

Units 5-7: The view from Earth

Topics

1. The “Celestial Sphere” (Earth spins)
2. Coordinates (On the Earth and in the sky)
3. Seasons (Earth orbits the sun on a tilt)
4. Time (defined by sun or stars?)

* Visualize in 3D!

* Ask “How do we know?”

These 4 topics are all related to the motion of the Earth:

- A. The Earth spins on its axis (once per day)
- B. The Earth orbits the sun (axis tilted with respect to orbit)
- C. The Sun orbits in the Milky Way
- D. The Milky Way moves relative to the rest of the universe

These 4 distinct ways that Earth moves
are central to all 4 of today's topics.

1- The Celestial Sphere

A. The Earth spins on its axis (once per day)

Everything in the sky appears to rise and set once per rotation (i.e. once per day).

Star trails show this motion.

Everything (beyond the solar system) appears fixed on the sky.

(why?)

(what are constellations?)

Earth's spin causes the illusion of a "Celestial Sphere" surrounding the earth.



1- The Celestial Sphere

A. The Earth spins on its axis (once per day)

Everything in the sky appears to rise and set once per rotation (i.e. once per day)

Everything (beyond the solar system) appears fixed on the sky.

(why?)

(what are constellations?)

Constellations = fixed arrangements of stars that are NOT physically related.



2- Coordinates (on the Celestial Sphere)

A. The Earth spins on its axis (once per day)

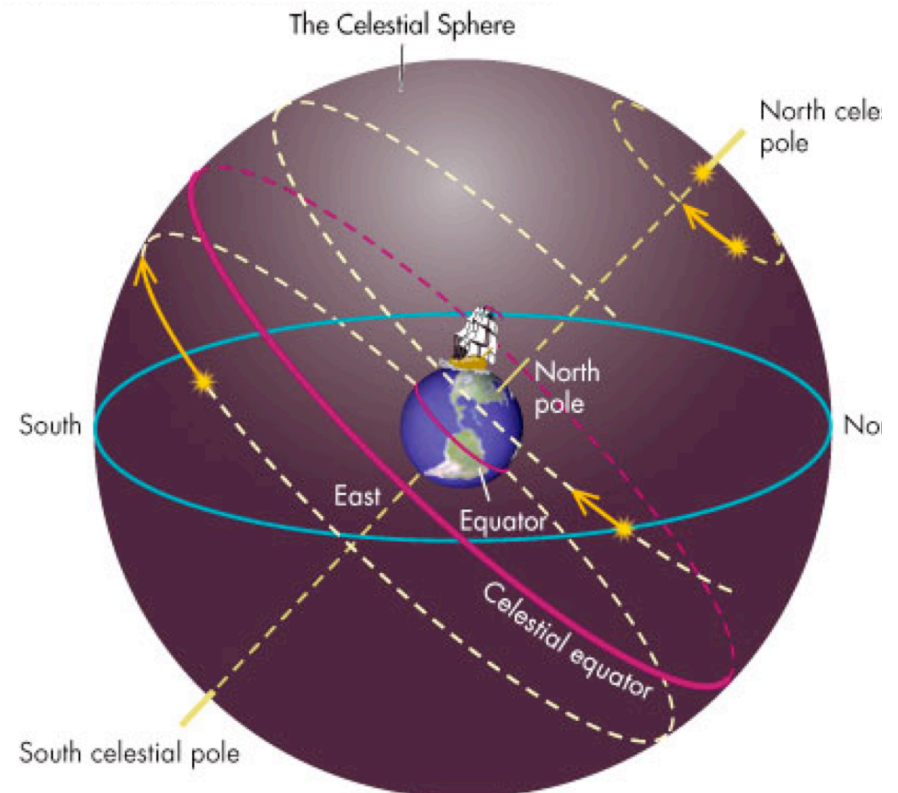
We can define a coordinate system as on Earth:

Absolute coordinates (unchanging):

North pole

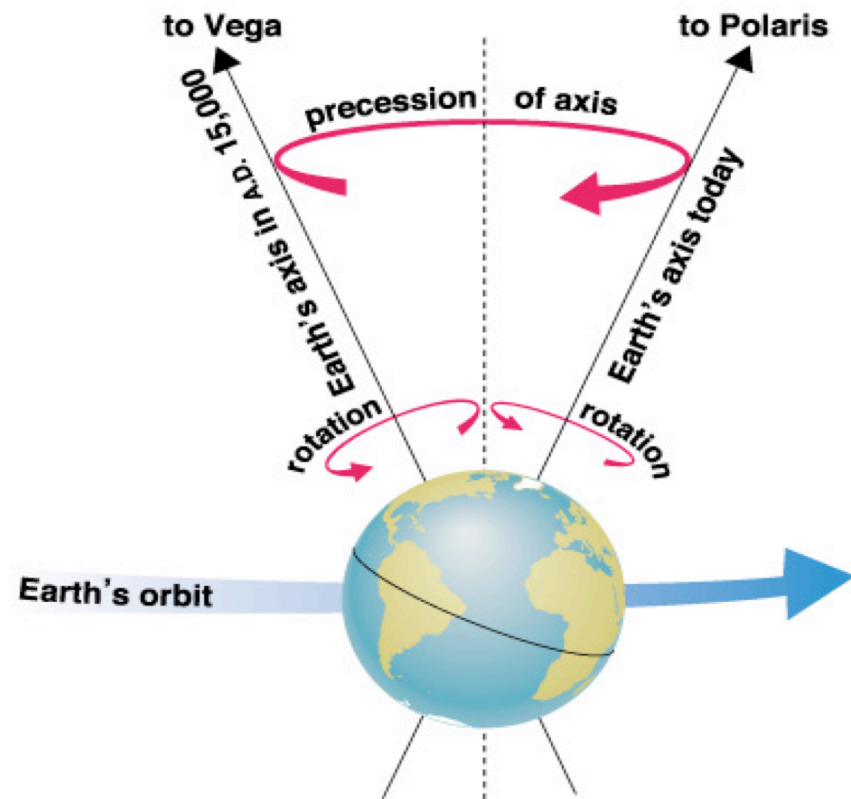
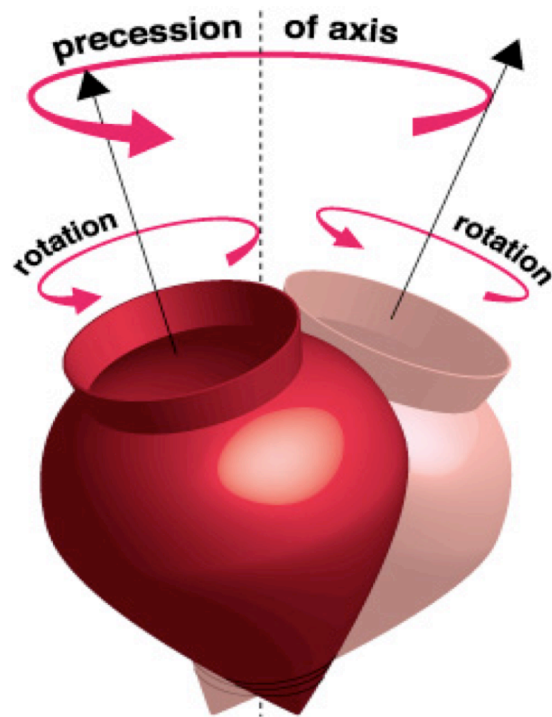
South pole

Celestial equator



An aside:

The Earth's precesses (like a top) once per 26,000 yrs.
The Celestial north pole moves in a circle over time.



2- Coordinates (on the Celestial Sphere)

A. The Earth spins on its axis (once per day)

We can define a coordinate system as on Earth:

NOT absolute (local to you).

- your zenith
- your horizon

Standing near the
Earth's equator

Standing
near the
Earth's
North pole



2- Coordinates (on the Celestial Sphere)

A. The Earth spins on its axis (once per day)

We can define a coordinate system as on Earth:

Absolute coordinates:

Declination (~ latitude)

Right Ascension (~ longitude)

2- Coordinates (on the Celestial Sphere)

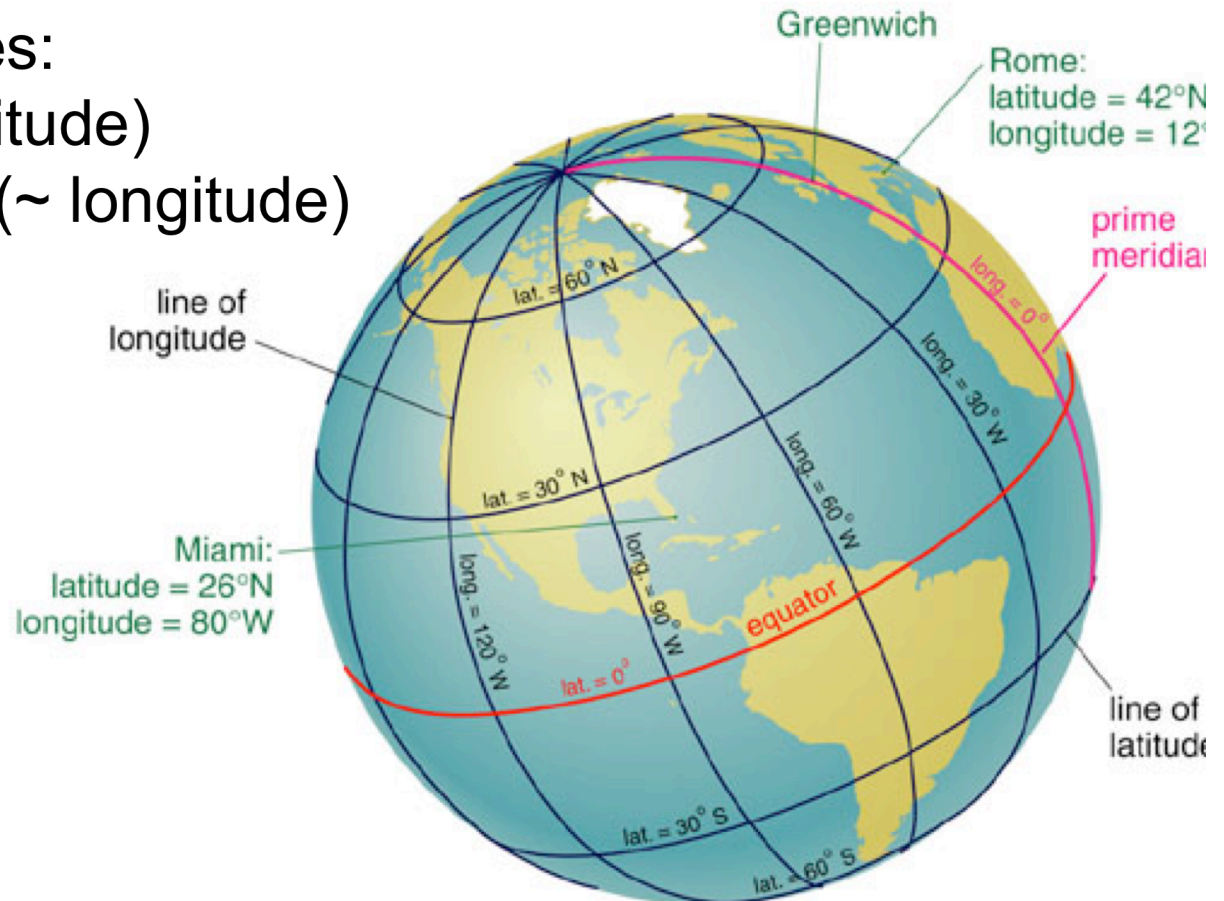
A. The Earth spins on its axis (once per day)

