

AY 2

- <https://astro2.sites.ucsc.edu>

ANNOUNCEMENTS

- Quiz 1: October 10 in class

Tutors

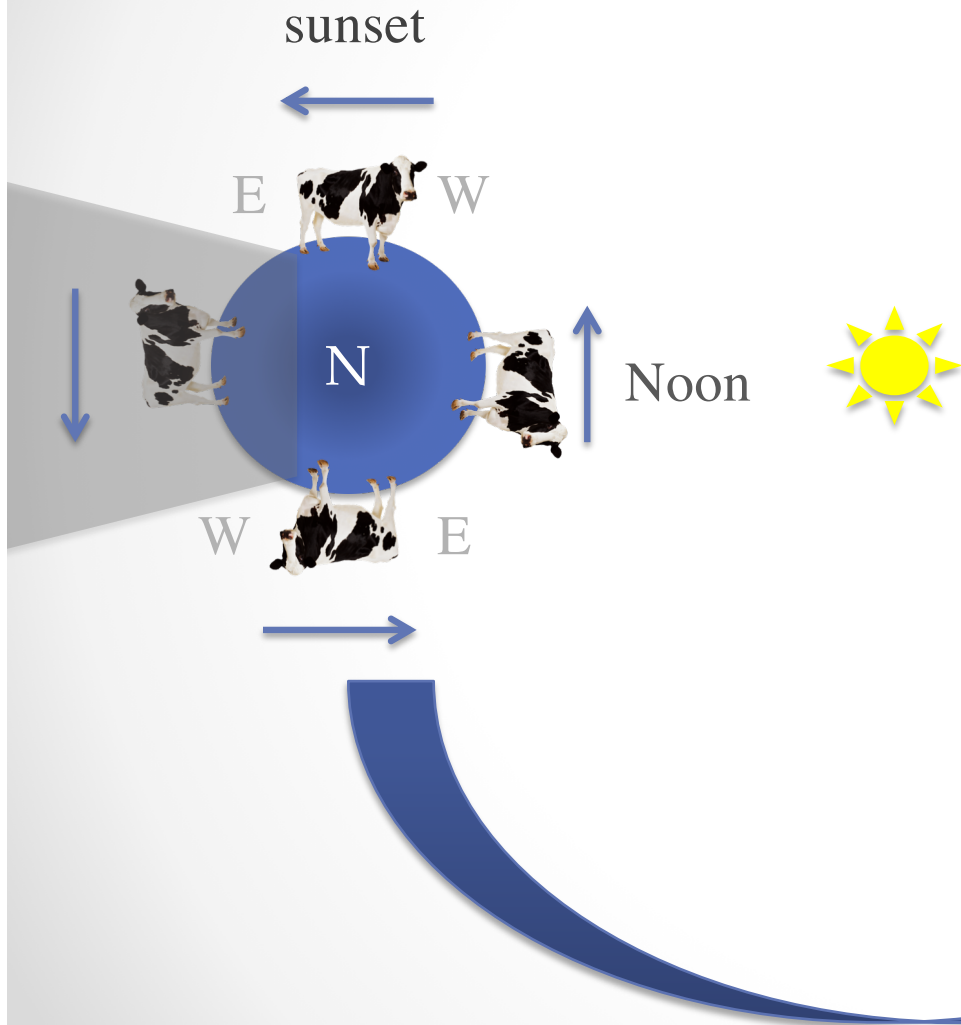
- [Learning Support Services](#) signup begins at noon October 4
- Sophie Shaw will be the Small Group Instructor (sokshaw@ucsc.edu)

Motions of the Earth



- Stuff everyone should know

Earth Motions

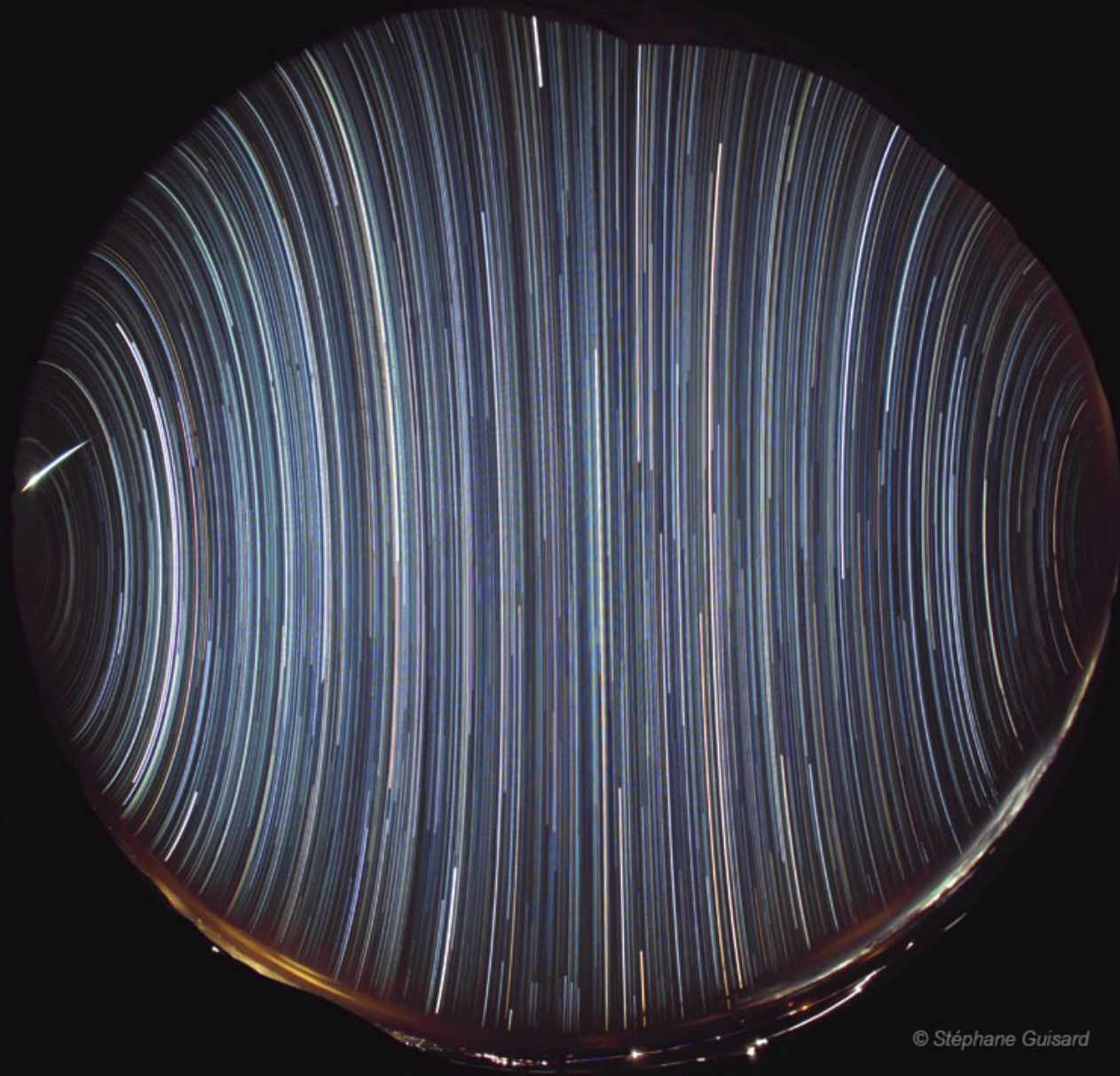


- Why is there day and night?
OR
- Why do the Sun and stars appear to move through the sky?

• Because the Earth rotates around its N-S axis once every 24 hrs •



Star trails that include the north celestial pole



© Stéphane Guisard

• Star trails at the equator •



- How fast is a gaucho napping at the equator moving due to the Earth's rotation (english units)?

Speed = Distance/time (units like miles/hr)

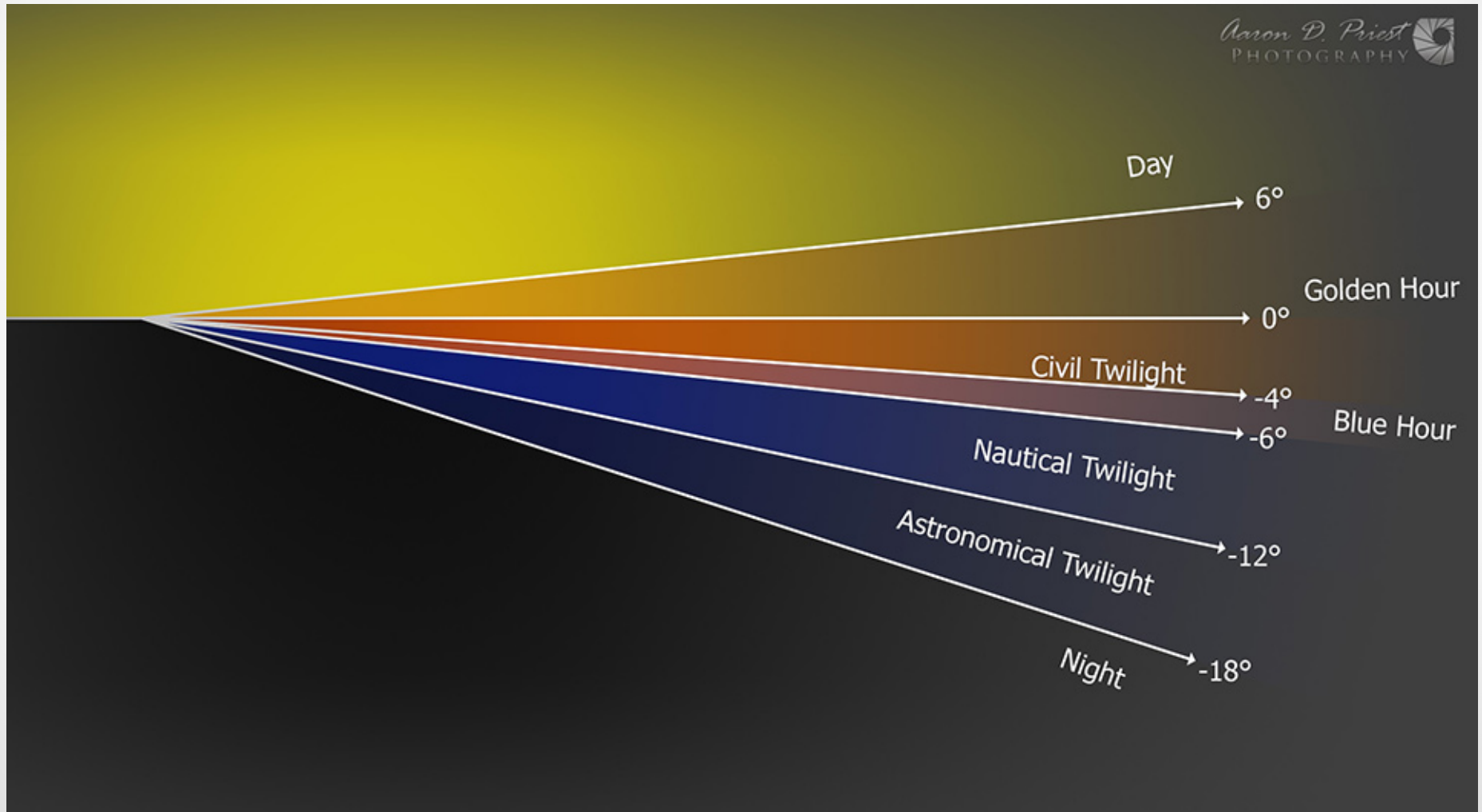
Distance = $2 \times 3.14 \times 3820 = 24,000$ miles

