

Today's Topics

Friday, August 30, 2019 (Week 0, lecture 2) – Chapters 1 & 2.

1. Scientific units (continued)
2. Scientific notation ... Exponents review
3. Length scales in the universe
4. Trigonometry review
5. Ancient Greek physics: radius of the Earth

Scientific Units

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]

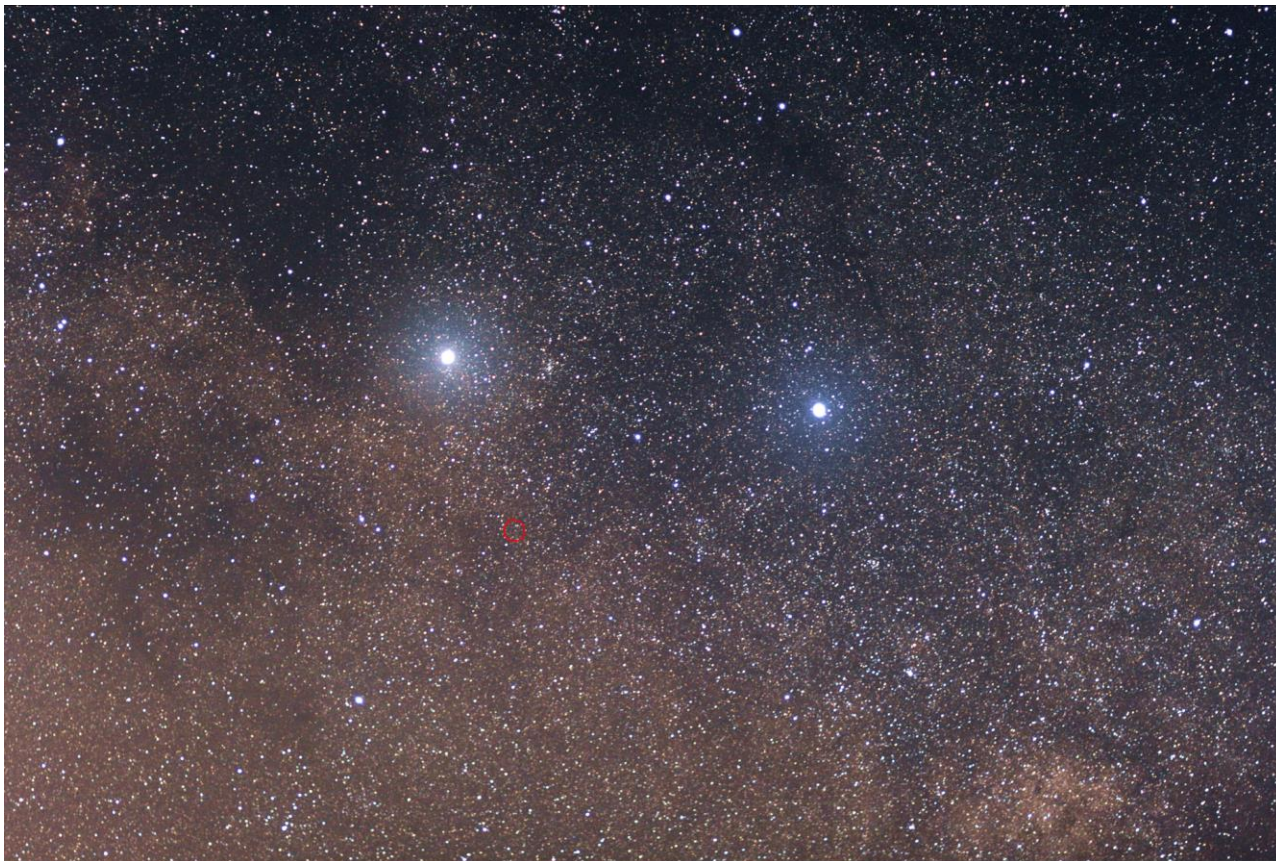
Distances with the Speed of Light

Sun – Pluto distance \approx 5.5 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

= 357×10^6

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= 3.57e8 = 3.57e+8 useful for computers

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“3.57 times ten to the power of eight”

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$$= 3.57 * 10^8$$

$$= 3.57e8 = 3.57e+8 \quad \text{useful for computers}$$

“3.57 times ten to the power of minus five”

