# Chapter 1

# The Changing Sky

### In This Chapter

- Understanding the changing sky
- Viewing the phases of the Moon
- Watching the daily, monthly and yearly changes

As a stargazer, you'll spend a lot of time outside at night. Although the thousands of stars in the sky overhead may seem a little overwhelming at first, you'll quickly become used to the changing sky.

In this chapter, I look at the ways in which the sky changes, whether over the course of a night, several nights or throughout the year, and explore the reasons behind these changes.

## Night and Day

Understanding the way the sky changes is an important part of stargazing. The earliest attempts to understand the universe were driven by the desire to mark out time, and ancient stargazers used the changing sky to do just that. Imagine that you're a stargazer thousands of years ago; what changes would you see happening in the sky, and how would you try to understand them?

The most obvious change in the sky happens every day as the Sun sets and the daylight fades, leaving a dark black sky studded with stars. If you have an accurate clock or stopwatch, you'll very quickly notice that the length of the day – that is, the daytime plus the night time – is the same every day. Add the time that the Sun spends above the horizon with the time it spends below the horizon, and you get one day of 24 hours.

## Your spinning planet

Even the language used today harks back to the days before astronomers knew that the Earth was spinning and orbiting the Sun. The Sun appears to move across the sky, rising and setting, but it's actually the Earth spinning about its axis that gives people this mistaken impression. The Sun stays still; it's you that's moving.

Each day is 24 hours long because this is the time it takes for the Earth to spin once about its axis. If the Earth spun more slowly, your days would be longer; if it spun faster, your days would be shorter. (For example, on slow-spinning Venus, a day is 5,832 hours long, or 243 Earth days, while on fast-spinning Jupiter, the day is a shade under 10 hours long!)

## Here comes the Sun (there goes the Sun)

Earth's local star, the Sun, gives you day and night as the Earth spins about its axis. The Earth spins anticlockwise if you're looking down on it from above the North Pole (see Figure 1-1), and so you see sunrise and sunset happening from specific directions.

### The 24-hour day

Actually, the Earth doesn't spin once about its axis every 24 hours; it spins once every 23 hours, 56 minutes and 4 seconds. So where do the missing 3 minutes and 56 seconds go? They're not really missing at all. It's just that in the 23 hours, 56 minutes and 4 seconds that it takes for the Earth to spin, it's already moved a little around the Sun in its orbit.

Down here on Earth, a day is the length of time the Sun takes to make one complete circle of the sky – for example, the time it takes for the Sun to go from noon today to return to the exact same part of the sky at noon tomorrow. Between two consecutive noons as seen from Earth, the Earth has spun around on its axis once but then has to spin *a little bit farther around* for the Sun to get back to noon again. This 'little bit extra' spin takes 3 minutes and 56 seconds, and so the length of a day here on Earth – measured as the time between two noons – is 24 hours.

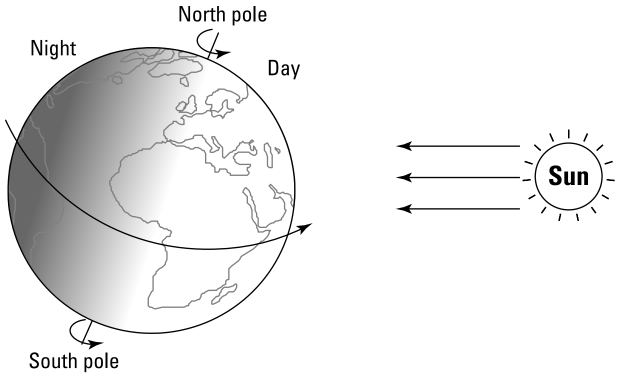


**Figure 1-1:** The Earth spins anticlockwise.

- **Sunrise:** Because the Earth spins anticlockwise, sunrise approaches from the east. Put another way, if the sky above your part of the Earth is just starting to brighten with the approach of dawn, somewhere a few hundred miles east of you, people will already have seen the Sun rising, while stargazers far west of you will still be enjoying dark skies.
- **Midday:** Once the Sun rises above the horizon, it continues to climb in the sky until it gets to its highest point at midday, or noon. At this point, people in the northern hemisphere see the Sun due south, while those in the southern hemisphere see it due north.
- **Sunset:** After midday, the Sun begins to sink towards the west, gradually setting until it disappears below the horizon. Just as your friends in a city farther east than you see the Sun rise before you do, they'll also see it set first.
- **Midnight:** Once it's below the horizon, the Sun continues to light up the sky for a while before the sky darkens altogether. The Sun then keeps sinking lower and lower until it gets to its farthest below the horizon at midnight, at which point it begins making its climb back up to the next sunrise.