We can define a coordinate system as on Earth:

Absolute coordinates:

Declination (\sim latitude)

Right Ascension (\sim longitude)



2- Coordinates (on the Celestial Sphere)

A. The Earth spins on its axis (once per day)

We can define a coordinate system as on Earth:

Absolute coordinates:

Declination (\sim longitude)

Right Ascension (\sim latitude)

Declination = -90 to 0 to 90

[pole – equator – pole]

Right Ascension = 0 - 360

[where is RA=0 ?]

2- Coordinates (on the Celestial Sphere)

A. The Earth spins on its axis (once per day)

We can define a coordinate system as on Earth:

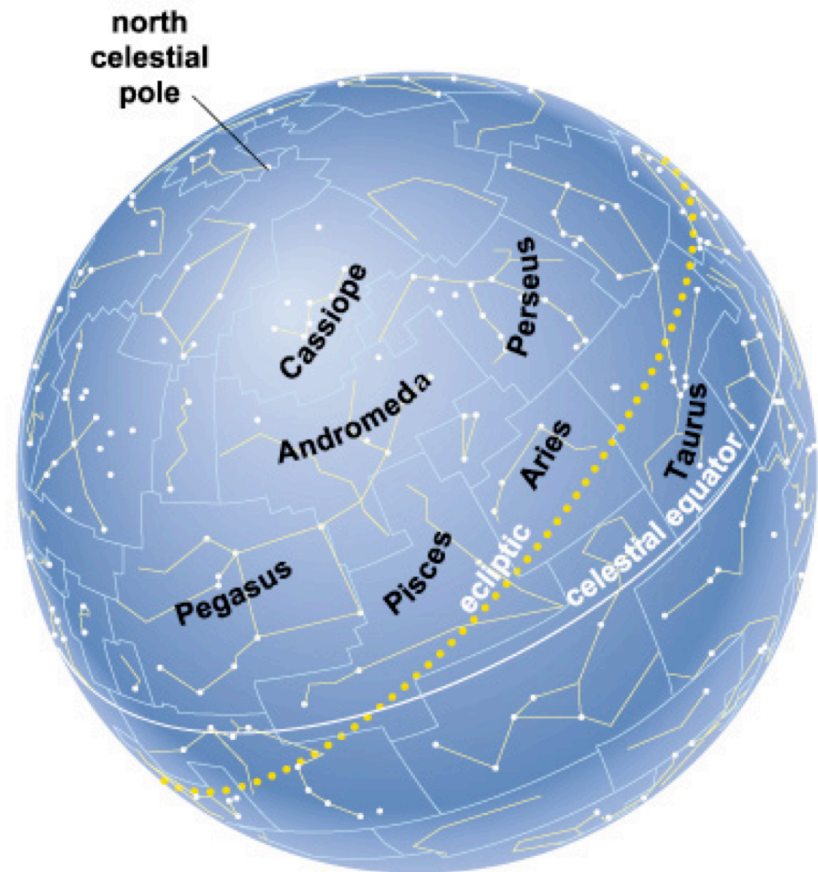
Absolute coordinates:

Declination (\sim longitude)

Right Ascension (\sim latitude)

Declination = -90 to 0 to 90
[pole – equator – pole]

Right Ascension = 0 - 360
[where is RA=0 ?]



iClicker question:

If I am standing at the north pole, which of the following is at the zenith?

- A. The celestial equator
- B. The moon
- C. The nearby galaxy, M31
- D. The north celestial pole
- E. The Sun

iClicker question:

Santa Cruz is at about 36° north Latitude and 122° west longitude (~ 8 hrs west of Greenwich, UK).

From here, can I see an object at

The south Celestial Pole?

a - yes

b - no

The celestial equator?

a - yes

b - no

The moon?

a - yes

b - no

The north Celestial Pole?

a - yes

b - no

2- Coordinates (on the Celestial Sphere)

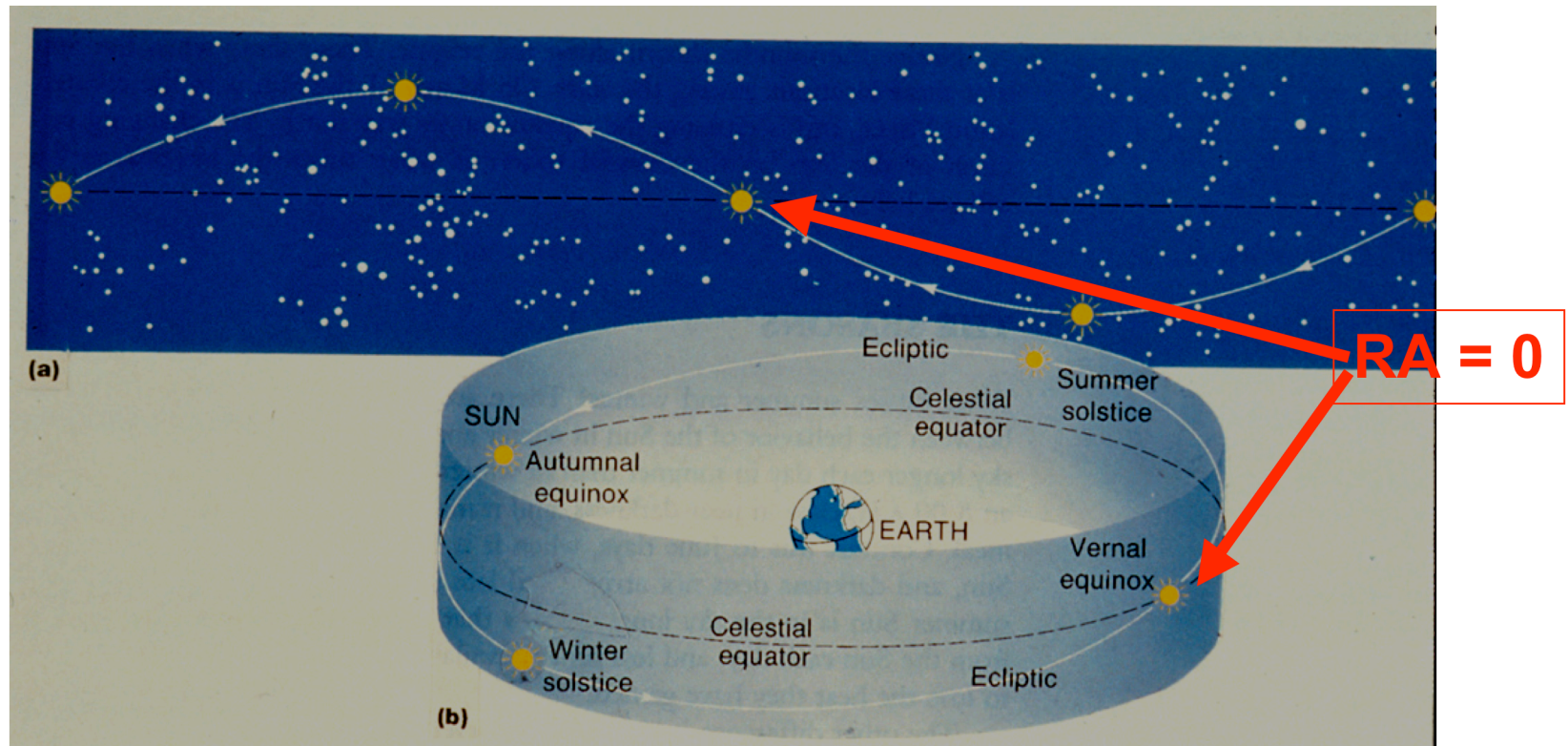
B. The Earth orbits the sun (once per year)

Half the sky is overhead during the day
... which half changes throughout the year!

2- Coordinates (on the Celestial Sphere)

B. The Earth orbits the sun (once per year)

This makes a convenient way to define $RA=0$...



