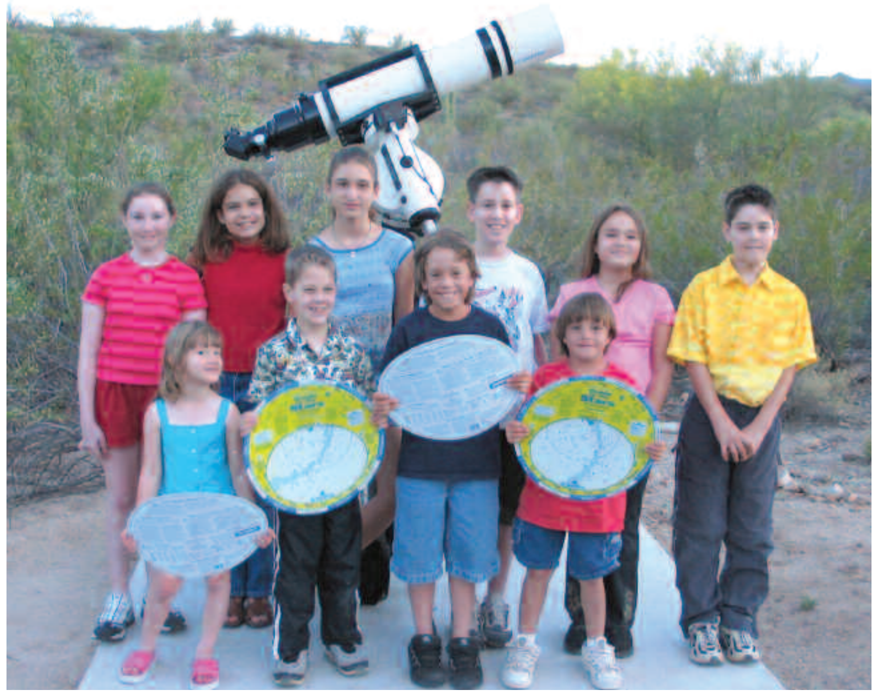
Introduction & Table of Contents

Top, from left: Adrea Graun, Sofia Lugo, Anna Lugo, Jimmy Broughton, Sonya Lugo and Ryan Lindsey.

Bottom, from left: Jasmine Council, Sean Lindsey, Jeremy Hibbs, and Elijah Hibbs.



A Key to the Heavens. Have you ever looked up at the stars and wondered about them? Asked yourself how many stars there are, how far away they are? Have you wondered how you can get to know them better? With this book your questions will be answered, but as you proceed, more questions will come to mind. That's the process of learning, and in the pages that follow you will begin to learn about the night sky.

I remember my first night viewing Jupiter and its moons with a small telescope. For me, that was a night of discovery. As you begin your own journey, you will make discoveries too. You will see constellations, the Moon, planets, meteors, and maybe a comet. They may even become friends to you, as they have for me. May this book help you enjoy your nights under the stars.

David H. Levy

June 25, 2003

SPECIAL NOTE on the names of CONSTELLATIONS and *Stars* used in this book.
All constellation names are in UPPER CASE and the names of stars, including our *Sun*, are in *Italics*. There are also other words that are in italics for emphasis.

Stars in the Sky

When you look up into the night sky, you see pinpoints of light that we call stars. For the longest time, no one knew what they were. In fact, some ancient cultures thought they might be candles or fires resting on the inside of a giant ball.

It took the invention of the telescope around 1690 to bring understanding to the true nature of these tiny lights. As scientists studied the stars, they slowly discovered that they were faraway suns, that is, the stars were like our *Sun*, just as big and bright but very far away. It is only their great distances from us that makes them appear as pinpoints of light. If our *Sun* was moved to the distances of even the closer stars, its brightness would fade to one of the fainter stars in the night sky.

Nighttime & daytime stars

Did you know that the stars are out during the daytime? However, you cannot normally see them because the bright light from our *Sun* is scattered by our atmosphere, making the whole daytime sky light up and wash out the stars. It is possible, however, to see the brightest stars through a telescope during the day if you know where to look.

