Today's Topics

Monday, January 27, 2025 (Week 1, 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]
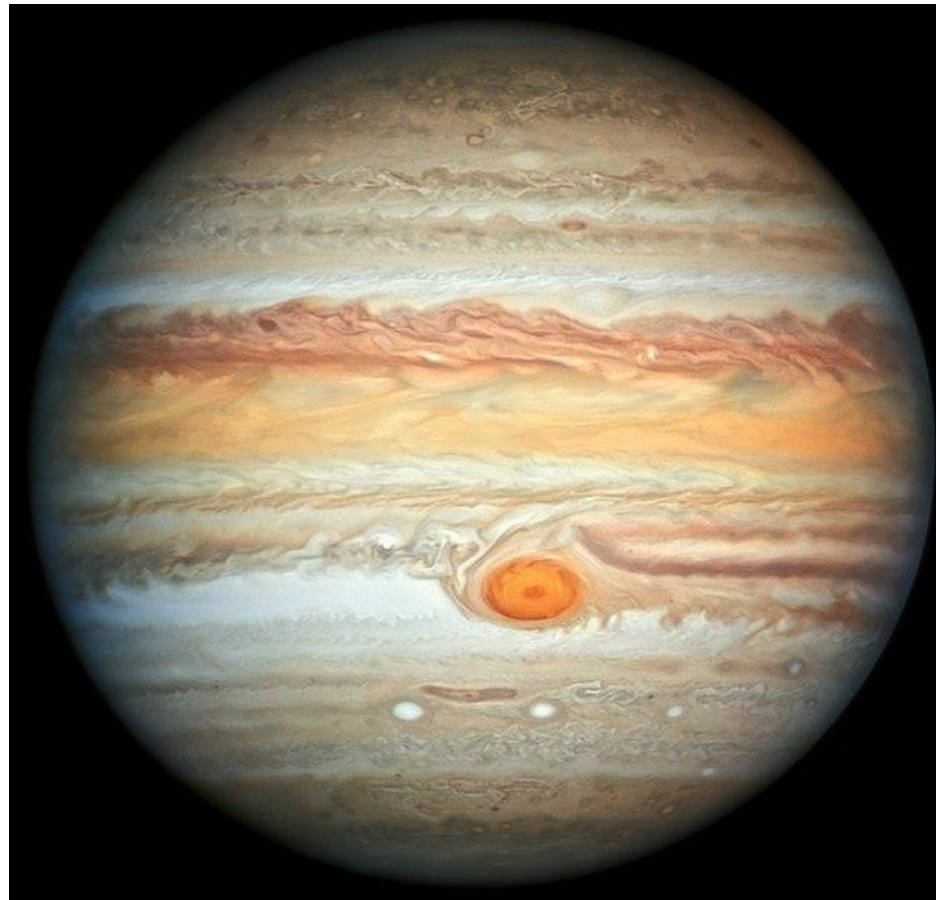
Distances with the Speed of Light

Sun – Earth distance $\quad$ = 499 s $\approx$ 8.3 minutes

$\qquad\qquad\qquad\qquad\quad$ = 149,597,870,700 m $\approx$ 150×10^6 km

$\qquad\qquad\qquad\qquad\quad$ = 1 Astronomical Unit = 1 AU

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

Distances with the Speed of Light

Sun – Jupiter distance ≈ 43 light minutes
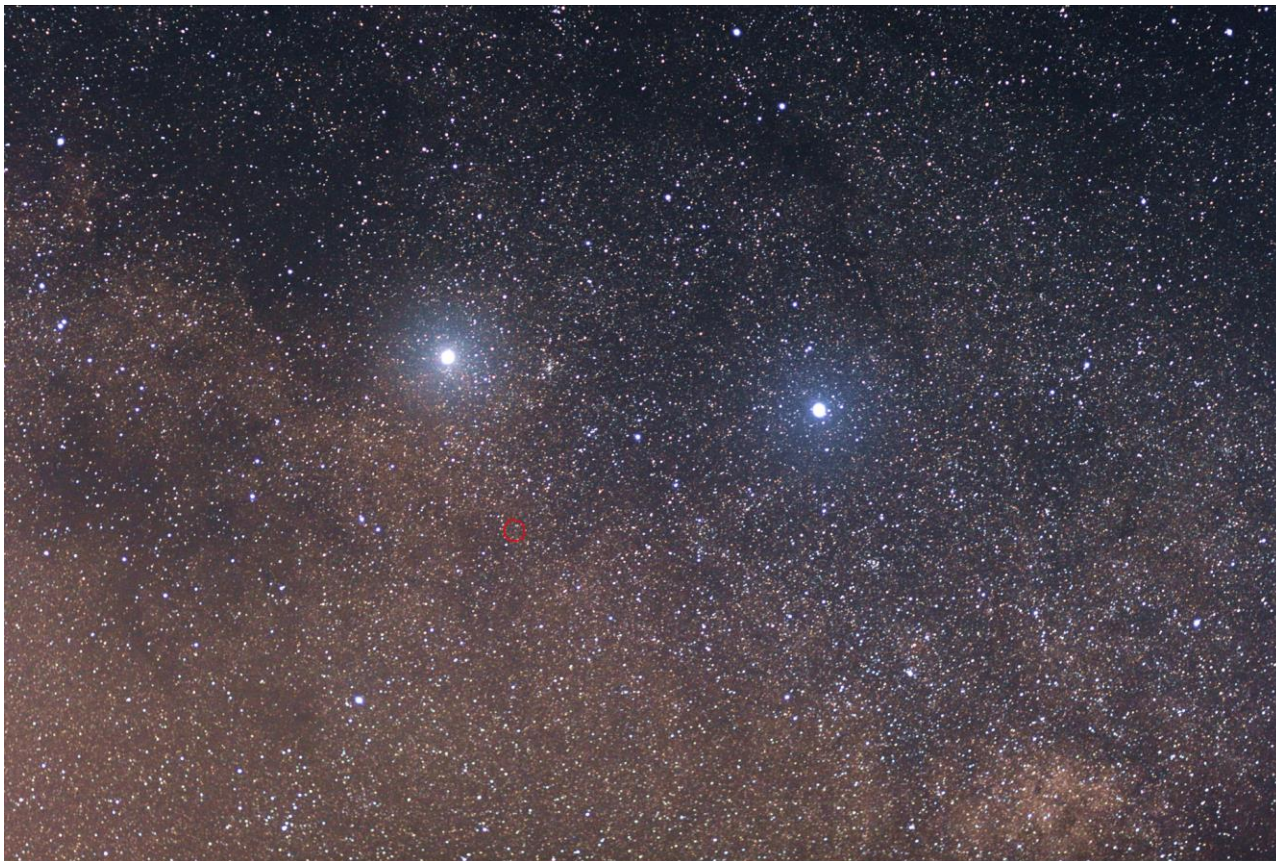

Jupiter viewed by Hubble telescope [Wikipedia, NASA]

Distances with the Speed of Light

Sun – Pluto distance ≈ 5.5 light hours

NASA/JHU APS/SWRI

Distances with the Speed of Light

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

By Skatebiker at English Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=46833562

Scientific

Notation

Scientific

Notation

Shorthand notation for very <u>large</u> and very <u>small</u> numbers.