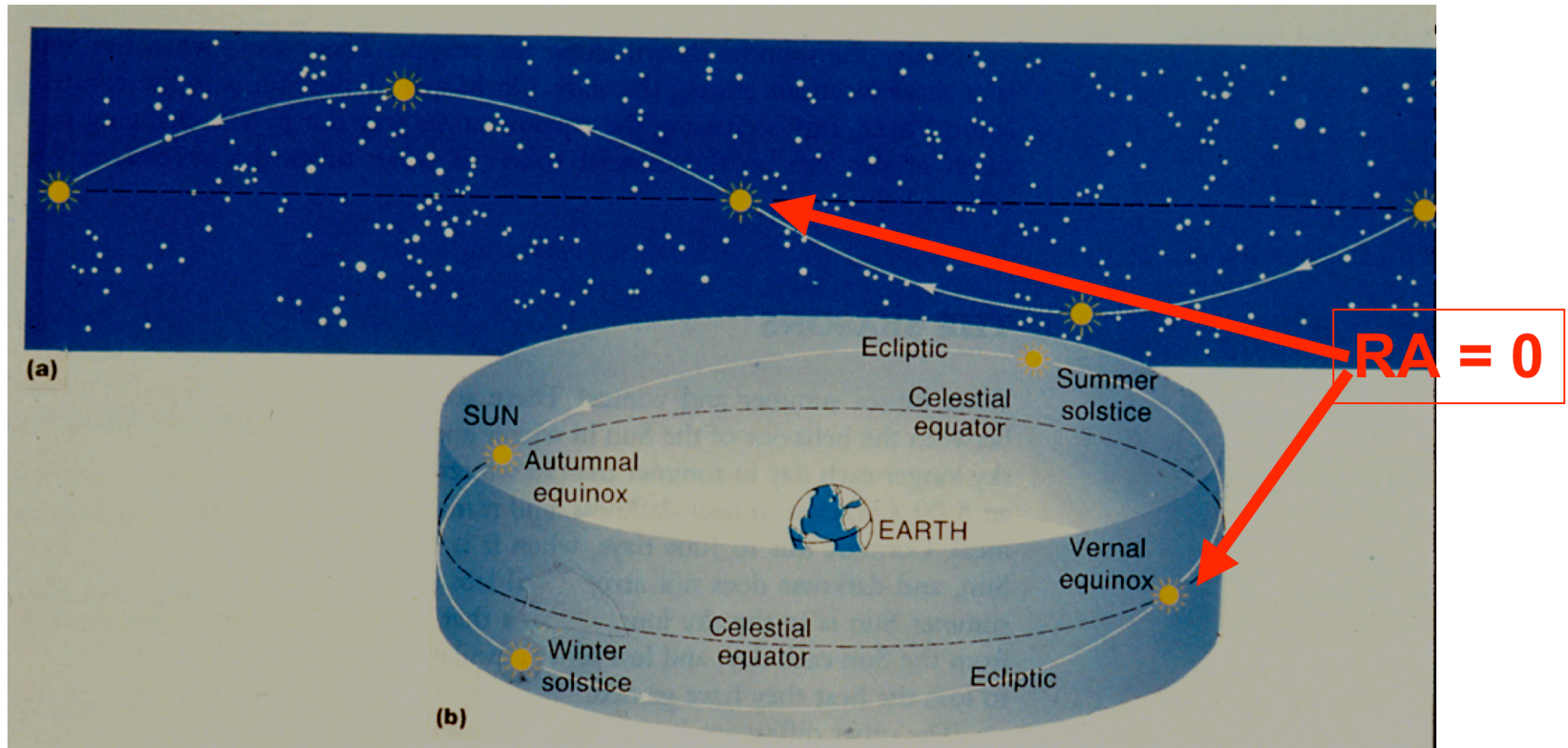
Ecliptic path = apparent path of sun through the stars.

Ecliptic plane = plane of the earth's motion (or the sun's apparent motion)

2- Coordinates (on the Celestial Sphere)

B. The Earth orbits the sun (once per year)

Let the sun mark the location of RA=0 deg on the Vernal equinox.

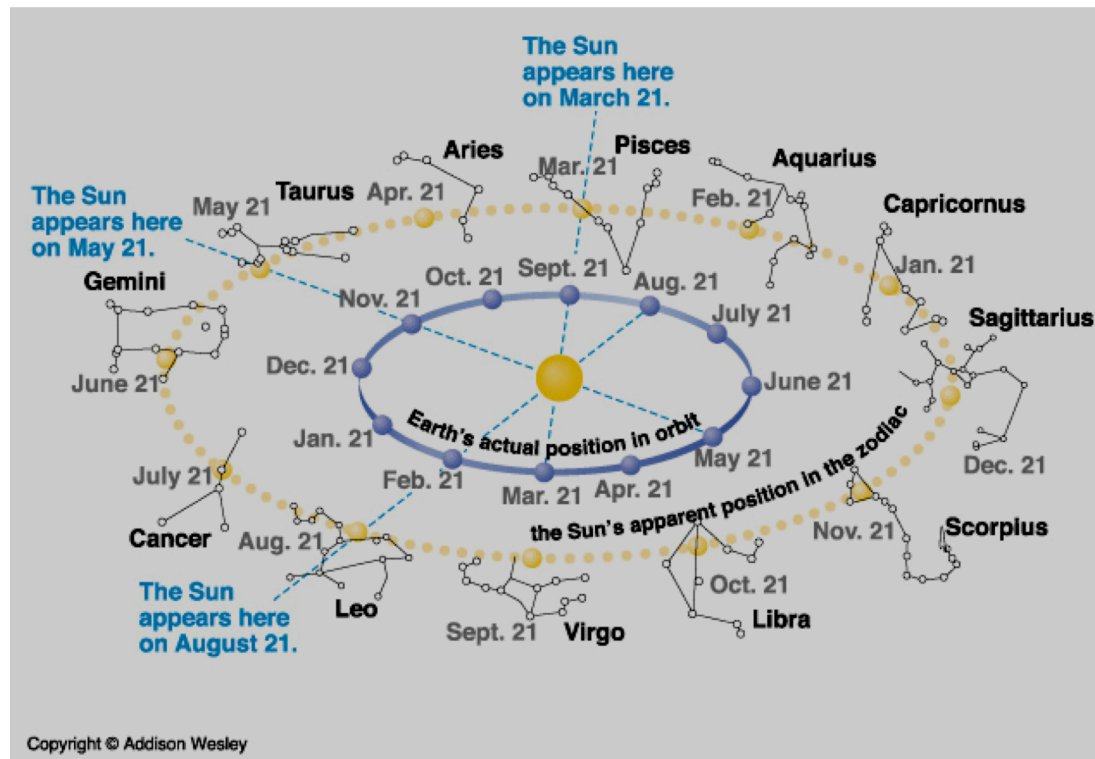


Stars at RA=0 can be seen in the fall.

2- Coordinates (on the Celestial Sphere)

B. The Earth orbits the sun (once per year)

Zodiac = constellations on the ecliptic plane

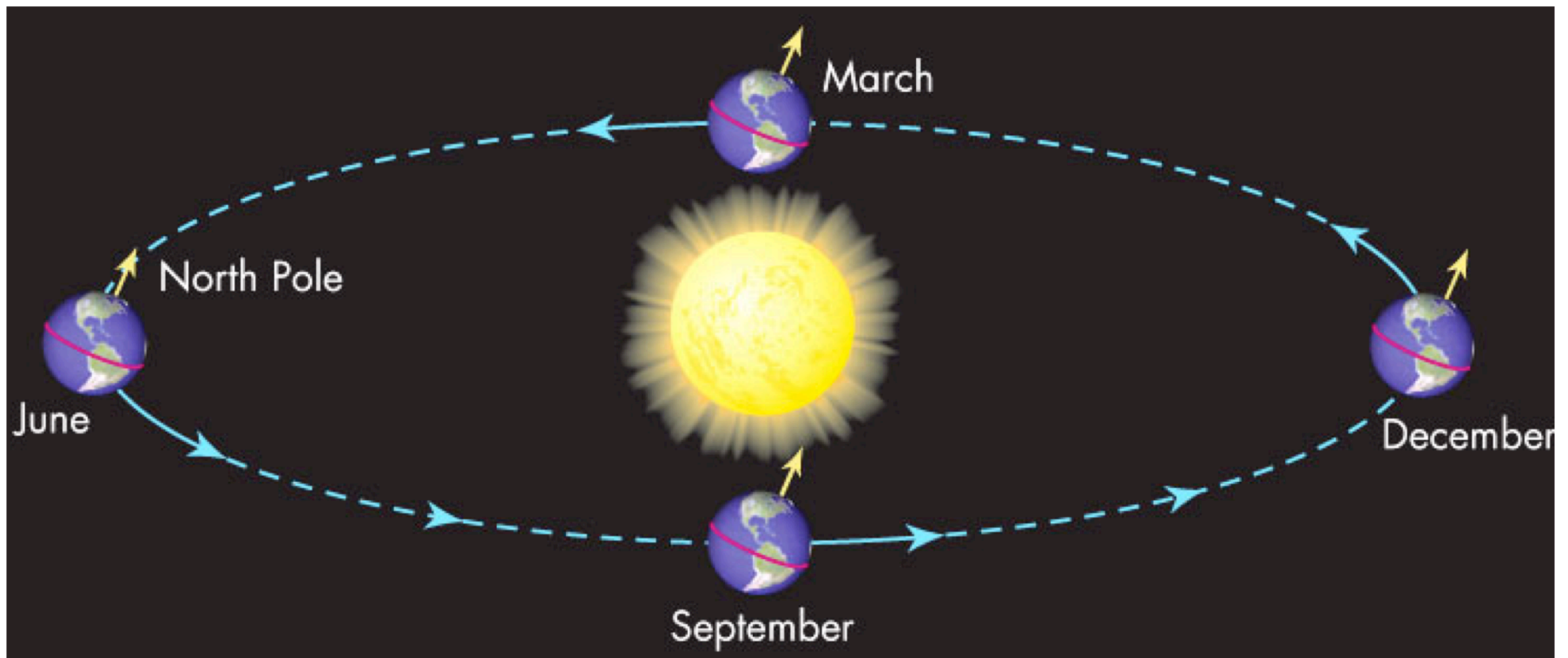


Defined in 100AD... constellations/dates are slightly off now. (Why?)

