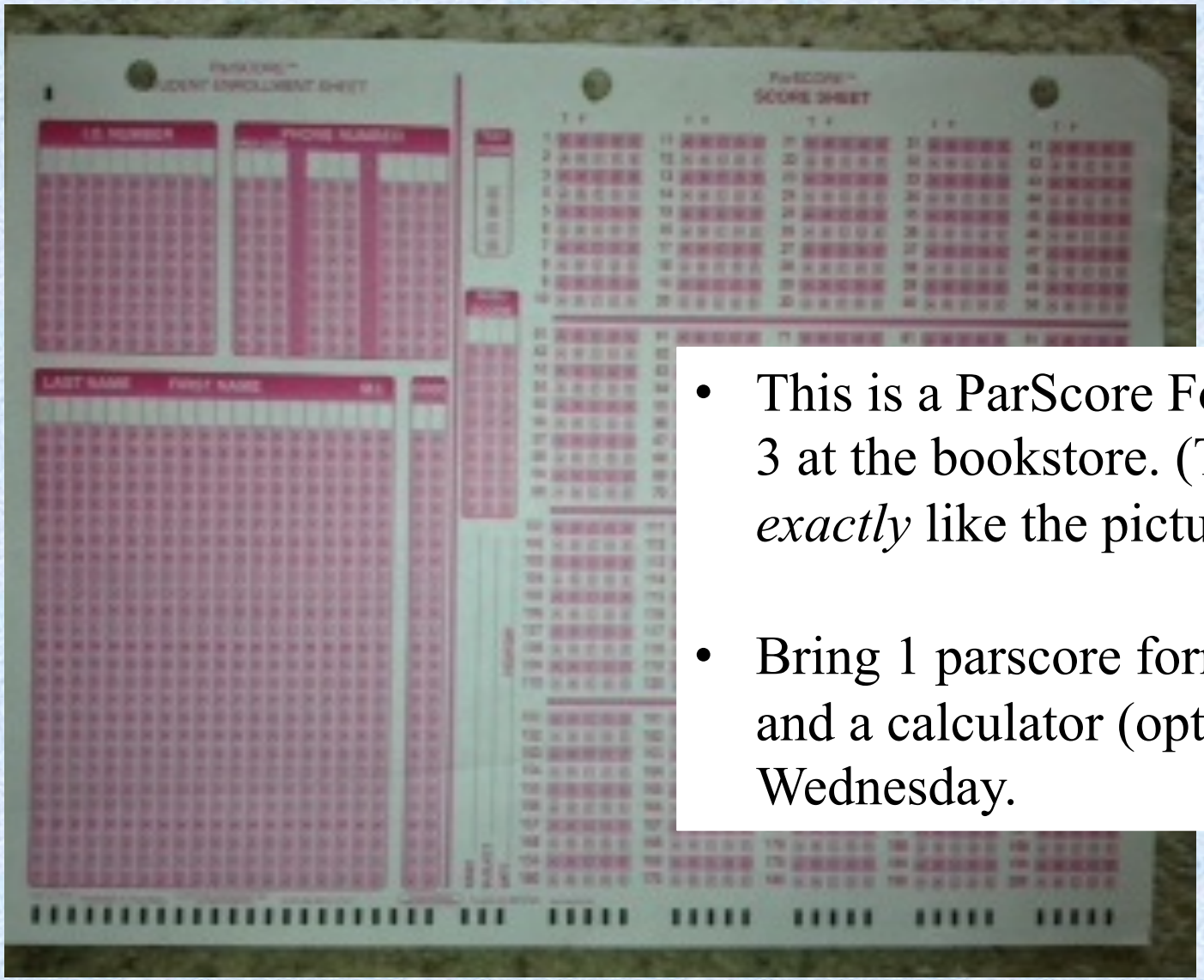
Astronomy 1 – Fall 2019



- This is a ParScore Form. Please buy 3 at the bookstore. (They should look *exactly* like the picture.)
- Bring 1 parscore form, a #2 pencil, and a calculator (optional) on Wednesday.

Astronomy 1 - Goals

- Understand the scientific method – what is science? What is NOT science?
- Improve your understanding of the universe – what are planets, stars, and galaxies? And black holes!
- Learn to critically evaluate data (images, graphs, tables, text).
- Develop strategies for problem solving.
  - NOTE: **Yes, this is a physics class.** We will use physics to understand the observed universe far, far beyond a terrestrial laboratory.

What is science?

Is Astrology Science?

Why?

Is the Scientific Method Good?

Does the question even make sense?

One view is that a method is good as long as it allows you to achieve what you want.

What do you want?

Does Every Question Have a Scientific Answer?

Can you think of one that doesn't?

Is it possible that science would answer it someday?

Does our society value scientific answers?

Methodological Introduction

- Science is **falsifiable**.
  - Measurements (and their uncertainties) test scientific theories.
  - The essence of science is that it can be proven wrong.
- Science is **repeatable.**
  - Determinism and probability
  - Contrast with the supernatural

What is a Scientific Theory?

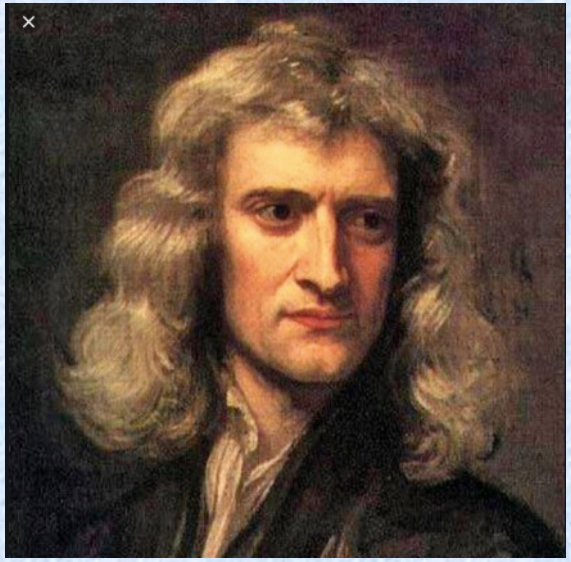
- A scientific theory is a logically self-consistent model or framework for describing the behavior of a related set of natural or social phenomena.
- In general it originates from experimental evidence
- A good theory is always corroborated by experimental evidence, in the form of successful empirical tests.
- In this sense a theory is a systematic and formalized expression of all previous observations that is **predictive, logical, and testable (falsifiable)**.

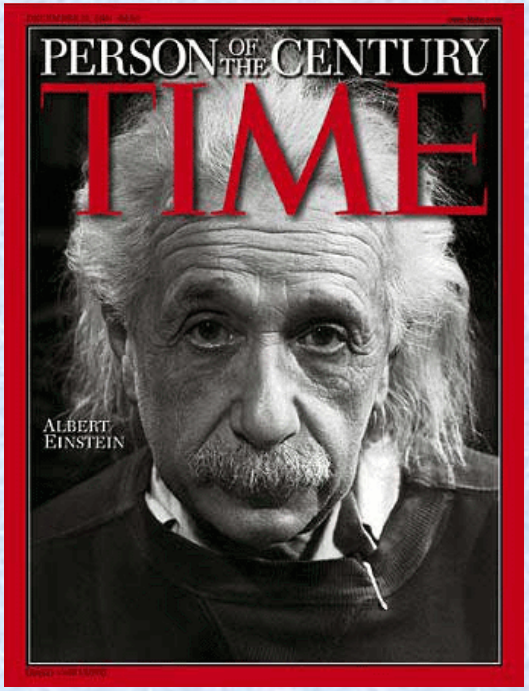
Examples of Scientific Theories

What scientific theories have you heard of?