"3.57 times ten to the power of eight"
= 357,000,000
= 3.57×10^8
= 357×10^6
=3.57*10^8
= 3.57e8 = 3.57e+8   useful for computers

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= 3.57e8 = 3.57e+8   useful for computers

"3.57 times ten to the power of minus five"
= 0.0000357
= 3.57×10^{-5}
= 357×10^{-7}
=3.57*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

10^{1} = deca (da)

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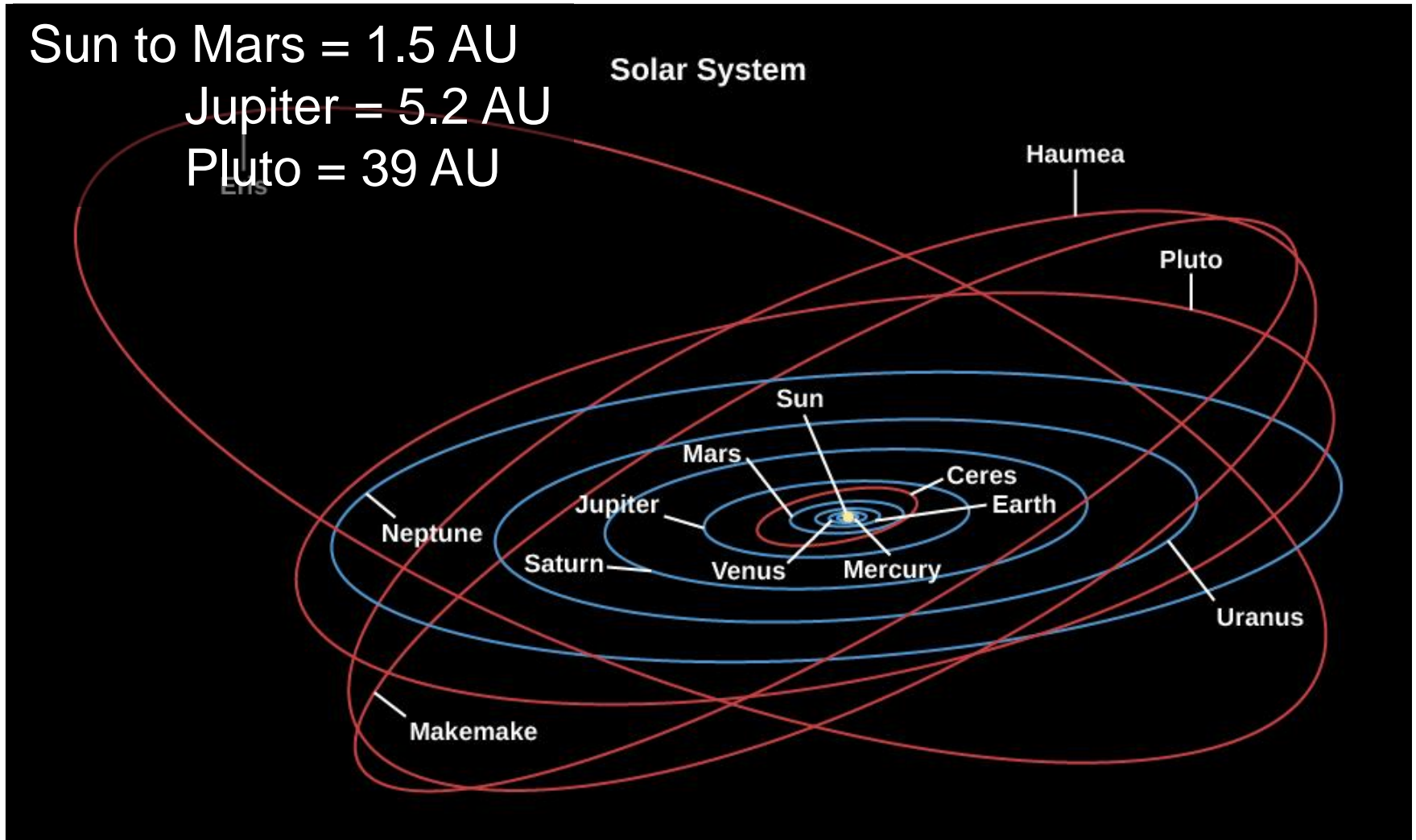
Length Scales in the Universe