$$= 0.0000357$$

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

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

$$= 3.57 * 10^{(-5)}$$

$$= 3.57e-8$$

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

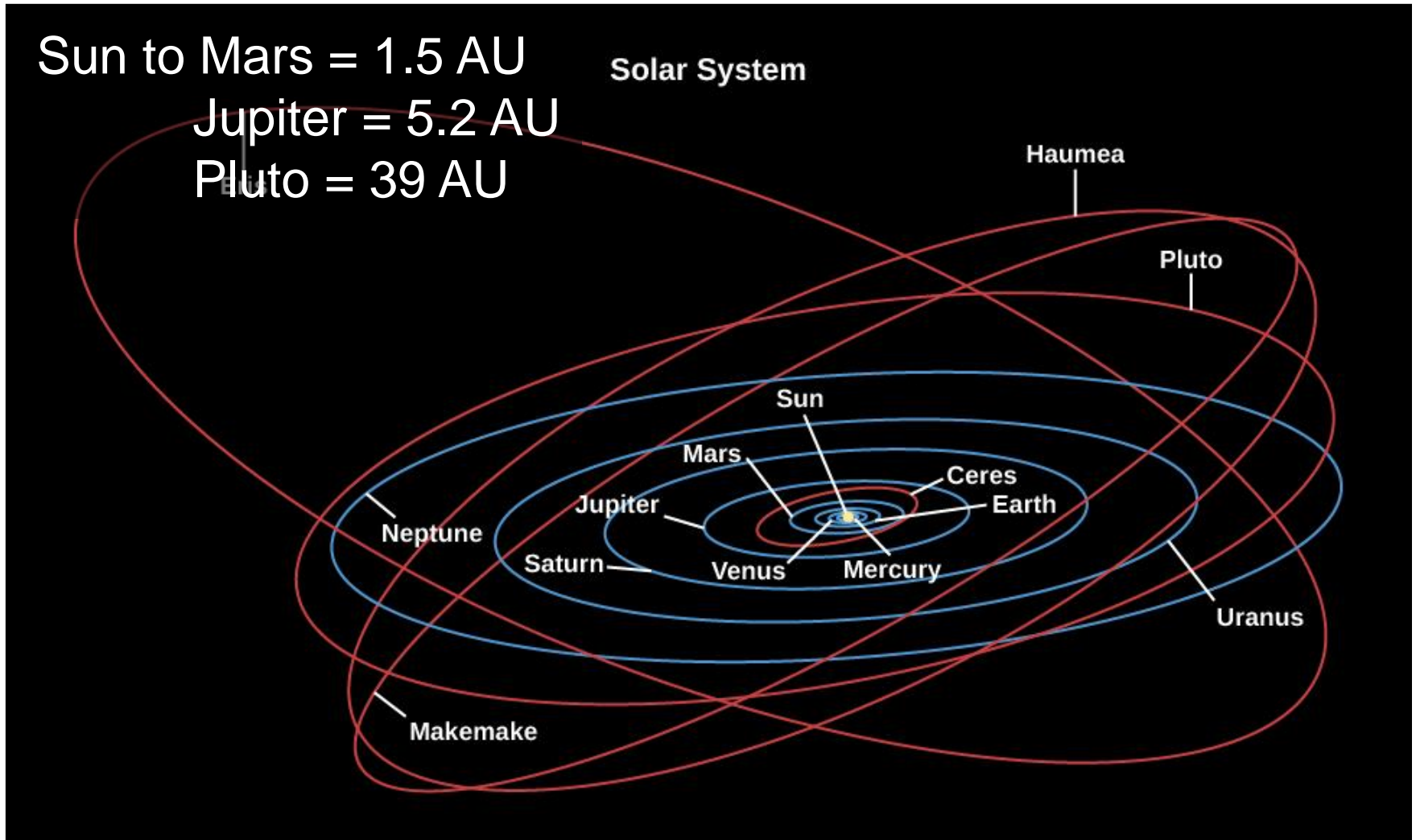
Reminder: Sun-to-Earth = 1 AU

Sun to Mars = 1.5 AU

Jupiter = 5.2 AU

Pluto = 39 AU

Solar System



Solar System Scale