Where do the stars come from?

Every star, including our *Sun* formed inside a giant cloud of hydrogen gas called a nebula. The stars condense out of these hydrogen clouds in space similar to rain drops condensing out of the clouds in our atmosphere. The energy of stars, some of which we see as light, is produced from nuclear reactions occurring at their cores where there is tremendous pressure and heat.

It can easily take a million or so years for a new star to form in a hydrogen cloud. Depending on a new star's starting size, it can last anywhere from just a few million years to billions of years. Stars the size of our *Sun* last about 10 billion years. Our *Sun* is about 4½ billion years old.

Normal sizes of stars

Although our *Sun* is an average-sized star, the sizes of *normal* stars range from about 1/10 to 40 times its diameter. Since the diameter of our *Sun* is 865,000 miles, the smallest *normal* stars have diameters around 87,000 miles while the largest *normal* stars are about 35,000,000 miles. There are *much* smaller and larger stars than these but they are in a special class of stars whose lives are ending.

Brightness of stars

The stars in the sky vary in brightness for two reasons. The first is because they are all at different distances. The farther away a star is, the fainter it will appear. The second reason has to do with their sizes. Larger stars have more surface area so they give off more light and appear brighter than smaller stars. Stars differ in brightness because of a combination of their size and distance from us.

Twinkling

Stars twinkle because of air movement in our atmosphere. When pockets of air move about, they act like lenses and prisms, bending and spreading light a little, causing a star's light to slightly but briefly change direction, brightness and color. Stars twinkle more when they are closer to the horizon because you are looking through more atmosphere and more pockets of moving air.

Colors

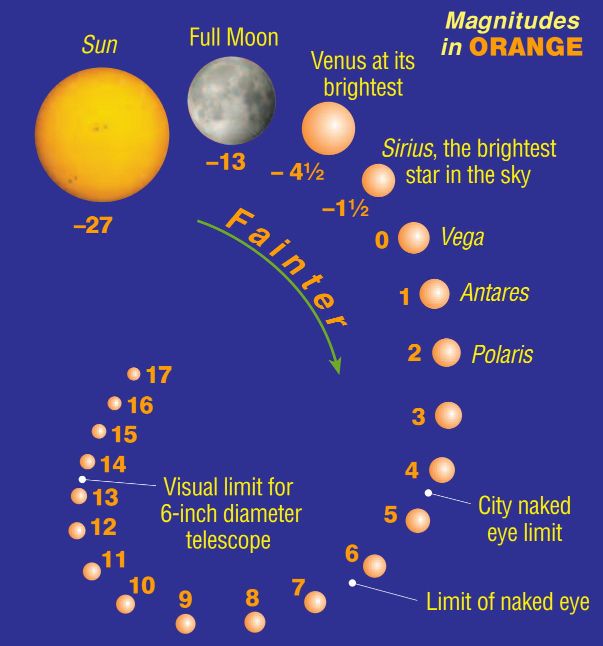
At first glance, all the stars might appear white, but if you look at them a little closer you will notice that some have color. Red is the easiest color to see, but you may also be able to discern orange, yellow and blue. The colors appear best through a telescope. The temperature of the outer gaseous layer of a star determines its color. Red stars have cooler surfaces than blue and white stars. Our *Sun* is yellowish with a surface temperature of 10,000° F.

A galaxy of stars

Our *Sun* and all of the stars that you see in the night sky are located in a galaxy that we call the Milky Way Galaxy. A galaxy is a grouping of billions of stars. Our *Sun* is just one star among 100 billion that make up our Milky Way Galaxy. Our Milky Way Galaxy is just one galaxy of about 125 billion in the Universe.

Magnitude of Stars

Long ago, when the ancients looked up and studied the stars, they classified them by their brightness. We still use this same system of **magnitudes** today, however, we now have instruments to accurately measure a star's brightness. The range of magnitudes varies from –27 (spoken as "minus twenty-seven" or "negative twenty-seven") for the *Sun* to over +30 (spoken as "thirty," "plus thirty" or "positive thirty") for the faintest stars. Ask a parent or teacher about negative numbers.