Solar System Scale

Reminder: Sun-to-Earth = 1 AU

Sun to Mars = 1.5 AU
Jupiter = 5.2 AU
Pluto = 39 AU
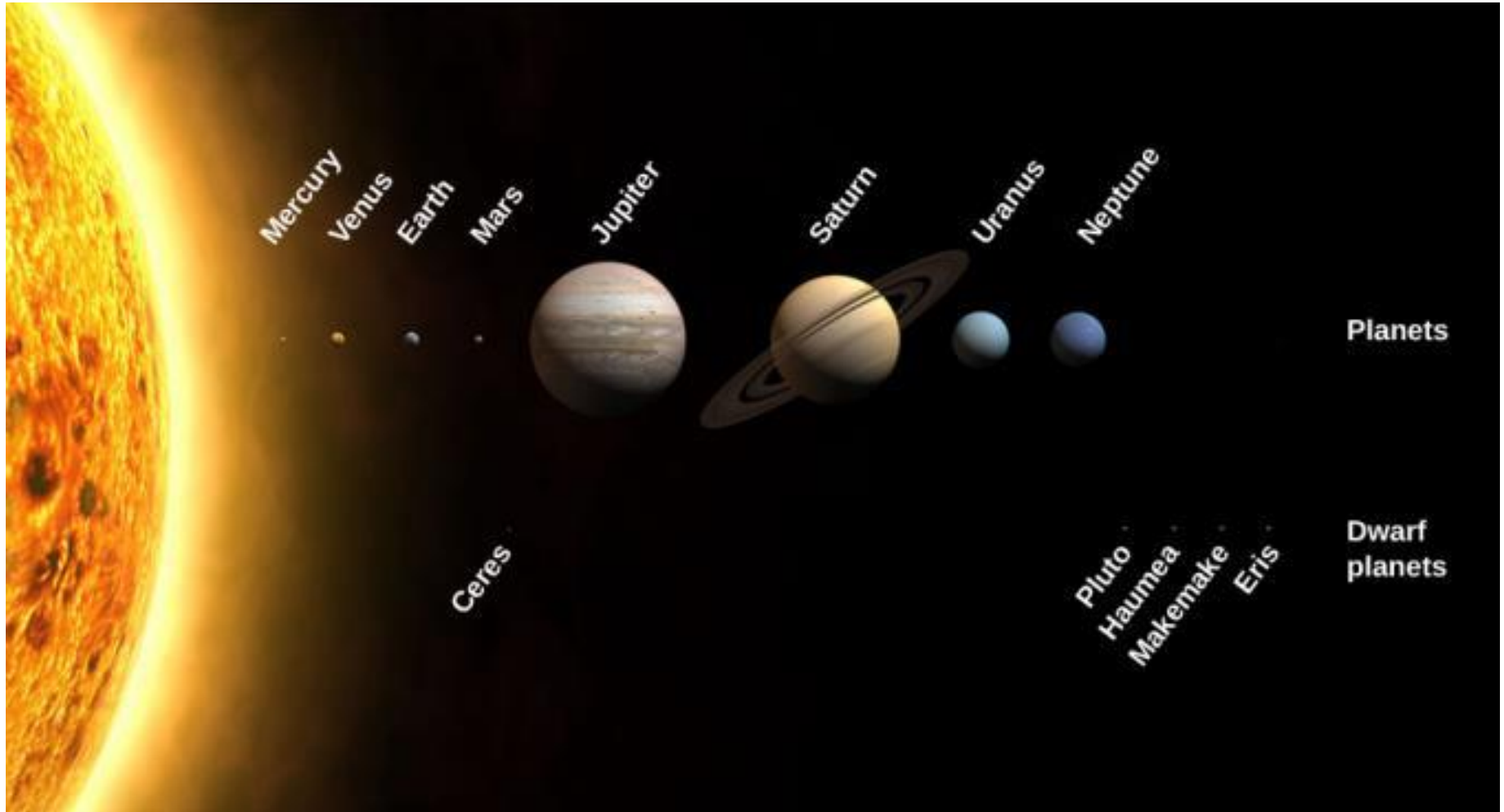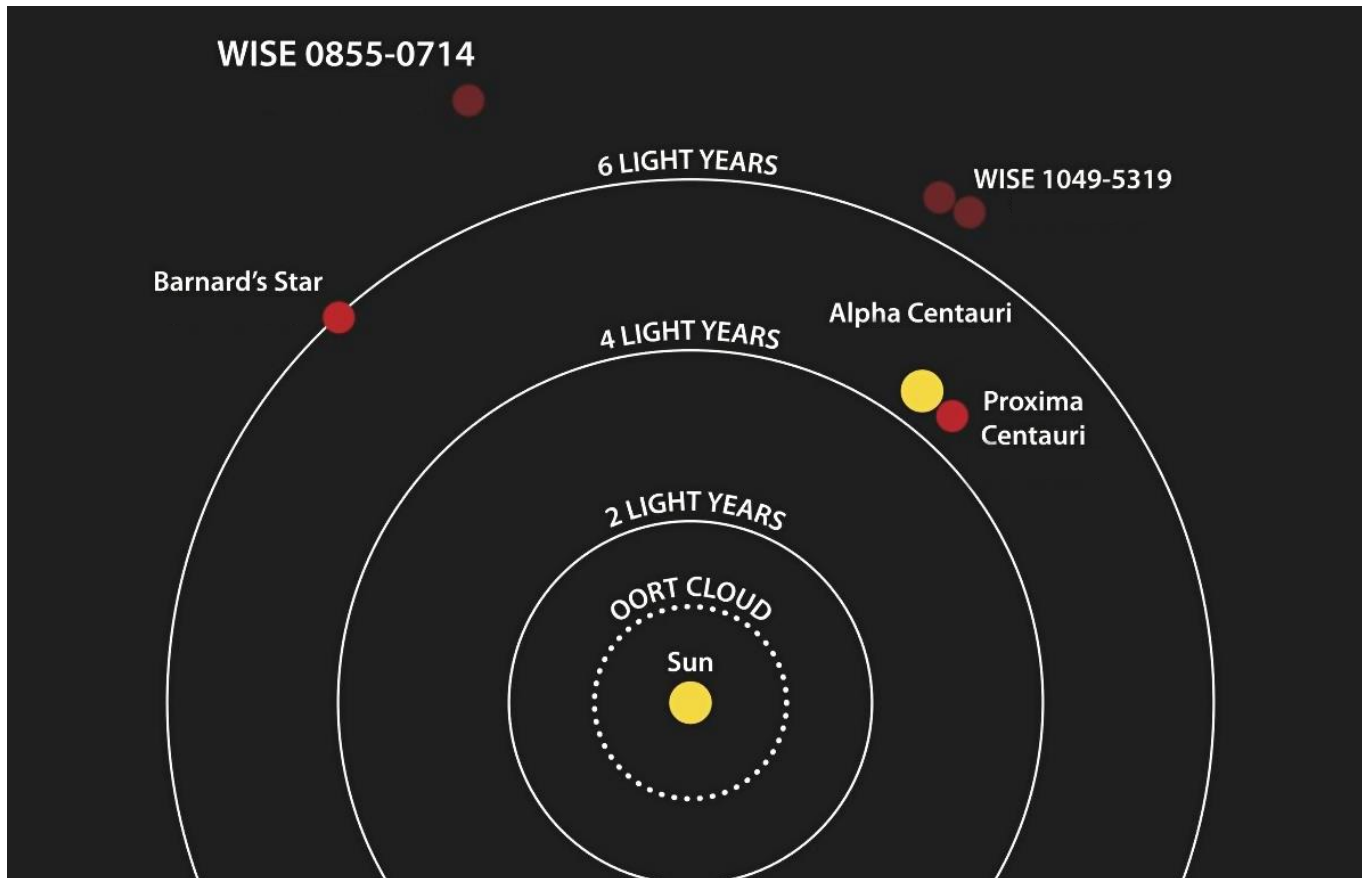
Solar System

[OpenStax: Astronomy]

Solar System Scale

Relative size of planets & Sun

- diameter of Sun ≈ 109 Earths
- diameter of Jupiter ≈ 22 Earths

[OpenStax; NASA]

