NASA 5th Eddy Symposium
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The Evolving State of the Ion Escape Process During the May 17, 2024 ICME Impact on Mars

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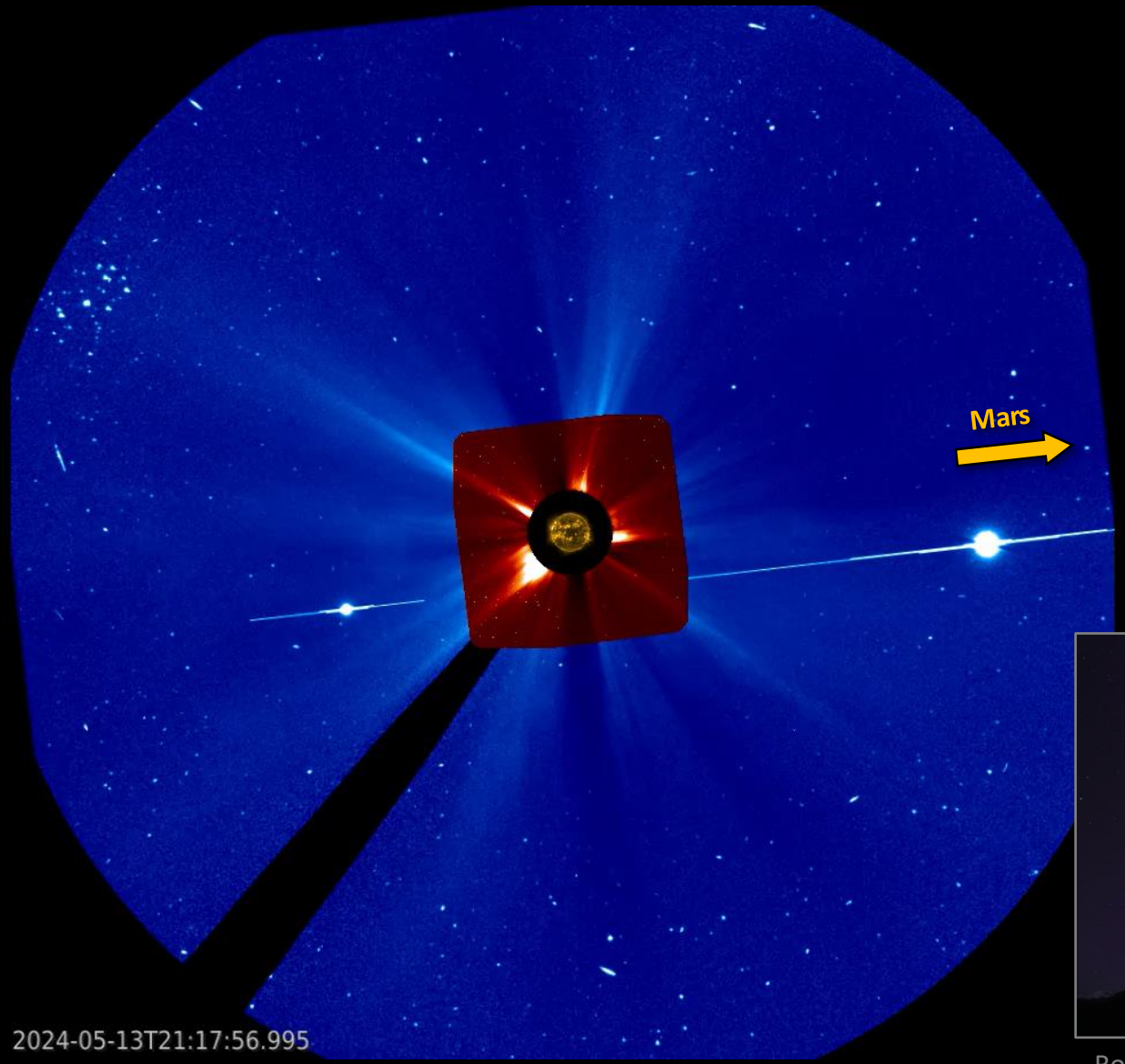
Jared Espley, David Brain, and Shannon Curry

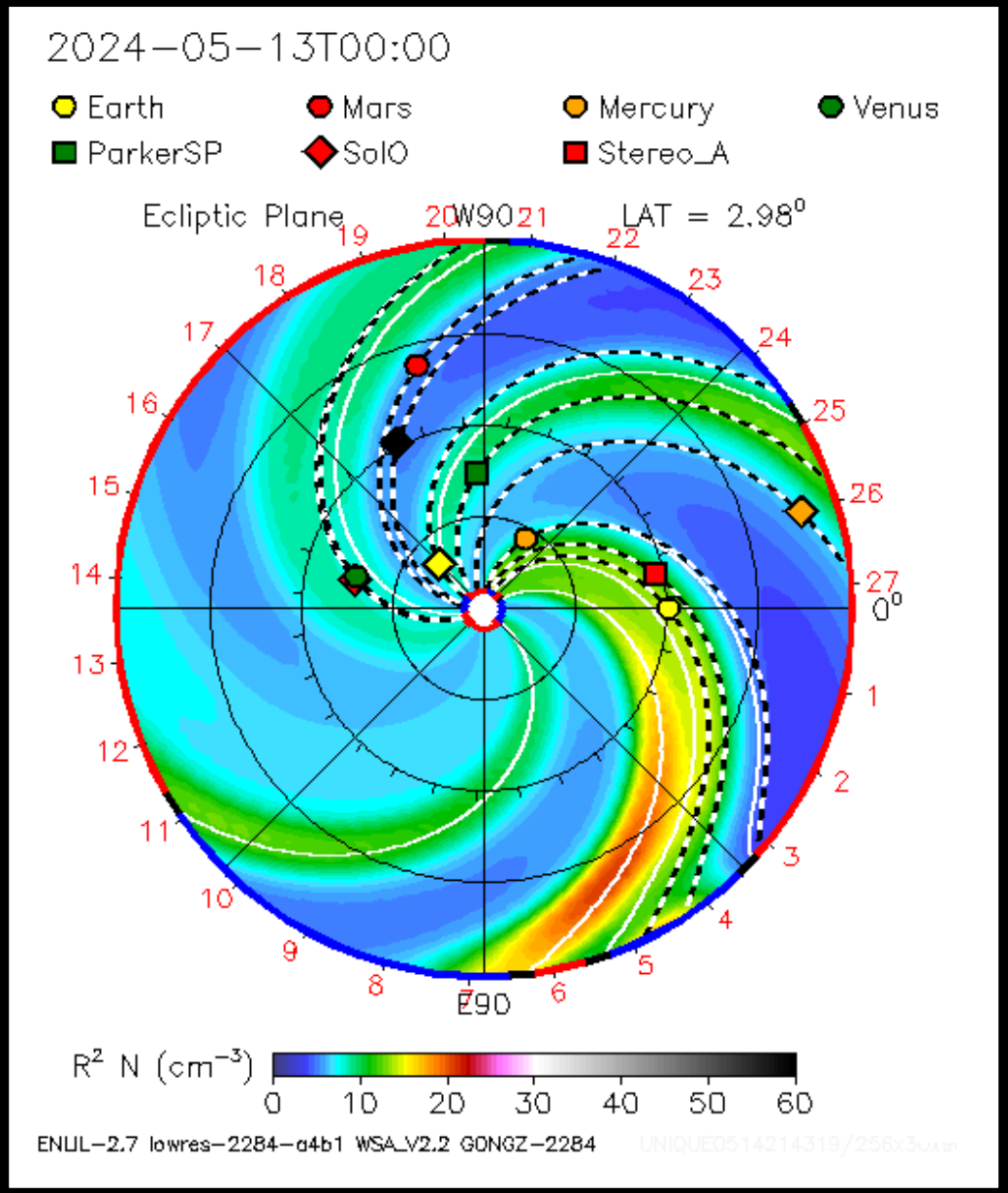
May 2024 events



- The Sun produced a series of ICMEs in May 2024
- ICMEs towards Earth created the May 10-13 Gannon storm
- ICMEs also launched towards Mars

