# Learn the Zodiac (Ecliptic Constellations)!

[Note: Material in [ ] are notes to the presenter. Material in ( ) are asides and can be left out of a shorter talk. Material in { } give alternative presentations, separated by a |, depending on the hemisphere that the audience is in. Some southern hemisphere presenters may want to use the traditional northern hemisphere versions of the terrestrial diagrams, numbers 3 and 10, but use correctly-oriented southern hemisphere versions for the sky and constellation diagrams, numbers 5 to 9, 11, 12 and 14 to 17.]



[I originally presented this talk on April 12, 2002 at the monthly meeting of the Skokie Valley Astronomers at the Ryerson Nature Conservancy in Deerfield, IL.]

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[Star position data were provided by the NASA-ADC database V/105 SKYMAP SKY2000 - Master Star Catalog Database, Version 3.]

[This talk is designed to be presented by an amateur astronomer to people who are interested in learning about the zodiac and the ecliptic constellations. The presenter should be familiar with the concepts presented here. Some of the charts use the abbreviations for the constellation names. A complete list of the constellations can be found at
http://www.DaleDellutri.com/consinfo.htm
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[The diagrams are all PDF files. You can get each diagram as its own individual PDF file, or one integrated PDF file with all of the diagrams (except diagram 12) in the order required for the talk.
If you need the free Acrobat Reader, you can download it at
http://get.adobe.com/reader/
.]

[The individual PDF files are meant to be printed on transparency film and used with an overhead projector. Please print all of them at the same scale. They will print properly on either US Letter (8.5 inch by 11 inch) or ISO A4 (210 mm by 297 mm) paper with a margin of at least 45 points (= 0.625 inch = 15.875 mm) along all edges. To ensure that all the diagrams are printed on the same scale, uncheck all re-sizing options in the Acrobat Reader print dialogue: "Shrink Oversize Pages to Paper Size", "Expand Small Pages to Paper Size", "Shrink Pages to Fit", etc.. You should check "Autorotate and Center Pages".]

[The integrated PDF, with all of the diagrams (except diagram 12) in the order required by this script, can be used to present the talk directly

from your computer, using either its diplay screen or an attached projector. To show it in "fullscreen" mode, open it in the Acrobat Reader, then choose "Full Screen" from the View menu (or simply type Ctrl-L). Once in full screen mode, the right and left arrow keys will move forward and backward one diagram respectively. Type escape (Esc) to return to normal, non-full-screen mode. The extra material which uses diagram 12 is not part of the integrated PDF because it requires cutting and positioning.]

[Diagrams:
   1: Title Page for Learn the Zodiac (Ecliptic Constellations)!
   2: The Zodiac Song and Zodiac Table.
   3: The Earth in Space.
   4: (this diagram number is not used)
   5: The Earth in its Orbit.
   6: The Ecliptic Constellations.
   7: The Celestial Equator.
   8: The Ecliptic Plane and the Planets.
   9: The Entire Celestial Sphere.
  10: A Flat, Rectangular Map of the Earth.
  11: A Flat, Rectangular Map of the Sky.
 (12: Two Scales for the Rectangular Map of the Sky.
  13: (this diagram number is not used)
  14: Fishes, Ram and Bull are flyin',
  15: Then the Twins the Crab and Lion,
  16: Virgin, Scales and Scrorpion,
  17: Archer, Sea Goat, Waiter, done!
]

[Before the talk, distribute handouts, which should include copies of at least:
   2: The Zodiac Song and Zodiac Table, and
  11: A Flat, Rectangular Map of the Sky.
If you're going to present the extra material about using the two scales to determine the visible part of the sky, it should also include:
  12: Two Scales for the Flat, Rectangular Map of the Sky (with
      appropriate latitude and hemisphere).
And you could also include the last 4 diagrams:
  14: Fishes, Ram and Bull are flyin',
  15: Then the Twins the Crab and Lion,
  16: Virgin, Scales and Scrorpion,
  17: Archer, Sea Goat, Waiter, done!
]

[===== Spoken script starts here =====]

[Show diagram 1: Learn the Zodiac (Ecliptic Constellations)!]

Today we're going to learn the ecliptic constellations -- the zodiac -- but first ...

