

Today's Topics

Friday, August 21, 2020 (Week 0, lecture 2) – Chapters 1 & 2.

- A. Distances using the speed of light
- B. Scientific notation ... Exponents review
- C. Length scales in the universe
- D. Trigonometry review (see problem session)
- E. Ancient Greek physics: radius of the Earth

Distances with the Speed of Light

Circumference of the Earth = 0.13 s = 130 milliseconds



OpenStax; R. Stockli, A. Nelson, F. Hasler, NASA/GSFC/NOAA/USGS)

Distances with the Speed of Light

Earth – Moon distance = 1.3 s



Earth and Moon, Drawn to Scale. [OpenStax; NASA]

Distances with the Speed of Light

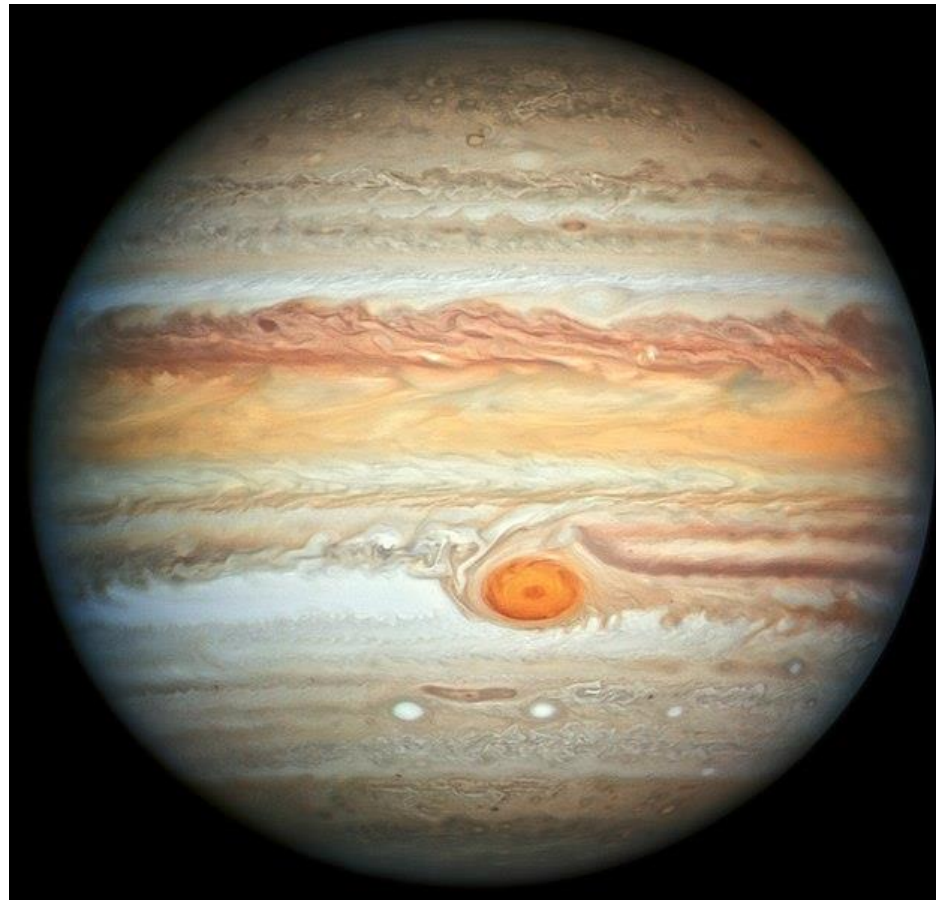
Sun – Earth distance = 499 s \approx 8.3 minutes
= 149,597,870,700 m \approx 150×10^6 km
= 1 Astronomical Unit = 1 AU



Earth and Sun seen from International Space Station [Wikipedia, NASA]

Distances with the Speed of Light

Sun – Jupiter distance \approx 43 light minutes



Jupiter viewed by Hubble telescope [Wikipedia, NASA]

