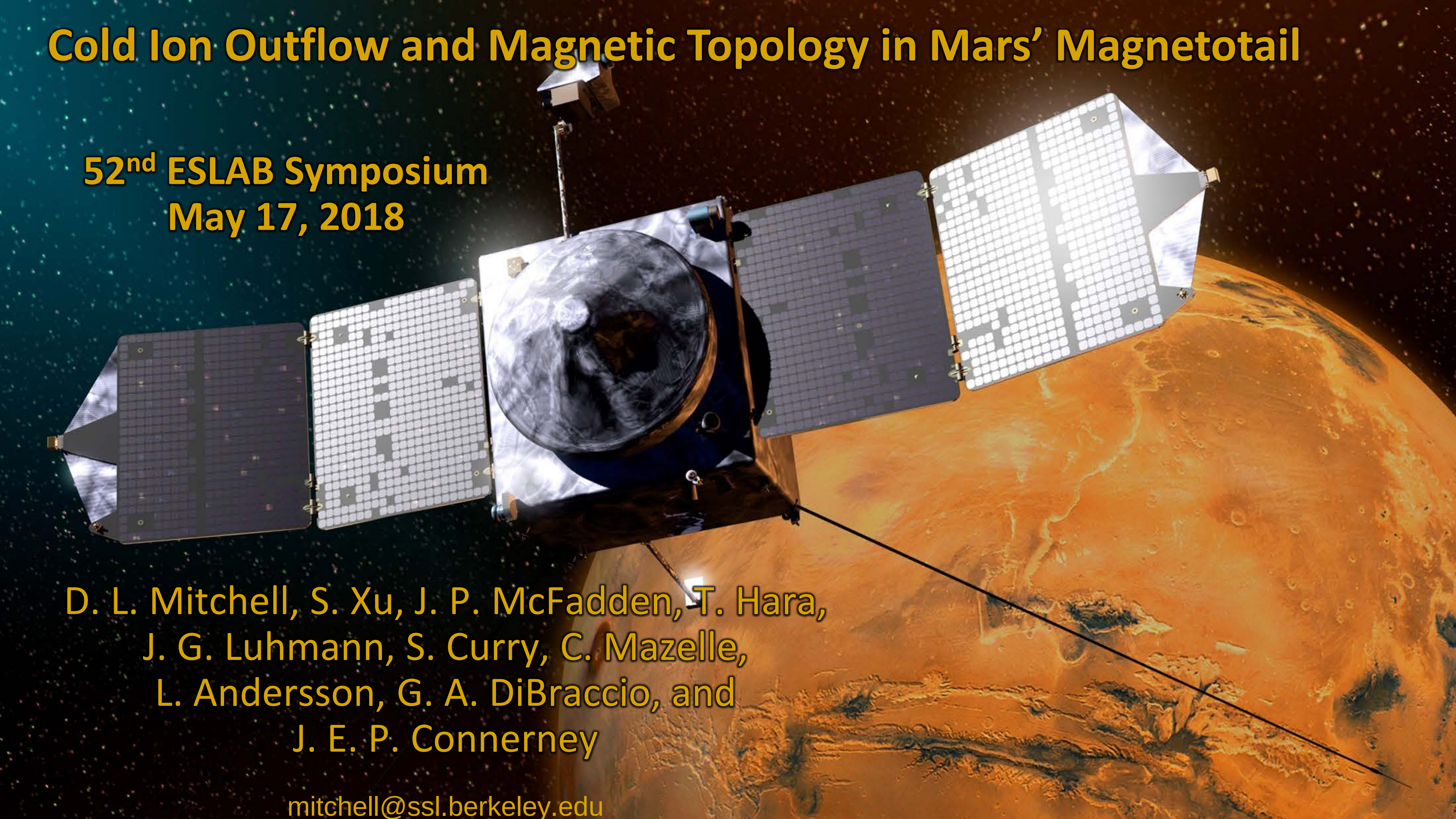

Cold Ion Outflow and Magnetic Topology in Mars' Magnetotail

52nd ESLAB Symposium
May 17, 2018

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L. Andersson, G. A. DiBraccio, and
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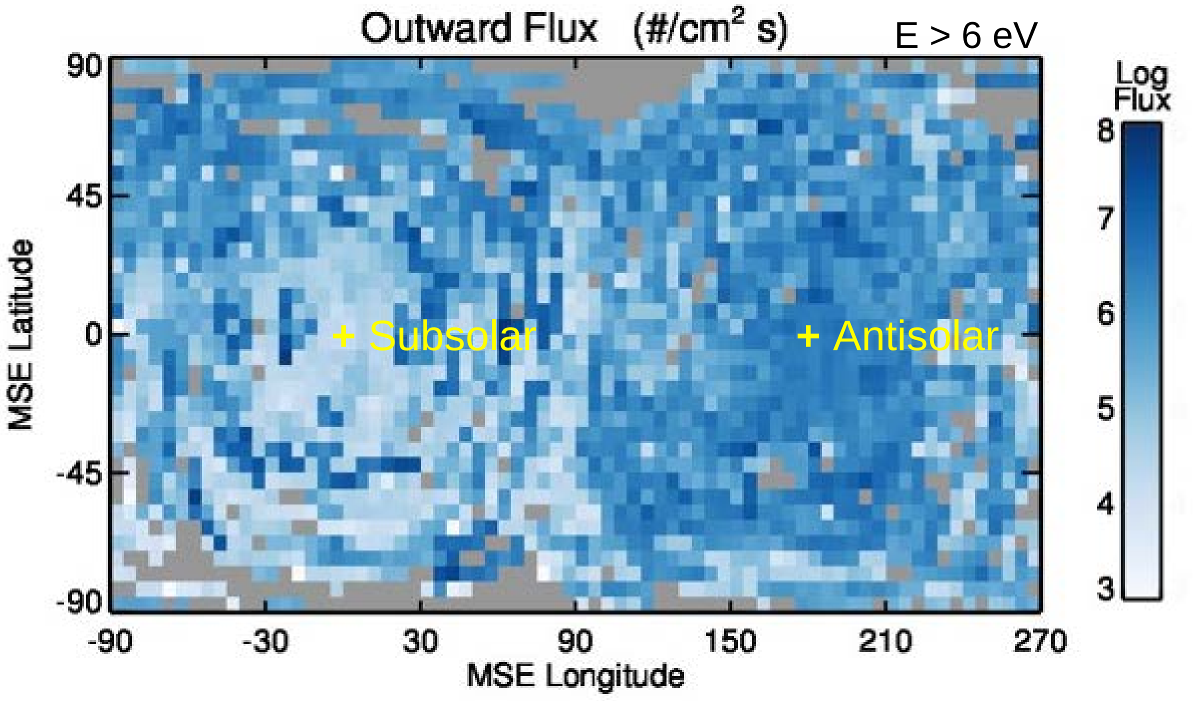
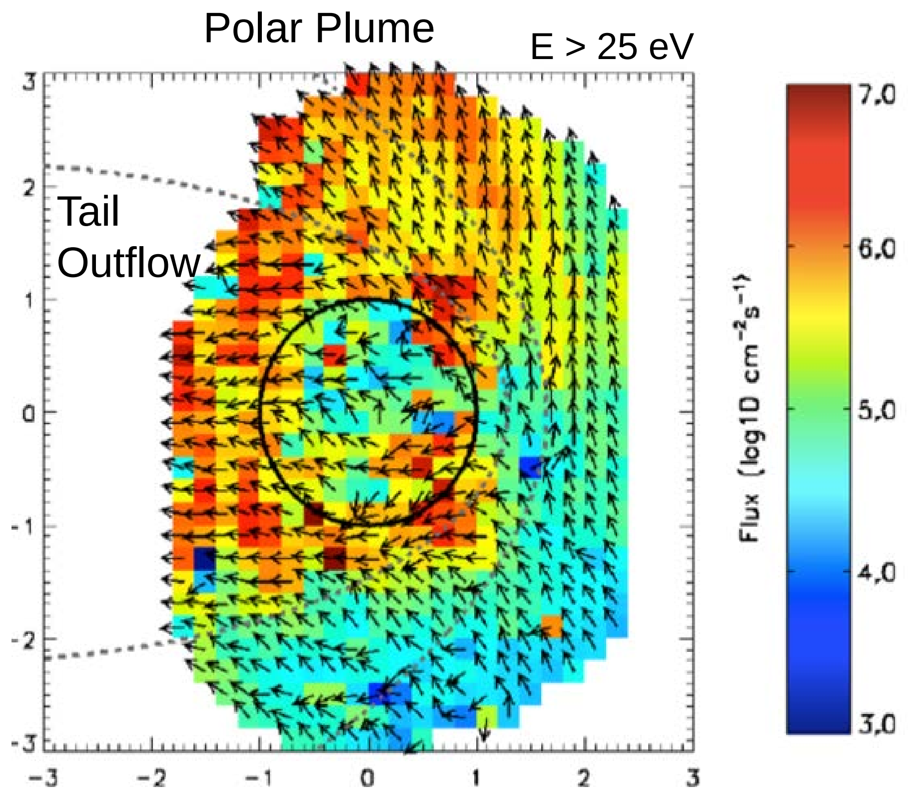
Oxygen Ion Loss from MAVEN

