SOAR
Lifelong Learning in the North Country

1816 Potsdam
THE STATE UNIVERSITY OF NEW YORK

SOAR: The Sky in Motion

The Year

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ST. LAWRENCE UNIVERSITY

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

Photo by Marc Staves 2011

The Tilted Teacup Ride

- ☆ Coordinates and the Day: 9/6/22
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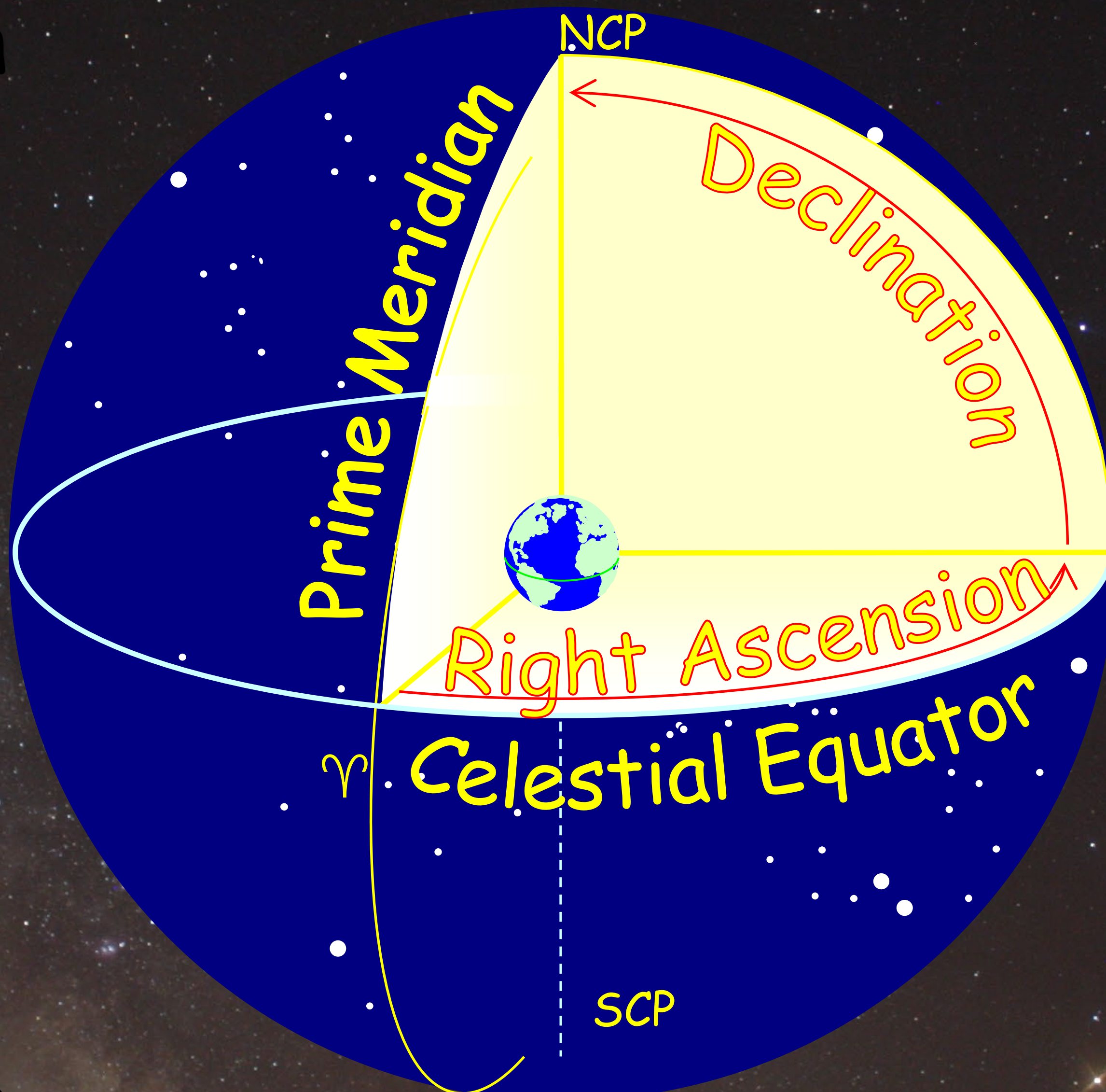
Celestial Coordinates

- ☆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°

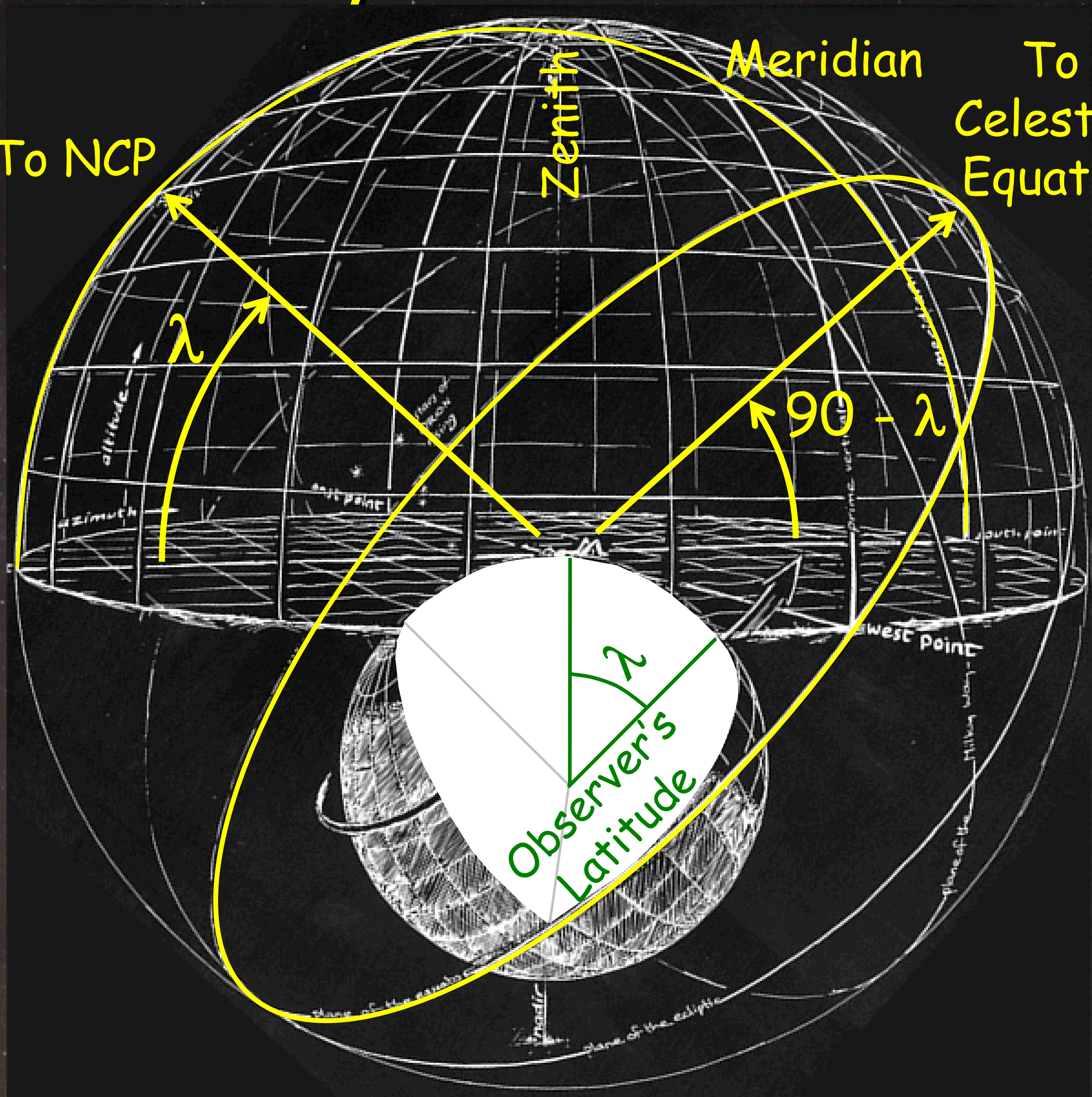


Tilted Sky

- ☆ Observers see sky "tilted" due to latitude

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

So we see sky motions tilted



Public Observatory

Horizon Coordinate System

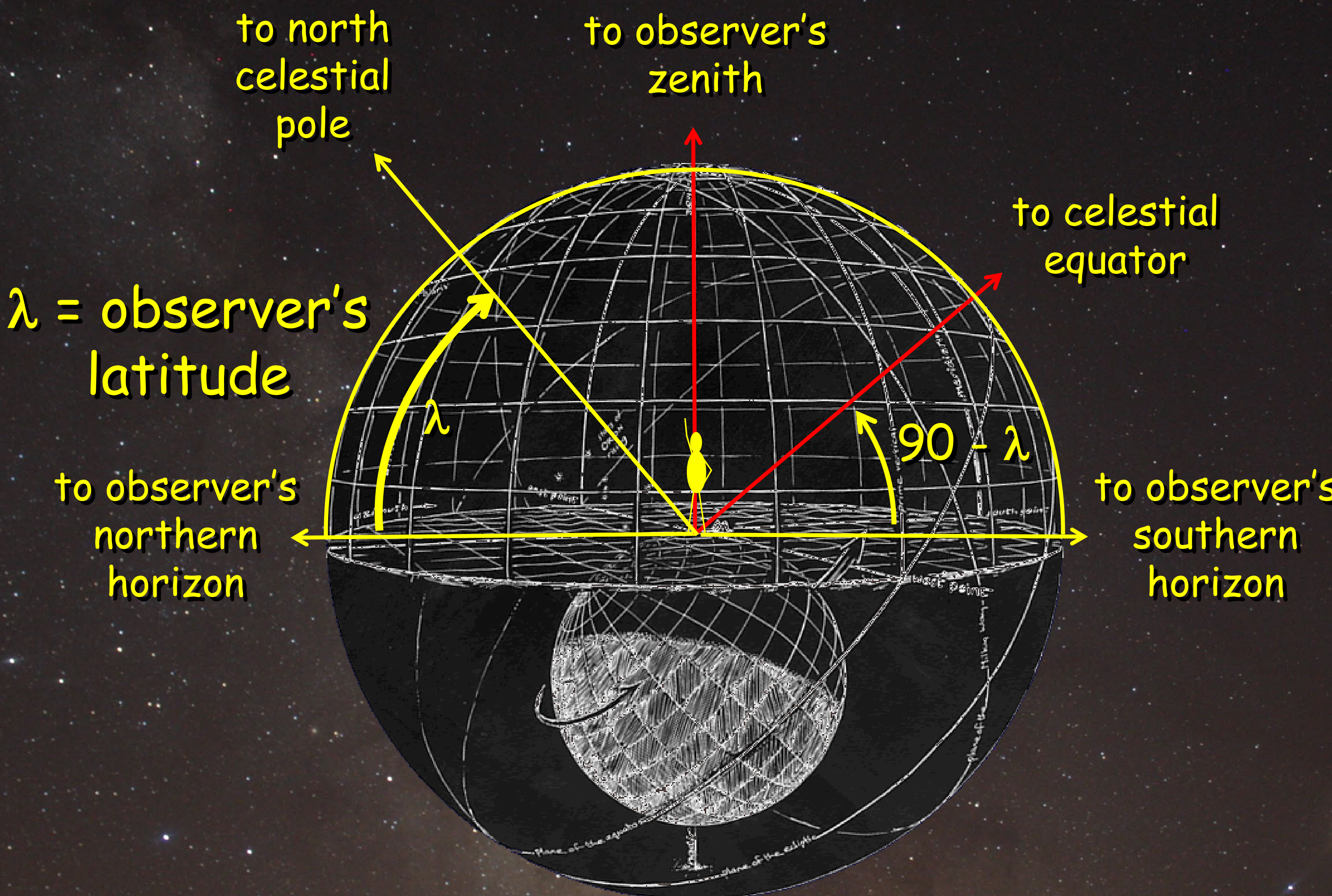
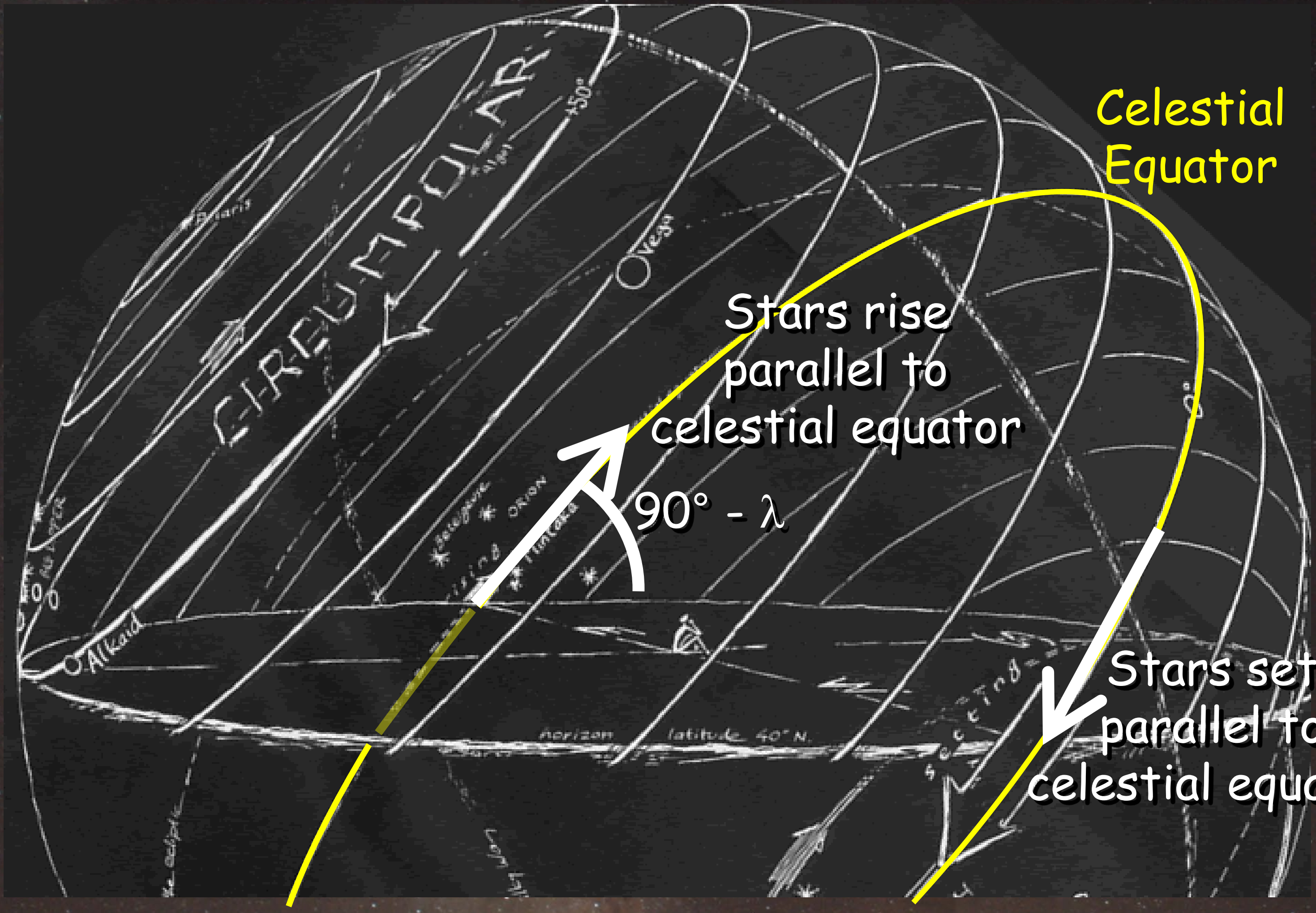


Photo by Marc Staves, Adirondack Public Observatory

View of Observers

- ☆ Diurnal circles are parallel to CE
  - Stars rise and set at CE's angle from horizon



Sunrise, Sunset …

- ☆ Everything in the sky (sun, moon, stars, etc.)
  - Rises in the east
  - Sets in the west

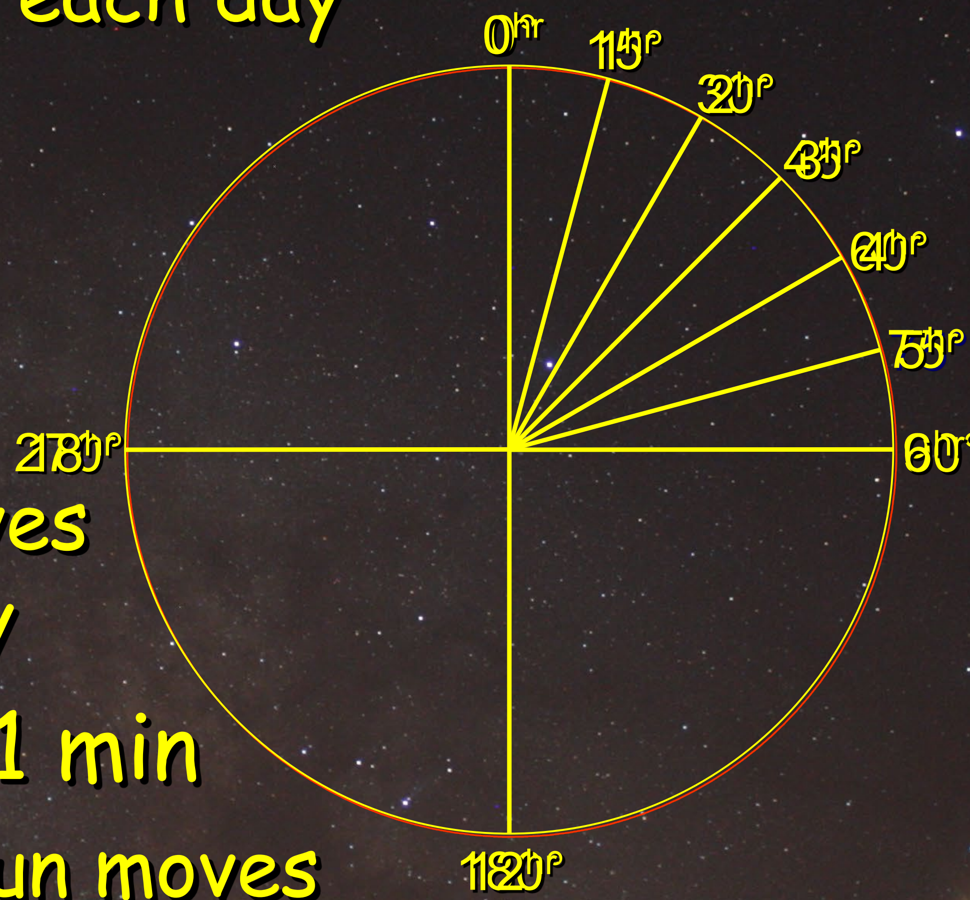
each day

Measuring Circles:

