SOAR
Lifelong Learning in the North Country

Potsdam
1816
THE STATE UNIVERSITY OF NEW YORK

SOAR: The Sky in Motion

The Analemma

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ST. LAWRENCE UNIVERSITY

The Tilted Teacup Ride

- ☆ Coordinates and the Day: 9/11/25
  - Celestial Navigation
- ☆ The Year: 9/18/25
  - Seasons and the Sun's motions
- ☆ The Month and Moon Phases: 9/25/25
  - The Harvest Moon
- ☆ The Day in All its Glory: 10/2/25
  - The Analemma and the Age of Aquarius

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Photo by Marc Staves 2011

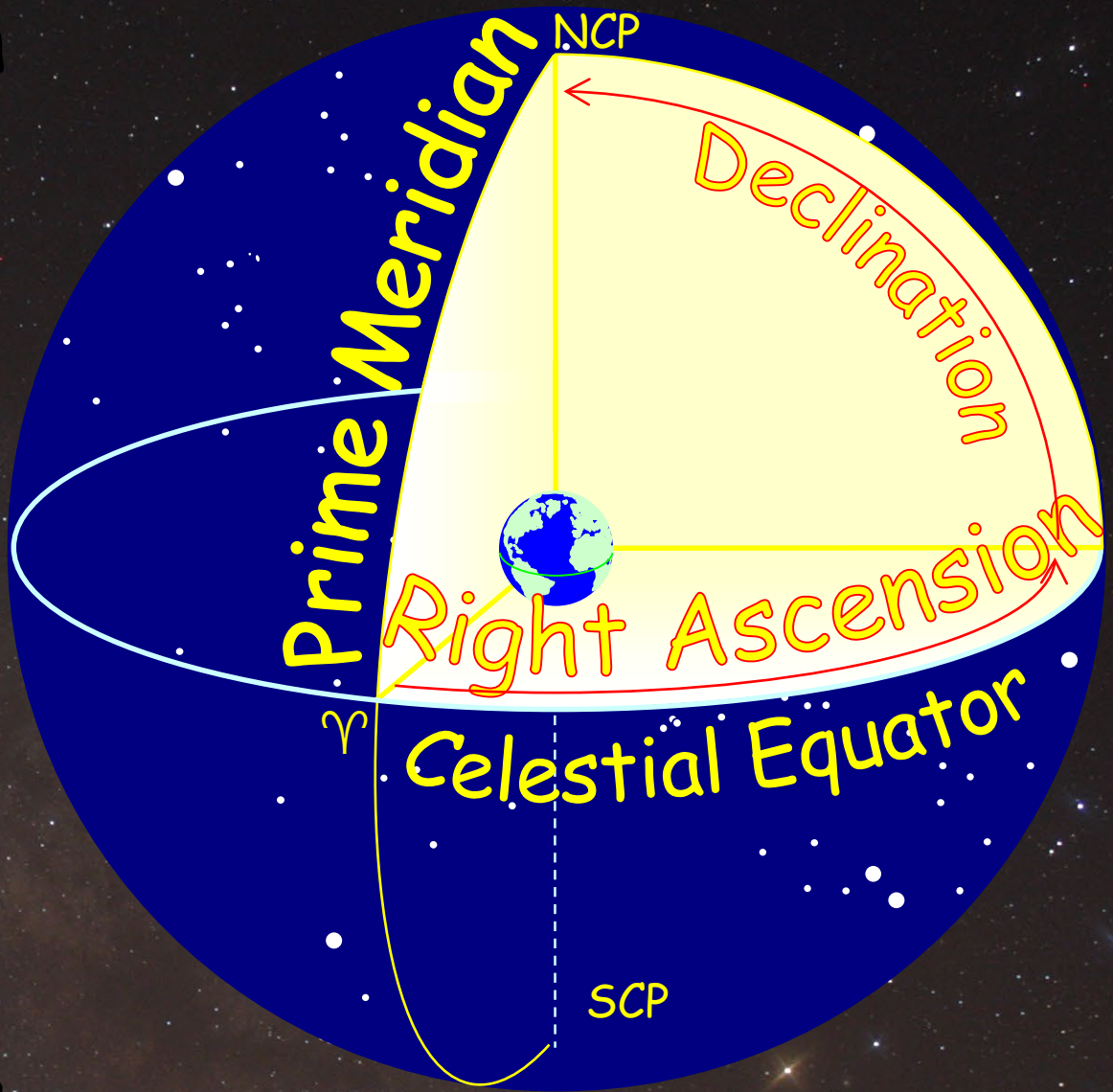
Celestial Coordinates

☆Right Ascension

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

☆Declination

- Dec or δ
- From celestial equator (0°) to poles N & S 90°



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

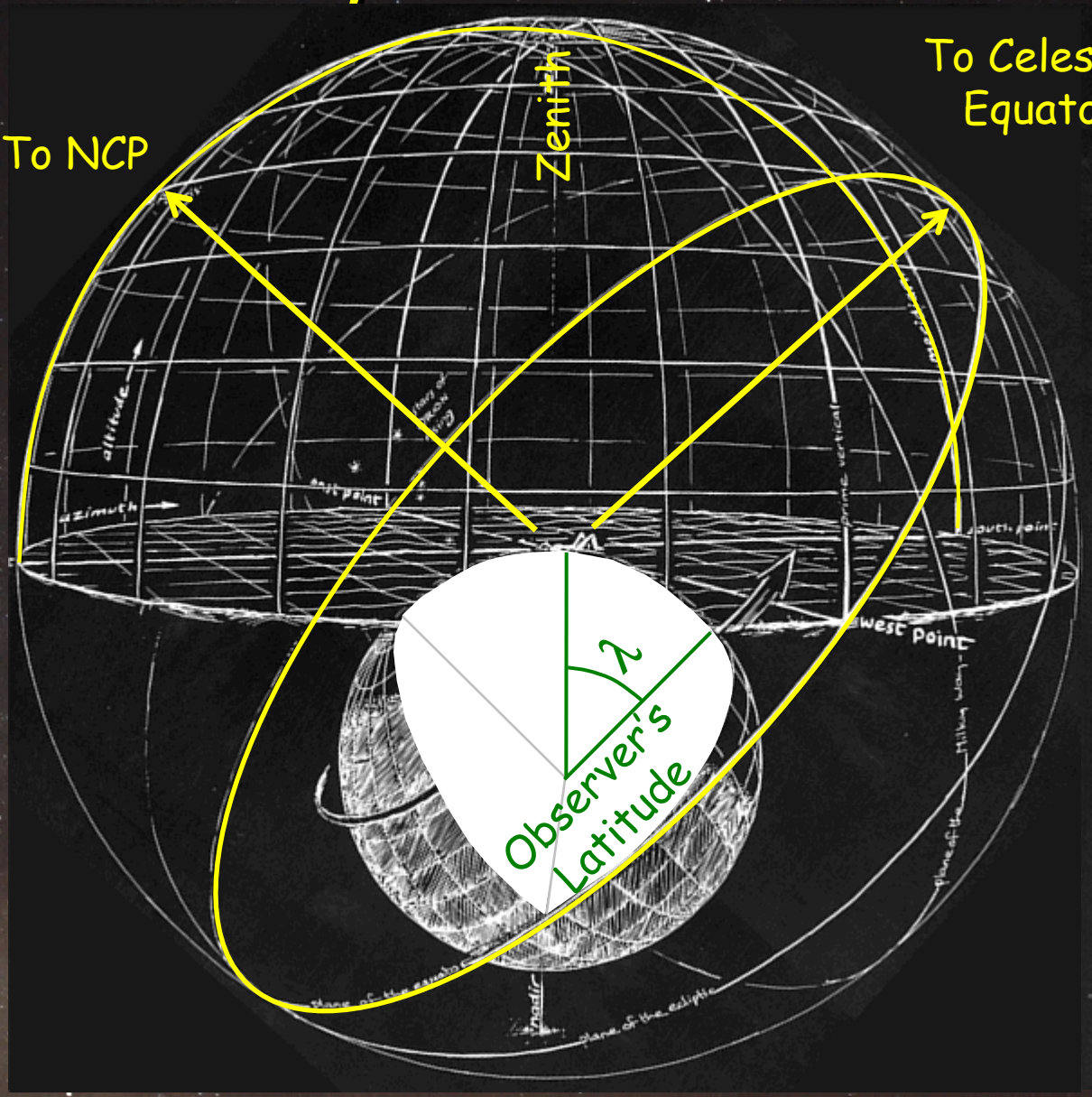


Photo by Marc Staves 2011

Standard Clock Time

☆ Every Longitude a[t] [a] different time

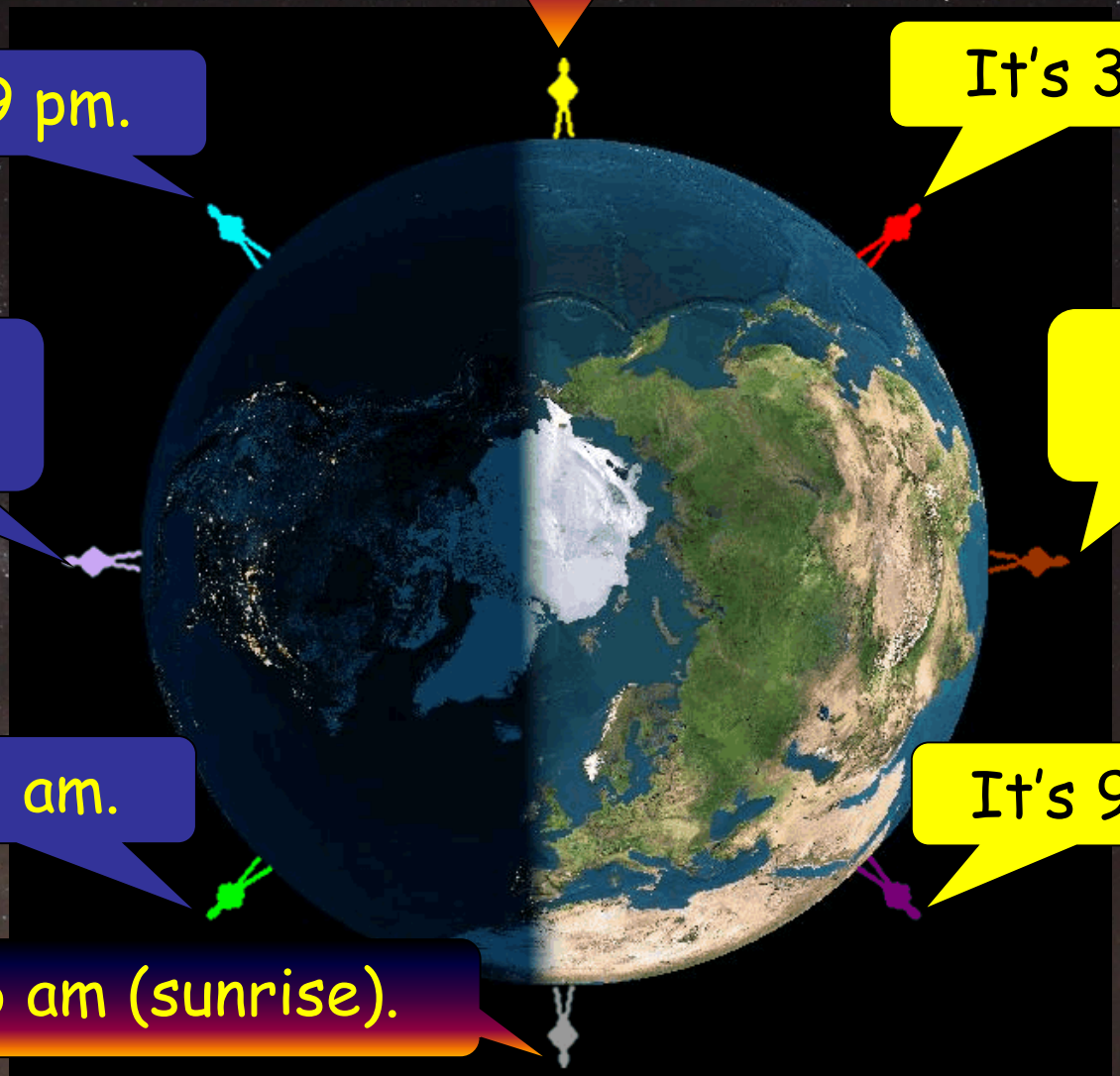
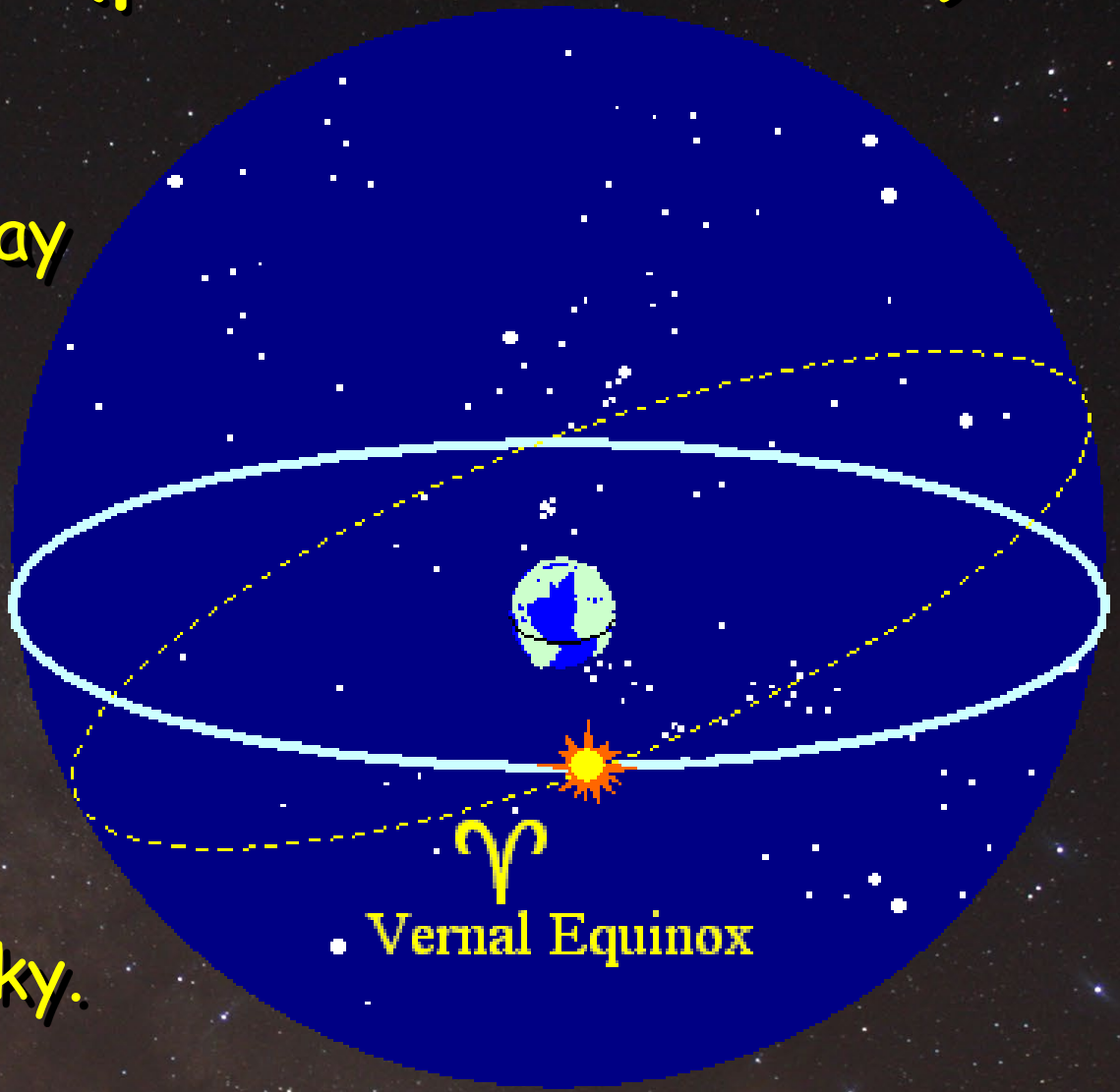


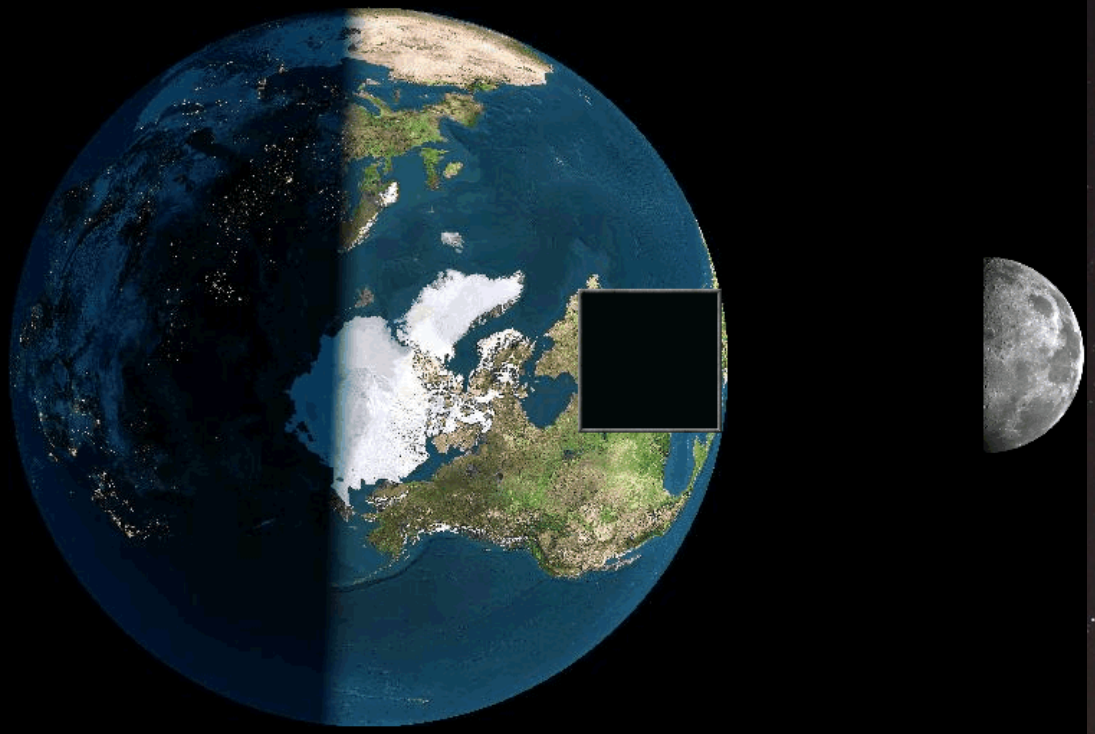
Photo by Marc Staves 2011

The Ecliptic (path of the sun)

- View from Earth
  - Sun moves ~1°/day eastward across stars
  - Sun moves north and south in declination
  - Solstices & Equinoxes are positions in the sky.



This motion is through the YEAR!



Moon Phase is lit moon visible

Insert is moon as see from Earth

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
- 1st Quarter: Oct. 2, 8:14 pm EDT
- Full Moon: Oct. 9, 4:54 pm EDT
  - ☽ The Hunter's Moon!!

Waxing: Light on the right!