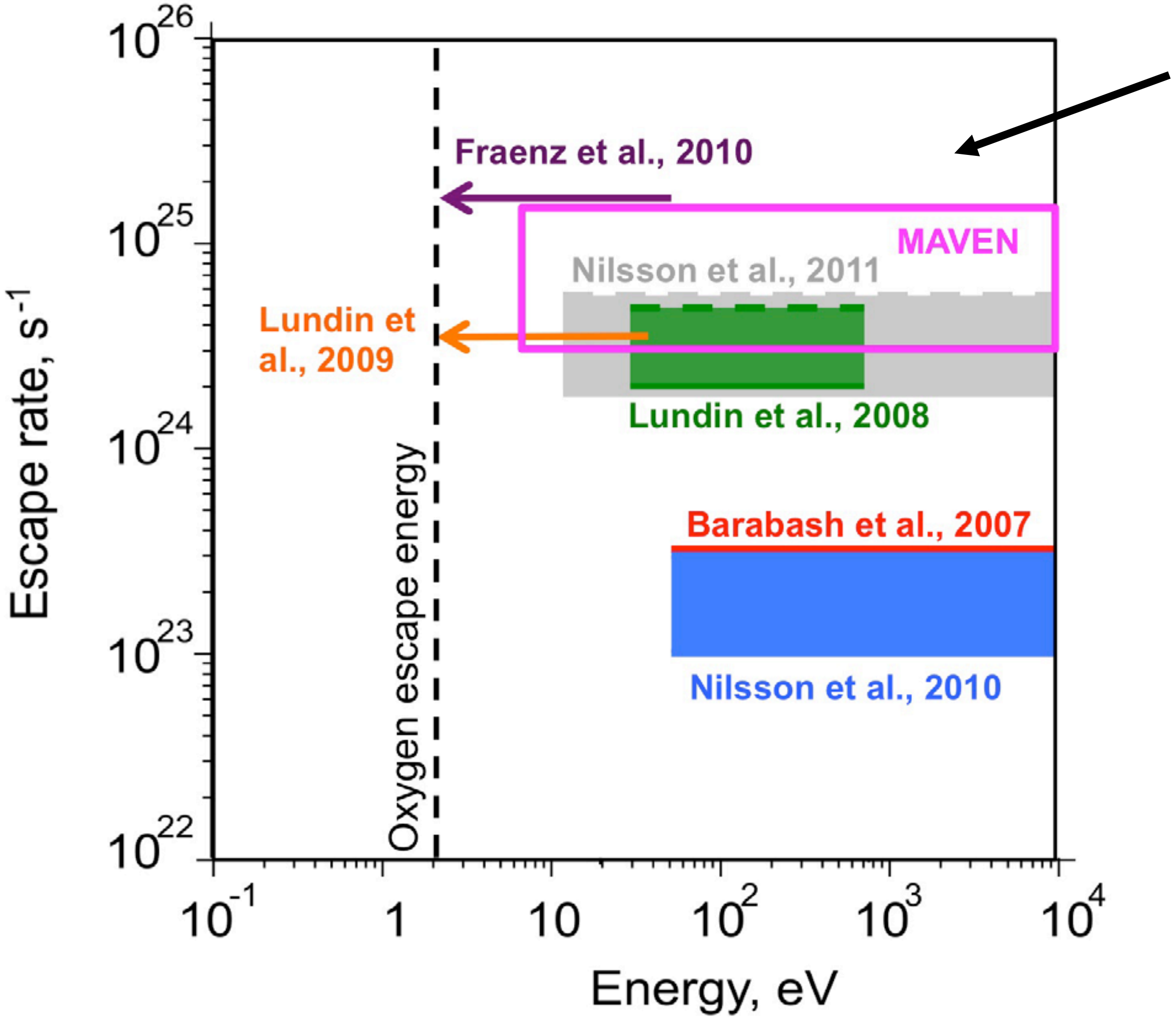


Brain et al. 2017



Dong et al. 2015

Oxygen Ion Loss from Mars Express



Escape rate increases as lower energy threshold decreases.

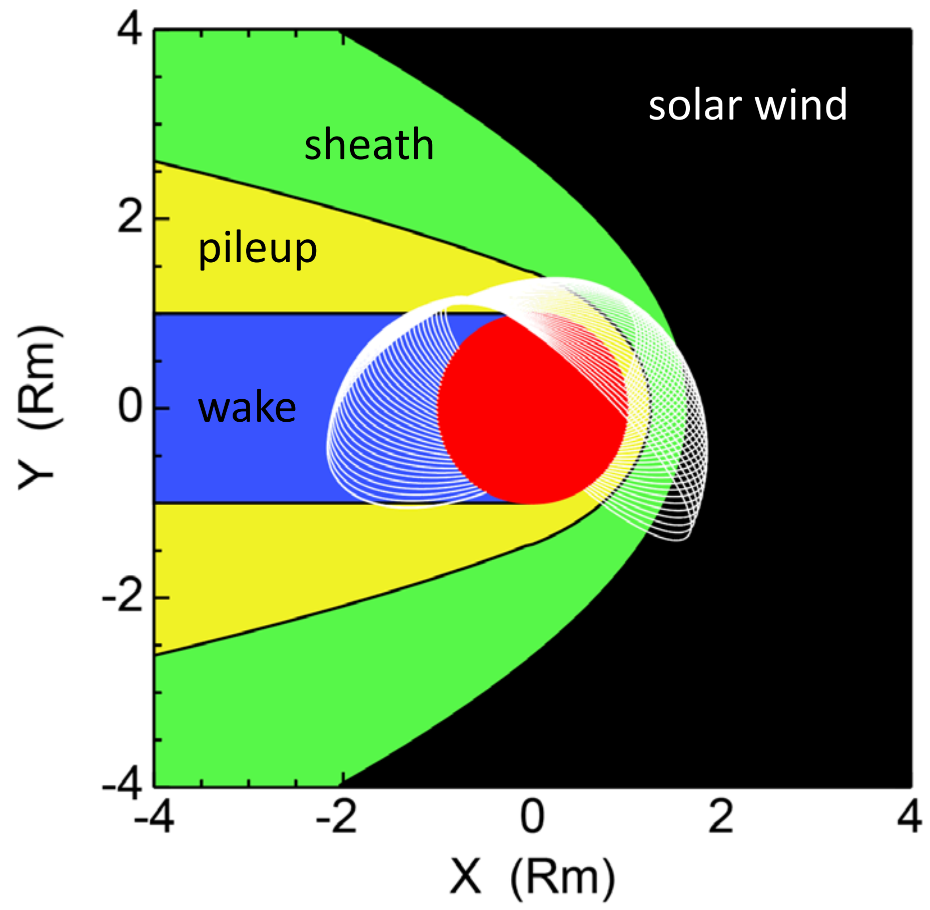
Trans-terminator flow (Fränz et al. 2010)

- Assume flow is strictly tailward with an isotropic temperature.
- Assume loss rate is cylindrically symmetric around terminator.

"Statistical" 3D distributions (Nilsson et al 2011)

- Combine many 2D observations in different orientations.

MAVEN Cold Ion Campaigns



- 5 sweeps through the tail
- 1200 – 5000 km altitude (1.3 – 2.5 R_M)
- STATIC and SWEA fields of view optimized

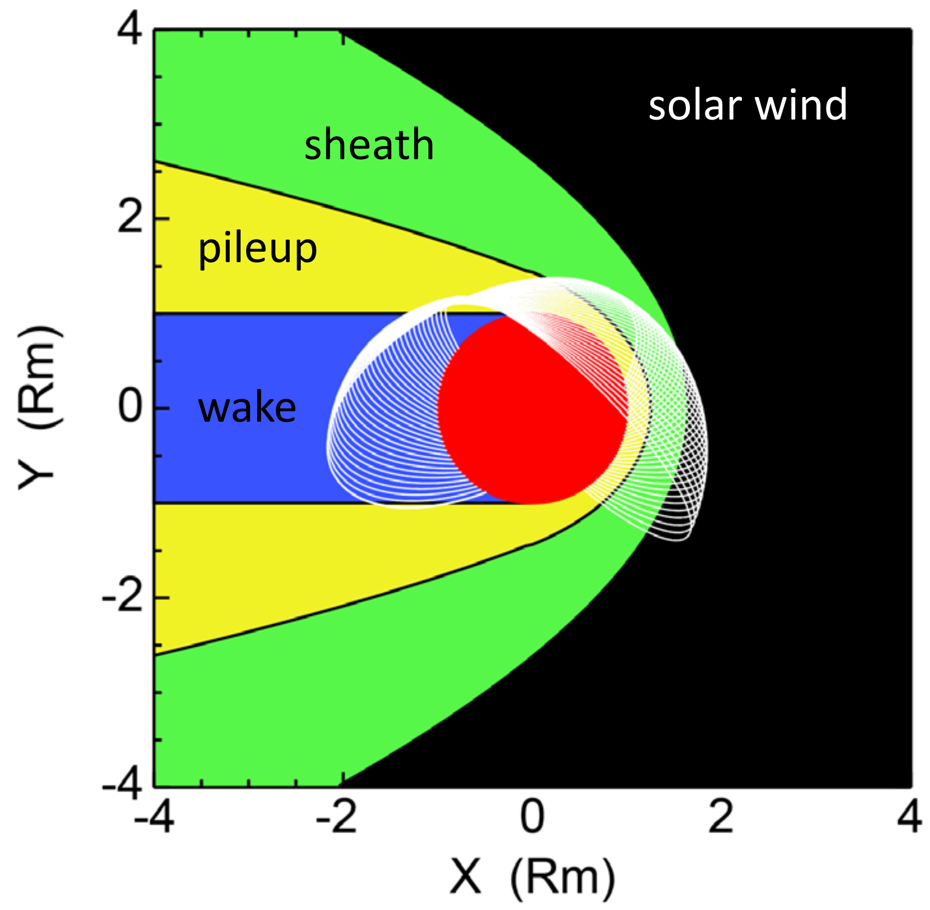
❖ Magnetic topology from SWEA and MAG

❖ Spacecraft potential from SWEA, STATIC, LPW

❖ Ion distribution functions from STATIC, corrected for spacecraft potential and motion

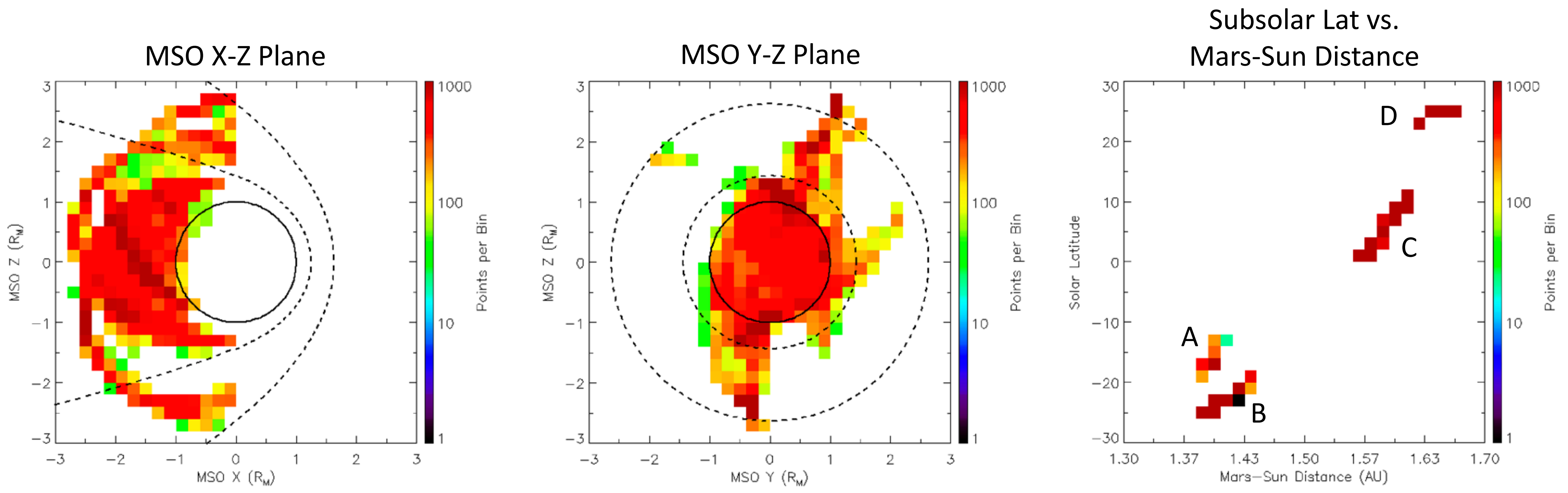
➢ Determine ion outflow down to and below escape velocity

