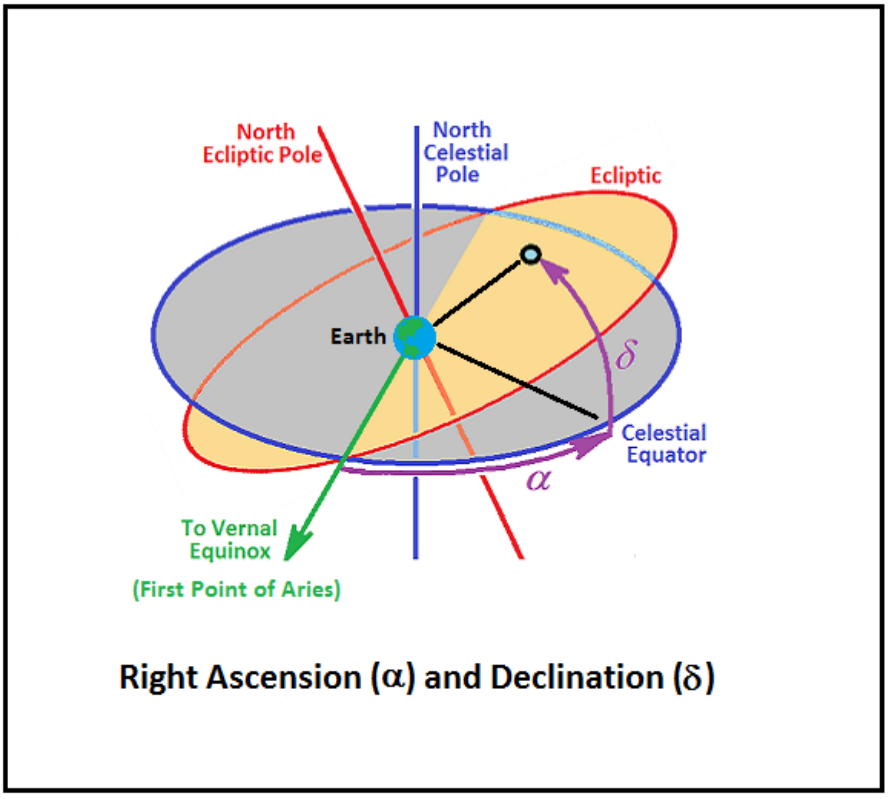
Using *Sun Moon Planets* - Right Ascension and Declination in the Celestial Sphere

Right Ascension (RA or Greek letter **α**) is the angular distance of an object (like a planet or star) that is east of the **First Point of Aries** (**Vernal Equinox** or ♈)and is measured along the **Celestial Equator**. The angle is measured in hours, minutes and seconds (h,m,s).

Declination (Decor Greek letter **δ**) is the angular distance of an object that is north or south of the **Celestial Equator**. The angle is measured in degrees (°), minutes (′), and seconds (″). The **Celestial Equator** is 0° and the poles are +90° (north) and -90° (south).



Right Ascension (α) and Declination (δ)

Where is the **First Point of Aries**? It is now in the constellation Pisces. Just click menu item **View** and select **Ecliptic View**. In the dialog box note the location of RA = 0 hours and Dec = 0°. You should see the constellation Pisces near that point.

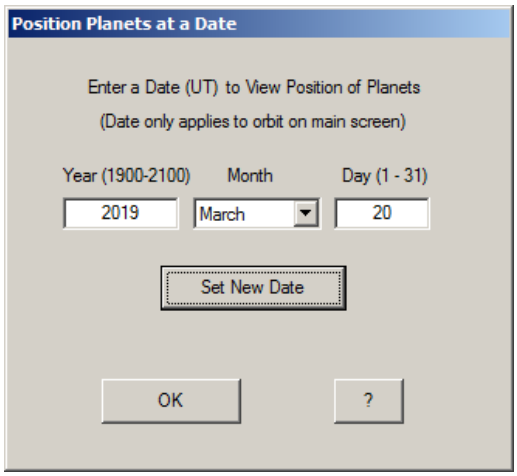
In the figure above there are several items that need to be clearly understood.

- Imagine that the Earth is at the center. The equator of the Earth extends out into space as the **Celestial Equator**. The north and south poles of the Earth also extend out as the **North Celestial Pole** and the **South Celestial Pole**.
- The Earth revolves around the Sun in a plane that is tilted at approximately 23.5° with respect to the **Celestial Equator**. This plane is called the **Ecliptic**. The **Ecliptic** also has a **North Ecliptic Pole** and a **South Ecliptic Pole**.
- Note the point where the **Ecliptic** rises through the **Celestial Equator**. Mentally a line drawn from the Earth to that point. That line would point in the direction of the **First Point of Aries** (**Vernal Equinox** or ♈). That direction is where the **Right Ascension** (RA) is equal to 0h, 0m, 0s and the **Declination** (Dec) is 0°, 0', 0".
- The **First Point of Aries** is our starting point. Now imagine a planet or star in the sky. The coordinates of that object would be stated in term s of RA and Dec. To get RA, move counter-clockwise from the **Vernal Equinox** along the **Celestial Equator**. That angle is shown in the figure above as **α.** Next, move up (northward) from the **Celestial Equator** to the object. That angle is shown in figure aboveas **δ**.

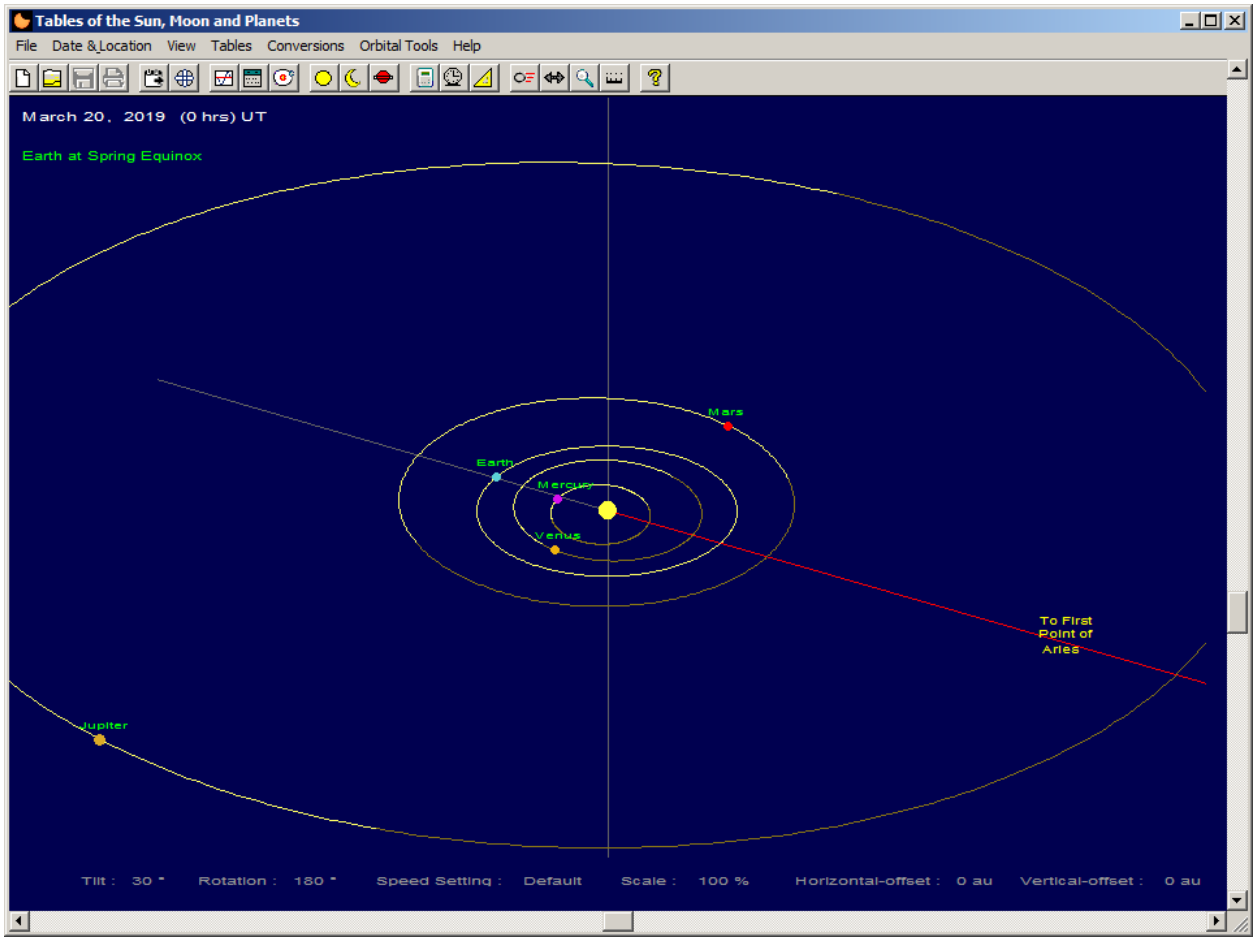
<u>Examples of Using RA and Dec in the Celestial Sphere</u>