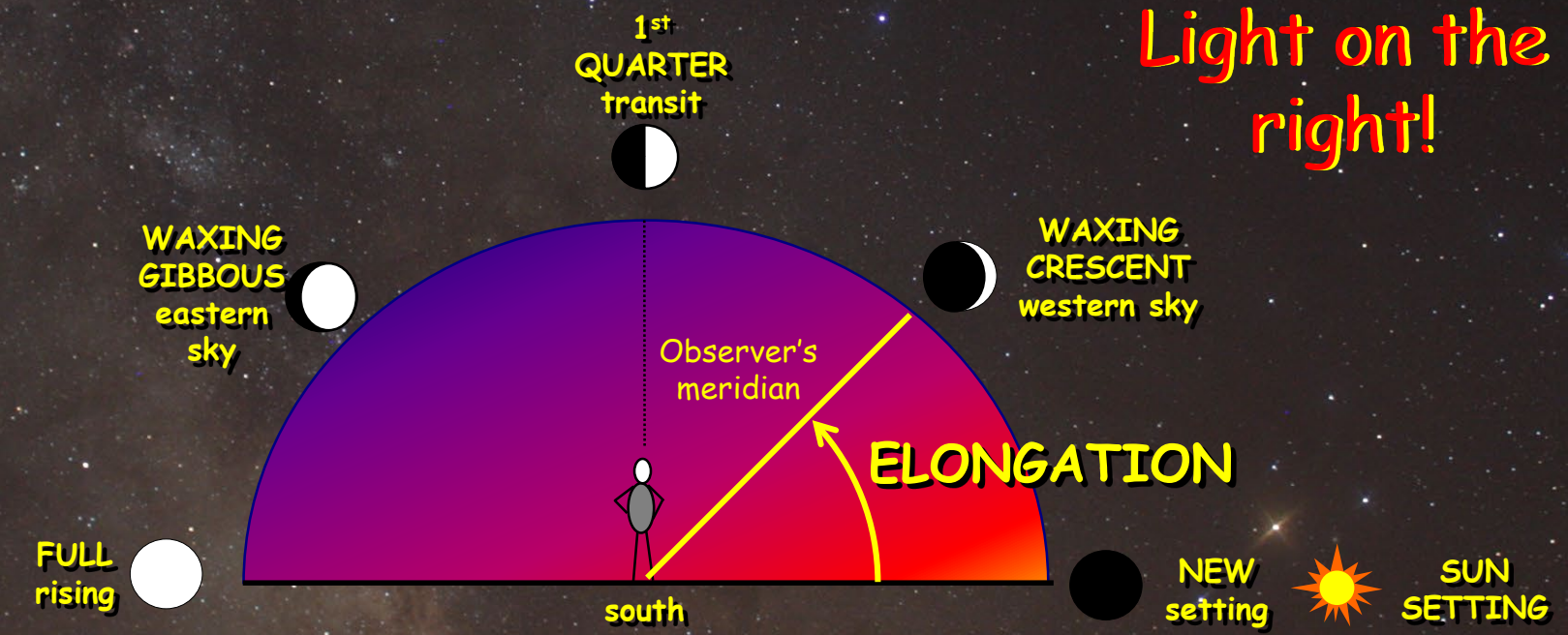


Photo by Marc Staves 2011

Waning Moon Phases

- ☆ Lunation Number 1234
  - ☆ Full Moon: Oct. 9, 4:54 pm EDT
  - ☆ 3rd Quarter: Oct. 17, 1:15 pm EDT
  - ☆ New Moon: Oct. 25, 6:48 am EDT

Waning:
Light on the left!

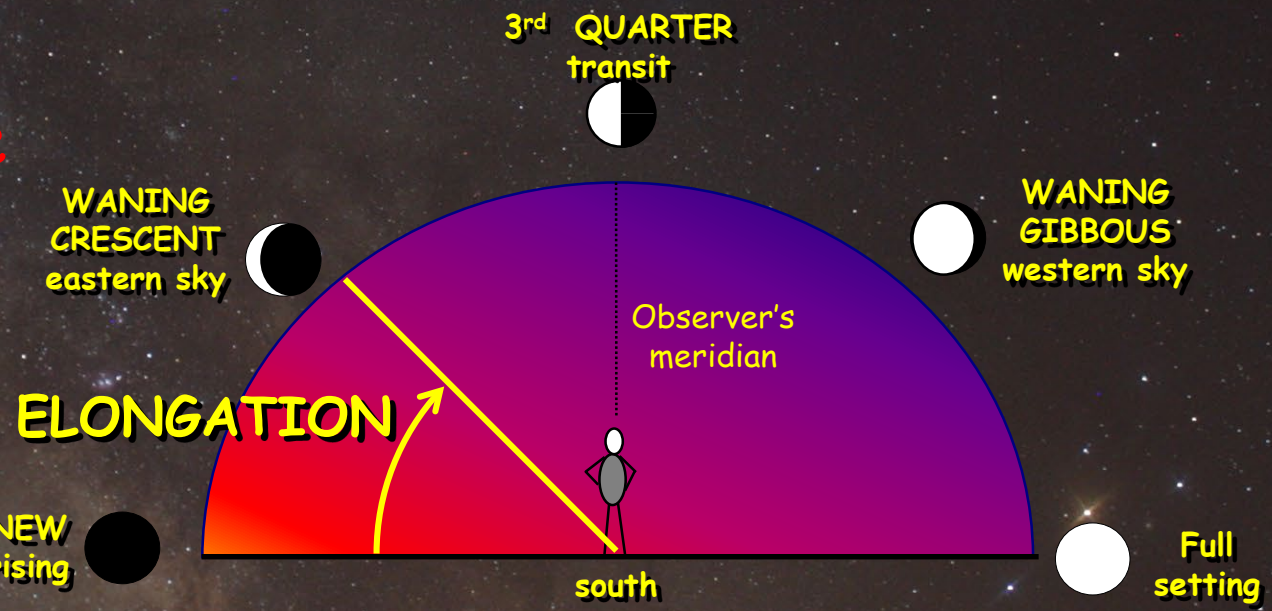


Photo by Marc Staves 2011

Fun with Time & Phase

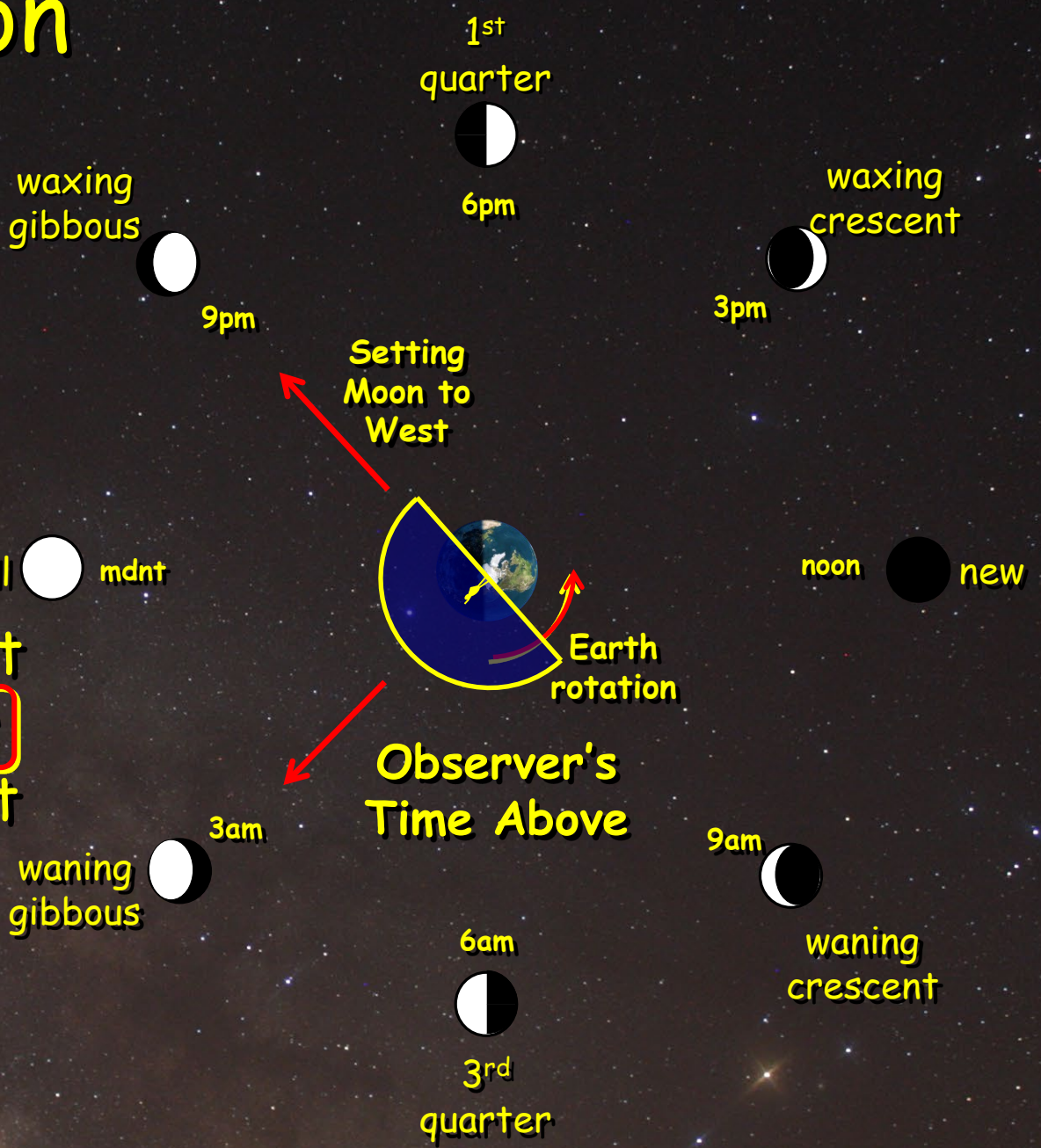
Determine rising, transit and setting times of each phase

Time is the one above the observer's head!

Question

An observer sees the moon set at 3 am.
What phase is it?

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



Time

- ☆ Clock Time
  - the position of the mean sun at TZ center
    - e.g. 12 pm = transit of mean sun (avg. of analemma)
  - Mean Solar Day = 24:00:00 (hours:min:sec of time)
- ☆ Solar Time
  - the position of the sun with respect to the observer
    - e.g. Noon = sun transits
  - Solar Day varies as shown by analemma
- ☆ Sidereal Time
  - the position of ♈ with respect to the observer
    - e.g. 0^h Local Sidereal Time (LST) = ♈ transits in Pisces
    - Sidereal time = R.A. on the meridian
  - Sidereal Day = 23:56:00

The Sidereal Day

Sidereal Day: 360° rotation puts star back on meridian

Photo by Marc Staves 2011

The Solar Day

Solar Day: 361° rotation puts sun back on meridian

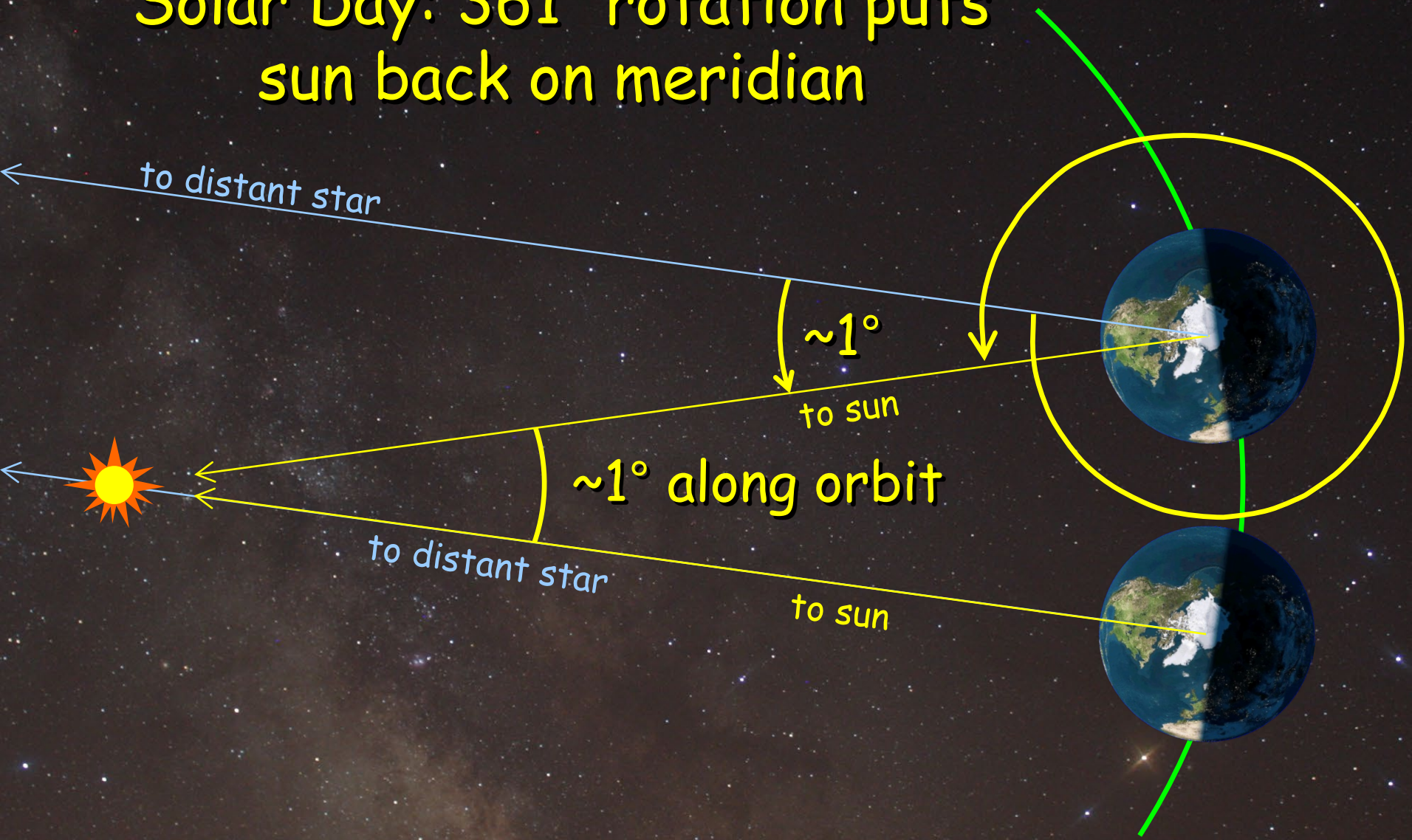


Photo by Marc Staves 2011

The Analemma

☆ Position of true sun at clock noon

- Clock Noon
  - 12:00 pm in a 24:00:00 day
  - Position of Mean Sun at noon
- True Sun's Position
  - varies due to Sun's speed along path
    - ♈ varies due to elliptical path
    - ♈ varies due to tilted path

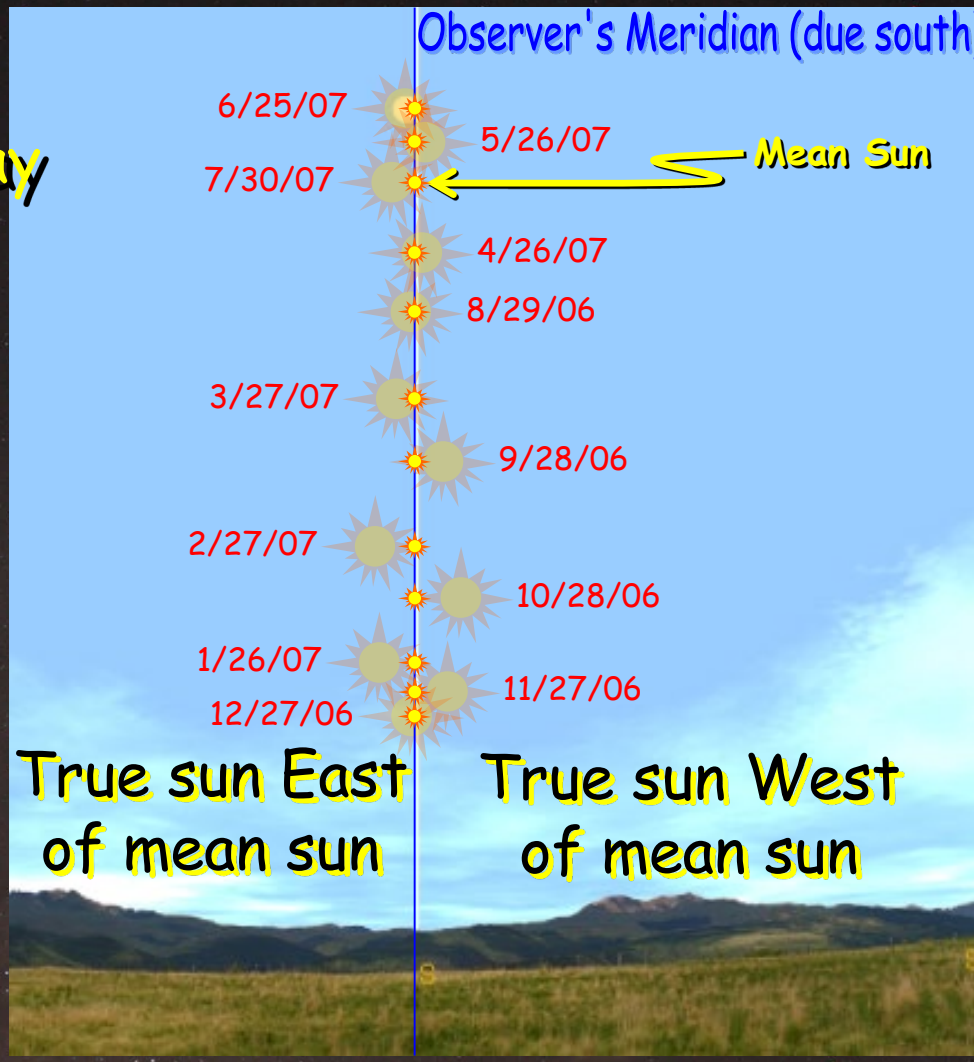


Photo by Marc Staves 2011

Mean Sun & True Sun

- ☆ Mean sun on meridian defines clock noon
- ☆ True sun on meridian defines solar noon

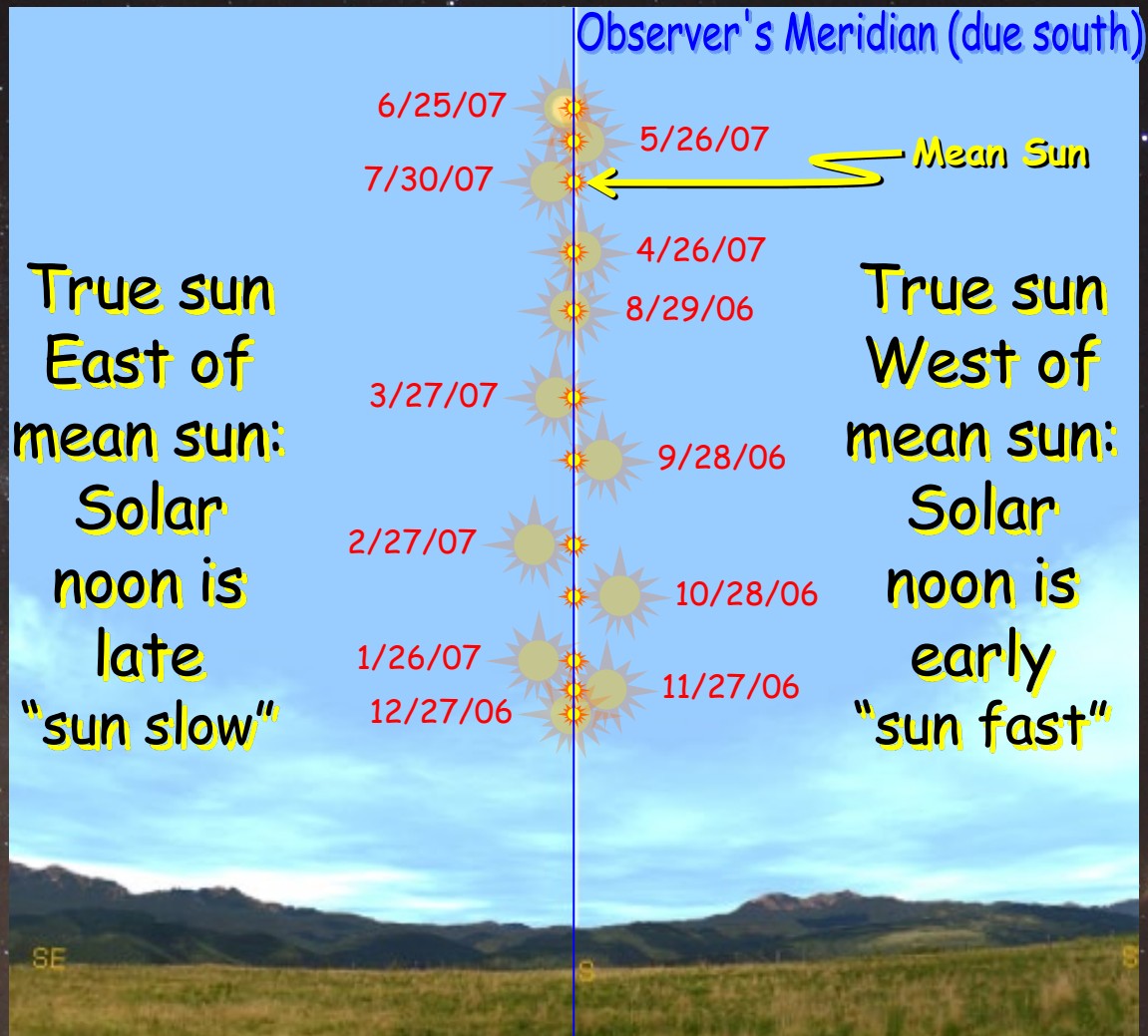


Photo by Marc Staves 2011

Doing the Math

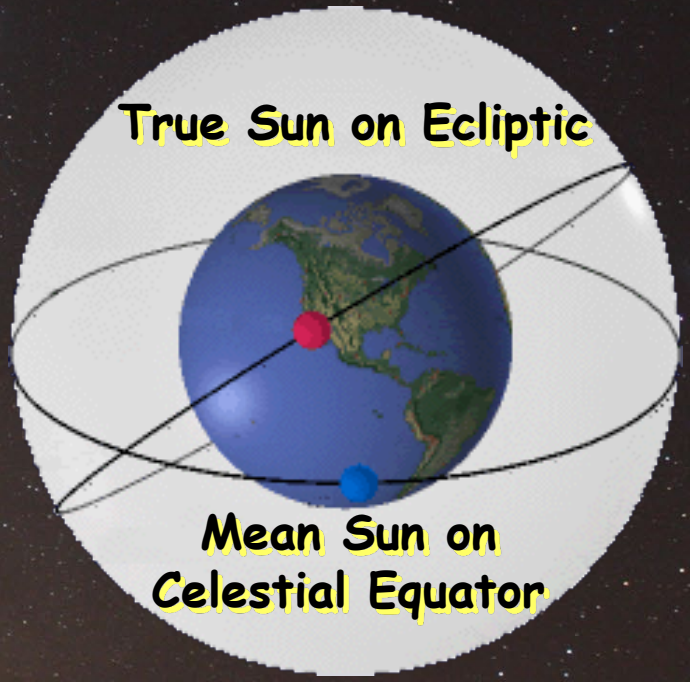
☆ Mean Sun

- Projection of sun onto Celestial Equator
  - moves 360° in one year (365.242191 days)

$$v_{\text{Mean Sun}} = \frac{360^\circ}{365.242191\ \text{days}} = 0.985647356\ ^\circ/\text{day}$$

