PHYS 162H Elementary Astronomy Honors Section

- instructor: Dave Hedin, FW 224, hedin@niu.edu
- Book: None required
- Grading course curve on syllabus
  - 4 exams, each 100 points. Lowest one dropped. You can drop the final
  - in class activities worth 100 points
  - project worth 100 points. Go over projects on Friday.

Course Structure and Web page

Monday and Wednesday “lecture”

Friday activities, movies, tests 1 and 2, project presentation

nicadd.niu.edu/~hedin/162/162h.html : Syllabus,

Example Tests, lecture transparencies (may have extras at end not shown in class and not on tests), links to “interesting” sites where mostly not time to go over in class, Hints for projects

Can always find by Googling “David Hedin” or “PHYS 162H”

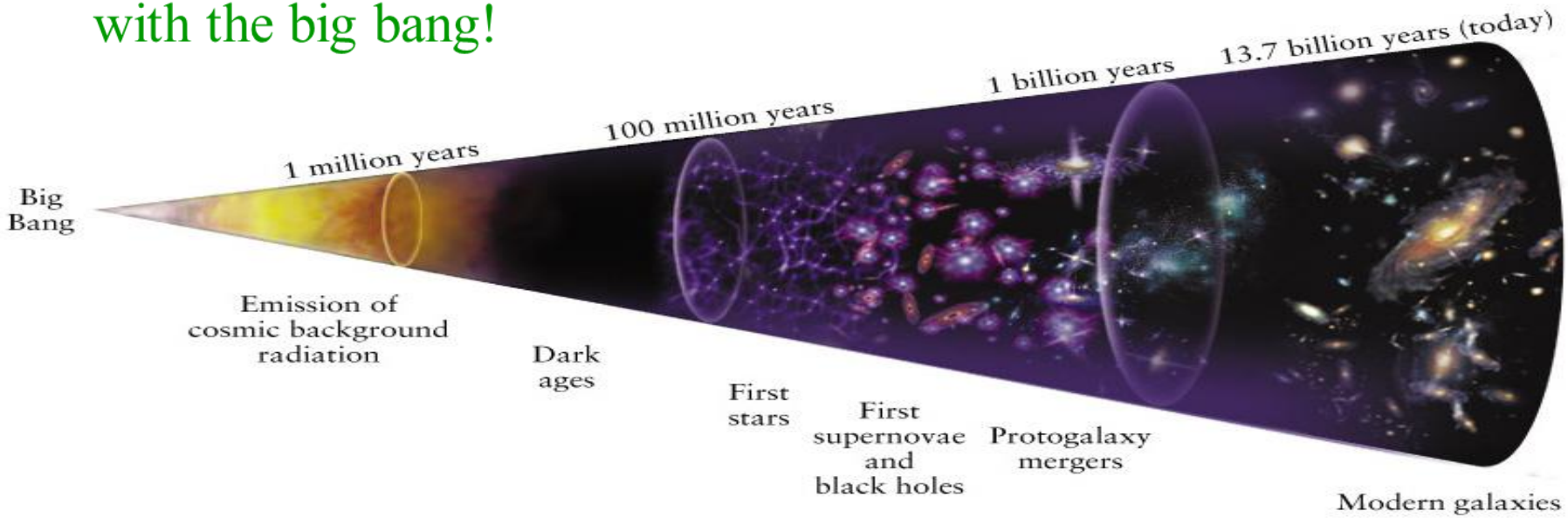
Will use Blackboard for posting grades. But Blackboard grade is meaningless

Extra Credit

- Can be a STEMfest volunteer → 10 EC points
- will show movies in class plus maybe have relevant physics colloquium. write a 1-2 page report on up to three of them → up to 10 points each report. Up to 2 reports.
- Due BEFORE final. DO NOT e-mail; print out a copy for me

Course Content: History of Universe

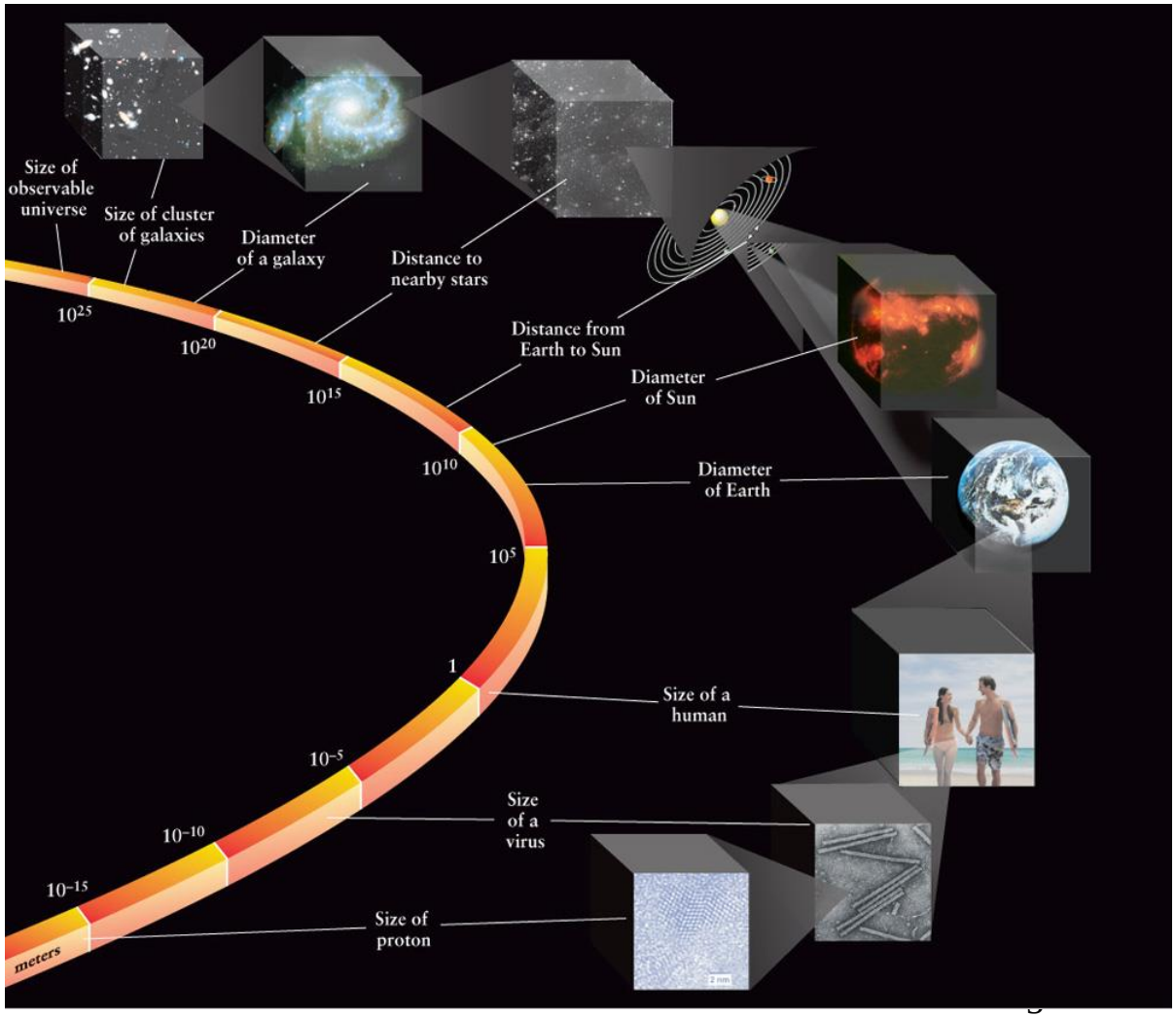
- Our whole universe was in a hot dense state, Then nearly fourteen billion years ago expansion started…. That all started with the big bang!



