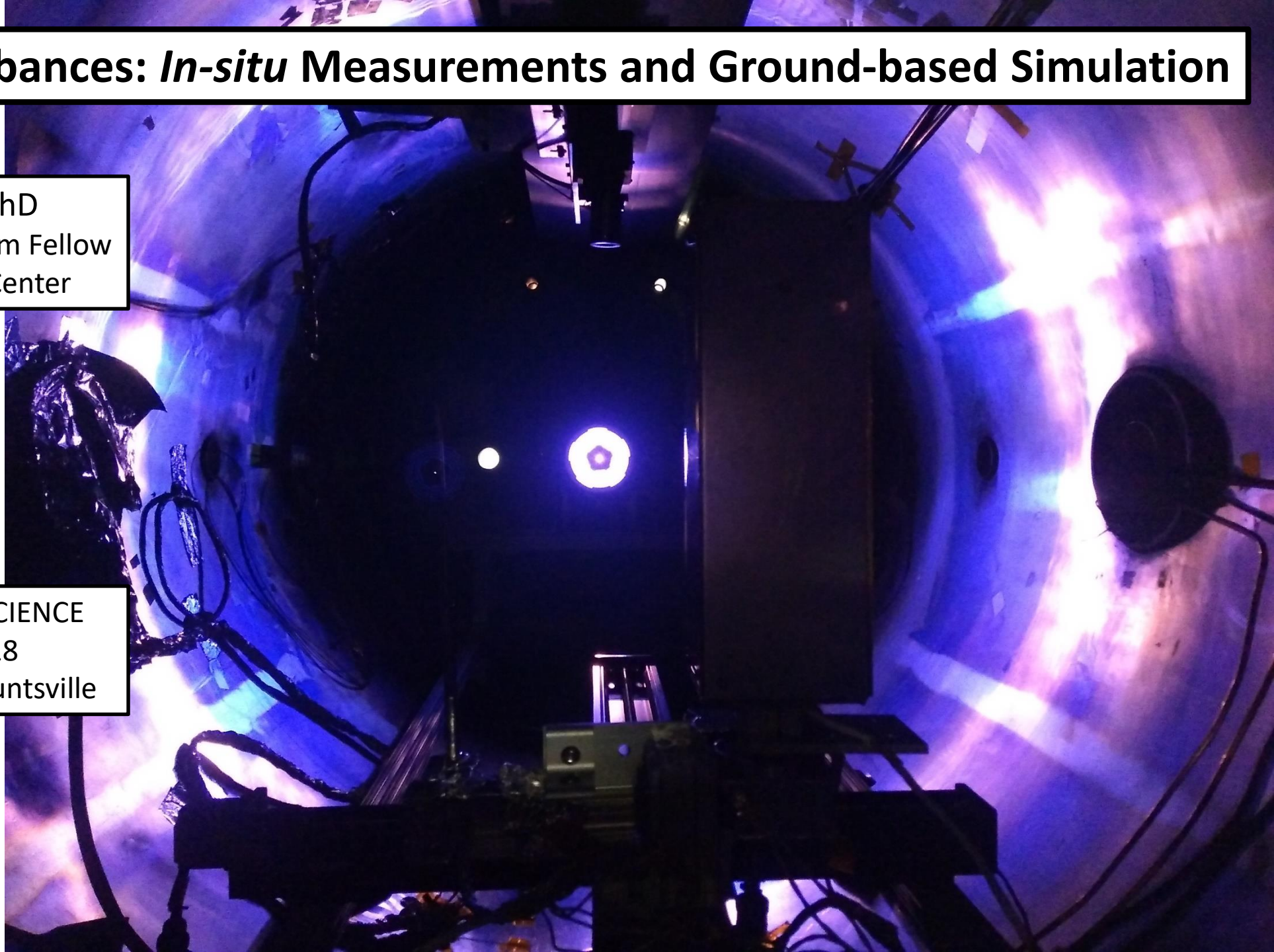
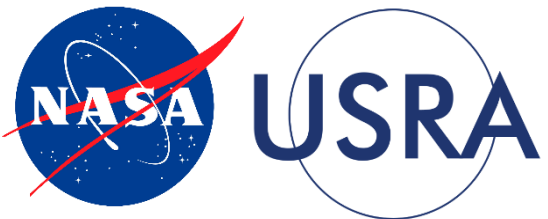


# Ionospheric Disturbances: *In-situ* Measurements and Ground-based Simulation

Jesse McTernan, PhD  
NASA Postdoctoral Program Fellow  
Marshall Space Flight Center

PH 110 FRONTIERS IN SCIENCE  
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University of Alabama Huntsville











# Radiation from the Sun establishes the low-Earth-orbit (LEO) environment

The ionosphere  
(a plasma shell)  
What's a plasma?

