PHYS 101:
Elementary Astronomy

Dr. Jared Workman

Introductions - I'll go first

Who are you…

- Introduce yourself to 2 neighbors:
  - Trade names, hometowns, interests, etc.
  - Why are you taking this course?
  - What topics do you most want to learn about in this class?
- I'll try to get to know you throughout the semester but you can help by…
  - Asking questions
  - Answering questions
  - Coming to see me in office hours
  - Tell me your name every time you ask a question

Required Text

- The Cosmic Perspective
  by Bennett et al., 7th ed

Includes:

Access code for website:

www.masteringastronomy.com

You will need your own "masteringastronomy" account!

YOU ARE EXPECTED TO READ THE BOOK

More on MasteringASTRONOMY

- Uses a tutorial method in which you are guided to the solution of multi-step problems
  - Wrong-answer feedback
  - On-demand hints (use them if you need them!)
- See course website for how to register and how to submit problems
  - Scores automatically submitted (if you see a grade, I see the grade too!)

This Course

- Reading – Mandatory
- Homework - 50 percent of your grade, there will be weekly Mastering Astronomy assignments
- Quizzes - 30 percent of your grade
- Final Exam – 20 percent of your grade

Keys to Success

- Attend Class
- Prepare and Participate
- Use Technology (but no cell phones, ipods, etc. If you use a laptop sit in the back rows)
- Campus Resources (Tutoring HH113)
- Come to my hours, work with friends
- Pay attention to financial aid policies, if you drop below 12 credit hours you aren't full time, if you fail a course you may lose financial aid

Course Website

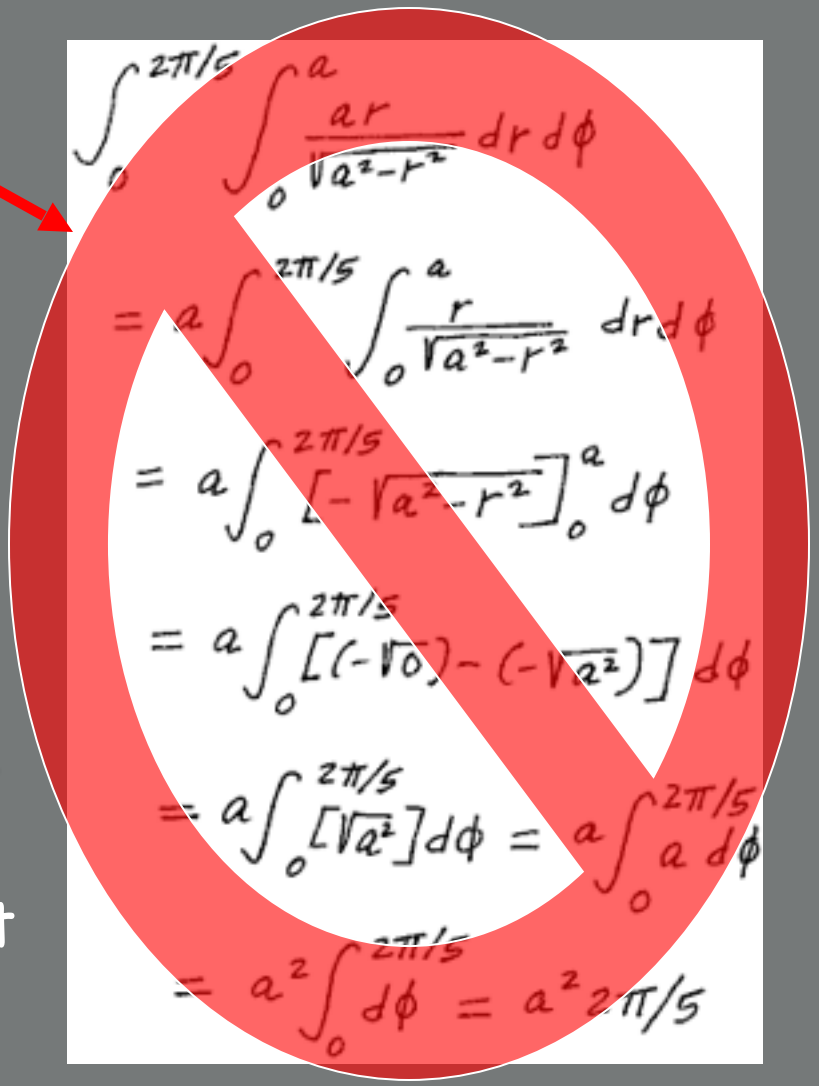
- http://org.coloradomesa.edu/~jworkman/teaching/fall15/101/index101.php
- Lectures
- Reading
- Syllabus
- How to set up and use Mastering Astronomy
- Exams

- Let's go over policies now

Did you know?

Will this course have MATH?!?!?

- YES
  - But not that kind!!
- Algebraic Manipulation
- Scientific Notation
- Areas
- Volumes
- Exponents



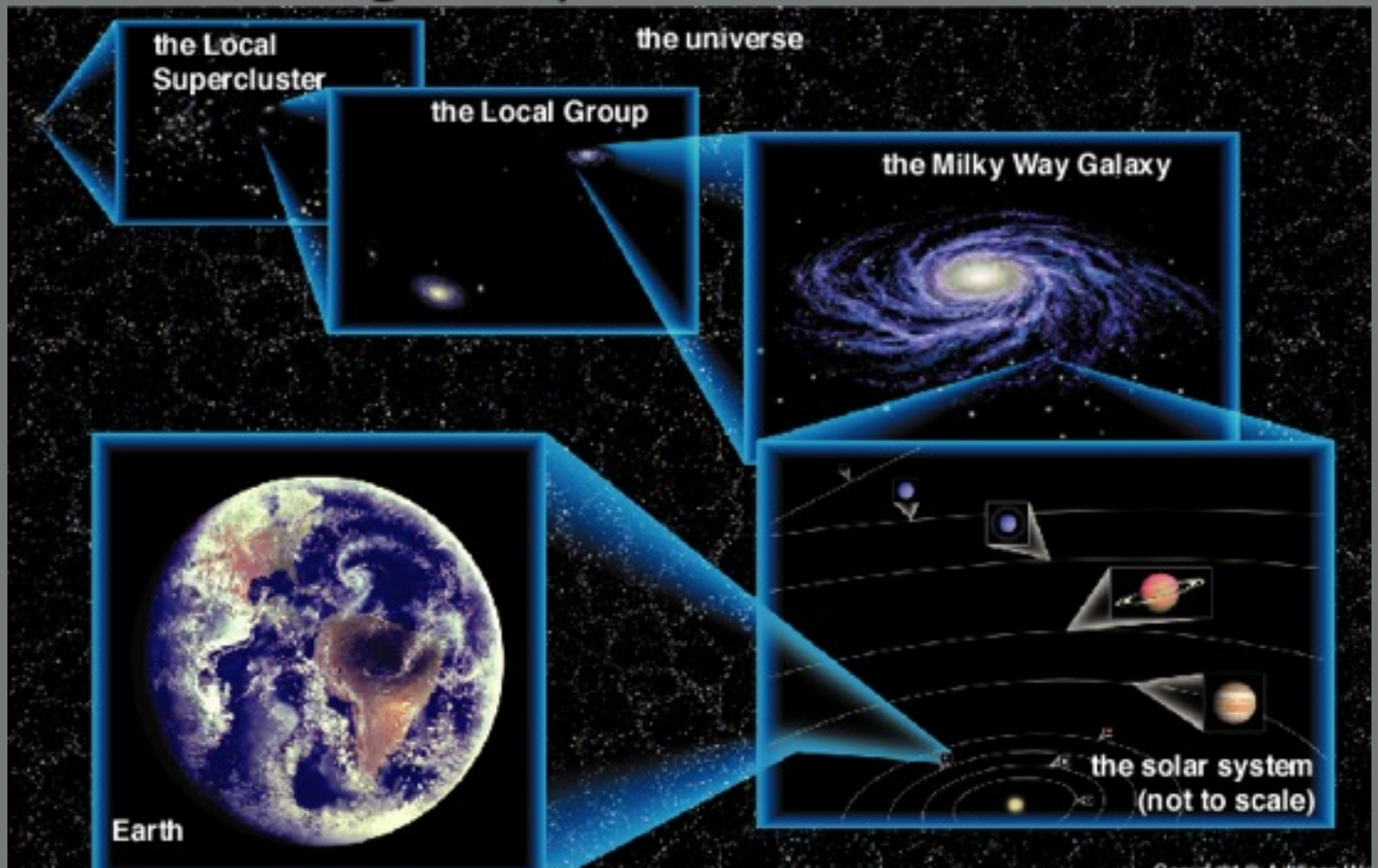
Need a Refresher?

Come See me, work with friends, use the resources on campus Tutoring Lab - Room HH113, look at the review at the end of this lecture

Course Overview:

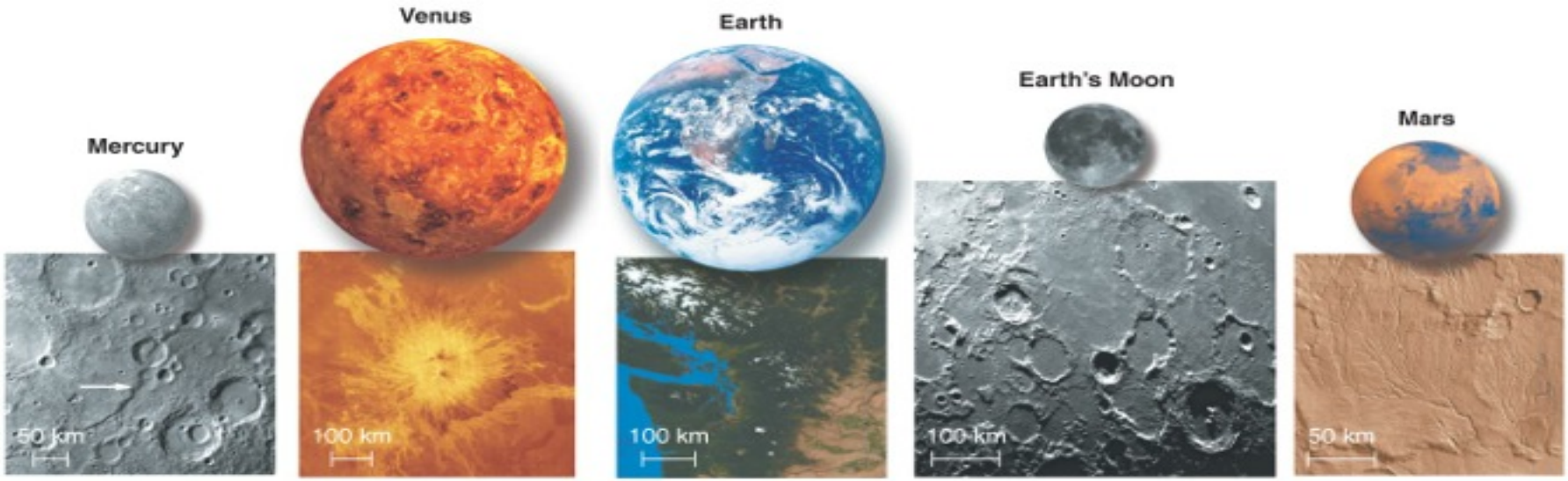
What we will study

- Vast range of SIZES and SCALES: Understanding our place in the universe



How does our position here on Earth affect us and what we see?

- Celestial Motions
- Eclipses
- Seasons
- Moon Phases



Heavily cratered Mercury has long steep cliffs (arrow).

Cloud-penetrating radar revealed this twin-peaked volcano on Venus.

A portion of Earth's surface as it appears without clouds.

The Moon's surface is heavily cratered in most places.

Mars has features that look like dry riverbeds; note the impact craters.

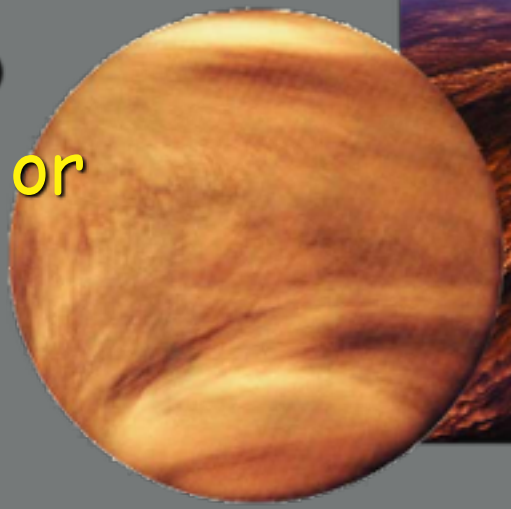
TABLE 10.1 Atmospheres of the Terrestrial Worlds

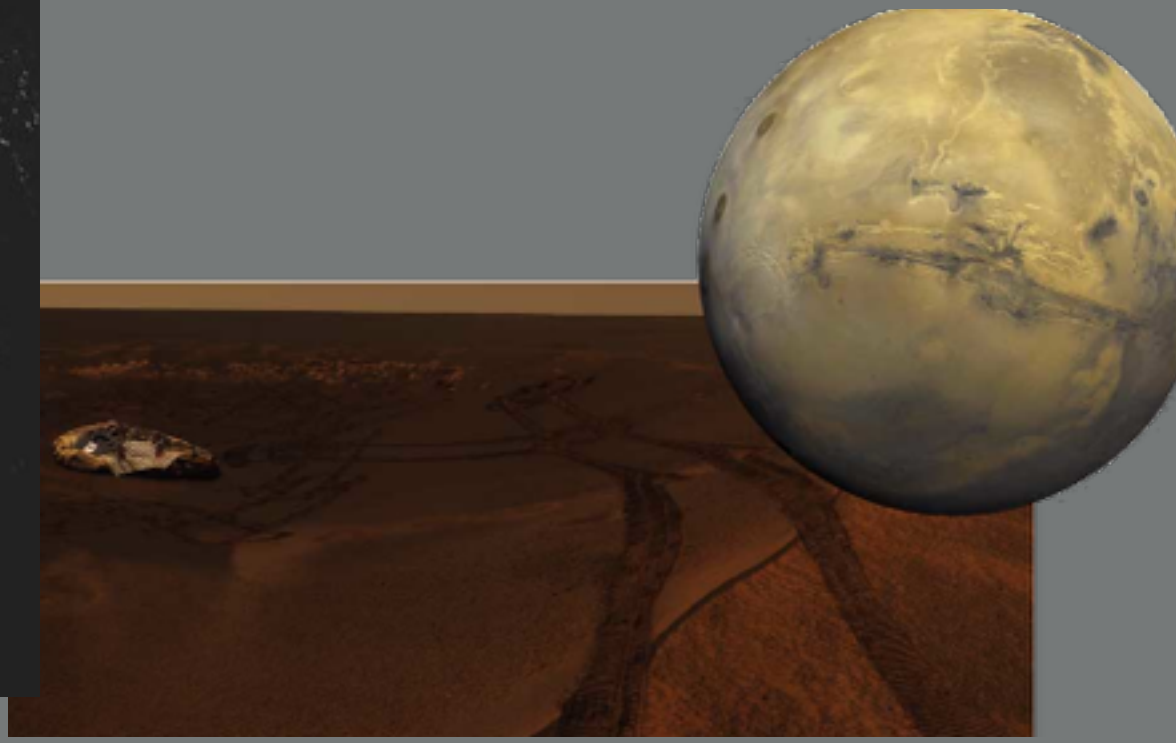
World	Composition of Atmosphere	Surface Pressure*	Average Surface Temperature	Winds, Weather Patterns	Clouds, Hazes
Mercury	helium, sodium, oxygen	10^{-14} bar	day: 425°C (797°F); night: −175°C (−283°F)	none: too little atmosphere	none
Venus	96% carbon dioxide (CO_2) 3.5% nitrogen (N_2)	90 bars	470°C (878°F)	slow winds, no violent storms, acid rain	sulfuric acid clouds
Earth	77% nitrogen (N_2) 21% oxygen (O_2) 1% argon H_2O (variable)	1 bar	15°C (59°F)	winds, hurricanes, rain, snow	H_2O clouds, pollution
Moon	helium, sodium, argon	10^{-14} bar	day: 125°C (257°F); night: −175°C (−283°F)	none: too little atmosphere	none
Mars	95% carbon dioxide (CO_2) 2.7% nitrogen (N_2) 1.6% argon	0.007 bar	−50°C (−58°F)	winds, dust storms	H_2O and CO_2 clouds, dust

*1 bar = the pressure at sea level on Earth.