Open the program Sun, Moon, Planets. On the main screen you should see the position of the planets orbiting the Sun. Also note the red line from the Sun pointing to the right side of the screen. That line is pointing towards the **First Point of Aries**. That is the direction for which **α**= 0h, 0m, 0s and**δ**= 0°, 0',0".

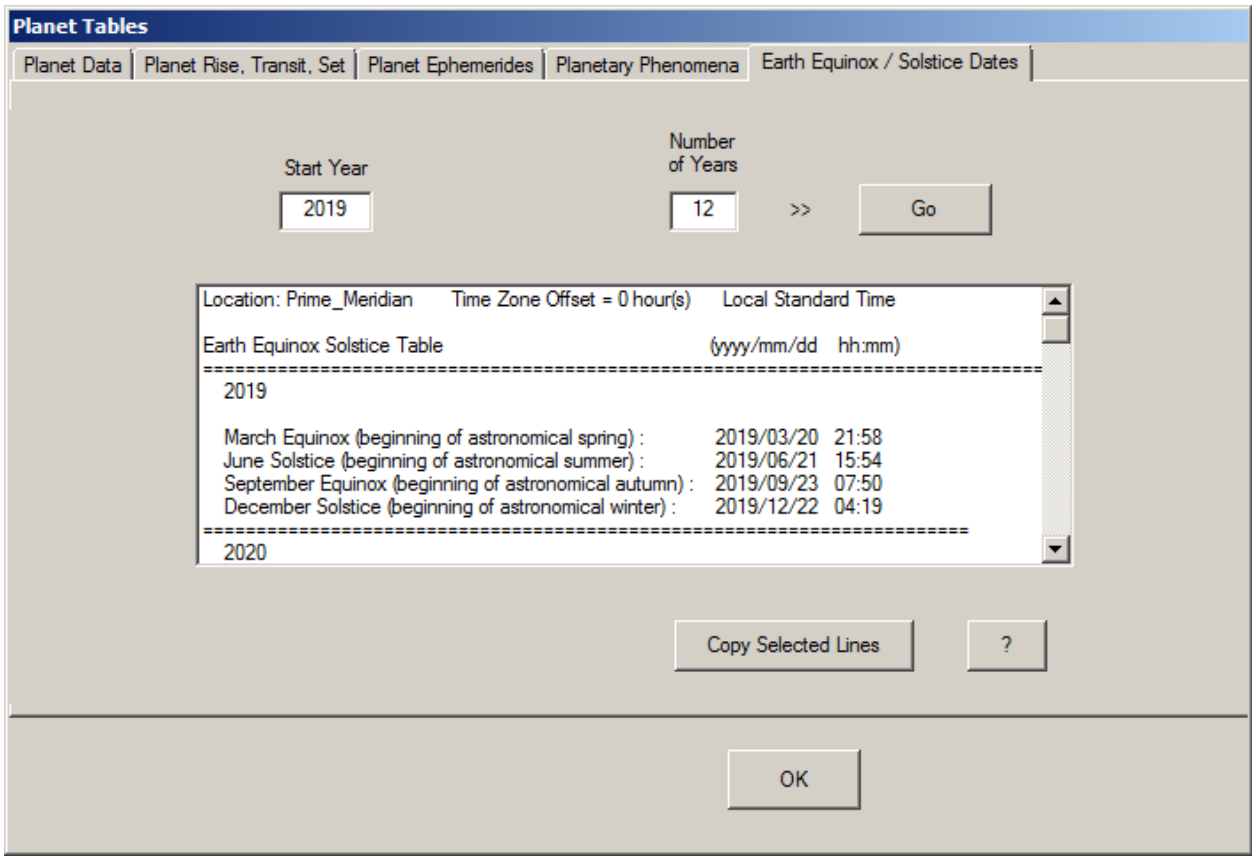
Using the **Date & Location** menu item, click **Select a Date**. In the dialog box, enter the date **2019, March 20** and click the button **Set New Date**. Then click the **OK** button.



Look at the position of the planets on the main screen. Note in green at top left that Earth is at **Spring Equinox**. Also note that Earth is in-line with the Sun and opposite the **First Point of Aries**.

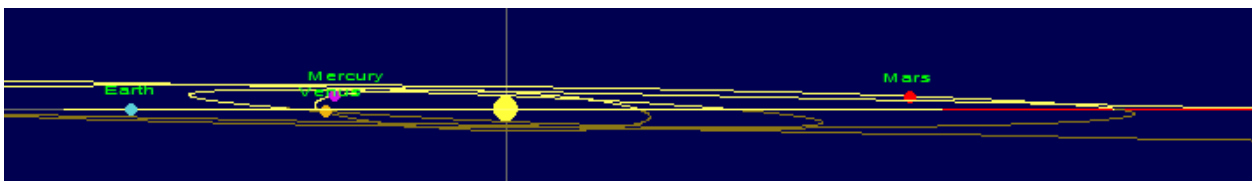


Next, select menu item **Tables** and **Planet Tables**. From that dialog box select the tab **Earth Equinox / Solstice Dates** as shown below.



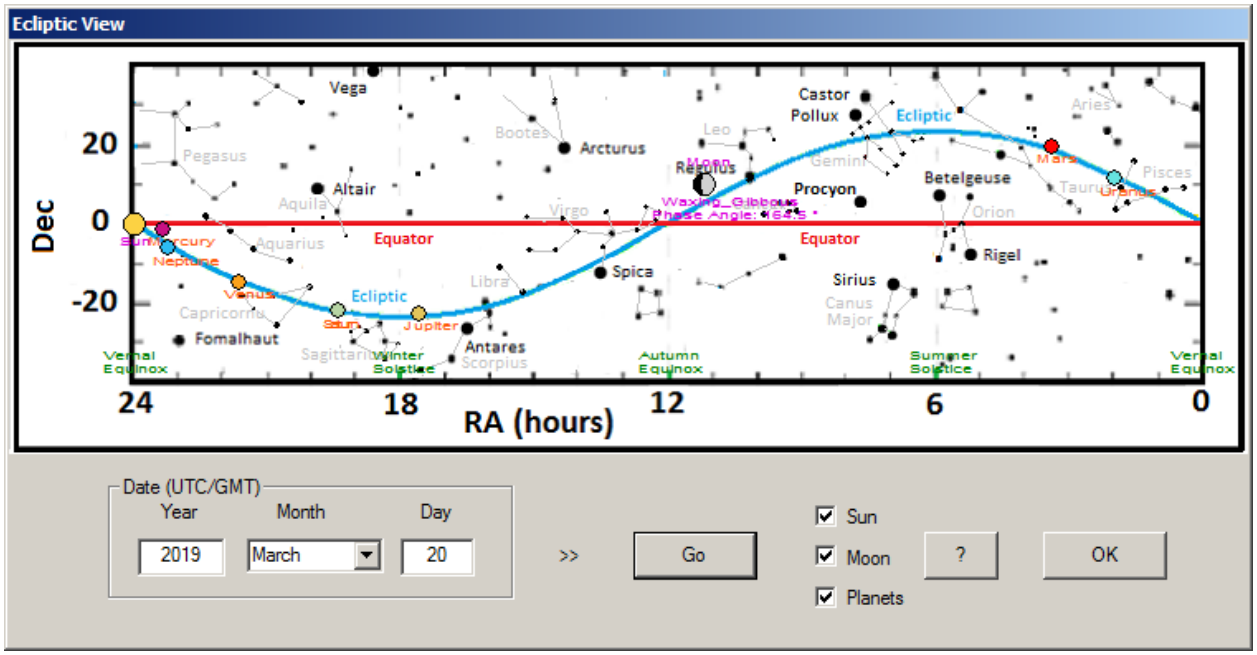
Note in the text box the date and time of the **March Equinox** - it is 2019/03/20 at 21:58. Also note the location is for the Prime Meridian. So, at that instant of time, the Sun would be rising through the Earth's **Celestial Equator**. It is at that instant of time that Spring begins. If you had chosen a different location (such as Toronto, Ontario) the first day of Spring would have begun at 16:58(4:58 pm).

