

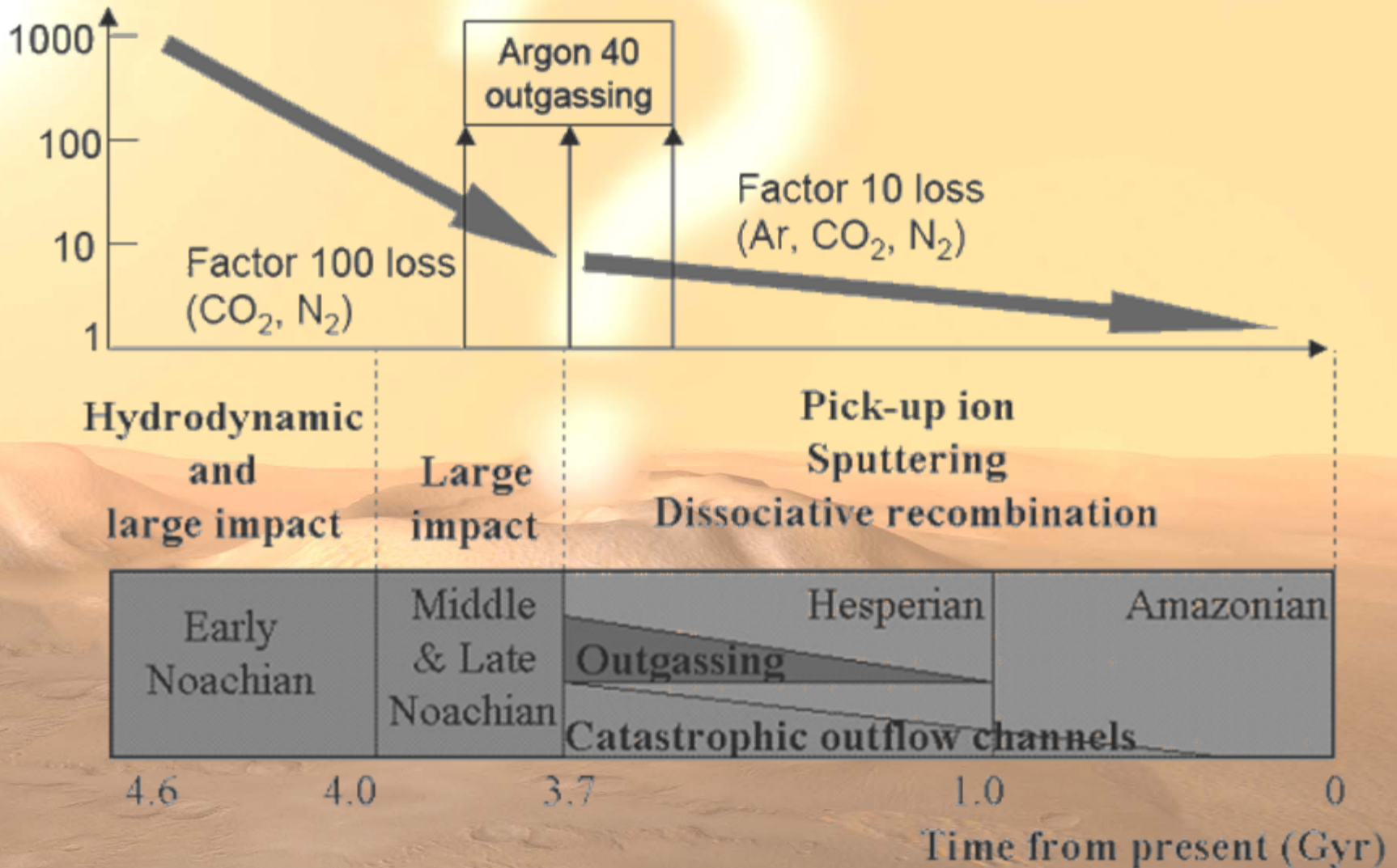
Aspects of the evolution of the atmosphere of Mars and Venus

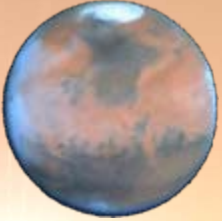
C. Gillmann, P. Lognonne, E. Chassefiere, M. Moreira, F. Leblanc





