

# SOAR: The Sky in Motion

## Phases of the Moon

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# The Tilted Teacup Ride

☆ Coordinates and the Day: 9/6/22

🌐 Celestial Navigation

☆ The Year: 9/13/22

🌐 The Age of Aquarius

☆ The Month and Moon Phases: 9/20/22

🌐 The Harvest Moon

☆ The Day in All its Glory: 9/27/22

🌐 The Analemma

# The Tilted Teacup Ride

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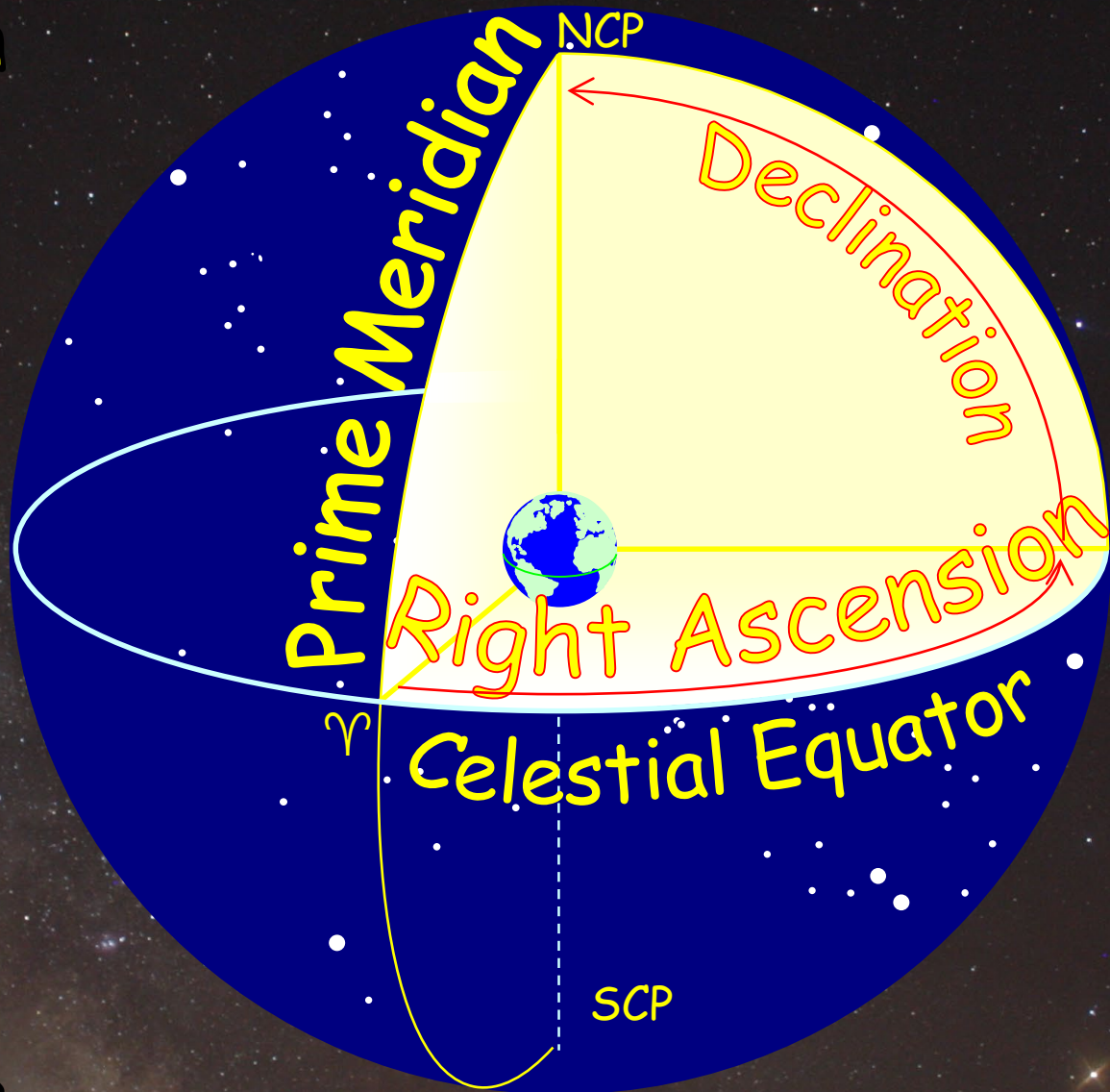
# Celestial Coordinates

## ☆ Right Ascension

- 🌐 RA or  $\alpha$
- 🌐 From prime meridian ( $0^h$ ) to  $23^h59^m59^s$  Eastward

## ☆ Declination

- 🌐 Dec or  $\delta$
- 🌐 From celestial equator ( $0^\circ$ ) to poles N & S  $90^\circ$

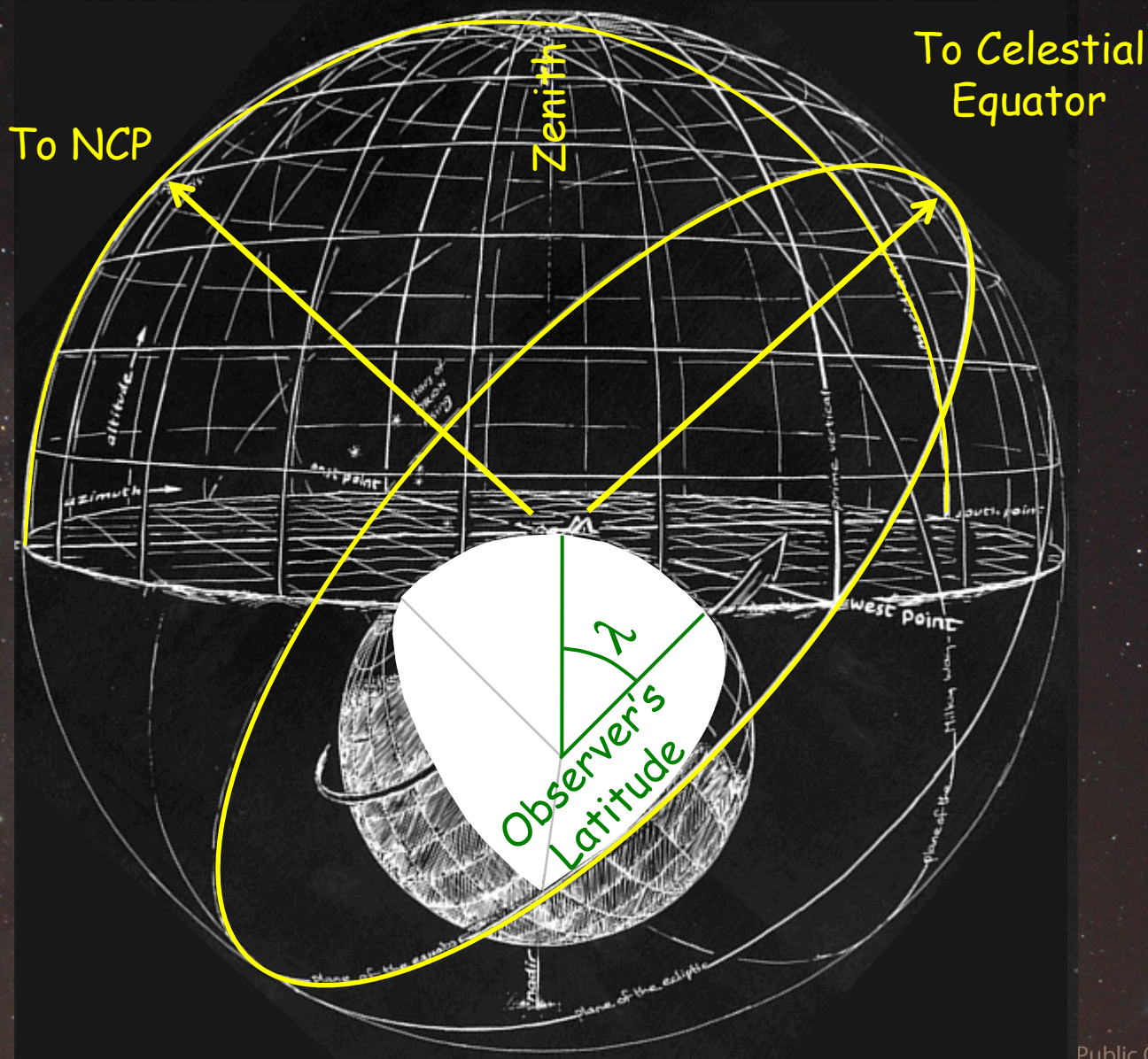


# Tilted Sky

☆ Observers see sky "tilted" due to latitude

We see ourselves "on top" of the Earth, beneath the sky.

So we see sky motions tilted



# Clock Time = Position of Sol

☆ Observers move through times

It's 6 pm  
(sunset).

It's 3 pm.

It's  
noon.

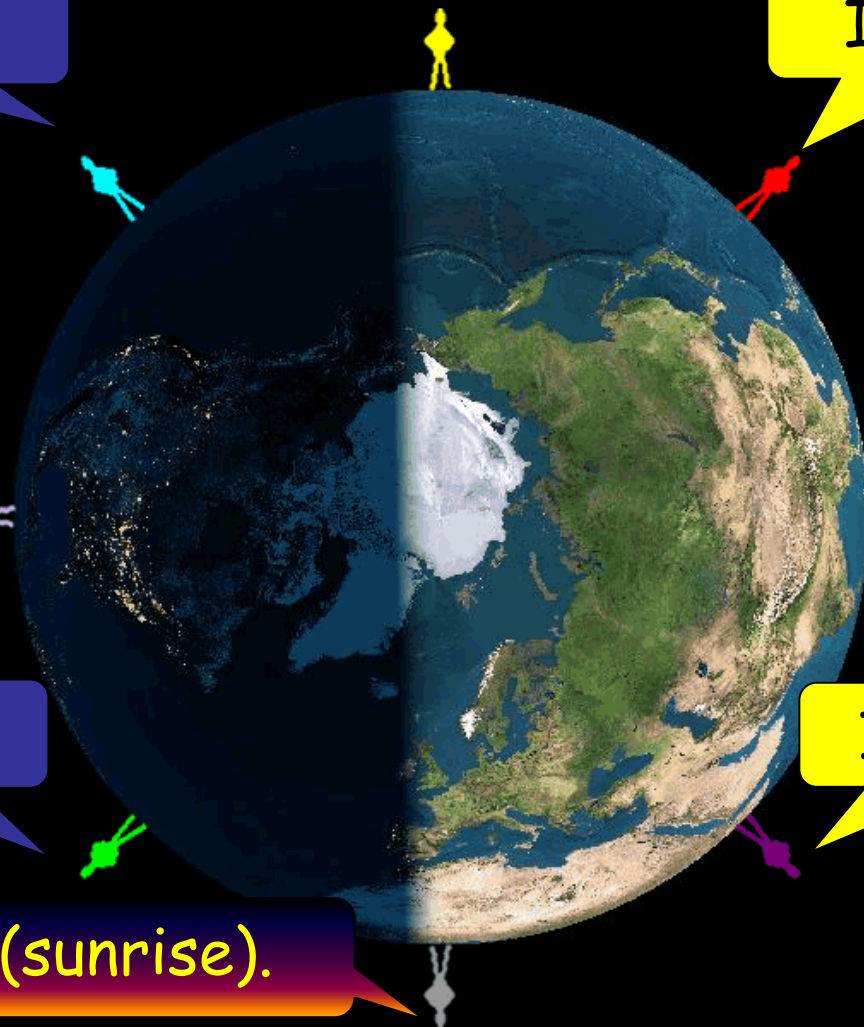
It's 9 am.

It's 9 pm.

It's  
midnight.

It's 3 am.

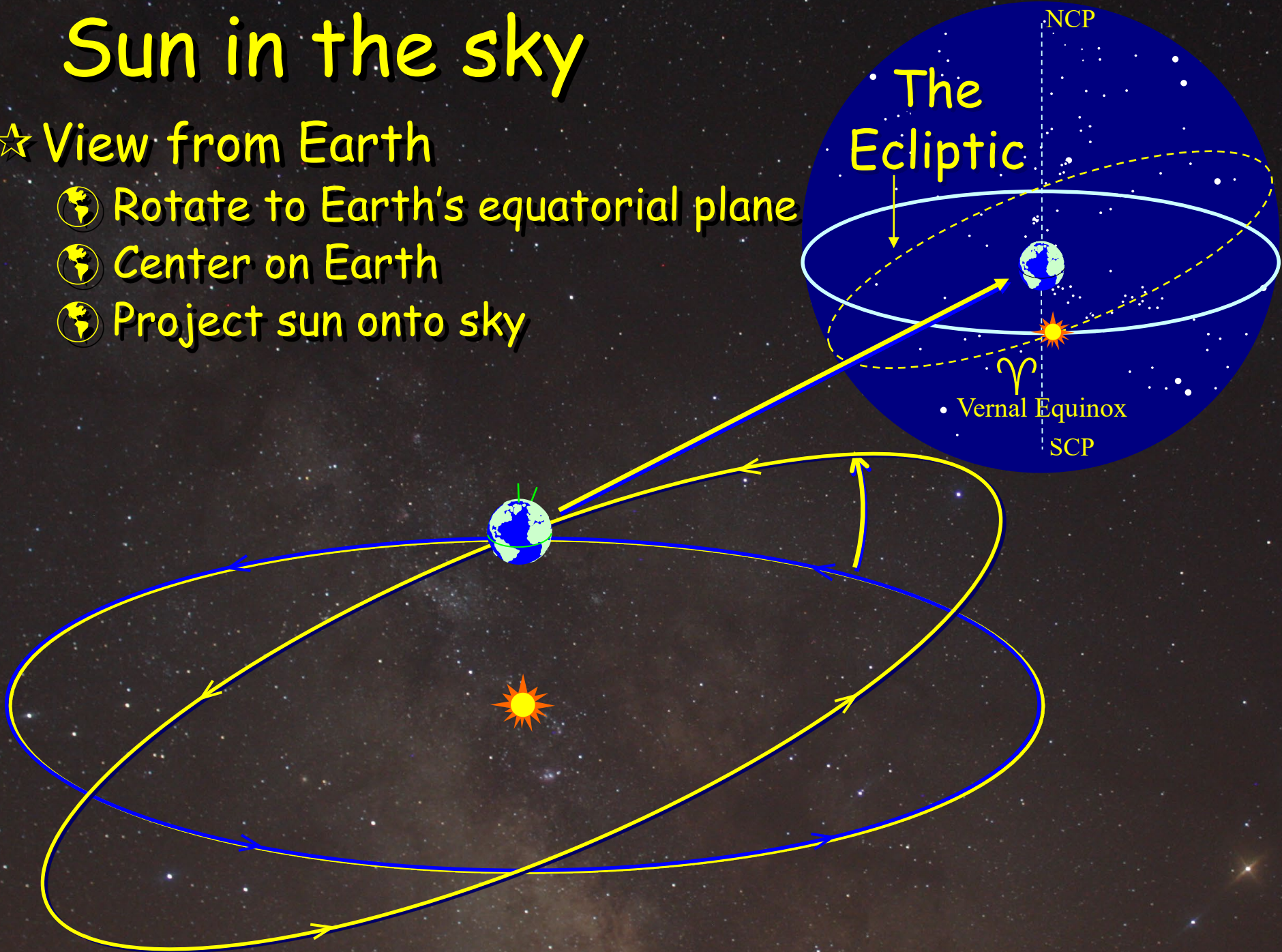
It's 6 am (sunrise).



# Sun in the sky

## ☆ View from Earth

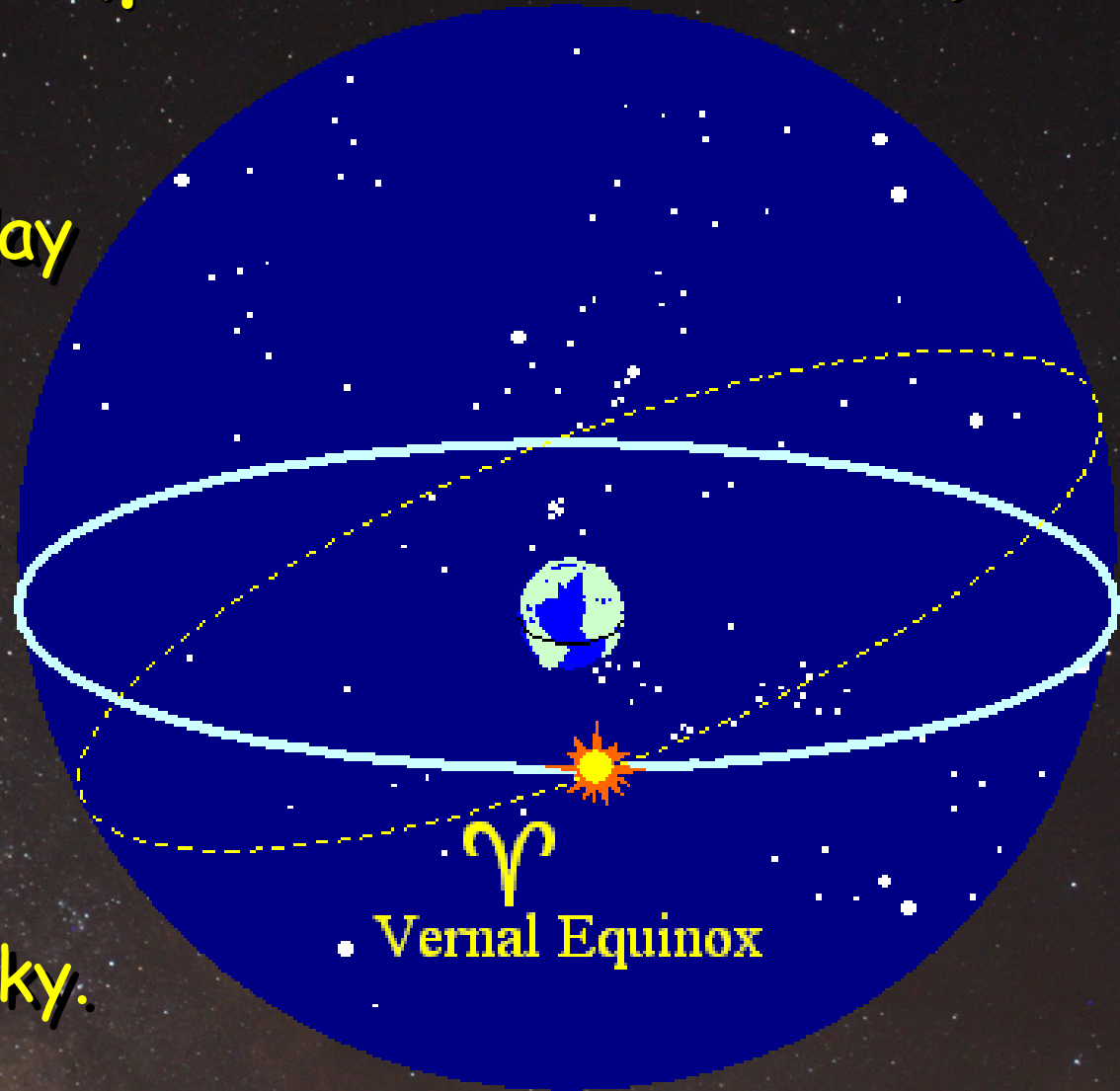
- 🌍 Rotate to Earth's equatorial plane
- 🌍 Center on Earth
- 🌍 Project sun onto sky



# The Ecliptic (path of the sun)

## ☆ View from Earth

- ☉ Sun moves  $\sim 1^\circ$ /day eastward across stars
- ☉ Sun moves north and south in declination
- ☉ Solstices & Equinoxes are positions in the sky.



