Latitude determines how far north or south (up or down) you see on the celestial sphere. But, what determines how far east or west (left or right)?

Hint: right ascension is measured in “hours”.

(But why does right ascension “go backward”?)

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4	Explain, define, and utilize the celestial equatorial coordinate system of right ascension and declination, celestial equator and celestial poles.	
5	Describe changes in position and appearance of the stars through time and explain in terms of the actual motion and position of the Earth.	5
6	Define, apply, and relate to astronomical events or cycles the following time concepts: sidereal and solar day, sidereal and tropical year, mean solar time, standard time, daylight savings time, and universal time.	6
7	Use a planisphere to locate celestial objects for a particular date and time and/or determine the date and time of certain celestial events.	7 – 8
8	Describe changes in position and appearance of the Sun through time and explain in terms of the actual motion and position of the Earth.	9
9	State the constellations of the zodiac in order and explain the relation between the zodiac and the Sun.	10 – 14
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Sidereal Time

- Sidereal time is defined as being equal to the right ascension of the observer's meridian – a value that increases as time goes on.
- This depends on the observer's location and is sometimes called "local sidereal time" or LST. (because it depends on the *locale*)

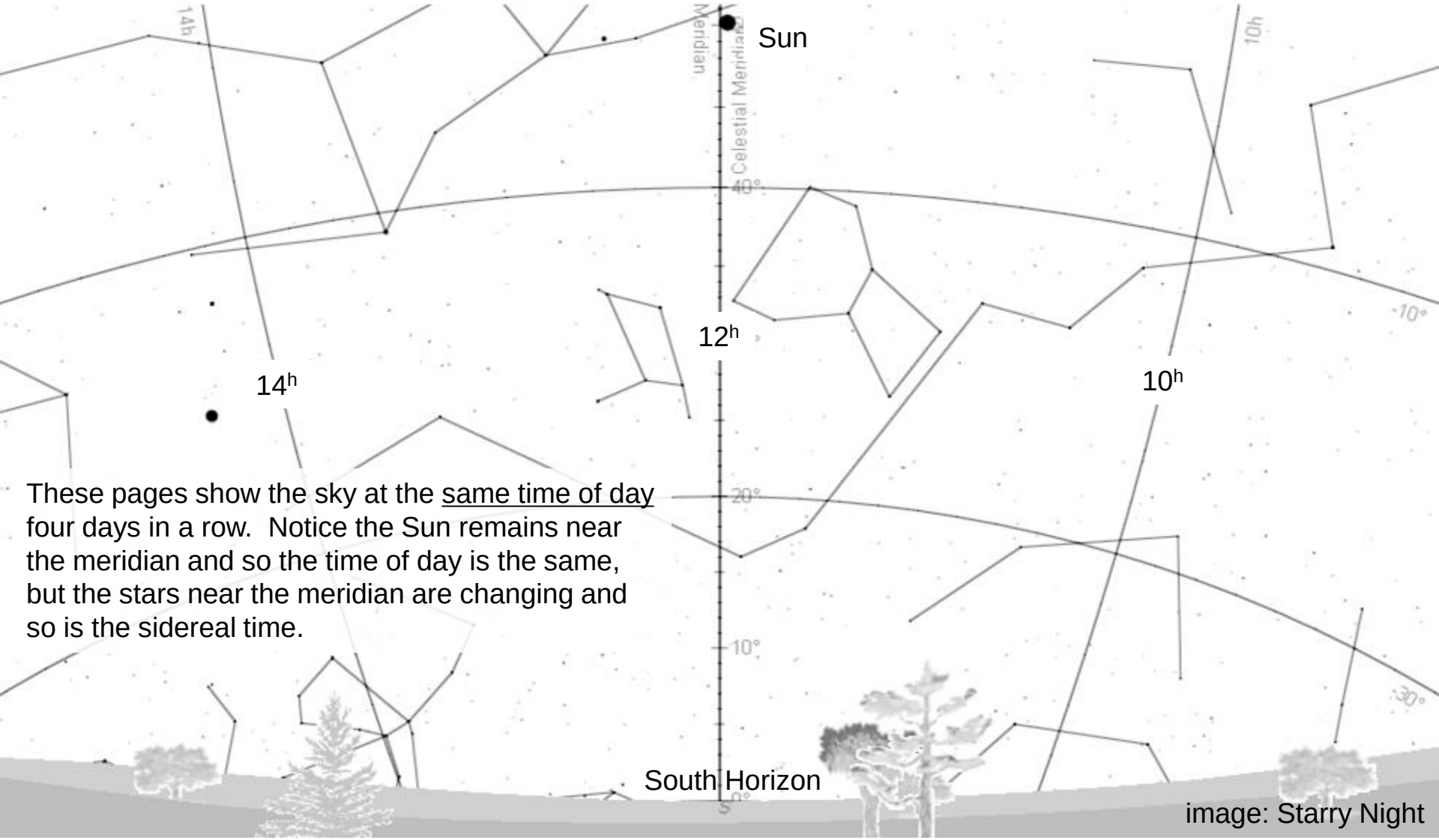
the Sidereal Day

- A sidereal day is the amount of time for the stars and the entire celestial sphere to complete one “rotation about earth”.
- One sidereal day is 23 hours, 56 minutes, 4.09 seconds.
- In this amount of time a star will rise and set and return to its original position.
- Because the sidereal day is not 24 hours, sidereal time is not equal to clock time.

the Solar Day

- A solar day is the amount of time for the Sun to complete one “rotation about earth”.
- The **mean solar day** is 24 hours.
- In this amount of time the Sun will rise and set and return to its original position.
- This is the time upon which our clocks are based.

Clock: 11:55 am Sidereal Time: $12^h\ 00^m$



These pages show the sky at the same time of day four days in a row. Notice the Sun remains near the meridian and so the time of day is the same, but the stars near the meridian are changing and so is the sidereal time.

image: Starry Night

Philadelphia: September 22, 2010

Clock: 11:55 am Sidereal Time: $12^h\ 04^m$

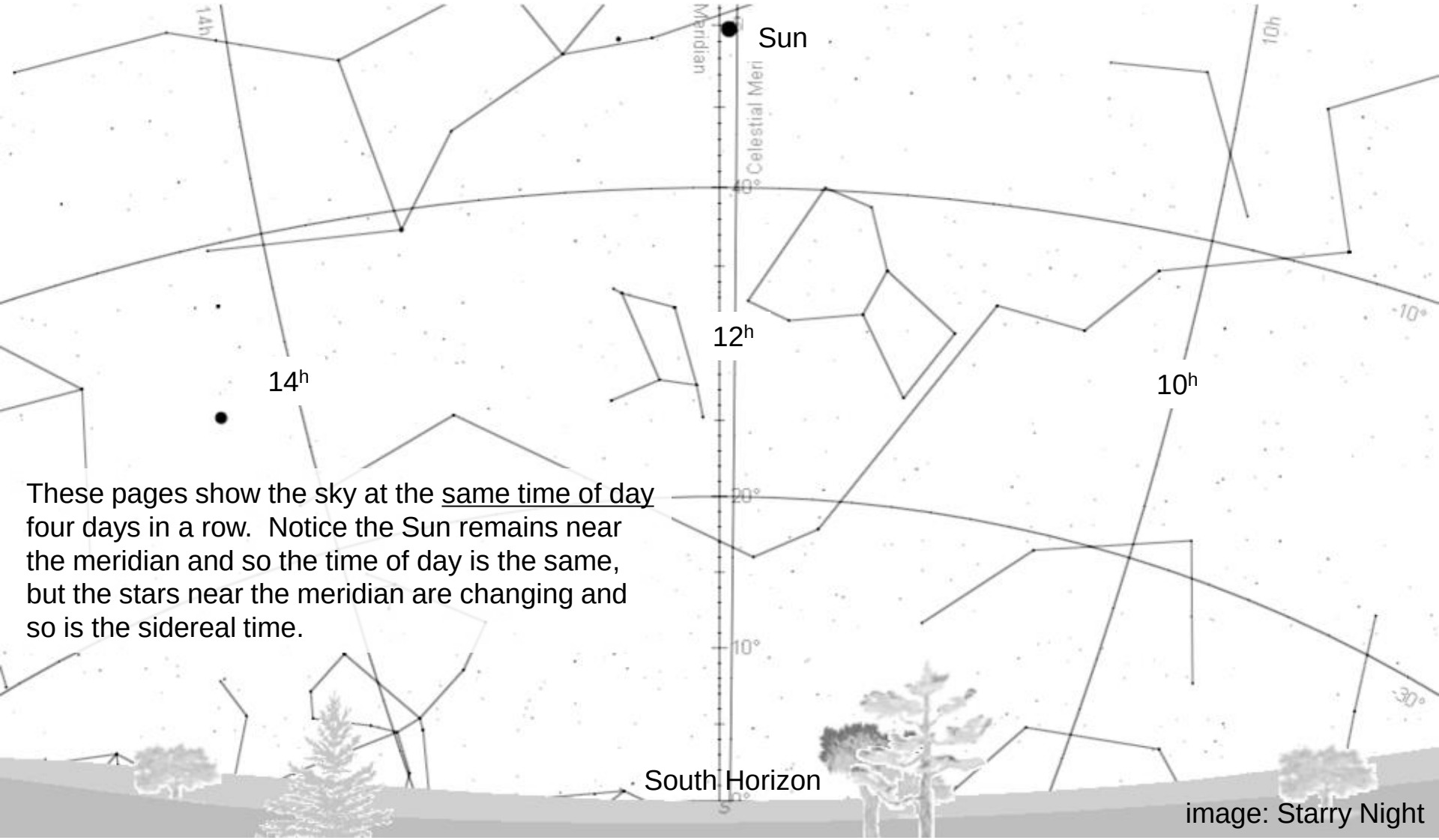


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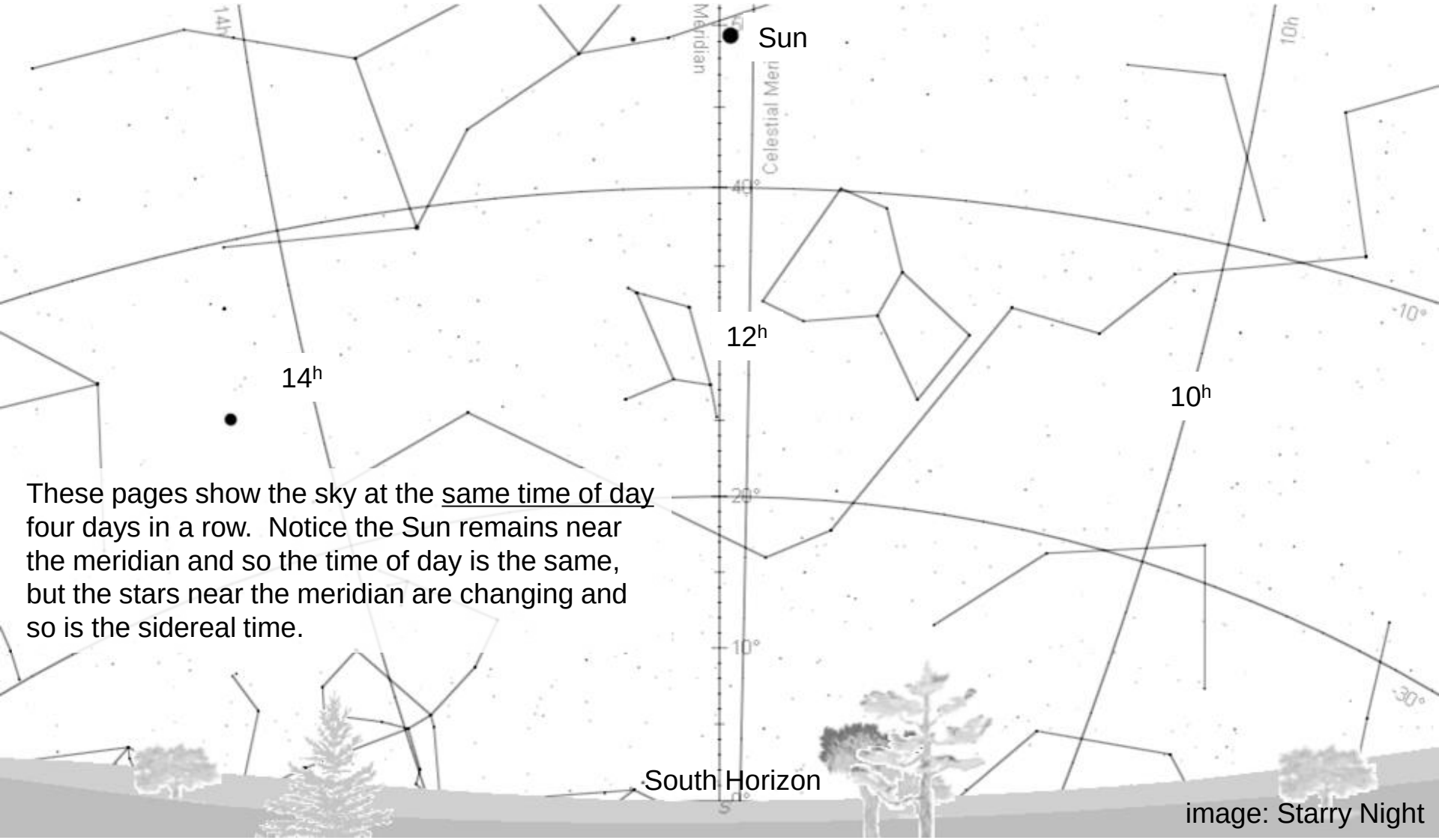
image: Starry Night

