Astronomy for Curious Kids

By Giles Sparrow

Secrets of the Stars

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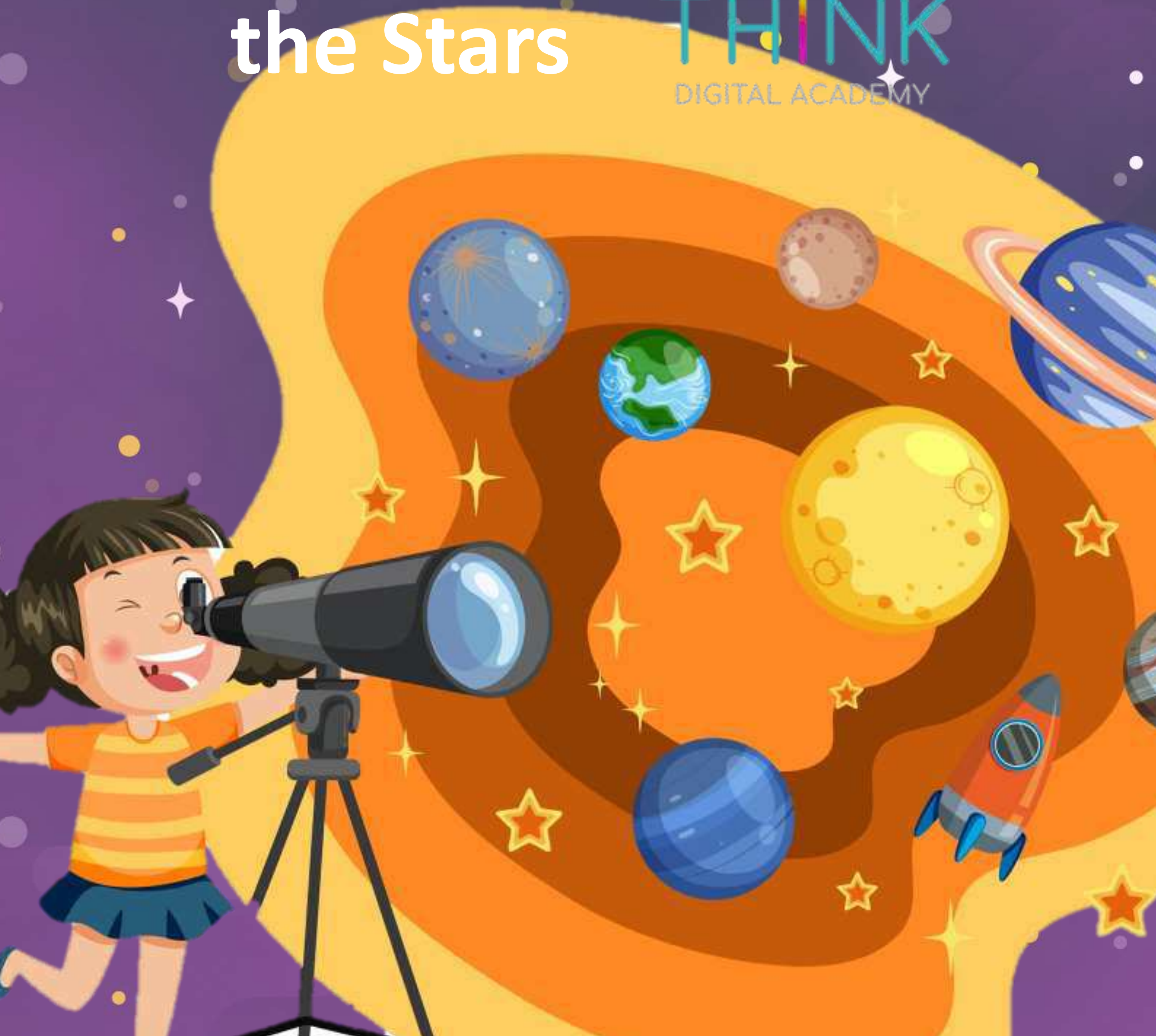


Chapter 4

Secrets of The Stars

Nearly all the lights you see in the sky are stars – distant objects that shine like the Sun and can be seen across vast expanses of space.

In this story, we'll find out how stars are born and how they die. We'll also compare the different types of stars, from red dwarfs to blue super giants and explore mysterious black holes.

What is a Star?

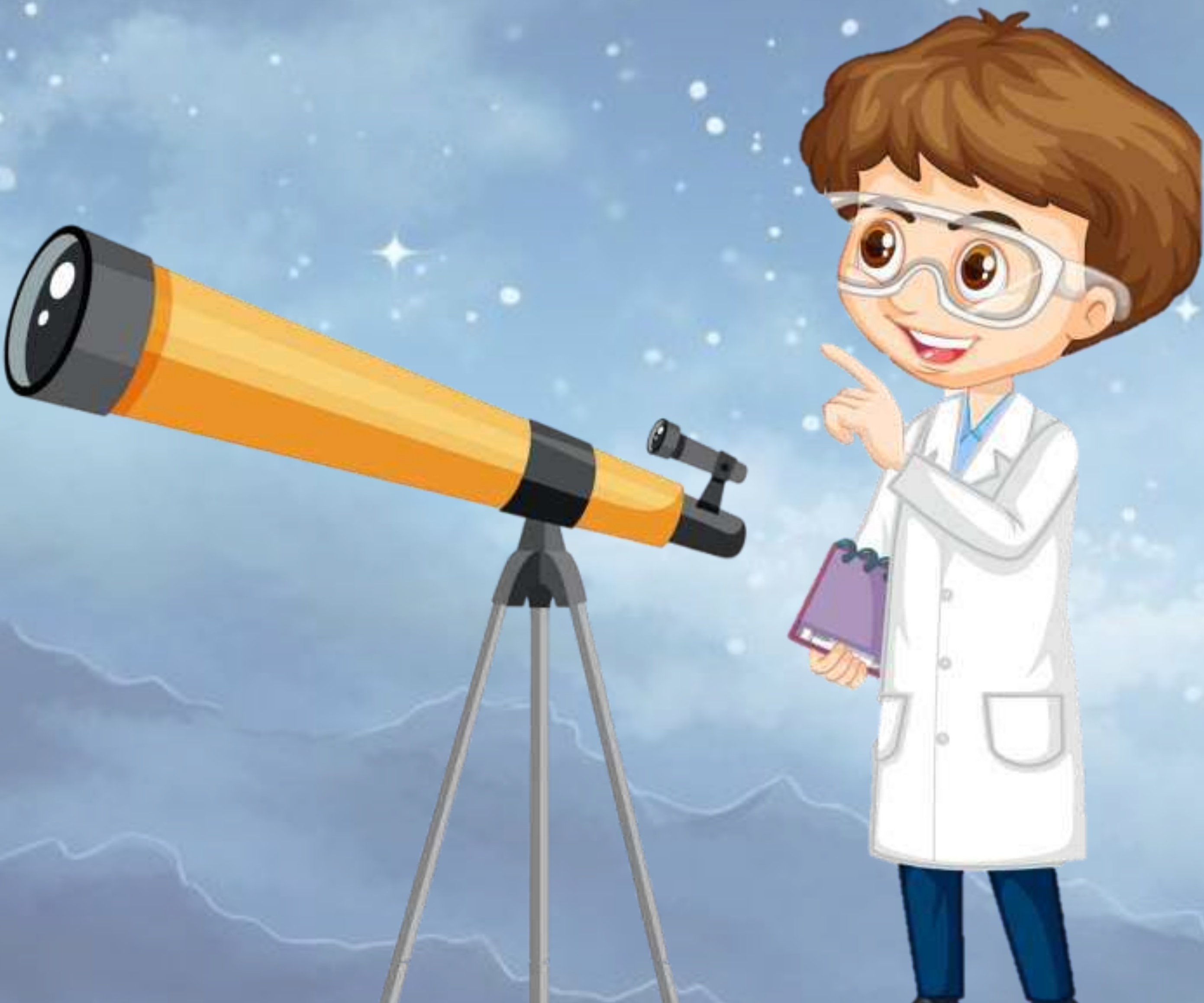
Not all stars are the same. Some are bright, some are faint, some are brilliant white and others a dull red. There are even stars that change their brightness over periods of hours or months. Stars vary hugely in their size, distance from Earth, energy output and other properties.

Out of Curiosity

Often, you'll notice that the brightest stars in the sky are constantly twinkling. This is because the moving air in Earth's atmosphere acts like a shifting lens that distorts the star's light rays and bounces them in various directions. Stars are affected by twinkling because of their vast distance from Earth. The planets in our solar system are much closer and their reflected light arrives on Earth in a much wider beam, so they twinkle much less.

Closest and Brightest

the closest star to our solar system, Proxima Centauri, is so faint that you can only see it with a telescope. It pumps out less than 1/600th of the light of the Sun. The brightest star in the sky, Sirius, is twice as far away as Proxima, but shines brilliantly because it is 25 times more luminous than the Sun.



Stars BIG and small

Despite being 1.4 million km (870,000 miles) across, the Sun is on the small side for a star. The largest stars of all, the supergiants, can grow to 1 billion km (620 million miles) across or more. If the red supergiant Antares was in the middle of our solar system, its outer layers would stretch almost to Jupiter. Stars with larger surfaces have more space to shed the energy they generate inside. This means that less energy passes through each unit of surface area and its surface is cooler.

Stellar Distances

If the solar system between the Sun and Saturn was scaled down to the size of this page, you'd have to keep going for 28,047 times the distance from the Sun to Saturn to reach the nearest star. Distances to stars are so vast that astronomers use a huge unit called a light year to measure them. A light year is the distance light (the fastest thing in the Universe) travels in one year. One light year is 63,241 times the distance from the Earth to the Sun. That's 9,5 trillion km (5.9 trillion miles). Proxima Centauri is 4.25 light years away, but most stars are even more distant.

