

# Astronomy 103

## Announcements

- Course info and syllabus on D2L
- Colored cards: bring to class
  - Get them today if you didn't on Wednesday
- Reminders:
  - Reading assignment 1: Appendices 1 & 2, Sections 0.1 and 0.2
  - **First quiz** due Monday 11:59 pm
  - Problem set 1 for practice

# Planetarium Show

- Planetarium shows
  - Across the hall from Physics 137
  - **Entire class: Monday September 22nd**
  - Door locks, so be on time!
  - Attendance will be taken
  - **Planetarium assignment: 100-150 word summary of show, due in class at next class after show**
  - **Summary must contain at least one fact you learn during the show**
  - Planetarium assignment is 5% of course grade

# Astronomy in the News

By **MIRIAM KRAMER** / **SPACE.COM** / August 27, 2014, 8:08 AM

## Rosetta space probe scopes out landing zone on comet



This illustration shows the Philae lander separating from Rosetta spacecraft and descending to the surface of comet 67P/Churyumov-Gerasimenko, as planned for November 2014. / **ESA/ATG MEDIALAB**

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More +

A European space probe is due to land on a comet in November, and now scientists have identified five sites where it could touch down.

# Rosetta's course through the Solar System



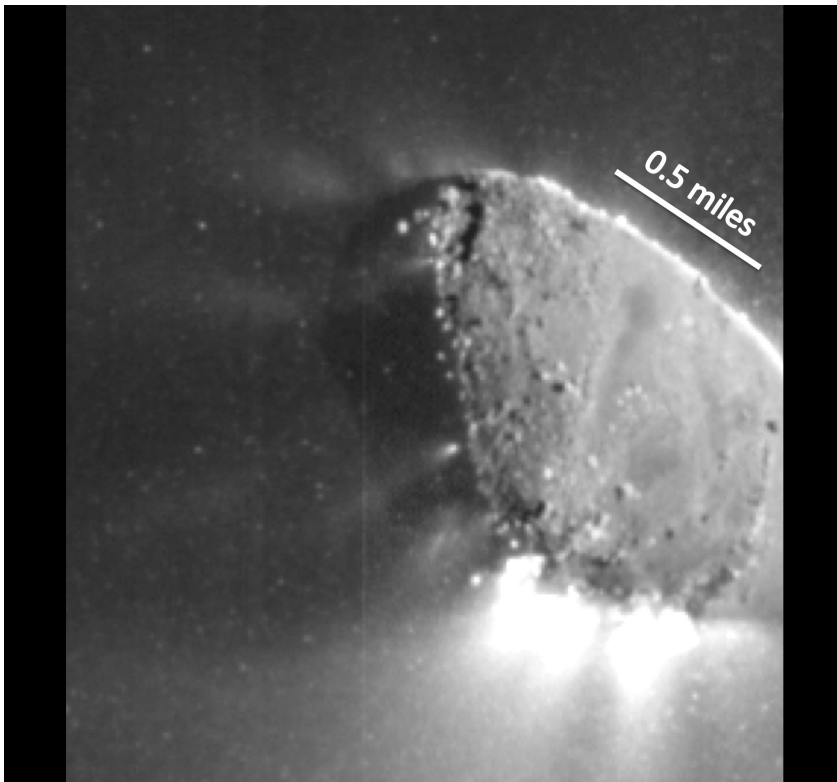
Watch online: [http://www.esa.int/spaceinvideos/Videos/2014/01/Chasing\\_a\\_comet](http://www.esa.int/spaceinvideos/Videos/2014/01/Chasing_a_comet)



July 10, 2010: Rosetta flies 1,864 feet  
from the asteroid Lutetia



In November it will release a robot lander for a soft landing on the comet



- So... what is a comet?
- Loose ball of ice and rock from the outer solar system
- Becomes bright and develops a tail (actually two!) when it comes near the Sun
- This will be the closest look at a comet yet

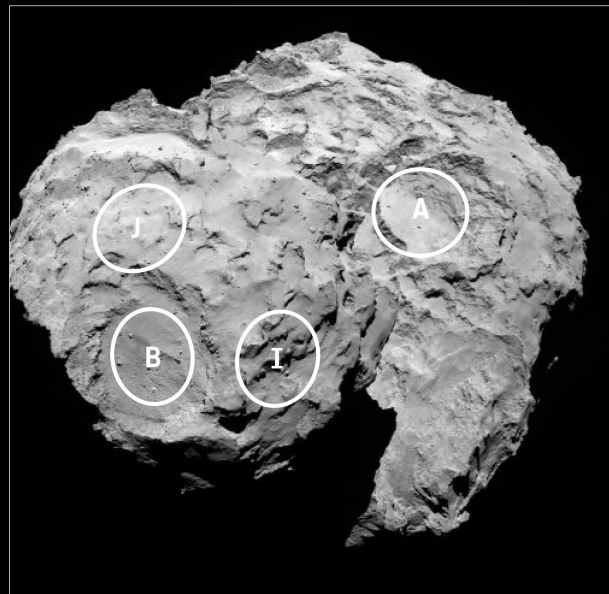
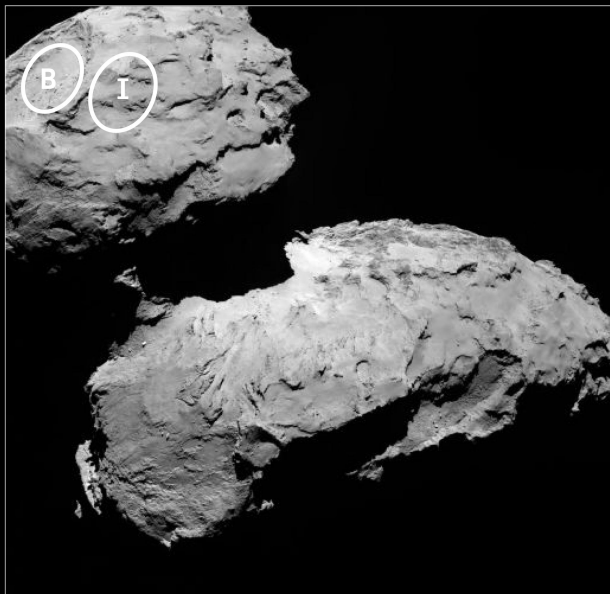
14 July 2014  
Rot = 0 deg

# Next up:

## Finding a suitable landing spot for Philae



5 km





# Astronomy in the News

The image is a screenshot of the Google News homepage. At the top left is the Google logo. Below it, the word "News" is displayed in red. To the right of "News" are two dropdown menus: "U.S. edition" and "Modern". A search bar with a magnifying glass icon is on the far right. On the left side, there is a vertical list of categories: "Top Stories", "News near you", "World", "U.S.", "Business", "Technology", "Entertainment", "Sports", and "Science". The "Science" category is highlighted in red. Below the "Science" category, there are three news articles. The first article, titled "New Gaia Observations Reveal The Galaxy Is Formed 'Inside-Out'", is circled in purple. It includes a thumbnail image of a galaxy and a blue button that says "See realtime coverage". The second article, titled "Get used to heat waves: Extreme El Nino events to double", is also circled in purple. It features a thumbnail image of Earth. The third article, titled "Sharks, Rays to Fall Victim to Shocking Levels of Extinction by Overfishing: Report", is circled in purple. It has a thumbnail image of a shark. On the right side of the page, there is a "Personalize this!" section with a play button icon and a "Personalize Google News" button. Below that is a "Spotlight" section, which is also circled in purple, containing two news snippets: "Mystery on Mars: Rock suddenly appears in front of Opportunity rover leaving ..." and "Scientists search for understanding of dark matter in deep underground lab".

Google

News

U.S. edition Modern

Top Stories

News near you

World

U.S.

Business

Technology

Entertainment

Sports

Science

Dolphins

European Space Agency

Southwest Florida

Air pollution

Observable universe

NASA

Science

**New Gaia Observations Reveal The Galaxy Is Formed 'Inside-Out'**

The Utah People's Post - 4 hours ago

A new breakthrough using data from the Gaia-ESO project provides new insight into our Milky Way galaxy. It supports the fact that the galaxy might have formed the inside-out with the inner region forming faster than the outer reaches.

See realtime coverage

Get used to heat waves: Extreme El Nino events to double

TG Daily - 13 hours ago

Extreme weather events fuelled by unusually strong El Ninos, such as the 1983 heatwave that led to the Ash Wednesday bushfires in Australia, are likely to double in number as our planet warms.

Sharks, Rays to Fall Victim to Shocking Levels of Extinction by Overfishing: Report

Design & Trend - 1 hour ago

Personalize this!

Tools to make Google News yours

Personalize Google News

Spotlight

Mystery on Mars: Rock suddenly appears in front of Opportunity rover leaving ...