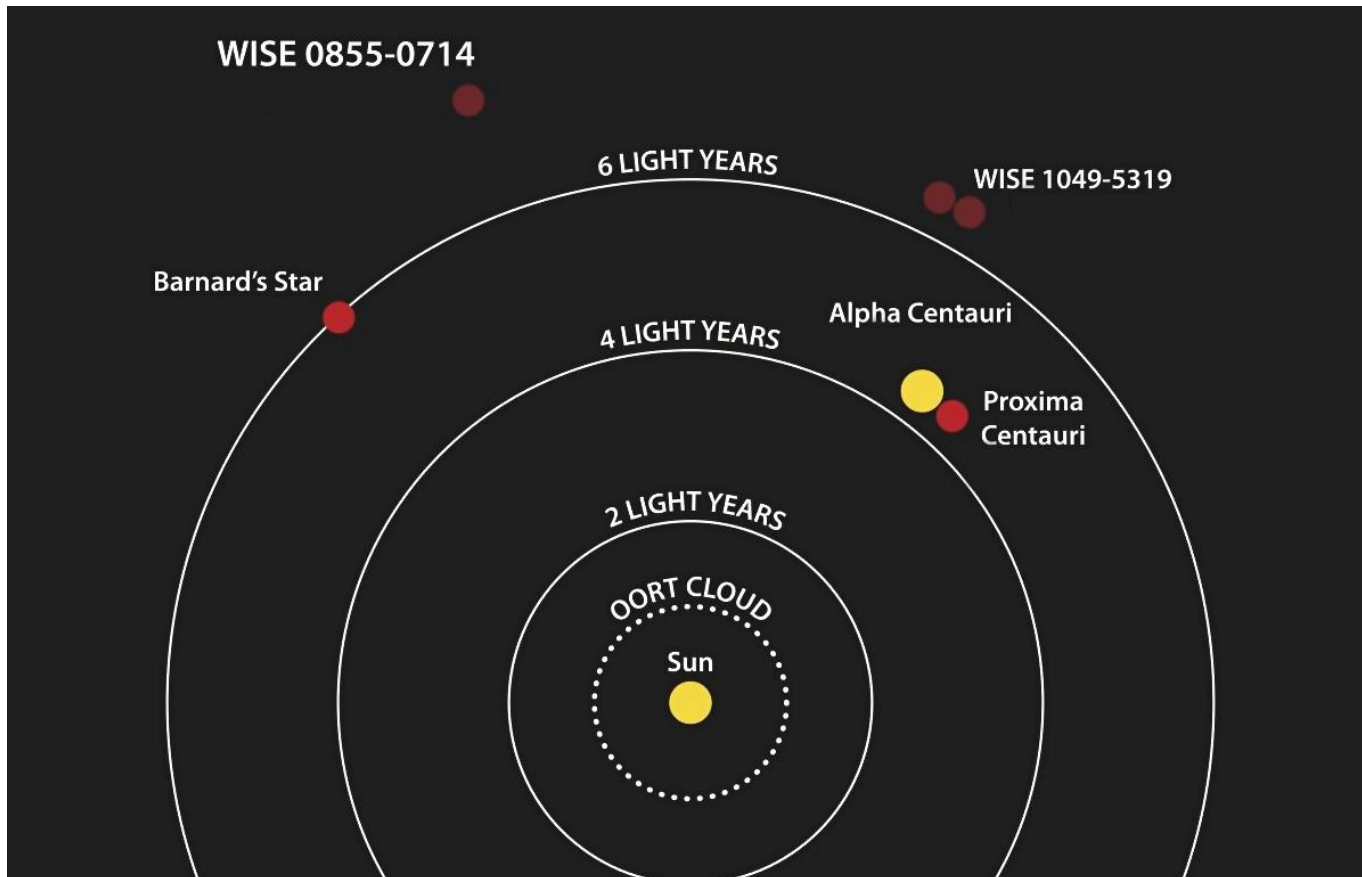
Relative size of planets & Sun

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



Nearby Stars Scale ~ 7 light years

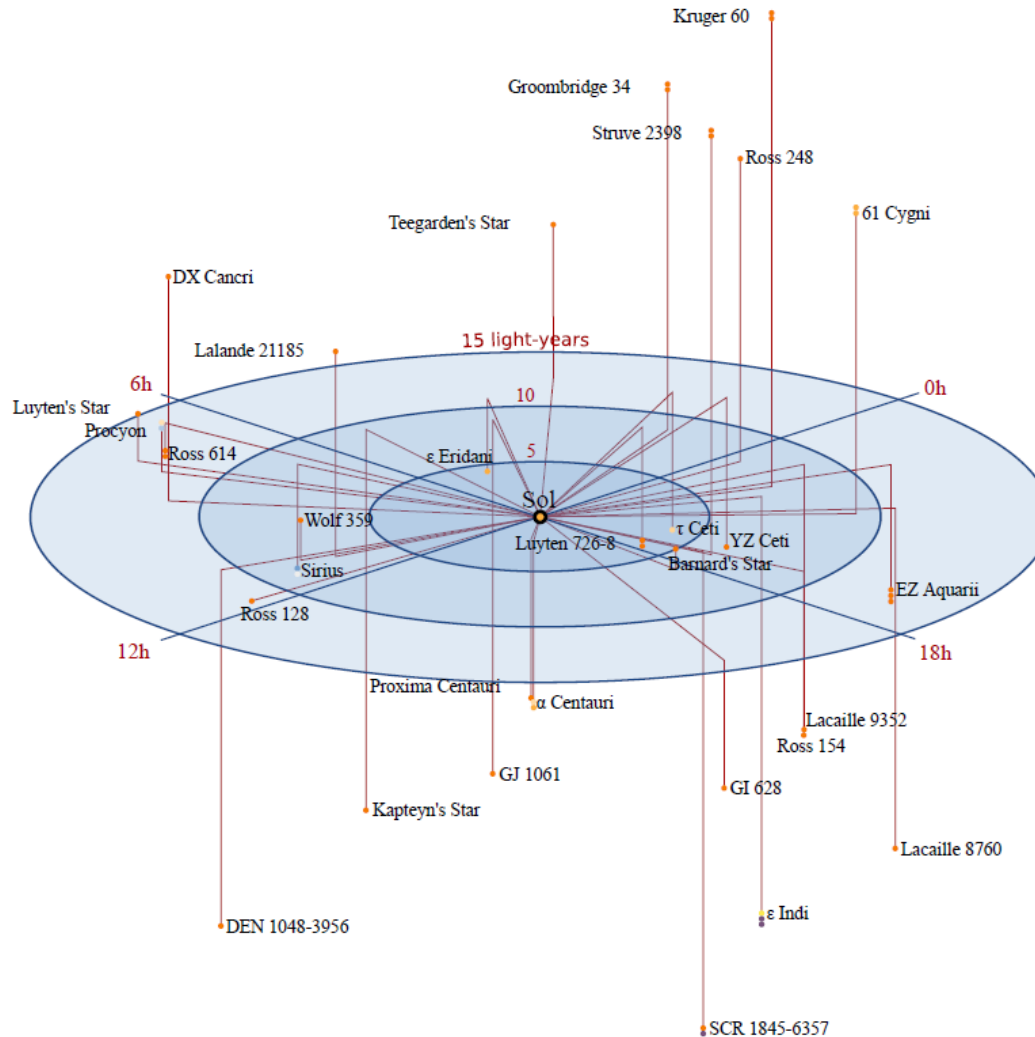
7 nearby stars



[Wikipedia; NASA, Penn State University]

Nearby Stars Scale ~ 15 light years

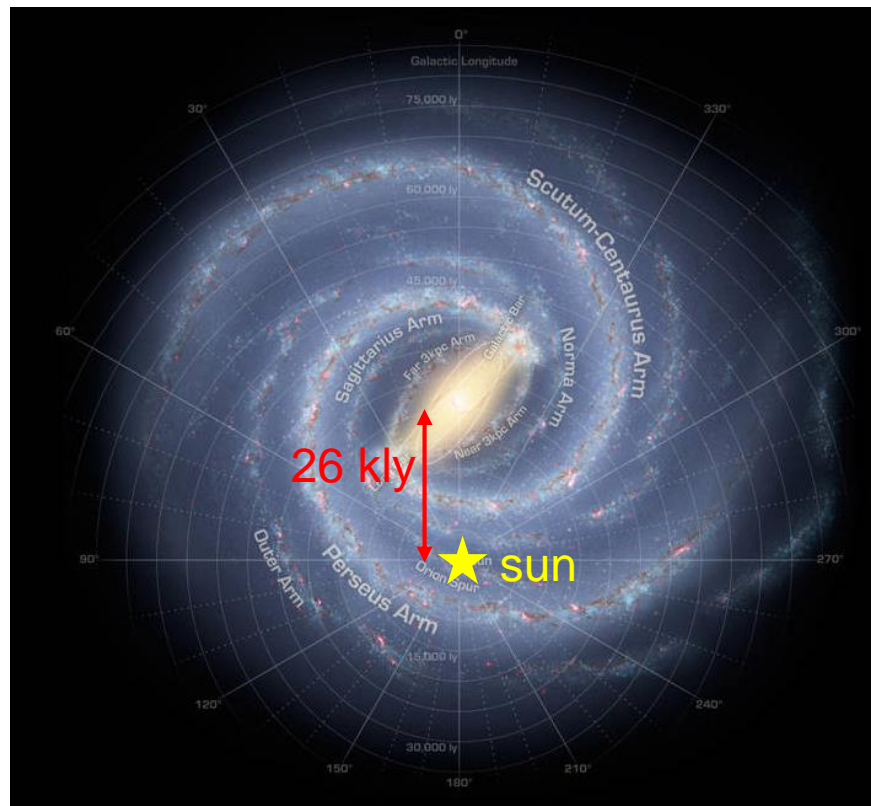
Several dozen stars in our stellar neighborhood