Measuring the Stars

To understand what stars are, astronomers need to measure their various properties. The most important of these are brightness (as seen from Earth), temperature and distance

Brightness of Stars

Astronomers measure the brightness of stars and other objects in the sky using a system called “apparent magnitude.” The idea began when ancient stargazers divided the stars into six ranks, from the brightest “stars of the first magnitude” to the faintest they could see with the naked eye in the sixth magnitude. Today, the system has been given a more scientific grounding using electronic measurements and has been extended to cover much the brighter and much fainter objects

Brightest

The sun: magnitude -268

Full moon: -12.7

Venus at its brightest: -4.9

Sirius: -1.5

Polaris (northern pole star): +2.0

Faintest naked-eye stars: 6.5

Faintest stars visible through average binoculars: 9.5

Dwarf planet pluto: 13.7

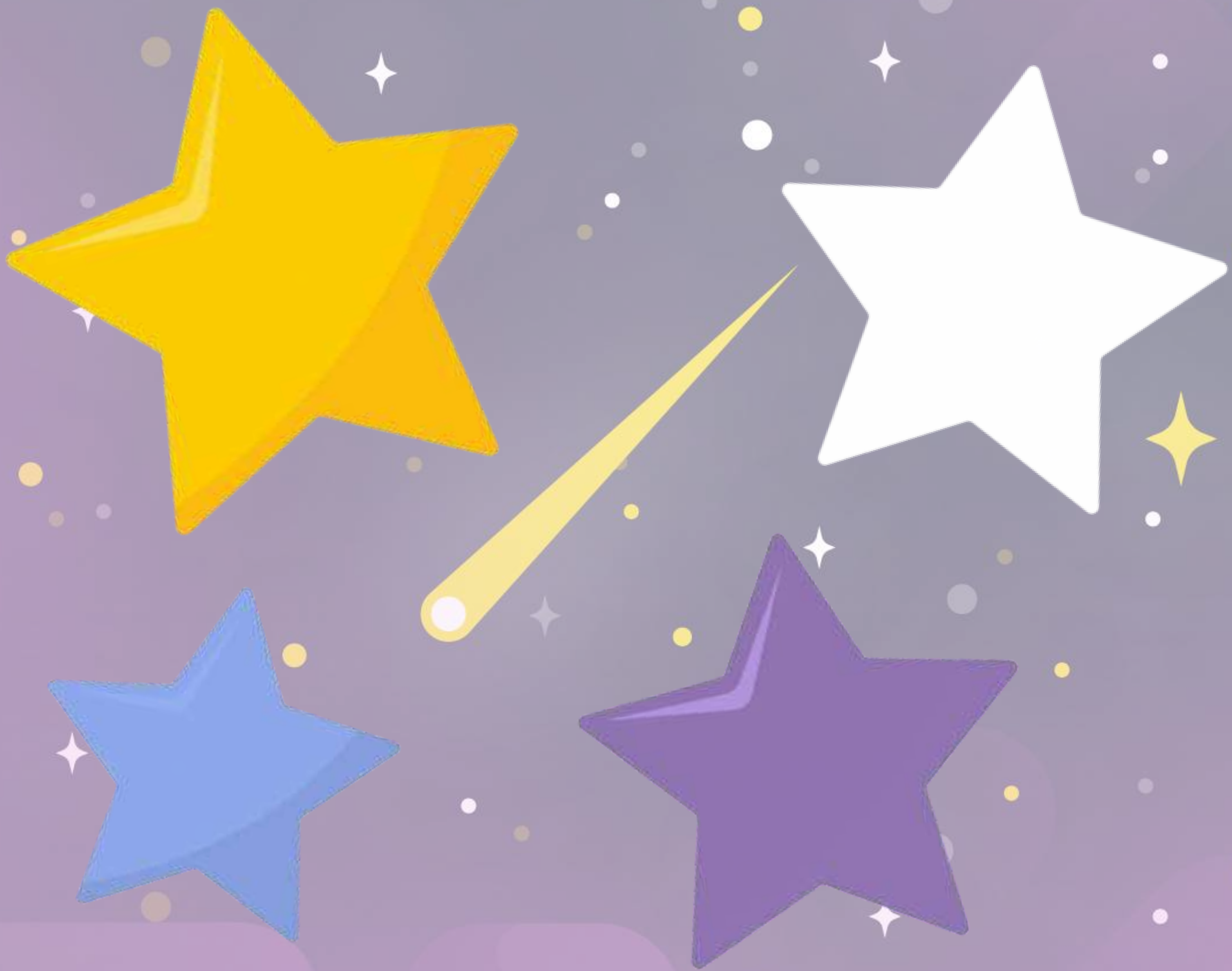
Faintest objects seen through hubble space telescope: magnitude 31.5

Out of Curiosity

A star's apparent magnitude does not reflect its actual light output, known as its luminosity. A sixth-magnitude star could be highly luminous but very far away, while a brilliant first-magnitude star could be fairly average but very close to our solar system. In order to measure a star's true luminosity, astronomers need to know both its apparent magnitude and its distance.

Colour and Temperature

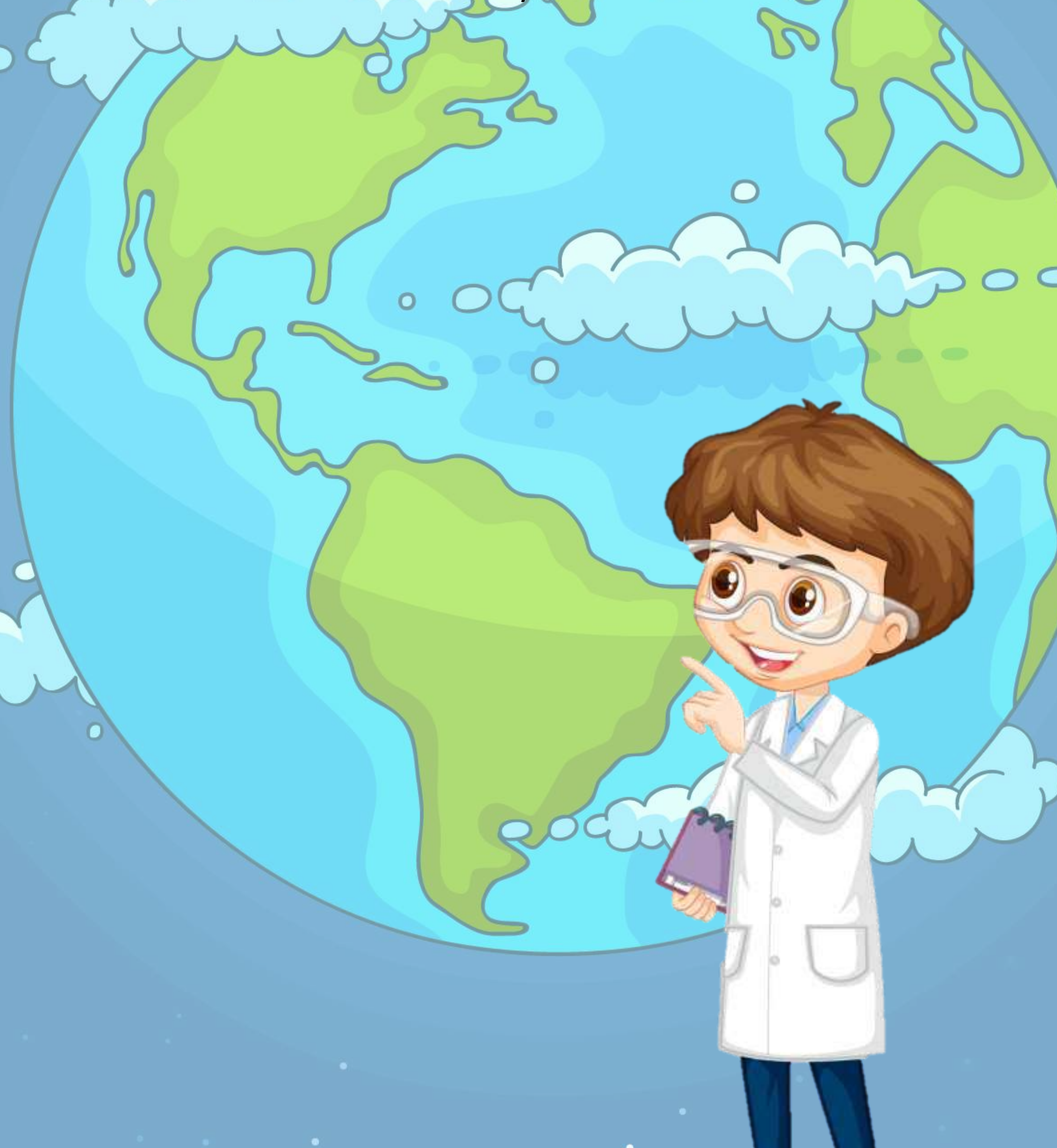
Stars vary in colour from red through orange and yellow to white, blue and even violet. The precise colour depends on the star’s surface temperature. Like a metal bar being heated in a furnace, stars glow red-hot at relatively low temperatures, then yellow and white hot, before eventually glowing blue if they get hot enough. Red stars have temperatures as low as 3000 °C (5800 °F), while blue stars may be ten times as hot. Our un is a yellow star with a surface temperature of 5,500 °C (9,900 °F).



Parallax and Distance

The distance to a star is one of the most valuable pieces of information astronomers can find out, but how can you measure such a huge distance when it's impossible to travel there? The most direct method, called parallax measurement, makes use of the way a nearby star's direction in the sky appears to change from different points of view on Earth.

As Earth moves from one side of its orbit to the other over six months, we see stars from two points of view separated by 300 million km (186 million miles). This is a large enough separation for the direction of nearby stars to change by a tiny detectable amount. The size of its parallax reveals how far away the star is.



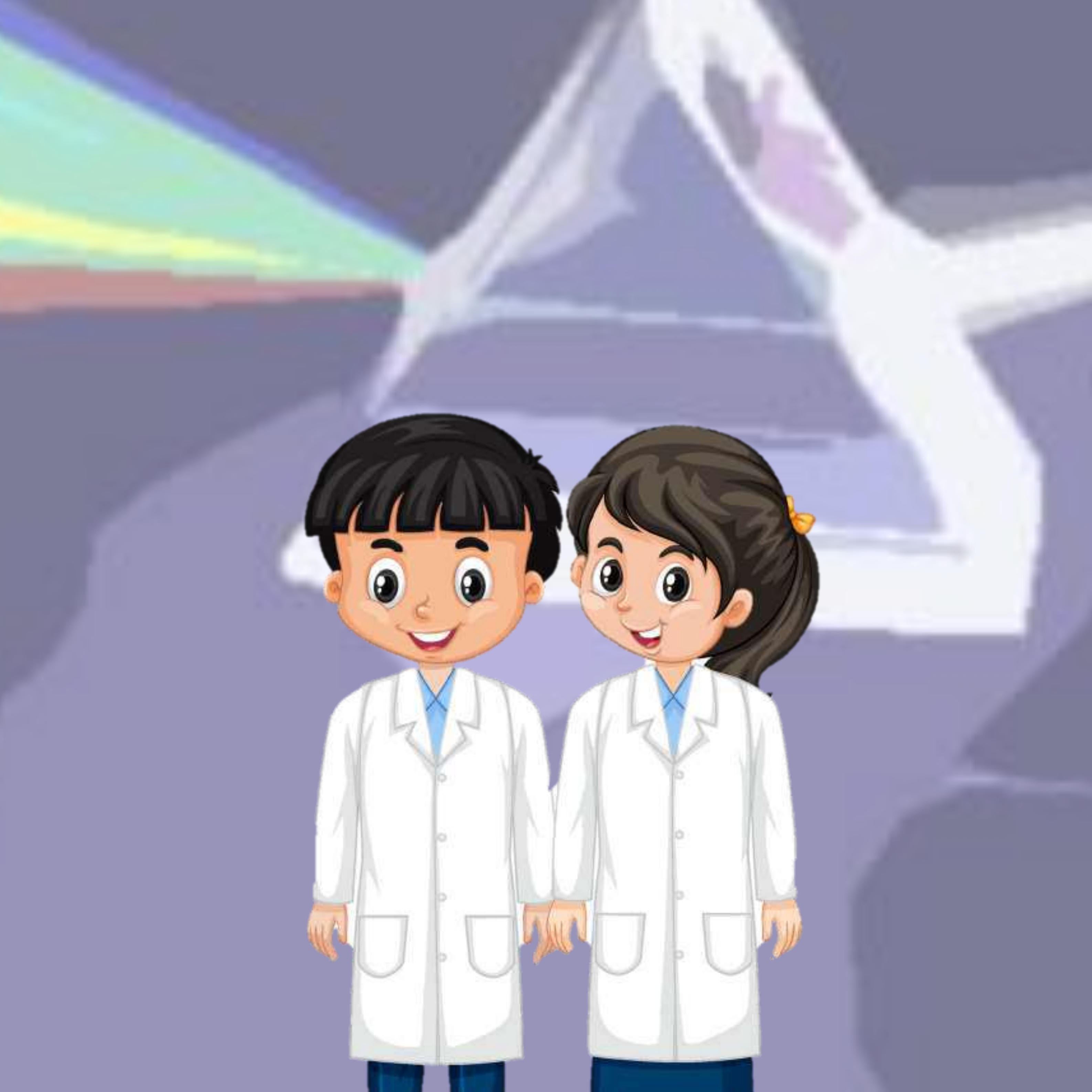
You can see the parallax effect for yourself simply by holding up a pencil at arm's length. Cover one eye and then the other, and you'll see that the pencil seems to shift direction because each eye has a separate point of view.