Number of stars visible to magnitude...

5	is 2,800
6	is 8,700
7	is 27,000
8	is 78,000
9	is 218,000
10	is 586,000
11	is 1,000,000

MAGNITUDE FACTS

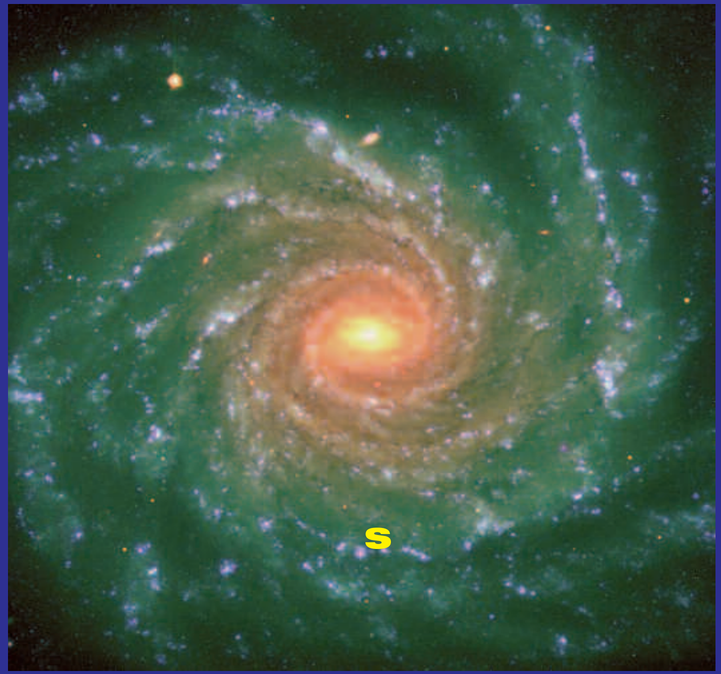
1. Each magnitude is about 2½ times brighter or fainter than the next magnitude.
2. The *Hubble Space Telescope*, in orbit about Earth, can record to magnitudes fainter than 30.
3. The magnitude of stars do not indicate their true brightness in comparison to the Sun.

Magnitudes of 10 brightest *Stars* & CONSTELLATIONS where they are located

Sirius	in CANIS MAJOR	–1½
Canopus	in CARINA	– ½
Rigil Kent	in CENTAURUS	– ¼
Arcturus	in BOOTES	0
Vega	in LYRA	0
Capella	in AURIGA	0
Rigel	in ORION	0
Procyon	in CANIS MINOR	½
Achernar	in ERIDANUS	½
Betelgeuse	in ORION	½

This is part of the Eagle Nebula that resides within the boundaries of the constellation SERPENS (see page 20). Stars form inside giant hydrogen clouds like this. The arrows point to little fingers. Inside, stars are forming, condensing out of these hydrogen clouds much like rain condenses out of water clouds. The width of these fingers have diameters 200 times greater than our solar system.

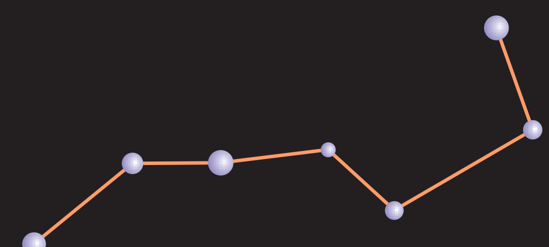
Our *Sun* is just one star in a galaxy that contains about 100 billion stars. Here is a galaxy that looks like our Milky Way Galaxy. This type of galaxy is called a spiral galaxy because it has arms that spiral or curve outward from a bulging center. The letter S marks where our *Sun* would be located if this were our galaxy.



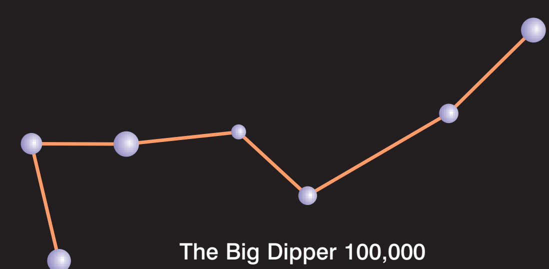
Well, the stars do move a little.

