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IDEALISED CONCEPT OF STAR BIRTH

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Abstract : Stars are born within the clouds of dust and scattered throughout most galaxies.A familiar example of such dust clouds is the Orion Nebula.In this paper, we have reviewed the stellar families,stages of stellar Gestation and process of star birth in detail. Thus make the idealised concept of star birth clearly understandable.

Keywords : Star birth,stellar families,stages of Gestation.

Introduction

Star formation happens in interstellar molecular clouds: opaque clumps of very cold gas and dust. The process starts when some of those clumps reach a critical mass,allowing them to collapse under their own gravity. The cause could be as simple as random fluctuations of density within the clouds or due to an outside influence: collision with other clouds,a supernova,a shockwave from a blackhole or even a disturbance from other stars forming close by. Some of the raw materials in the cloud form objects smaller than stars: planets and brown dwarfs,which fall between giant planets and stars in size. Planets form from protoplanetary disks around newborn stars; astronomers have observed around 150 protoplanetary disks inside the orion nebula. Studying star forming regions is also a way to understand how planets are born and how the interstellar environment shapes them.

Extrapolating from the observations,the Milky way probably produces three or four new stars every year on average in its various star forming regions;starburst galaxies,by contrast,can produce hundreds. Astronomers compare star formation across the galaxies to understand the difference.

EXPLORATION OF THE REGION

Visualisation of the Taurus Molecular cloud was observed by E.E Barnard in 1875 showing a nebulous region of darkness contrasted against the ambient star field. Study on Atlas of selected regions of the Milky way by Edward Emerson Barnard, Ed. Edwin, B. Frost and Mary R. Calvest , Washington DC; Carnegie Institution of Washington (1927).

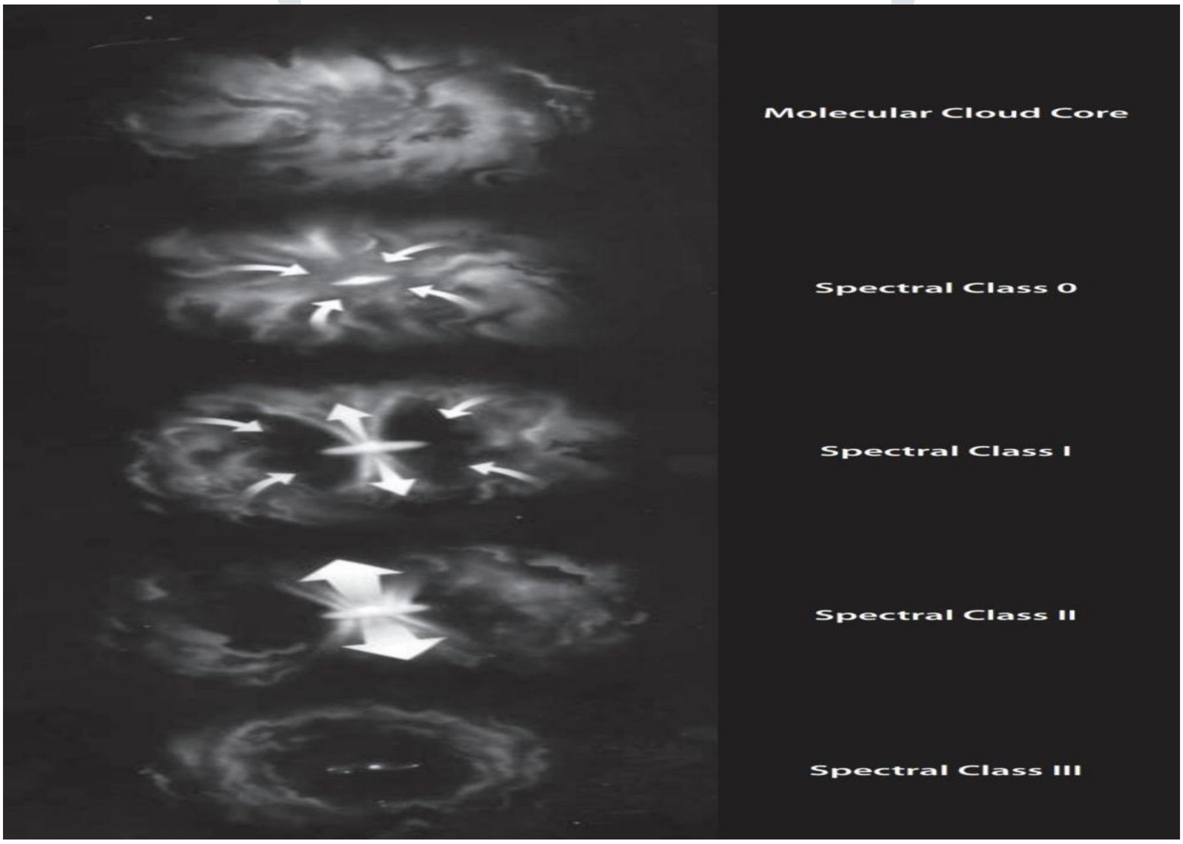
"The relation of the Gas and Dust in the Taurus Molecular Cloud" was observed with the courtesy of Paul Goldsmith(Jet propulsion laboratory, Caltech, NASA),with reference to J.pineda, P.F. Goldsmith,N.Chapman etc. The stages of stellar gestation were researched by Charles Lada and Rob Wood. Pipe nebula in ophiuchus the serpent Bearer is called as Brown dwarfs as observed by Yuri Beletsy(European Southern observatory) whereas 'The luminosity and Mass function of Trapezium cluster: From B-stars to the Deuterium-burning limit" was courtesies by A. Muench,E. Lada, C.Lada and J.Alves.

