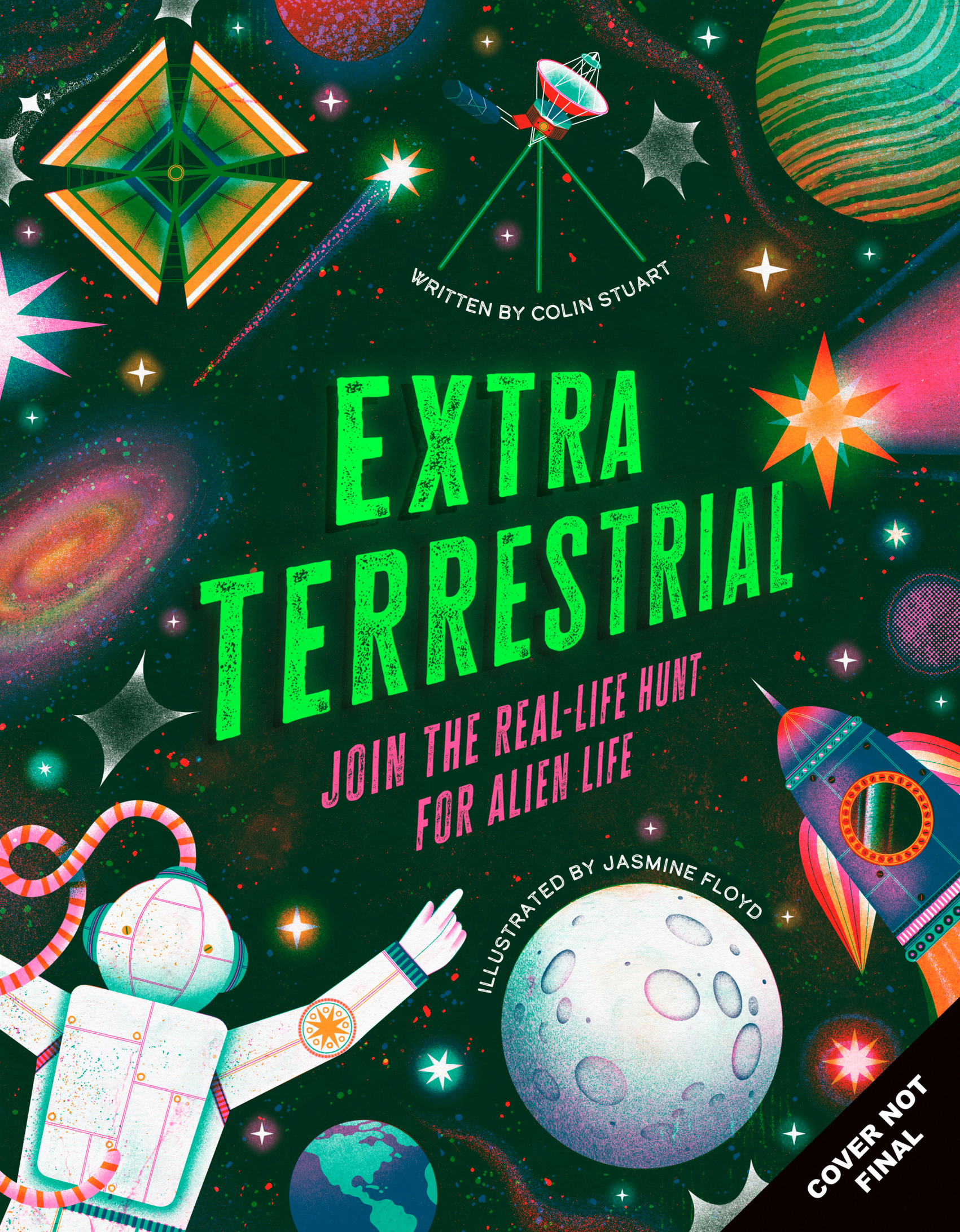

WRITTEN BY COLIN STUART
EXTRA TERRESTRIAL
JOIN THE REAL-LIFE HUNT FOR ALIEN LIFE
ILLUSTRATED BY JASMINE FLOYD
COVER NOT FINAL

ARE WE ALONE?

Our universe is a vast and wonderous place. There are more stars than you could count in thousands upon thousands of lifetimes. Each one a shining light calling out to us across the emptiness of space. But is there anyone looking back?

In this seemingly endless cosmic ocean, we know of just one tiny island with living things. A planet one of its lifeforms has come to call Earth. We humans have been staring up at the stars for generations, trying to work out how we fit. Asking whether there are others like us out there equally wondering if they too are alone.

You belong to the first generation of humans in the entire history of this planet with the chance to answer this ancient question.

