- Milky Way Galaxy
  - Determining the size/extent – counting stars (doesn't work)
  - Variable Stars
    - Red Giants/Supergiants
    - Instability Strip – Hydrostatic Equilibrium
    - Cepheids – characteristics
      - Type I, II – differences
      - Leavitt Law (period-luminosity relation) – used to get distances
    - RR Lyrae - characteristics
  - Clusters
    - Open Clusters - properties
    - Globular Clusters – properties
    - Ages of Clusters
  - Shapley's Model of Milky Way
    - Using globular clusters to determine our distance
  - Current Model for the Galaxy – major components
    - Bulge
    - Disk
    - Halo
    - Kiloparsec (kpc) = 1000 parsecs
  - Galactic Bulge
    - Center of the galaxy – direction of Sagittarius
    - Methods of seeing the center
    - Object at the Center
      - Sgr A*
      - Massive black hole
  - Disk
    - Characteristics
    - H I - 21 cm radio signal – main disk material
    - Spiral Arms
      - Finding location/number of spiral arms - Spiral Arm tracers
      - Very sloppy arms
    - Galactic rotation/motion of the disk
      - Rotation curve for the disk
      - Sun's motion around galaxy
      - Determine mass of galaxy (using Kepler's 3rd law)
      - Evidence for Dark Matter
    - Spiral Pattern motion
      - Spiral Density Wave theory (the nude-jogger)
  - Halo
    - Globular Clusters
    - Dark Matter
    - Streams of material
  - Stellar Populations
    - Population I Characteristics
    - Population II Characteristics

- Galaxies
  - Curtis-Shapley Debate (Harlow Shapley vs Heber Curtis)
    - Size of the galaxy
    - Nature of spiral nebula
  - Edwin Hubble, Milton Humason – distances to galaxies
  - Standard Candles
    - Definition
    - Examples
    - Best ones
  - Hubble Classification Scheme for Galaxies
    - Tuning fork diagram
    - Ellipticals
      - Criteria for classification (E0 – E7)
      - Characteristics
      - Giant Ellipticals (cD types)
      - Dwarf Ellipticals and Dwarf Spheroidals
    - Spirals
      - Criteria for Classification (Sa, Sb, Sc, Sd, SBa, SBb, SBc, SBd)
      - Characteristics
        - Barred
    - SO (Lenticular)
      - Characteristics
        - Barred
    - Irregular
  - Galaxy Names and Catalogs
  - Galaxy Velocity
    - Hubble Law
      - $v=H_o d$
      - Hubble Diagram – velocity vs distance for galaxies
      - Hubble Constant = H_o
      - Importance of Hubble's Law
        - Measurement of distances
        - Expansion of the Universe
        - Age of the Universe
  - Mass determination
    - Rotation Curve method
    - Binary motion
  - Mass-Luminosity Ratio
  - Galaxy evolution
    - Angular momentum
    - Other effects
- Galactic Clusters
  - Local Group
  - Rich vs Poor clusters
  - Megaparsec (Mpc) = a million parsecs
  - Dark Matter

- WIMPs
- MACHOs
- Superclusters
  - Local Supercluster
  - Clusters of Superclusters (?)
- Larger scale structures
  - Voids
  - Concentrations of galaxies

Active Galaxies

- Active galactic nuclei
- Criteria for active galaxies
- BL Lac
  - Variable brightness
  - Strong central source
  - Non-thermal light
  - Flat spectra
- Seyfert Galaxies
  - Variable brightness
  - Strong central source
  - Emission lines
  - Type I and Type II
- Radio Source Galaxies
  - Lobes
  - Jets
  - Cen A, M87
- Quasars
  - High redshift = high velocities = relativistic velocities
  - Emission lines
  - Great distance implied by Hubble's law
  - Variable brightness
  - Small energy source
- Gravitational Lensing
- Unified model for active galaxies
  - Massive Black Holes
  - Accretion Disk
  - High velocity clouds
  - Low velocity clouds
  - Dusty torus
  - Jets
  - Evidence for model
- Most distant objects
  - Galaxy evolution information
  - Hubble Deep Fields

Cosmology

- Newton's Universe - Static, Infinite
- Olber's Paradox - solutions

- Observable Universe
- Properties of the Universe -
  - Homogeneity, Isotropy, = Cosmological Principle
  - Universality
- Uniform expansion of the Universe
  - Curvature of the Universe
    - Flat
    - Positive (spherical)
    - Negative (hyperbolic)
- Einstein's view of the Universe
  - Introduced the Cosmological Constant
- Age of the Universe
  - Methods to estimate age

Big Bang - Cosmogony

- Big Bang Theory – Aleksandr Friedmann, George LeMaitre
  - Before the big bang?
  - Time =0
    - Supergravity
  - Planck Era
    - GUT
  - Unified Forces
  - Creation of matter
  - Inflation Era
  - Heavy Particle Era
  - Light Particle Era
  - Nucleosynthesis Era
  - Recombination (decoupling)
  - Galaxy Formation
    - Top-down vs bottom-up
    - Hot dark matter vs cold dark matter
  - Now
- Support for the Big Bang theory
  - Cosmic Background Radiation
    - Penzias and Wilson
    - 3 K
  - Later measurements
    - COBE
    - BOOMERanG
    - WMAP

Fate of the Universe

- Gravity
  - Critical Density
- Options:
  - Open – not dense enough
  - Closed – too dense
  - Flat (marginally open) – exactly equal to critical density

- Current View
  - Accelerating Universe
  - Dark Energy, Einstein's Cosmological Constant
  - Big Rip?
  - Currently observed characteristics of the Universe
    - 13.7 billion
    - Flat
    - Mainly Dark energy + dark matter