Stars, Galaxies, and the Universe

Instructor: Prof. Kaaret
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Lectures: MW 3:30 pm – 4:45 pm
Lecture Room 1 Van Allen Hall

Textbook: Investigating Astronomy
by Slater and Freedman

Clicker: Need to buy and register

Looking for Volunteers

Prof. Mutel is modifying the laboratories to be web-based. He is looking for volunteers from those enrolled in the laboratory to test out the new labs. The volunteers will likely be paid and should do very well in the laboratory part of the course.

If interested, see Prof. Kaaret after class or e-mail Prof. Mutel robert-mutel@uiowa.edu

Why study Astronomy?

From modern astronomy, we have our best answers, so far, to questions such as:

- How and where are the atoms in our bodies formed?
- Is there life anywhere else than on Earth?
- What is the history of the Universe and what will eventually happen to the Universe?

Why study Astronomy?

- Astronomy allows us to understand our place in the cosmos.
- Astronomy also reveals objects that stretch the imagination such as black holes, exploding stars, and giant jets of matter larger than a galaxy but moving at the speed of light.
- Astronomy shows us that the Universe is comprehensible.

How empty is the solar system?

- What fraction of the volume in the solar system (which we will take to be a sphere enclosing the orbit of Neptune) is taken up with solid stuff (the Sun, planets, asteroids, …)?

- Any guesses?

Scale model solar system

- To try to address this question, we are going to build a scale model of the solar system.

- So, what is a scale model?

A scale model …

A) is made out of plastic?
B) corresponds to a real object?
C) is a World War II airplane?
D) has the same proportions as a real object?
E) has the same colors as a real object?

Scale models

- A scale model is a representation of a real object or set of objects in which all of the different parts of the model have sizes in the correct proportions to the real thing.

Scale models

- For scale factor *s*, real dimension *D*
  then model dimension $d = sD$

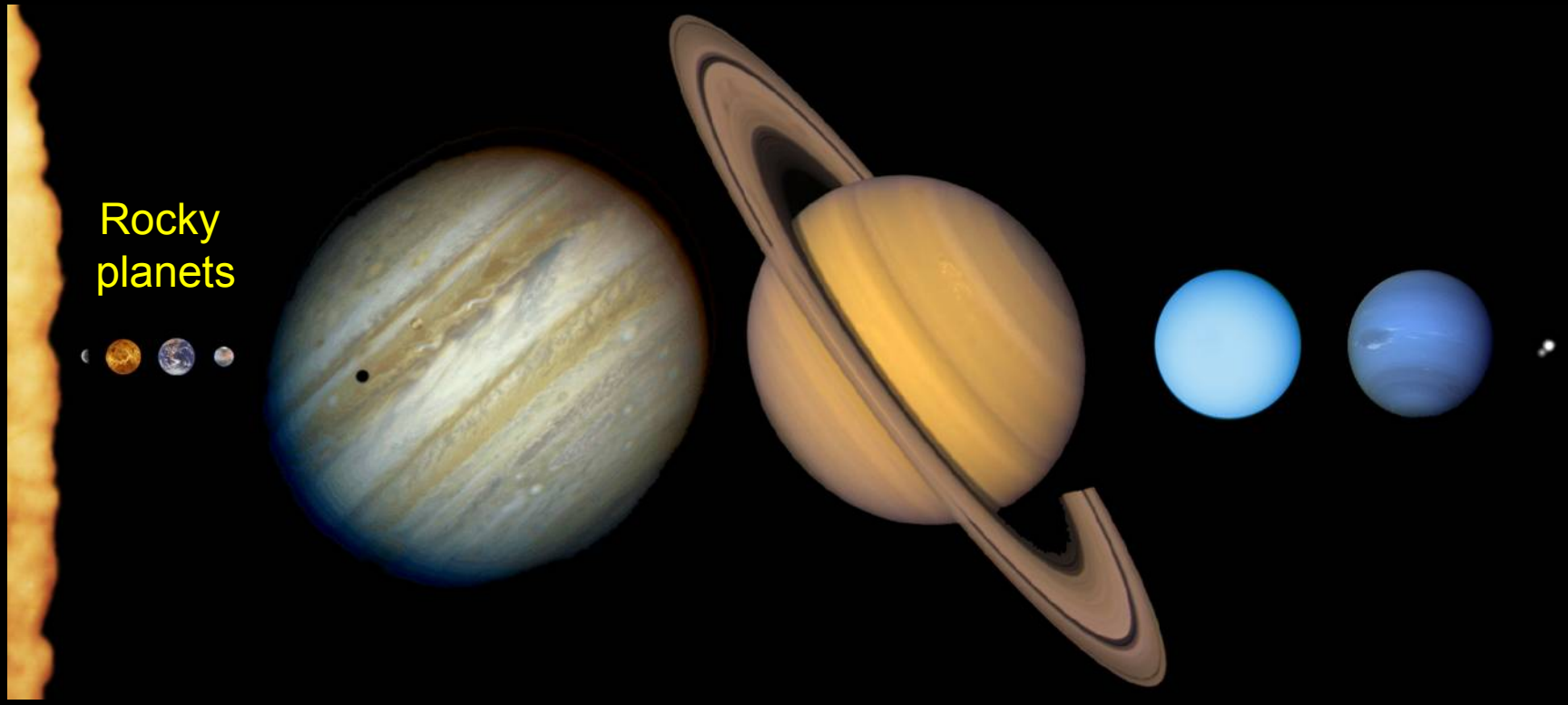
For example, with a scale factor
s = 1:160 = 1/160 = 0.00625, an airplane with
length D = 12 meters becomes a model with
length d = 0.00625*12 meters = 0.075 m
= 7.5 cm.