To get a different view of this event, adjust the orbit scale (**Scale Tool**) to about 250% and then use the vertical slider to set the **Tilt** to 0°. Look closely to see the Earth and the Sun directly in line with the **First Point of Aries**.



In the flat view above, what you are looking at is the **Ecliptic** plane. Most of the planets are very close to this plane.

For another view point select menu item **View** and then **Ecliptic View**. This brings upa dialog box that shows RA on the horizontal axis and the Dec on the vertical axis. In this dialog box, set the date to 2019, March 20.

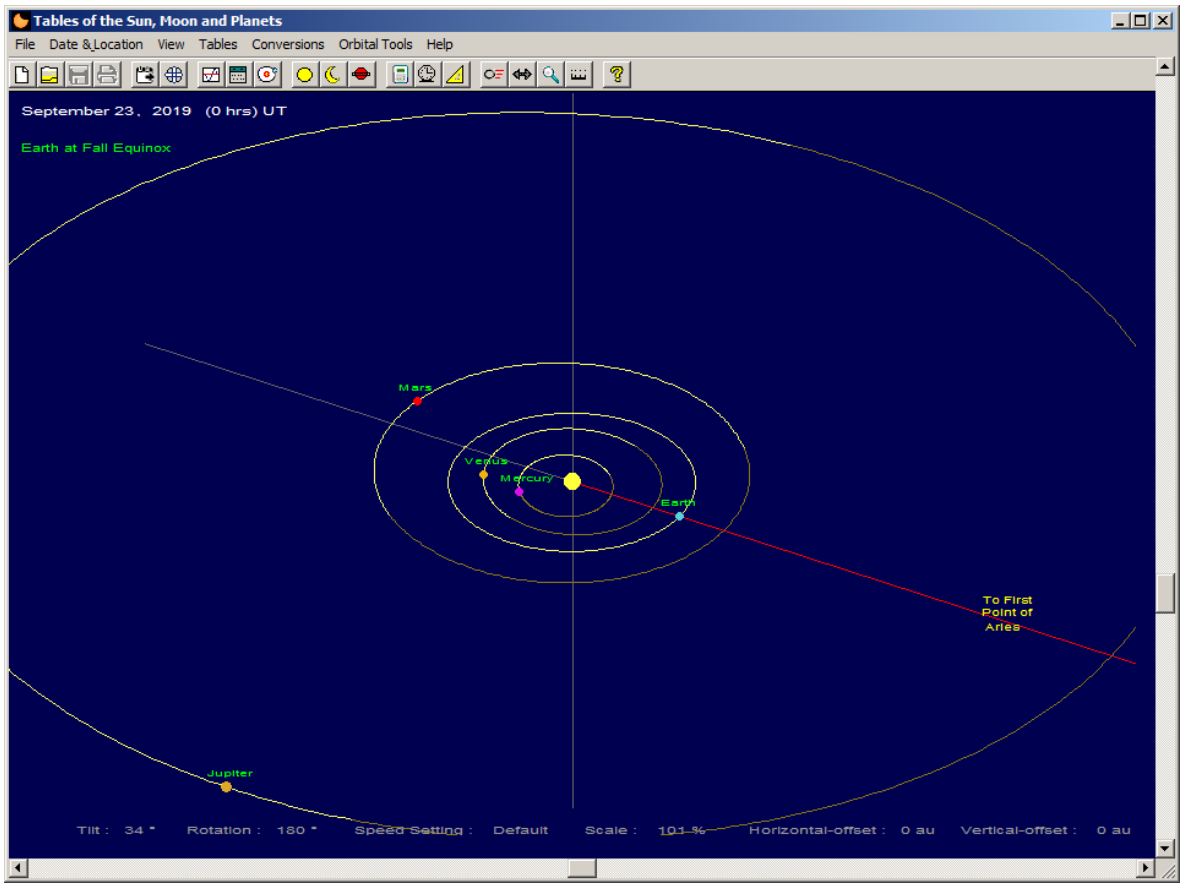


In the dialog box you can see the position of the planets, the Moon, and also the Sun, all generally following along the **Ecliptic**. Note that the Sun is located at RA = 24 hours and Dec = 0°. If you add one more day the Sun appears at 0 hours (RA). 24 hours and 0 hours are the same. The Sun is at the **First Point of Aries**.

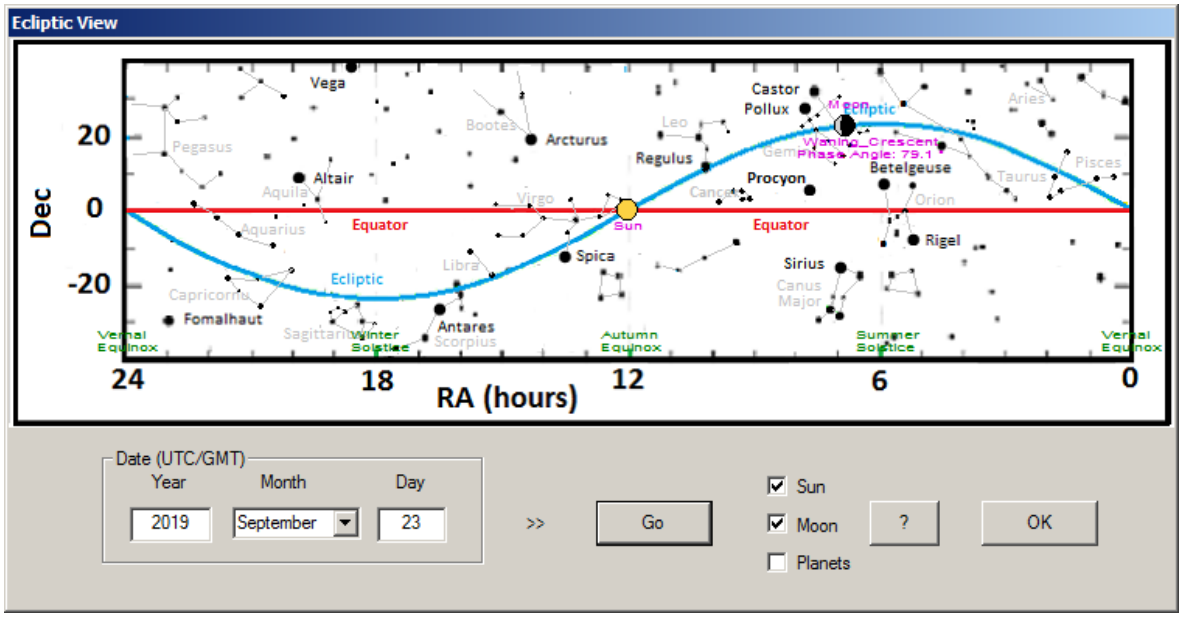
The **First Point of Aries** is a location; the **March Equinox**, **Spring Equinox**, **Vernal Equinox** is the date at which the Sun is at the **First Point of Aries**.