$S = 24000 \text{ miles} / 24 \text{ hours}$

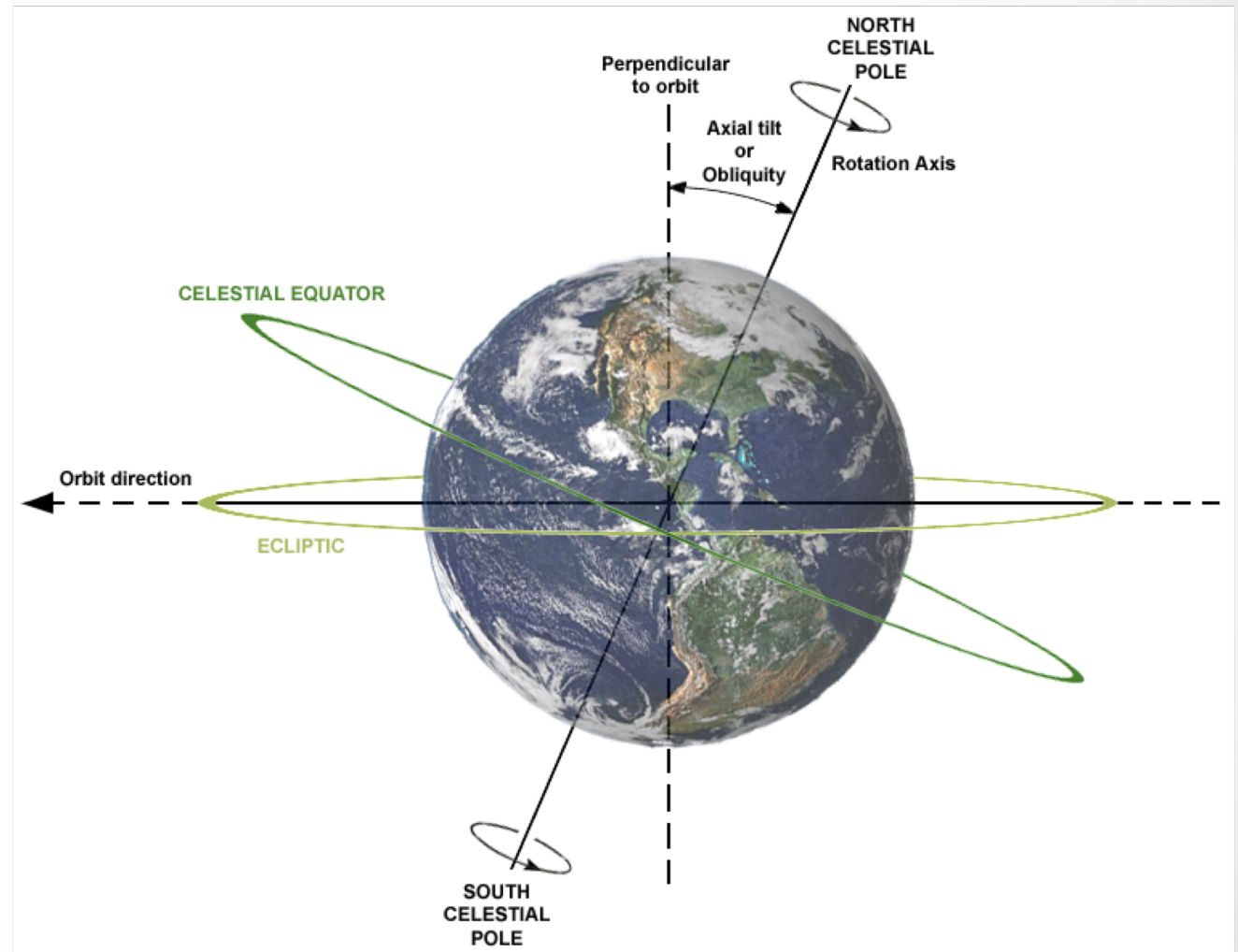
$S = 1000 \text{ miles/hour}$

Twilight

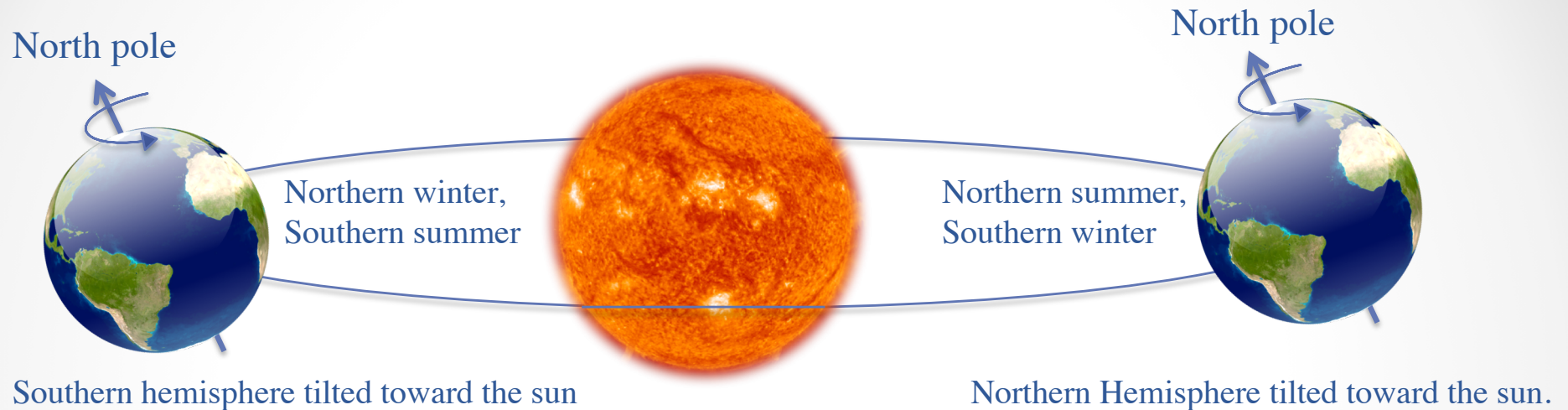
Aaron D. Priest
PHOTOGRAPHY 



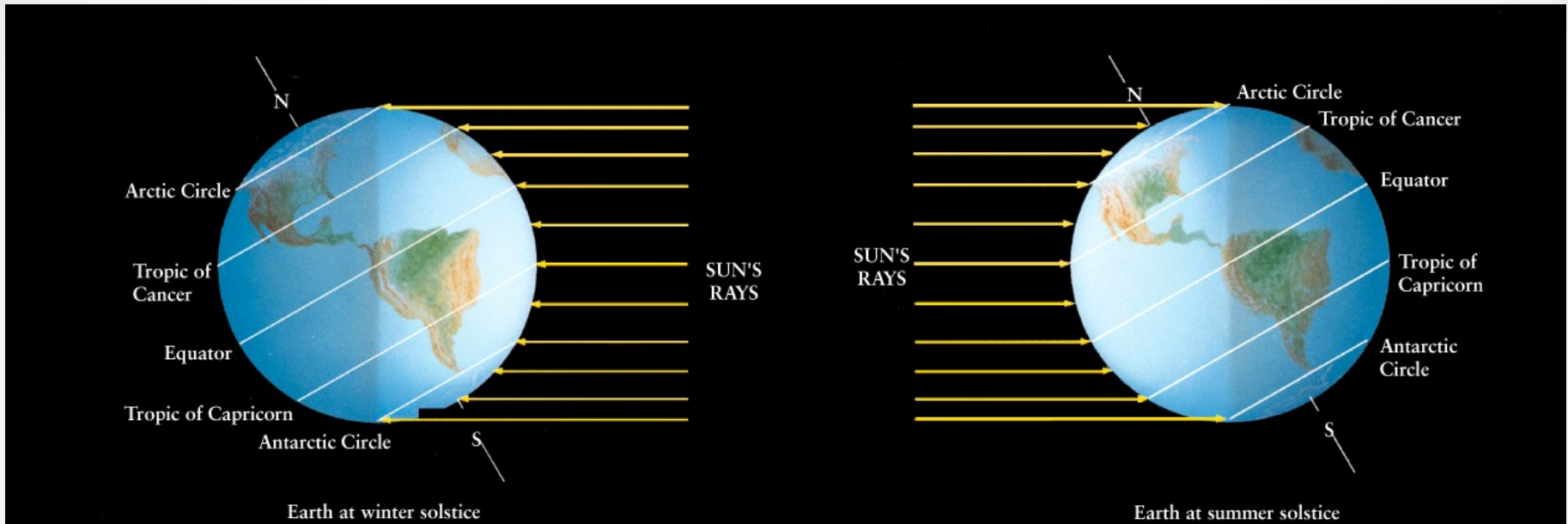
Seasons: Getting Oriented



The Reason for Seasons



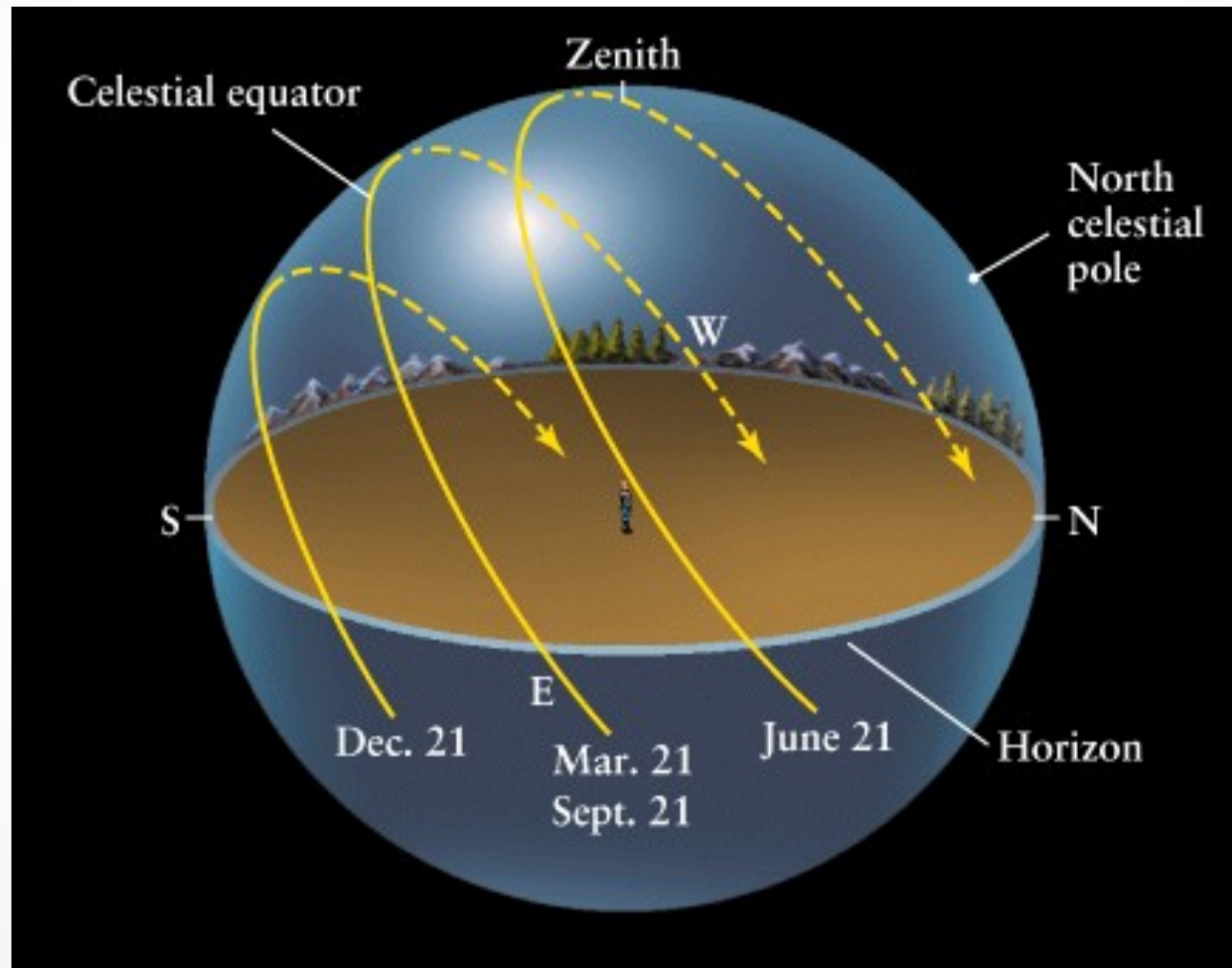
- The Earth is in a slightly elliptical orbit around the Sun - we are ***furthest*** from the Sun during the Northern Hemisphere summer.
- It is the ***tilt*** of the Earth's axis with respect to orbit plane that is the cause of the seasons.



Dec 21 Southern hemisphere summer, Sun is directly above the Tropic of Capricorn

June 21 Northern hemisphere summer, Sun is directly above the Tropic of Cancer

Sun's Path Through the Year



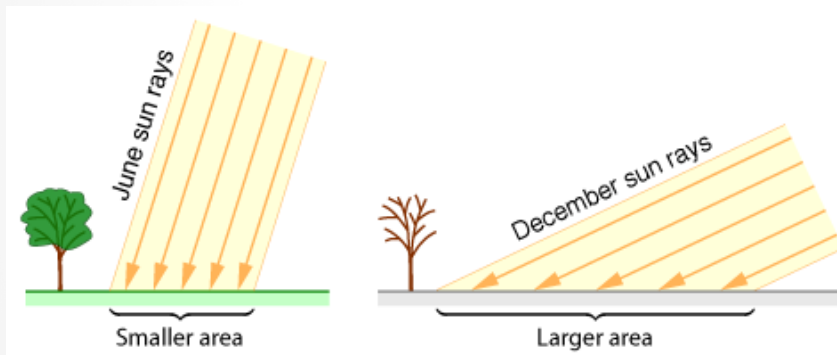
Reason for Seasons cont.

