“Twinkle, twinkle, little star,
How I wonder what you are!”

What We Will Learn Today

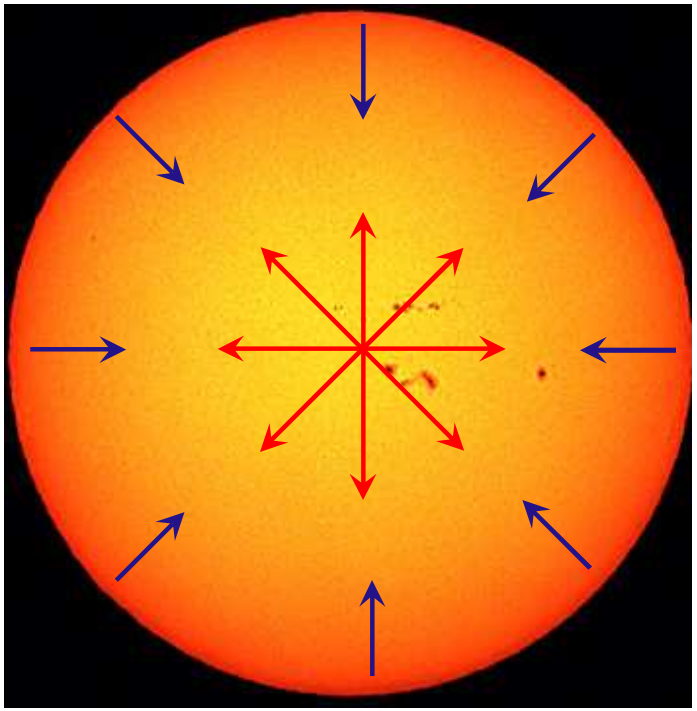
- How do stars work?
- What are the important properties of stars?
- How do we classify stars?
- How do stars evolve?

Exploration of the Solar System

- We begin our exploration with the Solar System's most influential member
- To understand what kind of a star the Sun is, let's take a look at stars in general

Stars Balance Gravity with Pressure

- Stars are massive balls of gas that shine through hydrogen fusion
  - 4 (^{1}H) → ^{4}He + energy
- A star's mass tends to pull it inwards due to gravity
- This force is balanced by pressure, which pushes outward
  - Pressure due to confinement
  - Pressure due to radiation i.e. interaction of light with matter



Why are there many types of Stars?

Mass is the most important parameter of stars

- The mass of a star determines
  - Its size (radius)
  - Its color
  - Its surface temperature
  - Its luminosity
  - Its lifetime
  - Its phases of life
  - Its method of death
- Mass and metallicity (composition) are the only fundamental properties of a star

Observed Features of Stars

- Apparent brightness
  - Brightness seen on Earth
  - Function of star's intrinsic luminosity and distance
  - Falls off as inverse square law
    - Like gravity
- Color
  - Blue is hot, Red is cool
- Parallax
  - Farther the star, smaller the parallax