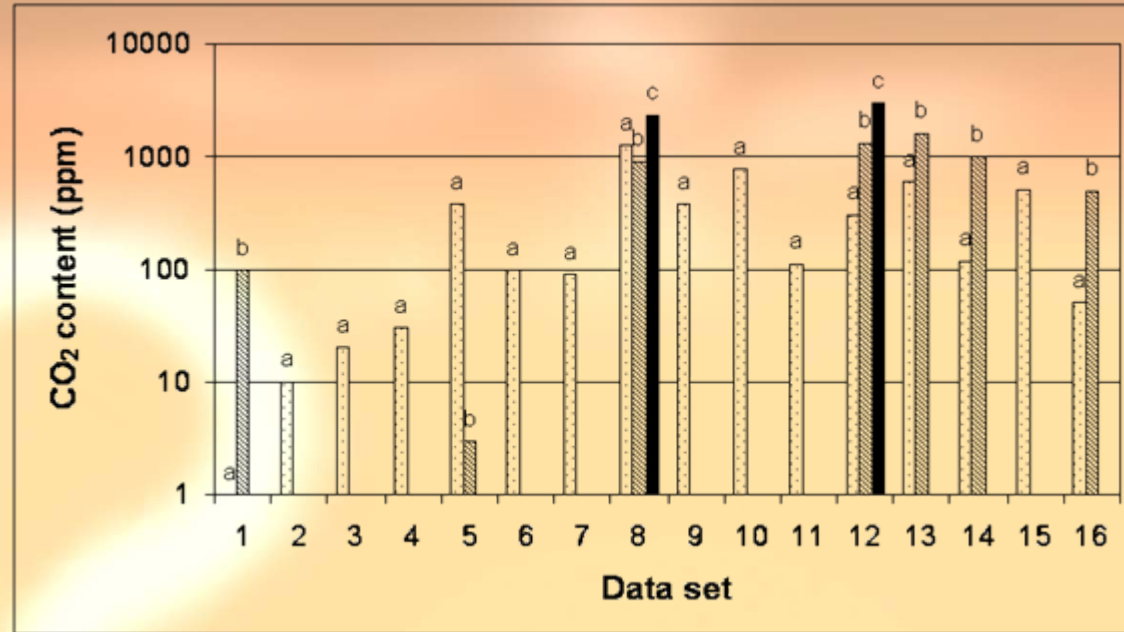
Evolution of the Martian atmosphere



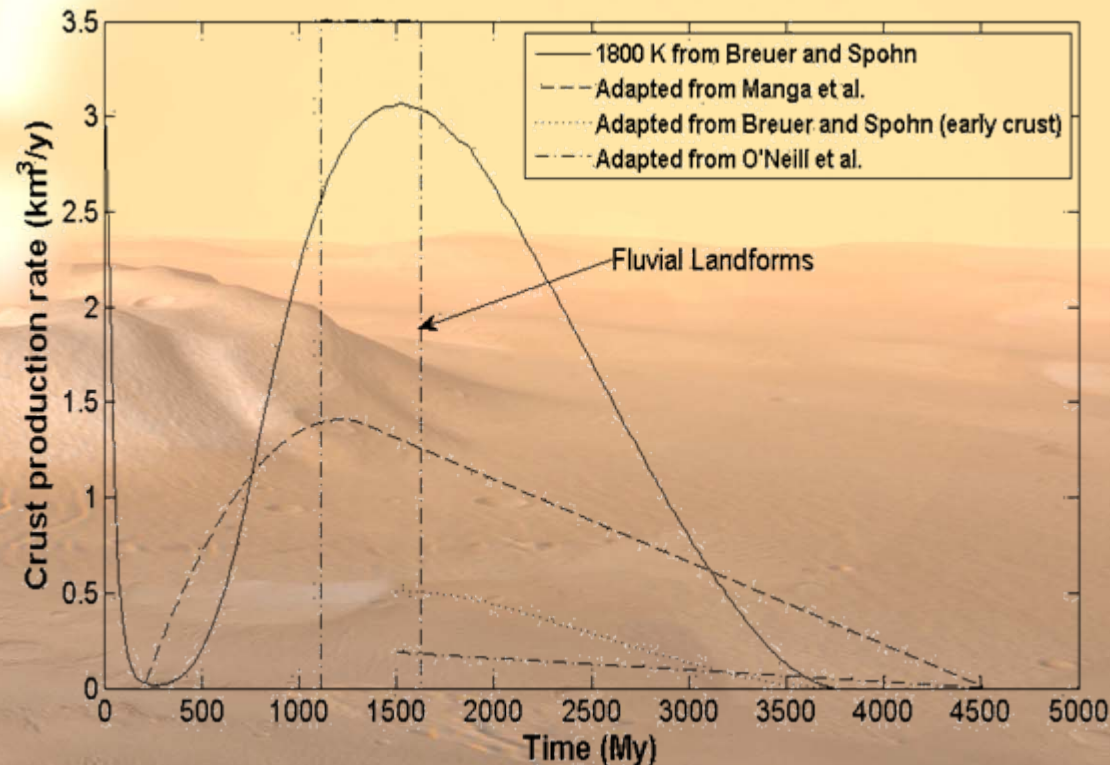


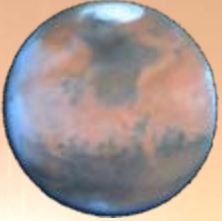
Volcanic Production

- CO₂ content is difficult to estimate. (SNCs, Earth-like values)