Scale model solar system

- We need the measurements of the real solar system. For our purposes, we will limit this to the diameter and distance from the Sun for each planet.

Planets

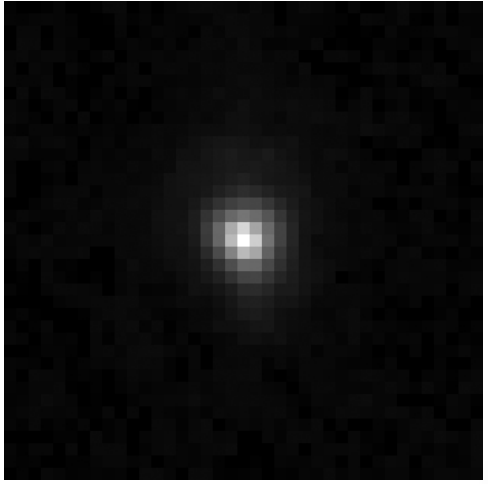
Gas giants

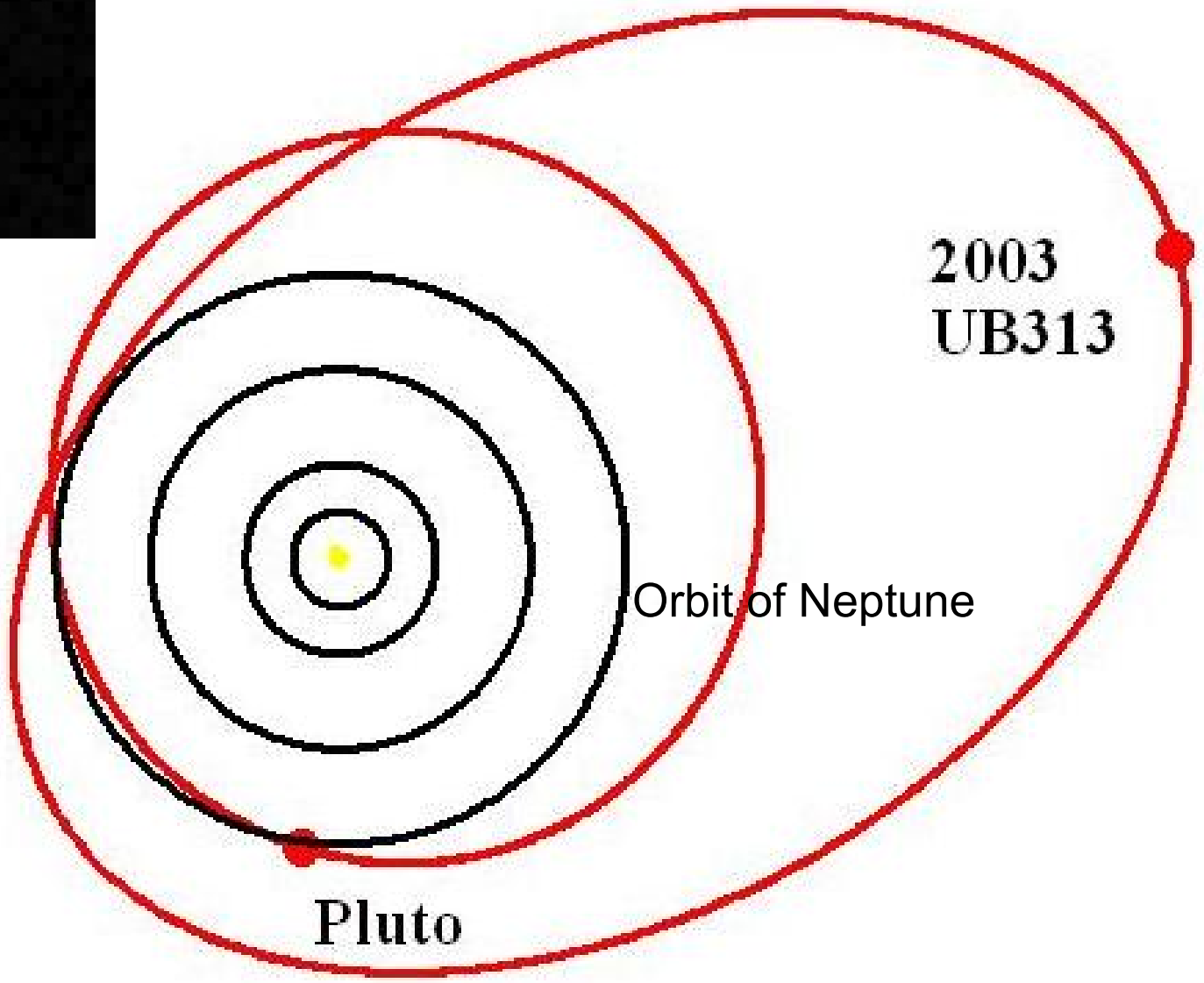


Is Pluto a Planet?

