

Astronomy 3:

~~Introductory Astronomy: The Solar System~~

Introductory Astronomy: Planetary Systems

Professor: Jonathan Fortney
jfortney@ucsc.edu

TA: Chris Mankovic
cmankovich@ucsc.edu

TA: Emily Cunningham
eccunnin@ucsc.edu



Finn, age 6, and Graham, age 4

About Me:

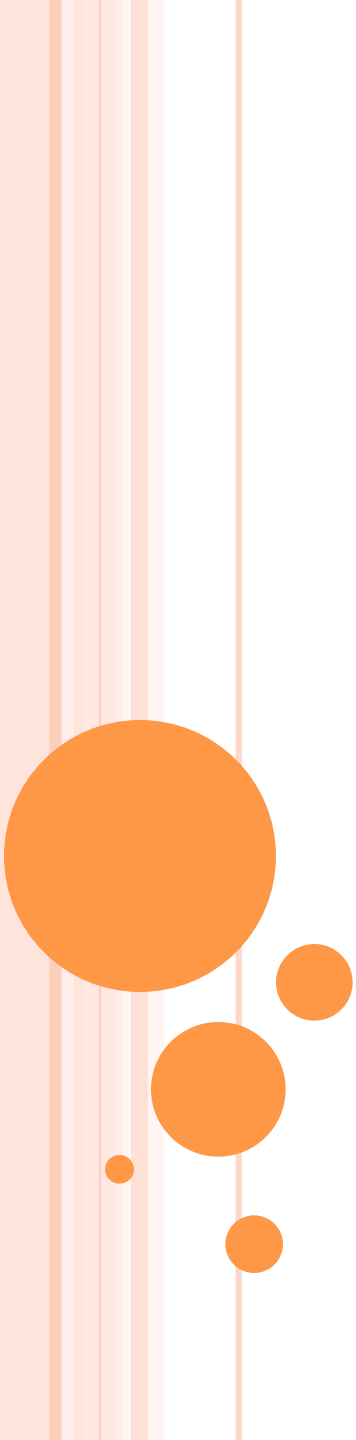
Age: 36

Previous Life: Mountain View and
NASA Ames (2004-2008),
University of Arizona (1999-2004),
Iowa State University (1995-1999),
St. Paul, Minnesota (1976-1995)

Married for 9 years, 2 kids

I mostly study that atmospheres
and interior structure of
“exoplanets” the planets that are
found around other stars.



- 
- I realize that the vast majority of you are here to fulfill a requirement
 - That being said, you chose this class from a variety of possibilities!
 - The #1 thing that I ask of you is to take ownership of your learning
 - This class is 40% first-year students
 - There isn't a tremendous amount of hand-holding, so seek out help when you need it
 - Try your best
 - Class web page:
<http://www.ucolick.org/~jfortney/3.htm>

THE CLASS

- This is a one-term introductory course on planetary systems, covering the properties of the solar system and other planetary systems.
- Topics include the Sun, solar system exploration, the physical nature of the Earth and the other planets, comets and asteroids, the origin of the solar system, the possibility of life on other worlds, planet formation, and
- The discovery and characterization of planets beyond the solar system, which puts our solar system in context. It is intended for nonscience majors.



Part I: Motion of the earth, moon, sun and planets in space
Gravity, explaining and predicting motion
Light, Energy, matter and how we observe the solar system

Part II: Overview of trends in the solar system
Formation the solar system
The Sun

Part III: Inner solar system
Atmospheres and Interiors

Part IV: Outer solar system
Atmospheres and Interiors
Satellite systems

Part V: Other planetary systems
Detecting exoplanets and characterizing them
Ways of making planetary systems



Exams

- Midterm: October 31st
- Final: December 10th, covering all course material
- Multiple choice, T/F and maybe short answer

Homeworks

Due basically every Thursday, plus the Tuesday after Thanksgiving

Office Hours

Professor Fortney: Wednesday, 1:30-3 pm

Emily Cunningham: Mon 3:30-4:30, Tues 5-6,
Weds 11:30-12:30

Chris Mankovich: Tues 11-12 and 4-5

Date		Due Topics	Chapters
9/26,	Th	intro, solar system in perspective, scales	1,2
10/1,	T	seasons, moon phases, history of astronomy	2,3
10/3,	Th	hw1 orbits, Kepler's laws, nature of science	3
10/8,	T	Newton's laws, energy	4
10/10,	Th	hw2 matter and light	5
10/15,	T	overview of the solar system	7
10/17,	Th	hw3 formation of planetary systems	8
10/22,	T	the Sun	14
10/24,	Th	hw4 geology/geophysics of terrestrial planets I	9
10/29,	T	geology/geophysics of terrestrial planets II	9
10/31,	Th	MIDTERM EXAM	
11/5,	T	atmospheres of terrestrial planets I	10
11/7,	Th	hw5 atmospheres of terrestrial planets II	10
11/12,	T	giant planets	11
11/14,	Th	hw6 satellites of the giant planets	11
11/19,	T	asteroids, meteorites, dwarf planets, comets	12
11/21,	Th	hw7 planetary systems around other stars I	13
11/26,	T	planetary systems around other stars II	13
11/28,	Th	THANKSGIVING	
12/3,	T	hw8 planetary systems around other stars III	13
12/5,	Th	life in the solar system and others	24
12/10	T	FINAL EXAM, 8-11 a.m.	



Basic high school math required
simple equations, ratios (no calculus)

Metric system

length: meters 1000 mm = 1 m, 1000 m = 1 km

1 m ~ 3 ft, 1 mile = 1.6 km

You are 1.5 - 2 m tall

Scientific notation: 0.001 m = 1×10^{-3} m

Distance to sun: 150,000,000,000 m = 1.5×10^{11} m

Wavelength of visible light: 0.0000005 m = 5×10^{-7} m

We (and your calculator) need scientific notation!

Review in Homework 1

Look at **Appendix C** in Cosmic Perspective

Review in Discussion Sections!

