I. Astronomical tools
  A. Optical (visible-light) telescopes
    1. Two basic types—refracting and reflecting
      a. Refracting telescope
        1) Uses a lens (called the *objective*) to bend (refract) the light to produce an image
        2) Light converges at an area called the *focus*
        3) Distance between the lens and the focus is called the *focal length*
        4) The eyepiece is a second lens used to examine the image directly
        5) Have an optical defect called *chromatic aberration* (color distortion)
      b. Reflecting telescope
        1) Uses a concave mirror to gather the light
        2) Advantages
          a) No color distortion—does not have chromatic aberration
          b) Does not need to be optically clear
          c) Can be supported from the back
        3) Nearly all large telescopes are of this type
    2. Properties of optical telescopes
      a. Light-gathering power
        1) Larger lens (or mirror) intercepts more light
        2) Determines the brightness
      b. Resolving power
        1) The ability to separate close objects
        2) Allows for a sharper image and finer detail
      c. Magnifying power
        1) The ability to make an image larger
        2) Calculated by dividing the focal length of the objective by the focal length of the eyepiece
        3) Can be changed by changing the eyepiece
        4) Limited by atmospheric conditions and the resolving power of the telescope
        5) Even with the largest telescopes, stars (other than the Sun) appear only as points of light
    3. space telescopes, like Hubble, do not have interference of atmosphere
  B. Detecting invisible radiation
    1. Photographic films are used to detect ultraviolet and infrared wavelengths
    2. Most invisible wavelengths do not penetrate Earth's atmosphere, so balloons, rockets, and satellites are used
    3. History of radio astronomy
      a. James Maxwell
        1) 1860-70 summarized known electrical and magnetic phenomena in theoretical equations showing these to be aspects of the same force

2) *"We can scarcely avoid the conclusion that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena." ~1862*

b. Heinrich Hertz demonstrated existence of em radiation 1888

c. Thomas Edison proposed experiment to detect em radiation from Sun in 1890—never explored

d. Guglielmo Marconi—sensitive radio receiver in 1901

e. Bell communications exploring transatlantic communications assigned Karl Jansky to determine cause of static

   1) Discovered radio frequency emitted from Milky Way--1933
   2) Bell dropped research because it did not interfere with communication

f. Grote Reber

   1) Built dish radio antenna in 1937 in his back yard
   2) Published galactic map of radio emissions in Milky Way—1949

4. Radio wavelength radiation

   a. Reaches Earth's surface

   b. Gathered by "big dishes" called radio telescopes

      1) Large because radio waves are about 100,000 longer than visible radiation
      2) Often made of a wire mesh
      3) Have rather poor resolution
      4) Can be wired together into a network called a *radio interferometer*
      5) Advantages over optical telescopes
         a) Less affected by weather
         b) Less expensive
         c) Can be used 24 hours a day
         d) Detect material that does not emit visible radiation
         e) Can "see" through interstellar dust clouds
      6) A disadvantage: hindered by man-made radio interference

   c. Radio astronomy

      1) Best resolution from 1 to 20 cm
         a) Longer wavelengths filtered by ionosphere
         b) Shorter wavelengths subject to atmospheric interference
      2) Components
         a) Large radio antenna
         b) Sensitive radio receiver

II. 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. Solar interior
   2. 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, produced by convection
d. Most of the elements found on Earth also occur on the Sun
e. Temperature averages approximately 6000 K (10,000˚F)

3. 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
4. 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
    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
2. Plages
    a. Bright centers of solar activity
    b. Occur above sunspot clusters
3. Prominences
    a. Huge arching cloudlike structures that extend into the corona
    b. Condensations of material in the corona
4. 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)

III. 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

IV. 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 event 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 surrounding it