Philadelphia: September 23, 2010

Clock: 11:55 am Sidereal Time: $12^h\ 08^m$

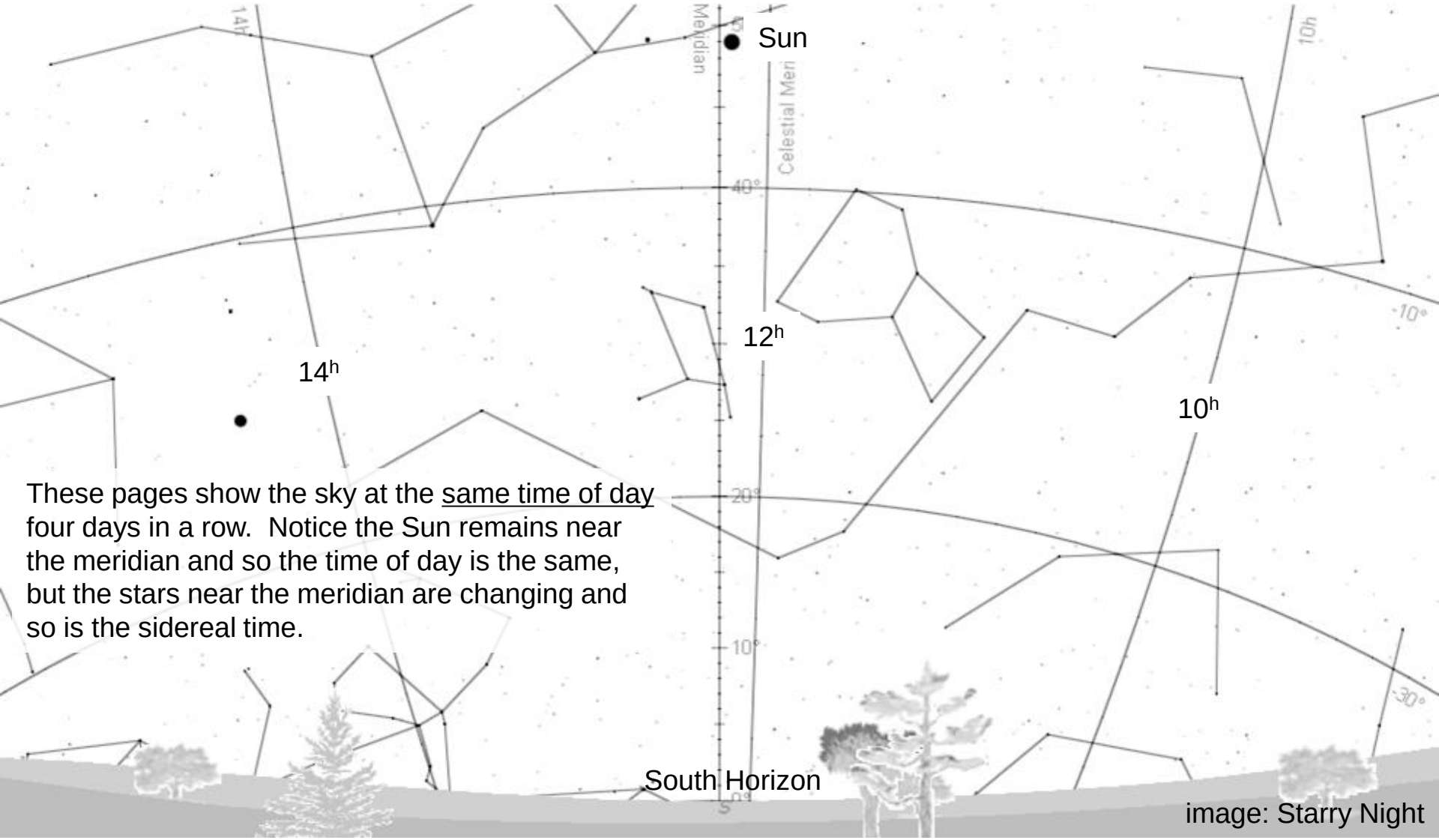


These pages show the sky at the same time of day four days in a row. Notice the Sun remains near the meridian and so the time of day is the same, but the stars near the meridian are changing and so is the sidereal time.

image: Starry Night

Philadelphia: September 24, 2010

Clock: 11:55 am Sidereal Time: $12^h\ 12^m$

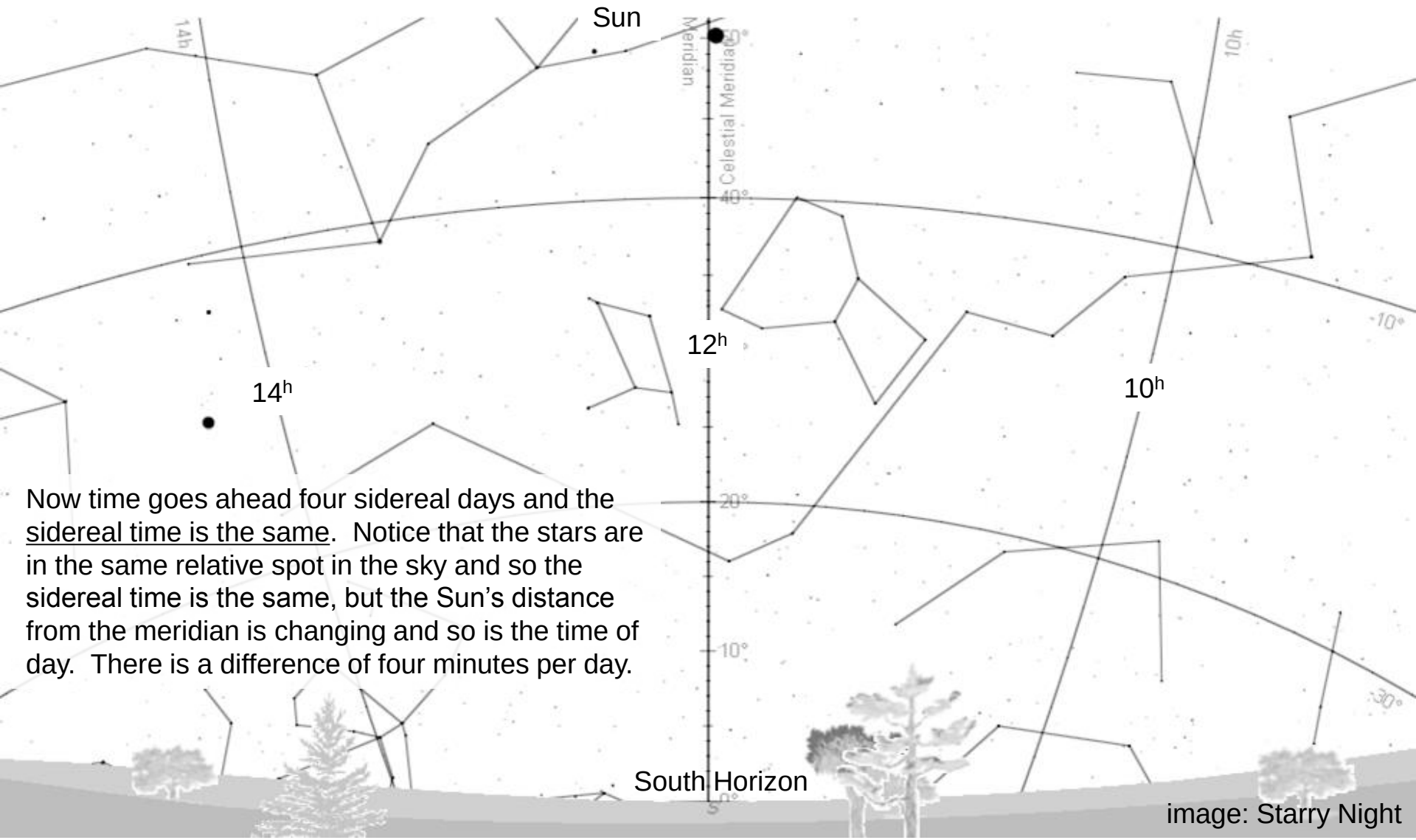


These pages show the sky at the same time of day four days in a row. Notice the Sun remains near the meridian and so the time of day is the same, but the stars near the meridian are changing and so is the sidereal time.

image: Starry Night

Philadelphia: September 25, 2010

Clock: 11:55 am Sidereal Time: $12^h\ 00^m$

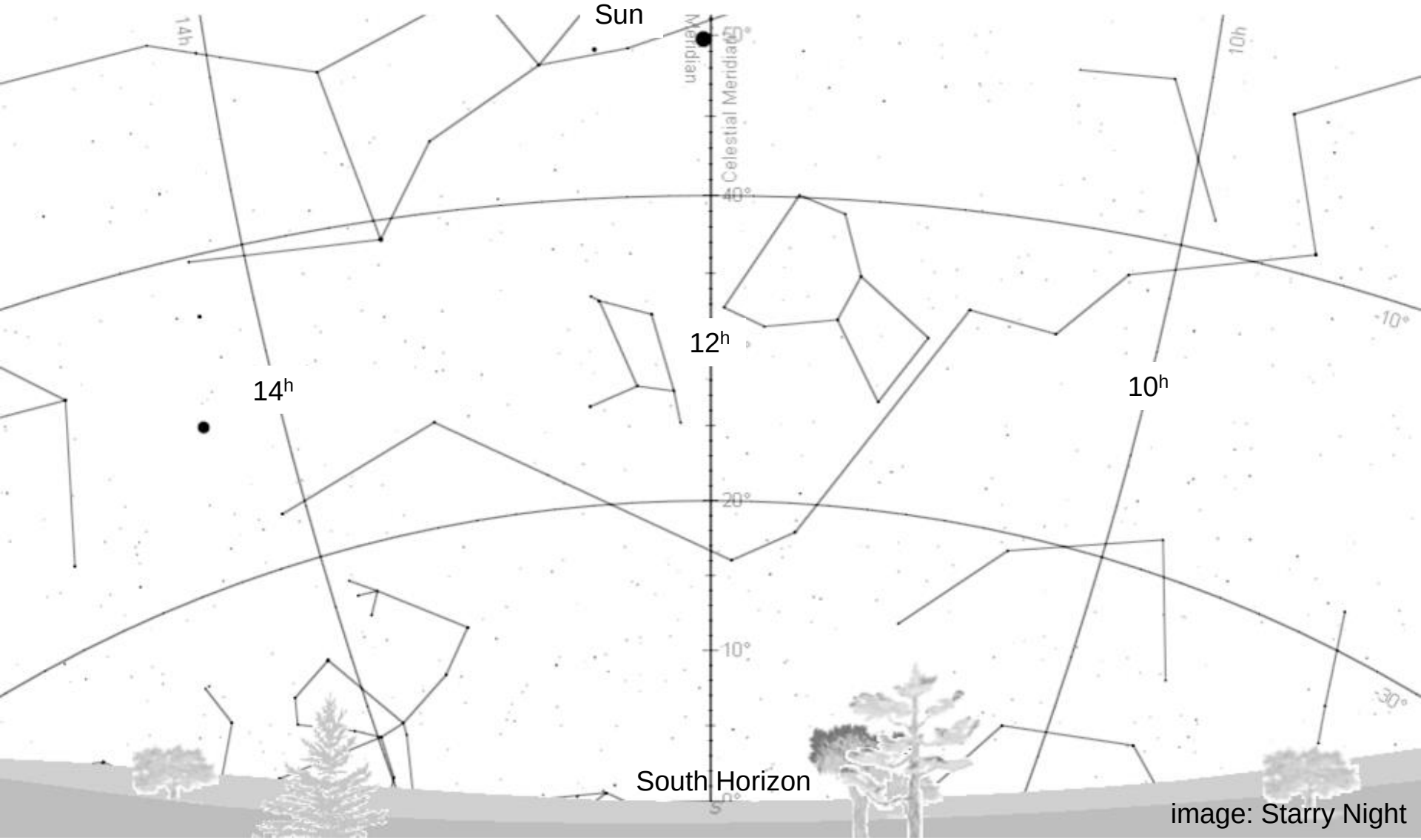


Now time goes ahead four sidereal days and the sidereal time is the same. Notice that the stars are in the same relative spot in the sky and so the sidereal time is the same, but the Sun's distance from the meridian is changing and so is the time of day. There is a difference of four minutes per day.

