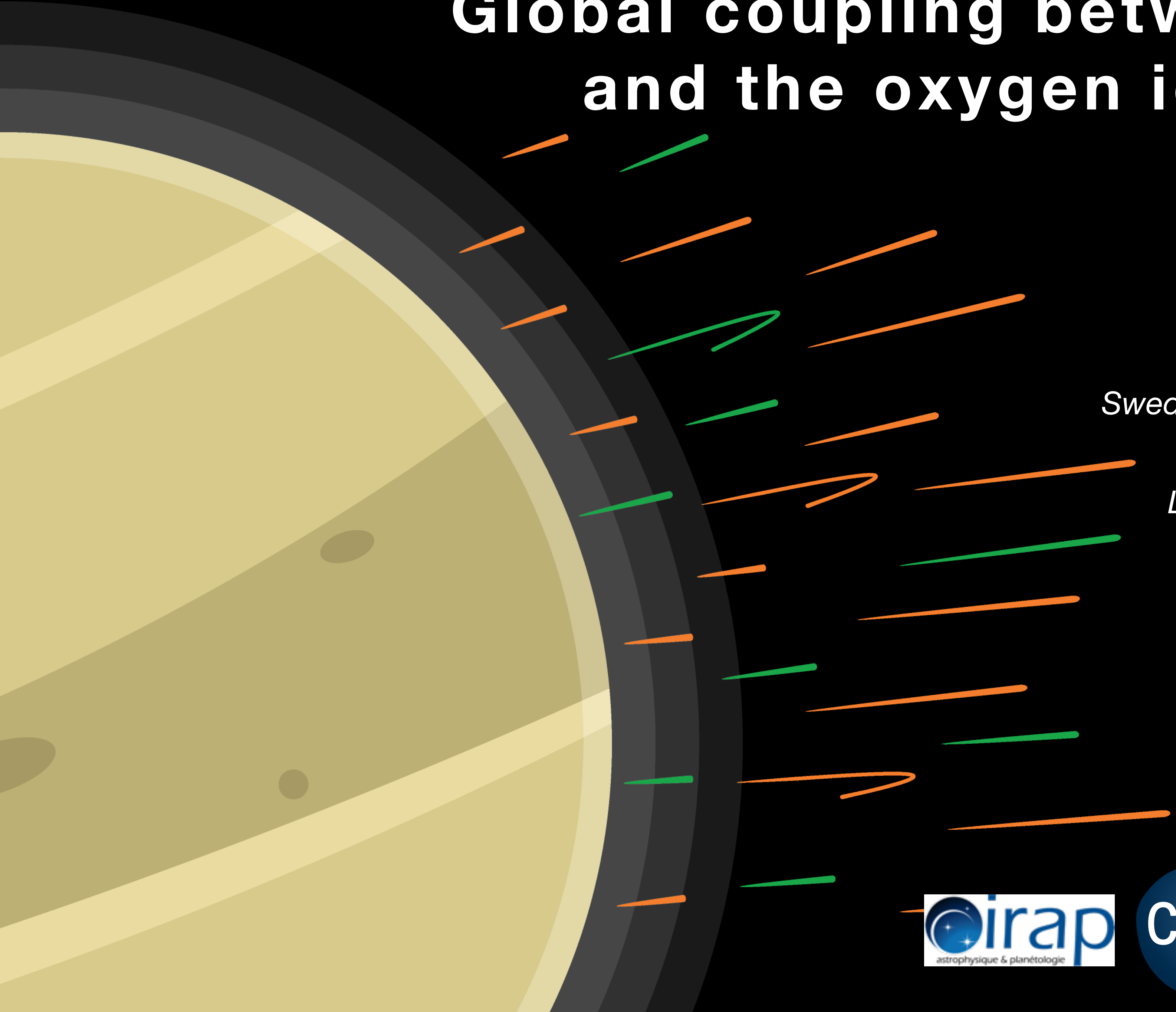
Global coupling between the solar wind and the oxygen ion escape at Venus