What shaped the Terrestrial planets and what are their atmospheres like?

Why is there abundant life on Earth but no apparent life on Mars or Venus?

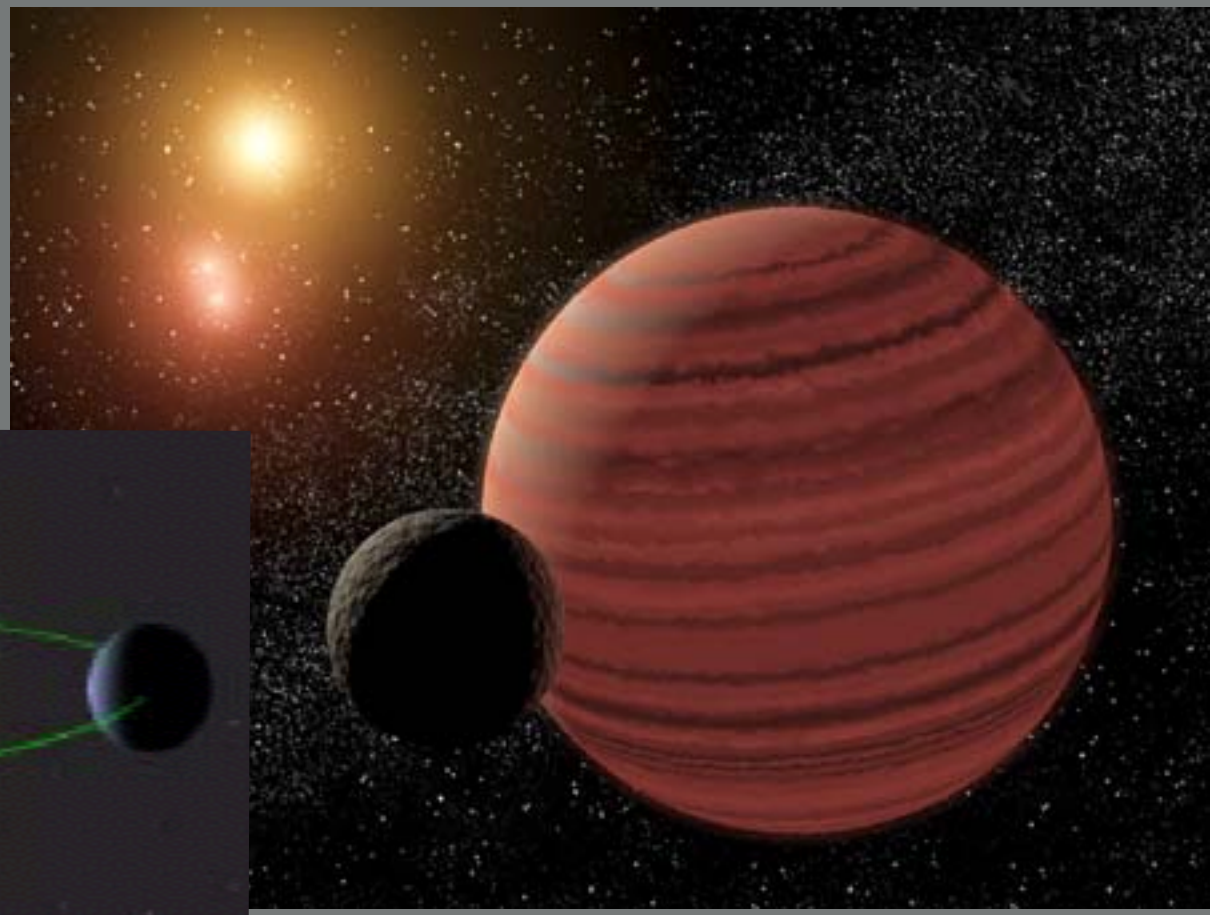


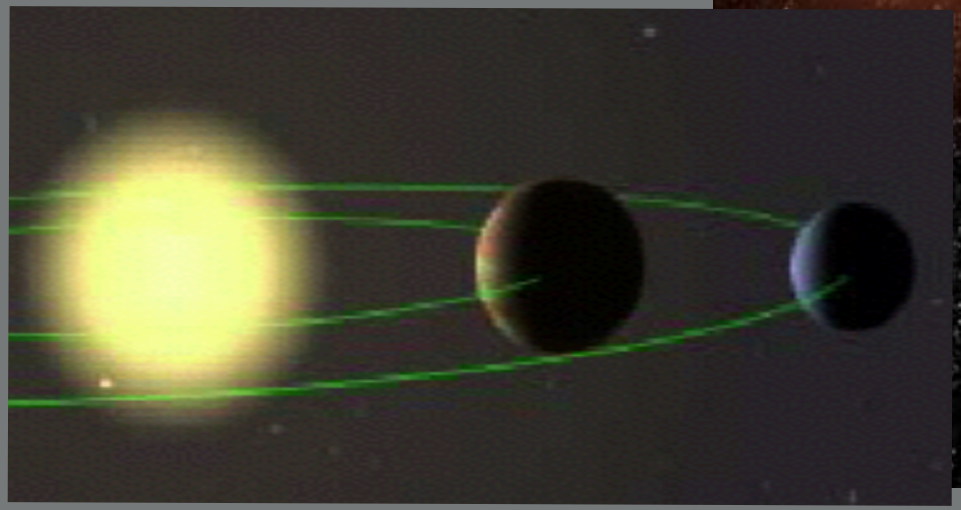


Why is Earth so different than Jupiter?

Why is there a debate about whether Pluto is a planet?

In What Ways Are Other Solar Systems Like Us… How Are They Different? How Do We Find Them?



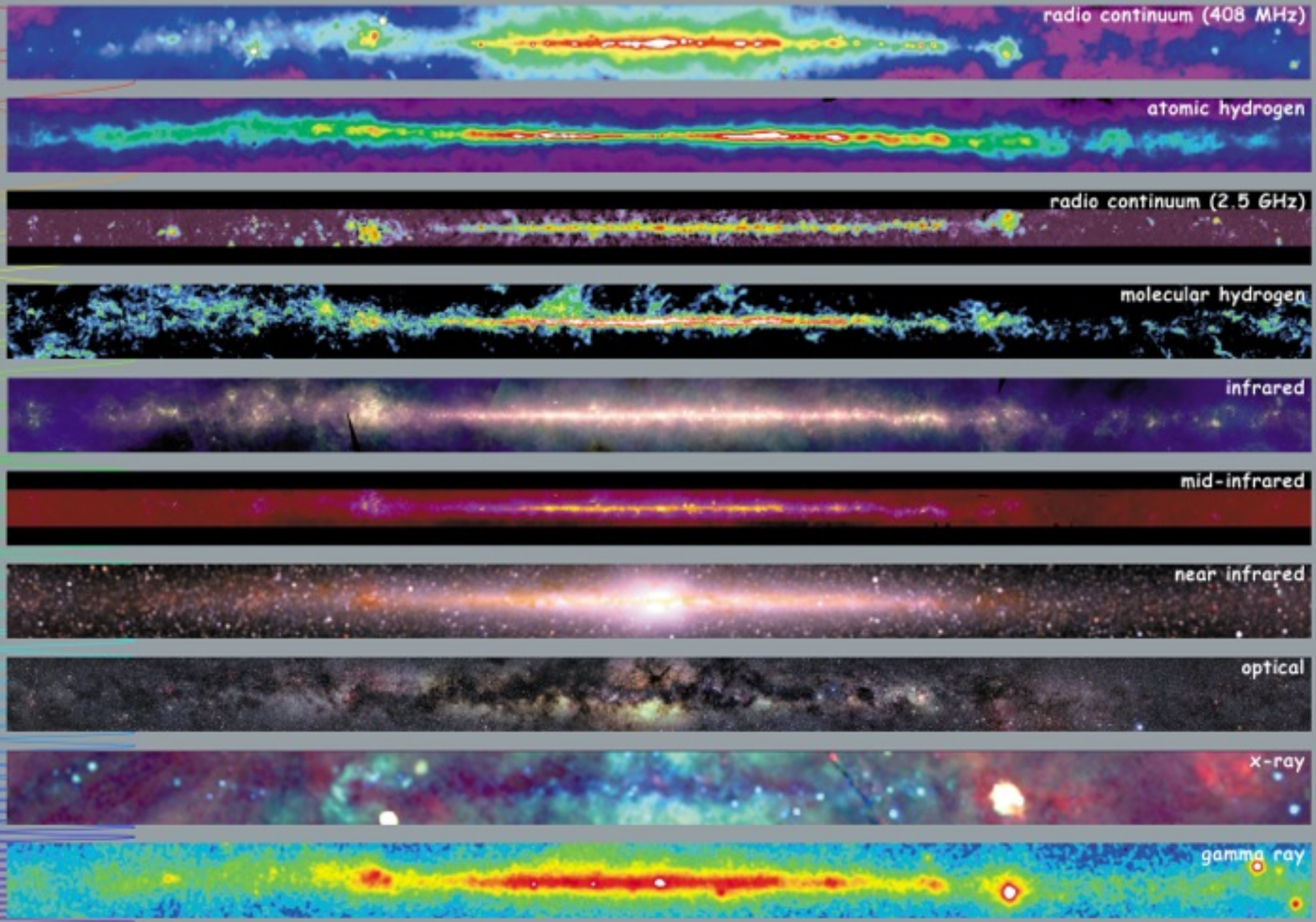


Energy, Gravity, Motion

LIGHT

Electromagnetic Radiation

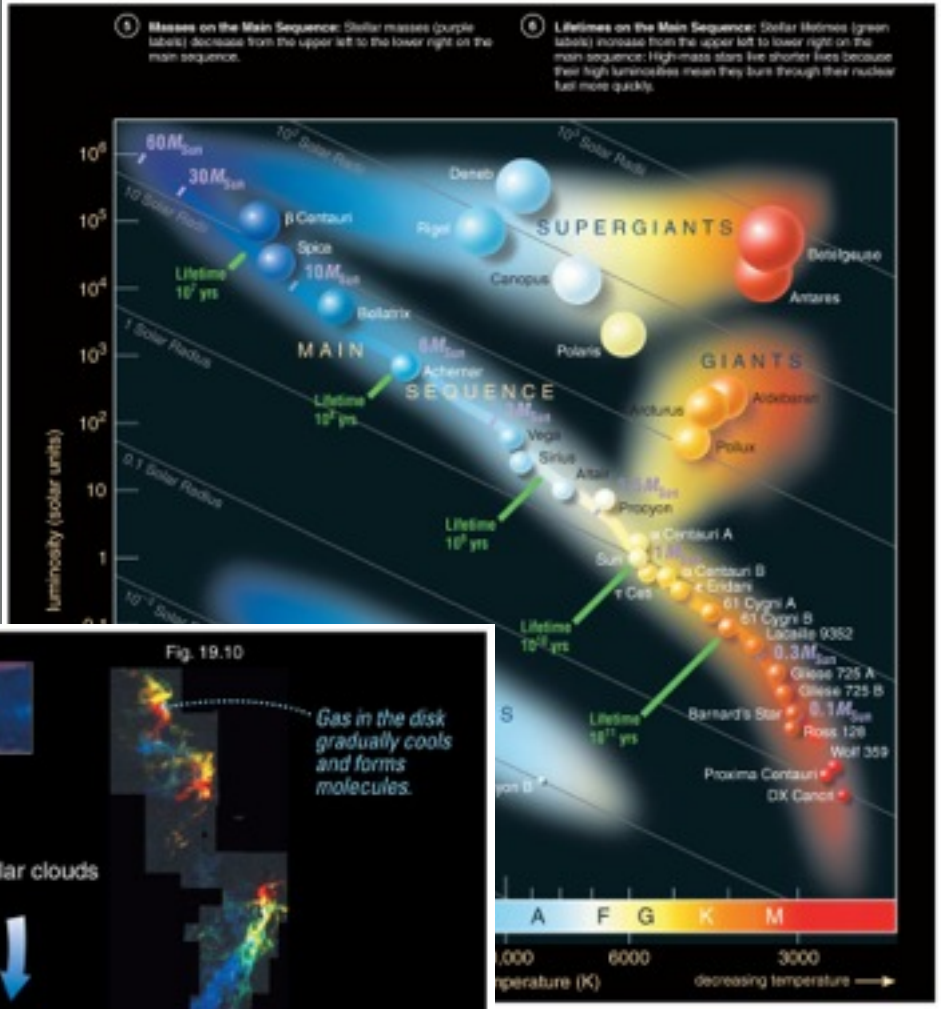
- What is light?
- What are the different forms in which we see it?
- How do we use it to find out what things are made of?

