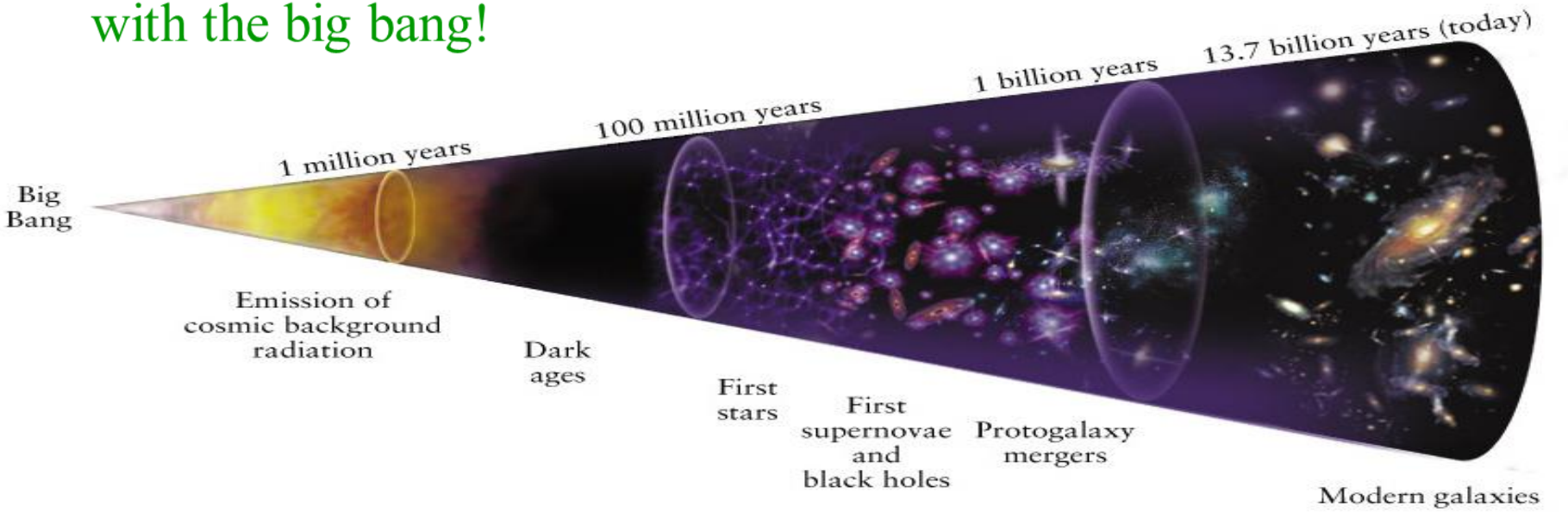
PHYS 162 Elementary Astronomy

- instructor: Dave Hedin, hedin@niu.edu
- No book required. Recommended book on syllabus
- Course taught via web page and e-mail. Have usually 2 “lectures” per week posted on web page, and course work e-mailed to me. Tests use Blackboard.
- The online version of this course began in 2017 and was designed for students who had difficulty due to their work or family situation to be on campus at specific times. As such we do not have a meeting time, and we will not have Zoom lectures. I have surveyed past classes and this met about 85% of the students needs. I also asked if they wanted me to post taped lectures and the response was overwhelmingly “No”.

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!



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

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 led to understanding of gravity and forces (physics, in this course). Modern studies of planets concern geology and weather (not in this course) or studies of exoplanets (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" and related to what stars/planets are suitable for life.

MAIN WEB PAGE

the course will be taught through this page

- https://nicadd.niu.edu/~hedin/162/162.html
- Syllabus, assignments and example tests
- lectures and links to other pages
- Can e-mail inquiries and assignments to hedin@niu.edu
- Google “David Hedin” or “PHYS 162” to find web page. Be sure you are on the Spring 2023 page

Blackboard Page

- Points from exams and assignments posted here.
- Used by me to send e-mails to class
- We will not use Blackboard as a place for you to "post" assignments; instead, you e-mail them to hedin@niu.edu
- Grade assigned by Blackboard is meaningless
- If you take 4 exams Blackboard won't know to drop the lowest score and so Blackboard point sum is then meaningless

EXAMS

- Will be a mixture of multiple choice and short answer
- Each worth 100 points and 4 exams including the final. The top 3 grades will count. A missed exam counts as 0. If you do the first 3 exams you can skip the final.
- All tests will be given through Blackboard. The “start” time of most exams (except the final) will be the day before the exam and I’ll give the time window close to the exam date.
- If you are unable to take the exam on the day of the test you need to communicate with me prior to that day.
- The exam is clearly open notes and so perfectly fine to look up answers while completing the exam.

ASSIGNMENTS

- Due 2-3 weeks after they are assigned, 6 assignments. 120 points total, ½ credit if late. Don't fall behind especially on first assignment.
- Send me by e-mail the assignment (pdf files are best). You can also take a photo of a completed assignment and e-mail that to me.

LECTURE FEEDBACK

- For each lecture e-mail me a short paragraph on one item you learned from that day's presentation. Also, there will be a phrase in each lecture which you should just restate after your paragraph.
- 4 points each. 100 points total. Due every other Friday and so 3-4 lectures in each group, and you can send me all of the group in the same e-mail. Due dates listed on web page, ½ credit if late.

Assignments and feedbacks can be turned in early and, if you wish, you can work through the entire term. **Late work will be accepted up to the day of the final.**

GRADING

- Exams (lowest score of 4 exams dropped) 300 points
- Assignments 120 points
- Lecture feedback 100 points

Class Curve 400+ A
360-399 B
310-359 C
260-309 D

The letter grades posted on Blackboard are meaningless. If you take 4 exams, Blackboard does not drop the lowest exam and so the Blackboard sum of points is incorrect

