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Universe

Tenth Edition

Chapter 1

Astronomy and the Universe

By reading this chapter, you will learn

- **1-1:** What distinguishes the methods of science from other human activities
- **1-2:** ~~How exploring other planets provides insight into the origins of the solar system and the nature of our Earth~~
- **1-3:** Stars have a life cycle—they form, evolve over millions or billions of years, and die
- **1-4:** Stars are grouped into galaxies, which are found throughout the universe
- **1-5:** How astronomers measure the positions and sizes of celestial objects
- **1-6:** How to express very large or very small numbers in convenient notation
- **1-7:** Why astronomers use different units to measure distances in space
- **1-8:** ~~What astronomy can tell us about our place in the universe~~

1-1: To understand the universe, astronomers use laws of physics to construct testable theories and models

Model/Theory

- A model performs like what it represents, but might not look like what it represents.
- A theory is *not* an educated guess!
- Theories describe the mechanism or process behind a series of facts, not whether the facts are true.
- Theories can never prove if something is true, only if something is false.

It's a Big Universe Out There

- We are at the center of the Universe, and there is no center of the Universe.
- By the end of the course you will understand why.

1-3: By studying stars and nebulae, astronomers discover how stars are born, grow old and die

Stars like Grains of Sand

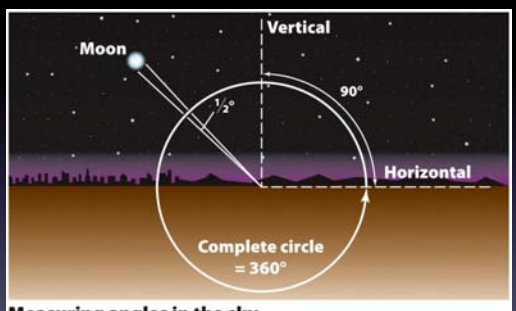
The Orion Nebula – Birthplace of Stars

The Crab Nebula – Wreckage of an Exploded Star

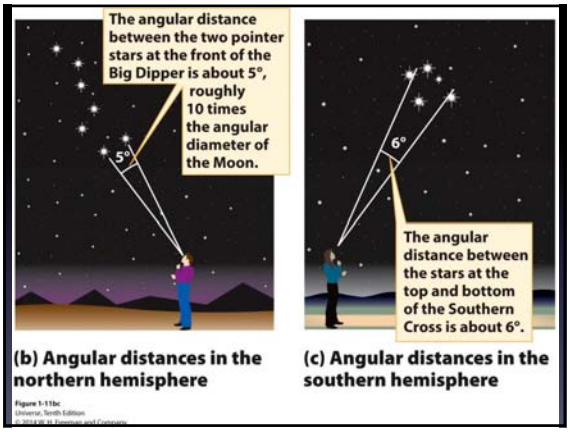
1-4: By observing galaxies, astronomers learn about the origin and fate of the universe

A Galaxy

1-5: Astronomers use angles to denote the positions and apparent sizes of objects in the sky



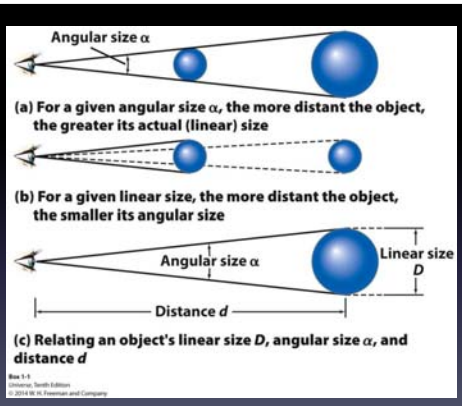
Measuring angles in the sky



(b) Angular distances in the northern hemisphere

(c) Angular distances in the southern hemisphere

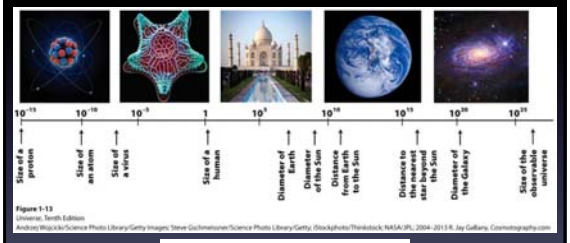
Estimating Angles with Your Hand



Big Numbers

- Before we can talk about time and space in quantified terms, we have to get past big numbers.
- Scientific Notation is both a method of denoting numbers and a way of looking at things.
- To understand Scientific Notation, you merely have to be able to count by tens.

