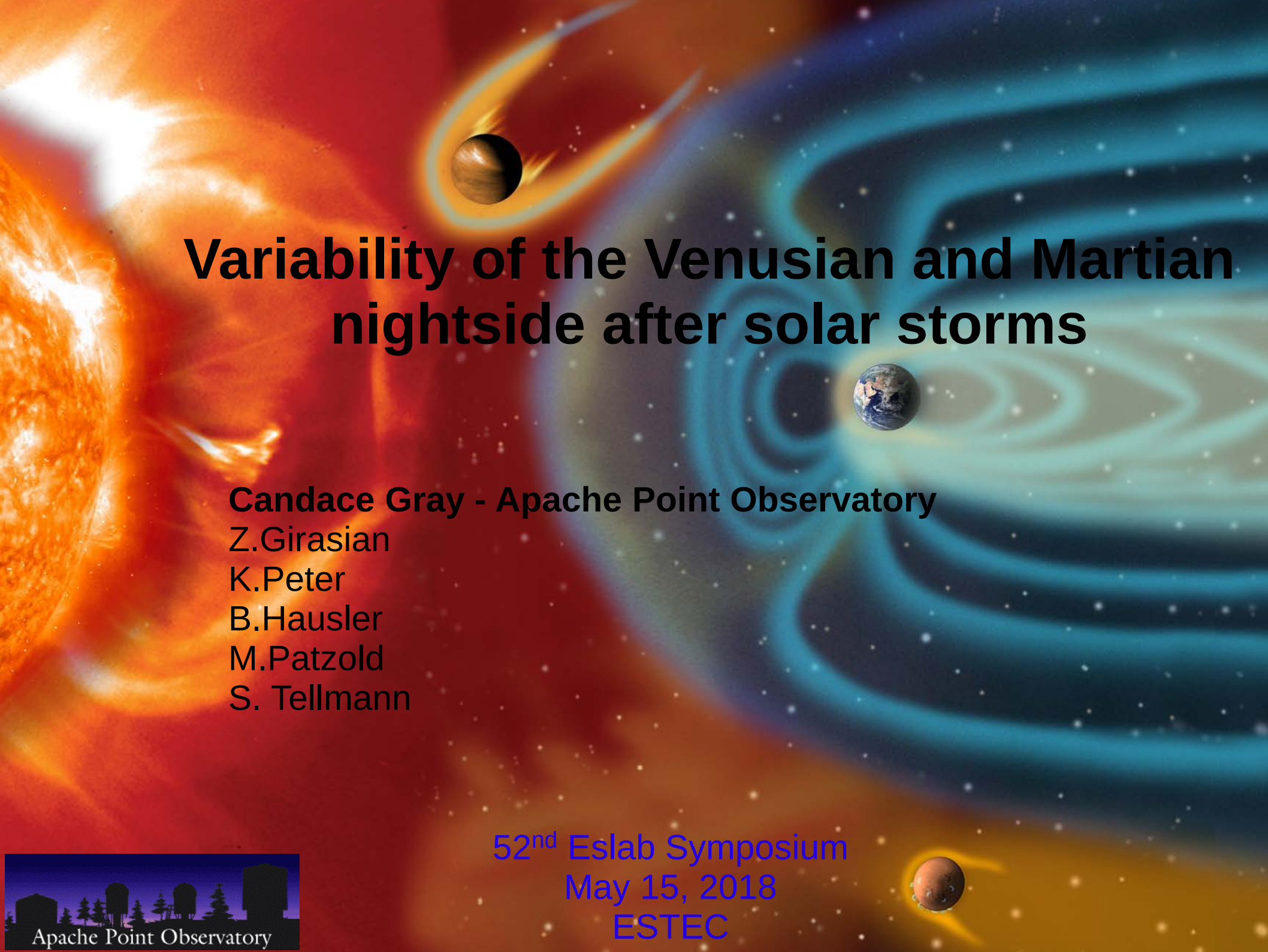


Variability of the Venusian and Martian nightside after solar storms

Candace Gray - Apache Point Observatory
Z.Girasian
K.Peter
B.Hausler
M.Patzold
S. Tellmann

52nd Eslab Symposium
May 15, 2018
ESTEC

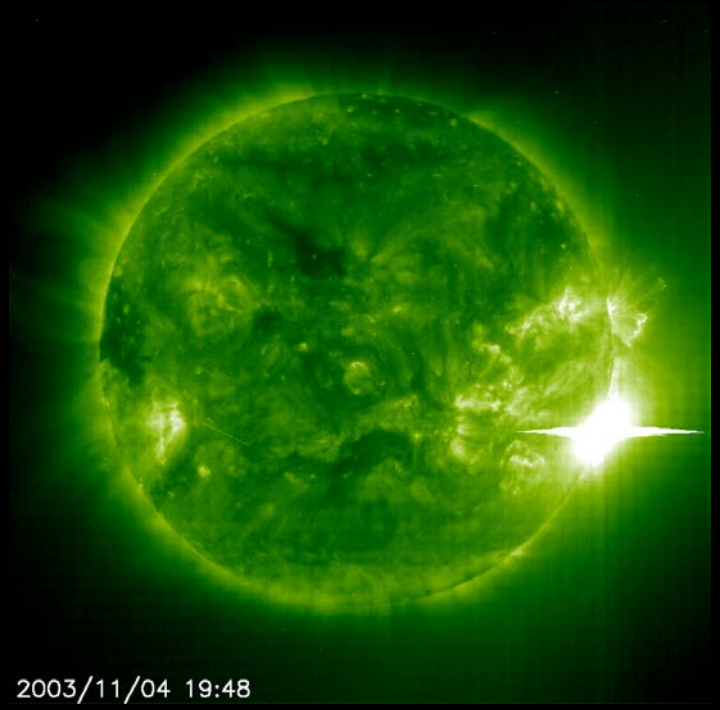
Apache Point Observatory

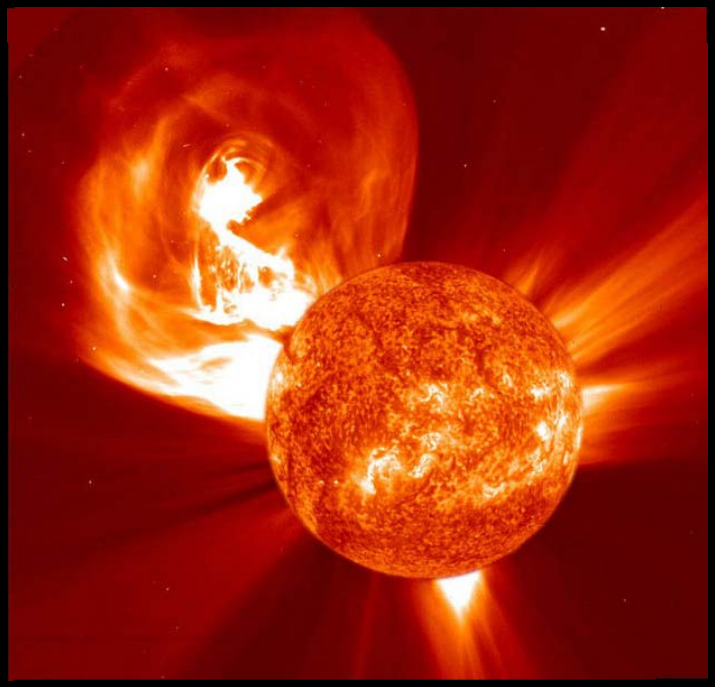
Importance of the upper atmosphere

- Things are highly variable!
- Flow dynamics
- Space weather interaction
- Comparative aeronomy
- Evolution

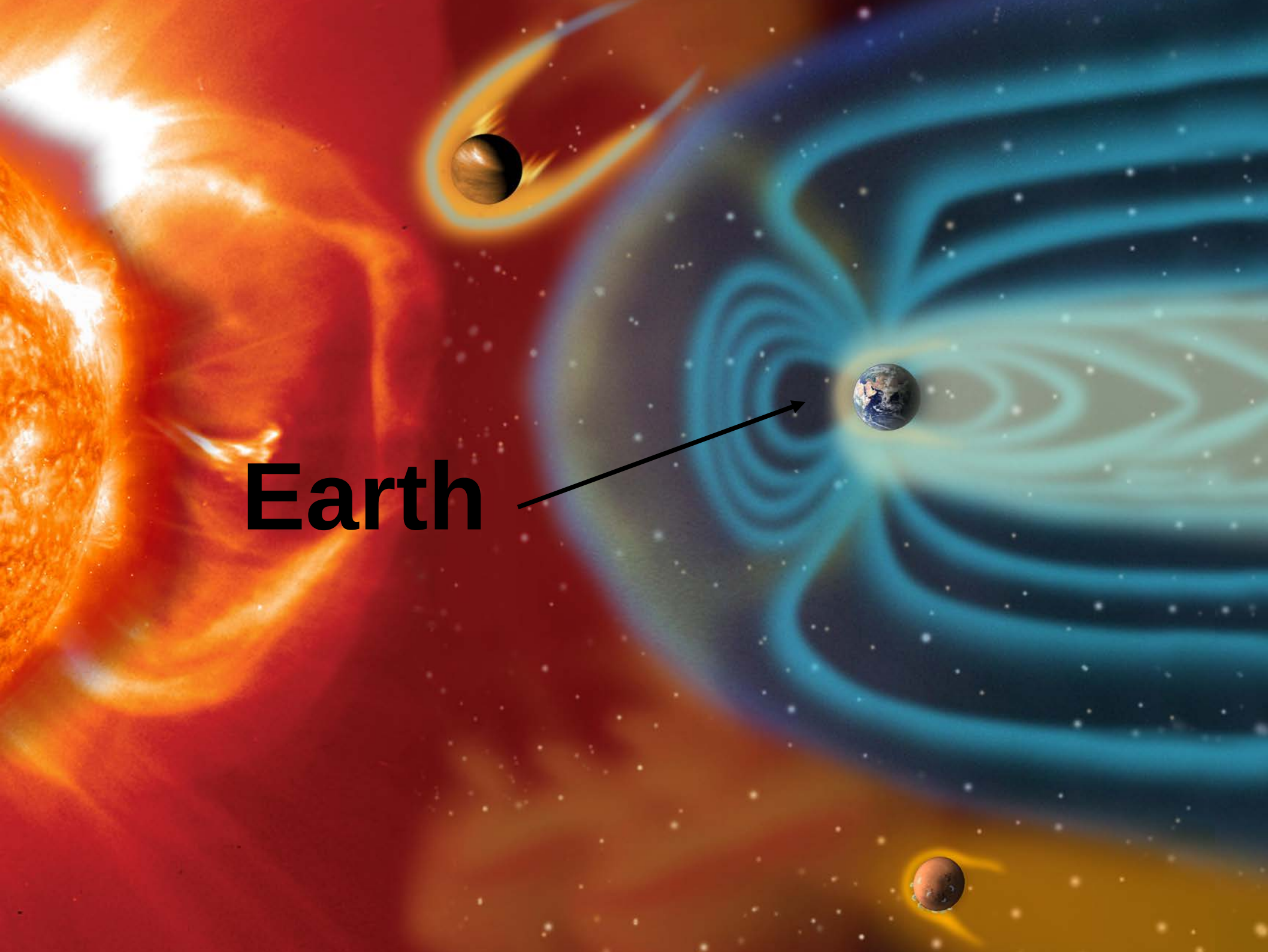
Solar Storms

- X-class solar flares
  - Strongest flares
  - Brightest EUV emission
  - Nightglow
  - Short duration (min - hours)





- Coronal mass ejections (CMEs)
  - Plasma ejection
  - Aurora
  - 1 - 2 day arrival time