3- Seasons

B. The Earth orbits the sun (once per year) ...on a tilt!

The Earth's spin-axis is tilted 23.5° relative to the plane of the orbit.

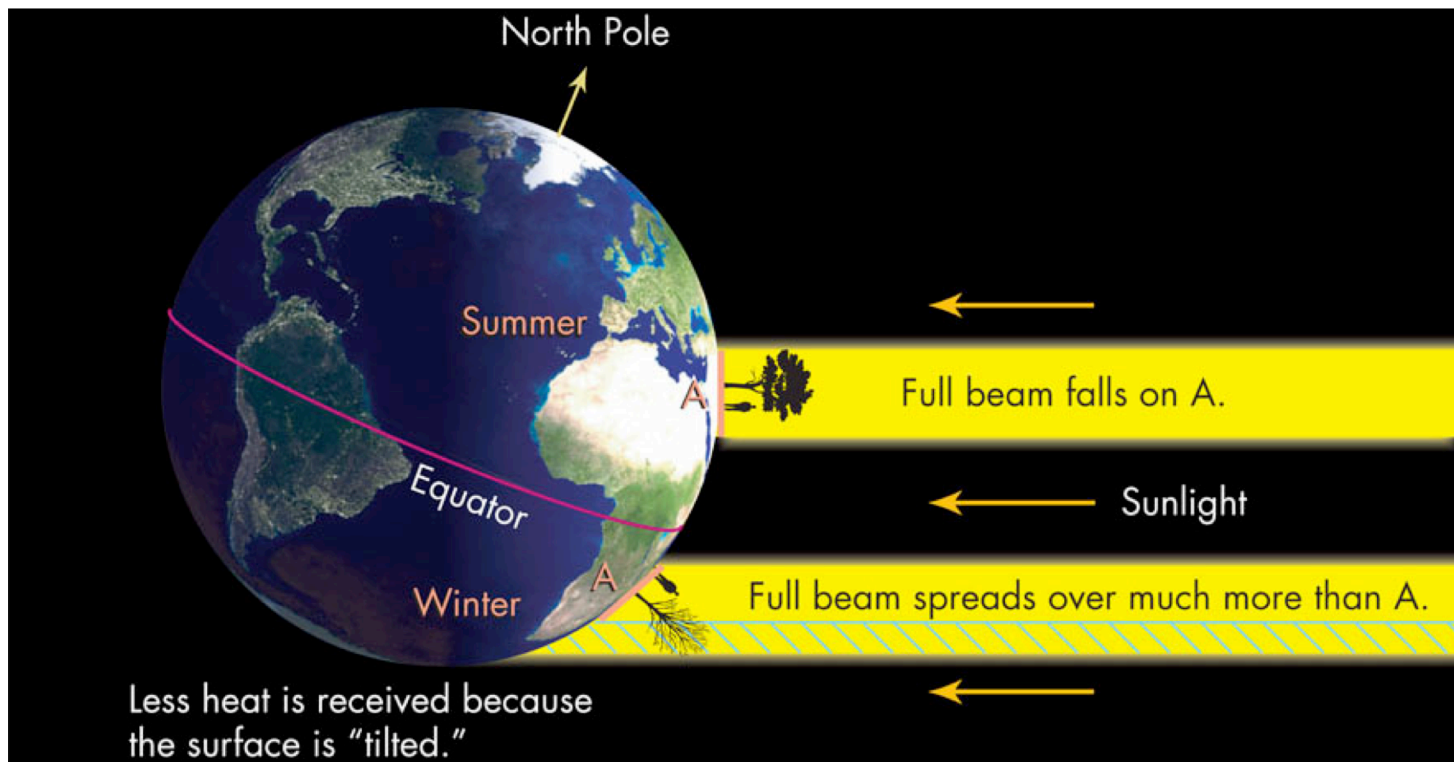


3- Seasons

B. The Earth orbits the sun (once per year) ...on a tilt!

Heating depends on Energy per unit Area!

Experience confirms! (Sun feels hotter at 1pm than 5pm.
Shoulders/head gets sunburned first.)



3- Seasons

B. The Earth orbits the sun (once per year) ...on a tilt!

Location of the sun at noon changes through the year

Photo taken every 10 days at noon. Records sun's highest point in sky through the year.

(Streaks are composite of photos taken every 2 minutes to show the sun ascending on 3 different days)

Which noontime location of the sun corresponds to:

Summer Solstice?

Winter Solstice?

Spring equinox?

Fall Equinox?



4- TIME

A+B. The earth orbits and spins....which defines time?

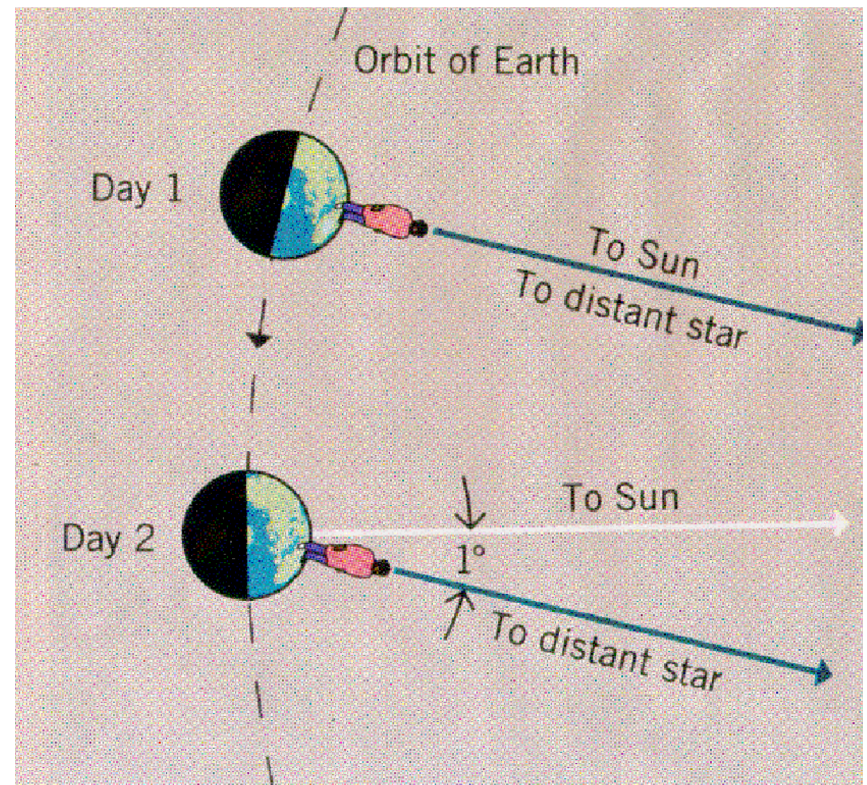
which motion defines **time**?

Solar time: relative to sun

Solar day = 1 revolution
relative to the sun

Sidereal time: relative to stars

Sidereal day = 1 revolution
relative to the stars



Two more ways we move through space...

3. The Sun orbits in the Milky Way

The sun (and nearby stars) orbit the center of the Milky Way once per 230,000,000 years.

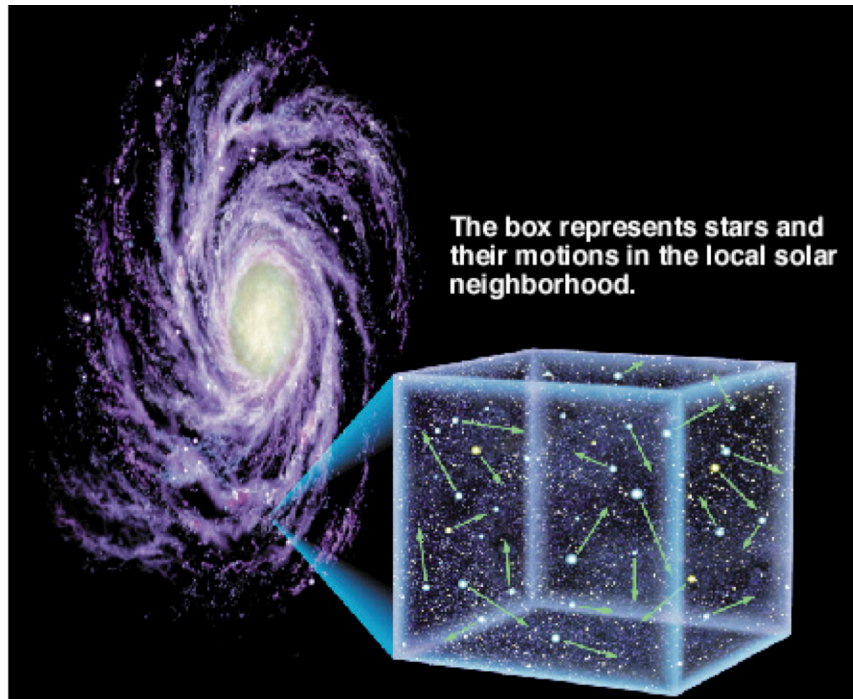
How do we know? (motion of other stars in the Milky Way wrt the Sun; careful study of stellar positions over time)