When the Sun is at 0 hours RA and 0° Dec then it is the **Spring Equinox**. Now if you go back to the main screen and change the Date to 2019,September 23rd then you will see that the Earth is again in-line with the Sun but this time it is on the opposite side, between the Sun and the **First Point of Aries**.

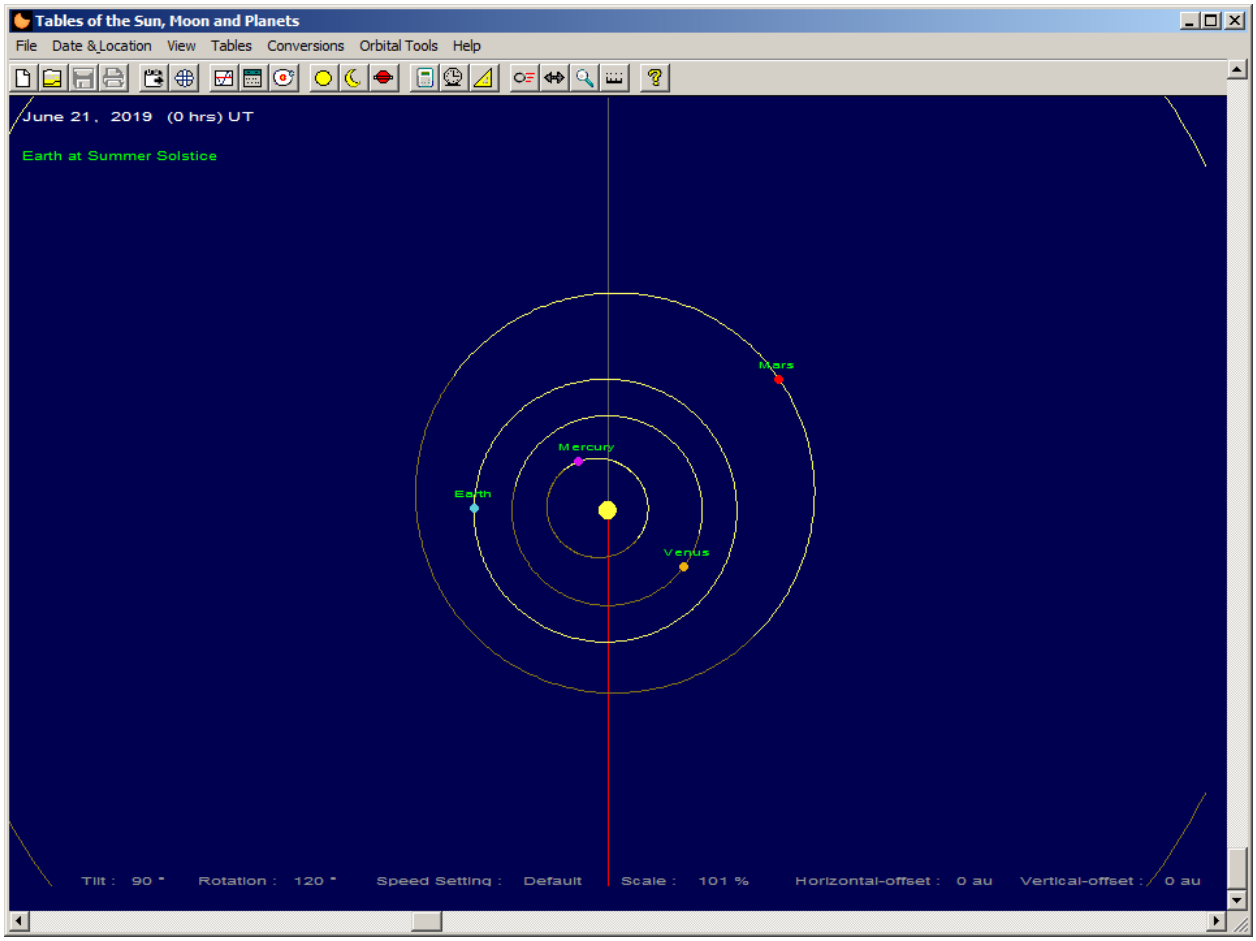
Note in the top, left corner the green text states the Earth is at **Fall Equinox**.



If you click menu item **View** and **Ecliptic View** and then in the dialog box set the date to 2019, September 23rd (same as on the main screen). Note that the Sun is now right in the middle at RA = 12 hours and Dec = 0°.

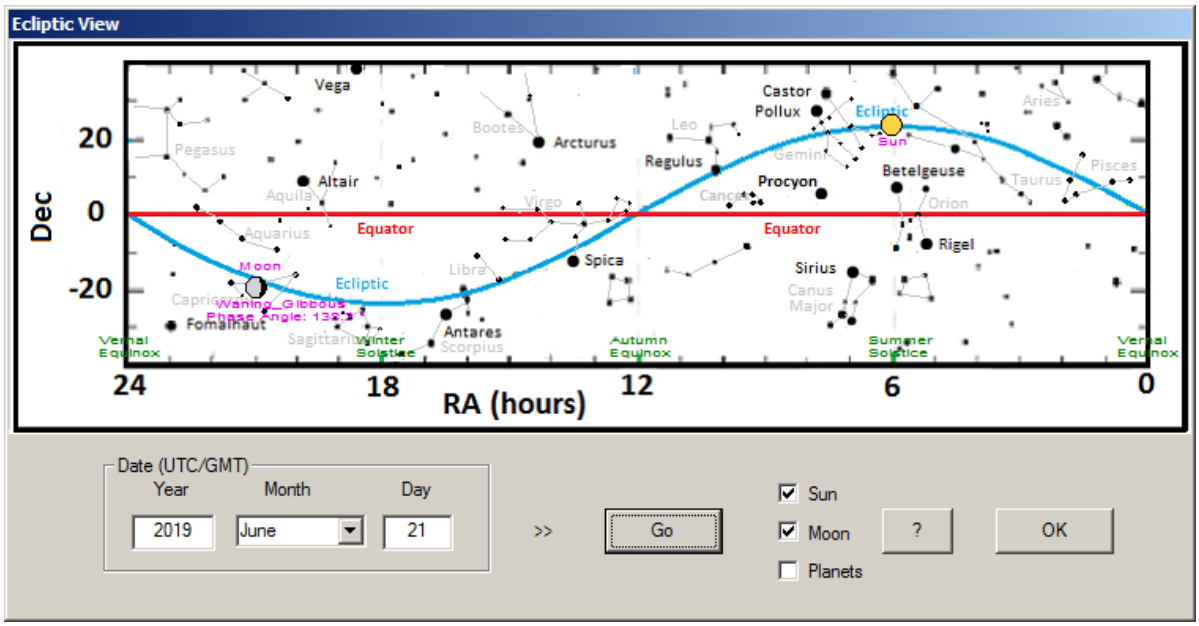


For the **Solstices**, first set the main screen date to 2019, June 21st.
On the main screen note that it is the date of the **Summer Solstice** and the position of the Earth is at 90° to the left of the Sun - or, the Sun is at 90° to the right of the Earth. Observe that the vertical slider (tilt) has been moved to the bottom (90°) and the horizontal slider (rotation) has been moved to 120°.



