

BBC

Sky at Night
MAGAZINE

DISCOVER SPACE

BACK GARDEN ASTRONOMY

All you need to know to begin
your stargazing adventure



THE MOON ♦ THE PLANETS ♦ STARS ♦ CONSTELLATIONS
NEBULAE ♦ GALAXIES ♦ METEORS ♦ COMETS ♦ THE AURORA

WELCOME



My first experience of truly dark skies came, as with most people, as a child while on holiday. We'd taken a ferry from Ilfracombe to the Isle of Lundy in the middle of the Bristol Channel. There, I remember the ocean view out across Atlantic from the top of the lighthouse by day and by night, the absolutely stunning dark skies, the summer Milky Way running up from the horizon.

Of course, I had no real idea what I was looking at, other than a morass of stars. A wonderful, glittering morass, but a morass all the same. And so it is the case for so many. With so much to see, where do you begin?

In *Back Garden Astronomy*, we're aiming to make the night sky a little bit less bewildering. Within, you'll find everything you could possibly need to know for your first night under the stars and beyond. We start with essential knowledge, including why the sky moves, what the constellations are and why you need them, how we map the positions of the celestial bodies and what to look for in your first stargazing session. We move on to equipment next, explaining how to

“We're aiming to make the night sky a little bit less bewildering”

choose a telescope, the value of binoculars and which accessories you might consider. Finally, we present the myriad delights that await – from the magnificent planets to meteors, comets, and the aurora.

This is the beginning of your astro adventure – and just so we're clear, you don't need to be on a small, remote island to get started. There is plenty you can see in the sky from a suburban back garden.

That leaves one last thing to tell you, and that's the astronomer's equivalent of 'break a leg'. I wish you clear skies.

Chris Bramley
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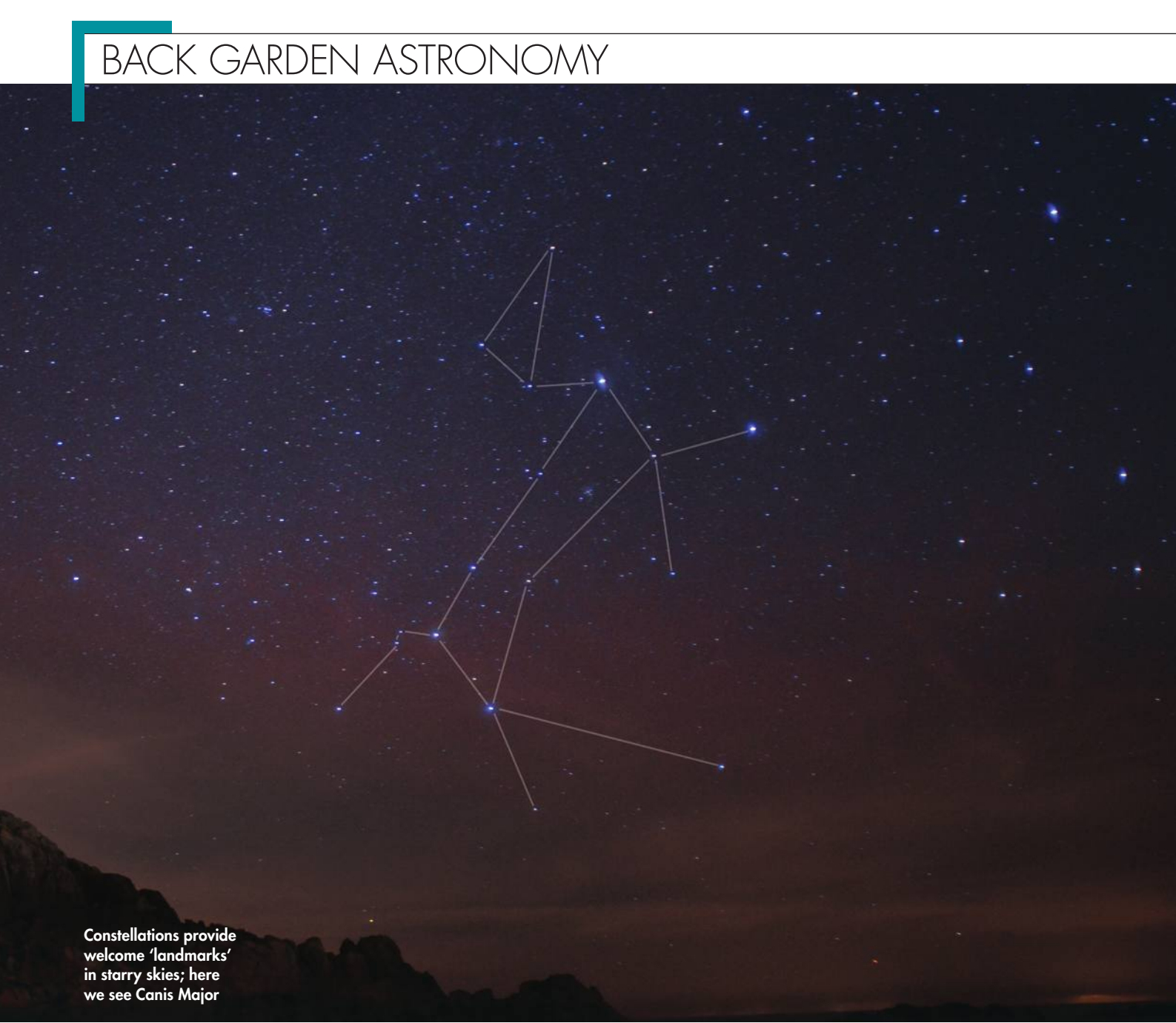
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Constellations provide welcome 'landmarks' in starry skies; here we see Canis Major

STARS, CONSTELLATIONS AND ASTERISMS

There are patterns in the skies that have been observed and mythologised for millennia

There are all sorts of celestial bodies to see in the night sky: the famous planets, wispy nebulae, far-flung galaxies and transient visitors such as comets and meteors. But it is best to start with the stars themselves.

At a glance they appear innumerable, and they may as well be. Under dark skies you can see a few thousand with the naked eye; peer through a pair of binoculars or a small telescope and

tens of thousands are within your reach. All of the individual stars that you can see exist within our Galaxy, the Milky Way, which is home to around 200 billion stars in all.

Stars are balls of hot plasma in which nuclear fusion reactions are taking place. The transformation of light elements into heavier ones, such as hydrogen into helium – and through successive cycles of reactions into carbon, nitrogen and

oxygen and on to iron – releases the energy that causes a star to shine.

Shining surprises

If you scan across the night sky you'll notice that the stars don't all shine with the same brightness, nor are they all the same colour, but a glittering array of rich golds, warm oranges, glinting sapphires and angry reds. The fact we see different colours is down to each star's surface

temperature: the hotter it is, the bluer the light it emits. They become more yellow in the middle of their lives and eventually red as they begin to exhaust their fuel and cool down. Stare long enough, and you will notice that the stars don't stay still, but appear to gradually move against the background sky. We'll find out why that's the case in a few pages' time.

The sky is split into zones called constellations, each of which is based on a pattern of stars that is said resemble an object, an animal or a figure from folklore or mythology. Some of these patterns are large and obvious, but others are much smaller, have fewer bright stars, and require a bit imagination to see what they are named after.

The stars that form the shape that gives each constellation its name are not necessarily related to each other – in fact many of them are vast distances apart, only appearing close in the sky from our perspective on Earth.

Constellation class

There are 88 recognised constellations in modern astronomy, and together they cover the entire sky. These aren't the only constellations that have ever existed – many more have faded into obscurity, been broken up or otherwise abandoned – but they are the only ones you need to know. Most people will be aware of at least 12 constellations, the ones that make up the astrological zodiac. (In astronomy there are 13 zodiacal constellations, the extra one being Ophiuchus).

Because the constellations span the entirety of the sky, by extension this means that every celestial object can be found within a constellation. For bodies beyond the Solar System, such as galaxies and nebulae, the constellation is 'fixed' – they will always appear to be in that one constellation. Bodies within the Solar System, such as the Moon and planets, appear to move across the constellations.

Particularly bright and easily identifiable star patterns are known as asterisms, and they can be comprised of stars within a single constellation or span several. For example, the Plough is entirely made up of stars within the constellation of Ursa Major, but the Summer Triangle comprises the brightest stars of Cygnus, Lyra and Aquila.

It's these brighter patterns that astronomers use as 'signposts' to help them identify other stars and find their way to the faint denizens of the deep sky.

STARTER STAR PATTERNS

Top constellations for amateurs learning the northern hemisphere sky



URSA MAJOR

Represents: The nymph Callisto, transformed into a large bear by Jupiter's jealous wife

Best visibility from UK: All year

Home to: The Plough asterism, easy to split double star Mizar and Alcor



ORION

Represents: Orion, son of Poseidon and the Gorgon Euryale. A gifted hunter

Best visibility from UK: December to March

Home to: The spectacular Orion Nebula and the Orion's Belt asterism



URSA MINOR

Represents: Arcas, son of Zeus and Callisto, turned into a small bear by jealous Hera

Best visibility from UK: All year

Home to: Polaris (the Pole Star)



CASSIOPEIA

Represents: The queen Cassiopeia, mother to Andromeda, sent to the sky as a punishment

Best visibility from UK: All year

Home to: The W asterism



PERSEUS

Represents: The Greek hero Perseus

Best visibility from UK: August to April

Home to: Algol, the best beginner variable star; the radiant of the Perseid meteor shower



PEGASUS

Represents: A winged horse, offspring of Poseidon and Medusa, ridden by Bellerophon

Best visibility from UK: August to December

Home to: The Great Square asterism

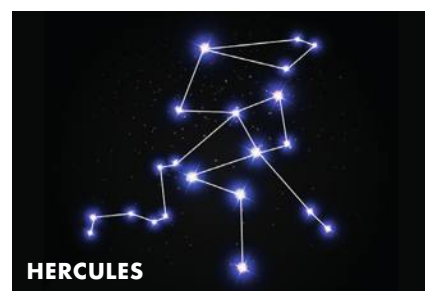


ANDROMEDA

Represents: The princess Andromeda, chained to a rock to be eaten by Cetus

Best visibility from UK: August to December

Home to: M31, the Milky Way's 'big brother' galaxy, 2.5 million lightyears away

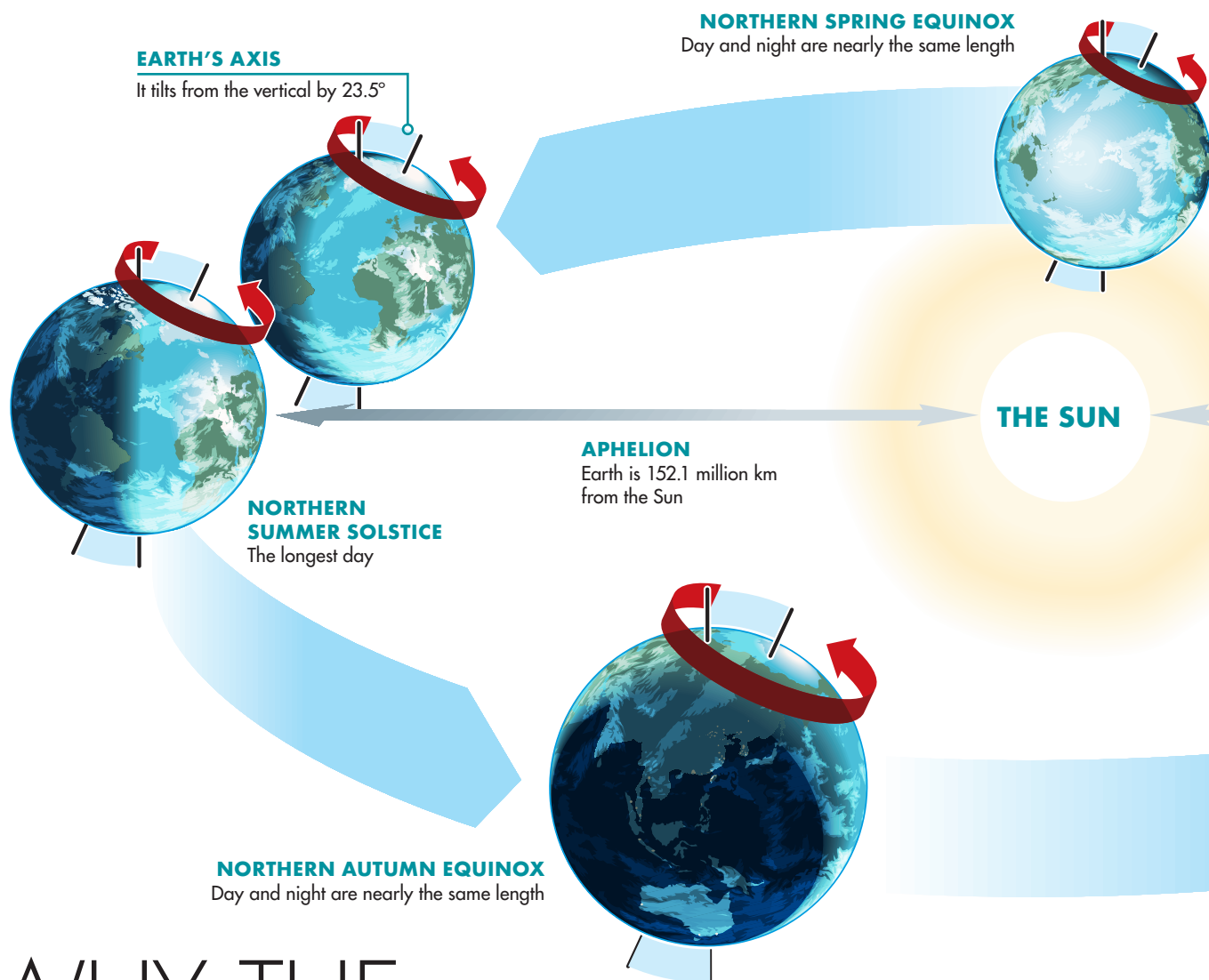


HERCULES

Represents: The Roman hero adapted from the Greek Heracles, with his club raised

Best visibility from UK: April to October

Home to: M13, the brightest globular cluster in the northern hemisphere



WHY THE STARS MOVE

The movement of Earth makes the stars appear to march across the sky

We take it for granted that Earth is spinning and travels around the Sun. We have to, because there is no way any of us can feel the spin or the speed of our planet as it travels through space.

Cast your mind back to when you were seven years old. You're informed that the Sun crosses the sky because Earth turns on its axis once a day. And before you've had time to take this in you're told the Earth takes a year to go round the Sun.

A day in this context is the solar day, the time it takes our planet to complete

one rotation on its axis relative to the Sun, which lasts for 24 hours. A year is the time it takes for Earth to complete an orbit of the Sun. It is the fact that Earth is spinning on its axis that gives us the impression that the Sun and every other celestial object move across the sky.

Many people think that Earth experiences seasons because of its changing distance from the Sun. The distance between Earth and the Sun does change, as our planet's orbital path is slightly elliptical (like a squashed oval)

rather than circular, which leads to a difference of 5 million km between Earth's closest point to the Sun (perihelion), and its farthest (aphelion) – but you might be surprised to know that during northern hemisphere winter, Earth is as close to the Sun as it can get: perihelion happens around 3 January.

The seasons are due to Earth spinning on a tilted axis as it moves around the Sun, which varies the duration of sunlight hitting each hemisphere throughout the year. Model globes of Earth show this:

EARTH'S JOURNEY ROUND THE SUN

As it orbits the Sun, Earth spins on a tilted axis. Either the northern or southern hemisphere gets more direct sunlight, causing the seasons

PERIHELION

Earth is 147.1 million km from the Sun

NORTHERN WINTER SOLSTICE

The shortest day

A YEAR

Earth orbits the Sun in 365.26 days



DAY AND NIGHT

Earth spins on its axis once every 23.93 hours

15 DECEMBER, 7PM



15 JANUARY, 7PM



15 MARCH, 7PM



15 MAY, 7PM



Earth's motion through space causes the stars to rise earlier by four minutes every evening, with the long-term effect of causing the constellations to move over the course of the year

they lean by 23.5° from the vertical. You can see this lean in relation to our orbital path around the Sun in the diagram above.

Poles apart

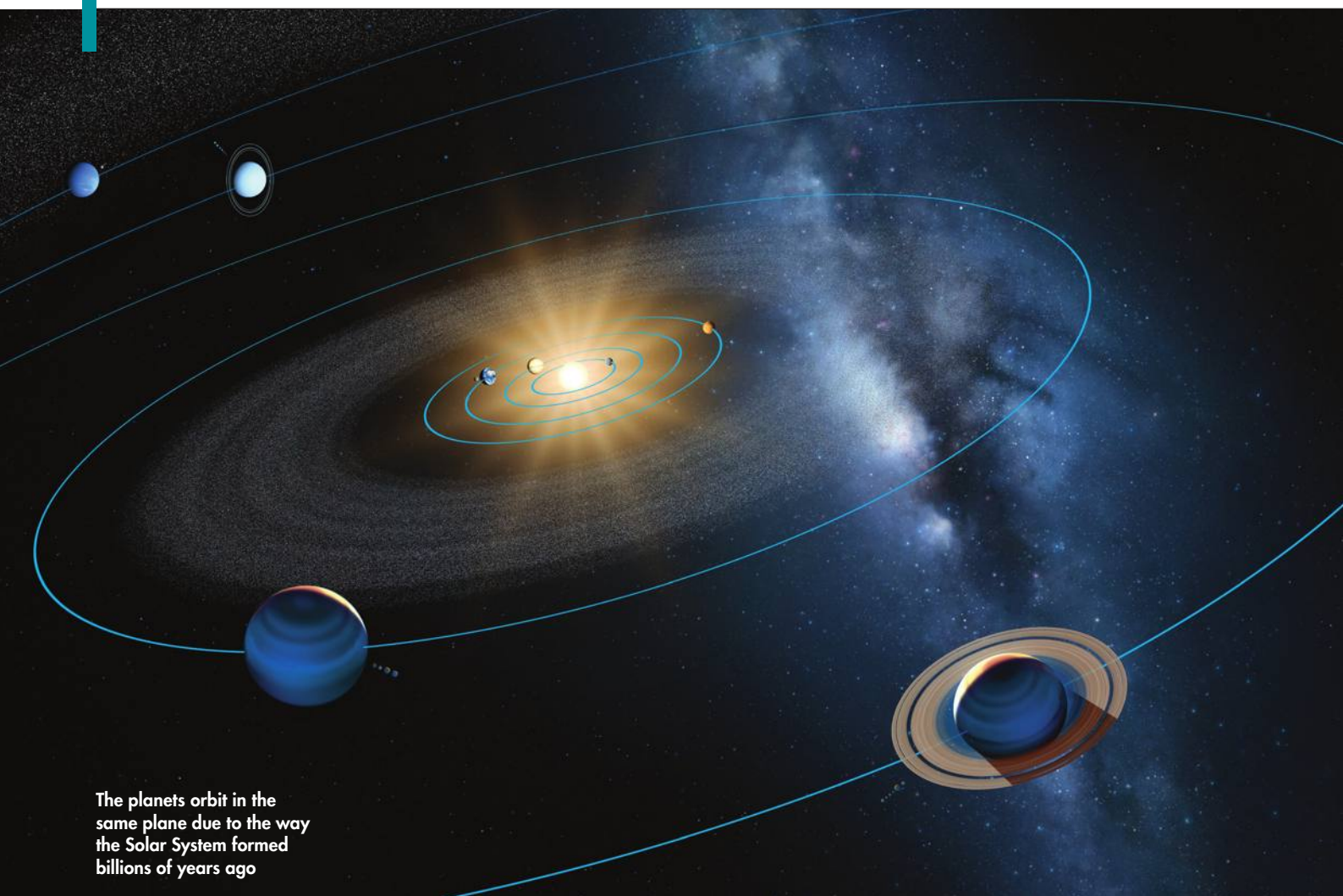
On the day that the north pole is tilted 23.5° towards the Sun, the south pole points away by the same inclination. For the northern hemisphere, the day this happens is the longest in terms of daylight hours (the summer solstice) and for the southern hemisphere it is the shortest (the winter solstice). Six months later, the tilt is reversed so that the south pole points towards the Sun and the

north pole leans away. This marks the shortest day in the northern hemisphere and the longest day in the southern hemisphere. As Earth goes round the Sun, its axis always tilts in the same direction in relation to the stars.

The Earth's motion doesn't just create the seasons. It also explains why our view of the constellations changes. We have covered how the solar day lasts for 24 hours, but Earth's rotation with respect to the stars is nearly four minutes shorter – it only takes 23 hours and 56 minutes for the stars to return to the same position that they were the night before, a period known as the

sidereal day. The reason for this discrepancy is that, from one day to the next, Earth completes $1/365$ th of its orbit around the Sun. So each night, if you were to look due east, you would be looking out onto a slightly different region of space.

This time difference between the solar and sidereal days, although short, causes the stars to rise almost four minutes earlier each day. Over the weeks and months, this causes the constellations visible in the night sky to change. After 12 months, the stars will have cycled all the way back to the same positions they were in a year ago.



The planets orbit in the same plane due to the way the Solar System formed billions of years ago

THE ECLIPTIC

The path of the Sun, where you'll find the rest of the Solar System's planets, is the second of two important lines that astronomers use to divide up the night sky

Up until the early 1600s, the idea that the Sun orbited the Earth was perfectly acceptable to a lot of people. The reason our ancestors believed in this geocentric (Earth-centred) model was, of course, because that's what we see happening in the sky. Or so it appears.

From our planet, it looks as though the Sun moves around us over the course of a year. As we now know, this isn't really the case – in truth our planet orbits the Sun, as do all the other planets in the Solar System. But this illusion forms one of the most important markers on the sky, the line we call the ecliptic.

The ecliptic is the invisible path that the Sun traces as it moves around the sky. Think of it like this: if the Sun were to drop breadcrumbs behind it like a

cosmic Hansel and Gretel, this is the trail it would leave behind. The Sun can always be found on the ecliptic – it never deviates from it. But it also represents something else: the orbital plane of our planet.

Disc formation

All of the planets in the Solar System occupy orbital planes similar to our own. This is because when the Solar System formed, billions of years ago, dust and

gas surrounding our nascent star was pulled into a disc under the influence of gravity. The planets we know today all formed within this disc, and hence they all occupy planes similar to the ecliptic. In plain terms, when the planets are visible, they will always be near to this line.

It's this 'coplanar' nature of the Sun and planets that allows many of the events that captivate astronomers to occur so often. When our Moon and

“The planets all formed within a disc, and hence they all occupy planes similar to the ecliptic”

the Sun line up, we see an eclipse. When a planet appears to be in the same region of sky as another, or our own Moon, we call it a conjunction. Even seemingly rare events, such as a transit of Venus, are really quite frequent in cosmological terms.

Equal nights

The two points at which the ecliptic crosses the celestial equator mark the moments when the hours of day and night are roughly the same. These are known as equinoxes, from the Latin for 'equal night'. In the northern hemisphere, the equinox in mid-March heralds spring, while the one in mid-September signals the beginning of autumn. At these two points in its orbit, Earth has no tilt relative to the Sun.

From the March equinox, the days slowly lengthen until mid-June, when Earth reaches the point in its orbit where it is at its greatest tilt relative to the Sun – a solstice. This is both the first day of summer and the longest day of the year. At this point, the ecliptic and the celestial equator are at their farthest apart.

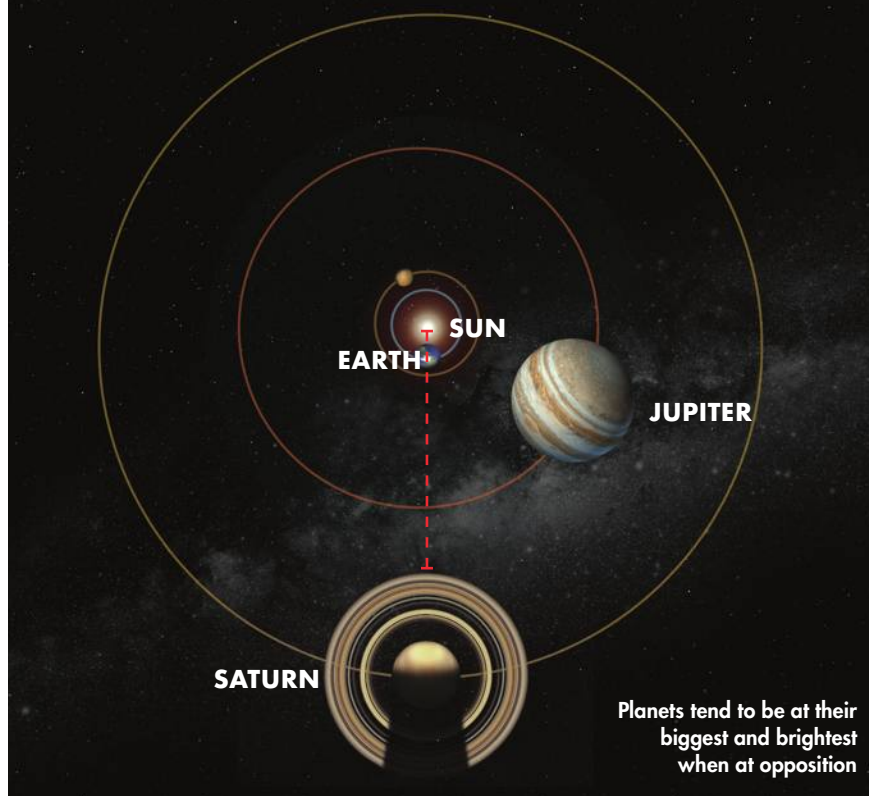
There's another solstice six months later in mid-December, when the tilt of the poles is completely reversed in relation to the Sun. In the northern hemisphere, this marks the start of winter and is also the shortest day.