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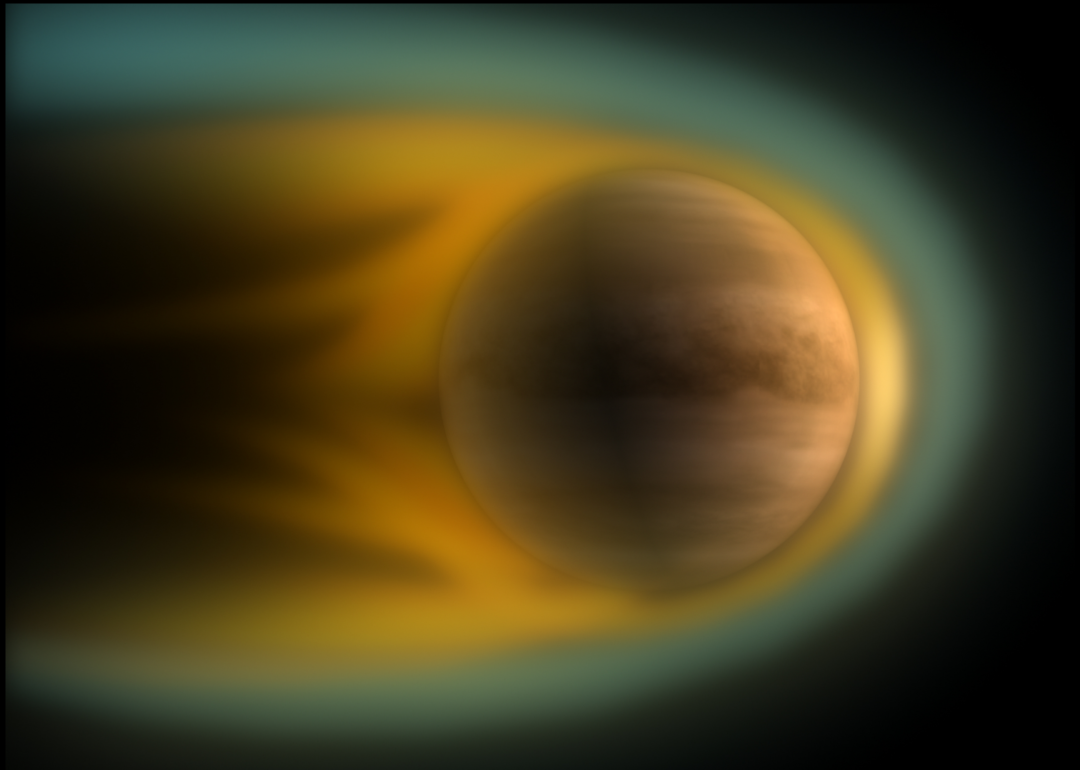
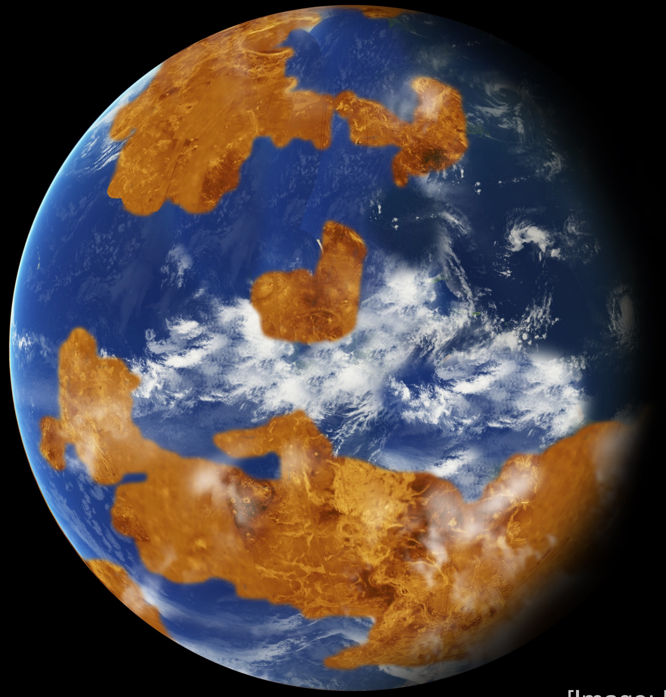
Evolution of the Venusian atmosphere

Venus once had water in its atmosphere,
but today Venus is arid
[Donahue et al., 1997, Way et al., 2018]

How has the atmosphere evolved?



[Image: ESA/C. Carreau]



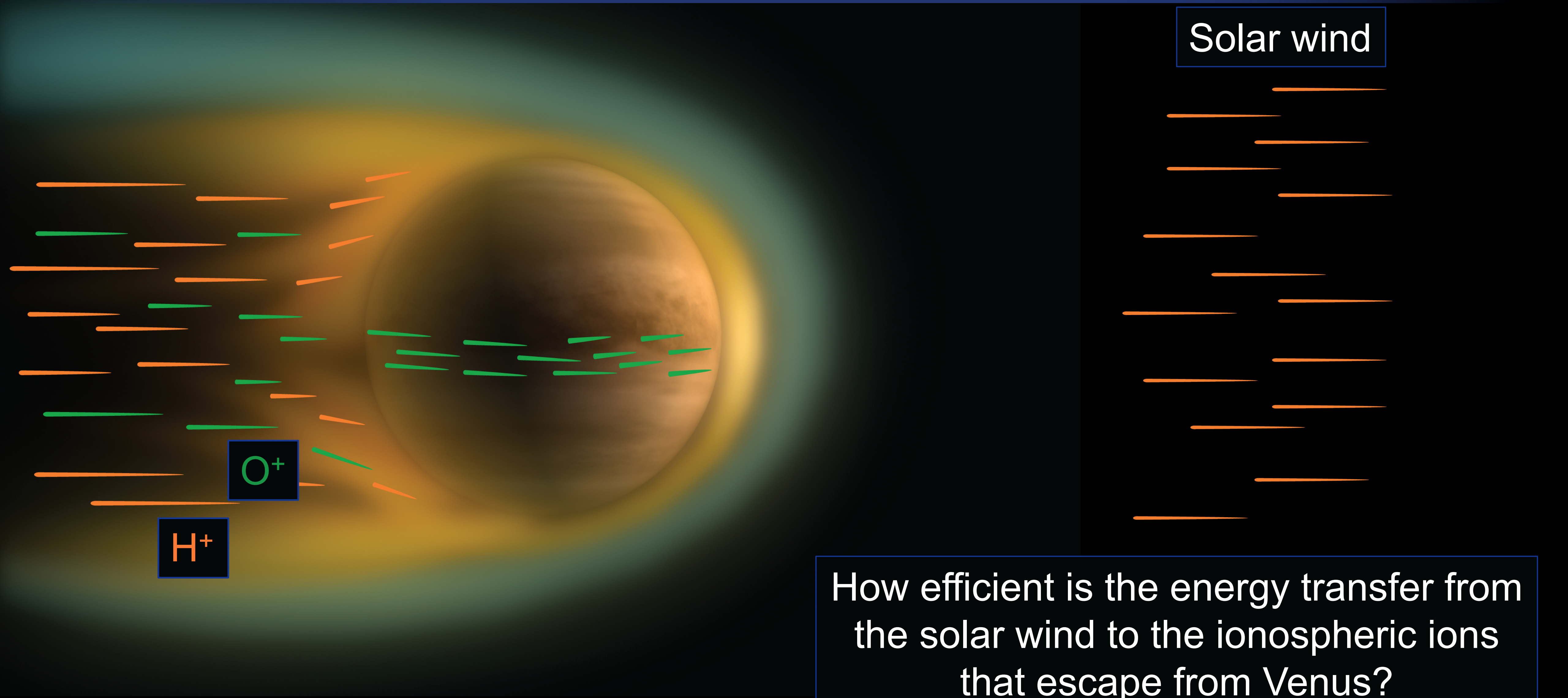
[Image: NASA]

Water loss mechanisms:

1. Interaction between surface and atmosphere
2. Escape of atmospheric constituents to space

→ Here we focus on escape to space

Ion flows in the Venusian induced magnetosphere



How efficient is the energy transfer from the solar wind to the ionospheric ions that escape from Venus?