In the last 30 years, astronomers have discovered thousands of planets beyond our solar system. Some familiar, some so utterly alien that they'll leave you astounded. We are starting to work out how like Earth they are and the chances of finding alien life there. If we are terrestrial, meaning of the Earth, that life would be **extra-terrestrial.**

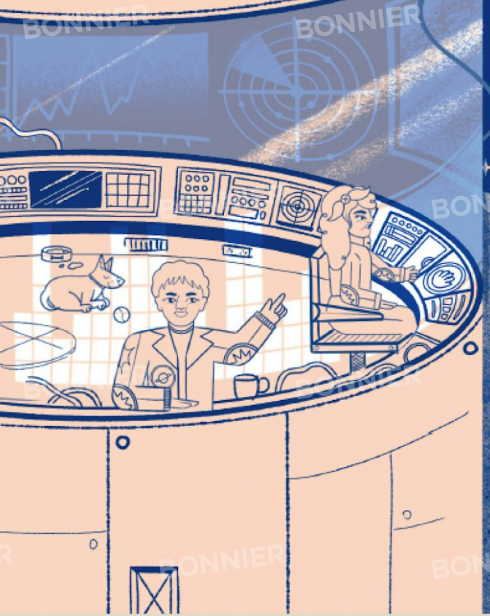
We need you to join this search. The book you're holding will get you up to speed, show you what we know already and set out the things we don't know but would love to. You'll discover cutting-edge ways to find alien planets and use your imagination to guess at what creatures living there might look like based on our best scientific ideas.

Perhaps you'll grow up to become an alien planet explorer. The first person to prove that we're not the only ones to call this mind-bendingly beautiful universe home. A place in the history books is yours for the taking. **Reach out and grab it.**

OUR BIGGEST CLUE: EARTH

The blue-green marble of Earth shines like a jewel against the blackest black. An oasis of life in the desert of the universe. As the only planet with life, it's all we have to go on. If we can work out what makes Earth special, it could help us search for similar places in our quest for extra-terrestrials.

So, what makes Earth unique?



A BIG MOON

For a smallish planet, we have a very big Moon. The pull of its gravity keeps us steady and stops the Earth wobbling around too much. This keeps the seasons steady and stops the planet getting too hold or too cold. Without the Moon, ice ages would be a lot more common. And if there's one thing life hates, it's change.

PUZZLE PIECES

The surface of the Earth is broken up into puzzle pieces called tectonic plates. They create mountains, volcanoes and earthquakes. Yet they also keep Earth's temperature steady by letting heat in and out of the planet. Earth is the only planet we know of with these plates.

A FORCE FIELD

Space is a pretty dangerous place, full of things that can kill you. Dying stars burp out particles called cosmic rays that can damage the cells inside your body and stop them working properly. Fortunately, the Earth has a force-field: our magnetic field. Formed deep inside the core of the planet, it bursts through the surface to create a protective cocoon around us. Along with our thick atmosphere, it stops cosmic rays from reaching Earth's surface and life can go about its business unharmed. But there is one thing above all others that life seems to need, and Earth has an awful lot of it: water.

THE GOLDILOCKS PLANET

Look at a map of the world and you might think that the Earth is mostly land. But that's because maps are drawn based on where people live. The Pacific Ocean is tucked away at the map's edges, but it covers a third of Earth's surface. It's bigger than all seven continents combined. Look at the Earth from space at just the right angle and you'll see no land at all.

HOW MUCH WATER?

There's so much water on Earth that if you collected it all into a ball, it would be bigger than the biggest asteroid in the Asteroid Belt. It would also weigh one hundred times more than Mars's two moons added together.

WHY IS IT LIQUID?

How hot a planet is largely depends on how close it is to the Sun. On Mercury and Venus – the planets closer to the Sun than us – the temperature soars above 400 degrees. That's about twice as a kitchen oven. By the time you get to Mars – the next planet out from us – the average temperature drops to minus sixty (about three times colder than the inside of a freezer).

EARTH

MERCURY

MARS

Every living thing on Earth, from the smallest bacterium to the biggest blue whale, needs liquid water to survive. Yet for water to be liquid you also need the right temperature. Lower than zero degrees Celsius and the water freezes into ice. Raise it beyond 100 degrees and it evaporates into water vapour.

Earth is in the perfect spot in between. Like the ideal porridge in the fairy tale Goldilocks and The Three Bears, our temperature is "just right".

That's why astronomers call Earth a "Goldilocks planet". There's only a narrow part of the solar system with temperatures right for a planet to have liquid water – the Goldilocks zone or habitable zone – and the Earth sits just inside the front edge of it.

