ESO/M. Kornmesser

Mike Follows

Proxima b

Have we discovered our next homeworld?

Extrasolar planets reside in solar systems beyond our own. Almost 3500 have been discovered since the first one in 1992. But on 24 August 2016 scientists excitedly announced the discovery of Proxima b. Because it resides in our nearest neighbouring solar system it is our closest **exoplanet**. Furthermore, it could support life and might even provide a future home for us.

Proxima b orbits a red dwarf star called Proxima Centauri, which is part of the triple star system Alpha Centauri, only 4.2 light years away – that's 40 trillion km, or more than 250 thousand times further away than the Sun. The star, too faint to be seen with the naked eye, is located in the constellation Centaurus, visible from the southern hemisphere.

A sun that never moves

Proxima b is twenty times closer to its star than we are to the Sun, which is part of the reason it only takes 11.2 days to make one orbit of Proxima Centauri. This also explains why the planet is 'tidally locked', always showing the same face to its star, in the same way we always see the same face of the Moon. This would make visiting the planet a strange experience. If you landed on the sunny side of the planet, the red dwarf star would hang motionless in the sky; it would never rise or set.

Most of the radiation from the star is in the infra-red region of the electromagnetic spectrum and, because Proxima b receives only 2% of the visible light that Earth intercepts from the Sun, it would be like experiencing permanent twilight. It has a mass 1.3 times that of Earth so we might feel a little heavier until we developed slightly bigger leg muscles.

How was it found?

A star like the Sun is about a billion times brighter than the light reflected by its orbiting planets. This means that it is virtually impossible to see a planet directly and astronomers resort to using indirect methods. Almost 70% of extrasolar planets have been detected by the transit method. Each time an exoplanet orbits between us and its host star some of the starlight is blocked so that there is a periodic dip in the amount of light reaching us – see ***Figure 1***.

An artist's impression of the surface of Proxima b, and the red dwarf Proxima Centauri on the horizon with stars Alpha Centauri A and stars Alpha Centauri A in the far distance.

Key words
exoplanet
transit
red shift
space travel

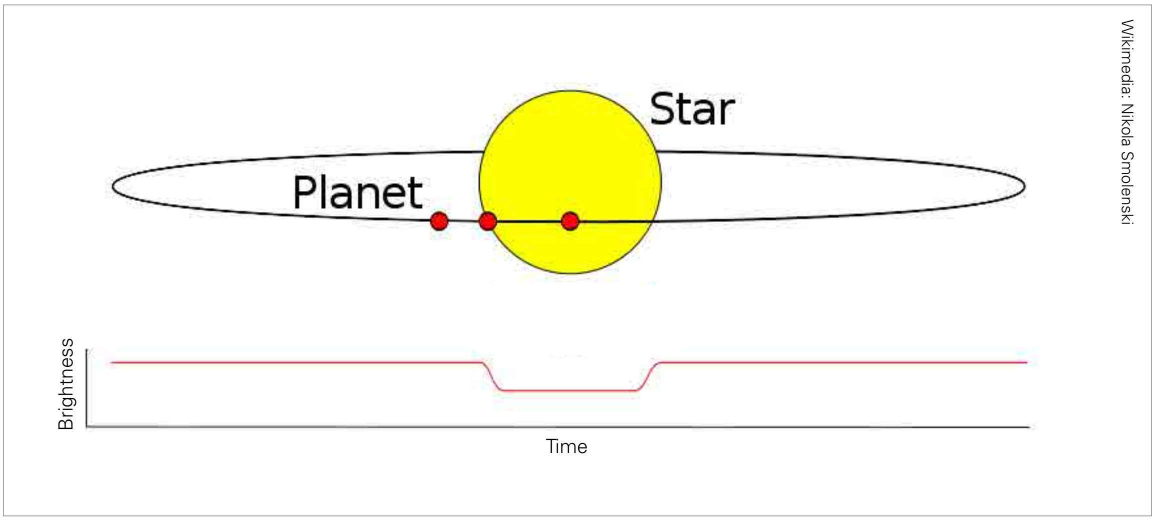


Figure 1 *A planet passing in front of a star blocks some of its light so that there is a brief dip in the star's brightness.*