First Local planets → then exoplanets
First Sun → then stars
Milky Way galaxy → other galaxies
Known physics → help explain the Universe
For this course, we start with local phenomena and end with Big Bang

Sizes in Astronomy

- Astronomy examines objects that range in size from the nuclei of atoms (~10^{-15} m) to the size of the observable universe (~10^{28} m).
- Scientific notation is a convenient shorthand for writing very large and very small numbers



Units and Powers of 10

- we won't use much "math" and **you don't have to remember these values**, just **don't get lost**. Use AU and LY for most distances
- Solar radius = 700,000 km = 7×10^5 km
- Distance Earth-Sun = 1 Astronomical Unit (AU) = 150,000,000 km = 1.5×10^8 km (= 8 light-minutes)

- Distance to the closest star = 4×10^{13} km = 4 Light Years = 4 LY

1 LY = distance that light travels in one year

= velocity x time

= 3×10^8 m/sec x 3.12×10^7 sec/year

= 10^{13} km

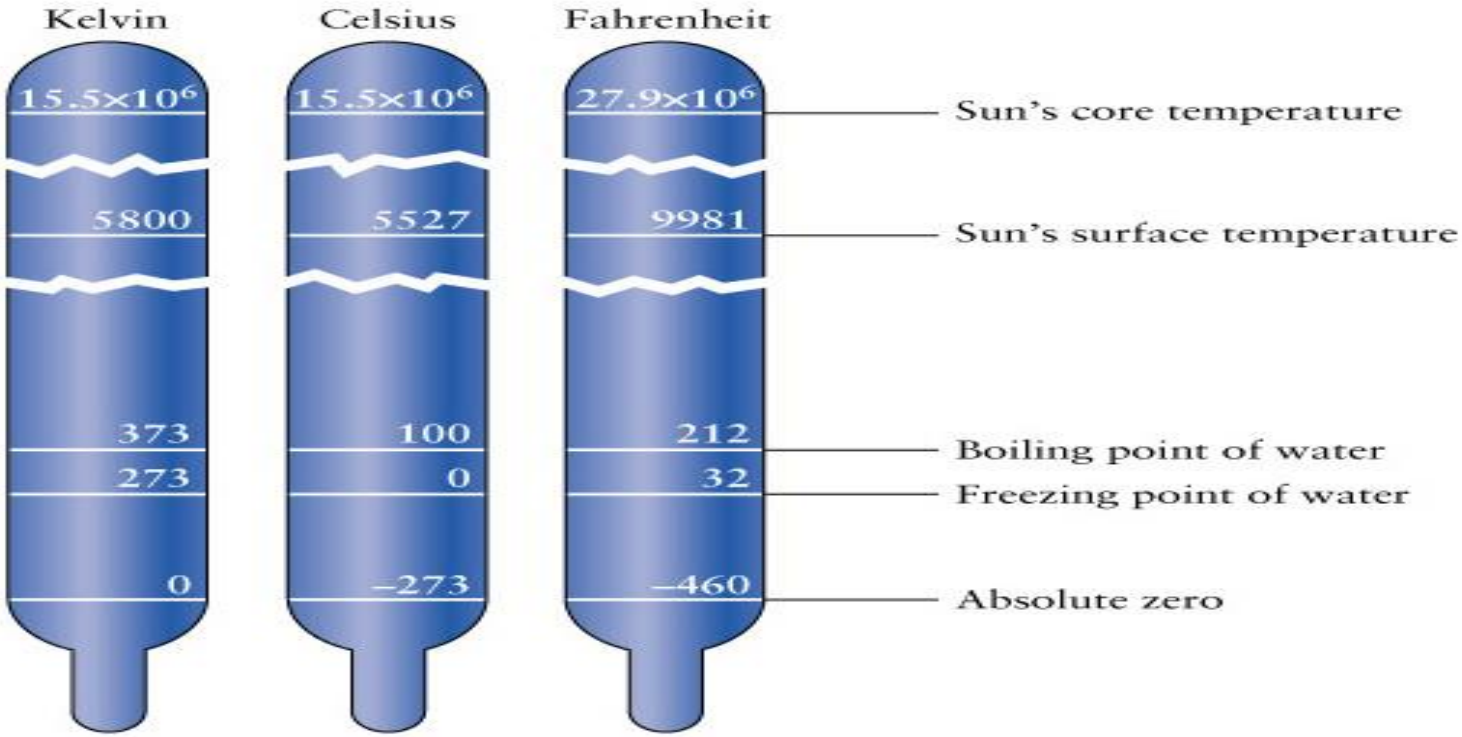
- 1 parsec = 3.3 LY

WE USE

AU and LY

Temperature Scale

- again don't really worry about this but **don't get lost**
- we use Kelvin Scale → temperature of space is almost 0 degrees Kelvin (actually 3 degree K)



Easy/Early Observations

- Sky is dark at night (means the universe is finite in space or time

Olber's paradox, do at end of course)

- Sun produces light and heat
- Moon 'produces' light but relative to Sun's position
- Earth, moon, Sun all spherical objects 'suspended' in space. See Earth's shadow on Moon during eclipses

Early confusion. Does the Earth spin? What "carries" Sun, Moon (other planets and stars) along their paths in the sky? (NOT crystal spheres as some people proposed.)

