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Abstract

On October 19th 2014, Mars experienced a close encounter with Comet C/2013 A1 (Siding Spring), at a distance of only 141,000 km, or one third the Earth Moon distance. The gaseous coma washed over Mars and Mars passed directly through the cometary debris stream [1]. As a close encounter of this type is predicted only once in 100,000 years, this is likely the only opportunity for measurements associated with planetary/cometary encounters. Additionally, the encounter was masked by the transit of a powerful Coronal Mass Ejection (CME) 44 hours before [2]. Thus, the comet flyby took place when the Martian plasma system was still recovering from the CME impact, whilst the solar wind passing Mars remained significantly disturbed. In this study, we investigate the interaction of the comet with the solar wind, and their effects on the shock-accelerated energetic particles that precipitate into the Mars' atmosphere. The study is based on data from MAVEN, Mars Odyssey, MSL and Mars Express missions.

1. Space weather context

This unique event allows us to investigate the response of Mars' upper atmosphere to such a rare encounter, as this may have implications for overall atmospheric evolution. However, the conditions were very complex due to the significant space weather variability, which makes discerning between space weather and cometary effects on the Martian plasma system difficult.

Numerous solar flares occurred on the Mars-facing side of the sun [e.g. 3], and two CMEs were launched. In particular, the second CME was one the largest of the current solar cycle and hit Mars ~44 hours before the comet flyby, creating a strong perturbation in the plasma system [2]. Although this perturbation somewhat diminished over the following hours, effects were still present during the comet passage. In addition, the encounter occurred while a fast solar wind stream was transiting Mars as observed by Mars Express and by solar wind simulations [2].

2. Comet encounter ephemerides

The Mars closest approach with Comet Siding Spring took place at 141,000 km, on 19 October 2014 at 18:30 UT. The comet passed Mars at a relative speed of 56 km/s, moving from below to above the ecliptic due to its high inclination orbit angle [4].

3. Energetic particle observations

In this work, the influence of the CME and of the comet's coma on the high-energy particles that reached Mars during the 10 hours of encounter is assessed with datasets from MAVEN-SEP, MSL-RAD and Mars Odyssey-HEND (an example is shown in Figure 1).

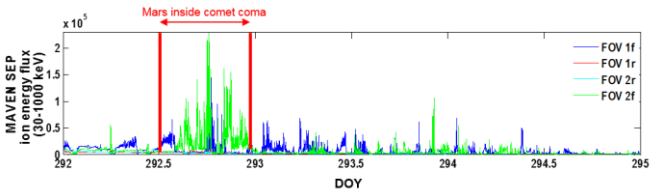

Figure 1: MAVEN-SEP ion energy flux measured during the comet encounter.

Also, the oxygen pick-up ions created and deposited in the Martian atmosphere during the following days are analysed. The study is supported with a pickup ion simulation based mainly on observations [5].

Results are compared with previous estimations pre-comet flyby [4, 6], and energy deposition in the atmosphere is assessed [see also 7 for its effects on the Mars ionosphere]. Finally, neutral sputtering from the comet tail up to a day and half after the closest approach is evaluated by using Mars Odyssey-HEND observations.

4. Conclusions

We investigate whether is possible to separate the effects of the comet coma and the space weather activity on the shower of energetic particles and pick-up ions observed at Mars by MAVEN, Mars Odyssey and MSL, or if these observations come from a mixed source of both phenomena. This is important in order to better understand the ionospheric variability detected during the comet flyby (possible energy deposition), as well as may have implications for overall atmospheric evolution.

Acknowledgements

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