





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**ASTRONOMY**  
Chapter 1 SCIENCE AND THE UNIVERSE: A BRIEF TOUR  
PowerPoint Image Slideshow

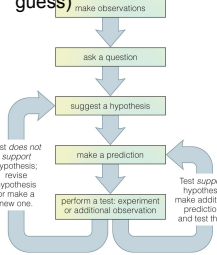



**1.1 NATURE OF ASTRONOMY,**

- ▶ **Astronomy**
  - ▶ The study of the objects that lie beyond our planet Earth and the processes by which these objects interact.
- ▶ **Why study astronomy**
  - ▶ Curiosity of our place in the cosmos.



**1.2 LAWS OF SCIENCE**

- ▶ **Hypothesis (educated guess)**


- ▶ **Scientific method**
  - ▶ Based on proposing and testing hypotheses.
- ▶ **Scientific theory**
  - ▶ A model that explains a wide variety of observations in terms of a few general principles and that has survived repeated and varied testing

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**1.3 NATURE OF NATURE**

- ▶ The consistency of the laws of nature gives us enormous power to understand distant objects without traveling to them and that is why astronomy is considered an observational science.
- ▶ **Axioms of science**
  - ▶ There is no absolute truth
  - ▶ All things being equal the simpler explanation is better


**Hallmarks of Science**

- ▶ Modern science seeks explanations for observed phenomena that rely solely on natural causes.  
(A scientific model cannot include divine intervention.)
- ▶ Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.  
(Simplicity = "Occam's razor")
- ▶ A scientific model must make testable predictions about natural phenomena that would force us to revise or abandon the model if the predictions do not agree with observations.  
(There is no absolute truth)

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### 1.4 NUMBERS AND VOCABULARY IN ASTRONOMY

- ▶ 1mi = 1.6 km
- ▶ 1km = 1000m
- ▶ 1m = 1 large step

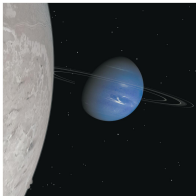


Earth is about 8000 miles across

d = 13000 km or  $13 \times 10^3$  km  
c = 40000 km or  $4 \times 10^4$  km

▶

### Planet



Neptune 50,000 km across

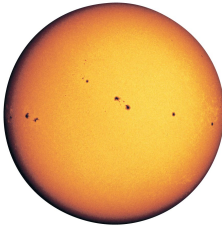
- ▶ 3 conditions (2006)
  - ▶ Orbits a star
  - ▶ Large enough for it's own gravity to make it round
  - ▶ Cleared most objects from orbital path

▶ A moderately large object that orbits a star

▶

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### Star



- ▶ Our sun is a star
  - ▶ 1 million km across
- ▶ Betelgeuse is a super giant star 1.6 billion km across
  - ▶  $1.6 \times 10^9$  km


▶ A large, glowing ball of gas that generates heat and light

▶

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### Moon (or Satellite)

- ▶ An object that orbits a planet
  - ▶ Ganymede is 5300 km across
  - ▶ Our moon is 3500 km across




Ganymede (orbits Jupiter)

▶

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### Asteroid

▶ A relatively small and rocky object that orbits a star

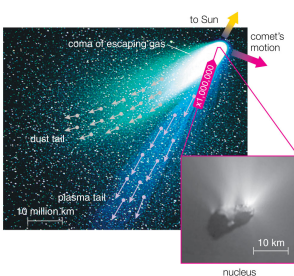


Eros: 33 km across      Ceres: 940 km across

▶

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### Comet



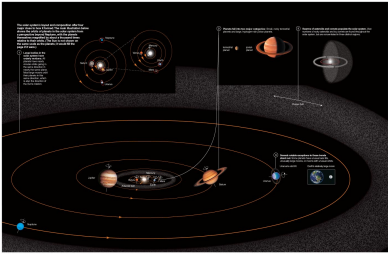
▶ A relatively small and icy object that orbits a star

Average comet nucleus is less than 10km across

▶

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### Solar (Star) System




- ▶ A star and all the material that orbits it.
- ▶ 285 billion km wide ~  $285 \times 10^9$  km

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### Galaxy

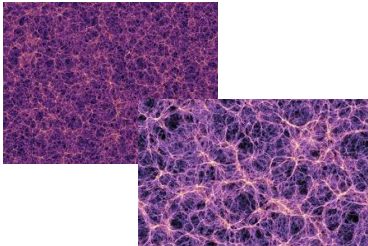
- ▶ A great island of stars in space, orbiting a common center
- ▶ Galaxies contain a million to a trillion stars
- ▶ Our galaxy the Milky Way contains over 100 billion stars
- ▶  $9.5 \times 10^{17}$  km wide