[Show diagram 2: The Zodiac Song and Zodiac Table.]

The tune for this song is a familiar one: "Twinkle, Twinkle, Little Star" or "The ABC's Song" (or (German) "Schlaflied" (Sleep Song)). It's about the zodiac, and it'll help you remember the ecliptic constellations (the constellations of the zodiac).

[Sing song.]

But what is the zodiac?  Let's start with a look at the Earth.

[Show diagram 3: The Earth in Space.]

Here is the Earth in space. It's turning like a big spinning top. The line of turning is called the "axis", like the word axle, and the turning itself is called "rotation", and this rotation gives us day and night as we alternately face toward and away from the Sun.

The axis of rotation defines the North and South poles (marked by short red lines on the diagram). Half-way between the poles is the imaginary line (marked in red) called the "equator."

I've shown it tilted in this diagram. But why is it tilted? What is it tilted in relation to?

[Solicit ideas.]

[Show diagram 5: The Earth in its Orbit.]

Please note that the diagrams are NOT drawn to scale. The Earth is shown too big, and the orbit is shown too small, in relation to the size of the Sun. The Earth orbits the Sun, moving along an elliptical path that's nearly circular. We say it "revolves" around the Sun and one "revolution" is called a year. The Earth is tilted in relation to the plane defined by the orbit, called the "ecliptic", and the way that the Earth is tilted, always pointing to the same point in space, is what makes the seasons. This diagram shows the Earth at four times in its orbit:

1. the March equinox, spring in the Northern Hemisphere and autumn in the Southern Hemisphere;

2. the June solstice, where the tilt causes the Northern Hemisphere to point toward the Sun and the Southern Hemisphere to point away from the Sun, so that it's summer north of the equator and winter south of the equator;

3. the September equinox, autumn in the Northern Hemisphere and spring in the Summer Hemisphere; and

4. the December solstice, where the tilt causes the Northern Hemisphere to point away from the Sun and the Southern Hemisphere to point toward the Sun, so that it's winter north of the equator and summer south of the equator.

(The Earth revolves counter-clockwise around the Sun as seen from north of the ecliptic. This is called the right-hand rule: take your right hand, with your thumb pointing north in the diagram, your fingers point in the direction of motion of the Earth in its orbit as seen from north of the ecliptic.)

(You'll note that the line of the Earth's poles always points to the same point in space as the Earth revolves around the Sun.)

Now we can add the stars of the zodiac, or ecliptic, constellations.

[Show diagram 6: The Ecliptic Constellations.]

This diagram, also not drawn to scale, makes it look as though the stars are all at a fixed distance from us. Of course, that's not true, but all the sky objects -- the Sun, Moon, planets and stars -- are so far away from us that when we look up into the night sky, they all seem to be at the same distance from us, embedded in an imaginary "celestial sphere" (actually, a half-sphere), a great inverted bowl, and so we show them that way in this diagram. In fact, we regularly speak of the projection of the Earth's poles and equator into this imaginary sphere as the "celestial poles" and the "celestial equator".

The diagram also makes it look as though we could see the stars from so far away from Earth that we could be behind some of them, outside that imaginary celestial sphere, an obvious impossibility. In fact, since we are showing them as though we were behind them, the constellations at the front of the diagram are backwards.

The stars are very far away, and stationary (for the purposes of this talk). As we go through the year, we see different stars at night because the night time side of the earth is pointing at different parts of the sky. If we could see the stars behind the Sun, we would see different stars behind it at different times of the year.

For example, at the December solstice (on December 21st or 22nd, position (4) in diagram), the midnight side of the Earth would point to the boundary between the constellations Taurus, the Bull, and Gemini, the Twins. The noon side would point to the Sun, and, if we could see beyond it, to the western edge of the constellation Sagittarius, the Archer. Six months later, at the June solstice, the situation would be reversed.

Thus, if we could see the constellations behind the Sun, as we can during a total solar eclipse, we would see the Sun among the stars of that constellation and we would say that the Sun is "in" that constellation. So at the December equinox, for example, we would say that the Sun is "in" Sagittarius, the Archer.

This narrow band of constellations that the Sun is "in" as the Earth

revolves around the Sun is called the zodiac and the traditional twelve constellations in the zodiac are the zodiacal, or ecliptic constellations.