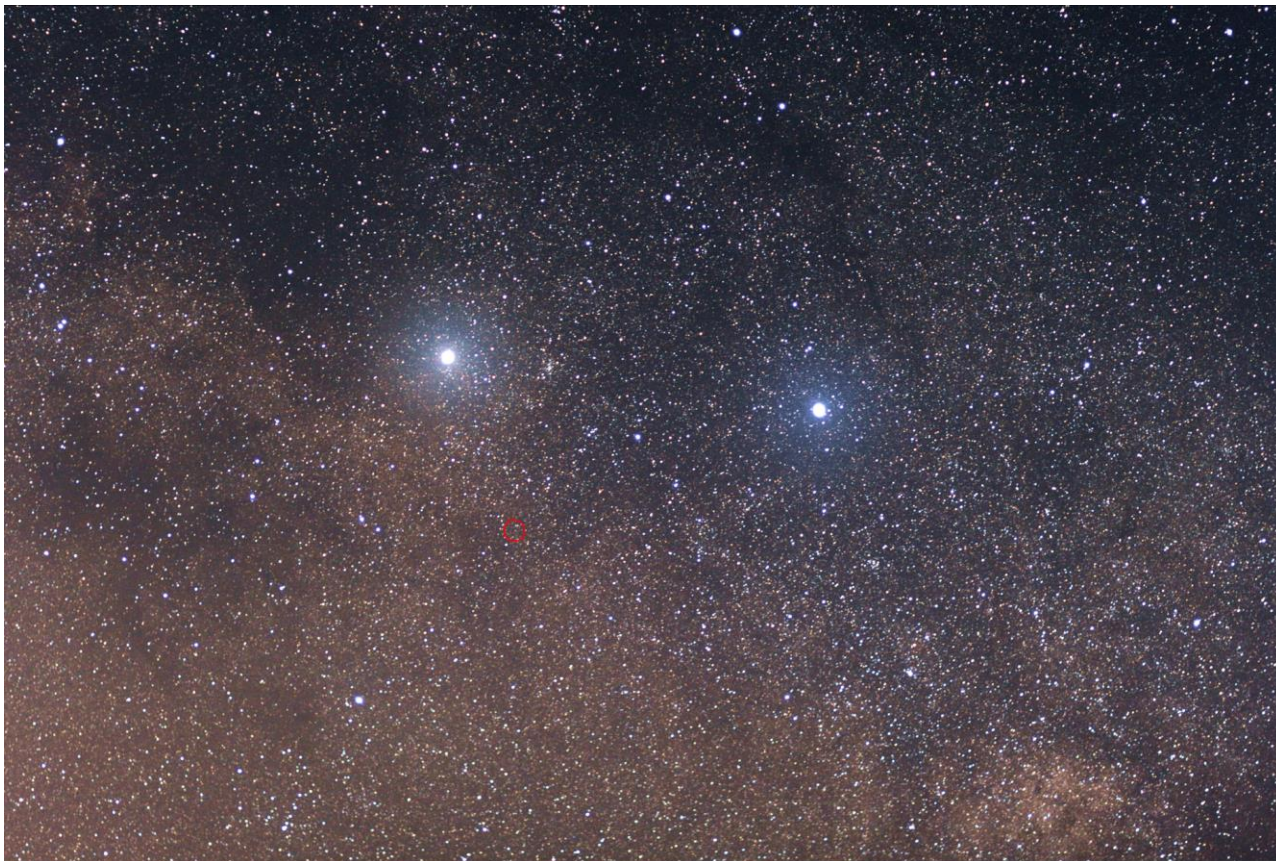
Distances with the Speed of Light

Sun – Pluto distance \approx 5.5 light hours



Distances with the Speed of Light

Sun to nearest star* (Alpha Centauri) = 4.3 years = 4.3 ly (light years)



Scientific Notation

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Shorthand notation for very large and very small numbers.

“3.57 times ten to the power of eight”

= 357,000,000

= 3.57×10^8

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= 3.57e8 = 3.57e+8 useful for computers

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“3.57 times ten to the power of minus five”

$$= 0.0000357$$

$$= 3.57 \times 10^{-5}$$

$$= 357 \times 10^{-7}$$

$$= 3.57 \times 10^{-5}$$

$$= 3.57e-5$$

Scientific Units -- Prefixes

Bigger

10^1 = deca (da)

10^2 = hecto (h)

10^3 = kilo (k) = thousand

10^6 = mega (M) = million

10^9 = giga (G) = billion

10^{12} = tera (T) = trillion

10^{15} = peta (P)

10^{18} = exa (E)

10^{21} = zetta (Z)

10^{24} = yotta (Y)

Scientific Units -- Prefixes

Smaller

10^{-1} = deci (d)

10^{-2} = centi (c) = 1/100th

10^{-3} = milli (m) = 1/1000th

10^{-6} = micro (μ) = millionth

10^{-9} = nano (n) = billionth

10^{-12} = pico (p) = trillionth

10^{-15} = femto (f)

10^{-18} = atto (a)

10^{-21} = zepto (z)

10^{-24} = yocto (y)

Bigger

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Length Scales in the Universe