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### Universe

- ▶ The sum total of all matter and energy

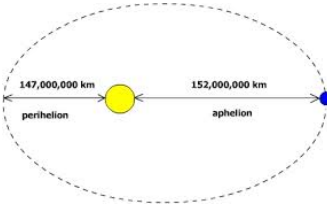


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### Astronomical Distance Measurements

AU

- ▶ The Earth is 1 AU (Astronomical Unit) from the sun
- ▶ 150 million km or 93 million miles



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### Light-year

- ▶ The distance light can travel in 1 year

$$1 \text{ light-year} = (\text{speed of light}) \times (1 \text{ year})$$

$$= \left( 300,000 \frac{\text{km}}{\text{s}} \right) \times \left( \frac{365 \text{ days}}{1 \text{ yr}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{60 \text{ s}}{1 \text{ min}} \right)$$

- ▶ About 10 trillion kilometers (6 trillion miles)

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### 1.5 CONSEQUENCE OF LIGHT TRAVEL TIME

- ▶ Light travels at a finite speed 300,000 km/s (or 187,000 miles per second)


***This is "fast" you could circle the Earth 8 times in one second.***

| Destination                          | Light travel time |
|--------------------------------------|-------------------|
| Moon                                 | 1 second          |
| Sun                                  | 8 minutes         |
| Alpha Centauri (closest star system) | 4 years           |
| Andromeda Galaxy (closest galaxy)    | 2.5 million years |

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### Looking back in time

- ▶ Light takes time to travel the vast distances in space. When we look deep into space, we see objects as they were when the light source left them:





**The farther away we look in distance, the further back we look in time.**

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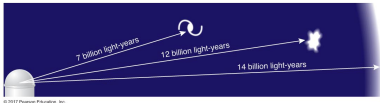
### far away means back in time

- ▶ This photo shows our closest neighbor the Andromeda Galaxy as it looked about 2½ million years ago.

- ▶ **Question: When will we be able to see what it looks like now?**

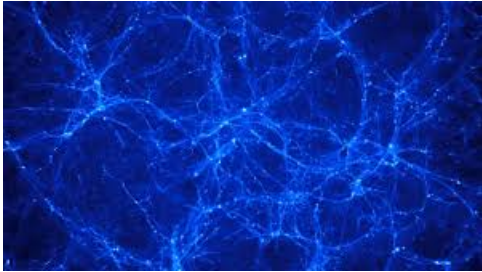
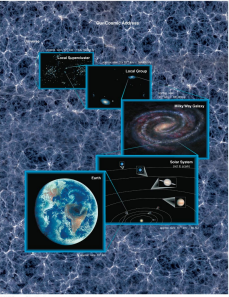
### The Observable Universe



- ▶ The universe is 14 billion years old ← Time
- ▶ We cannot observe light further than 14 billion light-years ← Distance

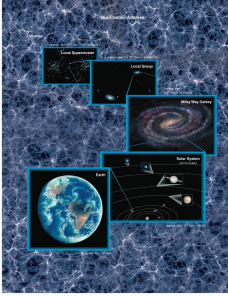
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### 1.6 A TOUR OF THE UNIVERSE?

- ▶ **Planet**
  - ▶ We live on planet Earth
- ▶ **Solar (Star) System**
  - ▶ Our solar system's star is the Sun
- ▶ **Galaxy**
  - ▶ Our galaxy the Milky Way contains over 100 billion stars


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- ▶ **Galaxy Cluster (Group)**
  - ▶ Local Group contains 40 galaxies
- ▶ **Super Cluster**
  - ▶ Clusters of galaxy clusters arranged in chains with huge voids between them
- ▶ **Universe**
  - ▶ Contains billions of galaxies


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▶ **Humanity's Home Base (Fig 1.6).** This image shows the Western hemisphere as viewed from space 35,400 kilometers (about 22,000 miles) above Earth. Data about the land surface from one satellite was combined with another satellite's data about the clouds to create the image.

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▶ **Earth and Moon, Drawn to Scale (Fig 1.7).** This image shows Earth and the Moon shown to scale for both size and distance.