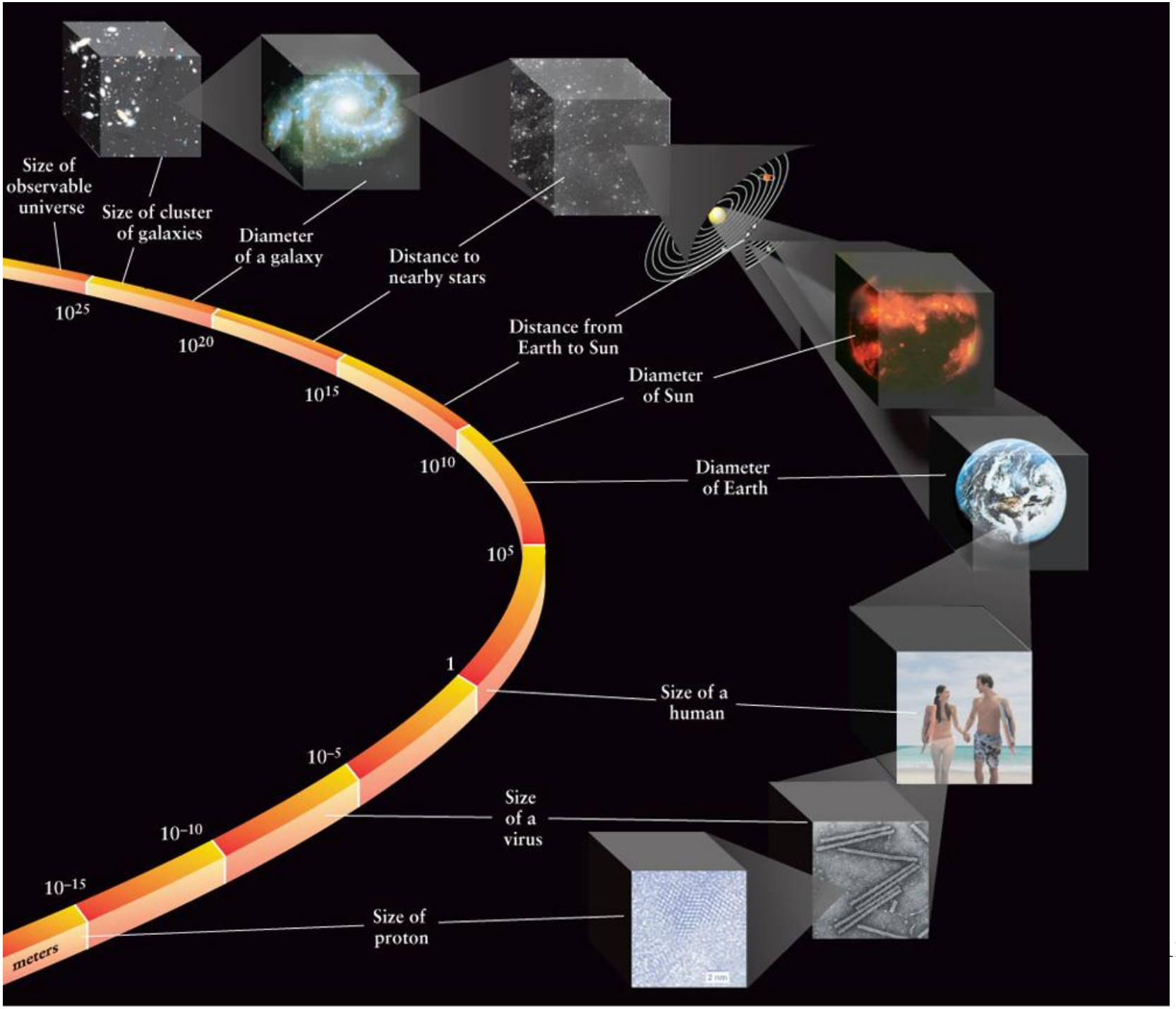
There will not be any "minus" grades in this class. I will award "plus" grades (like B+) as appropriate and will determine how to do so at the end of the term.

Hints on taking this course

- Get your assignments and lecture feedbacks in on time so you get full credit. The feedbacks are “easy” points
- Do not fall behind
- Do well on early tests and then skip the final

Quick Overview: Distances and Temperature

- Astronomy examines objects that range in size from the parts of an atom ($\sim 10^{-15}$ m) to the size of the observable universe ($\sim 10^{28}$ m).
- Scientific notation is a convenient shorthand for writing very large and very small numbers
- Try not to get lost as the concepts are more important than the “numbers”


Size of observable universe
Size of cluster of galaxies
Diameter of a galaxy
Distance to nearby stars
Distance from Earth to Sun
Diameter of Sun
Diameter of Earth
Size of a human
Size of a virus
Size of proton
10^{25}
10^{20}
10^{15}
10^{10}
10^{5}
1
10^{-5}
10^{-10}
10^{-15}
meters
2 nm

Distances: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.**
- Solar radius = 700,000 km = 7 x 10^5 km
- Distance Earth-Sun = 1 Astronomical Unit (AU) = 150,000,000 km = 1.5x10^8 km (= 8 light-minutes)
- Distance to the closest star = 4 x 10^{13} km = 4 Light Years = 4 LY

1 LY = distance that light travels in one year

= velocity x time

= 3 x 10^5 km/sec x 3.12 x 10^7 sec/year

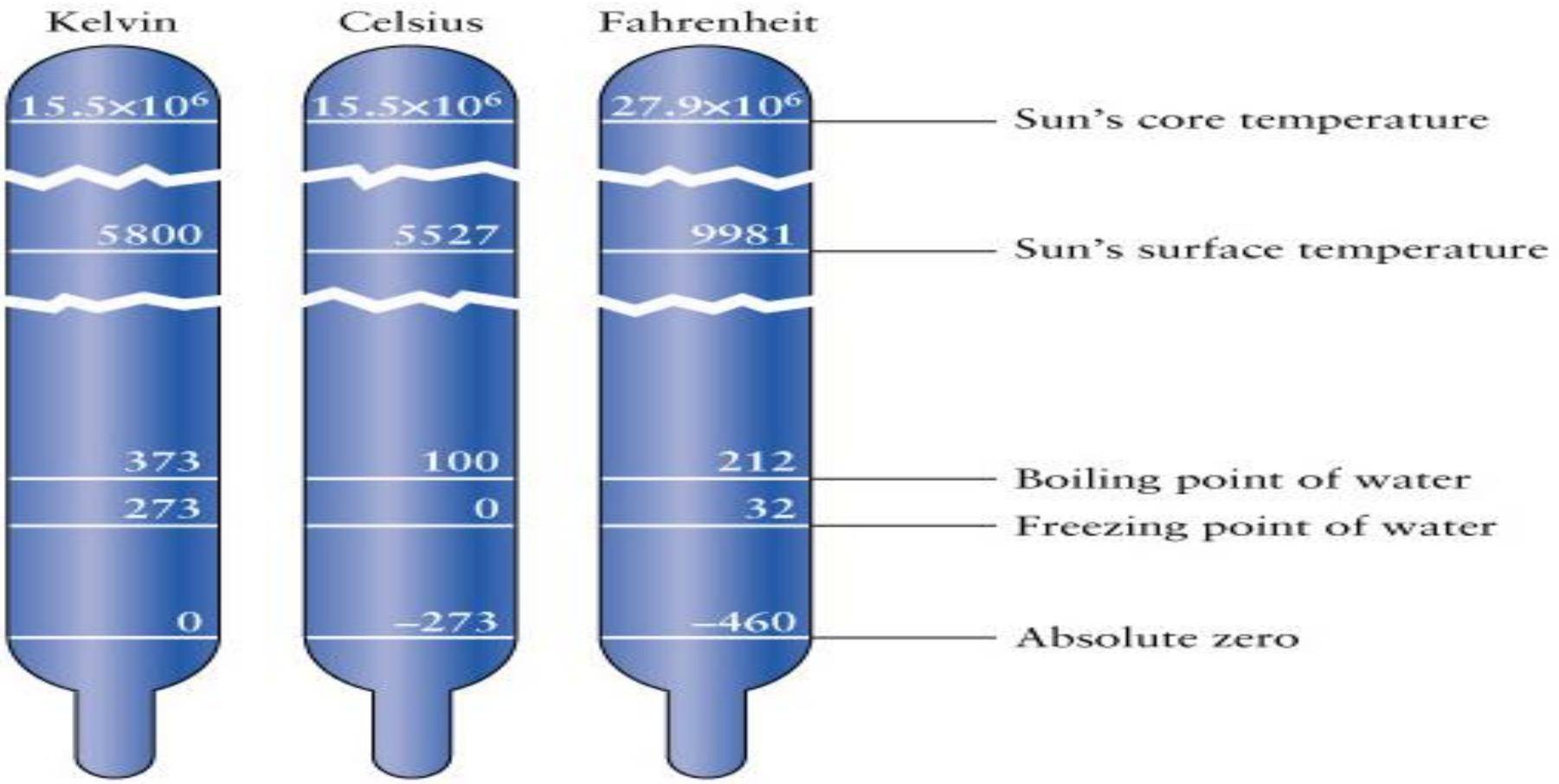
= 10^{13} km

- 1 parsec = 3.3 LY (another distance unit)