image: Starry Night

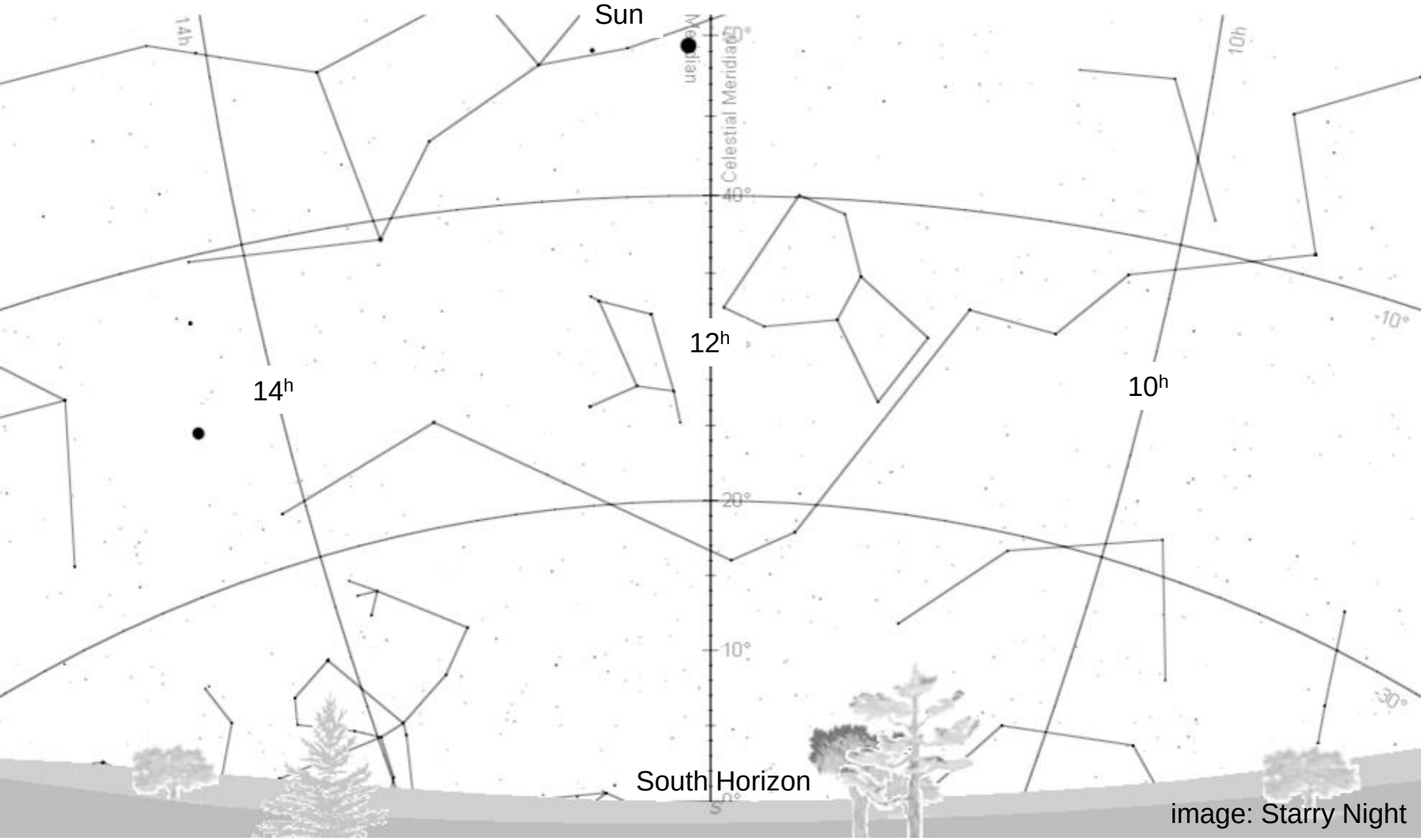
Philadelphia: September 22, 2010

Clock: 11:51 am Sidereal Time: $12^h\ 00^m$



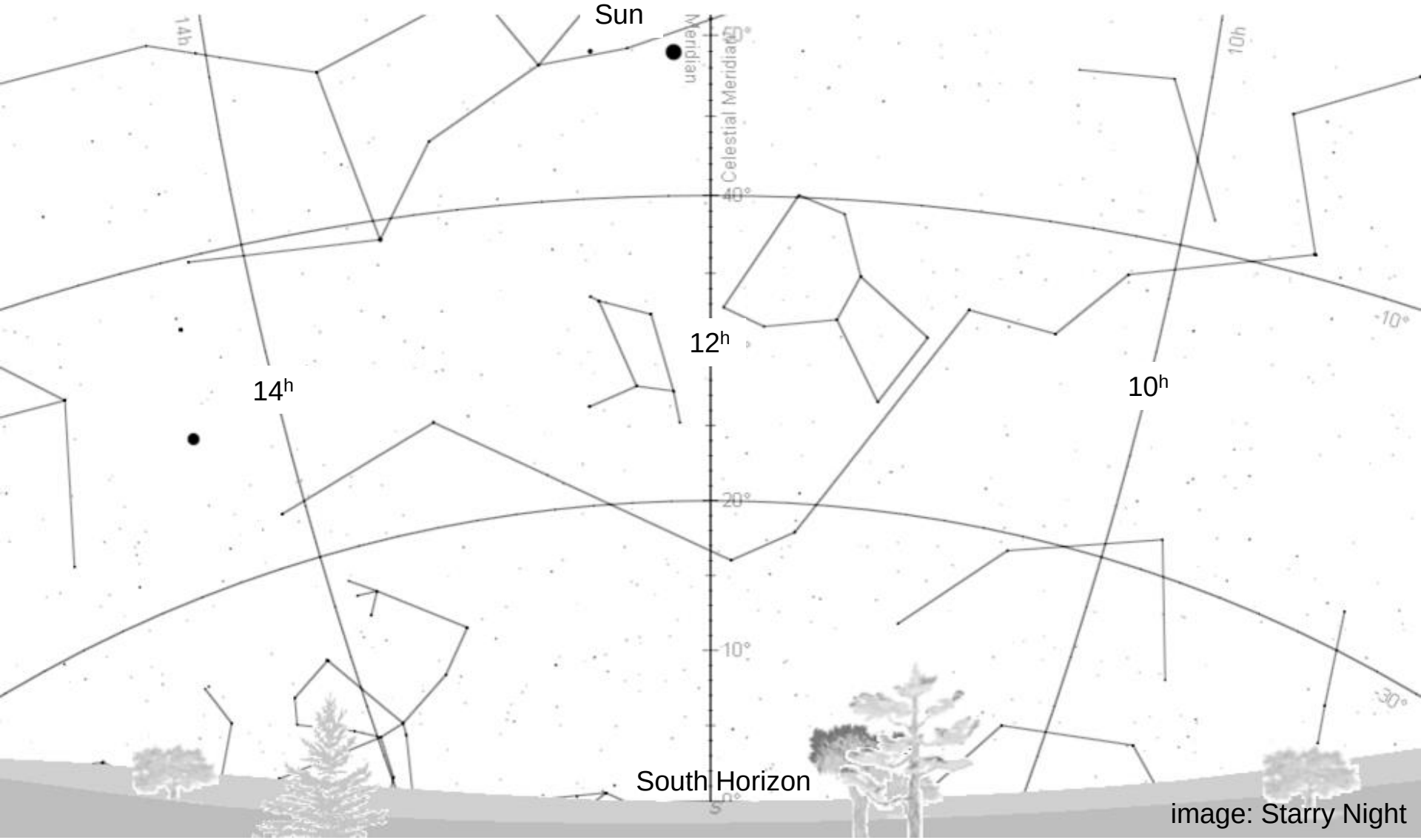
Philadelphia: September 23, 2010

Clock: 11:47 am Sidereal Time: $12^h\ 00^m$



Philadelphia: September 24, 2010

Clock: 11:43 am Sidereal Time: $12^h\ 00^m$



Philadelphia: September 25, 2010

Specifying Points in Time

different “types” of time

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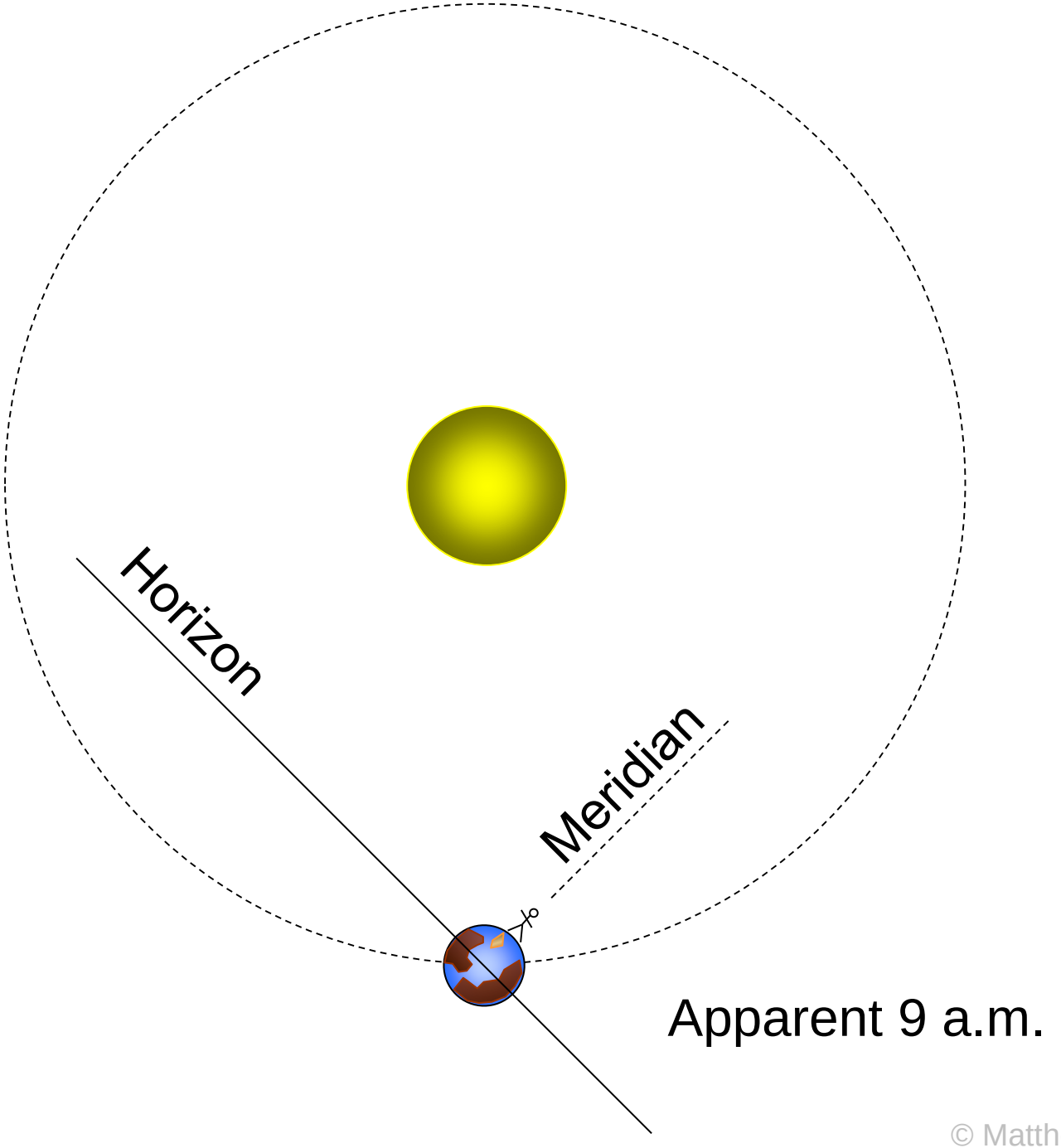
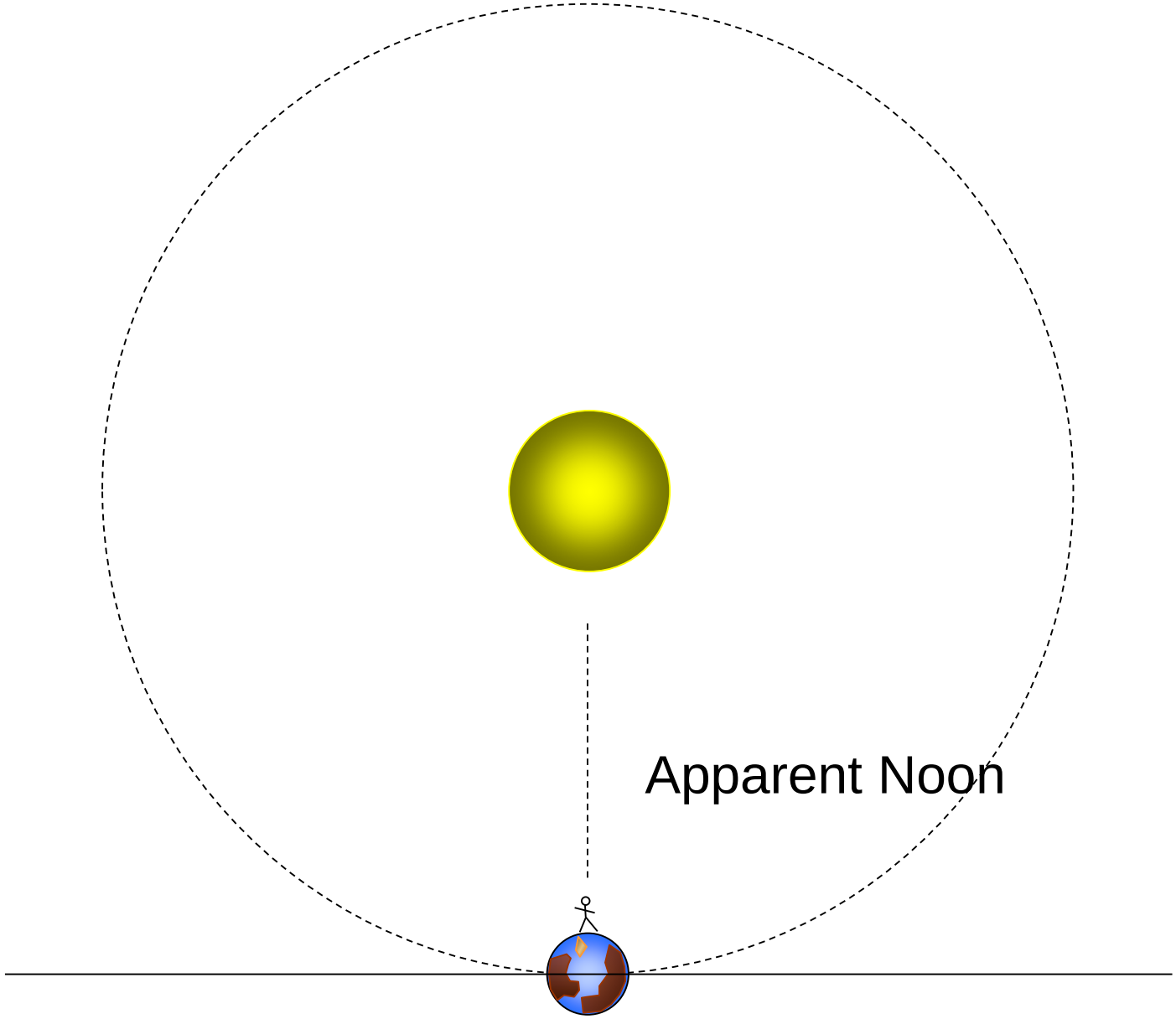
Apparent Solar Time

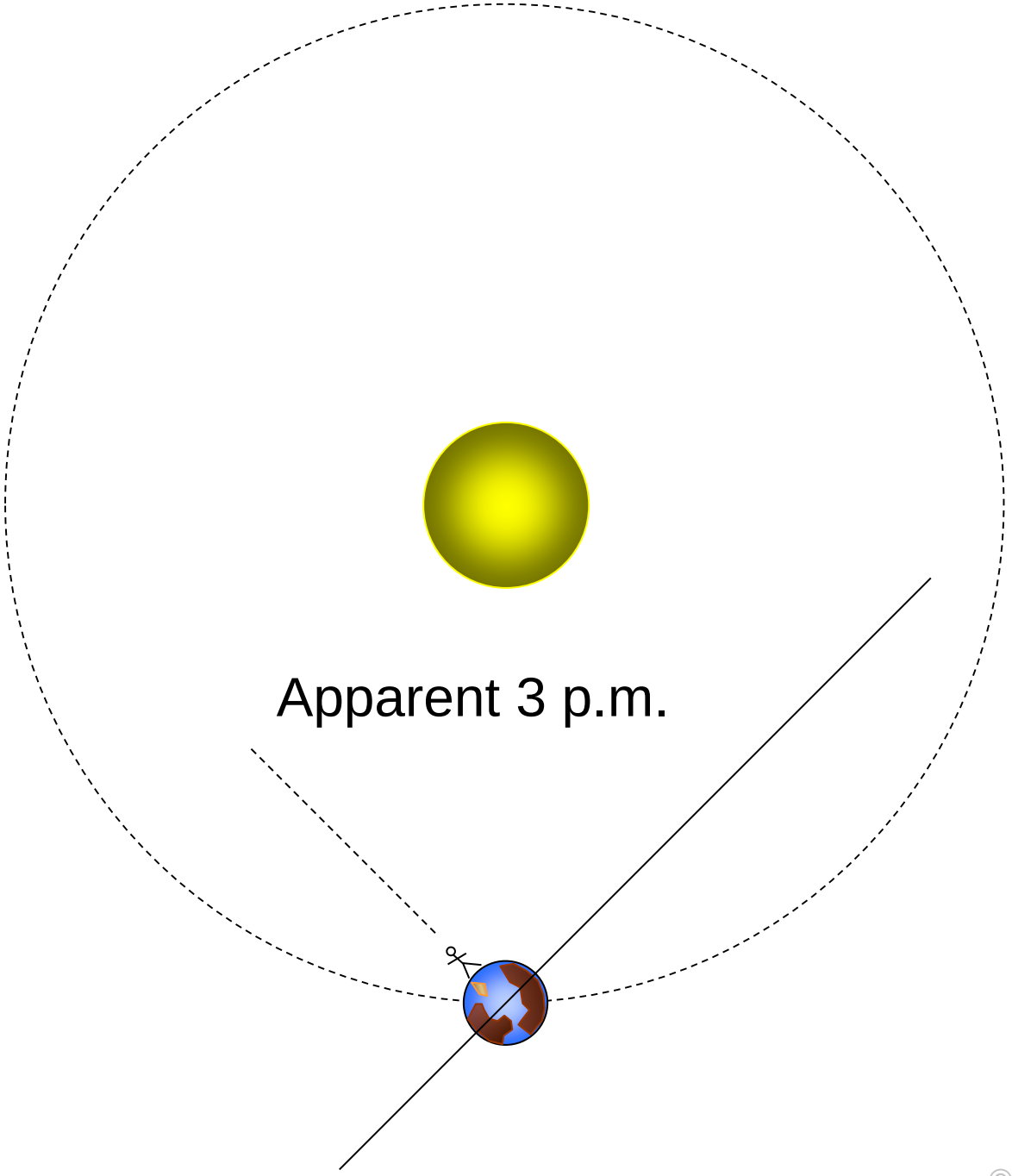
- Long ago time was judged only by the Sun.
- Noon would be the time at which the Sun was on the observer's meridian.
- "*Apparent* time" is measured by a sundial.
- There are problems with this concept:

  Noon occurs at different points in time for different observers.