(The zodiac is defined as the band of sky 8 degrees on either side of the ecliptic.)

And now it's time to sing the song again...

[Show diagram 2: The Zodiac Song and Zodiac Table.]

[Sing song.]

Now let's look at the Zodiac Table, which shows some information about the ecliptic constellations.

The first column is the name used in the song. We couldn't use the standard Latin names because they have too many syllables and no easy rhymes. All of the song names are the same as the standard English names except for the constellation Aquarius, the Water Carrier or Water Bearer. Instead, we use "Waiter" because we need a two-syllable name, and the waiter brings the water to your table at the restaurant sometimes, right?  So "Waiter" should remind you of "Water Carrier".

The next three columns are the standard English names, Latin names, and abbreviations. These are the names that are set by the IAU, the International Astronomical Union.

(The names used in astrology newspaper columns might be a little different: Scorpio instead of Scorpius.)

The next column gives the months that the Sun is "in" the constellation. The Sun is in that constellation from about the middle of the first month until about the middle of the second month. (The exact dates that the Sun is in a constellation depend on the somewhat arbitrary way that the IAU has set the boundaries of the constellations.)  There's one extra constellation shown: Ophiuchus. The IAU has defined the boundaries of the constellations in such a way that the Sun actually travels through this constellation during the months shown. But we'll just consider the twelve "traditional" constellations.

(The dates shown for the constellations in astrology are very different. They were set about 2,500 years ago and the Earth's rotation axis has moved, or "precessed", since then, so that the solar dates in astrology are wrong by about one month. Also, astrologers divide the sky into 12 equal parts of 15 degrees each instead of using the IAU boundaries.)

The last column gives the months that the constellation is on the celestial meridian at 10 PM. The "celestial meridian" is the imaginary line on the celestial sphere that goes from the {N: North celestial pole, through the zenith (the point directly overhead at your observing site), and then to the point due south on the horizon. | S: South celestial pole, through the zenith (the point directly overhead at your observing site), and then to the point due north on the horizon.}

When an ecliptic constellation is on the meridian, it's as high as it

ever gets in the sky from your observing location, and we say that it "culminates" or that it's at "culmination".

Please note that all the times that we use in this talk are "mean solar time". That's approximately equal to clock time, except that we ignore Daylight Saving Time. If Daylight Saving Time is in effect, then you must subtract one hour from the clock time to get the times that we're talking about, because the clocks are one hour fast during Daylight Saving Time. (It's actually even more complex. The time zones are based on the standard geographic meridians at 0 degrees, 15 degrees (West or East longitude), 30 degrees, etc.. If you're not exactly on the standard geographic meridian for your time zone, you have to adjust for the distance from it. For example, the standard meridian for the US Central Time Zone is 90 degrees West longitude. If you're at 88 degrees West longitude, you're in the US Central Time Zone, but the sky events occur 8 minutes (= 24 hrs * 2 degrees / 360 degrees) earlier than indicated.)

So the importance of the song is this: when we sing the song, we are singing the names of the constellations that the Sun travels through in the course of a year, in the order of the solar dates.

But why do we start with Pisces, the Fishes?

[Show diagram 7: The Celestial Equator.]

Eventually, we want to be able to tell where a star is in the heavens, to give it an address. For places on Earth, we have latitude and longitude. Latitude is the angle north or south of the equator, and longitude is the angle east or west of an arbitrary starting point. On Earth, the arbitrary starting point is the line going between the North and South Poles and through the Greenwich Observatory in Greenwich, England.

In a similar way, we can measure angles from the celestial equator and some arbitrary starting point on the celestial equator. The angle north or south of the celestial equator is called "declination". We measure declination in degrees, positive north of the celestial equator, negative south of the celestial equator. The angle around the equator is called "right ascension". We measure right ascension in hours, from 0 hours at an arbitrary starting point and increasing to the east. The entire circuit around the sky is 24 hours of right ascension (which equals 360 degrees, so that each hour of right ascension is equal to 15 degrees). The arbitrary starting point on the celestial equator is the point where the Sun crosses from south of the celestial equator to north of it. This happens at the March equinox on March 20th/21st.