Solar System Scale

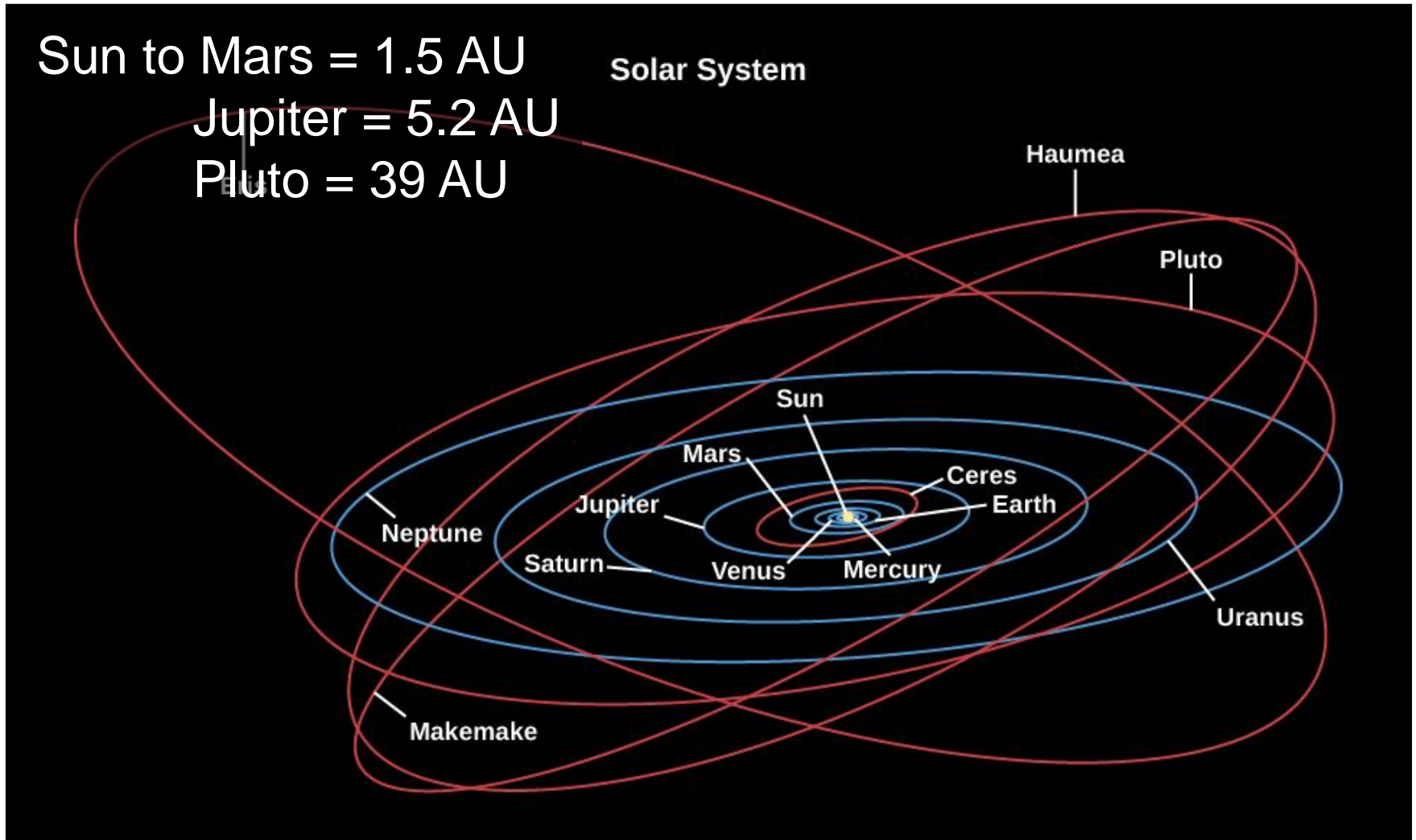
Reminder: Sun-to-Earth = 1 AU

Sun to Mars = 1.5 AU

Jupiter = 5.2 AU

Pluto = 39 AU

Solar System



Solar System Scale

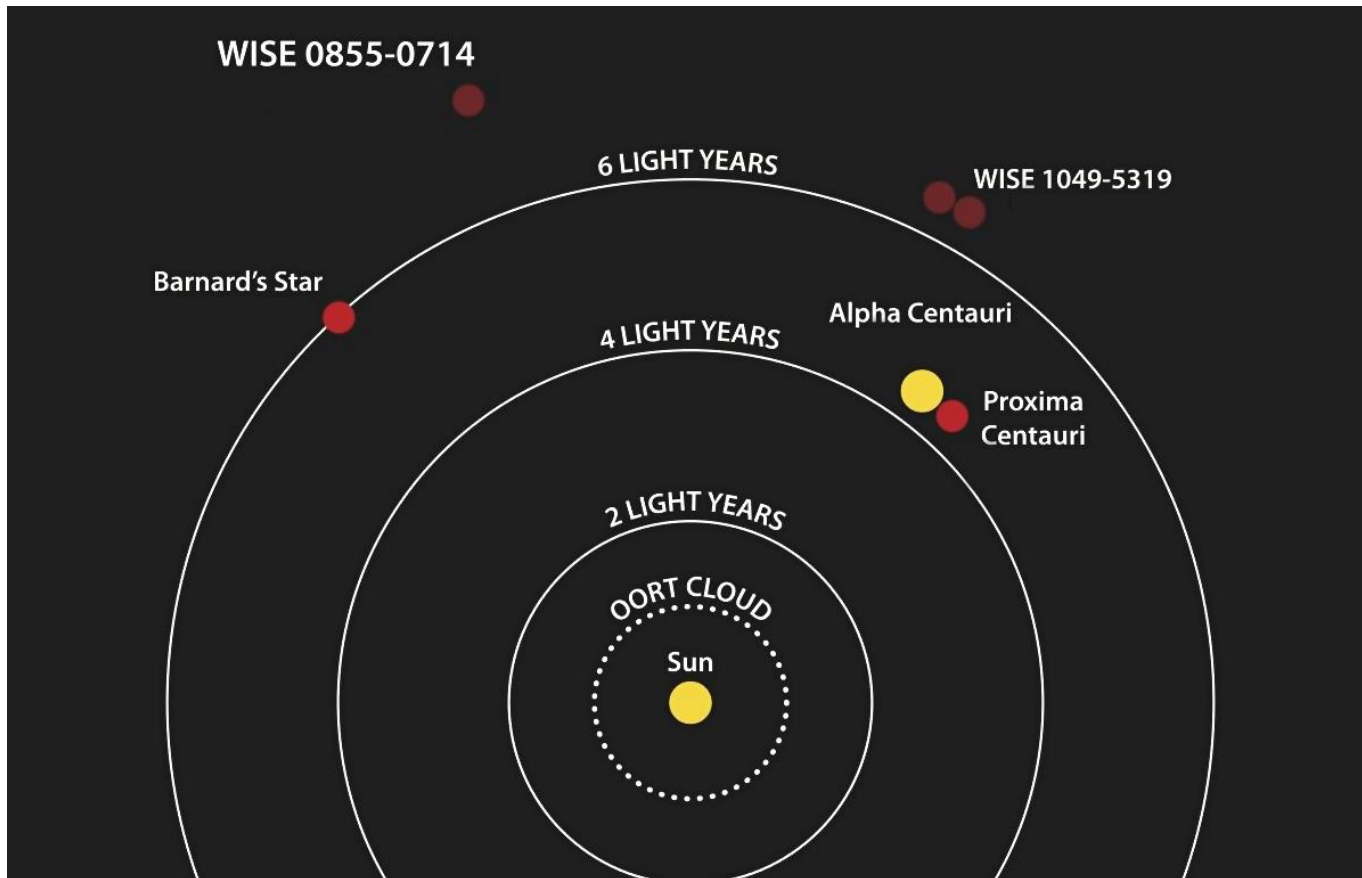
Relative size of planets & Sun

- diameter of Sun \approx 109 Earths
- diameter of Jupiter \approx 22 Earths



Nearby Stars Scale ~ 7 light years

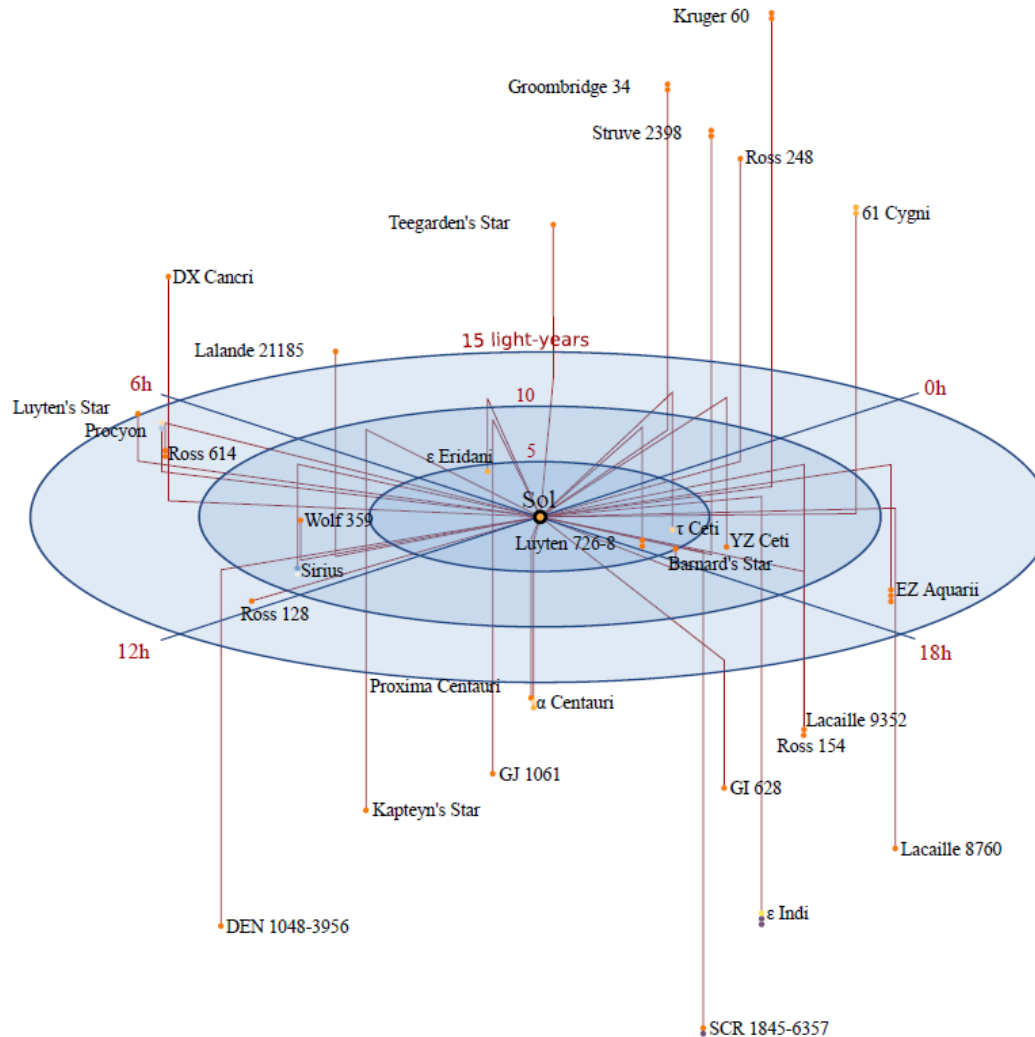
7 nearby stars



[Wikipedia; NASA, Penn State University]