360° = 24 hr

15° = 1 hr

Each hour, the sun moves 15 degrees in the sky

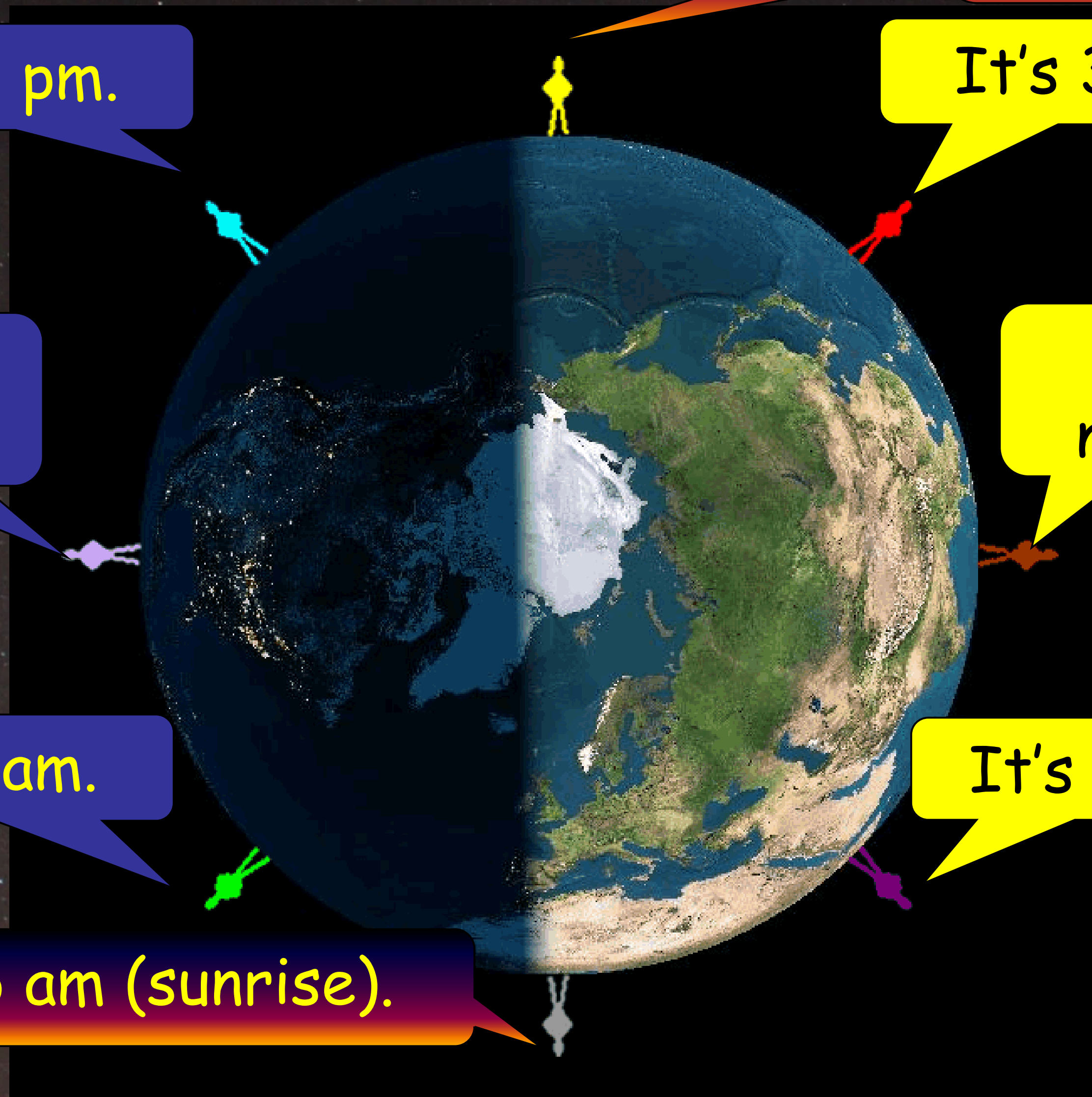


1° = 4 min or 15′ = 1 min

Every 4 minutes, the sun moves 1 degree = 60′ in the sky

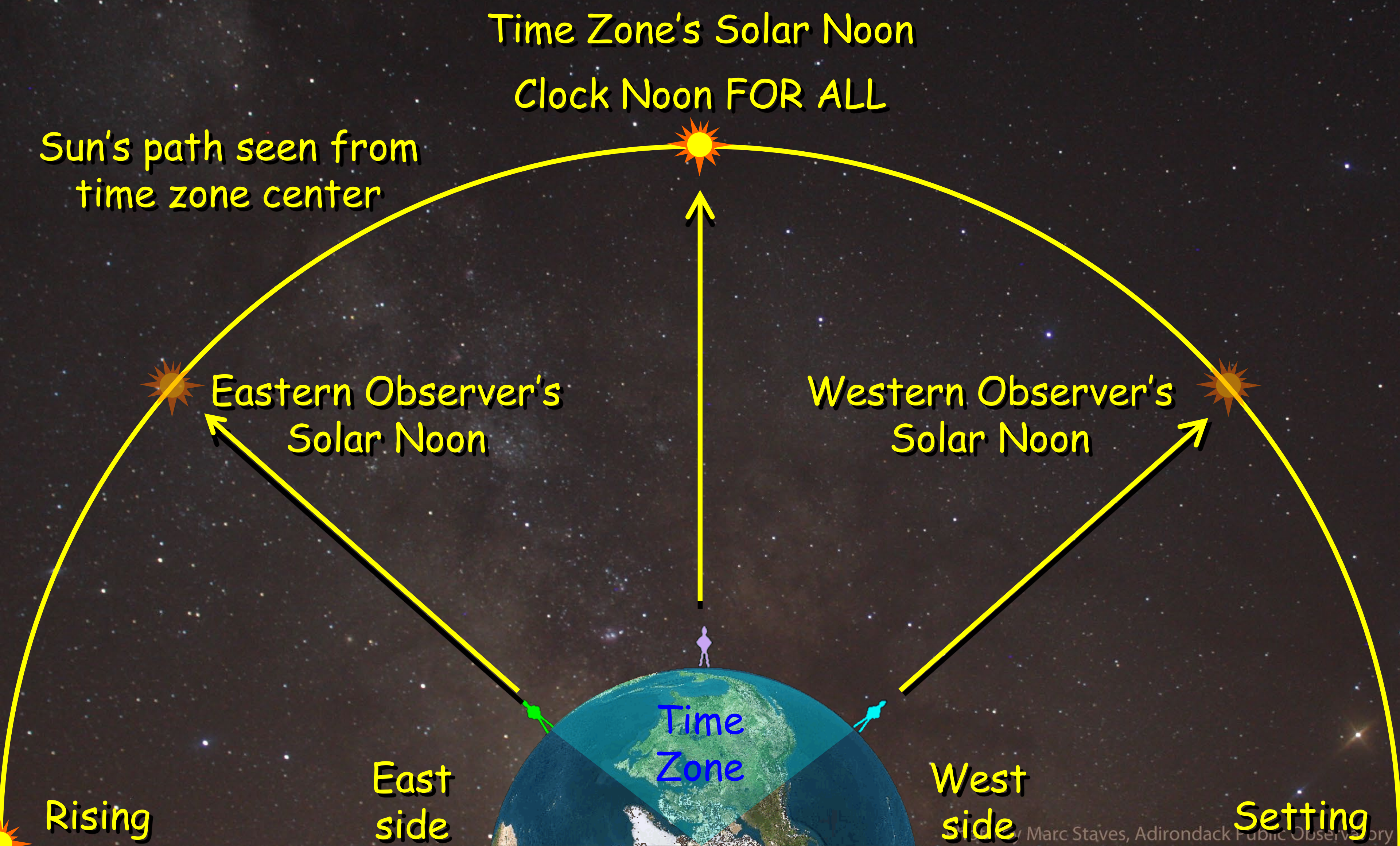
Clock Time = Position of Sol

☆ Observers move through times



Solar Time vs. Clock Time

- ☆ Solar time varies across time zones



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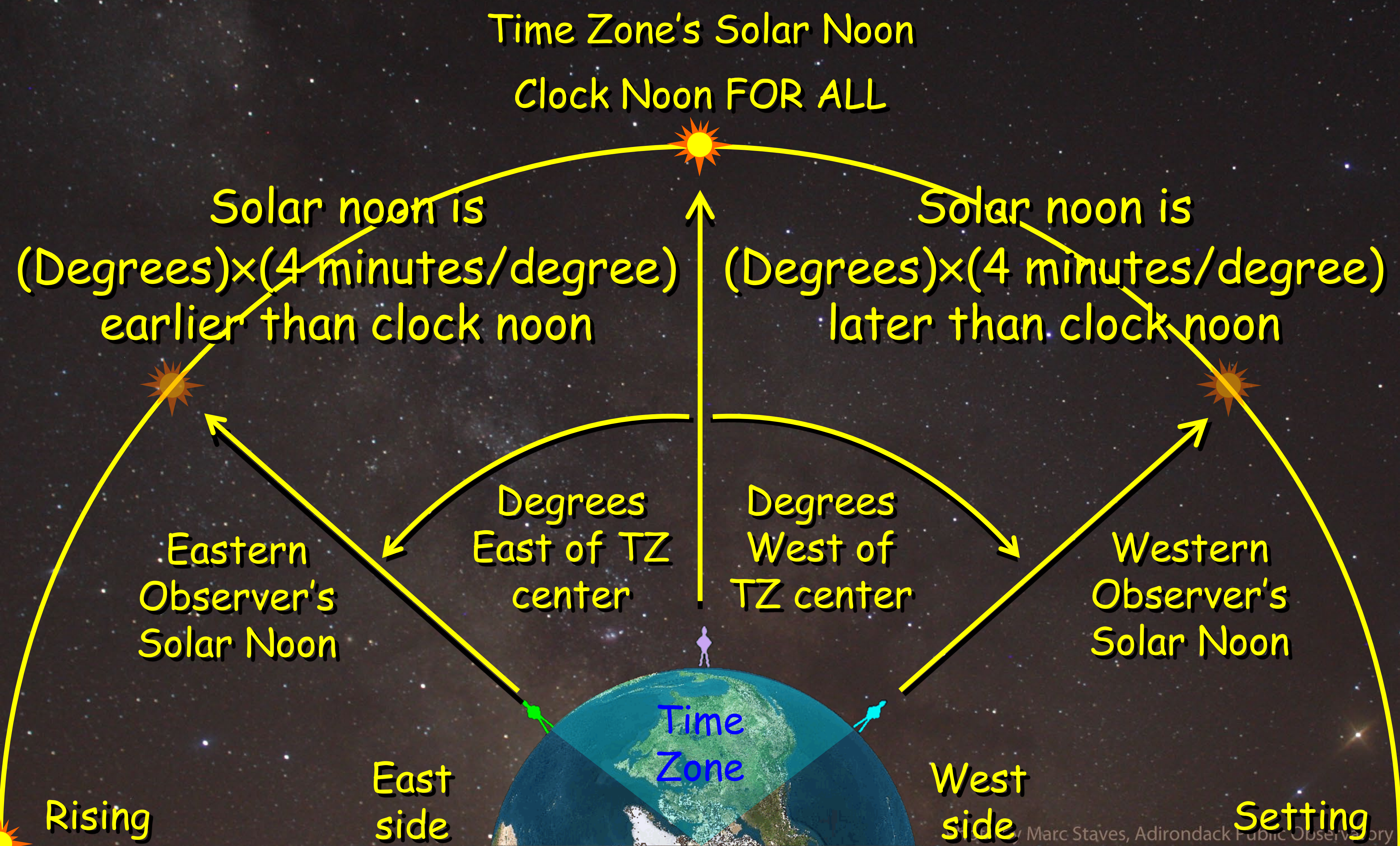
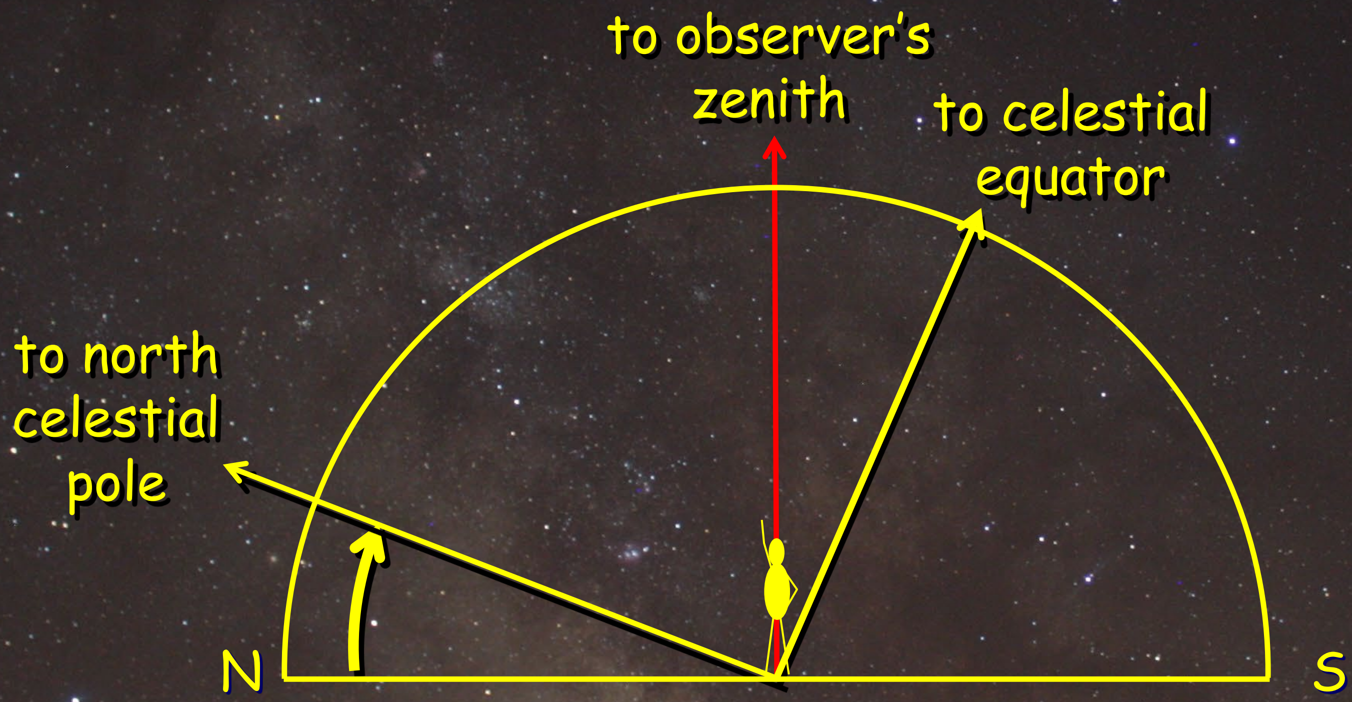


Celestial Navigation

- ☆ Finding Latitude & Longitude from
  - Altitude of Polaris (NCP)
  - Transit time of star
    - ☽ Looked up in an ephemeris (eg. Field Guide)



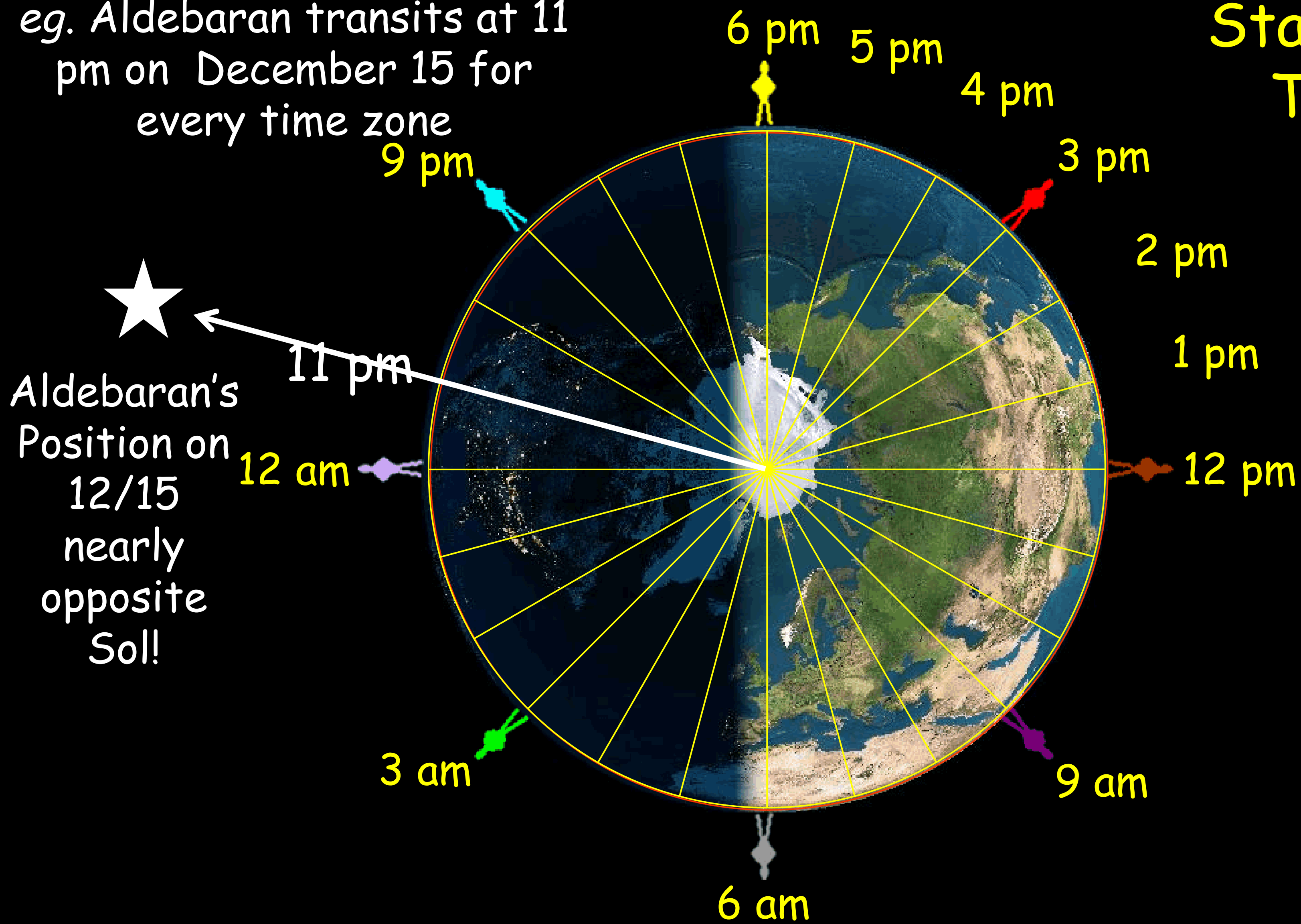
Observer at 20° N

Star Transit Time

Gives position of star with respect to the sun

eg. Aldebaran transits at 11 pm on December 15 for every time zone

Standard Time



Clicker Question

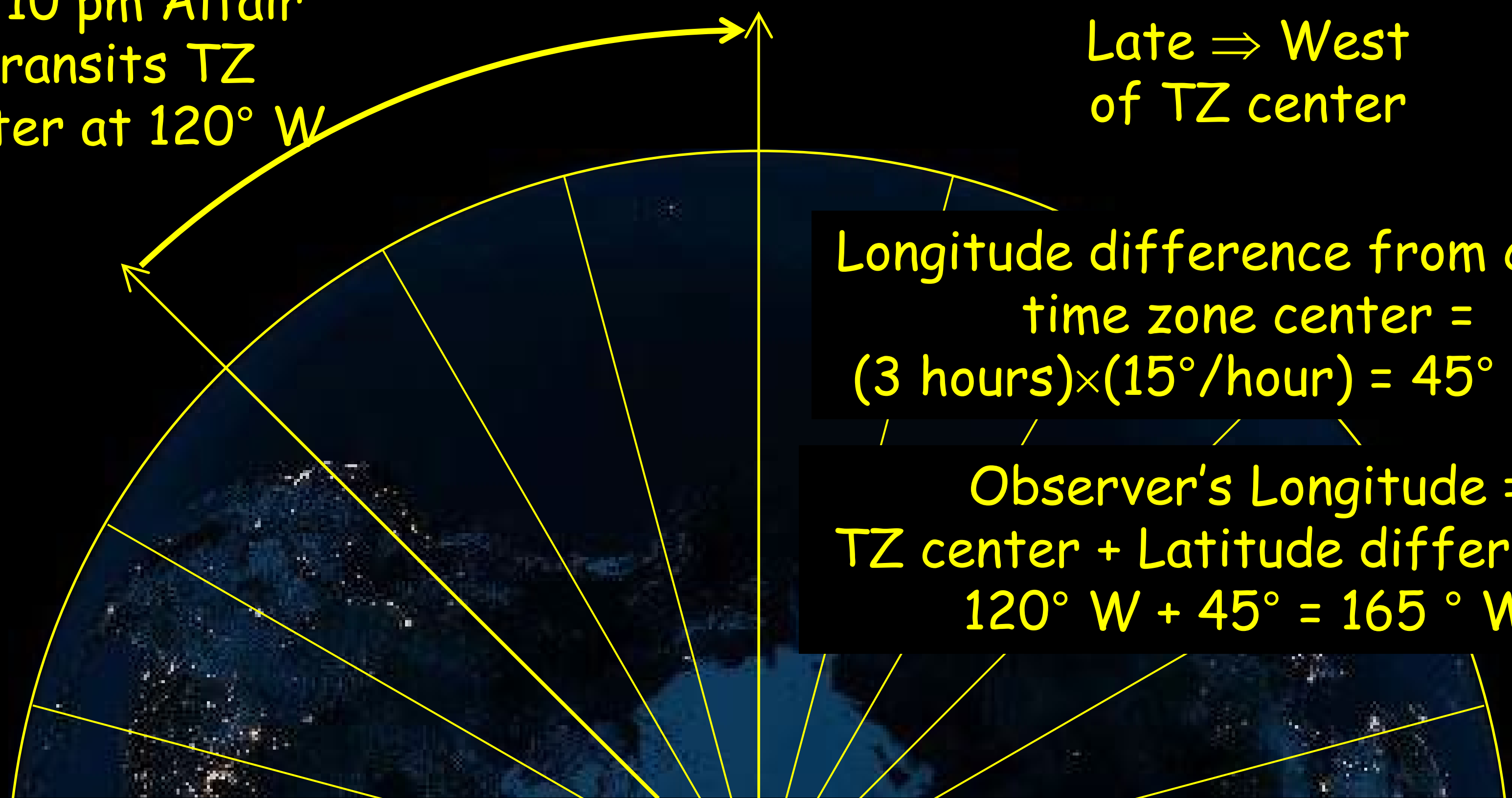
- ☆ What's your longitude if you see Altair transit at 1 am on September first and your watch is set for Pacific time?

On 9/1 Altair transits at 10 pm PDT

At 10 pm Altair transits TZ center at 120° W

Observer sees Altair transit at 1 am PDT

Late ⇒ West of TZ center



Longitude difference from clock's time zone center = (3 hours)×(15°/hour) = 45° West

Observer's Longitude = TZ center + Latitude difference = 120° W + 45° = 165 ° W

Models of Earth

Why are globes tilted?