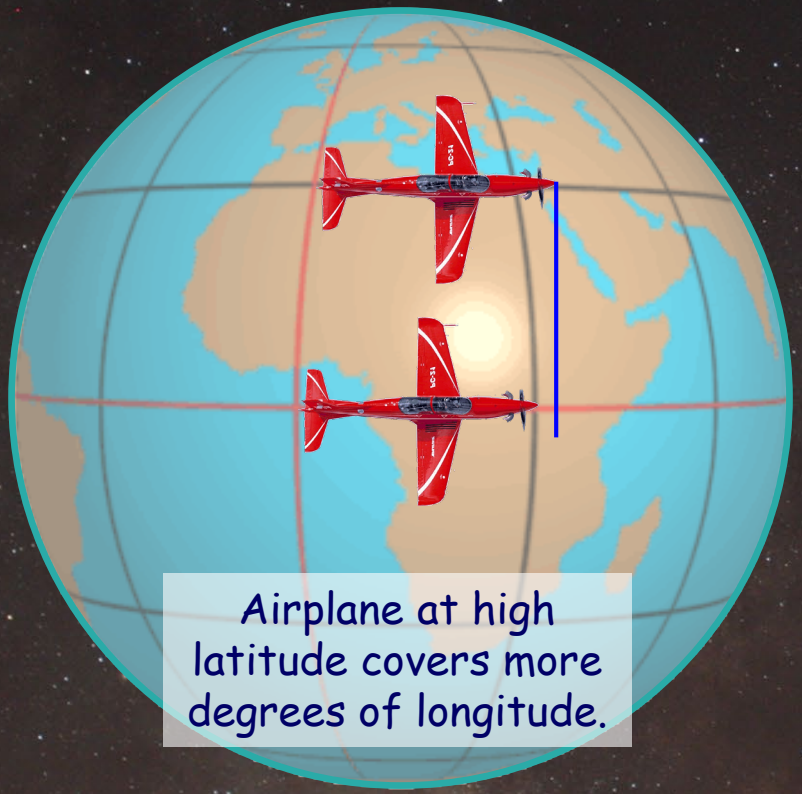
☆ True Sun

- speed varies due to
  - Sun's changing Declination
  - Elliptical orbit

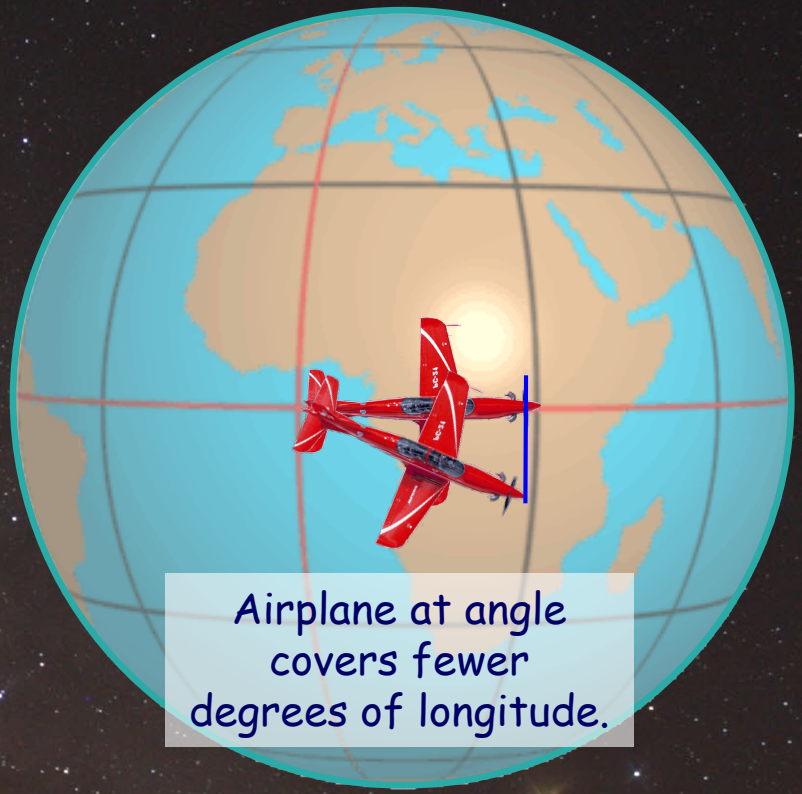


Speed Variation Due to Tilt

- Analogy: Airplanes on Earth
  - Both fly at same speed (mph)



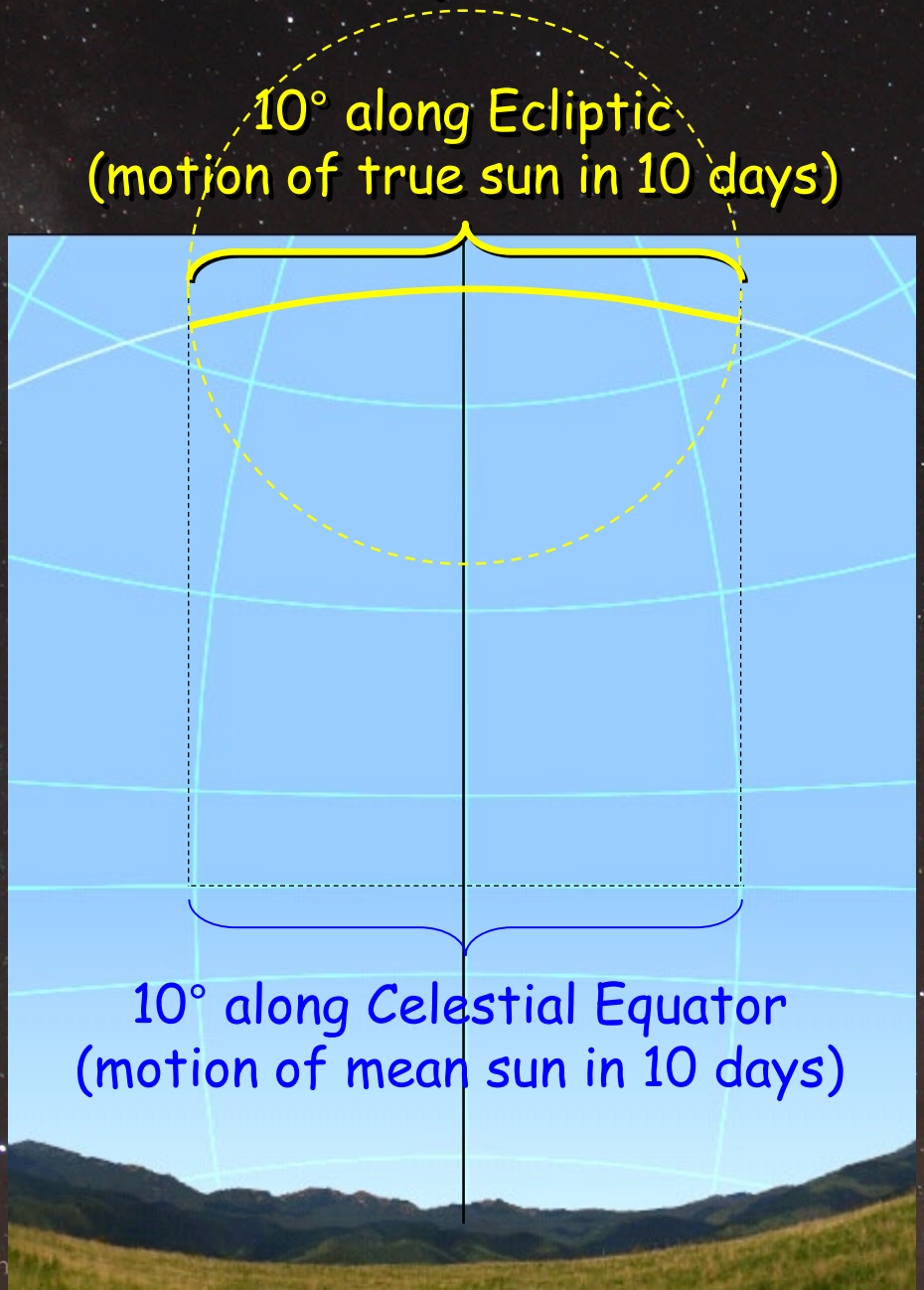
Airplane at high latitude covers more degrees of longitude.

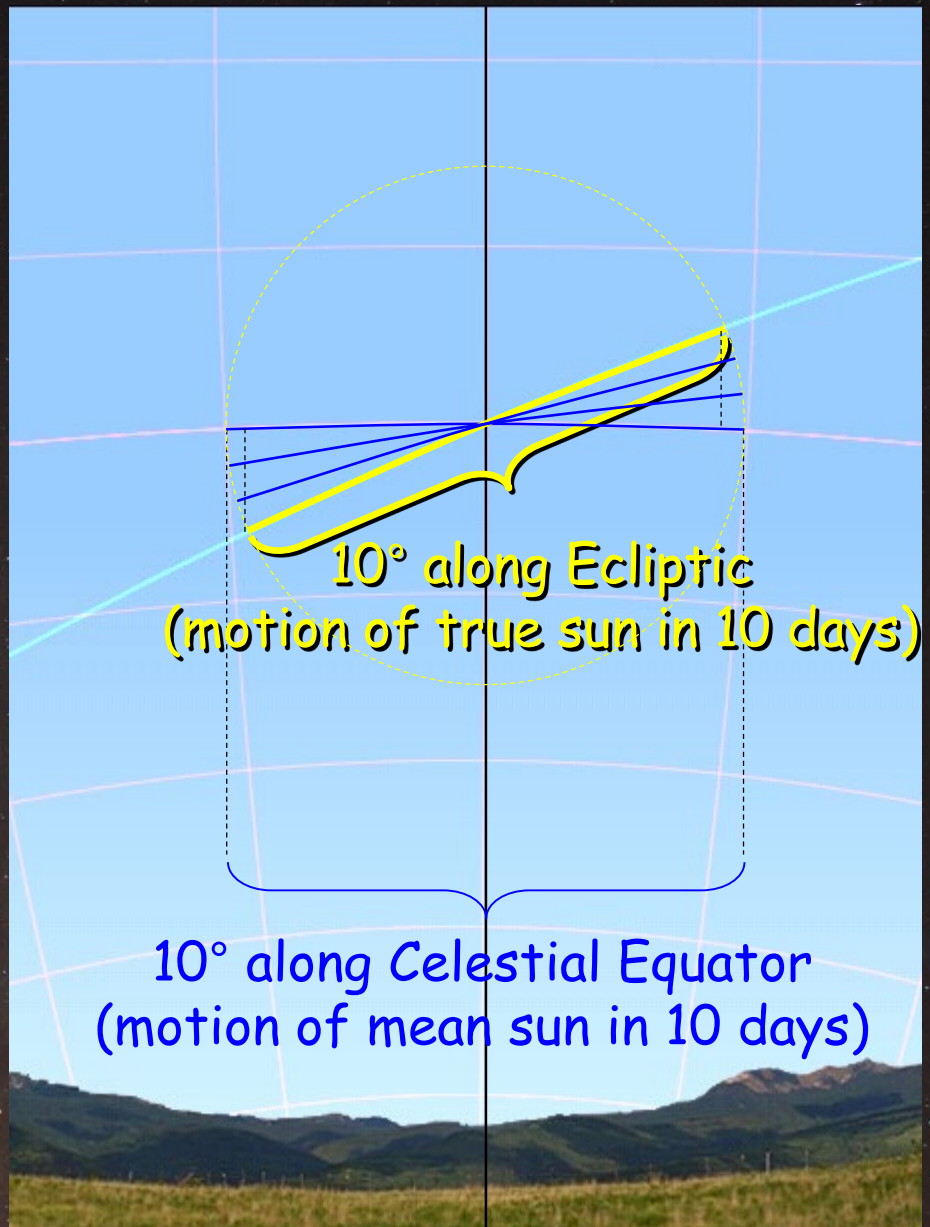


Airplane at angle covers fewer degrees of longitude.