In this chapter and throughout this book, it is stated that the stars don't move and are fixed in the sky. This is how astronomers look upon the stars for everyday use.

However, all stars including our *Sun* are moving through space. Individually the stars are moving quite fast but because they are very far from one other, they appear to be moving extremely slow. You have experienced this same effect when driving down a freeway. The more distant cars appear to be moving slower than those nearby even though all the cars are traveling at about the same speed. The Moon, which it the closest celestial body to Earth, appears to be standing still even though it is moving around the Earth at 3,300 miles an hour.



The Big Dipper today.



The Big Dipper 100,000 years from now.

This very slow movement of the stars is called "proper motion," and over very long periods of time will cause the shapes of the constellations to change.

The stars move because, like our *Sun*, they are all revolving around the center of our Milky Way Galaxy. It takes the *Sun* over 200 million years to complete a revolution about our galaxy's center.

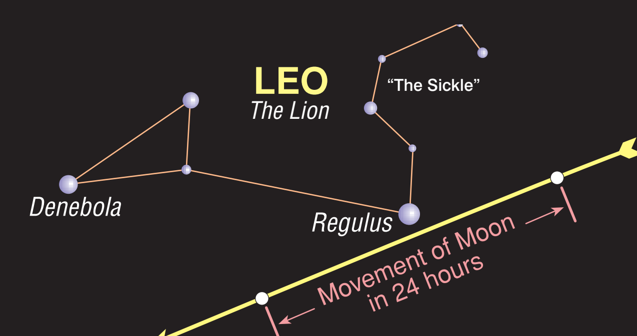
To the left is an example of what the Big Dipper will look like in the far future.

It *does* feel as though the Earth is standing still.

We cannot feel the Earth turning even though those living at the equator are moving over 1,000 miles per hour compared to someone at the pole who merely turns in a circle.

Why don't we feel the Earth spinning daily on its axis? Simply because this motion is constant and smooth. It is the same reason we don't sense any "speed" when we are in a plane or car (but we do feel all the bumps and turns which are not part of the constant, smooth motion). The ancients thought the Earth stood still because it feels that way. If you live at the equator, you are moving 1,038 miles per hour. If you are at a pole, you don't move, you just rotate in a circle once every 24 hours. Now get this, everyone on Earth is moving around the *Sun* at 67,000 miles per hour but we don't feel anything because this speed is also constant.

Moving Moon



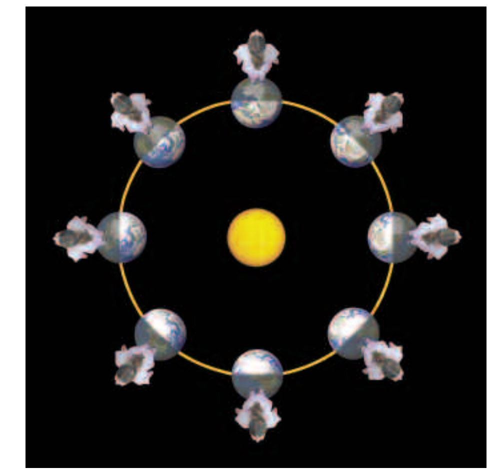
The yellow line indicates the path of the Moon. The two little circles represent the actual size of the Moon in the sky.

The Moon is *the* closest celestial body to Earth and orbits our planet every 29 days (New Moon to New Moon). At this rate of revolution, it moves in the sky by about 12 arc degrees (see Glossary) easterly from night to night, which is equivalent to 24 Moons lined up side by side. On average, this rate of movement results in the Moon rising about 50 minutes later each night. Watch the Moon from night to night and observe its journey through the stars.

Movements in the Sky

The *Sun* moves across the sky during the day while the stars and Moon move through it at night. Both of these movements occur because the Earth spins or rotates on its axis once a day.

