The habitability of Proxima Centauri b

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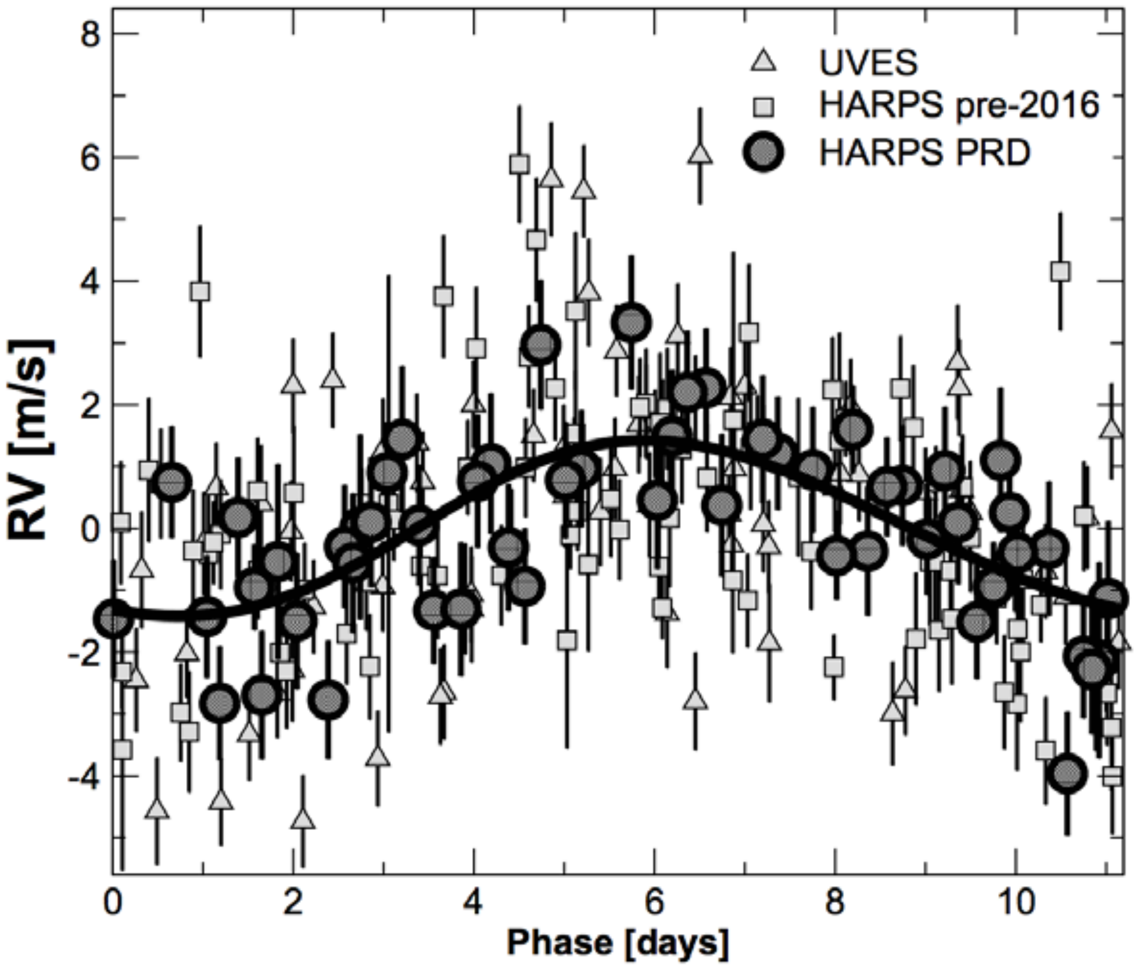
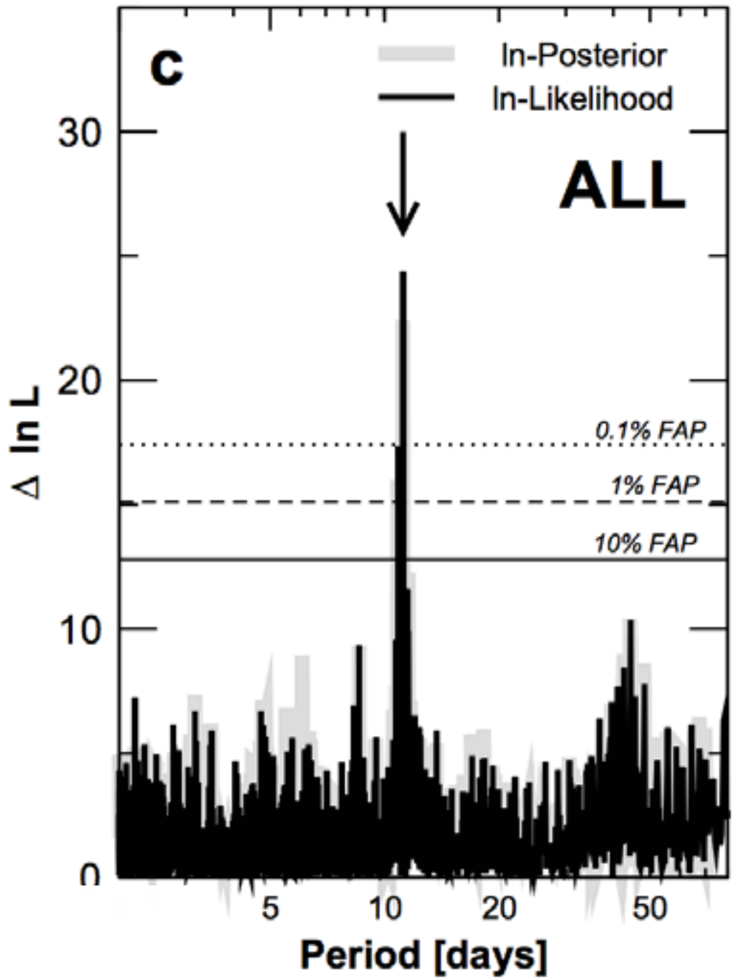
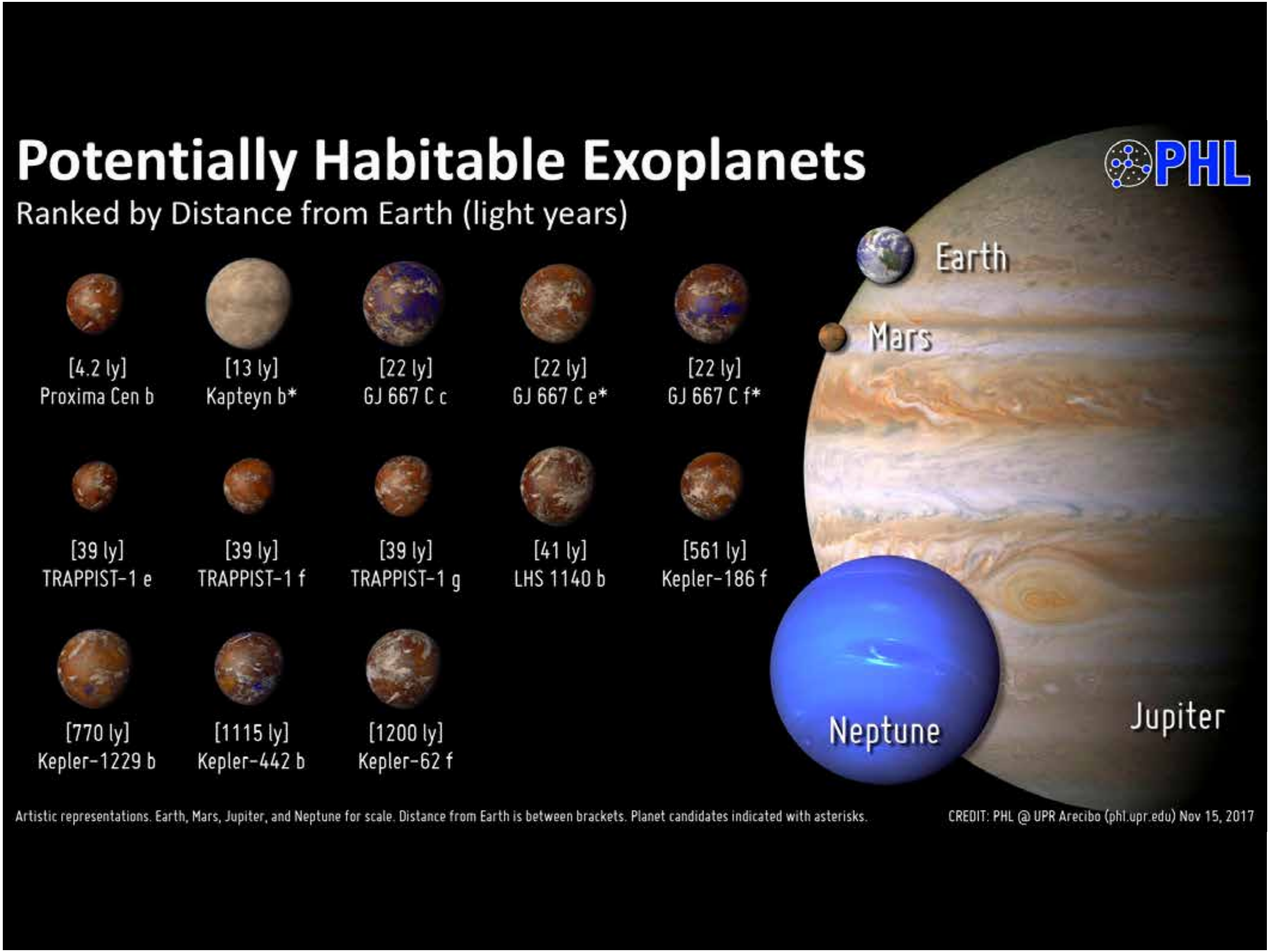
Anglada-Escudé et al. (2016, Nature)