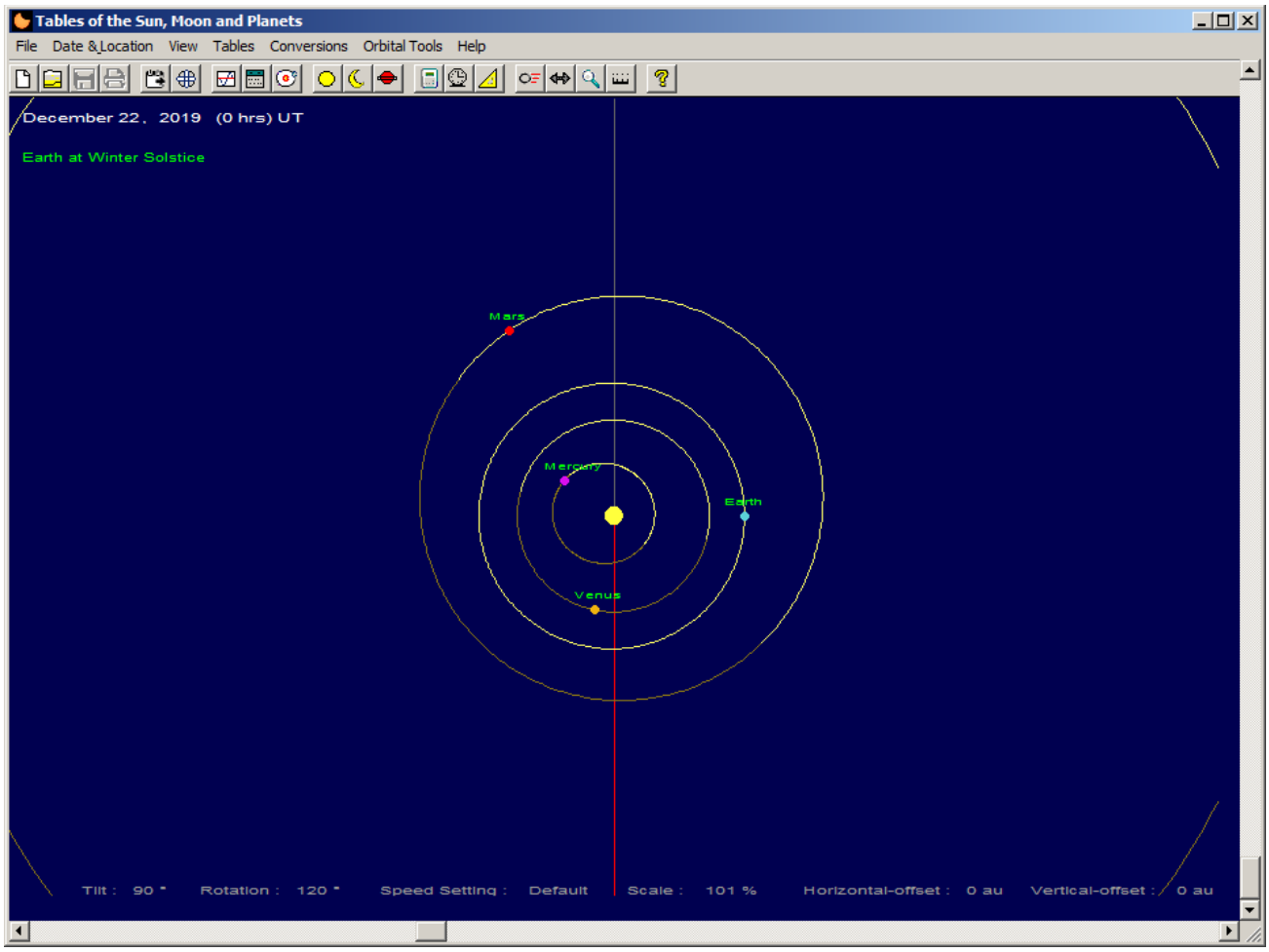
If you click menu item **View** and **Ecliptic View** and then in the dialog box set the date to 2019, June 21st (same as on the main screen). Note that the Sun is now at RA = 6 hours and Dec is approximately 23° (at its highest point).

Keep this 6 hours of RA in mind for a few minutes.

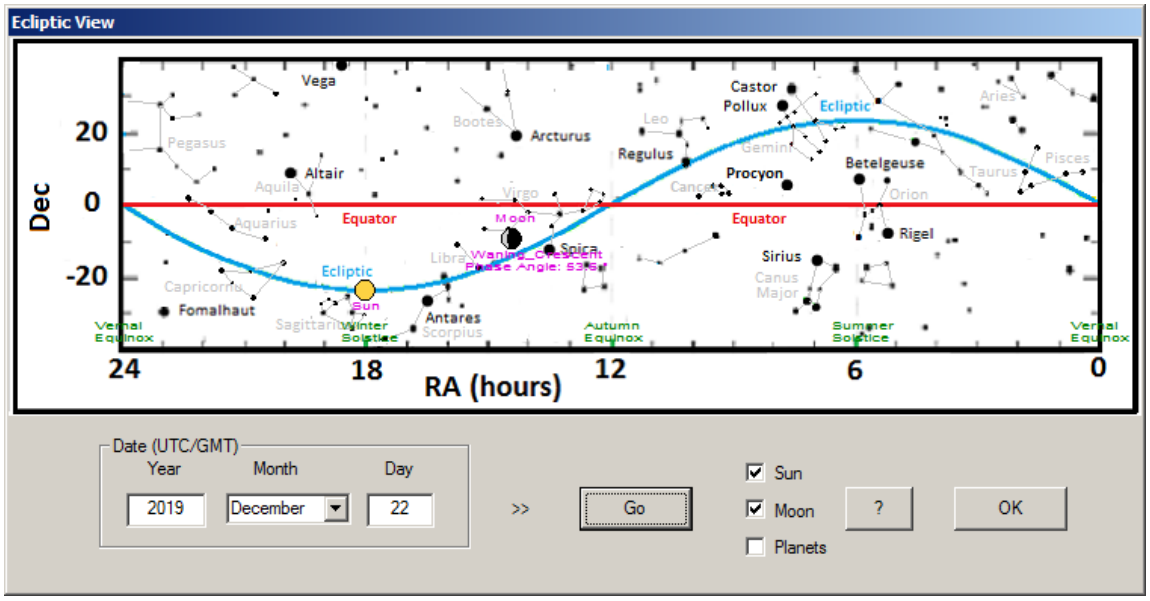


A bit of explanation here - Right Ascension (RA) runs from 0 hours to 24 hours similar to a clock. There are 360° degrees in a circle, same as the Earth orbiting the Sun. Therefore 24 hours corresponds to 360°. This means
1 hour of RA = 360° / 24 hours. Or, in other words, 1hour of RA corresponds to 15°. So, therefore 6 hours RA corresponds to 90° as is shown on the main screen.

Now, let's look at the last one, the **Winter Solstice**. Set the date on the main screen for 2019, December 22nd. Note the position of the Earth relative to the Sun. This time it's on the opposite side at 90° so that the Sun is to the left of the Earth.



In the **Ecliptic View**, the Sun is at 18 hours RA.