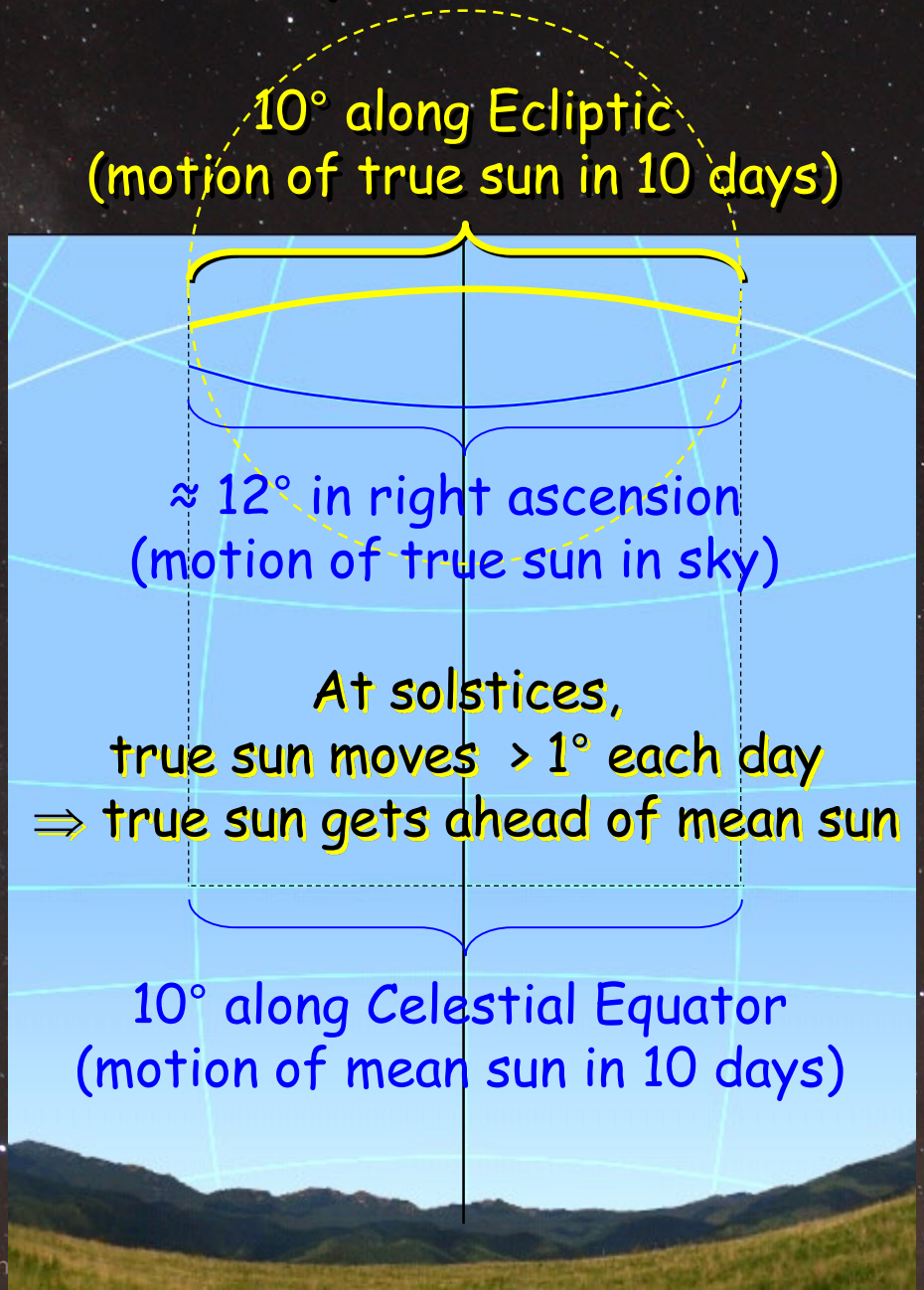
Photo by Marc Staves 2011

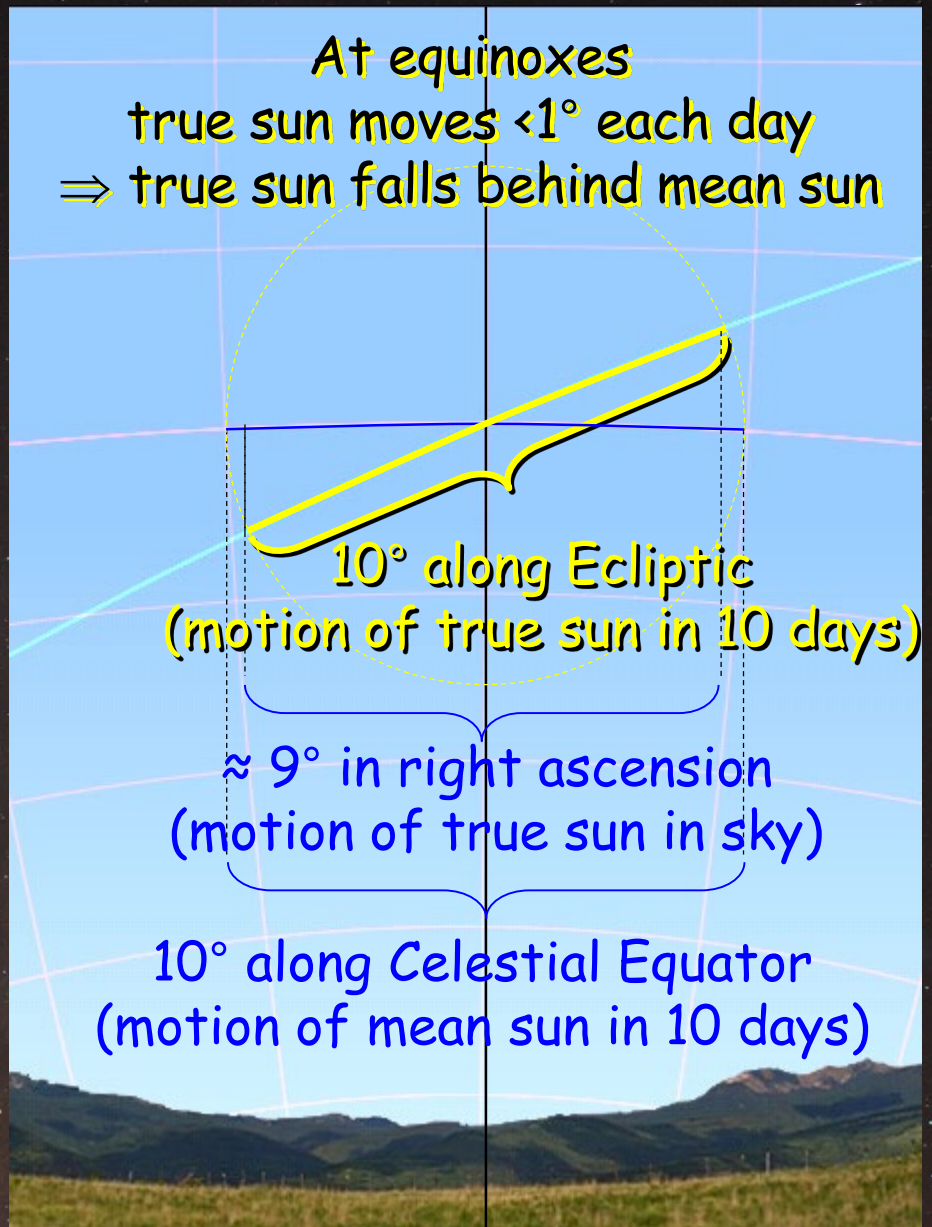
Sun Speed Variation Due to Tilt





Speed Variation Due to Tilt





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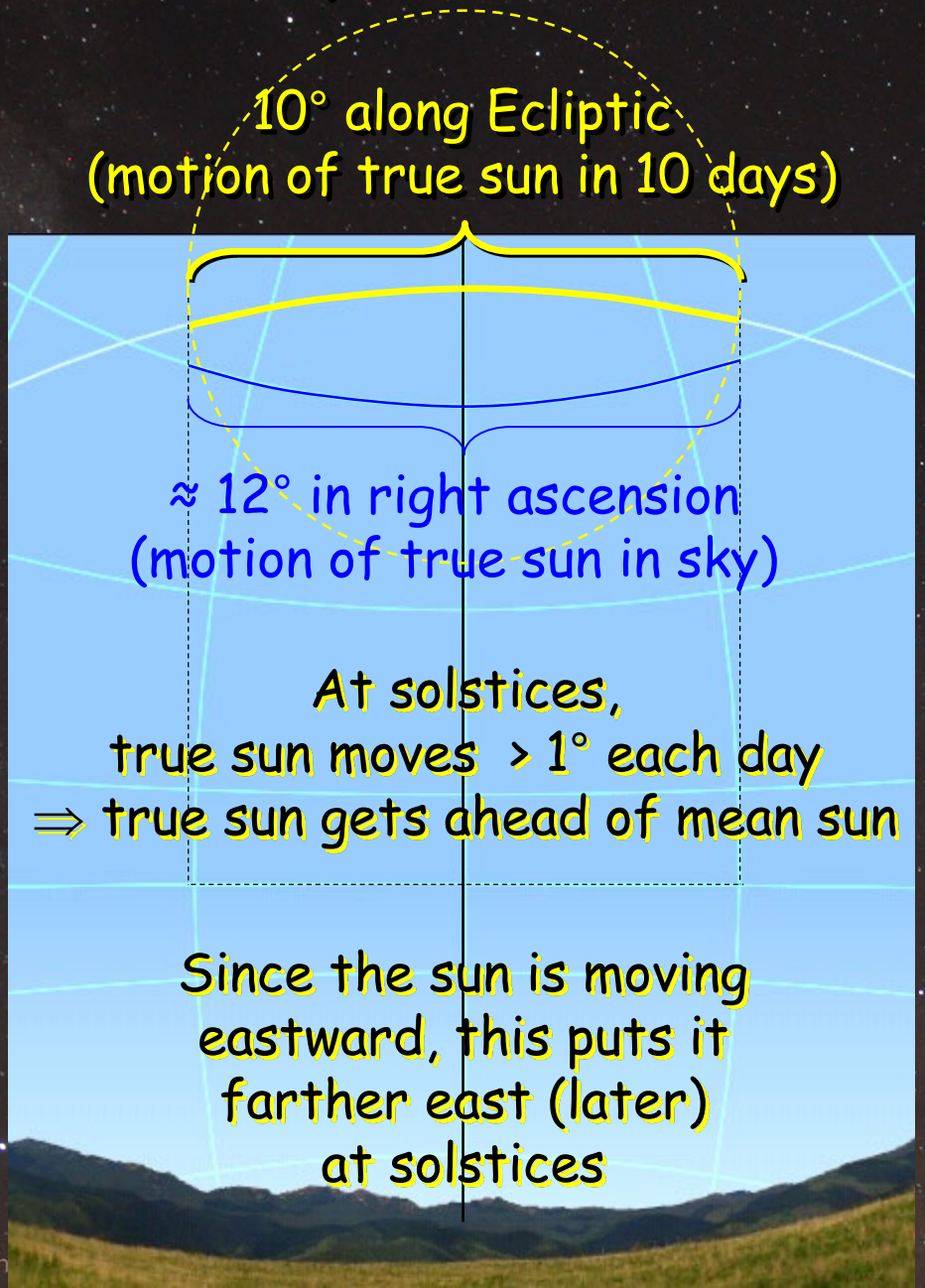
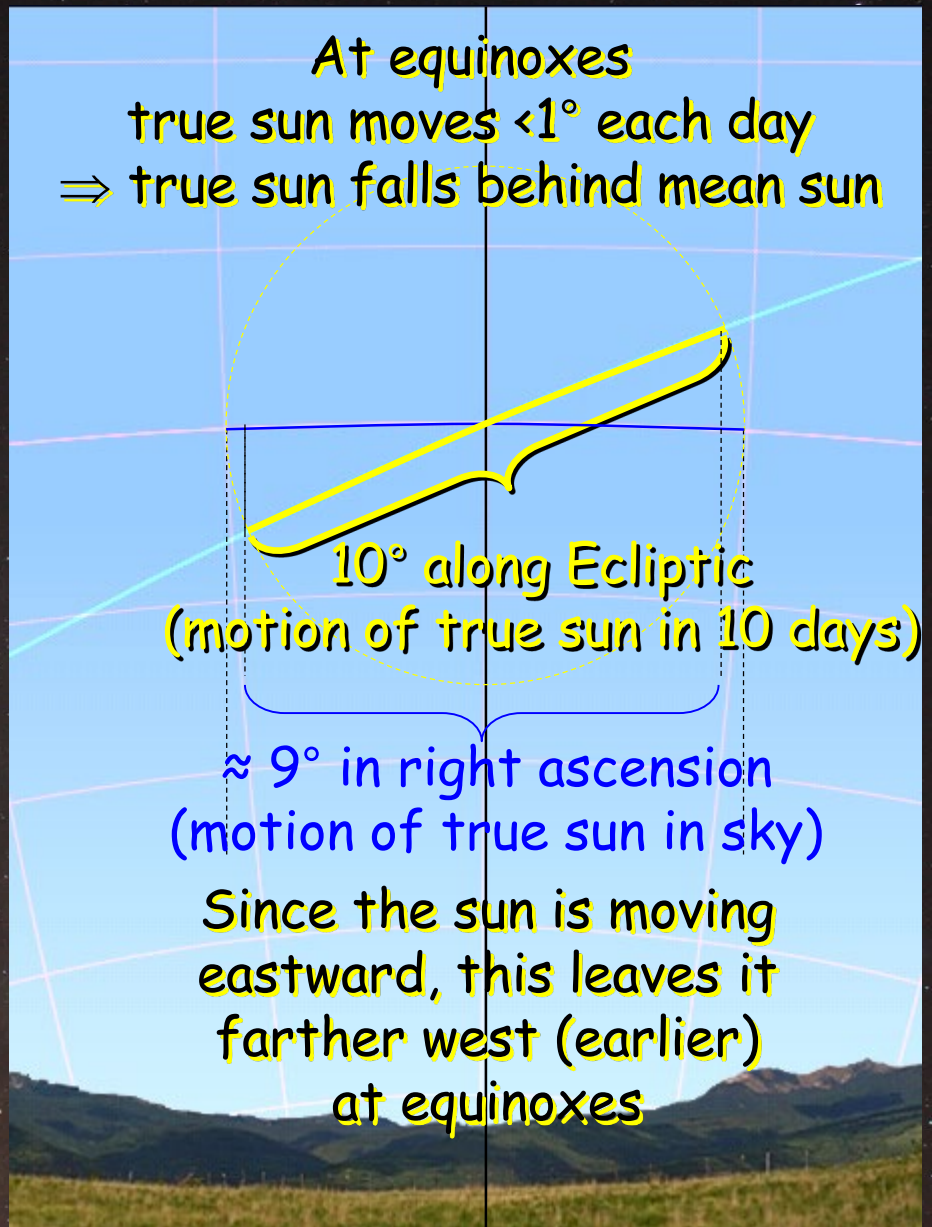


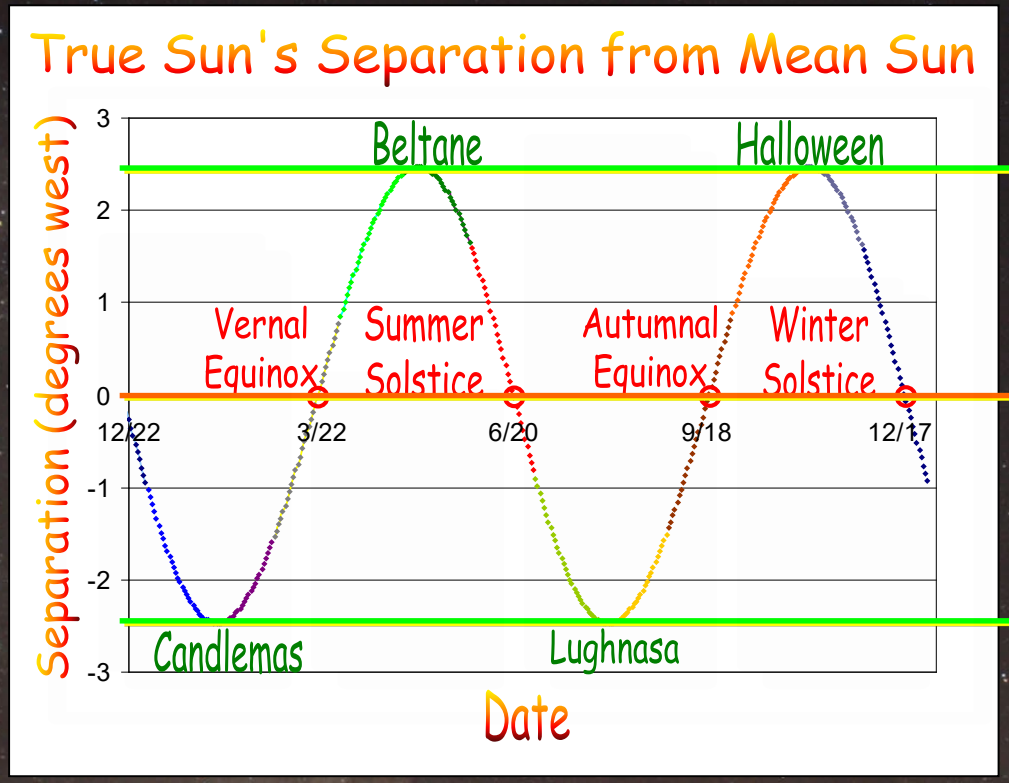


True Sun Speed Variation

- ☆ Solstices
  - True sun and mean sun aligned, but …
  - True sun getting ahead of mean at maximum rate
- ☆ Equinoxes
  - True sun and mean sun aligned, but
  - True sun getting behind mean at maximum rate
- ☆ Cross-Quarter Days
  - Between solstices & equinoxes
  - True sun farthest from mean
  - Switching between getting ahead & behind

Speed Variation Due to Tilt

- ☆ Solstices & Equinoxes (June & December)
  - mean and true sun align, fastest rate of change
  - Solstices: moving east, Equinoxes: moving west



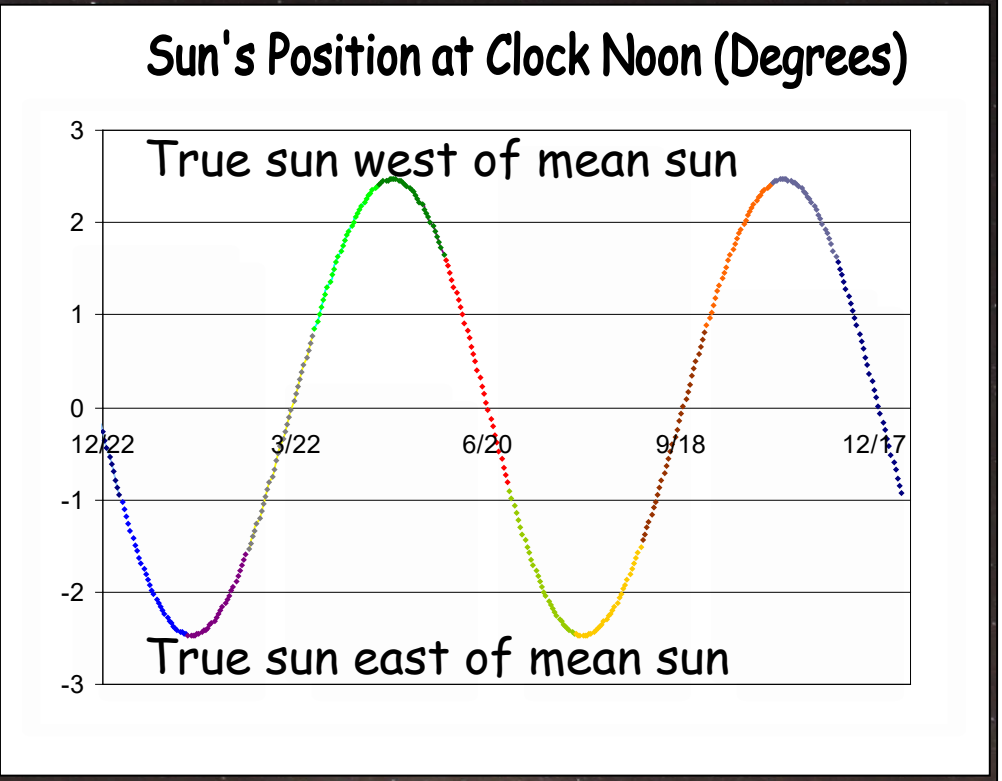
True sun farthest west (noon early)

Mean sun & true sun aligned

True sun farthest east (noon late)

Tilt Analemma

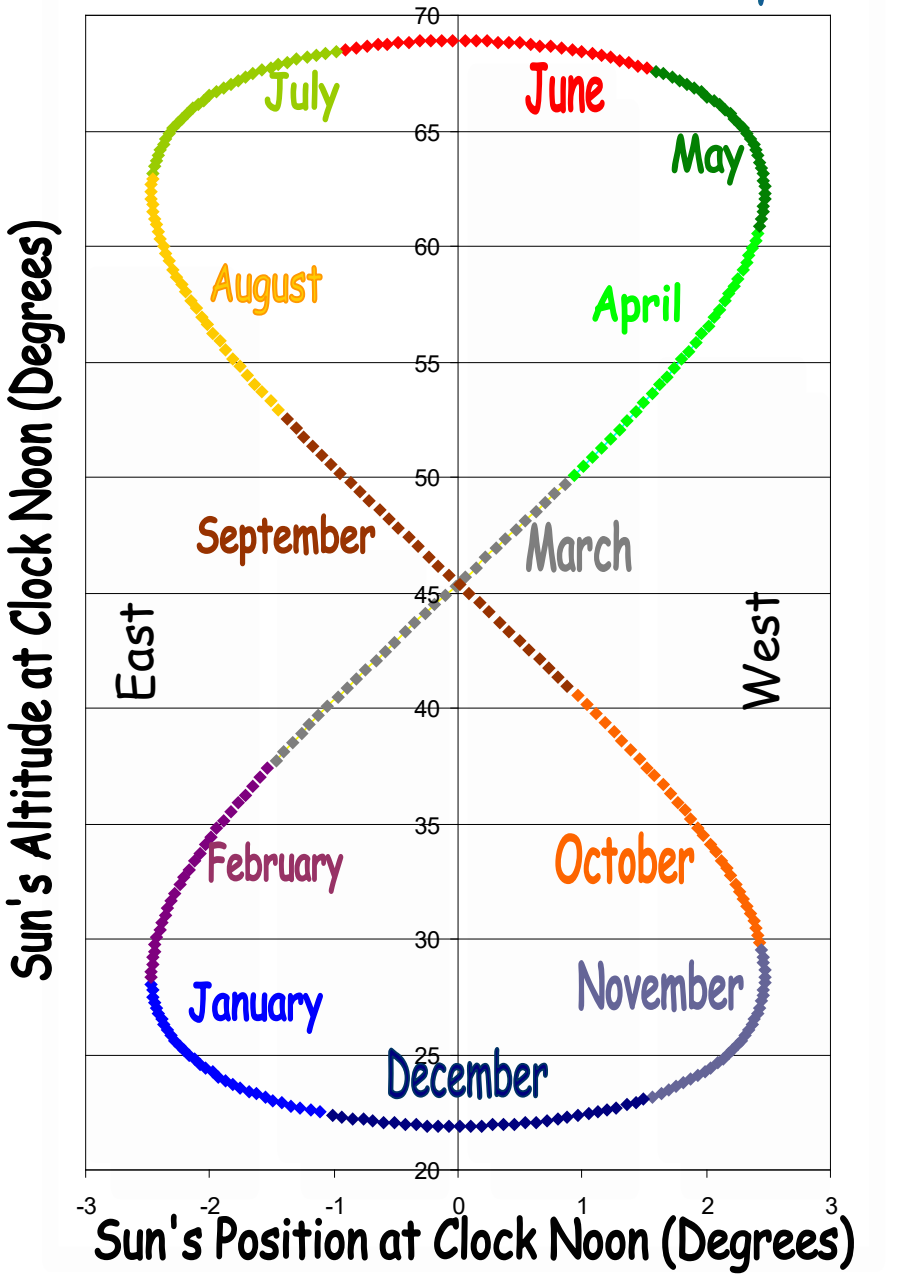
Position of true sun through the year for Earth in a circular orbit.