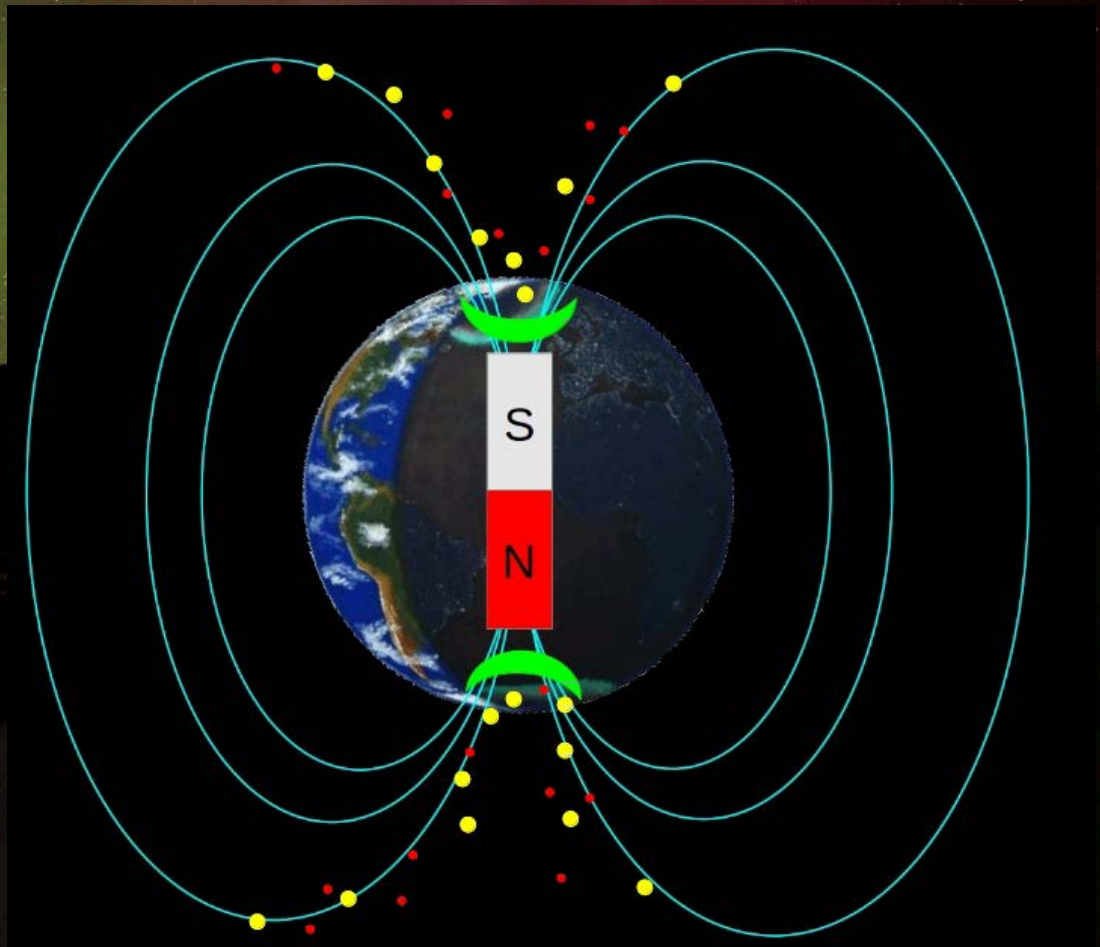

Earth

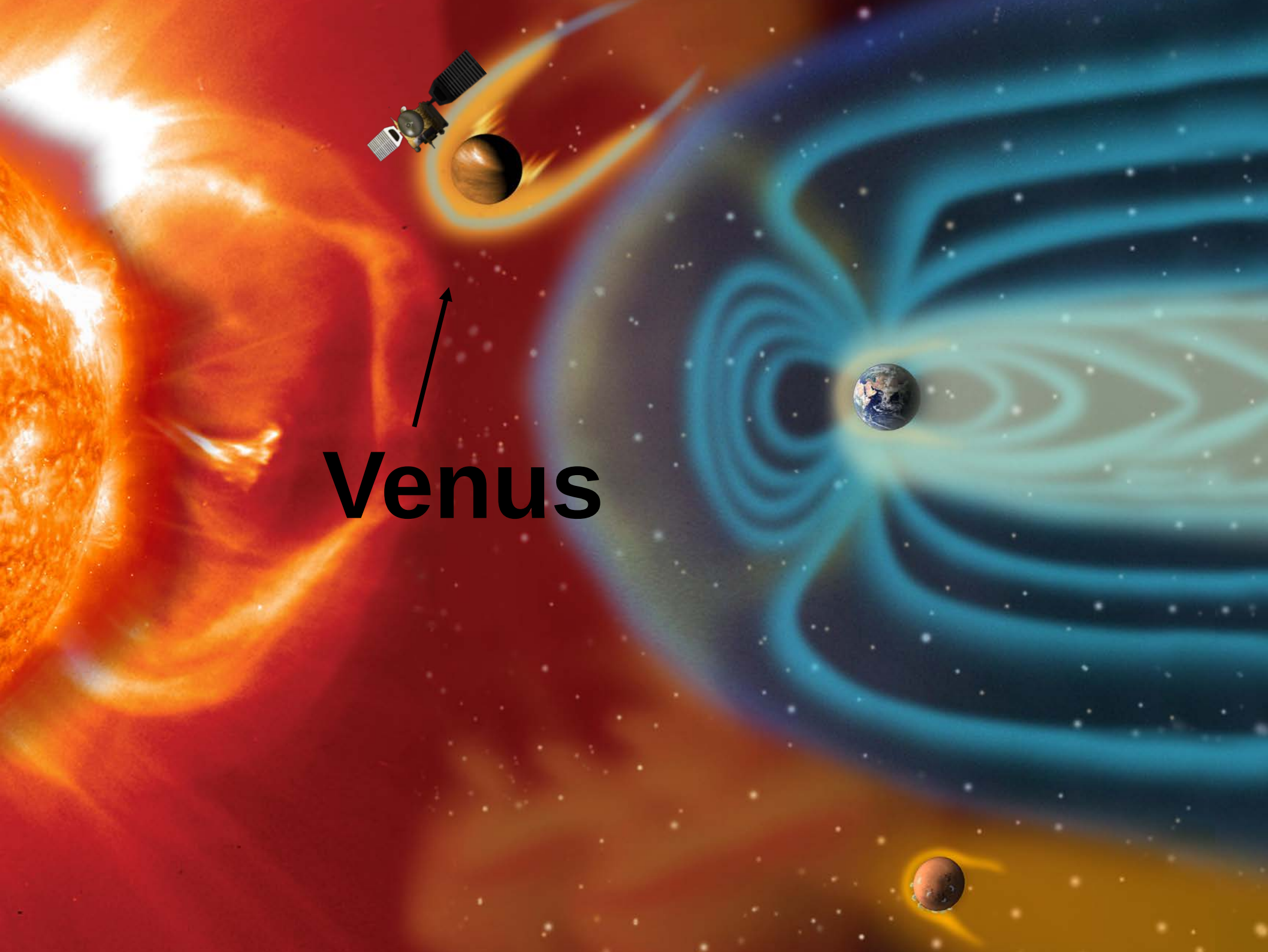
Aurora

- Particle precipitation magnetic field lines

  $O_2^+ + e \rightarrow O(^1S, ^1D) + O(^3P)$

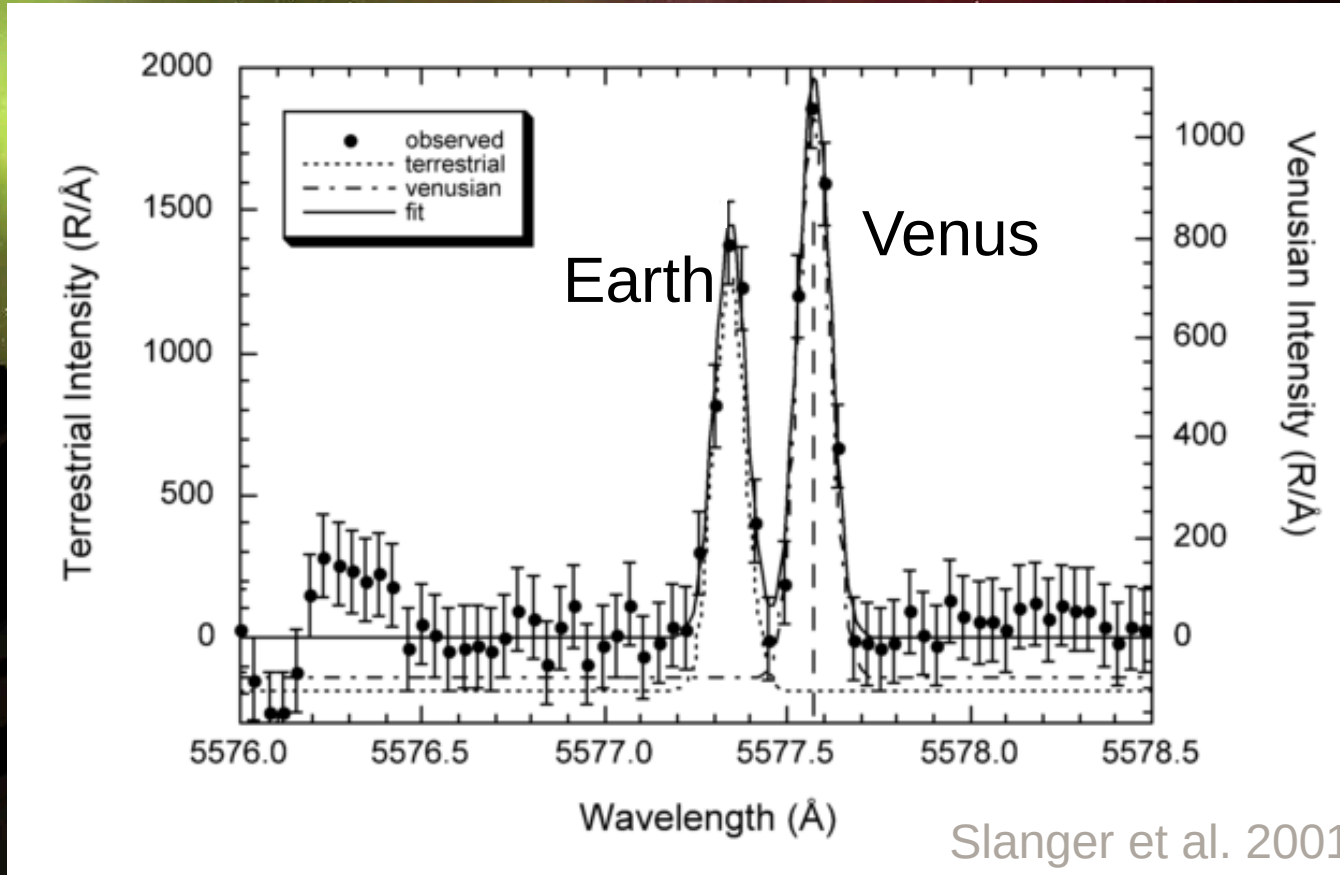
- Red – 630.0 nm
- Green – 557.7 nm
- Solar storms
- Tracer to space weather interactions




Venus

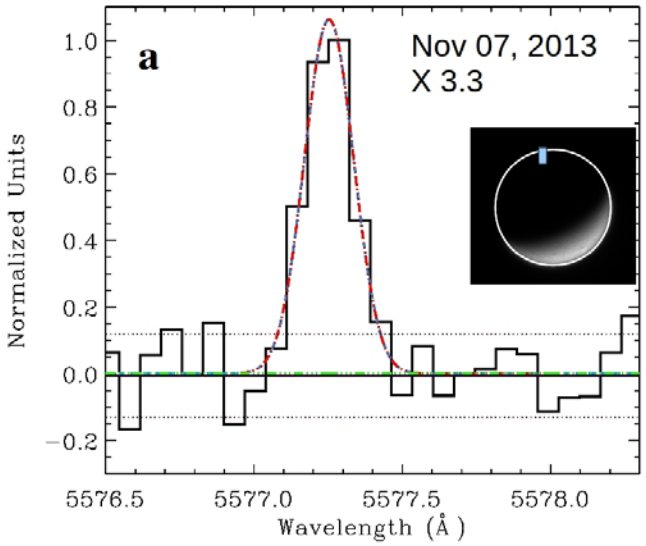
Aurora on Venus

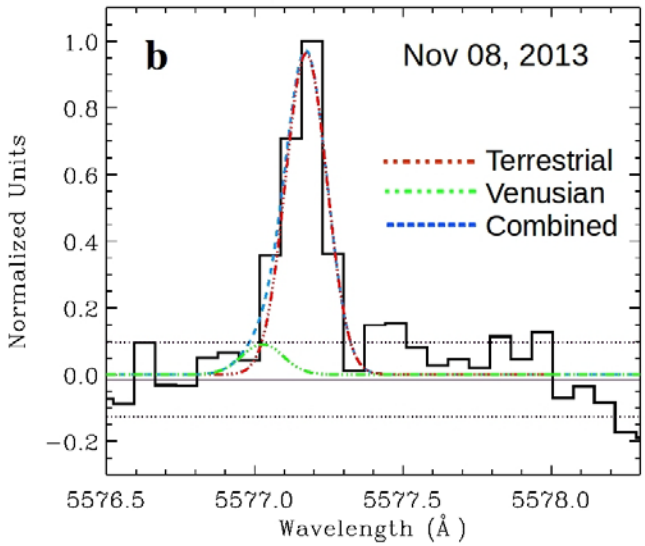
- 130.0 nm oxygen emission PVO
- Oxygen 557.7 nm
  - Highly variable
  - Solar storms
- Tracer
- No red line