You may also have noticed or been told that the stars in the summer night sky are not the same as those in the winter night sky. If you have not noticed this, then you probably have observed that the *Sun* is much higher in the summer sky at noon than during winter. These changes happen because the Earth orbits or revolves around the *Sun* once a year.



The reason that we see different constellations throughout the year is because the Earth's night side faces different directions.

Daily rotation

The Earth spins on its axis counterclockwise once a day. The axis is an imaginary line that passes through both the north and south poles. Any spinning object has an axis that it rotates about. Spin a small object and you will see that there is a center point around which the rest of the body spins. This center point is on the axis of the spinning object just like the poles are on the axis of the rotating Earth.

The most noticeable effect of the Earth's rotation is the daily rising and setting of the Sun, Moon and stars. These objects rise in the east and set in the west because the Earth rotates counterclockwise on its axis. The only place on Earth where the stars don't rise or set is at the poles. Here, they just circle around a point in the sky directly overhead. The stars near the horizon move in large circles around the sky while those closest to the top of the sky move in smaller circles.

Yearly revolution

Each day, the Earth makes a complete turn on its axis, but it takes one year for the Earth to orbit the *Sun*, that is, to revolve or circle around it. As the Earth orbits the *Sun*, the night side faces different directions in space, which allows us to see different sets of constellations over a year's time. It takes about one month to notice some new stars rising in the east and about five months to see an entire new set of stars in the evening sky.

Now you may think, "If the Earth turns completely around once a day, shouldn't we see all the stars in a day's time?" The answer to this question would be yes if it were not for the brightness of the sky during the day.

Stars so still

For all practical purposes, the stars in the sky do not move. You can think of them as pinholes in a giant ball that we call the "celestial sphere." Even though the Earth turns on its axis daily and circles the Sun yearly, the stars don't move. They only appear to move and change in the sky because of the Earth's turning and circling. Think of the stars as the pictures and nicknacks on the walls of your house. No matter how you turn or move about the house, the pictures and nicknacks stay in place.

Moon

Except for the *Sun*, the Moon is the most noticeable object in the sky. It is also the closest celestial body to the Earth and the only natural object to orbit our planet. The Moon circles the Earth counterclockwise about every 29 days, close to a month's time. This rate and direction of movement makes the Moon rise in the east about 50 minutes later each day.

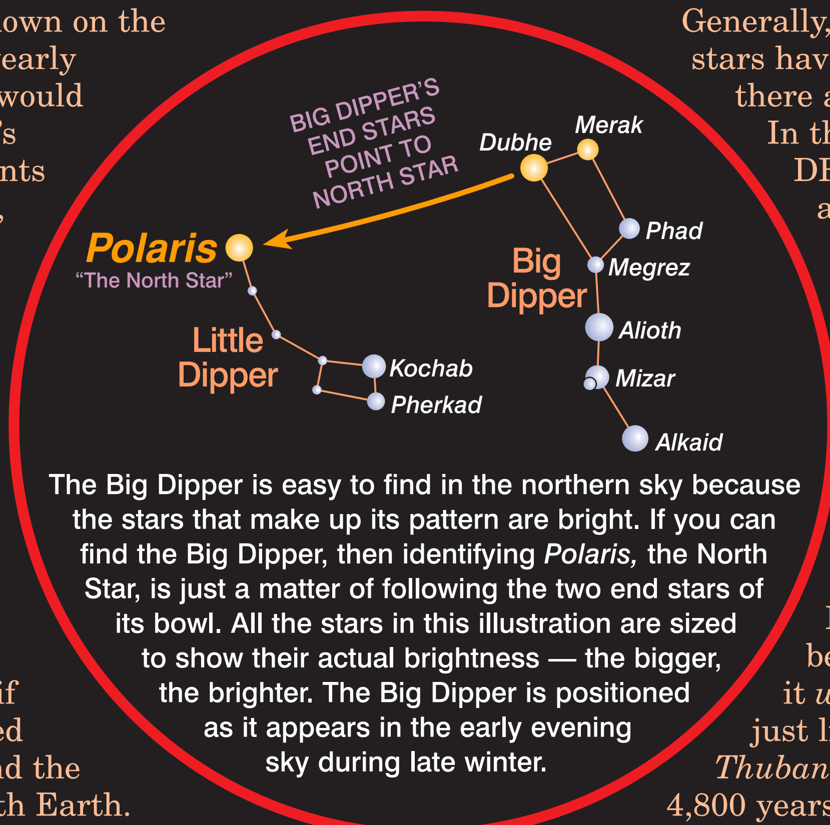
The phases of the Moon are nothing more than seeing part of its night side and day side at the same time. Remember, the Earth, as well as all the other planets and their moons, always has a night side and day side. Why do you think this is so? The Moon's phases change because we see the Moon from different angles as it circles the Earth over a month's time.