REMEMBER

Stargazers near the equator see the Sun rising and setting at nearly right angles to the horizon, while those farther north or south of the equator see it rising and setting at a shallower angle.

## The twilight zone

Just after the Sun sets in the evening or just before it rises in the morning, the sky is still lit up – a time known as *twilight.* This illumination is because the Sun can still shine its light on the atmosphere above you, even if it can't shine its light directly on you.

How much twilight you get depends on where on Earth you are: stargazers near the equator have far shorter twilights than those at higher latitudes.

Twilight actually comes in three types:

- **Civil twilight:** Civil twilight is what most people mean when they talk about twilight. It starts in the morning when the Sun is six degrees below the horizon, and ends at sunrise. In the evening, civil twilight starts at sunset and continues until the Sun is six degrees below the horizon. During civil twilight, the sky is still bright enough that, in general, you don't need lights when doing things outside.
- **Nautical twilight:** Nautical twilight is when the Sun is between 6 and 12 degrees below the horizon. During nautical twilight, you can still distinguish the sky from the distant horizon when at sea, which allows sailors to take measurements of bright stars against the horizon (hence the name). Most people consider this time dark, but it's still technically twilight.
- **Astronomical twilight:** Astronomical twilight is when the Sun is between 12 and 18 degrees below the horizon. During astronomical twilight, you can no longer tell the sky from the distant horizon when at sea, but crucially for stargazers, light is still in the sky. Not much light appears – indeed, you'd probably say it's properly dark at this point – but the faintest objects in the sky, such as nebulae and very dim stars, will be visible only after astronomical twilight ends. Also, any long-exposure photographs of the night sky may show up this twilight that your eyes may miss.

# Moonshine

After you've noticed the day and night cycle and the rising and setting of the Sun, the next most obvious change in the sky is the changing shape of the Moon. It's very obvious to anyone with even half an interest in what's going on overhead that the Moon looks different from night to night, and that sometimes it's fully round while at other times it shows a different shape, such as a crescent or a half Moon.

## The phases of the Moon

TIP

Try this experiment: keep a record of the shape of the Moon each night. Draw the Moon as accurately as you can, but don't worry too much about detail. After you've been recording the Moon's shape for a few weeks, your drawing may look something like Figure 1-2.

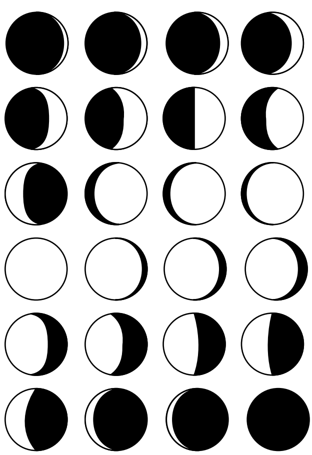

**Figure 1-2:** How the phases of the Moon look from Earth.

These changing shapes are the *phases of the Moon,* and they repeat in a regular pattern roughly every 29.5 days.

Each phase of the Moon has a name:

- New
- Waxing crescent

- First quarter (about a week after new)
- Waxing gibbous
- Full (about a week after first quarter)
- Waning gibbous
- Last quarter (about a week after full)
- Waning crescent
- New (about a week after last quarter)

The phase names look a little archaic, so you'll want to make sure you know what I mean when I say the Moon is waxing or waning, crescent or gibbous, new or full, and first or last quarter:

- **Waxing:** The adjective 'waxing' is used to describe a Moon that is growing in brightness – increasing in phase – from night to night. Consequently, the Moon can be waxing only between the new and the full phases. In the northern hemisphere, the waxing Moon grows from right to left; in the southern hemisphere it's left to right.
- **Waning:** Waning is the opposite of waxing, and describes the Moon when it's diminishing in brightness, or decreasing in phase. The Moon can be waning only between the full and the new phases.
- **New Moon:** A new Moon occurs when the Moon lies in the same direction as the Sun in the sky, so you can't see it at all. Half the Moon is still lit, though; it's just facing away from you.
- **Crescent Moon:** A crescent Moon (see Figure 1-3) is the familiar banana shape drawn by children the world over. When you see a crescent Moon, you see only a tiny sliver of the lit half of the Moon. Imagine that you're peeking around the edge, just catching a glimpse of the lit half.
- **Half Moon:** When the Moon is half way between new and full (and vice versa) it appears as a half Moon in the sky (see Figure 1-3). Just to confuse you, astronomers call these phases *first quarter* (when the Moon is between new and full) and *last quarter* (when it's between full and new). These names lead to all sorts of confusion. Why is it called a quarter Moon when it looks like half of a full Moon? The 'quarter' bit actually relates to how far the Moon is through its cycle of phases.

