Do you understand the reason for the “seasons”?

Your friend wonders *"Why are temperatures on Earth warmer in summer than winter?”*

You explain that the tilt of the Earth’s spin axis …

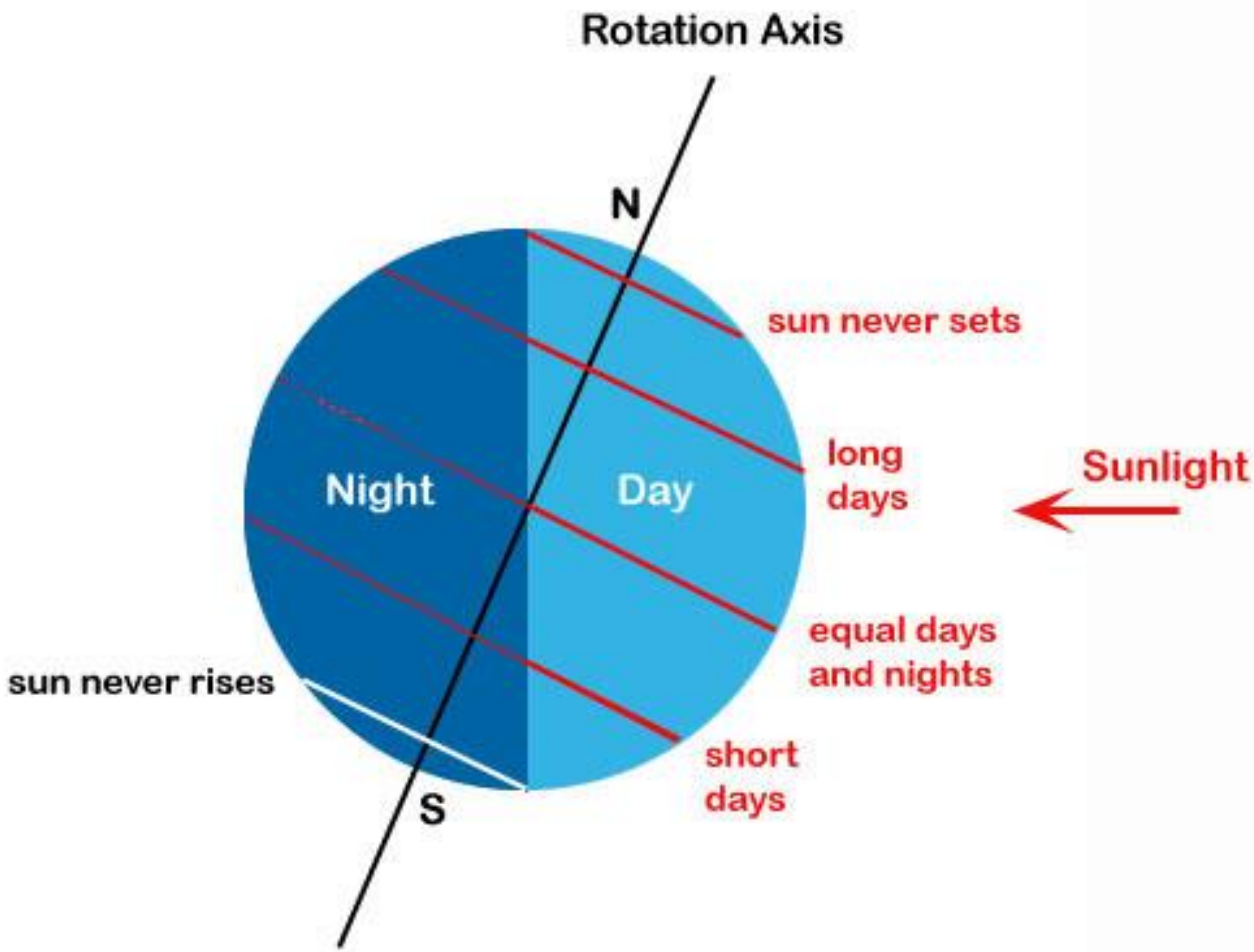
A. causes the Sun to be closer to Earth in summer.

B. causes sunlight to be concentrated more on the Earth’s surface in summer.

C. causes shorter days in summer.

D. all of the above

E. B and C


Rotation Axis
N
sun never sets
long
days
Sunlight
Night
Day
equal days
and nights
sun never rises
short
days
S

Notice PLEASE

- **Remember to turn in your Doodle sheets at the end of each class!**

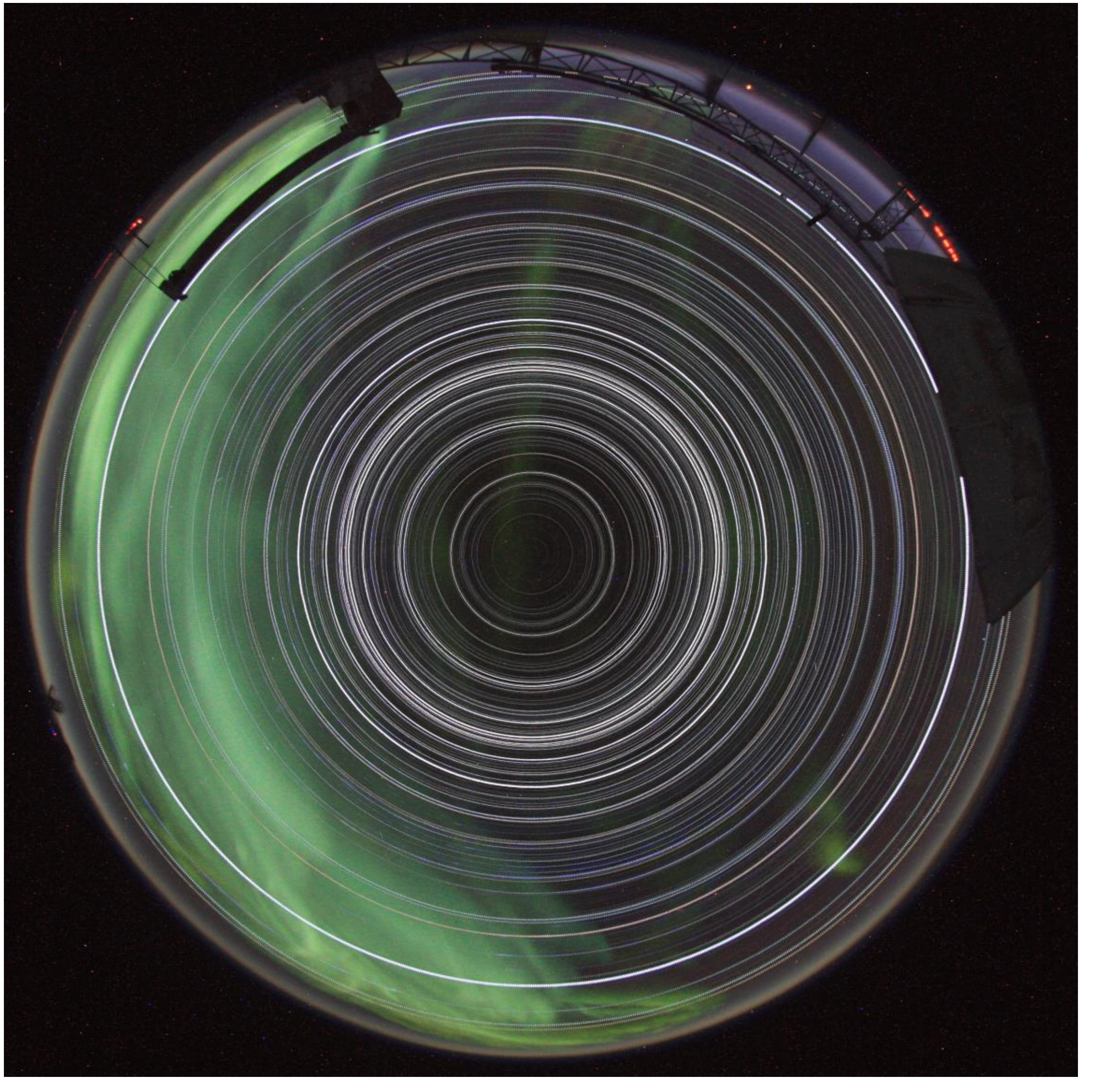
- ***"Aberration of Starlight"* in textbook:**
  - **Section 2.6.2 (pp. 57-58)**

- **Install "Stellarium"**

- **Astronomy Club (4 pm), N210**

Where was this picture taken?

exposure time = ?



What is a “day”?

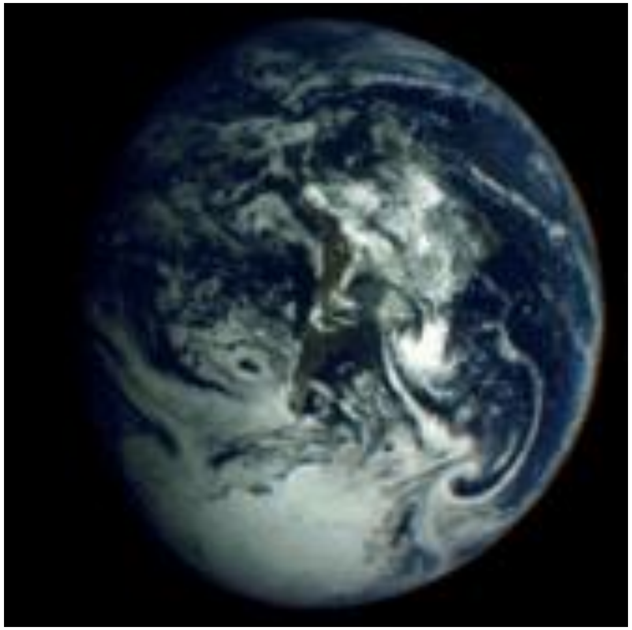
Polya: Understanding the problem

Draw a picture.

