National Aeronautics and Space Administration

SelenITA: A dual point lunar mission to characterize the near surface dust and electromagnetic plasma environment

Charles Swenson (USU), Heidi Haviland (NASA MSFC), Linda Krause (NASA MSFC), Yuki Harada (Kyoto Univ.), Jasper Halekas (Univ. of Iowa), Lon Hood (UA), Rhyan Sawyer (Univ of Iowa), Marco Ridenti (ITA), Mauro Alves (ITA), Peter Chi (UCLA), Mike Zimmerman (APL), Robert Loper (MSFC T13), Omar Leon (UM), David Miles (Univ of Iowa), Shahab Fatemi (Univ. of Umea), David Falconer (UAH retired), Jonas Sousasantos (UTD), Tiago Matos (ITA), Victoria de Souza Rodrigues (ITA), Luís Loures (ITA)

SelenITA

AEB AGÊNCIA ESPACIAL BRASILEIRA · APL · ARIZONA · IOWA · ITA · KYOTO UNIVERSITY · MICHIGAN · UMEA UNIVERSITET · UTD · UCLA

Outline

- Mission Overview
- Science Objectives
- The Lunar Electrostatic Environment
- Crustal Magnetic Fields
- Ion Cyclotron Waves
- Plasma Interactions with Crustal Magnetic Fields
- Surface Charging
- Dust
- Instruments
- Summary

Mission Overview

Image Credit: Astrobotic Cube rover

SelenITA Science Objectives

SelenITA is an international interdisciplinary low-cost mission consisting of a 12U CubeSat with a surface package that will provide novel multi-point measurement of dust, particles and fields for the characterization of the electromagnetic space environment, in support of Artemis crew, and the geosciences.

Candidate Science Objectives:

- Characterize lunar crustal magnetic fields processes including their contributions to volatile processes, space weathering, and magnetic reconnection.
- Determine the nature of plasma interactions with crustal magnetic fields.
- Characterize plasma waves and turbulence at the Moon.
- Characterize the lunar surface potential in all plasma environments.
- Constrain the composition, thermal state, and structure of the lunar upper mantle and crust.
- Determine ionizing radiation environment hazardous to human and robotic systems.
- Determine the density of the impact ejecta dust grains as a function of latitude, longitude, and altitude.

The Lunar Electrostatic Environment

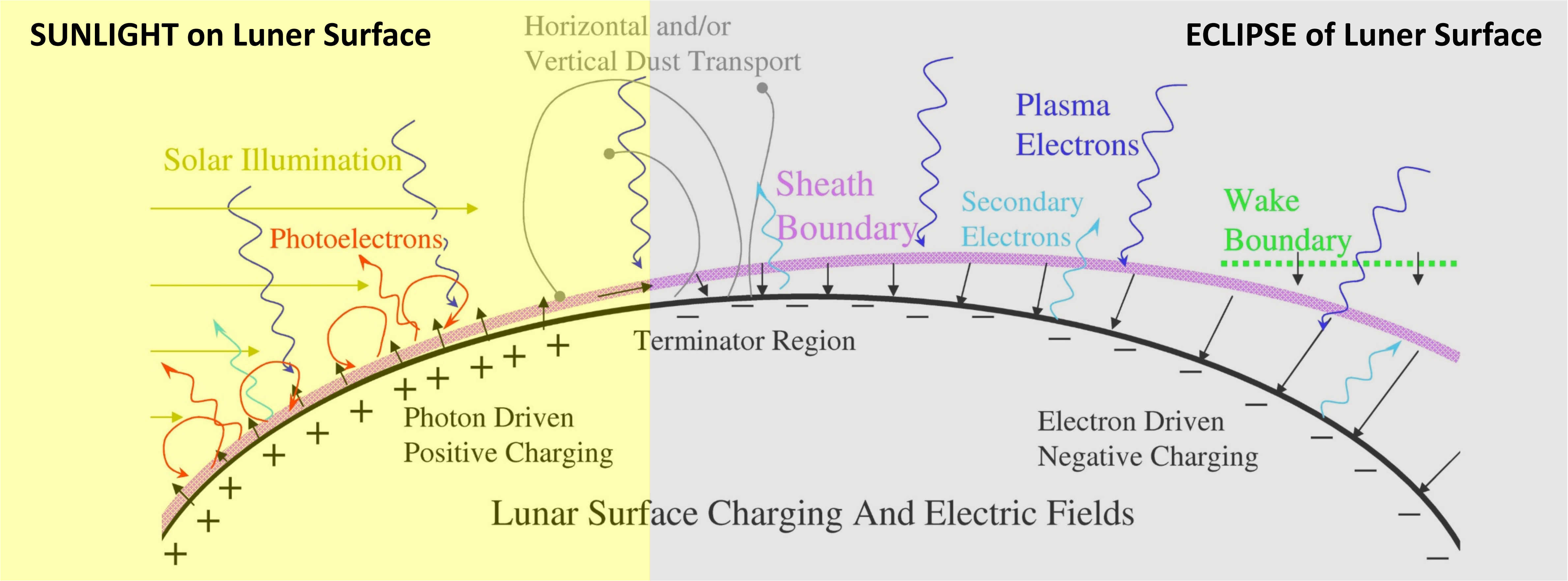
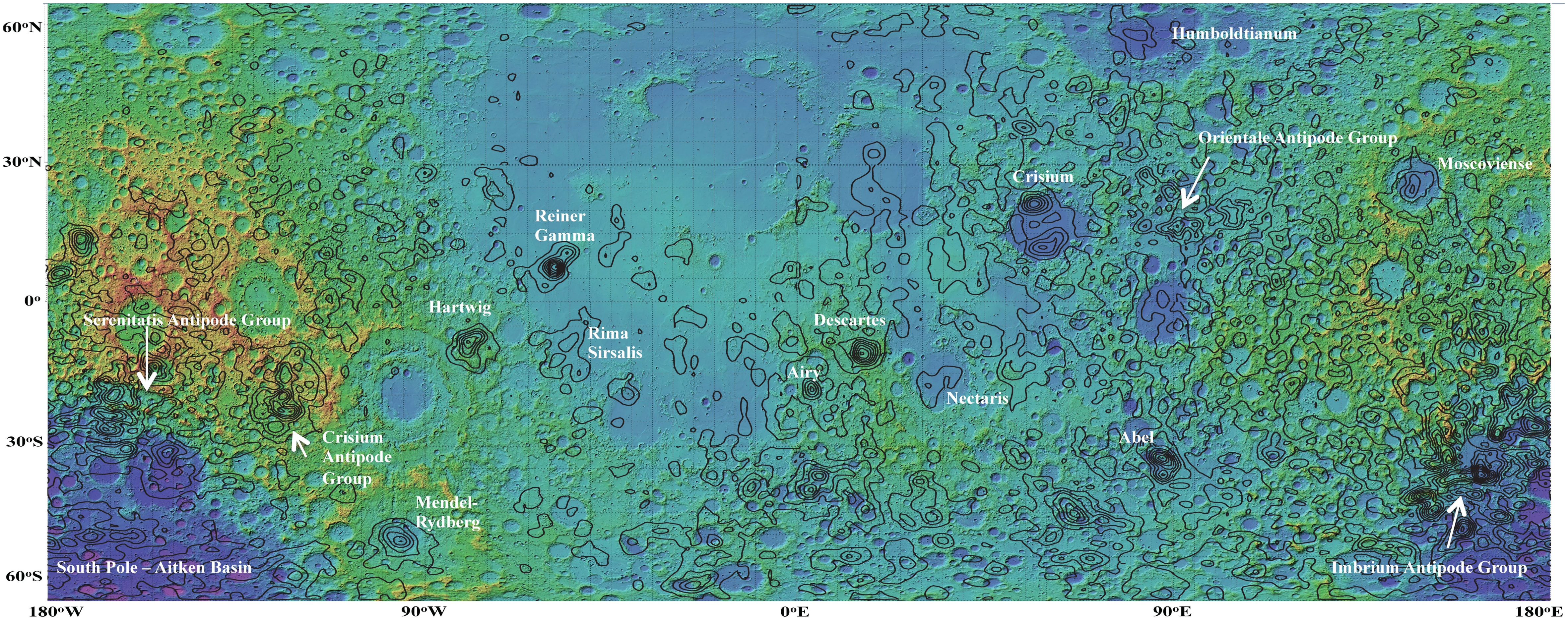


Figure 1. Schematic of the lunar electrostatic environment in the solar wind (not to scale).