Easy/Early Observations

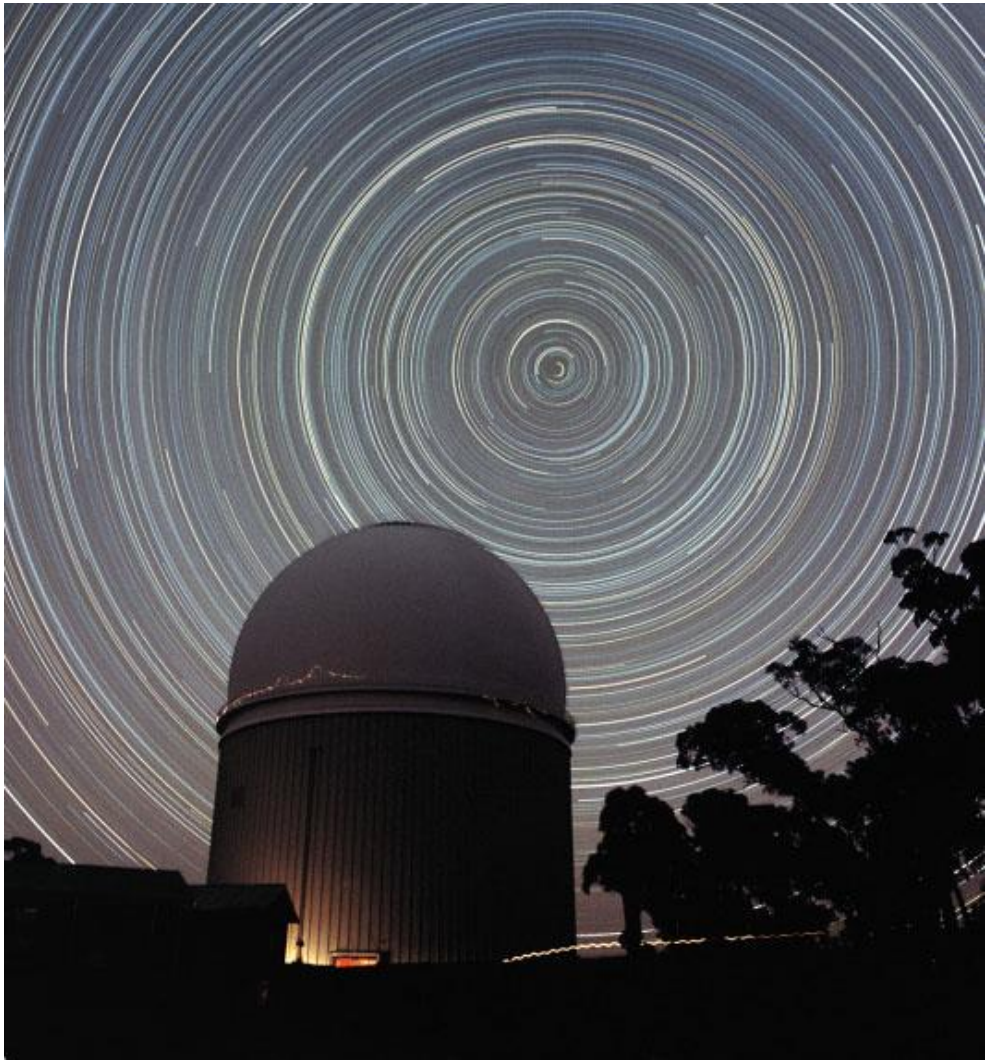
Regular predictable motion

sun,moon,stars	Daily
moon	Monthly
stars	Yearly
seasons	Yearly

which are easily explained by having the Earth spin (daily) and orbit the Sun (yearly). Though not “simple” relationship like 12 months of 30 days = 360 days/year. Philosophy+theology confused the understanding of this for thousands of years. Now know Earth day and Earth year uncorrelated except in the direction of their “spinning”

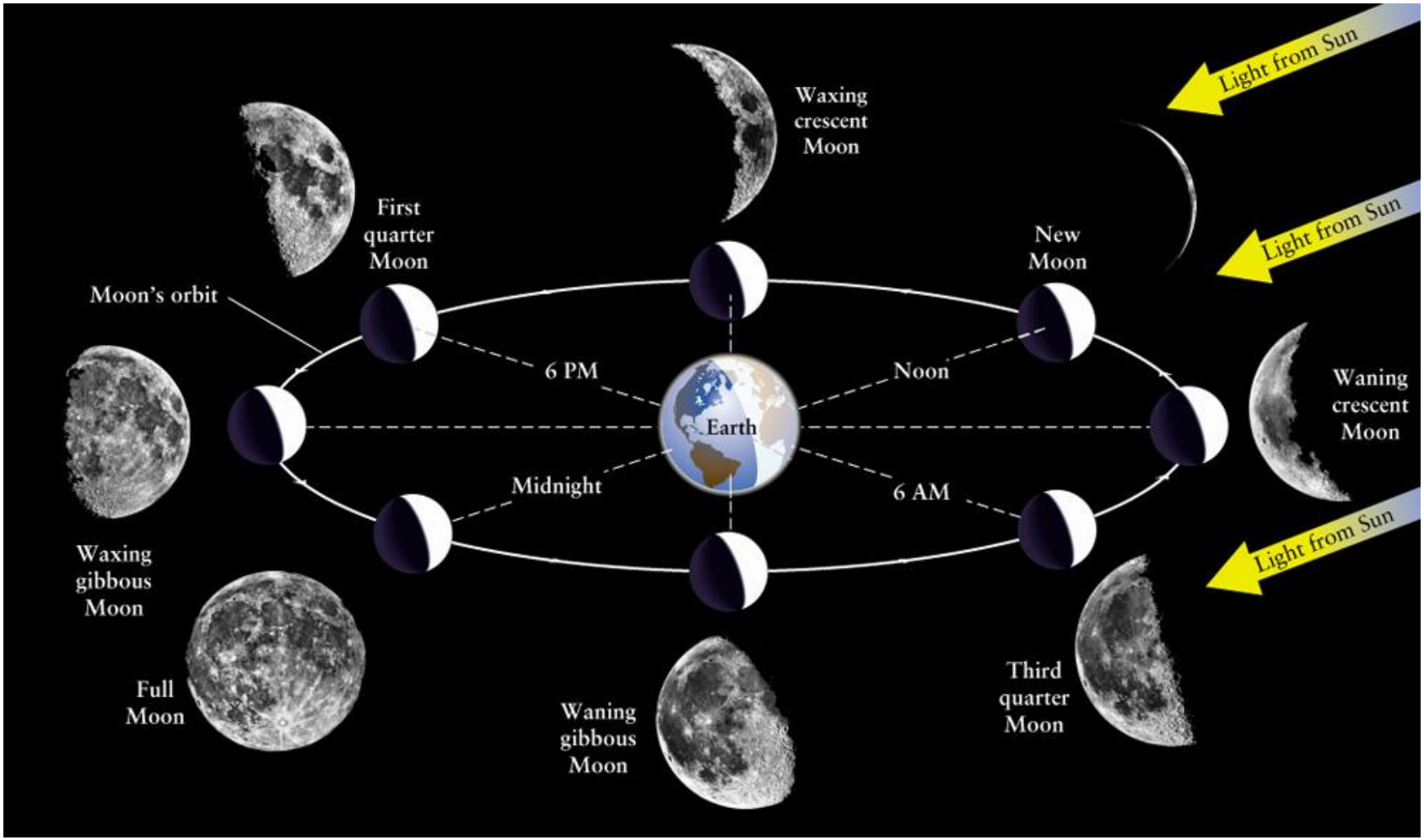
- unpredictable motion (comets,novas) use to be considered disturbing/evil before understood

