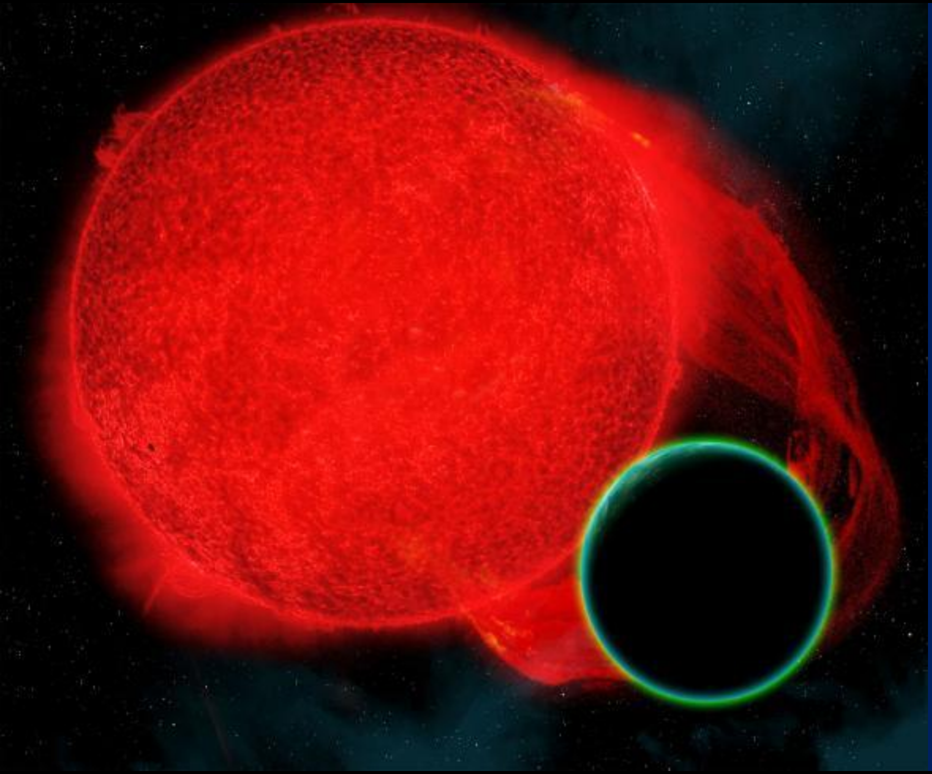
Biohabitability and life of M-star planets