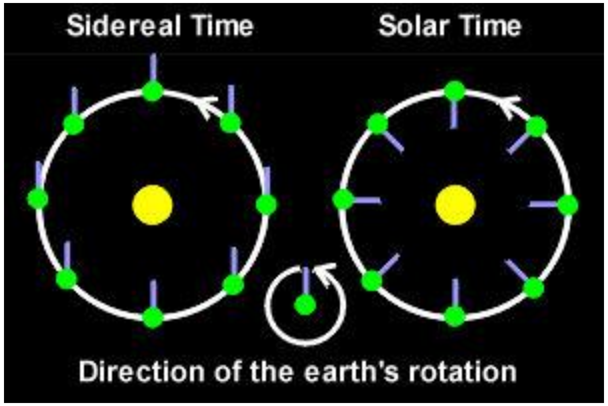
"Understanding the Problem"

What is "rotation"? What is a "day"?

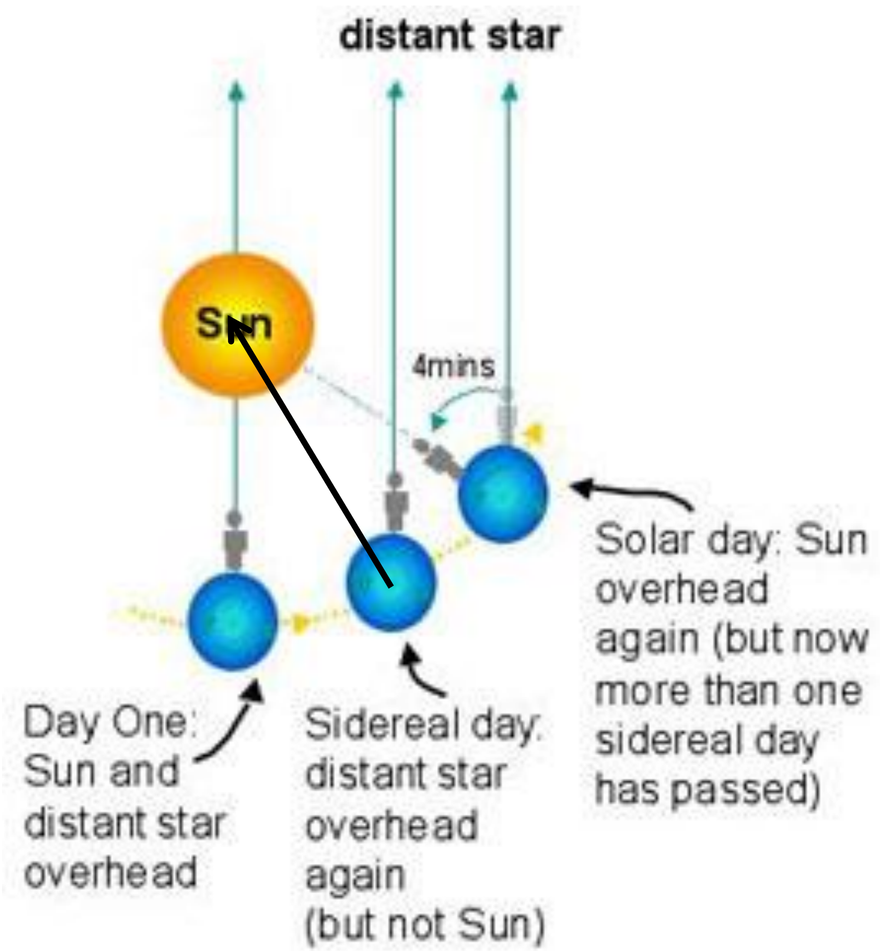
solar vs. sidereal day



- **Period with respect to the Sun**
  - **24 hours**
  - **varies (-18 sec; +30 sec) Why?**
- **Period with respect to stars ("sidereal")**
  - **$23^h\ 56^m\ 4.1^s$**
  - **23:56:04.1**
  - **23.93 hours**

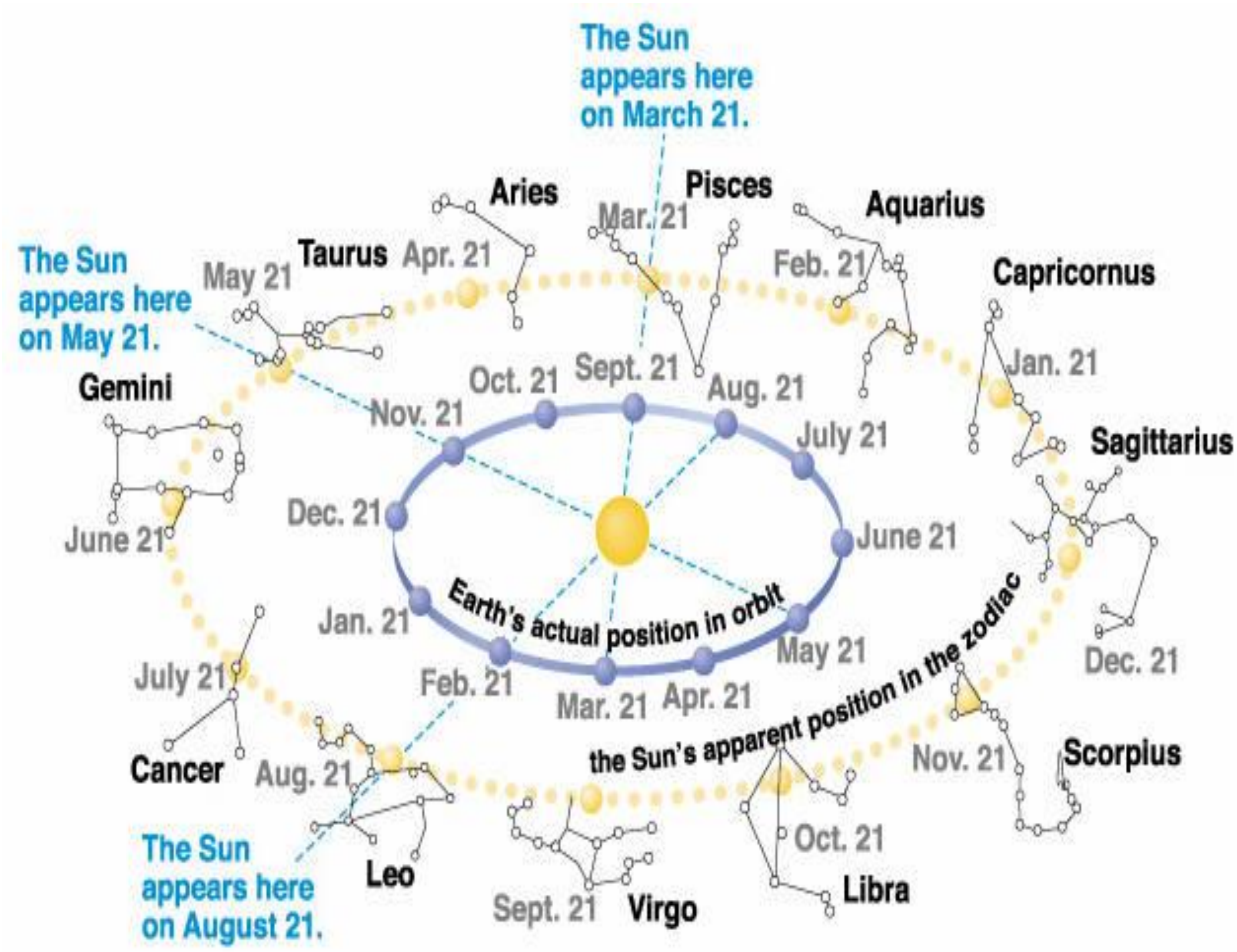


What is a "day"?
Draw a figure.
assumptions?