PLANET OPPOSITIONS

Oppositions, another result of the Solar System being coplanar, occur when the Sun, Earth and another planet form a line, with Earth in the middle. From our perspective, the planet is in the opposite position in the sky from our star. As such, only the superior planets – those with

orbits farther out from the Sun than Earth's – reach opposition.

A planet at opposition is usually at its closest to Earth, and therefore appears larger than at any other time. Due to its position relative to the Sun, a planet can be brighter than usual too.

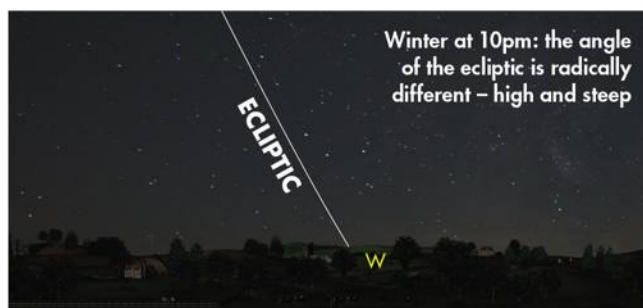
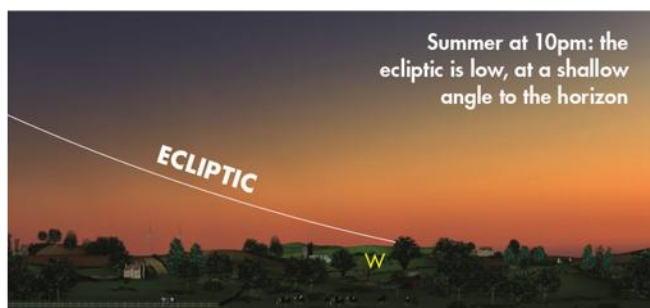


THE SHIFTING ECLIPTIC

The Sun always sits on the ecliptic, so it's easy to work out where the line is on any clear day. Looking at the whole year, we know that the

Sun – and hence the ecliptic – is higher in the sky through the day in the summer months and lower during the winter. But what about at

night? If you can work out where the ecliptic traces across the sky after darkness falls, you can work out where you might spot a planet.



SPRING

The ecliptic sits low down in the morning, but in the evening it stretches high across the sky from east to west, making the dusk skies the best time to see Mercury and Venus, as they never stray far from the Sun.

SUMMER

In summer the ecliptic sits at a low elevation by dusk, so any planets are mired in the atmospheric murk. The ecliptic's orientation swings from northwest-southeast in the evening to northeast-southwest in the morning.

AUTUMN

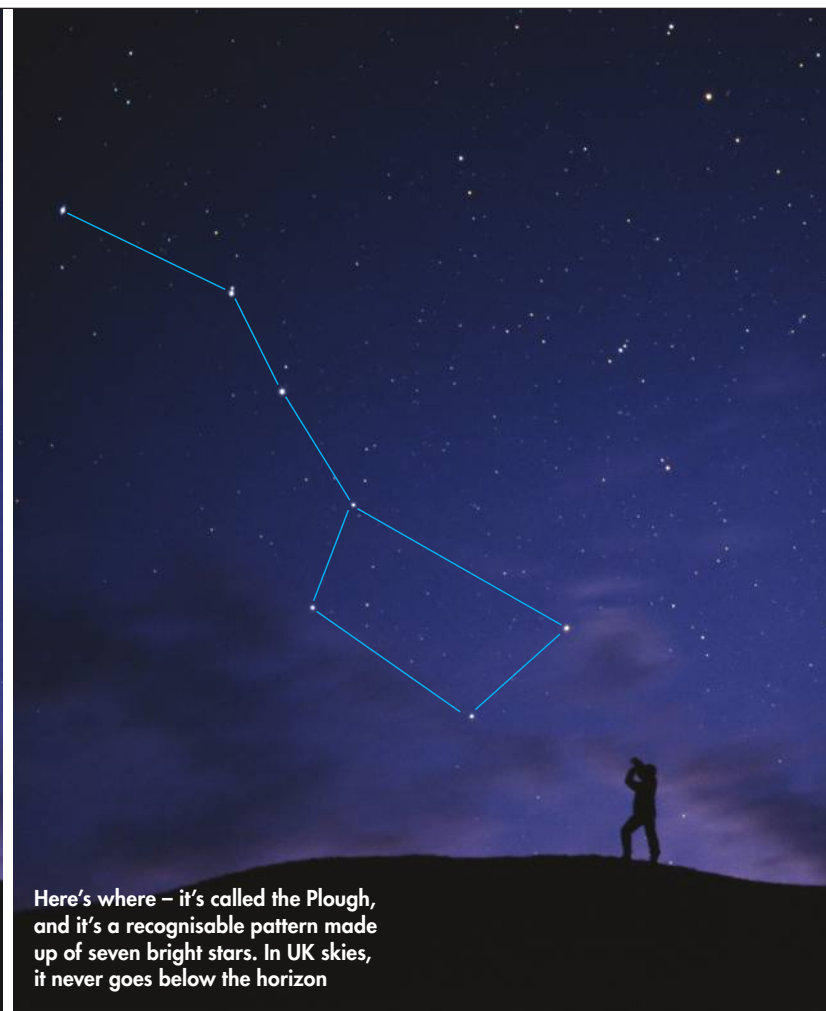
In a reflection of the northern hemisphere spring, the ecliptic's evening path is now low down, but in the morning it stretches high across the sky from east to west. This makes the dawn skies the best time to see Mercury and Venus.

WINTER

The ecliptic path in winter is quite high when it's dark, and moves higher until it reaches maximum elevation at midnight. This is a great time for observing planets, as you're able to look at them though less atmosphere.



So, you've found a nice dark spot in the northern hemisphere for your first night of stargazing, but where do you begin?



Here's where – it's called the Plough, and it's a recognisable pattern made up of seven bright stars. In UK skies, it never goes below the horizon

YOUR FIRST NIGHT OUTSIDE

Begin your astronomical adventure by learning your way around the Plough asterism and using it to find the pole star

Standing under a starry sky, awash with pinpricks of light, can as bewildering as it is mesmerising. So, once you have a clear night, where do you begin? Assuming you live in the northern hemisphere at a mid-to-high latitude – which do if you live in the UK – your first goal is to find the group of seven stars known as the Plough. The Plough is an asterism within the constellation of Ursa Major, the Great Bear; an asterism being a bright and recognisable pattern of stars often (but not always) from a single constellation. This one happens to look like a saucepan, and it marks the bear's tail and back.

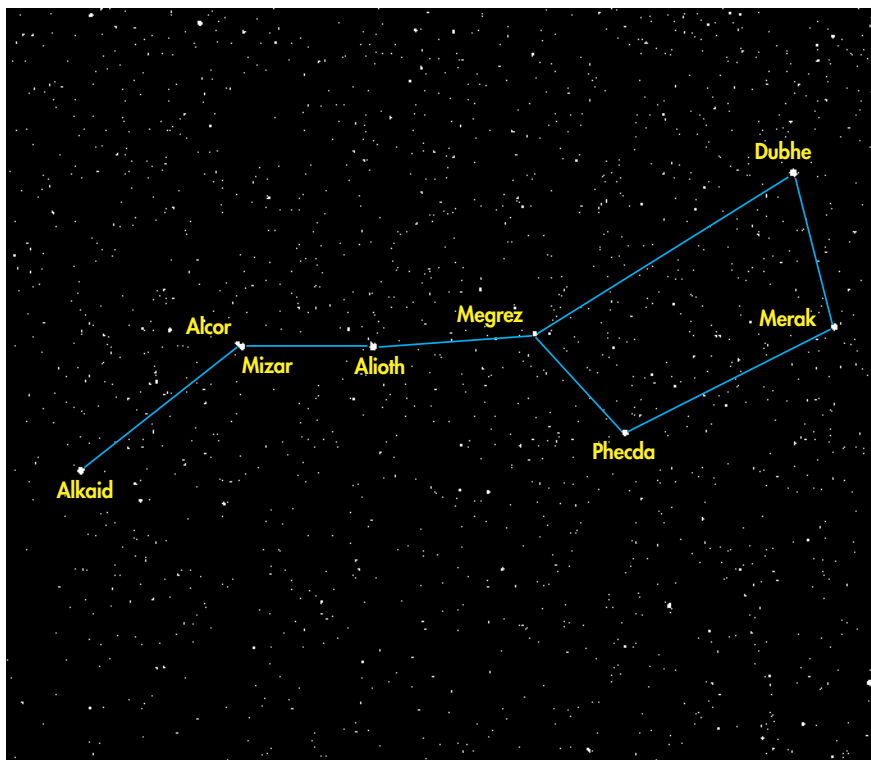
The reason we're starting here is not only because the Plough is bright and

easy to find, but because we have to take into account the rotation of the Earth. Just as the Sun rises, moves over the sky and sets, so many of the stars do the same thing at night – though not all. From UK latitudes some stars remain above the horizon all night long, including those in the Plough. As the Earth itself moves around the Sun we also see a slight shifting of stars night-by-

night, which means some constellations enter and leave our skies over the course of a year. Again, the Plough is a constant presence, visible throughout the year. Combined, this means it is a handy pattern to learn, and a good place from which to launch your stargazing quest and get to know the starry skies.

The Plough can be found in the northern sky. To locate it, you need to

“Just as the Sun rises, moves over the sky and sets, so many of the stars do the same thing at night”



Get to know the stars that make up the Plough: Alkaid, the Alcor-Mizar double, Alioth, Megrez, Phecda, Dubhe and Merak. In case you're wondering, these stars all owe their names to medieval Arabic astronomers. American sources may refer to it as the Big Dipper



A long-exposure photograph centred on Polaris will show the way the heavens rotate

know which direction north is. You could use the Sun to guide you: north will be to the left where the Sun rises, or to the right of where the Sun sets. The highest the Sun gets in any day is due south, so of course north is opposite to this. Alternatively, you can use a compass.

Name that star

It's worth noting that each of the Plough's seven stars has a name; not all stars do. We're going to start with the star at the crook of the Plough's handle, which is called Mizar. It has a companion that's not quite as bright, and together they form a well-known double star that is visible to the naked eye. Look above and left of Mizar at a distance of about one-third of the diameter of the Moon, and you should be able to spot the companion, Alcor. This is the first of many double stars waiting for you.

Both Mizar and Alcor are white stars, but on the other side of the Plough you'll find your first coloured star. The top-right star of the Plough's bowl has a slight orangey-yellow hue. This star is called Dubhe, and it is the brightest star in the asterism. The best way of seeing its orangey-yellow hue is to compare it with the star below it in the Plough: the pure white Merak. If you flip your gaze between the two, the orangey-yellow colour of Dubhe should become readily apparent.

Now that you know where Dubhe and Merak are, you've discovered two of the most useful stars in the night sky. These two stars are known as the Pointers, because they can make it easy to locate the Pole Star, which astronomers know by the name Polaris. We'll do this using a technique that has been tried and tested over thousands of years, known as star hopping.

Starting at Merak, draw an imaginary line through Dubhe and keep going. The next star of any note you come across is Polaris. Don't expect this to be a super-bright example of stellar marvellousness – it isn't. Polaris is just an ordinary-looking star. It's famous because it sits almost directly above Earth's north pole and so appears to stay practically in the same place as our planet spins, with the rest of the night sky rotating around it.

This is just the start. In the Plough, you have a launch pad from which you can explore many more stars and constellations.

THE SECRETS OF STAR HOPPING

You don't need to completely memorise the night sky to find things to look at; instead, you can jump from one star to another

For those new to astronomy, staring into the clear night sky and seeing hundreds of points of light can lead to a common conundrum: how will I ever find my way around this bewildering confusion of stars?

One way is to buy a telescope with a mount that can take you to any object in its database at the press of a button. But there is a much simpler alternative, tried and tested over thousands of years, which experienced observers still use to find objects we cannot see with the naked eye. We call it star hopping.

The brighter stars form recognisable patterns – constellations, asterisms, and even simple geometric shapes – and we can use those patterns as ‘jumping off

points to less obvious and fainter regions or objects of interest.

The key to star hopping is accurately estimating directions and distances. For directions, use pairs of bright stars that approximately align to your target, imagine a line between them and follow it to your destination. Alternatively, if you know the angular distance your target is from another star (how far away it is in degrees), you can use your hands to estimate those distances. Stretched out at arms length, your hand is a rudimentary angle measurer, offering easy approximations of angles ranging from 1° to 25°.

When you transfer these skills to binoculars or telescope finders, make sure you know the angular diameter of

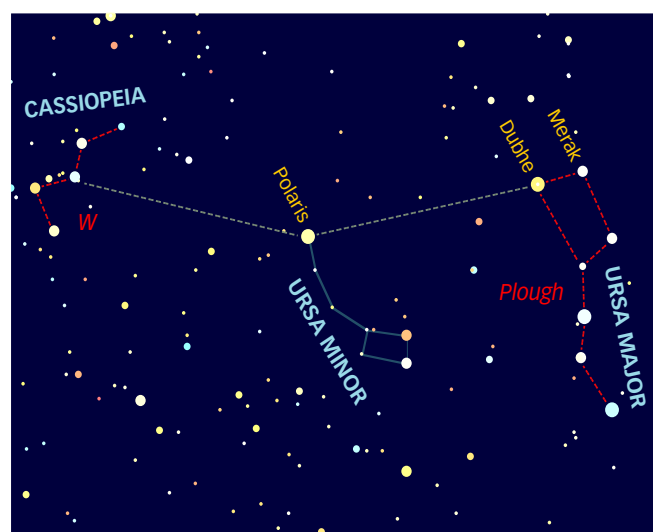
the field of view, as you can use this to estimate angular distances.

Surprising size

One thing you will need to practice is relating the scale of your star chart to the scale of the sky. Find a constellation or asterism in the sky and then locate the same group on your chart: you will probably be surprised at how much bigger it looks in the sky! Now look for other prominent groups of stars on your chart and locate them in the sky, trying to keep the relative scales in mind. Reverse and repeat. Take your time with this: you are building a firm foundation that will serve you well for the rest of your observing career. Here are a few to get you started.

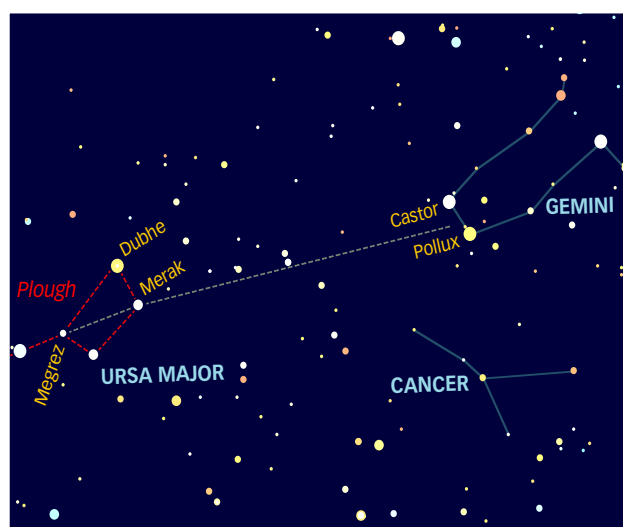
SIGNPOSTS IN THE STARS

The Plough is a useful asterism to know. Here are four celestial regions it can point you towards



THE W OF CASSIOPEIA

You've already seen how to locate Polaris. Now continue this imaginary line onwards for the same distance that you've already come from the Plough, take a slight bend to the right, and you arrive at the constellation of Cassiopeia (the Queen), which appears in the form of a W of stars.



CASTOR AND POLLUX IN GEMINI

To get to Castor and nearby Pollux, the main stars of Gemini (the Twins) start from the Plough star Megrez. Draw an imaginary line to Merak, diagonally opposite it, and keep going. Almost halfway to your target you'll pass the two stars that form the front paws of Ursa Major.

UNDERSTANDING THE NIGHT SKY

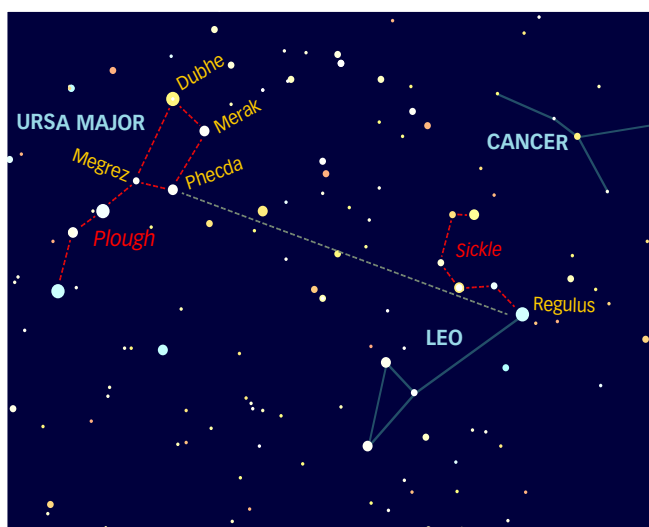
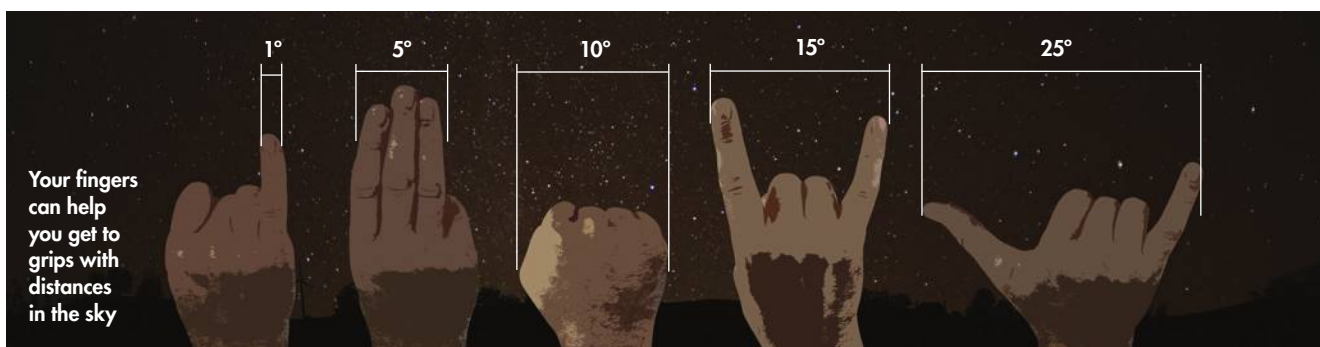
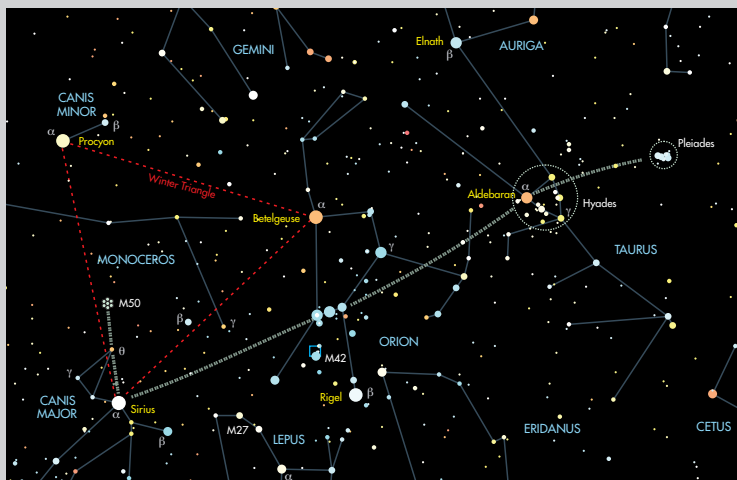
ADVANCED STAR HOPPING FROM ORION'S BELT

NAKED EYE Extend a line through Orion's Belt northwest for 22° , where you will find the bright orange star Aldebaran at one tip of a V of stars. This is the Hyades open cluster. Now extend it 14° farther on and you will find the Pleiades open cluster, commonly called the Seven Sisters.

NAKED EYE From Orion's Belt, look about 20° southeast to reach the bright star Sirius which, with Betelgeuse, is part of

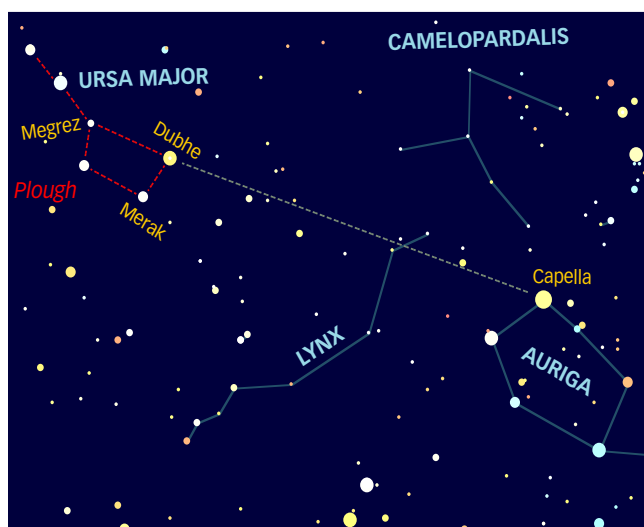
the Winter Triangle asterism. Imagine that Sirius and Betelgeuse are the base of an equilateral triangle. At the other apex is the third star, Procyon.

BINOCULARS Start at Sirius and look 5° towards Procyon, where you will find the star Theta Canis Majoris. Nearly the same distance farther on lies M50, an open cluster that will appear as a fuzzy patch in your binoculars.



REGULUS IN LEO

To get to Leo (the Lion) you also start from Megrez, but this time trace a line through Phecda, the star below it in the Plough. Continuing on this line will take you to Regulus, the brightest star in Leo. The head of the Lion is made by an easily seen hook-shaped asterism called the Sickle that works up from Regulus.



CAPELLA IN AURIGA

To find Auriga (the Charioteer) start again from Megrez, but this time take a route through Dubhe, to its right. After an expanse of emptiness that includes the very faint constellation of Camelopardalis (the Giraffe) you will eventually arrive at the yellow star Capella, the brightest star of Auriga.

START STARGAZING THE RIGHT WAY

Practical advice for a good first night under the stars



1. NO EQUIPMENT NEEDED

There is a widespread perception that to be a 'proper' astronomer you need to have a telescope. This is complete rubbish. There are a host of things you can see with the naked eye alone – from the constellations to meteor showers, the band of the Milky Way and even the occasional galaxy. If you want to take things further, consider buying a pair of binoculars before a telescope – you get to see more of the night sky without having to deal with the practicalities of setting up.

2. WRAP UP WARM

We know this sounds obvious, but astronomy involves a lot of time spent being still, so it's important to guard against the cold. Multiple thin layers of clothing are a good idea, as are waterproof shoes, a hat and gloves. If you have pages to turn or equipment (especially touchscreens) to operate, fingerless gloves may be best.



3. FIND SOMETHING TO LIE ON

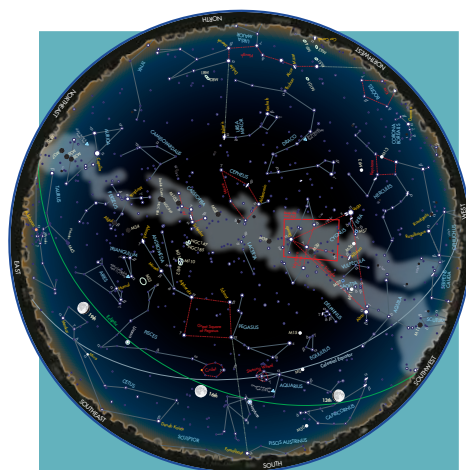
You'll find that you get neck ache within a very short amount of time if you stand still staring upwards at the sky. So avoid the pain entirely by finding

something you can lie back on. A reclining garden chair, a sunlounger or even an old-fashioned deck chair is ideal, but your spine will thank you even if all you have to hand is a camping groundsheet, a yoga mat or a blanket to spread over the grass.



4. LET YOUR EYES ADJUST

This is crucial. If you go outside from a brightly lit room, you'll probably only see a handful of stars. Wait and let your eyes adjust to the darkness – ideally for 30 minutes – and you'll notice an incredible difference. Doing so should allow you to see much fainter stars.