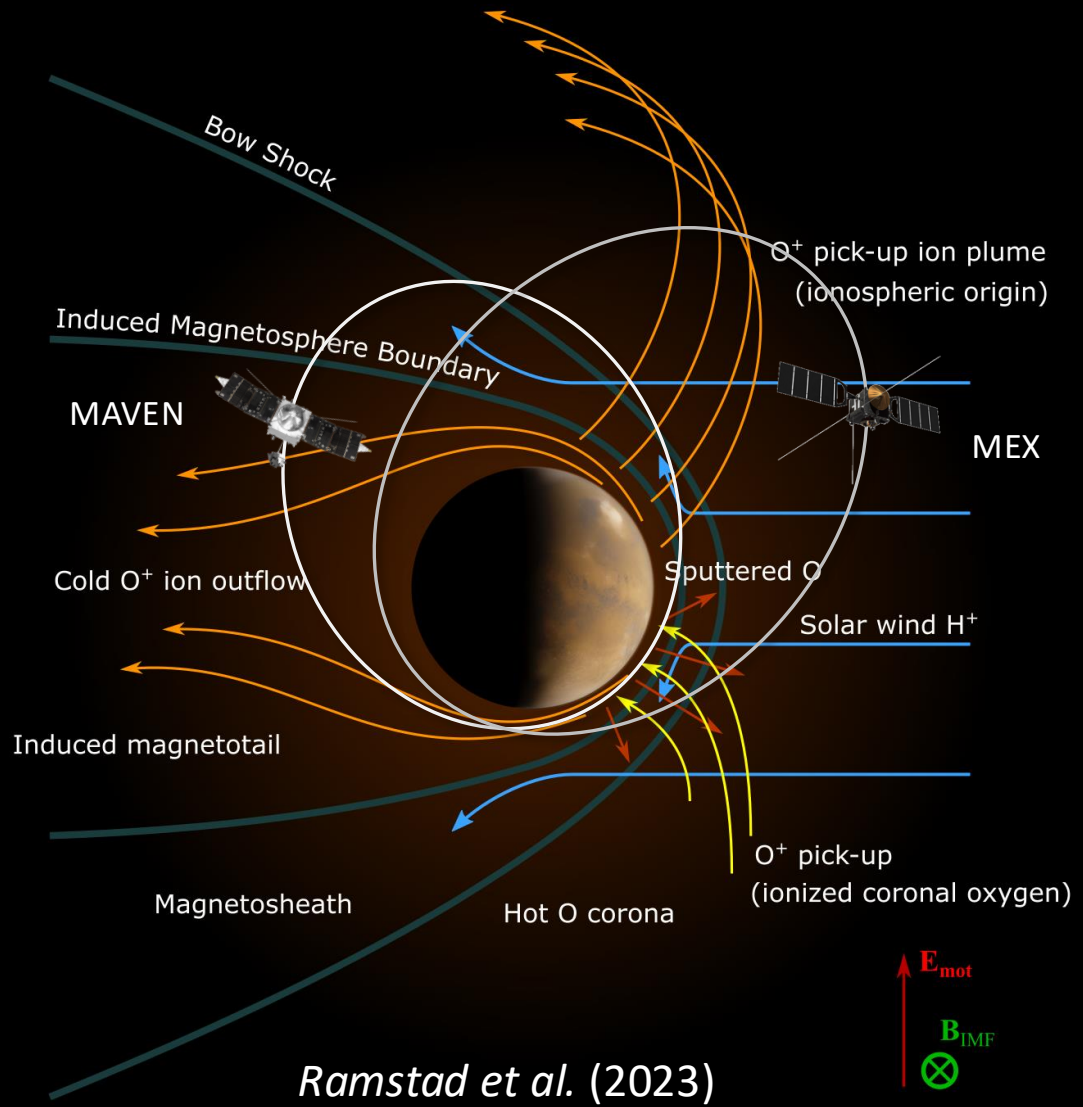
Robin's photo of Gannon storm aurora from Flagstaff mountain in Boulder (May 11)