[Image: ESA/C. Carreau]

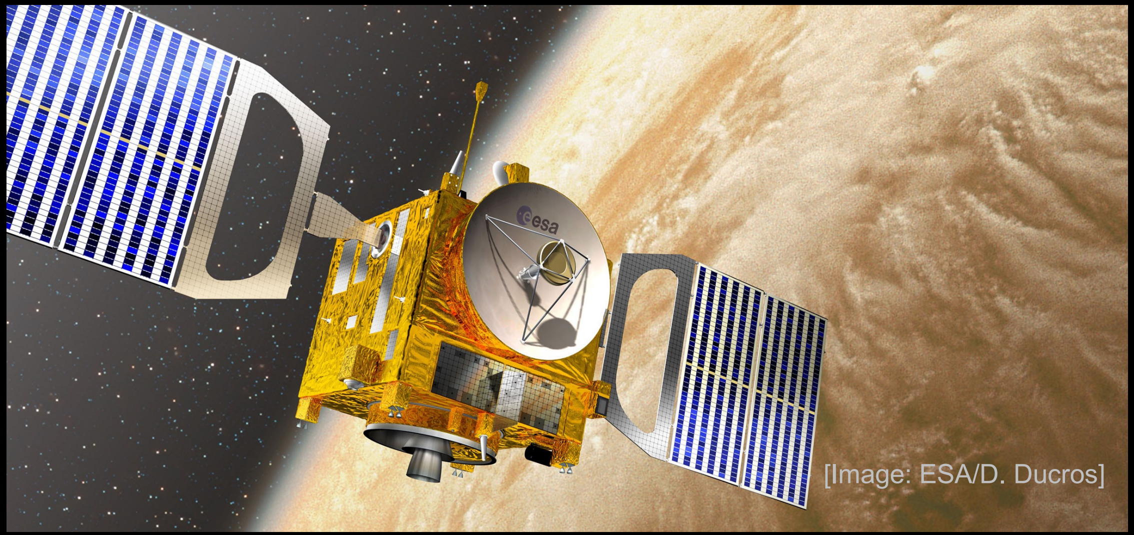
Ion Mass Analyser on board Venus Express

Venus Express

2006-2014

>3000 orbits

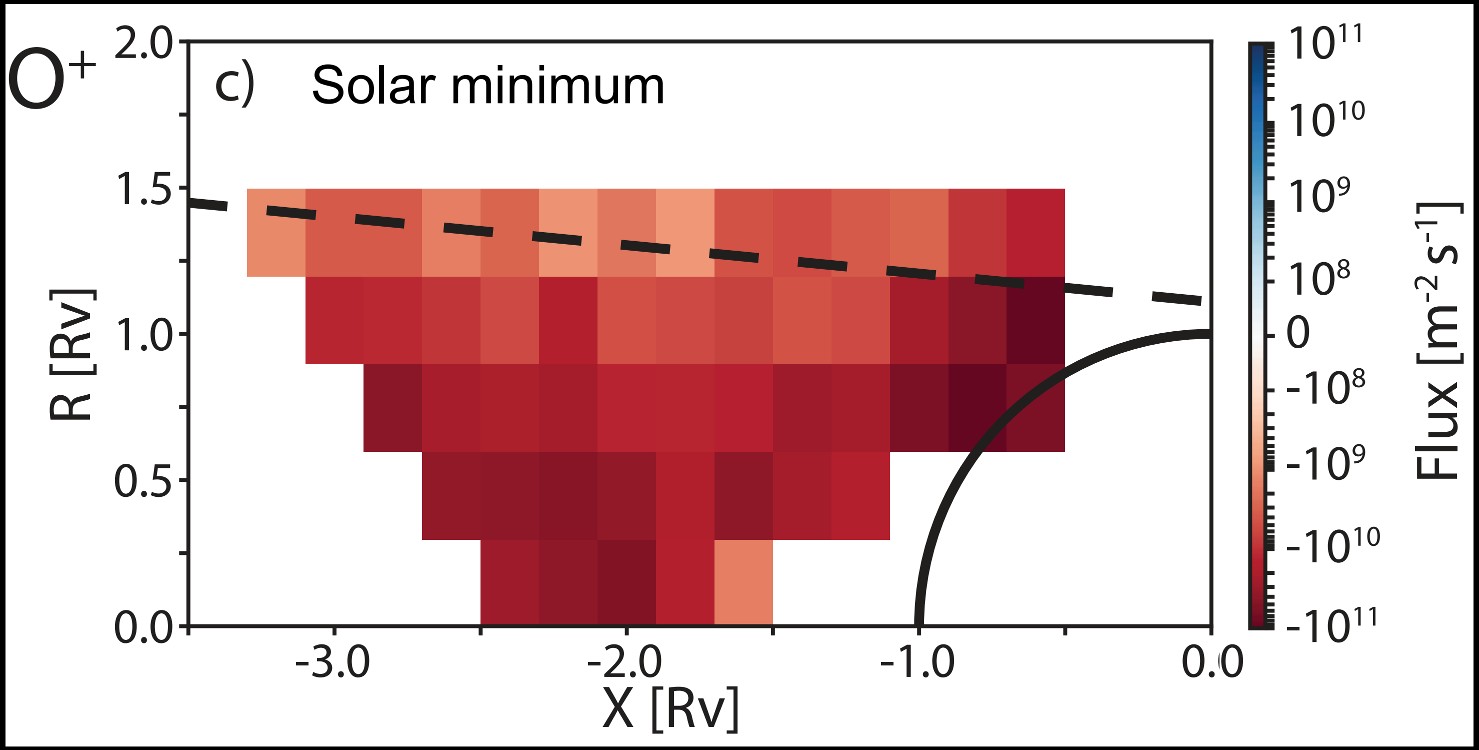
[Barabash et al., 2007]