The tilt has two main effects.

- 1) The path the Sun takes through the sky changes during the year (look to the South to see the Sun in the winter, over head in the summer). Fewer daylight hours in the Winter.
- 2) The intensity of sunlight decreases in the winter (the Sun is at a larger angle from the zenith).

Therefore: it is cold in the winter.





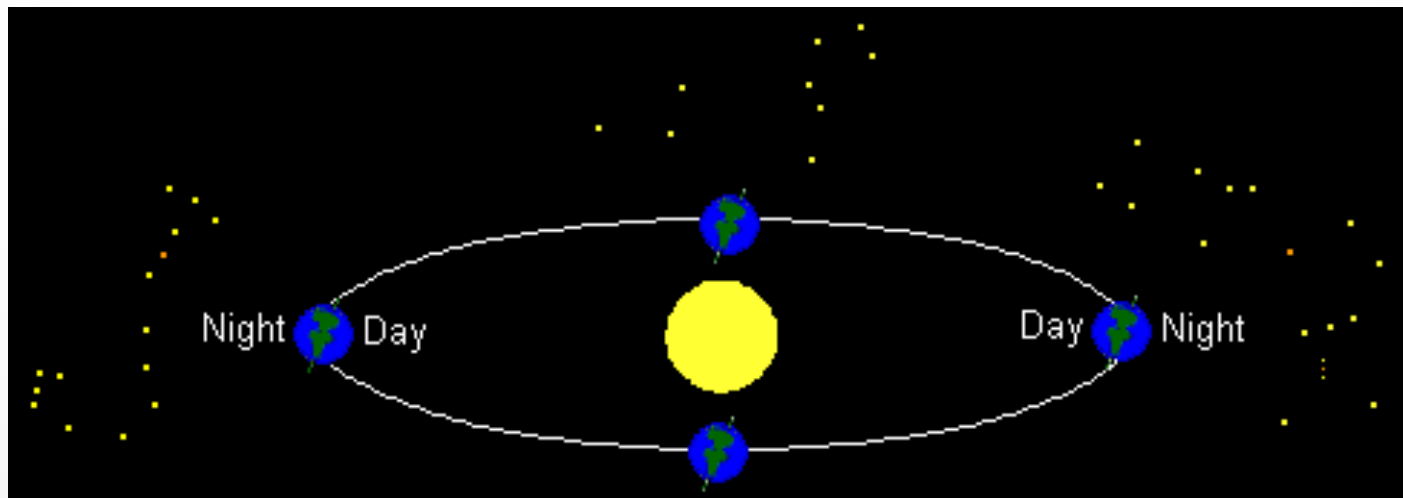
- The solar energy per unit area decreases as the Sun moves lower in the sky. This is the reason it is cooler in the winter and in the morning

iclicker quiz

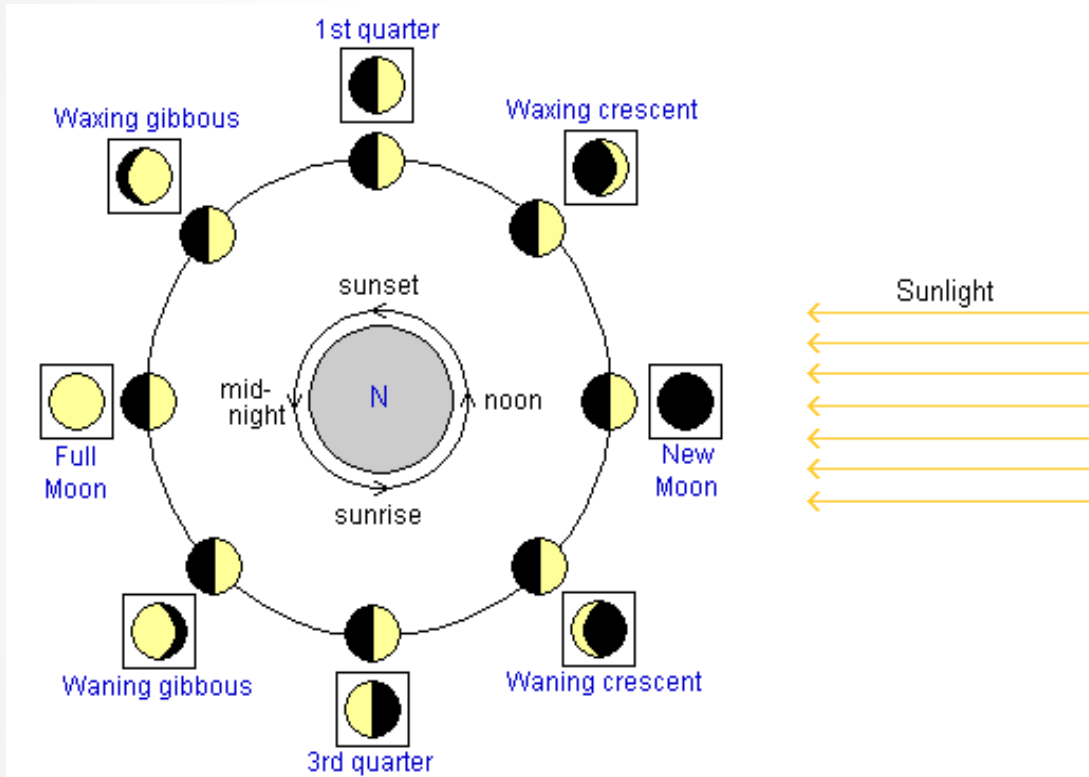
- The spin axis of Venus is aligned with the orbital axis. For Venus which of the following is true?
 - A. The length of a day is the same as the length of a year on Venus
 - B. "Star trails" on Venus would make straight lines in the sky
 - C. There would be no day and night on Venus
 - D. There would be no changing seasons (that is change in the number of daylight hours or change in the average temperature) over the Venus year

The Night Sky at Different Seasons

We see different stars at different times of the year. The stars are always there, but can only be seen against the dark night sky.



Moon phases



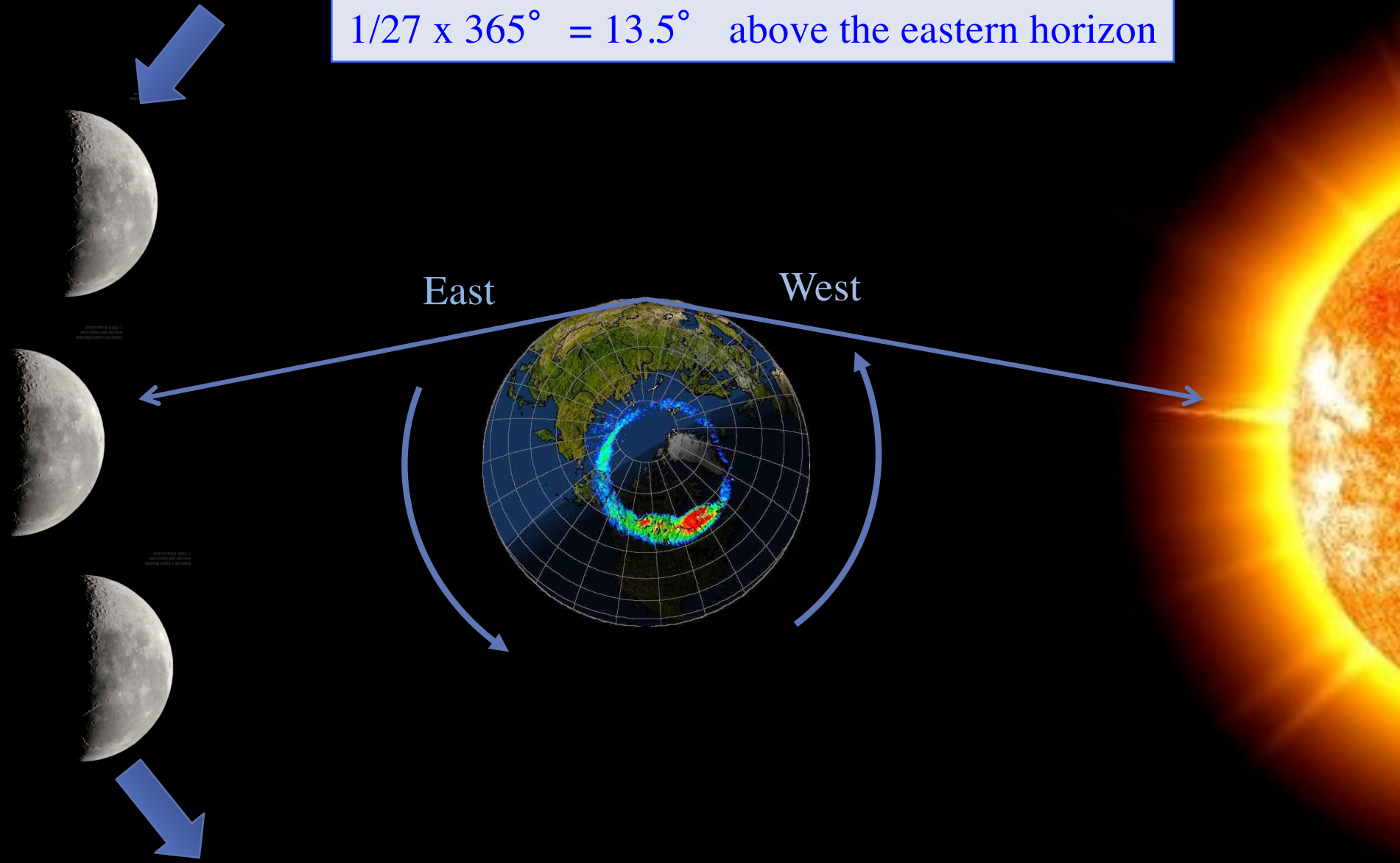
The moon phases are due to the relative positions of the Sun and moon. One half of the moon is always illuminated, it is only a question of what fraction of the illuminated face we can see from the Earth.

iClicker quiz

Q. What time does the full moon rise?

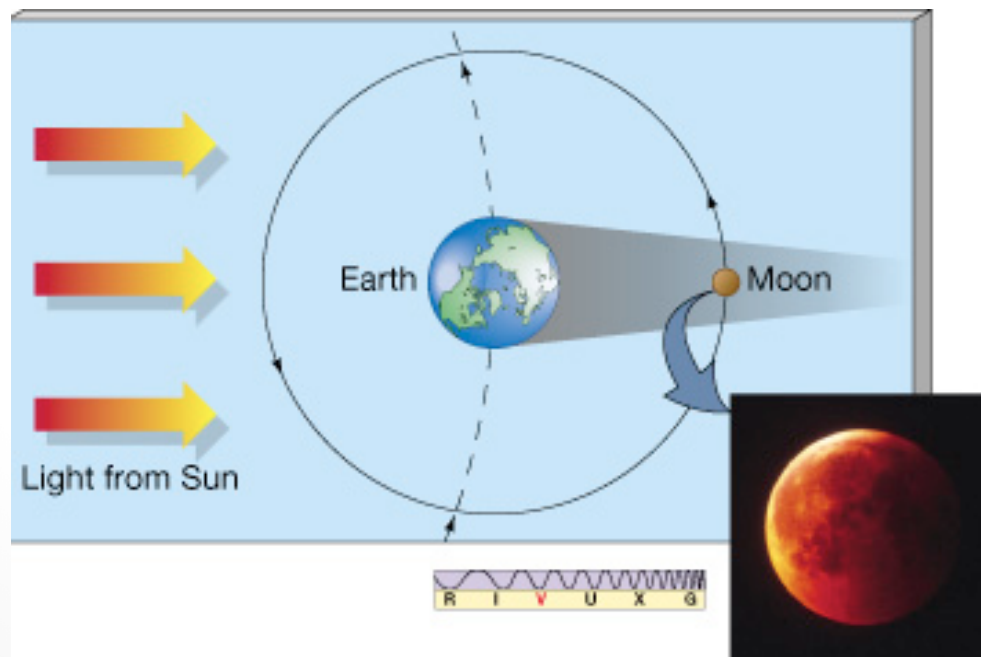
- a) At midnight
- b) At sunrise
- c) At sunset
- d) Any old time, this is a trick question.