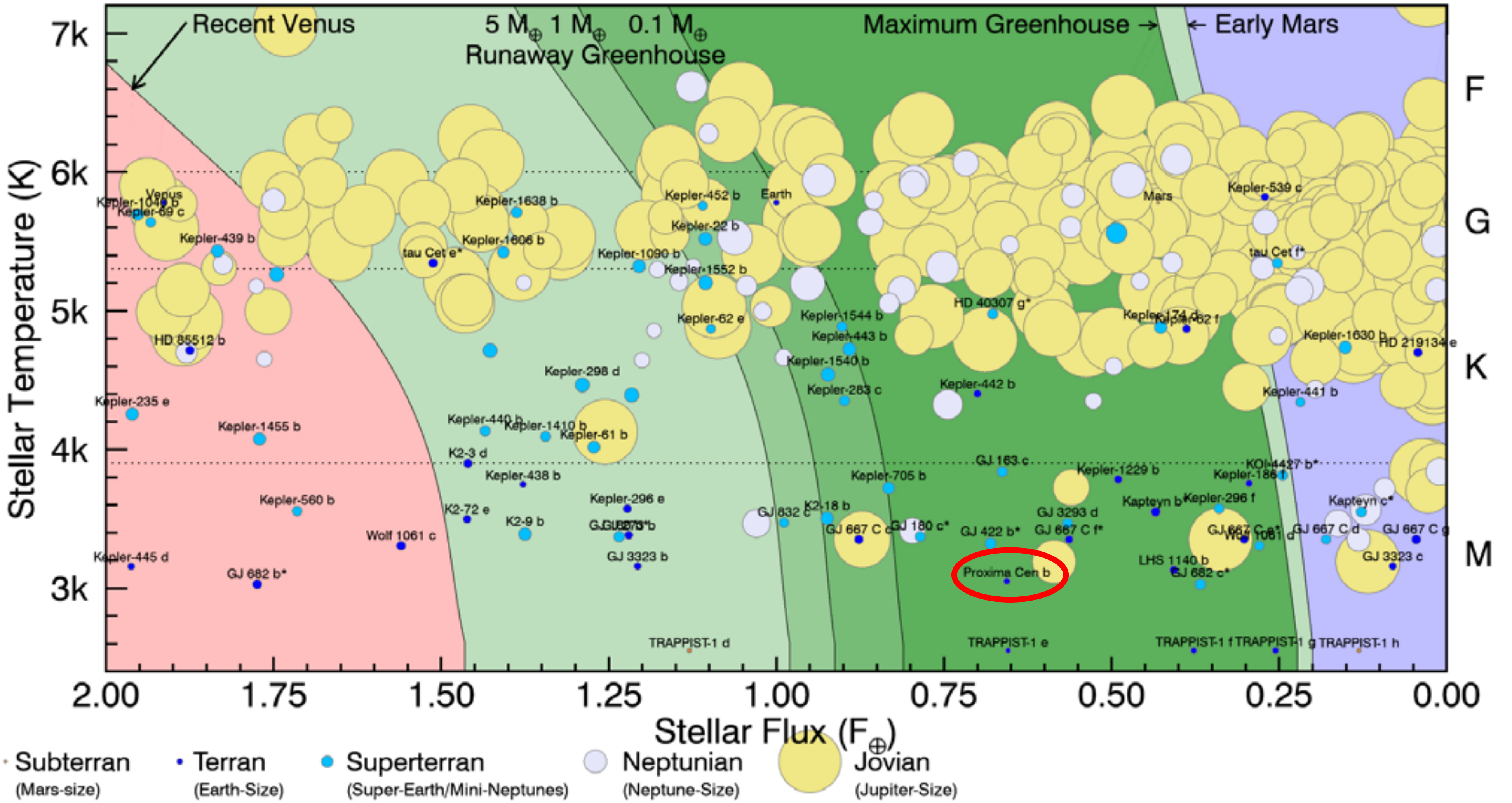


Period [days]	11.186 [11.184, 11.187]
Doppler amplitude [ms^{-1}]	1.38 [1.17, 1.59]
Eccentricity [-]	<0.35
Orbital semi-major axis a [AU]	0.0485 [0.0434, 0.0526]
Minimum mass $m_p \sin i$ [$M_\oplus$]	1.27 [1.10, 1.46]





Potentially Habitable Exoplanets
Ranked by Distance from Earth (light years)
PHL
[4.2 ly] Proxima Cen b
[13 ly] Kapteyn b*
[22 ly] GJ 667 C c
[22 ly] GJ 667 C e*
[22 ly] GJ 667 C f*
[39 ly] TRAPPIST-1 e
[39 ly] TRAPPIST-1 f
[39 ly] TRAPPIST-1 g
[41 ly] LHS 1140 b
[561 ly] Kepler-186 f
[770 ly] Kepler-1229 b
[1115 ly] Kepler-442 b
[1200 ly] Kepler-62 f
Earth
Mars
Neptune
Jupiter
Artistic representations. Earth, Mars, Jupiter, and Neptune for scale. Distance from Earth is between brackets. Planet candidates indicated with asterisks.
CREDIT: PHL @ UPR Arecibo (phl.upr.edu) Nov 15, 2017



phl.upr.edu, May 2017


Alpha Centauri AB
Proxima Centauri
Proxima b

Is Proxima b habitable?

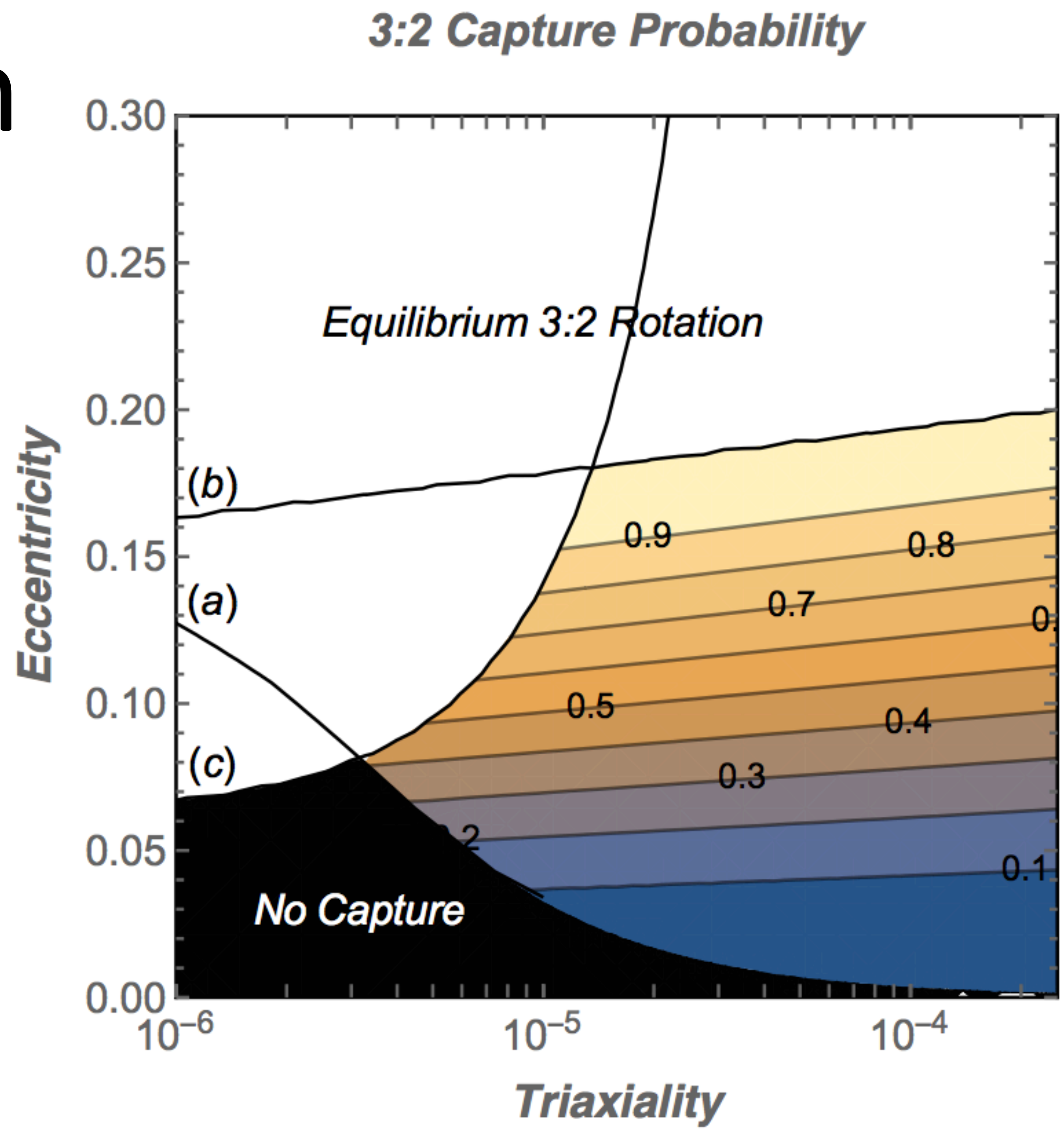
- No straight answer
- Very complex problem with many factors at play and lots of unknowns
- In Ribas et al. (2016, 2017, A&A) and Turbet et al. (2016, A&A) we use state-of-the-art data and tools to provide the best constraints
- Factors to take into account:
  - Initial water delivery
  - Loss of volatiles from high-energy irradiation (today and history)
  - Magnetic field
  - Tidal evolution