Ion Mass Analyser (IMA, part of ASPERA-4) provided measurements of ions separated by

- Energy — 0.01-36 keV, ΔE/E = 0.07%
- Direction — 90° x 360° (5.6° x 22.5°)
- Mass — 1 - >40 mass per charge
- in 192 s, with accumulation time 0.125 s

Create average O^+ ion distributions and flux maps



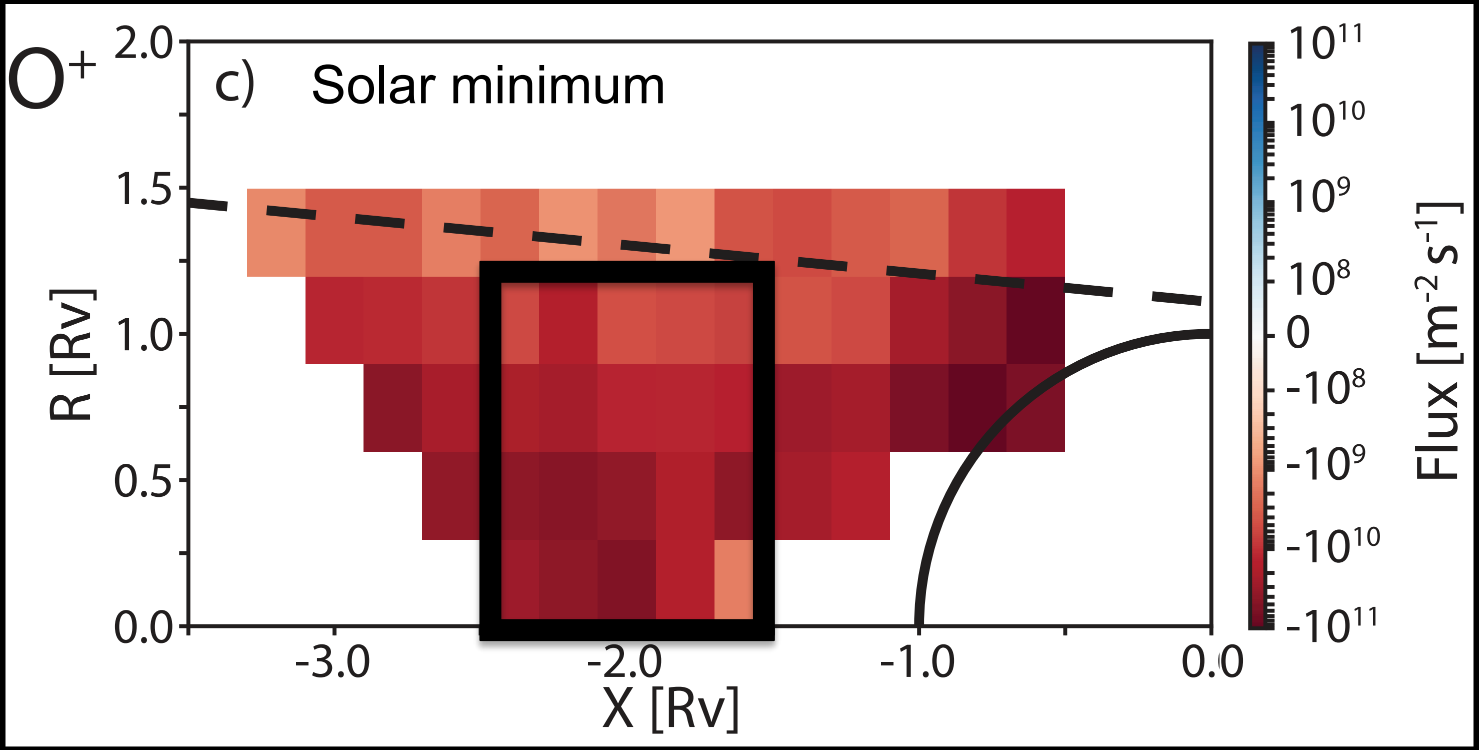
Combine measurements with spatial bins and upstream conditions

→ Create average ion distributions

→ Calculate ion flux in each spatial bin

[Persson et al., 2018]

