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)

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

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

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

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:

 $B_{\rm v}(T), \ L=4 \ \pi \ R^2 \ T^4, \ \lambda_{peak} \sim 1 \ / \ T$

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? $F_{\text{Gal}} = n_* F_*, F_* = \text{`Average star''}$ 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:

$$\frac{\mathbf{v}}{c} = \frac{\lambda - \lambda_0}{\lambda_0} = z$$

Lecture 5: Dark Matter

 Virial Equilibrium: Rotation = Gravity Calculate *M* given v and r

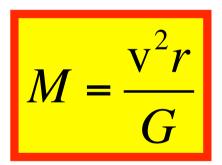
$$M = \frac{v^2 r}{G}$$

- Rotation curves: stars trace mass => v = √(G M / r) Observe: v = constant => Dark Matter
 v = const => M ~ r and ρ ~ 1 / r² => "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: 2GM

- SMBHs: observe large speeds at some given distance: derive mass:
- 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 ~10⁵ that of normal galaxies.
- Broad emission lines => rapid rotation (v~10⁴ km/s)
- Spectrum: blackbody (accretion disk) + power law (nonthermal) 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.