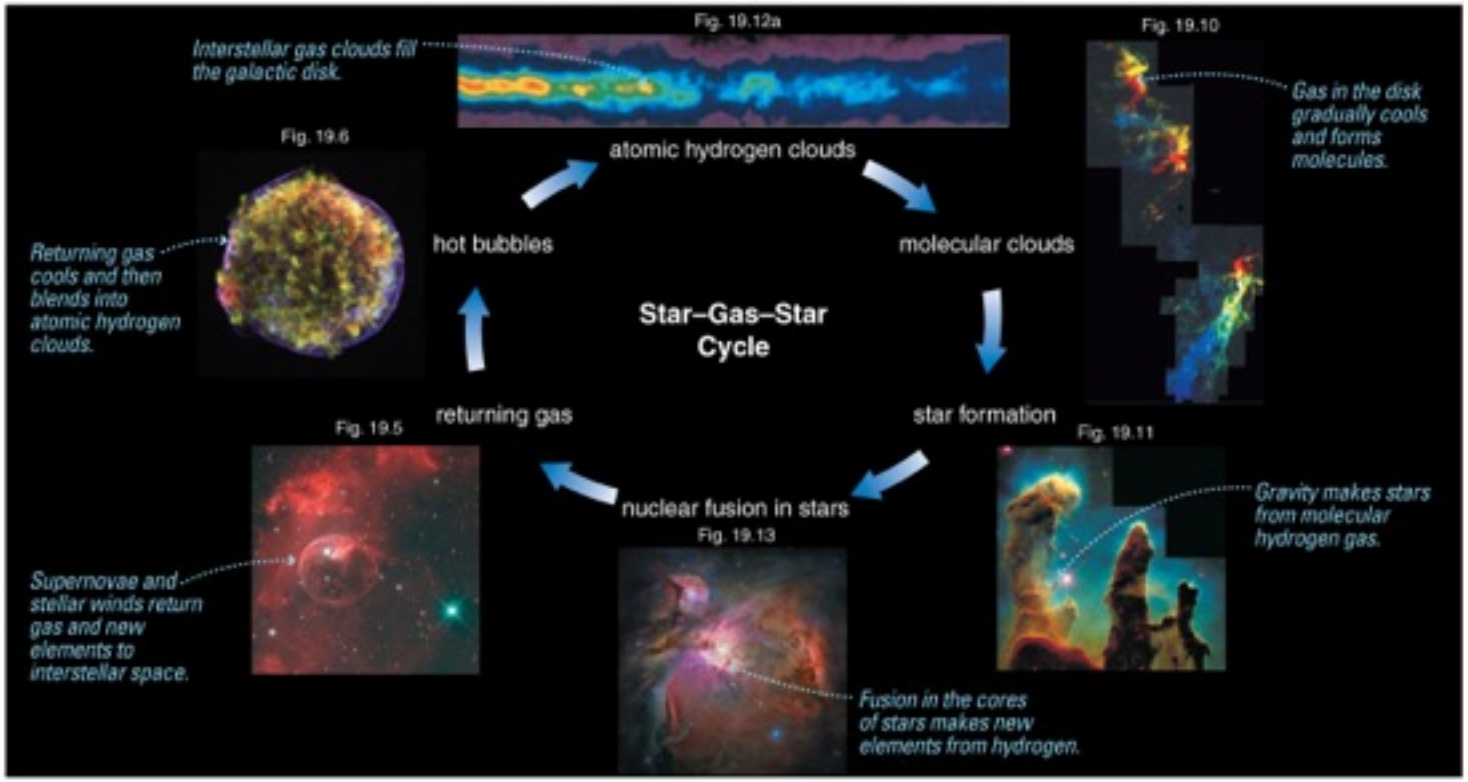


Multiwavelength Milky Way

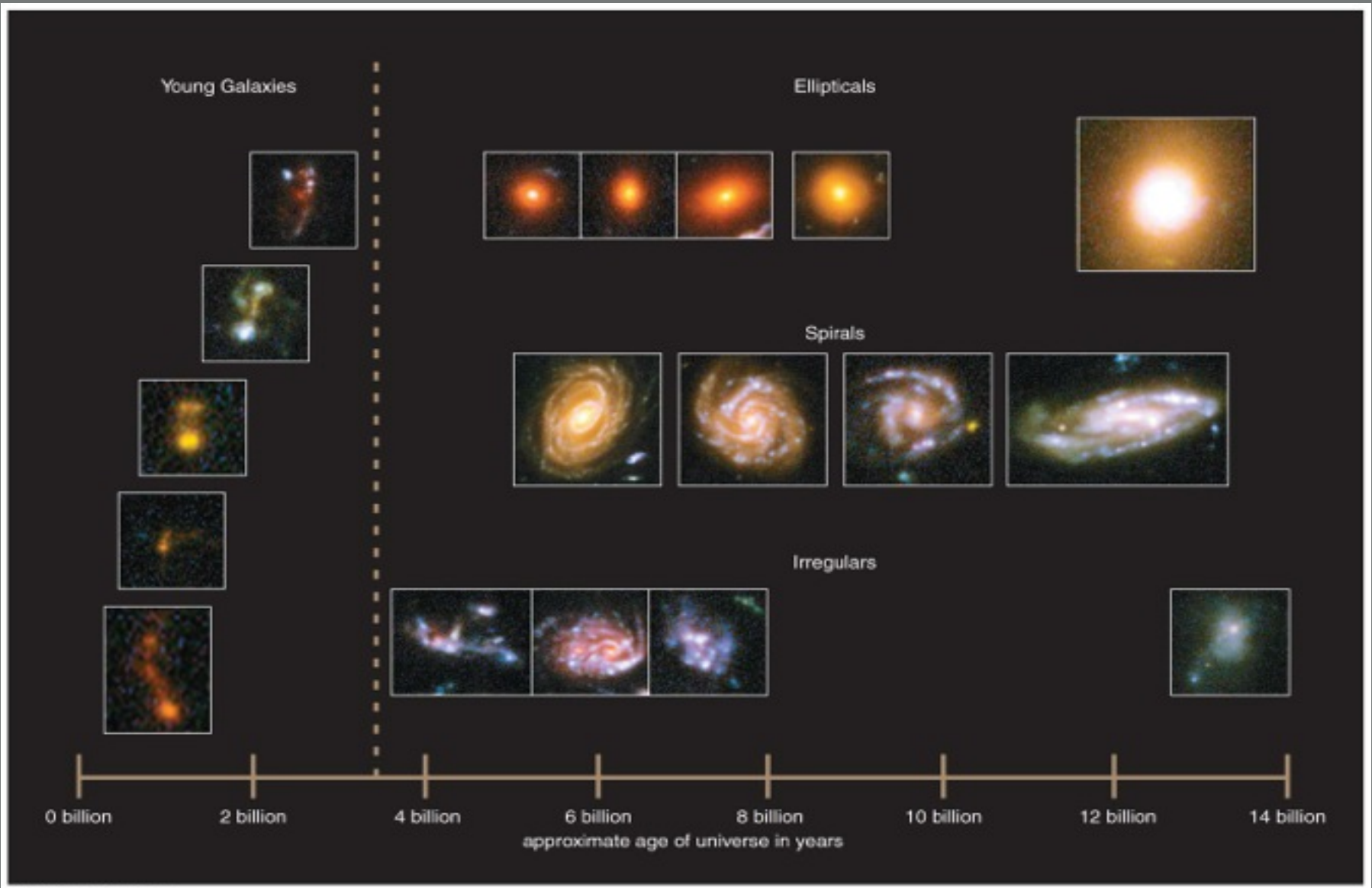
http://adc.gsfc.nasa.gov/mw

Stars, their births, lives, and deaths

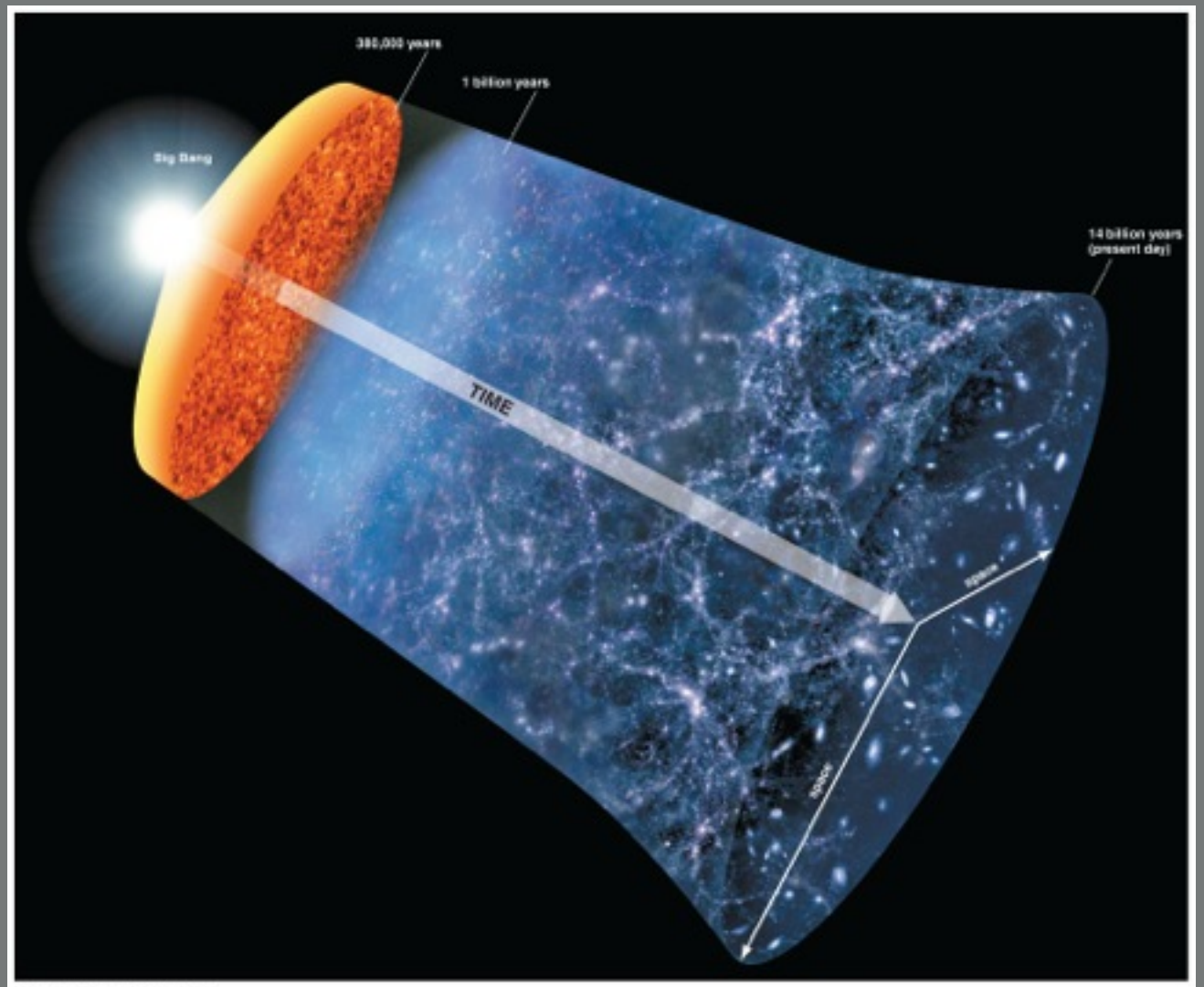




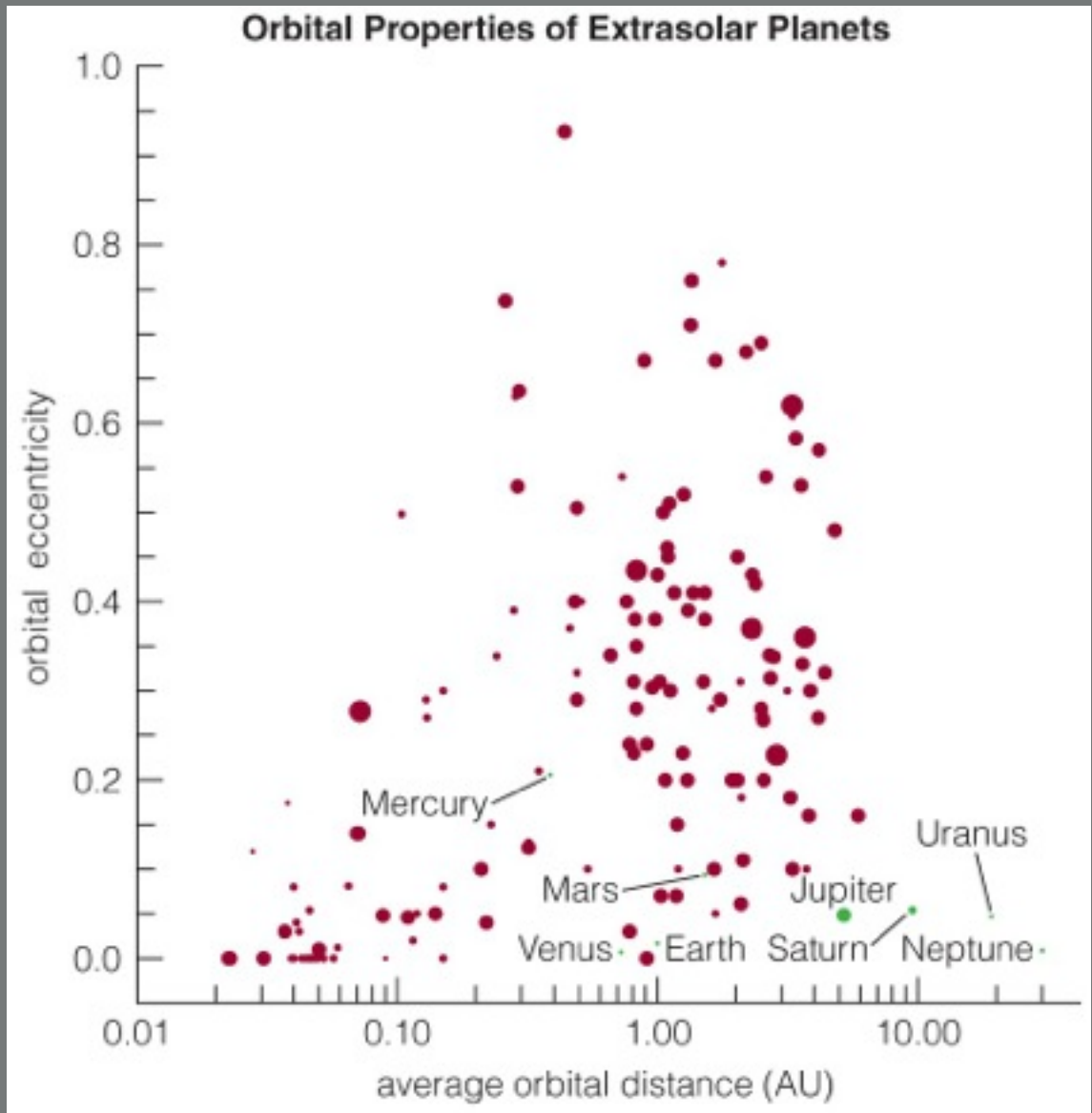
Galaxies



Cosmology - where did we come from and where are we going



Other Planets and Astrobiology



b The data from (a) are shown here as a graph. Dots closer to the left represent planets that orbit closer to their stars, and dots lower down represent smaller orbital eccentricities. Green dots are planets of our own solar system.

What is this course NOT?

Astronomy ≠ *Astrology!!!*

You aren't the symbol you think you are, more on this later.

What is this course NOT?

Just Memorizing Constellations

Why is this Profound?

Chapter 1
A Modern View of the Universe

Chapter 1 Goals

Our goals for learning:

- The scale of the Universe
- The history of the Universe
- How are things moving in the Universe?

How do we measure distances to things in space?

- Kilometers (km)
- Astronomical Units (AU)
- Light-years
- Parsecs (~3.26 Light-years)
- Kpc 1000 parsecs
- Mpc 1 million parsecs

Measuring cosmic distances

- Most useful measure is based on the speed of light ~ 300,000 km/sec
  - Nothing travels faster through space
  - All light travels at a constant speed in space.

Astroomical Unit = the distance between the earth and sun, useful in the solar system

~ 150,000,000 km or 90,000,000 miles

~ 500 light seconds

- Light-year = the distance light travels in a year

~ 300,000 km/sec x 60 sec/min x 60 min/hr x 24 hr/day x 365 days/year x 1 year

~ 10 trillion kilometers ~ 10^{16} m

- Like saying "I live 30 min from Boulder"
  - Your are giving a time… but are implying traveling at a certain velocity

Convert SPEED to DISTANCE

You know that

SPEED = DISTANCE / TIME

meters/sec = meters / sec (or think mph)

Multiplying both sides by **TIME** we can get

SPEED x TIME = DISTANCE

(m/s) x (s) = meters

Measuring Distances with Light

- Based on the finite speed of light (300,000 km/s).

Destination	Distance
Moon	1 light-second
Sun	8 light-minutes (1AU)
Outer Solar System	Few light-hours
Proxima Centauri	4.2 light-years
Andromeda Galaxy	2.5 million light-years

Thought Question

How much time does it take light to travel 1 Astronomical Unit (1 AU)?

A. Speed of light x 1 AU
B. Speed of light / 1AU
C. 1 AU / Speed of light
D. 1 light-year

How much time does it take light to travel 1 Astronomical Unit (1 AU)?

