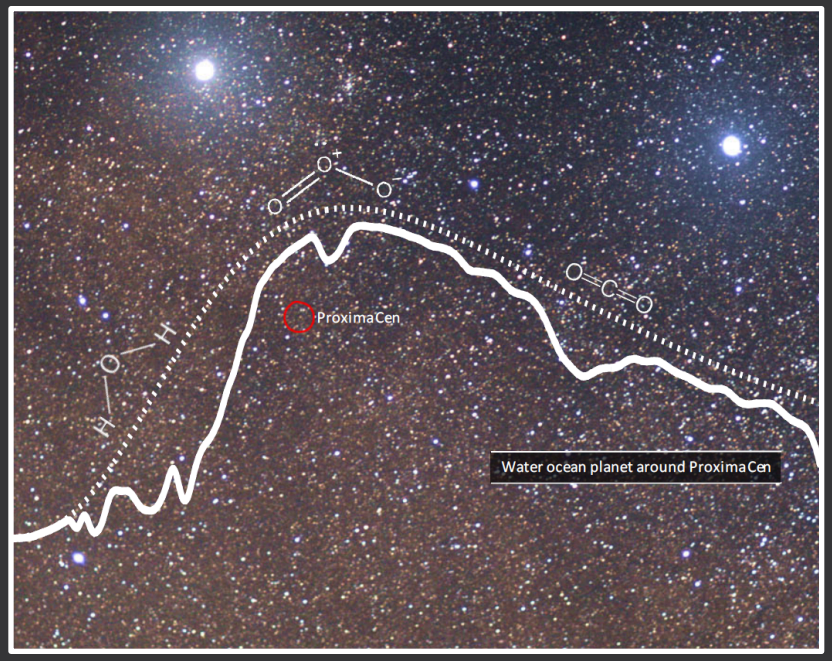
Université de Liège

Proxima Cen b: theoretical spectral signatures for different atmospheric scenarios

D. Defrère(1), A. Léger(2), J.L. Grenfell(3), M. Godolt(3), A Garcia Munoz(3), H. Rauer(3), and F. Tian(4)



(1) University of Liège, Belgium
(2) University of Paris-Saclay, France
(3) TU Berlin, Germany
(4) Tsinghua University, Beijing, China