Image Credit: LUNAR SURFACE CHARGING: A GLOBAL PERSPECTIVE USING LUNAR PROSPECTOR DATA , Timothy J. Stubbs1 et al
https://www.nasa.gov/centers/johnson/pdf/486015main_StubbsSurfaceCharging.4070.pdf

Lunar Crustal Magnetic Fields

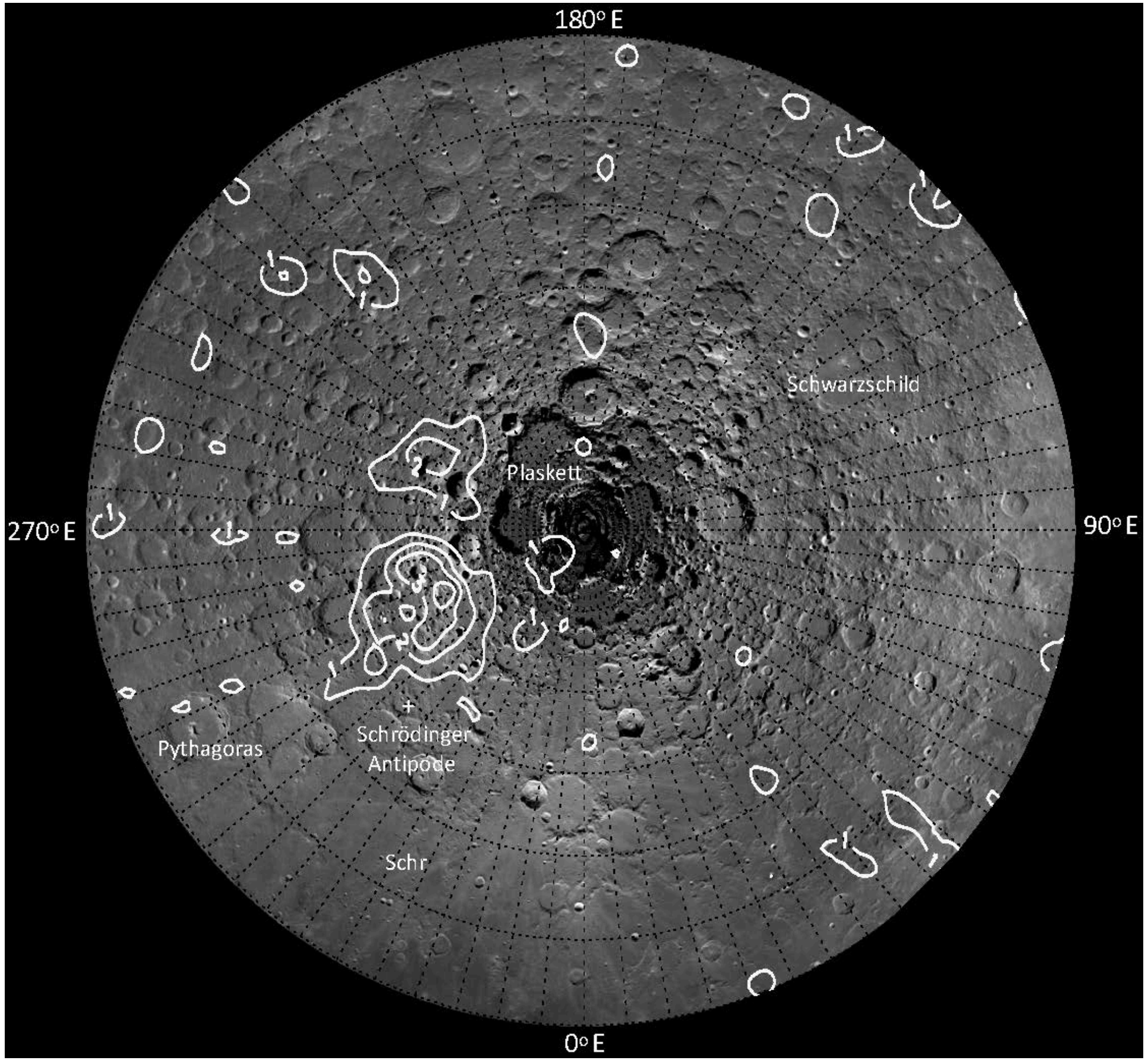


Global map of the Lunar Crustal Magnetic Fields at 30 km altitude, produced from Lunar Prospector (1998-99) and Kaguya (2009) Orbital Magnetometer Data (Contour Int., 1 nT), (Hood et al. 2021, JGRP). *Two-Dimensionally Filtered to Interpolate between good orbit tracks; effective resolution ~ 2 degrees of latitude or 60 km.*

Polar Crustal Magnetic Field Maps

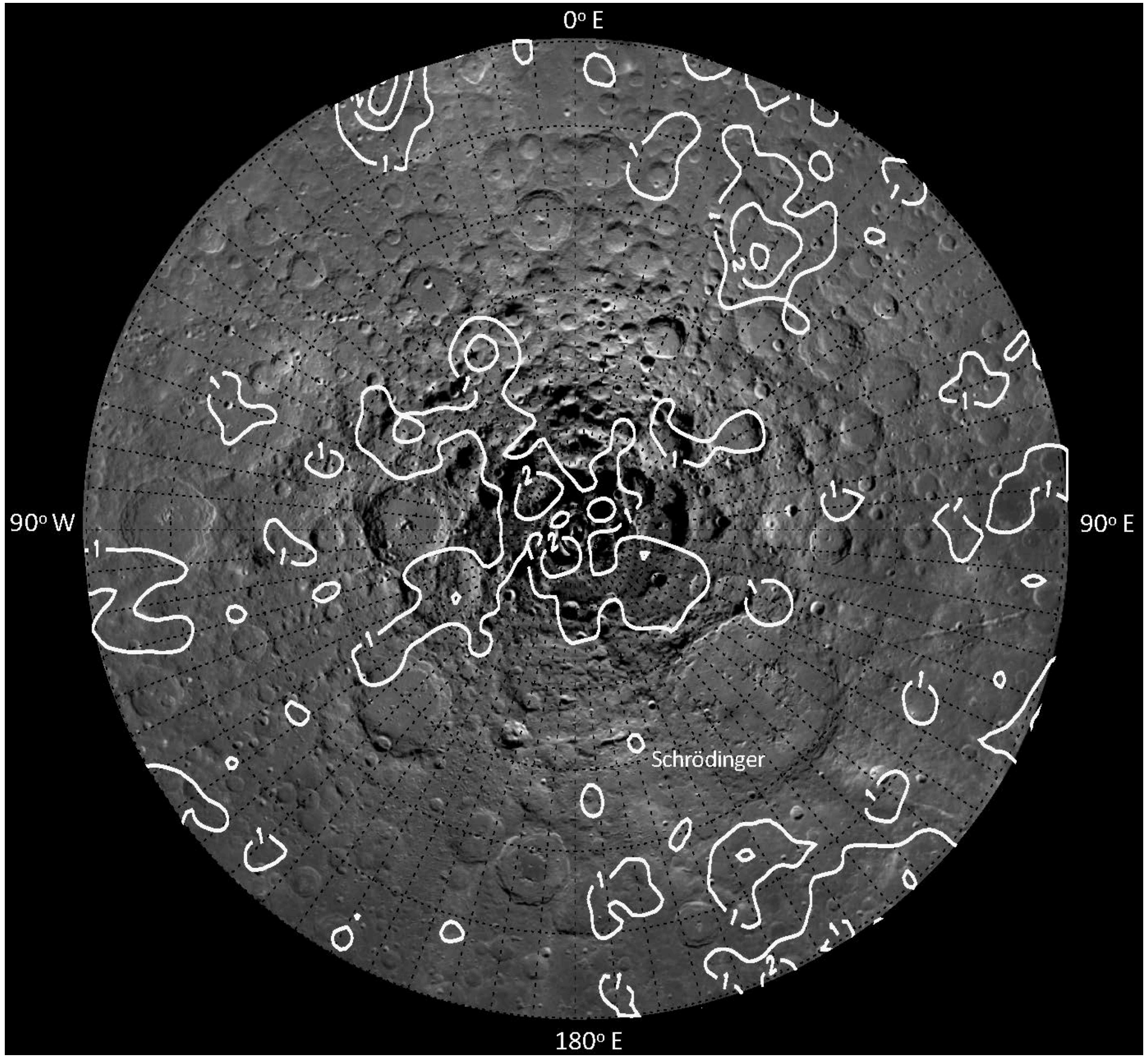
at 30 km Altitude, Resolution ~ 60 km after 2D Filtering

North Polar Region



60° N to 90°N

South Polar Region:

