Lunar Exospheric Ions Observed by LADEE and ARTEMIS

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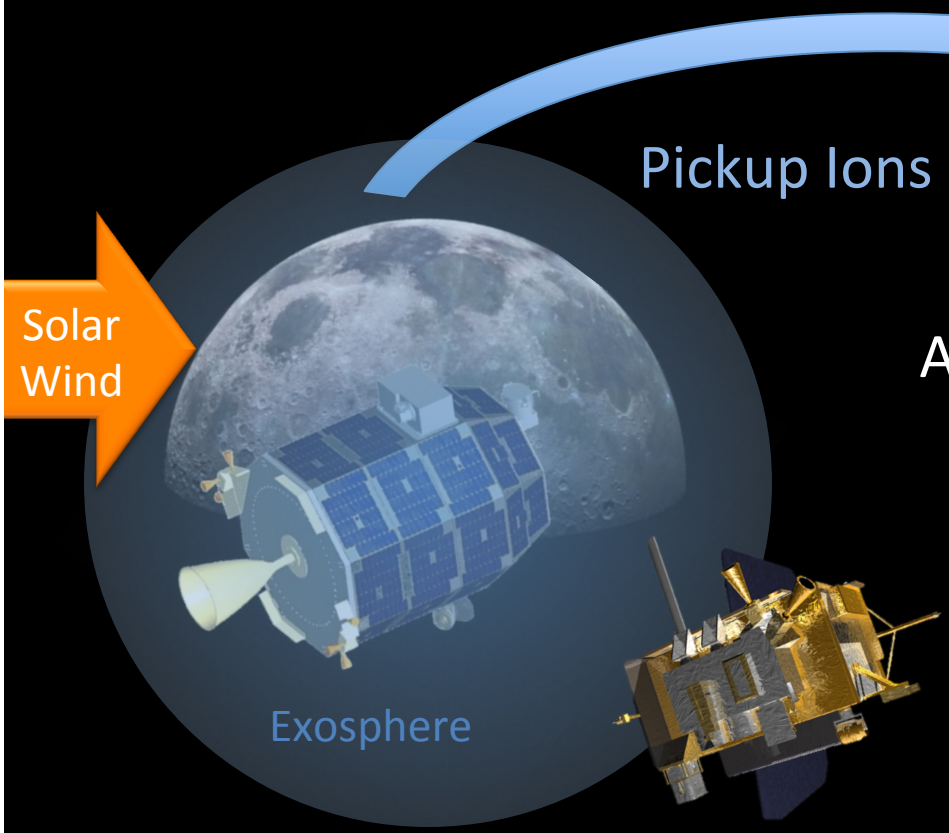
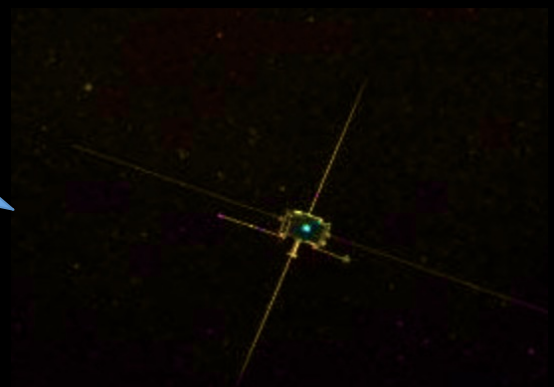
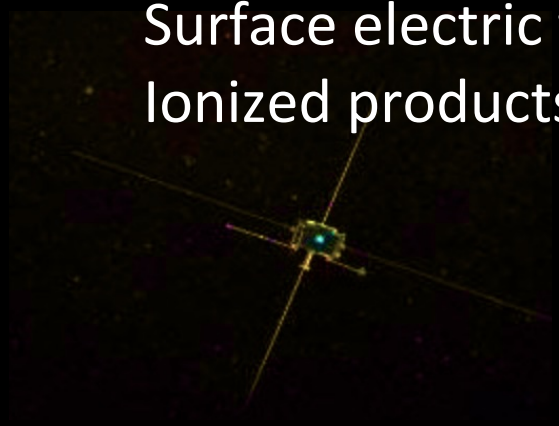
ARTEMIS, LADEE, and LRO: A Powerful Team to Study the Lunar Environment!