Nearby Stars Scale ~ 15 light years

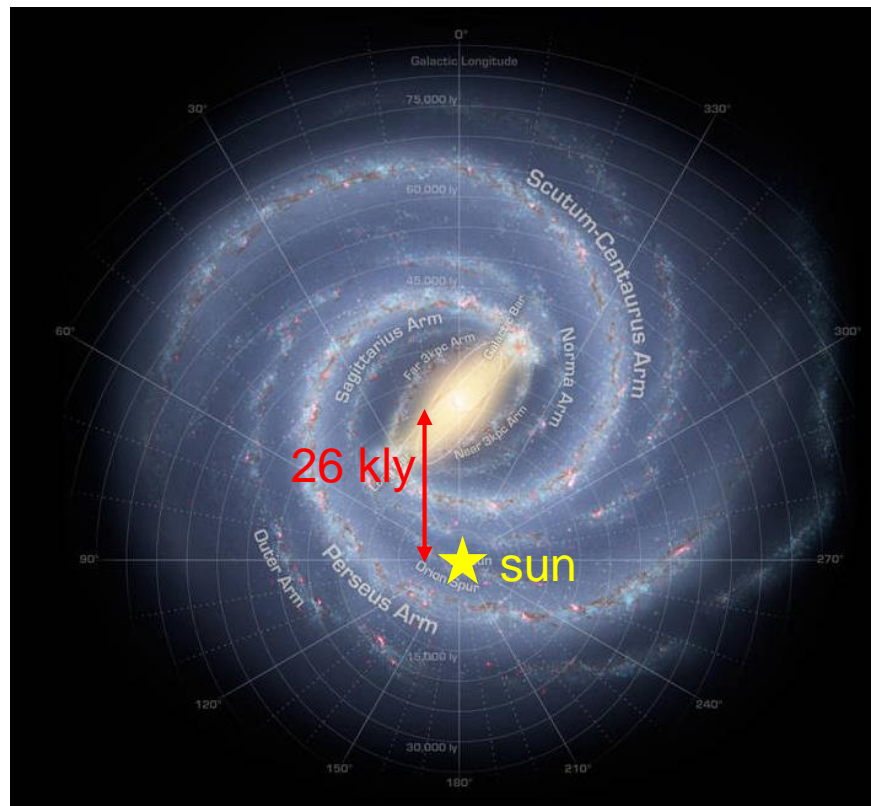
Several dozen stars in our stellar neighborhood



Milky Way Galaxy Scale

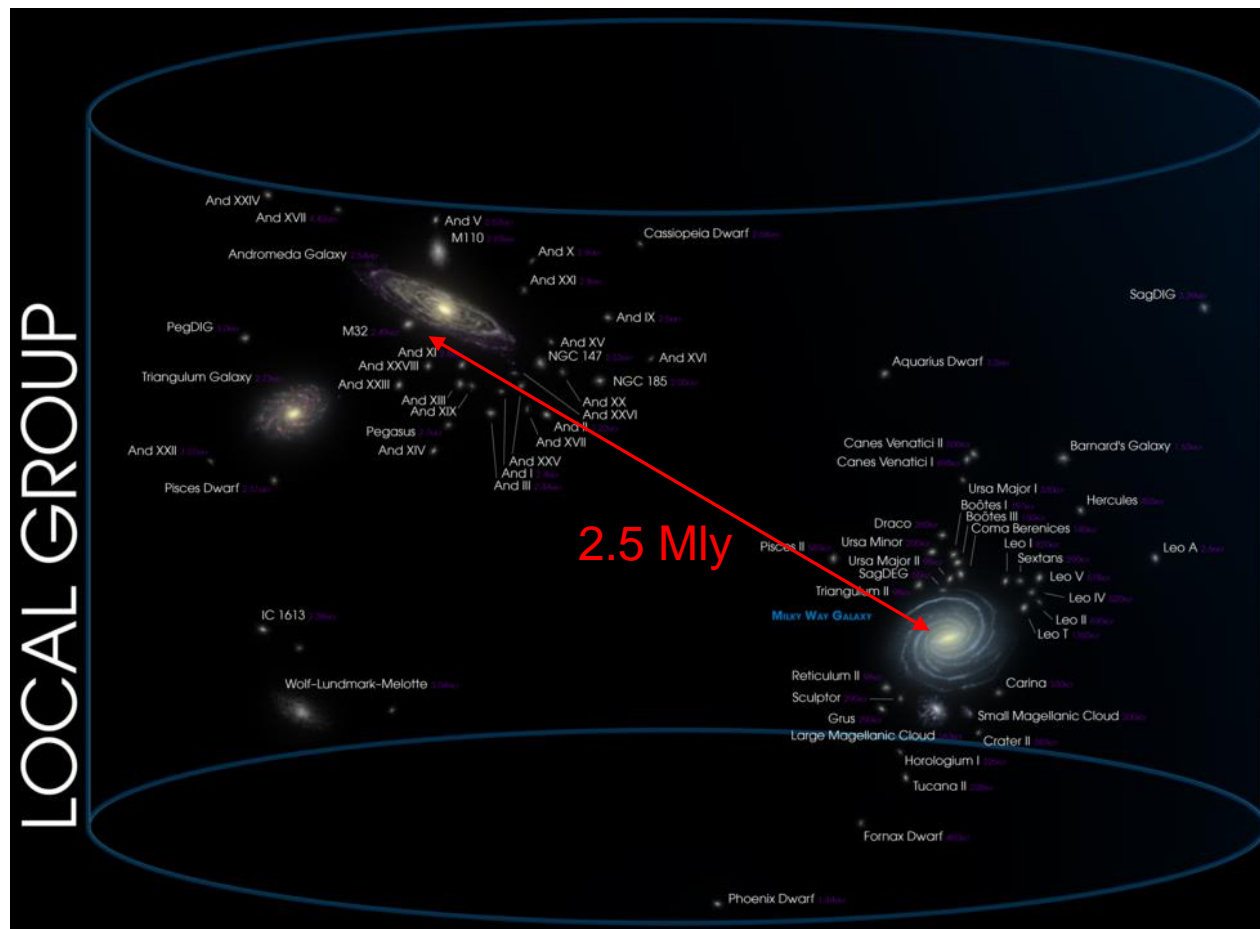
Diameter of our Galaxy = $150\text{-}200 \times 10^3$ ly