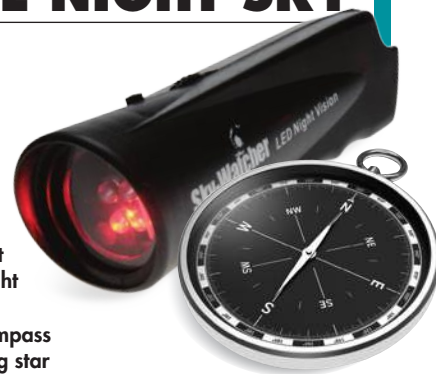


5. PICK UP A STAR CHART

We publish one of these in *BBC Sky at Night Magazine* every month, and they are a great way to learn your way around the night sky. You can begin by identifying patterns of bright stars. From there you can gradually learn your way around the constellations, and before too long they'll become familiar and you'll be able navigate your way around the night sky without reference to a book or chart. They frequently list the locations of prominent deep-sky objects, which, being dim, can be harder to locate.

6. TAKE A RED TORCH AND A COMPASS

Your eyes are dark-adapted, yet you'd still like to see charts and be sure that you're not about to step on a hedgehog. The answer is a red-light torch, as dark-adapted eyes are much less sensitive to red light than they are to white. You can buy dedicated red-light torches, or make a DIY one by taking a normal torch and fixing a piece of red acetate over the front. A compass will help you find north, and is useful not only in using star charts but also in setting up your telescope mount.



7. AVOID ARTIFICIAL LIGHTS

Make sure any light sources are obscured from your observing position, as they will prevent your eyes from acclimatising to the darkness properly. If you can get out to the countryside you can take advantage of properly dark skies – this will really make a difference.



8. TAKE YOUR TIME

The fact is that there is an awful lot to get your head around, and no one has ever looked at the night sky and instantly understood how to find their way around. Not even Sir Patrick Moore was immune to this; he did it by learning one new constellation each night.



ADVANCED TECHNIQUES

Get better views of night sky objects with these tips

AVERTED VISION

Averted vision is a way of seeing faint celestial objects through binoculars or a telescope more easily by looking using peripheral vision. This involves glancing to the side of your target rather than directly at it, to use your eye's more sensitive rod cells.

A good way to practice using averted vision is to seek out the Blinking Planetary Nebula, designated NGC 6826 (RA 19h 44m 48s, dec. $-50^{\circ} 31' 30''$). When viewed directly through a small telescope, the nebula's bright central star overwhelms the view; looking with averted vision reveals the nebula itself, which appears to 'blink' on and off as the viewer shifts their gaze.

LIMITING MAGNITUDE

It's really worthwhile getting to know the faintest stars you can see from where you live – in other words, the limiting visual magnitude of the skies above you.

As light pollution increases, so the number of stars you can see decreases. If your skies are very bad you may be limited to the second magnitude or worse, with only a handful of the brightest stars on show.

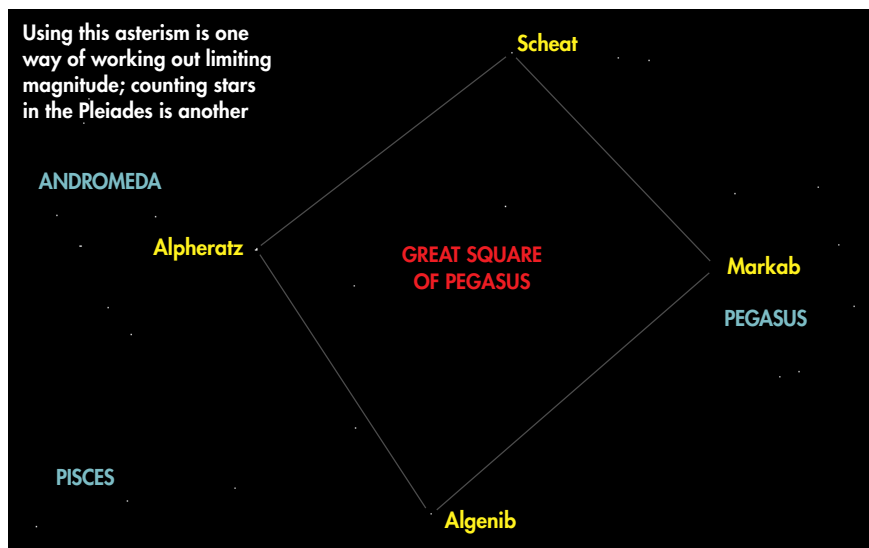
One way of determining your limiting magnitude is to use the Great Square of Pegasus asterism – it is comprised of four

stars, the dimmest of which is mag. +2.8. You need to wait for your eyes to adapt to the dark to do this accurately, so head outside a good 15 minutes in advance to acclimatise. Then look for the Great Square – with your eyes only – and count the number of stars you can see inside it. If you can't see any, then your limiting magnitude

is +4.0. If you can spot three, your site's limiting magnitude is +4.75; at five stars it is mag. +5.25; at nine stars it is mag. +5.75. If you can count all the way up to 13 stars, you can see down to mag. +6.0.

Try this on a few nights. You may find the atmospheric conditions are different each time, and this can affect what you can see.

Using this asterism is one way of working out limiting magnitude; counting stars in the Pleiades is another



HOW TO DEAL WITH LIGHT POLLUTION

Don't despair of your garden – there are many ways to fight glow and glare

Britain is blossoming with accredited dark skies. It was only in late 2015 that a 2,170km² chunk of Snowdonia National Park became the third swathe of Wales to gain endorsement from the International Dark Skies Association, meaning that nearly 18 per cent of the country now boasts night skies recognised for their lack of light pollution. It is the most recent member of a slowly growing club, joining Exmoor in Devon, Galloway Forest Park in Dumfries and Galloway, and the Isle of Sark in the English Channel to name a few.

These designations are great news in terms of protecting the skies for future generations, and indeed for a spot of practical astronomy if you are lucky enough to live within travelling distance of any of them. But for many of us, stargazing is the preserve of the back

garden, and that often means dealing with light pollution.

This vexation comes in two flavours: sky glow, the rusty orange haze cast by the massed lights over a wide area, and local glare from line-of-sight sources – nearby streetlights, security lights, car headlights, even the light emanating from your neighbours' windows. Sky glow washes out the night and blots out the stars, while local sources are more prone to ruining your night vision. Under dark skies you can see stars down to mag. +6.5 with the naked eye, but light pollution can cut this to just a handful of first magnitude stars. Another common casualty is the pale band of the Milky Way, the river of stars that stretches high across the autumn skies.

Not surprisingly, the worst places for light pollution are the major towns and

cities. However, stargazers who live in more rural locations can be just as bothered by the annoying bright light from a neighbour's badly adjusted security light. Thankfully, there are a few things you can try to mitigate their unwanted effects.

Focus on what you can fix

For local sources of light pollution, your biggest consideration is where you position your scope in your garden. You need to find a spot that puts a barrier between yourself and the irksome source of glare. That barrier could be anything – a fence, a tree, the side of a building – so long as it isn't so big it also masks the part of the sky you want to look at.

If no suitable cover already exists, consider making some. A simple 'shield' consisting of a frame of wood or plastic

The light pollution is particularly troublesome over cities, but there will be pockets of darkness wherever you are





Your scope should ideally be situated on grass, shielded from external lights and pointing between or away from heat sources such as rooftops

pipework with blackout cloth stretched across it can work wonders, though make sure you brace the legs. The last thing you want is for it to catch the wind and clatter into your setup mid session. If DIY is not your thing, ditch the frame and simply hang the blackout cloth from a washing line, a garden trellis or similar, though again you will need to weigh it down to forestall lift-off.

Getting to know your neighbours better can also go a long way, if the lights that are causing you consternation come from their home. Many astronomers report reciprocal arrangements that work well in this regard – in return for feeding the cat while they are on holiday, they may acquiesce to, say, drawing their curtains when you are in the garden observing. You can only ask.

Your next consideration should be optimising the equipment you have, and this can help you deal with both glare and generic glow. Your goals are to maximise the contrast of what you see and minimise the ingress of stray light. Opt for eyepieces that have eye guards to block extraneous light, and make sure their lenses are free from eyelash grease as this can degrade the view. As an

alternative to eye guards, throw another piece of blackout cloth over your head, just as a Victorian photographer would. It may look a little odd (another great reason to tell your neighbours what you are up to) but it can help you establish and preserve your night vision.

Adding a light pollution filter to your setup, and depending on your target, colour or narrowband filters, can increase clarity and enhance detail. At the opposite end, a dew shield can also help stop light getting in; if you don't own one, you can make one cheaply from a rolled up camping mat. If the glow above you is so bad that you have trouble navigating to your intended targets in the first place, purchasing a Go-To mount may be the least stressful way to reach them.

In many places there is a noticeable drop off in sky glow after midnight as more and more people and businesses turn off their interior lights, meaning the wee hours often offer better views. You may also find that your local authority turns off streetlights at a set time. If sky glow is a particular problem, make sure you wait until your chosen target is well clear of the horizon before you attempt to view it.

WHAT IF MY GARDEN IS HOPELESS?

If you truly cannot find a way to cut out the glare, see past the glow or simply don't have the space to create a dark corner, try looking for an alternative, darker location nearby. It's imperative to do some research before heading out in this case: once you have found a potential location, make sure that you have a right to be there and above all that it is safe at night, especially if you will be observing alone. Another option is to join your local astronomical society. Many host observing evenings for members, and it is likely that some of your fellow stargazers will be able to suggest some good observing spots in your area.



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INTRODUCING PLANISPHERES

Even in the digital age, the planisphere is an invaluable aid when you need to get your bearings in the night sky

As a budding stargazer, a planisphere is one of the greatest aids to helping you find your way around the night sky. They don't look like much – usually they're just two discs of cardboard or plastic fastened together with a central pin. But this deceptively simple design belies the fact that a planisphere allows you to work out which bright stars are in the night sky on any date and at any time throughout the year.

This basic knowledge is useful for casual stargazers and more serious

amateur astronomers alike. For example, it could help you to learn the constellations or even just identify a bright star you can see at a particular time. It can also be a useful aide-mémoire when planning an observing session.

Although the two discs are pinned together, they can still be rotated independently of each other. Printed over most of the lower disc are the stars,



constellations and brighter deep-sky objects that you can see from a given latitude. Marked around the outside of this lower disc are the days and months.

Talking circles

The upper disc will be slightly smaller than the lower one or will have a clear rim, so you can still see the day and month markings underneath. It also has an oval window in it, revealing part of the star chart on the lower disc. The edge of this window represents the horizon with appropriate north, south, east and west markings, and everything within it is the visible sky.

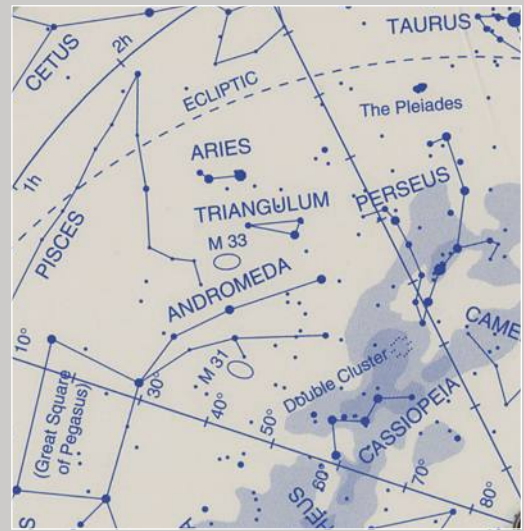
Just like the lower disc, the upper disc has markings around its edge. In this case, they denote the time of day. By lining up the date and time, the stars visible in the window will match the ones in the night sky at that time. We explain how to use the planisphere in the step-by-step guide below.

On some planispheres, you may notice that some of the stars (particularly those near the southern horizon) are rather stretched out. This is because the sky is 3D and it is being forced onto a 2D disc, so it has to be expanded towards the edge of the chart. This tool should be an essential part of your night-sky

THE PLANET PROBLEM

Why can't I use a planisphere to find the planets or the Moon?

Planispheres show objects that are 'fixed' in the night sky relative to Earth – that's why they can be used year after year. However, this means that they can't predict the location of planets or the Moon. Some manufacturers try to overcome this by printing details of planetary locations for several years on the back, but there is also a line printed on the chart itself that can help. The ecliptic, often shown as a dotted line, marks the plane of the Solar System, in which most of the planets orbit the Sun. If you discover a 'star' in the sky that's not shown on the planisphere, then it is probably a planet.



arsenal. Planispheres are cheap, easy to use, robust (plastic ones more so), lightweight, portable and – best of all – they don't need electricity.

The one important point to keep in mind when using one is that planispheres are designed to work at specific latitudes. If you try using one too far north

or south of the location it has been designed for, you'll find that the stars don't appear in the right positions. UK latitudes vary from 50°N (southern England) to 60°N (northern Scotland). Both Philip's and the David Chandler Company produce planispheres for this region.

HOW TO USE A PLANISPHERE

1 GET YOUR BEARINGS

There's one thing you need to know before using a planisphere, the cardinal points from where you live. If you don't have a compass, use the Sun. It rises roughly in the east and sets roughly in the west



2 SET THE PLANISPHERE

Let's say you're heading out at 9pm on 15 January. Align the 9pm marker on the upper disc with the 15 January marker on the lower disc. The stars in the oval window should now match those in the skies above.



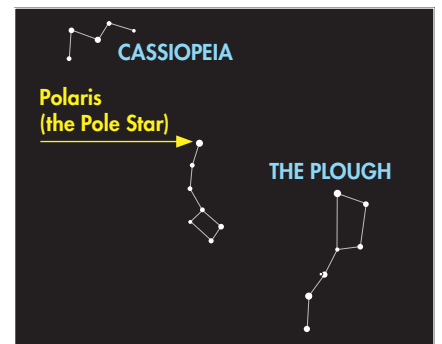
3 HOLD IT UP

To start with, look north, holding the planisphere so that the word 'north' is at the bottom. If you change the direction you're facing, move the planisphere round so that the corresponding compass point is now at the bottom.



4 STAR HOPPING

The central pin represents Polaris and the north celestial pole. Just to its lower right will be the seven bright stars of the Plough. Use these and the five stars forming the W shape of Cassiopeia to get to know the constellations.



THE VALUE OF BINOCULARS

Telescopes aren't the only option for observing astronomical objects

Starting out in astronomy and wondering what to buy for your first telescope? There's a simple answer to that question: don't buy one, buy two. Two small ones that are joined with a hinge so that the distance between them can be adjusted to exactly match your eyes. We are of course talking about binoculars – a valuable tool in the armouries of most active observers.

There are hundreds of astronomical bodies that a pair of binoculars will bring into view for you. Not only will they let you see many more objects than you can with the naked eye, but the detail and colour in those objects become a lot richer.

With binoculars, the Coathanger asterism in Vulpecula actually looks like a coathanger and the Orion Nebula becomes a fantastically detailed painting of light. The Milky Way is no longer a tenuous glowing band, but a knotted tangle of stars, interspersed with mysterious dark patches. Albireo goes from being an ordinary-looking star that marks the head of Cygnus

to an exquisite binary juxtaposition of gold and sapphire. And you can easily see galaxies by the light that left them millions of years ago, when our ancestors were thinking about leaving the trees.

Binoculars are still suitable even if you want to do 'serious' astronomy. There are

that the binoculars let you find as you cast your gaze among the stars. Before you even realise it, you have begun to learn the sky and you'll soon be able to navigate around it better than the entry-level Go-To telescope you nearly bought instead.

Best of all, you can have this complete observing system for two eyes for less than the price of one reasonably good telescope eyepiece.

“Binoculars are classified by two numbers: their magnification and aperture”

What to look for

Binoculars are classified by two numbers that refer to their magnification and aperture. A 10x50 pair of binoculars has a magnification of 10x, and each of the objective lenses has an aperture of 50mm. These numbers also enable you to calculate the size of the circle of light – or 'exit pupil' – that emerges from the eyepieces: all you have to do is divide the aperture by the magnification. This means a 10x50 pair of binoculars has an exit pupil of 5mm. The exit pupil should be no larger than the dark-dilated

variable star observing programmes specifically for binoculars, and their portability makes them ideal for taking to the narrow track where a lunar graze or asteroid occultation is visible.

Alternatively, you could wrap up warm, lie back on your garden recliner and just enjoy the objects



Don't be tempted to go for the biggest binoculars you can afford – larger pairs are harder to hold steady, and large night-sky features can be better seen with less magnification

CAN I USE ANY OLD BINOCULARS?

In principle, yes: even plastic-lensed 4x20 toy binoculars can show you astronomical objects that you otherwise couldn't see, such as the moons of Jupiter. If you already have a pair of small binoculars, for example a 6x30 or 8x32 pair, try them out under the stars: you'll be amazed at how much more you can see. The optical quality will also make a difference and you may find that there are things you can see with good-quality small binoculars like 8x42s that are beyond the capability of an entry-level 15x70. But avoid zoom binoculars: good ones don't exist.



Even toy binoculars give a decent view of the night sky if the kids will let you have them



The bigger your binoculars get, the harder they become to hold steady. A mount will provide a stable viewing platform for larger binoculars, and camera tripod adaptors are available

pupils of your eyes: a pupil of anywhere between 4–6mm is fine for your first pair of binoculars.

Larger apertures potentially show you more, but may need mounting if you want steady views over prolonged periods. Common sizes are:

- **8x40, which almost anyone over the age of 10 can hold steadily**
- **10x50, which most adults can hold**

steadily (this size is a popular compromise between size and weight)

- **15x70, which really needs to be mounted, although they can be briefly handheld**

You should also check that the distance between the eyepieces, or 'interpupillary distance' will adjust to your eyes. If you wear glasses, ensure that the binoculars have enough distance

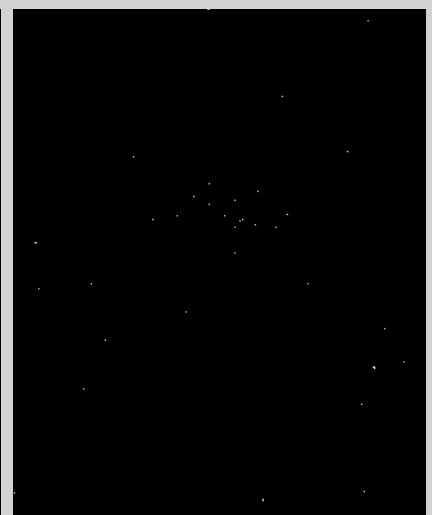
('eye relief') from the eyepiece to your ideal eye position; 18mm or more should be fine.

There are two basic types of binoculars: Porro-prism and roof-prism. In any price range, roof-prisms are lighter, but Porro-prisms tend to have better optical quality. Once you've decided on size and type, get the best quality you can for your budget and start exploring the night sky.

BETTER THAN A TELESCOPE?

If your passion is planetary detail, close double stars, globular clusters or planetary nebulae, then consider buying a telescope. But for the rest of the visible Universe, binoculars are the better option. Setting up handheld binoculars takes a few seconds, and even mounted ones can be set up in a few minutes, so you'll be observing long before your Go-To telescope-using buddies are ready to start.

Many objects are ideally framed in the wider field of handheld binoculars: asterisms like Kemble's Cascade or the Leaping Minnow overflow most telescope fields, as do large open clusters such as the Pleiades and the Beehive Cluster. Even large faint objects like the Triangulum Galaxy and the North America Nebula can be easier to see in budget 10x50 binoculars than in amateur telescopes of several times the price.



The Pleiades (left) and the Beehive Cluster (right) are popular targets for binoculars

YOUR FIRST TELESCOPE

Buying a telescope can sometimes be a daunting task. We cut through the jargon to help you make up your mind

Astronomy is an immensely rewarding adventure full of exploration and discovery. Planets, stars, nebulae and galaxies, among many other wonders, are all waiting to amaze and inspire you. But buying your first telescope is not always an easy business. There's

an array of equipment and technical terminology waiting to confuse and entice you as you start your journey of discovery. We'll take a straightforward look at the four most common types of telescope and how they work, to give you a better idea of your options.



REFLECTOR

Reflectors were invented by Sir Isaac Newton and use a specially curved main mirror to collect celestial light. In the Newtonian design (shown here), the light collected by the primary (main) mirror is reflected and focused back up the telescope's tube to a much

smaller, flat, 'secondary' mirror supported by wires in the centre of the tube; this secondary is angled at 45° to send the light beam out to the side, passing through a focuser and eventually into an eyepiece, which is what you look through.

SECONDARY MIRROR

The secondary mirror is located towards the front of the telescope tube and is set at a 45° angle. It reflects the light into the focuser, which is located on the side of the tube.

SLOW-MOTION CONTROLS

Slow-motion controls allow you to move the telescope manually in one or both axes. They allow you to carefully place a celestial object in the centre of the eyepiece's field of view and then keep it there.

COUNTERWEIGHTS

One or more counterweights are necessary to balance the telescope on the mount. This reduces the strain on any motorised drives and can prevent the scope from falling over.

JARGON BUSTER

APERTURE

The most important specification of a telescope. Aperture is the size of the main mirror or lens, usually given in inches.

MOUNT

The mount holds the telescope and allows you to point it at the sky. There are two main types:

EQUATORIAL

Mounts aligned to the night sky's axis of rotation. They use a coordinate system mapped onto the sky similar to longitude and latitude.

ALT-AZIMUTH

Mounts that move in two axes: azimuth (measured in degrees from north) and altitude (up and down from 0° at the horizon to 90° right above your head).

FINDERSCOPE

The finderscope helps you to home in on your target. It can either be a miniature telescope with a wide field of view or a zero-magnification red-dot finder.

FOCUSER AND EYEPIECE

The focuser allows you to adjust the position of the eyepiece in order to focus the view of what you're looking at. Eyepieces enlarge the view produced by the telescope. Different eyepieces can be used to increase the apparent size of your target.

TUBE RINGS AND DOVETAIL BAR

The tube rings hold the telescope tube and allow you to rotate it to a suitable viewing position. The rings attach to a 'dovetail' bar (the black bar running between the two tube rings), which is used to secure the tube to a mount.

PRIMARY MIRROR

Light from distant objects is collected by the primary (main) mirror, which is at the bottom of a Newtonian telescope's tube. The mirror is specially curved so that it focuses light back up toward the secondary mirror.

POLARSCOPE

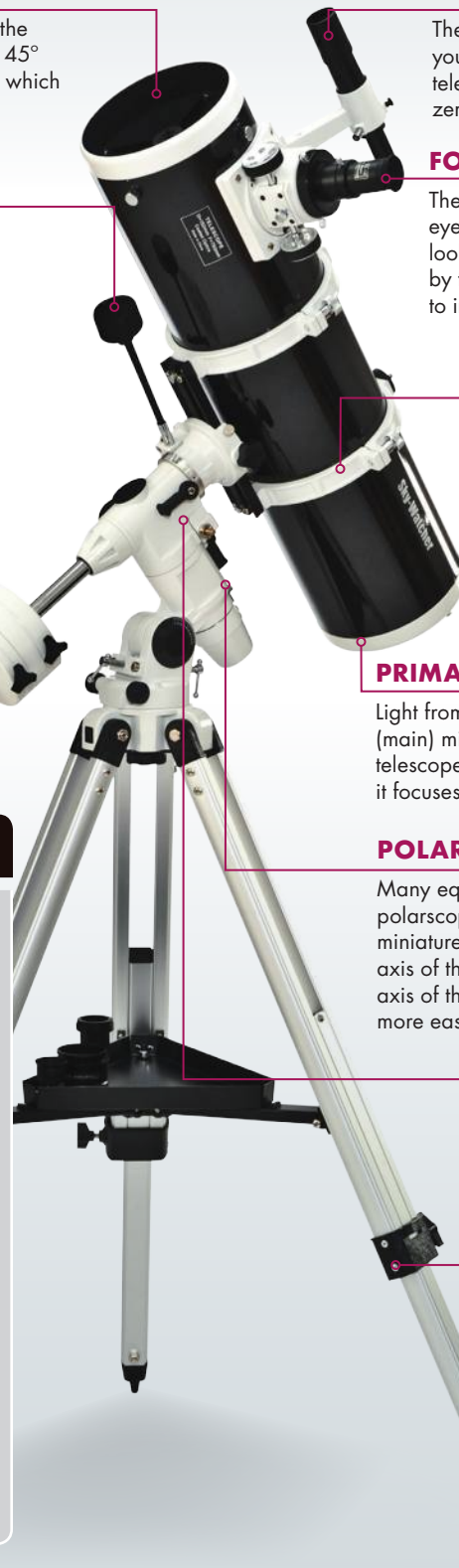
Many equatorial mounts have a built-in polarscope. The polarscope is effectively a miniature telescope that allows you to align one axis of the mount very accurately to the rotation axis of the night sky, allowing you to track the stars more easily.

MOUNT HEAD

The mount head for a Newtonian telescope is usually an equatorial design (see left). This allows you to align the mount to the night sky to track stars more easily.