- Initial water content unknown
- Water delivery from wet planetesimals
- Proxima b could be drier than the Earth if formed in situ

- But could have formed farther out and migrated
- For now we can just assume a broad range of initial conditions

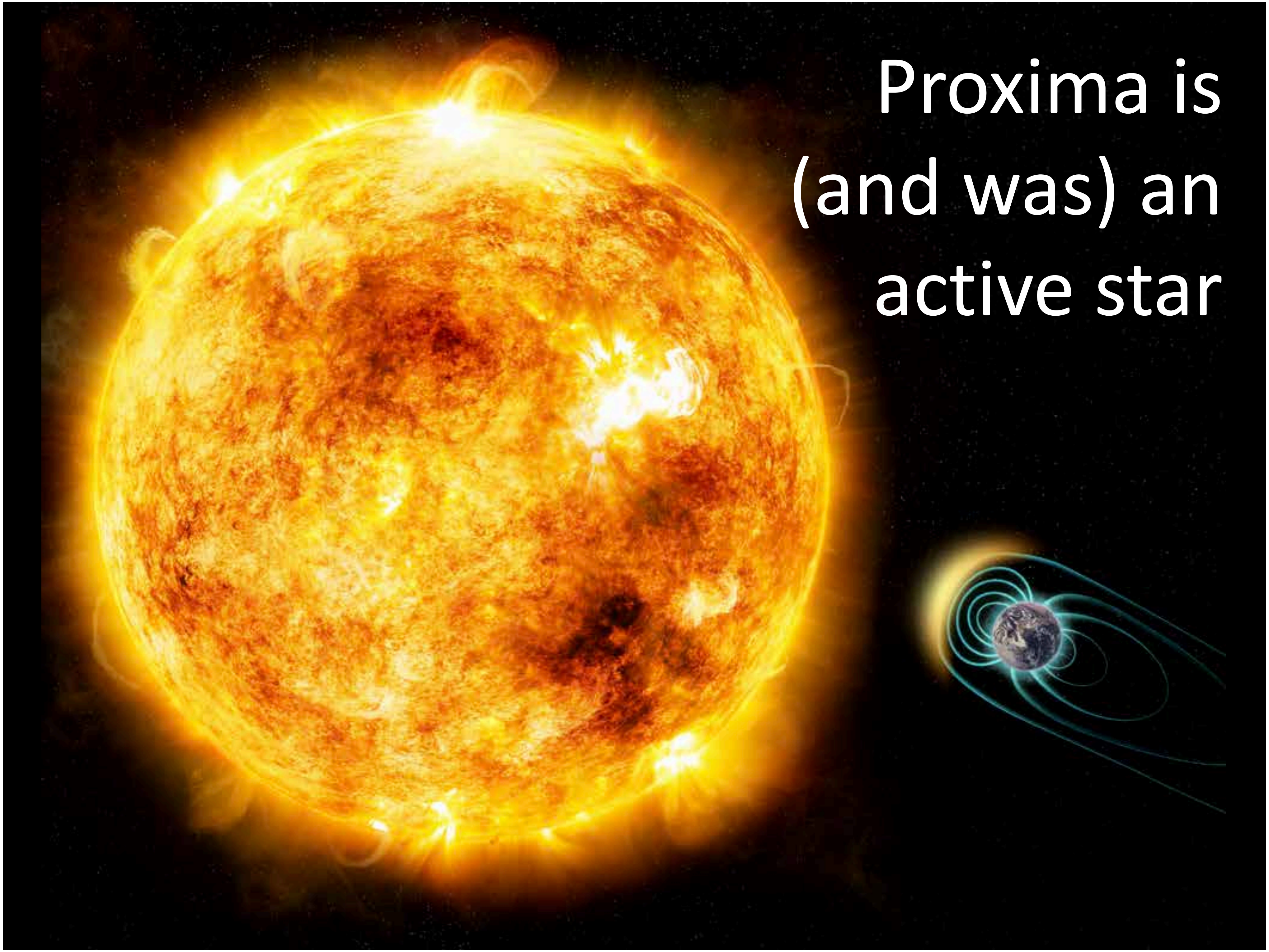
Tidal evolution

- Spin-orbit capture:
  - Synchronous
  - 3:2 resonance (3 rotations every 2 translations ⇨ 7.5 days)
- Depends on eccentricity (<0.35) and triaxiality (unknown)

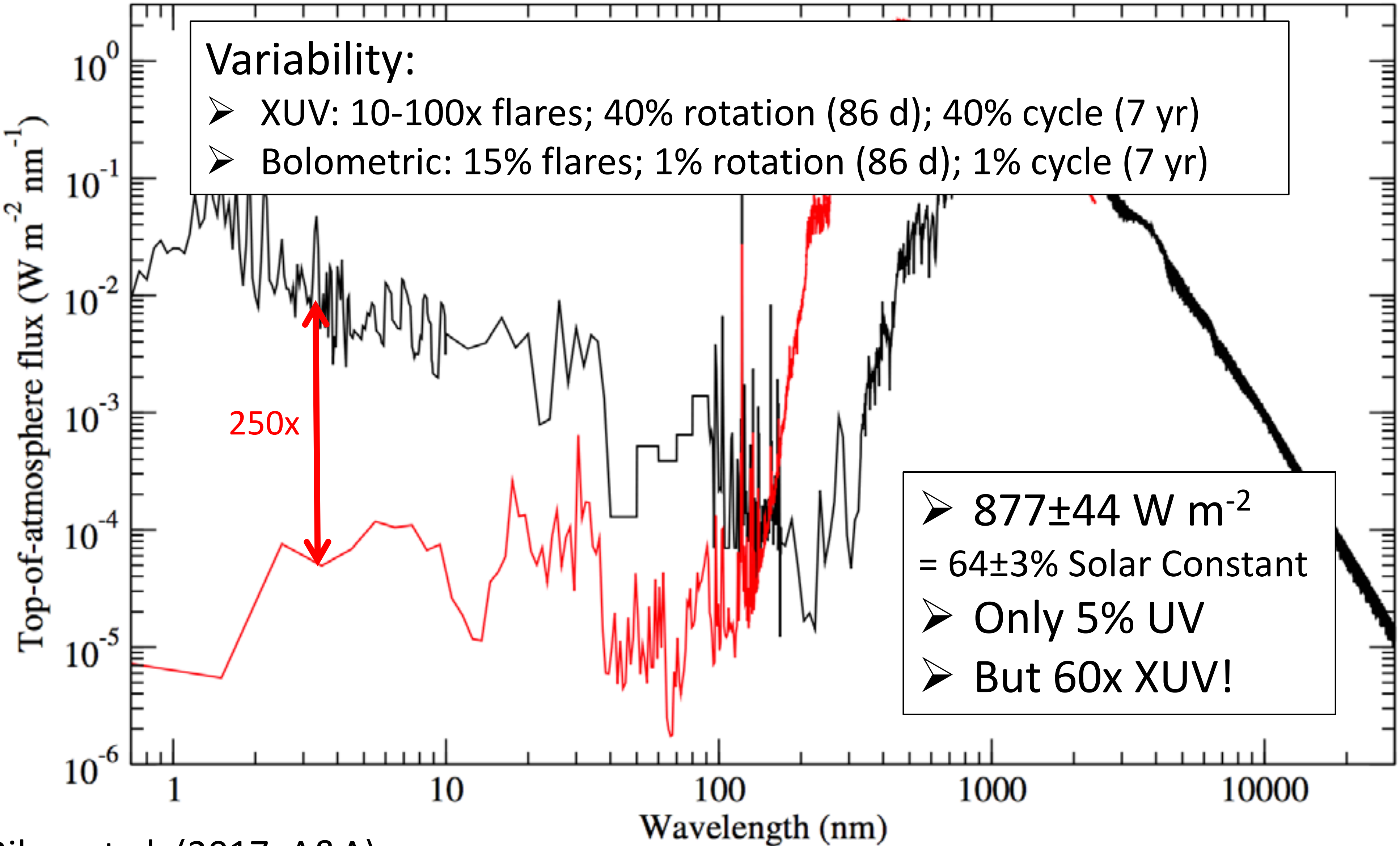


Ribas et al. (2016, A&A)

Note: Synchronous means apparent day on surface is infinitely long; 3:2 means apparent day = 2 x orbital period = 22.4 d