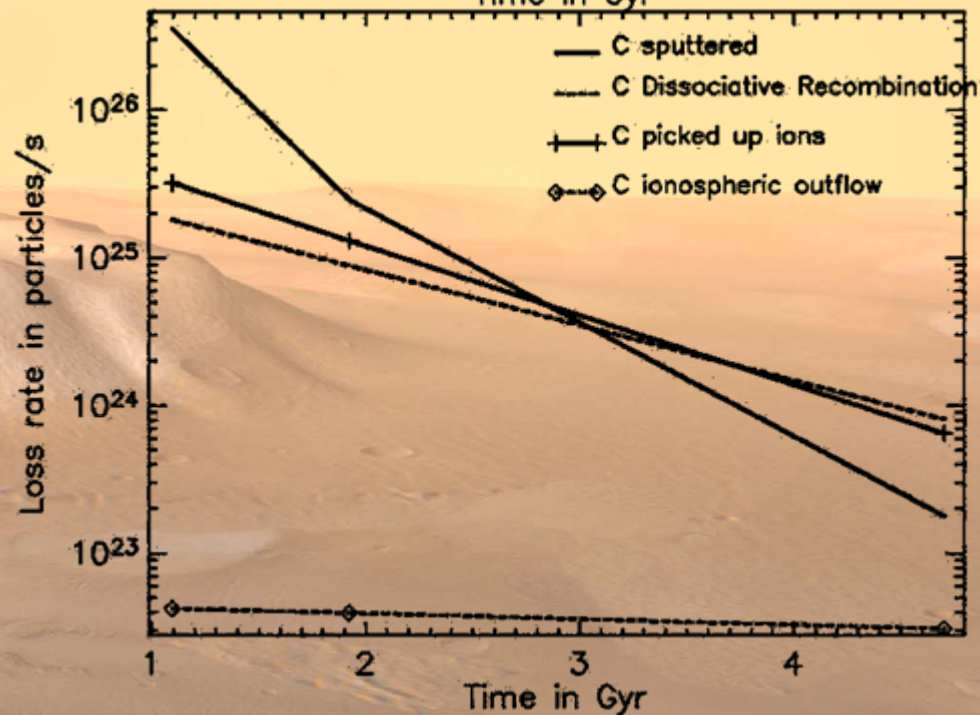
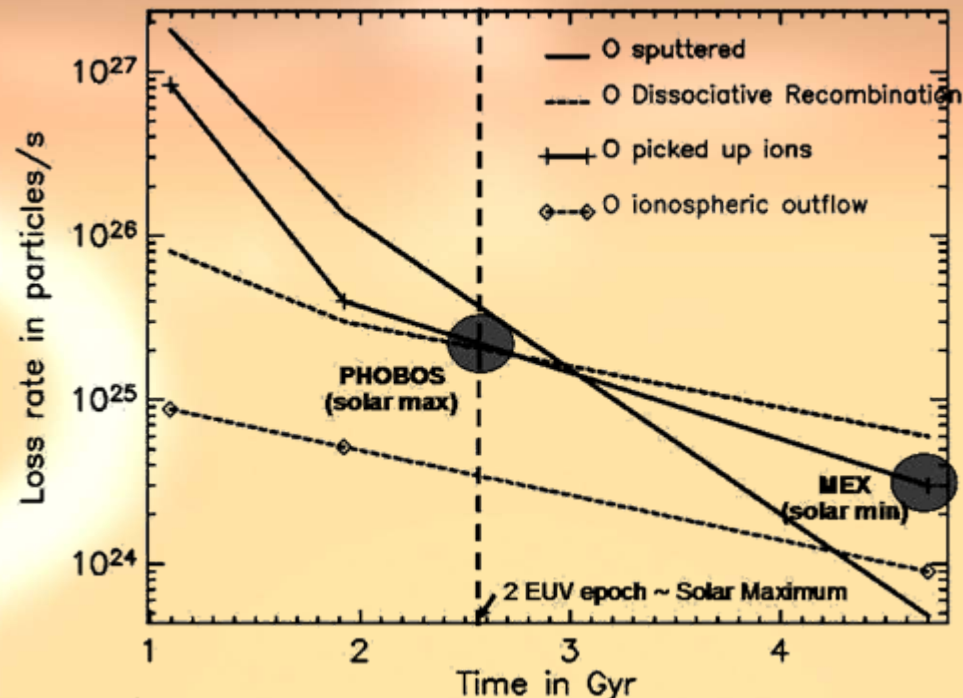
- Models for crust production rates vary over a wide range of values (0.17 km³/y for the Hesperian to around 10⁻⁴ km³/y at present)

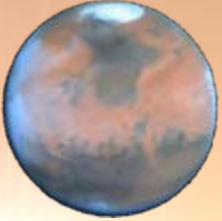




Atmospheric Escape

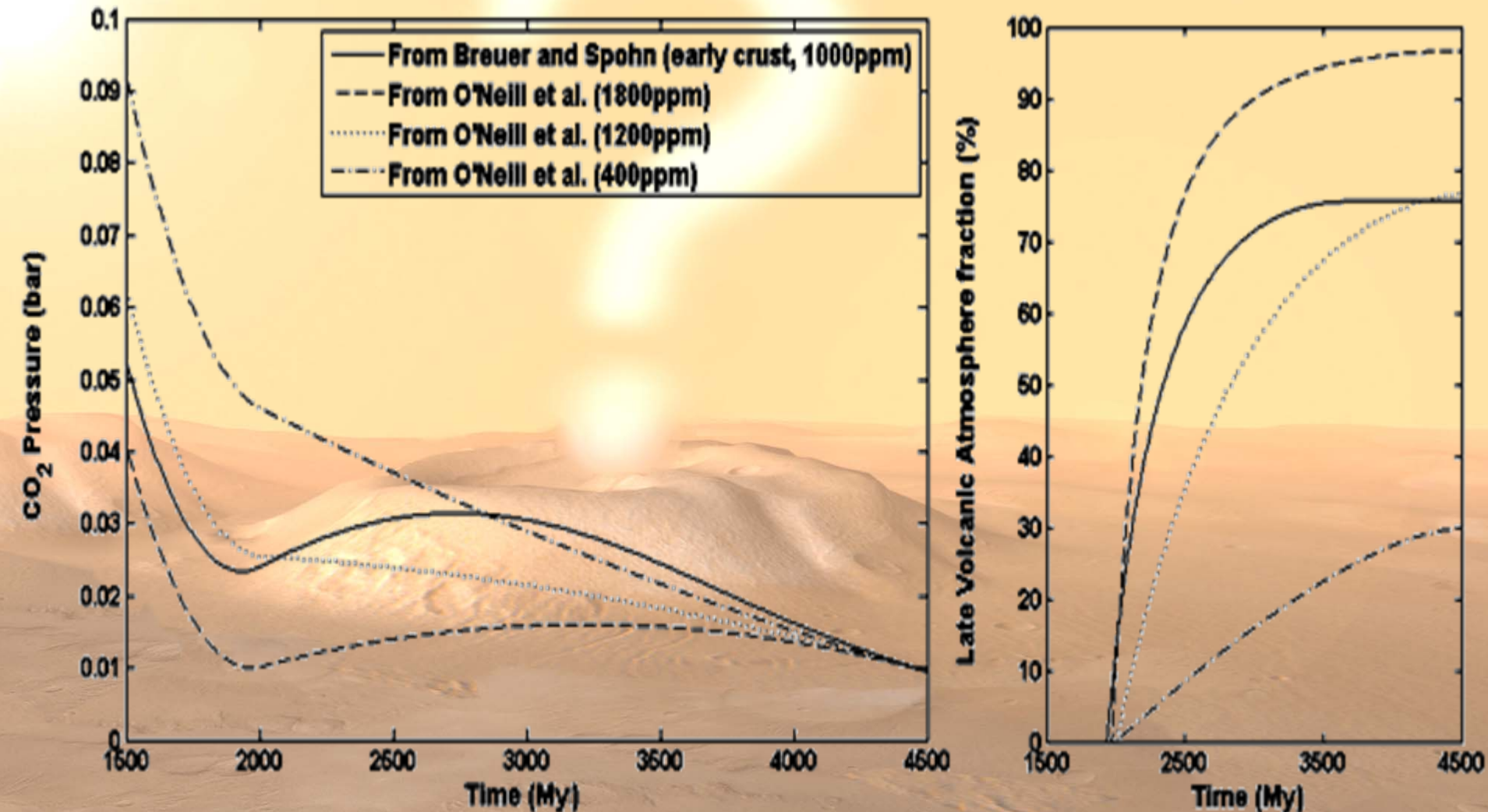
- Thermal processes such as hydrodynamic escape are not considered here.
- Here we neglect the effect of meteoritic bombardment
- Non-thermal processes are sputtering, dissociative recombination, ion pick-up and ionospheric outflow.
- They depend on the solar EUV flux that decreases with time.