Star Motion during One Night – Earth spinning



Early view of Earth motionless and stars (and Sun and planets) moving around the Earth disproven around 1600 though some Greeks in 200 BC had also figured this out. More later

Phases of Moon (skip tides)

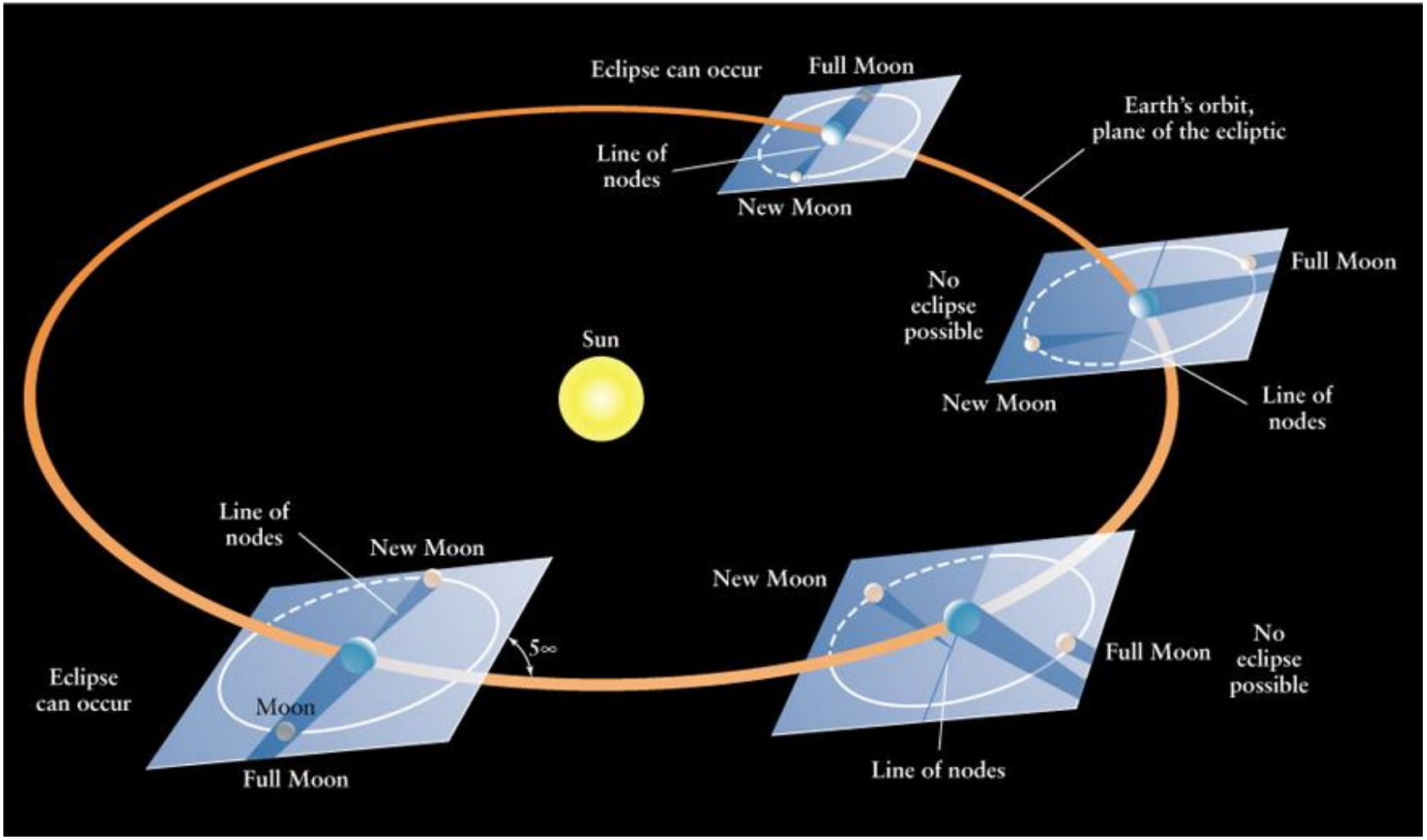


Phases and Orbit of the Moon

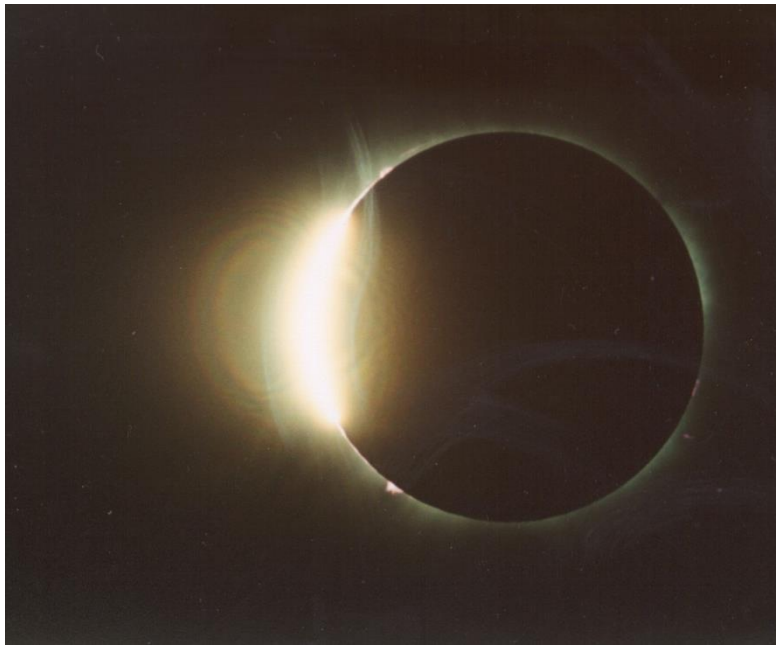
- Moon phases readily understood by relative position of Sun and Moon to observer on Earth
- 2200 years ago, using the triangular geometry of the Moon when it was at a half phase gave estimate of relative distance to Sun (extra slide)
- Moon's orbit about Earth tilted by 5 degrees compared to Earth's orbit about Sun → Moon is above or below the Sun's path through sky (Sun's path is called the ecliptic)
- Moon's orbit about the Earth is an ellipse. Moon's distance from Earth varies from 356,000 to 407,000 km (perigee/apogee) and so apparent size varies by about 15%