Secrets of Starlight

Stars give out light (and other types of electromagnetic radiation), with a range of energies and wavelengths. By measuring the radiation of different stars, astronomers can calculate their temperatures, what they are made of, and how they are moving.

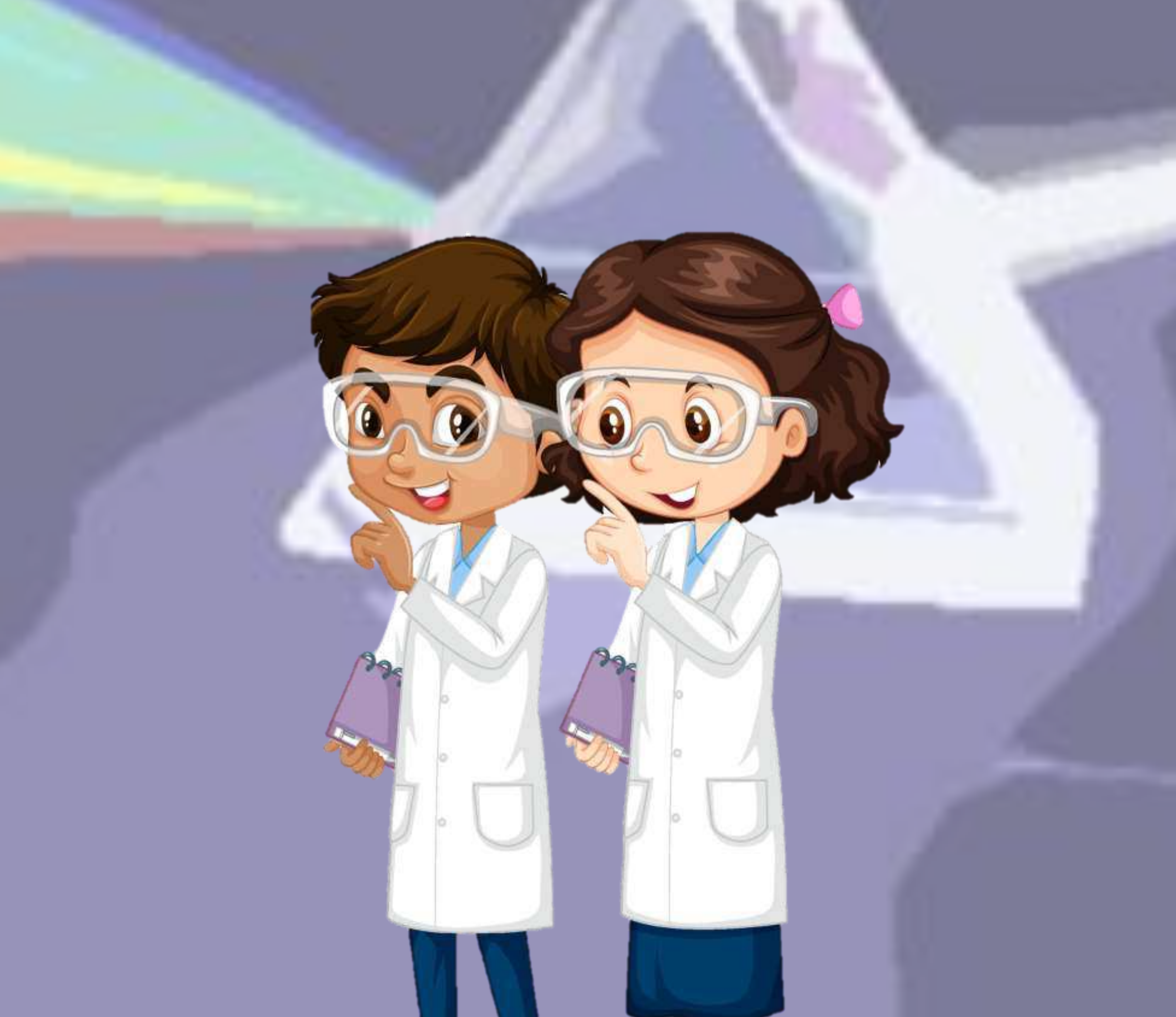
Spectroscopy

Visible light is made up of different colours of different wavelengths. These can be seen when light passes through a wedge-shaped glass called a prism and is split its rainbow colours. The rainbowlike band of colours given off by a star is called its emission spectrum. It can reveal a lot about the nature of a star. The study of a spectra is called spectra is called spectroscopy.



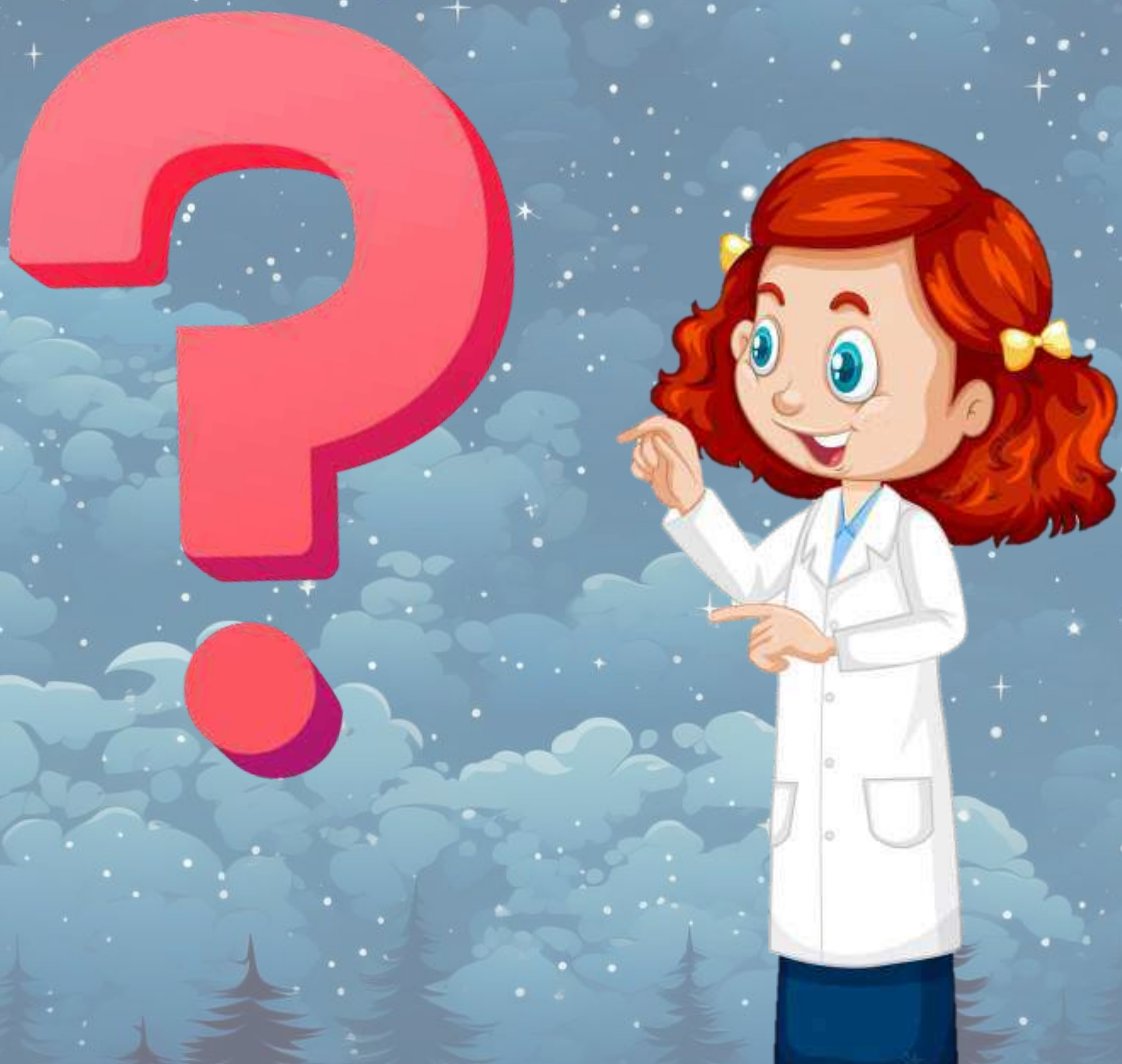
The band of star’s spectrum varies in both, colour and intensity. A star produces its most light at a wavelength and colour related to its surface temperature.

If the spectrum is spread out widely, dark absorption lines can be seen. This is where material between us and the light source (often gases in the star’s atmosphere), is absorbing certain light energies. The energy levels absorbed are unique to each type of atom or molecule doing the absorbing, so astronomers can identity the chemicals involved.



Out of Curiosity

A star's apparent colour depends on how our eyes interpret the mix of light that it emits – like paints mixed on a palette. The hottest stars emit lots of blue light but very little red. Because green lies in the middle of the spectrum, stars that emit the most green light tend to produce equal amounts of blue and red. The result is that the colours balance out to produce a white rather than a green star.



