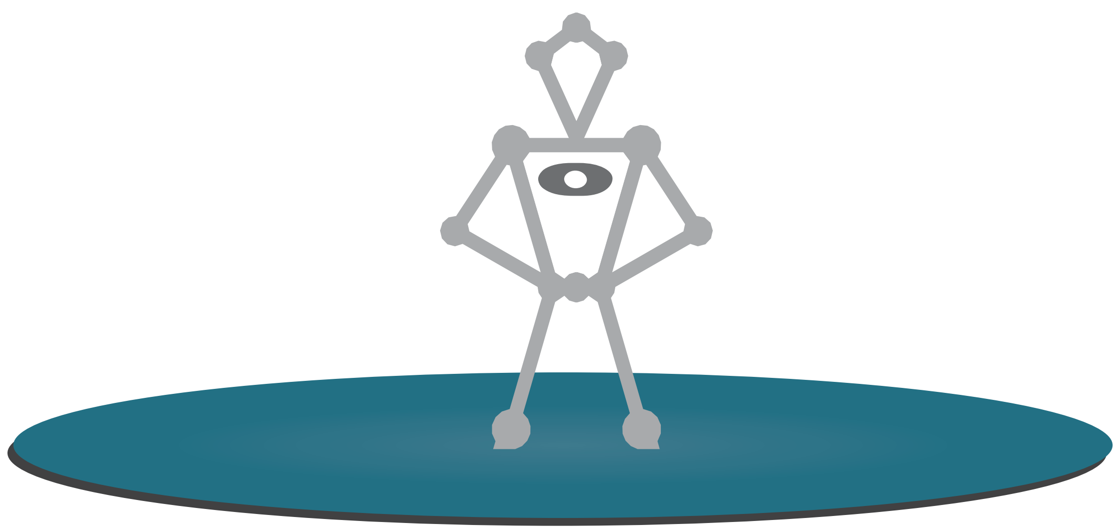
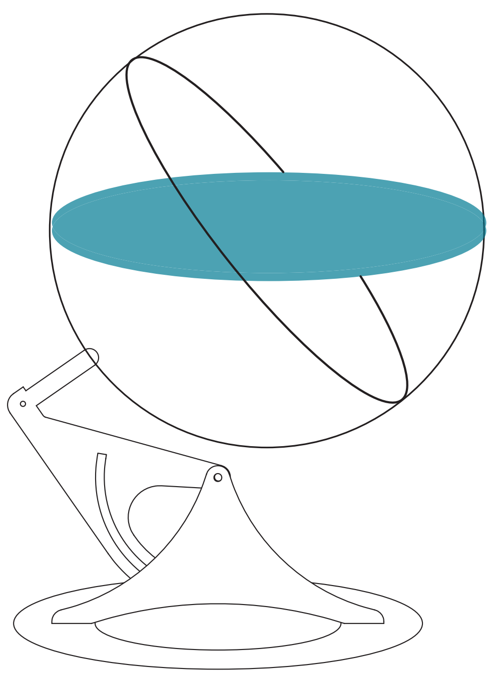
Observational
ASTRONOMY



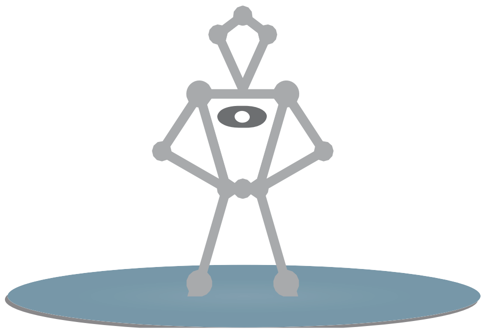
Tom VanDamme



Horizon Globe
rev 2.0

www.HorizonGlobe.us

Q&A with the Observer



Q. Learning astronomy seems hard. Is it?

A. Depends on what you mean when you say hard. The observational part of astronomy is simply about knowing where to look for what you want. We think it's pretty straightforward (and rewarding).

Q. You make astronomy sound easy. Does that mean there's a trick to it?

A. Yes.*

Q. If I read this whole book and do all the exercises, do you promise I'll know how to find stuff in the sky?

A. We could almost guarantee it!

Actually, we will guarantee it. If you don't learn what you want from this book, just return it for a refund. If you're trying to find objects in the sky, this book will show you how to do it.

Q. If Leo the Lion and Taurus the Bull got into a fight, who do you think would win?

A. The Bull is separated by the Twins (who are Crab-by) from the Lion, so I guess we'll never find out.**

Q. When would you rather take an evening stroll, during a New Moon or a Full Moon?

A. If you want to walk on a nicely moonlit path, there's an obvious choice.***

* And yes, we're going to show you the trick

**If you don't get it, check out "A Way to Remember the Zodiac" later in this book

***This one's pretty easy, we'll see why in the chapter "Full Moon"

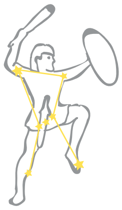
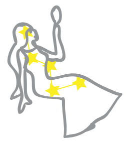
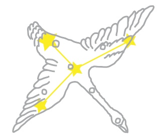
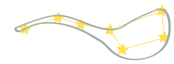
CONTENTS

Getting Started

Petruchio: ..How bright and splendid the moon tonight!
Katherine: The moon? You mean the sun! It is not nighttime now.
Petruchio: I say it's the moon that shines so bright.
Katherine: I know it's the sun that shines so bright.

–William Shakespeare

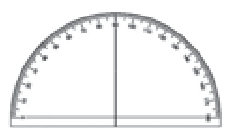
Sun and Moon

Constellations

Planets

Seasons



Latitude – Model LX only

The End

Become an Amateur Astronomer

Anyone who can tell day from night can learn to be an astronomer. It's relatively easy to find dozens of constellations, identify planets, track the Moon, and tell time by the Sun. In other words, you can become an amateur astronomer!

Astronomy holds a special place for humans. Any time you step outside, the sky is fully half of your surroundings (the top half). The Sun and stars mark the passing of hours, days, and years, and the Moon creates months. We all have a birth sign, the special stars that are near the Sun when we are born. Astronomy even defines directions and allows us to find our way, day and night.

The sky is also beautiful. Imagine hiking in the Grand Canyon with a star-filled sky, picking out familiar constellations. Or strolling along a lake with the moon reflecting off the water. Poets and writers from the earliest times have recorded the powerful emotions evoked by gazing at the sky. Stars and constellations, sunrises and sunsets, and all phases of the Moon cause stirrings in the heart of man. The planets are named after Roman gods. Venus is named for the goddess of beauty, Jupiter for the all-powerful, red Mars for war, and Saturn for time.

In ancient times when skies were dark (there were no city lights), everyone knew some astronomy. There were no clocks or electronic direction finders. Astronomy was a tool for daily living: telling time, marking the calendar, finding directions, contemplating the beauty of nature.

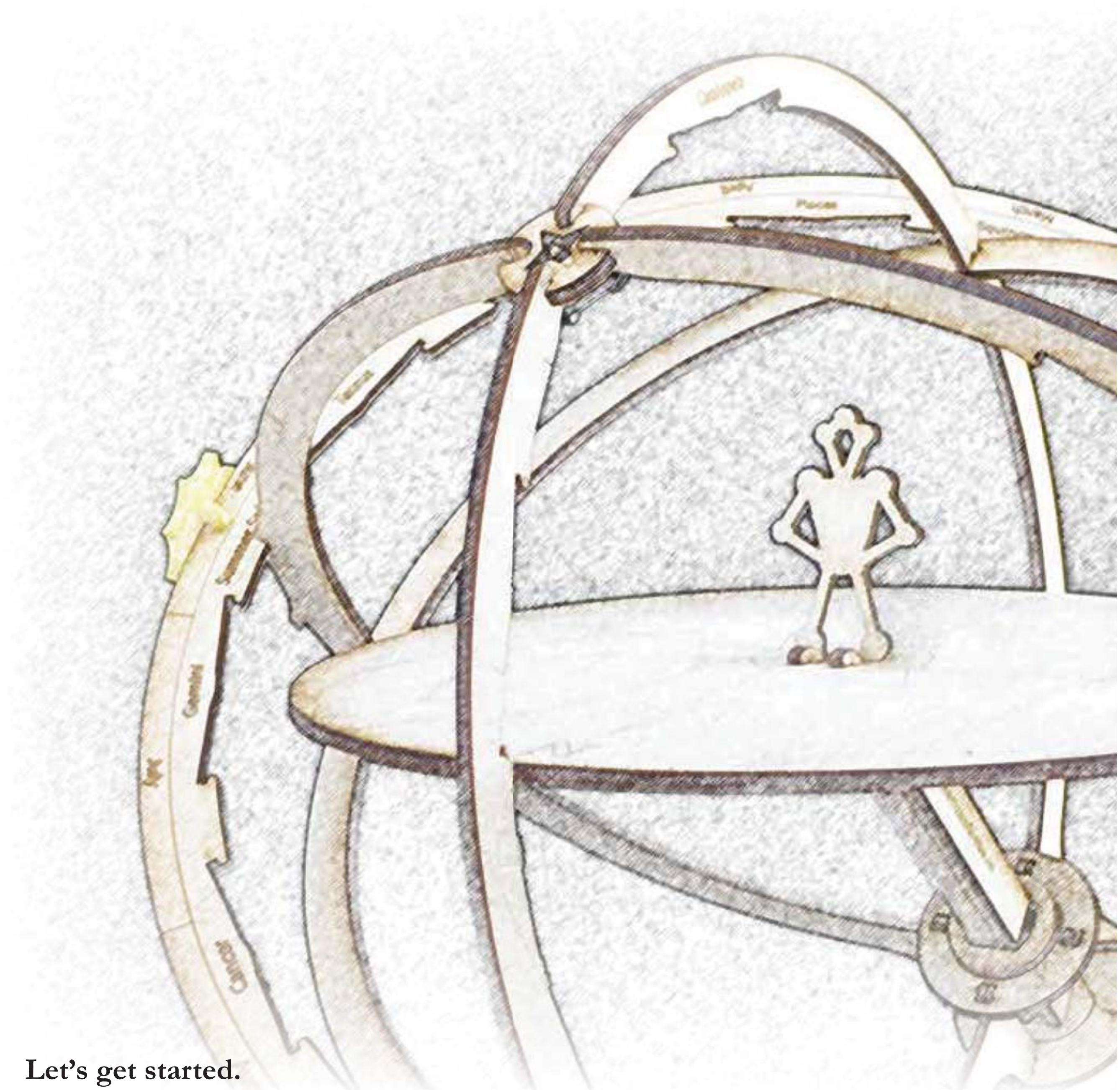
But astronomy has another powerful use aside from practical living. Detailed study of the sky led Isaac Newton to discover the law of gravity. Physicists today still scan the heavens in their quest to unlock the secrets of nature.

EXERCISE

1. *Write down everything you know about astronomy. Even though you're just getting started, you may surprise yourself.*
2. *Check over your list from #1. Did you list the Sun? Did you name any planets? Or stars or constellations? You probably already know a lot!*

Equipped with his five senses, man explores the universe around him and calls the adventure Science

— EDWIN HUBBLE



Let's get started.

This book is written for brand-new beginners, there is no need to have any prior knowledge of the sky. Your Horizon Globe will guide you with mechanical predictability every step of the way. Start with the Sun and keep going.

The sky's the limit!

Different Kinds of Astronomy, Part I

Welcome to the amazing world of astronomy!

The field of astronomy is so vast that many scientists spend their entire careers hanging around in far-off galaxies. Astronomy includes everything from moon phases to black holes to theories of relativity. All of it is fascinating and can be rewarding to study. So how do we get started?

Let's separate the field of astronomy into **three** general categories:

basic observational, solar system, and deep space

Basic Observational Astronomy

1

What is in the sky? Where and when should I look to find it?

Since the earliest times, humans have named the objects of the sky and tried to understand how they move. They learned to see groups of stars as pictures, or constellations, so they would be easier to remember. They noticed five wandering stars and called them planets. They learned to recognize and predict the daily, monthly, and yearly motion of the Sun, Moon, and Stars.

Without telescopes and with only simple instruments, they made accurate maps of the stars and could predict things like the first day of spring, lunar eclipses, and solar eclipses.

Tool needed for Basic Observational Astronomy: **Horizon Globe, quadrant**

Quadrant

a device used to measure angles up to 90°. Used to find the altitude of celestial objects

Astronomy is older than physics. In fact, it got physics started by showing the beautiful simplicity of the motion of the stars and planets, the understanding of which was the beginning of physics.

-RICHARD P. FEYNMAN

The observational part of Astronomy can be a lifelong source of joy. After completing the exercises in this book, you will know when and where to look for celestial objects: the Sun, moon, planets, and a few constellations. You will have the satisfaction of knowing how the stars move, and how other celestial bodies behave. You'll understand seasons, which will be beneficial to you in a way that you may find surprising.

The Horizon Globe is our modern tool for understanding the sky. You will find it indispensable for learning the relationships among objects in the sky.

Horizon Globe

the modern tool used by leading universities to understand observational astronomy

Before we get started using our Horizon Globe to master observational astronomy, let's take a quick look at the other two categories of astronomy. We won't be covering them in this book, but your solid foundation in observational astronomy will support further studies.

We've divided astronomy into 3 categories. The last chapter we looked at basic observational astronomy. Now let's take a look at the remaining two categories: *solar system* and *deep space*.

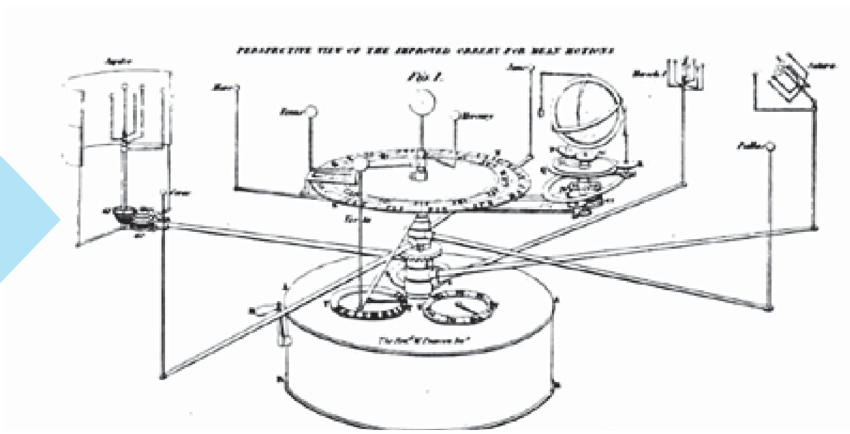
Solar System Astronomy

2

Why do celestial objects behave the way they do?

Orrery

a specialized device that shows balls orbiting a larger ball representing the planets and Sun



Astronomers were not content to just know where things are and what they are called. They wanted a system that explained why they behave the way they do. For example, why do Mercury and Venus stay near the Sun, but Mars, Jupiter, and Saturn make a full turn of the sky?

This part of astronomy reached maturity with the invention of the telescope and development of Newton's law of gravity.

Tools needed for Solar System Astronomy:
Telescope, Orrery

Those who study the stars have God for a teacher

— TYCHO BRAHE

3

Deep Space Astronomy

What are stars made of, and how did they form?

Just after the time of Isaac Newton the sciences of optics, physics, and chemistry advanced to the point where astronomers could determine what stars were made of and began to theorize about the history and future of stars and galaxies.

Study of this area of astronomy requires advanced knowledge of the nature of light, and topics such as relativity.

Tools needed for Deep Space Astronomy: **Advanced telescopes, computers**

The Right Tool for Observational Astronomy

Equipment needed: Horizon Globe with all accessories

The Horizon Globe is the right tool for observational astronomy. It will show you where objects are in the sky, so you can go outside and find them for yourself.

Let's get to know our globe. First we'll put all the accessories on the Horizon Globe and give it a spin, later we can talk about how it all works. There are two models of the Horizon Globe, let's see which one you have.

Horizon Globe SE

Has 16 crystal constellation discs, made up of 4 guidepost constellations plus 12 zodiac discs. Each constellation disc has its own labeled slot

Horizon Globe LX

Has four black precision-engineered guidepost constellations. The 12 zodiac constellations are printed on the outermost ring.

EXERCISE

1. Put each constellation in its labeled location.
2. Put everything else on the outer ring with the months printed on it.
3. Spin the globe. Notice:
   a) everything moves together.
   b) the Observer can only see what's above the platform.

Self-education is, I firmly believe, the only kind of education there is

— ISAAC ASIMOV

The *Sun*, *moons* (full, gibbous, quarter, crescent), and *planets* (Venus, Mars, Jupiter, Saturn) all belong on the outer ring, the one that is printed with the months. Don't worry about where on the ring to put them right now, just make sure they are all on the printed outer ring.

After everything is in its place, try turning the globe. Notice how everything moves together. Also notice that the Observer can see everything above the plate he's standing on, but that he can't see anything below the plate.

We can see everything on the globe, above and below the platform that the Observer is standing on. The poor Observer is stuck in a place where he can only see what is above but not what is below.

1

Horizon Globe SE

Put the constellation discs into the slots where they go. You may need to flex the discs a bit to get them into place

Horizon Globe LX

Place the four guidepost constellations in their marked locations

2 Put Sun, moons, and planets on outermost (printed) ring

3 Spin the globe and notice:
a) that everything moves together
b) that the Observer can only see what's above

Horizon Globe Features

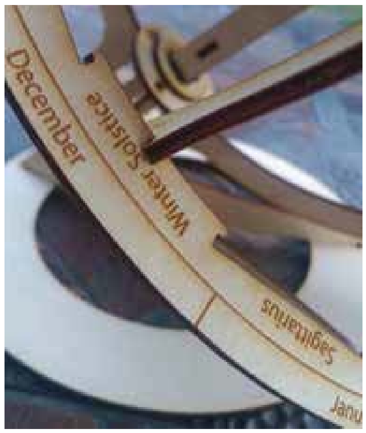
Let's take a look at a few features. These are the same for both models, **Horizon Globe SE** & **Horizon Globe LX**.

Observer

The little man who stands in the center of the globe is the Observer. He represents you, watching the celestial objects that move across the sky.

Horizon Plate

The round, flat circle that the Observer is standing on is the Horizon Plate. When you go outside and look around, it seems as though you are standing on a plate like this. Your horizon is where the sky seems to meet the ground.



Ecliptic Ring

The outermost ring of the globe, the one printed with the months and Zodiac constellations, is called the *Ecliptic Ring*. The Sun, Moon and planets always travel on this ring. It is called the ecliptic because lunar and solar eclipses always occur on this ring.

North Pole

The wooden star at the tip-top of the globe is the North Pole. When you spin the globe the star doesn't move, it just rotates.

Have you noticed?

When you turn the globe, the North Pole (and the North Star) don't move, they only rotate. Is this really true? Is the North Star always in the same place?

Have you ever noticed that when you go outside, it seems like you are standing on a flat plate? In ancient times, some people thought the world was a flat plate that you could fall off if you traveled too far.

Model SE features

The **Horizon Globe SE** comes equipped with one sun, four moons, four planets, and 16 constellations. Let's get acquainted with these globe accessories.

Sun

The big yellow disc.

Moon

The 4 white discs are the various moon shapes: full, gibbous, quarter, and crescent. We'll talk the meaning of the moon shapes in a later chapter.

Planets

The 4 colored discs represent planets: Venus, Mars, Jupiter, and Saturn.

Constellations

The 16 clear discs are constellations. They have star patterns and names etched on them. Twelve of these discs belong to a group that has a unique name that you might be familiar with. Later we'll introduce these plus four more special constellations that we call *guideposts*.

Zodiac Constellations

Guidepost Constellations

Hmmmm

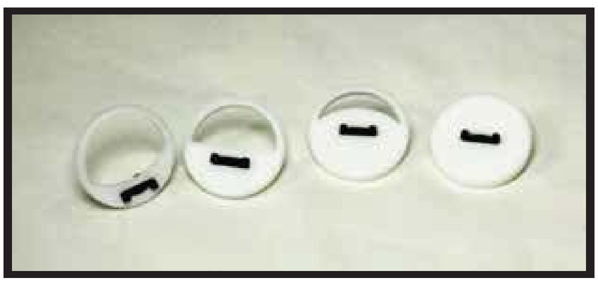
Have you ever seen a planet? Bet you have, even if you didn't know it.
Do you know your astrological sign? Your sign depends on which constellation was in a special place when you were born.
Have you ever seen the Big Dipper? How about Orion?

Model LX Features

The **Horizon Globe LX** comes equipped with one Sun, four moons, four planets, and 4 guidepost constellations. The LX model is also adjustable for latitude. Let's get acquainted with the accessories and learn more about latitude adjustment.

Sun

The big yellow disc.



Moon

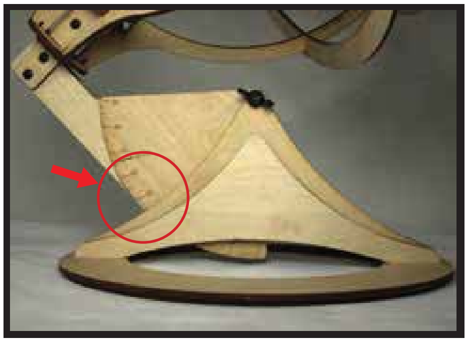
The 4 white discs are the various moon shapes: full, gibbous, quarter, and crescent. We'll talk the meaning of the moon shapes in a later chapter.

Planets

The 4 colored discs represent planets: Venus, Mars, Jupiter, and Saturn.

Constellations

The 4 guidepost constellations included with model LX are precision-engineered and reasonably accurate once placed. The zodiac constellations are printed on the outermost ring.



Latitude set to 45°

Latitude

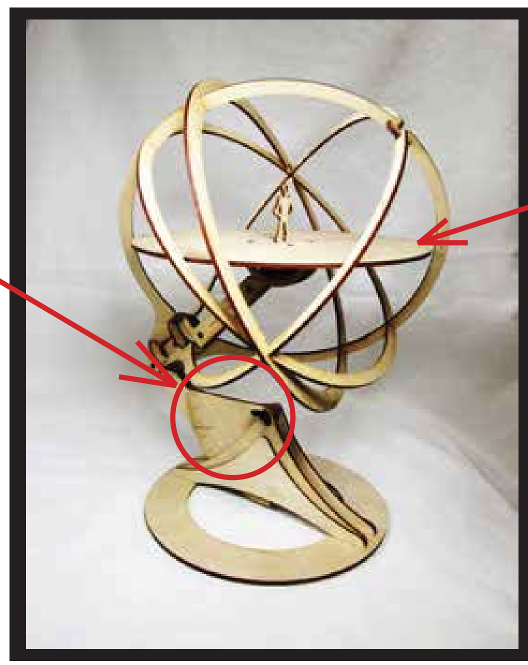
The LX model Horizon Globe has the capability of representing any latitude in the Northern Hemisphere. (Actually, in the entire world with a little imagination!)

We sometimes call this area of the globe the *protractor*. A protractor is used for measuring angles, exactly as we're doing here.

How to adjust latitude

1

- Loosen wingnut
- Rotate device to an angle
- Tighten wingnut



2

Make sure **Horizon Plate** is level

Many of the following chapters use descriptions and pictures of the SE model to demonstrate ideas. To follow along:

A) When constellations are mentioned, simply use the LX version of the constellation instead. If the reference is to a zodiac constellation, refer to the constellations printed on the outer ring of your globe.

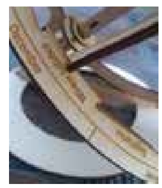
B) Set the latitude on your globe to 45° (as shown above), tighten the wingnut, and level the Horizon Plate. You're ready to go!

Getting Started – Day and Night

Equipment needed: Horizon Globe and sun

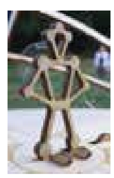
Place the Sun anywhere on the *Ecliptic Ring*, which is the outer ring that has months printed on it:

Sun



Ecliptic Ring

Give the globe a few turns. Notice how the Sun is sometimes above the Horizon Plate and sometimes below. The Observer can see the Sun when it is above the Horizon Plate but not when it is below.



Observer

Horizon Plate
(The Observer stands on it)

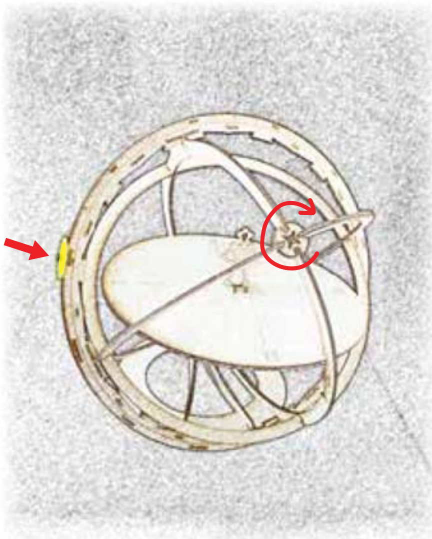
This makes the Observer just like you: when you go outside, you can see the Sun when it's above the horizon. We call this *daytime*. If the Sun is below the horizon it is *night*.

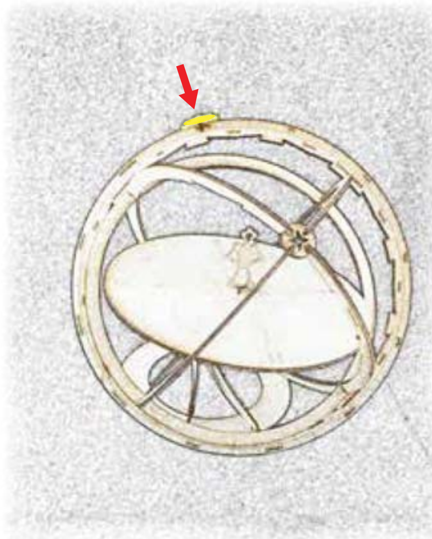
The same is true for the Horizon Globe. When the Sun is above the Horizon Plate it is day and when the Sun is below the plate it is night.

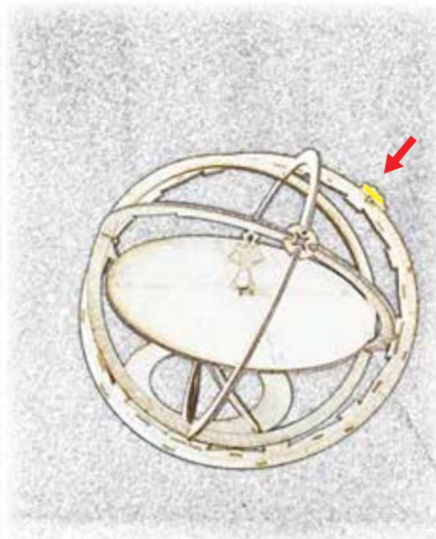
EXERCISE

1. Put the Sun on the Ecliptic Ring.
2. Spin the globe.
3. Notice what the Observer can and can't see.
4. Notice day and night.

For all Horizon Globe models from here on
(until we get to the chapters on Latitude)







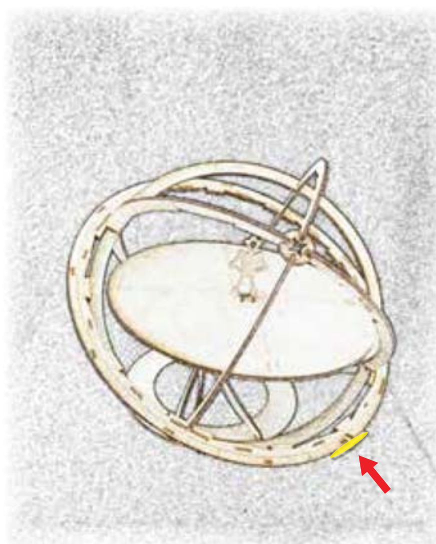
1

Put the Sun anywhere on ecliptic ring
(shown here in mid-August)

2

Spin the globe and watch the Sun move across the sky

(Remember, do not remove Sun from Ecliptic Ring--spin the globe to move the Sun)



What do you think?

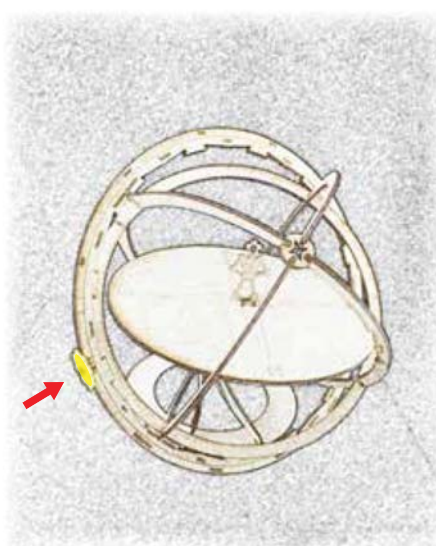
Do you think the Sun really does continue on its path after it sinks below the horizon at sunset?
Where else would it go?
How does it get back over to the sunrise side?

3

Keep spinning globe and watch Sun go below the Horizon Plate.
What can the Observer see?
What is hidden from his view?

4

Remember:
Sun above Horizon Plate = Daytime
Sun below Horizon Plate = Night



Spin the Globe Clockwise

Equipment needed: Horizon Globe and sun

Celestial objects are moving all the time, that's why we need the Horizon Globe to model where they are and where they're going. Let's make sure we spin the globe the same way the sky turns.

Place the Sun anywhere on the Ecliptic Ring. Spin the globe around and around so that the Sun rises and sets, rises and sets. Is it rising on the side labeled East? If not, spin the globe in the other direction. We want the Sun to rise on the East side and set on the West side. (East and West are marked by the letters "E" and "W" etched on the Horizon Plate.)

Spinning the globe the right way is easier if you place the globe with the North Pole pointed toward you, as shown in the photos on the next page. When the North Pole is toward you, if you turn the globe clockwise the Sun rises on your left and sets on your right, just like the hands on a clock. Double-check that the Sun rises in the East and sets in the West (maybe not exactly East-West, but from the side labeled East to the side labeled West). This is the most important part of learning to use your new Horizon Globe! From here we'll see that the Moon and stars and planets all move in a similar way.

Remember, the Sun is placed on the Ecliptic Ring and the motion of the Sun is shown by spinning the globe. (A common mistake is to remove the Sun from the globe and place it in a new location on the Ecliptic Ring to make it "move" through the day. The Sun *does* move on the ecliptic but only over longer periods of time, as we'll see in a later chapter. For now, make sure you spin the globe to move the Sun.)

EXERCISE

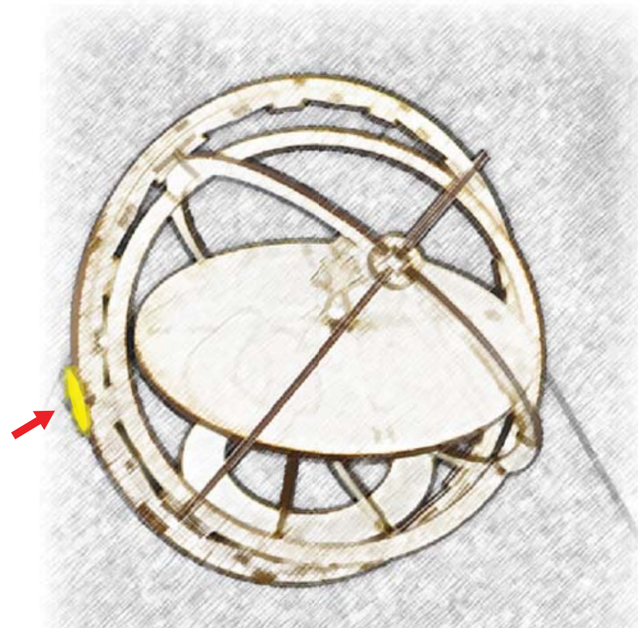
1. Start with North Pole pointed toward you and the Sun on Ecliptic Ring.
2. Spin the globe clockwise. Make sure the Sun rises on the East side and sets on the West side.

Wheel in the sky keeps on turnin'

—JOURNEY

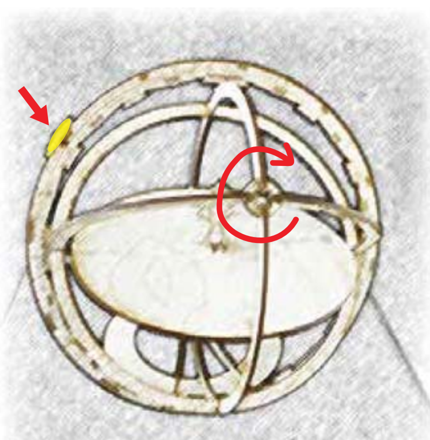
1 Start with:

- North Star pointing at you
- Sun on the ecliptic
- Sun positioned at sunrise

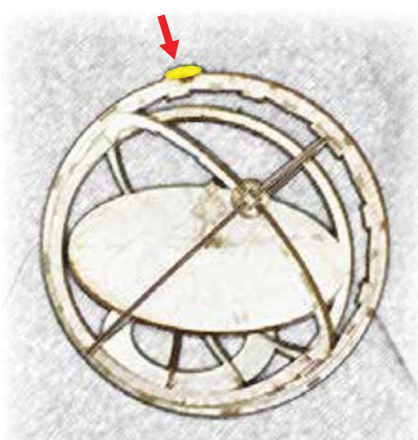


sunrise (east)

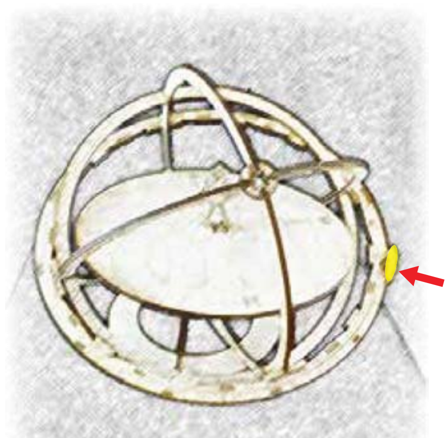
2 Spin globe clockwise, watch the Sun move across the sky from east to west



after sunrise



around noon



around sunset (west)

Where does the sun rise?

Did you notice that clockwise means a different direction depending on which way the globe is facing? Make sure the North Pole is facing you and the Sun rises on the East side.

Telling Time With the Sun

Equipment needed: Horizon Globe and sun

The Sun goes round and round creating day night. We can get more precise than just day and night, though. We can set the Horizon Globe to any particular hour we choose.

Put the Sun anywhere on the ecliptic. Turn the globe until the Sun reaches its highest point. This is *noon* (12:00 p.m.) for the Observer. Look at the photos on the next page to see noon and other examples of time shown on the Horizon Globe.

Now turn the globe until the Sun is at its lowest point (straight down, below the horizon). This is *midnight* (12:00 a.m.).

Halfway between midnight and noon is 6:00 a.m. Six a.m. is just about sunrise, or dawn. (It may be a little before or a little after dawn, depending on which month you placed the Sun on.)

Halfway between noon and midnight is 6:00 p.m., just about sunset or dusk.

You can get even closer by estimating. For example, a little past 6:00 a.m. is 7:00 a.m. Halfway between 6:00 a.m. and noon is 9:00 a.m.

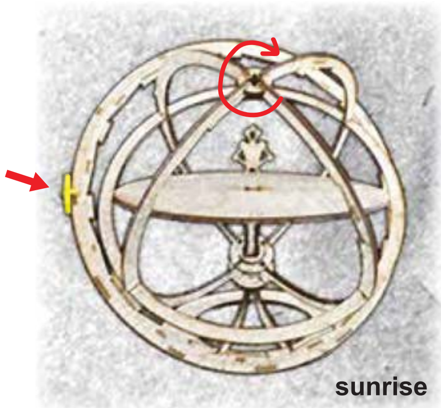
Become familiar with estimating time on the globe. It'll come in handy later when we're looking at the Sun and Moon together. Remember that it's the position of the Sun that determines what time it is!

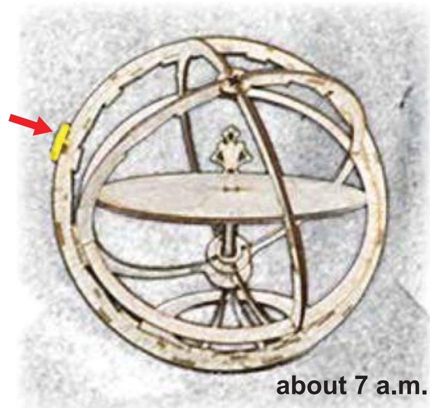
EXERCISE

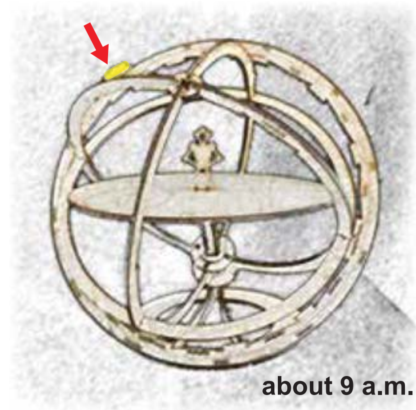
1. Put the Sun on the Ecliptic Ring, spin so the Sun rises and sets.
2. Leave Sun on Ecliptic Ring, spin globe to show various times.
3. Become familiar with sunrise, sunset, noon, and midnight.

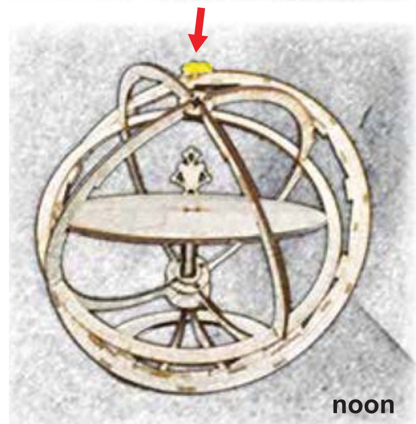
The oldest picture book in our possession is the Midnight sky

–E. WALTER MAUNDER


sunrise

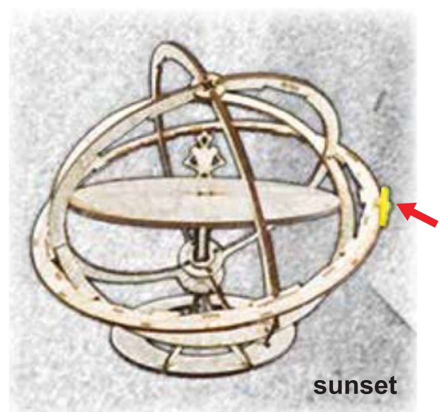

about 7 a.m.

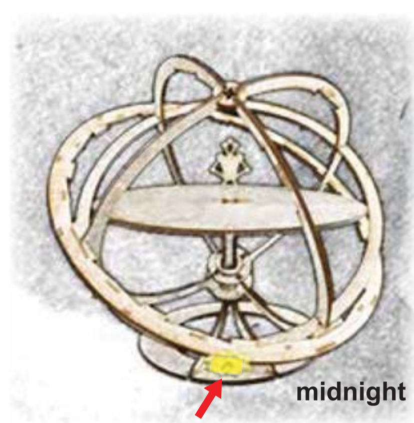

about 9 a.m.


noon

What time is it?

Can you tell time by the Sun when you are outside? Why not try it? You need a little more information to become really good at it though, and don't be surprised if your clock and the Sun don't match up perfectly.


sunset


midnight

Telling Time With a Special 24-Hour Clock

As the Sun moves across the sky, you can think of it as the hand on a giant clock.

Not an ordinary clock, though. Our special clock has *noon* at the top, representing the time when the Sun is highest in the sky. Twelve hours later is *midnight,* which is at the bottom of our special clock. A full day has 24 hours, so our clock also needs to have 24 hours for one revolution of the Sun.

The top circle on the next page shows this special clock. The position of the Sun in the sky points toward the time of day, shown here as 9:00 a.m. Note that noon is at the top of the circle and sunset is around 6:00 p.m., where the color of the circle changes from light blue to dark. Midnight is shown at the bottom, while sunrise is 6 hours later at 6:00 a.m. Light blue represents daytime, dark blue is night. Keep in mind that day is not exactly 6:00 a.m. to 6:00 p.m., but it's approximately so on average.

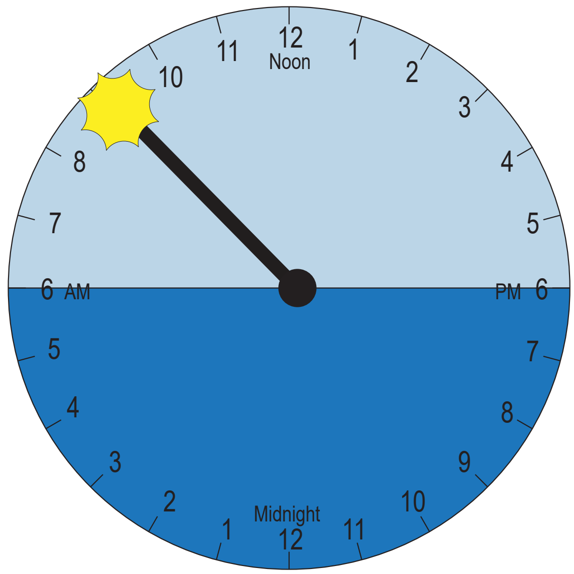
In the lower circle, we replace the clock hand with our Observer. If the Observer imagines this giant clock in the sky, he will be able to estimate by the Sun that it is about 9:00 a.m.

EXERCISE

1. Become familiar with 24-hour clock with noon at top, midnight at bottom.
2. Imagine 24-clock with Observer.
3. Estimate a few different times by Sun position.

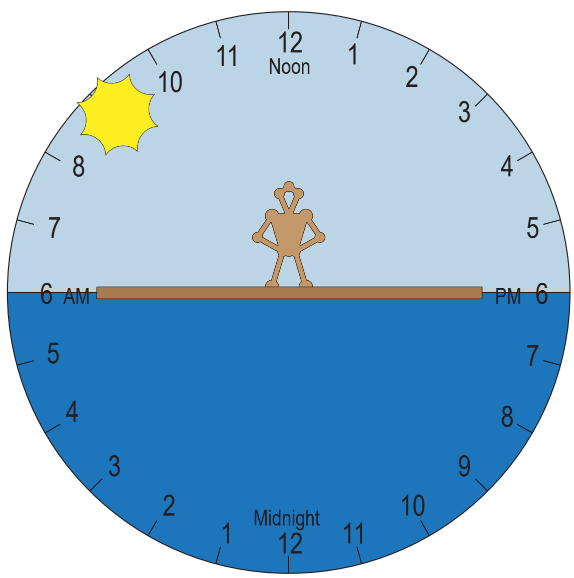
1

24-hour clock
(with a clock hand)
showing 9 a.m.



2

24-hour clock
(with clock hand replaced by Observer)
showing 9 a.m.



3

Where is the Sun at 3:00 p.m.?
How about at 9:00 p.m.?
What does the Observer see?

24-hour clock

Telling Time With the Horizon Globe

Equipment needed: Horizon Globe and sun

Now let's take a look at how the giant clock in the sky relates to our Horizon Globe.

Any time the sun disc is placed on the globe, it defines a particular time of day or night. In the day, we can estimate the time by the position of the Sun. In the night, we can estimate the position of the Sun by knowing the time.

In the following illustrations, the Observer imagines the giant clock to relate Sun position and time.

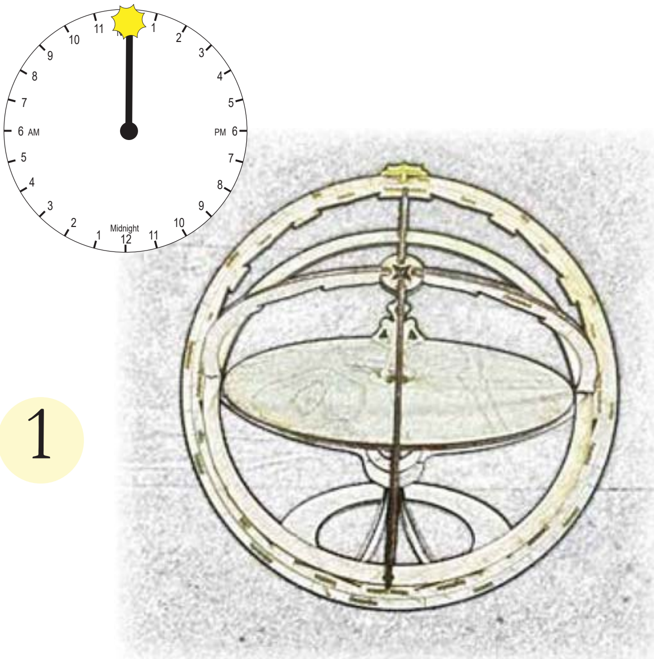
Midnight sun

Unlike the Observer, you can see the Sun at midnight on the Horizon Globe. Have you ever seen the Sun at midnight?

EXERCISE

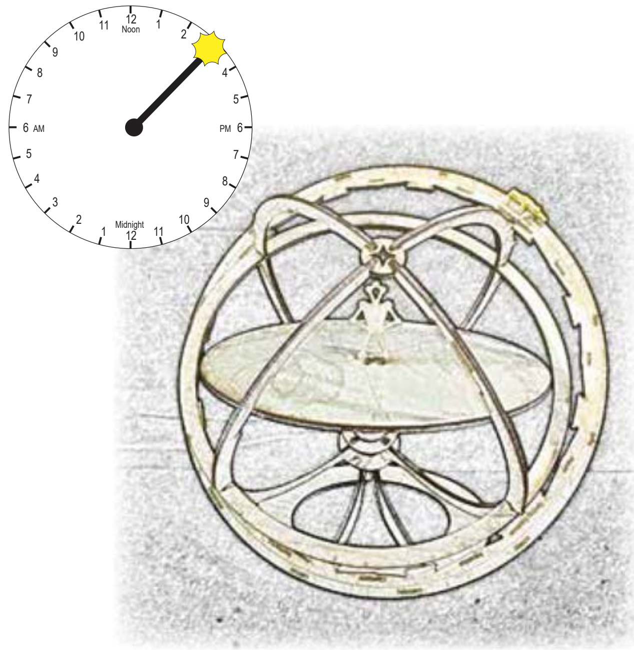
1. Put Sun at noon. Observer can estimate by the Sun position that it's approximately noon. Repeat for 3:00 p.m.
2. Put Sun at midnight. Observer knows by his watch that it's midnight, so he can estimate where the Sun is. Repeat for 4:00 a.m.

One complete turn of the globe equals 24 hours

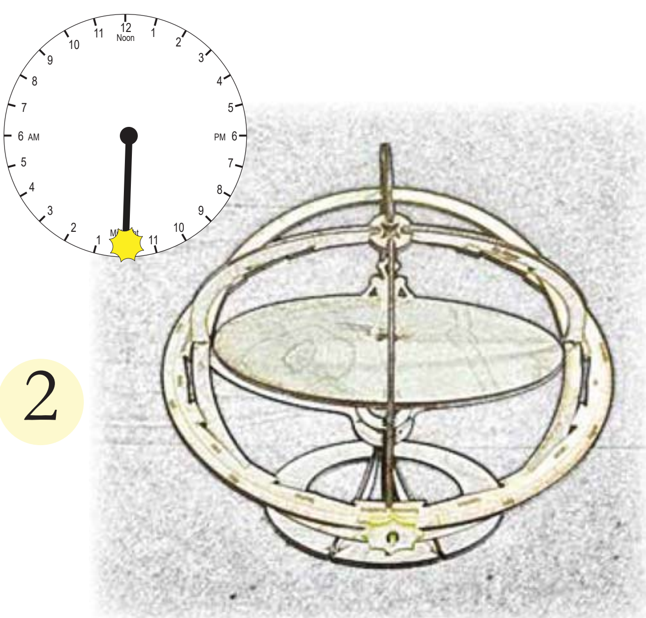


1

The Observer sees that the Sun is high in the middle of the sky, so he knows it's around **noon**

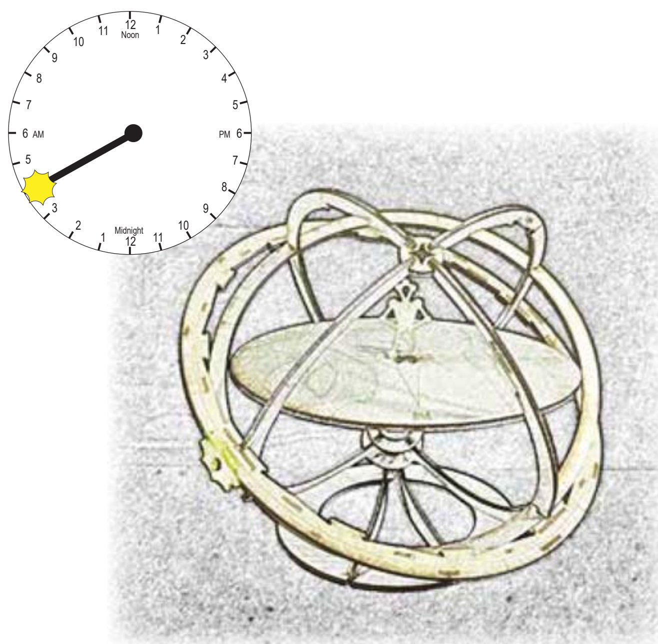


In mid-afternoon, the Observer can estimate it's about **3:00 p.m.** by looking at the Sun's position



2

The Observer knows by his watch that it is **midnight**, so he can estimate that the Sun is straight down



When the clock strikes **4 a.m.**, the Observer can estimate that the Sun is about ready to rise in the East

The Sun Moves on the Ecliptic

Equipment needed: Horizon Globe and sun

We've seen that the Sun moves from east to west over the course of a day. If you put the Sun on the globe and spin it around one complete circle, you've represented one entire 24-day, part of it daytime and part of it nighttime.

And what's more, as the Sun travels across the sky it marks the time. In fact, when we refer to a particular time of day, say noon, we are referring to where the Sun is at that moment.*

There is another phenomenon that we haven't discussed yet, but that you may have already noticed while using your Horizon Globe. When you place the Sun on the ecliptic, it matters *where* on the ecliptic you place it.

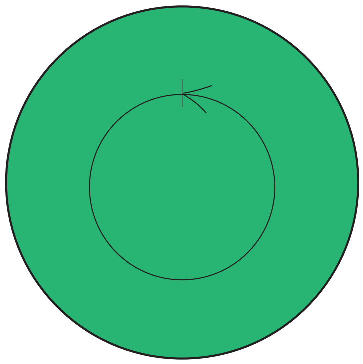
Try putting the Sun on the globe on the June mark and spin it once, noticing how the Observer would see the Sun move. Now check what he would see in December. You can see that there is more to the Sun's motion than just clock position. The path that the Sun takes across the sky varies dramatically depending on which part of the ecliptic the Sun is on. The location of the Sun on the ecliptic determines the time of year. We'll discuss the Sun's motion on the ecliptic further when we get to seasons.

* We are referring to solar time, which is based on where the Sun is located. Your clock may not say noon when the Sun is at its highest point. See Appendix A for clarification.

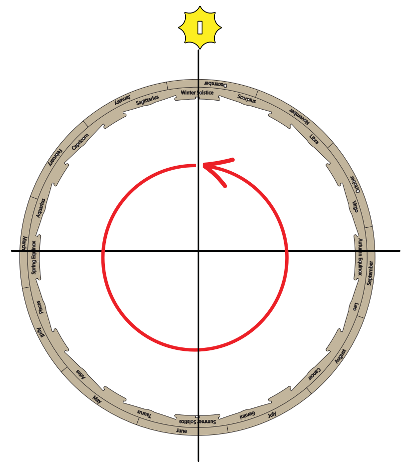
EXERCISE

1. Place the Sun at the June mark, spin and observe the Sun's path.
2. Repeat with the Sun placed in the month of December.

The Sun travels all the way around the ecliptic once per year



Full Circle = 360 degrees = 360º



All the way around once = 365 days

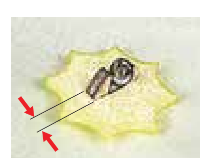
For now, if you want to model a particular day of the year on the Horizon Globe, you can get pretty close by estimating what portion of the month has passed. For example for June 1, put the Sun right on the line between May and June. June 30 would be the line between June and July. June 15 would be exactly in the center of June, etc.

Each time you spin the globe around once, you simulate a day. Another spin is another day. From one day to the next, the Sun moves a little bit along the ecliptic (you can tell which direction it moves by looking at the printed months). If you wanted to show the passing of one day, how much should you move the Sun?

In one year the Sun needs to go all the way around the ecliptic and back to where it started. For example if we start on the first day of June, the Sun needs to move through all the months—June, July, August, etc.—until it gets back around to June 1. Since there are 365 days in a year, each step must be 1/365 of a circle. In degrees a whole circle is 360°, so the Sun must move about a degree per day along the ecliptic.

On your Horizon Globe, that distance (the amount the Sun travels in one day) ends up being about the width of the clip on your Sun, moons, and planets.

One spin =
one day

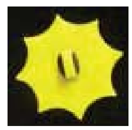


About one day

Now Add the Moon

Equipment needed: Horizon Globe, sun, full moon

Place both the Sun and Full Moon anywhere on the Ecliptic Ring.



Sun

Full Moon

Turn the globe clockwise. [Make sure the North Star is facing you. The Sun rises on the left (East) side.] Notice how the Moon travels. It does pretty much the same thing as the Sun. It rises in the East, sets in the West, and divides its time between being above the horizon and below the horizon.

Leave the Sun in one place and move the Moon to different places on the Ecliptic Ring. Try putting the Moon close to the Sun, then far away from the Sun.

When the Moon is close to the Sun how much of its time is spent in daylight vs. night? When the Moon is far from the Sun how much of its time is spent in the day vs. the night?

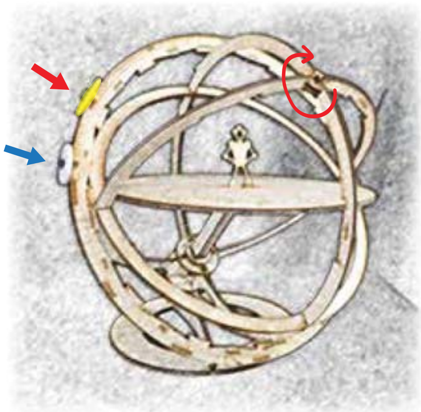
Notice what time the Moon rises and sets for each place you put it. (Remember, you can always tell what time it is by where the Sun is.)

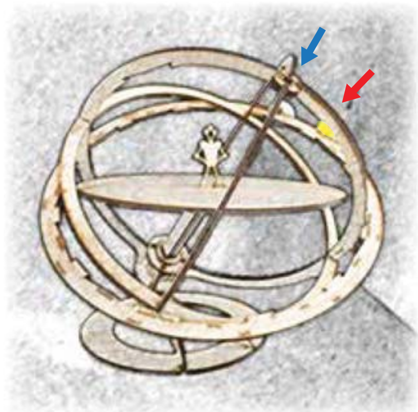
In the next section we'll talk about a way to describe where the Moon is compared to the Sun. *Angular measurement* is the technique used to denote the distance between the Sun and Moon. Angular measurement is regularly used by astronomers to describe where things are in the sky. It'll help us understand what we see, too.

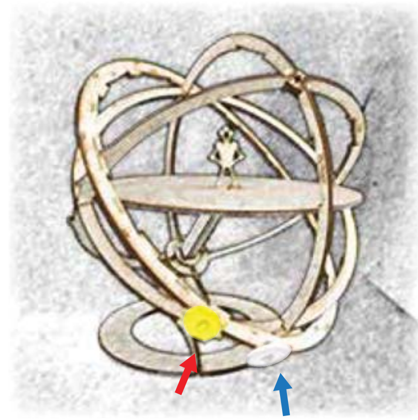
EXERCISE

1. Place both Sun and Full Moon anywhere on Ecliptic Ring.
2. Rotate globe, see them move together.
3. Leave Sun in place, move the Full Moon to a new location.
4. Spin the globe, observe.

Notice the Moon travels much like the Sun

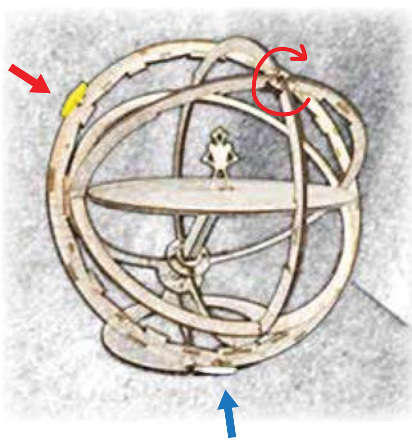


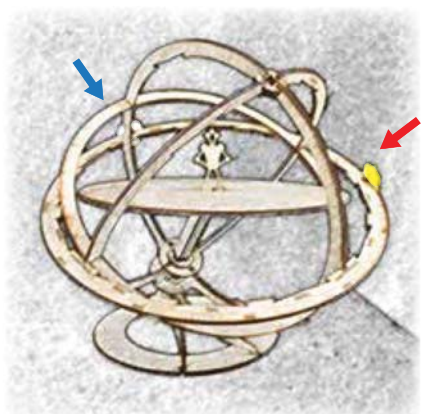


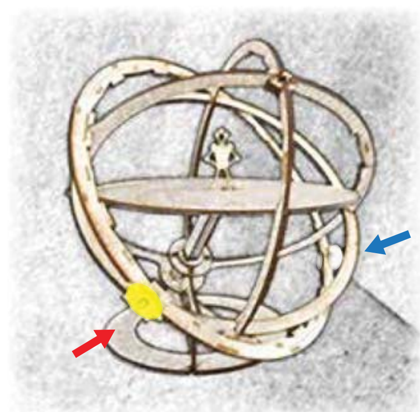


1 Place Sun and Moon anywhere on Ecliptic Ring

2 Spin Globe and watch Sun and Moon travel together







3 Move the Moon to a different location

4 Spin the Globe and watch the Sun and Moon make a revolution around the Observer

Moon sightings

Did you know that sometimes you can see the Moon during the day?

Have you noticed that some nights the Moon is nowhere to be found?

Measure Angles in Degrees

Now that we have two things in the sky, we need a way to talk about where they are relative to each other.

Let's do a quick review of how to measure angles using degrees. In the next chapter we'll talk about how to measure angles in hours.

As astronomers, we need a way to talk about where celestial objects are located. You could think of the Sun and Moon as located on the edge of a giant circle. Angles on a circle are easy to think about and measure, but let's just take a minute and review how it's done. A better understanding of how angles are measured on circles will help us grasp the relationship between the Sun and Moon.