Speed = Distance/Time

$\Rightarrow$ Time=Distance/Speed

Time = 1 AU / Speed of light

= 1.5×10^{11} meters

3×10^{8} meters/sec

= 0.5×10^{3} sec

= 500 seconds

≈ 8 minutes

Over astronomical distances, even light takes a lot of time to travel between the stars

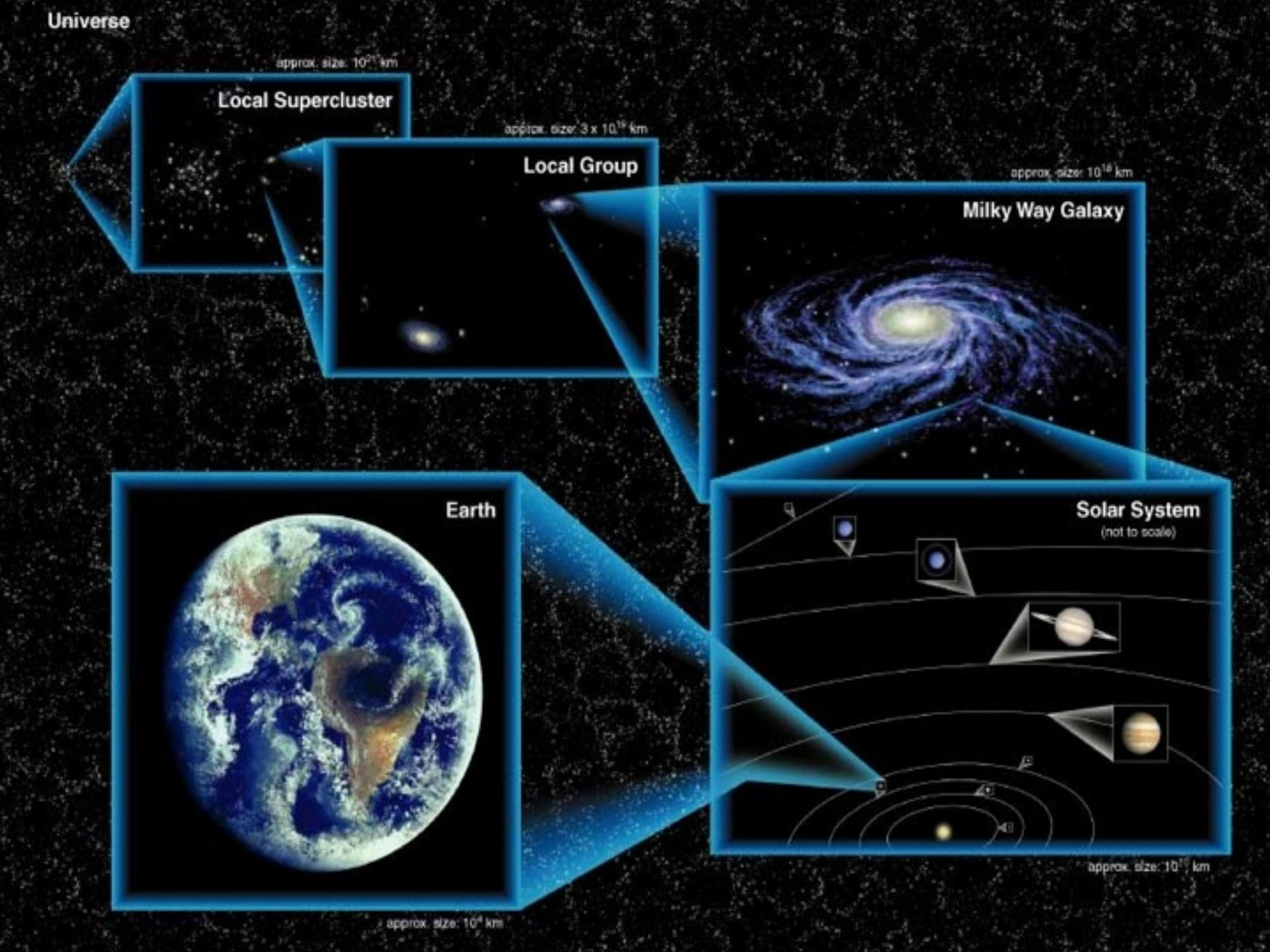
- This means that what we SEE in the distant universe is light that has traveled a long time.
- Our image of the universe is a delayed image. In looking out into space, we are looking back in time!
  - The farther away we look in distance, the further back we look in time.

Look Back Time

- What we SEE is always delayed by the speed of light.
- In the classroom, our view of each other is only about 10^{-7} seconds old, so we barely notice.
  - 10^{-7} sec = 0.0000001 sec

- Light travel time to the Moon ≈ 1 second
- Light travel time to the Sun ≈ 8 minutes
- Interplanetary probes incur noticeable delays

A brief tour of everything

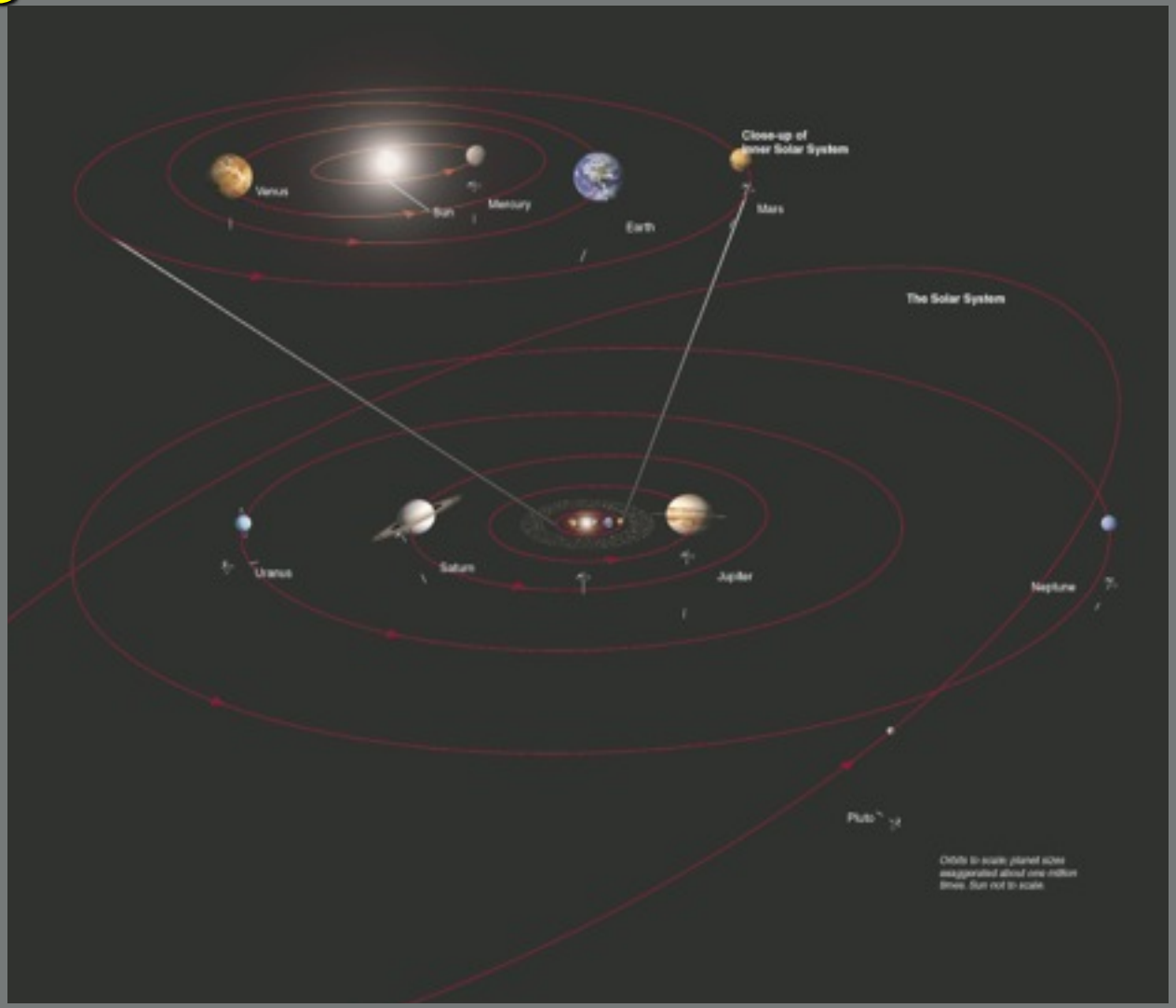

Universe
approx. size: 10^{23} km
Local Supercluster
approx. size: 3×10^{19} km
Local Group
approx. size: 10^{18} km
Milky Way Galaxy
Earth
Solar System
(not to scale)
approx. size: 10^{13} km
approx. size: 10^{4} km

Our Place

- I live in eastern Grand Junction, about 5 miles or 9 km from here.
- The United states is maybe 3000 miles or 4500 km across
- The Radius of the Earth is ~ 6370 km and its circumference is about 40,000 km ($2\pi R_{earth}$)
- Our earth orbits our sun at a distance of ~ 150 million km, what we call an Astronomical Unit or AU and is tilted 23.6 degrees to its orbital plane.
- Our sun orbits the center of the Milky Way about 8.5 kPc out.

Solar System

A star and all the material that orbits it, including planets and moons, asteroids and comets, etc

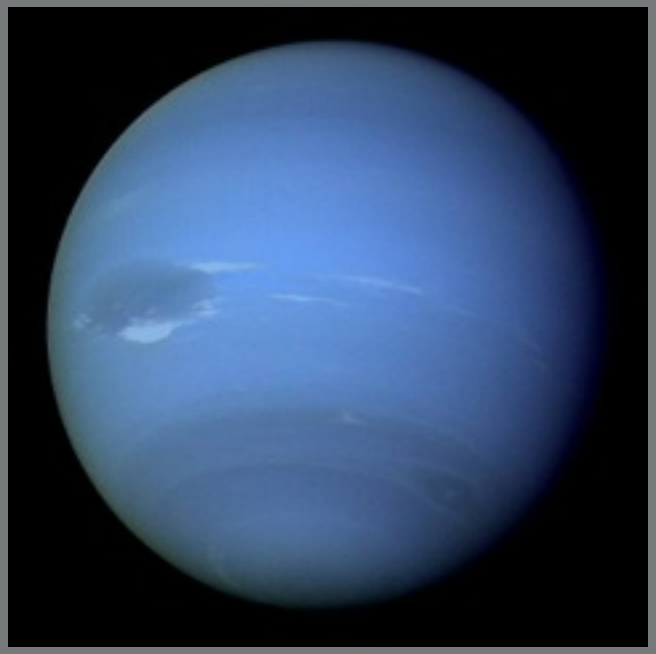


Our Solar System

- Sun at the center
- Planets orbit primarily in one plane (angular momentum conservation)
- Asteroids (failed planet?)
- Kuiper Belt (debris)
- Oort Cloud (debris)
- ~ 4.5 billion years old

Planet

Mars



Neptune

A moderately large object that orbits a star. No fusion, upper limit around 13 Jupiter Masses Planets may be rocky, icy, or gaseous in composition.

We define planets to be

A celestial body that is (a) in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

Which of the following is the correct ordering from largest to smallest?

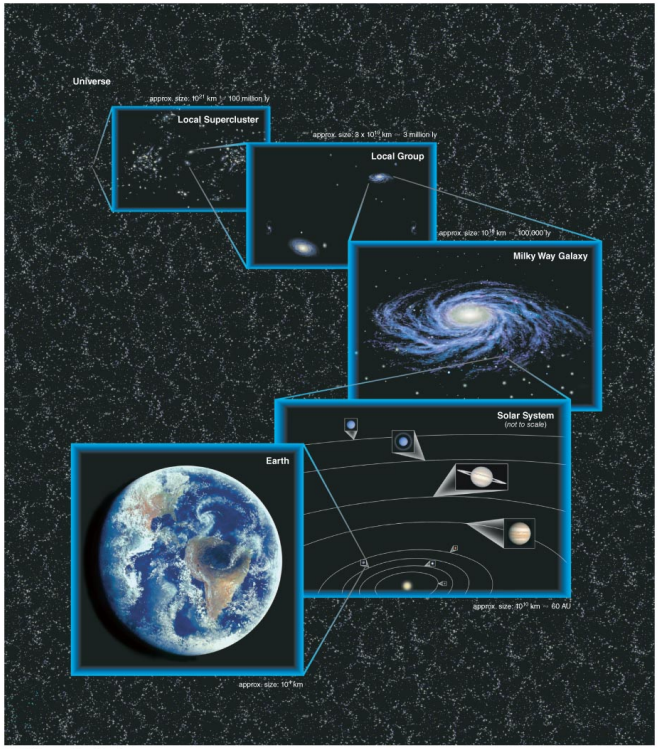
a) Solar System, Milky Way, Local Supercluster, Local Group

b) Milky Way, Solar System, Local Group, Local Supercluster

c) Local Group, Local Supercluster, Solar System, Milky Way

d) Local Supercluster, Local Group, Milky Way, Solar System

e) Local Supercluster, Milky Way, Solar System, Local Group



Planets

- In our solar system the planets are -
- Terrestial Mercury(.4 AU), Venus(.7 AU), Earth, Mars(1.5 AU)
- Gas: Jupiter(5 AU), Saturn(10 AU), Uranus(20 AU), Neptune(30 AU)
- NOTICE A TREND? ROCKY CLOSE IN/GAS FAR OUT
- WHY?
- To date we have found over 1000 planets around other stars, they do not follow the trend above. WHY?

Satellite (or moon)

Ganymede (orbits Jupiter)

An object that orbits a planet.

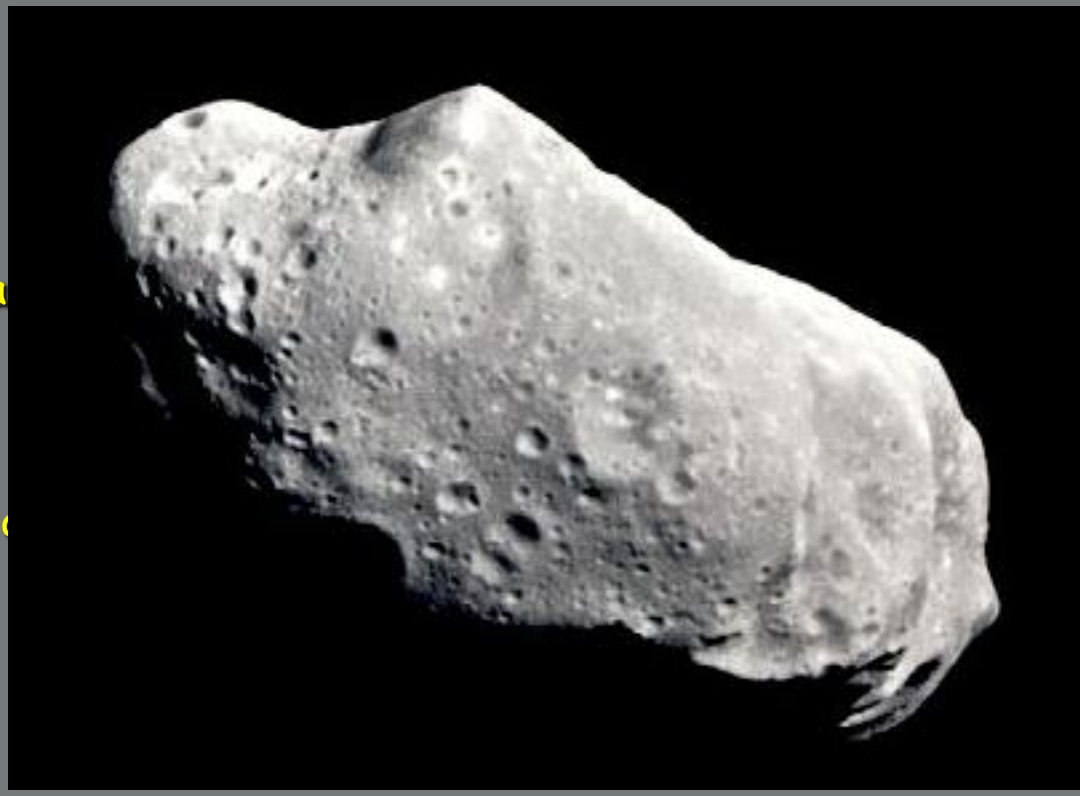
What is ours?

