Mars Corona and Solar wind interaction :

What has been done

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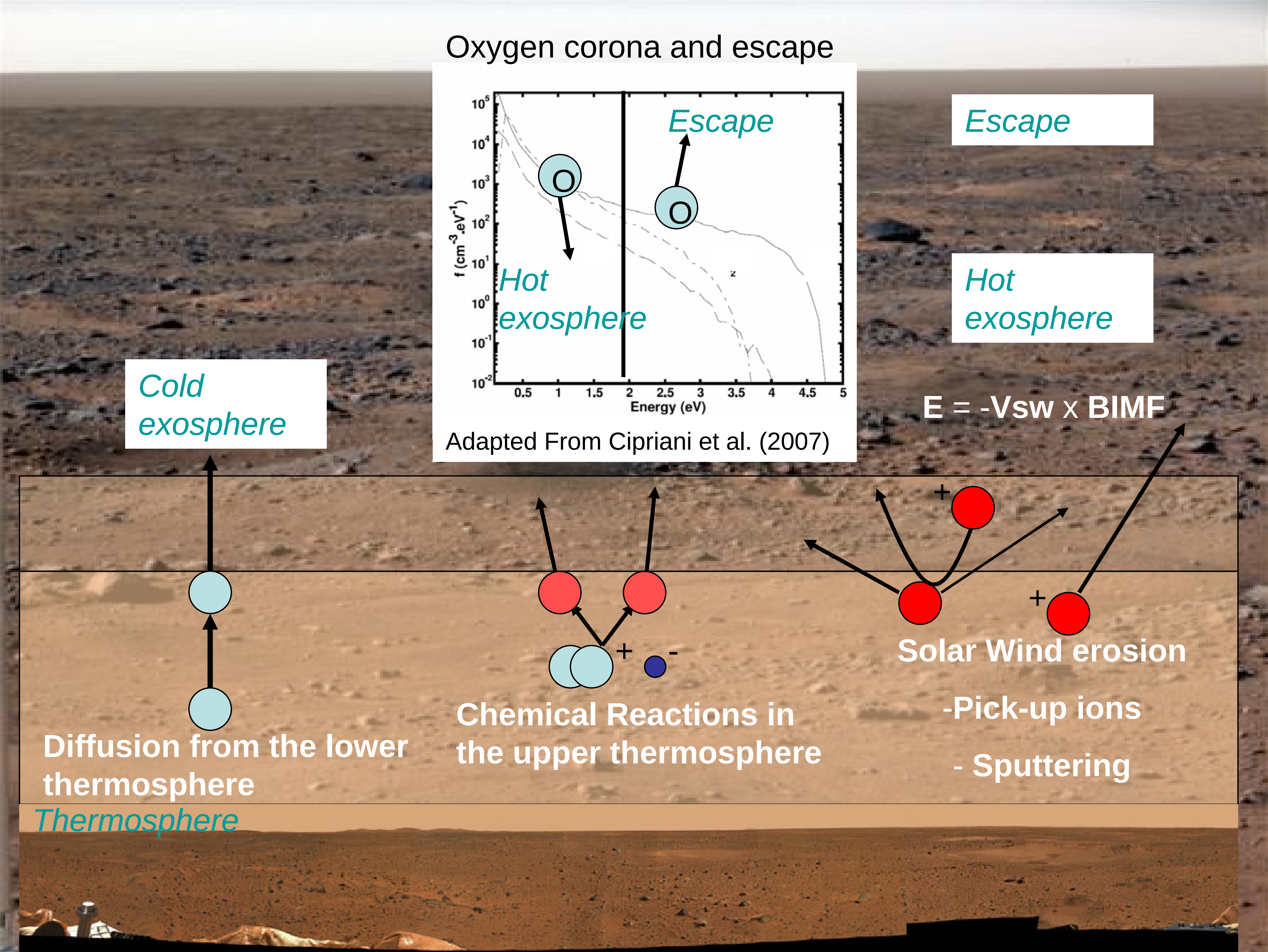
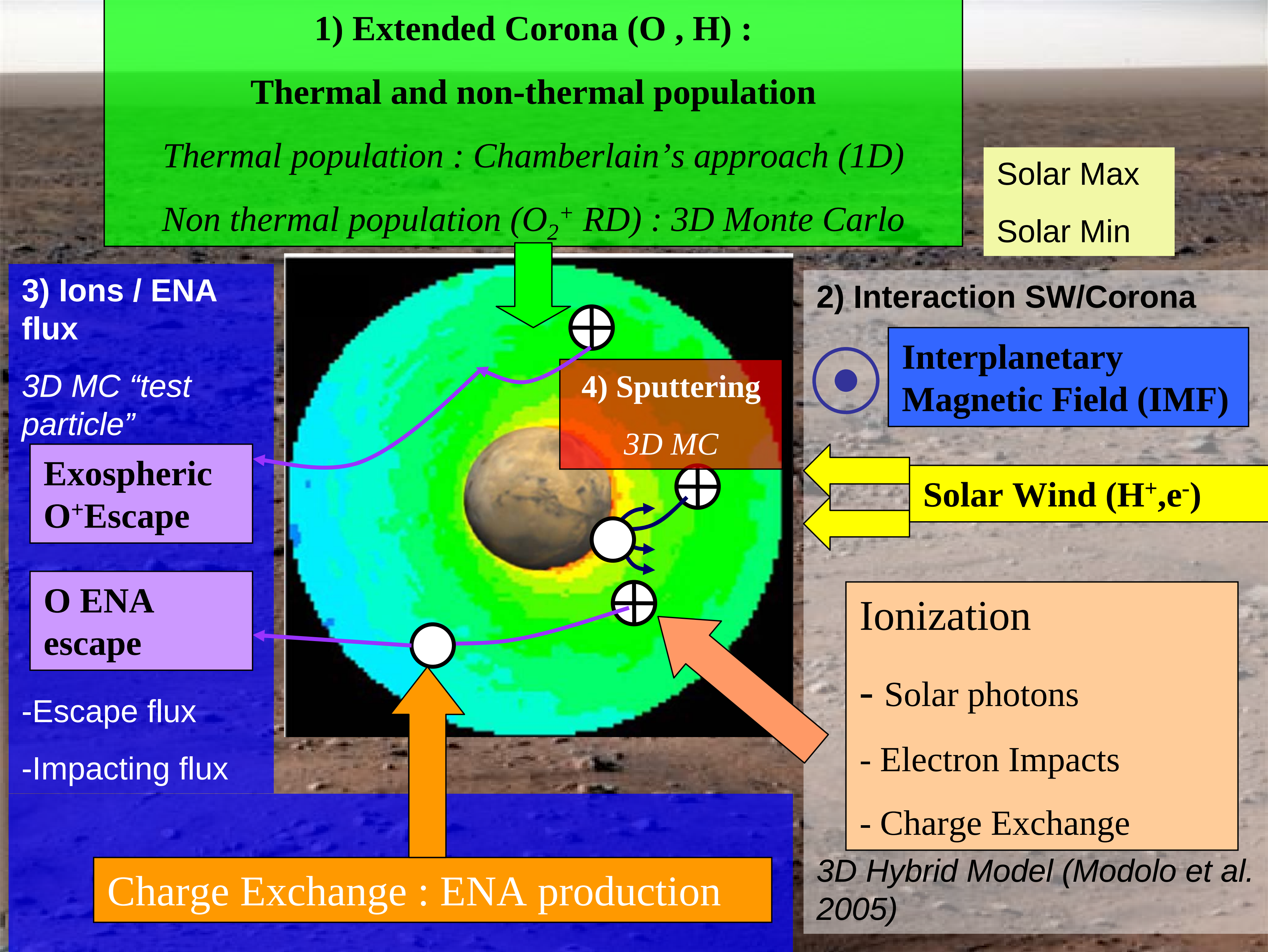