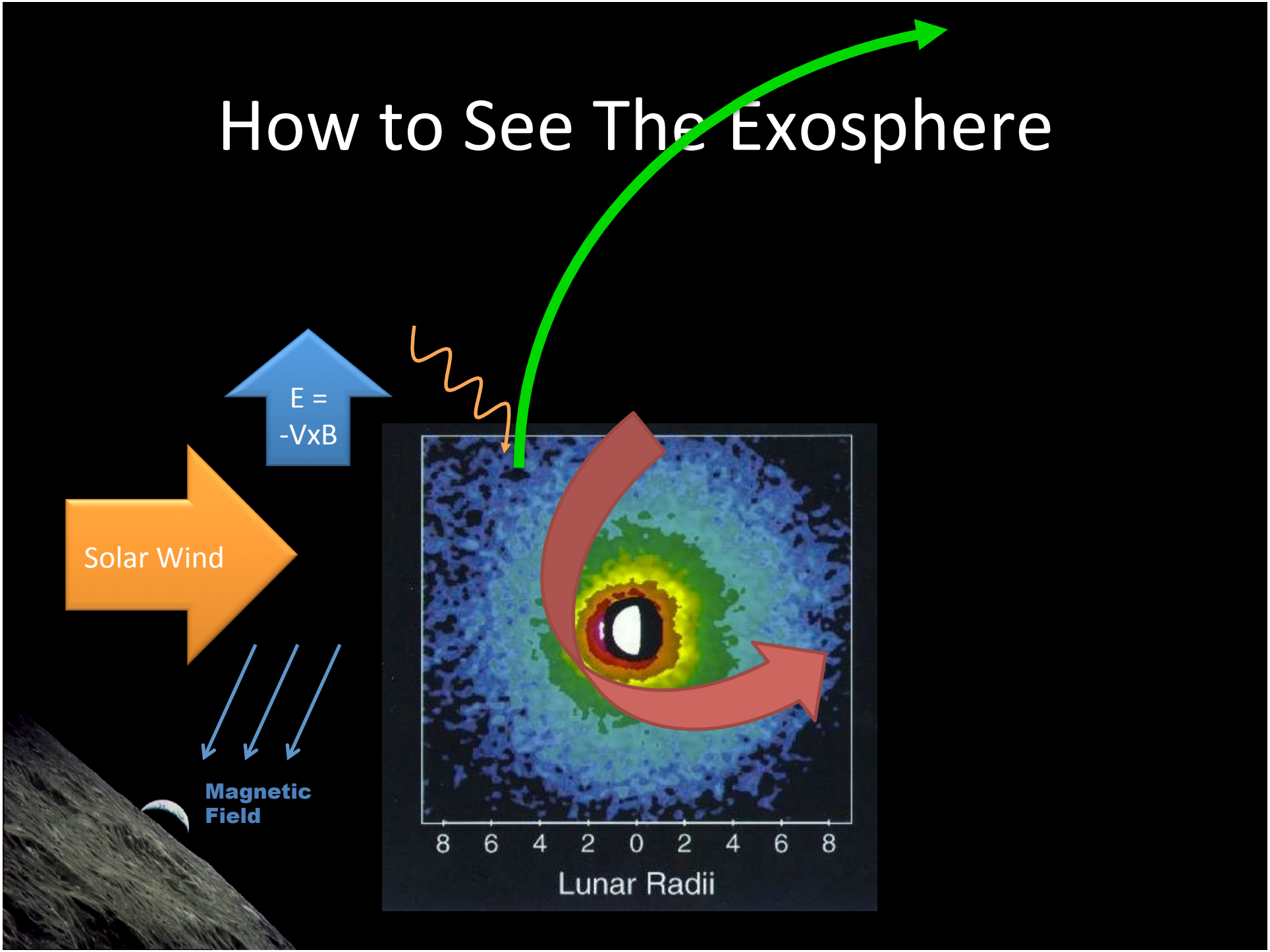


ARTEMIS: Solar wind inputs
Surface electric fields
Ionized products

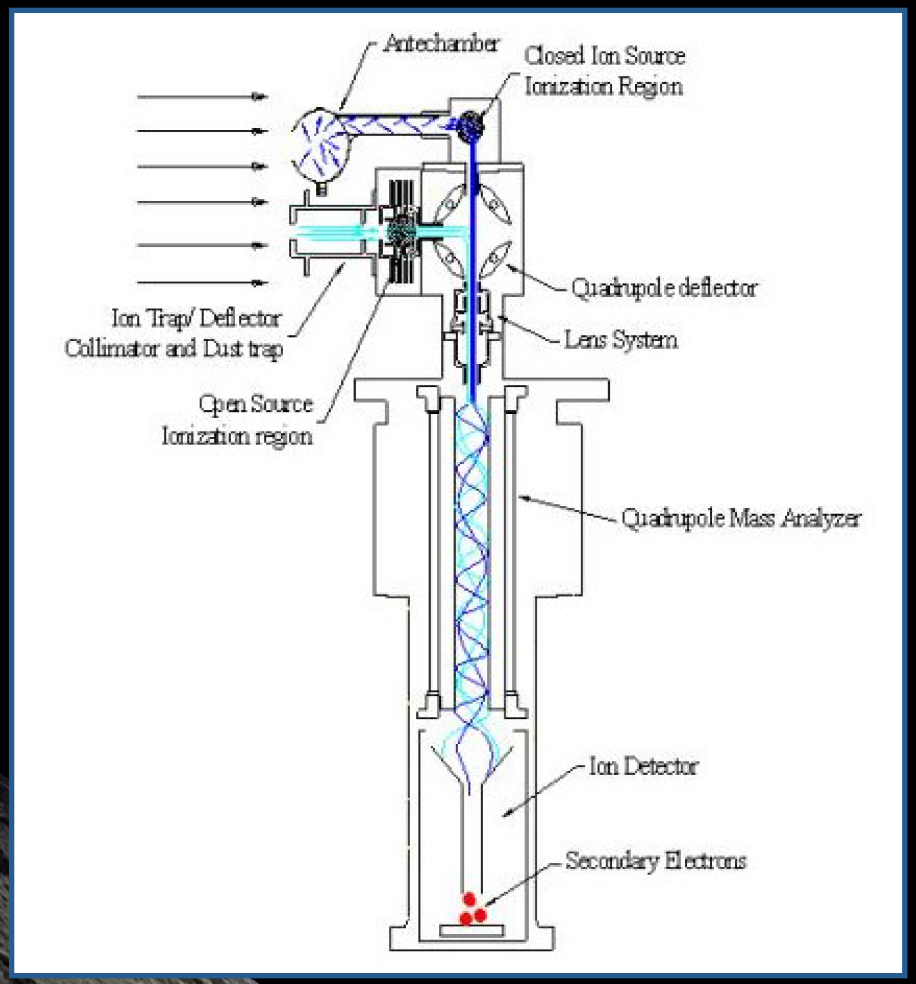


LADEE & LRO: Direct and spectroscopic observations of neutral species and dust

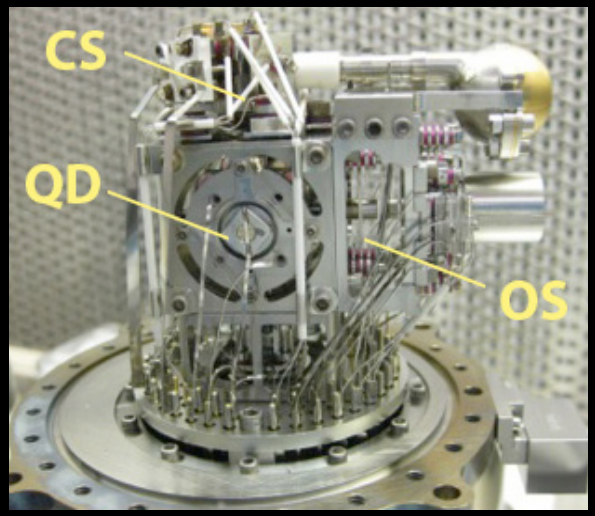
How to See The Exosphere



LADEE NMS Ion Mode Measurements

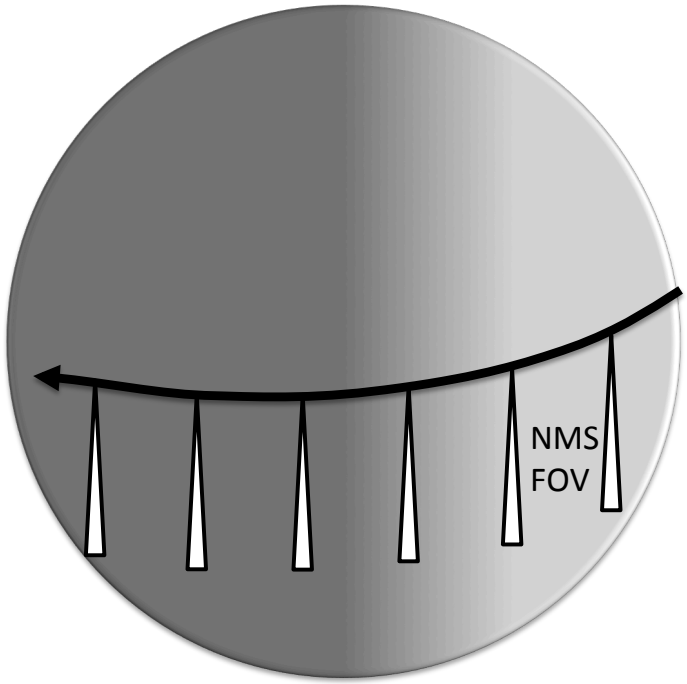


With ionization filament off, NMS measures ions ~<25 eV w/ narrow ~5° FOV



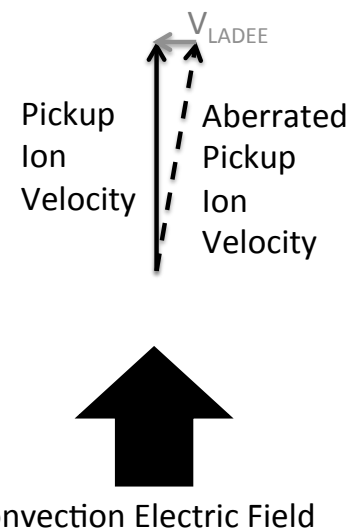
Mahaffy et al., 2014

NMS Ion Observation Strategy

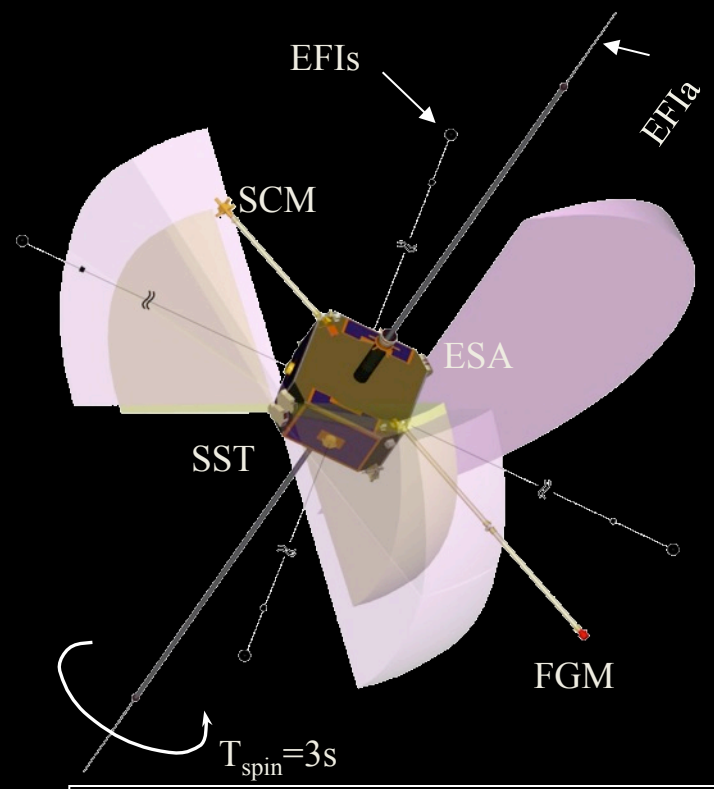


LADEE Orbit:
Retrograde
Near-Equatorial

Ion Mode Field-Of-View:
Southward out of Ecliptic



ARTEMIS (x2!)



Probe instruments:

ESA: ElectroStatic Analyzer
-Ions, Electrons ~3eV-30 keV

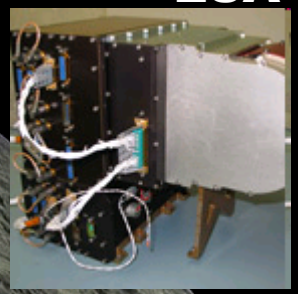
SST: Solid State Telescopes
-Ions, Electrons > 25 keV

FGM: FluxGate Mag.
-3-axis B measurements, 0.1 nT sens.