Looking at the table, we see that the Sun is in Pisces, the Fishes, on that date, and so we start with the Fishes. (Astrological tables generally start with Aries, the Ram, because that was the position of the northern hemisphere spring equinox about 2,500 years ago, when astrology was formalized. In fact, this starting point is still sometimes called the "first point in Aries", and is marked with the astrological symbol for Aries, which looks like a little ram's head, even though the point is actually in Pisces, the Fishes.) And now we know why we start with the Fishes. So let's sing the song again. This time, try it from memory.

[Sing song.]

[Show diagram 8: The Ecliptic Plane and the Planets.]

The Moon and the bright planets, the ones we can see with the naked eye -- Mercury, Venus, Mars, Jupiter and Saturn -- also have orbits that lie nearly in the plane of the ecliptic. These objects can appear in constellations that are not strictly part of the zodiac, but they'll be close to the zodiac. The Moon's orbit, for example, is tilted 5 degrees to the ecliptic and Mercury's orbit is tilted 7 degrees. The other bright planets' orbits have tilts that range from 0 degrees to 3 degrees. (Note: The orbits of Uranus and Neptune are also close to the ecliptic. Pluto is a notable exception, with an orbit tilted 17 degrees to the ecliptic.)

For example, this diagram shows the Earth at the June solstice. If Mars were at the position in its orbit marked by the small red ball, then observers on Earth would see Mars in the constellation Pisces, the Fishes. If Jupiter were at the position in its orbit marked by the large gray ball, then observers on Earth would see Jupiter in the constellation Libra, the Scales.

So the importance of the zodiac is this: the Sun, the Moon and the bright planets are always in or near some constellation of the zodiac, and the Sun's position in the zodiac indicates the month and the season of the year.

Now we'd like to show a map that includes most of the sky, and shows the ecliptic constellations in relation to the other constellations, but we can't just add all the stars to a spherical representation.

[Show diagram 9: The Entire Celestial Sphere.]

This does show the ecliptic as a dashed blue line and the equator as a solid red line. But it's difficult or impossible to make out the other constellations.

So we need to unroll this somehow and make a flat map of the stars. Before we do that, however, please note that making any kind of flat, rectangular map of the spherical sky has to be distorted in some way. It's like looking at a flat, rectangular map of the Earth.

[Show diagram 10: A Flat, Rectangular Map of the Earth.]

Here's a flat, rectangular map of the earth. The equator, latitude and longitude lines are all shown in red. You'll note that the North and South Poles, points on the Earth, have been distorted into lines. Greenland (840,000 sq mi = 2,176,000 sq km) looks like it's as large or larger than Australia (2,937,800 sq mi = 7,609,000 sq km), even though it's really one-third the size. In fact, the farther away from the equator, the more distorted the object. Antarctica (5,405,000 sq mi = 14,000,000 sq km), for example, a circular continent which surrounds the South Pole, has been distorted into a long narrow strip of land.

So here's how we'll create a map of most of the sky. First, we'll chop

off the top and bottom 25 degrees of the celestial sphere. That will reduce the distortion at the top and bottom of the map. It will also eliminate some of the northern- and southern-most constellations, but we're mainly interested in the zodiac. Then we'll cut the sphere along the line that goes through the celestial poles and the March equinox, spread the sphere open and flatten it, and the result is ...

[Show diagram 11: A Flat, Rectangular Map of the Sky.]

... this flat, rectangular map of most of the sky. To make it easier to see the constellation Pisces, the Fishes, we've repeated a small amount of the sky on the west ({N: right | S: left}) end of the map. You'll note that the lines in red -- the equator, declination and right ascension lines -- are all straight because we cut the sphere parallel to the right ascension lines and perpendicular to the declination lines.

But look what happened to the ecliptic, indicated by the blue dots. On the diagram showing the sphere, it was a great circle. Now it's been distorted into a curve. That's a consequence of the making of the map. If we were in a planetarium with a spherical dome, and we projected the celestial sphere on the inside of the dome, the ecliptic would look like a great circle around the sky, just like the equator, but tilted to the equator at an angle of 23.5 degrees to the equator.

But this map shows the ecliptic constellations in relation to the other constellations.

And it's time to sing the song again.  The words are printed below the map so that each constellation's name is approximately below its position on the map.

