

STAR FORMATION / STELLAR EVOLUTION

1. Nebula

- A vast cloud of **hydrogen, helium, and dust**.
- **Birthplace of stars**.
- Collapse begins due to **gravitational instability** (often triggered by shock waves from supernovae).



2. Protostar

- Early stage of star formation.
- **Nuclear fusion has NOT started**.
- Emits energy due to **gravitational contraction**, not fusion.
- Surrounded by dust → **visible mainly in infrared**, not optical light.



3. T Tauri Star

- **An intermediate stage** between a protostar and main sequence star.
- Still contracting under gravity.
- Commonly asked in UPSC as a **young stellar object**.



4. Main Sequence Star

- **Hydrogen** → **Helium fusion** occurs in the core.
- Produces stable energy due to a balance between:
 - **Outward radiation pressure**
 - **Inward gravitational force**
- About **90%** of all stars, including the **Sun**, are main-sequence stars.



5. Red Dwarf

- **Smallest and faintest** main-sequence stars.
- **Low luminosity**, surface temperature ~ **4000°C**.
- Make up ~**75%** of **Milky Way** stars.
- Example: **Proxima Centauri** (nearest star to the Sun).



6. Red Giant / Red Supergiant

- Occurs when **core hydrogen is exhausted**.
- Hydrogen fusion continues in a **shell around the core**.
- **Red Giant** → Low/medium mass stars
- **Red Supergiant** → Massive stars
- Helium fusion produces **carbon and heavier elements**.



7. Degenerate Matter

- *Forms when fusion slows, and gravity dominates.*
- *Electrons are forced closer to nuclei.*
- *Found in **white dwarfs and neutron stars**.*
- *Allows **extreme densities**.*



8. Planetary Nebula

- *Outer layers ejected by a dying **low-mass star**.*
- ***No planets involved** (name is misleading).*
- *Short-lived (tens of thousands of years).*



9. White Dwarf

- *Final stage of stars like the Sun.*
- *Made of **degenerate matter**.*
- *Extremely dense: **one spoonful weighs several tonnes**.*
- *No fusion; shines due to **residual heat**.*



10. Nova

- *Occurs in a **binary system**.*
- *A **white dwarf** pulls hydrogen from a companion star.*
- *Causes a **surface nuclear explosion**, but the star survives.*
- *Recurrent phenomenon.*



11. Black Dwarf

- *A **fully cooled white dwarf**.*
- ***Theoretical only** — none exist yet.*
- *Cooling time > **age of the universe (13.8 billion years)**.*



12. Brown Dwarf

- *Between **planet and star**.*
- *Insufficient mass for **hydrogen fusion**.*
- *Often called "**failed stars**".*



SUPERNOVA

Definition

- *Explosive death of a star.*
- *Can shine as brightly as **100 million suns**.*
- *A major source of **cosmic rays**.*



Types of Supernovae

Type Ia Supernova

- *Occurs in **binary systems**.*
- *White dwarf accretes mass → runaway carbon fusion.*
- ***Completely destroys the star.***
- *Used as **standard candles** to measure the expansion of the universe.*

Type II Supernova

- *Core collapse of a **massive star** (iron core).*
- *Leaves behind a **neutron star or black hole**.*

Importance of Supernovae

- *Create **elements heavier than iron** (gold, uranium).*
- *Spread elements into space → **stellar recycling**.*
- *Trigger formation of **new stars**.*

NEUTRON STAR

- Formed after a **Type II supernova**.
- Protons + electrons \rightarrow neutrons.
- Extremely dense: **3 solar masses in ~20 km**.
- Beyond a limit \rightarrow collapses into a black hole.

