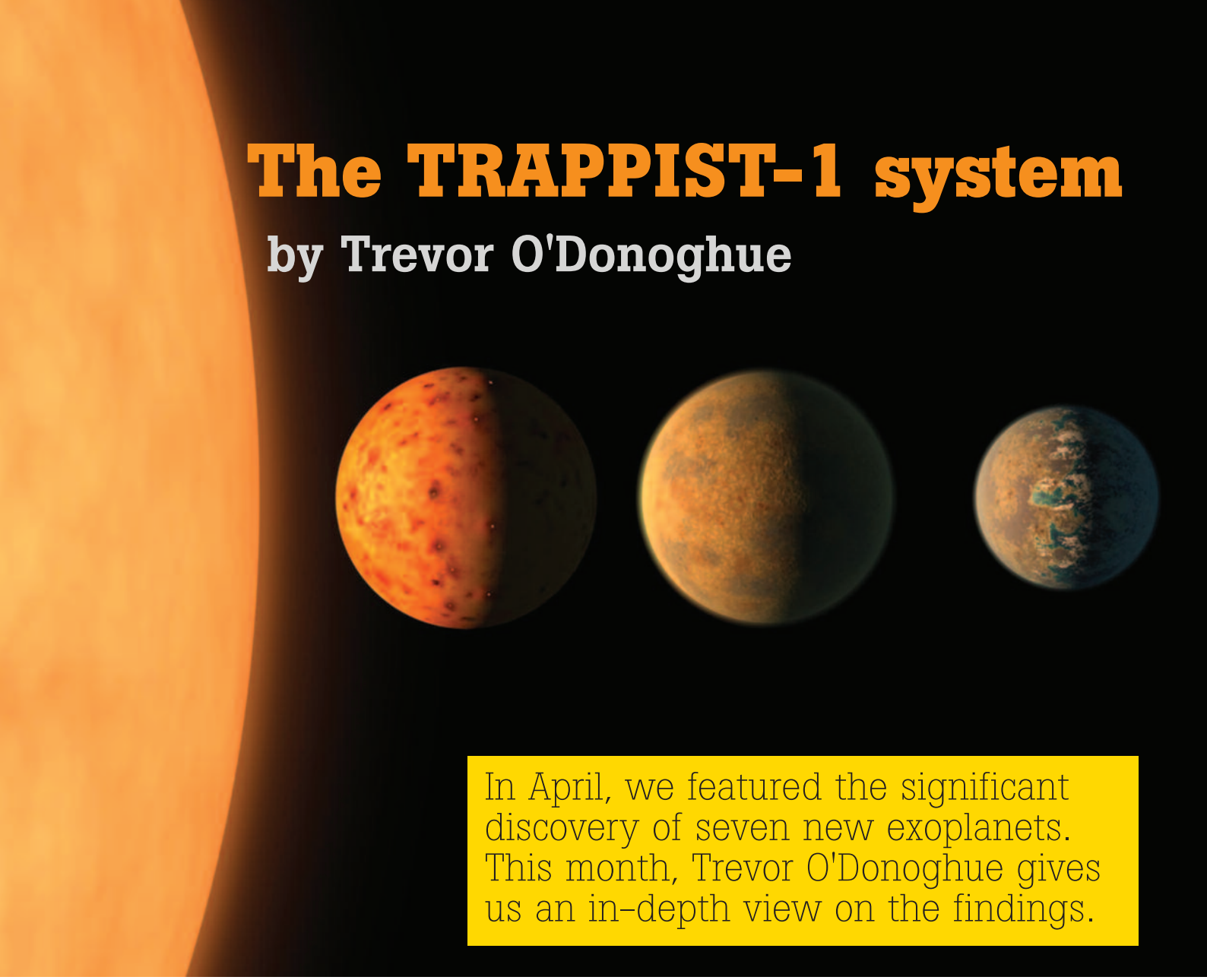
The TRAPPIST-1 system

by Trevor O'Donoghue



In April, we featured the significant discovery of seven new exoplanets. This month, Trevor O'Donoghue gives us an in-depth view on the findings.