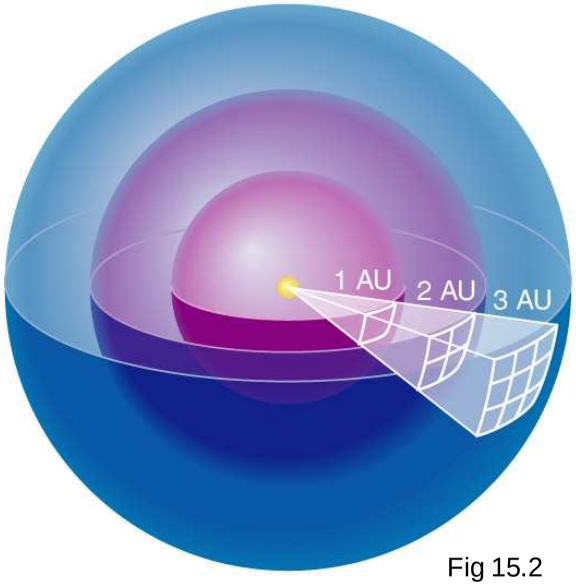


Fig 15.2

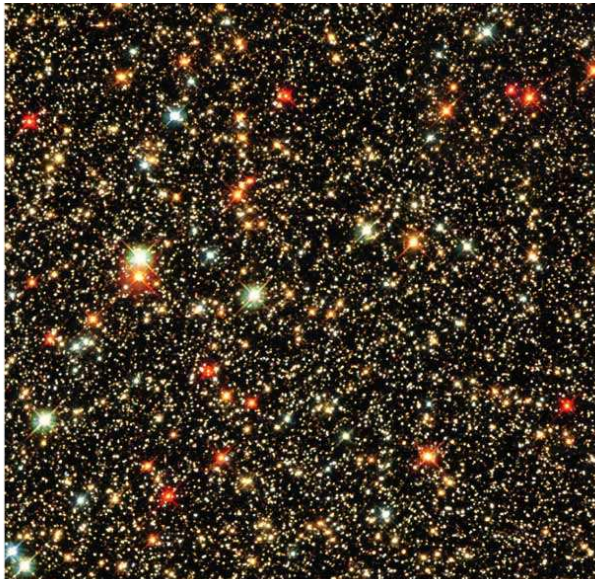


Fig 15.4

Surface Temperature and Color

A star's temperature determines

- Its color
  - Directly related to surface (photospheric) temperature
- The spectral lines observed
  - Hot stars have only Hydrogen and Helium lines
  - Cool stars have heavier elements and molecules
    - Many lines and bands