  The length of a day varies.







Mean Solar Time

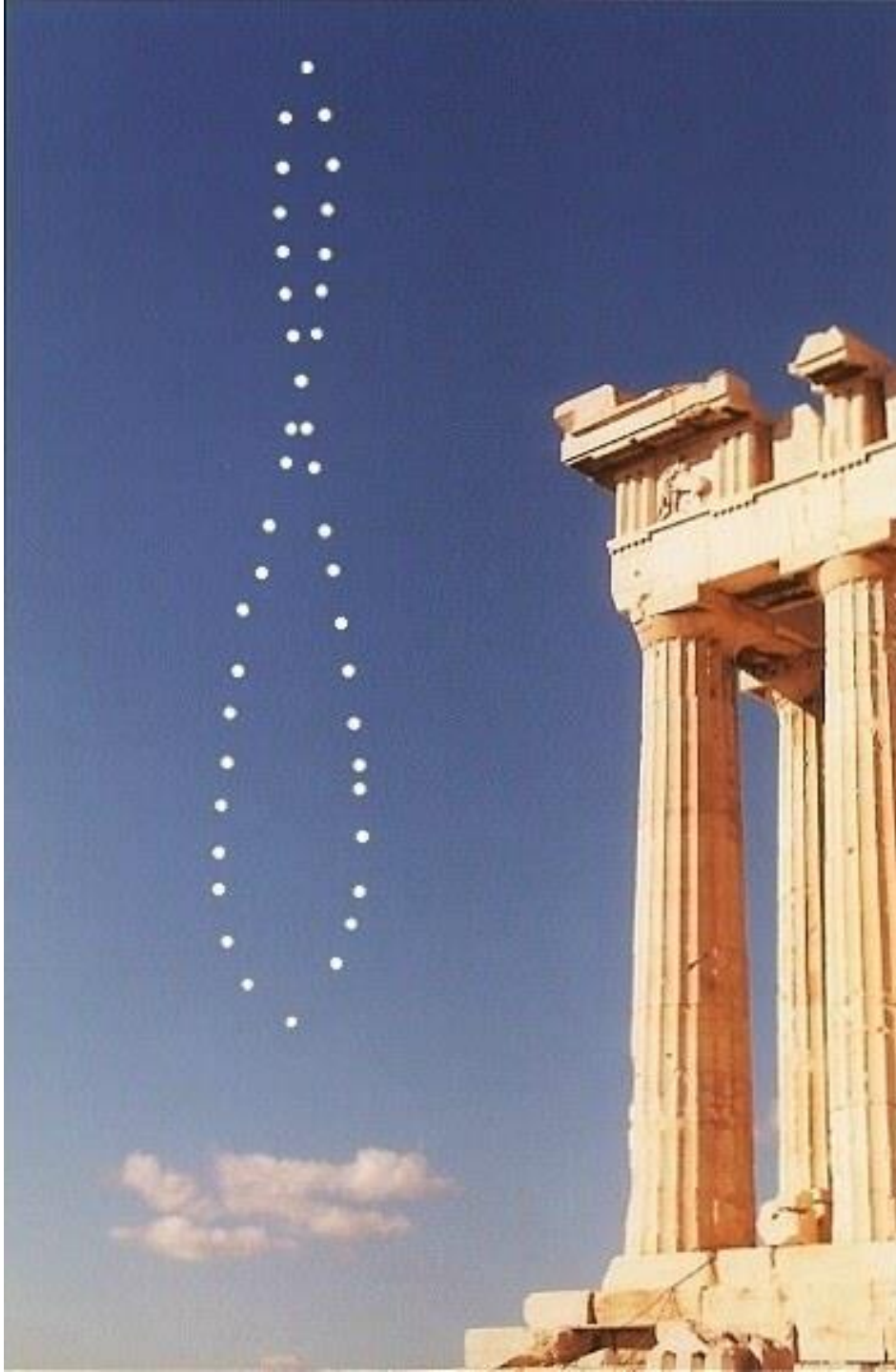
- “Mean solar time” is the same as “apparent solar time” except the length of a day is standardized at 24 hours.
- Because of variance in the motion of Earth “apparent time” runs slow and fast. The Sun appears to speed up and slow down slightly such that the rate of time passage varies as measured by a sundial.

Mean Solar Time

- Astronomers imagine a “fictitious Sun” that would have a more uniform appearance.
- A “fictitious Sun” travels at constant speed on the ecliptic so that length of each day is the same.
- Noon is the point when the “fictitious Sun” crosses the meridian.
- Mean Solar Time is the time as it would appear judging by the “fictitious Sun”.

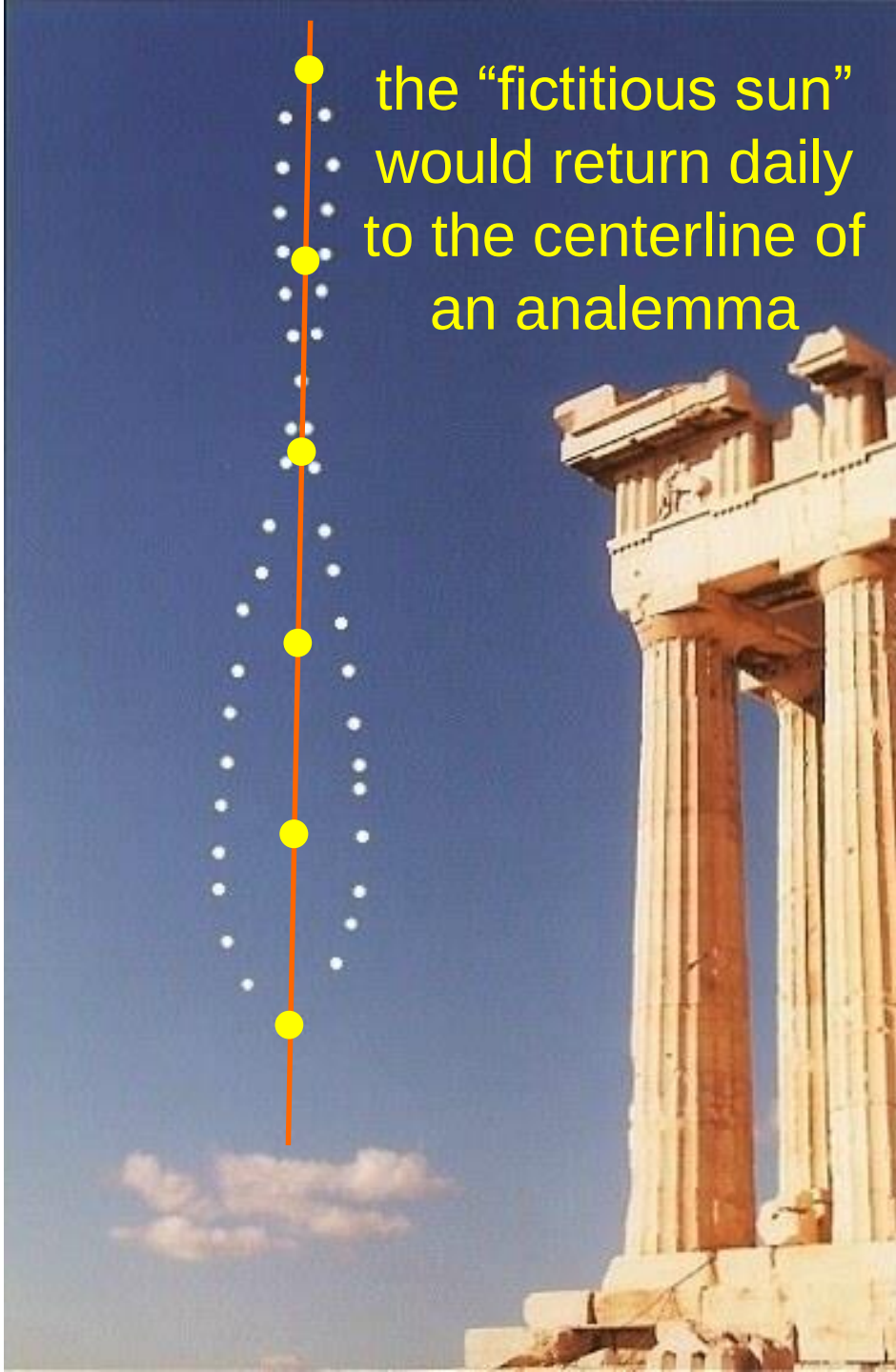
the Analemma

A diagram or picture showing the apparent position of the Sun at the ***same time of day*** (on the clock) for different dates through the year. A picture like this can be formed by taking pictures every few days with the camera fixed to a tripod and pointing in the same direction. Then the images are combined to give a time-lapse effect illustrating the long term variance in the Sun's position.