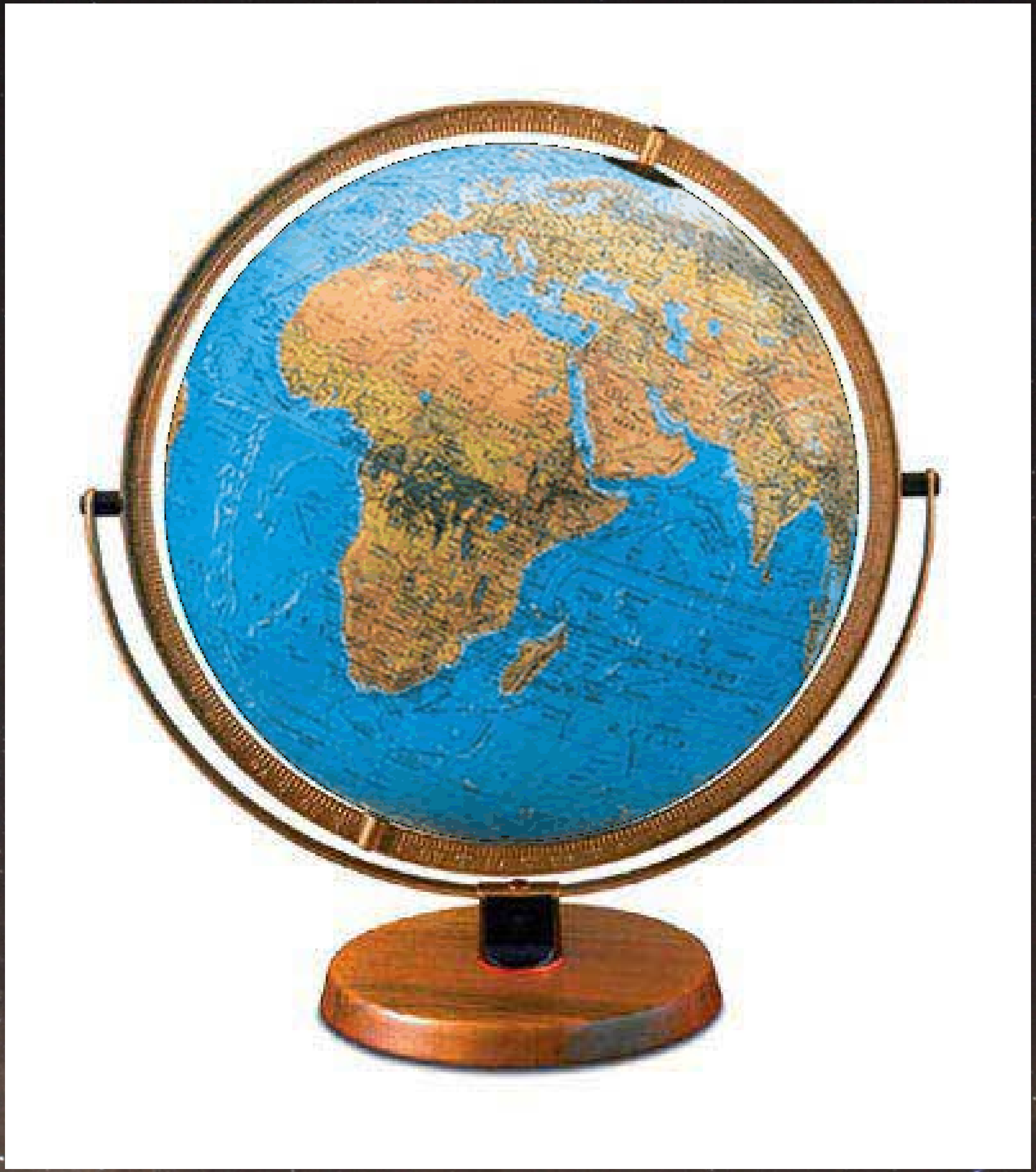


Photo by Marc Staves, Adirondack Public Observatory

Earth's Orbit

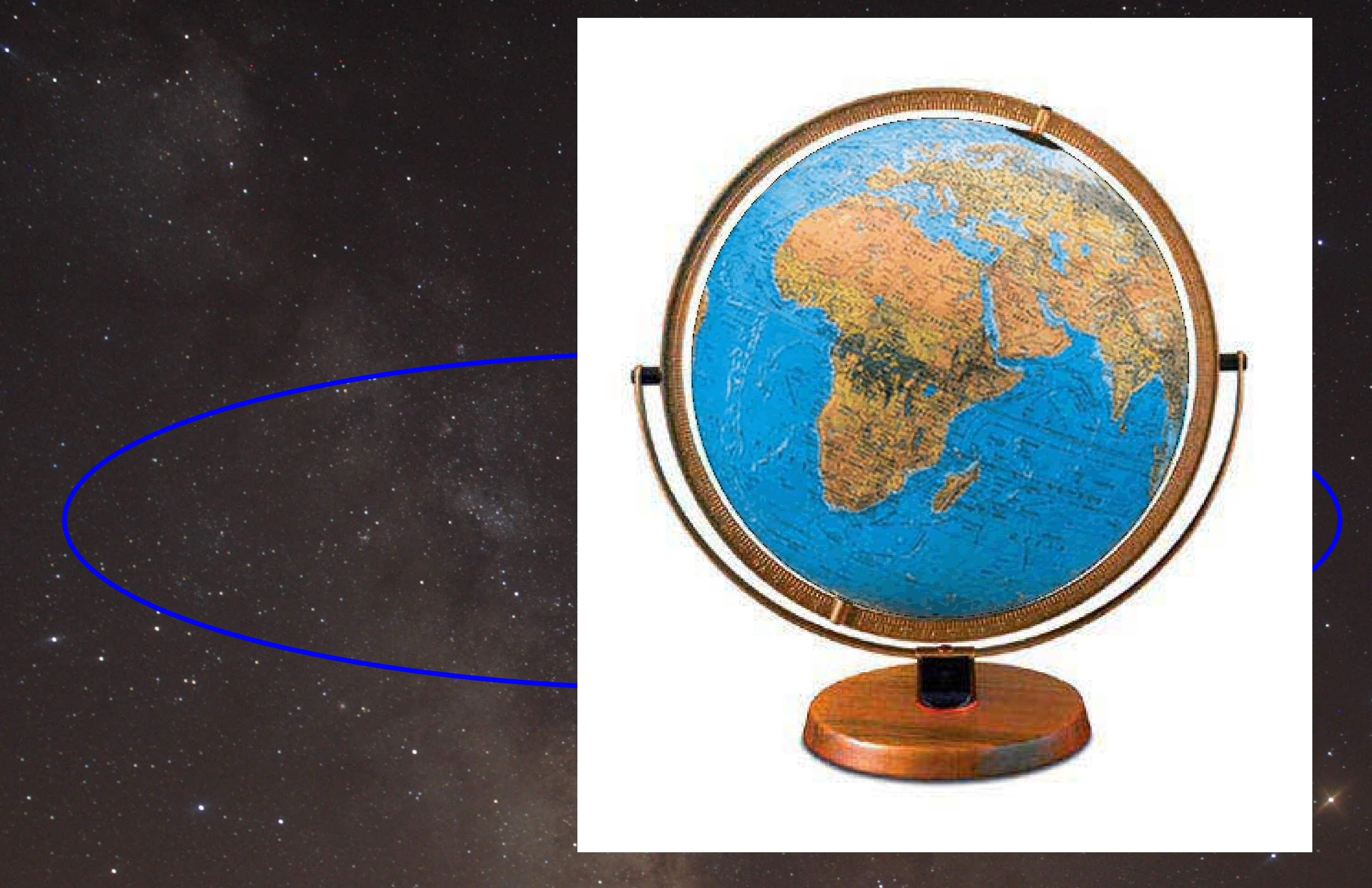


Photo by Marc Staves, Adirondack Public Observatory

Earth's Orbit

- ☆ Ellipse with Sun at one focus
  - perihelion – closest to sun
    - January 4, 2023 at 11:17 am EST
    - Earth moving fastest … Feb is short!
  - aphelion – farthest from sun
    - July 6, 2023 at 4:06 pm EDT
- ☆ N Pole toward Polaris

Earth's Orbit

☆ Rotation Axis tilted 23.5° from ⊥

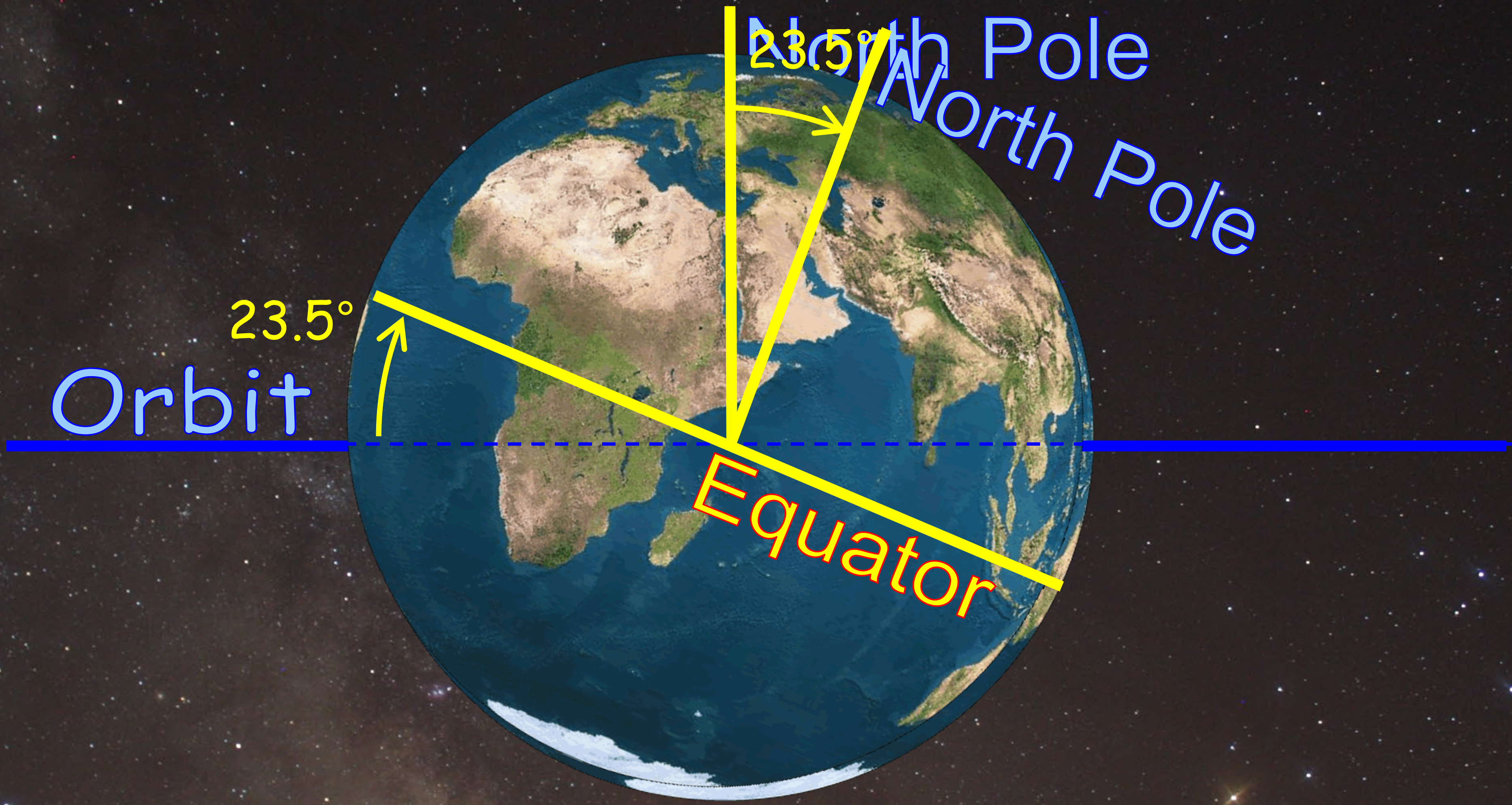
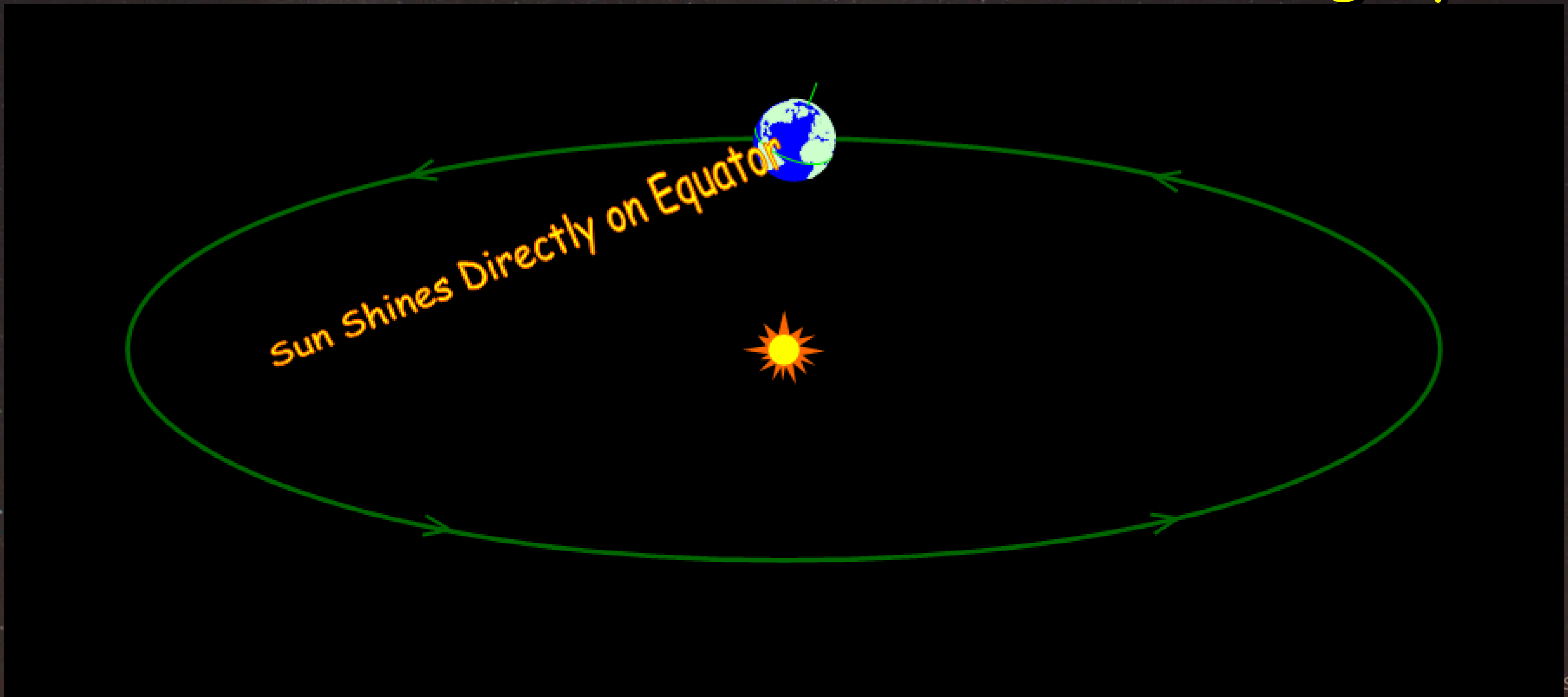


Photo by Marc Staves 2011

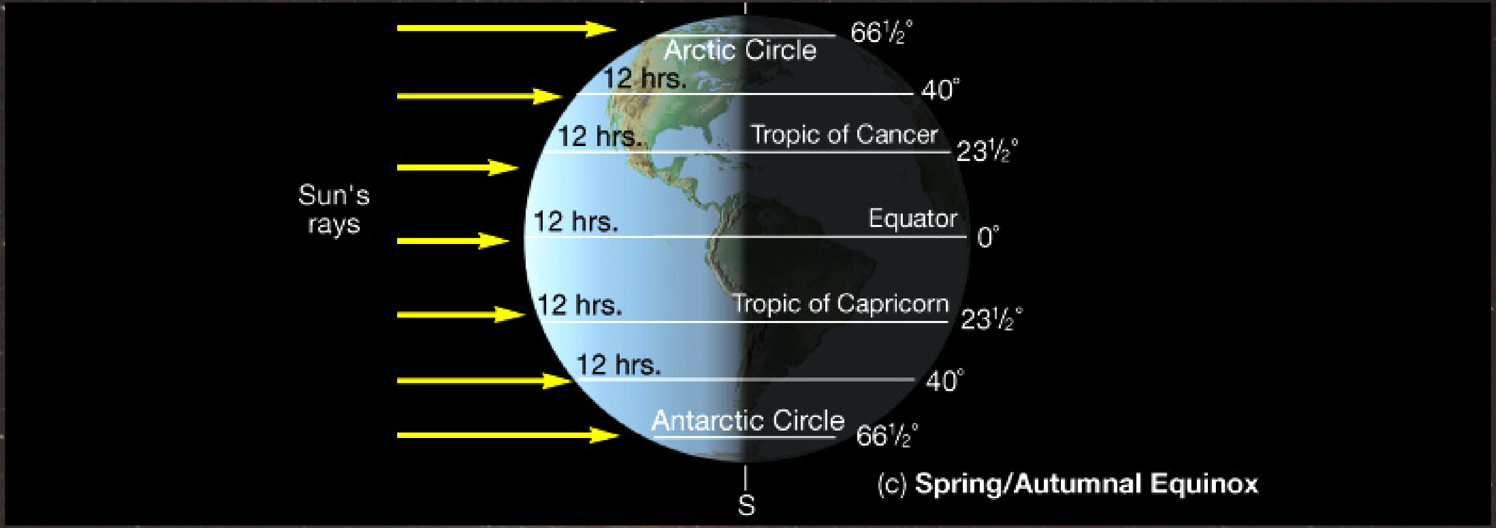
The Home World

- ☆ The Earth in space: Axis points at Polaris
  - 360° in 365 days ⇒ ~1°/day
  - Rotation axis tilted 23.5° from orbit axis
    - ⇒ Declination of sun varies through year
    - ⇒ subsolar latitude varies through year



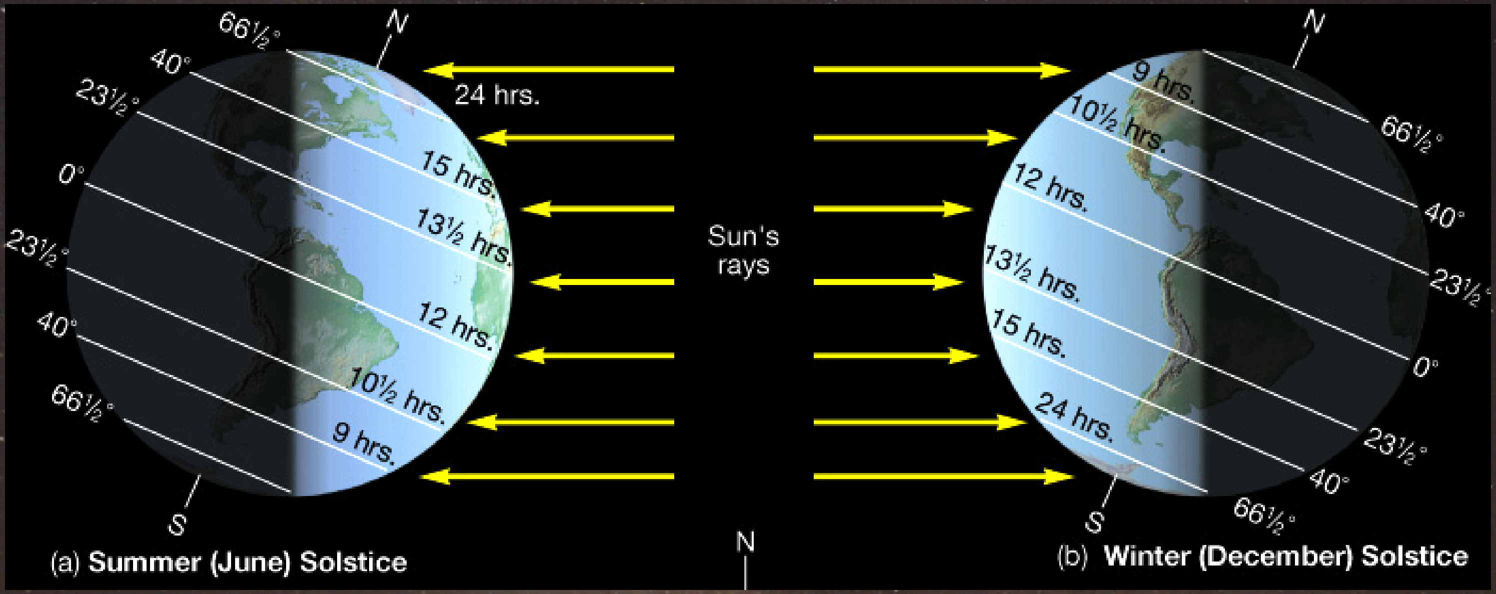
Seasons

- ☆ Equinox – sun on Celestial Equator
  - Vernal (spring): $\delta = 0°$, $\alpha = 0^h$
    - Sun crossing equator moving north
  - Autumnal (fall): $\delta = 0°$, $\alpha = 12^h$
    - Sun crossing equator moving south



Seasons

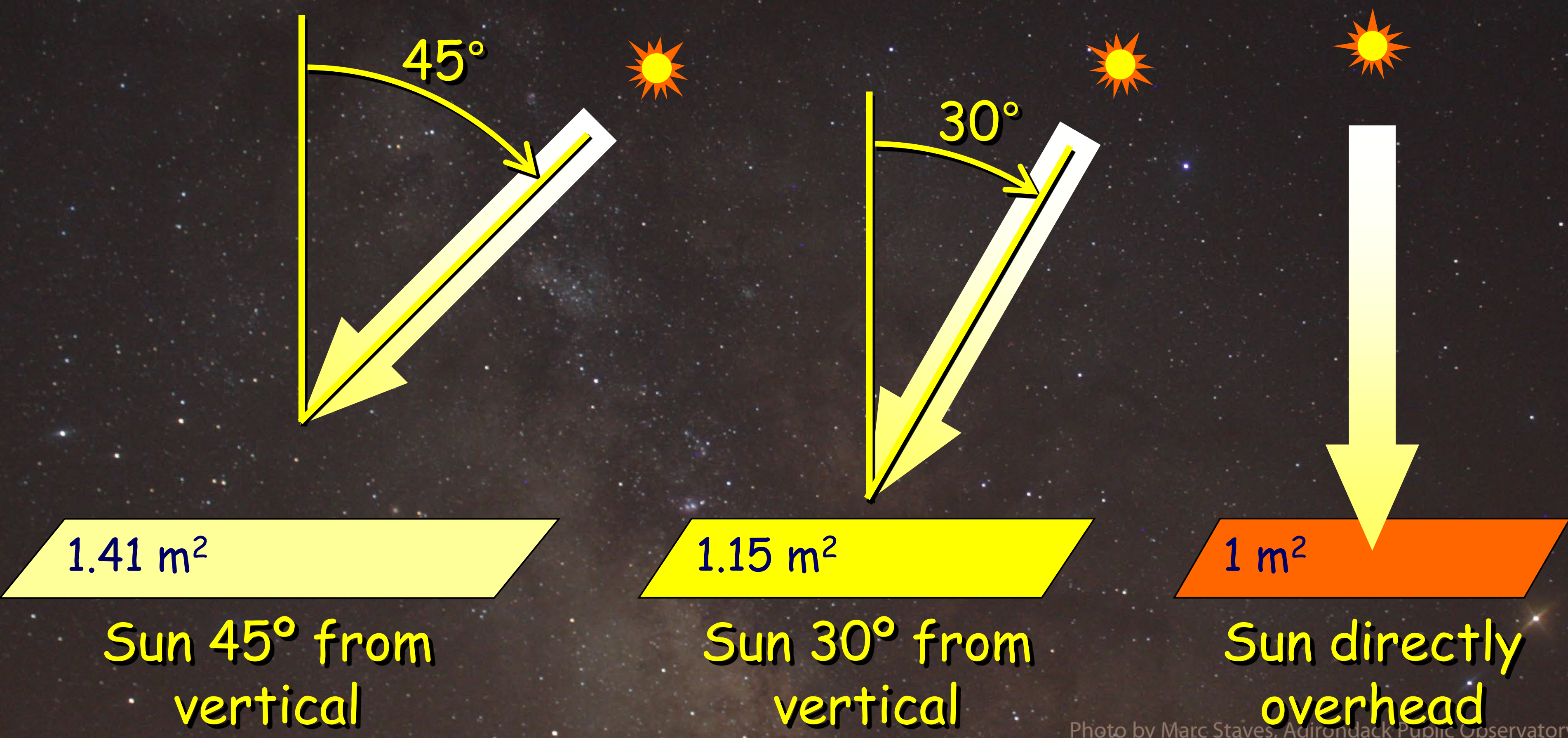
- ☆ Solstice – sun farthest north or south
  - Northern Summer $\delta = +23.5°$, $\alpha = 6^h$
    - Sun over Tropic of Cancer (23.5°N)
  - Northern Winter $\delta = -23.5°$, $\alpha = 18^h$
    - Sun over Tropic of Capricorn (23.5°S)