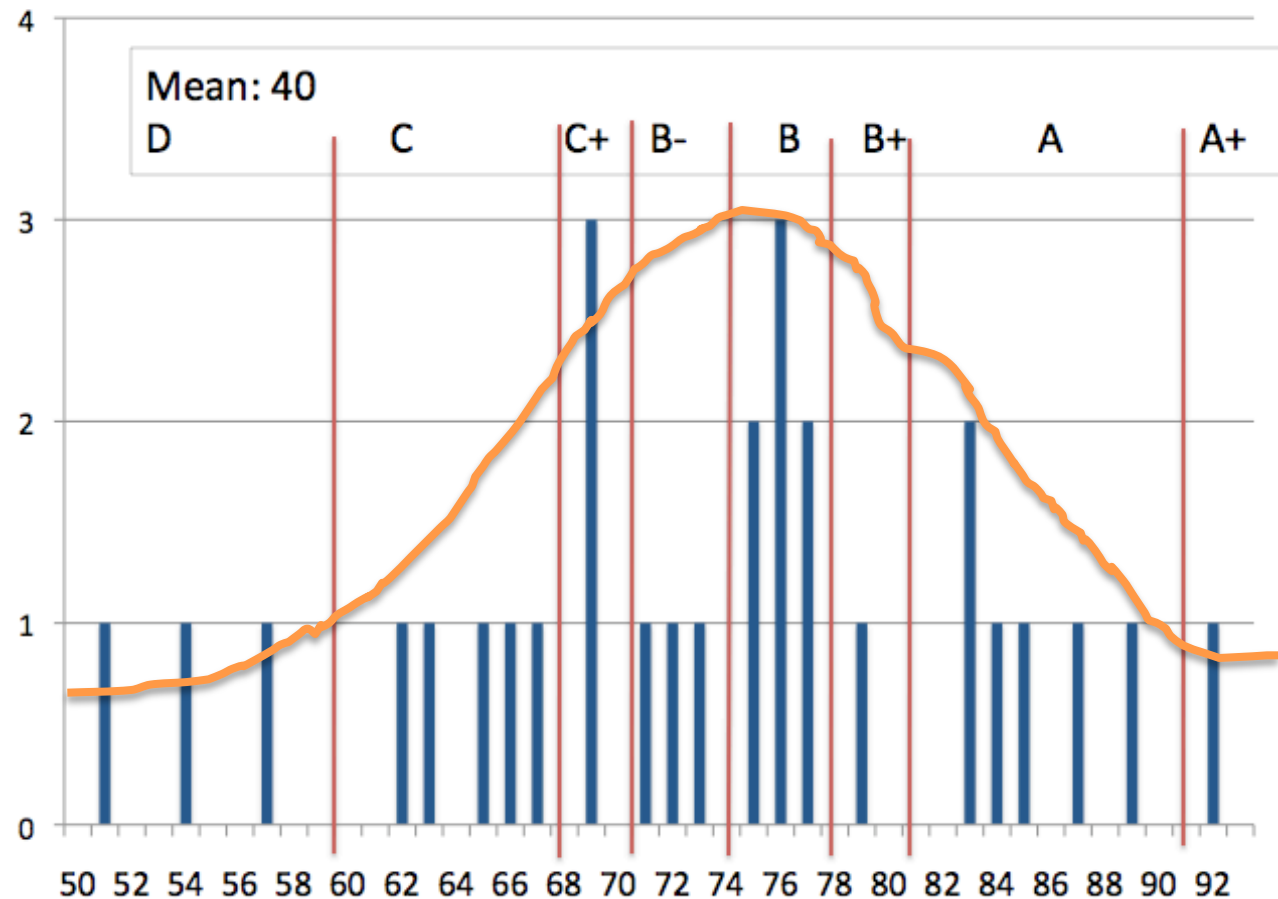


Grading

iClickers 10%
Homeworks: 25% (8 total)
Midterm: 30%
Final: 35%

Grading will be on a “curve”

Final Course Distribution



Mastering Astronomy

www.masteringastronomy.com

You must register. Instructions are on the class web site.
<http://www.ucolick.org/~jfortney/3.htm>

Homeworks will be done online

Tutorials and a vast array of additional material that is complementary to lectures and the textbook. Look for the “**Study Area**” link.



[Home](#)[Product Info](#)[Results](#)[Titles Available](#)[Support & Training](#)

Register

[High School teachers register here](#)[Students](#)[Instructors](#)

Sign In

Username:

Password:

[Sign In](#)[Forgot your username/password?](#)

Learn More

- >> [What is MasteringAstronomy?](#)
- >> [Learn what instructors are saying](#)

Learn about eTextbook options

- >> Students have a range of eTextbook purchasing options. [Learn more.](#)

Tutorials and Coaching

MasteringAstronomy allows students to learn science by practicing science, emulating the one-on-one office hour experience.

[Play Movie](#)

Teacher Talks: Ideas that Inspire Learning

Teacher Talks are inspirational speeches given by some of the world's most effective educators, designed to energize leaders on the front lines of our educational system.

[Watch the Teacher Talks](#)

Lectures

Posted on course web page as PDF the day of lecture

Clarify and highlight material

Not a substitute for reading the textbook!

iClicker

feedback (for both of us)

points for participating = responding to questions in lecture

1 point for a correct answer

1 point for a wrong answer!

can miss 4 lectures without penalty

Register your iClicker by Tuesday, 10/1!

Get a small, inexpensive calculator, that does does roots and powers.
No iphones/ipads during exams





Products

Solutions

Resources

Support

Purchase

Register

Register

Register an i>clicker

Find i>clicker ID

Register Your Clicker

Register your i>clicker remote so your instructor will be able to give you credit for using your clicker in class. Have questions? Visit our [student support portal](#).

Does your school use a Learning Management System (such as Blackboard, Moodle, etc.)?

No Yes Not Sure

First Name:

Last Name:

Student ID:

The ID assigned by your school. Check your syllabus or ask your instructor if you are unsure what to enter.

Remote ID:

The 8-character code found on your remote (see image). Codes only use letters A-F and numbers 0-9.

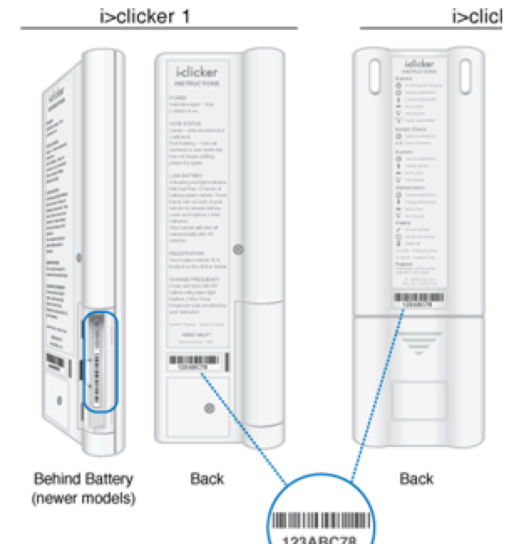


Image Code:

The verification code shown in the image above.

Register

Reset Form



CLICKER QUESTION:

HOW MANY COLLEGE SCIENCE CLASSES HAVE YOU TAKEN, INCLUDING THIS ONE?

- A) 1
- B) 2
- C) 3
- D) 4+



Sections:

Tuesday, 6:00-7:10 p.m., Phys Sciences 114 (Emily)

Wednesday, 8:00-9:10 a.m., Phys Sciences 114 ((Emily)

Wednesday, 11:00 a.m.-12:10 p.m., Nat Sci Annex 101 (Chris)

Friday, 3:30-4:40 p.m., Nat Sci Annex 101 (Chris)

Please attend the section that you signed up for.

Attendance is not require but is essential to your success.