1-6: Powers-of-ten notation is a useful shorthand system for writing numbers



Examples of Powers-of-Ten Notation

Characteristic

- If someone gave you ten $10 bills you would have 10X10 dollars or $100.
- A convenient way of writing 10X10 is 10^2. We say ten to the second power.
- If someone gave you ten $100 bills you would have 10 X 10X10 or 10^3 dollars.

- If someone gave you ten $20 bills you'd have 2 X 10X10 dollars, or $2X10^2$.
- You'd say "two times ten to the second." You could say "two hundred", but words will fail you if you try to say $4X10^{26}$.
  - Realize that some calculators display 4E26; it means the same as $4X10^{26}$.

Samples:

- US population: $3X10^8$
- World population: $6X10^9$
- 2012-2013 US federal budget: $\$4X10^{12}$
- Global Domestic Product (2011): $\$8X10^{13}$
  - Remember, the 3, 6, 4, and 8 are less important than the 8, 9, 12, and 13

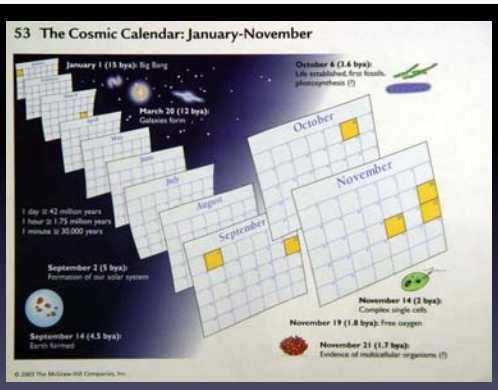
- Let's get a feel for number words:
  - 10^9 (a billion) seconds ago was 1976
  - 10^9 minutes ago was 100 AD
  - 10^9 hours ago was 112,000 BC
  - 10^9 days ago was 3 million BC
  - 10^9 years ago, the Earth had already been around for 3 ½ billion years, and the Universe had existed for almost 13 billion years.

BTW…

- $1X10^9$ dollars ago was less than 2½ hours ago in Congress.
  - $120,000 every second!
  - http://www.famousbirthdays.com/
  - Billion.xls

Cosmic Calendar

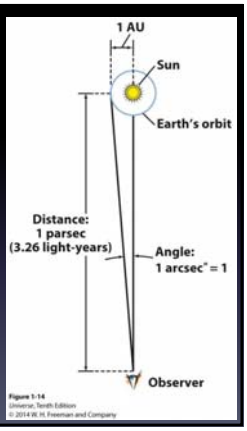
- Geologists have a term for very long spans of time: they call it *Deep Time*.
- Whenever you read about an outrageous process or event in this course and wonder how can this be, remember: the cosmological time scale is far, far longer* than human references. It is truly *Deep Time*.
  - *With one or two very important exceptions!



Logarithms

- Log, for short.
- Often used to squeeze a wide range of numbers onto a graph
- Log 10 = 1, Log 100 = 2, Log 1000 = 3 (get the pattern?)
  - Log 50? Between 1 and 2 (~1.7)
  - Log 900? Between 2 and 3, but closer to 3 (~2.95)

1-7: Astronomical distances are often measured in astronomical units, light-years or parsecs



Centimeters and Parsecs

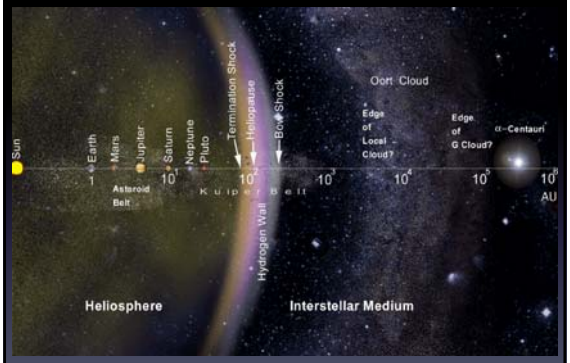
- When measuring anything, it is convenient to use units that correspond to the measured value without always resorting to huge or tiny numbers.
- Centimeters are fine when measuring your height, but lame when describing the distance to Las Vegas
  - BTW, that would be 44,256,960 cm!

Mostly Humongous

- With the exception of the atomic particles we will be discussing, everything about space is notoriously BIG.
- Therefore, kilometers will do only for nearby objects like the Moon: we need bigger distant units.