7 nearby stars

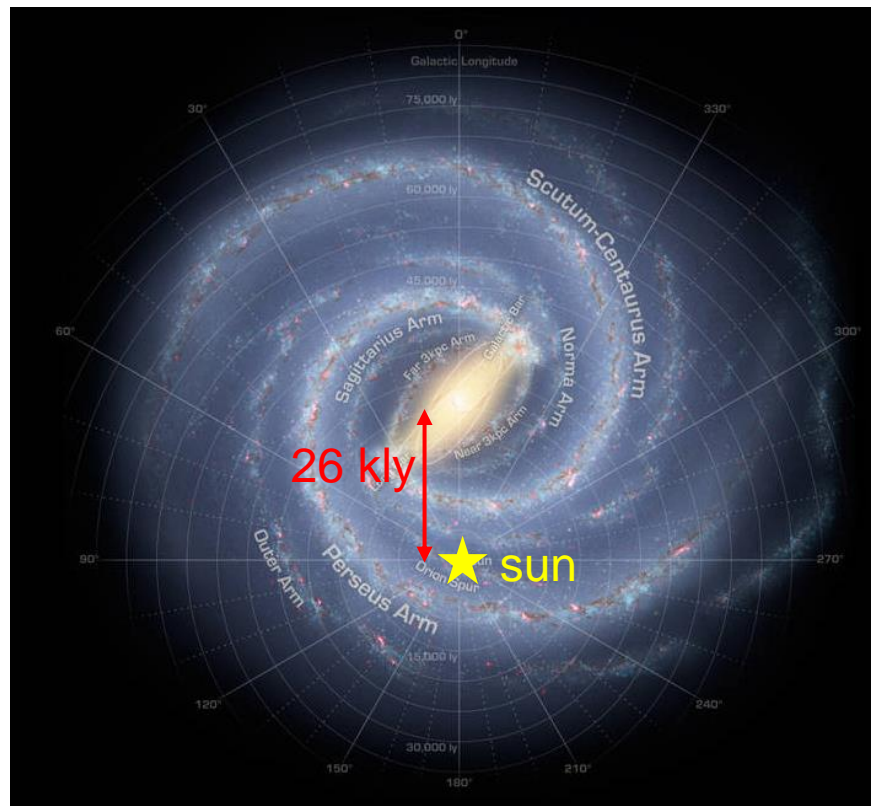[Wikipedia; NASA, Penn State University]

Several dozen stars in our stellar neighborhood
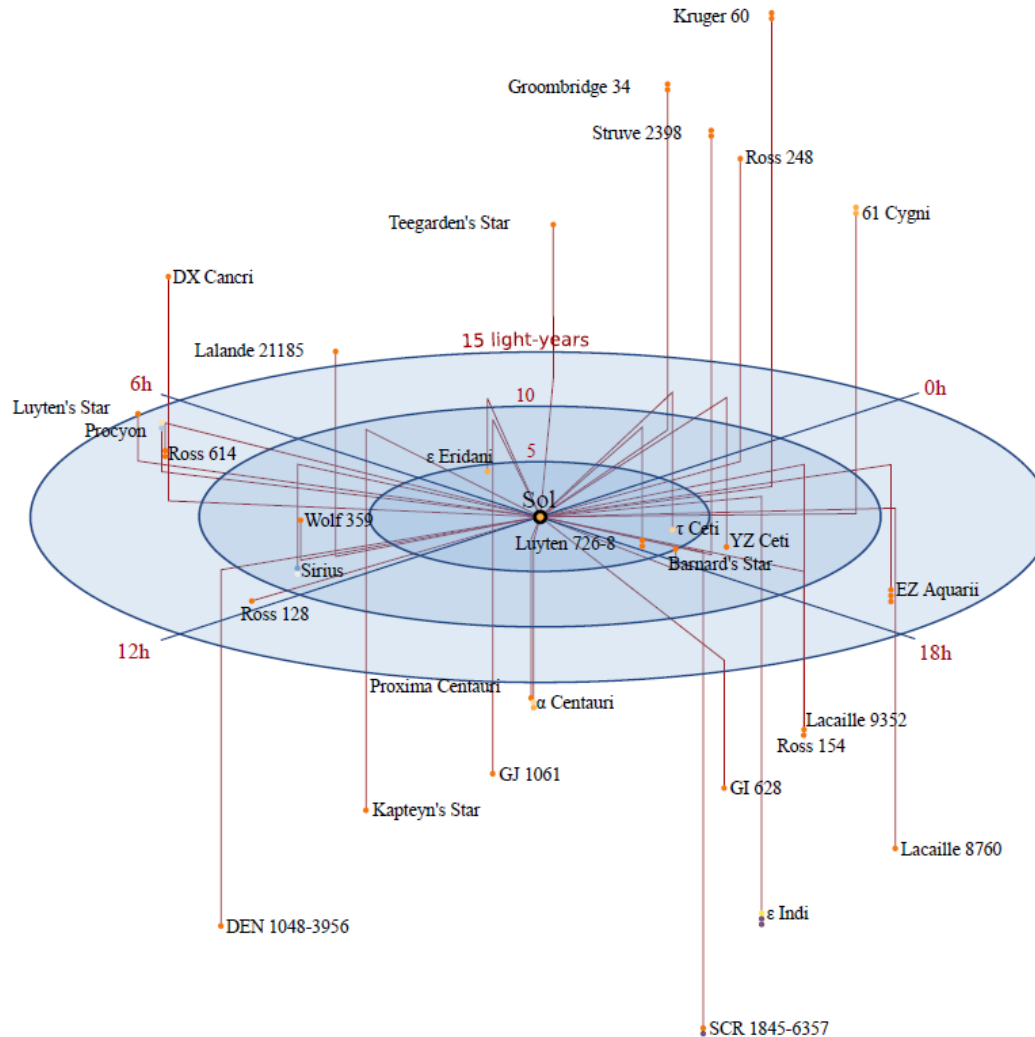
[Wikipedia]

Milky Way Galaxy Scale

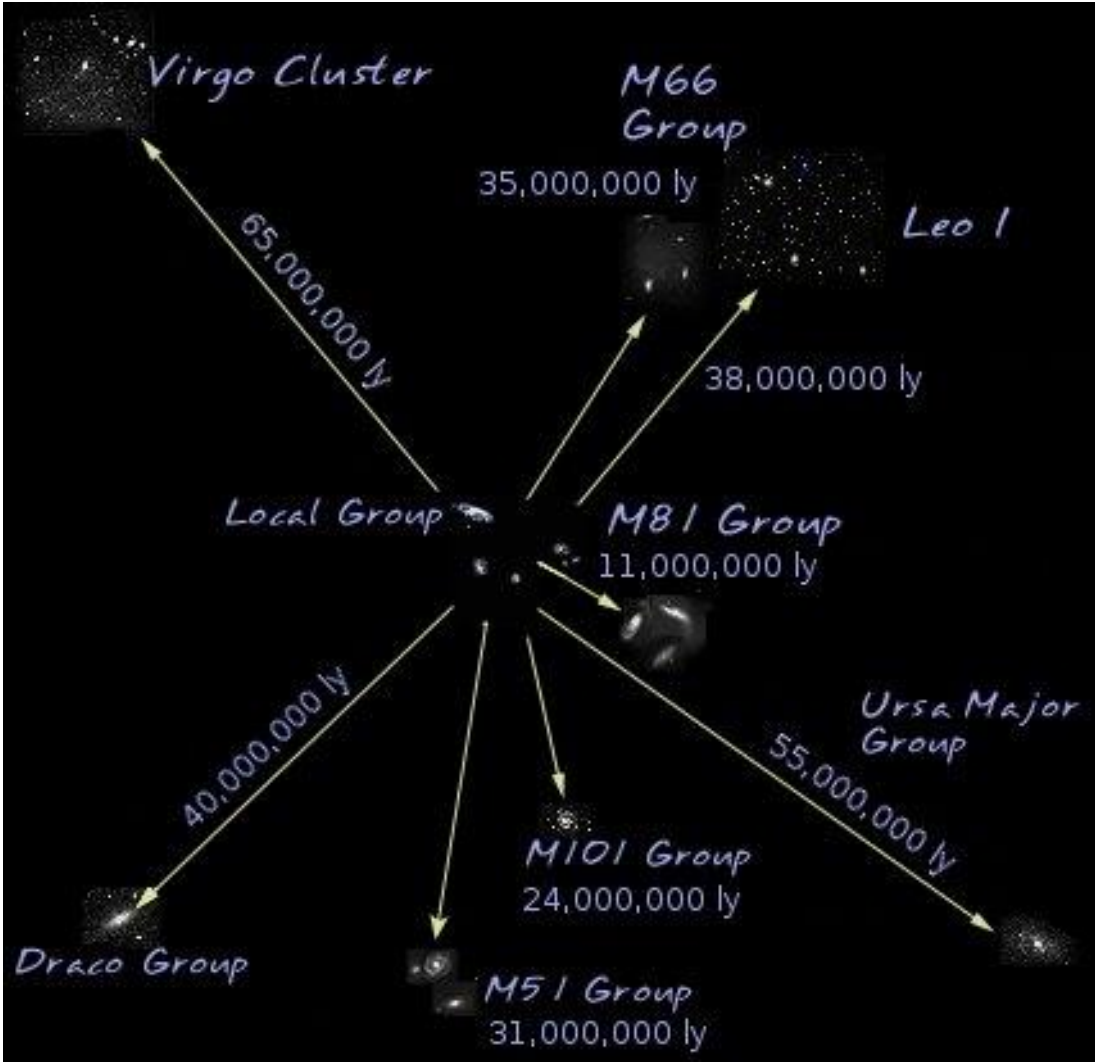Diameter of our Galaxy = 150-200 $\times$ 10^3 ly