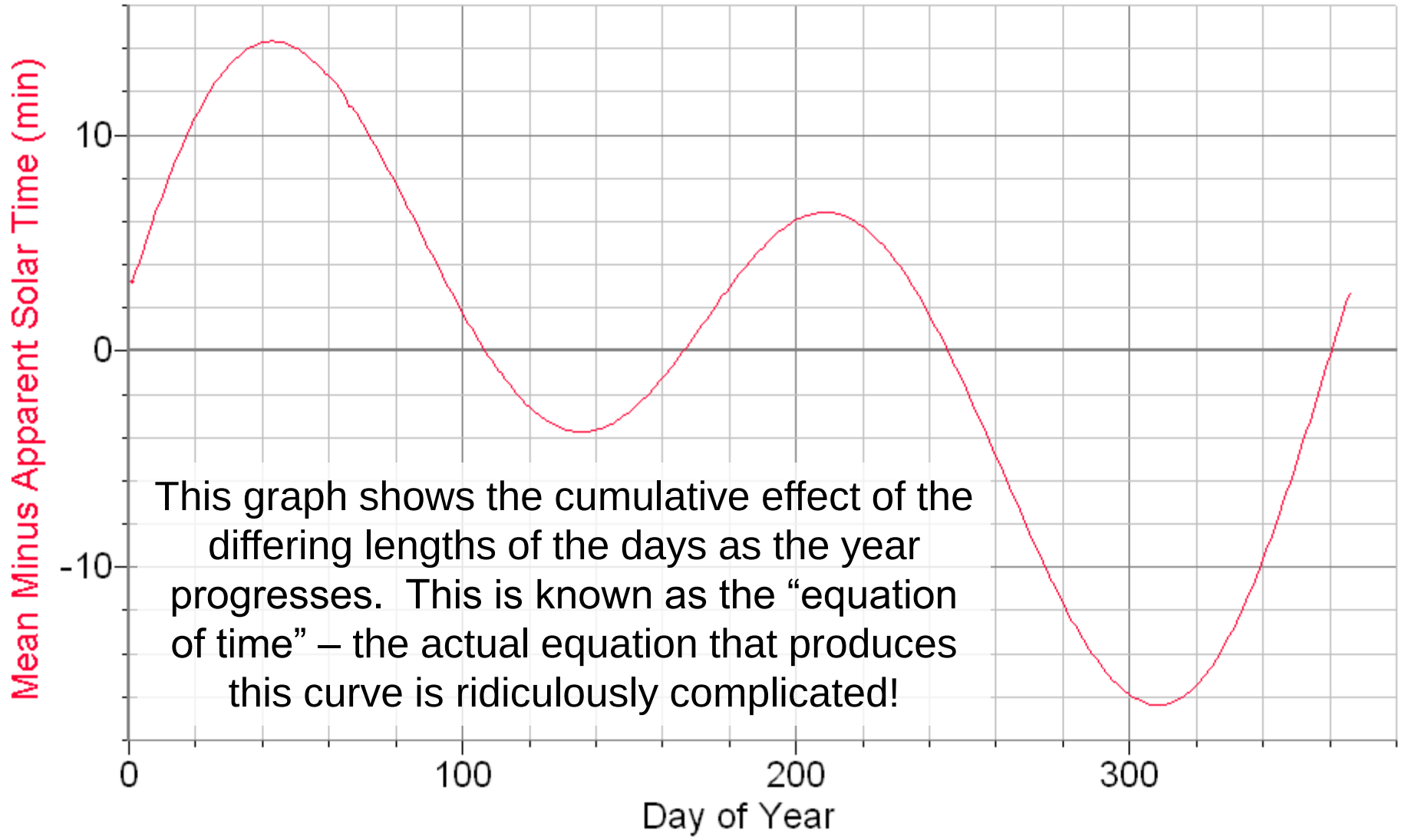


the Analemma

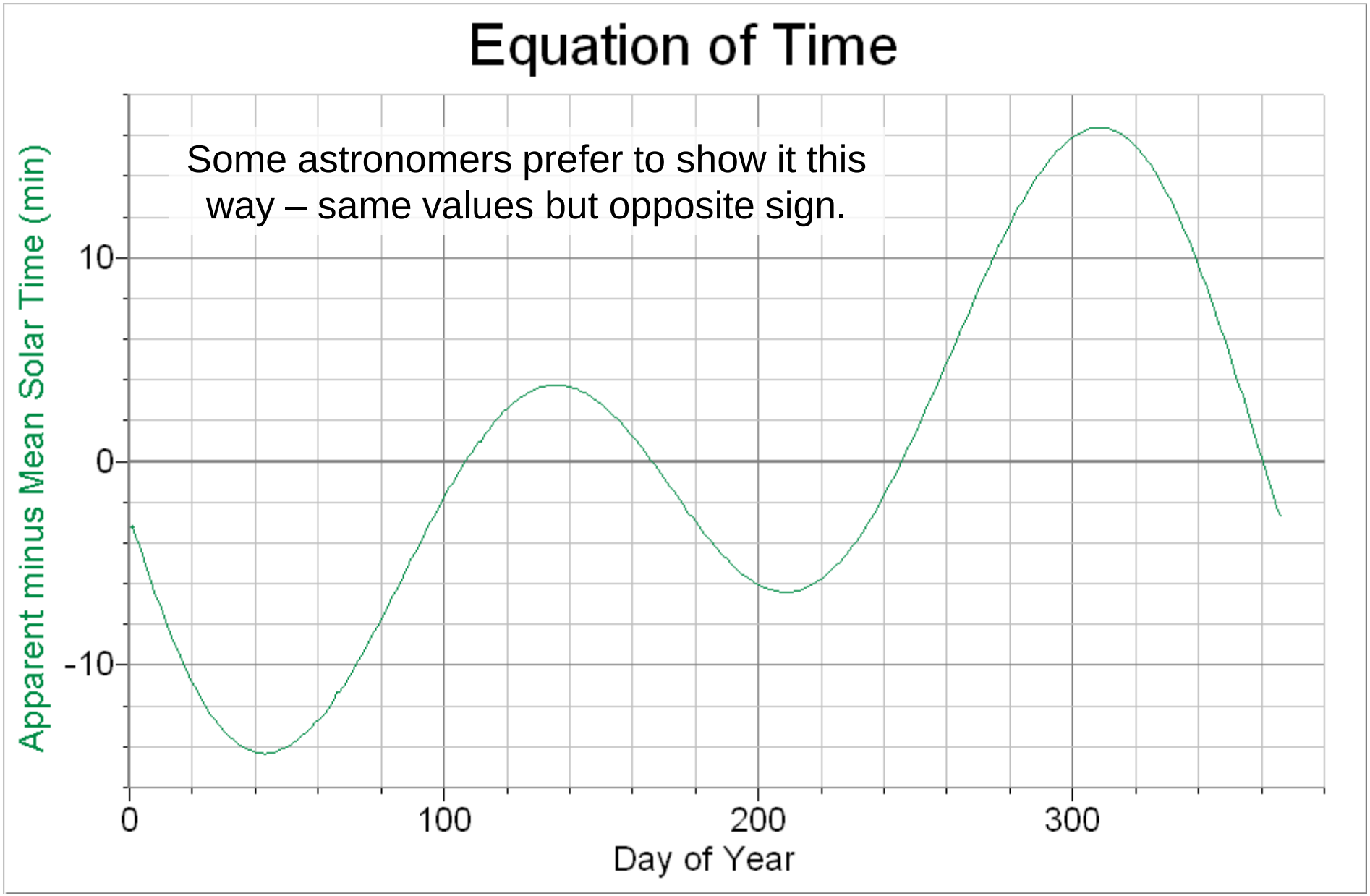
The figure 8 pattern is caused by variation in the length of a day – it is not always exactly 24 hours. Days can be shorter or longer by about 30 seconds. This causes the wavering about the centerline of the pattern.



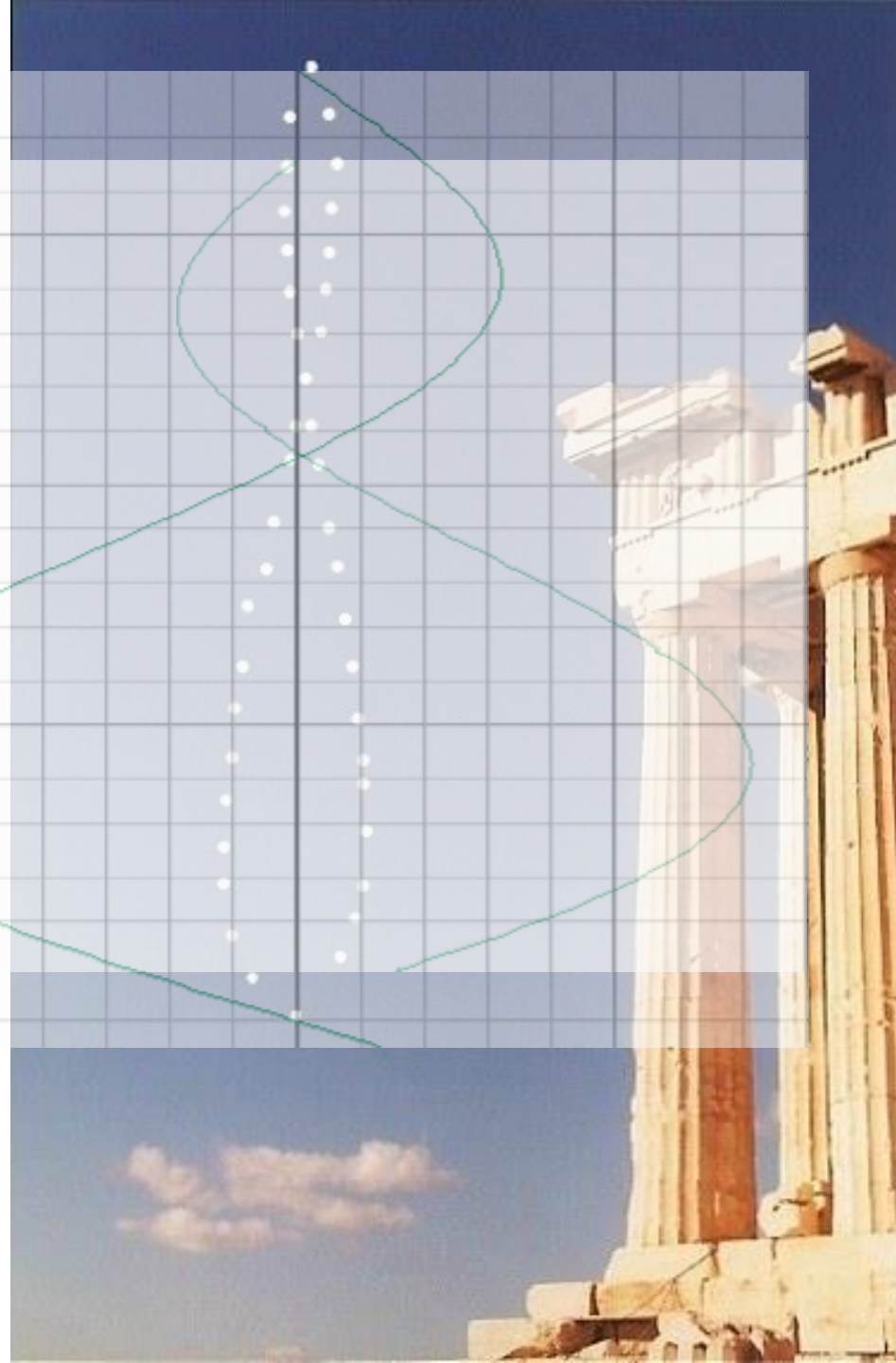
Equation of Time

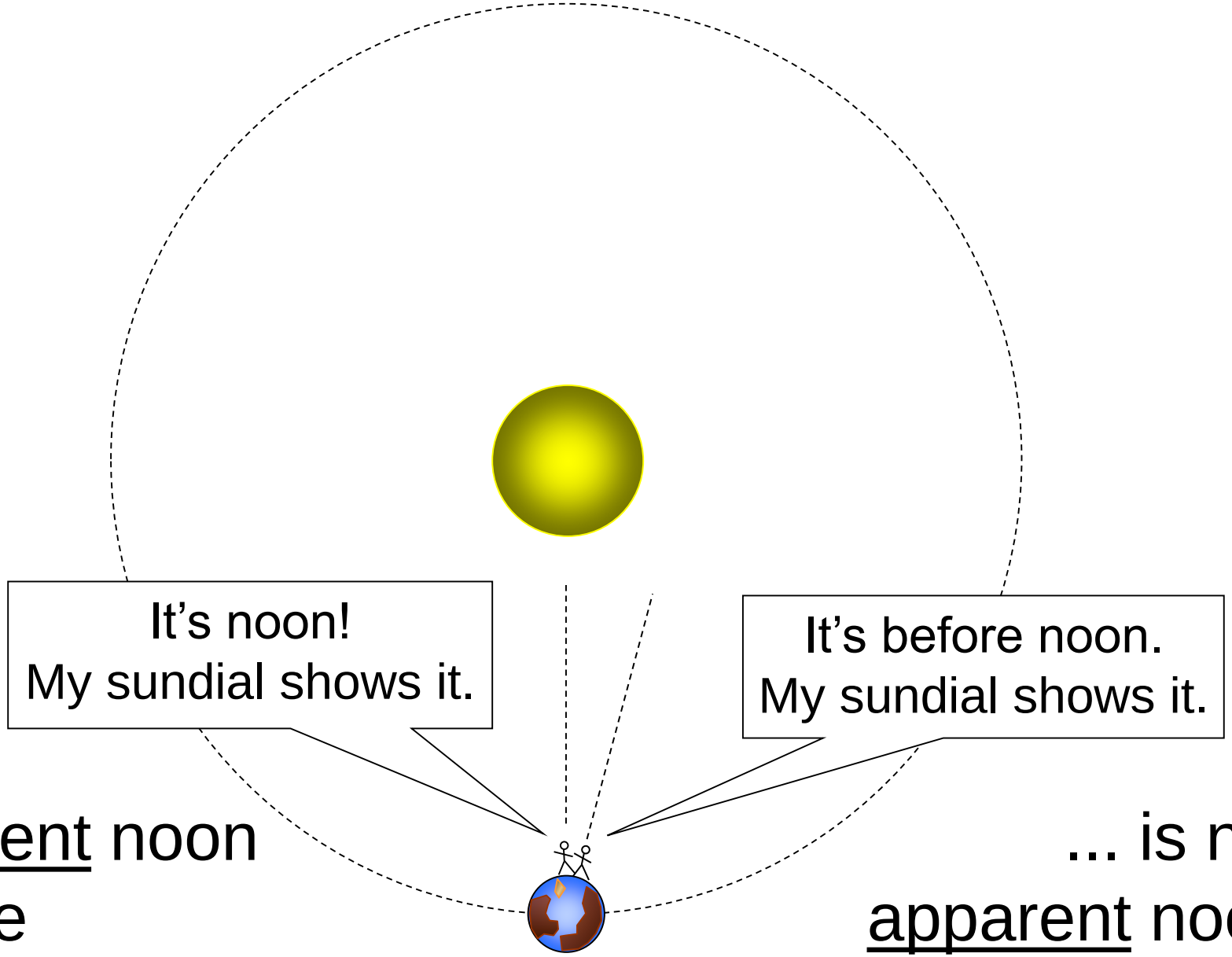


This graph shows the cumulative effect of the differing lengths of the days as the year progresses. This is known as the "equation of time" – the actual equation that produces this curve is ridiculously complicated!



Here the equation of time is appropriately superimposed on the analemma. The pattern of the analemma is like a natural graph in the sky!





Apparent noon for one observer ...

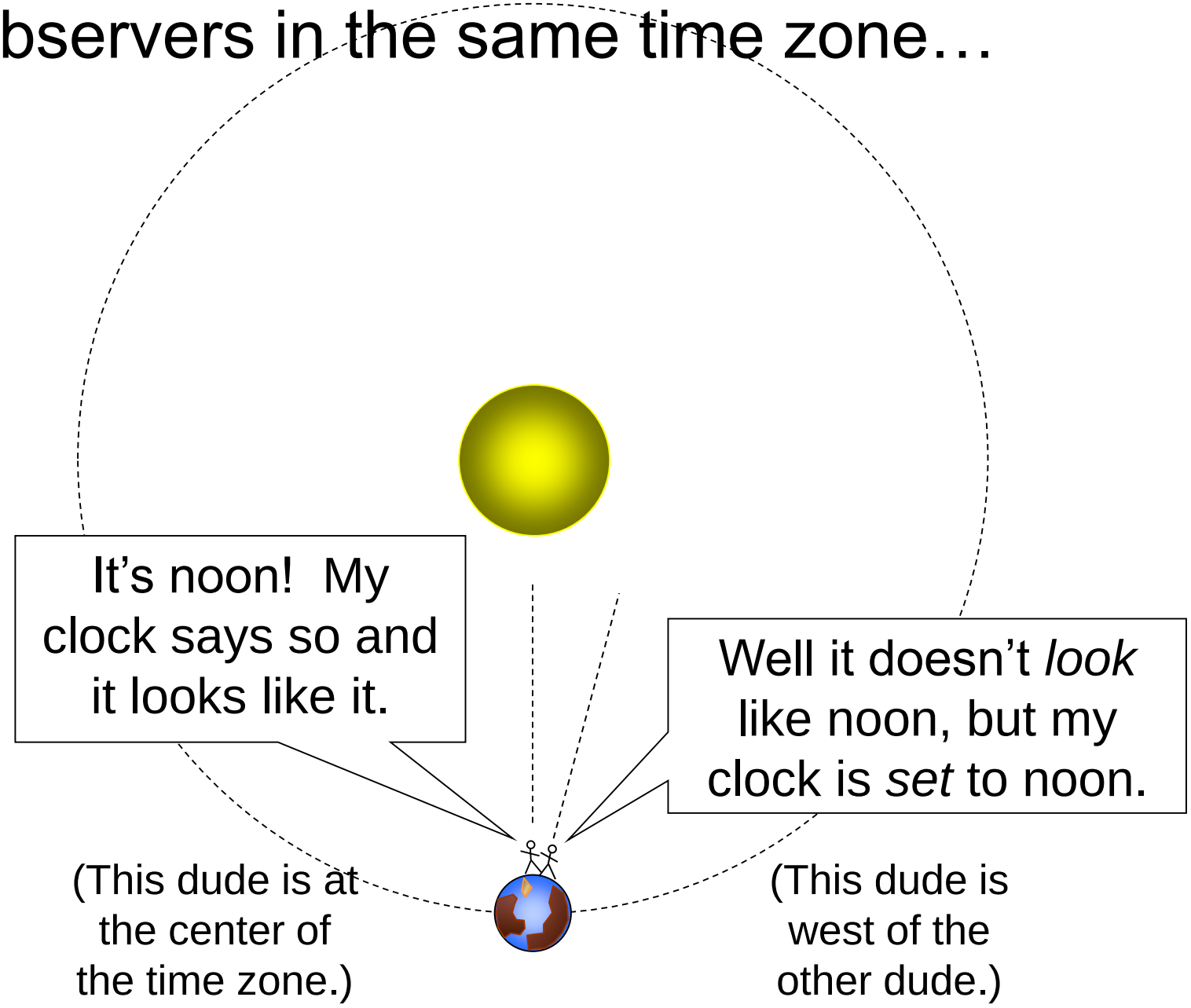
... is not apparent noon for another!

