Nitrogen and Oxygen Budget ExpLoration (NOBEL): A Planetary Mission to the Earth

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(proposal name is changed from NITRO to NOBEL to reflect clearer science)

Outline

Introduction (Objectives and tasks)

Science overview

1) Scientific goal: *Why nitrogen and isotope ratio?*
2) Mission rationale: *How will NOBEL answer?*

Mission overview

1) Orbit
2) Payload, accommodation, measurement resolution
3) Conjugate observations: *advantage of the Earth*

Extra science

Summary

Mission objectives

*** The Earth diagnosis (exosphere and escape)**

To study both thermal and non-thermal escape rate of major atmospheric components (nitrogen and oxygen) from the Earth, a magnetized planet. This requires the first-time exploration of the exosphere as well as the first-time examination of isotope ratios in the magnetosphere/ ionosphere.

*** Atmospheric evolution of a magnetized planet**

The measurement quality must enable modelling of the escape on a geological time scale, and should be a good reference in understanding planetary evolution from their isotope ratio and N/O ratio.

What is to be measured

(1) Density, fluxes, and energy-angle distribution for N^+, N_2^+, O^+, and H^+ in the magnetosphere.

(2) Neutral and ion densities for N, N_2, O, O_2, at upper exosphere/ionosphere (> 800 km).

(3) Isotope ratio of neutrals and cold ions ($^{17}O/^{16}O$, $^{18}O/^{16}O$, and H/D) in the upper ionosphere, exosphere, and magnetosphere.

*** All the above data for a wide range of solar wind and solar EUV conditions**

Why exosphere?

Mandatory information for escape modeling
(For thermal and some non-thermal escape)

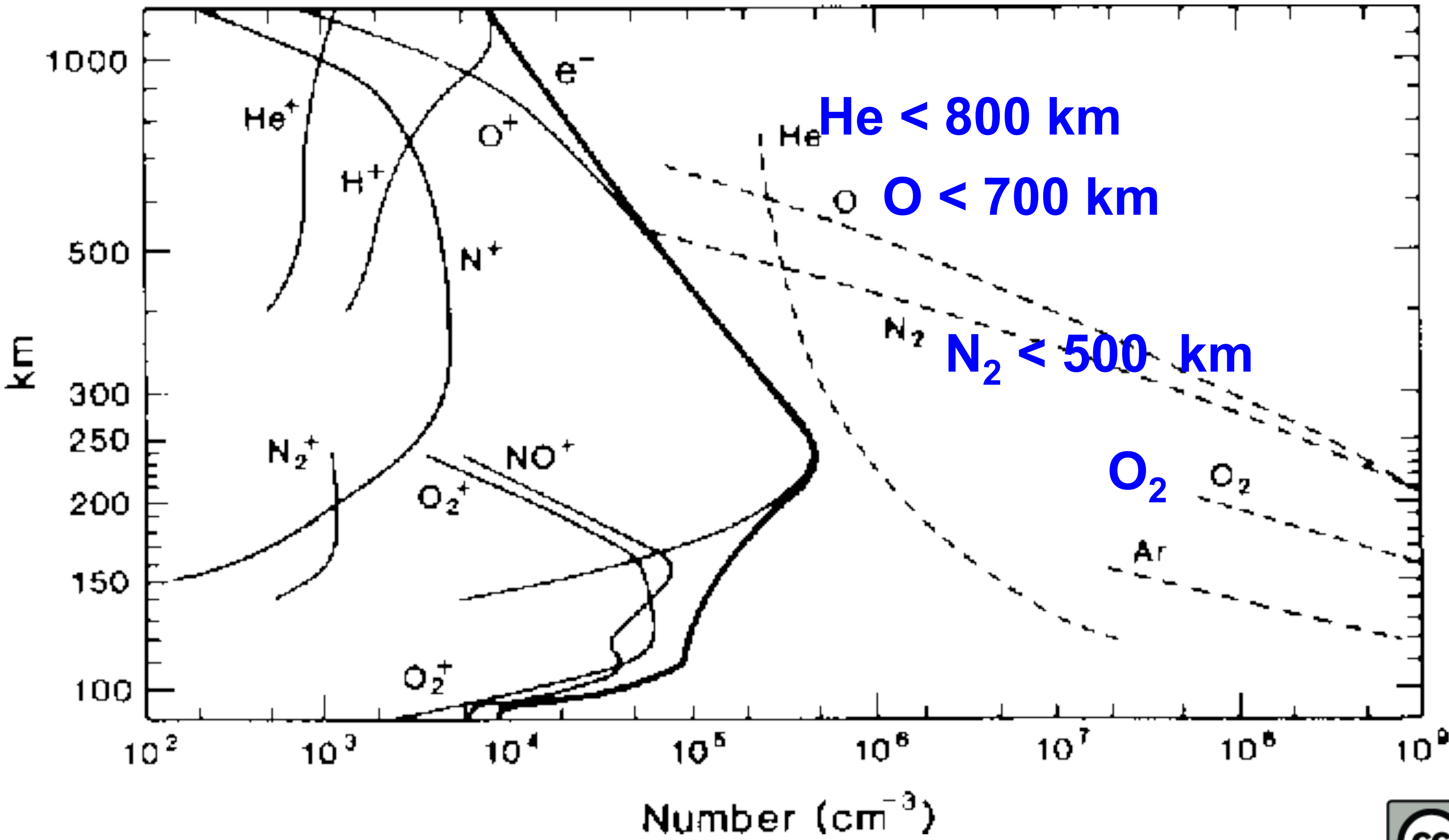
Very dynamic for both density and ionization
(Mars observation indicates very strong unknown factors other than EUV, e.g., atmospheric coupling)