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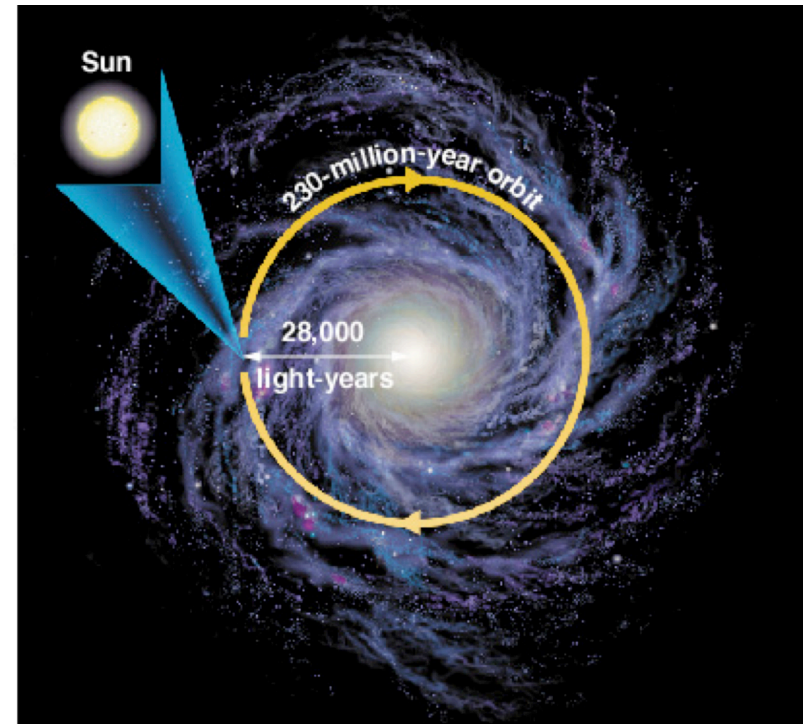
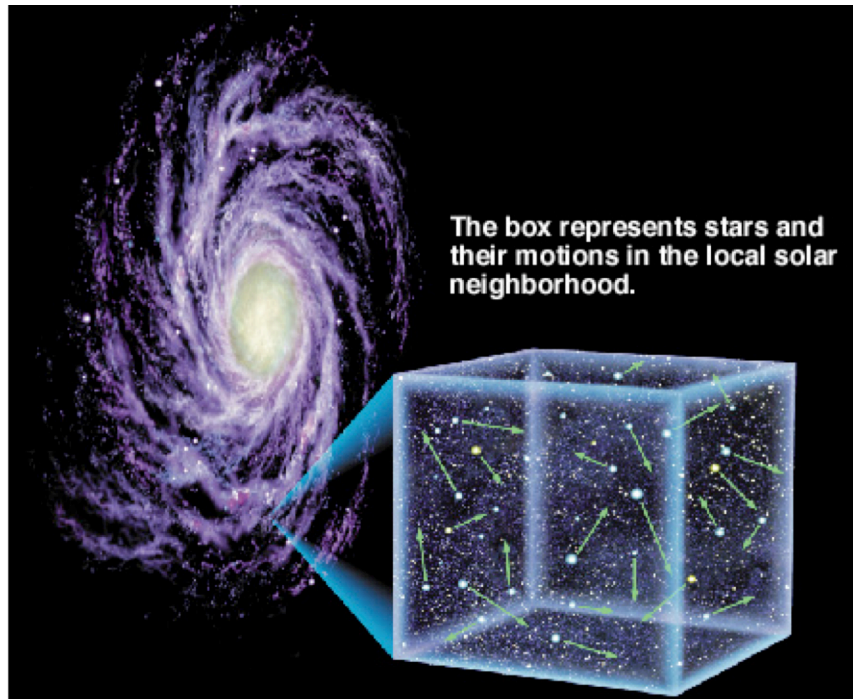


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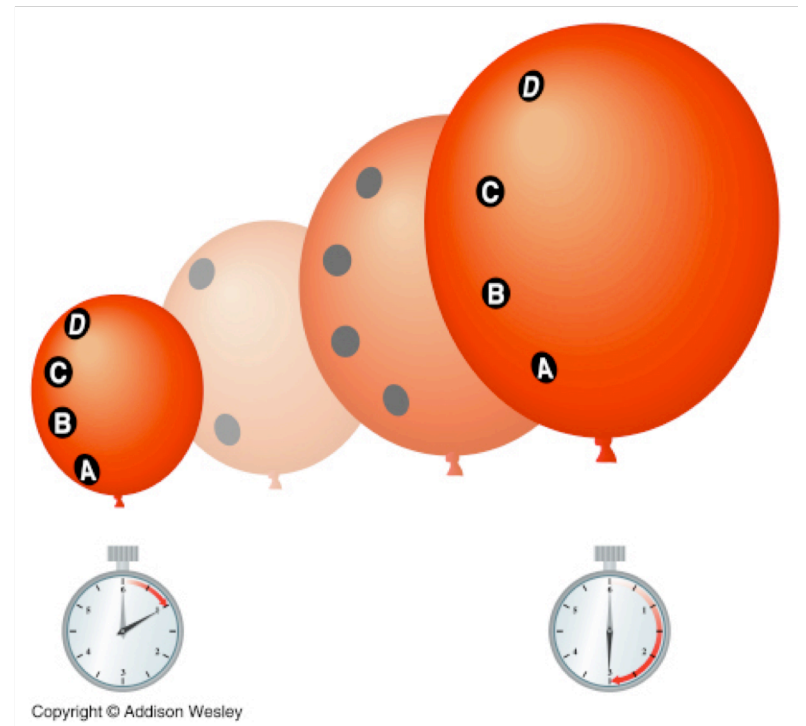
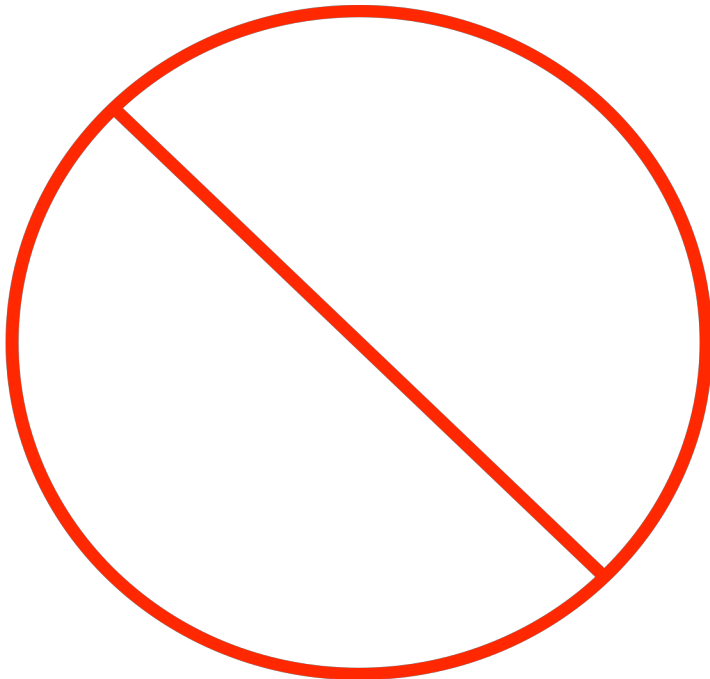
Two more ways we move through space...

4. The Milky Way moves relative to the rest of the universe

Space itself is expanding (the space between things is increasing!)

No center. No edge.

Think of the surface of a balloon...only in 3D



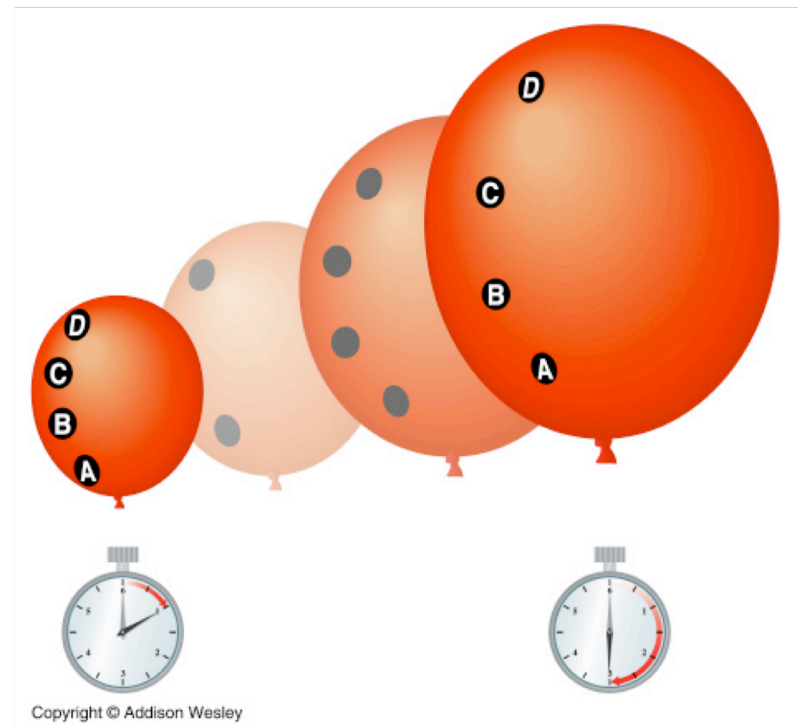
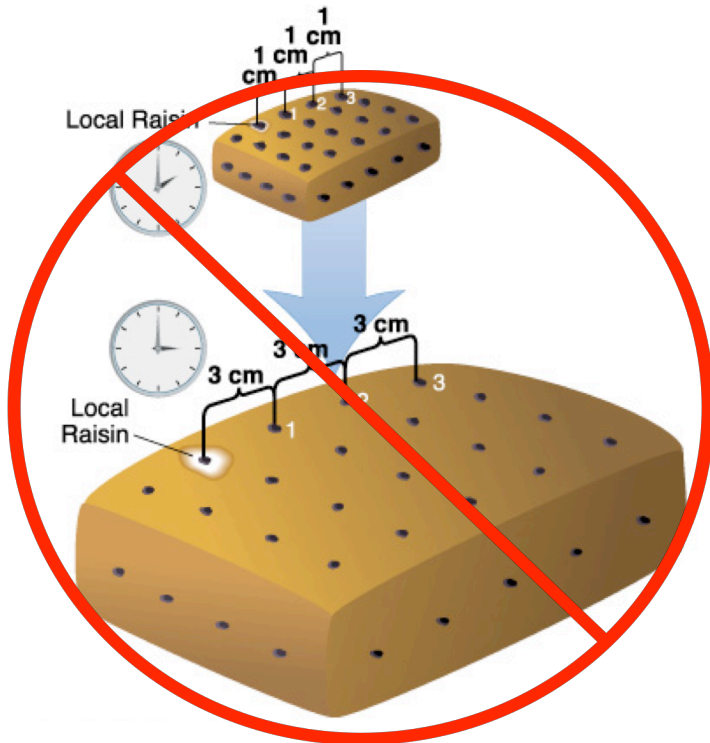
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Remember to ask: How do we know?