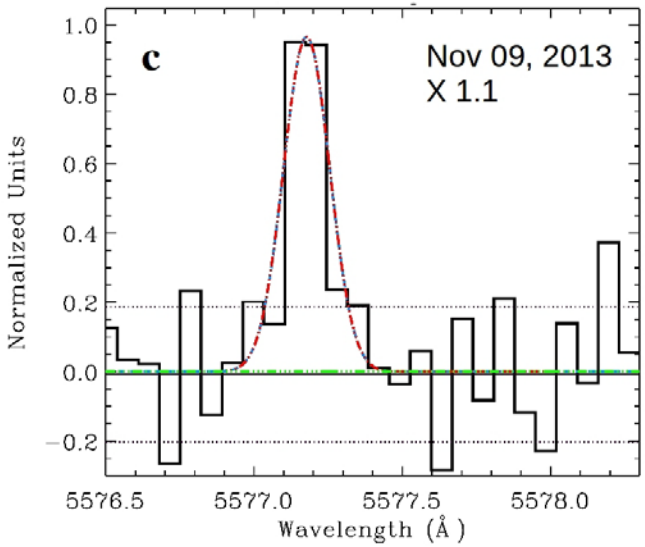


Slanger et al. 2001

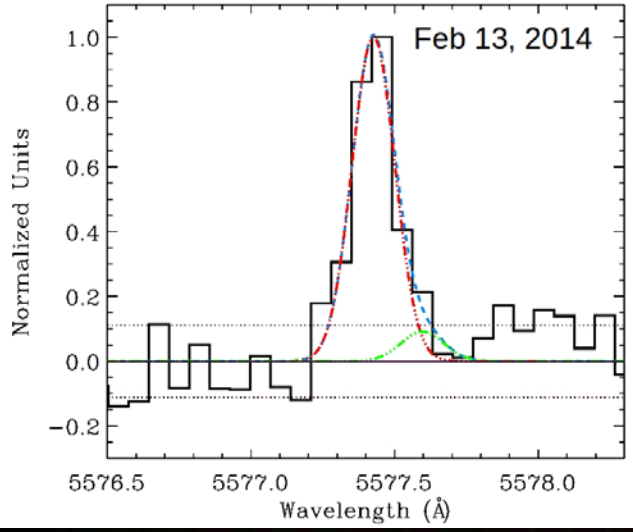
2013 - Isolated X Flare

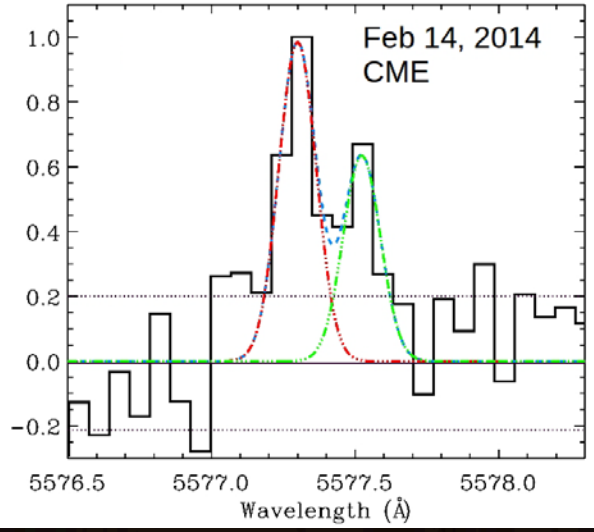


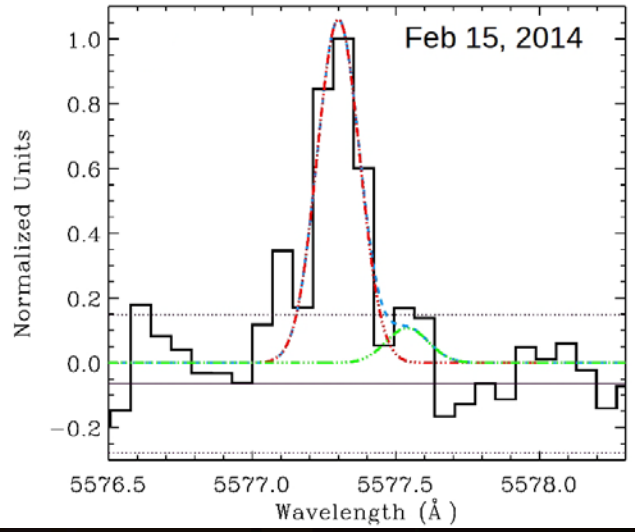




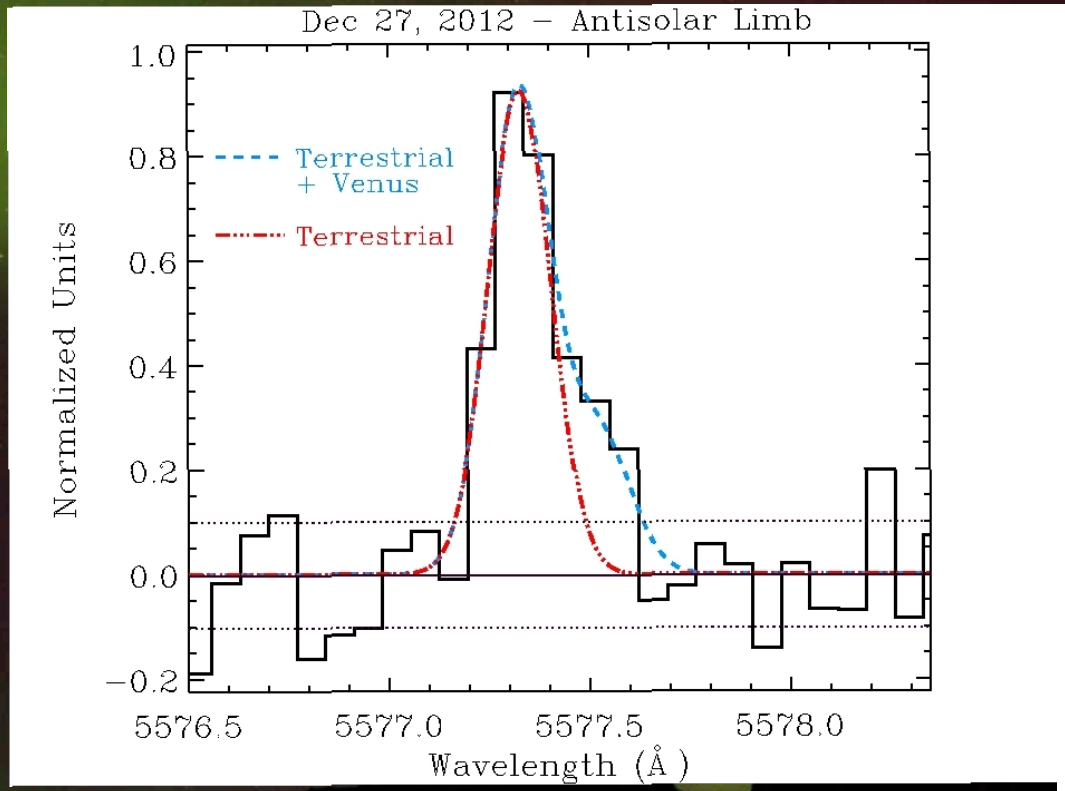
2014 – Isolated CME

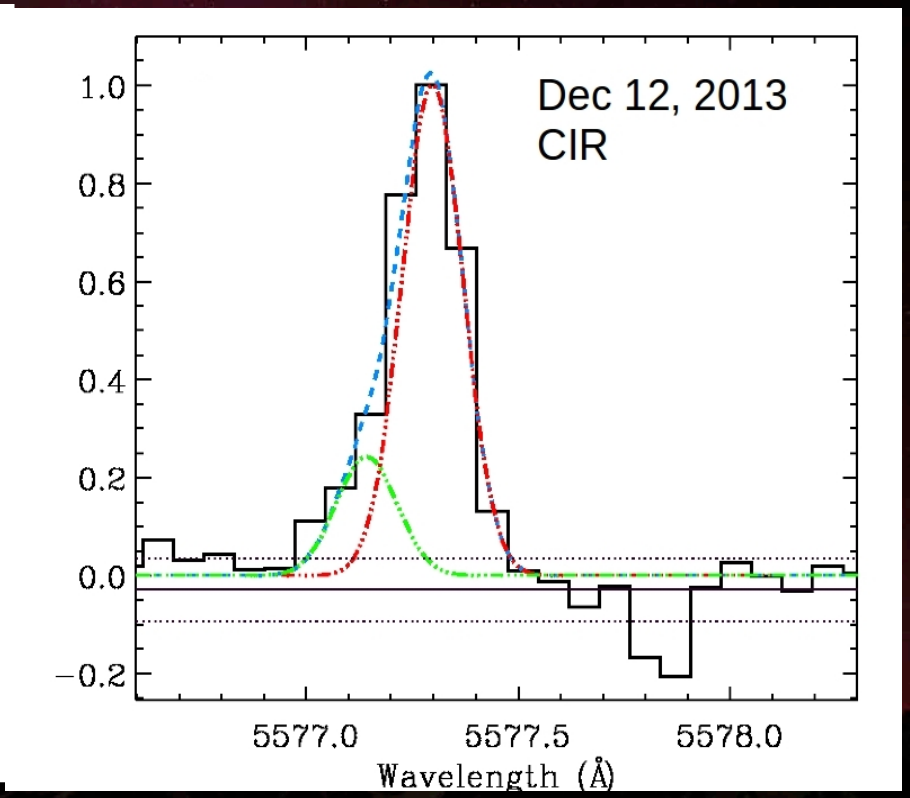






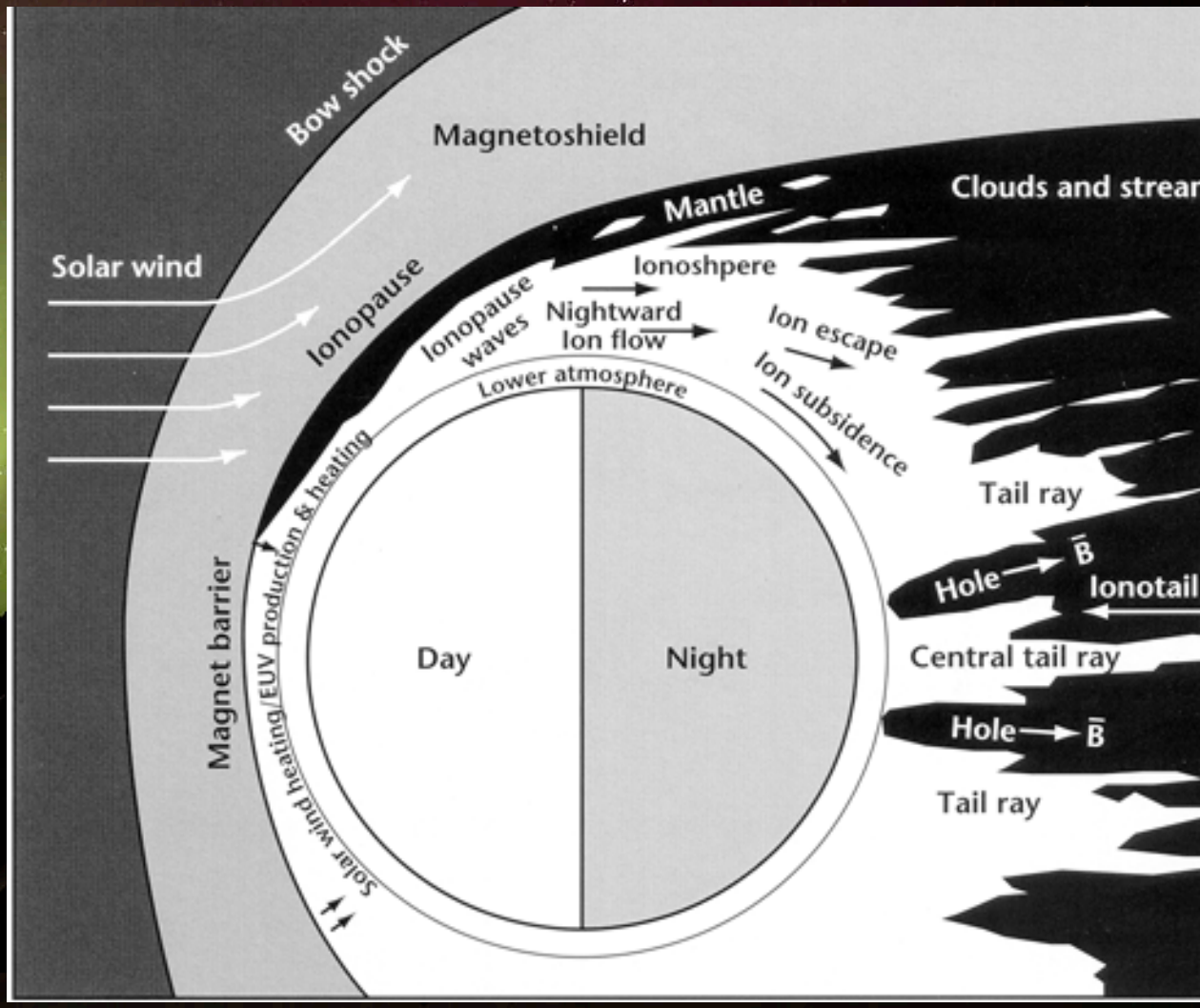
Isolated CIR





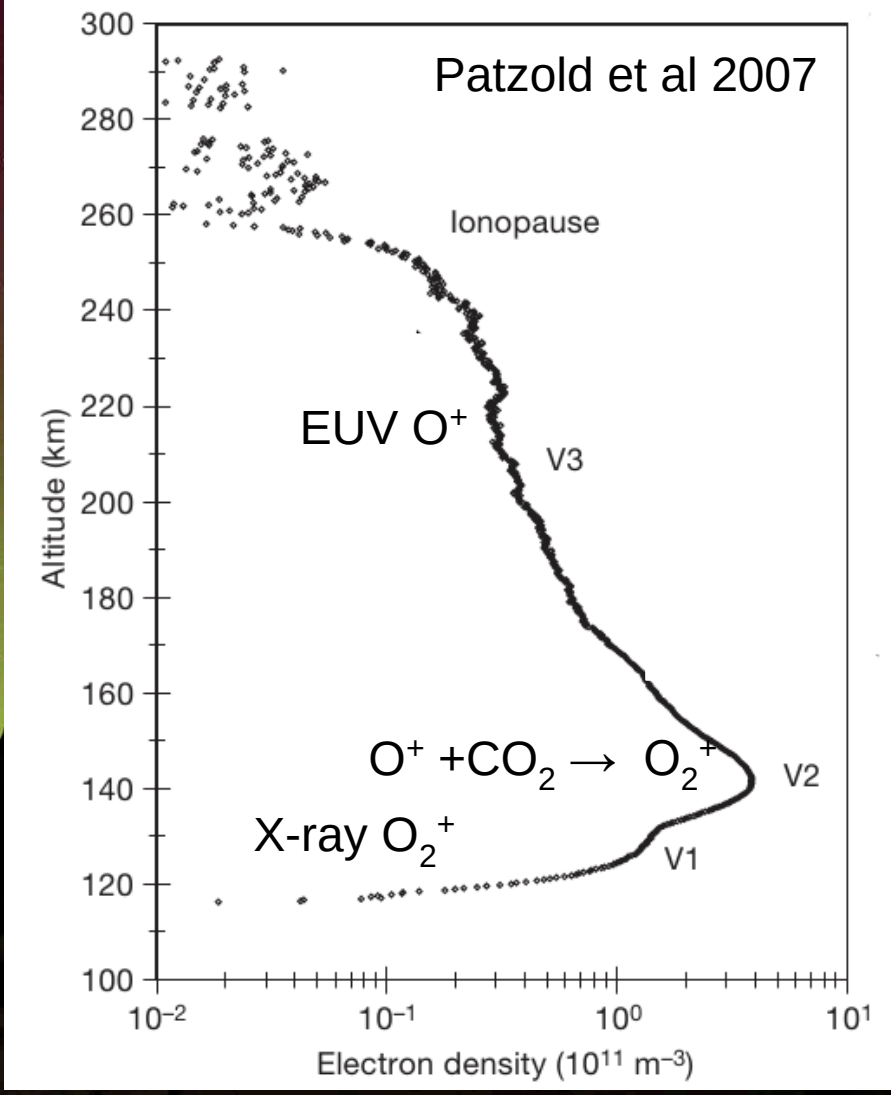
Aurora on Venus

- What's going on?
- Electron precipitation vs. dayside flow
  - Timing < 24 hr
  - SS-AS flow
  - No emission after isolated X-flare
- Chemistry



Venus Ionosphere

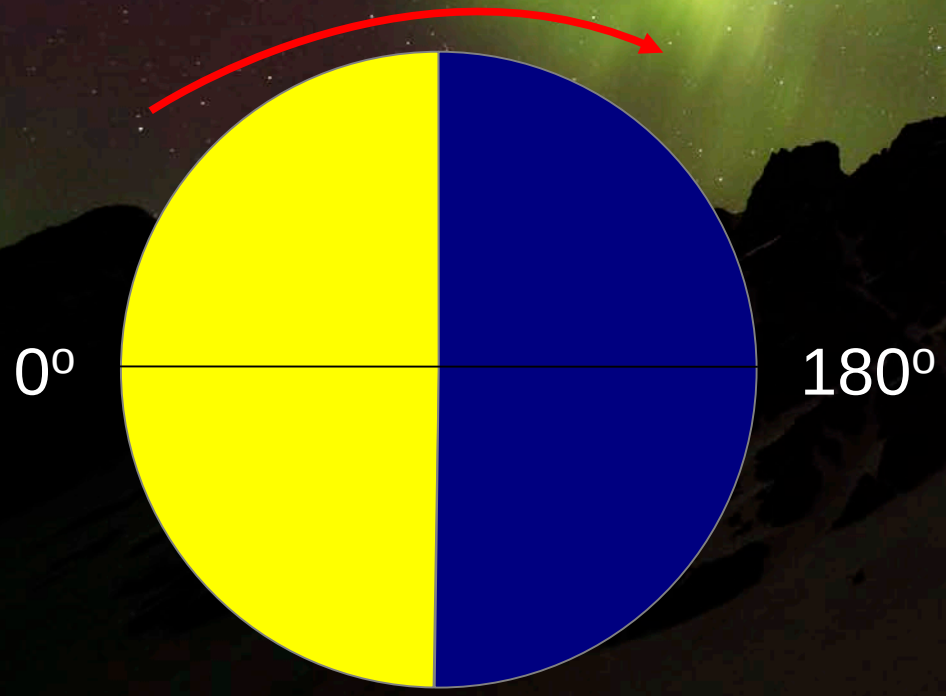
- Venus dayside ionosphere
  - V2 layer
    - 140 km
    - $O^+ + CO_2 \rightarrow O_2^+$
  - V1 layer
    - 125 km
    - O_2^+ (soft x-ray ionization)
- Distinct constant layers