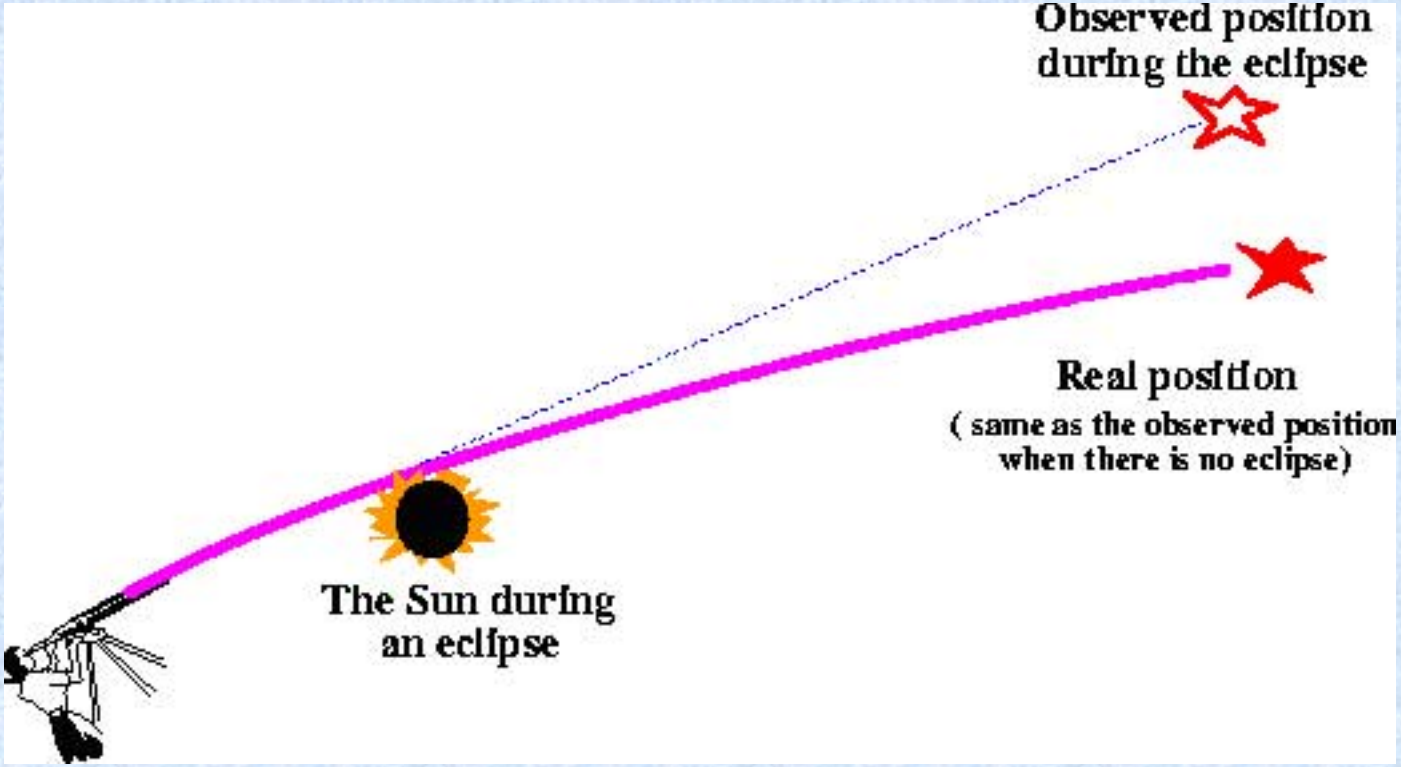
Scientific theories are always tentative, and subject to corrections or inclusion in a yet wider theory. A model does not aspire to be a "true" picture of reality.

Example: Gravity
From Newton to Einstein to ...





Newton ➔ Einstein



- 1919 solar eclipse measurement: 1.61+-0.40”
- Einstein 1.75”; Newton 0.875”

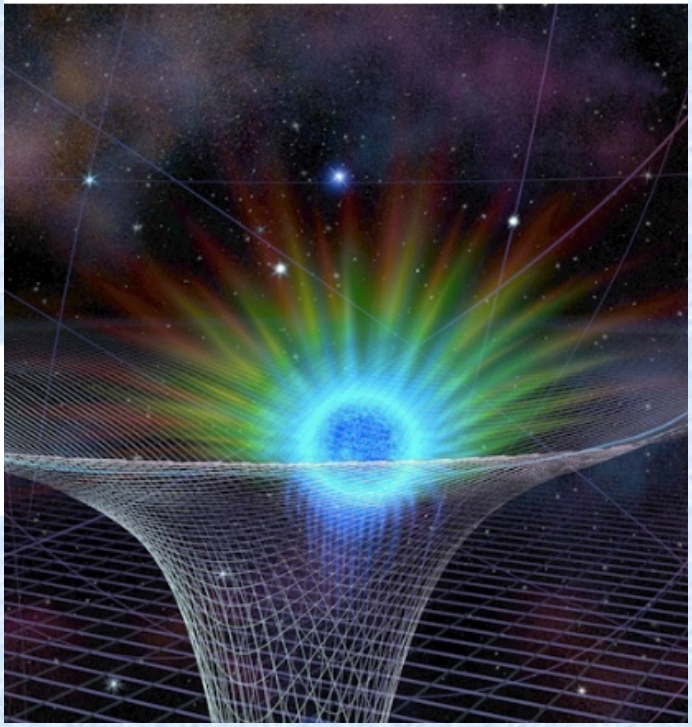
Einstein ➔ ?

Milky Way's central black hole puts Einstein's theories to the test

By Robert Sanders, Media relations | JULY 25, 2019 Tweet Share 394 Email Print

https://www.youtube.com/watch?v=tJ6lQHIDaEI#action=share

General relativity passes test at Milky Way's central black hole



A "good" scientific theory

- What constitutes a "good" scientific theory?
- If a theory can never be proven right, how is one theory better than another?
  - The better theory is the one that passes more stringent tests, both in number and in quality
  - The better theory is the more falsifiable one, if it doesn't fail
- Old theories often become limiting cases of new theories
  - (e.g. Newton vs Einstein)

Measurements

- Measurements must be REPEATABLE
- Measurements have errors
  - A measurement without an error is meaningless
  - EVERY MEASUREMENT HAS ERRORS
  - HOW TALL ARE YOU?

Probability and Science

- The results of experiments are often cast in terms of probabilities.
- The same is true for scientific theories: Probabilistic predictions are not in conflict with the scientific method because they can be falsified.

Heisenberg's Uncertainty Principle is an example.

- *The uncertainty on position and momentum (~speed) is larger than $\Delta x \Delta p > h/2\pi$, where h is Planck's constant.*
- *So the speed and location of a particle cannot both be precisely determined – on quantum scales!*

Scientific Language

Powers of 10: large numbers

Exponent tells how many times to multiply a number by itself: $10^2 = 10 \times 10 = 100$

$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$
$10^6 = 1{,}000{,}000$ (one million)
$10^9 = 1{,}000{,}000{,}000$ (one billion)
$10^{12} = 1{,}000{,}000{,}000{,}000$ (one trillion)

A positive exponent on the number 10 tells you how many zeros are in the number.

Powers of 10: small numbers

Negative exponents tell how many times to divide by ten:
$10^{-2} = 1/10 \times 1/10 = 1/10^2 = 0.01$

$10^0 = 1$
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/10 \times 1/10 = 0.01$ (one hundredth)
$10^{-3} = 1/10 \times 1/10 \times 1/10 = 1/10^3 = 0.001$ (one thousandth)
$10^{-4} = 0.0001$ (one ten-thousandth)
$10^{-6} = 0.000001$ (one millionth)

You can also think of the negative exponent as how many decimal places are in the number.

Scientific notation

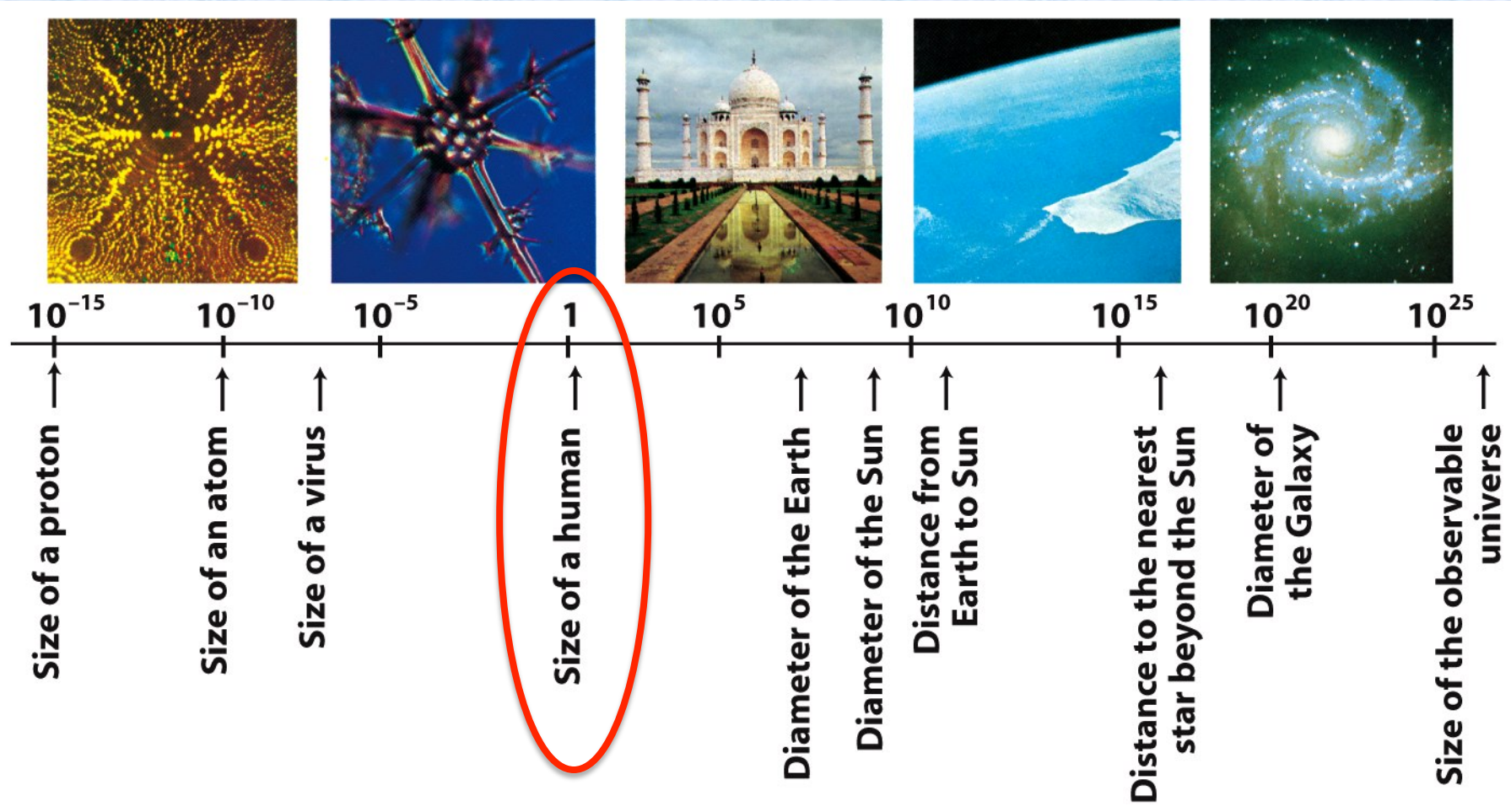
A way of expressing large or small numbers