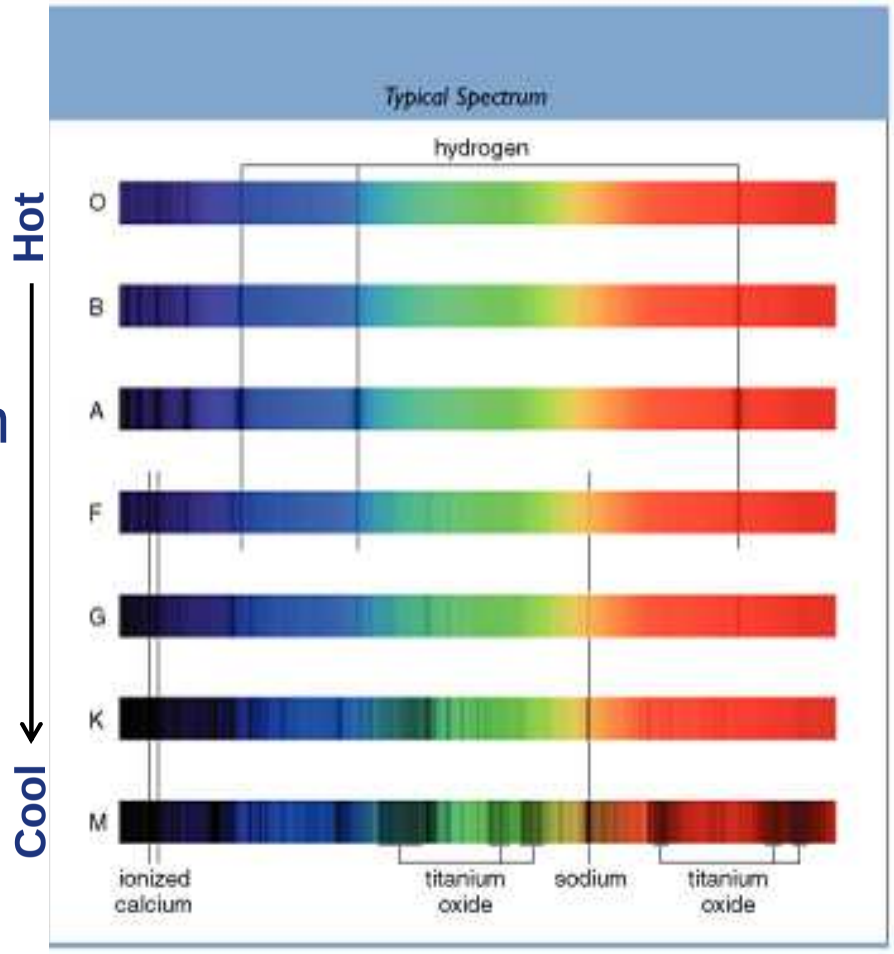


Table 15.1

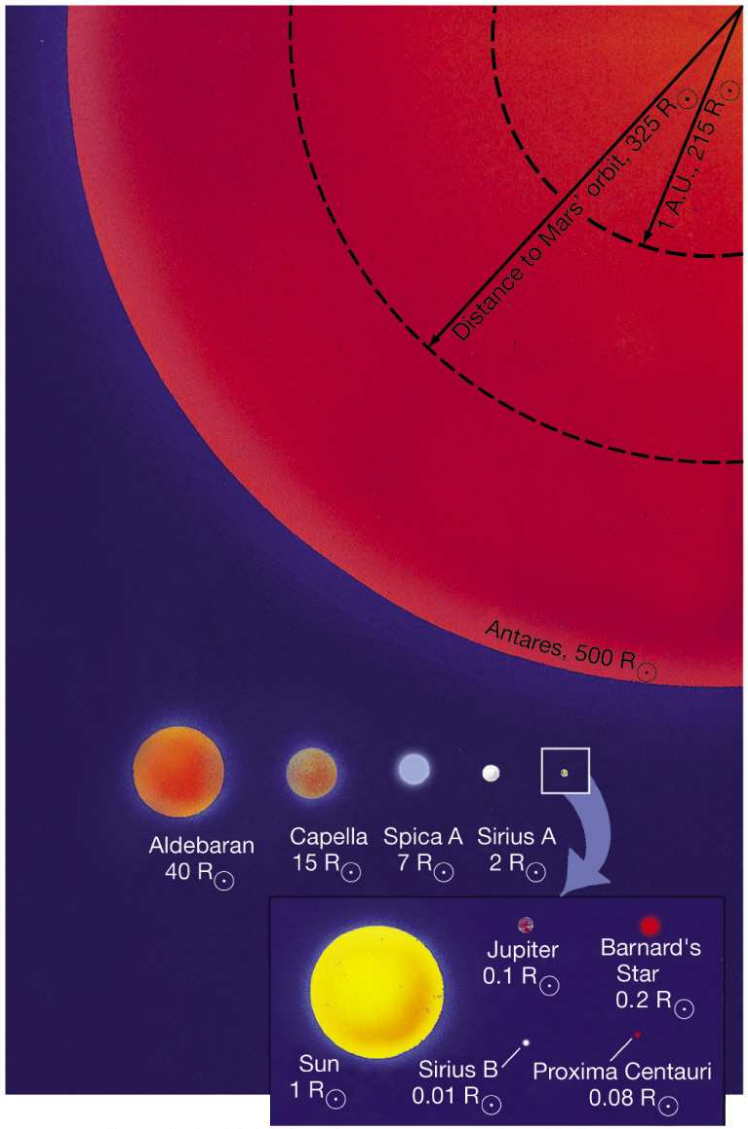
Spectral Classification

Mnemonic: "**O**h **B**e **A** **F**ine **G**uy/**G**irl, **K**iss **M**e!"

Class	Temperature (K)	Color	Example
O	30,000	blue-violet	Mintaka
B	20,000	blue	Rigel
A	10,000	white	Vega
F	7,000	yellow-white	Canopus
G	6,000	yellow	Sun
K	4,000	orange	Arcturus
M	3,000	red	Betelgeuse

Stellar Sizes

- Stars also come in a range of sizes
- The largest stars can be a hundred times larger than the Sun, while the smallest can be a hundred times smaller than the Sun



Putting It All Together

- The Hertzsprung-Russell diagram
  - Plotting temperature versus luminosity shows a clear pattern
  - Clear groups seen
    - Main sequence
    - Red Giants
    - White Dwarfs