Two Types of Spectra

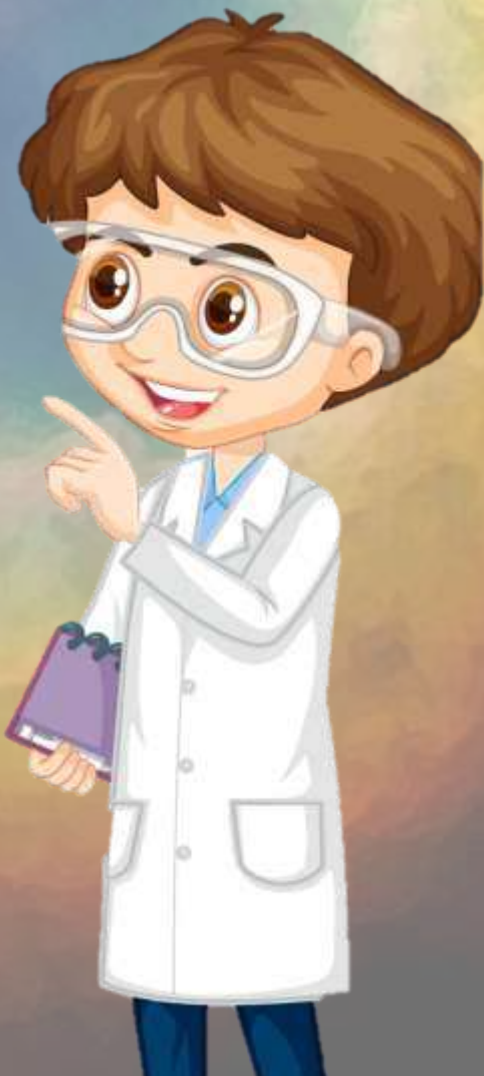
While stars produce a rainbowlike spectrum covering a wide range of wavelengths, other space objects, such as gas clouds, produce light by emitting energy in very narrow wavelength bands. The result is a spectrum that is largely black with a few bright lines called emission lines, just like dark absorption lines, these can be used to identify the chemicals involved.

How is it Moving?

Want to know how a star or other space object is moving? Just study its spectrum. If an object's absorption or emission lines seem to match up to a known element but are slightly out of place, then it's a sign that their source is moving toward or away from Earth. Light from sources moving towards Earth gets compressed into shorter wavelengths, or "blue shifted", while light from sources moving away from Earth is stretched into longer wavelengths, or "red shifted". Figure out the amount of red or blue shift, and you can discover the speed of the star's movement toward or away from Earth.

When Stars are Born

Glowing clouds of gas and dust called emission nebulae are some of the most beautiful sights in the night sky. These are where stars are born and go through their turbulent early years.



Star Birth Nebulae

Nebulae are large clouds of gas and dust floating in space. They may be hundreds of light years across. Some nebulae block light from objects behind them. Some reflect light. An emission nebula is a type that radiates its own light. Stars are born in nebulae when something pushes or pulls the gas together and some clumps become dense enough to start pulling in more material from their surroundings. These "protostars" rapidly grow in size and get hotter and denser in the middle, until they start to shine.

Triggers of Star Formation

What could push or pull a nebula's gas to trigger star formation? Astronomers believe there are three main causes:

1. Moving into a crowded region of the Milky Way called a spiral arm
2. Other stars drifting past and pulling material towards them
3. Shock waves from exploding giant stars pressing material together

Famous Star Birth Nebulae

Nebulae that are forming new stars glow because their has is energised by powerful radiation from hot newborn stars. Winds of material blown from these stars shape their surroundings, while dust-filled areas form pillars, canyons and blobs that appear dark against the glowing background. Here are some great nebulae to track down online or in the night sky.

Orion Nebula: Marking the sword of the constellation of Orion, the brightest nebula in the sky has a flower shape with four bright newborn stars in the middle.

Carina Nebula: This bright nebula, in the southern constellation of Carina the Keel, contains two young star clusters of different ages.

Eagle Nebula: This famous nebula, in the constellation of Serpens the Snake, is home to the "Pillars of Creation" (above), dark columns of gas and dust with stars forming inside them.

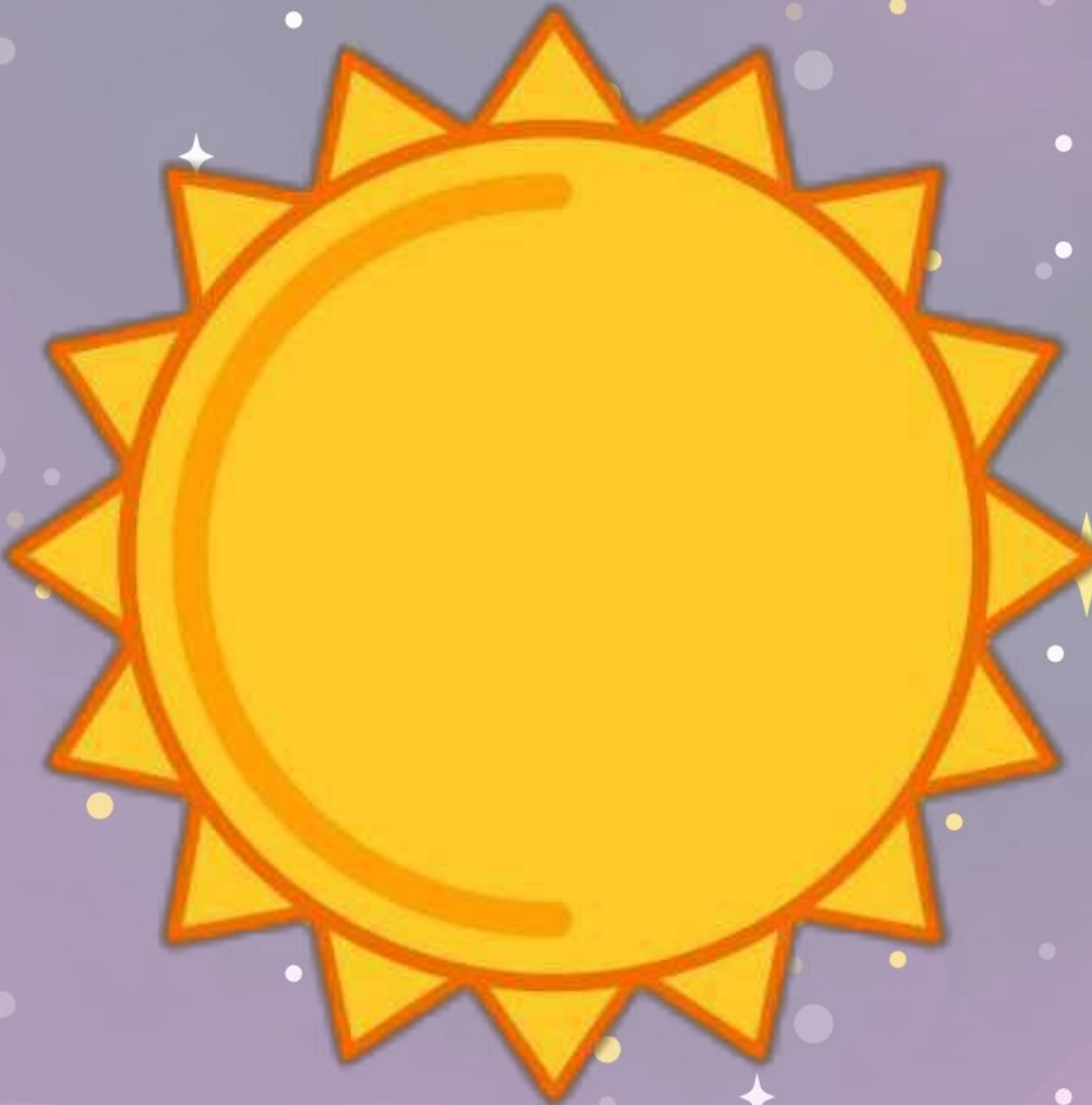
Young stars

Polar Stars

As a knot of gas collapses to form a star, it spins faster and faster. Leftover dust and gas from the star's formation flattens into a disk around the star, but some is thrown into space from the star's poles, creating narrow jets that billow out into huge clouds farther from the star.

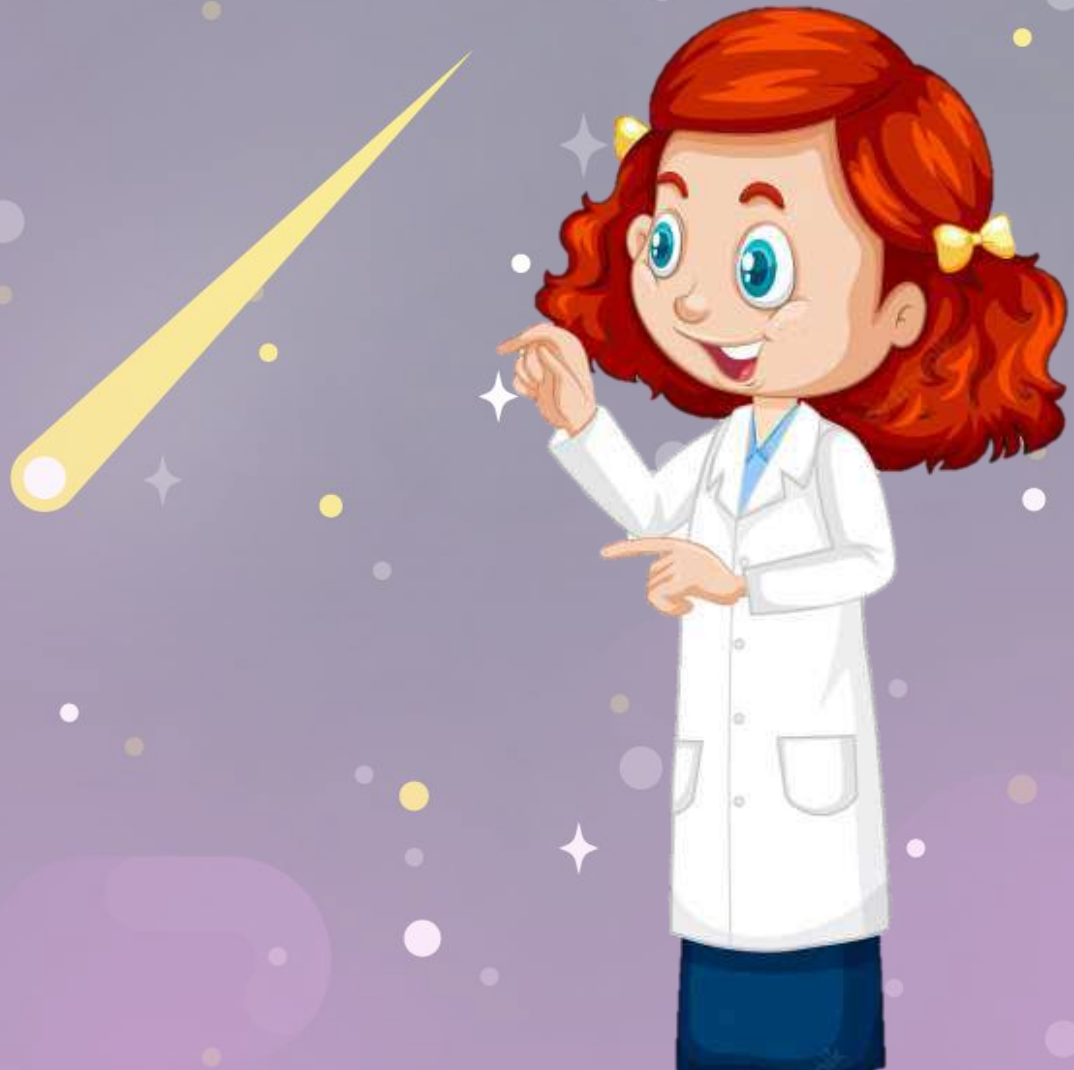
Unstable Youth

Young stars can vary in brightness as they gain material, but eventually they settle down as they get hotter and brighter. Material orbiting the star may become the building blocks of a new solar system, featuring planets and moons.



