Astronomy and the Universe

- **Goals:**
  - To understand the methods scientists use to study astrophysical problems.
  - To understand how studying the stars, and galaxies tells us about how the universe was created.
  - To use angles to measure size and distance.
- **Scientific method**
  - Foundations of modern astronomy are built on the laws of physics.
  - With only one view of the universe we must assume that these laws hold <u>everywhere</u> (we cannot experiment).
  - Scientific method is built on observation, logic and skepticism.

Scientific Method

- Hypothesis vs theory
  - Common usage hypothesis = theory
  - In science theory = law.
  - Theory provides understanding of facts.
- Developing new theories
  - We rely on new tools, techniques and data.
  - We can now study objects from the x-rays through to radio waves.
  - Each probe different physical aspects
  - Combined they can provide theories for how the universe formed and evolves.

Studying the stars

- **We have only one experiment**
  - Our own Galaxy contains hundreds of billions of stars. All with different ages, compositions and histories.
  - By studying the statistical and physical properties we can learn how they form, age and die.
- **Our own sun will eventually die**
  - Hydrogen is converted to Helium releasing energy (nuclear fusion - e.g. nuclear bombs).
    - $T_{surface}$= 5500 ^{o}C (10,000 F)
    - T_{center}= 1.5x10^{6} ^{o}C
    - Diameter = 1.39x10^{6} km
  - Eventually the hydrogen will be used up and the sun will begin to die.

Observing Galaxies

- Stars are not formed in isolation
  - Grouped in galaxies
  - >100 billion stars/galaxy
  - >100s millions of galaxies
- Galaxies can be observed to great distances.
  - Most distant galaxies are at redshifts > 5 (70,000,000,000 light years away).
  - The distribution of galaxies tells us about how they were formed and how old is the Universe (15 billion years).
- Fascinating new objects
  - Quasars (quasi-stellar objects) are star-like but radiate with the energy of >100 galaxies.
  - Even more energetic sources (Gamma-ray bursters).

Angles in Astronomy

- **We cant measure linear size**
  - Stars and galaxies appear as if on the surface of a sphere.
  - Angles measure the apparent separation and sizes of objects.
- **Definitions**
  - There are 360^o (degrees) in a circle
    - 1^o = 60 arcminutes = 60’
    - 1’ = 60 arcseconds = 60’’
  - Alternatively in radians
    - $360^o = 2\pi$ radians
    - 1 radian = 57.296 degrees
- **Rules of “thumb”**
  - Size of the moon = 0.5^o
  - Tip of your thumb (arms length) 4^o
  - Ursa Major (big dipper) $\alpha - \beta = 5^o$

Small Angle Approximation

- **Example 1: Space Telescope**
  - **How far could the space telescope see a dime (1.5cm) ?**
    - **The telescope can resolve objects 0.1 arcsecs in size**

$$1.5\text{cm} = \frac{0.1\,\text{arcsec x d}}{206265}$$

distance = 3093975cm = 31 km (20 miles)

- **Example 2: Man on the moon**
  - **How big an angle would a man on the moon project.**
    - **A basketball player 2m tall.**

$$\alpha = \frac{206265\text{ x 2m}}{384{,}000{,}000\text{m}}$$

α= 0.00107 **arcsec**

    - **Much smaller than we can resolve**

- **How well does your eye resolve?**

Powers of Ten and Exponents

- **Astronomy is a subject of extremes**
  - we study the largest objects in the Universe (galaxies and clusters).
  - we study the smallest objects (atoms and X-ray wavelengths).
- **Scientific Notation**
  - Large Numbers

$$10^0 = 1 \qquad \Rightarrow 1$$
$$10^1 = 10 \qquad \Rightarrow 10$$
$$10^2 = 100 \qquad \Rightarrow 10x10$$
$$10^3 = 1000 \qquad \Rightarrow 10x10x10$$

  - Small numbers

$$10^0 = 1 \qquad \Rightarrow 1$$
$$10^{-1} = 0.1 \qquad \Rightarrow \frac{1}{10}$$
$$10^{-2} = 0.01 \qquad \Rightarrow \frac{1}{10x10}$$
$$10^{-3} = 0.001 \qquad \Rightarrow \frac{1}{10x10x10}$$

