Deep Space Weather forecasting using radio sounding experiments with VLBI radio telescopes during the Martian solar conjunction

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University of Tasmania (UTAS), in collaboration with the Shanghai Observatory and the Joint Institute for VLBI-ERIC, conducts regular observations of deep space missions to study solar wind and forecast space weather. Tracking the radio signal transmitted by a spacecraft with VLBI ground-based antennas enhances the scientific outcome of the missions by providing interplanetary medium diagnosis. We use multi-frequency observations (in S, X and Ka-band), in-beam multi-spacecraft, and simultaneous VLBI radio telescopes at various locations on the ground [1]. Current tracking capabilities includes support to the European Space Agency missions of Bepi Colombo, Mars Express, Trace Gas Orbiter, Solar Orbiter, the Chinese National Space Agency Tianwen-1, and NASA's Mars Insight and Juno. The analysis of the fluctuations in amplitude, frequency and phase of the signal transmitted by each spacecraft provides characteristics of the propagation media such as electron density profiles for the line-of-sight, interplanetary scintillation of solar wind, magnetic field, and propagation orientation and speed of Coronal Mass Ejections [2].

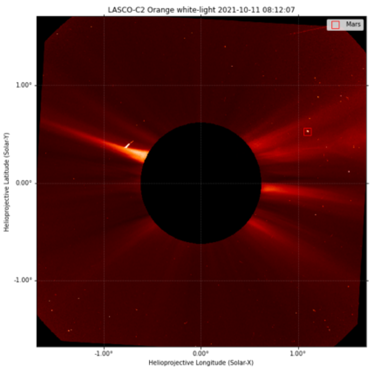

Figure 1. Geometry of Mars, Sun with respect the ground stations for the CME detections in October 2021.

In 2021 we conducted an extensive campaign to cover the ingress and egress of the solar conjunction of Mars to study the coronal structure heating and solar wind acceleration. Mars is an excellent target for radio experiments since several spacecraft are currently in operations. Here we present data from the last Martian solar conjunction, which occurred in October 2021. During the campaign, we detected CME and density enhancements that crossed along the ray paths of the telescope's sightlines. The phase fluctuations obtained from individual telescopes presented orders of magnitude higher than expected, even considering the proximity of the ray path to the Sun (closest approach). Using multiple antennas distributed across different continents allows us to calculate the propagation geometry and the lateral speed of these CMEs to improve forecasting models.

The ESA Jupiter Icy Moons Explorer (JUICE) space mission will be launched in April this year. Planetary Radio Interferometry and Doppler Experiment is a scientific instrument on board of the mission and lead by JIVE and this team. JUICE will provide a new insight of solar wind and space weather enabling observations at X and Ka-band during its phase cruise in the inner Solar System.

References

[1] G. Molera Calvés, et al., "High spectral resolution multi-tone Spacecraft Doppler tracking software: Algorithms and implementations", PASA, 2021 https://doi.org/10.1017/pasa.2021.56

[2] G. Molera Calvés et al., "Analysis of an Interplanetary Coronal Mass Ejection by a Spacecraft Radio Signal: A Case Study", *Space Weather*, 15, 1523–1534. https://doi.org/10.1002/2017SW001701

[3] M. Ma, G. Molera Calvés, et al., "Detecting the Oscillation and Propagation of the Nascent Dynamic Solar Wind Structure at 2.6 Solar Radii Using Very Long Baseline Interferometry Radio Telescopes", APJ, vol. 940, no. 2, 2022. doi:10.3847/2041-8213/ac96e710.48550/arXiv.2210.10324