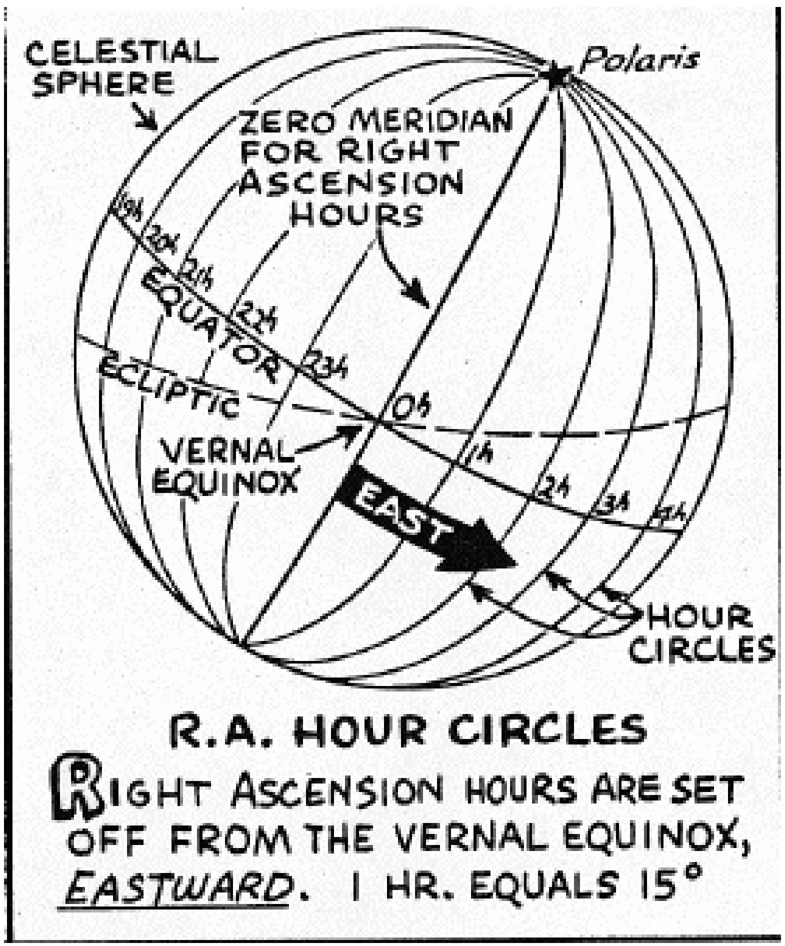


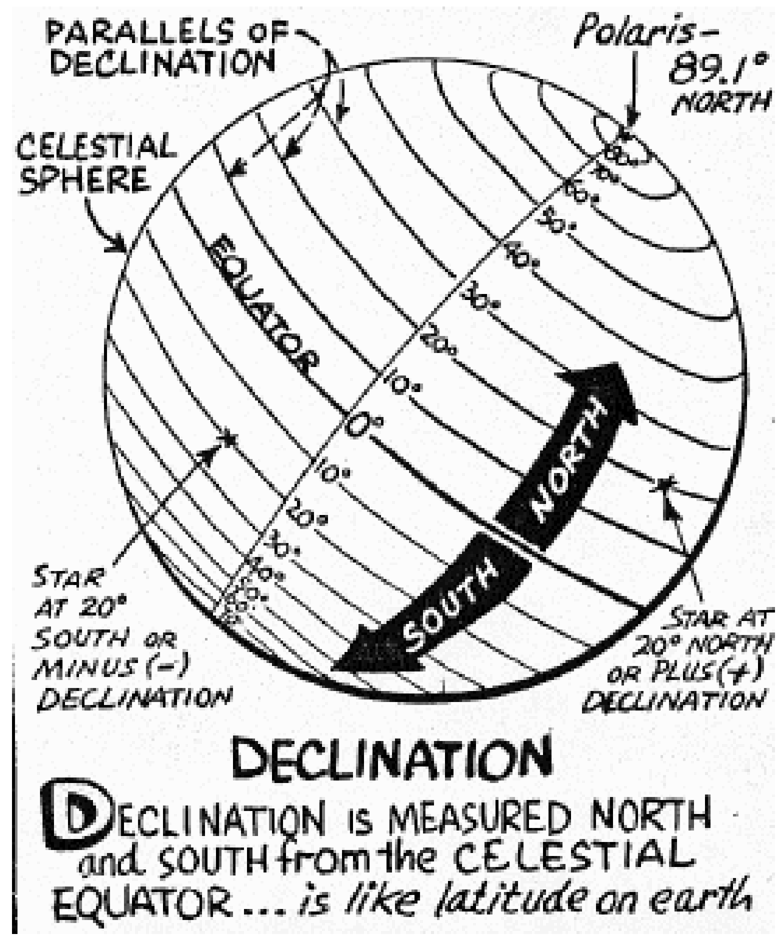
- **Earth revolves around the Sun.**
  - **360 degrees in 365 days**
  - **360 degrees in ~360 days = ~ 1 deg/day**
    - **to what accuracy?**
- **What does this mean?**
  - **Earth must rotate more to "reacquire" the Sun.**
  - **How long does the Earth require to rotate 1 deg?**
    - **360 degrees in 24 hours = ~15 deg/hour**
    - **How many degrees per minute?**
- **What information needed for Jupiter?**
  - **Physical intuition: What do you expect?**

“Sidereal Time” at Midnight
varies throughout the year



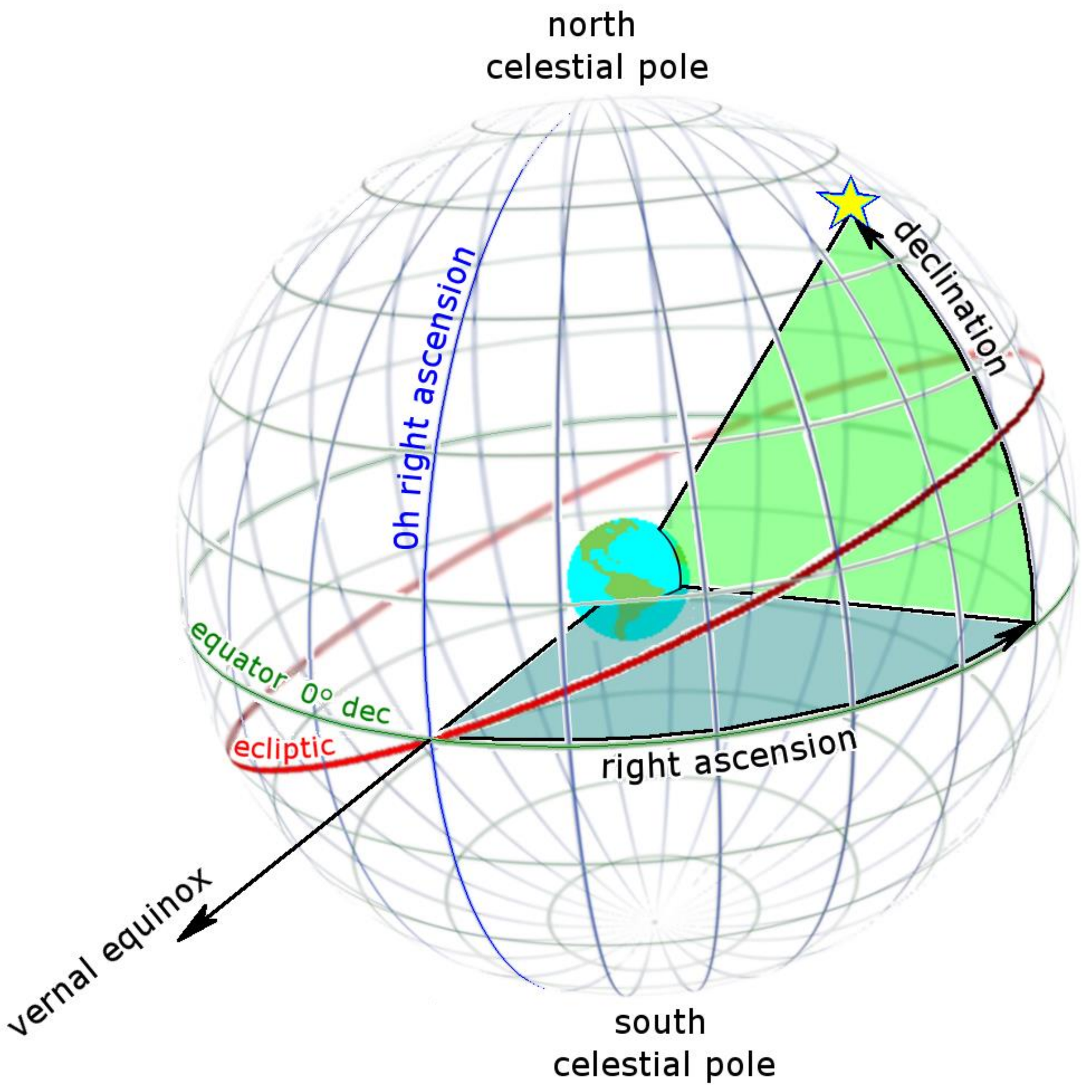
Equatorial Coordinates
Right Ascension, Declination





Add "Celestial Equator" as a path on your plastic ball.

Equatorial Coordinates



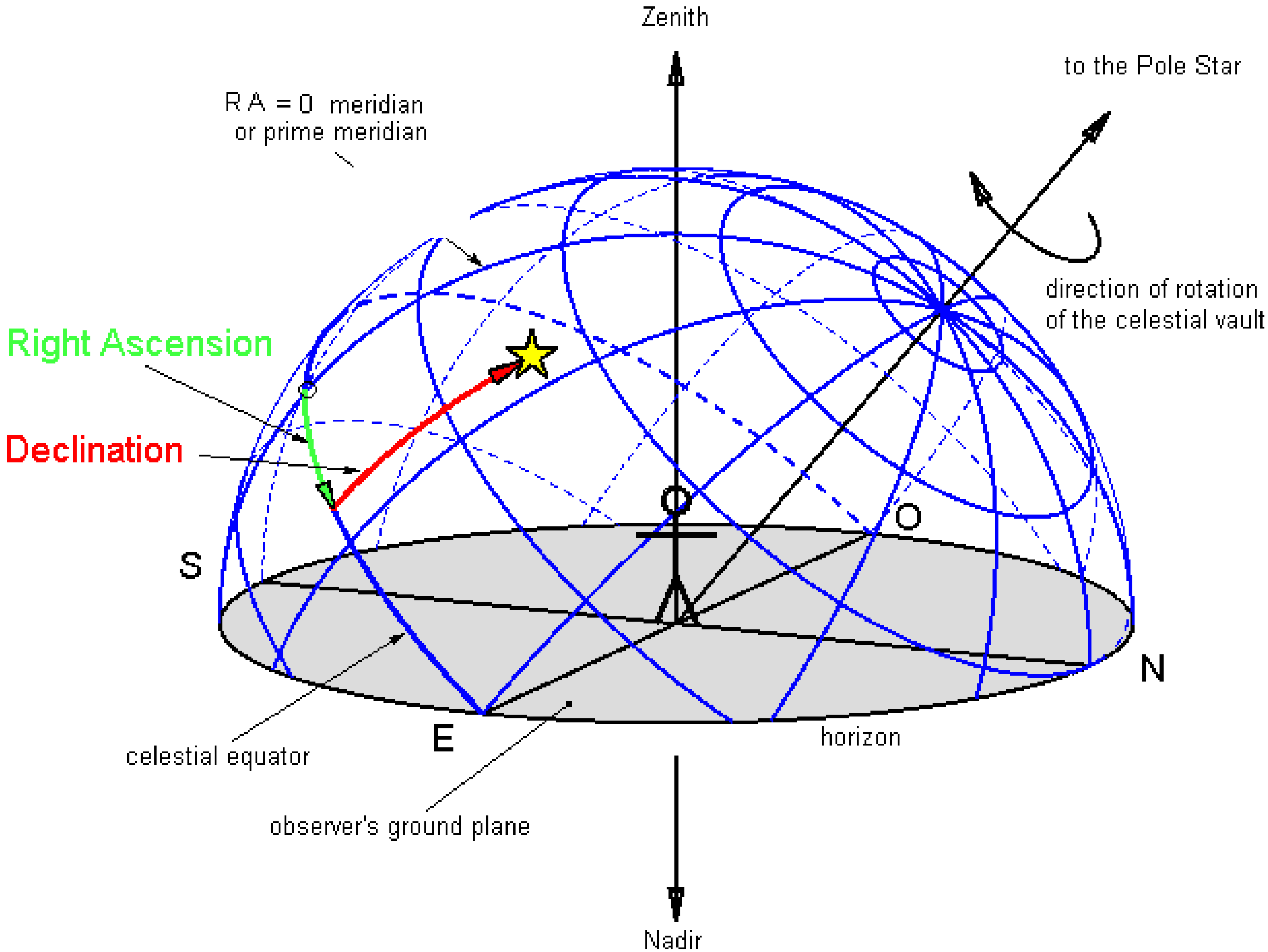
Problem #1
What information do you need?