Proxima b was detected by the radial velocity or 'Doppler wobble' method. Any star exerts a gravitational pull on an orbiting planet and, according to Newton's Third Law of Motion, the planet exerts an equal and opposite force on the star. So, as the planet orbits its star, the star also moves in a circle although, because the star is much more massive than the planet, its orbit is much smaller than the planet's.

Light waves from a star moving towards us are compressed. This means that their wavelength decreases and shifts towards the blue end of the visible spectrum. When a star is moving away from us, light waves are stretched – the light is red-shifted. This is the Doppler effect – see ***Figure 2***. Astronomers can use the shift in the wavelength of starlight to work out the speed of the star as it moves towards or away from us – see the box below.

Amazingly this can be used to work out the mass of the planet and its distance from the star.

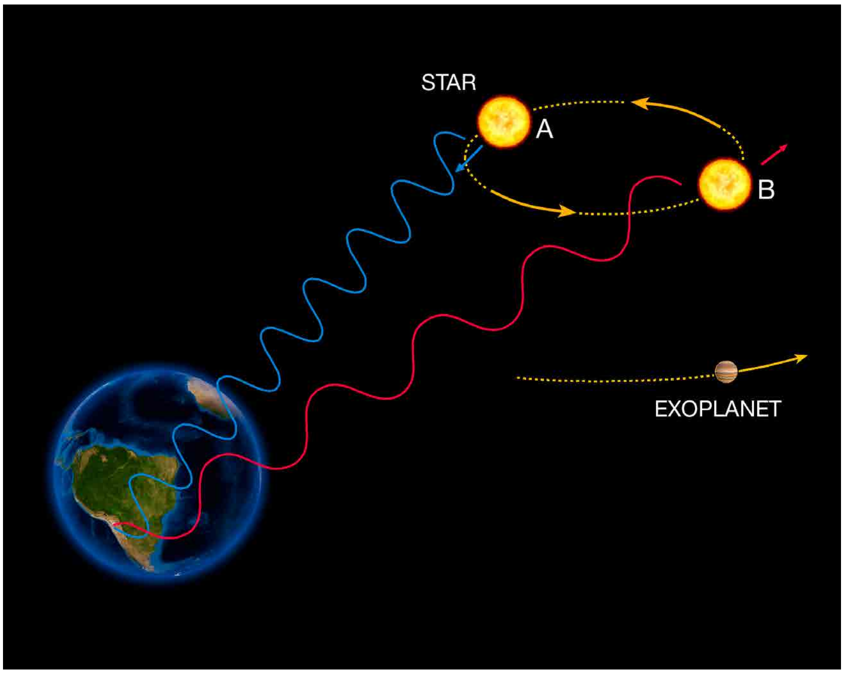


Figure 2 *At A, the star is moving towards the Earth and its light is blue-shifted. At B, it is moving away and its light is red-shifted.*

Temperature, brightness and mass

It is easy to work out the surface temperature of a star using its black body spectrum (see *Thermometry … a hot topic* in CATALYST volume 23, issue 3, February 2013). Knowing a star's apparent brightness and how far away it is we can work out its luminosity (or power output).

So many stars have been catalogued and they are so well understood that astronomers can use the Hertzsprung-Russell diagram to find the mass of a star (see ***Figure 3***). On this diagram, temperature is plotted along the horizontal axis while luminosity (or the power output of the star) is plotted along the vertical axis. Knowing the temperature and luminosity of a star, an astronomer can plot its position on the Hertzsprung-Russell diagram and infer its mass.