Powers of Ten and Exponents

- **Examples:**
  - Distance to the moon
    - $384{,}000{,}000\text{m} = 3.84\times10^{8}\text{m}$
  - Diameter of a hydrogen atom
    - $1.1\times10^{-10}\text{m}$
- **Arithmetic with exponents**
  - Multiplying numbers = add exponents
    - $100\times1000 = 10^{2} \times 10^{3} = 10^{5}$
  - Dividing by 10^{n} = multiplying by 10^{-n}

$$10^{-1} = \frac{1}{10}$$

$$10^{-n} = \frac{1}{10^{n}}$$

  - Exponents and numbers can be treated separately

$$\frac{1.3\text{x}10^{2} \ \text{x} \ 2.5\text{x}10^{4}}{1.4\text{x}10^{3}} = \frac{1.3\text{x}2.5}{1.4}\,\text{x}\,10^{2}\,\text{x}10^{4}\,\text{x}10^{-3}$$

$$= 2.32\text{x}10^{3}$$

Astronomical Distances

- Many units of distance, mass, time
  - Standard system is SI (Systeme International)

	S.I.	cgs	Imperial
Length	m	cm	ft
Mass	kg	gm	lb
Time	s	s	s
Temperature	K	K	F

  - T(Kelvins) = T(Celsius) + 273.15
- Combing exponents and SI
  - exponents can be included with these measures.

10^{-9} = nano = n

10^{-6} = micro = μ

10^{-3} = milli = m

10^{-2} = centi = c

10^{+3} = kilo = k

10^{+6} = mega = M

Astronomical Distances

- **New measures of distance:**
  - **Astronomers create units of distance to suit the application.**
    - **1 Astronomical Unit = Earth-Sun distance**
    - **1AU = 1.496×10^8 km = 93 million miles**
    - **Distance from Sun to Jupiter**
      5.2 AU = 7.779×10^8 km
  - **Distances to stars we calculate in light years (time it takes light to travel from point A to point B).**
    - **Light travels at 3.0×10^5 km/s (180,000 miles/hour).**
    - **1 ly = 9.46×10^{12} km = 63,240 AU**
    - **Light takes 8.3 minutes to reach us from the sun**
    - **Light Year is a measure of distance <u>NOT</u> time.**

Astronomical Distances

- **Scales of the Universe**
  - **Our Solar System**

Pittsburgh to California = 0.02 light second
Earth to Moon = 1.3 light seconds
Earth to Sun = 8.3 light minutes
Earth to Jupiter (closest approach) = 35 light minutes
Earth to Pluto = 4 light hours

  - **Distance from the Sun**

Mercury = 0.39 A.U.
Venus = 0.72 A.U.
Earth = 1.0 A.U.
Jupiter = 5.2 A.U.
Pluto = 40 A.U.

  - **Our Milky Way Galaxy**

Sun to Nearest Star (Proxima Centauri) =4.2 ly
Sun to the Distant Edge of our Galaxy = 1 x 10^5 ly
The Milky Way to most distant known quasar = 1 x 10^{10} ly

Parsecs: Another Measure

- Measuring large distances
  - Usually the distances to stars and galaxies are expressed in "parsecs"
  - Imagine looking at the sun from a distant star. The Sun would appear to be separated from the Sun by a small angle. The further away we are from the Sun the smaller the angle.
  - When the angle is 1 arcsec the distance of the star is defined to be one parsec
- The small angle approximation

$$D = \frac{\alpha\, d}{206265} \qquad \Rightarrow d = \frac{206265 \text{ x } 1\text{ AU}}{1\text{ arcsec}} = 1\text{pc}$$

$$d = 206265\text{ AU}$$

$$d = 3.09\text{x}10^{13}\text{ km} = 3.26\text{ ly}$$

  - very large distances we use kilo (10^3) and Mega (10^6) parsecs. The center of our Galaxy is 8 kpc away.