- During the 1990s more than 1000 objects orbiting beyond Neptune, theTrans-Neptunian Objects (TNO), were discovered.
- In 2003, Eris, a TNO was found that is larger than Pluto and has its own moon.
- So, add Eris as a planet or dump Pluto?
- The International Astronomical Union (IAU) made a new definition of a planet:
  - A celestial body that (a) is 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 neighborhood around its orbit.
- So Pluto and Eris are not “real” planets, they are dwarf planets.

Eris





Solar system data

	Diameter [meters]	Distance from Sun [meters]
Sun	1,392,700,000	0
Mercury	4,878,000	57,900,000,000
Venus	12,104,000	108,200,000,000
Earth	12,756,000	149,600,000,000
Mars	6,787,000	227,900,000,000
Jupiter	142,980,000	778,300,000,000
Saturn	120,540,000	1,427,000,000,000
Uranus	51,120,000	2,870,000,000,000
Neptune	49,530,000	4,497,000,000,000

Scale model of solar system

Scale factor s = 4:1,000,000,000,000 = 0.000000000004

	Distance from Sun meters	Scaled distance meters
Sun	0	0.0
Mercury	57,900,000,000	0.232
Venus	108,200,000,000	0.433
Earth	149,600,000,000	0.598
Mars	227,900,000,000	0.912
Jupiter	778,300,000,000	3.113
Saturn	1,427,000,000,000	5.708
Uranus	2,870,000,000,000	11.480
Neptune	4,497,000,000,000	17.988

Scale model of solar system

Scale factor s = 4:1,000,000,000,000 = 0.000000000004

	Diameter meters	Scaled diameter meters
Sun	1,392,700,000	0.005571
Mercury	4,878,000	0.000020
Venus	12,104,000	0.000048
Earth	12,756,000	0.000051
Mars	6,787,000	0.000027
Jupiter	142,980,000	0.000572
Saturn	120,540,000	0.000482
Uranus	51,120,000	0.000204
Neptune	49,530,000	0.000198

Scale model of solar system

- To fit the solar system into the classroom, we scaled the radius of the orbit of Neptune to be about 18 meters (59 feet)
- Sun is the size of a match head
- Jupiter is smaller than a grain of salt
- Earth has the diameter of a strand of hair

How far is the Moon from the Earth in our Model?

Moon is 384,400,000 m from Earth.

A) Strand of hair
B) Size of grain of salt (0.1 mm)
C) Thickness of paper clip (1 mm)
D) Width of nail on pinky (1 cm)

How far is the closest star in our Model?

Proxima Centauri is 39,900,000,000,000,000 m from Earth.

A) Old Capitol Building
B) Field House
C) Des Moines
D) New York
E) Beijing

Powers of ten are shorthand for writing very large numbers

$10^0 = 1$	One
$10^1 = 10$	Ten (deca)
$10^2 = 100$	Hundred (centa)
$10^3 = 1{,}000$	Thousand (kilo)
$10^6 = 1{,}000{,}000$	Million (mega)
$10^9 = 1{,}000{,}000{,}000$	Billion (giga)
$10^{12} = 1{,}000{,}000{,}000{,}000$	Trillion (tera)
$10^{15} = \ldots$	Quadrillion (peta)
$10^{54} = \ldots$	Septendecillion

They also work for very small numbers

$10^{0} = 1$	One
$10^{-1} = 0.1$	One tenth (deci)
$10^{-2} = 0.01$	One hundredth (centi)
$10^{-3} = 0.001$	One thousandth (milli)
$10^{-6} = 0.000,001$	One millionth (micro)
$10^{-9} = 0.000,000,001$	One billionth (nano)
$10^{-12} = 0.000,000,000,001$	One trillionth (pico)
$10^{-15} = \ldots$	One quadrillionth (femto)
$10^{-54} = \ldots$	One septendecillionth

Scale model of solar system

Scale factor $s = 4{:}10^{12} = 4 \times 10^{-12}$

	Distance from Sun meters	Scaled distance meters
Sun	0	0.0
Mercury	5.79×10^{10}	0.232
Venus	1.082×10^{11}	0.433
Earth	1.496×10^{11}	0.598
Mars	2.279×10^{11}	0.912
Jupiter	7.783×10^{11}	3.113
Saturn	1.427×10^{12}	5.708
Uranus	2.870×10^{12}	11.480
Neptune	4.497×10^{12}	17.988