We mostly 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). Celsius=Centrigrade



Easy/Early Observations

- Sky is dark at night → means the universe is finite in space or time. More at end of course: now know finite in time as began about 13 billion years ago with Big Bang.
- Olber's paradox. If infinite space with infinite number of stars with infinite time for light from those stars to travel to Earth, then their combined light would be greater than light from Sun. Clearly not
- It is dark at night (!!) →

Easy/Early Observations

- Sun produces light and heat

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

Early confusion. Does the Earth spin? If it spins, why aren't people "thrown off"? (need force of gravity to understand) What "carries" Sun, Moon (other planets and stars) along their paths in the sky? (NOT crystal spheres as some people proposed; again, it is gravity.)

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

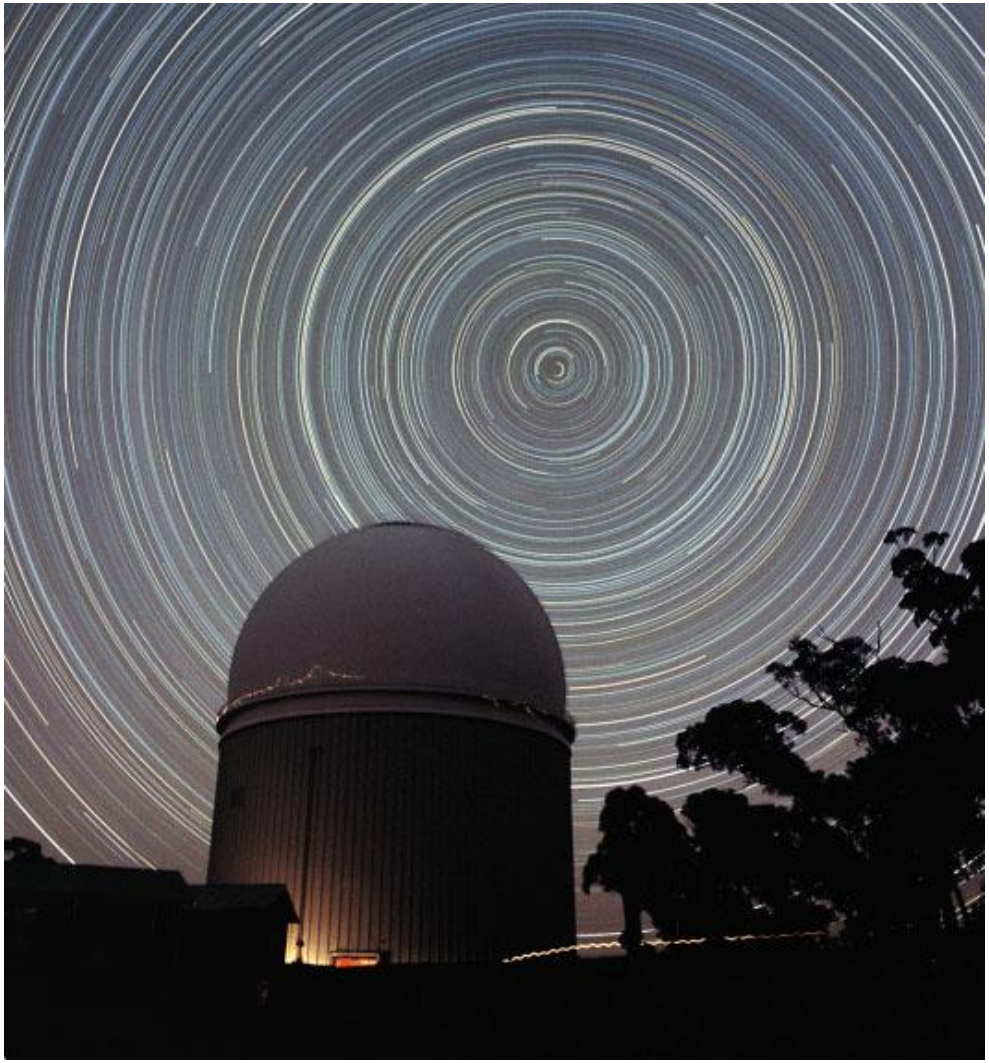
2023 comet

Comet C/2022 (E3) ZTF had its closest approach to the Sun on January 12 and will be closest to the Earth on February 2. This comet was last in the inner solar system about 50,000 years ago (ad so seen by Neanderthals).

Can be (maybe) seen in the morning sky in the northwest sky (near Polaris) and should be visible to the eye (if in a dark place). Many pages will tell you how to observe.