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▶ **Our Solar Family (Fig 1.8).** The Sun, the planets, and some dwarf planets are shown with their sizes drawn to scale. The orbits of the planets are much more widely separated than shown in this drawing. Notice the size of Earth compared to the giant planets. (credit: modification of work by NASA)

▶ **Alpha Centauri**

- ▶ Our closest neighboring star.
- ▶ It is a triple star system
- ▶ 4.4 light years away




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▶ **Orion Nebula (Fig 1.4).** This beautiful cloud of cosmic raw material (gas and dust from which new stars and planets are being made) called the Orion Nebula is about 1400 light-years away. That's a distance of roughly  $1.34 \times 10^{16}$  kilometers—a pretty big number. The gas and dust in this region are illuminated by the intense light from a few extremely energetic adolescent stars.

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▶ **Star Cluster (Fig 1.11).** This large star cluster is known by its catalog number, M9. It contains some 250,000 stars and is seen more clearly from space using the Hubble Space Telescope. It is located roughly 25,000 light-years away.

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▶ **Spiral Galaxy (Fig 1.9).** This galaxy of billions of stars, called by its catalog number NGC 1073, is thought to be similar to our own Milky Way Galaxy. Here we see the giant wheel-shaped system with a bar of stars across its middle.

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▶ **Closest Spiral Galaxy (Fig 1.13).** The Andromeda galaxy (M31) is a spiral-shaped collection of stars similar to our own Milky Way.

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▶ **Fornax Cluster of Galaxies (Fig 1.14).** In this image, you can see part of a cluster of galaxies located about 60 million light-years away in the constellation of Fornax. All the objects that are not pinpoints of light in the picture are galaxies of billions of stars.

**Thought Question**

Suppose you tried to count the more than 100 billion stars in our galaxy, at a rate of one per second...

How long would it take you?

- A. a few weeks
- B. a few months
- C. a few years
- D. a few thousand years

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**Are there an infinite number of stars in the universe?**

▶ **Olbers' Paradox**

If the universe were

1. infinite
2. unchanging
3. everywhere the same

then stars would cover the night sky.

▶

**Why isn't the night sky bright?**

The night sky is dark because the universe changes with time.

As we look out in space, we can look back to a time when there were no stars.

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### How many stars are there in the universe?



- ▶ The Milky Way is one of about 100 billion galaxies.
- ▶ There are about 100 billion stars in each galaxy

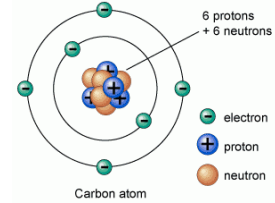
$$10^{11} \text{ stars} \times 10^{11} \text{ galaxies} = 10^{22}$$

$$10\,000\,000\,000\,000\,000\,000\,000$$

**There are as many stars as grains of (dry) sand on all Earth's beaches**

### 1.8 THE UNIVERSE OF THE VERY SMALL

- ▶ The air we breathe has about  $10^{19}$  atoms in each cubic centimeter.



- ▶ [VIDEO: Universe large to small \(8 min\)](#)

### 1.9 A CONCLUSION AND A BEGINNING



| December |    |    |    |    |    |    |
|----------|----|----|----|----|----|----|
| 1        | 2  | 3  | 4  | 5  | 6  | 7  |
| 8        | 9  | 10 | 11 | 12 | 13 | 14 |
| 15       | 16 | 17 | 18 | 19 | 20 | 21 |
| 22       | 23 | 24 | 25 | 26 | 27 | 28 |
| 29       | 30 | 31 |    |    |    |    |

- ▶ **Charting Cosmic Time (Fig 1.15).** On a cosmic calendar, where the time since the Big Bang is compressed into 1 year, creatures we would call human do not emerge on the scene until the evening of December 31.

### Cosmic calendar

| Date            | Event                 |
|-----------------|-----------------------|
| Jan 1           | The Big Bang          |
| Feb             | Milky Way forms       |
| Sept 3          | Earth forms           |
| Dec 26          | Rise of the dinosaurs |
| Dec 31(9pm)     | Early hominids        |
| Dec 31(11:58pm) | Modern humans evolve  |
| 11 seconds ago  | Pyramids built        |
| .05 second ago  | You were born         |

#### Links

- ▶ [VIDEO: Universe large to small \(8 min\)](#)

#### Reading

- ▶ 1.1
- ▶ 1.2
- ▶ 1.3
- ▶ 1.4
- ▶ 1.5
- ▶ 1.6
- ▶ 1.7
- ▶ 1.8
- ▶ 1.9

### What is our place in the universe?

Earth is part of a star system, which is in the Milky Way Galaxy consisting of 100 billion stars, which is a member of the Local Group of galaxies in the Local Super cluster, which reside in the Universe containing 100 billion other galaxies.

Some people think that our tiny physical size in the vast universe makes us insignificant.

Others think our ability to learn about the wonders of the universe gives us significance despite our small size.

**What do you think?**