Milky Way Galaxy Scale

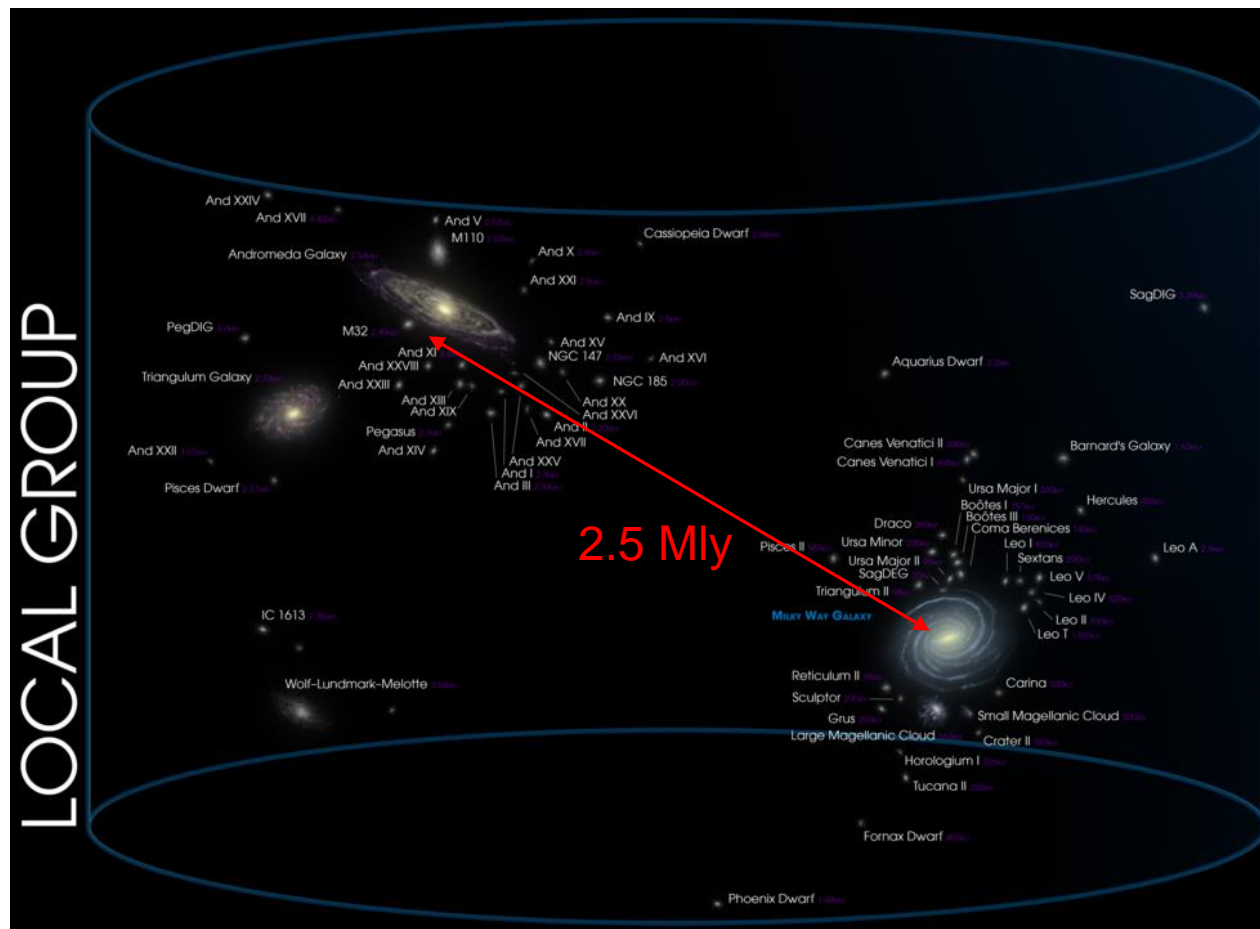
Diameter of our Galaxy = $150\text{-}200 \times 10^3$ ly