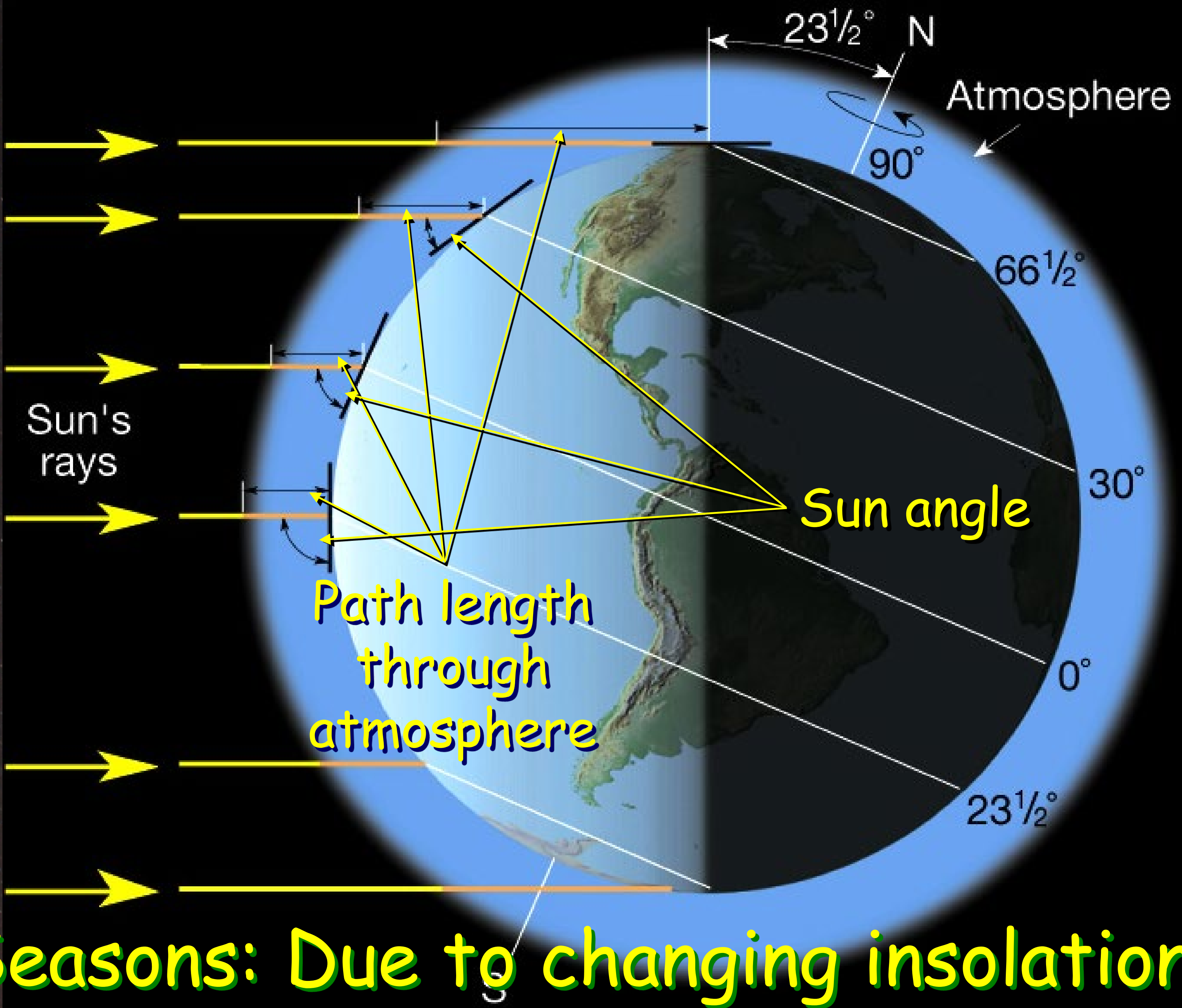


Seasons

☆ Due to changing angle of sunlight

- 🌎 At low angles, sunlight spreads out
  - ☽ less energy falls on any piece of ground

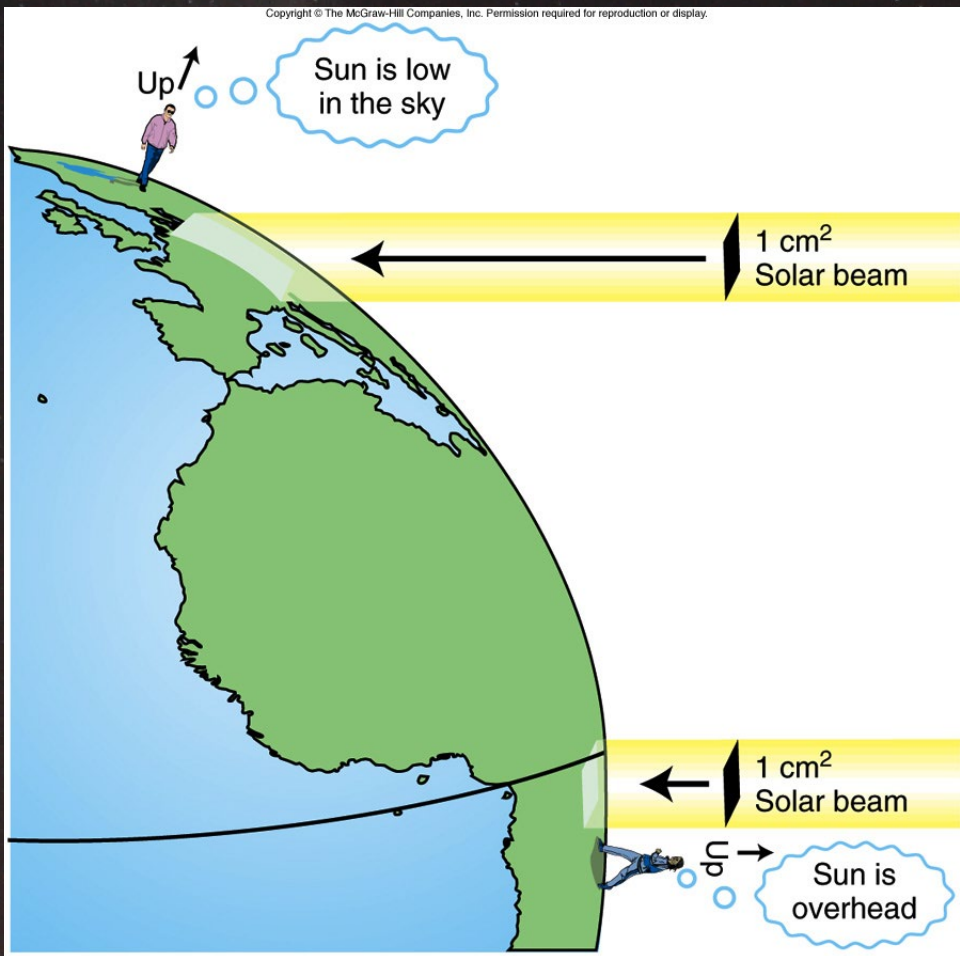


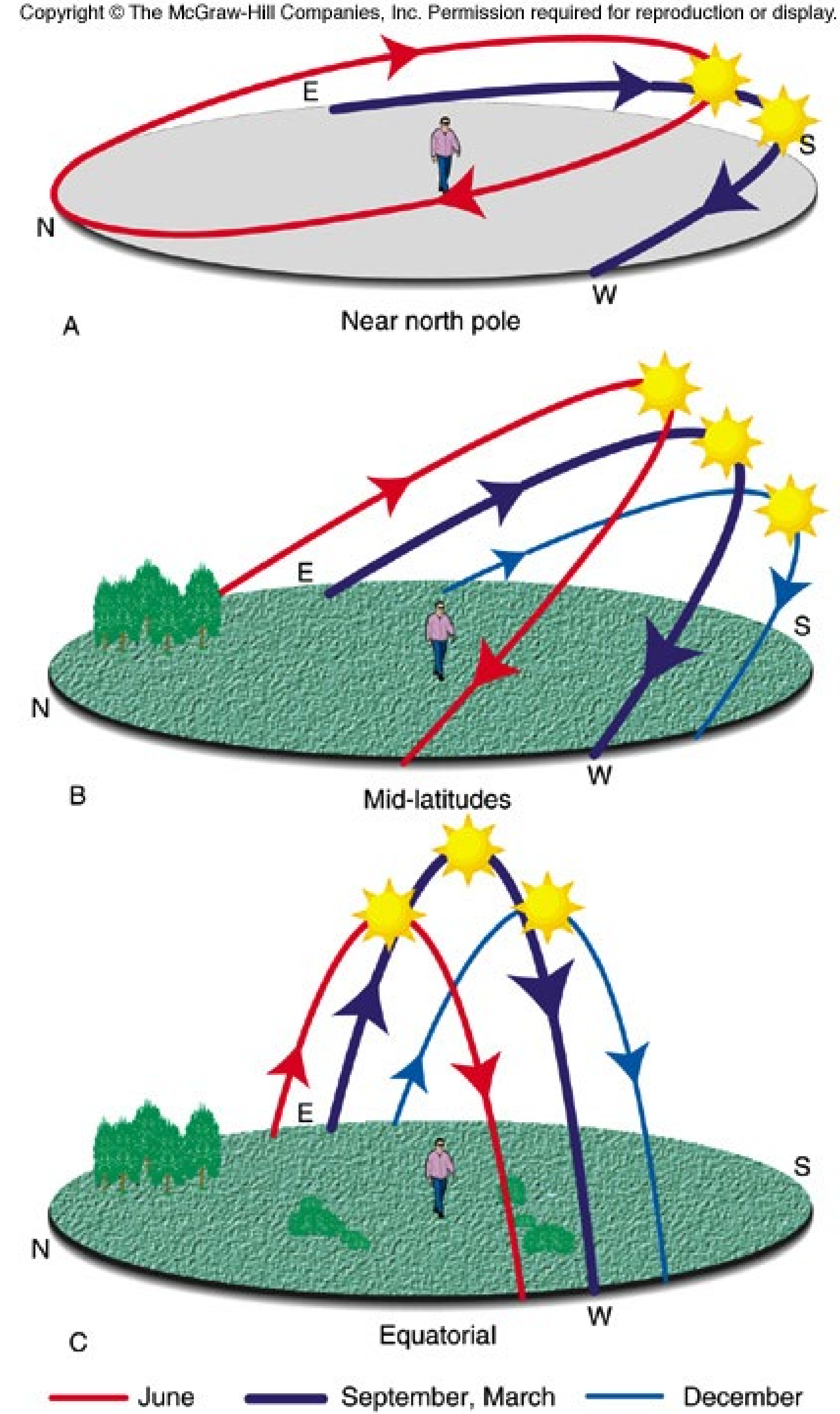


Seasons: Due to changing insolation.

Seasons

☆ Vary with latitude



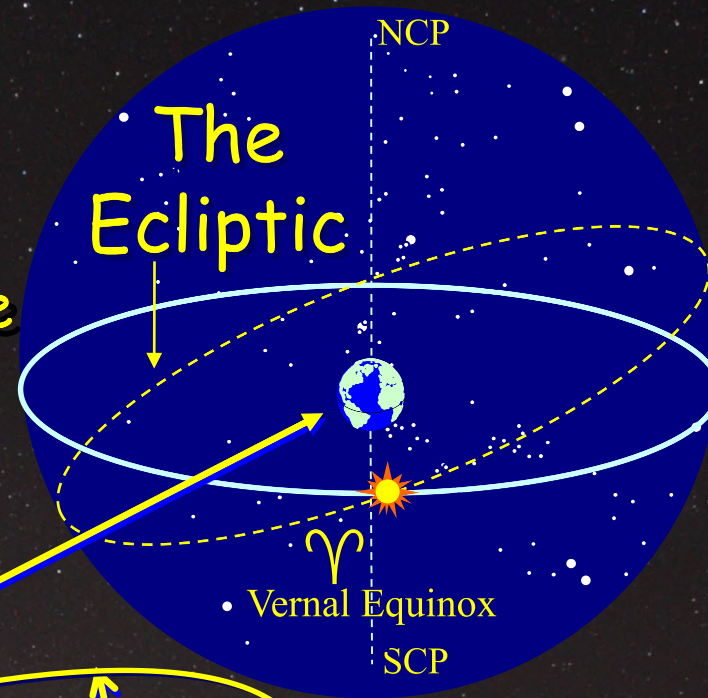


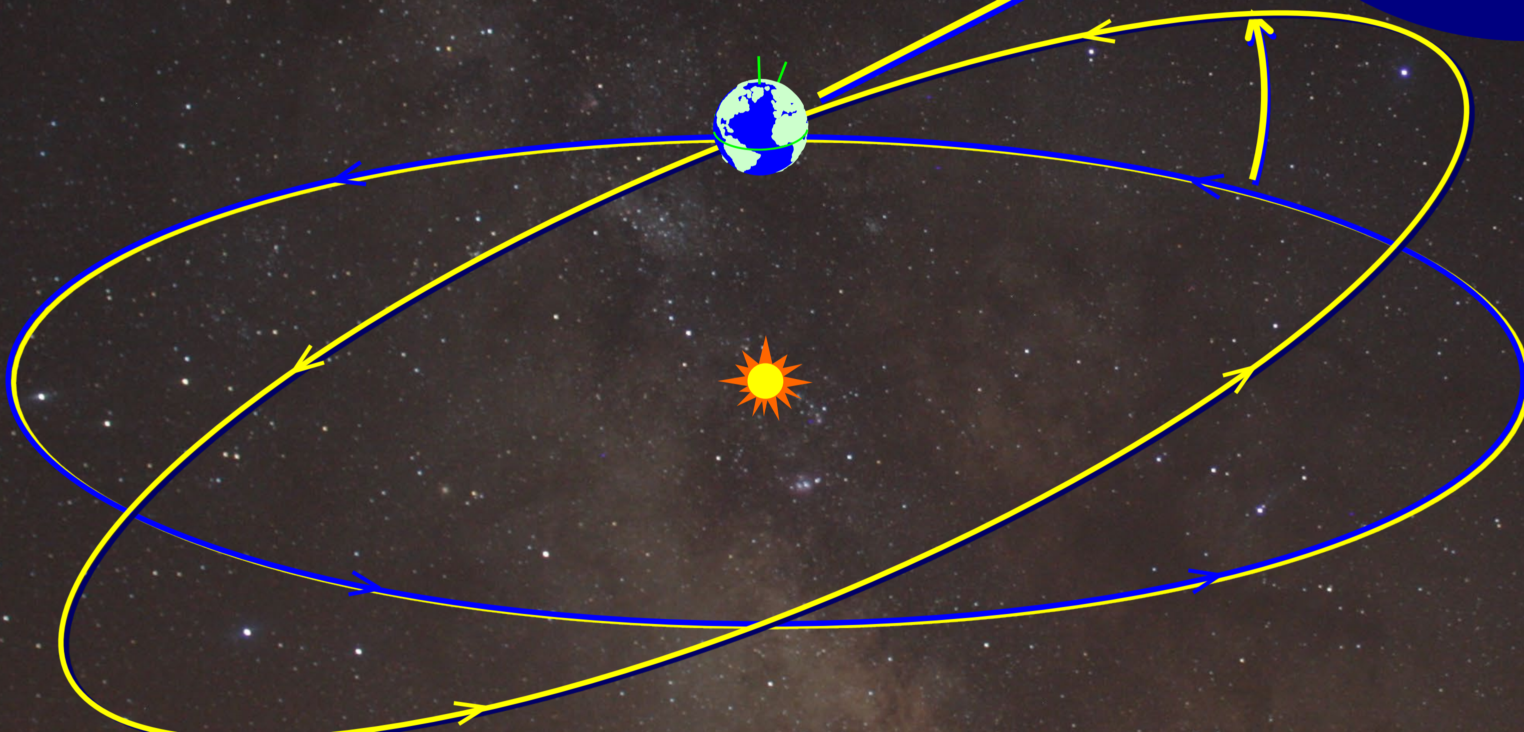
Seasons

- ☆ Equinox – sun on Celestial Equator
  - Vernal (spring) 0^h 0° — 5:24 pm, March 20, 2023
    - Sun crosses CE moving north
  - Autumnal (fall) 12^h 0° — 9:03 pm, September 22, 2022
    - Sun crosses CE moving south
- ☆ Solstice – sun farthest north or south
  - Northern Summer 6^h +23.5°
    - Sun northernmost (+23.5°) — 10:57 am, June 21, 2023
  - Southern Summer 18^h -23.5°
    - Sun southernmost (-23.5°) — 4:48 pm, December 21, 2022

Sun in the sky

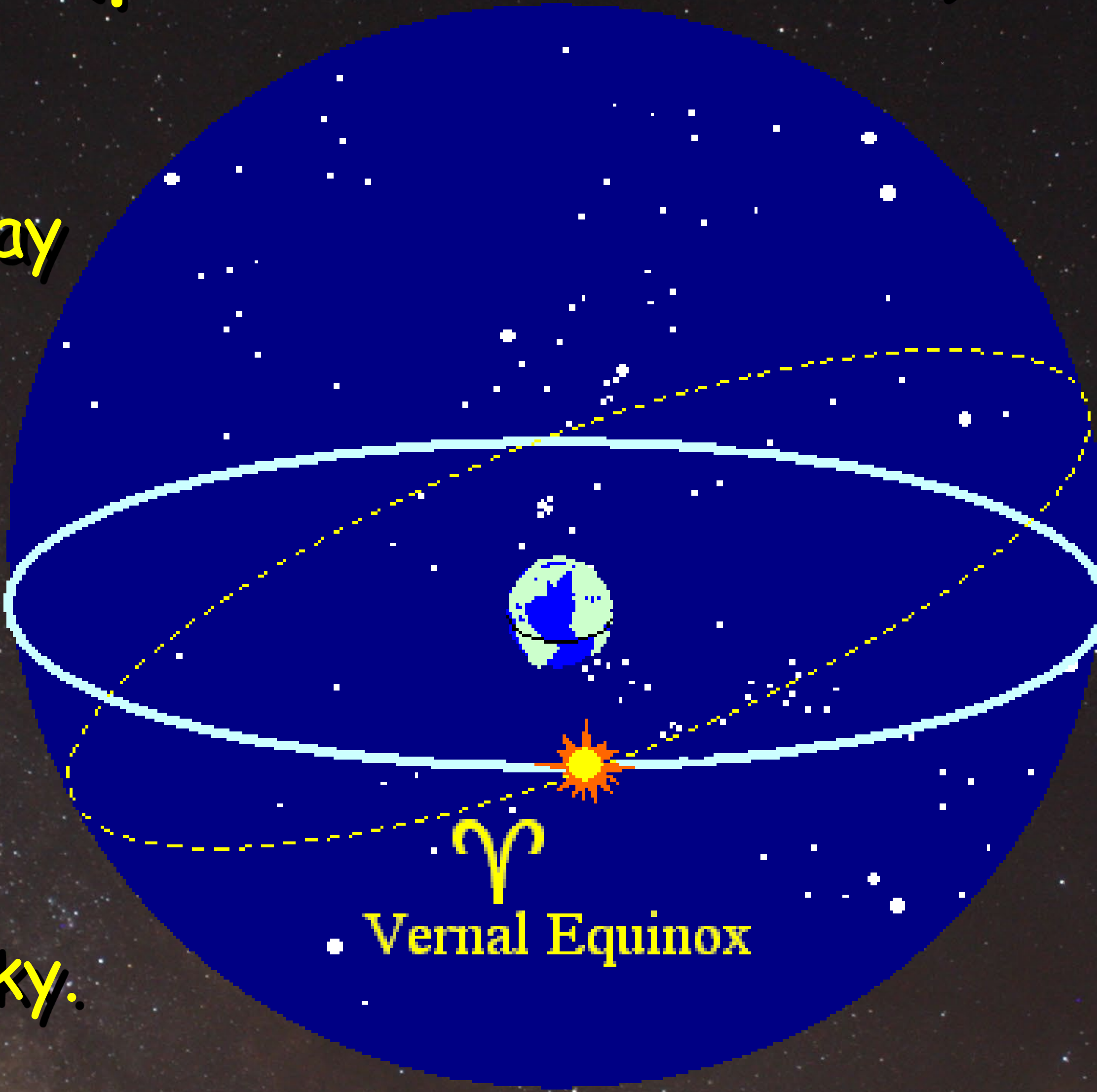
- ☆ View from Earth
  - Rotate to Earth's equatorial plane
  - Center on Earth
  - Project sun onto sky





The Ecliptic (path of the sun)

- ☆ View from Earth
  - Sun moves ~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!