100-400 billion stars

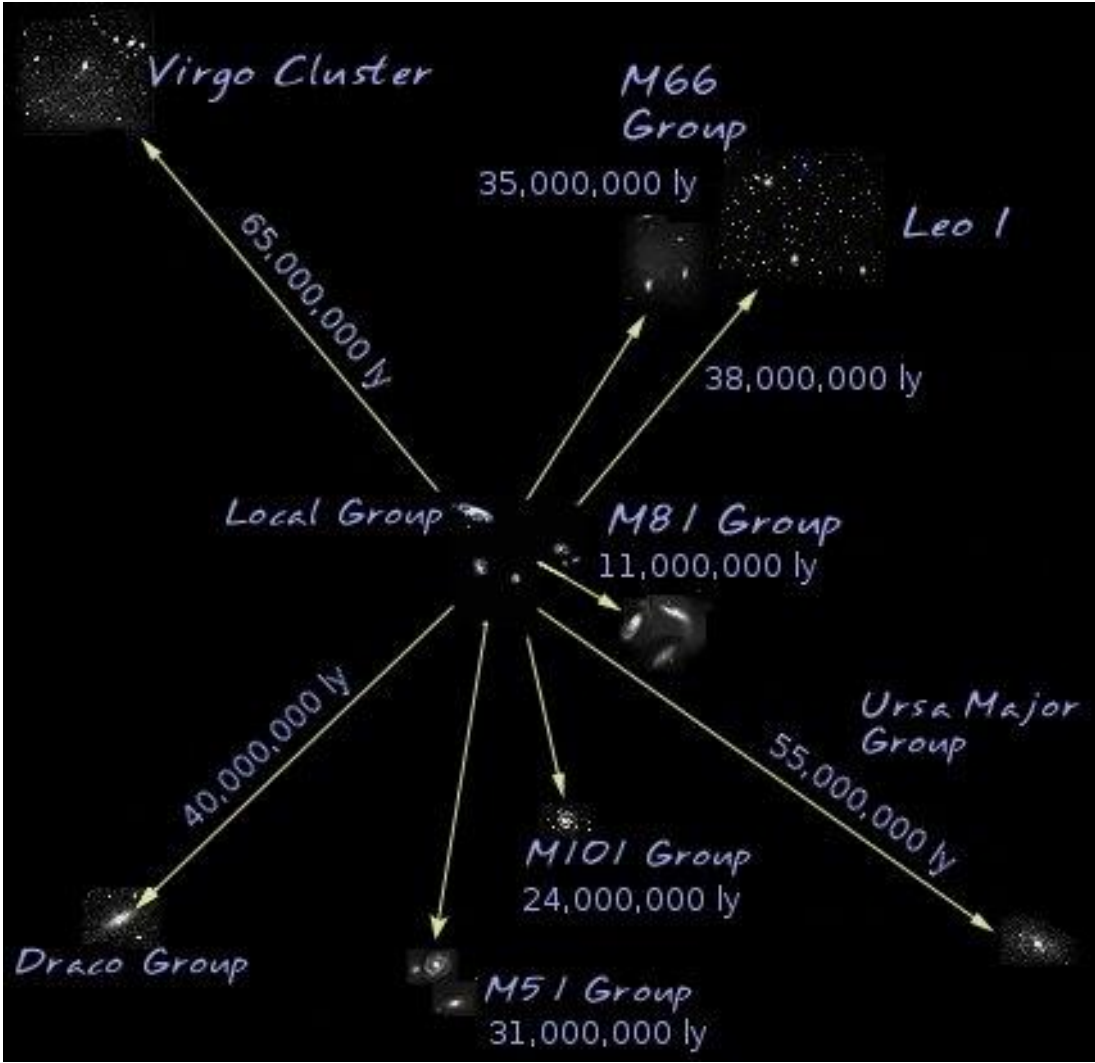


“Local Group” Scale

“Local Group” = cluster of ~ 50 nearby galaxies



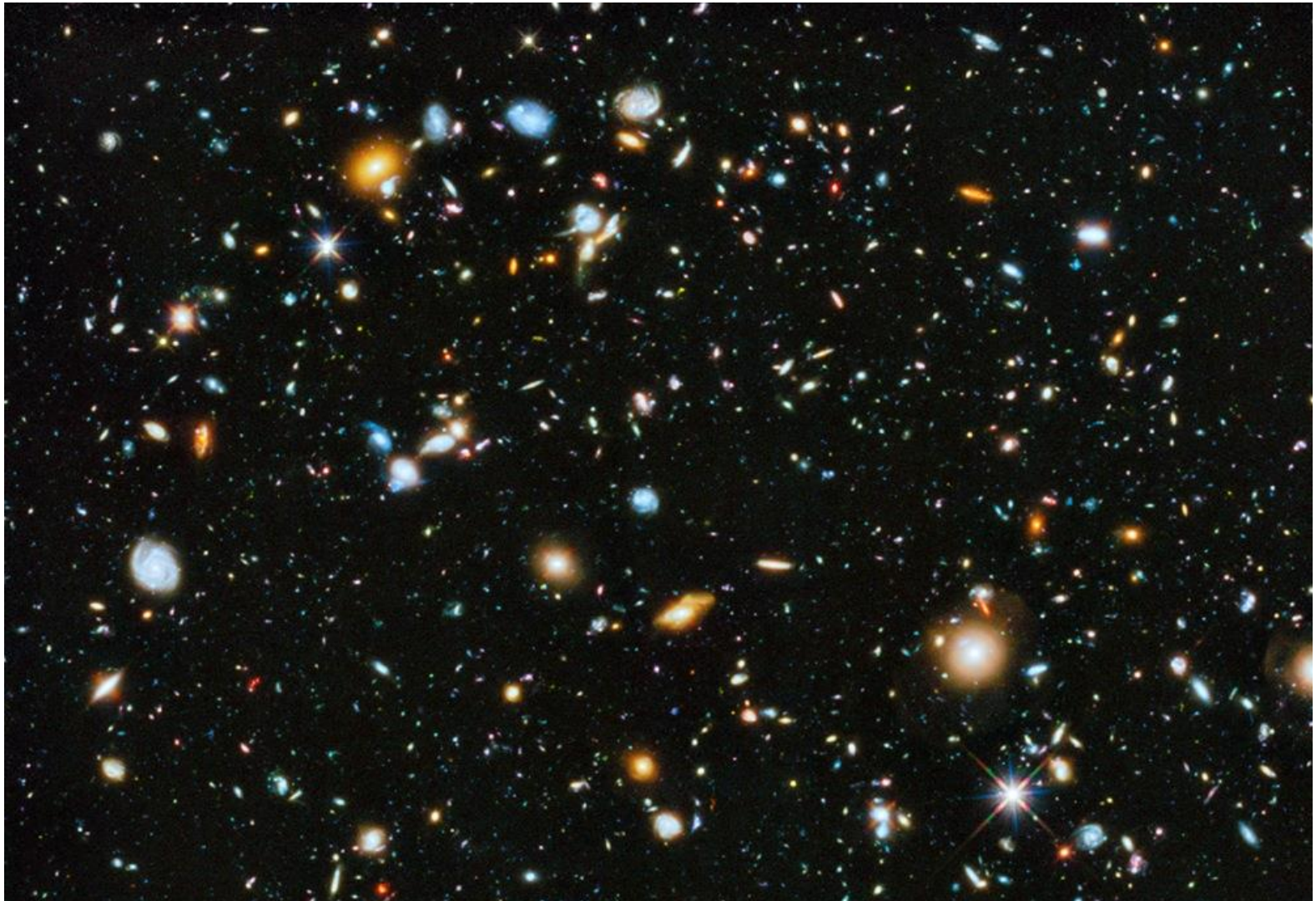
Local/Virgo Supercluster Scale



[Wikipedia; NASA]

Galaxies Everywhere

Point Hubble Space Telescope at “blank” part of the sky



[Hubble Deep Field 2014; NASA, ESA, H.Teplitz and M.Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst(ASU), Z. Levay (STScI)]

Universe Scale

~ 93 billion ly

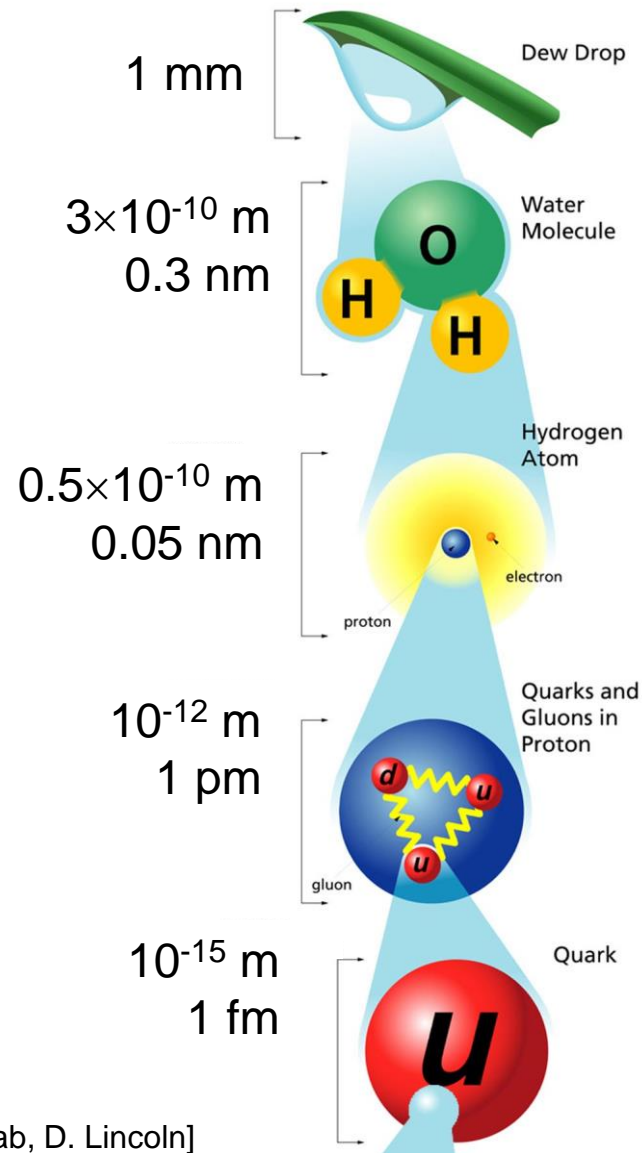
Number of galaxies in Universe ~ billions to trillions