100-400 billion stars

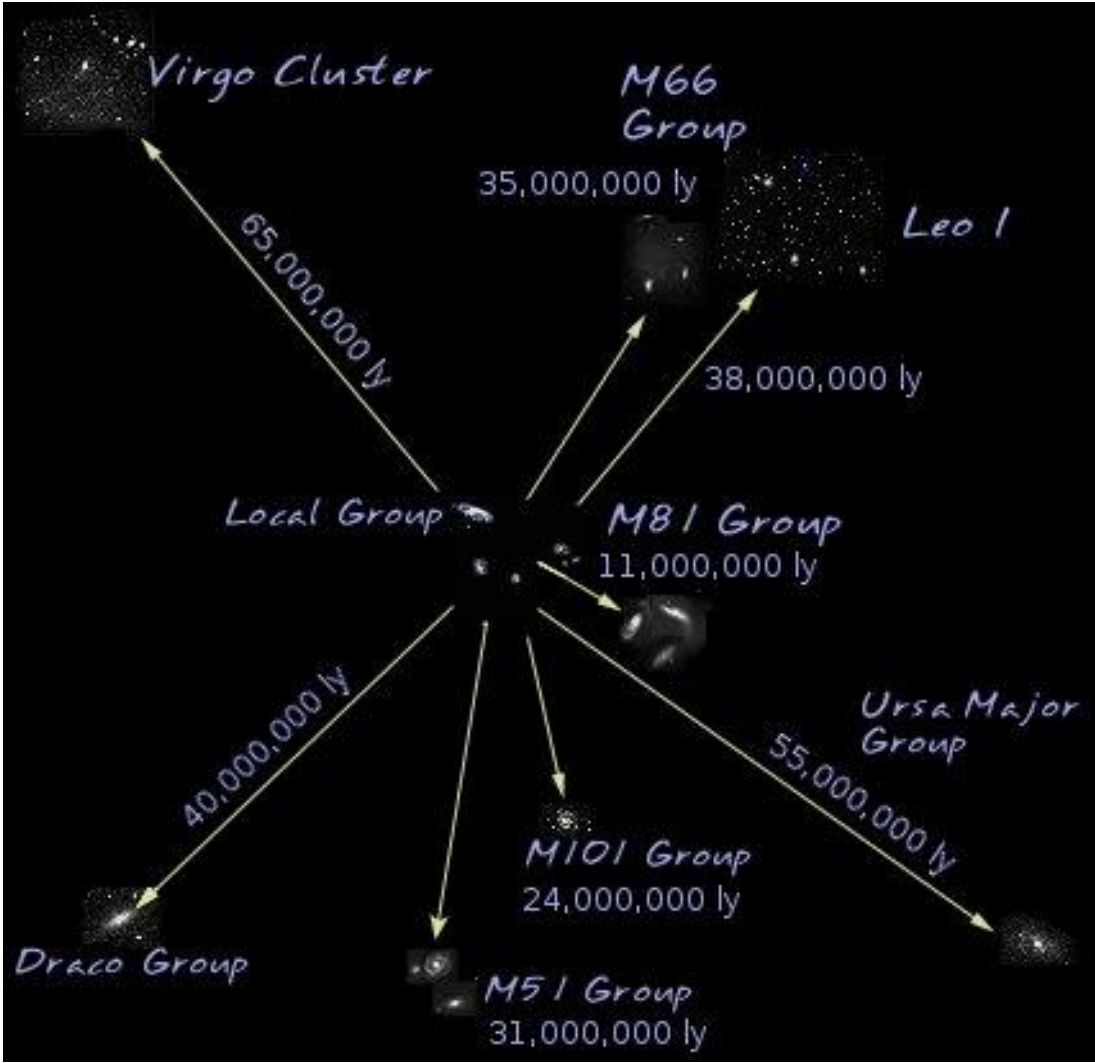


“Local Group” Scale

“Local Group” = cluster of ~ 50 nearby galaxies



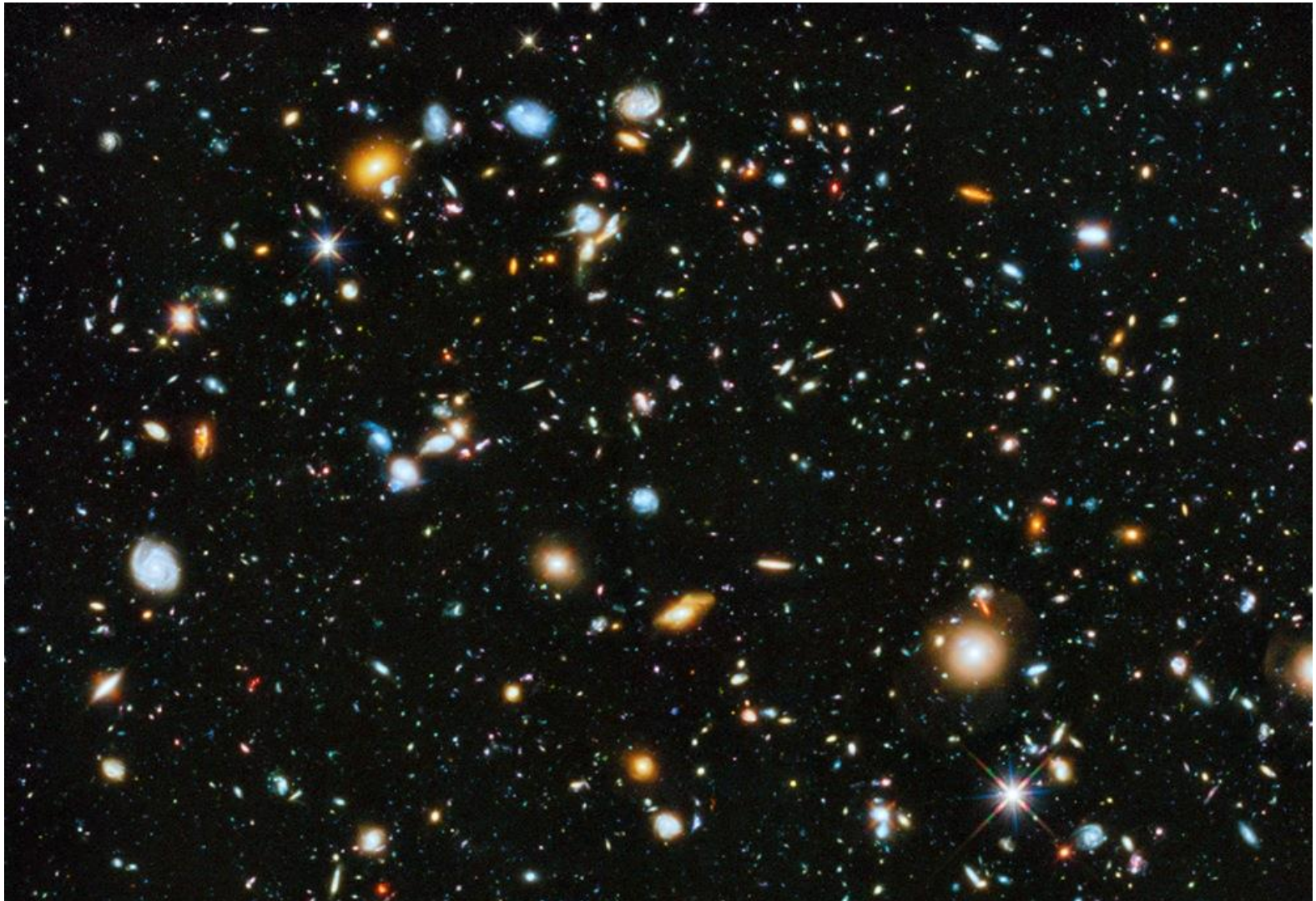
Local/Virgo Supercluster Scale



[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

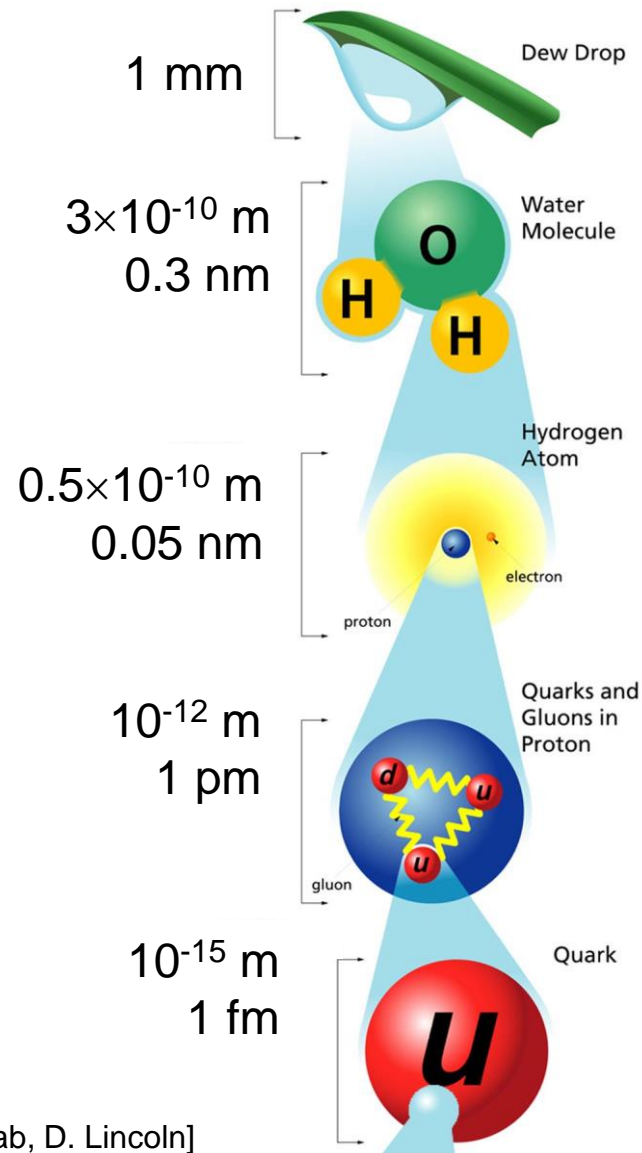
Number of galaxies in Universe ~ billions to trillions

“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]