This motion is  
through the YEAR!

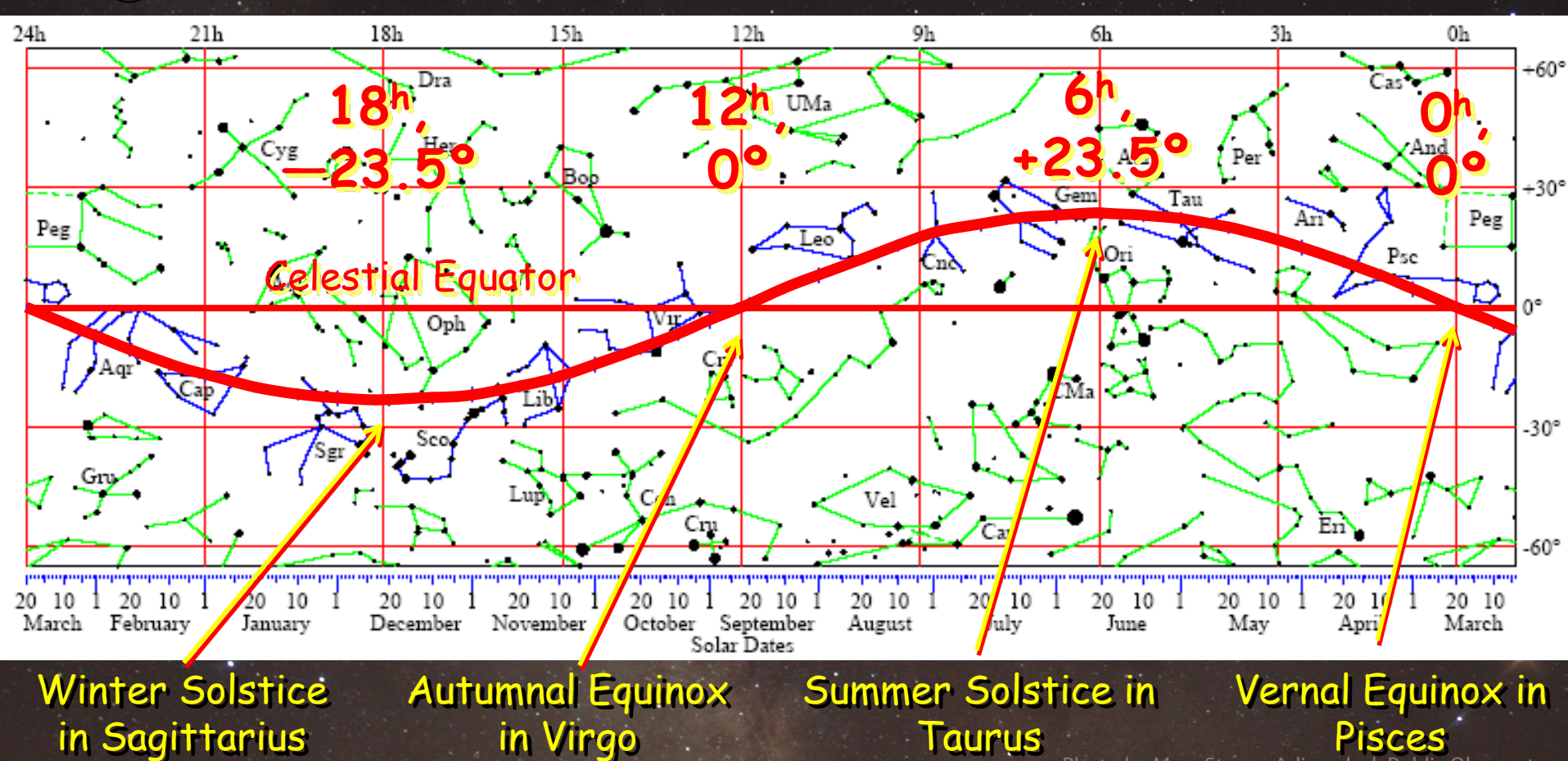


# Sun in the sky

## ☆ View from Earth

🌍 Sun moves  $\sim 1^\circ$ /day eastward across stars

🌍 Sun moves north and south in declination



# Position of Sunrise & Sunset

☆ Azimuth of rising depends on  $\delta$

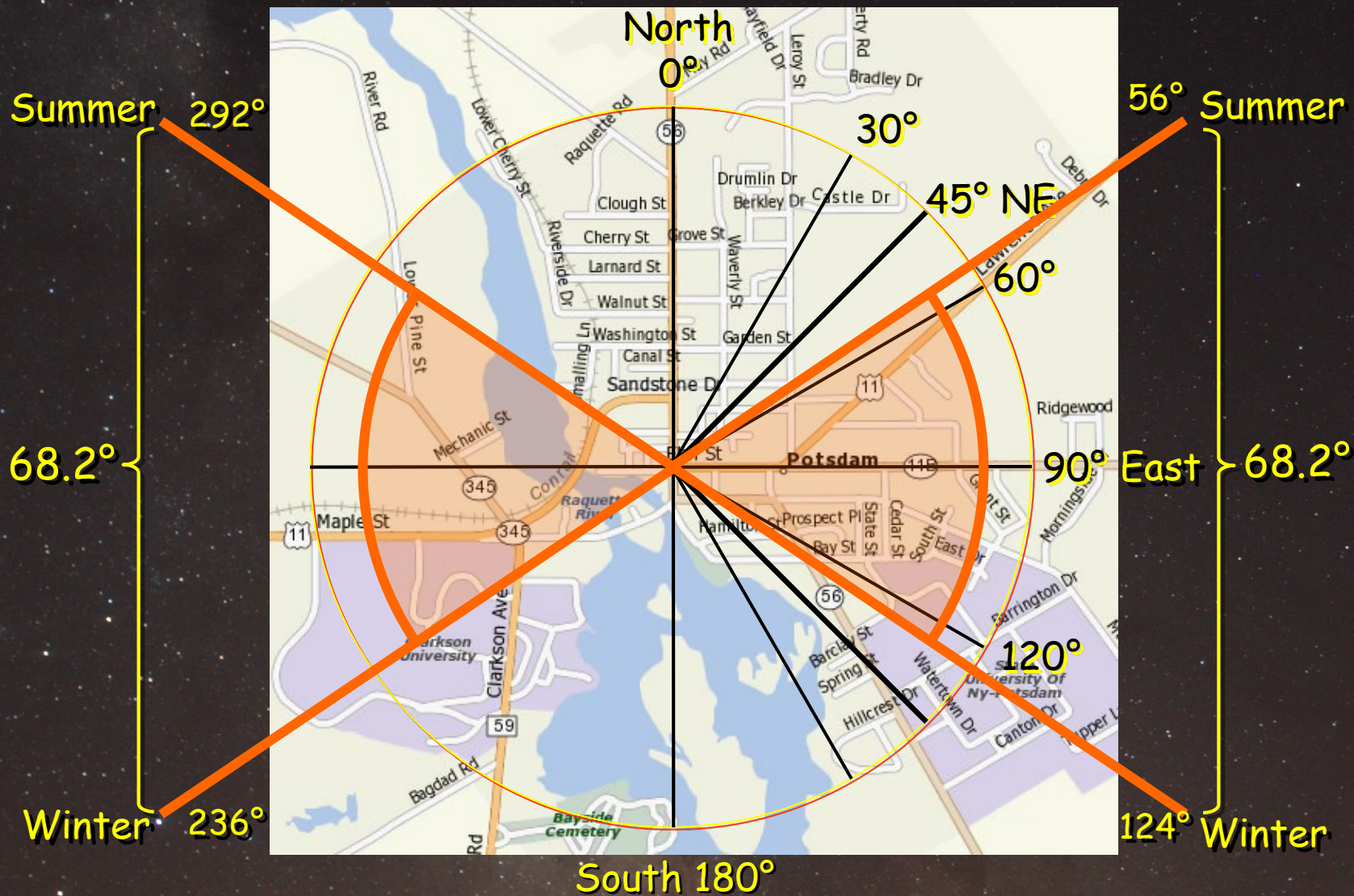
$$A_{\text{rise}} = \cos^{-1} \left( \frac{\sin \delta}{\cos \lambda} \right) \text{ degrees}$$

☆ In Potsdam ( $44^{\circ}40' \text{ N } 75^{\circ}59' \text{ W}$ )

$$\begin{array}{l} \text{Summer: } A_{\text{rise}} = \cos^{-1} \left( \frac{\sin 23.5}{\cos 44.67} \right) = 55.9 \text{ degrees} \\ \text{Winter: } A_{\text{rise}} = \cos^{-1} \left( \frac{\sin -23.5}{\cos 44.67} \right) = 124.1 \text{ degrees} \end{array} \left. \vphantom{\begin{array}{l} \text{Summer: } \\ \text{Winter: } \end{array}} \right\} 68.2^{\circ}$$

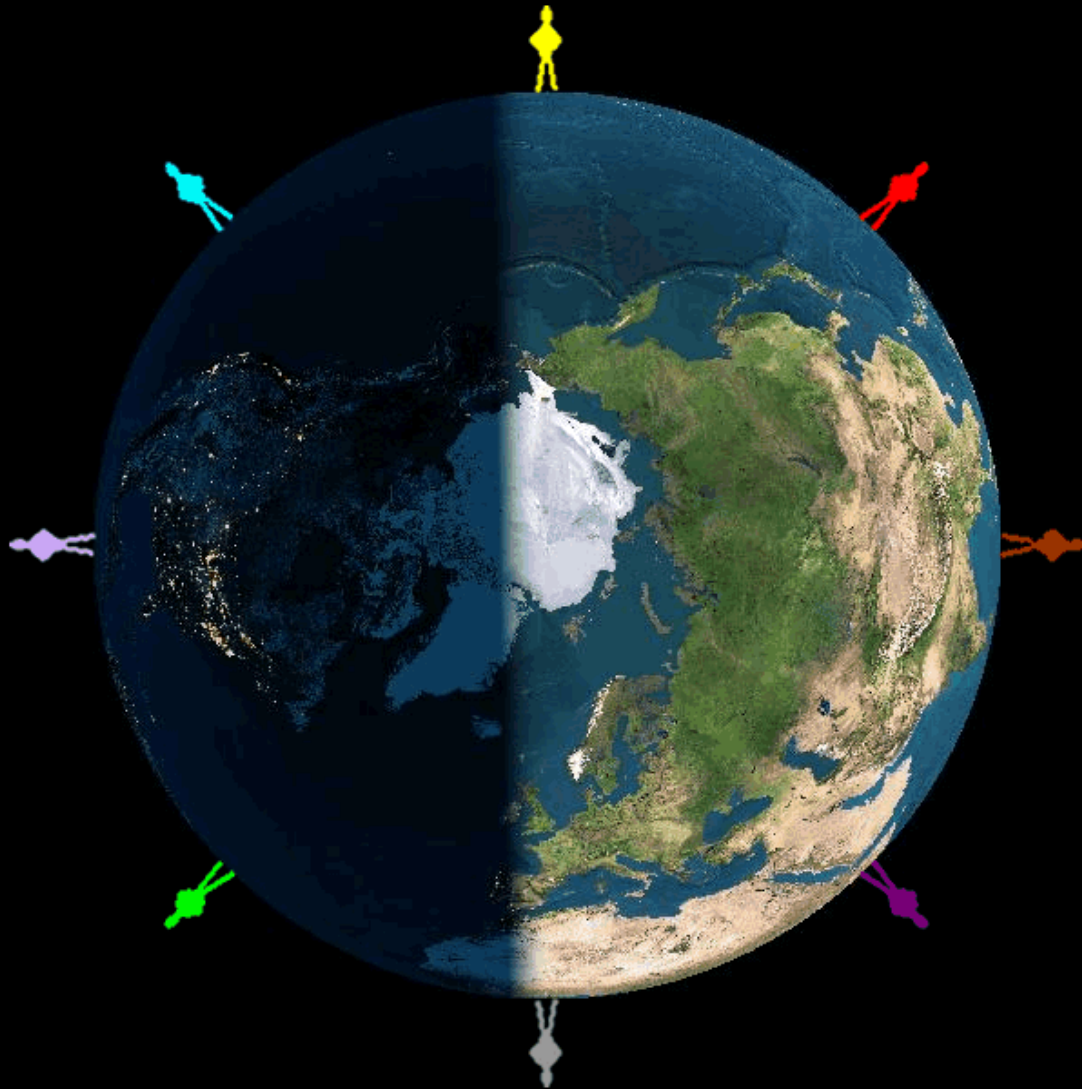
# Position of Sunrise & Sunset

☆ Sun rises at  $56^\circ$  in Summer,  $124^\circ$  in Winter



# When on Earth?

## ☆ Earth Rotates Once Each Day



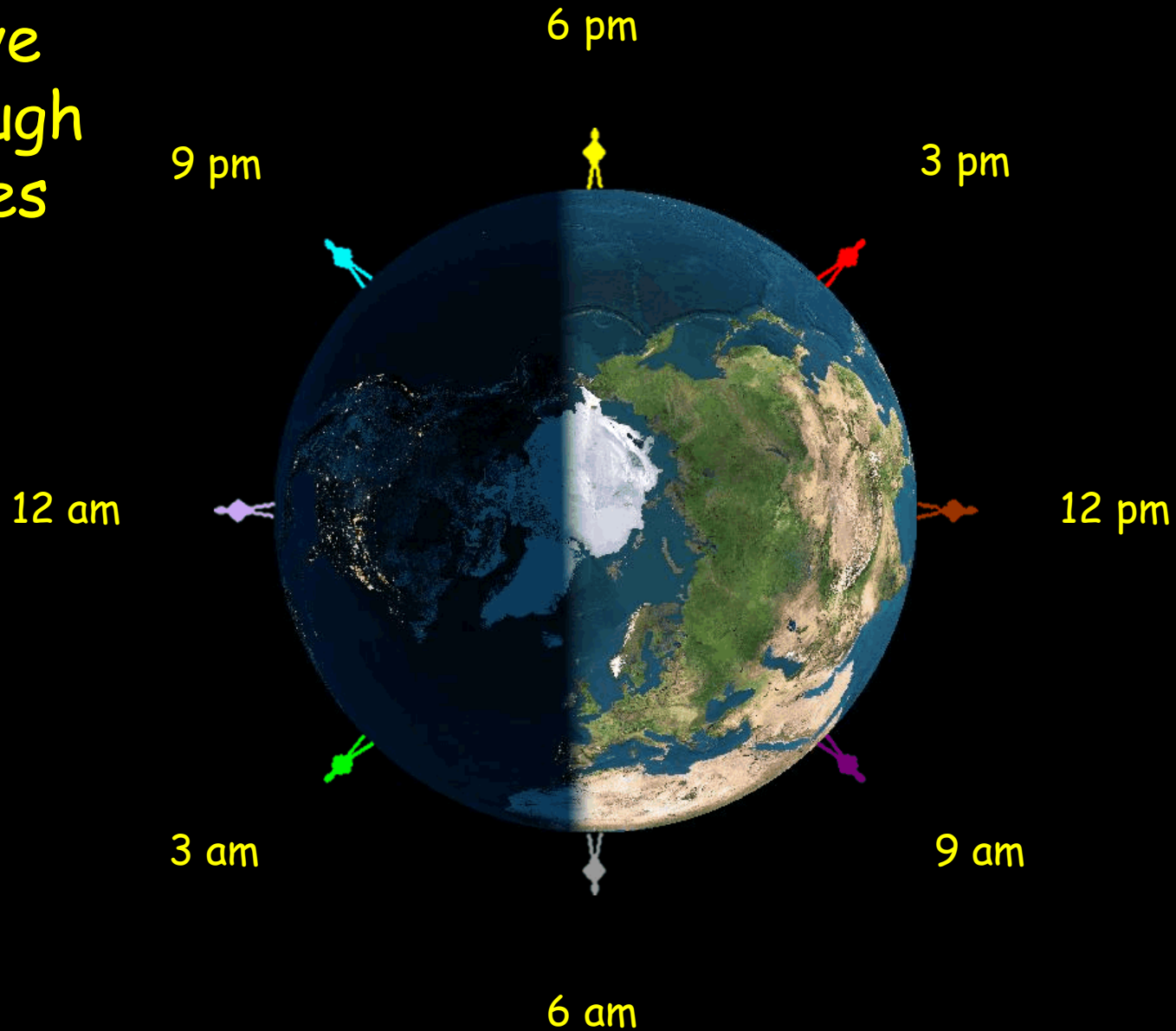
🌍 360° with respect to Earth-Sun line

🌍 All Earthlings ride along

→ To Sol

# Clock Time

Observers  
move  
through  
times



# Moon orbits Earth

## ☆ Solar Month

🌍 New Moon to  
New Moon

🌍 29d 12h 44m ~ 29.5d

## ☆ Sidereal Month

🌍 Moon moves 360°

🌍 27d 7h 43m

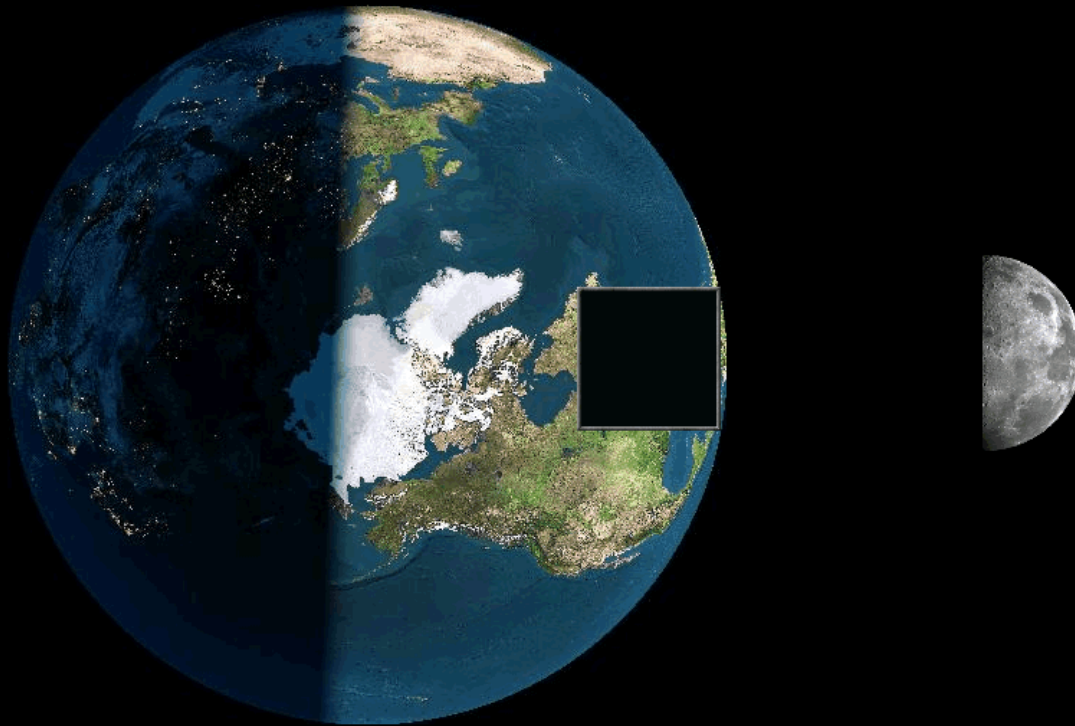
## ☆ Moon rotates on its axis once/month