Lyon – November 22nd

Overview

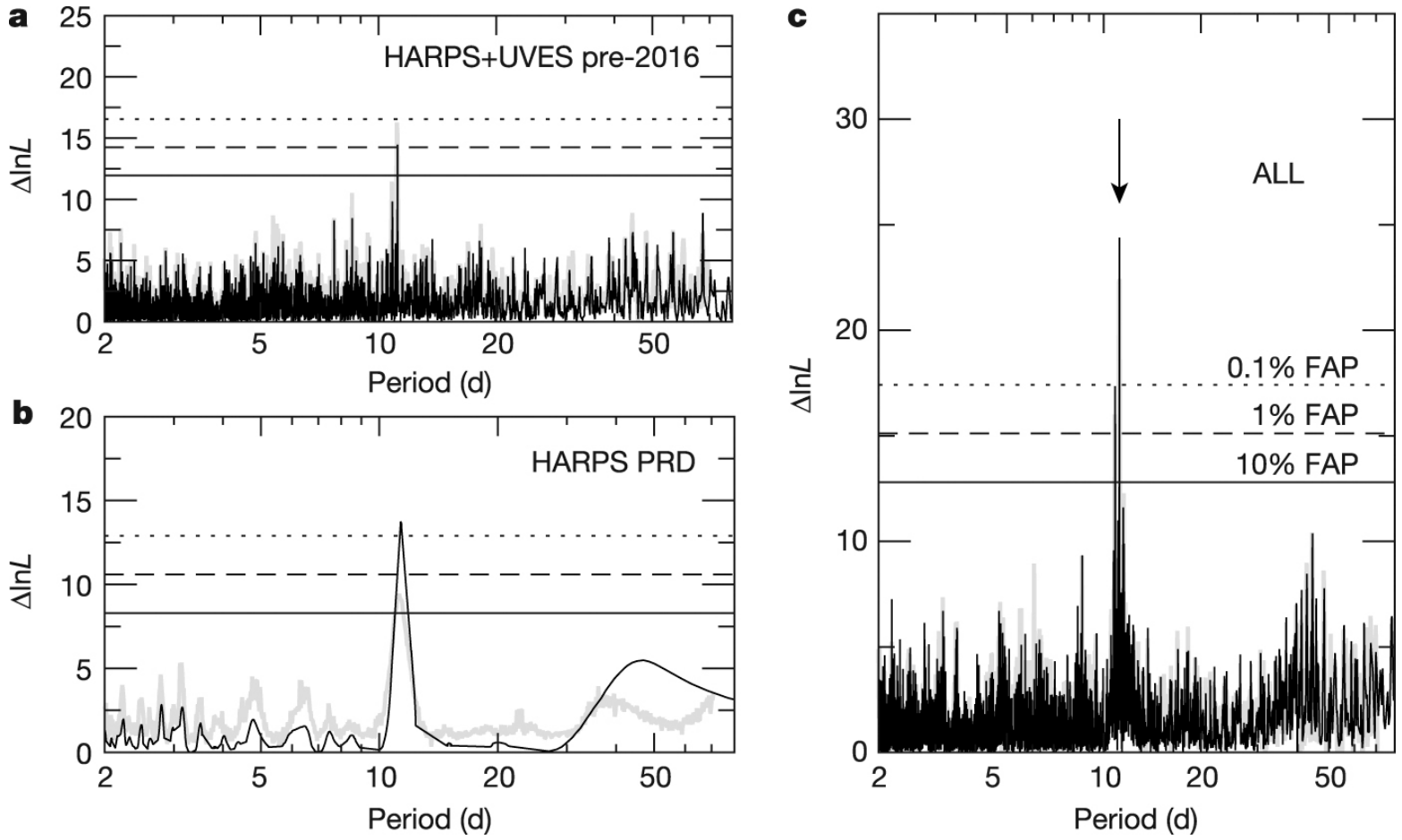
1. Proxima Cen b: status

2. Possible spectral signatures

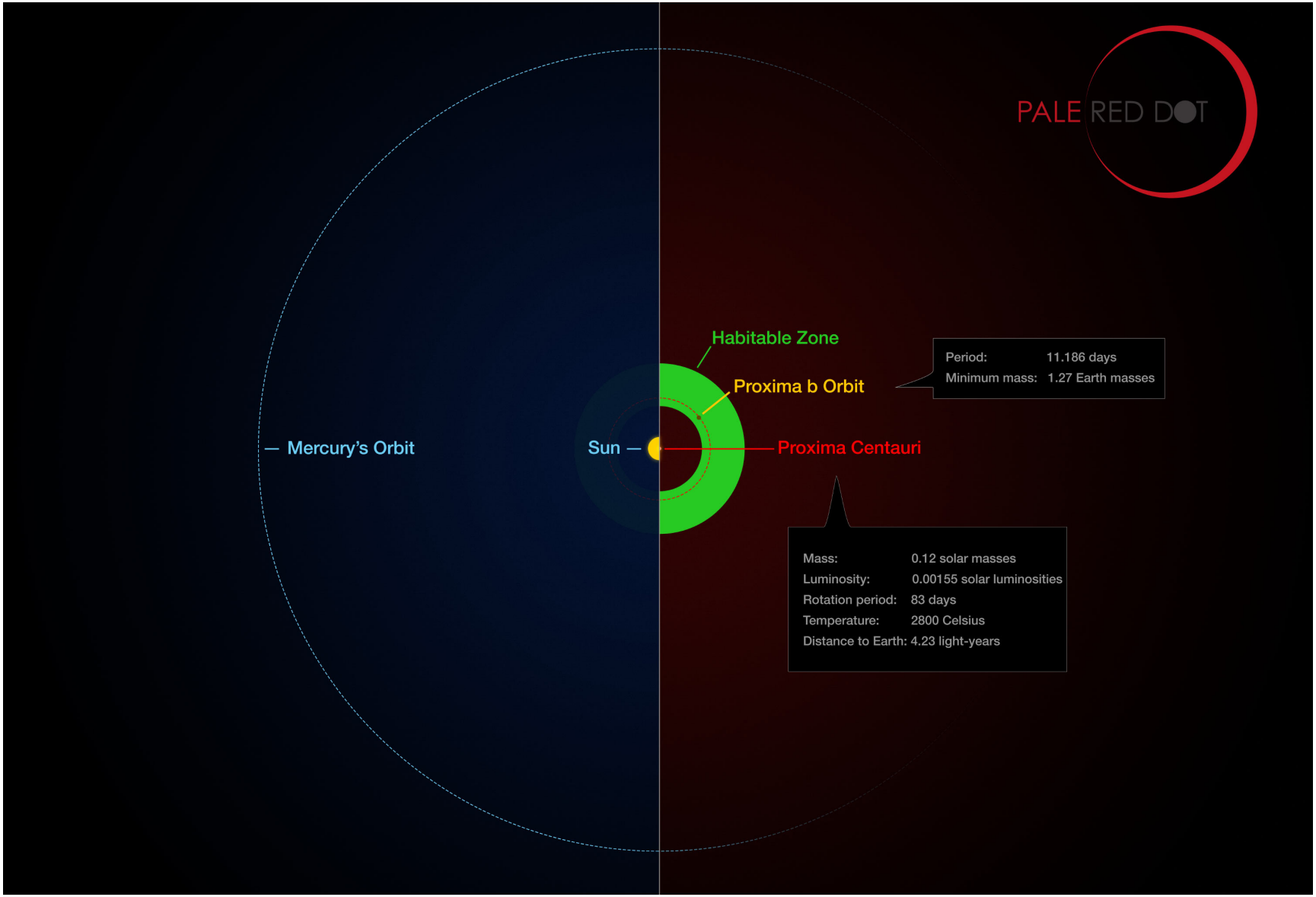
3. Prospects for direct detection

Proxima Cen b: discovery (1/2)

- Proxima Cen: M6V, 1.3 pc (4.2 al)
- Detection of a Doppler signal at 11.2 days (Anglada-Escudé *et al.* *Nature* **536,** 437–440, 2016).



Proxima Cen b: discovery (2/2)

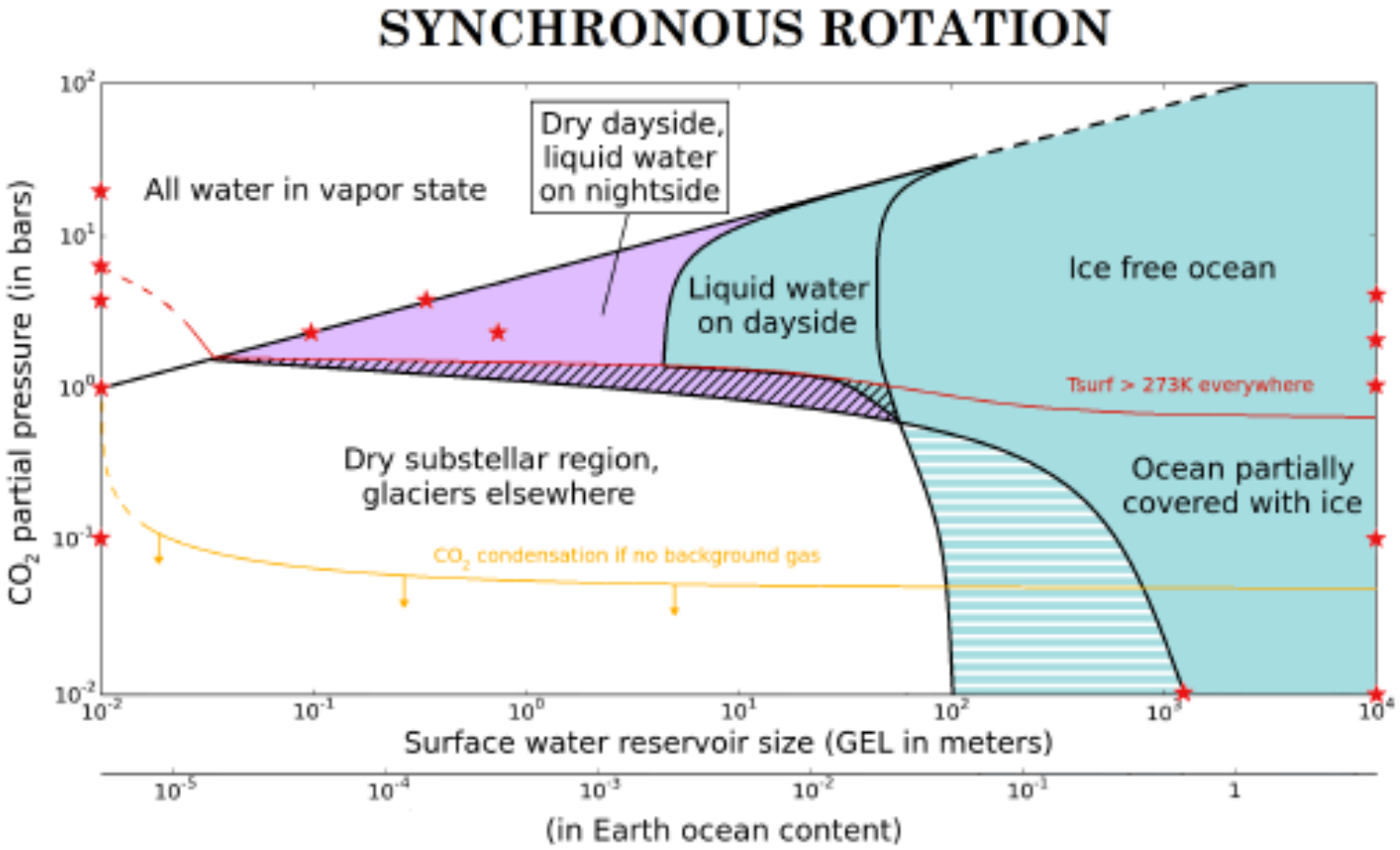


Proxima Cen b: habitability (1/2)

- Proxima Cen: 3050K => 0.65 to 0.7 S_{Earth} at 0.05 AU (HZ between 0.9 to 1.5 S_{Earth} and 0.2 S_E, Kopparapu et al. 2016)
- Receive 30 times more EUV and 250 more X-rays than Earth
- Viable habitable planet: likely lost less than Earth's ocean worth of hydrogen before reaching the HZ (100 to 200 Myr after formation, Ribas et al. 2016)

