Class Test Next Tuesday

- 8 questions, each worth 5 marks, try all 8
- 4 questions on The Galaxy
- 4 questions on Galaxies & Cosmology

- G&C: first 6 lectures
  - (not including Today's)

Lecture 1: Distances to Galaxies

How do we measure distances to galaxies?

- Standard candles
  - Cepheid Variables

  (don't memorise P-L relation, but know how to use it.)
- Distance modulus equation:
- m – M = 5 log (d / pc) – 5

  = 5 log (d / Mpc) + 25
- M = Absolute magnitude
- m = Apparent magnitude
- (M = m at d = 10 pc)

$$F = \frac{L}{4\pi d^2}$$

$$m_1 - m_2 = -2.5\log_{10}\frac{F_1}{F_2}$$

$$m - M = 5\log_{10}(d/10pc)$$

Lecture 2: Galaxy Morphology

- Hubble tuning fork; why NOT evolutionary sequence
- Galaxy types: Ellipticals, Spirals, Irregulars
- Main features / components of each type.
- Why are Ellipticals red?
- Understand blackbodies:

  $B_\nu(T)$, $L = 4\pi R^2 T^4$, $\lambda_{peak} \sim 1/T$
- Galaxy Colours

  blue = young hot stars
  red = old cool stars

Lecture 3: Galaxy Fundamentals

$$m - M = 5\log_{10}(d/Mpc) + 25$$

- How many stars? $F_{Gal} = n_* F_*$, F_* = "Average star"

  Use: $$m_{GAL} - m_* = -2.5\log_{10}\frac{F_{GAL}}{F_*}$$
- Formation scenarios. Observations for and against.
- Space density of galaxies: What *d* and *Volume* do we see down to limiting apparent mag $m = 14$ for galaxies with absolute mag $M = -20$?
- How far apart are galaxies?

Lecture 3: Galaxy Fundamentals

- How are galaxies clustered? Like soap suds, galaxies found on the bubble surfaces: hence voids, walls, filaments, clusters.
- Mass to Light ratios: $$\frac{\mathbf{M}}{L} = X\frac{\mathbf{M}_\otimes}{L_\otimes}$$

  $X = 1$ for Sun; $X \sim 10$ for a galaxy.

  Galaxy *M*/*L* ratios indicate Dark Matter
- Average density of Universe:

  from galaxy counts and masses.

Lecture 4: Galaxy Spectra

- Continuum, Absorption lines, Emission lines.
- 4000A break: Due to metal absorption lines in stellar atmospheres. Strong in ellipticals, weaker in spirals, absent in irregulars.
- Absorption lines: From metals in stellar atmospheres => old stars

  Seen in ellipticals, spiral bulges
- Emission lines: HII regions, gas ionized by hot stars => young stars in spiral disks, irregulars
- Radial velocities, redshift: $$\frac{v}{c} = \frac{\lambda - \lambda_0}{\lambda_0} = z$$

Lecture 5: Dark Matter

- Virial Equilibrium: Rotation = Gravity $M = \frac{v^2 r}{G}$
  Calculate *M* given v and *r*
- Rotation curves: stars trace mass => v = √(G M / r)
  Observe: v = constant => Dark Matter
  v = const => M ~ r and ρ ~ 1 / r^2 => "dark halo"
- Dark Matter in galaxy clusters:
  galaxies move too fast to stay bound
- Gravitational Lensing: M given D_L D_S and θ
- Conclusion: 90% of the mass is Dark Matter…
  OR gravity theory (General Relativity)
  needs to be modified

Lecture 6: Black Holes

- Black Holes: so massive & compact light cannot escape. Be able to derive Schwarzschild radius: kinetic energy = gravitational energy: $r_S = \frac{2GM}{c^2}$
- SMBHs: observe large speeds at some given distance: derive mass: $M = \frac{v^2 r}{G}$
- Hawking radiation, virtual pairs, BH evaporation
  (no need to memorise formula for T)

Lecture 6: Quasars

- SMBH => AGN when feeding.
- QSOs are bright AGN, star-like but at large redshift
  => Luminosity up to ~10^5 that of normal galaxies.
- Broad emission lines => rapid rotation (v~10^4 km/s)
- Spectrum: blackbody (accretion disk) + power law (non-thermal) Synchrotron radiation: relativistic jet with electrons spiraling in **B**-field
- QSO model + unification scheme for Quasars, Blazars, and Radio galaxies
- Many at large redshift (z ~ 2-3) but few nearby
  => common in early Universe, then died out.