May 2024 events



- ICME launched towards Mars on May 14, arrived May 17

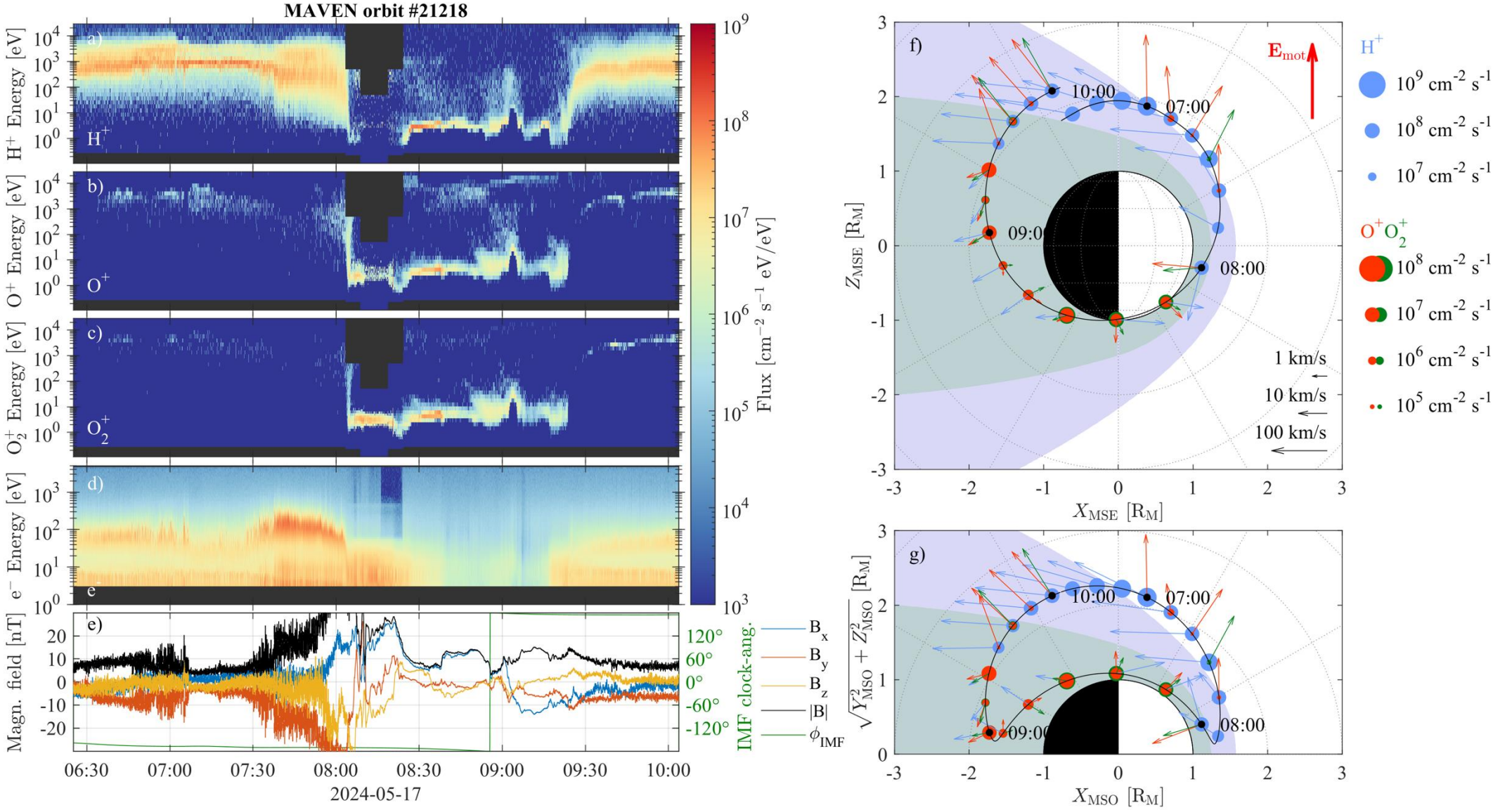
Observations at Mars



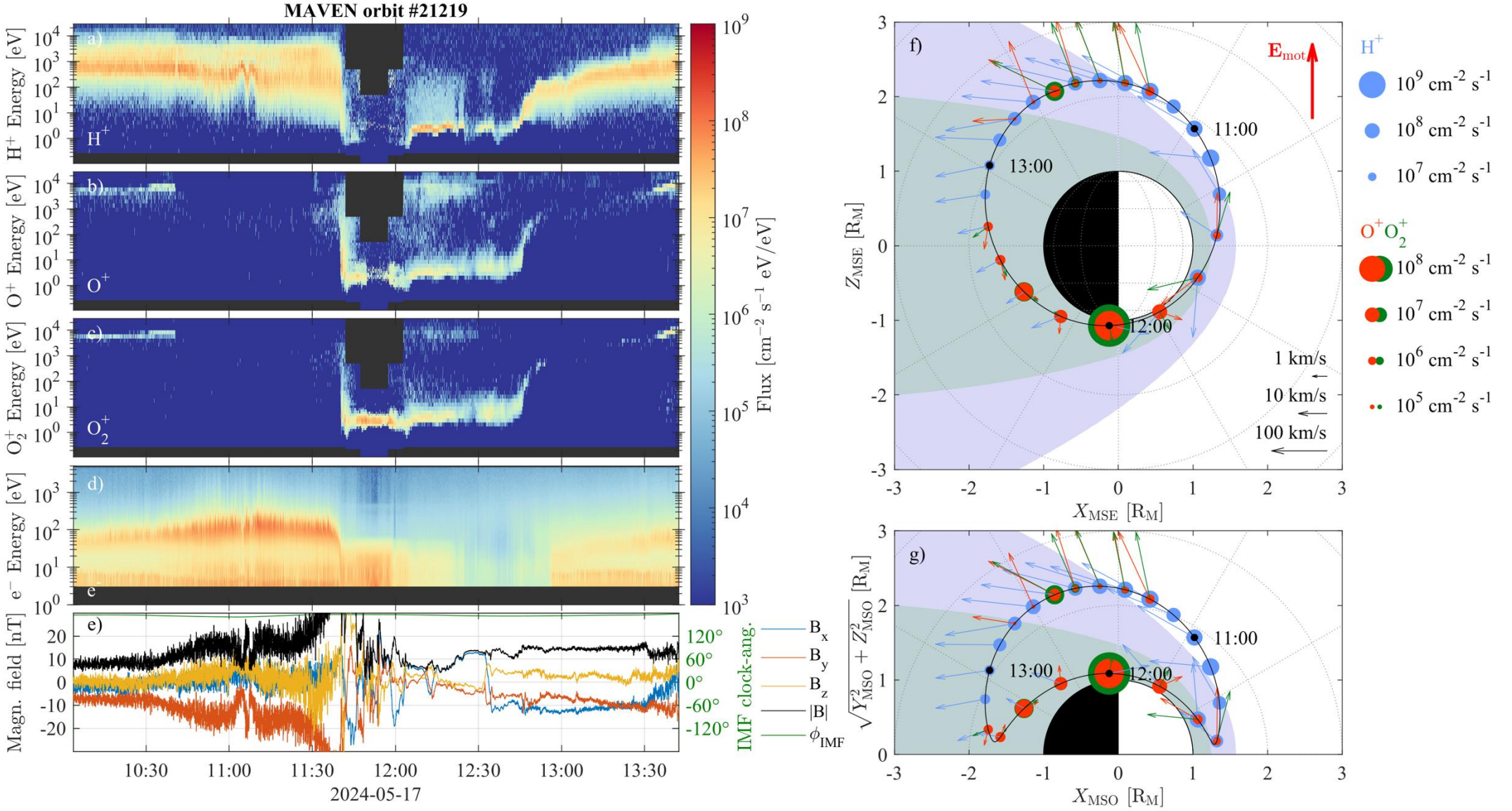
Ramstad et al. (2023)

- At Mars, ~80% of atmospheric ions escape through the tail
- MAVEN's orbit was ideal for measuring ions escaping through the deep tail
- Mars Express' orbit was ideal for simultaneously measuring the upstream solar wind