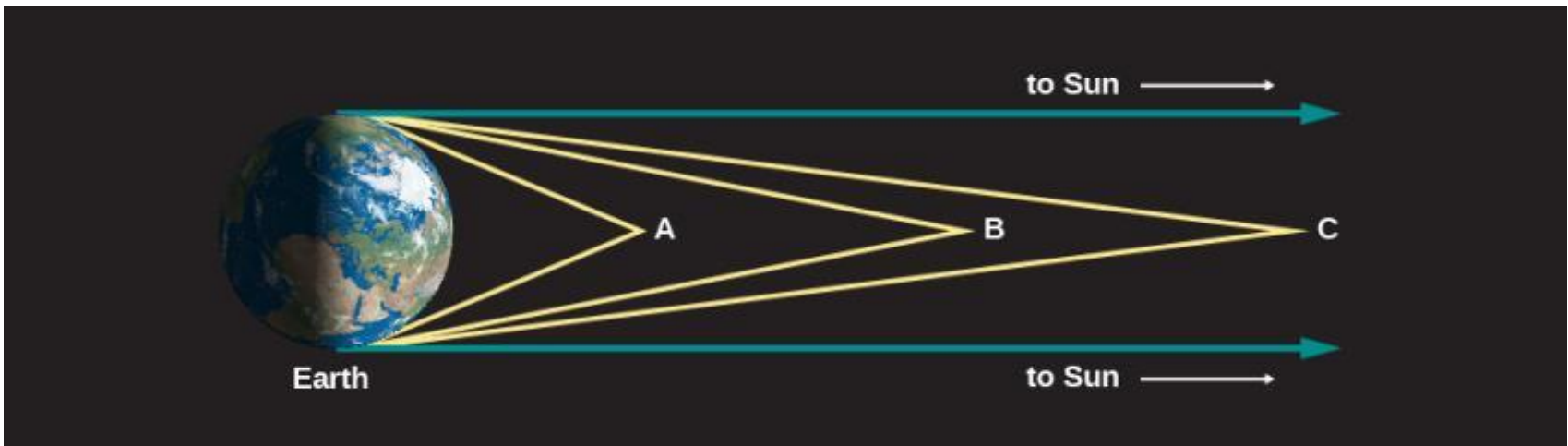
Trigonometry

Review

Ancient Greek Physics

Determining the Radius of the Earth

Parallel light rays from the sun

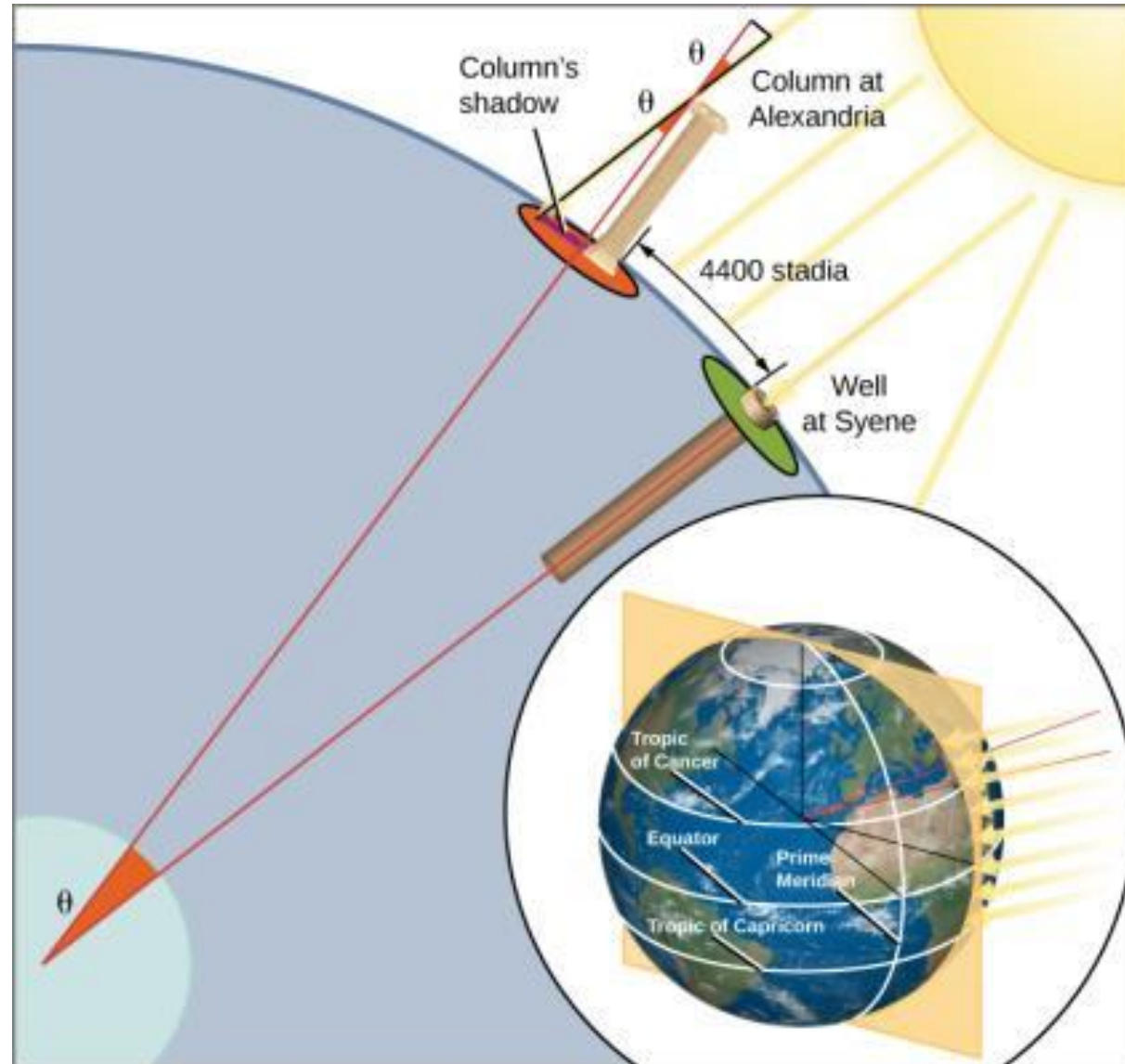


Light Rays from Space. The more distant an object, the more nearly parallel the rays of light coming from it.