Oxygen corona and escape
Escape
O
O
Hot exosphere
f (cm^-3.eV^-1)
Energy (eV)
Adapted From Cipriani et al. (2007)
Escape
Hot exosphere
Cold exosphere
E = -Vsw x BIMF
Diffusion from the lower thermosphere
Chemical Reactions in the upper thermosphere
Solar Wind erosion
-Pick-up ions
- Sputtering
Thermosphere


1) Extended Corona (O , H) :
Thermal and non-thermal population
Thermal population : Chamberlain's approach (1D)
Non thermal population (O_2^+ RD) : 3D Monte Carlo
Solar Max
Solar Min
3) Ions / ENA flux
3D MC "test particle"
Exospheric O^+Escape
O ENA escape
-Escape flux
-Impacting flux
4) Sputtering
3D MC
2) Interaction SW/Corona
Interplanetary Magnetic Field (IMF)
Solar Wind (H^+,e^-)
Ionization
- Solar photons
- Electron Impacts
- Charge Exchange
3D Hybrid Model (Modolo et al. 2005)
Charge Exchange : ENA production

Hot Oxygen Model

1) <u>Goal</u>

Hot oxygen corona produced by O_2^+ DR

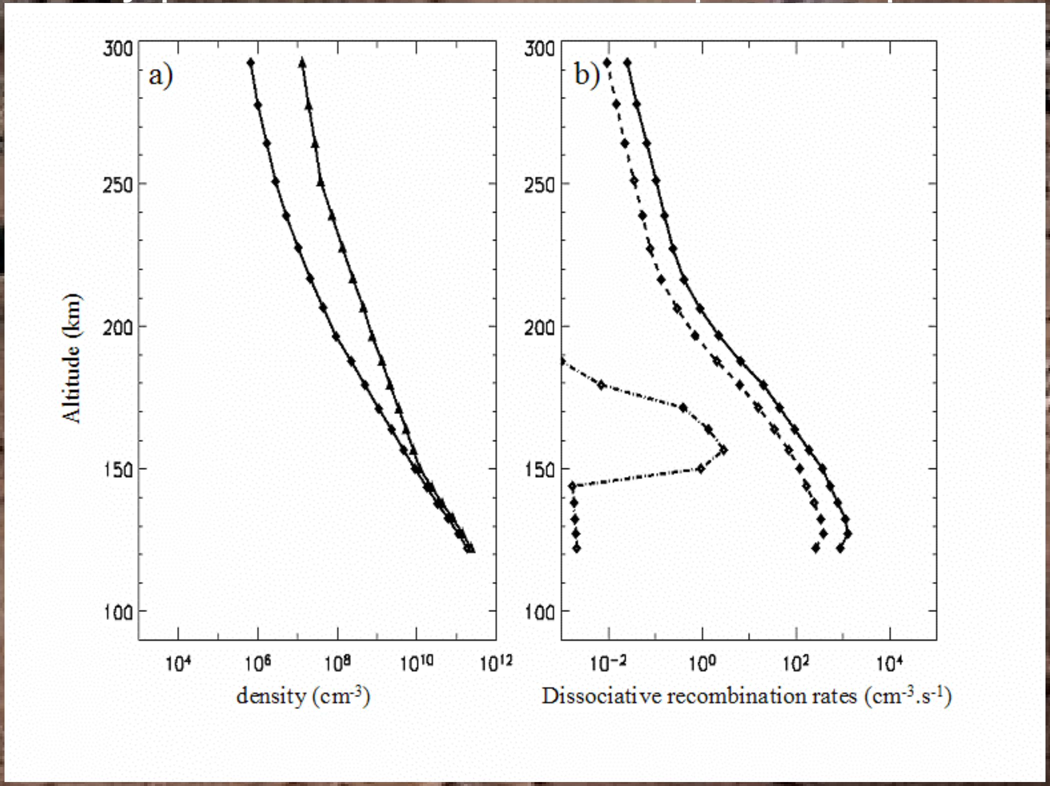
$O_2^+ + e^- \rightarrow O^* + O^*$ (4 different channels)

$$\alpha(z, sza) = 2.4\times10^{-7}\left(\frac{300}{T_e}\right)^{0.7} n(e^-)n(O_2^+)$$

2) <u>Input</u>

1D Thermospheric neutral atmosphere (CO_2, O Densities, Temperature)

2D O_2^+ density profiles ; 1D electron temperature profile



No production, no collisions above 300 km

Hot Oxygen Model

Resolution (spherical coordinates)

Δz ~ 6km (at 120 km) → 500 km (at 10,000 km)

$\Delta\theta$ ~ 3° (equator) - 20° (pole)

$\Delta\varphi$ ~ 6°

3) <u>Algorithm (DSMC code)</u>

- Track hot oxygen atoms along their trajectory (time step = 0.05s)
- Compute collisions below 300 km (no collisions above 300 km)
- Compute density and velocity distribution function in the corona (> 300 km)

<u>Atoms trajectory</u> : resolution of the movement equation in gravitation field