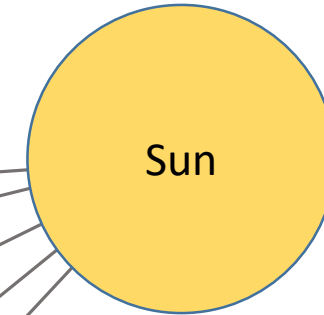
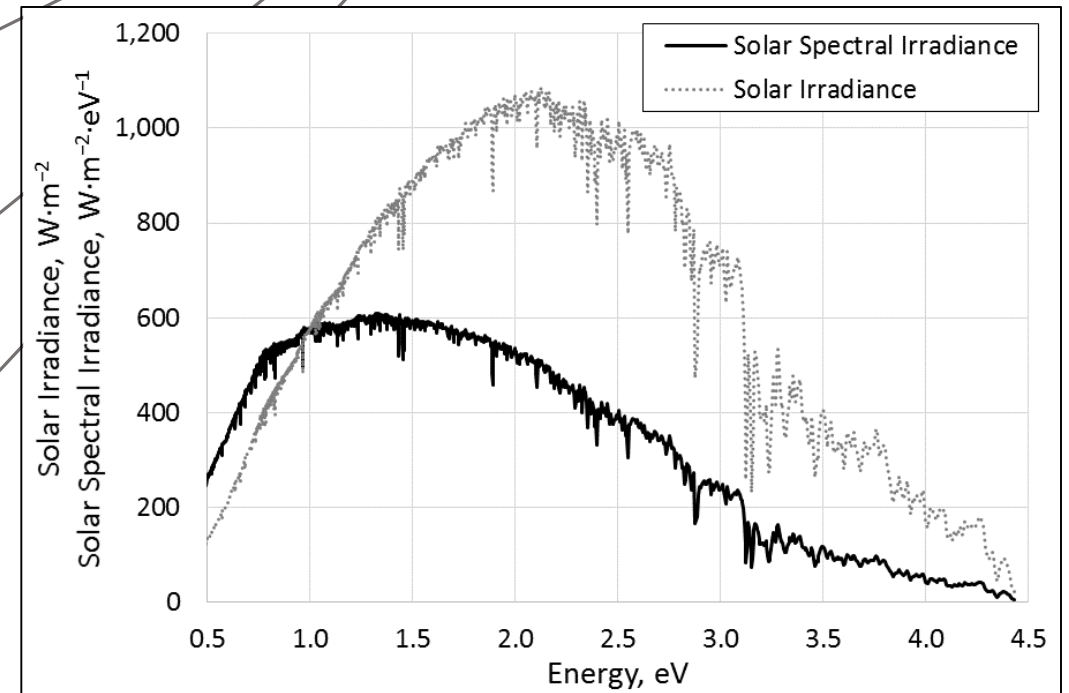
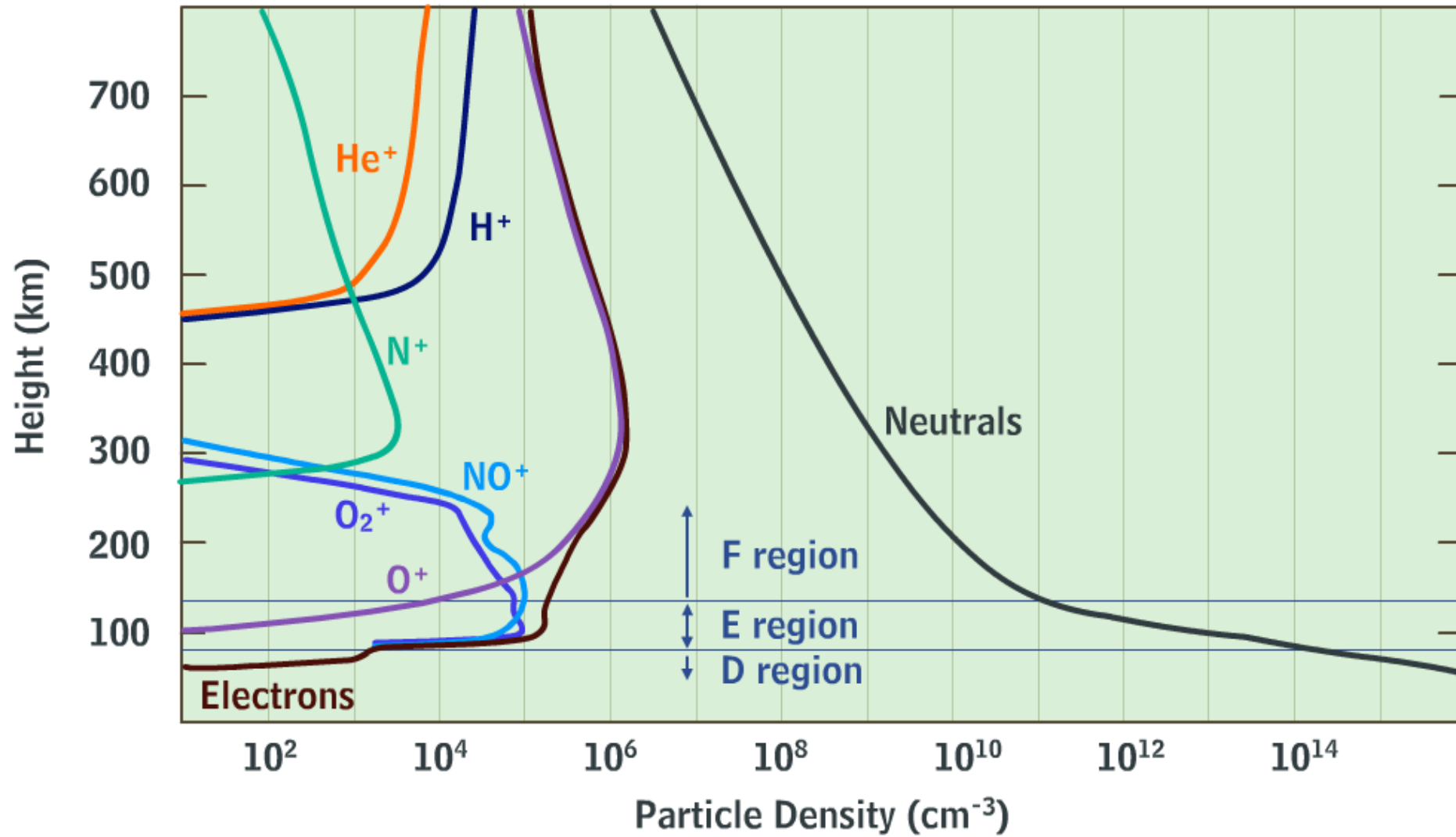