If a Near-Earth Object (aka, NEO) were discovered at midnight tonight, with the following coordinates, from Mt. Lemmon near Tucson, could it be observed simultaneously at Mauna Kea Observatory in Hawaii?

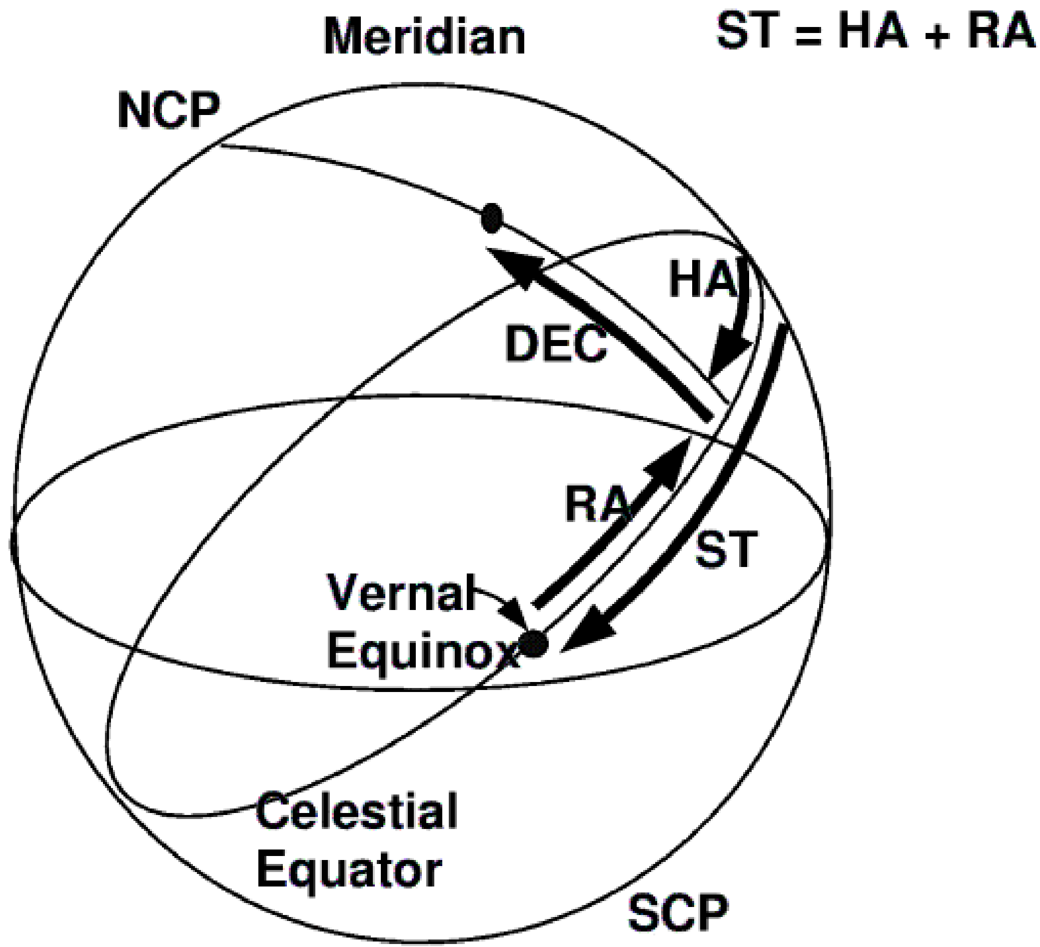
- **RA: 22:30:00**
- **DEC: +20:00:00**

- **Mauna Kea:**
  - **Longitude (155.47 deg W)**
  - **Latitude (19.82 deg)**

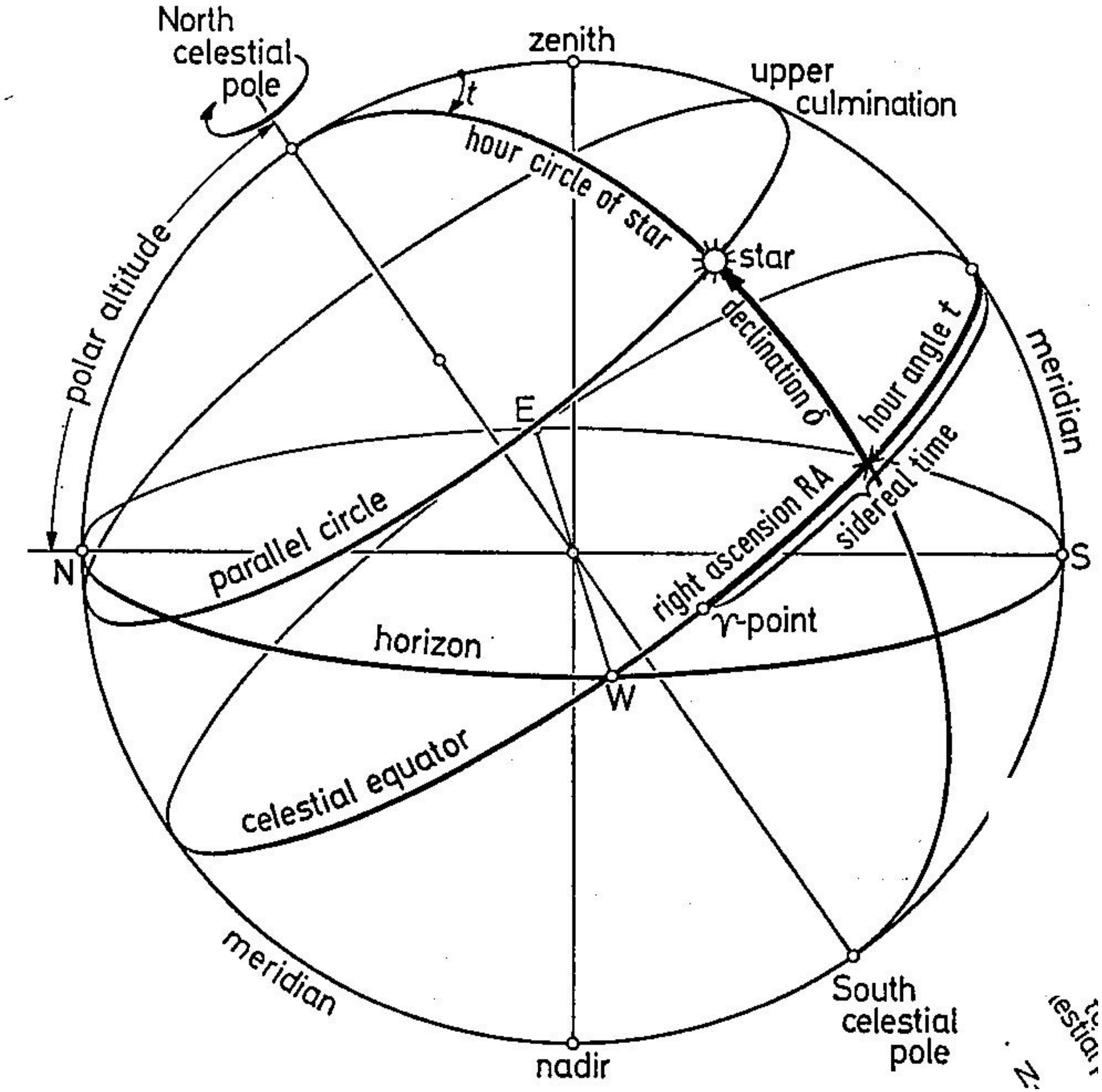
More Terms:
sidereal time, hour angle, transit



“Sidereal Time” and “Hour Angle”



“Sidereal Time” and “Hour Angle”



Problem #2
What information do you need?

When is the Galactic Center best studied throughout the night?

- **RA: 17:45:40.04 (h: m: s)**
- **DEC: -29:00:28.1 (deg: arcmin: arcsec)**

- **LST = 0 on September 26 at midnight**

Problem #3
today's optional homework problem

On 17 August 2017, 12:41:04 UT (i.e., Universal Time), the gravitational-wave observatory, LIGO, detected an event (aka, GW170817) from a pair of merging neutron stars. The estimated location had coordinates of (RA: 13:09:48.08; DEC: -23:22:53.3). Quickly, an electronic alert message was sent around the world, encouraging astronomers at observatories around the world to record the event across the spectrum of light. This event provided an opportunity for "multi-messenger" astrophysics.