The North Star

The North Star refers to the star named *Polaris* in the constellation URSA MINOR. *Polaris* is the bright end star that makes up the handle of a group of stars we call the Little Dipper. Several of the stars that make up the Little Dipper are very faint, so the whole Little Dipper is hard to see unless you live where the skies are very dark. *Polaris* is called the North Star because if you face it, you are facing north, no matter where you are on Earth.

Always points north

If you could look down on the Earth as it revolves yearly around the *Sun*, you would notice that the Earth's north pole always points in the same direction, which is close to the star *Polaris*. Why is this? As the Earth rotates daily on its axis, it acts like a gyroscope. All spinning objects act like a gyroscope. One of the natural properties of a gyroscope is that its spinning axis always points in the same direction, even if the gyroscope is moved about, or orbits around the *Sun* as is the case with Earth.



The Big Dipper is easy to find in the northern sky because the stars that make up its pattern are bright. If you can find the Big Dipper, then identifying *Polaris,* the North Star, is just a matter of following the two end stars of its bowl. All the stars in this illustration are sized to show their actual brightness — the bigger, the brighter. The Big Dipper is positioned as it appears in the early evening sky during late winter.

Polaris, the star

Polaris stands out as a fairly bright star in the northern sky but it is not the brightest star. This second magnitude star is a little brighter than most stars and overall it is the 46th brightest star in the sky. Also, the axis of the Earth does not exactly point to *Polaris*. *Polaris* is about half of the Moon's diameter from the true north point.

Polaris is 431 light years away (each light year is about 6 trillion miles) and is classified as a giant star because it is large, bright and "elderly." The diameters of elderly type stars often are greater than normal because they bloat up as their hydrogen fuel is depleted. Compared to the *Sun*, *Polaris* has a diameter 60 times greater and it shines 3,600 times brighter. An interesting fact about *Polaris'* brightness is that it varies slightly every four days, but the change is too small to be noticed with the eyes. This change in brightness happens to many elderly stars. Our *Sun* is middle aged and will be around for billions of years.

North stars

Generally, only the brightest stars have names. However there are exceptions. In the constellation DRACO, which wraps around the Little Dipper, there is a rather faint star that has been given the name *Thuban* (see star chart on page 16). *Thuban* shines a little brighter than magnitude 4, which makes it five times fainter than *Polaris*. It was given a name because at one time, it *was* the North Star, just like *Polaris* is today. *Thuban* was the North Star 4,800 years ago when the Egyptians were still building pyramids. Since that time, the direction that the Earth's axis is pointing has slowly changed toward *Polaris*.

Precession

Toy tops act like little gyroscopes and when they slow down, they start to wobble in a circle. This wobbling is caused by gravity tugging on the top, trying to bring it down. The spinning Earth also gets tugged on by a combination of the *Sun's* and Moon's gravity. This causes it to wobble similarly to a slowing top. However, the Earth's wobble, known as precession, is very slow, taking 25,800 years to complete a circle.