Standard Time

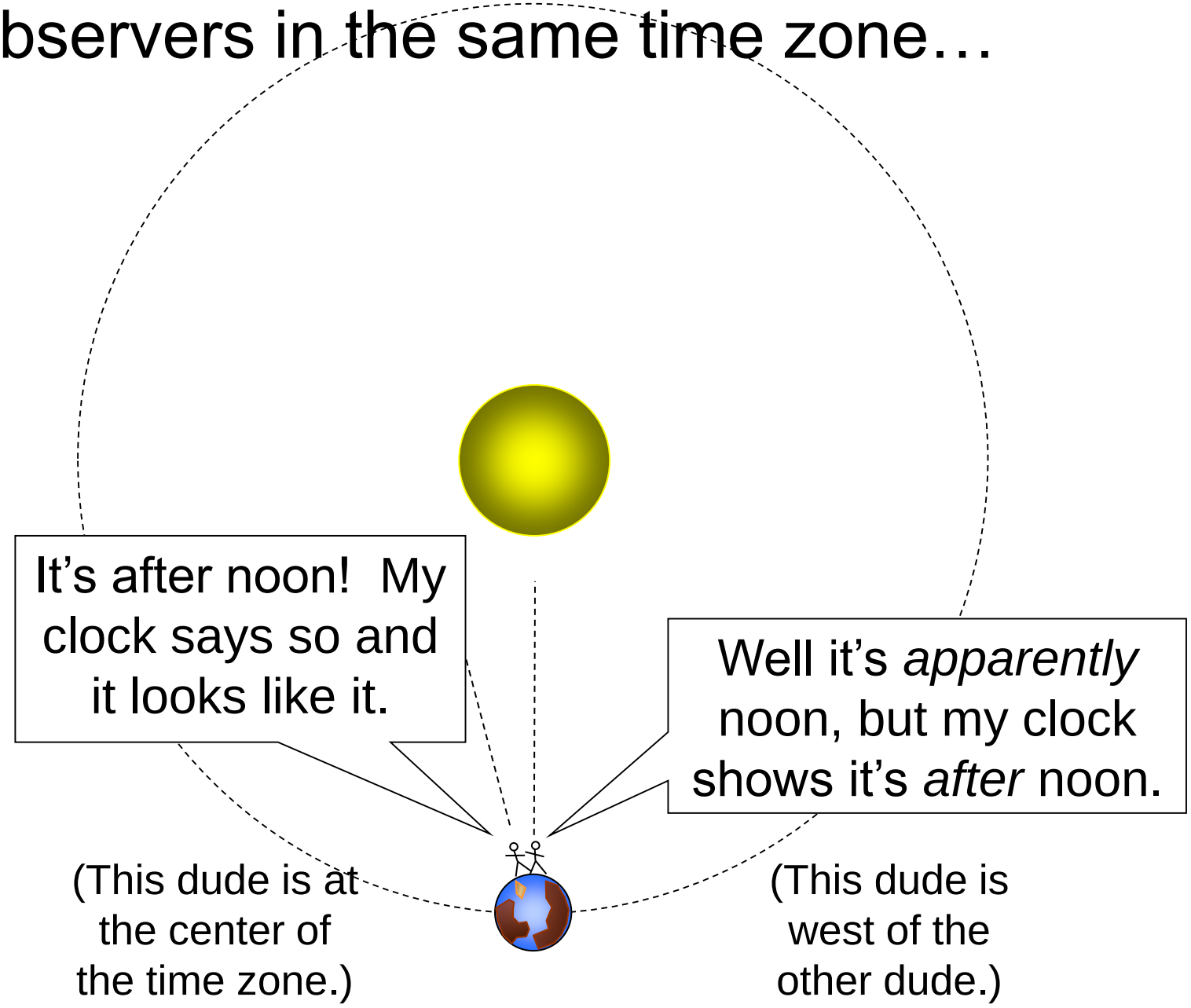
- So that noon will occur at the same time for different observers, time “zones” were established in which all observers’ clocks are synchronized.
- Noon for the entire zone is defined as the point when the “fictitious Sun” crosses the meridian at the center longitude of the zone.

TIME ZONES OF THE WORLD

Two observers in the same time zone…



Two observers in the same time zone…



Universal Time

- To avoid confusion about specifying a point in time, astronomers use universal time.
- Universal Time (UT) is the same as standard time for Greenwich, England.
- UT is given “military style” – *i.e.* 24 hour format starting, at midnight.
- UT = EST + 5 hrs = EDT + 4 hrs

Cycles of the Sun

Time and the Ecliptic

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Appearance of the Sun

- Everyone knows the Sun rises in the East and sets in the West. It does so every day.
- The rotation of the Earth on its axis is what causes this appearance.
- This cycle in astronomy is called the **Mean Solar Day** and is equal to 24 hours.
- Note: not all days are exactly the same length and can vary by as much as 30 seconds approximately!

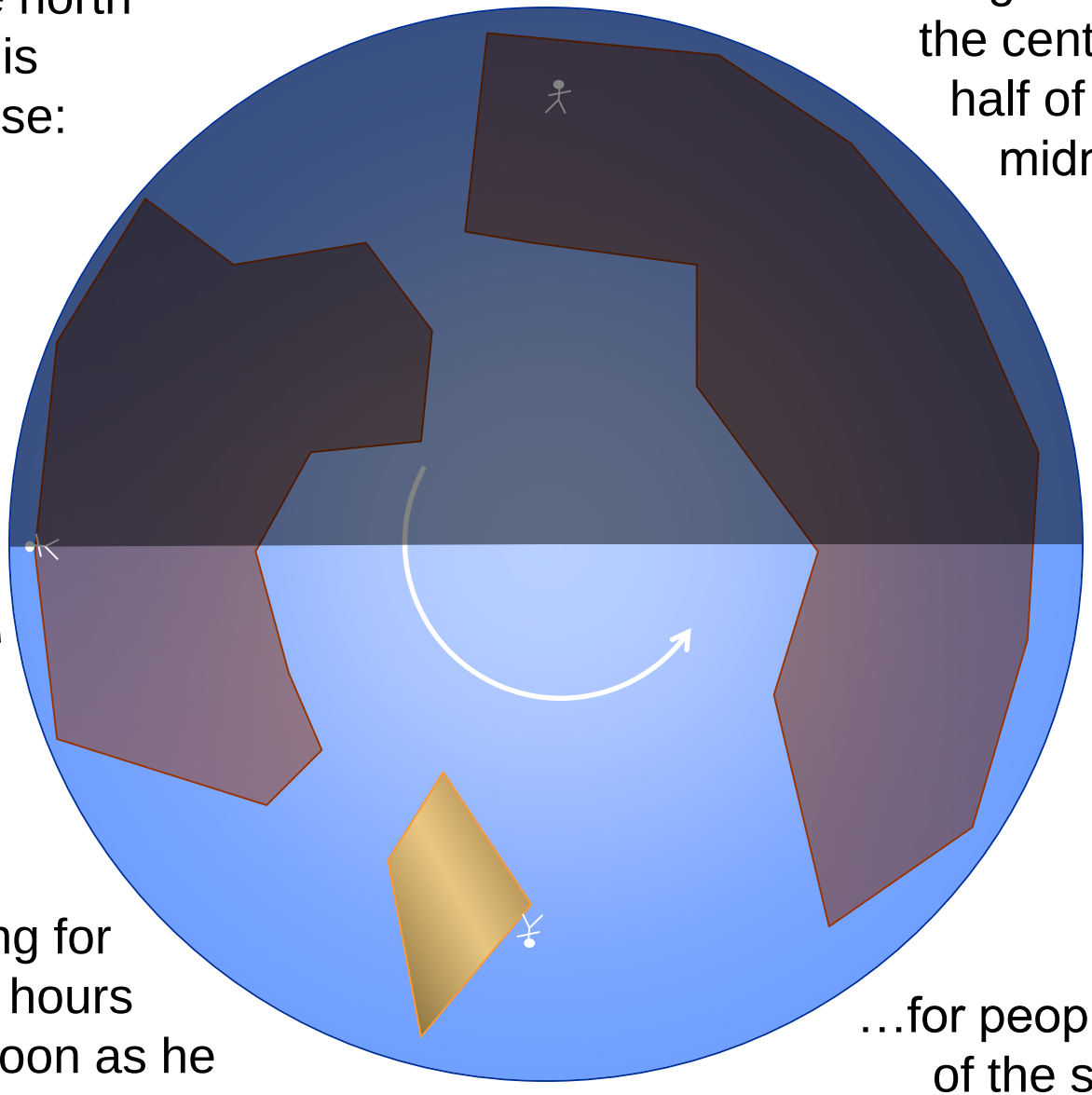
View of Earth as seen from above the north pole – rotation is counterclockwise:

12 a.m.

Time of day is based on sunlight – for people at the center of the dark half of the Earth it is midnight 12 am…

6 a.m.

6 p.m.



The Sun is rising for this person – 6 hours later it will be noon as he is rotated into the middle of the sunlit half of Earth.

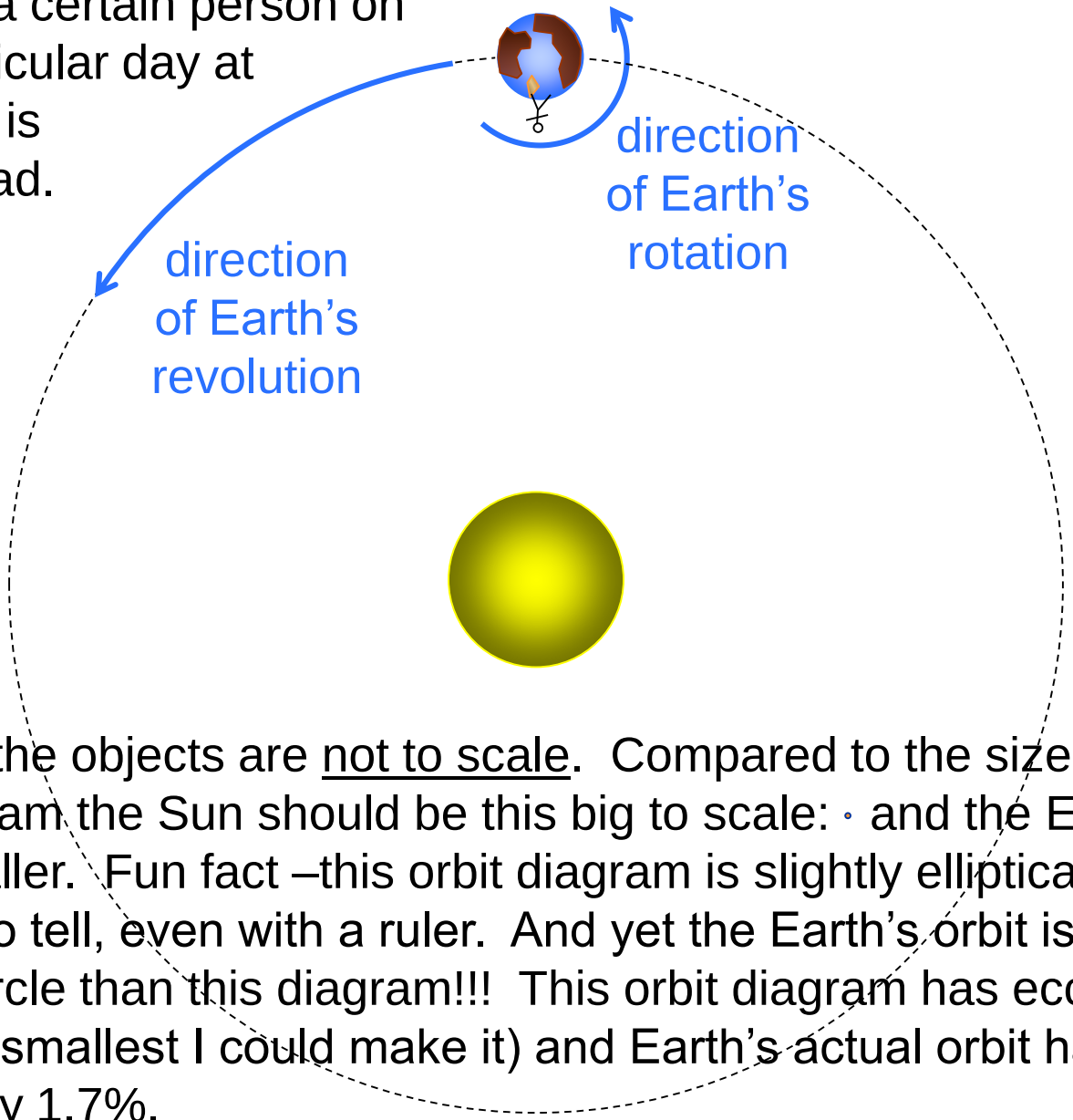
12 p.m.

…for people at the center of the sunlit half of the Earth it is noon 12 pm.

Appearance of the Sun

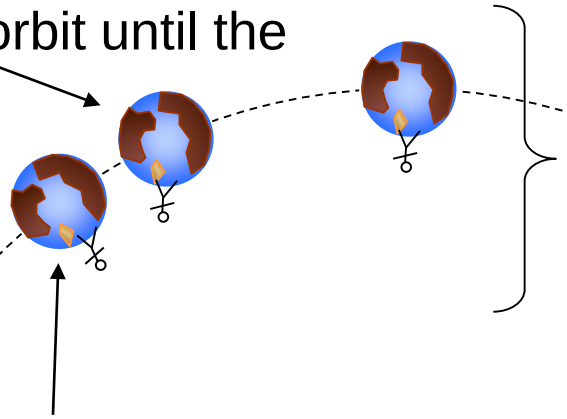
- The Sun also exhibits a longer cycle, during which it is appears higher and then lower in the sky at midday.
- The revolution of the Earth in its orbit around the Sun is what causes this appearance.
- It is also related to the orientation or “tilt” of the Earth’s axis.
- This is the cycle that defines the **year** and it lasts about 365 days.

Earth's orbit viewed from above the north pole. Imagine a certain person on Earth on a particular day at noon – the sun is directly overhead.

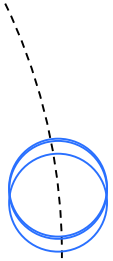


Note that the objects are <u>not to scale</u>. Compared to the size of this orbit diagram the Sun should be this big to scale: ◦ and the Earth is 109 times smaller. Fun fact –this orbit diagram is slightly elliptical, so slight it is hard to tell, even with a ruler. And yet the Earth's orbit is closer to being a circle than this diagram!!! This orbit diagram has eccentricity 2.8% (the smallest I could make it) and Earth's actual orbit has eccentricity 1.7%.