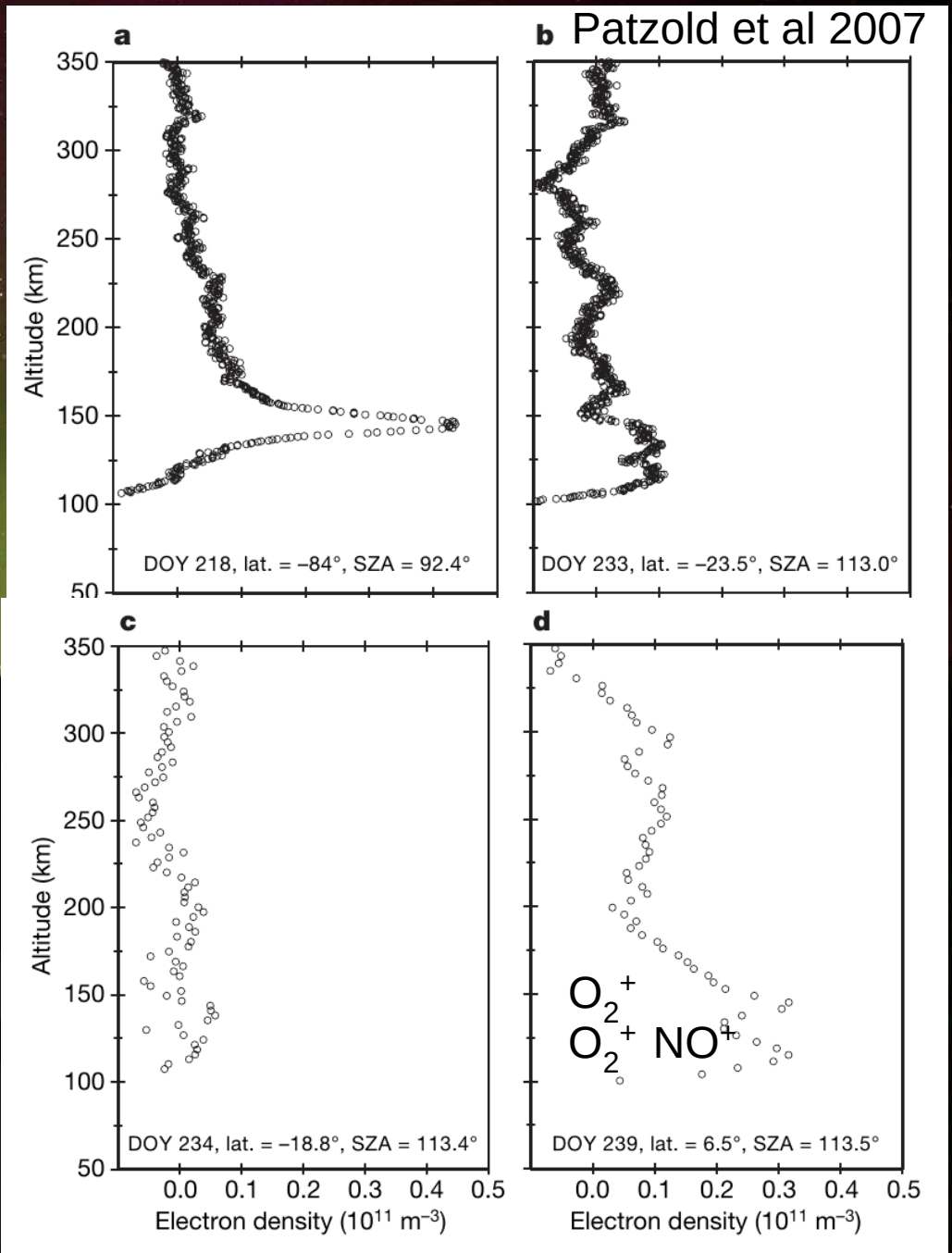


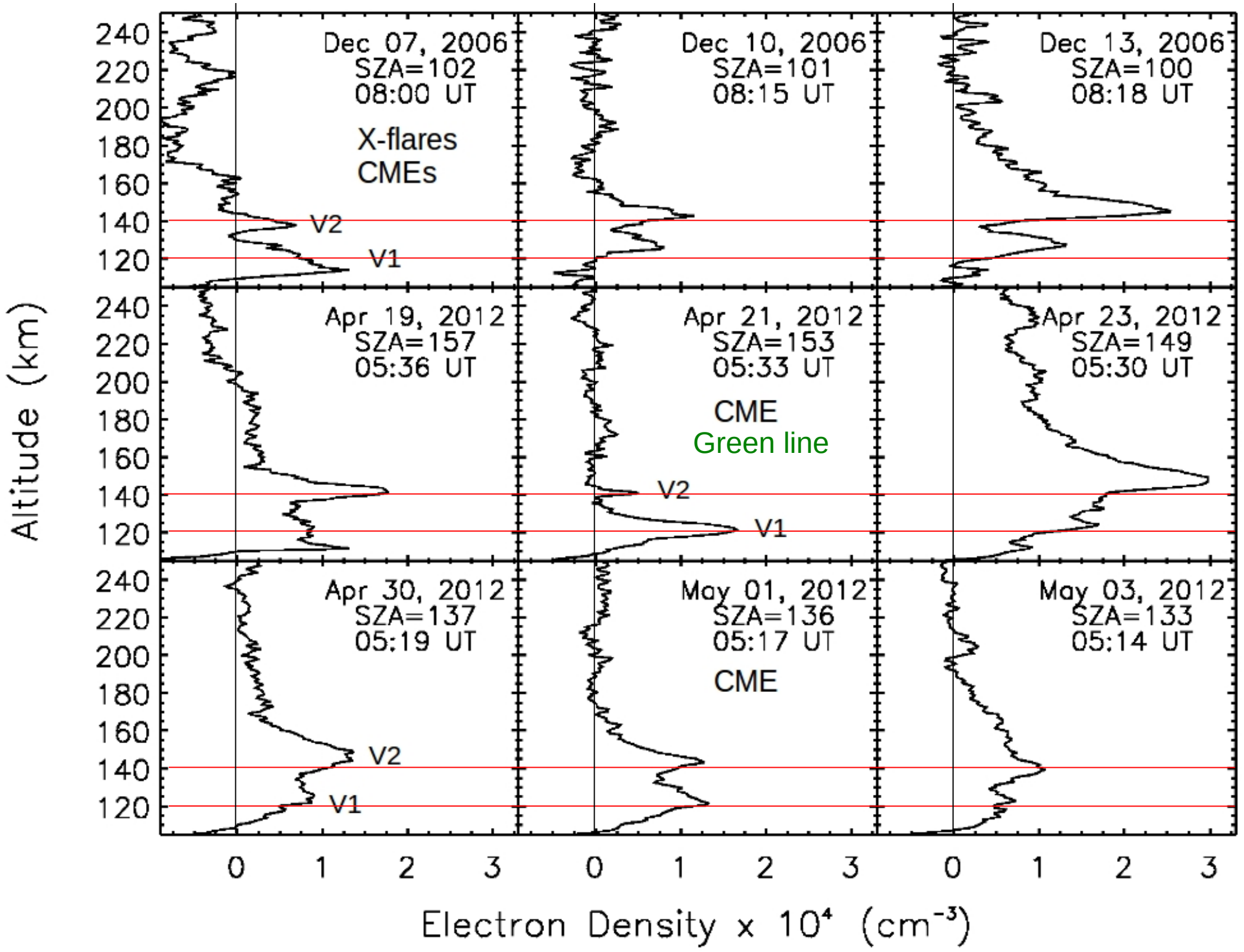
Venus Express

Venus Ionosphere

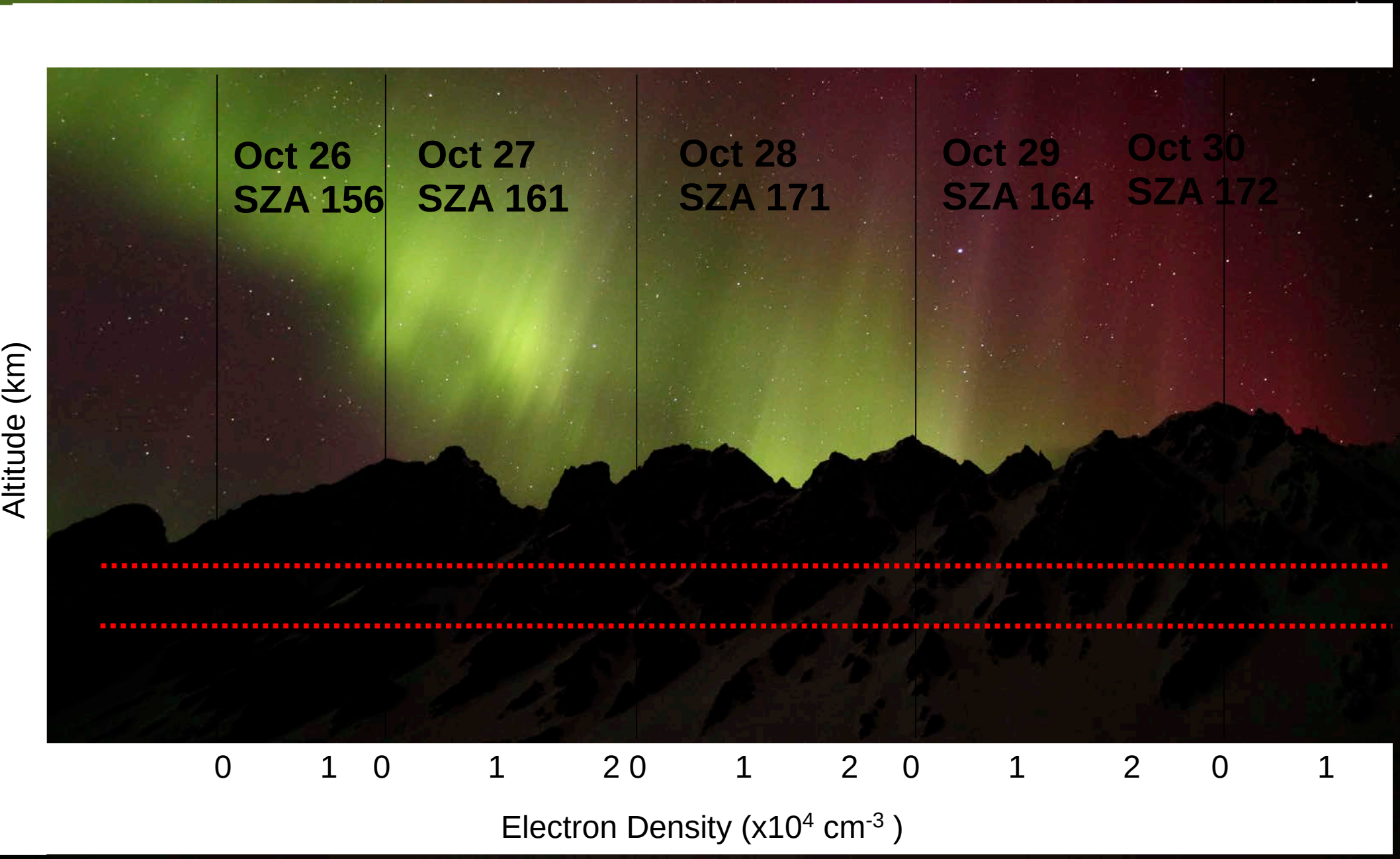
- Nightside ionosphere **highly** variable
- Ionospheric flow
- Electron precipitation
- V1 source?






Dec 07, 2006
SZA=102
08:00 UT
X-flares
CMEs
V2
V1
Dec 10, 2006
SZA=101
08:15 UT
Dec 13, 2006
SZA=100
08:18 UT
Apr 19, 2012
SZA=157
05:36 UT
Apr 21, 2012
SZA=153
05:33 UT
CME
Green line
V2
V1
Apr 23, 2012
SZA=149
05:30 UT
Apr 30, 2012
SZA=137
05:19 UT
V2
V1
May 01, 2012
SZA=136
05:17 UT
CME
May 03, 2012
SZA=133
05:14 UT
Altitude (km)
240
220
200
180
160
140
120
0
1
2
3
Electron Density x 10⁴ (cm⁻³)

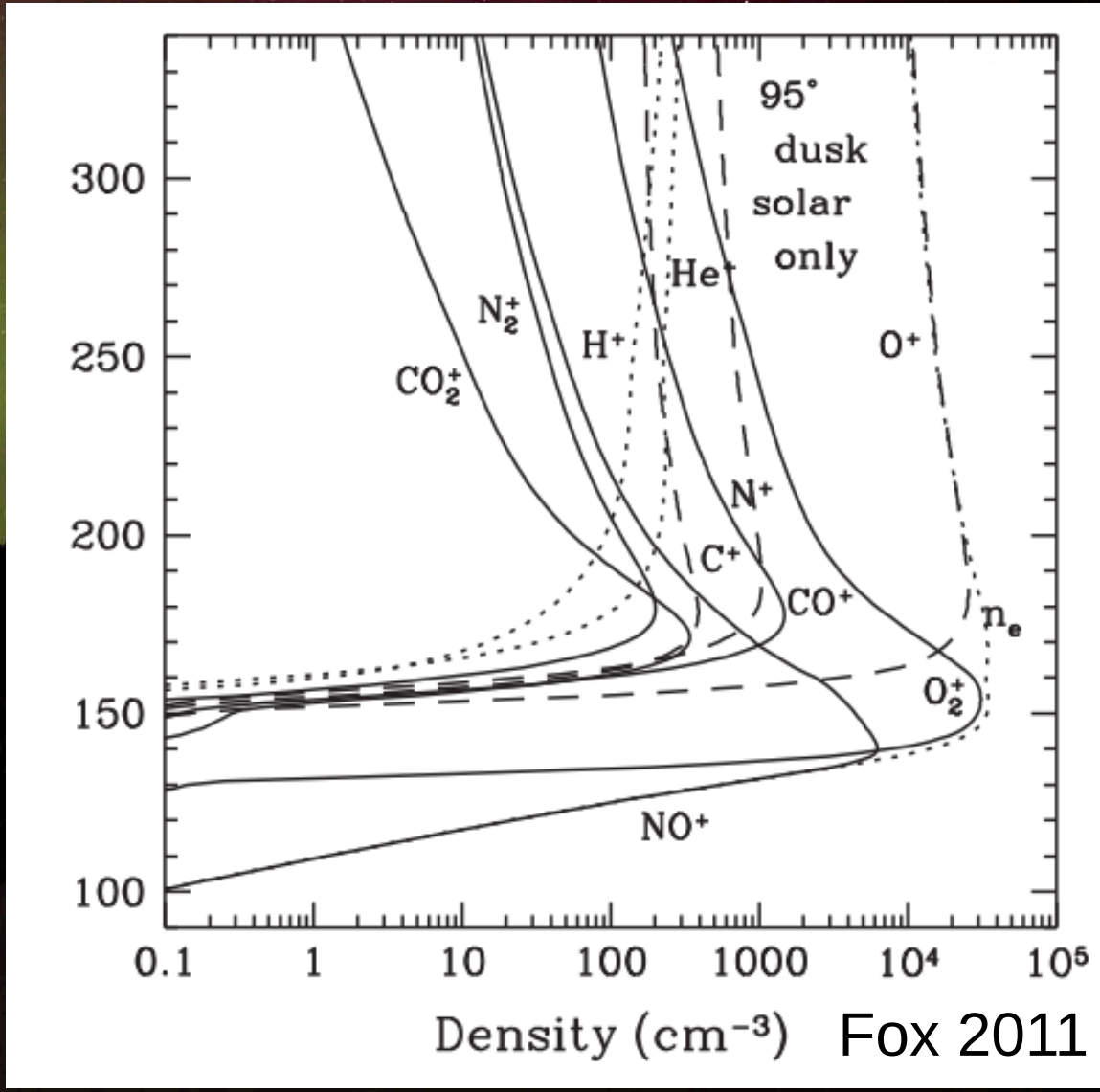
October 2013 multiple X flares and CMEs



Chemical Reactions

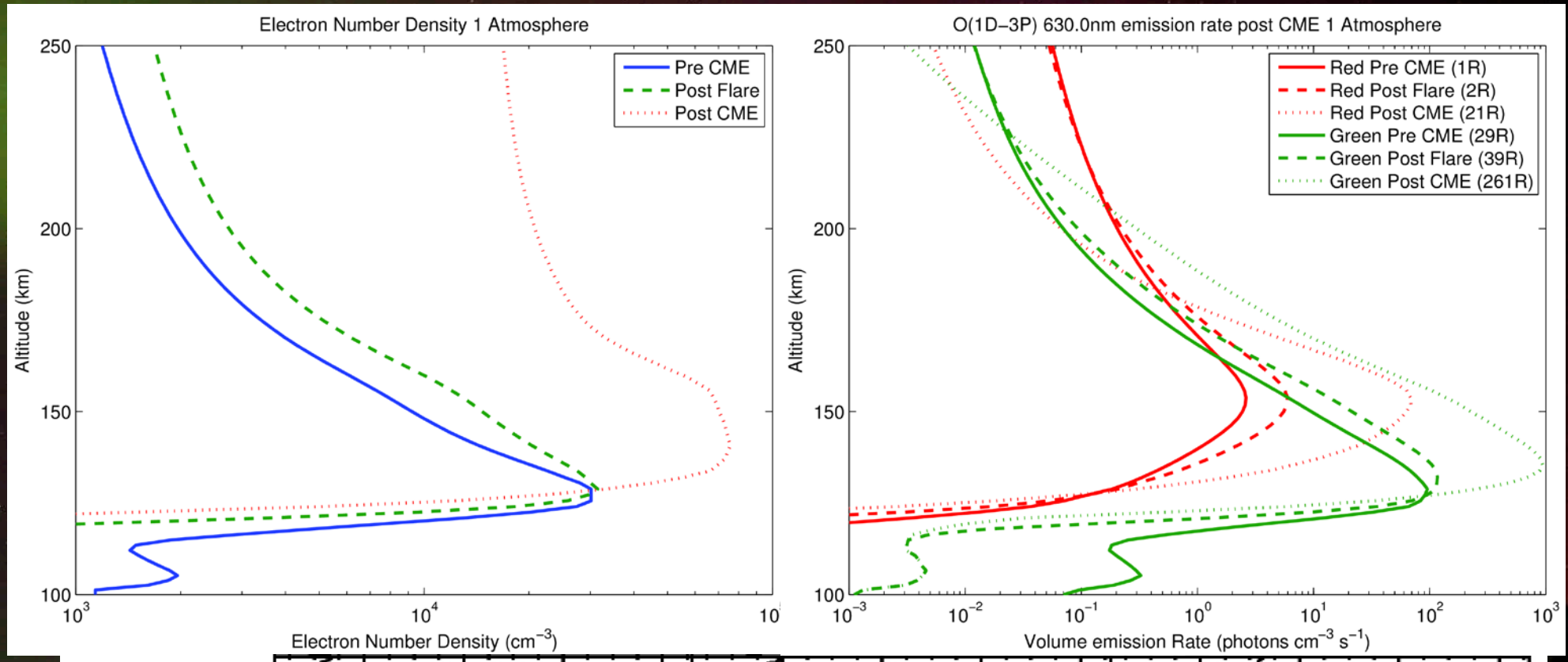
- $O_2^+ + e \rightarrow O(^1S)$
- $NO^+ + e \rightarrow NO + O\ (^1S)$
  - Low ionosphere
  - Red line quenched
  - Requires low