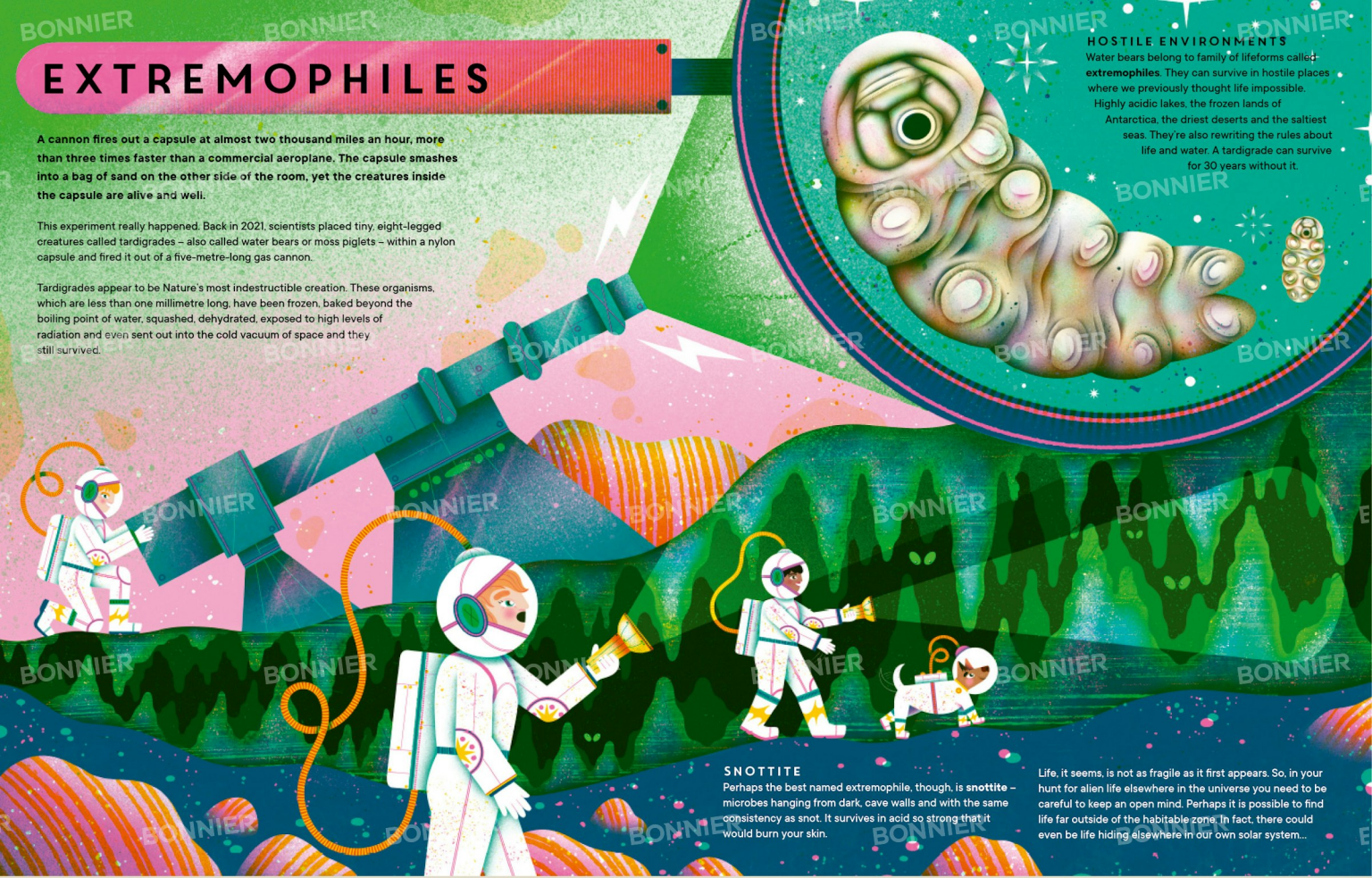
Although not all creatures that live here need the perfect conditions...

EXTREMOPHILES

A cannon fires out a capsule at almost two thousand miles an hour, more than three times faster than a commercial aeroplane. The capsule smashes into a bag of sand on the other side of the room, yet the creatures inside the capsule are alive and well.

This experiment really happened. Back in 2021, scientists placed tiny, eight-legged creatures called tardigrades – also called water bears or moss piglets – within a nylon capsule and fired it out of a five-metre-long gas cannon.

Tardigrades appear to be Nature's most indestructible creation. These organisms, which are less than one millimetre long, have been frozen, baked beyond the boiling point of water, squashed, dehydrated, exposed to high levels of radiation and even sent out into the cold vacuum of space and they still survived.



HOSTILE ENVIRONMENTS

Water bears belong to family of lifeforms called **extremophiles**. They can survive in hostile places where we previously thought life impossible. Highly acidic lakes, the frozen lands of Antarctica, the driest deserts and the saltiest seas. They're also rewriting the rules about life and water. A tardigrade can survive for 30 years without it.