Sun's path on a winter day

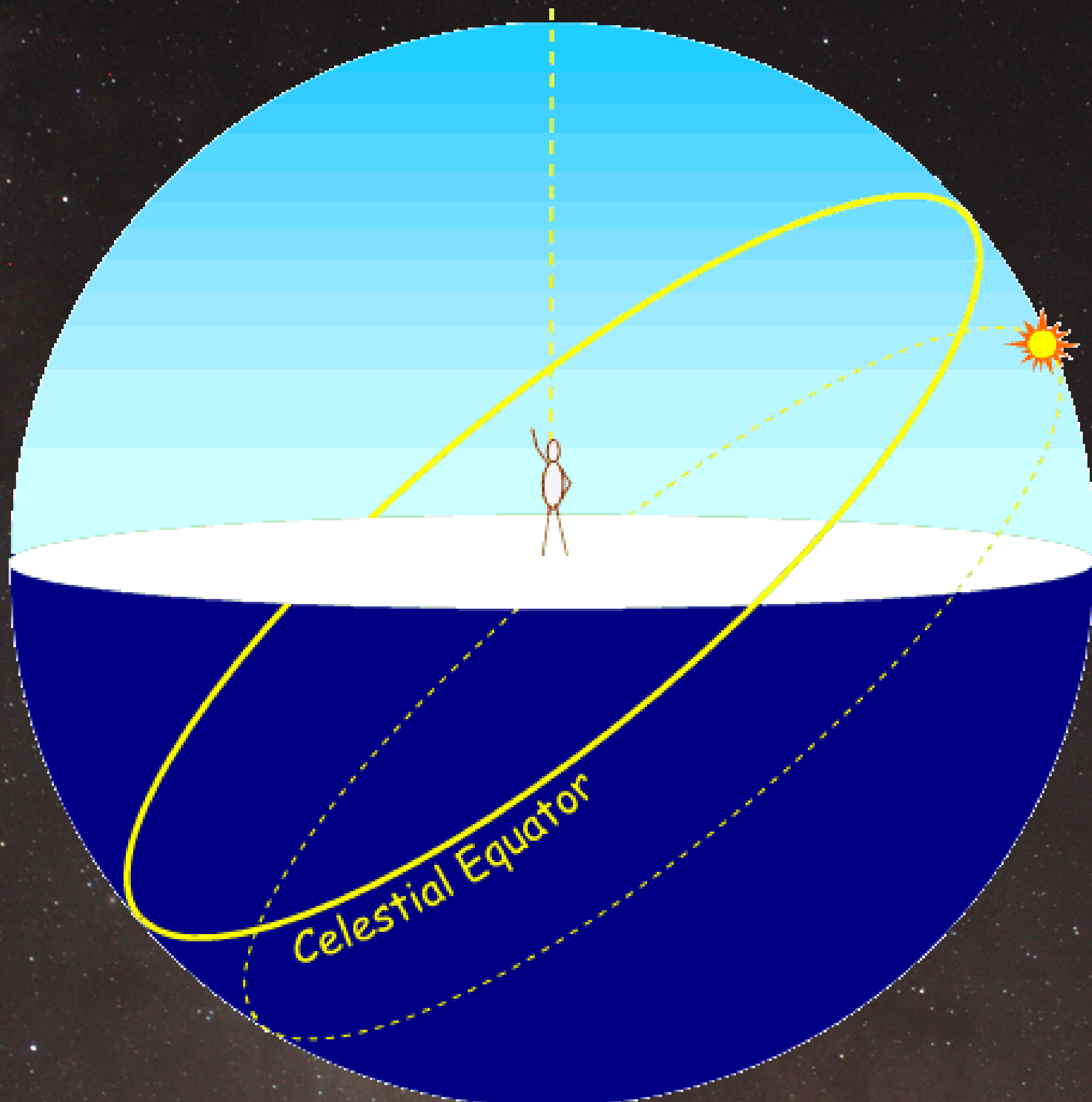


Photo by Marc Staves, Adirondack Public Observatory

Sun's path on a winter day

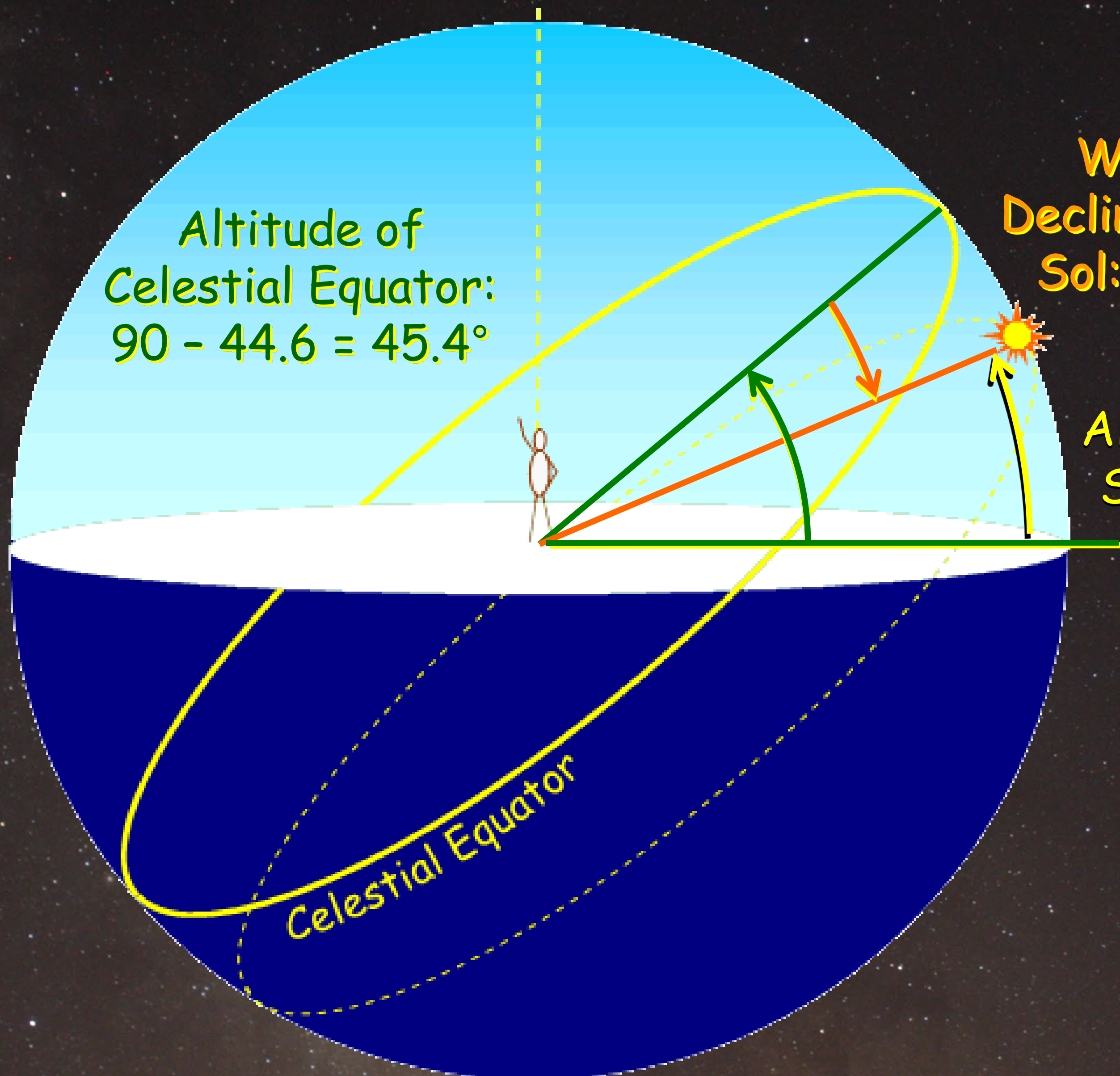
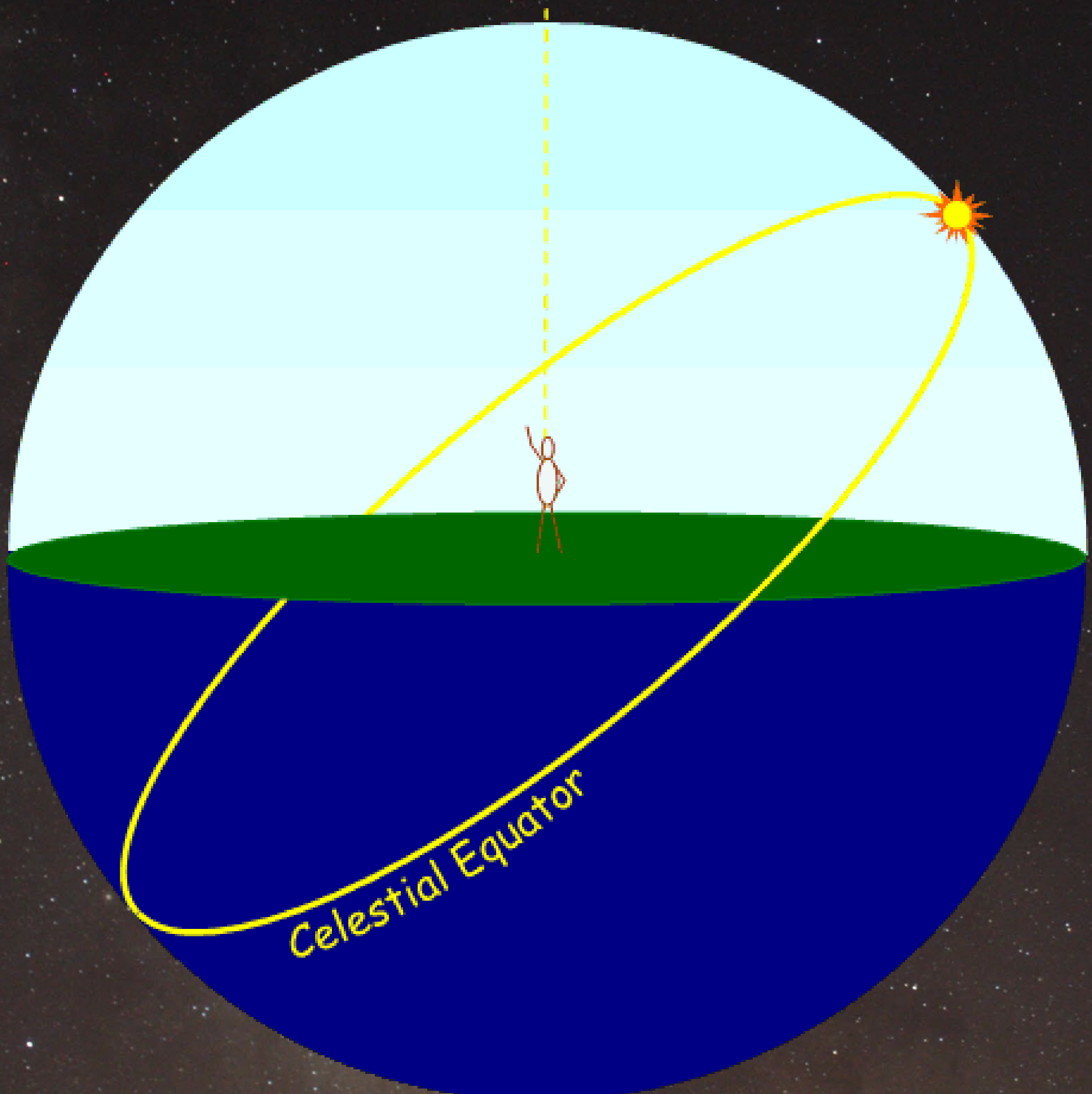
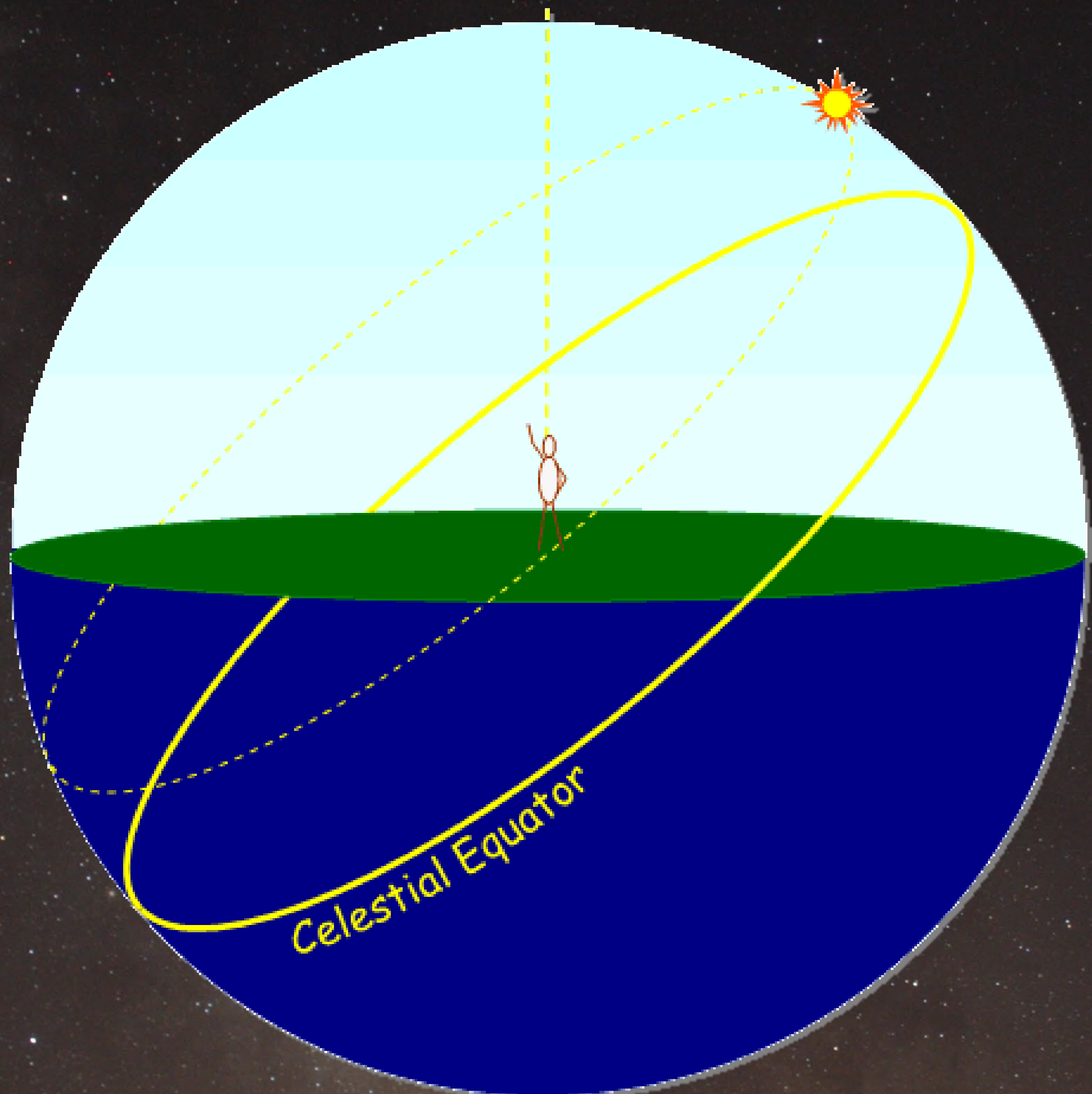


Photo by Marc Staves, Adirondack Public Observatory

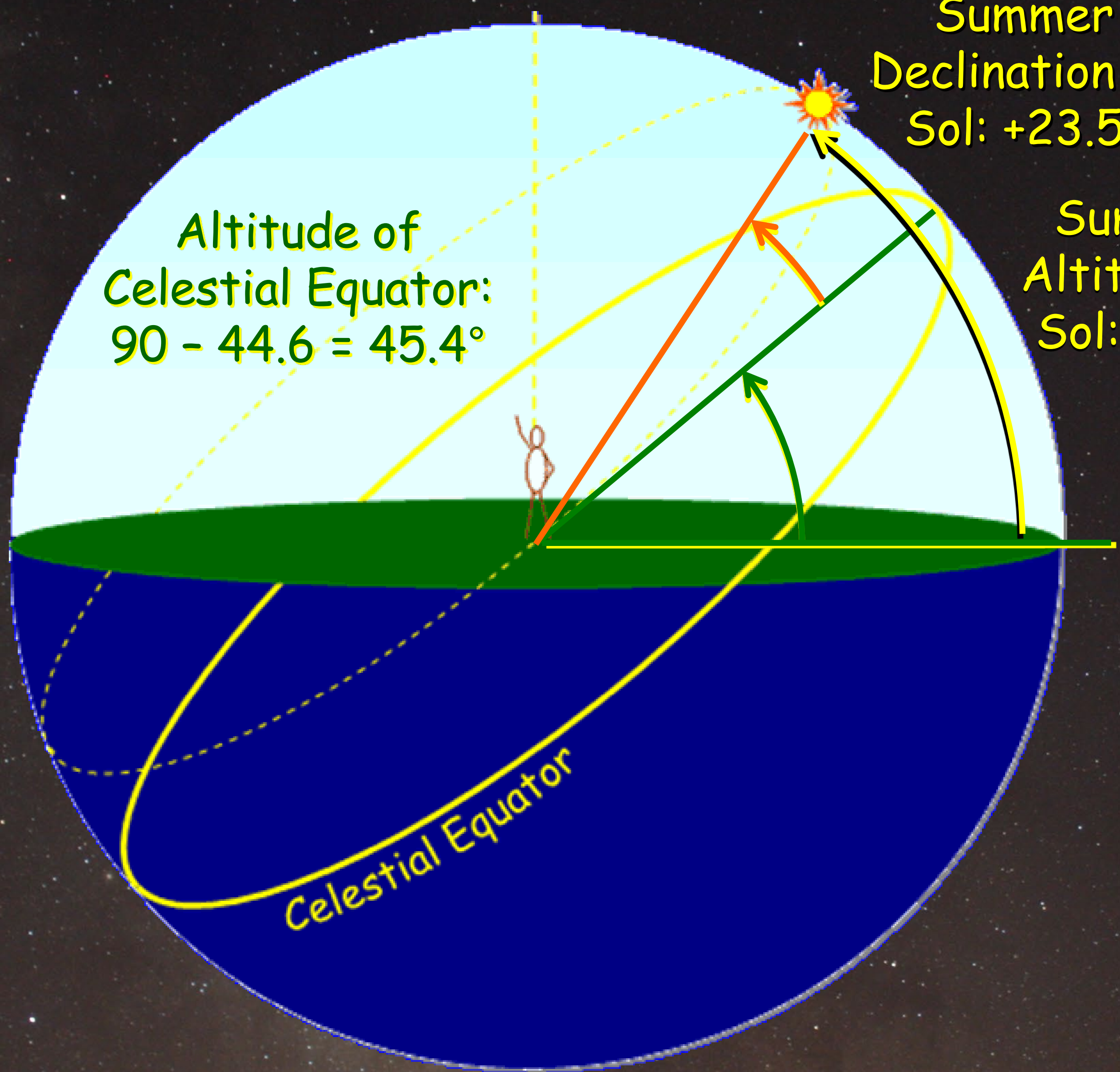
Sun's path on a fall/spring day



Sun's path on a summer day



Sun's path on a summer day



Clicker Question

At noon on the summer solstice, the sun's maximum altitude in Key West (24.6°N) is

A. 41.9°

B. 65.4°

C. 88.9°

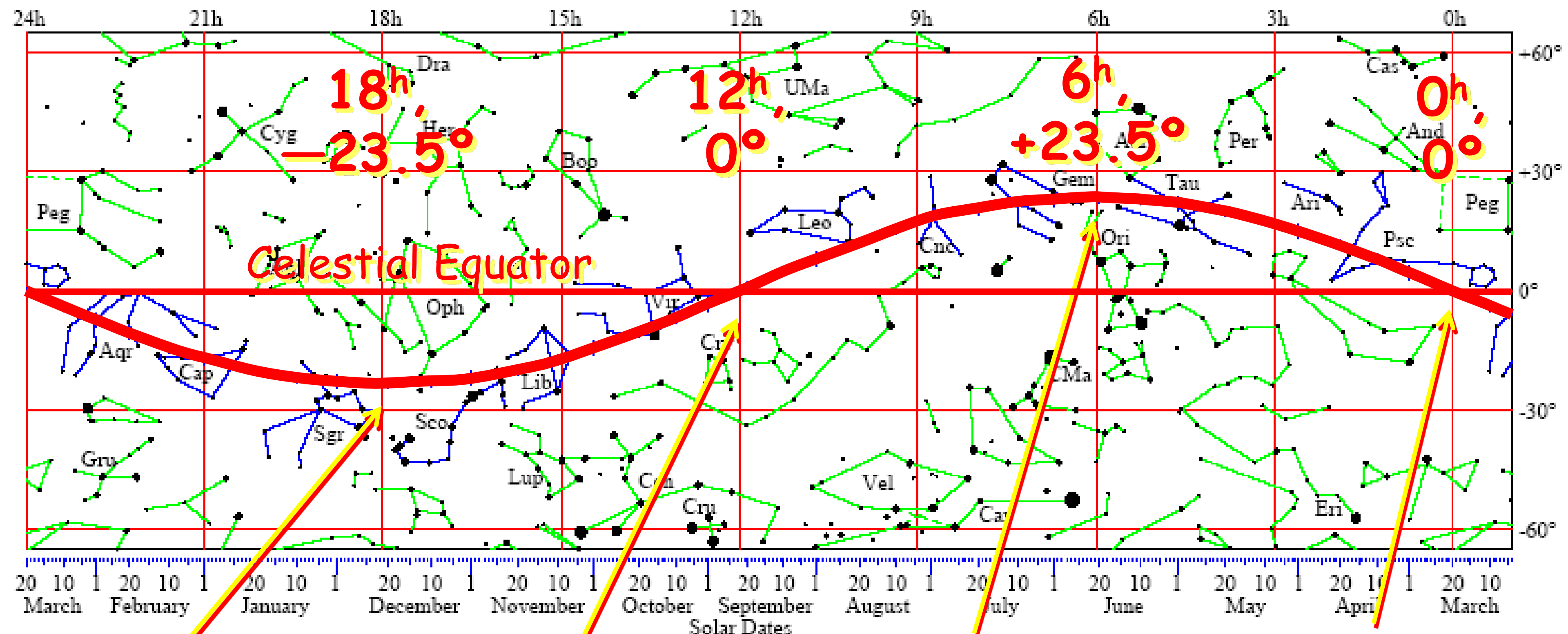
Hint:
90° – 24.6° = 65.4°

Hint: What is
65.4° + 23.5?

Photo by Marc Staves, Adirondack Public Observatory

Sun in the sky

- ☆ View from Earth
  - Sun moves ~1°/day eastward across stars
  - Sun moves north and south in declination



Winter Solstice in Sagittarius

Autumnal Equinox in Virgo

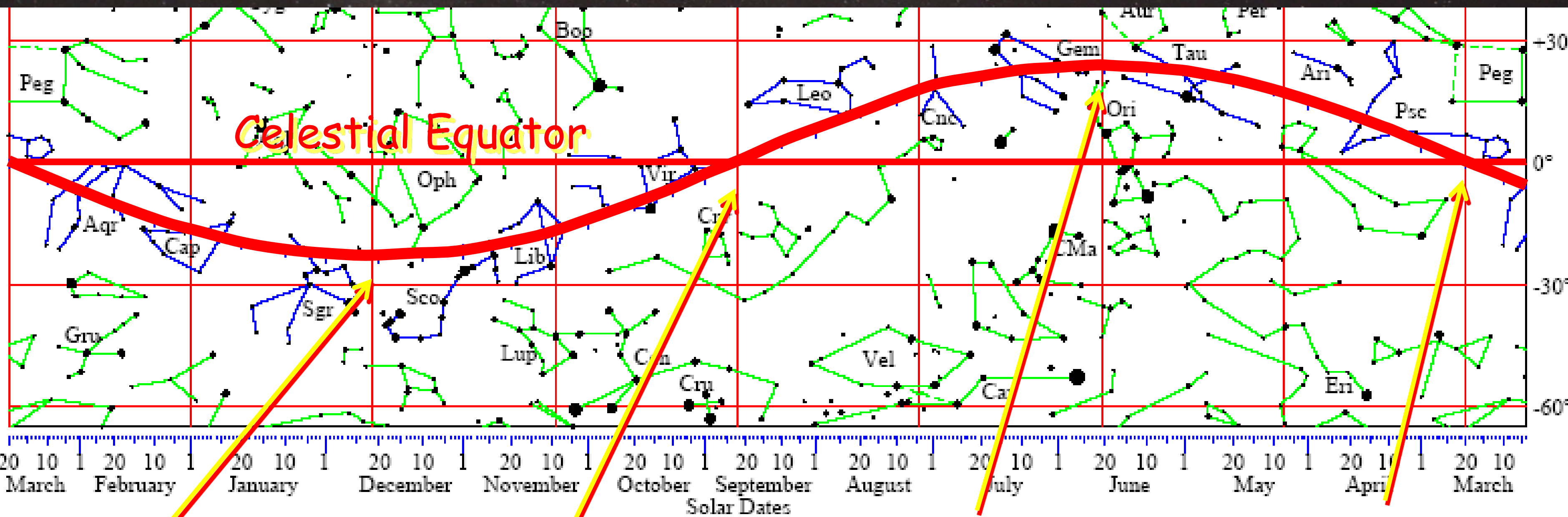
Summer Solstice in Taurus

Vernal Equinox in Pisces

Photo by Marc Staves, Adirondack Public Observatory

Stars in the sky

- ☆ Midnight view from Earth
  - Stars opposite sun's position
    - see opposite season's constellations,
      - eg. Gemini is a winter sky constellation, Scorpius summer
  - Midnight "window" shifts 1° eastward/day