TRIPOD

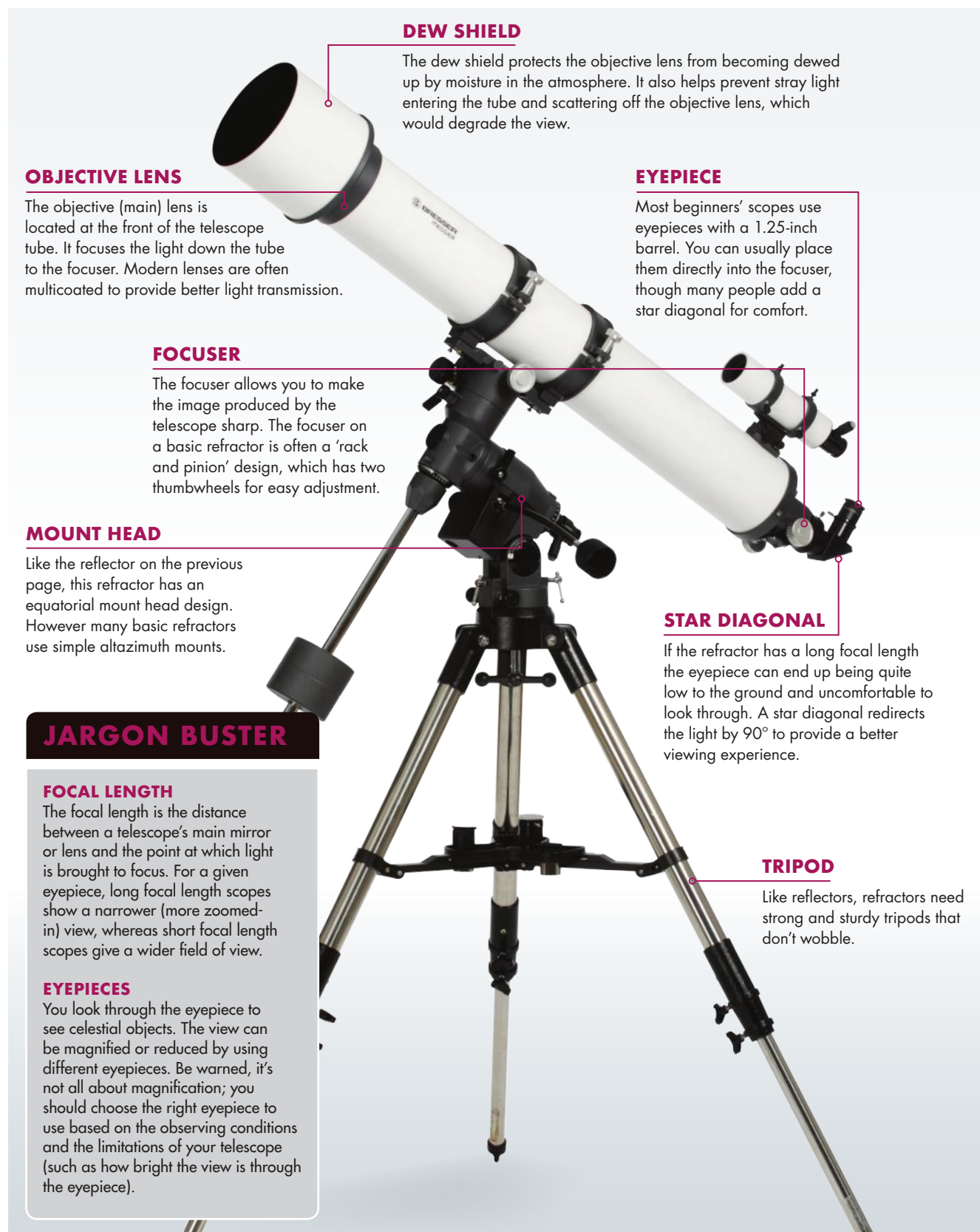
The tripod provides the support for the whole system. They are usually made of aluminium and have adjustable legs so that you can vary the height of the telescope for ease of use. The tripod needs to be stable and give firm support.



REFRACTOR

Refractors are the oldest and simplest telescope design – this is the type used by Galileo to record the phases of Venus, among other things. Refractors have a curved lens at the front, which focuses the

light down the tube directly to the focuser. A star diagonal, which bends the light through 90°, is often added between the focuser and the eyepiece to make viewing more comfortable.



DEW SHIELD

The dew shield protects the objective lens from becoming dewed up by moisture in the atmosphere. It also helps prevent stray light entering the tube and scattering off the objective lens, which would degrade the view.

OBJECTIVE LENS

The objective (main) lens is located at the front of the telescope tube. It focuses the light down the tube to the focuser. Modern lenses are often multic coated to provide better light transmission.

FOCUSER

The focuser allows you to make the image produced by the telescope sharp. The focuser on a basic refractor is often a 'rack and pinion' design, which has two thumbwheels for easy adjustment.

MOUNT HEAD

Like the reflector on the previous page, this refractor has an equatorial mount head design. However many basic refractors use simple altazimuth mounts.

EYEPIECE

Most beginners' scopes use eyepieces with a 1.25-inch barrel. You can usually place them directly into the focuser, though many people add a star diagonal for comfort.

STAR DIAGONAL

If the refractor has a long focal length the eyepiece can end up being quite low to the ground and uncomfortable to look through. A star diagonal redirects the light by 90° to provide a better viewing experience.

TRIPOD

Like reflectors, refractors need strong and sturdy tripods that don't wobble.

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FOCAL LENGTH

The focal length is the distance between a telescope's main mirror or lens and the point at which light is brought to focus. For a given eyepiece, long focal length scopes show a narrower (more zoomed-in) view, whereas short focal length scopes give a wider field of view.

EYEPIECES

You look through the eyepiece to see celestial objects. The view can be magnified or reduced by using different eyepieces. Be warned, it's not all about magnification; you should choose the right eyepiece to use based on the observing conditions and the limitations of your telescope (such as how bright the view is through the eyepiece).

DOBSONIAN

SECONDARY MIRROR

The secondary mirror redirects the light path through 90°, out towards the side of the tube to the focuser.

TUBE ASSEMBLY

The tube assembly houses the secondary and primary mirrors. The focuser and finderscope attach on the outside. Some Dobsonians use a truss system rather than an enclosed tube.

ALTAZIMUTH MOUNT

Dobsonians use an altazimuth mount, where one axis tilts up and down and the other rotates horizontally.

FINDERSCOPE

The finderscope is a miniature telescope with a wide field of view that allows you to home in on your target.

The Dobsonian telescope is a reflecting telescope mounted on a simple but effective altazimuth mount popularised by amateur astronomer John Dobson in the 1960s. It sits in a box (or cradle) that allows it to be tilted up and down. The box

itself is mounted on a rotatable platform, so you can turn the telescope around in azimuth. Basic Dobsonians can't track the stars, but their simple design means you can generally get a larger aperture telescope for your money.

FOCUSER AND EYEPIECE

As in the Newtonian design, the eyepiece and focuser assembly sits at the top of the tube and juts out from the side of the telescope.

PRIMARY MIRROR

The primary mirror collects and focuses the light from distant celestial objects and reflects it back up to the secondary mirror.

CATADIOPTIC

Catadioptric, or compound, telescopes use a combination of a mirror and a front corrector lens to capture and focus celestial light in a compact and much shorter tube than refractors or reflectors. Light emerges from the rear; a star diagonal and eyepiece are used for comfortable viewing position. Popular designs include the Schmidt-Cassegrain and Maksutov-Cassegrain. Compound scopes can be mounted on equatorial mounts, but are often found on altazimuth Go-To mounts.

JARGON BUSTER

GO-TO

Some mounts possess motorised drives and computer handsets that are capable of aligning and controlling a telescope as well as pointing it at selected celestial objects. These 'Go-To' mounts make viewing many objects light work, however it can be a hindrance to learning your way around the sky if you use one when starting out.

CORRECTOR PLATE AND SECONDARY MIRROR

The corrector plate is at the front of the tube. It both corrects the light path and supports the secondary mirror.

PRIMARY MIRROR

The primary mirror collects and reflects light from celestial objects. It has a central hole allowing the light to pass through it from the secondary toward the focuser and eyepiece.

EYEPIECE AND STAR DIAGONAL

In this design the eyepiece and star diagonal are located at the rear of the telescope.

GO-TO HANDSET

The mount is controlled by a Go-To handset, which holds a large database of celestial objects. You choose one, the telescope aims itself at it.

GO-TO MOUNT

The electronic Go-To mount carries the telescope, and is specially geared to allow fine and fast slewing rates for moving around the sky.

THE MOON

Our planet's only natural satellite is home to a wealth of interesting sights for all kinds of astronomers, and always has something new or interesting to show

The source of our ocean tides, subtle chronobiological cycles and the only other world that humankind has so far set foot upon, the Moon seems a familiar and tangible place. A quarter of Earth's diameter and just a quarter of a million miles away, it's 100 times closer than Venus. Given its proximity, brightness and large apparent size, it's easy to see why the Moon has enchanted humankind for centuries.

Pre-telescopic observers noticed an unchanging pattern of darker patches that would later become known as maria, or 'seas', because they were assumed to be vast bodies of water. They act as a Rorschach test for different cultures – the face of the 'Man in the

Moon' observed in Western tradition, the 'Rabbit' pounding rice of East Asian folklore, or the 'Lady Reading a Book' from the southern hemisphere, to give just three examples.

The reason we see the same lunar features staring back at us is because the Moon has a synchronous rotation with respect to Earth, meaning that spins once on its axis in the same 27.3 days (the sidereal month) it takes to complete an orbit of our planet.

It's equally obvious that the illumination of the Moon's Earth-facing hemisphere changes over the course of the month – a word, incidentally, that we get from 'Moon'. Although the Sun is always shining on a full half of the

Moon, the proportion of the lit side we are able to see depends on where the Moon is in its orbit around Earth, giving rise to the phases we see.

Imagine you are looking down on the Earth, Moon and Sun from above. When the three line up with the Moon in the middle, the Moon's lit half points away from us on Earth, producing a new Moon. Slowly emerging from its new phase into the evening sky, the lunar crescent thickens from one day to the next. The term 'waxing' is used to indicate this thickening phase. The waxing crescent leads to the Moon appearing as an illuminated semicircle roughly a week after new.

This is somewhat confusingly called 'first quarter', referring to the Moon's ►



position in its 29.5-day orbit rather than proportion of its disc is illuminated from our vantage point on Earth. The bulging phases after first quarter are known as waxing gibbous. These increase in size until, roughly two weeks after new, the Moon is on the opposite side of its orbit from the Sun and appears fully lit as a full Moon. The point of new and full Moon, when our planet, satellite and star are aligned, is known as a 'syzygy'.

After full Moon the phases reverse, and the illuminated part of the Moon begins to shrink or wane. After passing through the waning gibbous phases, the Moon reaches the three-quarter point of its orbit, giving rise to the 'last quarter'

phase. The Moon takes the appearance of a semicircle once again, although it's the opposite half that is illuminated than that at first quarter. After this, it takes approximately a week for the Moon to go through its waning crescent phases, visible in the early morning sky, before it once again becomes new again. It takes 29.5 days for the Moon to return to complete this cycle of phases or 'lunation', slightly longer than it does to complete an Earth orbit. This is known as a synodic month.

The Moon is the ideal place to begin your observing odyssey because it is big, bright and covered with amazing detail. But the thing that surprises most

novice observers is the variation it holds. Though the same hemisphere faces Earth at all times, what you can see on the Moon changes from night to night.

You may be forgiven for thinking that full Moon is the best time to examine our close companion – not so. While this is a good time to see the long, bright rays of ejecta surrounding prominent craters such as Tycho, the high altitude of the Sun in the lunar sky means no shadows are cast, resulting in a washed-out view of the Moon.

In general, the best time to view a given lunar feature is when the terminator, the demarcating line that separates lunar day and night, is nearby. This is the

THE MOON'S PHASES

The Moon's appearance changes because of its relative position to Earth and the Sun

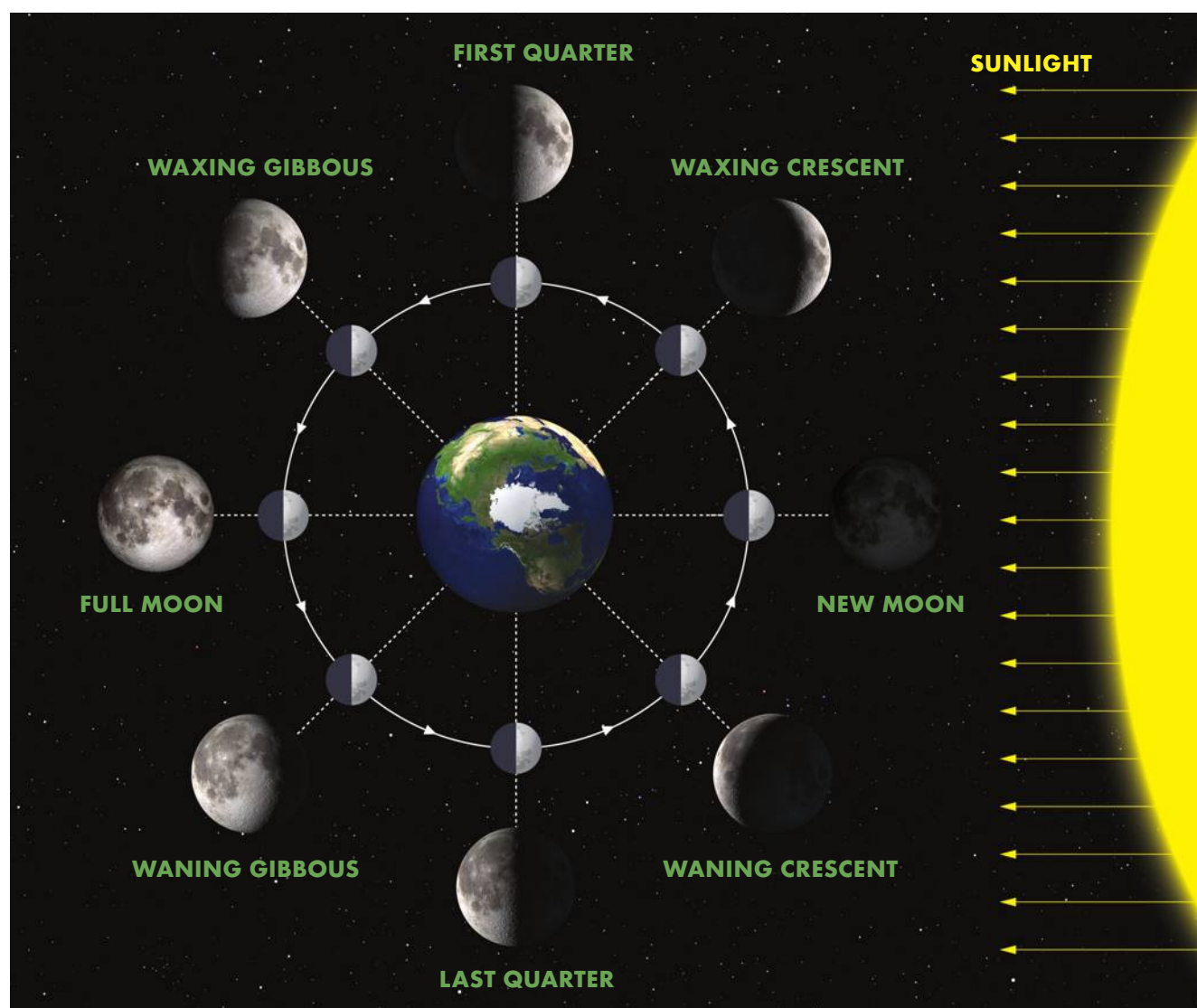


ILLUSTRATION STEVE MARSH, PHOTO LARRY LANDON/SCIENCE PHOTO LIBRARY

region where the Sun is either rising or setting, where crater rims and mountain peaks stand out in stark relief, casting inky black shadows across the lunar surface that exaggerate their presence. Those further from the terminator show hardly any shadows and are harder to make out.

At day zero of the lunar cycle – new Moon – the whole of the dark lunar hemisphere points towards Earth. Over the next 15 days the terminator slowly creeps across the lunar surface from east to west until the disc is fully illuminated at full Moon. Then the tables are reversed as the encroaching darkened hemisphere heads west with each passing day, until the diminishing crescent becomes lost in the pre-dawn twilight.

Moonrock and roll

The nature of the Moon's orbit generates another effect that is a boon to lunar observers, a rocking and rolling motion that we call libration. The Moon's orbit is elliptical, and as a result its distance from Earth does not remain constant. When closest it speeds up slightly; when more distant it slows down. This small variation is enough to cause the Moon to 'nod' back and forth on its axis, giving us an occasional chance to see a little more around its eastern and western edges.

The orbit is also slightly inclined, and this causes it to sometimes appear above the Earth's orbital plane and sometimes below. This gives us an opportunity to peek over the top, and under the bottom, of the Moon over time. Taken together, this libration allows us to see a total of 59 per cent of the Moon's globe, revealing

EARTHSHINE



The Moon is not solely lit by sunlight. When it is in a slender crescent phase in the evening or dawn twilight, it's sometimes

possible to see its dark portion gently glowing due to sunlight reflected off the oceans and clouds of planet Earth. This effect is

known as earthshine. Our planet actually reflects more light onto the lunar surface than the Moon gives us when it is full.

LUNAR LINGO

The Moon's features have Latin names – here's what they mean

Catena.....	Crater chain
Dorsum (pl. Dorsa)...	Mare ridge
Lacus.....	Lake
Mare (pl. Maria).....	Sea
Mons	Mountain
Montes.....	Mountain range
Oceanus	Ocean
Palus	Marsh
Promontorium.....	Cape
Rima (pl. Rimae)	Fissure
Rupes.....	Escarpment
Sinus.....	Bay
Terre (pl. Terrae)	Highland
Vallis.....	Valley

tantalising features normally hidden from our view.

With the naked eye it's easy to see the progression of lunar phases, full disc effects such as earthshine and the major lunar seas. Binoculars increase the detail you'll see: as well as dark seas, you'll now be able to spot individual craters and large mountain ranges, especially close to the terminator. The smallest craters you'll be able to pick out will depend on how still you can hold your binoculars, but a pair of 7x50s should comfortably reveal features down to about 50km across.

A telescopic view of the Moon is amazing and one that never gets old. At low magnifications, the amount of detail visible is breath-taking, especially close to the terminator where relief shadows really help to emphasise the detail. Upping magnification by using shorter focal length eyepieces will get you in

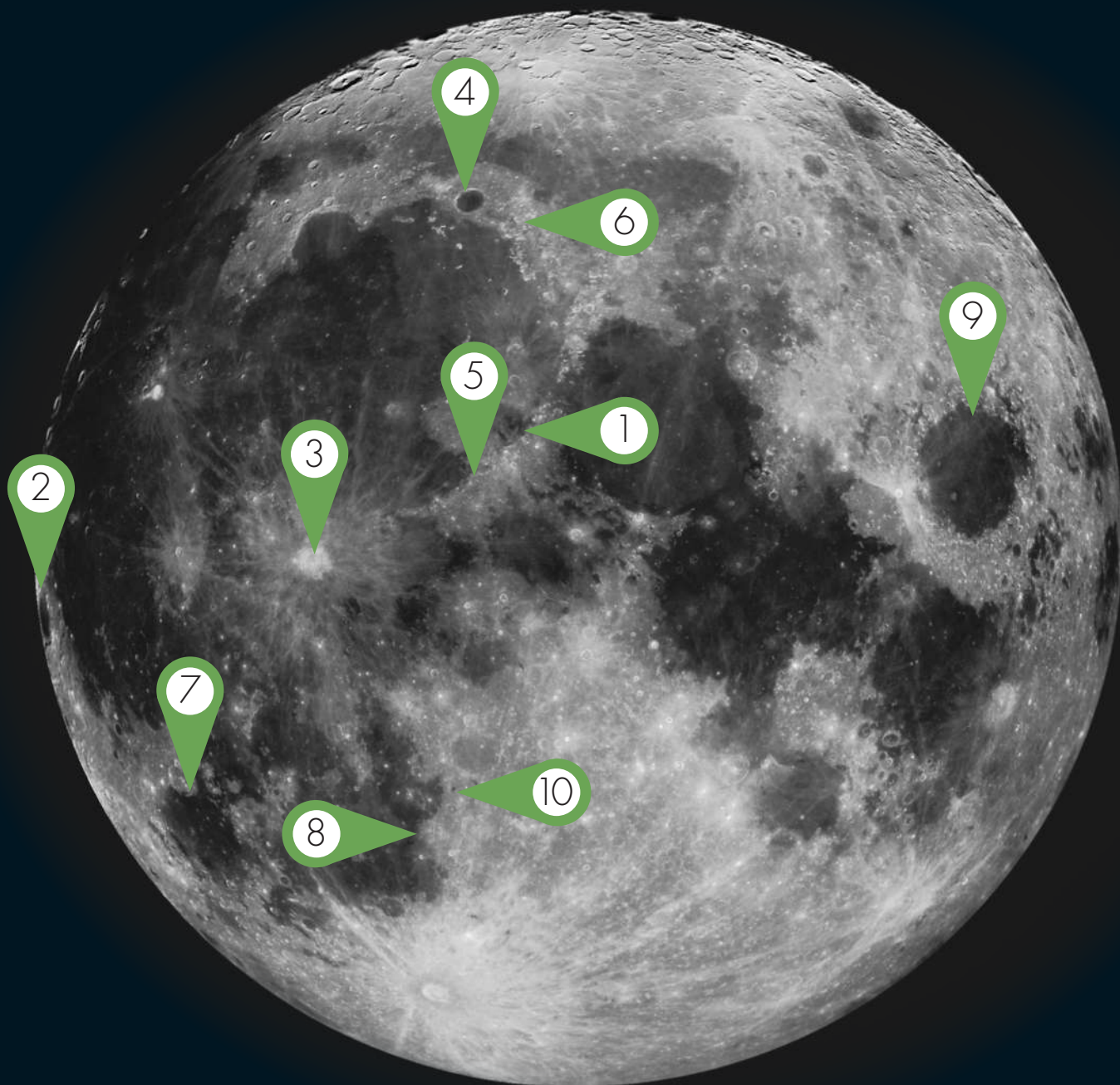
closer and give you opportunity to 'roam' around the lunar landscape.

The view you have of the Moon through a telescope will differ from what you see with the naked eye or binoculars depending on its optical arrangement. Through a refractor or compound instrument, the Moon will appear flipped west to east, while through a reflector the image will be inverted. With a telescope you may also notice the surface appears to gently wobble or sometimes even shimmer. This effect is caused by air moving through the atmosphere of our planet, and the greater the turbulence the worse the views.

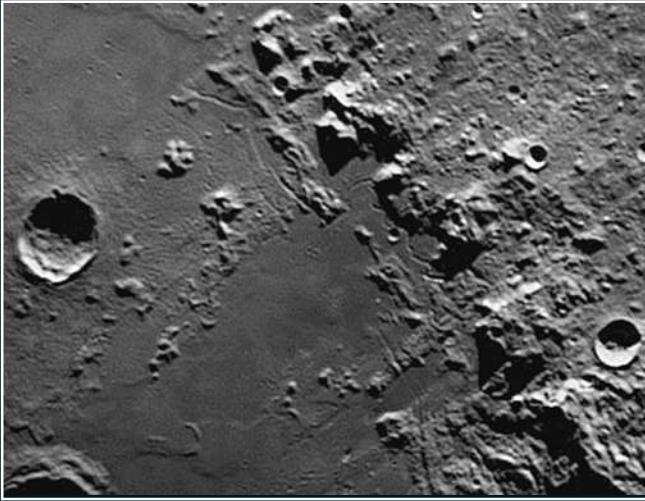
The 'seeing' can vary from minute to minute and night to night. The best views will always be when conditions are steady and the undulations are less intense; poor seeing, on the other hand, results in loss of detail and fuzzy lunar features.

TOP TEN MOON SIGHTS

Our celestial neighbour has enough to keep astronomers busy for a lifetime, but here are 10 highlights to get you started



WHAT TO SEE: SOLAR SYSTEM



1 HADLEY RILLE

EQUIPMENT: LARGE SCOPE

Famous as one of the features explored by the Apollo 15 astronauts, Hadley Rille is also a great target to look for with a large telescope. Under suitable illumination it appears as a little meandering black line near the northern end of the lunar Apennines.



4 CRATER PLATO

EQUIPMENT: SMALL SCOPE

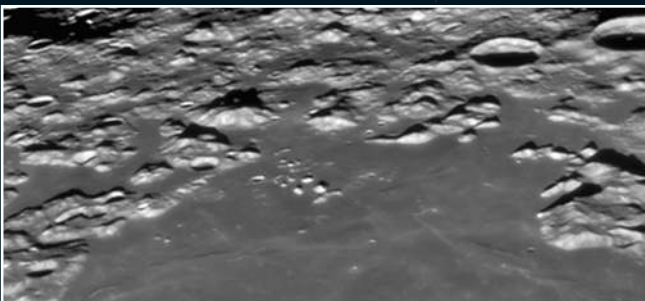
This beautiful 109km-wide crater lies nestled among the jagged landscape near the northern edge of the Mare Imbrium. It has a smooth floor and is surrounded by interesting features, including Rima Plato and the Montes Teneriffe.