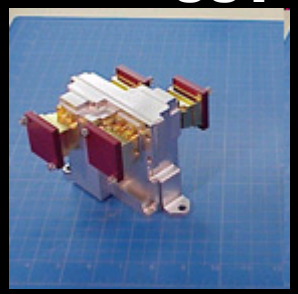
SCM: SearchCoil Mag.
-B at frequencies 10Hz-4kHz

EFI: Electric Field Instrument
-3-axis E fields: DC – 8kHz

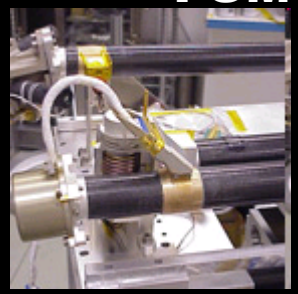
ESA



SST

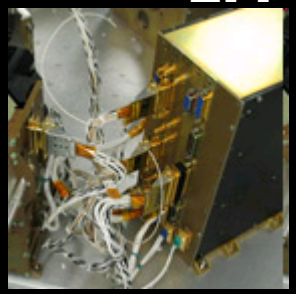


FGM

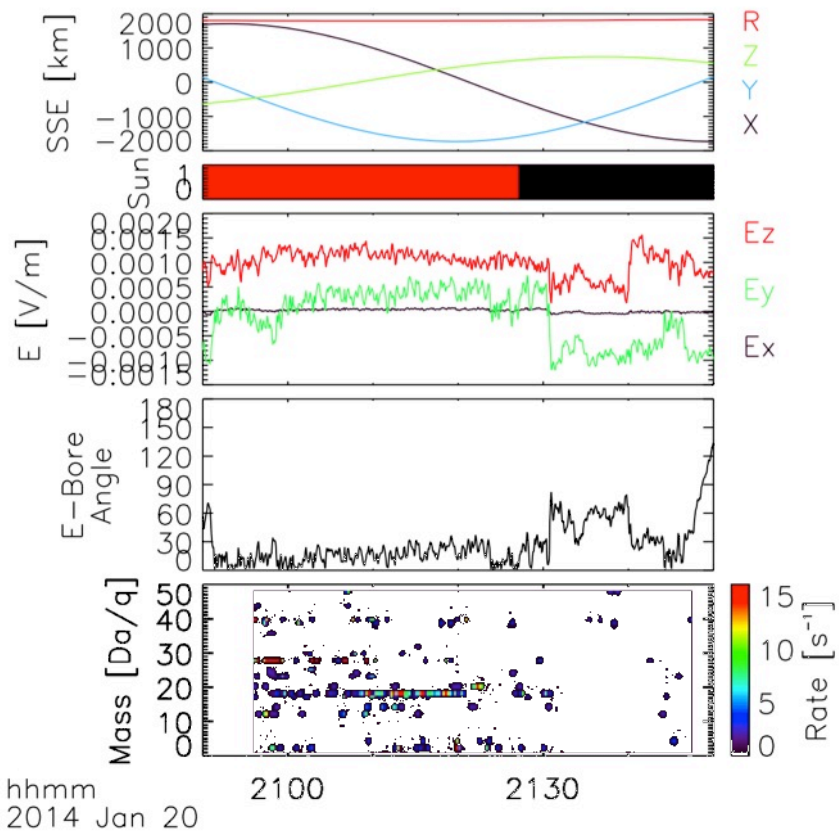


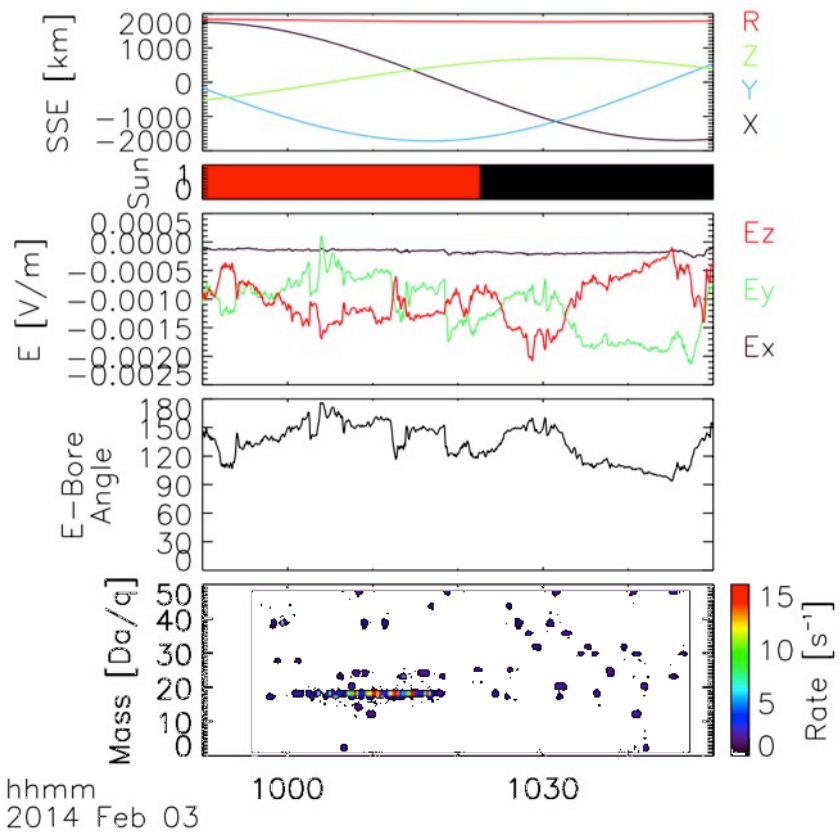
SCM

EFI

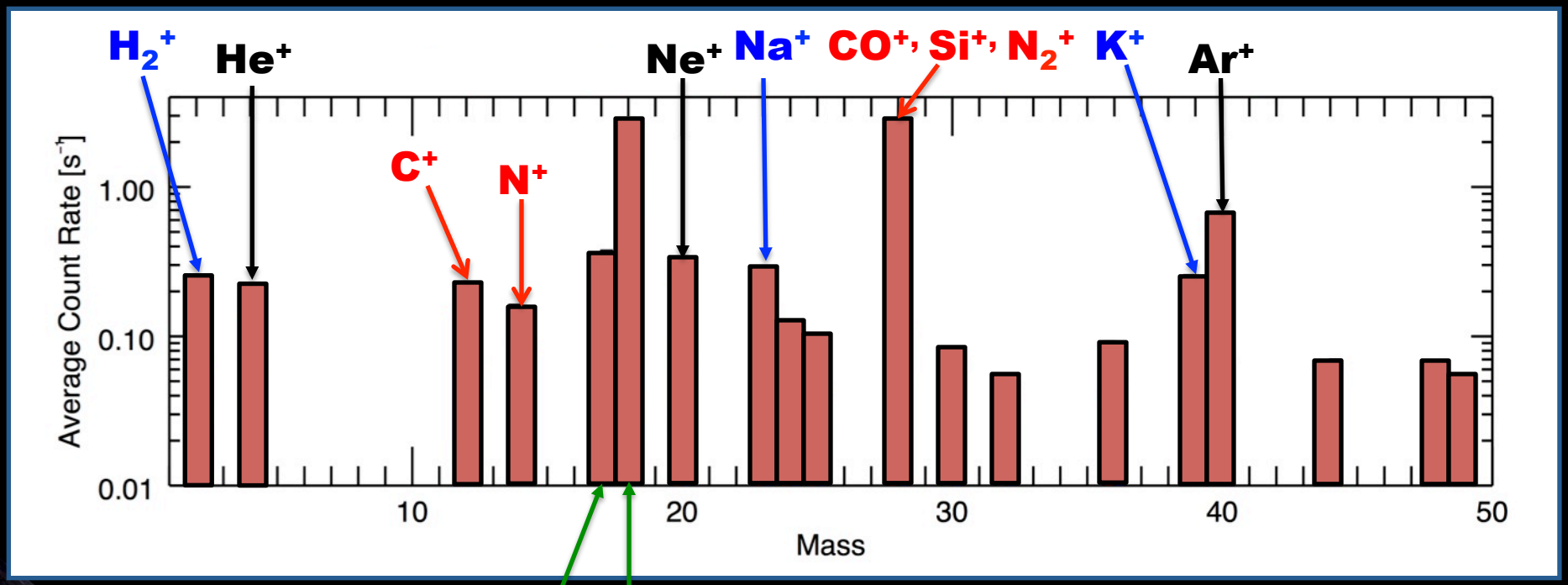


NMS Ion Scans





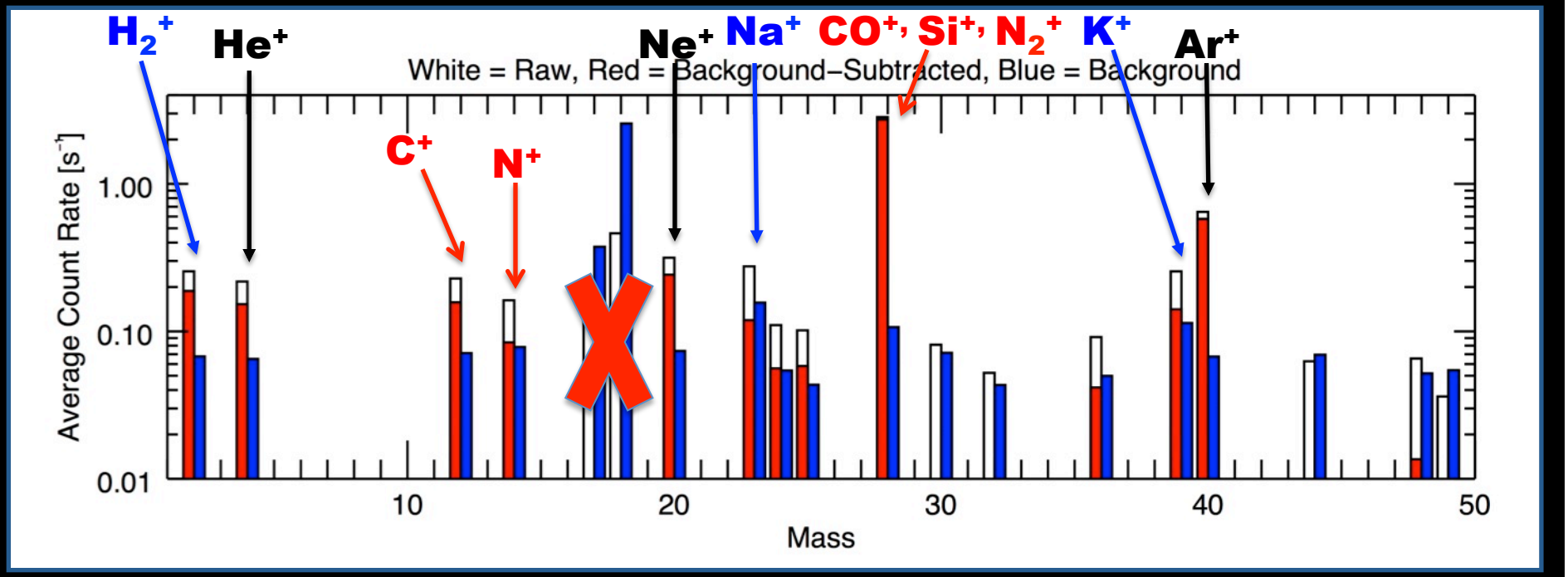
NMS Measurements