🌍 Keeps same face toward Earth

☾ hangs "heavy side down"

🌍 Appears larger at perigee than apogee

# Demonstration with Oranges!



Moon  
Phase is  
lit moon  
visible

Insert is  
moon as  
see from  
Earth

# Moon Phases

☆ **New Moon: Elongation =  $0^\circ$**  (angle from sun to moon)

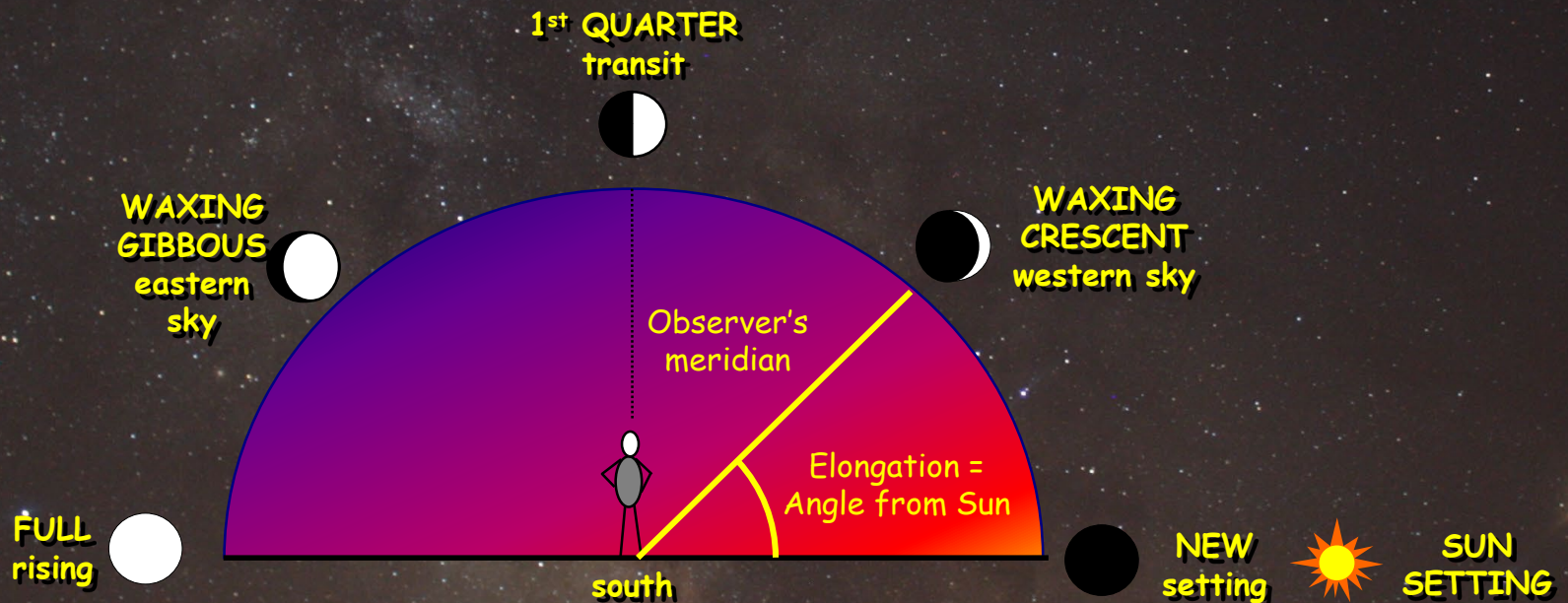
🌐 **Waxing Phases: visible after sunset**

› Waxing Crescent:  $0^\circ < \text{Elongation} < 90^\circ \text{ E}$

› First Quarter: Elongation =  $90^\circ \text{ E}$

› Waxing Gibbous:  $90^\circ \text{ E} < \text{Elongation} < 180^\circ$

☆ **Full Moon: Elongation =  $180^\circ$**





# Waxing Moon Phases

☆ Brown Lunation number 1234

› Since first new moon of 1923 (1/16/23, 9:41 pm EST)

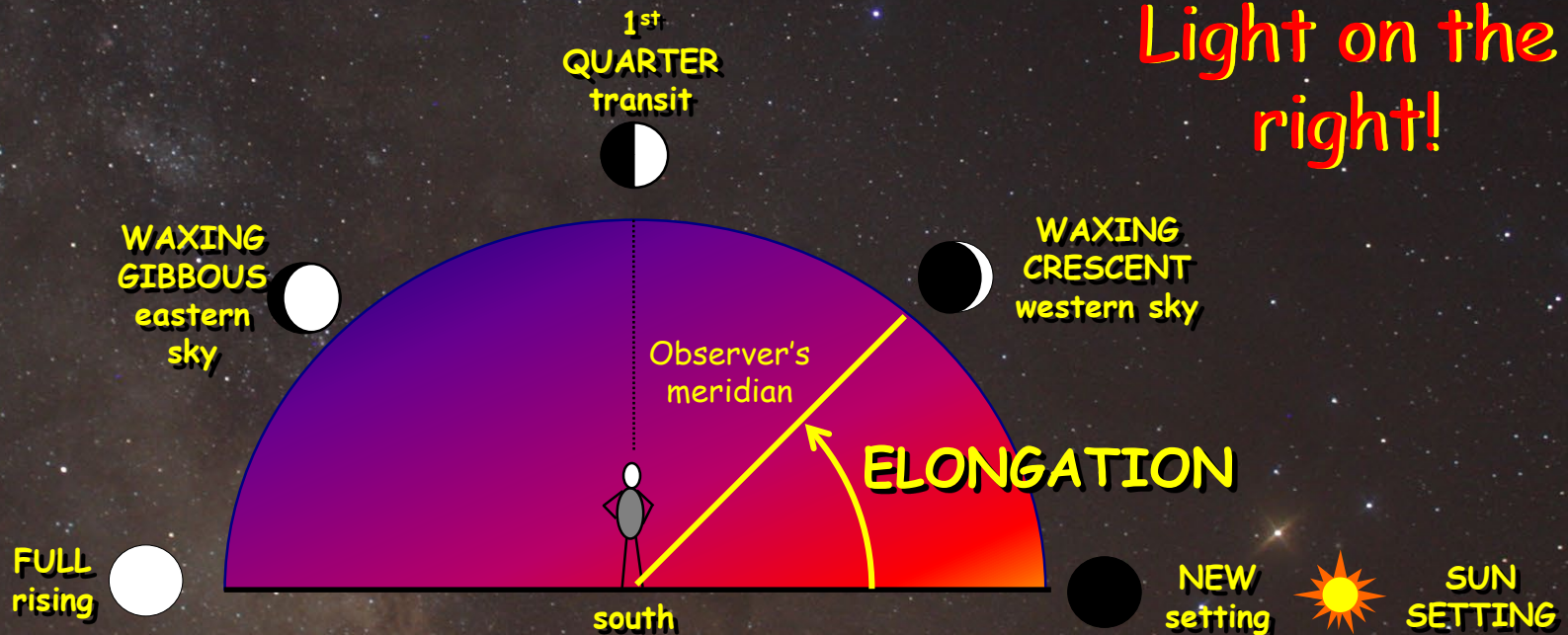
🌍 New Moon: Sep. 25, 5:54 pm EDT

🌍 1<sup>st</sup> Quarter: Oct. 2, 8:14 pm EDT

🌍 Full Moon: Oct. 9, 4:54 pm EDT

› The Hunter's Moon!!