SNOTTITE

Perhaps the best named extremophile, though, is **snottite** – microbes hanging from dark, cave walls and with the same consistency as snot. It survives in acid so strong that it would burn your skin.

Life, it seems, is not as fragile as it first appears. So, in your hunt for alien life elsewhere in the universe you need to be careful to keep an open mind. Perhaps it is possible to find life far outside of the habitable zone. In fact, there could even be life hiding elsewhere in our own solar system...

WATER, WATER, EVERYWHERE...

You're flying over a craggy ice sheet when suddenly you see it rising over the horizon. You're stunned into complete silence and can't look away. Saturn and its majestic rings appear almost 150 times wider than the Full Moon does in our night sky.

You are searching for life on Enceladus, one of Saturn's 117 known moons. Beneath its cracked, icy surface is an ocean of liquid water that's almost as big as the Arctic Ocean here on Earth.

OUTSIDE THE GOLDILOCKS ZONE

Enceladus is a long way from the Sun, more than five times farther than the outer edge of the solar system's habitable zone. And yet there's plenty of liquid water here despite Enceladus's surface temperature of minus 200 degrees Celsius.

How can this be? The secret is tidal heating. Enceladus orbits around Saturn in just 33 hours, meaning it's very close to the planet. During this orbit Enceladus gets severely stretched and squeezed by Saturn's strong gravity. This constant flexing warms up the inside of the moon, which is enough to keep the water liquid under its surface ice.

With its global ocean and internal heat, Enceladus could be a good contender for alien life.

A robotic spacecraft called Cassini discovered Saturn's ocean during a 13-year space mission.

Jets of icy particles and explosions of water and chemicals continuously spurt into space from its surface.

A TRIP TO JUPITER

The same thing is happening on Jupiter's moon Europa which NASA estimates has a sub-surface ocean containing twice the amount of water in Earth's oceans. Future missions such as NASA's Europa Clipper, scheduled for arrival in 2030, could help us work out if the conditions there are right for life.

Under its thick crust of ice, Europa's oceans or salty liquid reservoirs could be hatchable.

One rover discovered a type of silica which exists in hot springs on Earth. These sorts of springs might have been home to ancient microbes.

THE RED PLANET

Even our next-door neighbour, Mars, could be a living planet. Data from our Mars rovers tell us that the Red Planet, which today is cold and dry, used to be a lot more like Earth with oceans, lakes and rivers. If life got started when liquid water was everywhere on Mars, extremophiles could still be clinging on to this day in hard-to-reach places like underground caves. Imagine Martian snottite!

ANOTHER EARTH

Despite these possibilities, Earth remains the only place we've ever found life. There's only one planet like ours around the Sun, so to find another Earth we may have to widen the search. It's time we looked towards the other stars twinkling away in the night sky!

BEYOND OUR SOLAR SYSTEM

Space is big. Almost impossibly big. It contains more stars than the number of heartbeats in all of human history and we don't know if it ever ends. How do you even begin to search for life in such a vast and intimidating universe?

THE MILKY WAY

Every star in the night sky is a distant sun within a group of stars called the Milky Way galaxy. Each one could have planets swarming around it in a solar system of its own. We call them exoplanets. The problem is that the distance to the nearest solar system is over four light years away, meaning a beam of light travelling at 300,000 kilometres per second would take a little over four years to get there. So, sending a spacecraft for a closer look is currently out of the question (although there are tentative plans to try, see pp 58-59).

Scientists think there could be trillions of exoplanets, some orbiting stars and some just floating freely in space.

The first exoplanets were discovered in 1992, orbiting a pulsar (a dying star).

Scientists have now found more than 5000 exoplanets, of all different shapes, sizes and types.

THE FIREFLY AND THE LIGHTHOUSE

For now, you're left looking for exoplanets from afar, using big telescopes scattered around the world and lofted into space. But it's not simple: stars are incredibly bright and planets are very dim. Seeing a distant exoplanet is like trying to spot the light from a firefly in the glare of 250 lighthouses, both placed an Earth's width away from you (12,756 kilometres).

Telescopes/satellites - somehow referencing the firefly/250 lighthouses analogy.

We could show the James Webb telescope, beaming light onto a zoom-in, which shows a snapshot of an exoplanet - see image ref above. The exoplanet is simply a fuzzy blob!

To link the analogy visually, we could show some bright neon green fireflies in the foreground.

James Webb Space Telescope (JWST) is one of the most powerful telescopes ever built, specifically designed to study exoplanets.