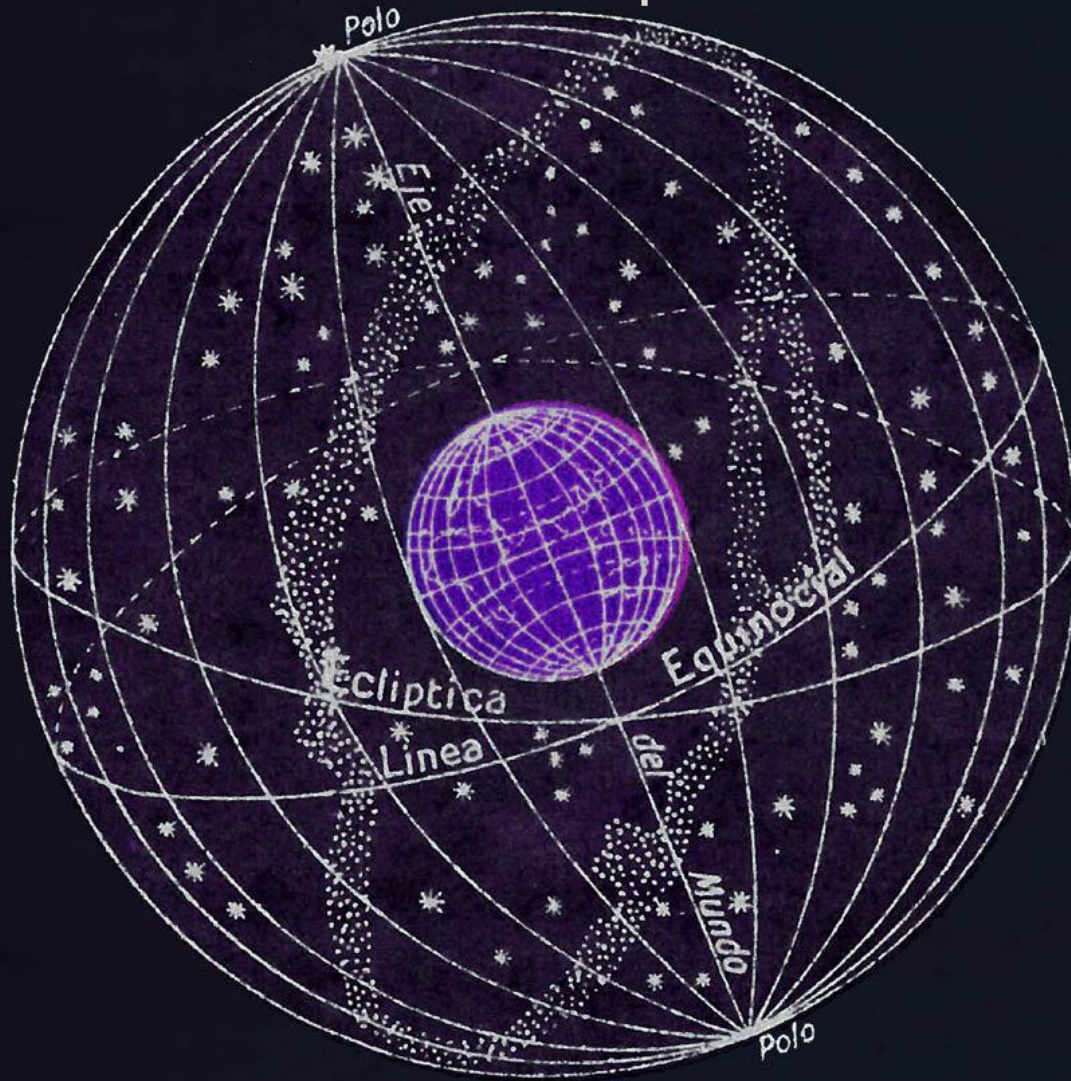
Daily Mail - Jan 17, 2014

Scientists search for understanding of dark matter in deep underground lab

PBS - 19 hours ago

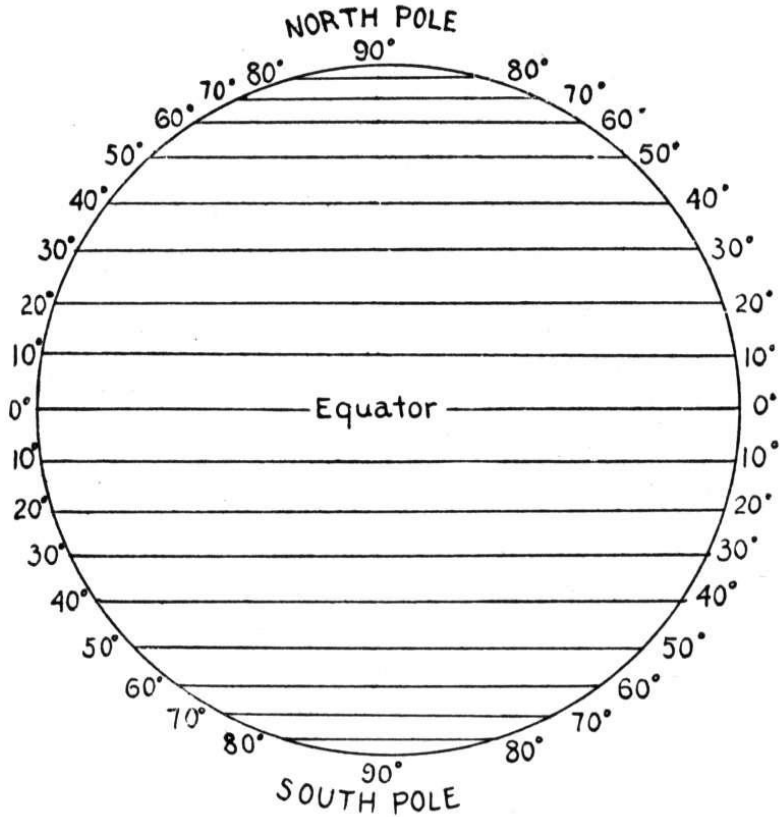
- Something almost every day
- Suggestions for class discussion? kotulla@uwm.edu
- Extra credit opportunities: more soon

# The Celestial Sphere and Motion of the Earth

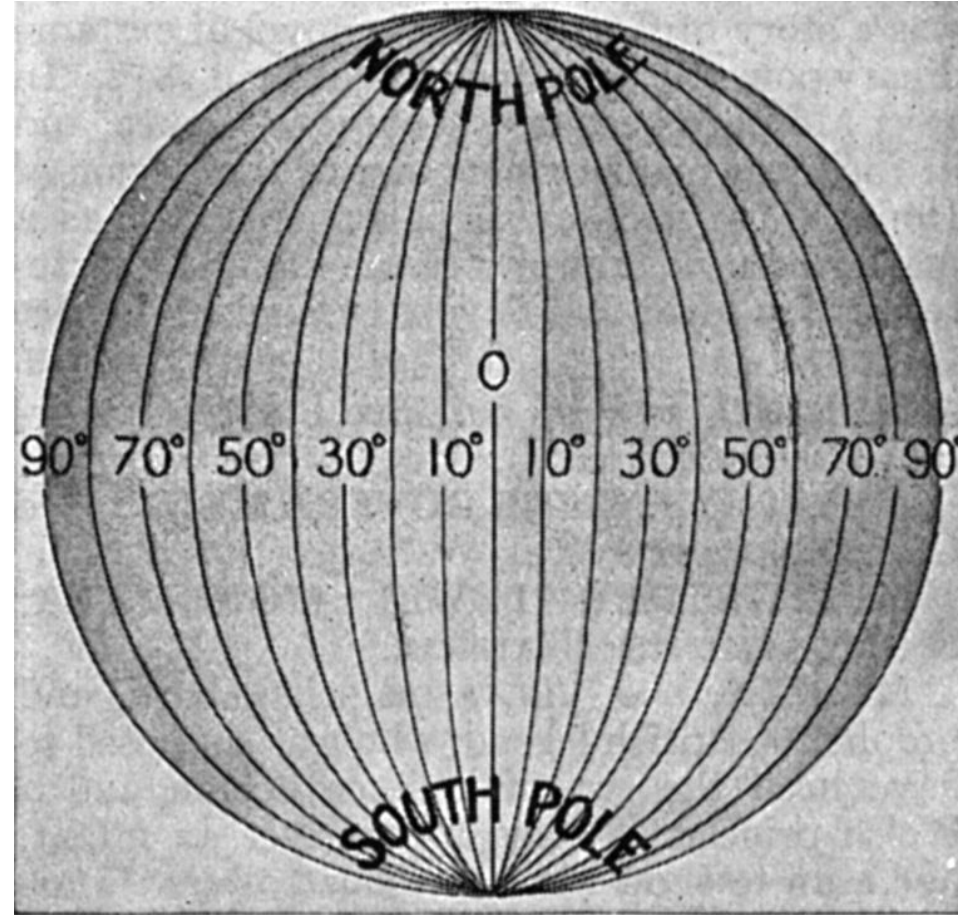


Esfera celeste y terrestre

# Latitude and longitude



Latitude lines



Longitude lines

# Coordinates on Earth

- The longitude of a place, say Milwaukee, is the number of degrees east or west of the meridian through Greenwich, England. (We're  $88^{\circ}$  W)

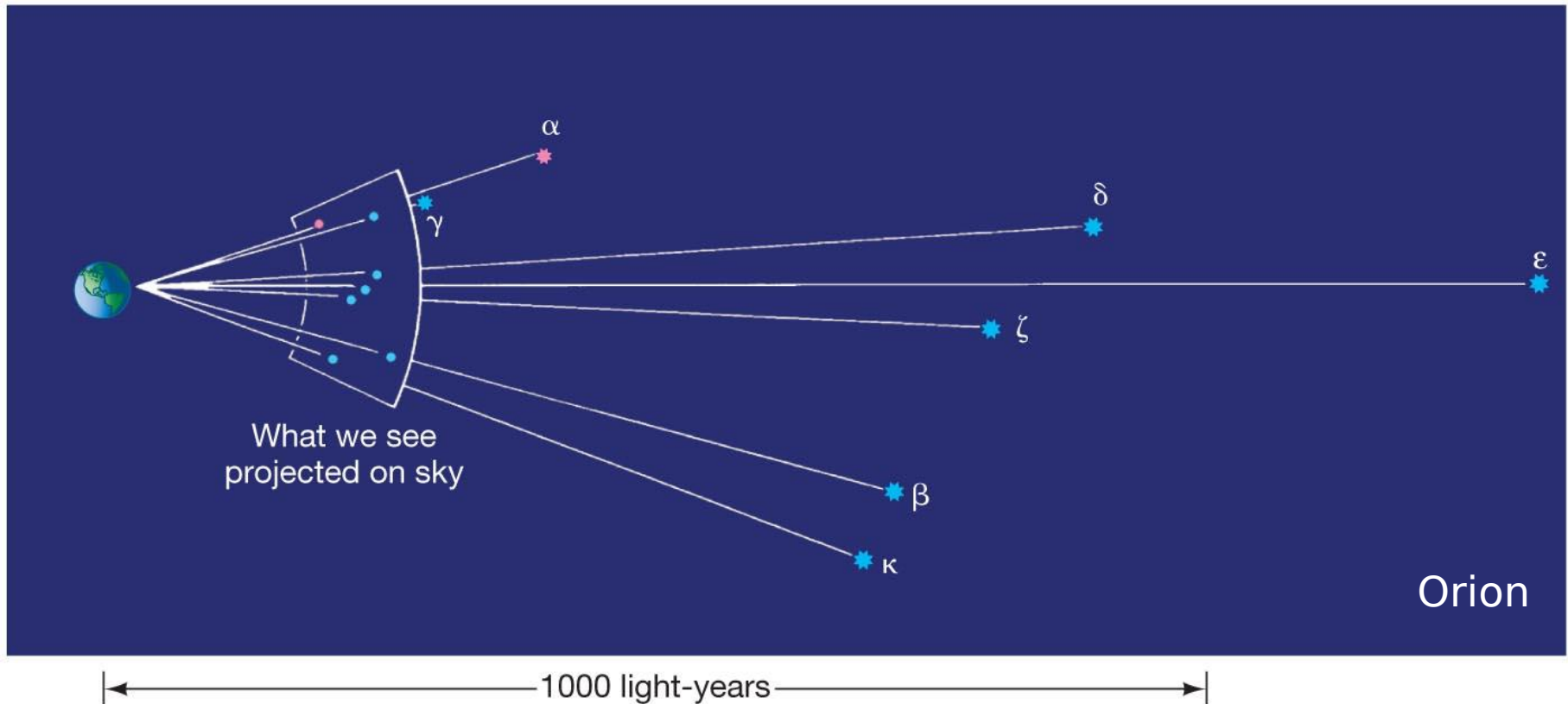


- The latitude of a place is the number of degrees north or south of the equator.
- What is Milwaukee's latitude?