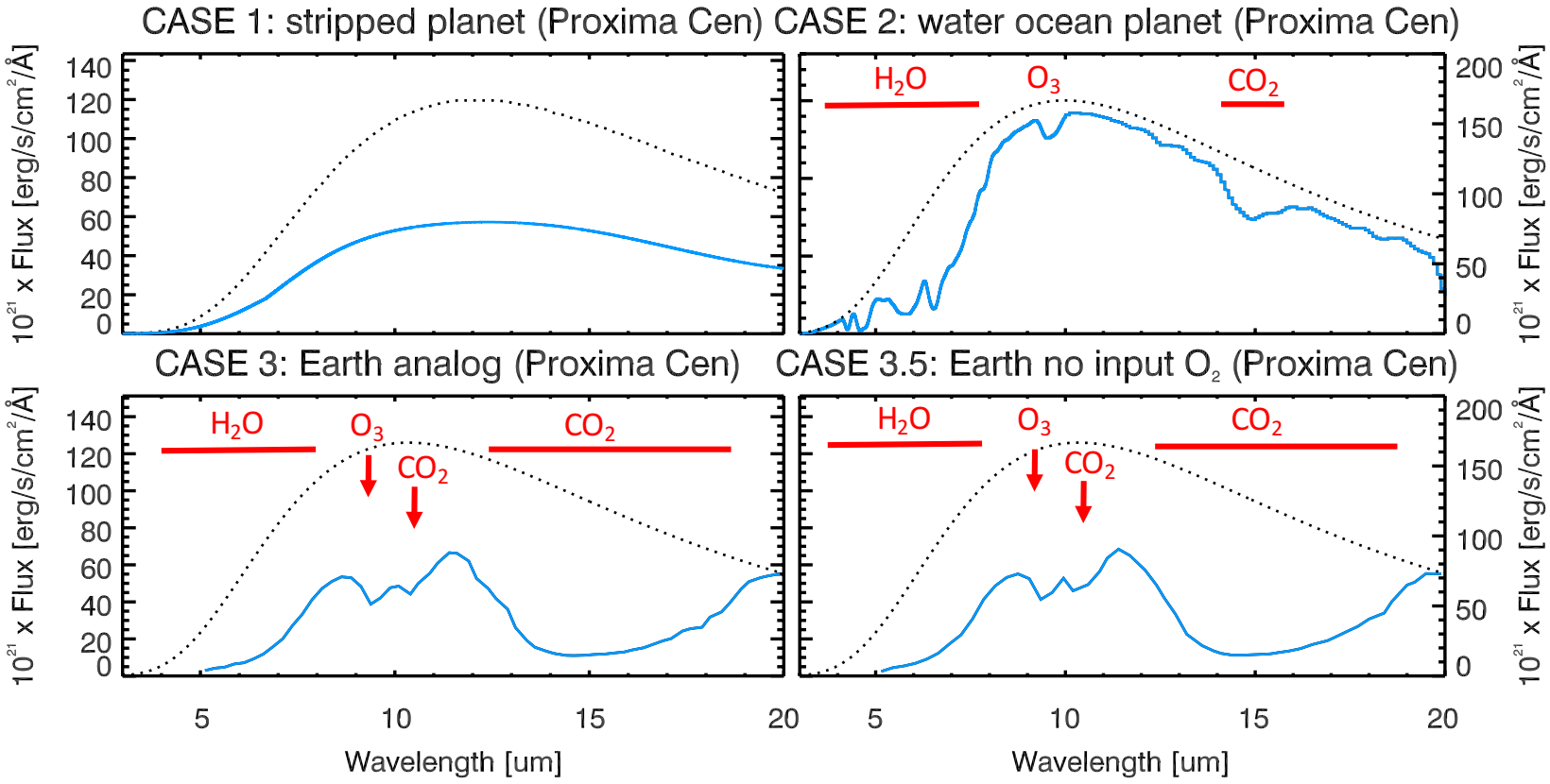
Proxima Cen b: habitability (2/2)

- Broad range of atmospheric pressures and compositions allows habitability (3D Global Climate Model, Turbet et al. 2016):



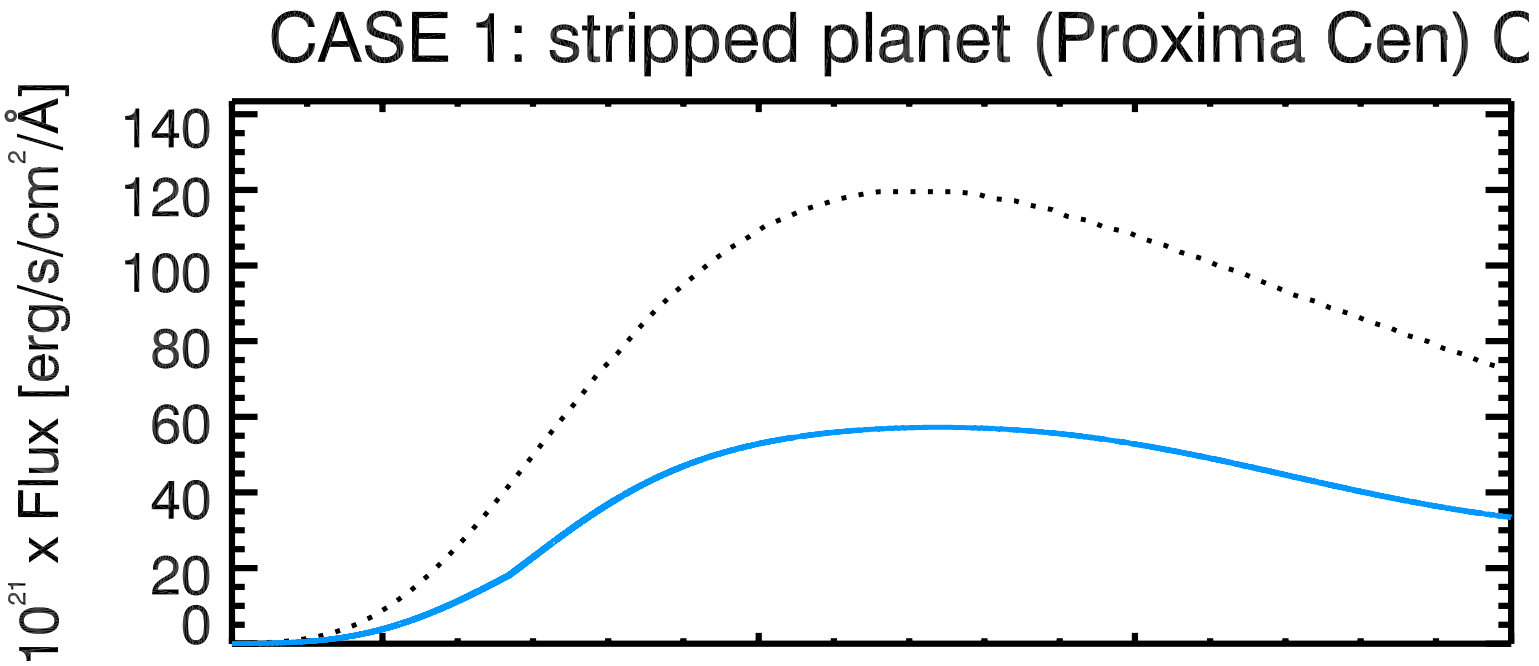
Possible spectral signatures (1/5)

- Simulated mid-infrared spectra of planets with various atmospheric properties computed by coupled climate chemistry models (Rauer et al. 2011; Tian et al. 2014):