How Eratosthenes Measured the Size of Earth

Eratosthenes (276-194 BC) observed that:

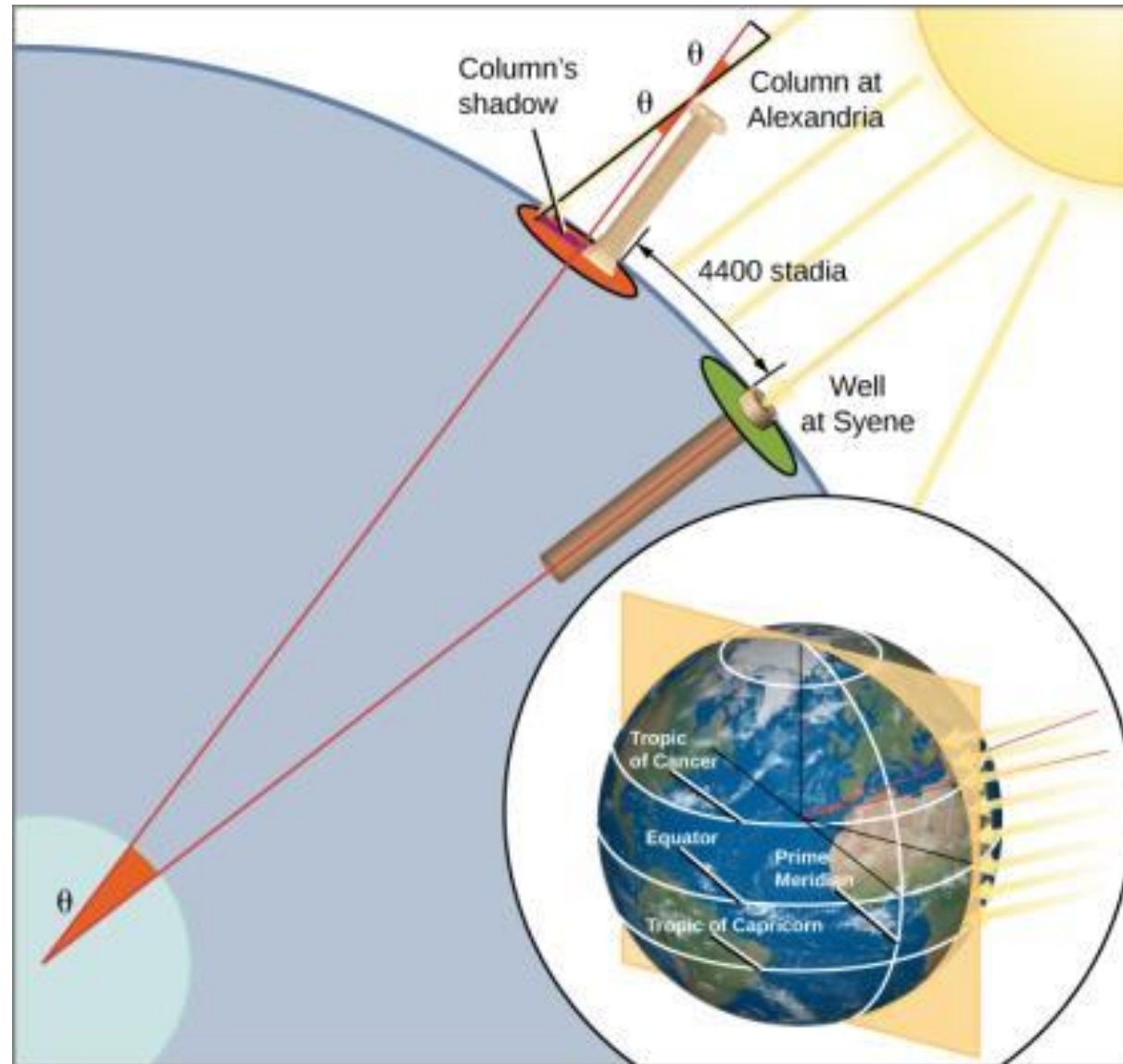
1. A Sun's ray at Syene comes straight down whereas a ray at Alexandria makes an **angle of 7° with the vertical**.