Diagram not to scale

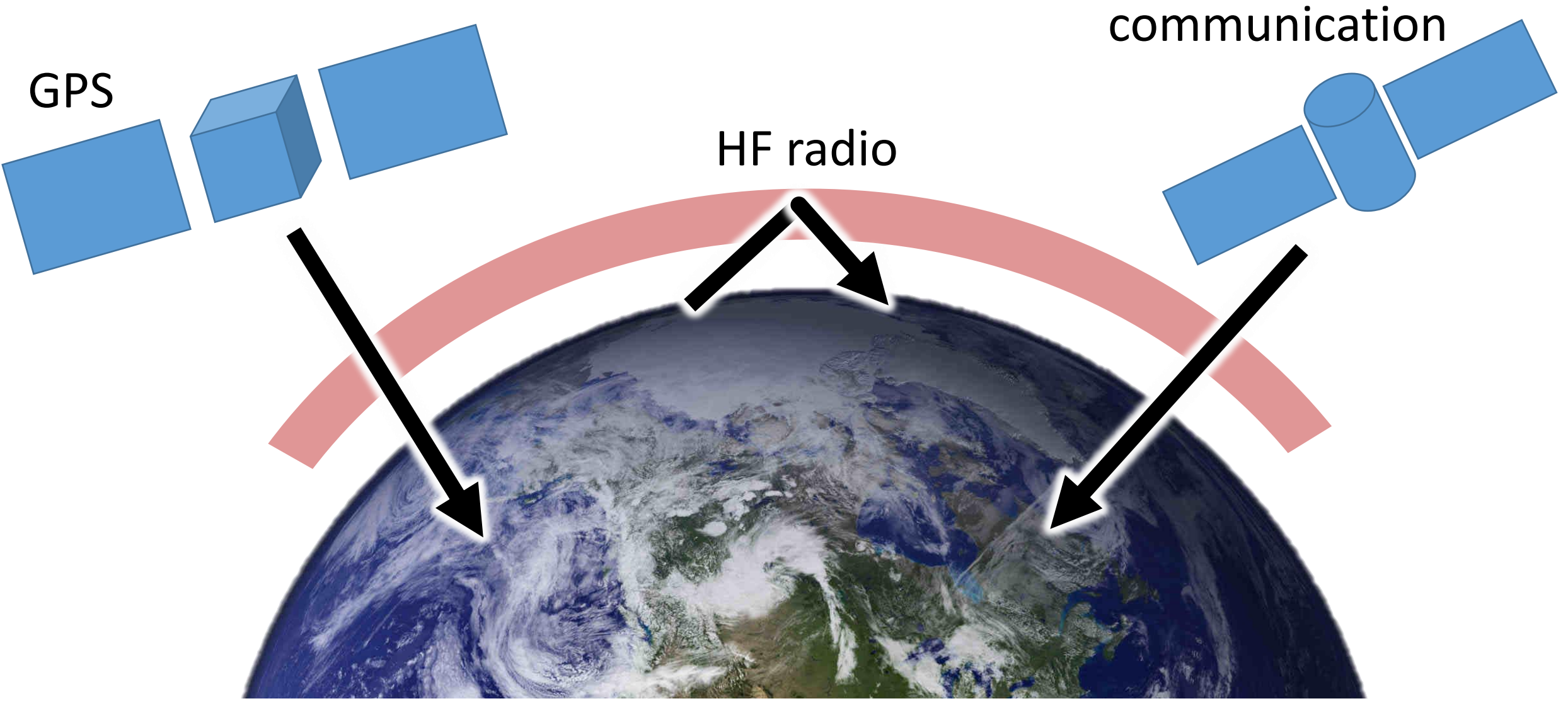


# Principal Constituents of the Ionosphere (45° N, Equinox)



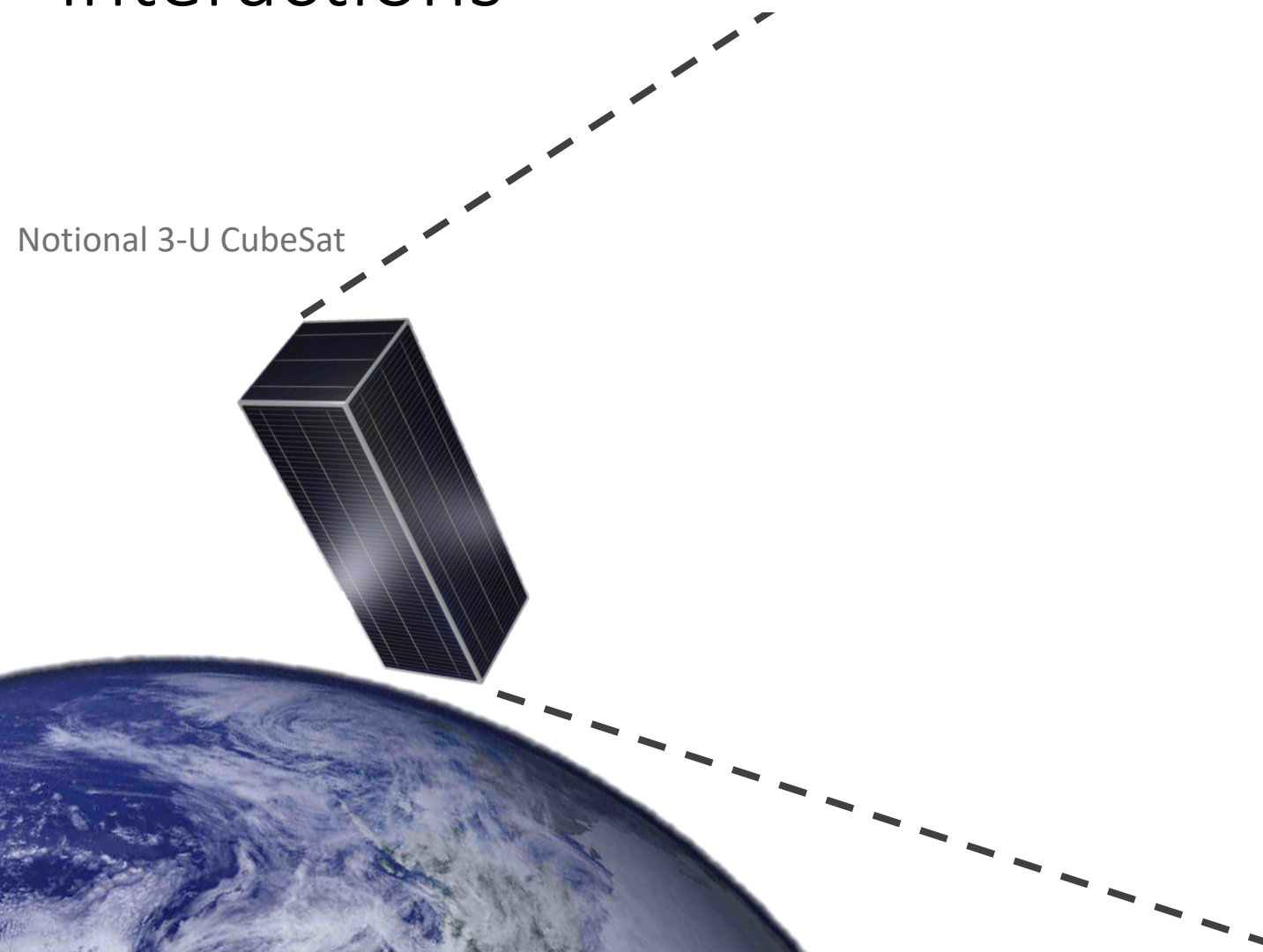
- Electrons
- H<sup>+</sup>
- N<sup>+</sup>
- NO<sup>+</sup>
- He<sup>+</sup>
- O<sup>+</sup>
- O<sub>2</sub><sup>+</sup>