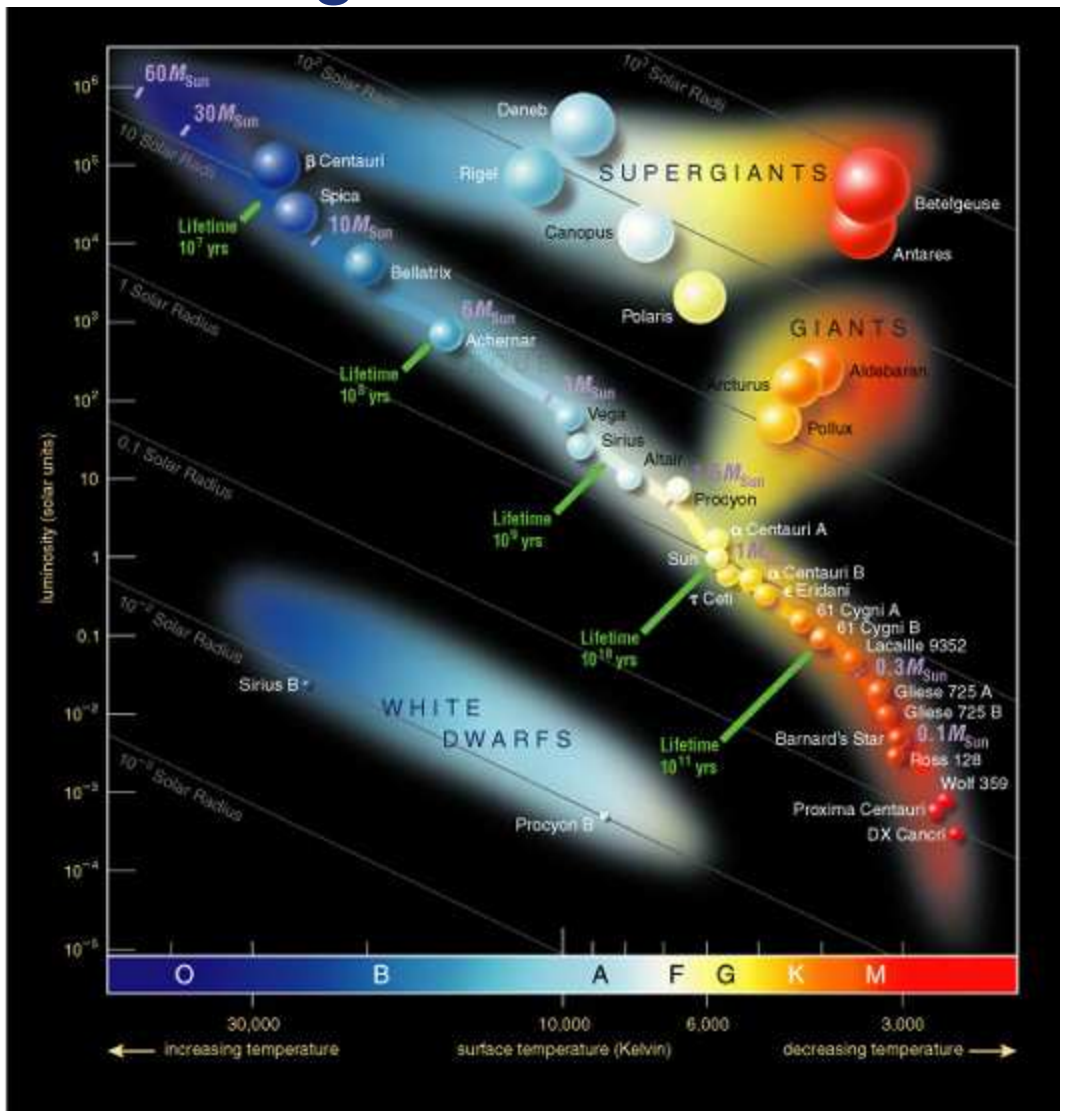
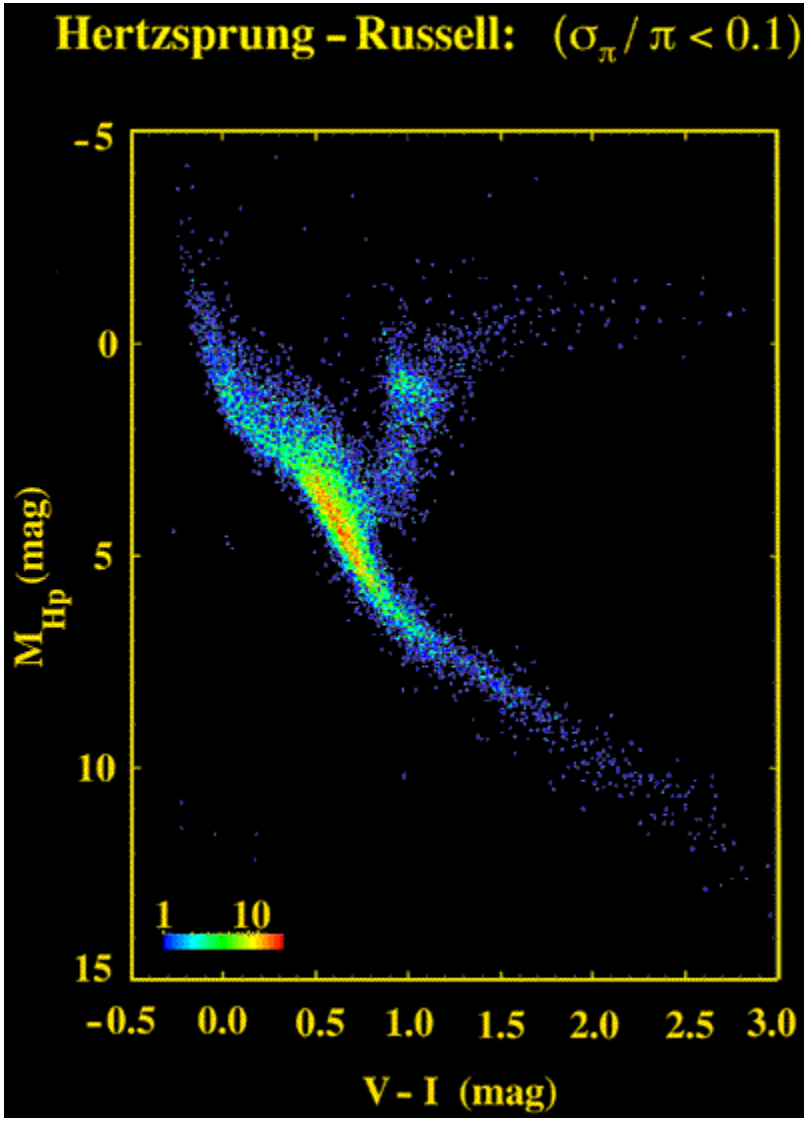