Questions from class

Help with homework

Help with mathematics

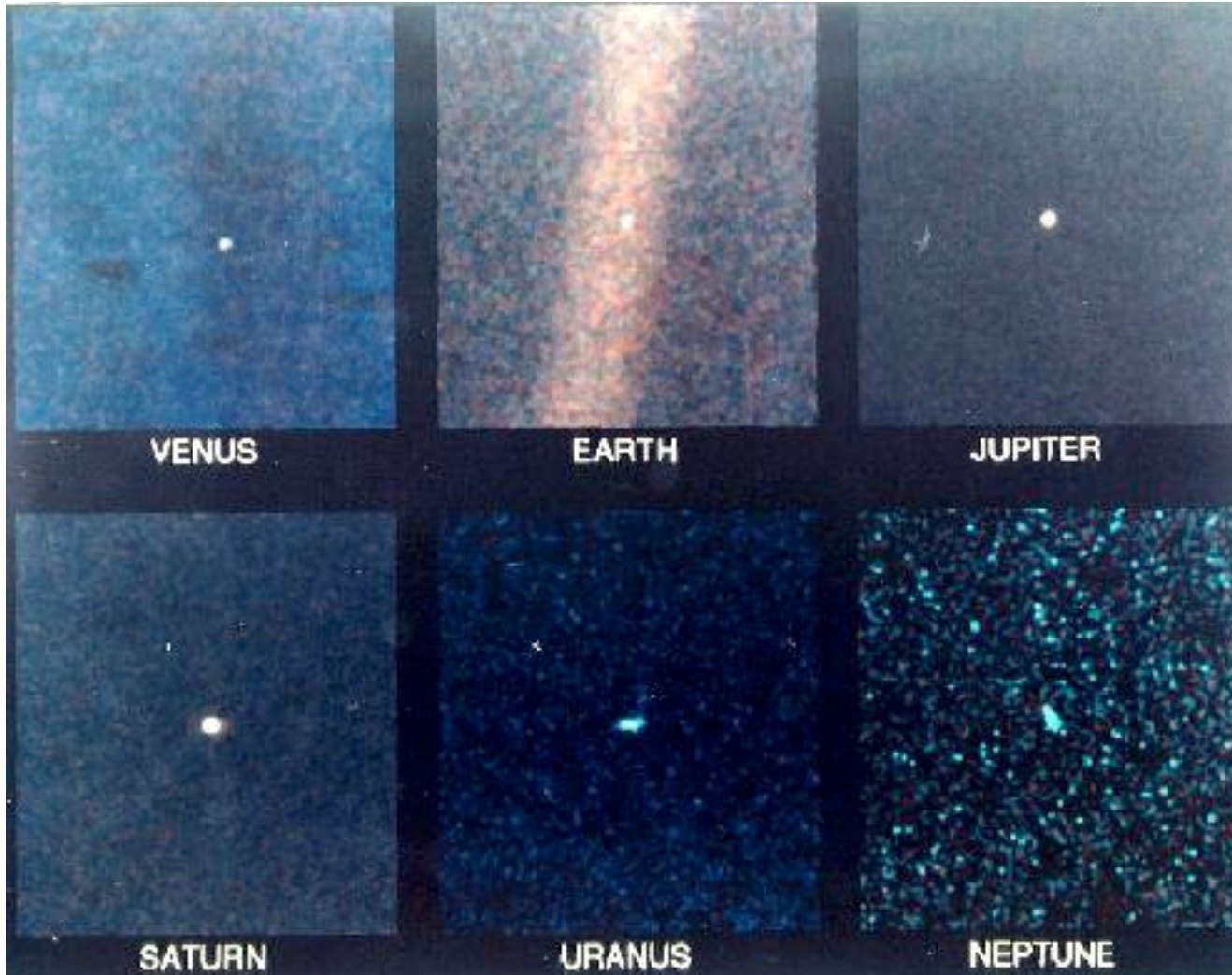


LAST PIECES OF ADVICE

- Understand your textbook
 - Read the Preface and the Forward
 - Stay ahead of class lecture material
- Meet the people in your class
- Use the masteringastronomy.com tutorials
- Attend Lecture and Discussion Section
- Get a small calculator that can do roots and exponents



The “Cosmic Perspective”



Earth as a Pale Blue Dot

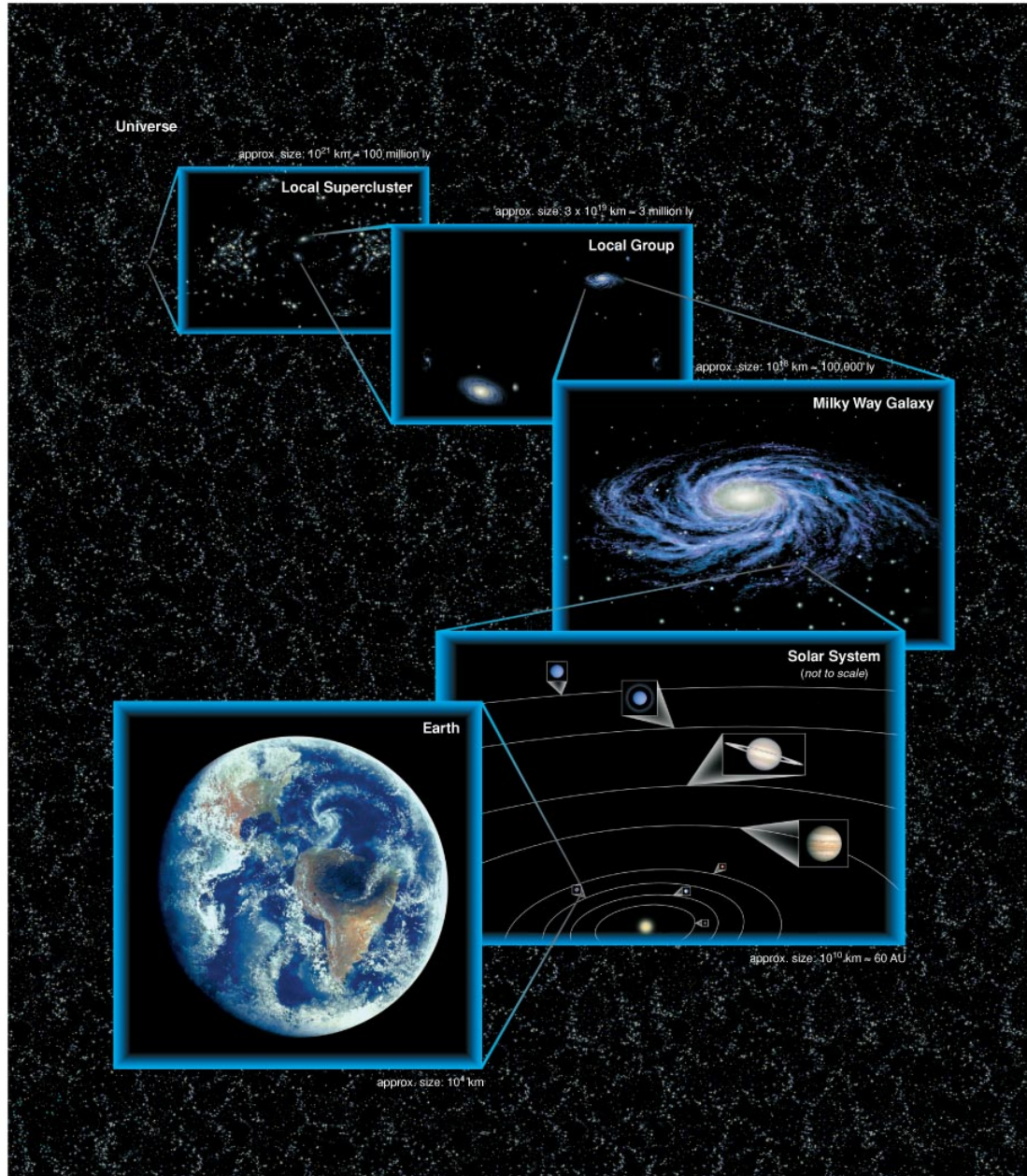
Read pages XXV-XXVII of the Forward



POWERS OF TEN

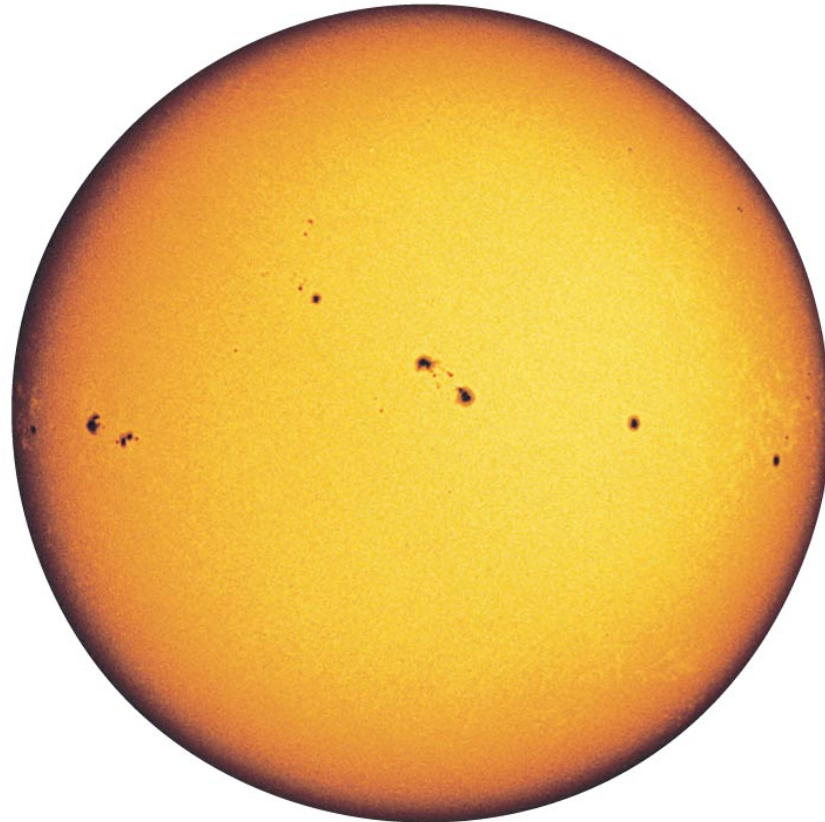


WHAT IS OUR PLACE IN THE UNIVERSE?