ALIEN PLANET TOOLKIT

Simply pointing your telescope at a star and hoping to photograph its planets is almost impossible. Instead, astronomers turn into detectives, carefully and cleverly unravelling clues that a star has alien planets. Future alien planet explorer, it's time that you learned these techniques!

- ☑ **Winks** [page xx] when planets pass in front of stars, creating dips in the starlight, alerting astronomers to their presence.
- ☑ **Wobbles** [page xx] detect exoplanets that make their stars wobble.
- ☑ **Wiggles** [page xx] monitor a star's movement, which will be slightly different if a planet is orbiting it.
- ☑ **Ticks** [page xx] look at any changes in radio waves.
- ☑ **Blips** [page xx] detect when an exoplanet's gravity bends starlight.
- ☑ **Snaps** [page xx] use space telescopes to take photographs of exoplanets.

EXOPLANET TOOLKIT: WINKS

All of a sudden, the temperature drops and the sky darkens – even though it's lunchtime. An eerie silence descends as birds stop tweeting, tricked into thinking night is falling. You're witnessing a spectacular solar eclipse, where the Moon temporarily blocks out the Sun.

TRANSITING METHOD

Astronomers call an event like this a transit. The Moon is passing in front of – or transiting across – the Sun. Distant exoplanets often transit in front of their stars, too. The planet is too small and dim to be seen directly, but during the transit it blocks out some of the star's light. You'll see the star get temporarily dimmer, like it's winking at you.

ORBIT TIME

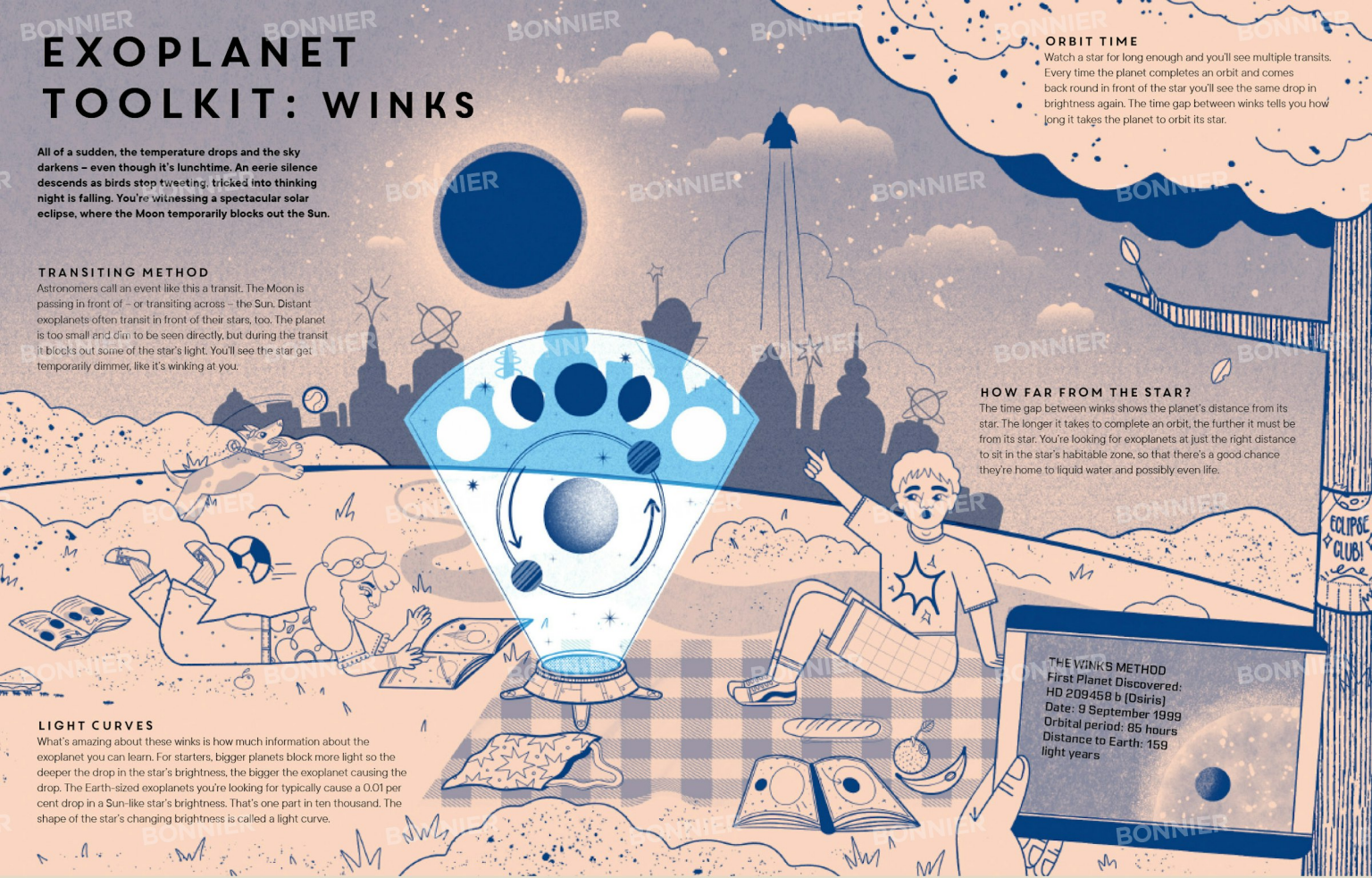
Watch a star for long enough and you'll see multiple transits. Every time the planet completes an orbit and comes back round in front of the star you'll see the same drop in brightness again. The time gap between winks tells you how long it takes the planet to orbit its star.