But there's more to it …

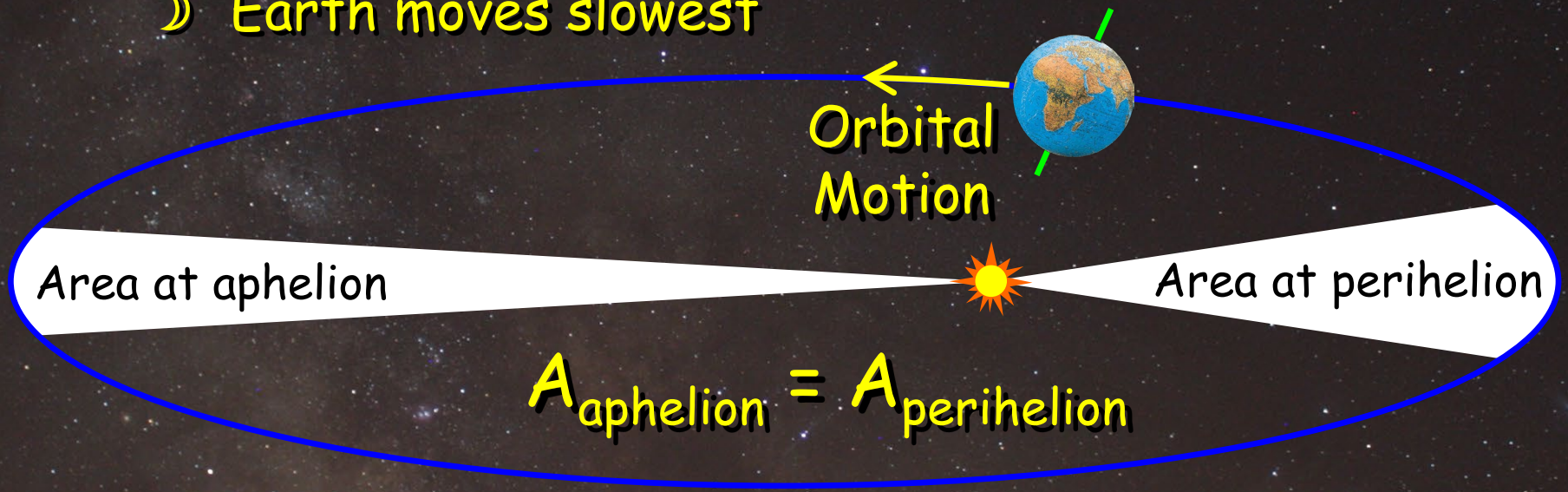
Photo by Marc Staves 2011

Tilt Analemma: Potsdam, NY



Earth's Orbit

- Earth's speed varies in orbit
  - area swept out in a given time stays equal
  - perihelion (~ January 4)
    - Earth moves fastest (February is shortest month!)
  - aphelion (~ July 4)
    - Earth moves slowest

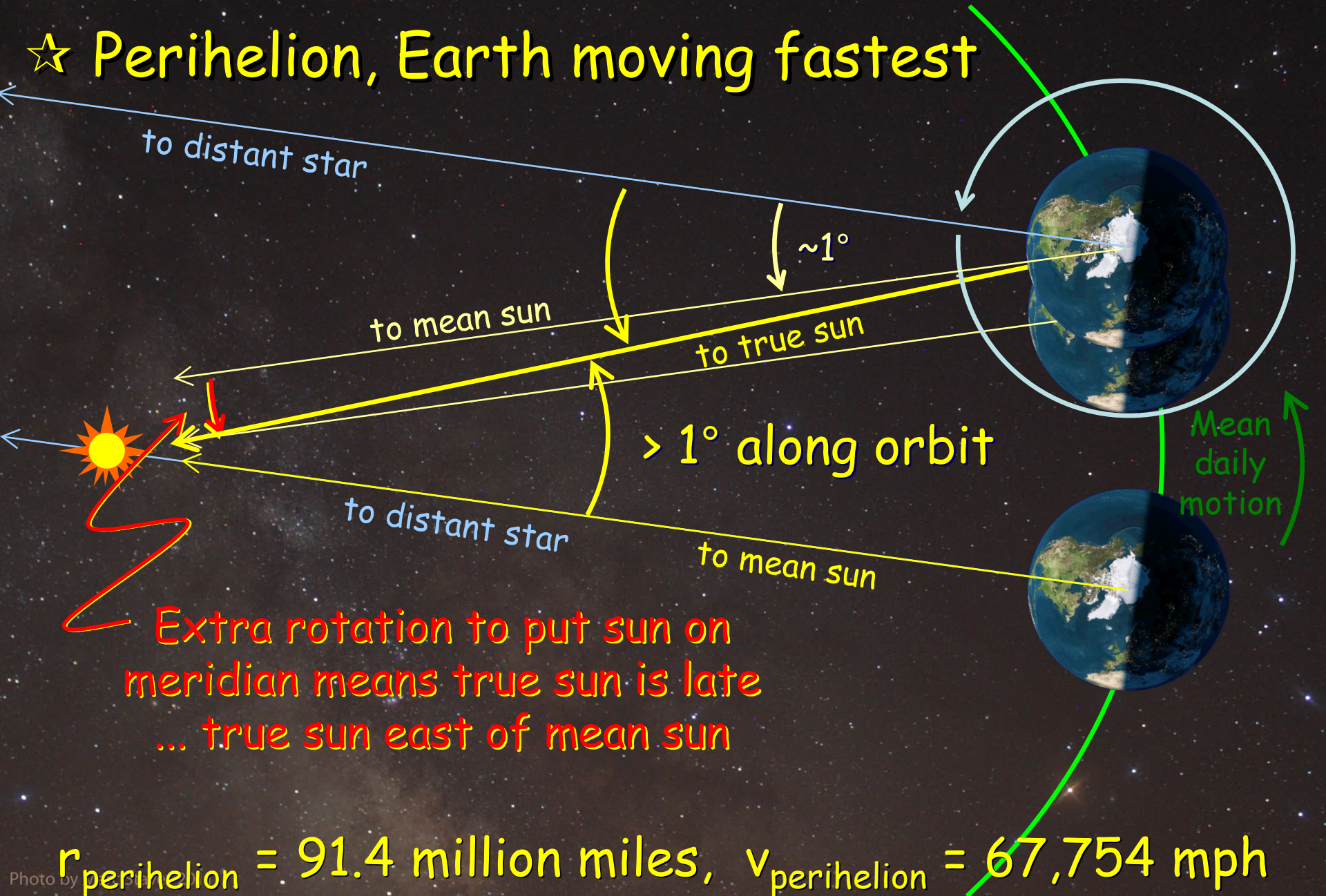


Orbital speed changes to keep swept areas equal

Photo by Marc Staves 2011

The Analemma

☆ Perihelion, Earth moving fastest



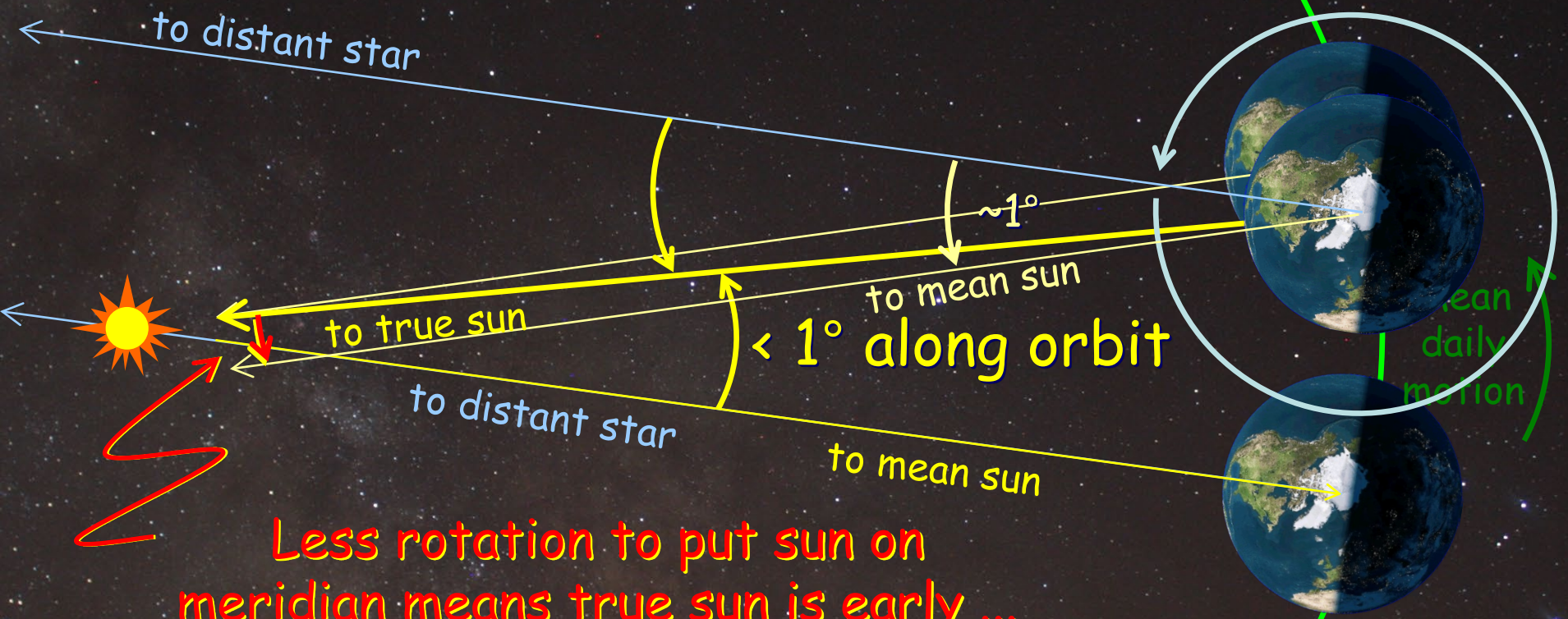
Extra rotation to put sun on meridian means true sun is late ... true sun east of mean sun

$r_{perihelion}$ = 91.4 million miles, $v_{perihelion}$ = 67,754 mph

The Analemma

☆ Aphelion, Earth moving slowest

< 1° along orbit

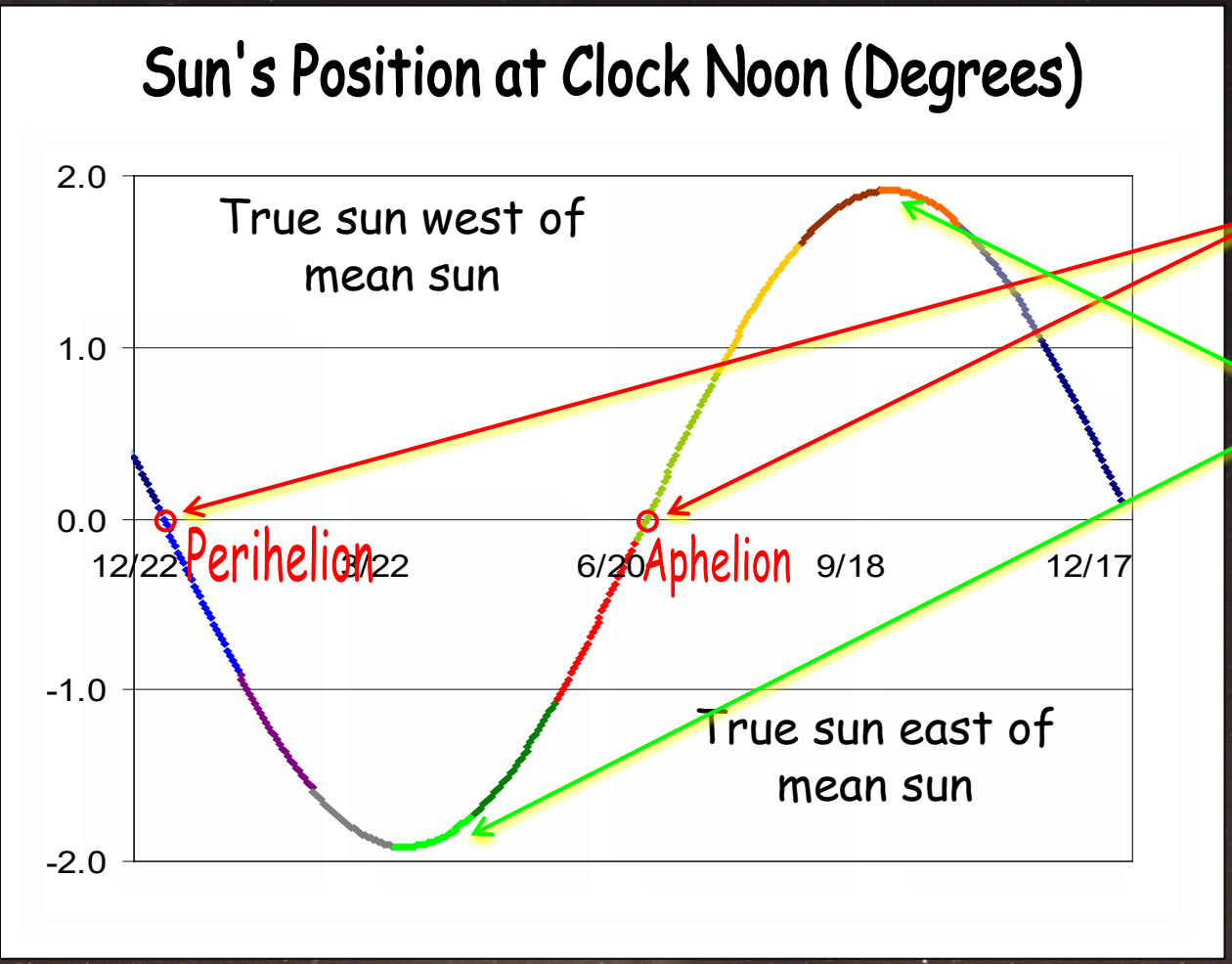


Less rotation to put sun on meridian means true sun is early ... west of mean sun

$r_{aphelion}$ = 94.5 million miles, $v_{aphelion}$ = 65,527 mph

Orbit Analemma

- Position of true sun through the year for Earth in an elliptical orbit just due to orbital speed variation



Maximum rate of change at perihelion & aphelion

Maximum difference at orbital mid-points (direction of change switches)

Orbit Analemma

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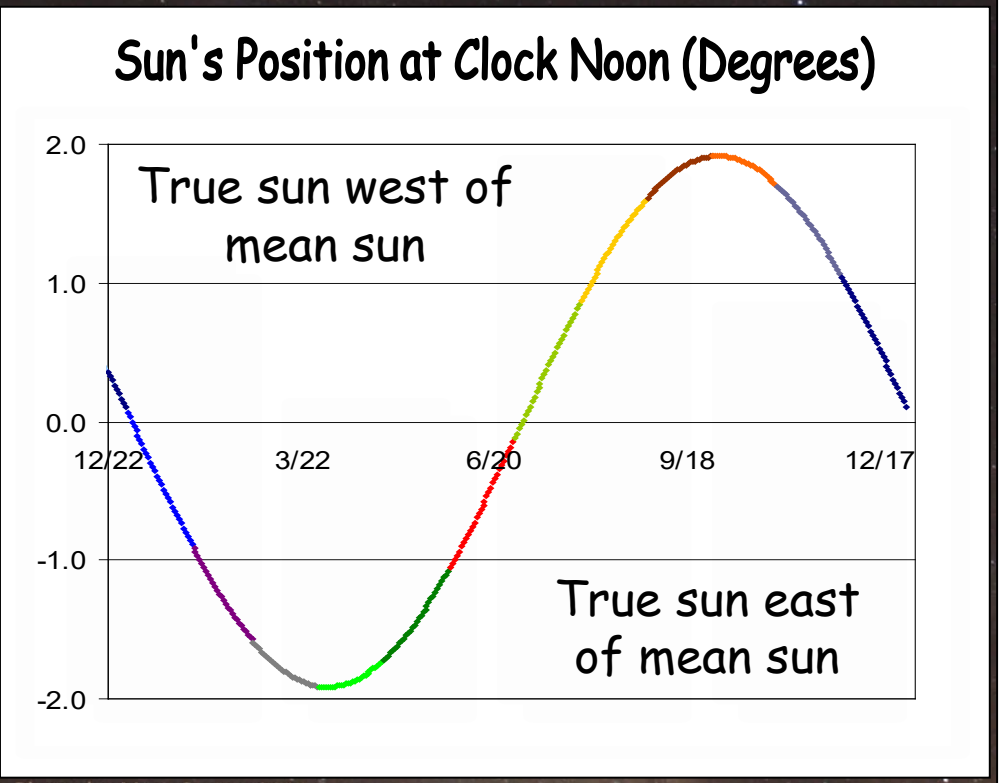
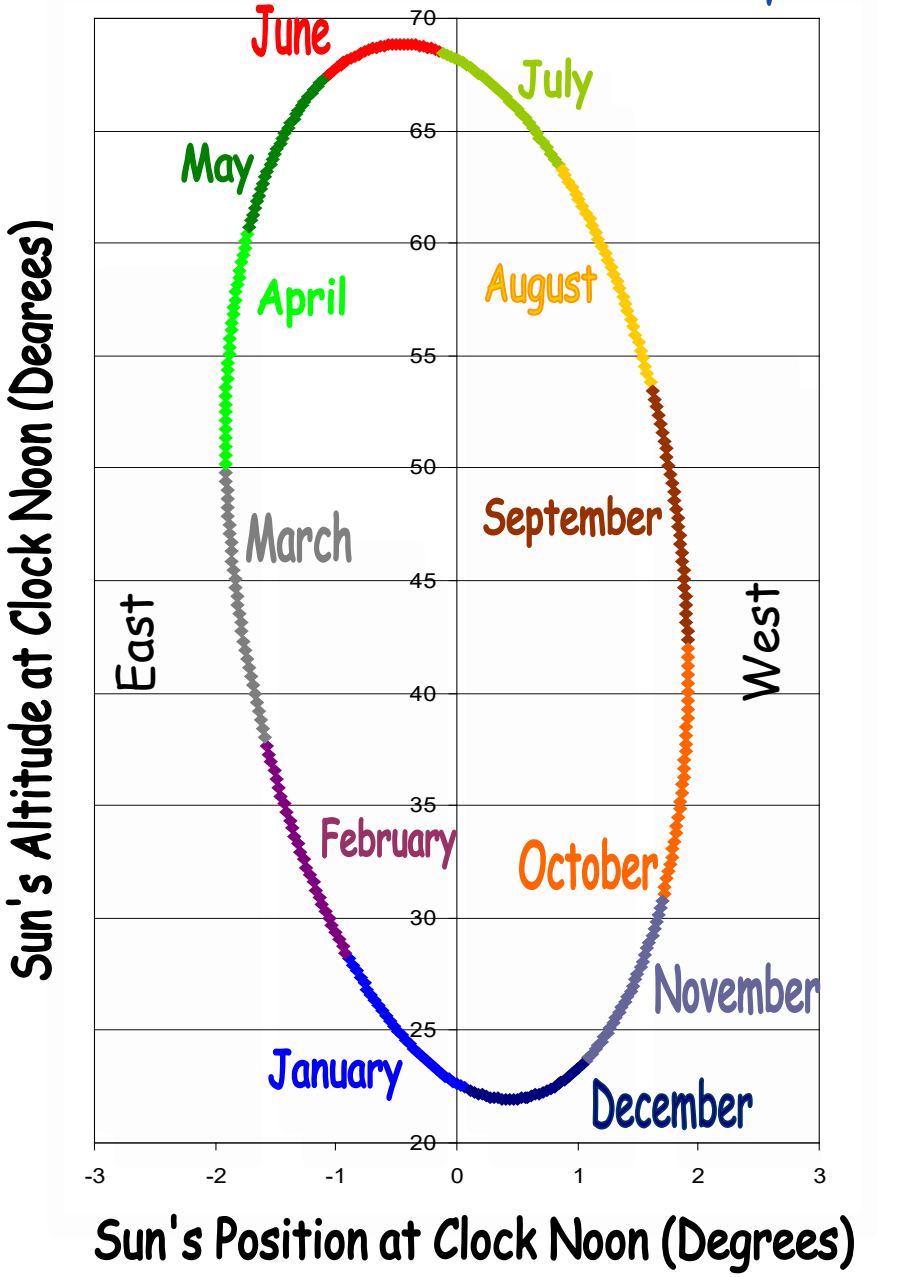