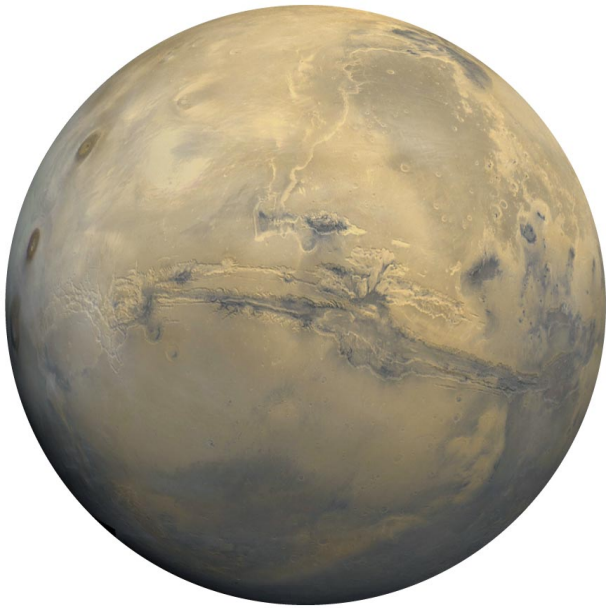


STAR

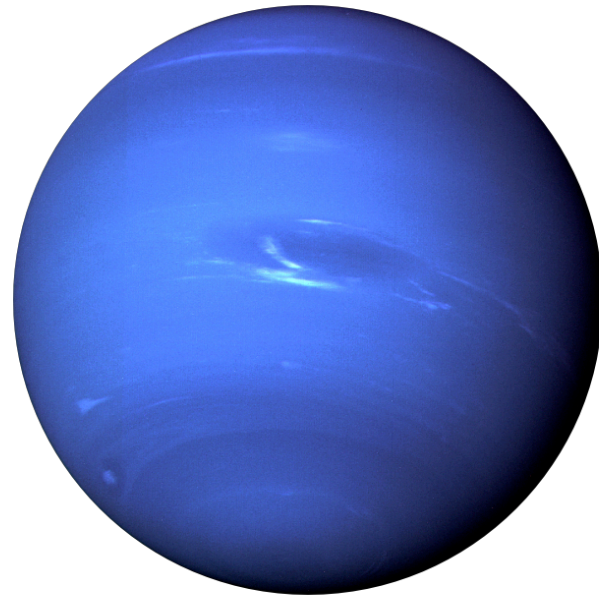
- A large, (10^{30} kg) ball of gas, mostly hydrogen, that generates heat and light via nuclear fusion
- Fusion happens because stars compress under their own gravity and create extremely high pressure in their centers



PLANET



Mars

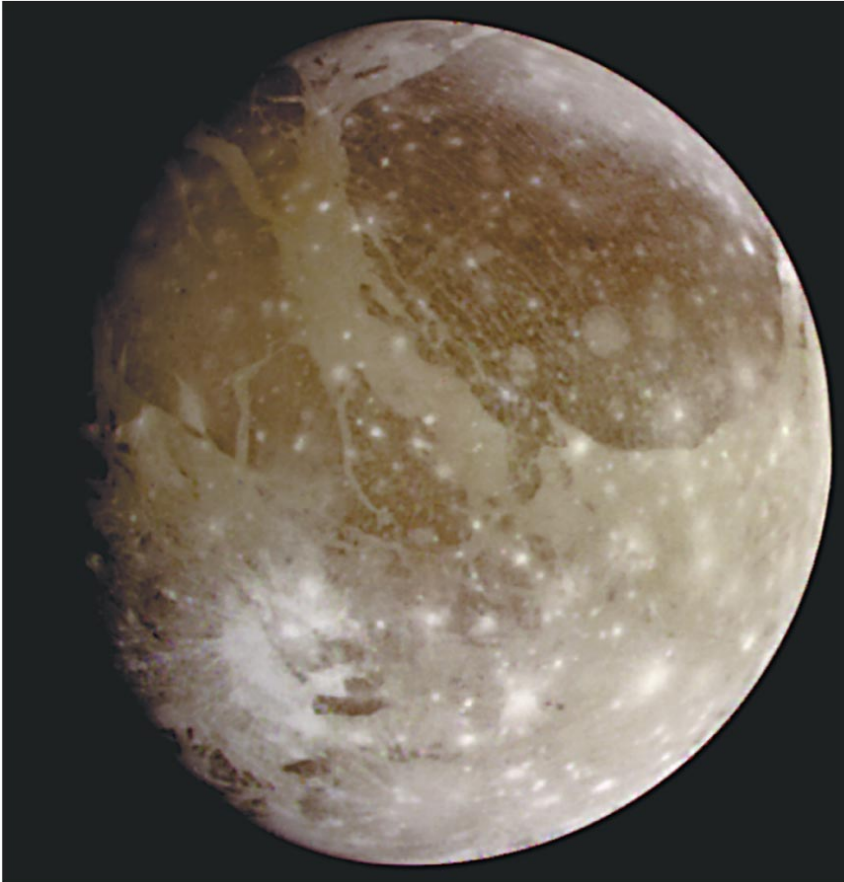


Neptune

- A moderately large object that orbits a star; it shines by reflected light. Planets may be rocky, icy, or gaseous in composition.
- Massive enough to form spherical objects



MOON (OR SATELLITE)



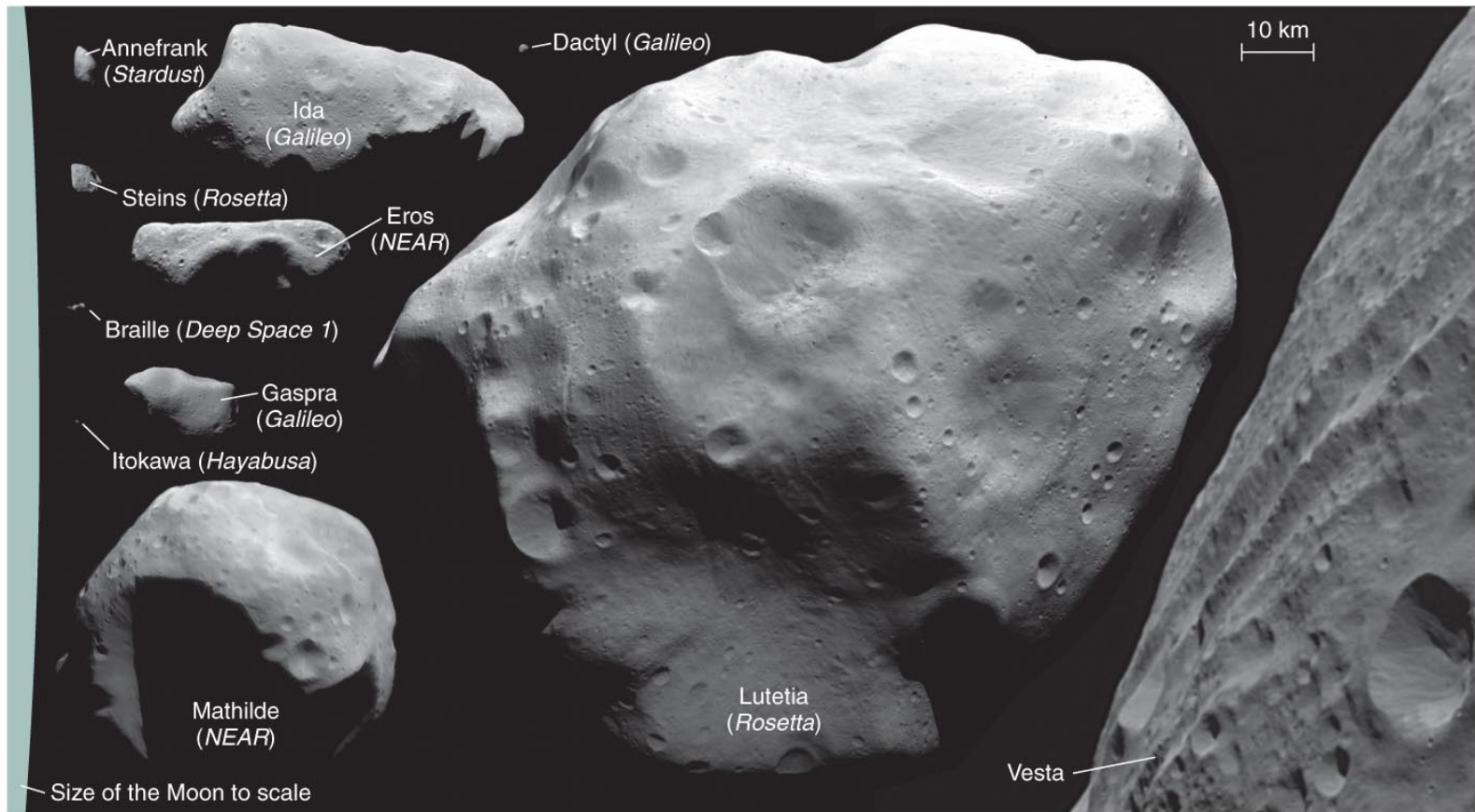
Ganymede (orbits Jupiter)