Poor observational knowledge
(No knowledge of > 800 km for nitrogen, > 1500 km for oxygen, and all altitude for isotope ratio)

Source of cold ions above the ionosphere
(They contribute feeding ions of non-thermal escape)

Why exosphere?

No direct neutral observations > 1500 km



Why nitrogen?

Behavior is different from Oxygen with similar mass
($N_2 \rightarrow N_2^+ \rightarrow N^+$ whereas $O_2 \rightarrow O \rightarrow O^+$, and completely different solar/geomagnetic dependence)

Scientifically important element
(a representative volatile, essential for amino-acid, and 5% change affect biology-induced circulation)

Escaped amount could be significant for biosphere
(atmosphere/soil inventory = 4–5 x 10^{18} kg. Escape matters if ≥ 10^{26} ions/s)

Not well known, but now possible to measure
(impossible 5 years ago)

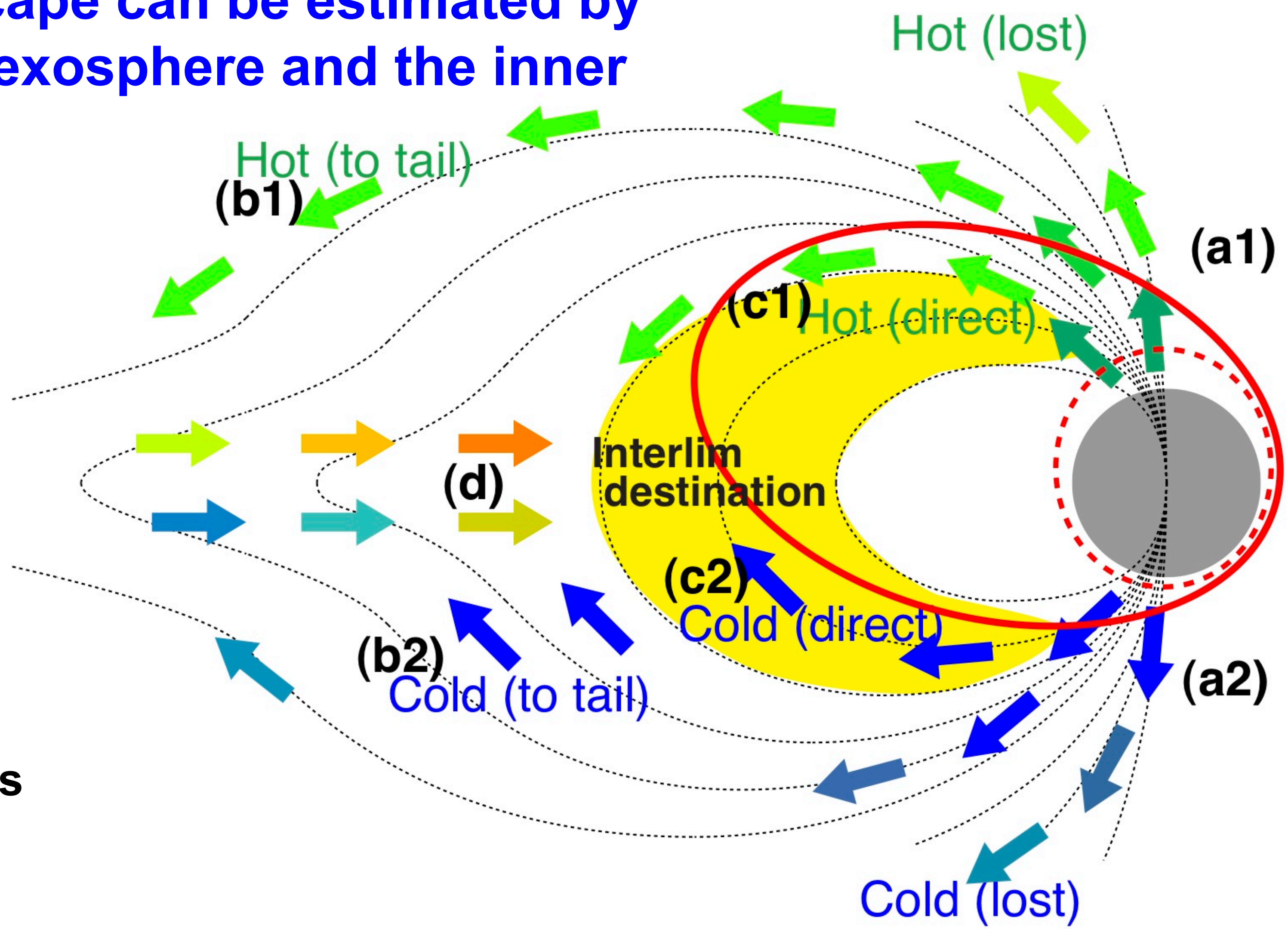
Why isotope ratio?