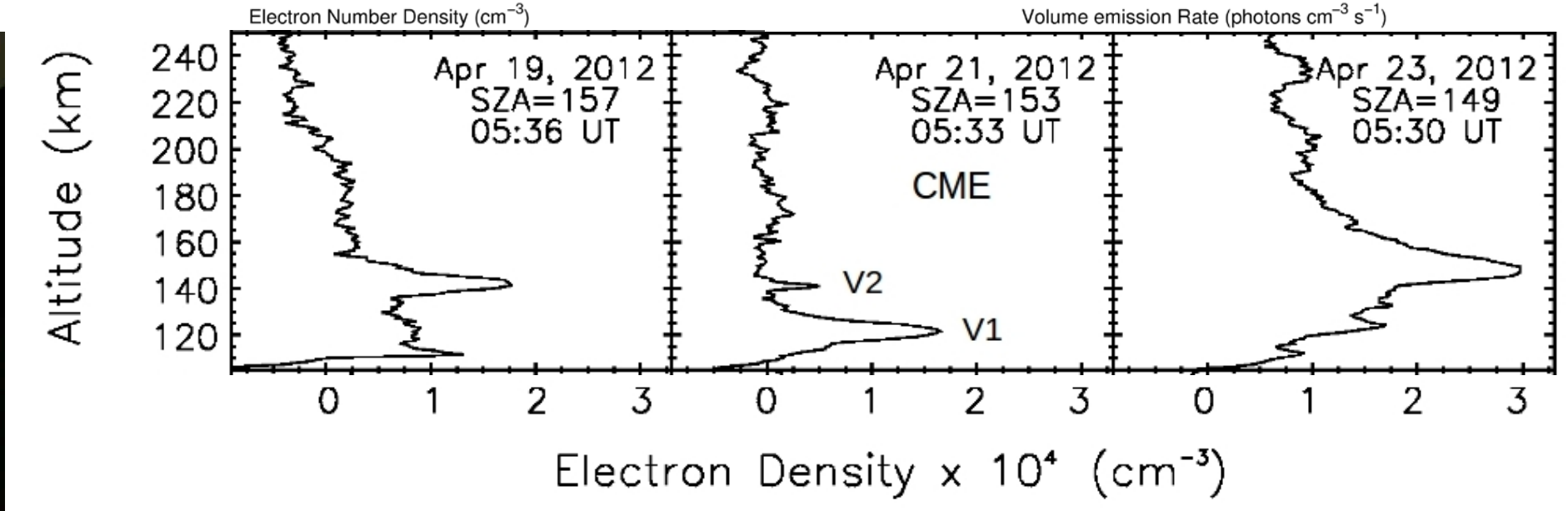
altitude higher energy electrons

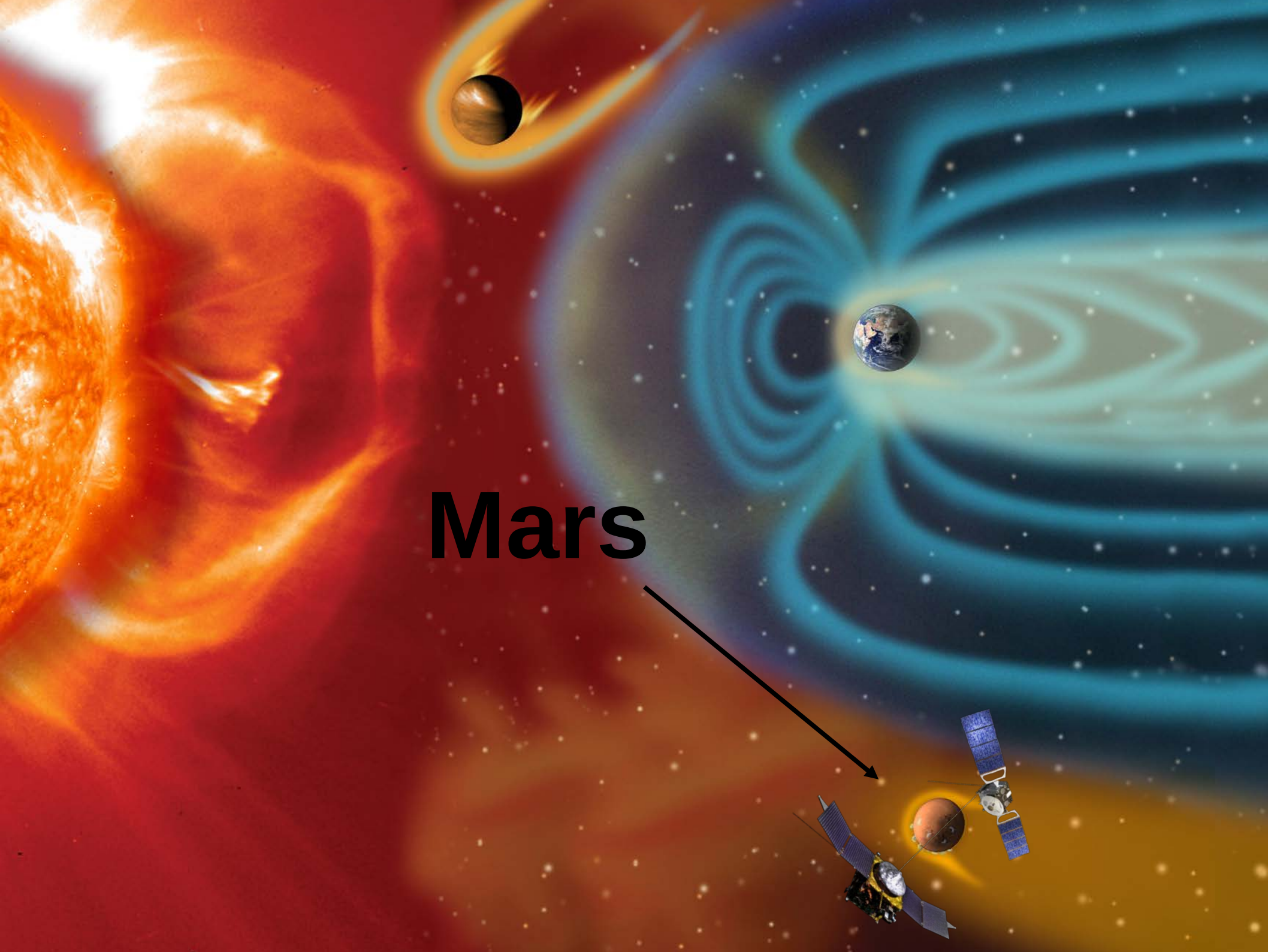


Fox 2011

TRANSCAR Modeling

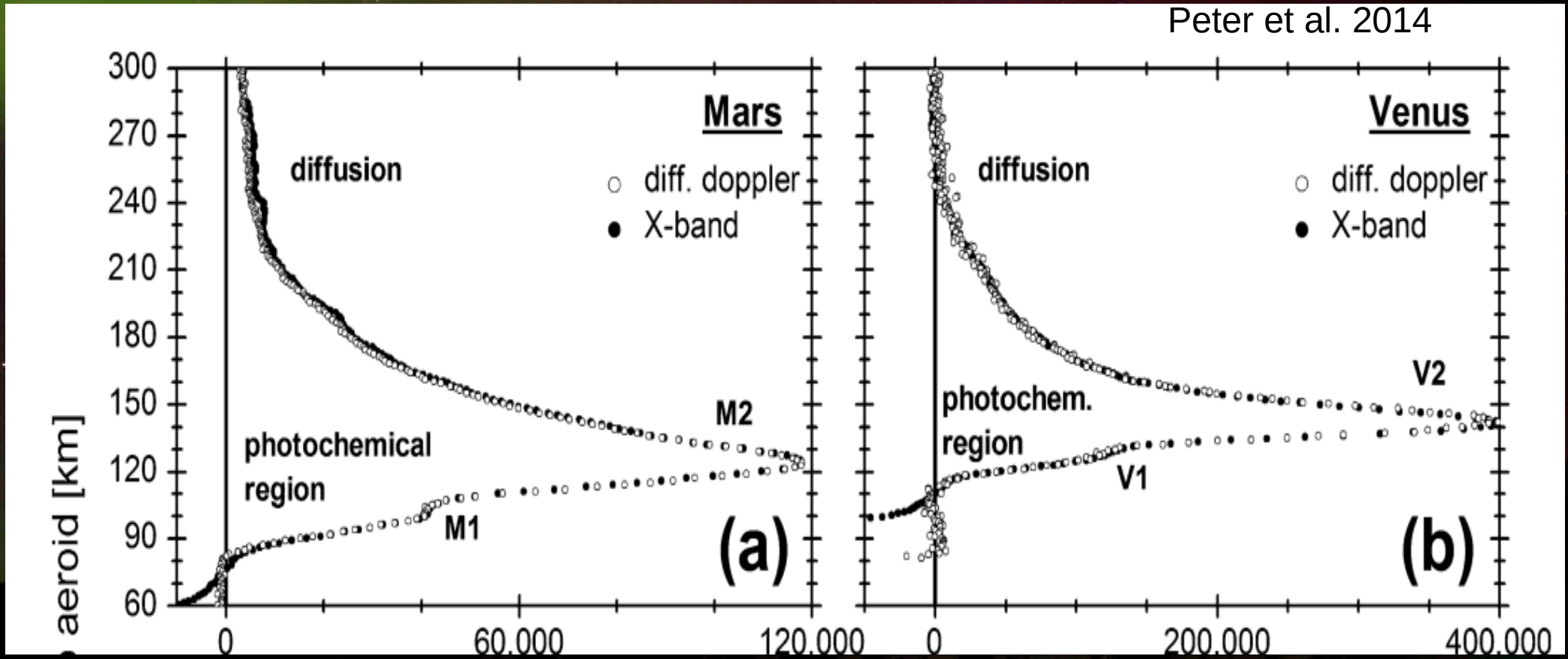




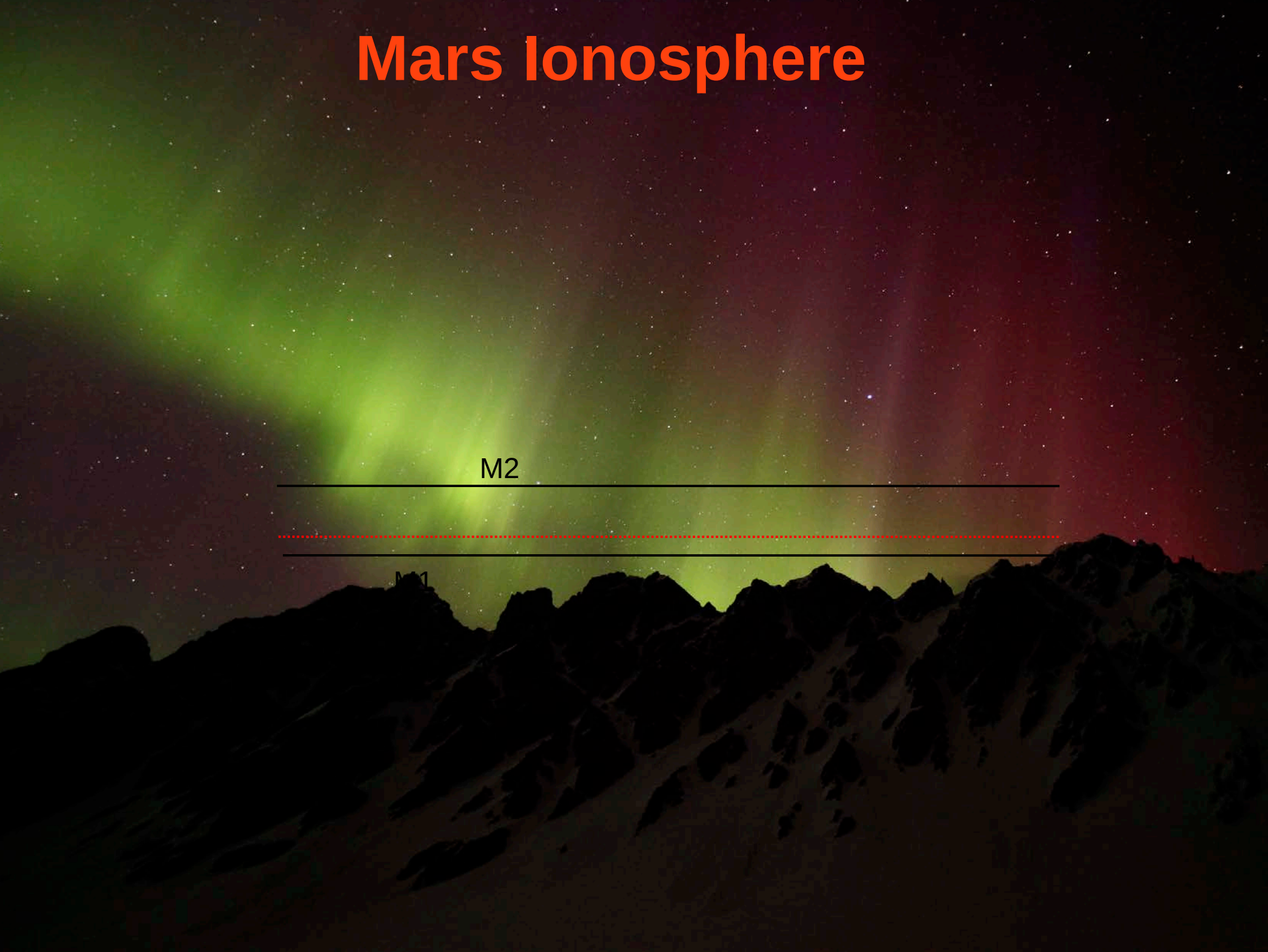

Mars

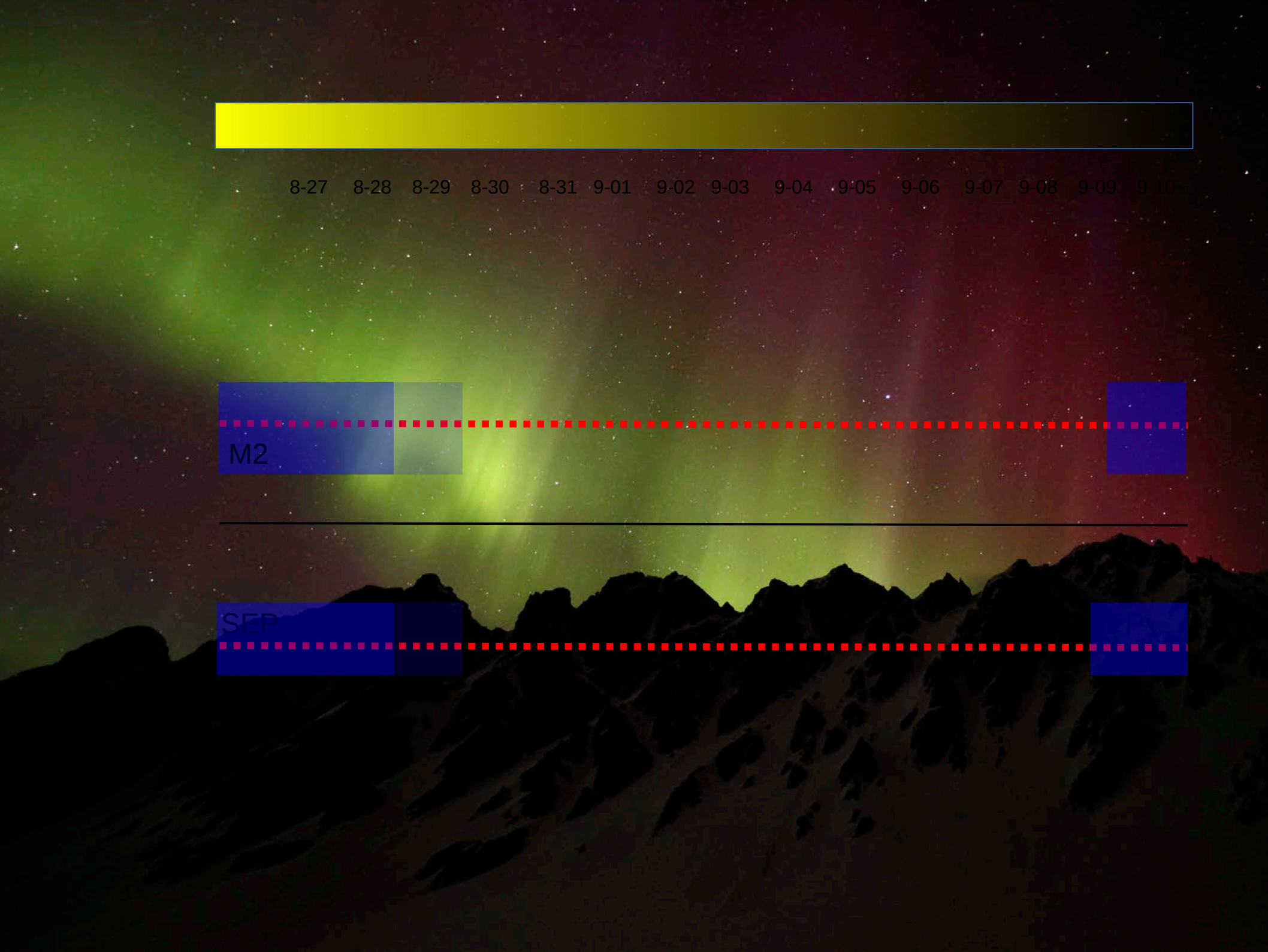
Mars Ionosphere
Mars Express

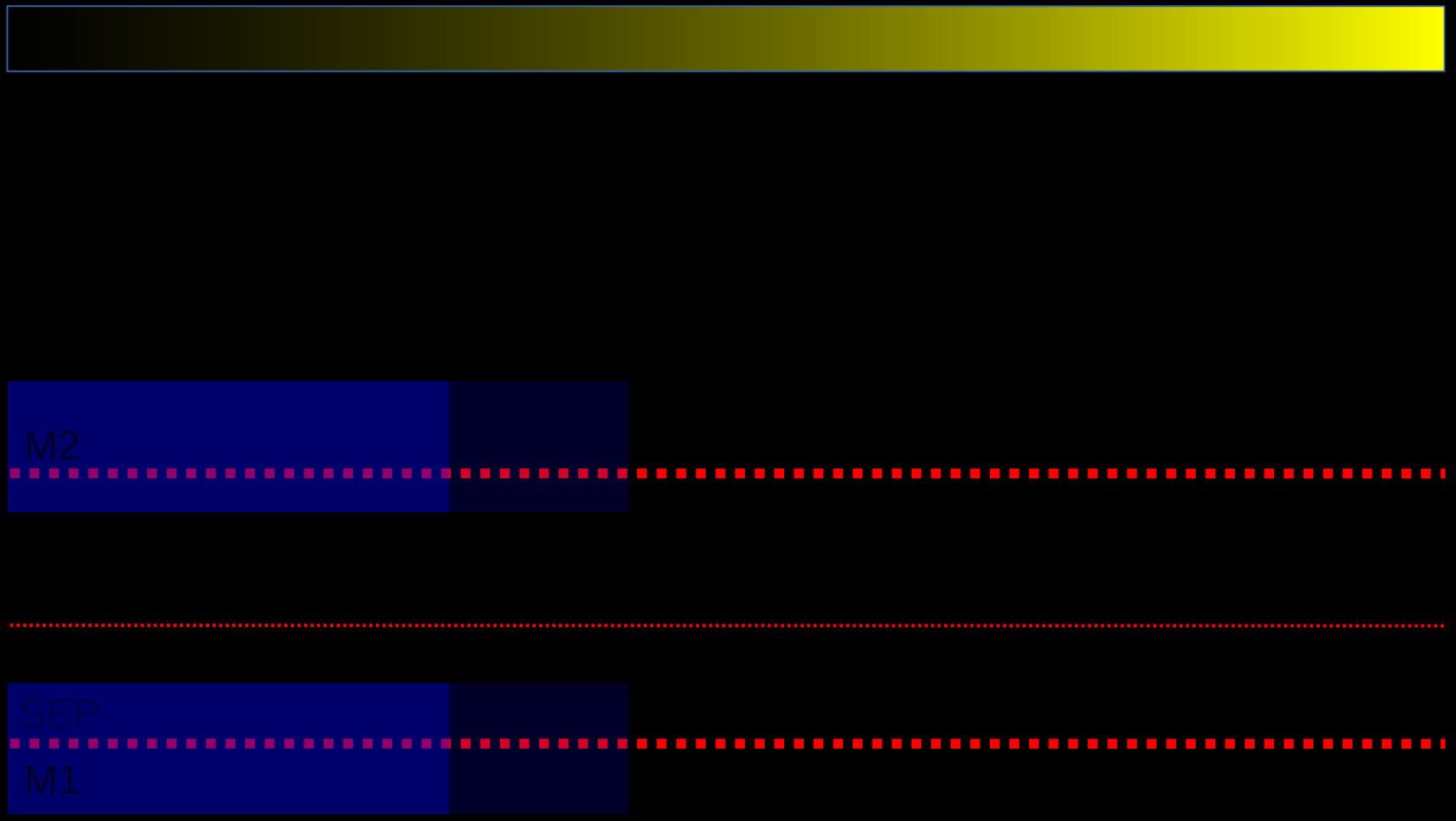
Peter et al. 2014



Mars Ionosphere

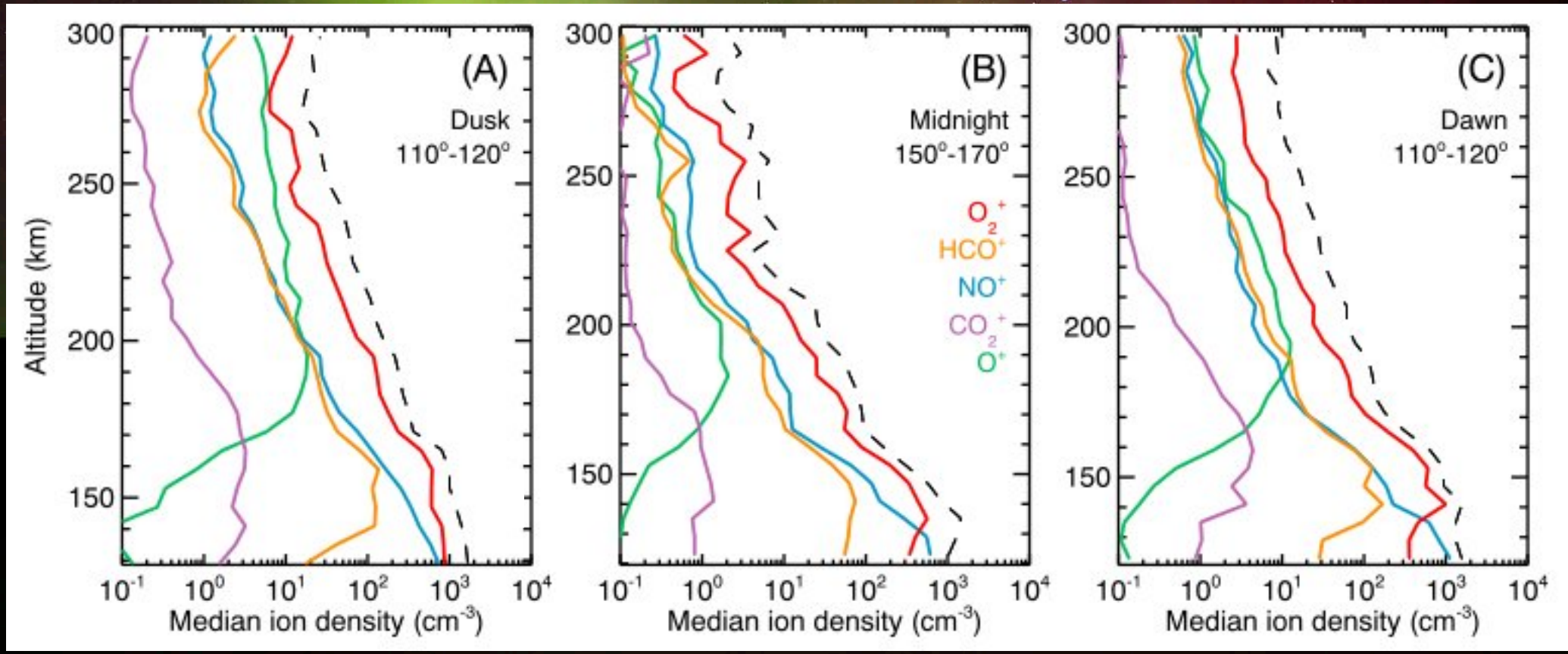



8-27
8-28
8-29
8-30
8-31
9-01
9-02
9-03
9-04
9-05
9-06
9-07
9-08
9-09
9-10
M2
SEP


M2
SEP
M1

Mars Ionosphere Composition

- Measured by MAVEN (Girzazian et al. 2017)
- M1 altitudes not sampled
