Exploring the Nearest Ultracool Dwarfs for Potentially Habitable Exoplanets Well-Suited for Detailed Atmospheric Characterization

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About Exoplanetology

Our view of our solar system has widened greatly within the last two decades, thanks to the thousands of exoplanet detections achieved since the seminal discovery of 51 Pegasi b in 1995. Most stars in our galaxy harbour their own cortege of planets, and most of these exoplanetary systems have an architecture very different from ours. Their global study has drastically improved our understanding of planetary formation and evolution mechanisms, while revealing their intrinsic stochastic natures. Furthermore, for a fraction of the exoplanets known to transit nearby stars, a detailed characterization is now within reach of our instruments: orbital parameters, precise measurement of the mass and size (the resulting density constraining the bulk composition), and study of the properties of the atmosphere, including its chemical composition.

Within the last decade, several molecules and atoms have already been detected in the atmosphere of highly irradiated giant planets. These pioneering results have inaugurated a new field of astronomy: comparative exoplanetology, the detailed study of planets orbiting stars other than the Sun. The best is yet to come for this nascent

field, as upcoming astronomical facilities like the James Webb Space Telescope should enable similar results to be obtained for smaller and more temperate planets, including potentially habitable rocky planets. The search for chemical traces of life beyond our solar system is thus within reach, but it requires the detection of suitable targets, i.e., temperate rocky planets transiting stars small and nearby enough to make possible their detailed atmospheric characterization with current technology.

The project SPECULOOS (Search for habitable Planets EClipsing ULtracOOl Stars) has grown out of these developments. This new exoplanet transit search targets the nearest ultracool dwarf stars, i.e., stars of very low-mass (<10% the mass of the Sun) and size (about the size of Jupiter), lying at the bottom of the main sequence. These tiny stars have been mostly overlooked by exoplanet searches so far, and their planetary population is poorly explored. Gillon's recent detection of the amazing TRAPPIST-1 planetary system with the prototype of SPECULOOS suggests that compact systems of temperate Earth-sized planets are frequent around ultracool dwarf stars, and that SPECULOOS should find many of them, which will become – like TRAPPIST-1 planets – exquisite targets for detailed characterization with James Webb and other upcoming facilities.

The Balzan Project

In this context, the goal of this Balzan project is to maximize the potential of SPECULOOS to explore the nearest ultracool dwarf stars. At the start of the project, SPECULOOS was based on only one facility, the SPECULOOS Southern Observatory (SSO), which is composed of four 1m robotic telescopes installed at Paranal Observatory in Chile between 2016 and 2018, and in operation since January 2019. The idea was to extend the project to the Northern sky, to perform a complete exploration of all nearby ultracool dwarf stars. In collaboration with MIT, Gillon and his team at the University of Liège initiated this extension by installing in 2019 a first 1m Northern SPECULOOS telescope at Teide Observatory in the Canary Island of Tenerife. This project funded a part of the installation cost of this new telescope (ground work plus cabling). It has also funded – or will fund – the salaries of several young scientists who are working hard to make SPECULOOS a success:

- A postdoctoral fellow, Dr. Daniel Sebastian, was hired in September 2018 for a three-year contract to take charge in the critical role of managing the technical and operational aspects of SSO and to work on the scientific exploitation of SSO data the other half of his time.

- The first six months of Lionel Garcia's PhD thesis (April to September 2019), which is devoted to the development of innovative methods to analyze SPECULOOS data and of a pipeline to analyze the data that the upcoming James Webb Space Telescope, will gather to probe the atmospheric composition of TRAPPIST-1 and SPECULOOS planets.
- The last part of Elsa Ducrot's PhD thesis (July 2020 to September 2021). Initiated in October 2017, Ducrot's thesis focuses on managing and optimizing (target selection, automation, strategy, etc.) the observations of the SSO and SNO telescopes, in contributing to the scientific exploitation of their gathered data (e.g., transit search, transit analysis), and to the detailed characterization of the planets (radius, mass, orbit, atmosphere, etc.) to be found by the project.