100-400 billion stars

"Local Group" = cluster of ~ 50 nearby galaxies

By Andrew Z. Colvin - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=71065238
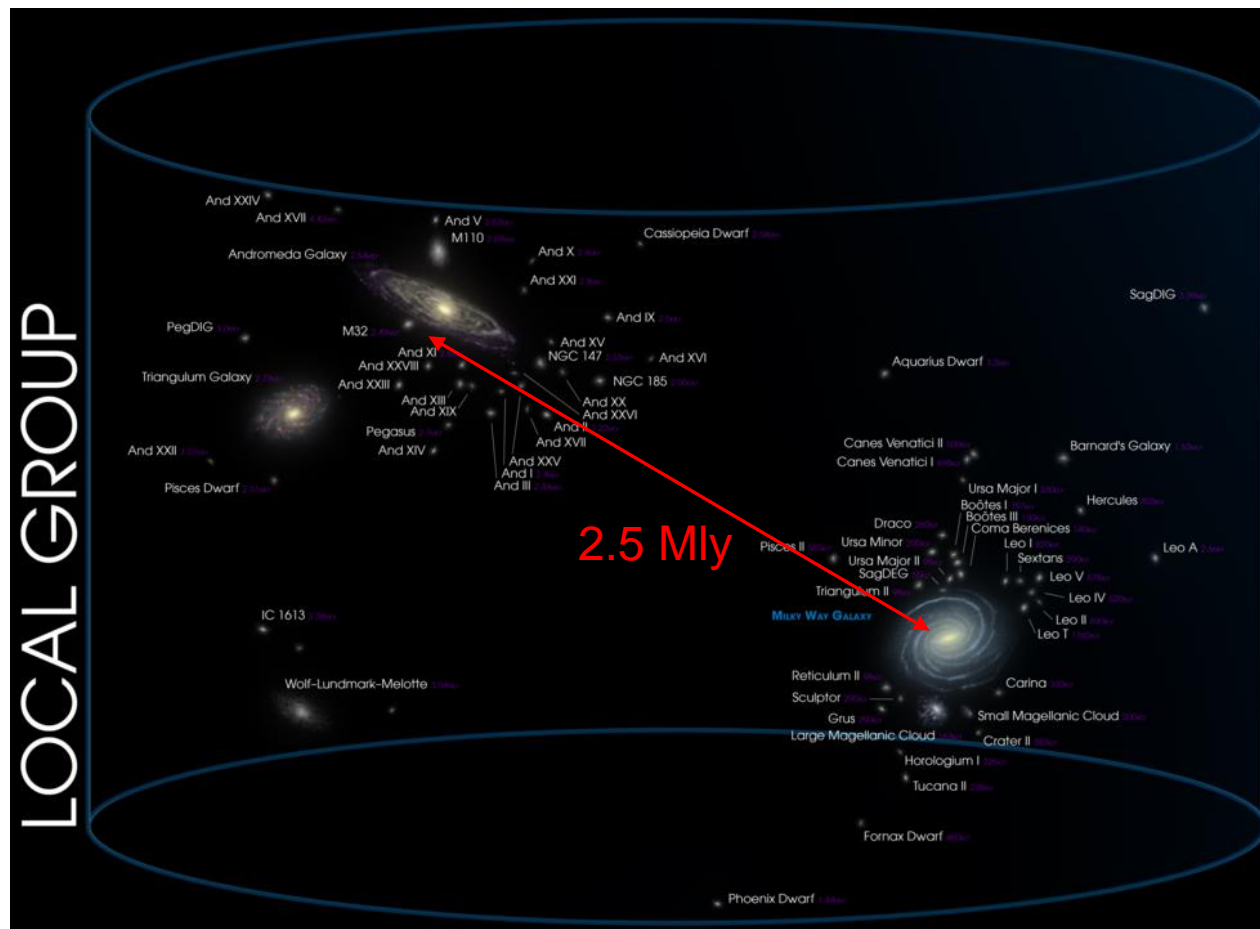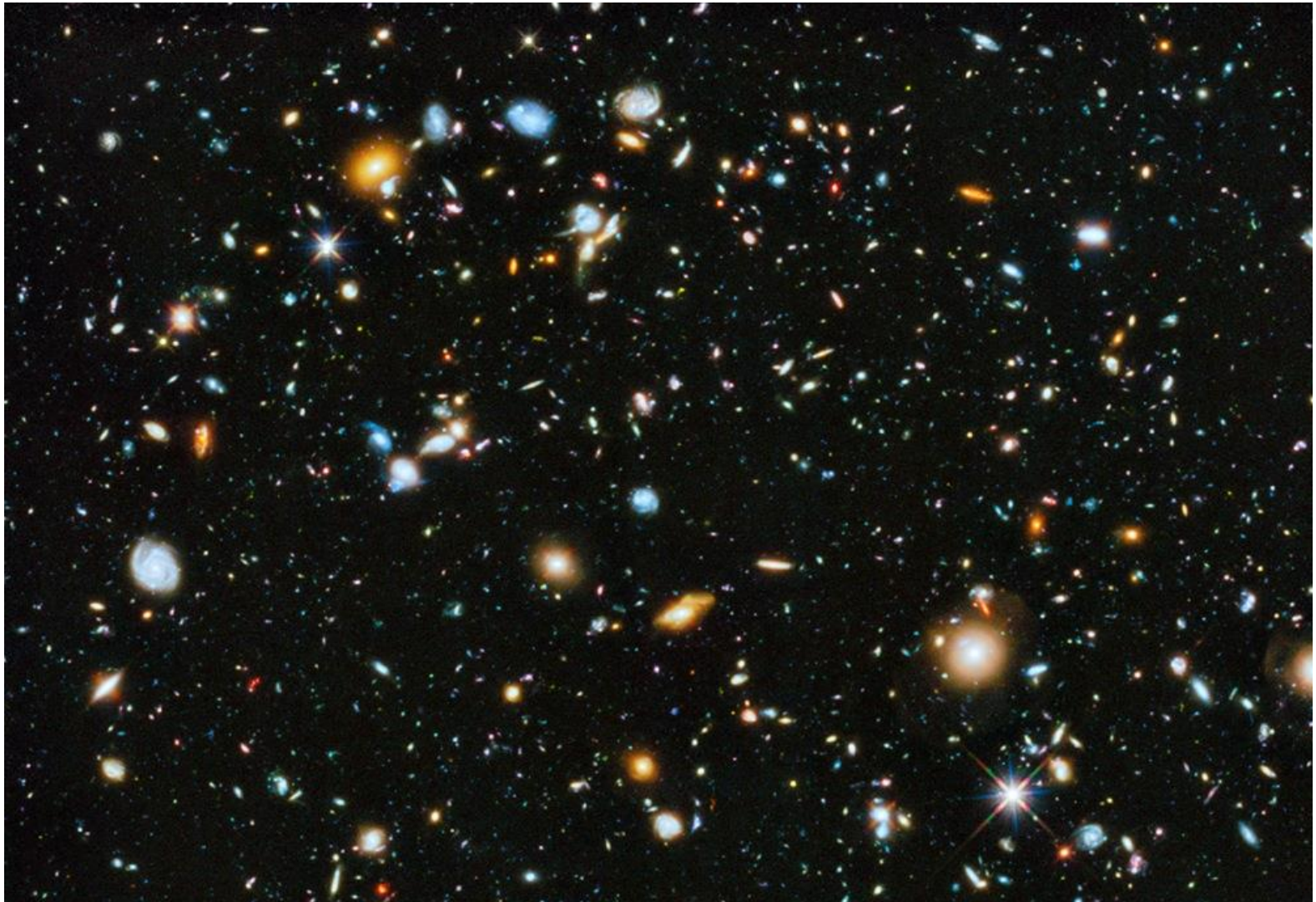
Local/Virgo Supercluster Scale