Hey You!

- When measuring distances in the Solar System, the AU, or Astronomical Unit, is the preferred measuring stick.
- 1AU = $1.5X10^{11}$ meters, the distance from the Earth to the Sun.
- The distance to Pluto, the once and future planet, is about 40 AU.
  - The next slide neatly wraps up AU, Scientific Notation, and Logs



Flash! IBEX space telescope fails to find bow shock!

Still too small

- But this is the Stars and Galaxies course!
- 1AU will quickly become too small to use, worse than centimeters to Las Vegas.

c

- It's time you are acquainted with the cosmic speed limit, "c".
- "c" is the speed of light in a vacuum, like space, the famous c in $E = mc^2$.
- Light travels at 300,000 km/second, which is about 670 million mph.
- Nothing goes faster than "c" in a vacuum.

Distance = speed X time

- If we use "c" for speed and 1 year for time, we get a distance* called the "Light Year" (LY).
- 1 LY is about 10^{16} meters, or 6 trillion miles.
- The second nearest star is 4.3 LY away.
  - (What star is nearer?)

*not a time!

Time and Space

- Critical to your understanding is the fact that, the farther away in distance we look, the further back in time we are seeing.
- It's like having the worst seats at a concert: every note emanating from the stage reaches you seconds after it was played.

A Time Machine

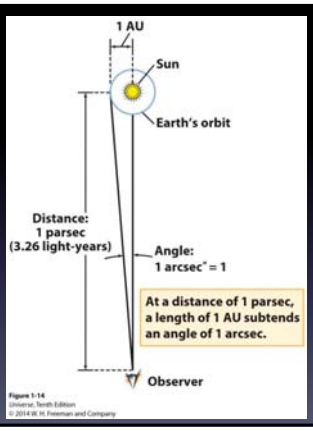
- When you look at a star 4.3 LY away, you are looking at it as it was 4.3 years ago.
- When you look at the Moon, you are seeing it as it was 1.5 seconds ago.
  - Its distance could be called 1.5 *light-seconds*
- When you look at the most distant reaches of the Universe, you are seeing it as it was ~10^{10} years ago!

Another Way to Measure Distance

- If you brought it to class, take out a thumb and hold it out in front at arm's length.
- Blink one eye and then the other. See how your thumb appears to move while something further away seems stationary?

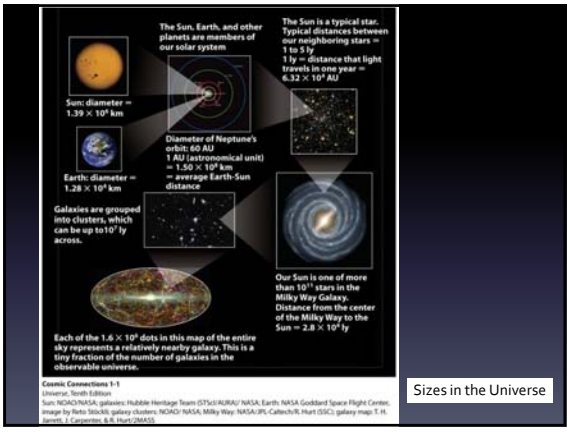
Parallax

- This is called *parallax*, and it offers another way to measure distance.
- Without going into the math, if you can measure the distance between your eyes, you can tell far distances by the angle at your thumb.



Prefixes

- Rather than say a billion years or a million parsecs, we use the prefixes mega- and giga-.
  - A billion years will be a Gigayear, or Gyr.
- A million parsecs will be a Megaparsec, or Mpc.
  - The Solar System is 5 Gyr old.
  - The distance to M31, the Andromeda Galaxy is 0.6 Mpc.



Sizes in the Universe

Key Ideas

- **Stars and Nebulae:** Studying the stars and nebulae helps us learn about the history and origin of the Sun and the solar system
- **Galaxies:** Observations of galaxies tell us about the origin and history of the universe.
- **Angular Measure:** Astronomers use angles to denote the positions and sizes of objects in the sky. The size of an angle is measured in degrees arcminutes and arcseconds.
- **Powers-of-Ten Notation:** A convenient shorthand system for writing numbers. It allows very large and very small numbers to be expressed in a compact form.
- **Units of Distance:** Astronomers use a variety of distance units. These include the astronomical unit (the average distance from the Earth to the Sun), the light-year (the distance that light travels in a year), and the parsec.