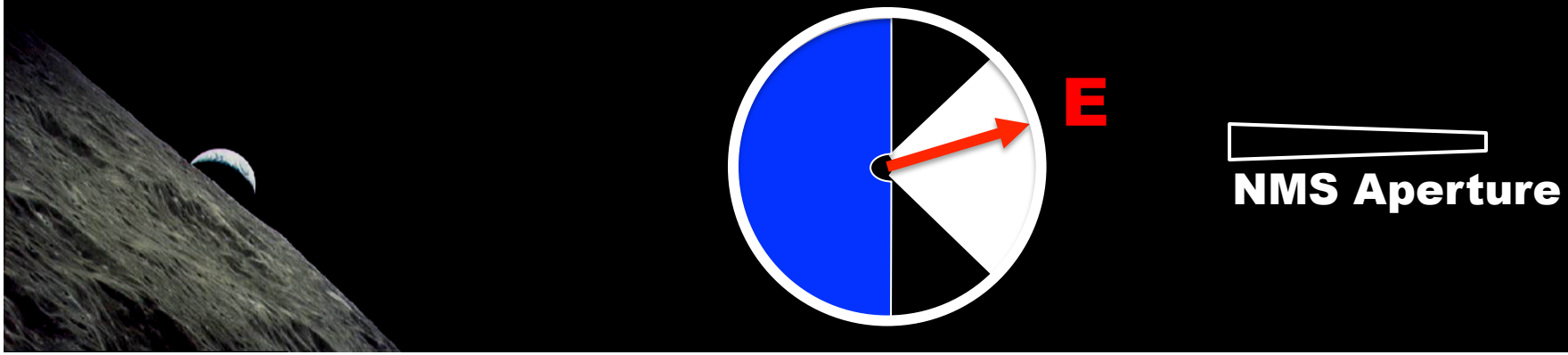


OH^+

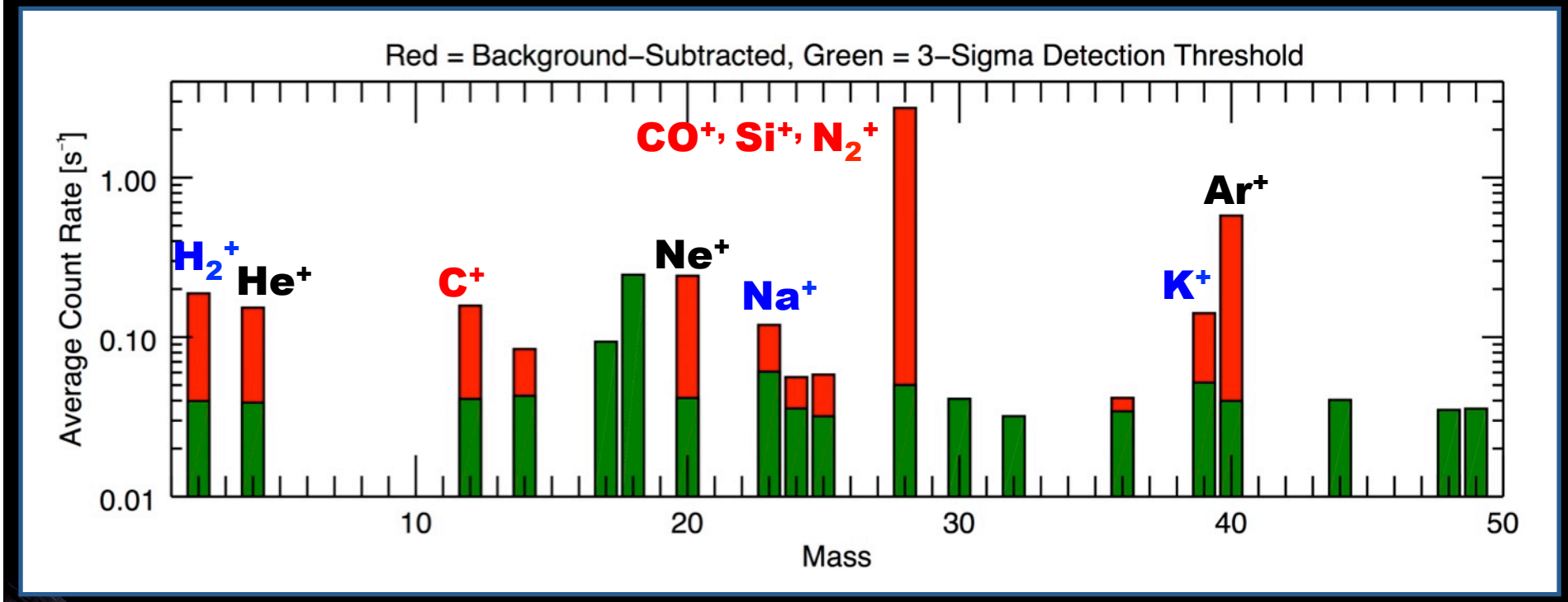
H_2O^+

NMS Measurements Organized

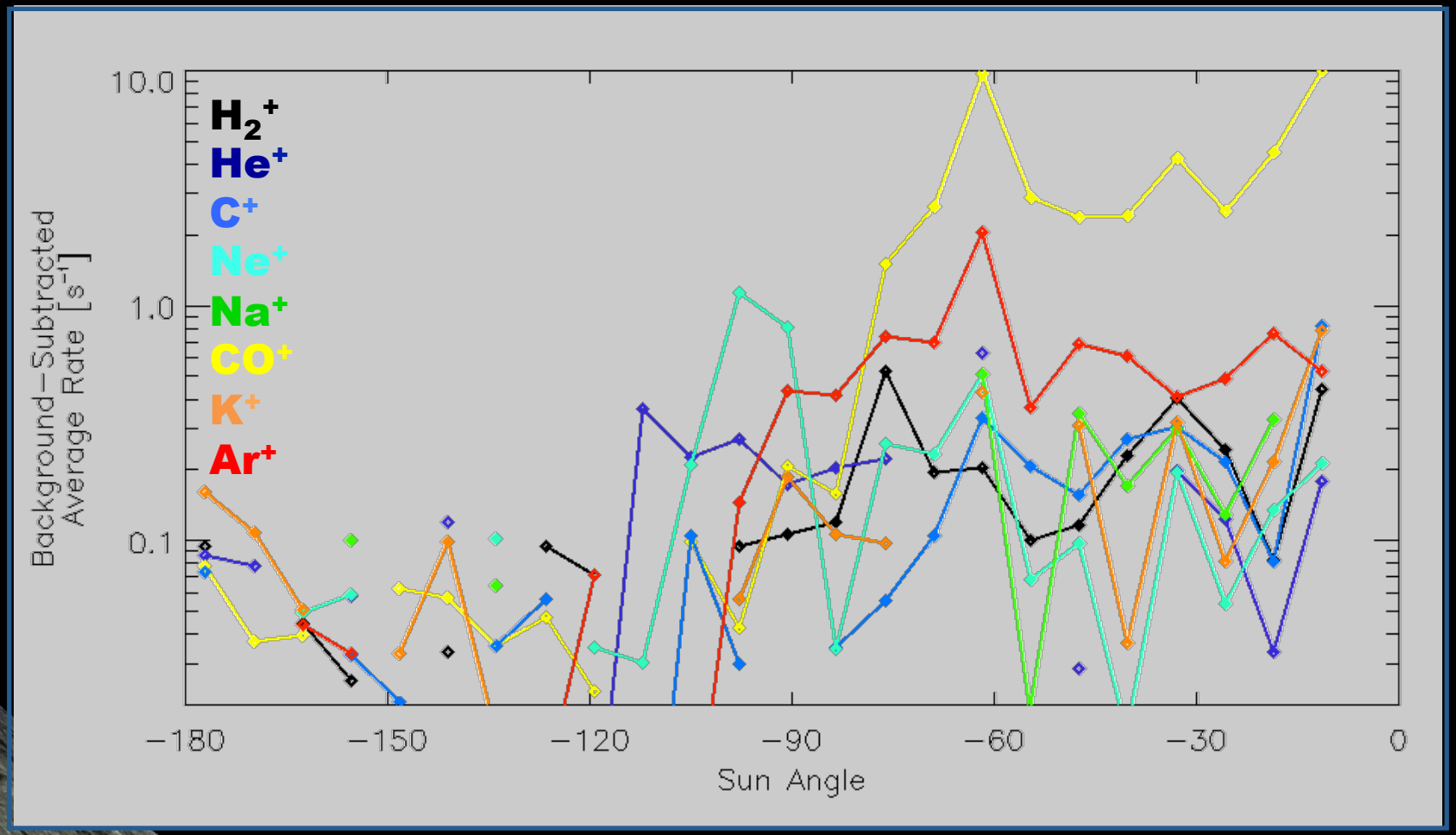




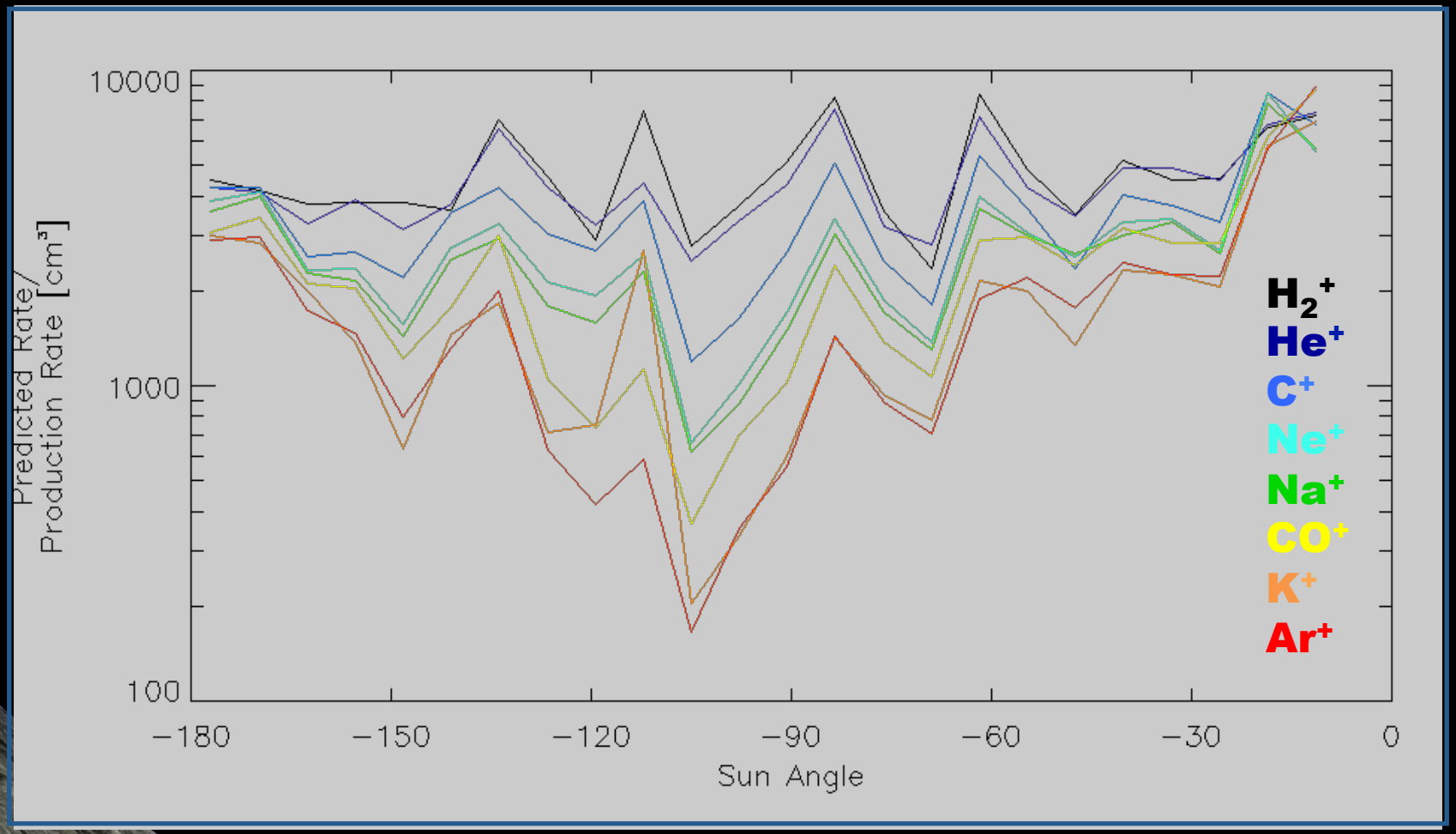
NMS Detections



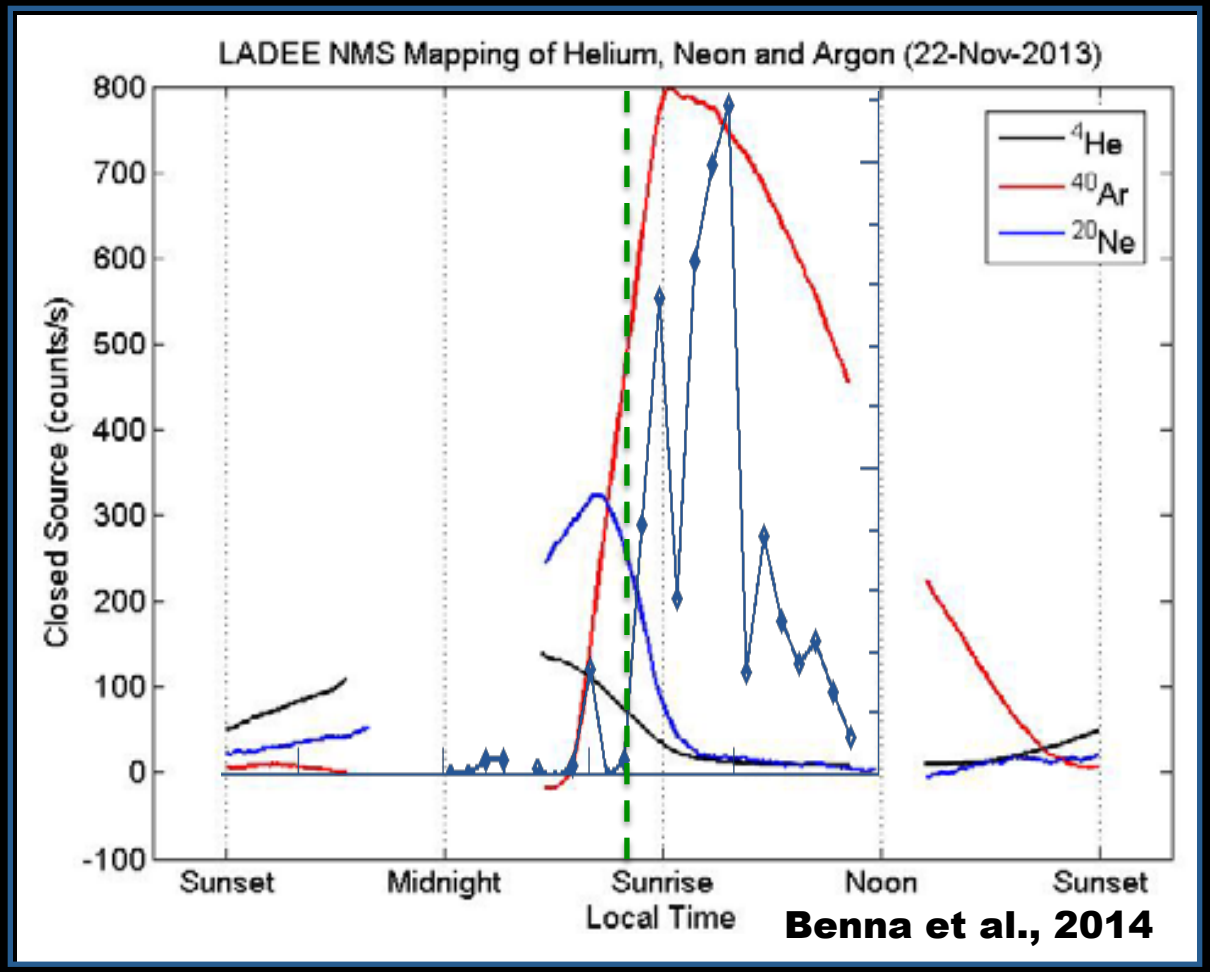