“Space is big. You just won't believe how vastly, hugely, mind-bogglingly big it is.”

- The Hitchhiker's Guide to the Galaxy

Very Small Length Scales

“There’s plenty of room at the bottom.”
- Richard Feynman



[Figure adapted from FermiLab, D. Lincoln]

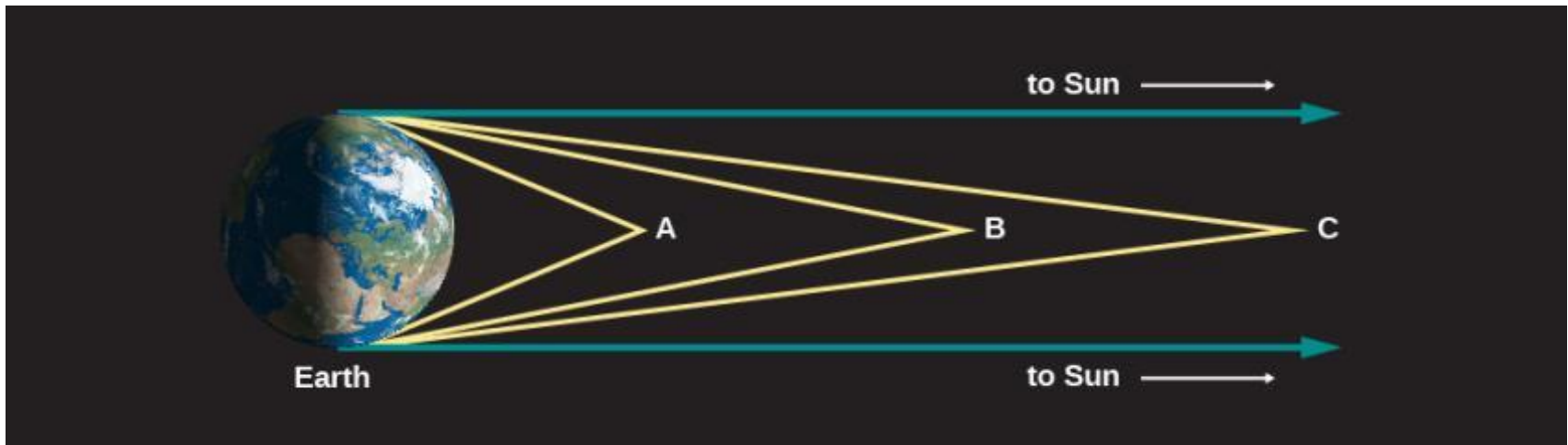
Trigonometry

Review

Ancient Greek Physics

Determining the Radius of the Earth

Parallel light rays from the sun



[OpenStax: Astronomy]

Light Rays from Space. The more distant an object, the more nearly **parallel** the rays of light coming from it are.