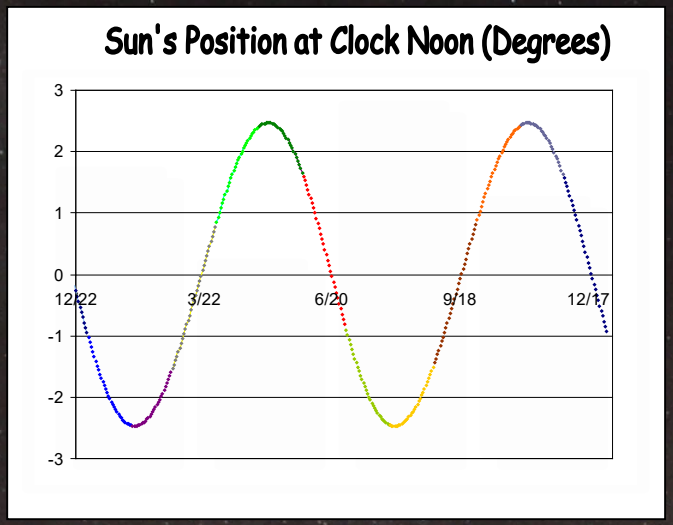
Photo by Marc Staves 2011

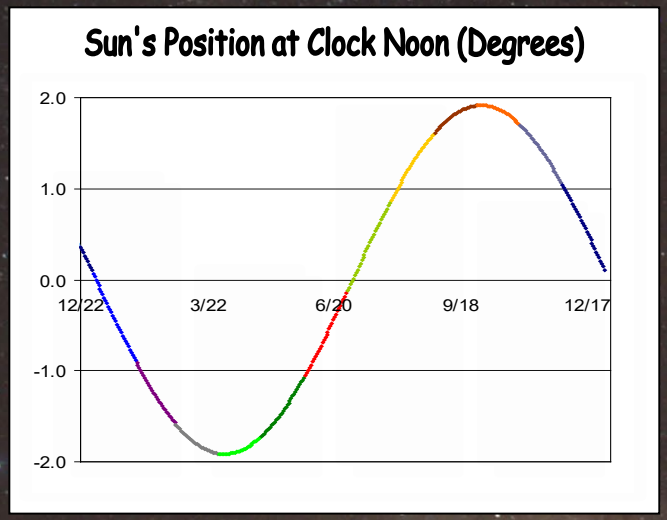
Oribt Analemma: Potsdam, NY



Total Analemma

☆ Tilt and Orbit effects add





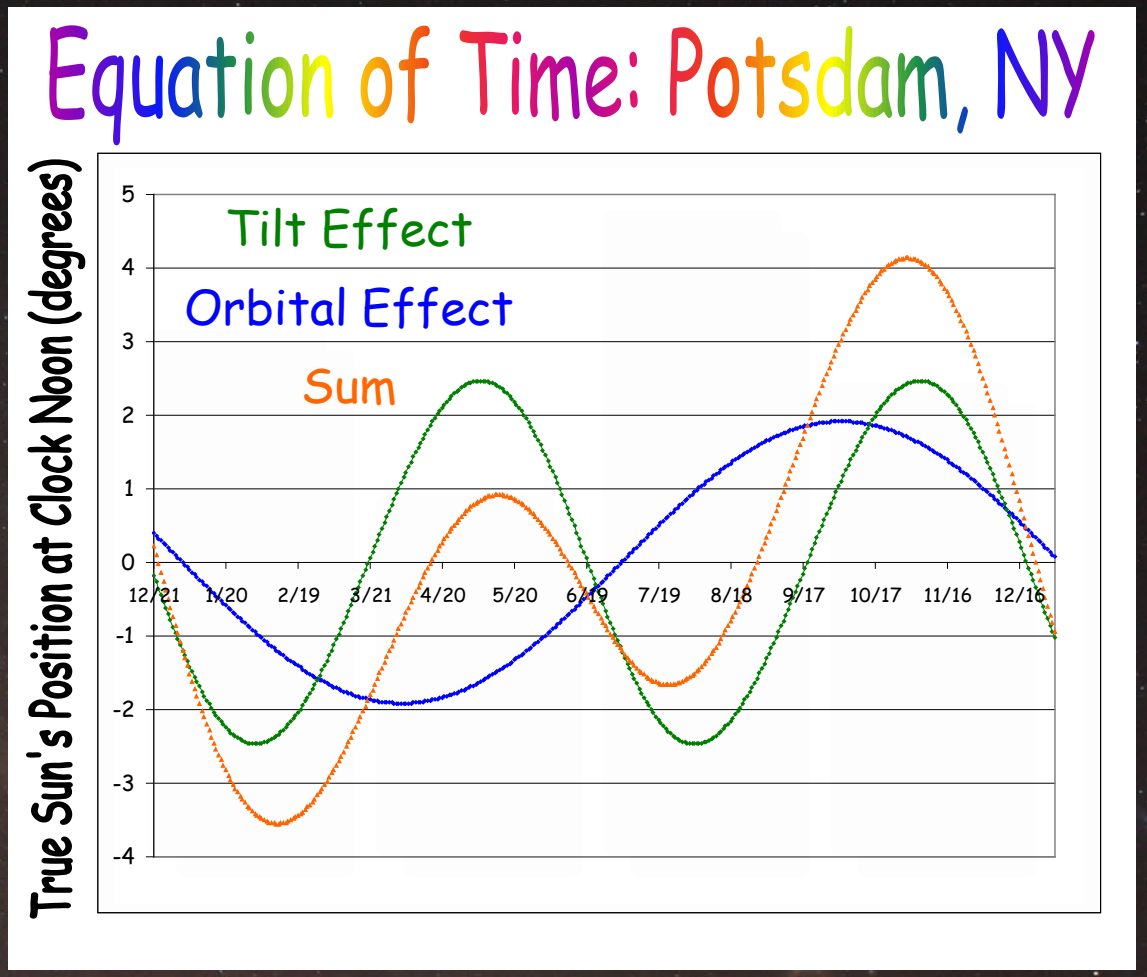


Photo by Marc Staves 2011

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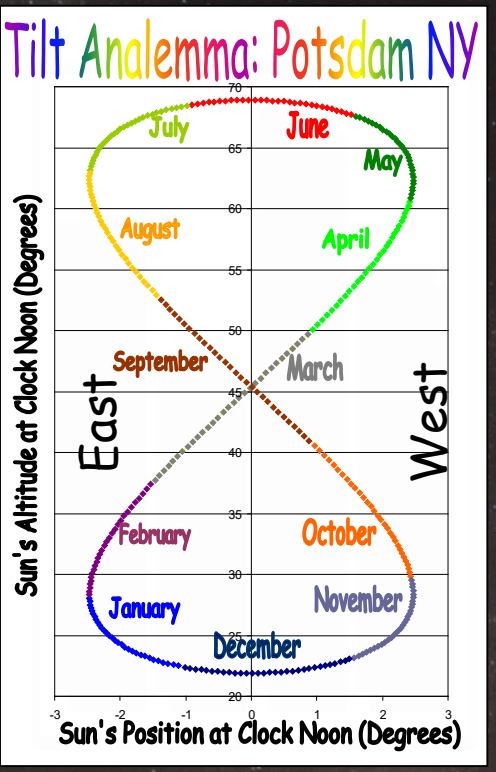
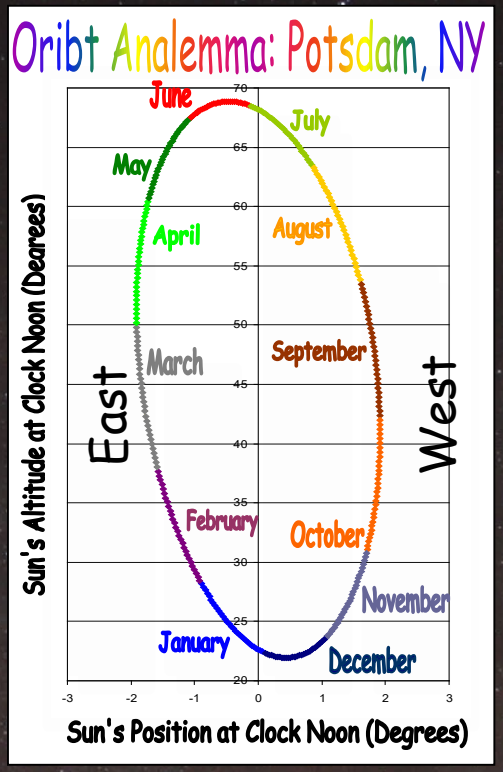




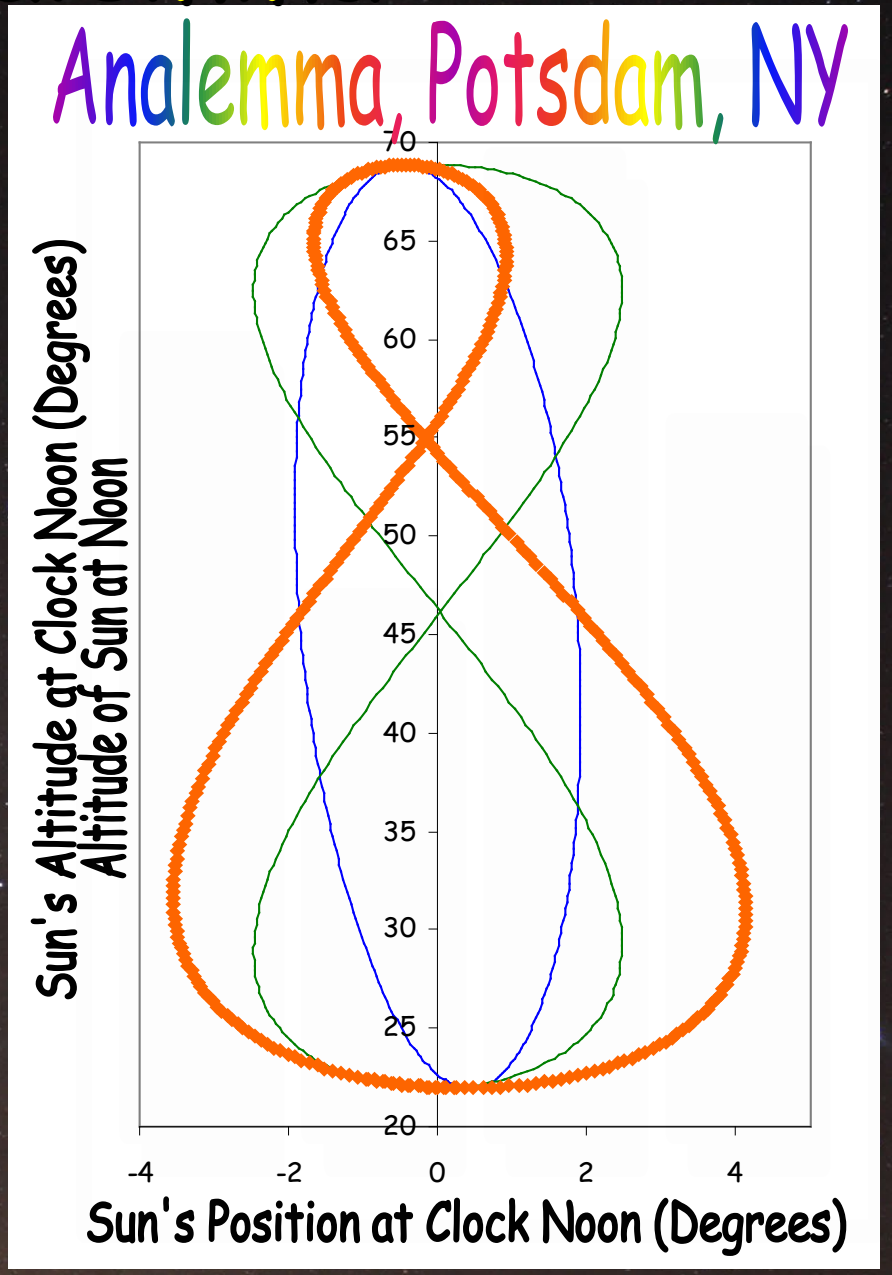
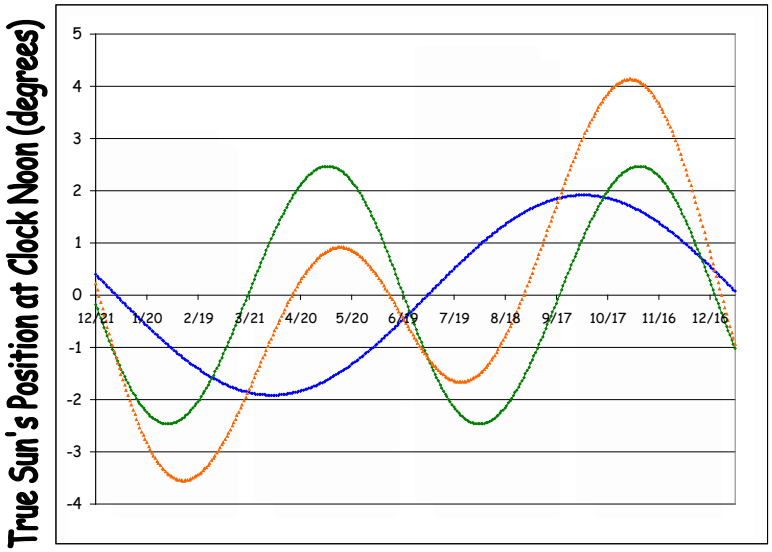


Photo by Marc Staves 2011

Potsdam's Analemma

Equation of Time: Canton, NY



Analemma, Potsdam, NY

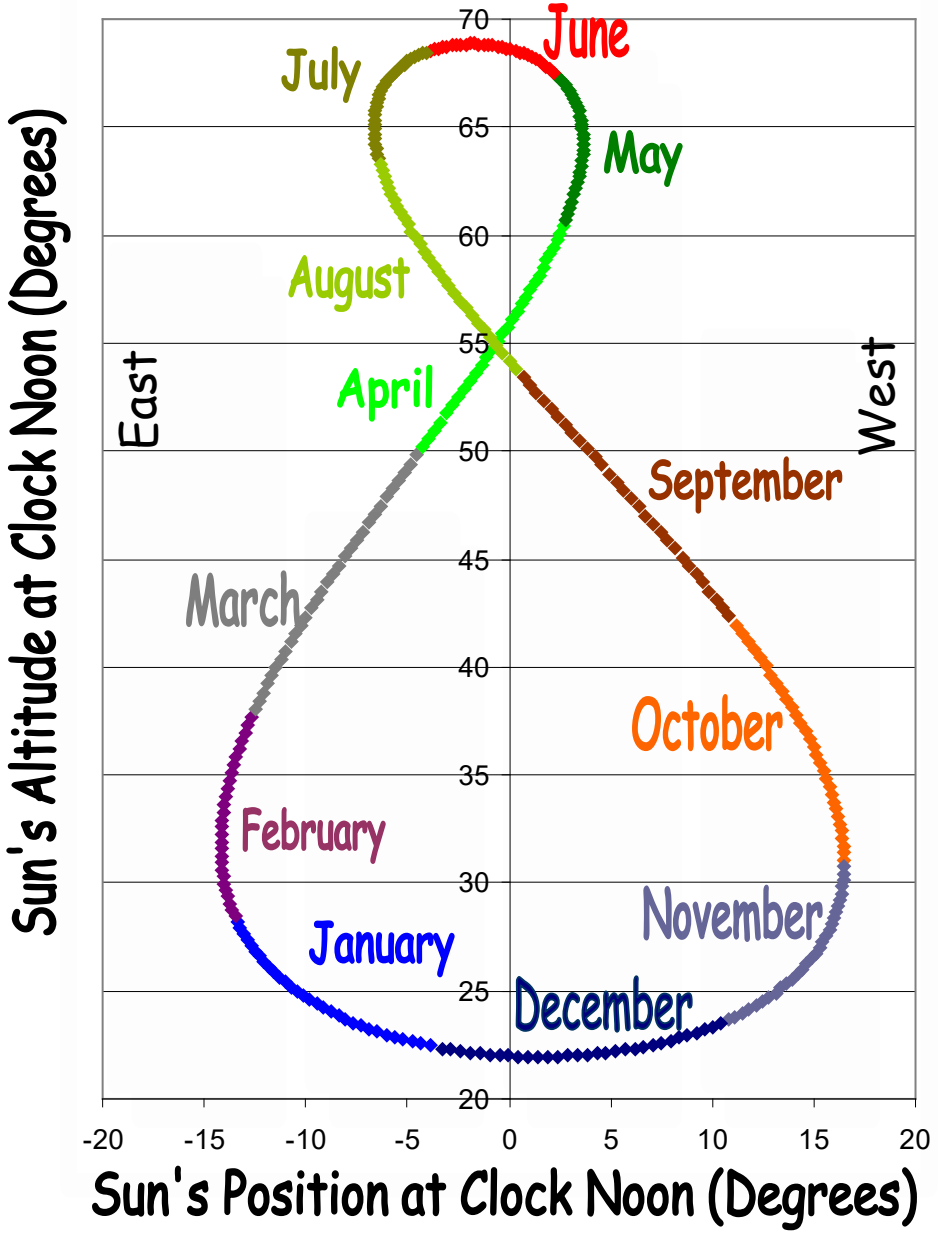


Photo by Marc Staves 2011

Why was the earliest sunset on December 7?

Sun position at 3:30 pm EST
through the year

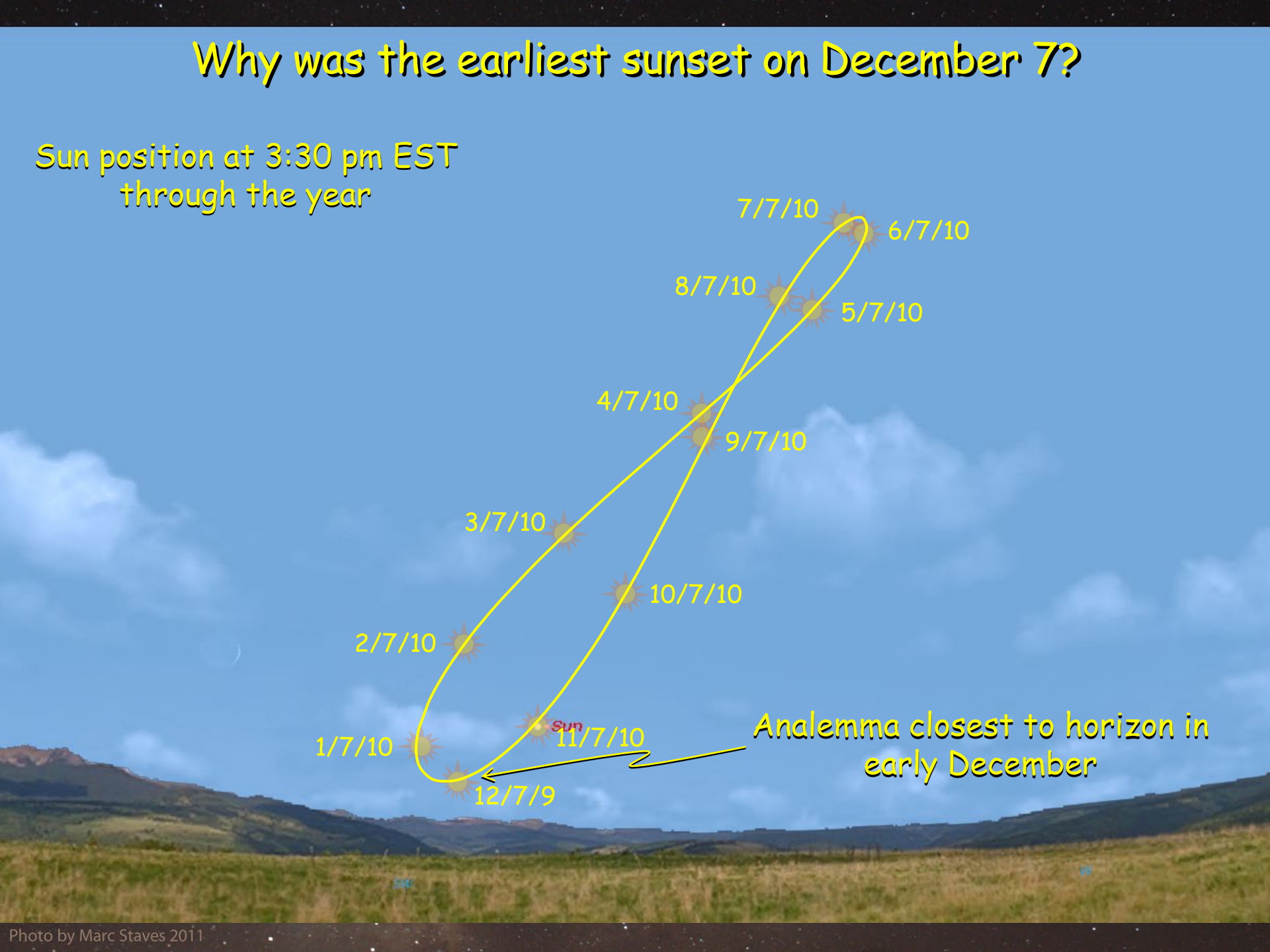
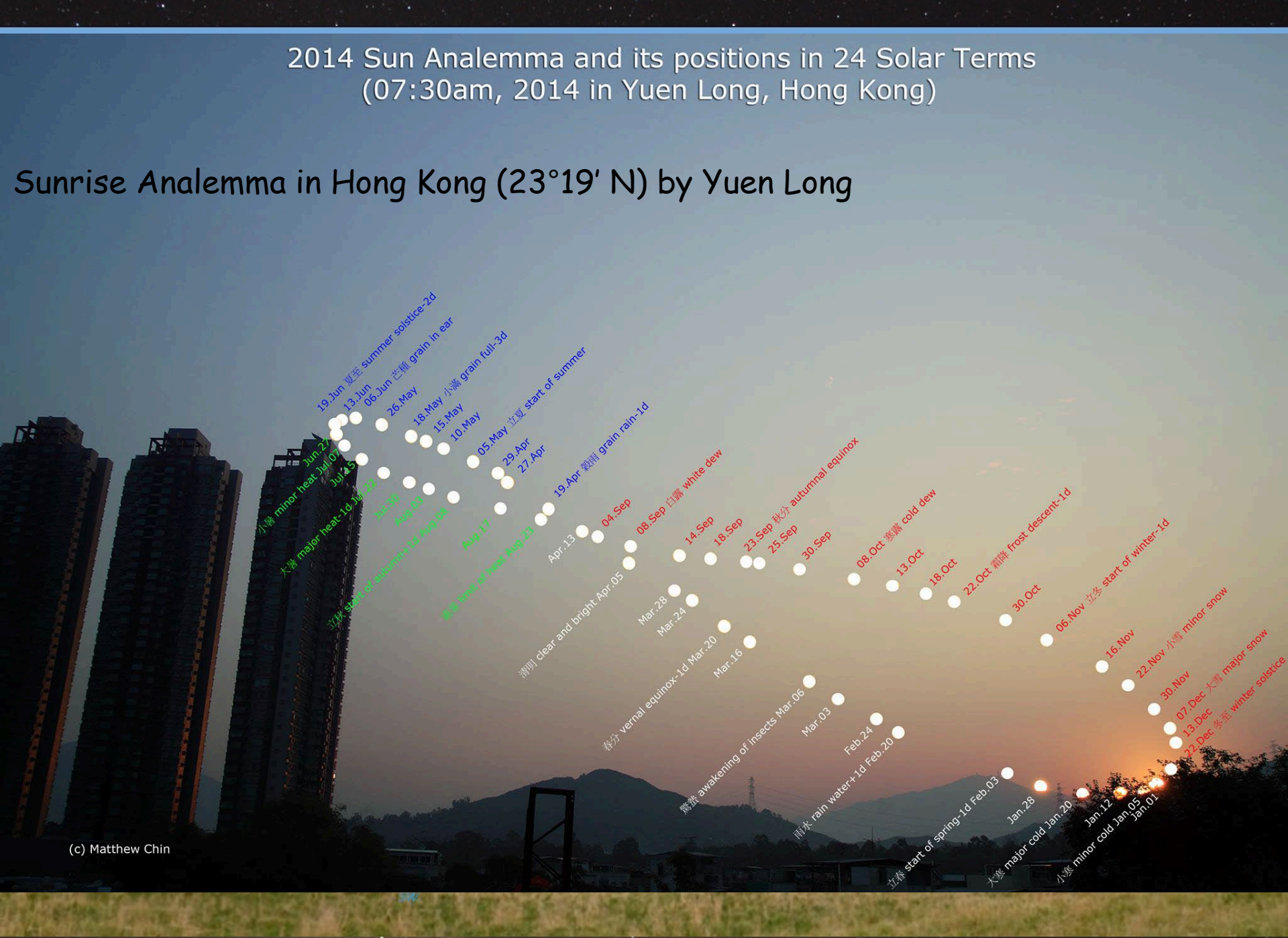