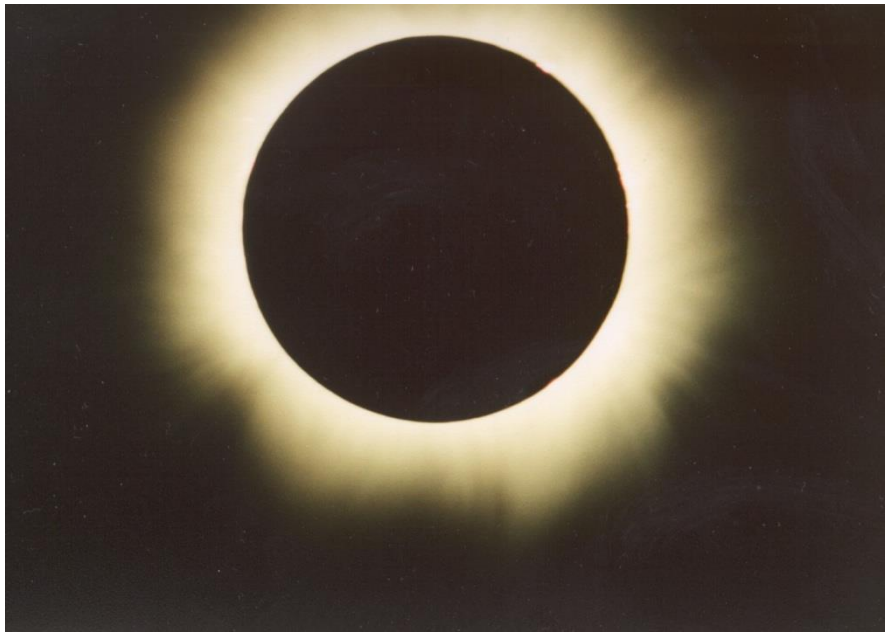
Lunar and Solar Eclipses

apparent size of Moon and Sun from Earth are accidentally almost the same. Moon was closer to Earth and so "bigger" (in angle) in the past → dinosaurs saw more and longer total eclipses (more in extra slide)



Total Eclipses – see Corona of Sun





Eclipse occurs when Sun-Moon-Earth aligned. Total = Sun 100% blocked (if moon further away doesn't completely block=annular)

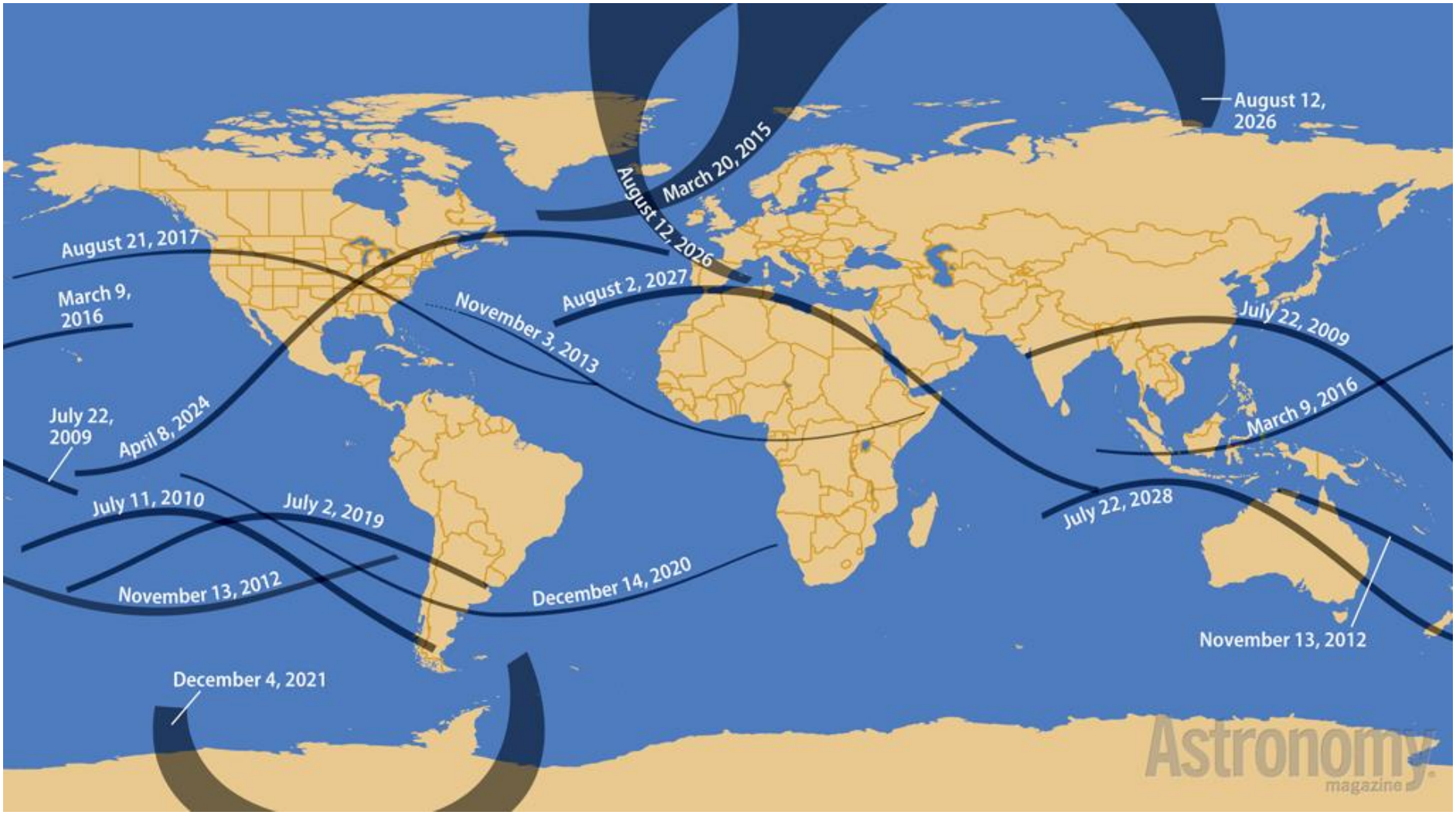
Total Solar eclipse – Turkey 8-11-1999 (NIU sponsored trip)

Recent US total eclipse → 8-21-2017, next 4-18-2024

Last total on continental US in 1979

Eclipse 8-21-2017 went through Carbondale as will 2024 eclipse

Total Eclipses: 14 from 2009-2028



Markers of Time

DAY: Sun at maximum height

MONTH: length of time it takes for the moon to make an orbit around the Earth (repeats phase every 29.5 days).

Most early cultures use the day and month to mark time

moon-month-measure-man may all have the same root

YEAR: Time it takes for Earth to orbit Sun

- changes of seasons (hard to tell if in tropics)
- changes of which stars are visible during the year

Due to Earth's daily motion and orbit around the Sun

→ Stars can serve as Clock and Calendar

→ Star can serve as a navigational aide (critical up to about 1950, even today taught to US Air Force and Navy personnel)

Length of Day and Month are changing

- Friction between the Earth and the Moon (seen daily in tides) caused Moon to stop spinning; always has 1 side pointed at Earth
- Day becomes .002 seconds longer each century
- Moon receding from the Earth by 4 cm each year

500,000,000 years ago there were

22 hours in a day

400 days in a year (as each day shorter, time to orbit Sun same)