HOW FAR FROM THE STAR?

The time gap between winks shows the planet's distance from its star. The longer it takes to complete an orbit, the further it must be from its star. You're looking for exoplanets at just the right distance to sit in the star's habitable zone, so that there's a good chance they're home to liquid water and possibly even life.

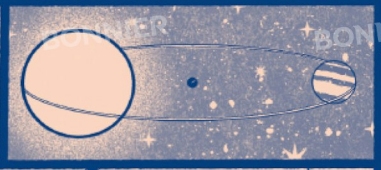
LIGHT CURVES

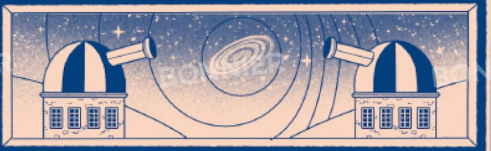
What's amazing about these winks is how much information about the exoplanet you can learn. For starters, bigger planets block more light so the deeper the drop in the star's brightness, the bigger the exoplanet causing the drop. The Earth-sized exoplanets you're looking for typically cause a 0.01 per cent drop in a Sun-like star's brightness. That's one part in ten thousand. The shape of the star's changing brightness is called a light curve.



EXOPLANET TOOLKIT: WOBBLES

Have you been taught that the Sun stays still while the planets move around it? Well, it's a little more complicated... The Sun actually moves or 'wobbles' around as it's pulled on by the gravity of its planets





WOBBLING STARS

Distant stars with exoplanets do the same, wobbling towards and then away from us. This wobbling affects the starlight you see. Think about a police car's siren as it hurtles by. The sound waves get squashed as it races towards you but are stretched out as the car speeds off and pulls them away. That's why you hear the pitch of the siren change.

With wobbling stars, the light changes instead. When a star wobbles towards Earth, the light waves bunch up and become slightly bluer. This is called blueshift. When the star wobbles away from us, the light waves are stretched out and become slightly redder. This is called redshift.

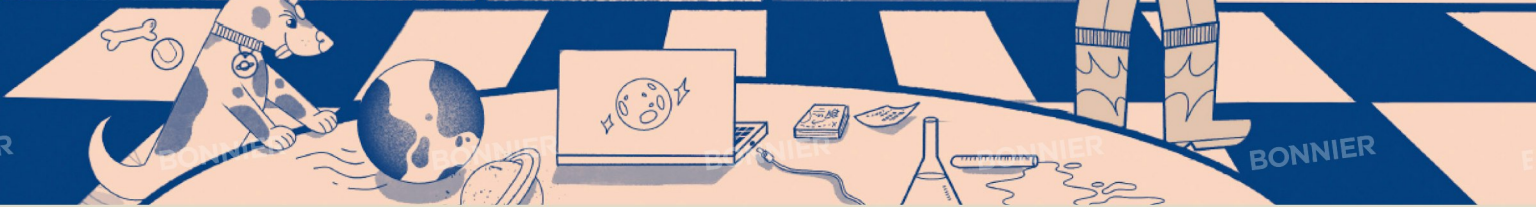
COLOURS OF STARLIGHT

Astronomers use a device called a spectrograph, which attaches to the telescope, to view these tiny changes of light. This breaks up the starlight into a kaleidoscope of colours called a spectrum. It's similar to the way raindrops split sunlight to make a rainbow.

The spectrum contains black lines, which move from the blue end to the red end as the star wobbles. This technique – the **radial velocity method** – is so sensitive that it can detect changes in the speed of a wobbling star down to ten centimetres per second. That's about the top speed of a sloth!