Disturbances in the ionosphere can have negative effects on many systems

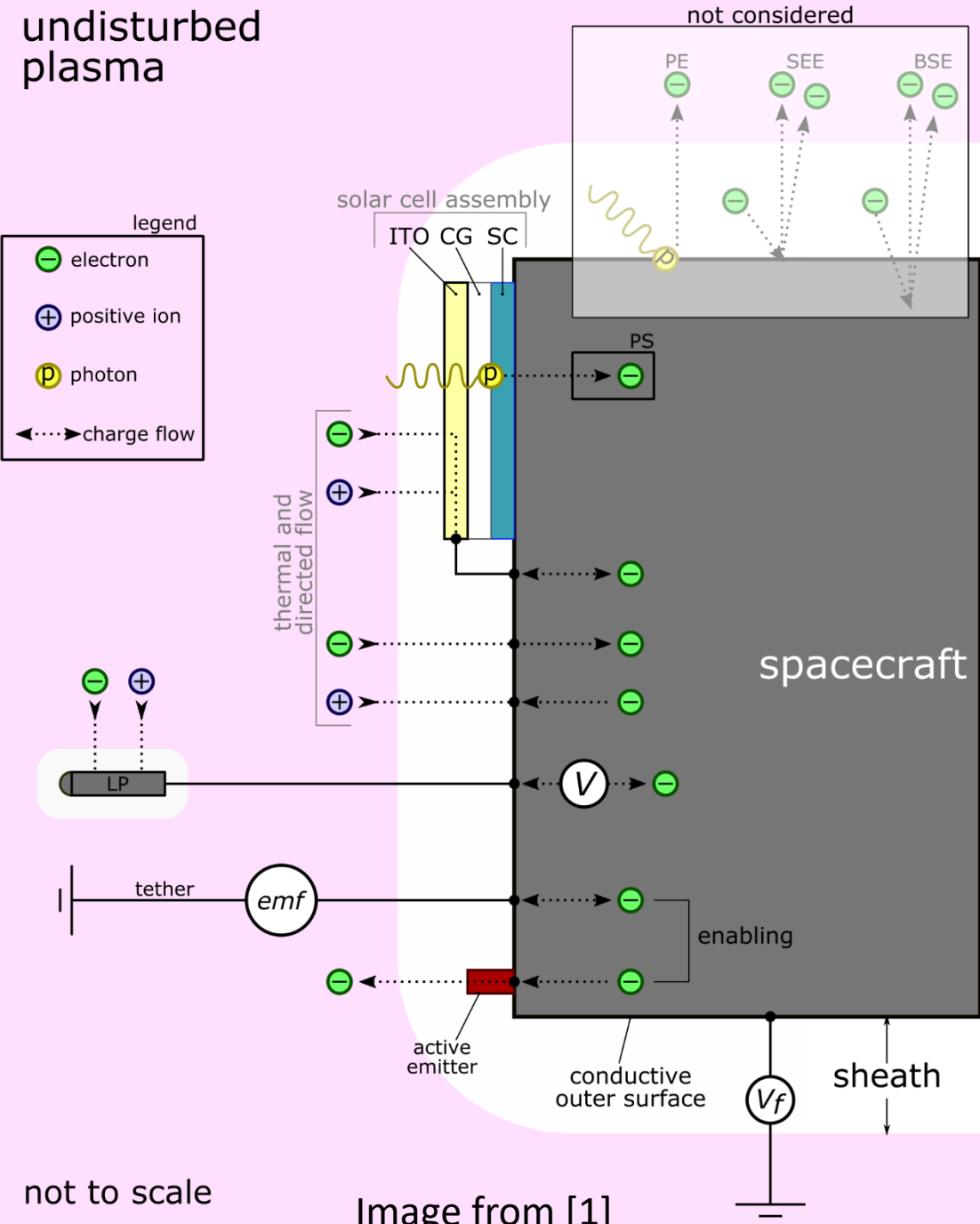
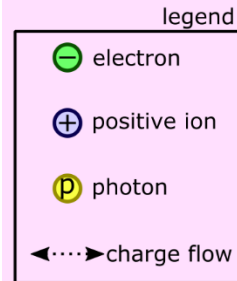