A. The Earth spins on its axis

... rather than the Sky spinning around the Earth?

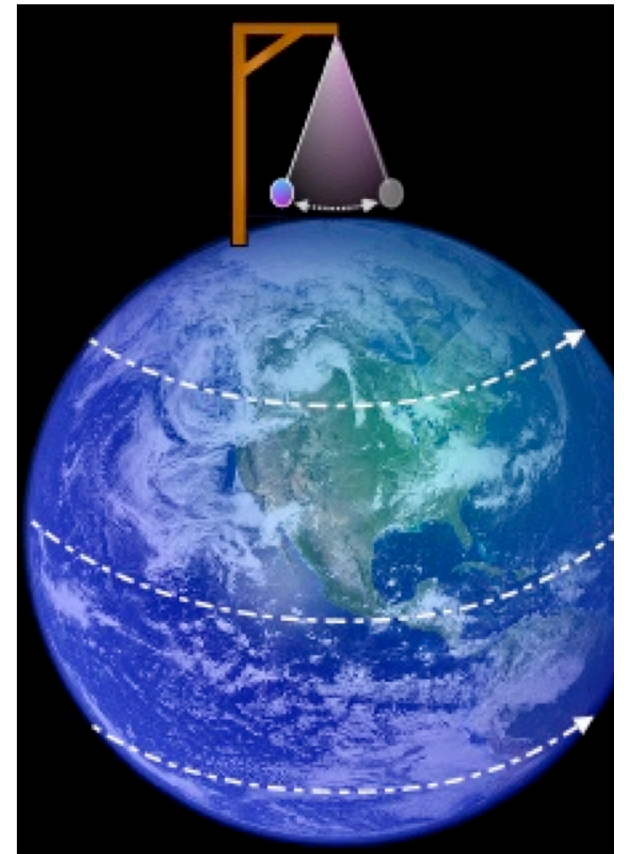
First real proof that Earth spins:

1851, Foucault's pendulum

Imagine a pendulum at the North Pole.

The only force on it is gravity,
so it swings 1 plane forever.

The fact that it appears to spin
means the Earth moves under it!



Remember to ask: How do we know?

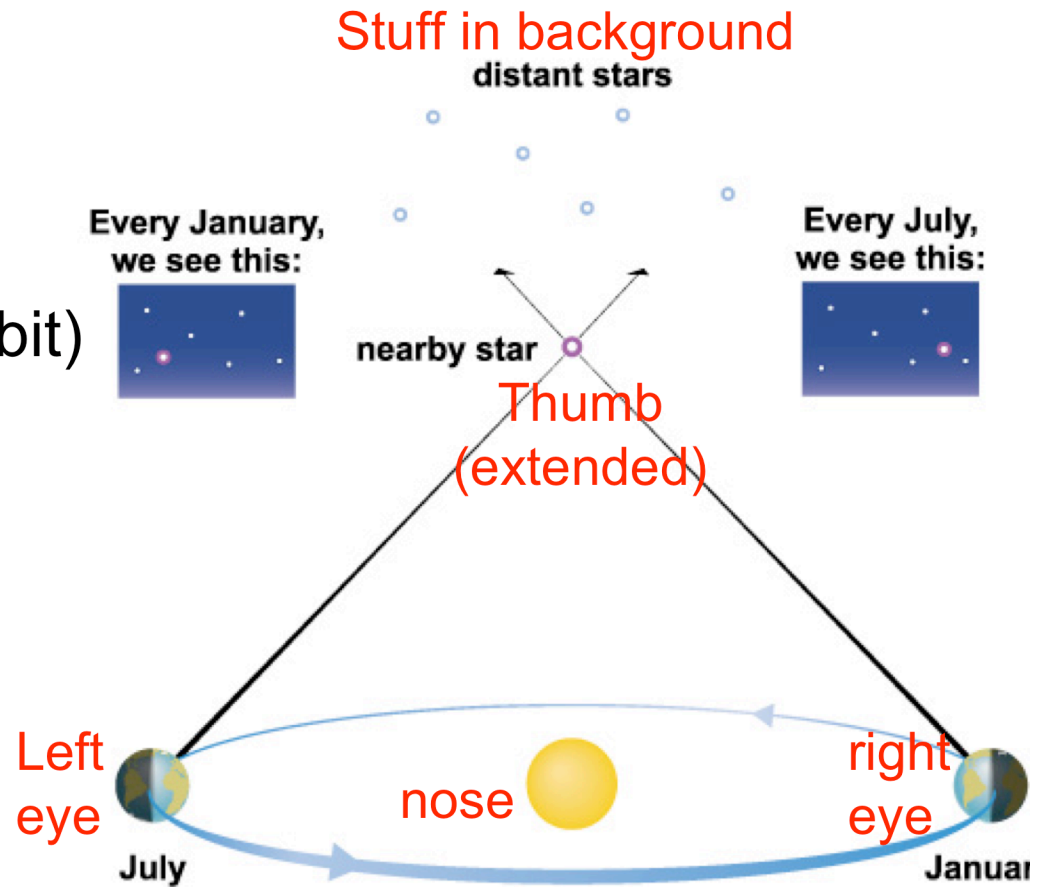
B. The Earth orbits the sun

... or does the Sun go around the Earth?

Stellar Parallax:

Earth (parallax+orbit) or
Sun (no parallax, only orbit)

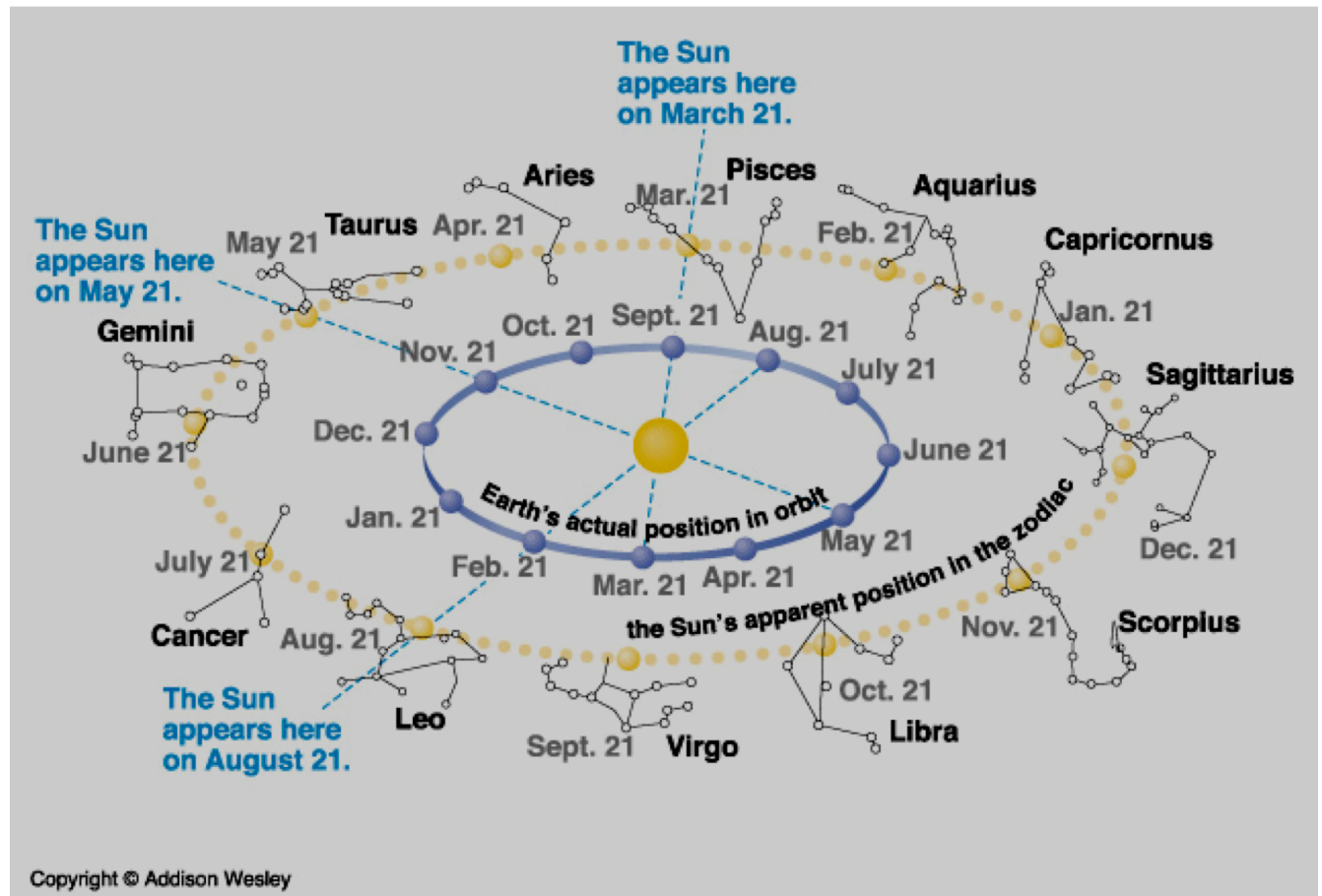
(demo: wink. background
still. thumb “moves.”)



iClicker Quiz #1 (09/30/09): Visibility of the Constellations at Different Times of the Year

From the image below, what constellation is overhead at midnight on the vernal equinox (March 21)?

- A- Virgo
- B- Pisces
- C- Sagittarius
- D- Gemini



Units 8-10: The Earth/Moon/Sun

Topics

1. Moon phases
2. Eclipses: shadows and visualizing the earth/moon/sun
3. Solar calendars vs Lunar calendars.
4. Distances and angles

* Visualize in 3D!

