the Visible Sky

I. Stars and Celestial Sphere
   Constellations & Coordinates

II. Sun
   Time, Seasons, Precession

III. Moon
   Phase, Orbit, etc.

IV. Eclipses
   Solar & Lunar

The student will be able to:		HW:
1	Explain and utilize constellations and asterisms as means of mapping and organizing the stars.	1 – 4
2	Explain and utilize the concept of the celestial sphere as a means of understanding the appearance of the universe as seen from Earth.	
3	Explain the significance of the pole star, Polaris, and its connection with the apparent motion of the celestial sphere.	
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
10	Explain, define, and utilize the concept of the ecliptic and the ecliptic plane.	
11	Illustrate and describe the connection between the seasons and the motion and orientation of the Earth in its orbit.	15
12	Explain the cause and effect of Earth's precession and state and apply the period of this cycle to solve problems.	16
13	Describe changes in the appearance of the Moon over the course of one day and night, from one night to the next, from one week to the next, from one month to the next, and from year to year.	17 – 20
14	Explain the apparent motion and changing appearance of the Moon in terms of the actual motions of the Earth and Moon relative to the Sun.	
15	Explain and illustrate how the motion and position of the Moon relative to the Earth and the Sun result in the phases: new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, third quarter, and waning crescent.	
16	Define, apply, and relate to astronomical events or cycles the following concepts: sidereal month, synodic month, lunar sidereal and solar days.	21 – 22
17	Explain and illustrate how the motions and positions of the Earth, the Sun, and the Moon result in lunar and solar eclipses – partial, total, and annular.	23
18	Explain and illustrate the concepts of umbra and penumbra in relation to eclipses.	24

The Celestial Sphere

Mapping the Stars

Mapping the Sky

- The celestial sphere is an imaginary sphere centered on the observer or any point of possible observation
- It is as if all of the stars are “painted” on an invisible globe and the observer is at the center of that globe.
- Two methods are used to map stars on this globe: constellations and celestial coordinates.

Constellations

- It is human nature to recognize patterns. Originally constellations were simply patterns of stars, usually attributed to mythological beings.
- The pattern may or may not look like what it is supposed to be!
- There is no “official way” to see the patterns – you can imagine the figure or “connect the dots” however you please …

image: Stellarium

image: Stellarium

image: Stellarium

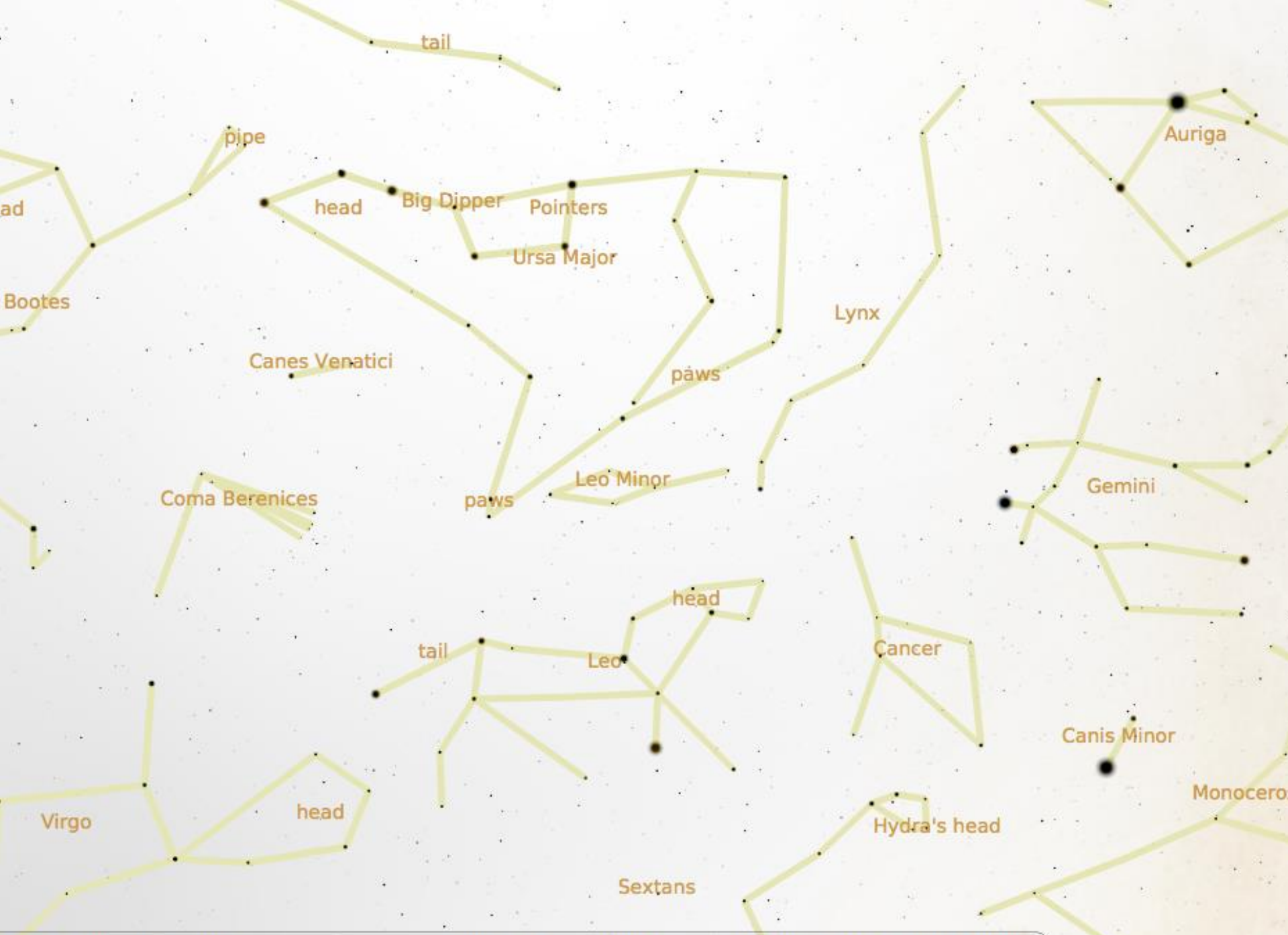


image: Stellarium

Constellations

- Eventually, boundaries were developed for constellations so that every star could be clearly designated as being “in” a particular constellation.
- In 1875 Gould defined boundary lines for about half and the rest were done by Eugene Delporte.
- In 1930 the International Astronomical Union defined official boundaries for 88 constellations. This is how constellations are defined scientifically currently.

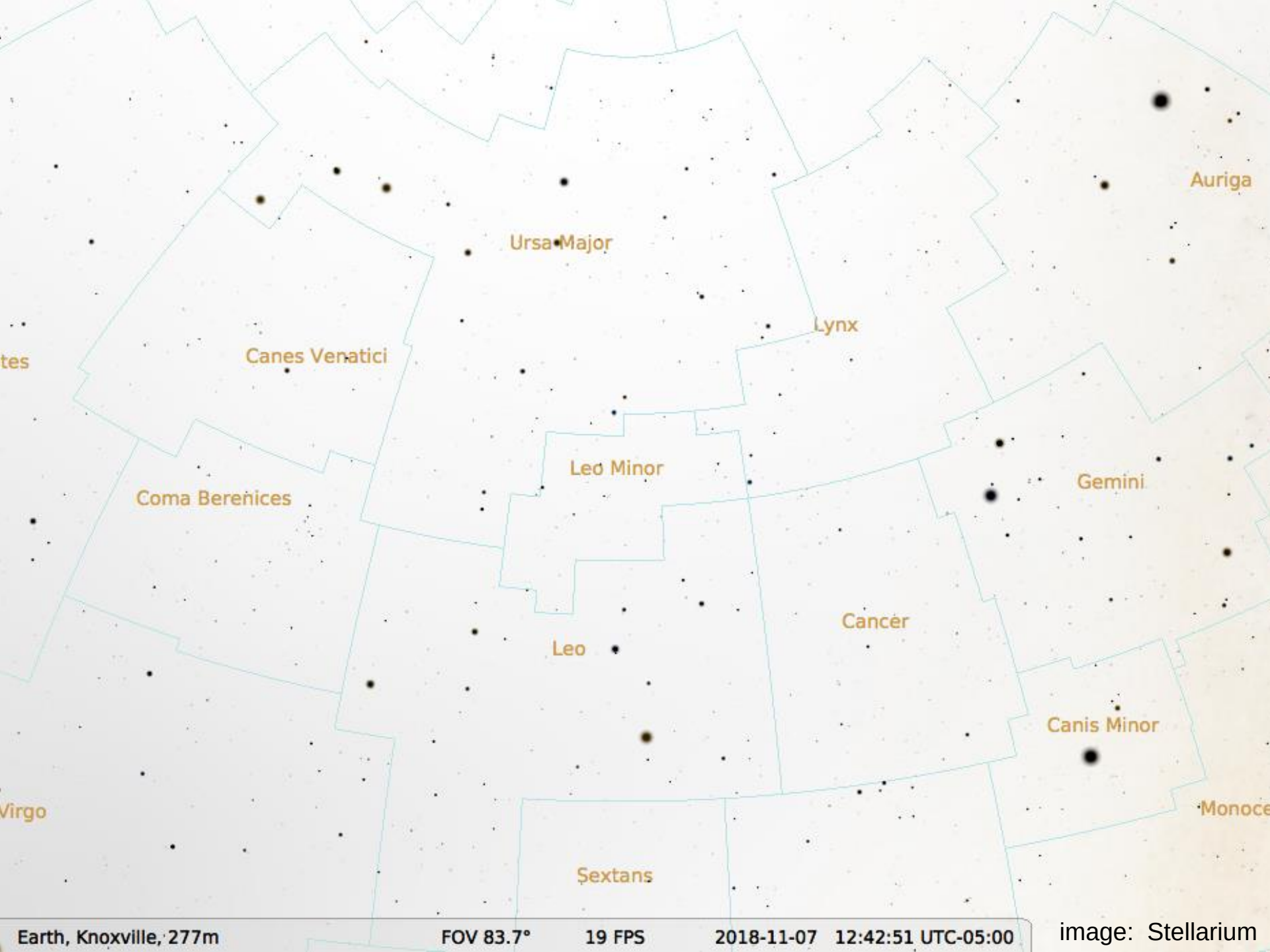


image: Stellarium

Constellations

- The 88 constellations completely “tile” the celestial globe – *i.e.* they fit together like jigsaw pieces.
- Serpens Cauda and Serpens Caput count as 1 out of the total 88.
- Stars within a constellation are designated with a Greek letter, usually in order of apparent brightness. Example: beta Leonis is the second brightest star in Leo.

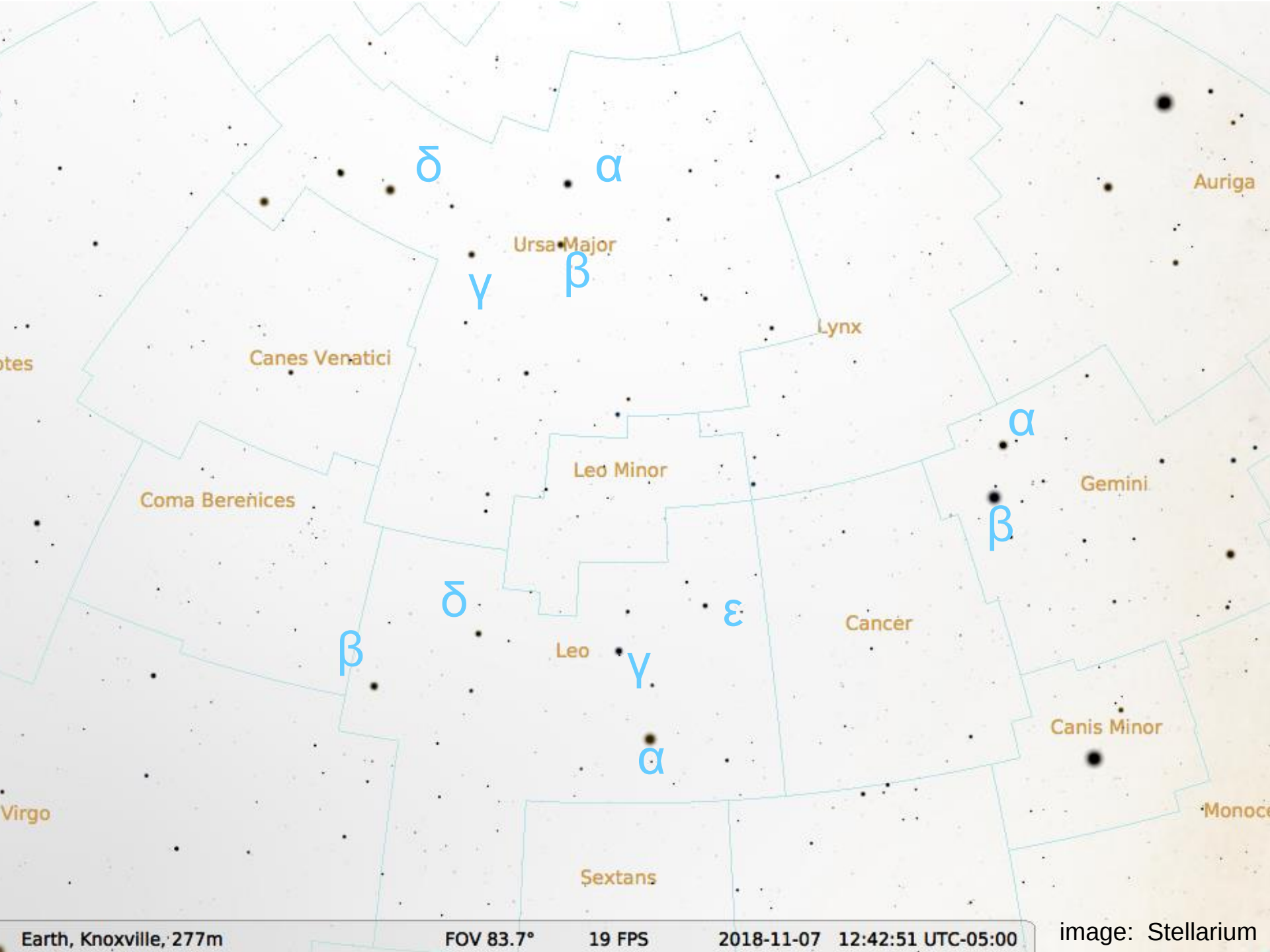


image: Stellarium

Asterisms

- These days a constellation is not a pattern of stars, but rather a well defined and bounded region in the sky.
- An “asterism” is an informal pattern of stars recognized by many people. Usually an asterism is named for what it looks like.
- An asterism is not “officially recognized” by astronomers. But asterisms are useful for learning your way around the sky!

image: Stellarium

The Evening Sky Map

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

NORTHERN HEMISPHERE
AUGUST 2018

Sky Calendar – August 2018

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

4 **Last Quarter Moon** at 18:19 UT.

6 **Moon near the Pleiades** at 3h UT (morning sky).

6 **Moon near Aldebaran** (morning sky) at 19h UT.

9 **Mercury at inferior conjunction** with the Sun at 2h UT. Mercury passes into the morning sky. Not visible.

9 **Moon near Castor** (morning sky) at 15h UT.

9 **Moon near Pollux** (morning sky) at 19h UT.

10 **Moon at perigee** (closest to Earth) at 18:10 UT (358,078 km; angular size 33.4').

11 **Partial Eclipse of the Sun** at 9:46 UT (greatest). Visible from northern Europe and NE Asia. Begins at 8:02 and ends at 11:31 UT.

11 **New Moon** at 9:58 UT. Start of lunation 1183.

12 **Perseid meteor shower peaks** at 20h UT. Peak lasts about 12 hours. Active from July 17 to August 24. Produces swift, bright meteors (50 to 100 per hour) many with persistent trains. Best viewing is after midnight. Favorable conditions in 2018.

12 **Moon near Regulus** (evening sky) at 4h UT.

14 **Moon near Venus** (evening sky) at 18h UT. Mag. –4.3.

15 **Moon near Spica** (evening sky) at 22h UT.

17 **Moon near Jupiter** (evening sky) at 13h UT. Mag. –2.0.

17 **Venus at greatest elongation east** (46° from Sun, evening sky) at 17h UT. Mag. –4.3.

18 **First Quarter Moon** at 7:49 UT.

19 **Moon near Antares** (evening sky) at 13h UT.

21 **Moon near Saturn** (evening sky) at 10h UT. Mag. 0.3.

23 **Moon at apogee** (farthest from Earth) at 11h UT (distance 405,746 km; angular size 29.4').