**Waxing:**  
Light on the  
right!

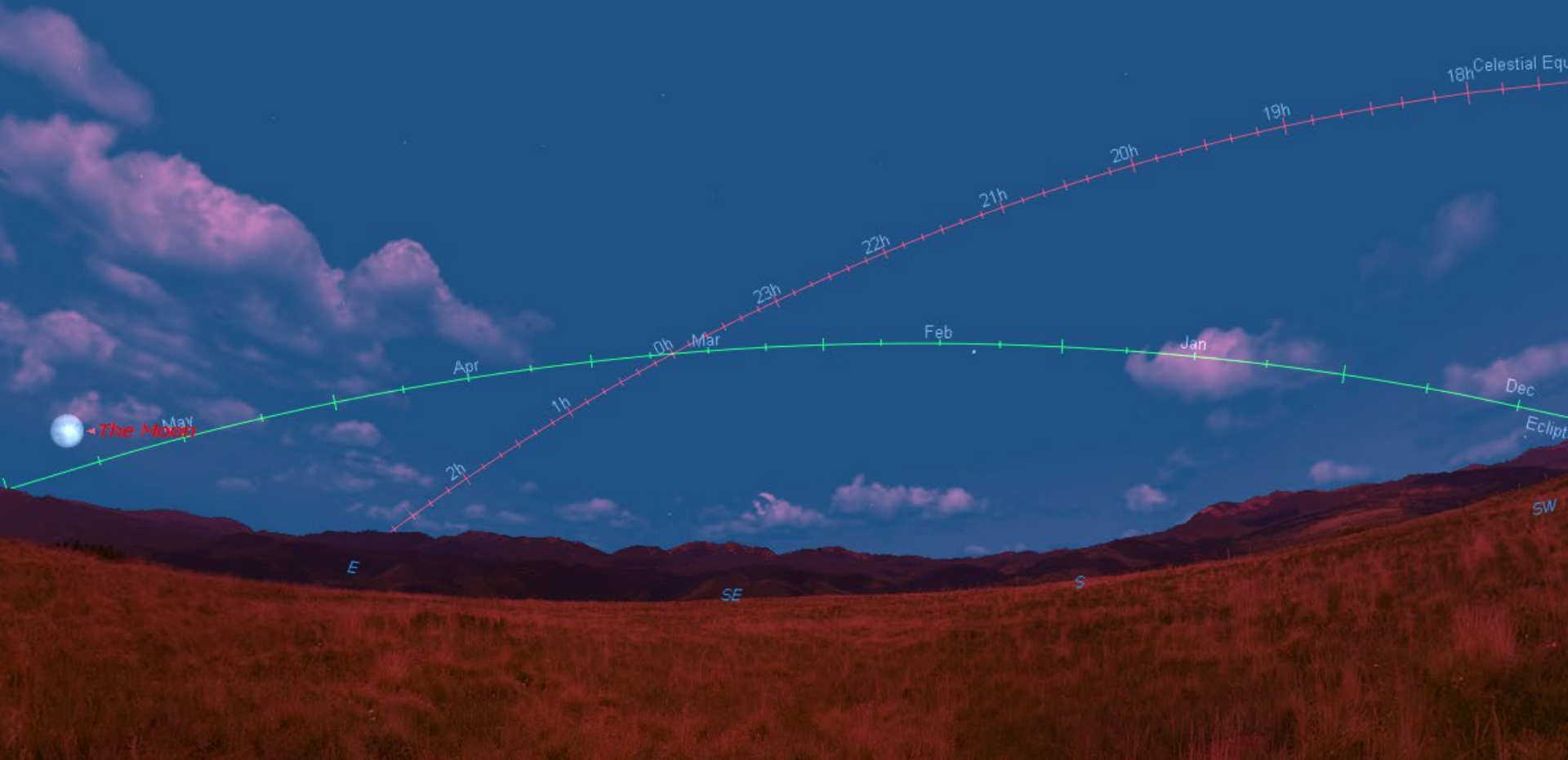


# Evening Moon Phases

☆ Look south at sunset

9/28/6 6:47:00 pm  
Waxing Gibbous

12/01/9 4:21:53 pm  
Almost Full



# Evening Moon Phases

☆ Look south at sunset

9/28/6 6:47:00 pm  
Waxing Gibbous

12/01/9 4:21:53 pm  
Almost Full





# Waning Moon Phases

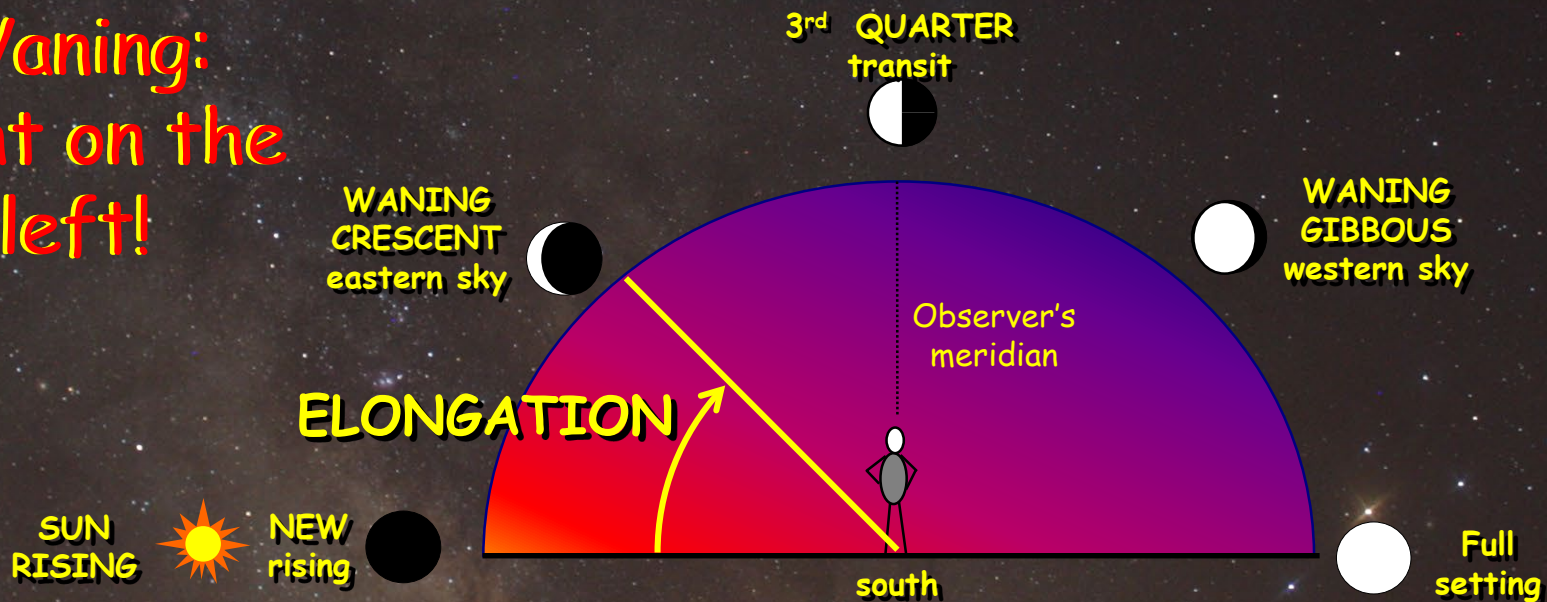
☆ Lunation Number 1234

☆ Full Moon: Oct. 9, 4:54 pm EDT

☆ 3<sup>rd</sup> Quarter: Oct. 17, 1:15 pm EDT

☆ New Moon: Oct. 25, 6:48 am EDT

**Waning:**  
**Light on the**  
**left!**

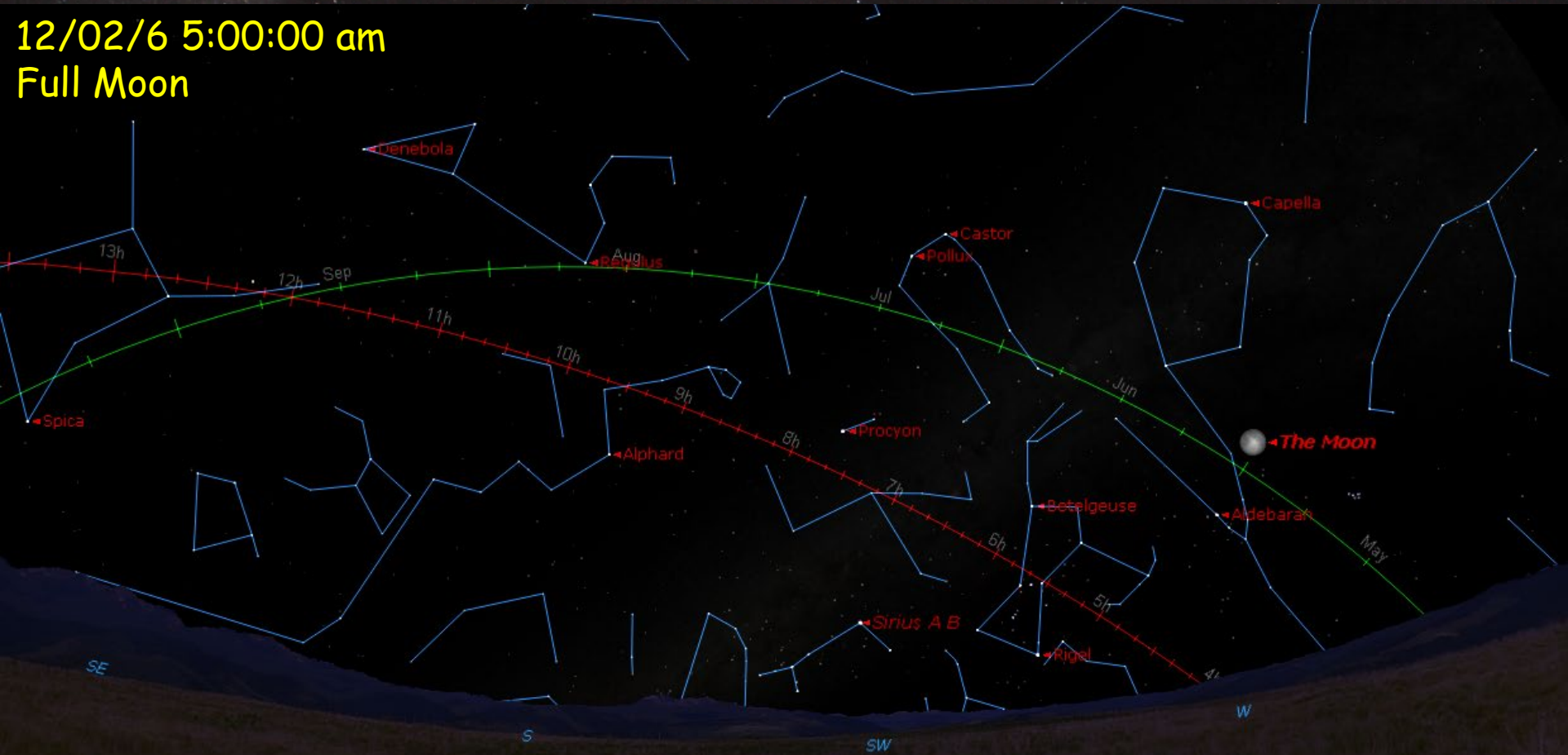


# Morning Moon Phases

☆ Look south at sunrise ... the cold moon

12/02/6 5:00:00 am

Full Moon



# Morning Moon Phases

☆ Look south at sunrise

12/15/9 7:30:46 am

Waning Crescent

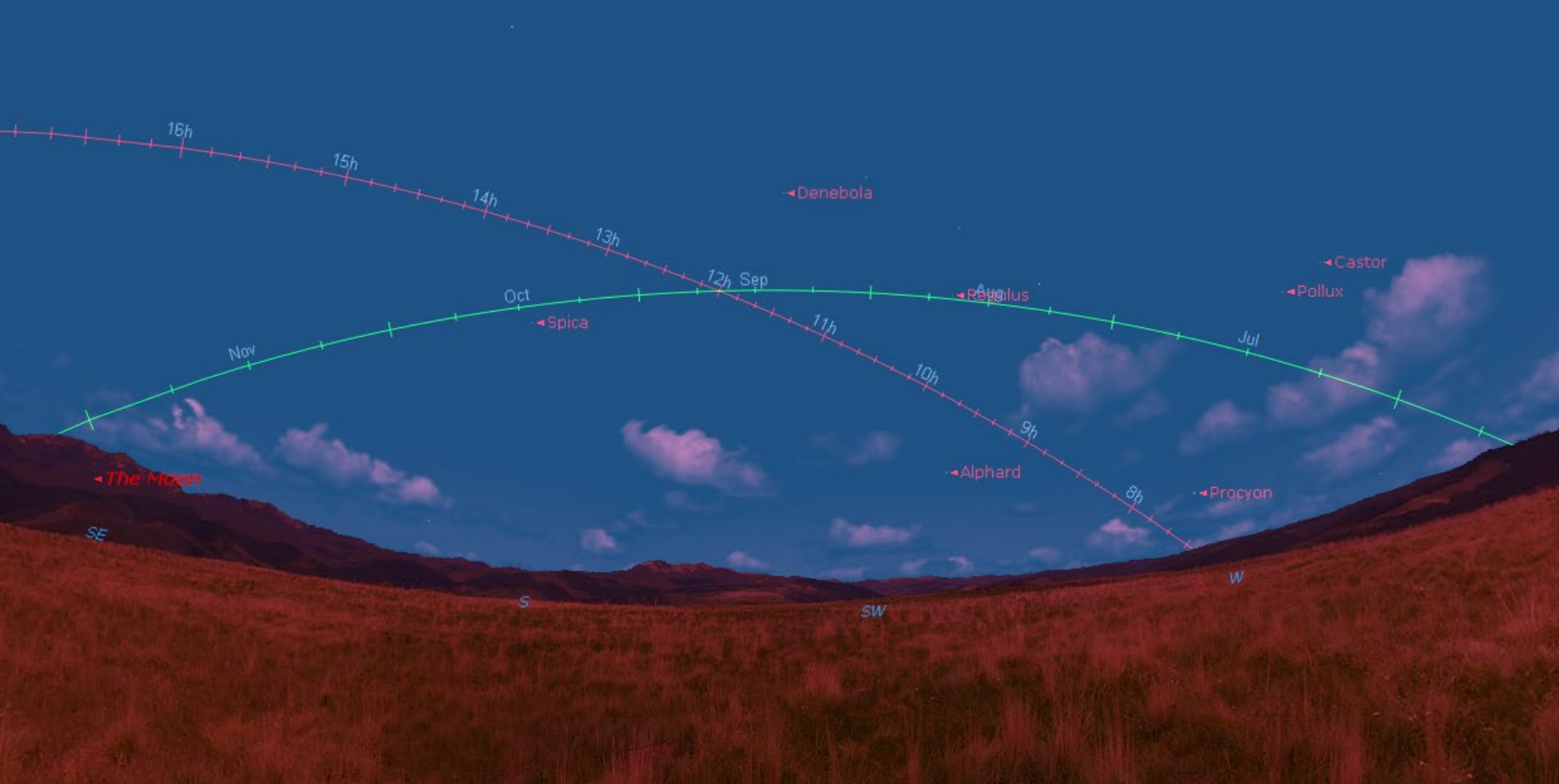


# Morning Moon Phases

☆ Look south at sunrise

12/15/9 7:30:46 am

Waning Crescent





# Moon Phases & Time of Day

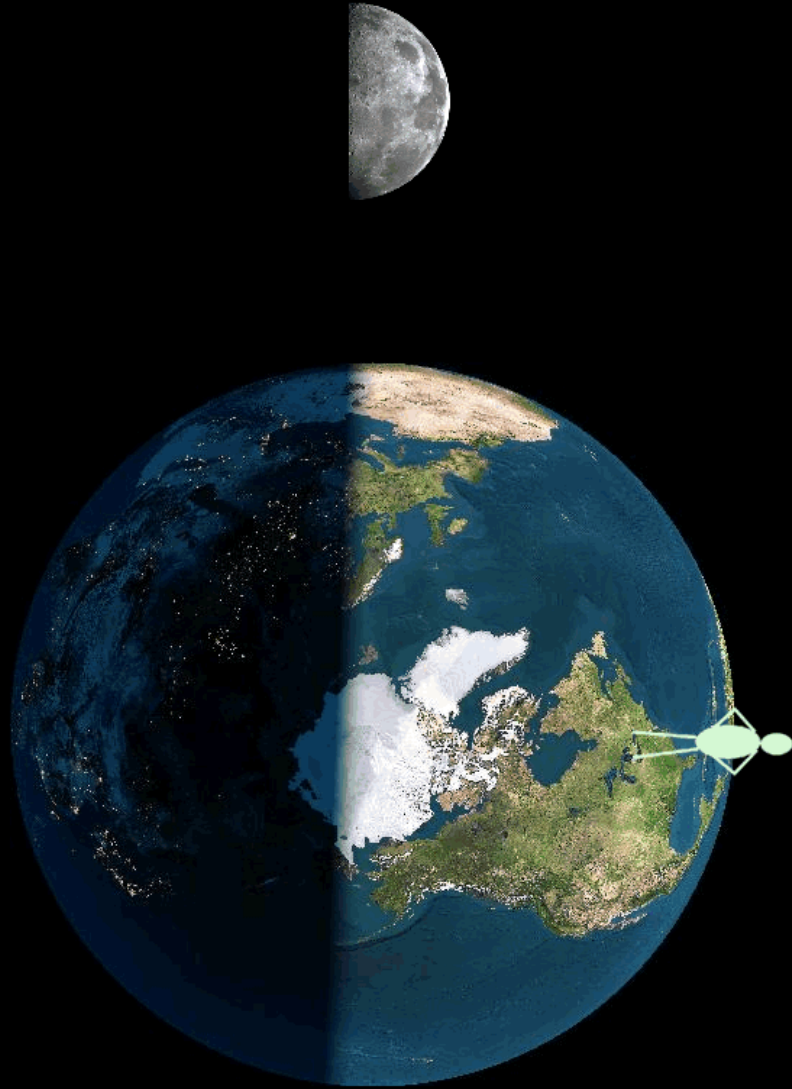
## ☆ Moon phase

🌍 Due to positions of Earth, Sun & Moon

## ☆ Time of Day

🌍 Due to positions of Earth, Sun & Observer

Position & Phase of Moon  
Gives Time of Day

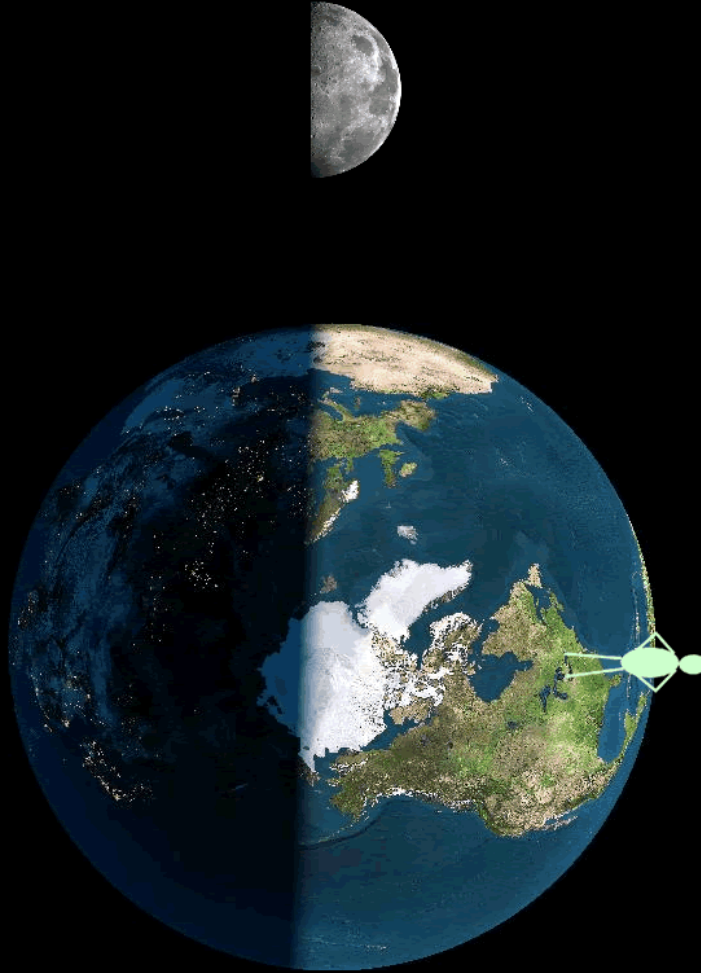


Earth  