Back to the solar system

Volume of solar system taken up by "stuff"

= (volume of Sun) / (volume of solar system)

= $(4/3)\pi$(radius of Sun)^3 / $(4/3)\pi$(radius of Neptune's orbit)^3

= (radius of Sun)^3 / (radius of Neptune's orbit)^3

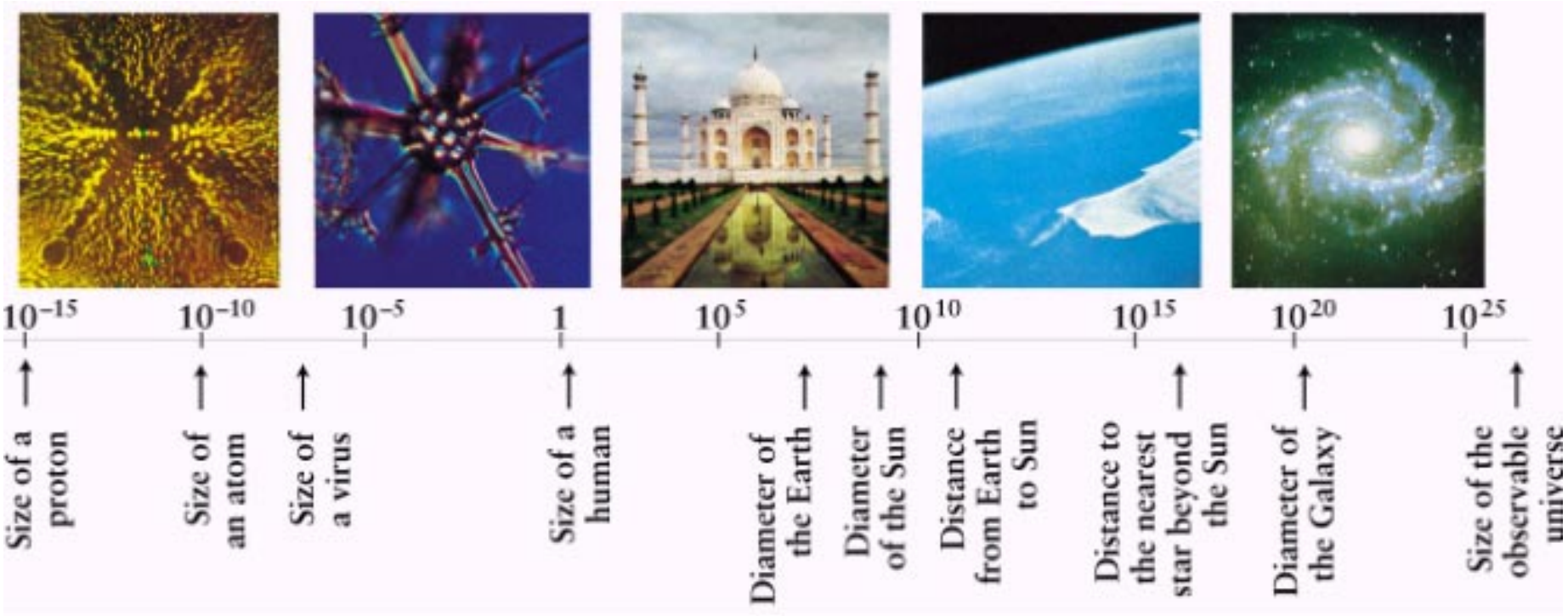
= $(7\times10^8)^3 / (4.5\times10^{12})^3$