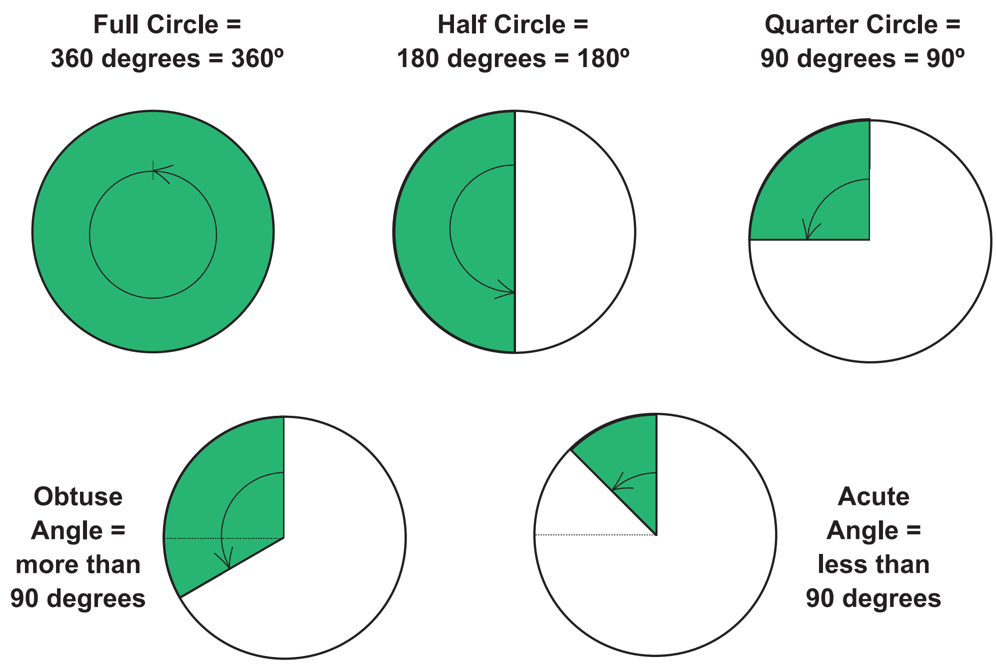
Let's start with the series of green circles on the facing page. A complete circle like the solid green one is considered 360 degrees (360º). Following along in the pictures, the half circle is 180 degrees, the quarter of a circle is 90 degrees. The second row shows examples of obtuse angles and acute angles. An *obtuse angle* is one that is more than 90 degrees. An *acute angle* is less than 90 degrees.

The Ecliptic Ring is just like a circle. It, too, can be divided into 360 degrees. The lower half of the following page shows how the Ecliptic Ring can be divided into parts of a circle. One-half of the Ecliptic Ring is 180 degrees, while one-quarter of the ring is 90 degrees.

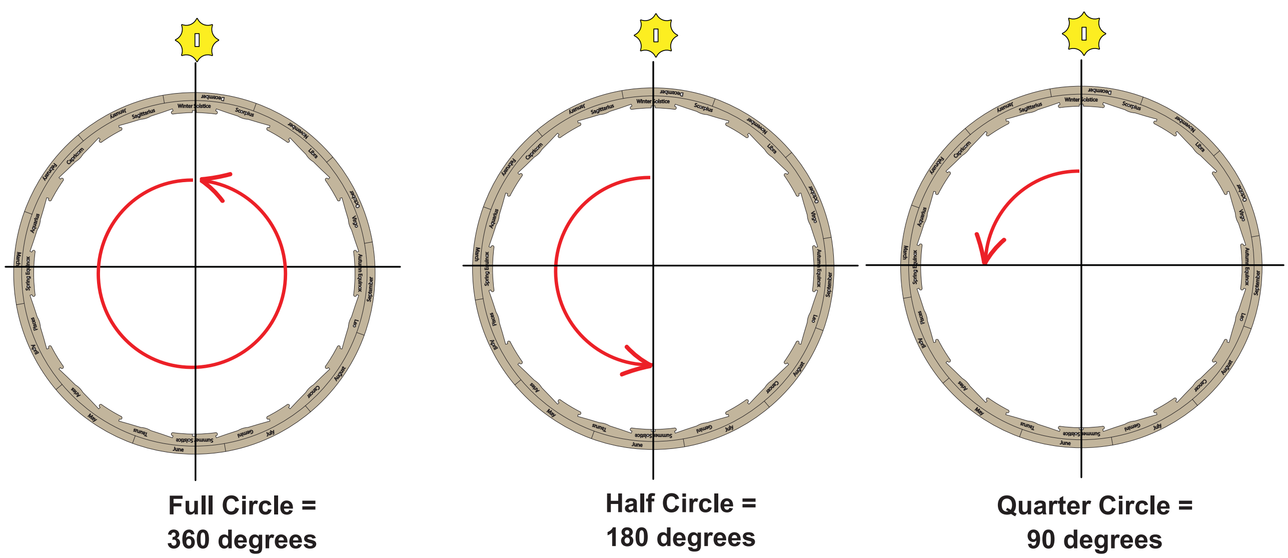
In a later section we'll put the Sun and Moon on our Horizon Globe and look at the various angles they make.

EXERCISE

1. Become familiar with circles measured in degrees. Compare obtuse and acute angles.
2. Notice that the Ecliptic Ring is a circle and can be divided into degrees.



1 PARTS OF A CIRCLE CAN BE MEASURED IN DEGREES



2 THE ECLIPTIC RING CAN ALSO BE MEASURED IN DEGREES

Measure Angles in Hours

Sometimes astronomers use degrees to measure the distance between two objects, other times they use hours instead of degrees. Let's take a look at how to use hours to measure the distance between objects.

Since the sky turns once around in 24 hours, astronomers measure the east-west distance between objects in hours instead of degrees. That way, if you see one object in a certain place, say the noon position, you know how long it will take for the second object to reach the same position.

If you know angles in degrees, it's easy to convert to hours. Look at the series of blue circles on the top of the following page. For the solid blue circle, instead of saying a whole circle is 360 degrees we say it is 24 hours. A half circle, 180 degrees, is 12 hours. A quarter circle, 90 degrees, is 6 hours. More than 6 hours makes an obtuse angle, and less than 6 hours makes an acute angle.

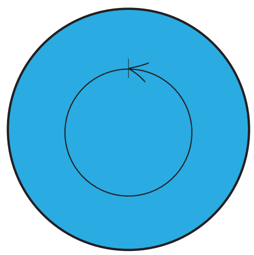
In the second exercise, the Observer knows how many hours are between the Sun and Moon by noticing the angle between them.

In the next section we'll attach the Sun and Moon to the Ecliptic Ring on our Horizon Globe and notice the angles they form.

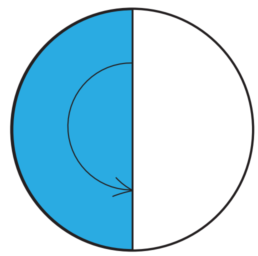
EXERCISE

1. *Become familiar with circles measured in hours.*
2. *Notice how the Sun and Moon form angles that you can measure in hours.*

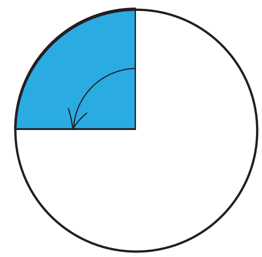
Full Circle =
24 hours



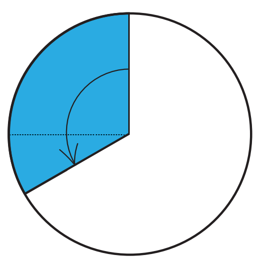
Half Circle =
12 hours

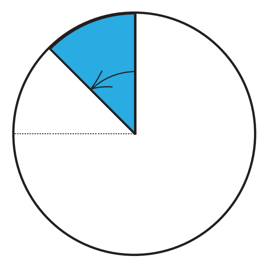


Quarter Circle =
6 hours



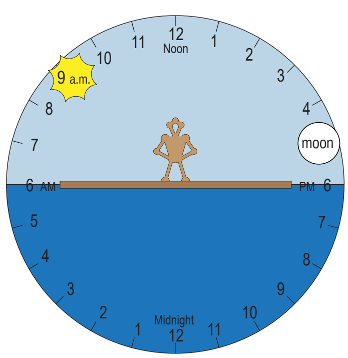
Obtuse
Angle =
more than
6 hours



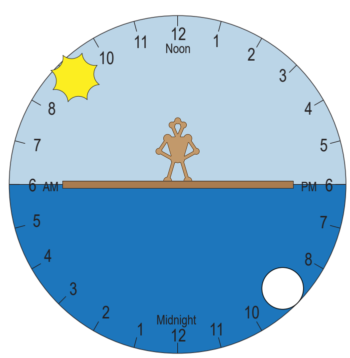


Acute
Angle =
less than
6 hours

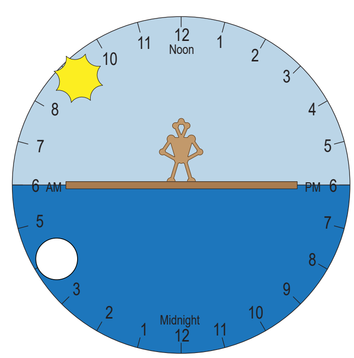
1 Parts of a circle can be measured in hours



Sun at 9 a.m. position*
Moon at 5 p.m. position
8 hour difference



Sun at 9 a.m. position
Moon at 9 p.m. position
12 hour difference



Sun at 9 a.m. position
Moon at 4 a.m. position
5 hour difference

**Remember that sun location determines the time of day*

2 Distance between Sun and Moon can be measured in hours

Sun – Moon Angle

Equipment needed: Horizon Globe, sun, full moon

We can talk about the location of the Moon by what angle it forms with the Sun.

On the following page the Sun stays in one place while the Moon is attached to the Ecliptic Ring in various locations.

(Remember, for this exercise we are not spinning the globe, we are moving the Moon from place to place on the ecliptic.)

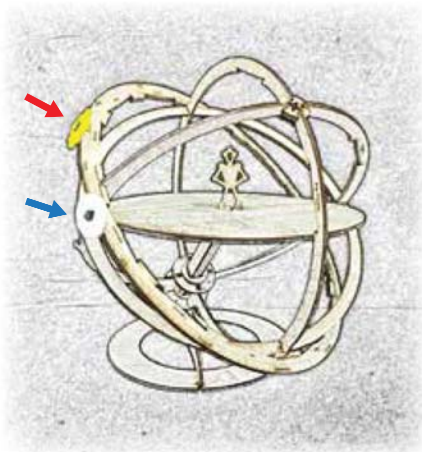
Get used to putting the Sun and Moon on the globe at different locations on the Ecliptic Ring. Notice the angle between the Sun and Moon.

Notice angles

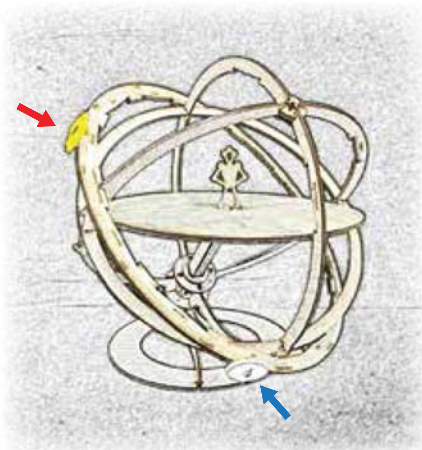
EXERCISE

1. Put the Sun and Moon at an acute angle anywhere on the Ecliptic Ring.
2. Leave the Sun in place. Move the Moon to new locations and notice angle the Moon makes with the Sun.

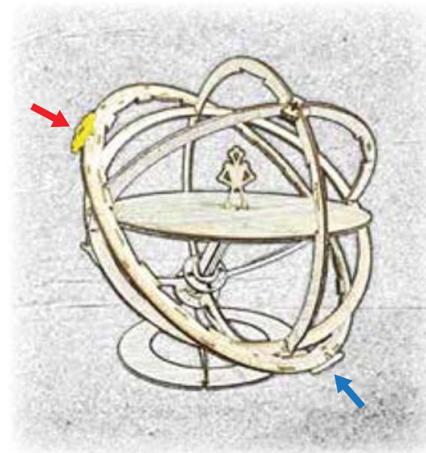
Use angular measurement to describe the distance between the Sun and Moon



acute



90 degrees



obtuse

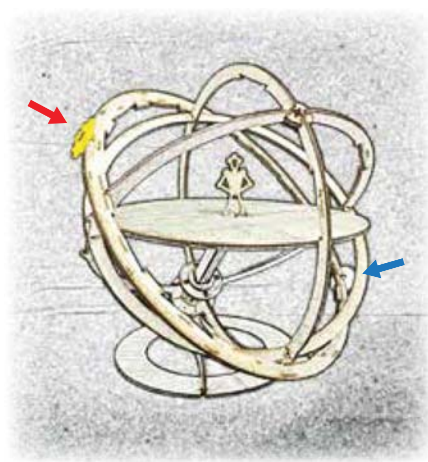
1

Place Sun and Moon anywhere on Ecliptic Ring so that they form an *acute* angle

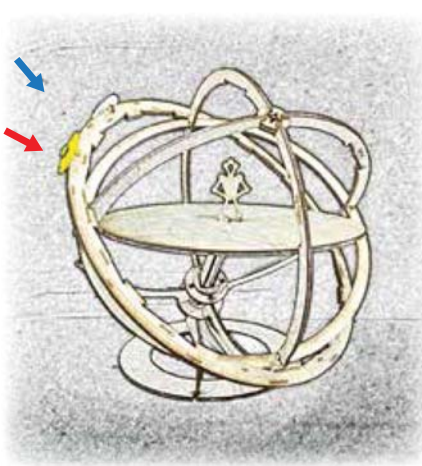
2

Now change the location of the Moon by taking it off the ecliptic ring and putting it back on in a new location. Notice the various angles that the Moon makes with the Sun.

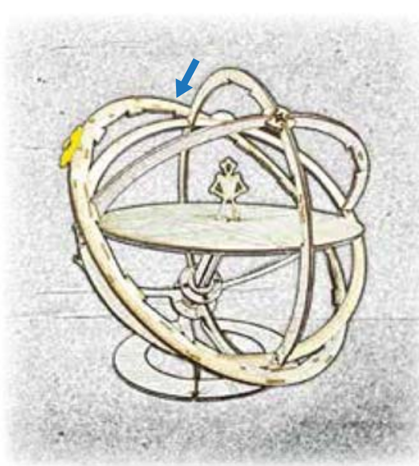
Note: Leave the Sun in one place for this exercise, and don't spin the globe.



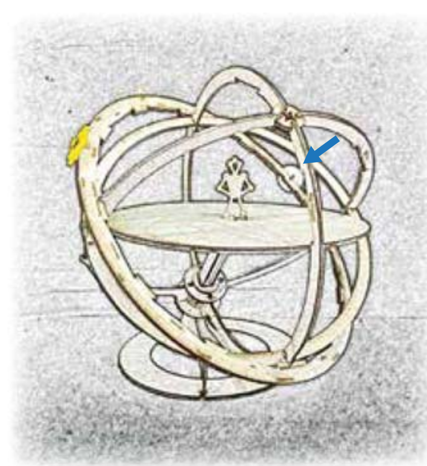
180 degrees



acute



90 degrees



obtuse

When the Moon is "Behind" the Sun

Equipment needed: Horizon Globe, sun, full moon

We can describe the Moon as being a number of hours "ahead of" or "behind" the Sun.

In these pictures, the Moon is a little more than 90 degrees, or about 8 hours behind (later than) the Sun. For this exercise the Sun and Moon stay in a constant location on the Ecliptic Ring while we spin the globe. At sunrise, the Sun is in the 6 a.m. position, while the Moon is below the horizon and invisible to us.

Spin the globe so the Sun is at around the 2 p.m. position. Notice that the Moon is rising. This is occurring about 8 hours later than sunrise, or about 8 hours *behind* the Sun.

Keep spinning the globe. Around 6 p.m. the Sun sets, while the Moon is at about the 10 a.m. position.

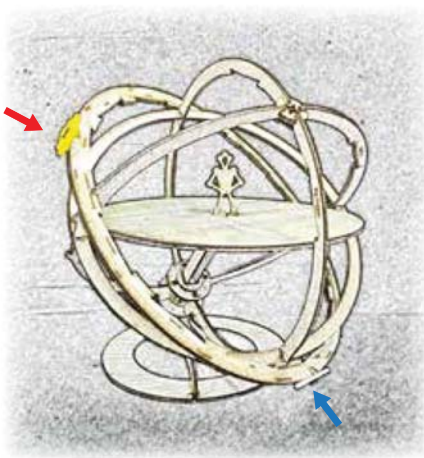
A few hours later the Moon sets, around 4 a.m. (very early in the morning). Remember that the position of the Sun determines the time of day or night.

We can see as we spin the globe that the Moon trails *behind* the Sun. The Moon rises *after* sunrise, the Moon sets *after* sunset.

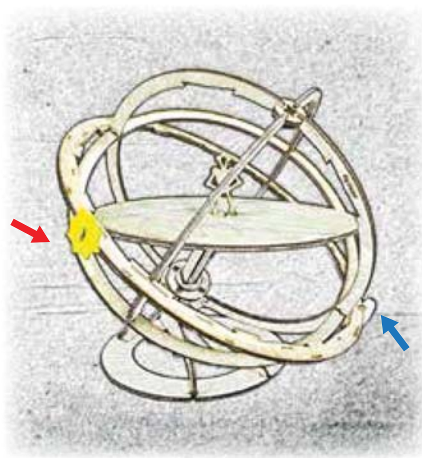
In the next chapter we'll take a look at what it means to be "ahead" of the Sun.

EXERCISE

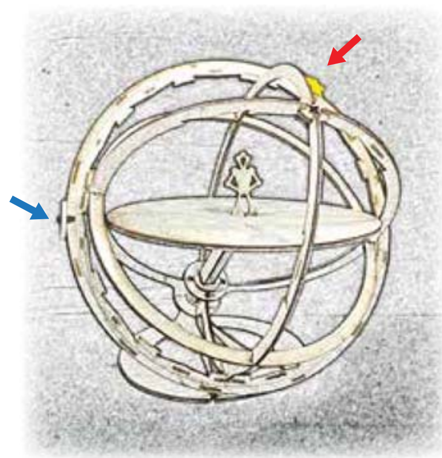
1. Put the Sun on Ecliptic Ring with Moon 8 hours behind.
2. Spin the globe and observe relationship between Sun and Moon.
3. Notice moonrise and moonset. At what time do they occur?



Moon 8 hours behind Sun



sunrise



moonrise

1

Place Sun on Ecliptic Ring. Put Moon 8 hours later than the Sun

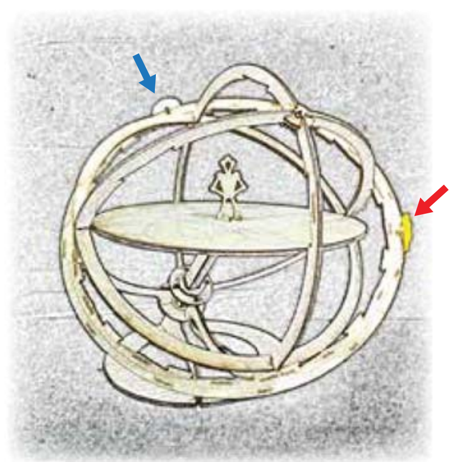
Note: Leave both Sun and Moon attached to the Ecliptic Ring in this position for the whole exercise

2

Rotate globe and observe relationship between Sun and Moon

3

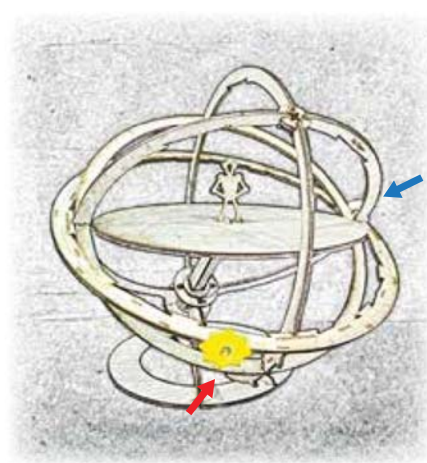
Notice moonrise and moonset



sunset

Sun behind the Moon

What time does the Moon rise and set? It depends on where it is relative to the sun. Remember, the Sun determines the time.



moonset

When the Moon is "Ahead" of the Sun

Equipment needed: Horizon Globe, sun, full moon

In the previous exercise we saw what the Sun and Moon look like when the Moon is "behind" the Sun. Now let's take a look at a time when the Moon is *ahead* of the Sun.

In these pictures, the Moon is a little more than 90 degrees, or about 8 hours ahead of (before) the Sun. For this exercise the Sun and Moon stay in a constant location on the Ecliptic Ring while the globe spins.

If we start at sunrise, the Moon is already high in the sky at the 2 p.m. position. We can say that the Moon is about 8 hours *ahead* of the Sun.

A few hours later, around 10 a.m., we can see that the Moon is setting.

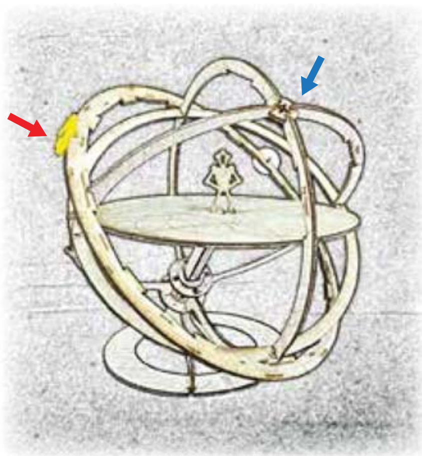
The Sun sets later in the day, and the Moon is still out of sight, having set earlier.

Just a little while later, around 10 p.m., we see the Moon rising.

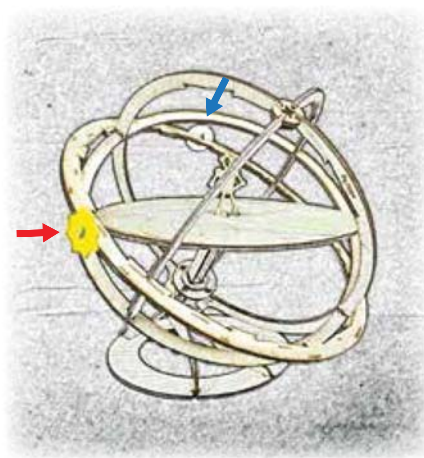
We can see as we spin the globe that the Moon leads *ahead of* the Sun. The Moon rises *before* sunrise, the Moon sets *before* sunset.

EXERCISE

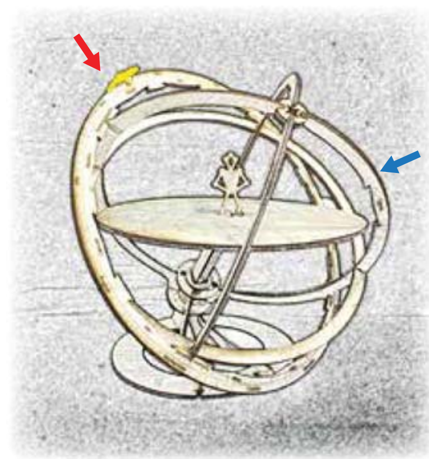
1. Put the Sun on the Ecliptic Ring with the Moon 8 hours ahead.
2. Spin the globe and observe .
3. Look at the Sun location to know what time the moonrise and moonset occur.



Moon 8 hours ahead of the Sun



sunrise



moonset

1

Place Sun on Ecliptic Ring. Put Moon 8 hours before the sun

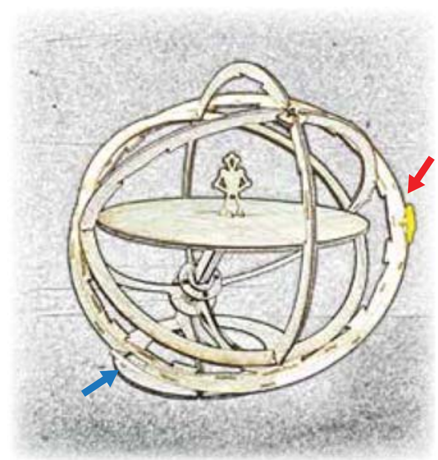
Note: Leave both the Sun and Moon attached to the Ecliptic Ring in this position for the whole exercise

2

Rotate globe and observe relationship between Sun and Moon

3

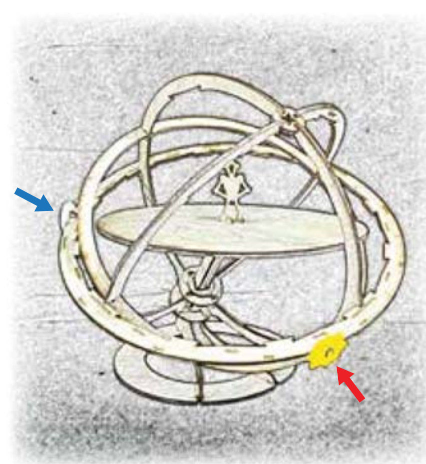
Notice moonrise and moonset



sunset

Sun ahead of the Moon

Knowing if the Moon is ahead of or behind the Sun will help us find it

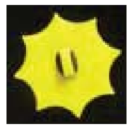


moonrise

The Moon is Slower than the Sun

Equipment needed: Horizon Globe, sun, full moon

Place the Sun anywhere on the Ecliptic Ring. Now place the Moon on the Ecliptic Ring as close as you can to where you put the Sun.


Sun


Full Moon

Turn the globe once around, stopping with the Sun at noon. Since the Moon was next to the Sun, the Moon did about the same thing as the Sun.

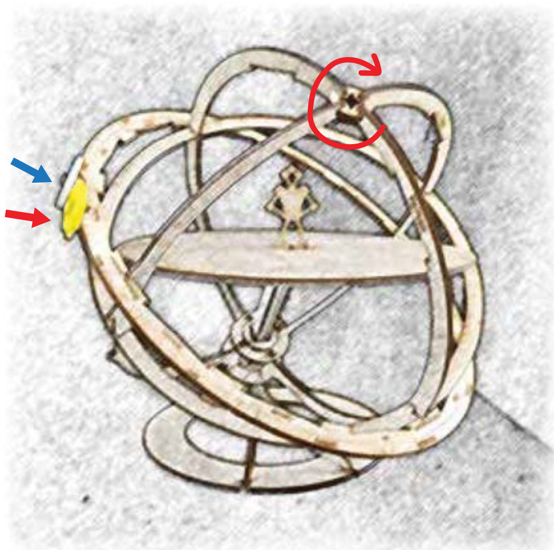
In the sky about you, this is close to what happens. The Moon travels like the Sun, but with a noticeable difference: the Moon is lazy. What does it mean for the Moon to be lazy? It means that it moves a little slower than the Sun.

As the Sun travels once around from noon to noon, the Moon doesn't make it quite as far because it's slower. When the Sun gets back to noon, the Moon has only made it back to about 11:00 a.m. Move the Moon on your globe to show this. (On the Horizon Globe, after one turn the Moon will be ½ of a month division farther East than, or behind, the Sun.)

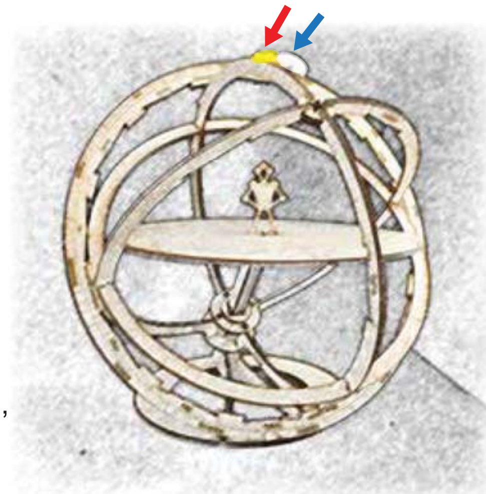
Turn the Globe again from noon to noon and the Moon falls back another hour (Move the Moon another ½ month division, or full month marker behind the Sun in total.)

EXERCISE

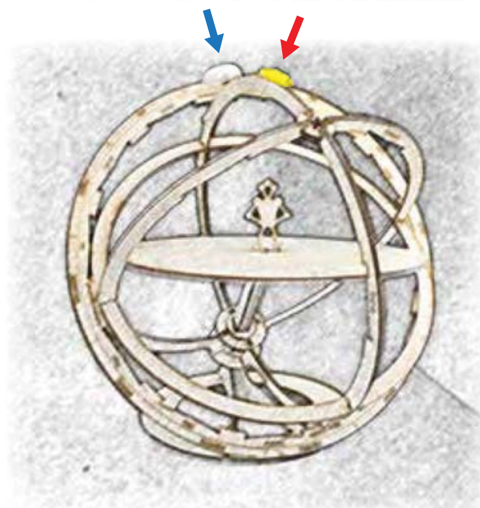
1. Place Sun and Moon close together on Ecliptic Ring, spin globe.
2. Spin globe so that the Sun is at noon.
3. Moon falls behind one hour (~½ month division) per spin.
4. After 2 spins Moon falls behind by 2 hours (1 month division).



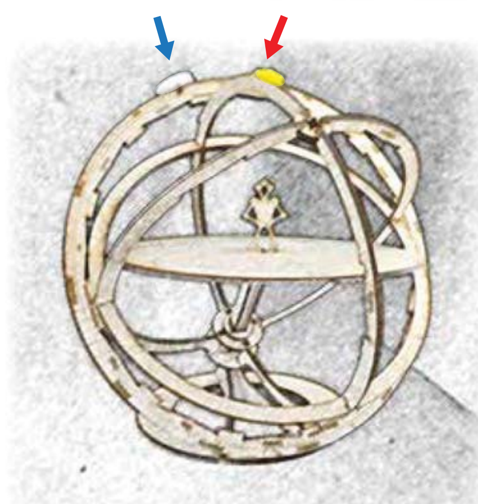
1 Place the Sun and Moon together on the Ecliptic Ring



2 Spin globe so that the Sun is in the noon position, Moon is with Sun



3 After 1 spin (1 day), Moon falls behind by 1 hour, (1/2 month division)



4 After 2 spins (2 days), Moon falls behind by 2 hours (full month division)

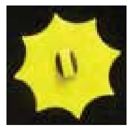
Lazy Moon

The Moon is like a lazy cow, trailing behind the Sun.

THE MOON TAKES A MONTH

Equipment needed: Horizon Globe, sun, full moon

Let's continue to look at how the Moon moves compared to the Sun. Place the Sun anywhere on the Ecliptic Ring.



Sun

Full Moon

Then place the Moon close to the Sun. Spin the globe so that the Sun is in the noon position, i.e. highest in the sky. Move the Moon back one hour (about ½ of a month division). Turn the globe again from noon to noon, and the Moon falls back another hour. Each turn of the globe, which represents one day, causes the Moon to fall back by almost another hour behind the Sun.

AFTER ABOUT 7 DAYS the Moon will be ¼ of a turn behind the Sun. Put it here and see that it will just be rising at Noon.

AFTER ABOUT 15 DAYS the Moon will be opposite the Sun. Now the Moon is straight down at the midnight position when the Sun is at noon.

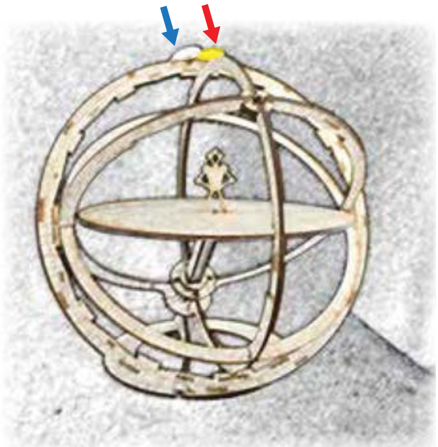
AFTER ABOUT 22 DAYS the Moon is ¾ of a turn behind, or ¼ turn ahead of the Sun. Now it will be rising at midnight and setting at noon.

AFTER 30 DAYS THE MOON HAS FALLEN BEHIND THE SUN BY ONE FULL TURN so it is right back to being next to the Sun. Now the whole cycle repeats.

The period of time it takes for the Moon to lose one full turn relative to the Sun is called a *month*.

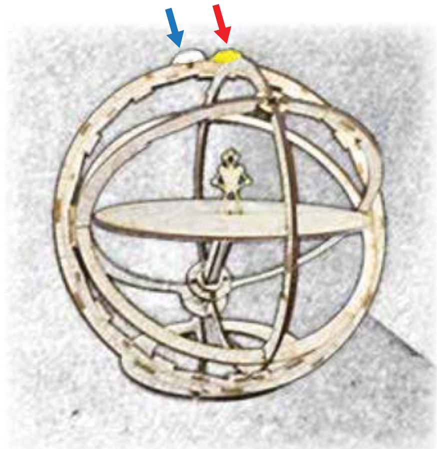
EXERCISE

1. Put the Sun and Moon close together on Ecliptic Ring.
2. Spin globe noon to noon, move Moon back every turn.
3. Watch the lazy Moon go through a complete Moon cycle.



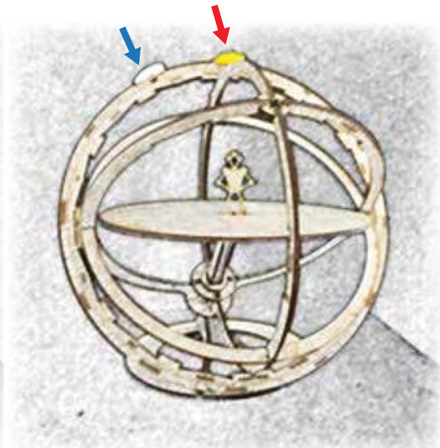
Day 0 & Day 30

Sun is in the **noon** position,
Moon is with Sun



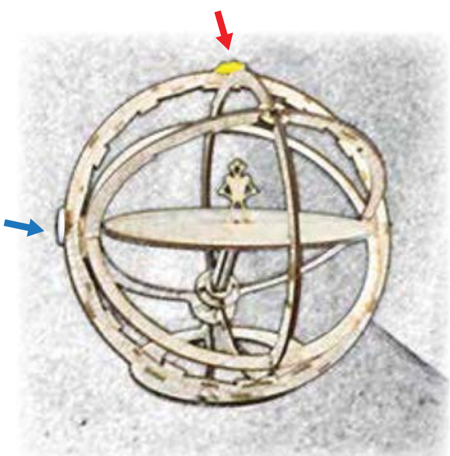
Day 1

After 1 spin,
Moon falls behind by ~1 hour,
(½ month division)



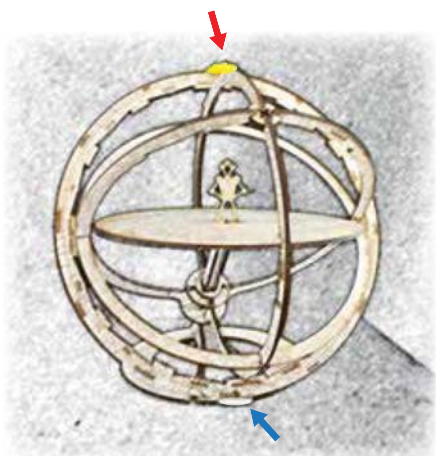
Day 2

After 2 spins,
Moon falls behind by ~2 hours
(full month division)



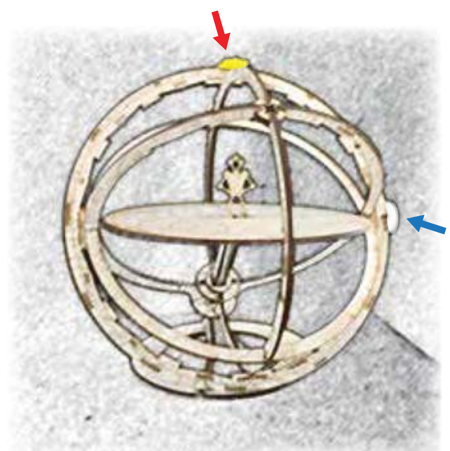
Day 7

After about 7 days,
Moon falls behind
by a quarter-turn



Day 15

After about 15 days,
Moon is opposite the Sun



Day 22

After about 22 days,
Moon falls behind by
three-quarters of a turn

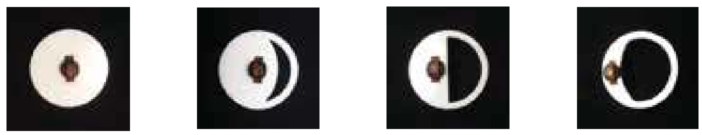
Moon month

The Moon is fun to watch. When it's at a quarter turn, you can see the Moon and imagine it lagging behind the Sun. A few days later it is opposite of the Sun. A few days after that when it's at ¾ of a turn, it looks like the Sun is catching the Moon!

Shapes of the Moon

Equipment needed: all four moon shapes

So far we've been using just the Full Moon to show how the Sun and Moon ride together on the Ecliptic Ring, and how the Moon moves relative to the Sun.



Full   Gibbous   Quarter   Crescent

But we know that the Moon doesn't always look the same to us--sometimes it's a full round circle, sometimes only part of a circle. The Horizon Globe uses different discs to represent the changing shape of the Moon.

Compare the sketches of Moon shapes with the photos of real moons on the facing page. Notice which parts are white and which parts are dark for each Moon shape. And for now, just focus on the shape and the name.

We know that during a month, the Moon slowly falls behind the Sun until the Sun passes the Moon and another month begins.

We also know that the shape of the Moon changes, as sometimes it is full and other times it has a different contour. What is it that's making the Moon change its appearance?

The fact that the Moon's angle relative to the Sun changes and the fact that the Moon's shape changes are definitely related. The shape, or *phase*, of Moon that we see depends on how far it is from the Sun.

On the next few pages we'll look at each Moon phase separately, starting with the Full Moon.

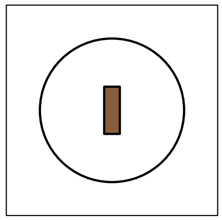
EXERCISE

1. *Become familiar with the Moon shapes included with your globe.*
2. *Compare your Moons to the photos on the next page.*

Become familiar with the different shapes of the Moon

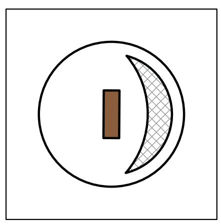
Full Moon
white disc that is solid

Horizon Globe Moon sketch

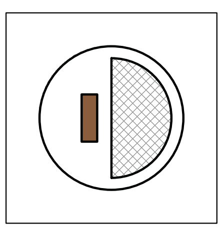


Real Moon photo

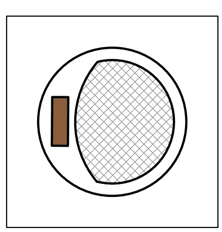
Gibbous Moon
white disc with a sliver missing



Quarter Moon
white disc that is half solid



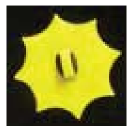
Crescent Moon
white disc with a large hole



Full Moon

Equipment needed: Horizon Globe, sun,full moon

The brightest and most prominent moon is a Full Moon. It looks like a completely round circle.


Sun


Full Moon

The Moon looks full to us when it is opposite the Sun. We could also describe this position as 12 hours behind or ahead of the Sun.

On your Horizon Globe, place the Sun anywhere on the Ecliptic Ring. Next, place the Full Moon disc on the ecliptic opposite the Sun. The Moon will be 180 degrees, or 12 hours, from the Sun.

Turn the globe until the Sun is at the noon position. Where is the Moon? It should be straight down, at the midnight position. Now turn the globe until the Sun sets. Where is the Moon now? It should be just rising.

At midnight, when the Sun is straight down, the Moon will be high overhead. Keep turning the globe until the Sun rises. Notice how the Full Moon sets right at sunrise.

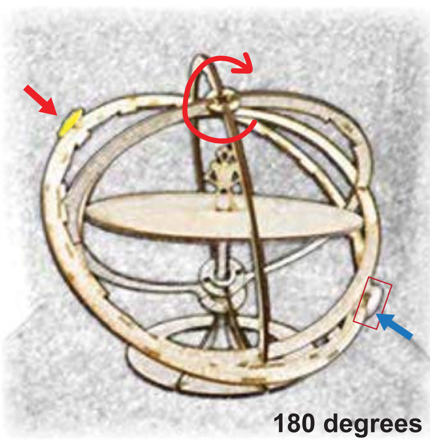
Technically, the Moon is only full for an instant when it is directly opposite the Sun, but it looks full for a few days every month when it is farthest from the Sun.

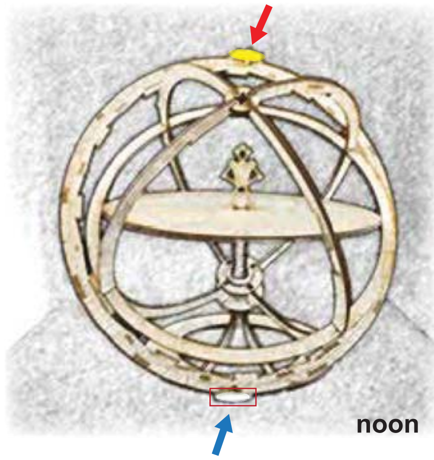
In the next section we'll take a look at the Sun and Moon when they are closer together.

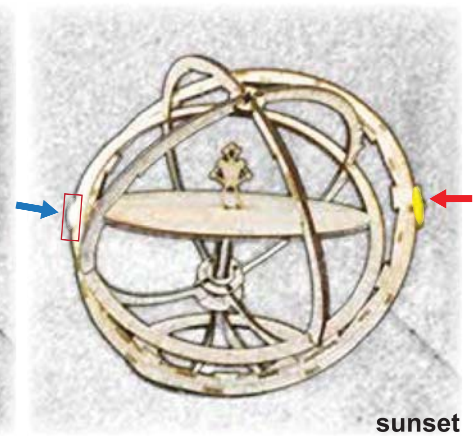
EXERCISE

1. Place Sun anywhere on Ecliptic Ring.
2. Place Full Moon 180 degrees from Sun on Ecliptic Ring.
3. Spin globe so Sun stops at noon. Observe Moon position.
4. Repeat for sunset, midnight, and sunrise.

During a Full Moon the Sun and Moon are 180 degrees apart







1 & 2

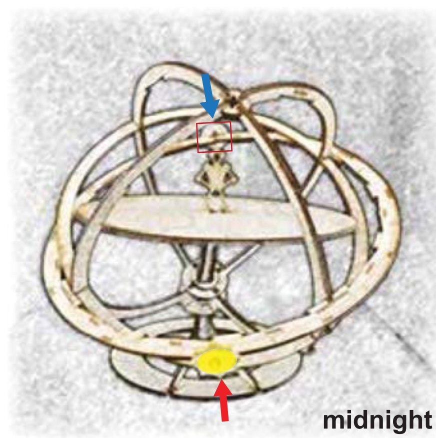
Place Sun and Moon anywhere on Ecliptic Ring 180 degrees apart

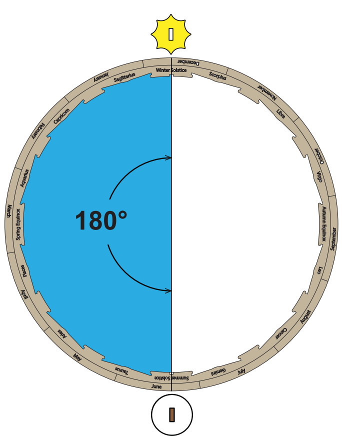
3

Spin the globe so that the Sun stops at noon position. Observe Moon location

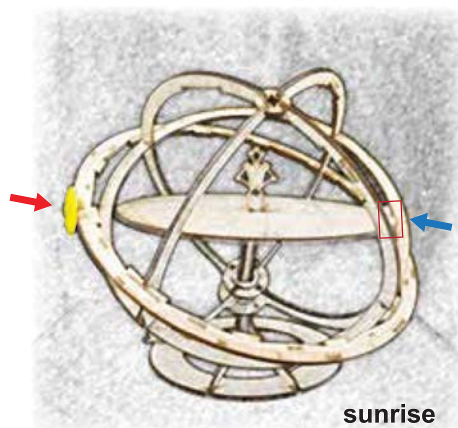
4

Repeat Step 3 for sunset, midnight, sunrise





Ecliptic Ring with Sun and Moon separated by:
a half-circle = 180º = 12 hours



Full Moon

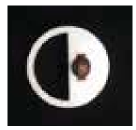
A perfectly full Moon can only be seen at night.

Waxing Quarter Moon

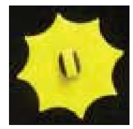
WAXING = GROWING

Equipment needed: Horizon Globe, sun, quarter moon

A complete round moon is called a Full Moon, but a half-circle moon is not called a half Moon, it's called a Quarter Moon.



Quarter Moon



Sun

It's called a Quarter Moon because the Moon is a ¼ of the way through its monthly cycle. The Quarter Moon is a quarter-turn from the Sun.

Place the Sun anywhere on the Ecliptic Ring. Turn the globe so the Sun is at noon. Now place the Quarter Moon on the ecliptic 6 hours behind the Sun. It will be near the horizon on the East side, halfway between the midnight and noon positions. A Quarter Moon that is 6 hours behind the Sun is *waxing*, or growing, and is called a *First Quarter Moon*.

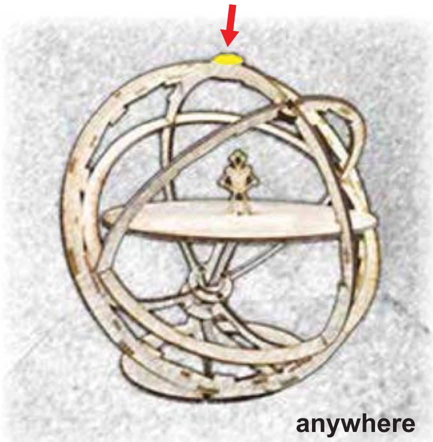
Make sure the solid side of the Quarter Moon disc is facing the Sun. With any partial Moon, crescent, quarter, or gibbous, the lighted side (represented by the solid side of the disc) always faces the Sun.

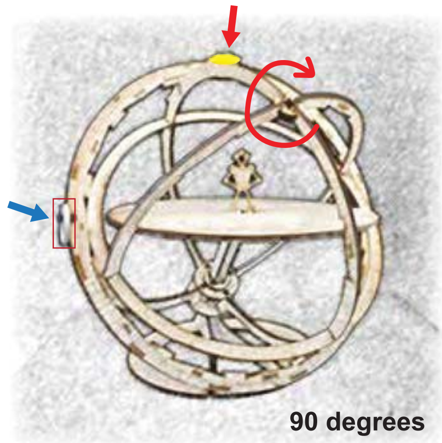
Turn the globe to sunset. Notice that the Moon is at its highest point. Keep turning to midnight, is the Moon setting now? Can you see the Moon at sunrise? When does the Moon reappear?

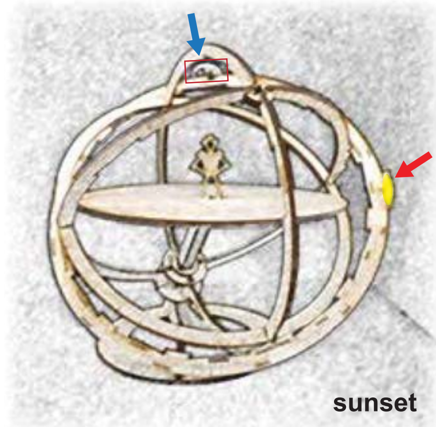
EXERCISE

1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Quarter Moon on Ecliptic Ring 6 hours behind Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

A Waxing Quarter Moon is
90 degrees behind the Sun and growing







1

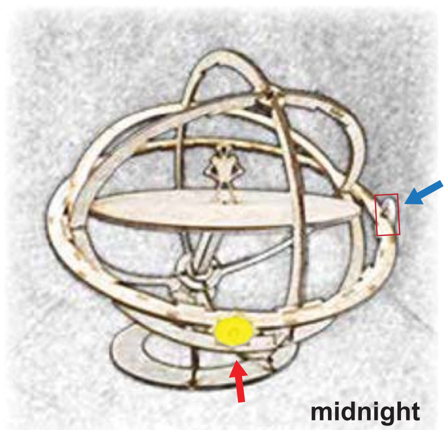
Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

Place Quarter Moon 6 hours behind Sun, the 6 a.m. position

3

Spin globe to sunset, observe Moon position

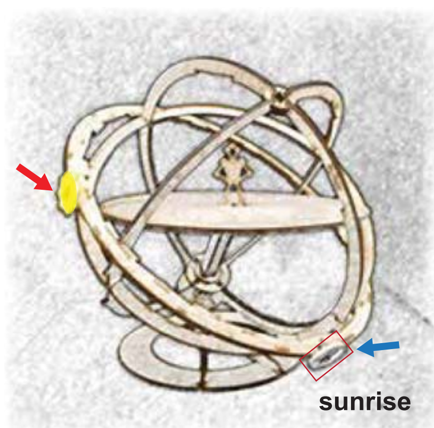


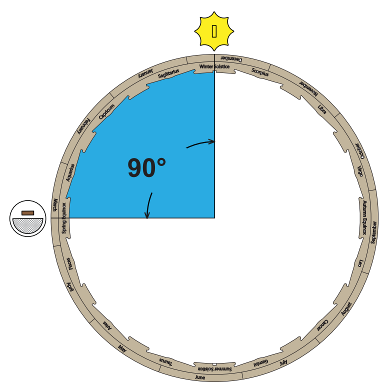
4

Spin globe to midnight, observe Moon position

5

Spin globe to sunrise, observe Moon position





Ecliptic Ring with Sun and Moon separated by:
a quarter-circle = 90º = 6 hours

Waxing Quarter

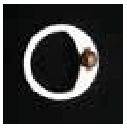
A waxing Quarter Moon is also called a First Quarter Moon. Can you guess why?

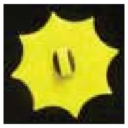
Waxing Crescent Moon

WAXING = GROWING

Equipment needed: Horizon Globe, sun, crescent moon

When the Moon is closer to the Sun than a Quarter Moon, it is a Crescent Moon.


Crescent Moon


Sun

The first week of a Moon cycle gives us a Crescent moon. When the Moon is first falling behind the Sun, before it grows to a Quarter Moon, we call it a *waxing* Crescent Moon. Waxing means growing, and the crescent of the Moon gets a little thicker each night.

Place the Crescent Moon disc on the globe between the Sun and where a First Quarter Moon would go. Notice that it forms an acute angle with the Sun. As always, make sure you put the Crescent Moon on the globe with the solid part facing the Sun.

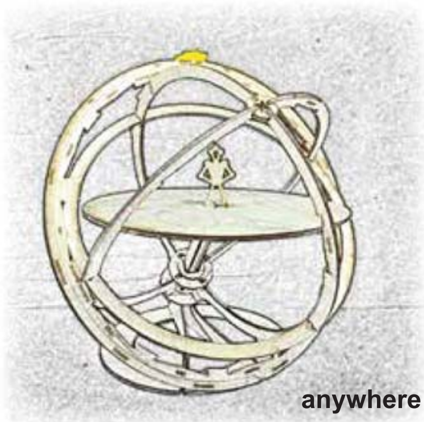
Turn the globe and notice that a waxing Crescent Moon rises just after sunrise and follows the Sun across the sky.

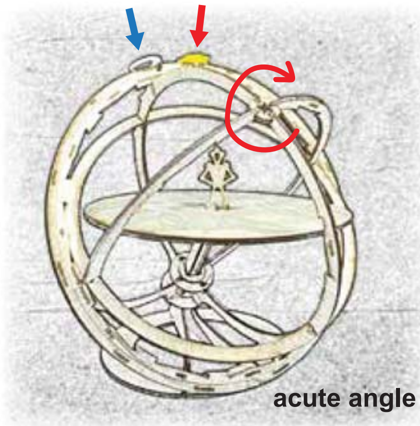
In the first couple of days after the Moon has fallen behind the Sun, it forms a very thin and dim crescent. When a waxing Crescent Moon is very thin you can only see it right around sunset, after the sky darkens, but before the Moon sets. As the Moon grows closer to a Quarter Moon it gets thicker and brighter and can easily be seen during the day.

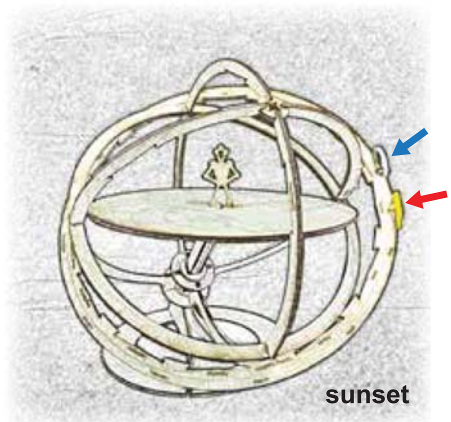
EXERCISE

1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Moon on Ecliptic Ring at an acute angle behind Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

A Waxing Crescent Moon is at an acute angle behind the Sun and growing







1

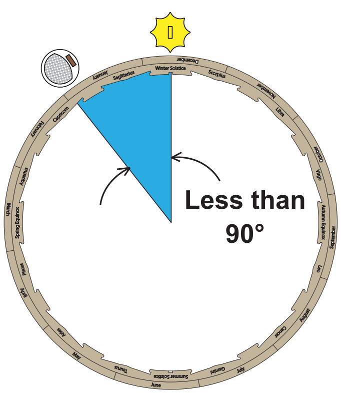
Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

Place the Crescent Moon at an acute angle behind the Sun

3

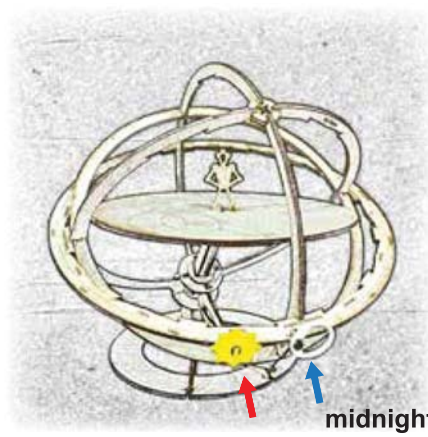
Spin globe to sunset, observe Moon position



Ecliptic Ring with Sun and Moon separated by:
an acute angle = less than 90º = less than 6 hours

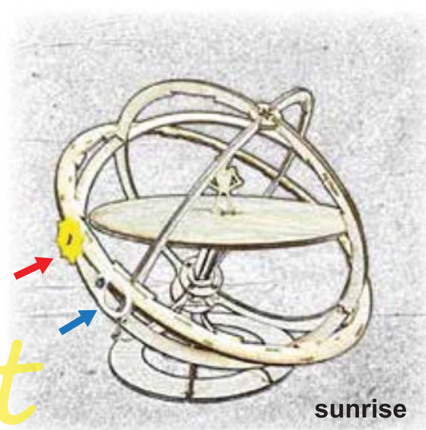
4

Spin globe to midnight, observe Moon position



5

Spin globe to sunrise, observe Moon position



Waxing Crescent

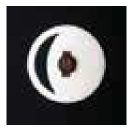
A thin Crescent Moon can be difficult to see. What time of the day would you be most likely to spot a waxing Crescent Moon?

Waxing Gibbous Moon

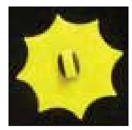
WAXING = GROWING

Equipment needed: Horizon Globe, sun, gibbous moon

When the Moon is more than a quarter, but not yet full, it is called a Gibbous, or "hump" Moon.



Gibbous Moon



Sun

Place the Gibbous Moon disc on the globe farther from the Sun than a First Quarter Moon, but not completely opposite like a Full Moon. A waxing Gibbous Moon rises in the afternoon. As with all partial Moons, make sure you put the Gibbous Moon on the globe with the solid part facing the Sun.

Turn the globe a few times to reveal the secrets of the waxing Gibbous Moon. When does it rise and set? When does it reach its highest point?

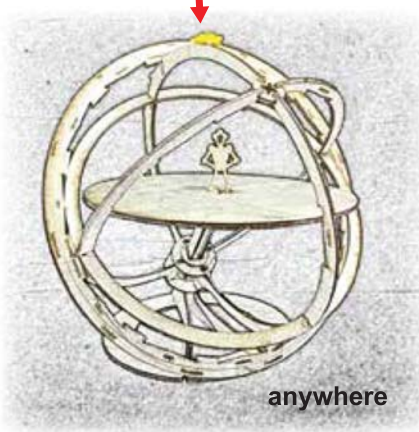
A waxing Gibbous Moon forms an obtuse angle with the Sun. It was recently a First Quarter Moon and is growing larger, but it won't be completely full until it is opposite the Sun.

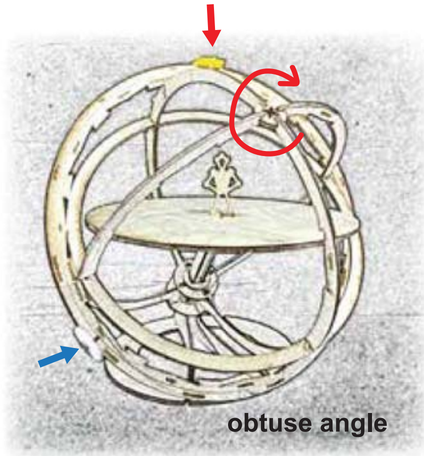
This Moon shape is always big and bright, so if its not cloudy and the Gibbous Moon is above the horizon you can easily see it, day or night.