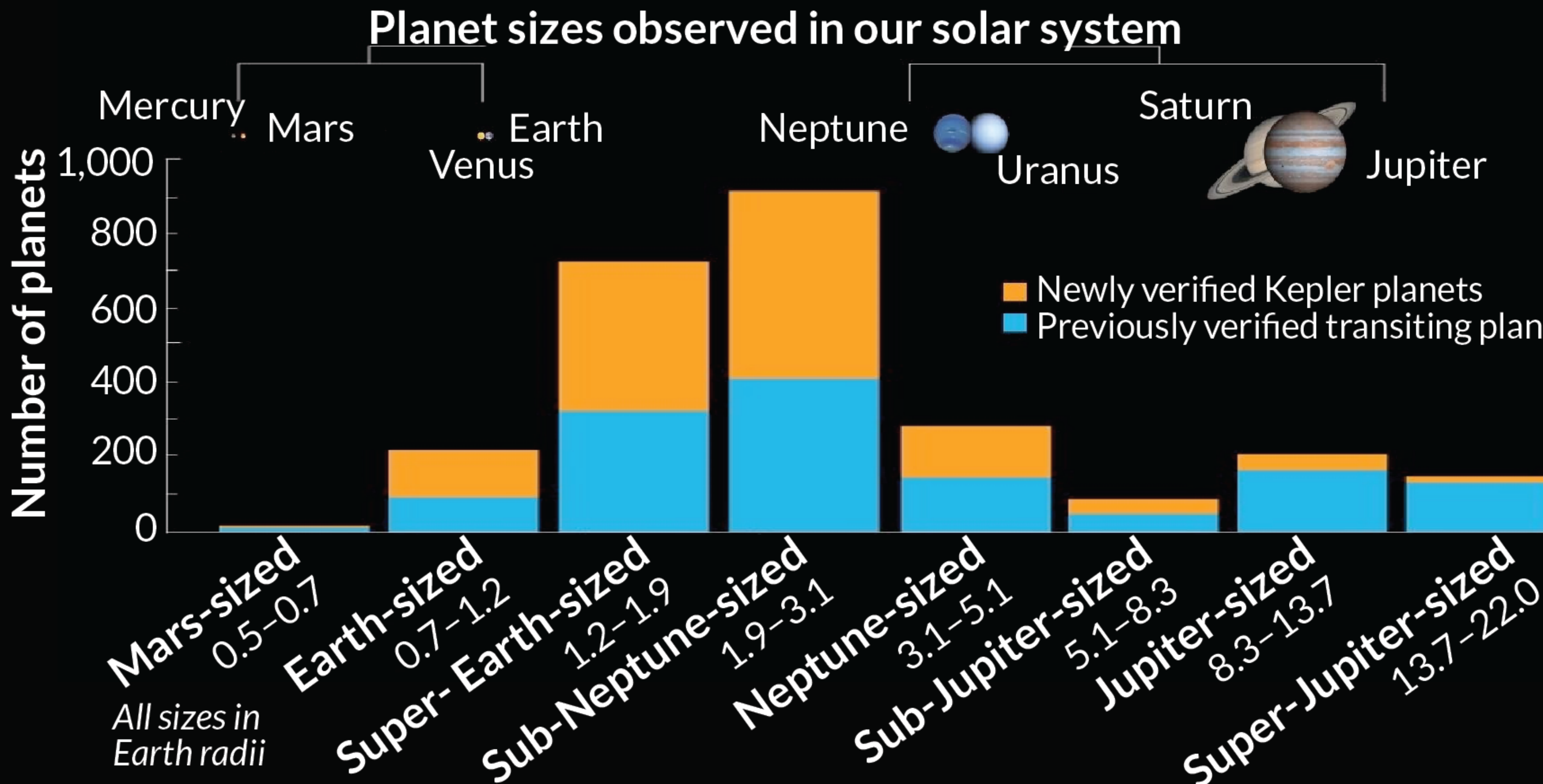
A. Wandel

The Hebrew University of Jerusalem

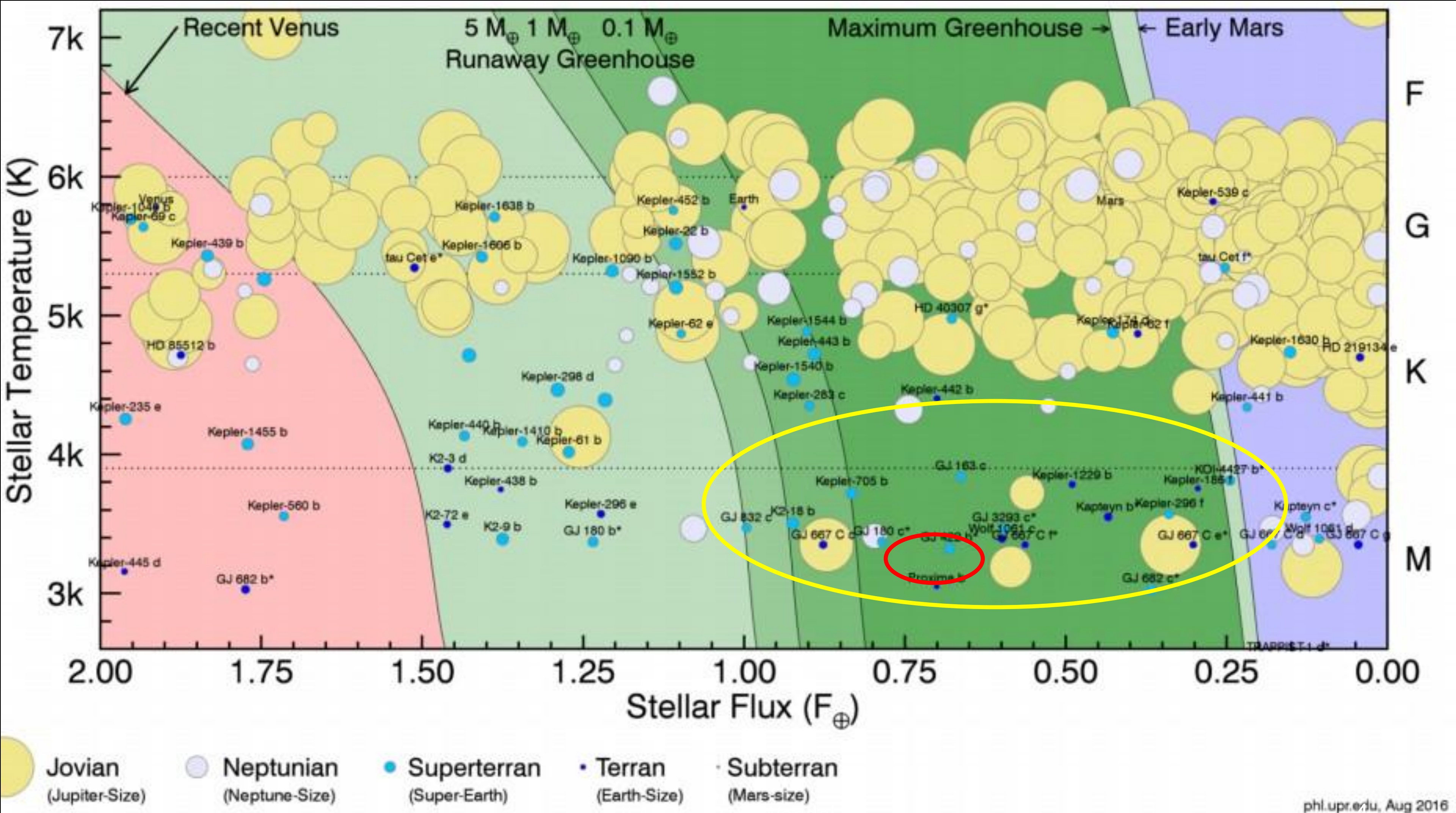
ILASOL, Jerusalem 2018

Earth-size planets in Habitable Zones of M-stars

Known transiting planets by size as of May 10, 2016

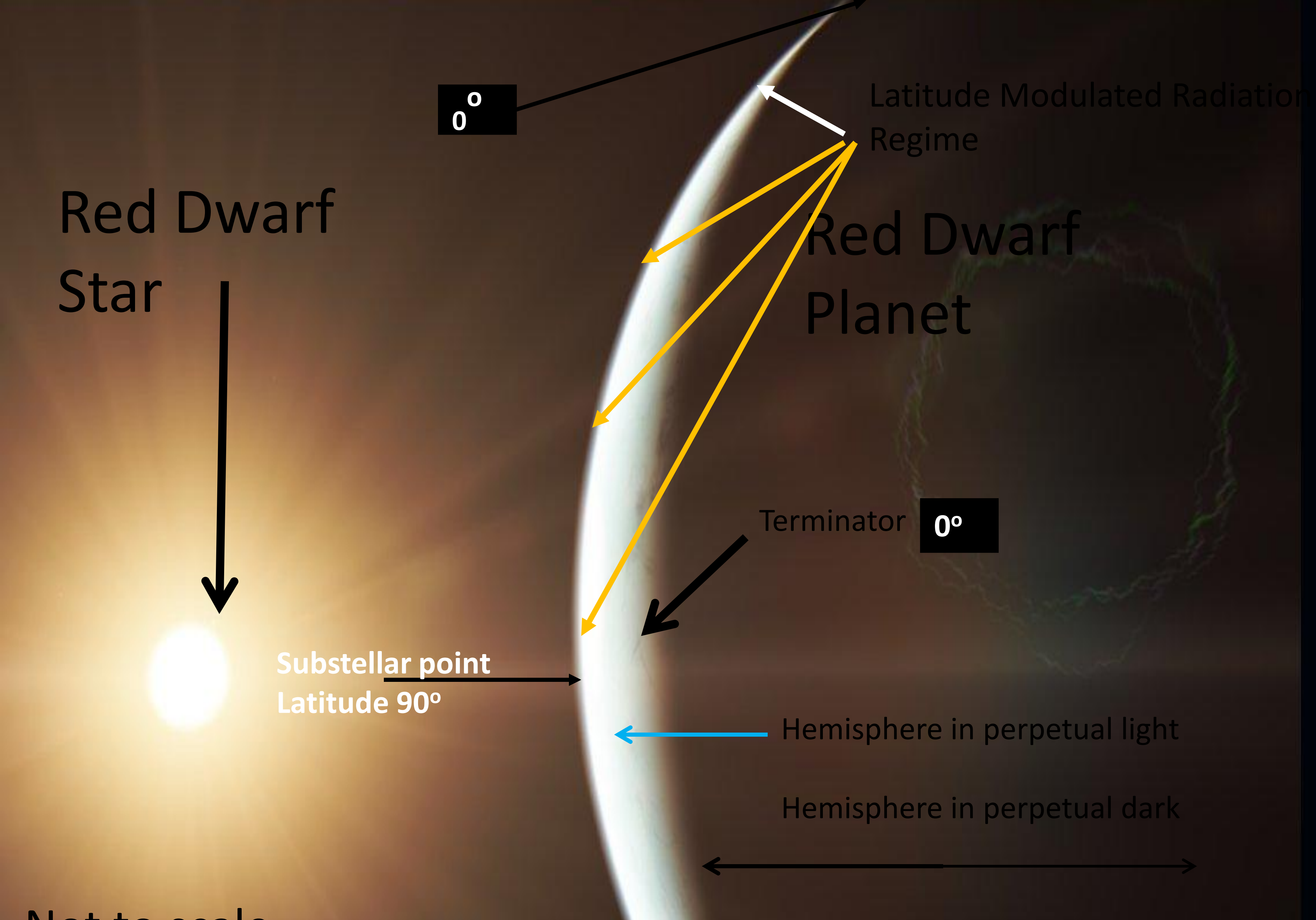


Discovered planets vs stellar flux & type and the Habitable Zone



Why M-dwarfs?