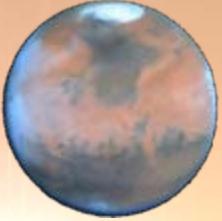




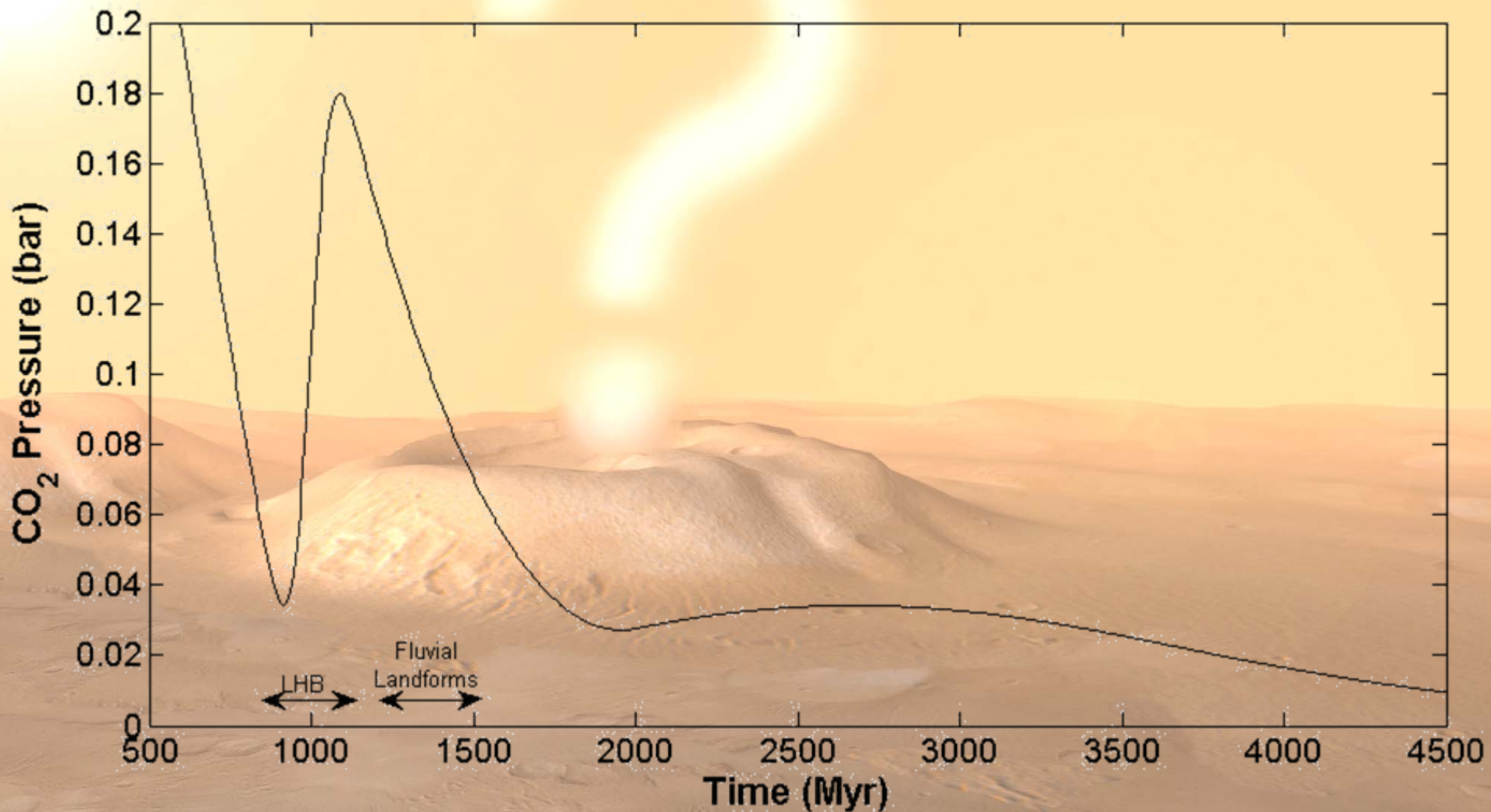
A young atmosphere ?

