

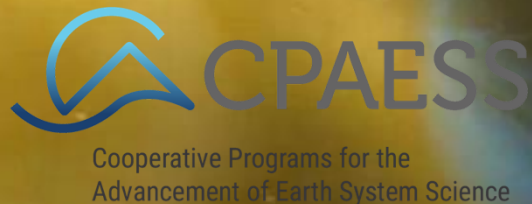
Earthward Transport of Lunar Metallic Ions: Implications of Heavy Ions in the Magnetosphere

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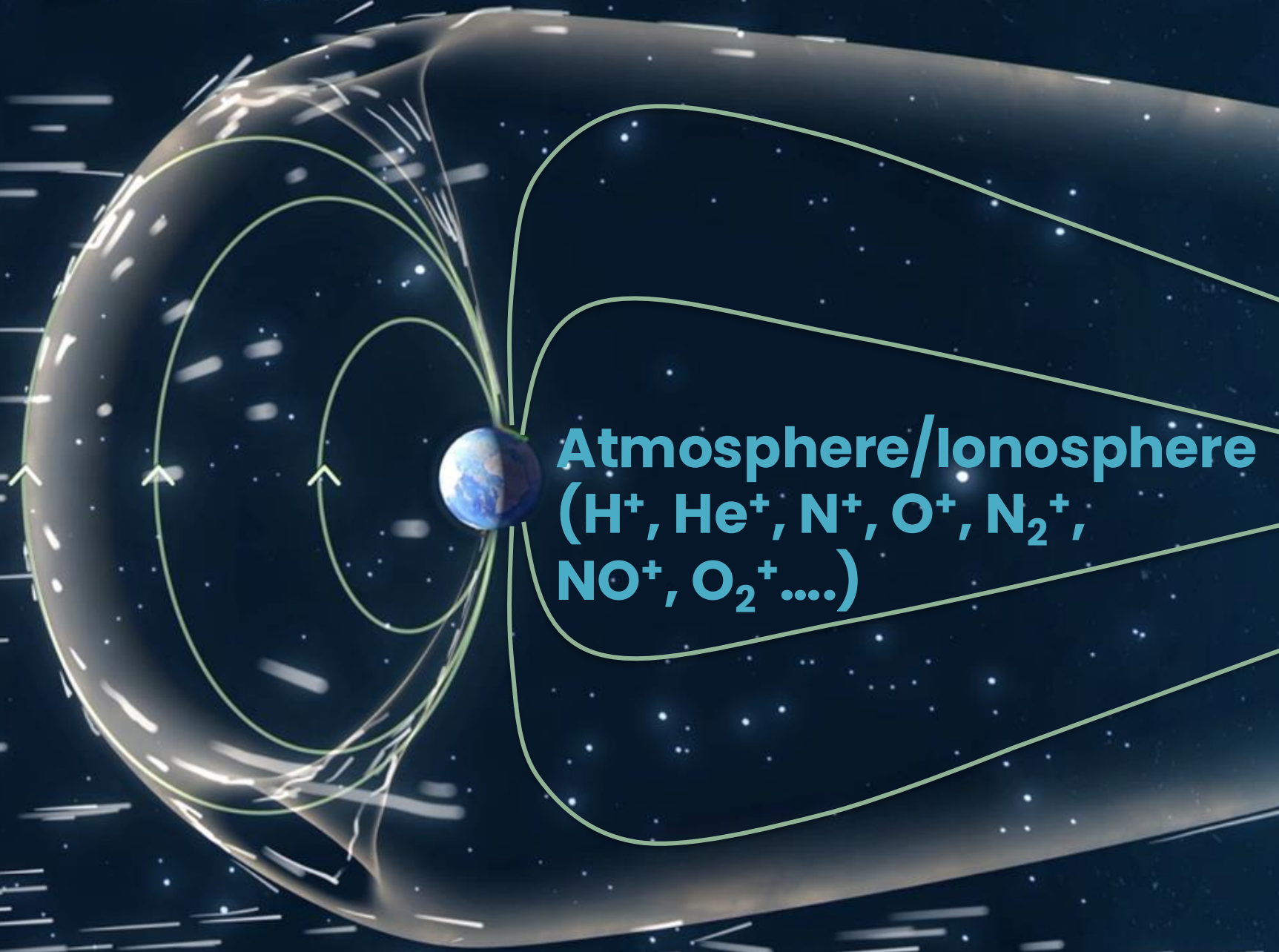


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Source of Plasma

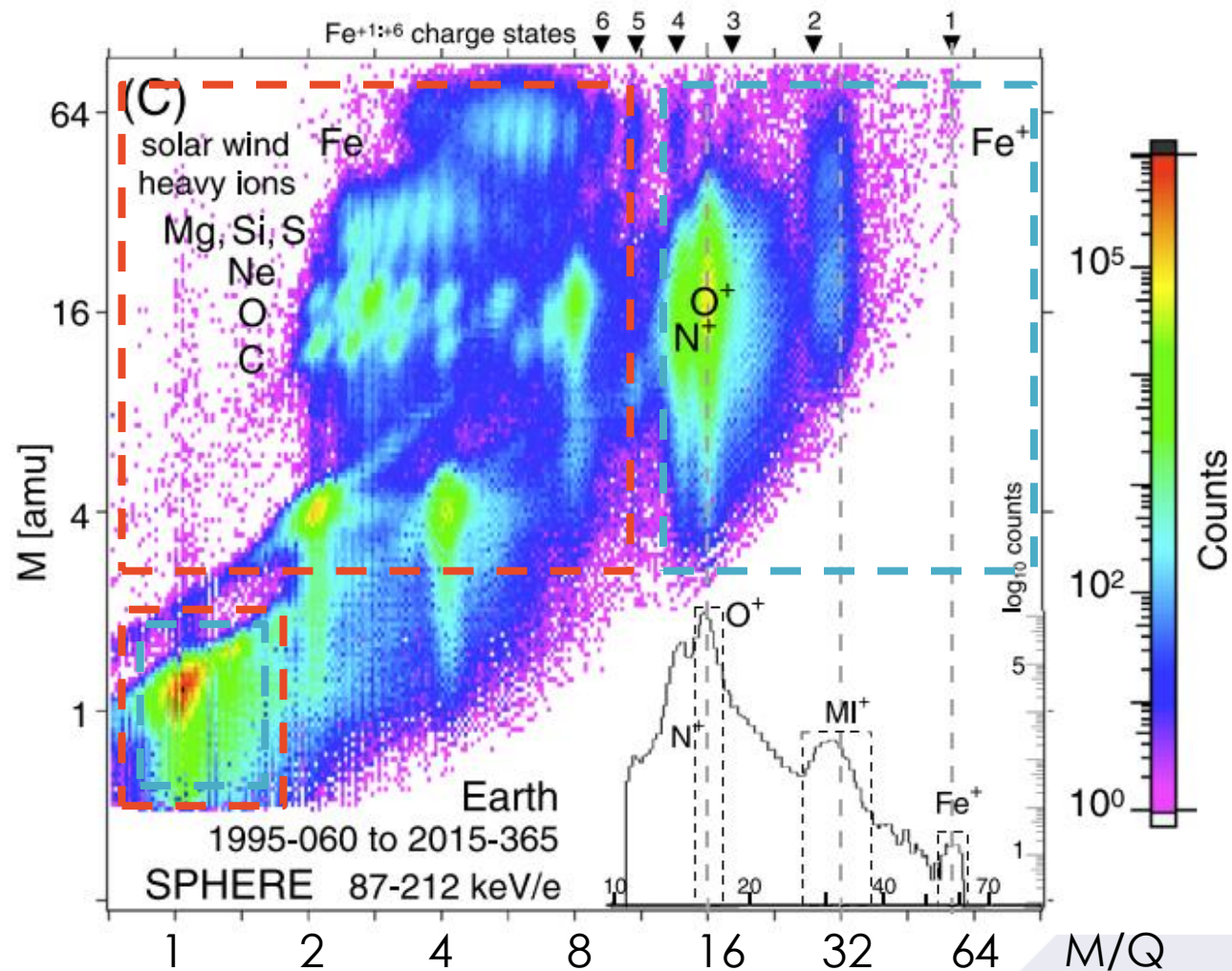
Solar Wind
(H^+ , He^{++} , O^{6+} ,
 O^{7+} , ...)



