Intro to Stellar Astronomy (Physics 260): 1st exam Review Notes

Atoms, ions, molecules

• Nucleus (positive charge) surrounded by electrons (negative charge).

• # protons determines chemical element.

• In normal atoms, charges "balance."

• Some atoms bond together to form molecules.

The Excitation of Atoms

• If atom absorbs energy, electron kicked to higher level, becomes "excited."

• When electron falls to lower level, photon emitted.

• Ionization: electron removed from (or added to) atom producing an ion.

• Excitation/ionization occurs when:

i) atoms collide (with sufficient energy)

ii) atom absorbs photon (with "correct" energy)

• Energy of a photon $E = hf = hc/\lambda$.

• Each chemical element has unique spectral "signature" due to position of energy levels in atom.

Spectral Classification

• Originally: A, B, C, ... P, Q (R, S) (strong to weak Balmer lines).

• Now: O, B, A, F, G, K, M (R, N, S) (decreasing temperature).

The Composition of the Stars

• Normally $\sim$ 75% hydrogen, 25% helium.

Radial velocity

$$\frac{V_r}{c} = \frac{\Delta\lambda}{\lambda_0}$$

The Formation of Stars

• Stars form in dense cores within GMCs.

• Observed as "hot spots" in IR.

• Gravity makes GMCs/cores collapse, but 3 factors resist gravity:

1. thermal motion;

2. magnetic fields;

3. rotation.

• 4 external mechanisms "help" gravity:

1. supernova explosions;

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2. stellar winds;

3. collisions of GMCs;

4. density waves.

• Result: core contracts, gets hotter → forms a protostar which contracts, gets hotter, until thermonuclear reactions begin: a star is born.

The Source of Stellar Energy

• Hydrogen fusion: 4H → He + energy.

• Calculation of energy released: use $E = mc^2$

Stellar Structure and Evolution

• Hydrostatic equilibrium: "balance" between gravity & pressure.

• Main sequence stars fuse H to He.

• O, B, A, F, G, K, M is also a *mass* sequence (O stars the most massive).

The Ends of the Main Sequence

• $M > 100M_\odot$: winds blow away material.

• $M < 0.08M_\odot$: nuclear reactions never begin (result: "brown dwarfs" or "failed stars").

The Life Expectancies of Stars

• O stars live $\sim 10^6$ years.

• M stars live $\sim 200 \times 10^9$ years.

Post-Main-Sequence (PMS) Evolution

• Most stars not well-mixed ⇒ when all H in core converted to He, have inert He core. Contraction ⇒ T increases ⇒ H burning shell around He core.

• Initially no He fusion because it requires higher T.

• Overproduction of energy during this phase forces stellar envelope outwards producing Red Giant.

• If star sufficiently massive, He fusion begins in core.

The Deaths of Stars

Lower Main-Sequence Stars

• Details depend on stellar mass.

• Lowest mass stars eventually run out of H, cool and fade.

• In solar-type stars, hot core blows away outer envelope. UV radiation from hot remaining center excites ejected gas ⇒ planetary nebula.

• Surviving core continues to contract. If mass $< 1.4 M_\odot$, forms a "white dwarf."

The Upper Main Sequence

• "Onion skin" model: massive stars have layers of burning shells with central core.

• Fe core can release no energy ⇒ star collapses, produces supernova explosion.

• Stellar remnant of such an explosion either neutron star or black hole.

Neutron Stars and Black Holes

• Neutron star: $1.4 M_\odot < M < 3 M_\odot$.

• Black hole: $M > 3 M_\odot$.

• Schwarzschild radius:

$$R_s = \frac{2GM}{c^2}$$

• Black holes have no hair: completely specified by mass, angular momentum (rotation), charge.