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vpl

Constraining Oxygen False Positives for Terrestrial Planetary around F, G, K, and M Stars

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The Big Picture

Life!

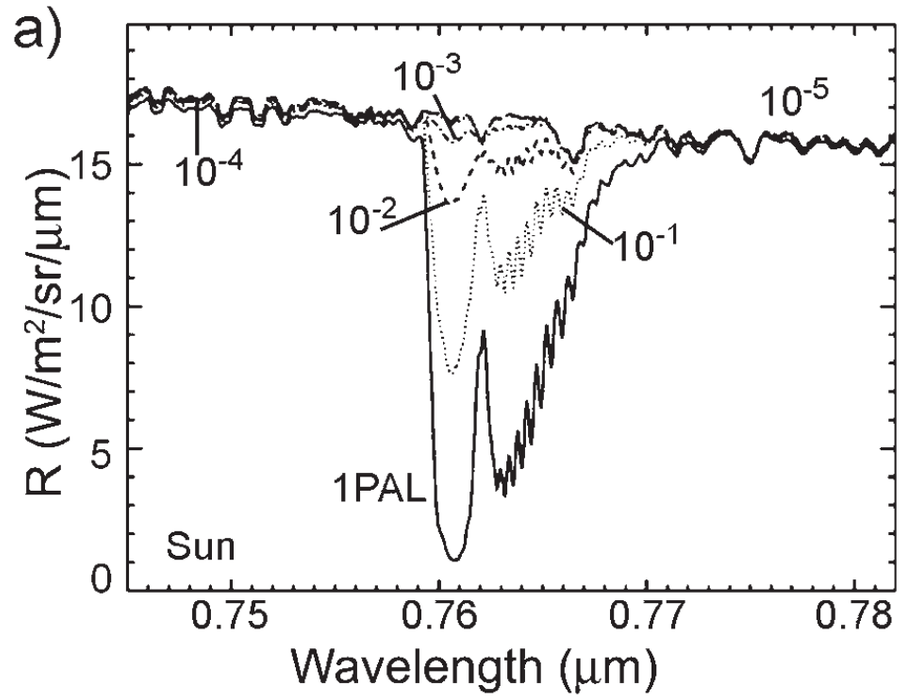
Signs of Life

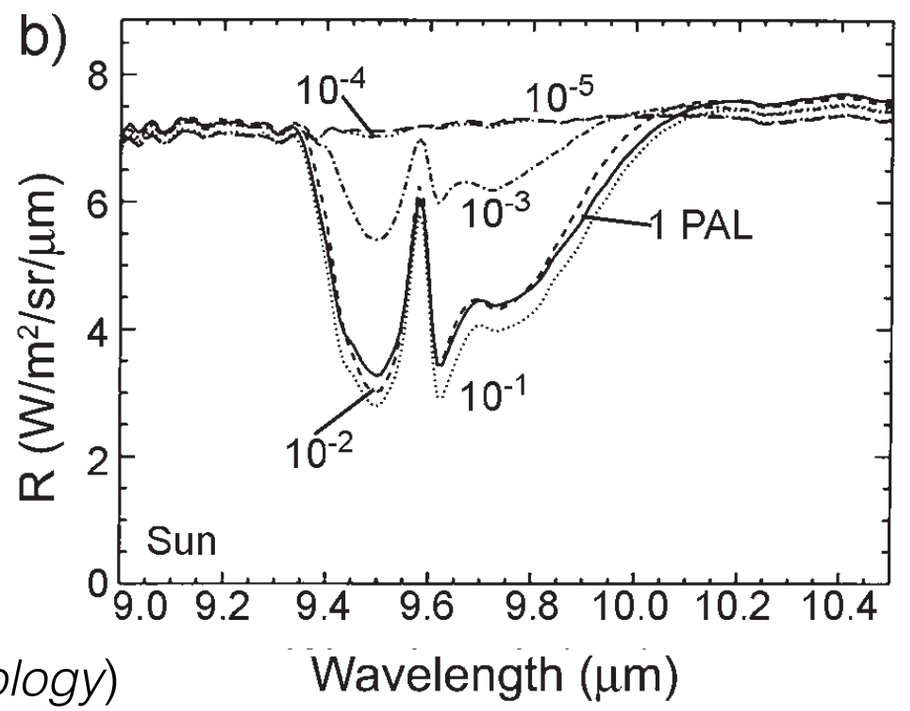
Life Elsewhere?