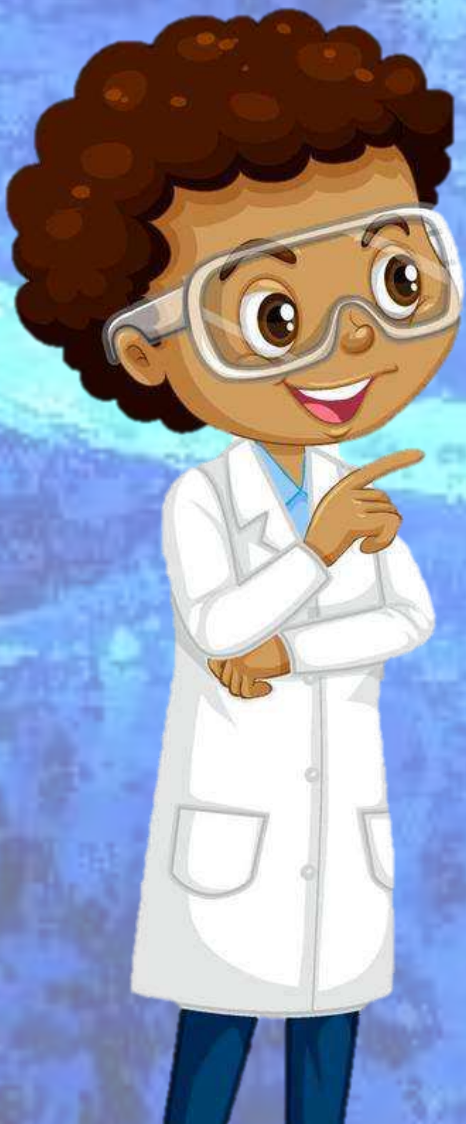
Drifting Apart

A single nebula can give rise to a cluster of hundreds or thousands of stars. Over millions of years, most of these stars will drift away, but astronomers can often trace these moving groups of stars back to their origin



The Power Source of Stars

Just like the Sun, all stars shine through a process called nuclear fusion. This can happen in various ways and the amount of power it generates determines not just a star's luminosity, size and surface temperature, but also how long it may live for.



What is Fusion?

An atomic nucleus is the central part of all atoms, the tiny particles that make up all visible matter. Normally, the nucleus is orbited by even smaller particles called electrons, but deep inside a star, the temperature and pressure is so great that the electrons are stripped away an the nucleus is exposed. The nuclei of lightweight elements can then be forced (fused) to create heavier ones.

The P-P Chain

The most common type of fusion reaction used (proton-proton) chain. This involves fusing nuclei of the lightest element, hydrogen, to make the next lightest element, helium. A hydrogen nucleus normally has just one “subatomic particle” called a proton, while a helium nucleus has four (two protons and two neutrons). It takes several steps to turn hydrogen into helium.

Two hydrogen nuclei fuse into a new form called deuterium. As a proton becomes a neutron it releases a positron.

The deuterium nucleus fuses with another proton, forming a helium-3 Nucleus.

Two helium-3 nuclei fuse to form a helium nucleus and eject two spare protons.

Fast or Slow

Because it involves so many stages, the p-p chain reaction releases energy at a slow rate, allowing stars that rely on it to shine for billions of years. The greatest a star’s mass, the hotter and denser it’s core and the faster this reaction runs.

Stars with a higher mass than the Sun, however, can turn hydrogen to helium using a different process called the CNO cycle. This involves protons fusing with heavier carbon nitrogen and oxygen before releasing helium and carbon that can be used again.

The CNO cycle turns hydrogen to helium much more quickly than the p-p chain, so stars heavier than the Sun can shine far more brightly, but also use up their hydrogen fuel more quickly. Because of this, a massive star may run out of fuel in just a few million years, while a low-mass faint star can keep shining for thousands of times longer

Out of Curiosity

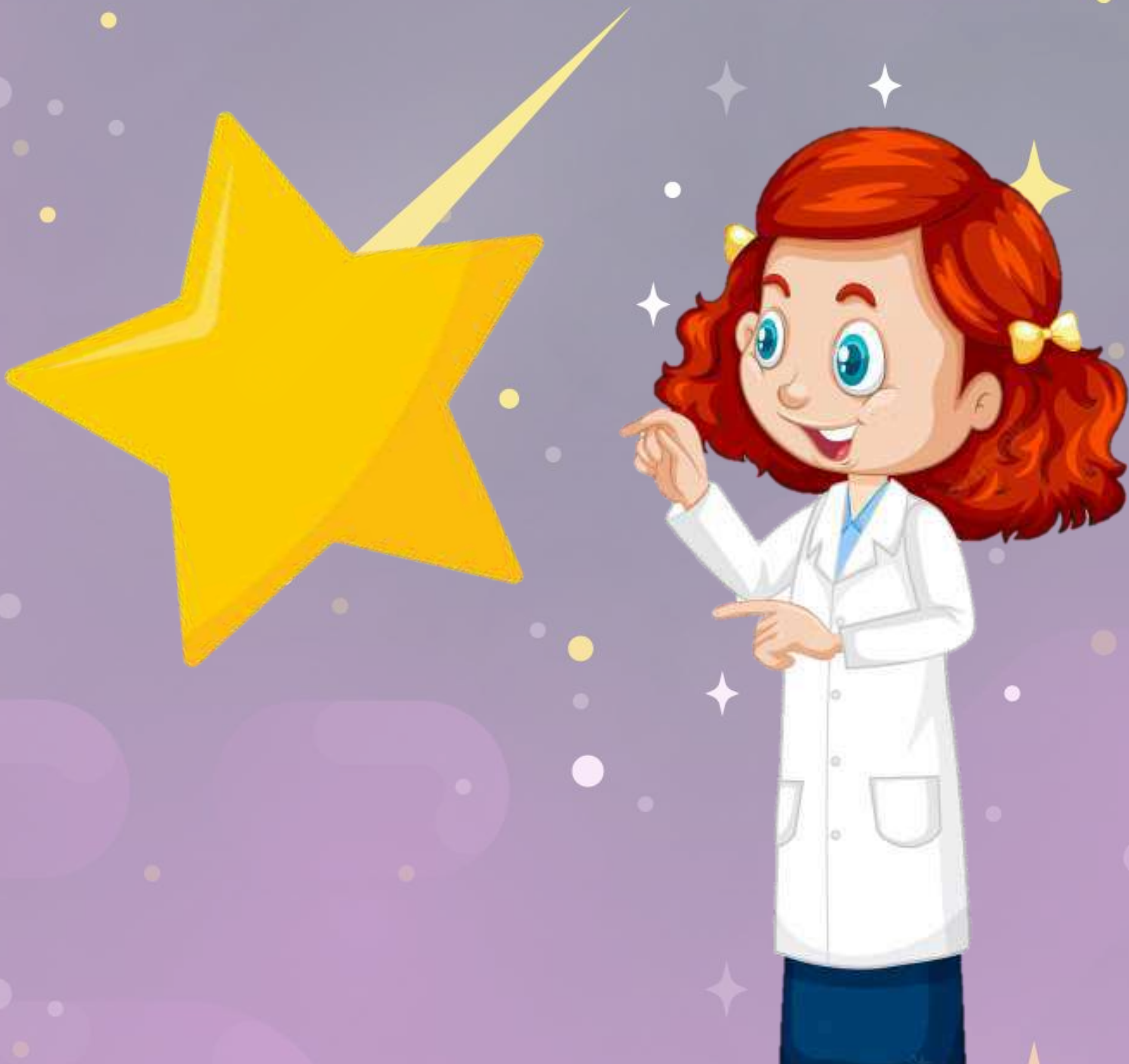
Each stage in the fusion process generates energy. This is because the particles made or released by the process weigh slightly less than the ones which go into it. the excess mass is converted into energy.

Balancing Act

Every star is caught in a balancing act between the inward pull of gravity on its outer surface and the outward push of hot inside. Both, gravity and the rate of energy generation depend on the star’s mass. Together they determine the size of the star, its temperature and colour. If nothing else changes, a larger surface provides more room for energy to escape, so the surface is heated less and is cooler than if the star was smaller.

Changing Stars

Not all of the stars in the sky shine steadily. Many brighten or dim from time to time. In some stars, changes in brightness occur regularly, while in others the change is unpredictable. Binary stars don't actually change their brightness, but the path of their orbits mean they appear to dim at times.