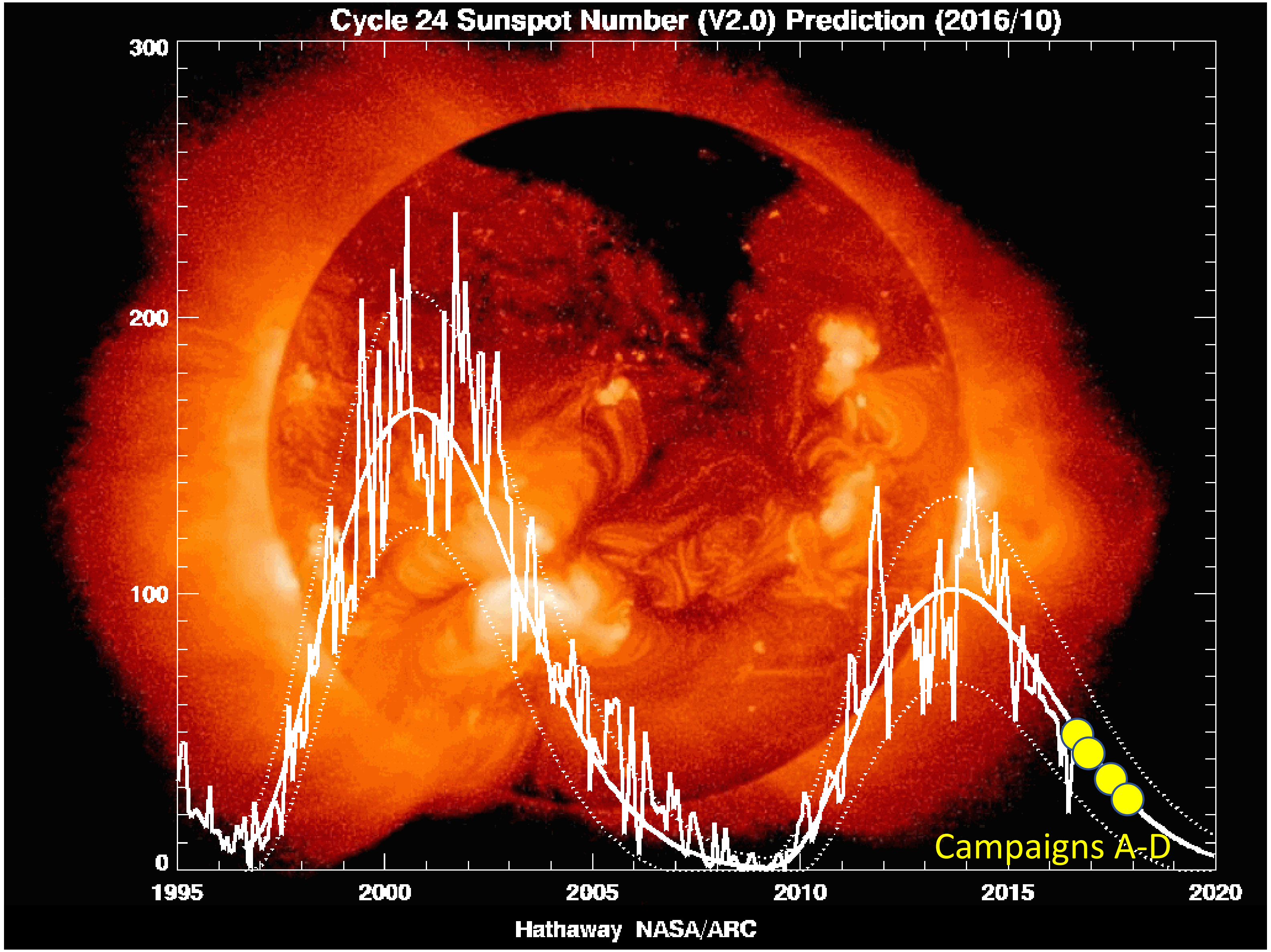
MAVEN Cold Ion Campaigns



- What are properties of the outflow?
  - composition, temperature, velocity
  - morphology and variability
- How does outflow depend on magnetic topology? What accelerates the ions?
- What are the loss rates of different species and the total loss rate, and how does this compare with previous estimates?
- How does outflow depend on drivers?