Fig 15.10

The Main Sequence

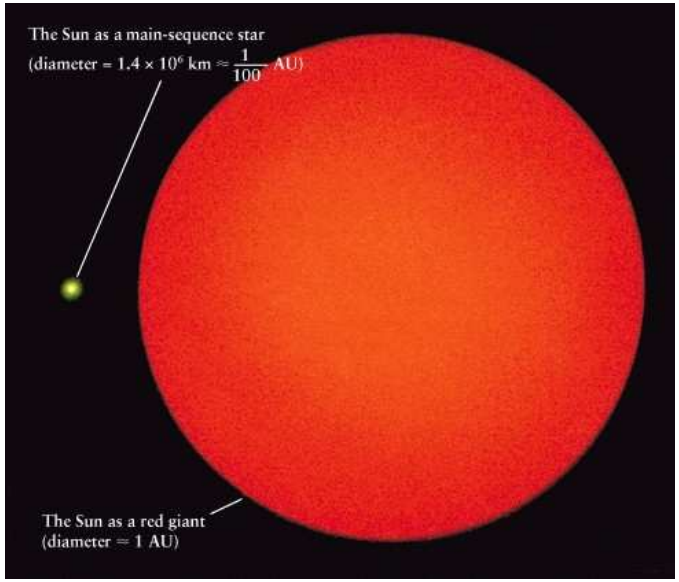
- Stars spend 90% of their lives in the main sequence (dwarf stars)
  - Fuse Hydrogen in core to Helium
  - Stable part of the star's life
  - Relatively modest change in size, temperature, and luminosity
  - A star's position in the MS is determined by its mass
    - More mass = blue star
    - Middle mass = yellow star
    - Less mass = red star