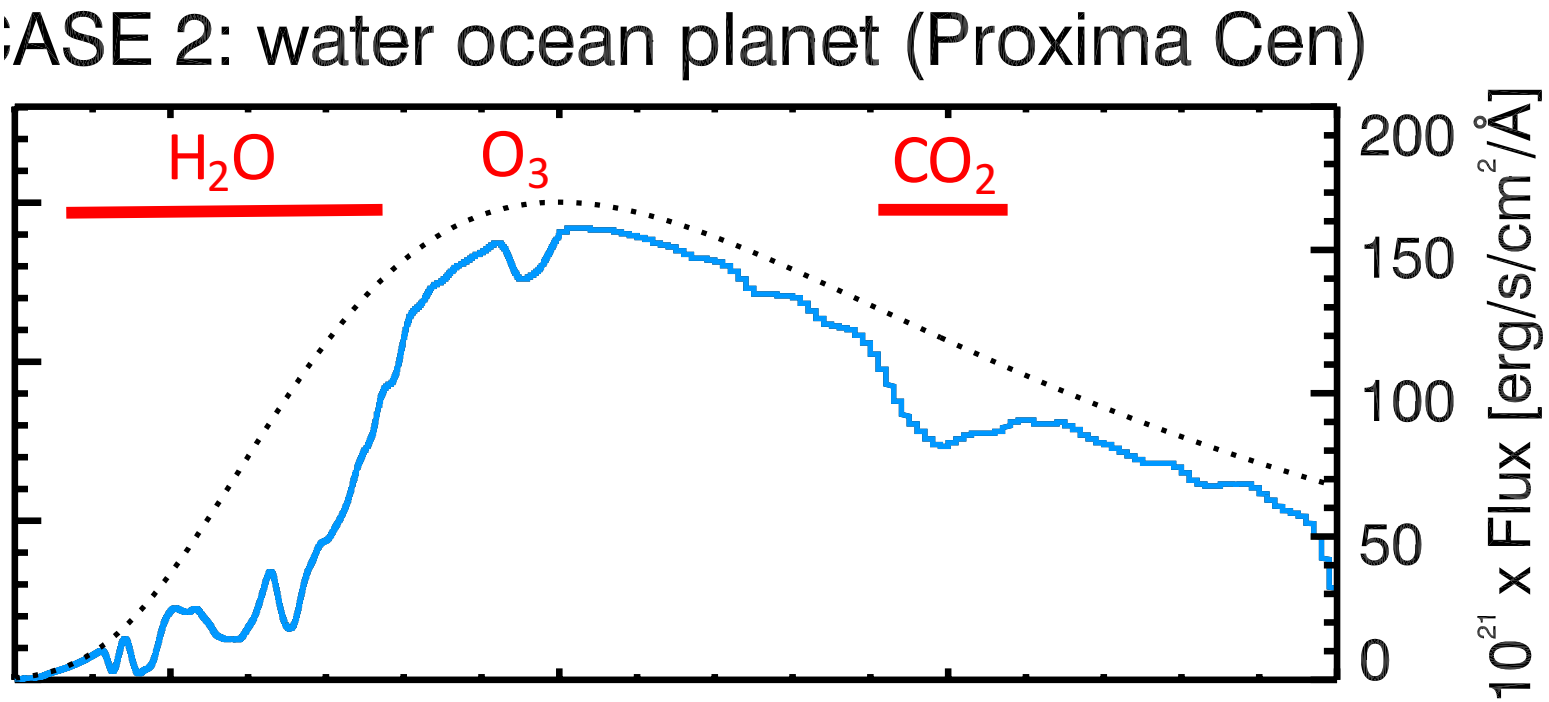
Possible spectral signatures (2/5)

Case 1: a rocky planet ($M=4.0M_E$, $R=1.5R_E$) in the HZ of Proxima Cen. The stellar insolation is 65% of that of Earth and $T_s=240$ K. No atmosphere (stripped planet), using Apollo Moon sample 15071 for IR emissivity.



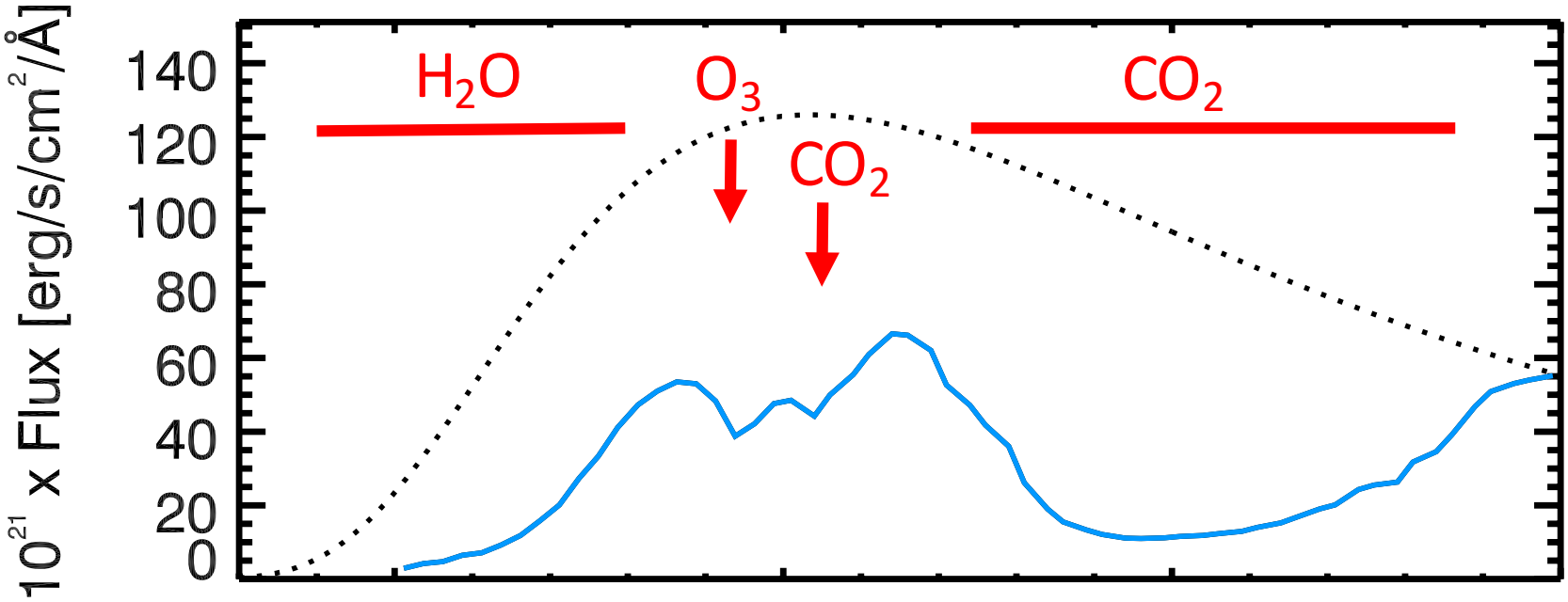
Possible spectral signatures (3/5)

Case 2: Water-ocean planet ($M=2.0M_E$, $R=1.5R_E$) in HZ of Proxima Cen ($S=1.05S_e$) with arbitrary O_2 input that could be due e.g. to strong H escape. Atmosphere: P_{N2}=1 bar, P_{O2}=200mbar, 1 ppm P_{CO2}, saturated H_2O vapour, T_s = 290 K, calculated O_3 with coupled chemistry.



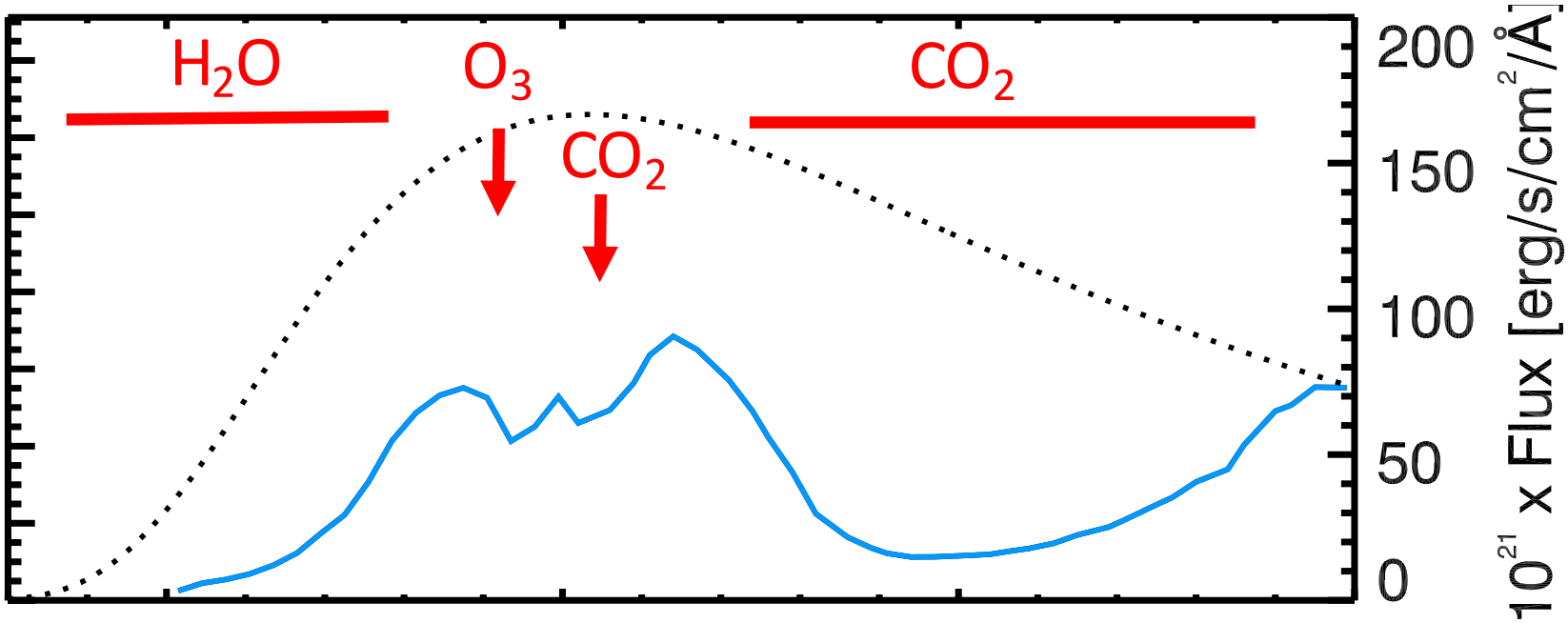
Possible spectral signatures (4/5)