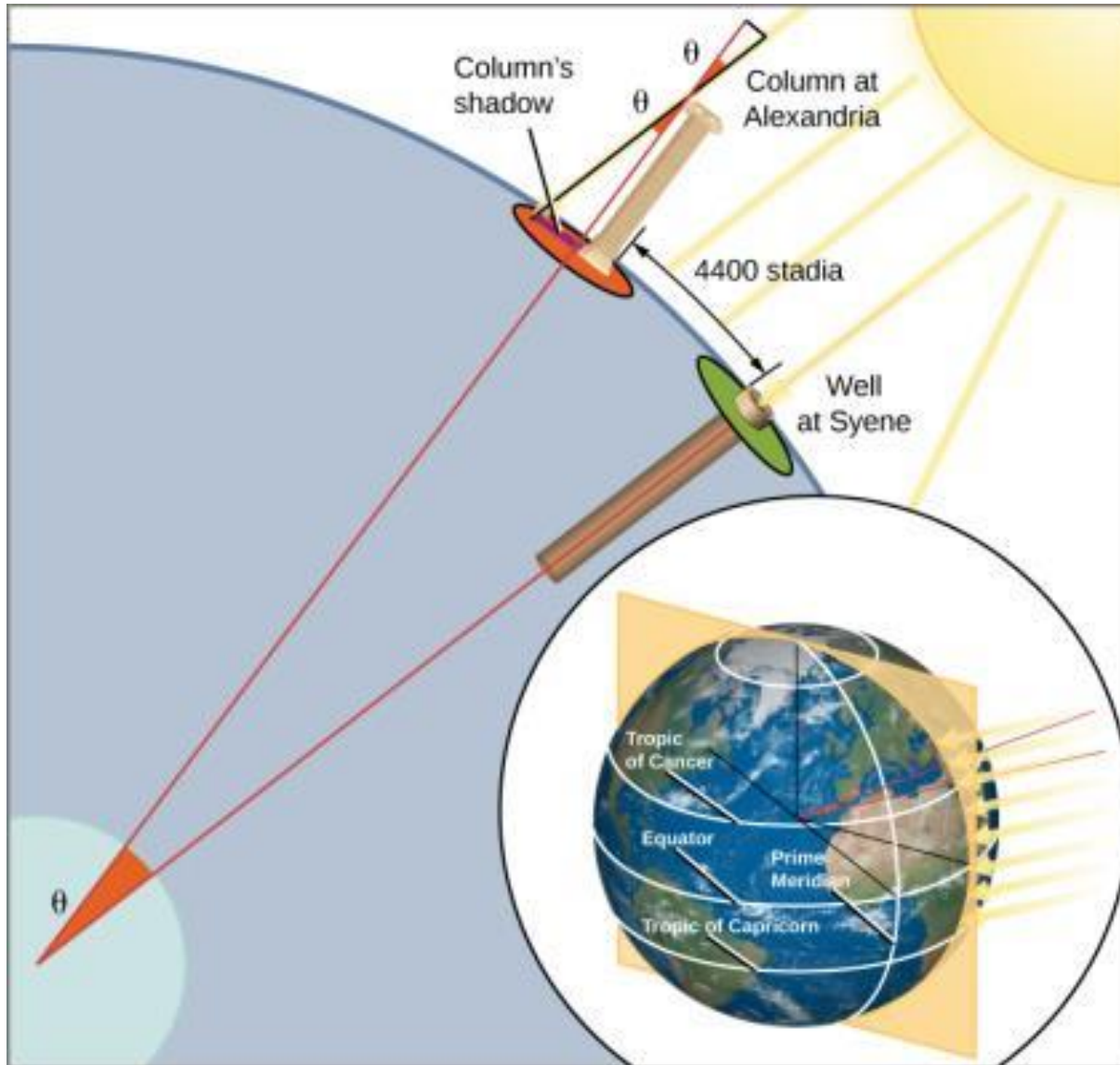
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2. At Alexandria, Earth's surface has curved away from Syene by 7° of 360° , or **$1/50$ of a full circle**.
3. The distance between the two cities, i.e. 5000 stadia, must be **$1/50$ the circumference** of Earth.

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