[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

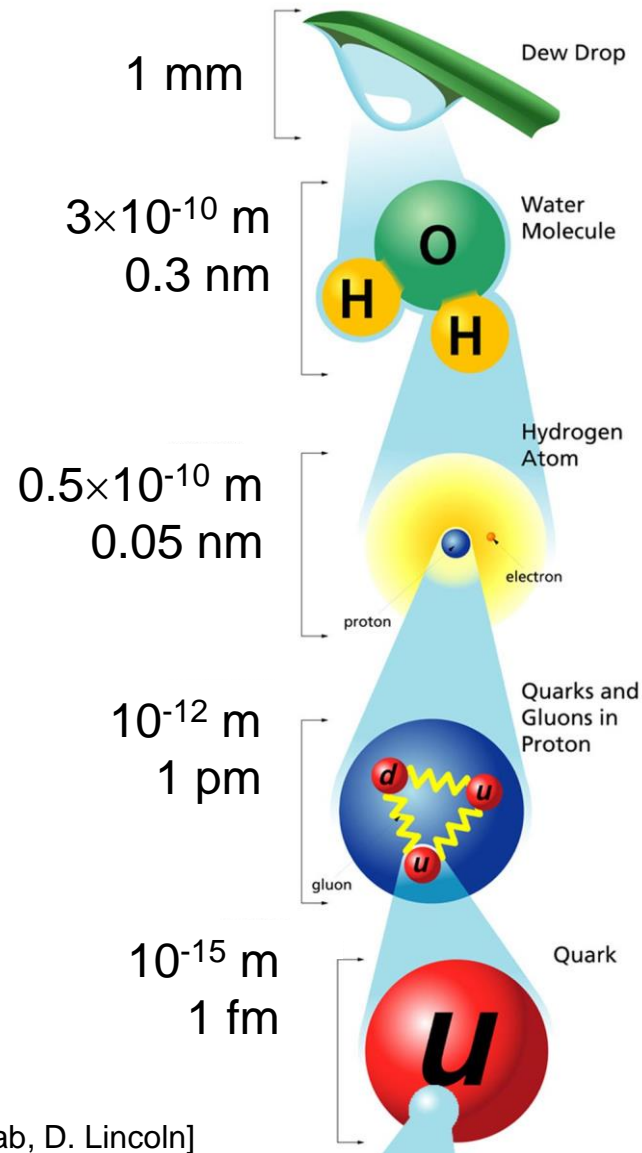Number of galaxies in Universe ~ billions to trillions

… maybe more

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

- The Hitchhiker's Guide to the Galaxy

PollEv.com/sethaubin

Very Small Length Scales

"There's plenty of room at the bottom."
                    - Richard Feynman

1 mm

Dew Drop

3×10^{-10} m
0.3 nm

Water Molecule

O

H   H

Hydrogen Atom

0.5×10^{-10} m
0.05 nm

electron

proton

10^{-12} m
1 pm

Quarks and Gluons in Proton

d   u

u

gluon

10^{-15} m
1 fm

Quark

u

[Figure adapted from FermiLab, D. Lincoln]

Powers of 10 videos

Original "Powers 10" video from 1977:

https://www.youtube.com/watch?v=0fKBhvDjuy0

(goes very big and very small)

New version of "Powers of 10" video (BBC, 2022):