5 THE LUNAR APENNINES

EQUIPMENT: SMALL SCOPE

The Apennines mountain range stretches over 900km across the lunar surface. It is particularly striking when lit from the side – when the peaks cast huge, inky black shadows onto the surrounding landscape.



9 MARE CRISIUM

EQUIPMENT: BINOCULARS

This 620x570km lunar sea is one of the most distinctive features on the Moon. Located close to the eastern limb, it's clearly visible to the naked eye as a dark oval patch. Unlike the other seas, the Mare Crisium is completely detached. Its dark, smooth-looking floor has a higher boundary that shows fantastic shadows as the terminator approaches and crosses the sea.



2 CRATER GRIMALDI

EQUIPMENT: BINOCULARS

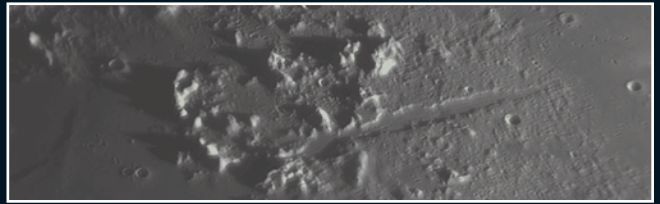
Visible to the naked eye, this dark, 173km-wide basin reveals lots of detail through binoculars and telescopes, including eroded walls, ridges and low hills.



3 CRATER COPERNICUS

EQUIPMENT: SMALL SCOPE

At the heart of a huge system of bright rays that spread for hundreds of kilometres, this 93km-wide crater has a distinctive terraced rim.



6 THE VALLIS ALPES

EQUIPMENT: SMALL SCOPE

Cutting through the lunar Alps, the 130km-long Vallis Alpes is one of the most interesting features on the Moon's surface. This valley can be spotted with even a small telescope.



7 CRATER GASSENDI

EQUIPMENT: SMALL SCOPE

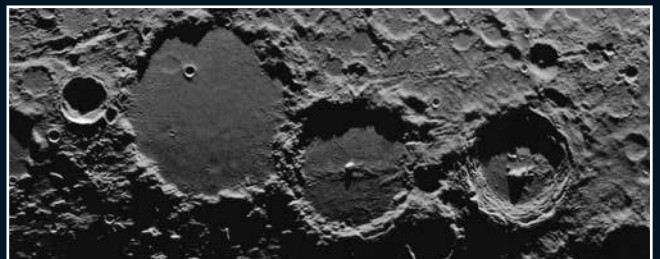
A fascinating 110km crater on the northern edge of the Mare Humorum. Under the right light, you'll be able to see a superb network of rilles on its floor.



8 RUPES RECTA

EQUIPMENT: SMALL SCOPE

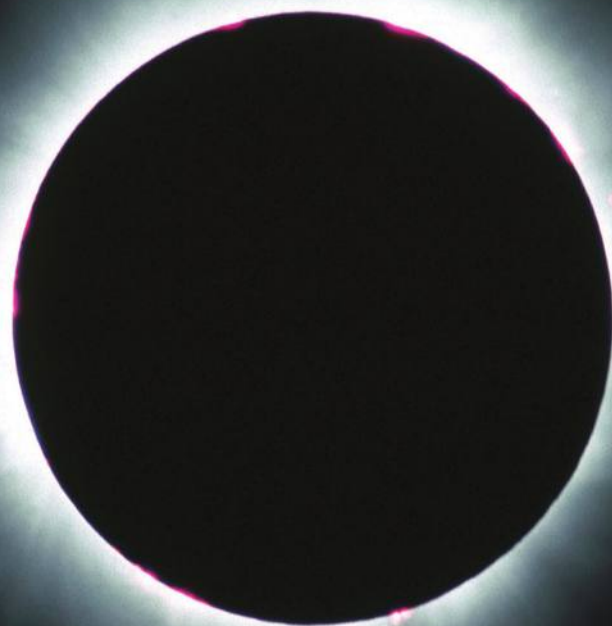
Best known as the Straight Wall, this 110km-long fault reaches over 270m above the lunar surface. Look for a thin black line near to crater Birt.



10 CRATERS PTOLEMAEUS, ALPHONSUS AND ARZACHEL

EQUIPMENT: SMALL SCOPE

These three imposing craters sit close to the centre of the Moon's near side. The largest of them, Ptolemaeus, has a smooth floor that is pockmarked with lots more tiny craters.



The ancient Chinese thought that total solar eclipses were the Sun being eaten by a dragon – now we know better

SOLAR AND LUNAR ECLIPSES

Eclipses are eerily beautiful events involving the Sun, Earth and the Moon – and the result of a piece amazing cosmic good luck

When most people think of an eclipse, they think of totality, the apex of a total solar eclipse, where the Sun, Moon and Earth are in perfect alignment and the Moon completely covers the Sun. Even here, the Sun's light doesn't completely disappear. With the central brightness gone, it's possible to see the beautiful arcing curves of the Sun's corona, while Earth is plunged into a false twilight.

Totality can only be seen if you happen to be along a narrow corridor on the Earth's surface, known as the path of totality. Observers situated away from this track will see a partial eclipse of

varying magnitude, depending on their distance from it. Some parts of the Earth are so far from the track that they won't see an eclipse at all.

That total solar eclipses can happen at all is the result of a fantastic cosmic coincidence – the Moon is both 400 times smaller than the Sun and 400 times closer to us, so they appear to be the same size in the sky. Most of the time, at least.

The Moon's orbit around the Earth is not a perfect circle, which causes the Moon's apparent size to change over the course of each month by 14 per cent. When the Moon appears smallest it no longer fills the Sun's disc. When

eclipses happen during this time, they are annular instead of total: a thin ring of solar disc remains visible around the edge of the Moon's silhouette, and this can be just as beautiful as totality. There are also extremely rare hybrid eclipses, which transition from total to annular mid-event.

Align in the sky

We know solar eclipses occur when the Sun, Moon and Earth line up in the sky. Why then, don't we see eclipses every month at new Moon? It's because the Moon's orbit is inclined by 5.3° to the ecliptic, the plane in which Earth orbits

THE PHASES OF A SOLAR ECLIPSE

FIRST CONTACT

The point at which the Moon first touches the solar disc, marking the beginning of the eclipse

SECOND CONTACT

The moment the Moon is fully within the solar disc, marking the start of annularity or totality. Partial eclipses do not have second or third contacts

GREATEST ECLIPSE

The point of totality or annularity

THIRD CONTACT

The instant the lunar disc touches the other side of the solar disc, ending totality/annularity and marking the start of egress

FOURTH CONTACT

The point when the edge of the Moon's trailing edge breaks contact with the solar disc, ending the eclipse

the Sun. That means that even if the Earth, Moon and Sun are aligned in a straight line as seen from above (known as a 'syzygy'), the Moon may be too high above or too low below the orbital plane to block the Sun's light.

While every eclipse is partial somewhere on the planet, there are some during which the darkest part of the Moon's shadow misses the Earth, meaning there is no totality anywhere on the planet. This happened on 23 October 2014, when there was a partial eclipse that could be seen from North America – but in order to see totality you would have had to have been several hundred kilometres above the north pole.

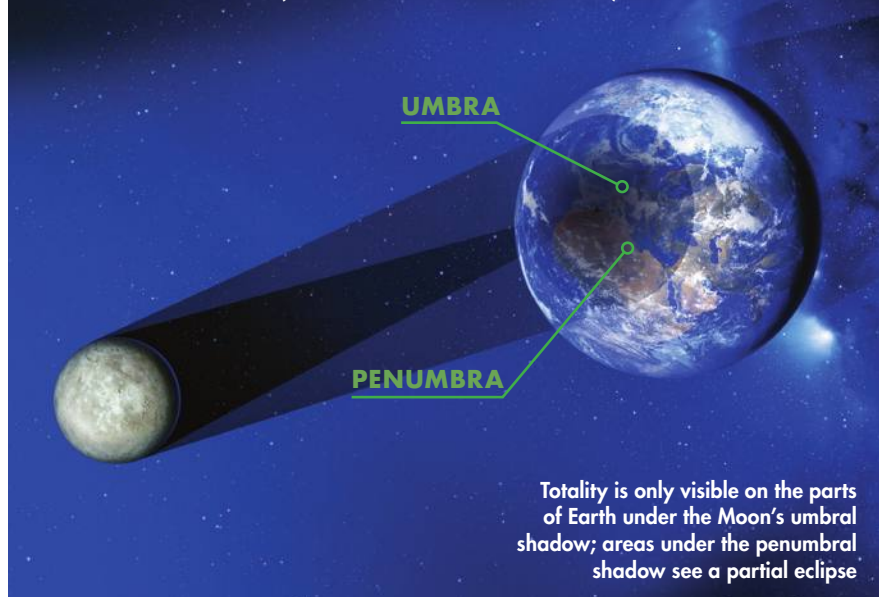
Like Sun, like Moon

Just as the Sun experiences eclipses, so does the Moon. Lunar eclipses, where the Moon passes into Earth's shadow, are more relaxed affairs than their solar counterparts, typically lasting for over an hour rather than a matter of minutes.

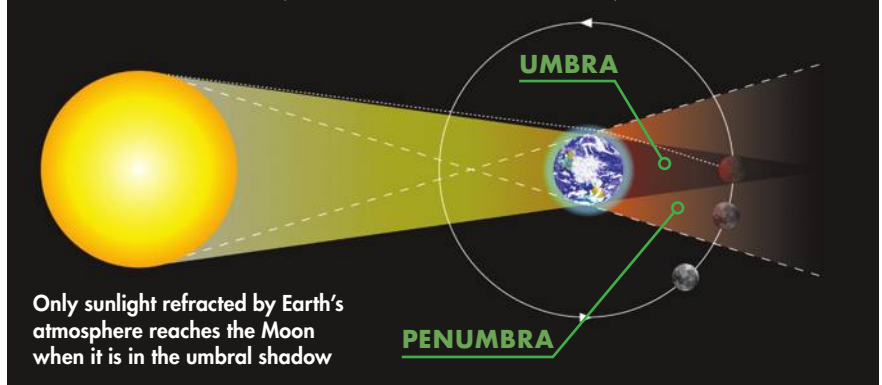
The intensity of a lunar eclipse depends on how much of the Moon passes into the Earth's shadow, and which part of the shadow it passes through from your viewpoint – the darker umbra or lighter penumbra.

During a total lunar eclipse, the entire Moon passes through the penumbra and into the umbra, gradually darkening until it is completely covered, a point known as totality. During totality no

SOLAR ECLIPSE (SUN-MOON-EARTH)



LUNAR ECLIPSE (SUN-EARTH-MOON)



sunlight shines directly on the Moon, but some is refracted onto it via Earth's atmosphere. As our atmosphere filters out blue light, the Moon often gains a strange orange-brown colour.

As the Moon goes into eclipse and dims, the sky gets darker too. You may not have realised how bright a full Moon can be. It lights up the sky around it with a blue haze, out of which only the brighter stars are visible. During a total lunar eclipse, the darker Moon means that the fainter stars can come out and we end up with the eerie sight of a deep-red Moon surrounded by twinkling stars.

How dark the Moon gets during a total lunar eclipse is described by the Danjon Scale, which runs from L0 through to L4. As the Moon is only lit by light that has passed through Earth's atmosphere, its precise colour and darkness will depend on how much dust, volcanic ash and water vapour is in the atmosphere to affect

the sunlight's path. The eclipse in 1884, after the huge volcanic eruption of Krakatoa, was so dark that the Moon could only just be made out, such was the amount of dust in the atmosphere.

There are two other types of lunar eclipse: partial, where only a portion of the Moon passes through Earth's dark umbral shadow, and penumbral, where part of the Moon only passes through the lighter, outer shadow. Partial eclipses can be quite noticeable, but penumbral eclipses often only cause a slight dimming.

Lunar eclipses can be observed without optical aids. For solar eclipses, you always need to use equipment with certified filters, or project the event onto a piece of card. The one exception is during the brief window of totality during a total solar eclipse. This is the only time it is safe to look directly at the Sun, and then only for a moment. The simple rule is: if you're not absolutely sure about safety, don't do it.

THE PLANETS

Our Solar System neighbours are popular targets for astronomers



NEPTUNE

The number of planets has changed over the years. Currently there are eight bodies recognised as planets and five as dwarf planets, including Pluto, Eris and Ceres. Pluto lost its planetary status in 2006, after other similar (and some larger) objects were found where it orbits. To meet today's definition of a planet, as well as being rounded by its own gravity and in orbit round the Sun, a body has to have cleared its orbit of other objects its size, which Pluto hasn't done.

All the planets move in the same anticlockwise direction around the Sun, if we take Earth's north pole as an arbitrary reference of 'up'. The Sun's gravity 'well' is immense – imagine a great bowling ball creating a dip in a trampoline. The planets are like marbles rolling along inside this dip around the bowling ball Sun. The closer they are to the Sun, the

stronger its pull of gravity and the faster it has to move to keep from being pulled into solar destruction.

All this speed, or lack of it, affects how a planet moves across the night sky as seen from Earth's surface. Whereas Saturn crawls around the sky, barely moving among the stars, Mercury's fast pace means it shifts considerably day by day. This is what the gravity of the Sun does, but there's also its light to consider. We only see the planets because the Sun lights them up. Their brightness is due to many things, including their actual distance from the Sun, the distance they are from your eye, and their size, composition and colour.

Mercury rising

Because Mercury and Venus are closer to the Sun than Earth, they are known as the inferior planets. The best time to observe them is when they are at their

farthest angular distance from the Sun, a position astronomers call elongation. At these times, the planets are only half lit by the Sun, but after this they swing back into the solar glare, where they become less visible. When Mercury and Venus are at eastern elongation, they set after the Sun in the evening; at western elongation they rise before the Sun in the morning. The Sun interferes with our views of the inferior planets twice during their orbits: when they all line up, the two points being known as inferior and superior conjunction.

The planets further out from Earth are called superior planets. These don't present the same problems for observers as Mercury and Venus in that they can be visible all night long. When any of them line up with Earth on the far side of the Sun, it is said to be in conjunction. The best time to observe the superior planets is when they are close to Earth. This happens at opposition, when the planet is on the opposite side of the sky to the Sun, so we are presented with a fully illuminated disc: visually it's close to or at its biggest and brightest.

“The Sun's gravity ‘well’ is immense – imagine a great bowling ball creating a dip in a trampoline”

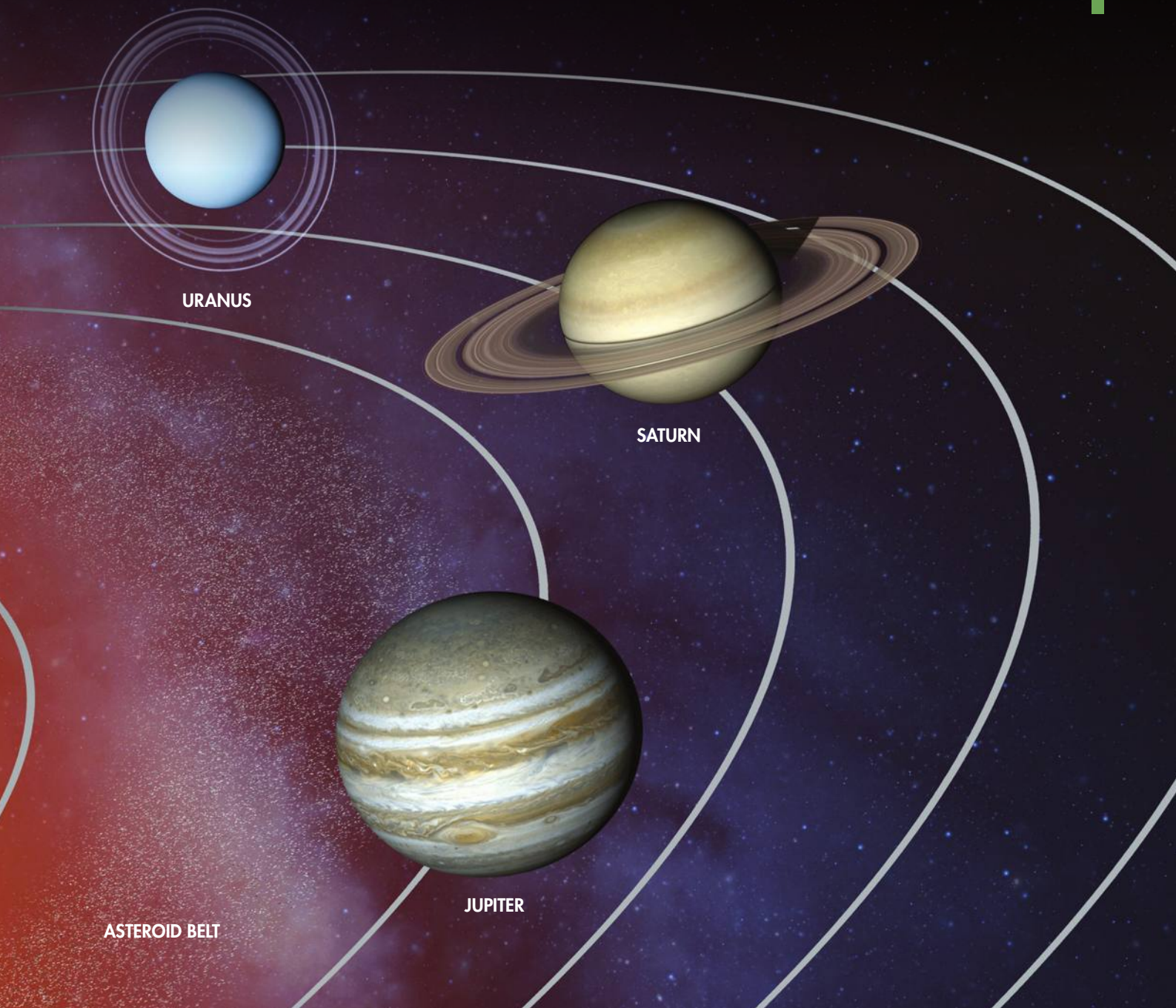
MERCURY

VENUS

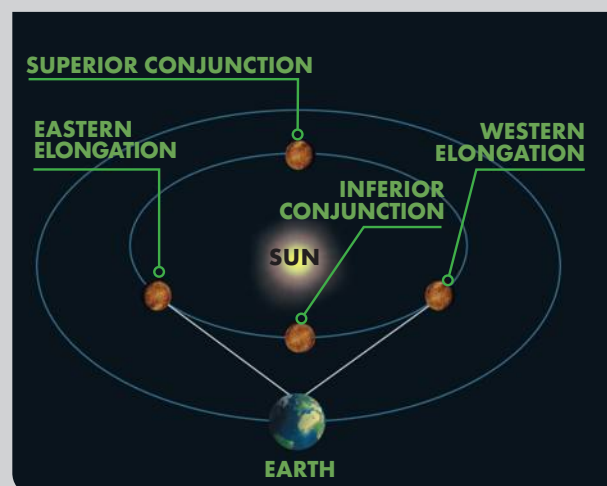
EARTH

MARS

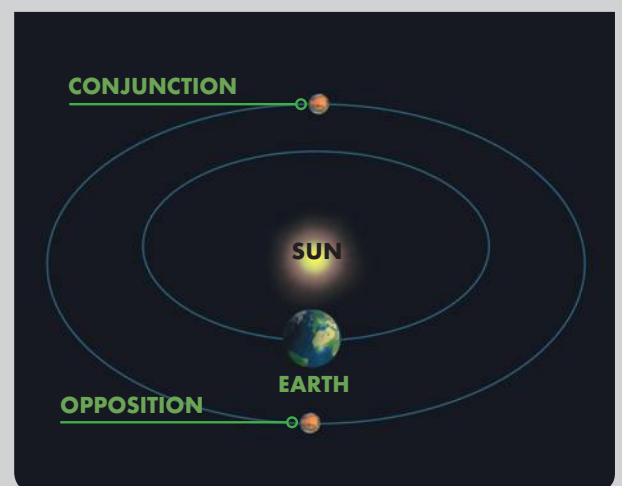
WHAT TO SEE: SOLAR SYSTEM



INFERIOR PLANETS



SUPERIOR PLANETS



THE ROCKY PLANETS

MERCURY

Diameter: 4,880km • Moons: 0 • Distance from Sun: 58 million km

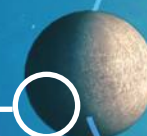


The closest planet to the Sun, Mercury is a place of extremes. It is the smallest and densest planet in the Solar System, barely larger than our Moon. It takes 59 Earth days to rotate once, and 88 to orbit the Sun, meaning its parched surface experiences temperatures hot enough to melt lead on the sunward side, but is sub-Antarctic on the side in shadow.

This small world is a real challenge to observe for a variety of reasons. It's a fast mover, travelling around the Sun four times more quickly than Earth, so don't expect it to

hang about in any part of the sky for very long. Mercury's orbit is a fairly eccentric oval shape, and it's on a bit of a tilt too, which means some times are better for viewing it than others: spring evenings and autumn mornings. If that's not tricky enough, you only have a relatively short observation window on any day you choose to look, as Mercury never strays very far from the Sun.

In spring, start looking 30 minutes after sunset, after which you'll have about another 45 minutes to see it. Autumn gives you a longer view, from about an hour and 45 minutes before sunrise, but that does mean getting up exceedingly early.



DWARF PLANETS

Diameter range: 975km to 2,330km

A dwarf planet is, according to the International Astronomical Union, a body that orbits the Sun (and is not a satellite), is spherical in shape (due to its own gravity), and is too small to have cleared its orbit of debris and so warrant being called a fully fledged planet. This classification was agreed after the 2005 discovery of Eris, an icy body in the outer Solar System very similar to Pluto, which was then considered a planet. In the fierce debate that followed Pluto was demoted into the newly created class, which also contains outer Solar System bodies Haumea and Makemake, and Ceres (pictured right) in the Asteroid Belt.

Ceres is the largest, but still comparatively small, so you will need binoculars to find it. Pluto is best seen by taking images of the region of sky it is in over consecutive nights and looking for the faint moving dot.

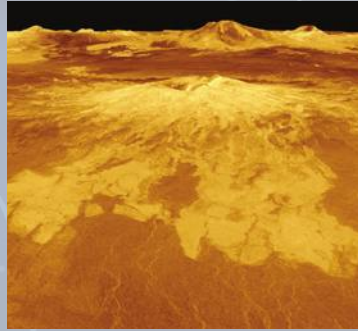


WHAT TO SEE: SOLAR SYSTEM



VENUS

Diameter: 12,100km • **Moons:** 0
Distance from Sun: 108 million km



Venus is sometimes called Earth's twin – occasionally its 'evil' twin. It is similar in size and composition to our planet, but a dense carbon dioxide atmosphere and sulphuric acid clouds make its surface a hellish 470°C. The planet spins slowly, in the opposite direction to most planets, and takes about the same time to rotate on its axis (243 Earth

days) as it does to travel around the Sun (225 days).

Because Venus's orbit is slower than Mercury's, it can be visible for months on end, and sometimes for up to three hours after sunset or before sunrise. When Venus is at its brightest, it becomes the third-brightest object in the sky, only beaten by the Moon and the Sun. This is caused by sunlight reflecting off its bright white carbon-dioxide clouds, and has led to Venus being called the 'Evening Star' or 'Morning Star' depending on when it appears. Venus can come very close to Earth, plus it's rather big, meaning that it's a good target for binoculars, through which you can easily see its larger phases.

MARS

Diameter: 6,800km • **Moons:** 2 • **Distance from Sun:** 228 million km

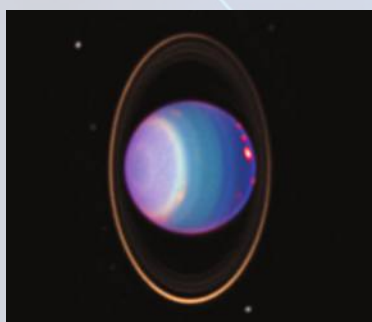
The Red Planet is the most visited extraterrestrial destination in the Solar System. Dozens of missions have ventured there, and they have explored the Martian landscape in incredible detail. Smaller than Earth but with the same land area, Mars is reminiscent of a cold rocky desert, littered by canyons and volcanoes. The planet has polar caps and a thin atmosphere of mostly carbon dioxide. Although dry today, Mars's mineral salts and rock formations suggest that it was wet in the past, and could possibly have harboured life.

Mars differs from Mercury and Venus in that its position in the Solar System – on the other side of Earth – means it can be 'up' from sunset until sunrise. A small telescope can reveal lighter, pale-reddish areas, the bright white of the ice caps, and darker patches, which it used to be thought were Martian 'cities'.