- An object that orbits a planet
- They can be be just as complex and interesting as planets



ASTEROID

- A relatively small and rocky object that orbits a star



COMET

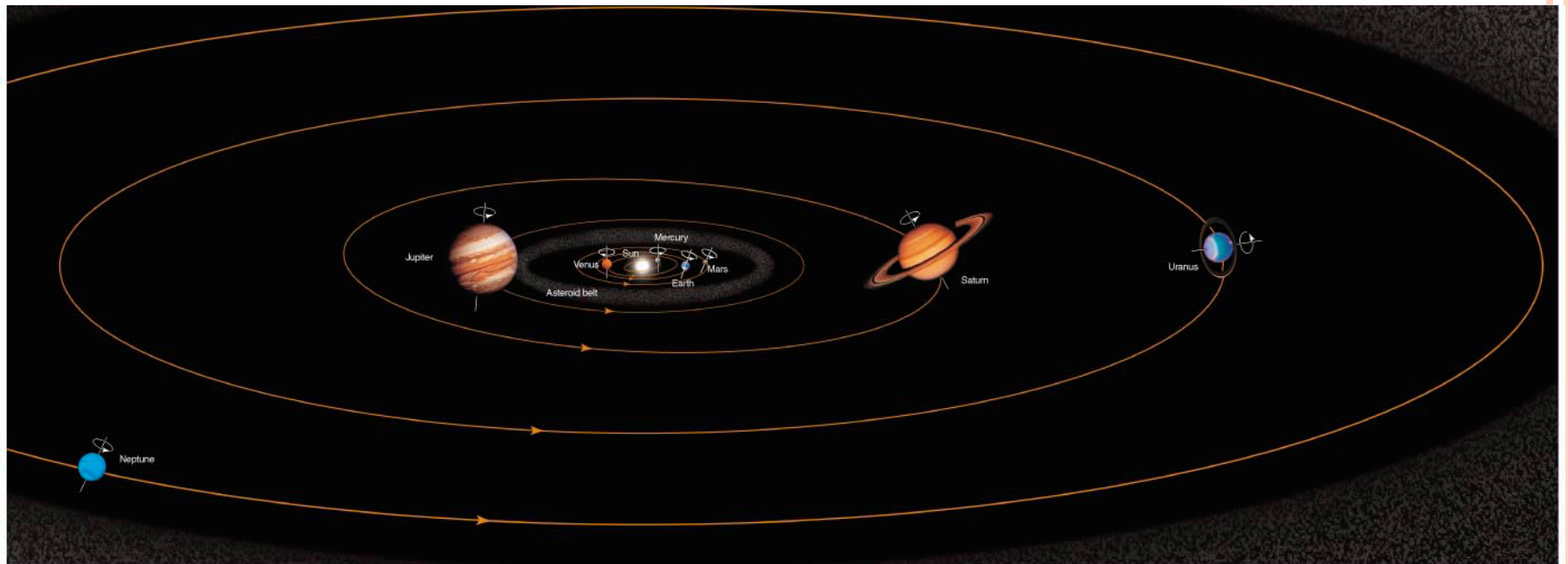


- A relatively small and icy object that orbits a star



SOLAR (STAR) SYSTEM

- A star and all the material that orbits it, including its planets and moons



GALAXY

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



**M31, the great galaxy
in Andromeda**



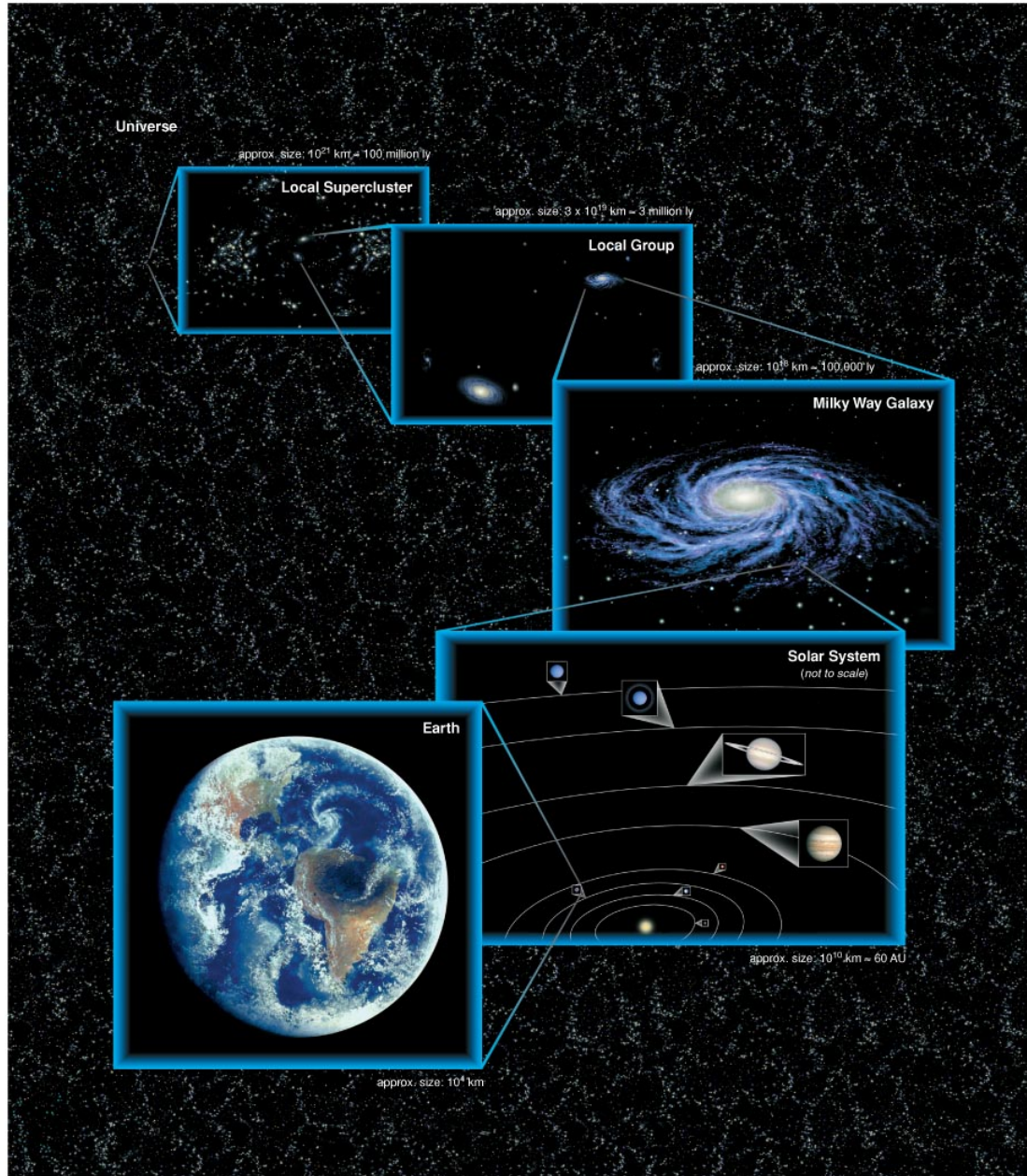
UNIVERSE

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

Observable Universe



WHAT IS OUR PLACE IN THE UNIVERSE?