Night before full moon, at sunset the moon is $1/27 \times 365^\circ = 13.5^\circ$ above the eastern horizon

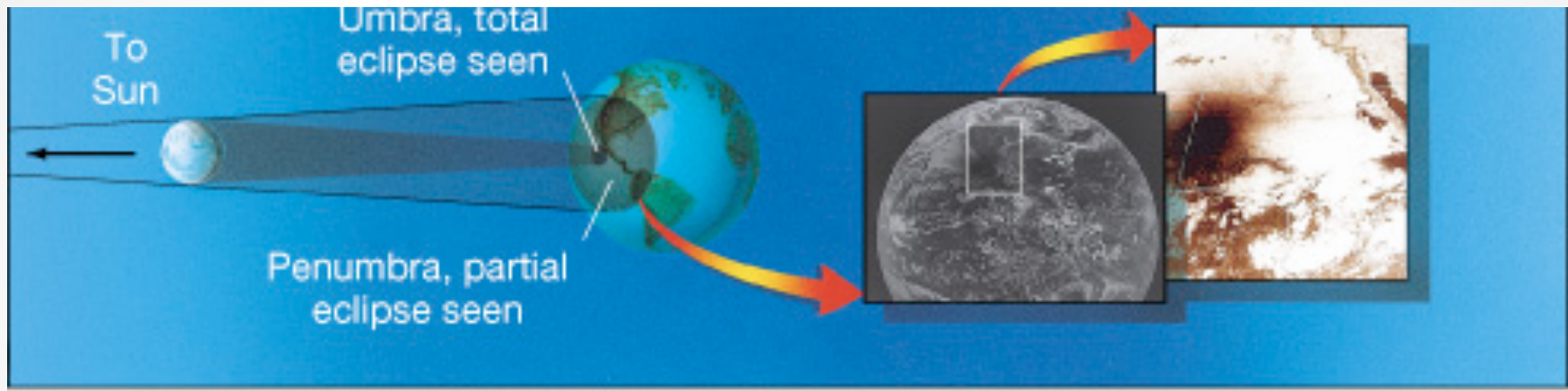


Lunar Eclipse

For a full moon, the Sun, Earth and Moon are all aligned. The Moon can fall into the shadow of the Earth. This is called a lunar eclipse.



Solar Eclipse



A similar thing can happen during the new moon. The Moon can cast a shadow on the Earth when it passes in front of the Sun.

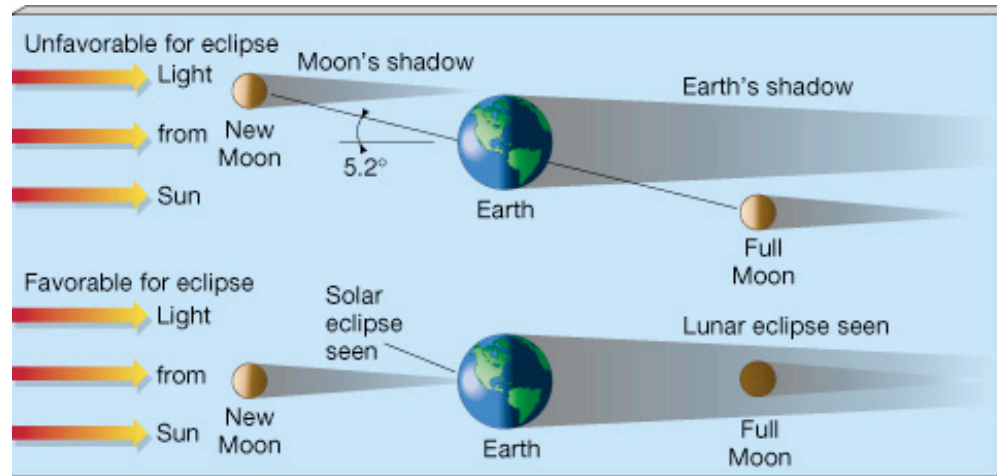




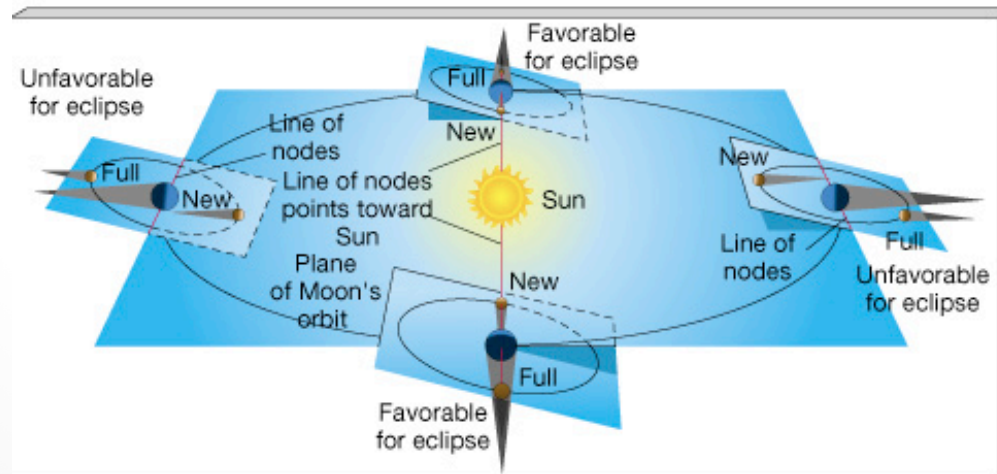




Why don't we have an eclipse every month?



(a)



(b)



21st Century Total Solar Eclipses

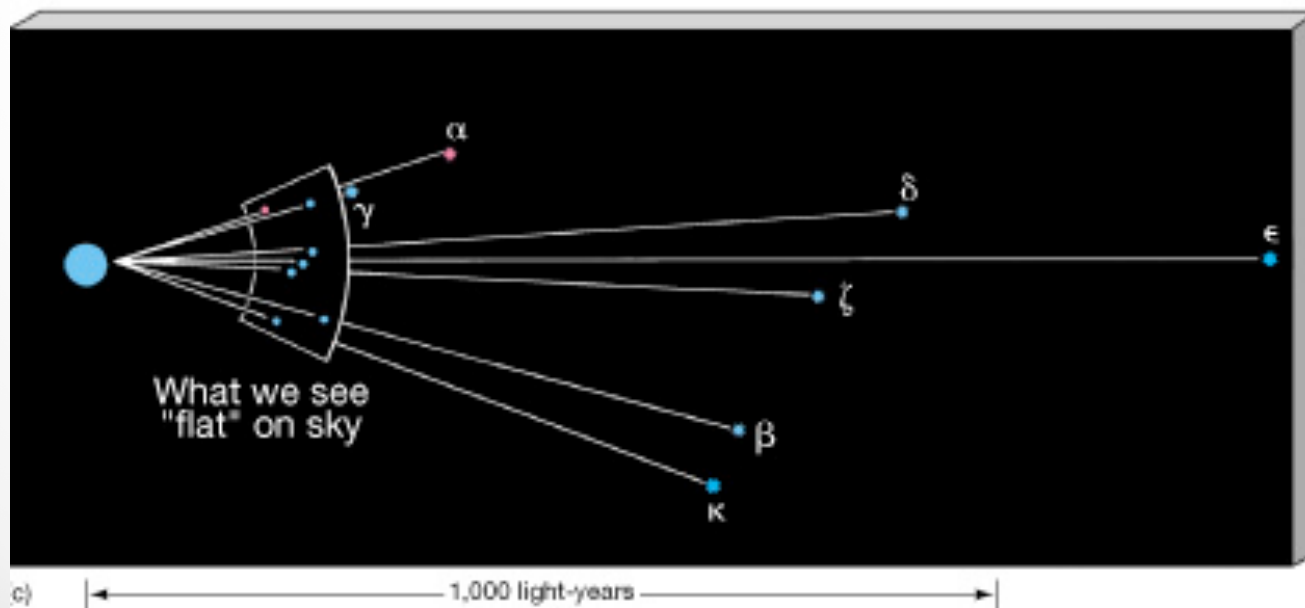
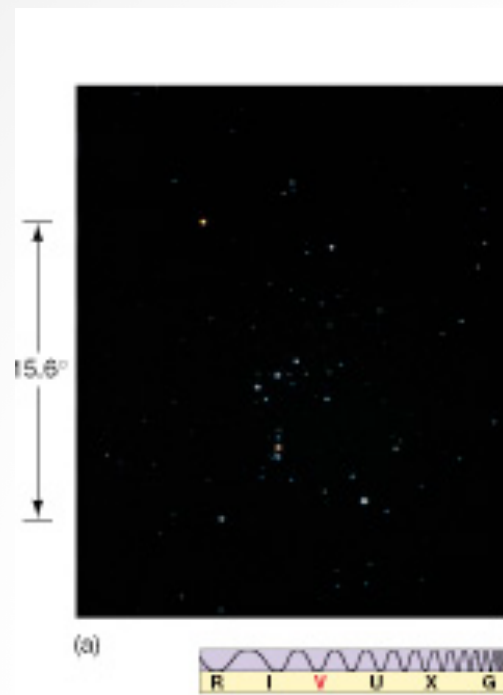
Total solar eclipses over
North America in the
21st century



Sky at night: constellations



- Stars are essentially fixed in the sky
- *Apparent* groupings of bright stars were connected by various cultures and given names
- Astrology has zero basis in science

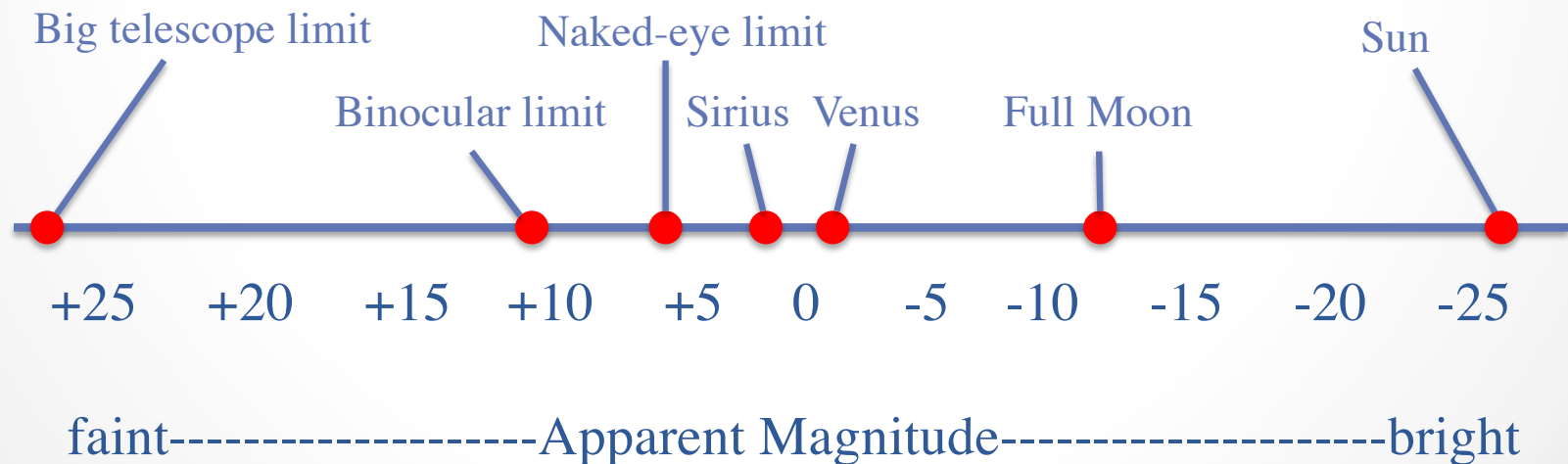


What about Star Names?

- The brightest stars have lots of names, none official. There are some widely-used catalogues.
- A convention often used in astronomy is to use the Greek alphabet to identify the brightest stars in the constellations.
 - Sirius = α Canis Majoris is the brightest star in the constellation Canis Major.
 - β Canis Majoris is the second brightest etc.

Stellar Brightness

- Will use brightness to be *apparent* brightness.
- This is not an INTRINSIC property of a star, but rather a combination of its Luminosity, distance and amount of dust along the line of sight.