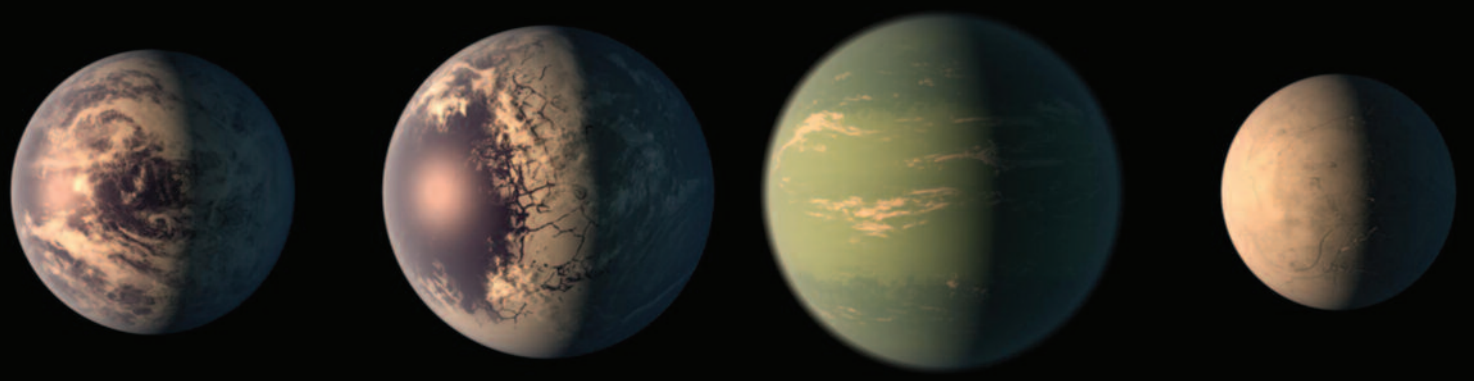
On February 22 at an eagerly anticipated press conference NASA announced that they had discovered a new exoplanet system. This one was different, the new system wasn't typical of exoplanet systems that we know about with large Jupiter-like planets whipping around their host star. This system had rocky planets. Not just that, it had seven planets, all of them rocky or Earth-like, three of which are found in the habitable zone where conditions are just right for liquid water to exist.

The TRAPPIST-1 system was originally discovered by the Transiting Planets and Planetesimals Small Telescope. A pair of small 60 cm telescopes operated by the University of Liege in Belgium and Geneva Observatory. The telescopes are located in Chile and Morocco respectively. In May 2016, the University of Liege announced that they had found three exoplanets in orbit around an ultra cool dwarf star located 40 light years away. The discovery was made using the telescope at La Salle observatory in Chile. At the time the scientists confirmed that the three planets were rocky or Earth-like. Follow up observations were carried out by the Hubble and Spitzer space telescopes and other ground based observatories. The key to unlocking the system came from over 500 hours of continuous observations by the Spitzer infrared telescope. The star shines relatively bright in the infrared and so Spitzer was ideally suited to the observation.

What they discovered was a complex star system home to seven rocky or Earth-like planets, three of which were clearly in the habitable zone. This was the first time that such a complex system consisting of Earth-like planets was found in another star system. The host star is an ultra cool dwarf star not much bigger than Jupiter. The TRAPPIST telescopes have been designed to look at systems like this. Where the parent star is relatively dim, it is easier to pick up the fluctuations in light that occur as a planet passes in front of the star as seen from Earth.

The host star is found in Aquarius and previously went by the catchy moniker 2MASS J23062928-0502285. It shines at a relatively dull 18.8 magnitude so is not suitable for visual observations.

Recording it photographically should be within the range of amateur observers with advanced set ups. It is relatively young, somewhere between



This artist's concept shows what the TRAPPIST-1 planetary system may look like. Credit: NASA/JPL-Caltech

500 million and 1 billion years old. It is slightly larger than the planet Jupiter and has a mass of 0.08 that of the Sun. It has a temperature of 2550 K where our Sun is double at almost 5800 K. It gives off 5% of the light of the Sun and consequently it's habitable zone is located much closer to the star. All seven planets orbit the star at a distance closer to the star than Mercury is from the Sun. The planets themselves have been imaginatively called TRAPPIST-1b through to TRAPPIST-1h. Because the planets orbit so close to their parent star, they are probably tidally locked, with the same side always facing the sun, consequently one side is always in perpetual daylight with the other experiencing perpetual night. This situation would up mean that one side of the planet is much hotter than the other and if an atmosphere is present, then it is likely that the planet would experience winds which would help to equalise the temperature planet wide.

The planets have short orbital periods ranging from 1.5 days for the closest planet to the star to 19 days for the planet furthest from the star. At the time of writing, the orbit of the furthest planet was still being refined. The planets display orbital resonances similar to the moons of Jupiter. According to the scientists responsible for the discovery, this could imply that the planets were formed further away from the star and migrated into their current position. This would be good news in terms of water content, as the further out they formed, the higher chance they were initially ice rich and so stand a good chance of having held onto the water when they migrated inwards.