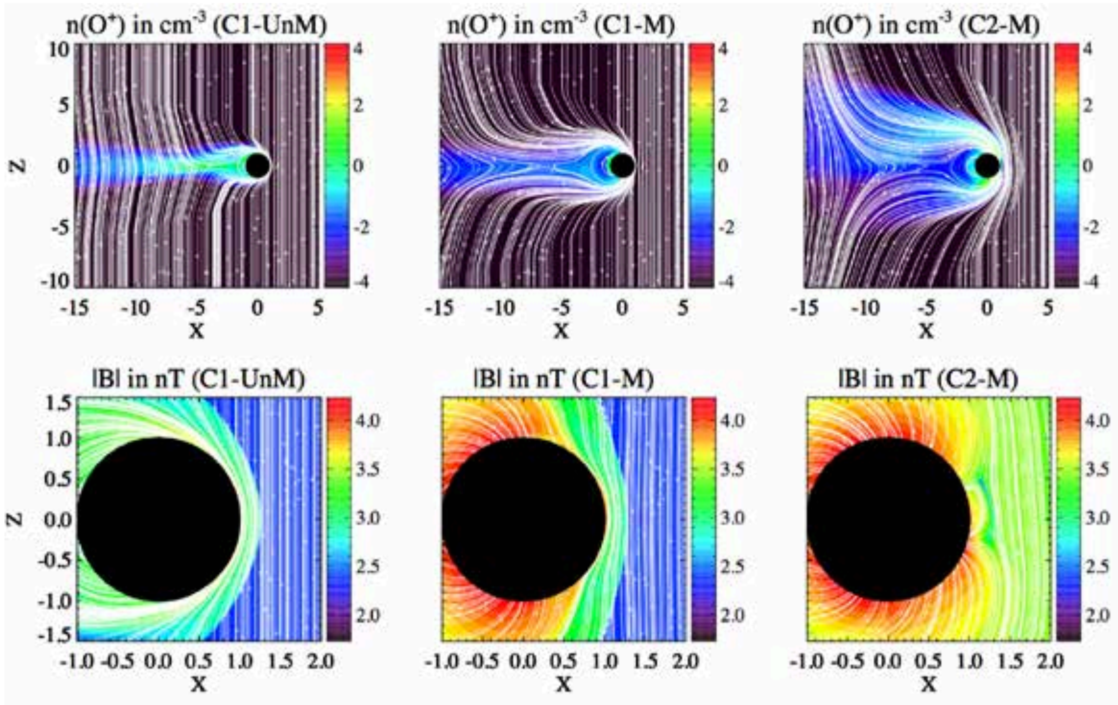

Proxima is
(and was) an
active star

- High-energy radiation (< 170 nm) is much more intense than received by Earth today, and variable!



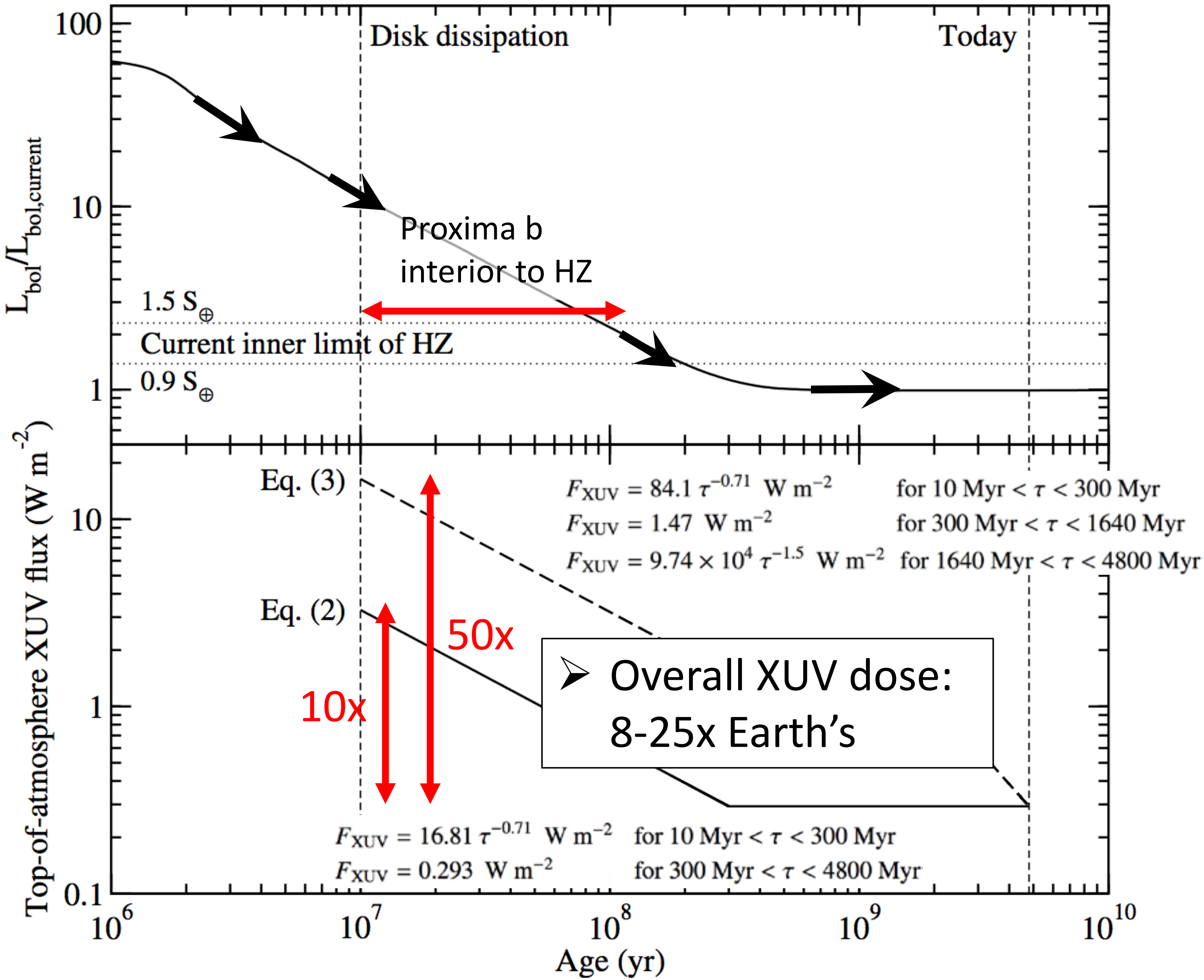
Ribas et al. (2017, A&A)

Loss processes



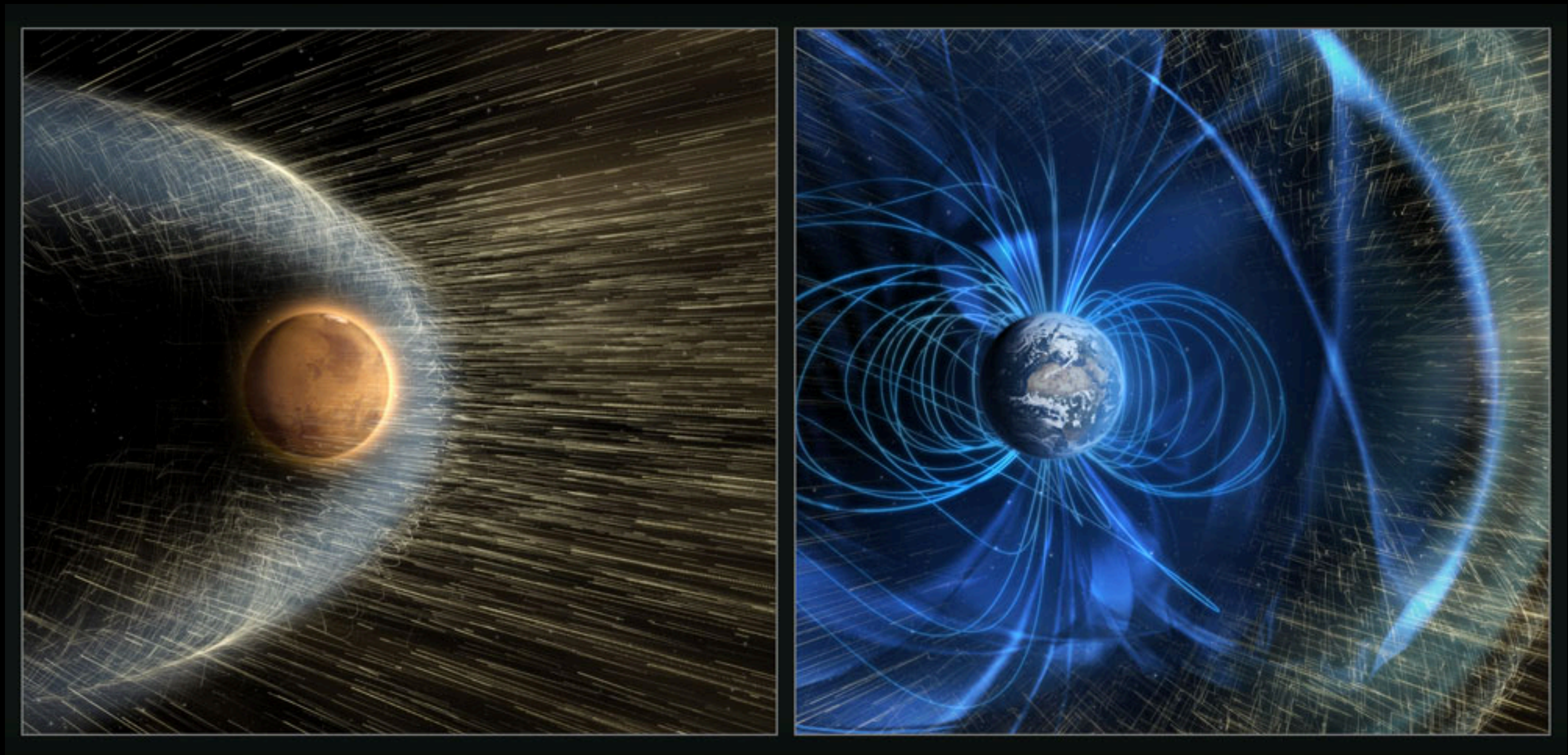
Dong et al. (2017, ApJ)