Case 3: a large **Earth-analog** planet ($M=4.0M_E$, $R=1.5R_E$) in HZ of Proxima Cen ($S=0.65S_e$), but with a strong CO_2 Greenhouse effect bringing T_s to 280 K. Atmosphere: P_{CO2}=300mbar, P_{N2}=500mbar, P_{O2}=200mbar (possibly biotic), H_2O from vapor pressure, calculated O_3 with coupled chemistry.



Possible spectral signatures (5/5)

Case 3.5: **a rocky planet** in HZ of Proxima Cen ($S=0.65S_e$), with P_{CO_2}=300mbar bringing T_s to 280 K, H_2O from vapour pressure, **no O_2 input**, calculated O_2 and O_3 from coupled chemistry induced by the UV of the M star.



Prospects for direct detection

- Direct imaging (planet at maximum 38 mas or 0.05 AU):
  - Too close for 8-m class telescopes;
  - Opportunity by combining direct imaging and high-resolution spectroscopy (5 sigma in 40 nights, Lovis et al. 2016);
  - E-ELT would reach an SNR of 10 (R=100) in 5 to 30 minutes (0.76 to 1.6 microns, Turbet et al. 2016).

- Thermal phase curves with JWST
  - Can constrain the thickness of the atmosphere

Prospects for direct detection

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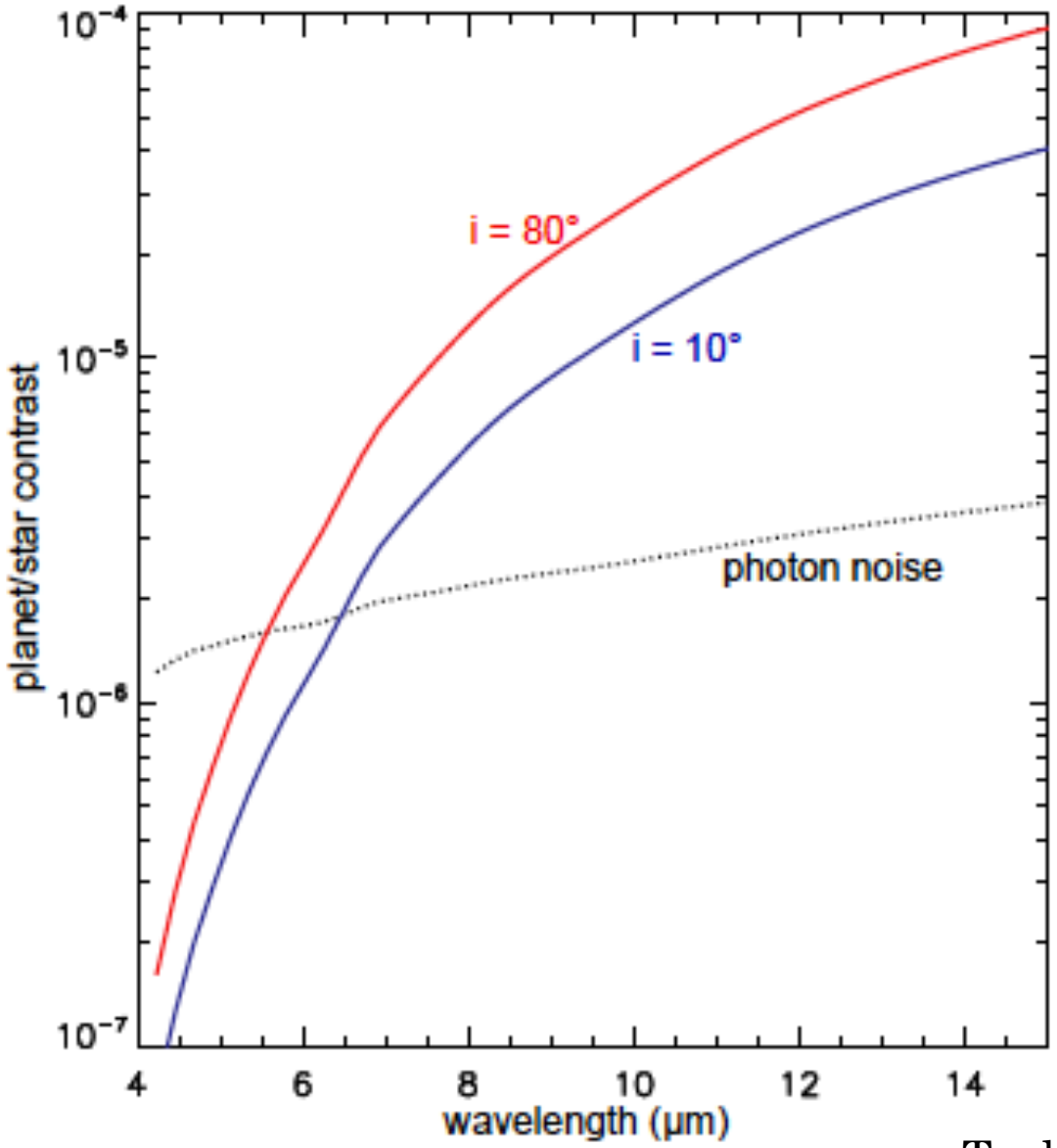