**$43^{\circ}$  N**

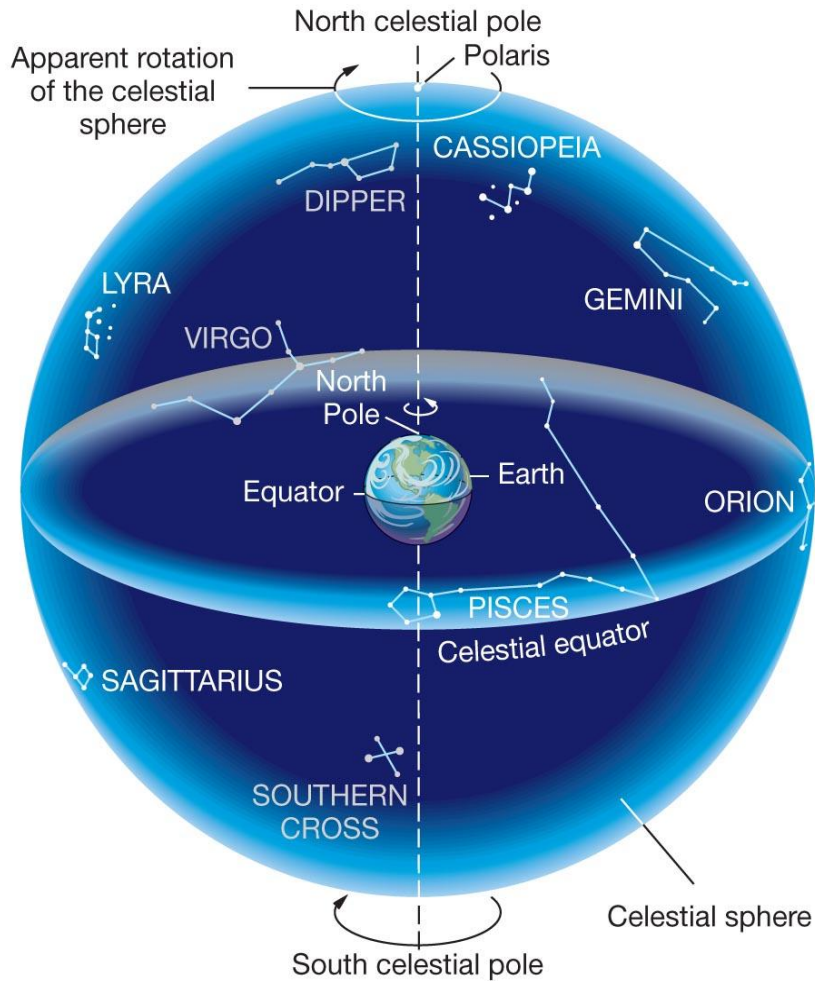
# What do we see in the sky?

- Constellations: *apparent* groups of stars
- Appear close together, may actually be at different distances
- Now refers to an **area** of the sky rather than collection of stars
- Sky is divided into 88 constellations



Stars that appear close in the sky may not actually be close in space.

# The celestial sphere



- The sky has the appearance of a sphere, and at night it looks like the sphere rotates, with all of the stars moving as if the sphere were rotating. The name given to this imaginary sphere is the **celestial sphere**
- The celestial sphere appears to rotate once a day from east to west (counterclockwise looking up at the north celestial pole). **This is because the Earth really rotates once a day from west to east: counterclockwise, looking down at the north pole.**

The **North Celestial Pole** and **South Celestial Pole** are the points on the celestial sphere directly over the Earth's North and South poles.

From northern hemisphere, stars, Sun, Moon and planets appear to move from east to west in a circle around North Celestial Pole:  
Polaris, the North Star

In a day, celestial sphere appears to rotate once  
→ rotates  $360^\circ$  in 24 hours, so each hour rotates  $360^\circ / 24 = 15^\circ$   
→ stars appear to move  $15^\circ$  per hour east to west



Approximately how long was the exposure for this photo?

A 15 minutes

C 6 hours

B 1 hour

D 12 hours





Approximately how long was the exposure for this photo?

A 15 minutes

C 6 hours

B 1 hour

D 12 hours



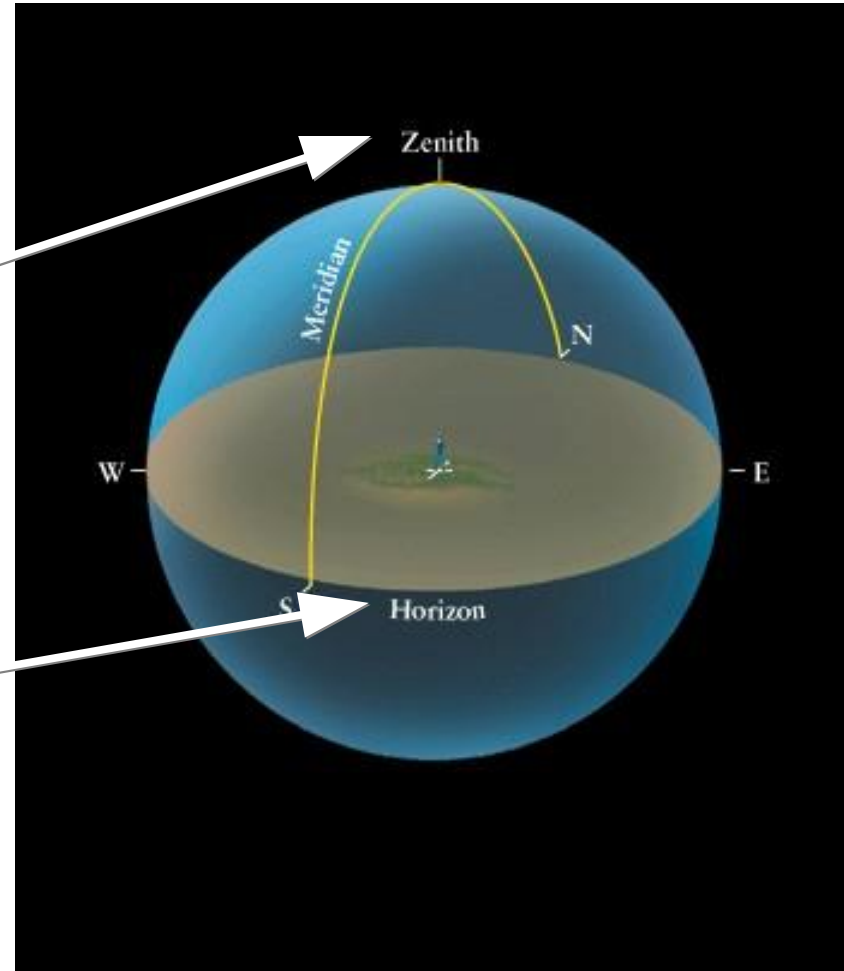
A single star has moved about  $\frac{1}{4}$  of a circle, or 90 degrees. A full circle takes 24 hours, so the exposure was about  $24/4 = 6$  hours.

# Some Terminology

**Zenith** is the point on the celestial sphere directly overhead.

The **horizon** is a circle on the celestial sphere 90 degrees from zenith.

The **meridian** is a line from horizon to horizon, passing through the zenith.

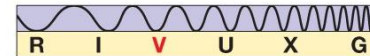
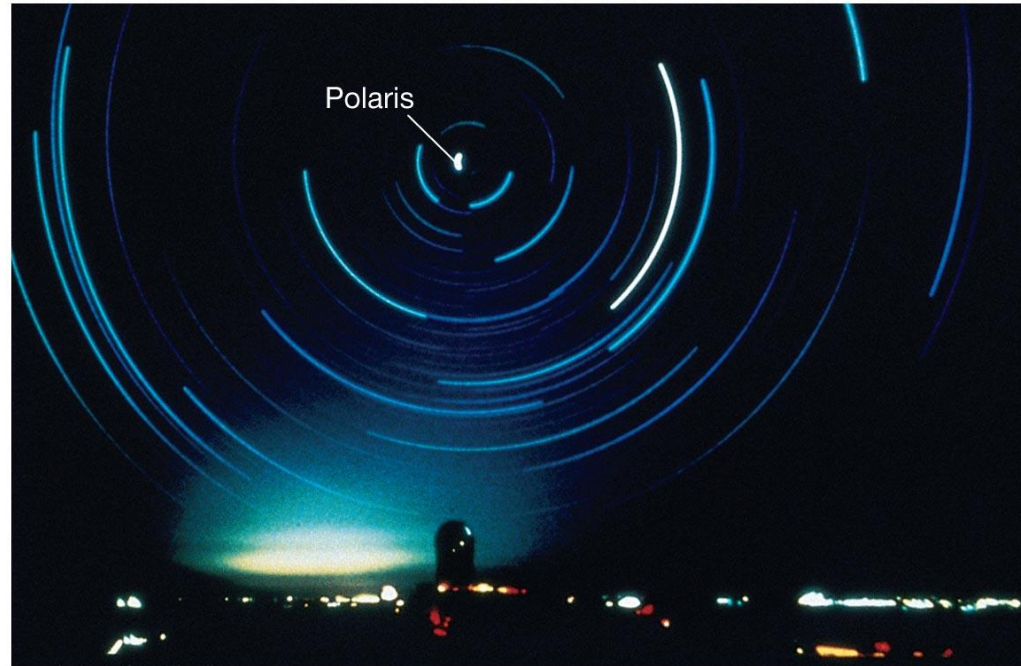


# What you see at night depends on where you are standing

You can see only half the sky: The Earth blocks light from stars that are below the horizon. As the Earth rotates, stars rise along the east half of the horizon, move in circles centered about the NCP, and set along the west half of the horizon.

The star *Polaris* (North Star) is close to the NCP. Stars appear to move in circles about Polaris.