- NO^+ continues to increase with decreasing altitude
- O_2^+ contribution?



Conclusions

- Similarity of nightside ionosphere of Venus and Mars
- Aurora present on both planets after solar storms
- Increase in V1 and M1 after solar storms
  - Observed immediately after storms
  - Electron precipitation (with some flow component?)
  - Persists for several days
  - NO+ dominate ion?
- Test GCMs with aurora and electron density profiles!
- New Venus neutral atmosphere

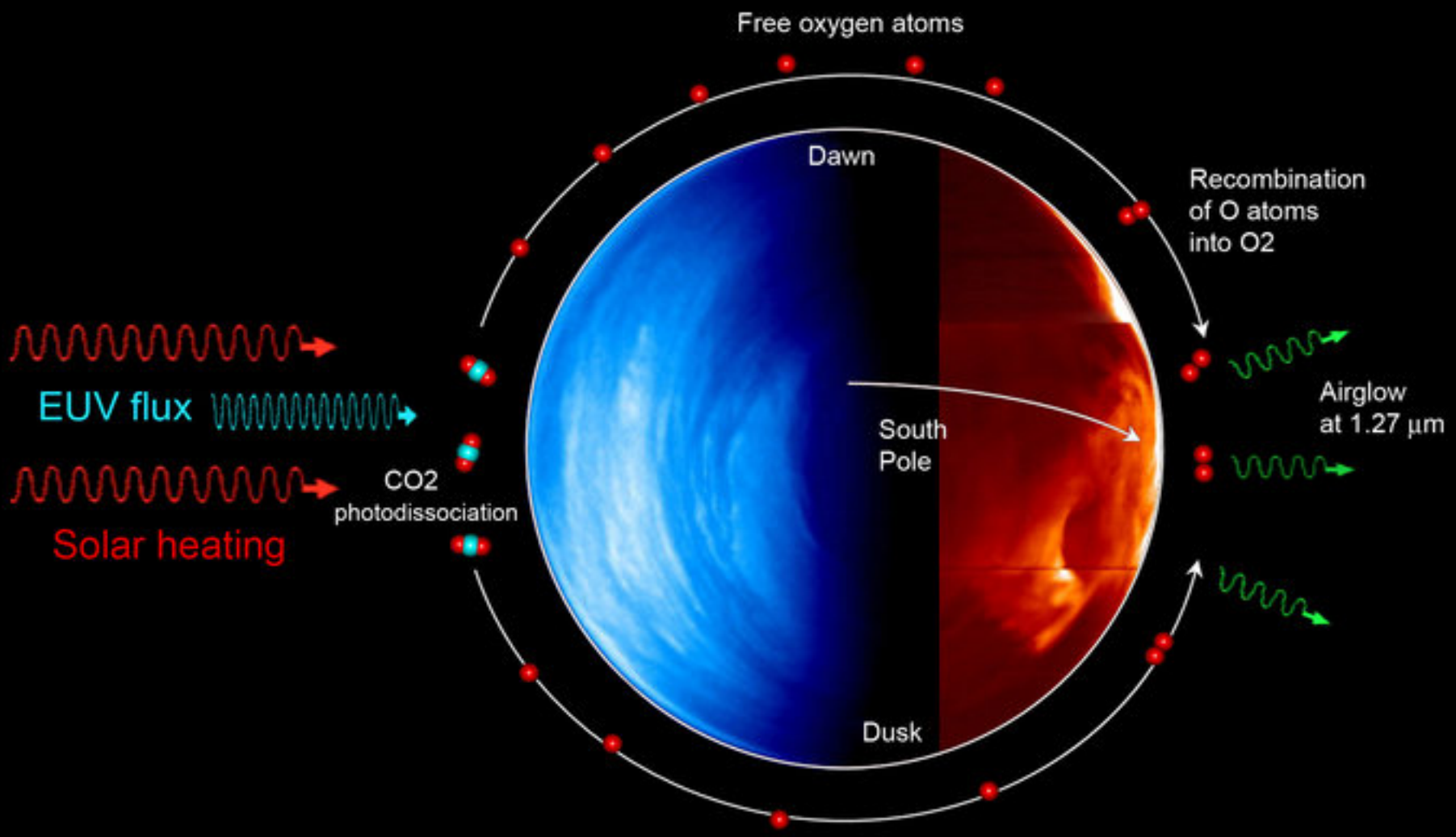

Thank You!

Some people think scientists exclaim

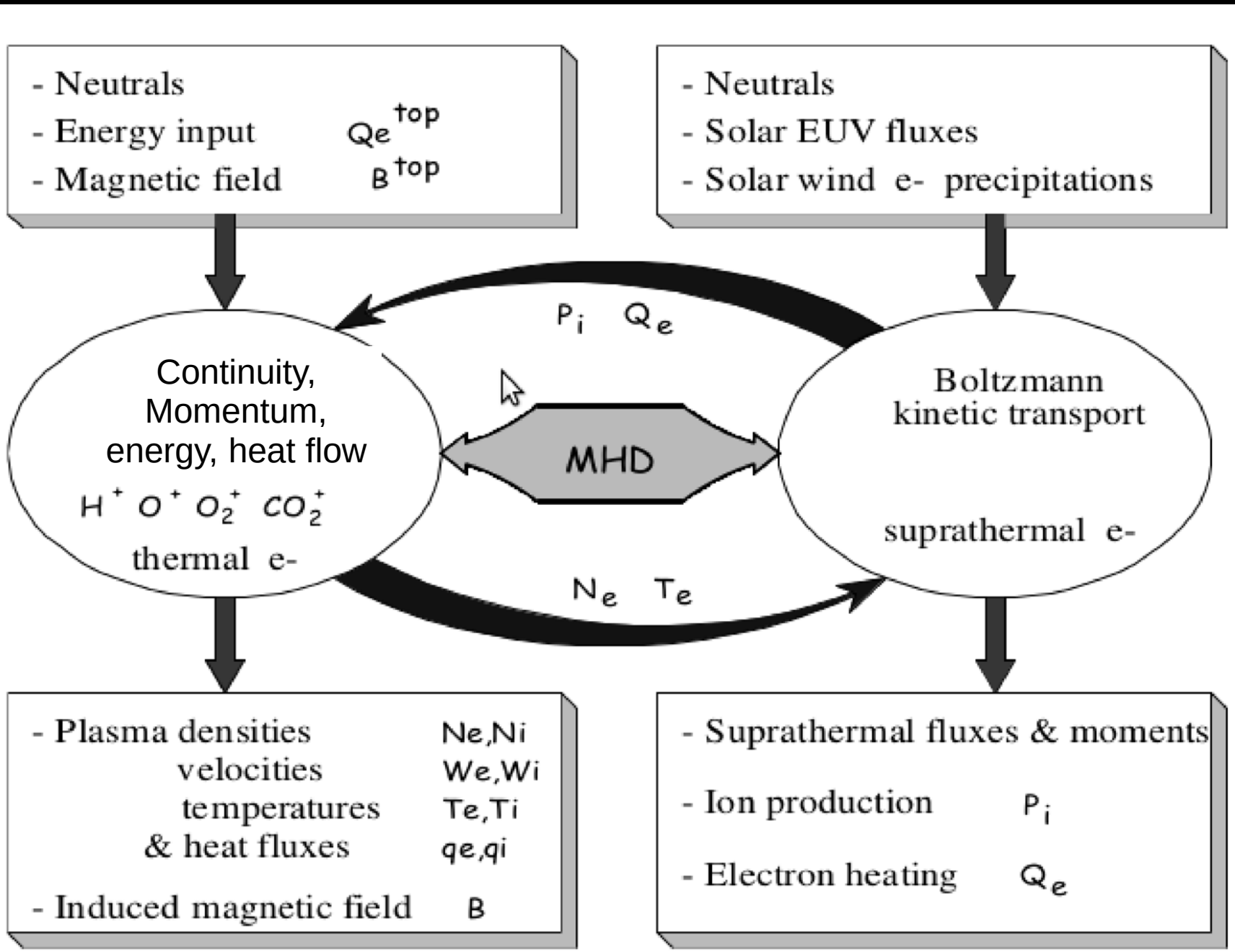
when doing experiments.