In Greenwich, the Local Sidereal Time (LST) was 10.35 hours. The 1-meter Swope Telescope in Chile (longitude: 70:42:05.9 W; latitude: -29:00:35.85) was the first facility to observe the object. At the time of the event, what was the object's Hour Angle at the Swope Observatory; in other words, could Swope astronomers have observed the event immediately or did they need to wait some amount of time for the object to rise in their sky? [NOTE that Right Ascension increases towards the east.]

Do you understand the problem?
What do we know?

When: 17 August 2017 at 12:41:04 UT
Where: RA: 13:09:48.08; DEC: -23:22:53.3

In Greenwich, the Local Sidereal Time (LST) was 10.35 hours.

The 1-meter Swope Telescope in Chile:
- **longitude:** 70:42:05.9 W
- **latitude:** -29:00:35.85

At the time of the event, what was the object's Hour Angle at the Swope Observatory.

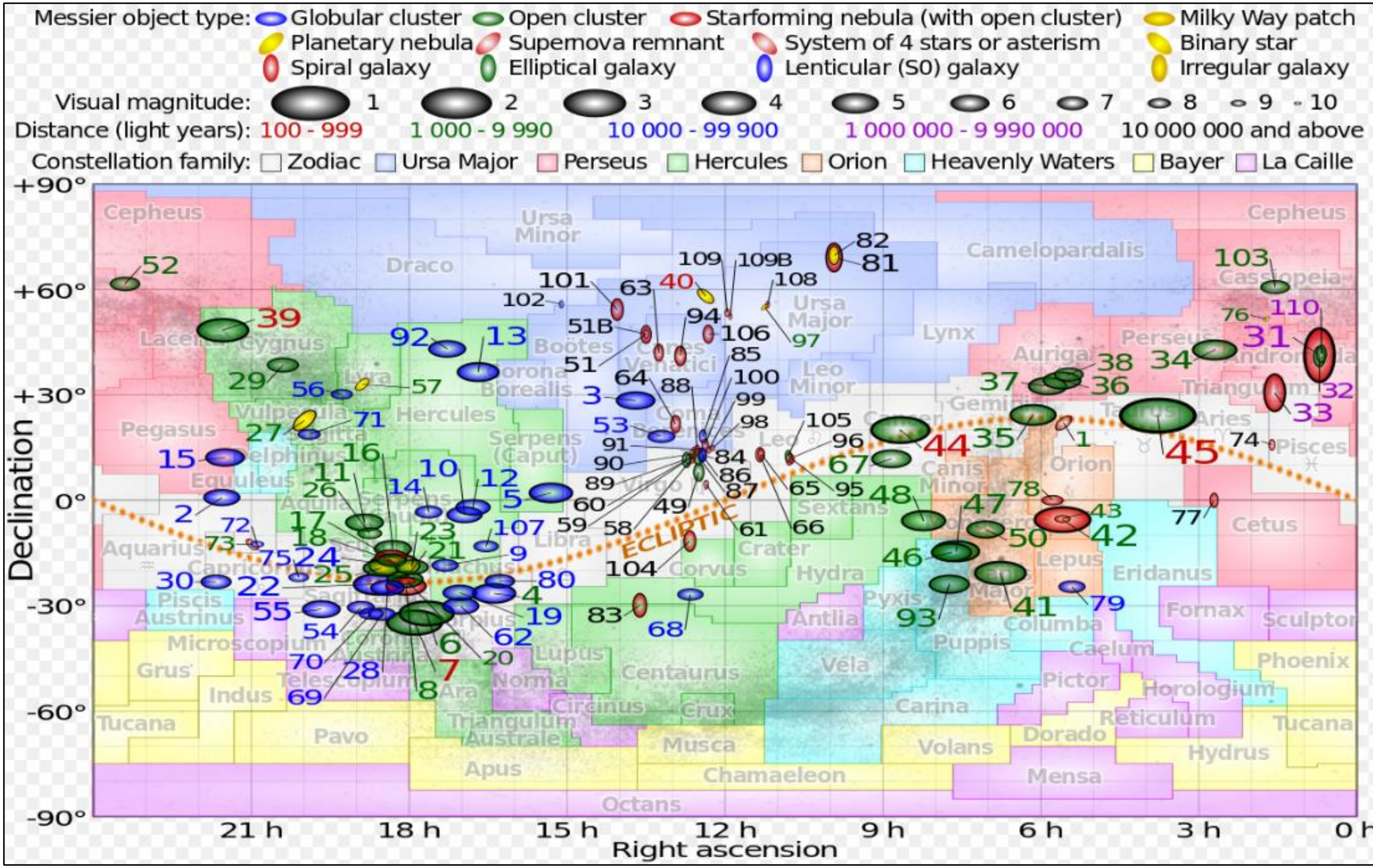
- Longitude: 70:42:05.9 W = 70.70 deg

- 70.70 deg / 15 deg per hour = 4.71 hours
- 4.71 hours earlier than Greenwich

- LST at Greenwich was 10.35 hours at midnight
- At Swope, LST then was 10.35 – 4.71 = 6.54 hours
- So an RA of 6:32:24 was transiting

- Object’s RA = 13:09:48.08
- So HA (east) = 6:37:24.08 = 6.62 hours
- So object had not yet risen above Chilean horizon

“Messier Marathon”

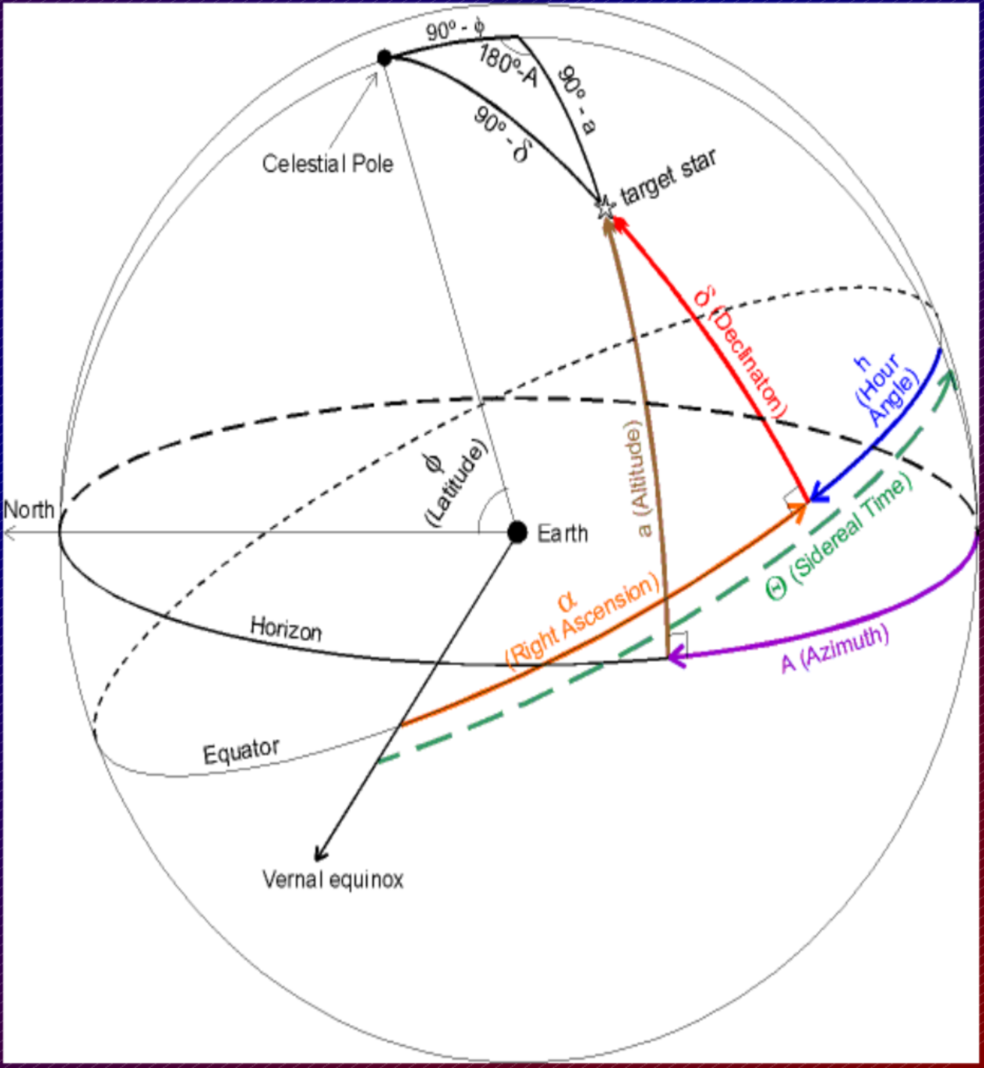


Sidereal Time and Hour Angle

Sidereal Time = *RA of stars crossing the meridian or HA of Vernal Equinox.*

For any star:
ST = RA+HA

Sidereal Day = *time between two successive meridian crossings of VE .*



Spherical Trigonometry

To convert from equatorial to horizontal coordinates:

Given RA α and declination δ, we have

Local Hour Angle H = LST - RA, in hours;

convert H to degrees (multiply by 15).

Given H and δ, we require azimuth A and altitude a.

By the cosine rule:

$\cos(90-a) = \cos(90-\delta)\cos(90-\varphi) + \sin(90-\delta)\sin(90^\circ-\varphi)$
$\cos(H)$

which simplifies to:

$\mathbf{\sin(a) = \sin(\delta)\sin(\varphi) + \cos(\delta)\cos(\varphi)\cos(H)}$

This gives us the altitude a.

