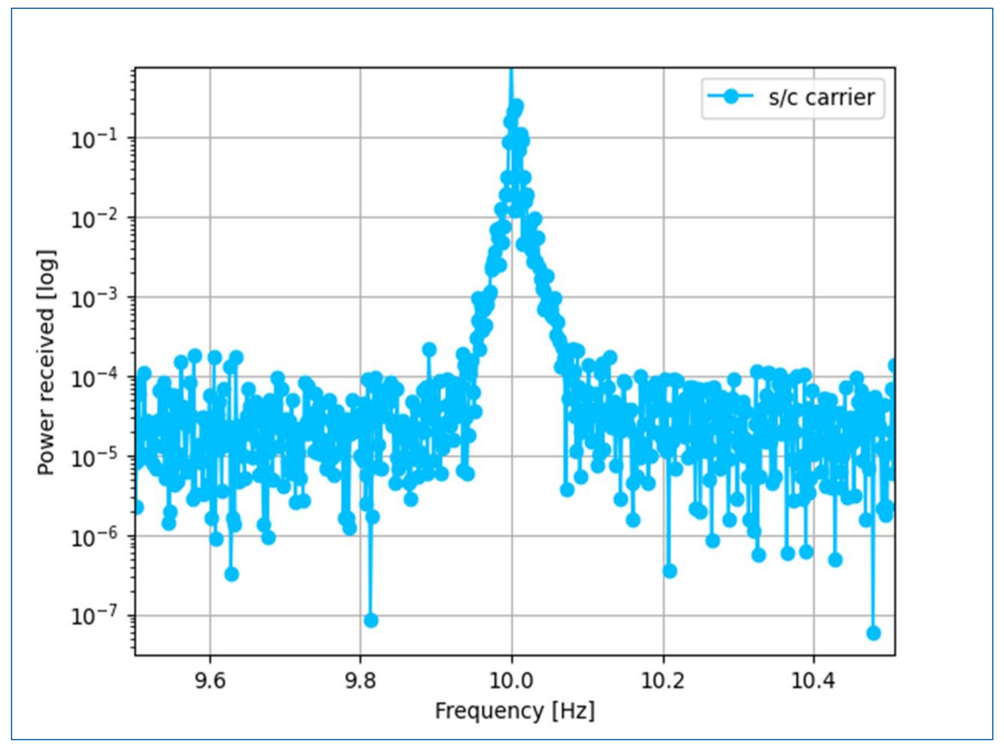

Figure 5: Power spectrum down converted with linear-trend free phase.

Conclusion

We present the initial results obtained from VLBI radio telescope observations of spacecraft stationed on Mars. The high precision of spatial positioning and multi-station Doppler data obtained by PRIDE allows for a reduction in the estimated uncertainty of Mars orientation parameters which are strongly linked to the behaviour of the Martian interior [2,4]. This experiment exhibits the effectiveness of modern radio observational methods when applied to spacecraft and is part of a broader range of experiments using similar techniques. Other capabilities include: accurate measurement of the state vectors of spacecraft, studying planetary atmospheres by radio occultation, measuring the effect of gravity on satellites conducting flybys and observing space weather events such as coronal mass ejections and solar wind. The capabilities outlined above provide a unique opportunity to increase the scientific return of current and future space missions cost effectively.

References

[1] Guifré Molera Calvés, Sergei Pogrebenko, Jan Wagner et al. High spectral resolution multi-tone Spacecraft Doppler tracking software. submitted, 2021.

[2] Dominic Dirkx, Leonid Gurvits, Valery Lainey et al. On the contribution of PRIDE-JUICE to Jovian system ephemerides planss, 147:14-27322(10), 2017.

[3] Dmitry Duev, Sergei Pogrebenko, Giuseppe Cimò et al. Planetary Radio Interferometry and Doppler Experiment(PRIDE) technique: A test case of the Mars Express Phobos fly-by A&A, 593:A34, 2012

[4] Kahan, Daniel S., Folkner, William, Dustin R. Buccino, Veronique Dehant, Sebastien Le Maistre, Attilio Rivoldini, Tim Van Hoolst, and J.C. Marty. 2021. "Mars Precession Rate Determined from Radiometric Tracking of the InSight Lander." *Planetary and Space Science*, 2021

For more information contact: jasper.edwards@utas.edu.au