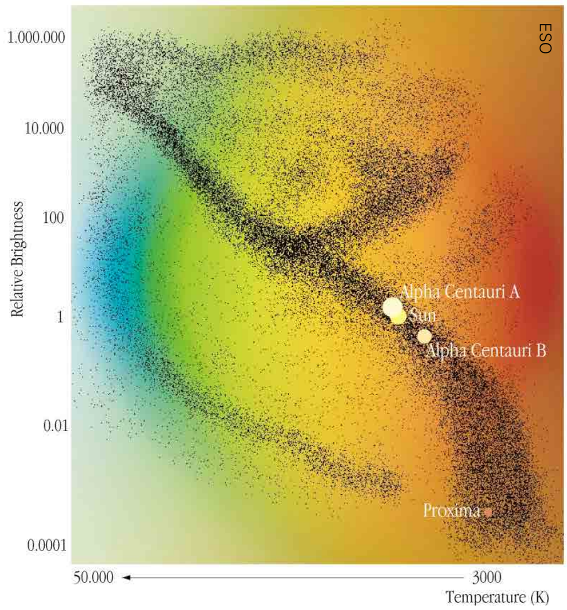
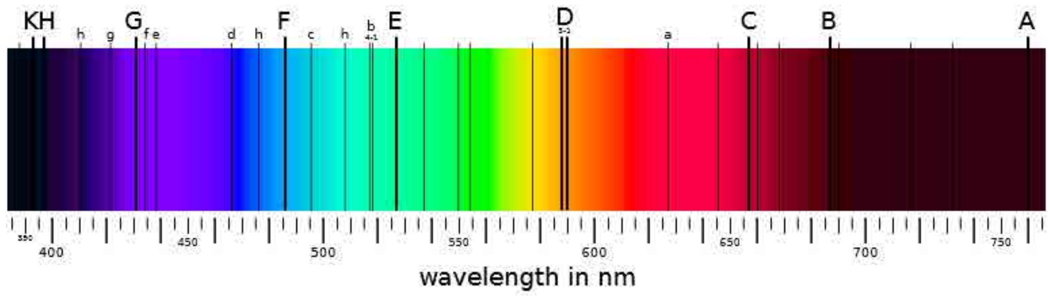
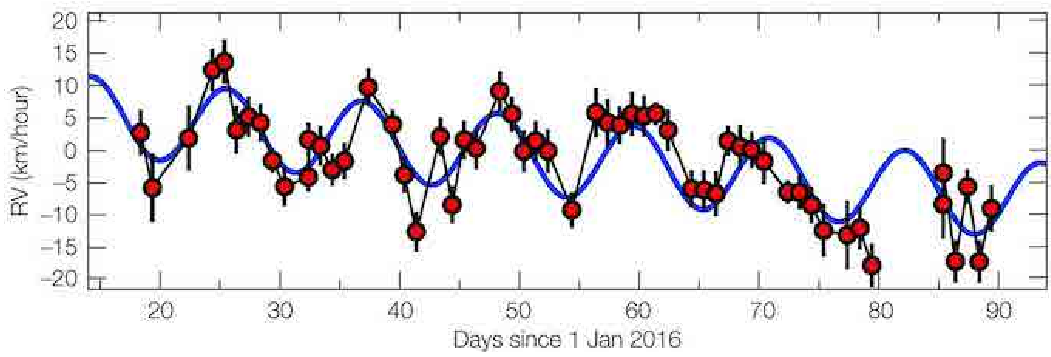


Figure 3 *Alpha Centauri is a triple star system. Each star is plotted on the Hertzsprung-Russell diagram according to its surface temperature and luminosity – notice Proxima Centauri at the bottom right among the coolest, dimmest stars.*

The radial velocity method



The spectrum of light from a star – this is an absorption spectrum because some wavelengths are missing and appear as black lines. These wavelengths have been absorbed by atoms of different elements in the star's atmosphere. If the star is moving towards or away from the Earth, the wavelengths of these lines are shifted towards the blue or red ends of the spectrum. The faster the movement, the greater the shift, and so astronomers can deduce the star's speed.