Atmosphere/Ionosphere
(H^+ , He^+ , N^+ , O^+ , N_2^+ ,
 NO^+ , O_2^+ )

Observations of Heavy Ions

- Observational data of plasma composition could be identified ions sourced from **Solar Wind** / **Ionosphere**.
- Presence of single-charge large-mass ions: **Additional source of particles?**



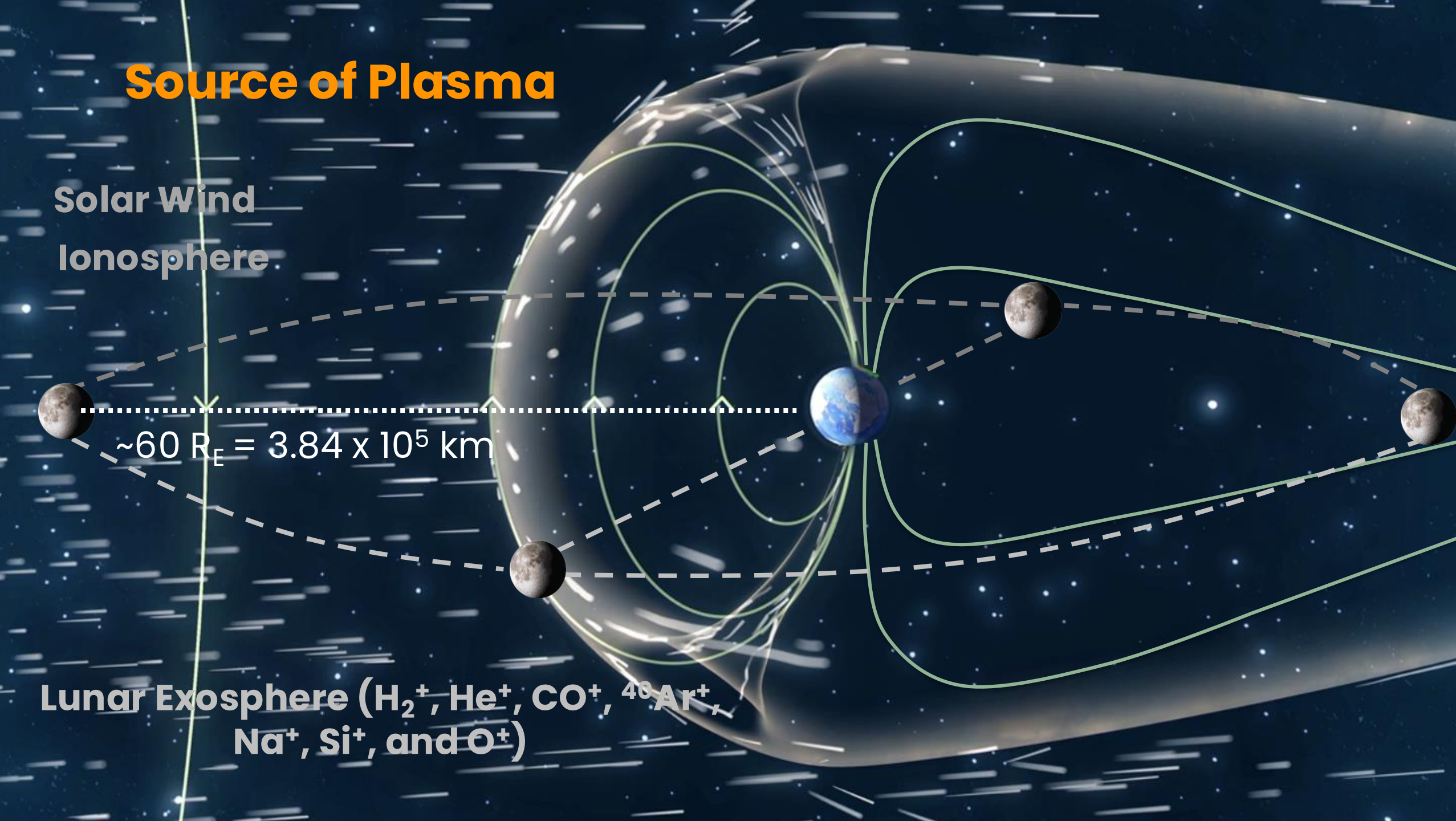
[Christon et al., 2017]