[Sing song and point to the constellations as we sing the names.  Sing the last two lines:
  Now I know the Zodiac;
  Someone pat me on my back.
from memory.]

This map shows the ecliptic constellations and their relation to the rest of the constellations and to the equator. To make this map, we cut the sphere along a line that goes through the celestial poles because that's the way the Earth is oriented in space.

When we look at the sky, the celestial equator, even though we can't see it, is always in the same position. It meets the horizon at exactly the East and West compass directions, and is always at the same angular height in the sky on the meridian. That height is 90 degrees minus your latitude.

But that's not true of the ecliptic, and this map also shows how far north or south of the equator it is. Since the Earth is tilted 23.5 degrees to the ecliptic, that's the maximum angular distance from the equator to the ecliptic. And, in fact, the constellations that are at the high and low points of the ecliptic -- {N: high | S: low} like Taurus, the Bull, or Gemini, the Twins, or {N: low | S: high} like Scorpius, the Scorpion, or Sagittarius, the Archer -- really are high or low in the sky when they're on the meridian.

What else can we do with this map? Each blue dot on the ecliptic shows the approximate position of the Sun on the solar dates printed below the map. The first, tenth and twentieth days of the month are indicated by a vertical line. The line for the first of the month is a little longer than the others.

Any object east of the Sun on that day will be in the evening sky when the Sun is setting. It trails behind the Sun. Any object west of the Sun on that day will be in the morning sky when the Sun is rising. It leads the Sun. For example, on December 22, the Sun is in Sagittarius, the Archer. Note how far south of the equator the Sun is. That's another indication that it's winter in the Northern Hemisphere and summer in the Southern Hemisphere. I'm sure you've all noticed how far south or north the Sun is at different times of the year.

([Show diagram 12: Two Scales for the Rectangular Map of the Sky.])

(Here are two scales which you can copy onto a transparent sheet and then cut along the dashed lines. The lower, narrow scale marks the hours of the day, with noon in the middle and midnight at both ends. The upper scale shows the horizon in green for your latitude.)

([Show diagram 11 overlayed with the two scales as discussed in the script below.])

(Now you can use the map and scales in the following way. Place the time scale along the solar date scale so that noon intersects the current date. But if Daylight Saving Time is in effect, place the time scale so that 1 PM intersects the current date.)

(As an example, we'll set the scales for to see what's in the sky at 9 PM on April 12.)

(First adjust the time scale so that noon intersects April 12.)

(The times on the narrow time scale show the time of day (mean solar time) that that part of the map is on the meridian. So place the horizon scale so that the horizontal line marked "0 degrees" coincides with 0 degrees declination, and the vertical line marked "Meridian" intersects 9 PM.)

(Now you know what constellations are in the sky at that date and time -- they're the ones that are above the horizon line, which indicates the visible limit of the sky. If you run off the map, remember that the sky is actually continuous -- the left end of the map overlaps the right end. So you could copy the map and overlap them at the ends, which would give you as much sky as you need. If the Sun's position is above the horizon, then, of course, it's daylight and you can't see the stars. For example, here's where the horizon scale should be placed if it's 5 PM, and you'll note that the Sun's position is above the horizon line.)

(Of course, you can try other dates and times.)

Now I'd like to talk about the individual ecliptic contellations. I'll look at them in groups of three, corresponding to the lines of the song.

Some of the constellations are brighter than others, but in each group of three, there's at least one prominent constellation to guide us.

Of course, if you want to see all of these constellations, you'll need to get to a dark sky, away from city and suburban lights.

[Show diagram 14: Fishes, Ram and Bull are flyin',]

The solar months for these constellations are mid-March to mid-June, so they're on the meridian at 10 PM seven months later, mid-October to mid-January.

Pisces, the Fishes, is one of the least prominent of the zodiacal constellations, and has only three stars brighter than 4th magnitude. That makes it difficult to see. Aries, the Ram, has two bright stars, and is a small constellation. Taurus, the Bull, is a very prominent constellation, very easy to see. Aldebaran is a very bright, orange star. All of the stars in the "V" of Taurus are bright enough to be easily seen. And the very beautiful cluster called the Pleiades is unmistakeable, and a favorite object for many people. So Taurus, The Bull, is the guiding constellation for this group of three. You can also see their relationship to Orion, the Hunter, and the Great Square of Pegasus, the Winged Horse. Both of these are easily recognized and they bracket these three ecliptic constellations.