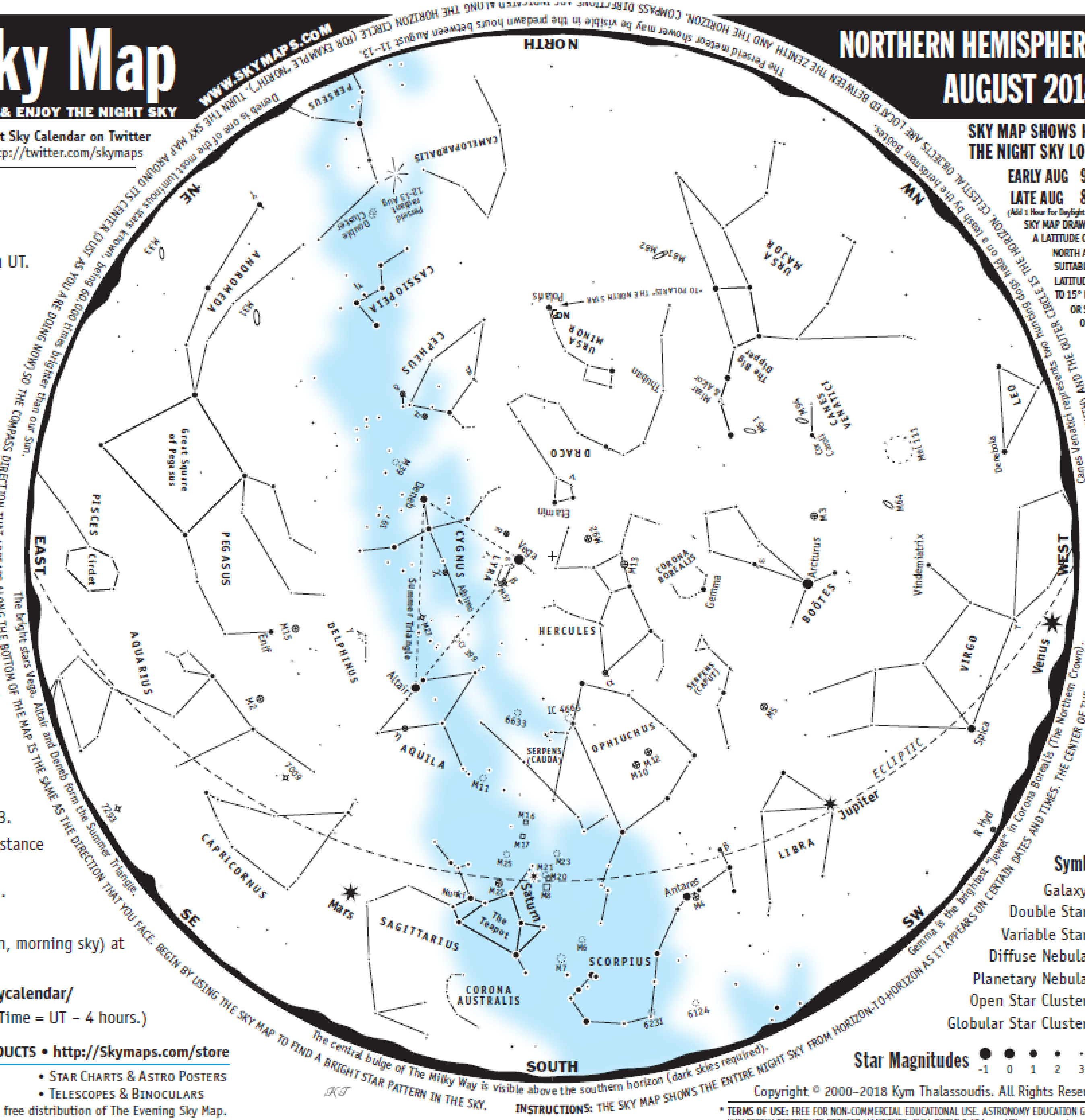
23 **Moon near Mars** (evening sky) at 16h UT. Mag. –2.3.

26 **Full Moon** at 11:57 UT.

26 **Mercury at greatest elongation west** (18° from Sun, morning sky) at 20h UT. Mag. –0.1.

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

All times in Universal Time (UT). (USA Eastern Daylight Time = UT – 4 hours.)



WWW.SKYMAPS.COM
The Perseid meteor shower may be visible in the predawn hours between August 11–13.
COMPASS DIRECTIONS ARE INDICATED ALONG THE HORIZON CIRCLE (FOR EXAMPLE "NORTH"). TURN THE SKY MAP AROUND ITS CENTER (JUST AS YOU ARE DOING NOW) SO THE COMPASS DIRECTION THAT APPEARS ALONG THE BOTTOM OF THE MAP IS THE SAME AS THE DIRECTION THAT YOU FACE. BEGIN BY USING THE SKY MAP TO FIND A BRIGHT STAR PATTERN IN THE SKY.
INSTRUCTIONS: THE SKY MAP SHOWS THE ENTIRE NIGHT SKY FROM HORIZON-TO-HORIZON AS IT APPEARS ON CERTAIN DATES AND TIMES. THE CENTER OF THE MAP IS THE PART OF THE SKY DIRECTLY OVERHEAD (ZENITH) AND THE OUTER CIRCLE IS THE HORIZON. CELESTIAL OBJECTS ARE LOCATED BETWEEN THE ZENITH AND THE HORIZON.
Deneb is one of the most luminous stars known, being 60,000 times brighter than our Sun.
The bright stars Vega, Altair and Deneb form the Summer Triangle.
The central bulge of The Milky Way is visible above the southern horizon (dark skies required).
Gemma is the brightest "jewel" in Corona Borealis (The Northern Crown).
Canes Venatici represents two hunting dogs held on a leash by the herdsman Boötes.
NORTH
NE
EAST
SE
SOUTH
SW
WEST
NW
PERSEUS
CAMELOPARDALIS
Perseid radiant 12-13 Aug
Double Cluster
CASSIOPEIA
ANDROMEDA
M31
M33
CEPHEUS
URSA MINOR
Polaris
NCP
- TO POLARIS THE NORTH STAR -
URSA MAJOR
M81
M82
The Big Dipper
Mizar & Alcor
Thuban
DRACO
Eltanin
CANES VENATICI
Cor Caroli
M51
M101
M64
Melotte 111
LEO
Denebola
Great Square of Pegasus
PEGASUS
PISCES
Circlet
Enif
M15
DELPHINUS
CYGNUS
Deneb
Albireo
M39
LYRA
Vega
M57
Summer Triangle
M27
Altair
AQUILA
HERCULES
M13
M92
CORONA BOREALIS
Gemma
BOÖTES
Arcturus
M3
Vindemiatrix
VIRGO
Spica
Venus
SERPENS (CAPUT)
M5
OPHIUCHUS
M10
M12
IC 4665
6633
SERPENS (CAUDA)
M11
AQUARIUS
M2
7009
7293
CAPRICORNUS
ECLIPTIC
Jupiter
LIBRA
R Hya
SAGITTARIUS
The Teapot
Nunki
Saturn
M8
M20
M21
M23
M25
M17
M16
M22
Mars
SCORPIUS
Antares
M4
M6
M7
6231
6124
CORONA AUSTRALIS

SKY MAP SHOWS HOW THE NIGHT SKY LOOKS
EARLY AUG 9 PM
LATE AUG 8 PM
(Add 1 Hour For Daylight Saving)
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

Practice

1. Notice on Sky Maps that some patterns are labeled with all capital letters and others are not – what is the difference?
2. Can you find the "Three Leaps of the Gazelle"?
3. The "Teapot" is a part of which constellation?
4. The stars Deneb, Vega, and Altair form what asterism and are found in what constellations?
5. What constellation is found between Serpens (Cauda) and Serpens (Caput)?
6. What planet is currently in Libra?

The Evening Sky Map

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WWW.SKYMAPS.COM

NORTHERN HEMISPHERE
JANUARY 2018

Sky Calendar – January 2018

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

1 **Mercury at greatest elongation** west (23° from Sun, morning sky) at 20h UT. Mag. –0.3.

1 **Moon at perigee** (closest to Earth) at 21:54 UT (356,565 km; angular size 33.5′). Closest of 2018.

2 **Full Moon** at 2:24 UT.

3 **Earth at Perihelion** (closest to Sun) at 6h UT. The Sun-Earth distance is 0.983284 a.u. or 147.1 million kilometers.

3 **Moon near Beehive cluster** M44 (morning sky) at 20h UT.

3 **Quadrantid Meteor Shower** peaks at 22h UT. Active between December 28 and January 12. Produces up to 120 meteors per hour. Radiant is in northern Boötes.

5 **Moon near Regulus** (morning sky) at 8h UT. Occultation visible from Alaska, northern Canada, Greenland and Iceland.

8 **Last Quarter Moon** at 22:25 UT.

9 **Venus at superior conjunction** with the Sun at 6h UT. Passes into the evening sky (not visible).

11 **Moon near Jupiter and Mars** (60° from Sun, morning sky) at 10h UT. Mags. –1.9 and 1.4.

13 **Mercury 0.6° S of Saturn** (20° from Sun, morning sky) at 8h UT. Mags –0.3 and 0.5.

15 **Moon at apogee** (farthest from Earth) at 2h UT (distance 406,464 km; angular size 29.4′).

17 **New Moon** at 2:17 UT. Start of lunation 1176.

24 **First Quarter Moon** at 22:20 UT.

27 **Moon near Aldebaran** (evening sky) at 9h UT. Occultation visible from NW Canada, Alaska, NE Asia.

30 **Moon at perigee** (closest to Earth) at 10h UT (358,994 km; angular size 33.3′).

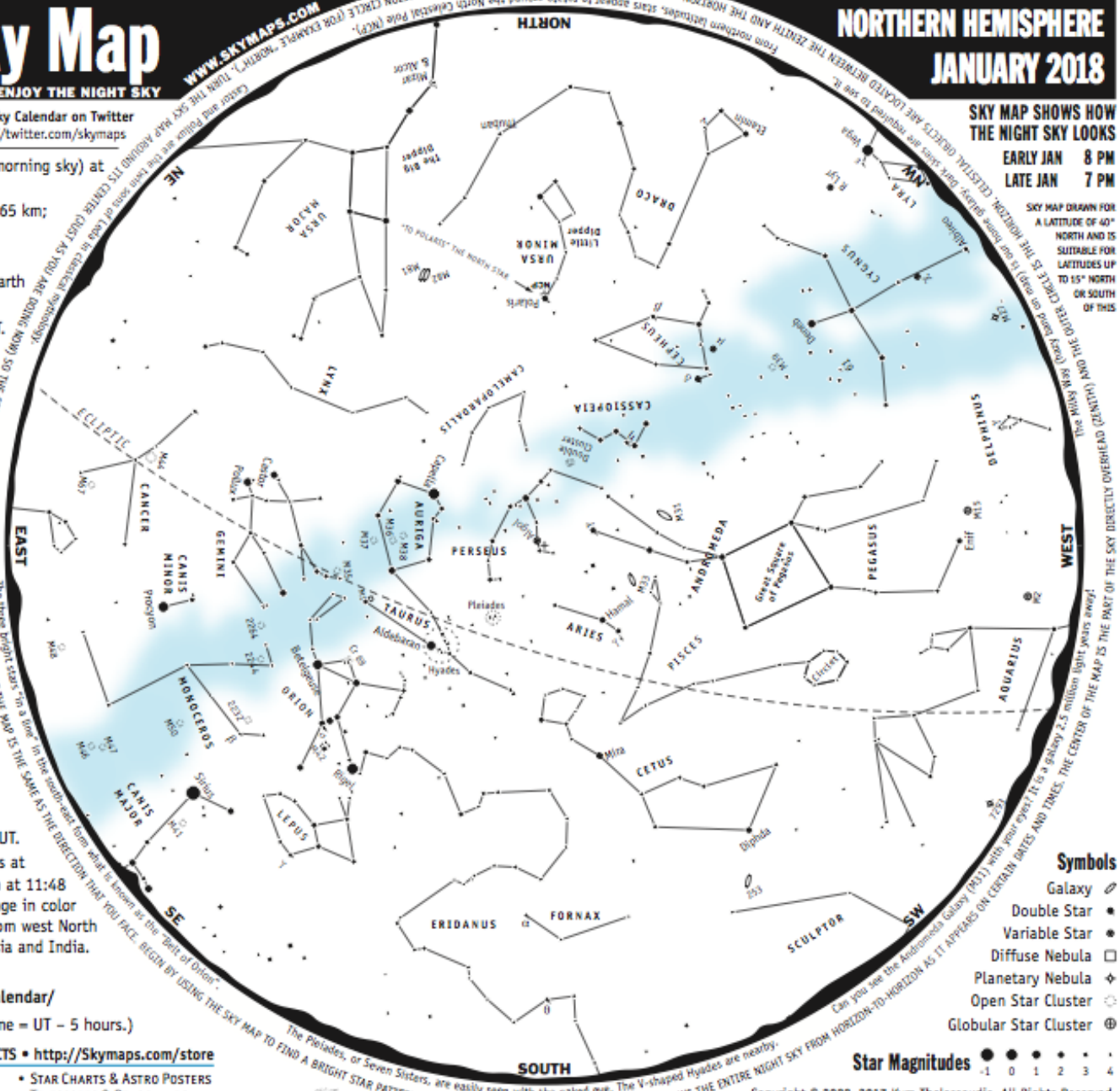
31 **Moon near Beehive cluster** M44 (midnight sky) at 7h UT.

31 **Total Eclipse of the Moon** begins at 12:52 UT and ends at 14:08 UT. Mid-eclipse at 13:30 UT. Partial phases begin at 11:48 UT and end at 15:11 UT. The Moon will appear red-orange in color during totality (the color of Earth's sunsets). Visible from west North America, the Pacific, Australia, New Zealand, Asia, Russia and India.

31 **Full Moon** at 13:27 UT.

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

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



Practice

1. Notice on Sky Maps that some patterns are labeled with all capital letters and others are not – what is the difference?
2. Can you find "Three Leaps of the Gazelle"?
3. The "Circlet" is a part of which constellation?
4. The stars Sirius, Procyon, Pollux, Capella, Aldebaran, and Rigel form an asterism. Can you guess its name? Hint: connect the dots!
5. What constellation is between Gemini and Lynx? The variable star Mira is found in what constellation?

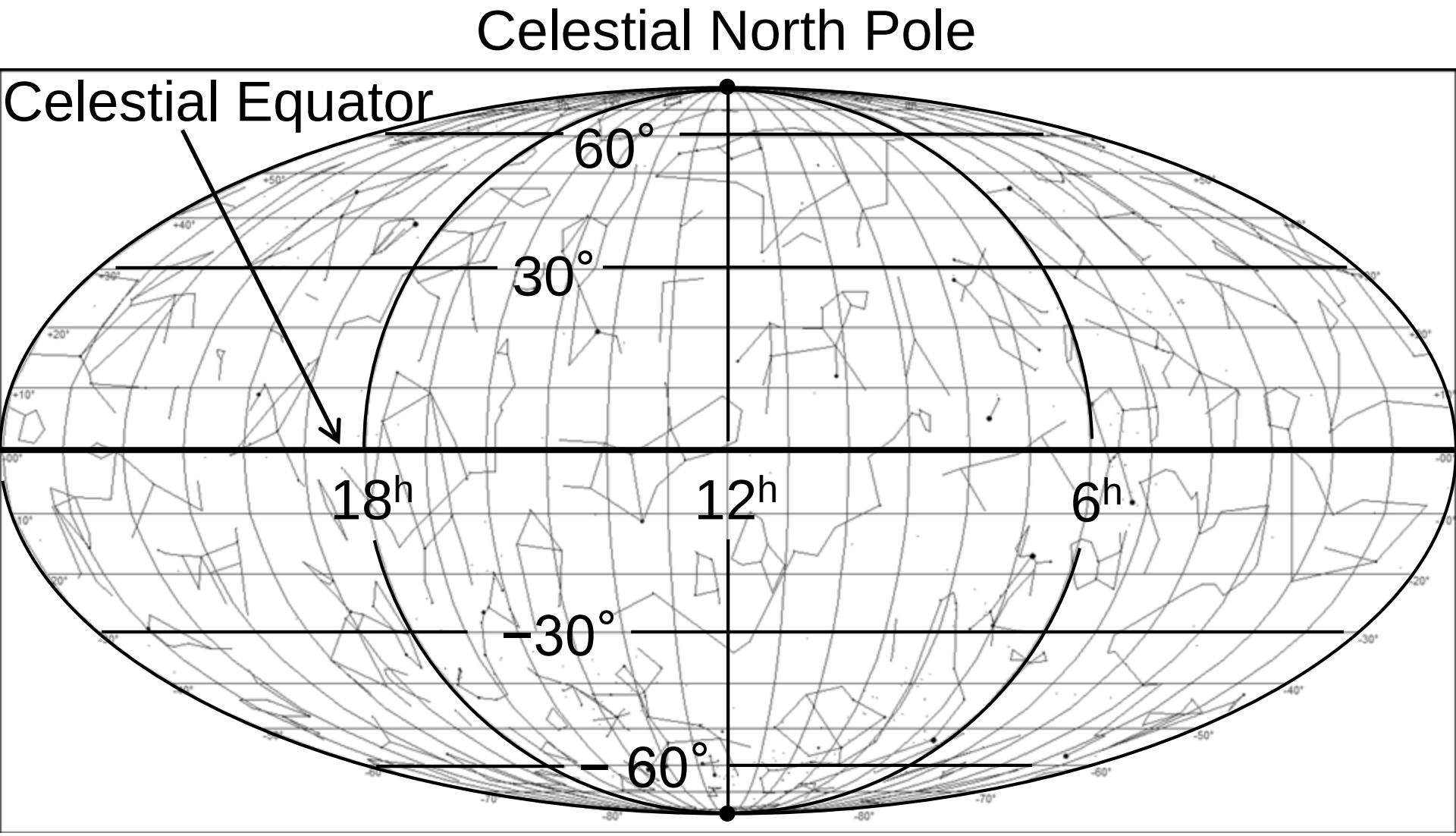
Celestial Coordinates

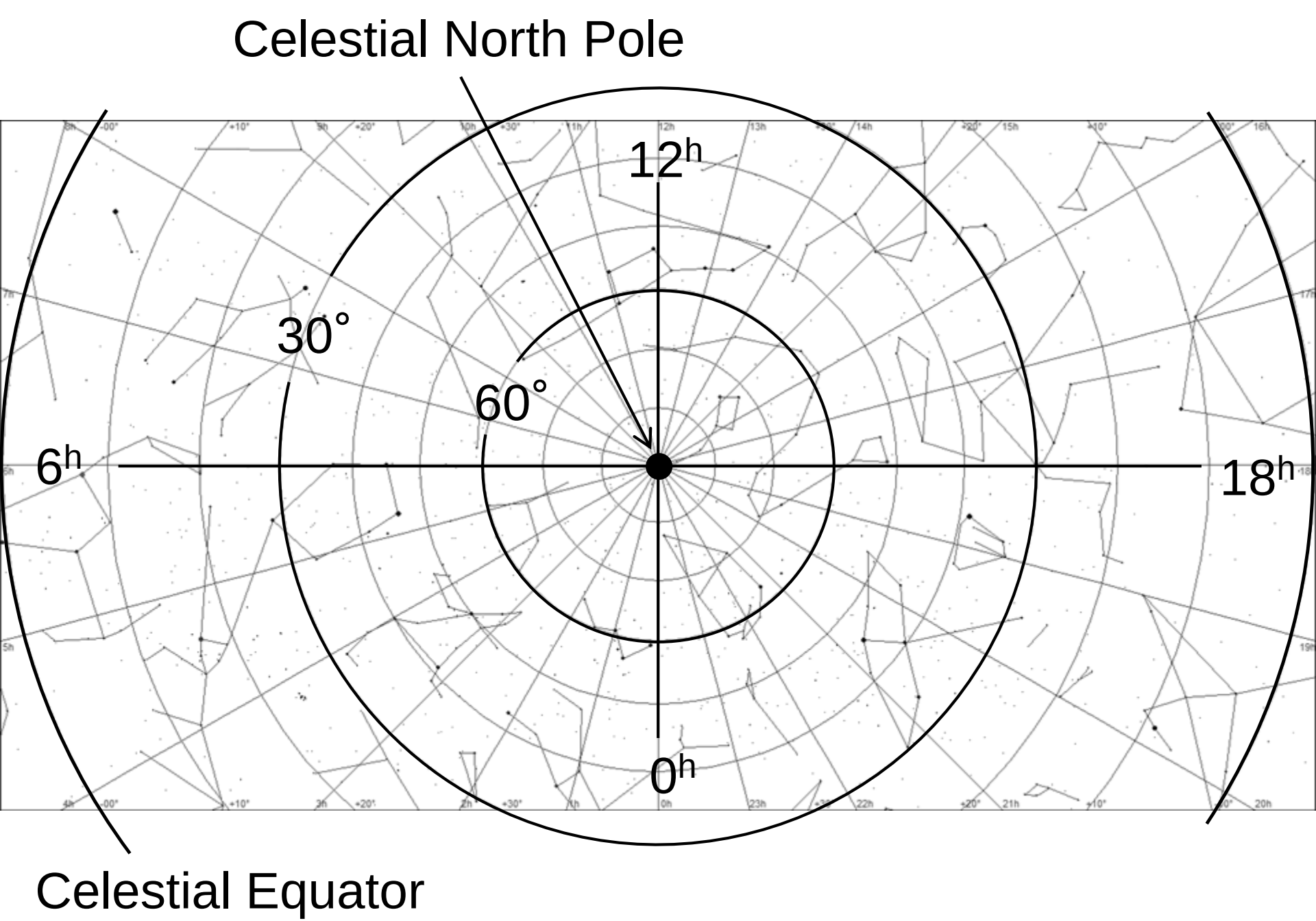
- The precise position of any object in the sky can be specified by celestial or “equatorial” coordinates of declination and right ascension.
- These spherical coordinates are very similar to latitude and longitude or altitude and azimuth.