Photo by Marc Staves 2011

2014 Sun Analemma and its positions in 24 Solar Terms
(07:30am, 2014 in Yuen Long, Hong Kong)

Sunrise Analemma in Hong Kong (23°19′ N) by Yuen Long



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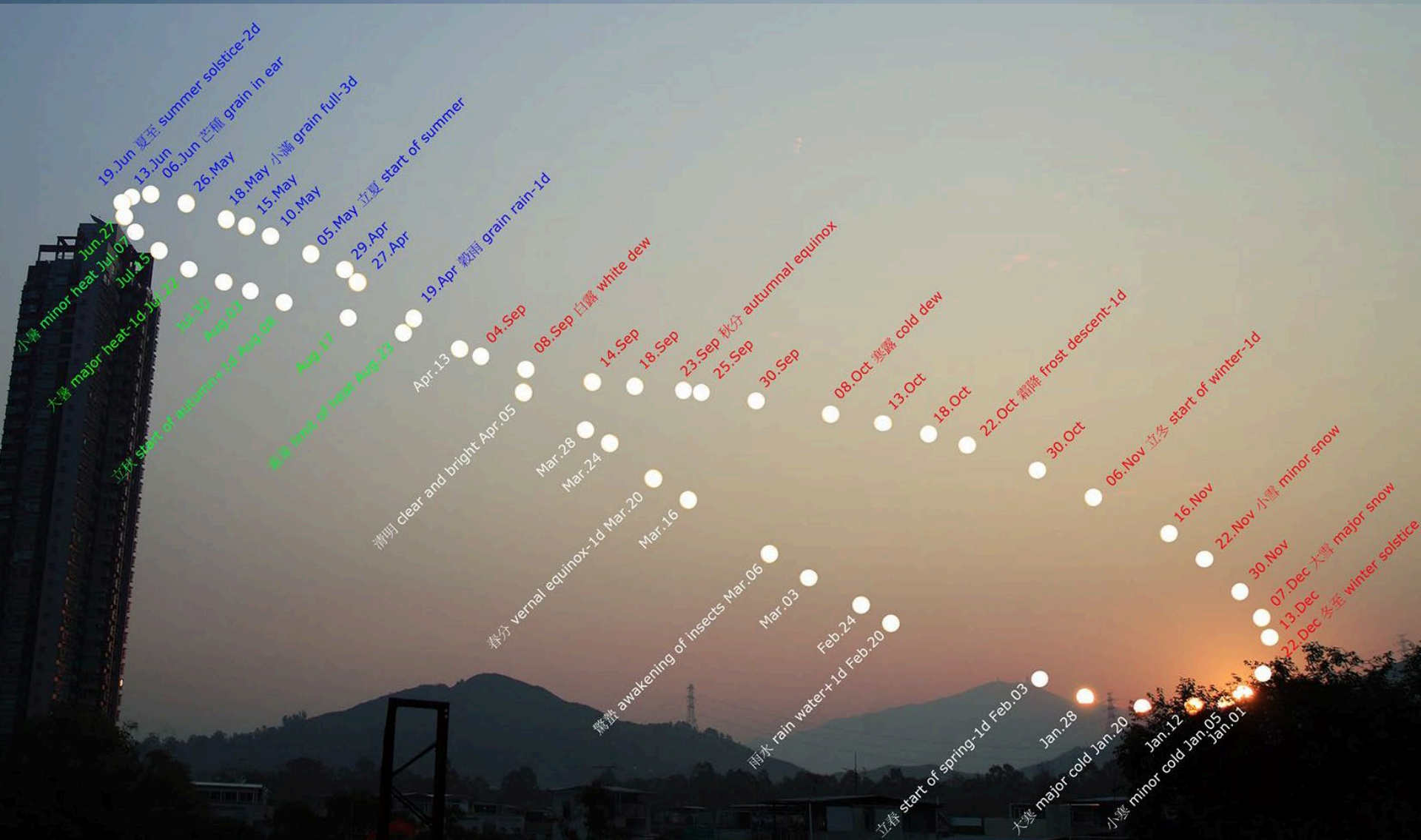
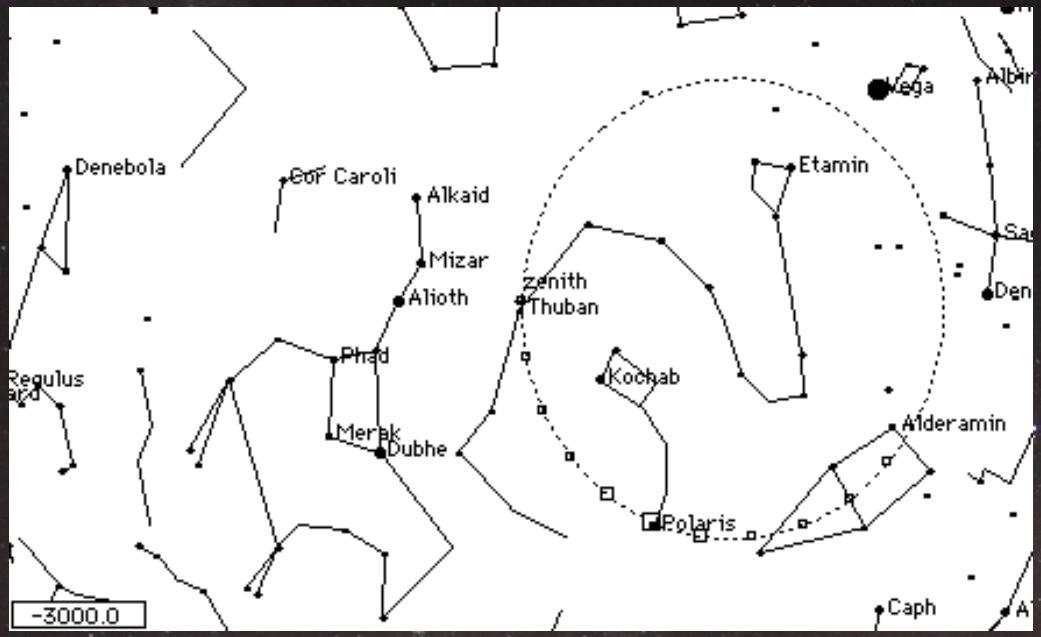


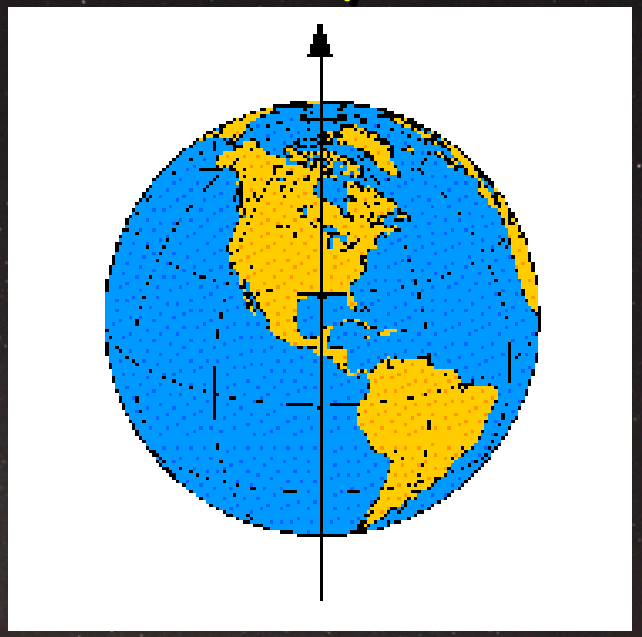
2014 Sun Analemma and its positions in 24 Solar Terms
(07:30am, 2014 in Yuen Long, Hong Kong)

Sunrise Analemma in Hong Kong (23°19′ N) by Yuen Long

The Age of Aquarius

☆ Earth's axis wobbles over 26,000 years

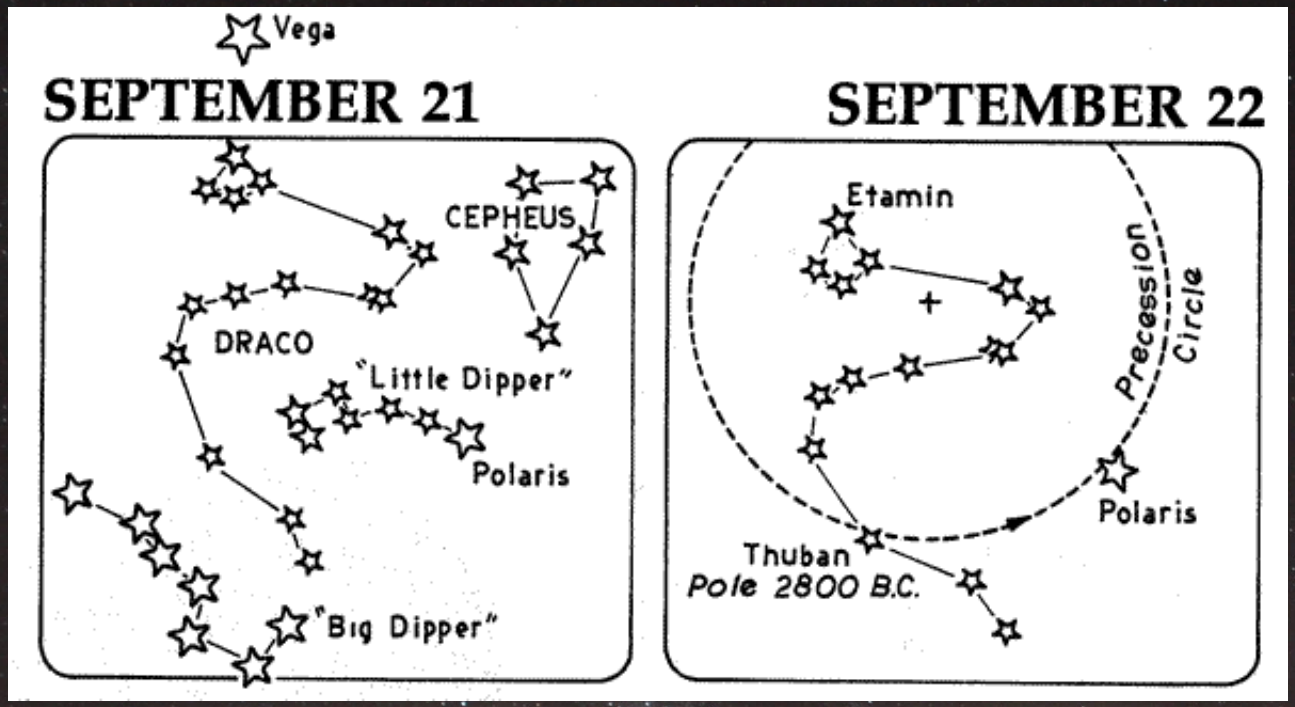




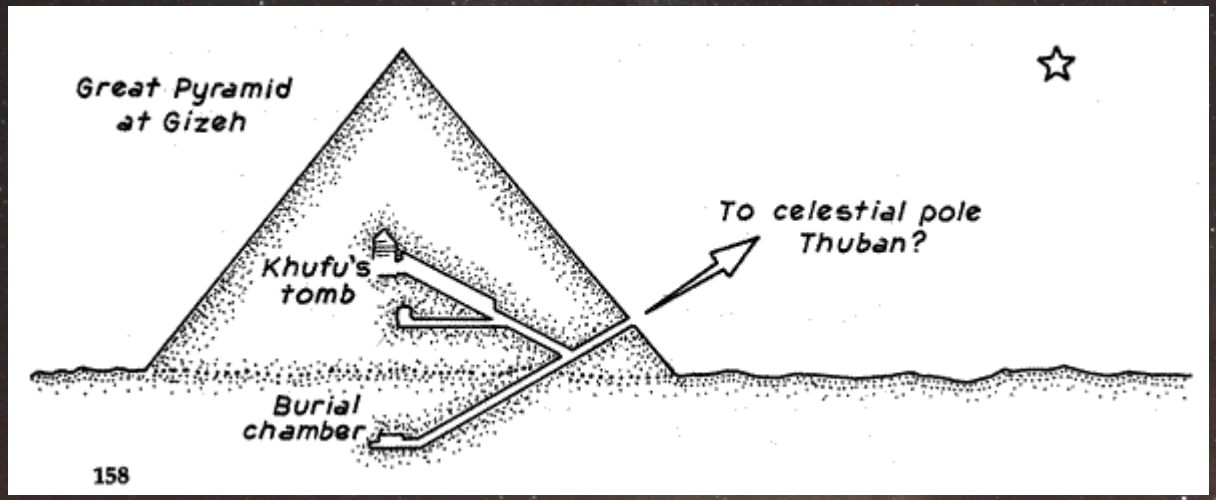
RA and Dec grid wobbles with pole, ecliptic does not wobble so solstices & equinoxes change position