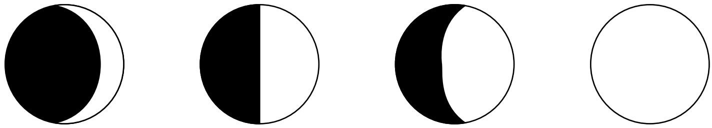

**Figure 1-3:** Crescent Moon, half Moon, gibbous Moon and full Moon.

- **Gibbous Moon:** The phase between quarter and full Moon – or between full and quarter Moon, depending on which part of the phase you're in – is called a gibbous Moon (see Figure 1-3). A gibbous Moon occurs when the Moon is a bit fatter than the quarter Moon but not quite full yet.
- **Full Moon:** The bright, round, full Moon (see Figure 1-3) is the midpoint of the cycle of phases; up until the full Moon, the Moon has been waxing, but after the full Moon, it begins waning back to new again, only to begin the cycle all over.

## Your mantra: 'Half the Moon is always lit'

The Moon is a sphere of rock in space, and like the Earth, it's lit up by the Sun. As the Sun's light shines on the Moon, it lights up one entire hemisphere – half the Moon is always lit. But from Earth, you can't always see all of the lit half of the Moon, because the Moon orbits the Earth and changes position relative to the Sun (see Figure 1-4). In fact, you can only see all of the lit half when the Moon is full, when it's directly opposite the Sun in the sky. At all other times, you see only a fraction of the lit hemisphere of the Moon. The varying amount of the Moon's surface that you can see is what accounts for all the different phases. At all times, though, keep repeating to yourself: 'Half the Moon is always lit, half the Moon is always lit'!

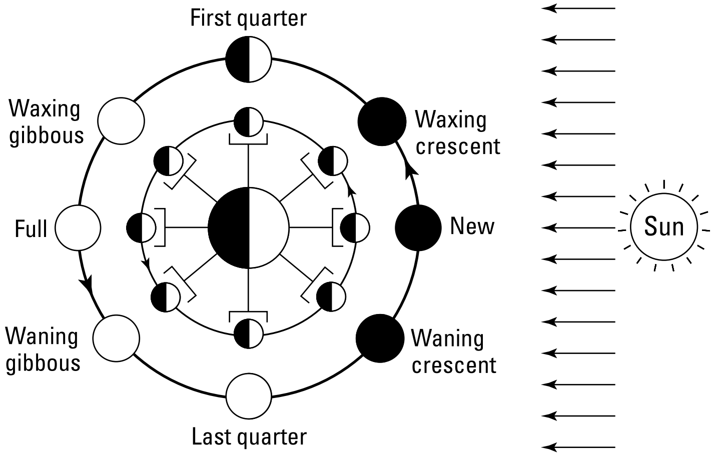


**Figure 1-4:** The phases of the Moon explained.

# The 'moonth'

The calendar month is based on the phases of the Moon, which repeat every 29.5 days, which is roughly one month. In fact, the word 'month' derives from the word Moon. Technically, you should pronounce it 'moonth', but that just sounds silly.

Putting aside the fact that a month with half-days in it would be altogether confusing, the reason that months aren't exactly one *moonth* long (or to put it another way, the reason why the full Moon doesn't fall on the same day each month) is that for most people, the calendar has derived from the Greek and Roman calendar, which was a *solar calendar,* connected with the seasons and the year, rather than a *lunar calendar* based on the phases of the Moon. Having said that, the Hebrew and Islamic calendars (along with many others) are lunar, and so their feast days, for example, are often based on the phases of the Moon.

### Once in a blue Moon

Because the Moon phases repeat every 29.5 days, and most months are 30 or 31 days long, you can have two full Moons in a calendar month; if one happens right at the start of a month, the second can sneak in right at the end. Some people call this a blue Moon, but the actual definition of a blue Moon is a bit more complicated than that description.

You can fit 12 lunar cycles of 29.5 days into a year of 365 days, and you'll be left with 11 days extra. As a result, every few years, you get 13 full Moons in a year rather than 12. This extra full Moon occurs as a fourth full Moon in a season of three, and this Moon is called the blue Moon.

# The Changing Seasons

Ancient stargazers, once they'd noticed the changing day–night cycle and the Moon phases, also realised that the sky changes from season to season, too. The sky changes aren't as readily evident from one night to the next, but if you're out every night, the effects mount up.