Naked-Eye Observations

- There are about 6000 stars you can see with your unaided eye at a dark site
- Limited by:
 - size of the human eye: 5 – 7 mm pupil
 - the eye's "integration time" of ~0.1seconds
 - resolution of ~ 1 arcmin



Planets in the sky



Mars retrograde motion

- Planet means “wanderer” and it was realized long ago that some “stars” moved against the fixed stars
- They are seen along the ecliptic. Mercury, Venus, Mars, Jupiter and Saturn are all naked-eye objects

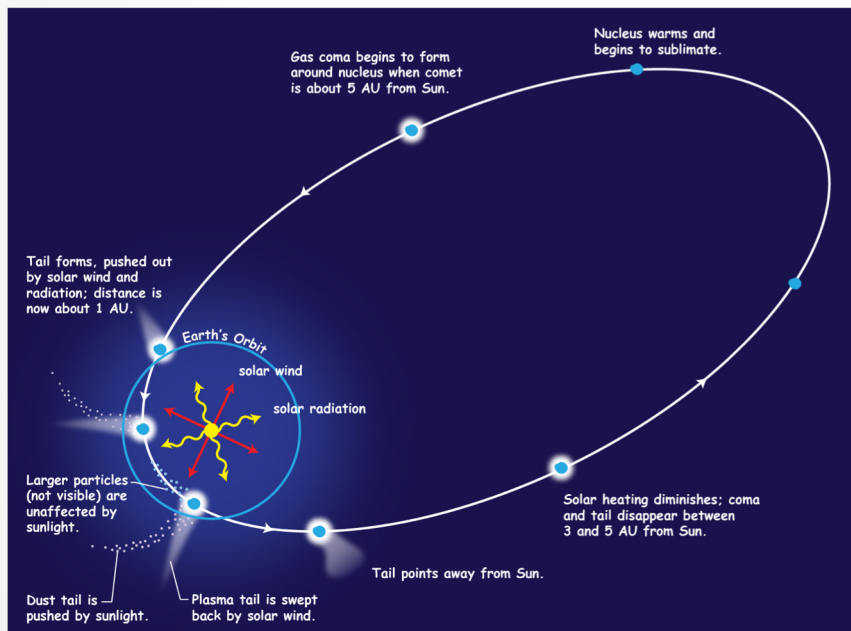
Other stuff in the sky



Perseid shower

- The Solar System is full of rocks and dust/ice balls
 - Comets
 - Asteroids
 - Meteoroid
 - Dust
- When small bits intersect with the Earth, (“crossing orbits”) they burn up as “shooting stars”
- Larger objects can survive and hit the ground (meteorite)

Comets



- In the outer solar systems are small icy bodies that sometimes have their orbits perturbed by one of the giant planets
- If their orbits take them close to the Sun, the solar wind and radiation pressure boils off material and results in a coma and tail
- Typical nucleus is 10km in diameter, tails can be 10^6 km in length

Comets II

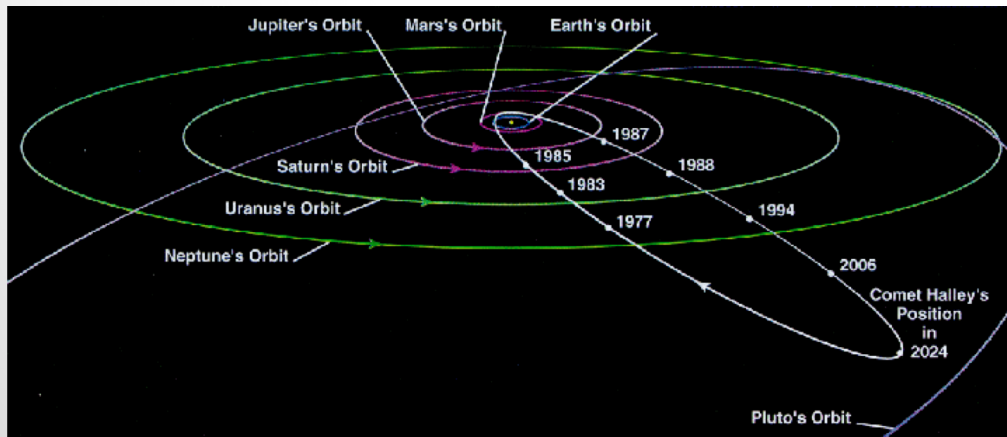


- Most comets are not bright enough to be seen with the unaided eye
- Some are spectacular and large
- About 1/3 of the comets discovered to date are periodic with periods < 200 years

Comets III



- Halley's comet with a 75-year orbit was first recorded in 240 BC
- Halley in 1701 identified a bright comet and put together the long history
- Provided a test of Newton's theory of gravity
- Some orbits it comes closer to Earth



Meteors



- The larger debris left behind a comet passage through the inner Solar System causes meteor showers at predictable times
- Showers are named after constellations, but each has a particular comet passage that is responsible for the shower

Major Meteor Showers in 2017

| Shower | Radiant and direction | Morning of maximum | Best hourly rate | Parent |
|-------------------------|-----------------------|--------------------|------------------|----------------------|
| Quadrantid | Draco (NE) | Jan. 3 | 60-100 | 2003 EH ₁ |
| Lyrid | Lyra (E) | April 22 | 10-20 | Thatcher (1861 I) |
| Eta Aquariid* | Aquarius (E) | May 6 | 20-60 | 1P/Halley |
| Delta Aquariid | Aquarius (S) | July 30 | 20 | 96P/Machholz |
| Perseid* | Perseus (NE) | Aug. 12 | 90 | 109P/Swift-Tuttle |
| Orionid | Orion (SE) | Oct. 21 | 10-20 | 1P/Halley |
| Southern Taurid* | Taurus (S) | Nov. 5 | 10-20 | 2P/Encke |
| Leonid | Leo (E) | Nov. 17 | 10-20 | 55P/Tempel-Tuttle |
| Geminid | Gemini (S) | Dec. 14 | 100-120 | 3200 Phaethon |

Meteor Storms



- Every now and then the Earth's orbit goes right through the densest part of a debris tail
- Great Leonid Meteor Storm of 1833 had an estimated 200,000 meteors per hour (50 is more typical)

Meteorites: meteor that reaches the ground



- Approximately 5 tons of material lands on Earth each day. Mostly in dust-sized material.
- Chances of your house being hit by meteorite in your lifetime:
1 in 4 trillion

Chelyabinsk superbolide

- 20-meter diameter thing entered atmosphere 15 Feb 2013 at 19 km/sec (42,000 mph)
- Shallow entry angle and it exploded at 30km above ground
- Released the equivalent of a 500kilo ton nuclear bomb (30x Hiroshima)
- Blast wave caused all the damage: 1500 people required medical attention
- [Bolide video](#)
- Not detected before it entered atmosphere...

Tunguska 1908 event



- Fireball and explosion heard 1200 km away
- Very remote site. On investigation, 2000 square km of forest (80 million trees) was flattened and thousands of reindeer carcasses were found
- 40-meter bolide, air detonation

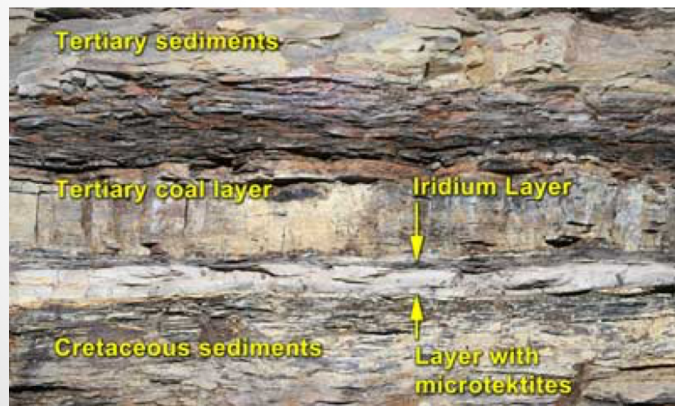
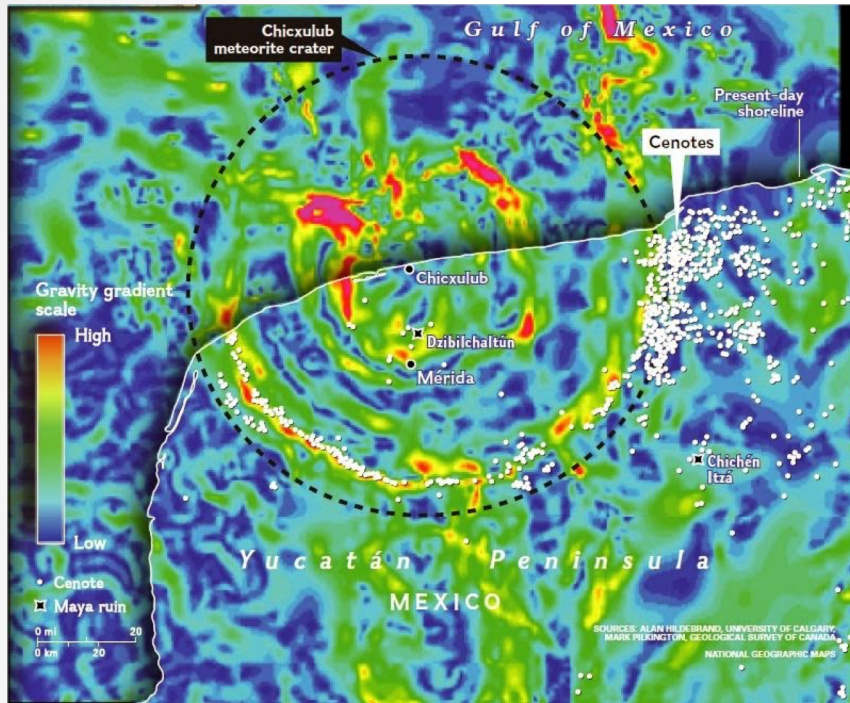
Large Meteorites



- Objects $> 50\text{m}$ in diameter make quite an impact (1 per 100 years)
- Most land in the ocean
- At 2km and above, has global consequences (once per 250,000 years)



K-T Boundary: 65 Million years ago

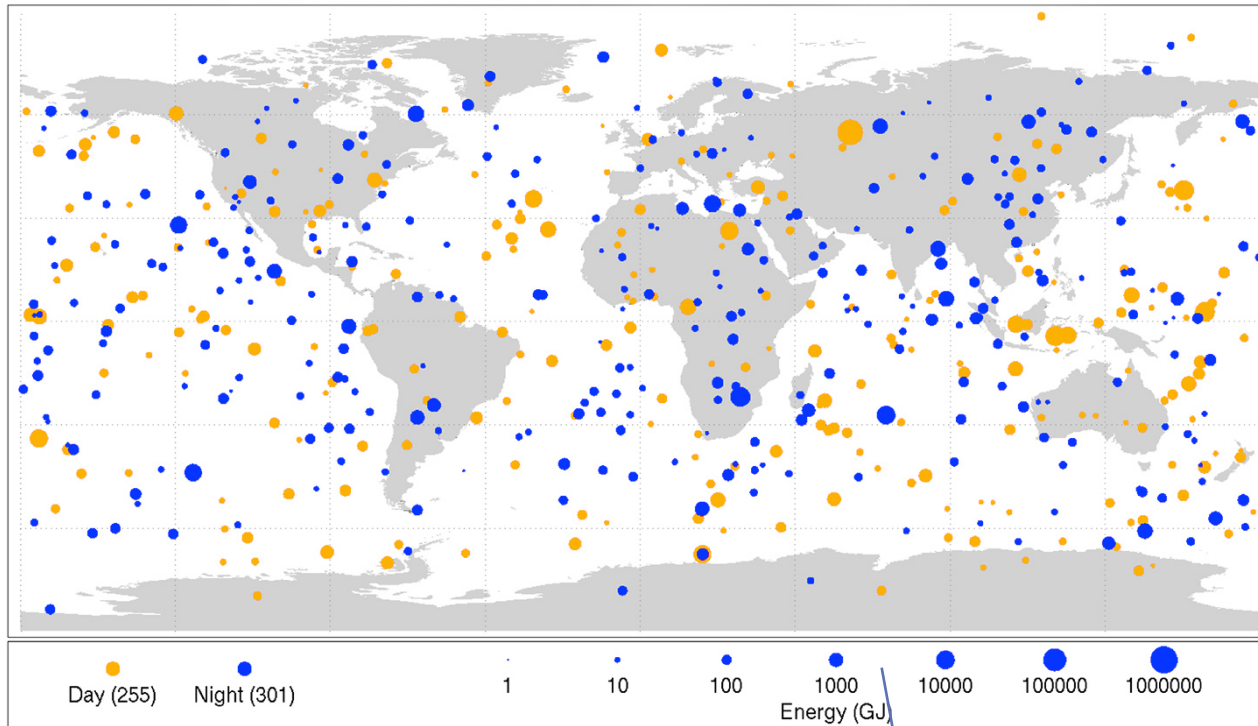


- Cretaceous-Tertiary Mass Extinction event
- high levels of iridium in the K-T boundary clay worldwide. Iridium abundance is very low in the Earth's crust, high in chondritic meteors
- K-T clay also contains soot and “shocked” quartz
- 50km impactor

| Meteor/Asteroid Size | Frequency | Damage |
|----------------------|-------------------------|--|
| 10^{-6} meters | 300,000 per second | Burns up in atmosphere |
| 10^{-3} meters | Every 30 seconds | Burns up in atmosphere |
| 1 meter | Every year | Fireball, minor airburst |
| 10 meters | Every 10 years | Airburst, sonic boom, fragments hit Earth. Russia Feb 2013 |
| 100 meters | Every 1000 years | Huge airburst, many fragments, ~hydrogen bomb in released energy |
| 10^3 meters | Every 100 million years | Planet-wide destruction |