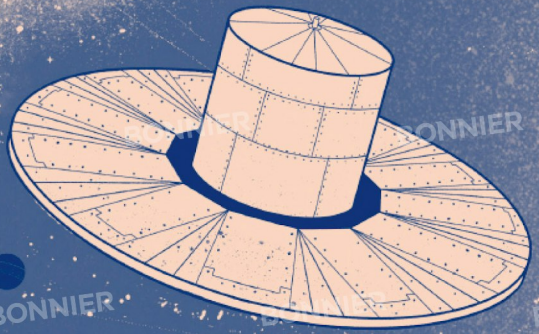
Heavier planets orbiting a star cause bigger wobbles, making the lines move more. You're looking for just the right amount of wobble to suggest a planet as heavy as Earth. This might mean it has the right properties to support extra-terrestrial life.

THE WOBBLES METHOD
First Planet Discovered: 51 Pegasi b (Dimidium)
Date: 6 October 1995
Orbital period: 102 hours
Distance to Earth: 50 light years



EXOPLANET TOOLKIT: WIGGLES

With just a few minutes until sunrise, a rocket ignites and soars into the air, a $1 billion telescope safely nestled inside. Once in space it is catapulted some 1.5 million kilometres away from Earth to a quiet spot where it begins looking at distant stars.



MISSION GAIA

This telescope, launched in 2013, is called Gaia. Its mission? To map the positions of the stars more accurately than ever before. In the process astronomers hope to find tens of thousands of alien worlds through a technique called astrometry.

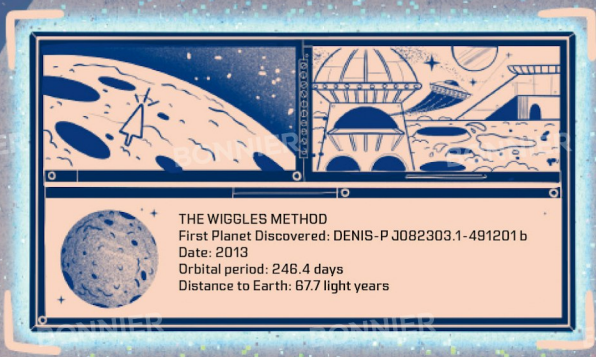
MAPPING STARS

Astrometry looks for stars that wiggle around in the night sky as they are pulled about by their planets. But these wiggles are almost impossibly small. So how do you find them?

Astronomers measure the night sky in degrees, the same degrees you use when talking about angles at school. The entire night sky spans 360 degrees, the same as a circle. We divide degrees the same way we split hours – into minutes and seconds – but we call them arcminutes and arcseconds. One degree is made of sixty arcminutes and each arcminute sixty arcseconds. The width of the Full Moon, for example, takes up half a degree of the sky – or 1800 arcseconds.

HEAVY PLANETS

An Earth-sized planet pulling on a Sun-like star will make that star wiggle in the night sky by just 0.3 millionths of an arcsecond – an amount that's 6 billion times smaller than the width of the Full Moon. Unfortunately, even Gaia isn't capable of making measurements that precise. However, it should still find heavier planets than Earth around smaller stars than the Sun where the wiggles are more obvious. And once you find an exoplanet, who knows what life might reside there?



EXOPLANET TOOLKIT: TICKS

Bang! A massive star collapses before exploding outwards, creating a searing flash of light brighter than one hundred billion stars. More energy is released in a few seconds than the Sun will emit in its entire ten-billion-year lifetime.

SUPERNOVA DISPLAY

This huge explosion – called a supernova – is one of the universe's most impressive firework displays. Deep in the heart of the explosion lie the smoked-out ruins of a once mighty star. This dead core is just 30 kilometres across – about the same size as a big city like London. Yet it still contains half the mass of the original star. Everything is so squashed together that a single teaspoon of its material weighs more than every person on Earth put together!

NEUTRON STARS

Astronomers call it a neutron star and they act as Nature's lighthouses, sending out beams of radiation into space as they spin. The beams arrive on Earth as pulses of radio waves so we also call them pulsars.

OUT OF TIME

Pulsars are super-reliable clocks. The gap between the pulses of radio waves hitting Earth is precisely the same. Tick after dependable tick. But an orbiting exoplanet throws the pulsar clock out of time. As with wobbles and wiggles, the planet disrupts the pulsar's usual steady rhythm.

NO SIGN OF LIFE

Pulsar timing is so sensitive that it can detect planets just one tenth as heavy as the Earth. Although, unfortunately, the supernova explosion that created the pulsar would have rendered the planet completely uninhabitable which is no good for extra-terrestrial life. So if you notice a tick, it's best to move on...

THE TICKS METHOD

First Planet Discovered: PSR B1257+12 B (Poltergeist)
Date: 22 January 1992
Orbital period: 25.3 days
Distance to Earth: 2300 light years

EXOPLANET TOOLKIT: BLIPS

Albert Einstein is arguably the most famous scientist of all-time. Along with the equation E=mc2, he changed the way we think about gravity forever and gave us a new way to hunt down exoplanets.