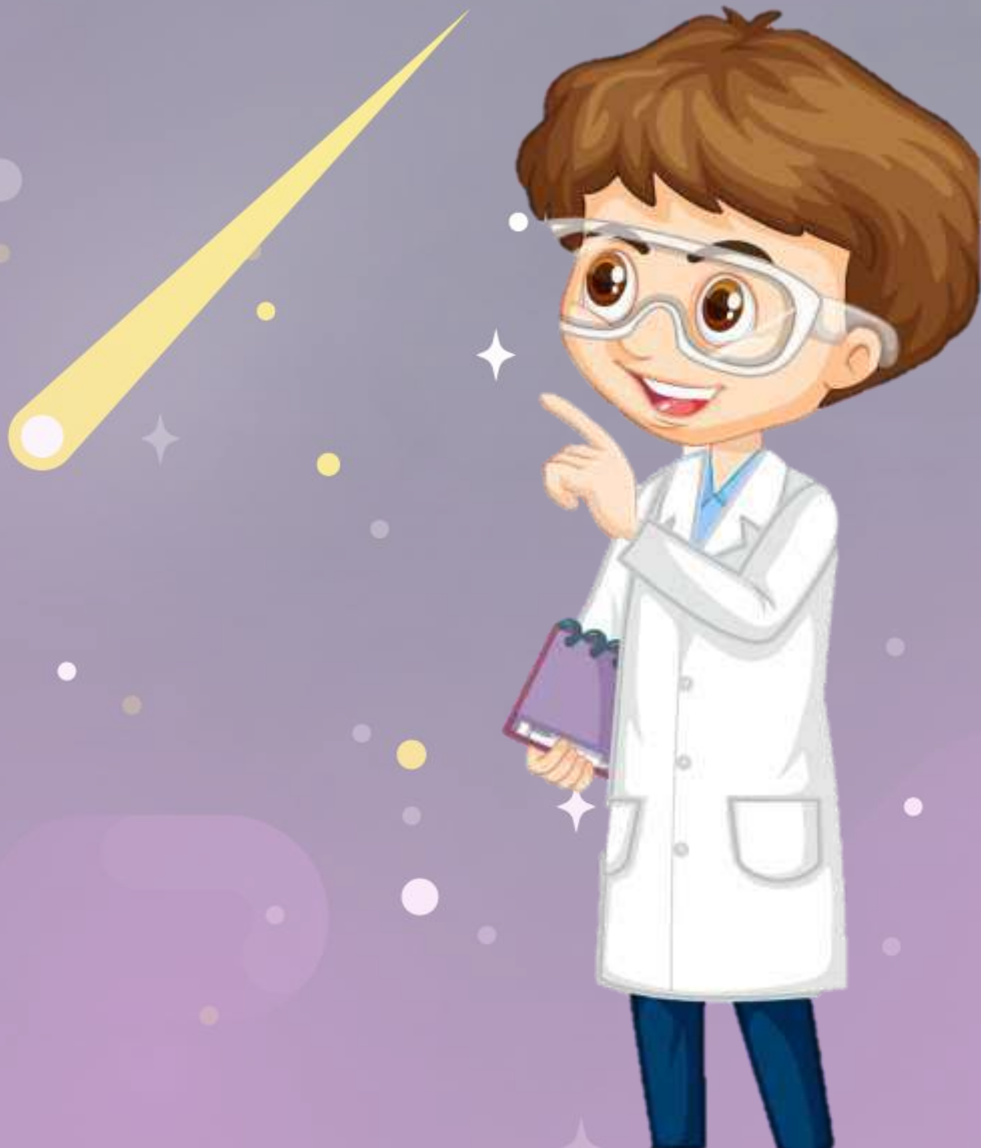


Pulsating Stars

Stars can pulsate (change their luminosity) at various times in their lives. This is usually due to changes in their internal structure. As the star expands and cools, pressure drops until gravity takes over and pulls the star inward. As it contracts and heats up, the star brightens until pressure from within pushes it outward once again. Pulsating stars can vary in brightness over hours or many months.

Eclipsing Binaries

Some variable stars are actually binary systems, a pair of stars whose orbits line up so that they pass in front of each other as seen from Earth. As each star blocks part of the other's light, their combined brightness dips.



Famous Variables

Delta Cephei

A bright yellow supergiant in the constellation of Cepheus that pulsates in a 5.4-day cycle.

Mira

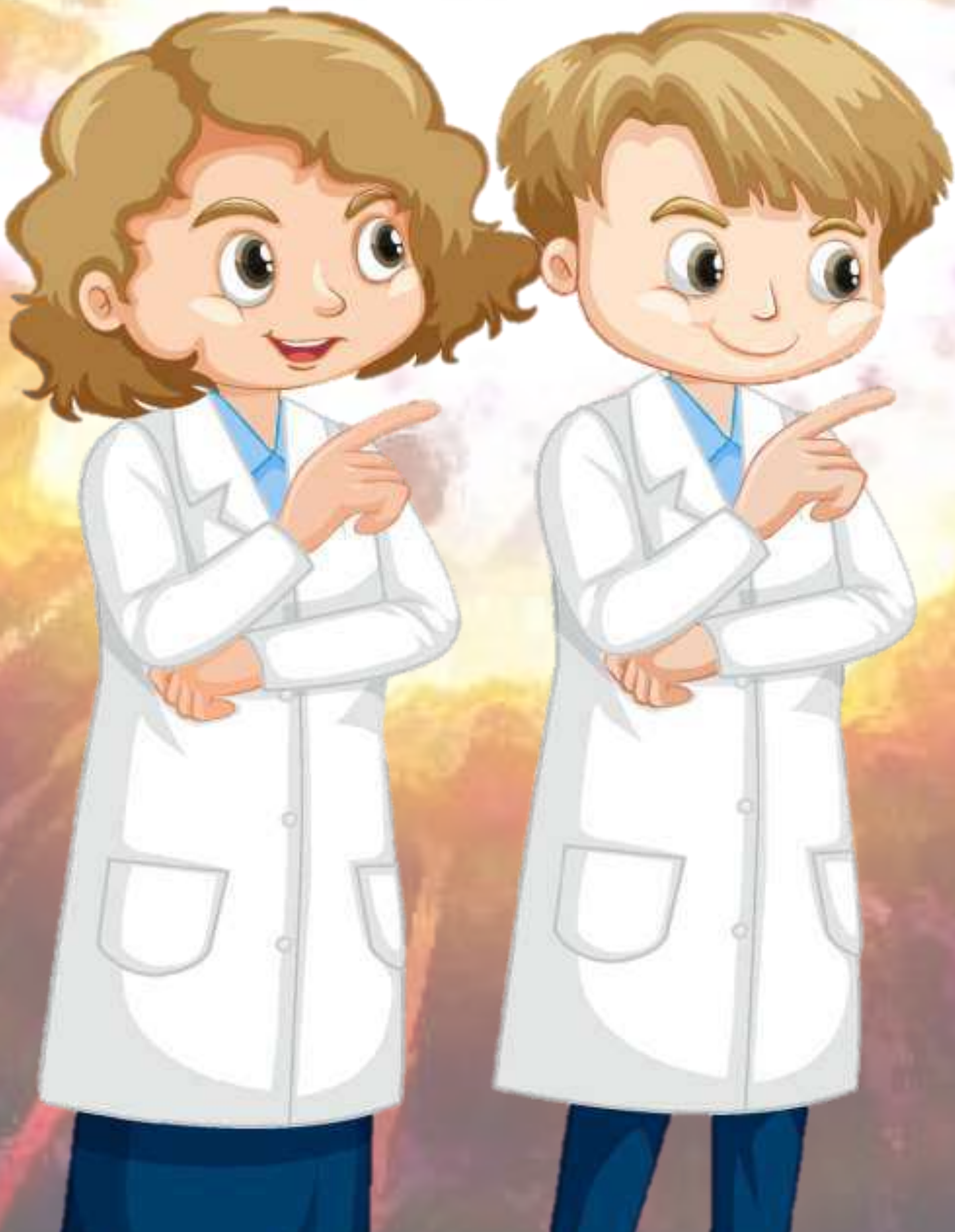
A pulsating red giant in the constellation of Cetus that varies in brightness over 332 days, from being a fourth-magnitude naked-eye star, to being visible only with a telescope.

Algol

An eclipsing binary in the constellation of Perseus that dips from second to third magnitude during 10-hour-long eclipses every 69 hours.

Imposter Eruptions

The most massive stars are doomed to end their lives in supernova explosions, but before they die they become increasingly unstable. This leads to outbursts called supernova imposters, where the star brightens enormously and throws out a huge cloud of gas, before fading and recovering. In the 1830s, a distant star named Eta Carinae erupted to become the second-brightest star in the entire sky. It's on its way to becoming a supernova.



Nova Systems

Another type of eruption is called a nova (Latin for “new star”). These happen in binary star systems where a white dwarf orbits close enough to its companion for its gravity to pull gas away from the other star. The white dwarf builds up layers of gas on its hot surface, which then ignites in a sudden burst of fusion, causing the system to brighten for weeks or months.

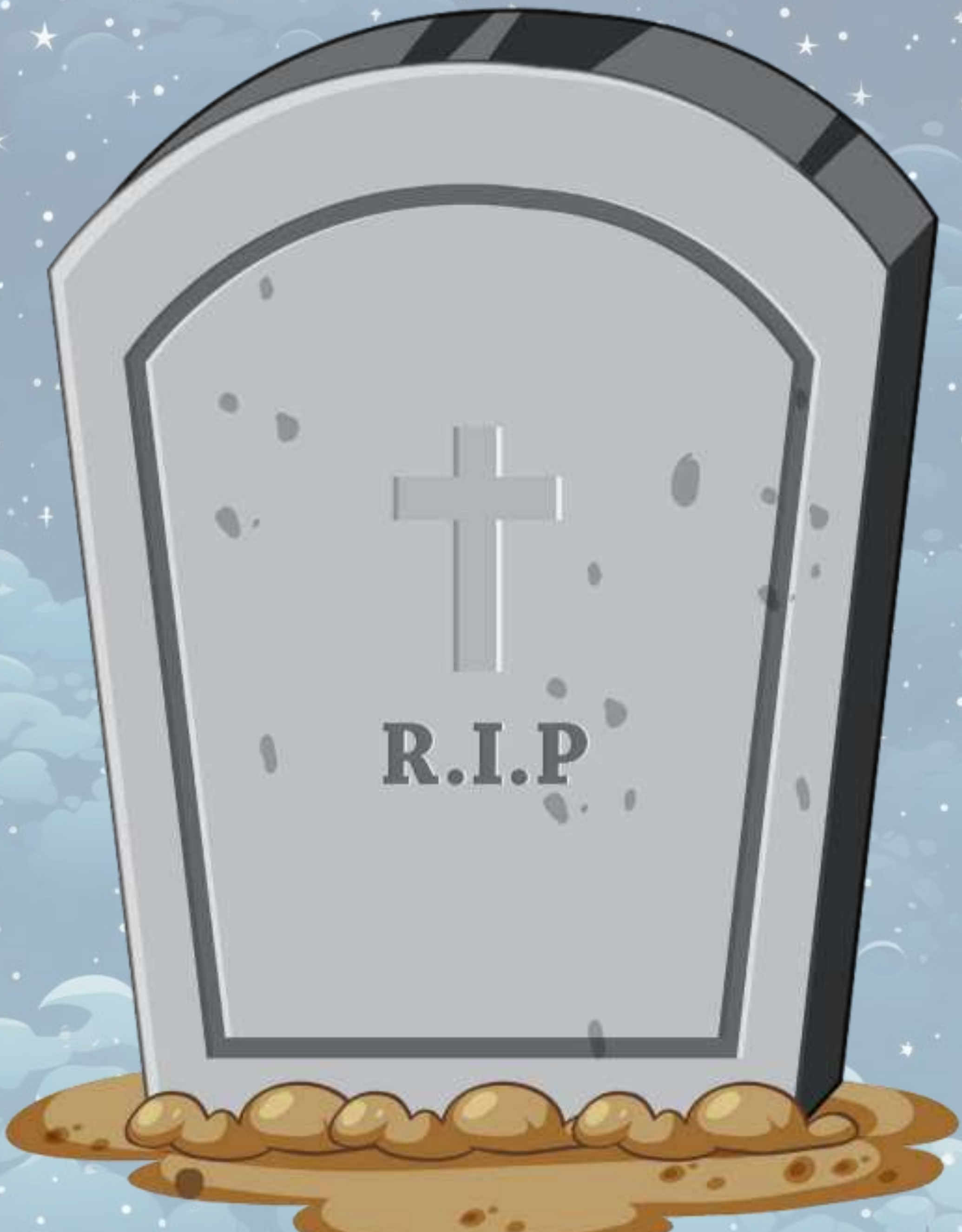
Sooty Stars

Some stars are prone to sudden dips, rather than increases, in their brightness. Some red giants, for example, can create huge clouds of dust at cool spots in their atmosphere. If these are blown out into space, they can block light reaching Earth, even though the star's overall brightness may not have changed.