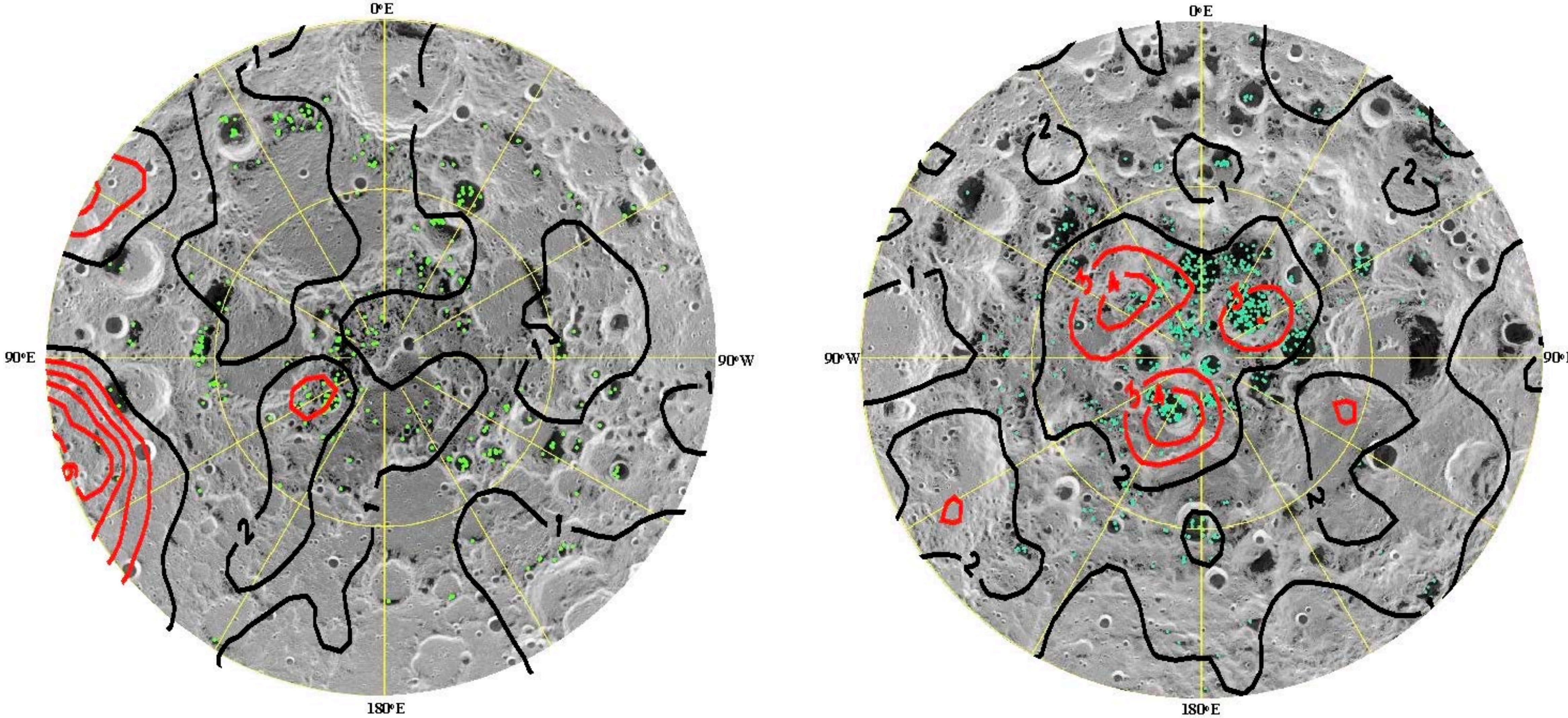


60°S to 90°S *Hood et al. (2022)*

LROC Imagery

Anomaly maps at 20 km superposed on the polar ice maps of Li et al. (2018)

80°N to Pole: 80°S to Pole:

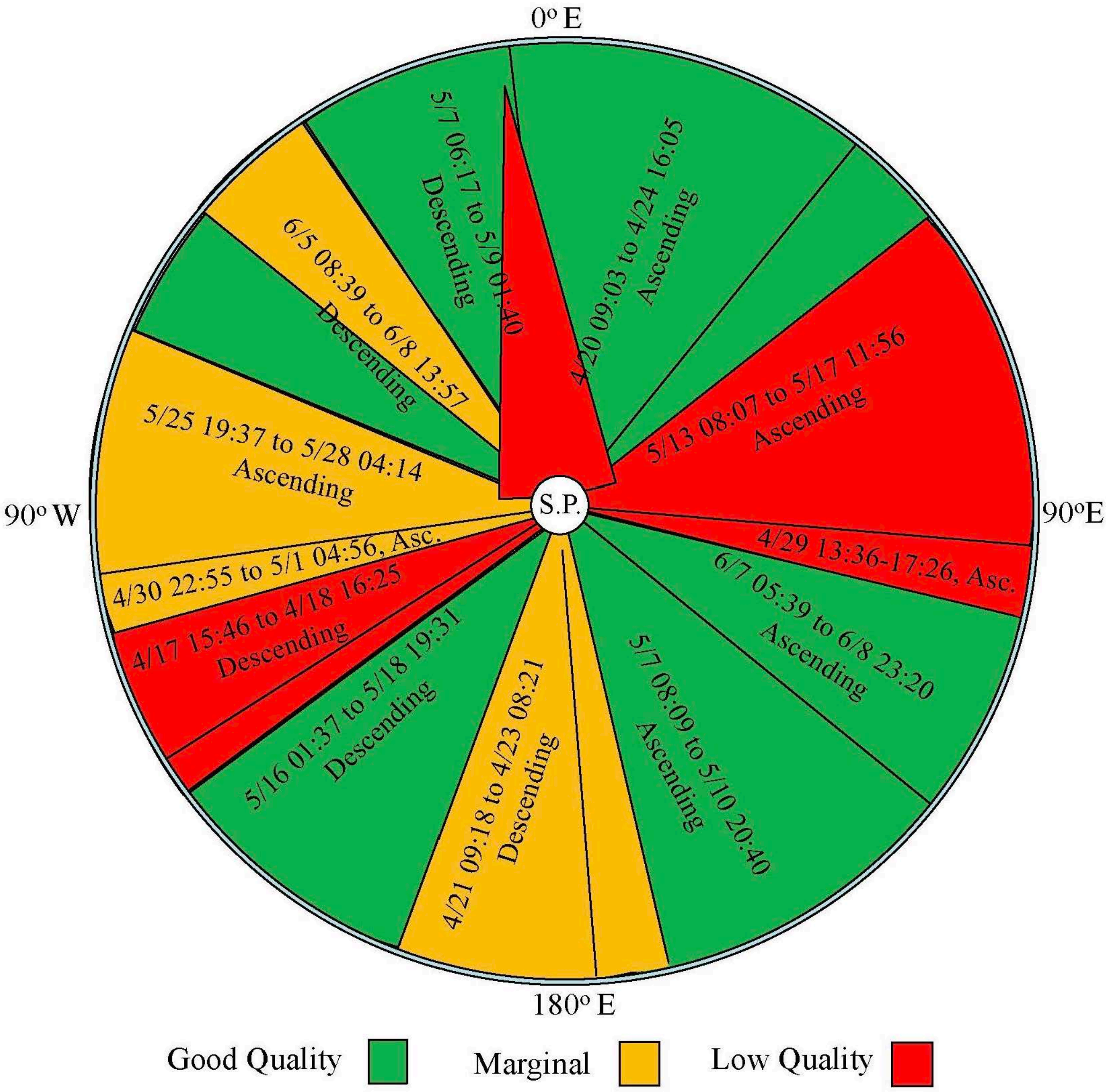


Background Maps: annual maximum surface temperatures calculated from Diviner data. Dr. Shuai Li, Univ. Hawaii