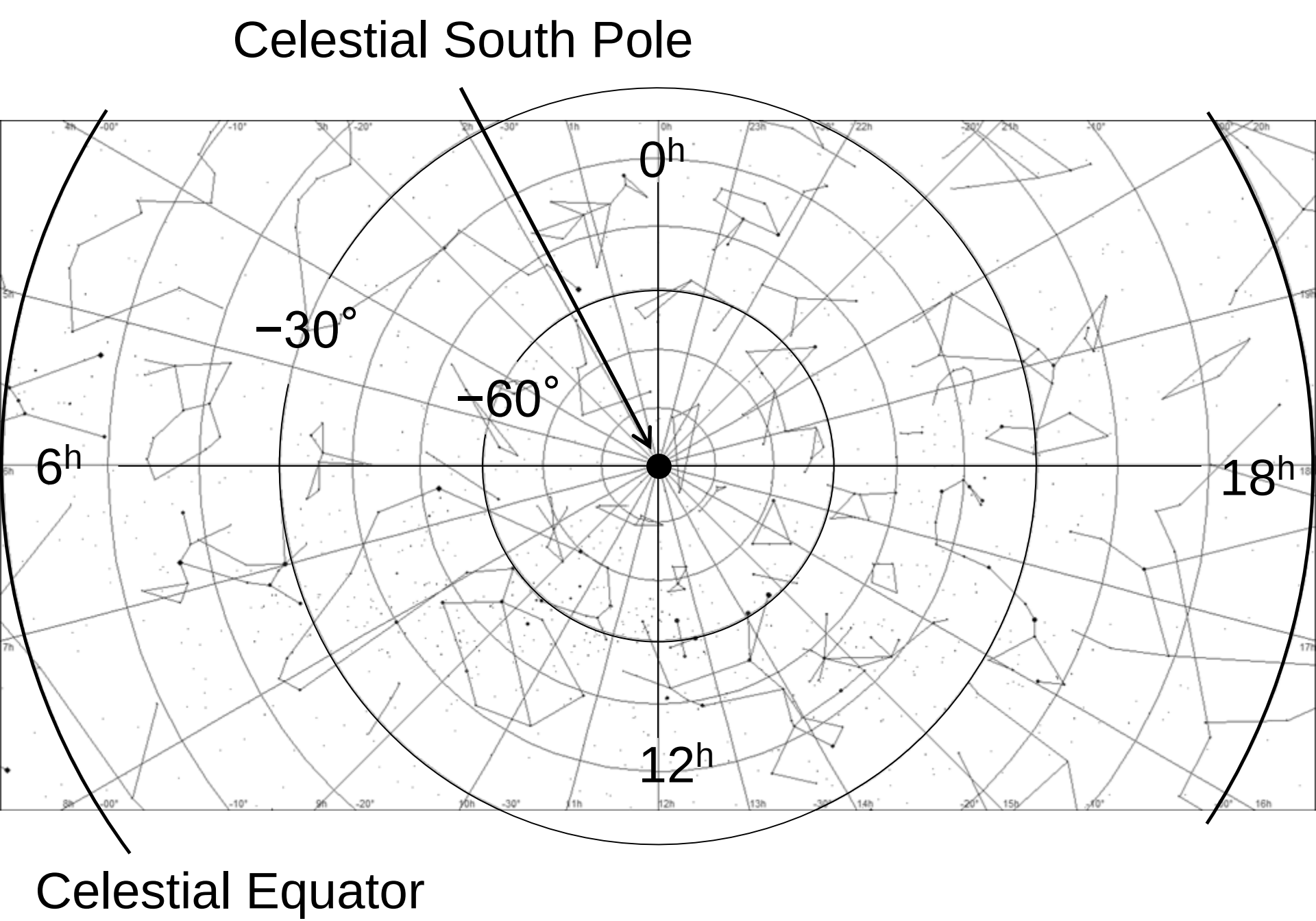

This time-lapse photograph shows the apparent rotation of stars that occurs in about 45 minutes. The center of this apparent rotation is reminiscent of the north pole on a globe. The star nearest the center is Polaris – the North Star!
© 2005 Jerry Lodriguss

Celestial Coordinates

- The **Celestial North Pole** and **Celestial South Pole** are the points at which the Earth's axis of rotation intersects the celestial sphere. The Earth's rotation is what causes the *apparent* rotation of the stars. Polaris, the North Star, just happens to be located very nearly along the Earth's axis of rotation and therefore is very near the Celestial North Pole.
- The **Celestial Equator** divides the celestial sphere into two equal hemispheres and lies in the same plane as the Earth's equator.

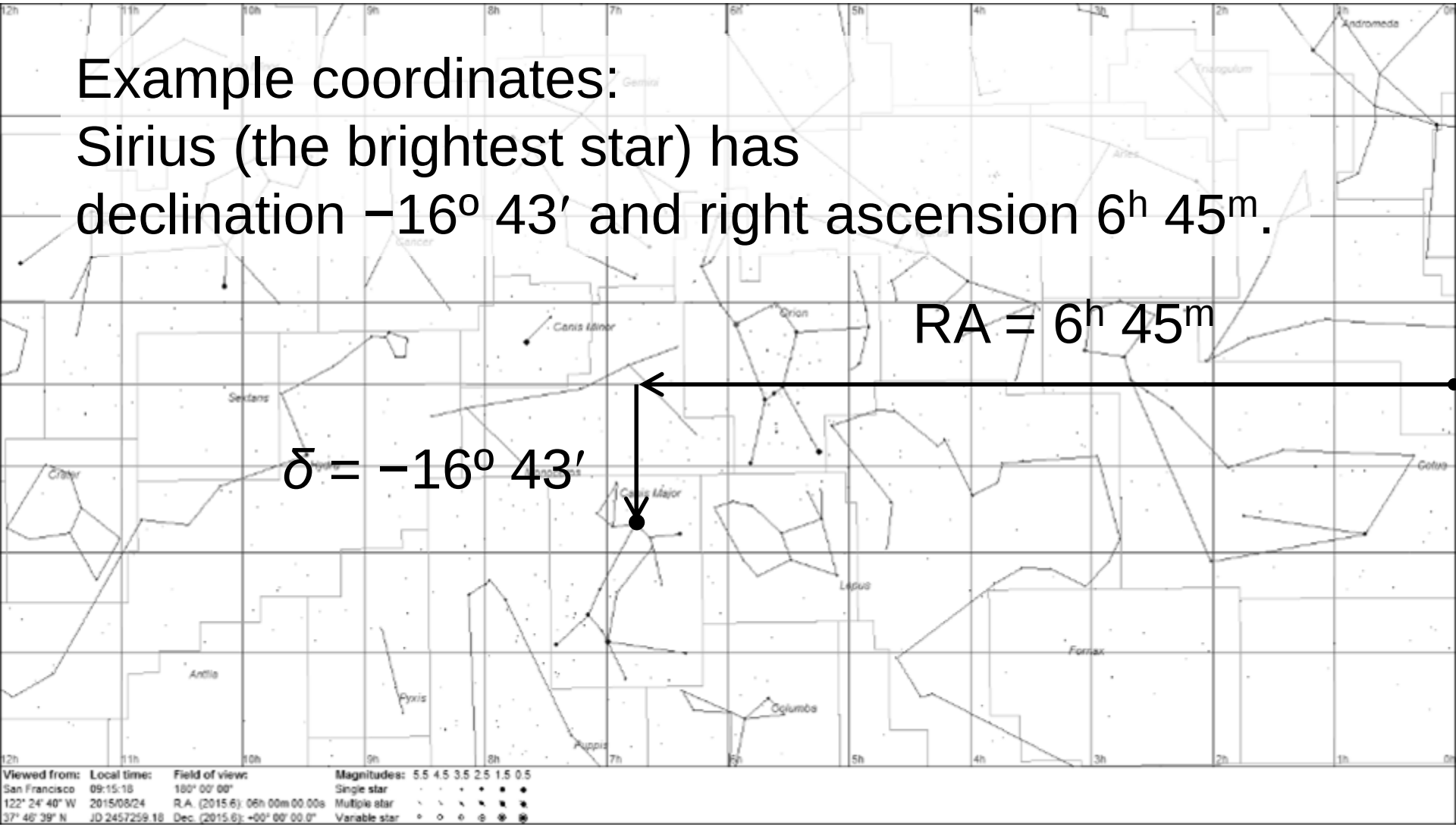






Celestial Coordinates

- Declination is the angular distance north or south of the celestial equator. It has a range of values: $-90^{o} \leq \delta \leq +90^{o}$
- Declination is "like" latitude or altitude.
- Right Ascension is the angular distance East of the Vernal Equinox. This angle is traditionally measured in hours minutes and seconds, where $24^{h} = 360^{o}$. It has a range of values: $0^{h} \leq RA < 24^{h}$.
- Right Ascension is "like" longitude or azimuth.


Example coordinates:
Sirius (the brightest star) has
declination −16º 43′ and right ascension 6h 45m.
RA = 6h 45m
δ = −16º 43′
Canis Minor
Orion
Sextans
Canis Major
Lepus
Fornax
Antlia
Pyxis
Columba
Puppis
Andromeda
Aries
Cancer
Gemini
Crater
Corvus
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h
0h
Viewed from: San Francisco 122° 24' 40" W 37° 46' 39" N
Local time: 09:15:18 2015/08/24 JD 2457259.18
Field of view: 180° 00' 00" R.A. (2015.6): 06h 00m 00.00s Dec. (2015.6): +00° 00' 00.0"
Magnitudes: 5.5 4.5 3.5 2.5 1.5 0.5
Single star
Multiple star
Variable star

About Right Ascension Angles

- One minute of right ascension is $1/60^{th}$ of one hour of right ascension and is not equal to one arc minute!
- One second of right ascension is $1/60^{th}$ of one minute of right ascension and is not equal to one arc second!
- $1^{h} = 15^{o}$
- $1^{m} = 0.25^{o} = 15'$
- $1^{s} = 0.25' = 15''$

Practice – Use a star chart to determine the missing information:

Name	Declination	Right Ascension	Constellation
Sirius	–16º 43′	$6^h\ 45^m$	Canis Major
	38º 47′	$18^h\ 37^m$	
	19º 11′	$14^h\ 15^m$	
	–52º 42′	$6^h\ 24^m$	
	–60º 50′	$14^h\ 40^m$	
Betelgeuse			Orion
Capella			Auriga
Antares			Scorpius
Deneb			Cygnus
Achernar			Eridanus

Practice – Use a star chart to determine the missing information:

Name	Declination	Right Ascension	Constellation
Sirius	–16º 43′	$6^h\ 45^m$	Canis Major
Vega	38º 47′	$18^h\ 37^m$	Lyra
Arcuturus	19º 11′	$14^h\ 15^m$	Boötes
Canopus	–52º 42′	$6^h\ 24^m$	Carina
α-Centauri	–60º 50′	$14^h\ 40^m$	Centaurus
Betelgeuse	7º 25′	$5^h\ 55^m$	Orion
Capella	46º 00′	$5^h\ 17^m$	Auriga
Antares	-26º 28′	$16^h\ 31^m$	Scorpius
Deneb	45º 21′	$20^h\ 42^m$	Cygnus
Achernar	–57º 14′	$1^h\ 38^m$	Eridanus

What *part* of the Celestial Sphere can *you* see?

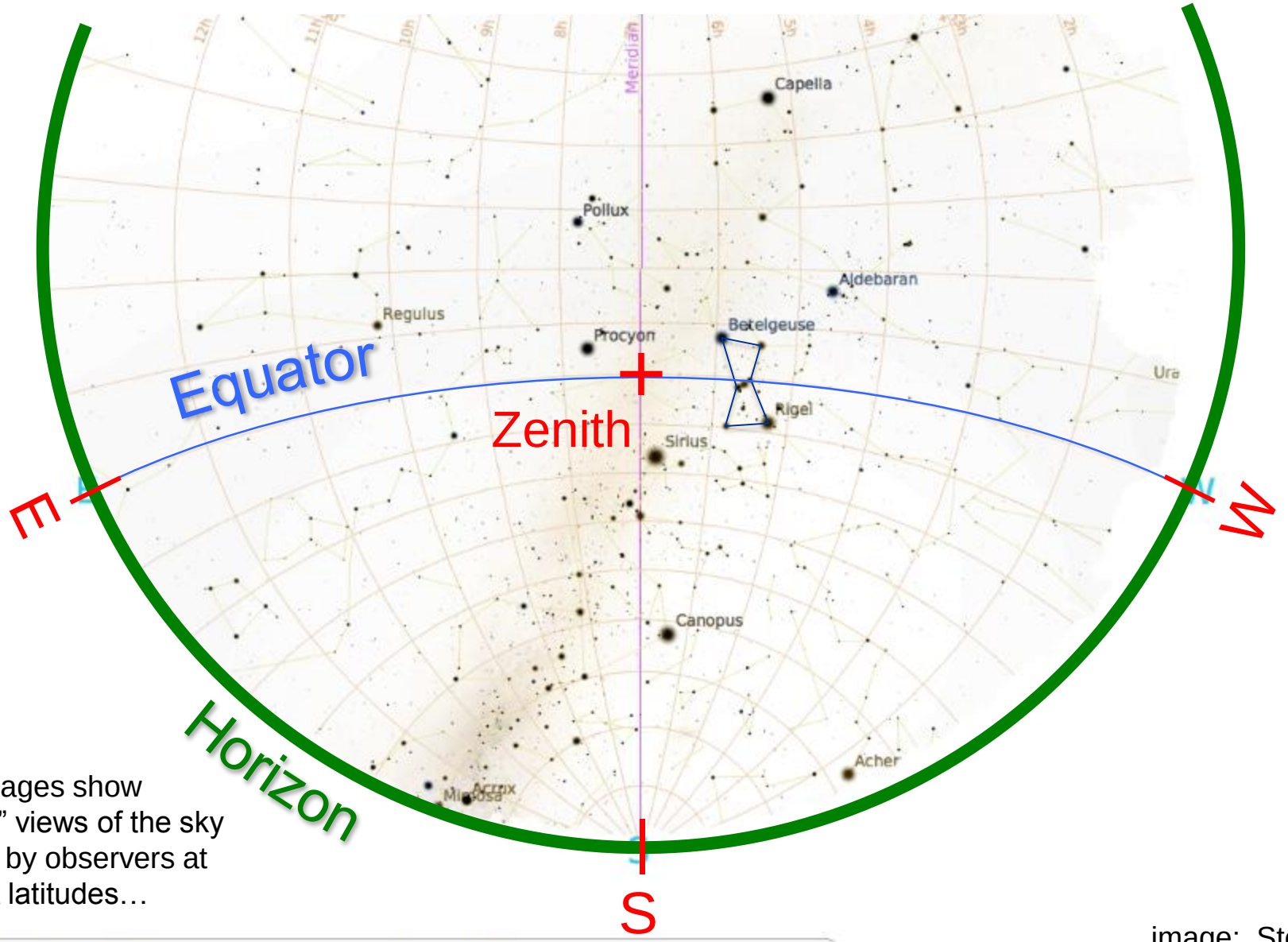
- At any one point in time an observer on Earth can only see half of the celestial sphere.
- *Which* half depends upon:

  latitude,

  time and date,

  and, to a lesser extent, longitude.