From 2019 to 2020, the bright red star Betelgeuse in Orion dimmed to two-thirds of its normal brightness when a vast cloud of soot blocked its light. As the dust cleared, astronomers were able to see the star at full brightness again.

How Stars Die

Stars spend most of their lives fusing hydrogen to helium in their cores. Once that fuel supply runs out, the star goes through major changes as it heads towards the end of its life.

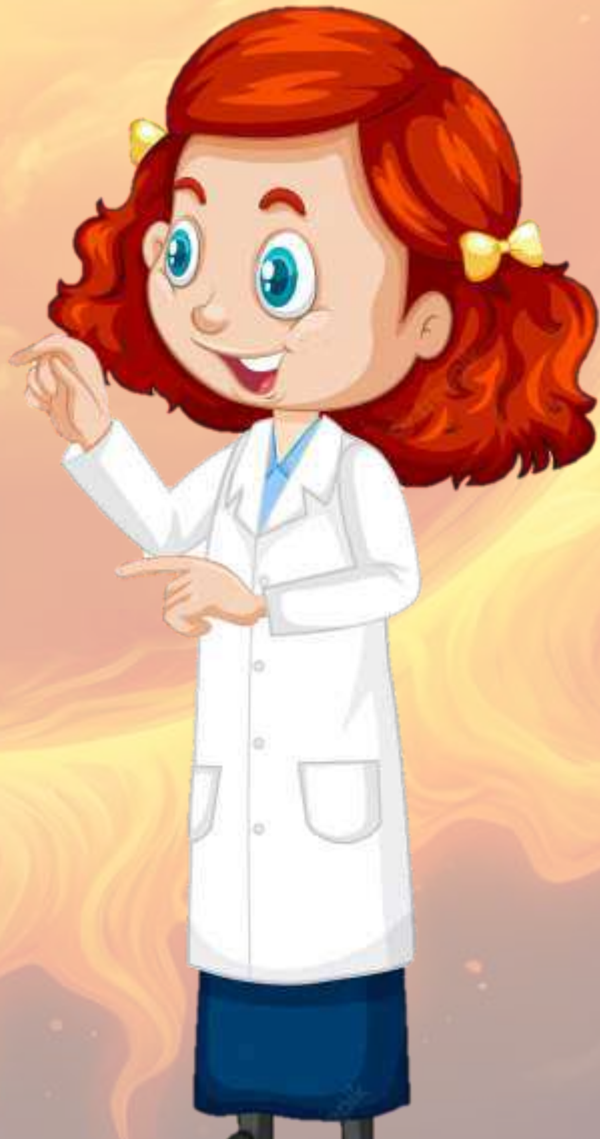


RED GIANTS AND PLANETARY NEBULAE

As the energy coming from a star's core grows weaker, the layers above it start to fall inward. This makes them hotter and denser and means that fusion can begin around the core. The increased heat makes the fusion run much faster, so the star glows brighter. Above the fusion layer, the star then expands and its surface cools, so it becomes a red giant.

Stars like the Sun can bounce back from their first red giant phase, restarting fusion in their cores, which now turns helium into heavier elements such as carbon. Eventually, the helium in the core runs out, and the star swells once again.

The dying red giant pulsates and creates powerful stellar winds that cast its outer atmosphere outwards to form a cosmic smoke ring called a planetary nebula. The nebula glows as it is energized by light from the star’s exposed super-hot core.



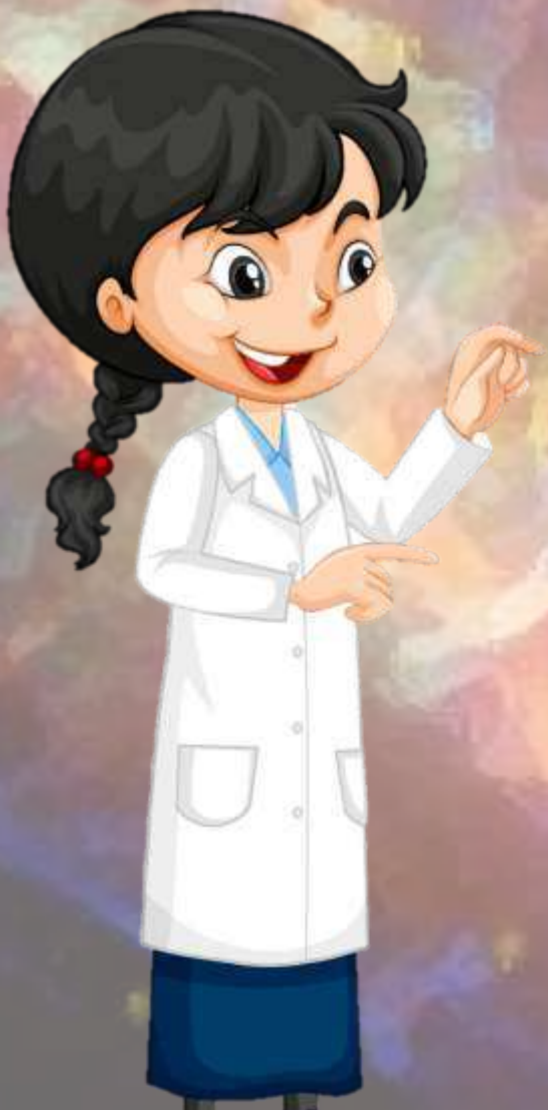
Out of Curiosity

Planetary nebulae have nothing to do with planets. The name comes from the first ones discovered in the late 1700s. several astronomers compared their glowing rings to ghostly planet like disks.

Supergiants and Supernovae

As their lives come to an end, the most massive stars of all, the supergiants, can fuse elements heavier than helium and develop a series of layers, or shells, around their core. Eventually, the star tries to fuse iron nuclei, a step which uses energy rather than generates it. with its energy source lost, the star's balancing act ends, and the core collapses with such force that a shockwave rebounds through the upper layers, tearing the star apart in a huge supernova explosion.

A supernova shockwave produces so much heat and pressure that many rare forms of fusion become possible, with nuclei fusing to form every possible natural element. The energy released by the exploding star can outshine an entire galaxy.



Supernova Remnants

As the explosion of a supernova fades, it leaves behind a rapidly expanding gas cloud called a supernova remnant. Gas inside the cloud may be heated to millions of degrees and emit powerful X-rays as well as visible light. Astronomers can track the expansion of supernova remnants from year to year, as they spread a rich mix of elements made in the supernova across nearby space.

The Crab Nebula in the constellation of Taurus, is the remnant of a supernova that was seen by Chinese astronomers in 1054.

What Stars Leave Behind

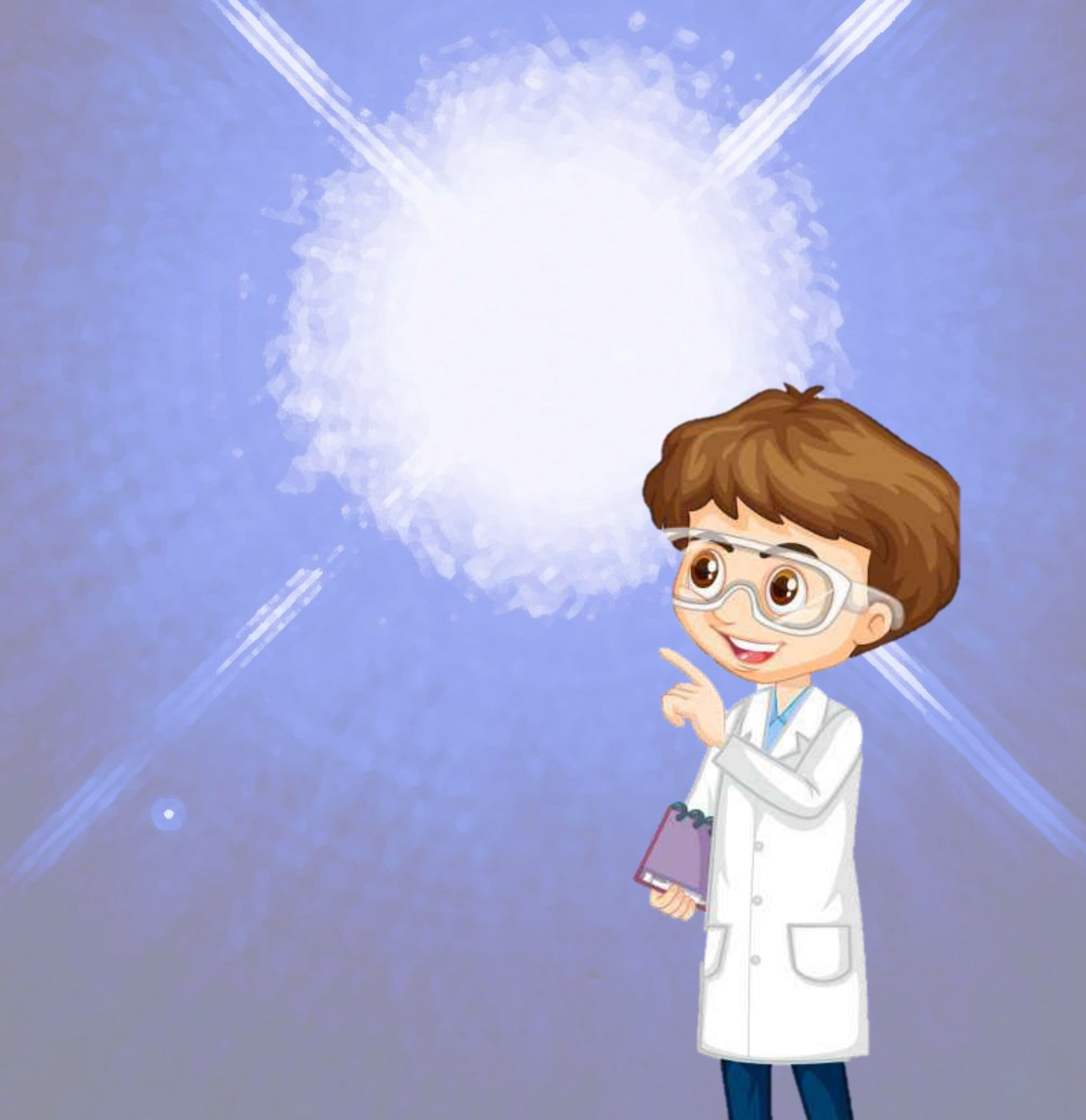
Most stars that die leave behind either a white dwarf or a neutron star. These pack much of the original core's mass into a much smaller space. The most massive stars of al produce an even stranger object – a black hole.