$2{,}230{,}000 = 2.23 \times 1{,}000{,}000 = 2.23 \times 10^{6}$

$0.0095 = 9.5 \times 0.001 = 9.5 \times 10^{-3}$

To use scientific notation on your calculator, use the EE or EXP key. For example, 2.23 EE 6.

Length (in Meters)



Dimensional quantities have units.

- How much does your Universe textbook weigh?
- How tall are you?
- Although units are arbitrary, dimensions are not!
- If you quote a length it should be in units of length, not time, etc. You cannot be 5 hours tall!

International System (SI)

- The standard system of units is the so-called **international system** (SI), based on meters, kilograms, and seconds.

- The system is convenient because conversion are trivial in exponential notation:
  - 1 km = 1000 m vs 1 mile = 5280 feet?

- When in doubt convert to SI.

Standard Units in Astronomy

- **Astronomy often uses non SI units for historical reasons.**
- Why? Here are some examples.
  - What is the mass of all the stars in the Milky Way galaxy?
    - 1 **solar mass** = 2×10^{30} kg = 2×10^{33} g
    - The Milky Way galaxy includes about 3×10^{10} solar masses of stars.
  - The average distance from the Earth to the Sun is called an **astronomical unit**.
    - 1 AU = 1.496×10^{8} km
  - The distance light travels in a year is **a lightyear (ly)**.
    - Note that a lightye**ar** is a unit of distance, not time.
    - The farthest thing you can see with your naked eye is M33, the Pinwheel Galaxy, 3 million lightyears away.

Do You Understand?

Let's Check.

Breakthrough Starshot hopes to build a nanocraft that can travel to the Proxima Centauri system in only 21 years.

The distance to Proxima Centauri is 4.2 ly.

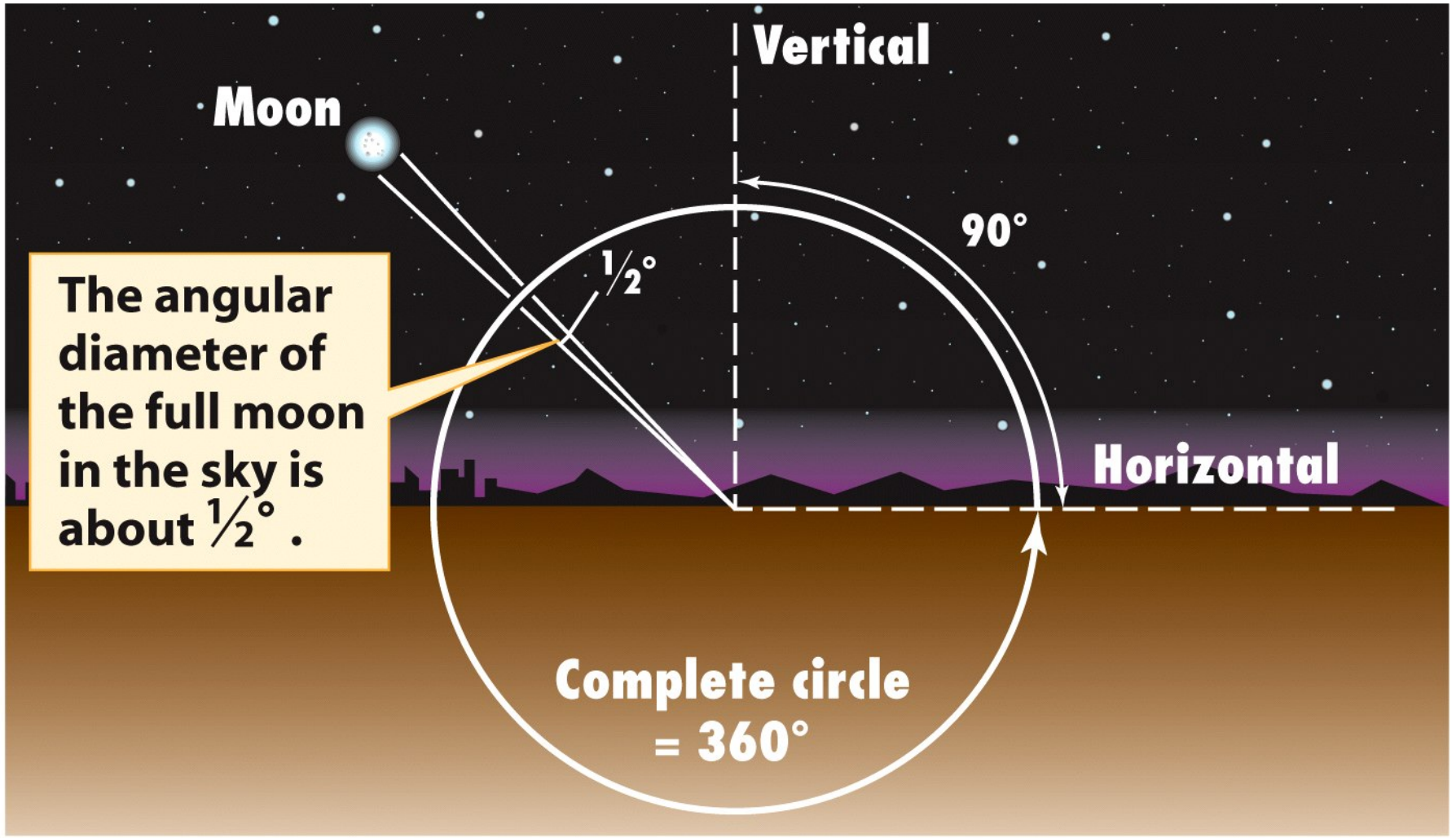
Question

How fast does the nanocraft need to travel to reach Proxima Centauri in 21 years?

1. distance traveled = **speed** × time
   - Write as $d = v \times t$
2. We are told d = 4.2 ly.
   - A photon would travel at v = c and take t = 4.2 years, so $d = c \times 4.2$ years = 4.2 ly.
3. Substitution gives
   - 4.2 years × c = v × 21 years
   - v = 4.2 years / 21 year × c
   - v = 0.20 c, or 20% the speed of light