THE GAS AND ICE GIANTS

URANUS Diameter: 51,000km • Moons: 27 • Distance from Sun: 2.87 billion km

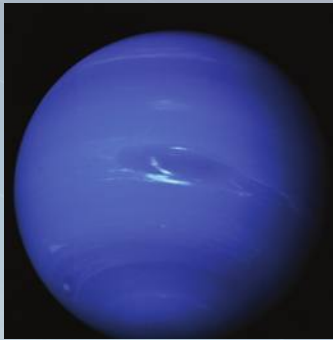


The first planet to be discovered with a telescope, found by William Herschel in 1781. Its blue-green hue comes from the abundance of methane ices in its hydrogen and helium atmosphere, which also contains water and ammonia ices. Like Venus, Uranus spins from east to west, but its axis of rotation is tilted almost 90° from the plane of its orbit, suggesting that it might have been knocked over by a collision. Five rings were discovered in 1977; in 1986 the Voyager spacecraft identified a further six, and two more were found by the Hubble Space Telescope in 2005, bringing the total to 13.

Visually, Uranus doesn't have much going for it, whether you use your eyes, a pair of binoculars or a telescope. By simply turning your head upwards, you can just about see this gaseous world as a very faint star at the limits of visibility (around mag. +5.6). You won't see much from anywhere with light pollution, however – the sky has to be very black indeed. The view does improve a little through a telescope, showing a greenish speck.

NEPTUNE

Diameter: 49,500km • Moons: 13 • Distance from Sun: 4.5 billion km



Neptune's composition is similar to that of Uranus, being mainly hydrogen and helium with methane-ices, water-ices and ammonia-ices mixed in. But unlike featureless Uranus, Neptune is wracked by stormy weather, with giant tempests boiling among the clouds. Its winds are the fastest in the Solar System, reaching an incredible 600m/s. Neptune has six known rings. They appear to have bright clumps within them, which may be short-lived collections of debris.

At around mag. +8.0 you need at least binoculars to see Neptune, and there isn't much else to say. Even when looked at through a telescope it looks like a 'star' with a hint of blue, but it is not as spectacular as its larger, closer compatriots. If you have a very large scope you can also catch a glimpse of Neptune's largest moon, Triton, which is mag. +13.5.

SATURN

Diameter: 120,500km • Moons: 62
Distance from Sun: 1.43 billion km

Saturn is known for its spectacular rings, made from millions of chunks of water-ice spread out into a thin disc only a few tens of metres thick but stretching 100,000km from the planet's surface. The rings form bands, some broad, some narrow. Scores of moons orbit within the rings, some carving out wide gaps. As with Jupiter, a handful of them are visible to amateur observers.

Saturn's brightness varies due to the way the rings are tilted and how much sunlight they reflect. The planet is not so bright when the rings are edge-on to us, but its brightness increases over 7.5 years as the rings open up to observers on Earth. Then it fades again over the same period. If you're wondering why this takes 7.5 years, it's a quarter of the time Saturn takes to go around the Sun.

The best way of understanding Saturn's tilting effect is to go out and look at the planet – it really is one of the telescopic marvels of the Solar System. It doesn't matter if you have a small scope: the sight of a world surrounded by rings is amazing. The view of this tiny ringed world hanging in a large, inky black field of view is magical. Larger scopes will start to show detail in the rings and on the planet.



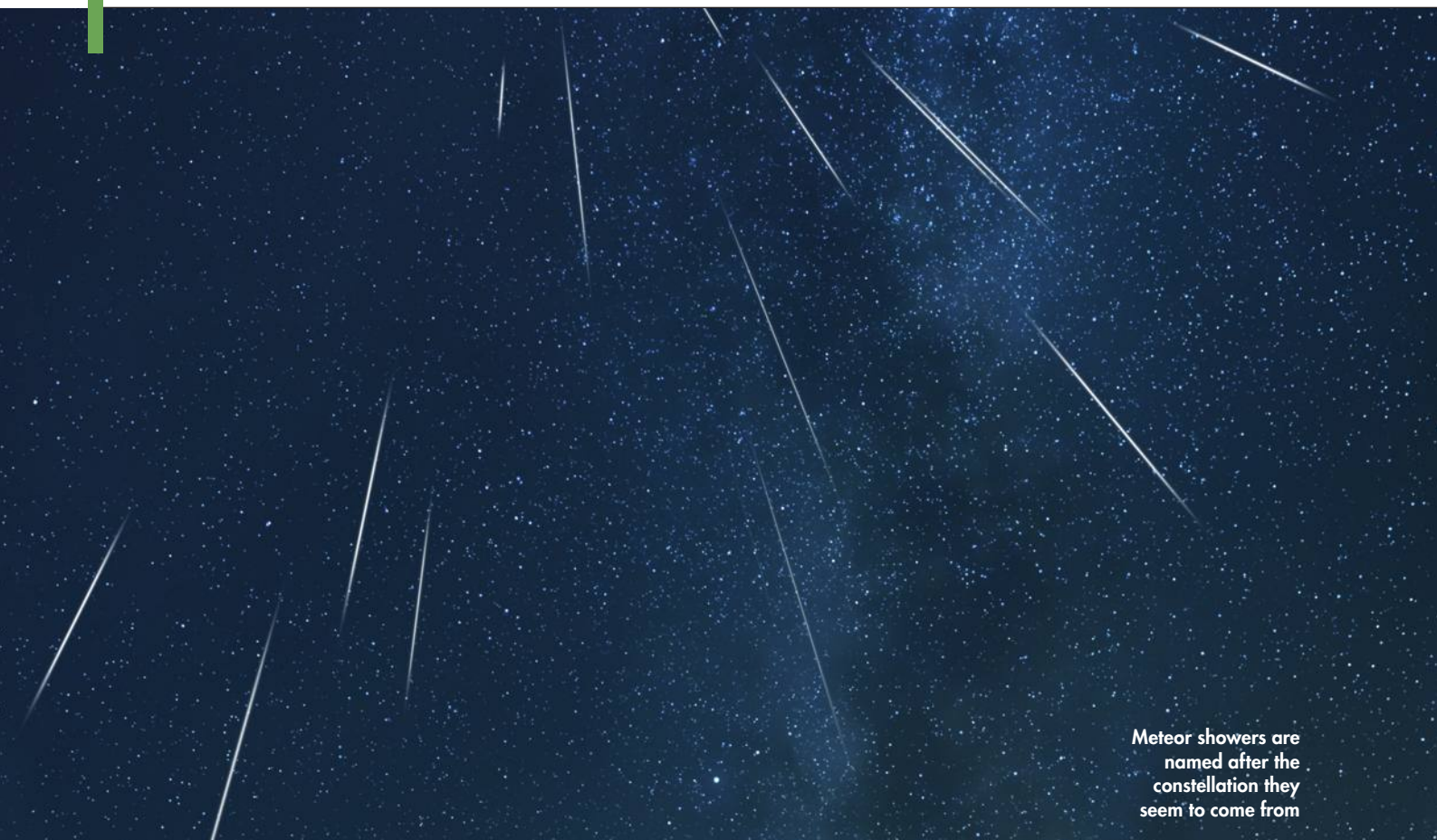
JUPITER

Diameter: 143,000km • Moons: 67
Distance from Sun: 778 million km

The largest planet in the Solar System, Jupiter has more mass than all of the other planets put together and is second only to the Sun in terms of gravitational power. In 1994 it enticed comet Shoemaker-Levy 9 to fragment and crash into its swirling clouds; other likely comet crashes were recorded in 2009 and 2010. Jupiter is mostly gas, its composition of hydrogen and helium similar to that of the Sun.

With a good pair of binoculars the first things you'll notice are its four most famous moons: Io, Europa, Ganymede and Callisto, spied by Galileo Galilei in 1610. With a telescope you'll see a slightly squashed sphere. This is due to its fast spinning 'day' of just under 10 hours, which causes the equator to bulge outwards and the poles to flatten. Jupiter's cloudy atmosphere will be revealed as dark bands separated by white zones. The longer you look, the more features appear, so keep an eye out for spots, wisps and kinks. The most famous feature is, of course, the Great Red Spot, a storm that changes shape, size and colour over time, often appearing quite greyish.





Meteor showers are named after the constellation they seem to come from

METEORS

Bright streaks across the sky made by tiny pieces of comets or asteroids, meteors are a spectacular sight

You may know of meteors as ‘shooting stars’, but the truth is there is nothing stellar here. The dramatic, bright trails that slash across the sky comes from a much more innocuous source: a dust particle the size of a grain of sand colliding with Earth’s atmosphere, causing it to glow.

You can see several random, or sporadic, meteors per hour on any clear night, but a more reliable approach is to look for them during one of the annual meteor showers. These occur when Earth passes through the debris trail of a long-gone comet – a collection of debris just waiting to burn up in our planet’s atmosphere.

Meteor showers have what’s known as a ‘peak’, the night when you can expect to see the greatest number of meteors. The rates can vary quite substantially, but prominent displays such as the Perseids can produce an average of one meteor a minute under clear, moonless skies at

their peak. There is also the chance an unpredicted dense swarm of meteoroids could lie along the path of debris in the wake of a shower’s parent comet; the dynamics of all showers are not fully understood and surprises can occur.

Yet it is important to bear in mind that most major showers will be active over a period of at least a few days – and some for a few weeks – so you should not restrict your observing just to the dates of the predicted maxima. The vagaries of cloud cover and moonlight mean that you should always be vigilant during the week of the shower, spreading your observing opportunities to bolster chances of success.

Practical considerations

The first thing to consider when meteor hunting is where you are going to watch the shower from. If you happen to live in a light-polluted area you can vastly improve your observing experience

JARGON BUSTER

METEOROID

A piece of rocky debris in space that is smaller than an asteroid.

METEOR

A small piece of space debris, typically the size of a grain of sand, that has entered Earth’s atmosphere. Heating causes it to glow, causing streaks to appear in the sky. They’re popularly known as ‘shooting stars’.

METEORITE

A meteor that survives being burnt up in Earth’s atmosphere and crashes into the ground. Such fragments are useful sources of information about the history of the Solar System.

RADIANT

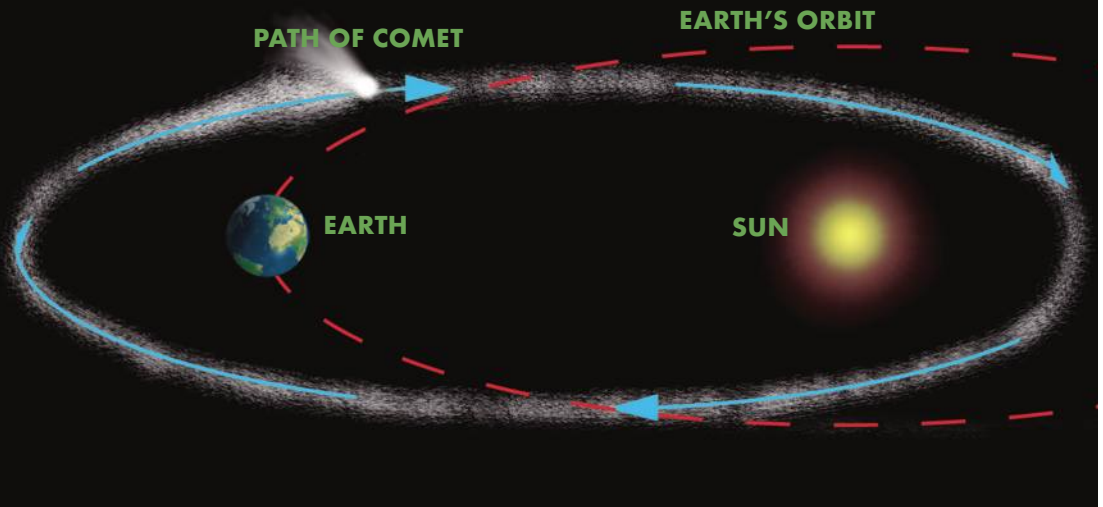
The radiant is the point in the sky where meteors (associated with a specific meteor shower) appear to come from. The constellation where the radiant is located determines the name of the meteor shower. So for example, the Orionids have their radiant in Orion.

ZENITHAL HOURLY RATE

A measure of meteor shower activity, ZHR refers to the number of meteors you would expect to see per hour under perfect conditions with the shower’s radiant overhead.

MAKING METEORS

By the time a comet approaches Earth, the Sun's heat has evaporated ice held by the comet. Much of the dust then follows the comet and, over time, can be spread out along the entire cometary orbit. When Earth intercepts this dusty path, lots of particles collide with the atmosphere and we see a meteor shower.



by travelling out of town to a more remote location, but be mindful of your personal safety. As with any form of observing it's important to be comfortable, but meteor-watching vigils in particular often require you to stay still for long periods.

Your best bet is to scour the sky from the comfort of a sunlounger or garden recliner. Since you'll be sitting for long periods it's important to keep warm, so

activity, when the sky is darkest and Earth's rotation faces into the direction of the planet's motion in space, giving additional swiftness to oncoming meteors. Don't look directly at the radiant, but concentrate your gaze high in the direction of the darkest portion of the sky that's free from obscuring trees and buildings. If you're observing in company, try to view different parts of the sky to each other so you catch as

“The best time to observe is shortly after midnight on the date of peak activity, when the sky is darkest”

wear a hat to prevent heat loss from the head and by all means snuggle into a sleeping bag. In the summer months you may also need to consider insect repellent. Bring along some food and a vacuum flask of your favourite hot beverage to drink at regular intervals – hydration is important, plus a little caffeine will certainly keep you alert.

Parallel lines

Debris from the same source tends to travel through space in parallel paths, so the effect of perspective means that their tracks through the atmosphere appear to converge on an area known as the 'radiant', where the meteors appear to emanate from. Meteor showers are named based on the constellation the radiant is in (and sometimes, the closest star).

The best time to observe is shortly after midnight on the date of predicted peak

many meteors as possible. On occasions when the Moon is unavoidably in the sky, try to ensure that it's not in your field of vision or reflecting off nearby walls or windows, as this will seriously degrade your night vision. As with any other form of observing, your eyes need at least 20 minutes to reach peak sensitivity in darkness.

If you need to refer to star charts or books to find the radiant, it's best to use a dim red light rather than a white one so that you preserve your dark adaptation; if you use a smartphone app for this purpose, place a red cellophane filter over the screen.

There's always a risk that you'll miss the best fireball of the night while taking notes, so it can be better to keep your eyes on the sky and use a voice recorder. Try to record the time, start and end points of the track and estimate the brightness of prominent meteors.

METEOR DIARY

QUADRANTIDS

Peak: Around 3 January
Max ZHR: 120 meteors per hour
Activity window: Early January

ETA AQUARIIDS

Peak: Around 6 May
Max ZHR: 60 meteors per hour
Activity window: Early May

PERSEIDS

Peak: Around 12 August
Max ZHR: 80 meteors per hour
Activity window: Mid July to mid August

ORIONIDS

Peak: Around 21 October
Max ZHR: 26 meteors per hour
Activity window: Mid to late October

LEONIDS

Peak: Around 18 November
Max ZHR: Usually 15 meteors per hour, but can be higher
Activity window: Mid to late November

GEMINIDS

Peak: Around 13 December
Max ZHR: 110 meteors per hour
Activity window: Mid to late December



Meteor trails often have tapered ends – this is one way you can tell it apart from a satellite

A spectacular comet visible to the naked eye can be given the title 'Great Comet' like C/2006 P1 McNaught



COMETS

The icy wanderers of the Solar System, spectacular comets may become visible only once in a lifetime

Wanderers of the Solar System, comets can be amongst the most spectacular of astronomical sights when they appear in our skies. These mysterious visitors never fail to capture imaginations when they pass by, and after years of careful observations astronomers have coaxed out the secrets hidden by their glow.

The heart of a comet is its nucleus, a core of ice laced with rock and dust, a

few kilometres wide. Though sometimes called a 'dirty snowball', the ice found on comets is far more exotic than that on Earth.

When the Rosetta spacecraft reached 67P/Churyumov-Gerasimenko it performed the first in-situ analysis of comet's nucleus, finding not only water ice, but also carbon dioxide and monoxide, as well as traces of

ammonia, methane and methanol. These highly volatile compounds are usually found as a gas or liquid on Earth, but the frigid depths of space have frozen them to ice as hard as rock.

These snowballs travel in huge elliptical orbits, briefly visiting the inner Solar System at one end before travelling billions of kilometres to the outer regions. Some, such as Halley's Comet, have an orbit that only takes a few years or decades and so are called short-period comets. Others, called long-period comets, travel much further into deep space, taking thousands of years to complete an orbit.

For most of these orbits, the nucleus remains an inert lump of ice, but this changes as the comet nears perihelion, its closest approach to the Sun. When close enough, the solar radiation heats the surface, causing the volatile components to boil. As the gas escapes into deep space it lifts off dust, creating a shroud that can stretch out over 50,000km around it – the coma.

Tale of a tail

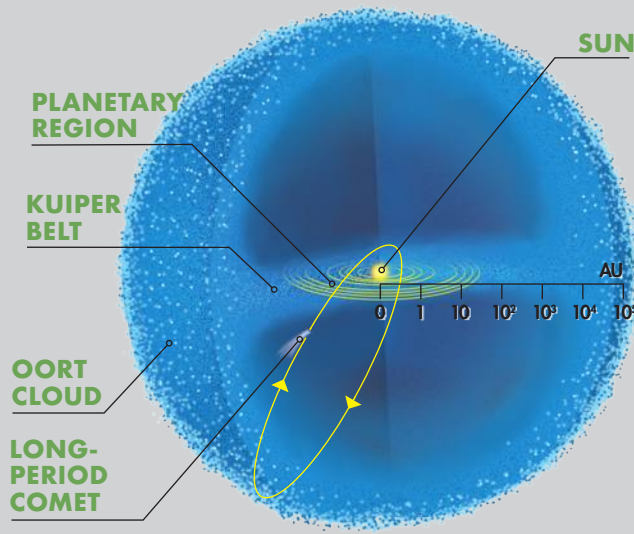
As the comet gets closer to the Sun, this envelope begins to feel the solar influence even more acutely, as its wind and magnetic field sweep the dust and gas out into a huge tail. This can extend for millions of kilometres, spanning huge swathes of the Solar System. Some of the tail's debris is left behind in its orbit to form a meteoroid stream. Several of these cross the Earth's orbit, and when we pass through them every year, we see the debris burning up in the atmosphere as a meteor shower.

For most comets, these close encounters with the Sun do little more harm than melting another layer off the nucleus. However, sometimes comets get too close, and the stresses caused by the intense heat and gravity cause them to break apart, as happened in December 2013 with comet C/2012 S1 ISON.

Sunlight reflecting off the coma and tail causes these celestial visitors to glow in the night, making them an ever-popular target for astronomers. Unlike the annual meteor showers their passing can create, comets are a much more transient phenomena adhering to a timetable all of their own. However, every year there are a handful of comets that can be seen with the aid of a small telescope. Websites such as International Comet Quarterly

WHERE DO THEY COME FROM?

After the planets formed, the remaining material coalesced into two regions. The inner of these, between 4.5 – 7.4 billion km out, is the Kuiper Belt. It's thought short-period comets come from here after being knocked out of orbit. Beyond this, the Oort Cloud stretches to 3.2 lightyears from the Sun. If a passing star kicks one of its bodies off course, it creates a long-period comet.



(www.icq.eps.harvard.edu/cometobs.html) and the British Astronomical Association's Comet Section (www.ast.cam.ac.uk/~jds) list all the comets that are currently active and visible with an amateur telescope, and where they might be found.

Even if we know when a comet is likely to appear and the path it will take, no one can guess what it will behave like once it approaches the inner Solar System. A comet could pass so close to the Sun that experts are sure it will be a spectacular view, only for it to break

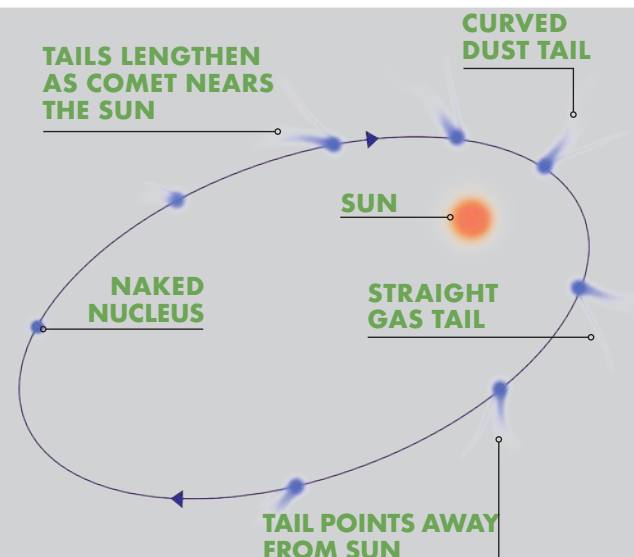
apart during perihelion, or give little more than a fizz of a tail.

However, once in a decade or so there is a comet that passes close enough to Earth and is bright enough to be seen with the naked eye. When one of these is truly exceptional it may be bestowed the moniker of 'Great Comet'; an apparition so magnificent it is remembered for centuries (or even millennia) to come.

In the past comets were portents of death and war, but now these capricious visitors are a highlight for anyone lucky enough to see one as it passes by.

CHASING THE TAIL

The most alluring part of a comet is surely its huge tail, but it's not always obvious is that there are two. The most apparent is the dust tail, swept out in an arc by the solar wind. However, the magnetic field captures the gas, forming a fainter second tail. Sometimes the comet's position relative to Earth means the tails appear to go in two different directions.



FAMOUS COMETS

Dominating the night sky or the landing site for a probe, these are among the best-known comets



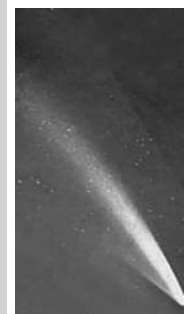
HALE-BOPP

Closest approach: 136 million km
Period: 2,520-2,533 years
Famed for: Naked eye visible for a record 18 months in 1996/97, Hale Bopp captured public interest the world over. It will return around the year 4385.



67P/CHURYUMOV-GERASIMENKO

Closest approach: 186 million km
Period: 6.4 years
Famed for: Target of the Rosetta mission, which studied the comet from orbit and sent the Philae lander to its surface, where it found water and organic compounds.



GREAT DAYLIGHT COMET

Closest approach: 19 million km
Period: 57,300 years
Famed for: Spotted in January 1910, this comet quickly brightened until it outshone even Venus. Visible from both hemispheres, its tail was noticeably curved.



HALLEY'S COMET

Closest approach: 88 million km
Period: 75.3 years
Famed for: The only known short-period comet regularly visible to the naked eye from Earth, this regular visitor has been observed as early as 240 BC.



IKIYA-SEKI

Closest approach: 450,000 km
Period: 876.7 years
Famed for: Its 1965 close pass of the sun made Ikeya-Seki one of the brightest comets in 1,000 years. It's thought to be a fragment of the Great Comet of 1106.

NOCTILUCENT CLOUDS

These eerie, glowing blue clouds can be seen in summer skies

From late May through to early August, there is an intriguing and unusual observing target that is only visible in summer's twilit skies – the eerie blue tendrils of noctilucent clouds.

Noctilucent clouds, also known as night shining clouds and more commonly referred to by the abbreviation NLCs, were only discovered in 1885, following the 1883 Krakatoa eruption. The massive explosion of this Indonesian volcano had an impact all over the world, dropping temperatures by 1.2°C, generating eye-catching sunsets, and leading to an increased awareness of related atmospheric phenomena.

NLCs are located in the upper fringes of Earth's atmosphere and are therefore a quite distinct and separate cloud type from the familiar weather or 'tropospheric' clouds of the lower atmosphere. They form in the mesosphere, just below the mesopause (the coldest part of the atmosphere), in a thin sheet at an average height of around 82km, close to the edge of space.

The precise nature of these clouds is not yet fully understood, but they are thought to form when water vapour condenses onto minute atmospheric particles and freezes. The most likely sources of such particles would be meteor debris (meteors can vaporise at around 100km, above the NLC layer) or volcanic activity. Studies indicate that NLCs need extremely cold temperatures, around -120°C, to form. The mesosphere is at its coolest in summer, which explains NLCs' seasonal behaviour.

NLCs only become visible against a twilight sky when the Sun lies between 6° and 16° below the horizon. Any less than 6° below the horizon and the background sky is too bright, swamping the fainter light of NLCs; on the other hand, if the Sun is more than 16° below the horizon, then the NLC sheet lies in the Earth's shadow, becoming invisible.

This 'Sun-Earth-Observer' geometry imposes geographic restrictions on NLC visibility, as does the physical location of

the NLC sheet itself, which is generally located from 60° to 80° latitude in each hemisphere. This explains why the bulk of NLC sightings are made from within the latitude band of 50° to 65°, which conveniently encompasses the UK and Ireland. Nonetheless, NLCs can be, and are, observed from outside this area. Rare, isolated sightings have been made from as far south as 40° latitude, both from Europe and the US.