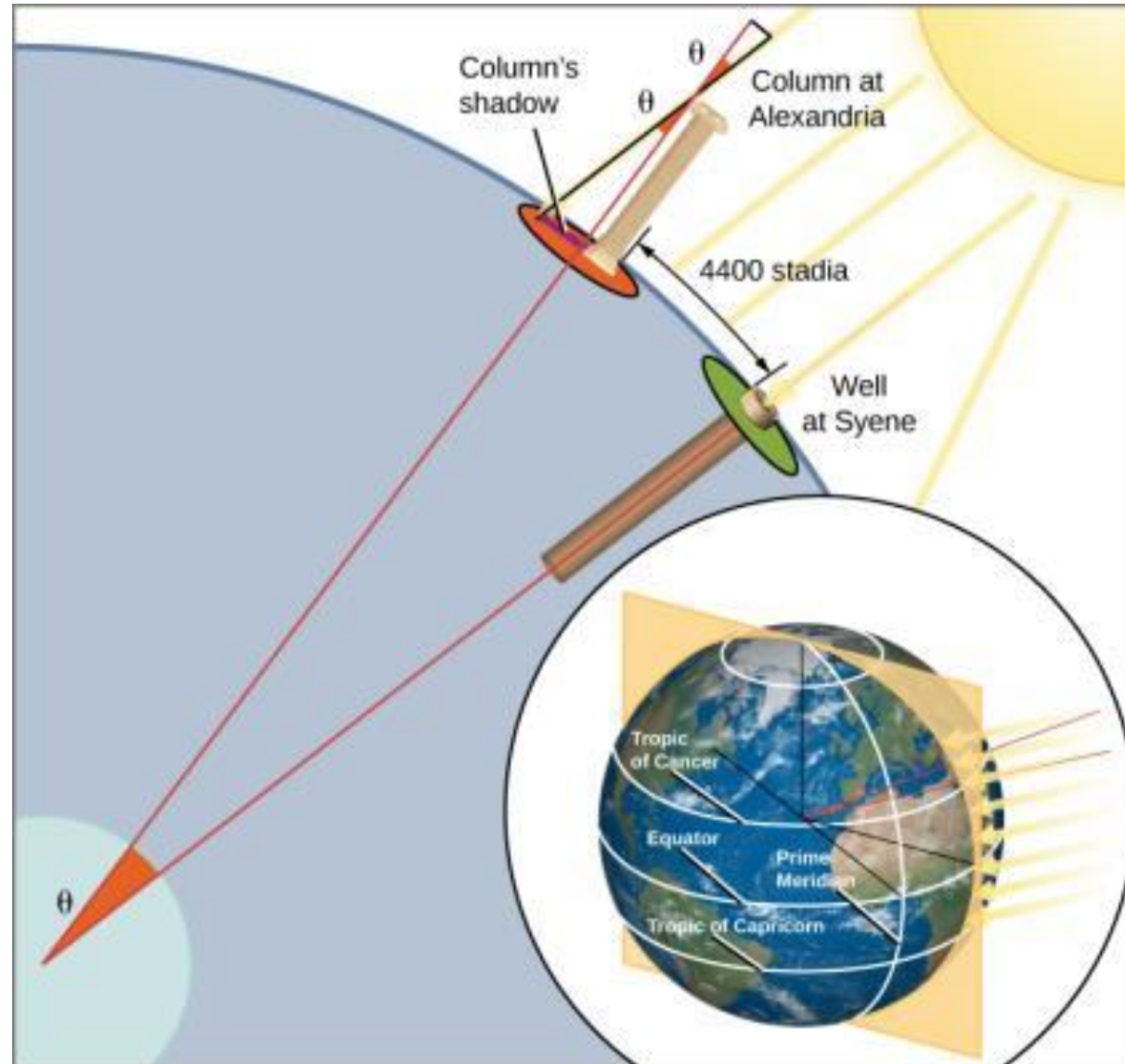
→ Light rays from Sun are quite parallel.

→ Light rays from stars are very parallel.

How Eratosthenes Measured the Size of Earth

Eratosthenes (276-194 BC) observed that:

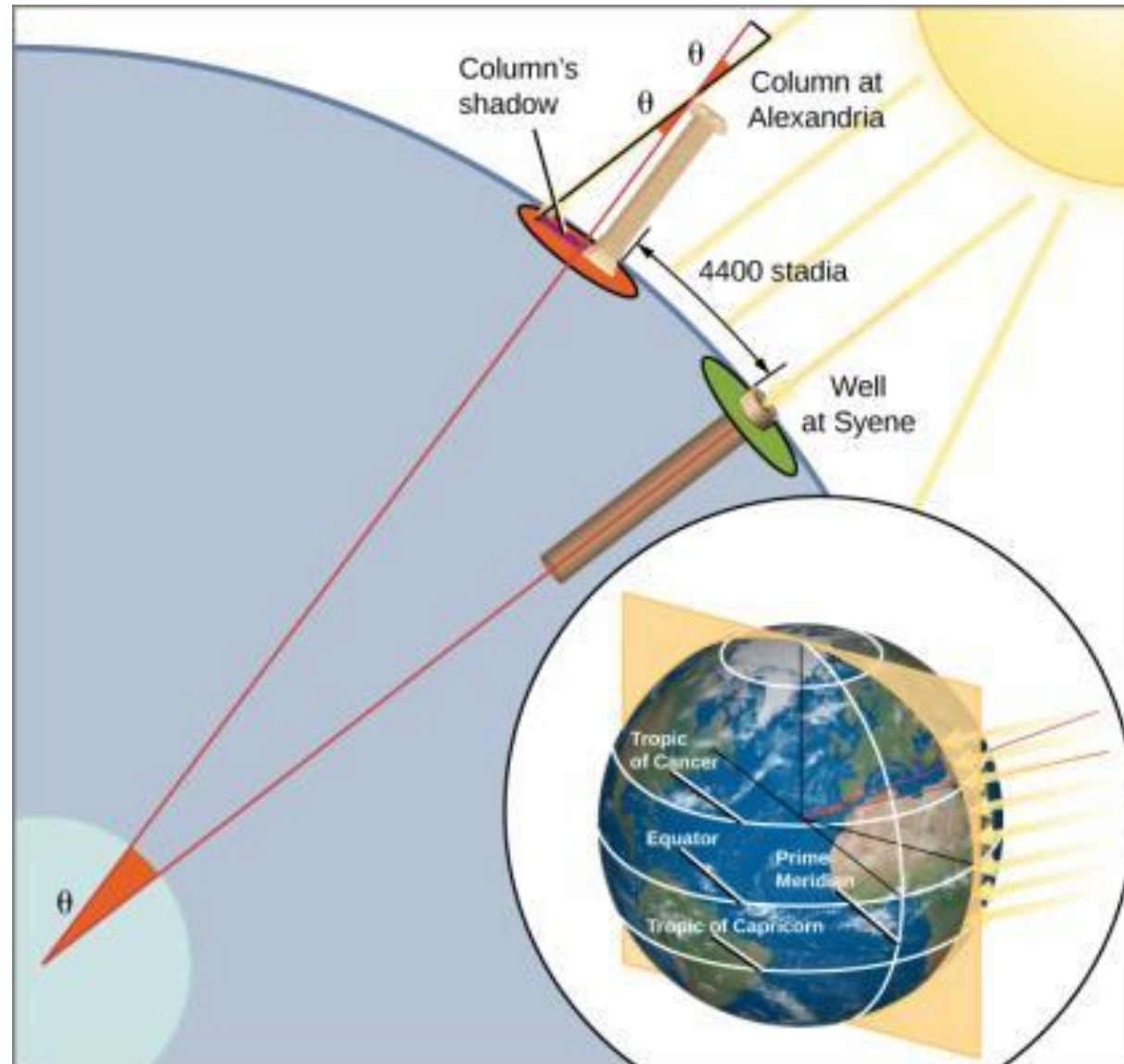
1. A Sun's ray at Syene comes straight down whereas a ray at Alexandria makes an **angle of 7° with the vertical**.



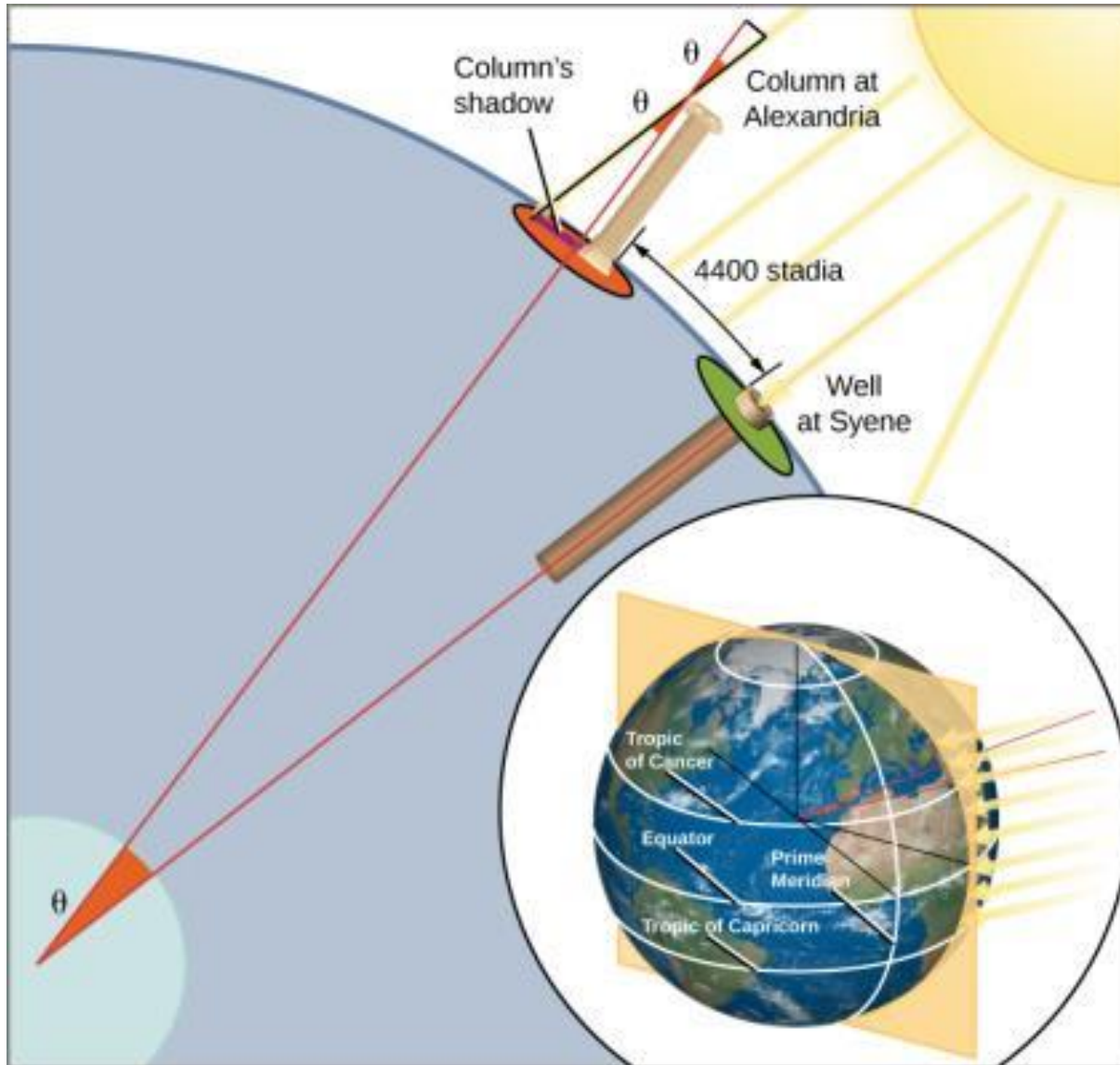
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3. The distance between the two cities, i.e. 5000 stadia, must be **$1/50$ the circumference** of Earth.

How Eratosthenes Measured the Size of Earth

$$\begin{aligned}\text{Circumference of Earth} &= 50 \times 5000 \text{ stadia} \\ &= 250,000 \text{ stadia} \quad (1 \text{ stadia} \sim 180 \text{ m}) \\ &\approx 45,000 \text{ km}\end{aligned}$$

Actual circumference of Earth = 40,000 km

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$$\begin{aligned}\text{Actual circumference of Earth} &= 40,000 \text{ km} \\ &\rightarrow \text{Radius} = 40,000 / 2\pi \approx 6,400 \text{ km}\end{aligned}$$