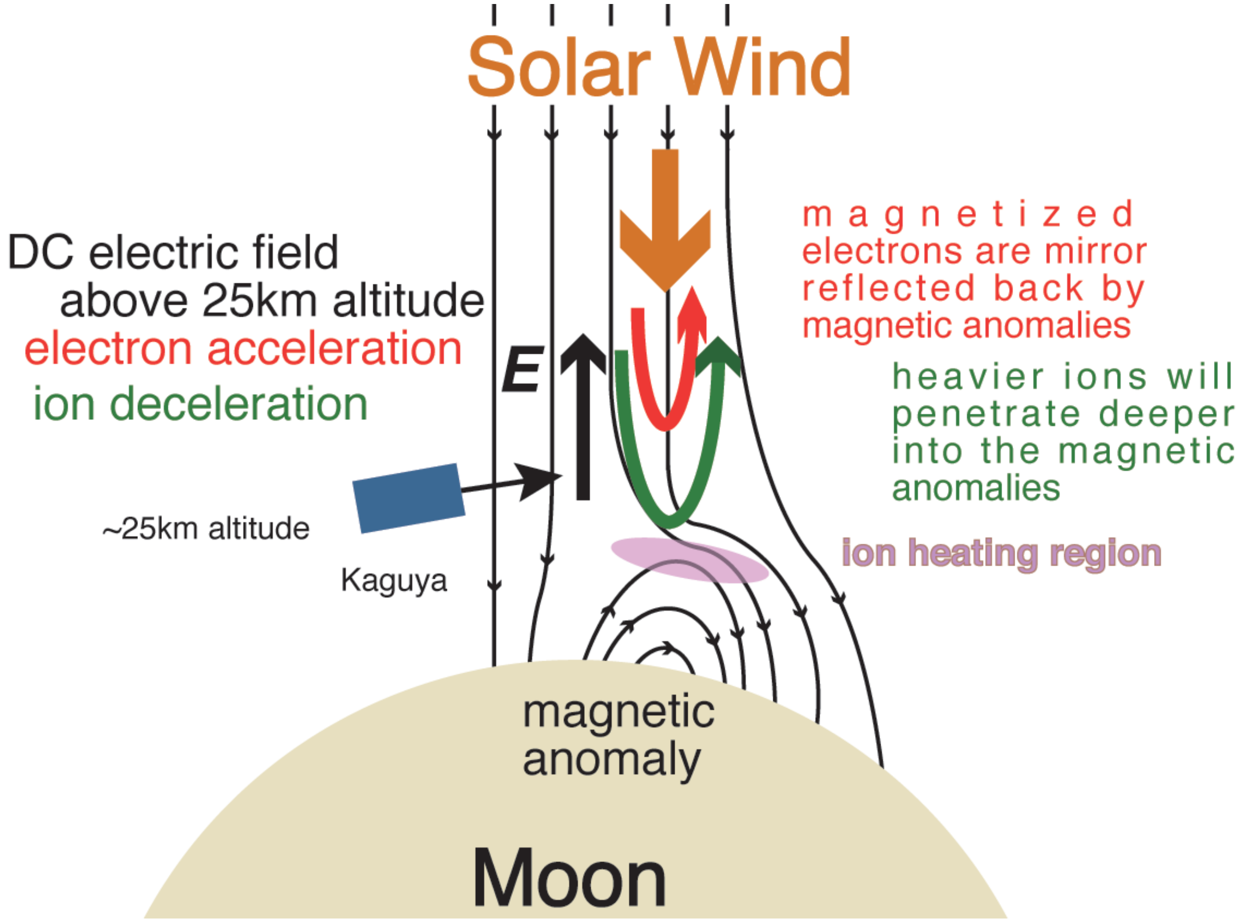
Summary of Data Quality In the South Polar Region (80°S to Pole)

Implication: We still need more polar orbital magnetometer data to produce the best possible crustal field maps.

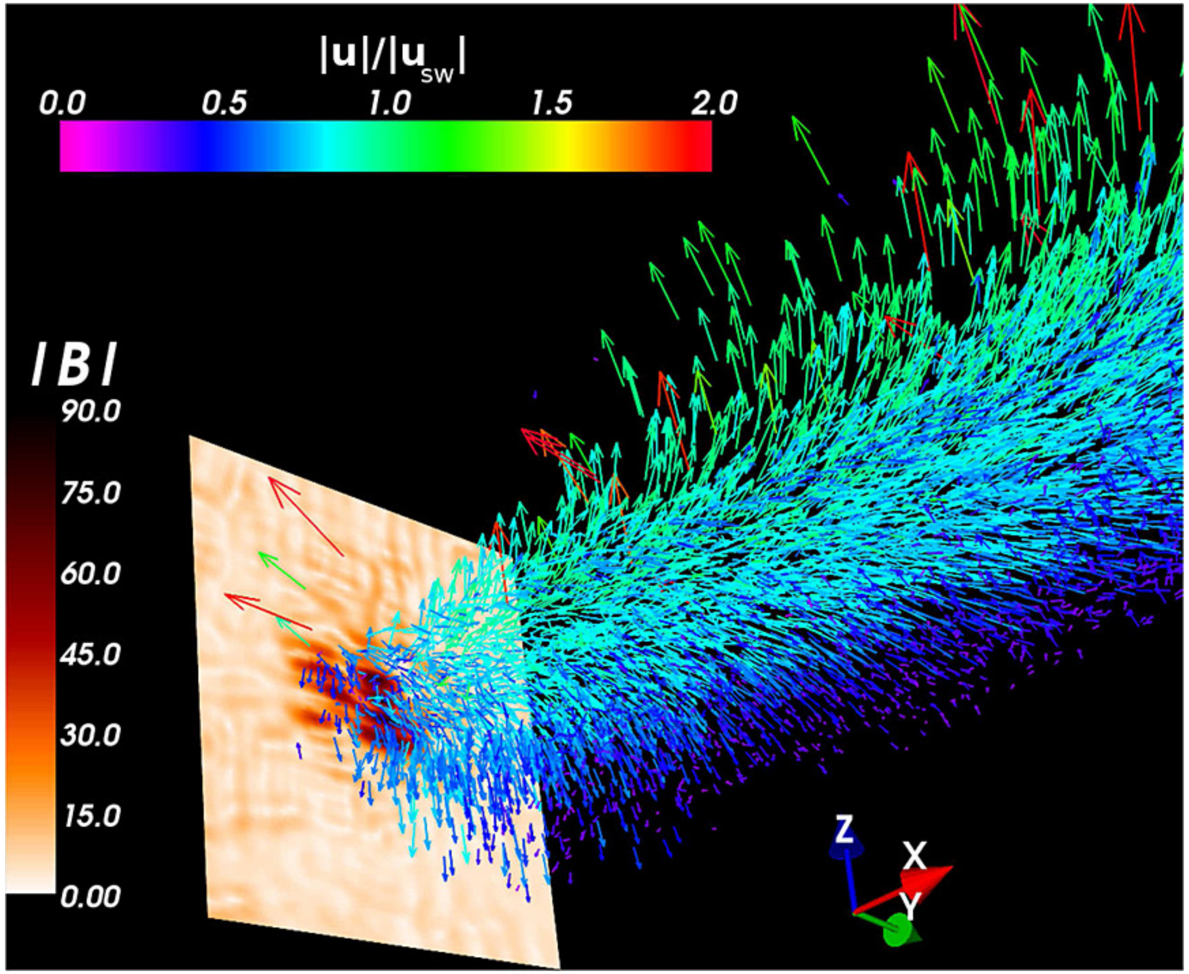
We need a horizontal resolution on the final maps that is comparable to the altitude (30 km or less).



Low Altitude Microphysics

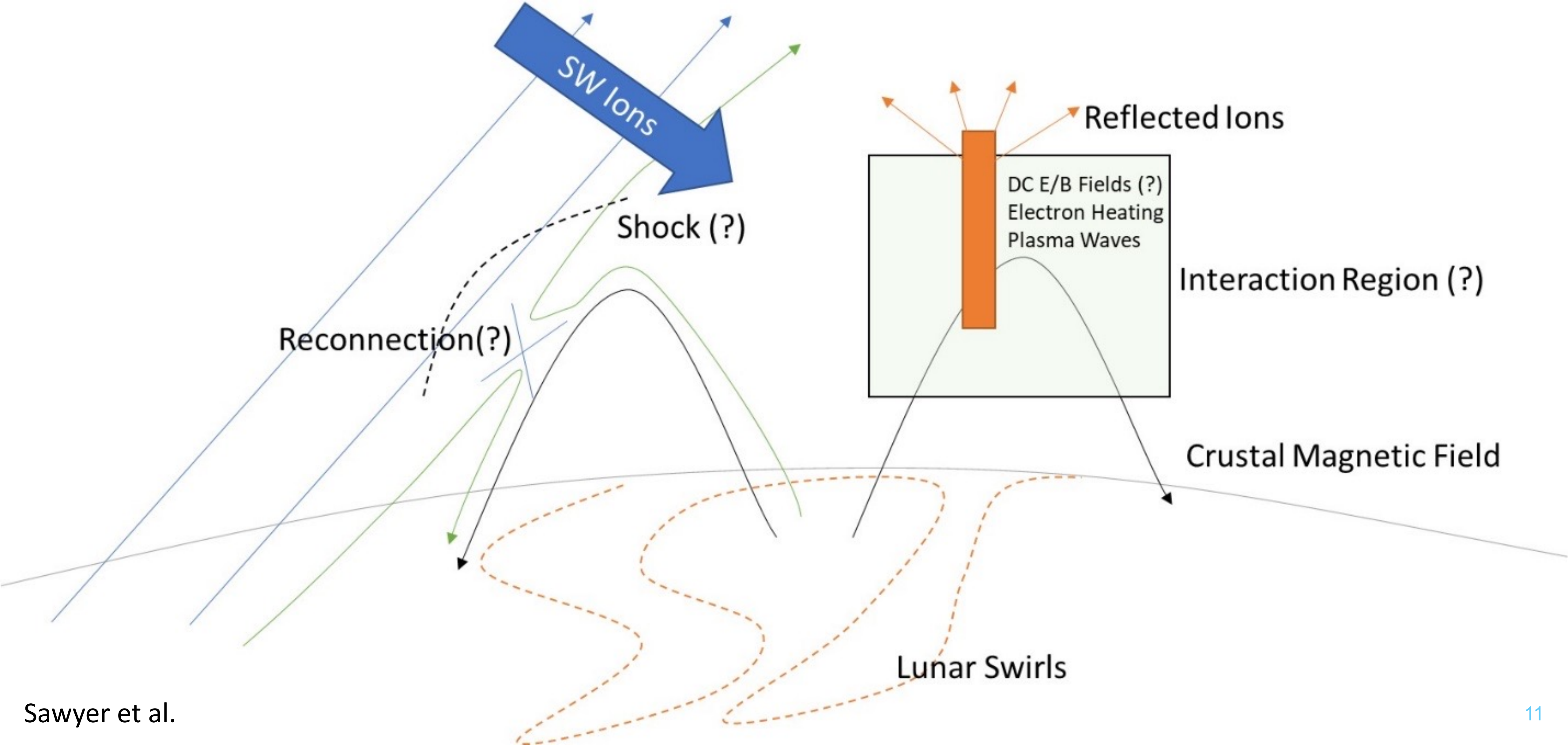


[Saito et al., 2012]



[Fatemi et al, 2015] (and many others)

Swirl Features



Sawyer et al.