But they're way more likely to say...

twistedtoodles.com

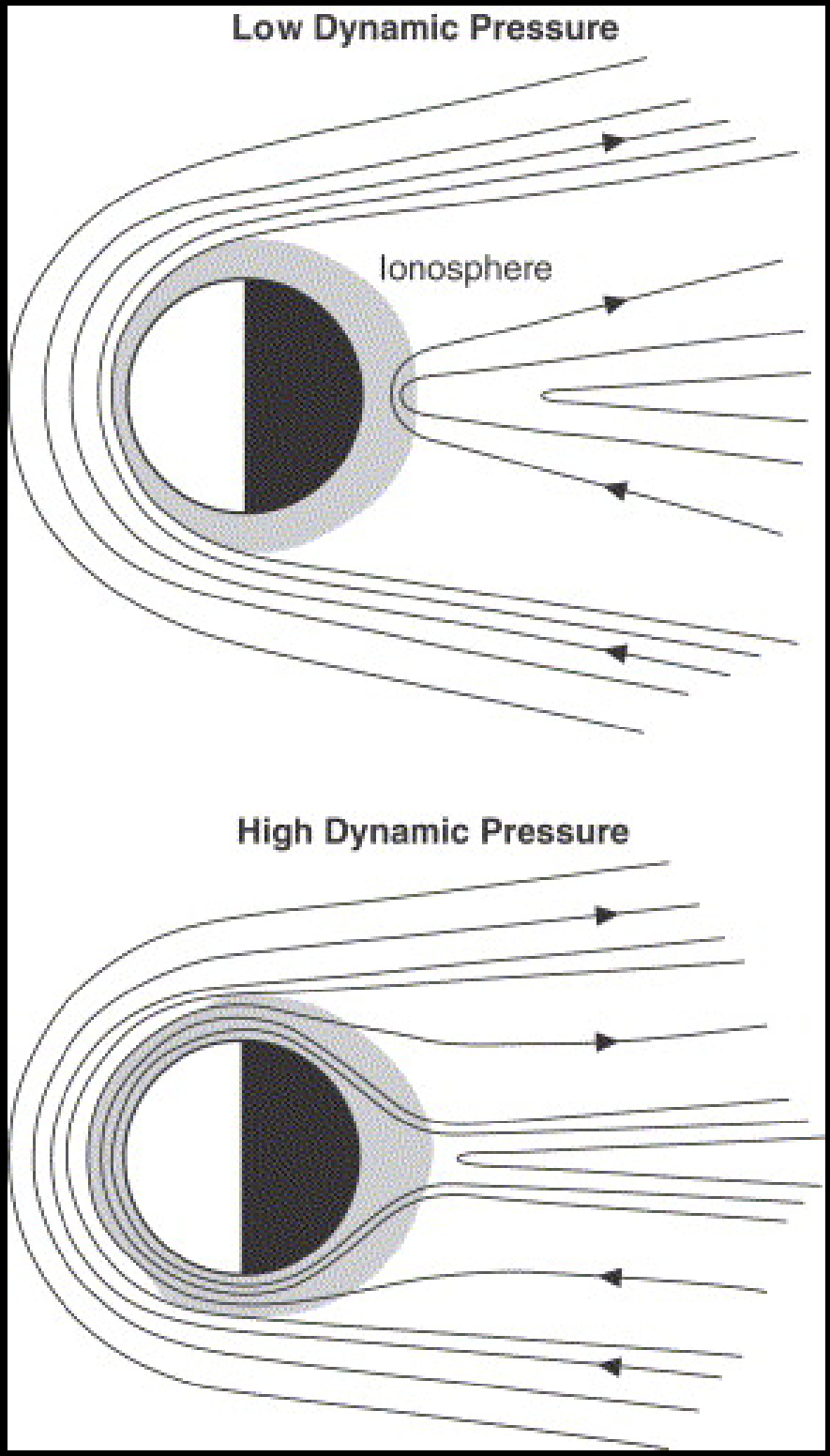

Free oxygen atoms
Dawn
Recombination
of O atoms
into O2
EUV flux
Solar heating
CO2
photodissociation
South
Pole
Airglow
at 1.27 µm
Dusk

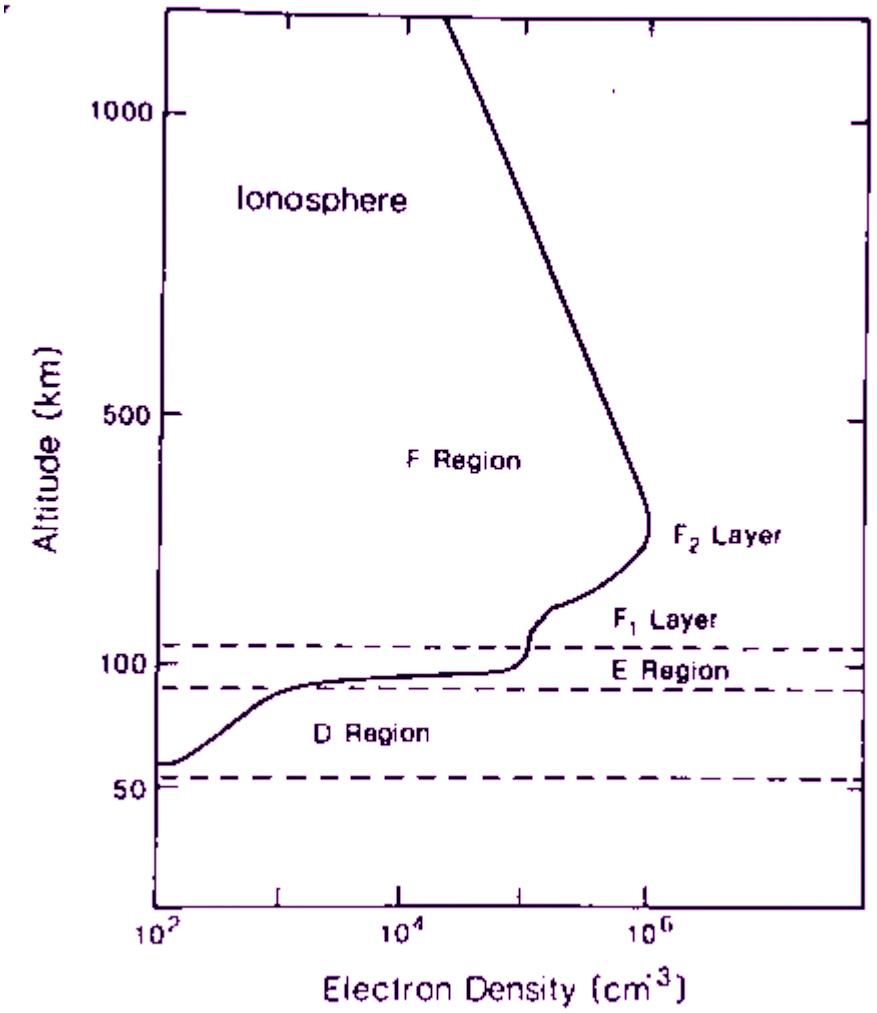
Modeling

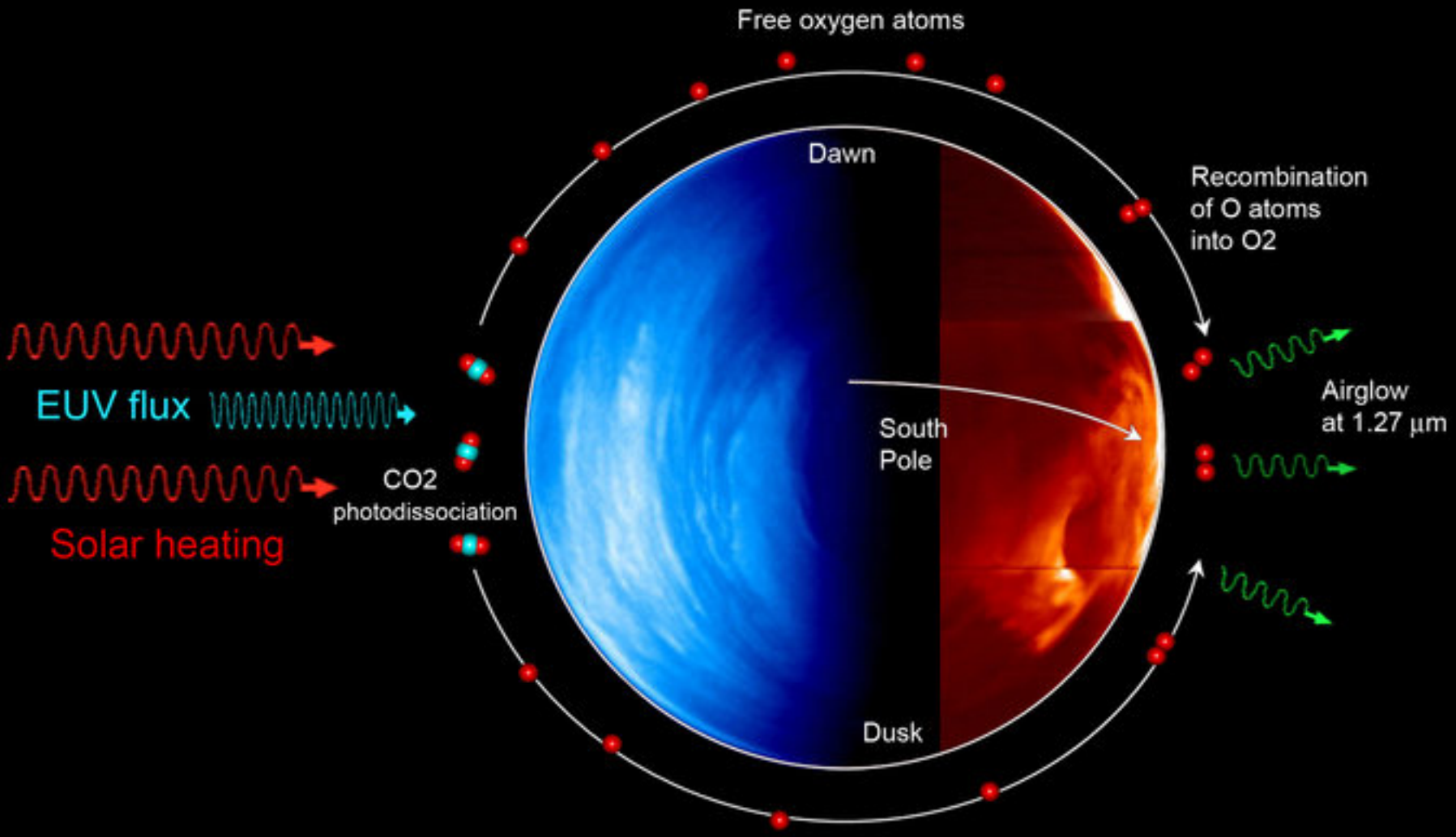

- Neutrals
- Energy input Qe top
- Magnetic field B top
- Neutrals
- Solar EUV fluxes
- Solar wind e- precipitations
Pi Qe
Continuity, Momentum, energy, heat flow
H+ O+ O2+ CO2+
thermal e-
MHD
Boltzmann kinetic transport
suprathermal e-
Ne Te
- Plasma densities Ne,Ni
velocities We,Wi
temperatures Te,Ti
& heat fluxes qe,qi
- Induced magnetic field B
- Suprathermal fluxes & moments
- Ion production Pi
- Electron heating Qe

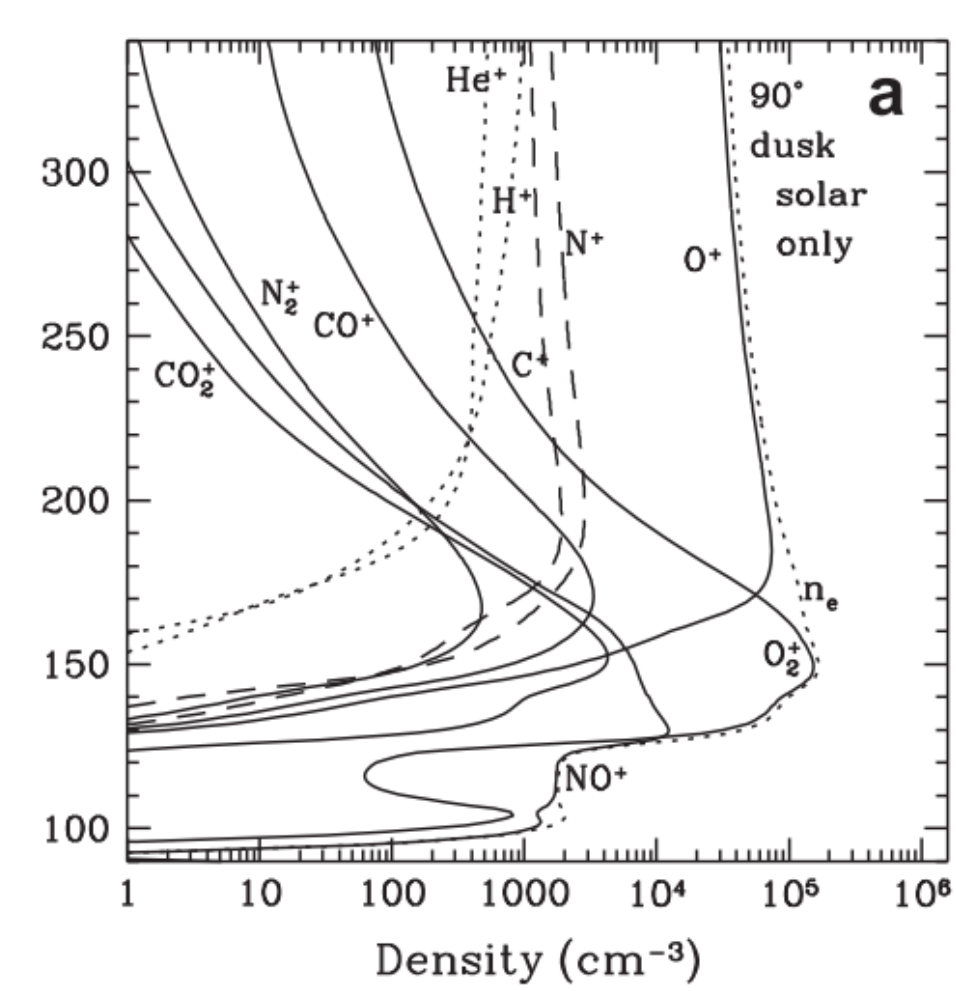
What happens to Venus when it is hit by a CME?