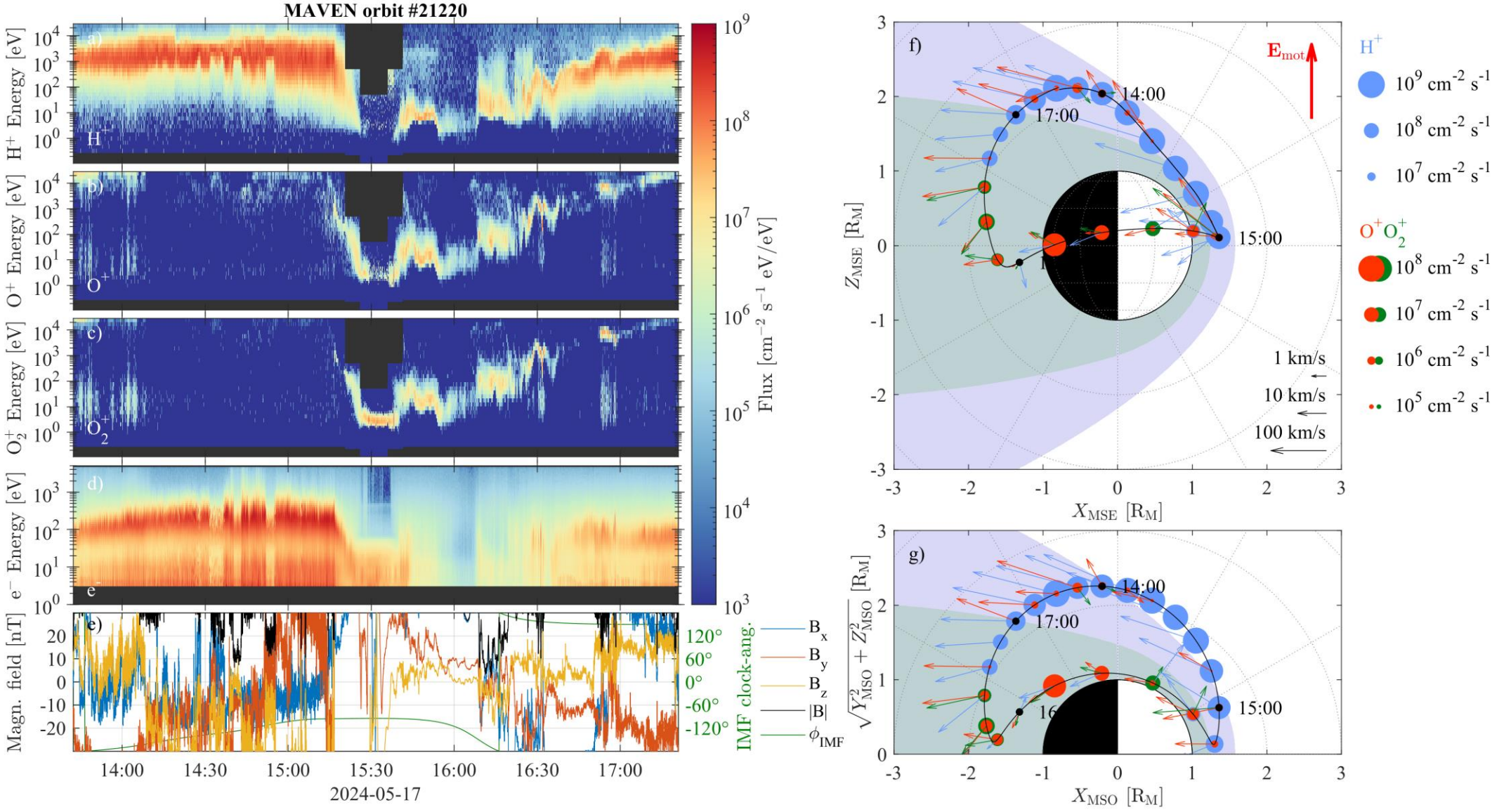
Before impact



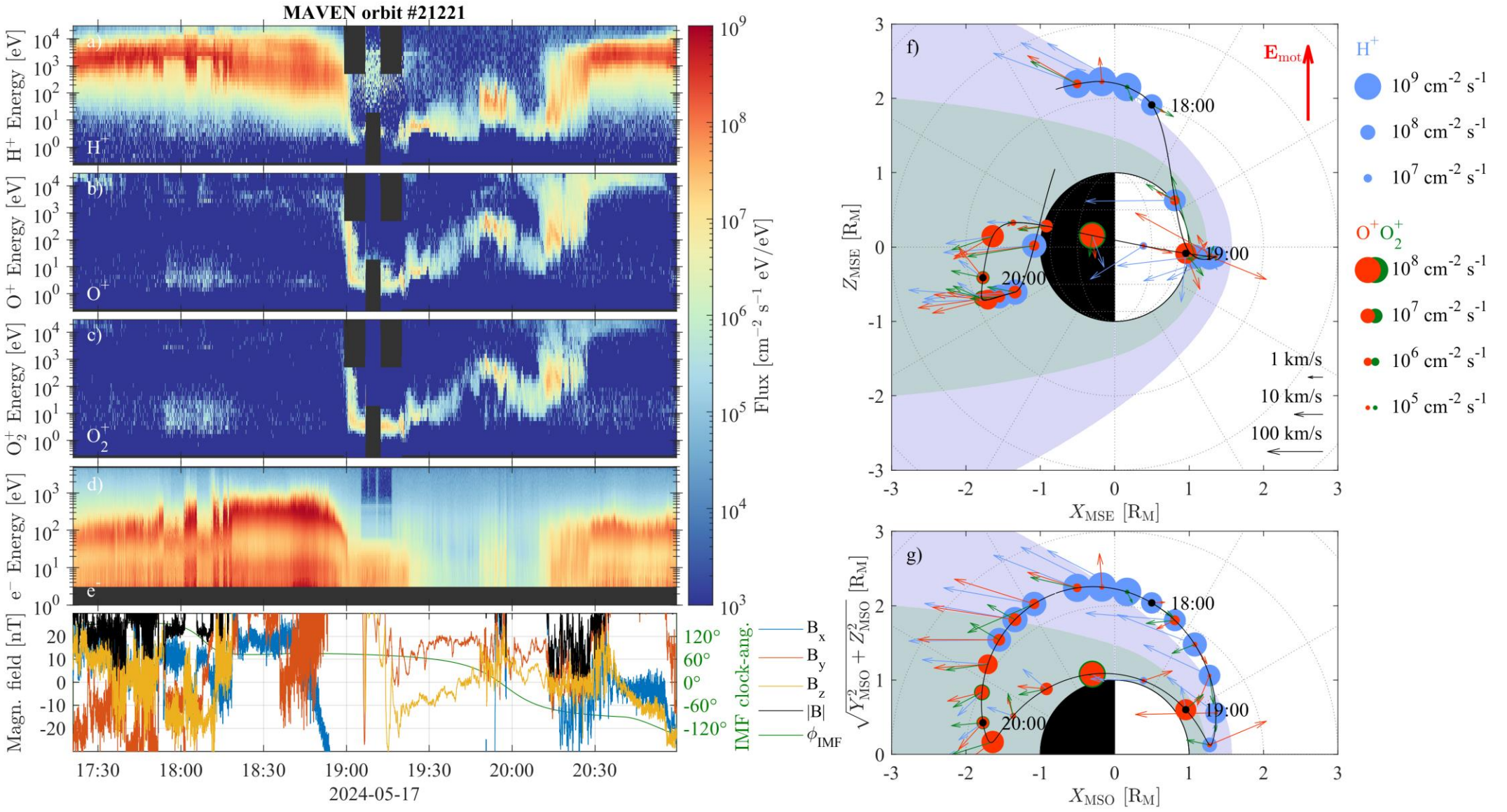
Before impact



Impact


MAVEN orbit #21220
H+ Energy [eV]
O+ Energy [eV]
O2+ Energy [eV]
e− Energy [eV]
Magn. field [nT]
Flux [cm−2 s−1 eV/eV]
IMF clock-ang.
Bx
By
Bz
|B|
ϕIMF
120°
60°
0°
-60°
-120°
14:00
14:30
15:00
15:30
16:00
16:30
17:00
2024-05-17
f)
g)
Emot
14:00
15:00
17:00
1 km/s
10 km/s
100 km/s
ZMSE [RM]
XMSE [RM]
XMSO [RM]
H+
O+O2+
10^9 cm^-2 s^-1
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
10^6 cm^-2 s^-1
10^5 cm^-2 s^-1

ICME


MAVEN orbit #21221
a)
H+
H+ Energy [eV]
b)
O+
O+ Energy [eV]
c)
O2+
O2+ Energy [eV]
d)
e−
e− Energy [eV]
Flux [cm−2 s−1 eV/eV]
Magn. field [nT]
IMF clock-ang.
120°
60°
0°
-60°
-120°
Bx
By
Bz
|B|
ϕIMF
17:30
18:00
18:30
19:00
19:30
20:00
20:30
2024-05-17
f)
Emot
18:00
19:00
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1 km/s
10 km/s
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ZMSE [RM]
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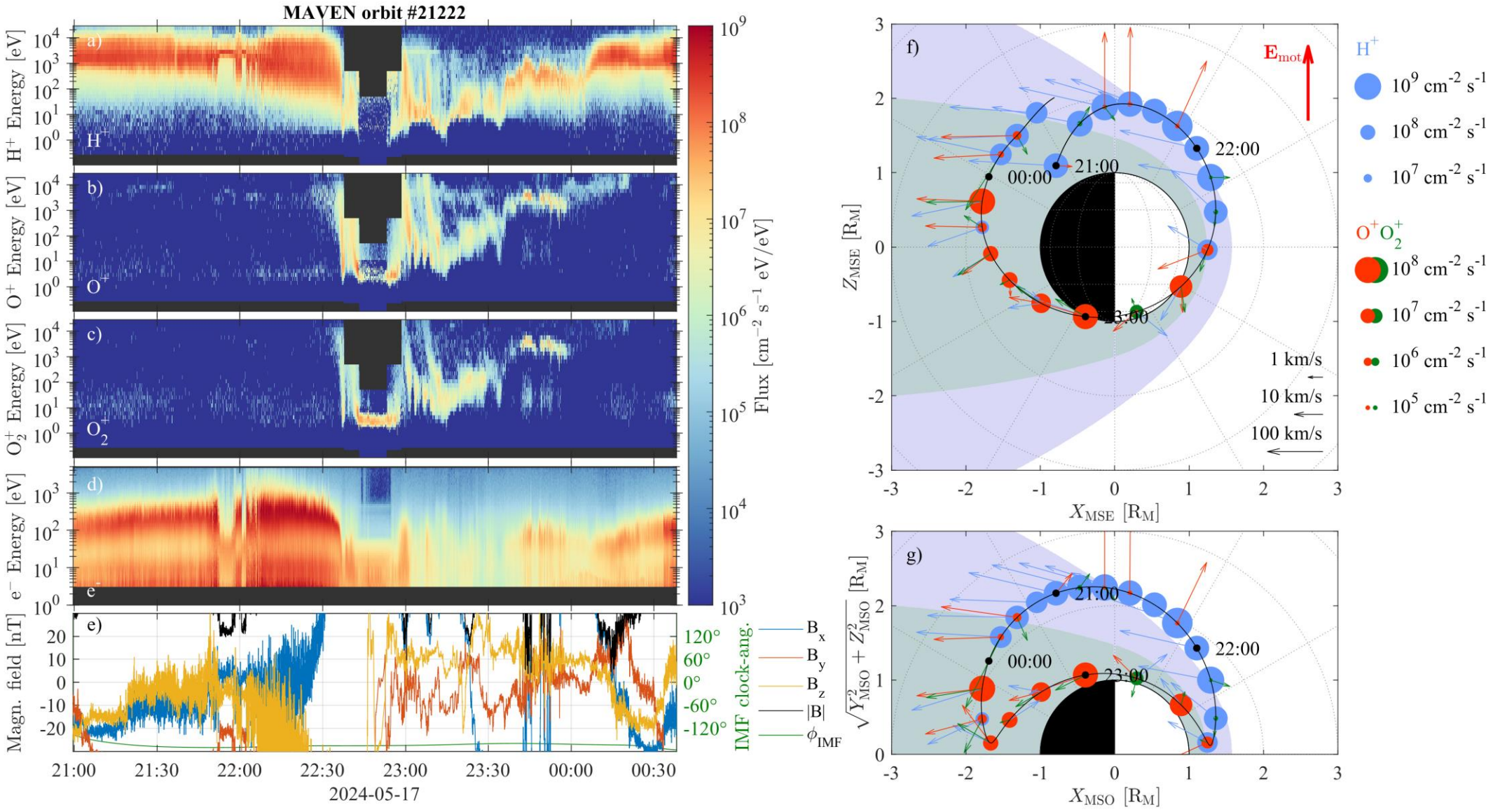
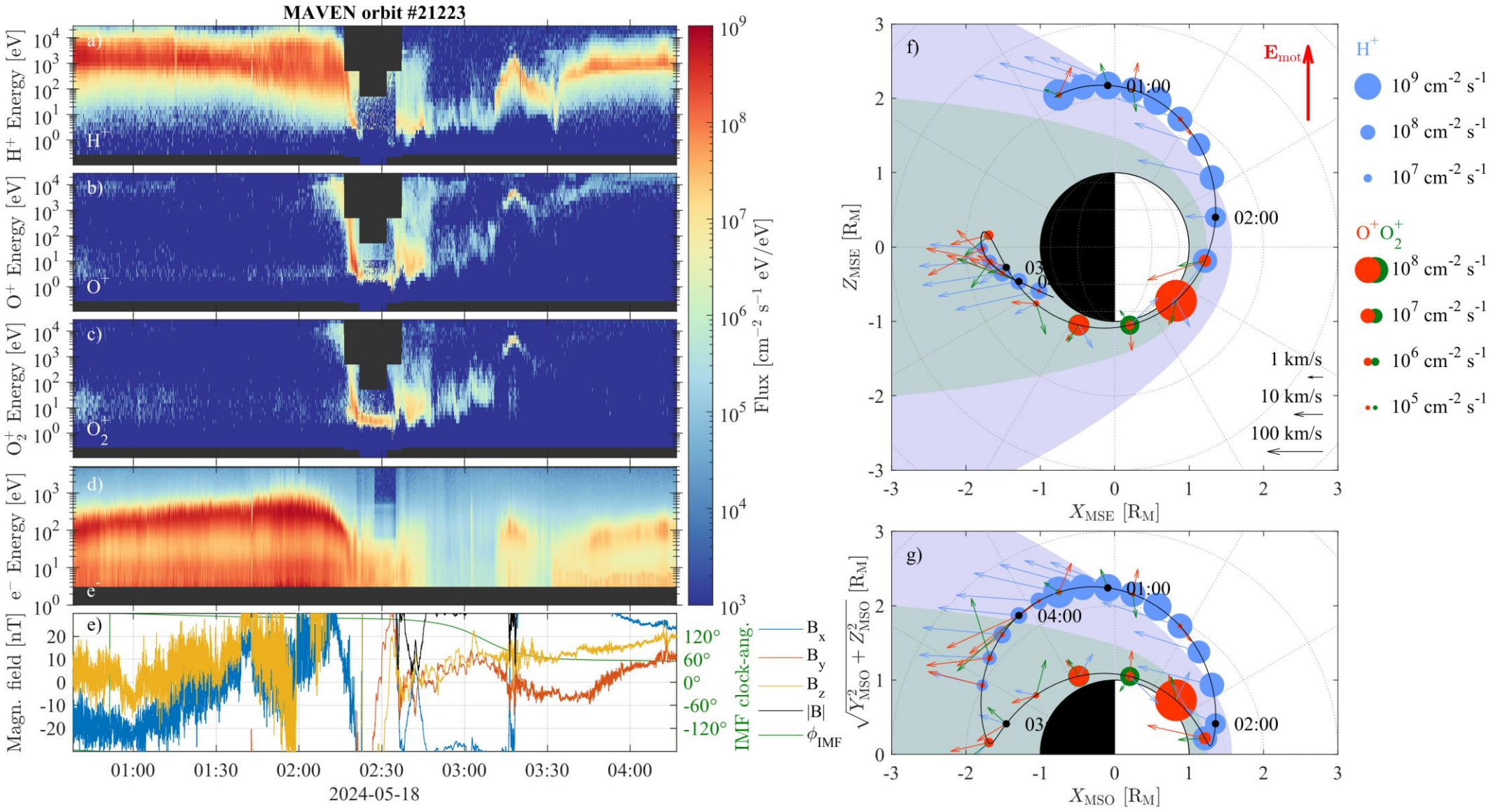
H+
10^9 cm^-2 s^-1
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
O+O2+
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
10^6 cm^-2 s^-1
10^5 cm^-2 s^-1
g)
18:00
19:00
20:00
√(YMSO2 + ZMSO2) [RM]
XMSO [RM]