Billions of years in the future there will be

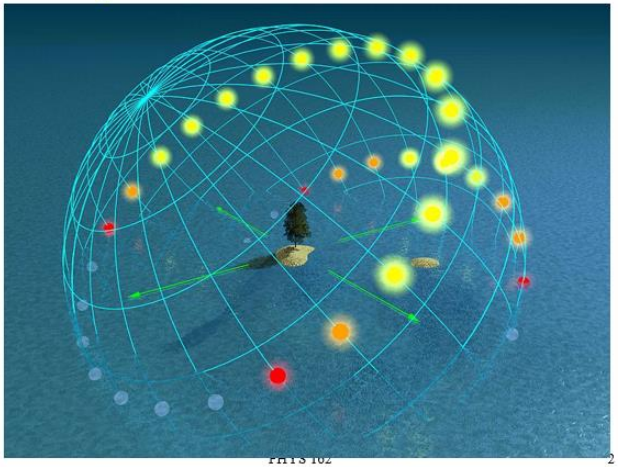
1 “day” = 47 present days

1 “month” = 1 “day”

Earth-Moon frozen with no additional spin for the Earth alone-just Earth-Moon system rotating. (later sees impact habitable planets in other Star systems)

The Year

Sun's path summer and winter solstices



Two Indicators

1. Due to the Earth's tilt the

Length of the Day and Sun's path through the sky vary. One year = returns to the same spot

More dramatic further north (Stonehenge). In tropics have 12 hour day all year. In January, length of day = 9.5 hours in DeKalb, 8.25 hours in London, 4 hours in Iceland

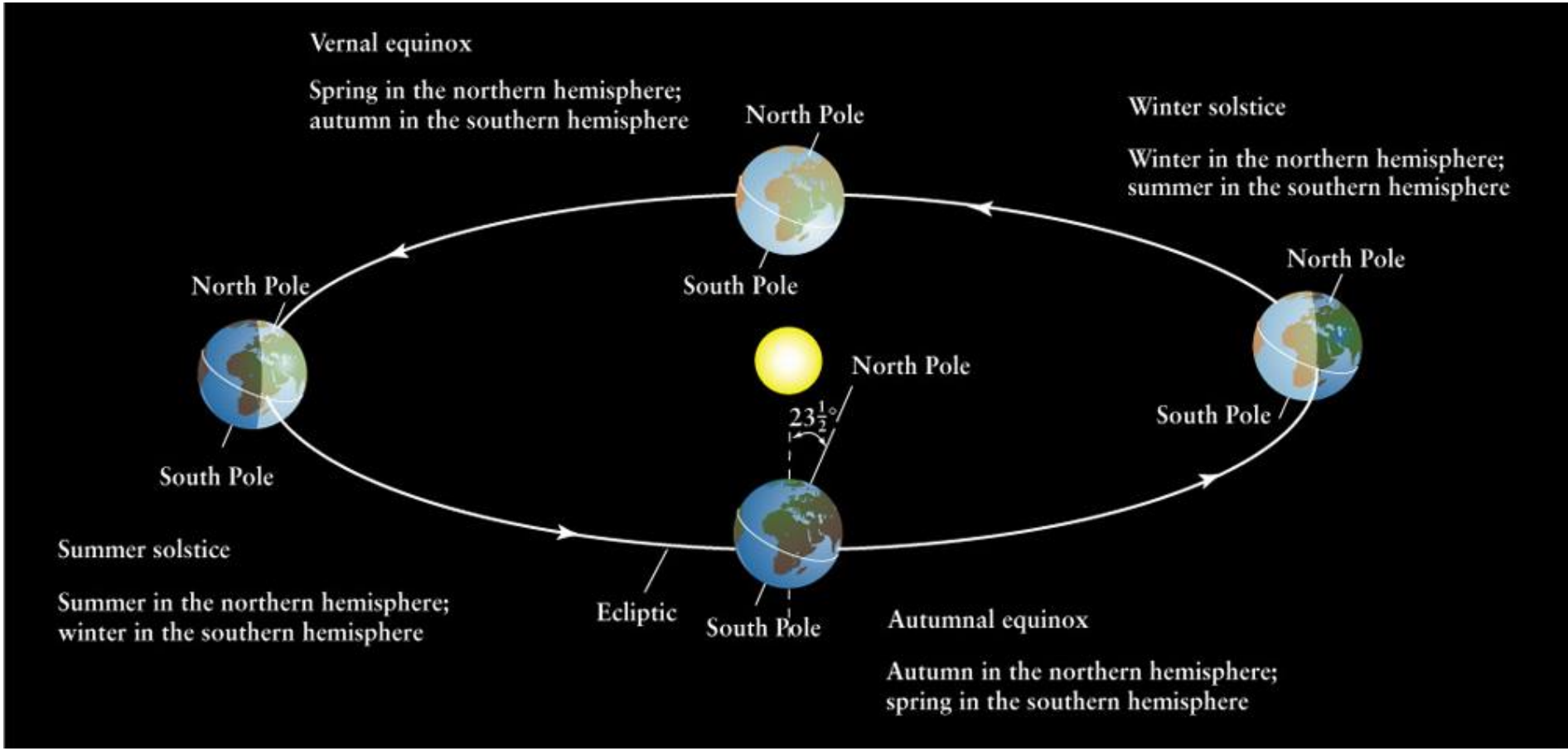
2. Which stars are overhead changes with seasons (more next class). Gives passage of year