<u>Collisions</u>

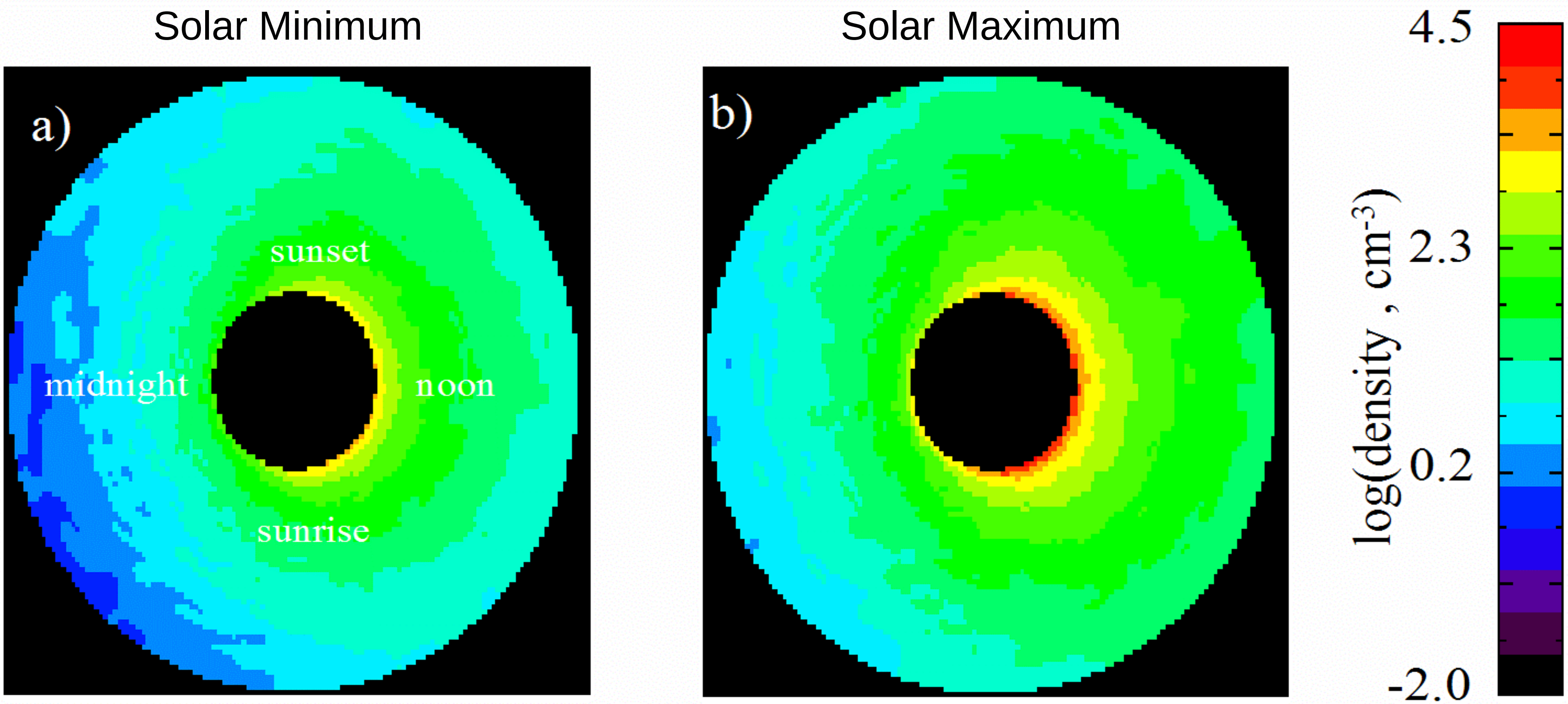
→ Number of collisions in each cell
→ Scattering angle (Universal Potential)
→ New velocity components

<u>Density corona</u> : update each time step : $n(i) = n(i) + \Sigma \text{Weight} \times dt$