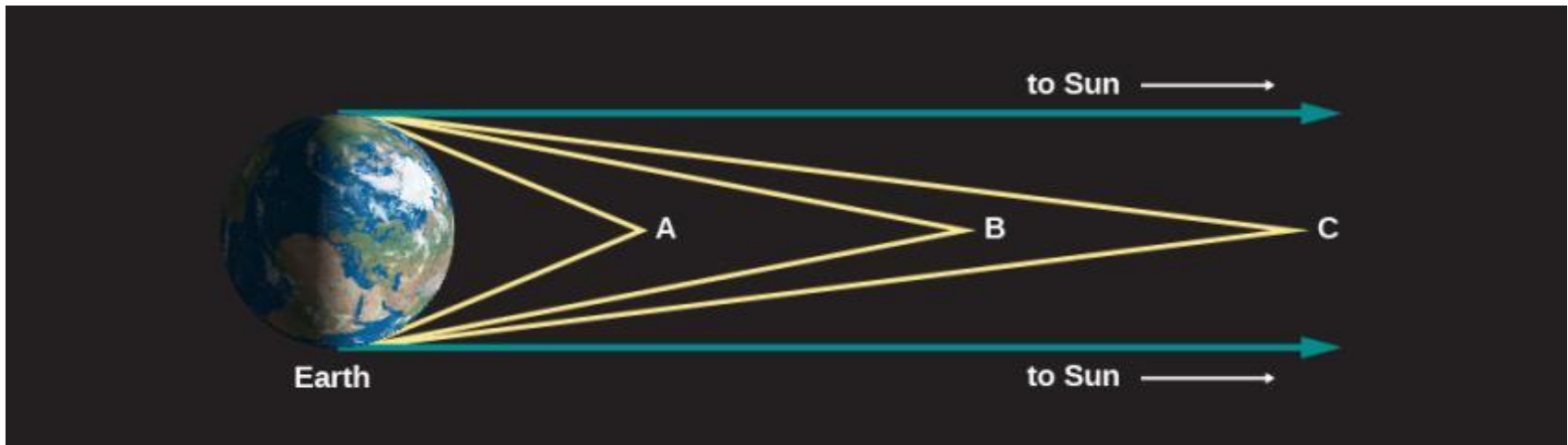https://aeon.co/videos/revisiting-powers-of-ten-what-weve-learned-about-the-universe-since-1977

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.
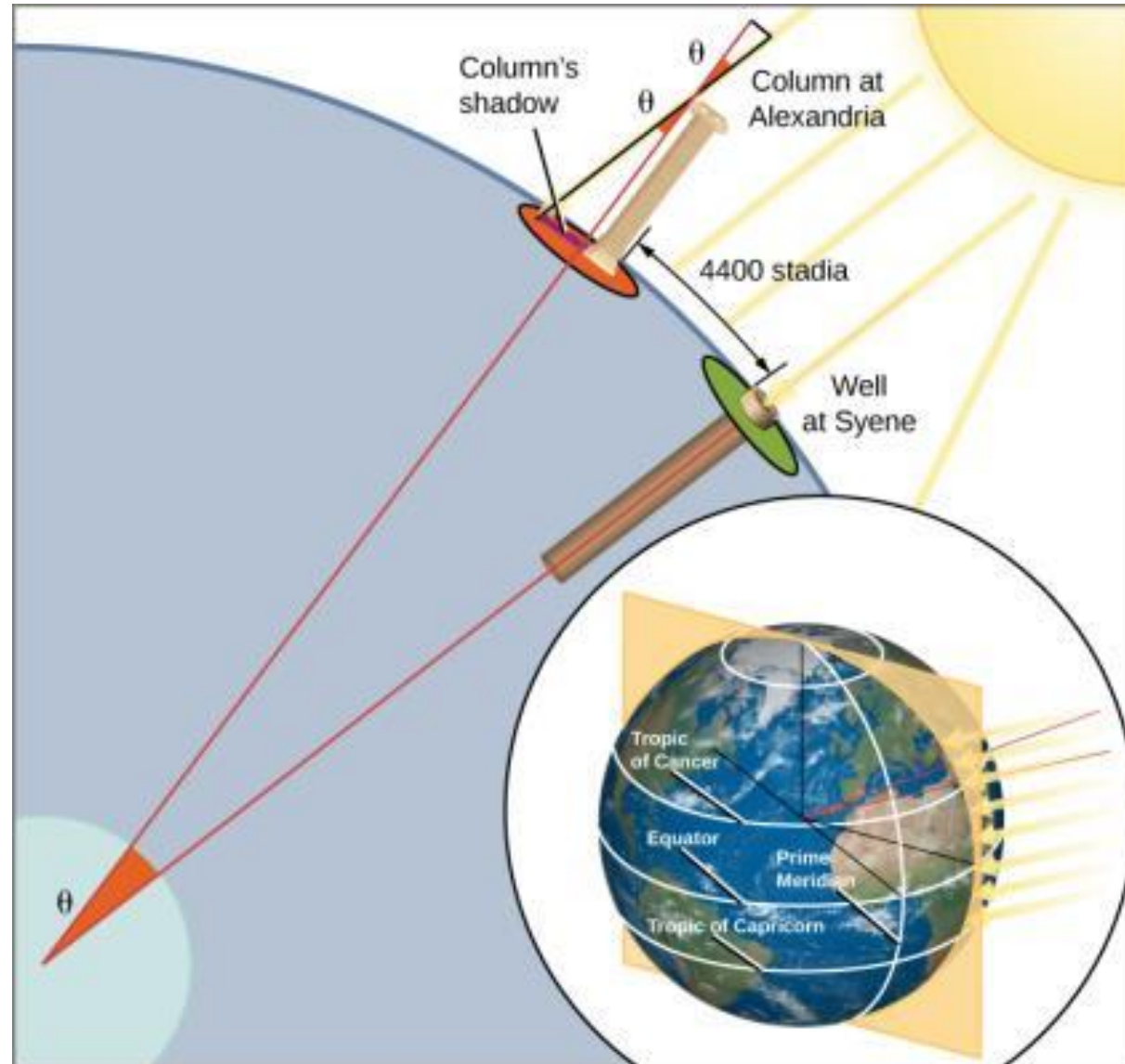
→ Light rays from Sun are quite parallel.

→ Light rays from stars are very parallel.