Source of Plasma

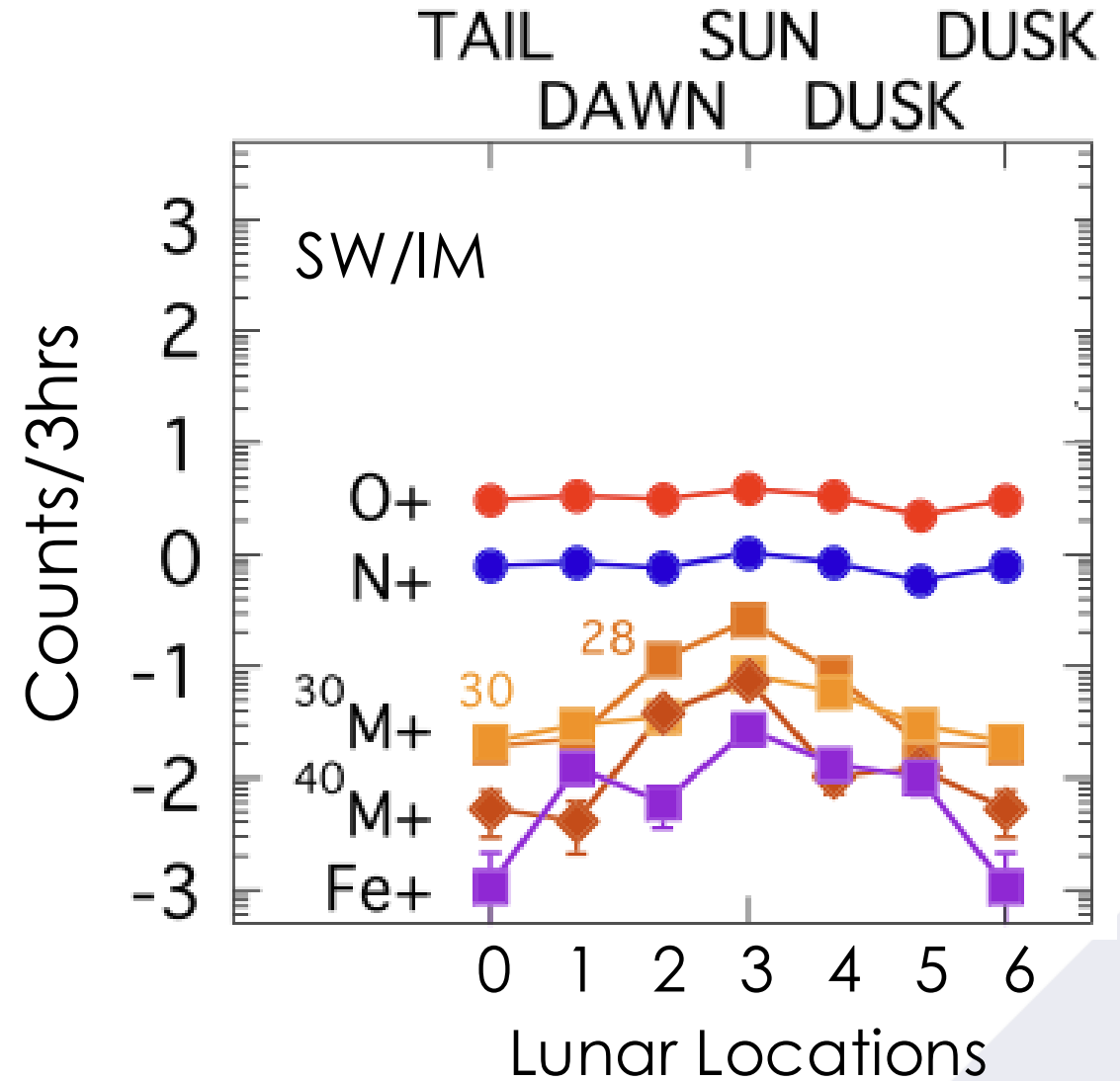
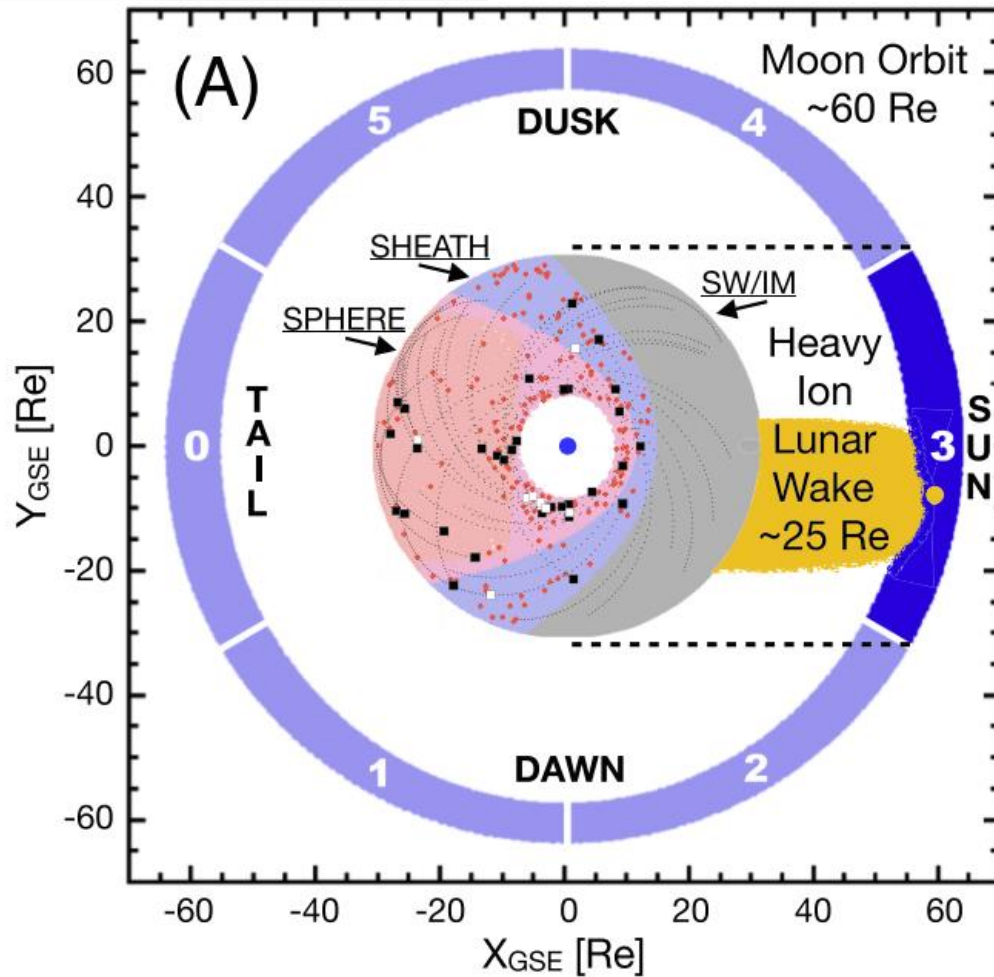
Solar Wind
Ionosphere

$\sim 60 R_E = 3.84 \times 10^5 \text{ km}$

Lunar Exosphere (H_2^+ , He^+ , CO^+ , $^{40}\text{Ar}^+$,
 Na^+ , Si^+ , and O^+)