https://www.skyatnightmagazine.com/advice/comet-c-2022-e3-ztf/

Star Motion during One Night → Earth spinning



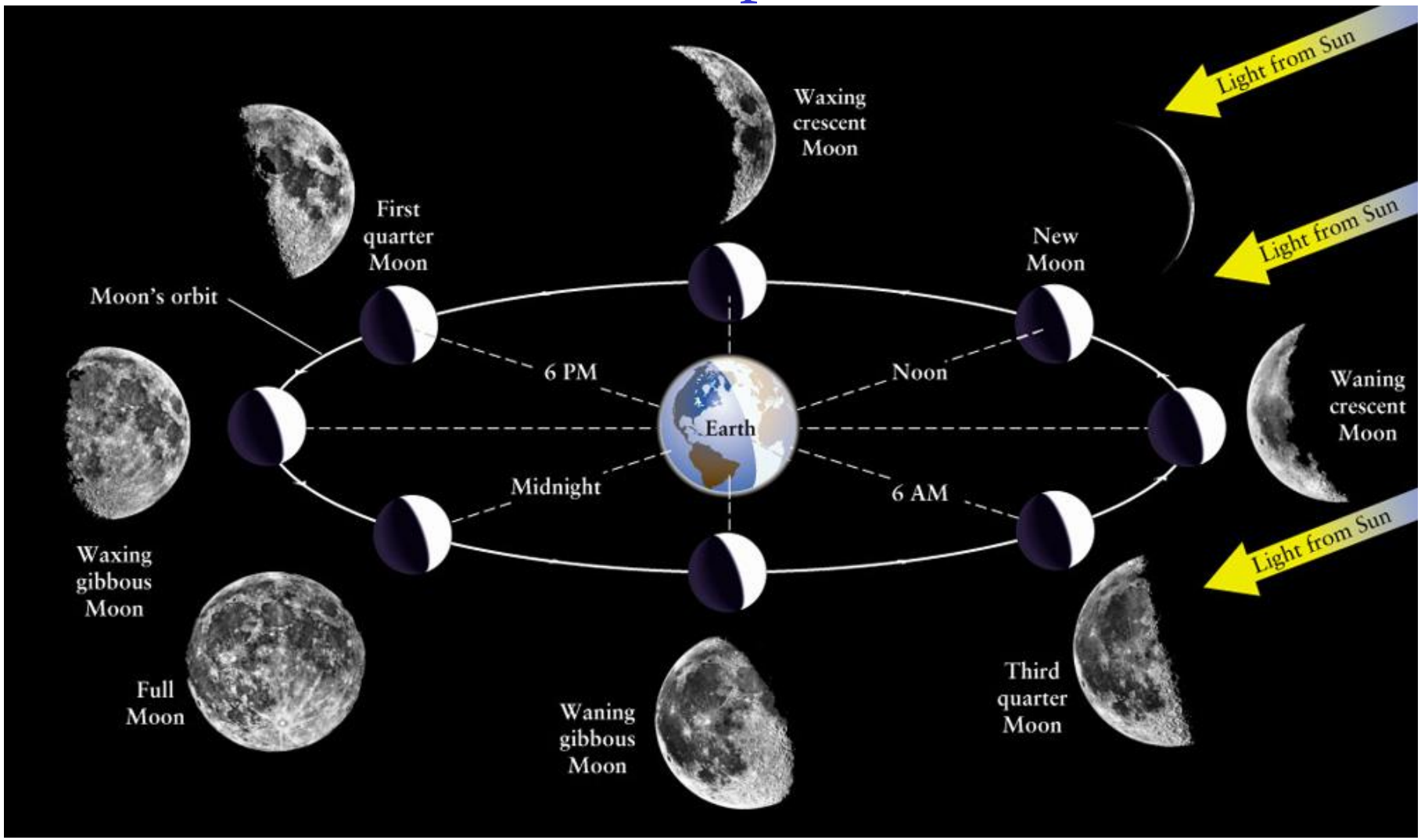
8 hour time exposure showing star paths

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

Phases and Orbit of the Moon

- Moon phases readily understood by relative position of Sun and Moon to observer on Earth with a ~month cycle
- 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%. January 20-21 2019 had a "super moon" where Moon was at its closest distance to Earth at the time of a full moon combined with a lunar eclipse
- 2200 years ago, Aristarchus using the triangular geometry of the Earth-Sun-Moon when the Moon was at a half phase gave estimate of relative distance to Sun and size of Sun (see extra slide)
- Moon's orbit about Earth tilted by 5 degrees compared to Earth's orbit about Sun → Moon is often above or below the Sun's path through sky (Sun's path is called the ecliptic)