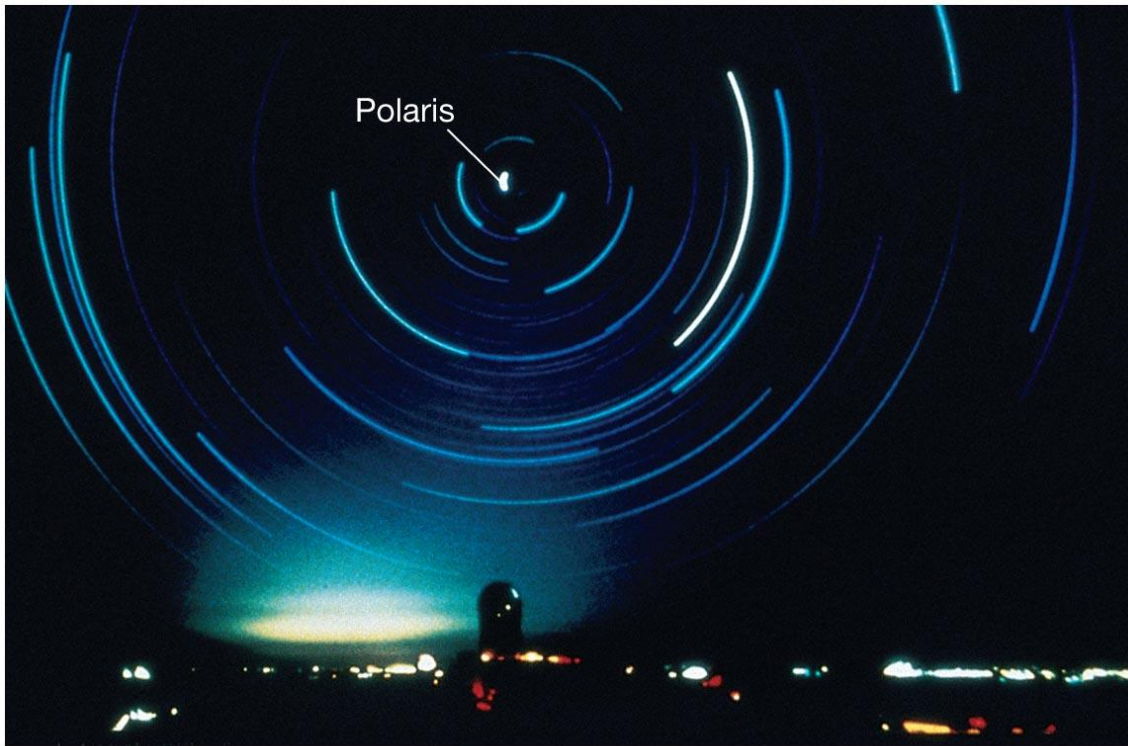
Some stars close enough to Polaris on the celestial sphere never rise or set and are called **circumpolar**



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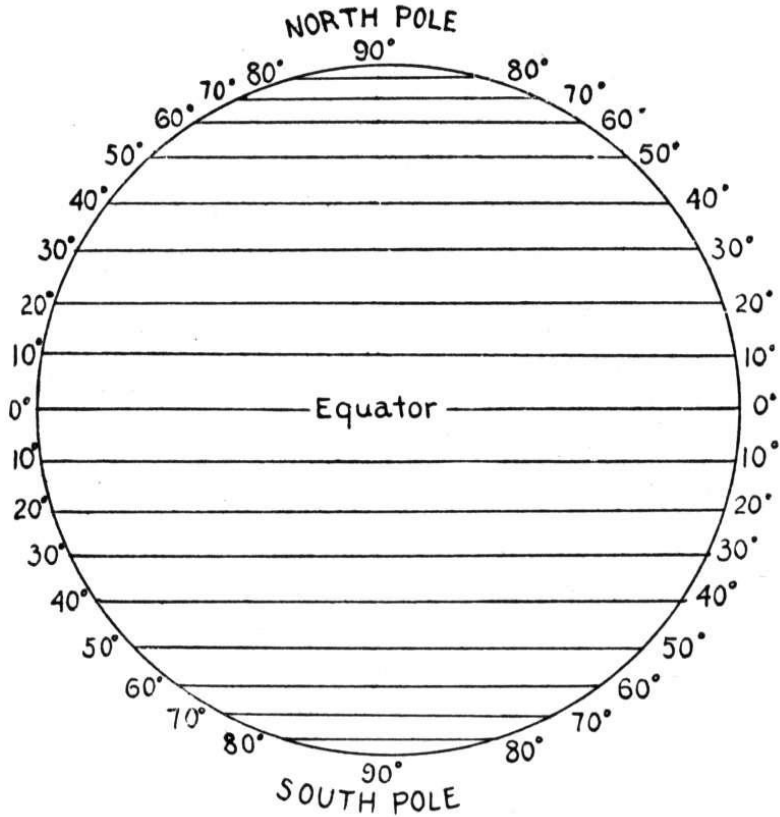
Seafaring Polynesians, Babylonians, and Libyans knew from sailing that as you move north, the NCP appears higher in the sky. (The Greeks finally understood the reason—that the Earth is round).

- As seen from the equator, Polaris is at the horizon. If you travel  $1^\circ$  north from the equator, Polaris will be  $1^\circ$  above your horizon.
- By the time you reach the North Pole,  $90^\circ$  N, Polaris is directly overhead,  $90^\circ$  above the horizon. In general:
- **The altitude of Polaris = your latitude**
- Because Milwaukee is 43 degrees north of the equator, Polaris is 43 degrees above our horizon. From south of equator, Polaris is below the horizon, never visible.
- There is no southern pole star

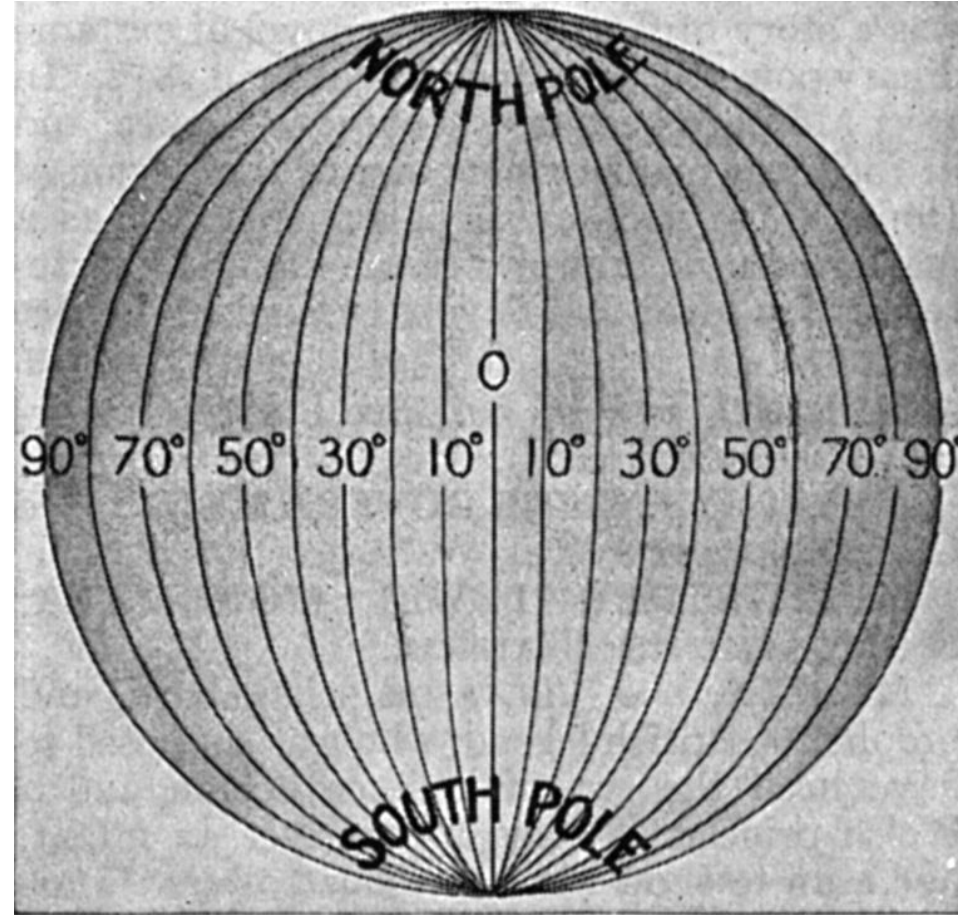


Celestial navigation:  
Altitude of Polaris =  
latitude!

# Latitude and longitude



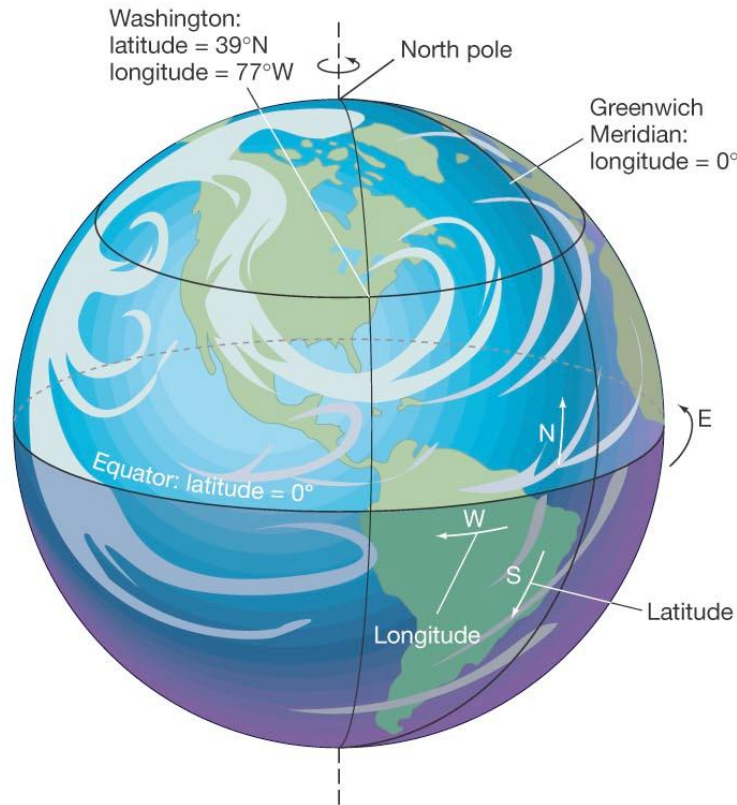
Latitude lines



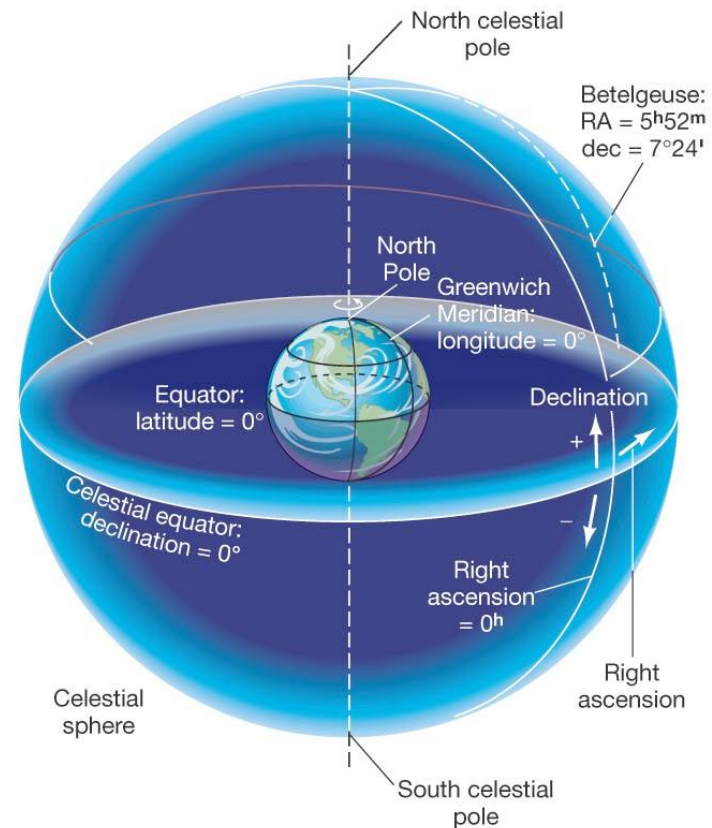
Longitude lines  
(meridians)