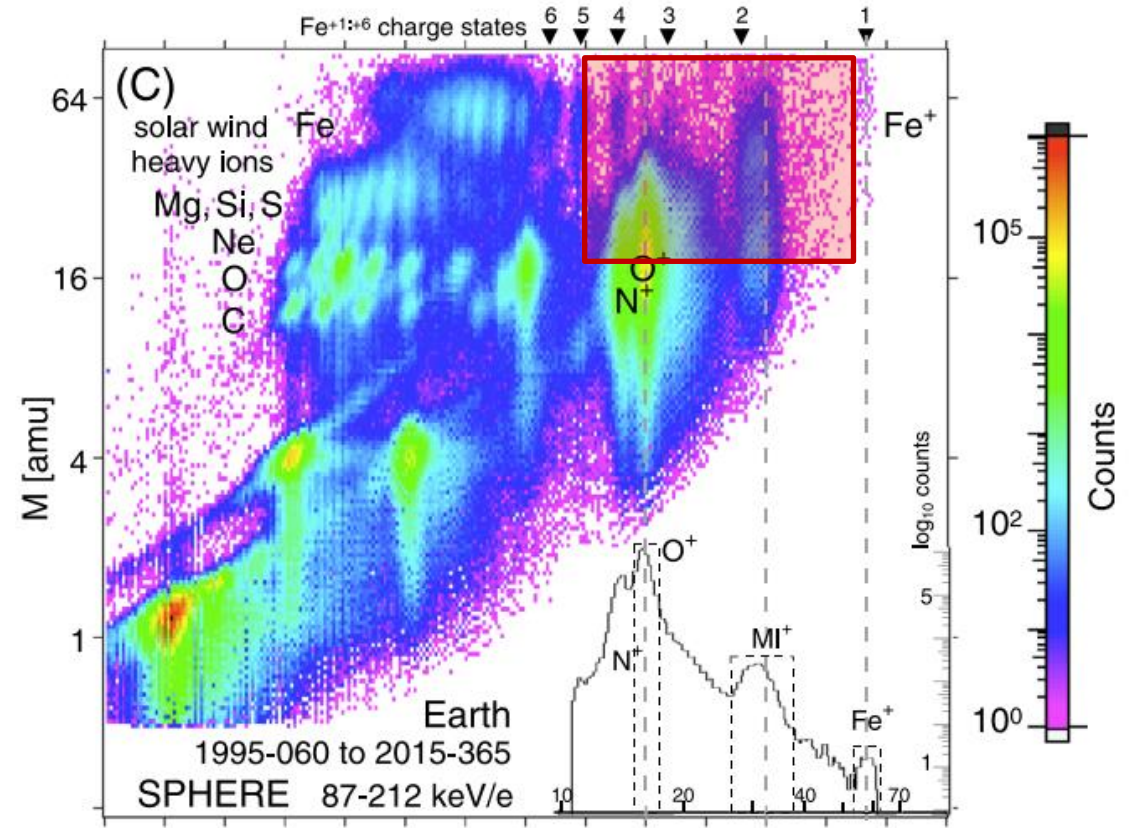
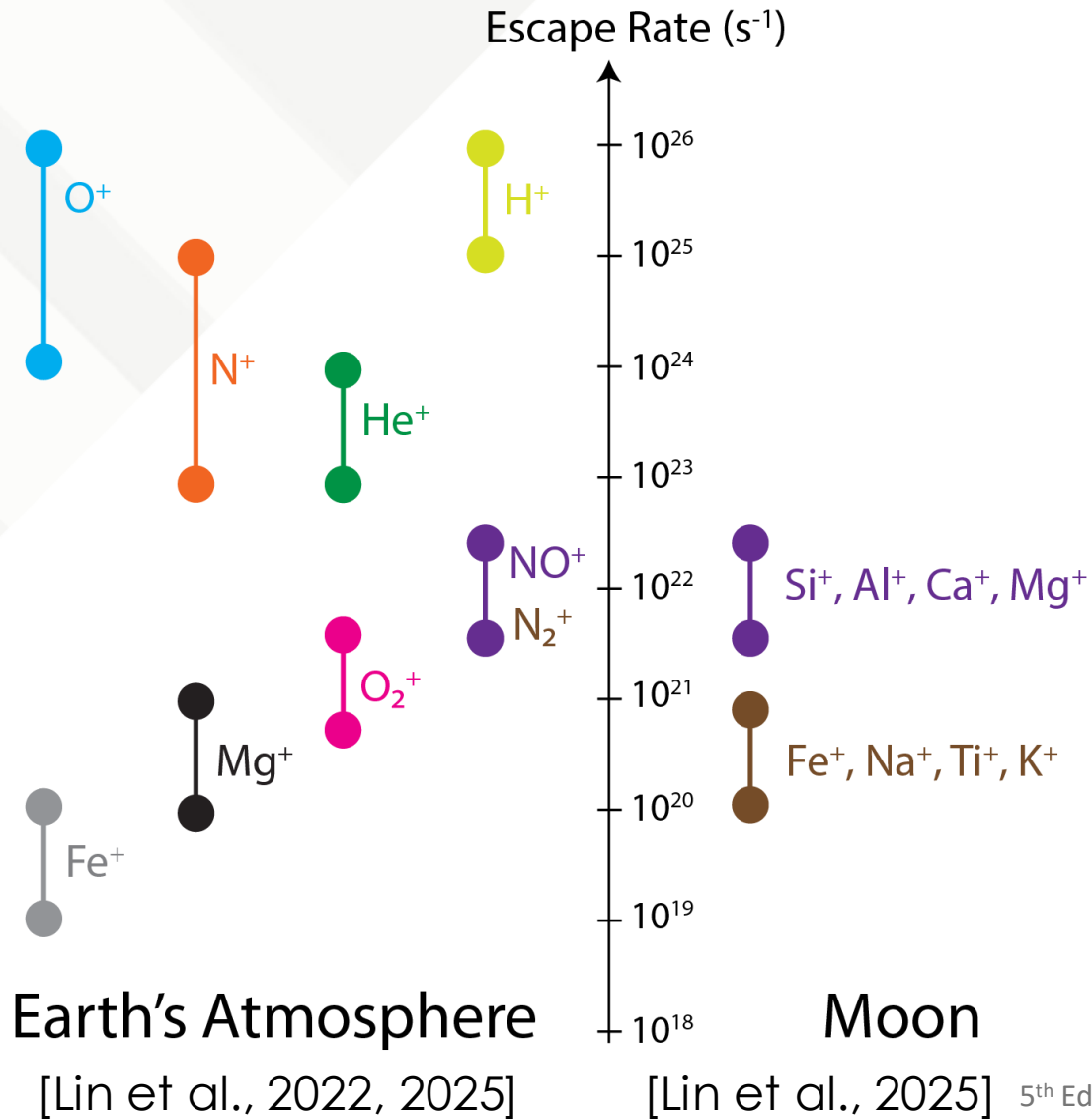