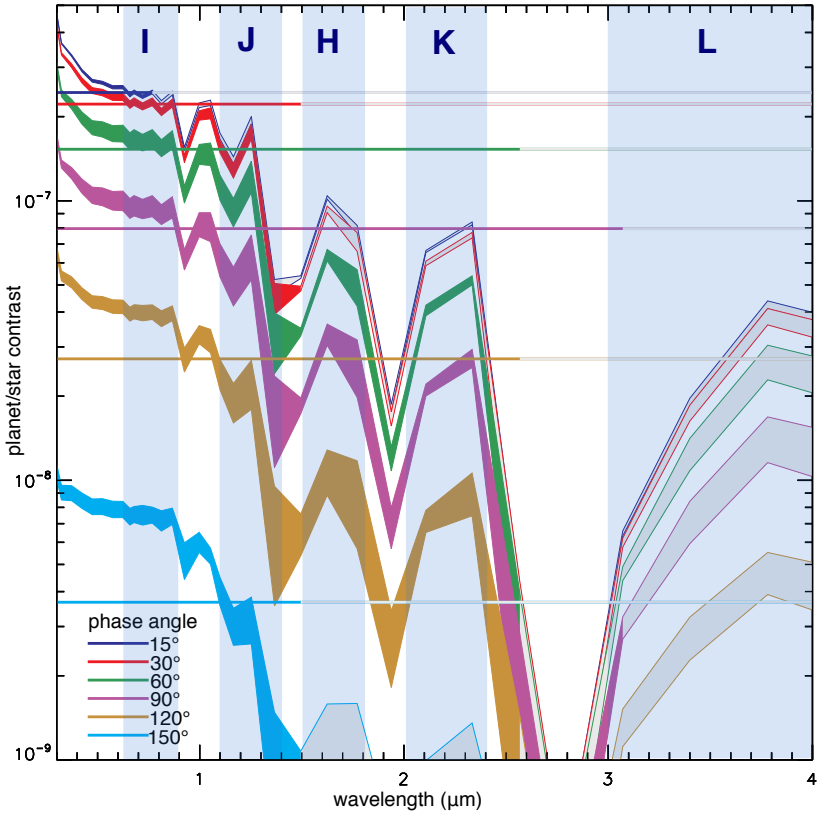
ma in 40

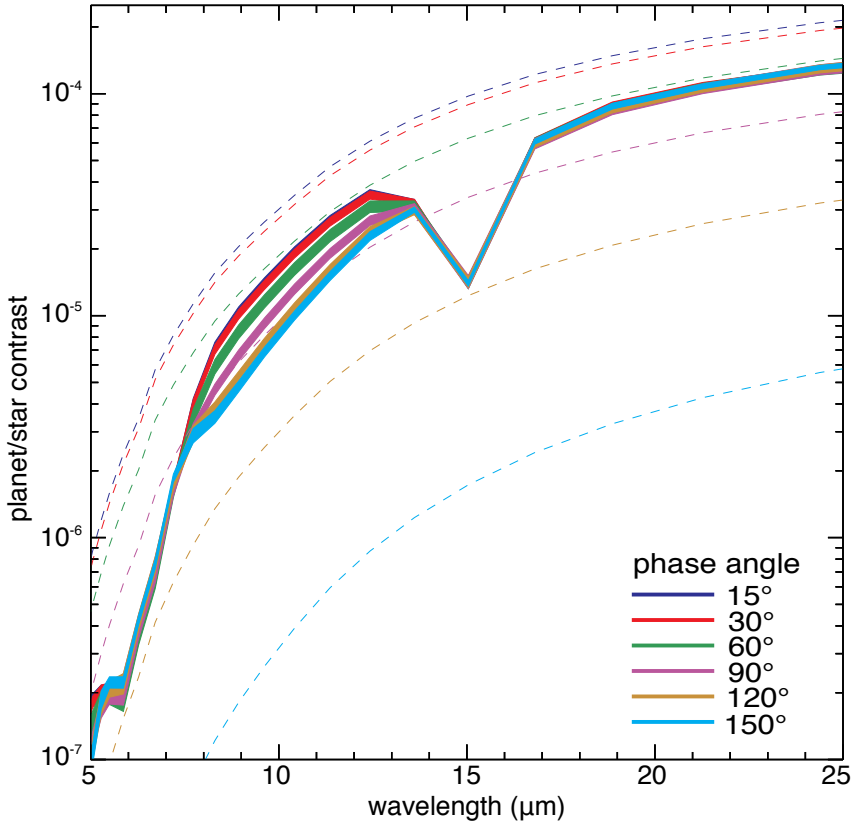
minutes

Turbet et al. 2016

Prospects for direct detection

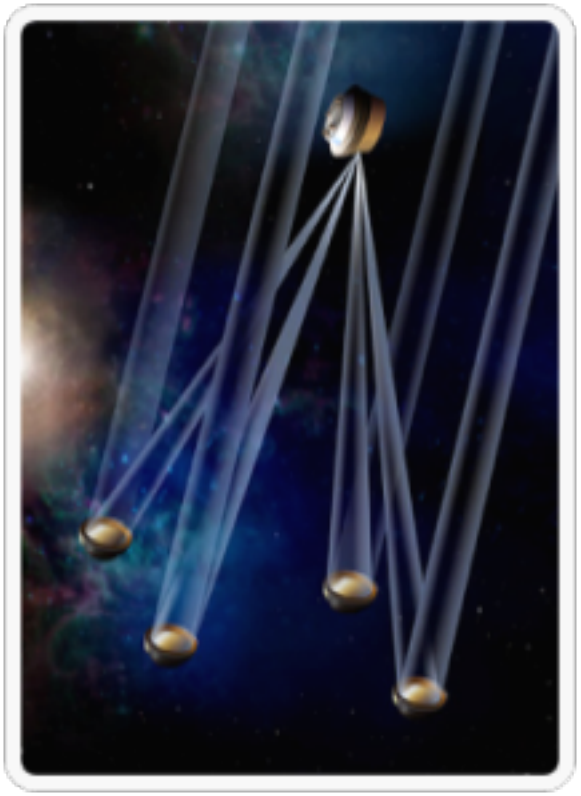
- Contrast favorable in the mid-infrared (only ~10^{-5})
- Reflection and emission spectra for the synchronous case with an Earth-like planet atmosphere (from Turbet et al. 2016):