# Celestial Coordinates

- **Declination** - Degrees north or south of celestial equator: **latitude** on celestial sphere
- **Right ascension** - Measured eastward from position of the Sun at vernal equinox (we'll learn what that is soon): **longitude** on celestial sphere

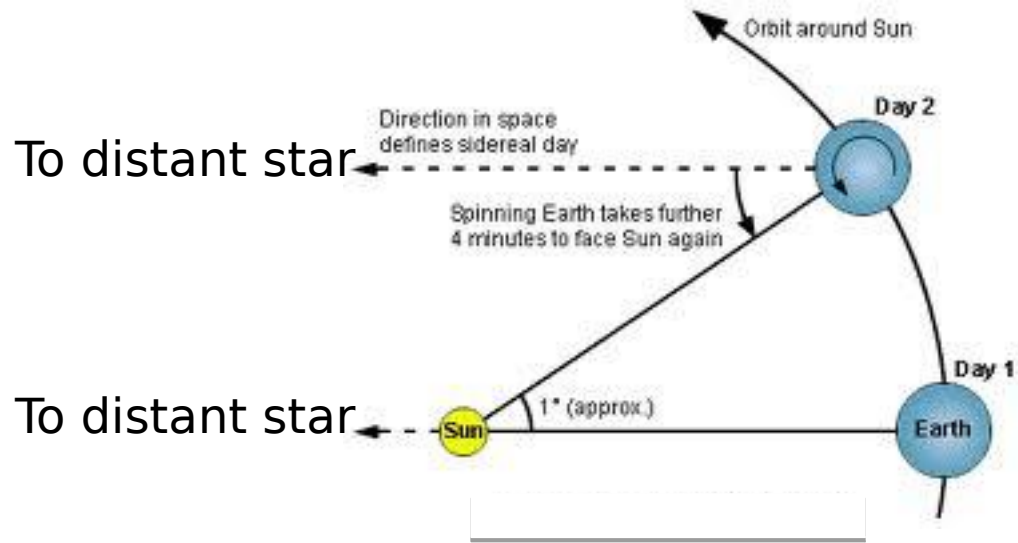


(a)



(b)

# Earth's Orbital Motion: **What is a day?**



- **One rotation of Earth about its axis**
- **Solar day:** Sun returns to same position
- **Sidereal day:** Stars return to same position
- Which is longer?
- Because of Earth's rotation around Sun, takes 4 minutes longer for Sun to return to same position
- Sidereal day is 4 minutes shorter

Each time Earth rotates on its axis, it also moves a small distance along its orbit. This means Earth has to rotate through a bit more than 360 degrees in order for the Sun to return to the same apparent location in the sky.

How much more? Earth takes 365 days to revolve around the Sun, so in 1 day it travels through  $1/365$  of its orbit or  $360/365=0.986$  degrees. This is the extra amount the Earth needs to rotate for the Sun to return to the same apparent position.

How long does this take?

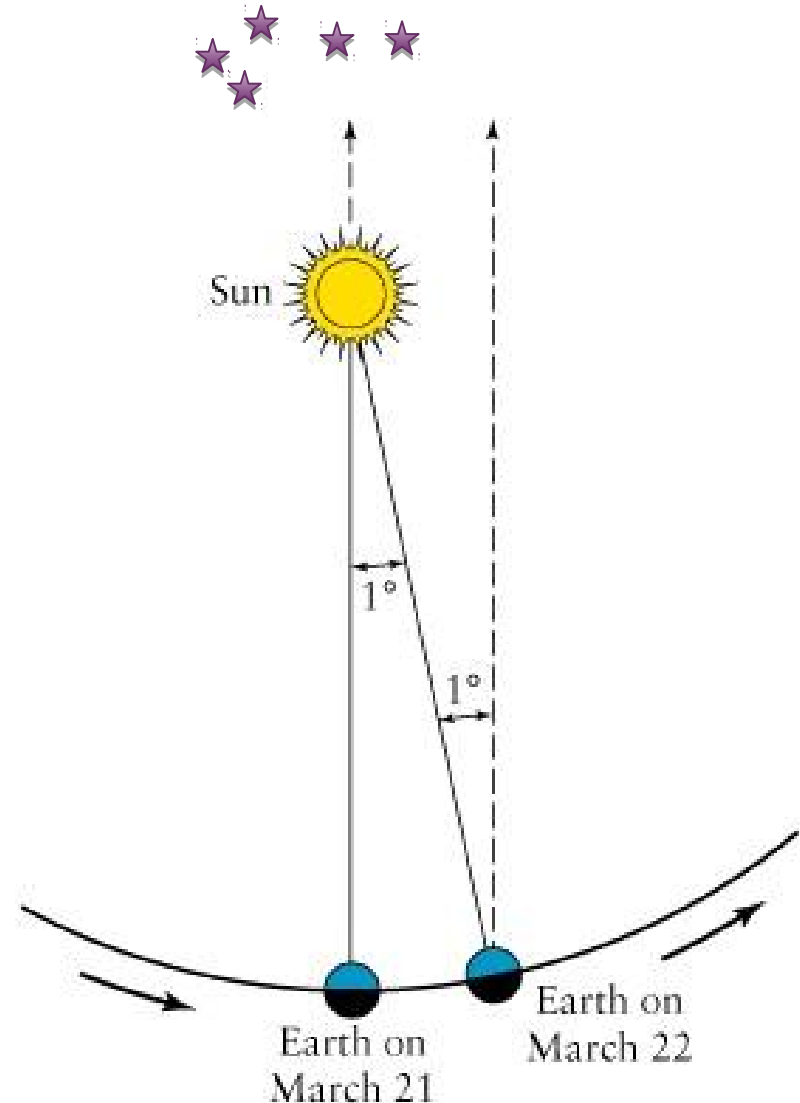
- The Earth rotates by 360 degrees in one day, so it rotates by 1 degree in  $1/360$  of a day. This is 4 minutes
- 1 day = 24 hours =  $24 \times 60$  minutes = 1440 minutes.  
 $1/360$  (1440 minutes) = 4 minutes (Or:  $24 \times 60 / 360 = 24 / 6 = 4$ )
- The time from sunrise to sunrise (1 day) is 4 minutes longer than the time from one rising of the star Betelgeuse (the brightest star in Orion) to the next.
- Stars rise 4 minutes earlier (and set four minutes earlier) each day, returning to their original positions after 1 year. This is why we see different stars in the summer and winter.



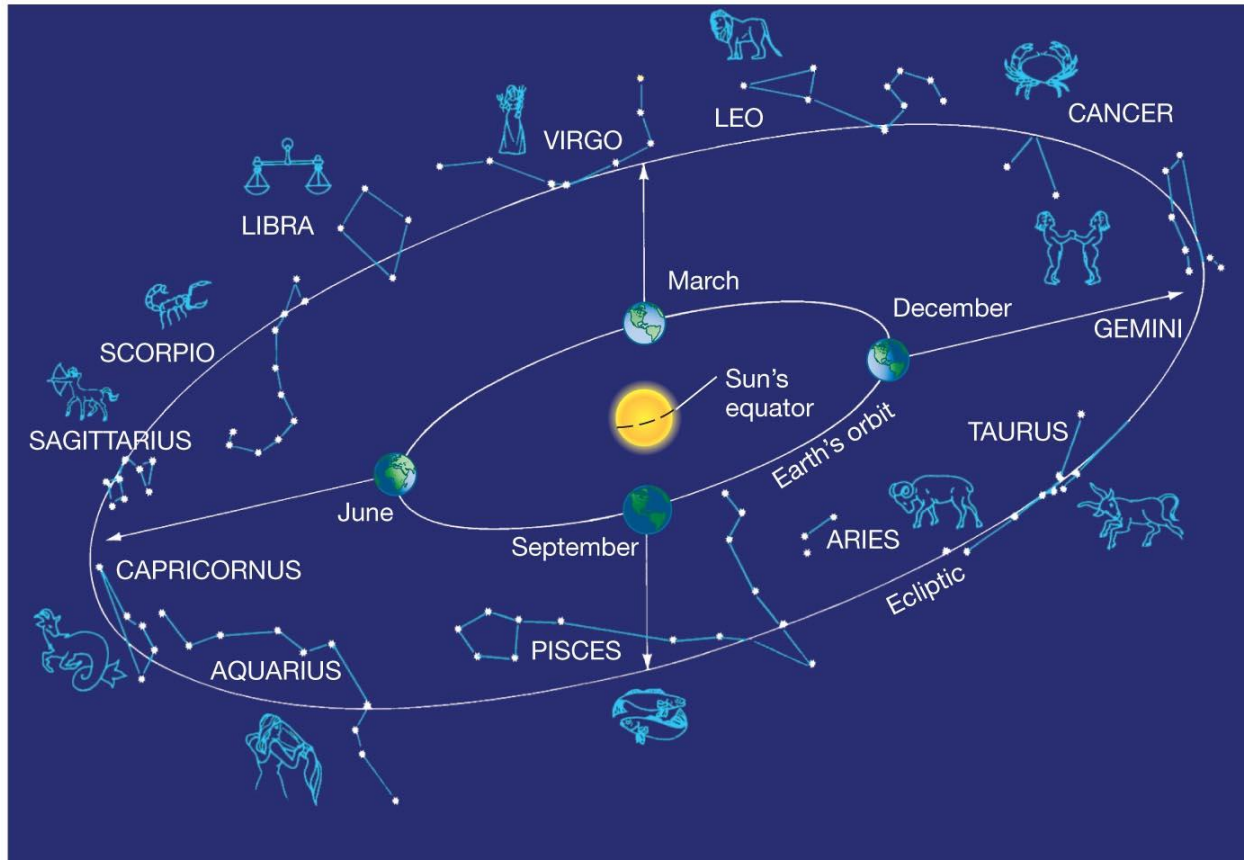
# Earth's Orbital Motion: Seasonal Changes

In a year the Earth moves 360 degrees about the Sun, so each day it moves about  $1^\circ$ .

The Sun appears to move against the background stars. As the Earth moves  $1^\circ$  from west to east, the Sun appears to move  $1^\circ$  from east to west.



The stars that the sun appears to move over are the constellations of the **Zodiac** – If we could see the stars in the day when the Sun is out (and we can in fact see them during a total eclipse of the Sun) we would see the Sun move through these constellations during the course of the year.