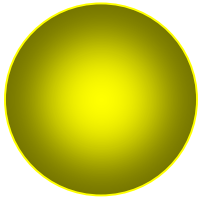
One *sidereal* day later – Earth has rotated and moved forward in orbit until the person faces the same direction in space.



Amount that Earth moves in a day has been exaggerated here. If shown closer to the correct amount that Earth moves in a day, the three positions would look like this:

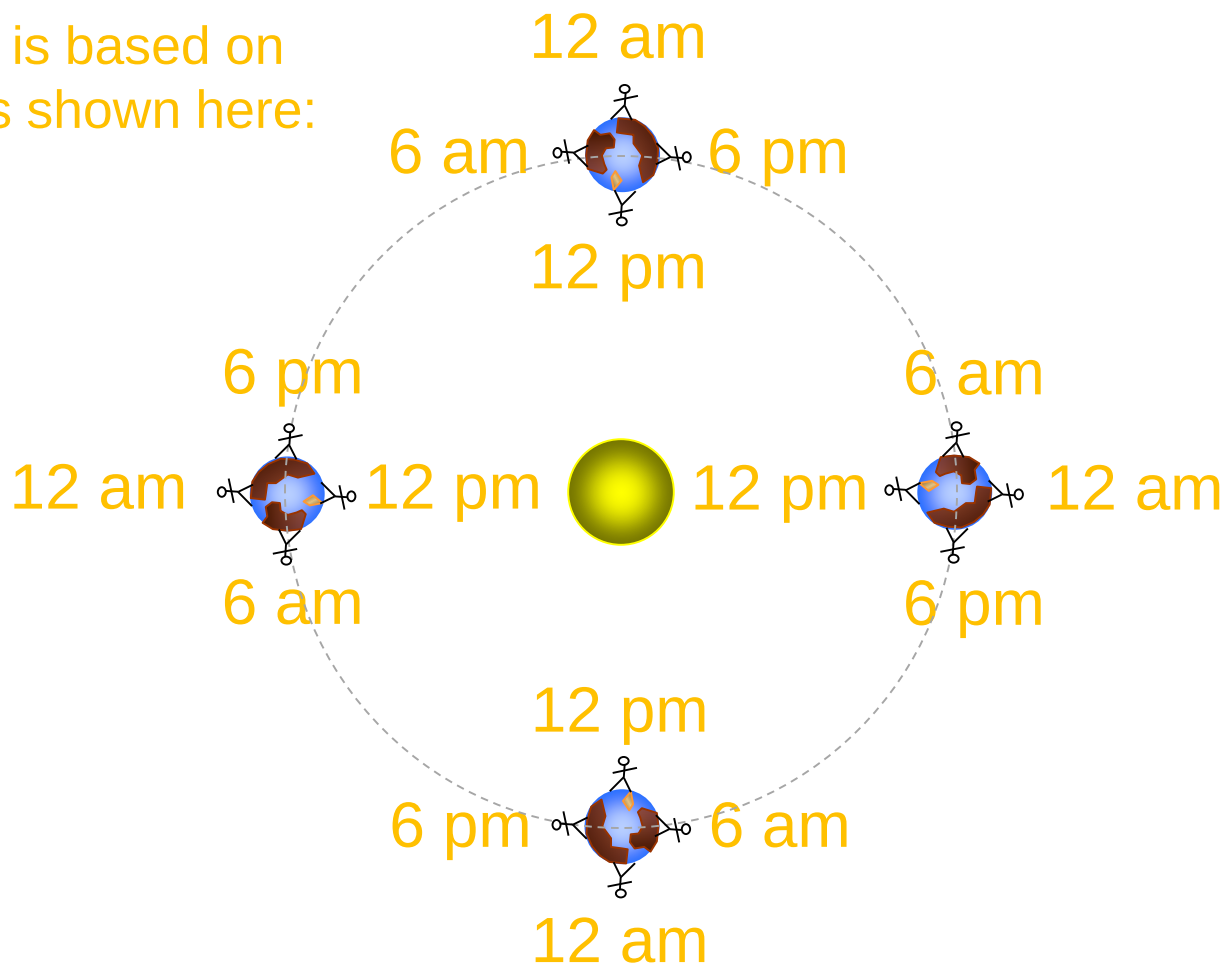


One *solar* day later – Earth has rotated and moved forward in orbit until the person faces the Sun once again. Because the Earth moves a little farther in its orbit and has to turn a little more for this to occur it takes more time – thus a solar day (24 hrs) is longer than a sidereal day (23 hrs 56 min).



Fun fact – over the course of one year the "little bit extra" that Earth rotates to make a solar day adds up to precisely one "extra" rotation. For this reason there are exactly one more sidereal days in one year than there are solar days – 366.24 vs. 365.24.

Solar time is based on
the Sun as shown here:



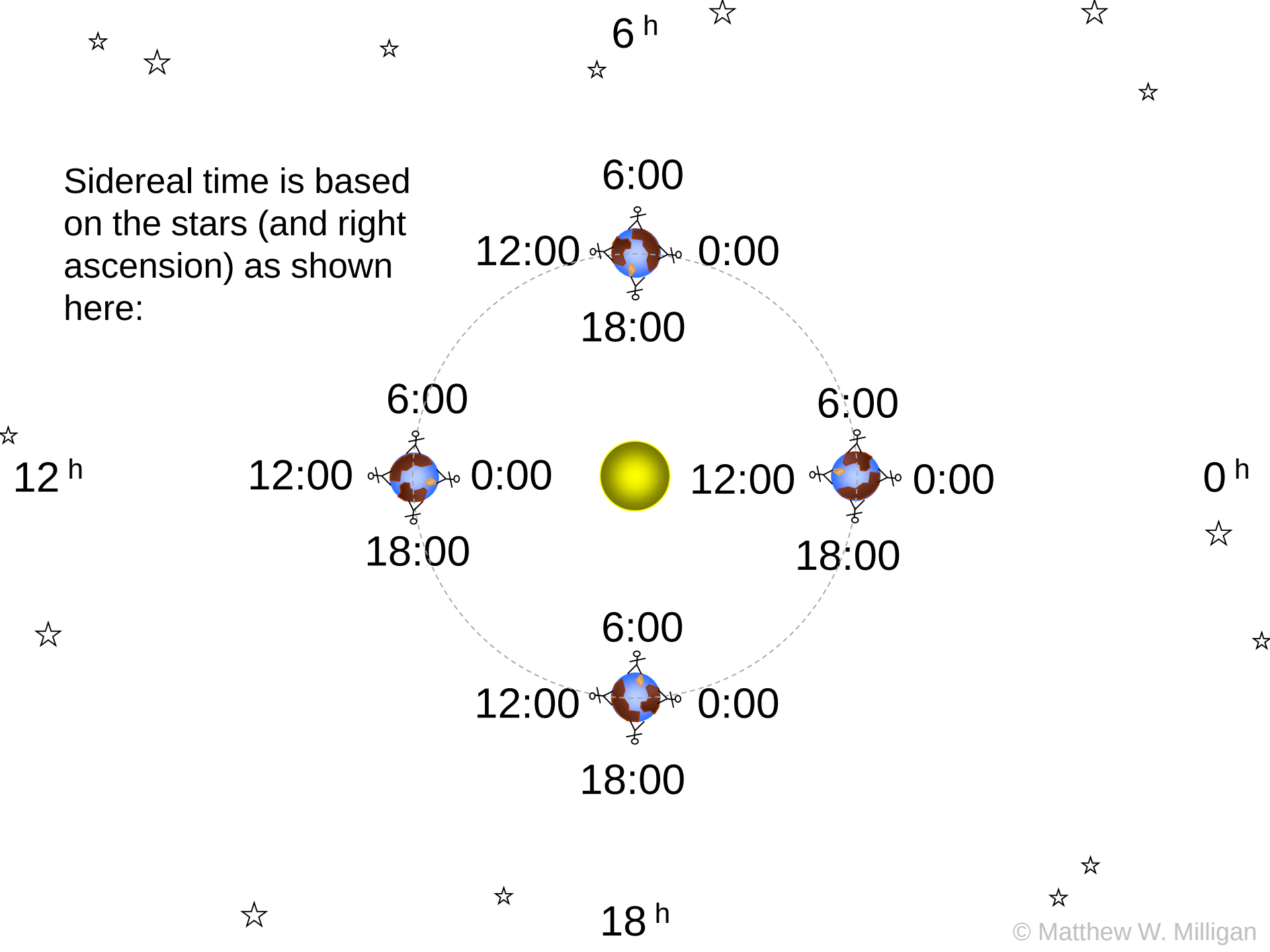
6 h

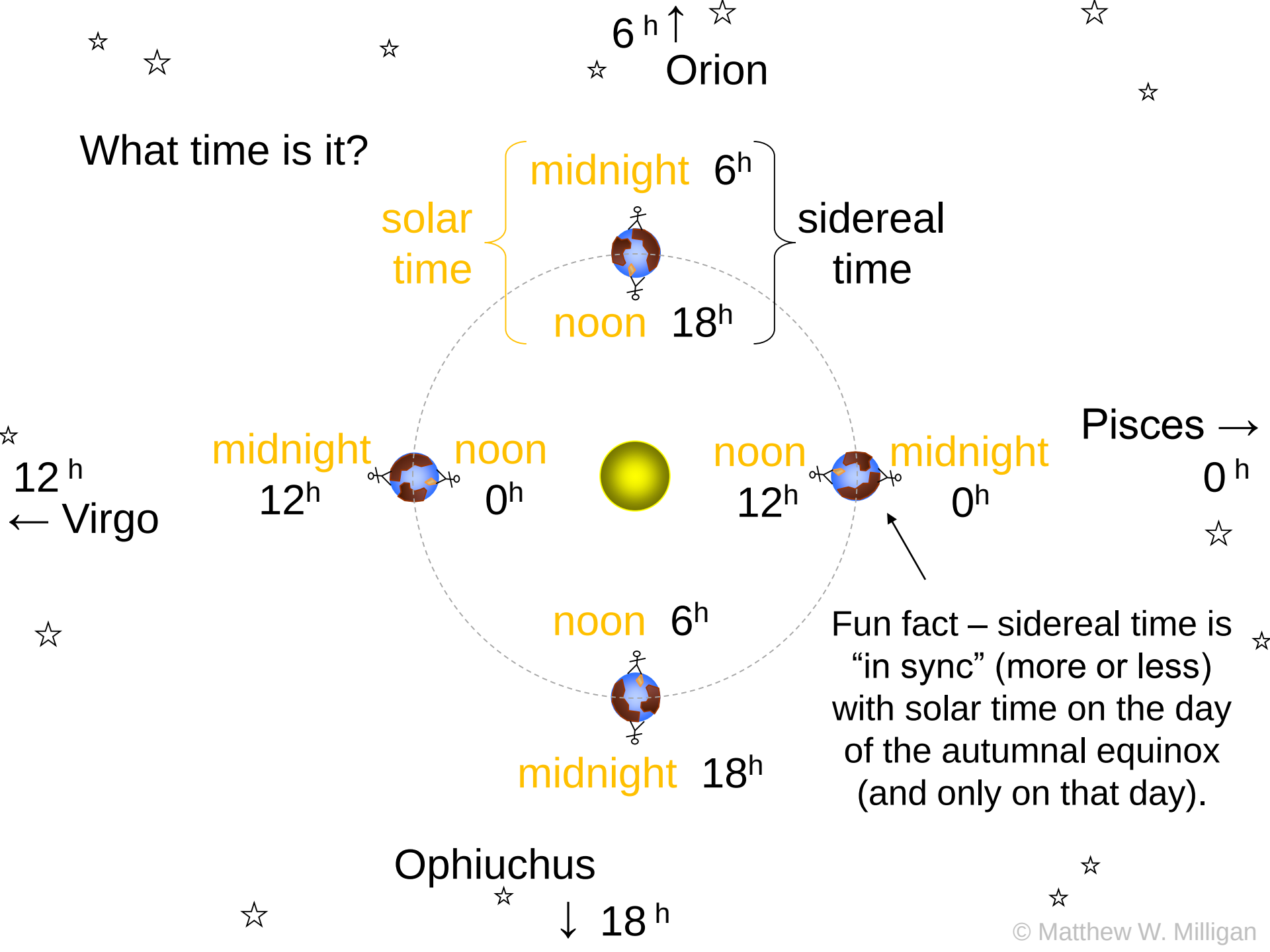
12 h

0 h

18 h

Sidereal time is based on the stars (and right ascension) as shown here:

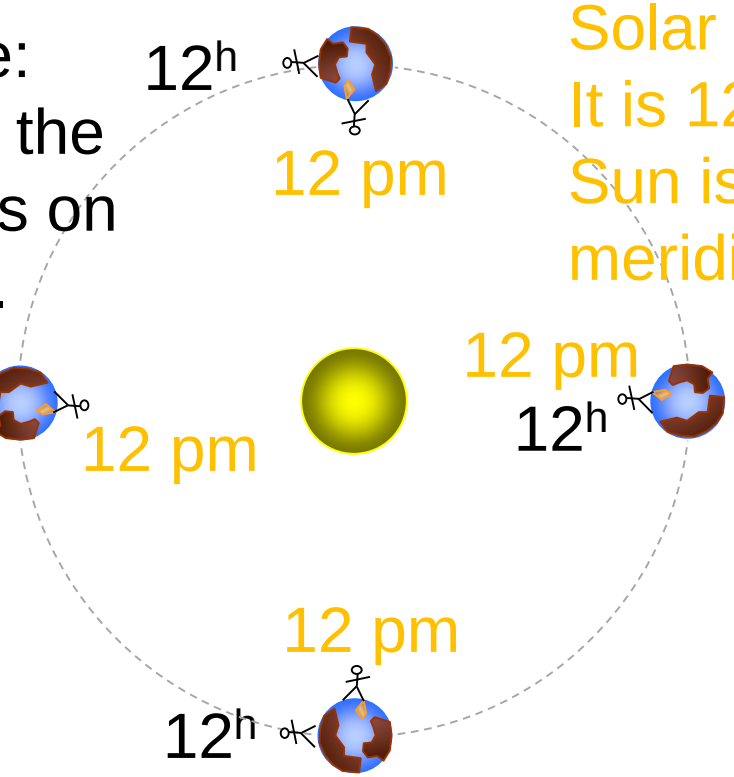




6 h ↑ Orion

When is it 12?

Sidereal time:
It is 12 when the star b Virgo is on the meridian.