latitude 0˚ midnight Jan. 14

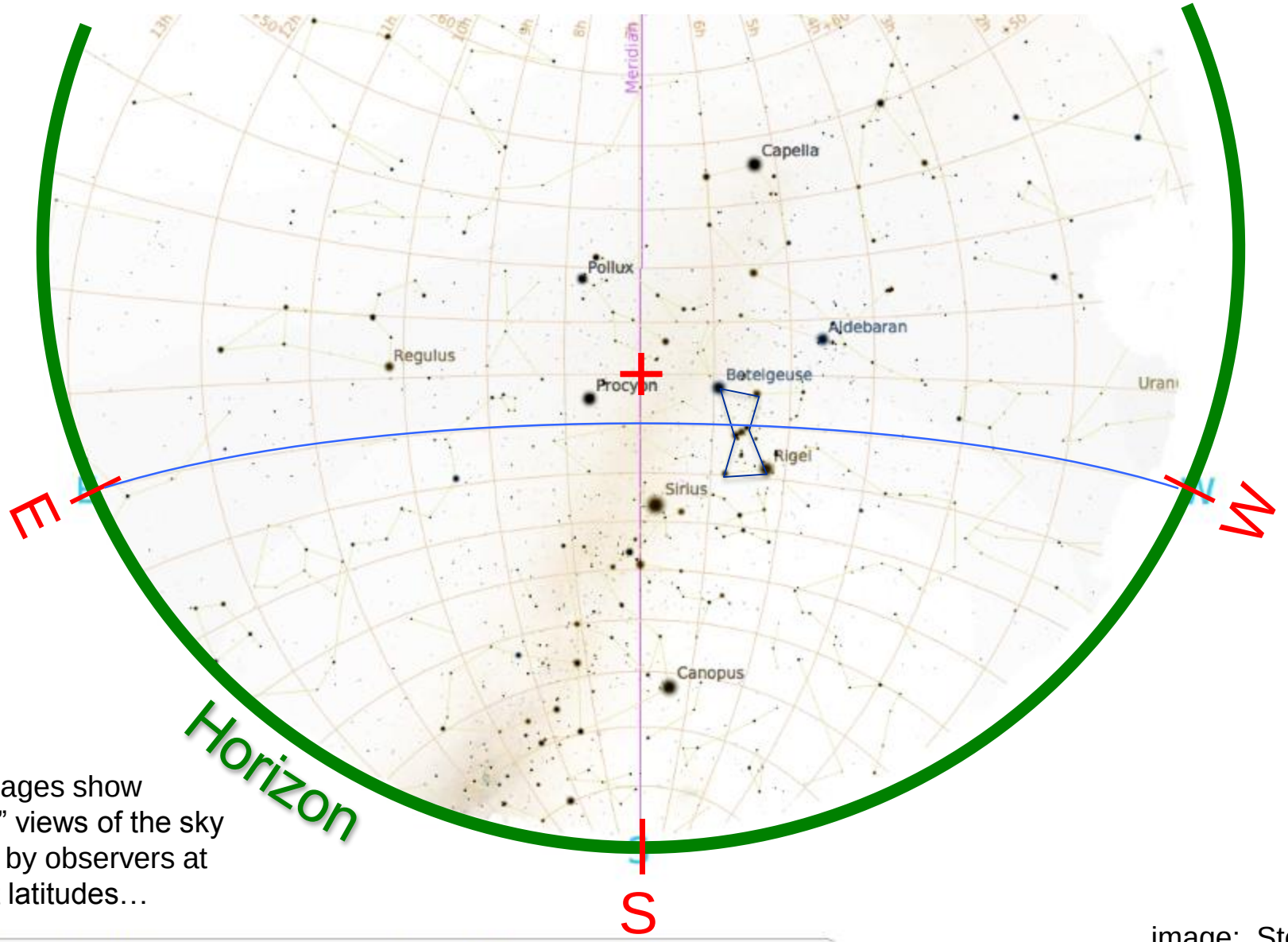


These pages show “fisheye” views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 10° N

