- Sun
  - Atmosphere – Observations via *SOHO*
    - Photosphere
      - "surface", 6000 K
      - Granules, granulation, convection
      - Spectra
    - Chromosphere
      - Pinkish
      - 10,000 K
      - UV source
    - Corona
      - Visible during eclipses
      - 1-2 million K, x-ray source
      - solar winds, aurora
  - Sunspots
    - Umbra, Penumbra, sunspot groups
    - Solar rotation – differential rotation
    - Sunspot cycle
      - 11 years – peak number of spots
      - location of spots – Maunder butterfly diagram
    - Magnetic Field
      - Zeeman effect
      - 22 year cycle – full sunspot cycle
      - Polarity of spots in each hemisphere – flips with next cycle
  - Solar Activity
    - Flares, Prominences
    - Coronal Mass Ejections
    - Spicules
  - Helioseismology
- Stars
  - Apparent Magnitude
    - Distances
    - Parallax $p = 1/d$
    - Parsec, Lightyear
  - Absolute Magnitude
  - Luminosity
    - Stefan-Boltzmann Law and Surface area
    - $L = R^2 T^4$ (in solar units)
    - Black body properties
  - Temperature determination
    - Wien's Law
    - Photometry
  - Spectra
    - Spectral Classification System – OBAFGKMLT
    - Temperature scale

- H-R diagram
  - Main Sequence
  - Red Giants
  - Supergiants
  - White Dwarfs
- Mass Determination
  - Binary Stars
    - Kepler's Laws
    - Center of Mass
    - Optical Binaries
    - Physical Binaries
      - Visual Binary- Mass determination
      - Spectroscopic Binary - Mass determination
      - Eclipsing Binary - Mass, Radius determination
- Mass – Luminosity relation (for Main Sequence)

Star formation

- Large Scale Star Formation
  - Giant Molecular Clouds
  - Types of stars formed
  - H II regions – Orion Nebula
- Small Scale Star Formation
  - protostars
  - T Tauri Stars
  - H-H objects – Jets, bipolar outflow

Main sequence properties

- Energy production – Fusion in the Core
  - Einstein's Special Theory
  - Proton - Proton Chain
    - protons = hydrogen atoms
    - helium, energy (gamma ray), neutrino, positron
    - deuterium
  - CNO cycle
- Radiative Zone
  - Random Walk
- Convective Zone

Stellar Interiors

- Helioseismology, asteroseismology
- Neutrino detectors
- Computer models
  - Hydrostatic Equilibrium
  - Conservation of Energy
  - Conservation of mass
  - Energy transport laws
- Zero-age Main Sequence (ZAMS)

Main sequence characterisitics

- Range of mass, temperature, luminosity, lifetime of stars on MS

Stellar Death
Very low mass – Brown dwarf, not even stars
Medium Mass – up to 8 solar masses
- Helium core
- Hydrogen shell fusion
- Thermal energy
- Red Giant
  - Electron degenerate core
  - Helium Flash
  - Helium fusion
    - Triple alpha process
    - Produces Carbon, Oxygen
  - Helium shell flashes, thermal pulses
- Planetary Nebula Stage
  - Helium shell flashes, Winds,
  - Mass loss – bipolar outflow
- White Dwarf
  - Electron Degenerate
  - Chandrasekhar Limit = 1.4 solar masses
  - Black Dwarf
  - White Dwarf Binary
    - Close binary
    - Roche Lobe
    - Mass transfer
    - Accretion disk
    - Nova
    - Recurrent nova – RS Oph

High Mass Stars (greater than 8 solar masses)
- Mass loss
  - Bipolar outflow
  - Strong winds
- Supergiants
  - More fusion stages - C, O, Ne, Si etc
  - Iron (Fe) fusion
  - Core collapse
  - Neutron degenerate core – neutron star
  - Supernova
    - Bright
    - Forms neutron star or black hole
    - Release of neutrinos
    - Shockwave
    - Production of Heavy elements
  - Two types of Supernova
    - Type I - White Dwarf pushed over Chandrasekhar limit
    - Type II - Large Mass star core collapse
  - Hypernovae – gamma-ray bursts

- Historical Supernovae & Supernovae Remnants
  - 1054 Supernova
  - Tycho's & Kepler's Supernovae
  - Cas A, Crab Nebula, Gum Nebula
- Supernova 1987A
  - Feb 1987
  - In the Large Magellanic Cloud
  - Pre-supernova star = Sanduleak -69 202
  - Detection of Neutrinos
  - Detection of heavy element production
  - Ring structures around it

Neutron stars
- Discovery – Jocelyn Bell
- Pulsars
  - Link between pulsars, supernova = Crab nebula/pulsar
  - Conservation of Angular momentum
  - Magnetic fields
  - Synchrotron Radiation – non-thermal radiation

Black Holes
- Special Theory of Relativity
  - Speed of light is constant
  - Nothing goes faster than light
  - Effects due to velocities close to the speed of light
- General Theory of Relativity
  - Matter warps space
  - Warped space influences matter, light in it
  - Mercury's orbital precession
  - Sun's deflection of light
- Black hole characteristics
  - Mass
  - Singularity
  - Schwarzschild Radius/Event horizon – depends only on mass
  - Tidal effects
  - Detection of black holes

Unusual objects
- PSR 1913+16
- PSR J0737-3039A
- Cygnus X-1
- XTE J0929-314
- Magnetars
- Quark/Strange Stars