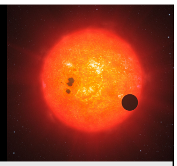
SPECULOOS

Search for habitable Planets EClipsing ULtra-cOOl Stars



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Transiting planets: treasures in the sky

Among the hundreds of planets detected outside our solar system, the ones that transit their parent star are genuine *Rosetta Stones* for the study of exoplanets, because they can be studied in greatest detail. Indeed, their orbital parameters, mass and radius can be precisely measured, and *their atmosphere can be probed* during and outside eclipses, bringing strong constraints on their actual nature (Winn 2010). Within the last two decades, more than three hundred transiting exoplanets have been detected. This large harvest includes many gas giants, but also a steeply growing fraction of *terrestrial planets.* In parallel to this galore of detections, many projects aiming to characterize giant exoplanets have been successful, bringing notably a first glimpse at their atmospheric properties (Seager & Deming 2010).

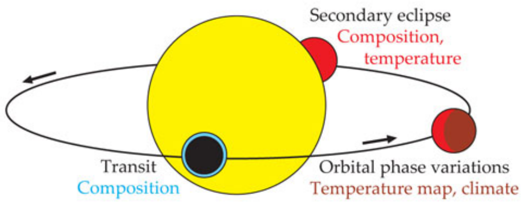


Fig. 1. Illustration of the techniques for studying the atmosphere of transiting exoplanets. During the transit, the wavelength dependence of the fraction of starlight absorbed gives information about atmospheric composition. When the planet passes behind the star (occultation), its emission is hidden, giving information about composition and temperature. Variations in the brightness of the planet as it revolves around the star constrains its atmospheric circulation. From Knutson (2013).

To export the techniques developed in these pioneering studies of giant planets to terrestrial worlds is the next step to put our Earth in a galactic perspective and to *search for life around other stars.*

The nearby ultra-cool stars opportunity

So far, only gas planets much larger than Earth could be characterized in detail. The smallest of them is GJ1214b, a 2.7 Earth radii planet transiting a nearby M4 red dwarf (Charbonneau et al. 2009). The most powerful future telescopes like the James Webb Space Telescope (JWST) or the European Extremely Large Telescope (E-ELT) should be able to study the atmosphere of Earth-size exoplanets, but only if they transit one of the nearest *ultra-cool stars* (Kaltenegger & Traub 2009; Snellen et al. 2013).

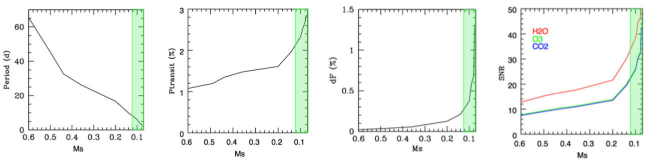
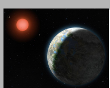
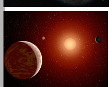
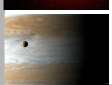


Fig. 2. From left to right, dependance to the stellar mass of the orbital period, geometric transit probability, transit depth, and signal-to-noise ratio for three spectroscopic biosignatures, assuming an Earth-twin planet transiting a M-dwarf at 10pc observed during 200h with a 6.5m space-telescope similar to JWST. For each panel, the stellar mass range of **ultra-cool stars** is outlined in pale green. Derived from Kaltenegger & Traub (2009).

These stars at the extreme bottom of the main-sequence are at least two times cooler than the Sun, and have sizes similar to Jupiter's. They are very frequent in the Galaxy. Their small mass, size, and temperature, make transits of habitable planets much more frequent and probable, and maximize the amplitude of the atmospheric signatures detectable with the transit techniques.





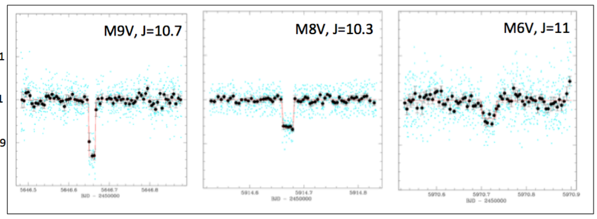


Ultra-cool stars and planets

No transiting planet has yet been detected around ultra-cool stars. Still, theory predicts for them a large population of close-in terrestrial planets (Raymond et al. 2007, Montgomery & Laughlin 2009), forming packed planetary systems very reminiscent of the Jovian moons system. If this prediction is correct, then *a few dozens terrestrial planets should transit ultra-cool stars nearby enough to make possible a thorough characterization with future giant telescopes.* Each of these stars is thus an opportunity to make exoplanetology enter the realm of terrestrial planets.

TRAPPIST/UCDTS : the prototype

No existing transit survey is optimized for detecting Earth-size planets transiting the nearest ultra-cool stars. Extensive simulations show us that robotic 1m-class telescopes equipped with modern CCD cameras highly sensitive in near-IR, operating from an exquisite astronomical site, and monitoring individually nearby ultra-cool stars, should be able to probe efficiently their habitable zone for terrestrial planets.



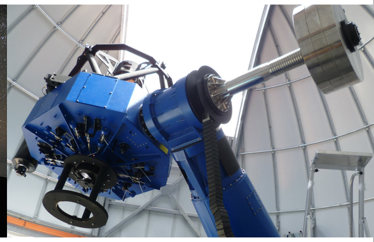
Detection limits from 0.6 to 1.1 R_{earth}

Fig. 3. Actual TRAPPIST/UCDTS light curves for three ultra-cool stars, after injection of a fake transit of an habitable Earth-size planet. The best-fit transit models are overimposed in red.

Validating this concept was mandatory, notably because the latest M-dwarfs often show some variability (e.g. Reid & Hawley 2005) that could preclude the detection of low-amplitude transits. We have thus initiated in 2011 a mini-survey called UCDTS (Ultra-Cool Dwarfs Transit Survey), using the TRAPPIST telescope (Jehin et al. 2011) at ESO La Silla Observatory to monitor the 50 brightest Southern ultra-cool stars. The partial results acquired so far for ~30 stars validate unambiguously the survey concept (Fig. 3), and demonstrate that the variability of ultra-cool stars does not preclude the detection of planets of Earth-size and below (Gillon et al. 2013).

SPECULOOS: phase I

The European Research Council has just funded through an ERC Starting Grant (2M€) the initiation of our project named **SPECULOOS** (**S**earch for habitable **P**lanets **EC**lipsing **UL**tra-c**OO**l **S**tars). This grant will make possible the installation of the first two telescopes and their operation until end-2018. Each telescope will have an aperture size of 80cm to 1m (still to be decided), and will be equipped with a 2k×2k deep-depletion CCD camera. The foreseen site of installation is ESO Paranal in the Chilean Atacama Desert, this site presenting all the qualities required by the project: excellent weather conditions, low sky brightness, and low humidity. The installation at Paranal would strongly strengthen the synergy between SPECULOOS and ESO follow-up programs.



The first light of SPECULOOS telescopes is planned for 2015. By end 2018, the survey will have monitored a significant fraction of the nearby Southern ultra-cool stars. Our plan is to make our survey data rapidly available to the community.

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