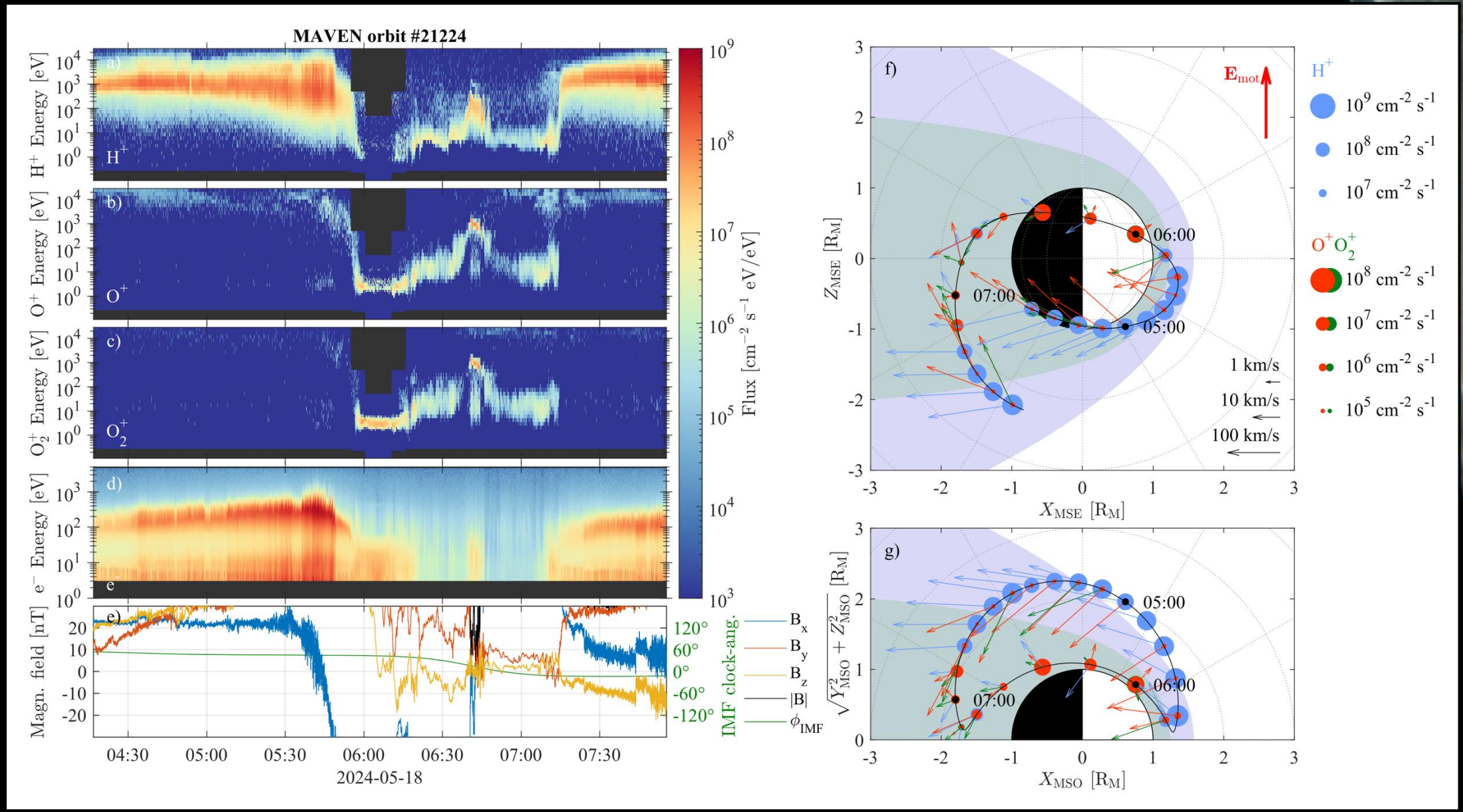
ICME


MAVEN orbit #21222
a)
H+
H+ Energy [eV]
b)
O+
O+ Energy [eV]
c)
O2+
O2+ Energy [eV]
d)
e−
e− Energy [eV]
e)
Magn. field [nT]
Flux [cm−2 s−1 eV/eV]
IMF clock-ang.
120°
60°
0°
-60°
-120°
Bx
By
Bz
|B|
ϕIMF
21:00
21:30
22:00
22:30
23:00
23:30
00:00
00:30
2024-05-17
f)
Emot
00:00
21:00
22:00
23:00
1 km/s
10 km/s
100 km/s
ZMSE [RM]
XMSE [RM]
H+
10^9 cm^-2 s^-1
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
O+O2+
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
10^6 cm^-2 s^-1
10^5 cm^-2 s^-1
g)
00:00
21:00
22:00
23:00
√(YMSO2 + ZMSO2) [RM]
XMSO [RM]