Bolide events 1994-2013

(Small asteroids that disintegrated in the Earth's atmosphere)



- Historical craters

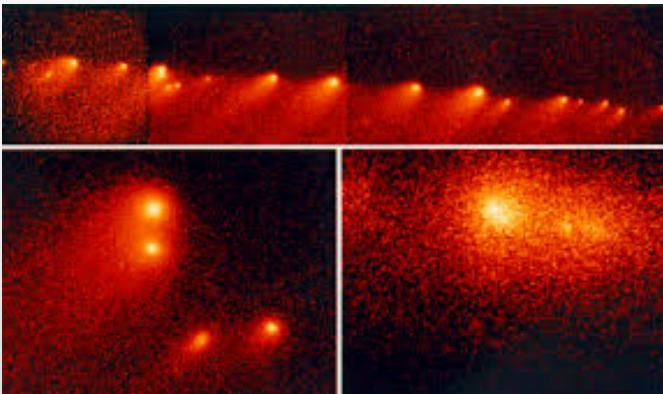
Lifetime odds of cause of death

| Cause of Death | Chances |
|-------------------|--------------|
| Heart disease | 1 in 5 |
| Cancer | 1 in 7 |
| Car accident | 1 in 100 |
| Homicide | 1 in 300 |
| Firearms accident | 1 in 800 |
| Electrocution | 1 in 5000 |
| Airline crash | 1 in 20,000 |
| Tornado | 1 in 60,000 |
| Lightning | 1 in 84,000 |
| Asteroid impact | 1 in 200,000 |
| Shark attack | 1 in 300,000 |

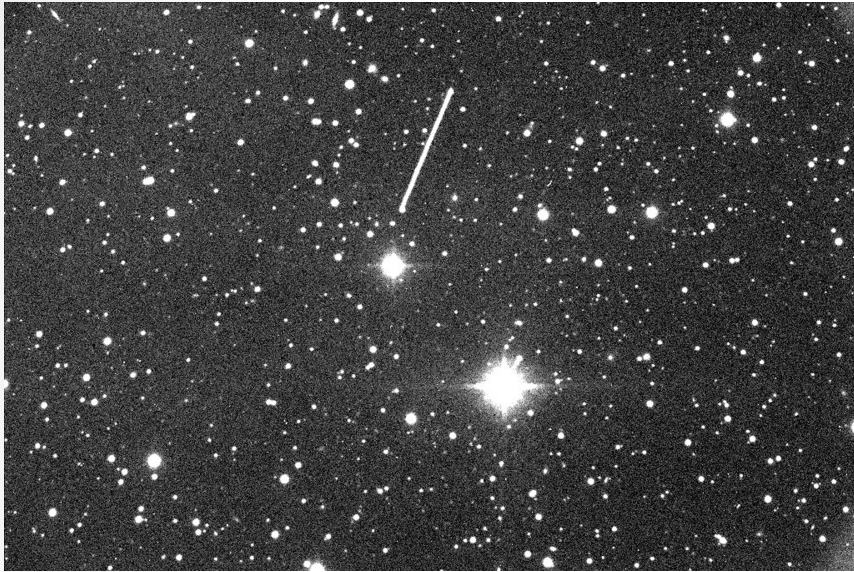
Comet Shoemaker-Levy impact on Jupiter



- 1994 collision of comet with Jupiter got people's attention
- Government initiated studies on identifying "NEOs" and identifying strategies for defending Earth from large impacts
- Spawned many terrible movies

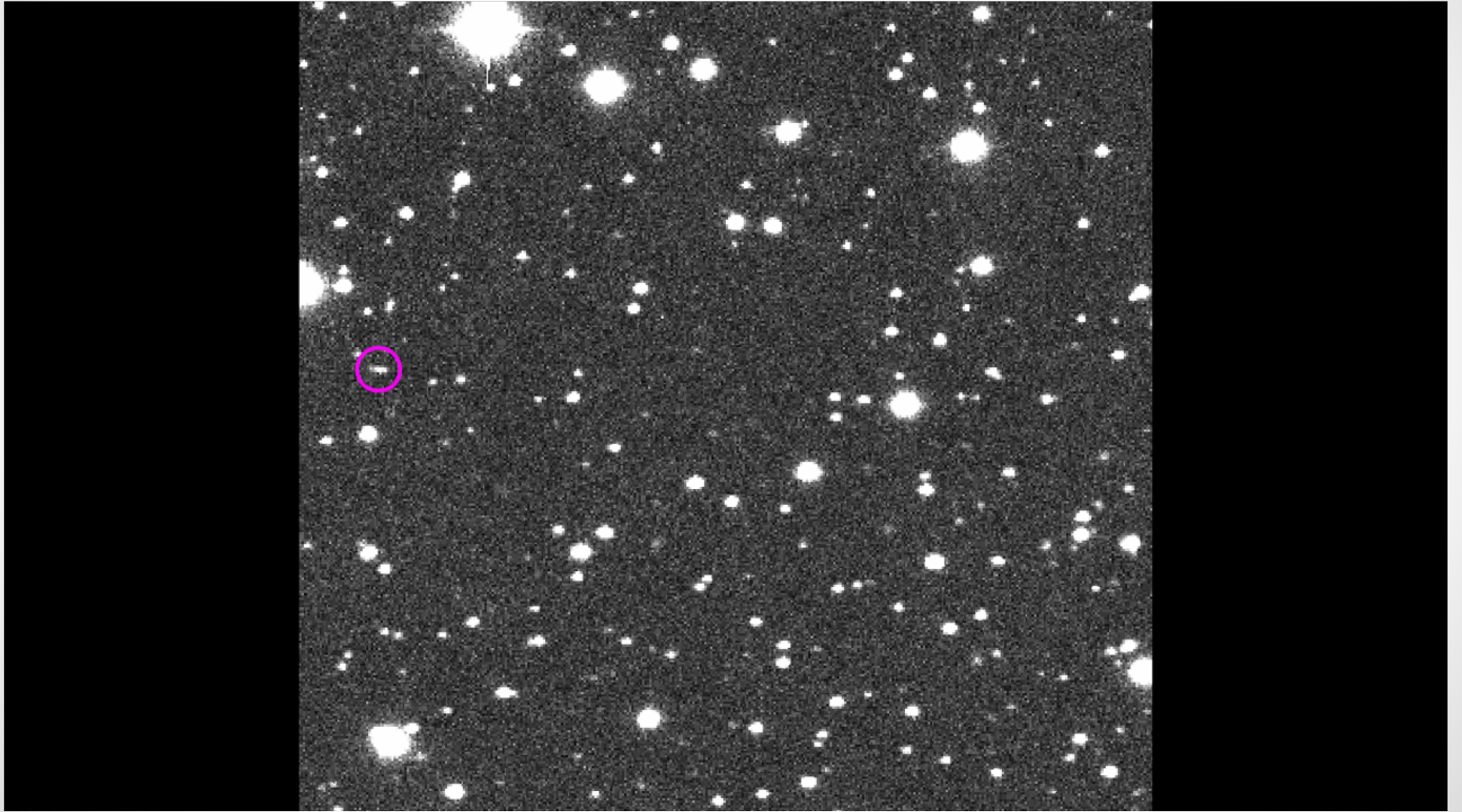


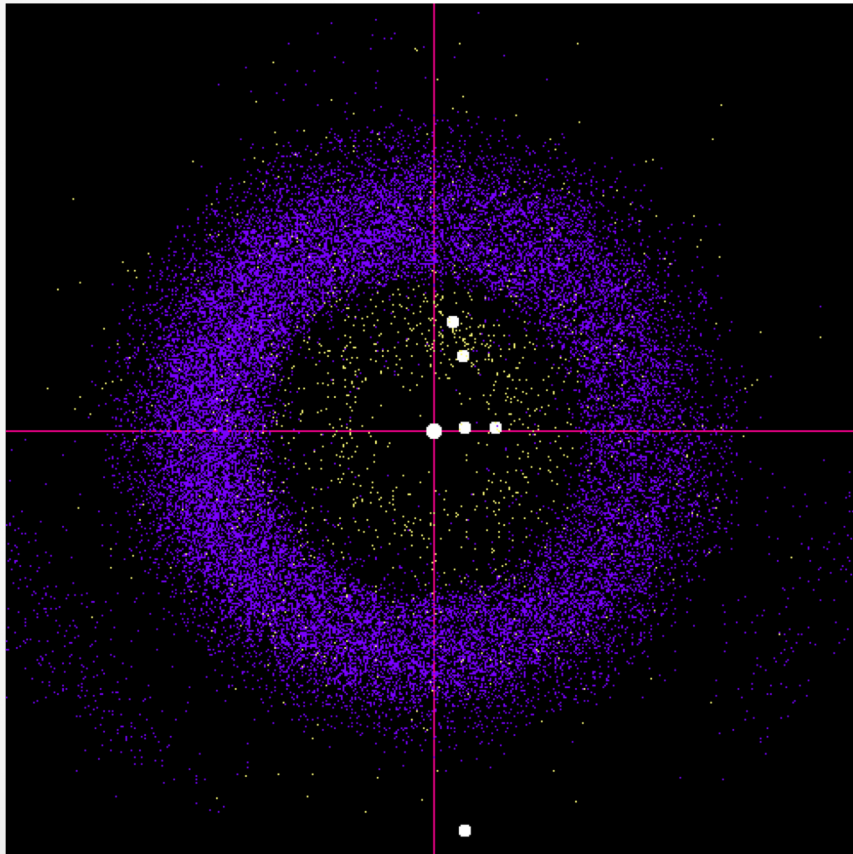
Early Warning



- Asteroids are easily detected when they are close to Earth (for sizes > 300 meters)
- All-sky imaging systems have been put in place to monitor the entire sky a few times per week
- [Planetary defense](#)