How Eratosthenes Measured the Size of Earth

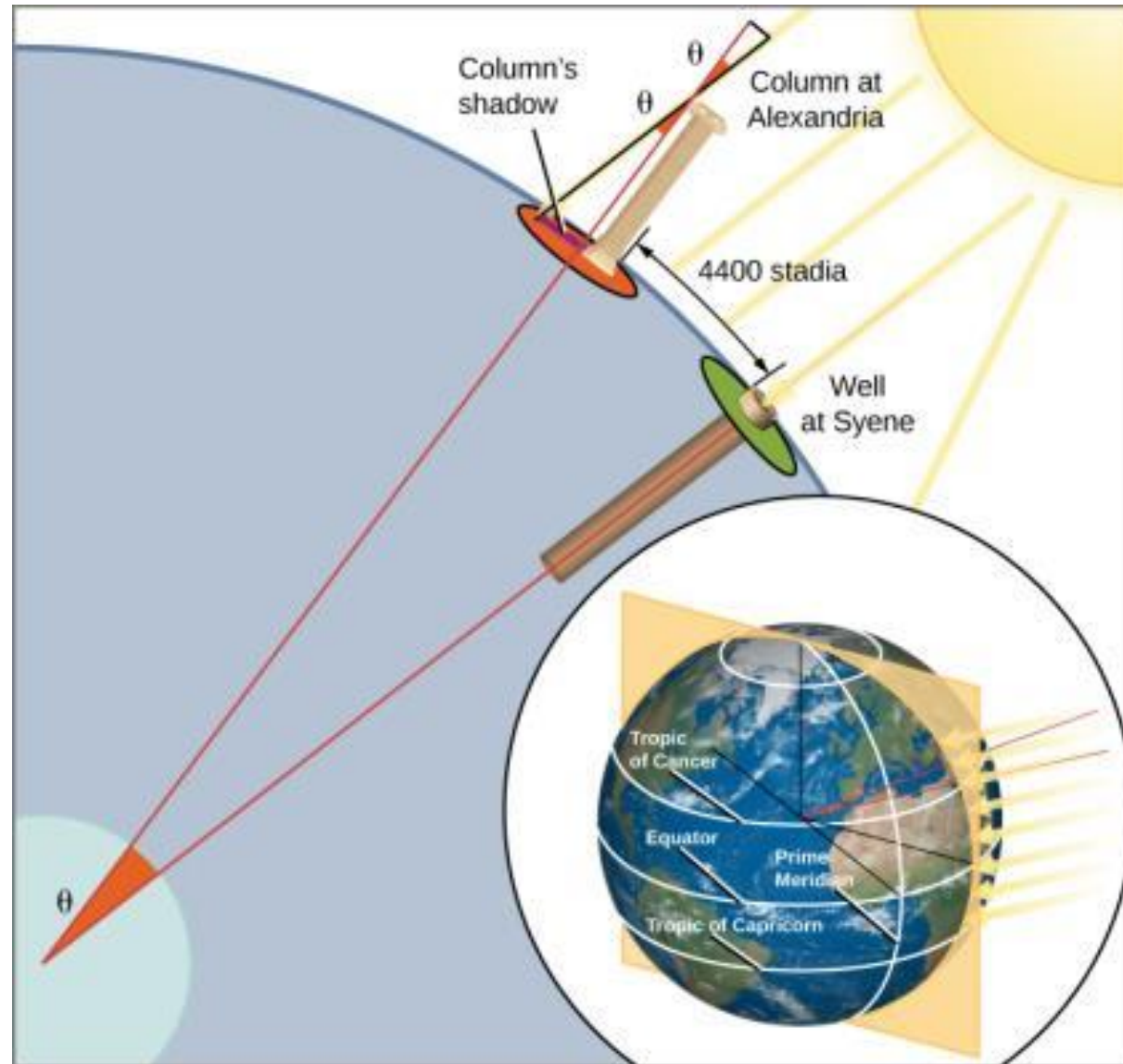Eratosthenes (276-194 BC) observed that:

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

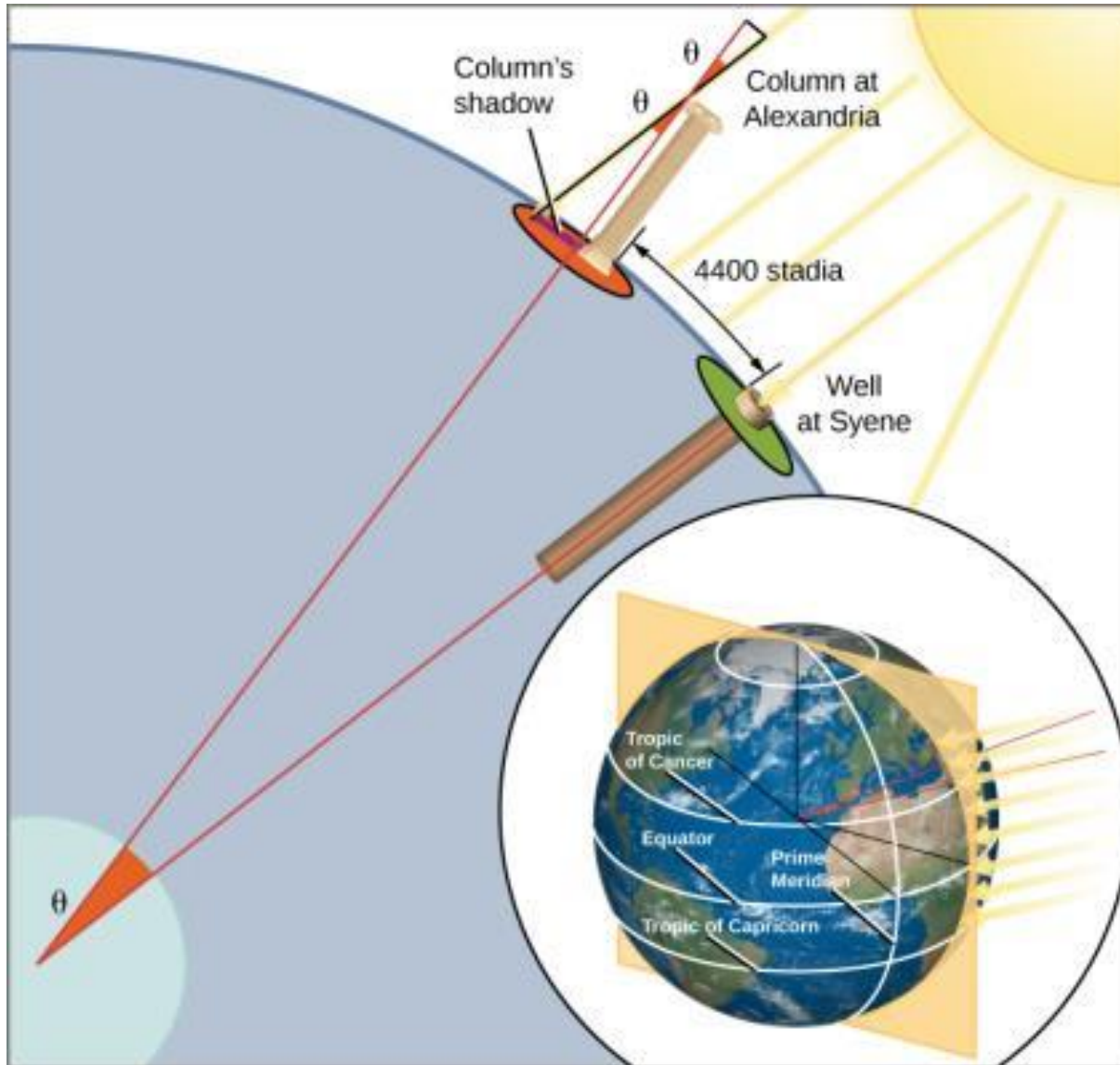[OpenStax; NOAA Ocean Service Education]

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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.**

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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.

[OpenStax; NOAA Ocean Service Education]

How Eratosthenes Measured the Size of Earth

Circumference of Earth = 50 × 5000 stadia

= 250,000 stadia   *(1 stadia ~ 180 m)*

≈ 45,000 km

Actual circumference of Earth = 40,000 km

How Eratosthenes Measured the Size of Earth

Circumference of Earth = 50 × 5000 stadia

= 250,000 stadia   *(1 stadia ~ 180 m)*

≈ 45,000 km

→ Radius = 45,000/2π ≈ 7,200 km

Actual circumference of Earth = 40,000 km

→ Radius = 40,000/2π ≈ 6,400 km