White Dwarfs

A white dwarf is left behind when a star with less than eight times the Sun’s mass sheds its outer layers in a planetary nebula. This leaves the star’s hot inner core exposed, but because nuclear reactions can no longer support it from inside, the core collapses under its own weight until it’s roughly the same size as Earth. The result is a slowly cooling dead star so densely packed that a teaspoon of its material would weigh as much as a full-grown elephant.

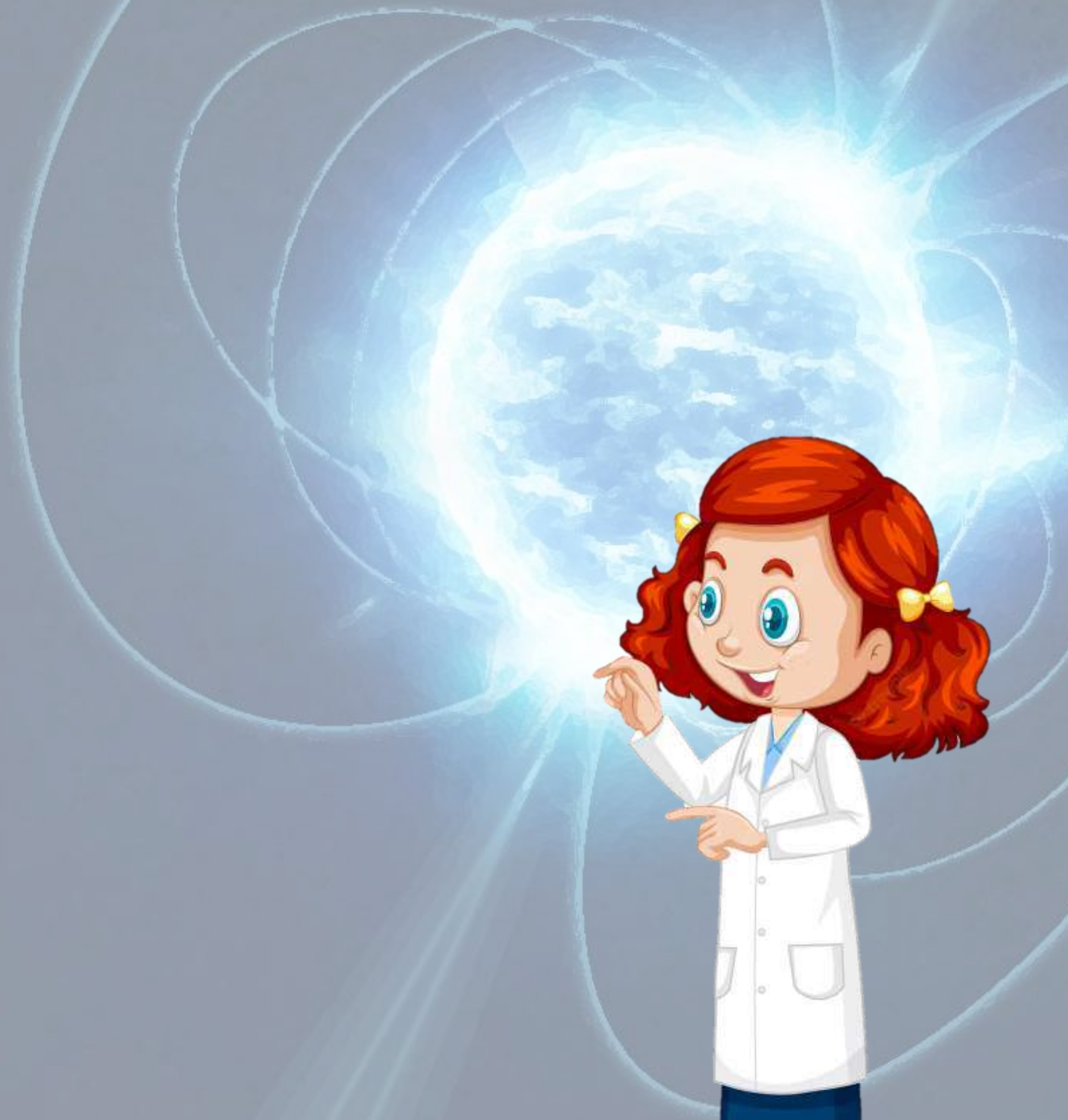
Sirius B

The most famous white dwarf is Sirius B, the faint companion of the brightest star in the sky. Sirius B is all that remains of a star that was once larger and brighter than the main star we know as Sirius A, but raced through its life cycle to leave a white dwarf behind.



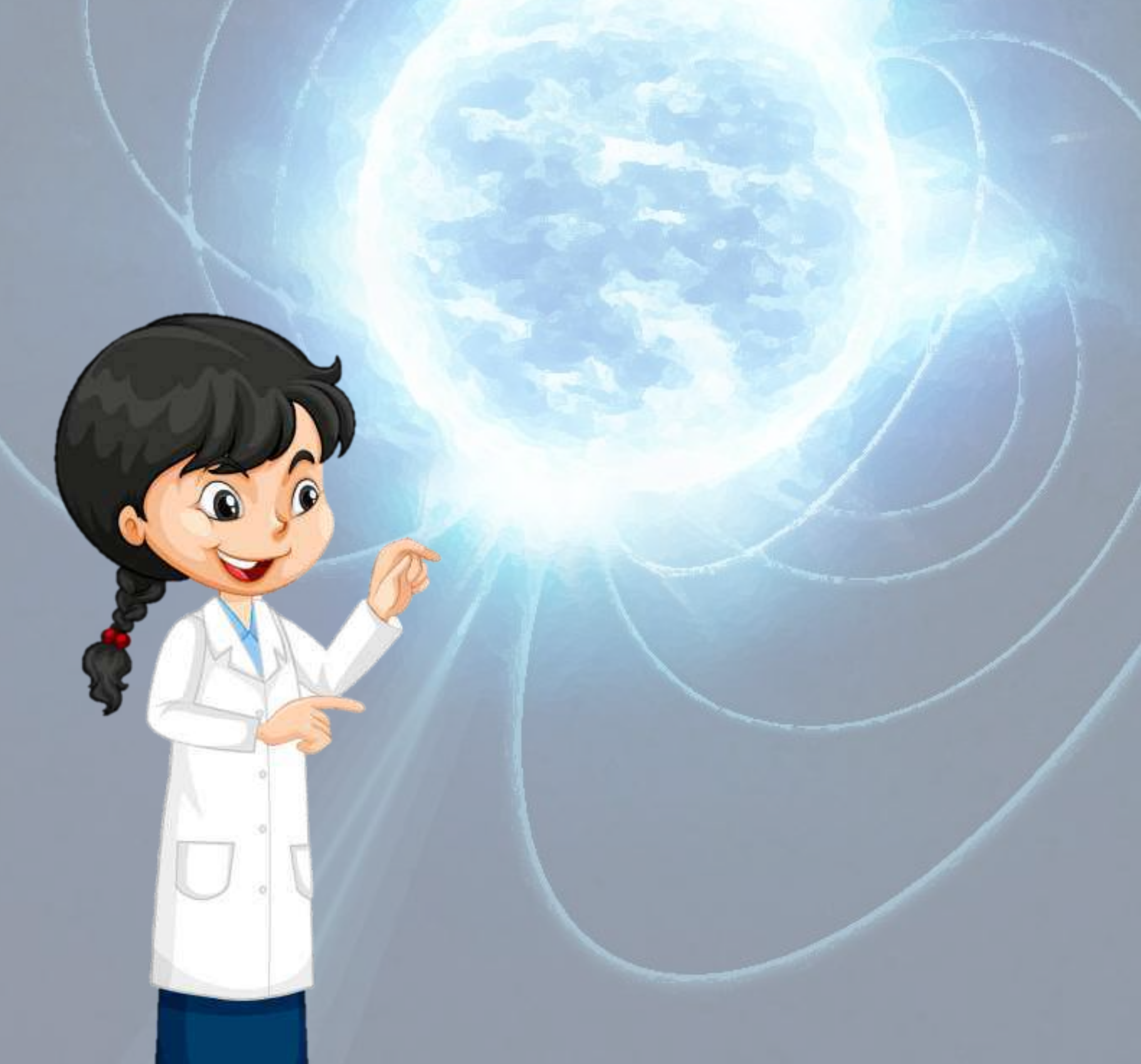
Neutron Stars and Pulsars

When a massive star dies in a supernova explosion, its core collapses so violently that it leaves behind fast-spinning remains called a neutron star, which is even denser than a white dwarf. A neutron star packs about 1.4 times the mass of the Sun into a city-sized ball.



A star's core collapses, it concentrates the original star's magnesium, creating a powerful magnetism, creating a powerful magnetic field that forces out jets of radiation from the poles.

Because the magnetic poles don't usually line up precisely with the star's rotation, the jets sweep around the sky as the neutron star spins. From a distance, the result is a pulsar, a rapidly blinking source of radio waves, light and other radiations..



Little Green Men?

When astronomers, Jocelyn Bell and Anthony Hewish discovered the first pulsar in 1967, they were so puzzled by its regular radio signal that they briefly wondered if it might be a beacon set up aliens. For a time, the pulsar was even known by the codename LGM-I, short for “Little Green Man.”

Back Holes

If the collapsing core of a supernova is heavy enough, then a massive star can leave behind the strangest stellar remains of all, a black hole.

Black home concentrate all the mass of the star's core into a single tiny point called a singularity.

The singularity's gravity is so strong that it pulls in anything that gets too close. Within a certain distance, even light, the fastest thing in the Universe, cannot escape from its gravity, so the singularity is surrounded by a wall of darkness called the event horizon, the outside surface of the black hole.

Out of Curiosity

A black hole itself doesn’t emit light or other radiation, but it can be detected in other ways, if one star in a binary system becomes a black hole, then the other star’s orbit will reveal the mass of its unseen companion. If material from nearby space is falling into the black hole, there are other signs. The material forms a disk that gets hotter towards the middle and emits powerful forms of radiation before it reaches the event horizon. Black holes also have powerful magnetic fields that can fling out some of the shredded material from this disk in high-speed jets

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