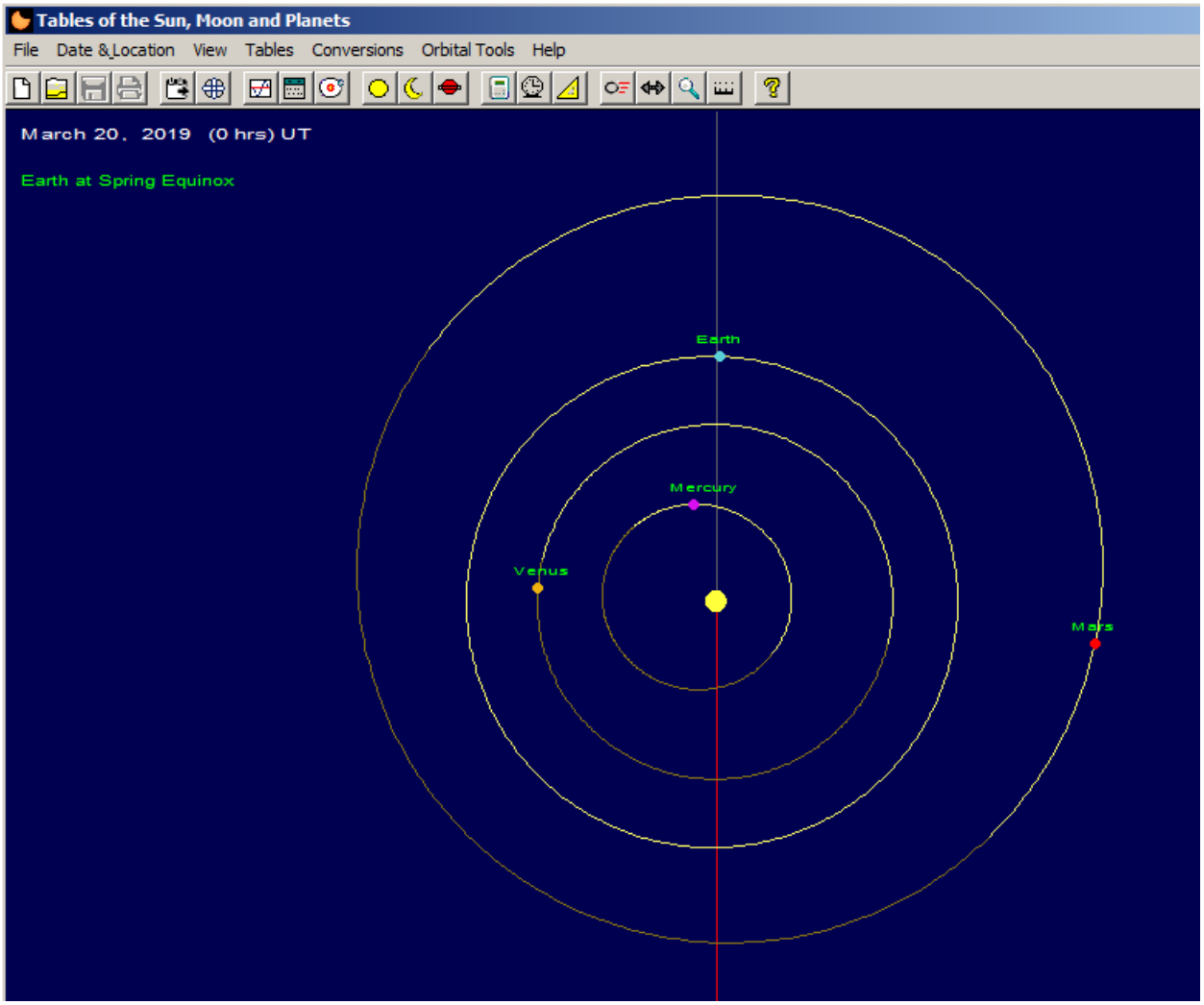
So, as the Earth revolves around the Sun throughout the year, the Sun appears to orbit the Earth and occupy a different position of Right Ascension (RA) and Declination (Dec) each day. This should not be confused with the apparent motion of the Sun as it rises and sets each day - this is due to the Earth's rotation on its axis, not on the Earths revolution around the Sun throughout the year.

To better understand this, suppose you were to pick any particular time of day (e.g. 12:00 noon) and observe the position of the Sun at the same time every day throughout the year. You would notice that the Sun appears to have slight changes in position at that same time every day. This is due to the revolution of the Earth around the Sun, not to the rotation of the Earth.

What we can take away from this is that from our position on Earth we can identify the position (RA and Dec) of any object in the sky including the Sun, Moon, planets, asteroids, comets, stars, etc. This gives every object in the sky a defined position that is not dependant on your latitude or longitude. This makes it much easier to communicate the position of an object to others without including your own particular latitude and longitude. It also allows you to standardize the position of objects such as stars that are very far away. For example, Betelgeuse (in the constellation Orion) has a **Right Ascension** of 5h 55m 10.3 s and a **Declination** of +7° 24' 25.4". It's position does not change.

But, as we have seen, celestial objects (within our solar system) are much closer and so when we state their position, it depends on the position of the Earth as it orbits around the Sun and also the position of that object as it orbits the Sun. For example: 2019, August 26, Mars is at RA = 10h 28m 47s and Dec +10° 43'24"; but later on 2019, September 26, Mars is at 11h 42m 17s and Dec +3° 0' 31".

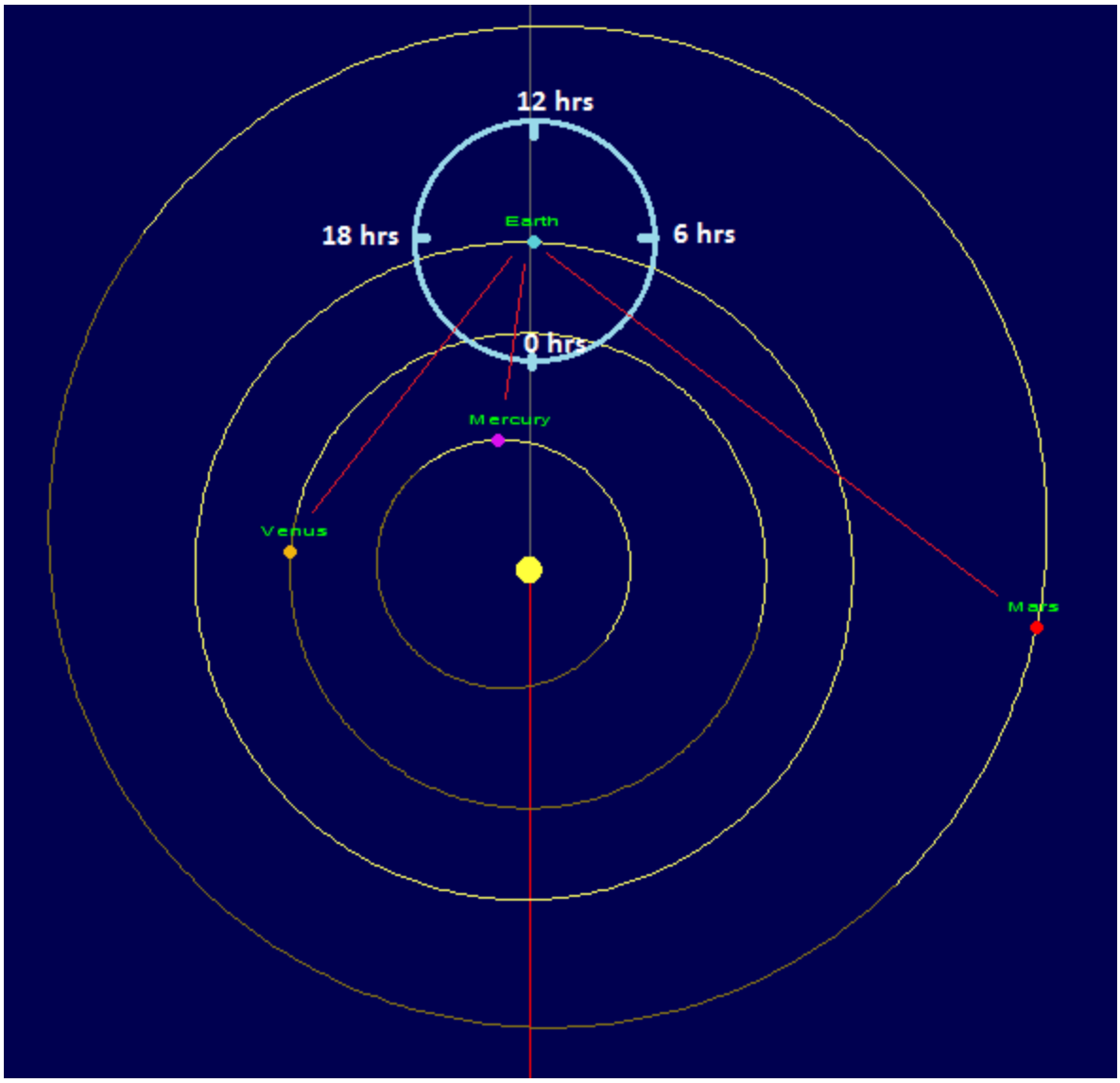
On the main screen set the date again for 2019, March 20 (although the following exercise can be done for any date). Next, move the vertical slider to the bottom so that **Tilt** is at 90° and then the horizontal slider so that **Rotation** is 120°. Here is what the main screen should look like.