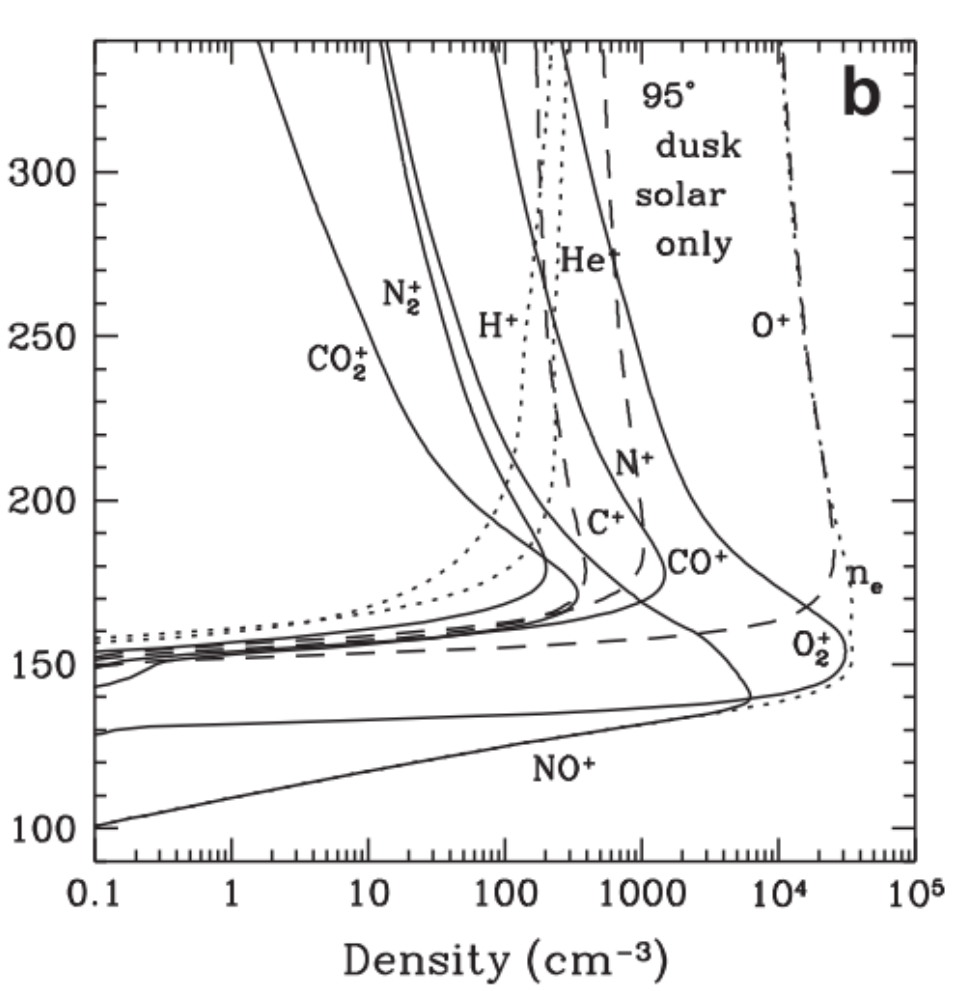
Compression of magnetic field and ionopause

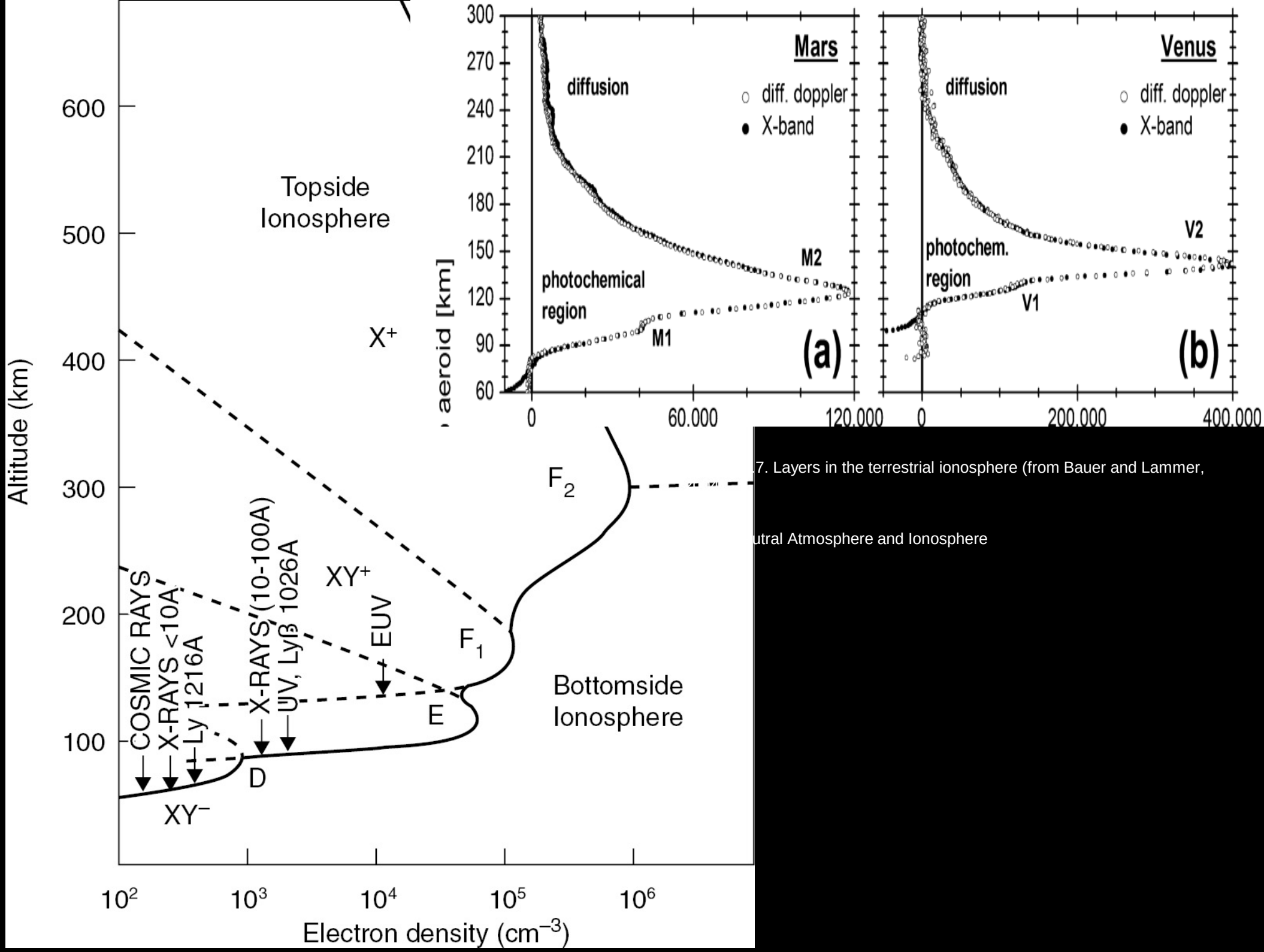



1000
500
100
50
Ionosphere
F Region
F_2 Layer
F_1 Layer
E Region
D Region
Altitude (km)
10^2
10^4
10^6
Electron Density (cm^{-3})


Free oxygen atoms
Dawn
Recombination
of O atoms
into O2
EUV flux
Airglow
at 1.27 µm
South
Pole
CO2
photodissociation
Solar heating
Dusk


a
90°
dusk
solar
only
He+
H+
N+
O+
N2+
CO+
CO2+
C+
ne
O2+
NO+
300
250
200
150
100
1
10
100
1000
10⁴
10⁵
10⁶
Density (cm⁻³)


b
95°
dusk
solar
only
N2+
H+
He+
O+
CO2+
N+
C+
CO+
ne
O2+
NO+
300
250
200
150
100
0.1
1
10
100
1000
10⁴
10⁵
Density (cm⁻³)

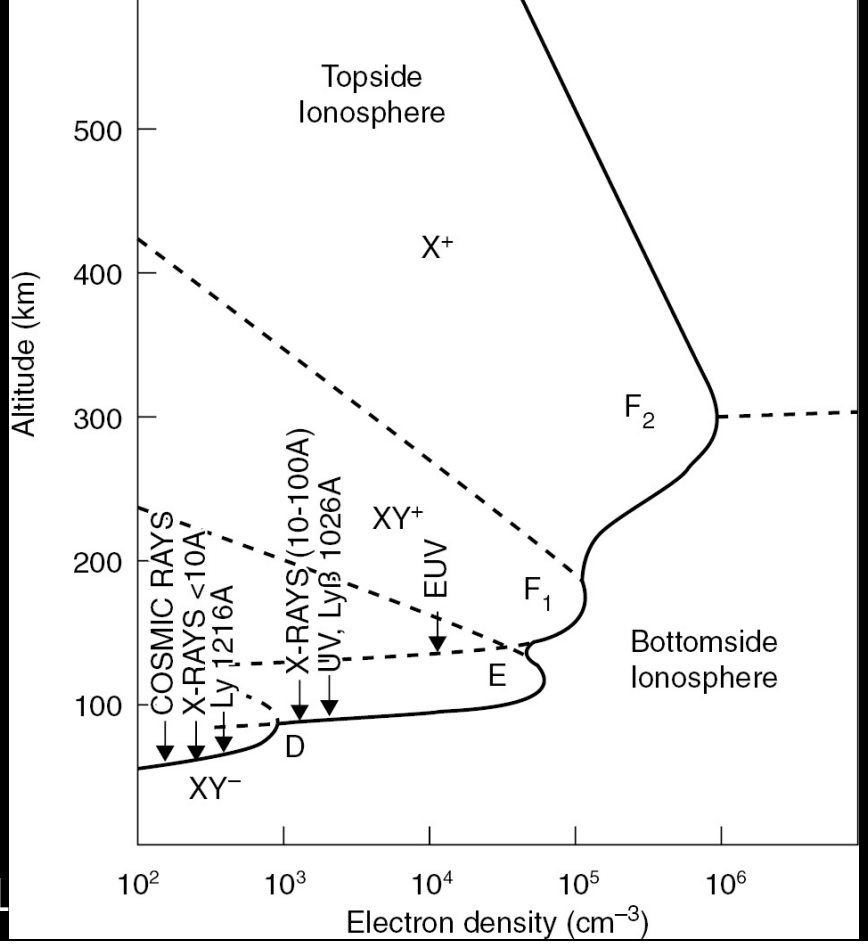


7. Layers in the terrestrial ionosphere (from Bauer and Lammer,

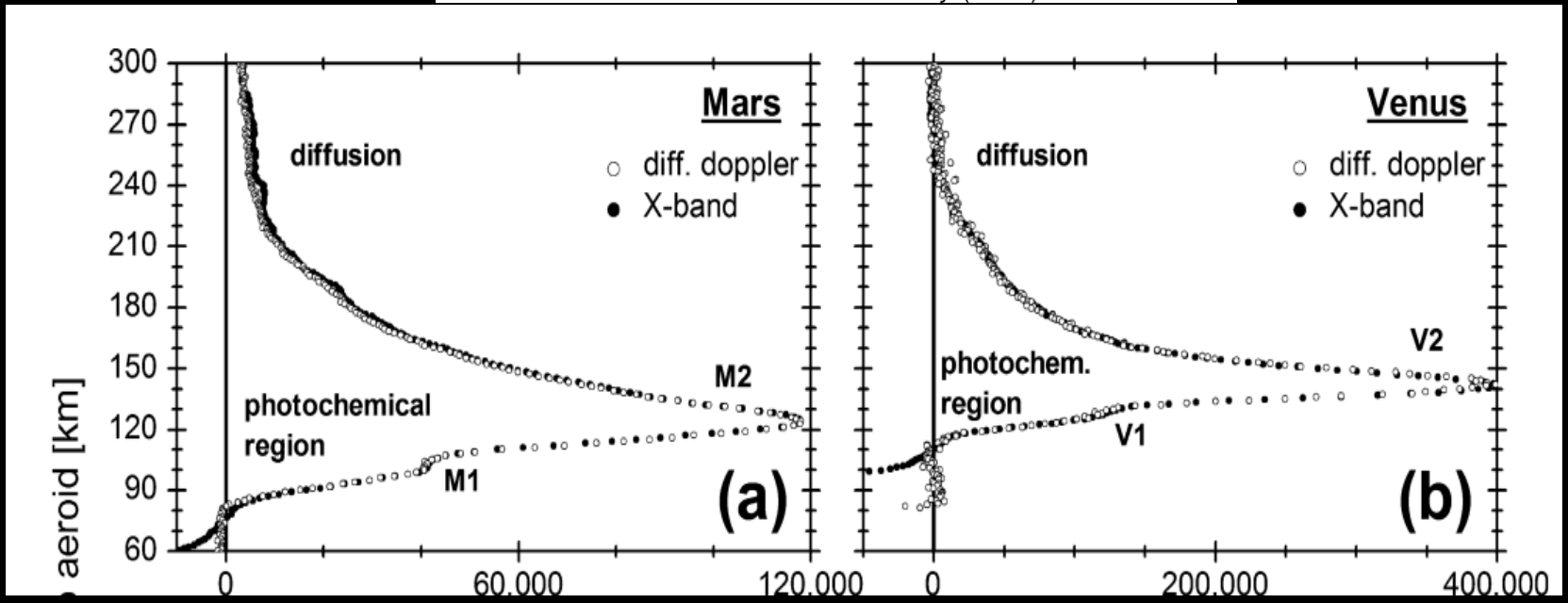
utral Atmosphere and Ionosphere

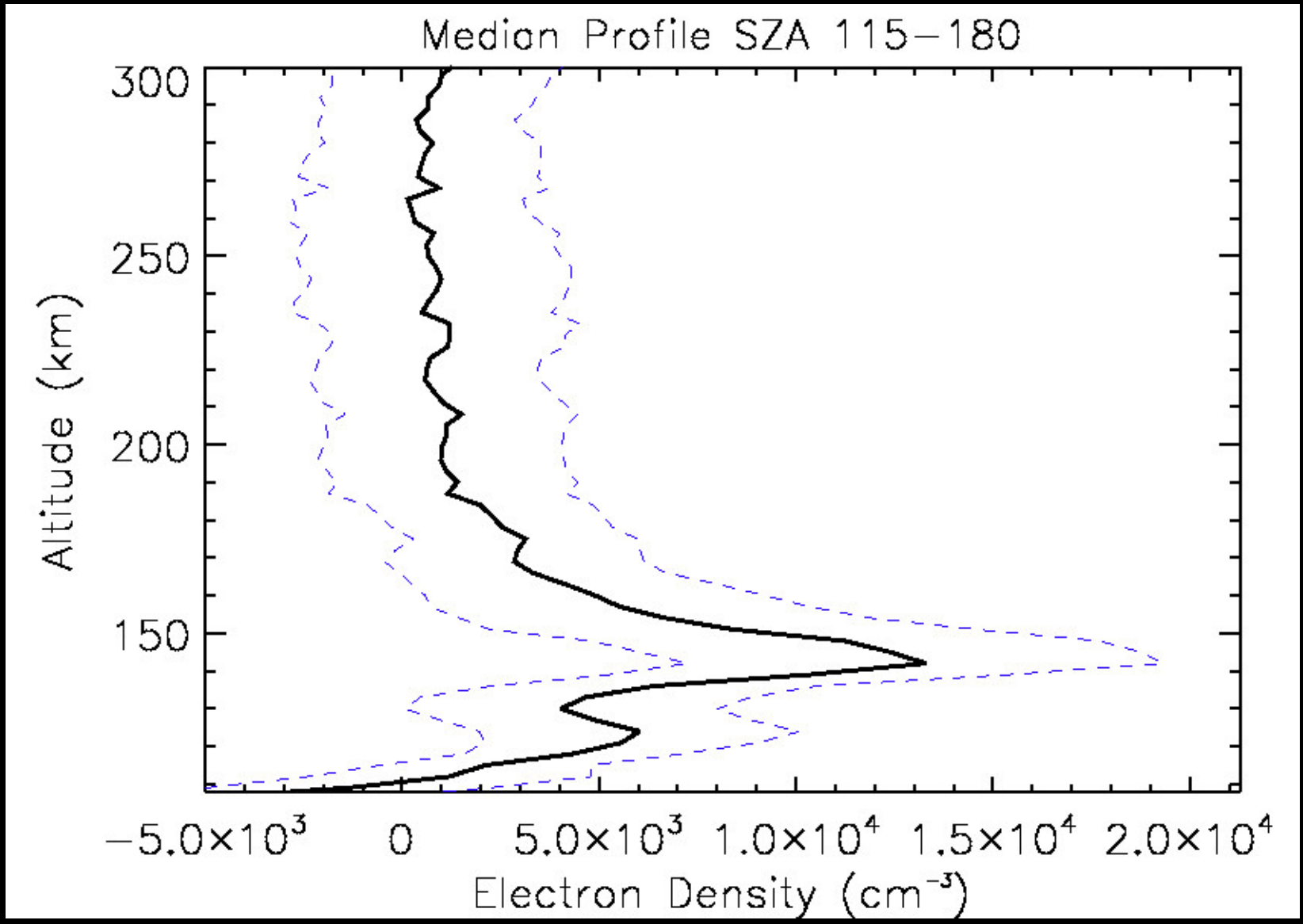
Figure 14.7. Layers in the terrestrial ionosphere (from Bauer and Lammer, 2004).

Upper Neutral Atmosphere and Ionosphere



From Peter et al 201




Median Profile SZA 115–180
300
250
200
150
Altitude (km)
−5.0×10³
0
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
Electron Density (cm⁻³)