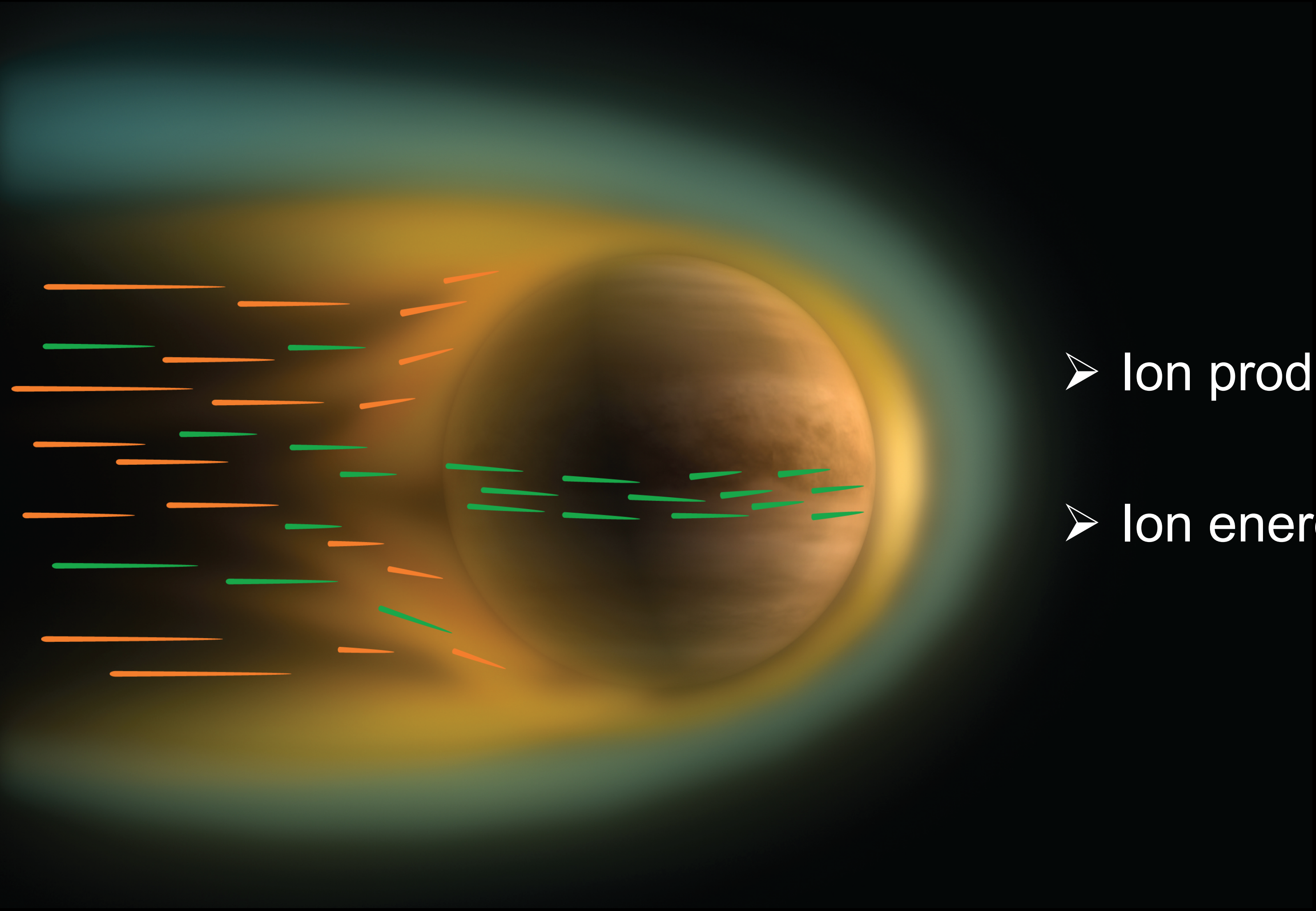
Calculate average escape rates



→ Calculate the total average escape rates by integrating the average flux multiplied with area over the magnetotail

[Persson et al., 2018]

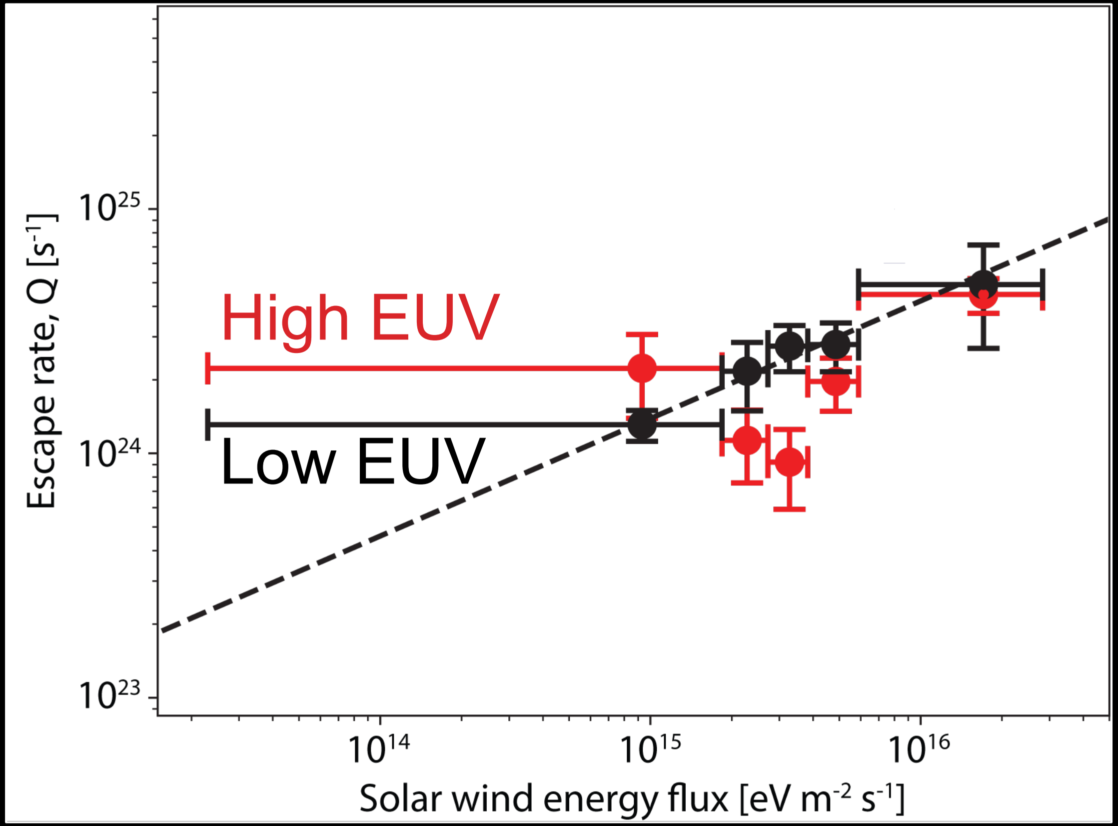
What drives the variations in the escape?