By the sine rule:

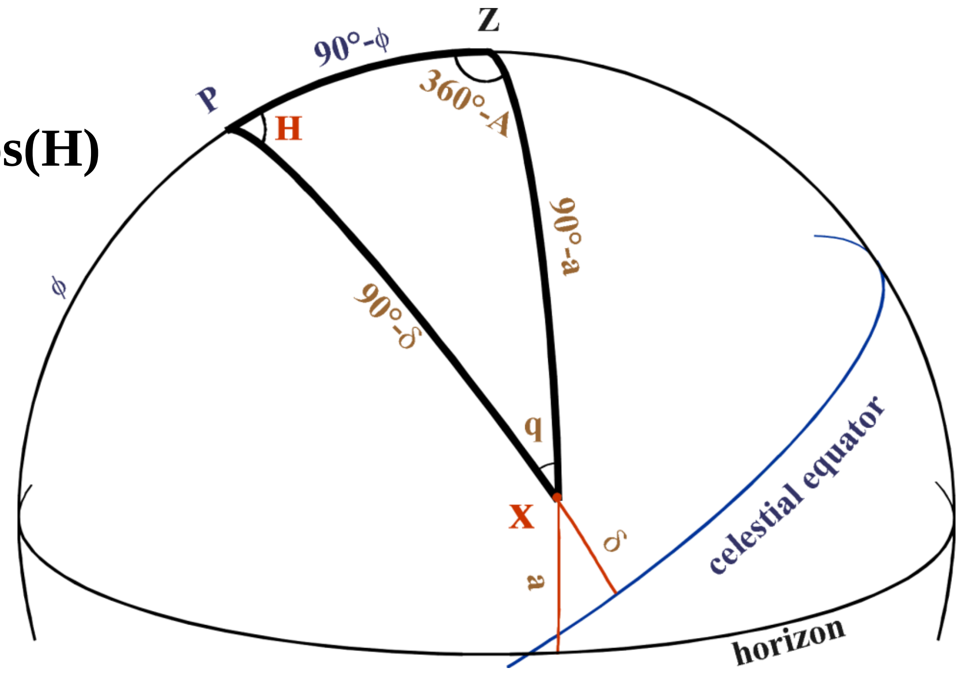
$\sin(360-A)/\sin(90-\delta) = \sin(H)/\sin(90-a)$

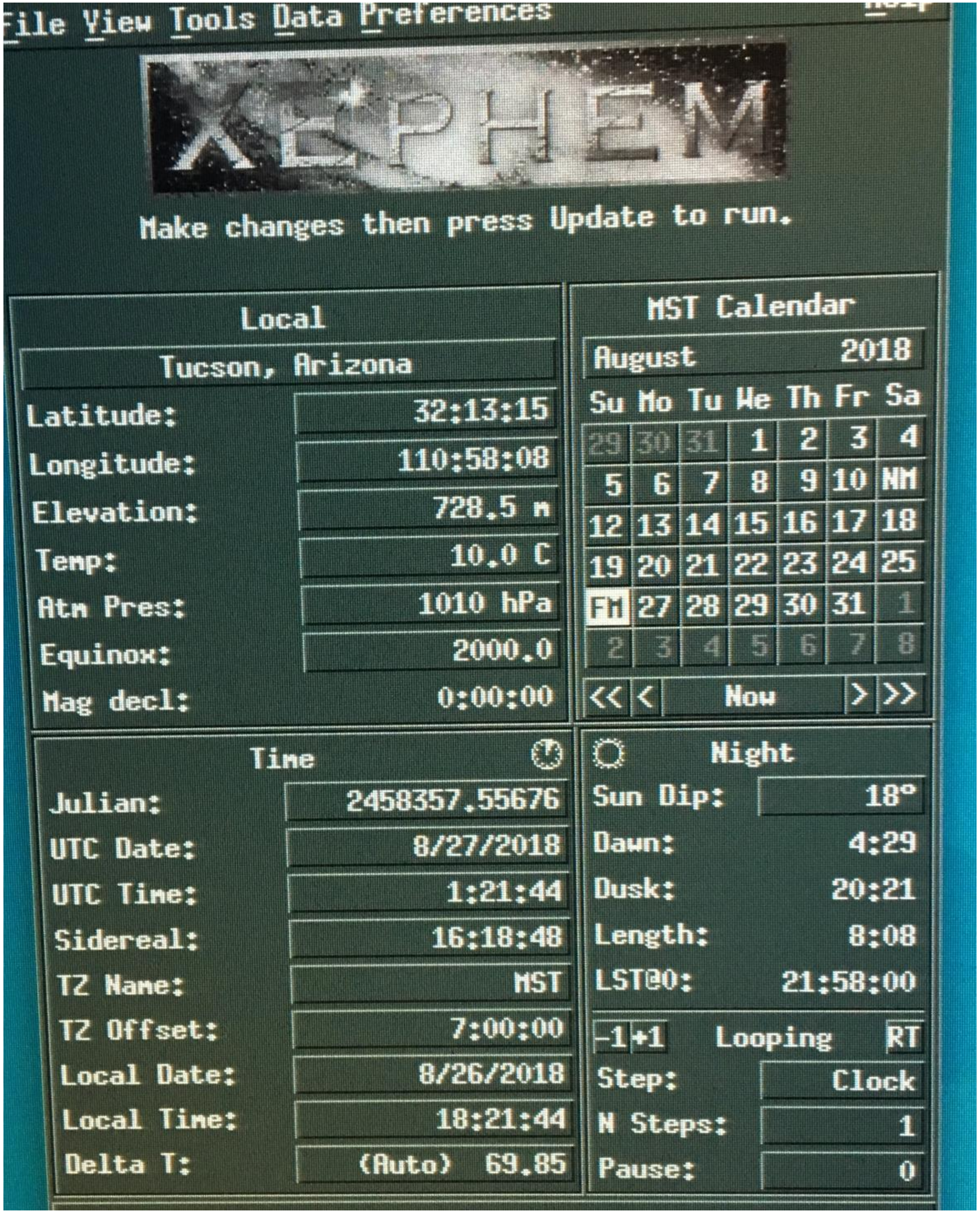
which simplifies to:

$-\sin(A)/\cos(\delta) = \sin(H)/\cos(a)$

i.e. $\mathbf{\sin(A) = -\sin(H)\cos(\delta)/\cos(a)}$

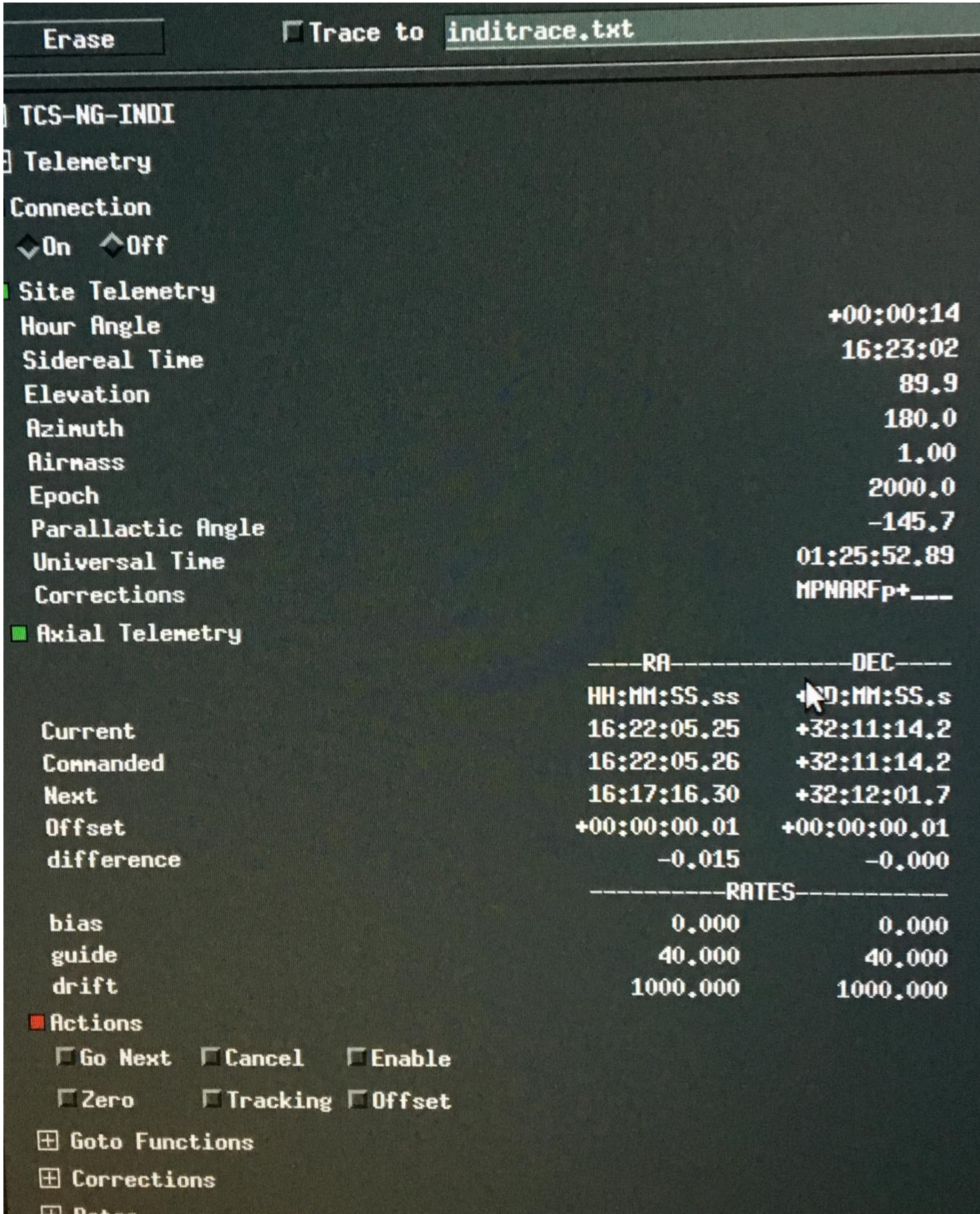
which gives us the azimuth A.