Angles

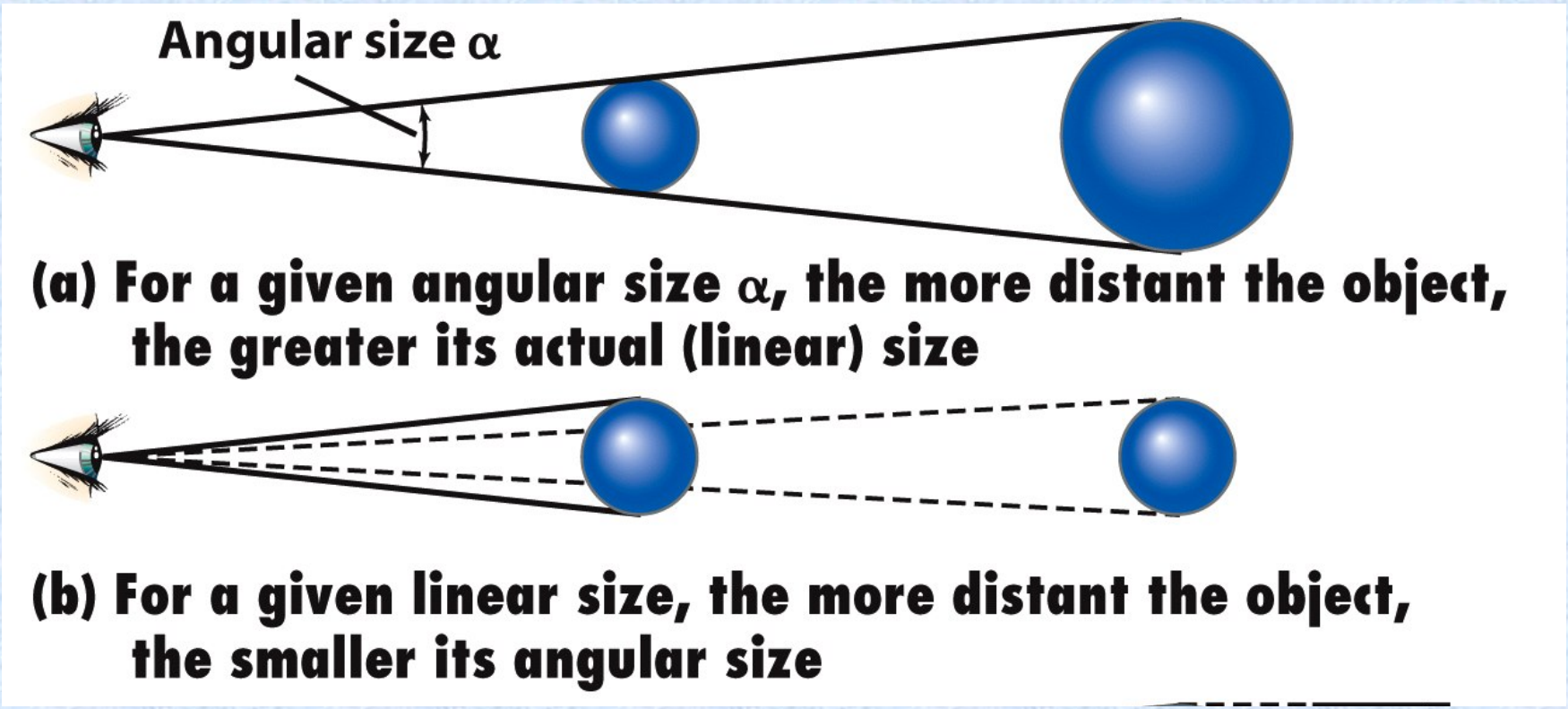
Astronomers Measure Angles on the Sky



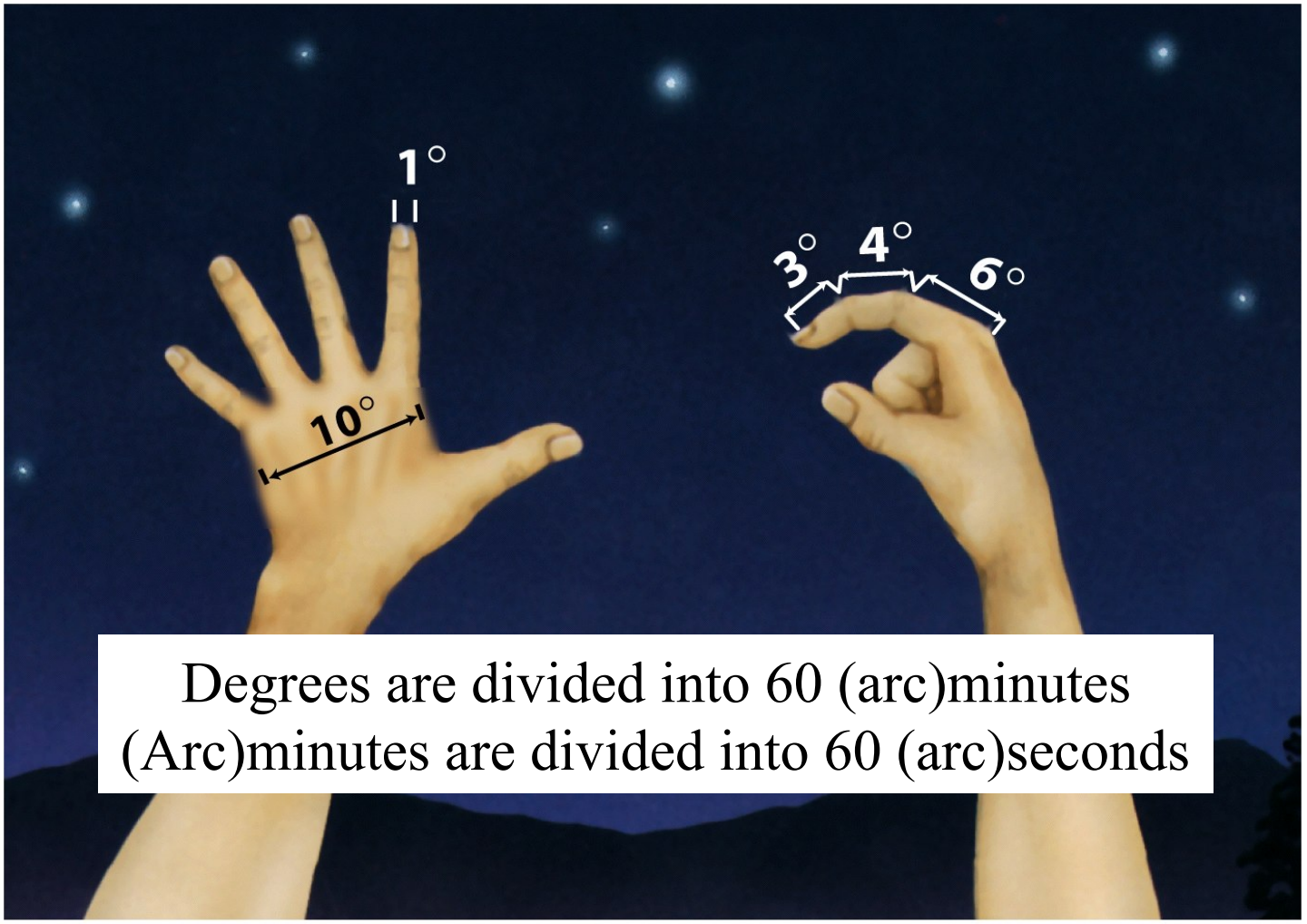
Measuring angles in the sky

We can turn an angular size into the diameter of an object.

Cleary this should depend on the distance to the object.

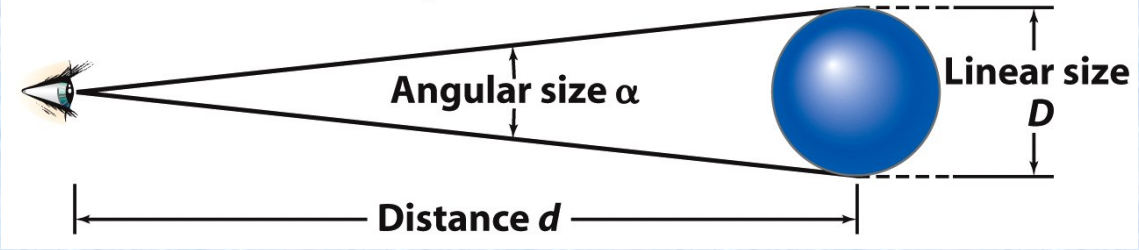


We use units of arcseconds for angles.



Degrees are divided into 60 (arc)minutes
(Arc)minutes are divided into 60 (arc)seconds

The Small Angle Formula



$$D = \alpha d$$

- Suppose you know the distance (d) to the object.
- **Turn an angular size (α) into the diameter of the object (D).**
- The **small angle formula** requires the angle to be in radians. *There are 206265 arcseconds in one radian*, so

$$D = \frac{\alpha(arcseconds)d}{206265}$$

- The diameter and the distance can have any unit of length as long as they are the same.

iclicker Question

The moon is half a degree wide. The moon is 400,000 km away. What is the linear diameter of the moon?

Recall:

$$D = \frac{\alpha d}{206265}$$

When using the equation in this form, the angle must be in arcseconds.

First step: How many arcseconds are in 0.5 degrees?

$$0.5\,\text{deg} = 0.5^{\circ}\left(\frac{60'}{1^{\circ}}\right)\left(\frac{60''}{1'}\right) = 1800''$$

Second step:

$$D = \left(\frac{1800''}{206265''}\right)400{,}000\,km$$

$$D = 3491\,km$$

Iclicker Answer

The moon is half a degree wide. The moon is 400,000 km away. What is the linear diameter of the moon?