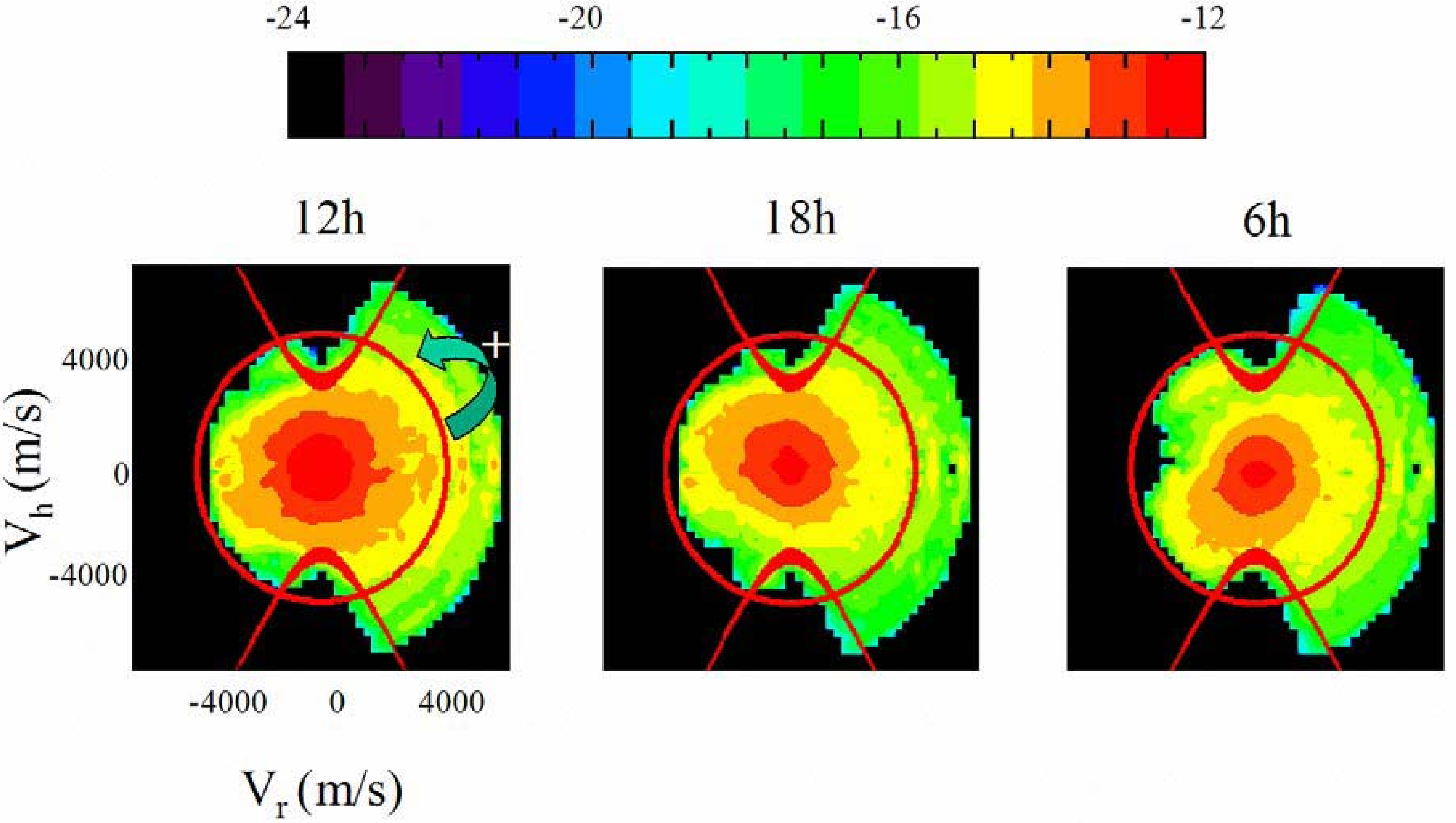
Hot Oxygen Model

4) **Main Output**

Hot Oxygen Corona density



Chaufray et al. 2007



-24
-20
-16
-12
12h
18h
6h
4000
0
-4000
V_h (m/s)
-4000
0
4000
V_r (m/s)

Solar wind interaction with atmosphere

1) **Goal**

Compute O+ production and escape flux

Compute O+ sputtering flux

Describe Hot O produced by charge exchange $O^+ + M \rightarrow O(hot) + M^+$

2) **Input**

Corona model (O cold and hot, H)