O_2 as a biosignature

O_2 visible at >1% PAL

O_3 visible at >0.1% PAL O_2





modified from Segura et al., 2003 (*Astrobiology*)

Sources of O_2

- Transient:
    - Lightning:

$$3(H_2O/CO_2) + N_2 \longrightarrow NO + O_2 + 3(H_2/CO)$$

    - CO_2 photolysis:

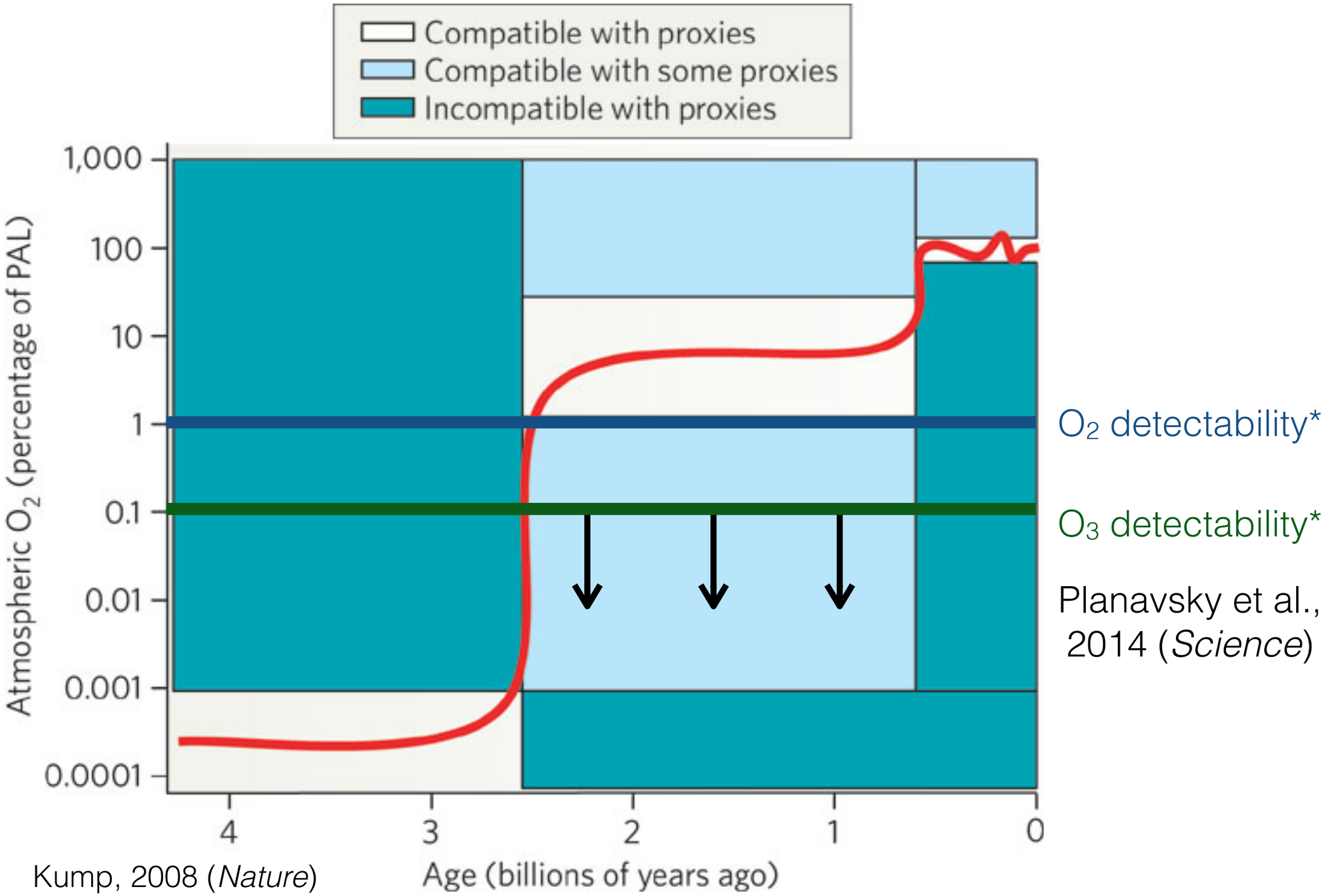
$$CO_2 + h\nu \longrightarrow CO + O$$
$$O + O + M \longrightarrow O_2 + M$$

- Persistent
    - Life:

$$H_2O + CO_2 \longrightarrow CH_2O + O_2$$

    - Hydrogen Loss

History of O_2



Planavsky et al., 2014 (*Science*)

Kump, 2008 (*Nature*)

What is a false positive?