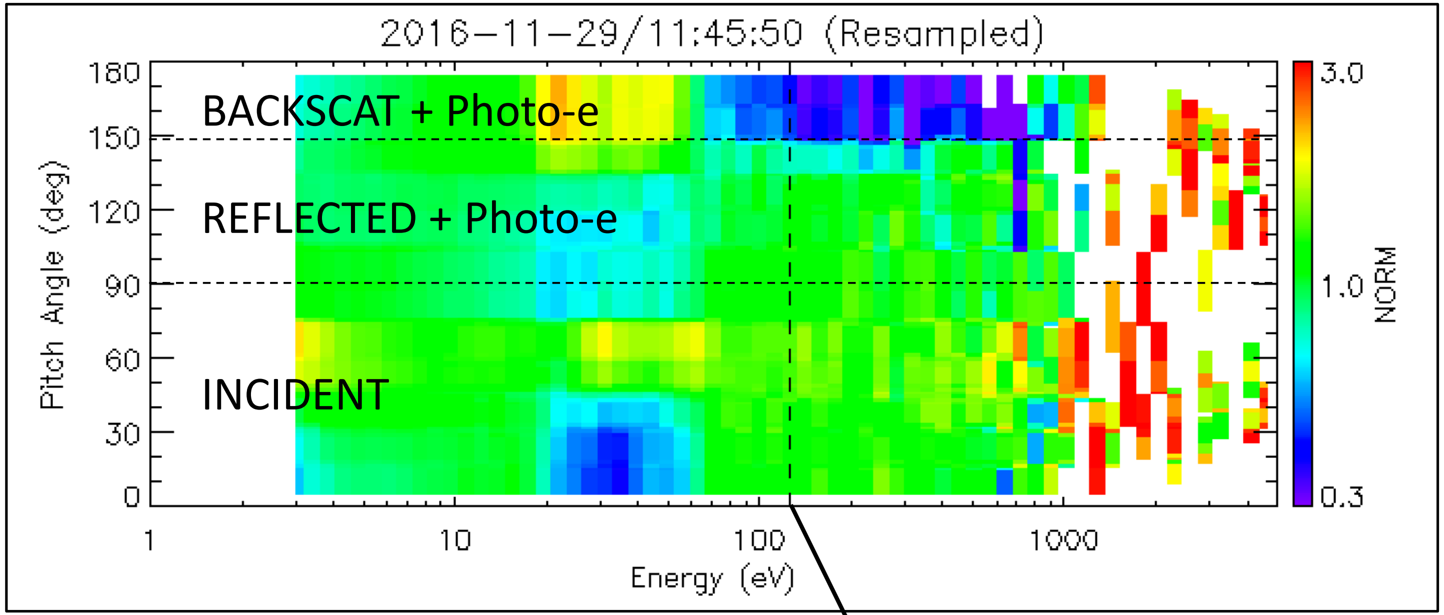
Sampling for Campaigns A-D

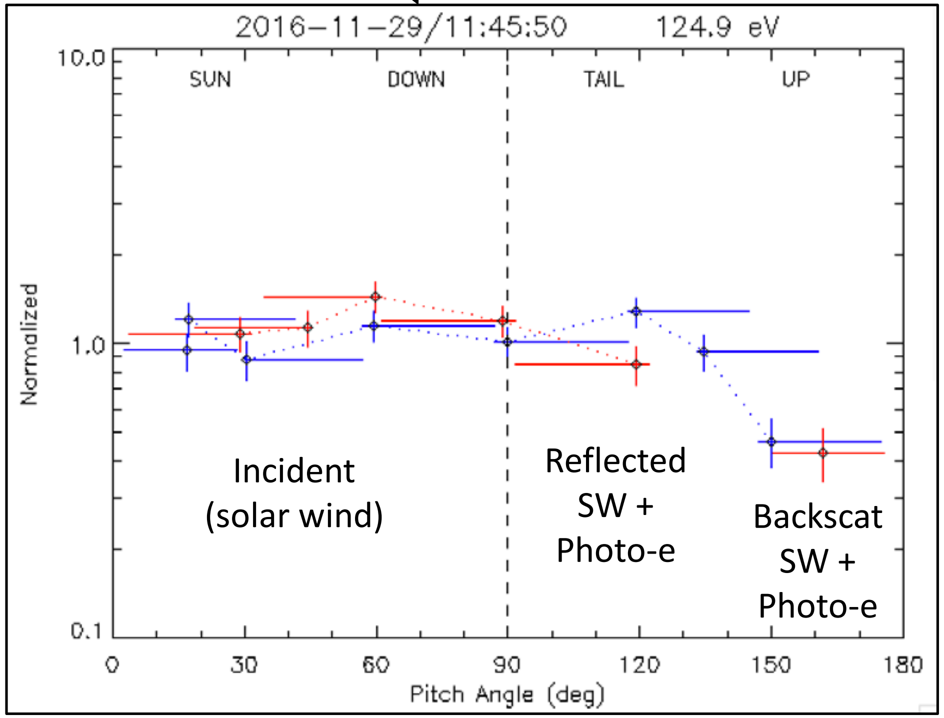




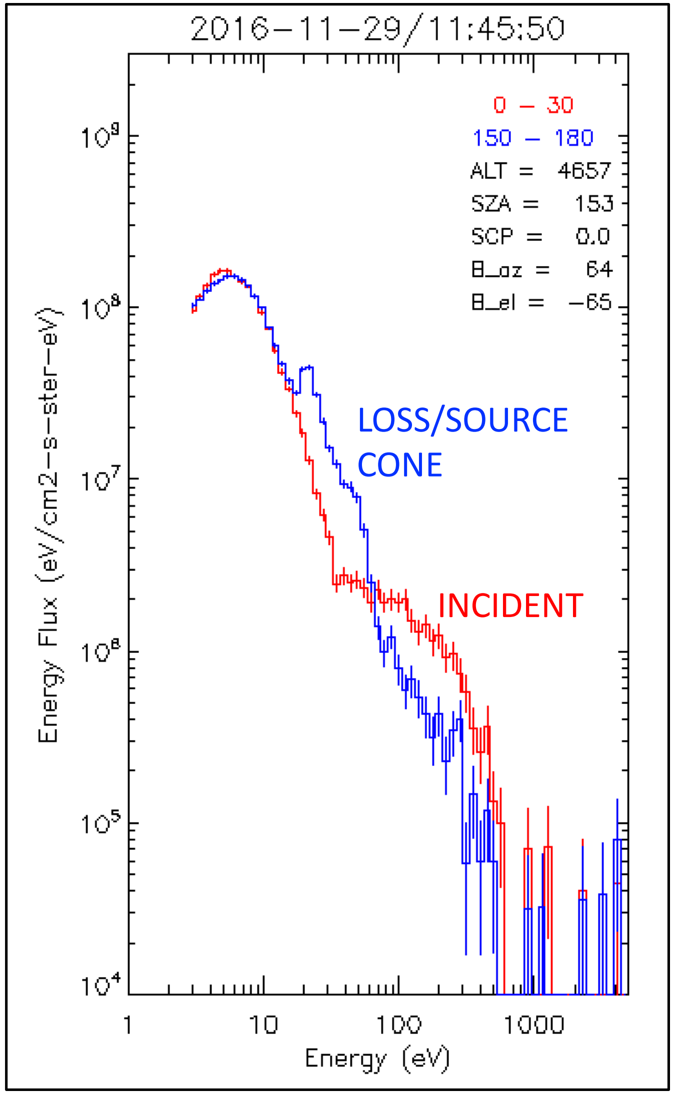
All measurements obtained during low solar activity.

(September 2017 event occurred between Campaigns C and D.)

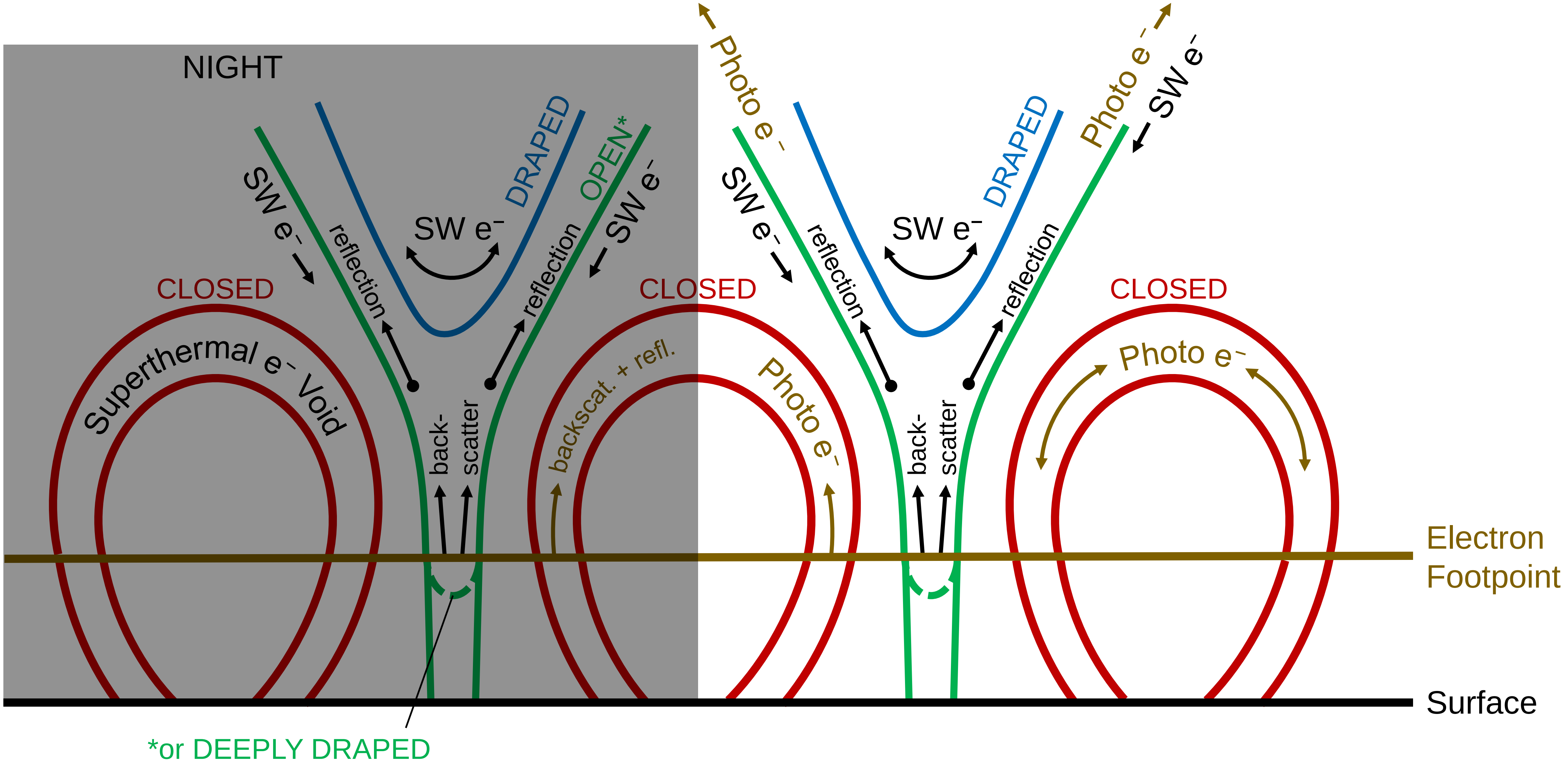




PAD Shape (Weber and Brain)



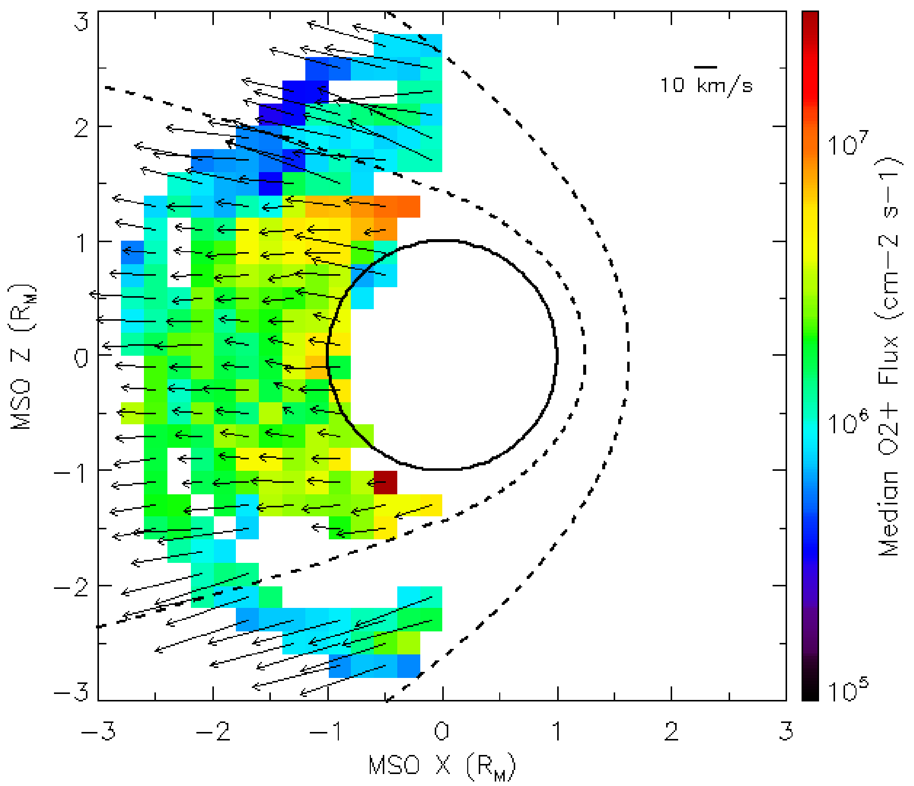
Two-Stream Shape Parameter (Xu and Mitchell)


NIGHT
SW e⁻
reflection
SW e⁻
DRAPED
OPEN*
SW e⁻
reflection
CLOSED
Superthermal e⁻ Void
back-
scatter
backscat. + refl.
CLOSED
Photo e⁻
SW e⁻
reflection
SW e⁻
DRAPED
Photo e⁻
SW e⁻
reflection
Photo e⁻
back-
scatter
CLOSED
Photo e⁻
Electron
Footpoint
Surface
*or DEEPLY DRAPED