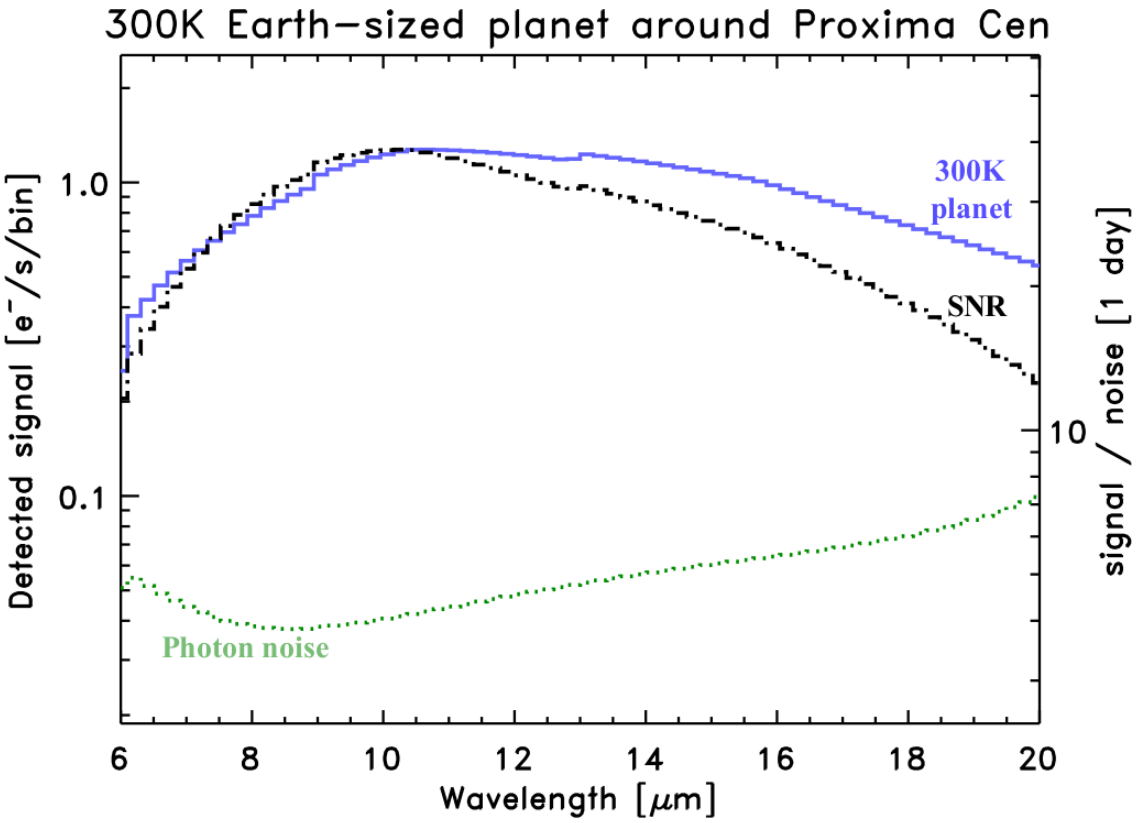




Direct detection: infrared interferometer

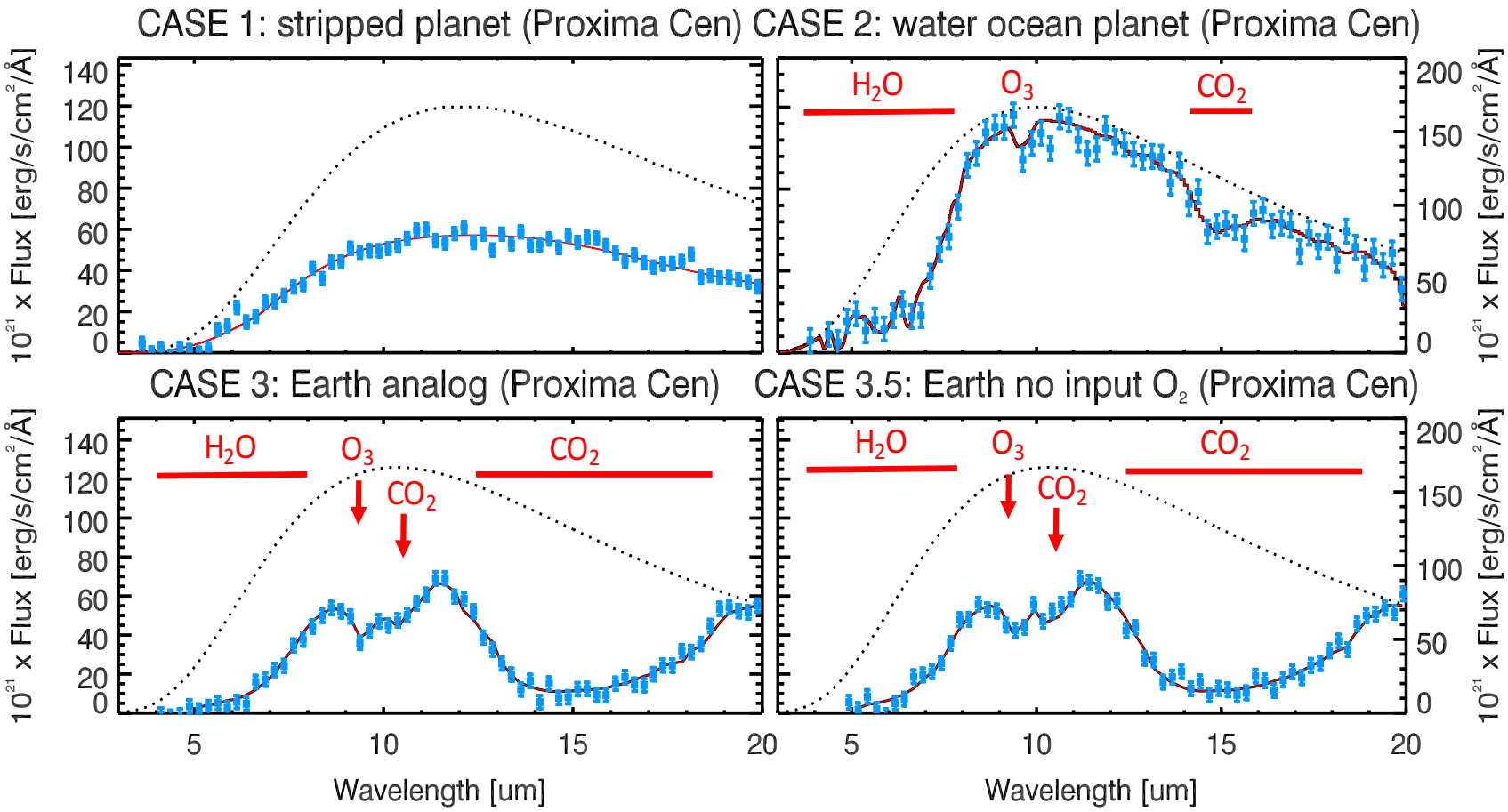
- Ideal target for mid-infrared interferometer.
- SNR in 1 day of integration with four 75-cm aperture and R = 40





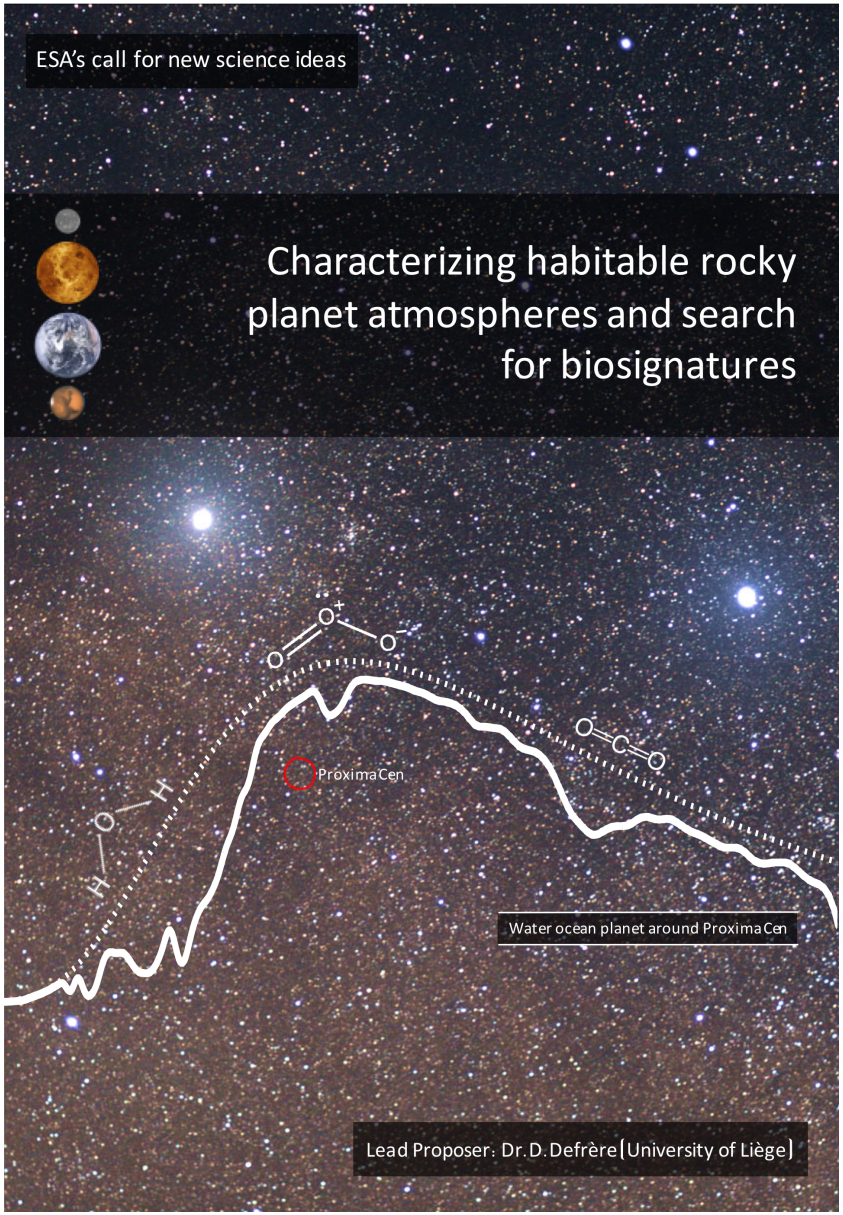
Direct detection: infrared interferometer

- Simulated observations (R=40, blue points) imposing a S/N of 20 on continuum detection at 10 μm).
- All spectral features detected in a single visit (besides O_3):



Direct detection: infrared interferometer

- Technology developments are required.
- Proposed to ESA in September in the context of the call for new science ideas .