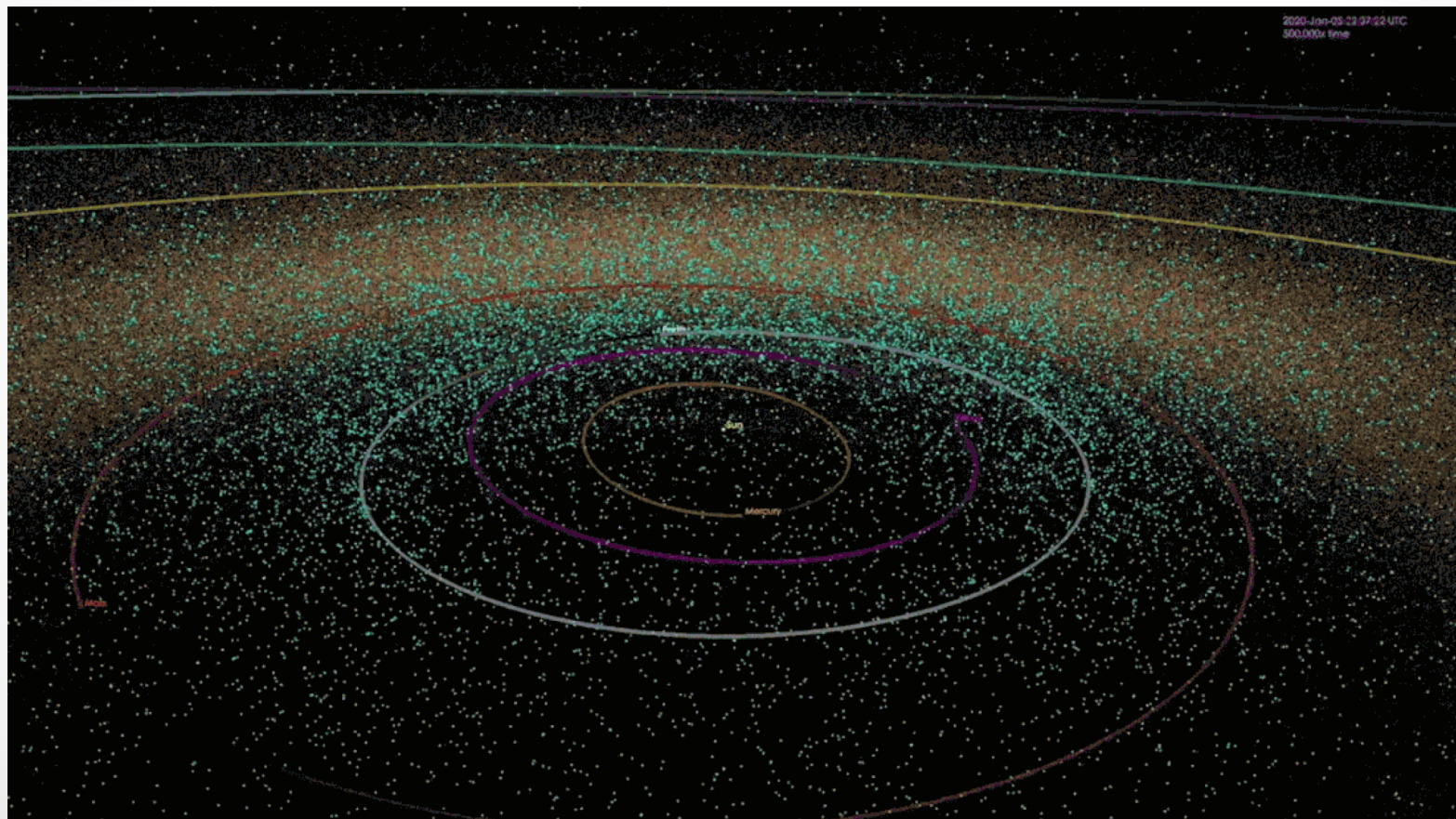




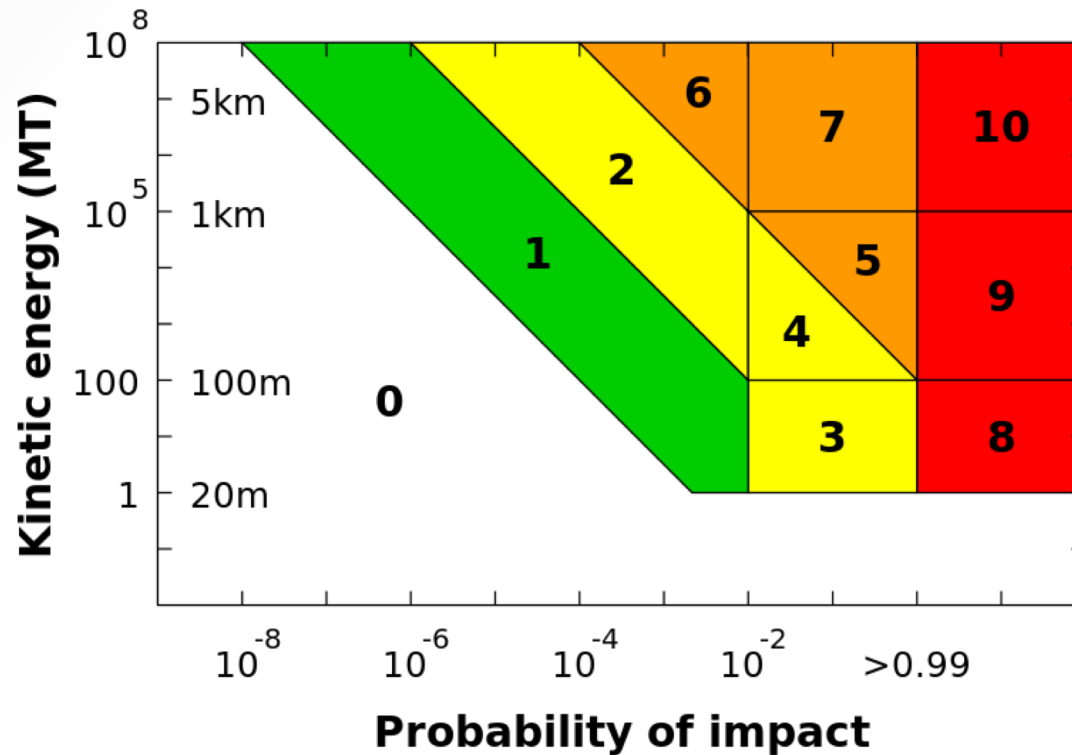
- White dots are Sun, Mercury, Venus, Earth, Mars and Jupiter
- Blue dots are asteroids that don't cross the Earth's orbit
- Yellow dots are asteroids with Earth-crossing orbits

(courtesy of N. Kaiser, U Hawaii)

- Discovery of new new-earth asteroids



Torino Scale



Richard Binzel in 1995 suggested “Near-Earth Object Hazard Scale” that became the Torino Scale

NEO Collision Avoidance

- Lots of “collision avoidance” schemes under discussion
- Most would require a few years or more to deploy
- Doesn't take much to nudge an asteroid enough to move it off collision course:

[0.035m/s] x [number of years to collision]

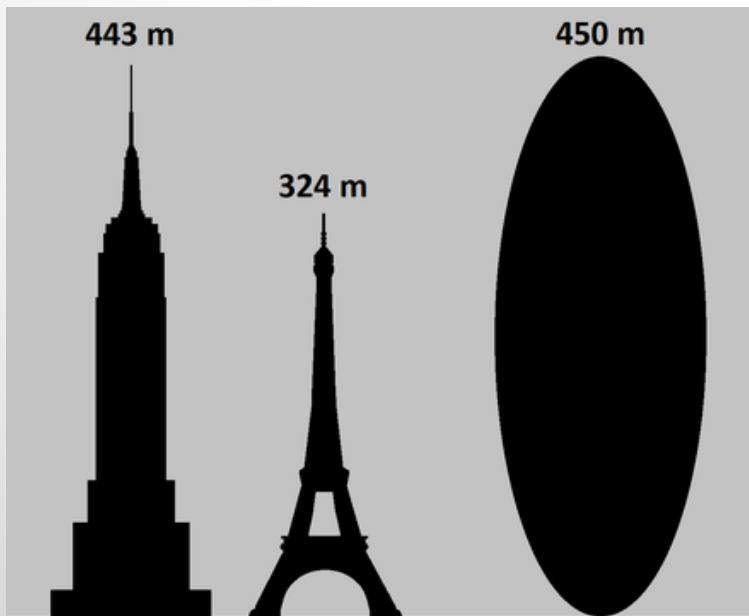
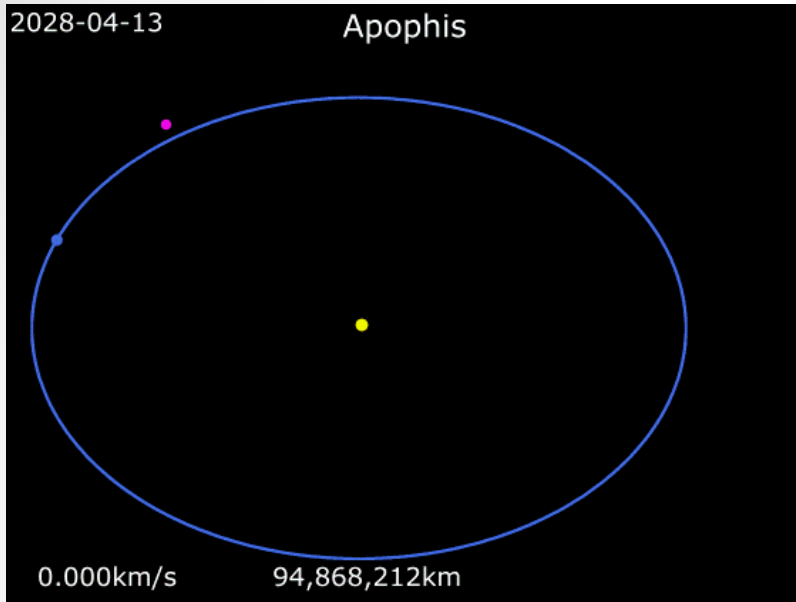
NEO collision avoidance

- Detonate nuclear bombs near asteroid surface
- Attach conventional rockets
- Ion or laser beam ablation
- Concentrated solar ablation
- Gravity tractors
- Kinetic impacts
- Change reflectivity

Every method's viability increases with amount of forewarning time



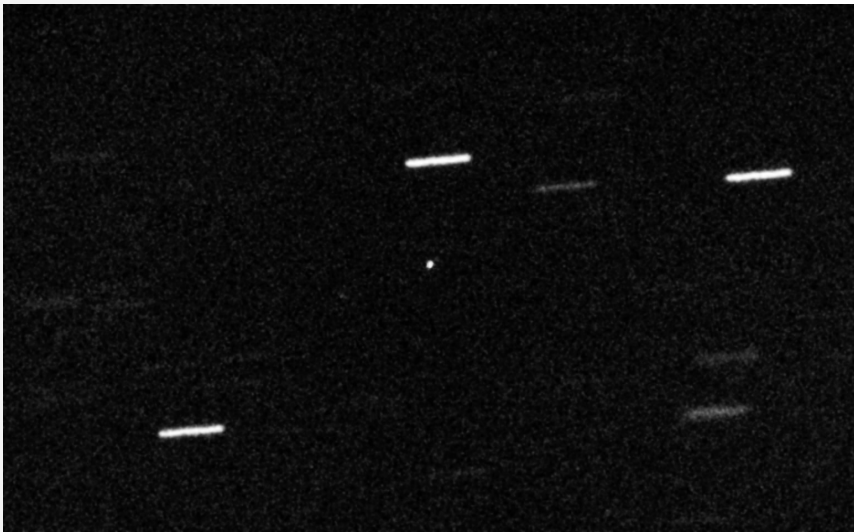
99942 Apophis

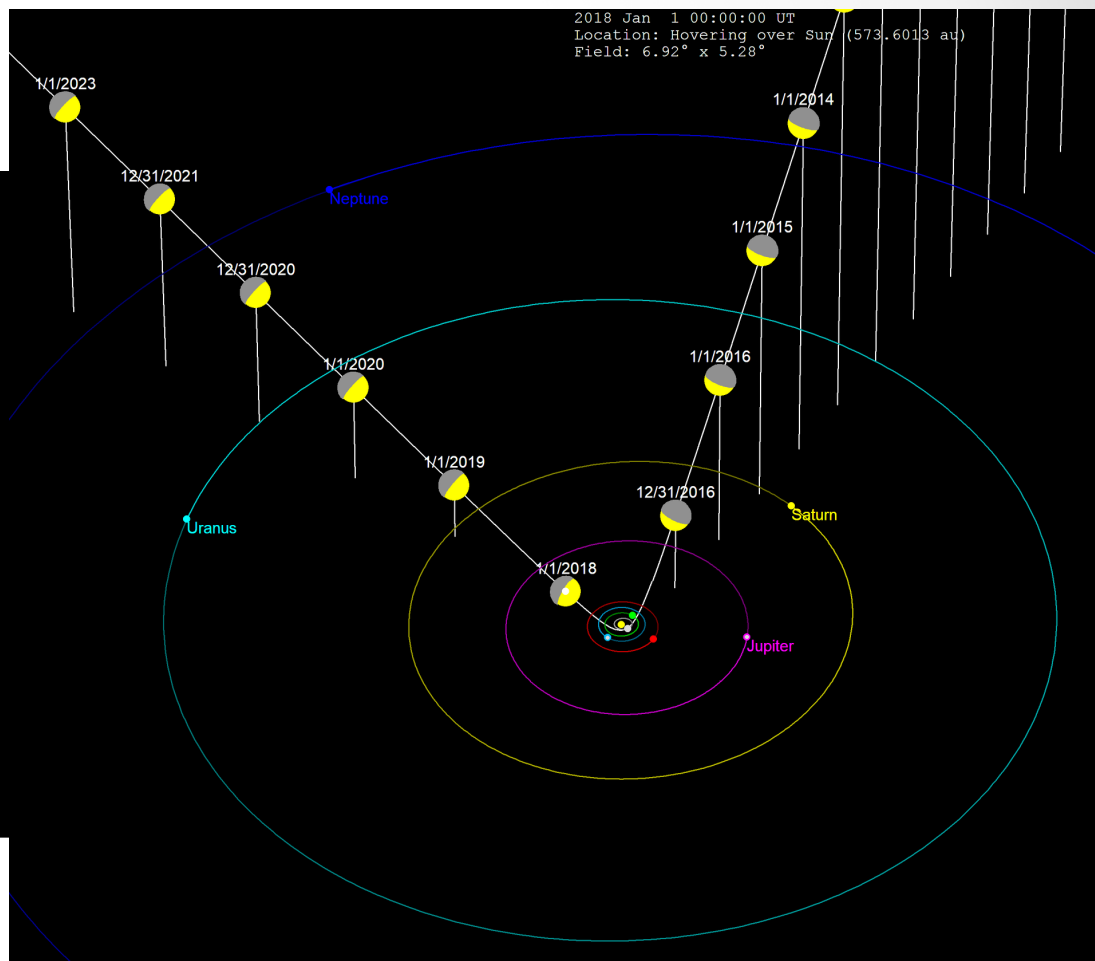
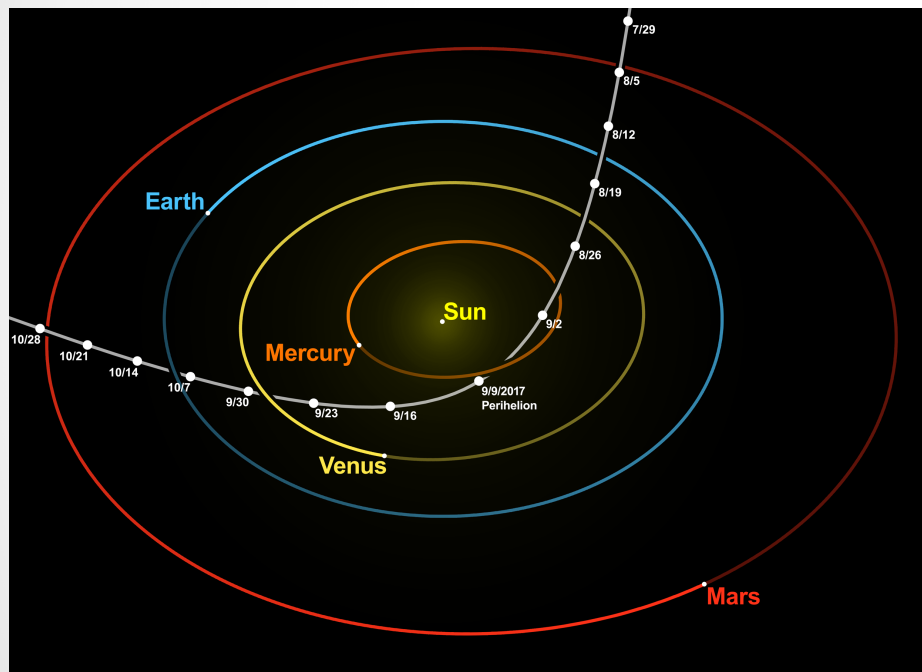