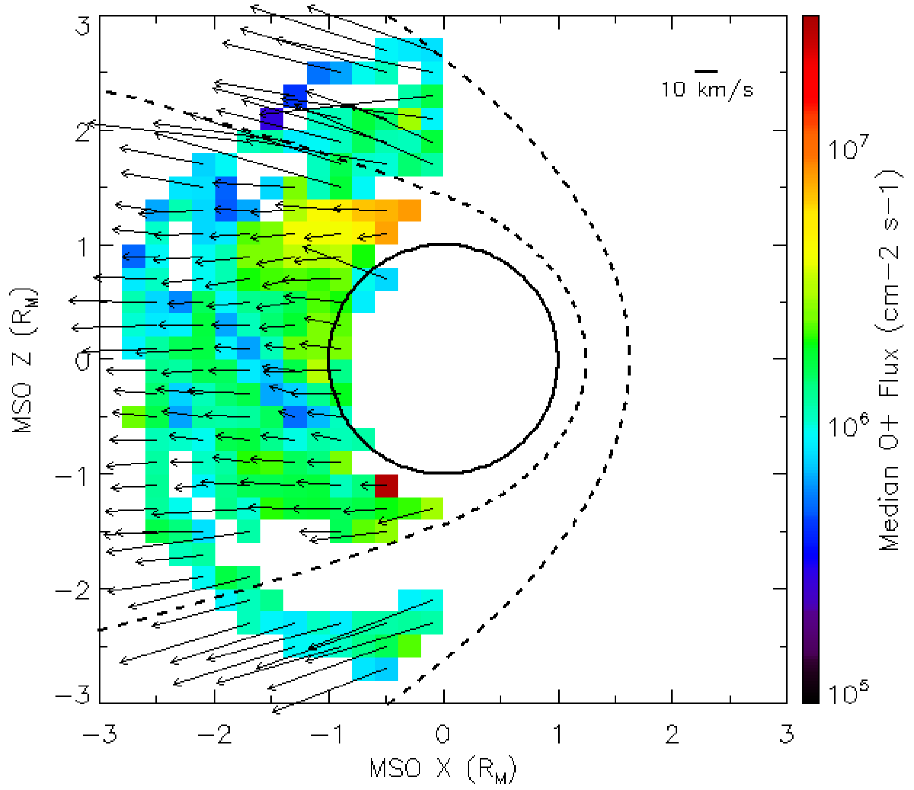
Ion Outflow in the Tail - Overall

All topologies, all crustal field orientations, all upstream conditions

O_2^+ Flux



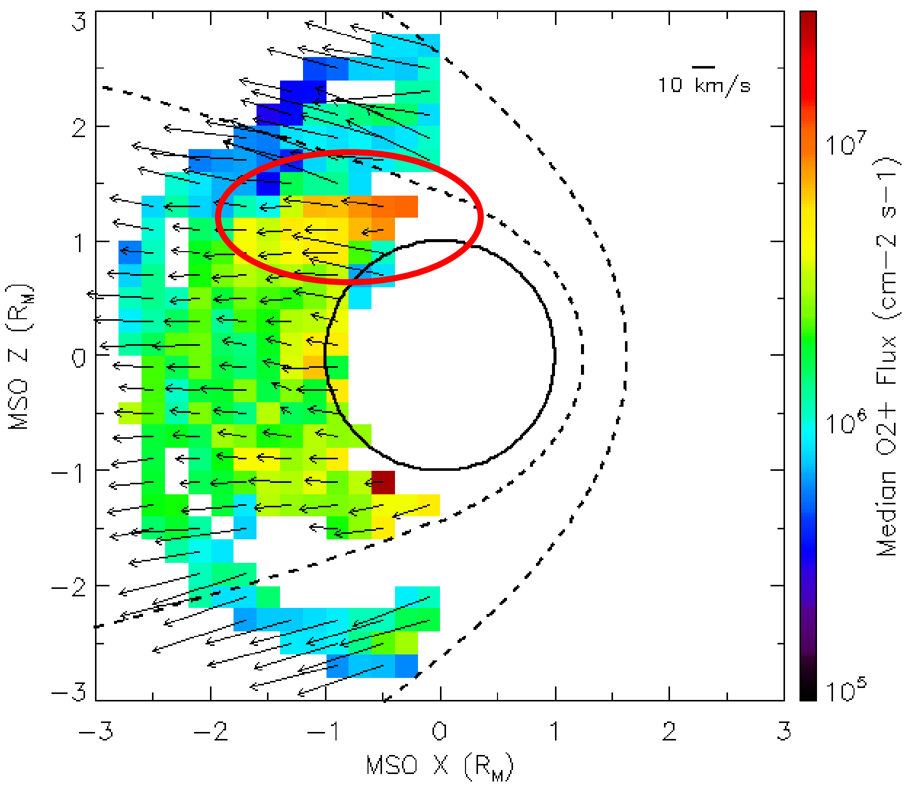
O^+ Flux



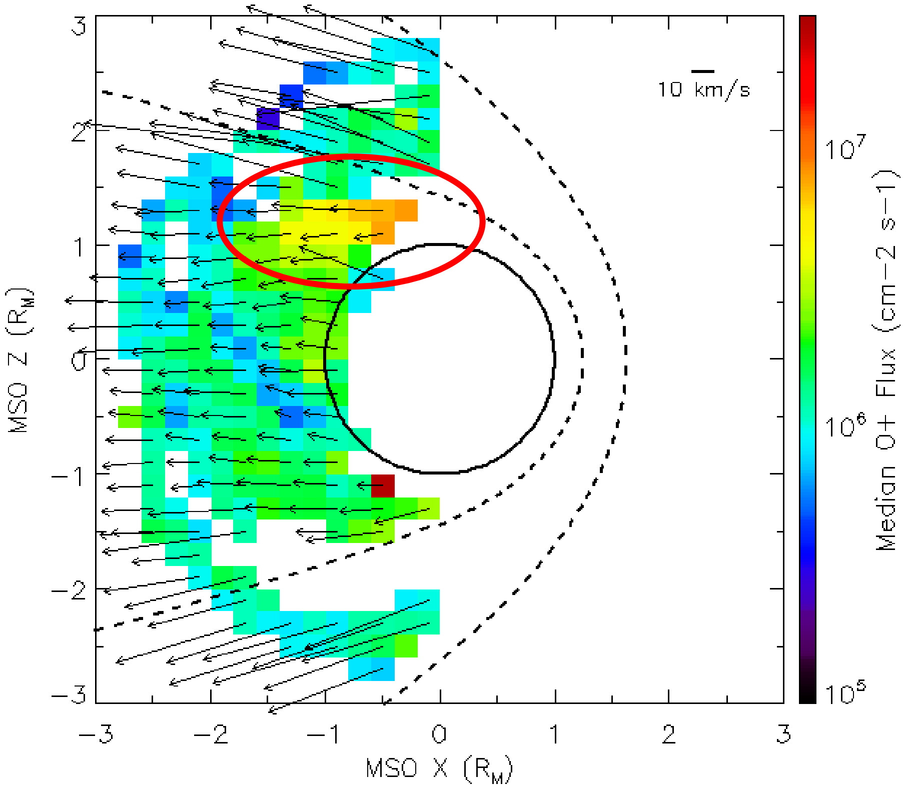
Ion Outflow in the Tail - Overall

All topologies, all crustal field orientations, all upstream conditions

O_2^+ Flux

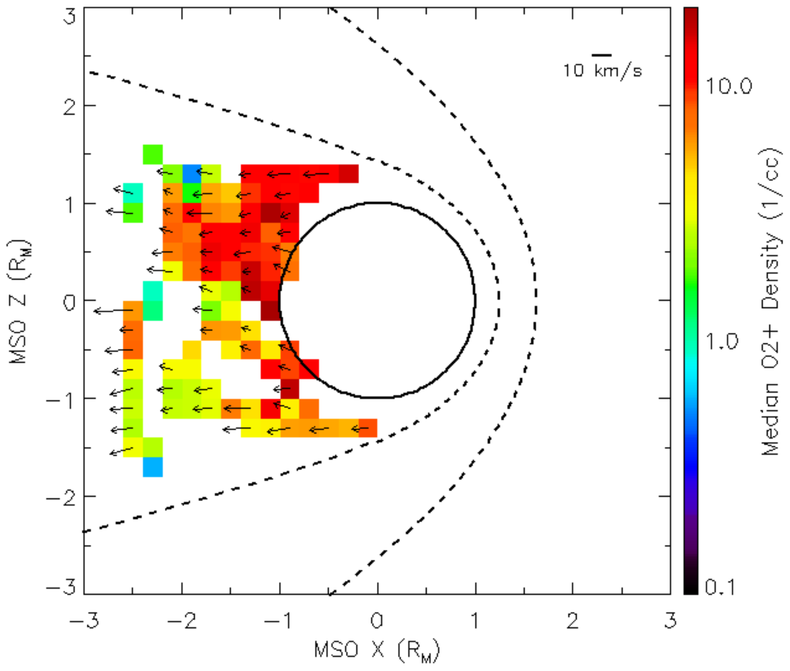


O^+ Flux

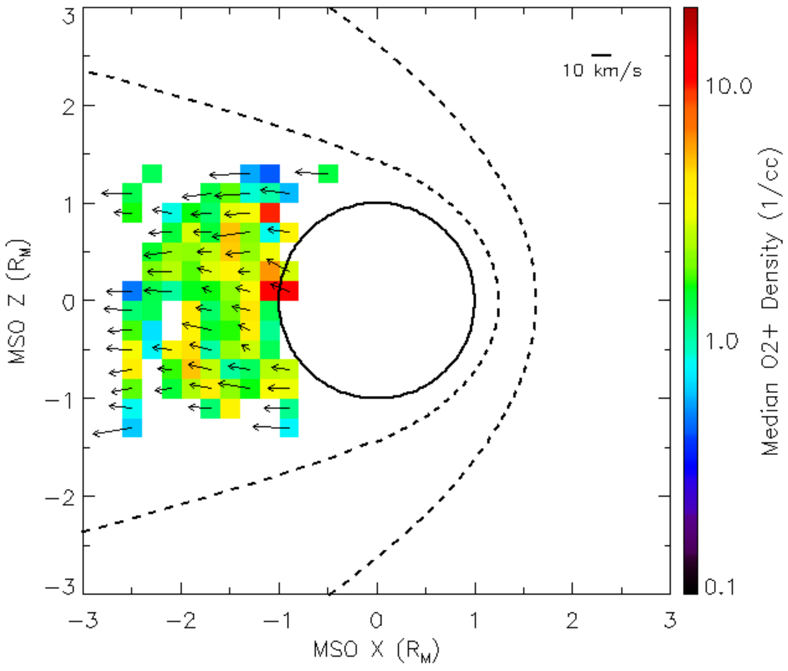


Magnetic Topology Organizes the Data

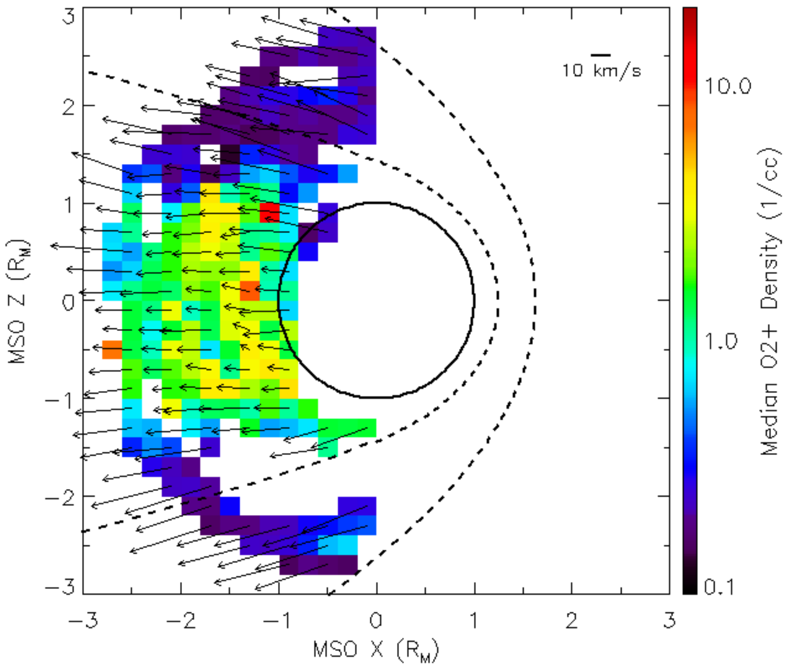
O_2^+ Density