Velocity data published for Proxima Centauri. It shows how the star moves towards us (positive speed) and away from us (negative speed) as it is tugged by Proxima b in orbit around it. The pattern repeats itself every 11.186 days and this is the orbital period – the time it takes Proxima b to make a complete circuit of its star.

Living on Proxima b

Could we make Proxima b our next homeworld? Obviously it would need water and a source of energy. Astronomers already knew the luminosity of Proxima Centauri and now the distance to the planet so can work out the temperature on its surface. Assuming that Proxima b reflects as much starlight as Earth does, it would have a global mean surface temperature (GMST) of 233 K. That's minus 40 °C, too cold for liquid water and possibly for life. But without the natural greenhouse effect provided by our atmosphere, Earth would have a GMST of minus 18 °C. Thankfully our atmosphere warms Earth by 33 °C to make life possible. So the presence of an atmosphere on Proxima b is key.

Like the planet Mercury, Proxima b is 'tidally locked' so there is a danger that the side permanently facing the Star will be unbearably hot while the 'dark' side could be freezing cold. But research suggests that, if Proxima b has an atmosphere with a pressure at least 30% of what it is here on Earth, winds could transfer sufficient thermal energy to the dark side of the planet, which would be sheltered from dangerous UV radiation emitted by the red dwarf. Any people who went to colonise Proxima b might have to live on the dark side and create day and night artificially.

In order to determine whether Proxima b is habitable (or even inhabited), scientists need to study its atmosphere to look for gases like methane, water vapour or oxygen. And the best hope of this is a **transit** – when the planet (and its atmosphere) passes directly in front of the star across our line of sight. The wavelengths of light absorbed by the atmosphere will betray its composition. But there is only a 0.02% chance of this happening. Astronomers might be able to observe the atmosphere directly using the James Webb Space Telescope or powerful ground-based telescopes currently under construction in Chile and Hawaii (with mirrors 20 to 40 meters in diameter) or perhaps we could send a spacecraft.

Mike Follows teaches Physics.

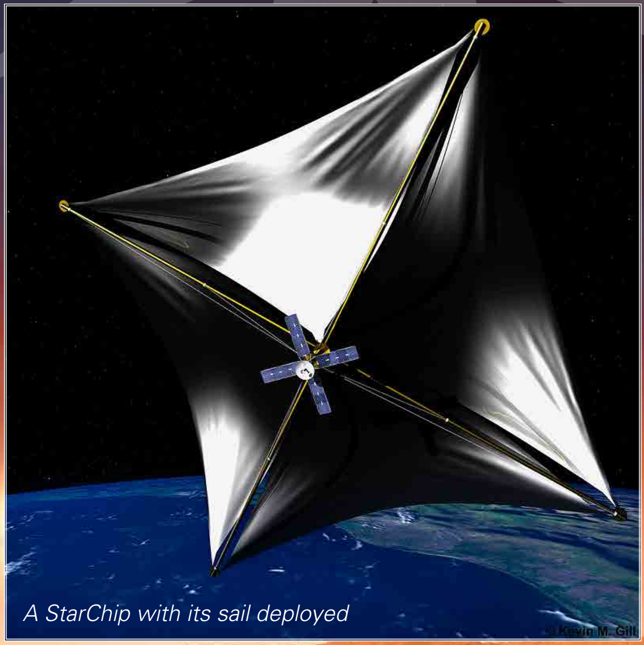
Turn to the back page where Mike describes a project to send miniature spacecraft to explore Proxima b.

Breakthrough Starshot

Physicist and venture capitalist Yuri Milner is planning to send a fleet of over 1000 nanobots to visit Proxima b, the nearest exoplanet to Earth.

What's a nanobot? Each StarChip is a tiny spacecraft about one cubic centimetre in size with a mass of a few grams. It will take pictures as it flies by the exoplanet and transmit them back.

Why send so many? Collisions with dust particles as well as other mishaps mean that a single one is unlikely to reach its target, but in 20 years they will be cheap to make in large quantities.