Sun



Earth

Jupiter



Jupiter

Saturn

Uranus

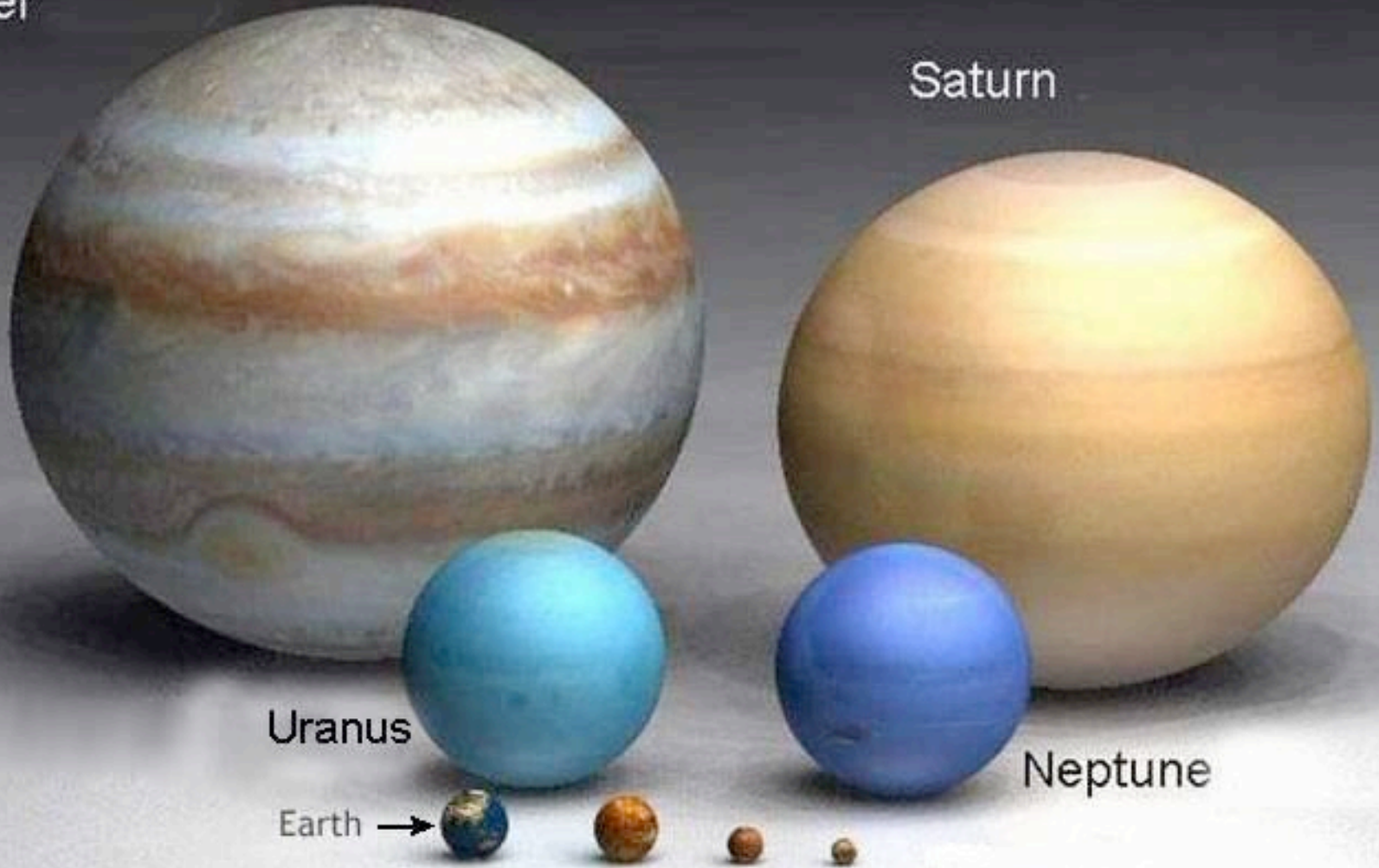
Neptune

Earth →

Venus

Mars

Mercury



FAR AWAY MEANS BACK IN TIME?

- Light travels at a finite speed (300,000 km/s).

Destination	Light travel time
Moon	1 second
Sun	8 minutes
Sirius	8 years
Andromeda Galaxy	2.5 million years

- Thus, we see objects as they were in the past:
*The farther away we look in distance,
the further back we look in time.*



FAR AWAY MEANS BACK IN TIME?

Example:

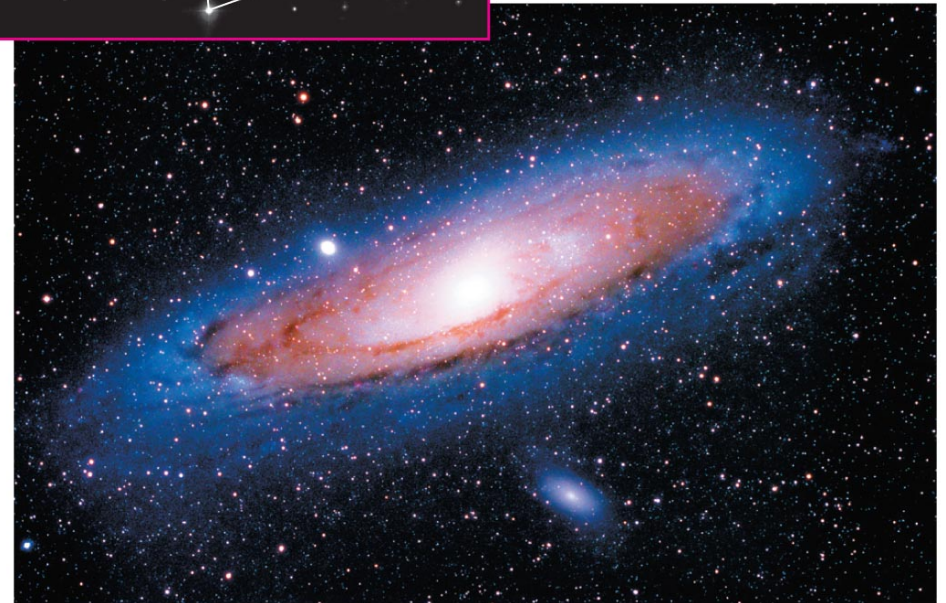
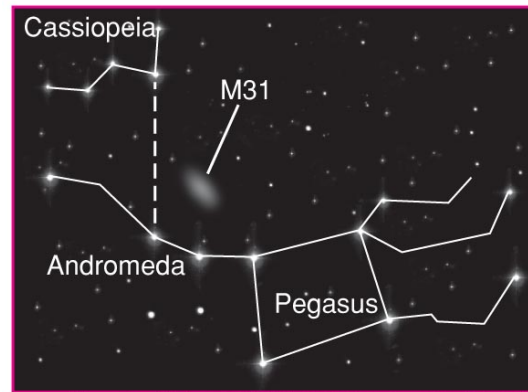
- We see the Orion Nebula as it looked 1500 years ago.



FAR AWAY MEANS BACK IN TIME?

Example:

- This photo shows the Andromeda Galaxy as it looked about 2 1/2 million years ago.