The changes you'll notice if you stargaze regularly are:

- The Sun rises and sets at different times in different seasons: in winter, the Sun rises later and sets earlier than it does in summer.
- The length of day changes over the seasons (and the length of night, too).
- The Sun rises and sets at different points along the horizon in different seasons.
- These changes repeat every year (roughly every 365 days).

## The Earth on tilt

All these changes happen because the Earth orbits the Sun once a year, and because the axis about which the Earth spins is tilted over (see Figure 1-5). In fact, the Earth's axis is tilted at 23.5 degrees to the straight up-and-down direction. This tilt gives you the seasons: if the Earth's axis tilted more, the seasonal changes would be more extreme; if it tilted less, they'd be less extreme. If the axis was perfectly perpendicular to the plane of orbit, then you'd have no seasons at all.

As the Earth orbits the Sun, and as it spins about its tilted axis, this axis always keeps pointing in the same direction. This means that in the northern hemisphere, the North Star, *Polaris,* which lies directly above the North Pole, stays in the same place in the sky.

As the Earth orbits the Sun, sometimes your hemisphere is tilted slightly towards the Sun, and at other times it's tilted away. The degree by which it's titled towards or away from the Sun dictates your season. In midsummer, the tilt towards the Sun is at its greatest; in midwinter, the tilt away from the Sun is at its greatest.

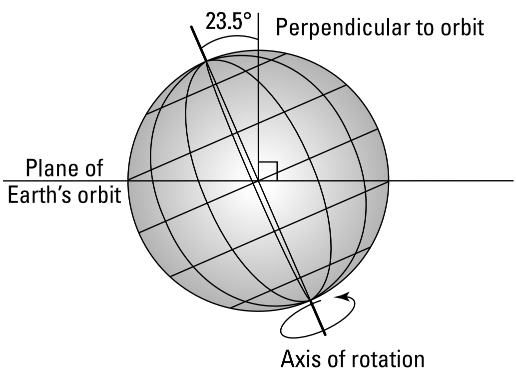


**Figure 1-5:** The Earth's tilted axis.

If you live in high latitudes, you'll notice these changes the most. Inside the Arctic and Antarctic circles, the seasonal changes are very extreme, with six months of daylight followed by six months of darkness. If you're at very high latitudes (but not quite inside the polar regions), you'll have long, dark winter nights followed six months later by long, bright summer days. If you're in mid latitudes, you'll notice less seasonal variation in length of day and season; if you're in the tropics or near the equator, you'll see virtually no difference at all in length of day or season.

One common misunderstanding is that it's hotter in summer than it is in winter because the Earth is nearer the Sun in summer. This belief isn't true; the heat is related to the tilt of the axis and whether your hemisphere is tipped towards or away from the Sun. The farther Earth's axis is tilted towards the Sun, the higher the Sun gets in the sky, and the hotter are your days (see Figure 1-6).

The Earth *does* sometimes get closer to the Sun, because its orbit isn't a perfect circle but rather an ellipse (a squashed circle). The date the Earth is closest to the Sun – a point called *perihelion* – is in early January, and the Earth is furthest from the Sun – at *aphelion* – in early July. This difference in distance from the Sun barely affects the temperature on Earth, though; any temperature difference is down to the height of the Sun in the sky and therefore the tilt of the axis.

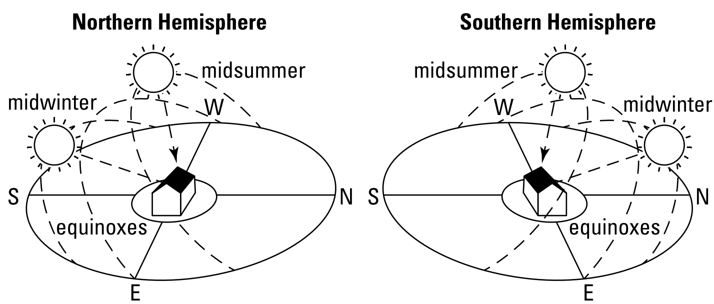


**Figure 1-6:** The Sun's height at midsummer and midwinter in the northern and southern hemispheres.

# Sunset and sunrise, time and place

Because the degree to which your part of the Earth is tilted towards the Sun changes over the year, the Sun appears to rise and set at different points along the horizon.

## Position of sunset and sunrise

Try this little experiment for yourself, especially if you have a clear eastern or western horizon: watch where the Sun rises or sets each day and remember that spot on the horizon.

Maybe the Sun rises behind a particular hill or tree on a certain day of the year. If you repeat this exercise every day, then over the course of months, you'll begin to see a pattern.

If you do this exercise for long enough, you'll notice that over the course of years, the sunrise and sunset positions swing back and forth along the horizon, with the Sun rising and setting at the same points on the same day each year (see Figure 1-7).