* Ask “How do we know?”



1- Moon phases

- What determines the appearance of the moon?
 - What is moonlight?
 - Why does the moon rise in the east, set in the west?
 - Why does the moon's appearance change?



1- Moon phases

- What determines the appearance of the moon?
 - What is moonlight? **Reflected sunlight!**
 - Why does the moon rise in the east, set in the west?
 - Why does the moon's appearance change?



1- Moon phases

- What determines the appearance of the moon?
 - What is moonlight? **Reflected sunlight!**
 - Why does the moon rise in the east, set in the west? **The earth spins!**
 - Why does the moon's appearance change?

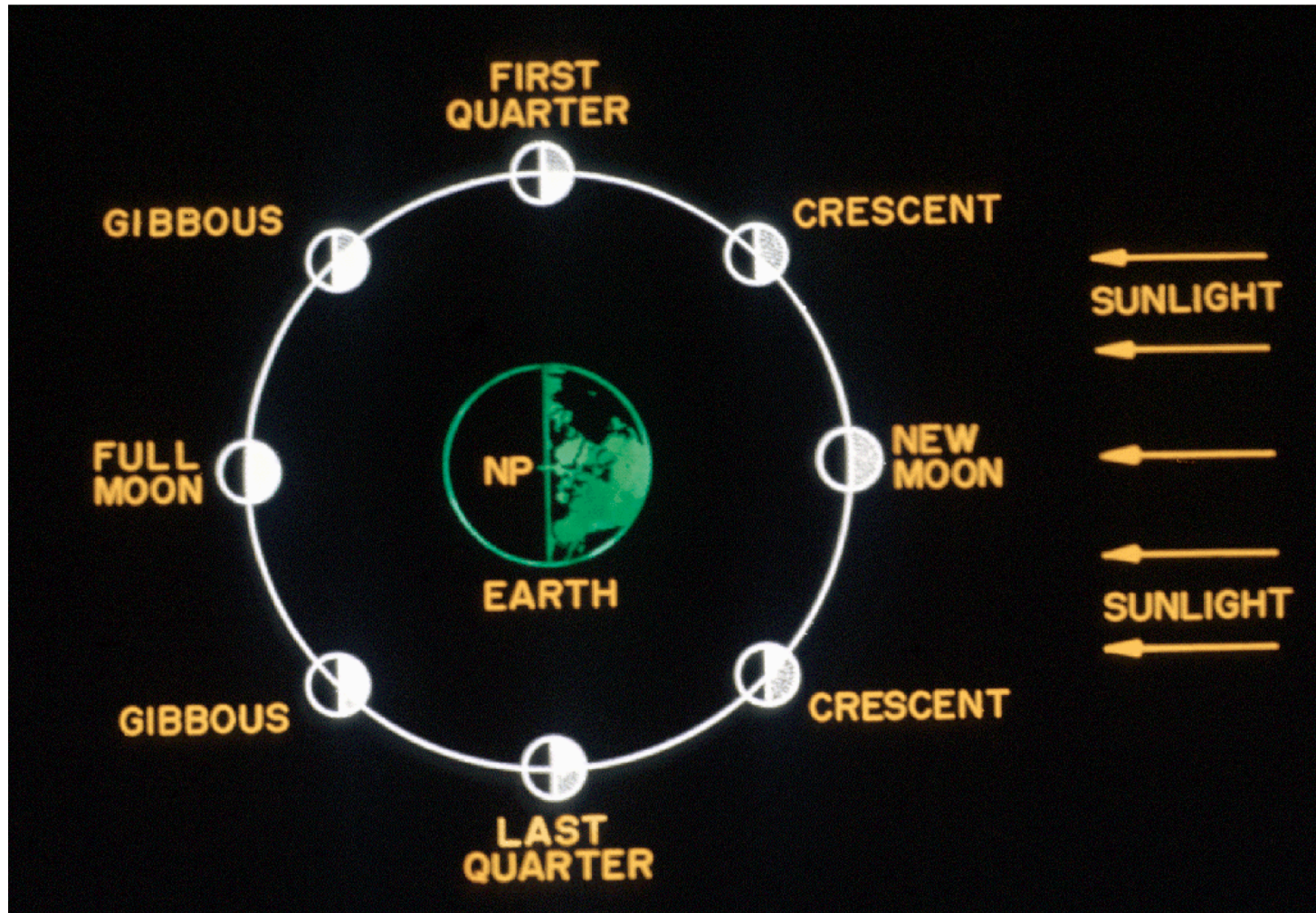


1- Moon phases

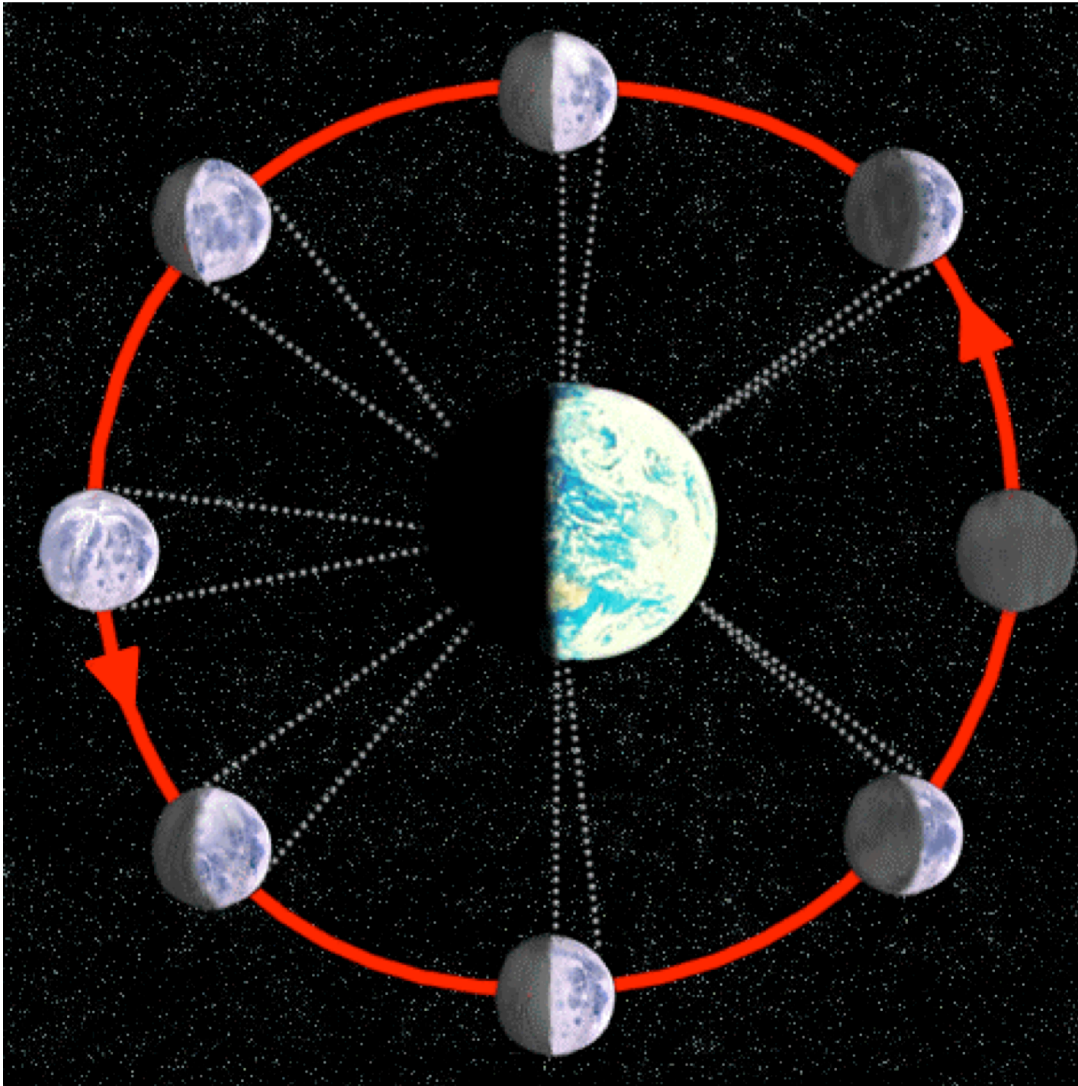
- What determines the appearance of the moon?
 - What is moonlight? **Reflected sunlight!**
 - Why does the moon rise in the east, set in the west? **The earth spins!**
 - Why does the moon's appearance change? **Because it ORBITS the EARTH!**