rotates  
beneath  
each  
phase

Example:  
First  
Quarter

Observer's time is 12:00

# Single observer sees moon in sky

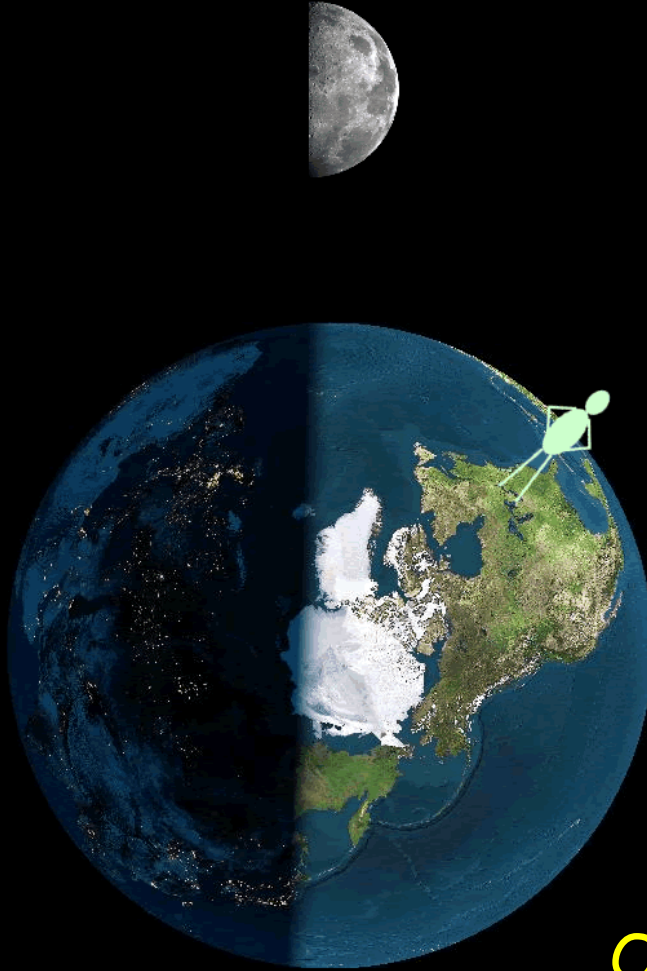


Observer  
sees moon  
rising

Observer's time is 12:00



# Single observer sees moon in sky



Observer  
sees moon in  
eastern sky

Observer's time is 15:00

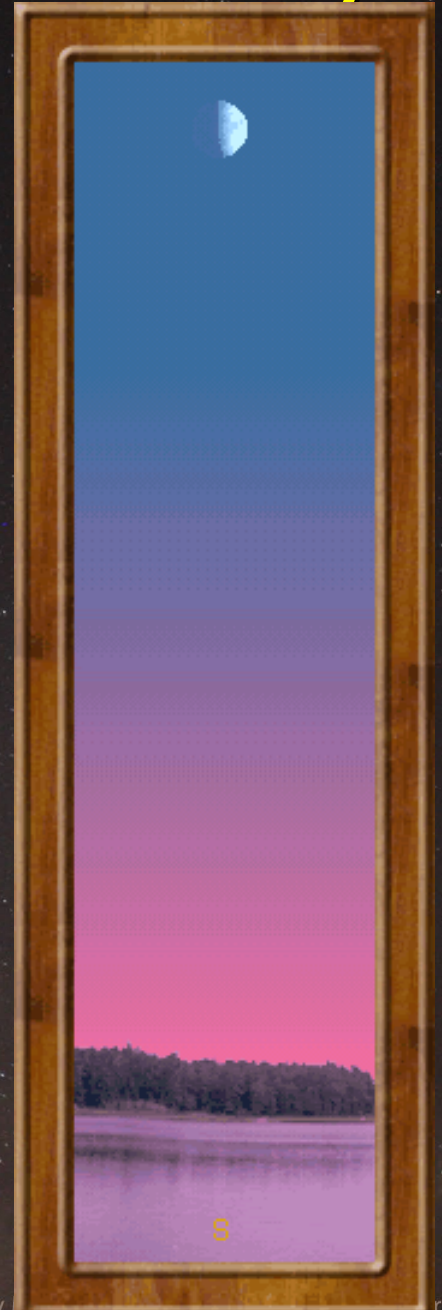


# Single observer sees moon in sky



Observer  
sees moon  
transiting as  
sun sets

Observer's time is 18:00

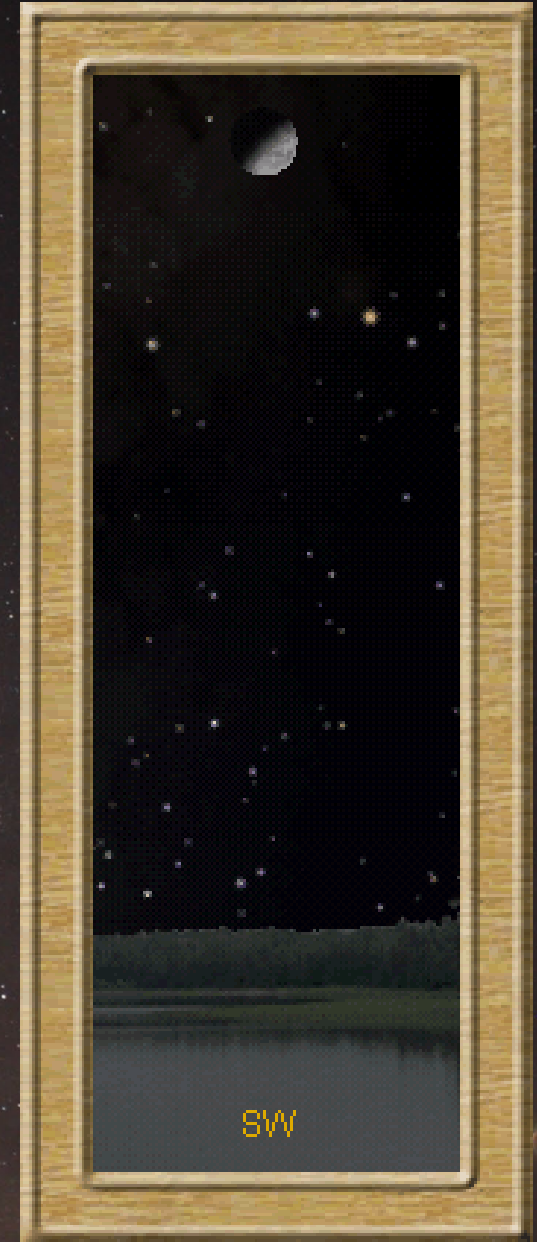


# Single observer sees moon in sky



Observer  
sees moon in  
western sky

Observer's time is 21:00



# Single observer sees moon in sky



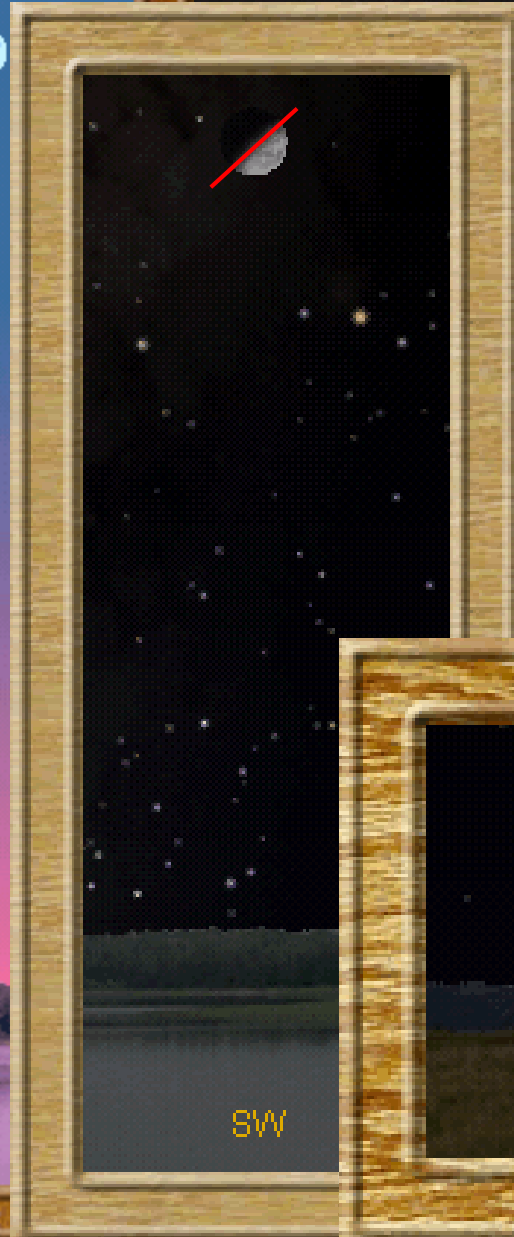
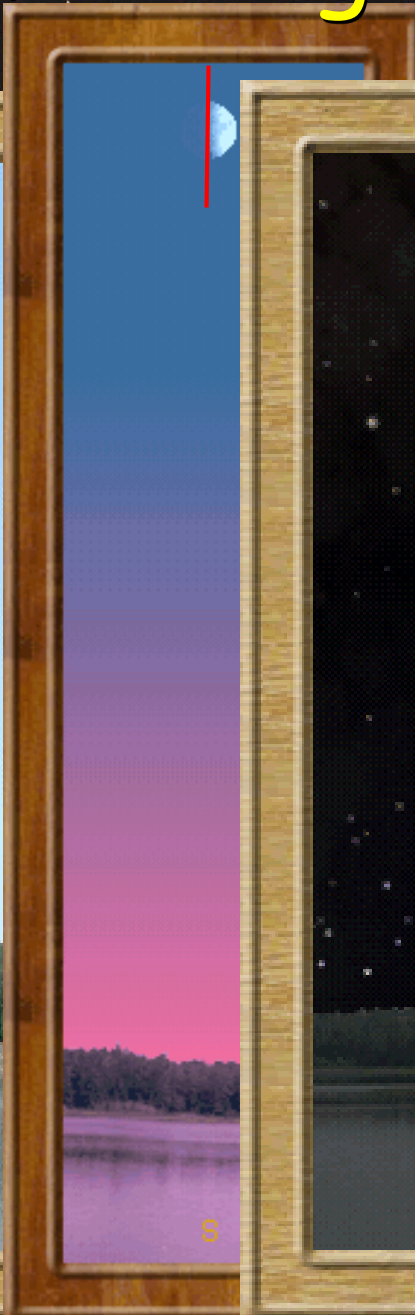
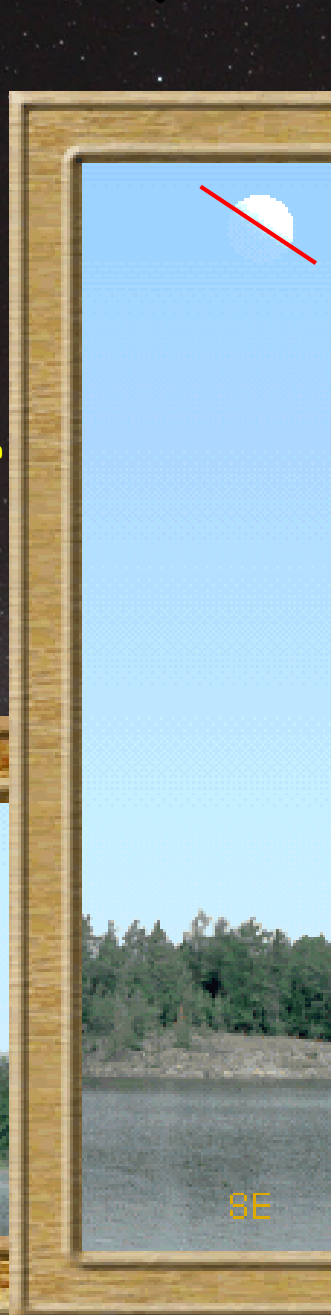
Observer  
sees moon  
setting

Observer's time is 00:00

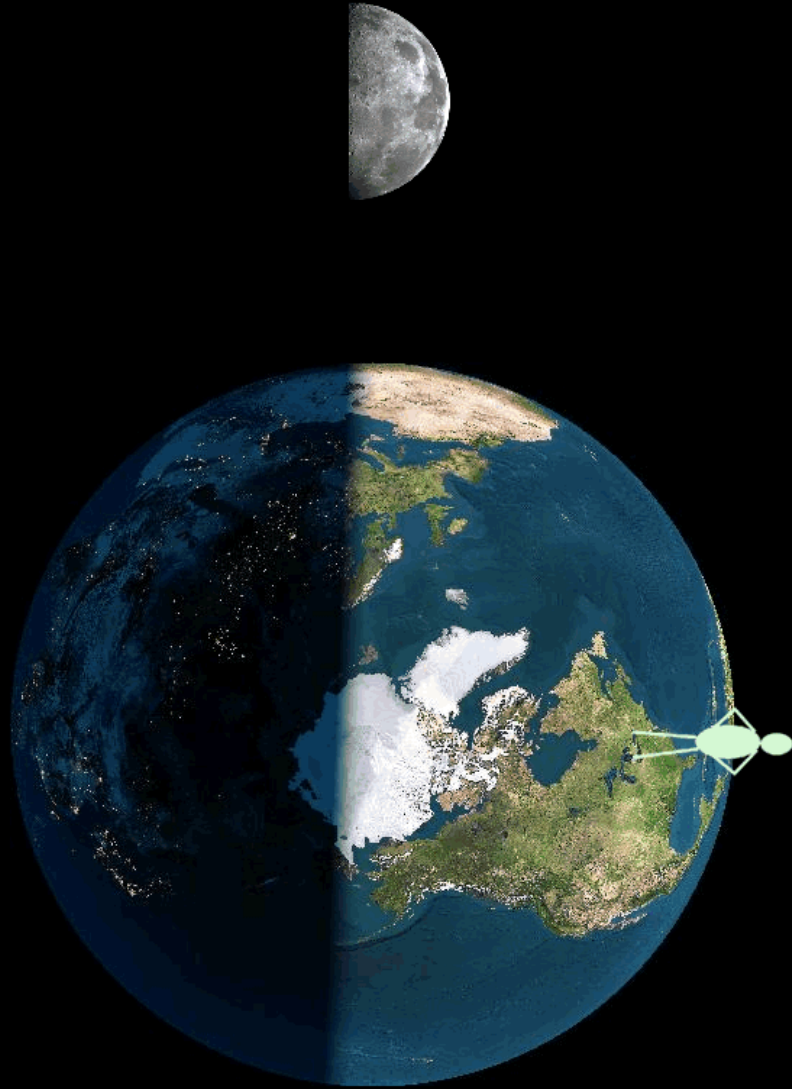


# Moon from Rising to Setting

Perpendicular  
to Ecliptic







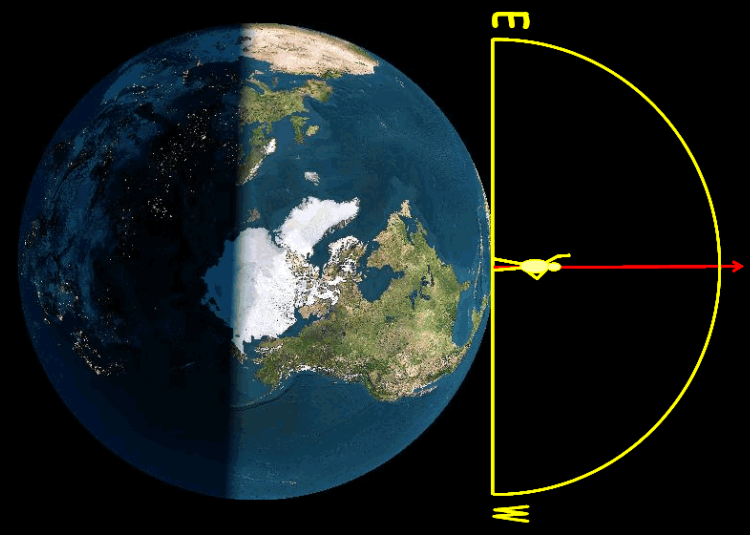
Earth  
rotates  
beneath  
each  
phase

Example:  
First  
Quarter

Observer's time is 12:00

# Earth Observer

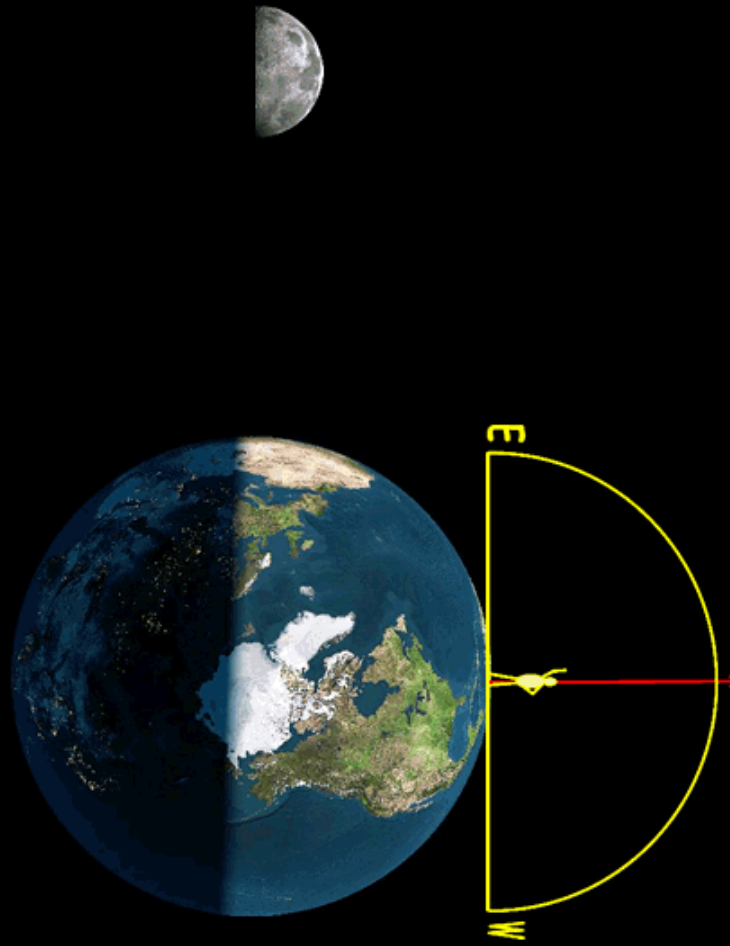
Observer  
views moon  
from own  
horizon  
system