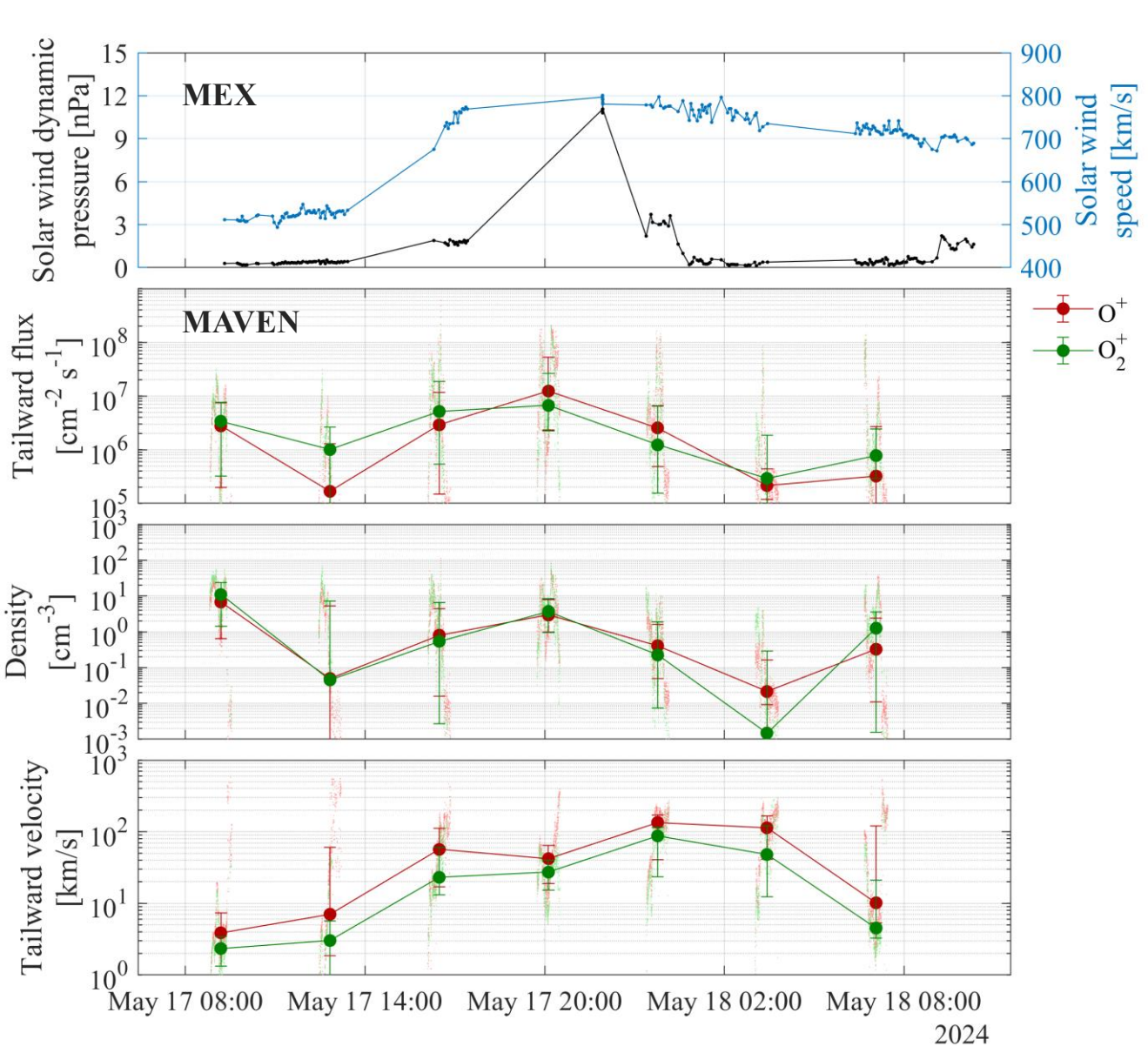
ICME


MAVEN orbit #21223
a)
H+
H+ Energy [eV]
b)
O+
O+ Energy [eV]
c)
O2+
O2+ Energy [eV]
d)
e−
e− Energy [eV]
e)
Magn. field [nT]
Flux [cm−2 s−1 eV/eV]
IMF clock-ang.
120°
60°
0°
-60°
-120°
Bx
By
Bz
|B|
ϕIMF
01:00
01:30
02:00
02:30
03:00
03:30
04:00
2024-05-18
f)
Emot
01:00
02:00
03:00
1 km/s
10 km/s
100 km/s
ZMSE [RM]
XMSE [RM]
H+
10^9 cm^-2 s^-1
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
O+O2+
10^8 cm^-2 s^-1
10^7 cm^-2 s^-1
10^6 cm^-2 s^-1
10^5 cm^-2 s^-1
g)
01:00
04:00
02:00
03:00
√(YMSO2 + ZMSO2) [RM]
XMSO [RM]

After impact

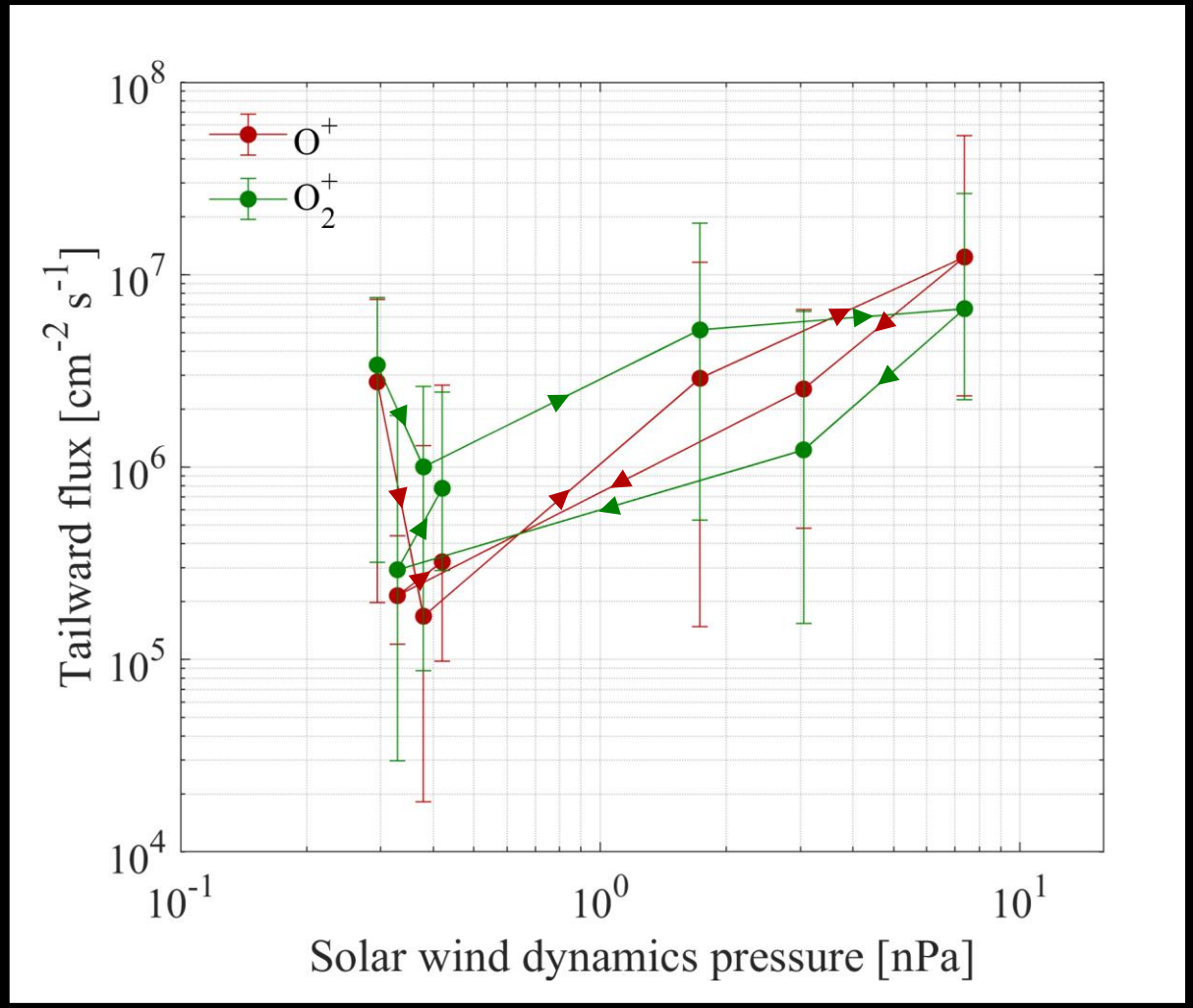


Timeline



- Tailward O^+, O_2^+ fluxes increase at ICME onset, reduce to below pre-ICME levels after impact
- O^+, O_2^+ velocities increase steadily
- The reduction in flux appears due to evacuation of plasma in the tail