= $(7^3\times10^{8\times3}) / (4.5^3\times10^{12\times3})$

= $(7/4.5)^3\times(10^{8\times3-12\times3})$

= 3.8×10^{-12} = a few millionths of a millionth

Volume of a sphere = $(4/3)\pi R^3$



Sizes are in meters

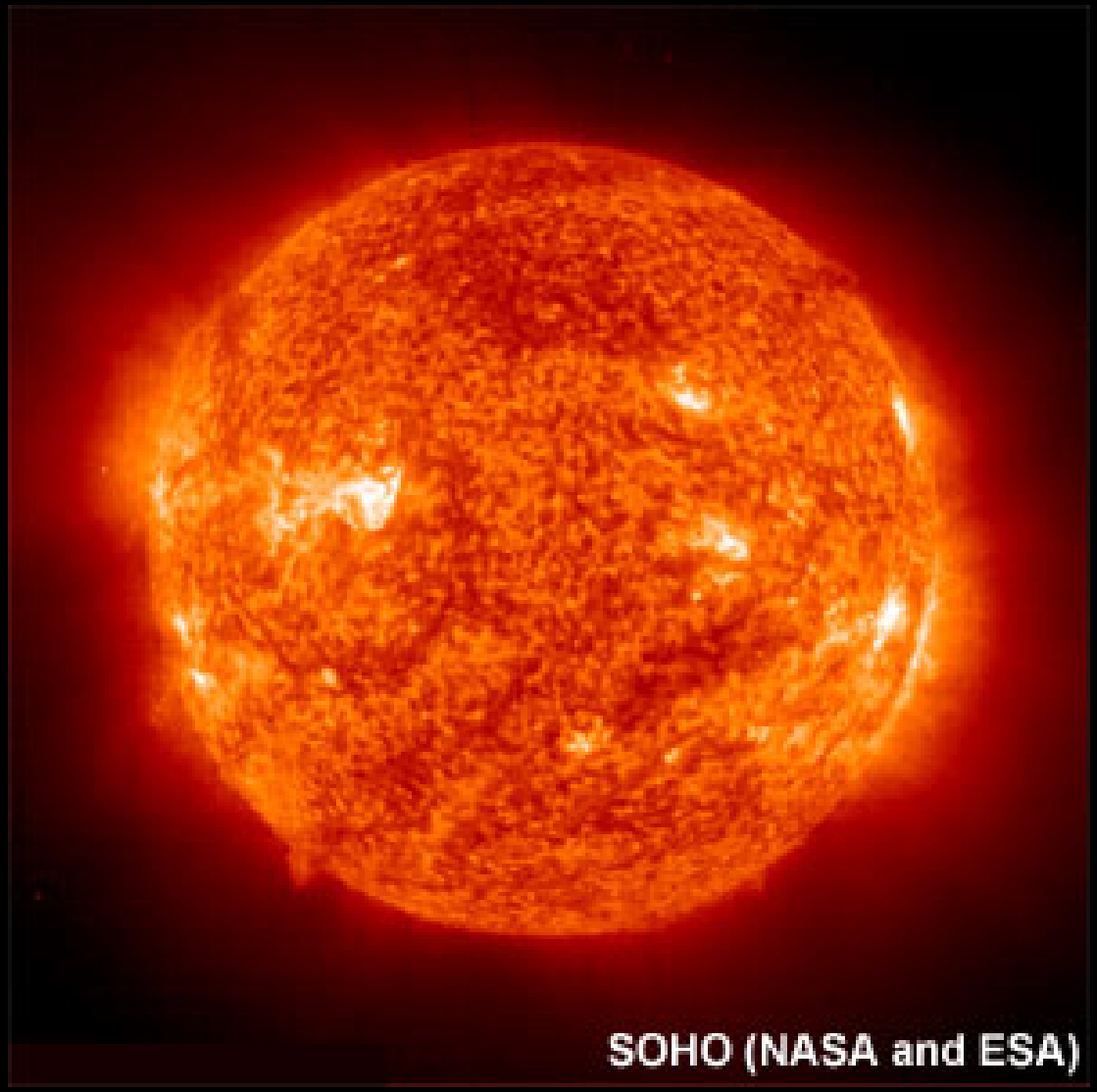
People

Height of (small) person is about 1.1 m

Earth

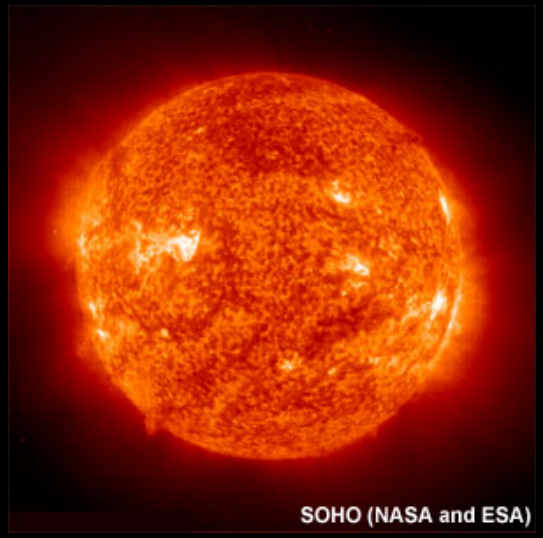
Radius of earth or $R_{\oplus}$ is 6.4×10^6 m