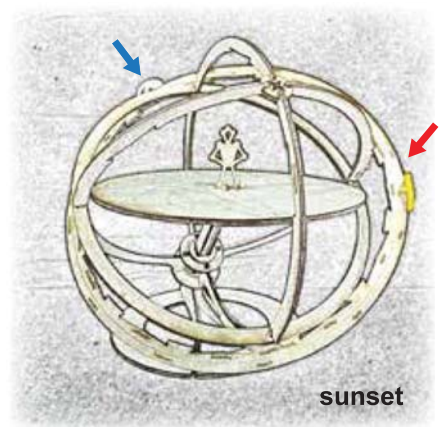
EXERCISE

1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place moon on Ecliptic Ring at an obtuse angle behind Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

A Waxing Gibbous Moon is at an obtuse angle behind the Sun and growing



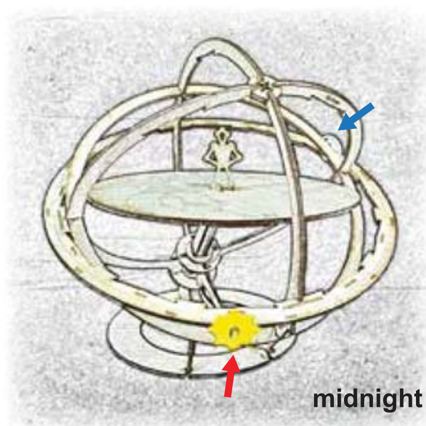




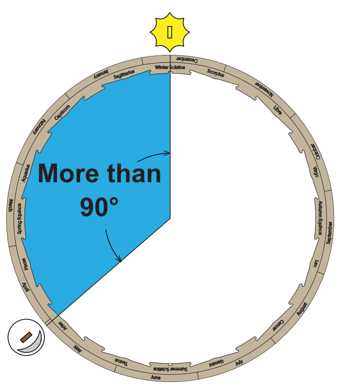
1. Place Sun anywhere on Ecliptic Ring and turn to the noon position

2. Place the Gibbous Moon at an obtuse angle behind the Sun

3. Spin globe to sunset, observe Moon position

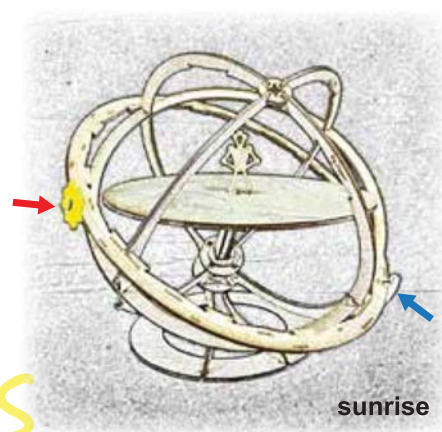


4. Spin globe to midnight, observe Moon position



Ecliptic Ring with Sun and Moon separated by:
an obtuse angle = more than 90º = more than 6 hours

5. Spin globe to sunrise, observe Moon position



Waxing Gibbous

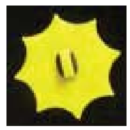
Gibbous Moons are big and easy to find, once you know where to look.

Waning Quarter Moon

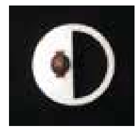
WANING = SHRINKING

Equipment needed: Horizon Globe, sun, quarter moon

We get a Quarter Moon when the Moon is a quarter-turn from the Sun. There are two Quarter Moons per month.



Sun



Quarter Moon

First let's review the waxing Quarter Moon from a previous chapter. Turn the globe so the Sun is at noon. Now place the Quarter Moon on the ecliptic 6 hours behind the Sun. It will be near the horizon on the east side, halfway between the midnight and noon positions.

Make sure the solid side of the Quarter Moon disc is facing the Sun. With any partial Moon, crescent, quarter, or gibbous, the lighted side (represented by the solid side of the disc) always faces the Sun.

Turn the globe to sunset. Notice that the Moon is at its highest point. Keep turning to midnight, is the Moon setting now? Can you see the Moon at sunrise? When does the Moon reappear?

There are two Quarter Moons per month. We just illustrated the first, which happens when the Moon falls behind the Sun by 6 hours. Now place the Quarter Moon disc one quarter-turn, or 6 hours ahead of the Sun. Make sure the bright side faces the Sun. This is the waning Quarter Moon.

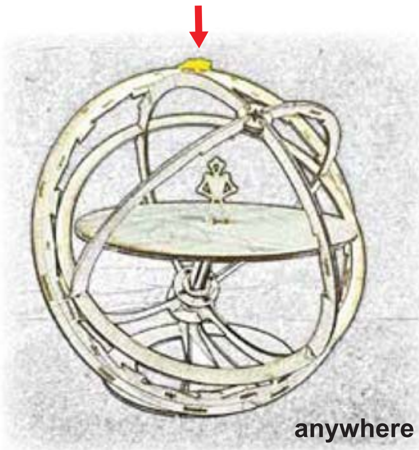
The waning Quarter Moon is also called a Last Quarter Moon. A Last Quarter Moon is a quarter-turn, or 6 hours ahead of the Sun (you could say it is ¾ of a turn behind the Sun). The Sun will catch this Moon in another week. Turn the globe to noon, sunset, midnight, and sunrise. When can you see a Last Quarter Moon?

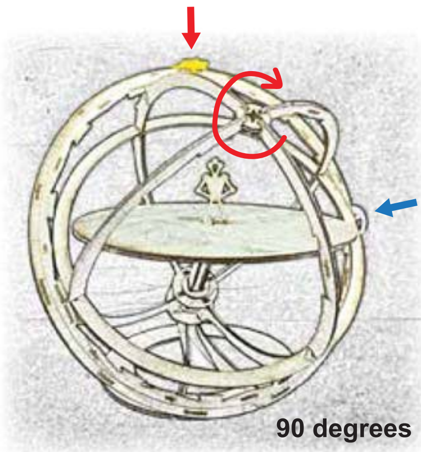
EXERCISE*

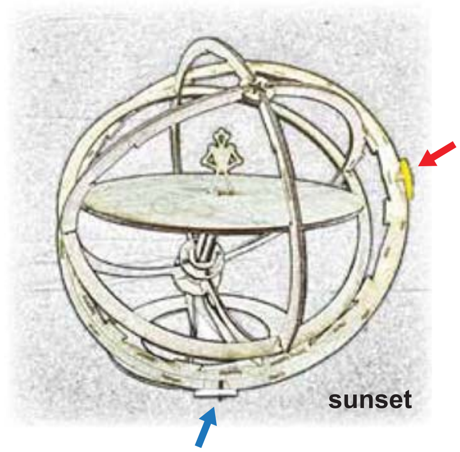
1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Moon on Ecliptic Ring at an 90° angle ahead of Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

*** note: review Waxing Quarter Moon**

A Waning Quarter Moon is
90 degrees ahead of the Sun and shrinking







1

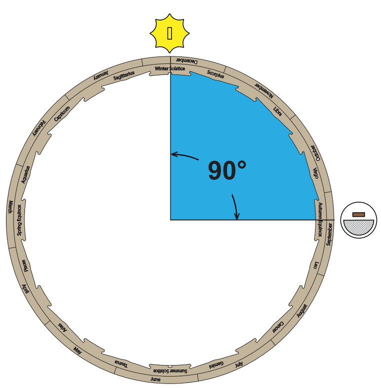
Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

Place the Quarter Moon at a 90° angle ahead of the Sun

3

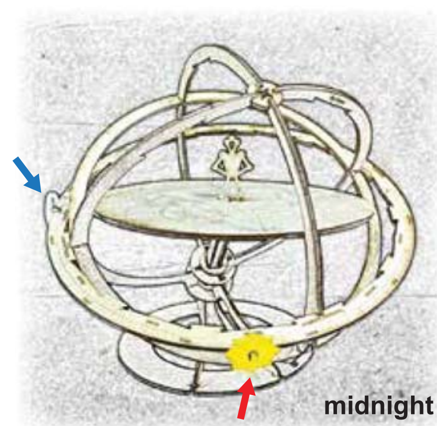
Spin globe to sunset, observe Moon position



Ecliptic Ring with Sun and Moon separated by:
a quarter-circle = 90º = 6 hours

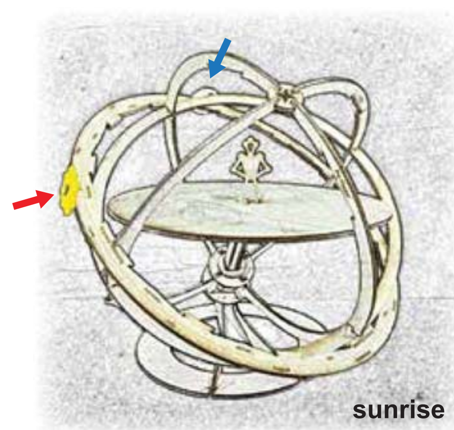
4

Spin globe to midnight, observe Moon position



5

Spin globe to sunrise, observe Moon position



Waning Quarter

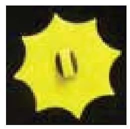
A waning Moon is shrinking. You could make up a rhyme to help remember: *waning is draining*

Waning Crescent Moon

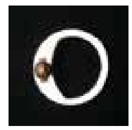
WANING = SHRINKING

Equipment needed: Horizon Globe, sun, crescent moon

When the Moon is closer to the Sun than a Quarter Moon, then it becomes a Crescent Moon.



Sun



Crescent Moon

First let's review the waxing Crescent Moon from a previous chapter. The first week of a Moon cycle gives us a Crescent moon. When the Moon is first falling behind the Sun before it grows to a Quarter Moon we call it a waxing Crescent Moon. Waxing means growing, and the crescent of the Moon gets a little thicker each night.

Place the Crescent Moon disc on the globe closer to the Sun than a First Quarter Moon. The waxing Crescent Moon rises just after sunrise and follows the Sun across the sky. It is best seen just after sunset when it starts to get dark. As always, make sure you put the Crescent Moon on the globe with the solid part facing the Sun.

Now move the Crescent Moon marker to the other side of the Sun, between the Sun and the Last Quarter Moon. This Moon, which is running for its life just ahead of the Sun is called a waning Crescent Moon. Waning means shrinking. A waning Crescent Moon starts out fat when it is near a quarter-turn away from the Sun, and gets thinner as the Sun catches up to it.

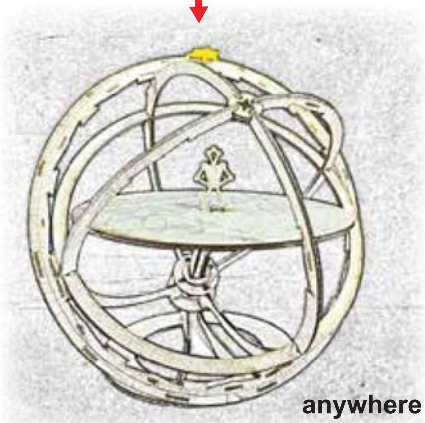
When is the best time to see a waning Crescent Moon?

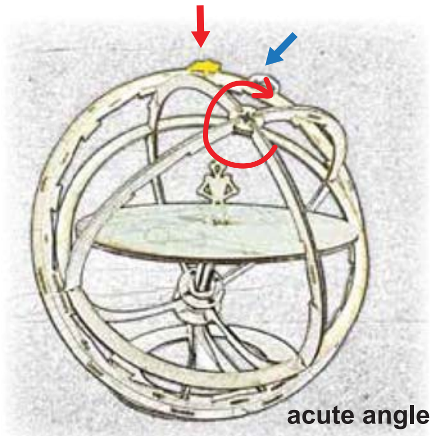
EXERCISE*

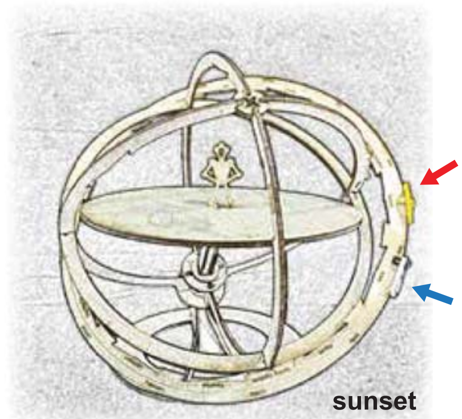
1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Moon on Ecliptic Ring at an acute angle ahead of Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

*** note: review Waxing Crescent Moon**

A Waning Crescent Moon is at an acute angle with the Sun and shrinking







1

Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

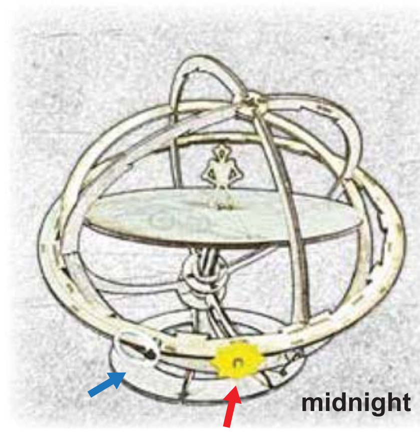
Place the Crescent Moon at an acute angle ahead of the Sun

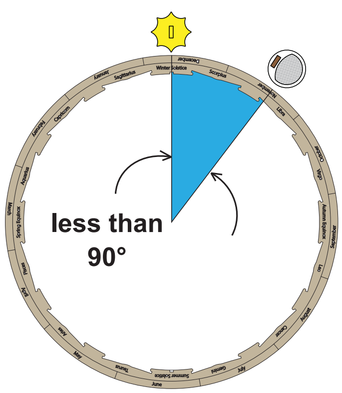
3

Spin globe to sunset, observe Moon position

4

Spin globe to midnight, observe Moon position

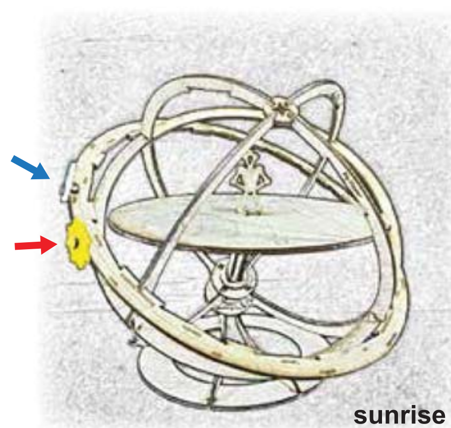




Ecliptic Ring with Sun and Moon separated by:
an acute angle = less than 90º = less than 6 hours

5

Spin globe to sunrise, observe Moon position



Waning Crescent

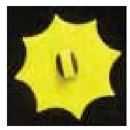
A waning Crescent Moon is moving closer to the Sun every day and getting harder to see.

Waning Gibbous Moon

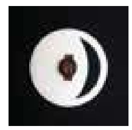
WANING = SHRINKING

Equipment needed: Horizon Globe, sun, gibbous moon

When the Moon is more than a Quarter, but not quite Full, it is called a Gibbous, or "hump" Moon.



Sun



Gibbous Moon

First let's review the waxing Gibbous Moon from a previous chapter. Place the Gibbous Moon disc on the globe farther from the Sun than a First Quarter Moon, but not completely opposite like a Full Moon. A waxing Gibbous Moon rises in the afternoon. As with all partial Moons, make sure you put the Gibbous Moon on the globe with the solid part facing the Sun.

Turn the globe a few times to recall the habits of the waxing Gibbous Moon, then move it to the waning side. Now your marker should be past full but not yet a Last Quarter Moon. Turn the globe to see how the waning Gibbous Moon behaves.

Except for when the Moon is full (directly opposite the Sun), all the time between the First Quarter and Last Quarter is the gibbous phase.

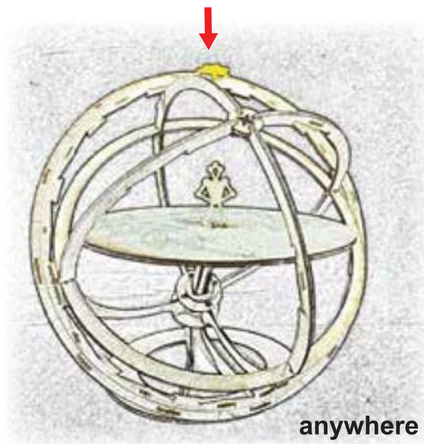
When is the best time to see a waning Gibbous Moon?

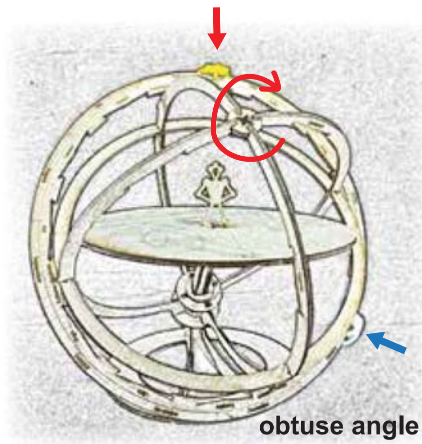
EXERCISE*

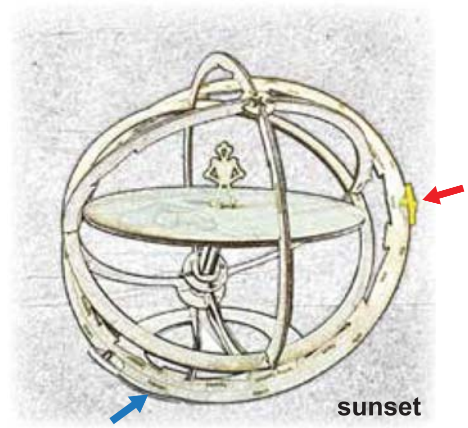
1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Moon on Ecliptic Ring at an obtuse angle ahead of Sun.
3. Spin globe so Sun is at sunset. Observe Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.

*** note: review Waxing Gibbous Moon**

A Waning Gibbous Moon is at an obtuse angle with the Sun and shrinking







1

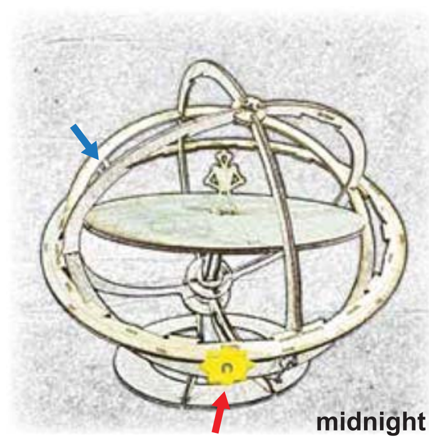
Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

Place the Gibbous Moon at an obtuse angle ahead of the Sun

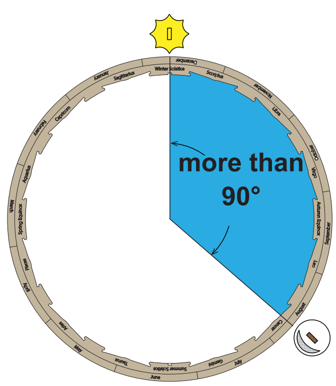
3

Spin globe to sunset, observe Moon position



4

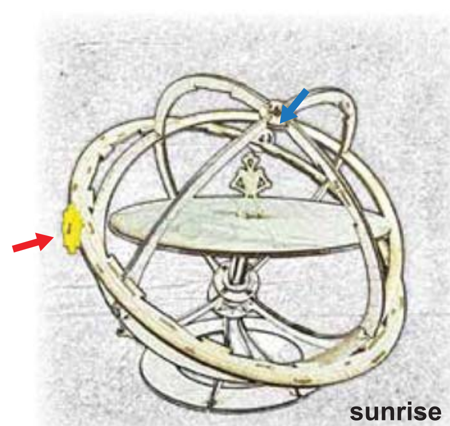
Spin globe to midnight, observe Moon position



Ecliptic Ring with Sun and Moon separated by:
an obtuse angle = more than 90º = more than 6 hours

5

Spin globe to sunrise, observe Moon position



Waning Gibbous

A waning Gibbous Moon is moving closer to the Sun every day. Next phase: waning Quarter Moon.

New Moon

Equipment needed: Horizon Globe, sun, crescent moon

Sometimes the Moon is so close to being in the same direction as the Sun that we can't see it at all. We call this a New Moon.

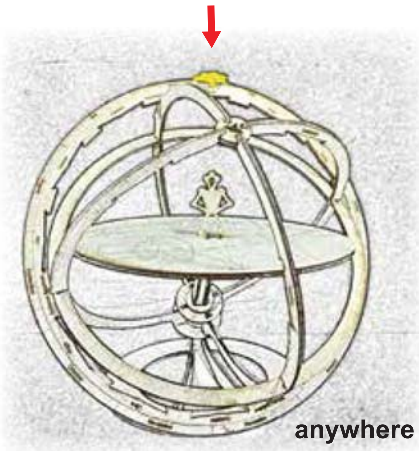
You can model a New Moon on your Horizon Globe by putting the Crescent Moon as close as possible to the Sun.

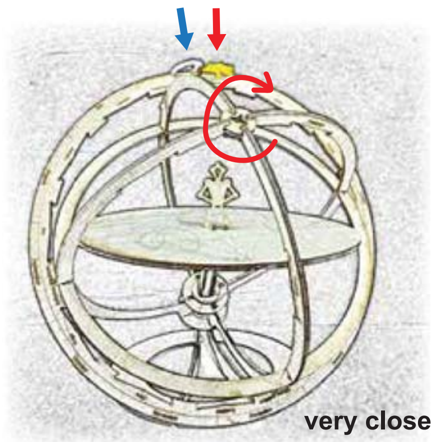
You can watch the Crescent Moon wane to nothing if you look for it just before sunrise, then it will be gone for a few days. The Moon will return as a very thin crescent, waxing in the evening sky.

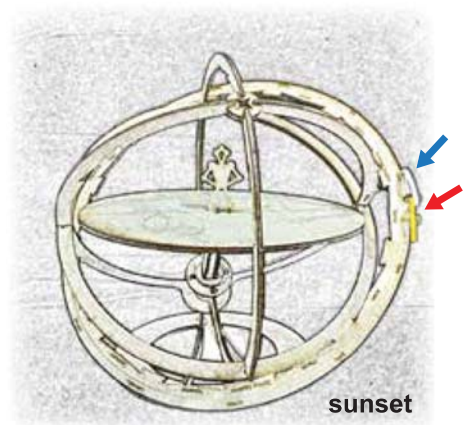
We begin counting each lunar cycle with the New Moon. It takes the Moon about 30 days to go through a full cycle of phases, from one New Moon to the next. In the next section we review the Moon phases to make them easier to remember.

EXERCISE

1. Place Sun on Ecliptic Ring, rotate Sun to noon.
2. Place Moon on Ecliptic Ring as close as possible to the Sun (or just leave it off, knowing that the Sun and Moon are very close together).
3. Spin globe so Sun is at sunset. Observe (or imagine) Moon position.
4. Repeat for midnight.
5. Repeat for sunrise.







1

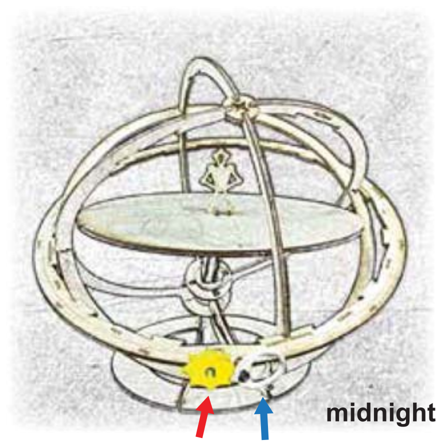
Place Sun anywhere on Ecliptic Ring and turn to the noon position

2

Place the Crescent Moon as close as possible to the Sun (or just leave it off)

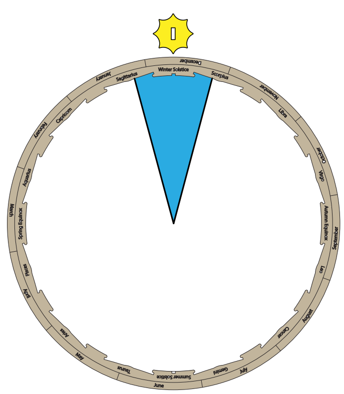
3

Spin globe to sunset, observe Moon position



4

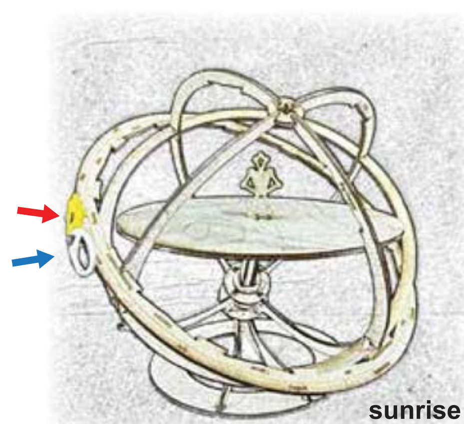
Spin globe to midnight, observe Moon position



Ecliptic Ring with Sun and New Moon: New Moon is too close to the Sun to see

5

Spin globe to sunrise, observe Moon position



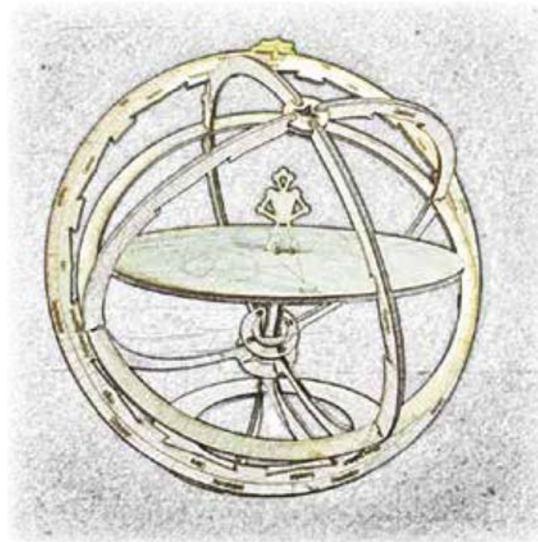
New Moon

The New Moon is hiding next to the Sun. You won’t see a Moon again until the waxing Crescent Moon becomes visible in a few days.

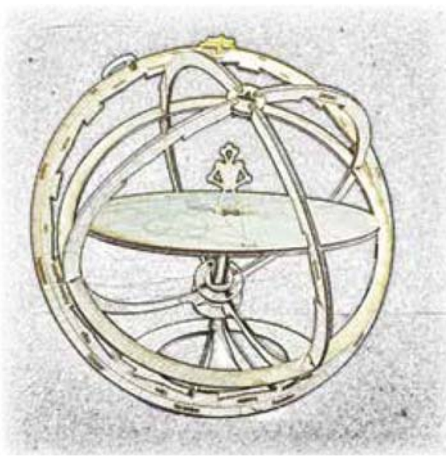
The Monthly Moon Cycle

Moon-watching can be one of the most fun and interesting parts of astronomy.

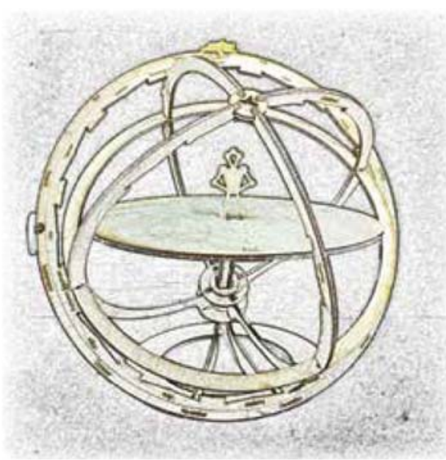
Just remember the Moon's monthly pattern and you will know where and when to look for it when you go outside.



1 **New Moon**
Too close to the Sun to see



2 **Crescent**
(Waxing)
after New Moon



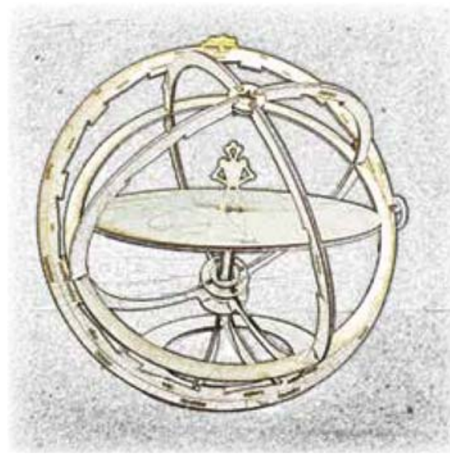
3 **First Quarter**
(Waxing)
~7 days after NEW MOON

4 **Gibbous**
(Waxing)
after FIRST QUARTER

The Moon goes through a complete cycle every month

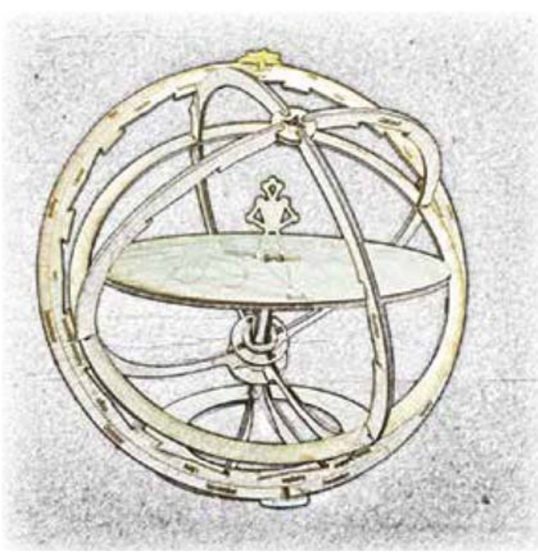
8

Crescent
(Waning)
after LAST QUARTER



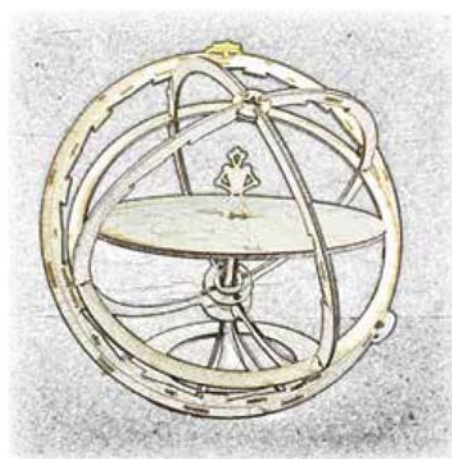
7

Last Quarter
(Waning)
~7 days after FULL MOON



5

Full Moon
Big round circle in the sky



6

Gibbous
(Waning)
after FULL MOON

Moon and Planet Calendar

Understanding the Moon cycle and modeling it on your Horizon Globe are very rewarding. Now let's see how to find the Moon in the sky.

The Moon and Planet Calendar on the following page tells you what phase the Moon is in on any particular day. If you know the phase, you can both model it on your Horizon Globe and find it outside in the sky.

Appendix B has Moon Calendars for every month from now until the year 2030.

Let's see how the calendar works. Start by finding the year and month that interests you. In this example, we will look at July, 1969. That's when humans first walked on the Moon.

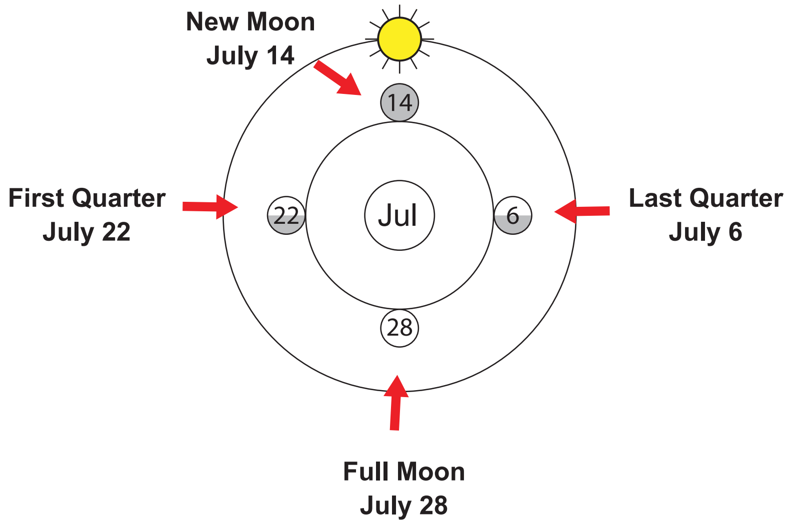
The circular calendar has the Sun at the top. The date of the New Moon is in the gray circle just below the Sun. In 1969 there was a New Moon on July 14. A week later, on July 22, the Moon had fallen back ¼ of a turn to a First Quarter Moon (the half-gray circle on the left). The Full Moon occurred on July 28 (the white circle near the bottom). The only Last Quarter Moon that occurred that month appeared before a week before the New Moon on July 6.

Keep in mind that even though months are based on the Moon cycle, calendar months don't usually match up with lunar months.

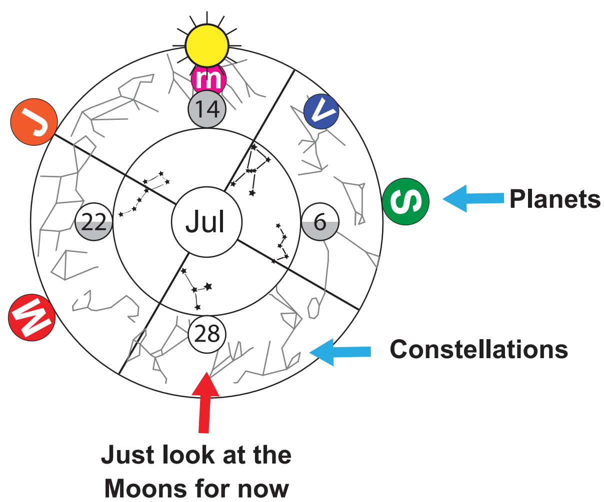
EXERCISE

1. Look at July 1969 on Moon Calendar, notice Moon phases. The date of New, Full, and Quarter Moons are shown. Take note of the Moon's angle with the Sun.
2. Study the Moon and Planet Calendar from Appendix B, ignoring everything but Moon phases for now. Later we'll look at the planets and constellations.

The Moon Calendar
tells you the phase of the Moon



1 **MOON CALENDAR 1969**



2 **MOON AND PLANET CALENDAR 1969 (FROM APPENDIX B)**

Using the Moon and Planet Calendar

Using the Moon and Planet Calendars, it's easy to find the New, Full, and Quarter Moons. But that is only 4 days out of 31 days in July. What about the rest of the days? What about the Crescent and Gibbous Moons?

To find the Moon phase for the other days of the month we can use a process called *interpolation*. Interpolation is estimating a value using the surrounding values.

For example, what was the phase of the Moon on July 20, 1969, the day men first walked on the Moon? If we look at the Moon Calendar for that month, we see that the New Moon was on July 14 and the First Quarter was on July 22.

Between a New Moon and a First Quarter Moon is a Crescent Moon.

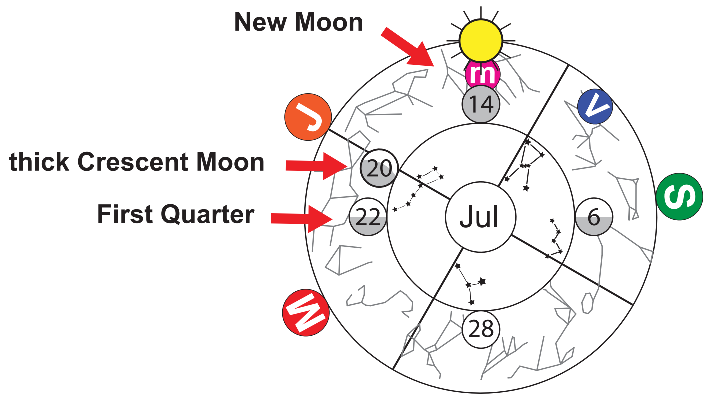
July 20, 1969, was two days before the First Quarter Moon and 5 days after the New Moon, so the Moon was a thick crescent on that day. Keep in mind that there are about 7 days between the New and First Quarter Moons, so on the 20th of July that year the Moon was 5/7 of the way between New and Quarter, closer to Quarter than to New.

From the Moon Calendar diagram, you can see that the thick Crescent Moon on July 20 was following the Sun by about 4 hours. To model that day on your Horizon Globe, place the Sun on the July part of the Ecliptic Ring, a little closer to August than June. Then place the Moon about 4 hours behind the Sun. Turn the globe and imagine astronauts walking on the Moon that Sunday afternoon.

Apollo 11 returned to Earth on July 24. Try using the Moon and Planet Calendar to find the phase on that day. What phase was the Moon when the astronauts returned?

EXERCISE

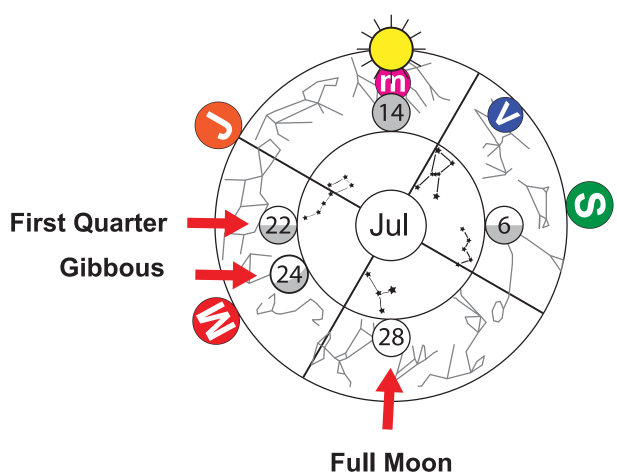
1. Look at the Moon and Planet Calendar to determine the Moon phase on July 20, 1969.
2. Determine Moon phase 4 days later. Four days later is July 24, 2 days past First Quarter, 5 days before Full. Use interpolation to find phase.
3. What phase will the Moon be in on your birthday this year? How about on Christmas Day?



1

MOON AND PLANET CALENDAR 1969

Estimate Moon phase on July 20



2

MOON AND PLANET CALENDAR 1969

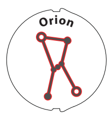
Estimate Moon phase on July 24

Constellations

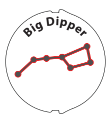
Equipment needed: constellations

The Horizon Globe shows you the location and motion of 16 of the most important constellations.

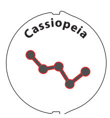
We call four of them Guideposts. These four are easy to find, and they will point you to all the rest of the constellations. Any time you see stars, you will be able to find at least one of the Guidepost constellations.



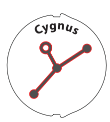
Orion - Guidepost #1
Very bright and easy to find.



Big Dipper* - Guidepost #2
Tied with Orion for being easy to find.



Cassiopeia - Guidepost #3
Almost as easy to find as the Big Dipper, and in a great spot.



Cygnus - Guidepost #4
Part of the Summer Triangle, and very distinctive.
If Cygnus is out you will be able to find it.

The other 12 constellations included with your Horizon Globe are significant for a different reason; they helped ancient astronomers tell the time of year and time of night before clocks were invented. You probably know the names of these special constellations, they are the signs of the Zodiac.

The Zodiac comprises Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces. These twelve constellations all fit on the ecliptic. Coincidence?

In the next chapter we'll get started by looking at one very important constellation. The first Guidepost, Orion, will help you find and remember the rest of the constellations.

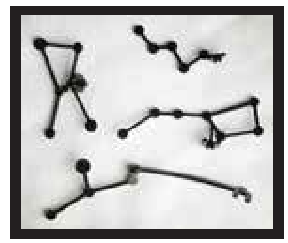
* The Big Dipper is technically an asterism, not a constellation. A *constellation* is one of 88 star groupings that have a definite names. An *asterism* is simply a group of stars. The Big Dipper is an asterism within the constellation Ursa Major.

Guidepost Constellations

Horizon Globe SE

Guideposts etched on 4 clear discs

Orion
Cassiopeia
Big Dipper
Cygnus



Horizon Globe LX

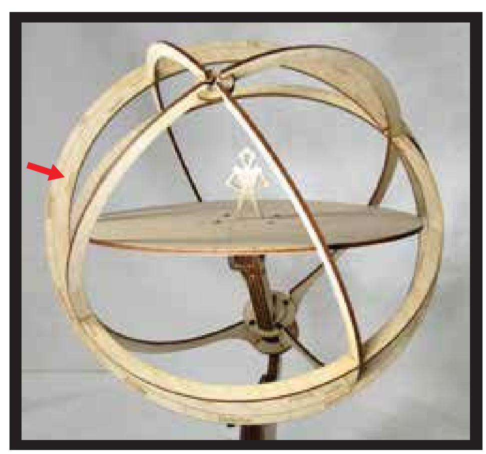
Guideposts clip directly to ecliptic

Zodiac Constellations

Horizon Globe SE

Zodiac etched on 12 clear discs

Aries
Taurus
Gemini
Cancer
Leo
Virgo
Libra
Scorpio
Sagittarius
Capricorn
Aquarius
Pisces



Horizon Globe LX

Zodiac printed on outermost ring

Guidepost #1: Orion

Equipment needed: Horizon Globe, Orion

Orion is arguably the most important constellation in the sky.

Named for a mythological hunter, the constellation Orion is a group of stars that form the shape of a man with a club, shield, and sword. As beginner star-gazers, we will just be looking for seven stars that form the shape of a man. Finding his weapons and shield is a more advanced task.

On the facing page you can see the main stars that form Orion. Of these seven stars, five are among the top 30 brightest stars in the sky. No wonder Orion is so famous!

Don't worry about recognizing Orion, he is very bright and distinctive. If you look in the right place you will always find him. The trick is knowing where to look.

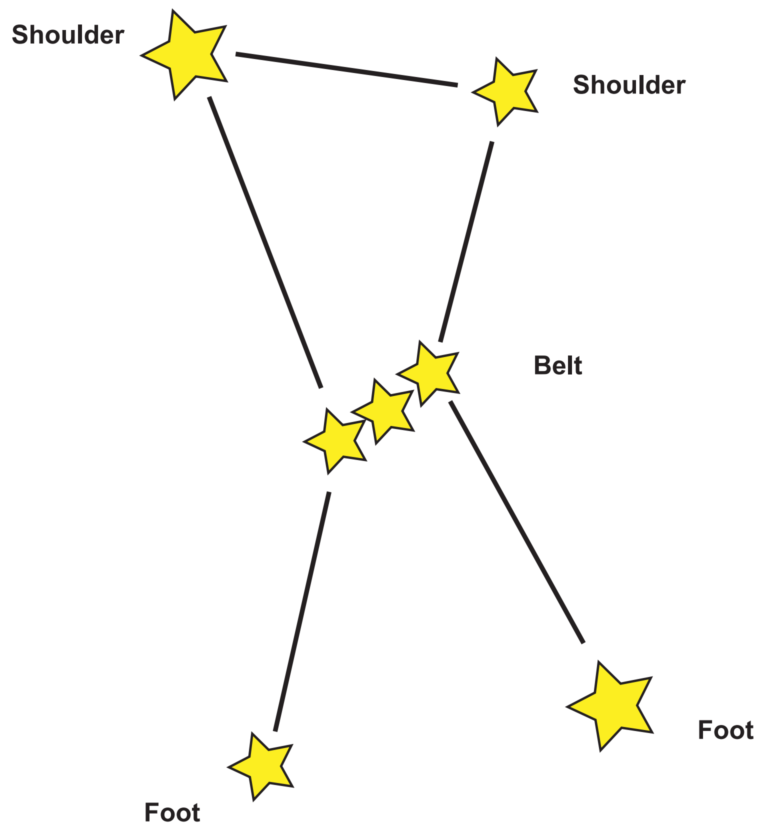
Learning to find Orion is the most important step in learning the stars. He is the leader of the sky. Everything else in the sky can be found by referencing where it is relative to Orion. This first Guidepost constellation occupies a great place in the sky and is one of the prime constellations used by mariners for celestial navigation. Further, Orion is one of the few constellations that can be seen from anywhere on Earth, even at the North and South Poles.

In a later chapter you will see how to amaze your friends and astound your rivals by knowing where Orion is day or night!

EXERCISE

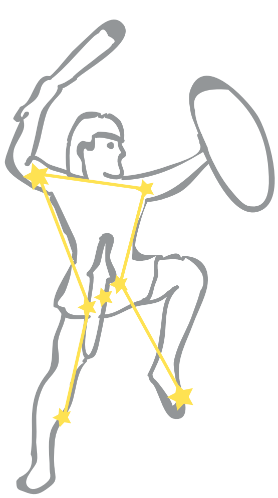
1. Find Orion among the constellations in the pack of discs that came with your Horizon Globe. (See "Model LX" on page 94)
2. Find the slot labeled "Orion" on your Horizon Globe (hint: he fits below the Ecliptic Ring under June.)
3. Place the Orion disc in the slot. Don't forget to flex it a little to snap it in. Wiggling is better than forcing.

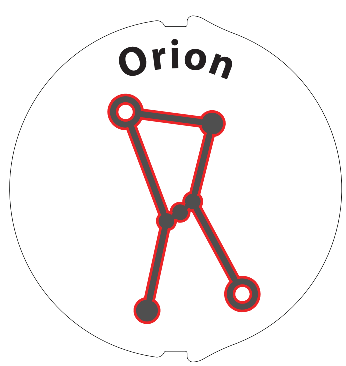
Orion is pronounced "uh-RAHY-uhn"

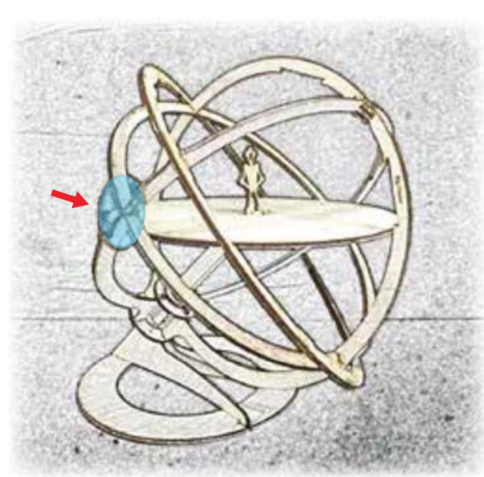


ORION

#1 of 4 guidepost constellations
The shape of Orion is easy to find in the sky if you know where to look.







Orion Moves Throughout the Day

Equipment needed: Horizon Globe, Orion, sun

Orion is a hunter who doesn't like to be seen. He uses two tricks to avoid detection:

#1 - He hides
#2 - He moves

Fortunately, there is a way to outsmart him. Let's take a look at his first technique.

Trick #1 - He Hides

Orion first trick is that he hides by the Sun during the long, hot days of Summer.

With Orion in his slot on the globe, place the Sun on June 21, the first and longest day of summer. Spin the globe to see when you might see Orion on this day. Would you see him when he's high in the sky? Would you see him when he's below the horizon?

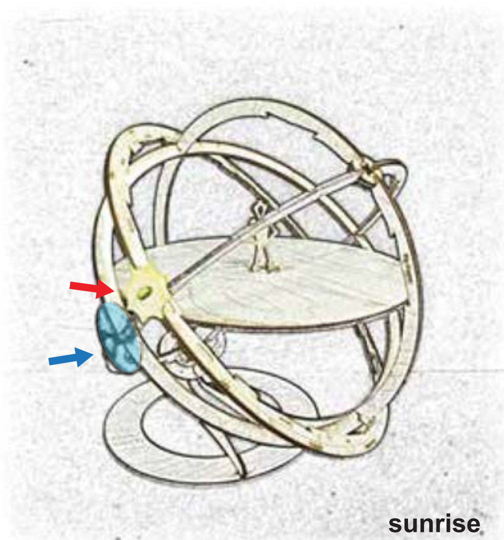
Orion's secret is that you can never see him during the long days of Summer. He travels with the Sun, so he is only above the horizon during daylight hours.

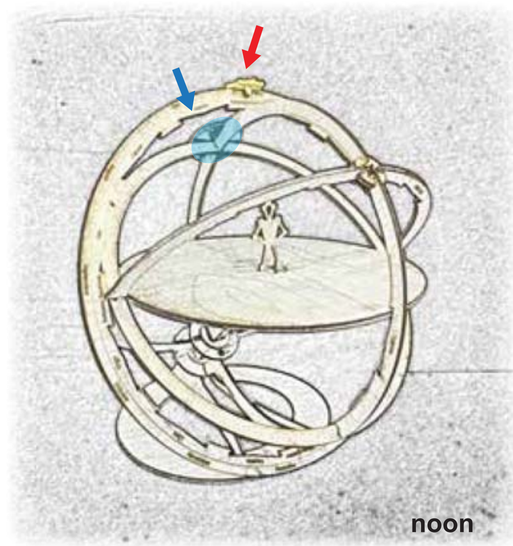
Notice that over the course of a single day, Orion acts the same as the Sun and Moon: he rises in the East and sets in the West, and travels across the sky at about the same speed.

In the next section we'll look at the second trick Orion uses to avoid being spotted.

EXERCISE

1. Place Orion on the globe. Place the Sun at the Summer Solstice, June 21.
2. Spin the globe and watch Orion travel across the sky with the Sun in the course of a day.



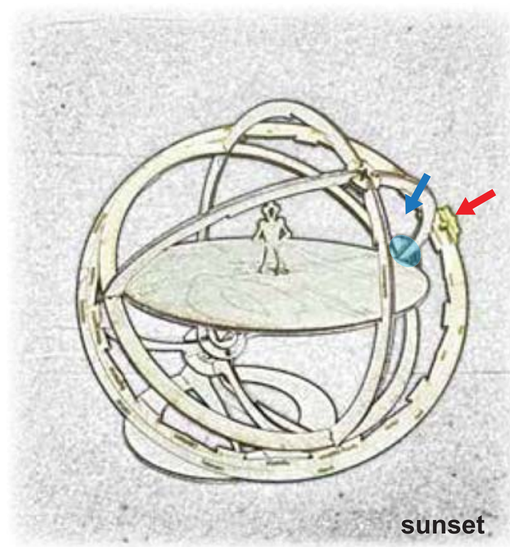


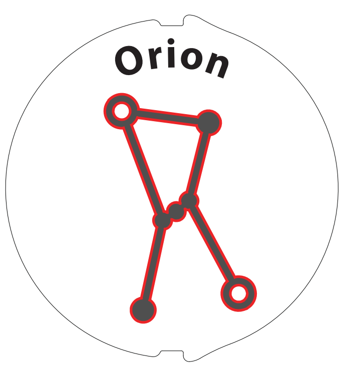
1

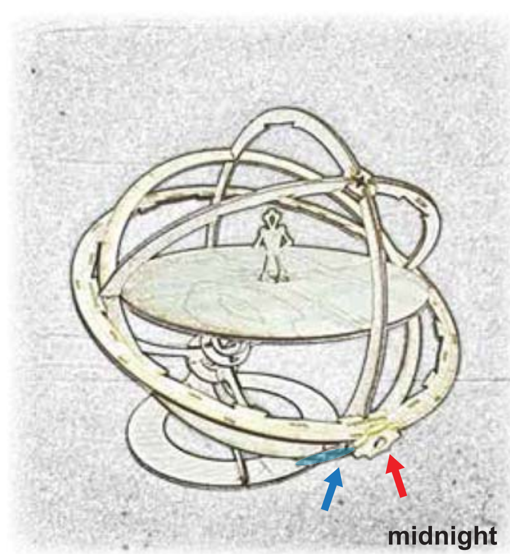
Orion and the Sun are together on June 21, the Summer Solstice

2

Spin the globe and watch Orion travel with the Sun for day







JUNE 21

Orion hides by the Sun

Orion Moves Throughout the Year

Equipment needed: Horizon Globe, Orion, sun

Orion is a hunter who doesn't like to be seen. He uses two tricks to avoid detection. In the last section we saw Trick #1, which is the fact that he hides by the Sun in June. Now we'll take a look at his second technique:

Trick # 2 - He moves

Orion keeps on the move, so he is out at a different time each night. The Sun, Moon, (and planets), all travel on the same ring of the Horizon Globe, the ecliptic. But Orion does not travel on this ring. In fact, he is anchored permanently in the same place, right under the part of the ecliptic labeled "June."

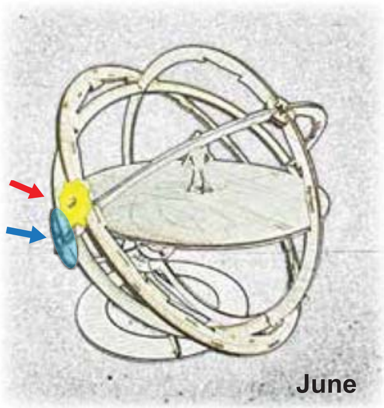
Orion's second trick is that he knows we are watching the Sun, not him. As the Sun travels along the ecliptic from June into July then August, Orion stays beneath the place marked June on your Horizon Globe. The result is that each day, Orion rises a little earlier. In a month, Orion ends up rising two hours ahead of the Sun. For each month the Sun travels on the ecliptic, Orion rises another two hours earlier. After a year, Orion catches and passes the Sun.

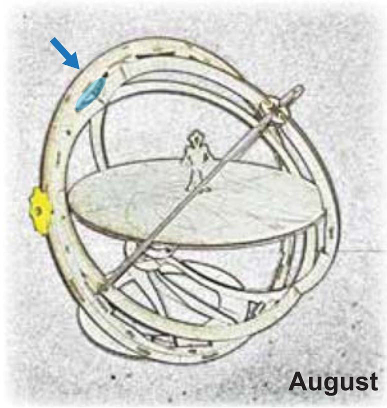
Place the Sun on the ecliptic directly over Orion. Turn the globe to watch Orion rise and set. Now place the Sun disc on the next month and spin the globe. Again, move the Sun disc and notice how Orion rises earlier and earlier as the year progresses.

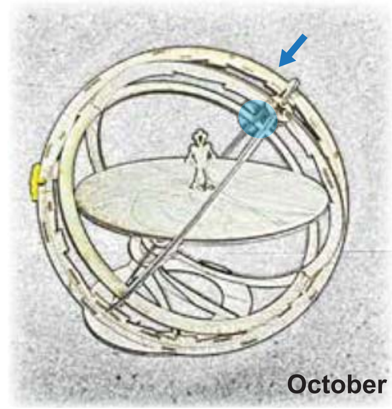
How to outfox Orion - You can use your knowledge of Orion as a parlor trick. Notice that you don't need a calendar chart to know where Orion is. In June he is always near the Sun so you can point at Orion simply by pointing just below the Sun. By the end of July he is two hours ahead of the Sun, end of August 4 hours, etc. By knowing the time of day you can point at the Sun any time, and by knowing how many hours Orion is from the Sun you can point at him, too, day or night. Try it, it's fun!

EXERCISE

1. Place the Sun on June and watch Orion travel with the Sun.
2. Place the Sun disc on different months and see how many hours ahead or behind the Sun Orion is.
3. Practice pointing at Orion, day and night, by knowing the number of months since (or until) June 21, and the time of day. Remember Orion moves 2 hours ahead for every month past June 21.





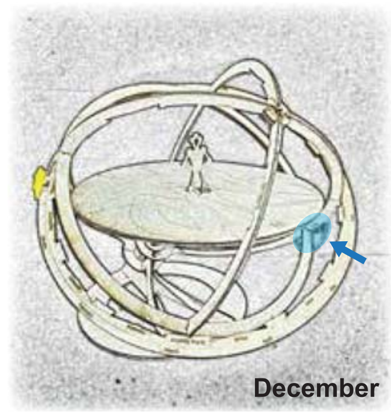


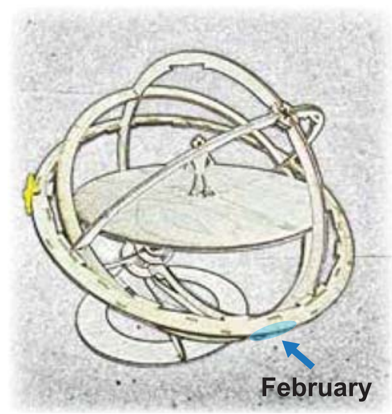
1

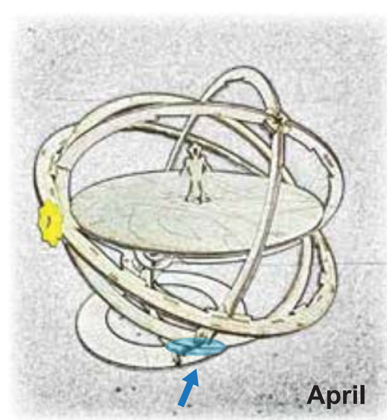
Orion starts with the Sun June 21, shown here around sunrise. Orion rises with the Sun on this day.

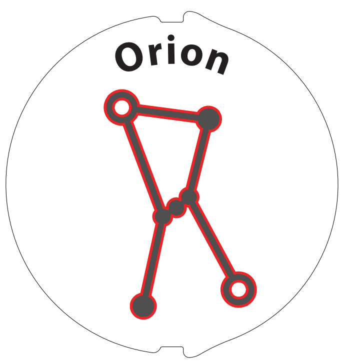
2

But Orion is faster than the Sun. He gets 4 hours ahead of the Sun every 2 months. In a year he will catch the Sun and rise on June 21 again.









Orion is tricky

Did you notice that Orion's motion through the year is similar to the Moon's motion through a month? The Moon falls behind the Sun by almost an hour per day, losing a whole lap in one month. Orion gains 2 hours on the Sun every month, catching and passing the Sun in exactly one year.

Guidepost #2: Big Dipper

Equipment needed: Horizon Globe, Big Dipper

The Big Dipper is perhaps just as famous as Orion, maybe even more famous.

The Big Dipper also comprises 7 stars, all of fairly even brightness. None of the 7 make the top 20 list of brightest stars.

The Big Dipper's fame comes partly from where it is in the sky. Place the Big Dipper on your Horizon Globe and give it a turn. Notice that, unlike Orion, the Big Dipper never sets*. It just turns round and round the North Pole. This means that you can see the Big Dipper all the time as long as the sky is dark and clear. Stars that never set are called *circumpolar stars*.

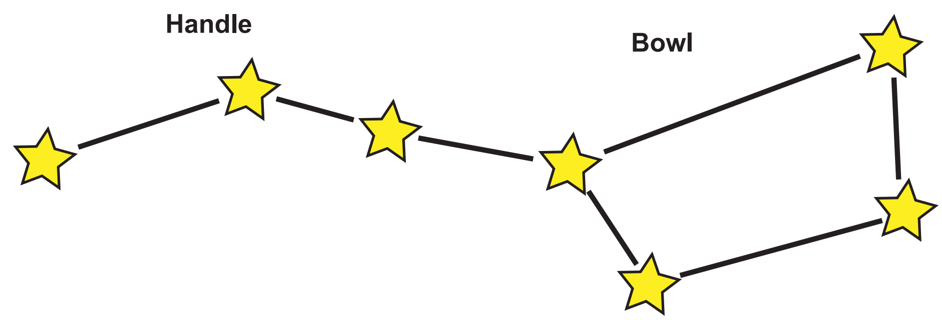
Notice that as the Dipper goes around, the bowl leads and the handle follows. Also notice that when the Dipper is low it is upright, as though scooping water, and when it is high it is upside down, as though pouring water.