Passage of time at night also given by stars' apparent motion

Stars = Calendar and Clock

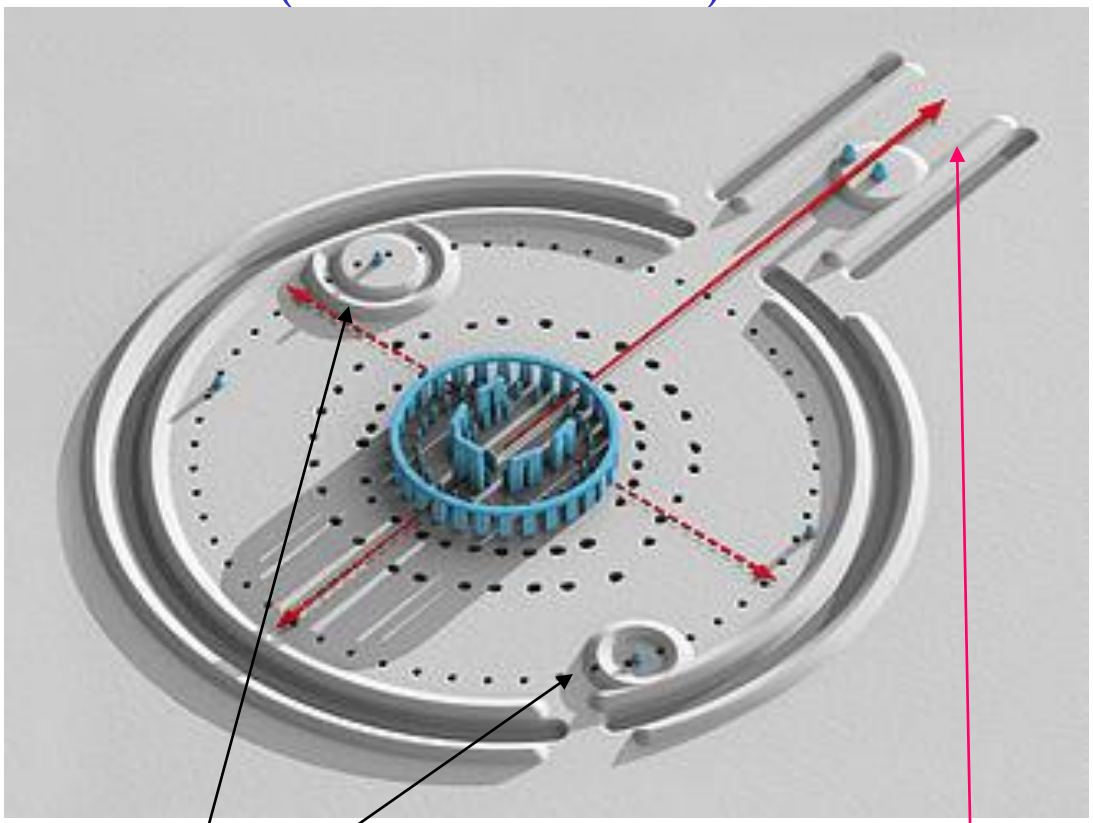
Yearly Motion: Earth orbits Sun

The "night" side of Earth points at different stars as orbits Sun



Stonehenge

Stonehenge – tracks path of Sun and Moon. Had 12.5 sections for moon in year plus has limits on moon's orbit above/below that of Sun's (365/29.5 = 12.4)



Moon above/below ecliptic

Points to Sun rising in June

Stars and Planets

- Stars are “fixed” relative to each other. They produce their own light which is independent of Sun’s location (thus indicating they are very far away - the Greeks understood this). Lecture 2
- Planets have complicated (but predictable) orbits when viewed from the Earth. Wanderers – wander through stars. Brightness does depend on Sun. Small numbers of such objects (5 planets visible to unaided eye). Lecture 3

Extra Slides

Projects

- Need to make “observation”, write a 10-20 page report (with references), and make ~10 minute presentation
- Can work in pairs. Will work directly with observatory manager to help select topic and collect “data”
- Examples of projects from previous years available. Will go over on Friday

Observatory

- Web page tells you schedule and if open/closed due to weather. Weather gets worse later in term. Can contact Chris Marshall.
- Fall objects: Double Cluster in Perseus, Moon, Andromeda Galaxy, Globular Cluster M22, some double stars, and later in term Orion Nebula and Pleiades Cluster, Saturn throughout term, Jupiter in evening just at beginning.
- Winter/spring objects: Moon, Andromeda Galaxy (early in year), some double stars, and Orion Nebula and Pleiades Cluster.

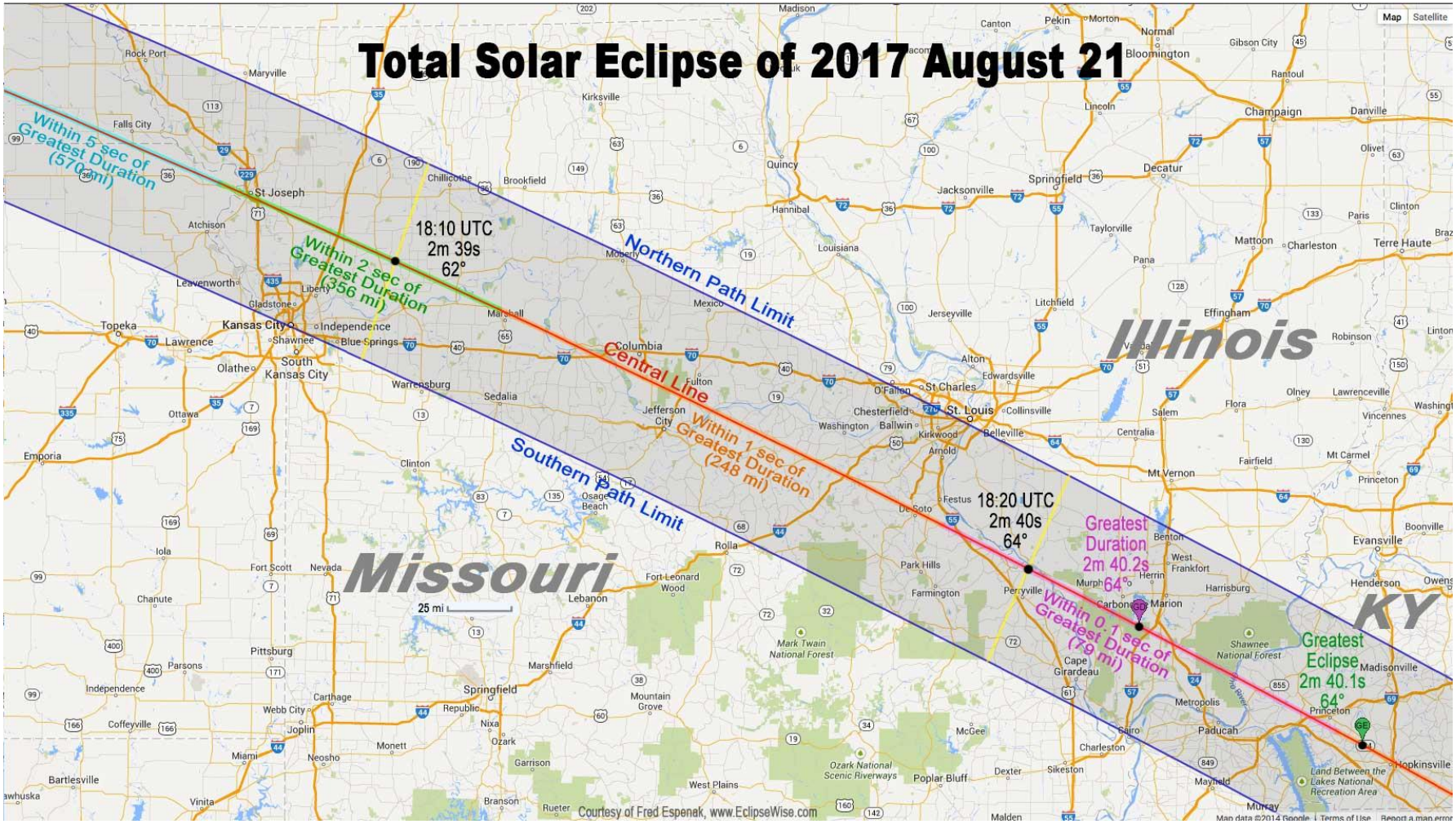
Course Content

- Definition of astronomy - the science of the stars and other heavenly bodies
- We use our knowledge of physics, chemistry, and geology to understand PLANETS, STARS, GALAXIES,UNIVERSE
- planets/stars/etc also serve as “laboratories” for conditions beyond human-built experiments and studying them increases understanding of sciences
- Early studies of planetary motion lead to understanding of gravity and forces (physics and in this course). Modern studies of planets concern geology and weather (not in this course). Studies of stars, the formation of galaxies and the universe depend on the properties of basic matter and forces (physics in this course) Also include astrobiology as interesting.