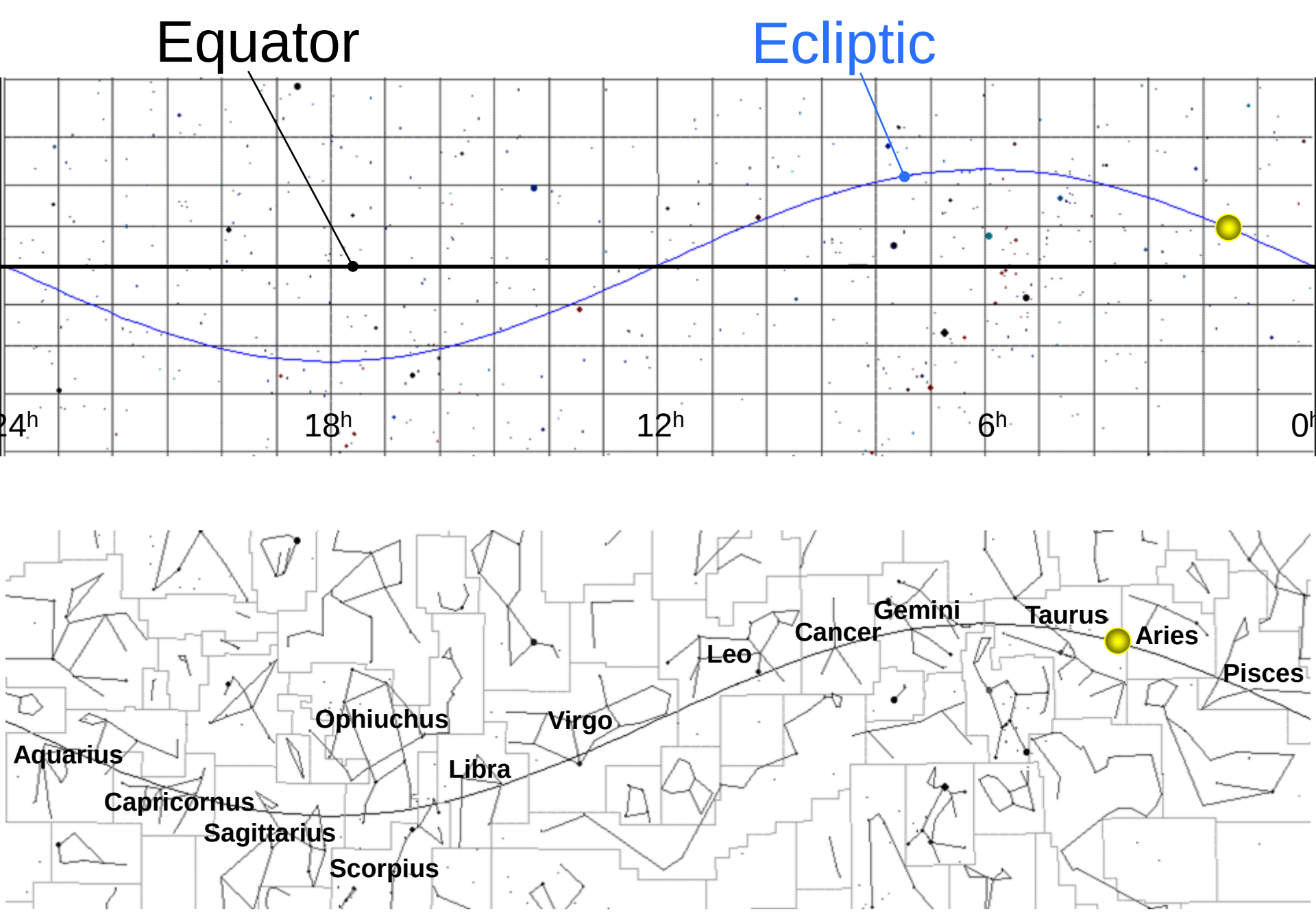
12 h ← Virgo

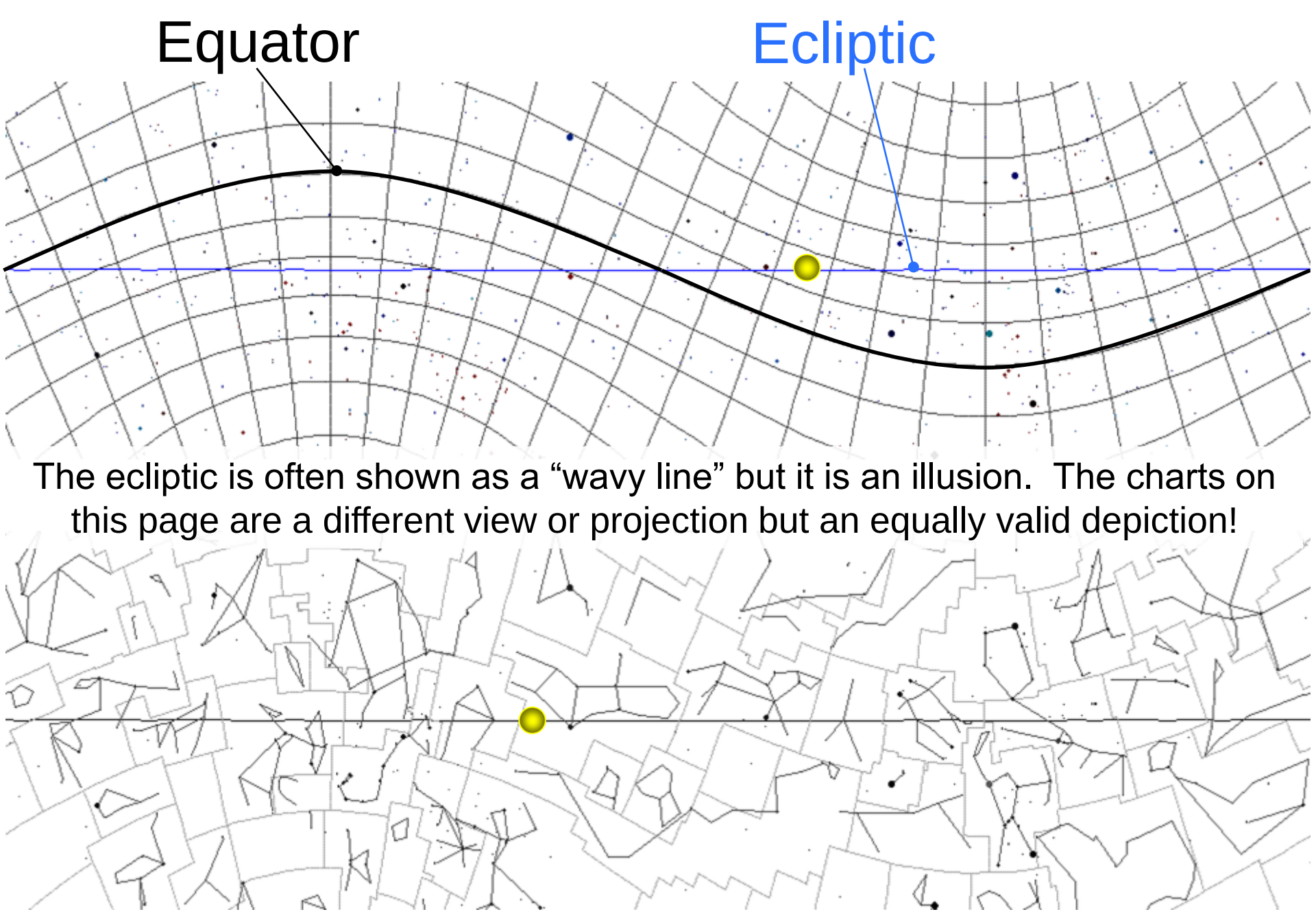
Pisces → 0 h

Ophiuchus ↓ 18 h

Sun on the Celestial Sphere

- As Earth orbits the Sun, the Sun's apparent position on the celestial sphere changes – the Sun appears to move relative to the stars.
- The apparent path of the Sun relative to the stars is called the **Ecliptic**.
- The Sun repeats its journey along the ecliptic once every year.
- The constellations through which it appears to pass are called the **zodiac**.





The ecliptic is often shown as a “wavy line” but it is an illusion. The charts on this page are a different view or projection but an equally valid depiction!

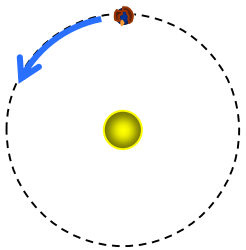
Alternate View of the Ecliptic

- The Earth orbits the Sun in a particular plane in space.
- Viewing from Earth the Sun always appears to be in this plane.
- The ecliptic may be thought of as a projection of the plane of the Earth's orbit about the Sun.

Cancer Gemini Taurus Aries

Leo

The Earth's orbit defines a plane (the piece of paper if you print this image). Extend this plane into space and it intersects distant constellations in space.



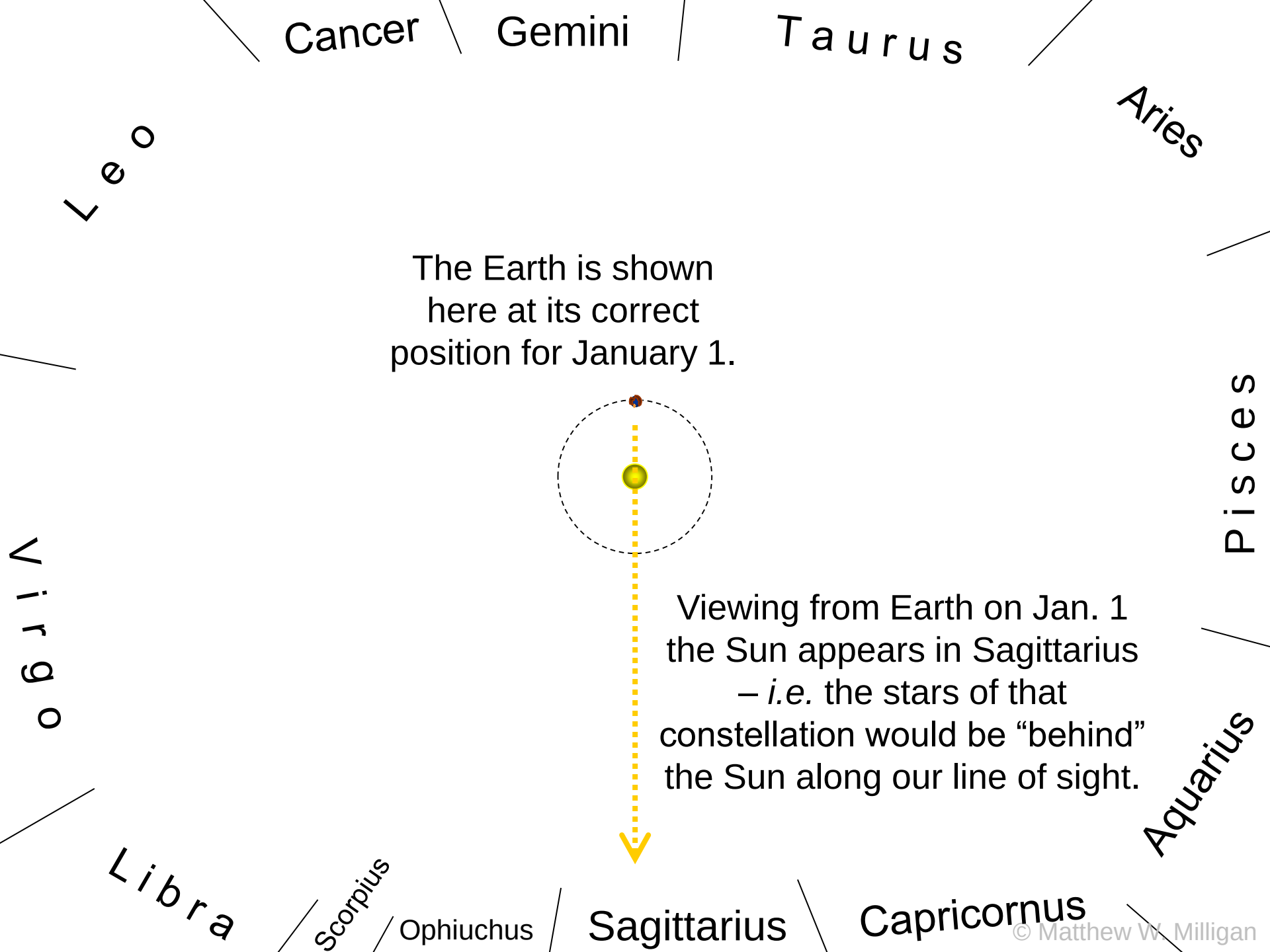
Pisces

Virgo

The particular constellations are correctly shown and labeled around the edges of the diagram. The lines represent the borders of the constellations.

Aquarius

Libra Scorpius Ophiuchus Sagittarius Capricornus


Cancer
Gemini
Taurus
Aries
Leo
The Earth is shown here at its correct position for January 1.
Pisces
Virgo
Viewing from Earth on Jan. 1 the Sun appears in Sagittarius – *i.e.* the stars of that constellation would be “behind” the Sun along our line of sight.
Aquarius
Libra
Scorpius
Ophiuchus
Sagittarius
Capricornus
© Matthew W. Milligan

Cancer

Gemini

Taurus

Aries

Leo

April 2nd is 91 days after Jan. 1 and the Earth has traveled 91/365 ≈ ¼ of its orbit:

Apr. 2

The Sun is in Pisces.

Pisces

Virgo

Aquarius

Libra

Scorpius

Ophiuchus

Sagittarius

Capricornus

Using the logic shown on the previous page one can determine the days of the year that the Sun resides in each constellation – these are the REAL “Sun Signs”:

Capricornus	Jan 23 – Feb 20	Leo	Aug 11 – Sept 16
Aquarius	Feb 21 – Mar 14	Virgo	Sept 17 – Nov 1
Pisces	Mar 15 – Apr 22	Libra	Nov 2 – Nov 24
Aries	Apr 23 – May 17	Scorpius	Nov 25 – Dec 1
Taurus	May 18 – June 22	Ophiuchus	Dec 2 – Dec 20
Gemini	June 22 – July 20	Sagittarius	Dec 21 – Jan 22
Cancer	July 21 – Aug 10		

Astrology is a pseudo science. An astrologer will "compute" the location of the Sun the day you were born and forecast your horoscope, but the results are false – the FAKE "Sun Signs":

Capricornus	Dec 23 – Jan 20	Leo	July 24 – Aug 23
Aquarius	Jan 21 – Feb 19	Virgo	Aug 24 – Sept 23
Pisces	Feb 20 – Mar 20	Libra	Sept 24 – Oct 23
Aries	Mar 21 – Apr 20	Scorpius	Oct 24 – Nov 22
Taurus	Apr 21 – May 21	Ophiuchus	ignored
Gemini	May 20 – June 21	Sagittarius	Nov 23 – Dec 22
Cancer	June 22 – July 23		

It is interesting to note that your astrological sign is usually "off by one" from the true constellation in which the Sun was located the day you were born. For example if you are "astrologically" a Cancer you are scientifically a Gemini. Curious, huh? There is an explanation for this…