midnight Jan. 14

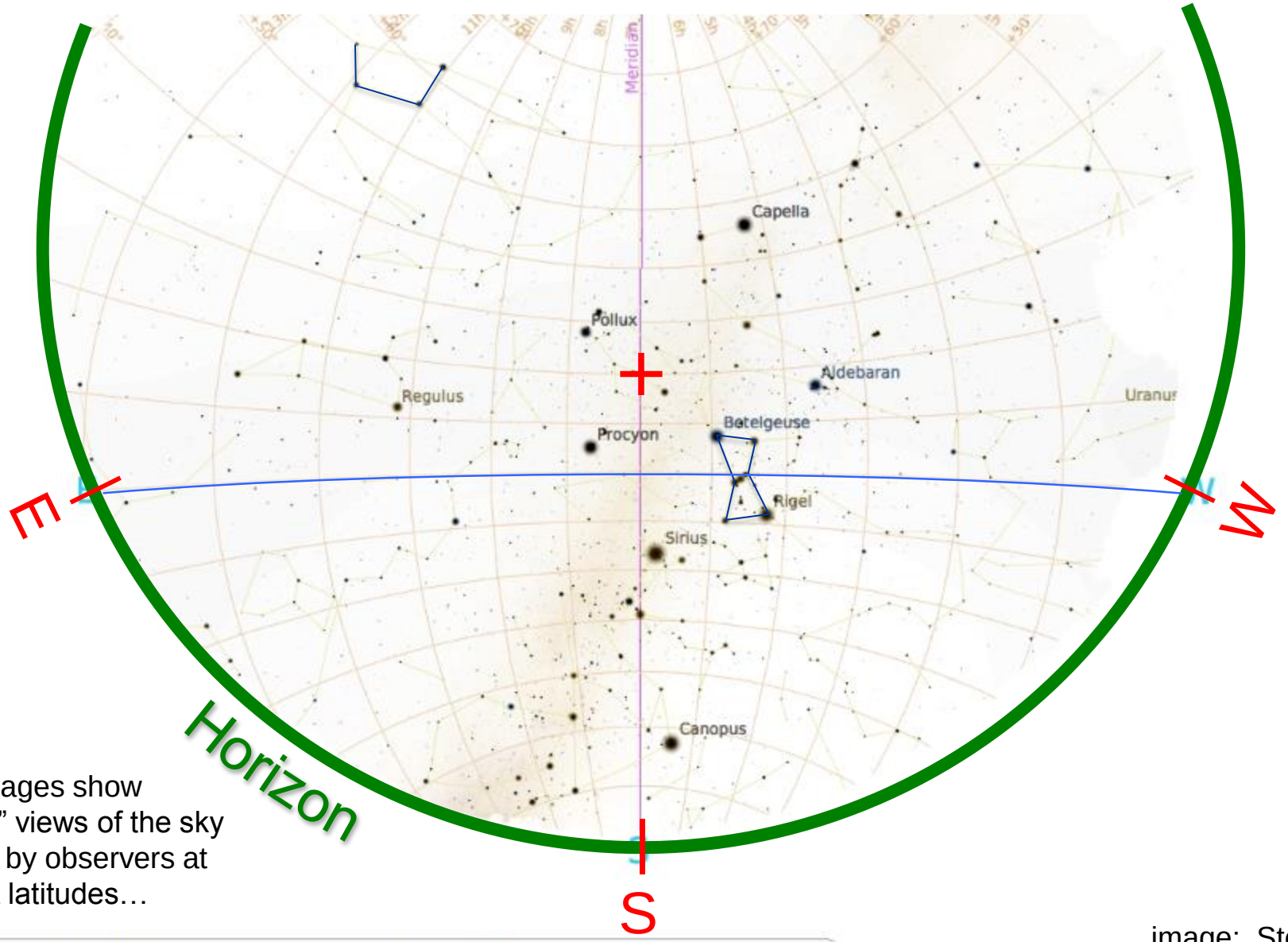


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 20° N

midnight Jan. 14

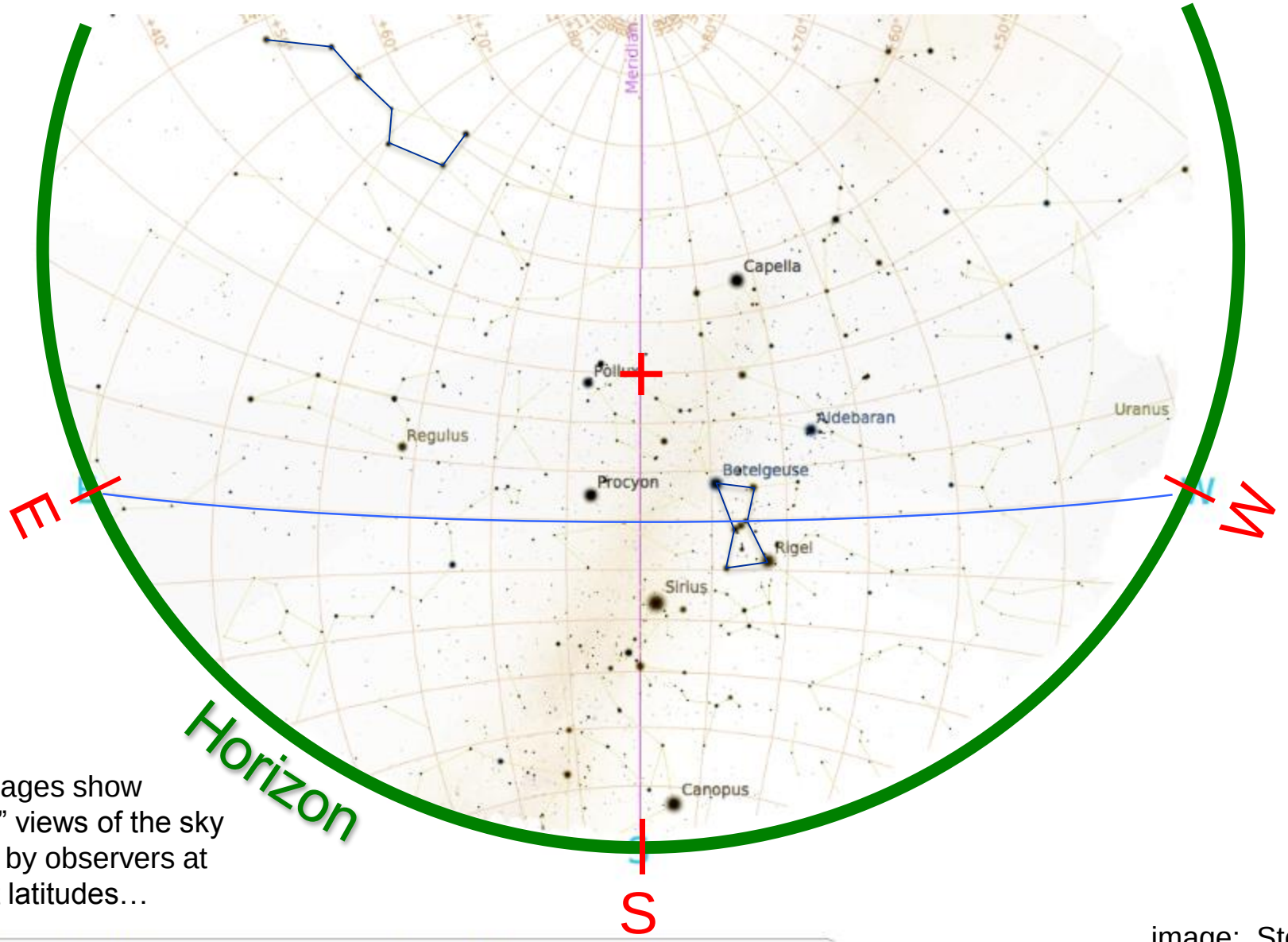


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 30° N

midnight Jan. 14

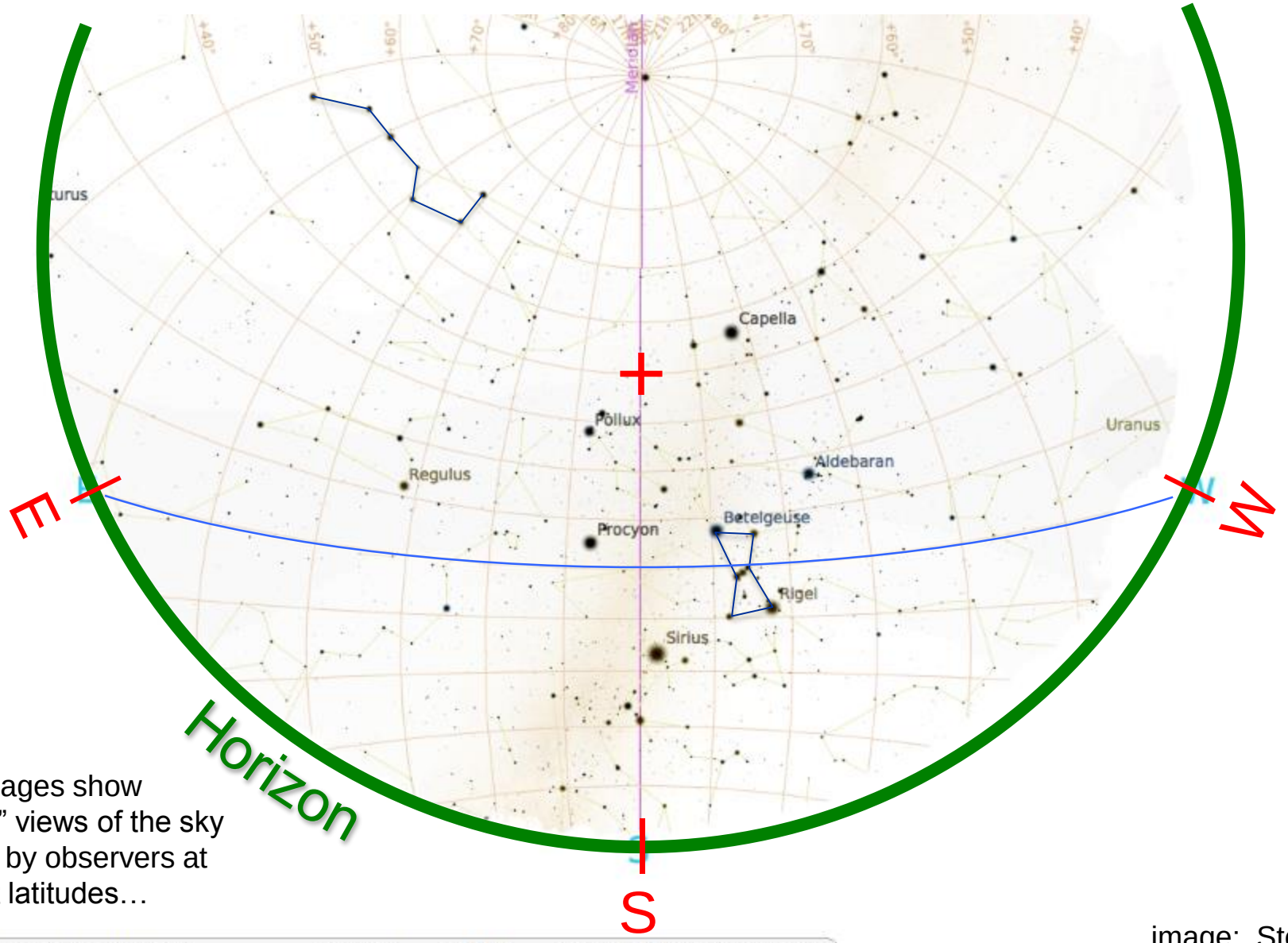


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 40° N

midnight Jan. 14

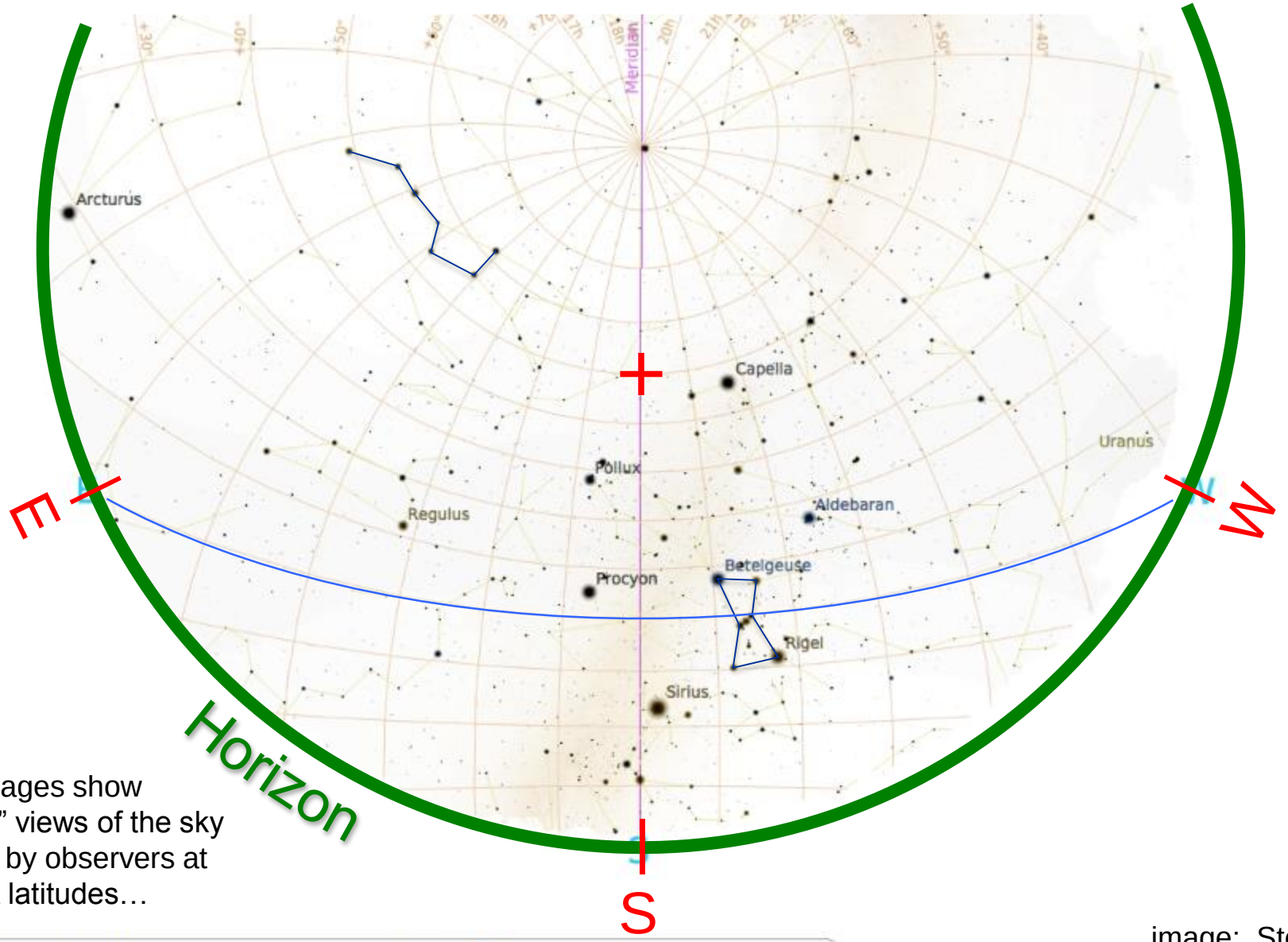


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 50° N

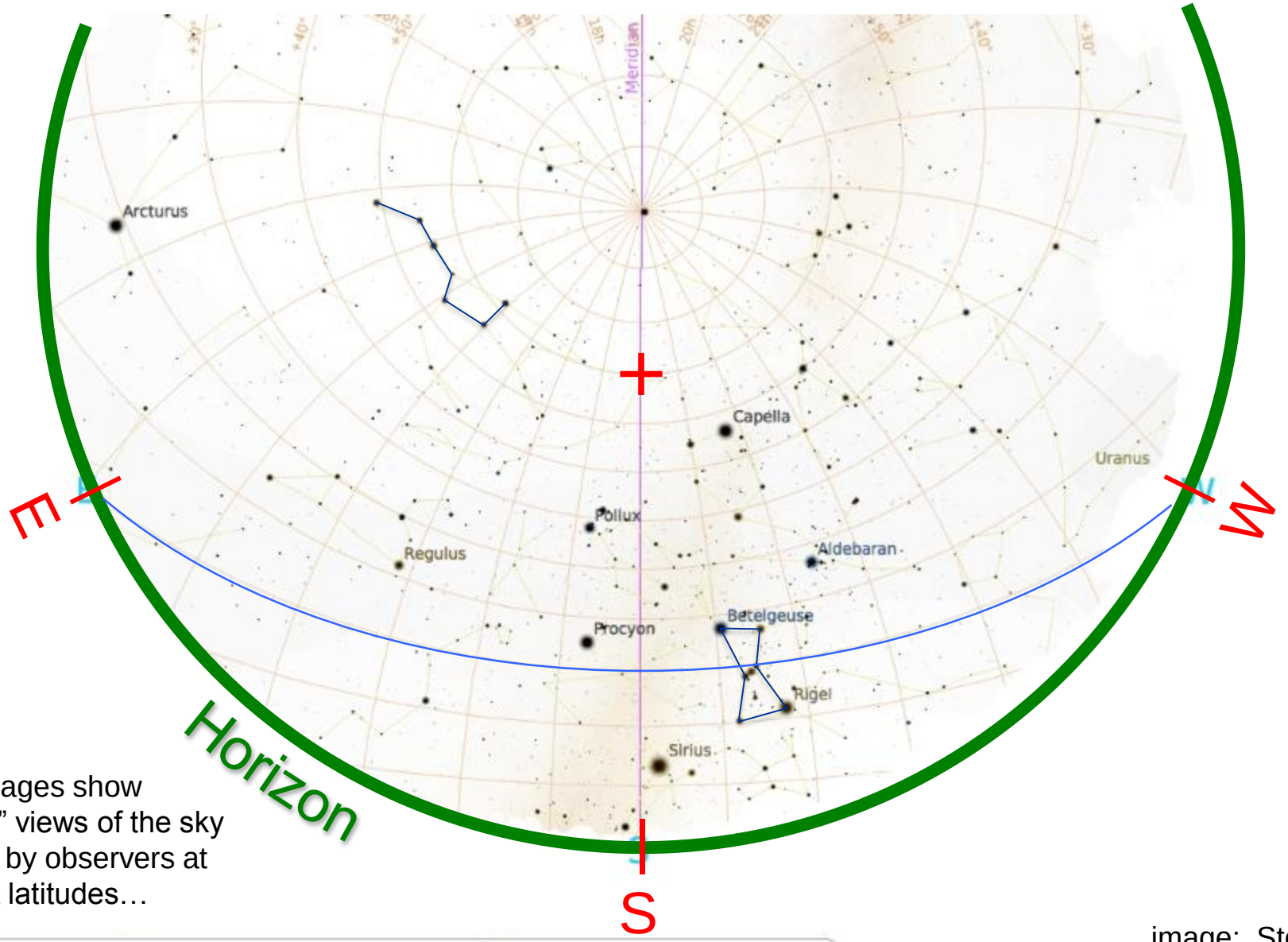
midnight Jan. 14



These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 60° N midnight Jan. 14

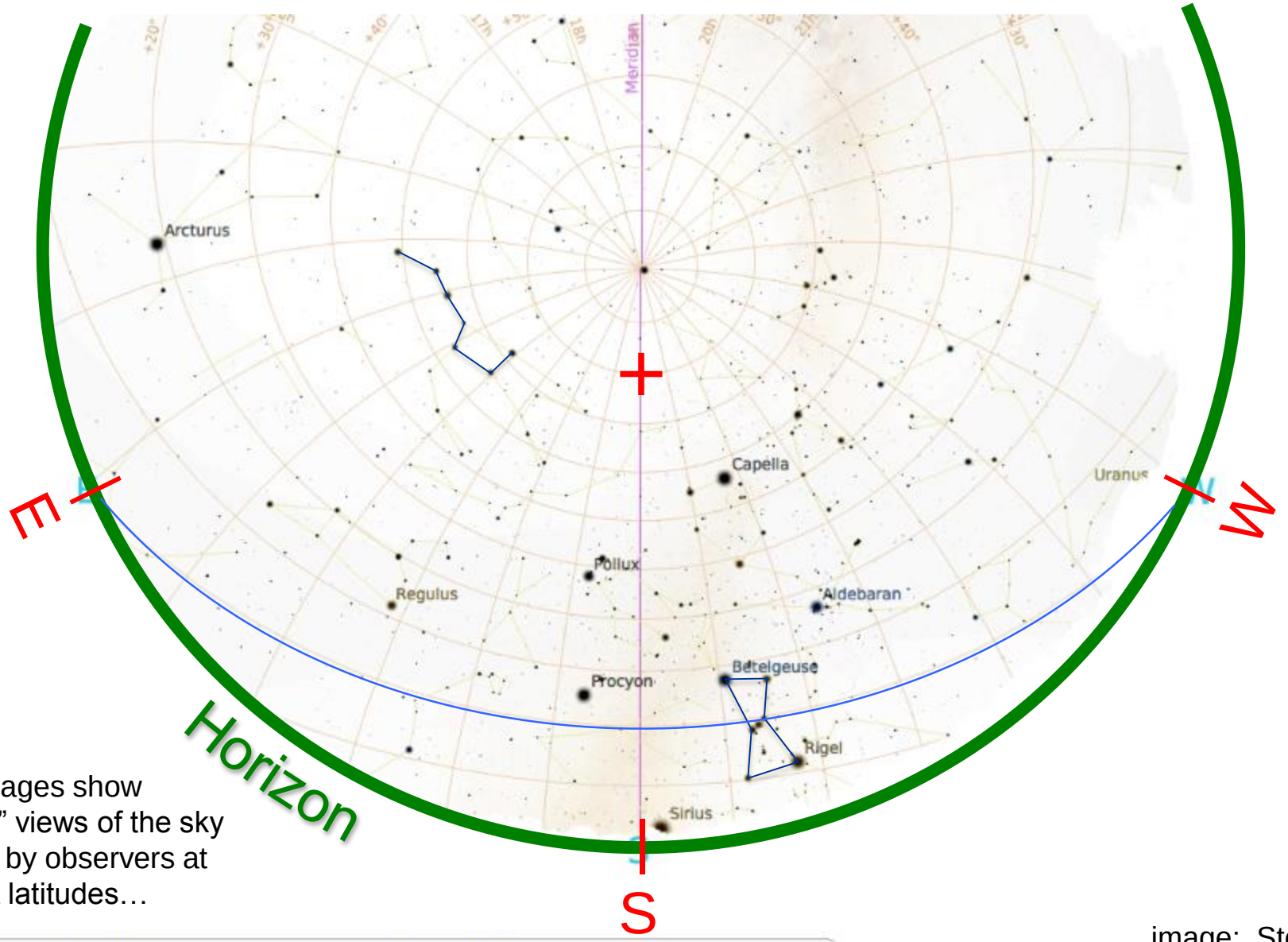


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 70° N

midnight Jan. 14

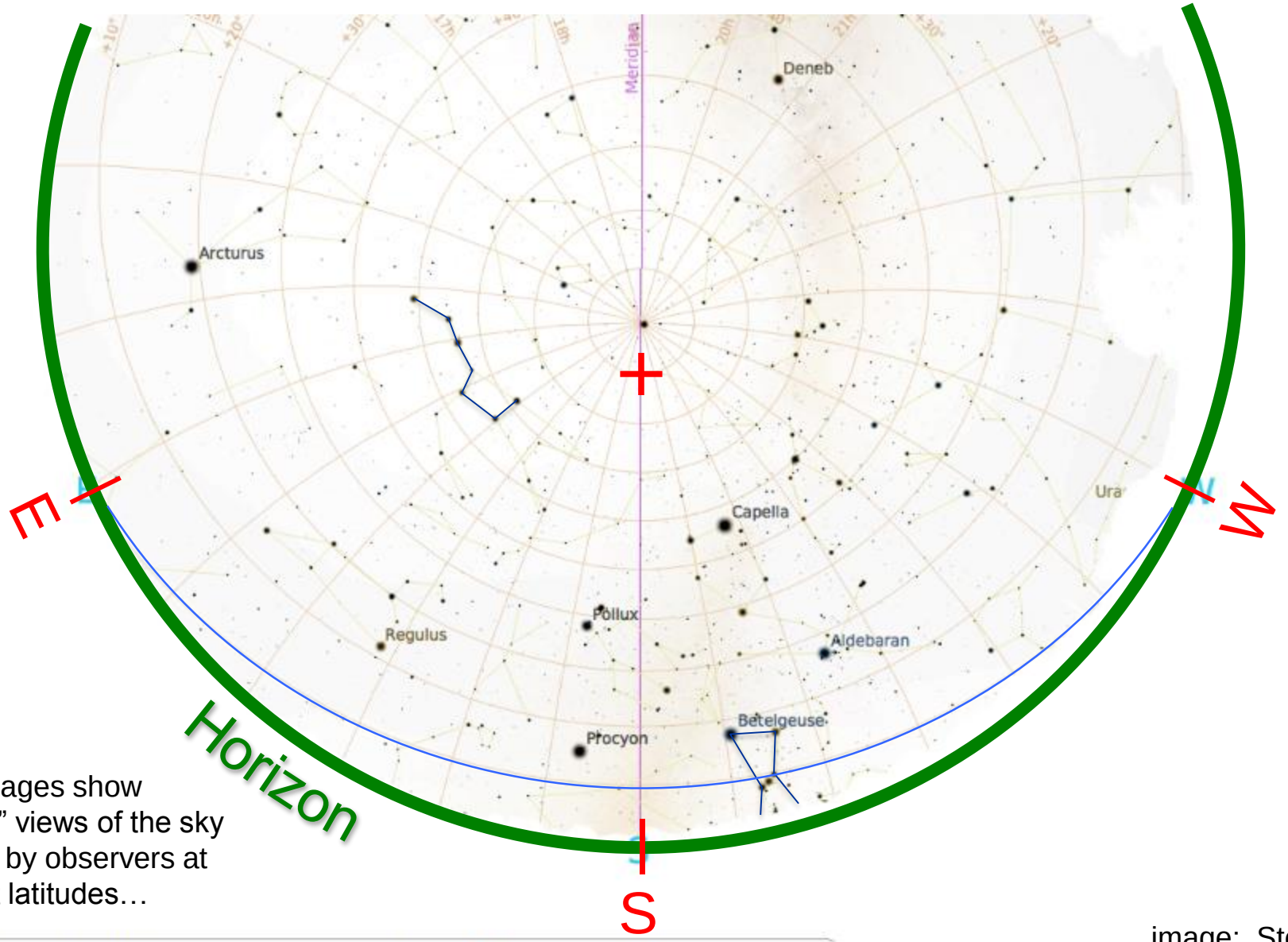


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 80° N

midnight Jan. 14

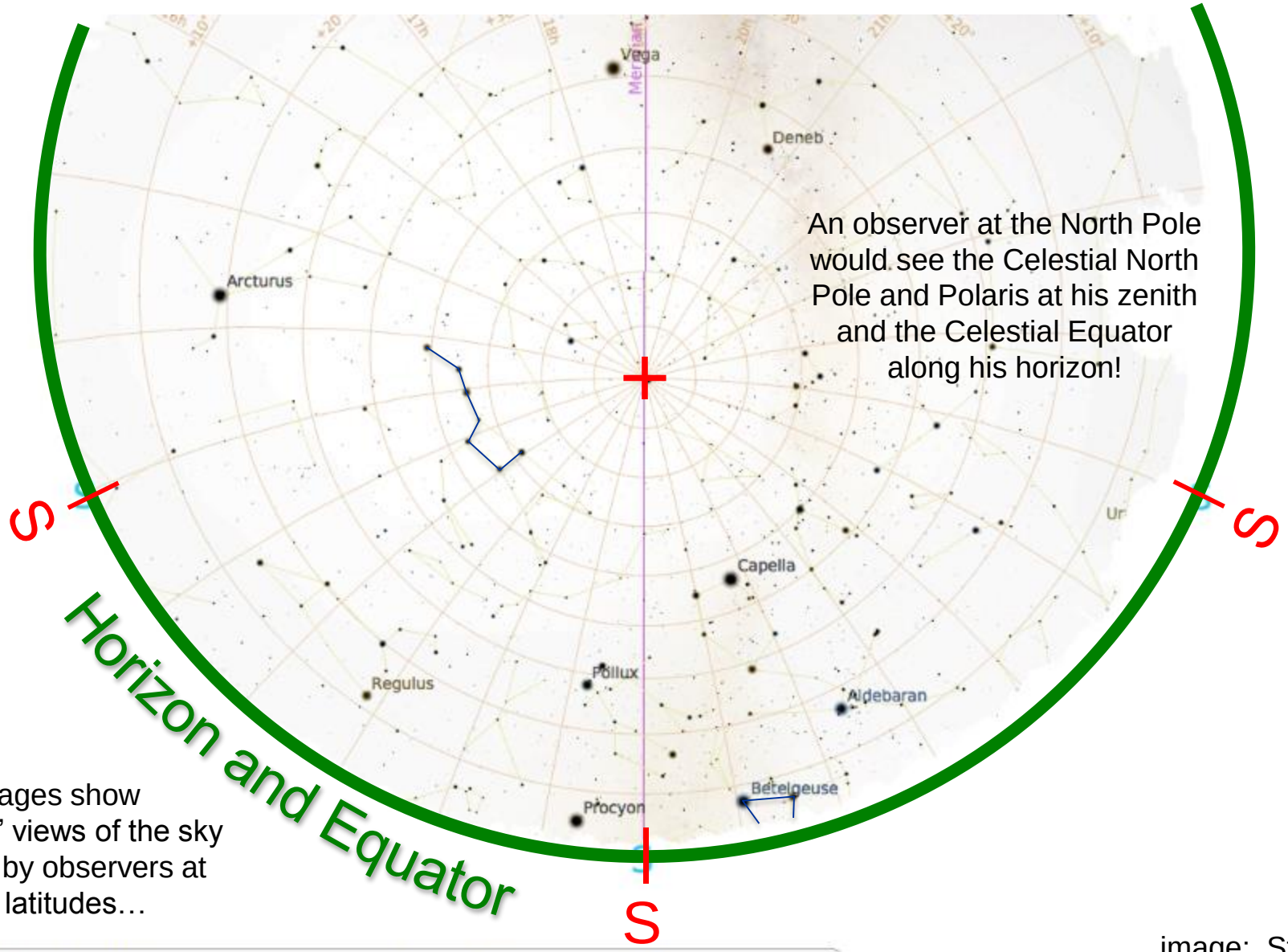


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 90° N

midnight Jan. 14

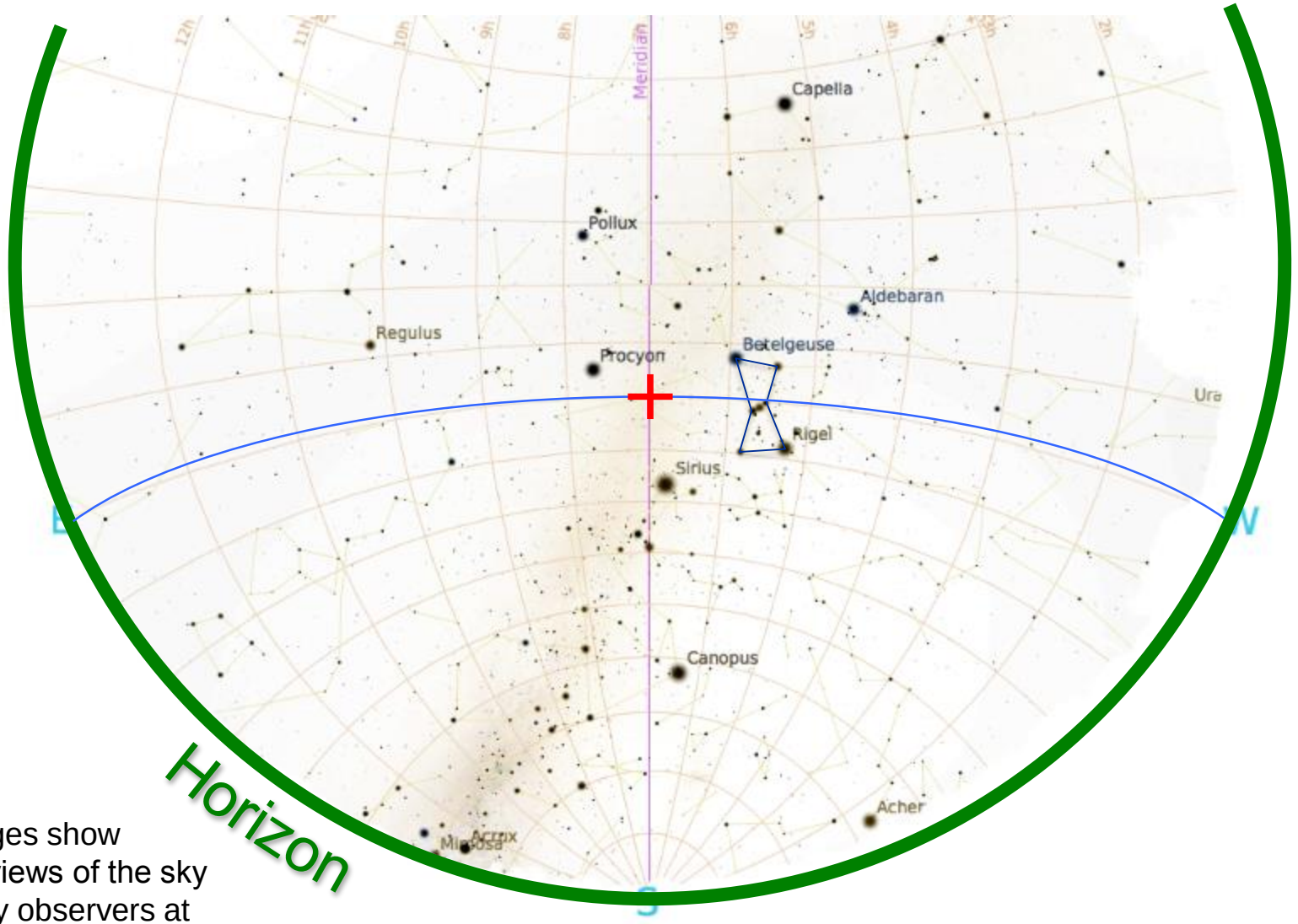


An observer at the North Pole would see the Celestial North Pole and Polaris at his zenith and the Celestial Equator along his horizon!