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A. 3491 km

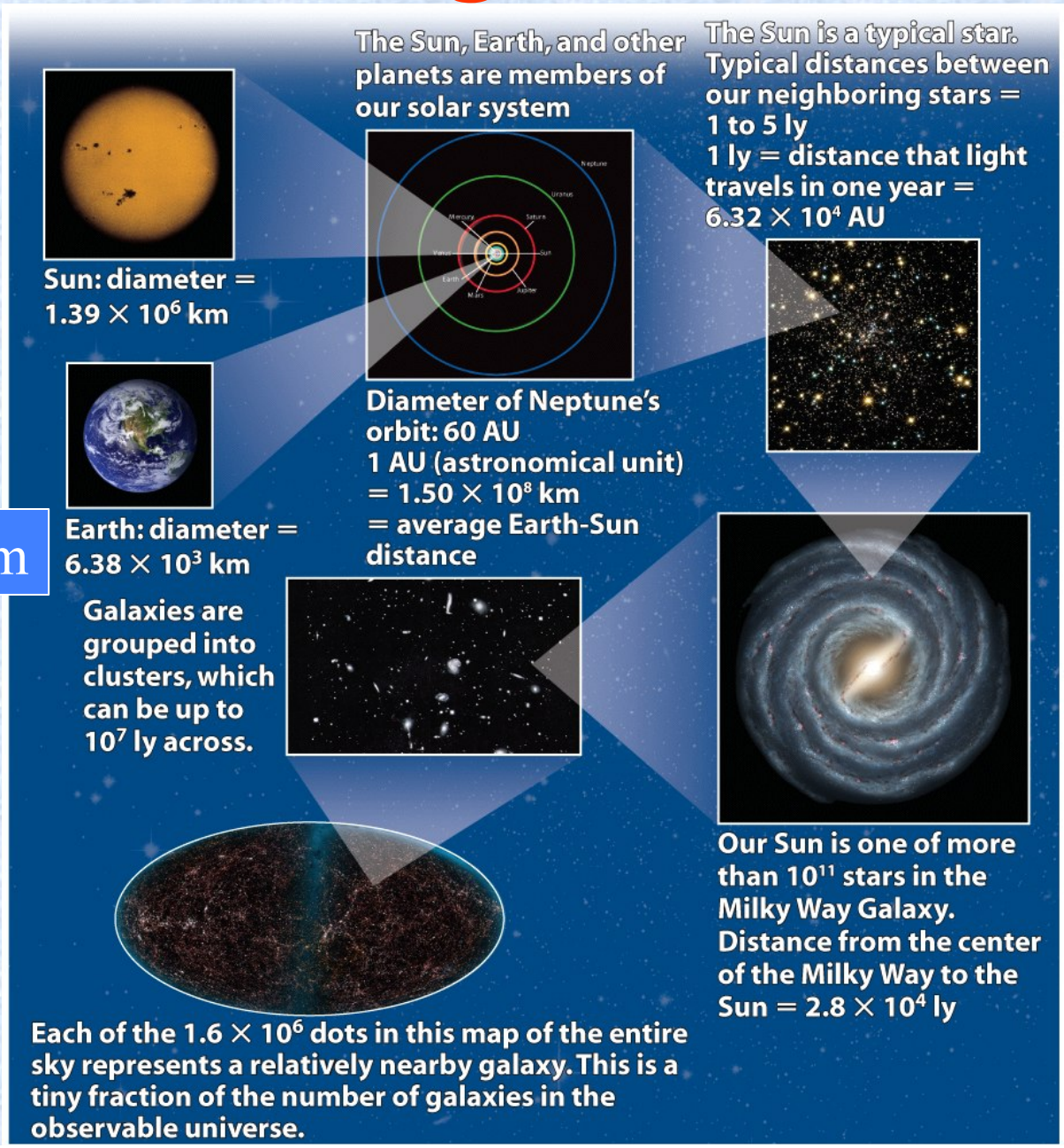
B. 206,265 km

C. 200,000 km

D. 2×10^{10} cm

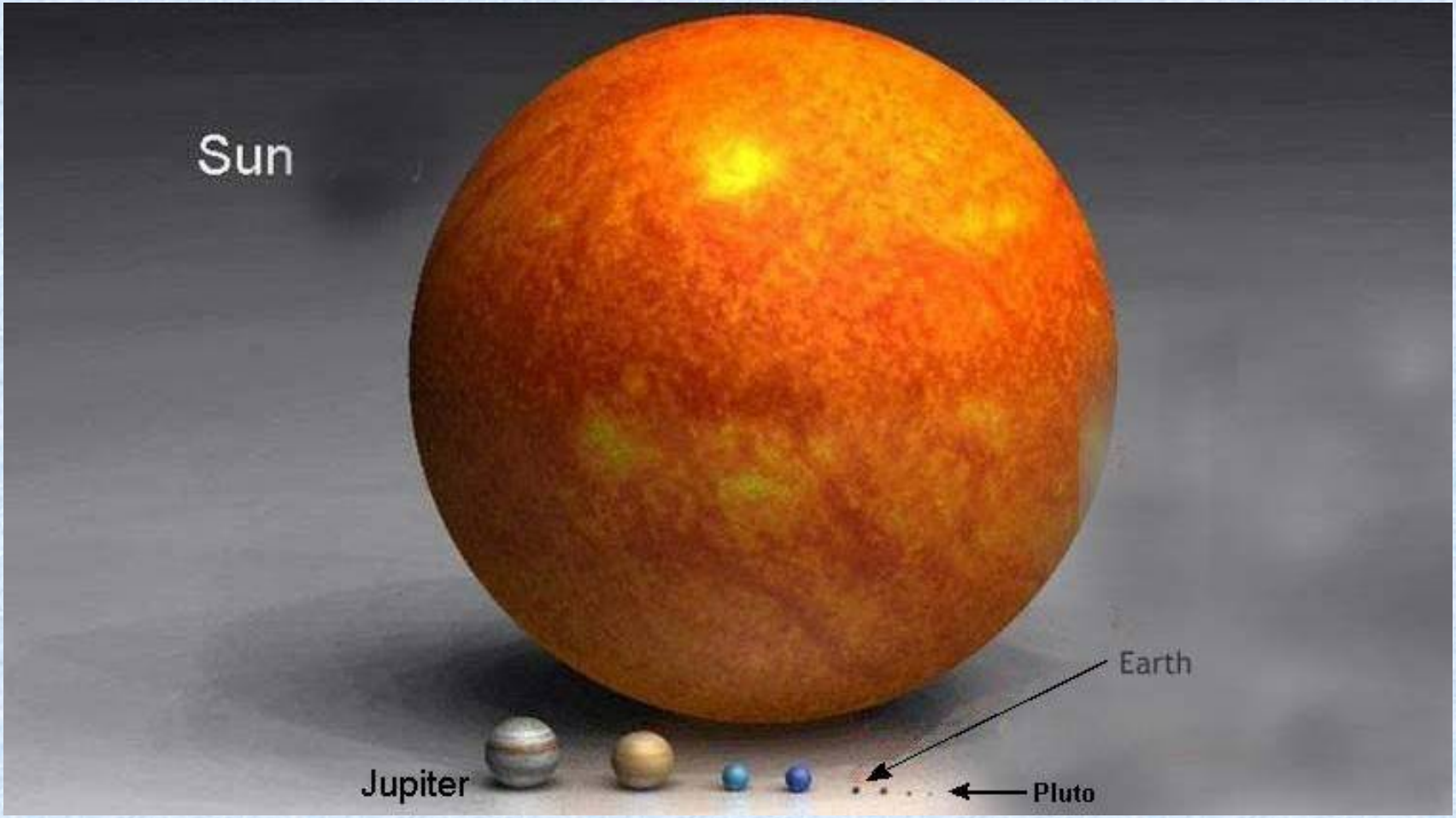
E. Both C and D are correct

The Big Picture