Abiotic O_2 > Proterozoic O_2 —> FALSE POSITIVE

(the nuts and bolts)

Chemistry

- CO_2:

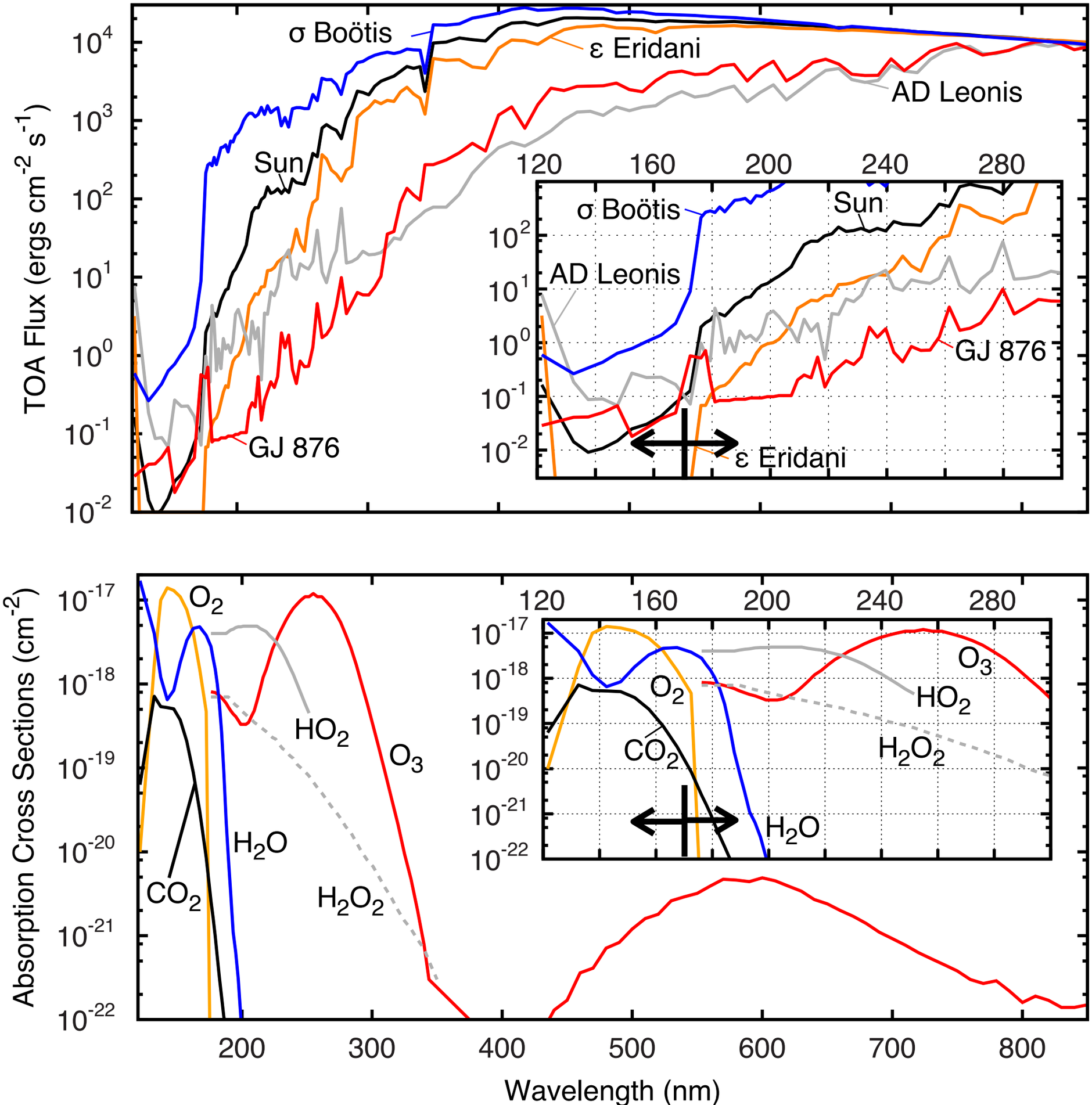
$$CO_2 + h\nu \longrightarrow CO + O$$

~~$CO + O + M \longrightarrow CO_2 + M$~~ Spin forbidden

- Catalytic cycles:

$$CO + OH \longrightarrow CO_2 + H$$
$$O_2 + H + M \longrightarrow HO_2 + M$$
$$HO_2 + O \longrightarrow O_2 + OH$$

$$CO + O \longrightarrow CO_2$$


TOA Flux (ergs cm-2 s-1)
σ Boötis
ε Eridani
AD Leonis
Sun
GJ 876
120
160
200
240
280
Absorption Cross Sections (cm-2)
O2
HO2
O3
H2O
CO2
H2O2
Wavelength (nm)

Global redox balance