These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 0˚ midnight Jan. 14

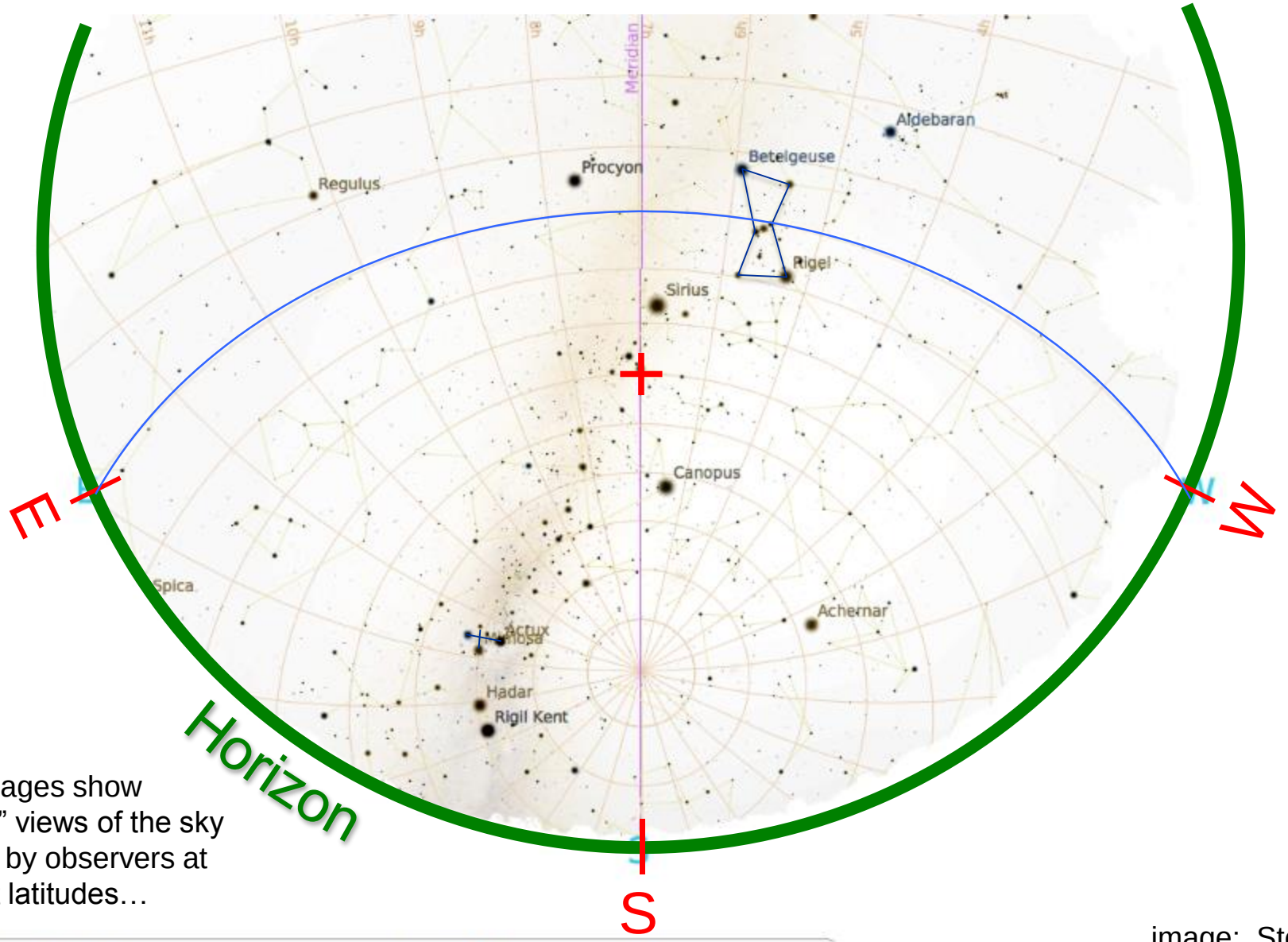


These pages show “fisheye” views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 30° S

midnight Jan. 14

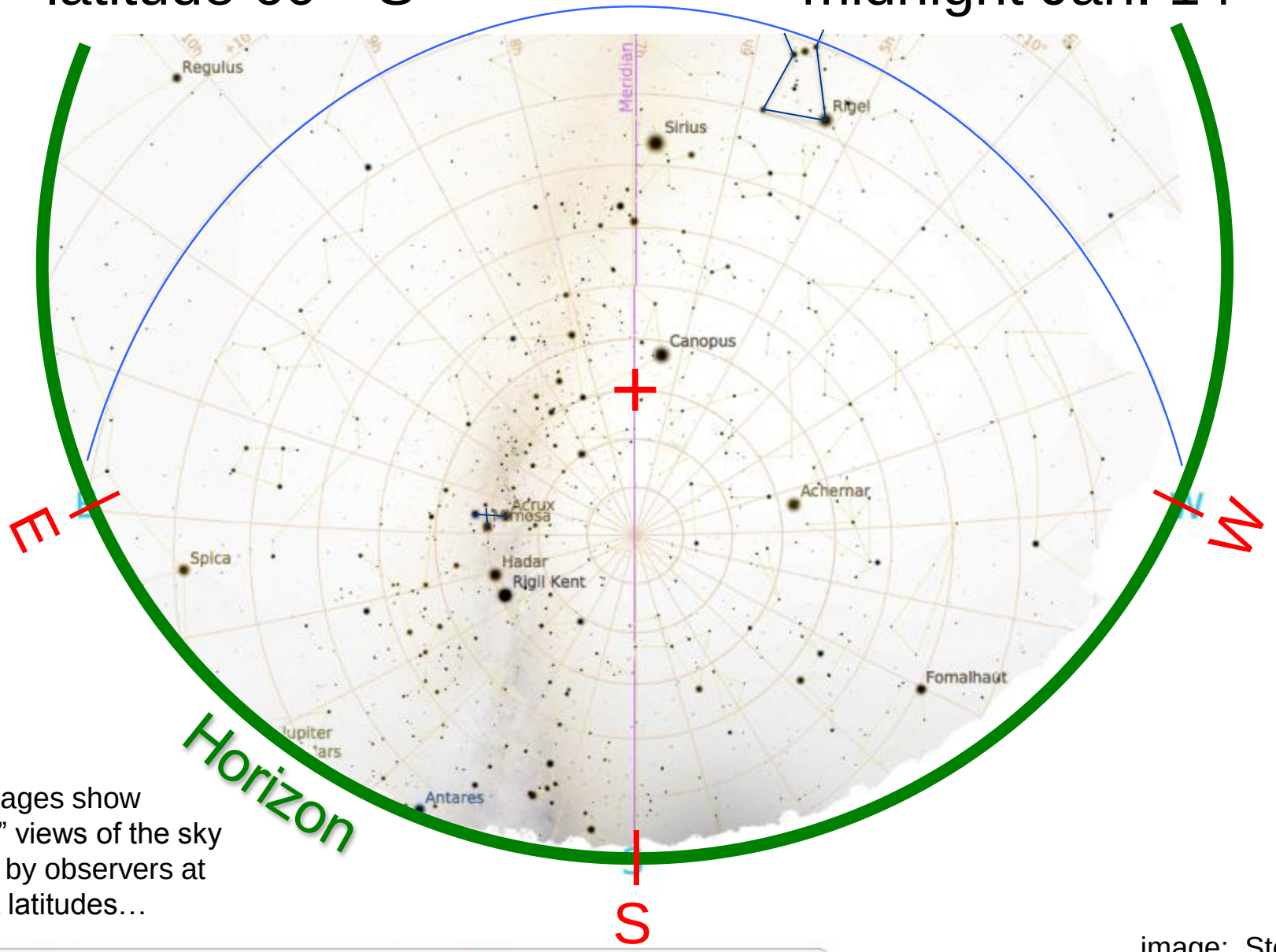


These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

latitude 60° S

midnight Jan. 14



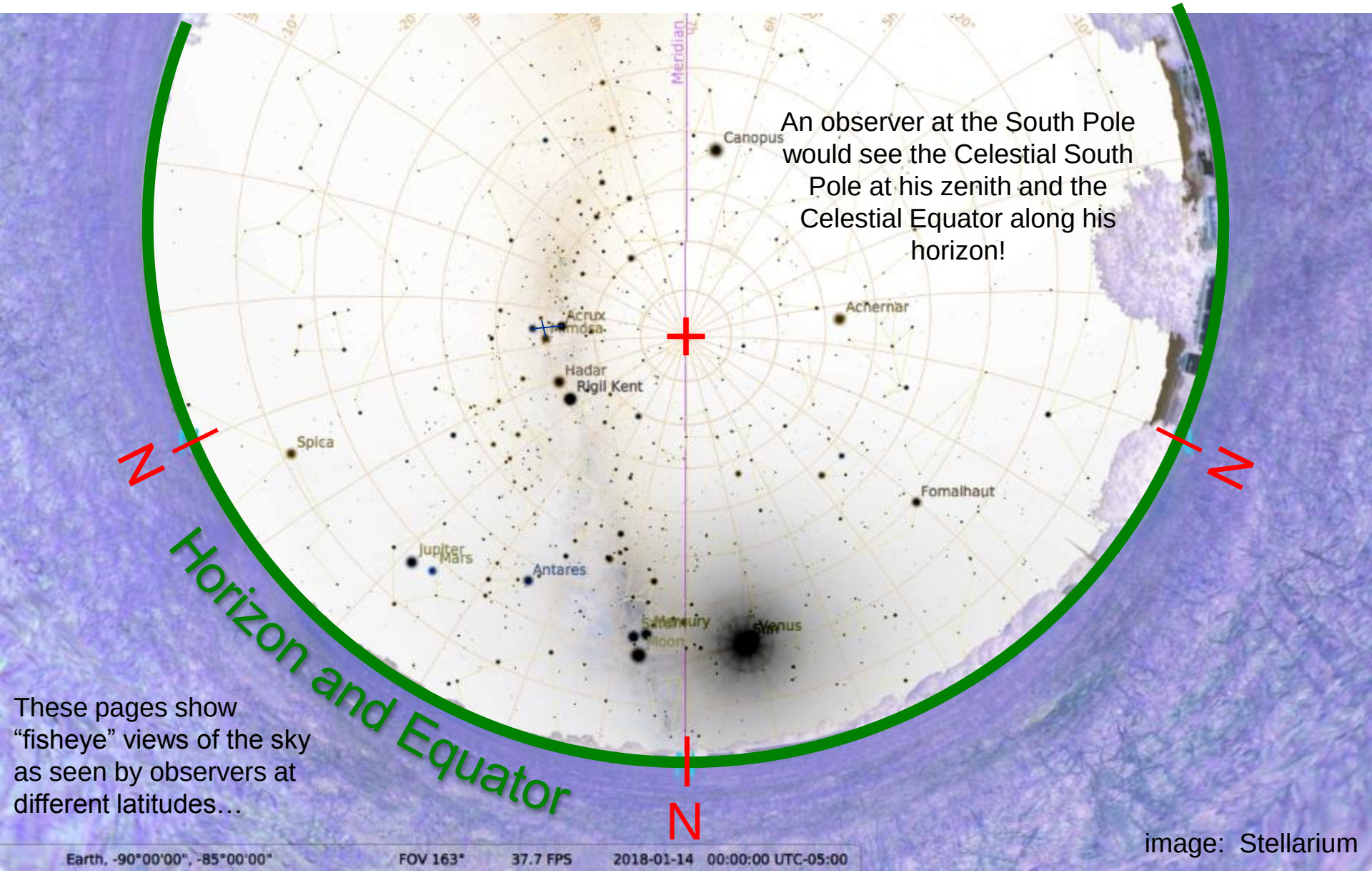
These pages show "fisheye" views of the sky as seen by observers at different latitudes…