Jupiter has 63

Asteroid

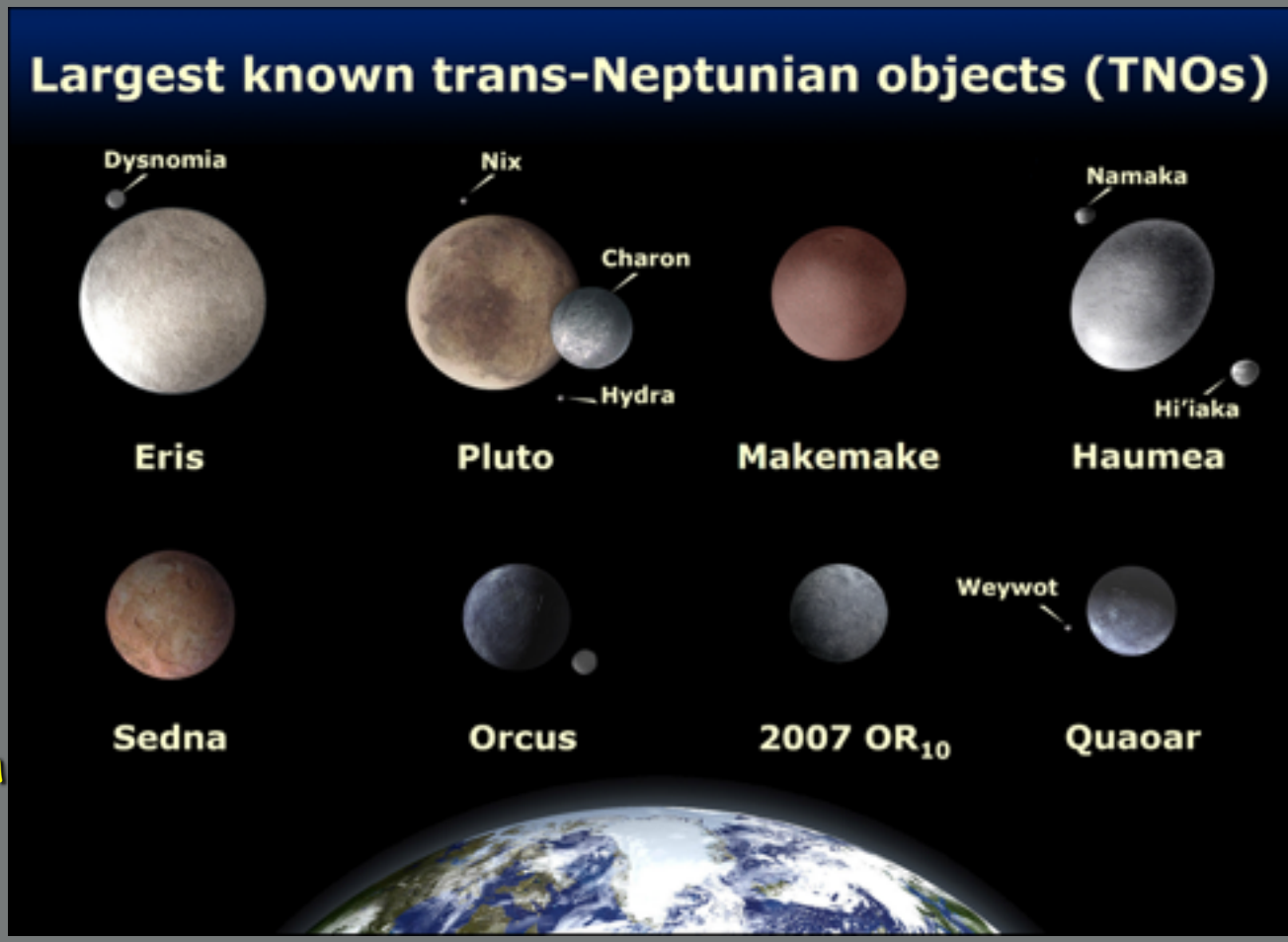
A relatively small and rocky object tha
orbits a star.

Our Solar system has an asteroid belt
between Mars and Jupiter, probably
failed planet due to Jupiter

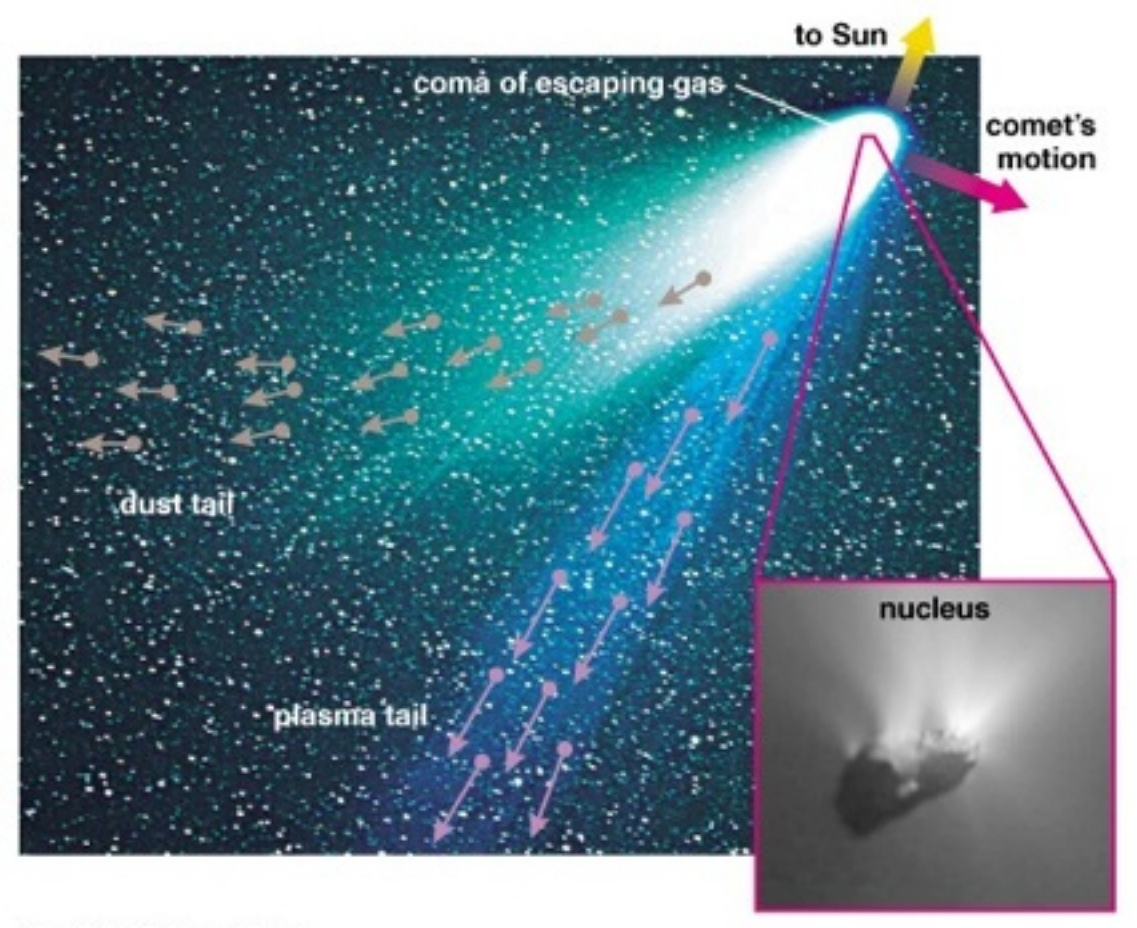


Kuiper Belt

- Small dwarf planets on eccentric orbits.
- Pluto is a kuiper belt object
- Extends from 30 - 100 AU
- Only .1-.01 M_{Earth}



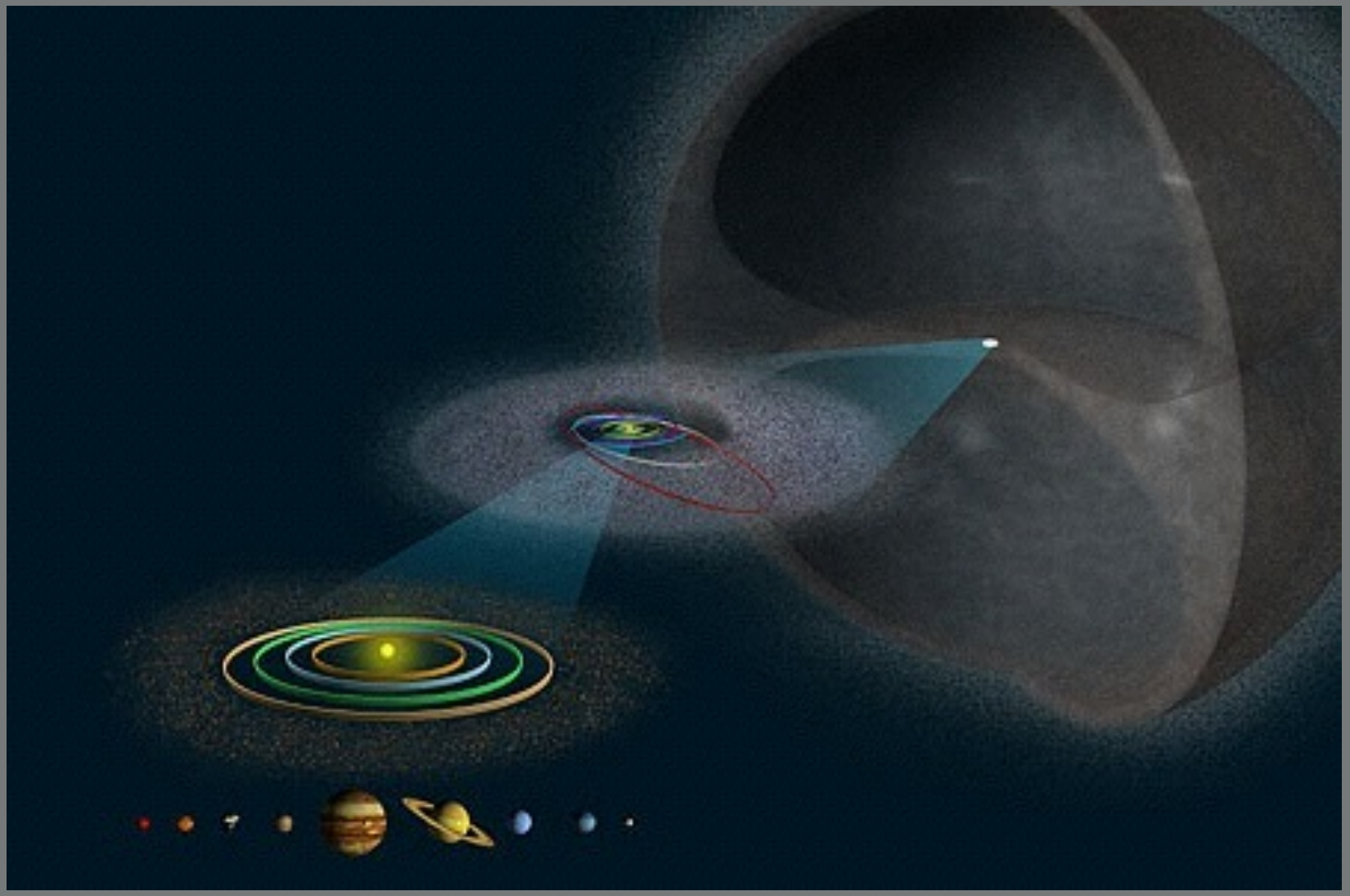
Comet

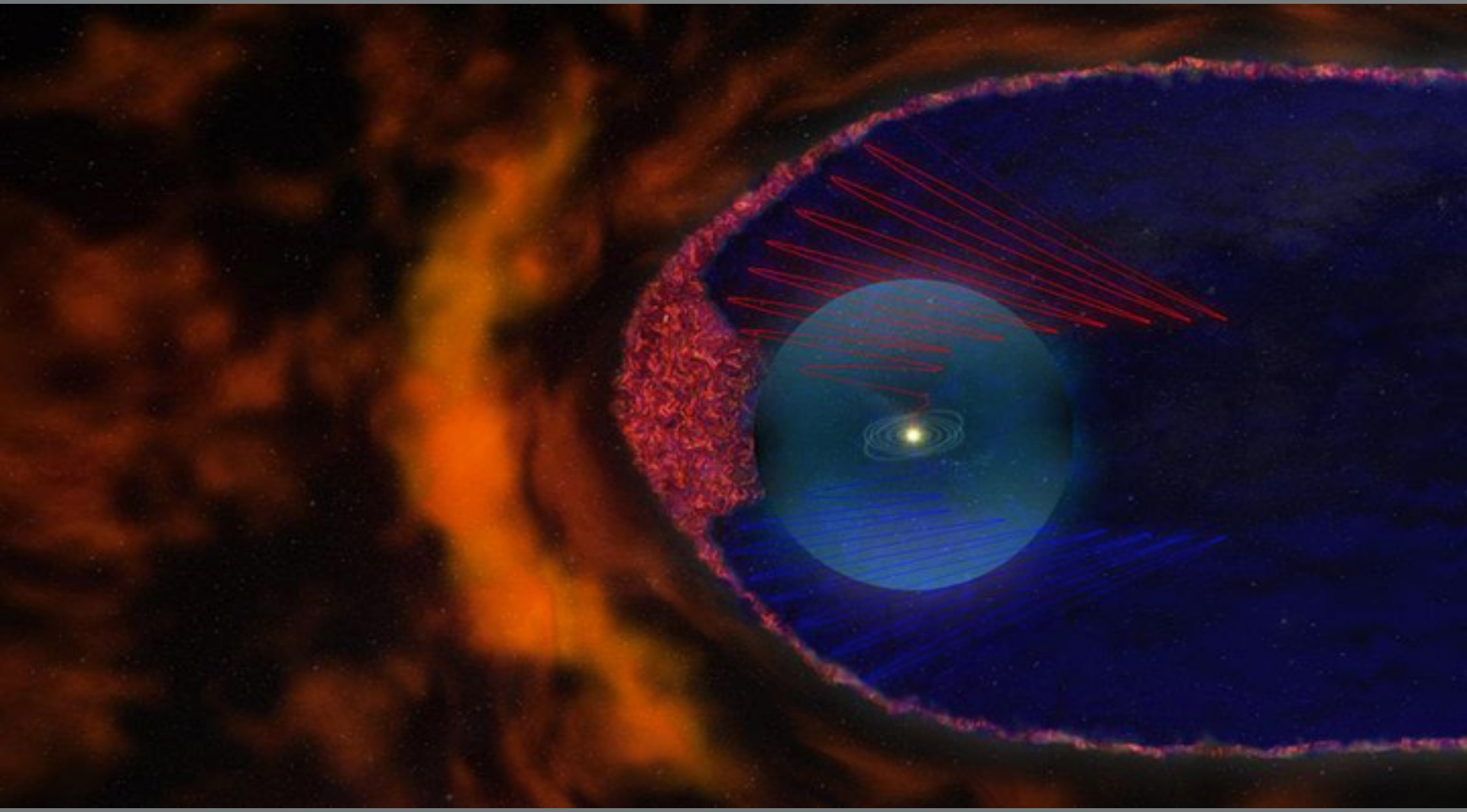


A relatively small and icy object that orbits a star.