Sun



Radius of Sun or $R_\odot$ is 7×10^8 m

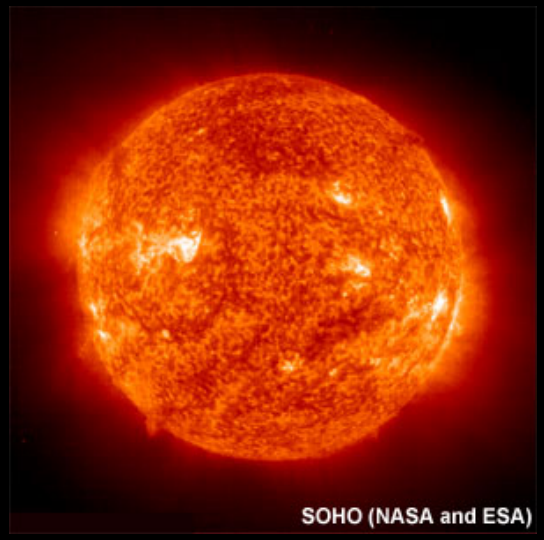
Earth to Sun

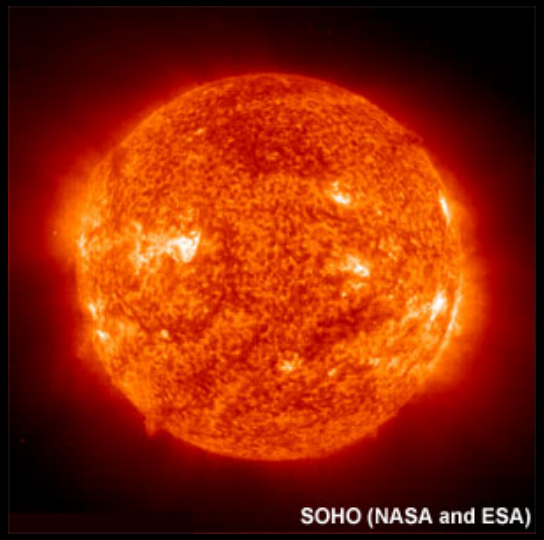


Distance from Earth to Sun is 1.5×10^{11} m

This is one “Astronomical Unit” = 1 A.U.