Swirl Features: Reflected Ion Beam

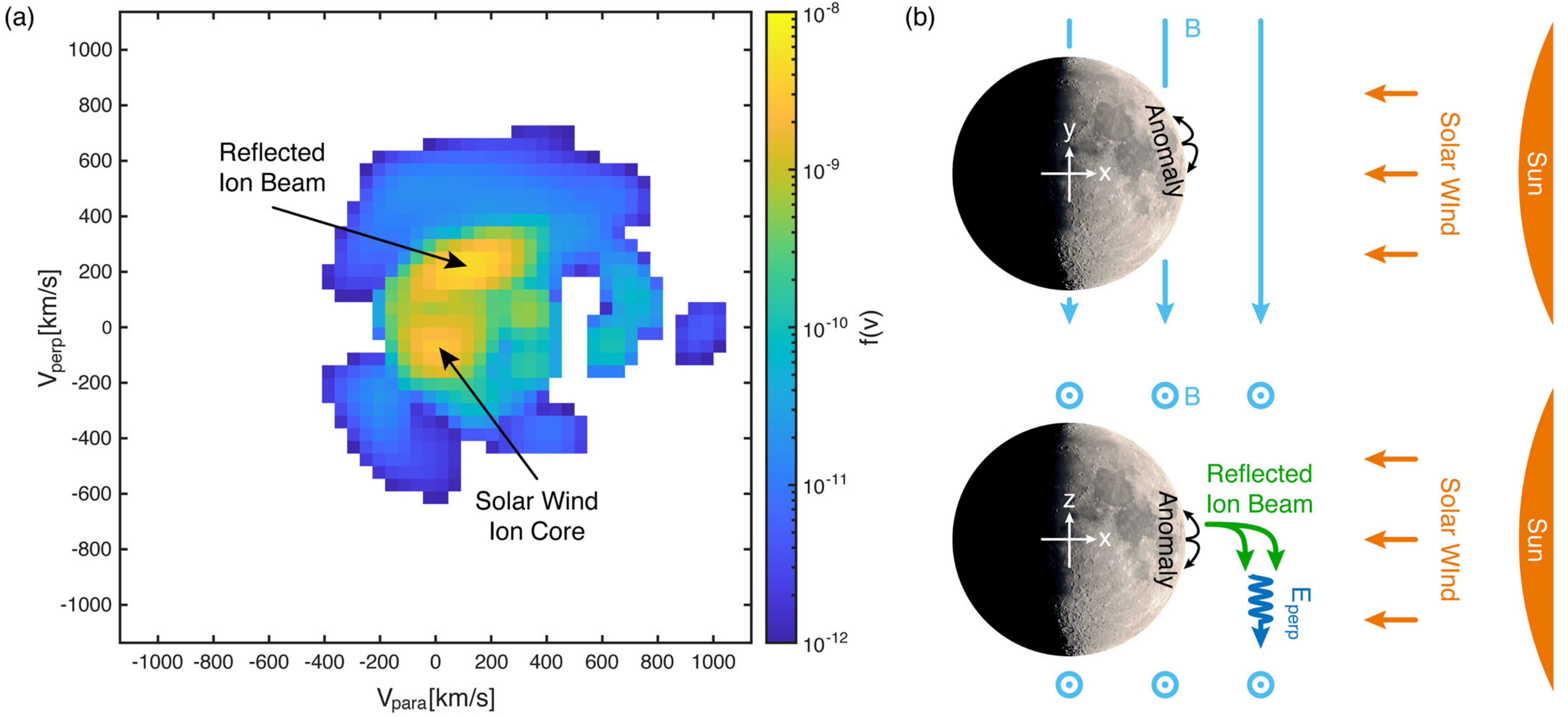
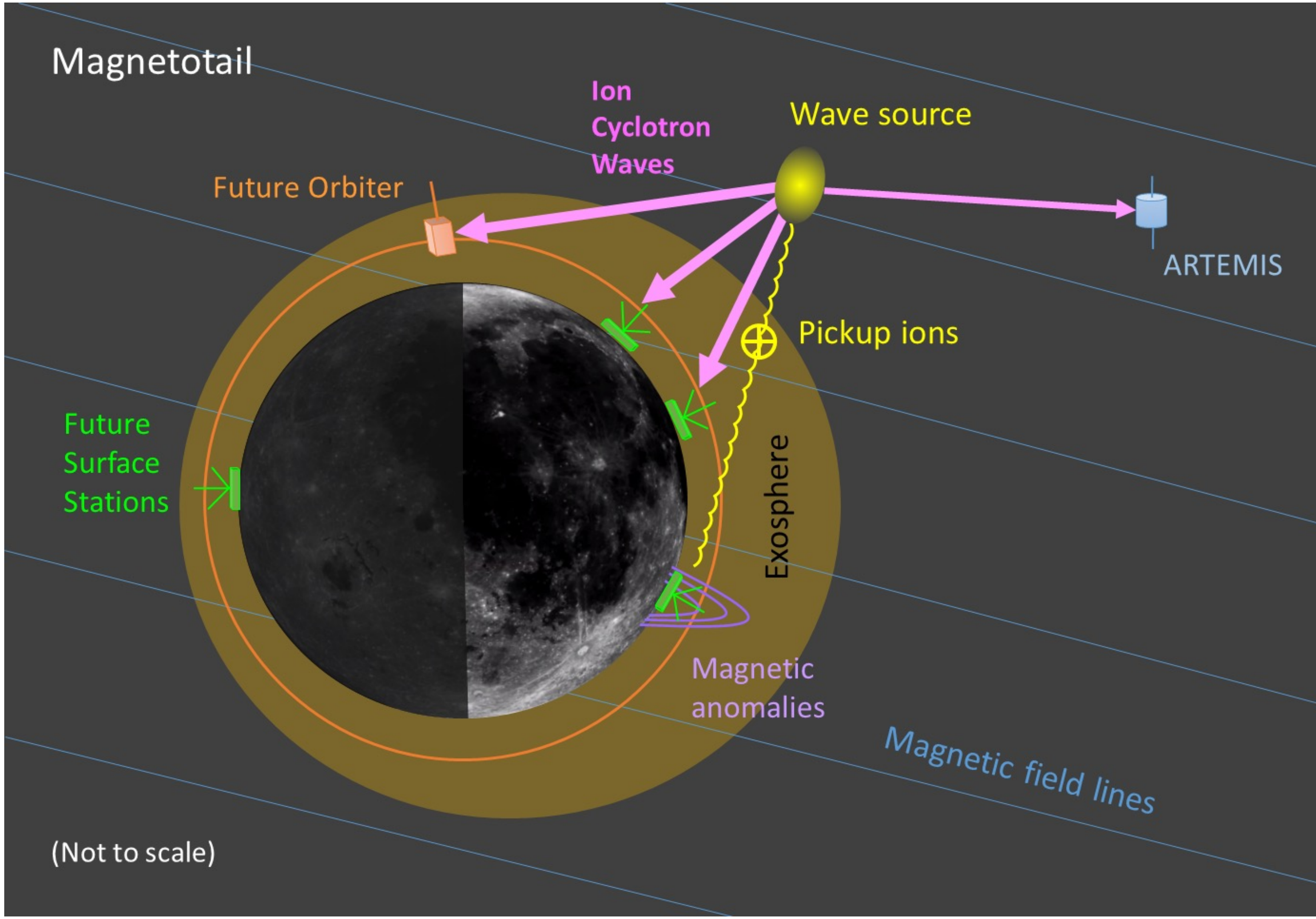


Image Credit: Chu et al. 2021, JGR Space Physics

SelenITA will make new observations to resolve outstanding questions regarding Ion Cyclotron Waves

- Q: Are ICWs truly present more frequently on the lunar surface? If so, why?
- Q: Where is the source location of ICWs? What does it tell us about wave generation?
- Q: Are ICWs generated by pickup ions from the Moon? If so, what does it tell us about the lunar exosphere?
- Key measurement: Magnetic field on the surface and in orbit
- Key measurement: Low-energy ions in orbit



Dust

Why is measuring dust near permanent shadowed regions (PSR) important?