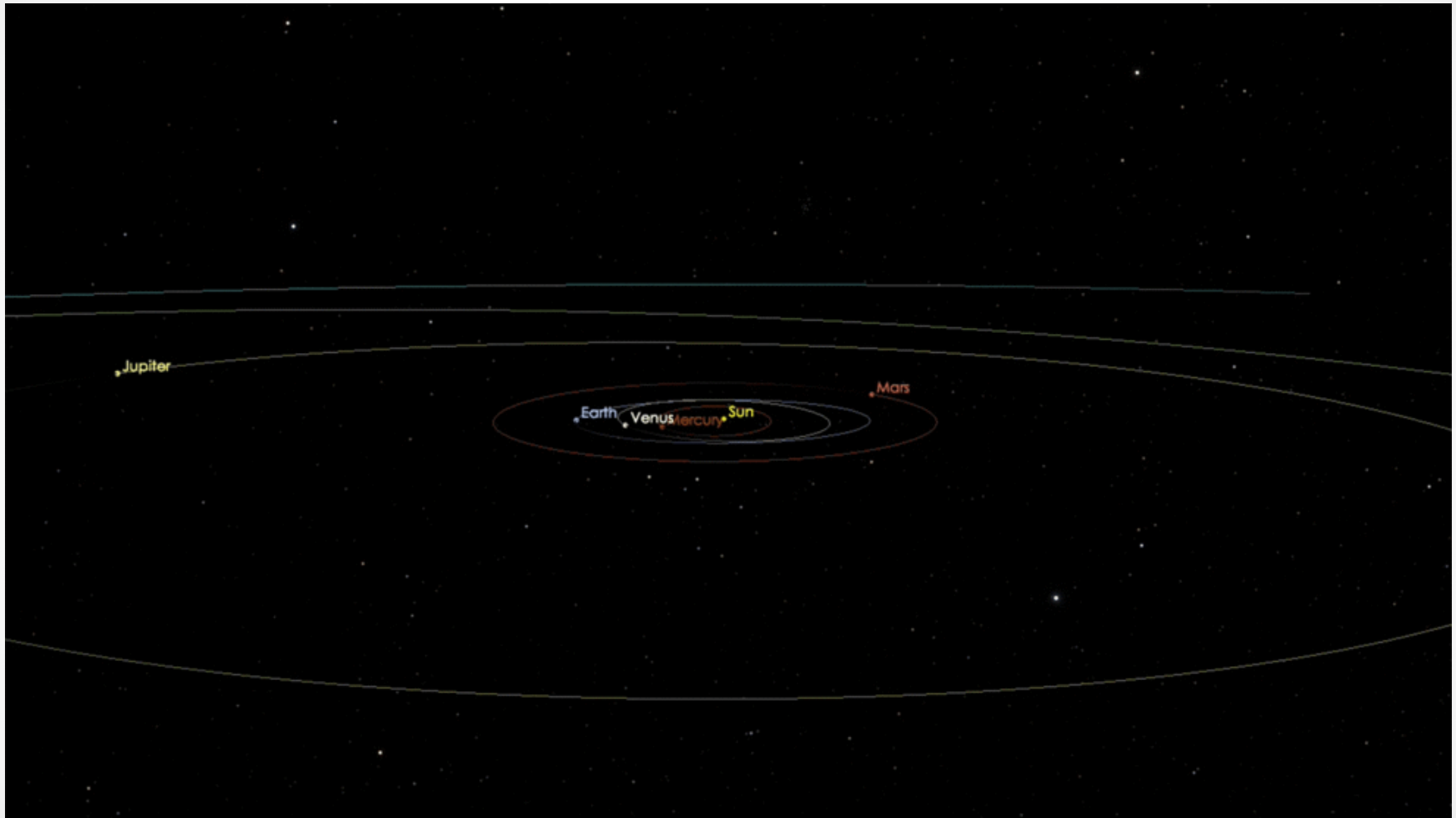
- Discovered in 2004 and initial orbit calculation had 2.7% probability of a collision on April 13, 2029
- Originally Level 4 on Torino Scale
- Subsequent observations changed chances to 1/45000
- Remains possibility of 2036 interaction

'Oumuamua

- “first distant messenger”
- Discovered in October 2017
- When orbit was calculated it was obviously hyperbolic
- First observed object from outside of the Solar System

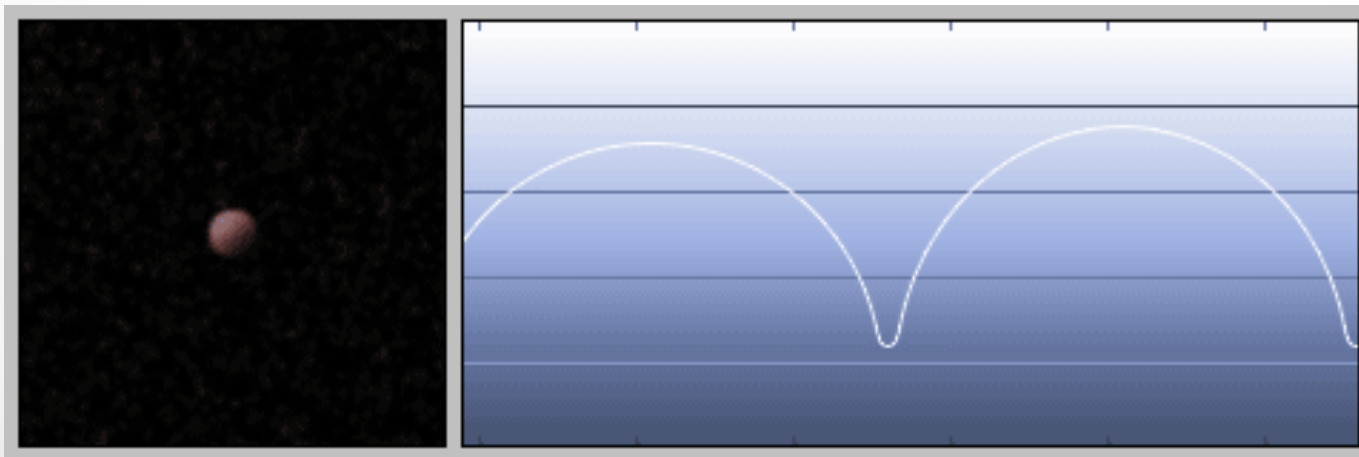
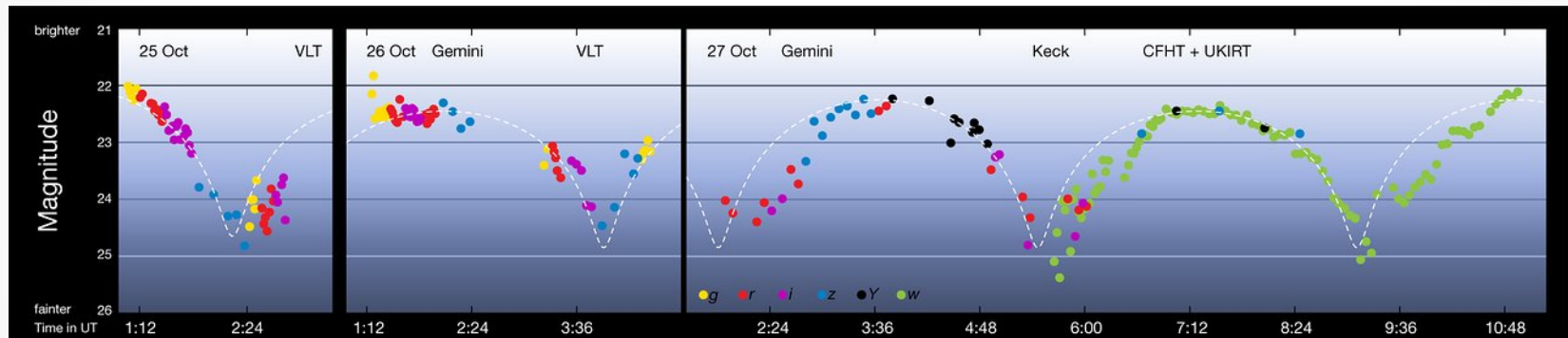




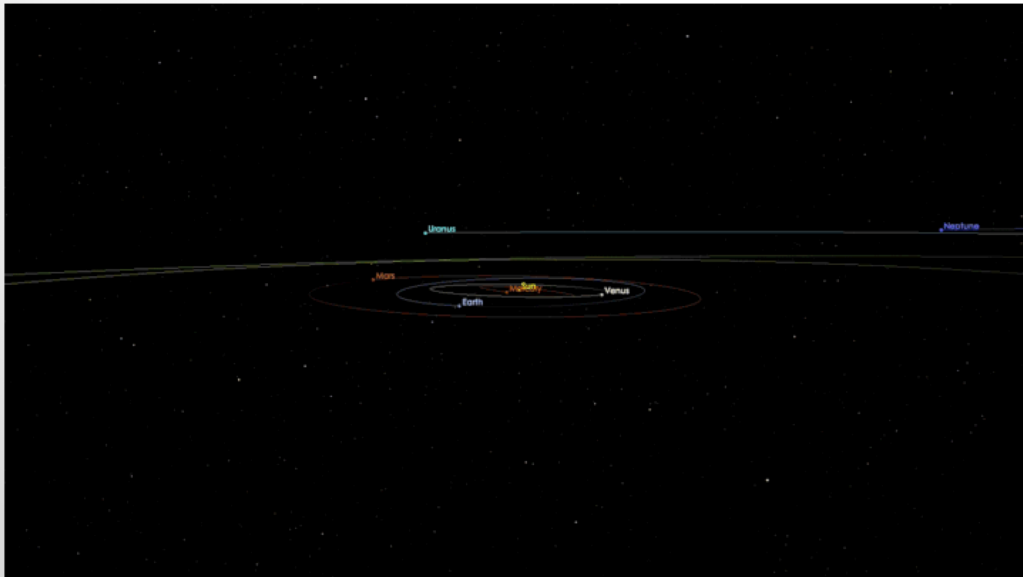


Light curve

- Highly variable light curve indicated cigar shape
- Changes in light curve suggested tumbling (outgassing jets more likely than spaceship controls)



Interstellar visitors



- The faintness of 'Oumuamua and its fast orbit made it very hard to spot: suggests there are many interstellar visitors
- August 2019 a second one was discovered. This time a comet
- With new facilities in the next few years, we will discover many of these objects



- Where is the North Star?

Next topic: Light

