Ion escape rates from non-magnetic Earth: On contribution of terrestrial ion flows to non-solar components in lunar soils

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Physical and chemical mechanisms responsible for the atmospheric escape from a planet dramatically change with the strength of its intrinsic magnetic field [1,2]. When the planet has substantial global intrinsic magnetic field as in the case of the present Earth, the planetary magnetic field provides a barrier against the solar wind (continuous and dynamic supersonic plasma flow from the Sun) and the solar wind cannot blow directly into the upper atmosphere. In the present Earth, the solar wind approaching to the Earth is stopped by the terrestrial magnetic field at the magnetopause (at about 10 Earth radii), where the magnetic pressure balances the kinetic pressure of the solar wind.

On the other hand, when the planet has no global intrinsic magnetic field as in cases of present Mars and Venus, the solar wind directly interacts with the planetary upper atmosphere and may cause efficient loss of heavy atmospheric constituents such as Nitrogen and Argon under certain solar wind conditions. In this study, we estimate the escape rates of H+, He+, N+, O+, Ne+, and 36Ar+ from the non-magnetic Earth, i.e., under assumption that the Earth does not have its intrinsic magnetic field, through the solar wind induced escape. In order to access whether these escaping ions contribute to non-solar components implanted in lunar soils, fluxes of the terrestrial ions at lunar orbit are discussed.

The results show that the ion escape rates vary dramatically with change in the solar wind dynamic pressure. If the solar wind dynamic pressure changes from 2 to 15 nPa, the ionopause altitude decreases drastically from 500 km down to ~250 km, and accordingly the escaping ion flux, especially of heavy ions, undergo significant increase. If the solar wind pressure exceeds 15 nPa, the ionopause becomes even closer. When the ionopause altitude decreases from 500 to 200 km, for example, the average terrestrial N+ flux at lunar surface increases from 3x10^3 to 2x10^6, Ne+ from 0.5 to 5x10^2, and 36Ar+ from 7x10^-5 to 13 ions/cm^2/s, respectively. Such high solar wind pressure as assumed above is still within the present variation and hence even higher solar wind flux would be expected from an active young Sun. In addition, low O2 pressure (and possibly CO2) in the paleoatmosphere further brings the ionopause closer to the Earth. All these factors tend to enhance the ion escape rate especially of heavy components. The high terrestrial ion fluxes from the ancient non-magnetic Earth with low atmospheric O2 (or CO2) pressure can be the source of non-solar components of N and light noble gases implanted in lunar soils [3].

References:

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