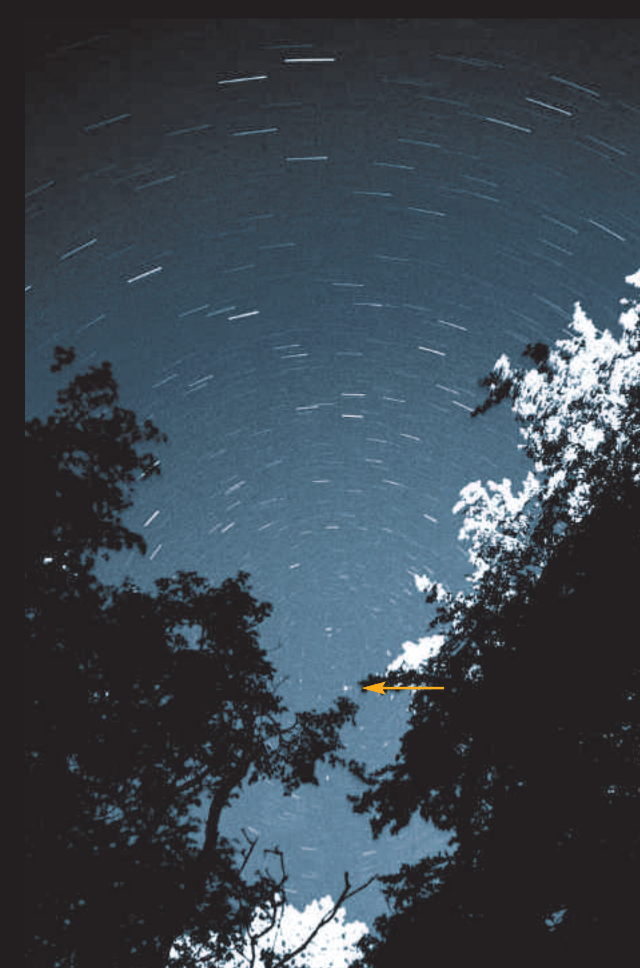
Although this movement may seem like it would be unnoticable, it was known by the ancient Egyptians because they took accurate measurements of where stars rose and set over hundreds and thousands of years.

The effect of precession is that the Earth's north pole points to different directions in the sky over the course of its 25,800 years wobble. During this lenthy period of time, it describes a circular path through several constellations. The Earth's axis will appear to point to any star on the path but most of the time it is not pointing at any star.

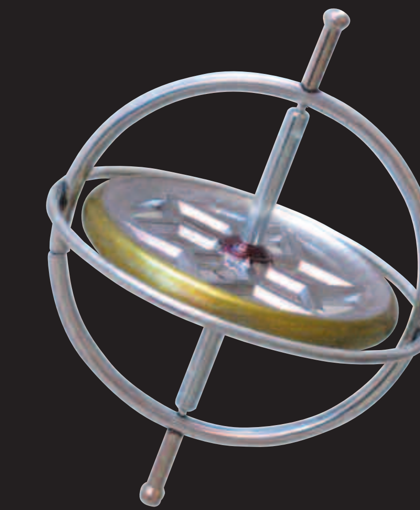
No South Star

Polaris is only visible from the northern hemisphere. Thus, it cannot be seen south of the equator because it is blocked by the ground or Earth.

So, how do you find your direction at night if you are in Australia, southern South America or southern Africa? It is difficult at these locations to use the stars because there is no South Star in the southern hemisphere to help you orientate yourself. In fact, there is not even a fairly bright star close to the south celestial pole, which is the point in the sky that the south pole points to. Your best bet is to use a compass.



This picture was taken by pointing a camera north and keeping the shutter open for 15 minutes. *Polaris* is indicated by the arrow. All the other stars appear to revolve around *Polaris* because the Earth's axis points to it, giving the illusion that the other stars revolve around this center point. The star-streaks would have become longer if the shutter had been left open longer. Some of the leaves of the trees are white because a light was shining on them.



Toy gyroscopes are fun to play with and their motion demonstrates how the Earth's axis can stay tilted at the same angle.

Precession may be difficult to comprehend because it takes so long for the Earth to "wobble" along the giant circle it makes in the sky. The orange-dotted line shows this circle, which is the path that the north pole points to over the 25,800 years that it takes to complete a whole wobble. We are lucky that we live during a time in history when the Earth's north pole points to a star. As you can see, most of the time, the Earth's axis does not point to any star.