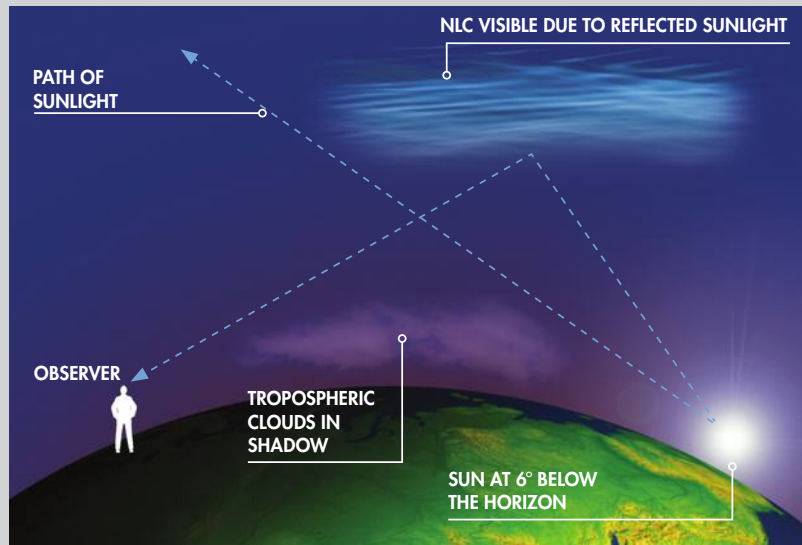
Pattern recognition

Each year, NLCs become visible in a fairly predictable pattern. The earliest sightings usually come near the end of May or early June, when cooling of the mesosphere sets in. Early sightings are normally of weak, simple formations, but as the season progresses displays tend to be brighter, more complex, endure for longer and occupy larger areas of sky. Records show a clear peak in activity from around mid-June through to mid-July, by which time the season starts to gradually tail

WHY DO WE SEE NLCS?

UK observers can see NLCs due to a bit of fortunate geometry. When the Sun is between 6° and 16° below the horizon, its light will hit any NLCs present in the

mesosphere, making them visible from Earth at latitudes of around 50° to 65°. Beyond this range, NLCs appear much less frequently.



off. By early August the season is all but over, though rare sightings have been made later in that month.

Wispy streaks

A typical display will commence about an hour or so after sunset, initially appearing as faint, wispy streaks, perhaps extending only a few degrees above the horizon. As the night unfolds and the twilight sky darkens, the NLCs become more obvious and may rise higher in the sky, often developing more intricate structure and becoming noticeably brighter. As local midnight nears, NLCs may fade somewhat and shrink in size as the solar illumination becomes less favourable. But after midnight, this pattern of behaviour is reversed: NLCs get brighter and stronger again until they are

swamped by the brightening sky, perhaps an hour or so before dawn.

NLCs can be easily misidentified. The key thing to remember is that weather clouds generally appear dark, silhouetted against the twilight, whereas NLCs will always appear brighter than the background sky, often exhibiting a signature bluish tone. Nonetheless, thin streaks of cirrus cloud, especially if illuminated by moonlight, can bear a striking resemblance to NLCs, and low bands of horizon haze can also create false impressions of Type II NLC bands. A good test to perform on any suspected NLCs is to examine the feature with binoculars. Tropospheric clouds tend to remain diffuse and blurred when magnified, while NLCs almost always reveal levels of finer detail.

WHEN'S THE BEST TIME TO LOOK FOR NLCS?

Typically 90-120 minutes after sunset, low in the northwest, or for a similar period before sunrise low in the northeast.

NLC STRUCTURES



TYPE I: VEIL

This type of NLCs appear as a patchy, fibrous sheet with little or no obvious structure, sometimes visible in the background of other forms. It can look like a glowing fog or mist.



TYPE II: BANDS

These NLCs feature horizontal lines or streaks that can be sharp (Type IIa) or diffuse (Type IIb). The bands may be parallel, or meet and cross.



TYPE III: BILLOWS

A distinctive structure of rippled or wavy bands, Type III NLCs are often compared to the sand patterns formed on a beach at low tide.



TYPE IV: WHIRLS

Looped, curved or twisted forms. Small whirls can be classed as Type IVa, medium size as IVb and large scale loops as IVc.

AUORAL DISPLAYS

These dancing curtains of light are magnificent, but not always easy to see

Shimmering, flickering drapes, rays and coroneae – the aurora is one of the most dynamic displays that the natural world, let alone the night sky, can offer. It gives us, here on the rocky surface of planet Earth, a rare and fleeting glimpse of how we are connected to the unseen forces at play out in space.

While some more energetic displays have been visible as far south as the UK, aurorae are more common if you're under the auroral oval. Centred on Earth's magnetic poles, the ovals trace rings of dancing light that roughly follow the Arctic and Antarctic Circles, and the best chances to view the aurora are from countries within this region. In the Arctic Circle this phenomenon is known as the aurora borealis, or Northern Lights; in the Antarctic Circle it is the aurora australis, or Southern Lights.

Auroral displays are caused by charged particles streaming out of the Sun and interacting with Earth's magnetic field – our planet's protective shield – which channels them down towards the

magnetic poles. As the particles reach lower altitudes, usually between 80km and 200km, they hit and excite the gases in Earth's atmosphere, causing a distinctive and colourful glow. This is far above the height that passenger aircraft typically fly (around 10km), but the International Space Station and other manned spacecraft have flown through the upper reaches of an energetic display, giving rise to some stunning views.

The magnetic poles are about 11° away from the geographical poles (the ones traditionally referred to as the North and South Poles). So you stand a much better chance of seeing all this activity in far northern or southern latitudes.

See the light

To observe them, you don't need a telescope or even binoculars: the best view is with your own eyes as their wide field of view is best suited to taking in the play of light across large parts of the sky.

An auroral display can take many forms and can change very quickly.

A general glow stretching across the sky from east to west is called an arc and usually has a well-defined lower edge. If the arc has an irregular lower edge, then it is known as a band.

Another common shape witnessed in a display are rays, which look like shafts of light stretching upwards into the sky and are, in effect, a direct way of seeing the Earth's magnetic field lines. These can occur on their own or in a group. If an arc or band contains rays, then it is known as a rayed arc or rayed band. If a

TOP TIPS FOR AURORAWATCHING

- Check space weather sites such as aurorawatch.lancs.ac.uk and spaceweather.com for aurora alerts.
- The further north you are, the better your chances of witnessing a display.
- Position yourself with a clear view of the northern horizon, where displays will appear.

band shows kinks and folds, these are known as curtains or drapery. Patches are just that – an auroral glow that has no particular shape and can come and go. Veils are a general glow covering more of the sky, but with little structure. In a very large and active display, the rays may even appear to converge directly above you, giving rise to an auroral crown or corona.

Aurora observers also add descriptions about how quickly a display changes. If it just hangs there in the sky with little or no movement, then it's said to be quiet. If it fades and brightens, a display can be called pulsating. When the aurora displays rapid but subtle changes, it is said to be flickering, while dramatic and quick-changing features – especially in the rays – are flaming. Lastly, streaming occurs along the length of a band when a bright patch ripples along it.

Whether you see colour in an auroral display depends on its brightness. Faint displays will appear monochrome, with differing shades of grey. However, most commonly the aurora has a green colour – light given off by oxygen in our atmosphere. Red can also be present, especially in the upper rays, as this colour comes from oxygen higher in our atmosphere, while blues and purples can appear in very bright displays when nitrogen becomes excited.

Brightness and contrast

There's an internationally recognised scale for measuring the brightness of the aurora, called the International Brightness Coefficient (IBC). This runs from I to IV – faint to bright. An IBC I display is about the brightness of the Milky Way, with minimal colour present. IBC II looks similar to moonlit cirrus cloud and may have a slight greenish colour. IBC III is similar to bright, moonlit, low-altitude clouds with obvious colour, while IBC IV is bright enough to read by, and to cast shadows.

In the past, auroral displays were difficult to predict, but now satellites such as the Solar Dynamics Observatory constantly monitor the Sun and the solar wind it throws off to provide early warning of its effects on Earth. There are several websites with email alert services that give early warning for potential displays, and with these space weather reports, we're better prepared than ever before for witnessing a display. All that remains then is for the local weather to play ball as well.

AURORAL STRUCTURES



ARCS

An auroral arc: a general glow across the sky with a well-defined lower edge



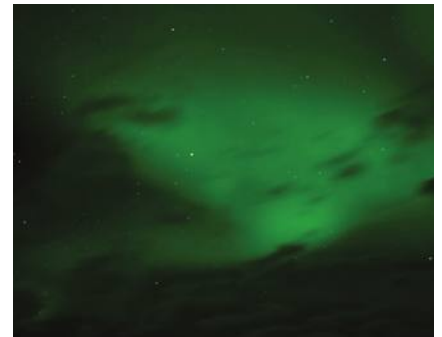
CURTAINS

A curtain aurora: a band of light that shows kinks and folds along its length



BANDS

An auroral band: similar to an arc but with an irregular lower edge



PATCHES

A patch aurora: these appear as a glow that has no particular shape



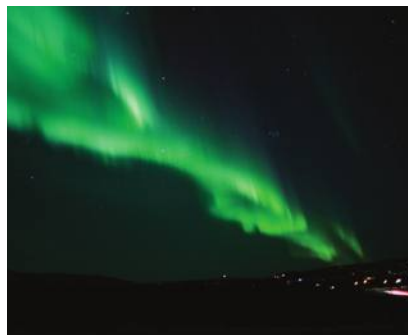
RAYS

Ray aurora: these present themselves as shafts of light stretching up into the sky



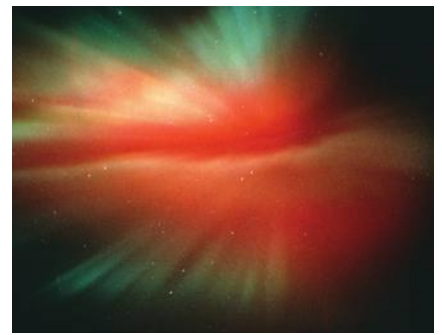
VEILS

An auroral veil: a general glow covering the sky with little structure to it



RAYED BANDS & ARCS

Rayed bands and arcs: similar structure to bands or arcs, also containing rays



CORONAE

A corona: rays that appear to converge at a point directly overhead

ASTRONOMY MYTHS DEBUNKED

Eight of the biggest astronomical myths, collected and comprehensively busted to help you become an expert in no time at all

THE MOON CAN'T BE SEEN IN THE DAYTIME

There's a common conception that just as the Sun can only be seen in daylight hours, the Moon only comes out at night. But Earth's rotation means that the Moon must be above the horizon for 12 hours out of every 24, regardless of the length of the night. As such, the Moon is often somewhere in the daylit sky. Whether we see it is down to two things – its altitude in the sky and its phase.



POLARIS IS THE BRIGHTEST STAR IN THE SKY

Polaris is certainly among the most famous, being star closest to the north celestial pole, but this usefulness does not make it the brightest in the sky. Spend an evening outside and it will become obvious that this honour falls to Sirius, in the constellation of Canis Major.

STARS TWINKLE

'Twinkle, twinkle, little star' has a lot to answer for. Stars often appear to flicker in the night sky, but this has nothing to do with the star and everything to do with our turbulent atmosphere. Once it reaches Earth, starlight is reflected, bent and contorted by this turbulence, until it reaches your eye. Viewed from space, stars would not twinkle at all.



EARTH'S DISTANCE FROM THE SUN CAUSES THE SEASONS

Not so – Earth is actually closest to the Sun during the northern hemisphere's winter. The real reason is due to Earth's 23.5° axial tilt, which means each hemisphere gets varying durations of sunlight over the year.

POLARIS HAS ALWAYS BEEN THE POLE STAR

Polaris's position next to the north celestial pole is a temporary one, a result of Earth wobbling on its axis as it spins. The change is about 1° every 72 years, with a full cycle taking around 26,000 years. In 3,000 BC the pole star was Thuban in Draco, but in 2,000 years time it will be Errai in Cepheus.

SHOOTING STARS ARE REALLY STARS

If you have ever wished upon a star, you may be shocked to learn it wasn't a star at all. What you saw was the bright flare of piece of debris, likely to be no bigger than a grain of sand, burning up in our atmosphere. They are properly known as meteors. If a fragment makes it to Earth's surface, it is called a meteorite.



THE POINT OF A TELESCOPE IS TO MAGNIFY CELESTIAL OBJECTS

While telescopes can make the denizens of the night sky appear bigger, this isn't their primary purpose. Their main function is gather light, using a lens or mirror depending on the design, so that we can see objects too dim to view with the naked eye.



THE MOON HAS A DARK SIDE

The phrase 'dark side of the Moon' is often and erroneously used to refer to the Moon's far side, which means something subtly different. The far side is the hemisphere of the Moon permanently turned away from Earth, but calling it the dark side implies it never sees any sunlight – which is not the case. The lunar far side goes through the same cycle of phases as we see on the near side from Earth, with the only period it can technically be called the dark side being the time of full Moon.



BBC
Sky at Night
MAGAZINE

GUIDE TO THE MOON

**Discover our celestial neighbour and
its most stunning features**



**FIND OUT ALL ABOUT
THE MOON'S ORBIT, PHASES
AND HOW IT FORMED**

**EXPERT ADVICE FOR VIEWING
THE SEAS AND CRATERS
ON THE LUNAR SURFACE**

**THE MOON ILLUSION
AND OTHER LUNAR
ODDITIES EXPLAINED**



NEED TO KNOW

AGE 4.5 billion years

DIAMETER 3,475km

MASS 0.0123 Earths

AVERAGE DISTANCE 384,400km

AVERAGE ORBITAL VELOCITY 3,679km/h

ORBITAL PERIOD 27.3 Earth days

LUNAR CYCLE 29.5 Earth days

SURFACE GRAVITY One-sixth that of Earth

OUR CONSTANT COMPANION

A familiar sight in our skies from ancient times, the Moon is threaded through humanity's history

The source of our ocean tides, subtle chronobiological cycles and the only other world that humankind has so far set foot upon, the Moon seems a familiar and tangible place. A quarter of Earth's diameter and just a quarter of a million miles away, it's 100 times closer than Venus. Given its proximity, brightness and large apparent size, it's easy to see why the Moon has enchanted humankind for centuries.

Before the emergence of widespread street lighting, the Moon was the primary source of light for nocturnal activities. Its sheer size and regular cycle of phases made it an obvious

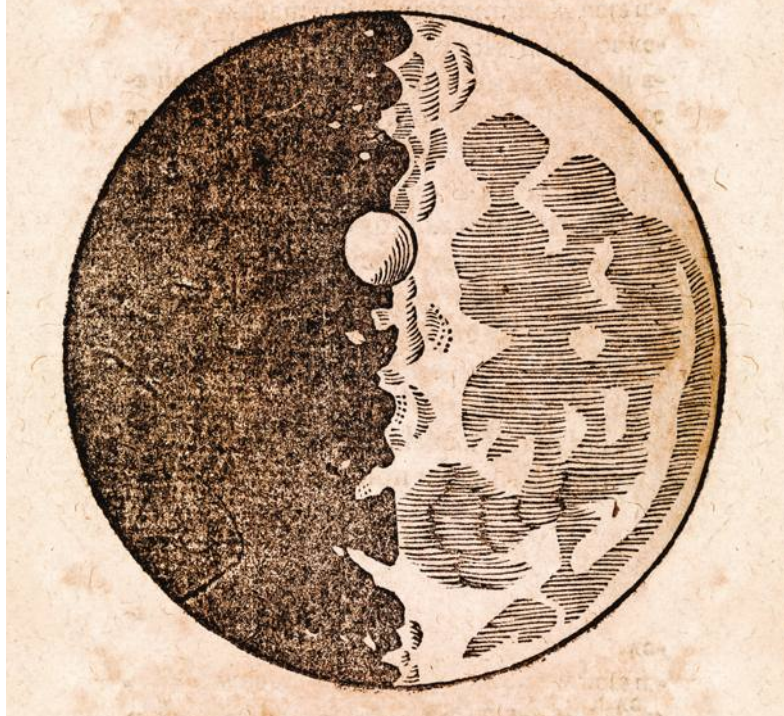
WHAT'S OUR MOON MADE OF?

Our natural satellite has a small core composed predominantly of iron, a distinct mantle, and a crust of varying thickness comprised of anorthosites and basalt

timepiece to our ancient ancestors, forming the basis of some early calendars, and in various cultures the Moon either had deities associated with it or was considered to actually be one. In the following centuries, when astrology and astronomy were one and the same, it continued to bear a supernatural significance, marking when certain activities and plans would go well – and when they were doomed to fail.

Pre-telescopic observers noticed an unchanging pattern of darker patches that would later become known as maria, or 'seas', because they were assumed to be vast bodies of water. They act as a Rorschach test for ►





► different cultures – the face of the ‘Man in the Moon’ observed in Western tradition, the ‘Rabbit’ pounding rice of East Asian folklore, or the ‘Lady Reading a Book’ from the southern hemisphere, to give just three examples.

Until the middle ages, the Moon was believed to be a smooth sphere, neatly slotting into the Aristotelian view of the ‘perfect heavens’. It wasn’t until after 1609, when Galileo turned his telescope to the Moon, that this perception was undone.

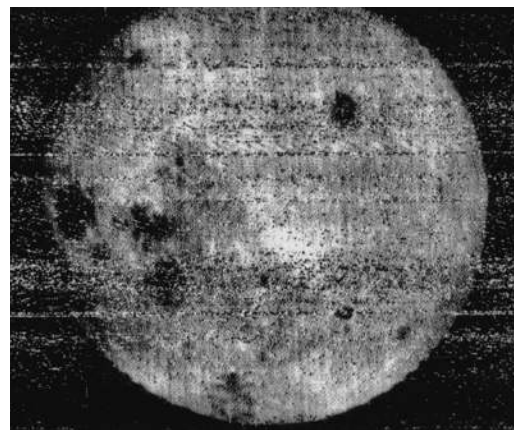
Galileo was not the first to examine the Moon through a telescope – that accolade falls to Englishman Thomas Harriot, whose sketches predate Galileo’s by several months – but he was the first to publish. In his *Sidereus Nuncius*, Galileo revealed a world pockmarked with craters and mountains. He had seen that the terminator, the line that divides lunar day and night, was often jagged, correctly inferring that this irregularity must result from shadows cast by topographical features.

About a dozen lunar landforms can be distinguished with a keen eye. A typical pair of binoculars, if suitably steadied, will transform your view of the Moon into a scarred, airless world, and most likely will give you a better view than Galileo had in the 1600s. Through even the smallest modern scope innumerable impact craters appear, often fringed by long rays of ejecta. Alongside them sit grand basins of solidified lava, soaring mountain peaks, curious fissures and escarpments – it’s a whole new world to explore.

Locked on Earth

You don’t need a telescope to reveal that night after night we always see the same lunar features staring back at us. This is because the Moon has a

▲ This is one of many lunar sketches Galileo made through his telescope in 1609, sketches that challenged prevailing views of what the Moon was like



▲ Our first view of the far side came from Luna 3 in 1959 – and revealed a startling lack of maria

synchronous rotation with respect to Earth, meaning that spins once on its axis in the same 27.3 days (the sidereal month) it takes to complete an orbit of our planet.

This is no coincidence. Earth’s gravitational pull on the Moon has caused a bulge in the body of the Moon itself, similar to the tides in Earth’s oceans. This bulge unbalanced the Moon’s gravitational force, slowing its rotation until the bulge aligned with the Earth. Despite its appearance in the sky, our Moon is nowhere near round; it is closer to a lemon shape.

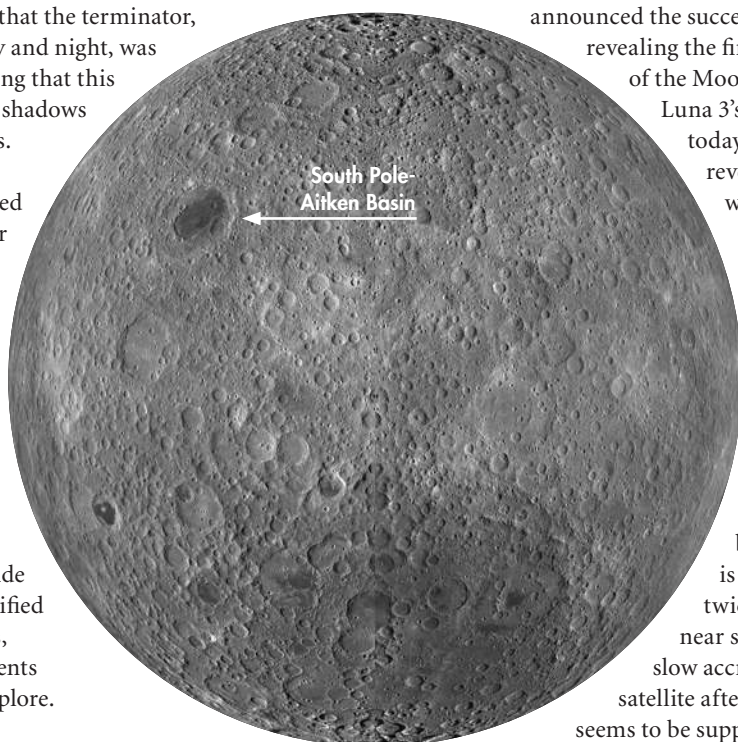
A consequence of this ‘tidal locking’ is that for much of human history the Moon held a closely guarded secret: no one knew what the far side was like. This didn’t change until 1959, when the Soviet Luna 3 probe became the first to pass image the hitherto unseen side.

In a memorable episode of *The Sky at Night* broadcast on 26 October 1959, Patrick Moore announced the success of the Soviet mission, revealing the first shadowy photographs of the Moon’s far side live on air.

Luna 3’s imagery was crude by today’s standards, but it revealed that the ‘dark side’ was strikingly different in a number of ways.

While 35 per cent of the Moon’s Earth-facing hemisphere is covered with mare lava, very little molten material made it to the surface on the far side, so maria account for just one per cent. It’s thought this is because the far side’s crust is thicker – it may be up to twice as thick as that of the near side – possibly due to the slow accretion of a companion satellite after an impact. This theory seems to be supported by the discovery

of the far side’s 3.9 billion-year-old South Pole-Aitken Basin, over 2,400km wide and around 13km deep. To date, our best views of the Moon come from NASA’s Lunar ►



▲ The far side as we know it today, forever turned away due to tidal locking

THE MAJOR CLASSES OF LUNAR FEATURES

VALLEYS

There are 14 official valleys on the Moon, the longest around 600km. Most are named after nearby craters. One of the most familiar is the 180km-long Vallis Alpes (pictured), which cuts across the northern Montes Alpes and almost connects the Mare Imbrium and the Mare Frigoris.

SEAS

These vast dark plains of solidified magma are notable for both their dark appearance and the fact that they are largely absent from the Moon's far side. One of the most distinct is the 560km-wide Mare Crisium (pictured) which is just visible to the naked eye.

CRATERS

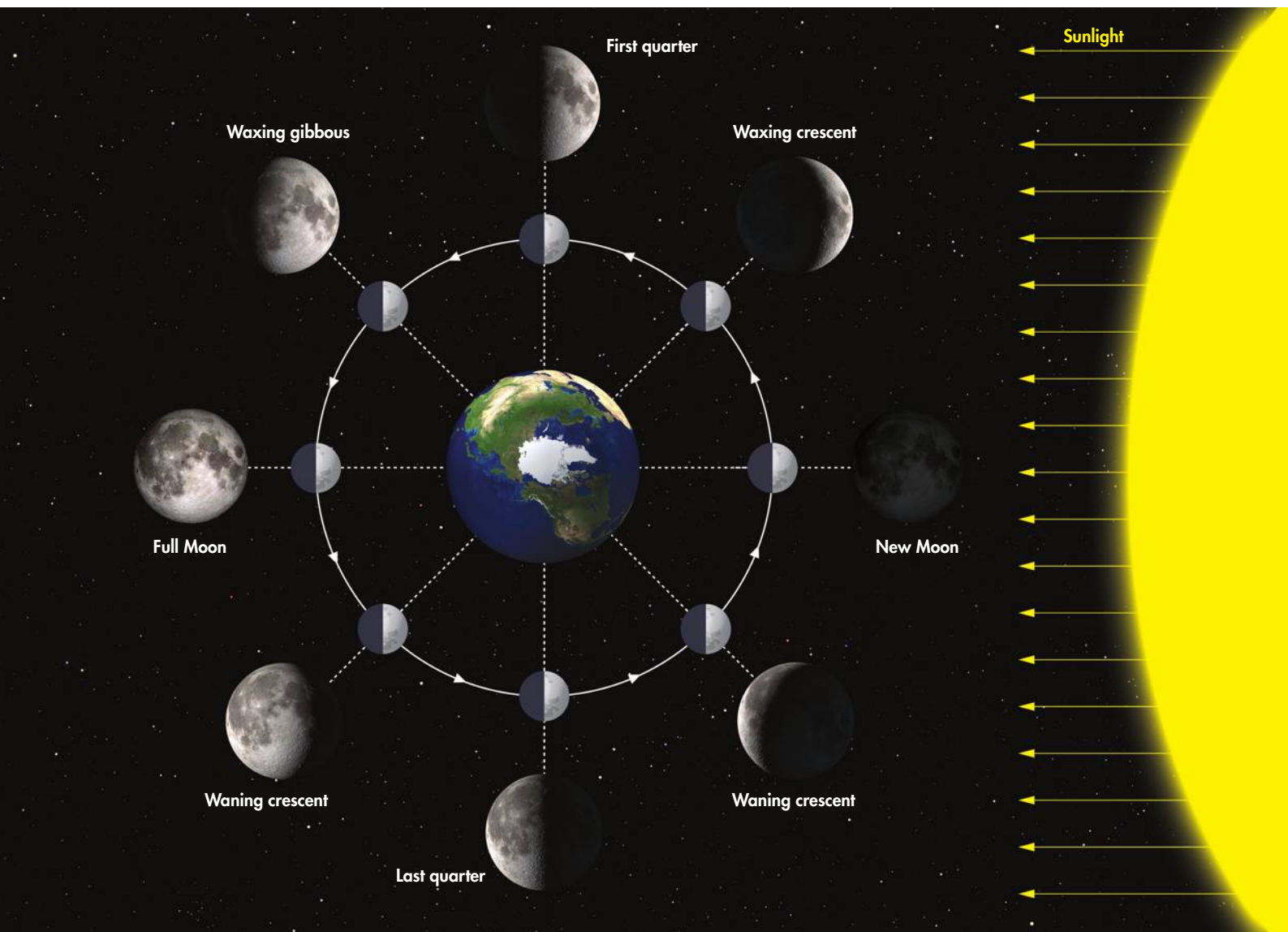
The ubiquitous lunar feature, varying in size from microscopic pits to sprawling depressions up to 350km in diameter — anything larger is a basin. Some were formed through volcanism but the majority, like Tycho (pictured) are the result of ancient impacts.