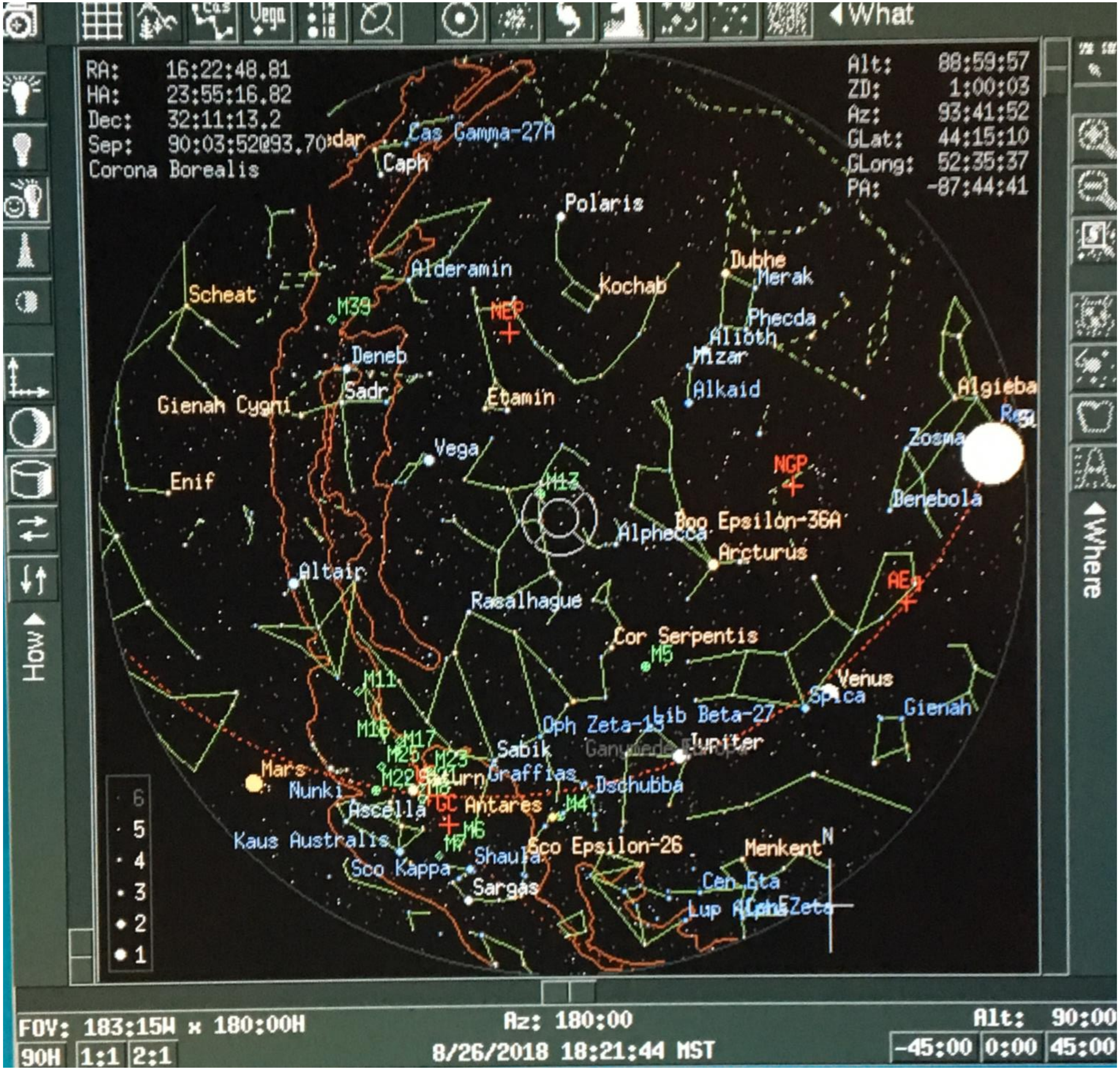
Let's practice at an actual telescope: Our 21"

Steward's Telescope Control System (TCS)



Where is the telescope pointed now?

Small angular corrections are applied


What
RA: 16:22:48.81
HA: 23:55:16.82
Dec: 32:11:13.2
Sep: 90:03:52@93.70
Corona Borealis
Alt: 88:59:57
ZD: 1:00:03
Az: 93:41:52
GLat: 44:15:10
GLong: 52:35:37
PA: -87:44:41
Cas Gamma-27A
Caph
Polaris
Alderamin
Scheat
Kochab
Dubhe
Merak
Phecda
Alioth
Mizar
Alkaid
M39
NEP
Deneb
Sadr
Gienah Cygni
Etamin
Algieba
Zosma
Vega
Enif
M13
NGP
Denebola
Alphecca
Boo Epsilon-36A
Arcturus
Altair
Rasalhague
AE
Cor Serpentis
M5
Venus
Spica
M11
Gienah
Oph Zeta-13
Lib Beta-27
M16
M17
M25
M23
Sabik
Jupiter
Mars
M22
Saturn
Graffias
Dschubba
Nunki
GC
Antares
M4
Ascella
M6
M7
Kaus Australis
Sco Epsilon-26
Menkent
N
Sco Kappa
Shaula
Cen Eta
Sargas
Lup
Where
How
6
5
4
3
2
1
FOV: 183:15W x 180:00H
Az: 180:00
Alt: 90:00
90H
1:1
2:1
8/26/2018 18:21:44 MST
-45:00
0:00
45:00