[Show diagram 15: Then the Twins, the Crab and Lion,]

The solar months for these constellations are mid-June to mid-September, so they're on the meridian at 10 PM seven months later, mid-January to mid-April.

This group has two very bright and recognizable constellations. Gemini, the Twins, is headed by two bright stars, Castor and Pollux. The feet of the Twins are also very bright. Together they make a large rectangular box in the sky. Cancer, the Crab, is very dim and difficult to see. However, it contains a beautiful open cluster, Praesepe, M44, called the Beehive or Manger. It's just barely a naked-eye object in a clear, dark sky, and shows about 50 stars in a large telescope. Leo, the Lion, the last of the three, is large, bright and easily recognized. From the Backwards Question Mark or Sickle to the tail, it is one of the most imposing of the ecliptic constellations. The bright star at the south end of the question mark is Regulus. Orion, to the south and east, also helps to find this group of three.

[Show diagram 16: Virgin, Scales and Scorpion,]

The solar months for these constellations are mid-September to mid-December, so they're on the meridian at 10 PM seven months later, mid-April to mid-July.

Virgo, the Virgin, has mostly dim stars, but the brightest is Spica, a very bright star. {N: In the northern hemisphere, we can use the handle of the Big Dipper (part of Ursa Major, the Big Bear) to "arc over to Arcturus (in Boï¿½tes, the Herdsman) and spike on to Spica." | S: In the southern hemisphere, Crux, the Sothern Cross, points into Virgo, the Virgin, though not directly to Spica.} Once you've found Spica, you may

be able to see the rest of the stars in this constellation. The area just northwest of this constellation, between Virgo, the Virgin, and Leo, the Lion, contains many deep sky objects. None of these are naked-eye, but scanning the region with a large telescope is very rewarding. Libra, the Scales, is very small and dim, but you have to love the names of the stars -- Zubenelgenubi, the southern claw, and Zubenelchemale, the northern claw. They have "claw" names because the Arabs who named these stars considered them to be part of the next constellation. These two stars are also sometimes called "the Gates", because the ecliptic, and therefore the Sun, Moon and planets, pass directly through them. Scorpius, the Scorpion, is the guiding constellation for this group. It's a very prominent constellation for any observer south of about mid- to high- northern latitudes, and perfectly placed for observers south of the equator. The entire constellation actually looks like a scorpion. The brightest star in this constellation is Antares, the "Rival of Mars", an orange star. It's near enough to the ecliptic so that Mars is sometimes very near, and it's interesting to compare the colors of Mars and Antares when that occurs. It's not shown on this chart, but the Milky Way goes through this constellation, and there are many deep sky objects. Also, note that Libra, the Scales, is about halfway between the two brightest stars in this group, Antares and Spica.

[Show diagram 17: Archer, Sea Goat, Waiter, done!]

The solar months for these constellations are mid-December to mid-March, so they're on the meridian at 10 PM seven months later, mid-July to mid-October.

Sagittarius, the Archer, is as far south as Scorpius, the Scorpion. The brightest stars of Sagittarius form an asterism called the Teapot. Again, though not shown on this chart, the Milky Way goes through this constellation, and some of the brightest star clouds seem to be {N: rising like steam | S: falling like smoke} from the spout of the Teapot. There are many deep sky objects, and, in a dark, clear sky, the region is thick with stars and clusters. Capricornus, the Sea Goat, is the shape of a triangle. The north side of the triangle possibly represents the goat's back, and the southern vertex his feet. Aquarius, the Water Bearer, which I called Waiter in the song, is not bright. Its shape is supposed to suggest a man bent over carrying water buckets. So in this group, Sagittarius, the Archer, and particularly the asterism called the Teapot, is the guide.

[Show diagram 11: A Flat, Rectangular Map of the Sky.]

And now it's time to sing the song. We'll sing it slowly and I'll point out the constellations as we sing.

[Sing song.]

And that's the end of the talk. I hope that you'll use your knowledge of the zodiac to find your way around the sky. Any questions?