[Image: ESA/C. Carreau]

- ➢ Ion production by solar EUV flux
- ➢ Ion energisation by solar wind

Average O^+ escape rates



- Escape rate increases with available energy in the solar wind
- Escape rate does not increase with EUV flux

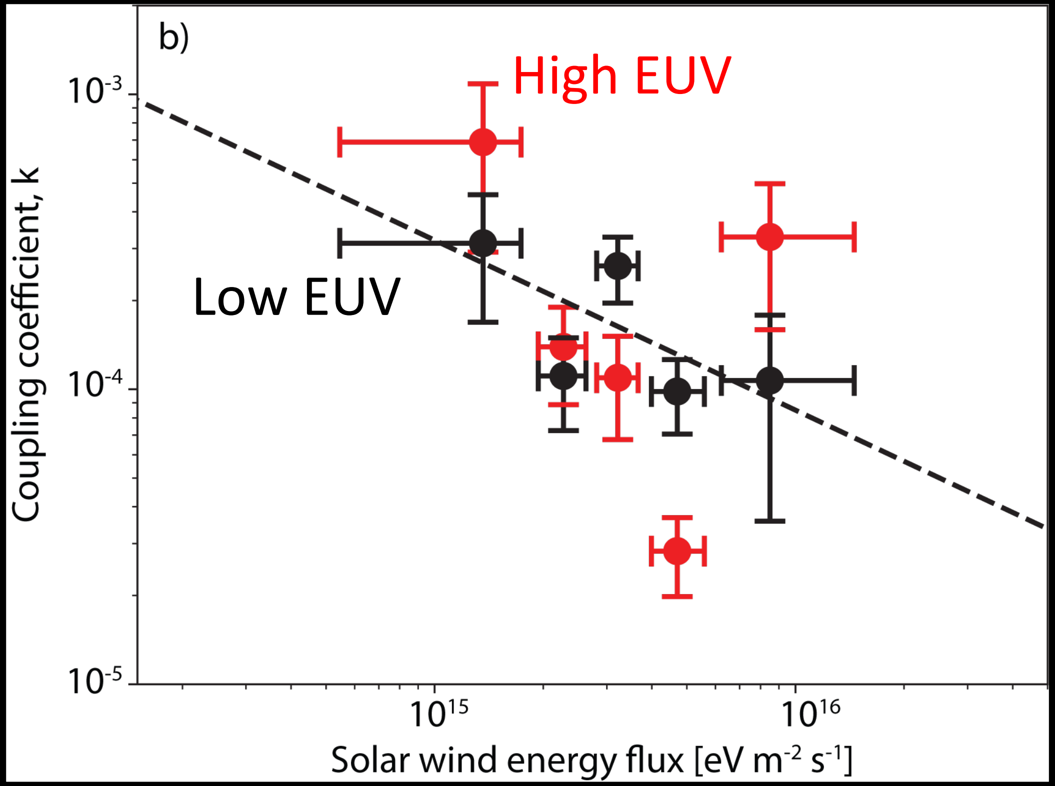
→ The escape velocity limit is more important than the creation of ions

[Persson et al., 2020]

How efficient is the energy transfer to the ions?

Coupling between power out from and into the system

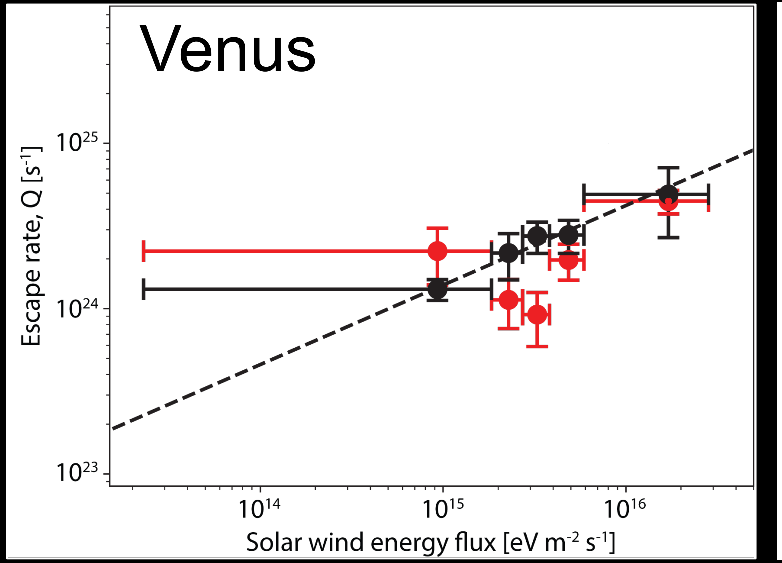
$$k = \frac{P_{escape}}{P_{SW}} = \frac{\sum Q(E) \cdot E \cdot \Delta E}{F_{SW,energy} \cdot A}$$