Even though the Big Dipper never sets, it is definitely more prominent when high in the sky than when low. The Big Dipper is high in the sky for more of the night when the Sun is on the opposite side of the globe in the spring.

* Depending on where you live, or if you stargaze when you travel, you may notice that in some places the Big Dipper actually does spend some time below the horizon. The farther south you are, the lower the Big Dipper gets. But that is a more advanced topic. The general idea is the same no matter where you are.

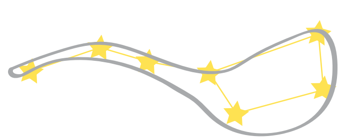
EXERCISE

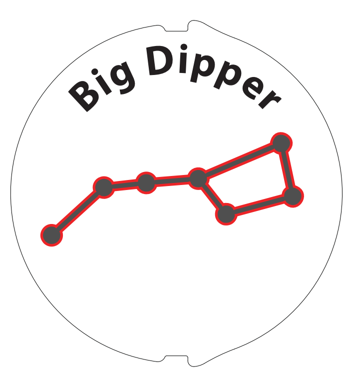
1. Find the constellation disc Big Dipper.
   (See "Model LX" on page 94)
2. Locate the slot labeled Big Dipper above the Autumn Equinox.
3. Turn the globe to watch the Big Dipper go around.

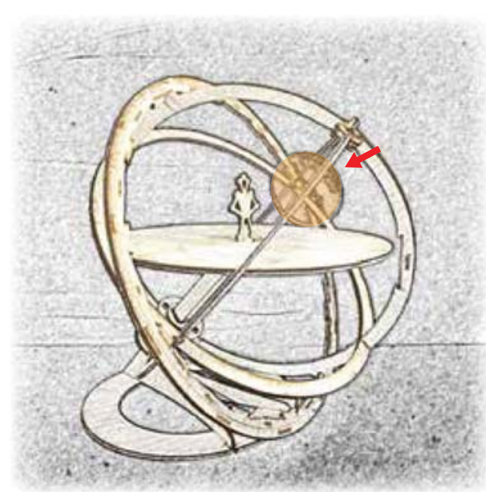


Big Dipper

#2 of 4 guidepost constellations
The Big Dipper turns around the
North Pole and never sets





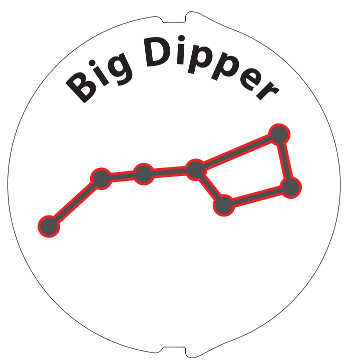


The Big Dipper Stalks Orion

Equipment needed: Horizon Globe, Big Dipper, Orion, sun

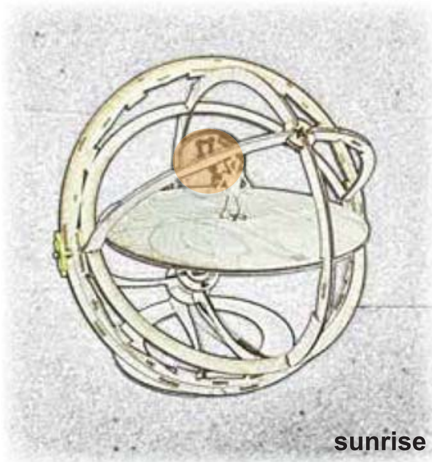
The Big Dipper makes one turn a day, just like everything in the sky.

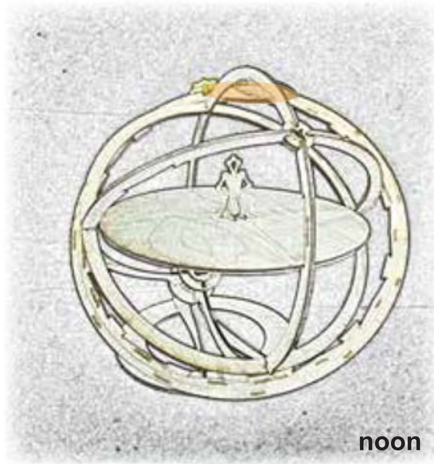
An easy way to remember where to look for the Big Dipper is to remember that it follows Orion by a quarter turn, or 6 hours. Think of it this way: The Big Dipper views Orion as a rival for the title of most famous constellation. As the proud Orion marches across the sky, the Big Dipper stealthily follows him with the intention of dousing him with a dipper full of water. Will the Big Dipper ever catch Orion?

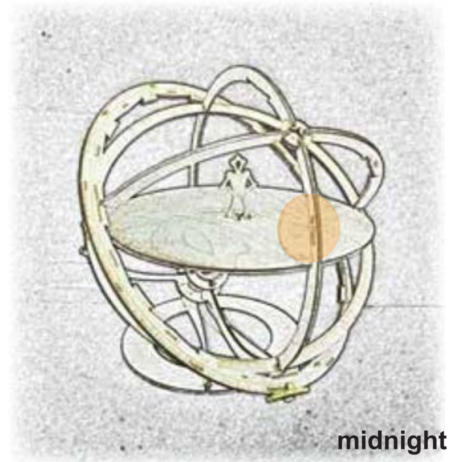


EXERCISE

1. Place the Sun on the ecliptic and watch the Big Dipper go around as the Sun rises and sets.
2. Move the Sun to different places and notice how it affects how you see the Dipper at night.
3. With Orion and the Big Dipper installed, turn the globe and notice how the Dipper always follows Orion by ¼ turn.

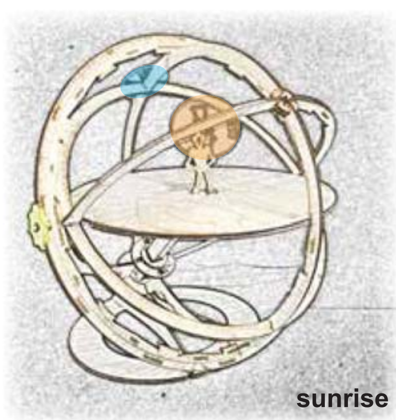


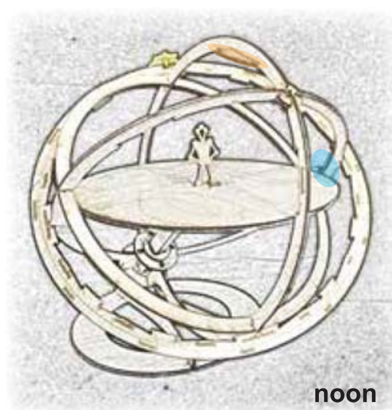


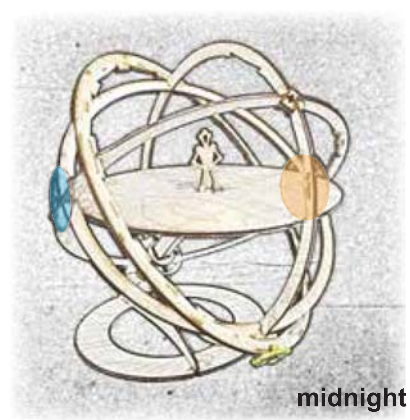


1 The Big Dipper

2 Big Dipper across a day







3 The Big Dipper with Orion

Big Dipper

Guidepost #3: Cygnus

Equipment needed: Horizon Globe, Cygnus

Cygnus is not as famous as Orion or the Big Dipper, but it plays an important role as a guidepost constellation.

We need an easily recognizable constellation for the part of the sky that follows the Big Dipper. Cygnus the Swan works well for this. You may not have heard of Cygnus the Swan, but you might have heard of a group that the swan belongs to, the Summer Triangle. Cygnus can be recognized as a simple "T" shape.

The advanced Cygnus constellation has full wings, feet, and a long neck, but for beginners, just look for the T, wings and a tail. The tail of Cygnus is a top twenty brightness star that forms a large triangle with two other bright stars. This shape, the Summer Triangle, is probably more well known than just the bird.

When you are outside looking for Cygnus in the sky, keep in mind that it may be easier to spot the whole Summer Triangle first, then look for the T-shape of Cygnus.

Cygnus is aimed toward the constellation Scorpius, just ahead of the Winter Solstice, but he moves sideways, following the Big Dipper. Turn the globe with Cygnus attached to see him move sideways as he flies.

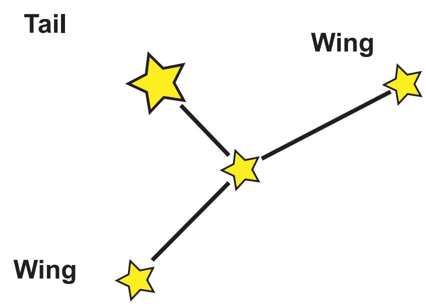
Remember that the guidepost constellations help you find the rest of the constellations.

To find constellations in Orion's part of the sky, first locate Orion, then look above, below, left or right of Orion. The same goes for the Big Dipper, which is a quarter-turn behind Orion. Cygnus is another quarter-turn behind and will help you find constellations in that part of the sky.

EXERCISE

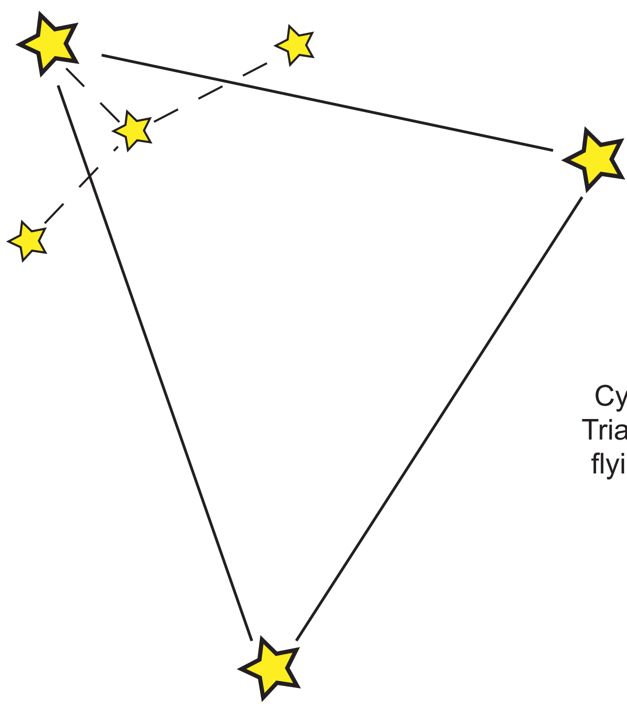
1. *Find the constellation disc Cygnus.*
   (See "Model LX" on page 94)
2. *Locate the slot labeled Cygnus above the Winter Solstice.*
3. *Turn the globe to watch the Cygnus go around, rising and setting.*

Cygnus is pronounced "SIG-nus"



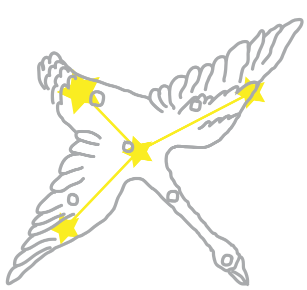
Cygnus

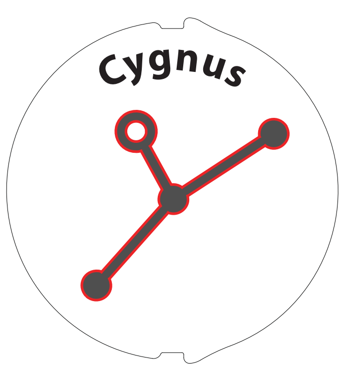
#3 of 4 guidepost constellations
Cygnus is part of a bigger group of stars shown below

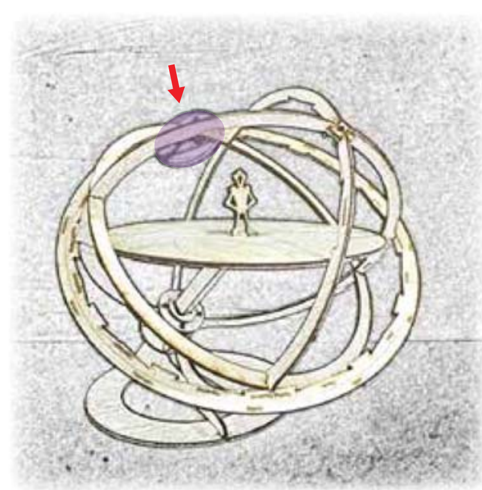


Summer Triangle

Cygnus is part of the Summer Triangle. The swan seems to by flying between two bright stars







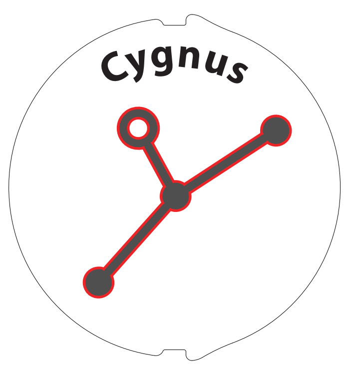
Cygnus Follows the Dipper

Equipment needed:
Horizon Globe, Cygnus, Big Dipper, Orion, sun

Cygnus and the Summer Triangle are a little more than 6 hours behind the Big Dipper, and a little farther South. Not as far south as Orion, but far enough to rise and set.

Place Cygnus on your Horizon Globe and turn it. Notice when you can see Cygnus. Move the Sun to different months to see how viewing of Cygnus changes throughout the year.

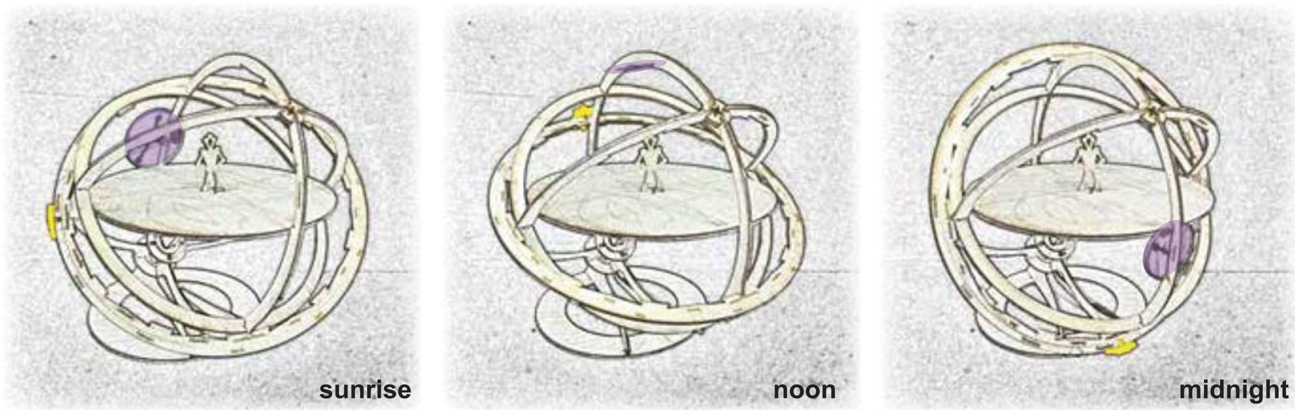
To remember where Cygnus is, think of a thirsty bird following the Big Dipper trying to get a drink of water.



EXERCISE

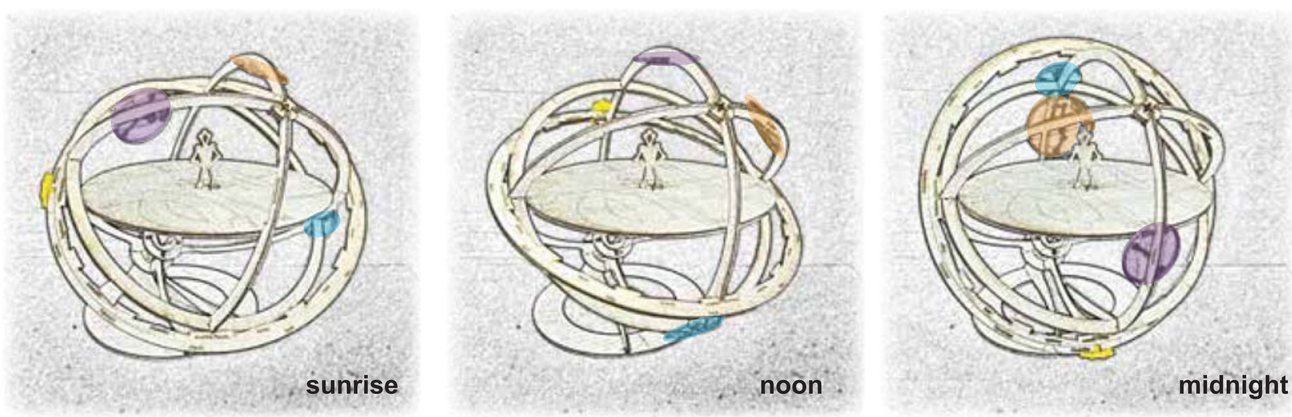
1. Place the Sun on the ecliptic and watch Cygnus go around as the Sun rises and sets.
2. Move the Sun to different places and notice how it affects how you see Cygnus at night.
3. With Orion, the Big Dipper, and Cygnus installed, turn the globe and notice how Cygnus always follows the Dipper by ¼ turn.

Cygnus is the Swan, part of the Summer Triangle



1 Cygnus at sunrise

2 Cygnus across a day



3 Cygnus with the Big Dipper and Orion

Cygnus

Guidepost #4: Cassiopeia

Equipment needed: Horizon Globe, Cassiopeia

Orion, the Big Dipper, and Cygnus help us map ¾ of the sky. The last quarter has another easy-to-find constellation, Cassiopeia.

Cassiopeia is supposed to be a mythical queen, but the best you can hope to see in the shape of the constellation is the queen's throne. It might be easier just to look for a W or an M, depending on where she is.

Place Cassiopeia on your Horizon Globe. The slot for Cassiopeia is above the Spring Equinox. The five stars of Cassiopeia are about as bright as the dimmer stars of the Big Dipper. Notice how the W-shape opens up toward the North Pole.

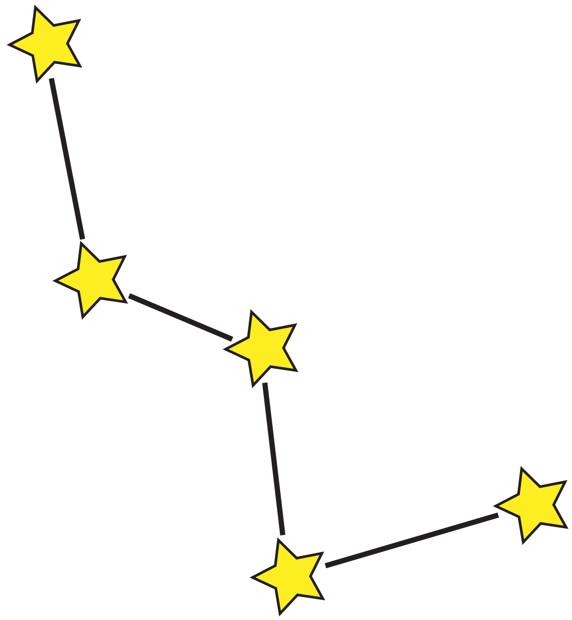
It can be helpful to notice that Cassiopeia is opposite the Big Dipper, with the North Pole between them. Place Cassiopeia on your Horizon Globe and explore how she changes through the months. On your globe, Cassiopeia is a circumpolar constellation, like the Big Dipper, so she never sets.

Notice that when Cassiopeia is low, the Observer sees a W-shape and when she is high he sees an M-shape.

EXERCISE

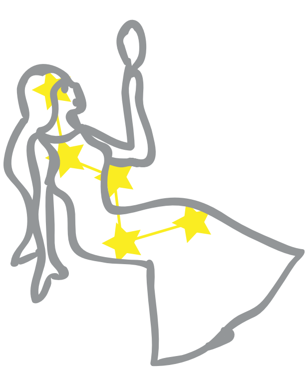
1. *Find the constellation disc Cassiopeia.*
   (See "Model LX" on page 94)
2. *Locate the slot labeled Cassiopeia above the Spring Equinox.*
3. *Turn the globe to watch Cassiopeia go around.*

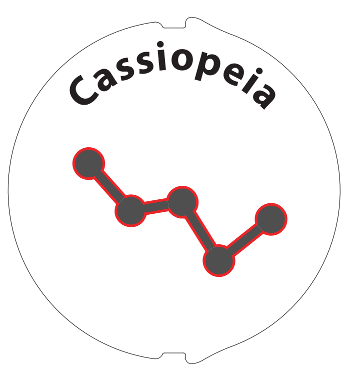
Cassiopeia is pronounced "kas-ee-uh-PEE-uh"

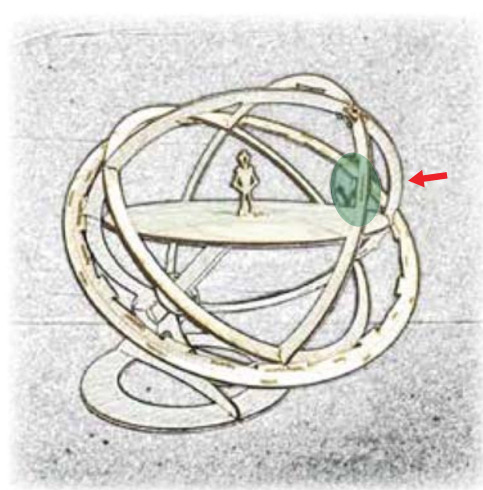


Cassiopeia

#4 of 4 guidepost constellations
Cassiopeia is known as the Queen, but looks more like a "W" in the sky







Cassiopeia Chases the Bird

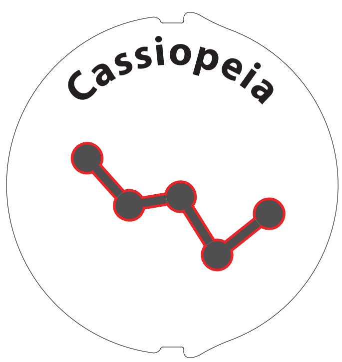
Equipment needed: Horizon Globe, Cassiopeia, Cygnus, Big Dipper, Orion, sun

The Queen is about six hours behind Cygnus and about six hours ahead of Orion.

She is about the same distance from the North Pole as the Big Dipper and her stars are about as bright.

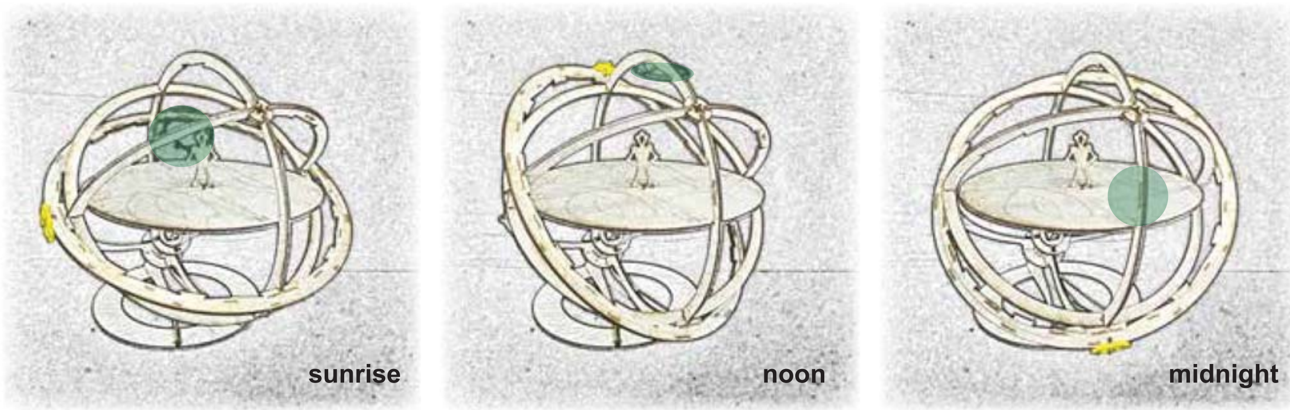
Place Cassiopeia on your Horizon Globe and turn it. Notice when you can see Cassiopeia, and how she turns from a W to an M and back. Move the Sun to different months to see how viewing of Cassiopeia changes throughout the year.

To remember where Cassiopeia is in the sky, think of her as chasing the Swan. She thinks the bird is pretty and wants it for her collection. And of course, Orion the Hunter sees the beautiful queen and pursues her.



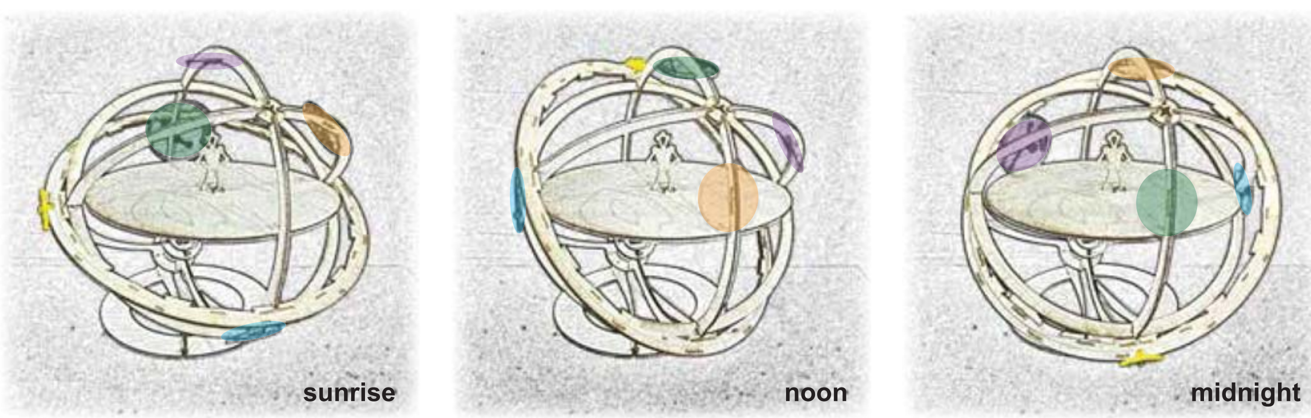
EXERCISE

1. Place the Sun on the ecliptic and watch Cassiopeia go around as the Sun rises and sets.
2. Move the Sun to different places and notice how it affects how you see Cassiopeia.
3. With Orion, the Big Dipper, Cygnus, and Cassiopeia installed, turn the globe and notice how she always follows the Swan and is followed by Orion.



1 Cassiopeia at sunrise

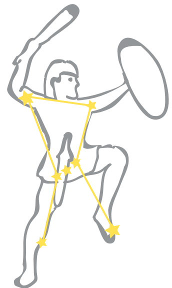
2 Cassiopeia across a day



3 Cassiopeia with Cygnus, the Big Dipper and Orion

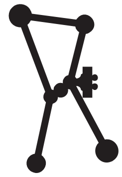
Cassiopeia

Model LX – How to Place Constellations



Orion

1



Locate Orion from the group of constellations included with your Horizon Globe LX

2

Find "Summer Solstice" on the ecliptic. Look for "Orion" and a slot printed on the celestial equator below it

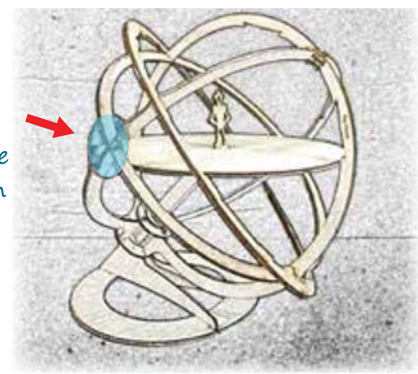
3

Attach Orion by sliding its clip onto the printed slot

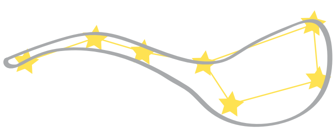
Orion looks like this on the Horizon Globe LX

but remember

Orion *looks like this for most of the exercises in this book*

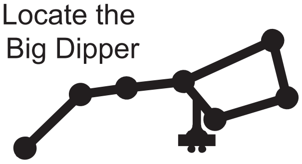


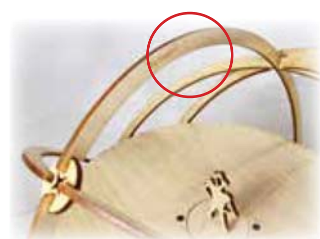
Big Dipper



1

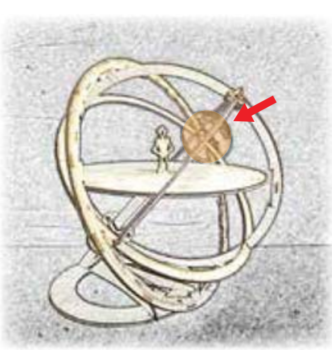
Locate the Big Dipper





2

Find "Autumn Equinox" on the ecliptic. Look for "Big Dipper" and a slot printed on the meridian between the ecliptic and the North Pole



The ***Big Dipper*** *looks like this for most of the exercises in this book*

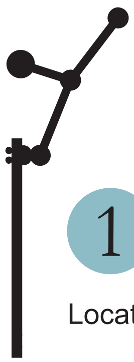
3

Attach the Big Dipper by sliding its clip onto the printed slot

The Big Dipper looks like this on the Horizon Globe LX

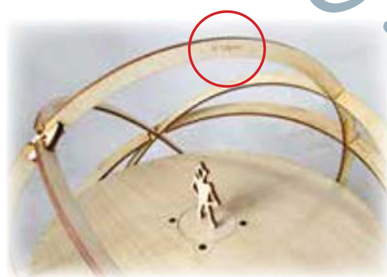
but remember

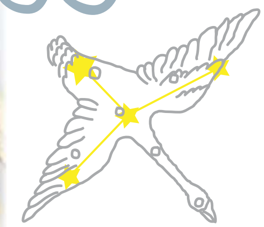
Cygnus



1 Locate Cygnus

2 Find “Winter Solstice” on the ecliptic. Look for “Cygnus” and a slot printed on the meridian between the ecliptic and the North Pole

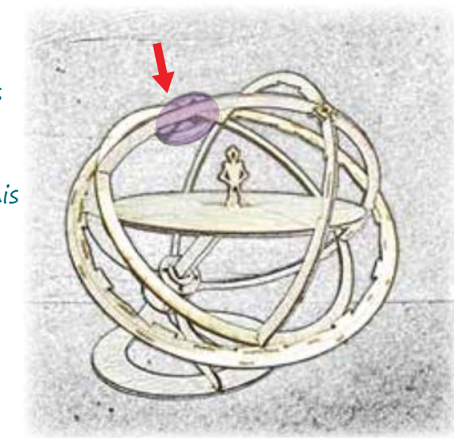




3 Attach Cygnus by sliding its clip onto the printed slot

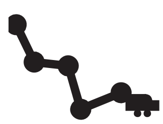
Cygnus looks like this on the Horizon Globe LX but remember

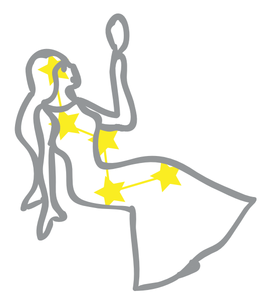
Cygnus looks like this for most of the exercises in this book



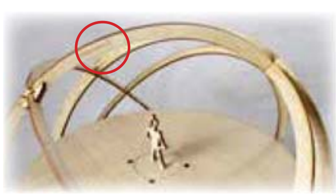
Cassiopeia

1 Locate Cassiopeia

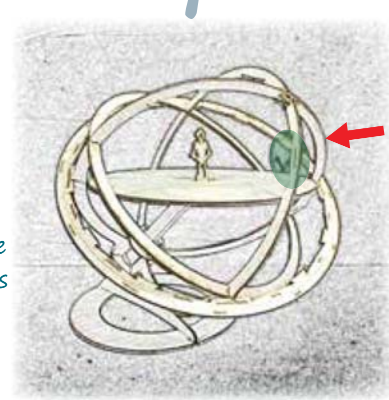




2 Find “Spring Equinox” on the ecliptic. Look for “Cassiopeia” and a slot printed on the meridian between the ecliptic and the North Pole



Cassiopeia looks like this on the Horizon Globe LX but remember that *Cassiopeia* looks like this for most of the exercises in this book



3 Attach Cassiopeia by sliding its clip onto the printed slot

Guidepost Constellations Map the Sky

Equipment needed: Horizon Globe, all Guidepost constellations, sun

Orion, the Big Dipper, Cygnus, and Cassiopeia are your keys to finding any constellation in the sky.

Any night that the sky is clear you will be able to see at least one of them. Your Horizon Globe will help you visualize the relationship between the guideposts so you always know where to look when you are stargazing.

As a beginner, it is important that any time you try to stargaze, you can find something familiar. Knowing the four guideposts will help you gain confidence. Once you find a guidepost, you can try to find another one, or move on to find other constellations.

Remember this simple story to remind yourself of where the guideposts are:

- The Big Dipper is envious of the proud and famous Orion, so he tries to douse him with a dipper full of water.
- Cygnus the Swan is thirsty, so it chases the Big Dipper to get a drink.
- Queen Cassiopeia thinks the bird is pretty and chases after it.
- Finally, Orion the Hunter pursues the beautiful Queen.

It can be helpful to remember that Orion is closest to the Sun on the longest day of Summer and farthest from the Sun on the shortest day of Winter. Orion must be hot in the summer and cold in the winter.

If you can remember these 3 things, you should be able to find the guidepost constellations any night without using a star calendar:

1. **The story.** Orion chases Queen chases Swan chases Dipper chases Orion.
2. **Orion is near the Sun** on the longest day of Summer, June 21.
3. **Orion moves 2 hours per month faster** than the Sun.

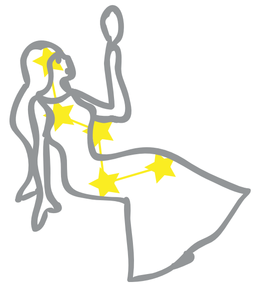
We'll talk more about Sun motion when we talk about seasons.

EXERCISE

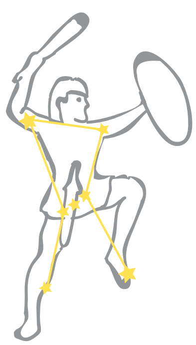
1. *Place all four Guidepost Constellations on the Globe.*
2. *Turn the globe and recite the story as they go by.*
3. *Place the Sun in different months to see which guidepost would help you most at different times.*

Cassiopeia

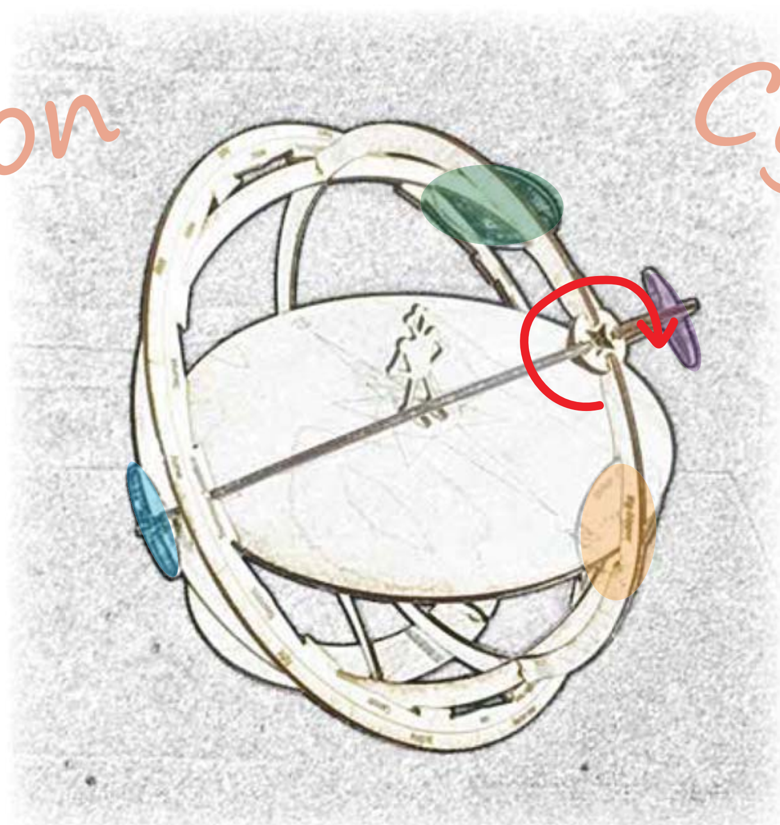
The Queen
chases the pretty
Swan



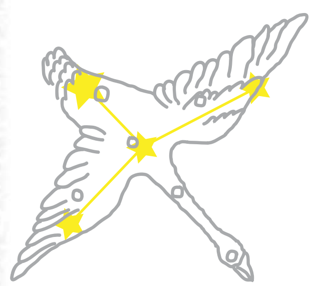
Orion



Orion chases
the beautiful
Queen

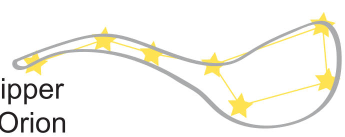


Cygnus



The thirsty swan
flies to get a
drink

The envious dipper
tries to douse Orion



Big Dipper

The Zodiac

Equipment needed: Horizon Globe, zodiac constellations

Most likely you have heard of the Zodiac constellations, but you may not know the astronomical significance of them. What is so special about these constellations?

Without knowledge of the ecliptic, it can be difficult to explain what is special about the Zodiac. Knowing about the ecliptic, it's easy. The Zodiac constellations are the constellations along the ecliptic.

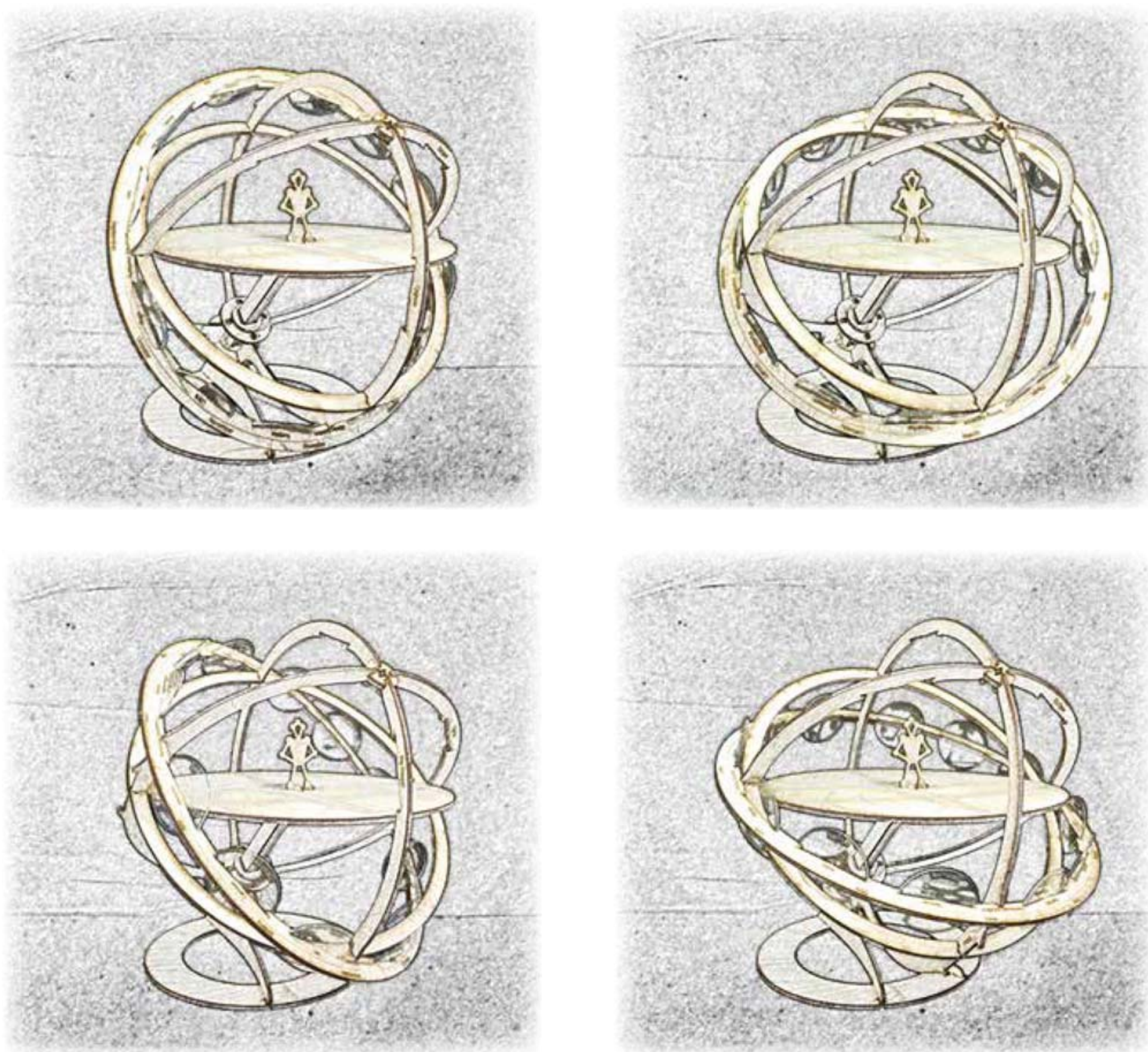
At night, when the Sun is down, you can tell where the ecliptic is by finding the Zodiac constellations. Ancient astronomers used the Zodiac to tell the time of night and the time of year.

Astronomers in ancient times divided the ecliptic into 12 parts and memorized the stars in each part by giving a name to the shape they formed. The were able to see a Ram in one group, a Bull in another, a Scorpion, a Goat, an Archer, and other shapes. Since many of the shapes they named are of animals, the group was called Zodiac, from the root word "zoo."

Place all of the Zodiac constellations on your Horizon Globe. Notice how they are all on the ecliptic, so that some of them are low and some are high, depending on what part of the ecliptic they belong to.

EXERCISE

1. Place all of the Zodiac constellations on your Horizon Globe.
2. Turn the globe and watch the Zodiac parade by the Observer.



Zodiac Constellations

Put all the Zodiac constellations on your Horizon Globe and watch them go around. Notice which ones are low and which are high as the globe spins.

Zodiac

A Way to Remember the Zodiac

Equipment needed: Horizon Globe, sun, zodiac constellations

There are twelve constellations in the Zodiac, too many to remember without some kind of trick.

Fortunately, H.A. Rey, creator of the mischievous cartoon monkey Curious George, wrote a mnemonic to help remember the whole Zodiac in order. It's worth memorizing his poem, as there is no easier way to know the Zodiac:

THE RAMBLE TWINS CRAB LIVERISH;
SCALY SCORPIONS ARE GOOD WATER FISH

the Ram-Bull Twins Crab Lion-Virgin;
Scales Scorpion Archer Goat Water-Carrier Fishes

These are the constellations the poem refers to:

1. Aries the Ram
2. Taurus the Bull
3. Gemini the Twins
4. Cancer the Crab
5. Leo the Lion
6. Virgo the Virgin
7. Libra the Scales
8. Scorpio the Scorpion
9. Sagittarius the Archer
10. Capricorn the Goat
11. Aquarius the Water Carrier
12. Pisces the Fishes

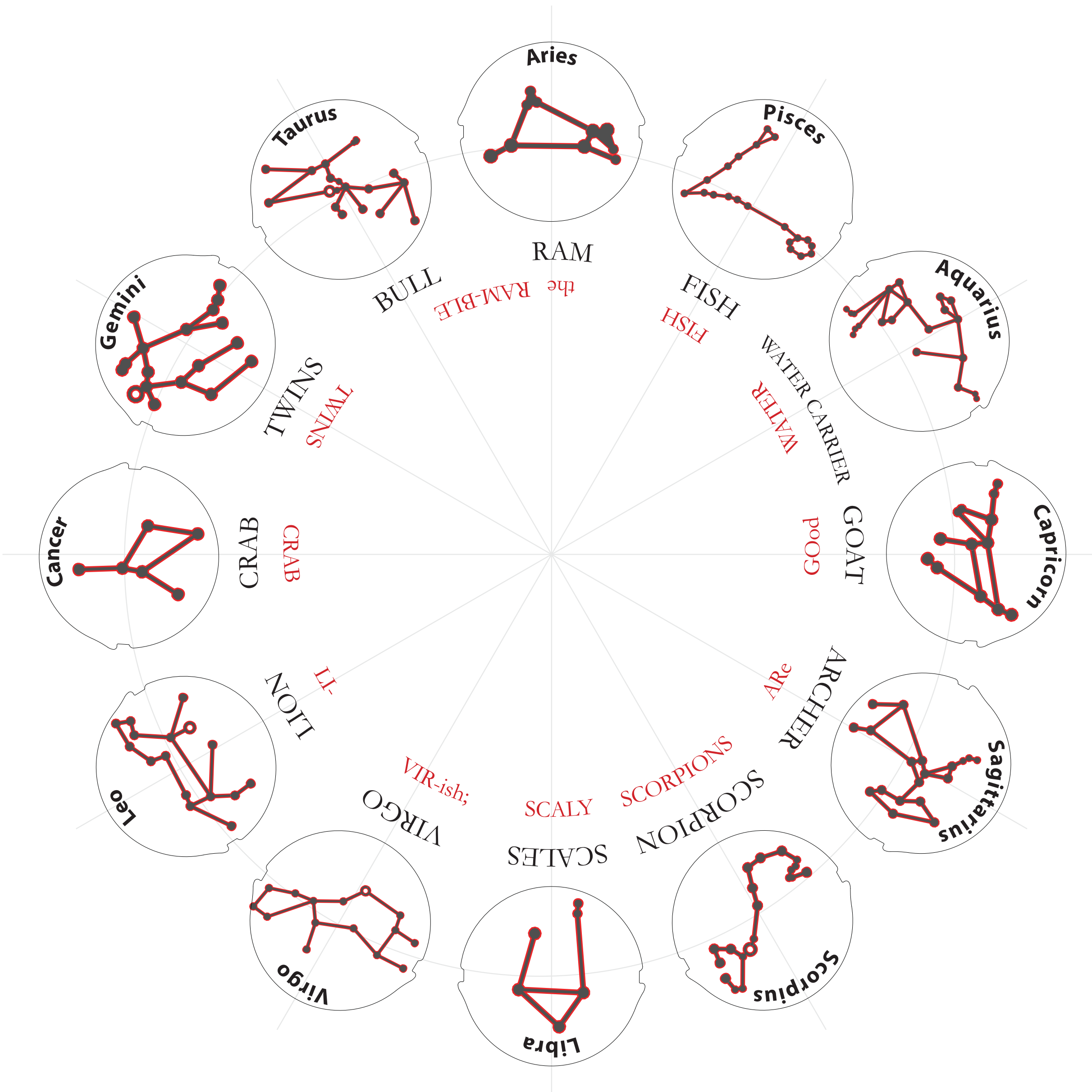
Find Aries on your Horizon Globe (April to May). Slowly turn the globe through a day and watch the Zodiac parade by in order.

Remember that not all the Zodiac constellations are especially bright or easy to discern. They get their significance is being on the ecliptic, the path of the Sun. Some people think that the location of the Sun along the Zodiac when you were born has something to do with your personality. What do you think? Stay tuned.

EXERCISE

1. Try to memorize the Rey poem, so you can recite the Zodiac constellations in order.
2. Put the Zodiac constellations on your globe and spin them through an entire day.

Use H.A. Rey's poem to help you remember the Zodiac in order



Zodiac Constellations

Twelve constellations that map out the path of the Sun on the ecliptic

Zodiac poem

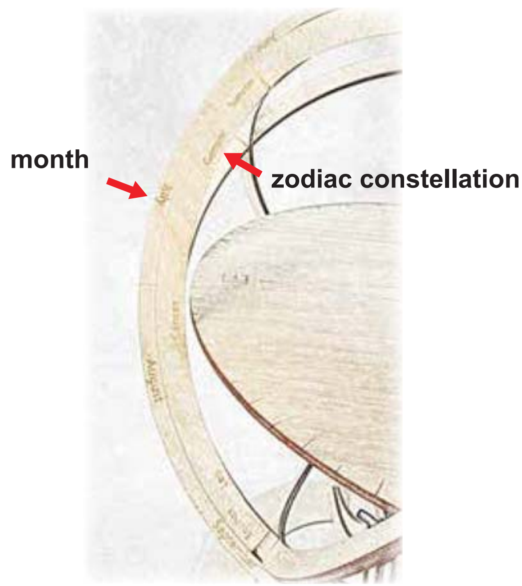
Using the Zodiac as a Calendar

Equipment needed: Horizon Globe, sun, zodiac constellations

If you've done all the exercises in this book, you should be fairly familiar with your Horizon Globe. You've put the Sun on the Ecliptic Ring and taken it off again dozens of times. But there's something interesting that you may not have noticed. Let's take a closer look.

Check out the labels on the Ecliptic Ring of your Horizon Globe. Notice how the Zodiac constellations and months are both permanently etched onto the ring.

Remember that the day of year is determined by where the Sun is on this ring.



Zodiac calendar

EXERCISE

1. Place the Sun on the ecliptic ring at mid-May
2. Turn the globe until the Sun has just set.
3. Notice the constellation that sets right behind the Sun is Taurus.
4. What activities do you think happen this time of year?

It's important, so let's say it again: the Zodiac constellations and months are permanently etched on the Ecliptic Ring. If you were to memorize the positions of the zodiac marks, the month marks would be redundant. You wouldn't even need them!

Maybe knowing the Zodiac constellations would be even better than knowing the months. After all, you can never see the months printed in the sky, but sometimes you can see the Zodiac. Recognizing the Zodiac constellations is like seeing a calendar printed in the sky. In fact, in ancient times people did use the Zodiac to tell the time of year. You can't see the Zodiac constellation that is currently behind the Sun, but you can estimate which one it is by watching which ones are visible just after sunset or just before sunrise. In a later chapter we'll talk about our Zodiac signs, which are determined by the Sun and Zodiac constellations.

1 Place Sun at mid-May

2 Spin globe to sunset

3 Taurus sets just after Sun

Example: Place the Sun on the Ecliptic Ring around the middle of May. Turn the globe until the Sun has just set. Notice that the Zodiac constellation that is setting right behind the Sun is Taurus. If you didn't have a calendar, you might use this information to decide it's a good time to plant a garden.

What's Your Zodiac Sign?

Equipment needed: Horizon Globe, sun, zodiac constellations

Everyone has an astrological, or Zodiac sign that depends on what day they were born.

The signs were established by the ancient Babylonians and Greeks who thought that the time of year you were born had some influence on your personality and fate.

What is your sign?

You can use your Horizon Globe to find out.

1. Place the Sun on the date of your birthday on the Ecliptic Ring.
2. Turn the globe until the Sun just sets.
3. Your sign is the last constellation visible in the west.

Example: Place the Sun on the Spring Equinox, March 21. The last Zodiac constellation still visible at sunset is Aries. So if you were born on March 21, your sign is Aries the Ram.

This process may seem needlessly complicated. Why didn't they just make your sign the constellation behind the Sun on the day your were born? Actually, that is what they did. But in the more than two thousand years since then, the constellations have moved.

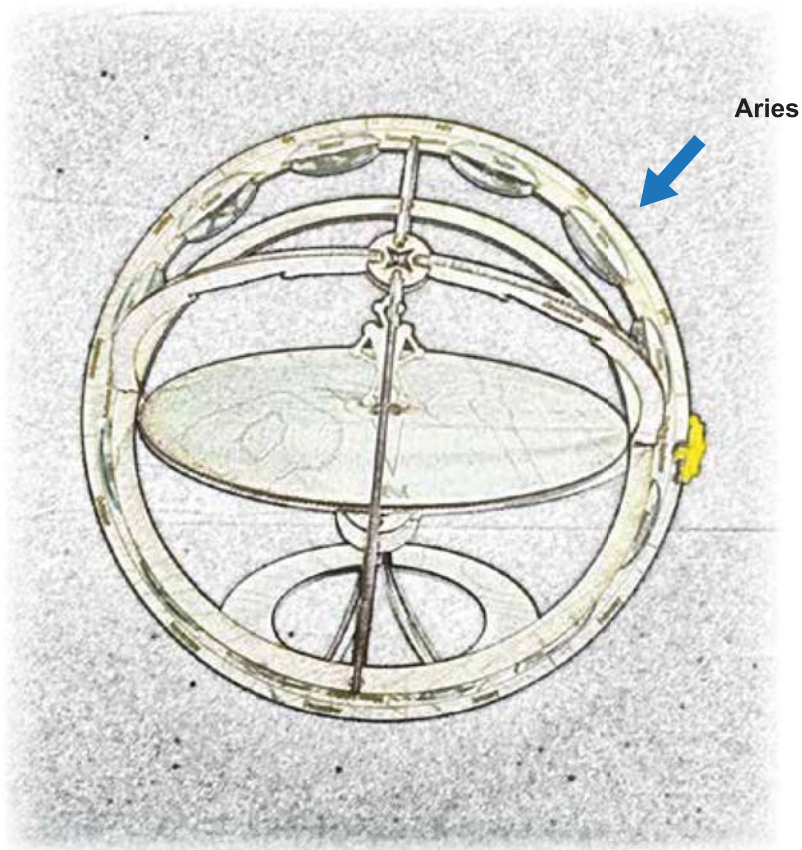
Zodiac signs are named for constellations, but are counted from the Spring Equinox. A phenomenon called *precession of the equinoxes* has shifted all the constellations since ancient times. Studying precession falls into the second phase of astronomy, solar system mechanics.

EXERCISE

1. Place all the Zodiac constellations on the globe.
2. Place the Sun on your birthday.
3. Turn the globe until the Sun just sets.
4. Find your sign, the last one visible in the west at sunset.

Pisces, Virgo rising is a very good sign, strong and kind

–KENNY LOGGINS



Example: Place the Sun on the Spring Equinox, March 21. The last Zodiac constellation still visible at sunset is Aries.

Zodiac signs

Using the Zodiac as a Nighttime Clock

Equipment needed: Horizon Globe, sun, zodiac constellations

We have seen how to estimate the time of day from the position of the Sun. But what can you do after sunset? Knowing the Zodiac constellations can help.

Put the Sun anywhere on the globe. Right after sunset, look to see which Zodiac constellation has just risen in the East. Now spin until the next Zodiac constellation has risen. That amount of time is two hours. There are 12 zodiac constellations that go around in 24 hours, so each constellation represents two hours.

After sunset, six zodiac constellations will rise before the Sun rises again. With a dark sky and knowledge of the Zodiac, you can tell time just as easily at night as during the day.

Try this on your Horizon Globe for different times of year and you may notice something interesting. In the winter, when nights are long, six constellations rise between sunset and sunrise. But in summer, when nights are shorter, six constellations still rise each night. How is this possible?

The only way to understand what is going on is to study your Horizon Globe. The answer has to do with the angle of the Ecliptic Ring. In fact, ancient astronomers had a long running disagreement over whether this was true or not. What do you think?

Notice that we counted 12 hours on winter nights and 12 hours on summer nights, even though the summer nights are shorter than winter nights In ancient times, before mechanical clocks, hours were not all the same length the way they are now. The summer day was divided into 12 hours the same as the winter day. Summer day hours were longer and winter day hours were shorter.

Would you rather be a night watchman serving a short 3-hour shift in the cold winter, or one serving a significantly longer 3-hour shift in the balmy summertime?

EXERCISE

1. Place all the Zodiac constellations on globe with Sun at sunset.
2. Which constellation has just risen? Spin until next one has risen.
3. Put Sun at sunset on Summer Solstice. Spin globe. How many constellations rise before sunrise?
4. Repeat for Winter Solstice. How many constellations did you see?

Six constellations rise after sunset and before sunrise, in spring, summer, autumn and winter

1

Zodiac constellations
Sun at sunset
(Spring Equinox shown here)

Which constellation has just risen?

2

Spin until the next constellation has risen. This is 2 hours later.

Spin until sunrise. How many constellations did the Observer see from sunset to sunrise?

3

Repeat for Summer Solstice.
How many constellations did the the Observer see?

Zodiac clock

4

Repeat for Winter Solstice.
How many constellations did the Observer see?
Was it the same as in summer?
How is that possible?

PLANETS

Equipment needed: Horizon Globe, planets

You have probably learned that there are eight or nine planets orbiting our Sun:

1. Mercury
2. Venus
3. Earth
4. Mars
5. Jupiter
6. Saturn
7. Uranus
8. Neptune
9. (Pluto)

This is a great list for advanced astronomy, but for beginning observational astronomy the list is much shorter. Here's why:

EARTH DOES NOT LOOK LIKE A PLANET TO US. To us, the Earth appears to be a large flat disc, like the Horizon Plate. When we are outside looking for planets, we won't be searching the sky for Earth.

MERCURY IS ELUSIVE. It can only be seen occasionally when viewing conditions are just right.

URANUS IS VERY DIM. You either need perfect conditions and perfect eyesight, or a telescope to see it.

NEPTUNE IS EVEN DIMMER THAN URANUS. You definitely need a telescope to see it.

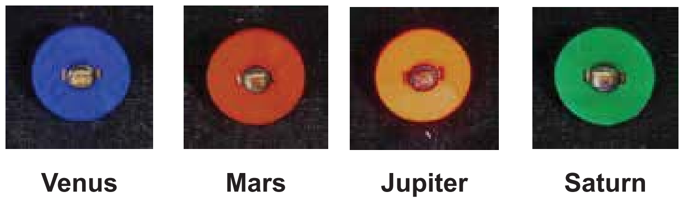
PLUTO HAS BEEN RECLASSIFIED AS A DWARF PLANET. Professional astronomers have decided that Pluto is not really a planet like the others on our list. Even if it were, you would not be able to see it without a giant telescope.