THE ASTRONOMICAL UNIT (“AU”)

- One of our units of choice in this class
- The average distance of the Earth to the Sun
- It sets our basic distance unit for planetary systems
- $1 \text{ AU} = 1.5 \times 10^{11} \text{ m}$
- $1 \text{ AU} = 1.5 \times 10^8 \text{ km}$
- $1 \text{ AU} = 93 \text{ million miles}$
- $1 \text{ AU} = 8 \text{ light minutes}$

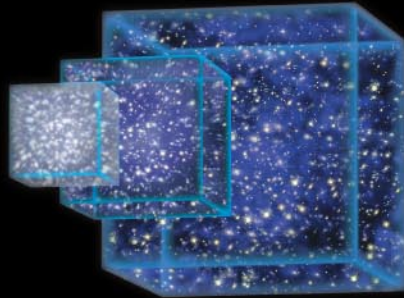
- Planetary orbits can be 0.01 AU to 1000+ AU.



HOW DID WE COME TO BE?

Throughout this book we will see that human life is intimately connected with the development of the universe as a whole. This illustration presents an overview of our cosmic origins, showing some of the crucial steps that made our existence possible.

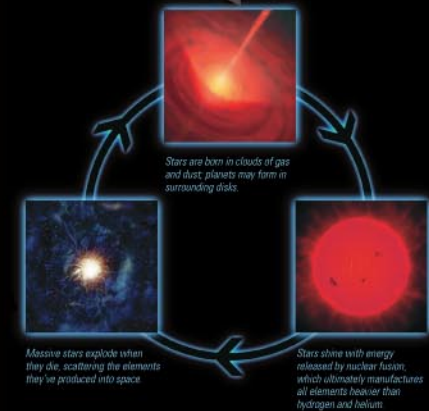
① **Birth of the Universe:** The expansion of the universe began with the hot and dense Big Bang. The cubes show how one region of the universe has expanded with time. The universe continues to expand, but on smaller scales gravity has pulled matter together to make galaxies.



② **Galaxies as Cosmic Recycling Plants:** The early universe contained only two chemical elements: hydrogen and helium. All other elements were made by stars and recycled from one stellar generation to the next within galaxies like our Milky Way.



④ **Earth and Life:** By the time our solar system was born, 4½ billion years ago, about 2% of the original hydrogen and helium had been converted into heavier elements. We are therefore "star stuff," because we and our planet are made from elements manufactured in stars that lived and died long ago.



③ **Life: Cycles of Stars:** Many generations of stars have lived and died in the Milky Way.


WHEN THE UNIVERSE FORMED, THERE WAS ONLY H, HE, AND LI

Periodic Table of the Elements

1 1IA 11A																	18 VIIIA 8A
1 H Hydrogen 1.0079	2 IIA 2A											13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.64	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90543	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown
Lanthanide Series		57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	
Actinide Series		89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0642	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]	
	Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetals	Nonmetals	Halogens	Noble Gas	Lanthanides	Actinides							

- Stars have created every other element, and are continuously making more

WHERE DID YOU COME FROM?

- Every atom in your body was manufactured in either:
 - **The creation of the Universe (13.8 billion years ago)**
 - **Stars living their normal lives, making, C, N, O**
 - **Supernovas (Exploded stars)**
 - We are made of parts of the Universe that came together via gravity to make a large rock/iron planet we call Earth, 4.5 billion years ago
 - Over the course of the next 4.5 billion years, a very small fraction of the elements on Earth were incorporated into carbon-based molecules that eventually obtained the ability to propagate, learn, and eventually examine the Universe around themselves
 - We are not IN the Universe, we ARE the Universe
- 

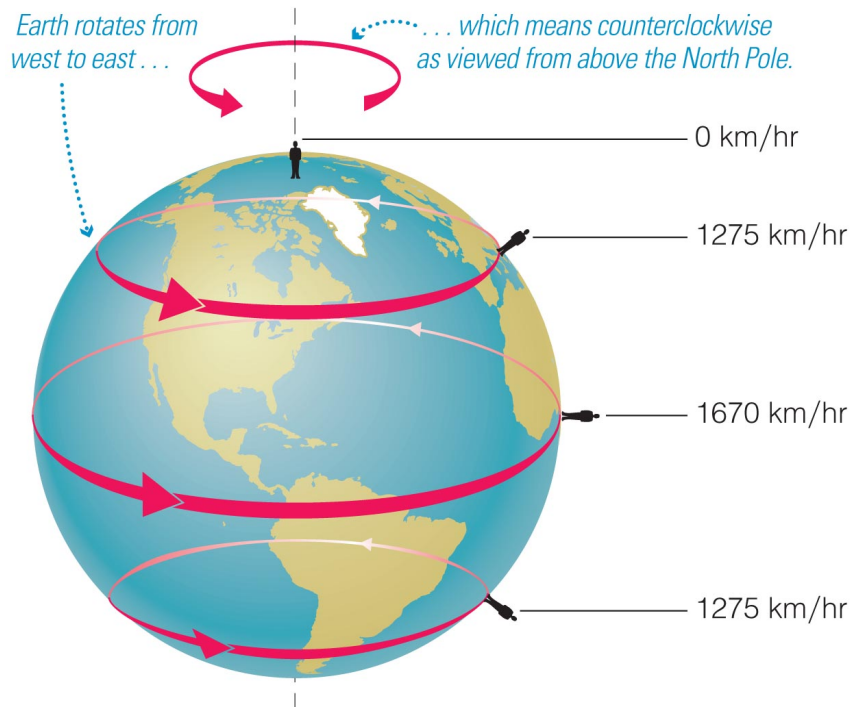
1.3 SPACESHIP EARTH

- Our goals for learning:
 - **How is Earth moving through space?**



HOW IS EARTH MOVING THROUGH SPACE?

- Contrary to our perception, we are not "sitting still."
- We are moving with Earth in several ways, and at surprisingly fast speeds.

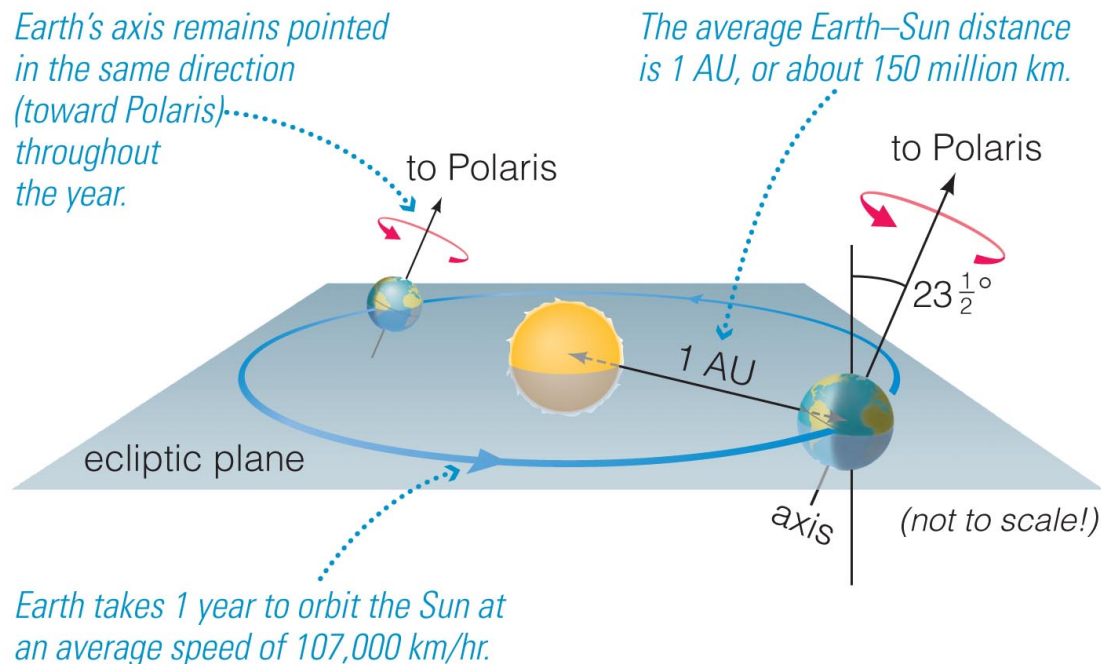


The Earth **rotates** around its axis once every day.



