Looking for New Worlds

An interview with KHALID BARKAOUI, postdoctoral researcher at the Astrobiology Research Unit at the University of Liège, by SENNE STARCKX, freelance science journalist and writer

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Time is money, even in the search for planets outside our solar system. While the list of potential exoplanets grows by a few every day, it usually takes several days before a candidate exoplanet can also be confirmed. In the beginning of June, when we visited astrophysicist and exoplanet hunter Khalid Barkaoui at his workplace at the science campus of the University of Liège, he was analyzing observations of a star located some hundreds of light years from Earth. The observations were made with the robotic telescopes of the SPECULOOS project (Search for habitable Planets Eclipsing ULtracOOl Stars) located in Chile, Tenerife, and Mexico. The project aims to find Earth-like planets that lie in the habitable zone of red dwarfs – relatively cold and small stars. The search is performed with the so-called transit method: as a planet slides in front of its star, it blocks some starlight, resulting in a dip in the star's brightness. This not only betrays the planet's existence, it also makes it possible to measure its size and – using a complementary method – sometimes its mass. Size and mass combined gives the planet's density, which can give planet researchers an idea of its composition. SPECULOOS is led by Michaël Gillon, astrophysicist at the University of Liège and laureate of the Balzan Prize in 2017 for his (exo)planet research. In addition, five other universities are involved in the project. Gillon spent half of the monetary amount of his Balzan Prize on SPECULOOS.

Khalid Barkaoui hopes to discover exoplanets around the stars that he is studying with the SPECULOOS telescopes based in Tenerife and Chile. Usually, every star is observed for two hundred hours. At the time of our visit, Barkaoui hadn't found pronounced brightness dips in the light of the star he was studying, which would indicate planet

transits. But he is far from giving up. "We select the stars we point our telescopes to on data from the space telescope TESS (Transiting Exoplanet Survey Satellite), which scours the nearby part of the Milky Way for stars that potentially have planets." TESS also searches for exoplanets using the transit method, but because its field of view is very wide, observing thousands of stars at once, its resolution is very low. "If TESS sees a brightness dip somewhere, it doesn't mean necessarily that this was caused by a transient planet. For example, it could come from a binary system of two orbiting stars." So data from TESS are just the beginning of the exoplanet search. The big work is done on the ground, with telescopes like SPECULOOS. "To give you an idea: of the many thousands of candidate exoplanets TESS has spotted, less than five hundred are currently confirmed."

Senne Starckx: **SPECULOOS stands for Search for habitable Planets EClipsing ULtra-cOOl Stars. Why do you focus your exoplanet search on these stars?**

Khalid Barkaoui: "We are looking for Earth-sized, rocky planets that are in the so-called habitable zone of their parent star – where conditions allow water to exist in liquid form. We focus on red dwarfs that are ten times brighter and seven times smaller than the Sun. As a result, they are a lot cooler and so their habitable zone is much closer to the stars. Moreover, they also shine much less brightly than the Sun, making it much easier for us to detect a planet transit. In addition, the orbital time of a planet in the habitable zone around a red dwarf is much shorter than, for example, in our solar system. This gives us a much better chance of being able to see several transits in a relatively short period of time. Because indeed, time is money."

S.S.: **You recently made headlines with two discoveries, albeit of very different exoplanets: SPECULOOS-3b and WASP-193b. How do these discoveries illustrate exactly what you do?**

K.B.: "SPECULOOS-3b, which is 55 light years away, is rocky and about the size of Earth. But the comparison ends here. The planet orbits its star, a red dwarf, in barely 17 hours, so a year on this planet is shorter than a day on Earth. But it is because it is so close to its star that we have been able to find it. By comparison, that would not be possible with our own planet if we had to look at it from light years away with

our telescopes. For that, Earth is too far from the Sun, and for that the Sun also shines hard – its blinding light would make it impossible to discern a brightness dip.

We don't think, by the way, that SPECULOOS-3b is livable. Because the planets we find are so close to their parent star, they are often tidally locked (so it's always day on one side and always night on the other) and they receive a lot of high-energy radiation. This also makes it unlikely that they possess an atmosphere, let alone that biological life can thrive there. Finally, for now, we don't know if the star SPECULOOS-3 possesses any other planets. We observed it for three hundred hours, but that didn't lead to the discovery of additional planets in the system.

The discovery of WASP-193b was an entirely different case. I worked on it myself for four years, much of it during my PhD research here (Barkaoui started in Liège in 2020, SST). That there's a planet orbiting WASP-193, a star some 1,200 light years from here, was suspected already years ago. But observations with our SPECULOOS and TRAPPIST (TRAnsiting Planets and Planetesimals Small Telescope) telescopes, among others, have allowed us to confirm this discovery. What's special is that this is a sun-like star. But we can still see and study the planet because it's so large: it's half bigger than Jupiter (approximately 1.46 times its radius, ndr) – and thus it's totally not Earth-like, which puts it somewhat out of our scope. But the planet orbits its star in barely six days, yielding relatively quickly successive transits. From the star's 'wobble' – a result of the planet's gravitational influence – we were able to derive its mass. Although the planet is much larger than Jupiter, it turned out to be seven times less dense. It is super fluffy, as if made of cotton candy. Of all the exoplanets discovered, it's the second least dense: only one other exoplanet has a lower density."

S.S.: **That you are looking for habitable planets is logical: the search for extraterrestrial life fascinates us all. But you will not discover life itself. In that respect, SPECULOOS, like TESS, is also more of an explorer, making preparations for further research.**

K.B.: "We primarily confirm candidate exoplanets and determine their orbit, size and mass. In addition, we can sometimes gather hints about

a possible atmosphere. After all, when a planet slides past behind its parent star, we can catch light coming directly from it.

But for a thorough investigation, you need a space telescope like James Webb, or a ground-based telescope like the Extremely Large Telescope (currently under construction in Chile, SST). However, there's no time to use these telescopes to study every exoplanet in detail. This will only happen for very interesting candidate planets. Besides that, Webb has already taken a brief look at the innermost planet of the famous TRAPPIST system – TRAPPIST-1b. The planet seems too hot for an atmosphere to persist.

Incidentally, today we call the star TRAPPIST-1, SPECULOOS-1. TRAPPIST was the precursor, the prototype actually of the SPECULOOS project. Our current project, SPECULOOS, runs until 2030."

S.S.: **In two years, a new planet hunter will be already launched: the European PLATO telescope (PLAnetary Transits and Oscillations of stars). What will it be able to contribute to the search for exoplanets?**

K.B.: "PLATO is special because the telescope will also search for Earth-like planets around sun-like stars. So that already comes close to planet systems like ours. The research with PLATO will also be done with the transit method, and we count on the fact that we should be able to observe a transit for Earth-like planets every year anyway – just as we would for Earth. Moreover, PLATO will also make it easier and more accurate to determine the mass of exoplanets."

S.S.: **You yourself are moving to Tenerife at the end of this year. What exactly will you be doing there?**

K.B.: "I'll be engaged in another search, and with telescopes other than those of SPECULOOS. Using data from the space telescope Euclid, among others, I will be looking for brown dwarfs, 'failed' stars that are larger than the biggest planets but smaller than the smallest stars. These celestial bodies can also orbit around stars… that's what we think, because this hasn't been observed yet. If I were to discover a brown dwarf near a star, of course this would be fantastic."