So, to start, we will be learning to find four planets: **VENUS, MARS, JUPITER, AND SATURN.**

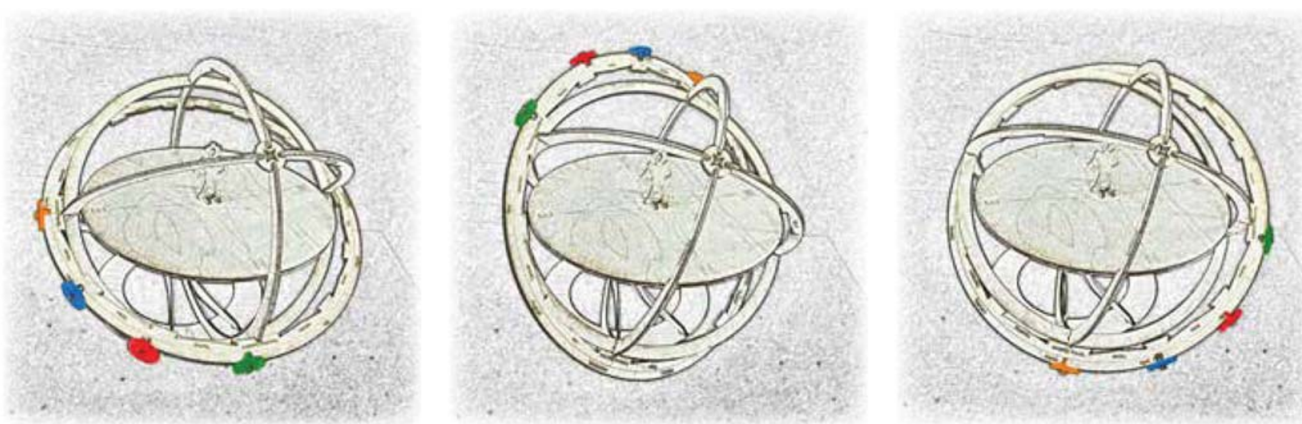
EXERCISE

1. Place all the planet discs in random places on the Ecliptic Ring.
2. Turn the globe to see how planets rise and set.

There are four planets to look for



PLANETS



1 Place all the planet discs anywhere on the ecliptic

2 Spin the globe and notice how the planets rise and set

Venus Mars
Jupiter Saturn

Planets are Wandering Stars

Today we know that planets are completely different kinds of things than stars are.

Planets are more like Earth, giant spheres that orbit the Sun. And Stars are like the Sun, just really far away. Some stars even have planets of their own.

But Ancient stargazers only knew what they saw, that planets look like stars. The reason they gave planets a different name is because they wander. The stars all move as you turn the globe, but they all move together; the constellations stay intact as they rise and set.

Planets are different. Planets move along the ecliptic like the Moon. If you know where Orion is, you know where any other star is because they always stay the same distance from each other. But you need a calendar to know where the planets will be.

The word planet means "wandering star," but on any given night you can't see them wander, you just see them move across the sky with everything else. The wandering can only be noticed over longer periods of time, weeks and months.

To find planets, it's nice to first know the stars. Every fixed star is part of a constellation. So if you know the constellations, you can pick out the wandering star that doesn't belong. That one is the planet.

This is easier than it sounds. Venus and Jupiter are much brighter than any star, so you are unlikely to mistake them for ordinary stars. Mars and Saturn stay on the ecliptic and are always at least as bright as the top 20 stars.

If we learn all the very bright fixed stars near the ecliptic, we will be able to distinguish them from planets. Luckily, there are only 6 bright stars that could be mistaken for planets. We will learn about these in a later chapter.

Planets are called wandering stars, but only Saturn is very much like the other stars. Here's how the planets stand out, aside from their wandering:

V	**VENUS** -	So bright that once you know about it, you can't mistake it for a star.
J	**JUPITER** -	Also too bright to be mistaken for an ordinary star.
M	**MARS** -	Bright red and also sometimes too bright to be a star. There is really only one star that looks very much like Mars.
S	**SATURN** -	Really the only true "wandering star" that looks like the other stars.

Venus is the Evening Star

Equipment needed: Horizon Globe, Venus, sun

Next time you view a sunset, watch for Venus.

This planet will appear as a brilliant star following the Sun. You won't mistake Venus for an ordinary star, as it is much, much brighter. It is almost as bright as a thin Crescent Moon.

When the sky turns a dark blue right after sunset, but just before the stars appear, Venus is a beautiful sight to behold. No wonder this planet is named after the Roman god of beauty and love.

Venus is the Evening Star about 1/3 of the time, it can be seen following the sunset for about six months out of every 19 months. The rest of the time Venus is either working as the Morning Star, or is too close to the Sun to see. In the following chapters, we will learn how to use charts to know when Venus is visible.

In the days just before Venus appears as the Evening Star, it is traveling with the Sun, just like the New Moon. Like the Moon, Venus falls behind the Sun a little more each day, until it gets far enough away for us to see after sunset.

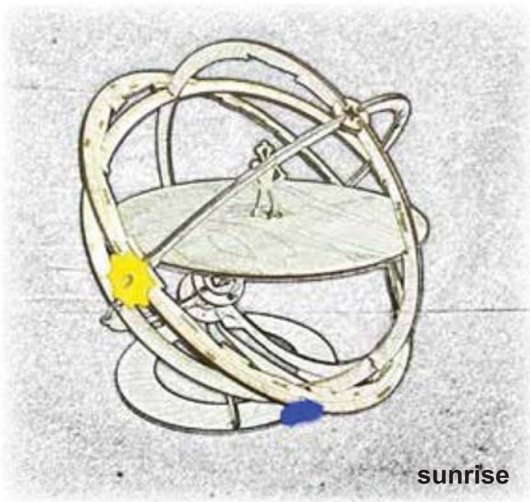
For the next five months, Venus appears a little higher and farther from the Sun each day, until it gets about three hours behind the Sun. When its shift as Evening Star is done, it rapidly sinks, appearing lower and lower in the West each evening until it is once again too close to the Sun to see. During this time Venus is moving fast and catching the Sun.

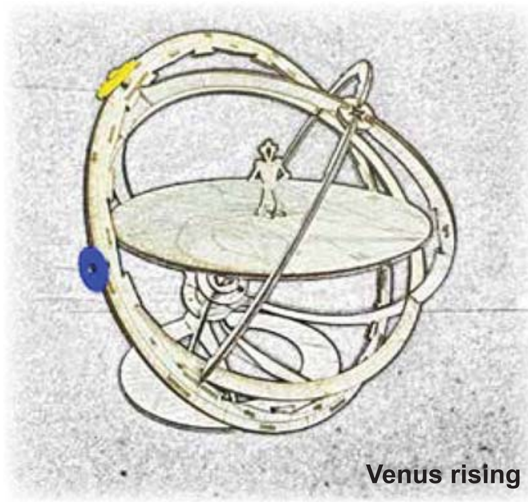
Now we have to wait about a year for our Evening Star to reappear.

Use your Horizon Globe to model the Evening Star. Place Venus on the Ecliptic Ring one to three hours behind the Sun. Turn the globe to see when Venus is visible.

EXERCISE

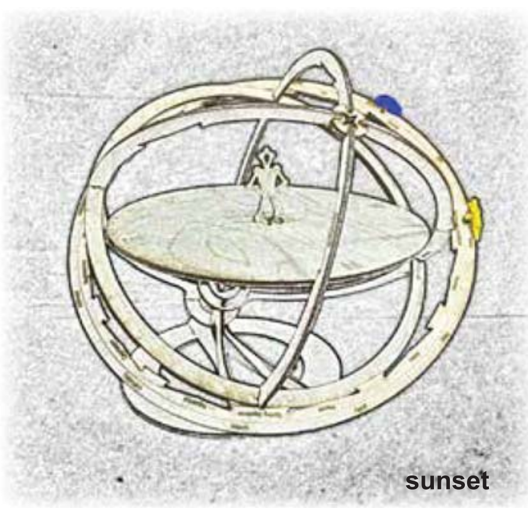
1. Place Venus on the Ecliptic 1 to 3 hours behind the Sun.
2. Turn the globe and notice when Venus rises and sets each day. When can you see Venus?

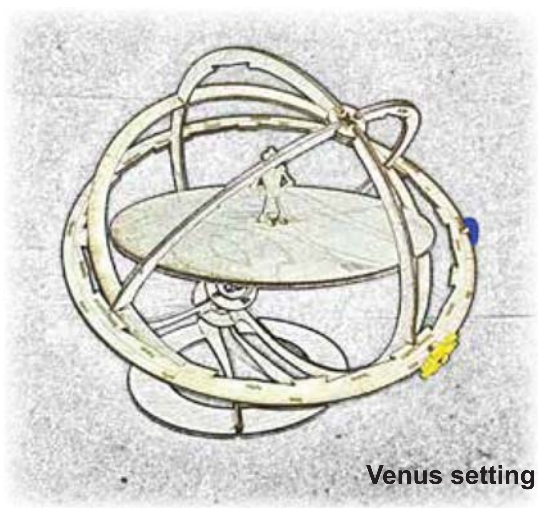




1 Place Sun on ecliptic. Place Venus three hours behind the Sun

2 Spin the globe and notice when Venus rises and sets





Evening Star

Venus

Venus is the Morning Star

Equipment needed: Horizon Globe, Venus, sun

Right after Venus leaves its post as the Evening Star, it rushes over to become the Morning Star.

Now you will see it rising ahead of the sunrise, holding out as the last visible night-sky object as dawn brightens the sky.

About 1/3 of Venus' time is spent as the Morning Star, making sunrise-watching more interesting for about six months out of 19 months.

Venus the Morning Star is like a mirror image of Venus the Evening Star. The Evening Star slowly drifts back from the Sun over five months, then quickly reverses course and catches up. The Morning Star quickly races ahead of the Sun, then slowly loses ground until it is too close to the Sun to see.

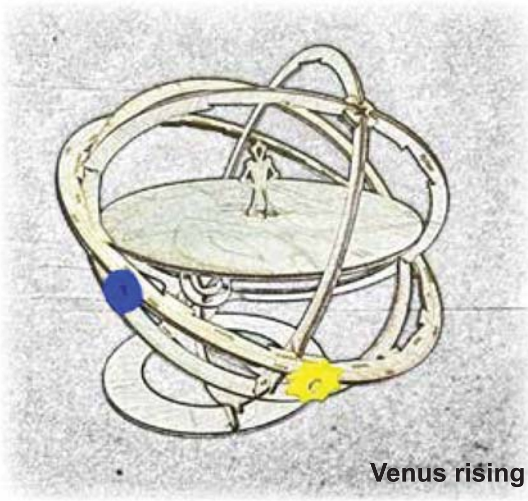
Just as with the Evening Star, we have to wait about a year between Morning Star appearances while Venus either hides by the Sun, or does its work in the West as the Evening Star.

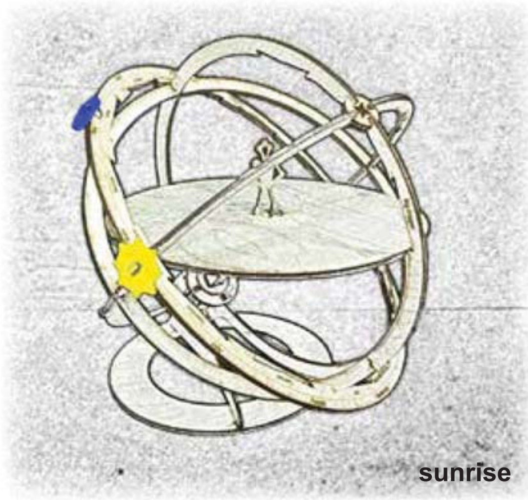
EXERCISE

1. Place Venus on the Ecliptic 1 to 3 hours ahead of the Sun.
2. Turn the globe and notice when Venus rises and sets each day. When can you see Venus?

Be daring: Venus herself assists the brave

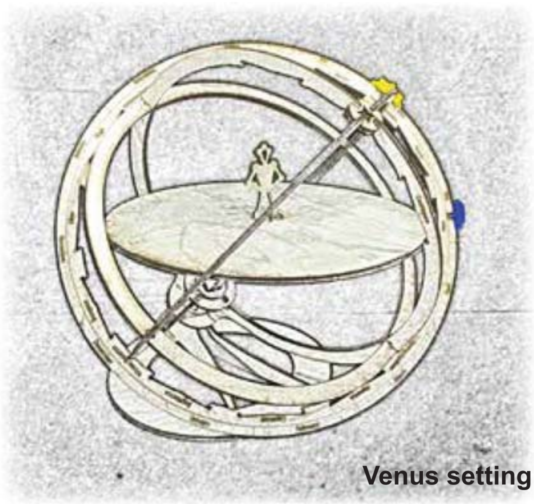
–TIBULLUS

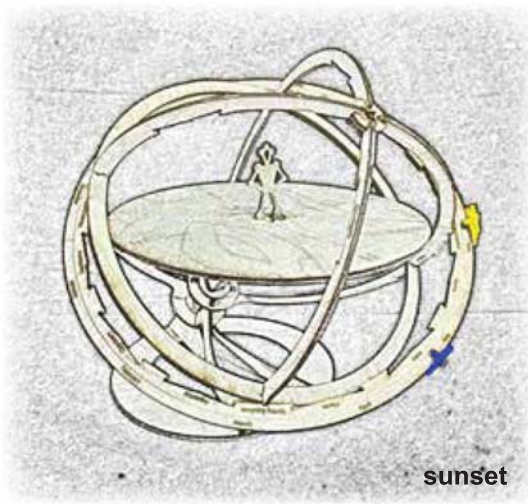




1. Place Sun on ecliptic. Place Venus three hours ahead of the Sun

2. Spin the globe and notice when Venus rises and sets





Venus

Morning Star

Venus is a Dog on a Leash

Venus is the easiest planet to find.

Equipment needed: Horizon Globe, Venus, sun

It is 10 times brighter than any star. In fact it is so bright that you can almost see it during the daytime. As soon as the sky darkens a little to twilight, Venus will appear, sometimes in the evening, and sometimes in the morning.

Venus is easy to see when it is out, but its pattern of motion relative to the Sun is strange and unique among celestial objects.* We saw that the Moon is consistently slower than the Sun, losing one lap on the ecliptic per month. Orion and the stars are consistently faster, gaining one lap on the Sun in a year.

Venus is different. Sometimes it is slower than the Sun, and sometimes faster. Ancient astronomers compared Venus to a dog on a leash. The leash is being held by the Sun and Venus runs back and forth.

Like a frisky dog, Venus runs ahead of the Sun to the end of its leash. The leash is only long enough for it to get ahead of the Sun by about three hours. It takes about one month for Venus to go from the Sun to three hours ahead.

After straining on the leash for a while, Venus starts sniffing around in the bushes and losing ground on the Sun. The Sun eventually catches and passes Venus, then keeps getting ahead until Venus trails by about three hours. It takes Venus about 17 months to go from ahead of the Sun to fully behind.

Then Venus races ahead again for two months and the cycle repeats. When Venus is ahead of the Sun it is the Morning Star and when it is behind it is the Evening Star. When it is close to the Sun, it is like the New Moon and we can't see it.

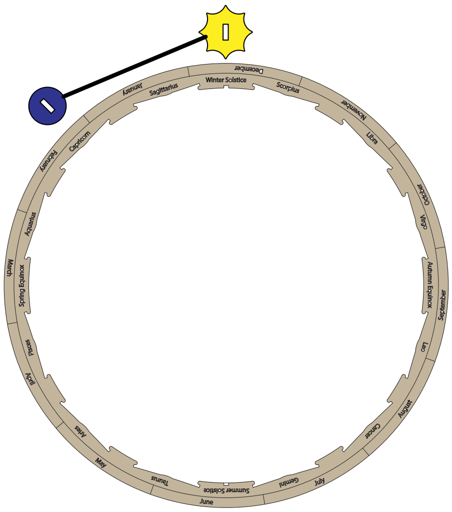
Remember, like all celestial objects, Venus moves relative to the Sun over weeks and months. On a daily basis it goes around East to West just like the Sun, at about the same speed.

EXERCISE

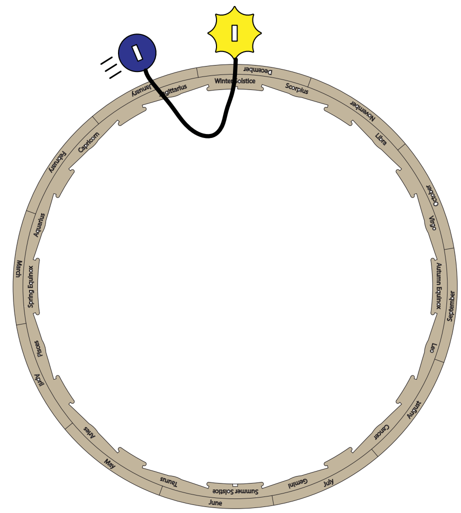
1. Place Venus near and far from the Sun, but always within 3 hours of the Sun.
2. Turn the globe to see if or when you can see Venus in each position.

* Only Mercury has a similar motion, which will be easy to understand after you get to know Venus.

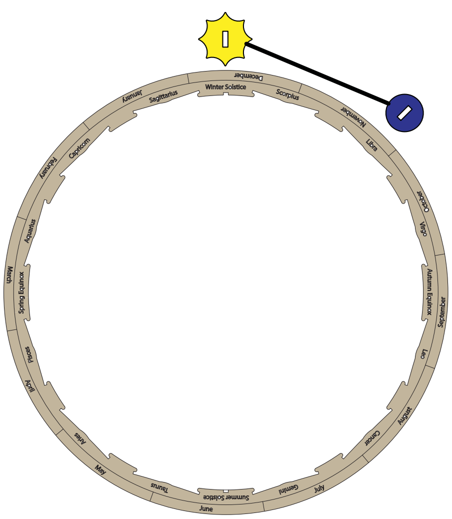
Venus is like a playful dog on a leash



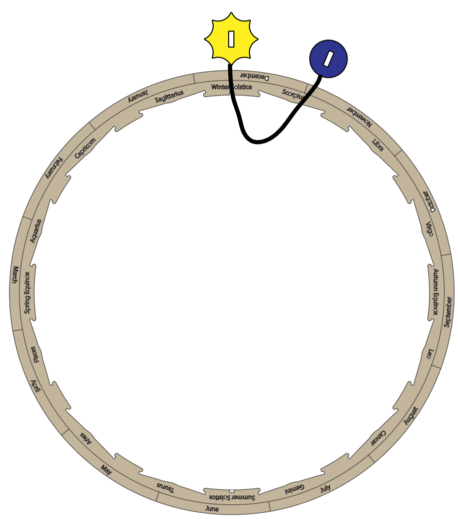
1 Venus can only get 3 hours away from the Sun because of the leash



2 After reaching the end of the leash behind the Sun, Venus races ahead



3 Venus runs faster than the Sun for 2 months before reaching the end of the leash again. Now it is 3 hours ahead of the Sun



4 Venus gets distracted and starts moving slower than the Sun for 17 months

Venus Acts Like a Dog on a Leash

How to Find Venus

Equipment needed: Horizon Globe, Venus, sun

Just like the Moon, Venus is easy to find if you know where to look.

If Venus is trailing the Sun, look for it in the West at sunset and for a few hours after sunset. If Venus is leading the Sun, you can see it rising in the East before the Sun in the early morning.

The facing page shows a Moon and Planet Calendar from Appendix B. Venus is represented by a dark blue circle with the letter "v."

In July, 1969 Venus was leading the Sun by about three hours. Place the Sun on your Horizon Globe. Then place Venus three hours ahead of the Sun.

Turn the globe to see that Venus rises in the morning before the Sun. On the day of the Moon landing, Venus was the Morning Star.

By January, 1970, Venus has fallen back to where the Sun is and in July 1970, Venus is three hours behind the Sun. Place the Sun and Venus on your Horizon Globe to model July, 1970. Turn the globe to see how Venus is now the Evening Star.

Use Appendix B to place Venus in its location right now, at the time that you are reading this book. Is it the Morning or Evening Star, or is it too close to the Sun to see? If it is visible, try to find it outside.

Scan through the Moon and Planet Calendars in Appendix B. Notice how Venus behaves like a dog on a leash, running quickly ahead of the Sun, then slowly lollygagging until it is behind.

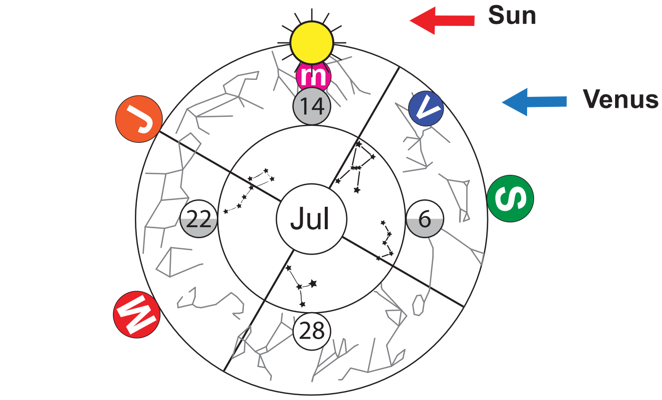
Remember, Venus is 10 times brighter than any star. If you are outside at dusk or dawn when Venus is out, you will surely spot it. Also remember that Venus never strays more than three hours from the Sun. You will never see Venus high in the sky at night.

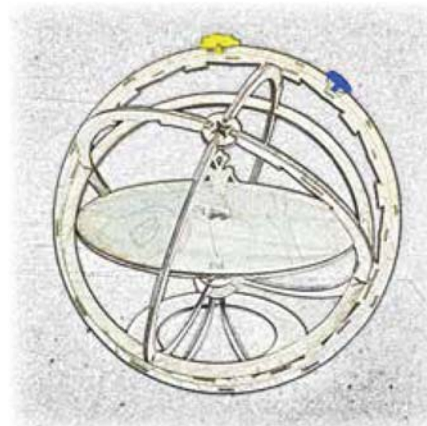
EXERCISE

1. Use the 1969 and 1970 Moon and Planet Calendars in Appendix B to model Venus around the time of the moon landing.
2. Use the current year charts to find where Venus is now.

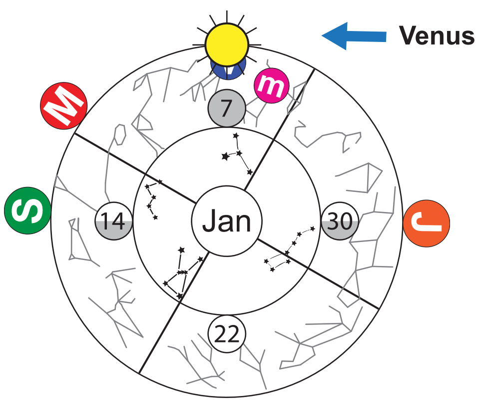
V

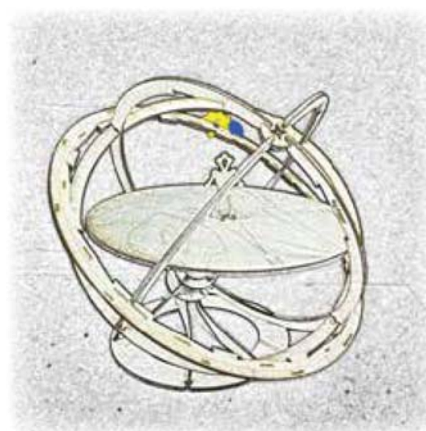
Find where Venus was during the moon landing



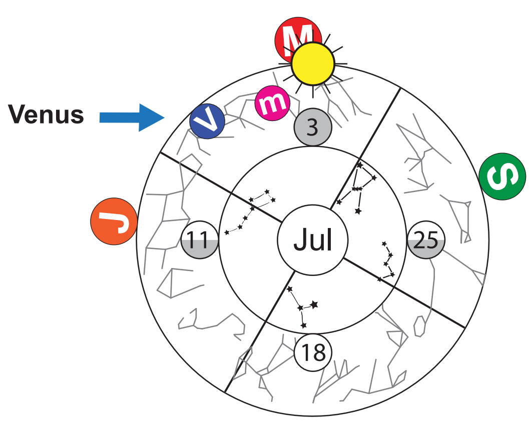


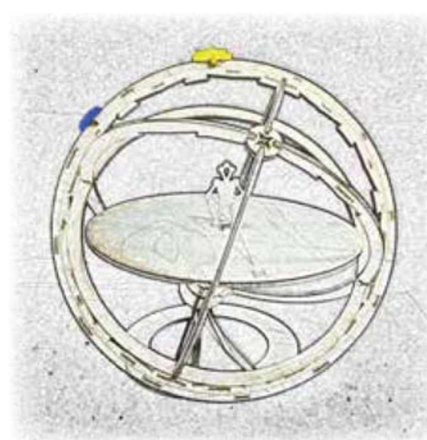
Venus is the Morning Star - July 1969





Venus is near the Sun - January 1970





Venus is the Evening Star - July 1970

Jupiter

Equipment needed: Horizon Globe, Jupiter, sun

Jupiter is the next brightest object after Venus, much brighter than any star.

Venus always stays near the Sun, in that sense it is like a Crescent Moon. You can only see Venus in the evening or morning, in the West or the East. The wee hours of the night and the middle of the sky are off limits to it.

Jupiter doesn't have such restrictions. Jupiter can appear at any time of night and across the whole span of the ecliptic. When you see a super-bright celestial object that is not Venus, it's sure to be Jupiter.

If Venus is like the Crescent Moon, Jupiter is like the whole Moon cycle. It can be too near to the Sun to see, like a New Moon, or opposite the Sun like a Full Moon. But we don't say planets are New, or Full. We say they are in *conjunction,* or in *opposition*.

Conjunction means in the same direction as the Sun, like a New Moon.
Opposition means opposite the Sun, like a Full Moon.

Jupiter travels along the ecliptic on its own schedule, it is not as lazy as the Moon, or as ambitious as Orion. It travels the ecliptic just a little slower than Orion, but still faster than the Sun. It takes Jupiter 13 months to lap the Sun (remember, it takes Orion only 12 months).

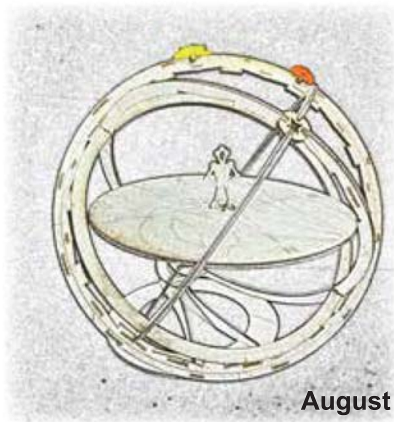
Jupiter is represented by the orange disc on your Horizon Globe. Place the Sun and Jupiter different places on the ecliptic and turn the globe to see when you might see Jupiter in that position.

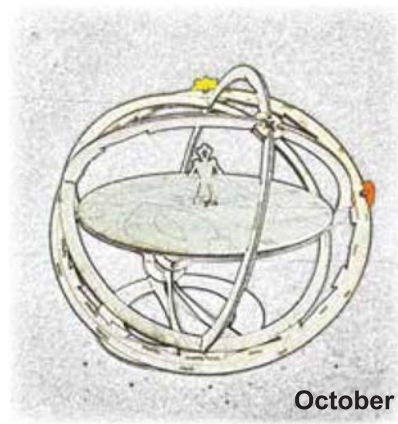
Like Venus, if you know generally where Jupiter is, you can't miss it. It is much brighter than any star. Once you catch a glimpse of Jupiter in the sky, you will wonder how you missed it before.

EXERCISE

1. Place the Sun and Jupiter various places on the ecliptic.
2. Turn the globe to see when you would be able to see Jupiter.


June


August


October

1

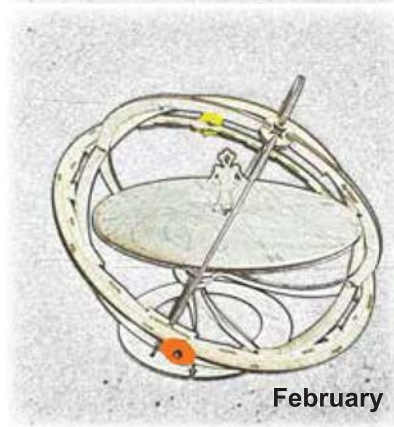
Jupiter in conjunction

2

Jupiter laps the Sun in 13 months

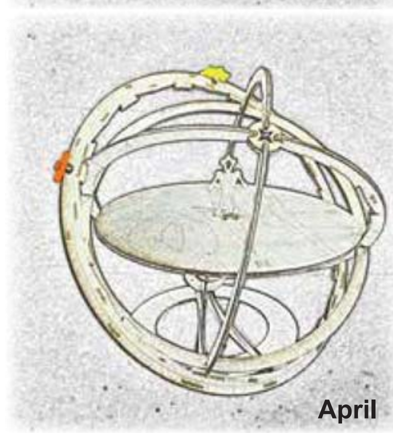

December

Note: In this example Jupiter is in conjunction in June. You need to consult the Moon and Planet Calendar to see when conjunction occurs for the year you are interested in.


February


Jupiter

Jupiter


April

How to Find Jupiter

Equipment needed: Horizon Globe, Jupiter, sun

We always know where to look for Orion, because he is in sync with the seasons and with our calendar. Orion is always near the Sun at the end of June.

Jupiter is just as regular, but it keeps a different schedule. We can't keep track of Jupiter by what month it is, but we can find it using the Moon and Planet Calendars in Appendix B.

Let's practice by finding where Jupiter was during the Moon Landing. The Moon and Planet Calendar on the facing page shows us that it was about four hours behind the Sun. Look for the orange circle with a white "J." In that month, Jupiter would be in the western sky at sunset. When Jupiter is here, be careful not to mistake it for Venus.

Three months later, in October 1969 Jupiter has caught up to the Sun and is in conjunction. In April 1970 Jupiter was in opposition.

Use Appendix B to place Jupiter in its current location on the Horizon Globe. Is it far enough from the Sun to see? When would be a good time to look for it? When is the next time Jupiter will be in conjunction, or in opposition?

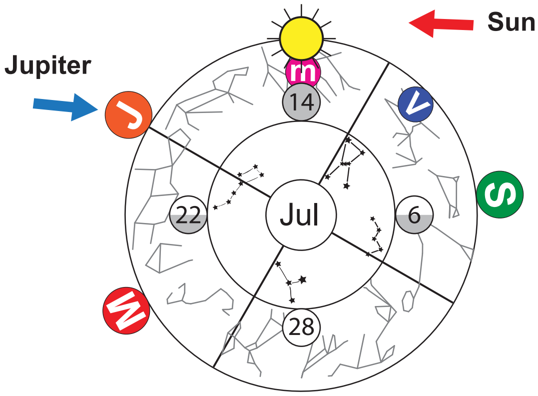
Look at the Moon and Planet Calendars in Appendix B. Notice how Jupiter catches and passes the Sun in a little more than a year. You may want to copy the Moon and Planet Calendar for this year from Appendix B to post on the refrigerator or hang on your wall so you remember to look for Jupiter when viewing is good.

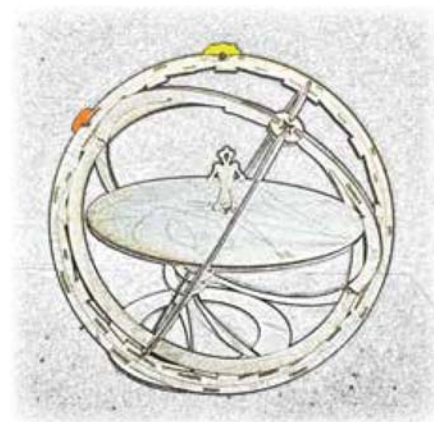
EXERCISE

1. *Use the calendar charts to place Jupiter in its current location.*
2. *Use the globe to go out and find Jupiter.*

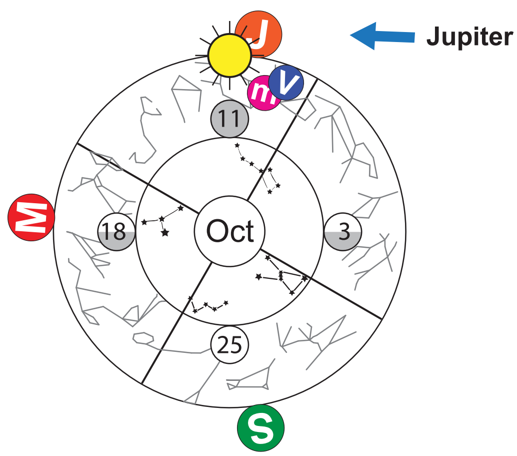
J

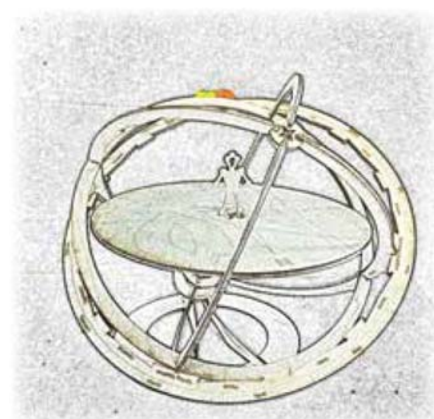
Find where Jupiter was during the moon landing



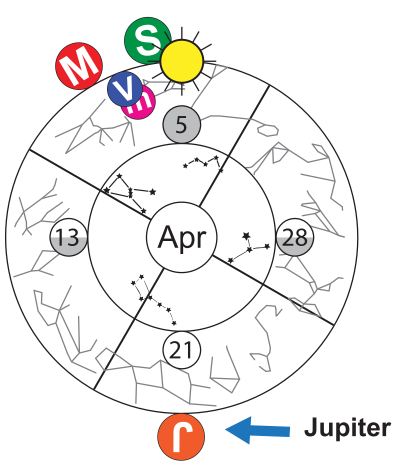


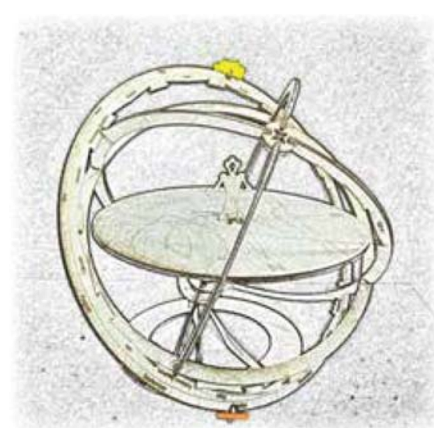
Jupiter on the Moon Landing - July 1969





Jupiter near Conjunction - October 1969





Jupiter in Opposition - April 1970

Saturn

Equipment needed: Horizon Globe, Saturn, sun

Saturn is the archetype wandering star. Unlike super-bright Venus and Jupiter, Saturn is about as bright as the top 20 brightest stars so it really does look like a star.

Saturn moves almost the same as Jupiter, lapping the Sun in 12 ½ months to Jupiter's 13 months. Like Jupiter, it traverses the entire ecliptic cycling from conjunction to opposition and back in just over a year. Saturn is faster than the Sun and Moon, but slower than Orion and the stars.

The challenge with finding Saturn is that it looks exactly like the top 20 stars. Since it stays on the ecliptic, Saturn appears as an extra star in the Zodiac constellations. You can confidently view Venus and Jupiter without knowledge of the constellations because they are both much brighter than any star.

But to find Saturn, you must know which bright star does not belong to the constellation it is in. That one will be the wanderer, Saturn. (Mars also poses as a bright star, but as we will see, Mars has other characteristics that make it easier to pick out).

Saturn is represented by the green disc on your Horizon Globe. Place the Sun and Saturn different places on the ecliptic and turn the globe to see when you might see Saturn in that position.

Which constellation is Saturn in? In a later chapter, we will discuss which Zodiac constellations have bright stars that Saturn could be mistaken for. But most of the time, Saturn will be the brightest "star" in its place on the ecliptic.

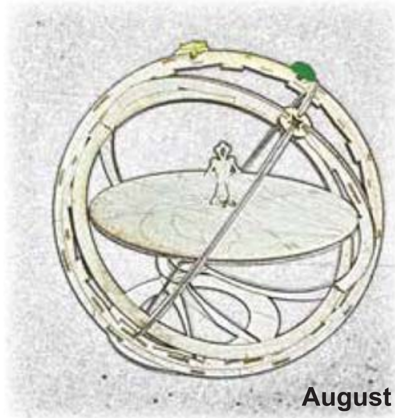
EXERCISE

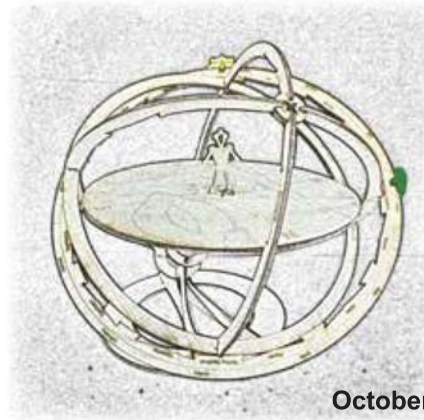
1. Place the Sun and Saturn various places on the ecliptic.
2. Turn the globe to see when you would be able to see Saturn.

...I still remember when the first time I pointed the telescope at the sky and I saw Saturn with the rings. It was a beautiful image

–UMBERTO GUIDONI


June


August

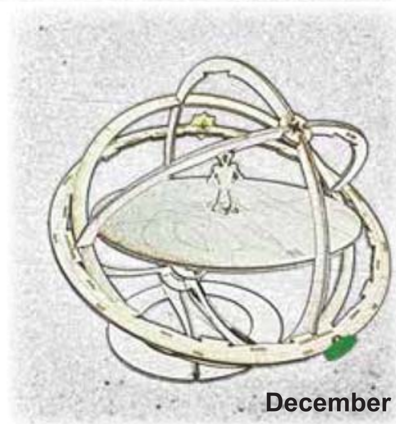

October

1

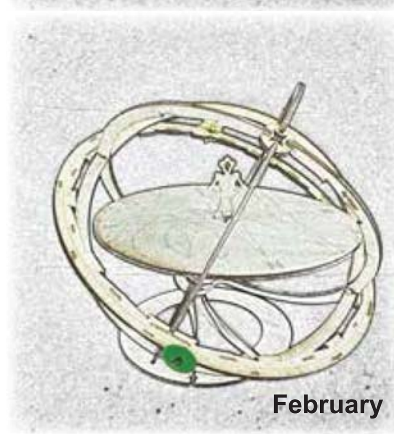
Saturn in conjunction

2

Saturn laps the Sun in 12 ½ months

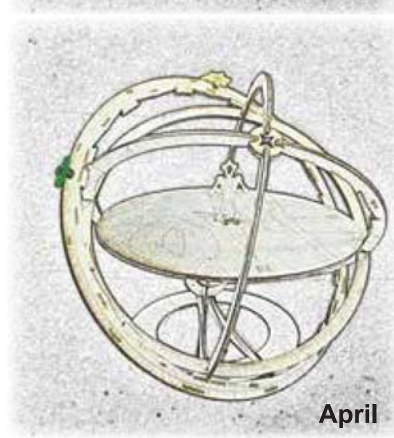

December

Note: In this example Saturn is in conjunction in June. You need to consult the Moon and Planet Calendar to see when conjunction occurs for the year you are interested in.


February


Saturn

Saturn


April

How to Find Saturn

Equipment needed:
Horizon Globe, Saturn, sun

We can find Saturn using the Moon and Planet Calendars the same way we found Jupiter.

Where was Saturn during the Moon Landing? The calendar chart on the facing page shows us that it was about five hours ahead of the Sun. Look for the green circle with a white "S." In that month, Saturn was rising in the East just after midnight.

Three months earlier, in April 1969, Saturn was in conjunction with the Sun. Six months later, in October 1969, Saturn reached opposition. In opposition, a planet rises at sunset and sets at sunrise, like the Full Moon.

In 1969, Saturn stays near the Zodiac constellation Aries. Since there are no bright stars in Aries, a viewer at that time would have been sure that he was looking at Saturn and not a bright star.

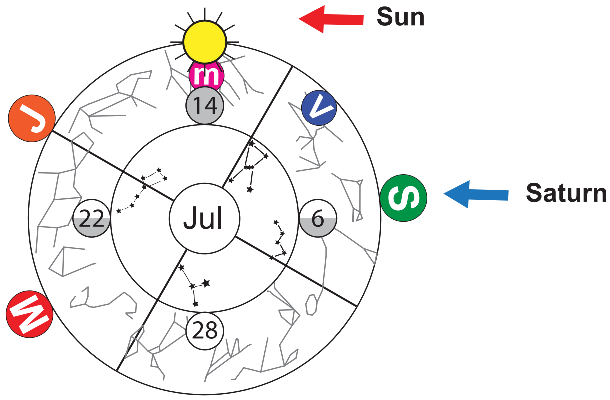
Use Appendix B to place Saturn in its current location on the Horizon Globe. Is it far enough from the Sun to see? When would be a good time to look for it? When is the next time Saturn will be in conjunction, or in opposition?

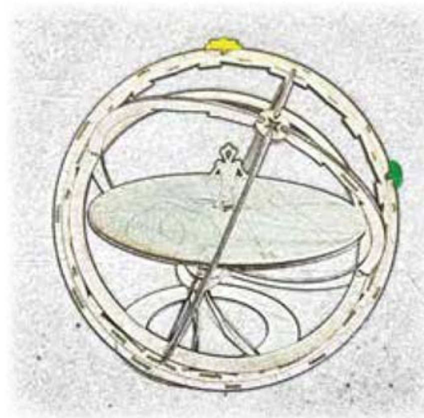
Look at the Moon and Planet Calendars in Appendix B. Notice how Saturn catches and passes the Sun in a little more than a year. Remember to post a copy of this year's Moon and Planet Calendar in a convenient place so it prompts you to look for Saturn and the other planets when you go outside at night.

EXERCISE

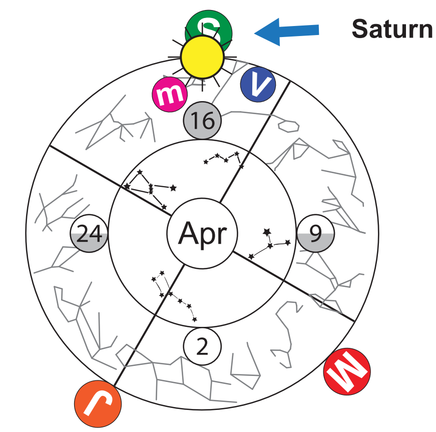
1. Use the Moon and Planet Calendar to place Saturn in its current location.
2. Use the globe to go out and find Saturn.

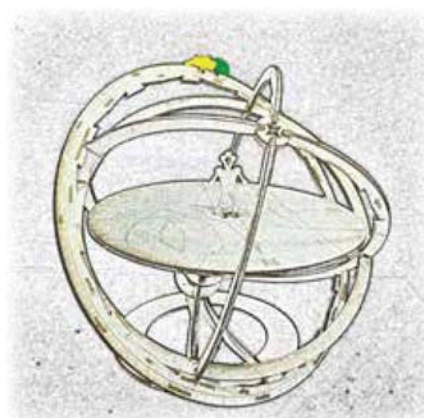
Find where Saturn was during the moon landing



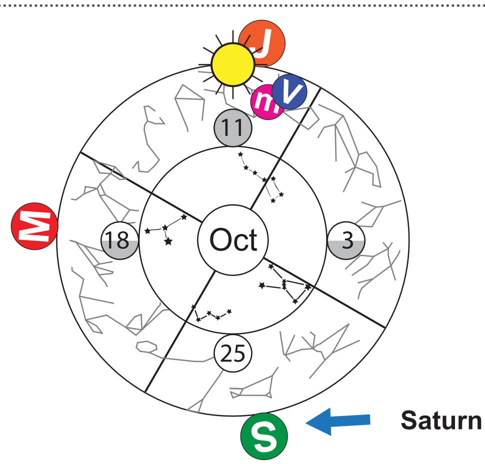


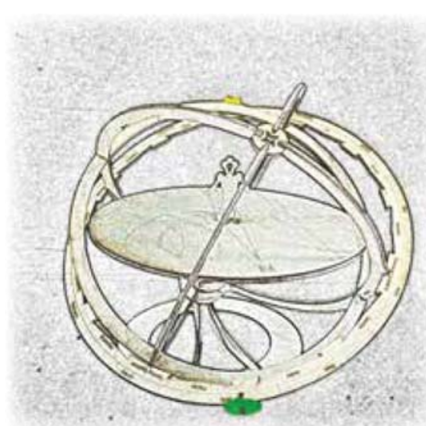
Saturn on the Moon Landing - July 1969





Saturn in Conjunction - April 1969





Saturn near Opposition - October 1969

Mars

Mars is a very interesting planet to track.

Equipment needed: Horizon Globe, Mars, sun

There are three characteristics of Mars that make it one of the most fun objects in the sky to find:

Color - Mars is bright red. Only the bright star **Antares** in Scorpio and **Betelgeuse** in Orion approach this color of red.

Brightness - Sometimes Mars is super bright, as bright as Jupiter. Other times Mars wouldn't even make the top 20 stars.

Speed - Mars changes speed radically, sometimes moving so fast that it would catch the Sun every seven months, other times slowing to a crawl that would take seven years to lap the Sun.

Mars is easier to track if you know a few things about his behavior.

In terms of brightness, think of Mars like the Moon: dim when near the Sun and bright when far away. In terms of speed, the brighter Mars is, the faster he goes. In opposition, Mars is bright and fast. In conjunction, Mars is dim and slow.

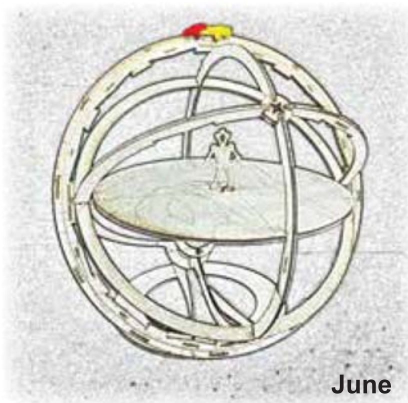
On average, Mars is the slowest planet, taking just over two years to lap the Sun, compared to Jupiter's 13 months, and Saturn's 12 ½ months.

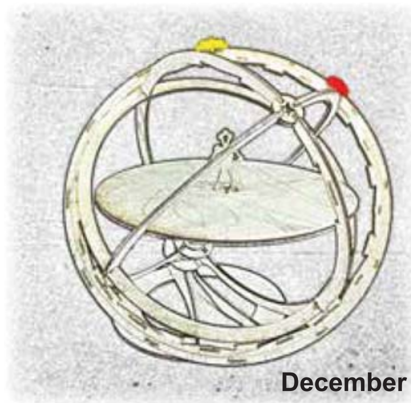
You should be able to find Mars if you know where to look because it is one of the only red objects in the sky. If you remember that its brightness changes with its angle with the Sun, you will know how bright of a wandering star you're looking for.

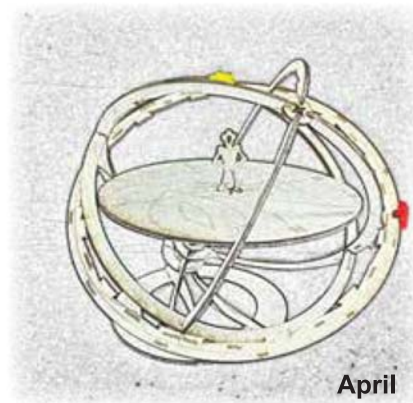
Mars is represented by the red disc on your Horizon Globe. Place the Sun and Mars different places on the ecliptic and turn the globe to see when you might see Mars in that position.

EXERCISE

1. Place the Sun and Mars various places on the ecliptic.
2. Turn the globe to see when you would be able to see Mars.





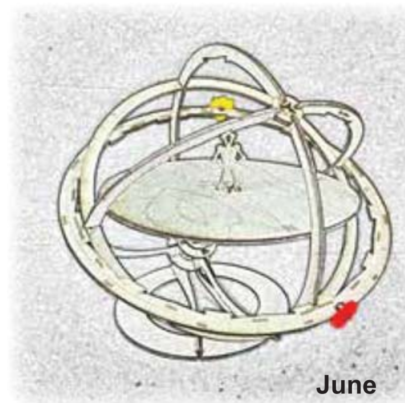


1

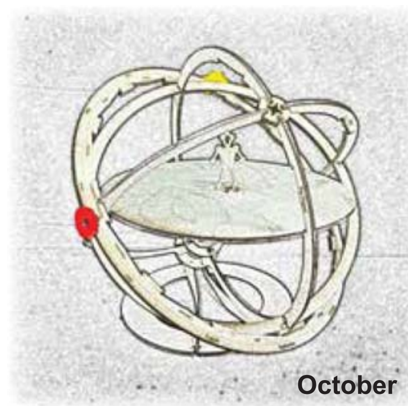
Mars in conjunction

2

Mars laps the Sun in ~2 years



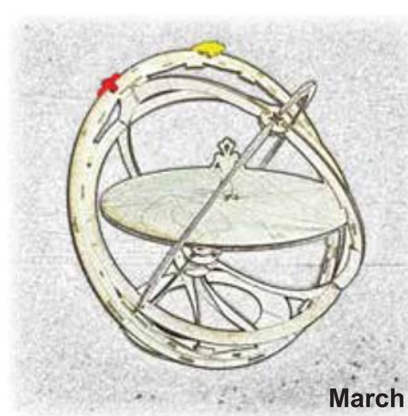
Note: In this example Mars is in conjunction in June. You need to consult the Moon and Planet Calendar to see when conjunction occurs for the year you are interested in.



Mars

Mars

Mars is dim and slow when in conjunction (near the Sun)
Mars is bright and fast when in opposition (opposite the Sun)



How to Find Mars

Equipment needed: Horizon Globe, Mars, sun

The Moon and Planet Calendars depict Mars the same way they show the other planets.

Where was Mars during the Moon Landing? The Moon and Planet Calendar on the facing page shows us that it was about eight hours behind the Sun. Look for the red circle with a white capital "M". On the day of the Moon Landing, Mars rose at about 2:00 p.m. and was visible high in the sky right after sunset. It was catching up to the Sun after opposition, so it was slowing down and getting dimmer.

Mars was nearing opposition two months earlier, in May 1969. It wouldn't reach conjunction for another year, July 1970.

Interestingly, Mars was near Scorpio during the Moon Landing. The red star **Antares** in Scorpio is the star most likely to be confused with Mars. In fact, the name "**Antares**" means "rival of Mars."

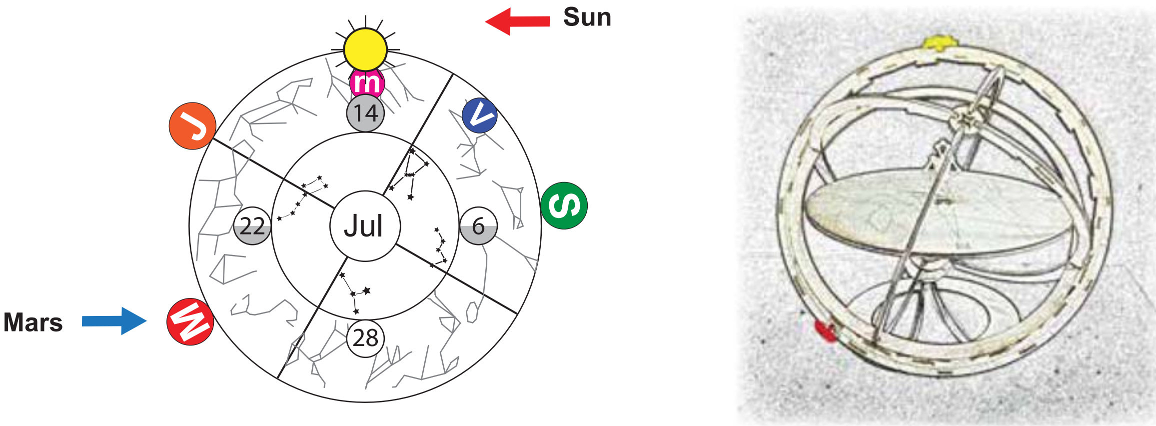
Use Appendix B to place Mars in its current location on the Horizon Globe. Is it far enough from the Sun to see? When would be a good time to look for it? When is the next time Mars will be in conjunction, or in opposition?

Look at the Moon and Planet Calendars in Appendix B. Notice how Mars takes over two years to catch and pass the Sun. Notice how much it jumps in a month when it is near opposition and how many months it takes to pass the Sun when it is near conjunction.

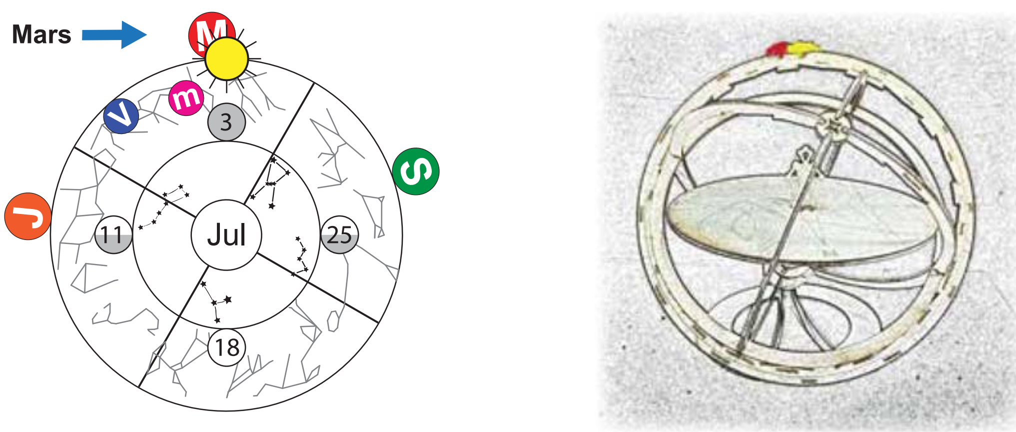
EXERCISE

1. Use the Moon and Planet Calendars to place Mars in its current location on the Horizon Globe.
2. Use your globe to help you go outside find Mars in the sky.

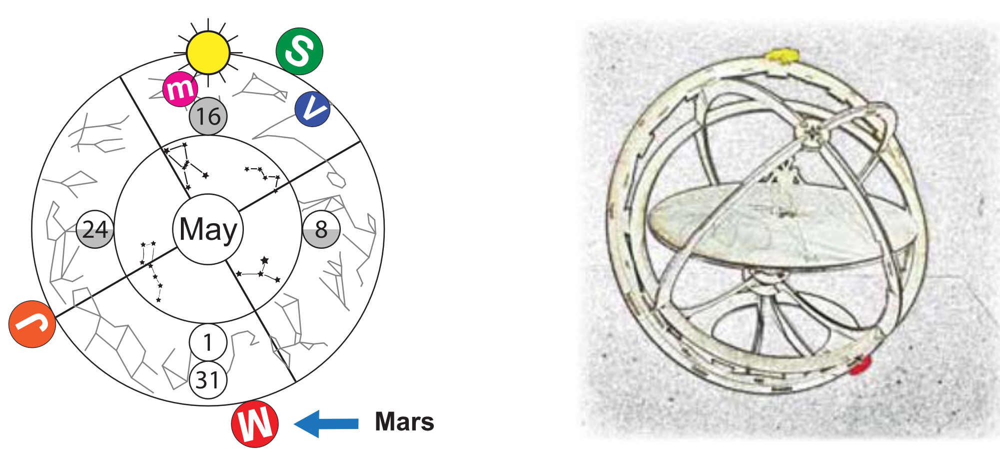
Find where Mars was during the moon landing



Mars on the Moon Landing - July 1969



Mars near Conjunction - July 1970



Mars nearing Opposition - May 1969

Telling Planets from Stars

Equipment needed: zodiac constellations

Let's take a look at the six stars that could be mistaken for a planet.

Start with the stars around Orion. There are quite a few bright stars in Orion's part of the sky, but only 3 are near the ecliptic. The distance from Orion's shoulders to the ecliptic is about the same distance as Orion's height, from his feet to his shoulders. If we can see Orion, we can estimate pretty accurately where the ecliptic is.

Taurus the Bull has a bright, orangish star in its neck called **Aldebaran**. Since it is orange, you probably won't think it's Saturn, which is more white in color. You may mistake **Aldebaran** for Mars if you are unfamiliar with the shape of the Bull. Follow Orion's belt up and to the right to find **Aldebaran**. Find it when Mars is not nearby so you know what it looks like.

Castor and **Pollux** are the two bright stars in Gemini the Twins. If you follow a line through the two bright shoulder stars of Orion, it leads to **Pollux** and **Castor**. They are whitish/yellowish so be careful not to confuse them with Saturn. As with **Aldebaran** in the Bull, your best bet is to learn to recognize them ahead of time, so when Saturn arrives, you will see the contrast.

Next look in the Big Dipper's part of the sky. Straight south of the Big Dipper there are two bright stars on the ecliptic. **Regulus** in Leo the Lion and **Spica** in Virgo the Virgin. If there is a third bright star in this area, you know it's a planet. Both of these stars are blueish, so Mars won't be a problem, only Saturn.

The only other bright star near the ecliptic is **Antares** in Scorpio the Scorpion. **Antares** is a bright red star just below the ecliptic in Cygnus the Swan's part of the sky. Remember that **Antares** looks very much like Mars. If your planet calendar places Mars near Scorpio, look for two bright red objects.

EXERCISE

1. Look carefully at the Zodiac discs on your Horizon Globe and find the double circles that represent bright stars.

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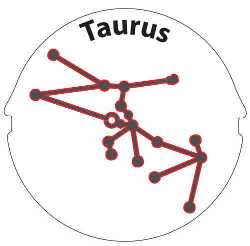
<td>
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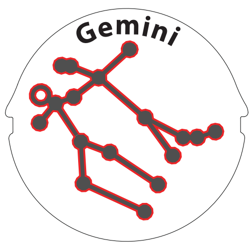
<td>
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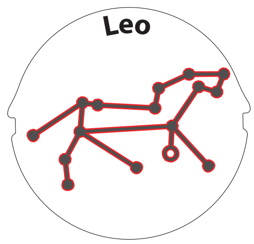
<td>
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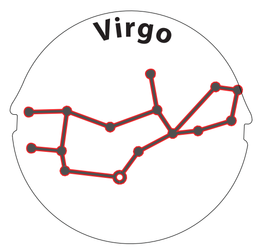
<td>
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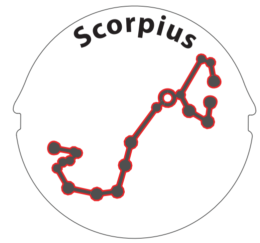
<td>
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</tr>
<tr><td>ALDEBARAN</td><td>CASTOR and POLLUX</td><td>REGULUS</td><td>SPICA</td><td>ANTARES</td></tr>
</table>

THESE BRIGHT STARS ARE SOMETIMES MISTAKEN FOR PLANETS

That's it. You can't mistake Venus or Jupiter for stars because they are so much brighter. That's also true for Mars when it is in opposition.