- Zuluaga & Bustamante (2016, arXiv) ⇒ Magnetic moment: 0.1-1 Earth's (UCERTAIN)
- Garraffo et al. (2016, ApJ) ⇒ Extreme space weather environment: wind density 100-1000x and pressure 2000x Earth's (UCERTAIN)
- Dong et al. (2017, ApJ)
  - If B=0, loss rates could be 100x higher than Earth
  - If B>0, lower loss rates but still higher than Earth today (UNCERTAIN)



Ribas et al. (2017, A&A)

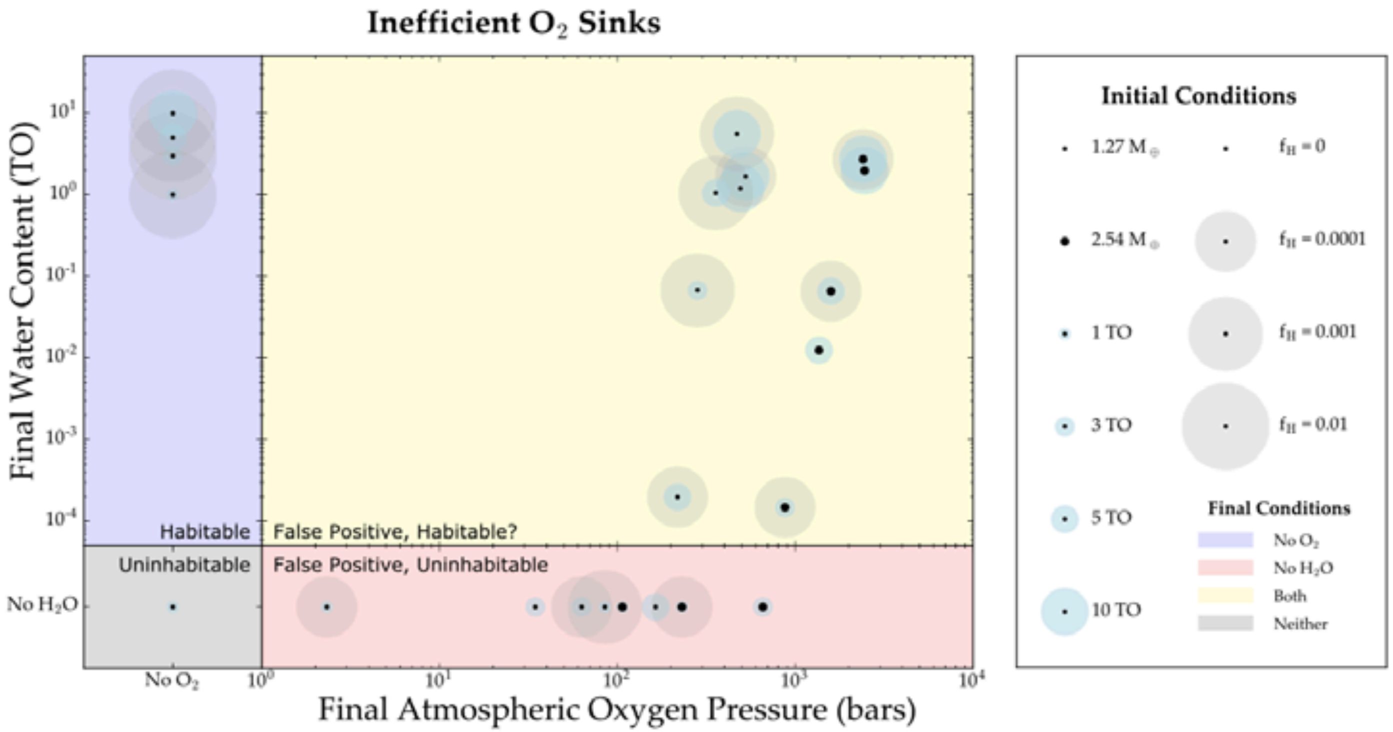
- Proxima b was worse off than the Earth during the early stages (runaway)
- This never happened to the Earth (star evolution & formation timescale)
- Volatile (and water) losses could have been intense, probably 0.5-2 Earth Oceans (1EO=total surface water)

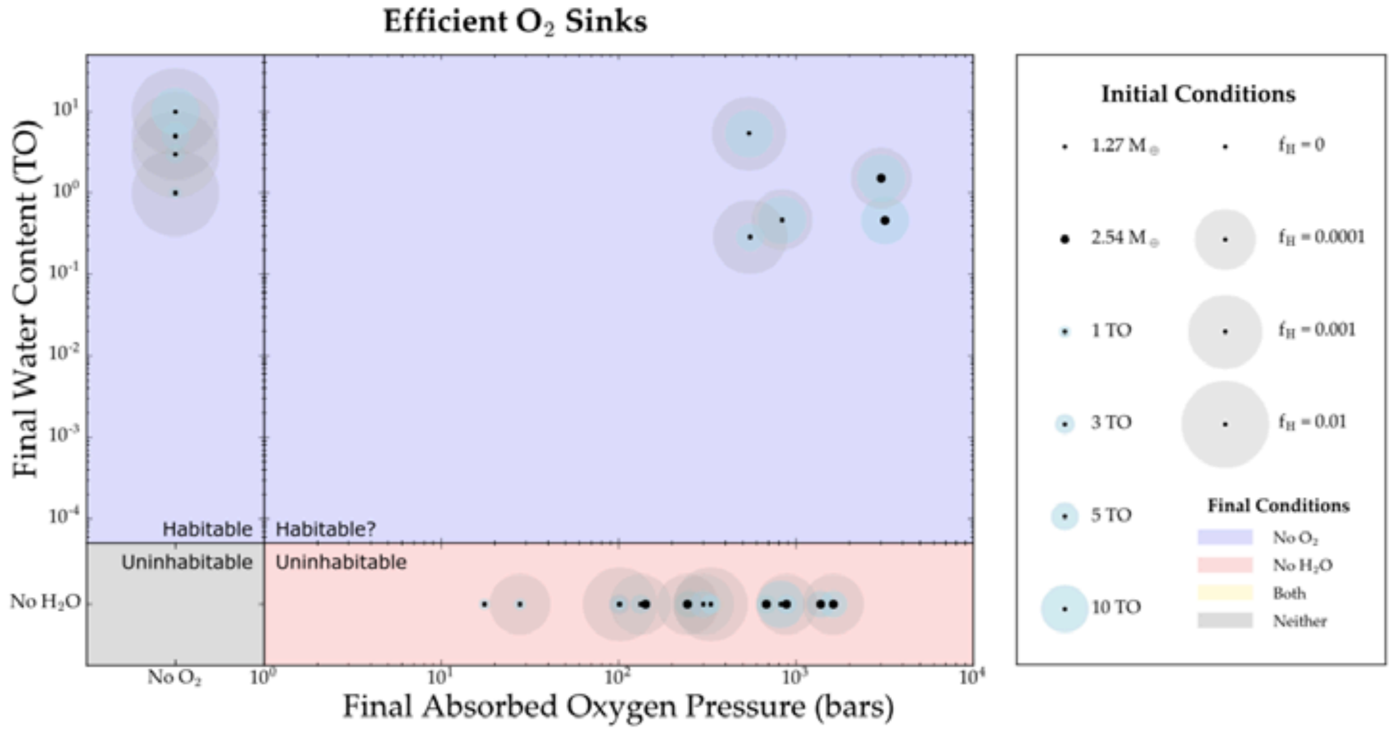


XUV prescription	H loss (EO_H)		
	HZ (1.5 $S_\oplus$) 90 Myr	HZ (0.9 $S_\oplus$) 200 Myr	Lifetime 4.8 Gyr
Eq. (2)	0.47	0.90	15.6
Eq. (3)	1.07	1.98	24.4

E. Bolmont

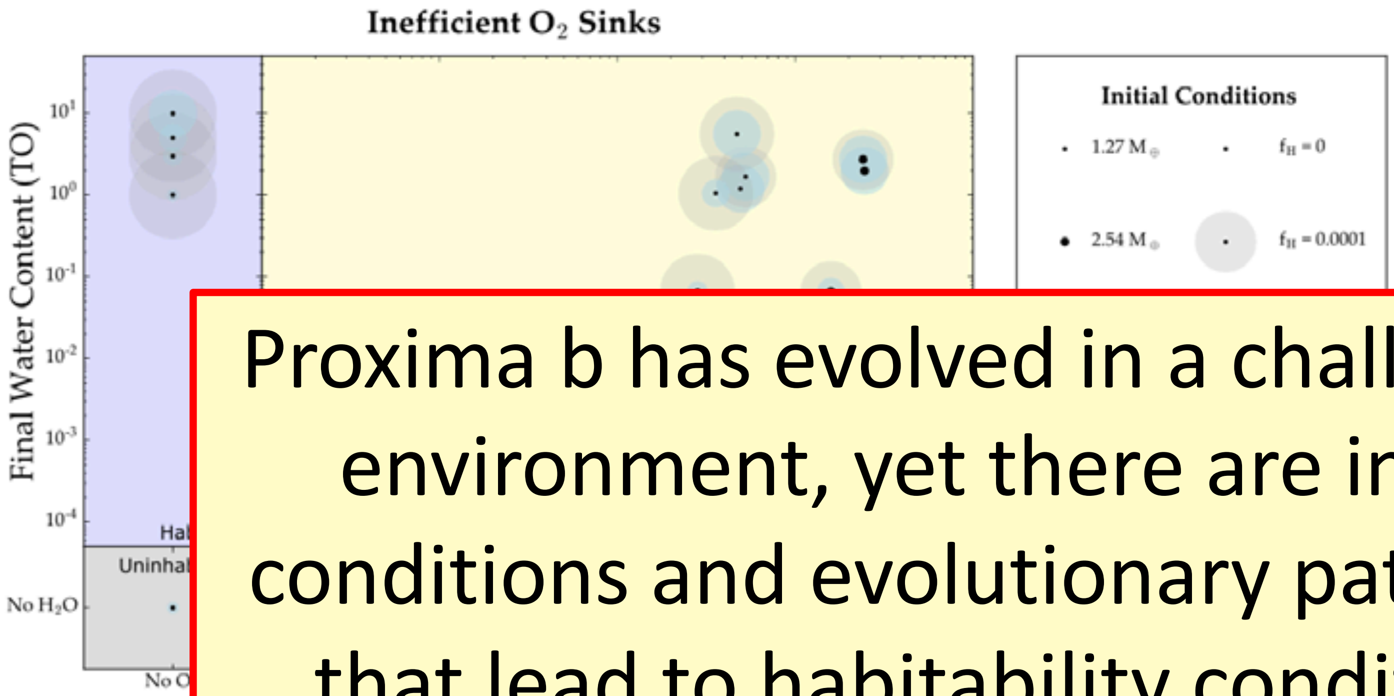
- Likely abiotic oxygen buildup
- What happened after entering the HZ is poorly constrained (lots of factors at play)