Photoionization frequencies

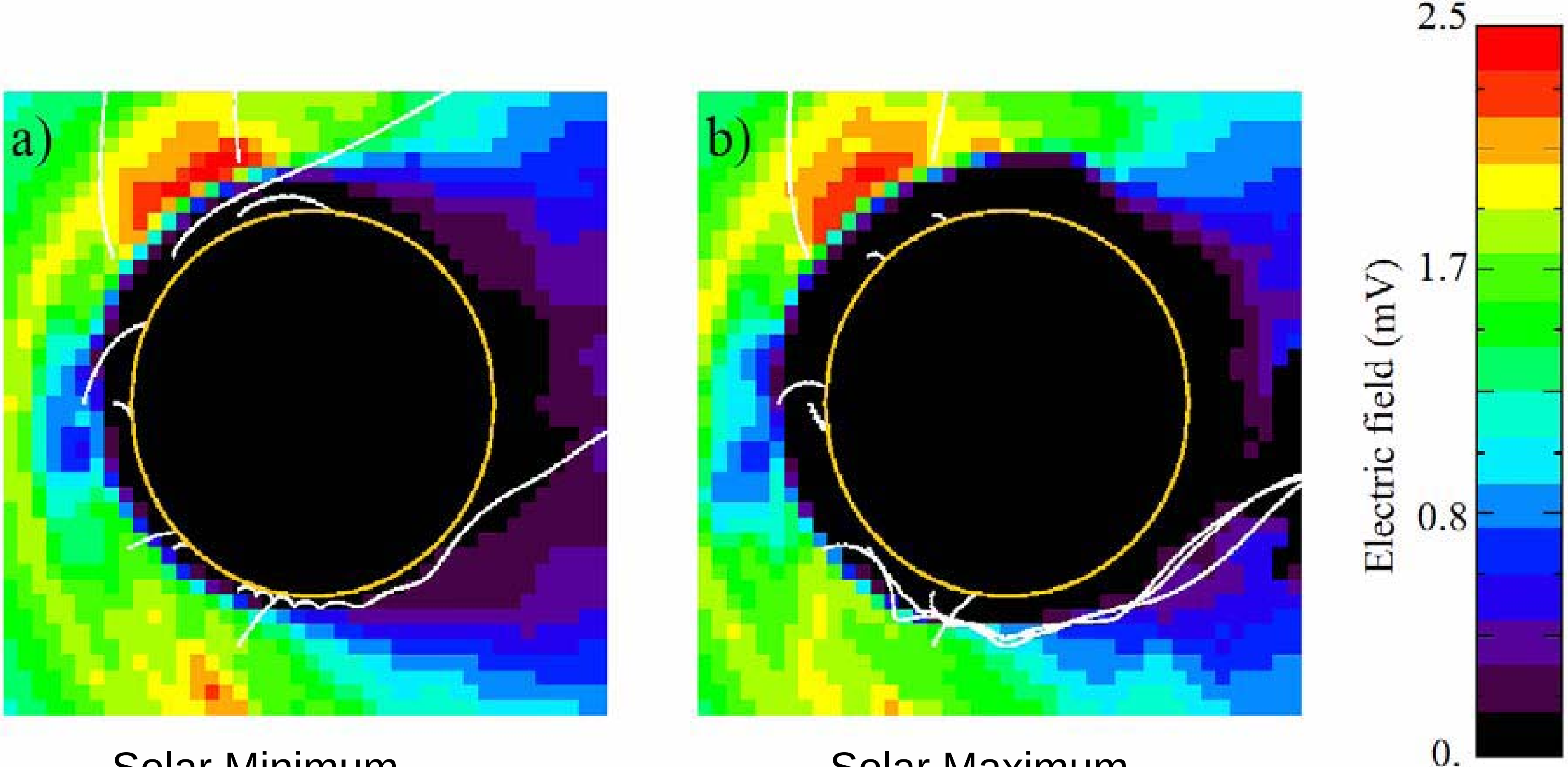
Solar wind parameters

3) **Hybrid code (Modolo et al. 2005)**

4) **Ions tracking code**

- Use the O^+ production rates from Hybrid code
- Track ions in the EM environment (from hybrid code)
- Compute escape and sputtering flux of O+ ; describe charge exchange with corona (H, O)
- Compute escape and sputtering flux of O ENA