- Abundant: 75% of all stars are M-dwarfs
- Easier biosignatureare detection in M-type planets
- Faint hosts → small habitable zones (HZ),
- → Planets in the HZ are near host star
- Shorter periods – easier detection by transit or Dopler
- Locked planets may have a wider surface temperature range
- → more possibilities for life


0°
Latitude Modulated Radiation
Regime
Red Dwarf
Star
Red Dwarf
Planet
Terminator
0°
Substellar point
Latitude 90°
Hemisphere in perpetual light
Hemisphere in perpetual dark
Not to scale

Bio-habitability

Liquid water

- Temperatures allowing complex organic molecules
- On at least part of the planetary surface
- For life as we know it on Earth (H_2O based):
- Biohabitable temperature range:
- T (night side) needs to be <~130 C
- T (substellar point) needs to be >0 C

1D Temp. model for locked planets

The heat transfer equation

$$\tau_{IR}^{-1}\sigma T^4 = \quad (1\text{-}a)\, F(f,\theta) \quad + \quad bQ_{adv}$$

IR opt depth Temp = albedo stellar flux. + Advection

+global heat redistrib

advective parameters:

f – global heat redistribution

b – local heat advection coeff. (relative to rad. flux)

heating factors:

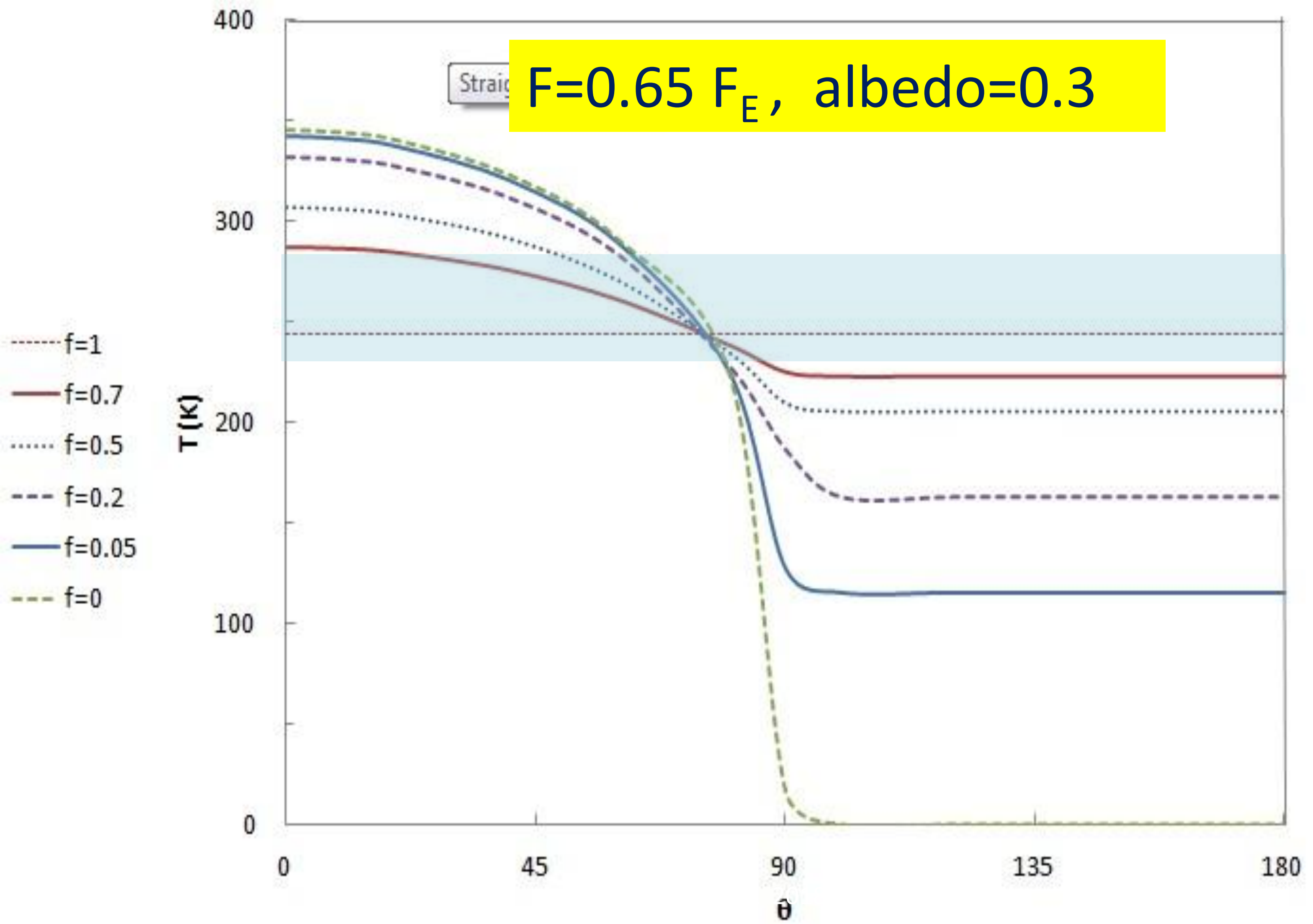
H_{atm} – Atmospheric heating (GE)+albedo $H_{atm}=(1\text{-}a)\tau_{IR}$

H – Atm. Heating + Stellar flux $H= H_{atm} \times F/F_E$

Wandel 2018
ApJ 856

Temperature profiles for Proxima b

f - heat redistribution factor (global advection)