Sun to Nearest Star



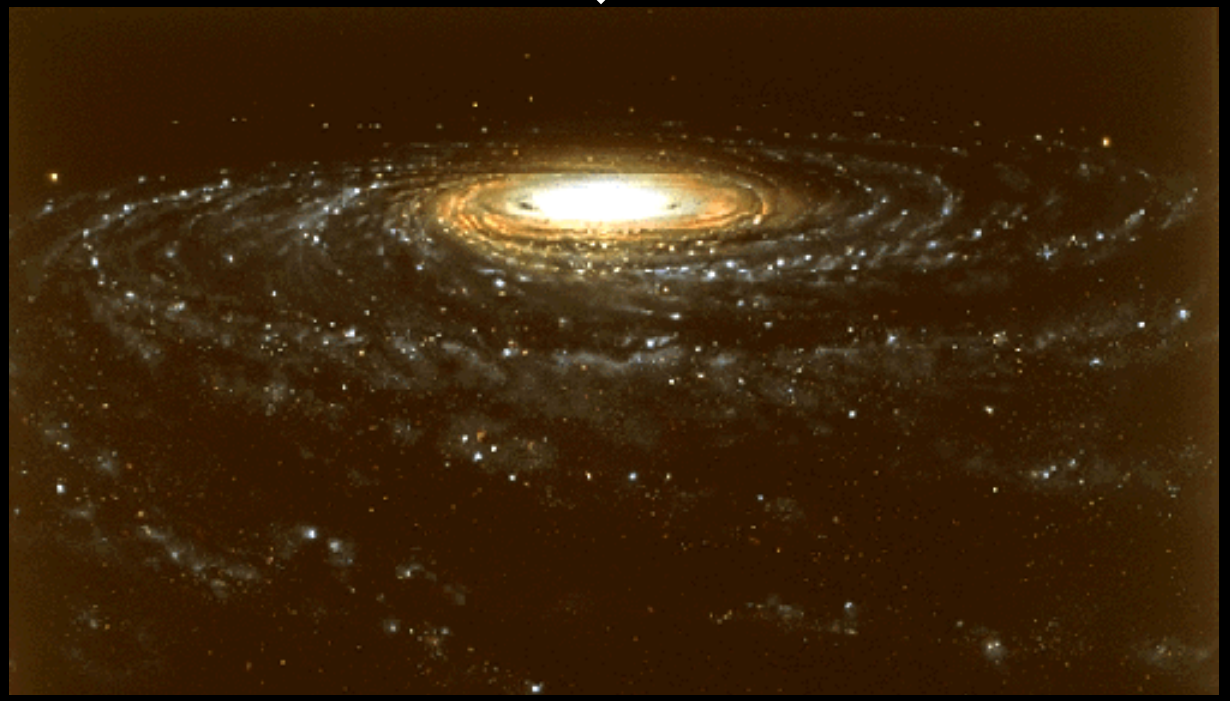


Distance from Sun to nearest star is 4.1×10^{16} m

Define light-year = ly = 9.46×10^{15} m

Distance from Sun to nearest star is 4.3 ly

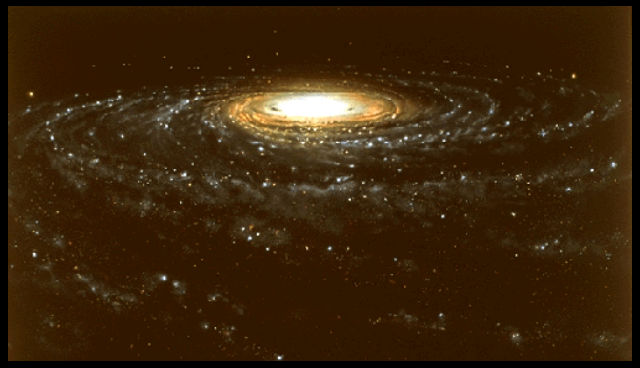
to Center of Milky Way



Distance to Center of our galaxy is 2.6×10^{20} m

or 28,000 ly

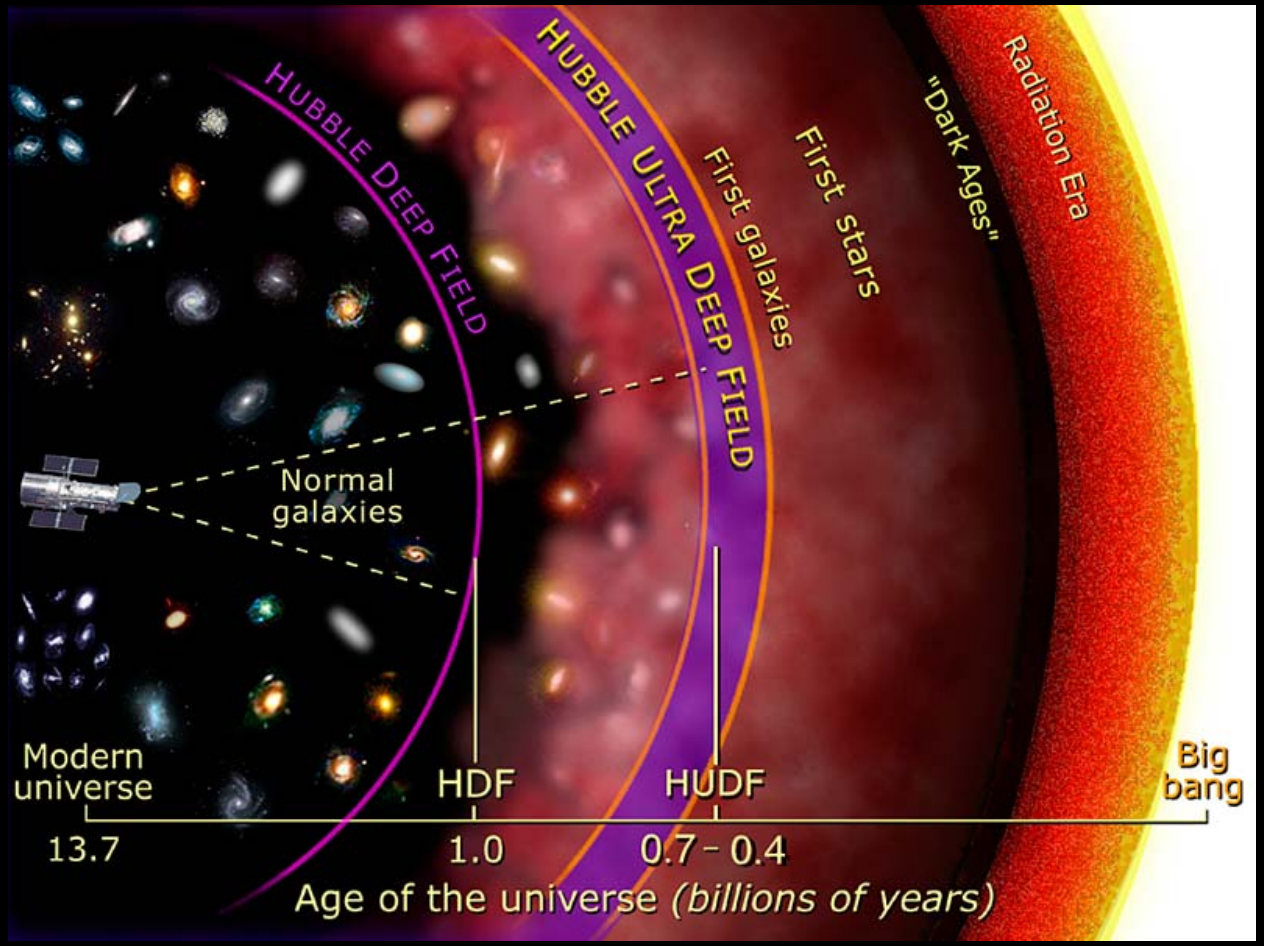
to Nearest (big) Galaxy



Distance to nearest (big) galaxy is 2.4×10^{22} m

or 2.6×10^{6} ly

to edge of Observable Universe



Distance to edge of observable universe is
1.3×10^{26} m or 1.4×10^{10} ly

Course information

- Website: http://astro.physics.uiowa.edu/~kaaret/f11
- Survey of modern astronomy, conceptual approach
- Course covers
  - Night sky, moon, eclipses
  - Search for extra-solar planets, life
  - Sun, stars
  - Black holes, neutron stars
  - Galaxies
  - Cosmology
- Does not cover solar system, extraterrestrial life in detail. Other classes are available for these topics.

Course information

- Some math will be needed
  - Simple algebraic equations
  - Plugging numbers into equations
  - Understanding powers of ten
  - Simple geometry

Course information

- Laboratory
  - If you are registered for 4 s.h., you are already assigned to a weekly laboratory section.
  - Laboratory sessions start next week.
  - Observing with a research-grade optical telescope in Arizona (Rigel telescope). You will be using this facility for a research project in the second half of the semester.
  - **Students in the lab must pass the lab to pass the course.**

Grading

The course grade (letter grade will include +/- grading) will be determined by the sum of points accumulated during the semester. The total possible points are given in the table below.

