I. Sun
   A. One of 200 billion stars that make up the Milky Way galaxy
   B. Only star close enough to allow the surface features to be studied
   C. An average star
   D. Structure can be divided into four parts
      1. Photosphere
         a. "Sphere of light"
         b. Sun's "surface" – actually a layer of incandescent gas less than 500 kilometers thick
         c. Grainy texture made up of many small, bright markings, called granules,
            1) produced by convection
            2) Sunspots are associated
               a) On the solar surface
               b) Dark center, the umbra, surrounded by a lighter region, the penumbra
               c) Dark color is due to a cooler temperature (1500 K less than the solar surface)
               d) Follow an 11-year cycle
               e) Large spots are strongly magnetized
               f) Pairs have opposite magnetic poles
         d. Most of the elements found on Earth also occur on the Sun
         e. Temperature averages approximately 6000 K (10,000˚F)
      2. Chromosphere
         a. Just above photosphere
         b. Lowermost atmosphere
         c. Relatively thin, hot layer of incandescent gases a few 1000 km thick
         d. Top contains numerous spicules – narrow jets of rising material
      3. Corona
         a. Outermost portion of the solar atmosphere
         b. Very tenuous
            1) Low density
            2) Low emission of radiation
         c. Ionized gases escape from the outer fringe and produce the solar wind
            1) Blows comet tails
            2) Creates the auroras in our atmosphere
         d. Temperature at the top exceeds 1 million K

E. Solar features
   1. Sunspots
   2. Prominences
      a. Huge arching cloudlike structures that extend into the corona
      b. Condensations of material in the corona
   3. Solar Flares
      a. Explosive events that normally last an hour or so
      b. Sudden brightening above a sunspot cluster
      c. Release enormous quantities of energy
      d. Eject particles that reach Earth in about one day and interact with the atmosphere to cause the auroras (the Northern Lights and Southern Lights)

II. Solar interior
   A. Cannot be observed directly
   B. Nuclear fusion occurs here
      1. Source of the Sun's energy
      2. Occurs in the deep interior
      3. Nuclear fusion reaction that produces the Sun's energy is called the proton-proton reaction
         a. Four hydrogen nuclei are converted into a helium nuclei
            1) Mass of 4 hydrogen = 4 x 1.008 = 4.032
            2) Mass of a helium = 4.003
            3) Difference of 0.029 atomic units
         b. Matter is converted to energy—released as photons
         c. 600 million tons of hydrogen is consumed each second
      4. Sun has enough fuel to last another five billion years

III. Sun history and future
   A. Nuclear fusion initiated by gravitational contraction and heating
   B. 5 billion years later, about ½ of hydrogen used up—now
   C. Core hydrogen exhausted in 1.5 billion years
      1. shell hydrogen begins to be consumed
      2. causes Sun to swell to more than 3 times, and become brighter—Red Giant
      3. Earth will be 100 degrees hotter than now!!
   D. Another ¼ billion years, Sun swells 100 times its present size
      1. Earth molten
      2. Sun’s core temperature high enough to fuse helium into carbon
      3. blast of this throws ~ 1/3 of Sun’s mass into space—Nova
      4. gravitational collapse and rebound creates a pulsing star
   E. eventual collapse into white dwarf with gas bubble around it

IV. Stars
- A. Stars have color, brightness, mass, temperature and size.
- B. Distances to stars are measured using stellar parallax
  1. The further away, the less offset
  2. Parallax angles are extremely small
  3. Measured using photographs six months apart
  4. Distances reported in light years--Light travels 9.5 trillion km/year
- C. Stellar brightness function of distance, temperature and size
  1. Color of stars tells us their temperature
     - a. Blue stars are hotter
     - b. Red stars are cooler
  2. Most stars have a specific ratio of absolute brightness to color
     - a. Shows mass of star—
       1) larger are hotter, bluer, brighter
       2) smaller are cooler, redder, dimmer
       3) Binary star pairs
          - a) Mutually orbit around a 'center of mass'
          - b) At least half of stars are binary
          - c) Speed of orbits tell us mass of each star
  3. Hertzsprung-Russell diagram
     - a. Main sequence stars
       1) blue, bright, large, hot
       2) yellow, medium
       3) small, dim, red, cool
       4) Sun
          - a) in middle of main sequence—between ends
          - b) More stars have been observed smaller, cooler than larger and hotter
     - b. exceptions include red giants and white dwarfs
       1) color vs brightness
          - a) color shows temperature
          - b) brightness shows size
       2) red giants
          - a) main sequence stars—larger brighter are bluer
          - b) these are brighter, but not bluer, must be cool
       3) white dwarfs
          - a) hotter by color
          - b) smaller by faintness
       4) there is a progression through star types with age

4. some stars have variable brightness
    a. pulsating of cepheid variables—
        1) Polaris has four day cycle—light varies about 10%
        2) absolute brightness related to period of brightness: longer period are brighter stars
    b. eruptive variables perhaps stellar pair swapping H_2—irregular period of nova stars: Nova Herculus, Nova Persei

D. Interstellar matter—dust and gases of Nebulae—large and massive
1. emission (bright) nebula absorbs ultraviolet, emits visible light—fluorescence: Orion Nebula
2. reflection nebula composed of interstellar dust reflects nearby star light: Pleiades star cluster
3. dark nebula has no nearby star light to reflect—appear opaque