Local Time Dependence



Predicted Sensitivity

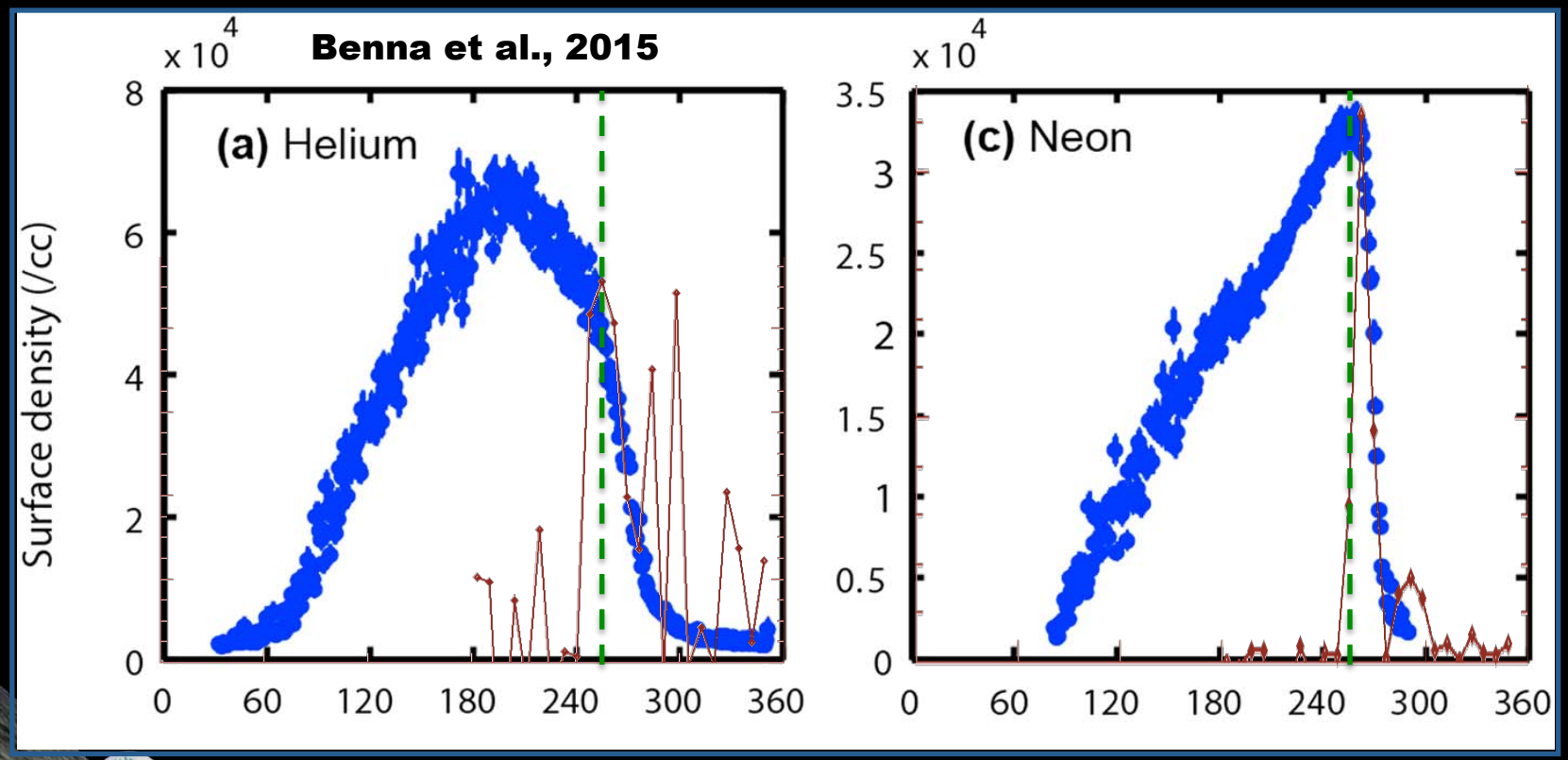


Noble Gases

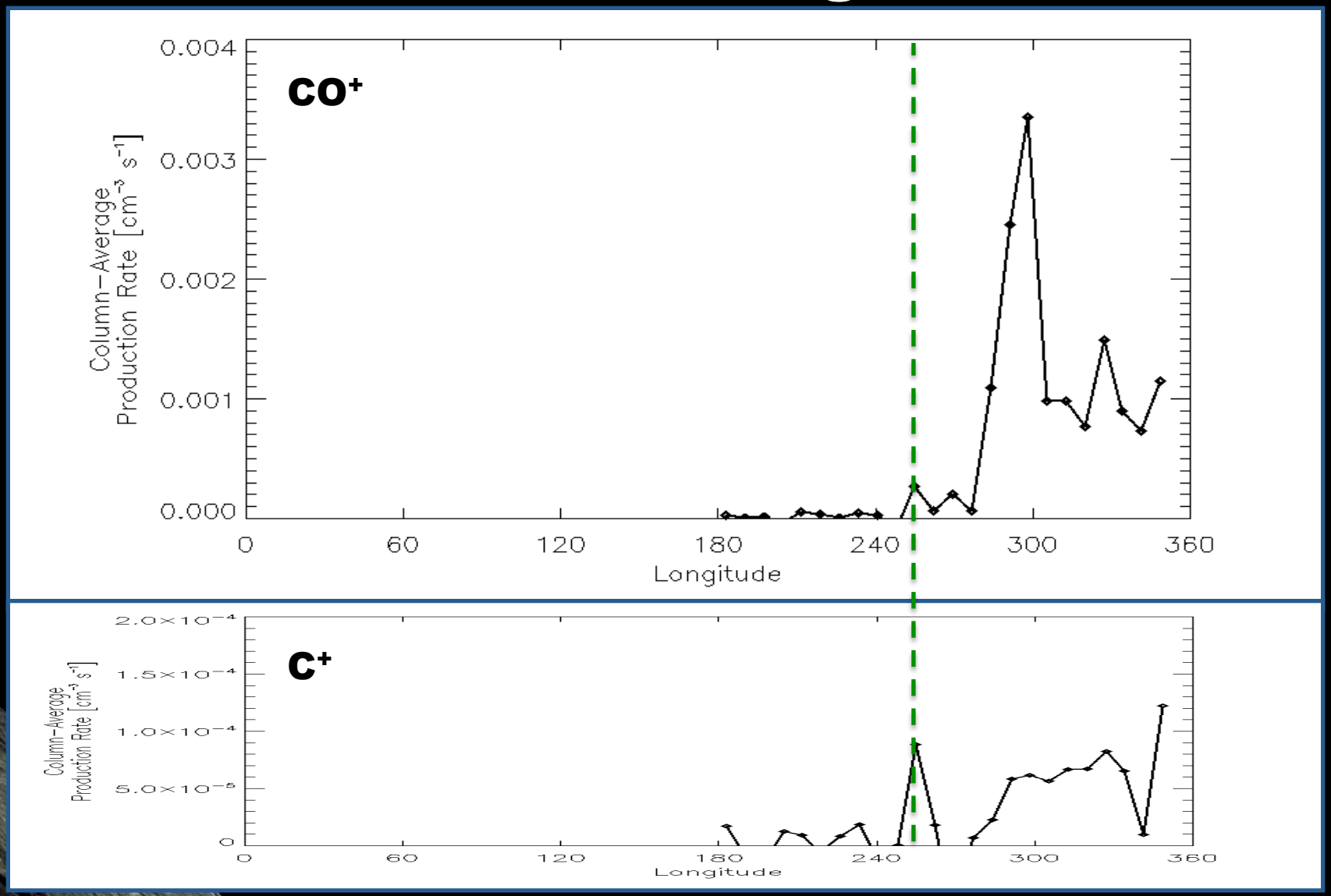


Benna et al., 2014

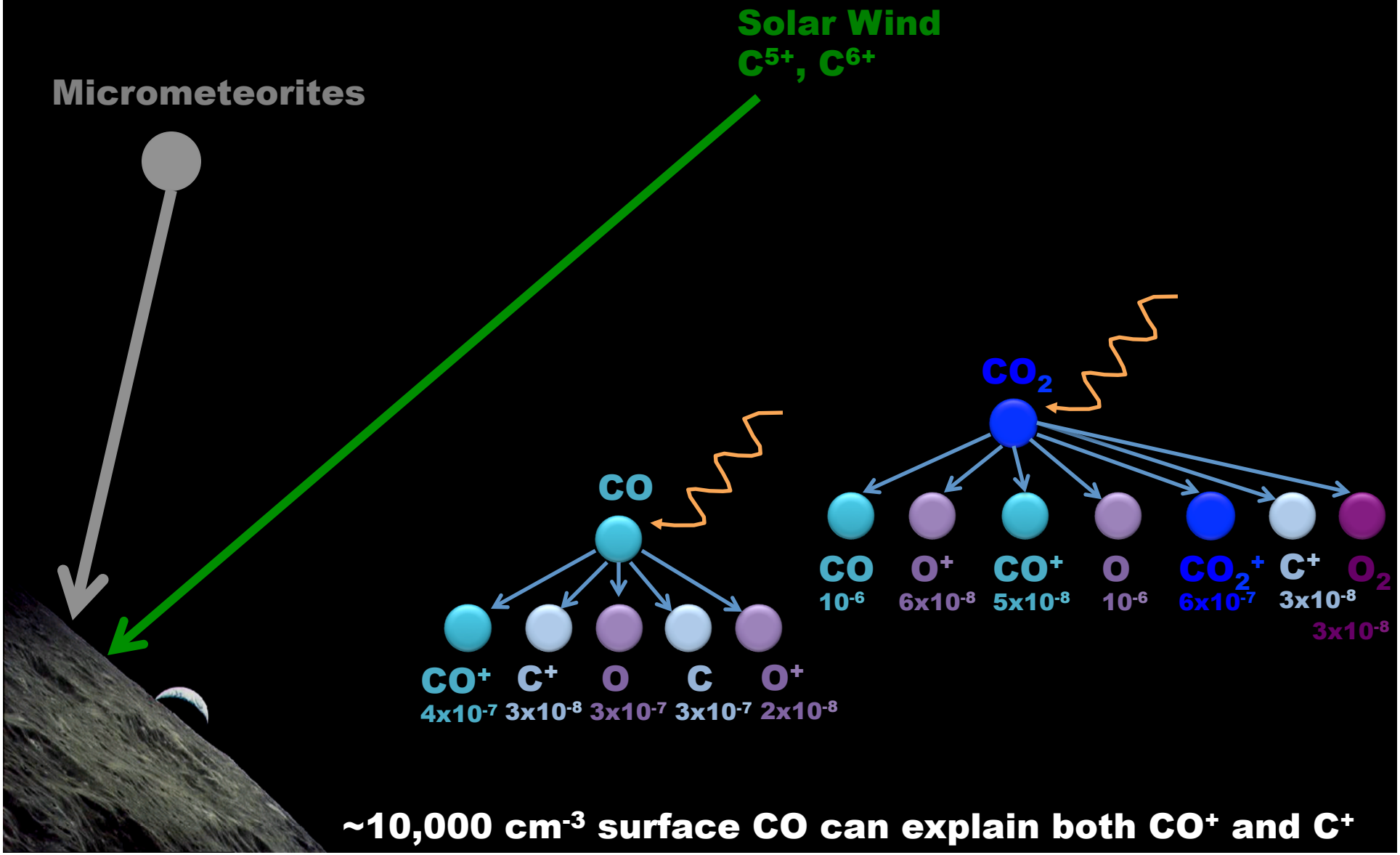
Noble Gases