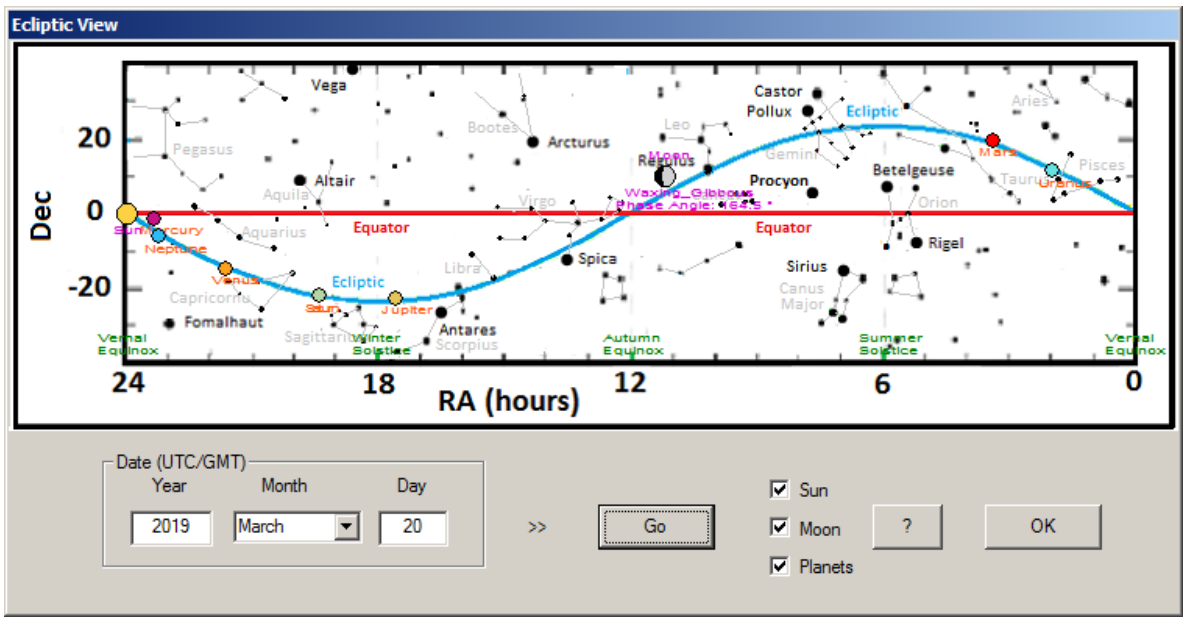
Note, the red line pointing to the **First Point of Aries** is straight down.

Now, imagine a 24 hour**Right Ascension** clock around the Earth as shown below. The circle around Earth is marked off at 0 hours (at the bottom), 6 hours, 12 hours (at the top), 18 hours, and back to 0 hours.

On this date, from the view at Earth, the Sun is at 0 hours.The angular position of Mars appears about halfway between 0 hours and 6 hours, so a quick estimate might be around 3 hours. A quick estimate of Venus might be around 21 to 22 hours and for Mercury around 23 hours. If you go to the **Planet Tables**and check the **Planet Ephemerides** for Mars, Venus, and Mercury for 2019, March 20, you should see that those approximations are reasonably accurate.



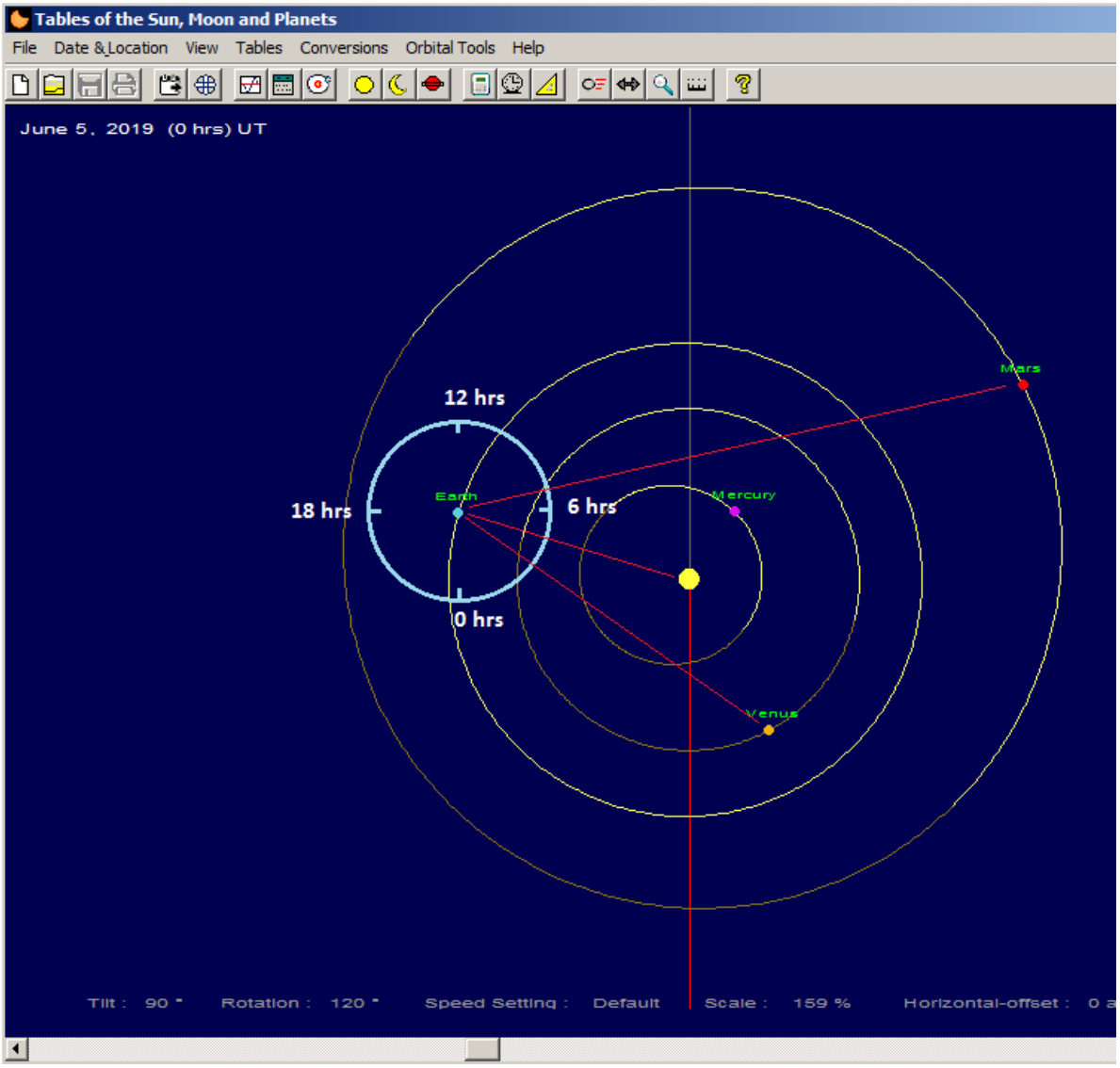
Also, if you bring up the dialog box for the **Ecliptic View**, set the date for 2019, March 20 and then look for the RA and Dec of those three planets. Again, Mars is around 3 hours RA, Venus is around 21 to 22 hours and Mercury is about 23 hours.