Heavy Ions vs. Lunar Position



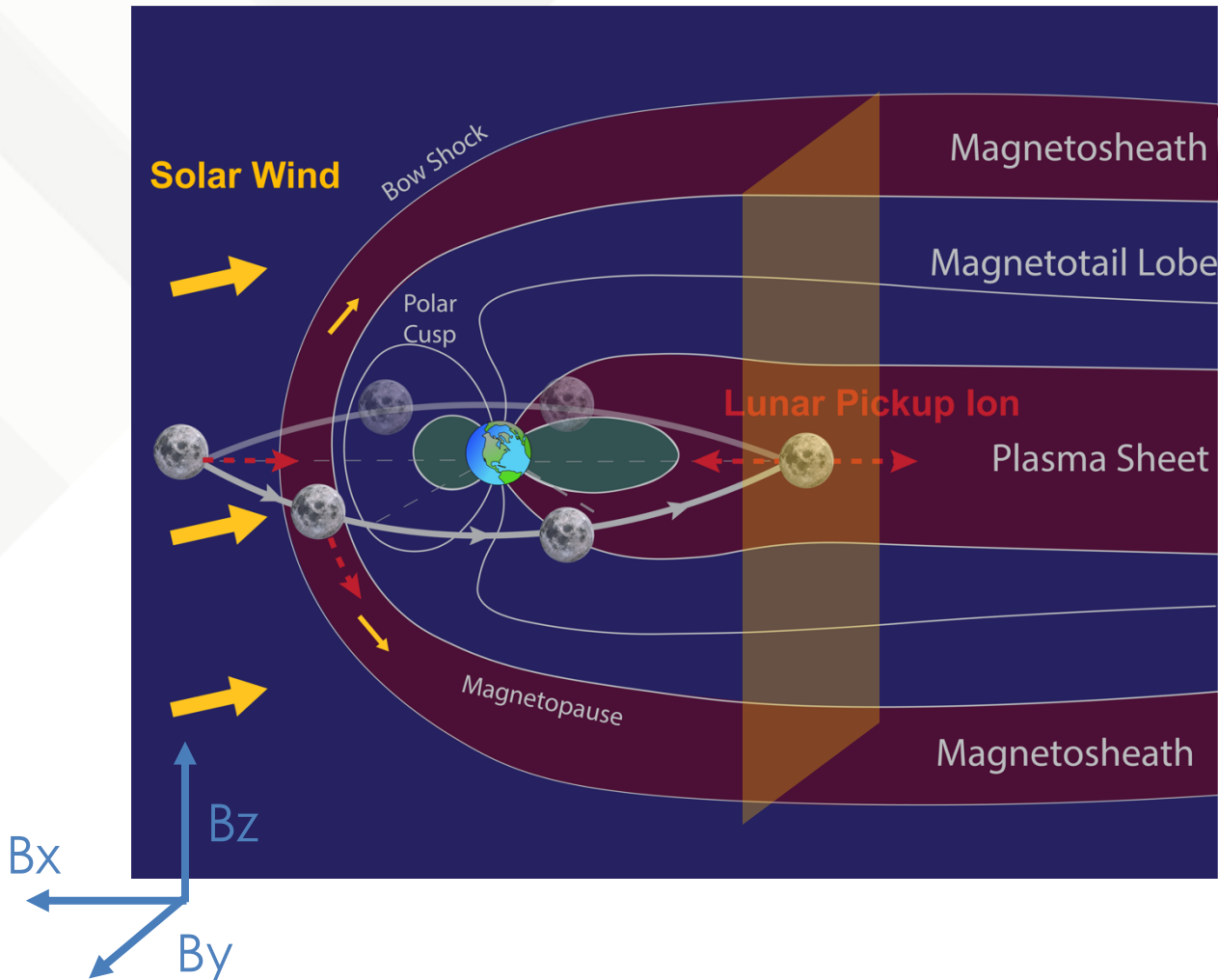
[Christon et al., 2017; Christon et al., 2020]

Compare Ionospheric Outflow and Lunar PUIs

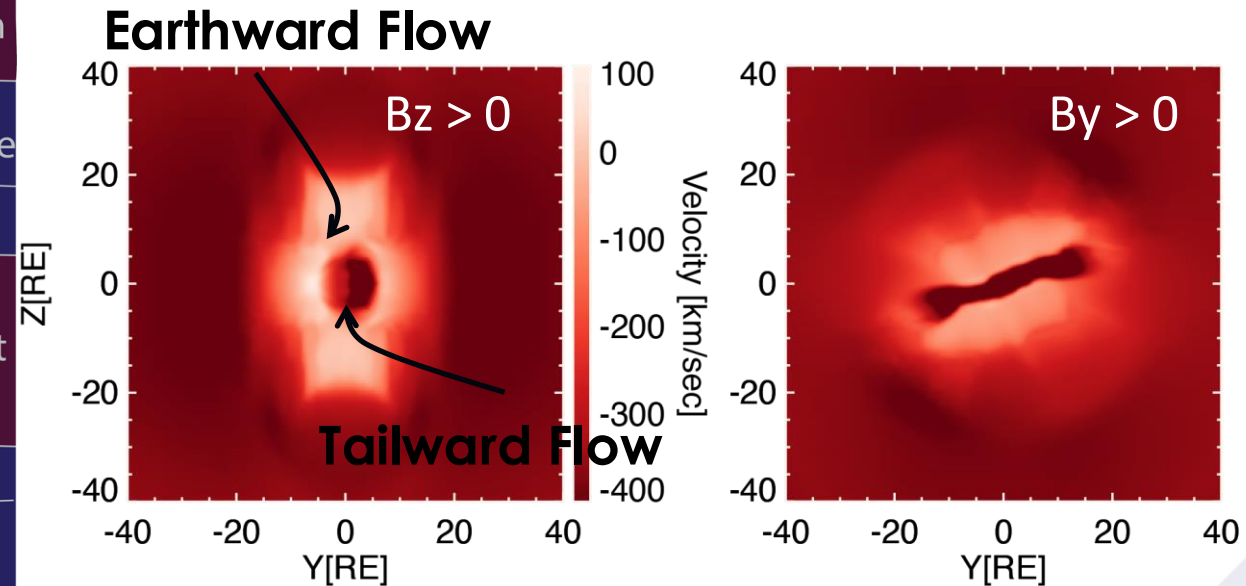


Ions with $M > 30$ amu could be more likely sourced from the Moon.

Will Lunar Metallic Ions Reach the Inner Magnetosphere?

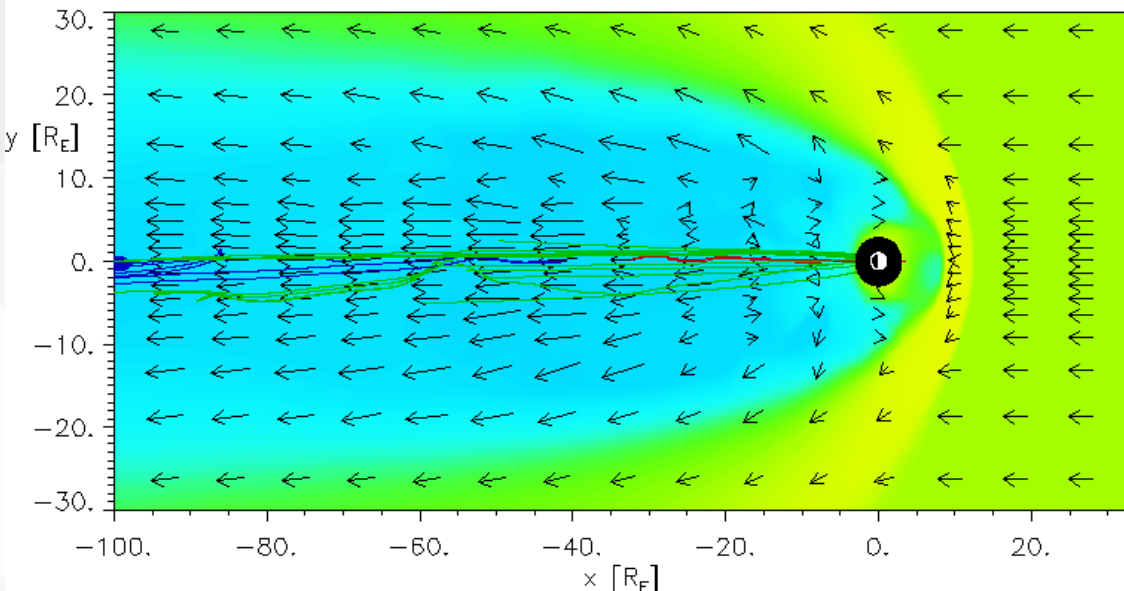


Solar Activity



Solar activity modulates the near-Earth electromagnetic field and bulk plasma velocity.

01/01/2000 Time = 00:00:00 UT z = 0.000R_E



v [km/s]

Min: 1.

Max: 1068.