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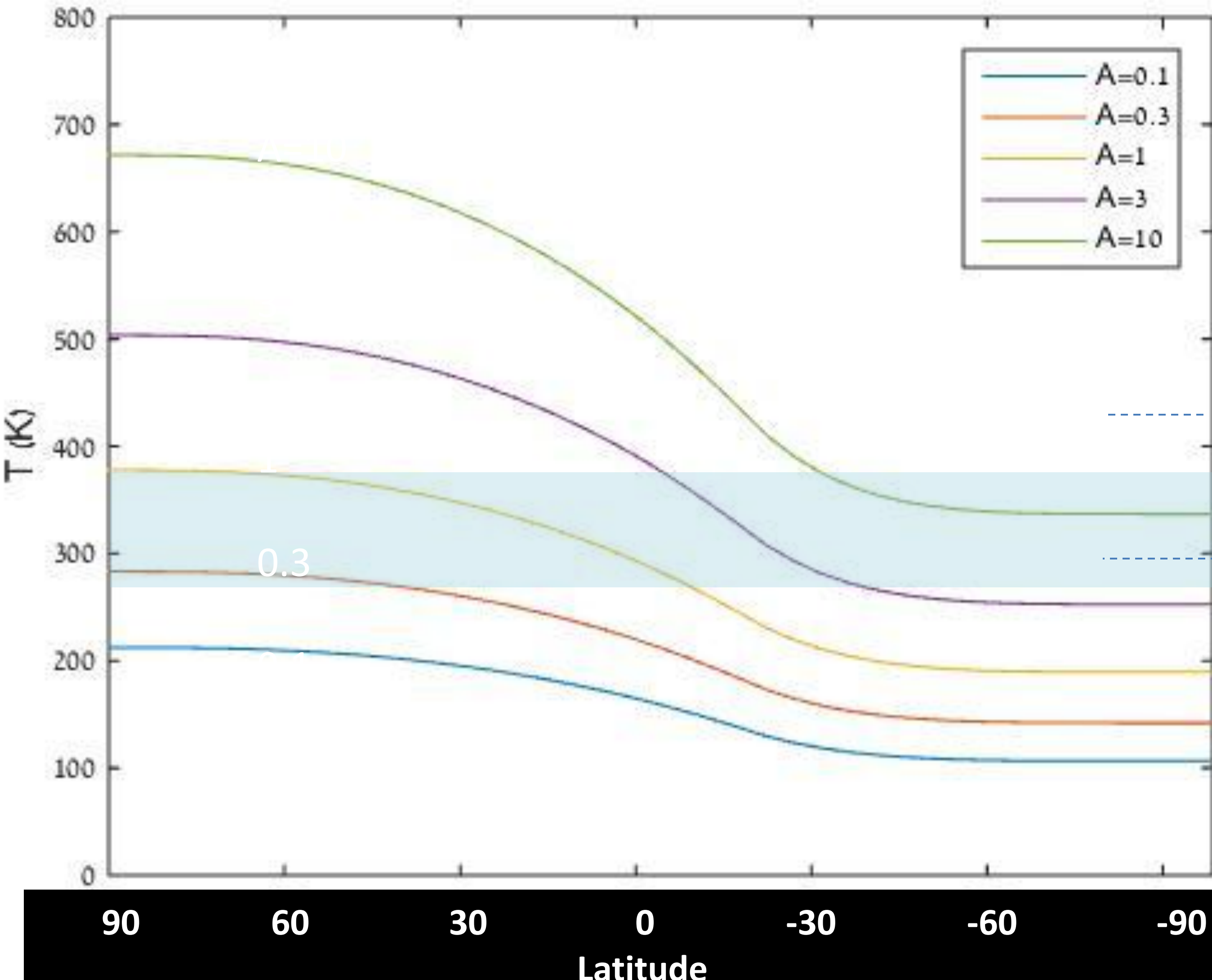
Temperature profiles for locked planet

A = combined heating factor

$A=(1-a)\,H_g F/F_E$

F/F_E stellar flux rel.ative to Earth

H_g= Greenhouse heating factor



←Venus (A=30)

A=10

← Mercury (6)

← Earth (1.2)

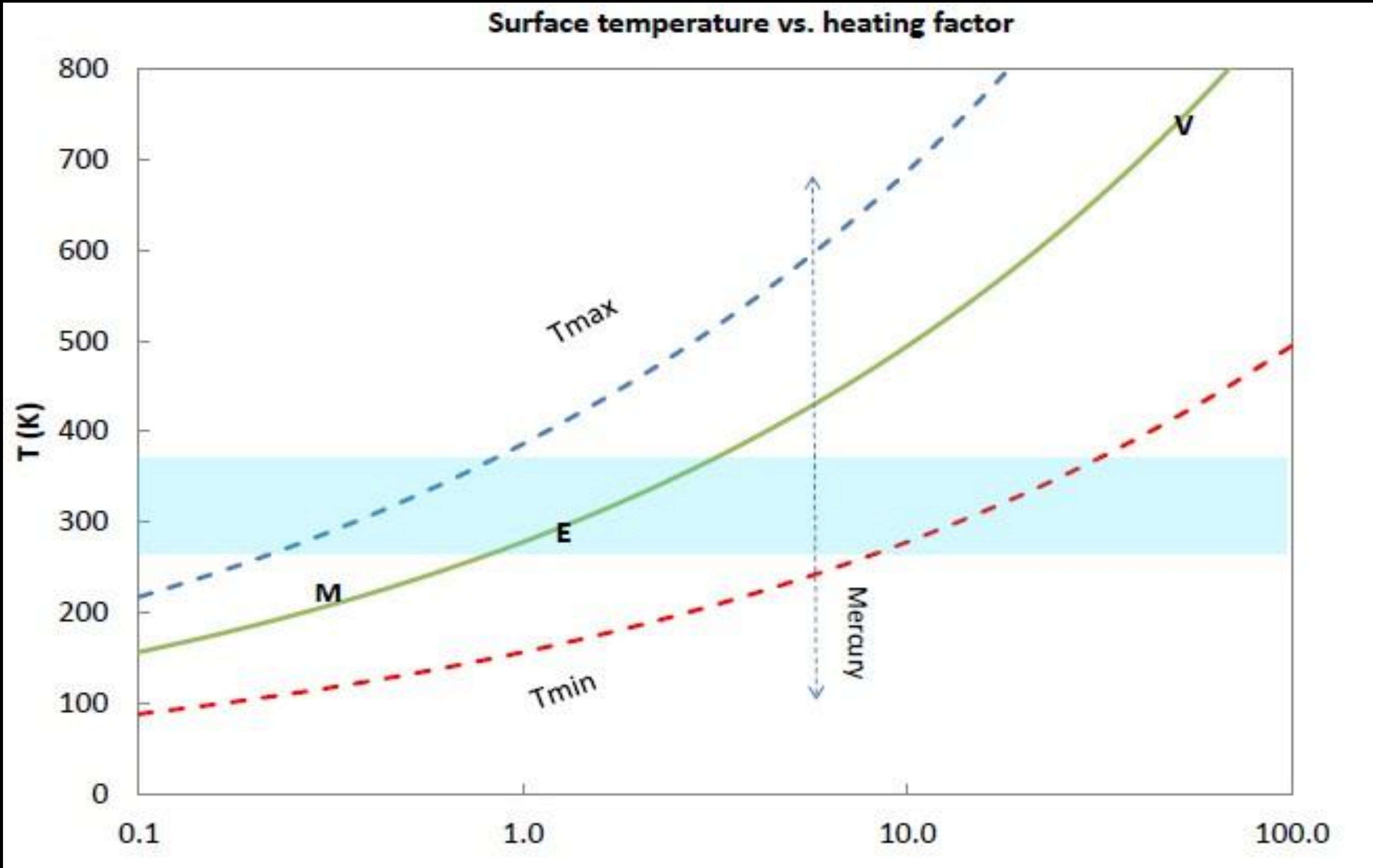
← Mars (0.3)