Barnes et al. (2016, arXiv)

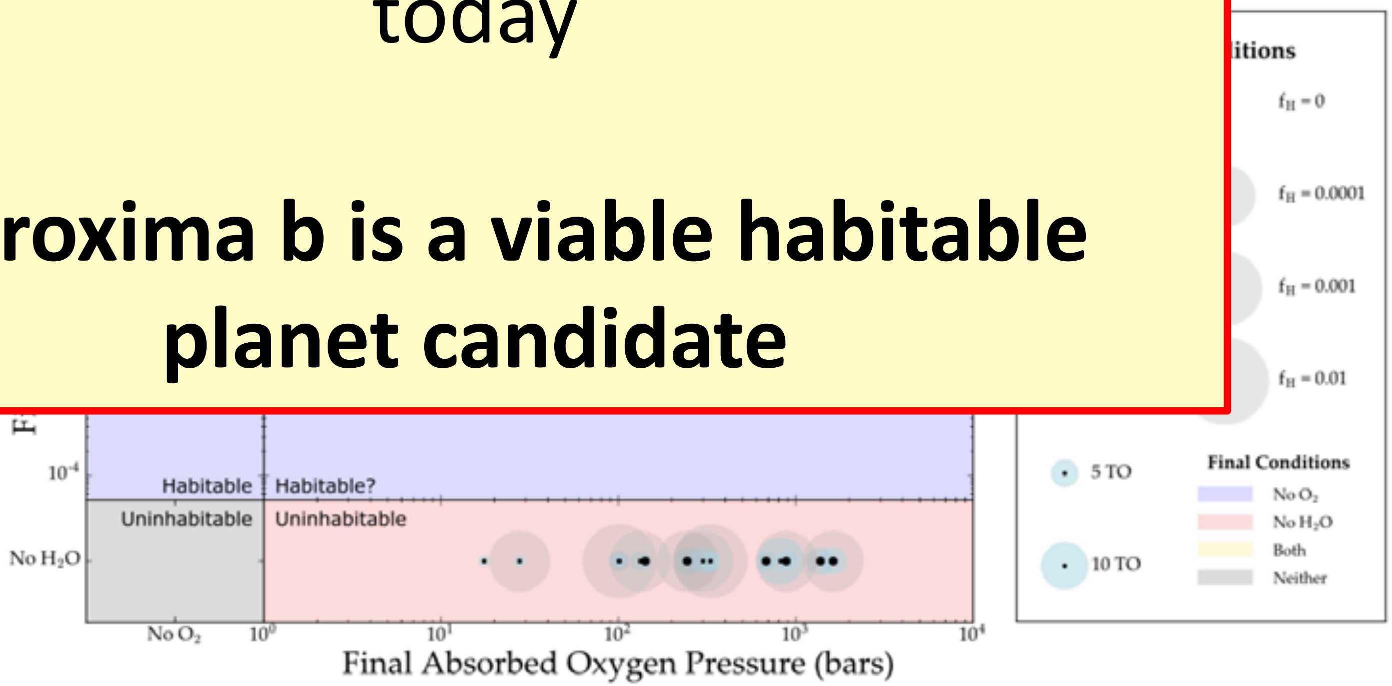
NOTE: XUV evolution recipe more extreme than found by Ribas et al. (2017)



Proxima b has evolved in a challenging environment, yet there are initial conditions and evolutionary pathways that lead to habitability conditions today

→ **Proxima b is a viable habitable planet candidate**

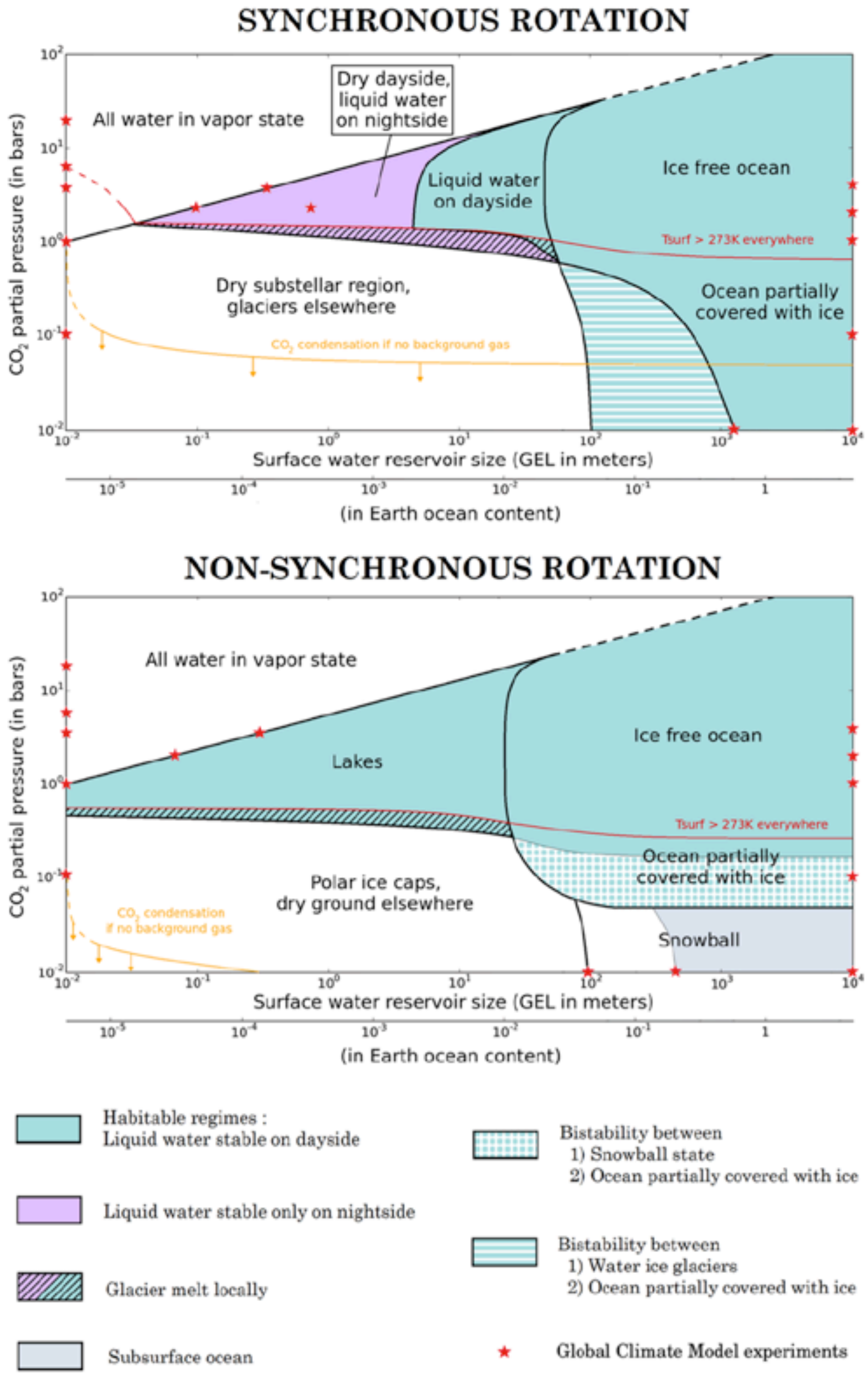
Barnes et
(2016, ar
NOTE: XUV
recipe mor
than found by Ribas
et al. (2017)



What is the climate like in Proxima b?