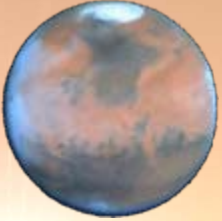
The importance of degassing



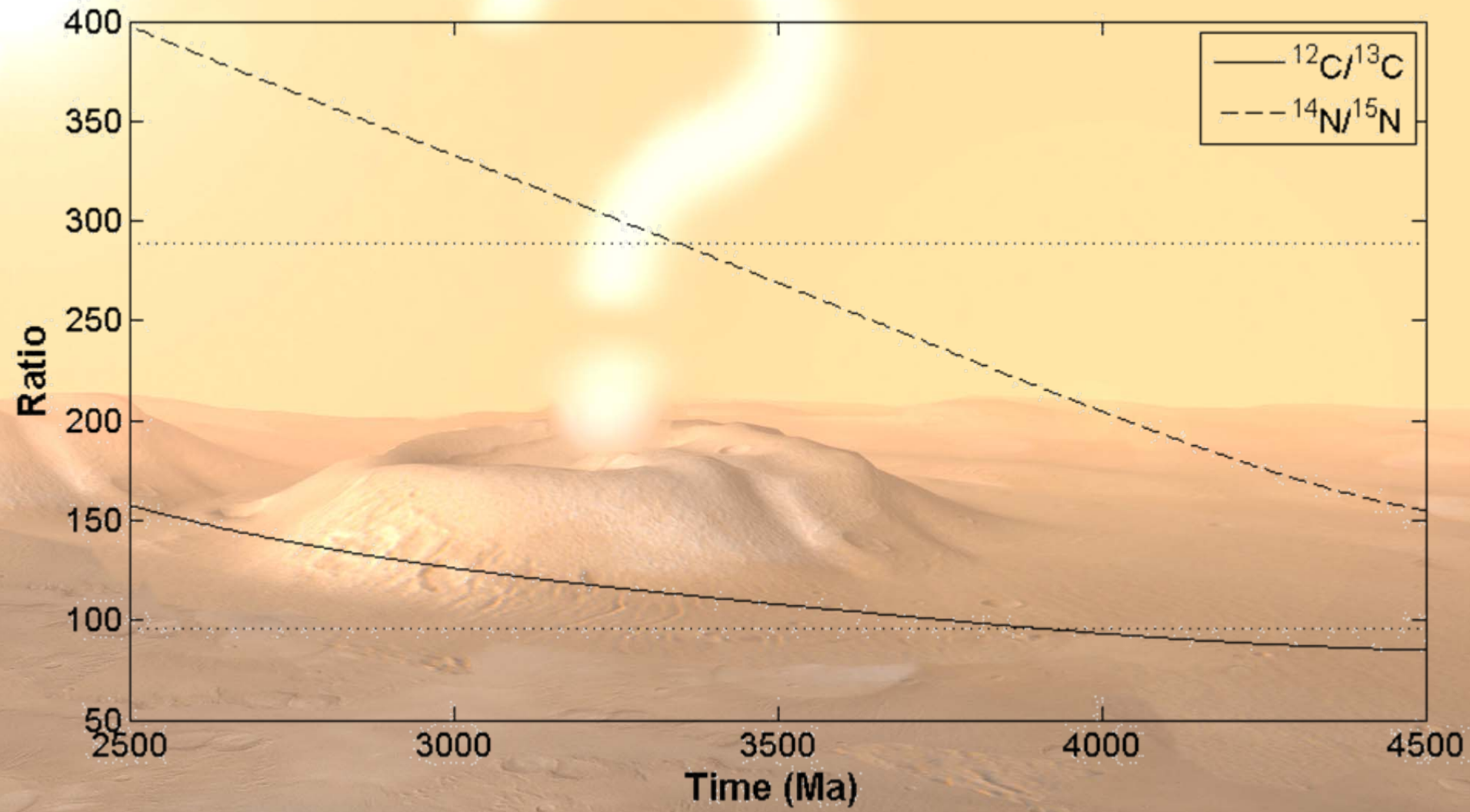


Earlier atmosphere.





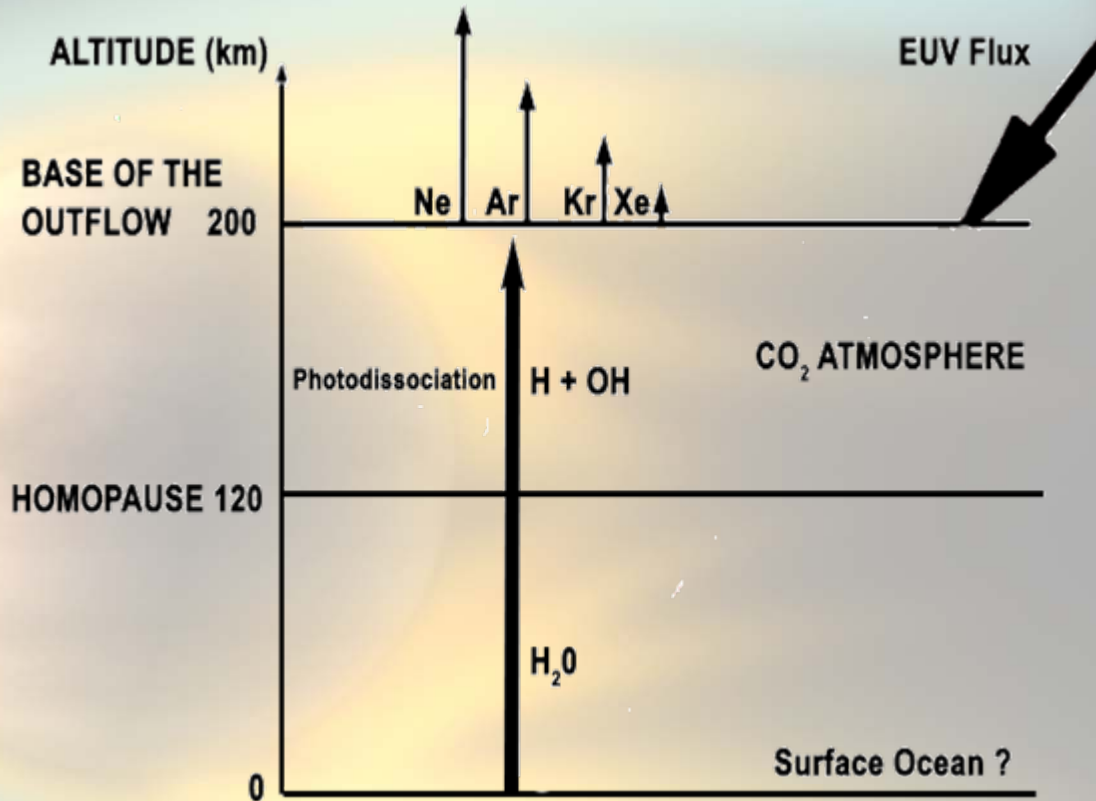
Isotopic constraints



The Early evolution of Venus

Hydrogen can easily escape from the atmosphere but what about oxygen ?