- Global redox balance:

$$\Phi_{out}(Red) + \cancel{\Phi_{OW} + \Phi_{burial}(CaSO_4) + \Phi_{burial}(Fe_3O_4)} =$$
$$\Phi_{esc}(H_2) + \cancel{2\Phi_{burial}(CH_2O) + 5\Phi_{burial}(FeS_2)}$$

- Global redox balance is then:

$$\Phi_{out}(Red) = \Phi_{esc}(H_2)$$

Atmospheric redox balance

- Atmospheric redox balance:

$$\Phi_{volc}(Red) + \Phi_{out}(Ox) = \Phi_{out}(Red) + \Phi_{esc}(H_2)$$

- Including global redox balance:

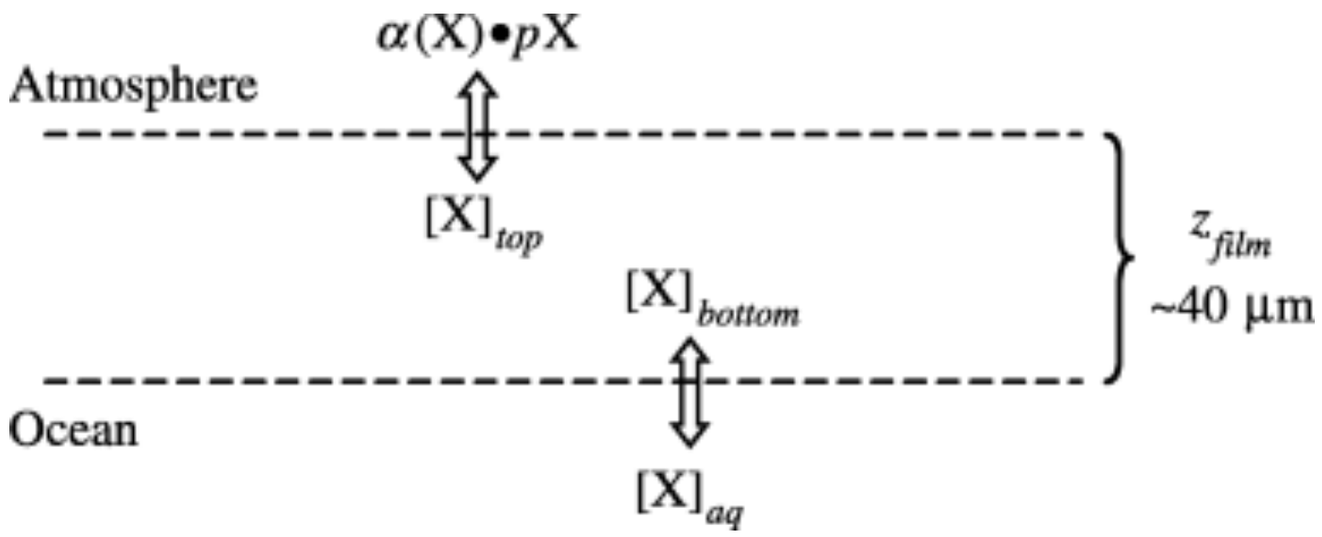
$$\Phi_{out}(Ox) = \Phi_{out}(Red)$$

We ensure this with the boundary condition on H_2.