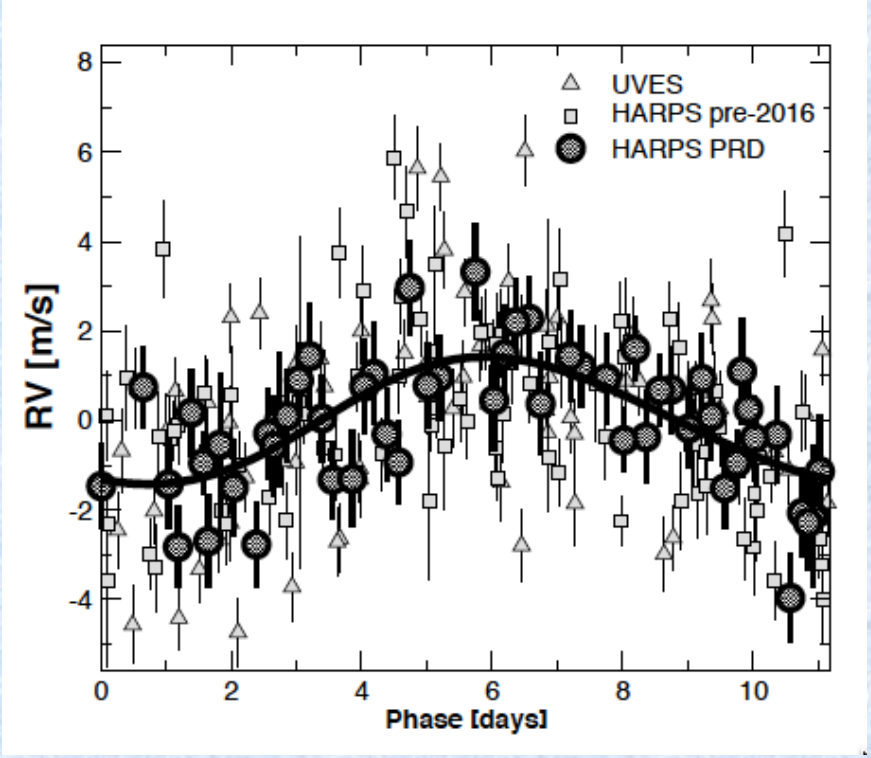
1.28×10^4 km

Our solar system

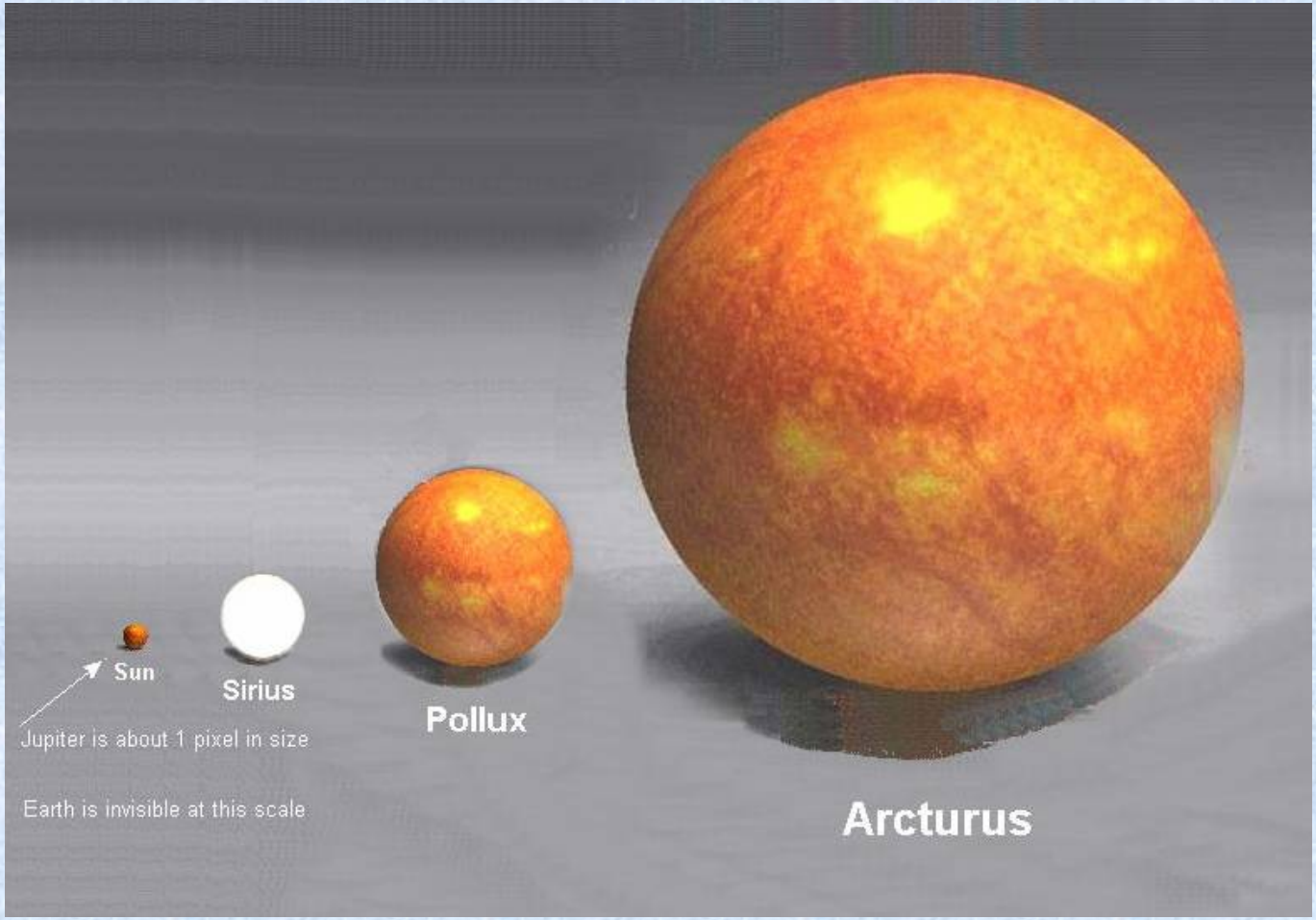


Do the nearest stars have planets?

- Proxima Centauri is the nearest member of the triple star system that includes Alpha Centrauri A and Alpha Centauri B.