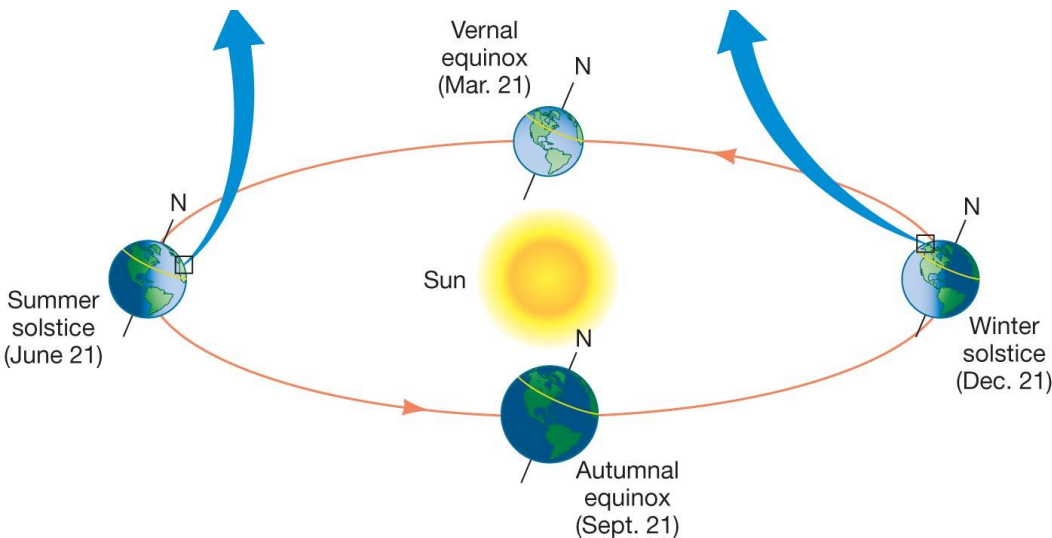


The path the Sun sweeps out against the background of stars is called the ***ecliptic***.

# The seasons and the tilt of the Earth

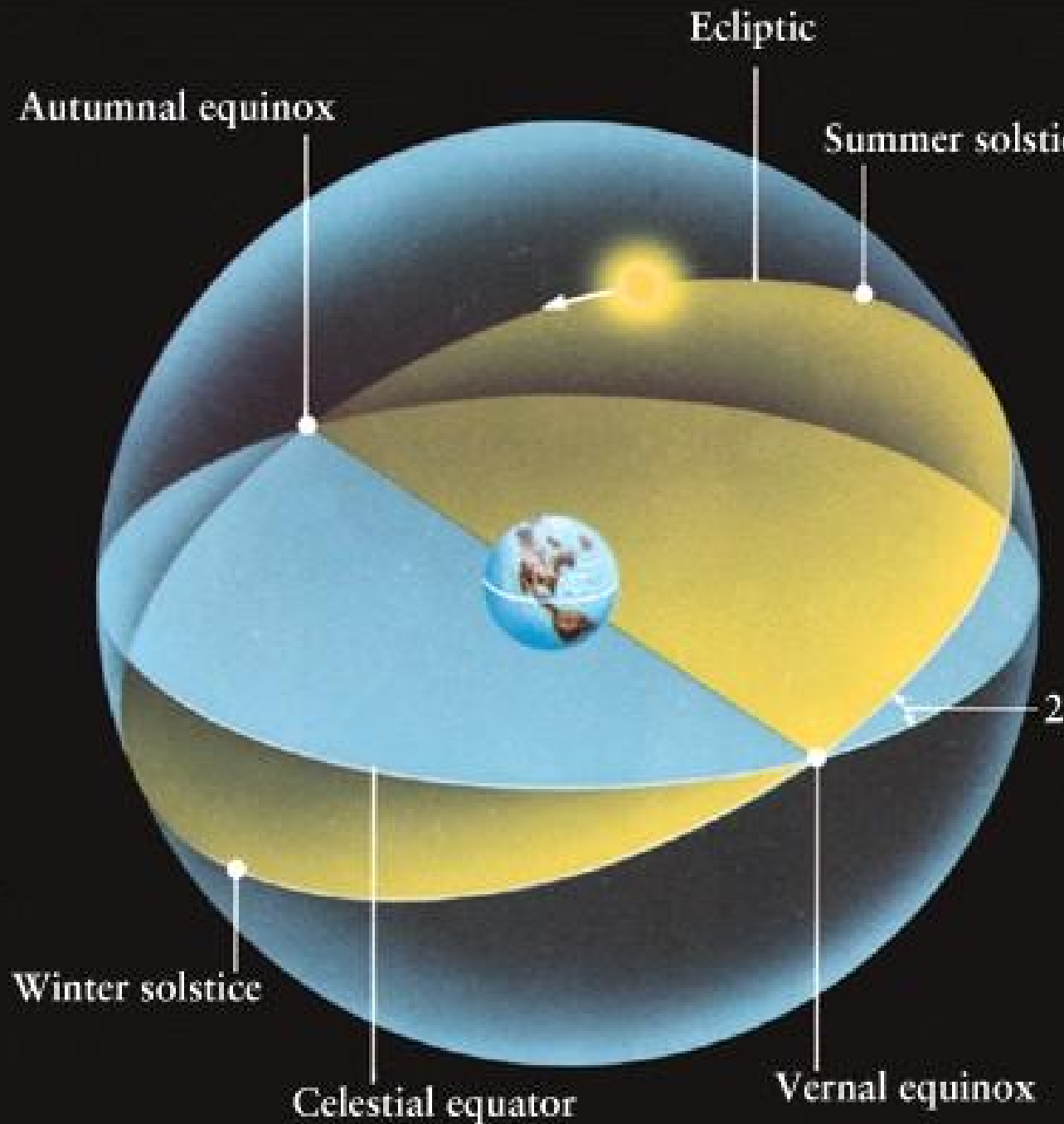
The Earth's axis of rotation is not perpendicular to the plane of the Earth's orbit about the Sun:

The Earth's rotation axis is tilted by 23.5 degrees away from perpendicular to its orbit—the plane of the equator is 23.5 degrees from the plane of the orbit.



On the summer solstice, when the axis is most directly tilted toward the Sun, the Sun is directly over a point 23.5 degrees north of the equator. On the winter solstice, with the north part of the axis tilted away from the Sun, the Sun is over a point 23.5 degrees south of the equator.

This means the ecliptic, the path the sun appears to follow in the sky, is on a plane tilted at  $23\frac{1}{2}$  degrees to the equator



The Sun is directly over the equator on the **Vernal Equinox** (spring) and the **Autumnal Equinox** (fall). These are the two points where the ecliptic intersects the celestial equator.

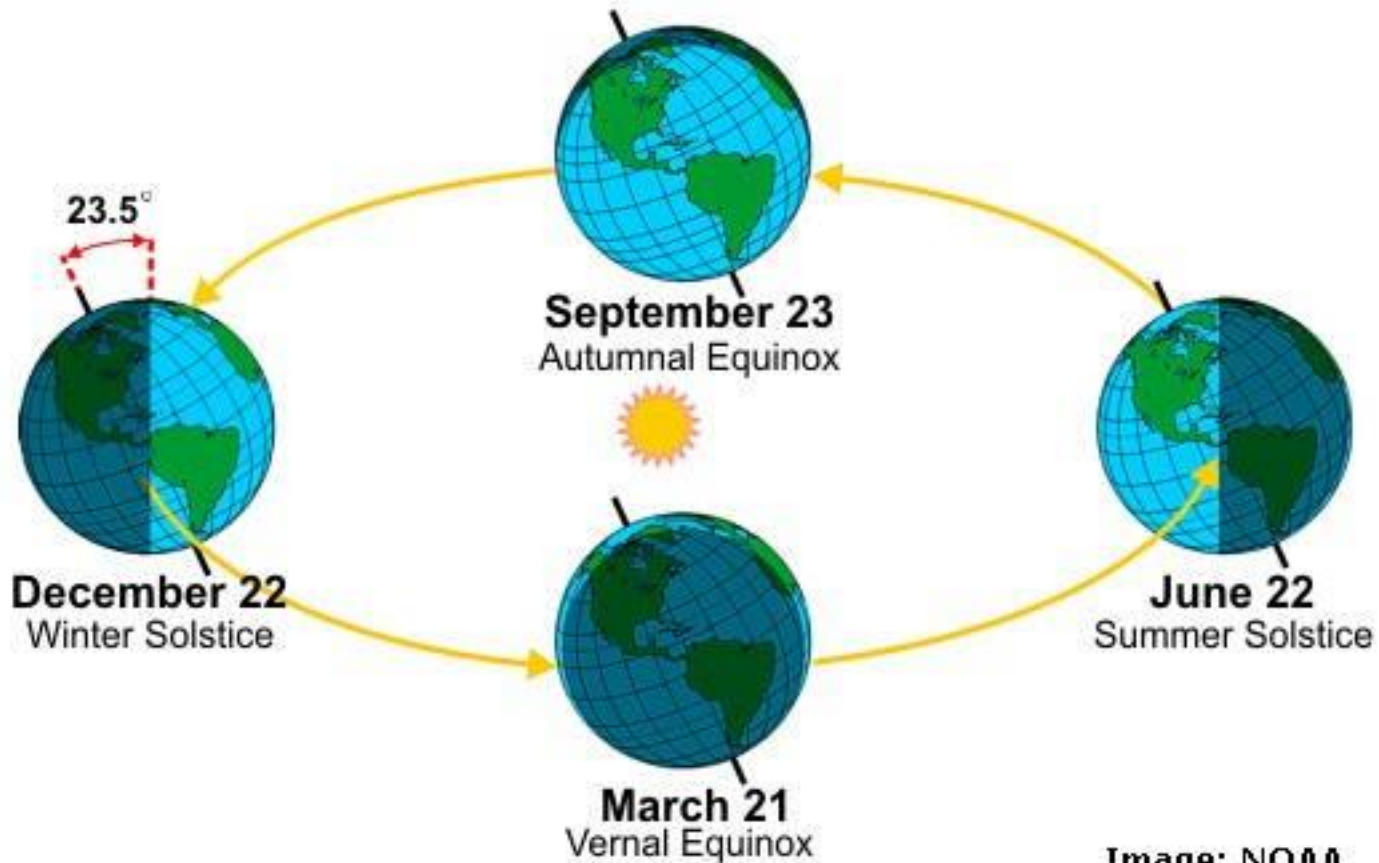
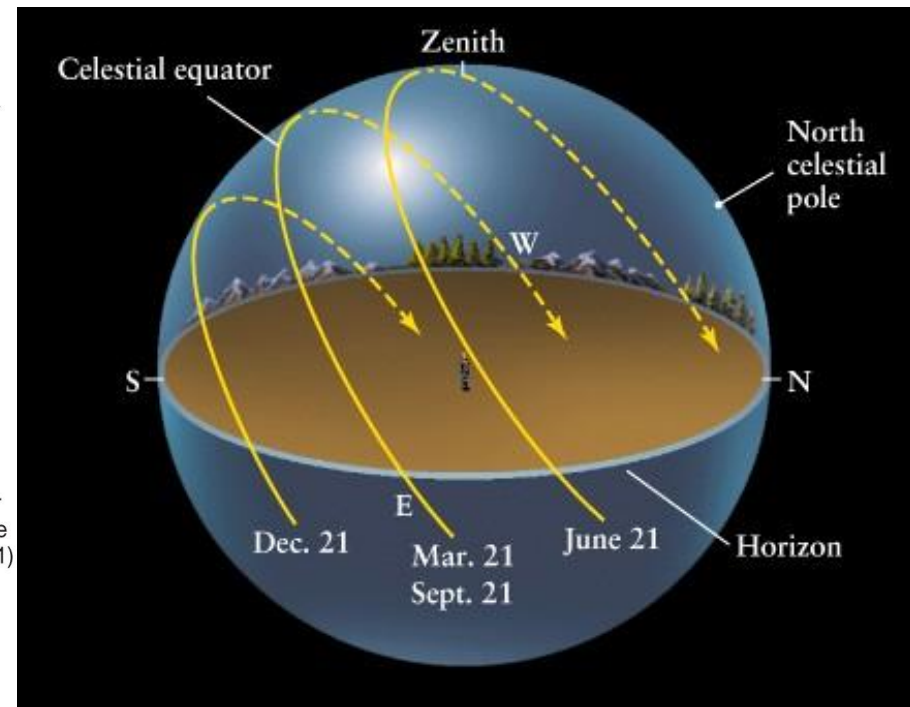
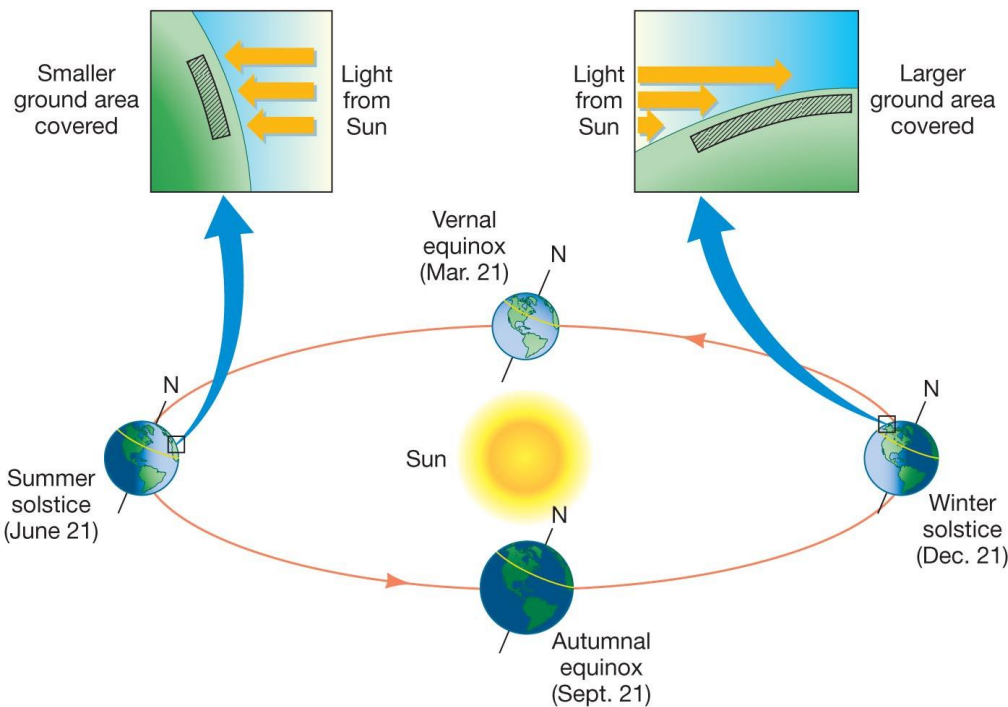