Phases of Moon (skip tides). Don't need to remember phase names

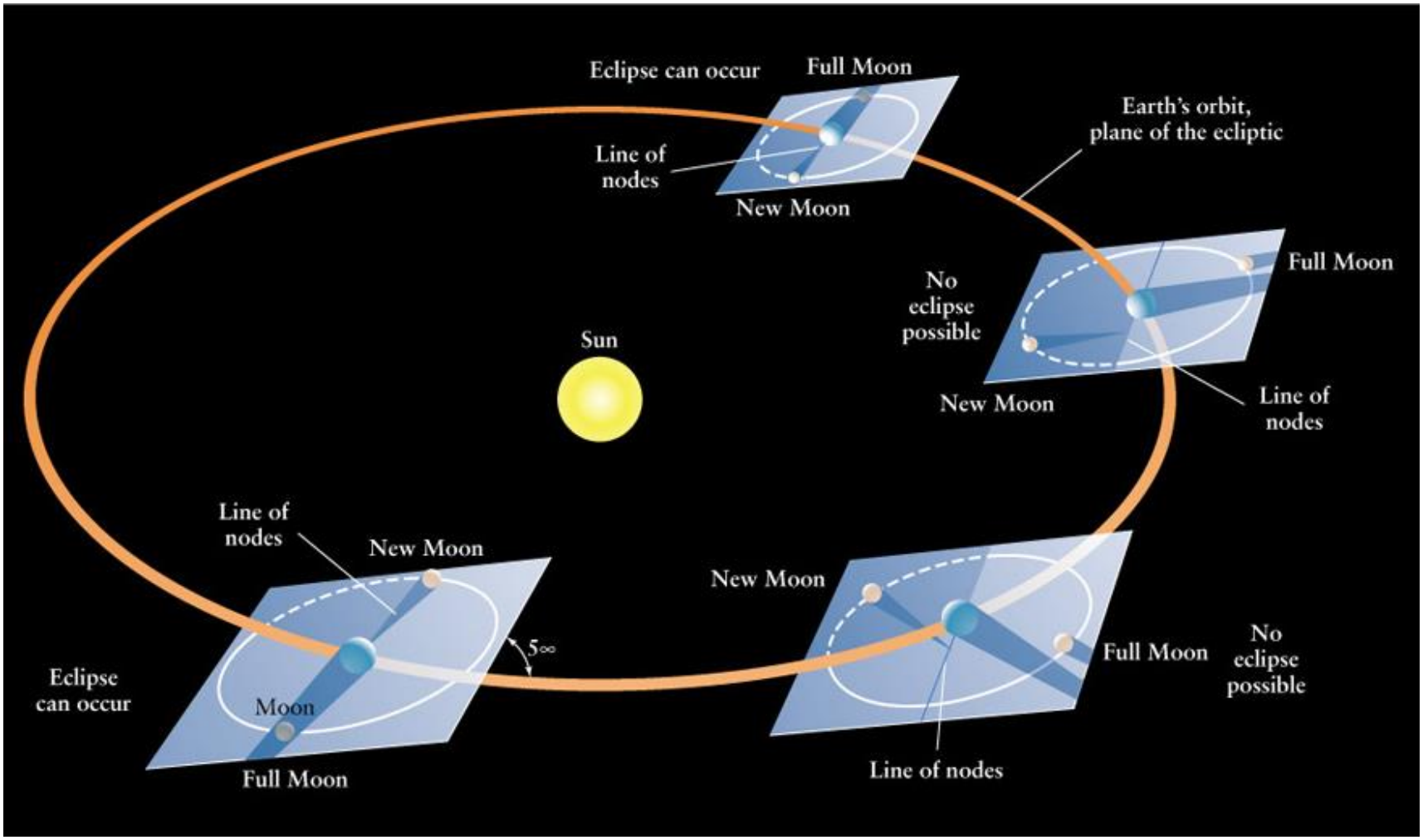


Eclipses

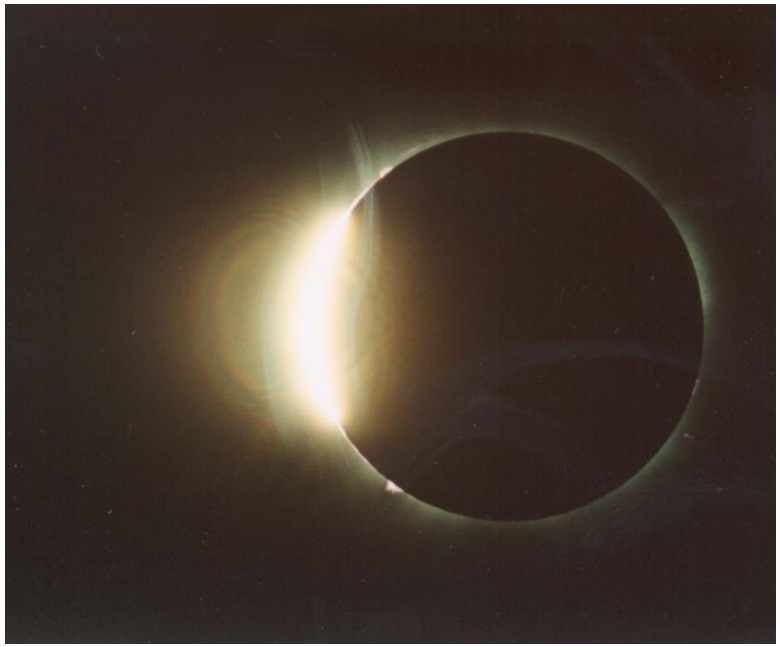
- Moon's orbit about Earth tilted by 5 degrees compared to Earth's orbit about Sun. Most orbits do not produce an eclipse
- But sometimes Moon-Earth-Sun all on same line → eclipse. If Moon between Earth and Sun get Solar eclipse. Happens during New Moon phase. If Earth between Moon and Sun get Lunar 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.

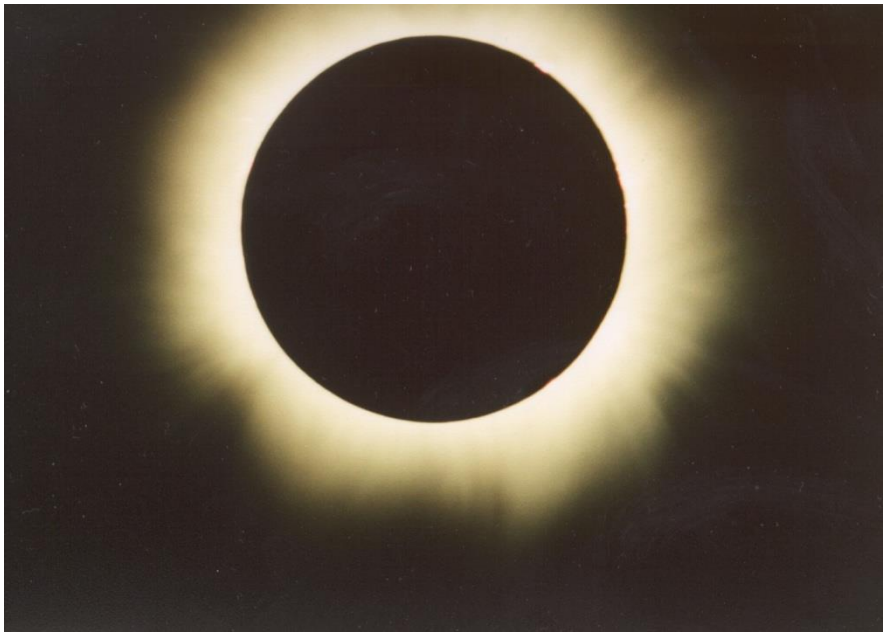
Lunar and Solar Eclipses

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



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)

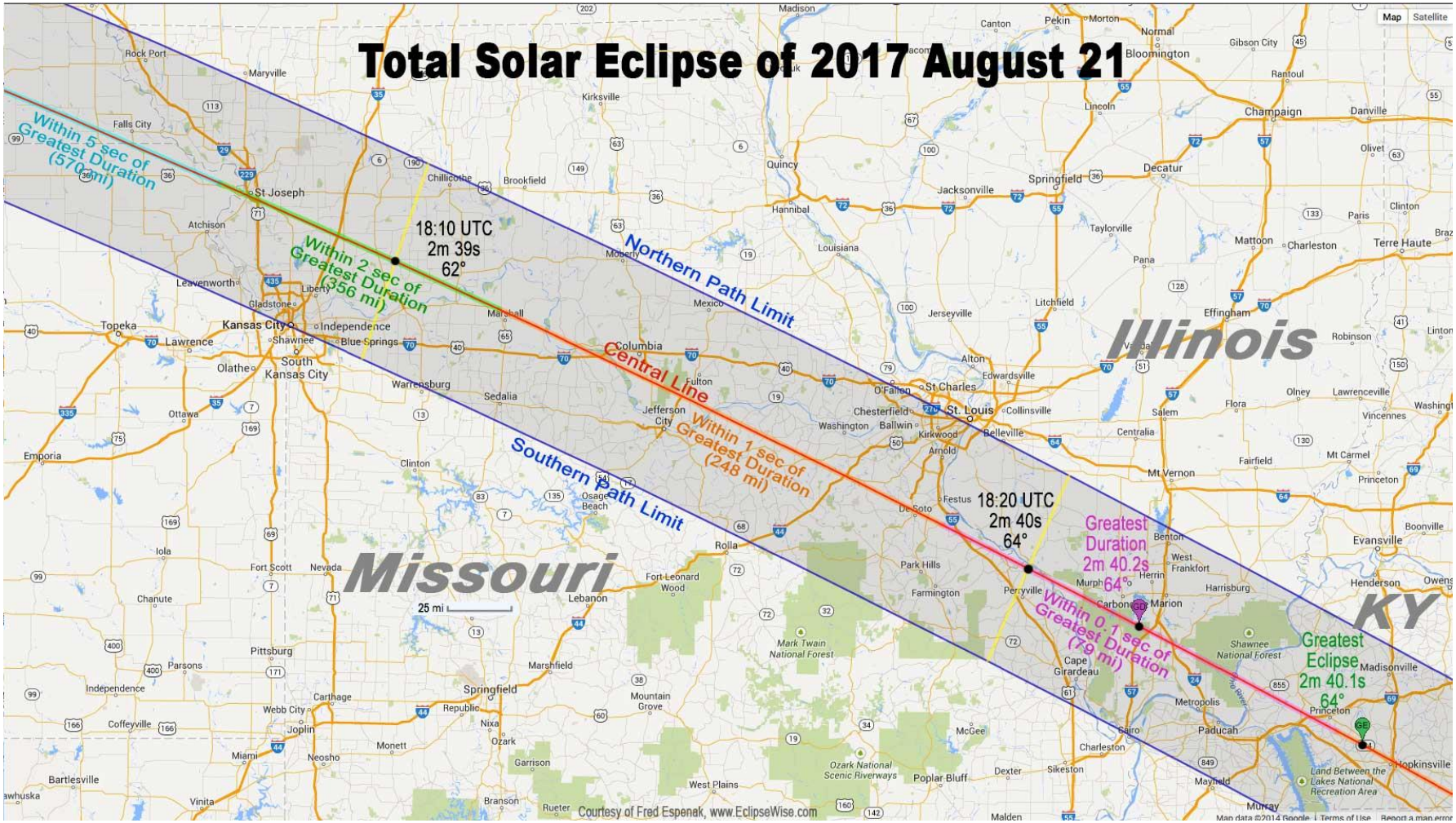
Total Solar eclipse – Turkey 8-11-1999 (NIU sponsored trip)