Questions during class	80
Homework	80
In-class exams	3×80
Final exam	160
Total	480, drop worst of questions, HW, or in-class exams

Questions will be asked during class and reponses made using clickers

- We will be using clickers for in-class questions.
- Every student must bring a clicker to class **every day**.
- Every student must **register** their clicker.
- Information about UI clickers at http://its.uiowa.edu/support/srs/student_faqs.shtml
- Questions will be graded as 1 point for a correct answer and 0.5 points for an incorrect answer. Total score will be normalized to 100 points with a maximum of 80 points awarded.
- We will have small group discussions between questions, so sit with a small group of about 4 friends.

Homework and Exams

- Homework will be assigned each week and due Tuesdays at midnight, starting next week. Homework will be turned in via ICON.

- There will be three in-class exams, all on Wednesdays. Questions will be multiple choice, matching, or true/false.

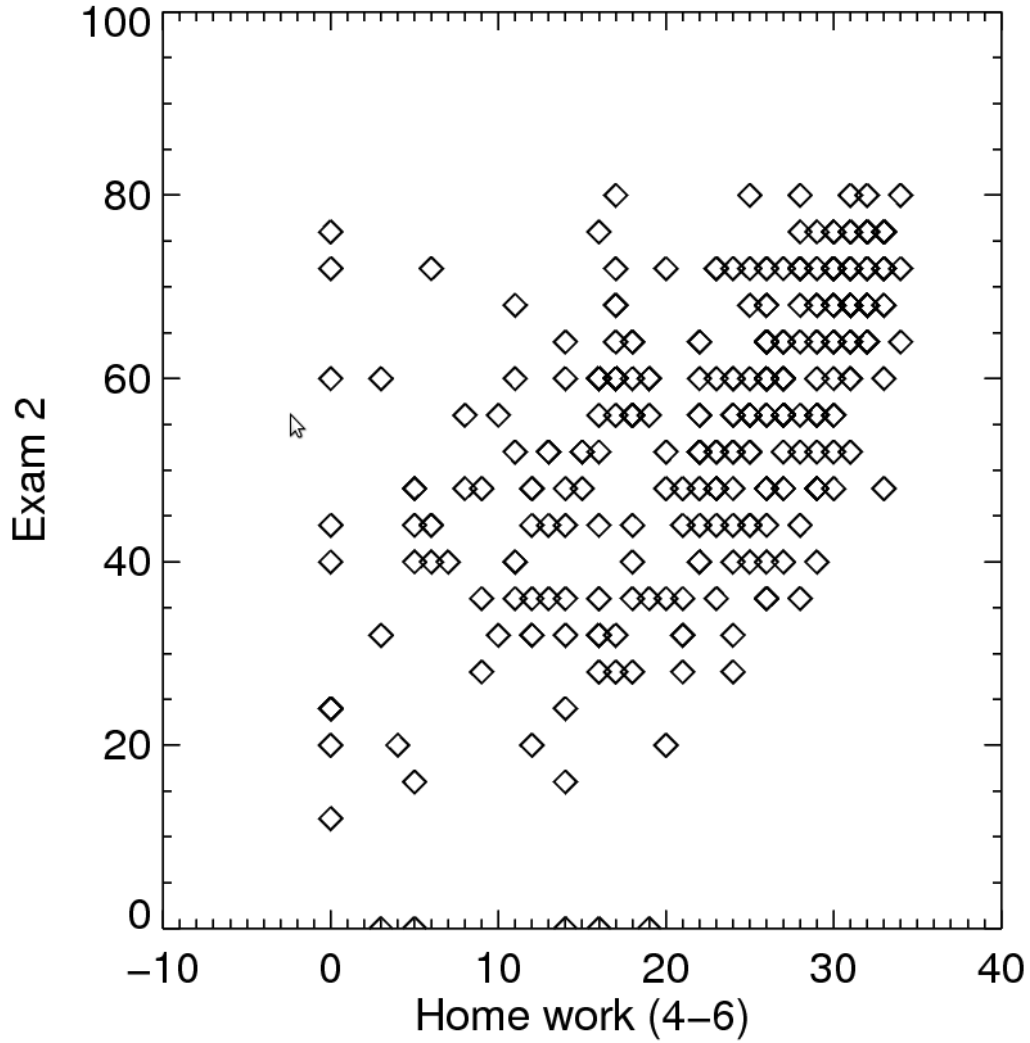
- There will be a final exam.

Extra Credit

- It will be possible to obtain extra credit by attending a public observing event at the Eastern Iowa Observatory and Learning Center. Students must look through a telescope at an astronomical object. Students earn 10 points per event for a maximum of two events.
- There is one event per month, starting Saturday, August 27. The schedule is at:

  http://www.cedar-astronomers.org/events.htm

How to do well in the class...



- Do the homework