A=0.1

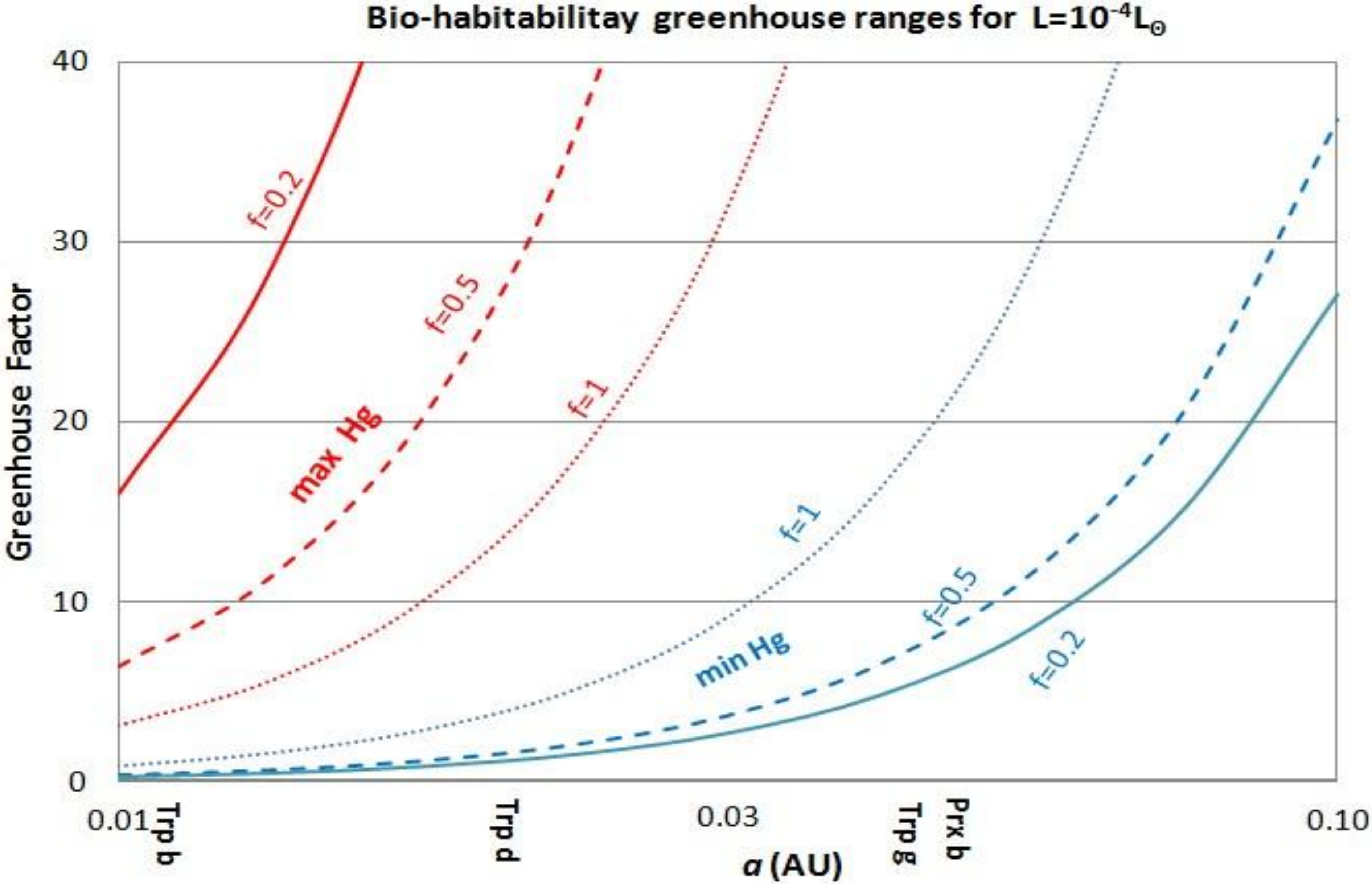
Prox- b

Wandel 2018

Surface temp. vs. combined heating



Bio-habitability range vs. orbital radius



Oxygenic Photosynthesis on habitable planets of M-dwarfs

Gale & Wandel 2017, IJA 16, 1

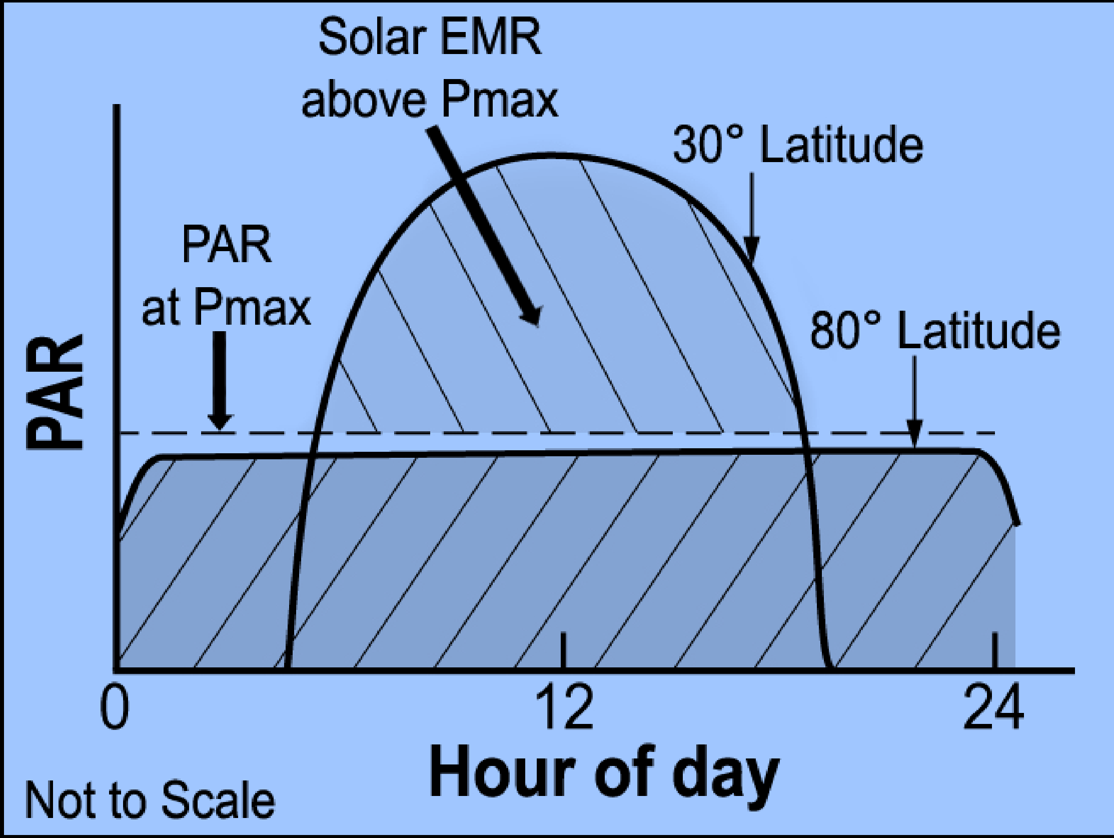
Requirements for OP:

- Moist atm: oceans/vapor
- Light: Photoynthesis Active Radiation (PAR)
- M-star spectrum: enough energy in visible <700nm

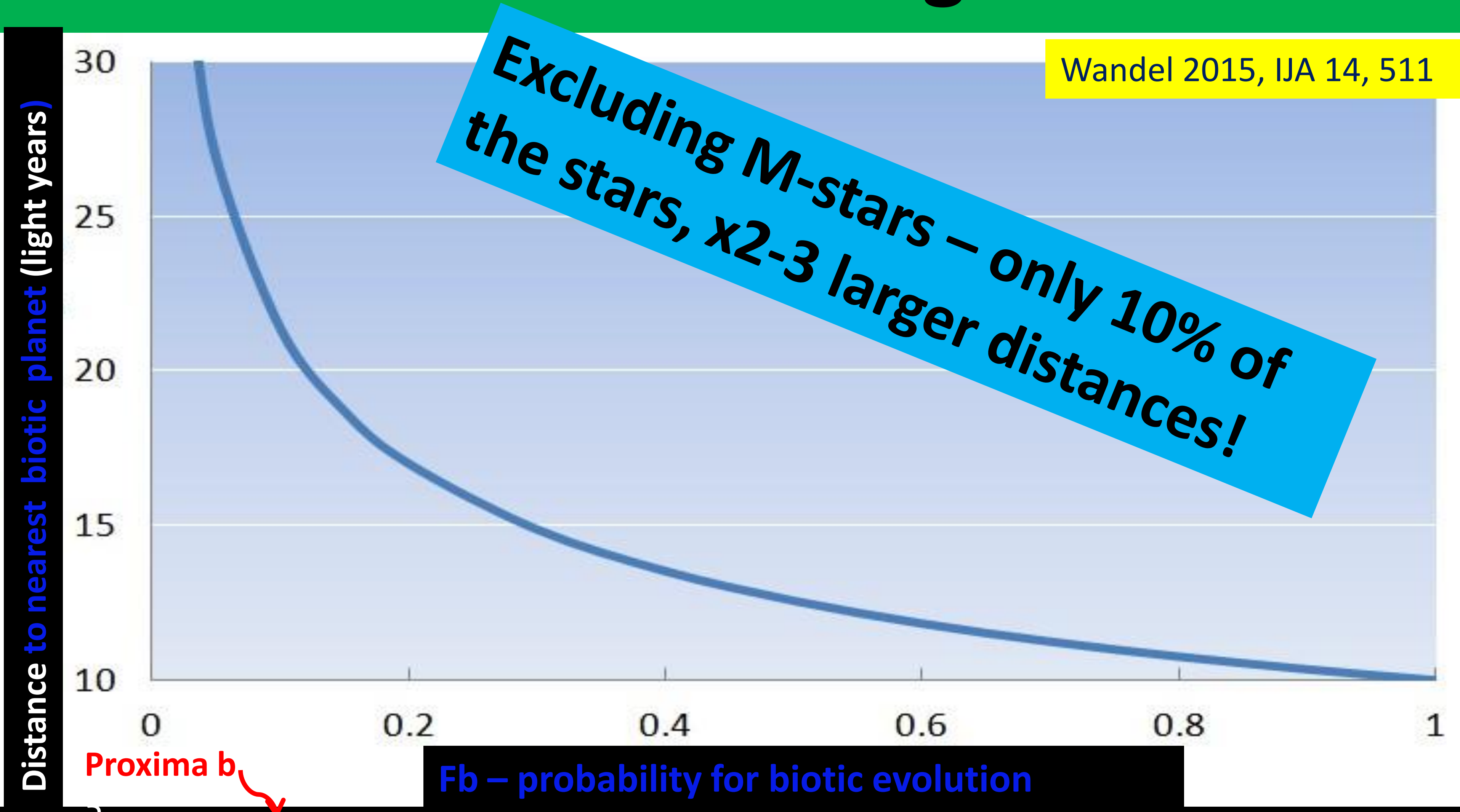
"Earthly" OP -signature:

- Oxygen /Ozone line
- can be a-biotic
- Chlorophyl abs. edge
- Low CO_2 , High N_2