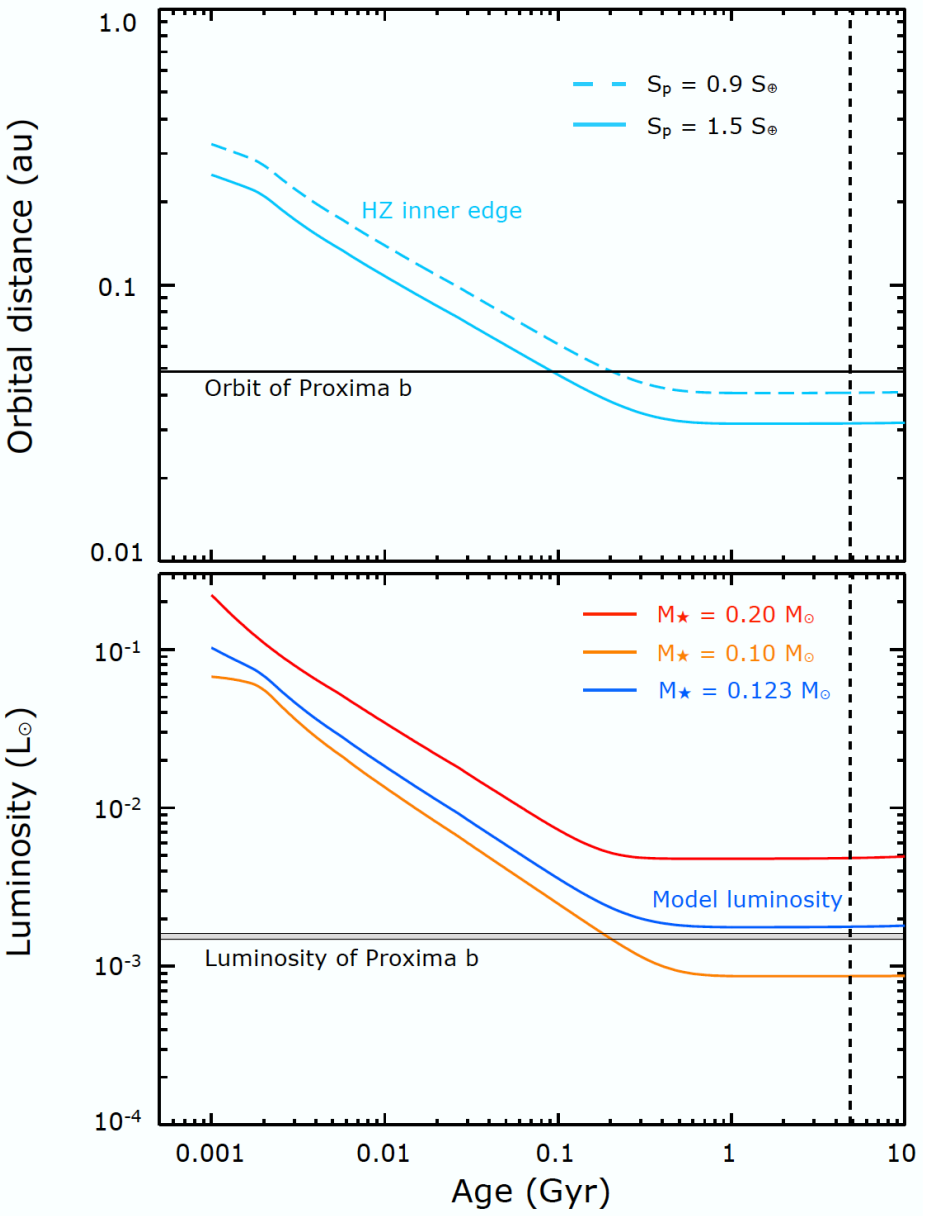
Summary

- Models show that Proxima Cen b can be habitable
- Atmospheric composition of Proxima Cen b can be probed remotely
- Small-scale infrared interferometers (4x0.75cm) could take a spectrum (R~40, S/N=20) in one day of integration.

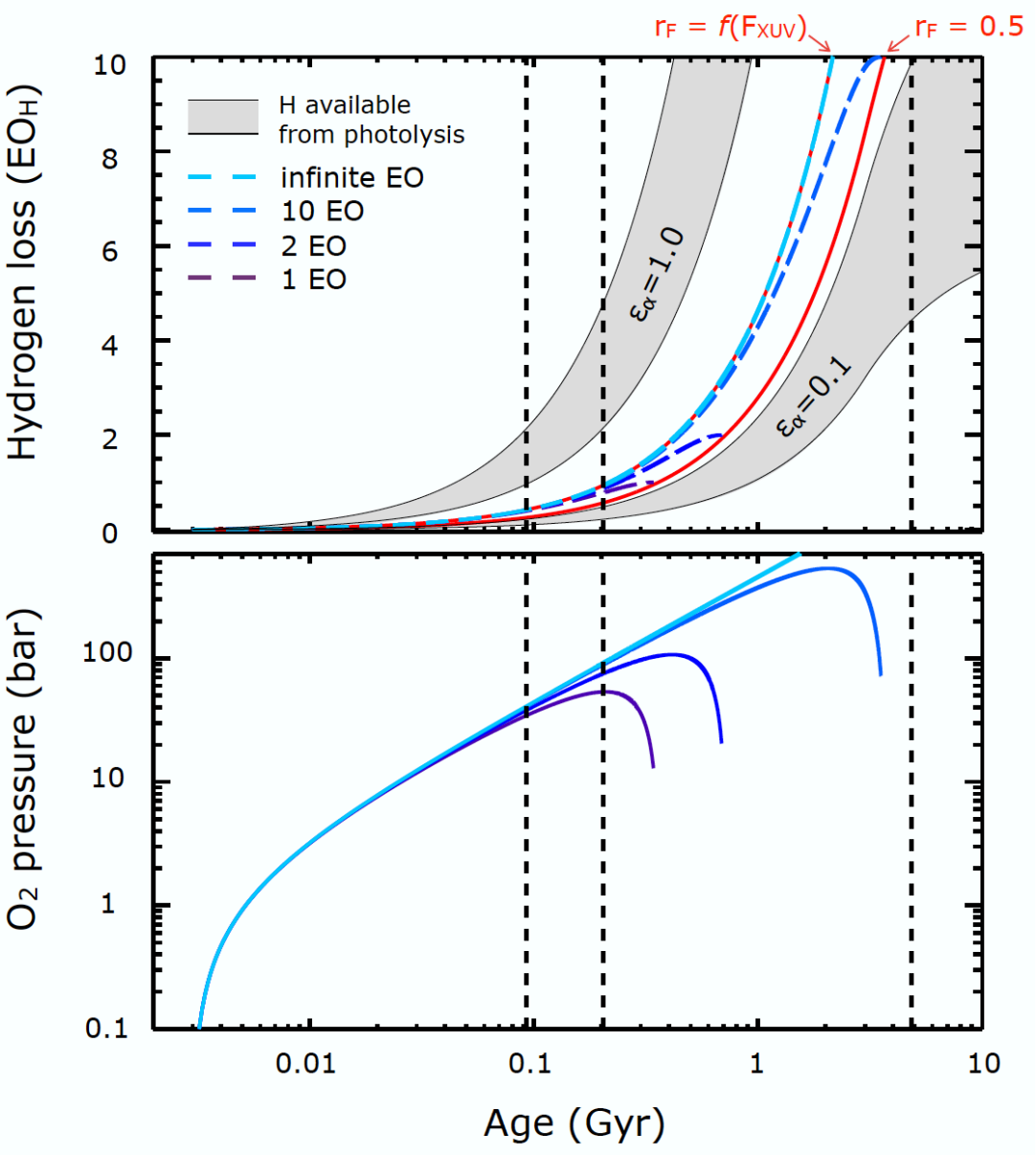
Backups: HZ with time

During the first few million years after the protoplanetary disk dispersion the planet is too hot for surface liquid water to exist; and (2) After the first few million years the planet enters the HZ. During these two phases Proxima b experiences atmospheric loss.

During the runaway phase the erosion of the water reservoir must have left large amounts of residual oxygen, possibly in the form of atmospheric O2 , of up to 100 bar.



Backups: hydrogen loss



Backups: hydrogen loss