Boundary conditions

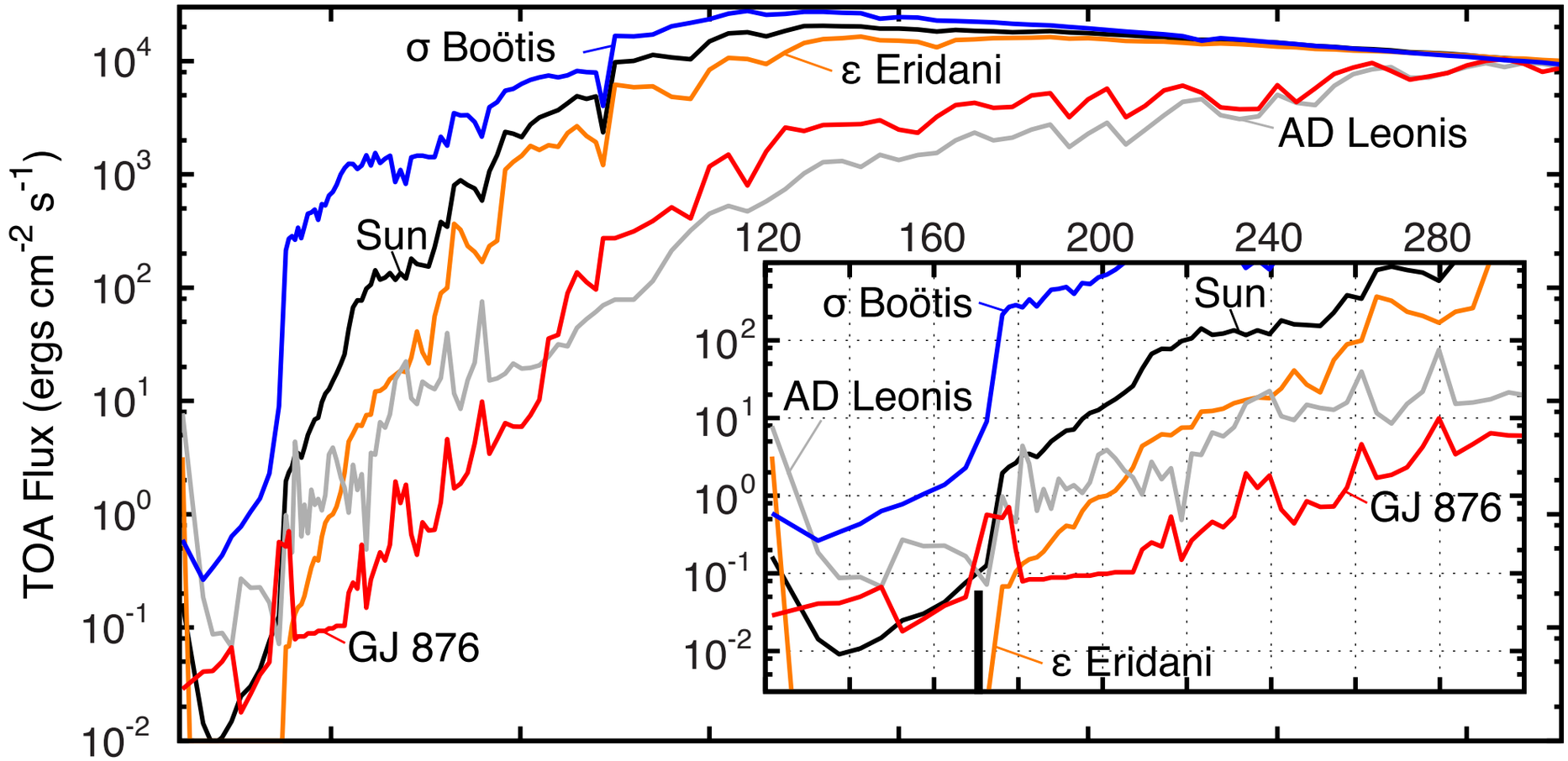
- Piston velocity:
  $v_p = K_{diff}(X)/z_{film}$