Solar Wind as a Driver of Ion Escape



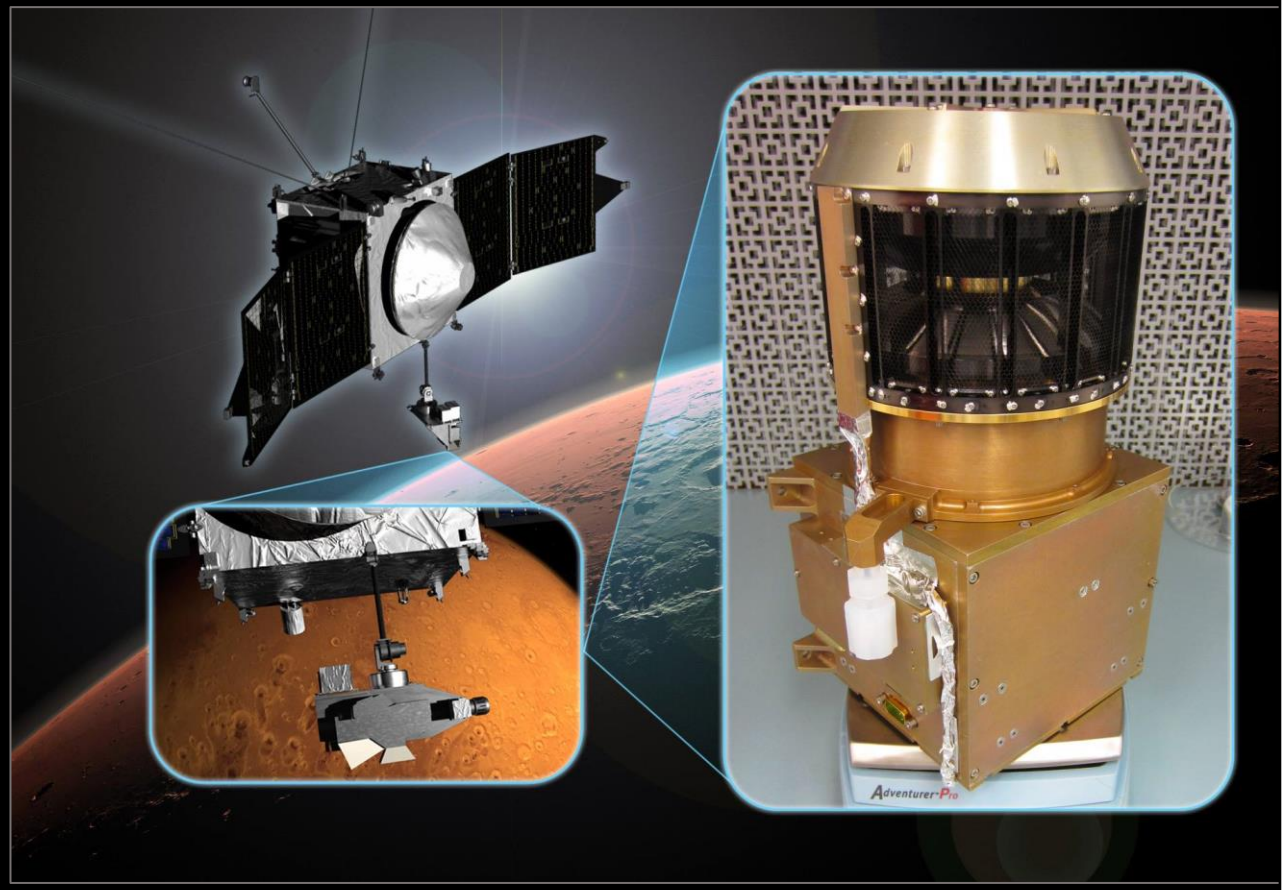
- The intense ICME solar wind drove a momentary increase in O^+, O_2^+ fluxes
- O_2^+ flux saturates and is lower for the descending phase of the event
- Ions cannot be resupplied at the rate they are energized to escape

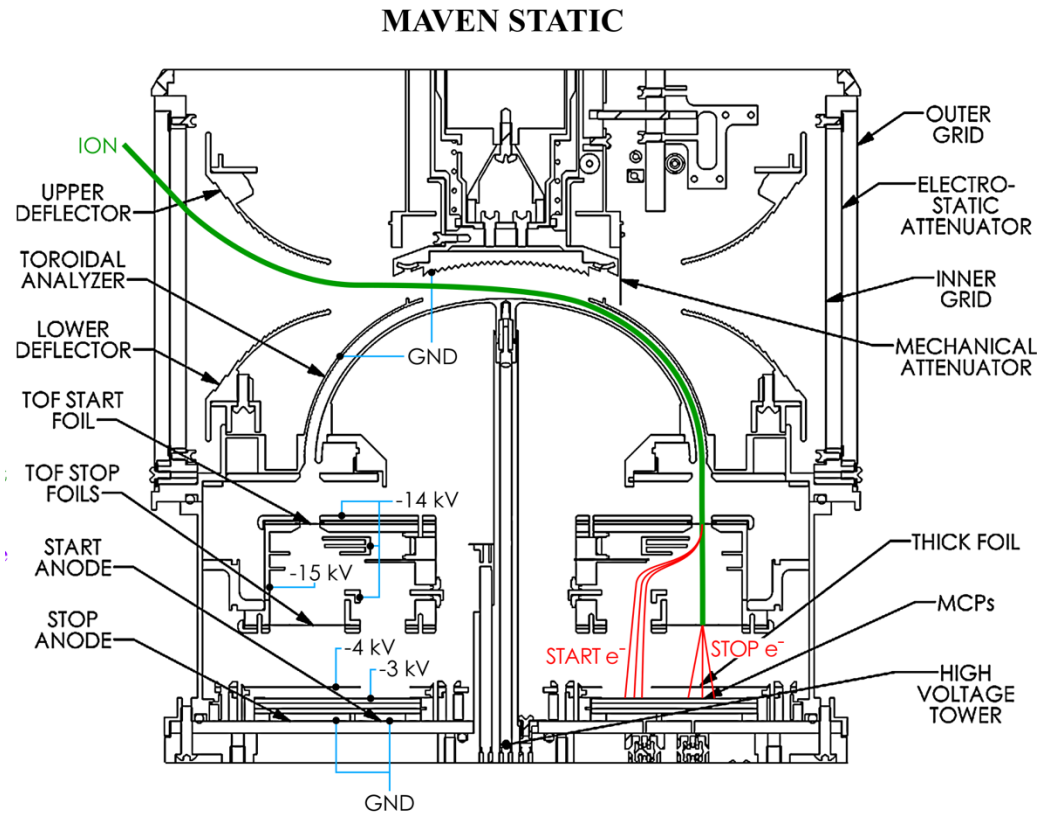
Summary

- An ICME impacted Mars on May 17, 2024, local effects observed by MAVEN and Mars Express
- O_2^+ escaping fluxes show a hysteresis in response to the ICME conditions with fluxes lower for the latter part of the impact, despite similar dynamic pressure
- Tailward velocities of escaping ions increase with time, reduction in flux appears due to evacuation of plasma in the tail and insufficient resupply feeding the process