Winter Solstice in Sagittarius

Autumnal Equinox in Virgo

Summer Solstice in Taurus

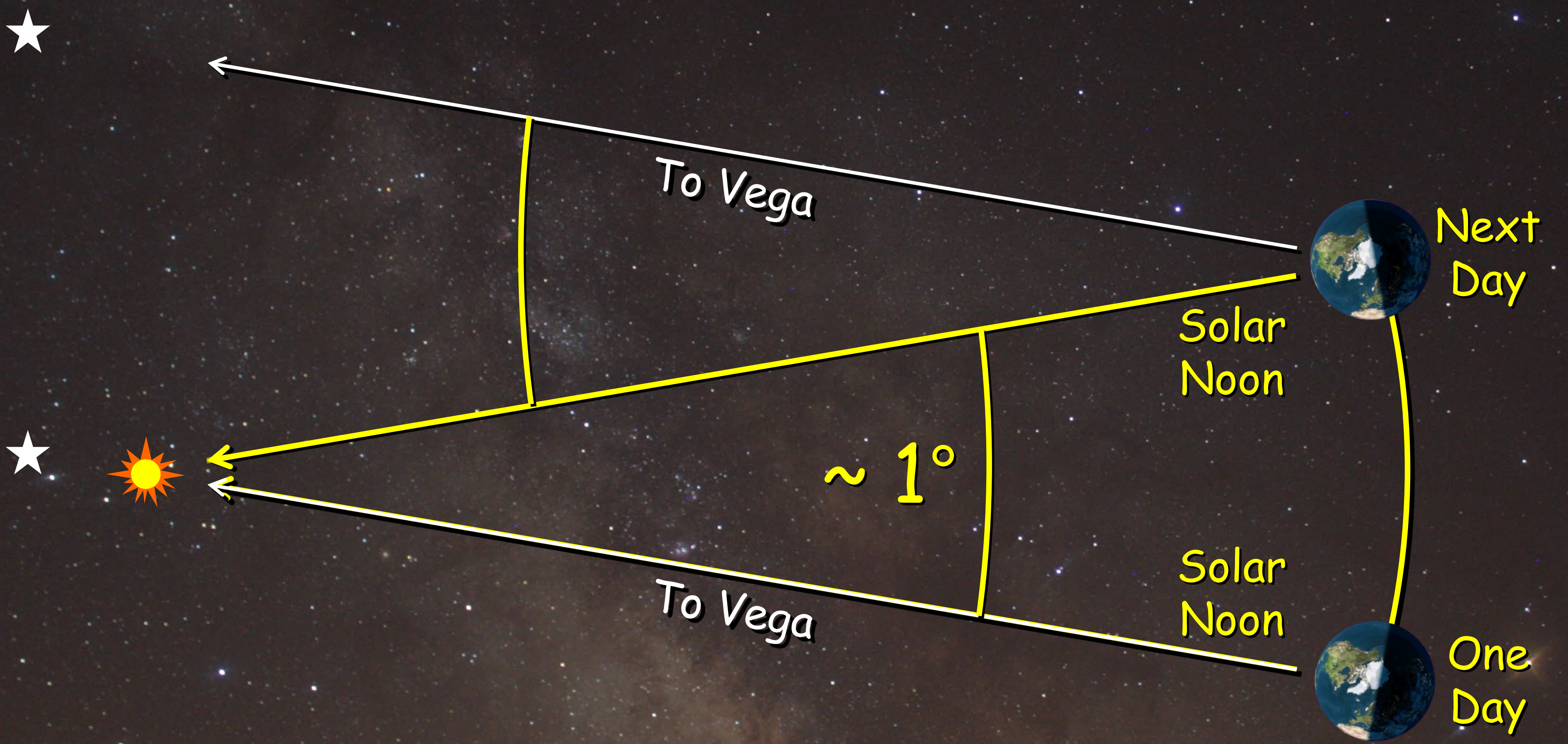
Vernal Equinox in Pisces

Time

- ☆ Clock Time
  - the position of the mean sun at TZ center
    - ☽ eg. 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 wrt the observer
    - eg. Noon = sun transits
  - Solar Day varies as shown by analemma
- ☆ Sidereal Time
  - the position of ♈ wrt the observer
    - ☽ eg. 0^h Local Sidereal Time (LST) = ♈ transits
    - ☽ Sidereal time = R.A. on the meridian
  - Sidereal Day = 23:56:00

The Sidereal Day

- Earth turns 360° with respect to stars
  - eg. Vega transit to Vega Transit
- 23:56:00



The Sidereal Day

- Earth turns 360° with respect to stars
  - eg. Vega transit to Vega Transit
- 23:56:00

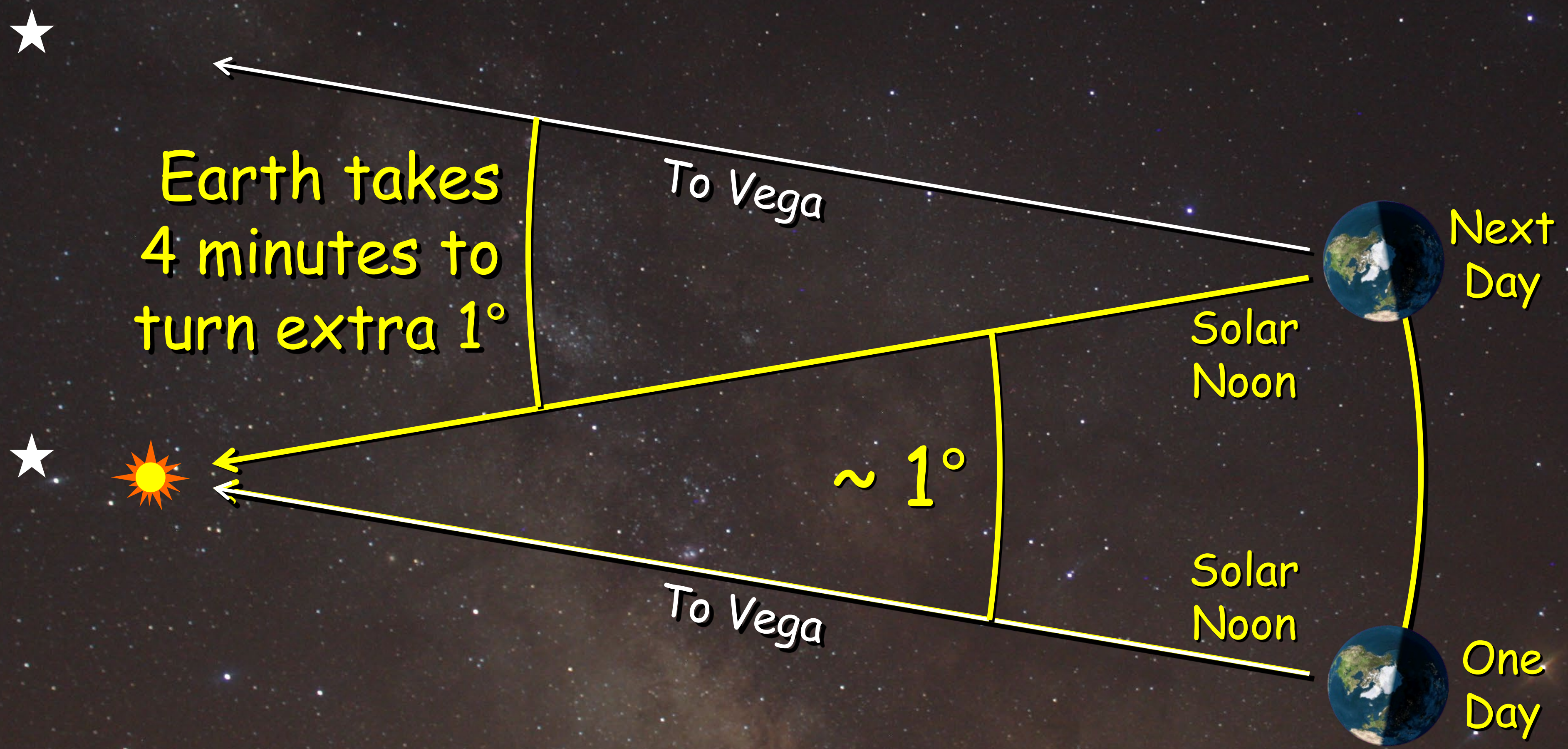
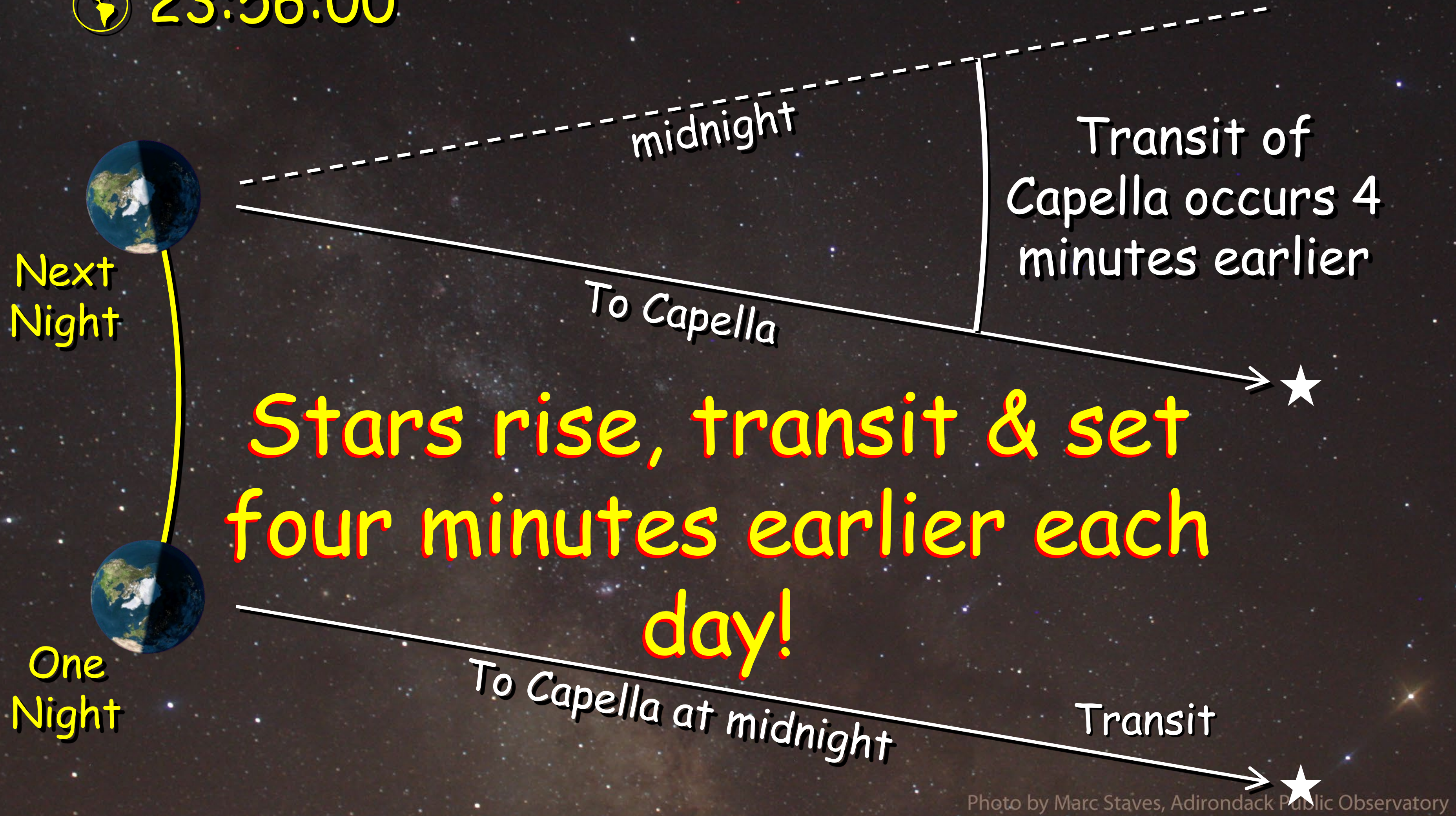


Photo by Marc Staves, Adirondack Public Observatory

The Sidereal Day

- Earth turns 360° with respect to stars
  - eg. Capella transit to Capella Transit
- 23:56:00



Stars rise, transit & set four minutes earlier each day!

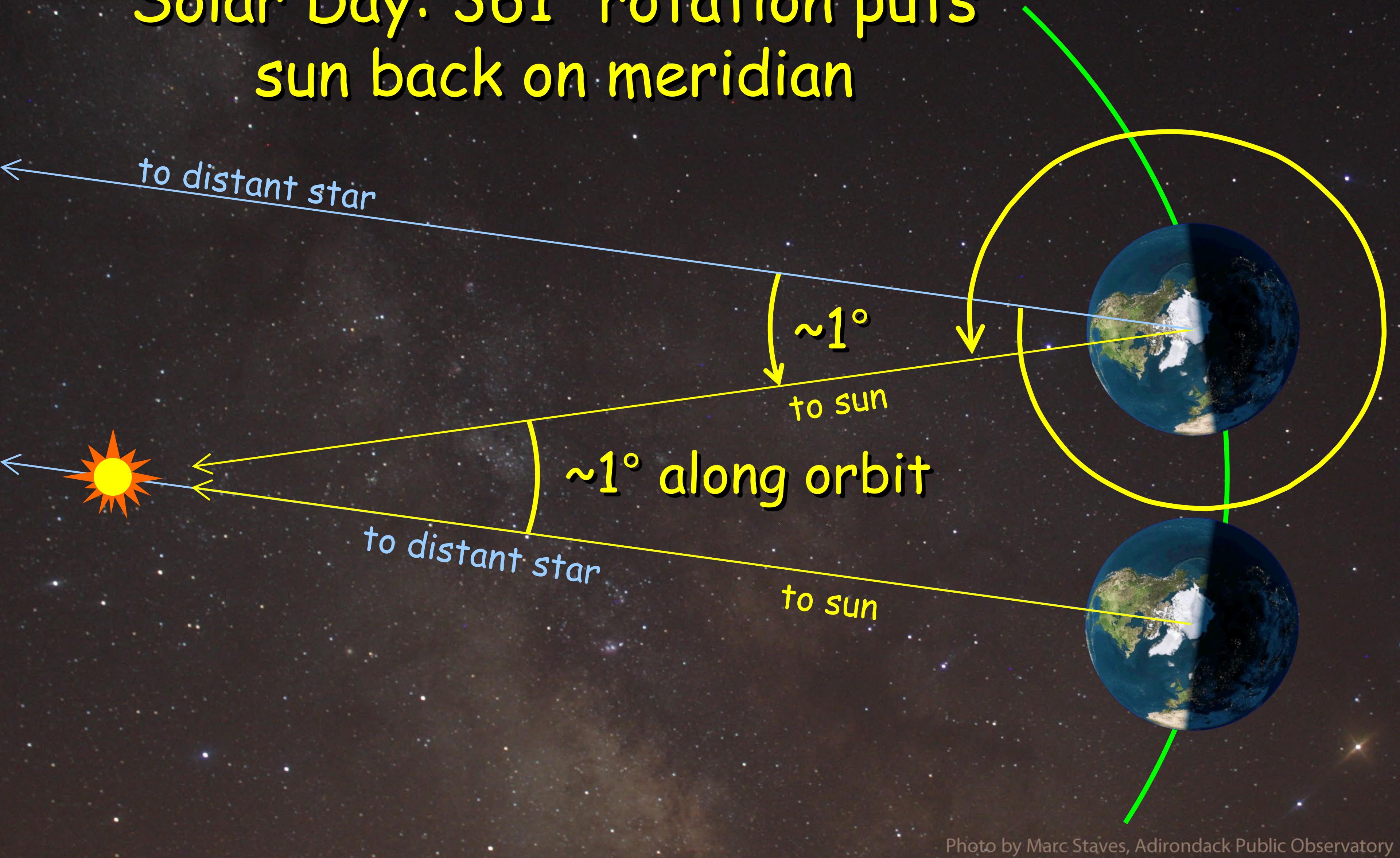
The Sidereal Day

Sidereal Day: 360° rotation puts star back on meridian

Photo by Marc Staves, Adirondack Public Observatory

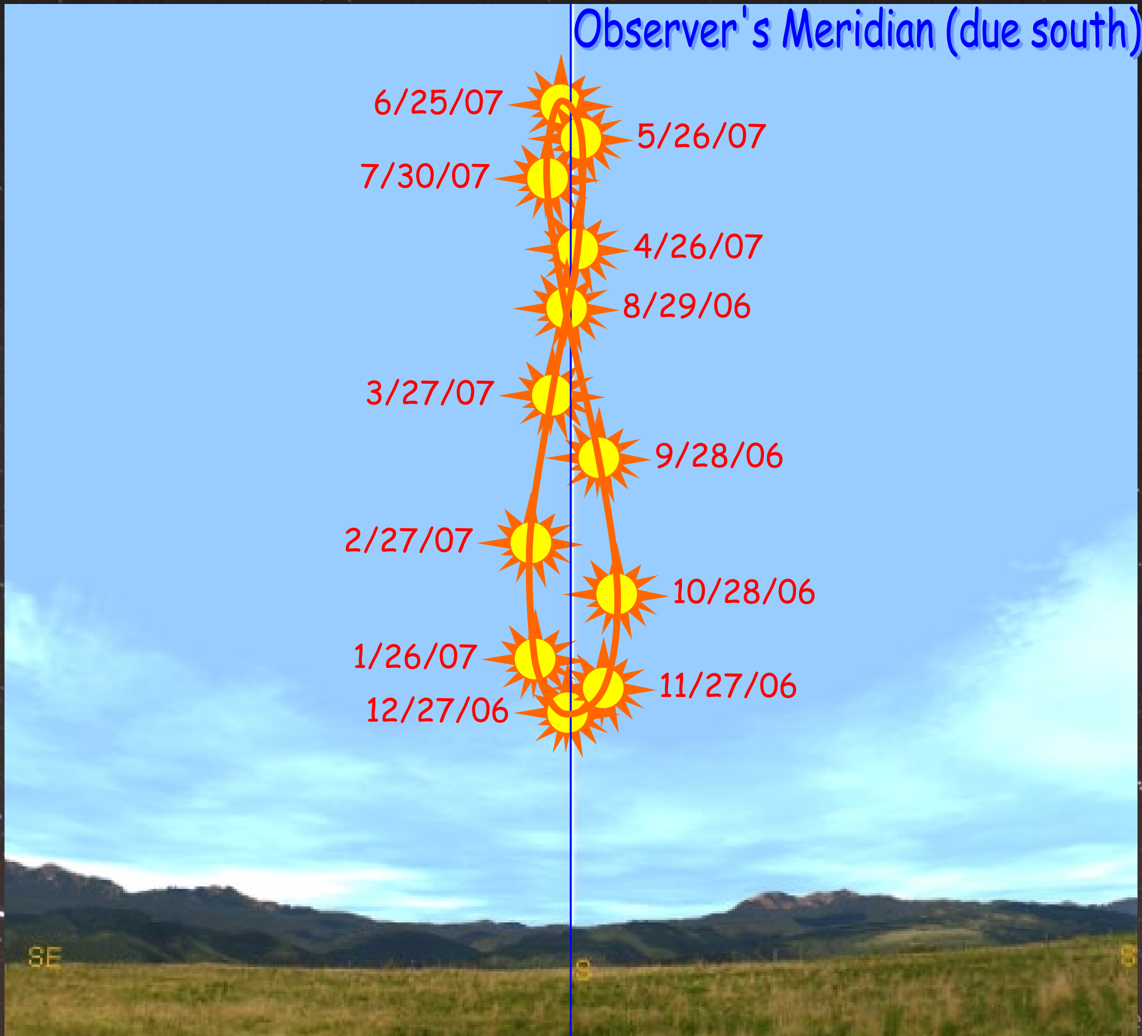
The Solar Day

Solar Day: 361° rotation puts sun back on meridian



The Sun at Noon

- ☆ Noon ⇒ Sun on meridian
- ☆ Sun's position varies: the Analemma



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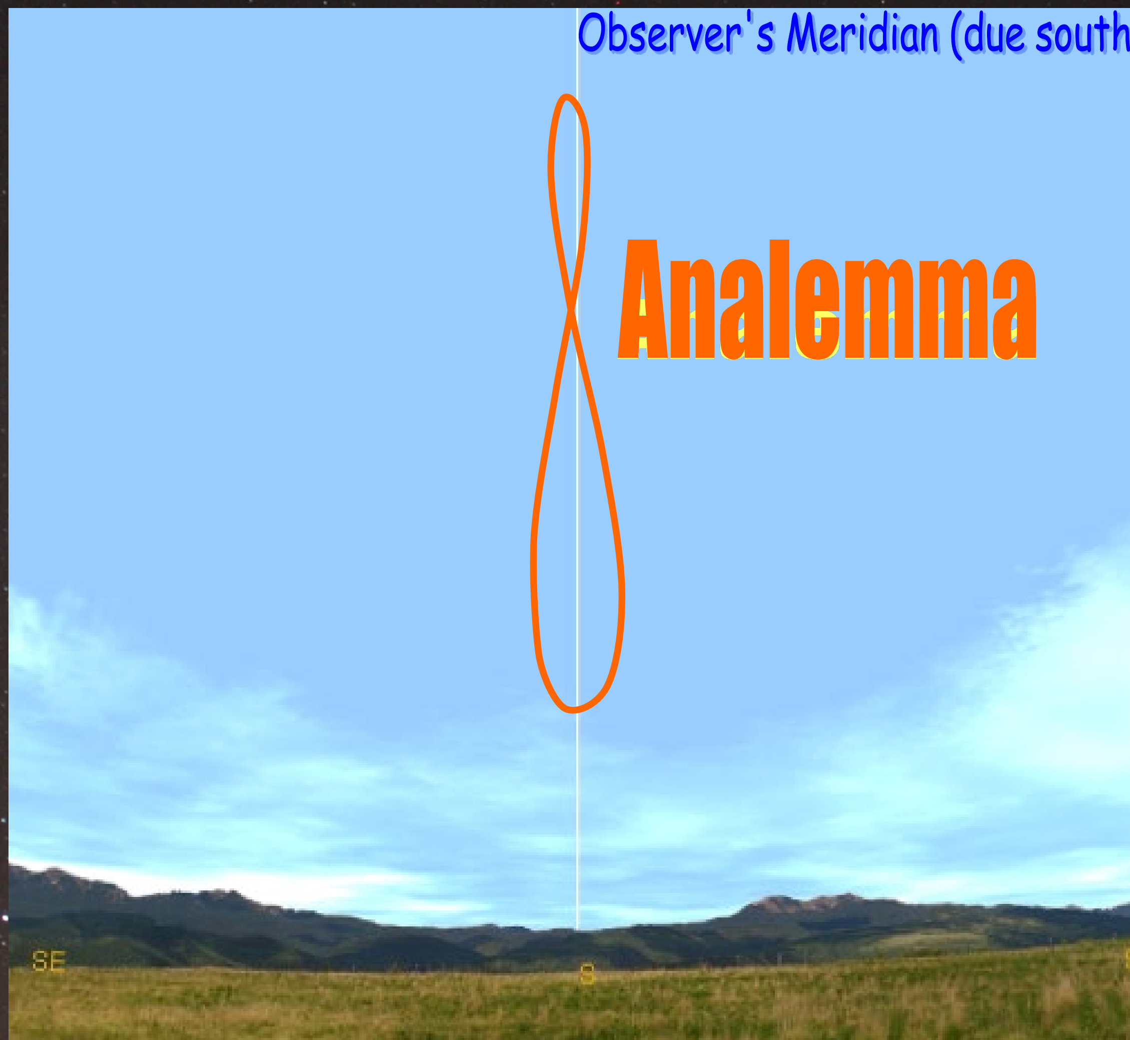