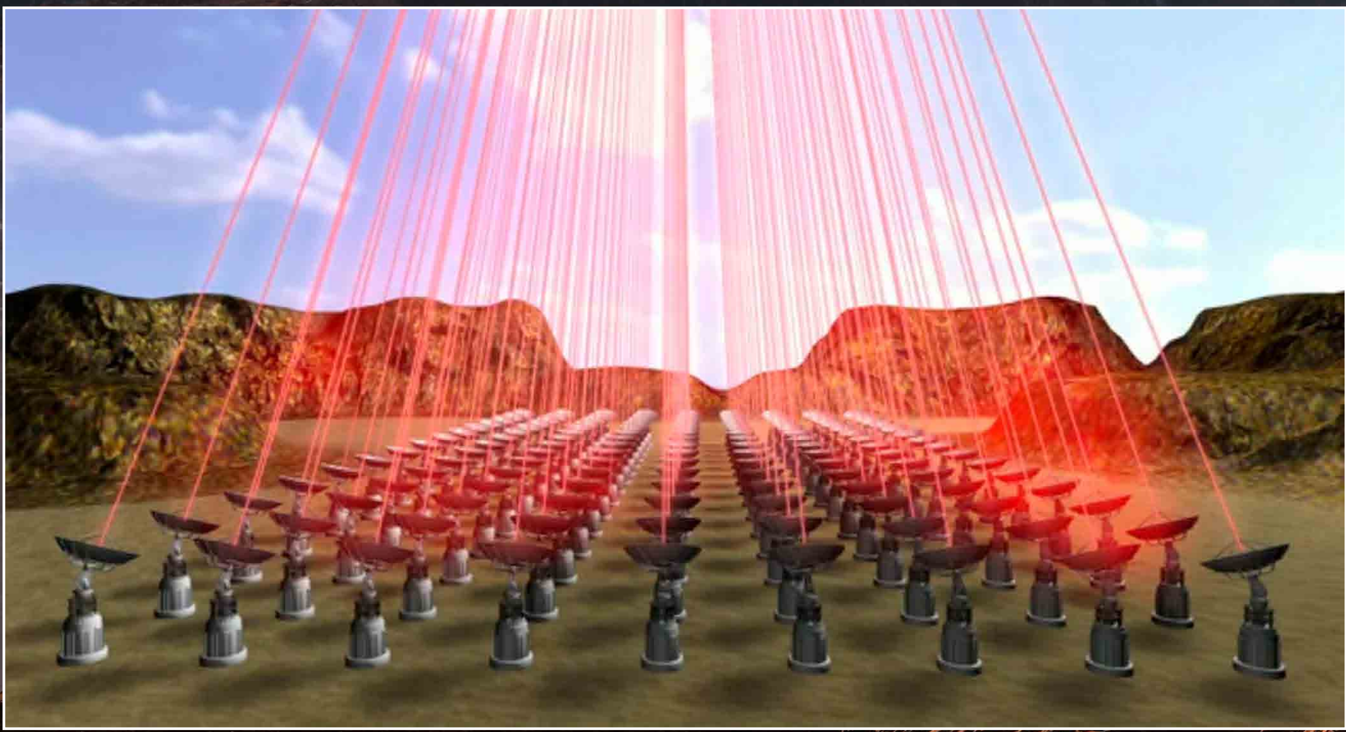


A StarChip with its sail deployed

Yuri Milner shows a mock-ip of a StarChip at the project launch.

How fast will they travel? At 20% of the speed of light; their journey will take about 20 years.

How will they be powered? Once released from their mothership, each StarChip will unfurl a 4 metre square solar sail. An array of ground-based lasers will focus their beams for 10 minutes on each sail in turn in order to transfer 1 TJ of energy and accelerate them at about 100 km/s^2 – 10 000 times the acceleration of free-fall.



Ground-based lasers will accelerate the StarChips.