Short Period Comets from the Kuiper Belt

Long Period Comets from the Oort cloud sorrounding our solar system out to 50,000 AU





Star

A large, glowing ball of gas that generates heat and light through nuclear fusion.

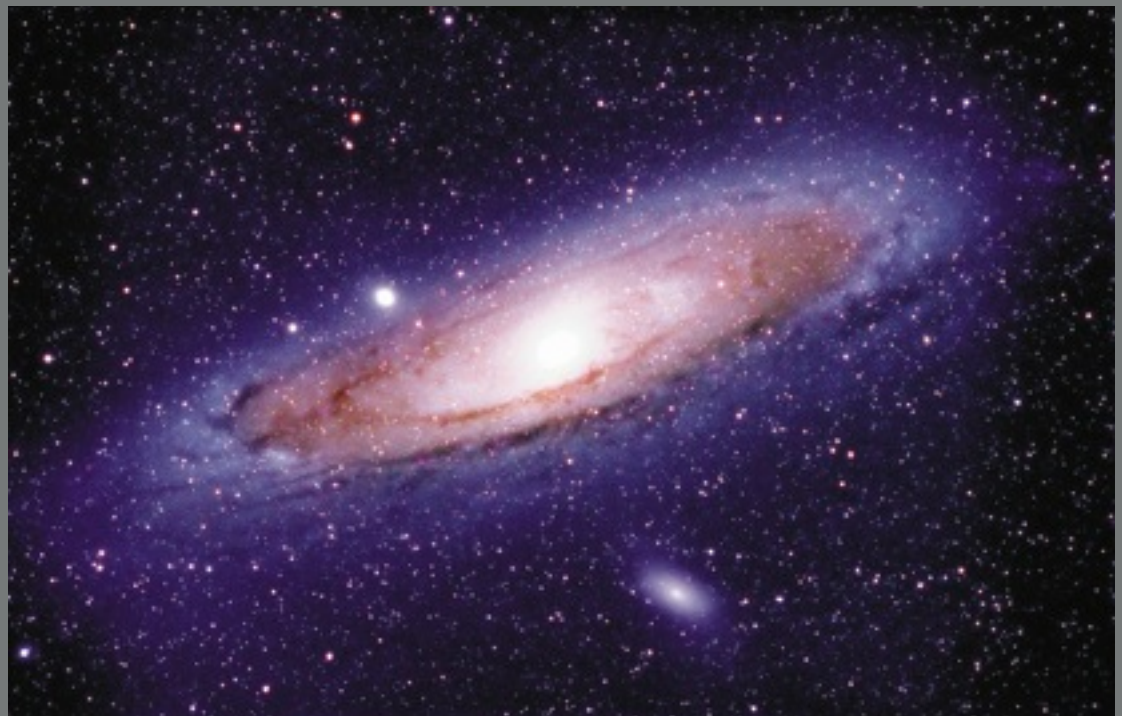
Range from 1/10,000 to 1 million in Luminosity and .1 to 100 in Mass

Our star is a moderately sized class G2V star with a diameter of 1.4 *10^6 KM (~110 times The Earth's Diameter)

1 million earths could fit into the sun (volume ~ r^3)

Galaxy

A great collection of stars in space, all held together by gravity and orbiting a common center

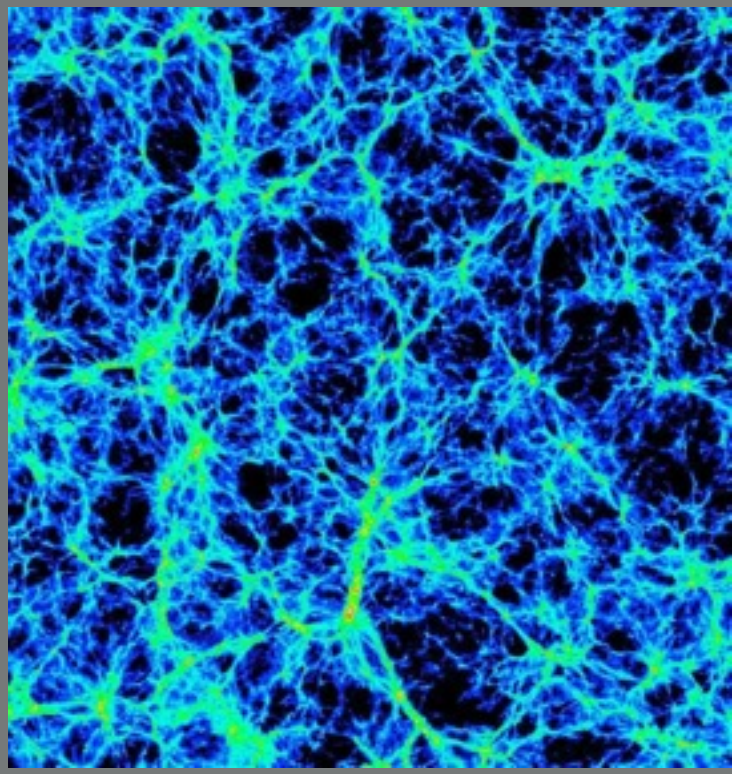


Milky Way

- ~100 billion stars
- ~100,000 Light Years Across
- Spiral Galaxy with extended halo, and a dark matter halo beyond that
- We are about 25,000 light years from the center and orbit once every 220,000,000 years
- 1 km/s ~ 2200 miles/hour
- The earth is moving (at the equator) ~ .5km/s
- We orbit the sun at ~30 km/s The Sun orbits the center of the Milky Way at ~220 km/s (or 100,000 km/hr)
- The Milky Way is moving ~552 km/s

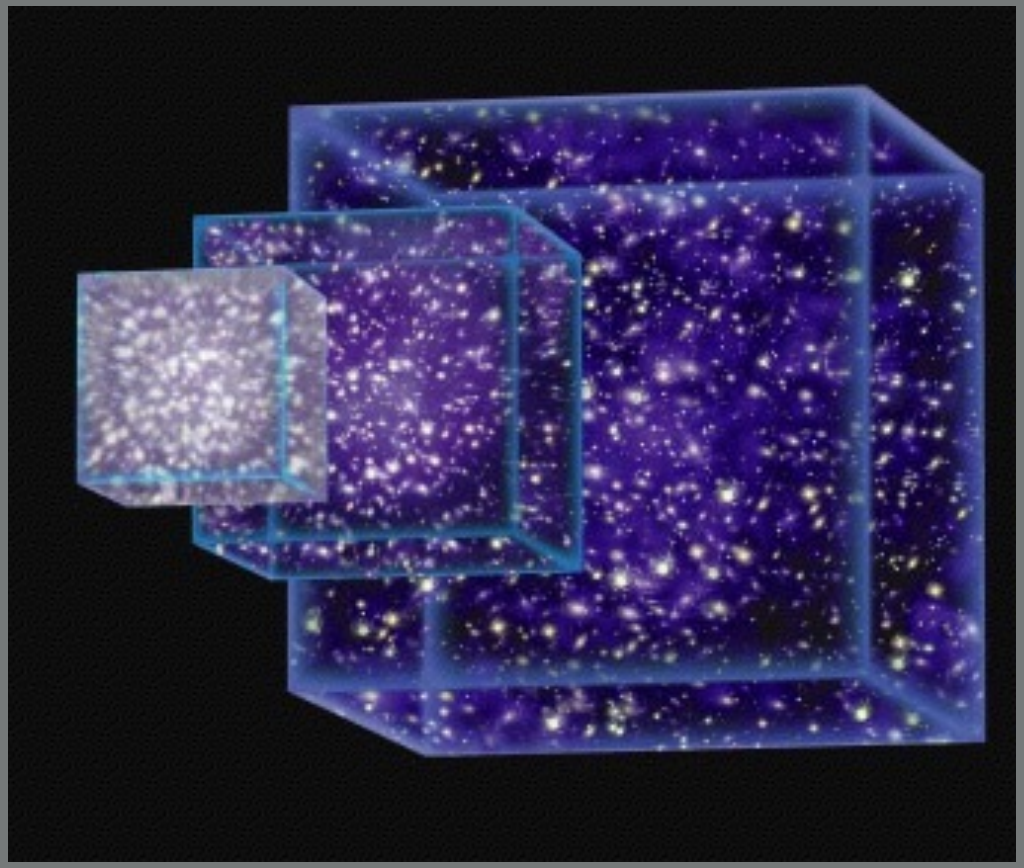
Even Bigger?

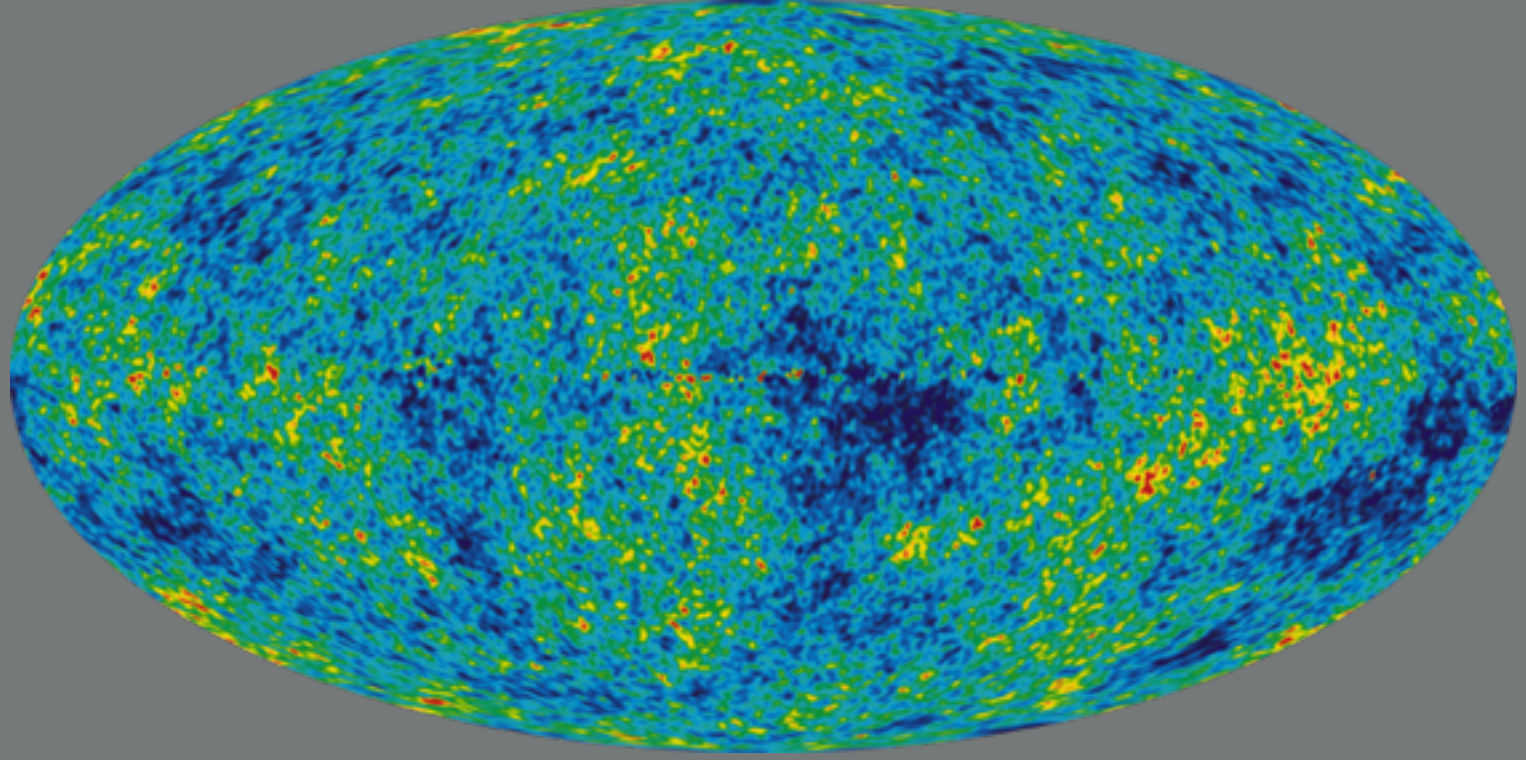
- The Milky Way is part of a local group of galaxies (40) about 10 million light years across. Our closest neighbor is the Andromeda Galaxy about 2.5 million light years away
- The local group is part of the Virgo Supercluster which contains about 100 groups of galaxies across 110 million light years
- Super Clusters form filamentary structures on scales of 300 million light years
- The Universe itself is ~13.7 billion years old



Universe

The sum total of all matter and energy; that is, everything within and between all galaxies





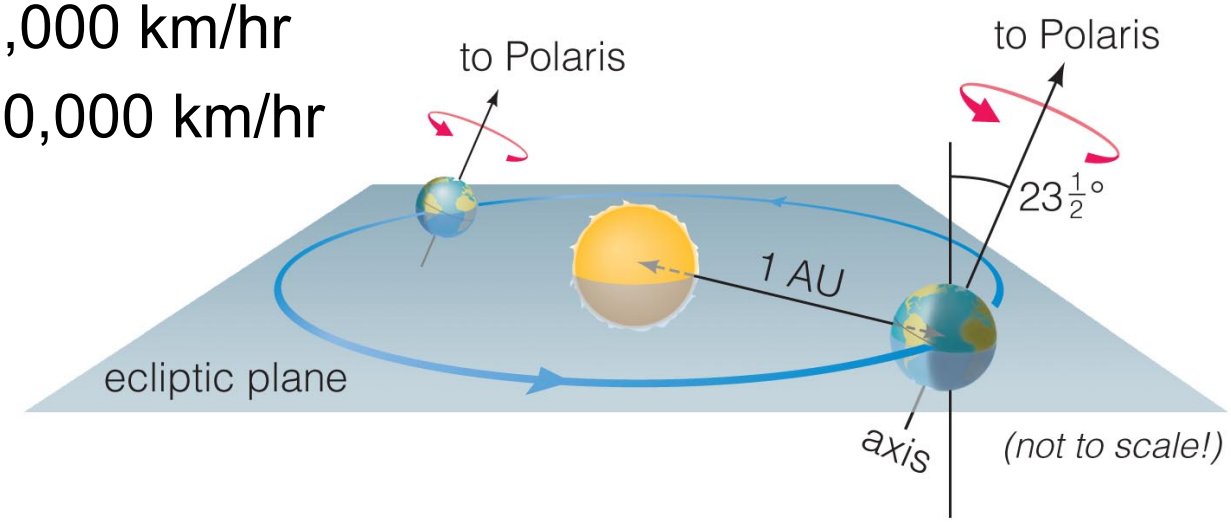
The whole universe glows with the embers of the big bang burning at 2.72 Kelvin above absolute zero with temperature fluctuations on the order of .0002 degrees