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

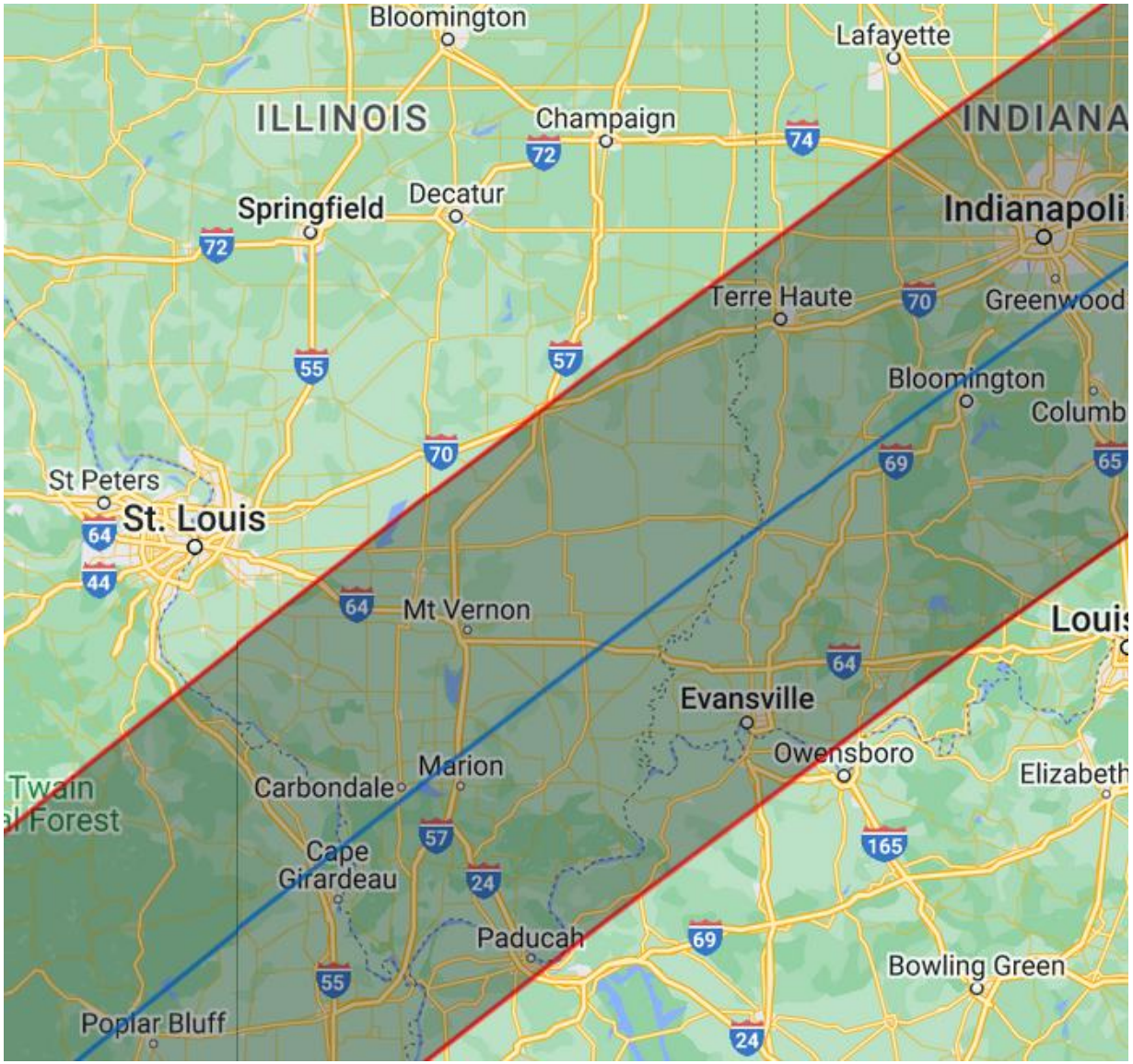
Previous last total on continental US in 1979

Eclipse 8-21-2017

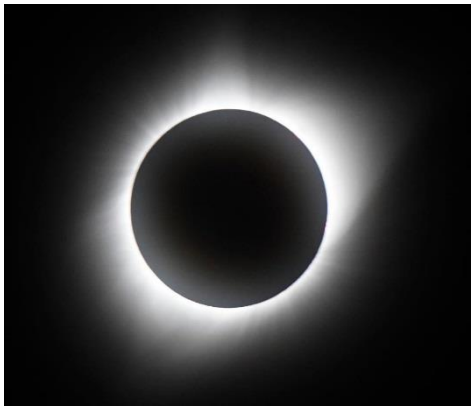
Eclipse 8-21-2017 went through Carbondale