BASINS

The oldest and largest impact craters on the Moon, exceeding 350km in diameter. All lunar maria are found within them. The South Pole-Aitken Basin on the Moon's far side holds the record for being the largest, at around 2,400km; the biggest on the near side is the Imbrium Basin, shown here, which stretches across 1,160km of the lunar surface.

MOUNTAINS

The Moon's peaks are named in two ways: 'Montes' for mountain ranges and 'Mons' for singular peaks and massifs. The most spectacular of the 18 named lunar ranges is the gently curved, 600km-long Montes Apenninus (pictured), which form the southeastern edge of the Imbrium Basin. Mons Huygens, the Moon's tallest mountain at 5.4km, soars skyward here.



► Reconnaissance Orbiter, now in its sixth year of operations and, at the time of its launch, the first US mission to the Moon in 10 years.

The Sun always shines

It's equally obvious that the illumination of the Moon's Earth-facing hemisphere changes over the course of the month – a word, incidentally, that we get from 'Moon'. Although the Sun is always shining on a full half of the Moon, the proportion of the lit side we are able to see depends on where the Moon is in its orbit around Earth, giving rise to the phases we see.

Imagine you are looking down on the Earth, Moon and Sun from above. When the three line up with the Moon in the middle, the Moon's lit half points away from us on Earth, producing a new Moon. Slowly emerging from its new phase into the evening sky, the lunar crescent thickens from one day to the next. The term 'waxing' is used to indicate this thickening phase. The waxing crescent leads to the Moon appearing as an illuminated semicircle roughly a week after new.

This is somewhat confusingly called 'first quarter', referring to the Moon's position in its 29.5-day orbit rather than proportion of its disc is illuminated from our vantage point on Earth. The

▲ **The Moon's cycle of phases is the result of its position relative to us and the Sun in its orbit**

bulging phases after first quarter are known as waxing gibbous. These increase in size until roughly two weeks after new, the Moon is on the opposite side of its orbit from the Sun and appears fully lit as a full Moon. The point of new and full Moon, when our planet, satellite and star are aligned, is technically known as a 'syzygy'.

After full Moon the phases reverse, and the illuminated part of the Moon begins to shrink or wane. After passing through the waning gibbous phases, the Moon reaches the three-quarter point of its orbit, giving rise to the 'last quarter' phase. The Moon takes the appearance of a semicircle once again, although it's the opposite half that is illuminated than that at first quarter. After this, it takes approximately a week for the Moon to go through its waning crescent phases, visible in the early morning sky, before it once again becomes new again. It takes 29.5 days for the Moon to return to complete this cycle of phases or 'lunation', slightly longer than it does to complete an Earth orbit. This is known as a synodic month.

Ellipse and eclipse

The Moon's elliptical orbit is inclined to Earth's by an average of 5°. This means that on most of the occasions that a full Moon occurs, it actually

passes above or below the shadow Earth casts into space. But in the instances that the full Moon passes into Earth's shadow we see a different phenomena: a lunar eclipse.

Because the Sun is much bigger than Earth, it splits our planet's shadow into two parts: the darkest, called the umbra, and a lighter outer ring, called the penumbra. The intensity of a lunar eclipse depends on how much of the Moon passes into Earth's shadow, and which part of the shadow it passes through.

In a total lunar eclipse, the entire Moon passes through the penumbra and into the umbra, gradually darkening until it is completely covered, a point known as totality. During totality no sunlight shines directly on the Moon, but some is refracted onto it via Earth's atmosphere. As our atmosphere filters out blue light, the Moon often gains a strange orange-brown colour.

As the Moon goes into eclipse and dims, the sky gets darker too. You may not have realised how bright a full Moon can be. It lights up the sky around it with a blue haze, out of which only the brighter stars are visible. During a total lunar eclipse, the darker Moon means that the fainter stars can come out and we end up with

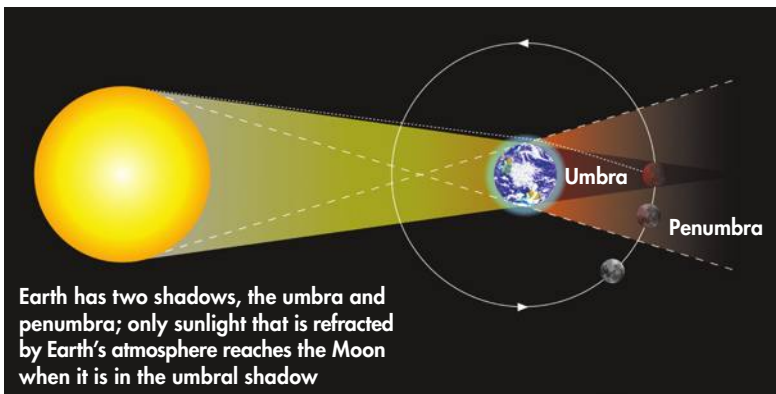
THE BIG MYTH

The dark side of the Moon



The Moon's north pole is home to permanently-shaded craters, some of which contain ice

The phrase 'dark side of the Moon' may evoke fond memories of Pink Floyd's 40-year-old prog-rock album to the baby boomer generation, but in an astronomical context it's often used to refer (erroneously) to the Moon's far side. The phrase is something of a misnomer, since the lunar far side goes through the same cycle of illumination as the phases of the Moon seen on the Earth-facing hemisphere. Technically, the far side is the 'dark side' at the instant of full Moon. The only places on the Moon's surface permanently bathed in shadow are a few deep craters at the north and south poles.



the eerie sight of a deep-red Moon surrounded by twinkling stars.

There are two other types of lunar eclipse: partial, where only a portion of the Moon passes through Earth's dark umbral shadow, and penumbral, where part of the Moon only passes through the lighter, outer shadow. Partial eclipses can be quite noticeable, but penumbral eclipses often only cause a slight dimming.

When the same thing happens at new Moon the opposite occurs, and we may see a partial or total solar eclipse. By staggering coincidence, right now the Moon is both 400 times smaller than the Sun ▶





► and 400 times closer, meaning that they appear to be the same size in the sky. The fact the Moon only just covers the Sun during a total solar eclipse allows us to glimpse our star's ghostly outer atmosphere, the corona.

▲ **Total solar eclipses can only happen because of a staggering cosmic coincidence**

was only 22,500km from our planet. Today, it's nearly 10 times farther away and getting more distant by 3.8cm a year – around the same rate as your fingernails grow. As a result, Earth's spin speed is slowing down and our days are getting longer.

Eventually, there will come a point when the length of the day and the month will be the same, and the Moon will cease to cross our skies. There will be no new or full Moon, only a small static disc in the night sky visible from one side of the planet, a situation we see today in the Pluto-Charon system. By the time that happens, humans will hopefully be looking out at other moons from distant planets.

A changing relationship

Life on Earth owes a lot to our rocky companion. Without it, our planet's axis would tilt wildly between 0° and 85°, albeit over a period of a million years, sending our hemispheres veering between chaotic ice ages and searing hellscapes. It would have been a death sentence for evolving life.

But our relationship with the Moon is becoming increasingly distant. When it formed, the Moon

NASA/JPL-CALTECH X 24, ISTOCK X 2, ISTOCK, WILL GATER

WHERE DID THE MOON COME FROM?

Most scientists now believe that the Moon was formed around 4.5 billion years ago when an object the size of Mars (and since named Theia) collided with the early Earth, giving it a glancing blow. The impact spewed debris into Earth's orbit, which coalesced to form the Moon at just the right distance to be an independent body; any closer and Earth's gravity would have pulled the material back.

This theory was born from the chemical analysis of lunar samples returned by the Apollo missions, which showed a remarkable similarity between Earth's composition – hinting at a common heritage. But there is a problem: the compositions look too similar. If this collision occurred, the Moon should have more of Theia's material and should therefore be more different from Earth.

The Apollo samples were obtained from a very small area – could this explain the similarities? It would seem not, because we do have other lunar material. The Russian Luna programme returned 0.33kg of Moon samples and we also have a number of lunar meteorites. Analysis of this material brings up a similar problem, it is just too similar to the composition of Earth.

So where does this leave the collision theory? It still has a lot of support, but what would be a great help is having more lunar samples from known but more varied locations.





THE BASICS OF **LUNAR** **OBSERVING**

Explore the seas and craters that texture the lunar surface with our beginners' observing guide ►

The Moon is an ideal object to begin your observing odyssey because it is big, bright and covered with amazing detail.

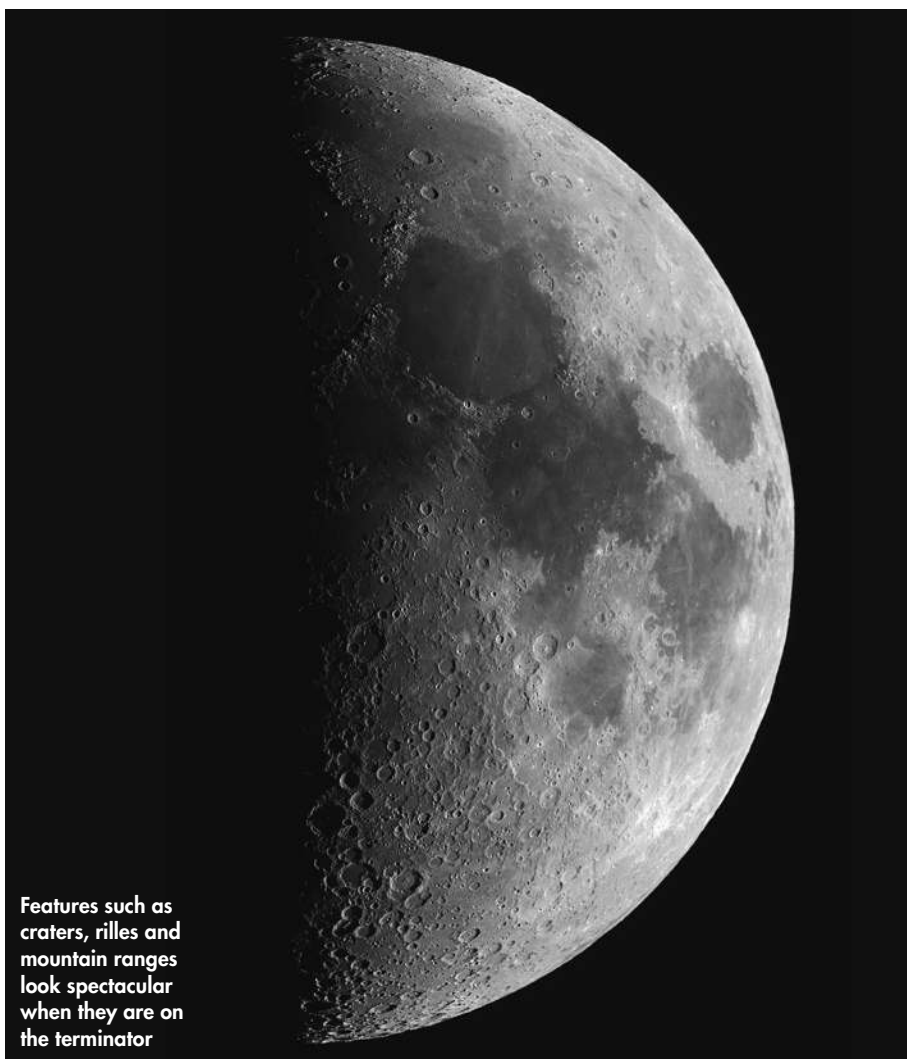
But the thing that surprises most novice observers is the variation it holds.

Though the same hemisphere faces Earth at all times, what you can see on the Moon changes from one night to the next.

You may be forgiven for thinking that full Moon is the best time to examine our close companion – not so. While this is a good time to see the long, bright rays of ejecta surrounding prominent craters such as Tycho, the high altitude of the Sun in the lunar sky means no shadows are cast, resulting in a washed-out view of the Moon.

In general, the best time to view a given lunar feature is when the terminator, the demarcating line that separates lunar day and night, is nearby. This is the region where the Sun is either rising or setting, where crater rims and mountain peaks stand out in stark relief, casting inky black shadows across the lunar surface that exaggerate their presence. Those further from the terminator show hardly any shadows and are harder to make out.

At day zero of the lunar cycle – new Moon – the whole of the dark lunar hemisphere points towards Earth. Over the next 15 days the terminator slowly



Features such as craters, rilles and mountain ranges look spectacular when they are on the terminator

THE MANY GUISES OF THE MOON

Even to the naked eye, our satellite is a beguiling subject



EARTHSHINE

The Moon is not solely lit by sunlight. When it is in a slender crescent phase in the evening or dawn twilight, it's sometimes possible to see its dark portion gently glowing due to sunlight reflected off the oceans and clouds of planet Earth. This effect is known as earthshine. Our planet actually reflects more light onto the lunar surface than the Moon gives us when it is full.



LUNAR HALOES

On frosty nights, often when the Moon is or near full, you may be able to spot a faint ring of light caused by ice crystals refracting the moonlight in the upper atmosphere. Since the ice crystals are normally all hexagonal, the ring is almost always the same size; it has a diameter of 22°. Sometimes it is also possible to detect a second ring, 44° in diameter.



RED MOON

There are two reasons the lunar disc may take on a ruddy hue. The first is if it is low in the sky, so light reflected from it passes through more of our atmosphere. Blue and violet light is scattered more easily, so we see a redder Moon. The other is during a total lunar eclipse: longer sunlight wavelengths are refracted by the Earth's atmosphere onto the eclipsed Moon.



SUPERMOON

A supermoon is a full Moon that coincides with the closest point to Earth in its orbit, causing the lunar disc to appear larger by as much as 14 per cent. The word is rooted in astrology but, given the correct astronomical term is a 'perigee-syzygy Moon', you can see how it caught on. A supermoon also occurs with a new Moon at perigee – but you aren't able to see this one.



▲ Though the Moon completes an orbit of Earth in 27.3 days, it takes 29.5 to complete a cycle of phases due to our planet's motion around the Sun

creeps across the lunar surface from east to west until the disc is fully illuminated at full Moon. Then the tables are reversed as the encroaching darkened hemisphere heads west with each passing day, until the diminishing crescent becomes lost in the pre-dawn twilight.

Peering beyond the limb

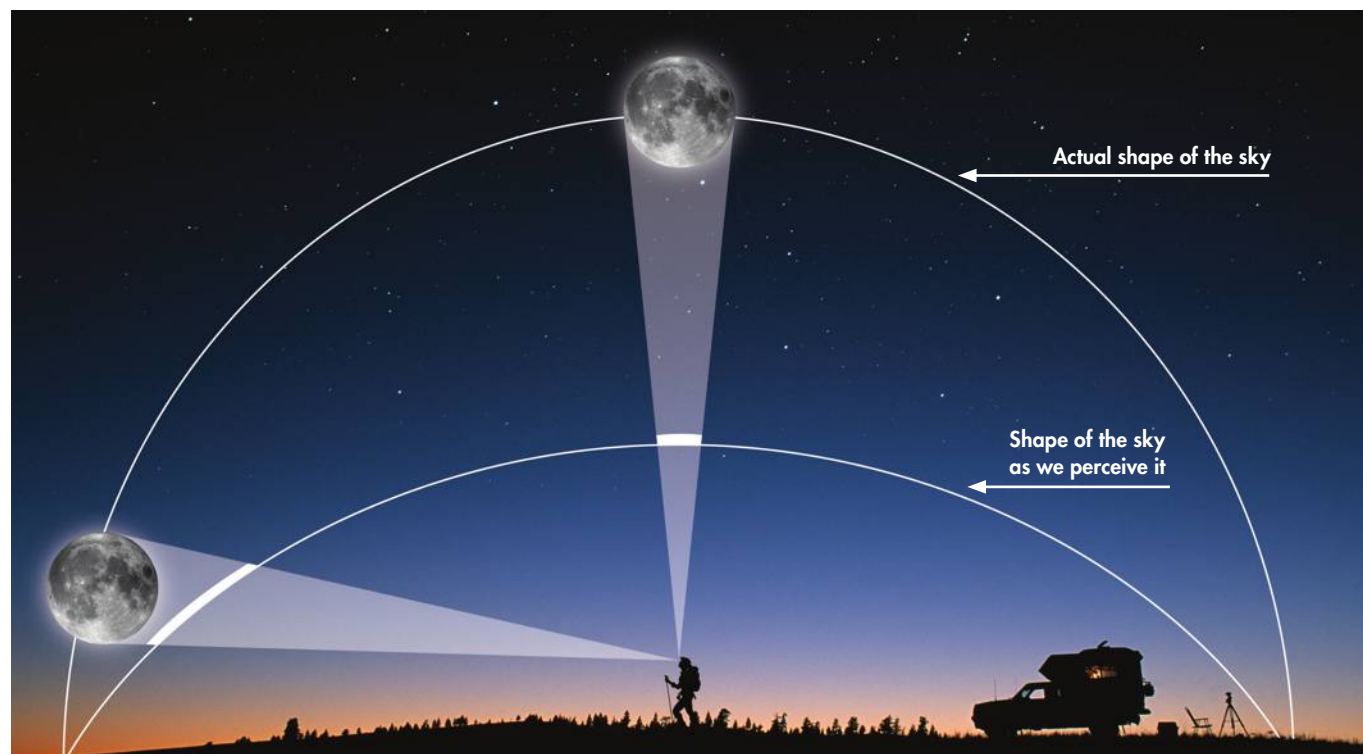
The nature of the Moon's orbit generates another effect that is a boon to lunar observers, a rocking and rolling motion

that we call libration. The Moon's orbit is elliptical, and as a result its distance from Earth does not remain constant. When closest it speeds up slightly; when more distant it slows down. This small variation is enough to cause the Moon to 'nod' back and forth on its axis, giving us an occasional chance to see a little more around its eastern and western edges.

The orbit is also slightly inclined, and this causes it to sometimes appear above

the Earth's orbital plane and sometimes below. This gives us an opportunity to peek over the top, and under the bottom, of the Moon over time. Taken together, this libration allows us to see a total of 59 per cent of the Moon's globe, revealing tantalising features normally hidden from view – some of which we'll cover later on in this special edition.

With the naked eye it's easy to see the progression of lunar phases, full disc effects such as earthshine and the ►



THE BIG MYTH The Moon illusion

Look for the Moon when it is low to the horizon and you may get the impression that it is unnaturally large – this is the phenomenon known as the Moon illusion, and it appears to be more pronounced around full Moon when the maximum area of its disc is illuminated. In reality, the Moon has more or less the same apparent diameter of around 0.5°,

whether it is looming over the horizon or riding high in the sky.

One explanation for the illusion arises from our perception of the shape of the celestial sphere above us; instead of a hemisphere, we perceive the sky to be a flattened dome. Consequently the lower the Moon is in the sky, the farther away and larger it is perceived to be. When the Moon

is high in the sky we conversely perceive it to be closer to us and therefore smaller in apparent size.

Few people seem to be immune to the Moon illusion, even though the viewer may be fully aware that for any given evening there is actually no appreciable difference in the Moon's apparent diameter, regardless of its height above the horizon.

THE RAREST MOON

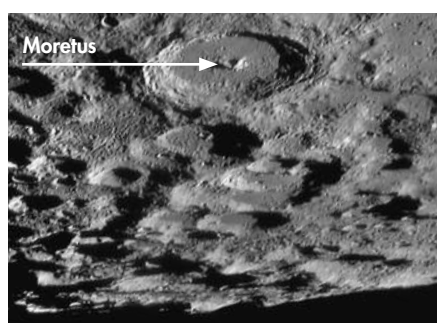
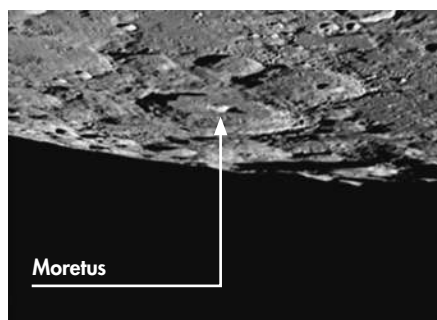
No doubt you've heard the expression 'once in a blue Moon' – meaning something that is exceptionally rare. But what exactly is a blue Moon, and does our neighbour ever adopt an azure appearance?

When astronomers use the term, they are most likely referring to one of two lunar events – neither of which cause the Moon to turn blue.

Traditionally, a blue Moon is considered to be the third full Moon in a season that has four. Normally, there are only three. The second and more modern interpretation is that it is the second full Moon that occurs in a calendar month, which can happen as a lunar cycle only takes 29.5 days to complete.

Why the discrepancy in definitions? It appears to be the result of a publication mistake that appeared in 1946 that confused the traditional meaning, which dates back to 19th-century editions of the *Maine Farmers' Almanac*.

And yet there is circumstance that can cause the Moon to truly appear bluish, as it did in the wake of the Krakatoa eruption in 1883, and it is exceptionally rare. The secret is that the atmosphere needs to be flooded with dust particles of a specific size – slightly smaller than the wavelength of red light – and that size alone. These particles scatter red light, causing the Moon to take on a slight cerulean cast.



▲ Libration brings features on the lunar limb into better view, as seen here. Crater Moretus appears squashed and foreshortened (top) but this changes under favourable libration (above)

► major lunar seas. Binoculars increase the detail you'll see: as well as dark seas, you'll now be able to spot individual craters and large mountain ranges, especially when they are close to the terminator. The smallest craters you'll be able to pick out will depend on how still you can hold your binoculars,

but a pair of 7x50s should comfortably reveal features down to about 50km across.

A telescopic view of the Moon is amazing and one that never gets old. At low magnifications, the amount of detail visible is breath-taking, especially close to the terminator where relief shadows really help to emphasise the detail. Upping magnification by using shorter focal length eyepieces will get you in closer and give you opportunity to 'roam' around the lunar landscape.

Trifles and troubles

The view you have of the Moon through a telescope will differ from what you see with the naked eye or binoculars depending on its optical arrangement. Through a refractor or compound instrument, the Moon will appear flipped west to east, while through a reflector the image will be inverted.

If you look at the Moon with a telescope you may also notice the surface appears to gently wobble or sometimes even shimmer. This effect is caused by air moving through the atmosphere of our planet, and the greater the turbulence the worse the views.

Such 'seeing' conditions can vary from minute to minute and night to night. The best views will always be had when the seeing is steady and these undulations are less intense; poor seeing, on the other hand, results in loss of detail and fuzzy

lunar features.

For centuries, telescopic observers have also reported seeing short-lived changes in brightness on the surface of Moon, events that are collectively referred to as transient lunar phenomena, or TLPs. They have been described as luminous spots that suddenly appear and vanish, localised patches of colour and temporary blurring or misting of the Moon's fine surface detail. However, despite several high-profile reports – including those from Sir William Herschel in 1787 and French astronomer Audouin Dollfus in 1992 – their existence remains debated to this day.

The problem is that TLPs, being transient by nature, are hard to independently verify and impossible to reproduce. Most are spotted by lone observers, or are only witnessed from a single location on Earth, casting doubt on whether they truly occurred at all. Some believe that TLPs are little more than the result of poor observing conditions or equipment issues. Assuming they do occur, the most popular theory to explain them is residual outgassing from below the lunar crust.

What does seem clear is that TLPs, whether real or imagined, are more prone to occur on some areas of the lunar surface than others, with more than one-third of official reports coming from the region around the Aristarchus plateau.