And The Universe Itself Is Expanding

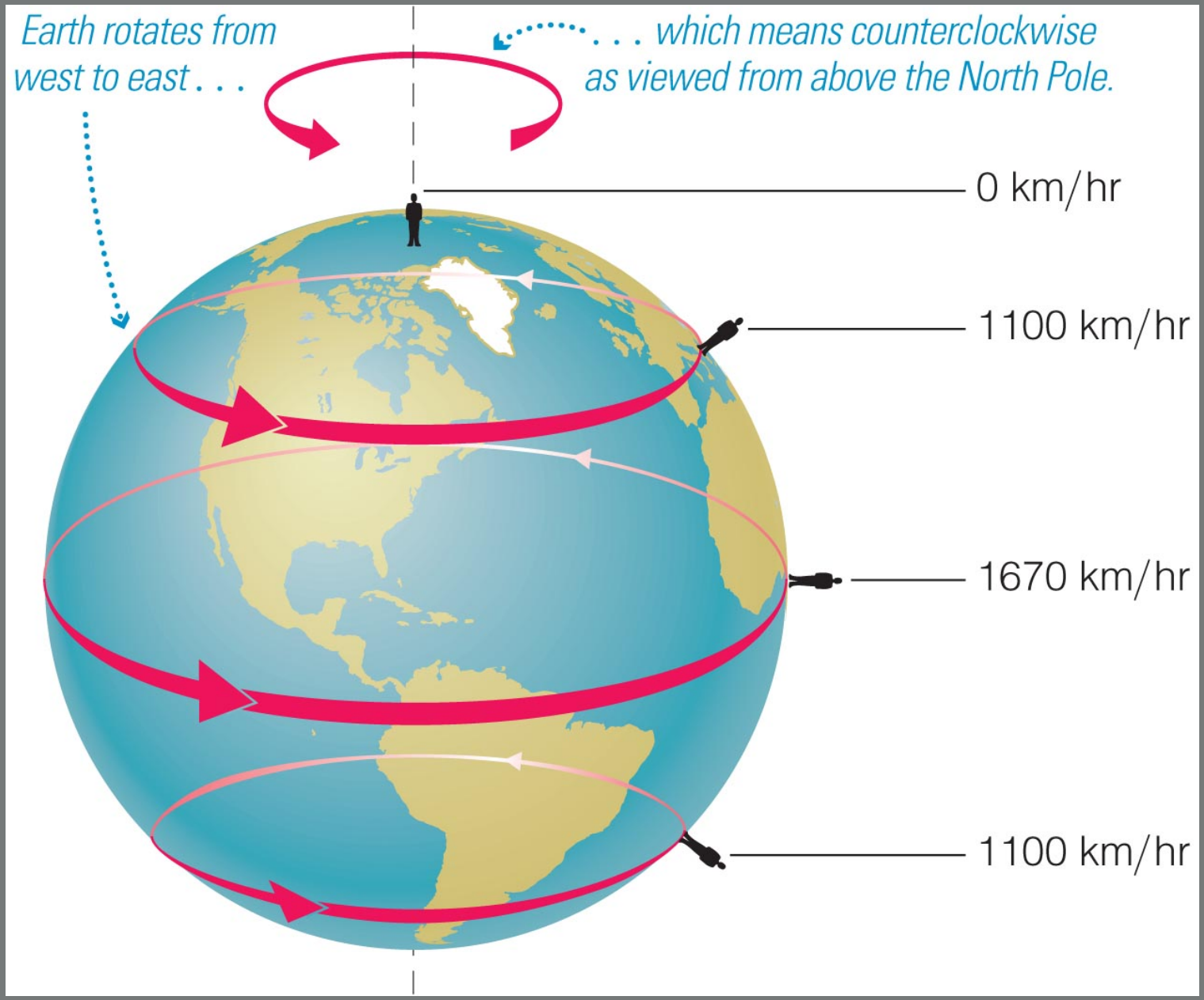
- The age of the Universe is about 13.7 billion years, but due to the expansion of space we are now observing objects that are now considerably farther away than a static 13.7 billion light-years distance.
- The edge of the observable universe is now located about 46.5 billion light-years away.

About how fast is Earth orbiting the Sun?

a) About 600 km/hr
b) About 1000 km/hr
c) About 60,000 km/hr
d) About 100,000 km/hr



A review of where things are and how they move


Earth rotates from west to east . . .
. . . which means counterclockwise as viewed from above the North Pole.
0 km/hr
1100 km/hr
1670 km/hr
1100 km/hr

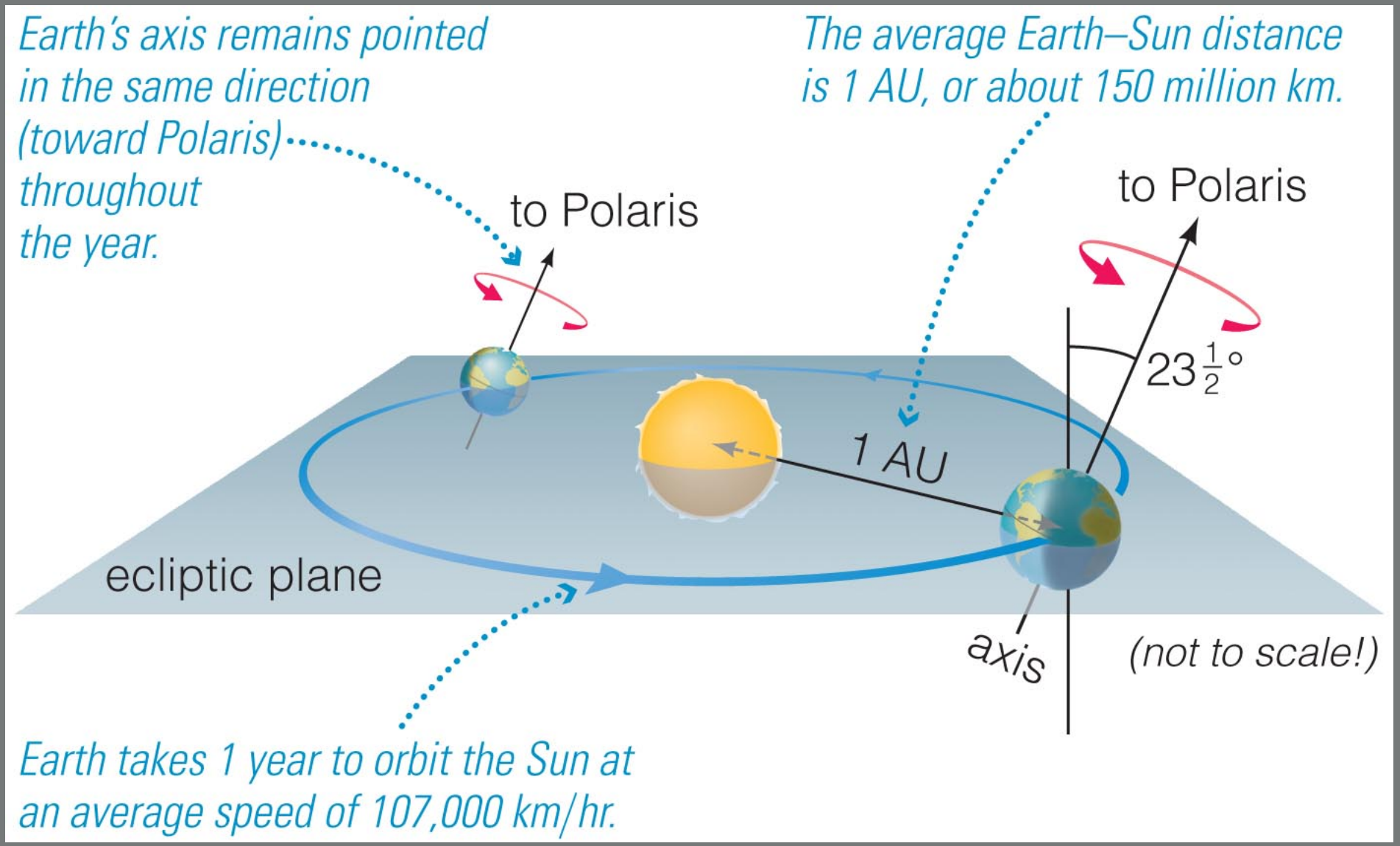
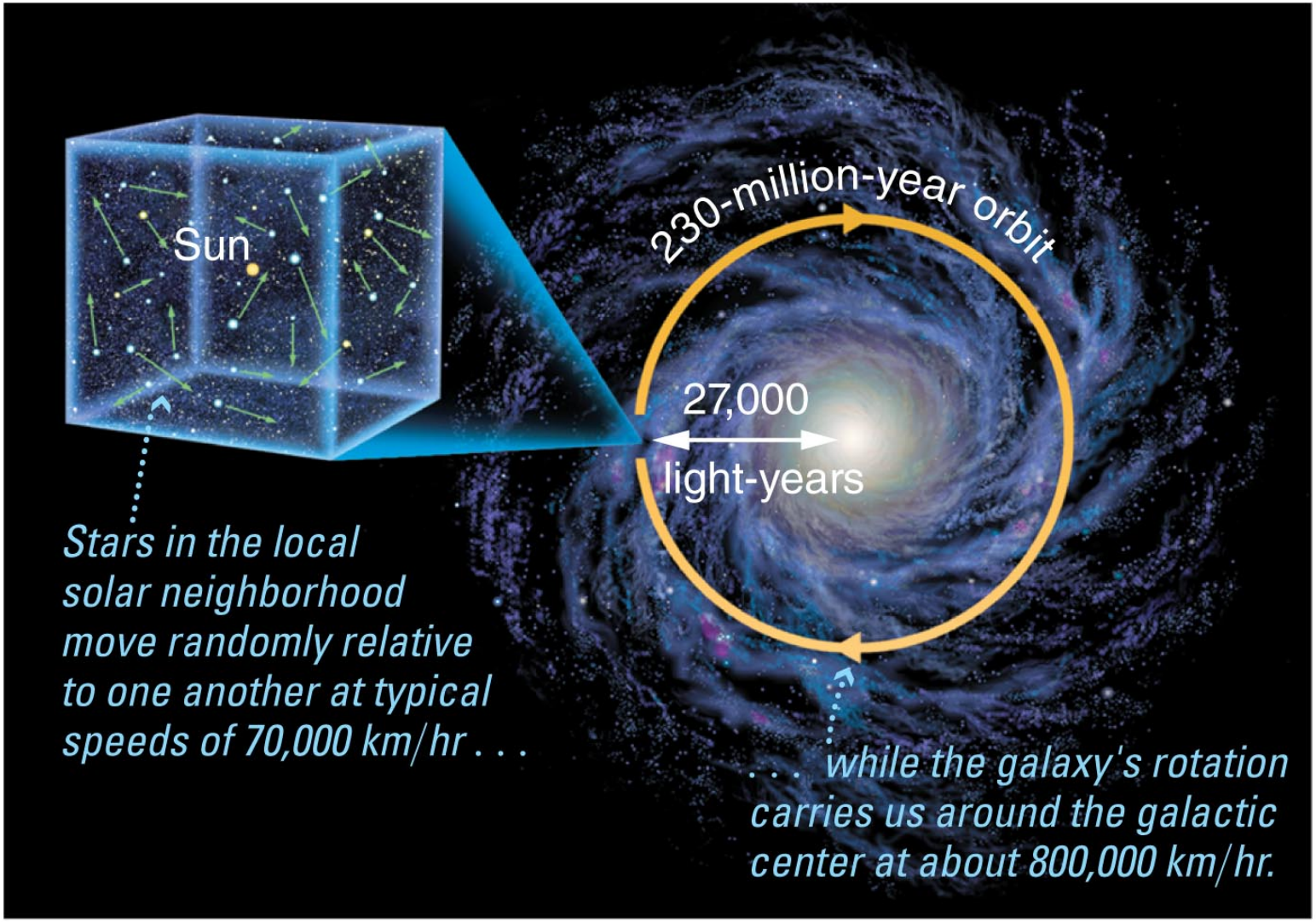
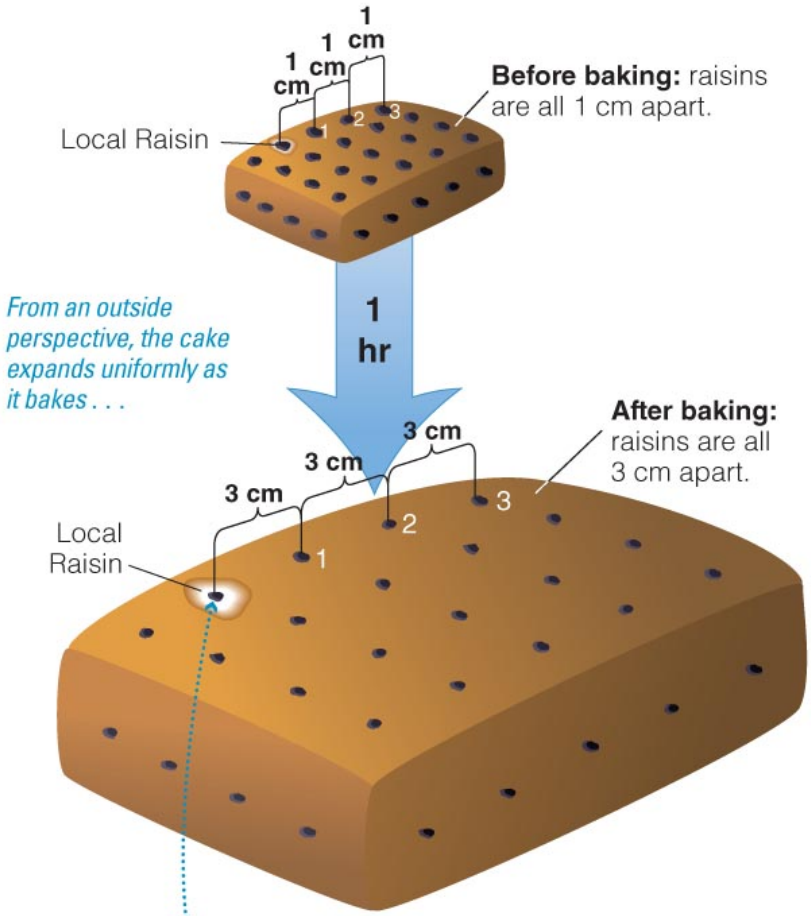

Earth's axis remains pointed in the same direction (toward Polaris) throughout the year.
The average Earth–Sun distance is 1 AU, or about 150 million km.
to Polaris
to Polaris
$23\frac{1}{2}°$
1 AU
ecliptic plane
axis
(not to scale!)
Earth takes 1 year to orbit the Sun at an average speed of 107,000 km/hr.

Figure 1.13 This painting illustrates the motion of our solar system within our local solar neighborhood and around the center of the Milky Way Galaxy.