Observer's time is 12:00

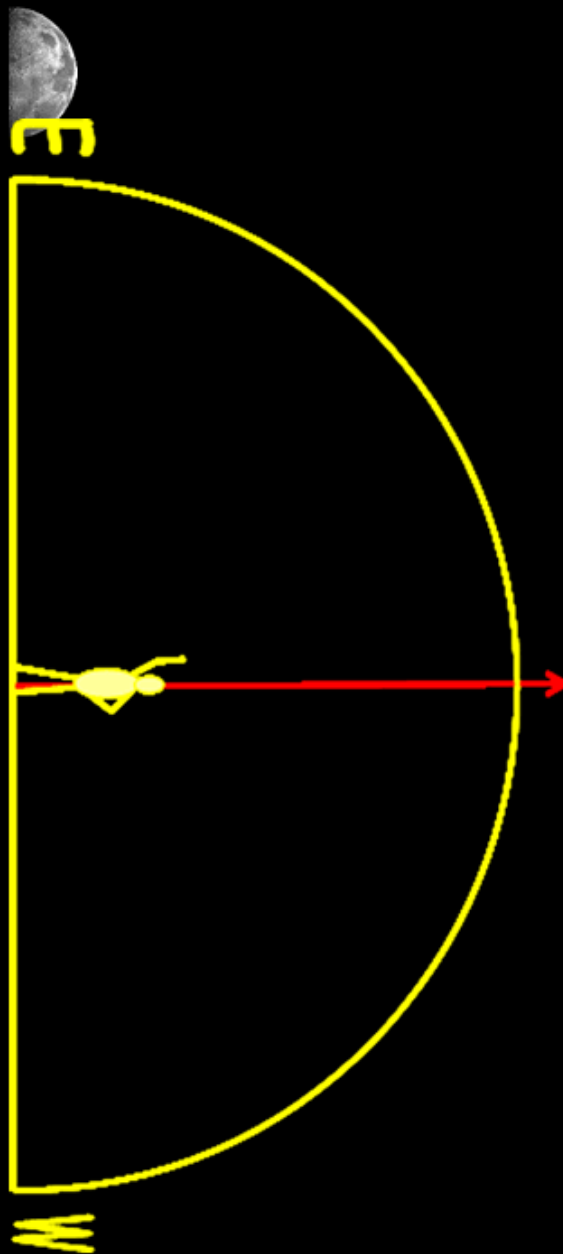
# Earth Observer

Observer  
only aware  
of own  
horizon  
system



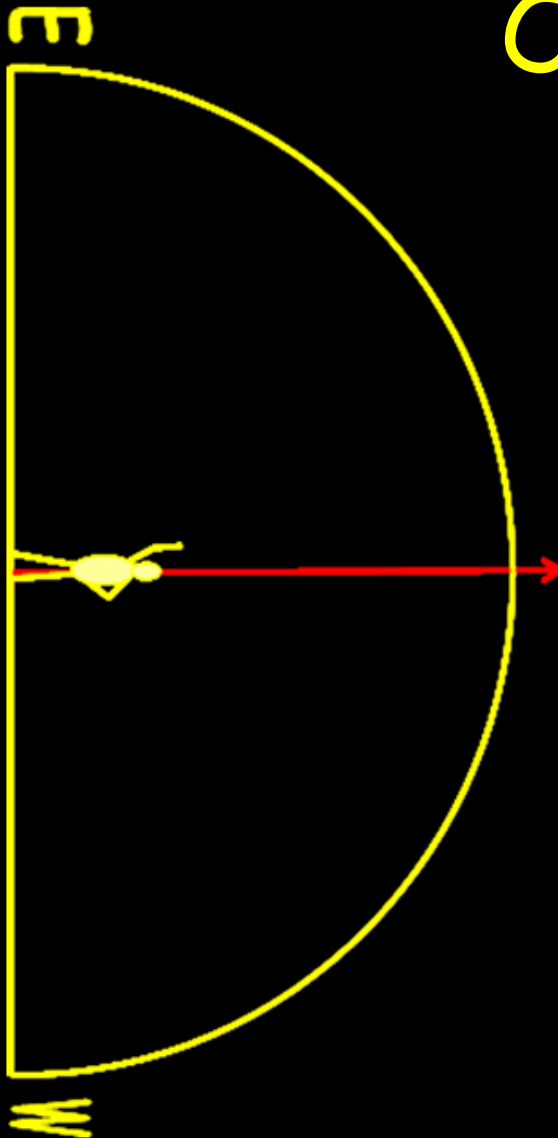
Observer's time is 12:00

# 1<sup>st</sup> Quarter Observer



Observer's time is 12:00 1<sup>st</sup> Quarter moon is rising

# Waning Gibbous Observer

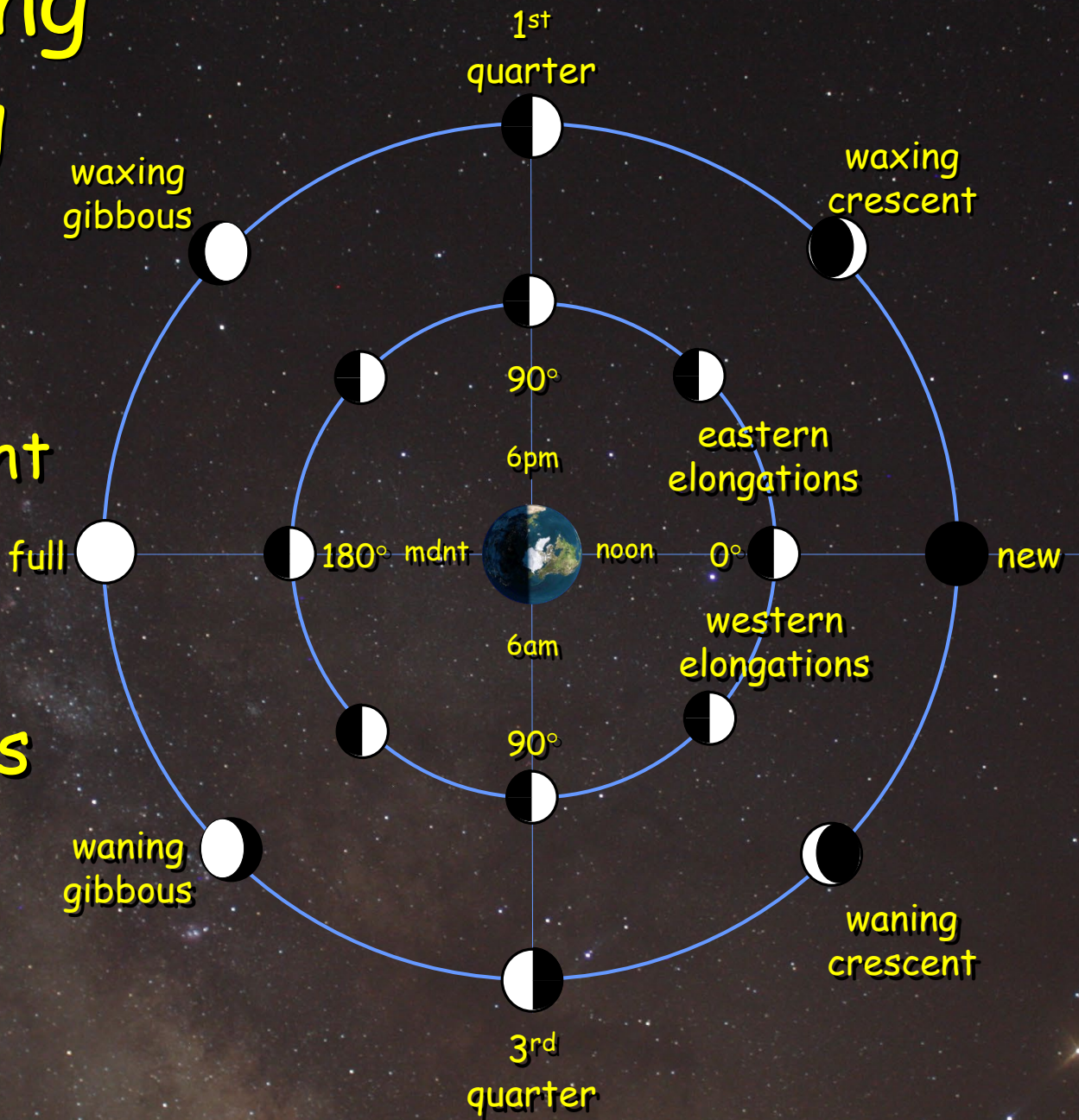


Observer's time is 12:00 waning gibbous moon is invisible

# Phases Rising & Setting

**1st Quarter**  
Rises at noon  
Sets at midnight

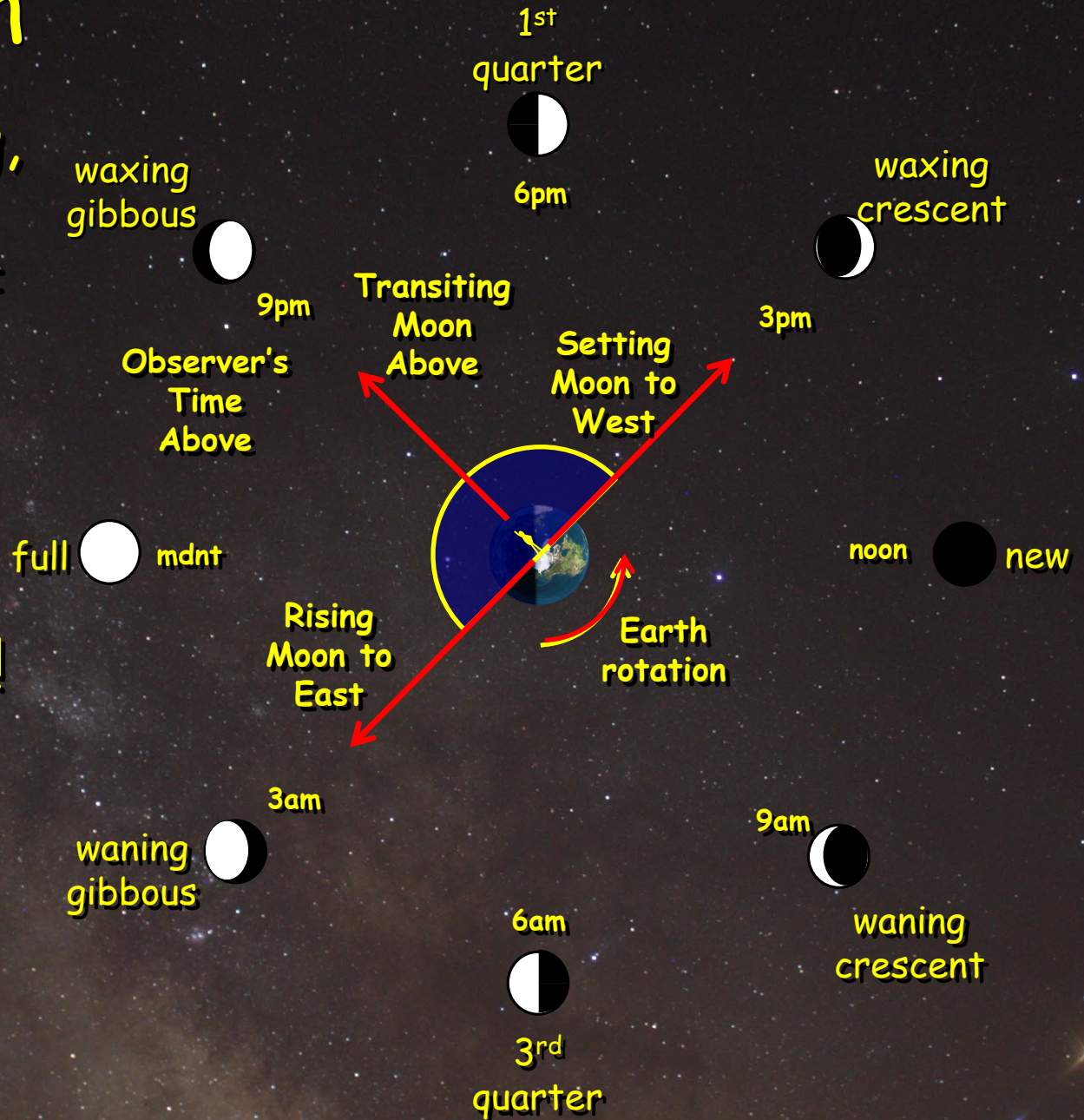
**Waning Gibbous**  
Rises at 9 pm  
Sets at 9 am



# Today's Fun

Determine rising, transit and setting times of each phase

Time is the one above the observer's head!



# Phases & Times

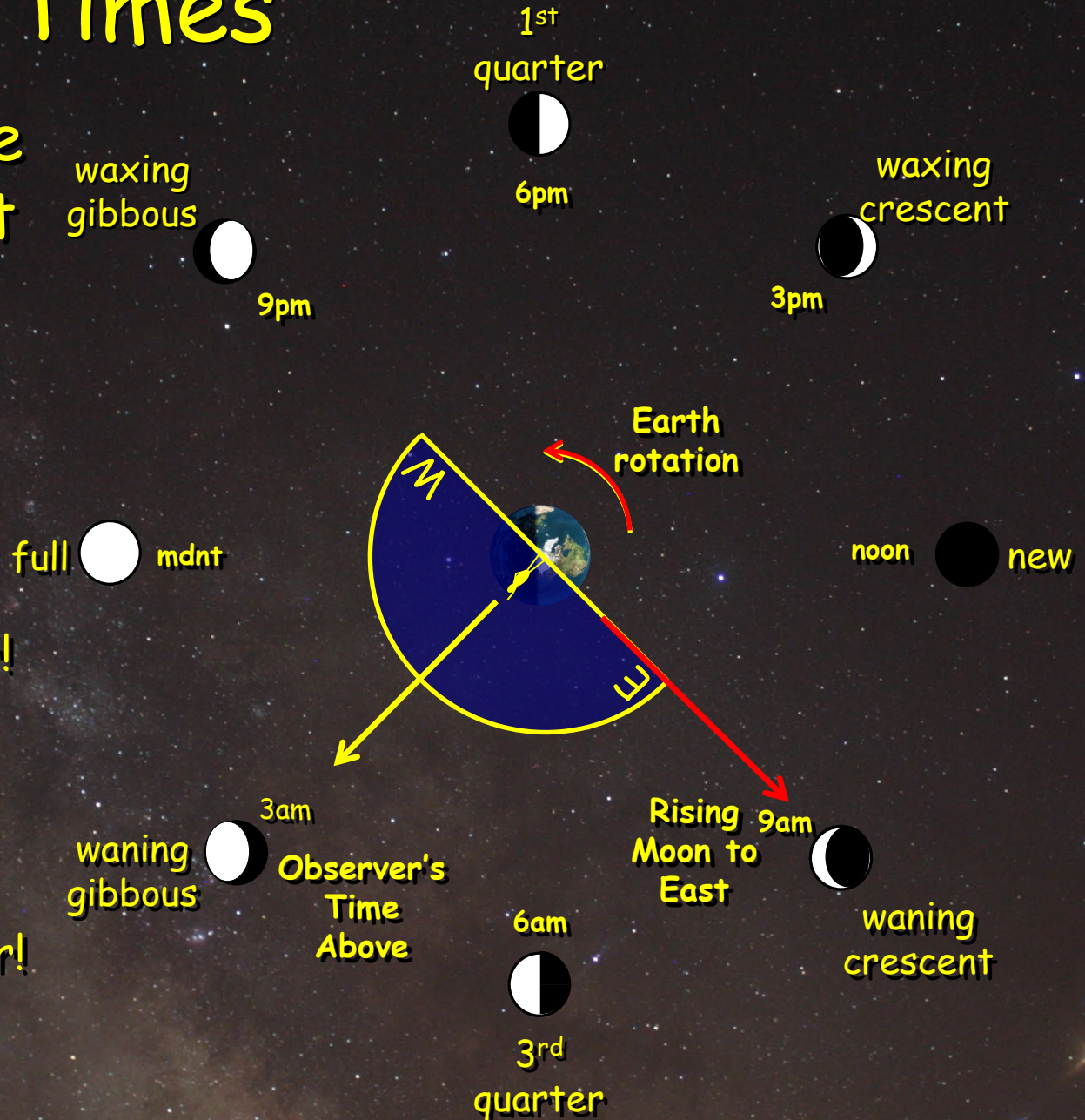
What's the phase of the moon that rises at 3 am?

3 am is the  
**OBSERVER'S  
TIME!**

No other times matter!

Rising moon on  
eastern horizon

No other phases matter!