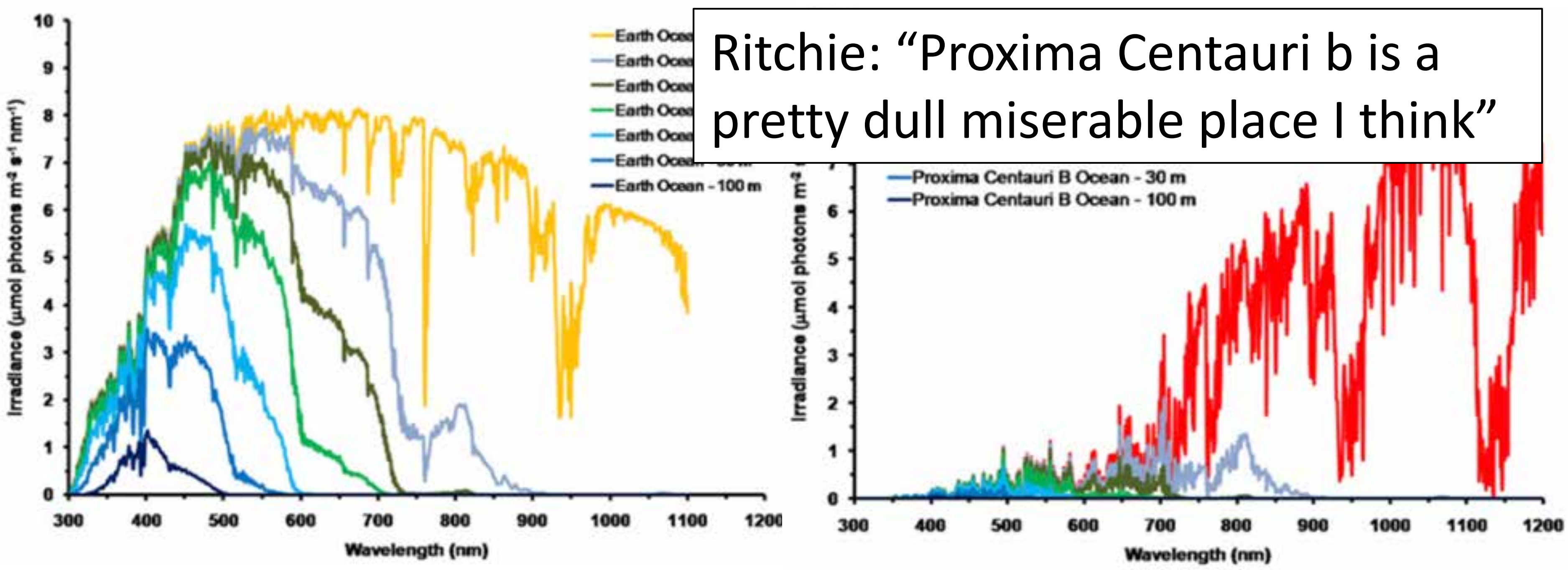
- Calculations using a sophisticated GCM
- Climate depends a lot on CO_2 pressure and on amount of water
- But stable solutions with liquid water with many configurations

Turbet et al. (2016, A&A)



Could photosynthesis be at work on Proxima b?

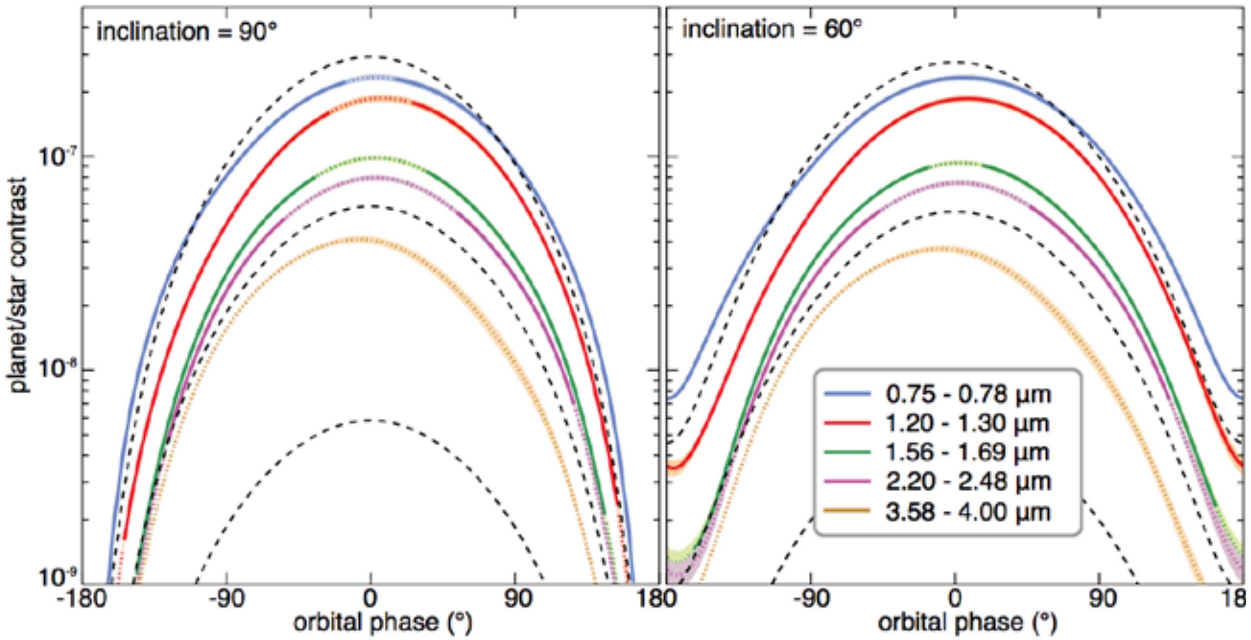
Ritchie, Larkum, Ribas, “Could Photosynthesis Function on Proxima Centauri b?” (2017, International Journal of Astrobiology, in press)

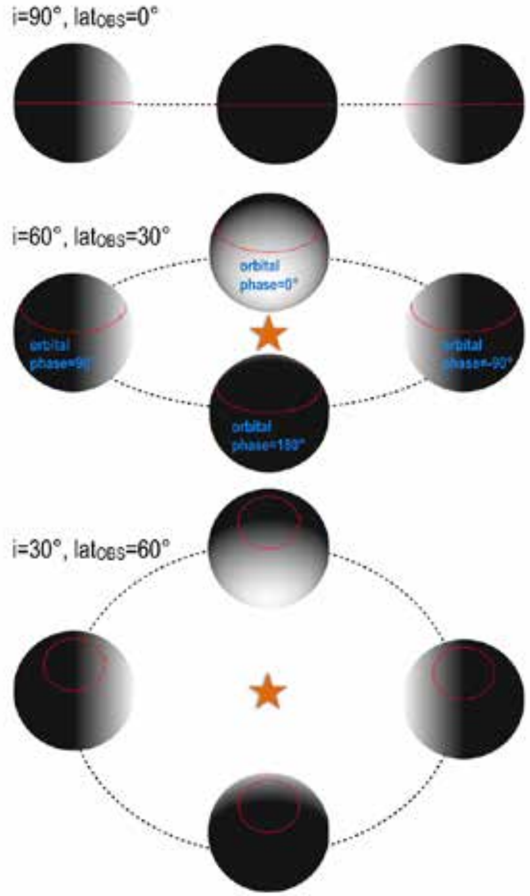


Ritchie: “Proxima Centauri b is a pretty dull miserable place I think”

- Proxima b is unfavorable for anoxygenic aquatic photosynthesis. Nevertheless, a substantial aerobic or anaerobic ecology is possible. (anoxygenic photosynthesis uses visible to NIR light, abundant in Proxima)