Element	Venus value	Earth value
$^3\text{He}/^4\text{He}$	$<3 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$
$^{20}\text{Ne}/^{22}\text{Ne}$	11.2-12.6	9.8
$^{21}\text{Ne}/^{22}\text{Ne}$	<0.067	0.029
$^{36}\text{Ar}/^{38}\text{Ar}$	5.45 ± 0.1	5.32
$^{40}\text{Ar}/^{36}\text{Ar}$	1.11 ± 0.02	295.5

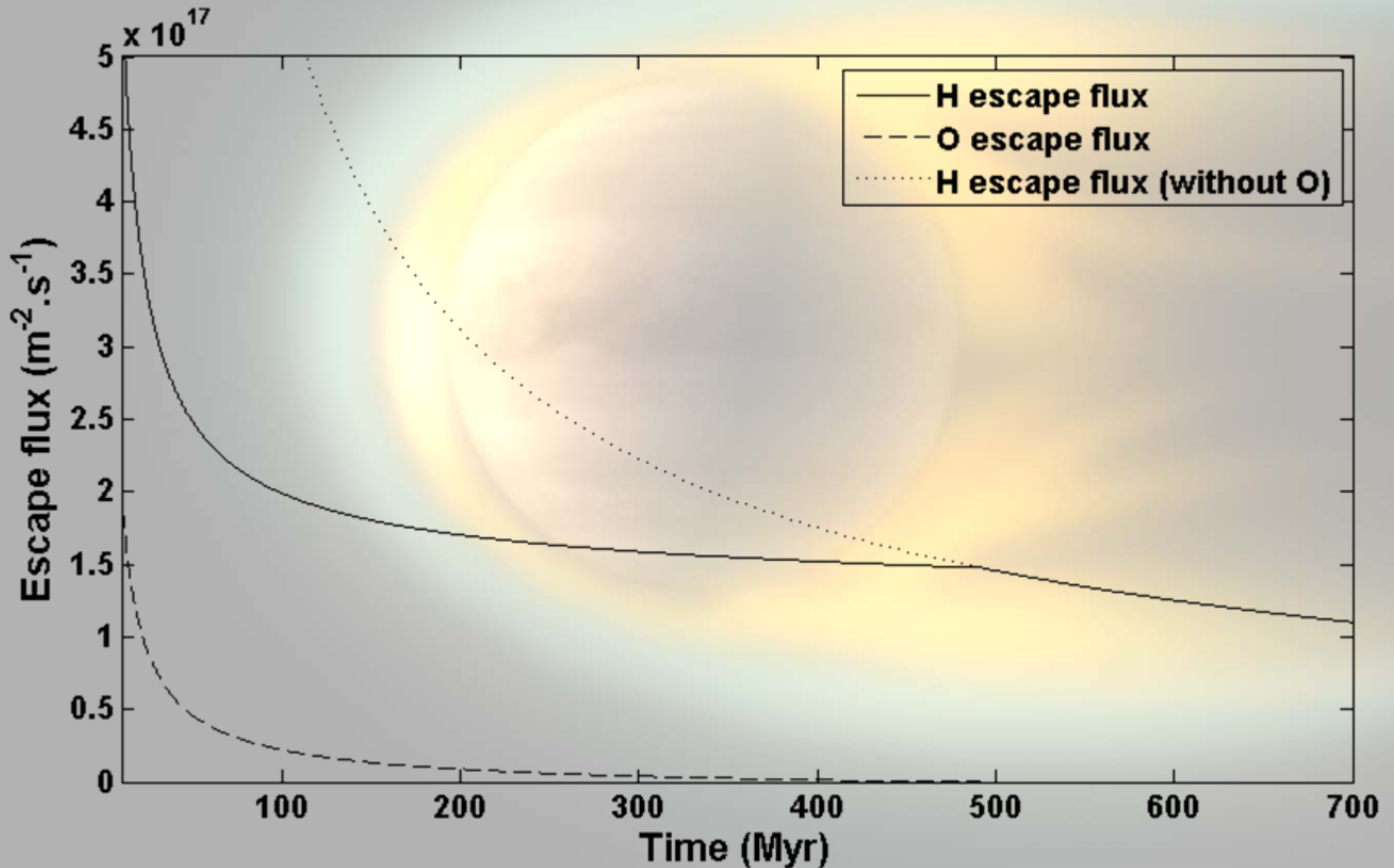


Theory adapted from Hunten et al. with joined H and O escape.

Powered by EUV flux and solar wind.