Hipparcos stars plotted in H-R Diagram

The End of Main Sequence

- Eventually, the supply of hydrogen at the center of a star runs out
- The core of the star will become a lump a helium, with a hydrogen burning shell surrounding it
- The energy supply of the star has become unstable and its outer layers begin to 'puff' out
- The star becomes a **Red Giant**
  - Red because surface expands and cools
  - Giant because it gets a lot bigger
  - Luminosity grows even with drop in temperature
- Sun will swallow Mercury & Venus!

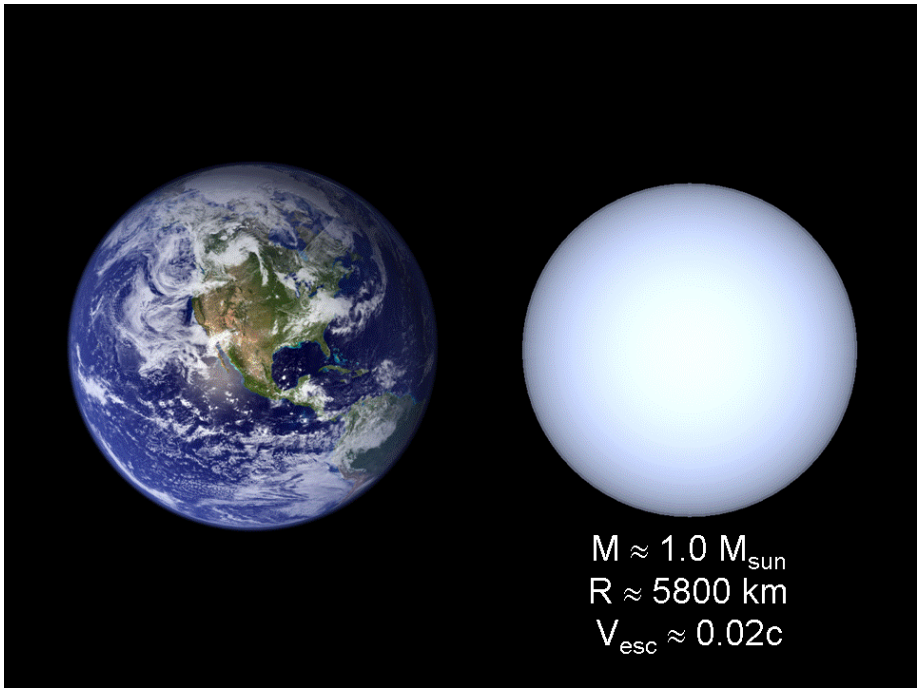


The Sun's Final Display

- Planetary Nebula
  - So called because of "disk" seen as opposed to point light of stars
  - Outer layers expand into space
  - Hot core lights them up
  - Very beautiful
  - Many seen by Hubble
  - This is our Sun's fate in about 4.5 billion years

The Sun's Resting State

- Eventually, the Sun will become a white dwarf
- White dwarfs are very dense remnants of stars
- Mass few tenths to 1.4 solar masses
- Size of the Earth
- One teaspoon would weigh a few tons!



Other Stars End Differently

- Even more interesting end!
  - Neutron stars
    - Densest objects known
    - One teaspoon weighs a *billion* tons!
    - Some of these are pulsars
  - Black holes
    - Ultimate victory of gravity
    - Collapse to infinite density
    - Even light can't escape them