Benna et al., 2015
x 10^4
(a) Helium
Surface density (/cc)
8
6
4
2
0
0
60
120
180
240
300
360
x 10^4
(c) Neon
3.5
3
2.5
2
1.5
1
0.5
0
0
60
120
180
240
300
360

Carbon-Bearing Ions

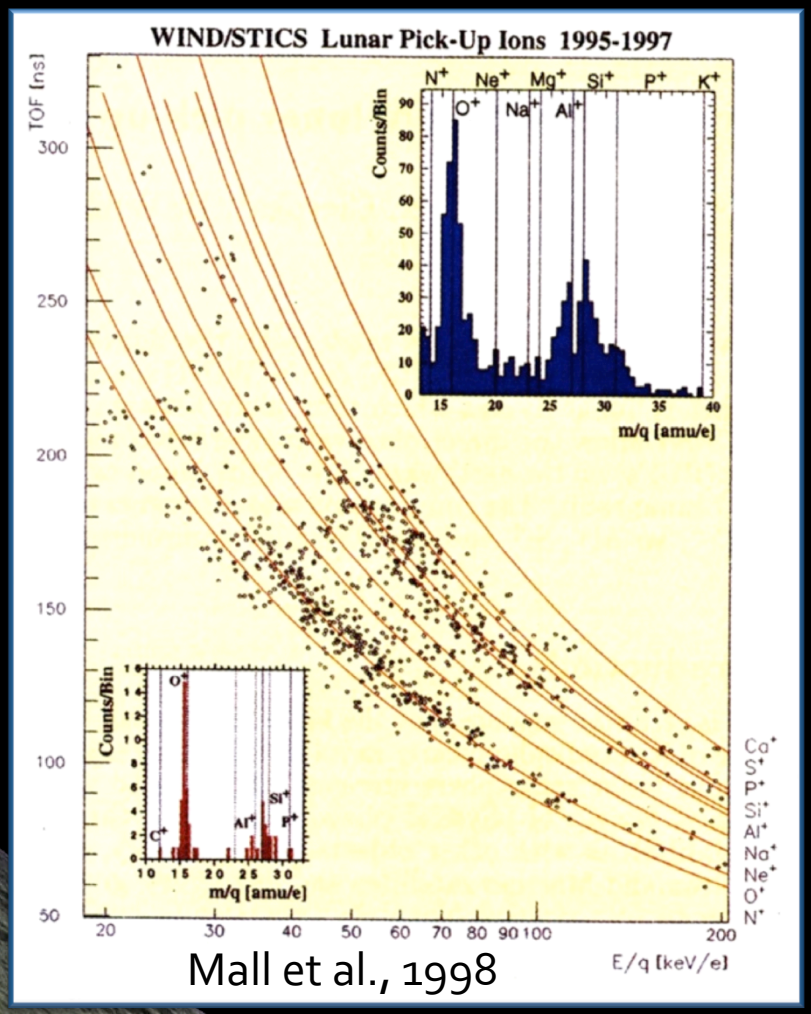


Carbon-Bearing Ions: How?