- Deposition velocity:
  $v_{dep}(X) = v_p[\alpha \cdot pX - [X]_{aq}] \cdot C/n_X$



Kharecha et al., 2005 (*Geobiology*)

some results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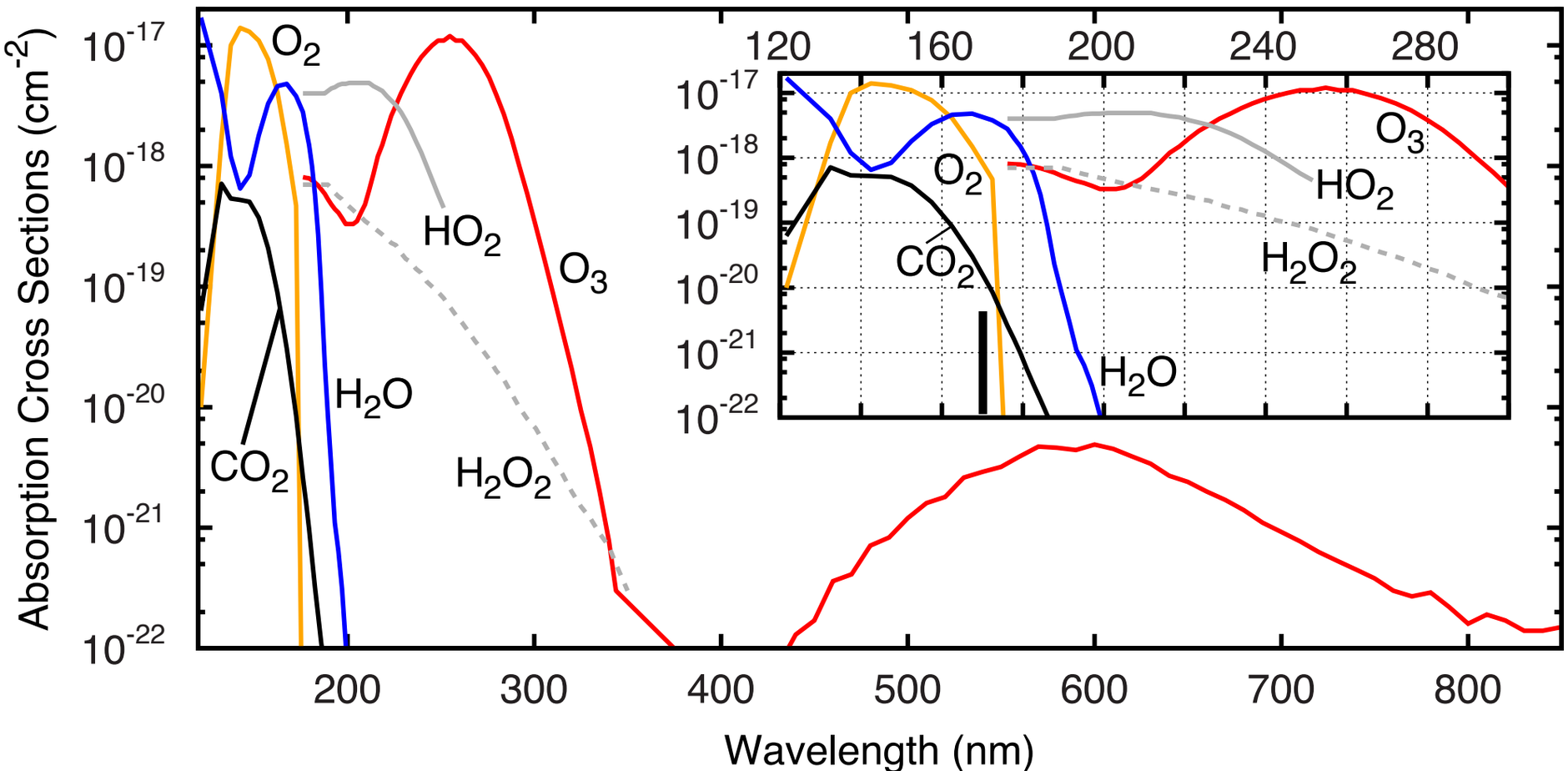