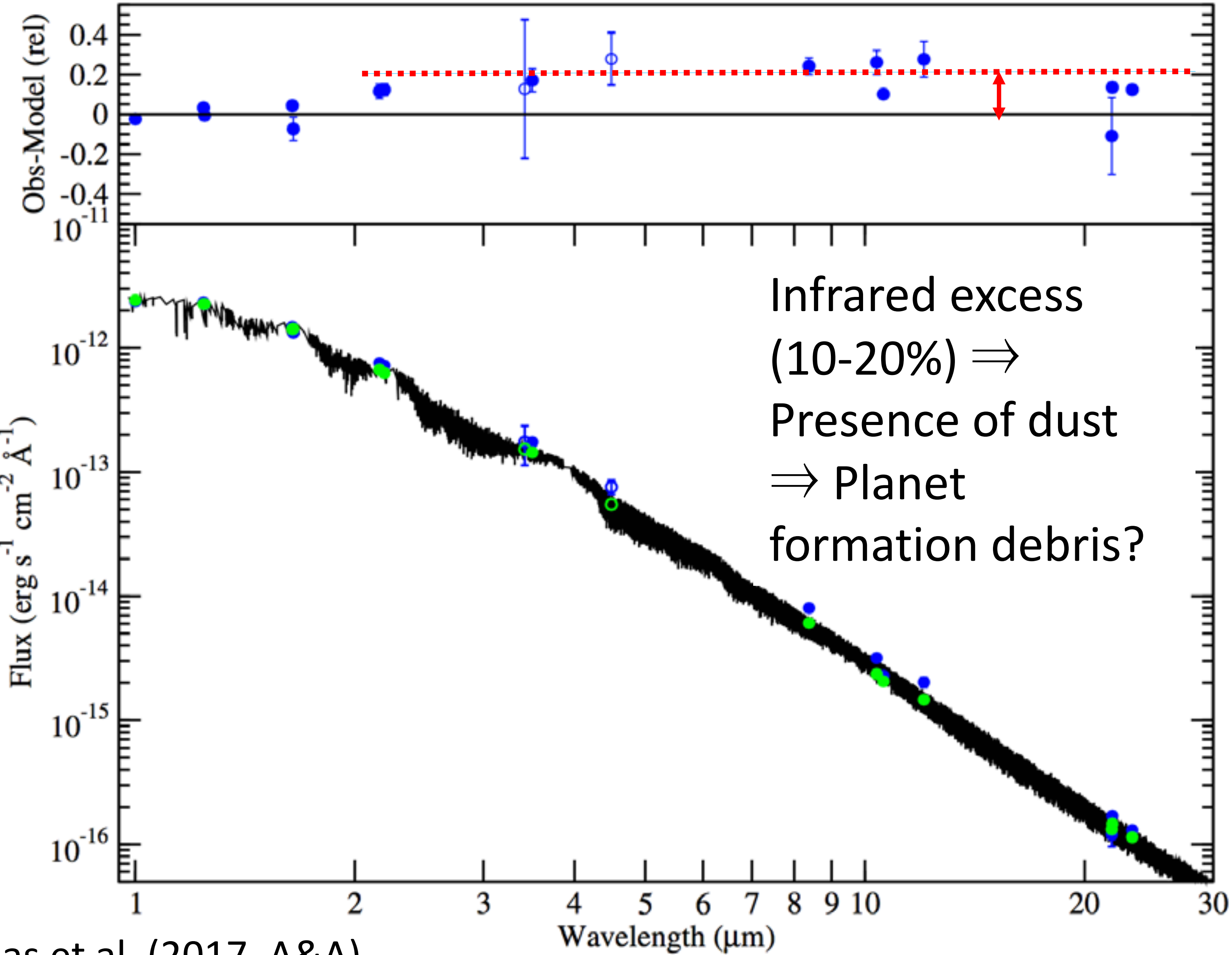
What's next?
Seeing it…





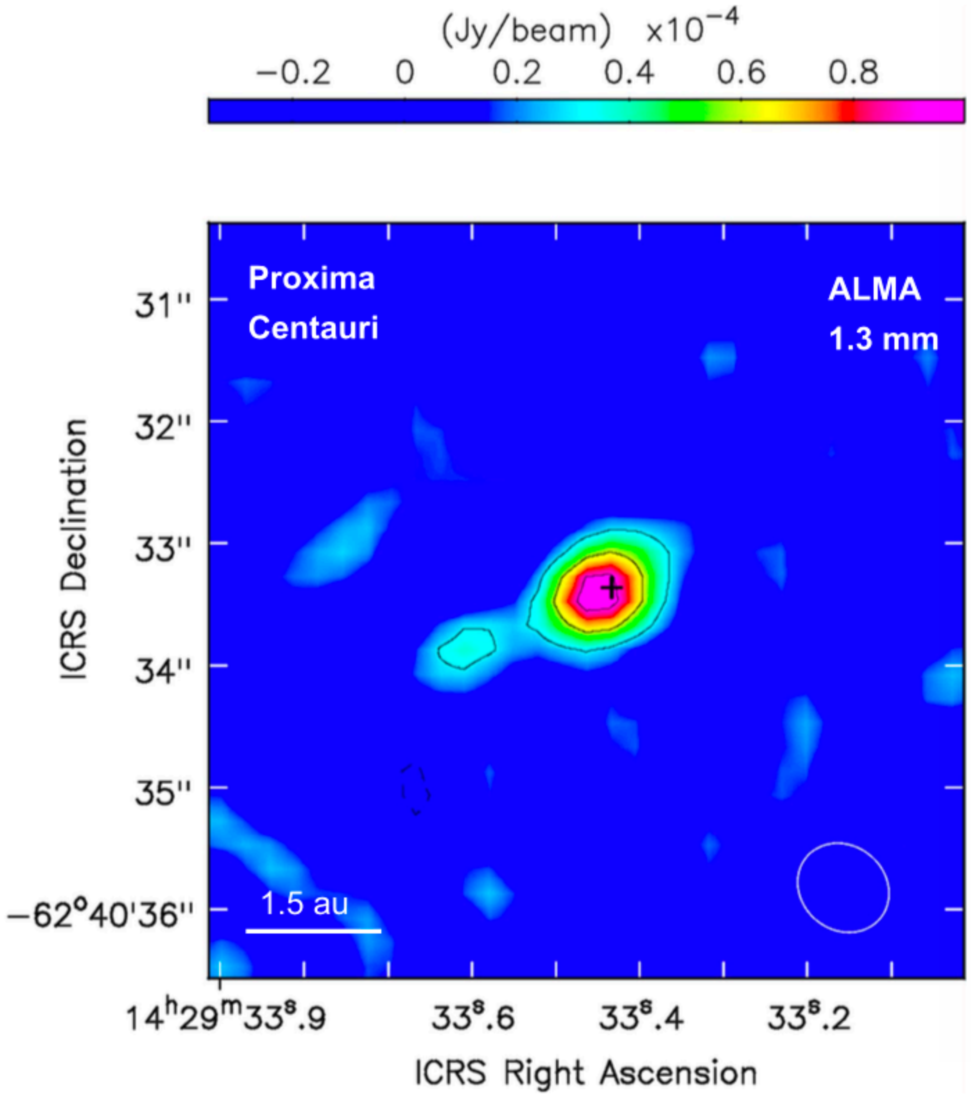
- Doable with the E-ELT
- Perhaps even with a combination of SPHERE and ESPRESSO in the VLT! (Lovis et al. 2017, A&A)

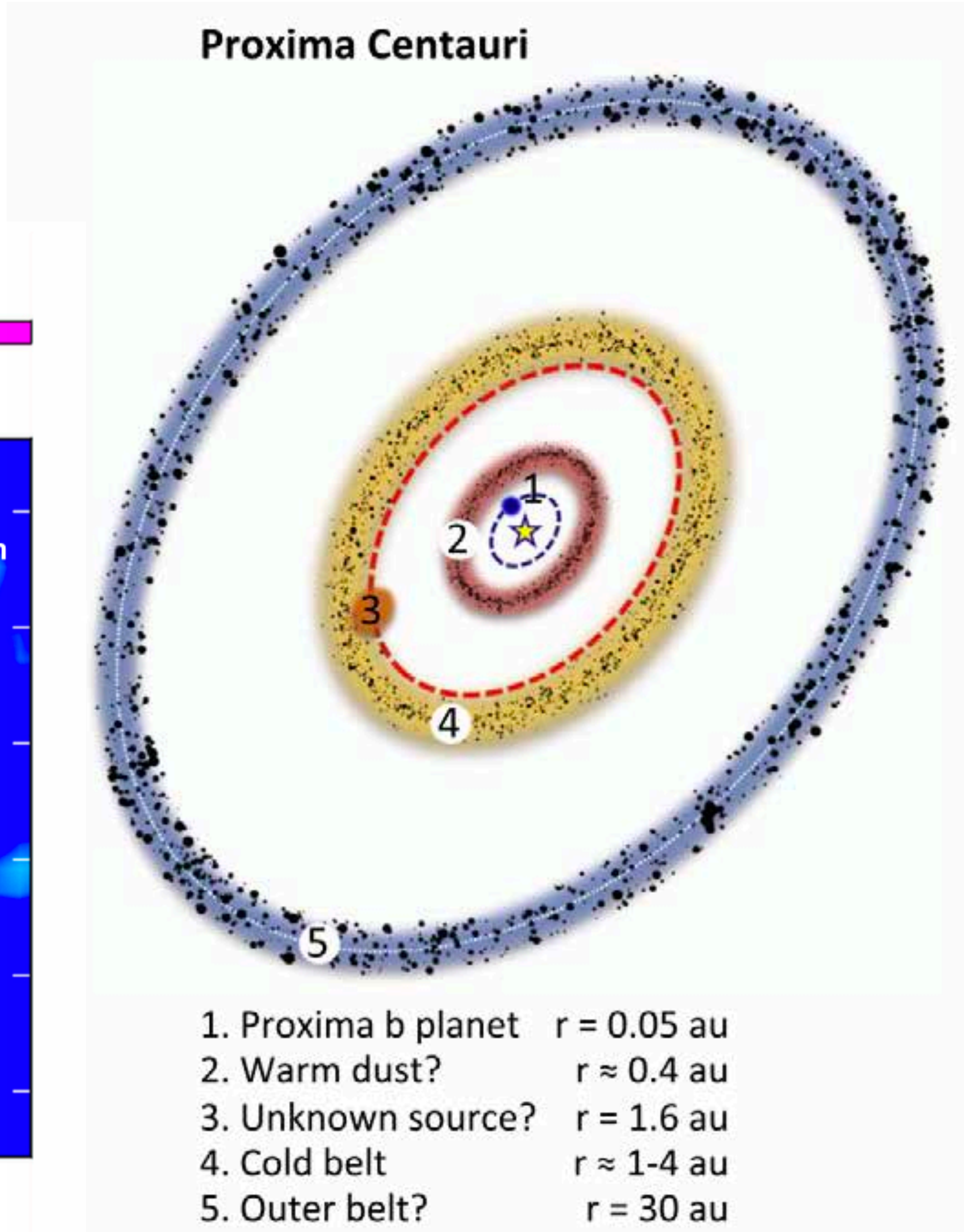
Warm dust in Proxima



Ribas et al. (2017, A&A)

A rich system





Anglada et al. (2017, ApJLett)

What's next? More pale red dots

carmenes

MPIA (Heidelberg) • **IAA** (Granada) • **LSW** (Heidelberg) • **ICE** (Barcelona) • **IAG** (Göttingen) • **IAC** (Tenerife) • **TLS** (Tautenburg) • **UCM** (Madrid) • **HS** (Hamburg) • **CAB** (Madrid) • **CAHA** (50% MPG + 50% CSIC)

MAX-PLANCK-GESELLSCHAFT

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