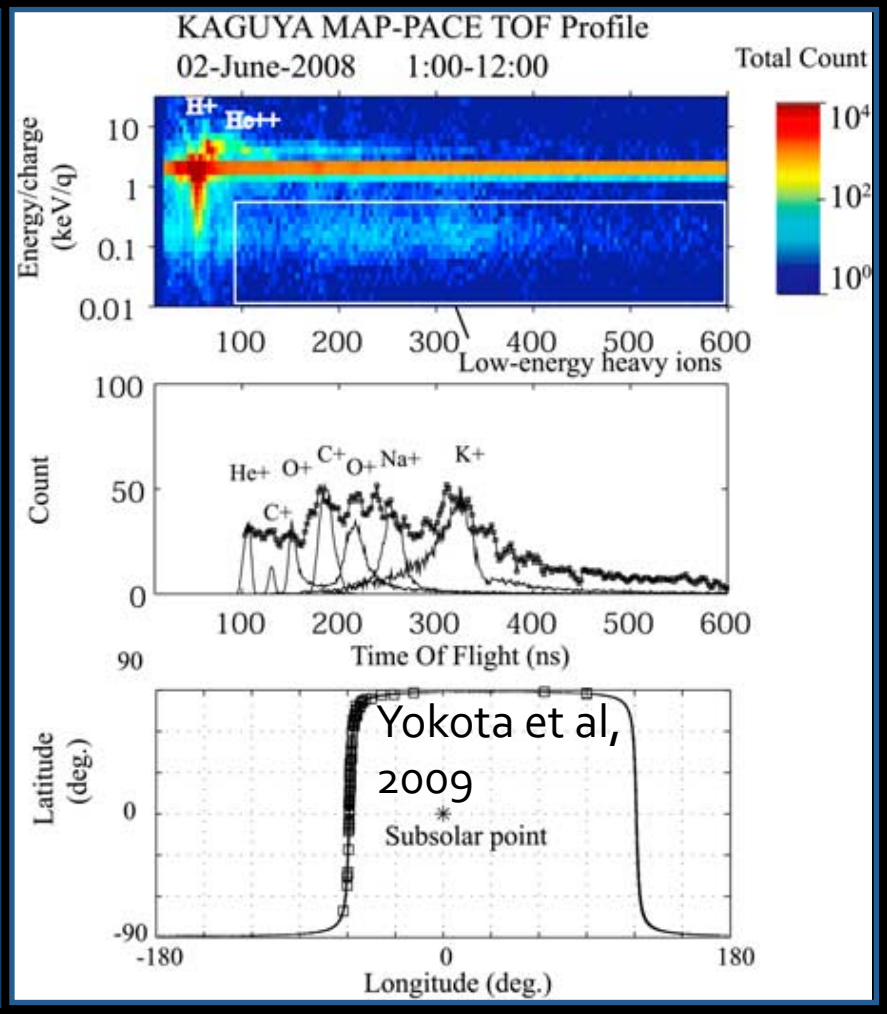


~10,000 cm^{-3} surface CO can explain both CO^+ and C^+

Previous Pickup Ion Measurements

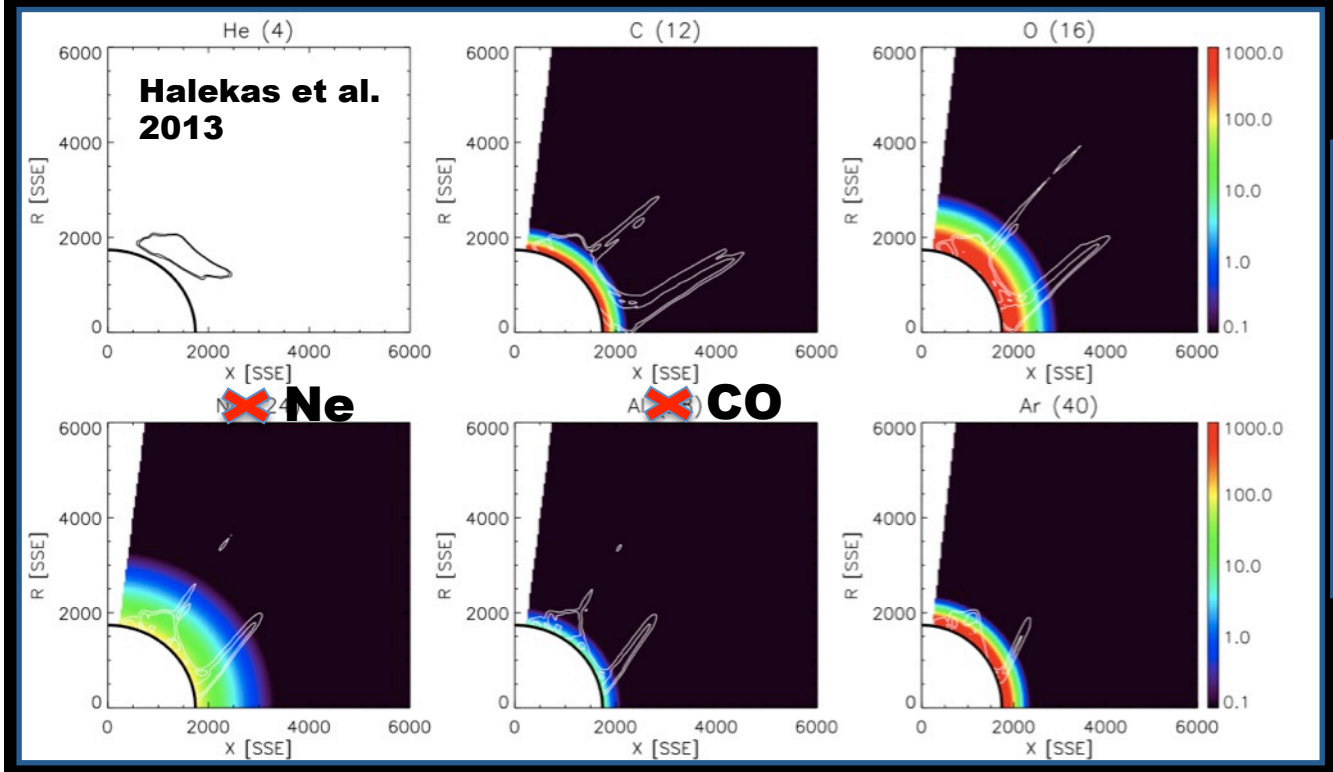


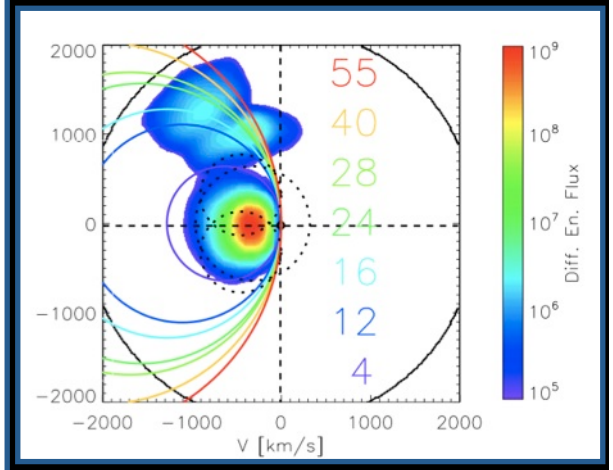
Mall et al., 1998



Yokota et al, 2009

Previous Pickup Ion Measurements



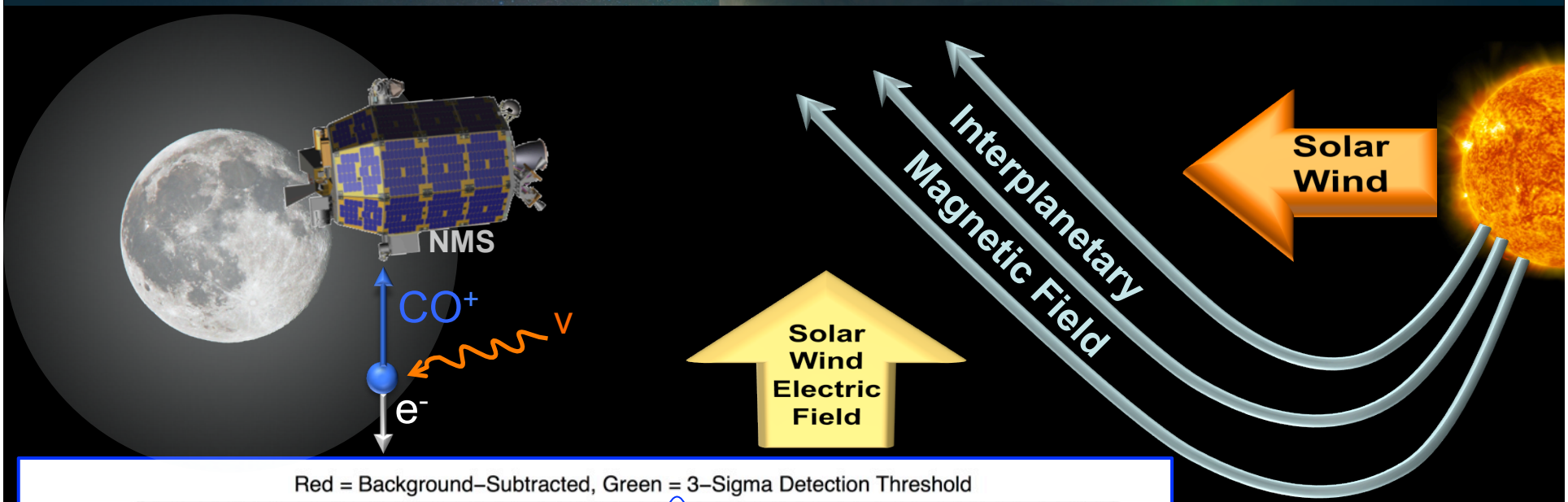


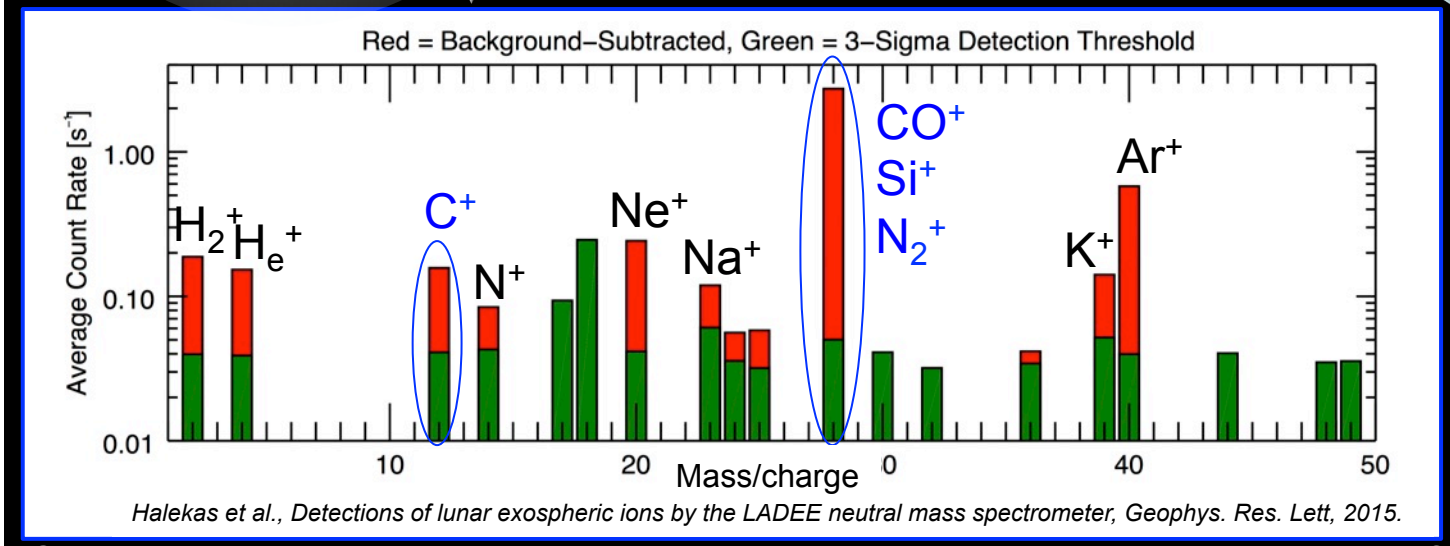
Species	Surface Density	Scale Height
C	2100-3200	31-58 km [160]
O	8500-11400	98-126 km [120]
Ne	4200-26000	97-424 km [80]
CO	6300-15000	71-173 km [70]
Ar	15000-19700	43-66 km [50]

Future Work

- Re-Analyze ARTEMIS data using composition information from NMS
  - Long baseline compared to LADEE
- Utilize LADEE LDEX ion measurements
  - Very high sensitivity

LADEE has discovered an unexpected population of carbon-bearing ions around the Moon





Halekas et al., Detections of lunar exospheric ions by the LADEE neutral mass spectrometer, Geophys. Res. Lett, 2015.

LADEE NMS ion scans utilize the Sun as an ionization source and the solar wind as an accelerator to detect new species in the lunar exosphere.

Carbon-bearing species in the lunar exosphere preserve an imprint of the delivery of volatiles to the lunar regolith by solar wind and micrometeorite bombardment over the Moon's history