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DR-induced O and C in the thermosphere of the early Mars

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Mars atmospheres changed a lot during its evolution and especially for the early period. Based on previous researches, DR-induced photochemical escape due to dissociative recombination (DR) reactions is an important escape mechanism at early stages. Energetic O and C atoms generated through DR photochemical reactions could overcome collisions with the surrounding background gases then escape. Meantime, surrounding inactive particles could be accelerated by transferred momentum from those hot atoms. Afterwards secondaries formed and could have played an important role in shaping the Martian Coronae especially during its earlier evolution.
In order to understand Mars atmospheric stability and evolution, we built a 3-D Monte Carlo Model to simulate atmospheric structures in different period of its history. DR reactions of O_2+, CO_2+, and CO+ are considered as the sources of energetic O and C. Different thermosphere structures for 1, 3, 10, and 20× present solar XUV conditions, corresponding to solar activity levels 2.5, 3.8, and 4.1 Gyr ago, are considered in this model. The code also simulated contributions of secondary O and C atoms resulting from collisions between DR-induced primary energetic atoms and neutral background species C, O, CO, and CO_2.
Our previous research, focused on the DR-induced O and C escape from early Mars, reveal that: (1) escape rates of both O and C increase non-monotonically with solar soft X- ray and extreme ultraviolet (XUV) fluxes, because column densities of background species were larger at early times, when the solar XUV flux was larger, deflecting energetic particles through collisions more efficiently. However, due to the same reason the contribution of secondary particles was significantly larger during earlier periods. As high as 30∼40% and 10% secondaries contribute to the total escape of O and C at 20× present solar XUV condition respectively. (2) The time-integrated DR-induced escape of O and C is equivalent to only 1 m global water layer and 20 mbar of CO_2 escaping early Mars since 4.5 billion years ago. So the contribution of DR-induced escape to the atmosphere loss is modest during the entire evolution of Mars. That means building a 3-D model to trace the motion and the distribution of those less energetic neutral atoms which trapped in the atmosphere through collision processes, can help us to understand Martian Coronae structure and its interactions with surrounding space environment during different evolution periods.