1- Moon phases



1- Moon phases



phases:

new

waxing crescent

first quarter

waxing gibbous

full

waning gibbous

third quarter

waning crescent

new



1- Moon phases

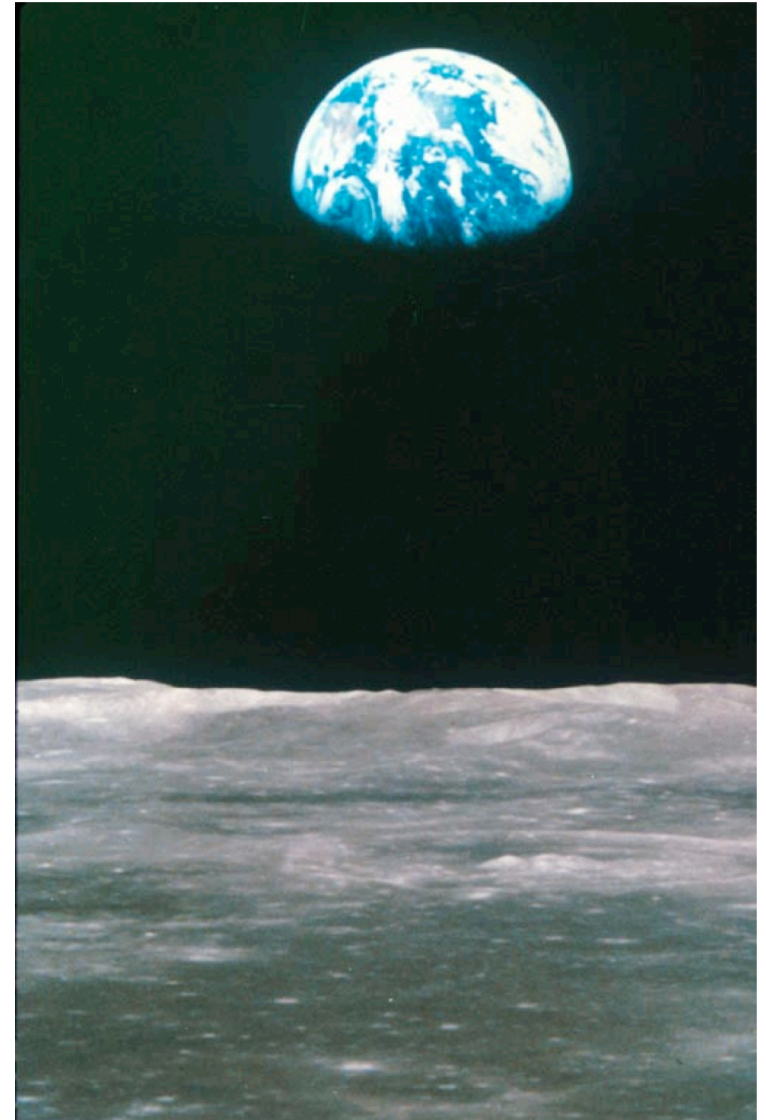
When does a FULL MOON rise?

When does a NEW MOON rise?

Does an astronomer on the moon see the Earth “rise” or “set”?

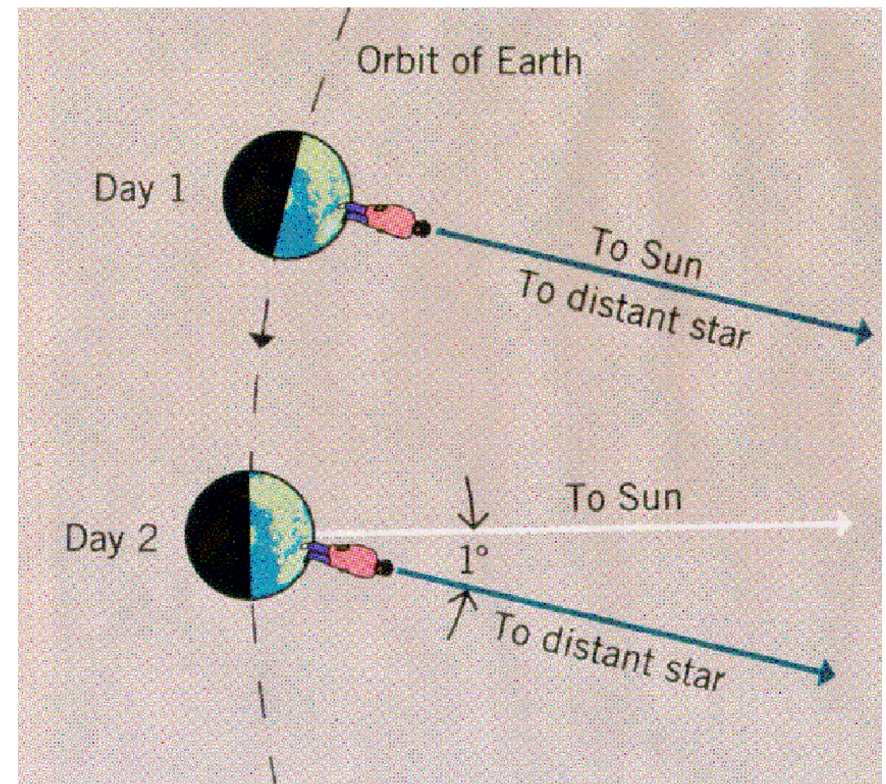
Does he/she see phases of the Earth?

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Background for iClicker Quizzes: Siderial vs Solar Time

1. The earth orbits around the Sun and spins on its own axis in the **same** sense (i.e. both clockwise or both anticlockwise)
2. A **siderial** day is defined as the time it takes the Earth to make a complete spin on its axis **relative to distant stars**
3. A **solar** day is defined as the time it takes the Earth to do a complete spin on its axis **relative to the Sun**
4. The length of a siderial day is about **4 minutes shorter** than the length of a solar day



iClicker Quiz #2 (10/02/09): Siderial vs Solar Time

If the earth's orbit around the Sun and the earth's spin on its own axis were in **opposite** senses (i.e. one clockwise and one anticlockwise), which of the following would be true:

- A.** A siderial and solar day would be of the same length
- B.** A siderial day would be 4 minutes longer than a solar day
- C.** A siderial day would be 8 minutes longer than a solar day
- D.** A solar day would be 4 minutes longer than a siderial day
- E.** A solar day would be 8 minutes longer than a siderial day

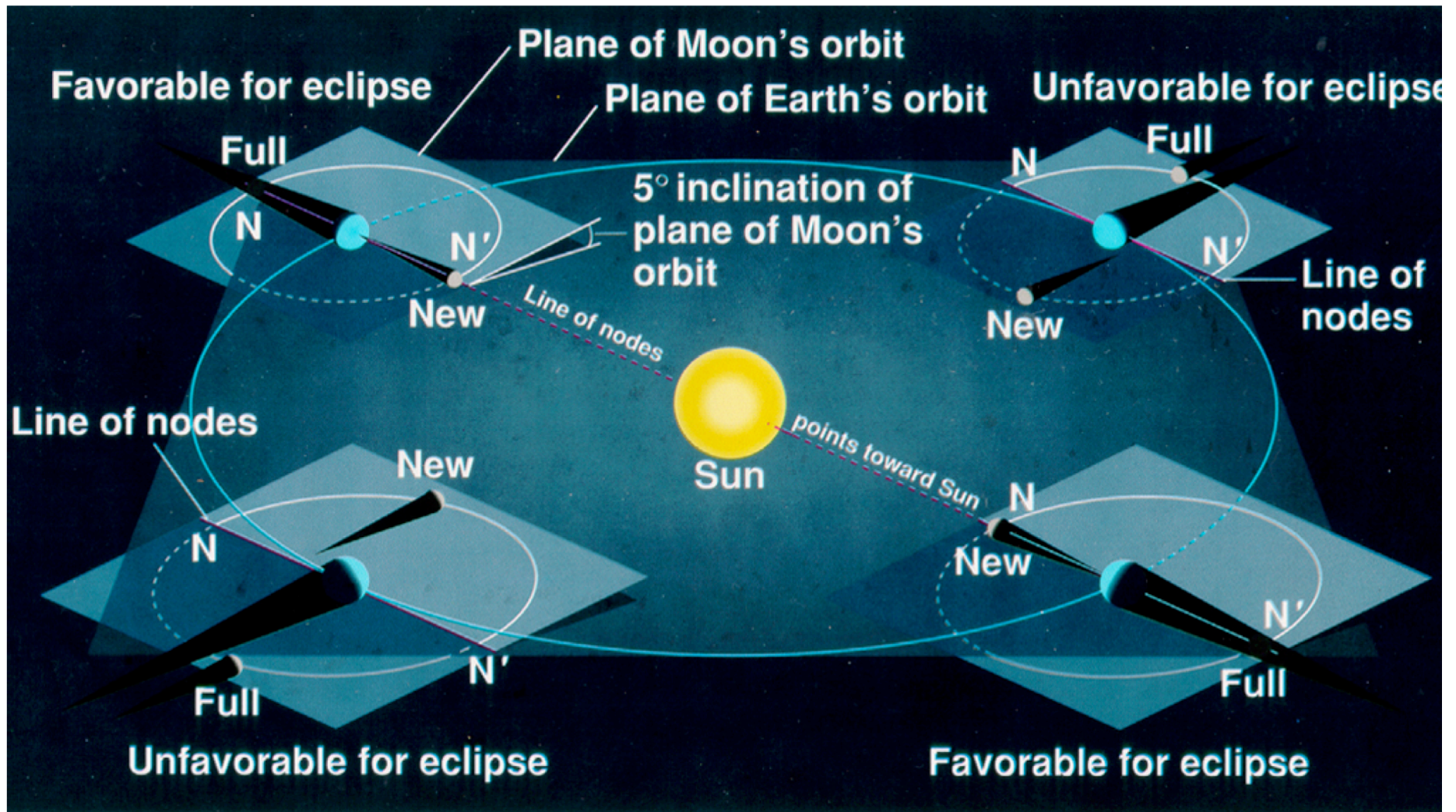
iClicker Quiz #3 (10/02/09): Siderial vs Solar Time

If the earth's spin rate about its own axis were to slow down to **half** its present rate (while spinning in the same sense as its orbit around the Sun), so that the length of the day became 48 hours, which of the following would be true:

- A. A siderial and solar day would be of the same length
- B. A siderial day would be 4 minutes longer than a solar day
- C. A siderial day would be 8 minutes longer than a solar day
- D. A solar day would be 4 minutes longer than a siderial day
- E. A solar day would be 8 minutes longer than a siderial day

2- Eclipses

- Lunar eclipse = Earth blocks sunlight from hitting the Moon
- Solar eclipse = Moon blocks sunlight from hitting the Earth



2- Eclipses – Lunar

Partial vs Full shadows ... the sun is not a dot!

- Full = Umbra
- Partial = Penumbra



2- Eclipses – Lunar

Total Lunar Eclipse, Jan 9/10, 2001



Animations (week 2)

Coordinate Systems Comparison

Celestial and Horizon Systems Comparison

Seasons Simulator (NAAP)

Sun's Rays Simulator

Union Seasons Demonstrator

Sun's Position on Horizon

Daylight Hours Explorer

Big Dipper 3D

Synodic Lag

Lunar Phases Simulator (NAAP)

Lunar Phase Vocabulary

Three Views Simulator

Moon Inclination

Tidal Bulge Simulation