Open to Day

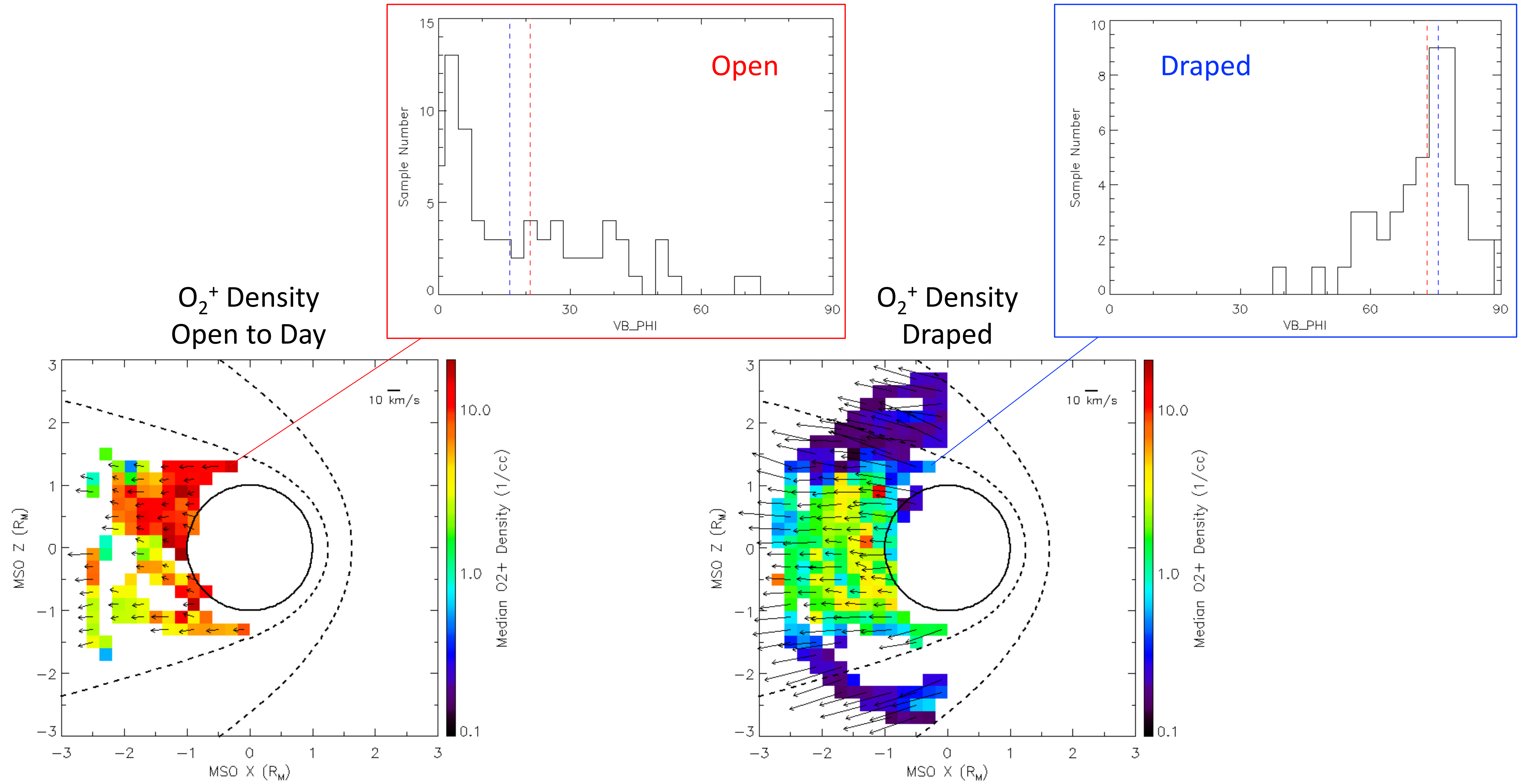


O_2^+ Density
Open to Night

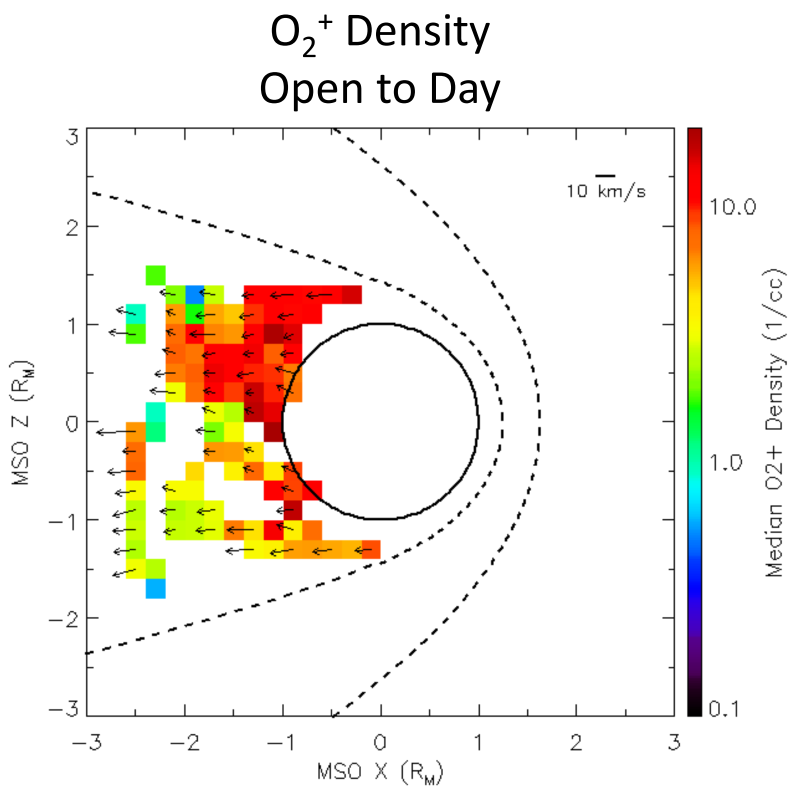


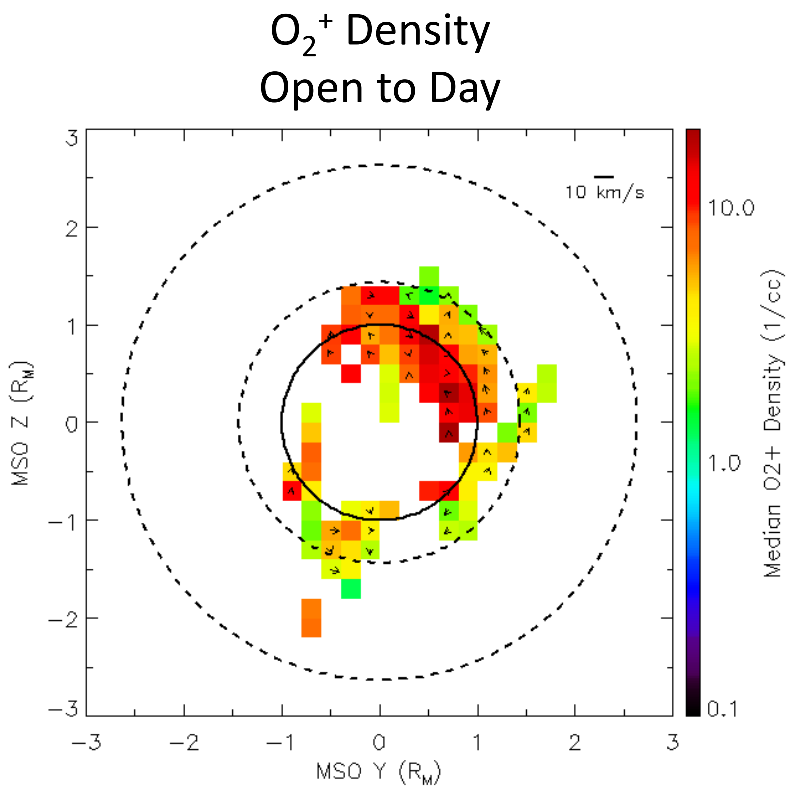
O_2^+ Density
Draped



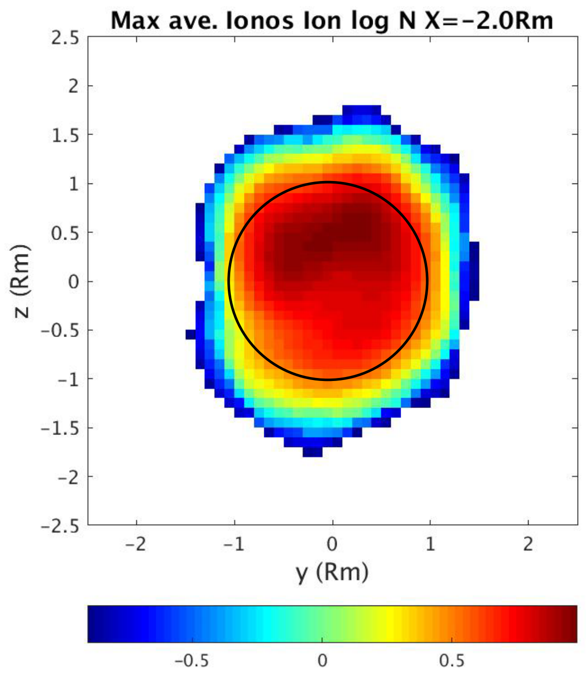

Open
Sample Number
VB_PHI
0
5
10
15
0
30
60
90
Draped
Sample Number
VB_PHI
0
2
4
6
8
10
0
30
60
90
O_2^+ Density
Open to Day
O_2^+ Density
Draped
10 km/s
MSO Z (R_M)
MSO X (R_M)
Median O2+ Density (1/cc)
10.0
1.0
0.1
−3
−2
−1
0
1
2
3
10 km/s
MSO Z (R_M)
MSO X (R_M)
Median O2+ Density (1/cc)
10.0
1.0
0.1
−3
−2
−1
0
1
2
3