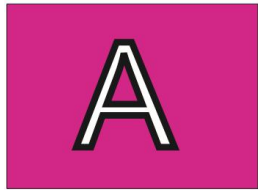
Image: NOAA

The seasons are caused by the tilt of the Earth's axis. The tilt has two effects:

1. Sunlight is more direct in the summer. In our summer, the northern hemisphere is tilted toward the Sun, in winter it is tilted away from the Sun.
2. The Sun is up longer in summer than in winter.



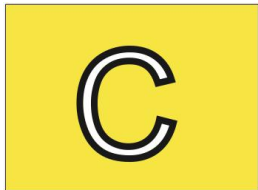
If Earth were upright with no tilt, would the temperature in Milwaukee in January be colder, warmer or the same as it is currently during the month of January?



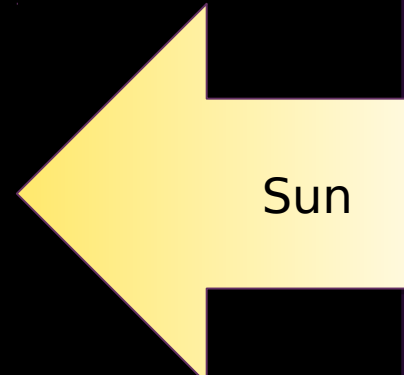
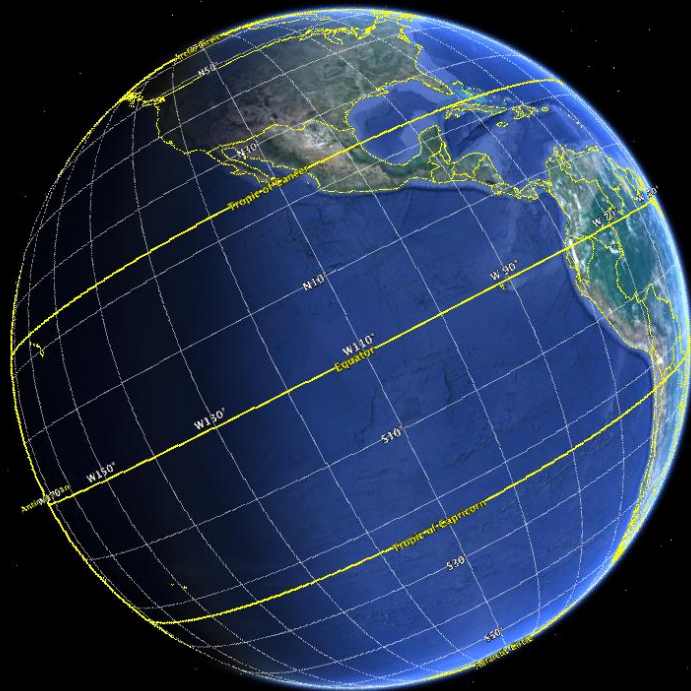
Colder



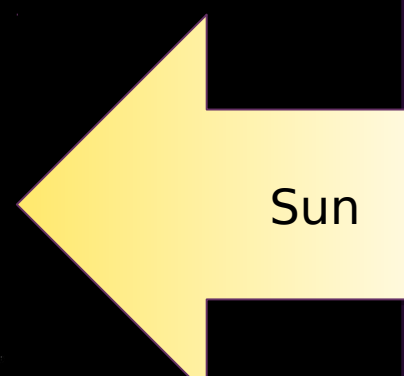
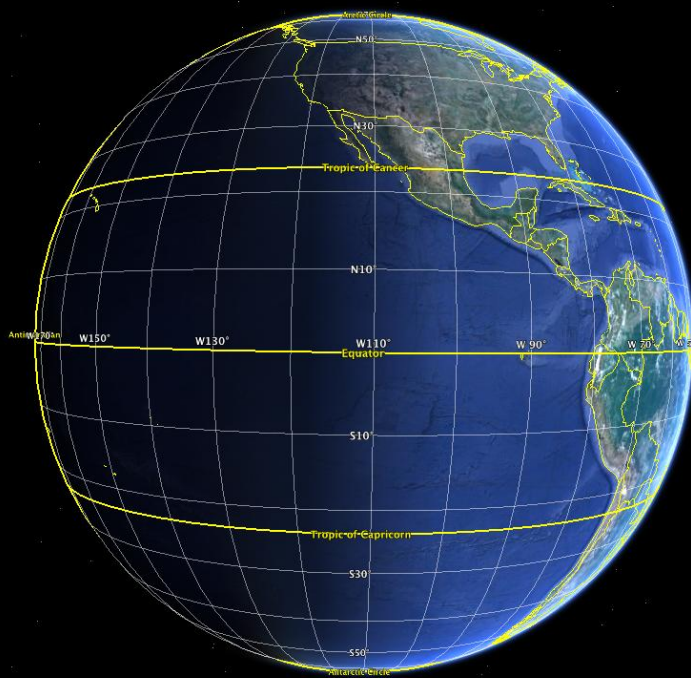
Warmer



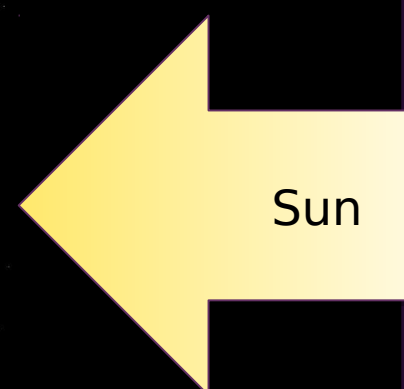
The same



Sun





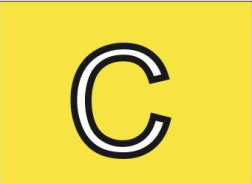
Sun



Sun

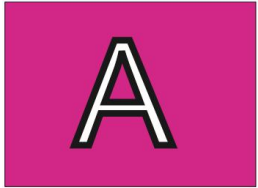


If Earth were upright with no tilt, would the temperature in Milwaukee in January be colder, warmer or the same as it is currently during the month of January?

-  **A** Colder
-  **B** Warmer
-  **C** The same

True or False:

Summer is warmer than winter because the Earth is closer to the Sun.