# A spacecraft orbiting in LEO experiences complex plasma interactions



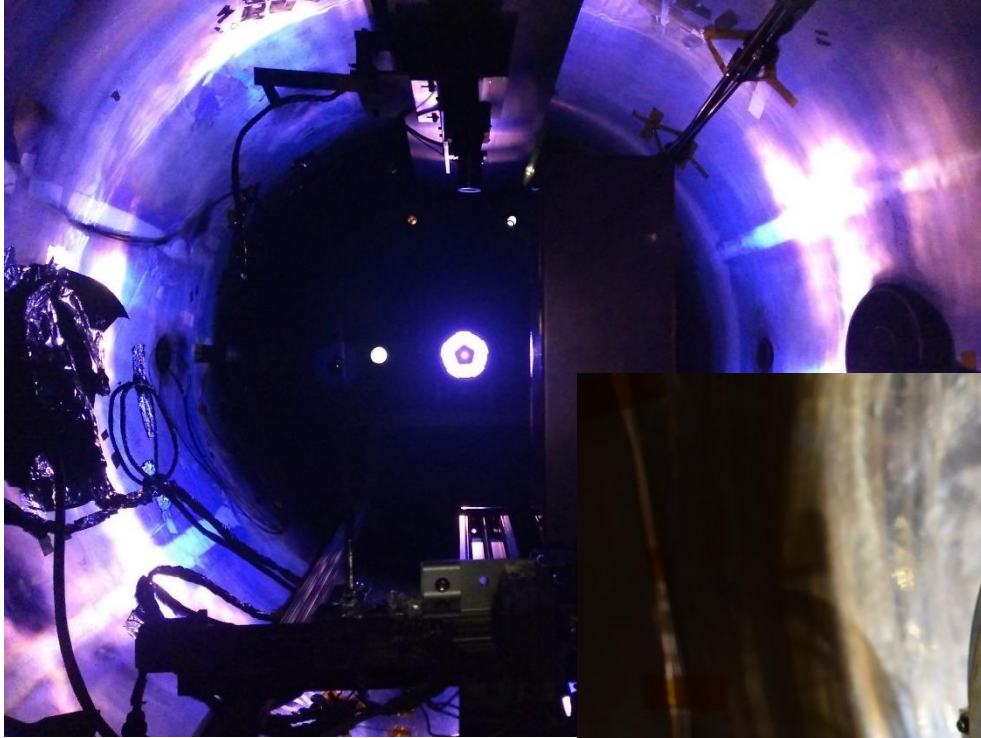
undisturbed plasma



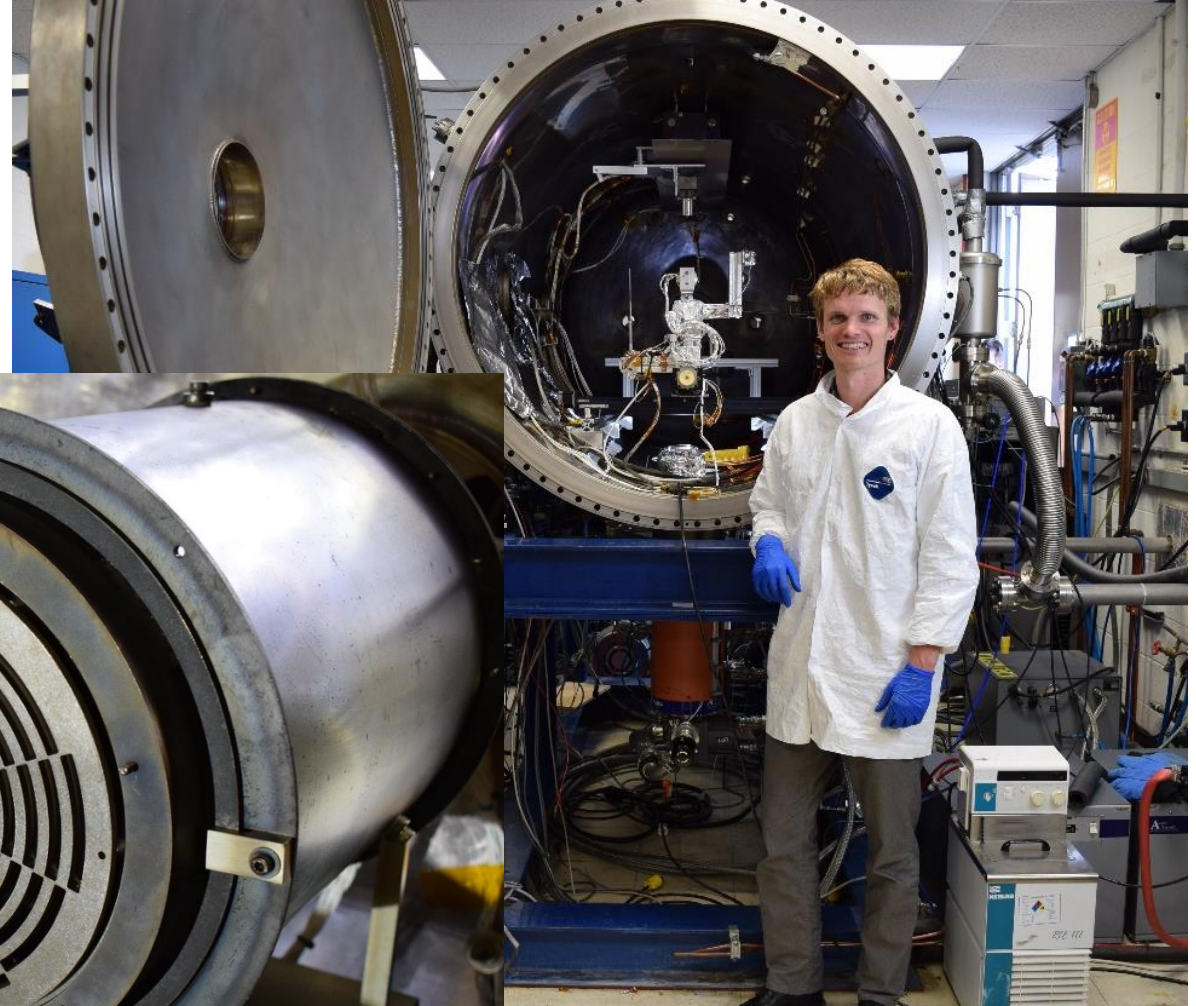
not to scale

Image from [1]