If you can distinguish star colors, only the stars in Scorpio and Taurus could be Mars, though Taurus' star is more orange than red. Only the stars in Gemini, Leo, and Virgo could be mistaken for Saturn.

Of course separating planets from stars requires that you know where the ecliptic is. Luckily, you will become an expert at finding the ecliptic through using your Horizon Globe and watching the Sun and Moon in the sky.

Later, when you learn more about identifying and locating stars and constellations, you will never confuse a planet with a star.

Star or planet?

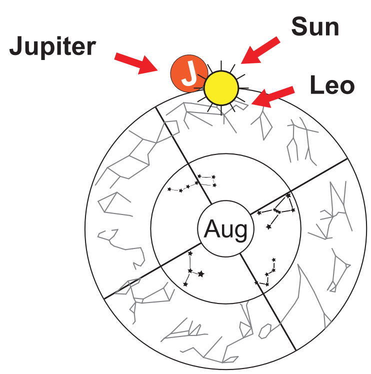
ANOTHER WAY TO THINK ABOUT PLANETS

One of the reasons that learning astronomy the Horizon Globe way is so easy is that we relate everything to the Sun.

That is because we want everything to relate to you! The way things are presented in this book and on the Horizon Globe are the same as the way you experience them outside. As a human, the Sun is by far the most important and noticeable celestial object. The location of the Sun must be taken into account no matter what else you are trying to view. The Sun is the elephant in the room of astronomy, so to speak.

That is why when we discuss planets and planetary motion, we do so by relating the planet's position and motion to that of the Sun. There is no easier way to understand the complicated motion of the planets.

Let's look at an example. Say Leo, the Sun, and Jupiter are all aligned, which happened when Jupiter reached conjunction in August of 1968.



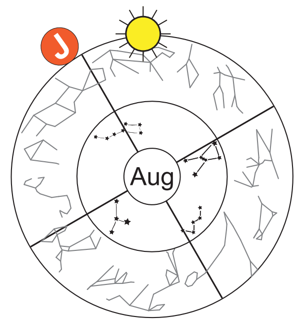
Leo, Sun, and Jupiter in alignment August 1968

EXERCISE

1. Look at the Moon and Planet Calendars in Appendix B. Locate Jupiter in a particular month, notice which constellation it's in. Check that month every year until you see Jupiter back in the same constellation. How many years did it take?
2. Repeat for Saturn and Mars, but not Venus. Why?

Fly me to the moon, let me play among the stars
Let me see what spring is like on Jupiter and Mars

–FRANK SINATRA



Leo and Sun aligned.
Jupiter lagging behind.
August 1969

Now wait one year. During that time, Leo lapped the Sun once. Jupiter hasn't quite lapped the Sun, it needs 13 months to accomplish that. Comparing their speed to the Sun is by far the best way to think about the speed of Leo and Jupiter.

But now instead of comparing them both to the Sun, what happens when we compare speed of Jupiter to the speed of Leo? Which is another way of asking, 'what is the speed of Jupiter compared to the speed of the stars?'

If we compare our two August examples, we can see that Jupiter is lagging behind Leo after one year. That means that the stars move just a little faster than Jupiter. The stars travel in one year the amount that it takes Jupiter to travel in one year and one month. They are like two racehorses running neck and neck, with Leo slowly gaining ground and winning at the end.

Each year Leo gets another month ahead of Jupiter, until after 12 years Leo has caught up with Jupiter again. We say Jupiter has an orbital period of 12 years (actually, closer to 11.86). Flip through the calendar charts in Appendix B to see this phenomenon. Choose a month and see which constellation Jupiter is in. Check Jupiter's location in the same month for a few years. How many years does it take for Jupiter to be in that constellation again?

You can do the same experiment with Saturn and Mars. We can estimate Saturn's orbital period to be about 30 years (29.5 years). An easy way to remember Saturn's orbital period is to remember that it's like the Moon cycle, except that the Moon cycle is measured in days instead of years. Mar's orbital period is about 2 years (1.88).

If you live to be 100 years old, Mars will be in your birth Zodiac sign just over 50 times in your life. Jupiter will only pass through eight or nine times. And you will only have three or four chances to see Saturn in your sign. Better not miss any!

Planets vs. Stars

Seasons

Equipment needed: Horizon Globe and sun

You don't need to understand any astronomy to know that the year is divided into seasons. Spring, Summer, Autumn, and Winter each have a feeling and certain events that make us aware of their changing.

Spring brings thawing where there was snow and new plants springing up.

Summer has long, hot days. The Sun is more intense. You will get sunburned faster in summer than in winter.

Autumn brings ripening crops, cooler weather, and changing colors on the trees.

Winter brings long, cold nights and snow and ice.

Seasonal changes are obvious to all. But you may not have noticed the connection between seasons and astronomy. How do you know when each season begins and ends? Why is the Sun more intense in the Summer? Why are days long in summer and short in winter?

These questions are answered by astronomy.

Place the Sun on your Horizon Globe in each of the four places marked Spring Equinox, Summer Solstice, Autumn Equinox, and Winter Solstice. Turn the globe with the Sun in each place and see if you can notice what is different for the Observer for each season.

There is a common misconception that the Sun is closer to Earth in the summer than in winter, therefore it is more intense and hotter. But observations do not support this view.

How do we know the Sun doesn't move closer to the earth in summer? Let's take a close look on the next page.

EXERCISE

1. *Find the season markings on your Horizon Globe.*
2. *Place the Sun at Spring Equinox. Turn the globe and notice how the Sun moves. Repeat for summer, autumn, and winter.*

Time will pass and
seasons will come and go

We have observations that contradict (or are not explained by) the idea that the Sun moves closer to us in summer.

> **First**, the Sun does not appear to be larger in summer. If the Sun moved significantly closer to Earth in the summer, it would appear bigger to us.
>
> **Second**, the idea that the sun is closer does not explain these seasonal observations:
> a) the changing length of day and night
> b) the changing height of the noon Sun
> c) the changing direction of sunrise and sunset from summer to winter

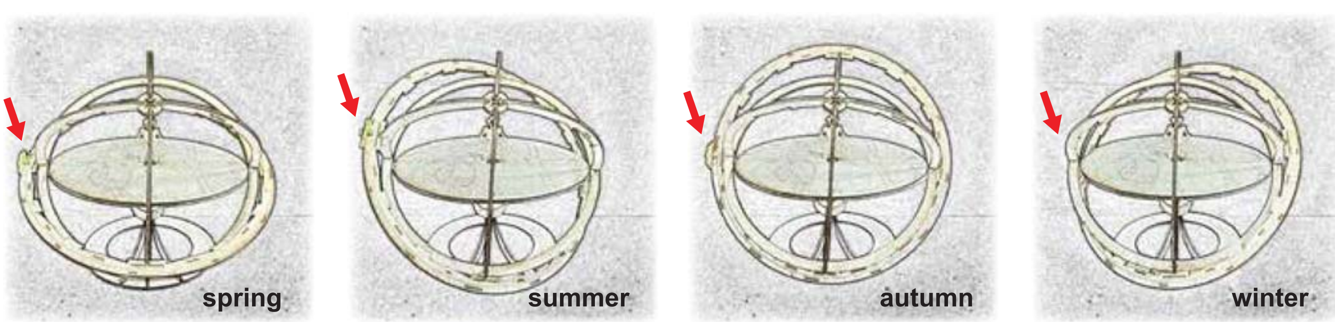
In the next pages, we will use the Horizon Globe to show the real differences in the Sun from season to season. We will also learn how seasons are defined and how to determine when each season begins and ends.

Once you know the differences in the Sun's behavior from season to season, the changes we notice between the seasons won't be hard to explain if we keep one simple fact in mind: the Sun feels more intense when it is higher in the sky.

Compare the early morning Sun to a summer noon Sun. You won't get sunburned right after sunrise, but it may only take a few minutes to get burned at midday. Think about the Sun's height vs. intensity as you study the chapters on seasons.

1

Find seasons on your globe:
"Spring Equinox"
"Summer Solstice"
"Autumn Equinox"
"Winter Solstice"



2

Place the Sun on the Ecliptic Ring at each season. Spin the globe and observe.

Altitude, Azimuth, and Length of Day

Equipment needed: Horizon Globe and sun

We know that the location of the Sun is constantly changing, because we've seen it do so. Sometimes its high in the sky, sometimes low. Sometimes in one direction, sometimes in the other.

If you were to step outside right now, you could say something about the location of the Sun. If it's morning, then maybe the Sun is low in the sky, about to make its daily journey across the sky. Or maybe it's closer to noon, when the Sun is high in the sky. Maybe it's evening, and the Sun has already set and is not visible at all. Wherever the Sun is, it would be nice to have a way to talk about its location that would be more accurate than saying "It's over there somewhere, on the other side of that tree."

So what makes the Sun so confusing to track down? There are three things about the Sun that change simultaneously as the seasons change. We'll discuss each of these separately.

1. Height the Sun reaches at noon
2. Direction of sunrise and sunset
3. Relative lengths of day and night

- **Height the Sun reaches at noon**

The height of a celestial object is measured in **degrees of altitude**. The altitude of an object is the angle the object appears to be above the horizon. The unit of measurement for altitude is degrees. See the first sketch on the next page.

To find the altitude of the Sun, measure from a flat horizon to the center of the Sun's disk. Any object visible in the sky always has an altitude that you can measure. Every day, the Sun starts with a low altitude, rises to its maximum at noon, then sinks back down. When an object is on the horizon we say its altitude is zero degrees. If the object is straight up (vertically above you) we say it is at the **zenith.** The zenith at 90 degrees of altitude.

EXERCISE

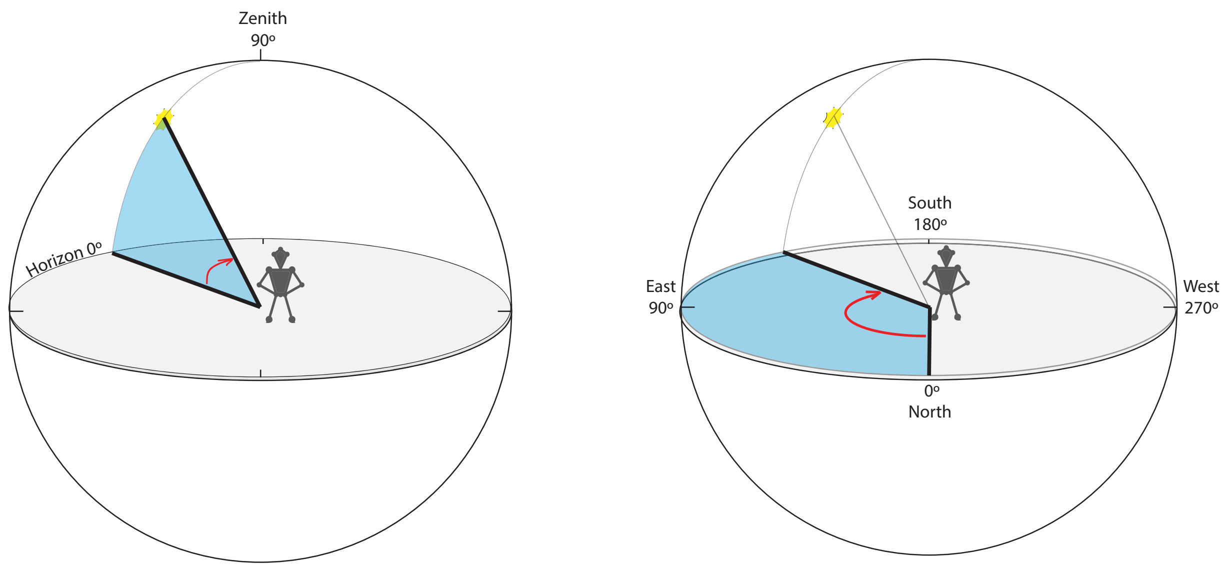
1. Put the Sun at the Summer Solstice, sunrise position.
2. Notice altitude and azimuth of the Sun.
3. Spin globe from sunrise to noon. Notice the changing altitude and azimuth. Now spin globe from noon to sunset. Notice changes.
4. Repeat for Winter Solstice, Spring and Autumn Equinoxes

Lost time is never found again.

–BENJAMIN FRANKLIN

- **Direction of sunrise and sunset**

The direction of the sunrise and sunset is measured in **degrees of azimuth**. The azimuth is the angular distance along the horizon to the location of the object. It is also measured in degrees, just like altitude. In Astronomy, by convention the measurement starts from north and goes clockwise (towards east), as shown below in the second sketch.



Altitude
is the height (in degrees)
above the horizon

Azimuth
is the distance (in degrees)
along the horizon

- **Relative lengths of day and night**

One turn of the Horizon Globe represents one 24-hour day.*
One-half of one turn is 12 hours. The Sun's position on the ecliptic determines how many hours it is above or below the horizon. Sometimes the Sun is above the horizon for more than ½ a turn, sometimes less.

*the globe actually turns a bit more than one turn in a 24-hour day because during that time the Sun slips back about a degree. We define a 24-hour day as the time from one midnight to the next.

SPRING

Equipment needed: Horizon Globe and sun

The Horizon Globe provides an easy way to understand seasons.

Place the Sun on the Ecliptic Ring at the place marked "Spring Equinox," around March 21. Spin the Globe around and notice 3 things:

WHAT DIRECTION DOES THE SUN RISE AND SET? On the Spring Equinox, the Sun rises exactly East and sets exactly West.

HOW HIGH DOES THE SUN GET AT NOON? Take note of how high the Sun gets, and notice that the Sun is on the *celestial equator** on this day.

WHAT PORTION OF A FULL TURN IS THE SUN ABOVE THE HORIZON PLATE VS. BELOW THE HORIZON PLATE, i.e. how do the lengths of day and night compare. At the equinox (which means "equal nights") the day and night are each ½ of a turn, or exactly 12 hours each.

* **The Celestial Equator**
Astronomers measure how far North-South objects are by how far they are from the Celestial Equator. This is the imaginary ring that divides the top from the bottom half of the celestial sphere. It is analogous to the Equator on a terrestrial globe.

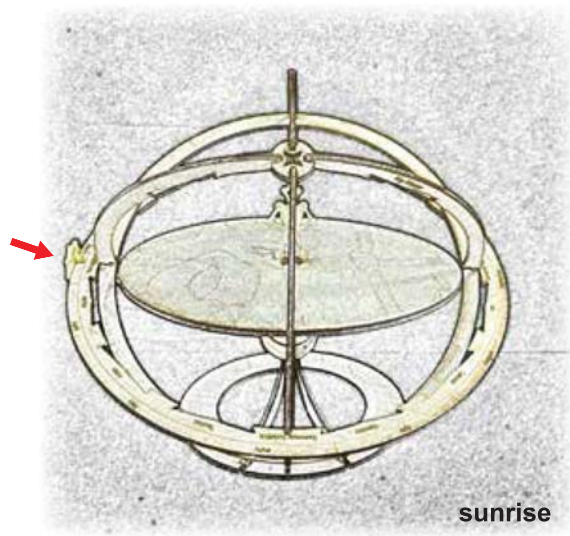
Your Horizon Globe has a physical ring to represent the celestial equator. The celestial equator ring is always East-West, no matter what angle the Ecliptic Ring has.

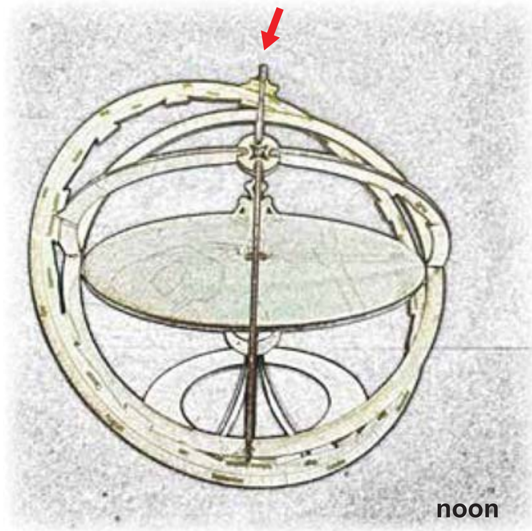
EXERCISE

1. Place the Sun on the Ecliptic Ring at "Spring Equinox."
2. Spin the globe and make observations:
   a. What is the direction of sunrise and sunset?
   b. What is the height of the noon Sun?
   c. How long are day and night?

If winter comes, can spring be far behind?

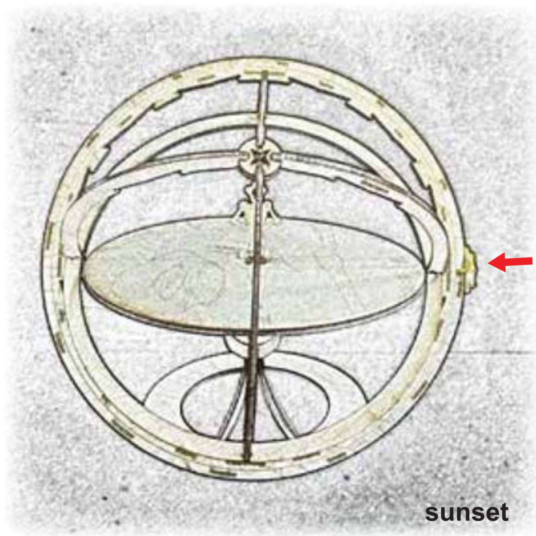
–SHELLEY





1

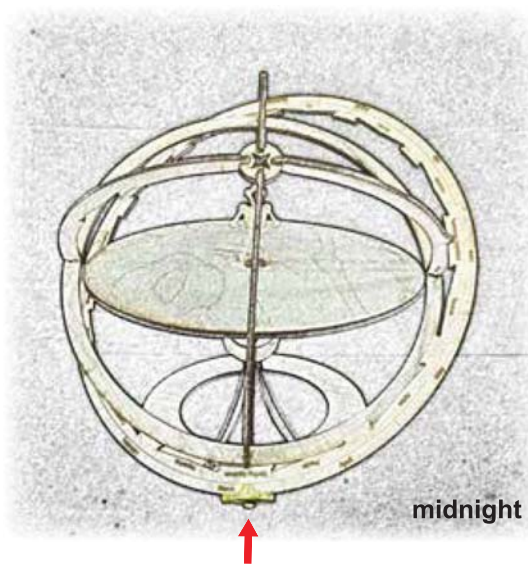
Place the Sun on the Ecliptic Ring at "Spring Equinox"



2

Spin the globe and notice three things:

1) Direction of sunrise and sunset
2) Height of noon Sun
3) Length of day and night



Spring Equinox

Summer

Equipment needed: Horizon Globe and sun

Every time you spin the globe one revolution, you need to move the Sun back a little. Just like the Moon goes slower than the Sun, the Sun goes slower than the stars, which are fixed on the globe.

Ten turns after the Spring Equinox, the Sun should be on the first of April. Thirty more turns and it will be on the first of May. Three months after the Spring Equinox, the Sun will be on about June 21, or the Summer Solstice*.

Place the Sun on your Horizon Globe at the point labeled "Summer Solstice." Turn the globe and notice the same 3 things as we observed for spring:

Where does the Sun rise and set?
How high does it get?
How long is the day vs the night?

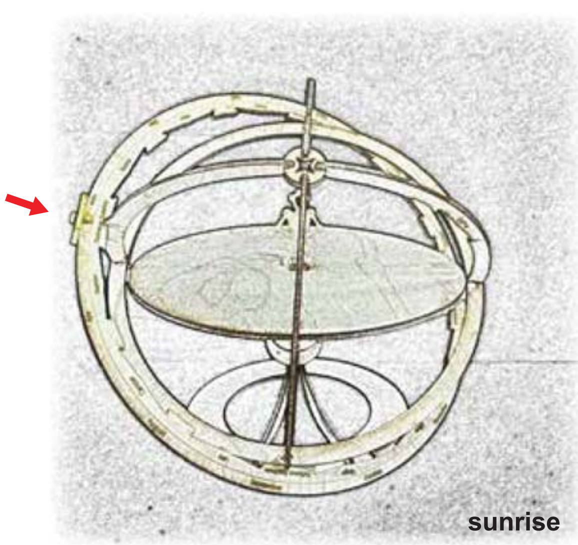
In summer, the Sun rises in the northeast and sets in the northwest. At noon it is much higher than in spring, far higher than the celestial equator. The Sun spends the majority of its time above the horizon and only a little while below.

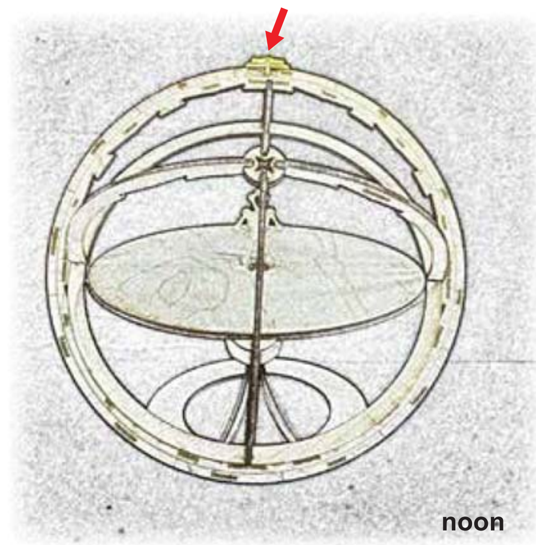
* **Solstice**
Solstice means "Sun Stops." Notice that when the sun moves a month from March 1 to April 1, it changes height significantly, from below the equator to above it. Now move the Sun from June 1 to July 1. It moves the same distance along the ecliptic but hardly changes its noon height at all. This is why we call it the solstice. The Sun seems to stop changing height at this point.

EXERCISE

1. Place the Sun on the Ecliptic Ring at "Summer Solstice."
2. Spin the globe and make observations.

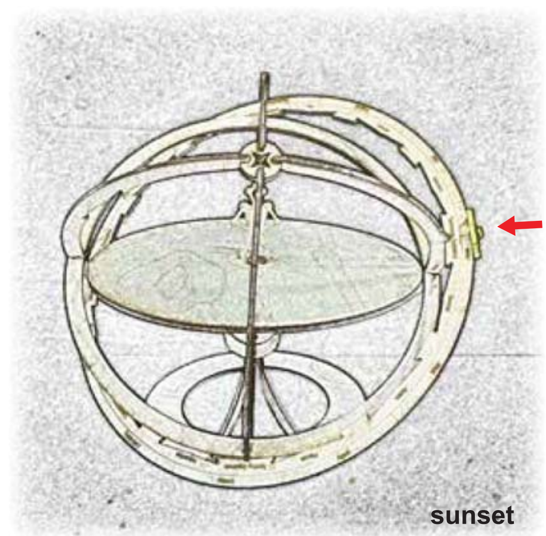
In summer the Sun reaches its highest





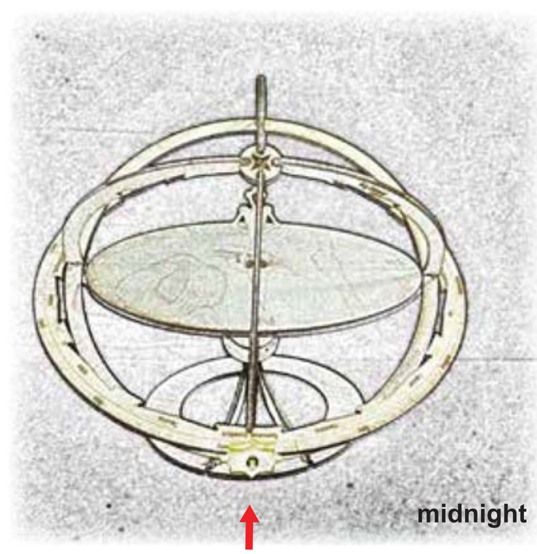
1

Place the Sun on the Ecliptic Ring at “Summer Solstice”



2

Spin the globe and notice three things:
1) Direction of sunrise and sunset
2) Height of noon Sun
3) Length of day and night



Summer Solstice

Autumn

Equipment needed: Horizon Globe and sun

Three months after the Summer Solstice comes the Autumn Equinox, around September 21. Place the Sun on "Autumn Equinox" on your Horizon Globe and spin it.

Look for the 3 changes:

Where does the Sun rise and set?
How high does it get?
How long are the days and nights?

You have probably noticed that the Sun behaves exactly the same on the Autumn Equinox as on the Spring Equinox.

When we talk about seasons, sometimes we just mean summer is the warm time and winter is the cold time. But in astronomy we have precise definitions for these terms.

Spring - Spring Equinox to the Summer Solstice.
Summer - Summer Solstice to Autumn Equinox
Autumn - Autumn Equinox to Winter Solstice
Winter - Winter Solstice to Spring Equinox

The Spring Equinox is defined as the exact time when the Sun crosses the equator. This doesn't always happen on the same day each year, but it is always close to March 21.

The Summer Solstice is the day when the Sun reaches its highest point above the equator. The Summer Solstice usually occurs on June 21 or 22.

The Autumn Equinox occurs around September 21, usually the 22nd or 23rd of the month.

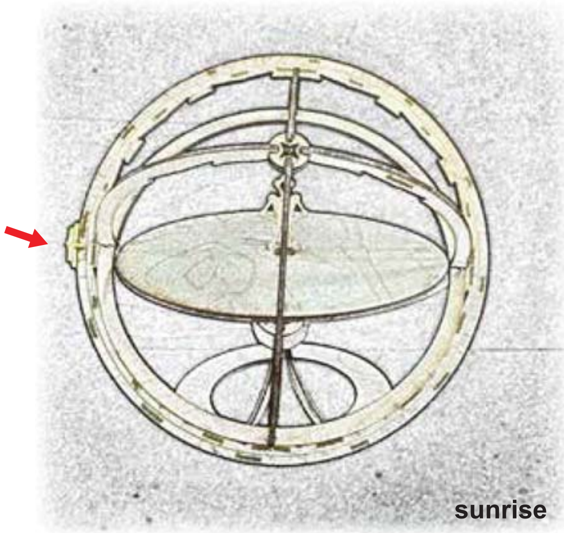
The Winter Solstice, the Sun's lowest point below the equator, occurs on December 21 or 22.

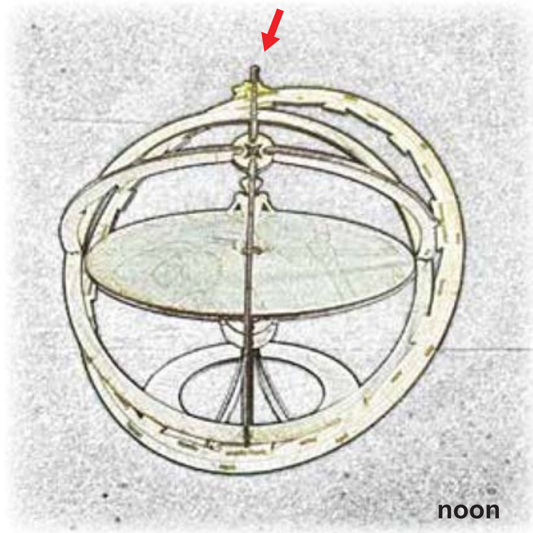
EXERCISE

1. Place the Sun on the Ecliptic Ring at "Autumn Equinox."
2. Spin the globe and make observations.

Autumn's the mellow time

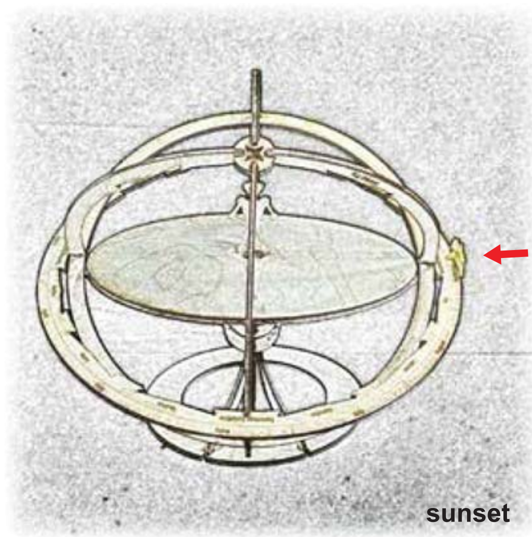
–WILLIAM ALLINGHAM





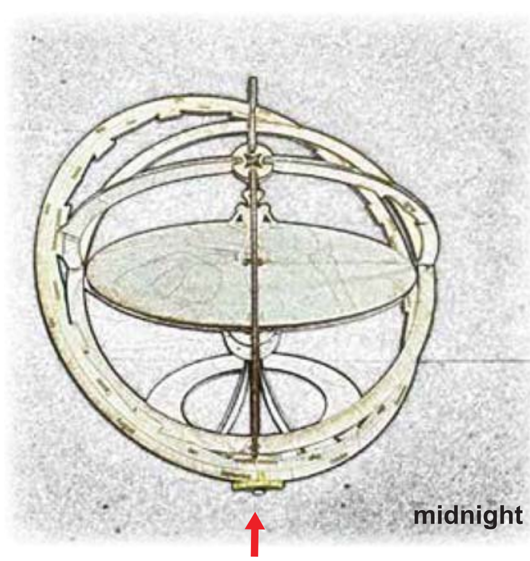
1

Place the Sun on the Ecliptic Ring at "Autumn Equinox"



2

Spin the globe and notice three things:
1) Direction of sunrise and sunset
2) Height of noon Sun
3) Length of day and night



Autumn Equinox

Winter

Equipment needed: Horizon Globe and sun

A quarter of a year after the Autumn Equinox we get to the Winter Solstice. Place the Sun at "Winter Solstice" on your Horizon Globe and spin it.

Look for the 3 changes:

Where does the Sun rise and set?
How high does it get?
How long are the days and nights?

The Sun rises in the southeast and sets in the southwest. It does not get very high at noon, nowhere near up to the equator. The day is short and the night is long.

It is interesting to note that winter is like a mirror image of summer. The winter night is the same length as the summer day and the winter day is the same length as the summer night.

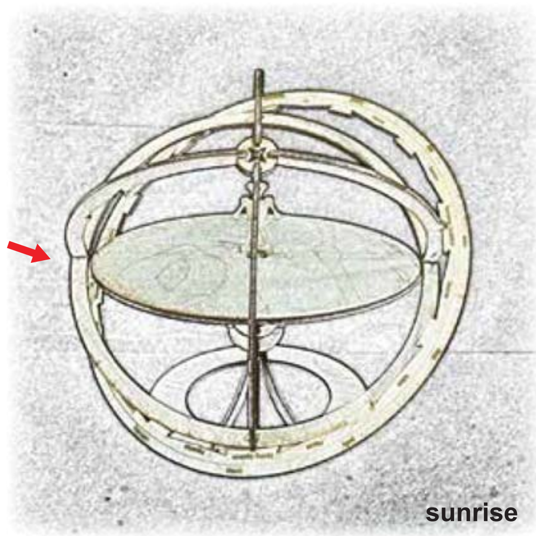
There is also symmetry between sunrise and sunset. Notice that the amount south of east the sun rises is the same as the amount south of west that it sets. This symmetry applies all year long, not just on the solstice.

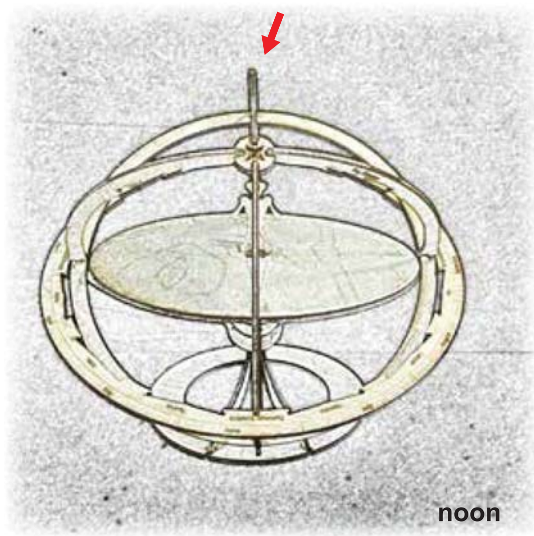
Step back and take a look at the ecliptic ring. Now that we have studied seasons, we can see that seasons are caused by where the Sun is on the ecliptic. The high part of the ecliptic is summer, the low part winter, and in-between are spring and autumn.

Learning to visualize the entire ecliptic is one of the keys to effective observational astronomy. Learn to imagine where on the ecliptic the Sun is for a given time of year. Then learn to imagine where the rest of the ecliptic is.

EXERCISE

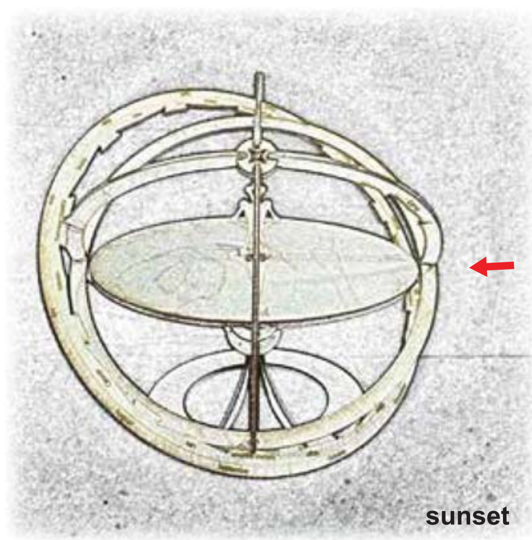
1. Place the Sun on the Ecliptic Ring at "Winter Solstice."
2. Spin the globe and make observations.





1

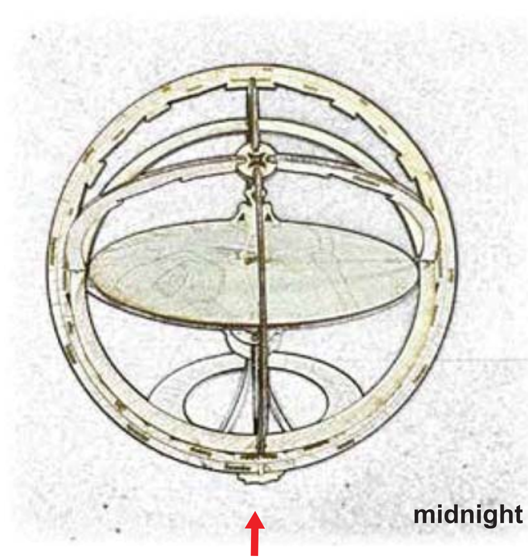
Place the Sun on the Ecliptic Ring at "Winter Solstice"



2

Spin the globe and notice three things:
1) Direction of sunrise and sunset
2) Height of noon sun
3) Length of day and night

Winter Solstice



The Sun's Angle

Equipment needed: Horizon Globe and sun

You can use your knowledge of astronomy to be wiser about avoiding sunburn.

No one likes getting a sunburn, but sometimes we get caught off guard and end up over-exposed and burned. Your new knowledge of astronomy can help you be more aware of when the Sun is particularly intense.

If the Sun were the same intensity any time it was out, it would be easy to avoid sunburn. You could just monitor the number of minutes of Sun exposure and make sure you stay under the limit. But the Sun is not so regular. The intensity of the Sun changes radically through the day and throughout the year.

Think about the Sun on a beautiful 4th of July day. Early in the morning, 6 or 7 a.m., your skin can be exposed to the Sun with no problem. Around mid-day, you had better be careful, just a few minutes of exposure will burn you unless you have a good base tan or apply sunscreen. As the Sun gets low in the sky around sunset, the danger goes away again.

Now think of a bright Christmas Day. Unless there is a lot of reflection from the snow or water, or if you are in the mountains, you can let the Sun warm your skin all day without getting burned.

So sometimes the Sun will burn you and other times it won't. What is the pattern?

It turns out there is a simple way to know the Sun's intensity and therefore your risk of burning. It is the altitude, or height, of the Sun. When the Sun is high you will burn, when the Sun is low, you won't.

EXERCISE

1. Place Sun on a summer month on Ecliptic Ring.
2. Spin the globe and see when angle is steeper than 45°.
3. Move Sun to a winter location. Notice Sun angle never reaches 45°.

How high is too high? A rule of thumb is 45 degrees. When the Sun is higher than 45 degrees above the horizon it is dangerous for sunburn, below 45 degrees it is generally safe.[1] A rule of thumb is valuable, but you still need to use common sense. Water, snow, and altitude can all amplify the Sun's danger, and prolonged exposure at near 45 degrees will burn you.

With the knowledge you have of the Sun's behavior from this book and your Horizon Globe, you can develop an awareness of the Sun that will protect you from inadvertently getting too much Sun exposure.

Place the Sun on a summer month of the Ecliptic Ring. Turn the globe and notice when the Sun reaches an angle steeper than 45 degrees. Now move the Sun to a winter month. Notice how the Sun never gets higher than 45 degrees during this half of the year. Your Horizon Globe is fixed for a 45 degree latitude. If you live farther south, the Sun will reach higher angles for more of the year and more of the day than is shown on the globe, so adjust accordingly.

1

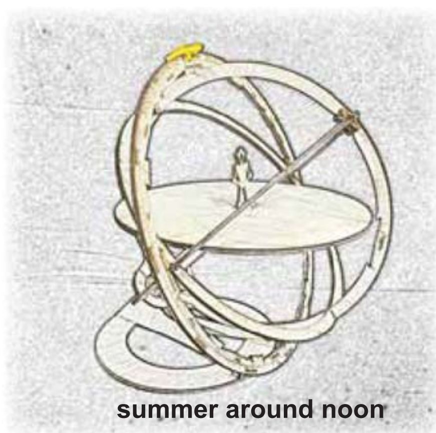
Place the Sun on the Ecliptic Ring on a summer month

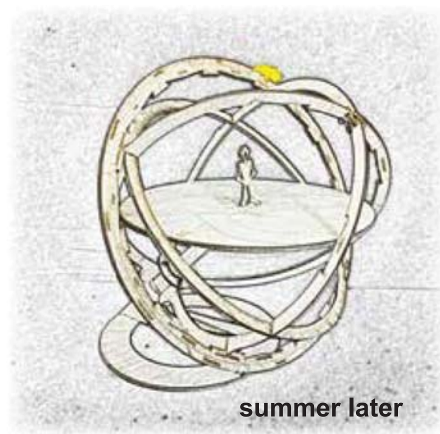
2

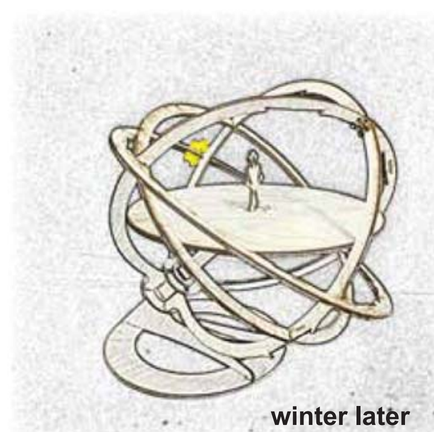
Spin globe and notice angle

3

Move Sun to winter location and notice angles







[1] The Shadow Rule: A Simple Method for Sun Protection, Thomas F. Downham, MD., Southern Medical Journal July 1998.

Shadows and Sunburn

Equipment needed: Horizon Globe **and flashlight**

You can avoid a painful sunburn if you check the length of your shadow.

The length of your shadow can tell you if the Sun is higher or lower than 45 degrees. As we saw in the previous chapter, if the Sun is lower than 45 degrees the chance of sunburn is low.

If your shadow is longer than you are tall, the Sun is lower than 45 degrees. If your shadow is shorter than you are tall, then the Sun is higher than 45 degrees and you are in danger of getting a sunburn.

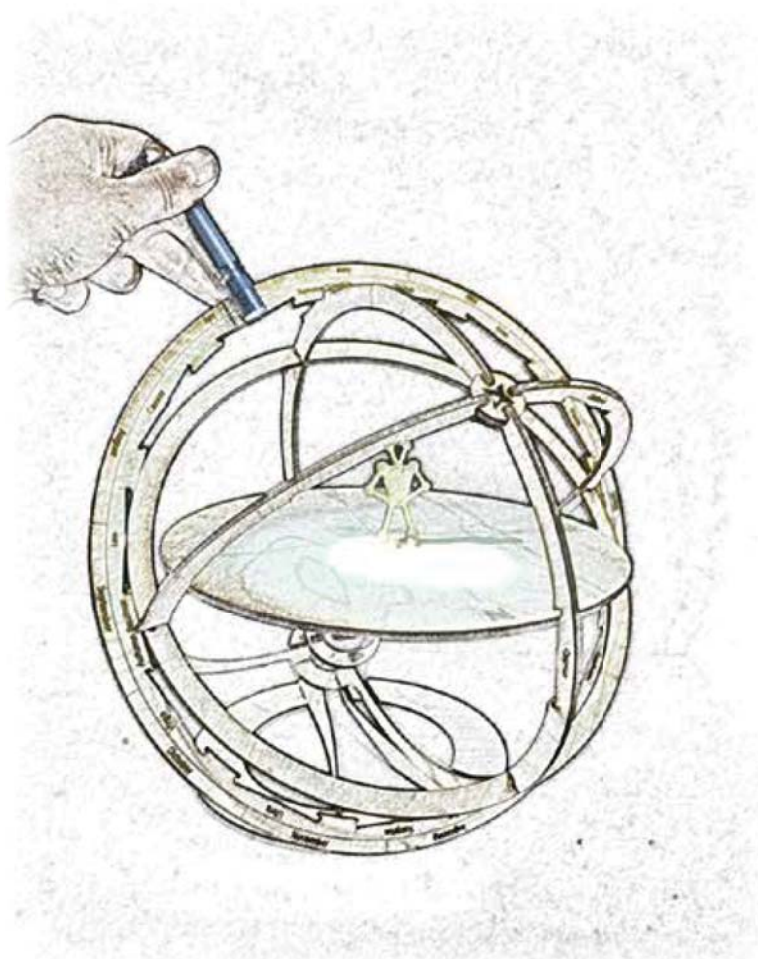
Hold a flashlight near a point on the Ecliptic Ring and shine it on the Observer. How long is his shadow? Try different times of day and different times of year.

Use your knowledge of astronomy to enjoy the sunshine without worry. Stay protected from the Sun when it is dangerous, and enjoy its warmth and light when it is safe.

Shadows

EXERCISE

1. Hold a flashlight up to the globe.
2. Spin the globe and make observations.



There are three things that serve to defeat our intuitive sense of when the Sun is dangerous for sunburn:

When we do get burned, we don't feel it until later. Morning feels safer than afternoon because even though we may have burned at 11:00 a.m., we don't feel it until afternoon.

Solar noon is usually at 1:00 p.m. or later, especially during Daylight Savings Time. Civil time, or clock time is not the same as Sun time, and can be off by as much as 2 hours depending on where you live. Sunburn danger goes by solar time, not civil time.

The Sun changes height faster in the Spring and Autumn than in the Summer and Winter. Use your Horizon Globe to compare the height change of the Sun from March 1 to March 31 and the height change from June 1 to June 30. The altitude changes much more per day in spring than in summer, so in just a few days the Sun goes from pleasant to dangerous for sunburn.

Seasons and the Full Moon

Equipment needed: Horizon Globe, sun, full moon

In earlier chapters, we learned that the Moon travels across the sky daily, just like the Sun. We also know that the Moon is lazy, so it loses almost an hour a day relative to the Sun.

As the Moon falls behind, its angle with the Sun changes and we see different phases as a result.

The Sun takes different paths throughout the year depending on where it is on the ecliptic. The Moon also travels around the ecliptic, so it, too, takes different paths depending on its position on the ecliptic.

We know that the Moon is full when it is opposite the Sun. Place the Sun on your Horizon Globe at the Spring Equinox. For the Moon to be full, it must go on the Autumn Equinox, opposite the Sun.

Spin the globe. Notice that the Full Moon takes the same path as the Sun, just as the autumn Sun takes the same path as the spring Sun.

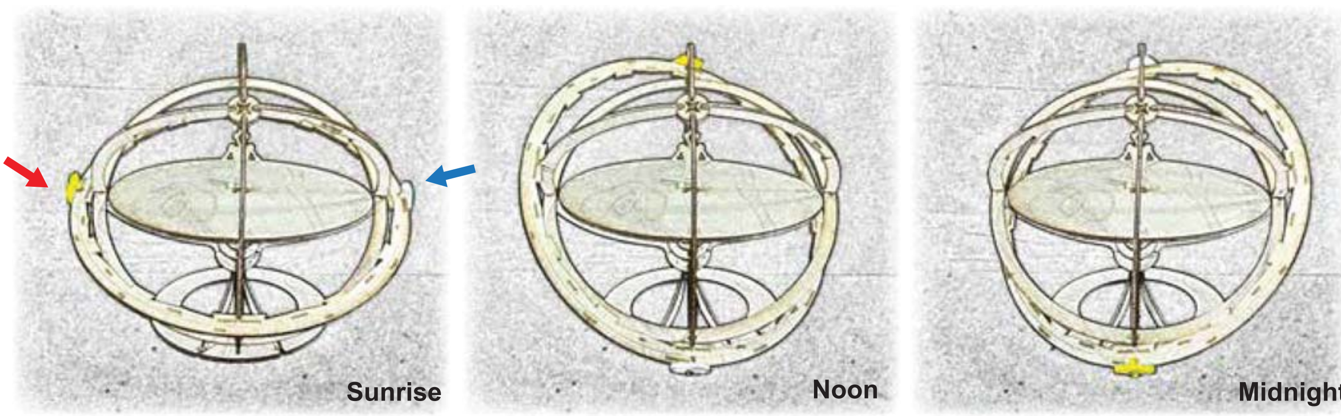
Now move the Sun to summer. The Full Moon now goes in the Winter Solstice position. Now spin the globe. You may be surprised to see that he summer Full Moon takes the low path that the winter Sun takes. Have you ever noticed that you never see a Full Moon high in the sky in summer?

Move the Sun to winter, and the Full Moon to summer. Now we see the Full Moon taking a high path across the sky. Can you remember seeing bright, high Full Moons on cold winter nights? This can be particularly dramatic when the ground is covered with snow.

EXERCISE

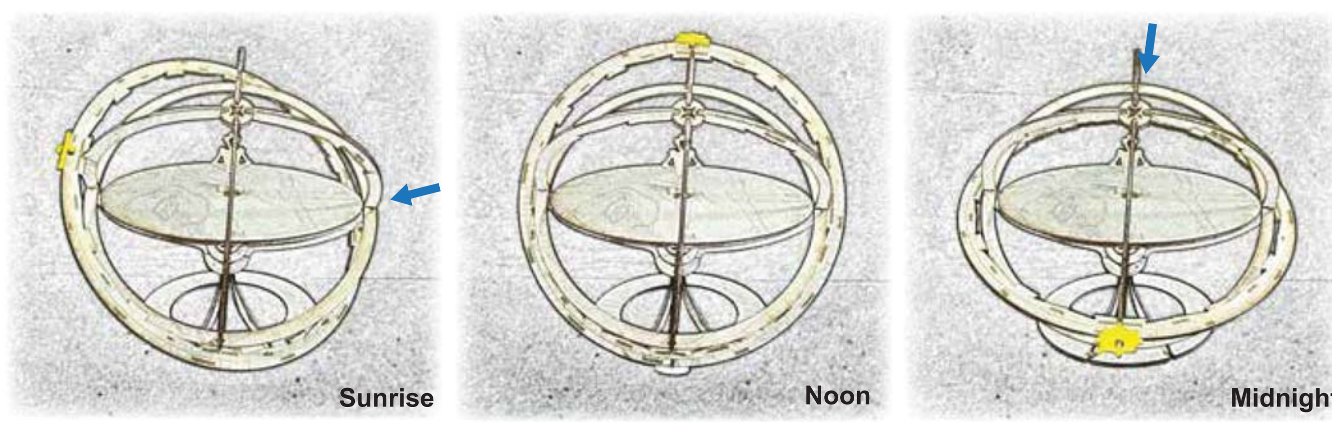
1. Place Sun on "Spring Equinox." Place Full Moon. Spin and observe path of Moon compared to path of Sun.
2. Repeat for Sun starting at "Summer Solstice."
3. Repeat for Sun starting at "Winter Solstice."
4. Repeat for "Autumn Equinox." Notice how the Autumn Equinox and Spring Equinox are about the same.

The full moon in summer is low,
in winter high



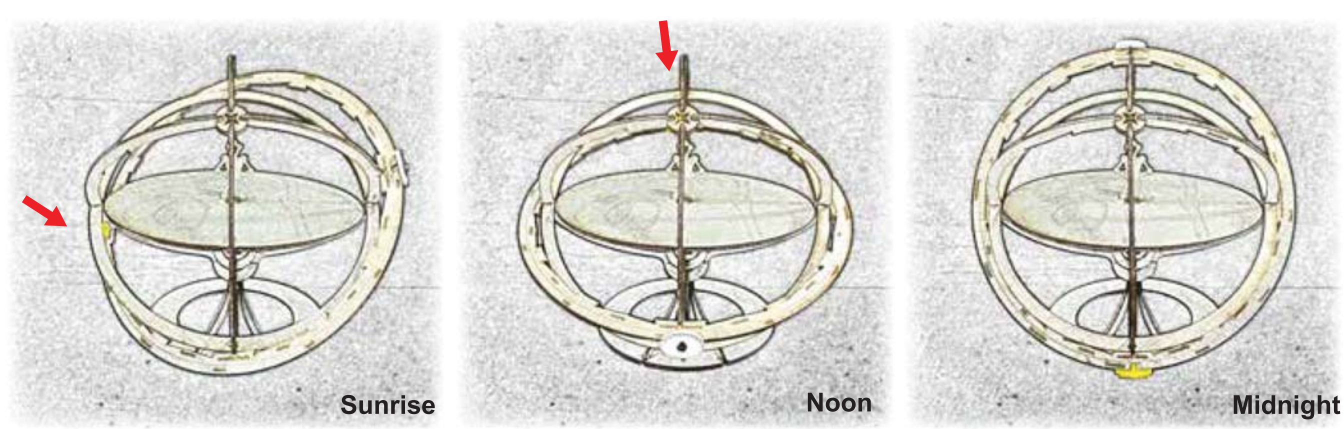
1 & 4

Spring and Autumn Equinoxes



2

Summer Solstice



3

Winter Solstice

Seasons and the Quarter Moon

Equipment needed: Horizon Globe, sun, quarter moon

The Full Moon showed us some interesting facts about the sky. Let's take a closer look at the Quarter Moon and how it acts during various seasons.

Put the Sun at each season, spring, summer, autumn, and winter, and place the Quarter Moon accordingly. Notice how the Quarter Moon is always one season away from the Sun. When the Sun is in spring, the First Quarter is at summer and the Last Quarter is at winter. When the Sun is in winter or summer, both Quarter Moons fall on the equinoxes.

Try the same thing with the Crescent and Gibbous Moons. When you use your Horizon Globe for Moon watching, try to notice the angle of the Moon with the Sun and both of their positions on the ecliptic.

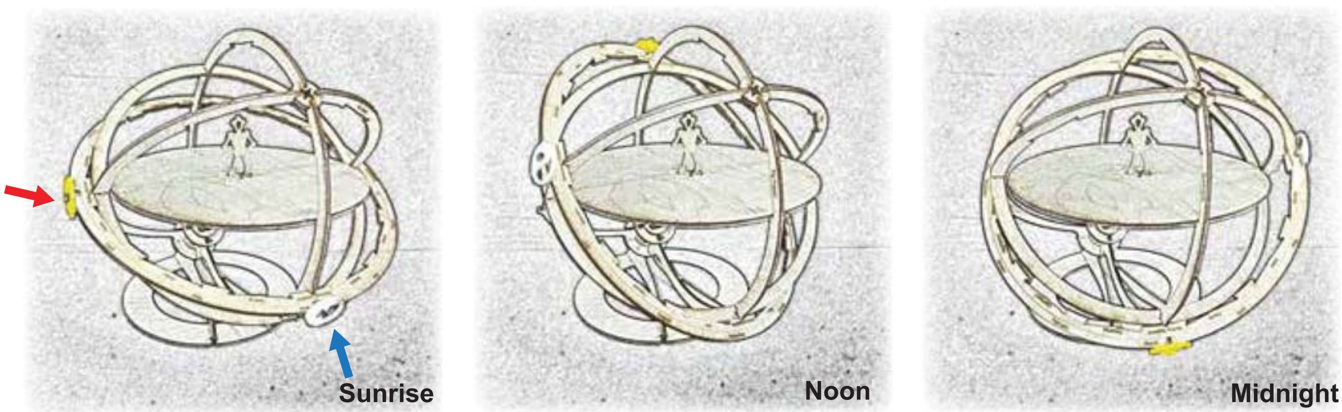
Noticing what part of the ecliptic the Moon is on makes Moon watching fascinating. Since the Moon travels completely around the ecliptic every month, you can see where the ecliptic is all year round, no matter where the Sun is.

Being able to see the ecliptic in your mind will make finding stars, constellations and planets much easier and more fun.

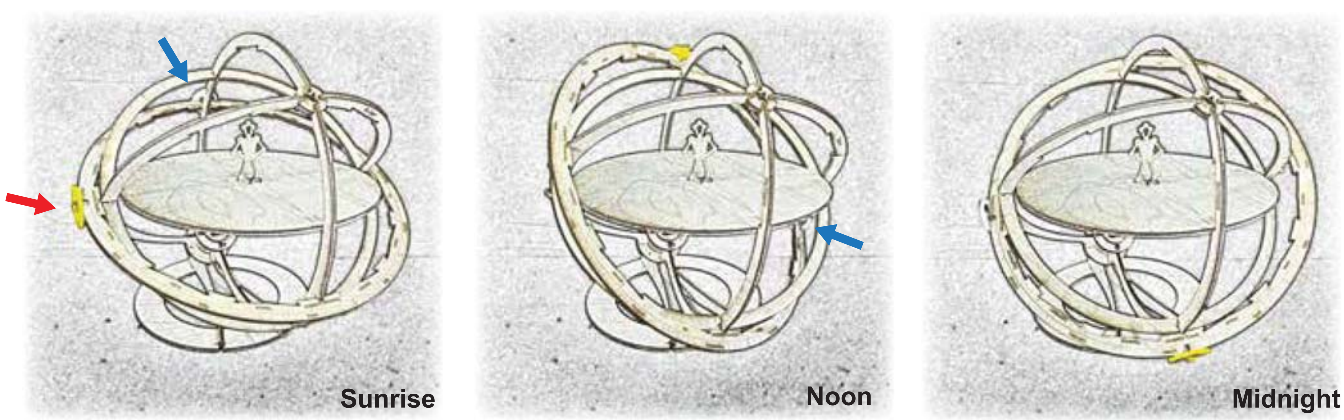
EXERCISE

1. Place Sun on "Spring Equinox" with the waxing Quarter Moon. Spin and notice the path the Moon travels.
2. Replace waxing Quarter Moon with waning Quarter Moon and again spin and notice how the Moon travels.
3. Repeat Exercises 1-2 for the following:
   a. Sun at "Summer Solstice"
   b. Sun at "Autumn Equinox"
   c. Sun at "Winter Solstice"

The Quarter Moon is always one season away from the Sun



1 Spring Equinox and the Waxing Quarter Moon



2 Spring Equinox and the Waning Quarter Moon

Quarter Moon and Seasons

The Quarter Moons will help you imagine the path of the ecliptic.

Find the Ecliptic using the Moon

Equipment needed: Horizon Globe, sun, all moons

You need to track the Sun for a year to define where the ecliptic is, but the Moon shows you every month.

The crafty sky uses two devices to confuse beginning astronomers. One is that everything in the sky turns around once a day. The second is that the Sun, Moon, and planets move along the angled ecliptic. Without a clear understanding the ecliptic, it's hard to imagine sky-watching ever moving beyond chaos.

Hopefully, if you have completed the previous chapters, you have a pretty good grasp of the ecliptic and how the sky works. This last chapter will reinforce that understanding.

Complete the following exercises with your Horizon Globe:

Place the Sun on the Spring Equinox. Then place all four Moon discs at once in their proper places along the ecliptic, first waxing, then waning. Notice how the waxing Moon traces out the high, summer half of the ecliptic, and the waning Moon traces the low, winter half.

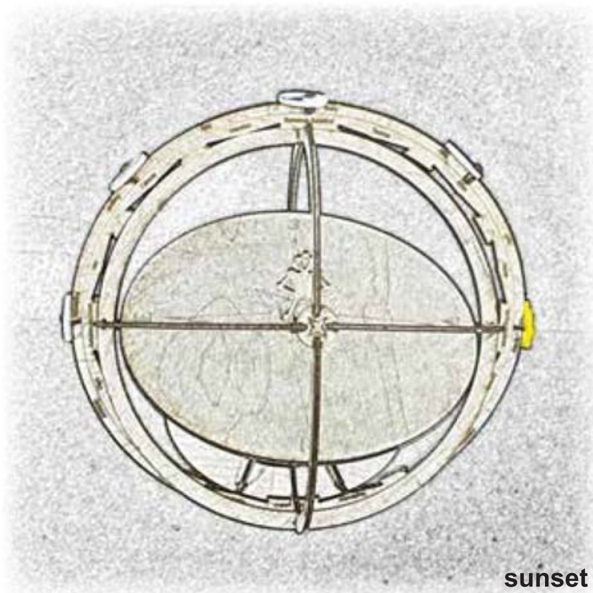
Move the Sun to the Summer Solstice. Again, place all four Moon discs first waxing then waning. Notice how the Moons trace the path of the ecliptic from Summer to Winter.

Of course you never see all the Moon phases together in real life, but seeing them this way on the Horizon Globe can be a powerful reminder of the path of the ecliptic.

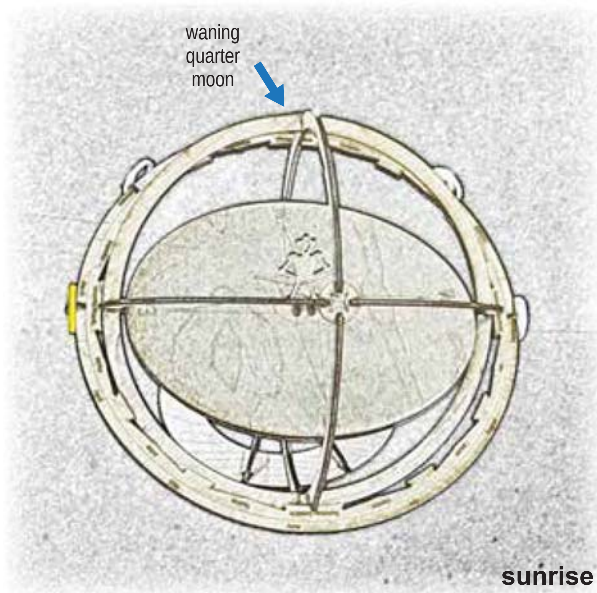
Being able to identify the Zodiac constellations is another way to visualize the ecliptic, but this is a more advanced skill, and only works at night in fairly clear and dark skies. The Moon is a more accessible guide.