True



False

# True or False: Summer is warmer than winter because the Earth is closer to the Sun.

**A**

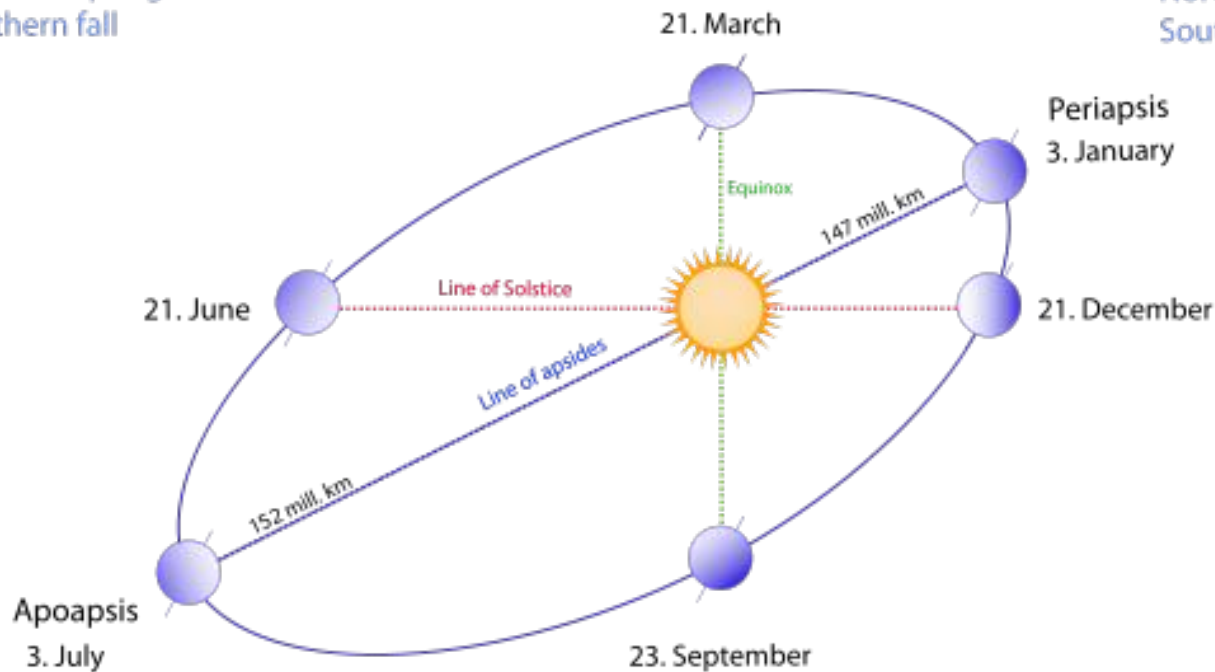
True

**B**

False

Northern spring/  
Southern fall

Northern winter/  
Southern summer



Earth is closest to Sun in January

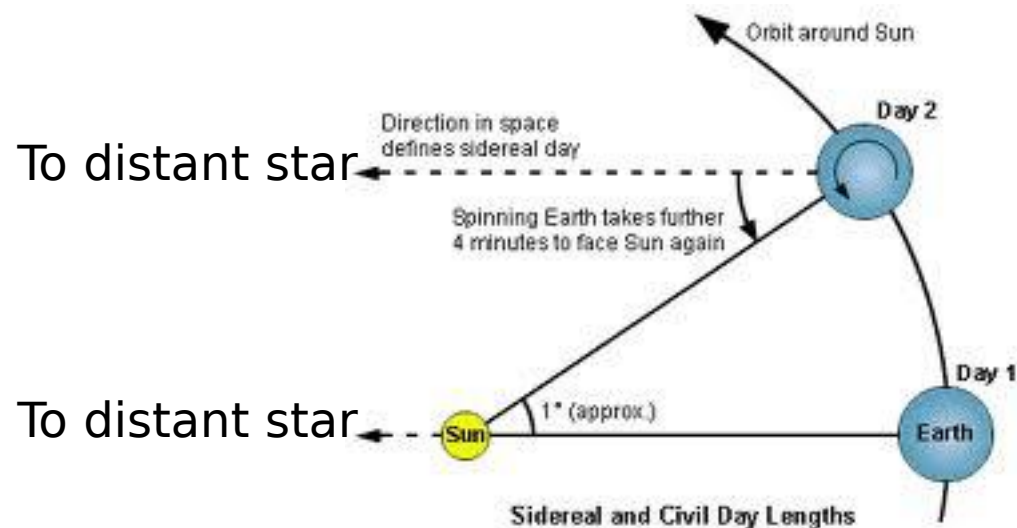
Difference in distance is small - diagram not to scale!

Northern summer/  
Southern winter

Northern fall/  
Southern spring

# Motions of the Earth: Recap

- Earth rotates on its axis every **24 hours**
- Earth revolves around the Sun every **year**
- There is one more motion we will discuss...

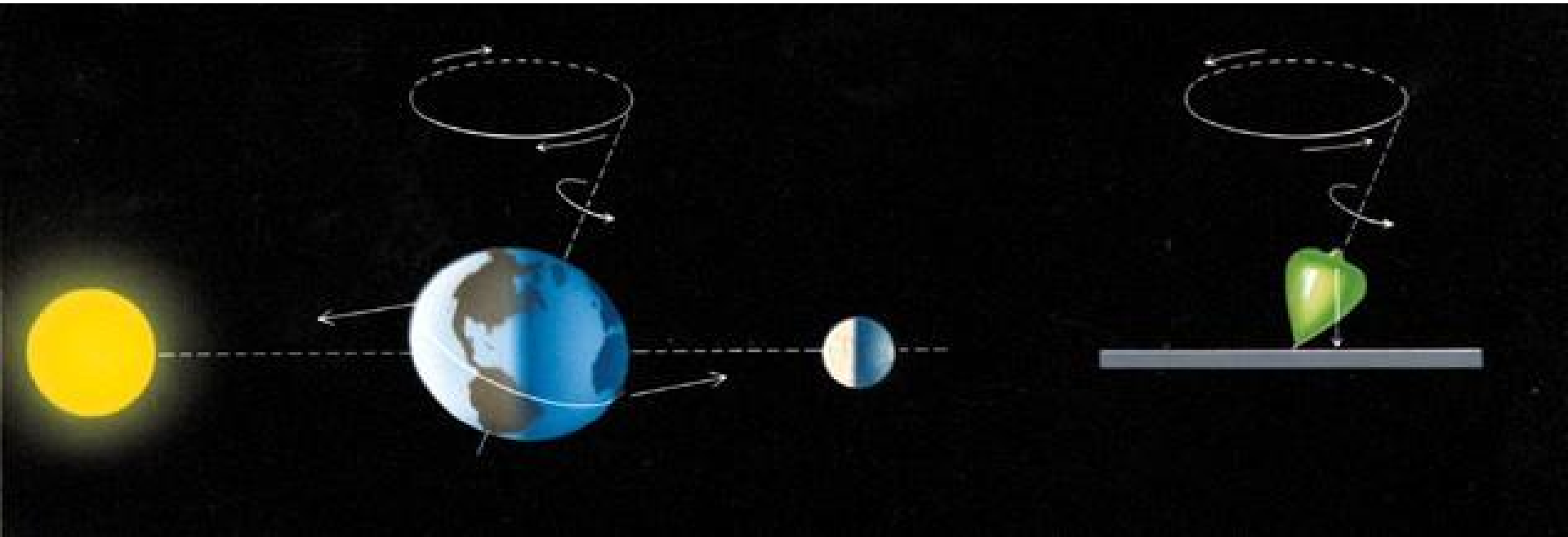


# Precession



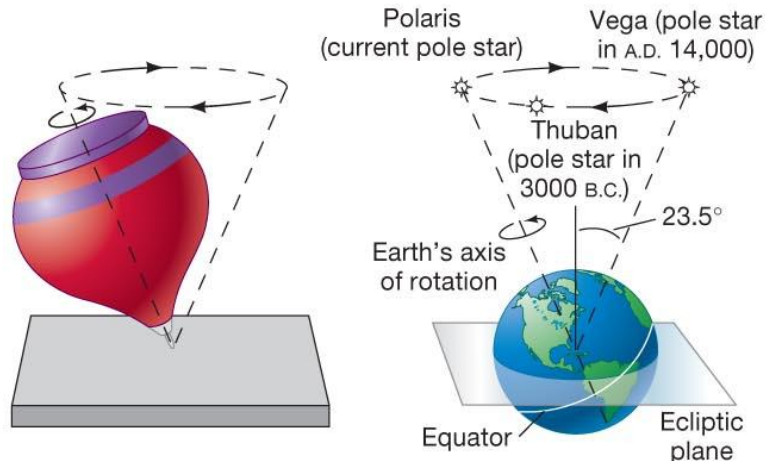
- Precession: **change in the orientation of the rotational axis** of a rotating body
- Direction of axis of Earth's rotation changes on 26,000 year cycle: **precession of the equinoxes**

# Precession

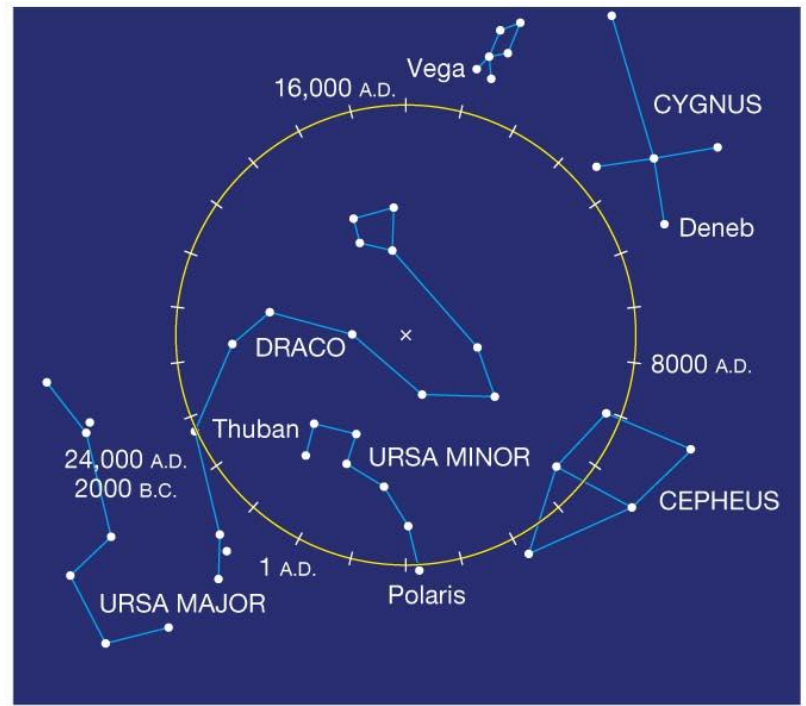


A spinning top precesses instead of falling: the direction of its spin slowly changes. The Earth's spin also precesses. The Earth bulges at the equator, and because the Sun's gravity gets stronger as you get closer to the Sun, the part of the bulge that is closer to the Sun is pulled slightly more strongly toward the ecliptic. If the Earth did not spin, the Sun would pull the bulge so that the equator was aligned with the plane of the Earth's orbit. Because the Earth spins, its axis precesses instead.

Earth's axis of rotation precesses with a 26,000 year period: In 13,000 years, what are now winter stars will be summer stars, and vice-versa. In 13,000 years, Vega, not Polaris will serve as our north star. In 26,000 years, the Earth's axis will again point in the direction it now points, and Polaris will again be the North Star.



(a)



(b)

*This effect was first observed by the Greek astronomer Hipparchus (in about 150 BC). He saw the position of the stars on the same day of the year had changed slightly over the 50 years he had made observations.*

# Review

- Earth rotates about its axis in **1 day**
- Earth revolves around the sun in **1 year**
- Seasons are caused by 23.5 degree tilt of Earth's axis
  - Sunlight is more direct in summer
  - Days are longer in summer
- Orientation of Earth's axis changes on **26,000 year** cycle: precession
- Next: **1 month** cycle of Moon phases