Extra

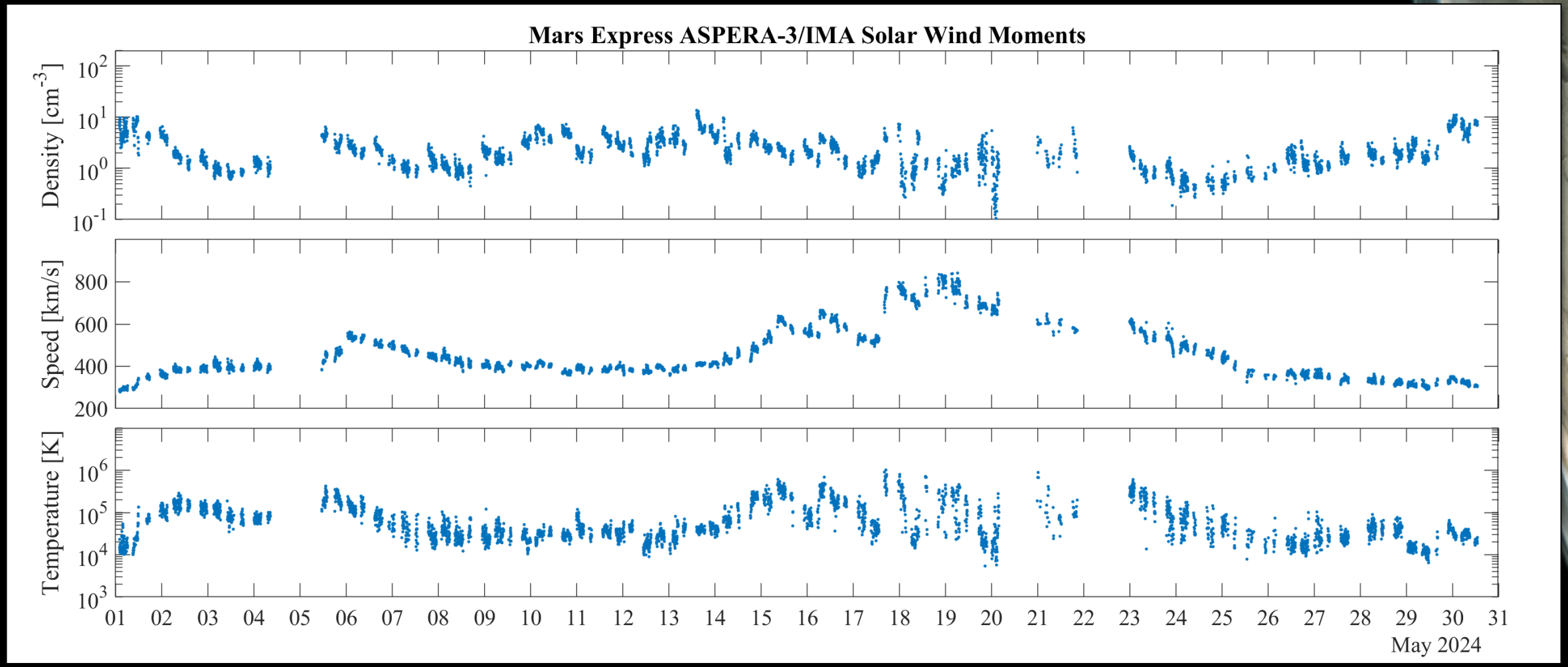
MAVEN/STATIC



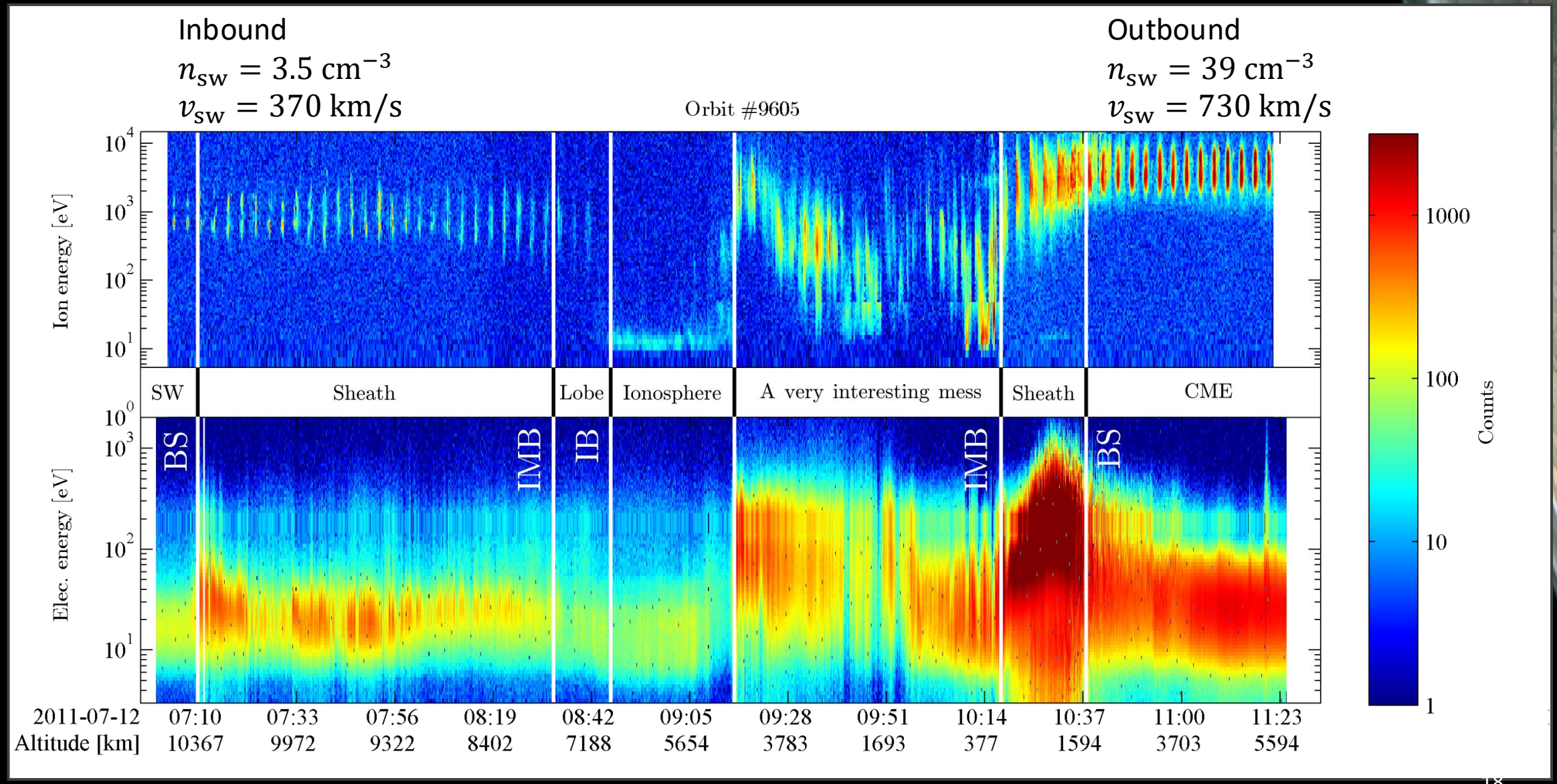


Measurement:
Differential flux $j(\theta, \phi, E, m)$ $[\mathrm{cm}^{-2}\ \mathrm{s}^{-1}\ \mathrm{sr}^{-1}\ \mathrm{eV}^{-1}]$

May 2024 events

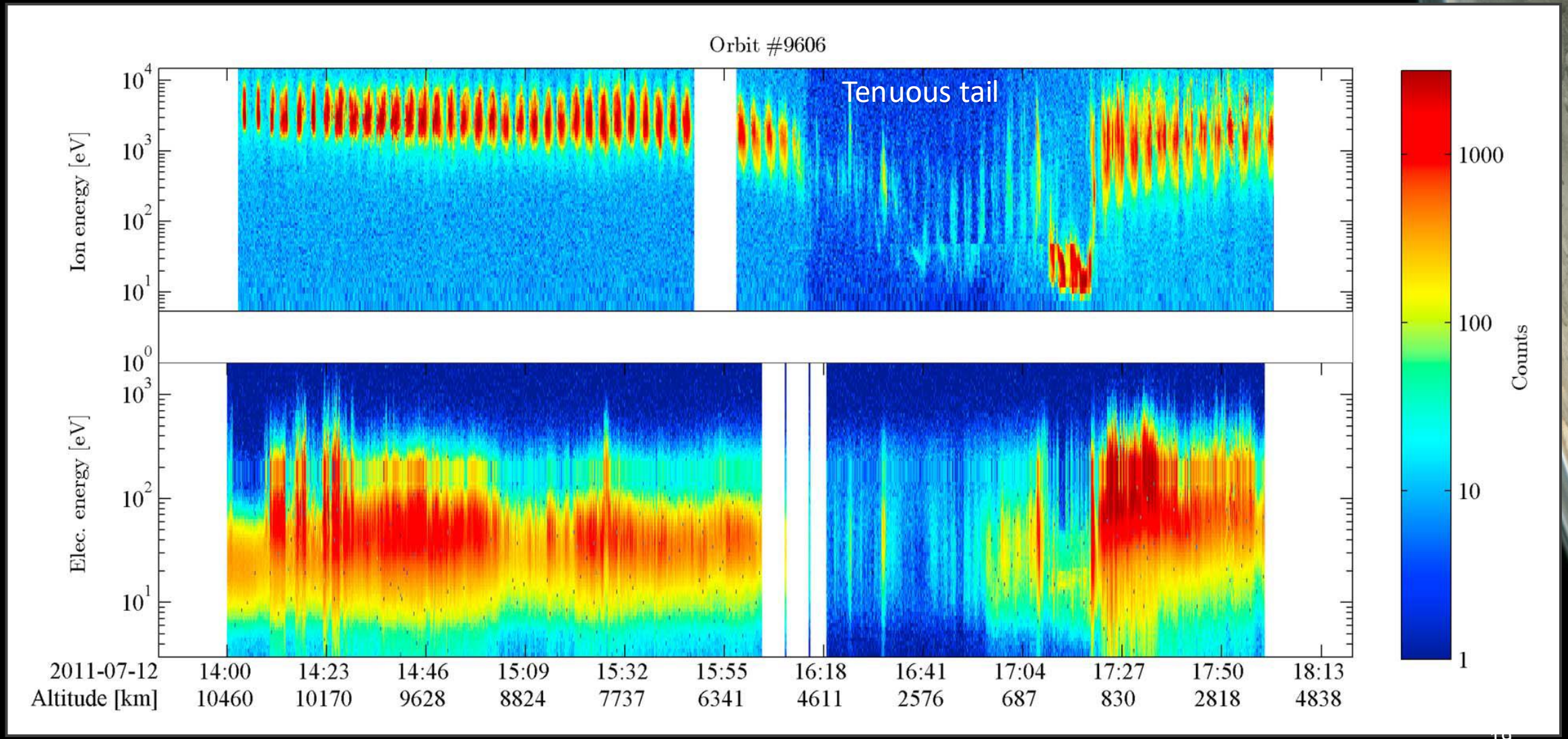


July 2011 Primordial Solar Wind Event



Ramstad et al. (2017)

July 2011 Primordial Solar Wind Event



Ramstad et al. (2017)