If one happened to live on one of the planets, then the night sky would be a spectacular sight. The planets are all Earth-like in size and are close to each other in real terms so that they would appear large in the night sky, some larger than our moon. Features on the surface and in the atmosphere of neighbouring planets would be clearly visible.

The Spitzer space telescope precisely measured the sizes of the planets and for six of them their mass was also preliminary measured. The measurements were quite precise and the measurement of mass of one of them was so precisely measured that it suggests a water rich composition. The good news is that this planet lies in the habitable zone.

In terms of the individual planets, here's what we know.

TRAPPIST-1b is the closest planet to the host star and whips around it in 1.5 Earth days. It is a rocky world with a radius 1.09 times the size of Earth and a mass of 0.85 that of Earth's. Hubble has already had a look at this planet and has managed to rule out any gaseous hydrogen in an atmosphere. It's extremely close to it's parent star, which means any water it did have is likely to have boiled away. It is a mere 0.011 astronomical units away from the star. An astronomical unit is the distance from the earth to the sun, approximately 150 million kilometres.

TRAPPIST-1c is another hot, rocky world, orbiting at a distance of 0.015 AU from the star and completes an orbit every 2.42 days. It is slightly larger than the Earth with a radius 1.06 that of Earth and a mass of 1.38 of the Earth's.

TRAPPIST-1d is the smallest and lightest planet of the system. Its radius is 0.77 times that of Earth's and it's mass is just 0.41 that of Earth's. It orbits in 4.05 days and does so at a distance of 0.021 AU. Outside the habitable zone, any surface water is likely to have boiled away.

TRAPPIST-1e is the innermost planet within the habitable zone. It has a radius of 0.92 that of Earth's and a mass of 0.62 that of our planet. It orbits at a distance of 0.028 AU and does so every 6.10 days. If the planet is tidally locked, as it is assumed the rest of the planets are, and it has an atmosphere, then it is theorised that a breeze may equalise the temperature on the planet. This planet receives the same amount of light as Earth.

TRAPPIST-1f is the planet that holds the most hope for any possibility of life. Smack bang in the middle of the habitable zone, this planet has a radius only 4% larger than that of Earth, but has a mass 0.62 times that of Earth, which leads scientists to think it is potentially water rich. It gets about the same amount of light as Mars, even though it is located at a distance of 0.037 AU from the star. It's takes 9.21 days for it to complete an orbit.

This illustration shows the seven planets orbiting TRAPPIST-1, an ultra-cool dwarf star, as they might look as viewed from Earth using a fictional, incredibly powerful telescope.
Credits: NASA-JPL/Caltech

TRAPPIST-1g is the largest of the planets in the system with a radius 1.13 times larger than Earth's and a mass 1.34 times larger. In terms of the light hitting it, it receives the same amount of light as if it were located somewhere between Mars and the asteroid belt. It is right on the outer edge of the habitable zone, but could still host liquid water on its surface. A year is 12.35 Earth days and it orbits at a distance of 0.045 AU. Mercury by contrast is almost ten times further away from our Sun at 0.39 AU.

TRAPPIST-1h is the furthest out of the planets and the planet that scientists are least certain about. At the time of writing, they haven't managed to observe two full orbits yet and so mass and orbit are a little uncertain. Their best guess is that the planet is three quarters the size of Earth and takes 19 days to complete an orbit. It's mass still hasn't been established, but it is liable to be a rocky, icy world.

Up until now, we knew of a few dozen exoplanets in the habitable zone of stars and a handful of those may be rocky Earth-like worlds. Here in one fell swoop we have a whole host of rocky worlds in orbit around a nearby star, three of which are in the habitable zone and should be able to support liquid water on their surface. Under the right conditions, these could be right for supporting life.

We will have to wait until the James Webb telescope launches in 2018 and turns towards the system to ascertain if any of the planets have an atmosphere, and if indeed these atmospheres contain gases such as methane and oxygen, which will give us a hint that life may exist on these worlds. However, a certain amount of caution should be advised with the planets being so close to the star. Shortly after forming, the planets may have been exposed to high amounts of ionising radiation which would be harmful to life as we know it. Secondly, the planets are relatively young, at between 500 million to one billion years old and so, might not be old enough to allow life to have started. On Earth, our best guess is that life took over 500 million years to get going. Even then, life on Earth could be a one off. We simply don't know if life will arise when conditions are right, or if we are truly alone in the universe. Probing of our solar system and systems like the TRAPPIST-1 system will hopefully help us to get closer to understanding life as we know it.