- Impact bombardment is one of the few processes involved in the evolution of volatiles at the lunar polar regions including PSRs yet are not constrained by current observations of the Moon.
- Future observations are needed to understand the evolution of volatiles (like water) in the polar regions.

Dust

What is the primary purpose of measuring dust as a part of the SelenITA mission?

- To determine the latitudinal dependence on the distribution of dust near the lunar surface.
  - This measurement is important because dust at orbit altitudes is a risk factor for satellites.
  - To understand how the latitudinal dust distribution is related to meteoroid impact patterns.
  - To characterize contributions from CLPS and Artemis landers.

Dust

Mechanism of signal formation:

Pulse formation phases

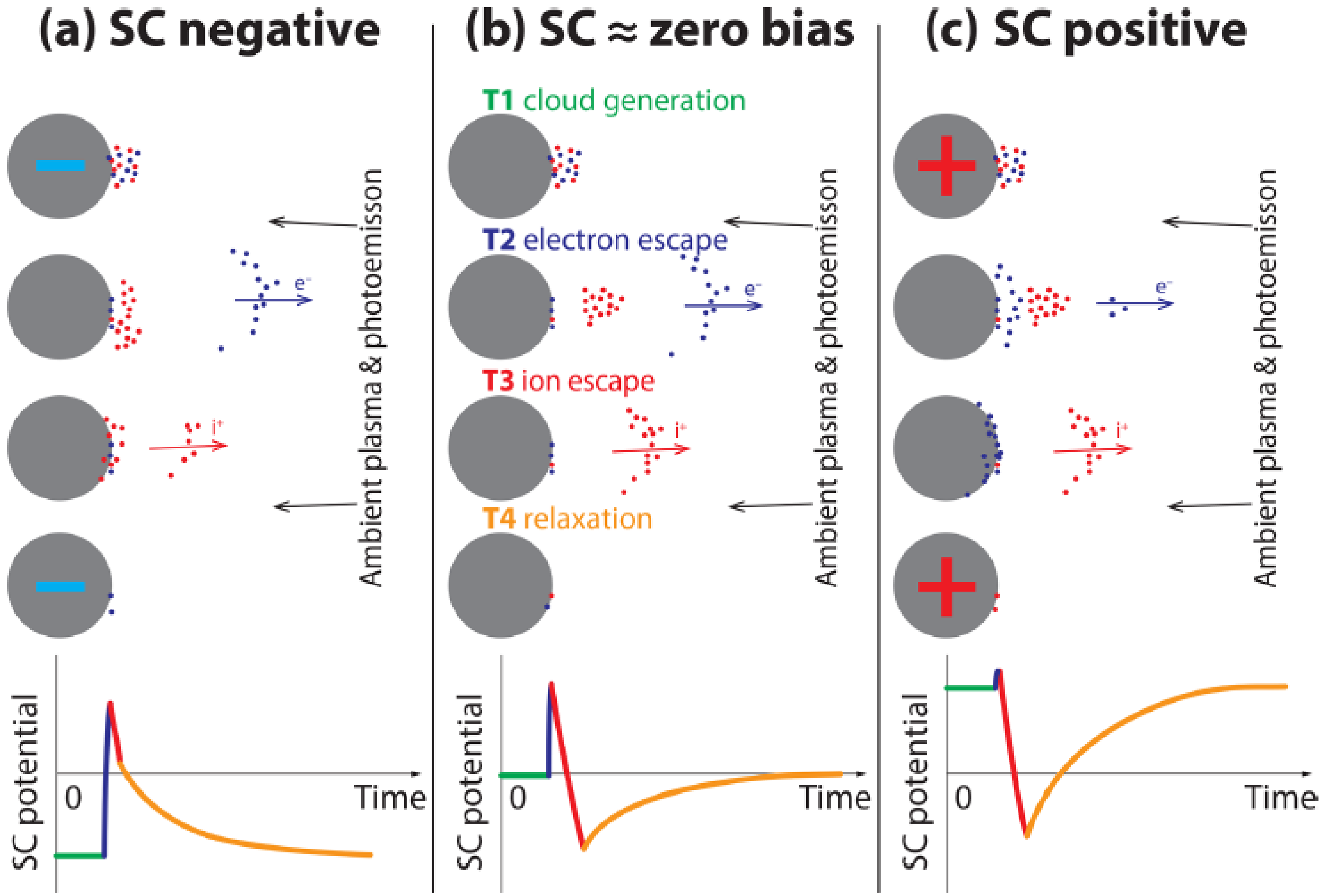
T1 cloud generation

T2 electron escape

T3 ion escape

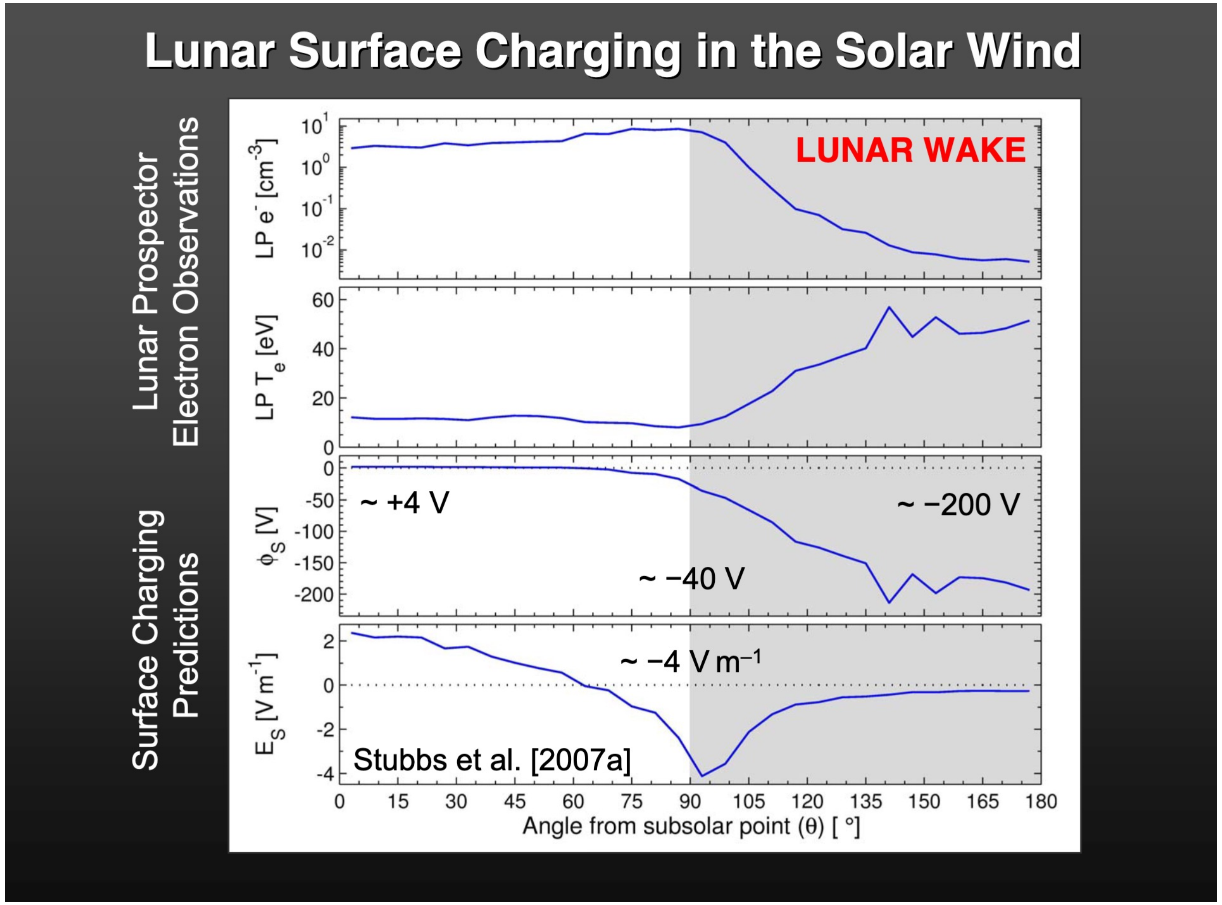
T4 relaxation

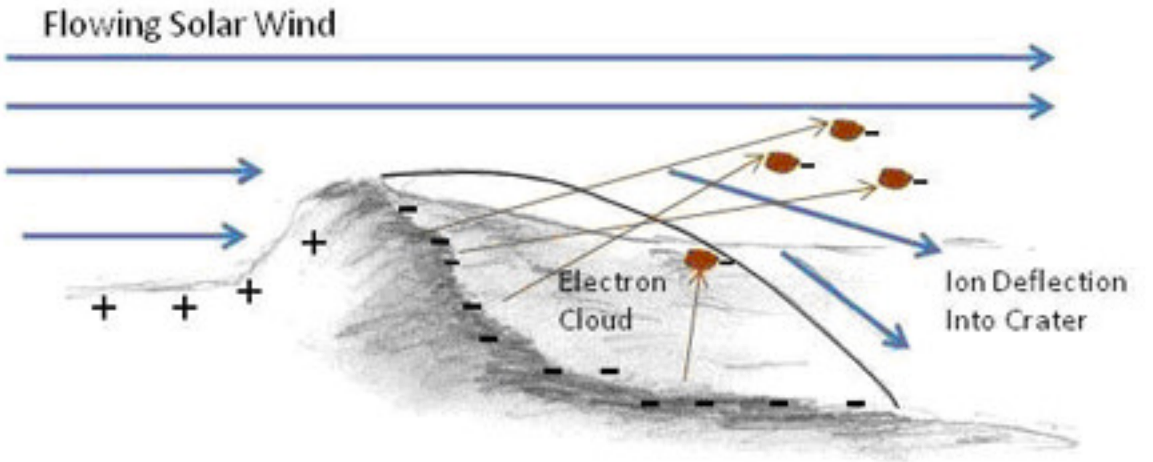
Relaxation time, τ, V ~ exp(-t/ τ), typically 100 µs up to several milliseconds

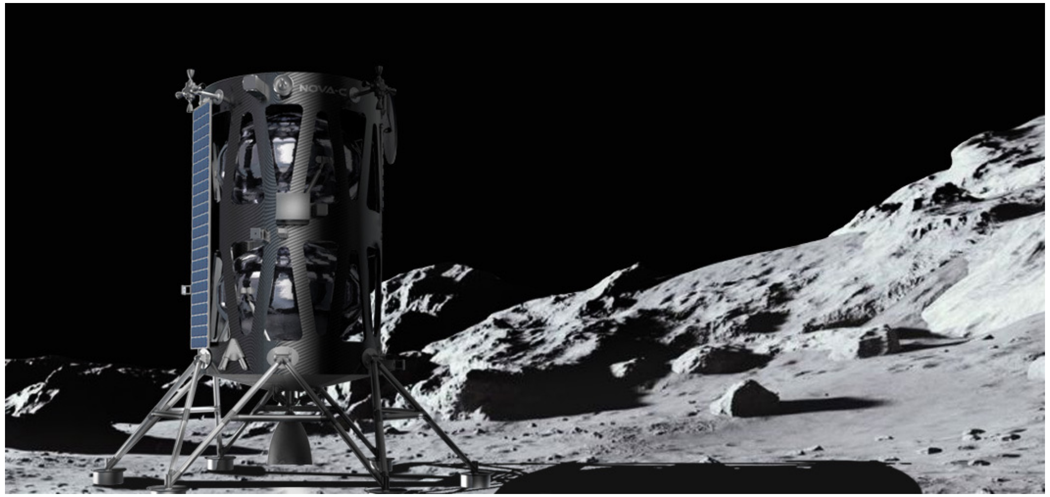


Mann, I *et al.* (2019) *Annales Geophysicae* (Vol. 37, No. 6, pp. 1121-1140)

Lunar Surface Charging

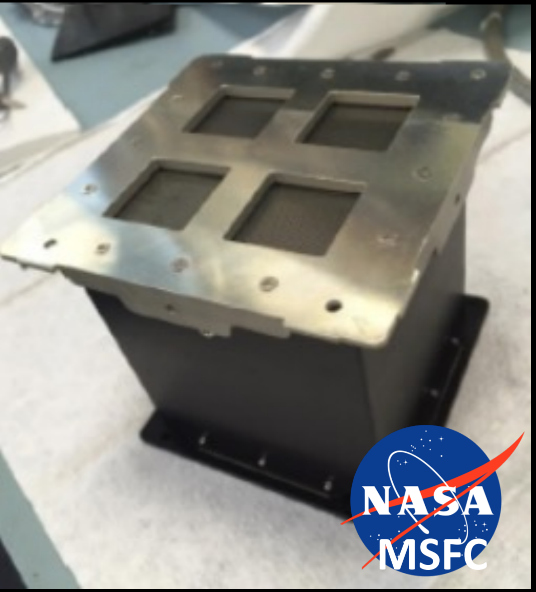




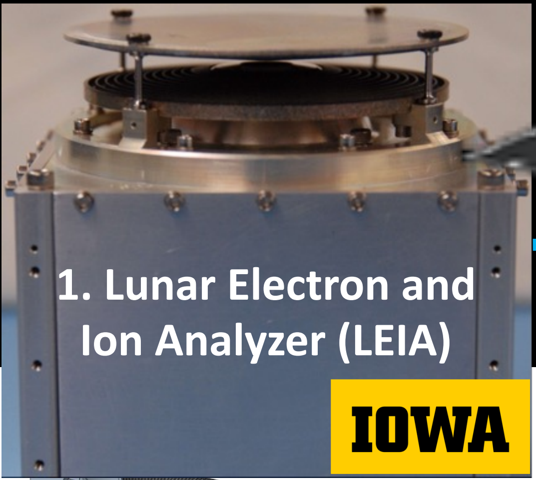


Graphic of how the solar wind flows over the Moon. Credit: NASA Lunar Science Institute. Graphic of lander by Intuitive Machines.