B fieldlines

— IMF
— Polarcap
— closed

log(N)

[cm⁻³]

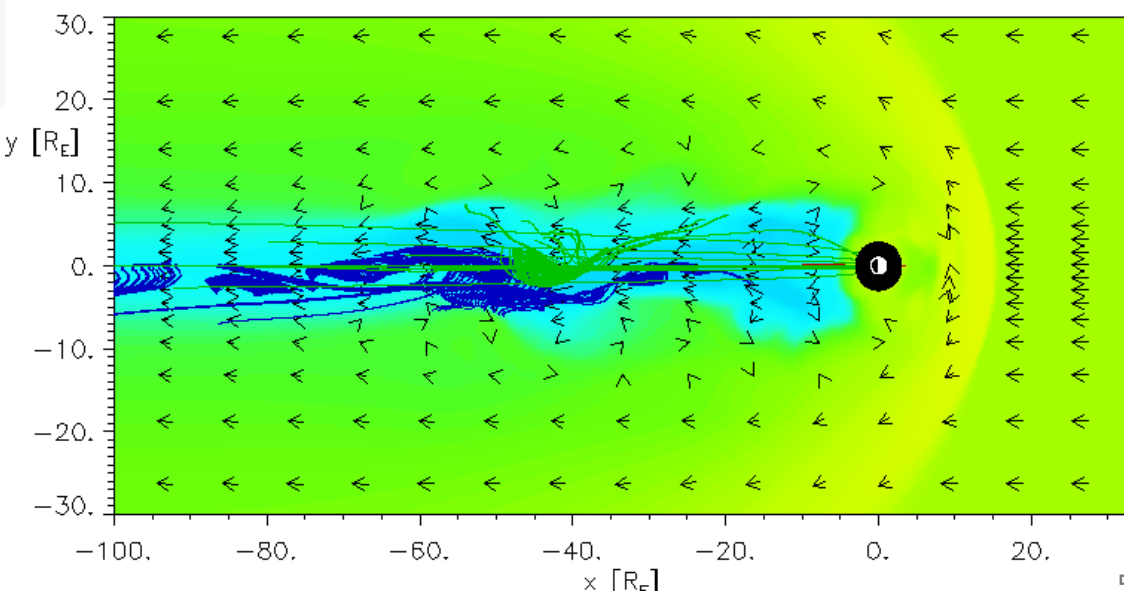
+3.00

0

-2.00

Model at CCMC: OpenGGCM

01/01/2000 Time = 00:00:00 UT z = 0.000R_E



v [km/s]

Min: 0.

Max: 1038.

B fieldlines

— IMF
— Polarcap
— closed

log(N)

[cm⁻³]