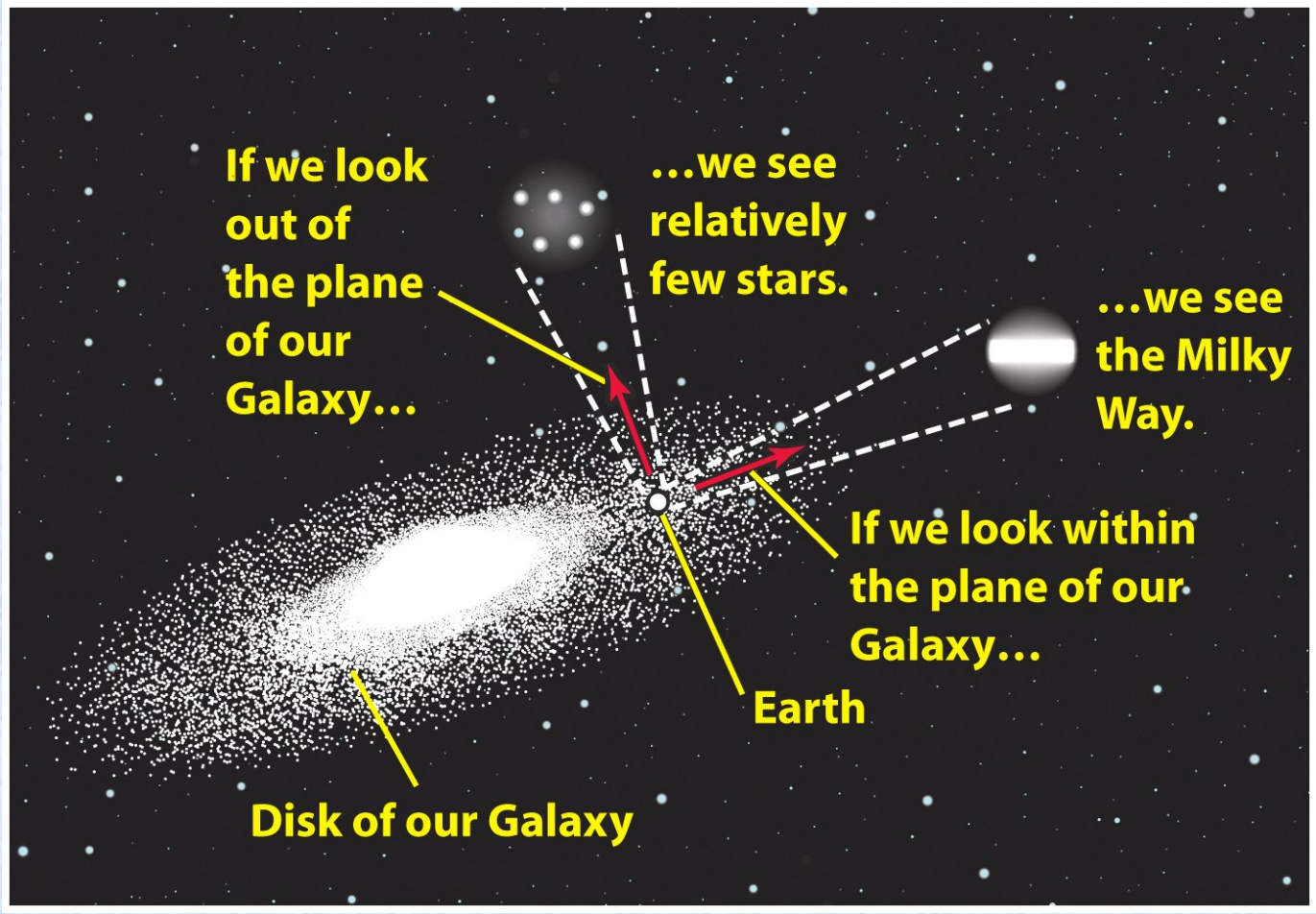


Many Types of Stars



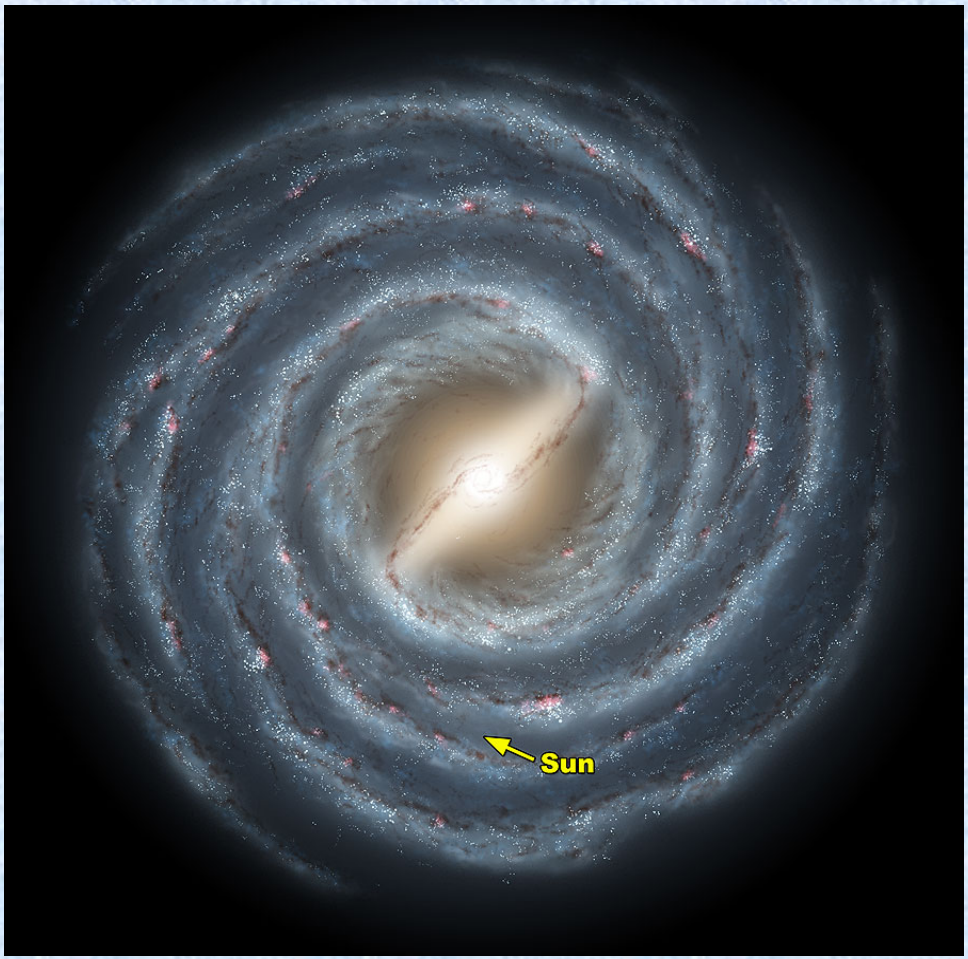
Our galaxy. What is it?

Our Milky Way



Where are we in our Galaxy?

- Somewhat in the outskirts…
- 25,000 ly away from the center
- Moving at about 200 km/s around the center of the Milky Way
- TRUMPLER's (1930) discovery of dust



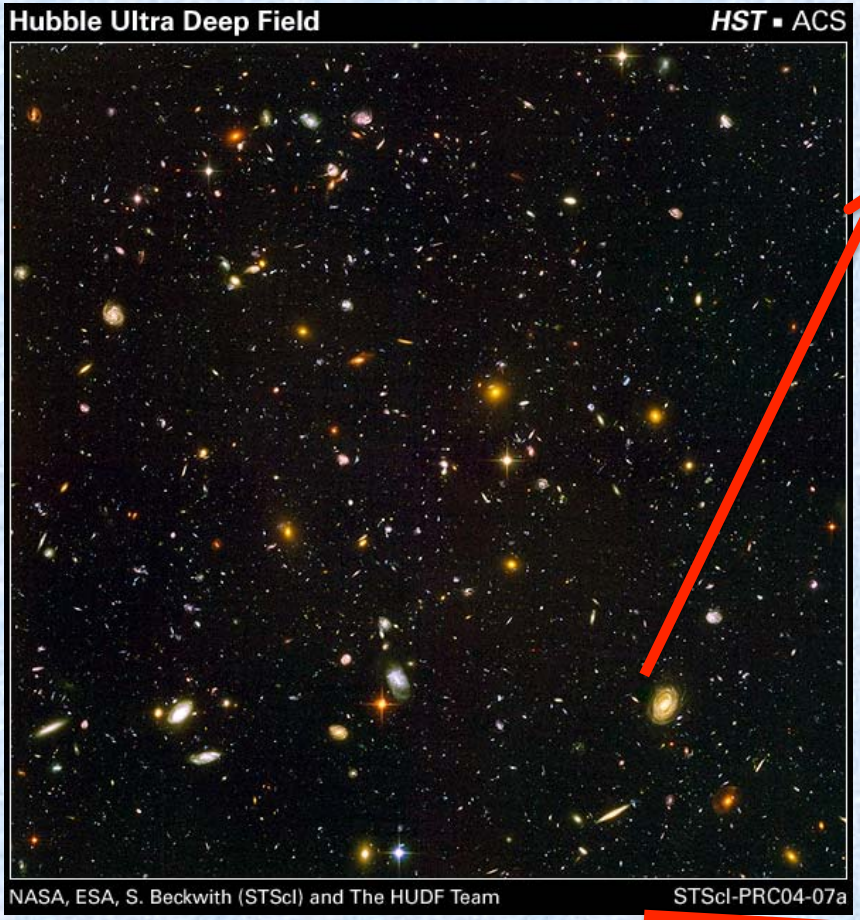
External Galaxies

What are they? How far are they? How big are they?

What are galaxies?

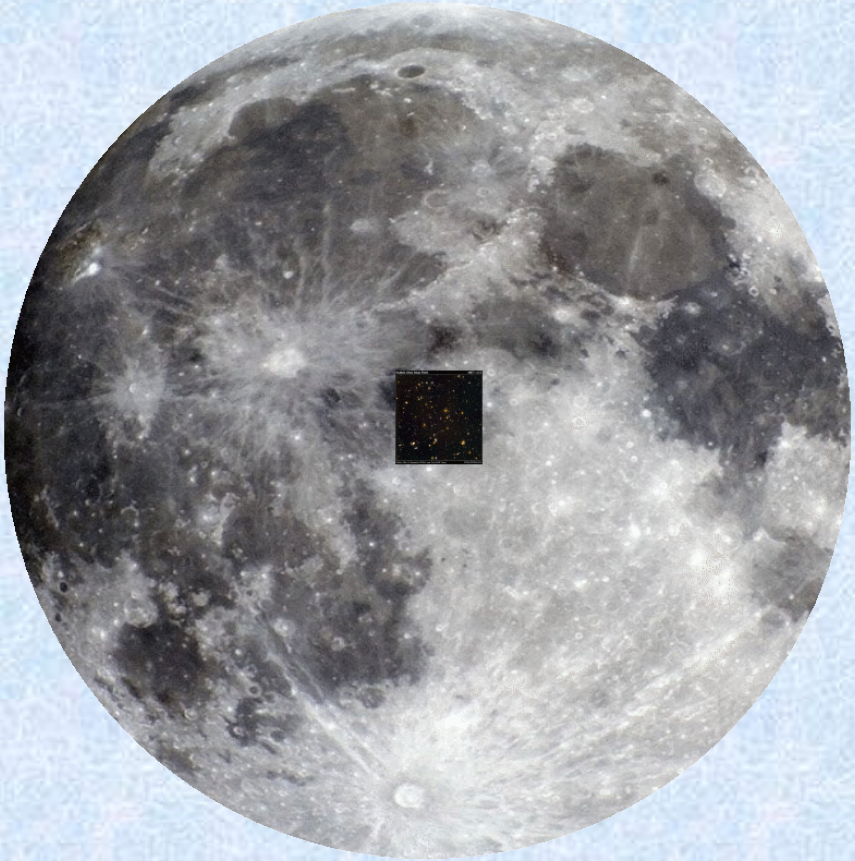
- Until 1923 there was a debate on the distance of "nebulae" (galaxies)
- Are they small objects inside our galaxy or are they "external"?
- Hubble settled this by measuring the distance to Andromeda
  - A whopping 2.5 million light years!