Cold Ion Loss on Open Field Lines Exhibits a North Bias



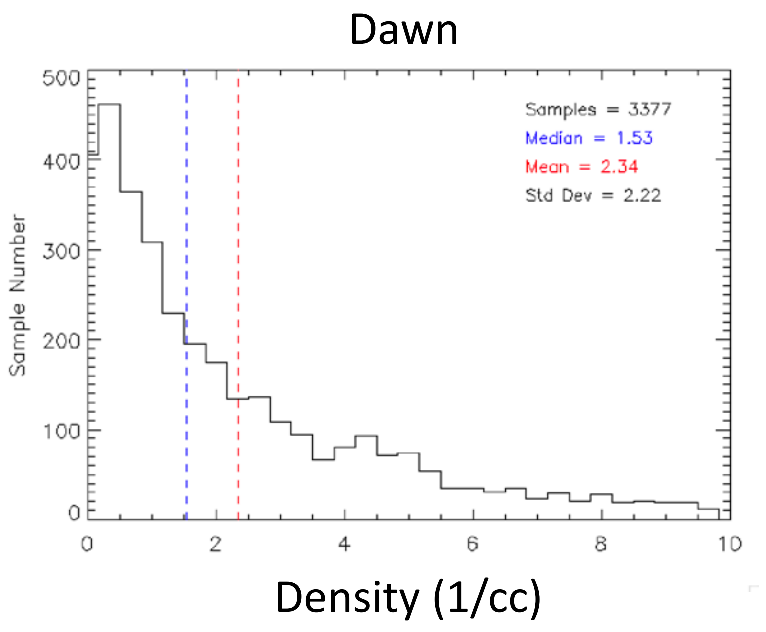


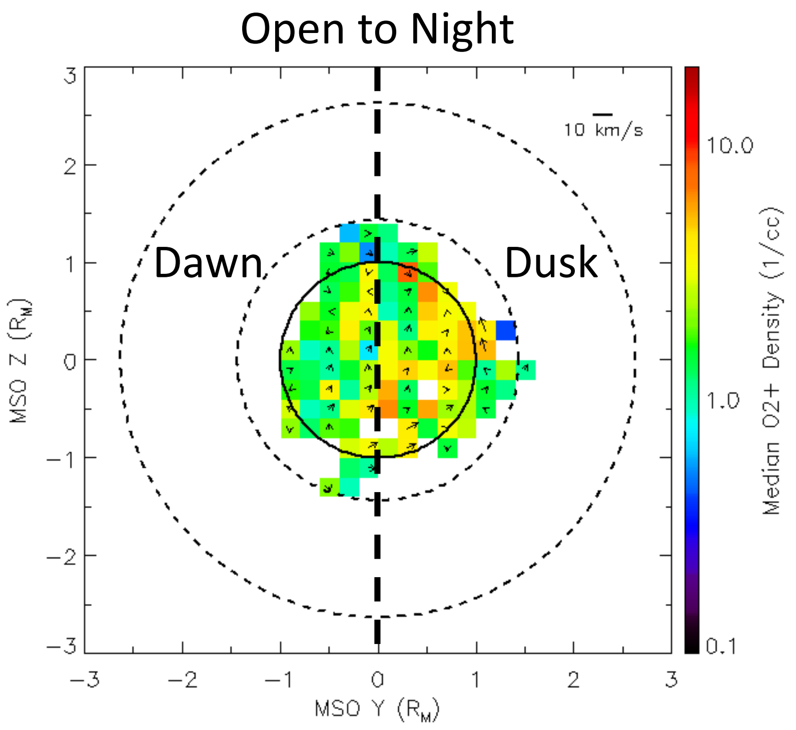
Data: all upstream conditions and planet rotations

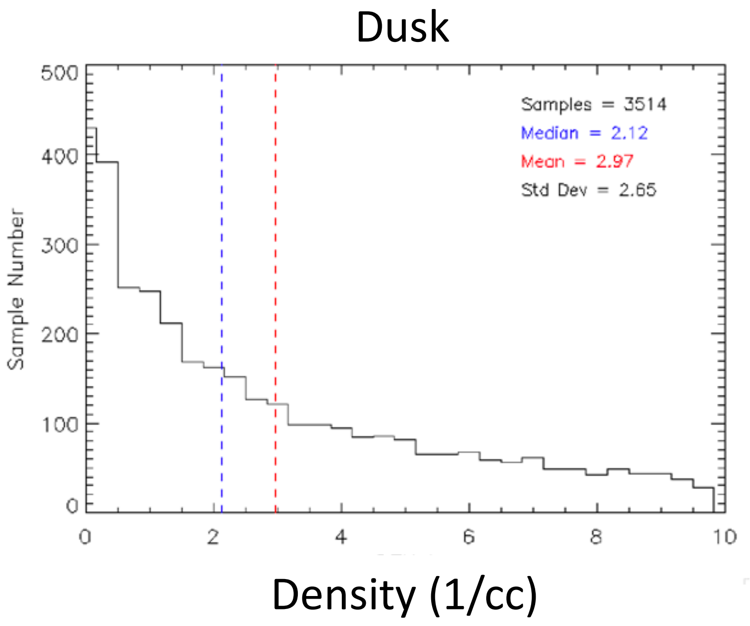


Simulation: ensemble of 8 multi-species, single-fluid models (C. Dong, Y. Ma, J. Luhmann)

O_2^+ Night-Side Density: Dawn-Dusk Asymmetry?

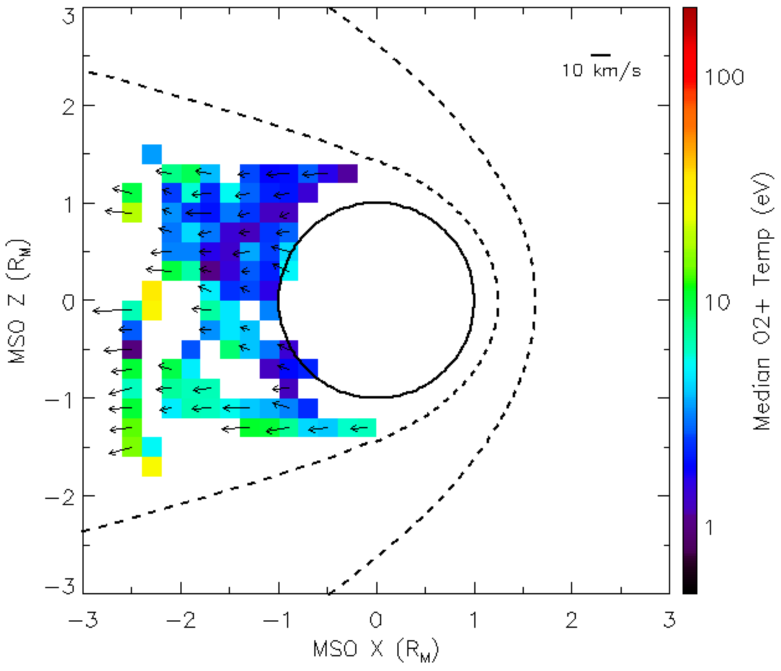




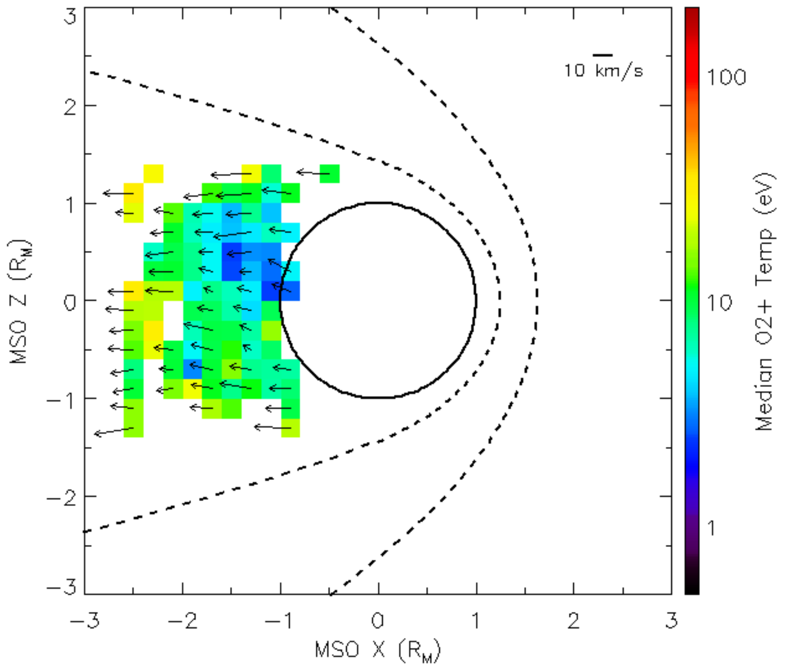


O_2^+ Temperature: How Cold is Cold?

