Option F – Astrophysics

F.1 Measuring Stellar radiation

F.1.1

Galaxies:
- Huge mass of stares, nebulae, and interstellar material.
- 3 types: elliptical, spiral (arms spiraling outwards from a central bulge), and irregular.

Clusters:
- groups of stars
- Types:: Open: loose groups of a few 1000 young stars drifting apart / Globular: densely packed (roughly spherical groups of hundreds of thousands of older stars.

Nebulae:
- Cloud of dust and gas inside a galaxy
- Emission nebulae: their gas emits light when stimulated by young star radiation
- Reflection nebulae: dust reflects light from stars in or around nebulae
- Dark nebulae: silhouettes since they block light from shining nebulae or stars
- Other types: planetary nebula (gas shell drifting away from dying stellar core) / supernova remnant (gas shell moving away from stellar core at great speed after supernova)

Red Giants: (Duration: 100 million yr. / Diameter: at least 40 million miles)
- Forms when the hydrogen in a star’s core has converted into helium, the helium contracts again and fuses to form carbon while the outer layers expand cool and shine less brightly
- Large, massive, very luminous, but cool.

White dwarves: (diameter 8,000 miles)
- The red giant’s core after its outer layer has drifted off.
- Very dense core, one teaspoonful weighs about 5 tons.
- Eventually cools and forms a black dwarf (cold, dead core)
- Small, dim, but hot.

Supernovae: (Duration of visibility 102 yr.)
- Massive star (3 times mass of sun at least) ⇟ Red Super giants ⇟ Iron core ⇟ Core collapses in less than a second, causing explosion called Supernova.
- Shine brighter than an entire galaxy for an instant.

Neutron Stars:
- If the supernova core survives and is between 1.5 and 3 solar masses it becomes a neutron star
- Dense (one teaspoonful weighs about a billion tons), tiny, diameter of about 6 miles.
- Consist almost entirely of neutrons.

Black holes:
- If surviving supernova core is considerably greater than 3 solar masses it contracts to form a black hole.
- Strong gravity (even light cannot escape), therefore invisible, but are detected if there is a close companion star. Black hole pulls gas from companion star, forming an accretion disk that spirals around the black hole at high speed, heating up and emitting radiation.

Pulsars:

- Rotating Neutron Star.
- Emit 2 beams of radio waves (detected as short pulses)

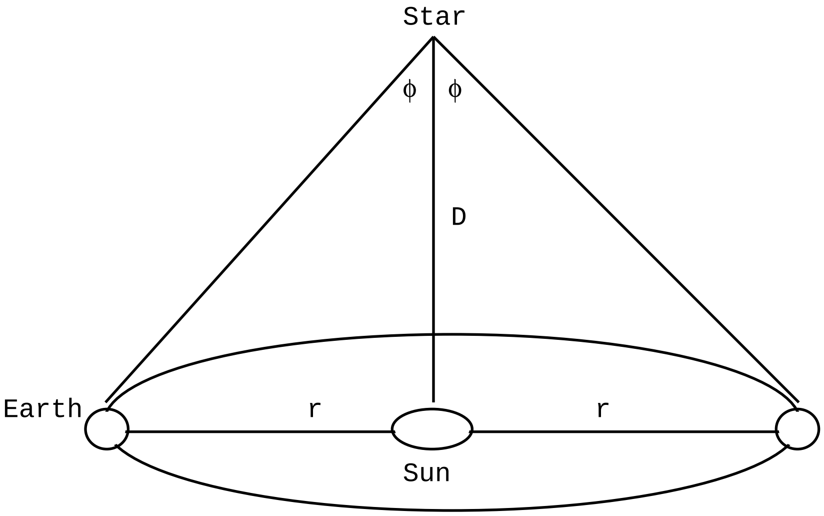
Quasars:

- Appears as a point of light but far more powerful source of radio waves than any known star.
- Most distant objects in the known universe
- Giving off energy at prodigious rates.

F.1.2

Parallax: apparent motion of a star
Parsec: 3.26 light years “the distance to a star whose parallax is 1 arc second”

The distance to stars as far as 100 light years is measured using a parallax angle.



$D = r/\phi$

F.1.3

Apparent magnitude: depends on the absolute luminosity (intrinsic brightness)of the star and its distance from earth(decreases by 1/d2)
Absolute magnitude: the apparent magnitude a star would have if it was 10 parsecs away (32.6 light years)

F.1.4

$L=\sigma AT^4$ (σ = Stefan-Boltzmann constant / A = surface area / T = absolute temperature / L = energy radiated)

F.1.5

Wien’s law: relationship which gives the temperature of a black body in terms of the wavelength at which it radiates the maximum amount of energy in its spectrum.

$\lambda(max) = 2.9x10^{-3}$ (mK)/ T (*on formula sheet)*

- The **higher the temp. the lower the wavelength at which most of the energy is radiated.**
- Useful way of measuring temperature of an object (radiating like a black body) from measurement of the intensity of its

emission at different wavelengths around the peak in the spectrum.