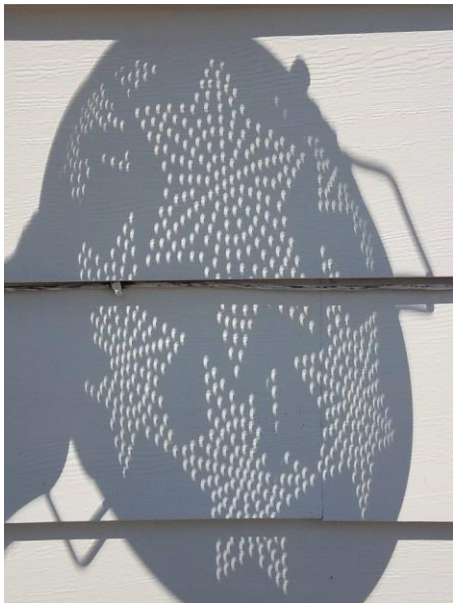


Eclipse 4-8-2024 path through Illinois



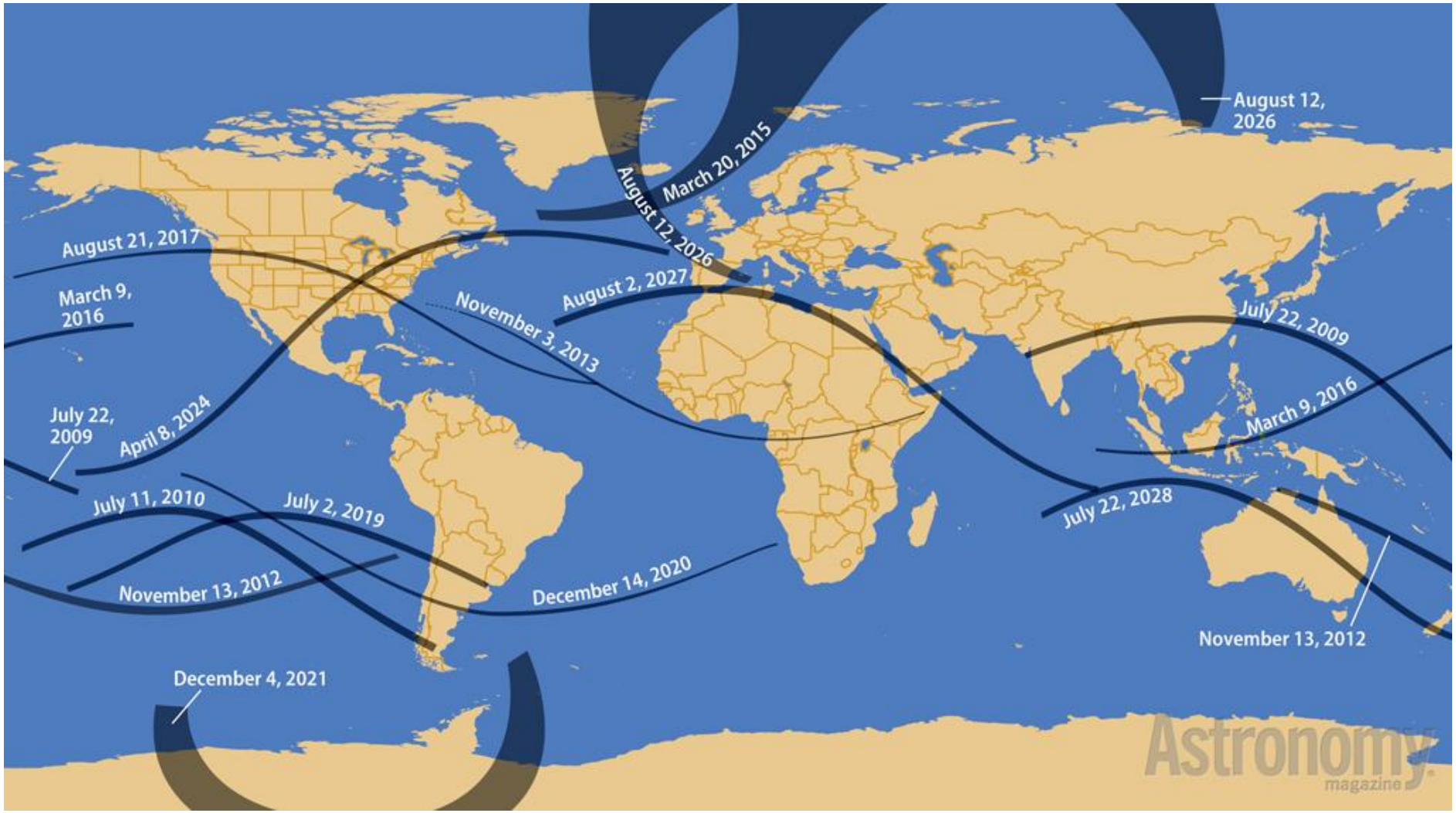
Solar Eclipse 8-21-17 Sparta Illinois





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 partially eclipsed image, or colander, or leaves of a tree.

Total Eclipses: 14 from 2009-2028



Markers of Time

DAY: Sun at maximum height (week discussed with planets)

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 (modulo wobbles)
- Moon receding from the Earth by 4 cm each year

500,000,000 years ago there were about

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.

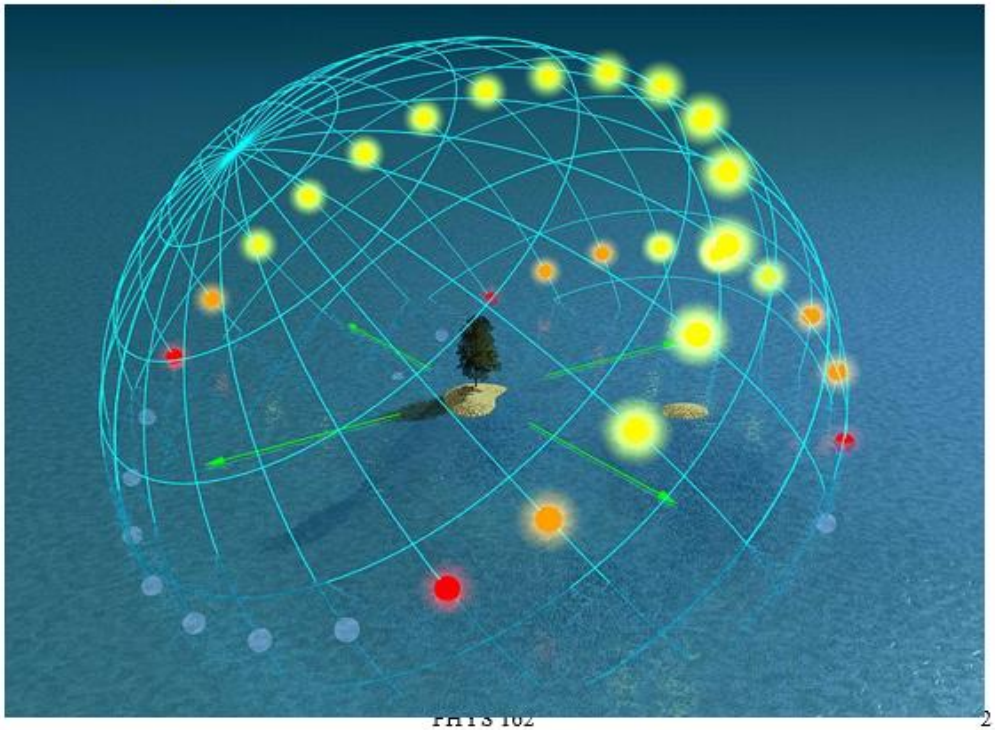
Earth having a large moon helps to keep it spinning. See later and related to habitable exoplanets

The Year

Two Indicators

1. Due to the Earth's 23.5 degree tilt with respect to the plane of its orbit about the Sun, the Length of the Day and Sun's path through the sky vary – long in summer and short in winter. One year later returns to the same spot

Sun's path summer and winter solstices



The Year

Two Indicators

1. Due to the Earth's tilt the Length of the Day and Sun's path through the sky vary. One year later returns to the same spot

More dramatic further north (Stonehenge). In tropics have ~12 hour day all year and similar path for the Sun though the sky - almost directly over head. In December, length of day = 9 hours in DeKalb, 7.75 hours in London, 4 hours in Iceland. For London/DeKalb/Iceland, Sun always to our South with long path in summer and short path in Winter. Point on horizon where rises/sets moves further to north in summer and further to south in winter. At spring and fall equinoxes, have 12 hour days and sun rise directly from east, set directly in west for all latitudes.