+3.00

0

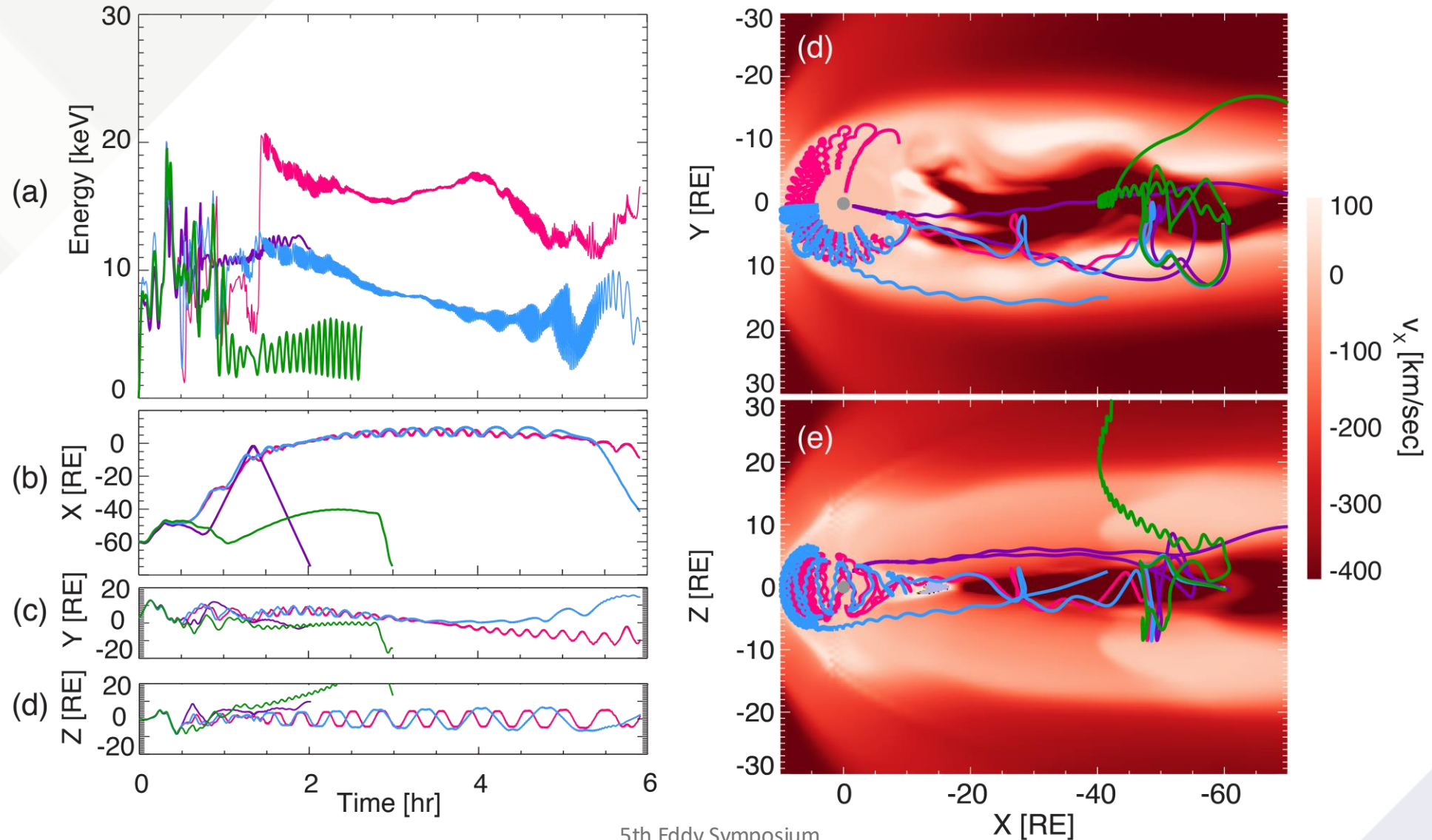
-2.00

Model at CCMC: OpenGGCM

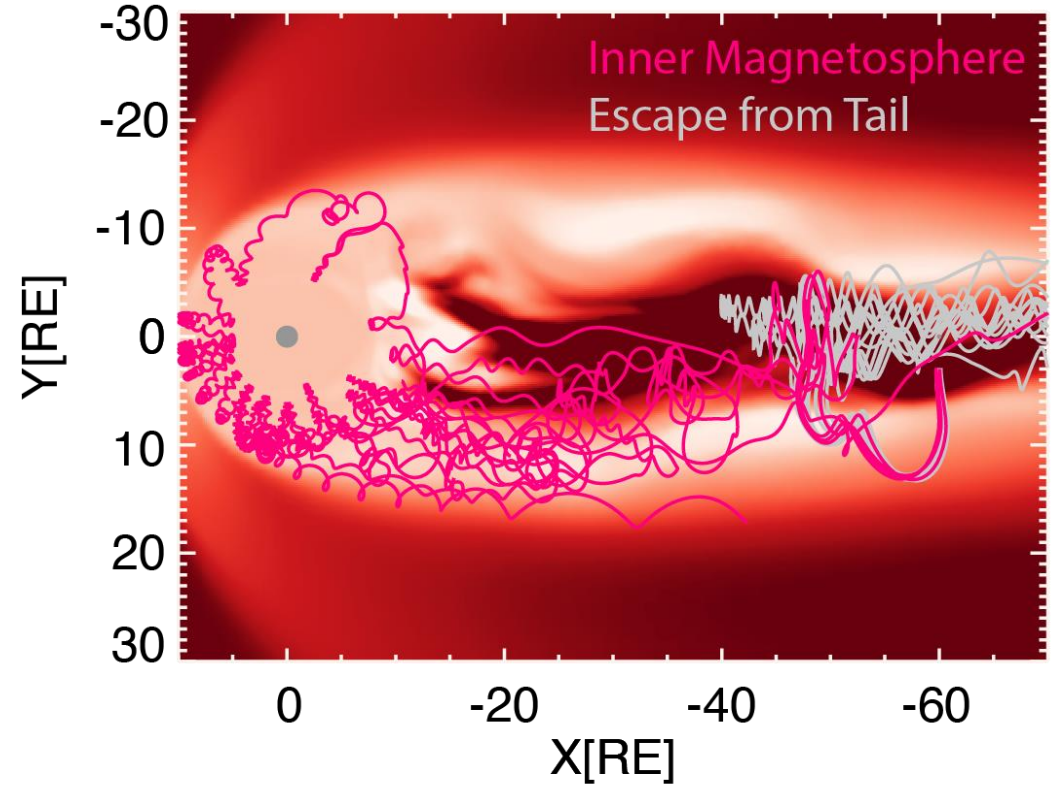
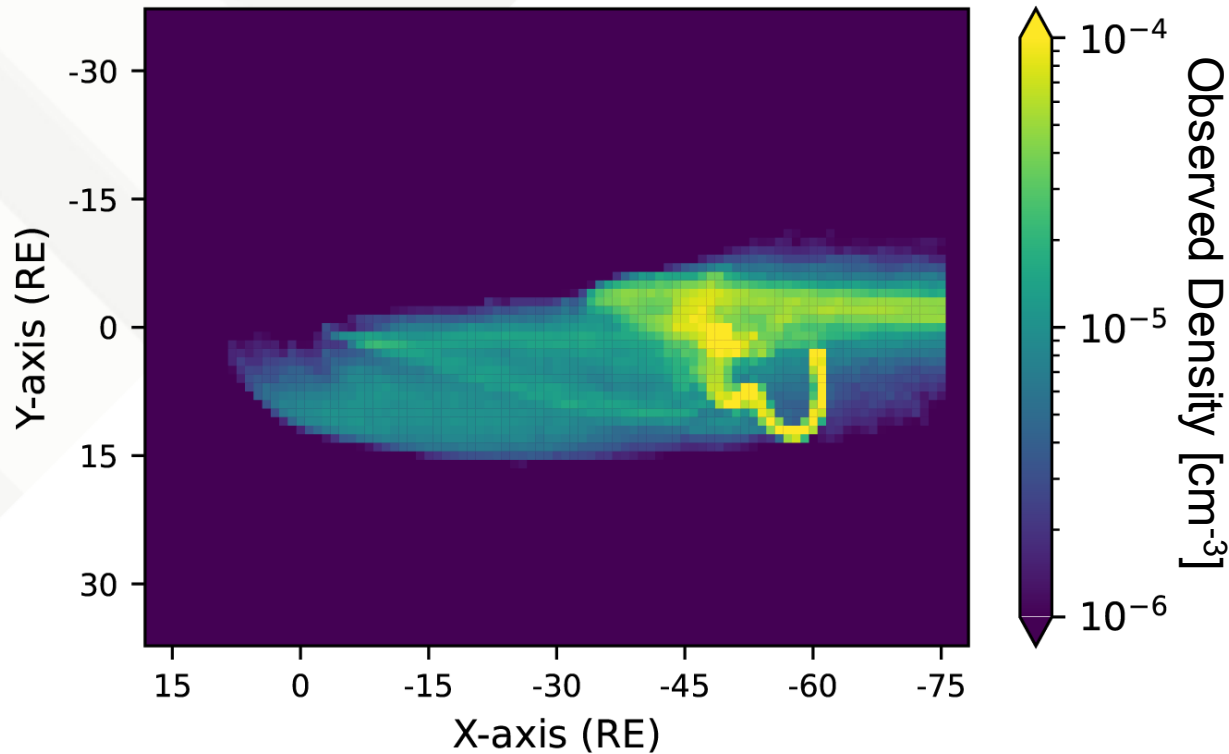
Particle Tracing + MHD

- Particle tracing requires the temporal magnetic and electric field, provided by the OpenGGCM simulation results using CCMC.
- 5 idealized conditions: $[B_y, B_z] = [\pm 5, 0], [0, \pm 5], [0, 10]$ (nT).

Trapped Metallic Ions in the Inner Magnetosphere



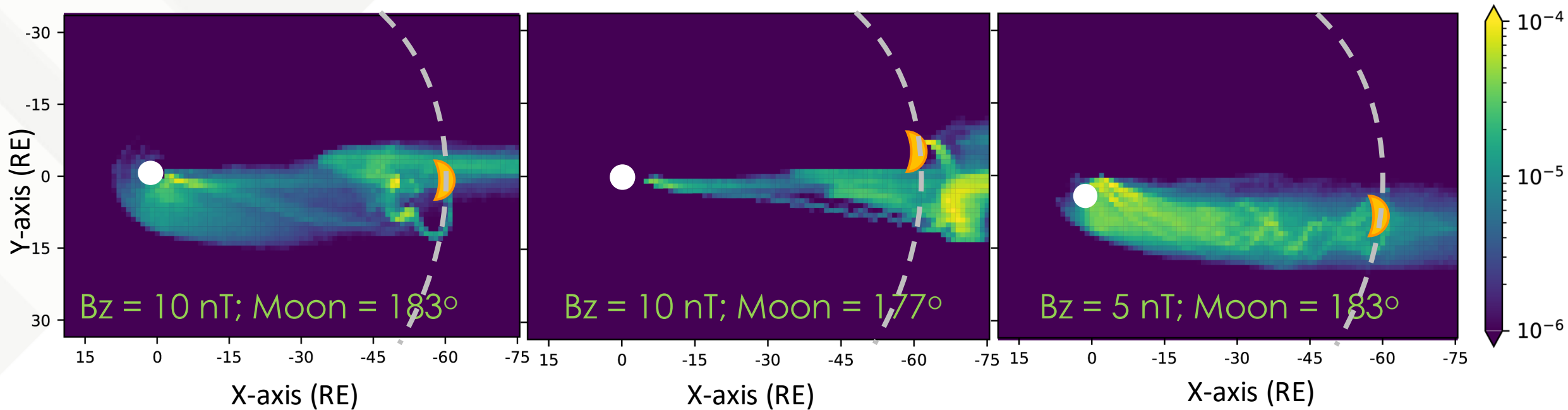
Collective Results of 10,000 Particles' Trajectories



- The magnetosphere has been divided to 90x90x90 cells, which count the presence of particles.