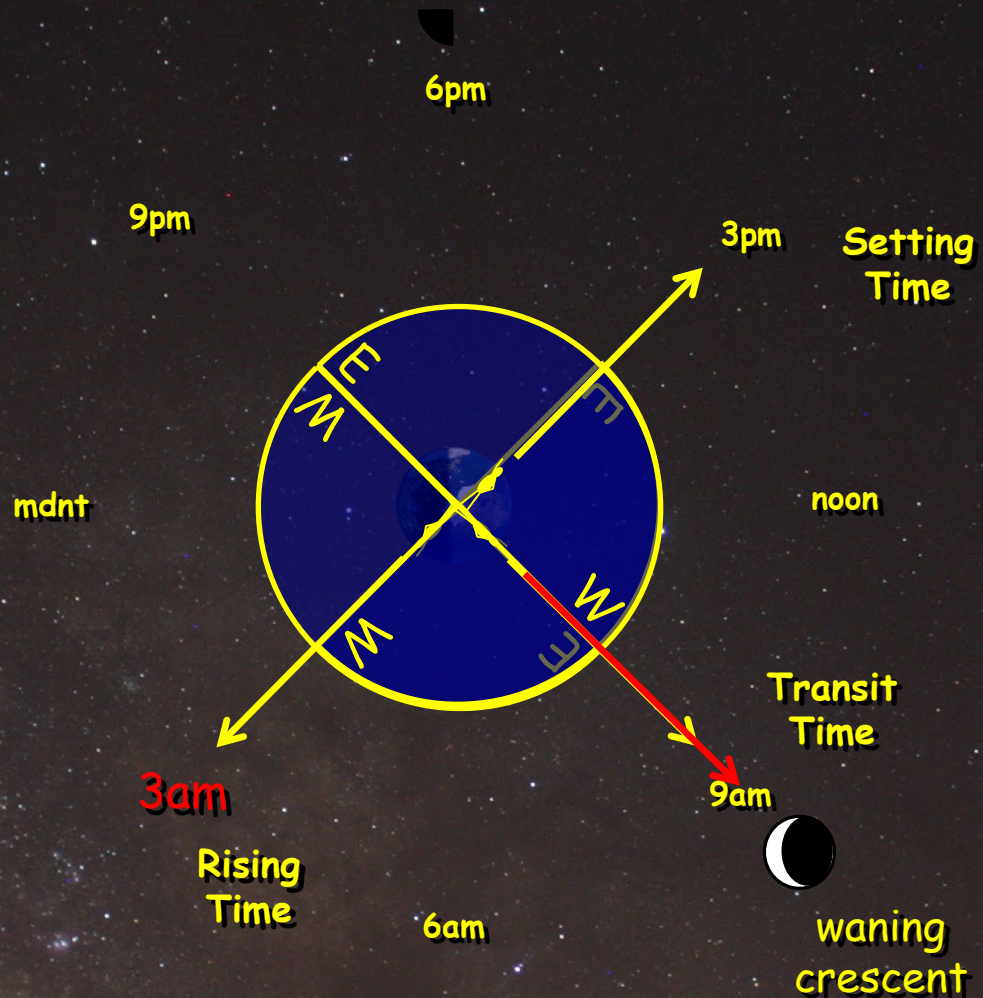
# Phases & Times

What time does the phase rise & transit

Turn observer through day

Find time for transit

Find time for setting

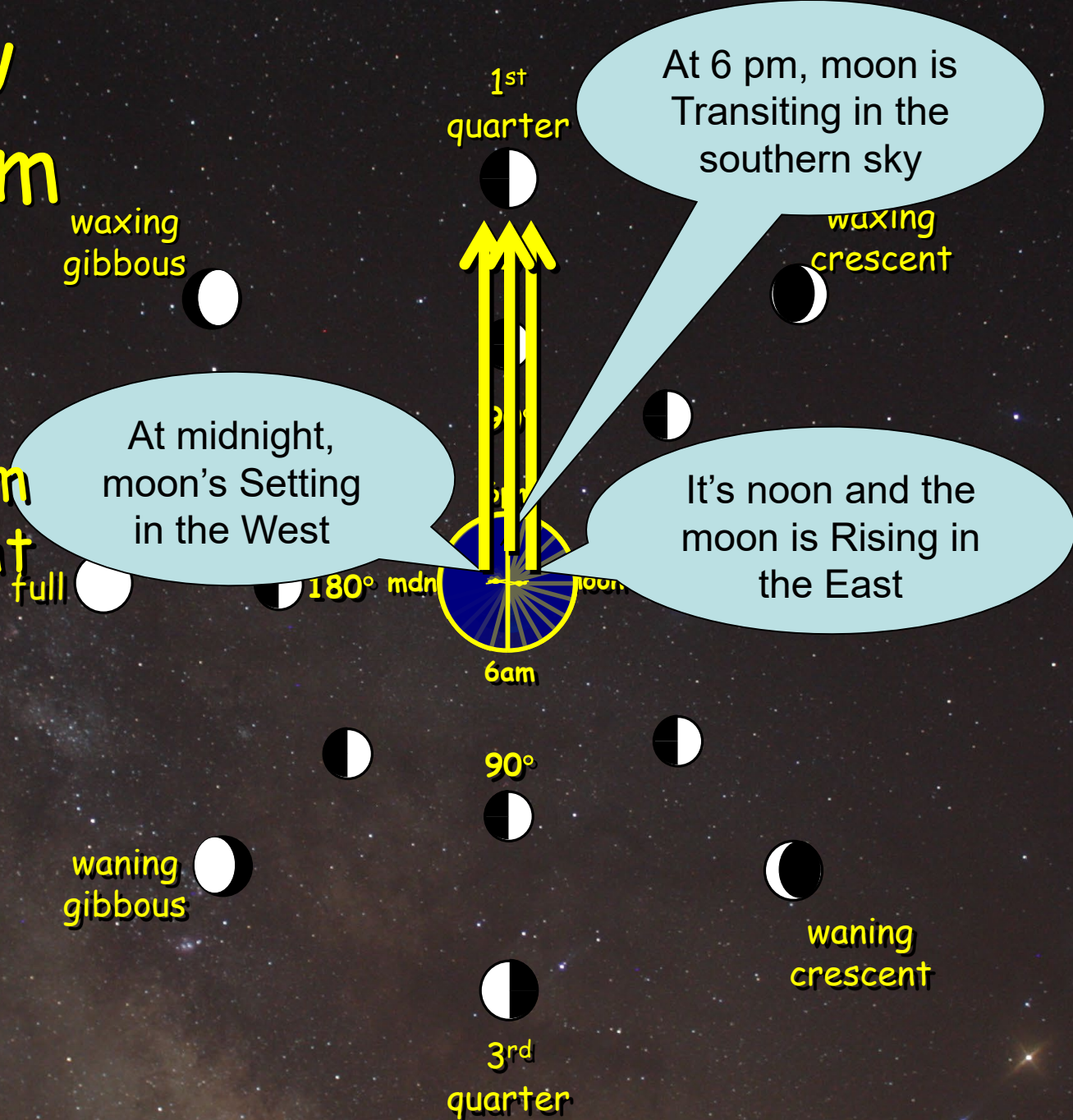


Waning Crescent rises at 3 am, transits at 9 am, sets at 3 pm

# Now show the diagram

## 1st Quarter

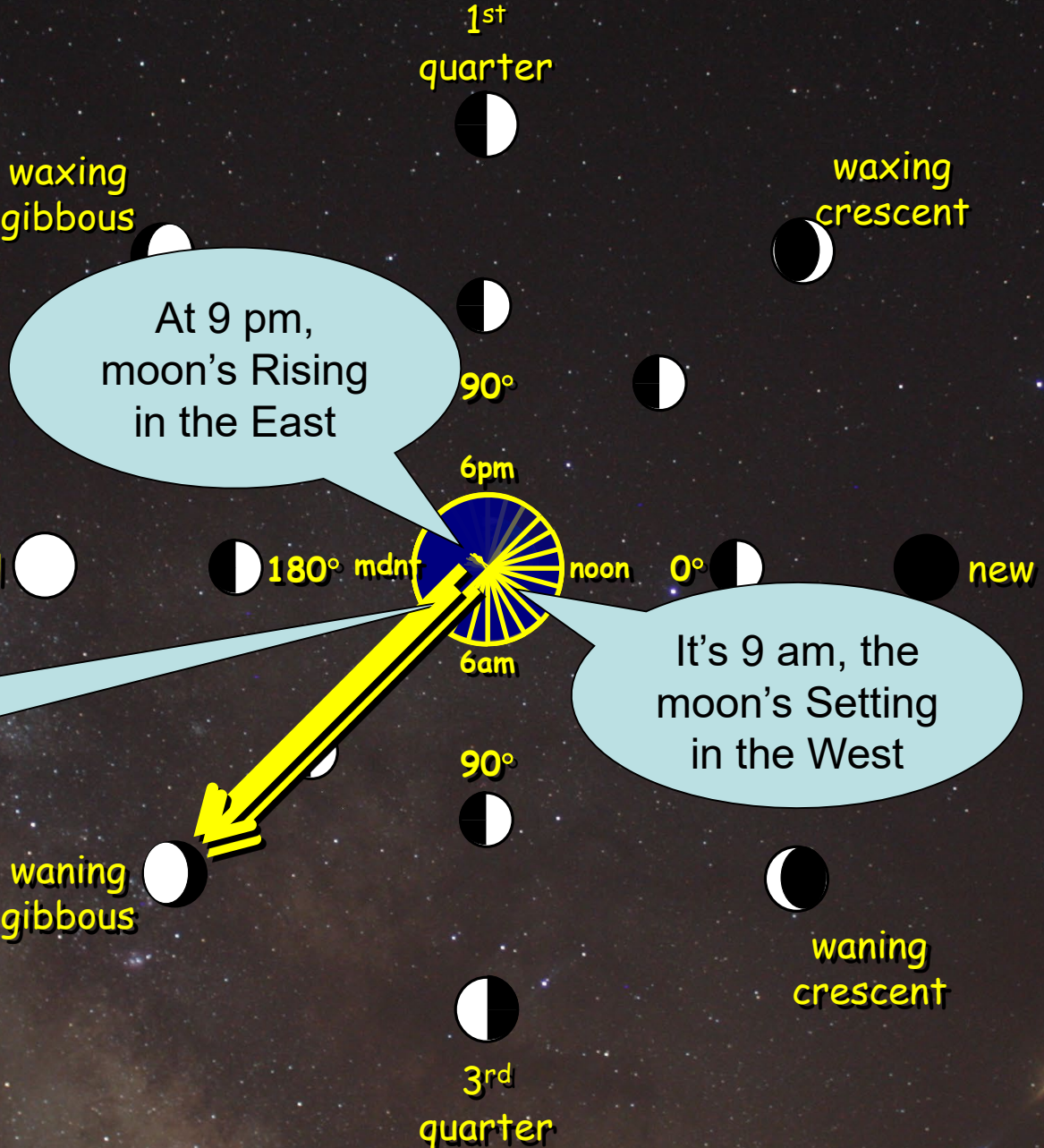
Rises at noon  
Transits at 6 pm  
Sets at midnight



# Now show the diagram

**Waning Gibbous**  
Rises at 9 pm  
Transits at 3 am  
Sets at 9 am

At 3 am, moon's transiting in the southern sky

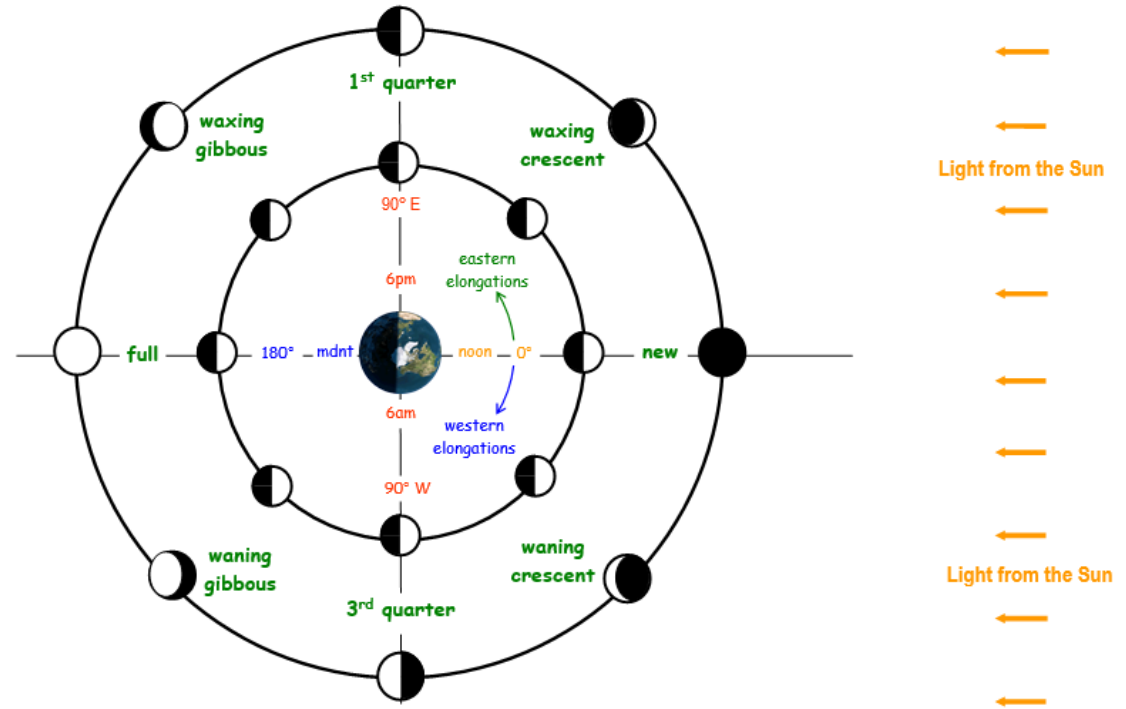


# Today's Fun: Moon Phases

- ☆ phase name
- ☆ elongation
- ☆ rising time
- ☆ setting time
- ☆ transit time

## PHASES OF THE MOON

The inner circle shows the moon in its orbit, the outer circle shows how each phase appears as seen from Earth

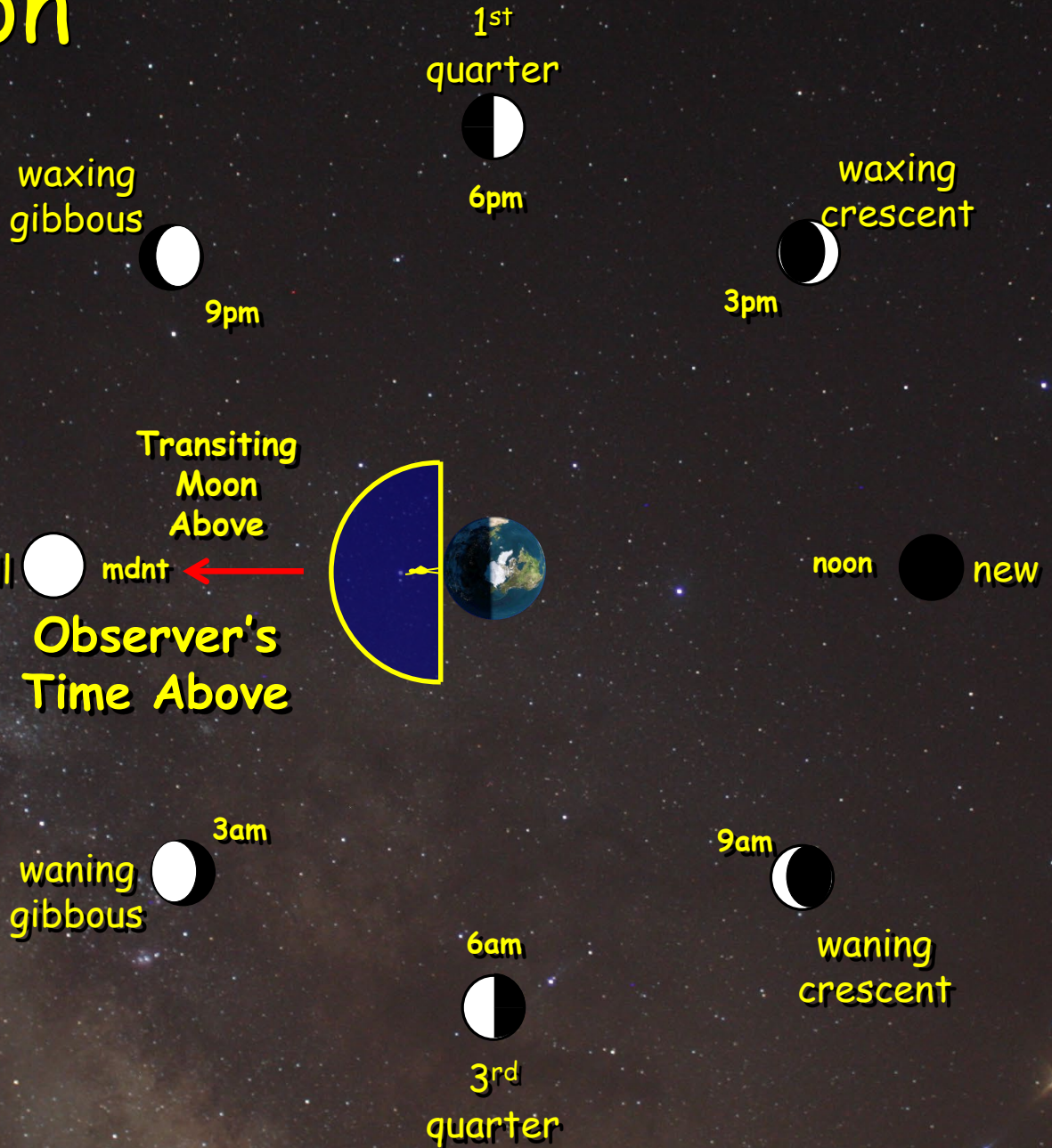


Complete the following table for the phases of the moon, assuming a 12-hour "moon day" (phases are not in order of occurrence). **THE PHASES ARE NOT IN ORDER!**

PHASE	ELONGATION	RISING TIME	TRANSIT TIME*	SETTING TIME
				Midnight
	~135° W		3 am	
New				
	~45° W			
		MIDNIGHT		
Waxing Gibbous				
				6 am
		9 am		

# Question

An observer sees  
the full moon  
transit.  
What time is it?

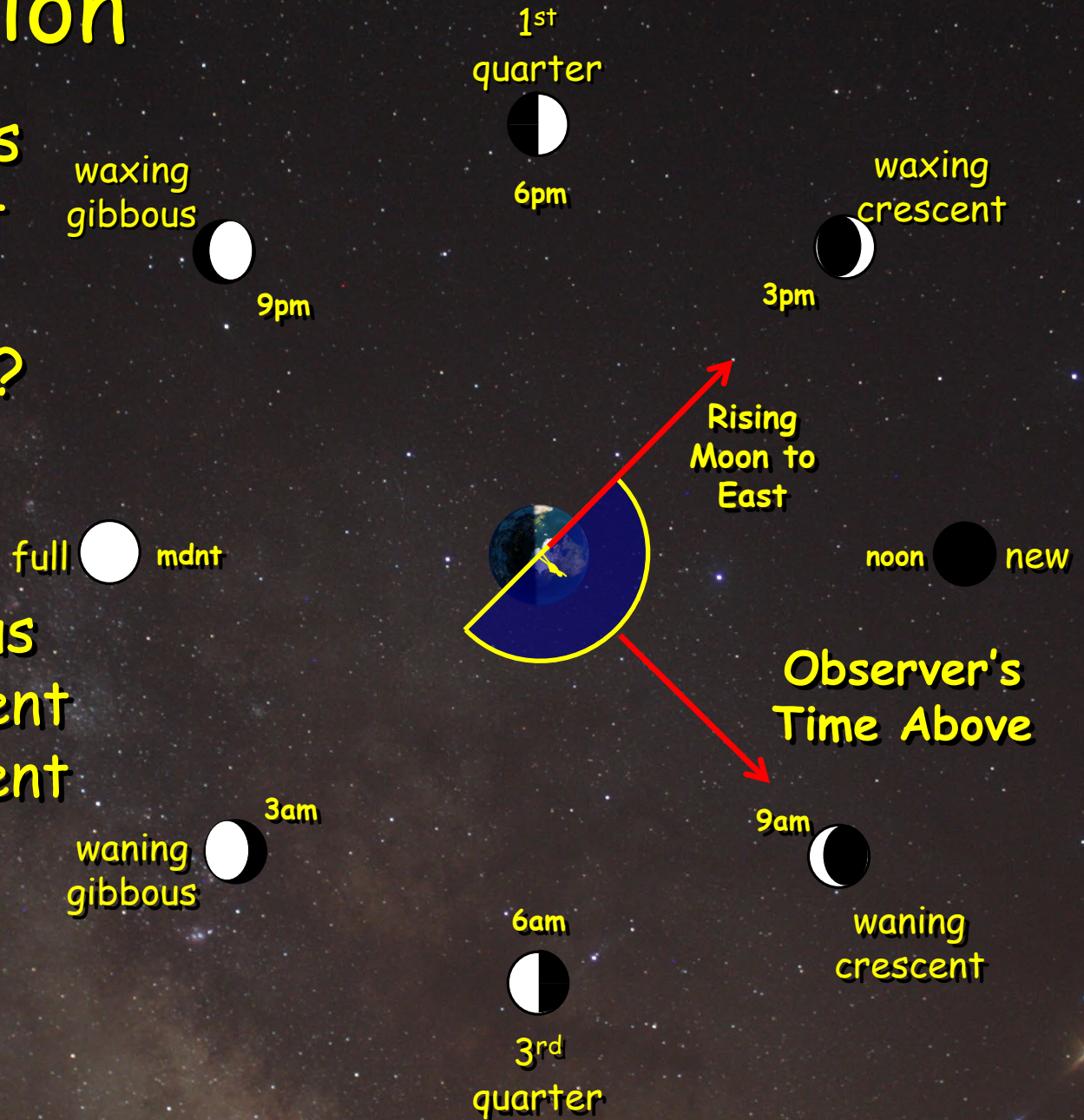


- a) 6 pm
- b) Midnight
- c) 6 am

# Question

An observer sees the moon rise at 9 am.  
What phase is it?

- a) Waning Gibbous
- b) Waning Crescent
- c) Waxing Crescent



# Question

An observer sees the moon set at 6 pm.  
What phase is it?

- a) New Moon
- b) First Quarter
- c) Full Moon

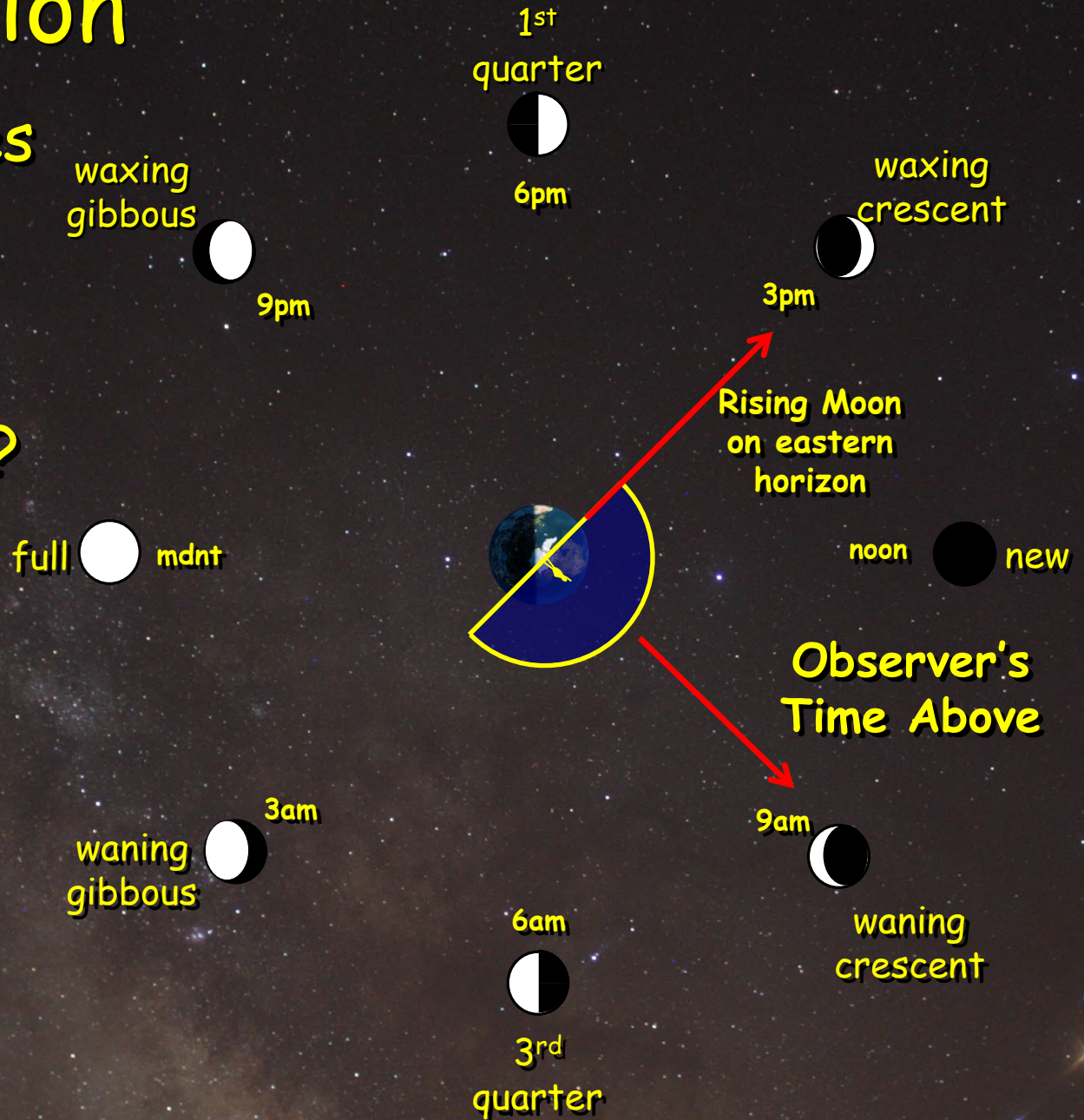


# Question

An observer sees  
the waxing  
crescent moon  
rise.