This Balzan project has also funded – and will go on funding – equipment and operating credit (PC/laptops, replacement hardware pieces, travel cost to Chile or Tenerife or to conferences, team meetings). Furthermore, it funded the TRAPPIST-1 Conference that took place at the University of Liege in June 2019 (https://events.uliege.be/trappist-1/). This multidisciplinary conference was named after the extrasolar system of Gillon's studies, and had the aim of bringing together scientists of various disciplines to share the latest observational and theoretical results on the system, discuss its astrobiological importance and its future characterization from a scientific and technological point of view. It also included a special session called "TRAPPIST-1: between science and fiction", during which some artists, writers, game developers, etc., presented their works related to TRAPPIST-1 to the participating scientists, enabling the two communities to discuss their visions of a fascinating planetary system.

This Balzan project represents a significant contribution to the development of the SPECULOOS initiative and to the search for life elsewhere in the Universe, by optimizing SPECULOOS potential for detecting potentially habitable rocky planets well-suited for detailed atmospheric characterization.

Publications

Peer-Reviewed Papers

Triaud A. et al. 2020. An eclipsing substellar binary in a young triple system discovered by SPECULOOS, Nature Astronomy, Advanced Online Publication, DOI: 10.1038/s41550-020-1018-2

Ducrot E. et al. 2019. The 0.8-4.5 μm Broadband Transmission Spectra of TRAPPIST-1 Planets, The Astronomical Journal, Volume 156, Issue 5, article id. 218, 16 pp., 2018AJ....156..218D

Grimm S. et al. 2018. The nature of the TRAPPIST-1 exoplanets, Astronomy & Astrophysics, Volume 613, id.A68, DOI: 10.1051/0004-6361/201732233

De Wit J. et al. 2018. Atmospheric reconnaissance of the habitable-zone Earth-sized planets orbiting TRAPPIST-1, Nature Astronomy, Volume 2, p. 214-219, DOI: 10.1038/s41550-017-0374-z

Van Grootel V., et al. 2018. Stellar Parameters for Trappist-1, The Astrophysical Journal, Volume 853, Issue 1, article id. 30, 10.3847/1538-4357/aaa023

Papers (Unreviewed)

Gillon M., et al. 2019. The TRAPPIST-1 JWST Community Initiative.

Gillon M., 2019. Searching for red worlds, Nature Astronomy, Volume 2, p. 344-344, DOI: 10.1038/s41550-018-0443-y

Jehin E. & Gillon M., 2019. L'observatoire SPECULOOS-Sud, Le Ciel, Vol. 81, p. 76-90, https://ui.adsabs.harvard.edu/abs/2019Ciel...81...76J/abstract

Jehin E. et al., 2018. The SPECULOOS Southern Observatory Begins its Hunt for Rocky Planets, The Messenger, vol. 174, p. 2-7, DOI: 10.18727/0722-6691/5105

Book Chapters

Burdanov A., et al. 2018. SPECULOOS Exoplanet Search and Its Prototype on TRAPPIST, Handbook of Exoplanets, ISBN 978-3-319-55332-0. Springer International Publishing AG, part of Springer Nature, 2018, id.130, DOI: 10.1007/978-3-319-55333-7_130

Conference Proceedings

Ducrot E. & Gillon M. 2019. Latest news of SPECULOOS and TRAPPIST-1, EPSC-DPS Joint Meeting 2019. held 15-20 September 2019 in Geneva, Switzerland, id. EPSC-DPS2019-1974, https://ui.adsabs.harvard.edu/abs/2019EPSC...13.1974D/abstract

Queloz D. & Gillon M. 2019. On the hunt for TRAPPIST-1 siblings, American

Astronomical Society, Extreme Solar Systems 4, id. 401.03. Bulletin of the American Astronomical Society, Vol. 51, No. 6, https://113qx216in8z1kdeyi404hgf-wpengine.netdna-ssl.com/wp-content/uploads/2019/09/exss4_abstracts.pdf#abs401.03

Delrez L. et al. 2018. SPECULOOS: A network of robotic telescopes to hunt for terrestrial planets around the nearest ultracool dwarfs, Proceedings of the SPIE, Volume 10700, id. 107001I 21 pp., DOI: 10.1117/12.2312475