SelenITA Science Instruments

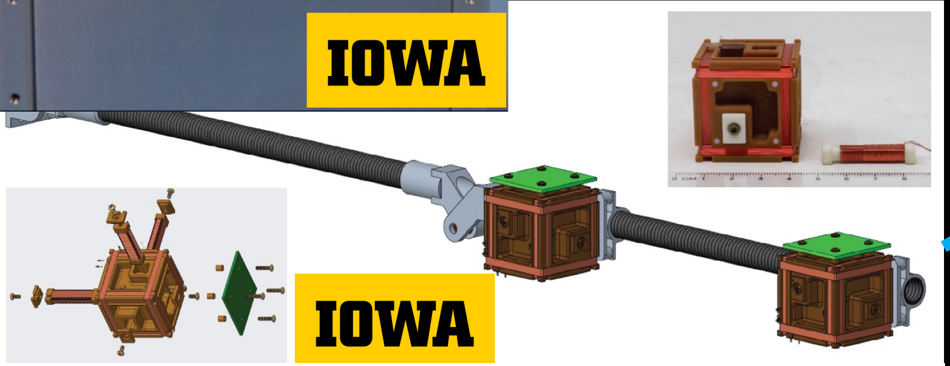


6. Charge Analyzer Responsive to Local Oscillations - Solar Wind (CARLO-SW)



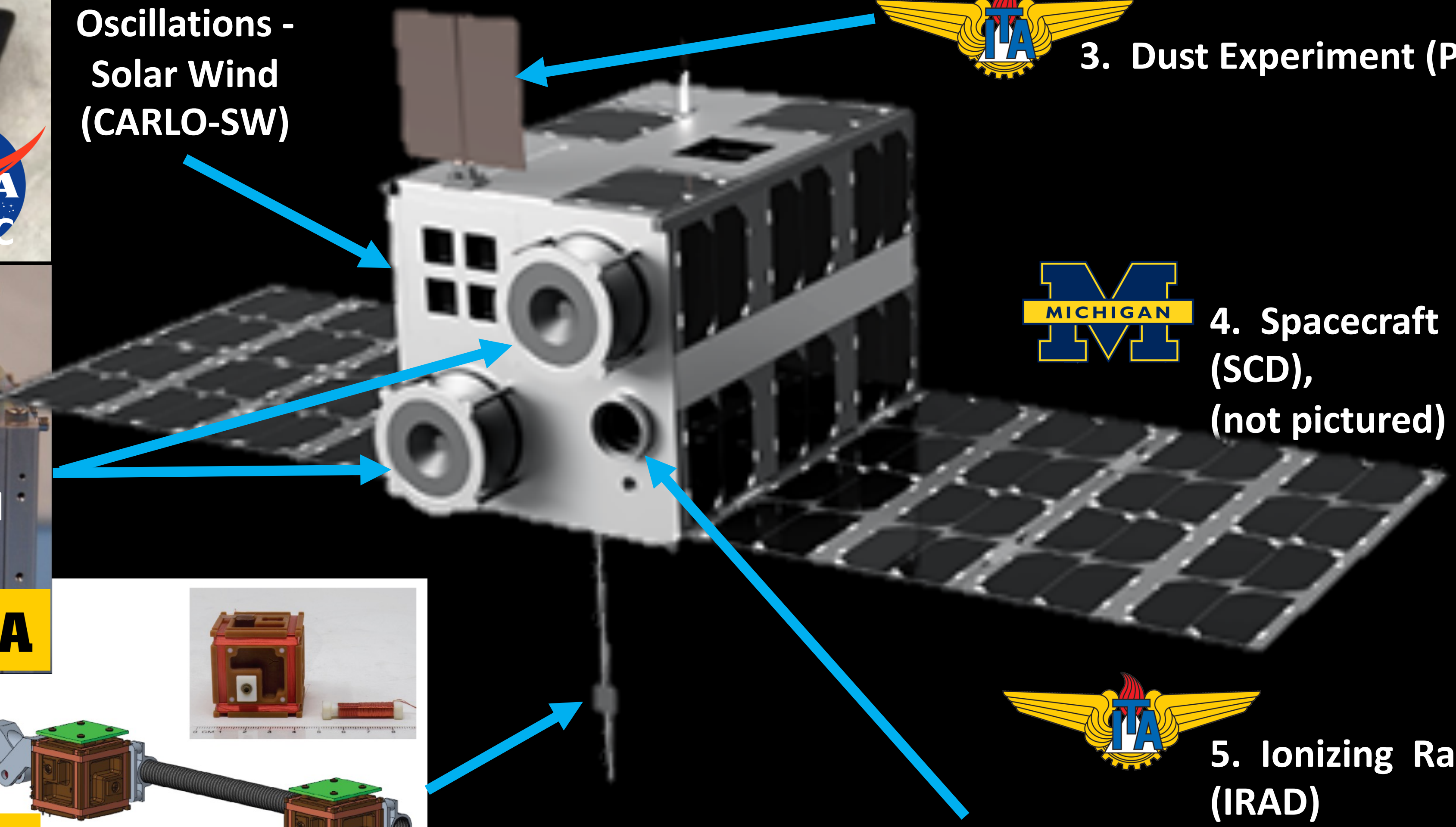
1. Lunar Electron and Ion Analyzer (LEIA)

IOWA



IOWA

2. Magnetometer & boom



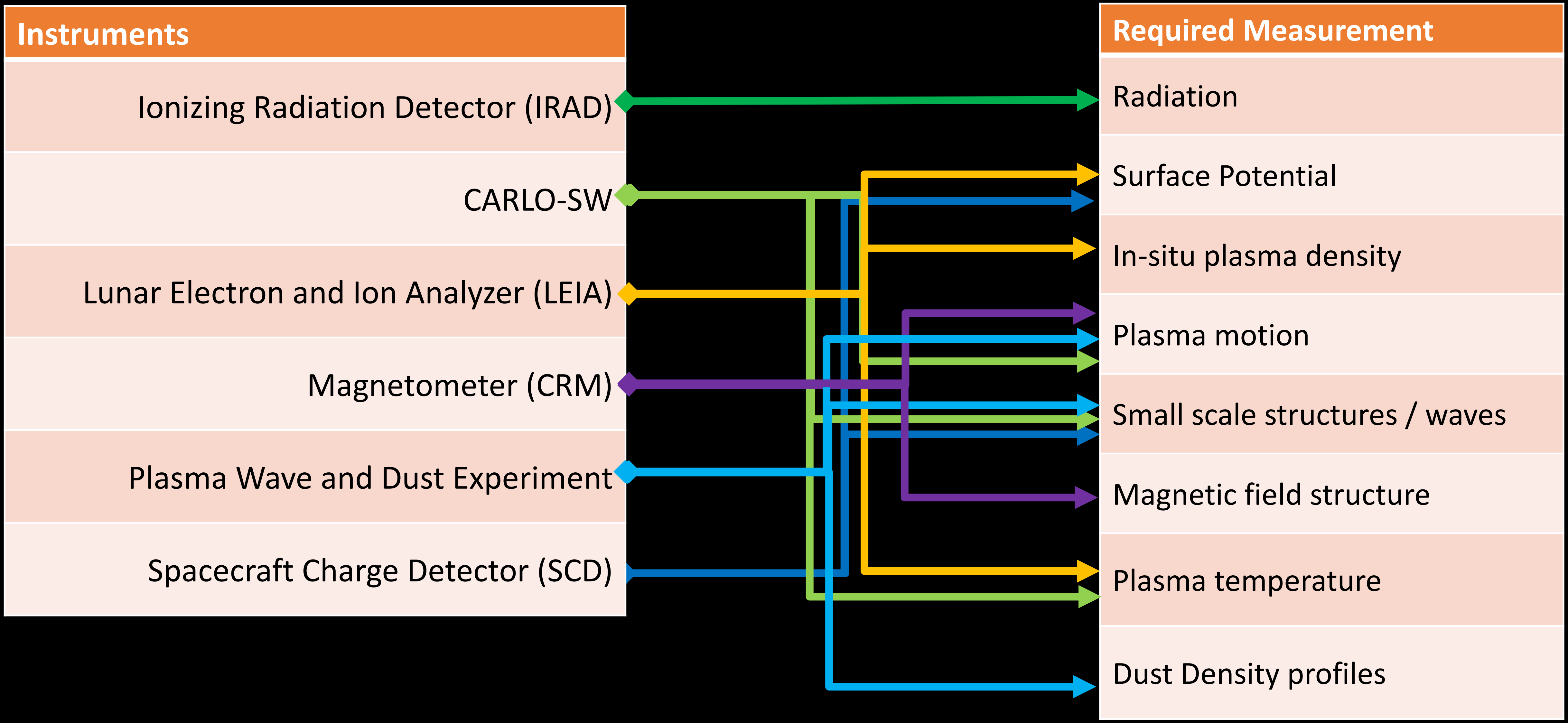
3. Dust Experiment (POWDER)

4. Spacecraft Charge Detector (SCD), (not pictured)

5. Ionizing Radiation Detector (IRAD) (not pictured)

7. Camera (EPO)

SelenITA Instrument Measurements



SelenITA Mission Summary

- SelenITA is an international interdisciplinary low-cost mission consisting of a 12U CubeSat with a surface package that will provide novel multi-point measurement of dust, particles and fields for the characterization of the electromagnetic space environment, in support of Artemis crew, and the geosciences.
- New observations of plasma, dust, and fields at lunar low altitudes is needed to advance current understanding of the near surface plasma environment including its interactions with crustal fields, crustal magnetic fields, and dust.
- Global maps of the lunar crustal magnetic field have been produced from available orbital data at 30 km altitude but are limited in resolution to ~50 or 60 km due to the need to interpolate across gaps in good orbit tracks.
- Large areas in the south polar region have poor coverage and would benefit from acquisition of future data at altitudes of 30 $\pm$ 15 km.
- Moderately strong anomalies are present near the south pole where more water ice and permanently shadowed regions (PSRs) have been mapped. These anomalies may be effective in preserving the water ice there by reducing the solar wind ion sputter-erosion rate in PSRs.

Questions?

Image Credit: NASA

SelenITA Team

- Heidi Haviland – NASA MSFC, PI
- Linda Krause – NASA MSFC DPI, instrument lead (CARLO)
- Mike Zimmerman – APL, plasma physics, modeling
- Jasper Halekas – Univ. of Iowa, plasma physics, instrument lead (LEIA)
- David Miles – Univ of Iowa, plasma physics, instrument lead (CRM)
- Charles Swenson – Utah State University
- Rhyan Sawyer – Univ of Iowa, post doc, plasma physics
- Yuki Harada -- Kyoto Univ., plasma physics, waves
- Shahab Fatemi – Univ. of Umea, physics, modeling
- Luis Loures – ITA PM
- Tiago Matos – ITA Sys Engineer
- Victoria Rodriguez – ITA ADC
- Marco Riditeni – ITA, plasma physics, instrument lead (PWDE)
- Jonas Sousasantos – UTD, plasma physics
- Omar Leon – Univ. of Michigan, plasma physics, instrument lead (SCD)
- Peter Chi – UCLA, plasma physics
- Lon Hood – Univ. of Arizona, crustal magnetism

SelenITA (SITA) Science Objectives map into the Artemis III SDT Objectives

- *SDT Objective 1: Understanding Planetary Processes*
  - SITA: Origins of crustal magnetic fields
  - SITA: Plasma interactions with crustal magnetic fields
  - SITA: Interior composition, state, and structure
- *SDT Objective 2: Understanding Volatiles Cycles*
  - SITA: Plasma interactions with crustal magnetic fields
  - SITA: Polar dust populations
- *SDT Objective 7: Investigating and Mitigating Exploration Risks to Humans*
  - SITA: Ionizing radiation environment hazardous to human and robotic systems
  - SITA: Polar dust populations