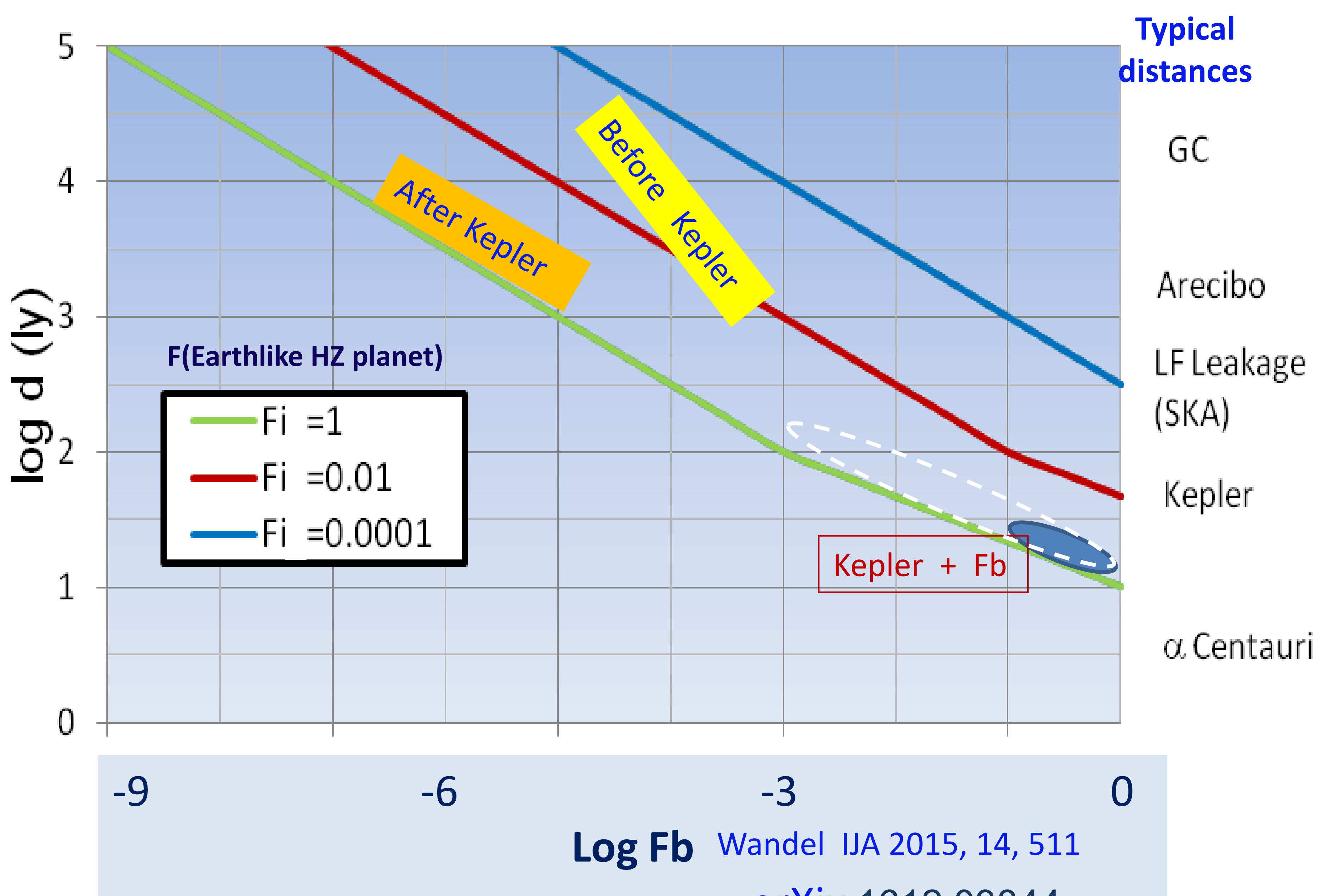
An Earth analog of locked planet flux



Biotic abundance: the distance to our nearest biotic neighbors



Distance to nearest **biotic** planet vs Fb



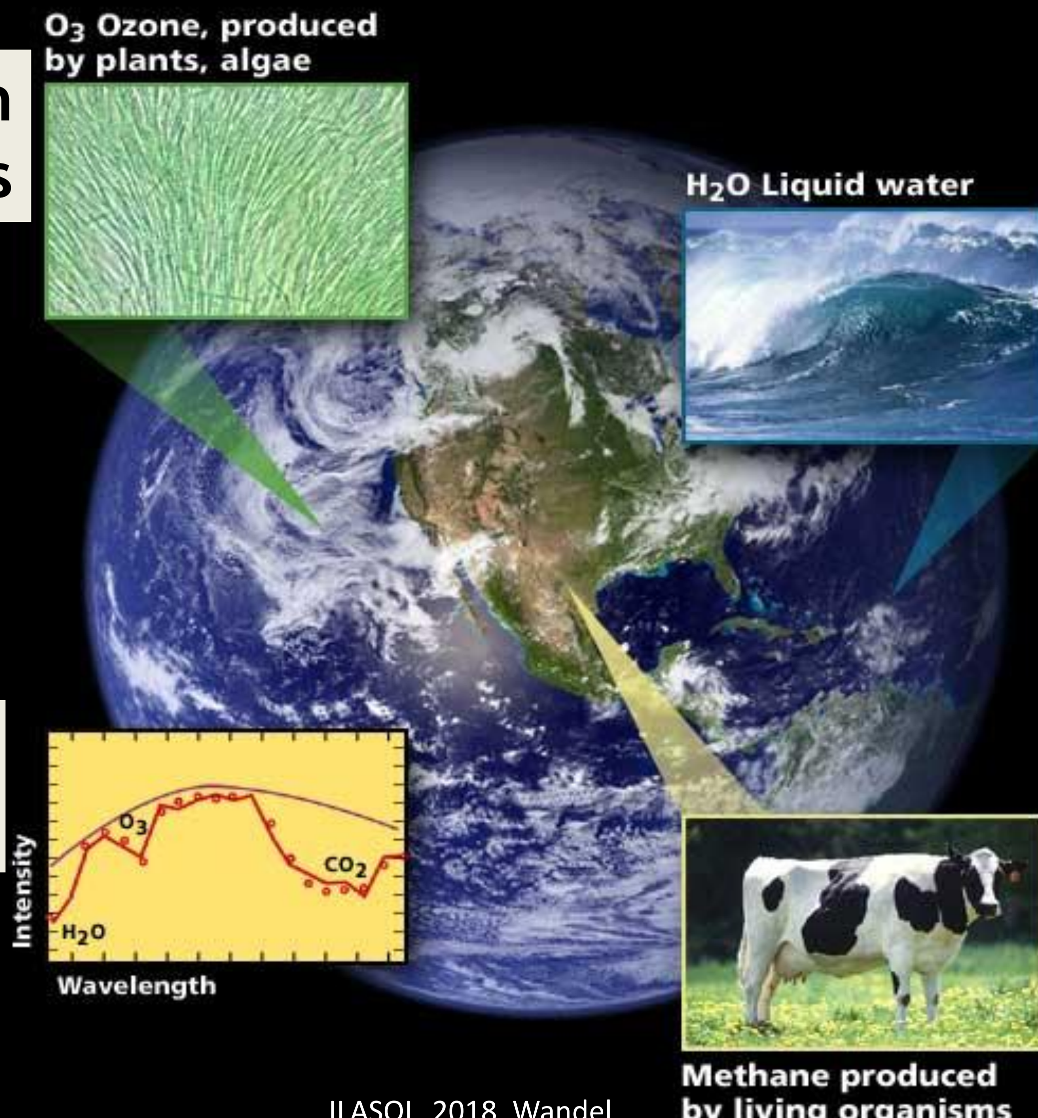
Bio-signatures

Oxygen photosynthesis

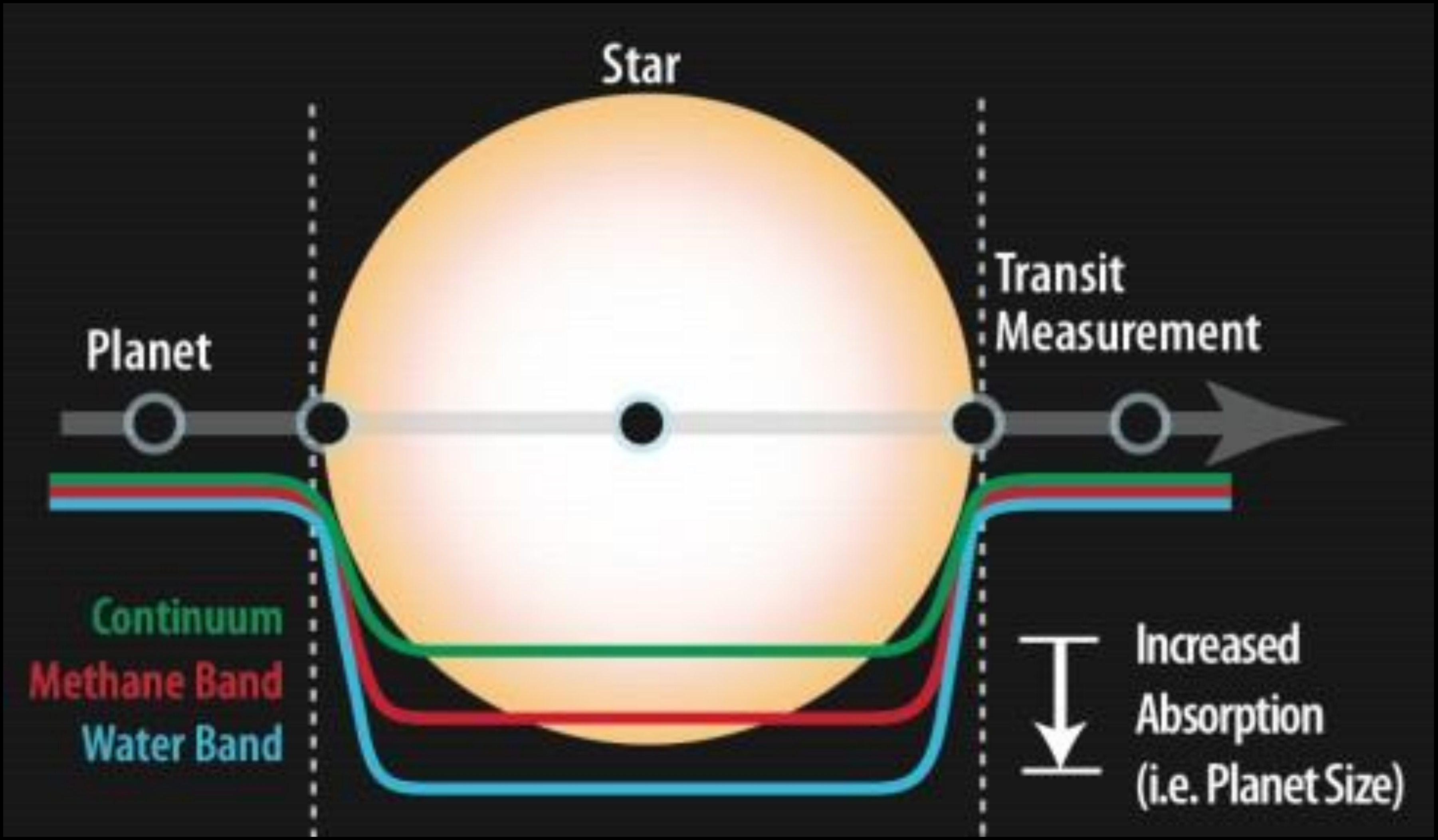
Water vapor

Spectral analyses

Methane



Transiting Bio-signatures



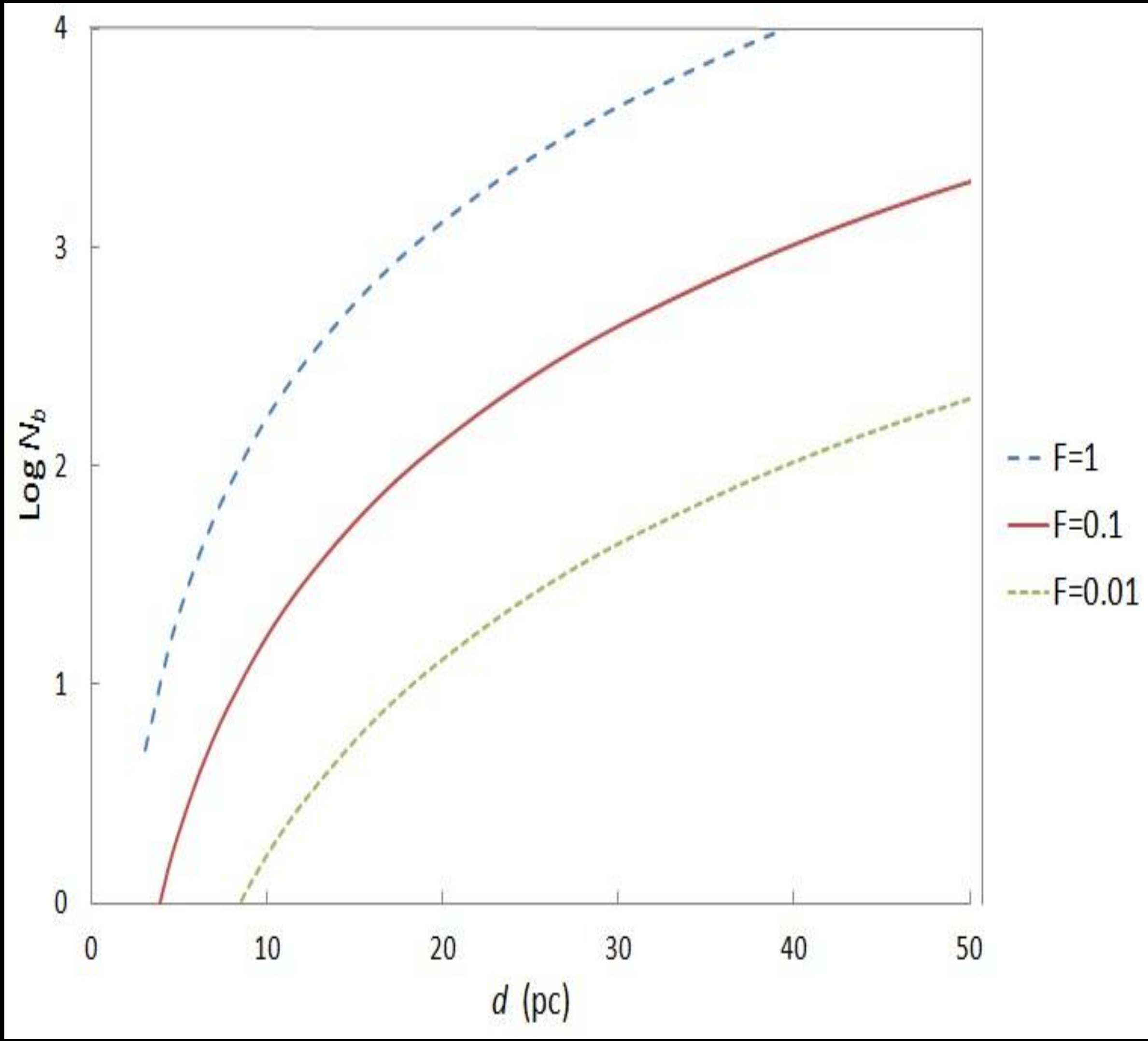
Expected # of transiting HZ planets vs. *d* - bio-signature detection range

BioSig of transiting planets of M-dwarfs

Spectroscopy: JWST(2018)

Sample: TESS (2018)

N(d) depends on the abundance parameter F



Conclusions

- Habitable Zone planets of M-stars (RDP) may actually have conditions suitable to life
- Liquid water could exist on RDPs for a wide range of atmospheres
- conditions on RDPs may be suitable for earthlike oxygenic photosynthesis
- JWST may be able to detect bio-signatures for dozens of nearby transiting RDPs
- This may be enough estimate the abundance of biotic planets and the probability of life