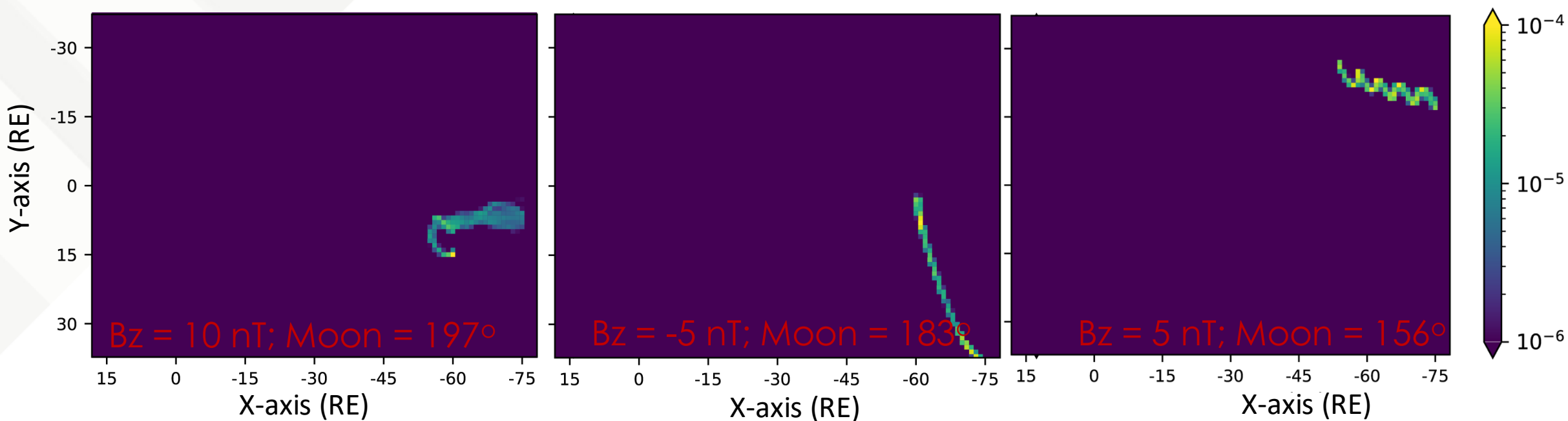
$$n(x, y, z) = \frac{\Sigma \Delta t R_{metal}}{N_{total} V}$$

Metallic ions in the Inner Magnetosphere



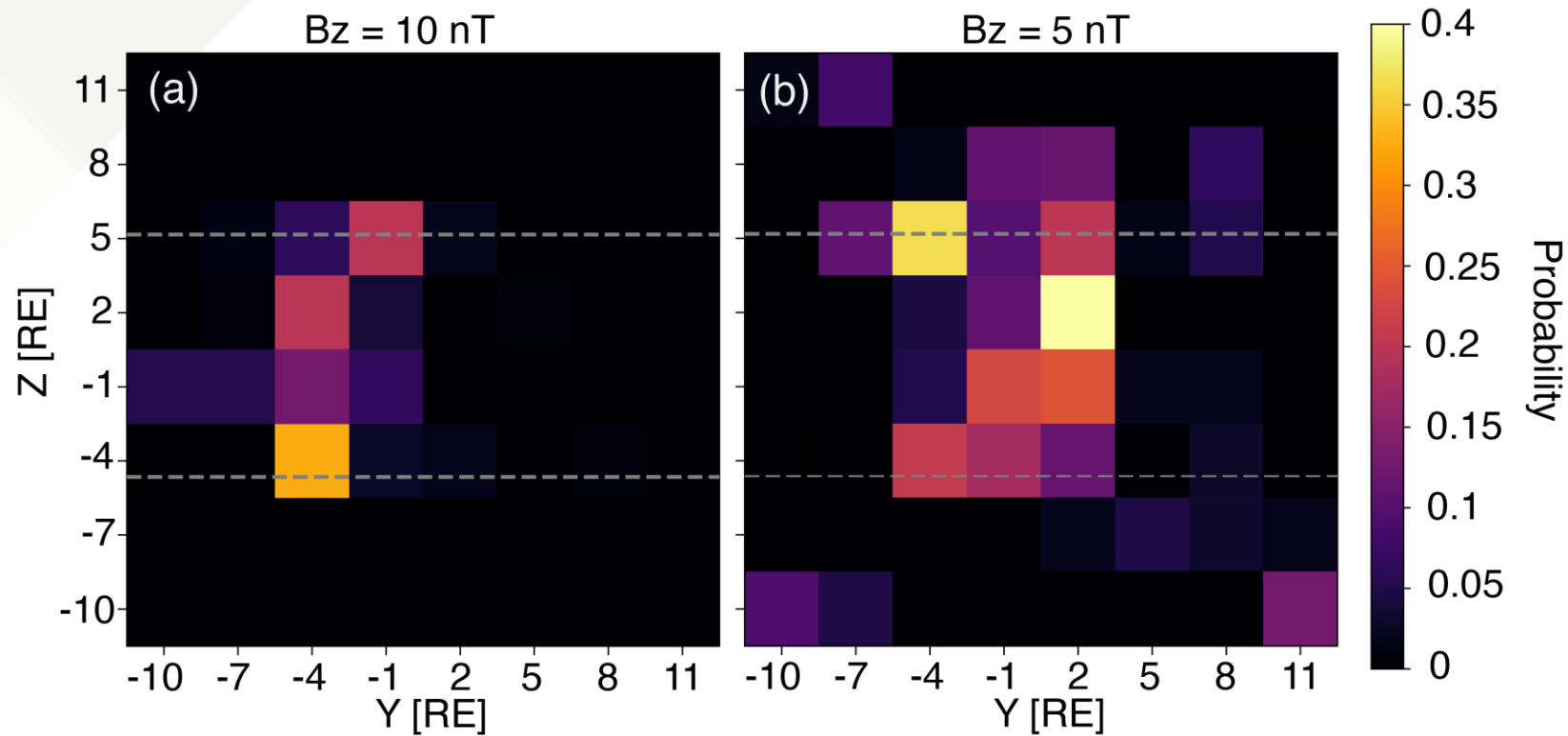
- Solar Activity: Positive B_z condition.
- Lunar Position: When the Moon passes through the midnight plane.

Not all the conditions...



- Right time ($B_z > 0$) **and** right lunar position.
- Otherwise, ions are transported to escape the magnetosphere.

Probability to Reach the Inner Magnetosphere



- 20—30% of released particles could reach the inner magnetosphere when the Moon transverse to the midnight plane.

Conclusion

- This study employed a particle-tracing model to evaluate the contributions of lunar plasma to the terrestrial magnetosphere.
- When the Moon is near the midnight plane, up to 20—40% of lunar-origin ions are transported to the inner magnetosphere during northward IMF.
- The ions may be trapped in open field lines connected to the inner magnetosphere, when transporting to the nightside plasma sheet.