EXERCISE

1. With the Sun at the Spring Equinox, place all the Moon discs on the ecliptic in their proper places, first waxing, then waning.
2. Move the Sun to the Summer Solstice and repeat. Notice how the Moon traces out the ecliptic in each case.

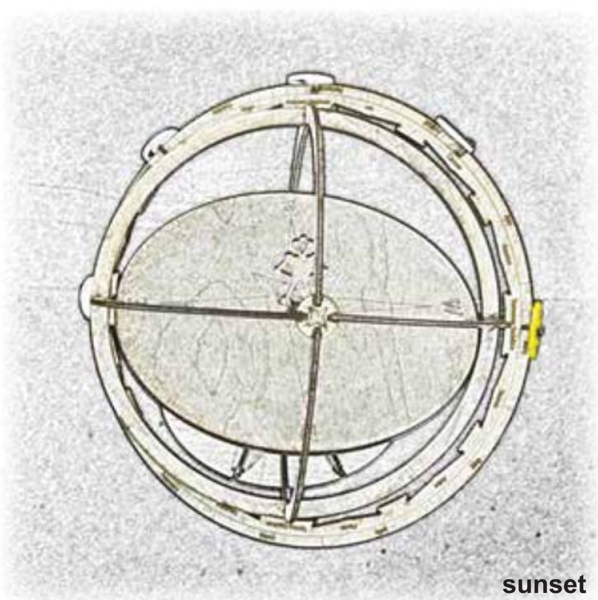


Waxing Moon

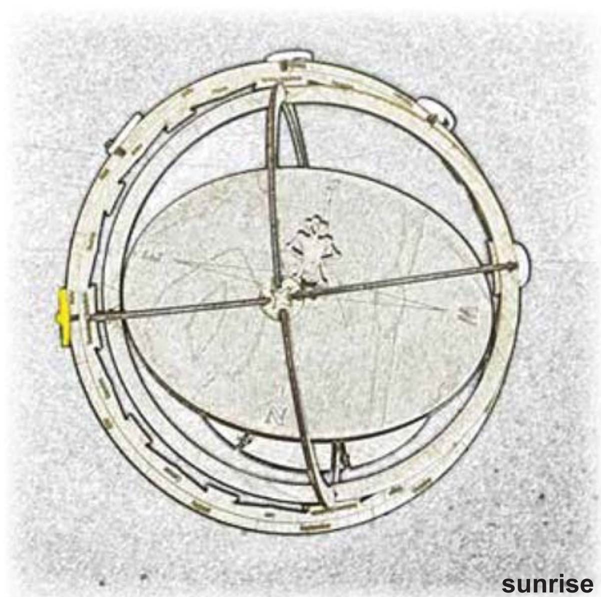


Waning Moon

1 **Spring Equinox**



Waxing Moon



Waning Moon

2 **Summer Solstice**

Learn the Ecliptic using the Magic Horizon Globe

Equipment needed: Horizon Globe, sun, quarter moon, planets

In the last chapter we talked about the importance of understanding the ecliptic. If you can imagine where the ecliptic is in the sky, you'll have an easier time finding the constellations and planets.

We have seen that the rapidly changing position of the Moon can help us visualize the line of the ecliptic.

Now we'll look at the ecliptic from another perspective, a view only possible with the magic Horizon Globe.

Set up your globe with the Sun on "Summer Solstice." Place the constellations, Moon, and planets in their proper place. For our example, we've chosen the summer solstice, June 21, 1969. (See Appendix B for placement of Moon and planets on that date, or choose your own date. What is important is that the Sun is on "Summer Solstice")

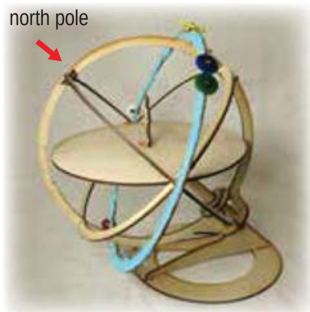
The entire sky and everything in it makes one complete revolution per day. The rising and setting of the Sun is the prime example of this motion. Over time, things in the sky shift relative to each other, but in a single 24-hour day, we can estimate that everything goes around once. Start with the Sun at noon, as shown in the first image on the next page. Spin the globe and follow along with the images. Notice how the Sun, Moon, planets and zodiac constellations are always on the ecliptic and the ecliptic is constantly shifting its orientation in the sky.

(Notice that the ecliptic has been highlighted in aqua blue to make it easier to see).

EXERCISE

1. Put items on globe to model June 21, 1969. Rotate globe, notice how everything moves together over the course of a day.
2. Spin globe to noon on June 21. Notice the location of the ecliptic.
   a. Repeat for 6 p.m., midnight, and 6 a.m.
   b. Notice how the ecliptic changes

The Horizon Globe doesn't really use wizardry. It just seems like it does!



1

Start
Sun about **noon**

Ecliptic
high in the sky
east to west

2

Spin globe 6 hours
to about **sunset**

Ecliptic
diagonal
southeast to northwest

3

Spin another 6 hours
to about **midnight**

Ecliptic
low in the sky
east to west

4

Spin another 6 hours
to about **sunrise**

Ecliptic
diagonal
northeast to southwest

Now let's take a closer look at #1 and #3 above. The Sun is at the noon and midnight positions in these images. You can see how the angle of the ecliptic changes drastically from one to the other. At noon the ecliptic is nearly overhead for the Observer. At midnight the ecliptic is low on the horizon. How does it change from one position to the other?

Let's look at #2 and #4 above. The Sun is at sunset and sunrise, respectively. Here the ecliptic seems to cross diagonally above the Observer. Slowly spin the globe from sunrise, to noon, to sunset, to midnight. Notice how the ecliptic keeps changing direction.

Imagine a summer evening, just after sunset. Because it's the summer solstice, the Sun sets in the northwest. Now that it's dark you have an opportunity to find a few constellations and maybe a planet or two. Where do you look? The Sun rose that morning in the northeast so you might be tempted to look in the same place to find a rising planet, but you'd be disappointed.

Set your globe to sunset, to match #2 above. Where should you look to find a rising planet? What does the magic Horizon Globe tell you? (See answer below)

At the summer solstice, if the sun has recently set, a planet should rise in the **southeast**.

Latitude 45°, 0°, 90°

Equipment needed: Horizon Globe LX, sun

The Horizon Globe LX has adjustable latitude, while the Horizon Globe SE has fixed latitude. For previous observations and examples in this book, we set our adjustable latitude globes to 45° so we could simulate the fundamental motion of the sky. The two globes are equal in their capacity to show the *diurnal*, or daily, turning and the shifting ecliptic.

Now we turn our attention to changing latitude, which can only be shown on the Horizon Globe LX. There are two main benefits to having an adjustable-latitude globe:

1. you can model tropical and Arctic regions of the earth
2. there is greater precision in modeling your location

The fixed-latitude globe showed us the phenomena of different paths and changes through the seasons, but only at an average. As you travel north and south, seasonal changes and celestial object paths actually differ in amount. The relative amounts can only be modeled on an adjustable-latitude globe, the LX. See "Model LX Features" on page 20 for a reminder of how to adjust the latitude on your globe.

EXERCISE

1. Set your Horizon Globe LX to 0° (the equator). Adjust the horizon plate so that it's flat. Put the Sun on the ecliptic, spin and observe.
2. Repeat step 1 with the globe set to 90° (the North Pole).
3. These latitudes will be covered in depth in later chapters. For now, just get familiar with the Sun and changing latitude.

0° (Equator)

45° North

90° North (North Pole)

Latitude Adjustment

Latitude is a measure of how far north or south a place on Earth is located. We measure latitude in degrees, from **0°** at the equator to **90° North** at the North Pole and **90° South** at the South Pole.

Horizon Globe SE is fixed at **45° North**, and that is the latitude used for the examples in this book. The latitude **45° North** runs through the northern part of the United States (Portland, Minneapolis), southern Canada (Montreal), southern Europe (Geneva, Switzerland), and northern China and Japan (north of most big cities in these countries). A latitude of 45° is the perfect starting point for learning observational astronomy for people who live in the Northern Hemisphere. It's best to keep the latitude fixed while you are learning the fundamental motions of the sky, even if you have the LX model globe.

With the adjustable-latitude globe, you can start to look at what happens when you move away from 45° North. When you travel south (decreasing latitude), seasonal changes are less pronounced and celestial objects shift in altitude. If you travel south far enough, you will reach a point that the Sun is directly overhead for part of the year. This area is defined as the *tropics*.

If you travel north from **45° North** (increasing latitude), seasonal changes become more extreme. The most notable are very long summer days and very short winter days. Keep traveling north and you will reach a point where the Sun never sets in the summer and never rises in the winter. This area is called the *Arctic*.

The Arctic and tropics will be discussed in later chapters.

Latitude 45°, 60°, 30°

Equipment needed: Horizon Globe LX, sun

We can use the Horizon Globe LX to see how the sky changes as we travel north and south.

Let's start with our globe set at 45°, the latitude we're most familiar with. Start with the Sun anywhere on the ecliptic and spin the globe one day (one revolution). Notice the Sun's height and the location of sunrise and sunset. Now move the Sun through the seasons. As the Sun travels along the ecliptic, the Sun's noon altitude, rising and setting azimuth, and hours of daylight are constantly changing.

Now adjust the latitude to 60°. Repeat the process of observing the Sun's height, sunrise and sunset. You will notice that rising and setting azimuth and length of day change more radically when you move farther north. Also note that Cygnus becomes a circumpolar constellation.

Repeat for 30° latitude. Notice how rising and setting azimuth and length of day change less at lower latitudes. This far south the Big Dipper and Cassiopeia lose their status as circumpolar, they dip just below the horizon.

The Horizon Globe LX is labeled for use in the Northern Hemisphere (North America, Europe, Asia), so it can model areas from the equator to the North Pole.*

*You can model the Southern Hemisphere (South America, Africa, Australia), but you must ignore or change the labels.

EXERCISE

1. Set your Horizon Globe LX to **45°**, Sun at "Summer Solstice"
2. Spin the globe and notice the Sun's noon altitude, rising and setting azimuths, and length of day. Repeat for autumn, winter, spring.
3. Change latitude to **60°** (e.g. Anchorage, Alaska) and repeat.
4. Change latitude to **30°** (e.g. New Orleans, Louisiana) and repeat.

Set globe to 45° latitude

1

2

Put Sun at Summer Solstice. Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

Repeat for:

- Autumn Equinox
- Winter Solstice
- Spring Equinox

Set globe to 60° latitude

3

Put Sun at Summer Solstice. Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

Repeat for:

- Autumn Equinox
- Winter Solstice
- Spring Equinox

Set globe to 30° latitude

4

Put Sun at Summer Solstice. Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

Repeat for:

- Autumn Equinox
- Winter Solstice
- Spring Equinox

Latitude by Observation

It's easy to set latitude on your Horizon Globe LX using the protractor. But could you find your latitude by astronomical observation?

In the last chapter we set the LX to various latitudes and watched for changes in the Sun's position and saw some differences in how constellations behave. For example, the Big Dipper becomes circumpolar at northern latitudes but not at more southerly ones.

The easiest way to measure your latitude on Earth is to find the altitude of **Polaris**, the North Star. In the Northern Hemisphere, your latitude is always equal to the altitude of **Polaris**. In fact, if you get good at estimating the angle of **Polaris** above the horizon on your LX Model, you wouldn't even have to use the protractor to set the latitude. **Polaris** makes it easy to measure your latitude because it never moves, just rotates. But you can find latitude by measuring any celestial object if you know its position on the celestial sphere.

Another convenient star for measuring latitude that is popular with mariners is **Mintaka**, the top right star in Orion's belt. This star is special because it is easy to find and is very nearly on the Celestial Equator, exactly 90° from **Polaris**.

If you measure the altitude of **Mintaka** at its highest point as it crosses the sky (when a star reaches its highest point we say it culminates) you know the altitude of the Celestial Equator. Your latitude is always 90° minus the altitude of the Celestial Equator.

Mariners use charts to calculate their latitude by measuring **Mintaka** even when it is not culminating. They also know other stars so they can navigate by the stars any time of year or time of night.

The Sun also crosses the Celestial Equator twice per year, so it's easy to find latitude from the noon Sun on the spring and autumn equinoxes. Actually, you can find latitude by the altitude of the noon Sun on any day of the year, it just requires a little more calculation.

EXERCISE

1. Practice determining latitude by estimating the altitude of Polaris. Move Polaris to a random altitude on your globe and try to guess the latitude. Check the protractor to see how close you got.
2. Repeat using Mintaka and subtracting the altitude of the Celestial Equator from 90° to find latitude. It doesn't take long to get good at it!

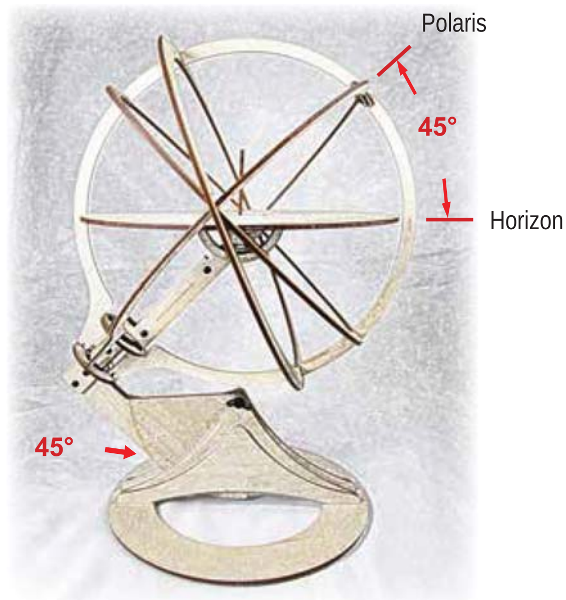
Find Latitude using Polaris, the North Star

Polaris
the North Star

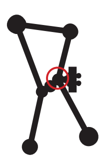
1

Use Polaris to estimate your latitude
(shown here at 45°)

- Move **Polaris** to a random altitude.
- Try to guess the latitude.
- Check the protractor to verify.



Find Latitude using a Star on the Celestial Sphere



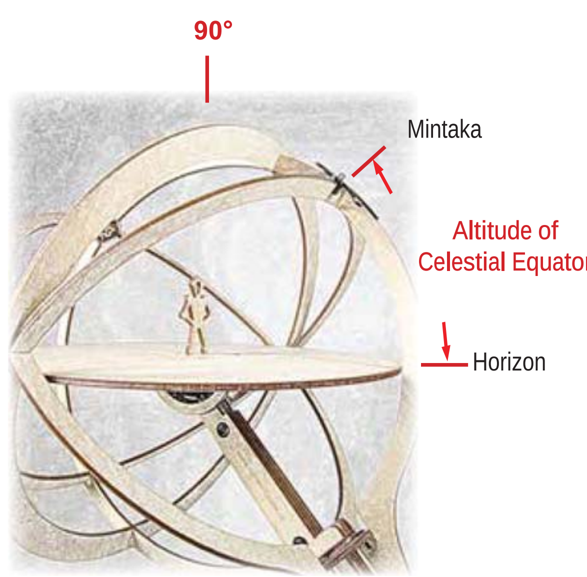
Mintaka
is the top-right star in Orion's Belt

2

Use a star to find your latitude
(Mintaka in this example)

Mintaka
sits nearly on the celestial equator

- Move **Mintaka** to a random altitude.
- Subtract that altitude from 90°.
- Check the protractor to verify.



Equator 0°

Equipment needed:
Horizon Globe LX, sun

We saw how we can use the Horizon Globe LX to show how the sky changes as we travel north and south. Let's take a trip south all the way to the equator.

Set your globe to 0° latitude. This represents standing on the Earth's equator

We'll move the Sun through the seasons again, just as we did in the last chapter, but this time with the globe set to 0° latitude. Put the Sun at the Summer Solstice, spin the globe, and notice: maximum altitude of the Sun, the changes in the azimuth of sunrise and sunset, and the length of the day.

There are some interesting things to observe. We remember that in more northern latitudes the Sun's maximum altitude is on the Summer Solstice. At the equator the maximum altitude occurs on the Spring and Autumn Equinoxes.

Notice also the change in azimuth of sunrise and sunset. Only at the equator is the change in azimuth the same number of degrees as the change in altitude. This is the smallest azimuth change of sunrise and sunset of any place on earth.

You may be surprised to see that the length of day never changes on the equator. Move the Sun through the seasons to prove this to yourself.

Also notice that there are no circumpolar constellations at the equator; everything rises and sets every day.*

*except maybe the North Star, but even Polaris moves in a little circle, even if it is too small to notice

EXERCISE

1. Set Horizon Globe to 0°. Put the Sun on "Summer Solstice."
2. Spin the globe and notice the Sun's noon altitude, rising and setting azimuths, and length of day.
3. Repeat Step 2 for autumn, winter, and spring.

Set globe to 0° latitude

Equator

1

Put Sun at Summer Solstice

2

Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

3 **Repeat for:** Autumn Equinox ● Winter Solstice ● Spring Equinox

Autumn Equinox
Sun at noon

Winter Solstice
Sun at noon

Spring Equinox
Sun at noon

Tropics

Equipment needed: Horizon Globe LX, sun

In the last chapter, we saw what happens at the equator. Now let's move somewhat north and explore another interesting and significant location, the *tropics*.

In past exercises we set the latitude first, then looked at what that did to the Sun position. In this exercise, we're going to reverse that and put the Sun on the ecliptic first, and then adjust the latitude.

If we start from 0° latitude, when we place the Sun on the globe at the Summer Solstice we see that at noon the Sun is not overhead for the Observer. Adjust the latitude so that the Sun is overhead for the Observer, and this latitude defines the edge of the tropics. A tropical place is defined as a place where the Sun reaches directly overhead at some point during the year.

Check the protractor of your globe, and you will see that it is 23.5 degrees. If you move any further north, the Sun never quite reaches the spot directly above the Observer, even on the longest day of summer. South of this tropic, the Sun reaches straight up on two days per year, one day when the Sun is moving from south to north, and one when the sun is moving from north to south. In the tropics, the Sun follows the pattern of migrating birds, north in the summer and south in the winter.

Which Zodiac constellation is the Sun near on the summer solstice? Gemini is the nearest, so the logical name for this latitude would be the "Tropic of Gemini." But unluckily, the tropics were named thousands of years ago and the stars have moved since then. The northern tropic is called the *Tropic of Cancer*.

Move the Sun through the seasons at the Tropic of Cancer and notice our three usual variables: noon altitude, rising and setting azimuth, and length of the day and night.

EXERCISE

1. Put the Sun on "Summer Solstice". Spin globe so Sun is at noon.
2. Adjust the latitude until Sun is directly overhead for the Observer.
3. Check the latitude markings on the globe, should be 23.5 degrees.
4. Spin globe and notice altitude, azimuths, hours of daylight.
5. Repeat for autumn, winter, spring.

Tropics

1

Put Sun at Summer Solstice

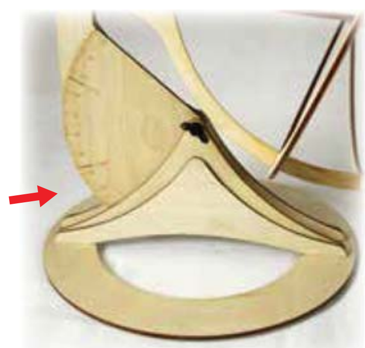
Notice that the Sun is not directly overhead at noon for the Observer, it is shifted to the north

2 3

Start from 0°

Adjust the latitude until Sun is directly overhead at noon

What latitude do you see?



4

Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

5

Repeat for: Autumn Equinox • Winter Solstice • Spring Equinox

North Pole 90°

Equipment needed: Horizon Globe LX, sun

We've seen what happens at the equator and at the tropics. Now let's move all the way north to 90° latitude. This will represent standing at the North Pole, and let's just say this right away: things get very strange at the North Pole.

Set your globe to 90° latitude. This represents standing at the North Pole

Time gets weird, directions get funky, and our whole notion of what day and night mean crumbles. Put the Sun at the Summer Solstice and spin the globe. Notice how the Sun doesn't rise and set like we are used to. It just goes around in a circle. At the North Pole you could use the altitude of the Sun as a calendar (instead of a clock!) in the summer months.

How about making a sundial at the North Pole? You could just stick a pole in the ice and the shadow will act like the hand on a clock. You could find the time of day by measuring the azimuth of the Sun. But here's where it gets tricky: since there is no "north" direction at the North Pole, it doesn't matter where you start from. Just choose somewhere to start and measure the arc the Sun makes as it moves. Voila, an easy sundial.

Day and night are peculiar at the pole, too. We usually think of a day as part of a 24-hour period, with some daylight and some nighttime. But at the North Pole, instead of rising and setting in a day, the Sun rises in the spring and sets in the autumn. Does that mean that there's only one "day" in a whole year? No wonder the cartoon character Bugs Bunny was glad to vacation here. That would mean his two-week vacation would last fourteen years!

At the North Pole, all the stars and constellations are circumpolar. Never rising or setting, they just go round and round. Stars are easier to find, but there are fewer to see. Only half of the zodiac constellations can ever be seen from the North Pole.

EXERCISE

1. Set Horizon Globe to 90°. Put the Sun on "Summer Solstice."
2. Spin the globe and notice the Sun's noon altitude, rising and setting azimuths, and length of day.
3. Repeat Step 2 for autumn, winter, and spring.

SET GLOBE TO 90° LATITUDE

North Pole

1

Put Sun at Summer Solstice

2

Spin globe and notice:

- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

---

3 **Repeat for:** Autumn Equinox • Winter Solstice • Spring Equinox

Autumn Equinox
Sun at noon

Winter Solstice
Sun at noon

Spring Equinox
Sun at noon

The Arctic

Equipment needed: Horizon Globe LX, sun

In the last chapter, we saw the quirkiness of the North Pole. Now let's move somewhat south from there and hope that everything returns to normal. Let's look at the *Arctic*.

To find the Arctic Circle, we'll use a process similar to how we found the tropics. We'll put the Sun on the ecliptic, then we'll adjust the latitude.

First place the Sun on the Summer Solstice position and spin the globe. We can see that the Sun just goes around in a circle, never changing in height. Spin the globe so that the Sun is to the north. Now adjust the latitude to the point where the Sun sinks just to the level of the horizon at midnight. Check the latitude on the LX globe protractor, it should read 66.5°. Every place north of here experiences the *Midnight Sun* during the long days of summer, and 24 hours of darkness in the middle of winter.

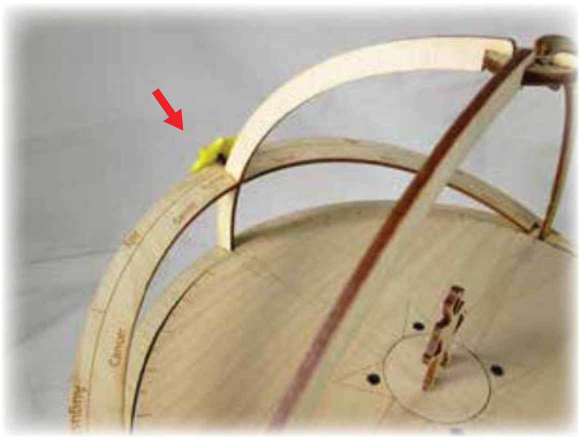
The Midnight Sun is an interesting phenomenon where the Sun stays visible all night, even at midnight. It occurs at high latitudes, and the Sun is not the only celestial object affected. With your globe set to the Arctic, put the Moon through its phases at different times of year. In winter, when the Sun doesn't rise, the full Moon stays out all night. In summer, when the Sun is out all day and night, the full Moon never appears.

A similar pattern plays out with the planets. When planets are near the winter solstice, then they are either never visible or peek just above the horizon, depending on your exact position and time. When the planets are on the summer solstice part of the ecliptic, they stay above the horizon for extended periods.

EXERCISE

1. Put Sun on "Summer Solstice". Spin globe so Sun is to the north.
2. Adjust the latitude until the Sun is just below level of the horizon.
3. Check the latitude markings on the globe, should be 66.5 degrees.
4. Spin globe and notice altitude, azimuths, hours of daylight.
5. Repeat for autumn, winter, spring.

The Arctic



1

Put Sun at Summer Solstice

Spin the globe and notice that you can't tell noon from midnight by spinning the globe

Spin so that Sun is due north

2 3

Start from 90°

Adjust the latitude until the Sun is just below the horizon at midnight

What latitude do you see?

4

Spin globe and notice:
- How high is the Sun at noon?
- What is azimuth of Sun at sunrise and sunset?
- About how many hours of daylight?

5

Repeat for: Autumn Equinox ● Winter Solstice ● Spring Equinox

Twilight

Equipment needed: Horizon Globe LX, sun

The time between when the Sun sets and when it actually gets dark outside is a special time. You might not think much about this transition time between day and night, but if you visit Alaska you will probably notice something a little different from what you are used to.

Let's visit Alaska on June 21st, the Summer Solstice. If you happen to be north of the Arctic Circle, you experience a day where the Sun never sets This is the Midnight Sun that we talked about in the previous chapter. But if you travel further south, for example Fairbanks, Alaska, you'll notice that on June 21st that the Sun sets but it never gets dark outside. The reason is that the Sun doesn't get far enough below the horizon for darkness to be complete before it rises up again.

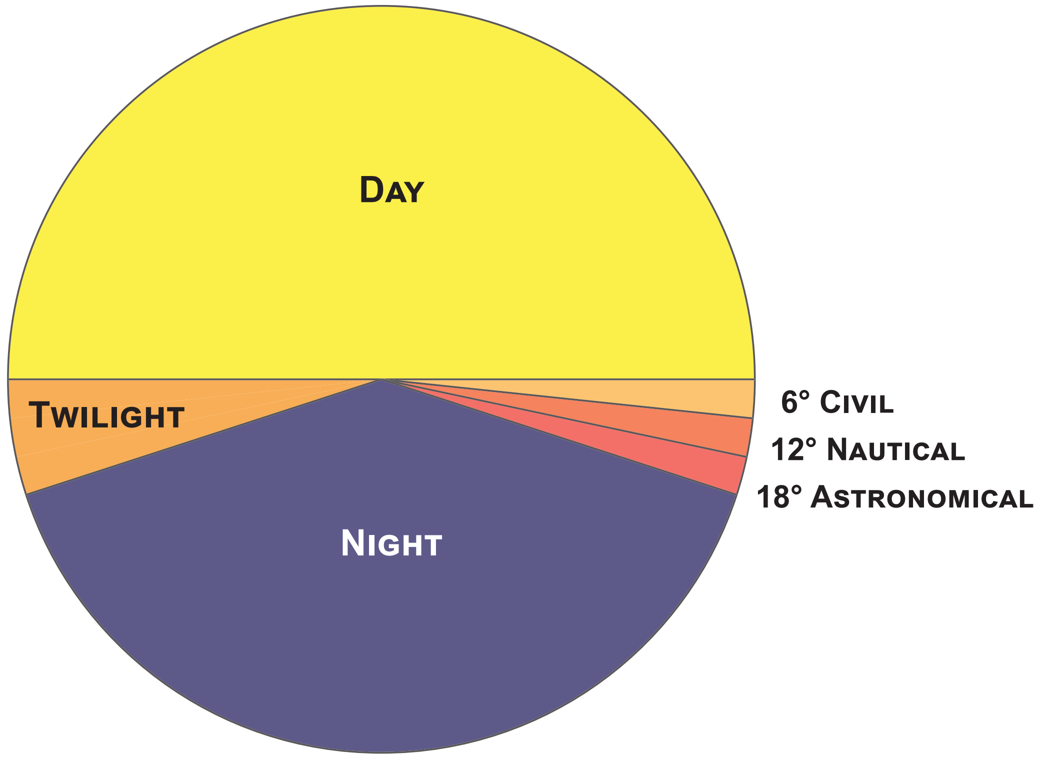
The time after sunset but before complete darkness is called *twilight*, or dusk. Similarly, the time before sunrise is also considered twilight, but is better known as dawn. The morning and evening twilights, dusk and dawn, are mirror images of each other.

Twilight is defined in three stages: Civil, Nautical, and Astronomical.

Compare twilight at near Arctic regions to tropical regions. Notice that northern latitudes have longer periods of twilight than latitudes closer to the equator.

EXERCISE

1. Put Sun on "Summer Solstice".
2. Adjust latitude to the tropics, observe length of twilight.
3. Change latitude to the Arctic, observe length of twilight.
4. Compare the two--which twilight seems longer?



	CIVIL	NAUTICAL	ASTRONOMICAL
Time between day and night, when it's still light outside but Sun has set is known as **TWILIGHT**	Sun is between horizon and 6° below the horizon	Sun is between 6°-12° degrees below the horizon	Sun is between 12°-18° degrees below the horizon
Morning Twilight is also known as **DAWN**	Morning Sun is 6° below horizon	Morning Sun is 12° below horizon	Morning Sun is 18° below horizon
Evening Twilight is also known as **DUSK**	Evening Sun is 6° below horizon	Evening Sun is 12° below horizon	Evening Sun is 18° below horizon
	During twilight there is still enough light outside for most activities without outdoor lighting	After nautical dusk it is too dark for sailors to navigate by the horizon	After astronomical dusk the sky is not illuminated by the Sun at all and we get complete darkness

What Do You Know

We hope you have enjoyed learning about astronomy using your Horizon Globe. If you have done and understood the exercises in this book, you know more about observational astronomy than most people, even some who know a lot about deep-space astronomy.

Enjoy your new knowledge of the sky. There is **great joy** to be had from the basics of astronomy. You don't need telescopes or sky maps to enjoy these things on a daily basis. There is always something fun to watch, the Sun changing through the seasons, the monthly Moon cycle, nightly stars and planets.

You can **tell time by the Sun.** Any time you see the Sun, you can notice how its position relates to the time of day. At night you can estimate how far below the horizon the Sun must be. Noticing where the Sun rises and sets and which direction it is highest at noon can help you find directions. Enjoy noticing how the direction of sunrise and sunset relate to the day of the year.

Moon watching will never be the same. You know the Moon follows the Sun, but is lazy and falls behind by almost an hour per day. Notice how the angle between the Sun and Moon determine the shape, or phase of the Moon. It's fun to see the Moon and know where it will be tomorrow.

But that's not all. Any time you see the Moon you can try to imagine where it is on **the ecliptic**. It may be much farther north or south than the Sun, or it may be the same. Don't try to explain it to your friends without a Horizon Globe!

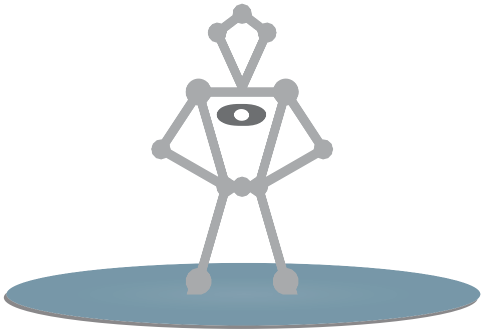
When the Sun goes down, **watch for planets**. Is Venus out? In the evening or in the morning? Jupiter shines bright on most nights, but check the calendar, he may not appear until the wee hours of the morning. Try finding Saturn. Are you sure it's not a star? When Mars gets super-bright for a few months every two years, you will know what is going on.

Any time you see stars in the sky, feel the confidence of knowing at least one important constellation, whichever guidepost is high. You know the significance of **the Zodiac** and their order on the ecliptic. Tell your friends what makes them a Leo or a Scorpio!

On the following page is a summary of some of the things we've covered in this book. In the next installment of the series we'll talk more about constellations and great ways to remember how to find them. Stay tuned!

Anyone who reads this book will know a substantial amount of observational astronomy.

–THE OBSERVER



More Q&A with the Observer

Q. I read the whole book and I still don't know the trick to astronomy that you promised to tell.

A. It's because the trick seems too easy. You probably didn't even recognize it!
It's actually 2 tricks:
#1 Everything goes around once per day
#2 The Sun, Moon, and Planets all travel on the ecliptic.

Q. That does seem too easy. Is there more?

A. Well, yes and no.
#1 Everything goes around once per day
(but over larger time spans things shift relative to each other)
#2 The Sun, Moon, and Planets all travel on the ecliptic.
(and remember that the ecliptic is sneaky--it's constantly shifting, but the Observer can help you figure it out). See page 158.

Q. This book is not like some other science books I've read. Why?

A. We hope you mean that in the best possible way. Many science books do jump right into the deep water of theory. The Observer likes to keep it close to the shore.

Summary

A brief summary of what was covered in this book:

Astronomy

- Why astronomy?
- Different types of astronomy: Observational, Solar System, Deep Space

The Sun

- How to tell time by the Sun
- How to talk about where celestial bodies are: angles, hours

The moon

- Full moon is opposite the Sun
- Crescent Moons are near the Sun
- Quarter Moons are 90 degrees from Sun
- Gibbous Moons are far from Sun, but not yet full
- Waxing Moons are lagging behind the Sun and growing
- Waning Moons are ahead of the Sun and shrinking
- Moon phases make a complete cycle in a month
- How to use a Moon Calendar to find the current phase
- How to map the ecliptic using the Moon or the Horizon Globe
- How to use the Horizon Globe to get a mental map of the motion of the ecliptic

Constellations

- How to find a guidepost constellation: Orion, Cassiopeia, Cygnus, Big Dipper
- How to find Orion, day or night
- Zodiac constellations, names and locations

Planets

- Which planets are easily visible: Venus, Mars, Jupiter, Saturn
- How the motion of Venus differs from the rest
- How to make sure it's a planet and not a star
- How to use the Moon and Planet Calendars to find any planet

Seasons

- What causes seasons
- Altitude, azimuths, length of day
- How to avoid sunburn
- How the Moon changes with seasons

Latitude (for Model LX only)

- What happens at lower latitudes like the equator and the tropics
- What happens at higher latitudes like the North Pole and Arctic Circle
- Twilight, dusk, and dawn for Civil, Nautical, and Astronomical

Astronomy compels the soul to look upwards and leads us from this world to another.

-PLATO

Remember these TWO IMPORTANT THINGS about the sky:

1. Everything in the sky makes **one complete turn every day**
2. The Sun, Moon, and planets **all travel on the ecliptic**

Over longer periods of time, we can notice things moving at different speeds:

Object	Speed
Sun	Makes one turn in 24 hours or 1 day. The Master of the Sky. We measure speed of other objects compared to the Sun.
Moon	Lazy. Slower than the Sun. Lapped by the Sun every 30 days
Stars (Orion)	Faster than Sun by 4 minutes per day. Laps the Sun in 1 year
Saturn	Faster than Sun. Laps the Sun in 1 year, 2 weeks
Jupiter	Faster than Sun. Laps the Sun in 1 year, 1 month
Mars	Faster than Sun. Laps the Sun in 2 years, 2 months

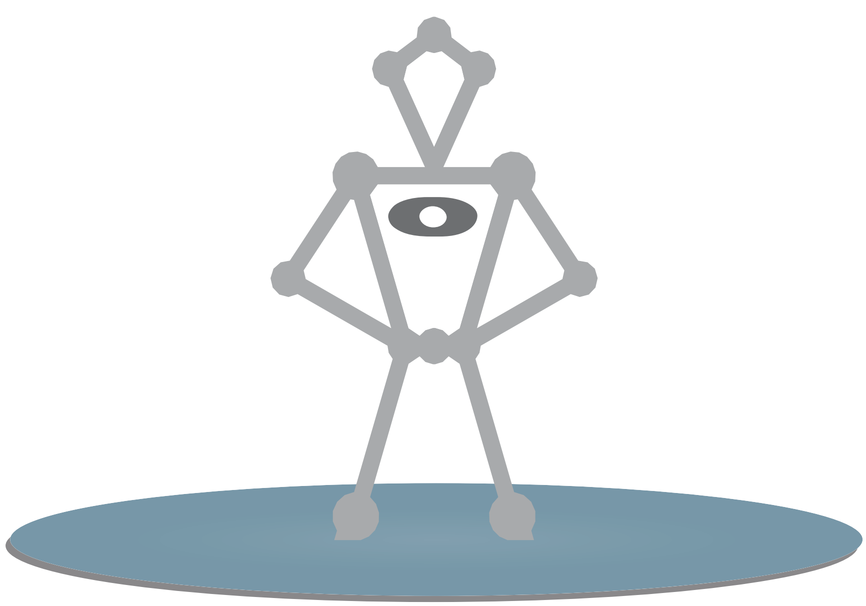
Review

What's Next?

If you have learned the contents of this book you have an excellent foundation in basic astronomy.

At this point you may be surprised at what we didn't include here. We did not talk about planets going around the Sun, or about galaxies or black holes. We purposely left those things out. A proper start in astronomy requires that you know the basic workings of the sky: the daily turning and the complexity caused by the angled plane of the ecliptic. All more advanced study of astronomy depends on this.

Hopefully, after studying the material in this book you are eager to learn more. Now that you understand the Sun, the Moon, planets, and how stars move, the next step is to learn the shapes of the major constellations and how to find them. Your Horizon Globe gives you the general layout of the sky and how it moves, but finding additional stars and constellations beyond the guidepost constellations is another skill. The next book of this series will present the sky as an unforgettable story that will make finding your favorite constellations a piece of cake.



Work hard to find something that fascinates you. When you find it, you will know your lifework.

–RICHARD P. FEYNMAN

Horizon Globe will be publishing a guide to finding stars and constellations based on the guidepost-system presented in this book. In the meantime, we have two books to recommend that we think are the best resources out there for stargazing:

The Stars: A New Way to See Them
H.A. Rey

This book was a major influence on getting us into astronomy and showing us how to do it. It makes a great sky encyclopedia, but does not offer a guidepost-type way to systematically learn the constellations.

The Stars: Learn the Bright Stars and Important Constellations
Tom VanDamme and David Harriman

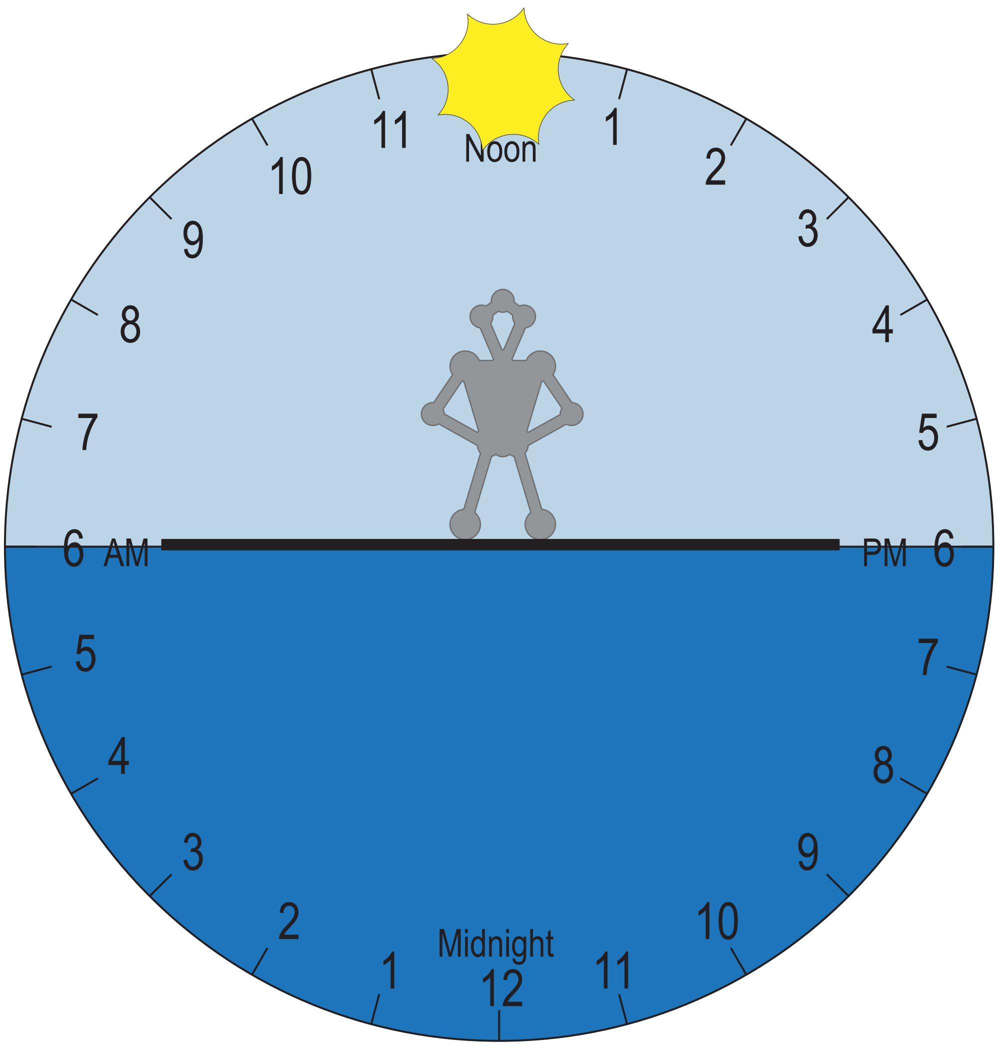
This book is available through Amazon. It outlines an easy way to learn the major constellations based on the guidepost system. This book shows a great way to learn the stars, but its black-and-white format makes the constellations harder to imagine. The H.A. Rey book listed above gives you a better feel for how the constellations look in the sky.

If you wish to advance into applying math to astronomy, Falling Apple Science Institute has published two more books that show step-by-step how to measure the Earth, understand sundials, measure the sky, understand and predict solar and lunar eclipses, and other mathematical astronomy.

Early Astronomical Measurement I
Tom VanDamme and David Harriman

Early Astronomical Measurement II
Tom VanDamme and David Harriman

Both of these books are available through Amazon.



11
Noon
1
10
2
9
3
8
4
7
5
6 AM
PM 6
5
7
4
8
3
9
2
10
Midnight
1
12
11

Appendix A: Solar Time and Civil Time

In this book, when we say "noon" we mean the time of the day when the Sun is at its highest point. This is *solar time*, which is based on Sun position. Your watch may not (and probably won't) read "noon" when it is solar noon. If you're curious about why this is so, read on.

In astronomy, the time of day means "where is the Sun?" When the Sun is at its highest point we say it is noon. Opposite that, when the Sun is at its lowest point below the horizon we say it is midnight. This is a great system, and it was used to tell time for most of history. But when people started to communicate by telegraph and travel by train problems arose.

Time gets tricky when you instantly communicate long distances or travel rapidly. The north-south direction is not really an issue. It's easy to tell how far north and south you are on Earth (your latitude) by taking simple altitude measurements of, say, **Polaris** or **Mintaka**. For how to make these measurements, see "Latitude by Observation" on page 164. The east-west direction, however, is another story. To figure out how far east and west you are on Earth (your *longitude*) is fairly complicated.

An astronomer in North America at a particular latitude sees exactly (almost) the same sky as an astronomer in China. The person in China just sees it up to 12 hours earlier (or later). As the Sun travels across the sky from east to west, you could follow it. If you moved fast enough (750 mph at 45° latitude), you could enjoy noon 24 hours per day. Another way to look at it is that noon sweeps across the Earth like the hand of a clock. See "Telling Time With a Special 24-Hour Clock" on page 28 for review. Your experience of noon (Sun highest in the sky) depends on how far east and west you live.

Now, back to the telegraph and train. Everyone today has some sort of mechanical or electronic clock to tell the time. We don't set our clocks by the Sun anymore, rather the government of each place decides what the time will be in that region. This system (*civil time*) took over from solar time in the 19th century when electronic communication and rapid travel by train became common. The result is that your watch doesn't necessary correspond to solar time, even if you set it correctly.

By convention, the Earth is divided into 24 time zones. Everyone in a particular time zone sets their clock to the same time. If you are on the eastern edge of your time zone, you experience solar noon about an hour before someone on the western edge, even though your clocks are set the same. Only one exact longitude of a time zone will experience civil noon at the same time as solar noon. Everyone else will be off a little.

To make matters worse, some governments decree *Daylight Savings Time* (DST). During DST everyone sets their clock one hour ahead. If you live at the western edge of a time zone, civil noon can be up to two hours before solar noon. Talk about confusing!

Luckily, for our purposes solar time is sufficient, and we can ignore civil time for now. When we say "noon", we mean that the Sun is at its highest in the sky.

Appendix B: Moon and Planet Calendars

The Moon and Planet Calendars are easy to use.

- Place the Sun on your Horizon Globe on the day of interest and turn the Sun to noon.
- Check the date to find the Moon phase.
- Hold the calendar over the North Pole and place each planet according to its clock position. Use the Zodiac, Guideposts, Solstice and Equinox lines to confirm positioning.

The Moon and Planet Calendars provide a snapshot of where the planets are on the 21st day of each month. We chose the 21st to align with the Solstices and Equinoxes. Of course the planets don't jump from month to month, they move continuously. For greater accuracy, use the adjacent months to interpolate planet positions.

Year

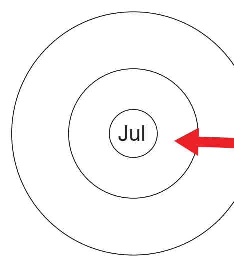
Start by finding the year of interest

1969

Year is listed at the top of the page

Month

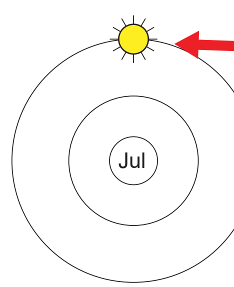
Next, find the month of interest



Month is in the center of the circles

Day & Hour

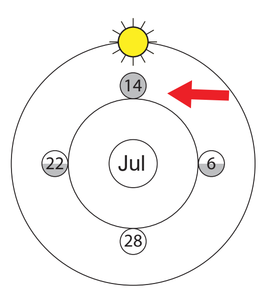
Place the Sun on your Horizon Globe on the day of interest. Turn it to noon.



The Sun is always shown at noon on the ecliptic ring. You are looking down at the Ecliptic Ring from the North Pole.

Moon Phase

Find the phase of the Moon for the day of interest. Interpolate to find the dates of Crescent and Gibbous Moons. (see page 60).

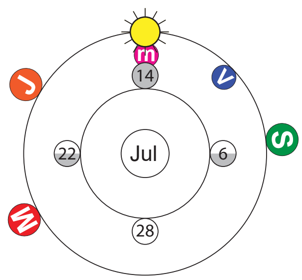


Moon phases. New Moon near the Sun, Full Moon opposite. Numbers indicate the date of each phase.

Planets

Planets are shown as colored circles with letters inside. As you look down from the North Pole, place each planet in its clock position from the noon Sun.

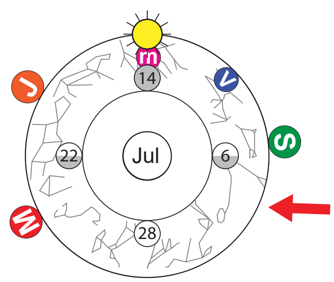
- J Jupiter
- M Mars
- S Saturn
- m Mercury
- V Venus



If a planet seems to be missing, it may be covered up, or *occulted*, by another planet. Check adjacent months to confirm.

Zodiac

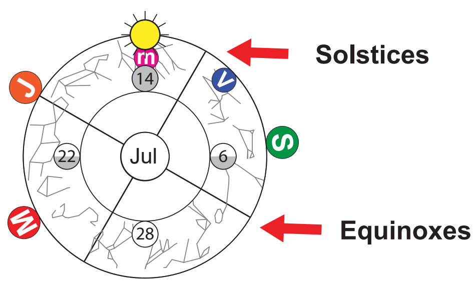
Notice that the Zodiac constellations are shown for reference. You don't need a chart to know where these are, they are the same every year.



Zodiac constellations in order.

Solstice and Equinox

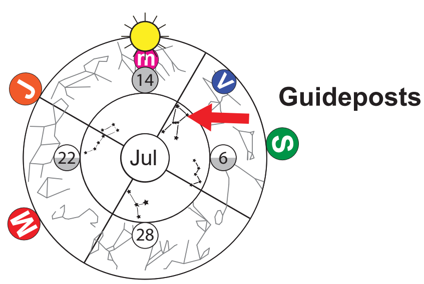
The straight lines mark the Solstices and Equinoxes. They are not labeled, but you can tell which is which by the month and the Zodiac.



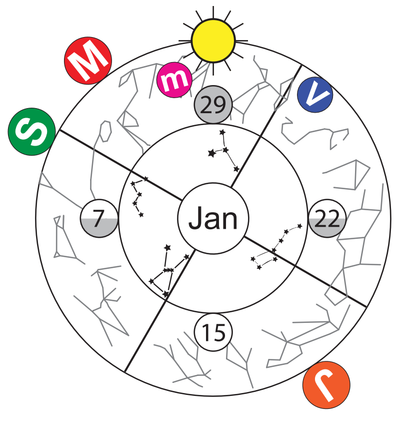
Solstice and Equinox lines rotate from month to month along with the Zodiac.

Guidepost Constellations

Guidepost Constellations are included for reference. Only the clock position of these is correct, they are north or south of the ecliptic.