Trajectories of ions in the Martian EM environment

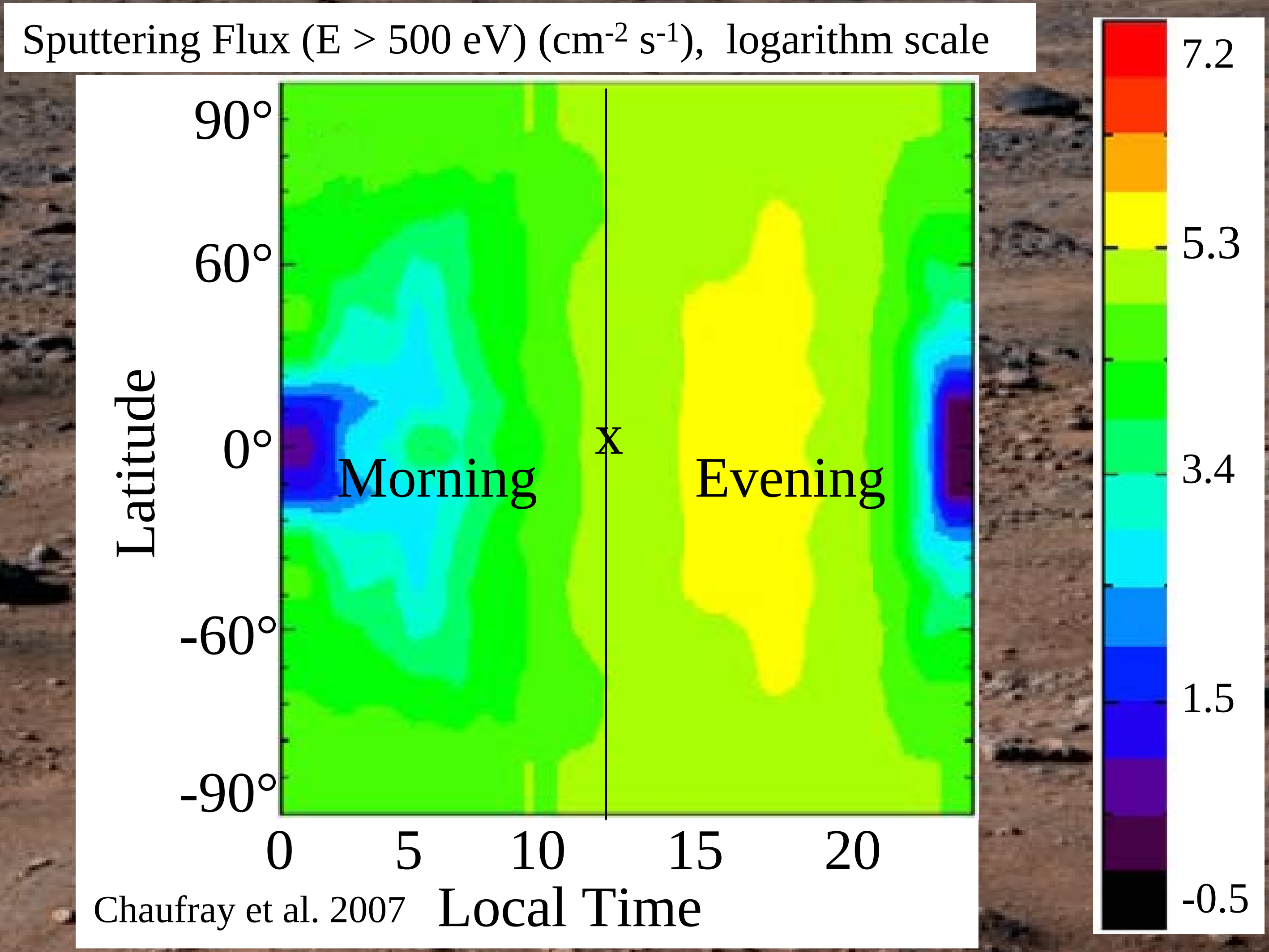


Solar Minimum

Solar Maximum

Chaufray et al. 2007

Sputtering flux reimpacting the planet (at 300 km)