Earth, -60°00'00", -85°00'00" FOV 163° 18.6 FPS 2018-01-14 00:00:00 UTC-05:00

image: Stellarium

latitude 90° S

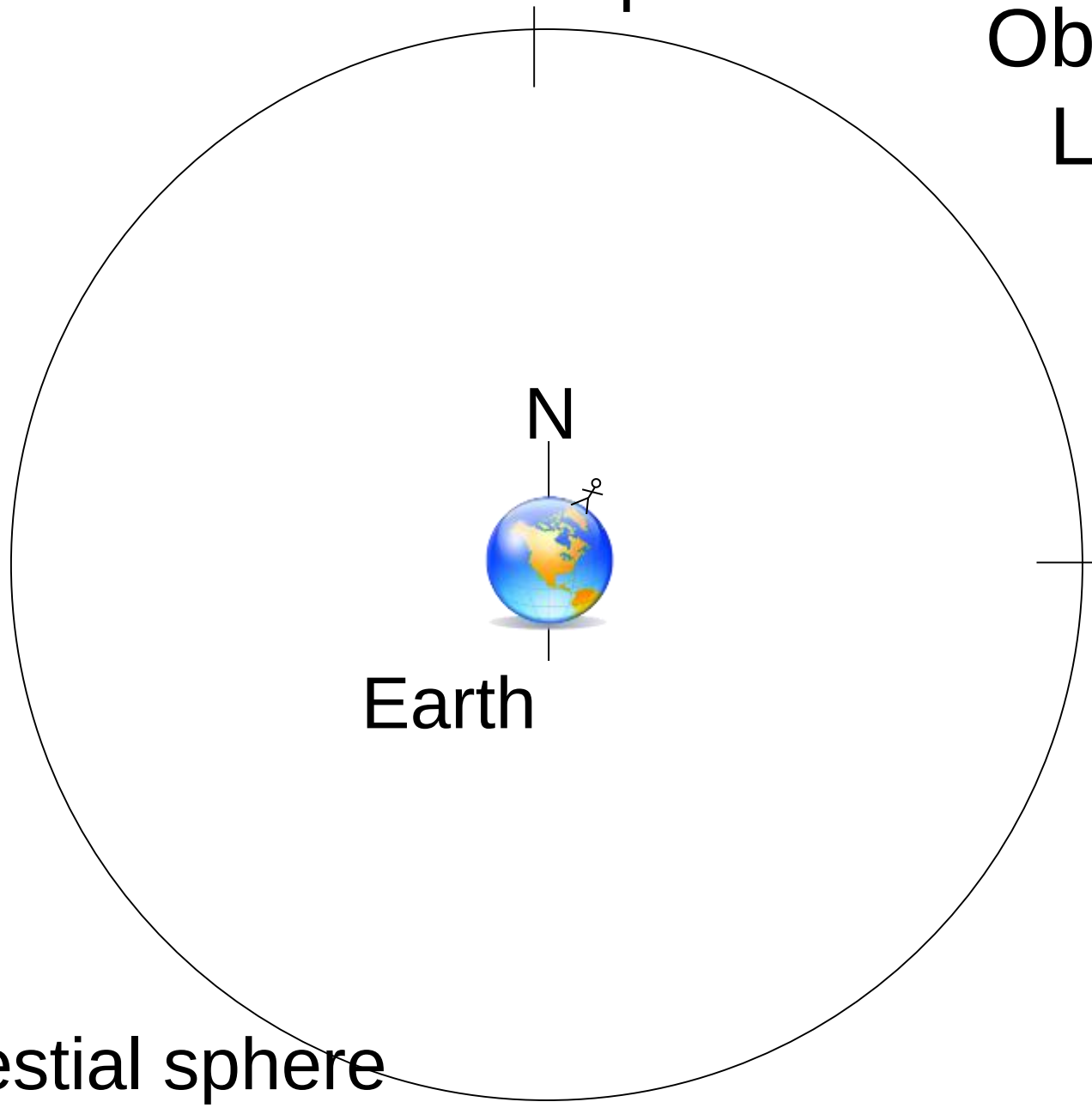
midnight Jan. 14

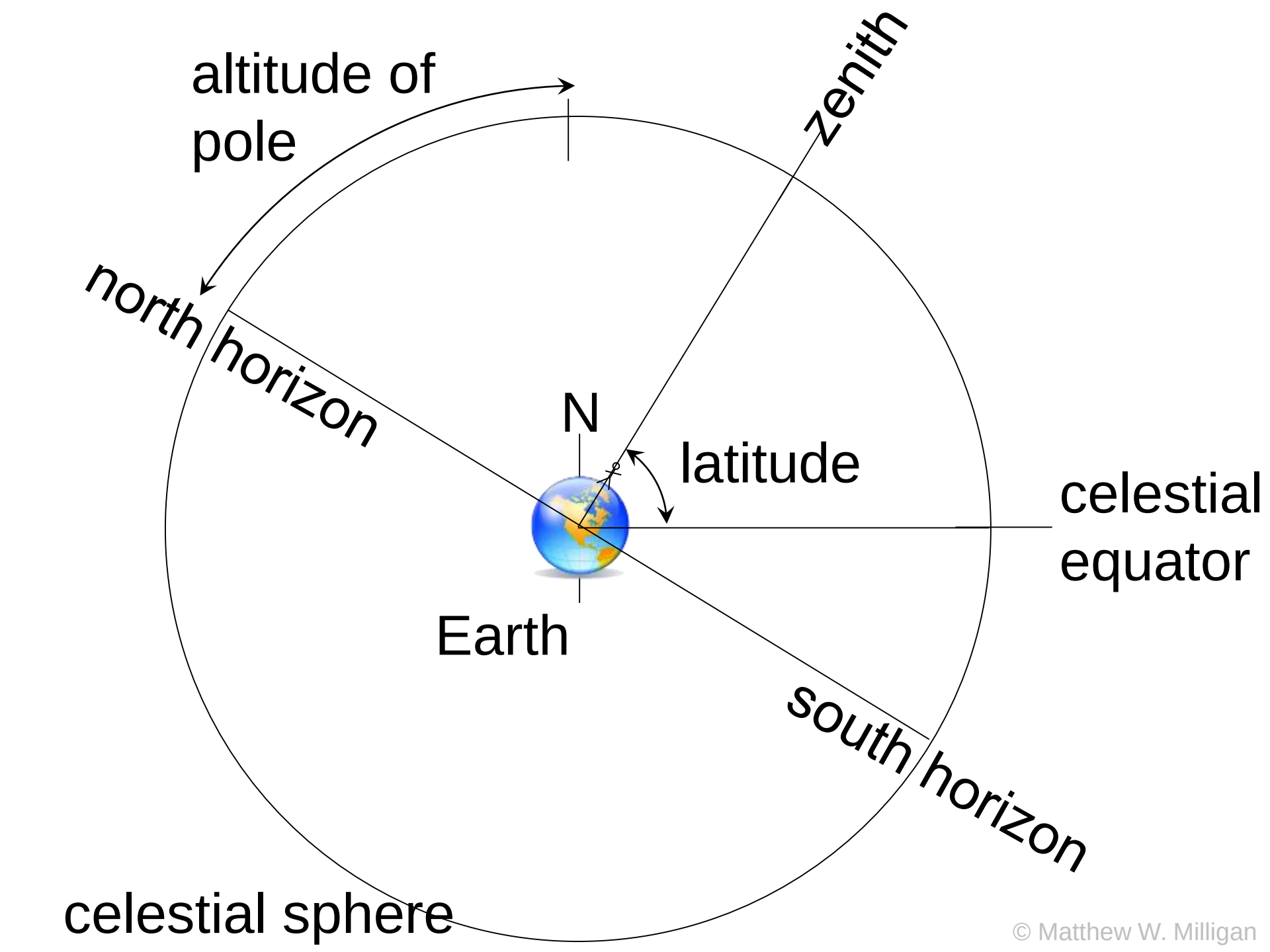


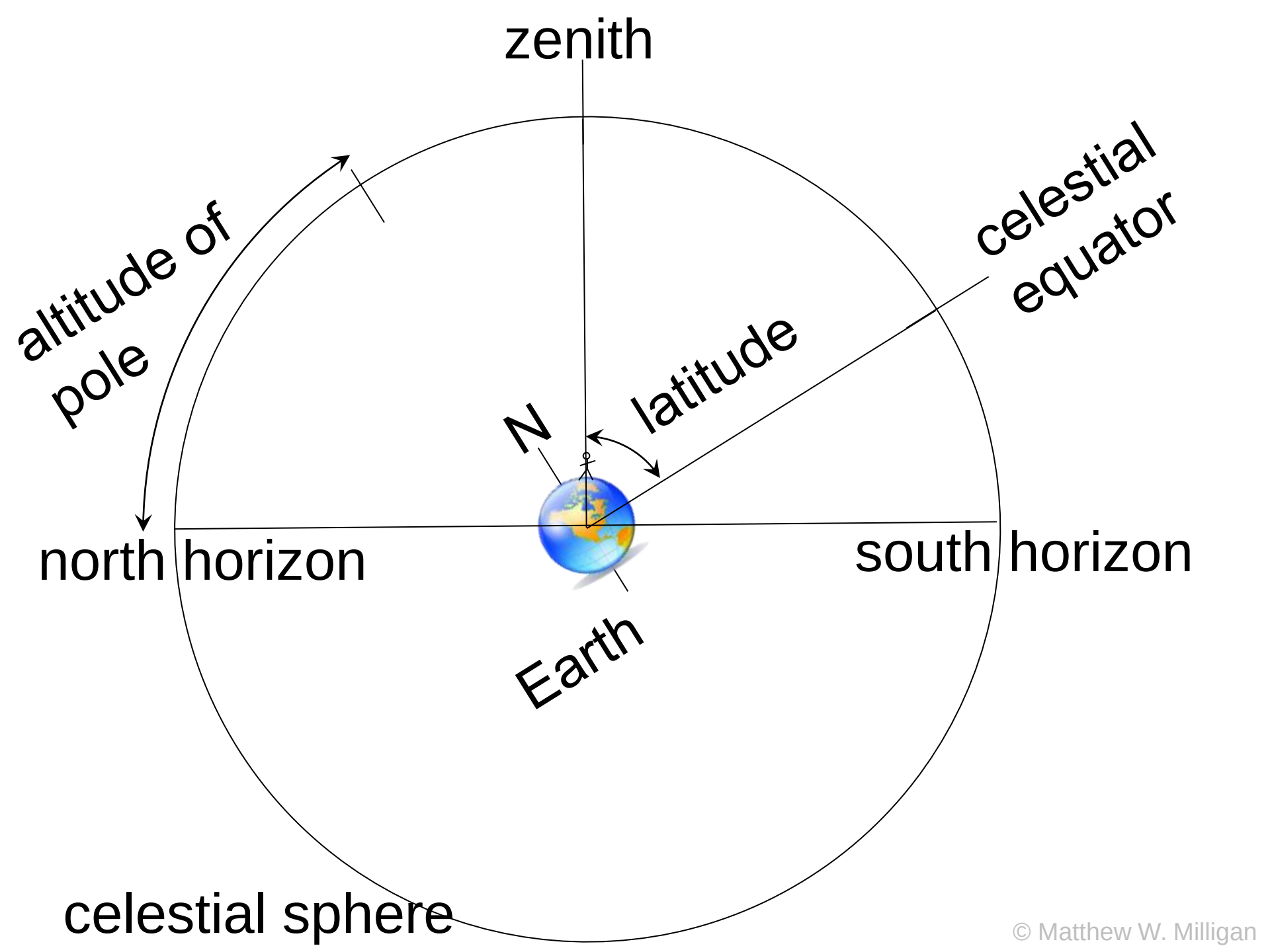
These pages show "fisheye" views of the sky as seen by observers at different latitudes…

image: Stellarium

Effect of Observer's Latitude



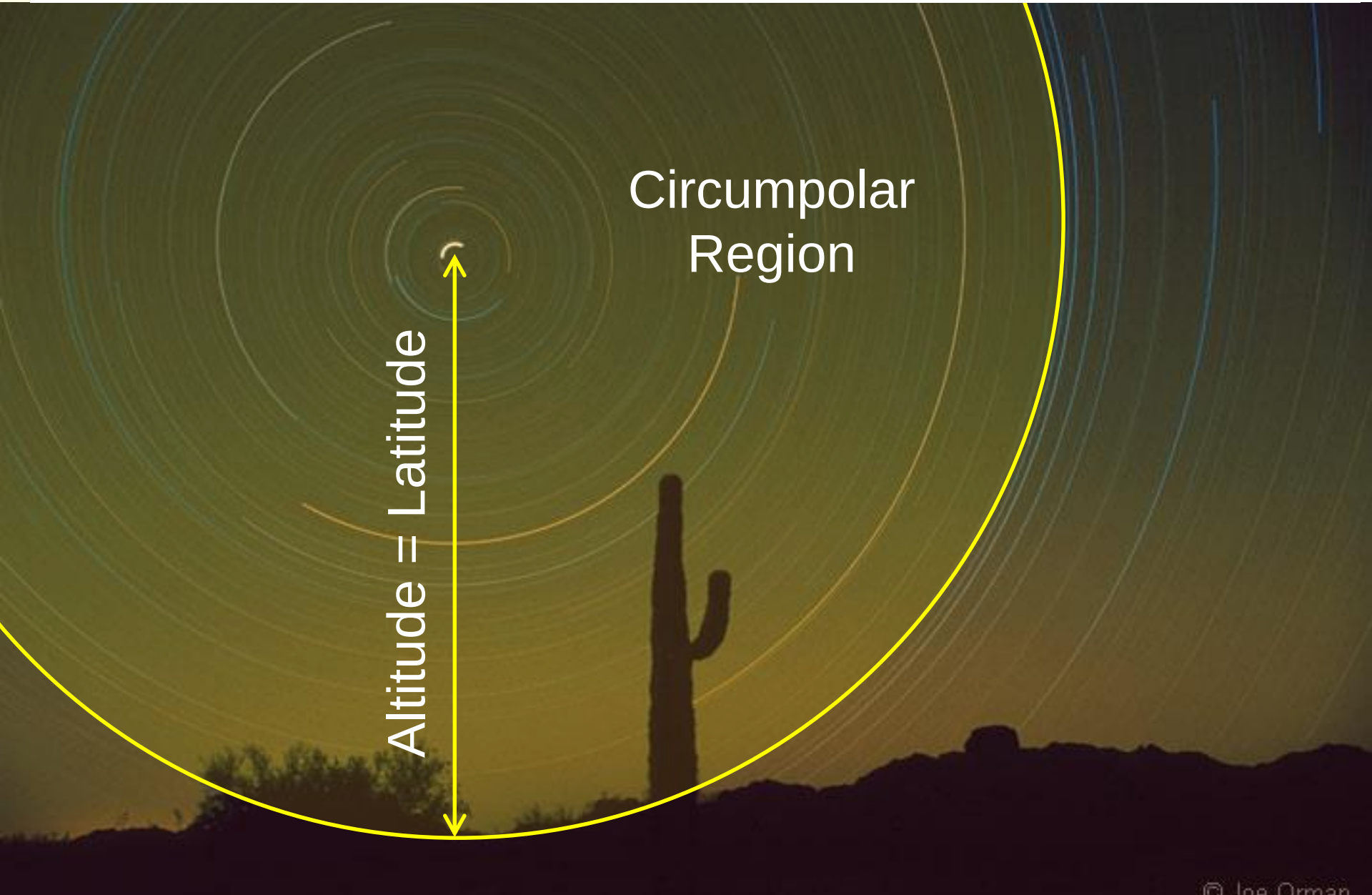


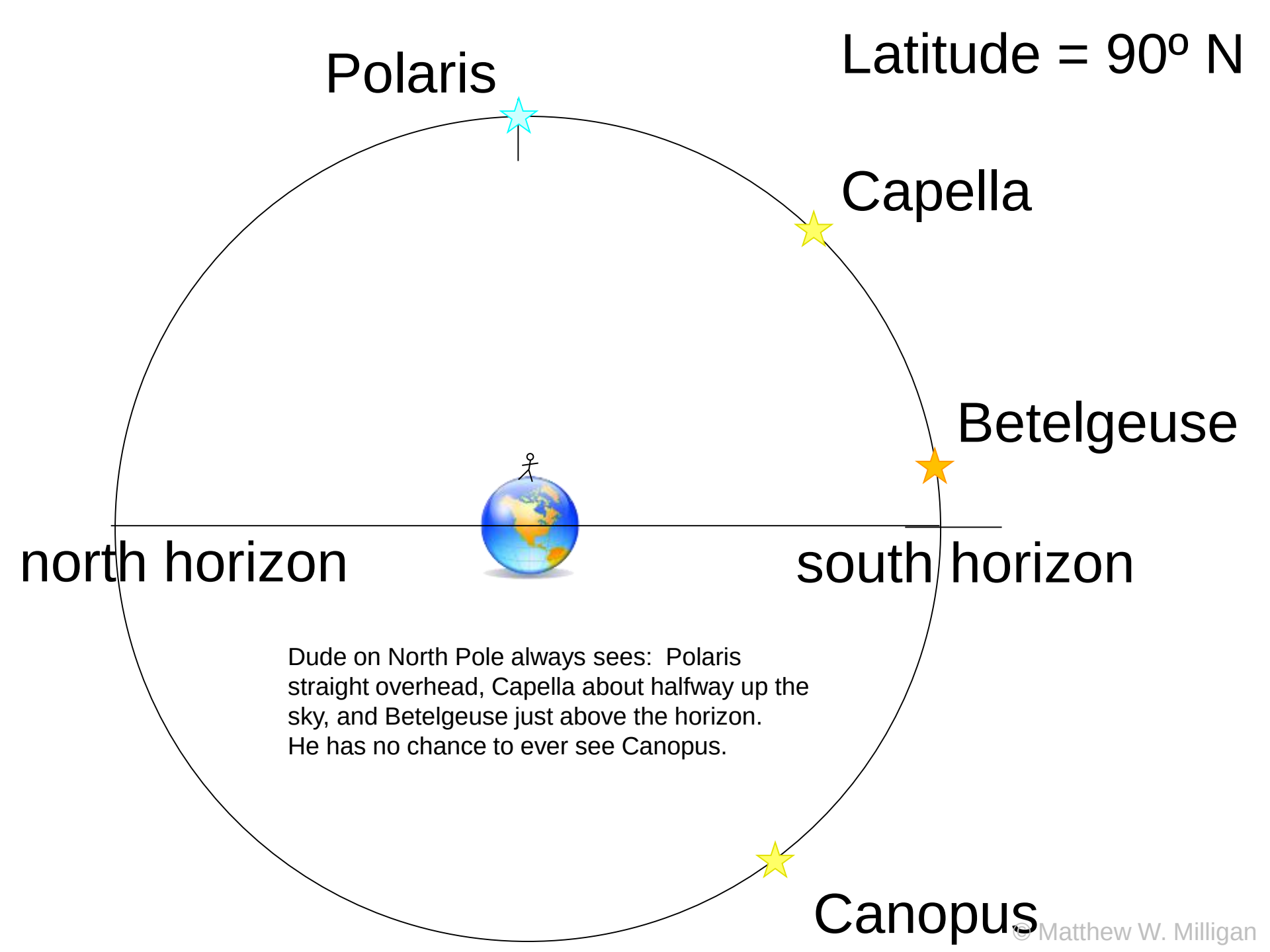


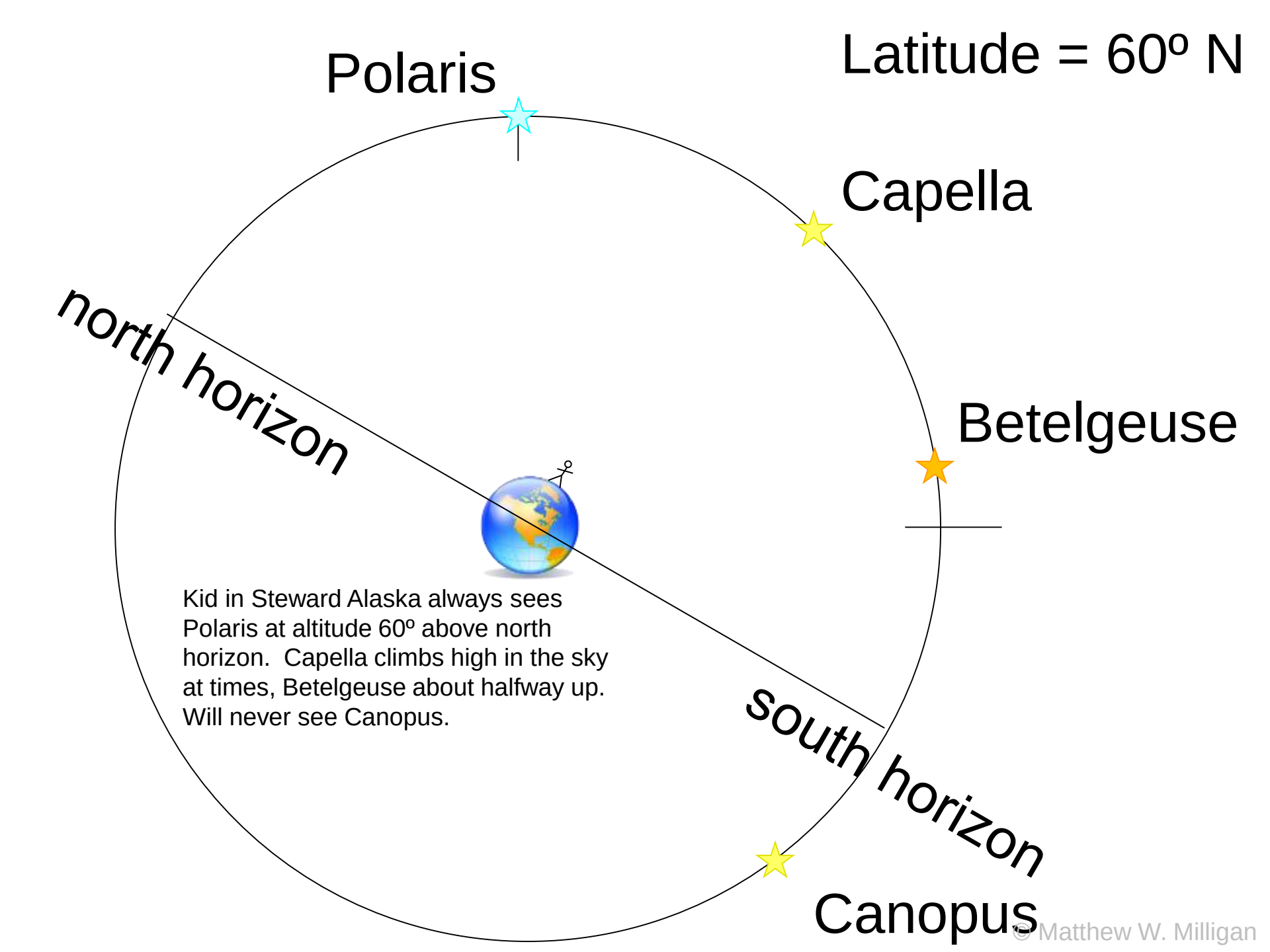
Effect of Latitude

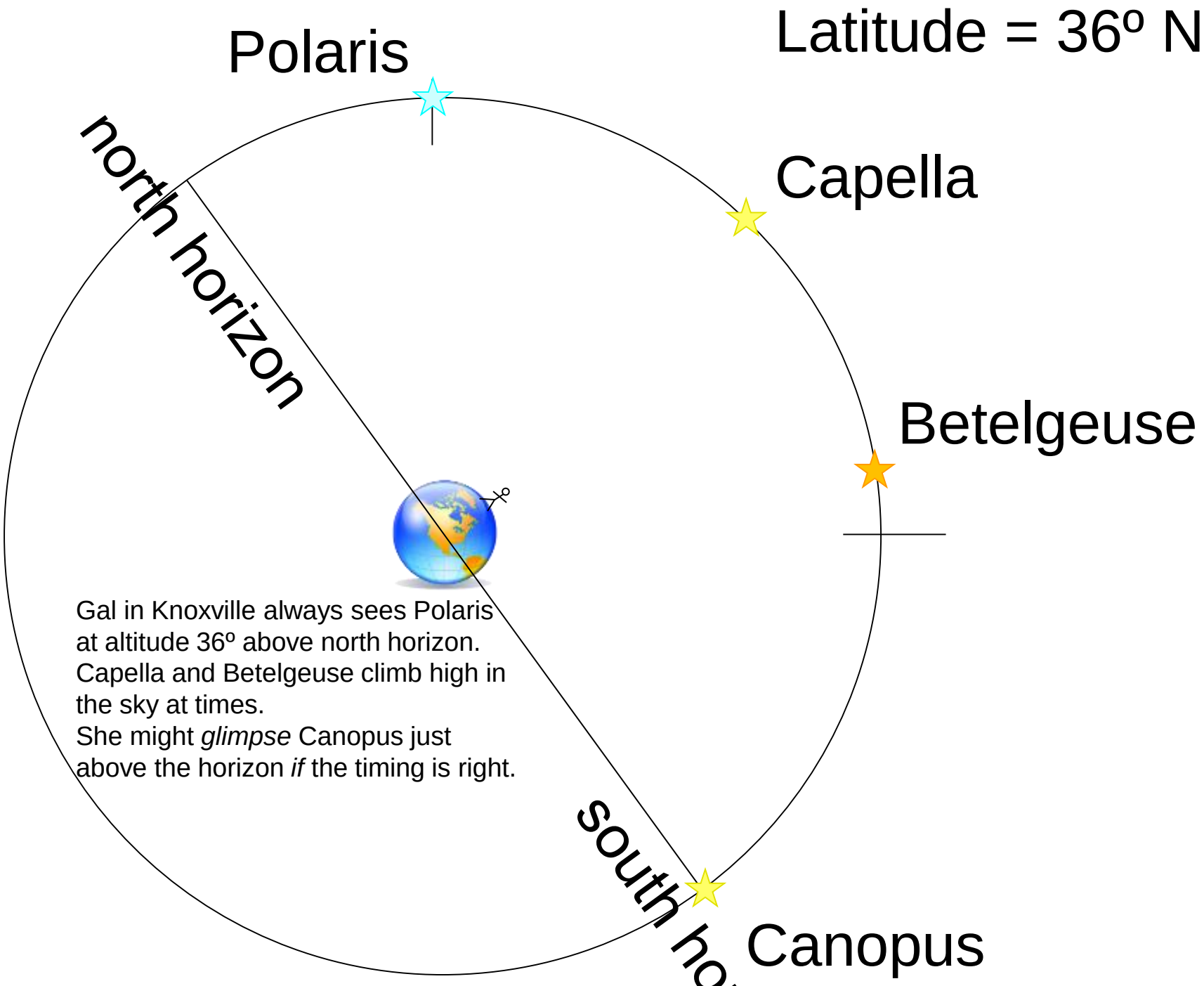
- The declination of an observer's zenith is equal to the observer's latitude.
- If in the northern hemisphere, an observer can never see south of a declination equal to latitude minus 90 degrees.
- The altitude of the celestial north pole is equal to the observer's latitude.
- Stars within "latitude degrees" of the celestial north pole never set below the observer's horizon; these are called "circumpolar stars".