The Universe is full of galaxies!



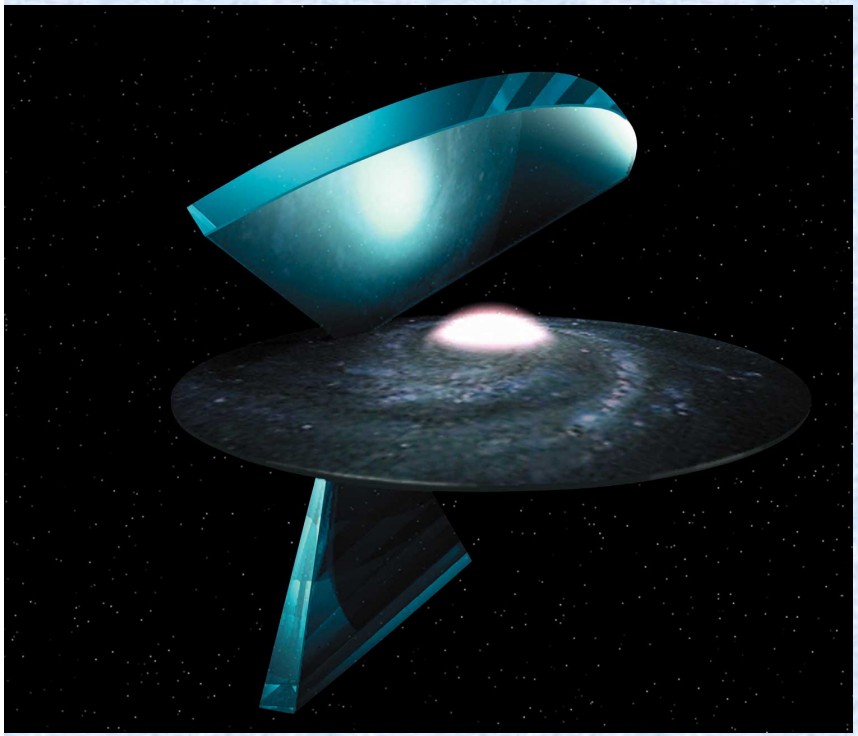
10,000 galaxies in a tiny piece of sky! 1/150,000 of the sky

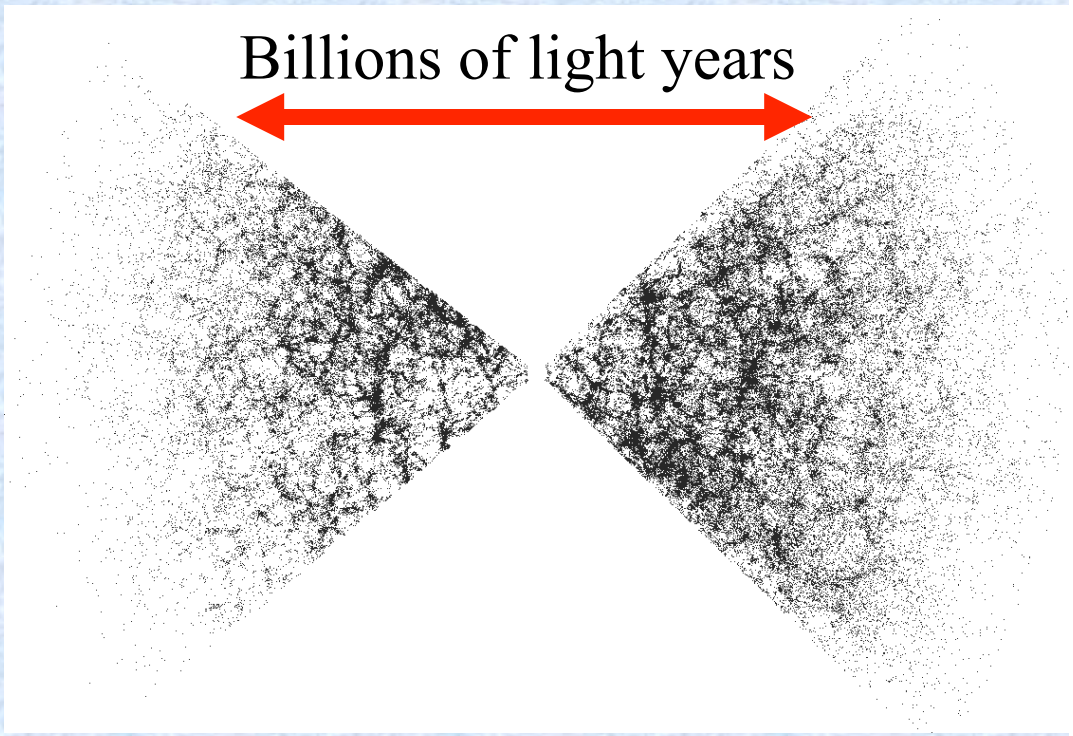
How many galaxies?



Based on the deep fields we estimate of order a billion visible galaxies

Large scale structures





SDSS and 2dF mapped the positions of about 1,000,000 galaxies

iclicker Question

eso1629 — Science Release

SPACE SCOOL

Planet Found in Habitable Zone Around Nearest Star

Pale Red Dot campaign reveals Earth-mass world in orbit around Proxima Centauri

24 August 2016

The scientific method requires which of the following actions?

A. No action is required because this fact has been reported in a peer-reviewed journal.

B. Astronomers not involved in the original study need to confirm the measurement.

C. Other interpretations, such as variability of the star, need to be investigated and disproven.

D. Other methods of the detecting the planet (such as direct imaging) should be pursued.

E. Actions B, C, and D will all strengthen the claim.

Iclicker Answer

eso1629 — Science Release

SPACE SCI

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Summary

- What is science?
  - Falsification: scientific theories are testable.
  - Repeatable: different people agree on measurements
- The big picture
  - The Universe is huge and awesome and we will make a "Grand Tour"
- Learning scientific language
  - Science terms have very precise definitions, with sometimes somewhat different meaning than in the current language

HW #1 – Due Friday 10/04/2019

- On your own: answer all the review questions in chapter 1.
- Turn in answers to U11 − 1.19, 1.31, 1.38, 1.47.
- Use box with your TA name and section number in 1610 lobby.
  - This notation means problems 19, 31, 38, and 47 at the end of chapter 1 in Universe **11th edition**.
  - Reinforce concepts we discussed today.
  - Practice using scientific notation on your calculator.
  - Advice:
    1) What quantity are you trying to find?
    2) Estimate an answer
    3) Identify the tools you need to solve the problem
    4) Do the calculation
    5) Review your result. Does it make sense?

Astronomy 1

SYLLABUS

Fall 2019

This course introduces the students to the basic concepts of modern astronomy. The main focus of the course will be on the scientific foundations of astronomy (physics and the scientific method), our understanding of the basic physical mechanisms at work in the solar system, stars, and galaxies..

LECTURES: MW 2:00 - 3:15; BROIDA 1610

LECTURE SCHEDULE

OFFICE HOURS AND CONTACT INFORMATION:

Prof: Crystal Martin	W 11:00-11:50 and by appointment on Mondays	Broida 2015-D	cmartin@ucsb.edu
TA: Connor FitzGerald	(6 hours per week)	PSR	ctfitzgerald@ucsb.edu
TA: Tin Long Sunny Wong	M 6-8pm, T 5:30-8	PSR	tinlongsunny@ucsb.edu
TA: James Bird	M 1-2, W 1-2, F 1-2	PSR	james_bird@ucsb.edu

Lecture notes and homework assignments can be found on the website.

Your Professor and your Teaching Assistants (TAs) want to help!

Course Material:

This Syllabus: http://web.physics.ucsb.edu/~astro1/f2019/
Universe, 11th edition, by Geller, Freedman & Kaufmann III
iClicker II

Grading:

15% class participation (Pre-test, iClicker, Discussion Sections)
20% homework (click here for a list of homework assignments) and discussion sections attendance and participation
25% midterm
40% final

Pre-test on Wednesday October 2nd counts as 'participation.'

Attendance at **Discussion Sections** is required.

Discussion Sections:

Time (Place)	Notes/Instructor
W 12:00-12:50pm (GIRV 1119)	Bird
W 1:00-1:50pm (GIRV 1119)	FitzGerald
W 4:00-4:50pm (GIRV 1115)	Wong
F 12:00-12:50pm (GIRV 1119)	Bird
F 1:00-1:50am (ARTS 1349)	Wong
F 3:00-3:50pm (GIRV 1112)	FitzGerald

iClickers

- I will use iclickers to assign points for class participation
  - You earn points by selecting an answer; it does not matter if you give the correct answer!
  - Available from bookstore
  - Register online at ***https://www1.iclicker.com/register-clicker/***