The Analemma

- ☆ 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

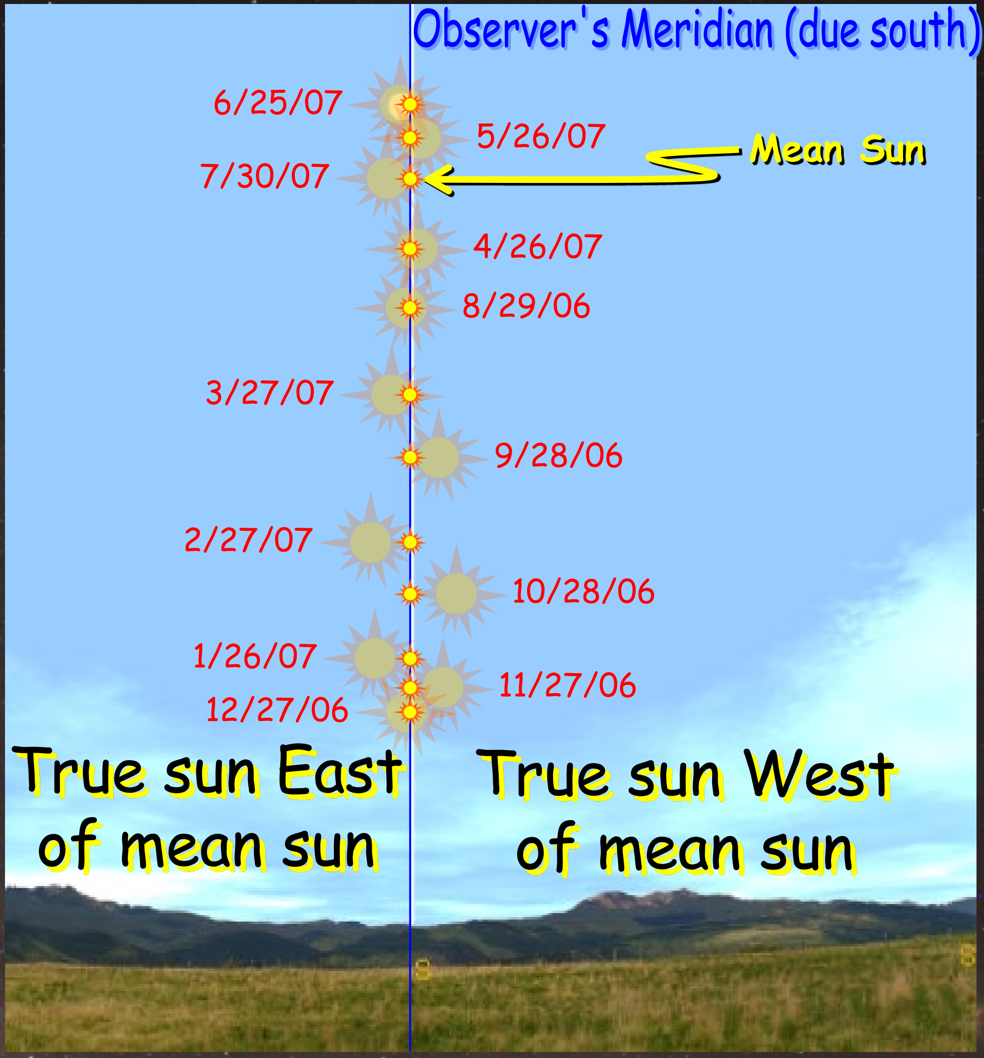
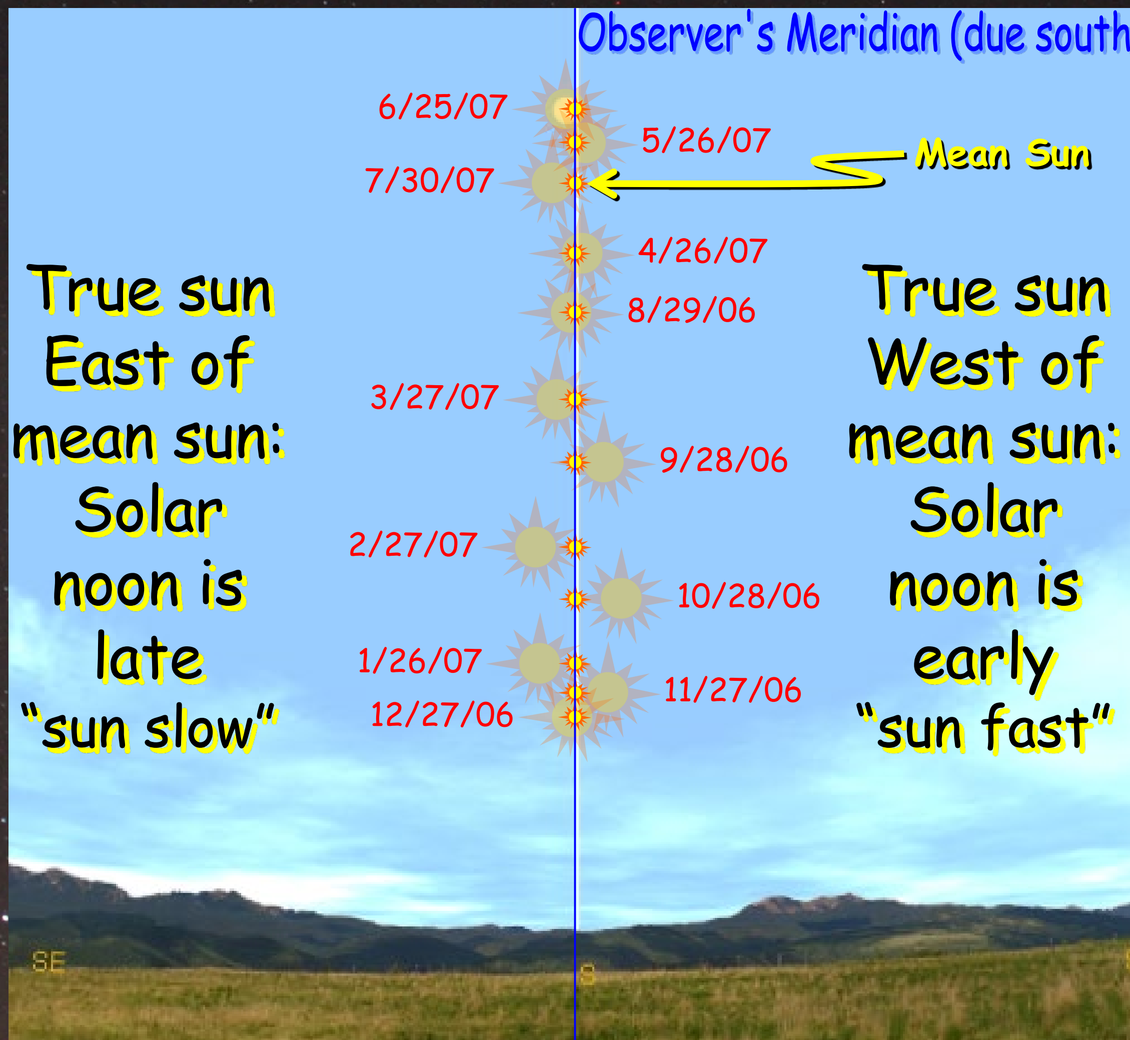


Photo by Marc Staves, Adirondack Public Observatory

Mean Sun & True Sun

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



Solar Noon Today (9/13/22)

- ☆ Potsdam (44° 40′ N, 75° 00 W)
  - Standard time of solar noon = 11:55:51 am
  - Daylight time of solar noon = 12:55:51
- ☆ Canton (44° 36′ N, 75° 10 W)
  - Standard time of solar noon = 11:56:31 am
  - Daylight time of solar noon = 12:56:31
  - 40 seconds later than Potsdam
    - ☽ Earth turns 1° in 4 minutes
      - ⇒ Earth turns 15′ in 1 minute
      - ⇒ Earth turns 10′ in 40 seconds!!
      - ⇒ Celestial events in Canton 40 seconds later than in Potsdam!!

Photo by Marc Staves, Adirondack Public Observatory

Solar Noon Today (9/13/22)

☆ www.spot-on-sundials.co.uk/calculator.html

Print Your Solar Noon Calendar

Our latitude and longitude page will help you to find the input data you need for our unique Solar Noon Calculator

The time of solar noon depends on the Equation of Time and on the difference in longitude between your location and the standard meridian of the time zone you are in. It is slightly different for every day of the year. Our unique Solar Noon Calculator will provide you with a table showing the exact time of solar noon for your location for each day of the year. If you prefer, you can print out the values of the Equation of Time, which gives you the difference between solar time and clock time for each day of the year.

Note that our calculator requires that your latitude and longitude be in decimal format. If your co-ordinates are in Degrees, Minutes, Seconds please click here.

	Example	Your Details	Comments
Location	Epsom England		*this information is displayed across the top of your calendar, it is not included in any calculations*
Latitude	51.33250 N		*optional - enter your latitude if you want your latitude/longitude co-ordinates to be displayed on your calendar*
Longitude	0.26722 W	W	*required - Longitude is used in the calculations*
Time Zone	US Eastern Montreal, New York, Columbia, Peru		*required - select your time zone from the drop-down list*
Type of Calendar	Solar Noon ◉ Equation of Time ○		***Solar Noon** displays the exact time of solar noon each day. **Equation of Time** displays the difference between solar time and the standard time where you are.*

Display Calendar

If your area has daylight saving time in the summer, we recommend that you highlight or draw a box round the relevant time, and write "Add one hour for daylight saving time" at the foot of the relevant months.

Note: The values given by the Calculator are averages for the full leap year cycle of four years (1,461 days) and change slightly from year to year. The range of variation for the 1st day of each month is shown below:

Jan - 21 secs	May - 5 secs	Sept - 6 secs
Feb - 6 secs	June - 7 secs	Oct - 15 secs
Mar - 9 secs	July - 9 secs	Nov - 1 sec
Apr - 14 secs	Aug - 2 secs	Dec - 17 secs

Photo by Marc Staves, Adirondack Public Observatory

Solar Noon Today (9/13/22)

Solar Noon Calendar for Potsdam, NY at 44.67N : 75.0W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12:03:32	12:13:32	12:12:13	12:03:44	11:57:06	11:57:57	12:04:01	12:06:23	12:00:03	11:49:35	11:43:31	11:49:06
2	12:04:00	12:13:39	12:12:01	12:03:27	11:56:59	11:58:07	12:04:12	12:06:19	11:59:38	11:49:16	11:43:30	11:49:29
3	12:04:28	12:13:46	12:11:48	12:03:09	11:56:53	11:58:17	12:04:23	12:06:14	11:59:18	11:48:57	11:43:30	11:49:53
4	12:04:55	12:13:52	12:11:35	12:02:52	11:56:48	11:58:28	12:04:34	12:06:08	11:58:58	11:48:38	11:43:30	11:50:17
5	12:05:22	12:13:57	12:11:22	12:02:35	11:56:43	11:58:38	12:04:45	12:06:02	11:58:38	11:48:20	11:43:32	11:50:42
6	12:05:48	12:14:01	12:11:04	12:02:18	11:56:38	11:58:49	12:04:55	12:05:55	11:58:18	11:48:02	11:43:34	11:51:07
7	12:06:14	12:14:05	12:10:53	12:02:01	11:56:34	11:59:01	12:05:04	12:05:48	11:57:57	11:47:44	11:43:38	11:51:33
8	12:06:39	12:14:07	12:10:38	12:01:45	11:56:31	11:59:12	12:05:13	12:05:40	11:57:37	11:47:27	11:43:42	11:51:59
9	12:07:04	12:14:09	12:10:23	[illegible]	11:56:29	[illegible]	[illegible]	12:05:32	11:57:16	11:47:11	11:43:47	11:52:26
10	12:07:29	12:14:10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:56:55	11:46:55	11:43:53	11:52:53
11	12:07:53	12:14:11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:46:39	11:43:59	11:53:21
12	12:08:16	12:14:10	12:09:36	12:00:42	11:56:24	12:00:00	12:05:46	12:05:03	11:56:13	11:46:24	11:44:07	11:53:48
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:55:51	11:46:09	11:44:15	11:54:17
14	12:09:00	12:14:07	12:09:03	12:00:12	11:56:24	12:00:26	12:06:00	12:04:41	11:55:30	11:45:55	11:44:25	11:54:45
15	12:09:22	12:14:04	12:08:46	11:59:58	11:56:25	12:00:39	12:06:06	12:04:29	11:55:09	11:45:41	11:44:35	11:55:14

Potsdam 11:55:51 am

Location	Epsom England		*this information is displayed across the top of your calendar, it is not included in any calculations*

Solar Noon Calendar for Canton, NY at 44.6N : 75.167W

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	12:04:12	12:14:12	12:12:53	12:04:24	11:57:46	11:58:37	12:04:41	12:07:03	12:00:43	11:50:15	11:44:11	11:49:46
2	12:04:40	12:14:19	12:12:41	12:04:07	11:57:39	11:58:47	12:04:52	12:06:59	12:00:18	11:49:56	11:44:10	11:50:09
3	12:05:08	12:14:26	12:12:28	12:03:49	11:57:33	11:58:57	12:05:03	12:06:54	11:59:58	11:49:37	11:44:10	11:50:33
4	12:05:35	12:14:32	12:12:15	12:03:32	11:57:28	11:59:08	12:05:14	12:06:48	11:59:38	11:49:18	11:44:10	11:50:57
5	12:06:02	12:14:37	12:12:02	12:03:15	11:57:23	11:59:18	12:05:25	12:06:42	11:59:18	11:49:00	11:44:12	11:51:22
6	12:06:28	12:14:41	12:11:44	12:02:58	11:57:18	11:59:29	12:05:35	12:06:35	11:58:58	11:48:42	11:44:14	11:51:47
7	12:06:54	12:14:45	12:11:33	12:02:41	11:57:14	11:59:41	12:05:44	12:06:28	11:58:37	11:48:24	11:44:18	11:52:13
8	12:07:19	12:14:47	12:11:18	12:02:25	11:57:11	11:59:52	12:05:53	12:06:20	11:58:17	11:48:07	11:44:22	11:52:39
9	12:07:44	12:14:49	12:11:03	12:02:08	11:57:09	12:00:04	12:06:02	12:06:12	11:57:56	11:47:51	11:44:27	11:53:06
10	12:08:09	12:14:50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:57:35	11:47:35	11:44:33	11:53:33
11	12:08:33	12:14:51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:47:19	11:44:39	11:54:01
12	12:08:56	12:14:50	12:10:16	12:01:22	11:57:04	12:00:40	12:06:26	12:05:43	11:56:53	11:47:04	11:44:47	11:54:28
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11:56:31	11:46:49	11:44:55	11:54:57
14	12:09:40	12:14:47	12:09:43	12:00:52	11:57:04	12:01:06	12:06:40	12:05:21	11:56:10	11:46:35	11:45:05	11:55:25
15	12:10:02	12:14:44	12:09:26	12:00:38	11:57:05	12:01:19	12:06:46	12:05:09	11:55:49	11:46:21	11:45:15	11:55:54

Canton 11:56:31 am

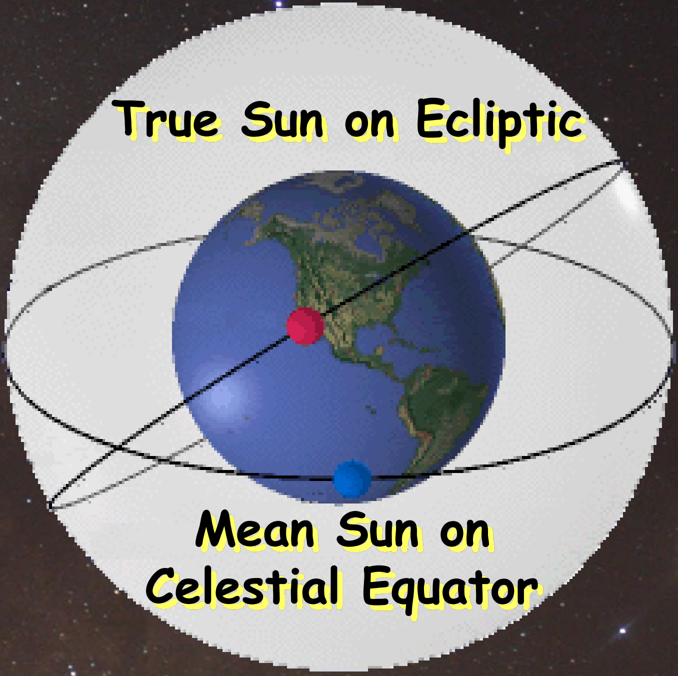
Apr - 14 secs	Aug - 2 secs	Dec - 17 secs

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



The Calendar

- Solar Calendars (Tropical Year = 365.2421897d)
  - Attempt to keep dates aligned with seasons
  - *e.g.* Vernal Equinox near March 21 {First Council of Nicaea, 325 CE
- Julian Calendar
  - Instituted by Julius Caesar in 46 BCE
    - Rounded Tropical Year to 365.25 d
    - Added one day every 4 years ($\frac{1}{4}$ = 0.25 day/year)
      - Added too much time!
      - 365.25 – 365.2421897 = 0.00781 extra days/year (10.153 days in 1300 years)
      - After 1300 years, Vernal Equinox occurred on March 31!
        - Messed up date of Easter!!
        - Easter = first Sunday after first full moon after ♈

Photo by Marc Staves 2011

The Calendar

- Gregorian Calendar (Year = 365.2421897d)
  - Instituted by Pope Gregory XIII, 1582
    - Dropped 10 days
      - Thursday, Oct. 4 1582 followed by Friday Oct. 15
      - British Empire & American Colonies:
        Wed. Sep. 2, 1752 followed by Thu. Sep. 14

The Calendar

- Gregorian Calendar (Year = 365.2421897d) Close!
  - Instituted by Pope Gregory XIII, 1582
    - Dropped 10 days
      - Thursday, Oct. 4 1582 followed by Friday Oct. 15
      - British Empire & American Colonies:
        Wed. Sep. 2, 1752 followed by Thu. Sep. 14
    - Century Years not divisible by 400 not leap years
      - Leap years 97 in 400 ($\frac{97}{400} = 0.24219$)
      - 365.2425 – 365.24219 = 0.00031 extra days/year
        (0.403 days in 1300 years)
      - 1600 = leap year for everyone
      - 1700 = leap year only for those on Julian Calendar (Brits)
        - British Empire had to drop 11 days, not 10!
        - George Washington 's Birthday
          Julian: Feb. 11, 1731
          Gregorian: Feb. 22, 1731

Photo by Marc Staves 2011

Cross Quarter Days

- Days $\frac{1}{2}$ way between solstices & equinoxes
- 1st days of seasons on some calenders (Celt)
  - Beltane ~May 1
    - $\frac{1}{2}$ way from Vernal Equinox to Summer Solstice
  - Lughnasa ~ August 2
    - $\frac{1}{2}$ way from Summer Solstice to Autumnal Equinox
  - All Hallows (Samhain) ~November 1
    - $\frac{1}{2}$ way from Autumnal Equinox to Winter Solstice
  - Candlemas (Imbolc) ~ February 2
    - $\frac{1}{2}$ way from Winter Solstice to Vernal Equinox

If Candlemas Day be fair and bright,
Winter will have another flight

If Candlemas Day be damp & black,
It will carry cold winter away on its back.

Photo by Marc Staves 2011

Position of Sunrise & Sunset

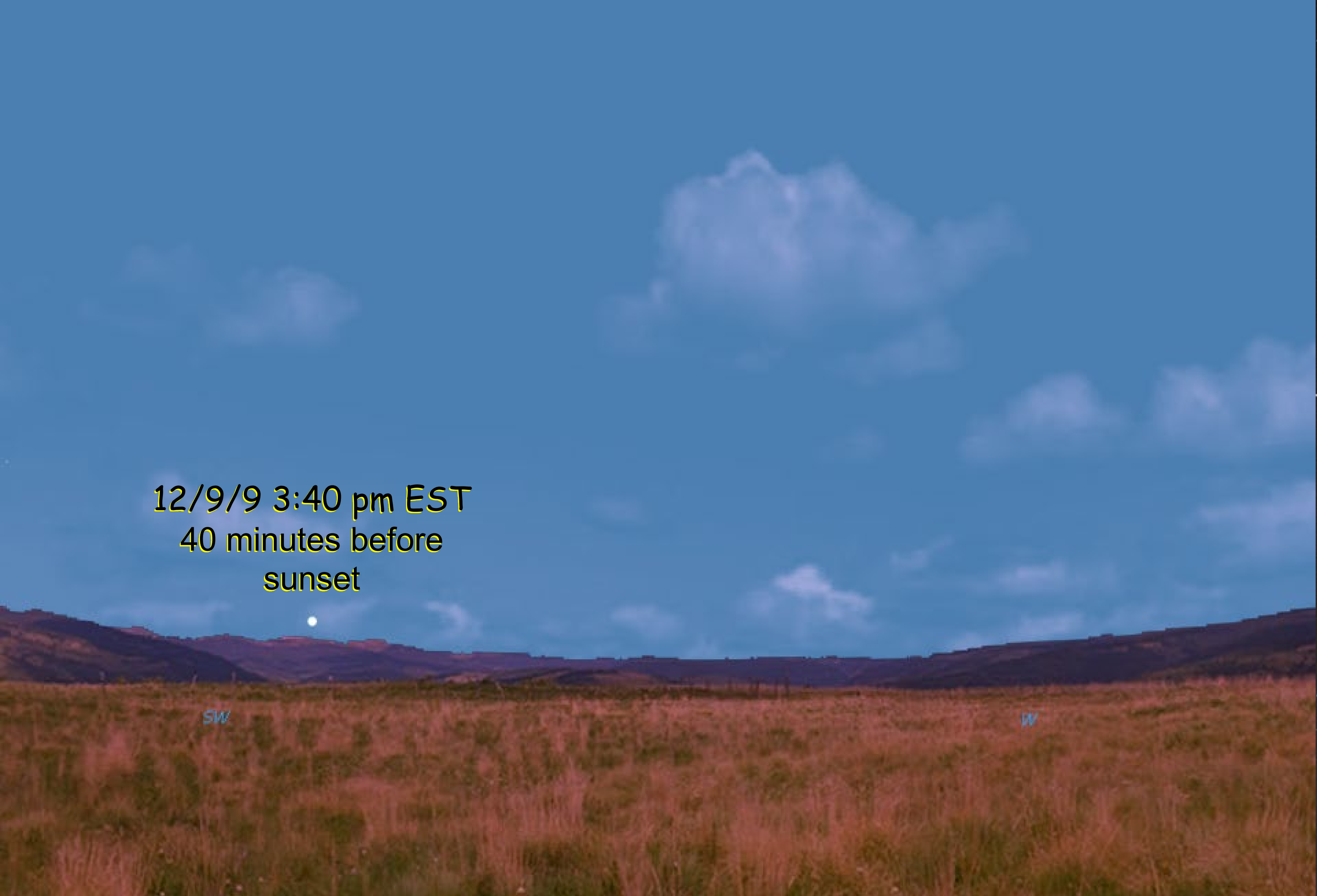
- ☆ Azimuth of rising depends on δ

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

- ☆ Sunrise appears to move along horizon
  - original calendar!
    eg. Stonehenge, Machu Pichu, Woodhenge (Illinois)