Any time you look at the main screen, note the position of Earth and the other planets. Imagine the 24 hour**Right Ascension** clock with 0 hours straight down and 12 hours straight up. Then try to guess at the RA of the planets relative to the Earth. To check your guess just go to the **Planet Tables** and select the **Ephemerides** tab, set the date and select the planets. Compare your approximations of RA with those in the table.

Try any different date - for example, set it to 2019, June 5. Make sure the red line for the **First Point of Aries**is pointing straight down.

Check the figure below. In this position, the view from Earth, the Sun appears to be around 5 hours (RA). The angular position of Mars appears to be about 7 hours. A quick estimate of Venus might be between 3 and 4 hours and for Mercury around 6 hours. If you go to the **Planet Tables**and check the **Planet Ephemerides** for Mars, Venus, and Mercury for 2019, June 5 you should see that those approximations are reasonably accurate. Also, the **Ephemerides** in the **Sun Tables**(set the date) shows the Sun to be 4h 50m 55s, very close to the estimated 5 hours.



If you bring up the **Ecliptic View** and make sure the date is the same, 2019, June 5, you should note the Sun appears to be around 5 hours, Venus is close to 4 hours, Mars at 7 hours, and Mercury at 6 hours.

So, using Sun, Moon, Planet tables allows you to very quickly get an estimate of the position (RA) of the Sun, Moon, or planets on any date. Just move the red line straight down and imagine a **Right Ascension** clock around Earth.

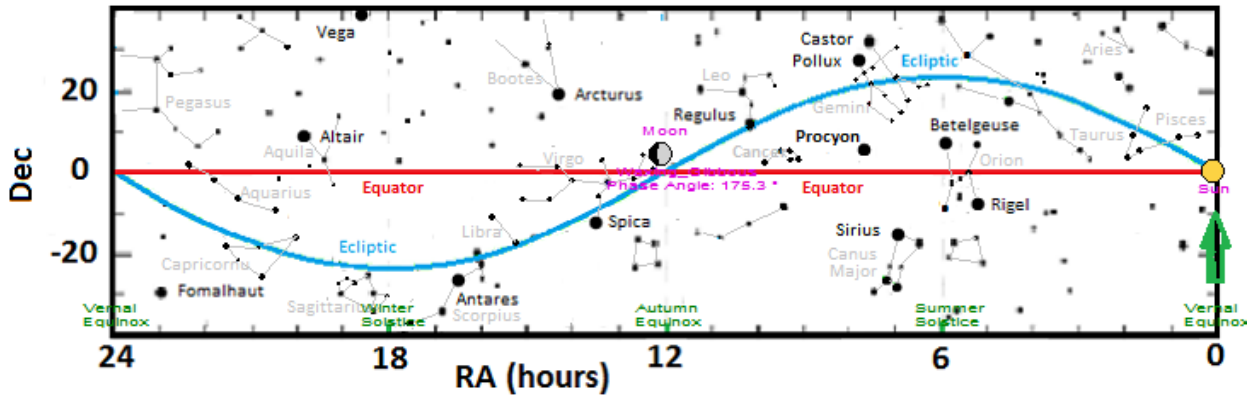
When you are outside observing the night sky, if you know the fixed RA of a well-known star, and the current RA of a planet, you can use the star to quickly find the planet.

For example, Betelgeuse (in the constellation Orion) is a well-known star, easy to find, and has a **Right Ascension** of approximately 6 hours and is a bit below the **Ecliptic**. On 2019, June 5, we find in this program that Mars is positioned around 7 hours. If you went outside at night on that date, found Betelgeuse, looked up a bit and about 15° to the left (east), there was Mars.

On June 5, 2019, the difference between Mars at 7 hours and Betelgeuse at 6 hours is 1 hour. Recall that 1 hour of Right Ascension is equivalent to 15°.

Precession

The **First Point of Aries** at RA = 0 hours and Dec = 0° (see green arrow below). At this point the **Ecliptic** (blue line) and the **Celestial Equator** (red line) intersect. As shown below, **Right Ascension** increases east (left) of that point. This is the point where the Sun appears to cross the **Celestial Equator** going north (+ Dec.) and the length of day and night are equal. Note the date of the **Vernal Equinox**.

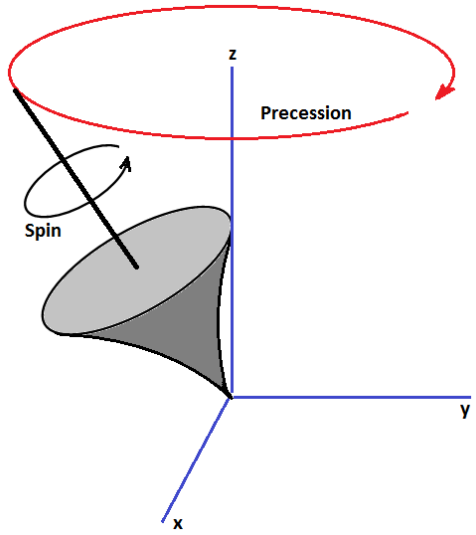


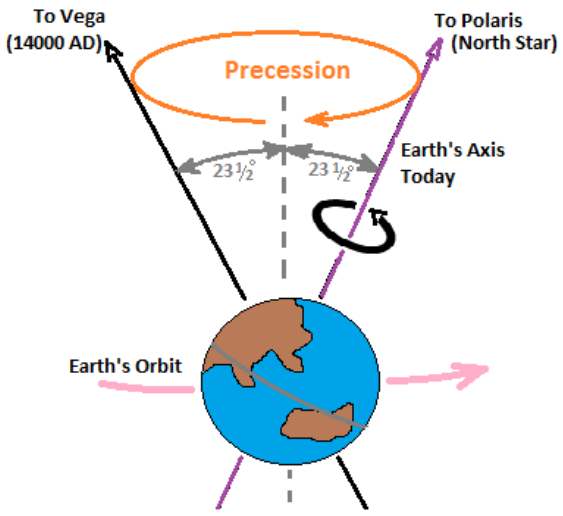
To see this dialog box, click menu item **View** and select **Ecliptic View**.
Why is the **First Point of Aries** now located in the constellationPisces?Observe in the dialog box the location of RA = 0 hours and Dec = 0°. You should see the constellation Pisces (light gray letters) near that point.If you look carefully in the dialog box, Aries is a bit above Pisces and east (left) of it. The **First Point of Aries** used to be in the constellation of Aries but has moved westward (to the right) towards the constellation Pisces.

Precession can be described as the wobble in the rotational axis of a rotating body (such as a top, or the Earth). Earth's precession has resulted in theequinoxes slowly moving westward relative to the background stars. In other words, the **Ecliptic** itself is moving westward. Precession is a result of the Earth's rotation and the gravitational pull of the planets, the Moon and the Sun. The Moon and the Sun are by far the most significant cause of precession.

The rate of precession is about 1 degree every 71.6 years (or 50.3 seconds of arc per year). In 14000 AD the Earth's axis will be pointing at Vega. For the Earth to complete a full cycle of 360° will take nearly 26000 years. At that time Polaris would be the North Star again.

The point at where the Sun crosses the **Celestial Equator** heading north along the **Ecliptic** is in the direction of the **First Point of Aries**. In 150 B.C. when Ptolemy mapped the constellations, Aries was in that position.





Hopefully, this exercise has cleared up some ideas about **Right Ascension** and **Declination**.

If you have any questions or comments, just send an email to **dgarner@astrotables.com**