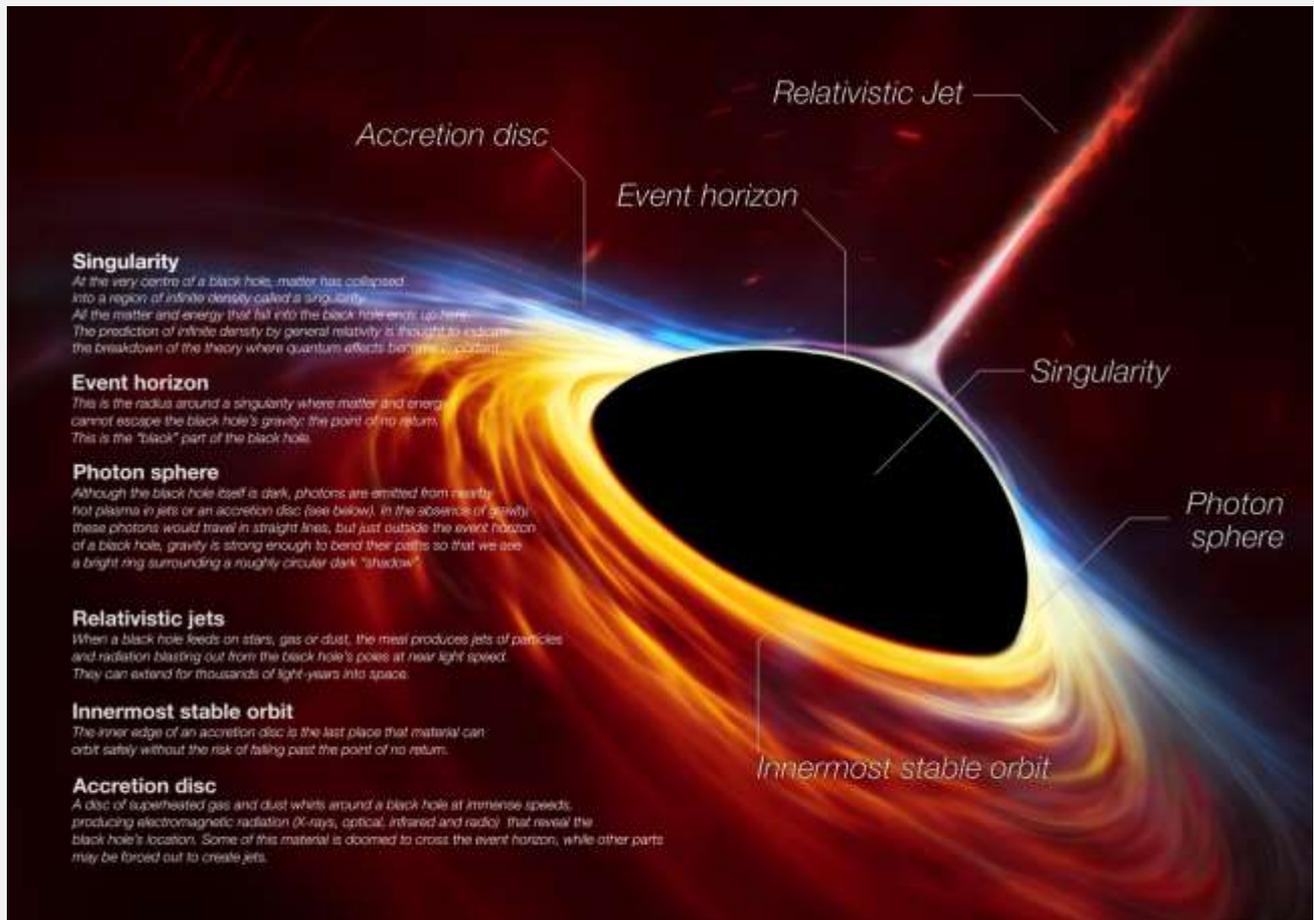


Chandrasekhar Limit

- The maximum mass for a white dwarf \approx **1.4 solar masses**.
- Beyond this \rightarrow neutron star or black hole.

BLACK HOLES

- End stage of very massive stars.
- Gravity is so strong that **not even light escapes**.
- Density \rightarrow effectively **infinite**.
- Distorts spacetime and can absorb nearby matter.



CONSTELLATIONS

- A group of stars forming a recognisable pattern.
- Examples:
 - **Ursa Major (Saptarshi / Great Bear)**
 - **Orion**
 - **Cassiopeia**
 - **Leo Major**

