Habitability in the Trappist-1 and other exoplanetary systems around red dwarfs

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1. Introduction

The very recent discovery of planets orbiting very low mass stars such as Proxima-b [1] and the TRAPPIST-1 system [9, 10] sheds light on these exotic objects. Planetary systems around low-mass stars and brown dwarfs (or ultra-cool dwarfs) are very different from our solar system: the planets are expected to be much closer than Mercury, in a layout that could resemble the system of Jupiter and its moons. The recent discoveries point in that direction with, for example, the system of Kepler-42 [13] and especially the system of TRAPPIST-1 [10] which hosts planets in a mean motion resonance configuration comparable to the one of the moons of Jupiter.

Ultra-cool dwarfs are thought 1) to be very common in our neighborhood and 2) to host many planetary systems [6]. As is the case for TRAPPIST-1, we expect that ultra-cool dwarfs can host a suite of small rocky planets. The planets orbiting in the habitable zone of these objects thus represent one of the next challenges of the following decades. Understanding the dynamical evolution of such systems and investigating their possible climates is now necessary. Indeed, planets in the habitable zone of ultra-cool dwarfs are the only planets of the habitable zone whose atmosphere we will be able to probe (e.g., using transit spectroscopy with the JWST, e.g [3], [4]).

2. Importance of stellar history on the potential habitability of planets

One major difference between ultra-cool dwarfs (UCD; T_{eff} <~ 3000 K) and Sun-like stars is that they cool down to settle on the main sequence after about 1 Gyr (see Figure 1 for TRAPPIST-1). Their habitable zones (HZ) thus sweeps inward at least during the first Gyr of their lives. Assuming they possess water, planets found in the HZ of UCDs have experienced a runaway greenhouse phase too hot for liquid water prior to enter the HZ. It has been proposed that such planets are desiccated by this hot early phase and enter the HZ as dry worlds [2,11].

Here, we present results of the modeling of the water loss during this pre-HZ hot phase taking into account recent upper limits on the XUV emission of UCDs and using 1D radiation-hydrodynamic simulations. We applied this model to Proxima-b in [14] and to the planets of TRAPPIST-1 in [5, 7, 8]. We find that there is a possibility that Proxima-b and the outer planets of TRAPPIST-1 to have retained a part of their potential initial water reservoir. However, our model shows that TRAPPIST1-b and c are likely dry.

3. Potential climates of planets around UCDs

Assuming a synchronized rotation, an important water content for the planets, a N_2, CO_2 atmosphere and using a global climate model (LMDz, e.g. [17]), we simulated the potential climate of Proxima-b [15] and the outer TRAPPIST-1 planets [16].

We find that there are configurations for which Proxima-b, TRAPPIST-1 e, f and g can harbour surface liquid water. While TRAPPIST-1 h is too cold to sustain liquid water.

We also investigated the impact of tidal heating on the climate of the TRAPPIST-1 planets. Just as in the Jovian system, the planet-planet interactions excite the eccentricities of the orbits [12]. The resulting eccentricities lead to an important tidal heat flux which can impact broad characteristics of the climates like the condensation of particular species on the night side.

We also looked at the feasibility of potential observations for Proxima-b with the E-ELT.

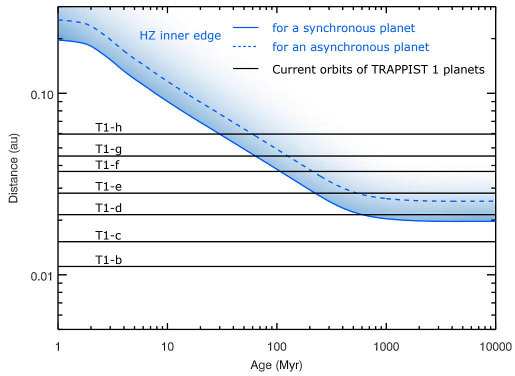

Figure 1: Architecture of the TRAPPIST-1 system and evolution of the inner edge of the habitable zone for two different hypotheses for the rotation rate of the planet: synchronized and asynchronized.

4. References

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Short Summary

The recent discoveries of planets around red dwarfs rise several questions regarding the habitability of these extreme worlds. How different is their history is compared to Earth? Could they host surface liquid water? What are the observational prospects?

I will talk about the efforts made to answer these questions.