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Wavelength (nm)
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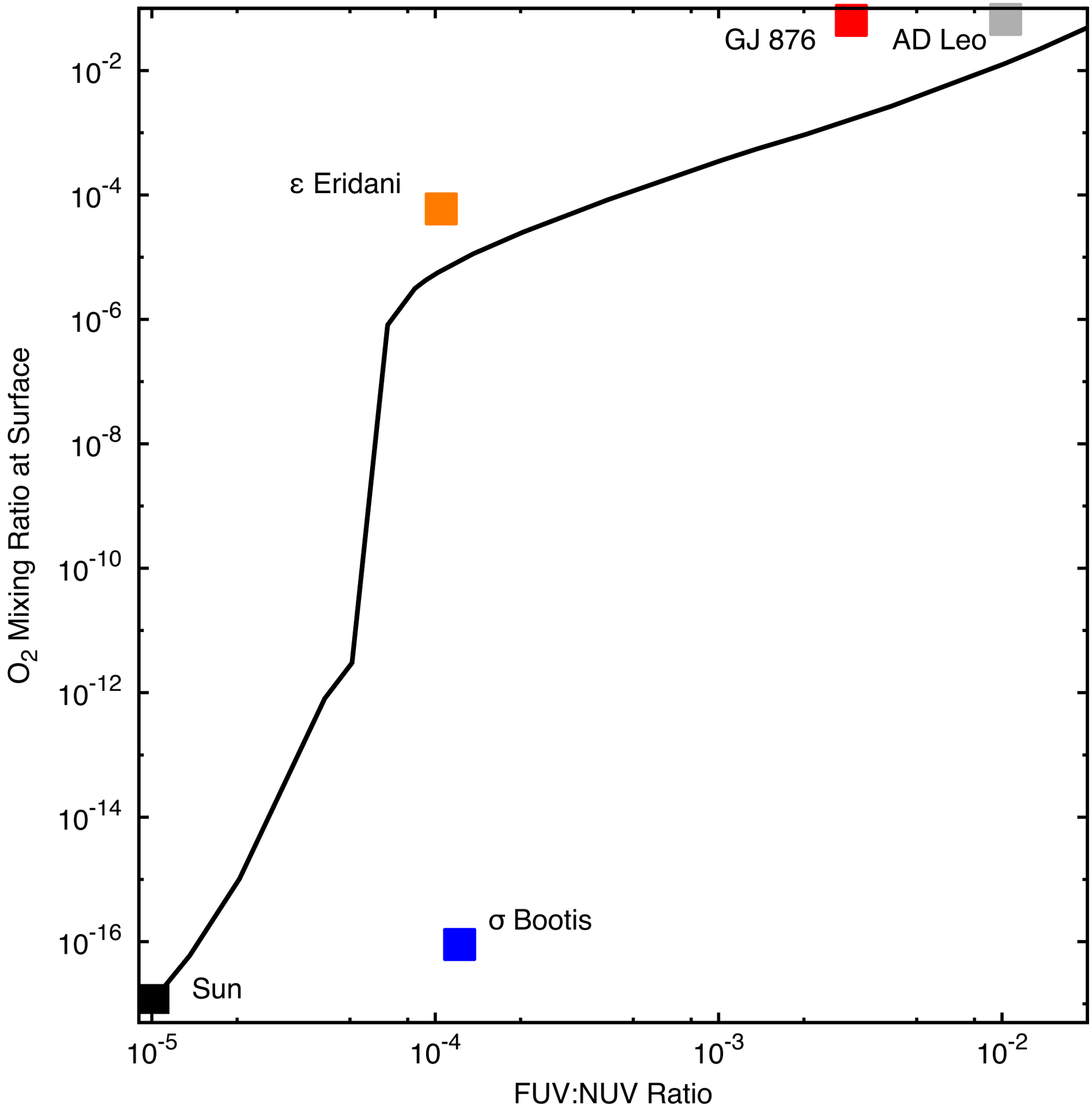
600
700
800

