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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 ~138,000 km. The coma washed over Mars and the planet passed directly through the cometary debris stream, producing significant effects in Mars' upper atmosphere. We present here an overview of ionospheric measurements performed during the comet encounter with Mars Express, MAVEN, and Mars Reconnaissance Orbiter. We discuss the comet's influence on the ionosphere through different processes that work at different altitudes: magnetospheric disturbances, impact of cometary pick-up ions, and deposition of cometary dust.

1. Geometry and timing of the comet encounter

The closest approach with comet Siding Spring took place at a distance of ~138,000 km from the center of Mars, on 19 October 2014 at 18:28 UT (Solar longitude Ls 217, Martian Year 32). It flew by Mars at a relative velocity of ~56 km/s, moving from South to North (retrograde orbit, 129 degrees inclination).

2. Context of the comet encounter

The context is essential to properly analyse the data taken during this unique event. Since we are dealing here with dust and upper atmosphere, it is important to characterise the space weather and the seasonal dust contexts.

The space weather conditions are peculiar: a large interplanetary coronal mass ejection hit Mars about 44 hours before the comet closest approach, disturbing the Mars' plasma environment [1]. Many solar flares also occur in this period, some of them could have hit Mars. Moreover, this cometary flyby took place at the start of a dust season, as indicated by Mars Express PFS dust opacity measurements and data assimilation [13,14].

Obviously, this context implies that the data analysis is not trivial.

3. Measurements and data sets

The following data sets are used in this study: Data recorded by the MARSIS radar aboard Mars Express in the active ionospheric mode [2] give access to local electron densities at the spacecraft altitude, electron density profiles and an indication of the signal attenuation (due to electrons present at low altitudes [3]). The data recorded by the SHARAD radar aboard Mars Reconnaissance Orbiter give access to the Total Electron Content [4]. The data recorded by the MAVEN orbiter include information on the magnetic field [5], the metallic ions originating from the comet [6,7], and energetic particles possibly identified as pick-up ions [8].

4. Effects on the Mars' ionosphere

The interaction of the Siding Spring coma and the Mars' ionosphere can be characterized by several processes. First, the magnetosphere was severely distorted during the comet's passage [5]. As a consequence, we can expect some disturbances in the topside ionosphere. A second effect is the flux of pickup O^+ ions originating from the coma interacting with the solar wind. These pickup ions precipitate primarily on the dayside hemisphere and can increase ionospheric densities around 110-120 km altitude [9,10]. Finally, the cometary dust is deposited in the atmosphere, mainly below 100 km altitude, and is responsible for the formation of a low altitude ionospheric layer [2,6,7,11].

These mechanisms and effects are discussed and compared, with the support of modeling and data analysis. In particular, we propose some explanations to understand those ionospheric compressions and bulges observed in the Mars Express data set (see Figure 1), and explore the complex interaction dust-ionosphere.

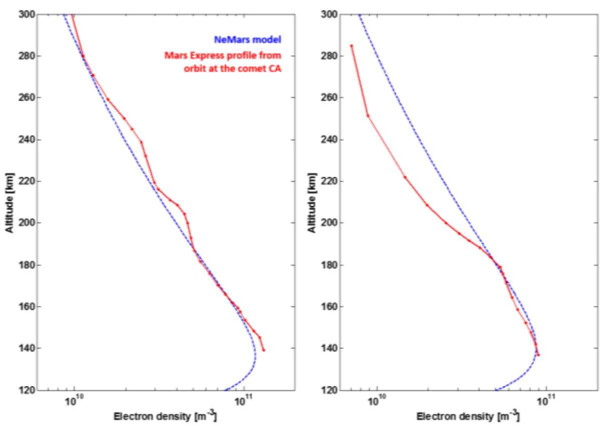

Figure 1: Mars Express MARSIS electron density profiles obtained within 5 minutes of difference from the orbit at the time of the comet closest approach, on the dayside hemisphere. Left panel: electron density profile showing two bulges centered around 200 and 240 km. The solar zenith angle is 71 degrees. Right panel: electron density profile where a clear compression of the ionosphere is found above 180 km. The solar zenith angle is 80 degrees. In both panels, the NeMars model [12] was plotted to compare with a predicted and undisturbed ionosphere.

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