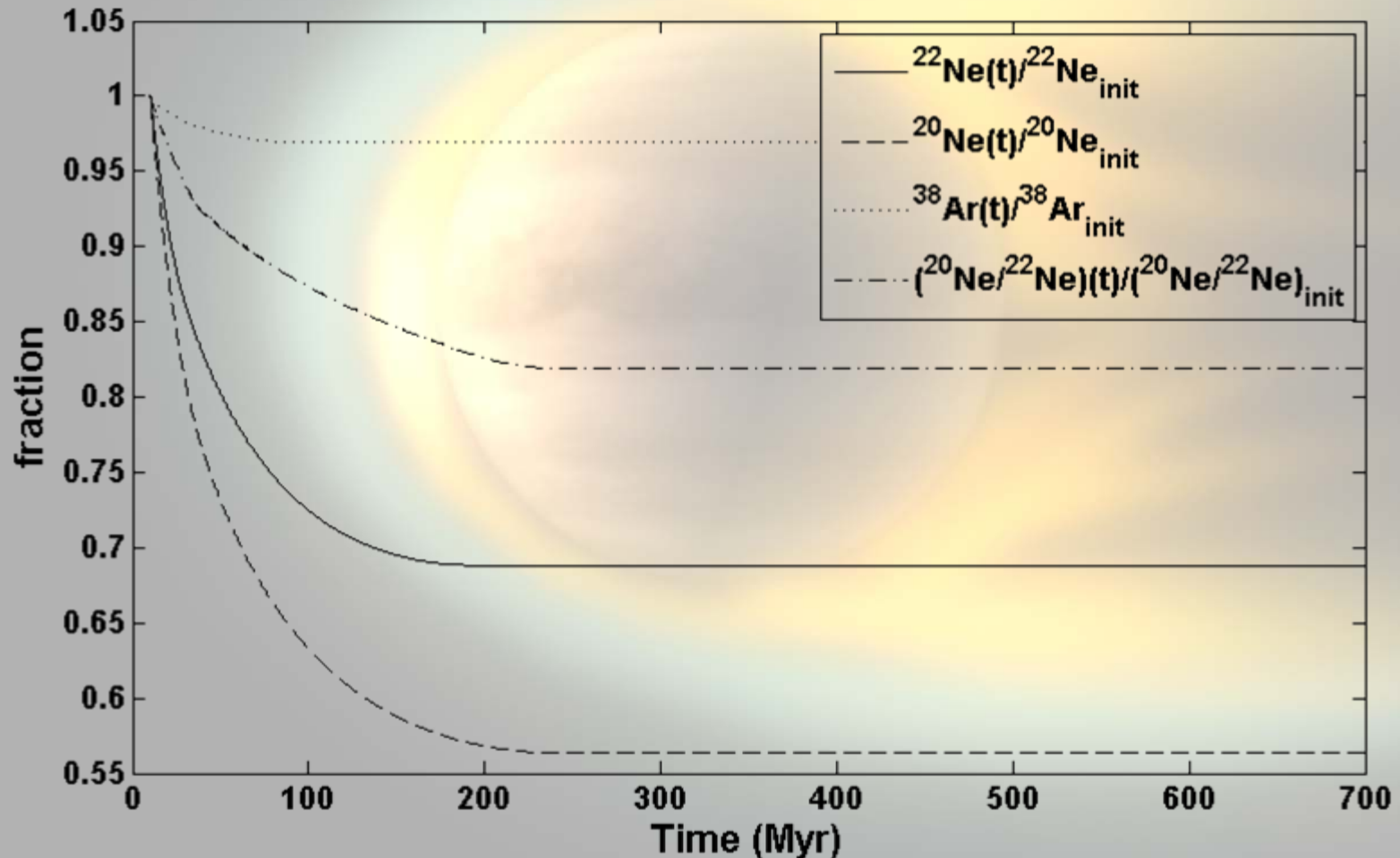
Gravitational fractionation is taken into account.