The Evening Sky Map

FREE* EACH MONTH FOR YOU TO EXPLORE, LEARN & ENJOY THE NIGHT SKY

NORTHERN HEMISPHERE
JANUARY 2020

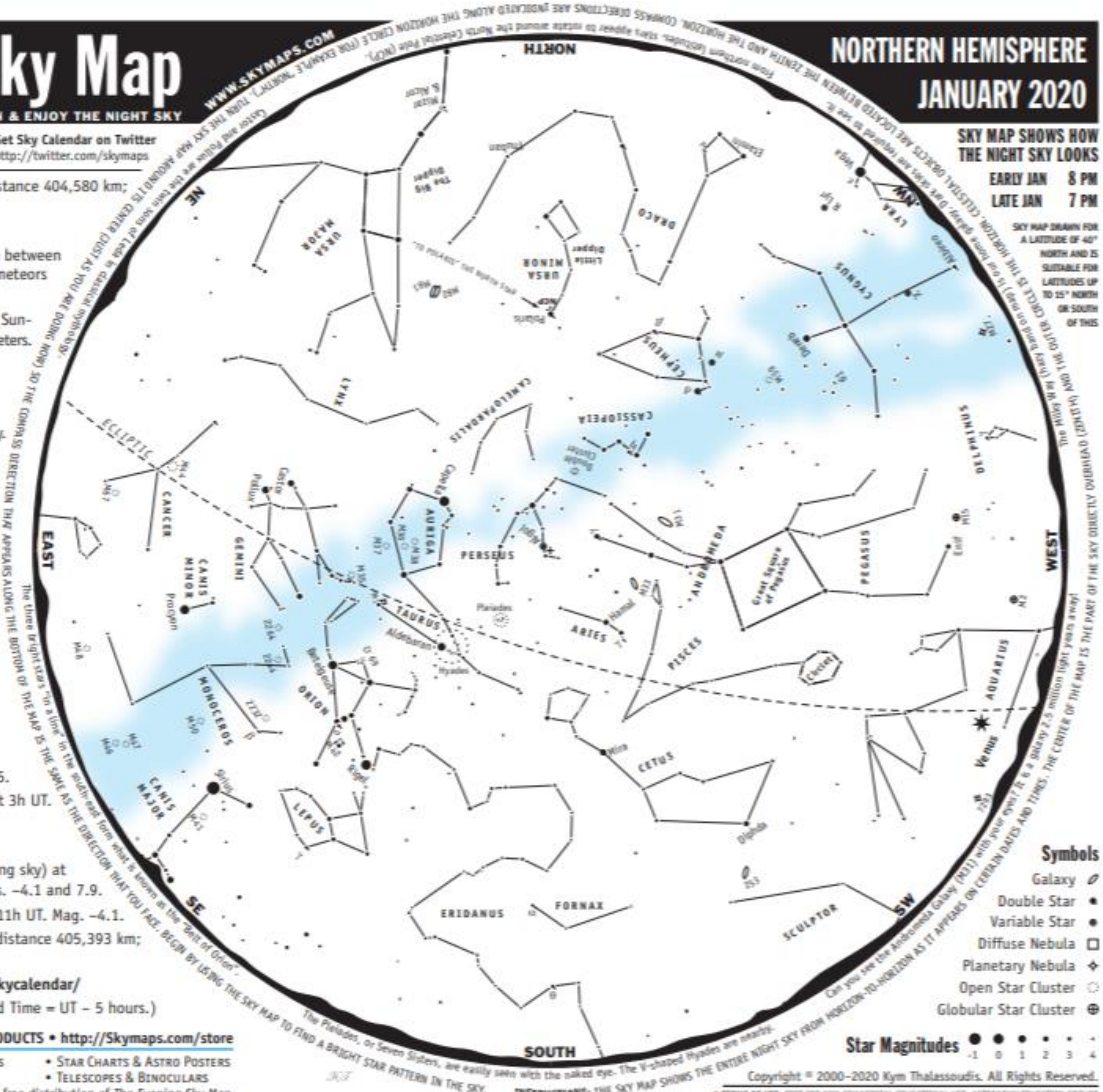
Sky Calendar – January 2020

Get Sky Calendar on Twitter
http://twitter.com/skymaps

- 2 **Moon at apogee** (farthest from Earth) at 1h UT (distance 404,580 km; angular size 29.5').
- 3 **First Quarter Moon** at 4:46 UT.
- 4 **Quadrantid Meteor Shower** peaks at 8h UT. Active between December 28 and January 12. Produces up to 120 meteors per hour. Radiant in northern Boötes.
- 5 **Earth at Perihelion** (closest to Sun) at 8h UT. The Sun-Earth distance is 0.983244 a.u. or 147.1 million kilometers.
- 7 **Moon near the Pleiades** (evening sky) at 4h UT.
- 7 **Moon near Aldebaran** (evening sky) at 21h UT.
- 10 **Mercury at superior conjunction** with the Sun at 15h UT. The elusive planet passes into the evening sky.
- 10 **Full Moon** at 19:22 UT.
- 10 **Penumbral Lunar Eclipse** from 17:08 to 21:12 UT, mid-eclipse at 19:10 UT. Best seen near mid-eclipse. Visible worldwide except most of N and S America.
- 12 **Moon near Beehive cluster M44** (morning sky) at 2h UT.
- 13 **Moon near Regulus** (morning sky) at 15h UT.
- 13 **Moon at perigee** (closest to Earth) at 20:23 UT (distance 365,958 km; angular size 32.7').
- 17 **Moon near Spica** (morning sky) at 9h UT.
- 17 **Last Quarter Moon** at 12:59 UT.
- 18 **Mars 4.7° N of Antares** (morning sky) at 9h UT. Mags. 1.5 and 1.0.
- 20 **Moon near Antares** (morning sky) at 18h UT.
- 20 **Moon near Mars** (morning sky) at 21h UT. Mag. 1.5.
- 23 **Moon near Jupiter** (21° from Sun, morning sky) at 3h UT. Mag. –1.9.
- 24 **New Moon** at 21:43 UT. Start of lunation 1201.
- 27 **Venus 0.07° SE of Neptune** (40° from Sun, evening sky) at 21h UT. Neptune appears like a pale blue dot. Mags. –4.1 and 7.9.
- 28 **Moon near Venus** (40° from Sun, evening sky) at 11h UT. Mag. –4.1.
- 29 **Moon at apogee** (farthest from Earth) at 21h UT (distance 405,393 km; angular size 29.5').

More sky events and links at http://Skymaps.com/skycalendar/

All times in Universal Time (UT). (USA Eastern Standard Time = UT – 5 hours.)



SKY MAP SHOWS HOW THE NIGHT SKY LOOKS

EARLY JAN 8 PM
LATE JAN 7 PM

SKY MAP DRAWN FOR A LATITUDE OF 40° NORTH AND IS SUITABLE FOR LATITUDES UP TO 15° NORTH OR SOUTH OF THIS

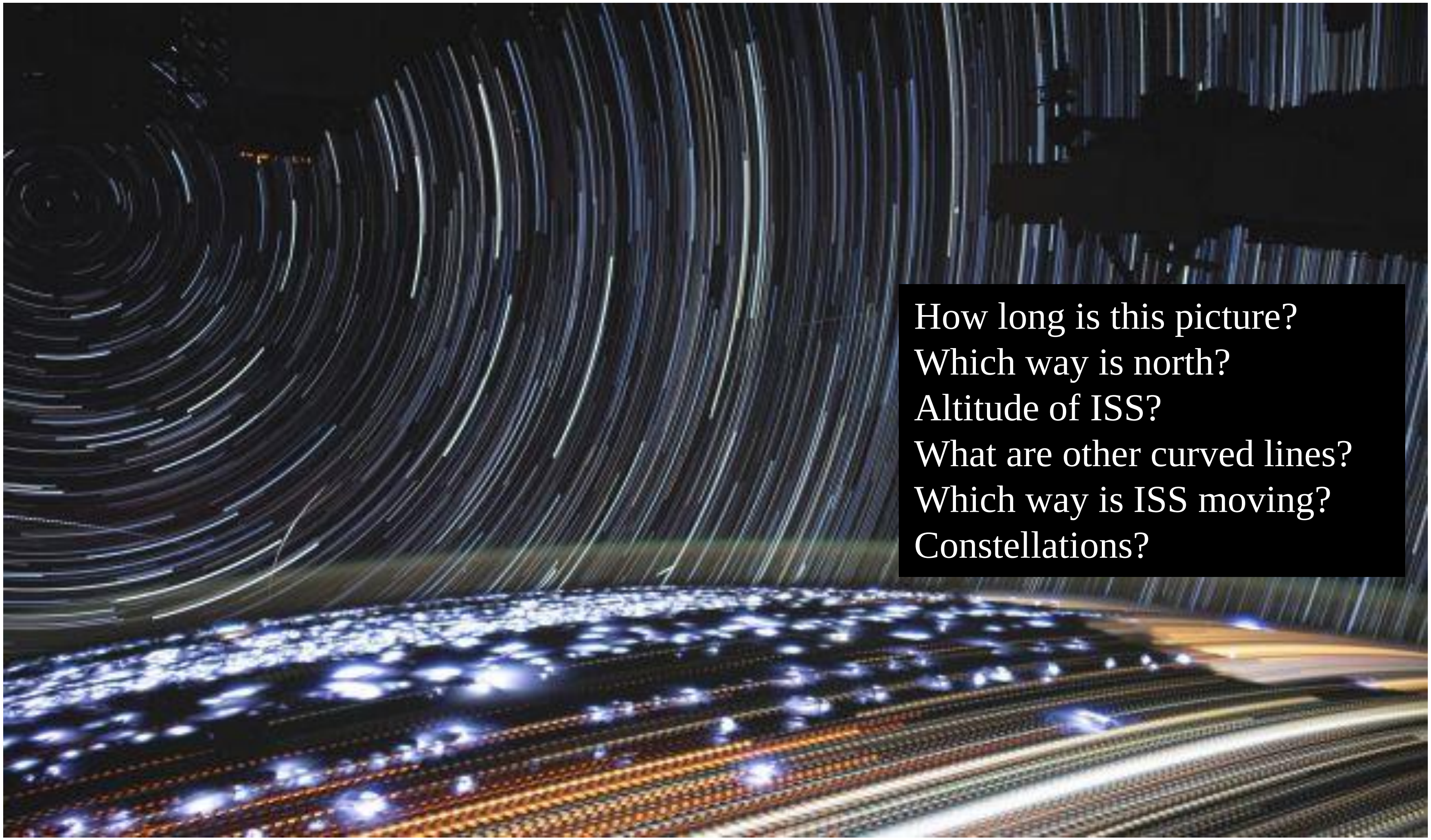
Symbols

Galaxy
Double Star
Variable Star
Diffuse Nebula
Planetary Nebula
Open Star Cluster
Globular Star Cluster

Star Magnitudes -1 0 1 2 3 4

Where was this picture taken?

Exposure time = ?



How long is this picture?
Which way is north?
Altitude of ISS?
What are other curved lines?
Which way is ISS moving?
Constellations?

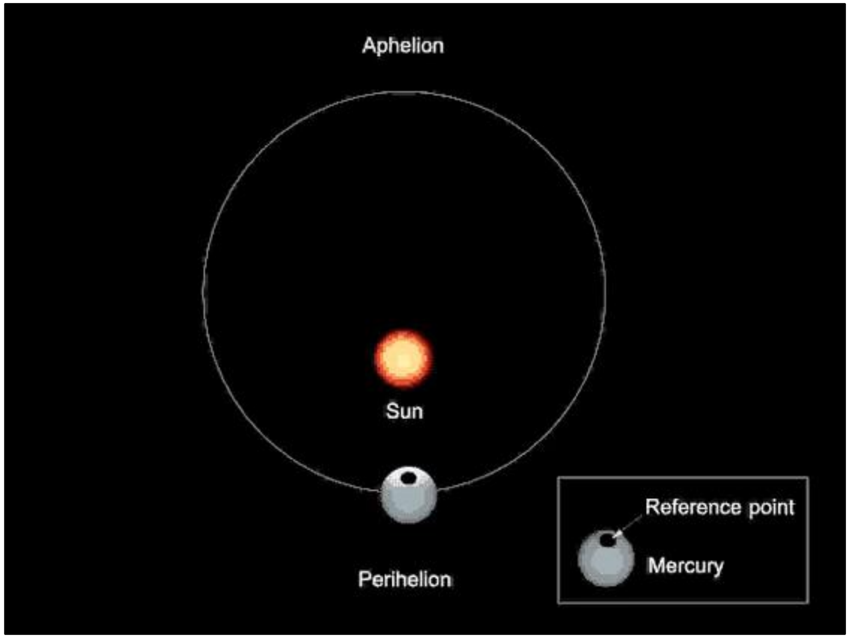
Mercury: Solar vs. Sidereal Day

How long is a "day" on Mercury?

Mercury rotates on its axis exactly 1.5 times for each revolution around the Sun.

Revolution period
87.969 days

Rotation period
58.646 days



Mercury rotates exactly 3 times during two orbits around Sun.

RATIO = 87.97/58.65 = 3:2
["3:2 spin-orbit resonance"]

What does it mean to “revolve”?
How long is a “year”?

- **Synodic period = 29.53 days**
- **Sidereal period = 27.32 days**