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The September 2017 events and their imprints at Earth and Mars

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During the declining phase of the current quiet solar cycle, heliospheric activity has suddenly and drastically increased starting from a simple sunspot in Active Region (AR) 2673, which transformed into a complex region with three X-flares accompanied by several Earth-directed Coronal Mass Ejections (CME) from 4th to 6th of September.

Four days later, on 10th September, the same AR produced solar energetic particles (SEPs) which were registered as a ground level enhancement (GLE) at Earth and the biggest GLE on the surface of Mars as observed by the Radiation Assessment Detector (RAD) since the landing of the Curiosity rover in August 2012. Both Earth and Mars saw an impulsive and intense enhancement of the accelerated protons with energies larger than hundreds of MeV whereas STEREO-A, despite being at the back-side of the event, detected gradually increasing fluxes of particles transported there across the heliospheric magnetic field. Such high energetic particles were mainly accelerated by shocks associated with the CMEs also launched on 10th of September.

Three CMEs with similar longitudinal launch directions (between Earth and Mars with the central axis approximately 100 degrees from Earth and 40-50 degrees from Mars) can be identified based on STEREO-A and SOHO LASCO chronograph images. The first two had moderate launch speed while the last one had an extremely fast launch speed ($\sim$ 2500 km/s). The merging and interactions of the three CMEs into an interplanetary CME (ICME) were very complex through the inner heliosphere and caused a very significant Forbush decrease at Mars three days later, even before the enhanced particle flux recovered to quiet-time level. The arrival of the ICME at Mars is only a few hours later than that at Earth, despite Mars being 0.5 AU further away from the Sun than Earth. This timing difference between the ICME arrival at Earth and Mars is likely due to (1) the earlier ICMEs from 4th and 6th which have considerably changed the interplanetary conditions and (2) the interaction of the ICME with a High Speed Stream structure passing by Mars.

The 3D launch geometry and direction of the CMEs has been reconstructed based on the Graduated Cylindrical Shell (GCS) model and the subsequent ICME propagation has been performed using the WSA-ENLIL plus cone model, as well as the Drag Based Model (DBM) and CDPP propagation tool. Such modeled ICME arrivals at Earth and Mars are compared with in-situ measurements and the comparison shows that it is essential to consider the interactions of different CMEs as well as the spatially and temporally varying interplanetary conditions in order to better predict the ICME arrival at Earth and other planets.