Escape-Driving fluxes

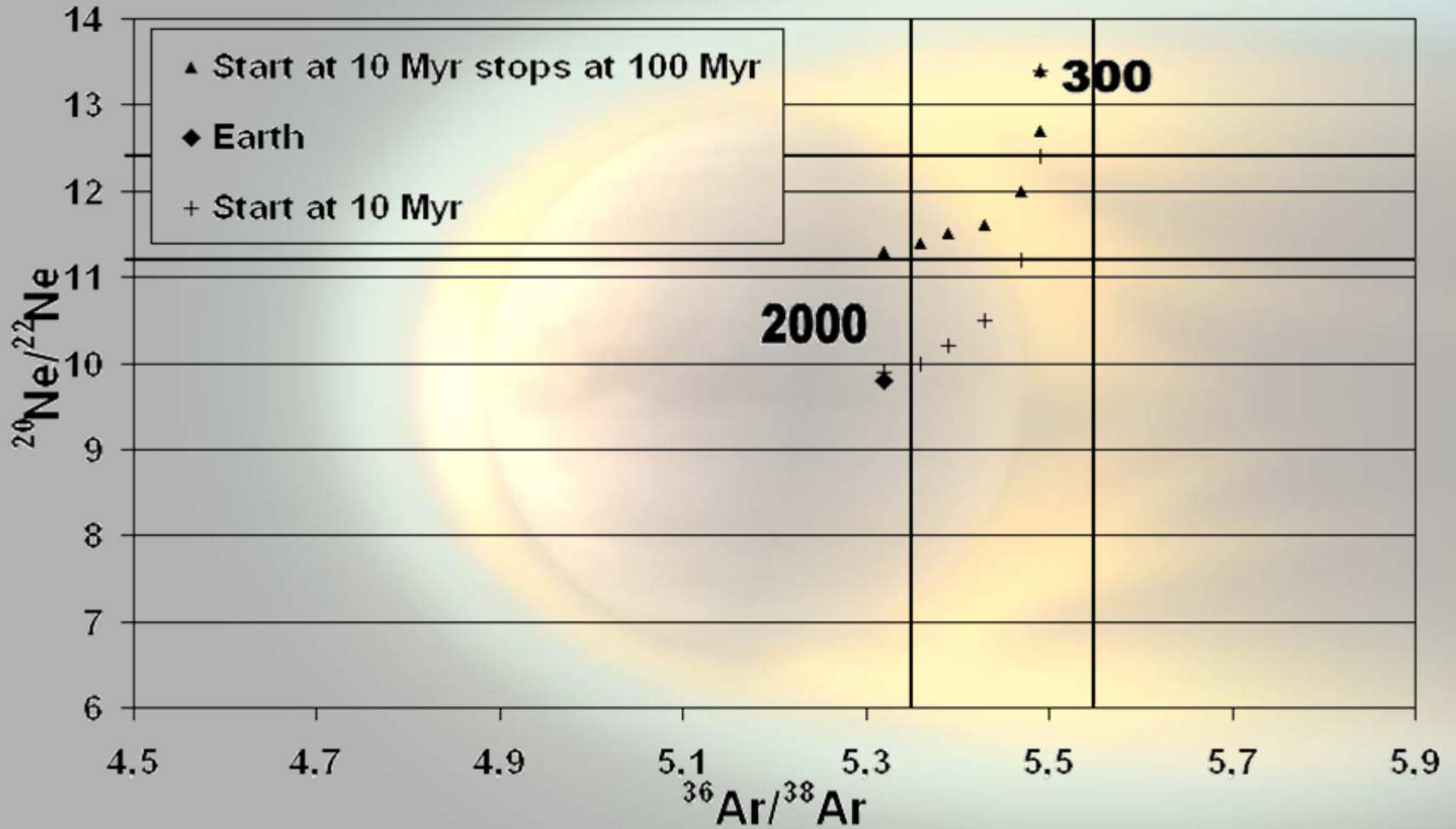


Consequences on the isotopic ratios

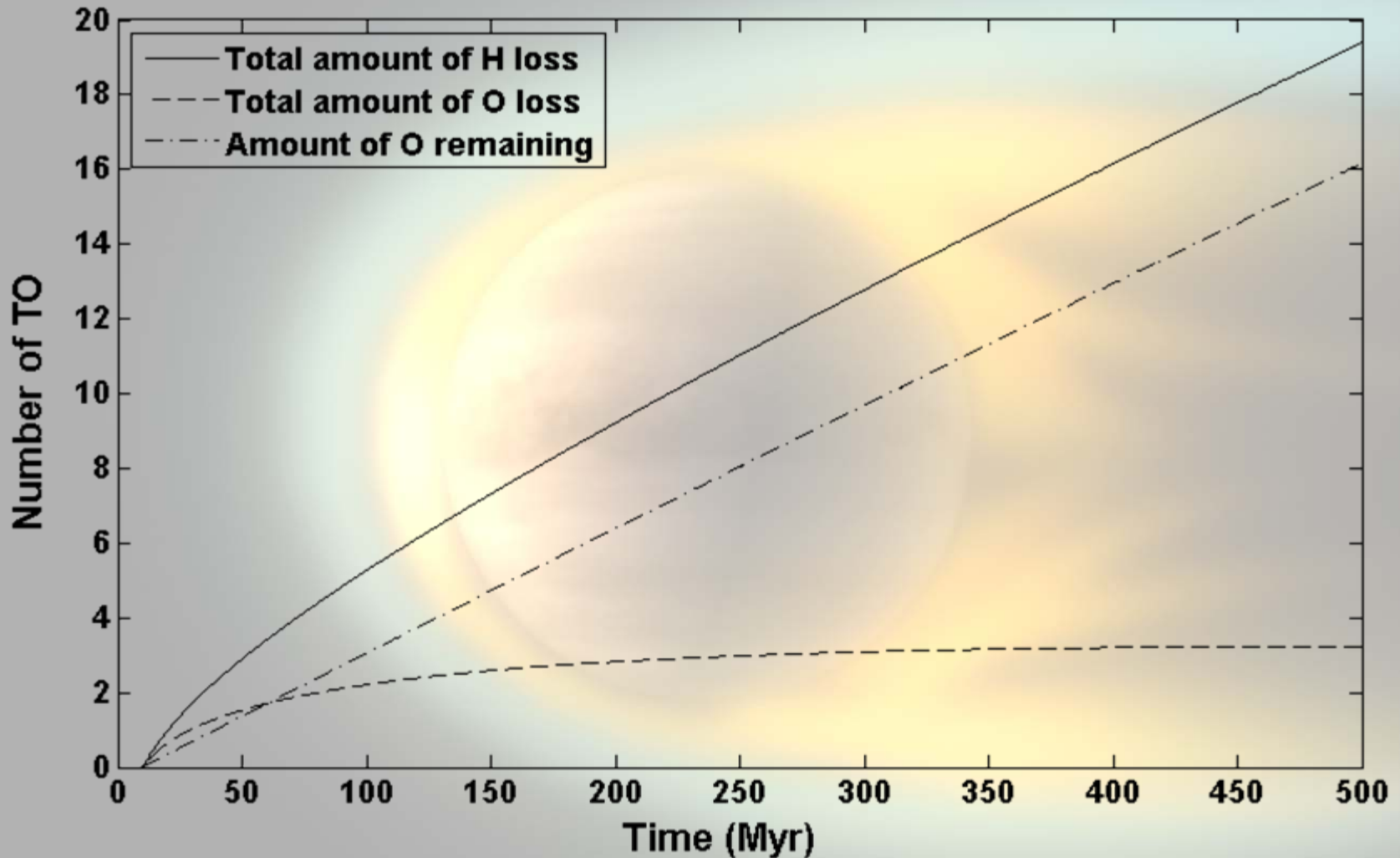
- Xe and Kr do not escape significantly.



Isotopic ratios



Atmospheric loss



- Water is mainly brought by late accretion planetary embryos from the outer solar system (Raymond et al., Morbidelli et al.)

A scénario for the evolution of the atmosphere of Venus.

Accretion of 5 TO of water from embryos

- Hydrodynamic escape of hydrogen (all) and oxygen (most)
- Fractionation of Ne to present value
- Build up of a transient massive O₂ atmosphere (a few 100 bars)
- Loss of O₂ to the magma ocean by iron oxidation

Magma ocean

10-100 Myr

Accretion of 0.1 TO of water from comets

- Hydrodynamic escape of hydrogen (all) and oxygen (few)
- Build up of a ≈15 bar O₂ atmosphere
- Subsequent loss of O₂ to the rock surface by iron oxidation

100-500 Myr

- Non-thermal escape of H₂O contained in a GEL of a few meters depth
- Fractionation of H to present value
- Continued loss of O₂ to the rock surface by iron oxidation

500 Myr-Now