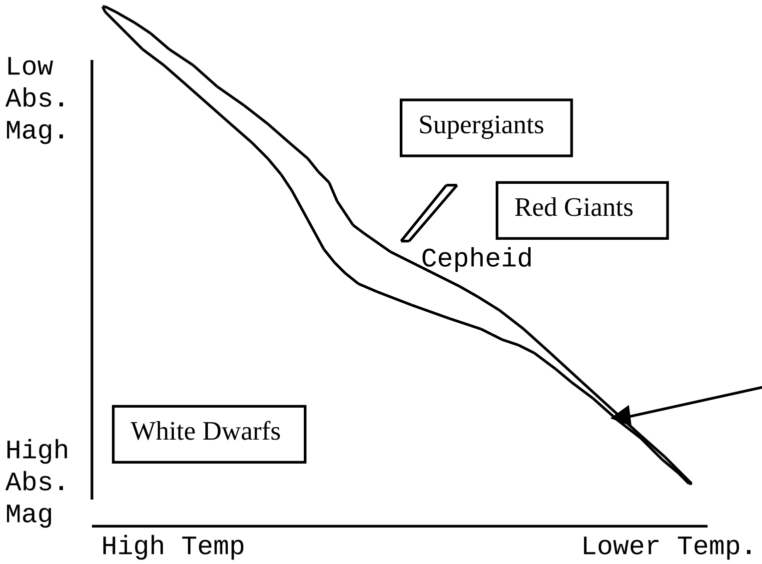
F.1.6

Study of the spectra of stars allows the identification of the elements making up the star.

F.2 Types of stellar object

F.2.1

Hertzsprung-Russell Diagram



Low Absolute Magnitude fl‡ High Mass and vice-versa.
For main sequence: upper left = large, more massive than sun, hot and bright stars / lower right = small, less massive than sun, cool and faint.
Main Sequence: luminosity increases w/ mass.
Red Giants: Very large in size, cooler in temp., very large luminosity compared to main sequence stars of the same temp.
White Dwarfs: small size, high surface temp, faint, v. high density.
Cepheid Stars: variable star where there exists a relationship btw the period of the light curve and the absolute average luminosity of the star.

F.2.2

(see above descriptions of stars)

F.2.3

Variable Stars: Stars which vary in brightness, a variation which may be either periodic or non-periodic.

- Pulsating variable stars: pulse in and out at a particular frequency
- Irregular variable stars: behave in a completely unpredictable way.
- Flare stars: flares created by magnetic effects in red dwarf stars may result in a sudden increase in light output.

F.2.4

Binary Stars:

- *Eclipsing binaries*: two stars which cross in front of each other as they orbit.
- *Visual*: two separate stars orbiting around a common center.
- *Spectroscopic binaries*: binaries detected by changes in their spectra.
- *Close binaries*: pair of stars that are close enough to stretch each other into a pear like shape.

Nova outbursts result from mass transfer between close binaries.

F.3 The Expanding Universe

F.3.1

The energy carried by radiation emitted from a moving source is decreased if the source is moving away and vice versa. (??????)

F.3.2

Redshifts: when a source of lights is moving away from the observer, the wavelength is longer and shifted towards the red end of the visible spectrum.

F.3.3

Hubble’s Law: the velocity of a galaxy moving away from us is proportional to its distance from us.
v = Hd (v = vel / H = Hubble’s constant / d = distance)
T = 1 / H = age of the universe.

F.3.4

Hubble and the expanding universe: if distant galaxies are moving away from the observer and even with greater speed further from the observer, this suggests that a great explosion could have occurred at some distant time in the past.

F.3.5

1964, Penzias and Wilson discover a cosmic microwave background radiation at a temperature of 3K by trying to eliminate all static from their radio telescope (but they could not eliminate the 3K microwave radiation). It is significant because it provides evidence for the Big Bang theory and gives us some idea of conditions in the early universe.

F.4 The Big Bang model of the creation of the universe

F.4.1
Olber’s Paradox:

If the universe is infinite, with stars uniformly distributed, the night sky would be bright everywhere.

F.4.2

Consequences of Olber’s Paradox:

It was found the universe was not static, and *might* not be infinitely old, these two 20th century discoveries provide a solution to his paradox.

F.4.3 + F.4.5

History Of the Universe: (*The Standard Model*)

1. Big Bang :: incredibly hot + dense
2. Grand Unified Era (GUT) [t=10^-43 s], gravity 'condensed out' as a separate force, no distinction between quarks and leptons. Temp = 10^32 K.
3. 10^-35 s after Big Bang :: temperature dropped to about 10^27 K, universe filled with leptons (included electrons, muons, taus, neutrinos and all their antiparticles.) and quarks. Quarks began to 'condense' into nucleons (protons and neutrons) and the other hadrons and their antiparticles. Universe enters the Hadron Era, where particles and antiparticles collide and exchange energy.

- 10^-35 s :: excess of quarks over antiquarks must have formed.
- 10^-6 s / 10^13 K :: majority of hadrons disappeared / one nucleon per 10^10 photon / protons, neutrons and all other heavier particles reduced in number fl all due to a process of annihilation which was not countered by a process of creation due to the decreasing average kinetic energy (under 940 MeV)
- 10^-4 s last hadrons to go.

4. Lepton Era (after 10^-4 s) era of lighter particles.

- 1 s :: universe cooled to 10^10 K // average KE = 1 MeV // electrons could still be formed.
- Then annihilation (e+ + e- = photon) continued while electrons could not be formed.

5. At t=10 s, the universe entered the Radiation Era / main constituents are photons and neutrinos / universe was radiation dominated.

- 2/3 min after Big Bang :: nuclear fusion began to occur / Temp = 10^9 K, average KE = 100 keV / nucleons could fuse and this period called nucleosynthesis lasted _ hour.

6. _ million years later :: universe expanded to 1/1000 of present size, temp = 3000 K, KE was a few electron Volts / birth of atoms / total energy contained in radiation had been decreasing (redshifting) ‡ energy became increasingly concentrated in matter rather than radiation. The universe had become matter dominated.
7. Million years later :: formation of stars and galaxies (through self-gravitation)

F.4.4

"The curvature of space is an important one in cosmology. If the universe has a positive curvature then the universe is finite or closed. If the curvature is zero or negative, then the universe would be open and infinite.