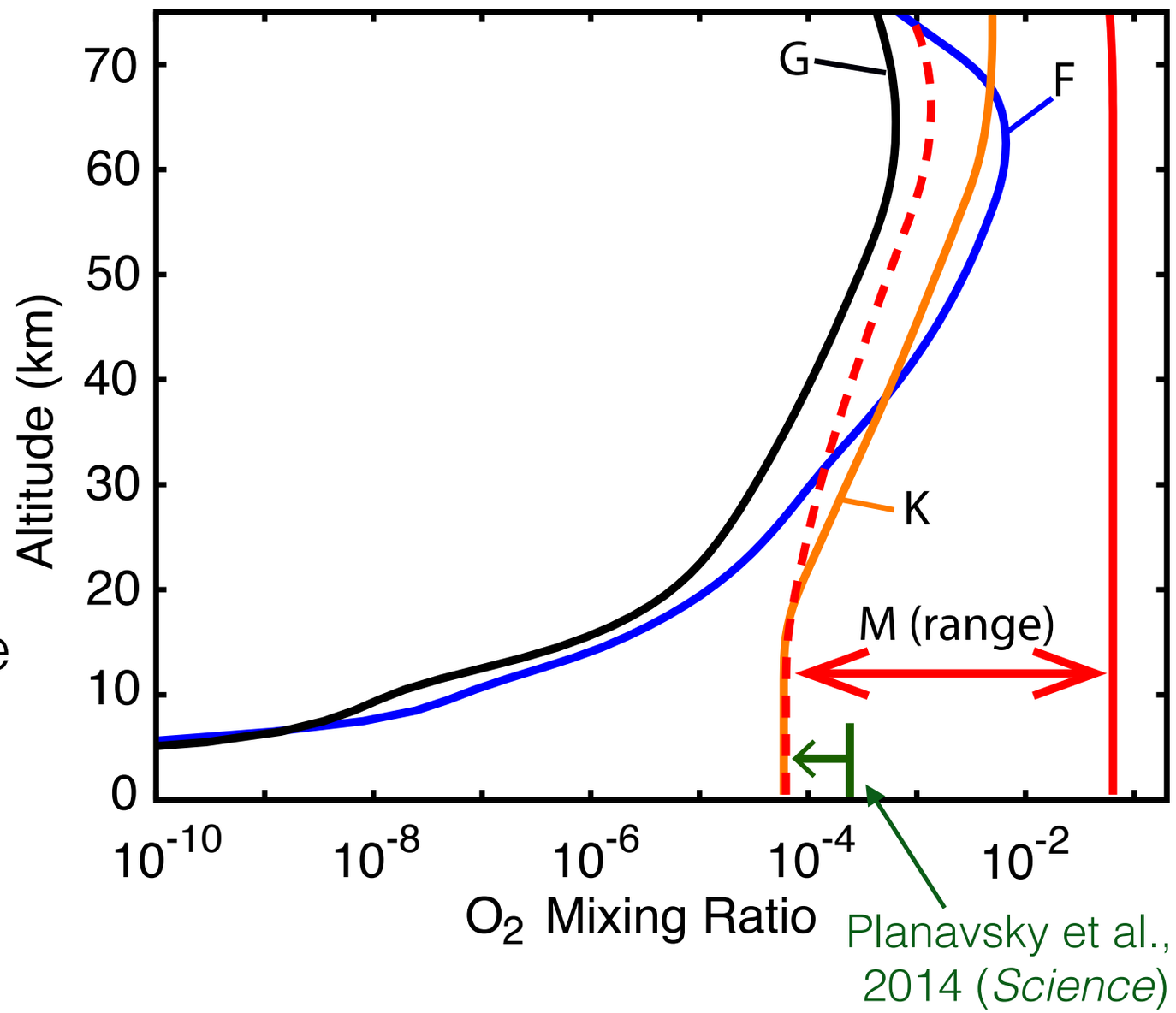

GJ 876
AD Leo
ε Eridani
σ Bootis
Sun
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
O_2 Mixing Ratio at Surface
10^{-5}
10^{-4}
10^{-3}
10^{-2}
FUV:NUV Ratio

The Takeaway

- Little O_2 (or O_3) produced around F- and G-type stars

- Modest (and potentially detectable) O_2 around a K-type star

- Detectable O_2 around M-type stars in <u>some</u> cases



Questions?

- Little O_2 (or O_3) produced around F- and G-type stars

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