What time is it?

- a) 9am
- b) 3 pm
- c) 9 pm





# Harvest Moon 2022

☆ Some full moons are named

🌍 Harvest moon = full moon closest to equinox

› September 10, 5:59 am EDT

∩ Exact time of moon at elongation of  $90^\circ$  E

› Moon bright at rising for days

› Allowed farmers to work into the night

🌍 Hunter's moon = follows Harvest moon

› October 9, 4:54 pm EDT

∩ Exact time of moon at elongation of  $180^\circ$

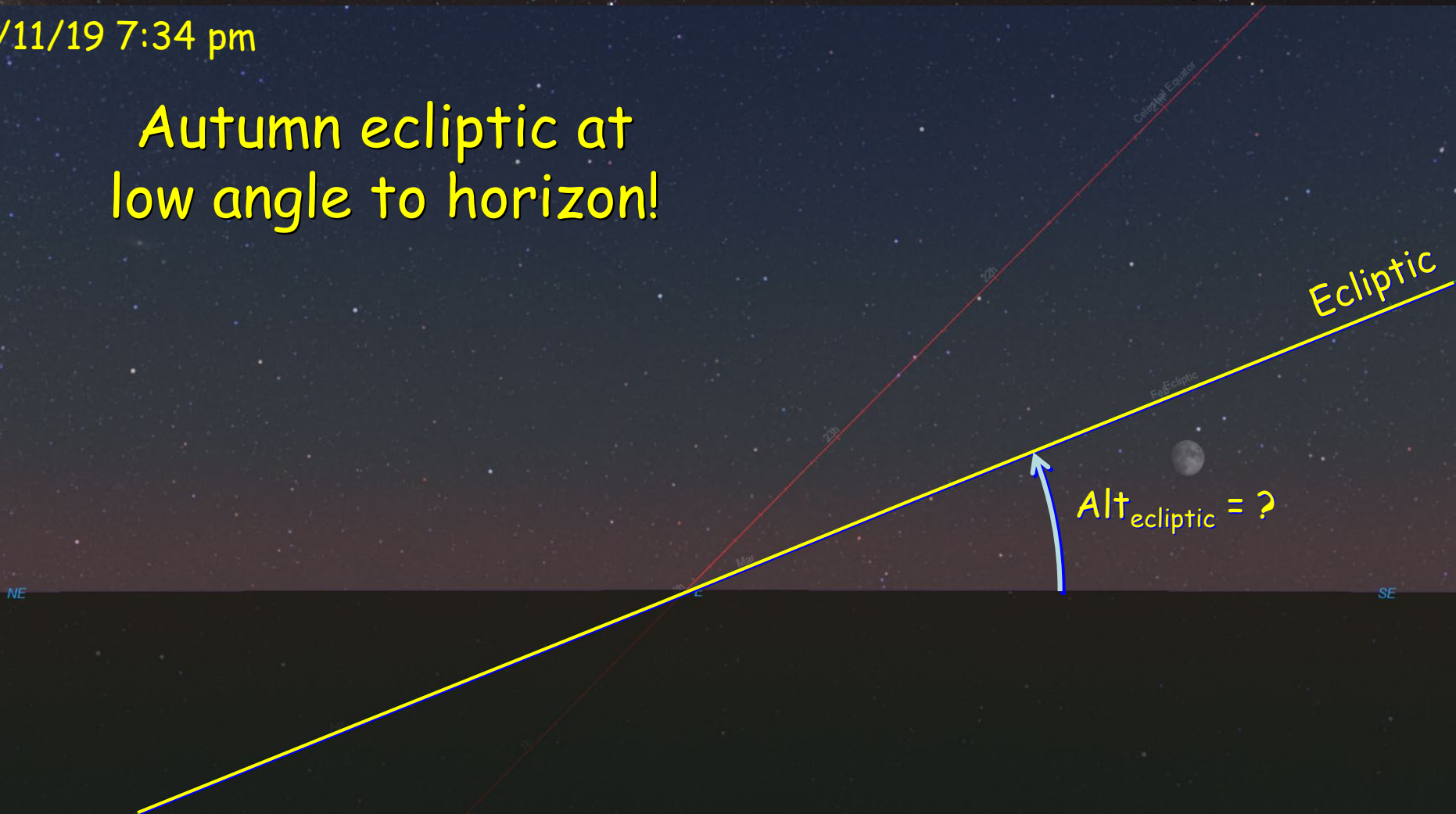
# Harvest Moon 2019

☆ Some full moons are named

🌍 harvest moon = full moon closest to equinox

9/11/19 7:34 pm

Autumn ecliptic at  
low angle to horizon!

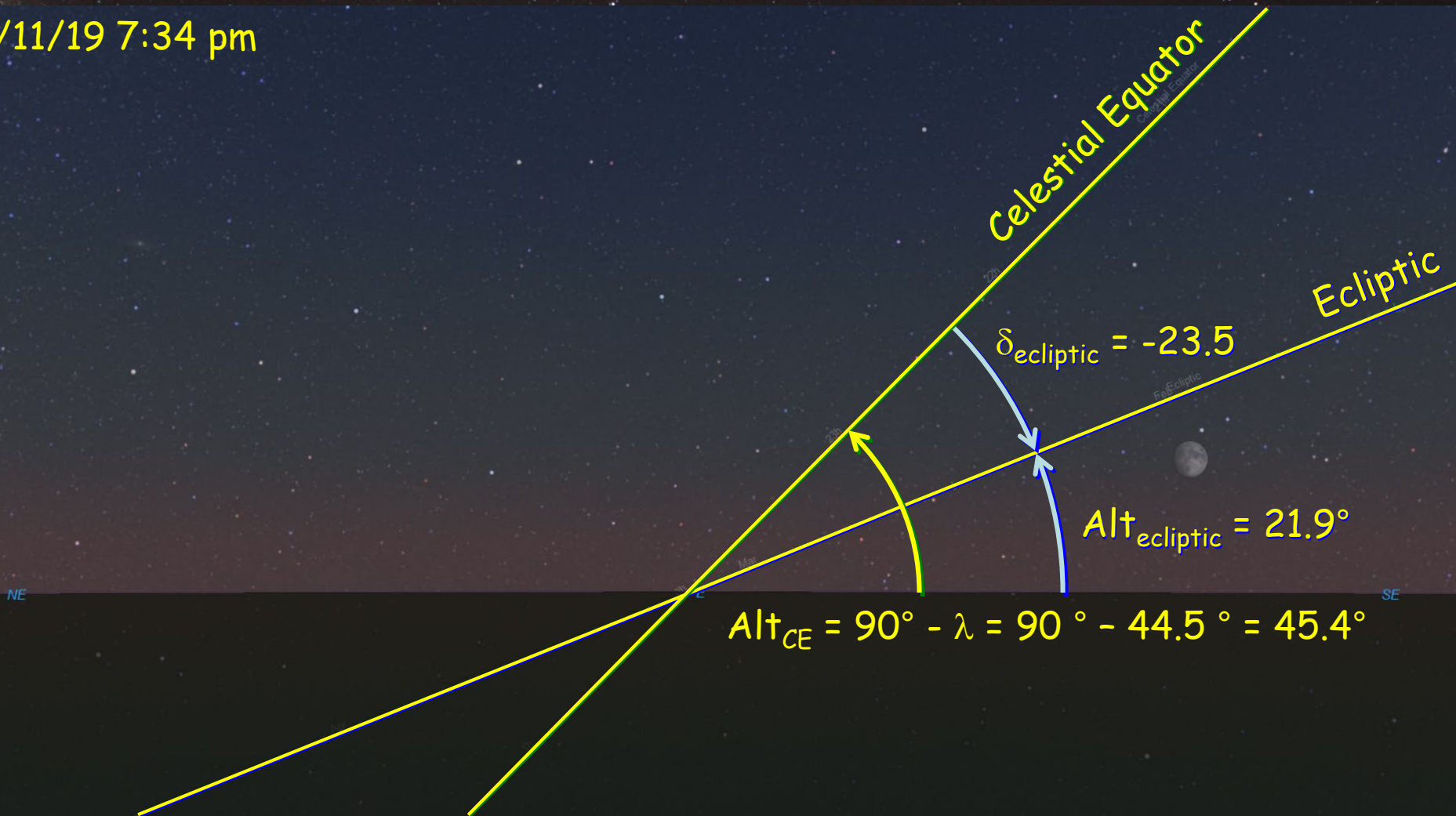


# Harvest Moon 2019

The altitude of the autumnal ecliptic is

$$\text{Alt}_{\text{Ecliptic}} = \text{Alt}_{\text{CE}} + \delta = (90^\circ - \lambda) + \delta = 45.4^\circ - 23.5^\circ = 21.9^\circ$$

9/11/19 7:34 pm



# Harvest Moon 2019

☆ Some full moons are named

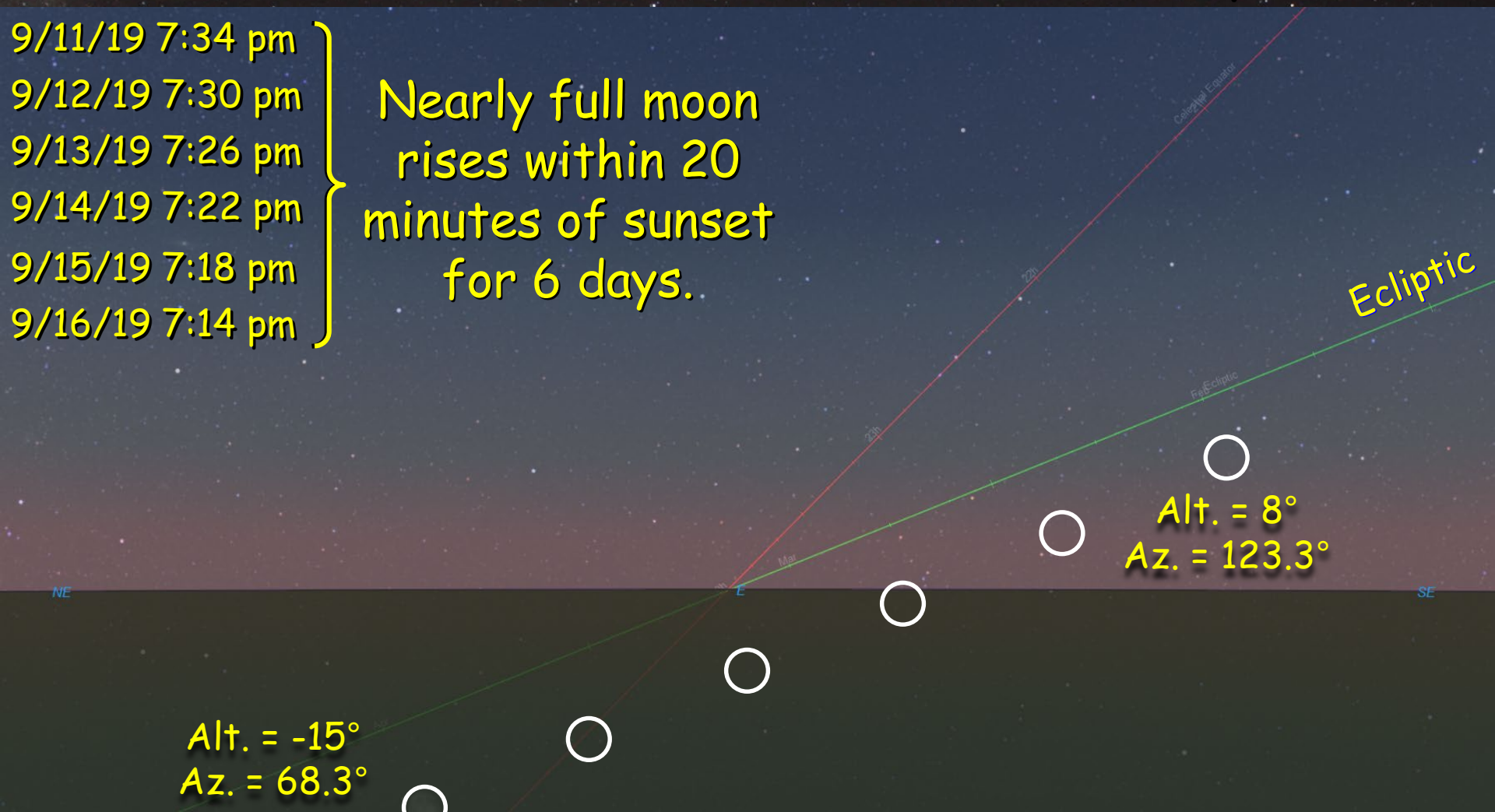
🌐 harvest moon = full moon closest to equinox

9/11/19 7:34 pm  
9/12/19 7:30 pm  
9/13/19 7:26 pm  
9/14/19 7:22 pm  
9/15/19 7:18 pm  
9/16/19 7:14 pm

Nearly full moon  
rises within 20  
minutes of sunset  
for 6 days.

Alt. =  $8^\circ$   
Az. =  $123.3^\circ$

Alt. =  $-15^\circ$   
Az. =  $68.3^\circ$

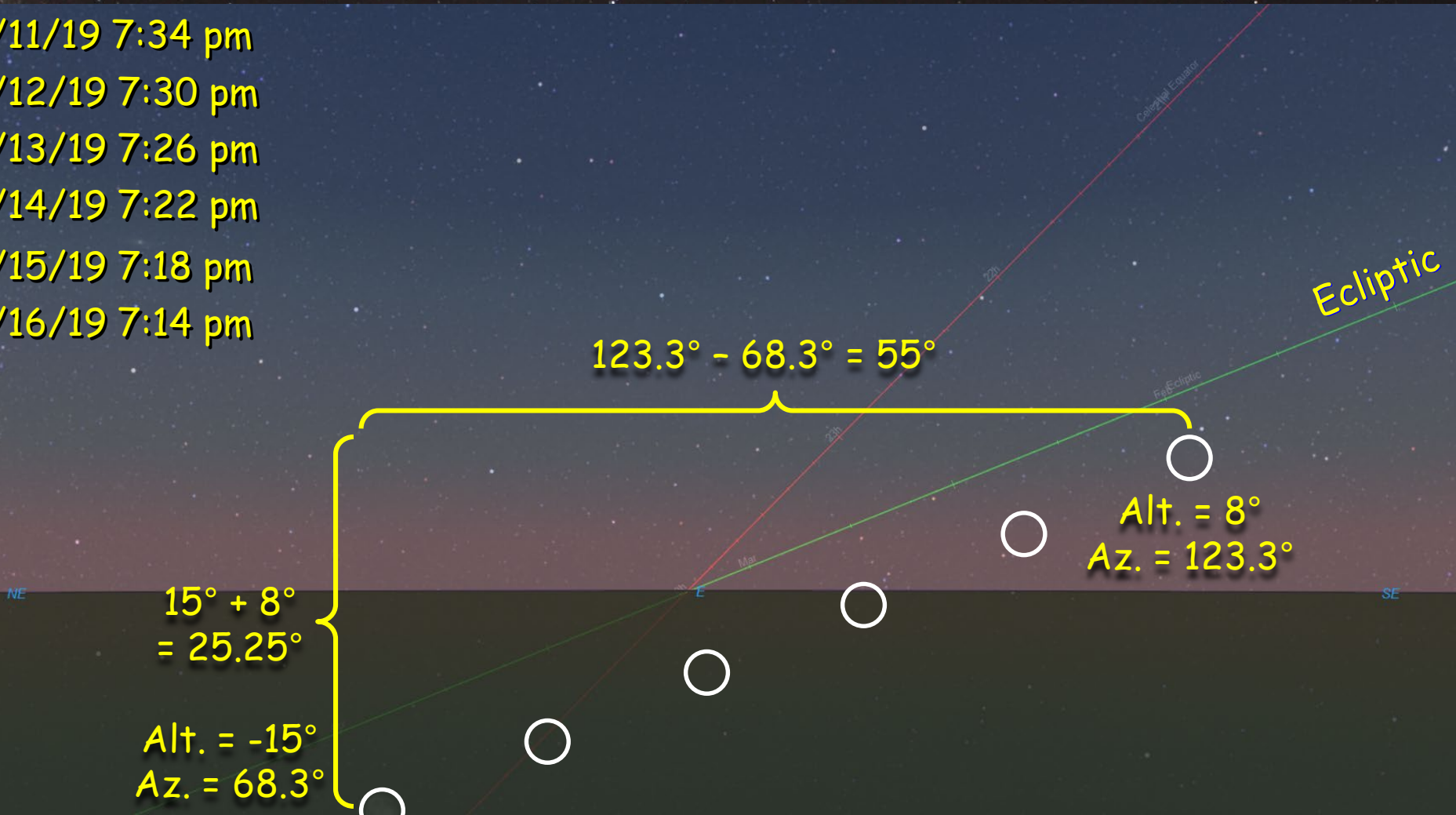


# Harvest Moon 2019

☆ Some full moons are named

🌐 harvest moon = full moon closest to equinox

- 9/11/19 7:34 pm
- 9/12/19 7:30 pm
- 9/13/19 7:26 pm
- 9/14/19 7:22 pm
- 9/15/19 7:18 pm
- 9/16/19 7:14 pm



# TRADUCCIONES CONTINUAS