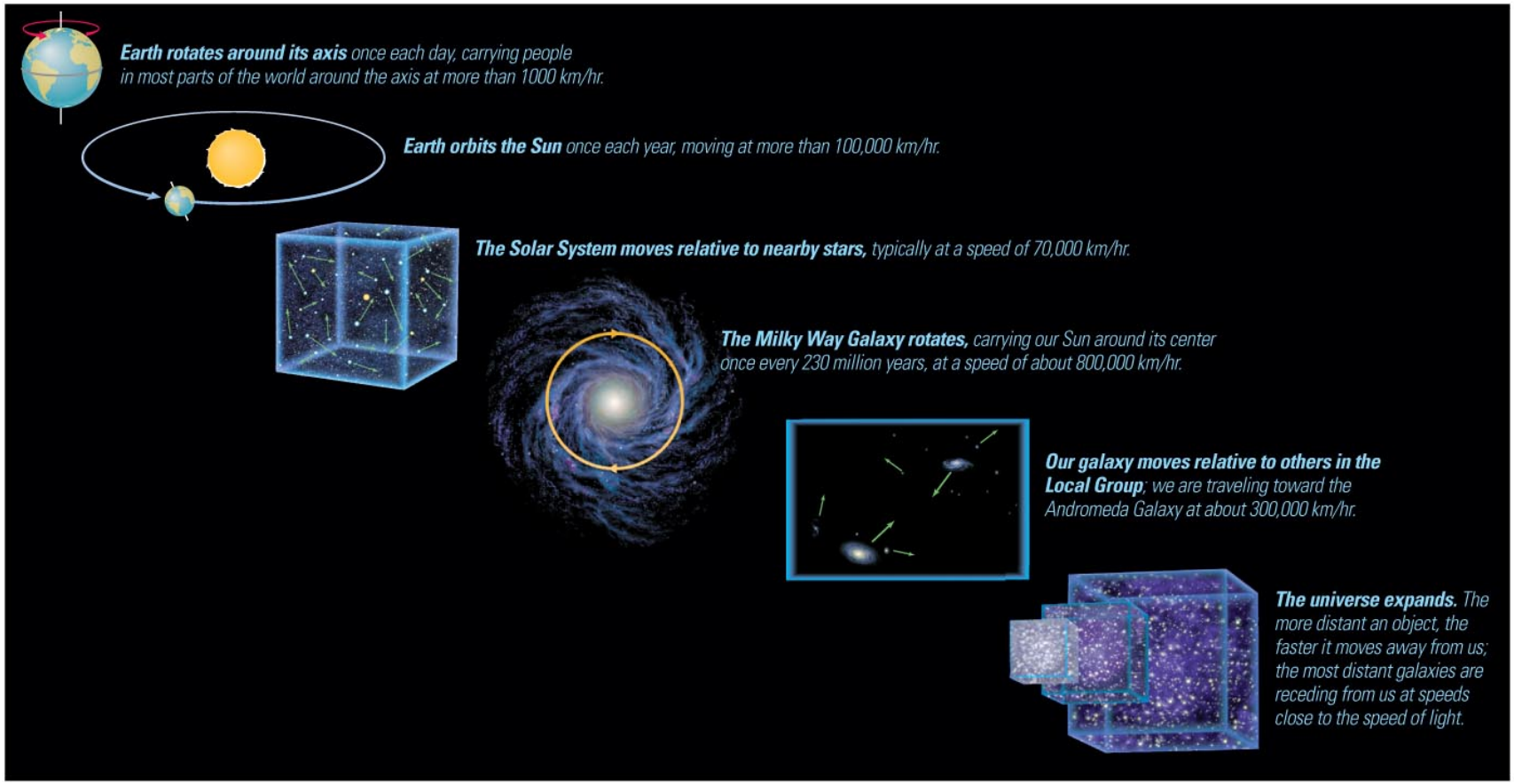




Distances and Speeds as Seen from the Local Raisin

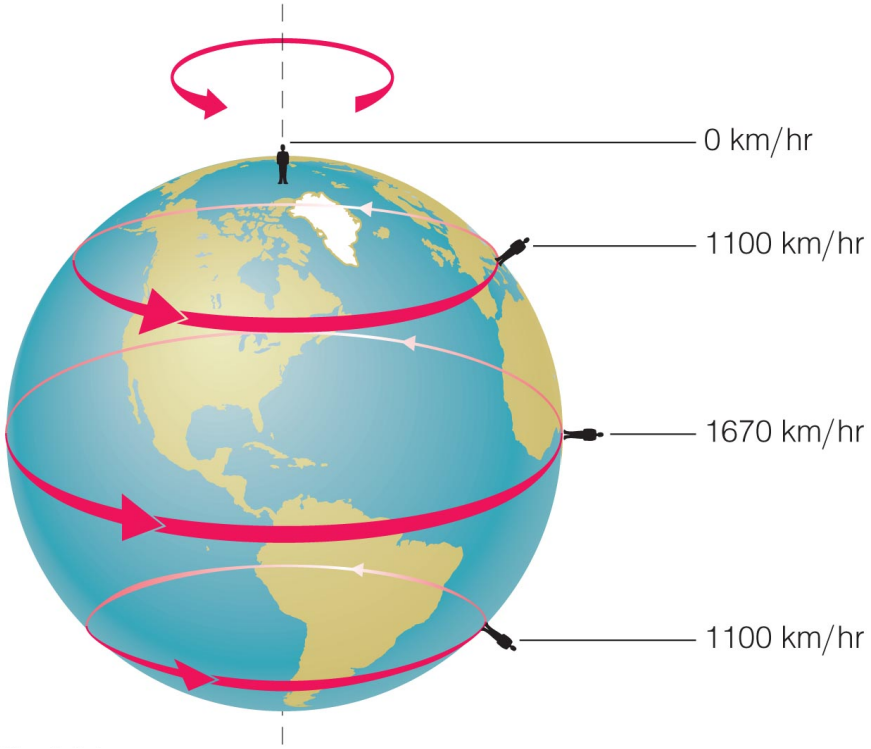
Raisin Number	Distance Before Baking	Distance After Baking (1 hour later)	Speed
1	1 cm	3 cm	2 cm/hr
2	2 cm	6 cm	4 cm/hr
3	3 cm	9 cm	6 cm/hr
⋮	⋮	⋮	⋮

Figure 1.16 This figure summarizes the basic motions of Earth in the universe, along with their associated speeds.

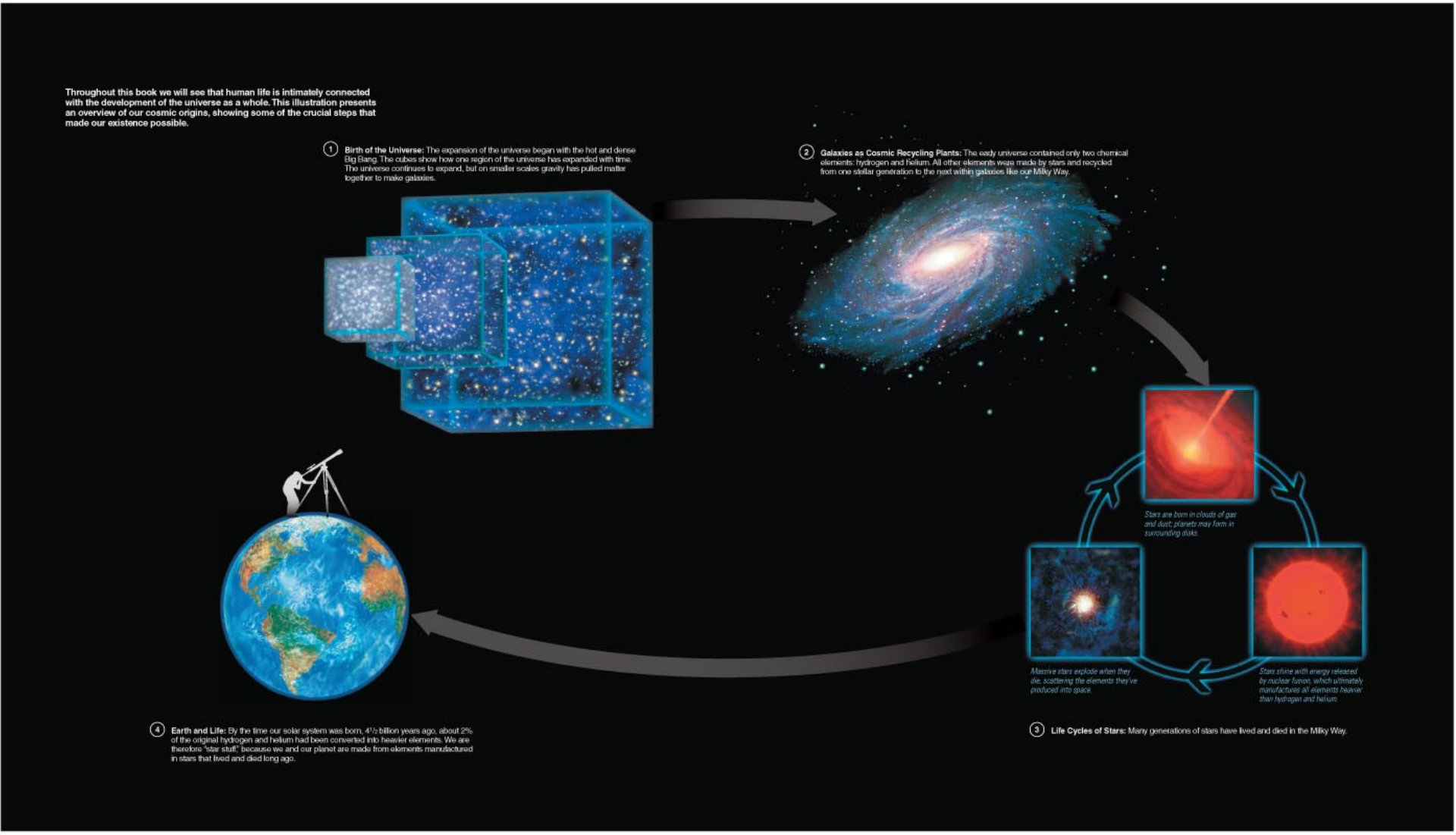


About how fast are you moving because of Earth rotating on its axis?

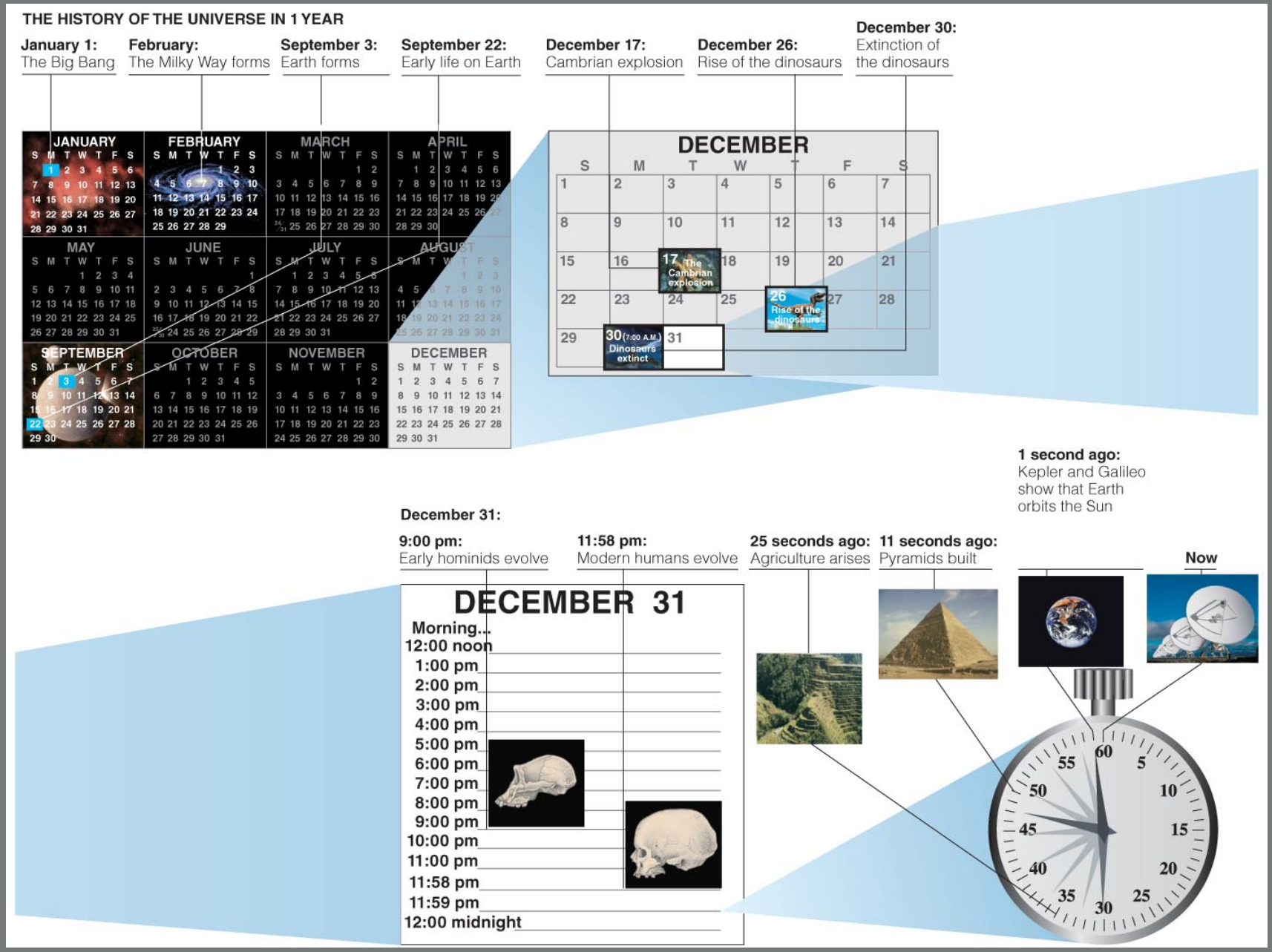
a) About 600 km/hr
b) About 1000 km/hr
c) About 60,000 km/hr
d) About 100,000 km/hr



How did we come to be?



How long have we been here?



Which is the correct order in which things occurred, according to the current accepted scientific theory of the creation of the universe?

a) Birth of the Universe, Earth and Life, Life Cycle of Stars, Galaxies as Cosmic Recycling Plants
b) Birth of the Universe, Life Cycle of Stars, Earth and Life, Galaxies as Cosmic Recycling Plants
c) Birth of the Universe, Galaxies as Cosmic Recycling Plants, Earth and Life, Life Cycle of Stars
d) Birth of the Universe, Galaxies as Cosmic Recycling Plants, Life Cycle of Stars, Earth and Life

MATH REVIEW/PRACTICE

- Units
- Scientific Notation
- Exponents
- Ratios

Units

- Length, Time, Mass
- ALWAYS KEEP UNITS IN ANALYSIS
- What do you weigh versus what is your mass?

Scientific Notation

- Which is easier to write 10^{18} or 1,000,000,000,000,000,000

BIG NUMBERS

Powers of 10:

Scale of the Universe

$10^0 = 1$

$10^3 = 1{,}000$ kilo-

$10^6 = 1{,}000{,}000$ mega- (aka million)

$10^9 = 1{,}000{,}000{,}000$ giga- (aka billion)

$10^{12} = 1{,}000{,}000{,}000{,}000$ tera- (aka trillion)

$10^{15} = 1{,}000{,}000{,}000{,}000{,}000$

$10^{18} = 1{,}000{,}000{,}000{,}000{,}000{,}000$

$10^{21} = 1{,}000{,}000{,}000{,}000{,}000{,}000{,}000$

(You get the picture).

Little NUMBERS

$10^{-1} = 1/10 = 0.1$

$10^{-2} = 1/100 = 0.01$ centi-

$10^{-3} = 1/1000 = 0.001$ milli-

$10^{-4} = 1/10000 = 0.0001$

Exponents

- $X^a X^b = X^{(a+b)}$
- $(X^a)^b = X^{ab}$
- $X^{(-a)} = 1/X^a$

Ratios

- JUST MEANS TO DIVIDE
- Can be units - Speed = miles/hour
- Can be expressions or equations
- Unit Ratios are important in this course
- 12 inches/1 foot
- 300,000KM/second