# The LEO environment can be simulated in ground-based vacuum facilities



Argon's purple glow



Dr. McTernan at NASA MSFC



Our space simulation chamber establishes an effective “wind tunnel” for the LEO environment



This screenshot was captured during the test flight of the Falcon Heavy developed by SpaceX (Feb. 2018)

# The LEO source can produce a relevant plasma environment

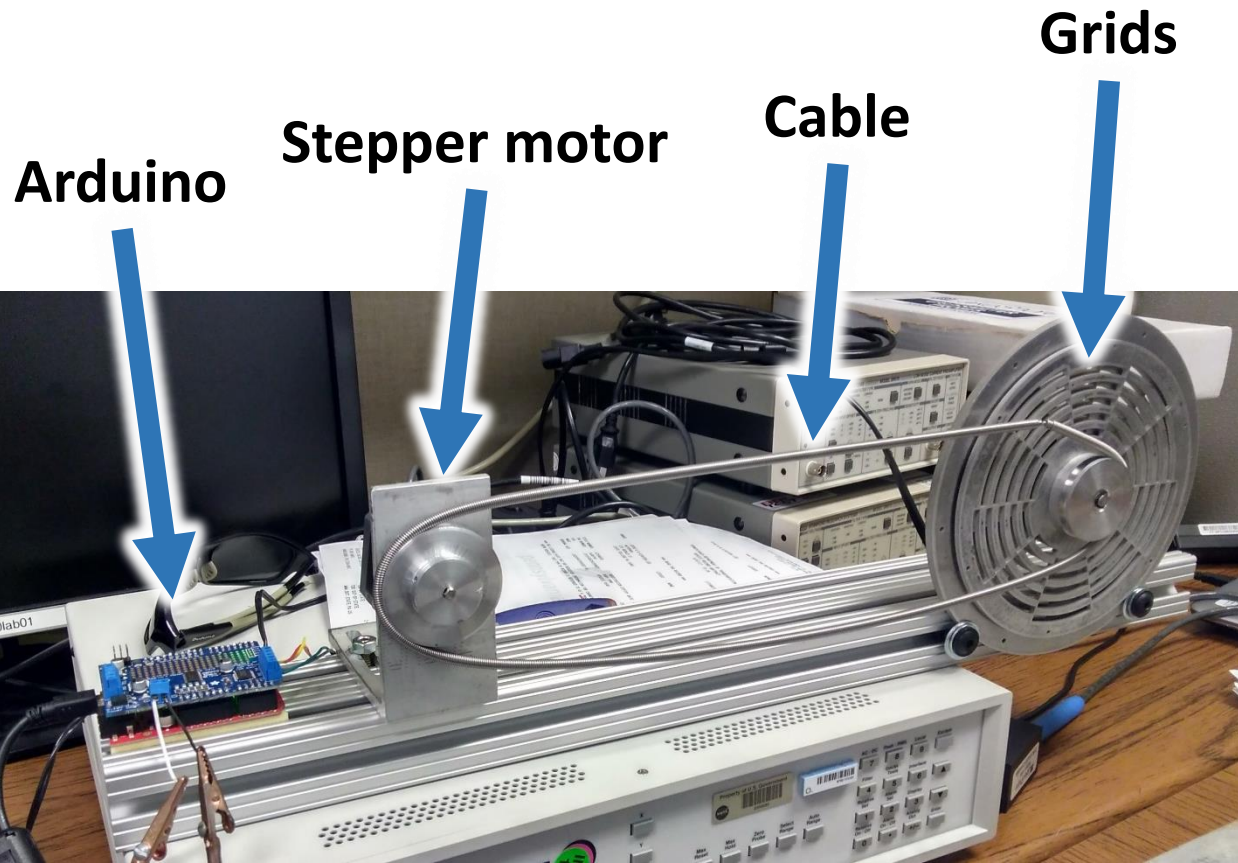
## Specifications

- Argon gas
- 10 sccm flow rate
- $\sim 0.1$ -eV electrons
- $\sim 5$ -eV ions
- Magnetic filter