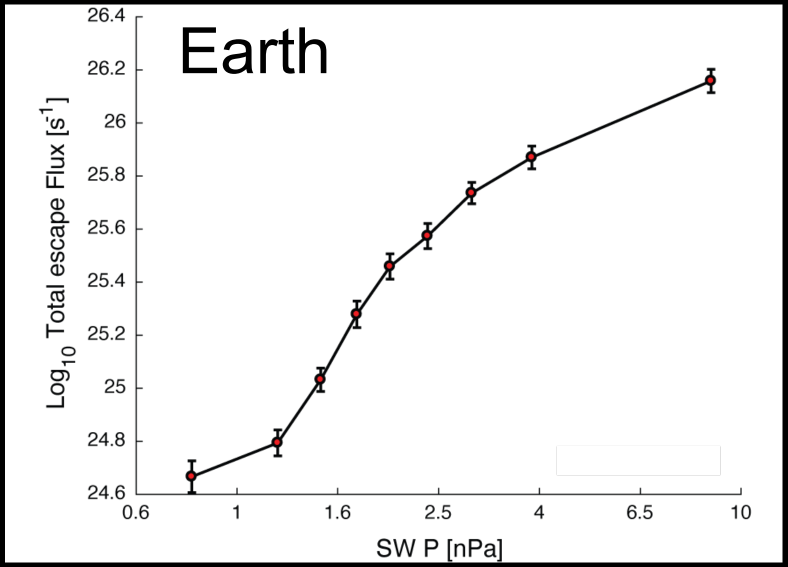
- Coupling coefficient decreases with increased energy available in the solar wind
- ➢ Energy transfer becomes less efficient with higher energy in solar wind
- ~0.01 % of solar wind power is transferred to escaping O^+ ions
- ➢ The induced magnetosphere efficiently screens the atmosphere from the solar wind

[Persson et al., 2021]

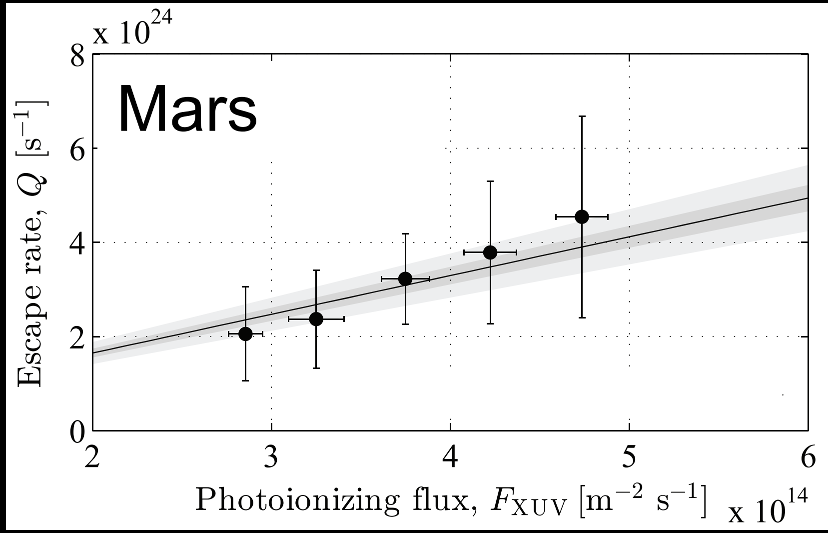
O$^+$ escape rate comparison between Venus, Earth and Mars



[Persson et al., 2020]



[Schillings et al., 2019]

