I. Stellar evolution
  a. Knowledge of age of stars
    i. Know distance to stars by parallax calculations
    ii. Know speed of light
      1. calculate how long it takes to get light here
      2. what we see happened a long time ago—when star was young
    iii. Distant stars are different uniformly than closer ones!!
    iv. Implication that older stars are different than young ones
  b. Stars exist due to gravity
    i. Gravity compresses H_2 into He—nuclear fusion releases energy
    ii. Gases of stars held out of complete collapse by its gravity by thermonuclear energy released by the fusion of H_2 into He
  c. Stages
    i. Star birth from contracting cloud of 92% H_2, 7% He
    ii. Protostar gravity heats mass to 10 million K, begins fusion
    iii. Main sequence stars— stable because gravity balanced with outward pressure of release of thermonuclear energy of fusion
      1. massive ones fuse H_2 ('burn' fuel) more quickly than smaller stars
      2. depletion of fuel after ~90% of lifespan
        a. upon depletion of H_2 rapid evolution
        b. dies shortly unless:
      3. may extend lifespan by becoming 'red giant'
    iv. Red Giant Stage
      1. hydrogen becomes depleted in core, 'burning' continues in outward migrating area
        a. no fusion in core has no support
        b. gravity begins to contract He core
      2. core collapses,
        a. gravitational contraction increases temperature
          i. heat invigorates hydrogen fusion in outer star shell
          ii. expands outer envelope of star to giant
          iii. outer surface is cooler, because of large size compared to total energy
          iv. can becomes oscillating in size from porpoise of expansion and contraction
        b. increased gravitational contraction in core raises temp. to point where He fuses to C
        c. can fuse up to element 26: Fe, in hotter stars

v. Burnout and death—exhaustion of nuclear fuel
   1. low mass stars collapse to white dwarf,
      a. never hot enough for helium fusion to carbon—do not become red giants
      b. emission of heat energy of gravitational collapse—to 25,000 K
      c. no nuclear fusion—glow because of heat
      d. eventual cooling goes to black dwarf
      e. extremely dense—spoonful=several tons
   2. medium stars like Sun
      a. may go through giant phase before becoming white dwarf
         i. giant phase accelerates burning of H_2
         ii. white dwarf is as dense of matter as physics will allow
      b. cast off their outer atmosphere into a nebula during red giant phase
      c. Helix Nebula in Aquarius nearest to us
         i. 450 light years away
         ii. ring shape is the greater material we see through in sides of sphere
      d. eventual collapse of core into white dwarf
   3. large stars explode in a supernova
      a. consumes fuel rapidly
      b. collapses in without fusion pressure to hold it out
      c. implosion shock wave causes explosion as a supernova, 1 million times brighter than before
         i. blows outer shell into space
         ii. interior collapses into dense material: denser than matter
         iii. becomes neutron star or black hole
         iv. Crab Nebula
            1. from supernova event observed in 1054 AD
            2. 6300 light years away means…?
         v. Veil Nebula in Cygnus—
            1. supernova 5000 to 10,000 years ago
            2. 1400 l.y. away
         vi. Eagle Nebula in Serpens
            1. example of supernova
            2. creating stars in present nebula
            3. stars have heavier elements from supernova event than original generation of star formation

d. neutron star—
    i. electrons collapsed to combine with protons→neutron
    ii. pea-size=100 million tons
    iii. strong magnetic field, rotation, radio emissions=pulsar
    iv. Crab nebula supernova observed in 1054 AD has a pulsar at center
e. black hole
    i. so much gravity that photons cannot escape
    ii. matter being engulfed emit x-rays

Gravity of an object depends upon its mass. When stars collapse, those more massive have more gravity, to pull its material a greater amount inward. The more massive the star, upon its collapse, the smaller the resulting body becomes, with greater gravity than collapsed stars with lower-mass.

II. Stellar remnants
  a. White dwarfs—extremely small with high density
    i. Degenerate matter with electrons displaced inward toward nucleus of atom
    ii. Very hot 25,000 K,
      1. without energy source
      2. remnant heat from gravitational collapse
    iii. will cool over time to become 'black dwarf'—none yet in universe, due to length of time and cooling time
  b. neutron stars—smaller in radius, more massive than white dwarfs
    i. electrons combine with protons to become neutrons
    ii. Earth-sized body collapse to density of neutron star—size of a football field
    iii. Supernova event collapses star to neutron body that
      1. has a very strong magnetic field,
      2. has high rotation rate,
      3. generates radio waves from magnetic poles
    iv. result is 'pulsar'
      1. there is a pulsar in Crab Nebula
      2. remnant of star that exploded in supernova
  c. black holes
    i. extreme collapse into ultra-dense material
    ii. gravity of extremely massive object so great that even light does not have velocity to escape its grasp
    iii. extremely hot
    iv. generate x-ray frequency of electromagnetic radiation when matter is engulfed
    v. can find them by looking at binary star systems
      1. x-ray source in Cygnus found by satellites
      2. orbiting supergiant star around x-ray source

III. Galaxies
   a. Milky Way Galaxy
      i. 100 billion stars, interstellar matter,
      ii. spiral arm structure
         1. extremely flat
         2. bulge in center
      iii. 100,000 light years across
   b. Types of galaxies
      i. Spiral like the Milky Way and Andromeda—
         1. most are large
         2. mixed ages of stars
            a. older in central part
            b. youngest in arms
      ii. Elliptical galaxies often much smaller—
         1. most galaxies are of this type (60%)
         2. stars in these are old stars
      iii. Irregular galaxies like the Magellanic Clouds—stars are forming in the Magellanic Clouds—mostly young stars in these
   c. Galaxies occur in clusters, and clusters occur in superclusters

IV. Red Shifts
   a. Most galaxies have 'red shift' of spectrum
   b. Dimmest ones have greatest red shift
   c. Implications
      i. they are going away from us, and
      ii. farther ones going away faster
   d. The 'raisin bread dough' analogy
      i. Every raisin is moving away from every other raisin
      ii. Those further apart are moving away faster than those close together

V. Big Bang
   a. 14 billion years ago there was a cataclysmic explosion
   b. All matter and space were created at this moment
   c. Cooling and condensation created stars
   d. Will there be an end to the expansion??
      i. Either we will keep moving away from other galaxies or
      ii. At some ultimate distance, the galaxies will begin to be drawn in by gravity to the 'Big Crunch'
   e. "Absence of evidence is not evidence of absence"