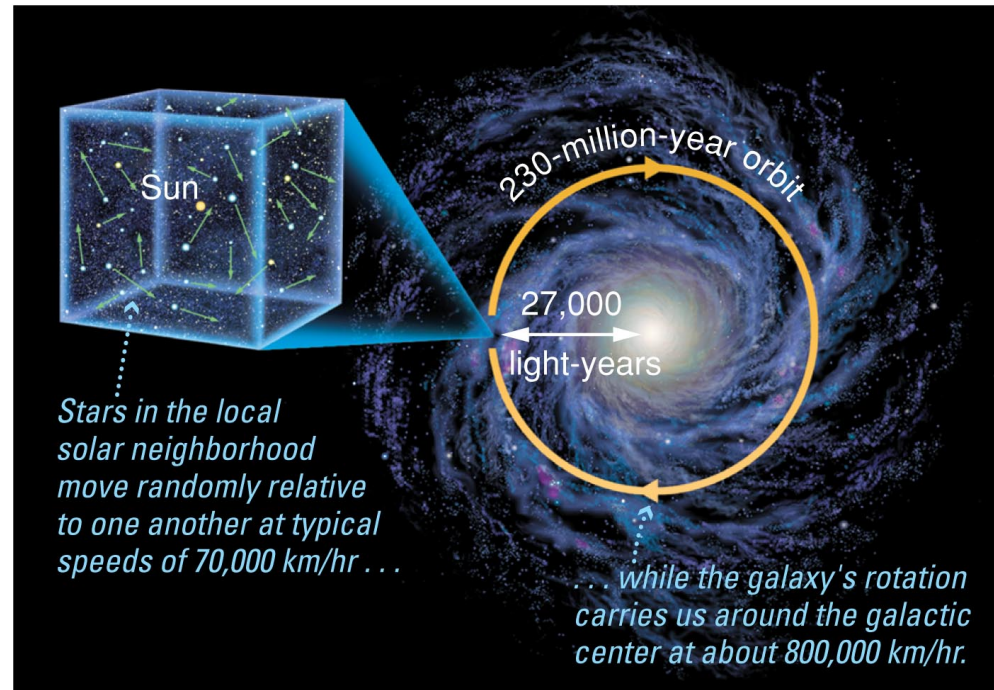
HOW IS EARTH MOVING THROUGH SPACE?

- Earth **orbits** the Sun (revolves) once every year:
 - at an average distance of 1 AU \approx 150 million kilometers.
 - with Earth's axis tilted by 23.5° (pointing to Polaris)
- It rotates in the same direction it orbits, **counterclockwise** as viewed from above the North Pole.



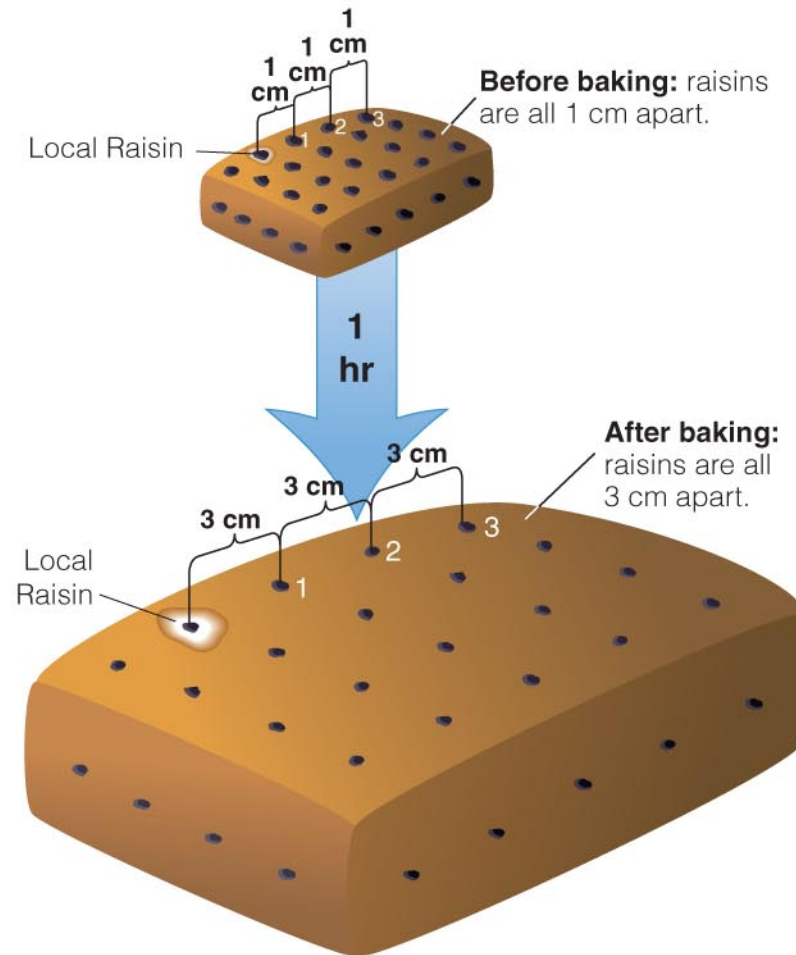
HOW IS OUR SUN MOVING IN IN THE MILKY WAY GALAXY?

- Our Sun moves randomly relative to the other stars in the local solar neighborhood...
 - typical relative speeds of more than 70,000 km/hr
 - but stars are so far away that we cannot easily notice their motion
- ... and orbits the galaxy every 230 million years.



HOW DO GALAXIES MOVE WITHIN THE UNIVERSE?

- Galaxies are carried along with the expansion of the universe.



ARE WE EVER SITTING STILL?



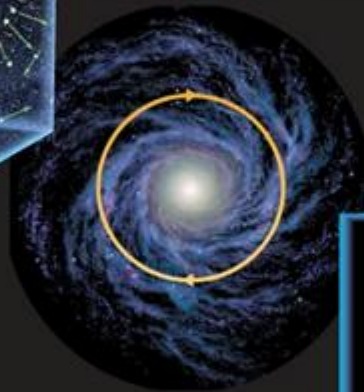
Earth rotates on axis: > 1000 km/hr



Earth orbits Sun: $> 100,000$ km/hr



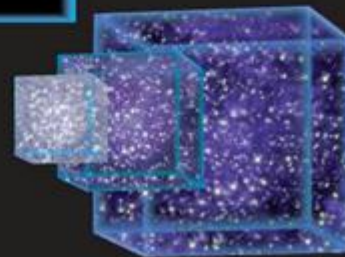
solar system moves among stars: $\sim 70,000$ km/hr



Milky Way rotates: $\sim 800,000$ km/hr



Milky Way moves in Local Group



universe expands

WHAT HAVE WE LEARNED?

○ **How is Earth moving through space?**

- It rotates on its axis once a day and orbits the Sun at a distance of 1 AU = 150 million kilometers.
- Stars in the Local Neighborhood move randomly relative to one another and orbit the center of the Milky Way in about 230 million years.



HOW HAS THE STUDY OF ASTRONOMY AFFECTED HUMAN HISTORY?

- The Copernican revolution showed that Earth was not the center of the universe (Chapter 3).
- Study of planetary motion led to Newton's laws of motion and gravity (Chapter 4).
- Newton's laws laid the foundation of the industrial revolution.
- Modern discoveries are continuing to expand our "cosmic perspective."



For Next Week:

Check the class web site: <http://www.ucolick.org/~jfortney/3.htm>

Register at www.masteringastronomy.com

- You will need to purchase access if you didn't buy the textbook package at the bookstore
- I will e-mail you the class code this afternoon.

Register your iClicker:

www.iclicker.com/support/registeryourclicker/

Do the reading (check syllabus on web page)

HW 1 will be posted Friday by noon. Do it by next Thursday!

Go to section, meet your TA, get started on the homework



