Searching for red worlds

The SPECULOOS project aims to detect terrestrial exoplanets well suited for detailed atmospheric characterization, explains Principal Investigator Michaël Gillon.

Studying alien worlds circling stars other than the Sun is no longer science fiction. Within the last 15 years, the first observational constraints have been gathered on the atmospheric properties of some giant exoplanets in orbit around bright nearby stars[1]. Extending these pioneering studies to smaller and more temperate exoplanets holds the promise of revolutionizing our understanding of rocky planets by enabling us to assess their diversity at the Galactic scale, not only in terms of orbits, but also in terms of atmospheric compositions, surface conditions, and, eventually, habitability. A promising shortcut to this revolution consists of the detection of temperate rocky planets transiting host stars that are small, cool, and nearby enough to make their detailed atmospheric characterization — including the detection of potential biosignatures — possible by eclipse spectroscopy with the James Webb Space Telescope (JWST) and other upcoming facilities[2].

The SPECULOOS (Search for habitable Planets EClipsing ULtra-cOOl Stars) project aims to seize this opportunity by exploring the nearest 'ultracool dwarf'[3] stars for transits. With masses ranging from 7–10% of the Sun, these Jupiter-sized stars are located at the extreme bottom of the main sequence. Their luminosities are less than 0.1% of the Sun, which makes their habitable zones correspond to orbits of only a few days, maximizing the transit probability and frequency of a putative temperate planet. Their Jupiter-like sizes translate into transit depths of ~1% for an Earth-sized planet — within reach of ground-based telescopes.

The basic concept of SPECULOOS is to search for transits in the ~1,000 ultracool dwarf stars that are bright enough in the near-infrared to make the atmospheric characterization of an Earth-sized planet with the JWST possible. For this purpose it uses ground-based 1-m-class optical telescopes, equipped with robotic equatorial mounts and deeply-depleted 2k × 2k CCD cameras that individually monitor each of the project's 1,000 targets. The telescopes have a Ritchey–Chrétien optical design with a focal length of 8 m that translates into a field of view of

Fig. 1 | The SPECULOOS Southern Observatory at Paranal. Credit: M. Gillon.

12 × 12 arcmin and a pixel scale of 0.35 arcsec on the CCD. The observations are carried out using a single 'I + z' filter that has a transmittance of more than 90% from 750 nm to beyond 1 μm, with the red end of the effective bandpass being defined by the spectral responses of the CCD. The typical exposure times are between 30 and 60 s. The mean monitoring duration per target is ~19 nights, and is fine-tuned as a function of each target's spectral type so as to reach a 70% probability of observing the transit of a planet that receives the same irradiation from its host star as the Earth does from the Sun. For a given night, each SPECULOOS telescope observes the same target continuously, so as to maximize its capacity to detect a low-amplitude transit.

SPECULOOS will eventually be based on two nodes, one in each hemisphere. The southern one, the SPECULOOS Southern Observatory (SSO), is currently being commissioned at the ESO Paranal Observatory in the Chilean Atacama Desert (Fig. 1). It consists of four 1-m telescopes that will explore ~500 southern ultracool dwarf stars for transits. This exploration should take ~7 years. The northern node of SPECULOOS, the SPECULOOS Northern Observatory (SNO), is also planned to consist of four 1-m telescopes, and it will be located at Teide Observatory in Tenerife (Canary Islands). Its first telescope will be installed at the end of 2018, and the full observatory is planned to be operational for early 2020. SAINT-EX, a new robotic 1-m telescope being installed at San Pedro Mártir Observatory (Mexico) will also partially contribute to SPECULOOS. Finally, two 60-cm robotic telescopes, TRAPPIST-South (La Silla Observatory, Chile) and TRAPPIST-North (Oukaïmeden Observatory, Morocco), also participate in SPECULOOS, focusing on its ~100 brightest targets. In fact, SPECULOOS started back in 2011 as a prototype mini-survey on TRAPPIST-South with a target list composed of the 50 brightest southern ultracool dwarf stars. The goal of this prototype was to assess the feasibility of SPECULOOS, but it did much better than expected. Indeed, it detected around one of its targets, TRAPPIST-1, an amazing planetary system composed of seven Earth-sized planets in temperate orbits of 1.5 to 19 days[4,5], at least three of which orbit within the habitable zone of the star.

The detection of TRAPPIST-1 out of a target list of only 50 objects, and the apparent low densities of most of its planets, suggest that compact systems of water-rich rocky planets could be very common around ultracool dwarf stars, in agreement with recent theoretical predictions[6]. If this is the case, then SPECULOOS should find many other TRAPPIST-1-like systems, to eventually produce a catalogue of several dozen temperate rocky planets well suited for detailed atmospheric characterization.

SPECULOOS is a project led by the University of Liège (Belgium) and carried out in collaboration with MIT, the Universities of Cambridge, Jeddah, Bern, Birmingham, California (San Diego), Cadi Ayyad and the Astrophysics Institute of the Canaries. It is primarily funded by the European Research Council and several private sponsors and the Simons and the Heising-Simons foundations. ❐

Michaël Gillon
FNRS Research Associate at the University of Liège, Liège, Belgium.
e-mail: michael.gillon@uliege.be

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