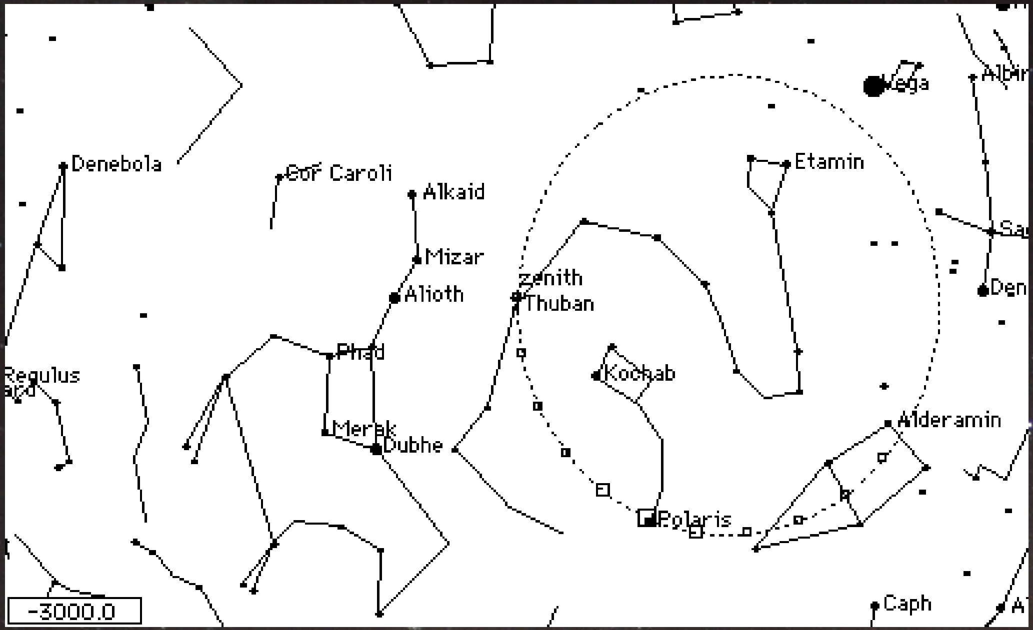
Photo by Marc Staves, Adirondack Public Observatory

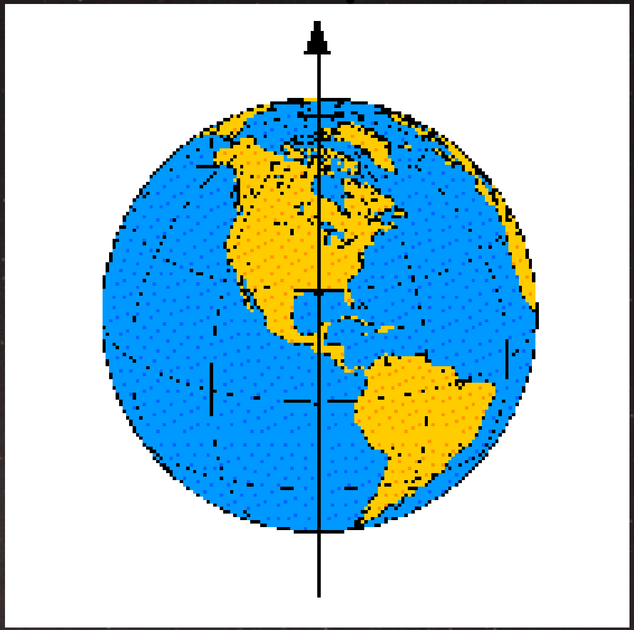
Position of Sunset



Precession

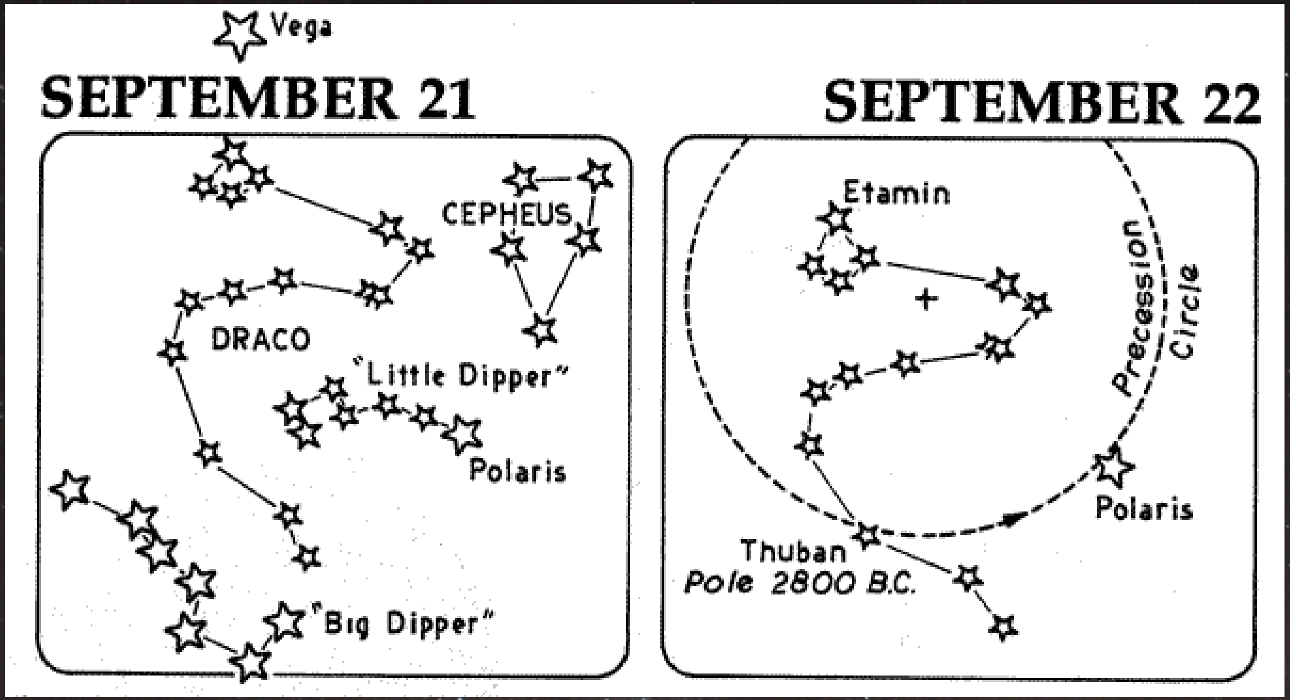
- ☆ Earth's axis wobbles over 26,000 years



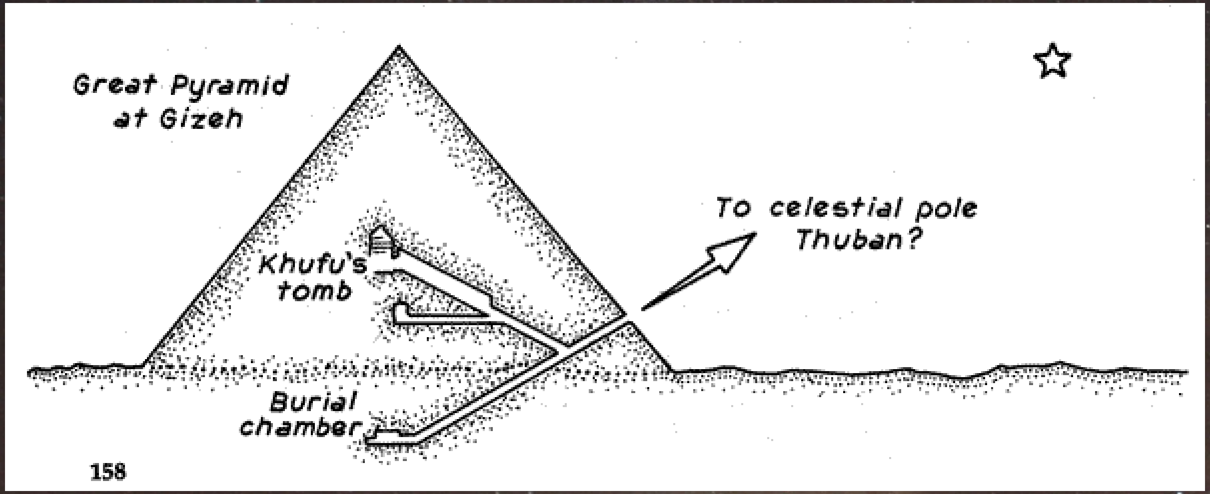


RA and Dec grid wobbles with pole, ecliptic does not wobble so solstices & equinoxes change position

Raymo's 365 Starry Nights

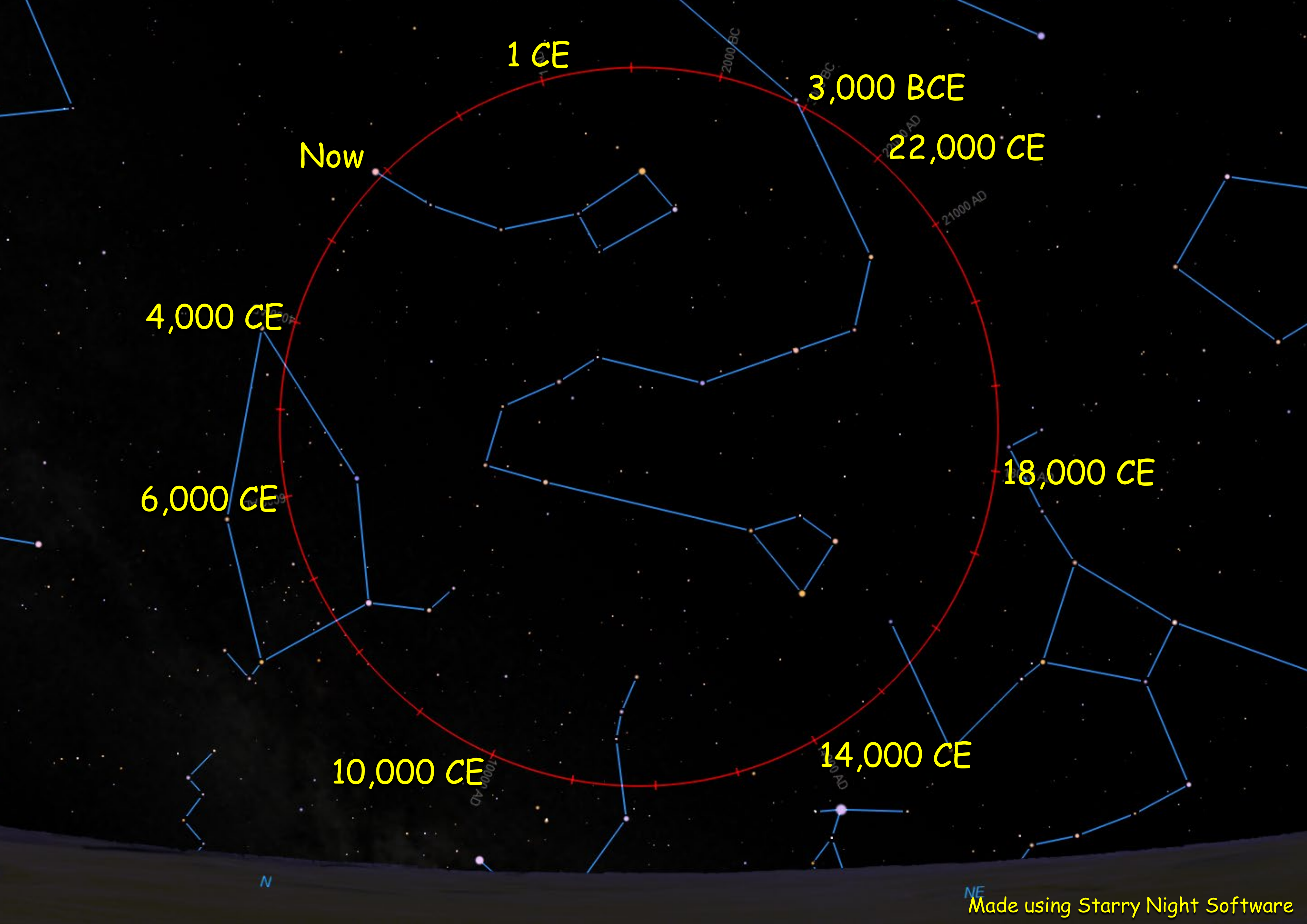


Precession Circle



View from the Pyramids

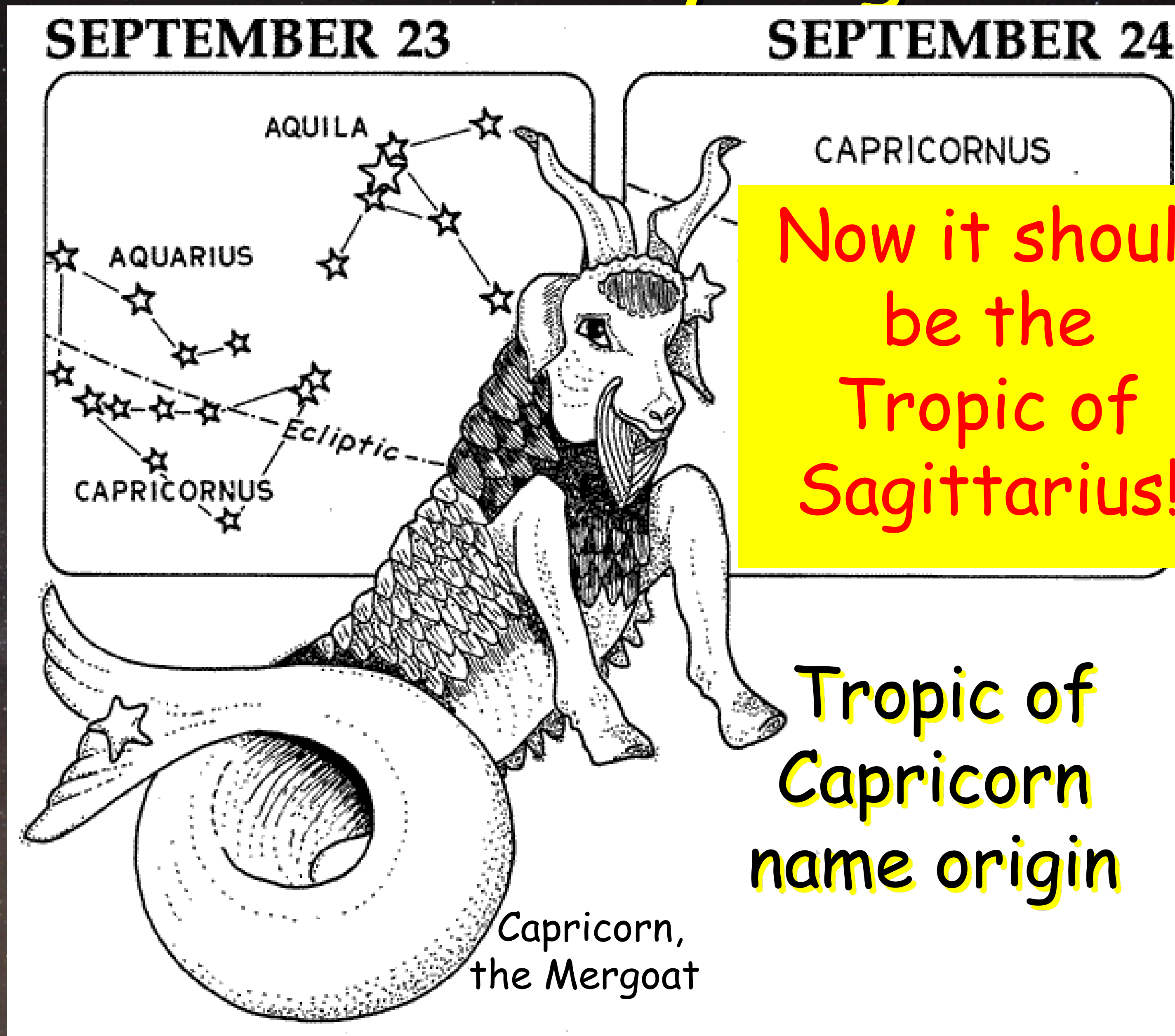
View from Canton, NY at 11:30 am on 9/18/19



Made using Starry Night Software

Raymo's 365 Starry Nights

Position of the winter solstice in 1000 BCE

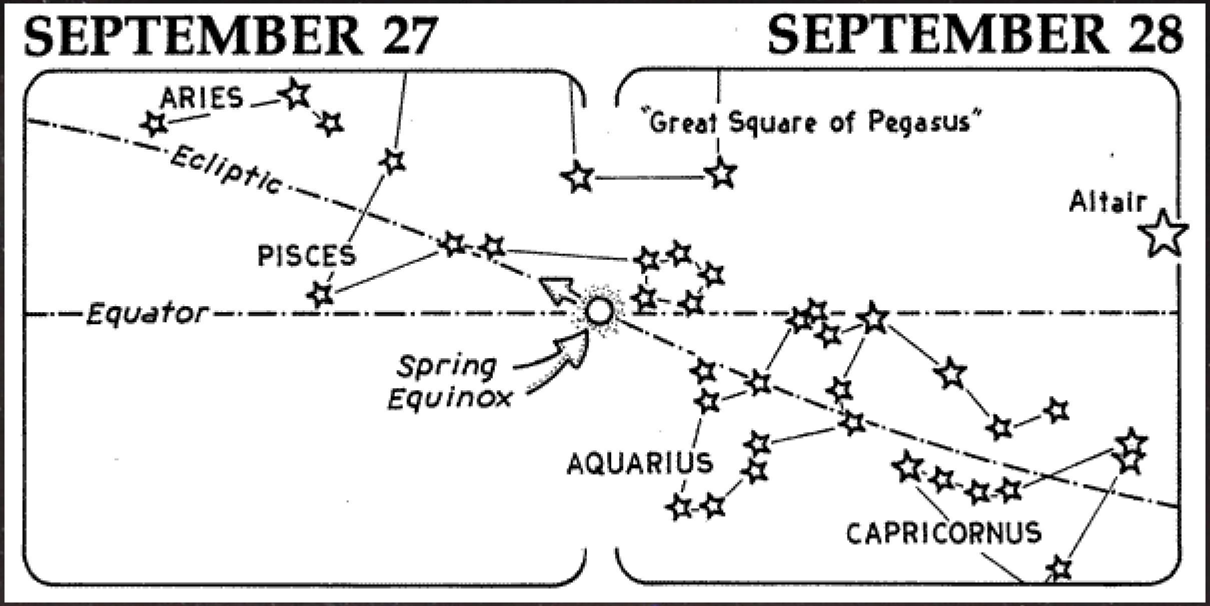


Capricorn, the Mergoat

Now it should be the Tropic of Sagittarius!

Tropic of Capricorn name origin

Raymo's 365 Starry Nights



Position of the Vernal Equinox now

Motion of the Vernal Equinox ...

To the "Age of Aquarius"

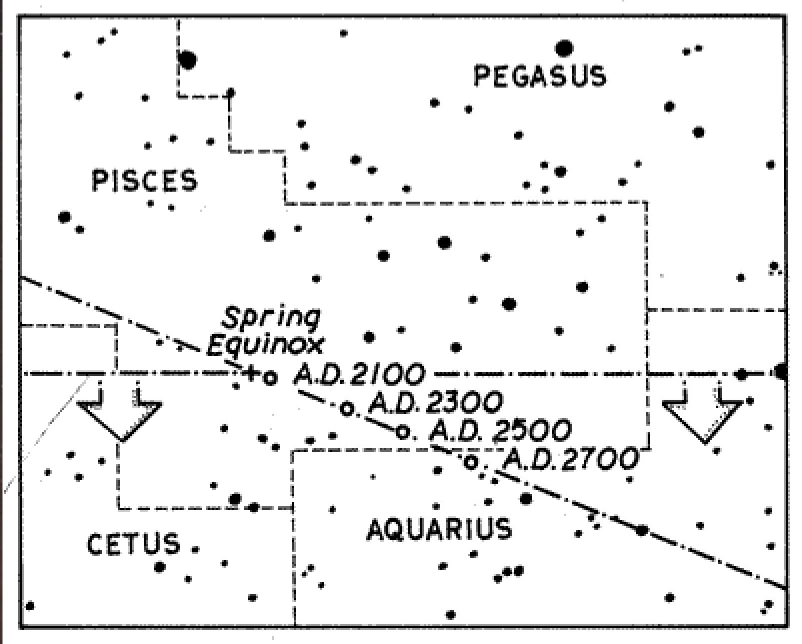
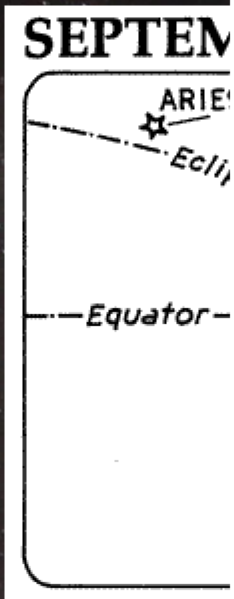


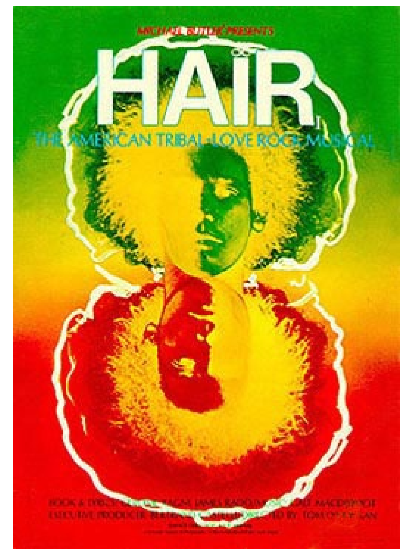
Photo by Marc Staves 2011



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!



"Age of Aquarius"

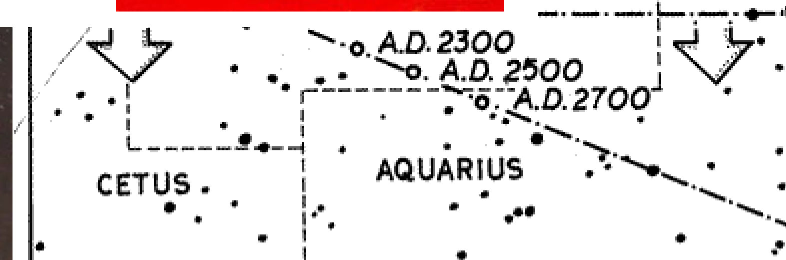


Photo by Marc Staves 2011


The adventure continues ...
Photo by Marc Staves 2011