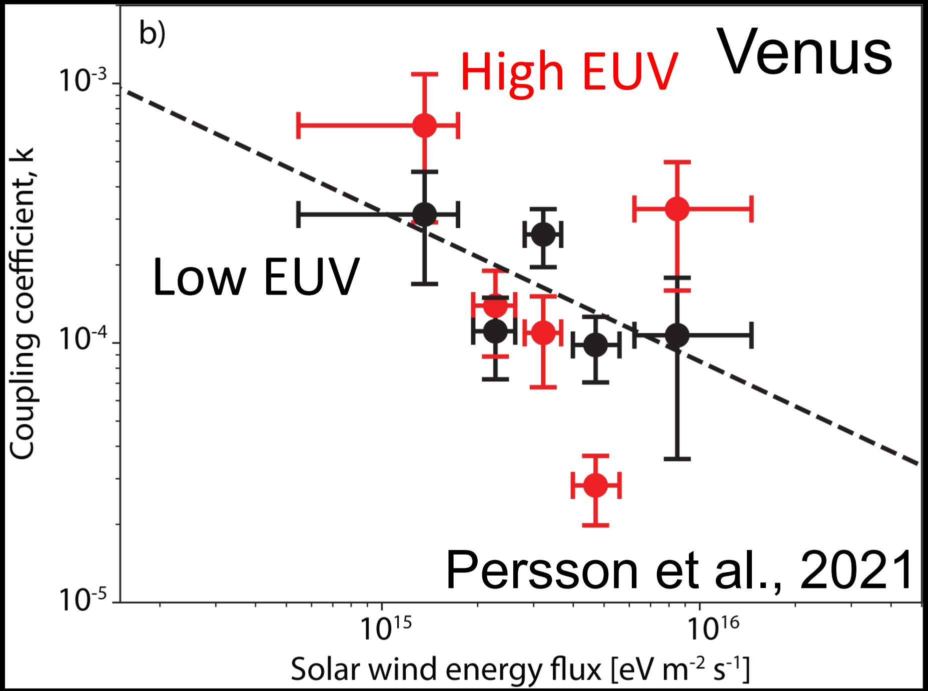


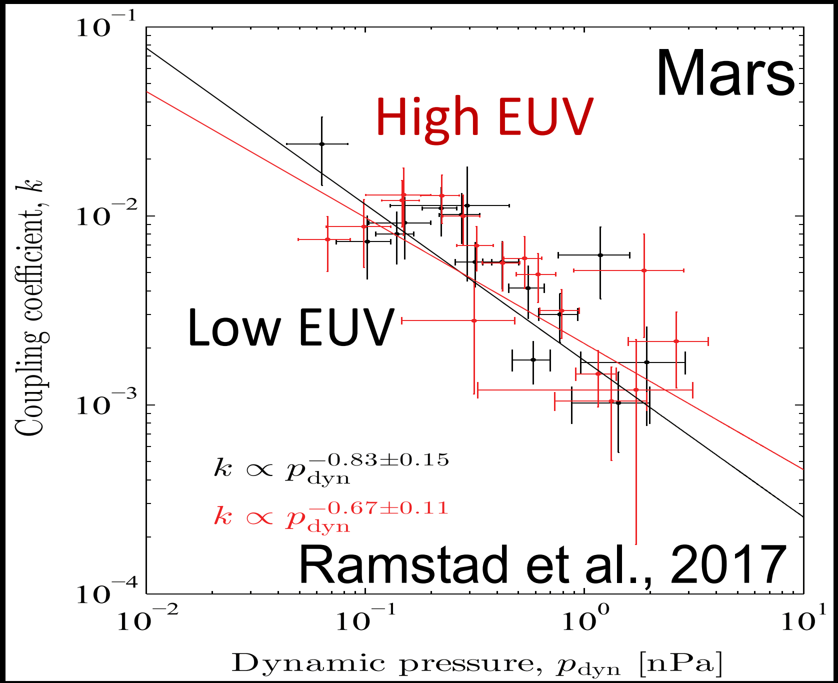
[Ramstad et al., 2017]

O$^+$ escape rate dependent on energy input

O$^+$ escape rate dependent on ion production

Comparison between Venus and Mars



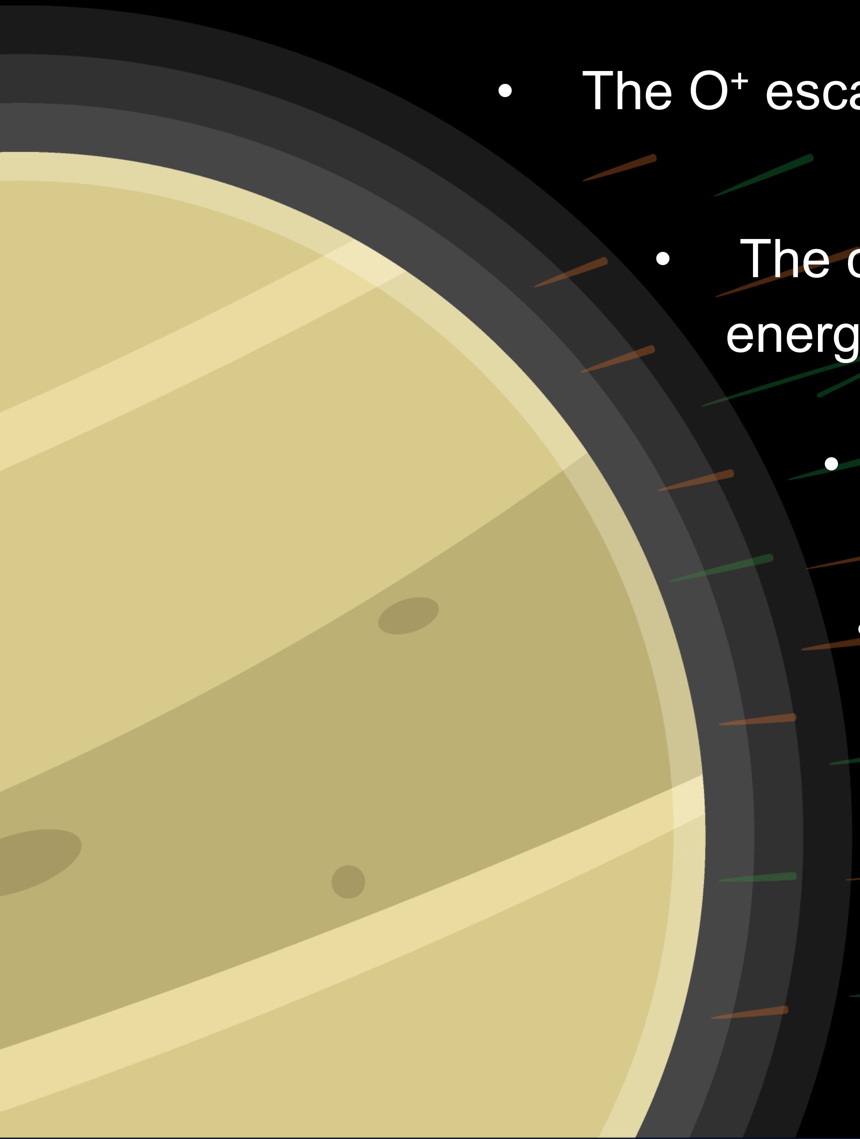


→ The coupling behaves similarly at Venus and Mars

→ Fraction of energy transmitted from solar wind is lower at Venus than Mars

→ A comparison with Earth is challenging, but initial calculations indicate a higher fraction of energy transferred, and a different dependence with upstream solar wind

Conclusions



- The O^+ escape rate increases as the solar wind energy flux increases
  - The coupling between the solar wind and the ion escape decreases as energy increases in the upstream solar wind
    - Venus efficiently screens itself from the solar wind
      - The coupling trend is similar at Mars, but a higher fraction of energy is transferred from the solar wind than at Venus
      - Preliminary comparisons with Earth indicate that the coupling trends for Mars and Venus are different from that at Earth

Persson et al. (2021). *Global Venus-Solar Wind Coupling and Oxygen Ion Escape*, GRL, 48.