The Year

Two Indicators

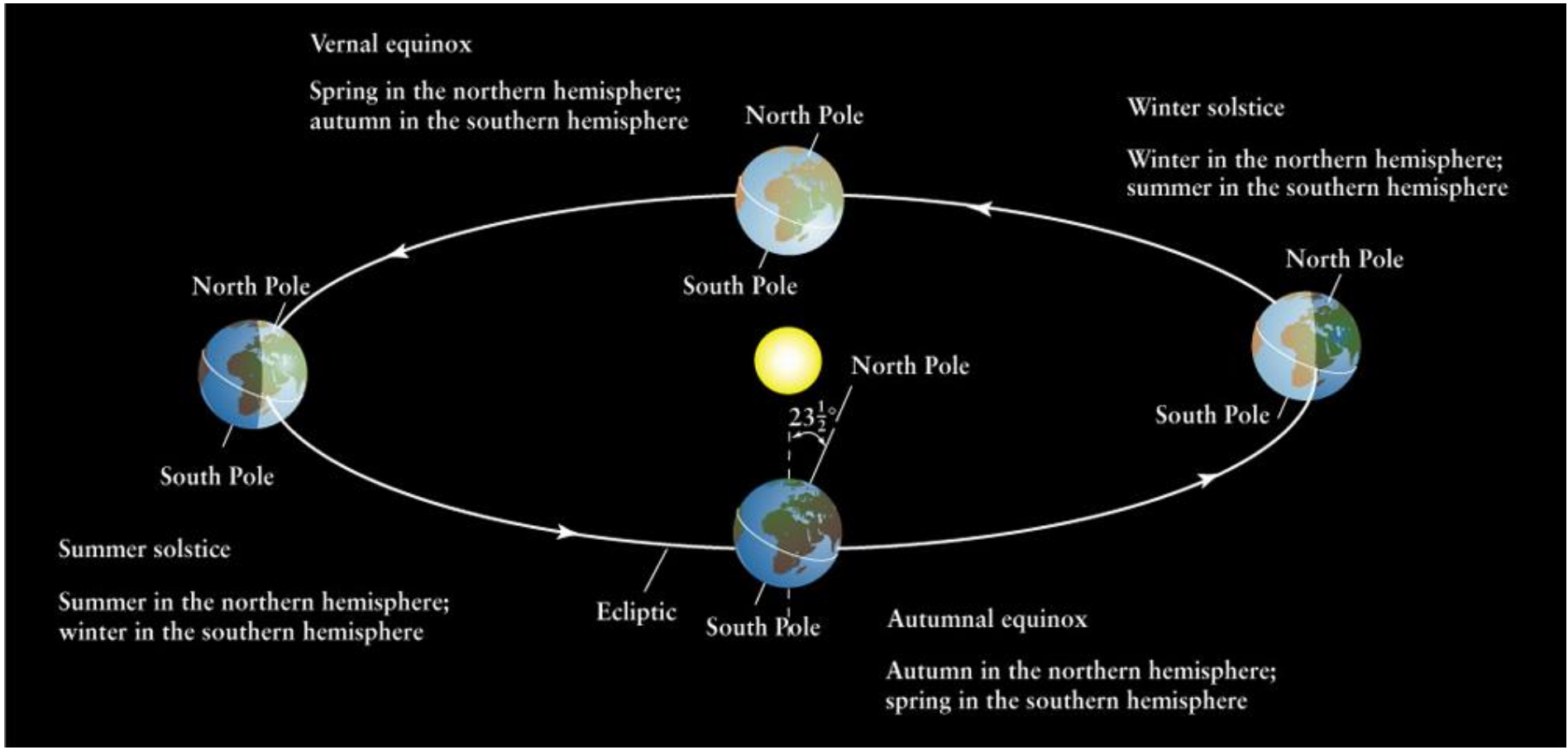
2. Which stars are overhead changes with seasons. Gives passage of year. Due to the "night" side of Earth points at different stars as orbits Sun. More next class.

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

Stars = Calendar and Clock

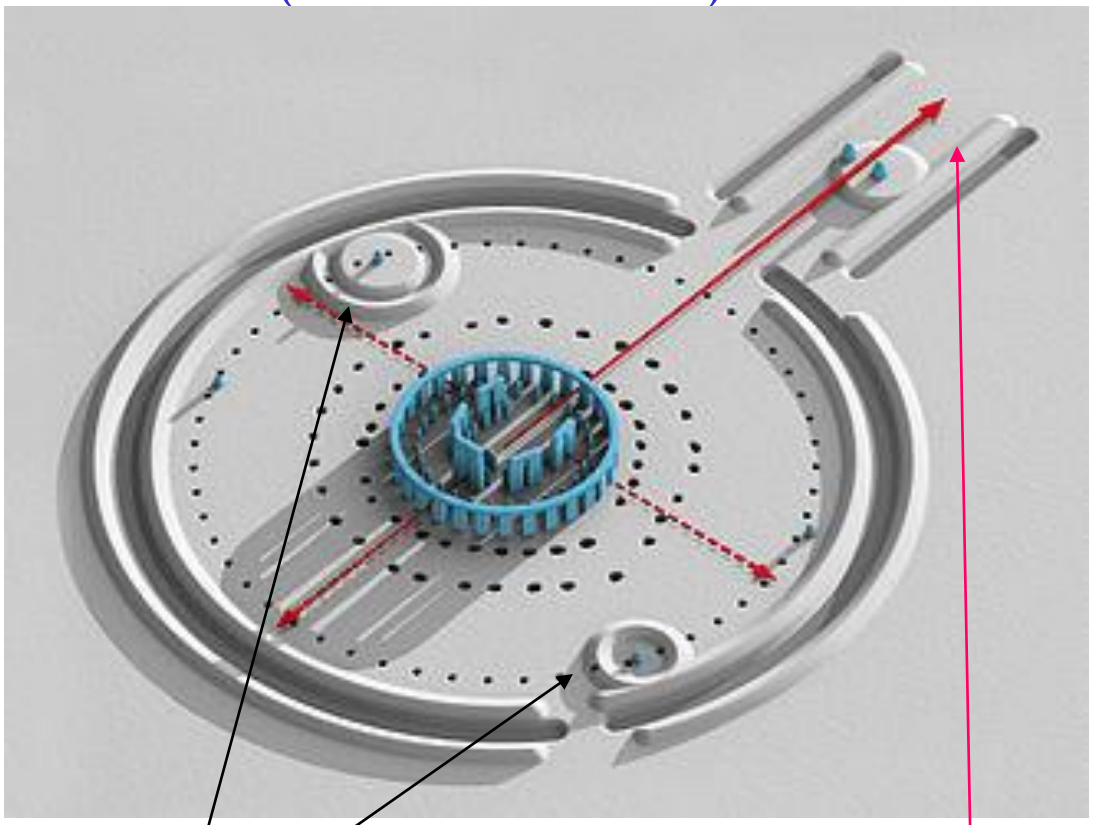
Yearly Motion: Earth orbits Sun

The “night” side of Earth points at different stars as orbits Sun. Note the tilt of Earth



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

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. Now essentially Jewish and Muslim calendars). They gave us hour, minute, second and zodiac/astrology.

  Egypt - 12 months each 30 days plus 5 extra days

  Polynesia - 13 lunar months drop 1 occasionally

- Priests would determine when to add extra months and days
- 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 and so extra 25 days/century. And so 8 too many days every 1000 years
- And 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)

Lecture Feedback

E-mail me a paragraph describing one topic you learned from this set of presentations. Also please write down the phrase “The Universe is finite in time” at the end of your mini-report; this is in addition to your “one topic”.

Extra Slide – don't need to know

Aristarchus in about 200 BC estimated the size of the Sun and its distance from Earth using eclipses and geometry. He also assumed Sun was at the 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