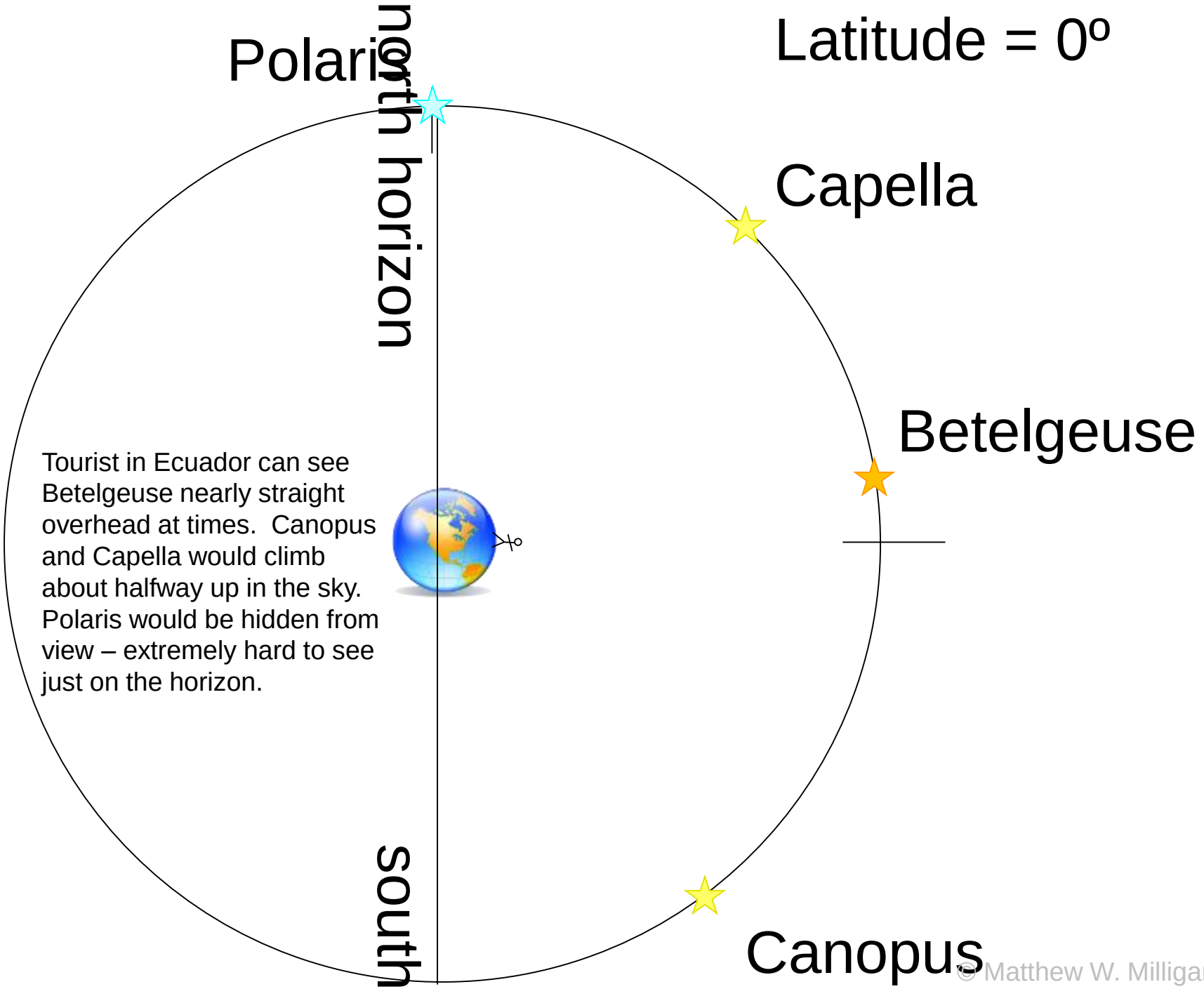
This picture was taken from a location with *latitude* ≈ 32º and therefore the Celestial North Pole has *altitude* 32º. Stars within 32º of the pole are in the circumpolar region and never go below the horizon at this location.

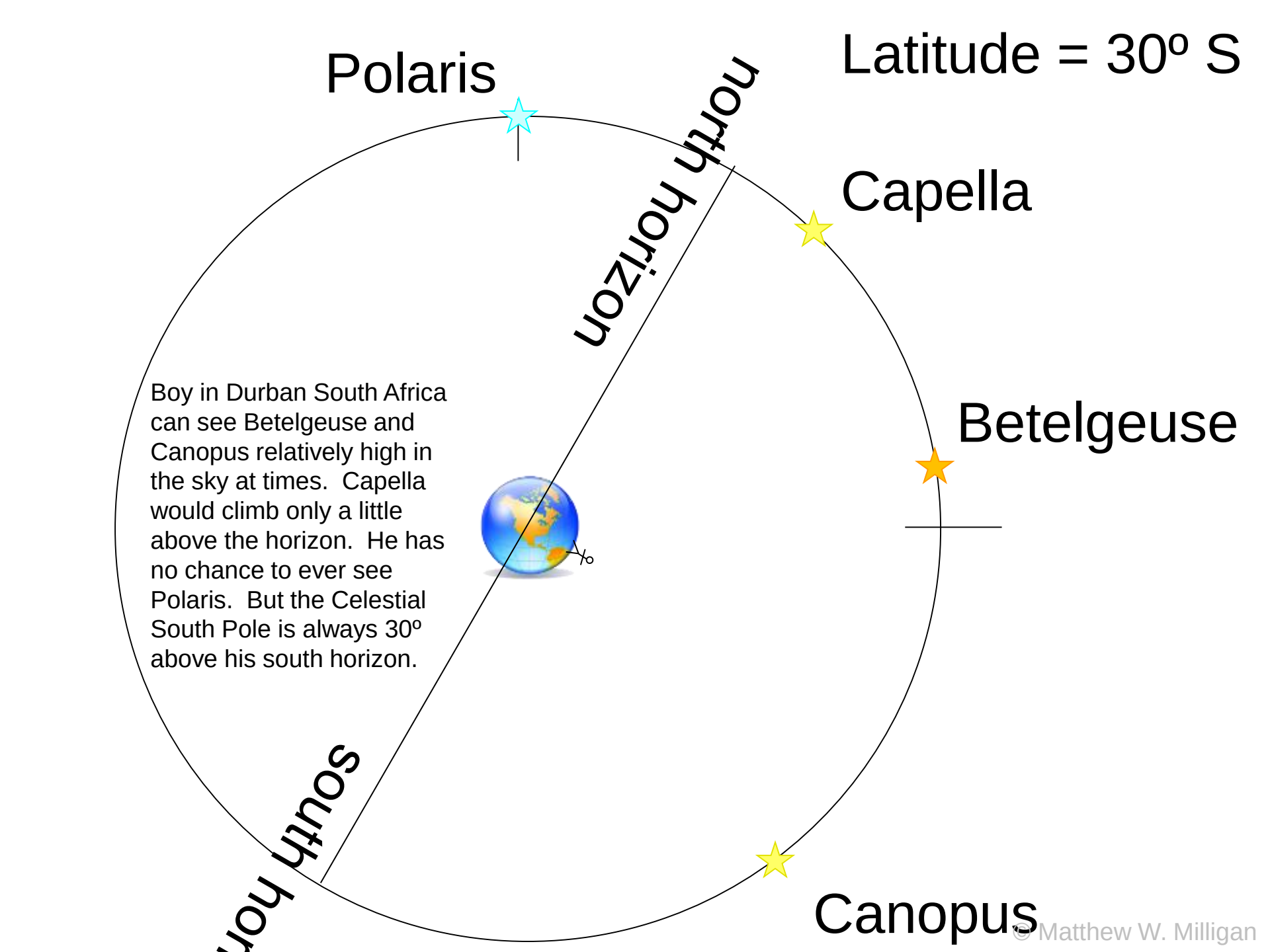






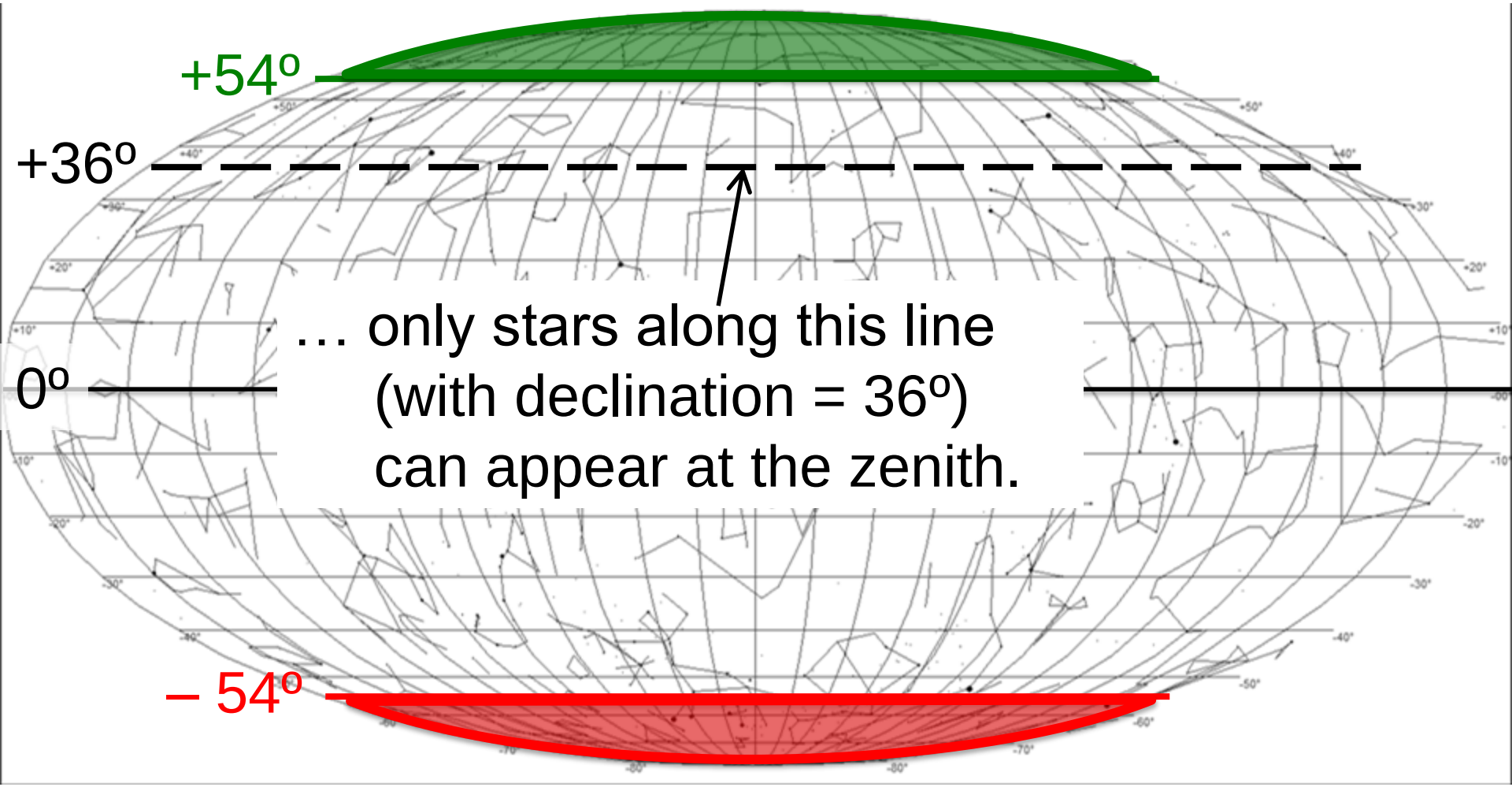

Latitude = 36º N
Polaris
Capella
Betelgeuse
north horizon
south ho
Canopus
Gal in Knoxville always sees Polaris at altitude 36º above north horizon.
Capella and Betelgeuse climb high in the sky at times.
She might *glimpse* Canopus just above the horizon *if* the timing is right.





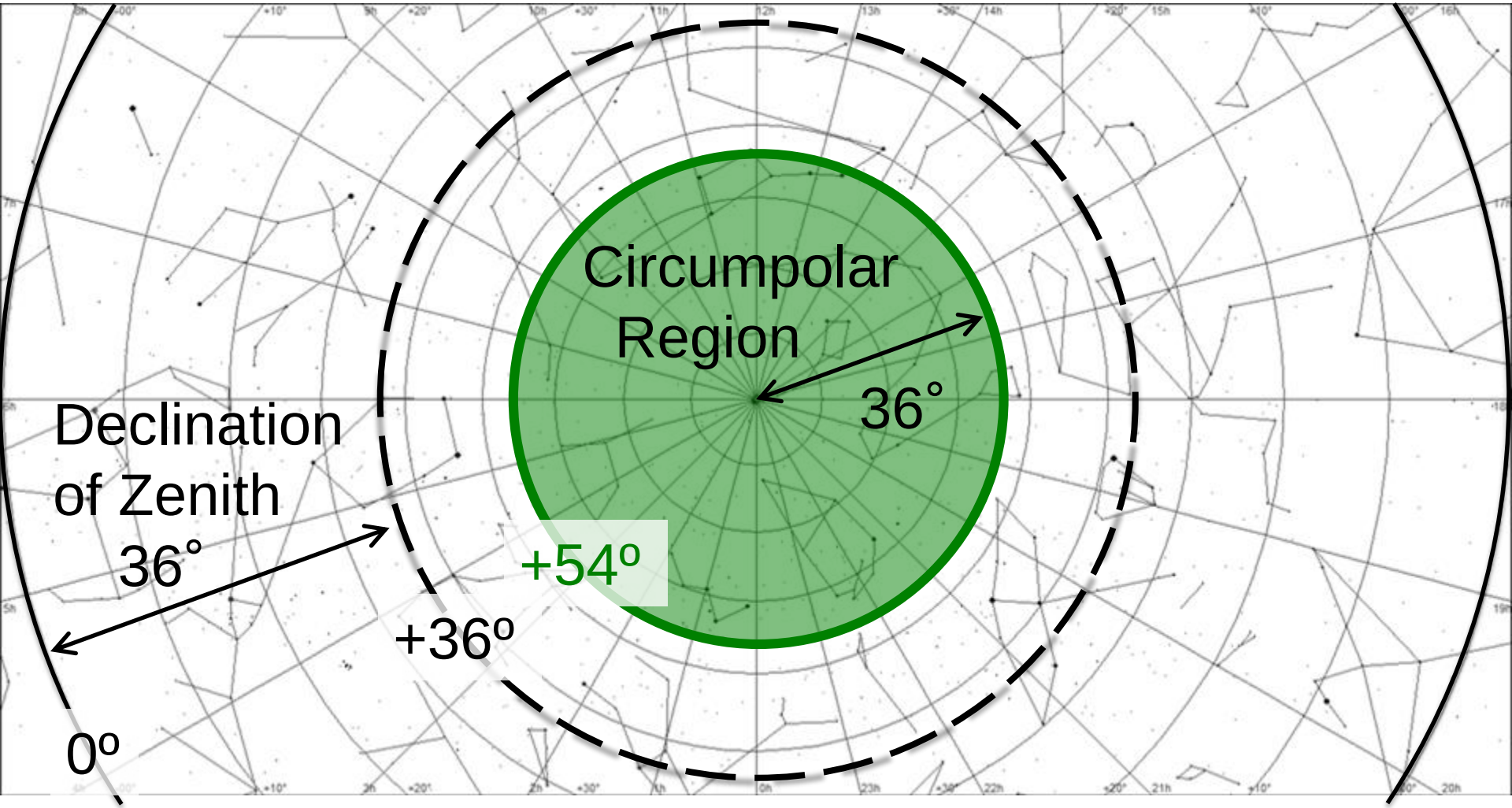
In Knoxville…
(or any location with latitude 36º N)

In Knoxville… stars within 36º of the N. Pole are always <u>above</u> the horizon (circumpolar region).



… stars within 36º of the S. Pole are always <u>below</u> the horizon and can never be seen.

In Knoxville (or any location with latitude 36º N)…



In Knoxville (or any location with latitude 36º N)…