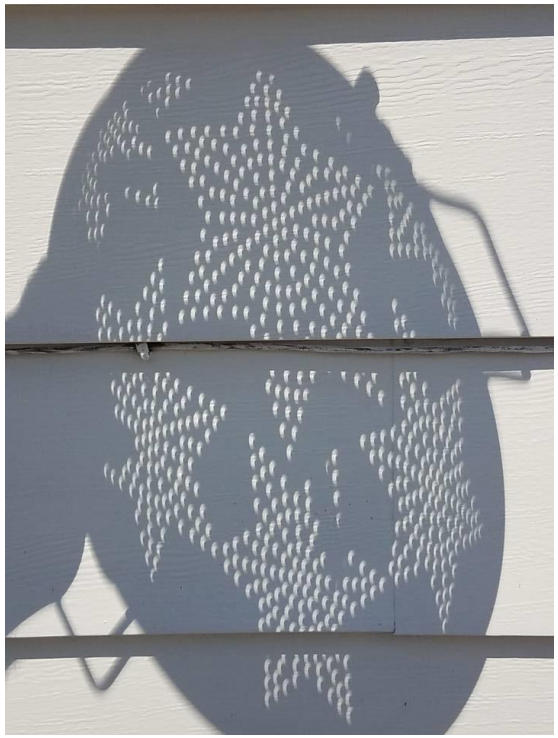
Eclipses

- Moon's orbit about Earth tilted by 5 degrees compared to Earth's orbit about Sun. Most orbits do not produce an eclipse
- But sometimes Moon-Earth-Sun all on same line → eclipse. If Moon between Earth and Sun get Solar eclipse. Happens during New Moon phase. If Earth between Moon and Sun get Lunar eclipse. Happens during Full Moon phase.
- Solar eclipse details. The angular sizes of the Moon and Sun are accidentally almost the same (about ½ degree). As Moon's distance from Earth varies (perigee/apogee), if too far away get annular eclipse (not total) as Moon "size" is smaller than the Sun's. If Moon is closer get longer total eclipse as Moon's angular size just slightly bigger than Sun's.

Eclipse 8-21-2017 went through Carbondale as will 2024 eclipse



Solar Eclipse 8-21-17 Sparta Illinois



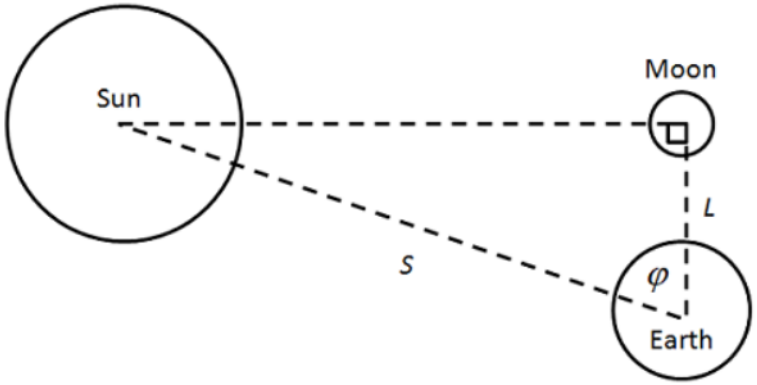
Two minutes of totality. Very clear skies. Had “diamond ring” effect at beginning and end. Details of corona visible by eye. Venus and Jupiter visible during totality. Before totality used small telescope to project image, or colander, or leaves of a tree.

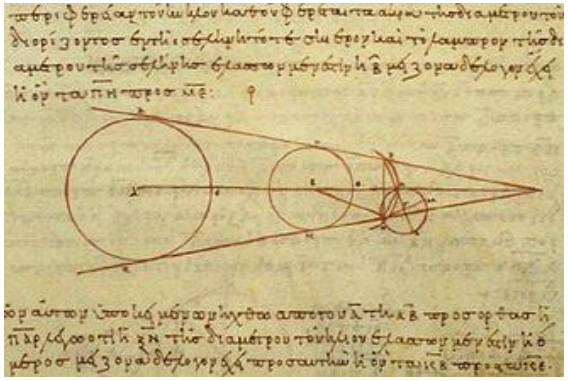
Extra Slide – don't need to know

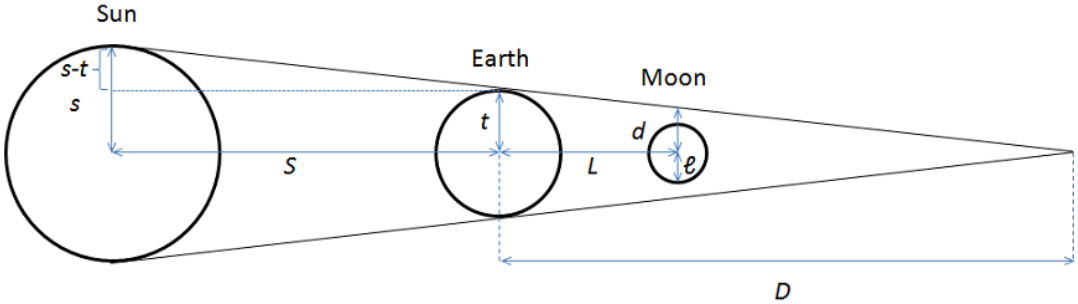
Aristarchus in about 2500 BC estimated the size of the Sun and its distance from Earth using eclipses and geometry. He also assumed Sun a center of solar system.

Half Moon [edit]

Aristarchus began with the premise that, during a half moon, the moon forms a
Sun and Moon, φ, the ratio of the distances to the Sun and Moon could be ded







365.242 days in a year - not on tests

- "Ancient" calendars were Lunar

Babylon - 12 months 6 with 29 days and 6 with 30. Add 13th month occasionally (also used in India and similar in China)

Egypt - 12 months each 30 days plus 5 extra

Polynesia - 13 lunar months drop 1 occasionally

- Priests would determine when to add extra months and day
- Very tempting to have 360 days in a year and 12 months of 30 days. "nice" numbers

Lack of correlation between day-month-year "bothered" philosophers and theologians. Understanding this "random" motion (and the planets were even worse) by Copernicus, Kepler, Galileo, Newton gave us modern science

365.242 days in year- not on tests

- If normal year has 365 days need extra 24 days/century and extra 2 days/millennium
- 46 BC Julius Caesar (really Sogigula an Egyptian) - Julian calendar with leap day every 4 years. But 8 too many days every 1000 years so….
- Gregorian calendar adopted

Spain and Catholic Europe	1582
England	1751
Russia	1918

which immediately skipped 10 days (in 1582). No leap day on century years 1700, 1800, 1900, 2100, 2200 (just those divisible by 400 like 2000)