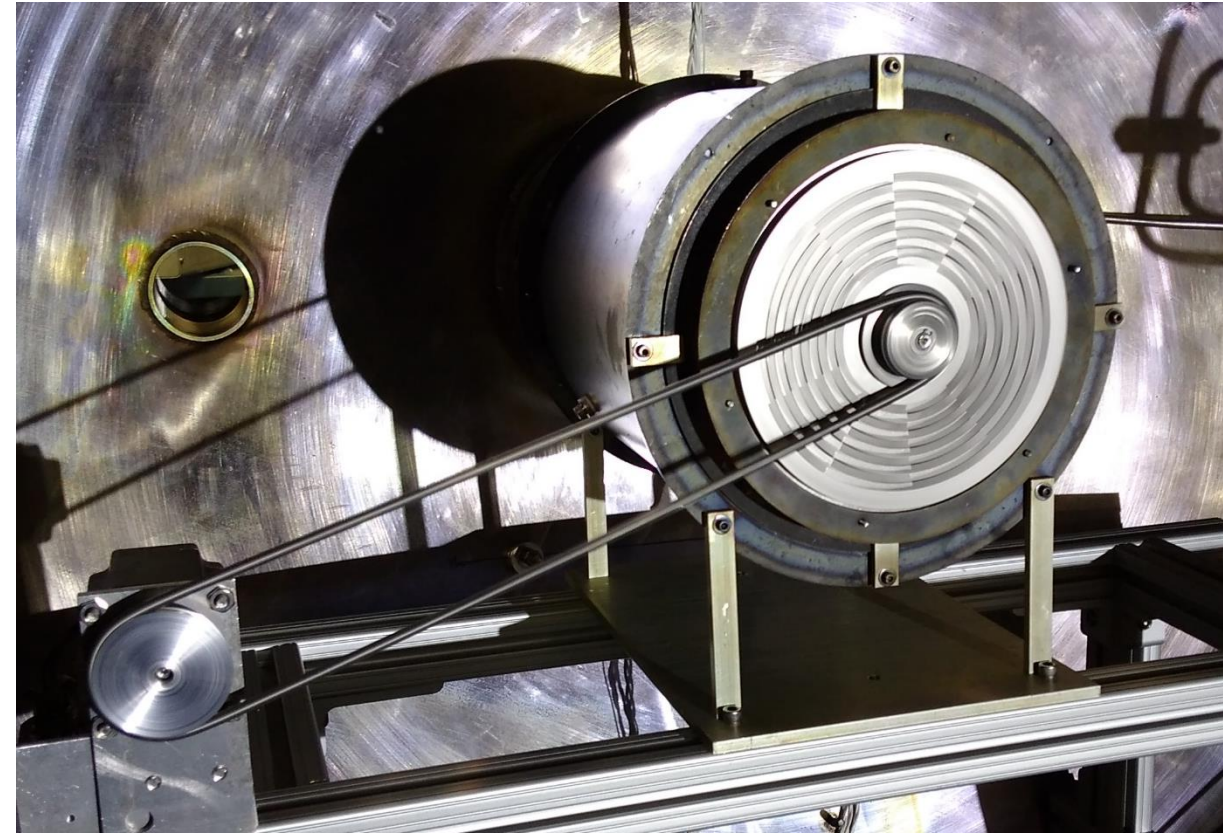


Close-up image of the modified LEO plasma source installed in the facilities at MSFC.

# We modified the LEO plasma source with a spinning grid

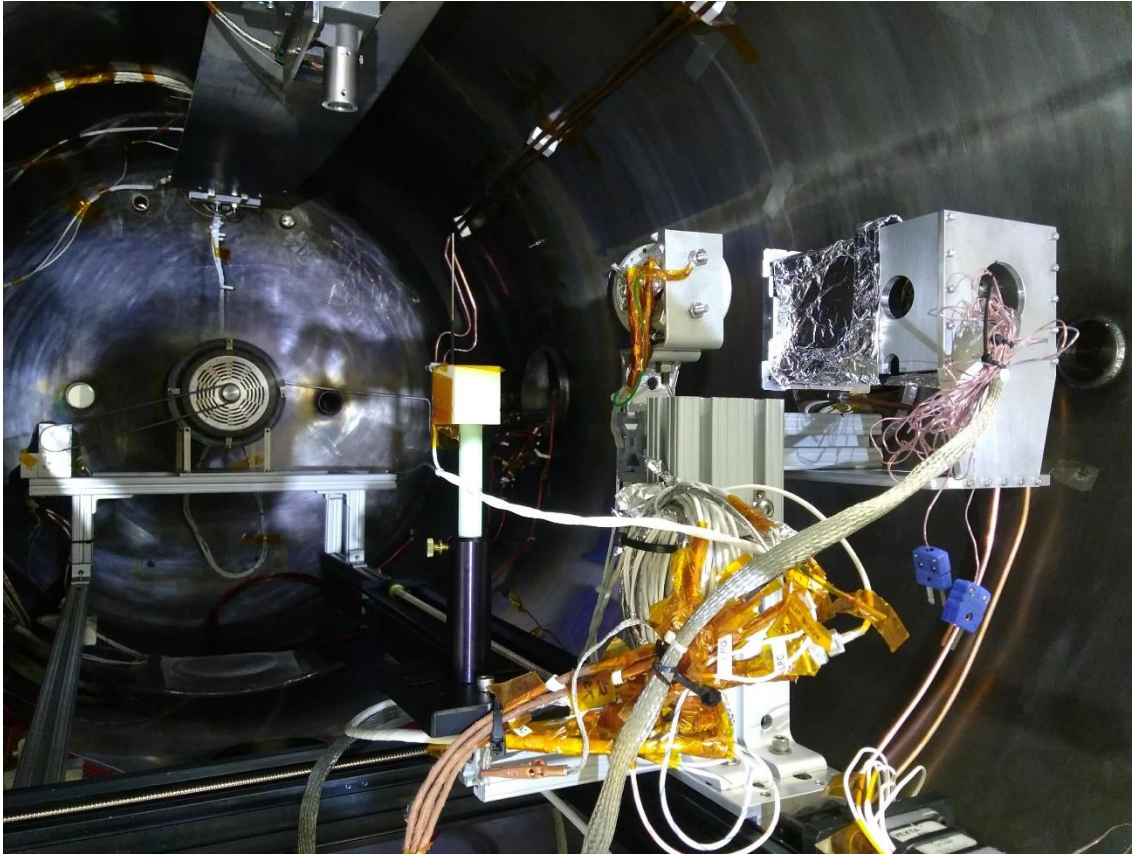


Benchtop prototype demonstrating basic proof of concept.