Sputtering Model

1) <u>Goal</u>

Compute oxygen escape flux from sputtering

Compute hot oxygen corona created by sputtering

2) <u>Input</u>

2D Sputtering Flux at 300 km

Thermospheric profile : same profile than oxygen corona model

3) <u>Algorithm (DSMC code)</u>

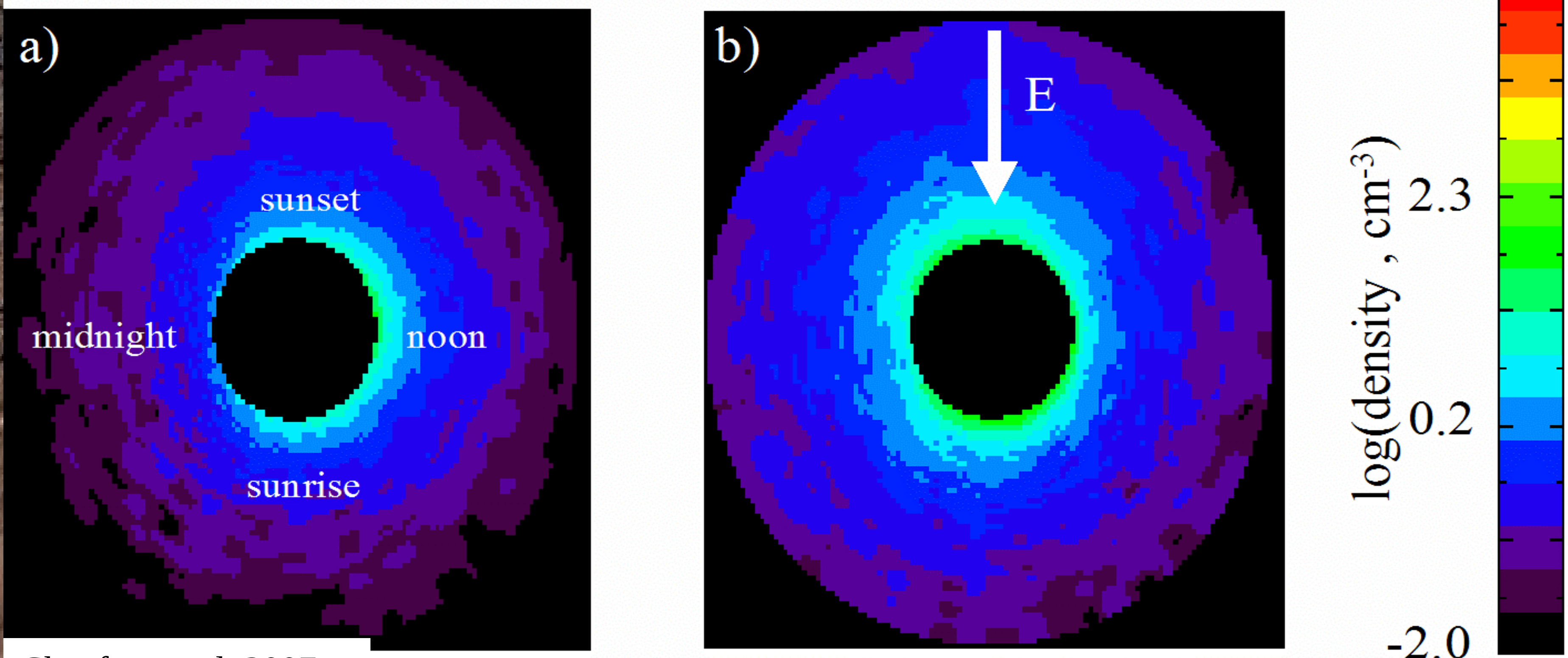
Same algorithm than hot oxygen corona model

Sputtering Model

4) **Main Output**

Solar Minimum

Solar Maximum



Chaufray et al. 2007

Escape processes

	Escape Flux (s^{-1}) *Solar Min*		Escape Flux (s^{-1}) *Solar Max*
Dissociative Recombination	$1x10^{25}$	X 4 →	$4x10^{25}$
O^+ exospheric escape	$2x10^{23}$	X 15 →	$3x10^{24}$
O ENA escape (charge exchange)	$4x10^{22}$	X 10 →	$4x10^{23}$
Sputtering	$2x10^{23}$	X 3.5 →	$7x10^{23}$

Conclusion

<u>Main results</u>

First consistent study of oxygen escape /corona for current solar conditions (solar max and min)

Oxygen escape is dominated by dissociative recombination

<u>Main Limits of the current study</u>

- Simplification of the thermosphere (spherical symmetry, no wind,…)
- Resolution of hybrid model ~ 300 km (not very accurate near the exobase where interactions become important)
- No crustal field
- Limited to atomic oxygen escape
- No description of past conditions (water escape along martian history)