GRAVITY WELL

Imagine taking the sheet off your bed and roping in some friends to hold each corner. You then put a basketball in the middle, which creates a dip in the centre of the sheet. Next you take a tennis ball and roll it rapidly around the rim of the dip. In other words, you make the tennis ball orbit the basketball.

Now, let's pretend the basketball is the Sun and the tennis ball is the Earth. The tennis ball isn't orbiting the basketball because it is being pulled around by it. What happens is that the basketball changes the shape of the sheet and the tennis ball is simply follows that shape. This is Einstein's explanation of gravity and the dip is a called a gravity well.

NEUTRON STARS

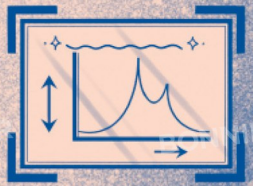
Scientists use gravity wells to see if distant stars have exoplanets using a technique called gravitational microlensing. Here's how:

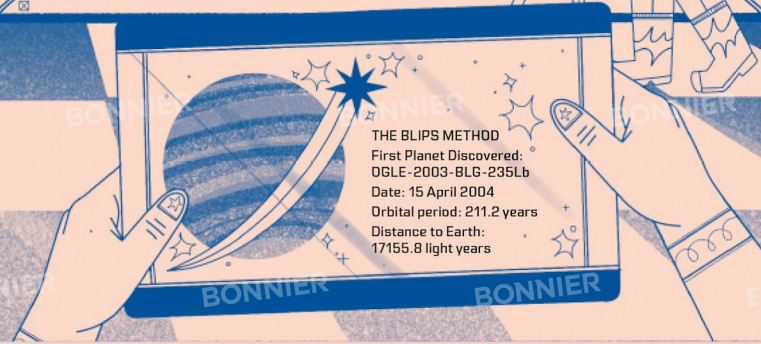
Wait for a nearby star to pass directly in front of a more distant star.

As the light from the distant star approaches the star in front, it encounters its gravity well.

The distant star's light curves around the rim of that well before hitting your telescope.

The effect of this is that you'll see the distant star's light get temporarily brighter as if the front star is acting like the lens of a magnifying glass. If the front star has an exoplanet then you'll also see a small extra 'blip' where the planet's own gravity well has added in some extra magnification.





THE BLIPS METHOD

First Planet Discovered:
OGLE-2003-BLG-235Lb

Date: 15 April 2004

Orbital period: 211.2 years

Distance to Earth:
17155.8 light years

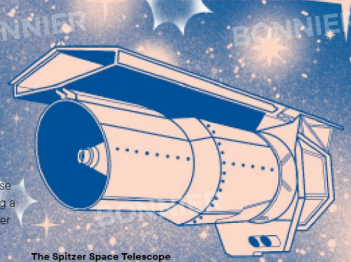
EXOPLANET TOOLKIT: SNAPS

Stars are so bright that taking a photo of one of its planets is almost impossible. Almost, but not quite. Astronomers have photographed around fifty distant exoplanets, including one in the closest solar system to ours. But how?

HOT PLANETS

Why is this important? Planets form when small lumps of space rock called planetesimals collide. The energy released by these collisions means that young planets are still very hot and give out lots of infra-red light. Planets under 100 million years old are easiest to photograph amid the glare of their star using infra-red telescopes.

Infra-red imaging also works well for big, bright gas planets – those even larger than the solar system's biggest planet, Jupiter. Seeing a planet is easier, too, if it orbits really far from the bright star, further out than any of the planets in our solar system.



The Spitzer Space Telescope discovered seven Earth-sized planets around a star 40 light years away.

SEARCHING FOR LIFE

But these planets sound nothing like Earth – a small, rocky planet that's billions of years old, orbiting close to its star in the Goldilocks zone. So how can we find a planet that has the right conditions for life? Well, we're building better telescopes all the time.

In 2027, NASA will launch the Nancy Grace Roman Space Telescope. It will be able to photograph large, old planets like Jupiter using visible light instead. Perhaps the next generation of telescopes after that will be able to take photos of small planets, like Earth, that are more likely to be home to extra-terrestrial life.

INFRA-RED LIGHT

The light that your eyes can see is called visible light. It spans the colours of the rainbow, from red to violet. But just as there are frequencies of sound too high and low for your ears to hear, some frequencies of light are too high or low for your eyes to see.

Move beyond the red end of the visible spectrum and you enter the infra-red.

TV remotes use beams of infra-red light to talk to your television. Infra-red cameras can be used to track animals at night by sensing their body heat.

THE TICKS METHOD
First Planet Discovered: Fomalhaut b (Dagon)
Date: 13 November 2008
Orbital period: 1,700 years
Distance to Earth: 25 light years