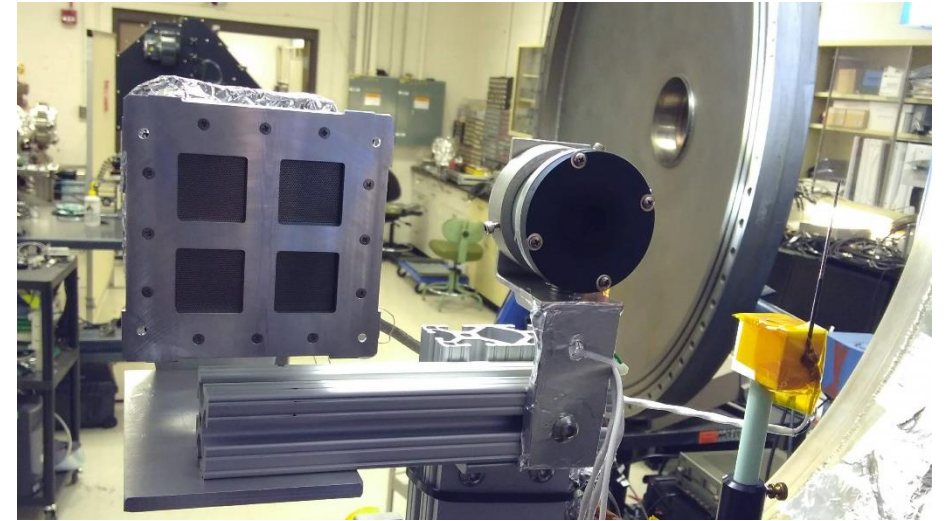
Working prototype installed and operating at MSFC.

# Charge Analyzer Responsive Local Oscillations (CARLO)

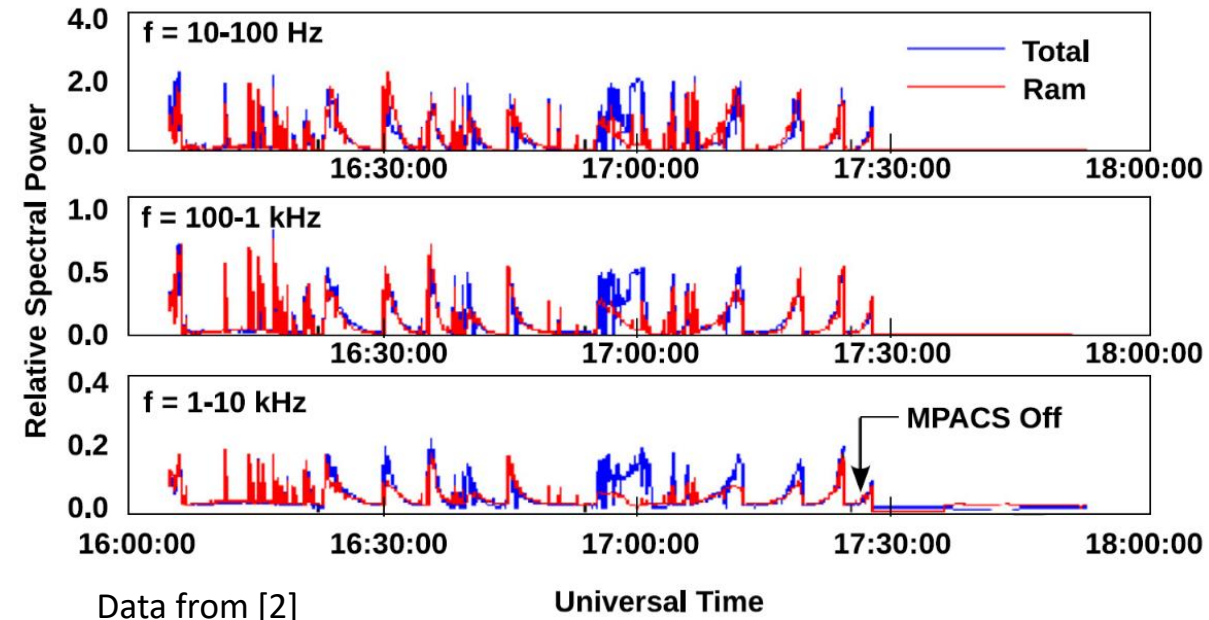


CARLO installed in the facilities at MSFC (back view)

- Frequency-domain ion spectrum analyzer
- Measures turbulence from 1 Hz to 10 kHz
- Important for VHF/UHF
- Length scales from a few kilometers to a few centimeters



CARLO installed in the facilities at MSFC (front view)



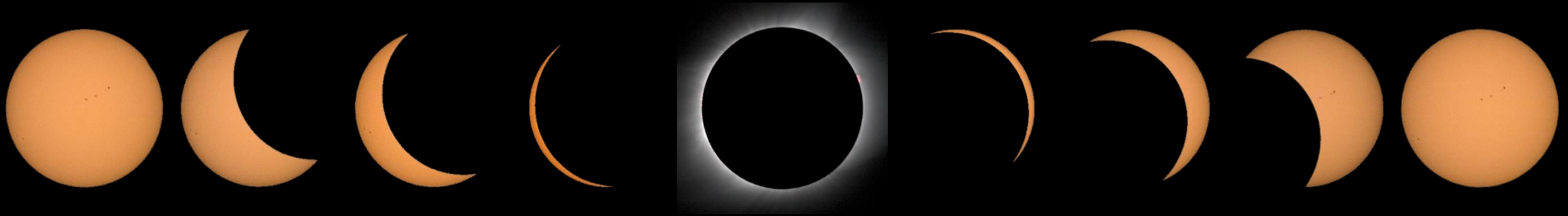
# Short story

- We are developing a new scientific instrument to measure the ionosphere, *in situ*
- We are developing test facilities in support of the new instrument

# References

1. J. McTernan, *Passive plasma contact mechanisms for small-scale spacecraft*, Ph.D. Dissertation, The Pennsylvania State University, 2017.
2. L. Habash Krause, C.L. Enloe, and M.G. McHarg, “*In situ* measurements of ionospheric plasma turbulence over five frequency decades: Heritage flight of the Plasma Local Anomalous Noise Experiment (PLANE)”, *Advances in Space Research*, vol. 52, pp. 2006-2014, 2013.





Thank you for listening!

Psalm 19

Extra Material

## Structure of the Neutral Atmosphere and the Ionosphere