Remember the Guidepost story:
The Dipper stalks Orion.
Cygnus flies to the Dipper.
The Queen chases Cygnus.
Orion pursues Cassiopeia.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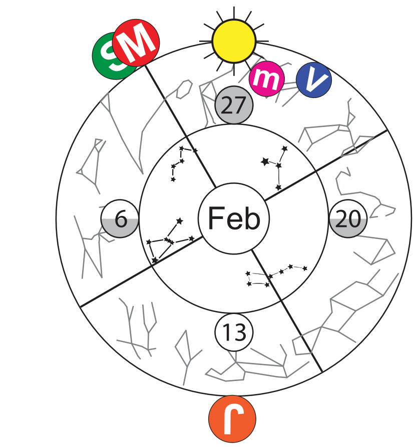
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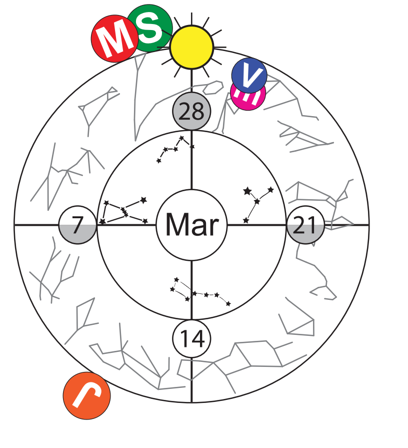
Mar
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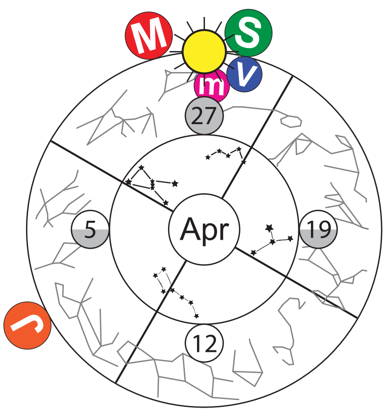
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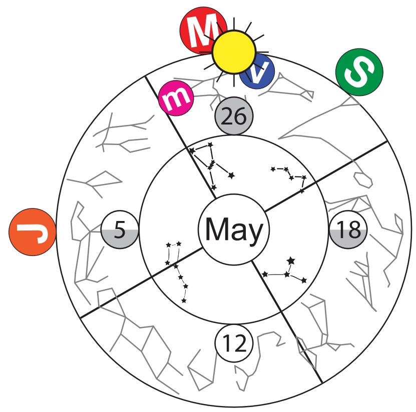
May
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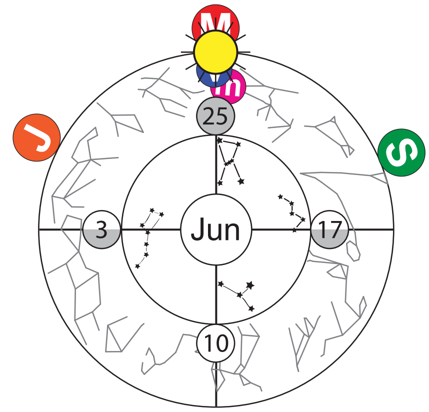
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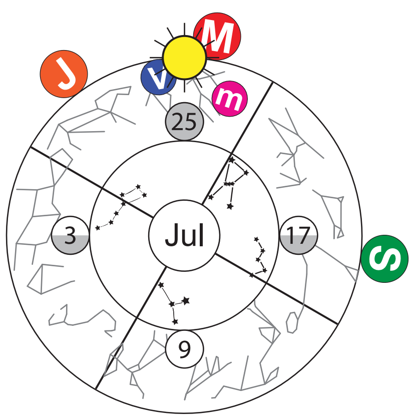
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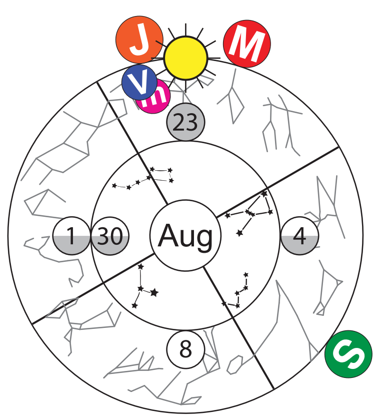
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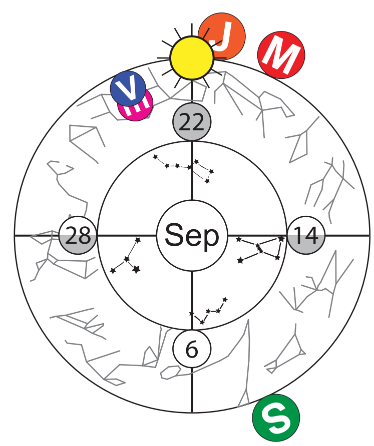
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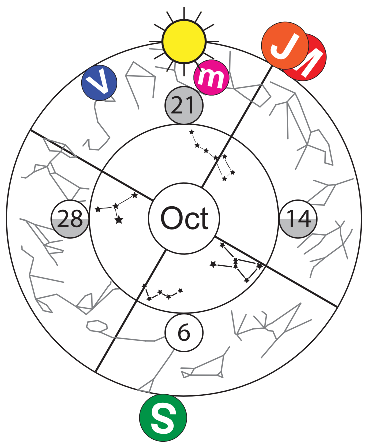
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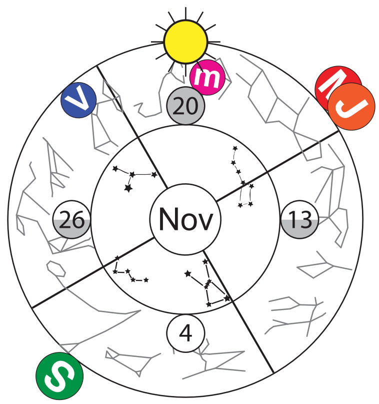
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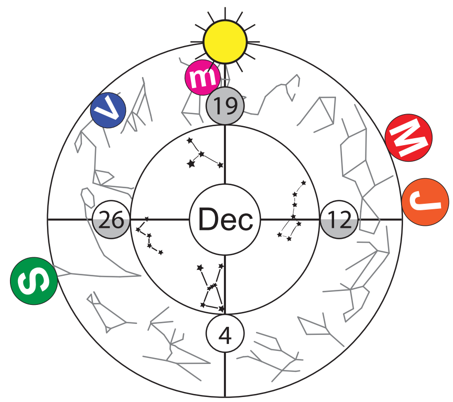
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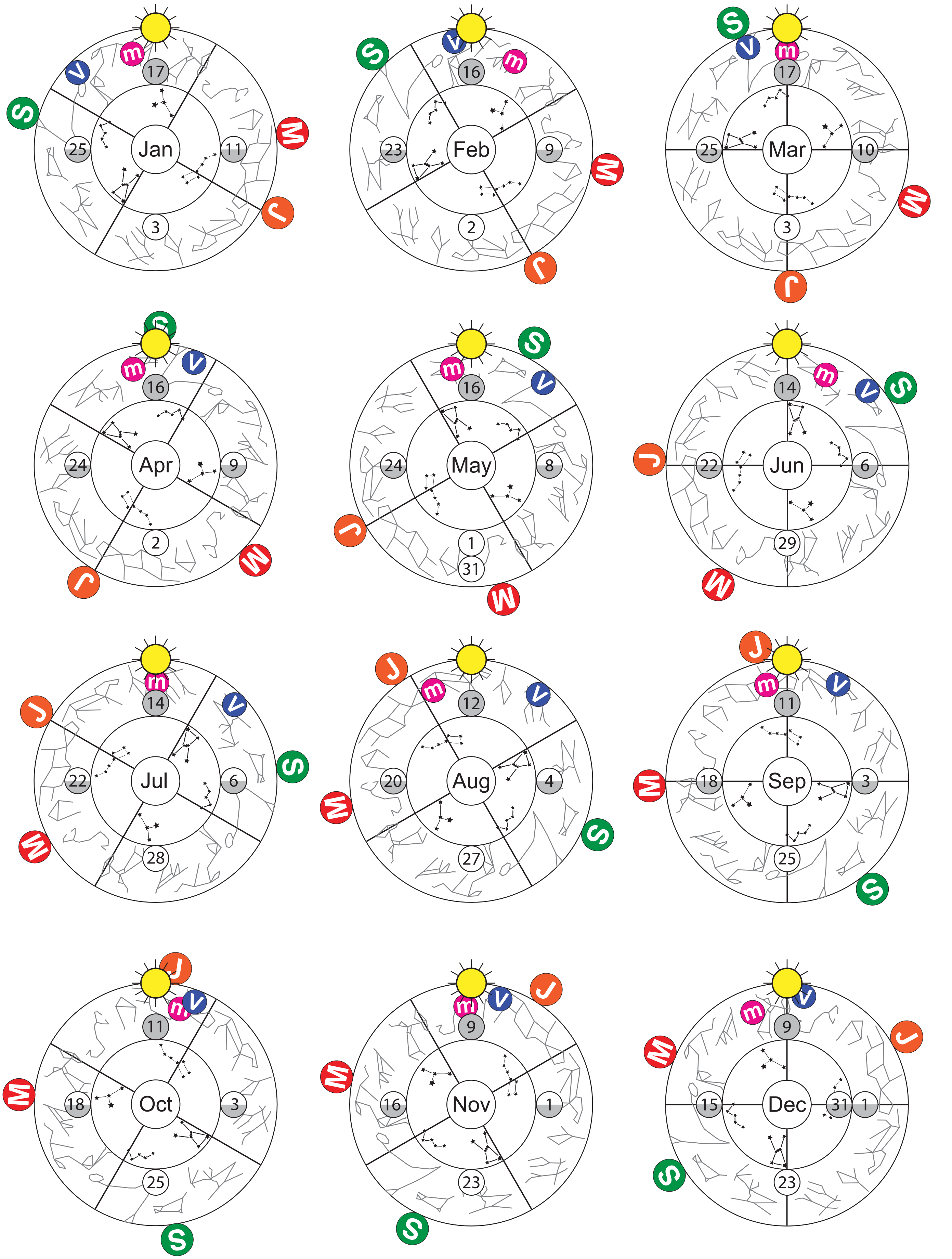
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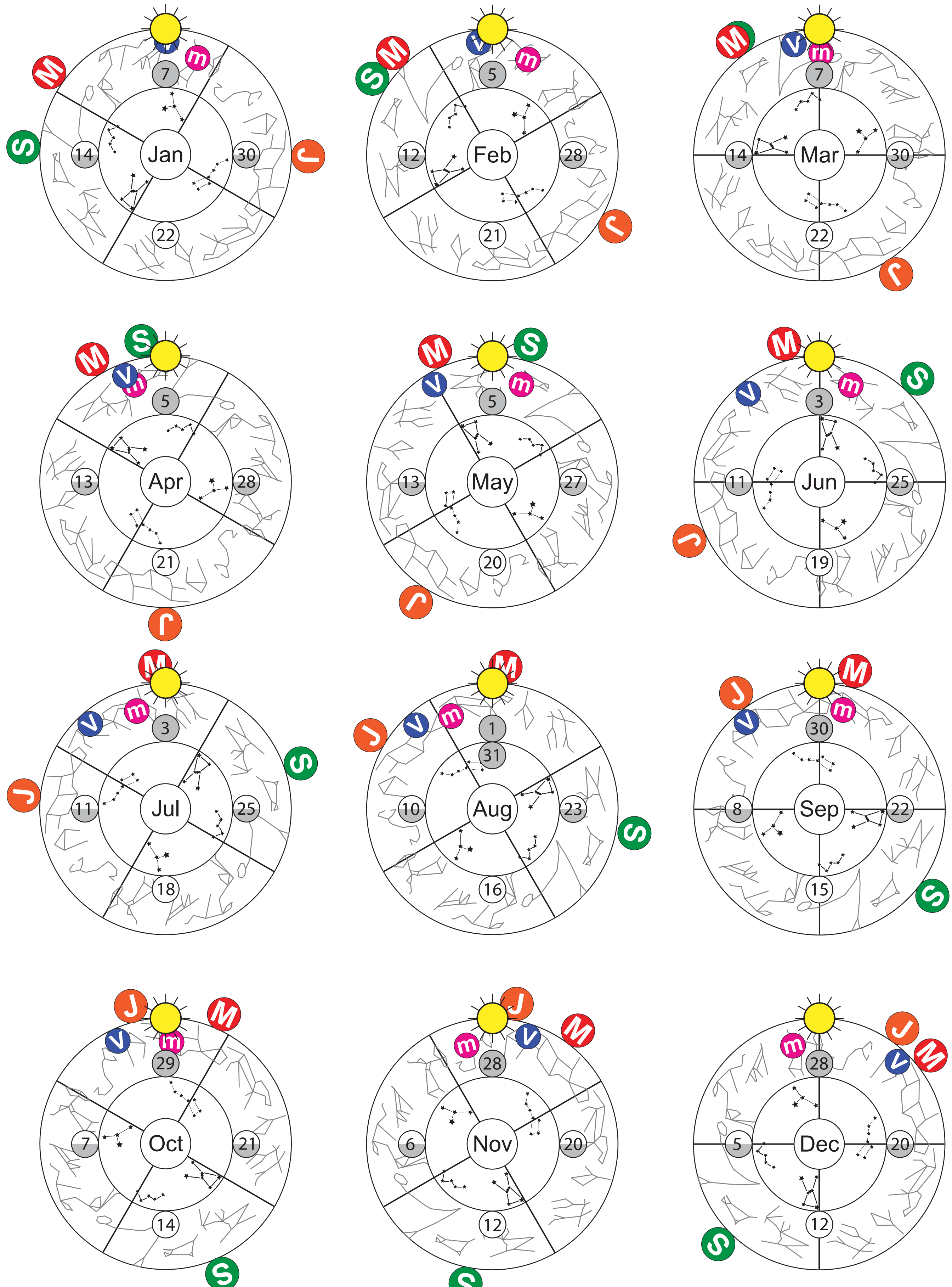
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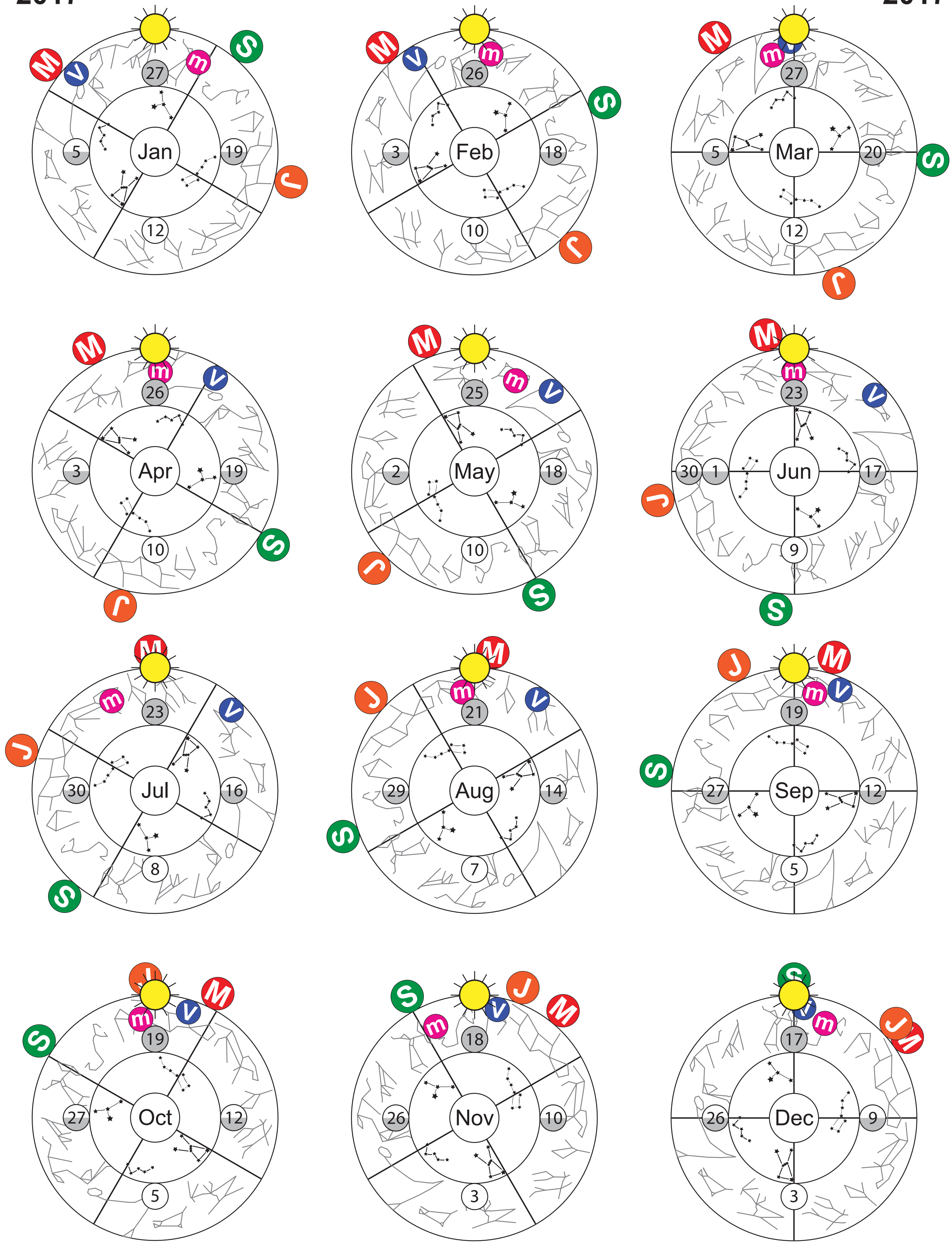
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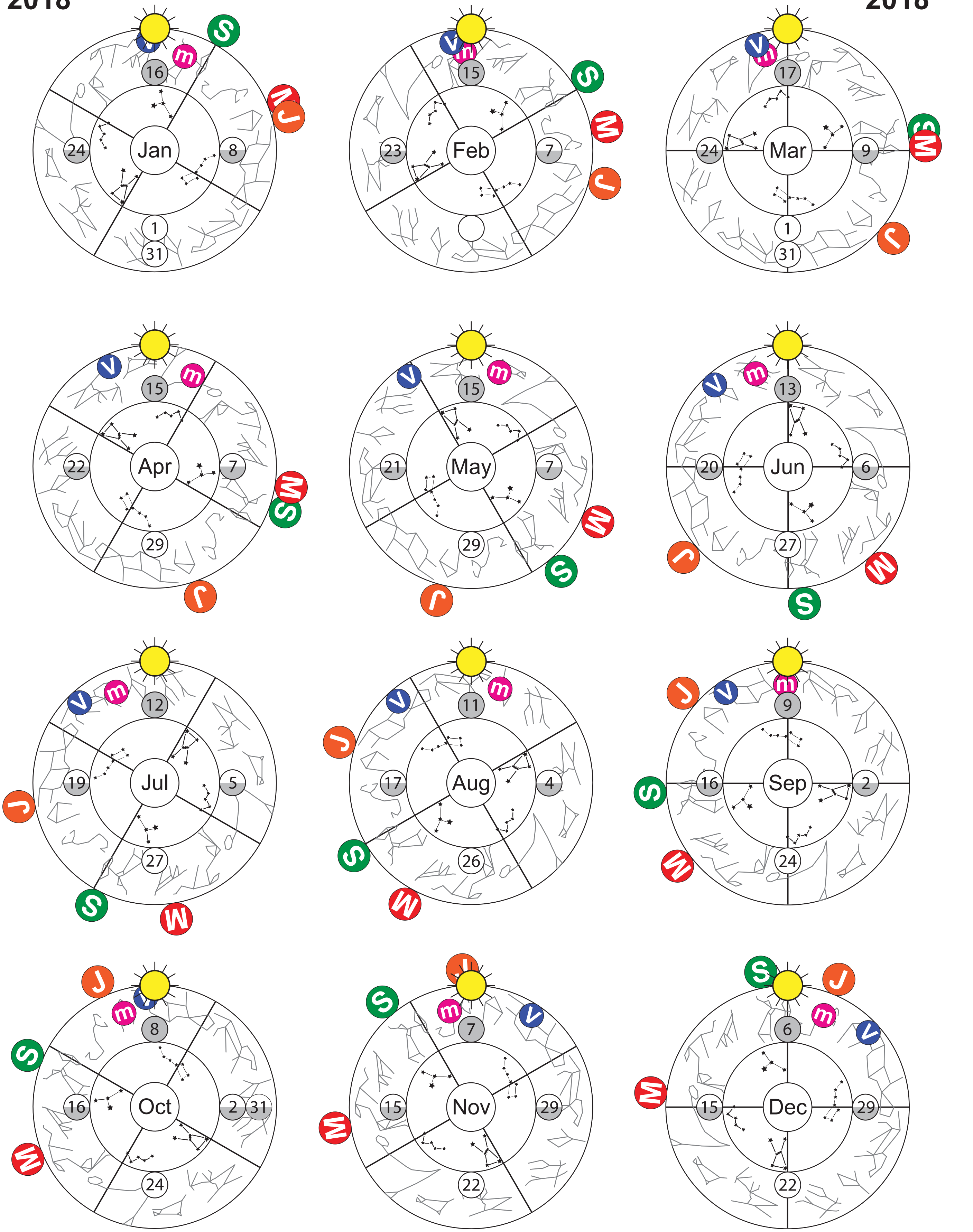
2018 **2018**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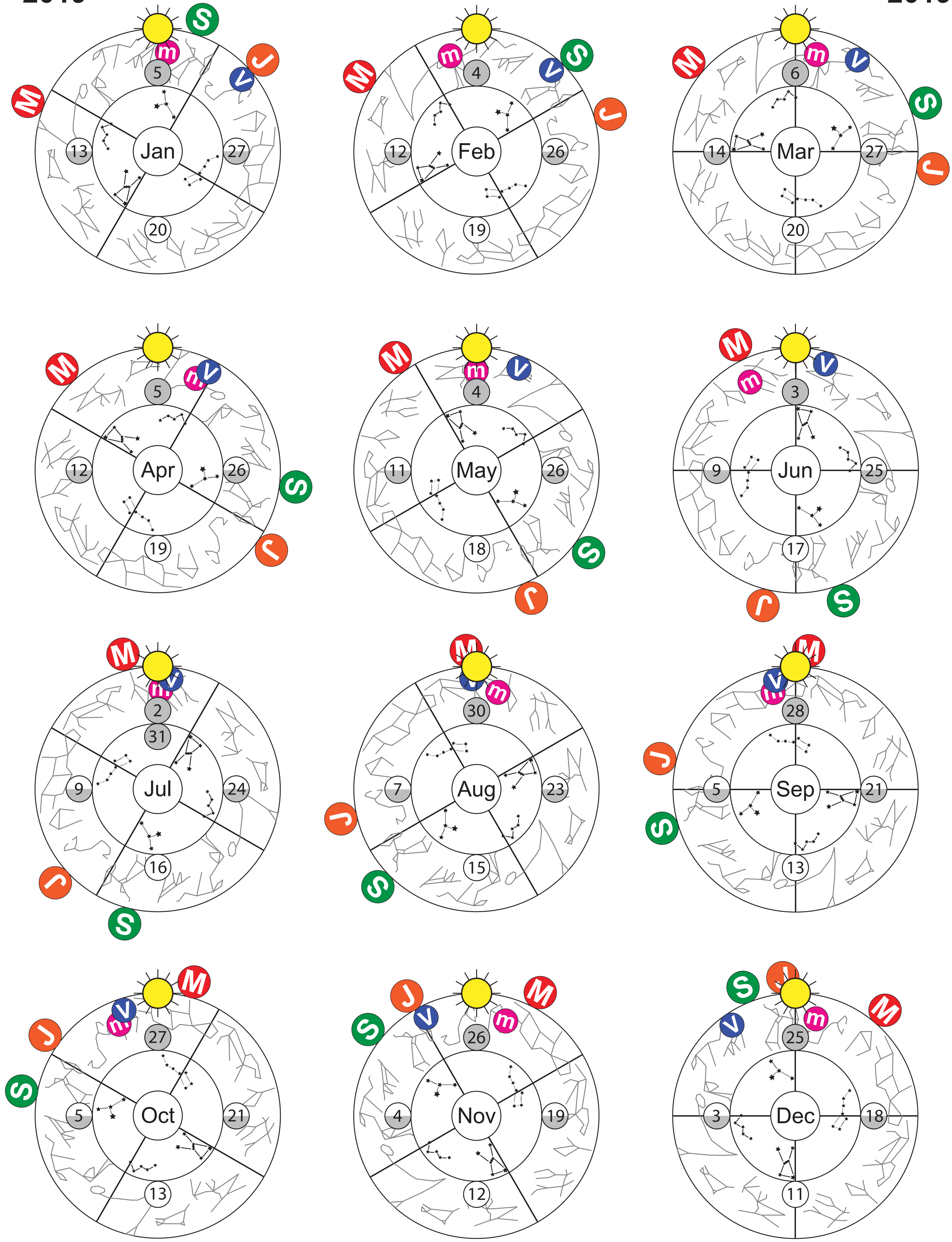
Nov 7 29 15 22
Dec 6 29 15 22

2019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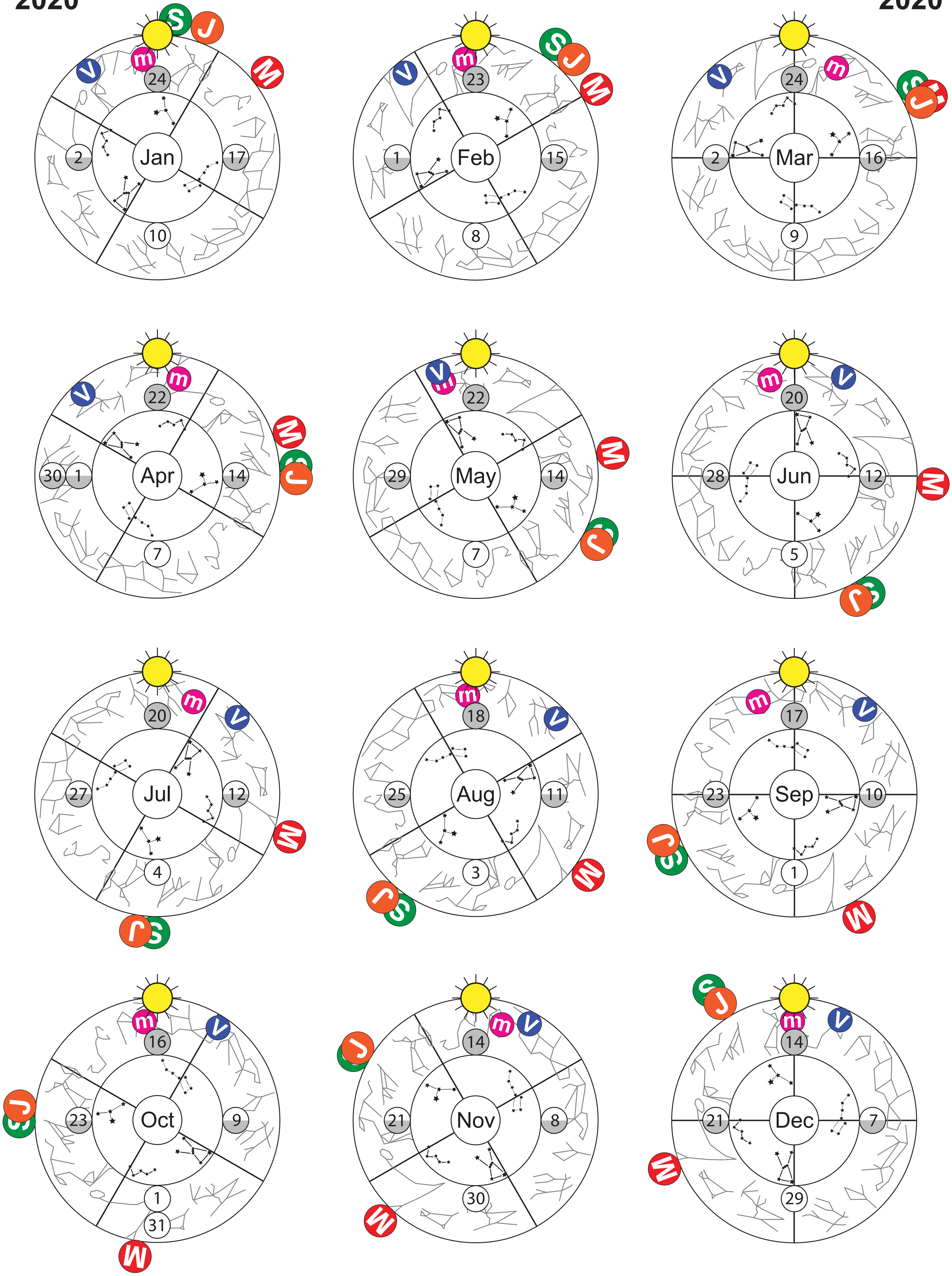
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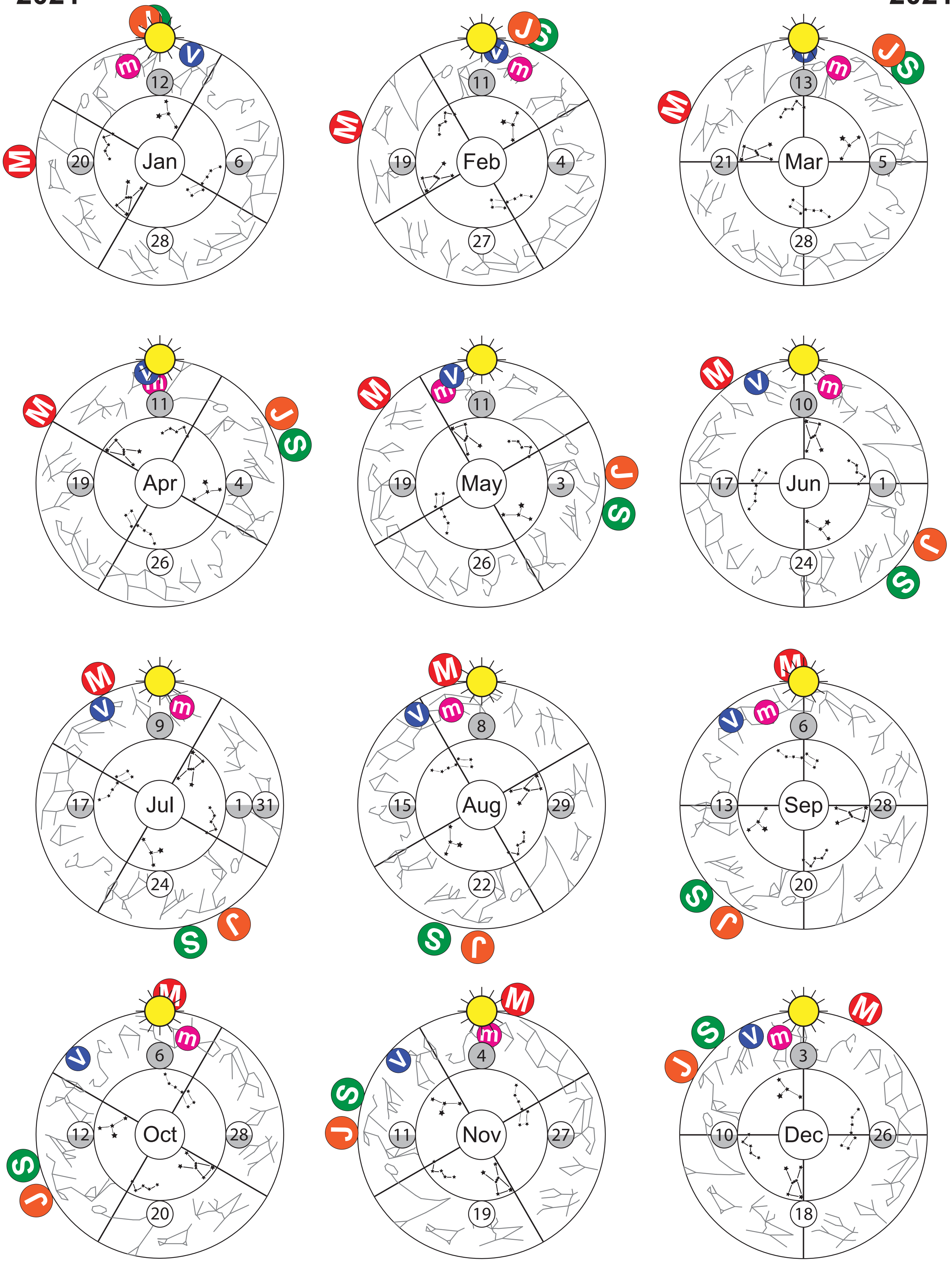
2021 **2021**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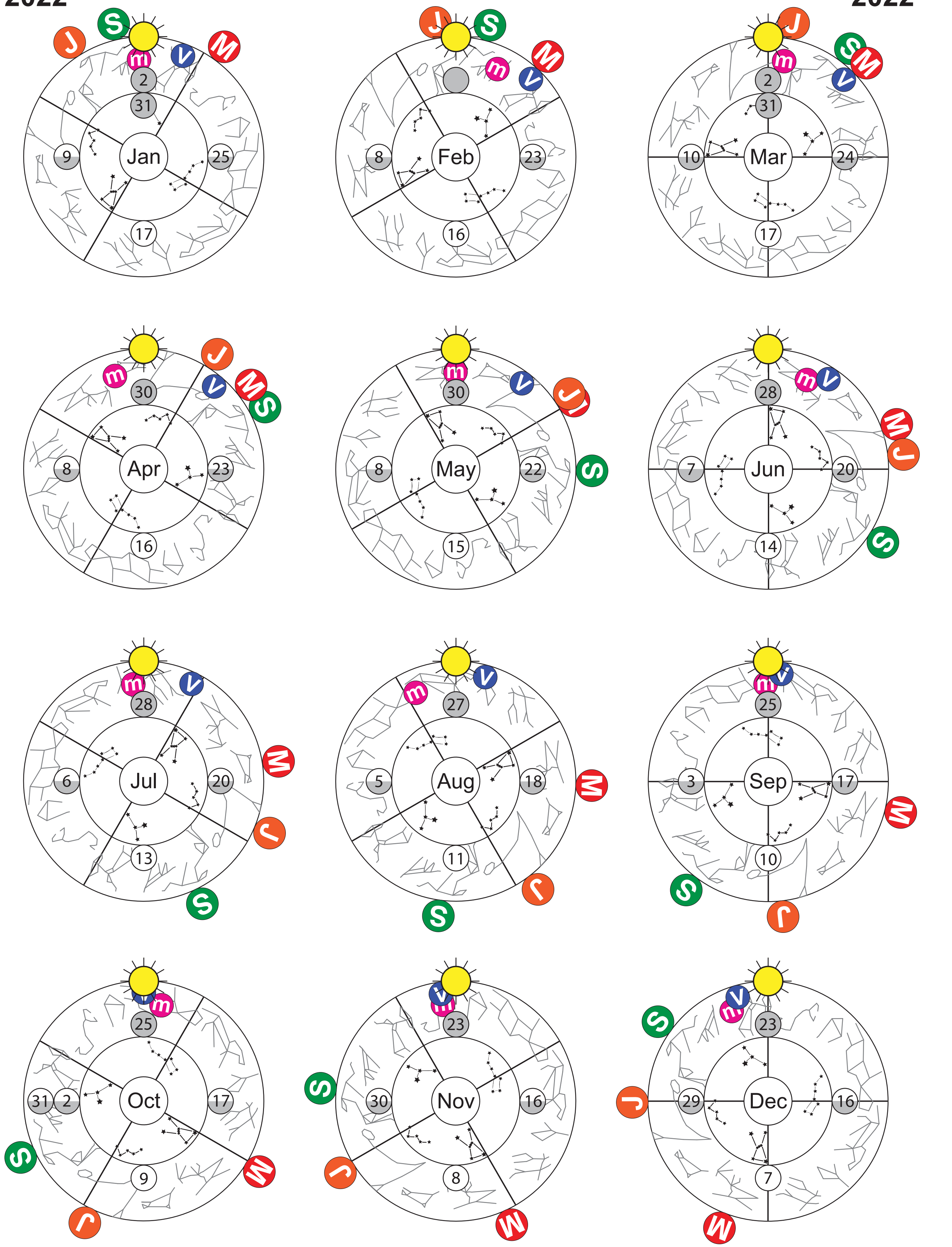

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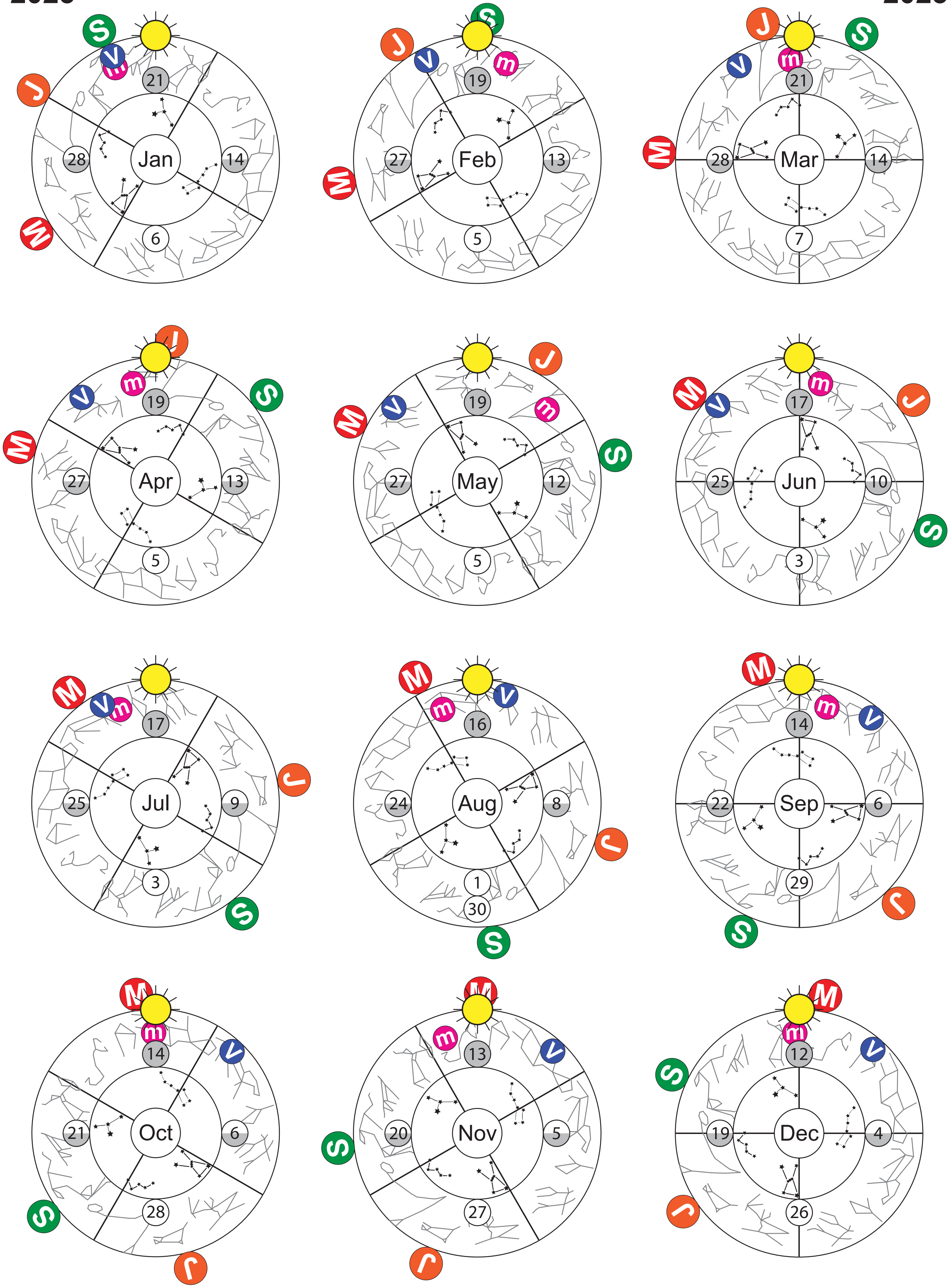
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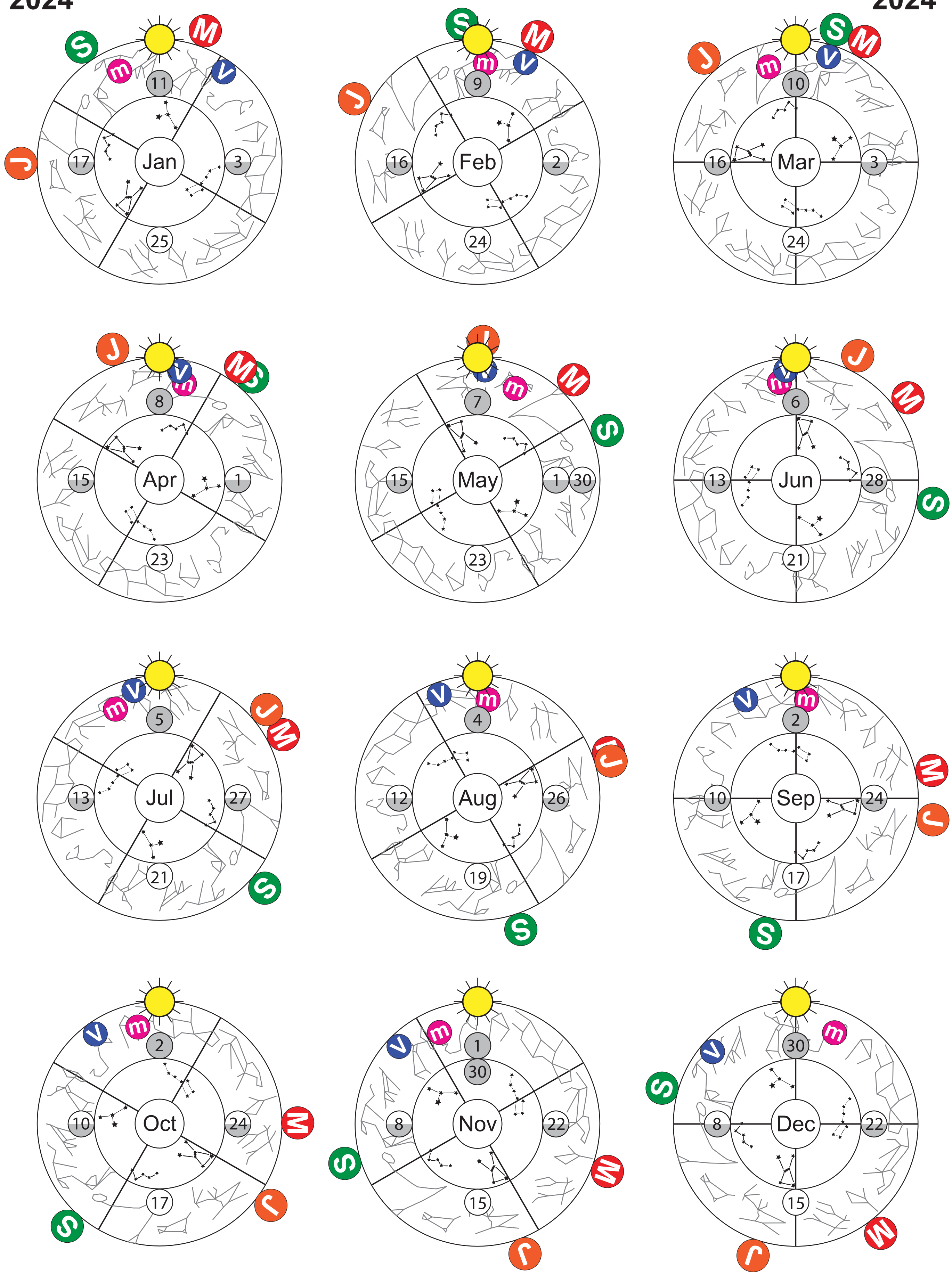
2024 **2024**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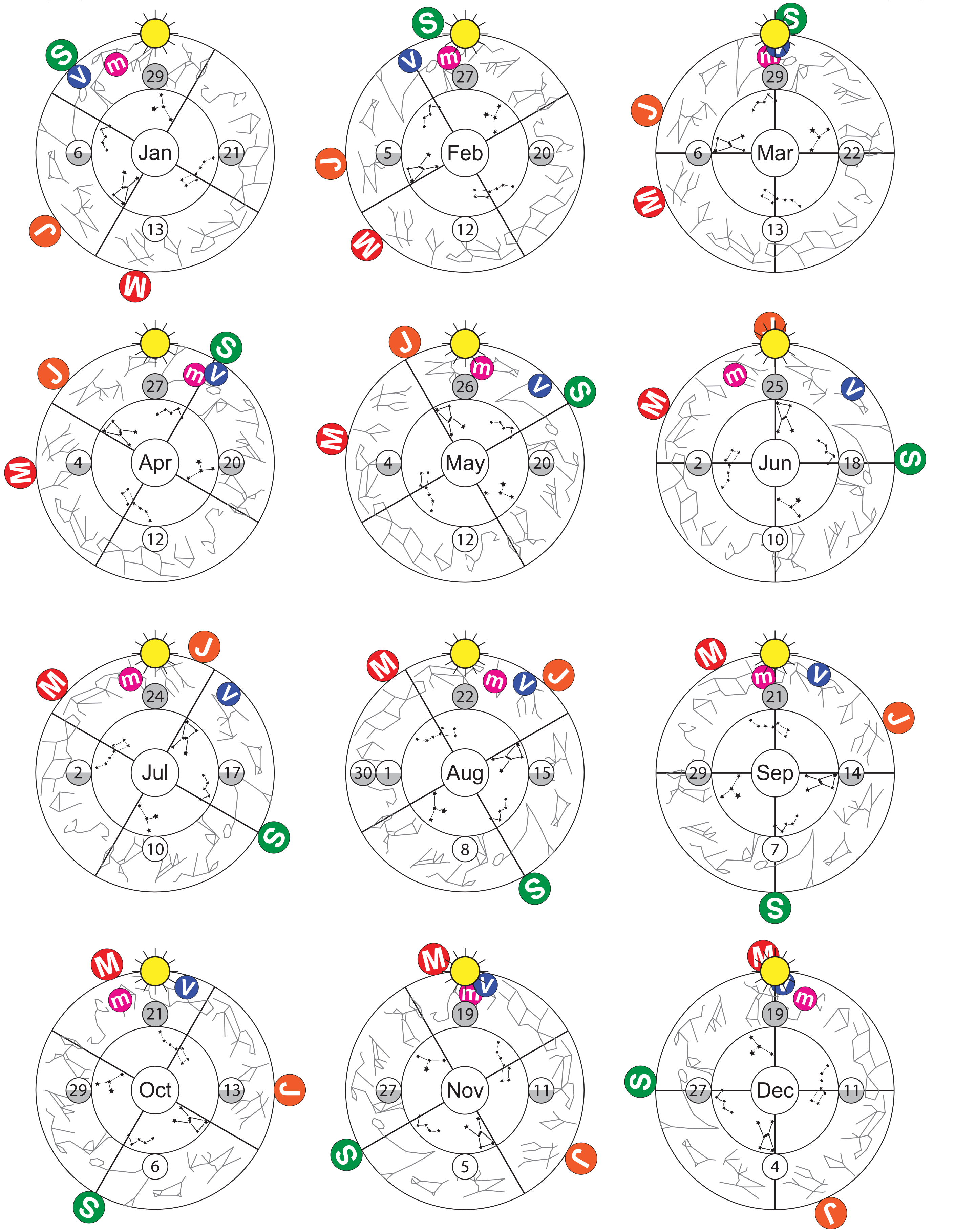

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Nov 19 27 11 5
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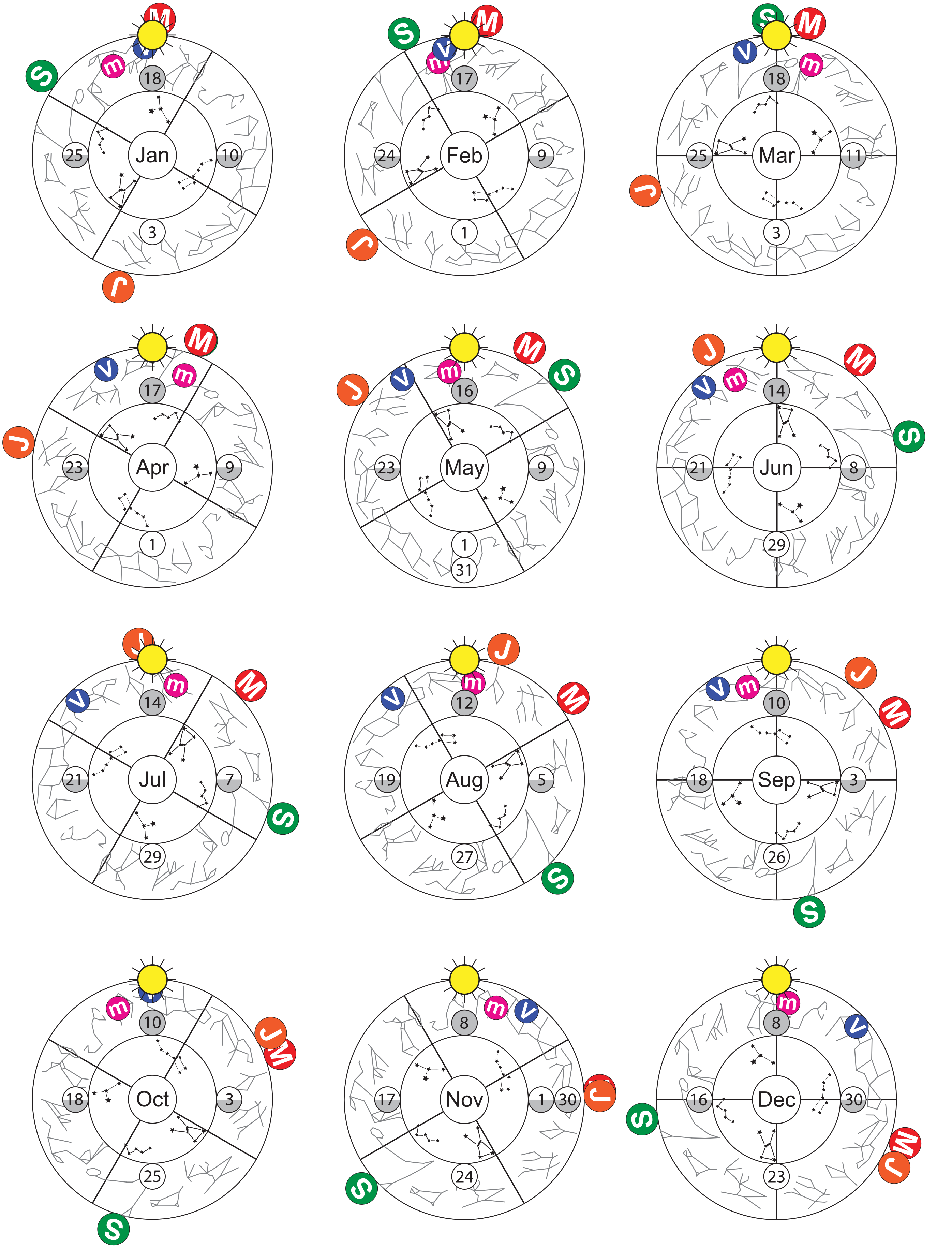
S V m J M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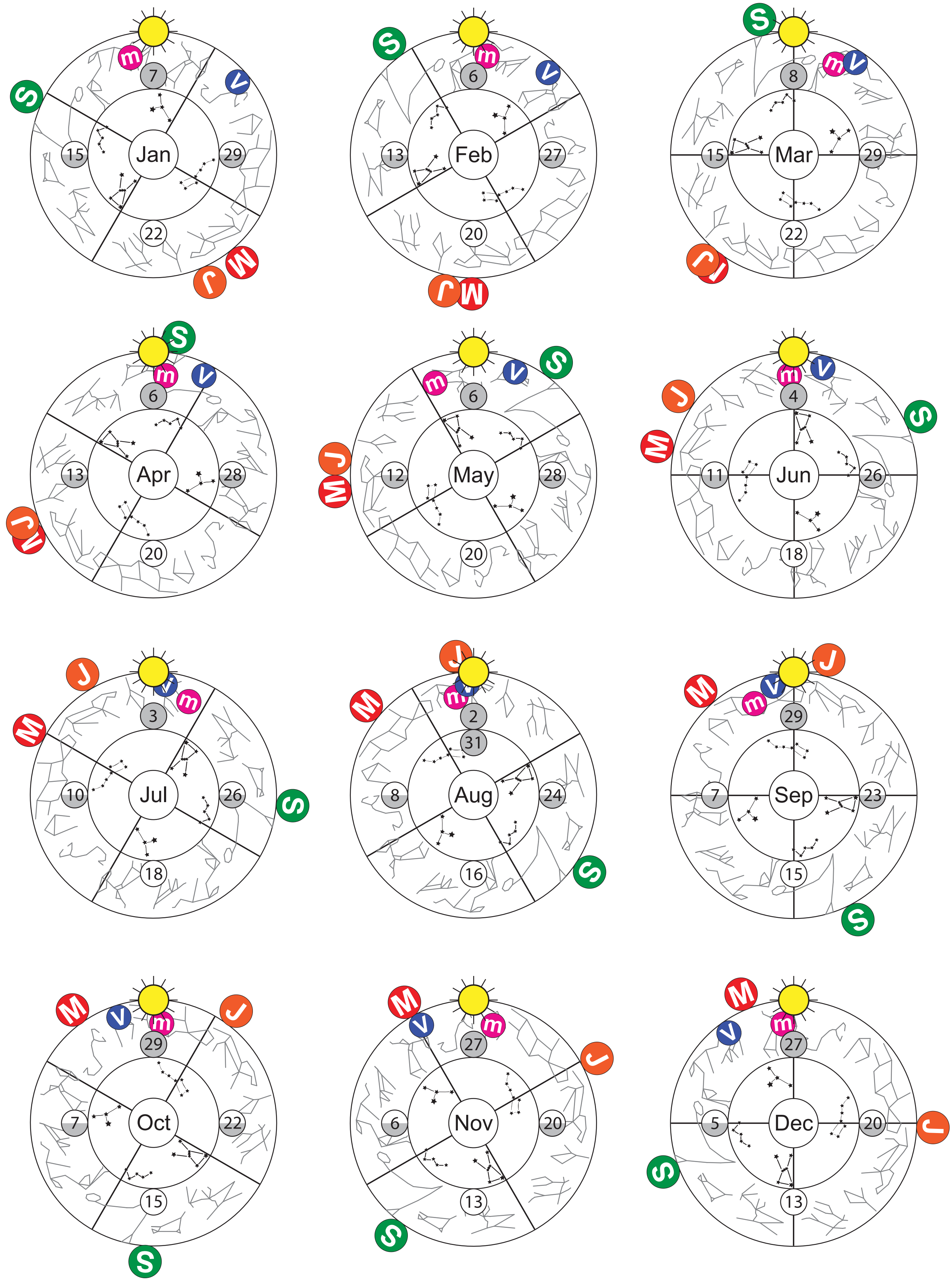
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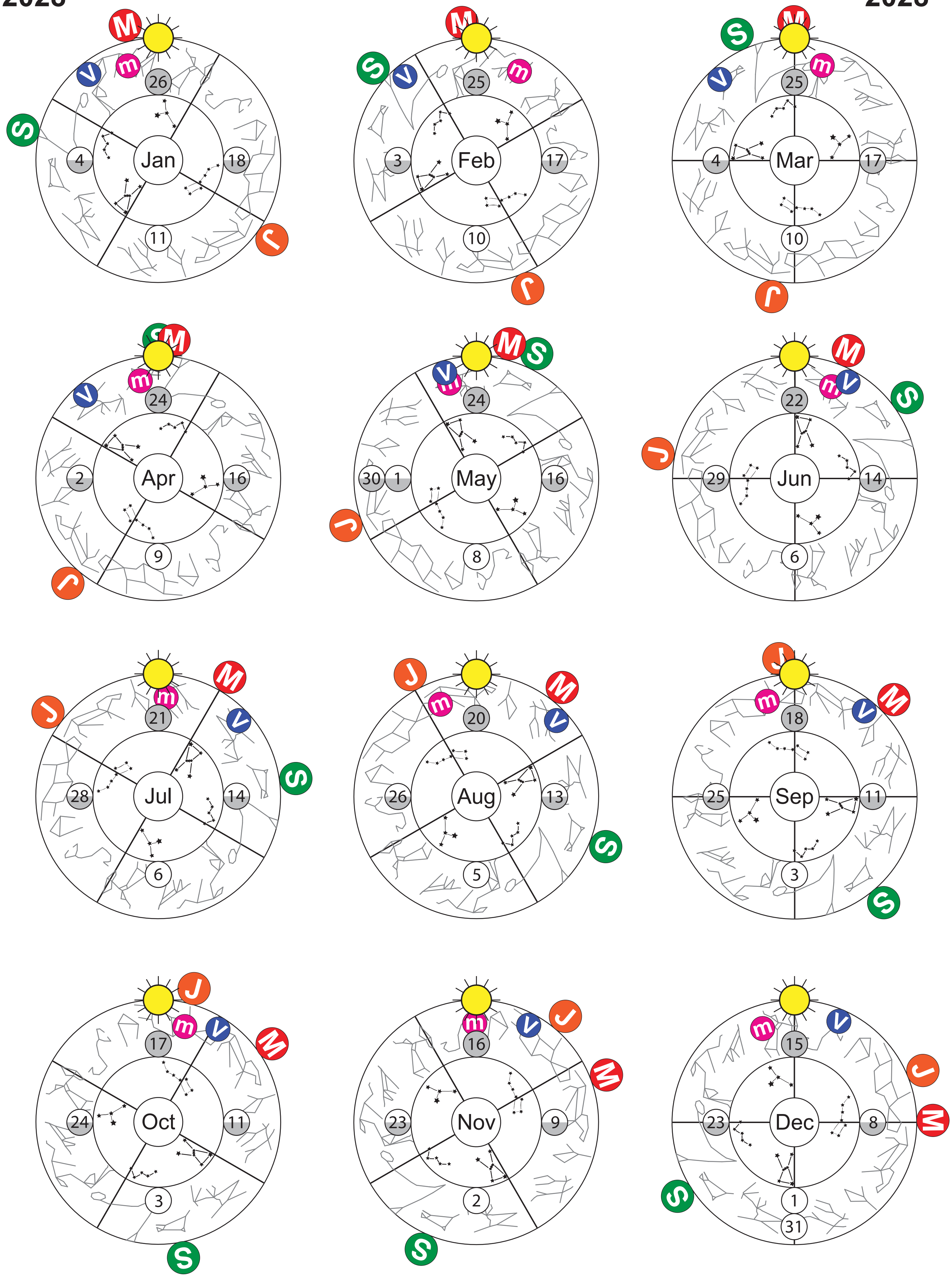
2028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Apr 24 2 16 9
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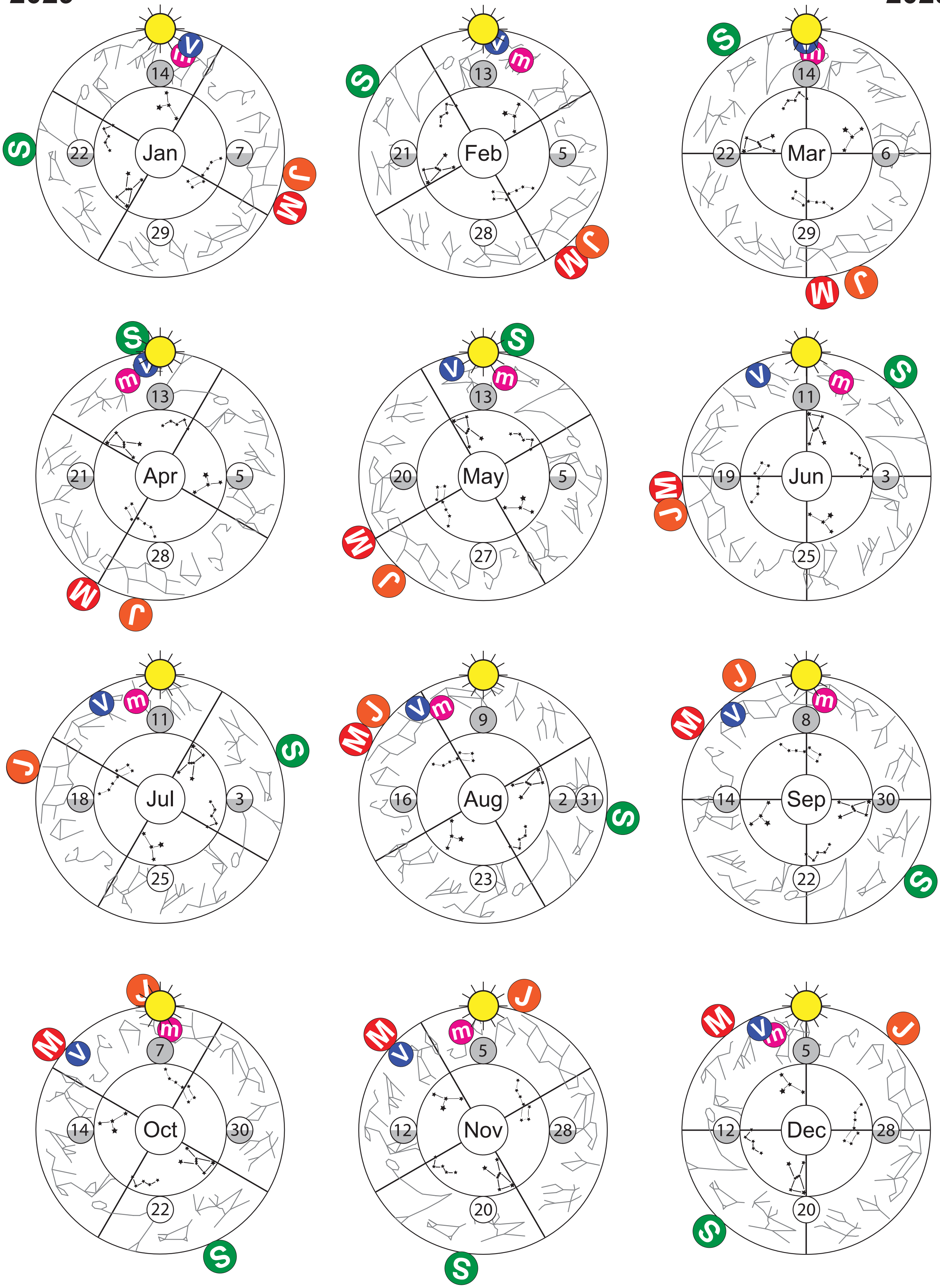
Nov 16 23 9 2
Dec 15 23 8 1 31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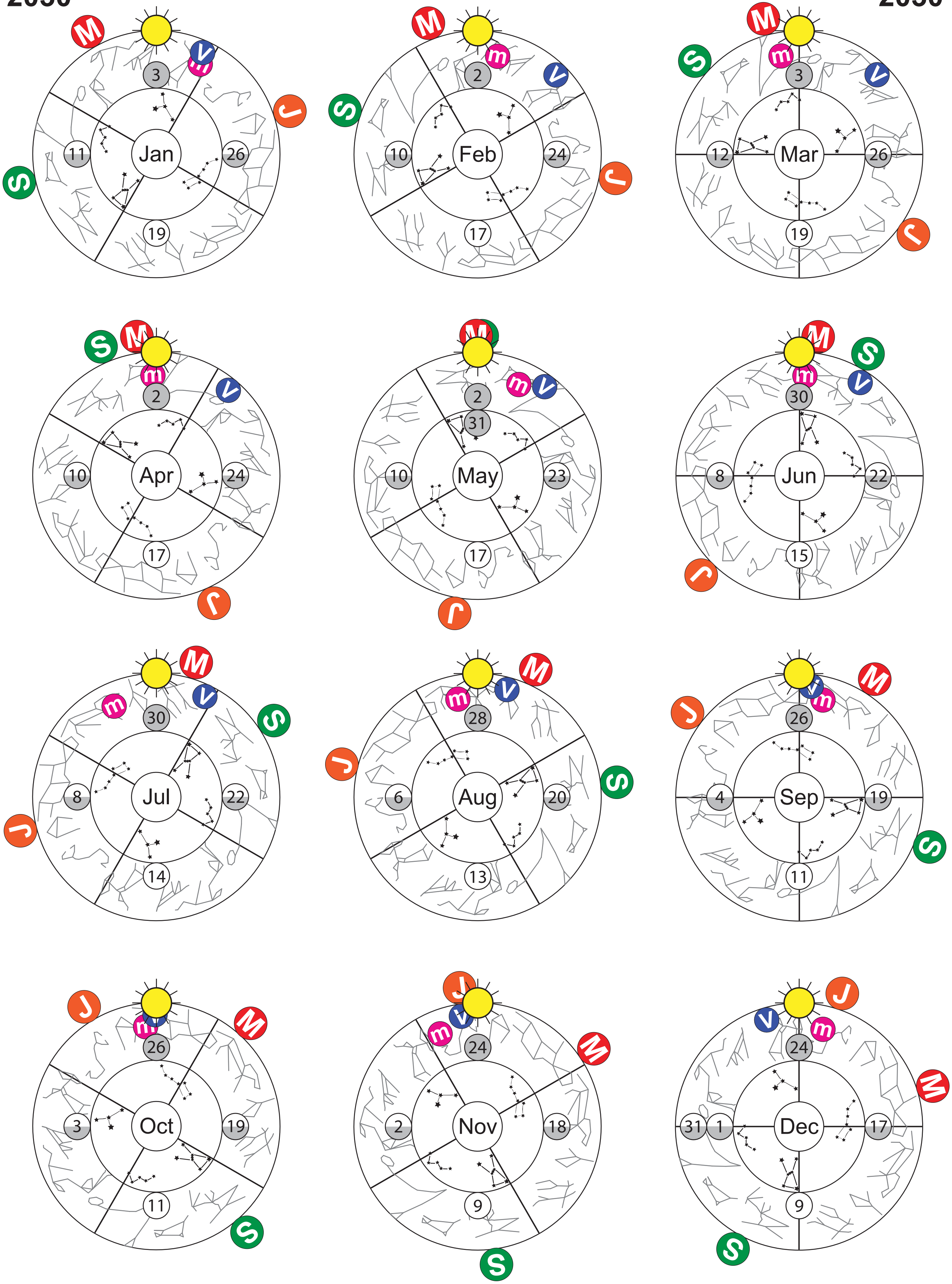
2030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M m V S 2 10 Feb 24 J 17
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M m V 30 S 8 Jul 22 J 14
M m V 28 J 6 Aug 20 S 13
J M V m 26 4 Sep 19 S 11
J M m V 26 3 Oct 19 11 S
J V m 24 M 2 Nov 18 9 S
J V m 24 M 31 1 Dec 17 9 S