Used as indicator of escape from planet
(the isotope ratios are different between different escape processes)

Poor observational knowledge
(no knowledge in the magnetosphere/ionosphere)

Where is the optimum orbit?

1. Non-thermal escape can be estimated by covering both the exosphere and the inner magnetosphere.



Non-thermal route

(a): all ions escape

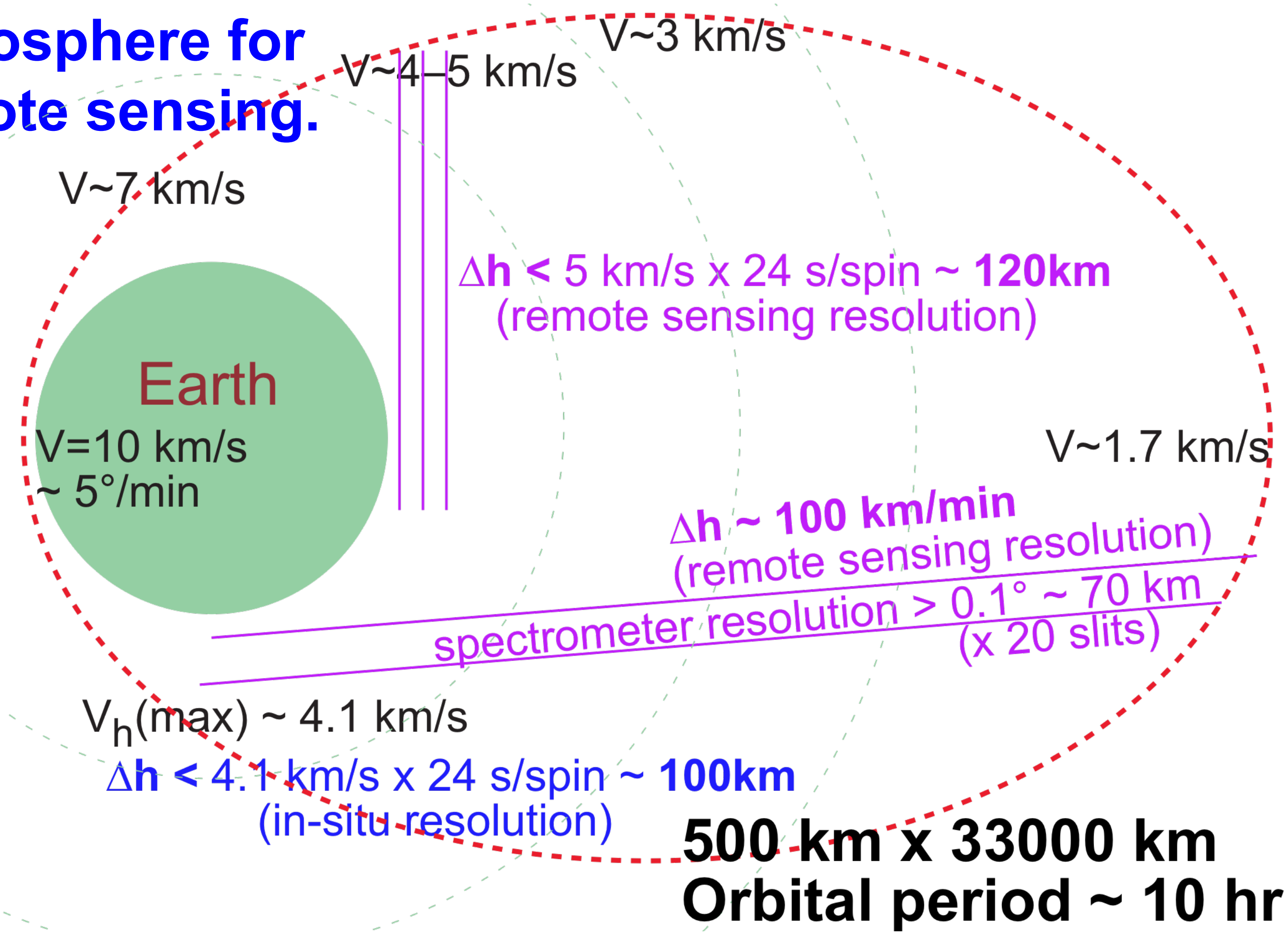
(b): only a part returns

(c): majority escapes

(d): majority escapes

Where is the optimum orbit?

2. The same orbit enables measurements of exosphere for both in-situ and remote sensing.



500 km x 33000 km
Orbital period ~ 10 hr

Altitude resolution ~ 100 km

Payload

Baseline

*** Cold ion/neutral mass spectrometer**
(1) m/Δm ~ 2000 /slow *(Bern)*
(2) m/Δm ~ 50 / fast *(could be optional?)*

*** Ion mass analyzers (0.03 – 30 keV):**
(1) m/q < 20 *(Toulouse)*
(2) m/q > 10 *(Kiruna)*

*** Energetic Ion mass analyzer *(UNH)***

*** Magnetometer *(Graz)***

*** Langmuir probe (*Brussels*)**

*** Electron analyzer *(London)***

*** UV/visible emissions *(Tokyo?)***
N^+, N_2^+, N_2, O^+, O^+

* Potential control *(SC subsystem)*

Optional

* Waves analyser with search coil *(Prague and Orleans)*

* Auroral / airglow camera (*could be baseline?* *Tohoku)*

* ENA monitoring (*TBD*)

* IR emissions *(if sensitivity is high)*

Advantage of the Earth

Sufficient dry mass
(many heavier instruments)

Sufficient telemetry
(without large antenna that blocks FOV)

Low altitude conjugate observations is possible
(any low-altitude spacecraft such as NASA mission, and Ground-based observations such as EISCAT_3D: conjugate > 20 passes/yr)

Extra science

Planetary Evolution: meaning of isotope ratio and N/O ratio of a planet in terms of the escape history.

Exoplanet modeling: tuning interpretation of optical data on exoplanets by having both spectral and in-situ measurements.

Ionosphere Physics: ionization chemistry and transport for different external conditions, and 3-D dynamics in the upper ionosphere together with EISCAT_3D.

Inner Magnetospheric Dynamics: using nitrogen as an independent tracer from oxygen.

Space Plasma Physics (acceleration): different initial velocities between M/q=14 and M/q=16 give extra information.

Summary

With recently developed reliable instrumentation, NOBEL will systematically study
- the exospheric conditions,
- nitrogen budget,
- isotope ratio of cold ions/neutrals above 1000 km

The knowledge is mandatory in estimating present-day's thermal/non-thermal escape as well as behaviors of exosphere.

The required instrumentation can also answer questions in the other areas.