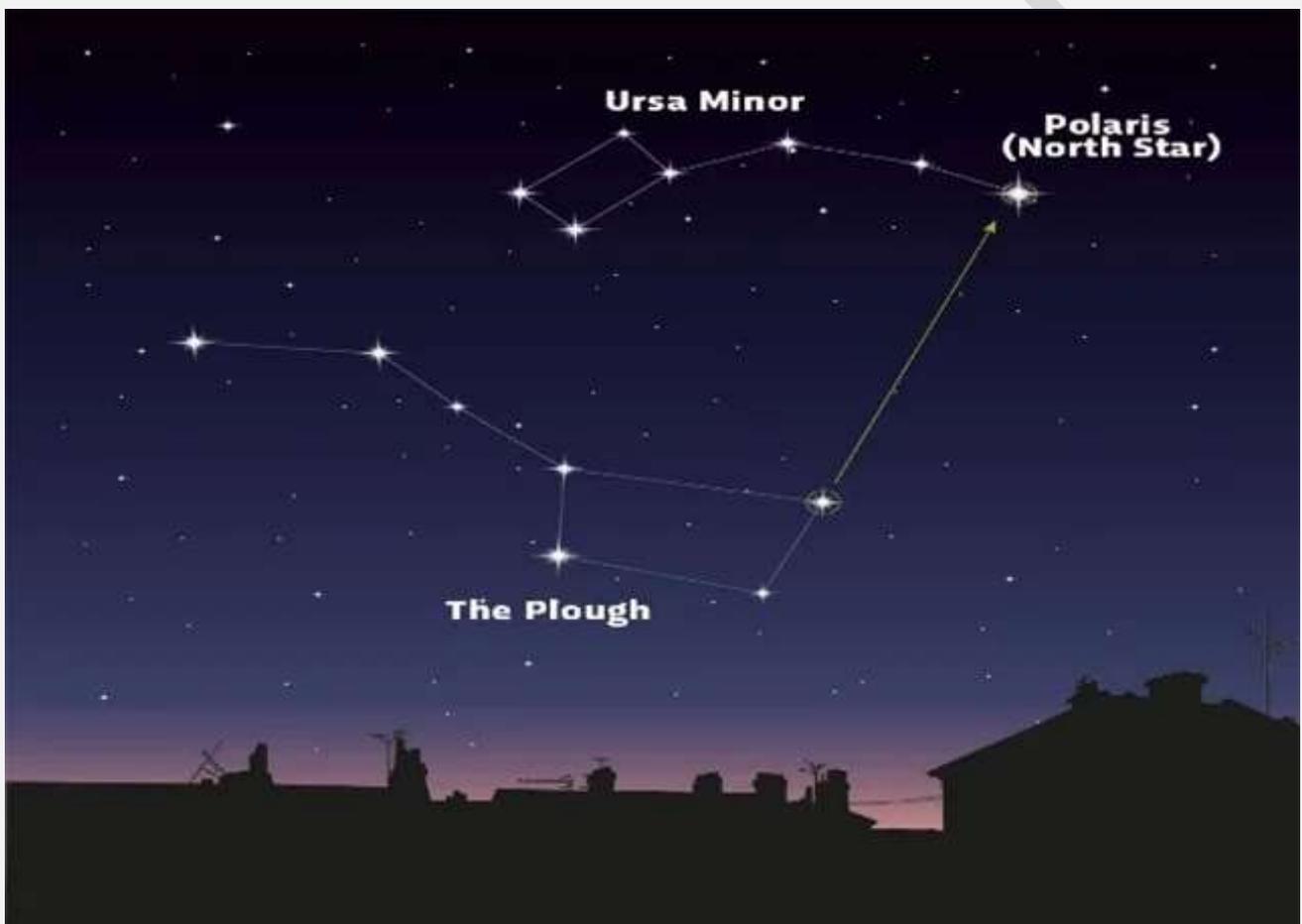


Key Facts

- Stars appear to revolve around the **Pole Star**.
- Some northern constellations are **not visible** from the southern hemisphere.
- **Orion is visible in winter evenings**.
- **Sirius** (the brightest star) lies near Orion.

POLE STAR (POLARIS)

- Lies along **Earth's rotational axis**.
- Appears **stationary** in the sky.
- Visible **only from the Northern Hemisphere**.
- Actually, a **triple star system**.



MCQs

Q1. With reference to a nebula, consider the following statements:

- I. Nebulae are regions composed mainly of hydrogen and helium gas.
- II. All nebulae are remnants of supernova explosions.
- III. Star formation begins inside nebulae due to gravitational collapse.

Which of the statements given above is/are correct?

- (a) I and III only
- (b) II and III only
- (c) I and II only
- (d) I, II, and III

Answer: (a)

Q2. Which of the following stages occur before a star enters the main sequence phase?

- I. Nebula
- II. Protostar
- III. T Tauri star

Select the correct answer using the code below:

- (a) I and II only
- (b) II and III only
- (c) I, II, and III
- (d) III only

Answer: (c)

Q3. With reference to main-sequence stars, consider the following statements:

- I. Nuclear fusion of hydrogen into helium occurs in their core.
- II. Most stars in the universe belong to this category.
- III. Red giants are a subtype of main-sequence stars.

Which of the statements given above is/are correct?

- (a) I and II only
- (b) I only
- (c) II and III only
- (d) I, II, and III

Answer: (a)

Q4. Red dwarf stars are characterized by which of the following features?

- I. Very low luminosity
- II. Short lifespan compared to the Sun
- III. Large proportion of stars in the Milky Way

Select the correct answer using the code below:

- (a) I and II only
- (b) I and III only
- (c) II and III only
- (d) I, II, and III

Answer: (b)

Q5. Which of the following correctly describes a planetary nebula?

- (a) A nebula formed from interstellar dust before star formation
- (b) An expanding shell of gas ejected by a dying low-mass star
- (c) A region where planets are formed around stars
- (d) The remnant core of a massive star after a supernova

Answer: (b)

Q6. With reference to white dwarfs, consider the following statements:

- I. They are supported by electron degeneracy pressure.
- II. Nuclear fusion reactions occur in their core.
- III. Their density is extremely high.

Which of the statements given above is/are correct?

- (a) I and II only
- (b) I and III only
- (c) II and III only
- (d) I, II, and III

Answer: (b)

Q7. The Chandrasekhar Limit is associated with which one of the following?

- (a) Maximum size of a red giant star
- (b) Minimum mass required for hydrogen fusion
- (c) Maximum mass of a stable white dwarf
- (d) Upper mass limit of a neutron star

Answer: (c)