http://www.opencourse.info/astronomy/introduction/03.motion_earth/

Raymo's 365 Starry Nights

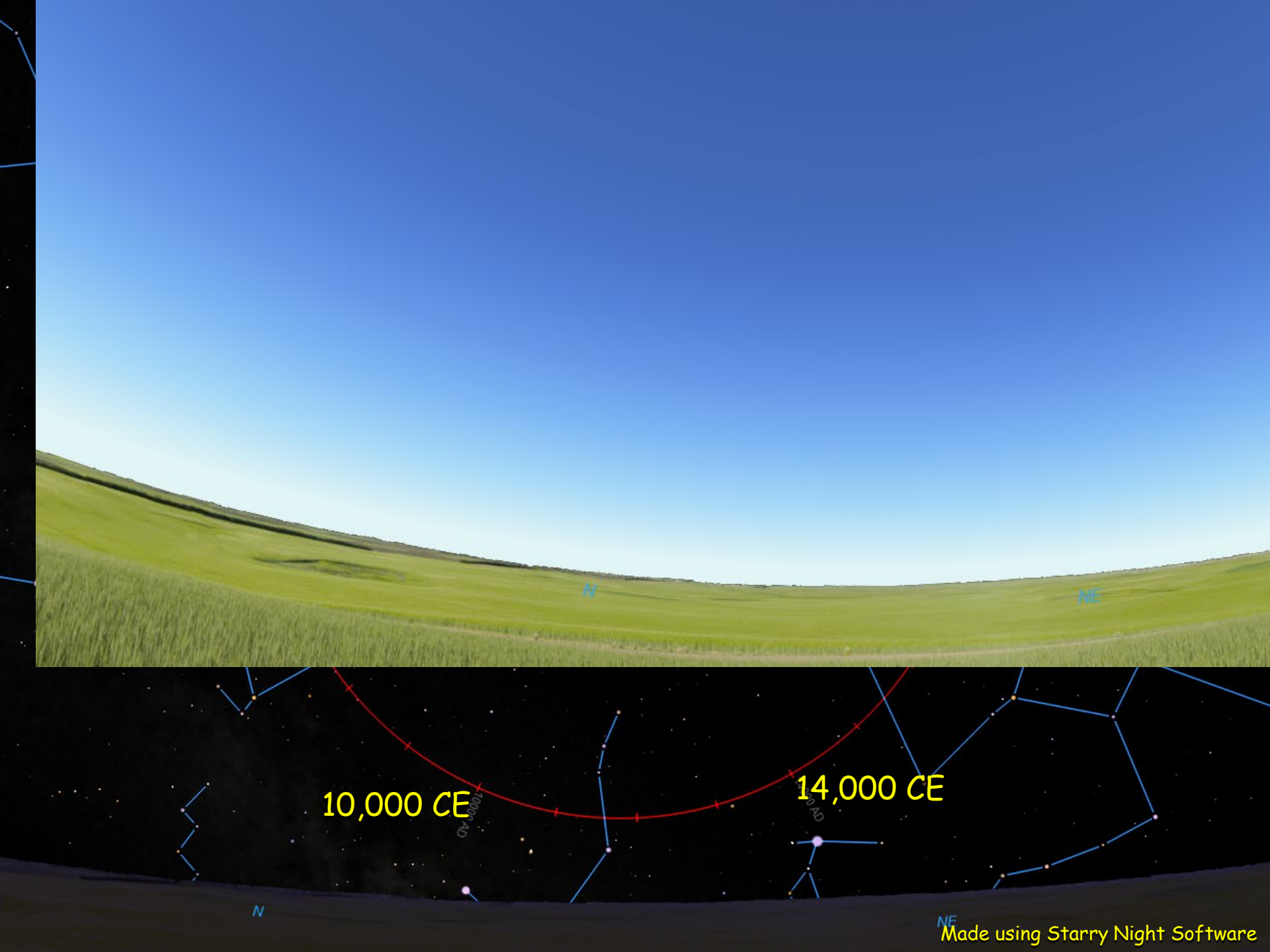


Precession Circle



View from the Pyramids

Photo by Marc Staves, Adirondack Public Observatory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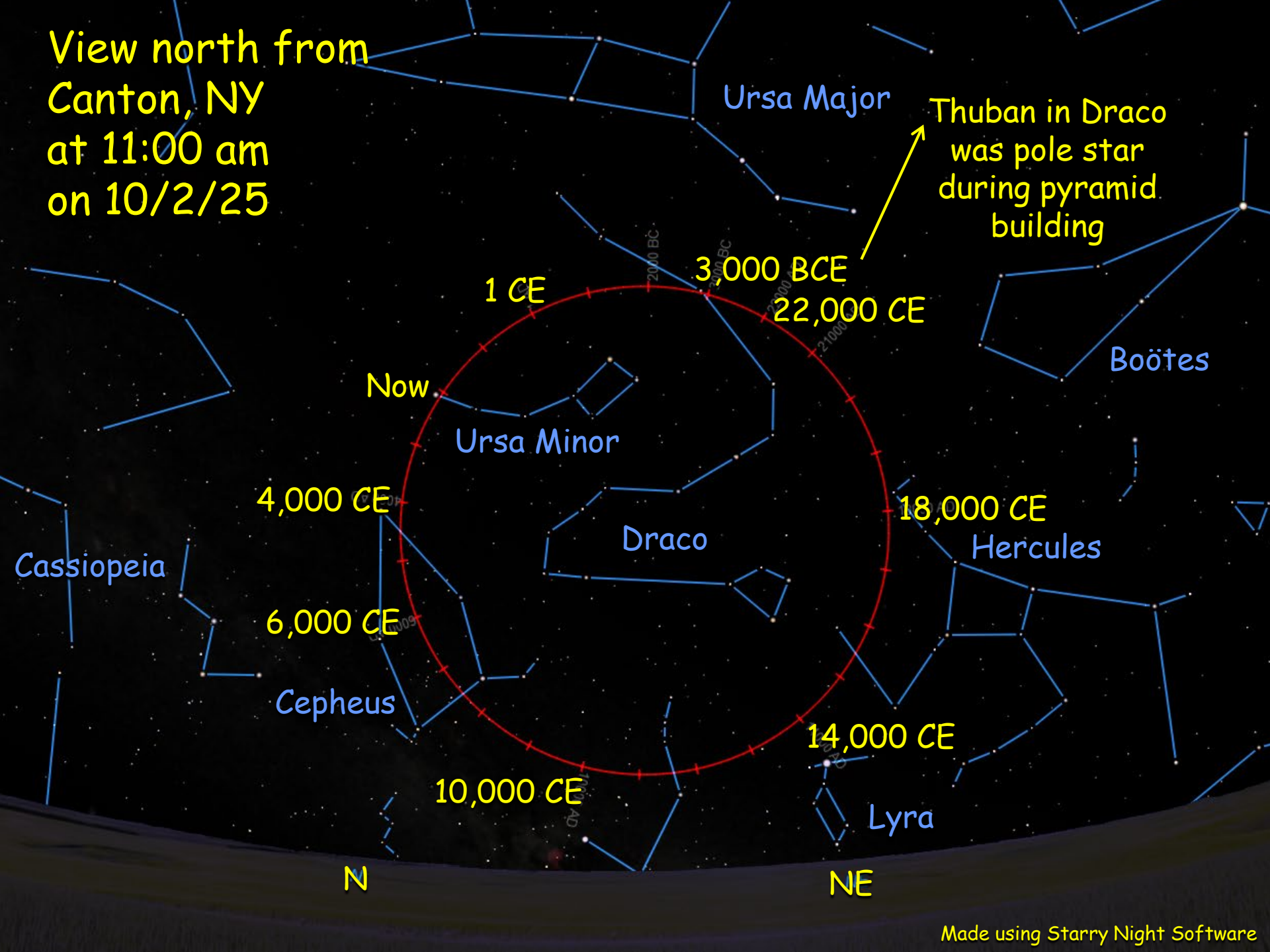
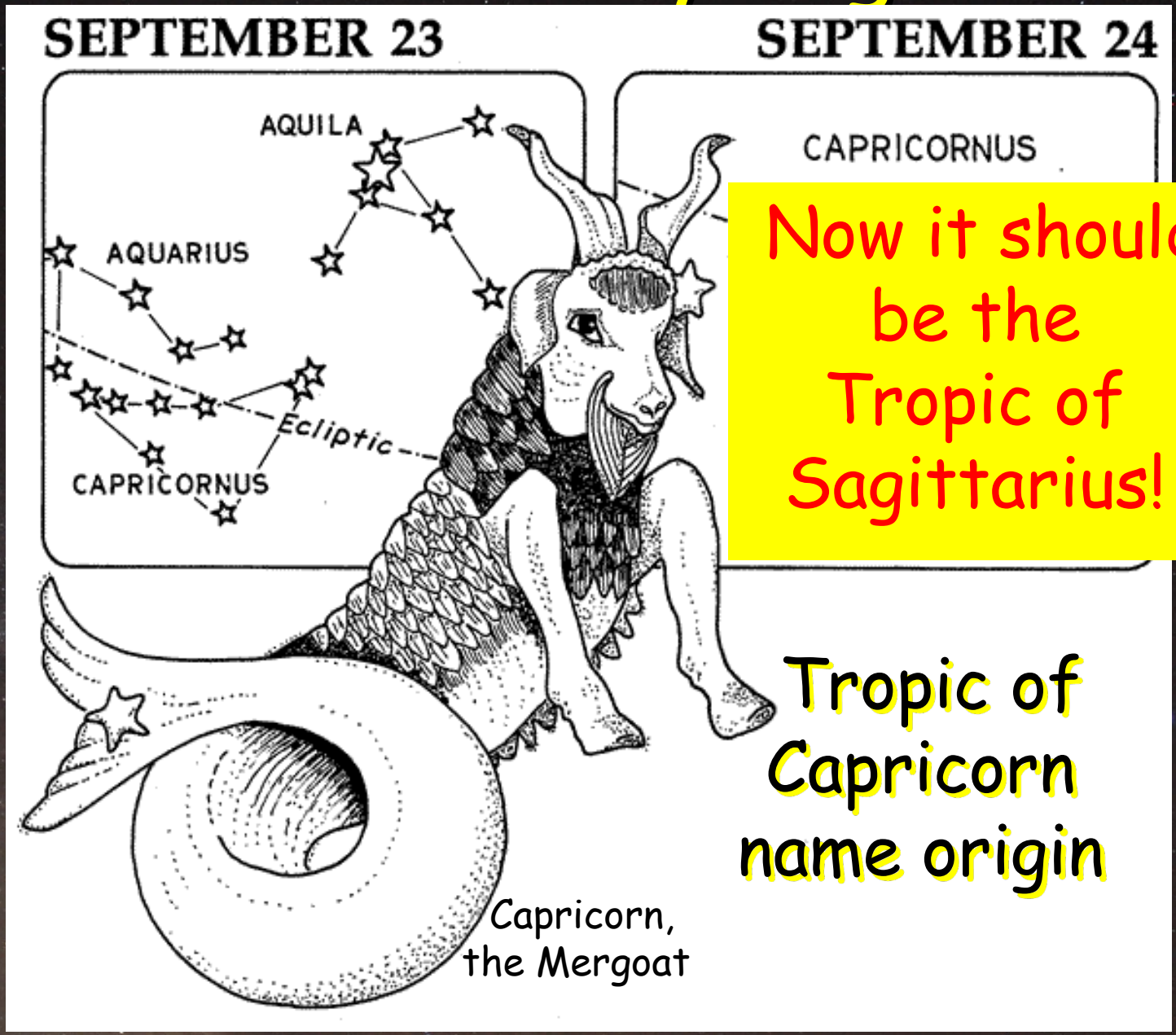
10,000 CE
14,000 CE
N
NE
Made using Starry Night Software


View north from
Canton, NY
at 11:00 am
on 10/2/25
Ursa Major
Thuban in Draco
was pole star
during pyramid
building
3,000 BCE
22,000 CE
1 CE
Boötes
Now
Ursa Minor
4,000 CE
18,000 CE
Draco
Hercules
Cassiopeia
6,000 CE
Cepheus
14,000 CE
10,000 CE
Lyra
N
NE
Made using Starry Night Software

Raymo's 365 Starry Nights

Position of the winter solstice in 1000 BCE

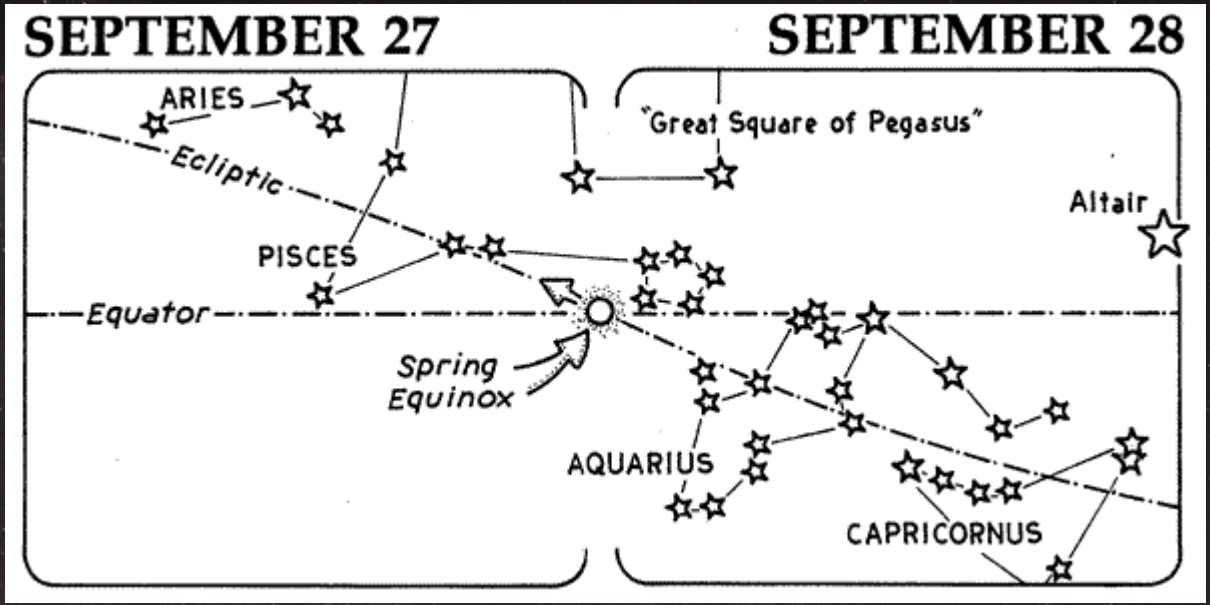


Now it should be the Tropic of Sagittarius!

Tropic of Capricorn name origin

Photo by Marc Staves 2011

Raymo's 365 Starry Nights



Position of the Vernal Equinox now

Motion of the Vernal Equinox ...

To the "Age of Aquarius"

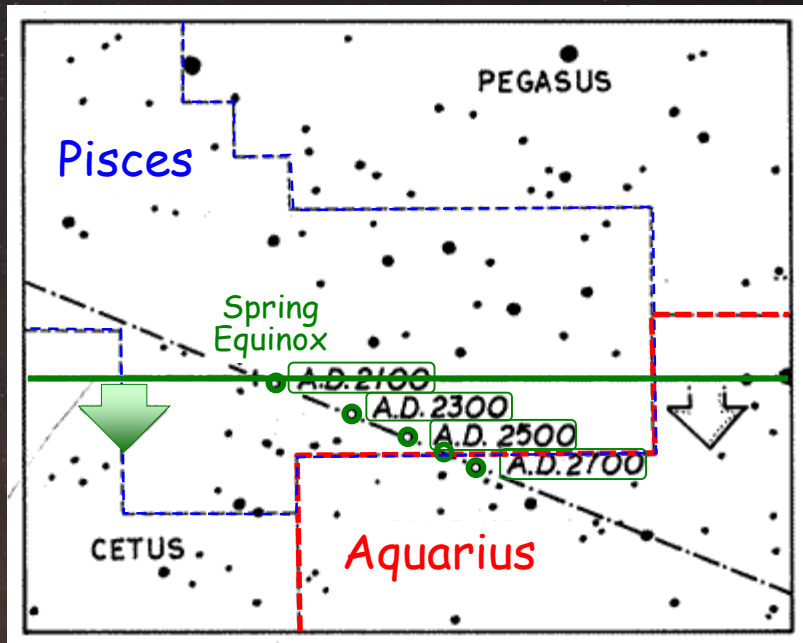
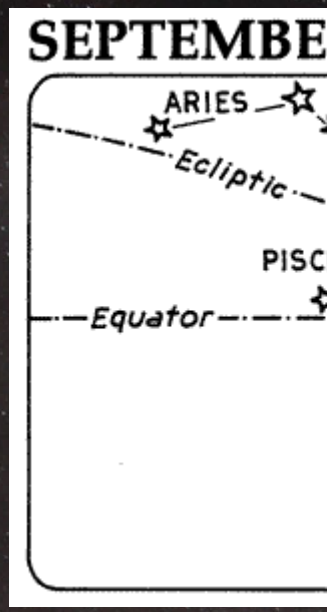
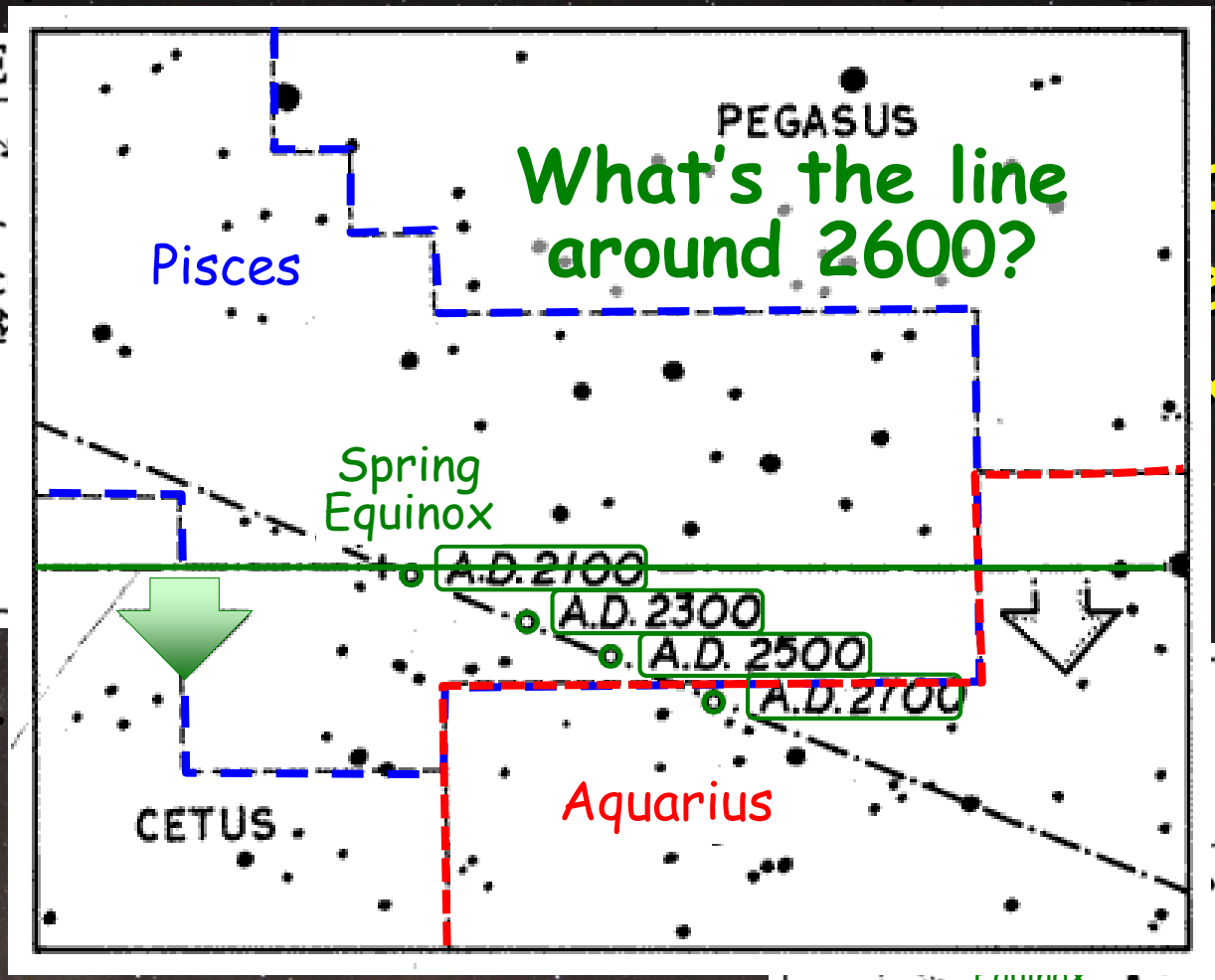


Photo by Marc Staves 2011

Raymo's 365 Starry Nights





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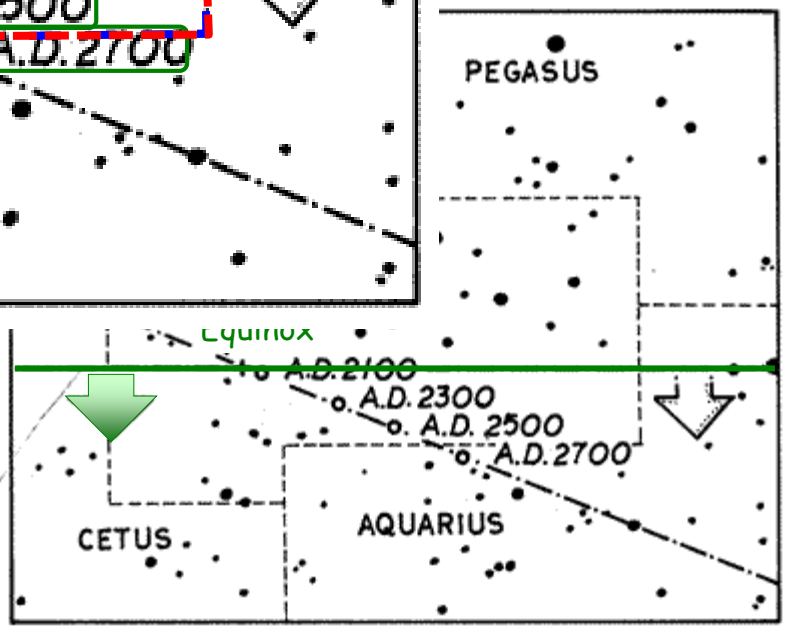
Mot



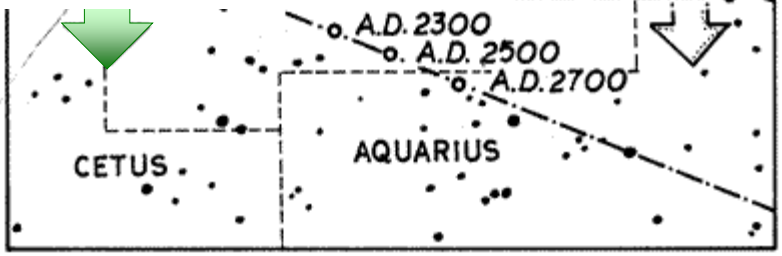
In 2600, equinox moves into "Age of Aquarius"

Photo by Marc Staves 2011

When the moon is in the Seventh House
And Jupiter aligns with Mars
Then peace will guide the planets
And love will steer the stars

This is the dawning of the Age of Aquarius
Aquarius! Aquarius!

Harmony and understanding
Sympathy and trust abounding
No more falsehoods or derisions
Golden living dreams of visions
Mystic crystal revelation
And the mind's true liberation
Aquarius! Aquarius!



In 2600, equinox moves into "Age of Aquarius"

Photo by Marc Staves 2011


The adventure continues ...
Photo by Marc Staves 2011