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Nitrogen Ion TRacing Observatory (NITRO): A planetary mission to the Earth

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Abstract

The NITRO mission that was proposed for the recent ESA M-class mission call (M4) in January 2015 studies the budget and dynamics of magnetospheric nitrogen ions (N^+ and N_2^+) by separating them from O^+ as well as the structure of the exosphere. This presentation summarizes the importance of such studies in the context of the planetary atmosphere formation and the measurement strategy of the proposed mission.

1. Introduction

Behavior and budget of nitrogen ions (N^+) in the magnetosphere have not been well investigated in the past due to the difficulty in separating N^+ from oxygen ions (O^+) in the in-situ measurements. However, the nitrogen budget could be more important than the oxygen budget in modeling the ancient atmosphere of the Earth, and even Venus and Mars. Also the terrestrial exosphere is very little known, particularly for nitrogen, although it is a key region for the atmospheric escape.

2. Scientific importance

The observation of non-thermal escape of nitrogen is a mandatory step in examining any theory on the atmospheric formation of Earth/Mars/Venus and other planets/moons. For nitrogen, the total amount of N^+ escape over 4 billion years can be comparable to, or higher than, the present day's nitrogen inventory of the Earth (and much higher than present day's nitrogen inventory of Mars), because of the following reasons:

The total amount of nitrogen on Earth (the majority is in the atmosphere, where it constitutes 78% of it) is about $4\text{-}5 \cdot 10^{18}$ kg. Consequently, if the non-thermal escape rate reaches 10^9 kg/year (10^{27} ions/s), one can no longer ignore the non-thermal nitrogen escape over the Earth's history compared to the present days nitrogen inventory.

To the present day's knowledge, heavy ion escape is of the order of 10^{25} ions/s in average[1] and this amount varies by more than three orders of magnitude from geomagnetically quiet periods (quiet Sun) to magnetic storm times (active Sun)[2]. Furthermore, the very limited observations of the cold N^+ outflow above the ionosphere indicate that the N/O ratio increases to nearly unity (or even more) during major geomagnetic storms[3].

The conditions for a high escape rate for heavy ions and particularly N^+ (high EUV flux and large geomagnetic activity) correspond to the ancient Earth conditions, because the early Sun is believed to have had high EUV flux (one order of magnitude higher than present), stronger magnetic field due to faster rotation, and faster solar wind velocity. Therefore, it is quite possible that the total amount of non-thermal escape of nitrogen could be comparable to or more than the present nitrogen inventory.

In such a case, one of two major models of nitrogen atmosphere formation (outgassing models of NH_3) becomes more likely than the other (N_2 delivery models by comets or asteroids)[4]. This also constrains planetary formation models in how the volatiles are included in the proto-Earth (this is not simple because of very low condensation temperature of N_2 and NH_3).

If the total nitrogen escape is less than the present inventory, the initial nitrogen inventory of the Earth would be much less than that of Venus. This would also constrain the planetary formation model because more volatiles should have been condensed at locations closer to the Sun. In both cases, the combination with the measured exospheric distributions (no direct measurements exist today above 1500 km altitude) would provide an improved estimate of the evolution of the terrestrial atmosphere.

The study of nitrogen ion dynamics and its budget has many other scientific merits on the topics of the interpretation of $^{14}N/^{15}N$ ratio of solar system bodies and atmospheres (non-thermal escape leads to a different isotope ratio than thermal escape that is gravity-mass-filtered), the magnetosphere-ionosphere coupling and basic space plasma physics (different initial velocity between M/q=14 and M/q=16 gives extra information on energization mechanisms in space).

3. Mission

The proposed baseline mission consists of two spacecraft for full science. However, a back-up option using a single spacecraft could still fulfill the most important science goals, but with lower spatial/temporal resolution. The two-spacecraft baseline consists of a spin-stabilized (22-26 s) spacecraft (800 km x 33000 km, 68.5° inclination) for in situ plasma measurements, and of a 3-axis stabilized remote sensing spacecraft (500 km x 2400 km, 88.35° inclination) for line-of-sight integrated optical measurements and for direct measurements for neutrals and ions in the exosphere and topside ionosphere. With these orbit parameters, the two spacecraft orbital planes would have the same longitudinal drift velocity.

The details of the proposal will be presented during the Congress.

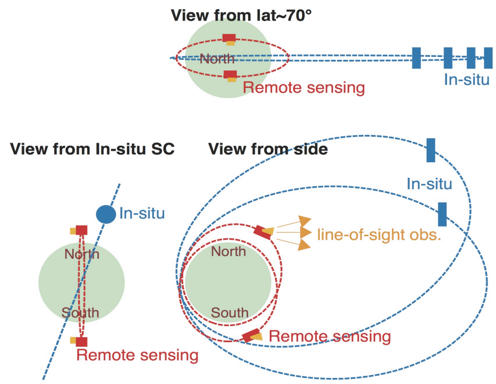

Figure 1: Proposed orbit for two spacecrafts. They have an identical longitudinal drift velocity.

Acknowledgements

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