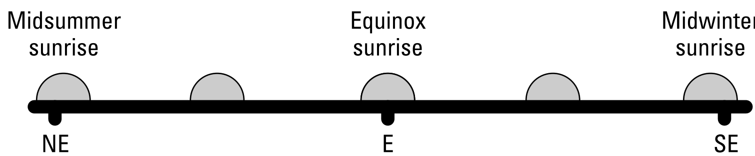


**Figure 1-7:** Sunrise and sunset positions throughout the year for a northern hemisphere stargazer.

REMEMBER

These changes in sunrise and sunset position are more pronounced the higher your latitude.

### Times of sunset and sunrise

As the position of sunrise and sunset changes over the year, you'll notice that the length of day changes too.

In winter in high northern latitudes, the Sun rises in the southeast, barely lifting itself up above the southern horizon before setting again in the southwest In a southern winter in the southerly latitudes latitudes, the sun rises in the northeast and sets in the northwest. As a result, the days are short, and you get great long nights for stargazing.

In summer in high northern latitudes, the Sun rises in the northeast, climbing high above the southern horizon before setting again in the northwest. In the southern hemisphere the Sun rises in the southeast and sets in the southwest, but rises just as high. Consequently, you get long, bright days with very little darkness at night for stargazing.

This is why winter is often a stargazer's favourite season!

## The Sun at a standstill

On two days each year, the Sun is said to be at *standstill,* on what astronomers call the *solstices.* These days usually fall on 20 or 21 June (northern summer, southern winter solstice) and 21 or 22 December (northern winter, southern summer solstice) each year.

The *summer solstice* occurs in midsummer. It's the day when the Sun climbs to its highest above the horizon, and when it spends longest above the horizon. For this reason, it's also known as the longest day.

The *winter solstice* happens in midwinter. It's the day when the Sun's noon position is the lowest it is all year, and when it spends the least time above the horizon. For this reason, it's also called 'the shortest day'.

## Equinox

On two days each year, the Sun rises exactly due east and sets exactly due west, *everywhere on Earth,* and you get equal amounts of day and night. These two days are the *equinoxes.* These days usually fall on 20 or 21 March (northern spring, southern autumn equinox) and 22 or 23 September (northern autumn, southern spring equinox) each year.

The *spring equinox* (it's also called the *vernal equinox*) happens between the winter and summer solstices. The Sun spends 12 hours above and 12 hours below the horizon, before the days lengthen over the coming months as midsummer approaches.

### Why 'standstill'?

The reason these solstices are called 'standstills' is that up until the summer solstice, the Sun has been gradually climbing higher in the sky at noon each day, spending a little bit more time above the horizon each day. Then, on the solstice, this gradual lengthening of the days stops – it's at a standstill. From then on, it's all downhill, with days shortening and the Sun rising lower and lower at noon each day, until the winter solstice when the Sun starts to climb again.

The *autumn equinox* happens between the summer and winter solstices. Like on the spring equinox, the Sun spends 12 hours above and 12 hours below the horizon, before the days shorten with the coming midwinter.

## A very exact science

Although most people talk about solstices and equinoxes in terms of certain days, the reality is that they occur at an exact *instant* on a particular day.

A solstice is actually defined as the instant when the Earth's axis is most tilted towards or away from the Sun, while an equinox is defined as the instant when the Earth's axis is neither tilted towards or away from the Sun. This means that you'll often see the times of the solstices or equinoxes quoted to the nearest minute. However, it's still true to say that the day on which the solstice or equinox occurs is the summer solstice or vernal equinox, or whichever it happens to be.

The following table lists the solstices and equinoxes for 2012 to 2018.

| Year | Solstices | | Equinoxes | |
|---|---|---|---|---|
| 2012 | Jun 20 23:09 | Dec 21 11:12 | Mar 20 05:14 | Sep 22 14:49 |
| 2013 | Jun 21 05:04 | Dec 21 17:11 | Mar 20 11:02 | Sep 22 20:44 |
| 2014 | Jun 21 10:51 | Dec 21 23:03 | Mar 20 16:57 | Sep 23 02:29 |
| 2015 | Jun 21 16:38 | Dec 22 04:48 | Mar 20 22:45 | Sep 23 08:21 |
| 2016 | Jun 20 22:34 | Dec 21 10:44 | Mar 20 04:30 | Sep 22 14:21 |
| 2017 | Jun 21 04:24 | Dec 21 16:28 | Mar 20 10:29 | Sep 22 20:02 |
| 2018 | Jun 21 10:07 | Dec 21 22:23 | Mar 20 16:15 | Sep 23 01:54 |