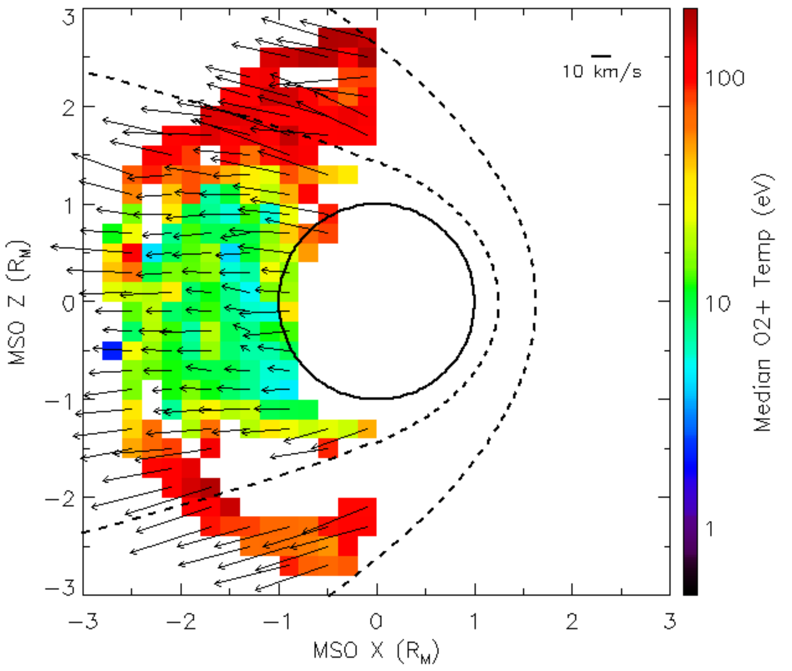
Open to Day



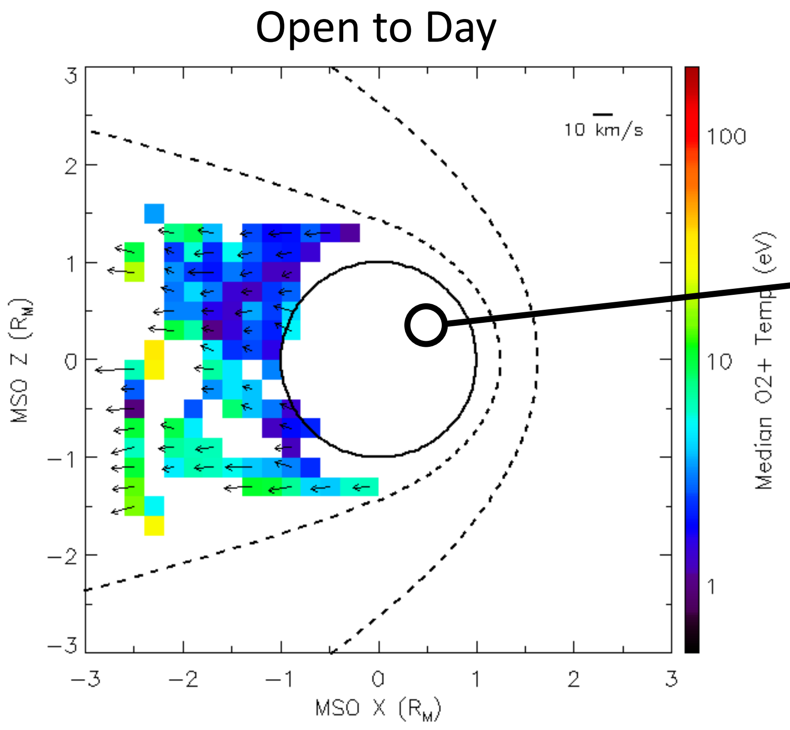
Open to Night

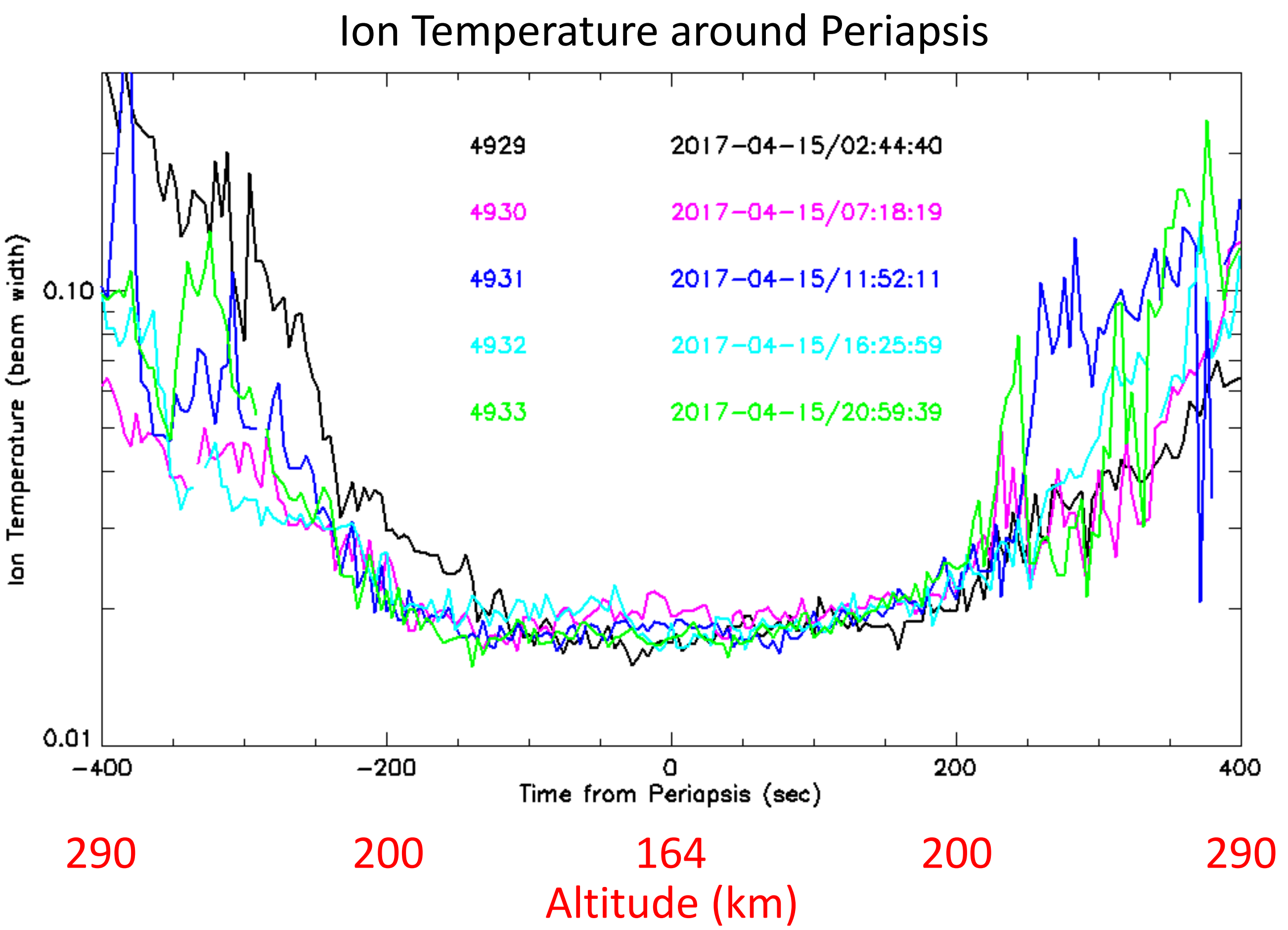


Draped

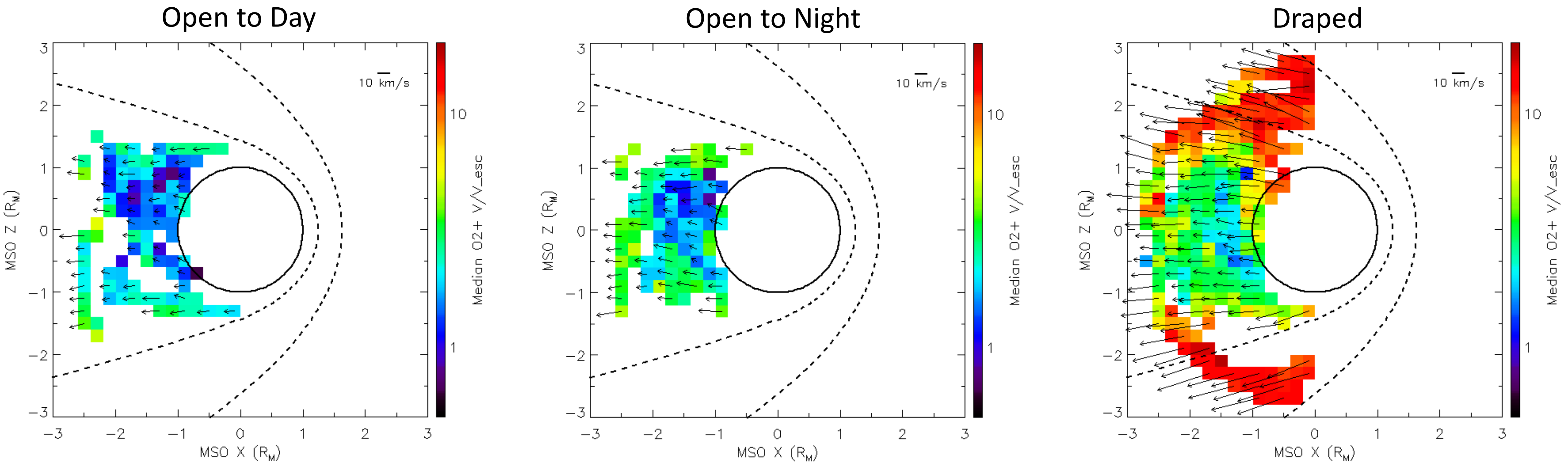


O_2^+ Temperature: How Cold is Cold?





O_2^+ V_{BULK}/V_{ESC} vs. Topology



Statistics for $R < 1.5\ R_M$ and $-3 < X < 0$ (all upstream conditions) : Topology Distribution

Topology	Number of Measurements	O2+ loss (s^{-1})
Open	18484	1.9×10^{24}
Draped	31732	2.4×10^{24}
All	**50216**	**4.3×10^{24}**

Topology	Number of Measurements	O+ loss (s^{-1})
Open	17587	1.0×10^{24}
Draped	27951	1.4×10^{24}
All	**45538**	**2.4×10^{24}**

O_2^+ / O^+ loss ratio

- Open : 1.9
- Draped : 1.7

Draped / Open loss ratio

- O_2^+ : 1.3
- O^+ : 1.4

Total Oxygen Atom Loss in Tail as Ions:

Loss (O) = 2 x Loss(O_2^+) + Loss(O^+) = $1.1 \times 10^{25}\ s^{-1}$

Statistics for R < 1.5 R_M and -3 < X < 0 (all upstream conditions) : Energy Distribution

Energy	Number of Measurements	Fraction of Total O loss (s^{-1})	
< 5 eV	24468	0.19	
< 6 eV	28247	0.27	
< 7 eV	32116	0.31	
< 8 eV	35627	0.41	
< 10 eV	41414	0.46	<-- 50% of loss
< 25 eV	64548	0.73	
< 50 eV	74829	0.80	
< 100 eV	81238	0.84	
All energies	**96367**	**1.00**	

Key Points

- Cold ion loss occurs mainly in a cylinder about the MSO X axis with a radius of 1.5 R_M
- Loss is organized by magnetic topology
- Loss exhibits a north bias on open field lines
- ~50% of oxygen loss occurs below 10 eV
- O_2^+ and O^+ are lost in close to a 2:1 ratio
  - occurs on both open and draped field lines
  - consistent with ionospheric source region near the exobase
- Total oxygen loss in tail: ~10^{25} O atoms/s