Stages of Stellar Gestation

"Understanding the star-forming process is a challenging task for astronomers, but significant progress has been made in identifying key stages . These stages include:

1. Cloud Aggregation: The molecular cloud forms through various mechanisms. Observations in far-infrared maps reveal evidence of stellar winds or supernova explosions shaping the interstellar medium into shells and filaments.. Spiral density waves and turbulence within the interstellar medium can also contribute to cloud aggregation. Turbulence creates a hierarchical structure, where smaller cloudlets cluster into larger clouds, exhibiting self-similar architecture similar to other fractal patterns in nature such as snowflakes and coastlines. This structure arises as turbulent energy cascades from larger to smaller scales.

2. Core Condensation: Gravity begins to dominate, causing the cloud to fragment into denser cores. Gravitational condensation occurs when the gravitational forces outweigh various resistive factors, including thermal, turbulent, and magnetic energies. Sir James Jeans established the energetic criteria for gravitational fragmentation and condensation in the 1920s, and the threshold mass for gravitational instability is known as the Jeans mass. The Jeans mass increases with the temperature of the cloud (resisting agent) and decreases with cloud density (abetting agent). In regions like Taurus, typical Jeans masses are several solar masses, making it favourable for the formation of intermediate-mass stars, as well as lower-mass stars and brown dwarfs.

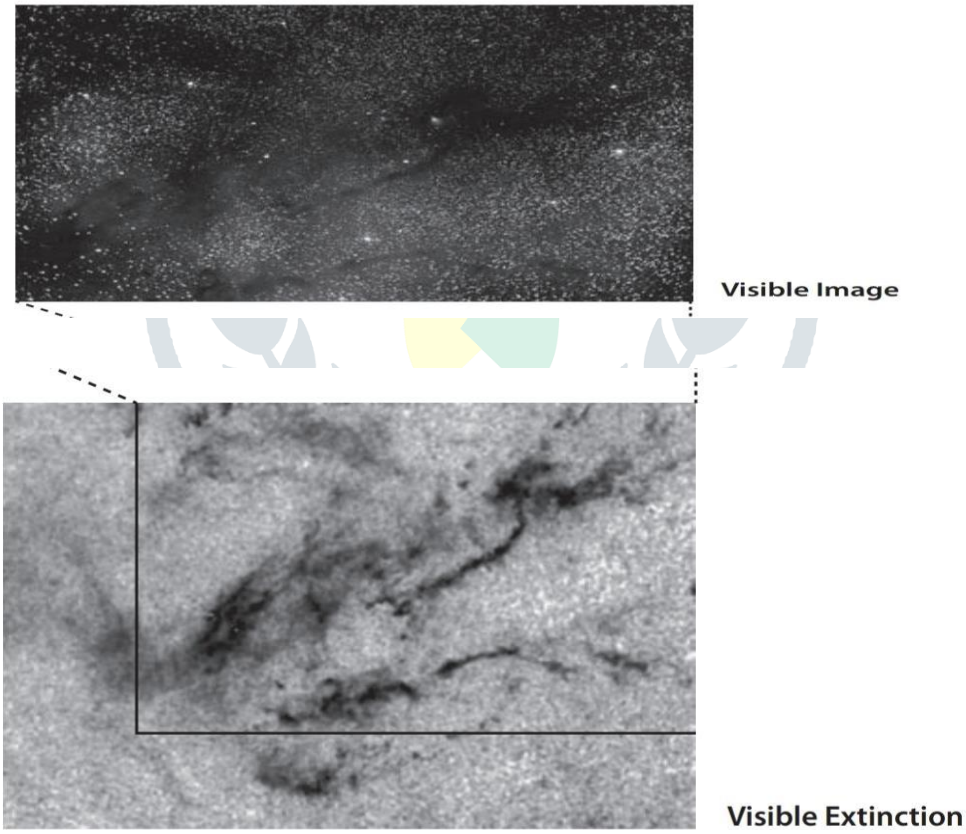


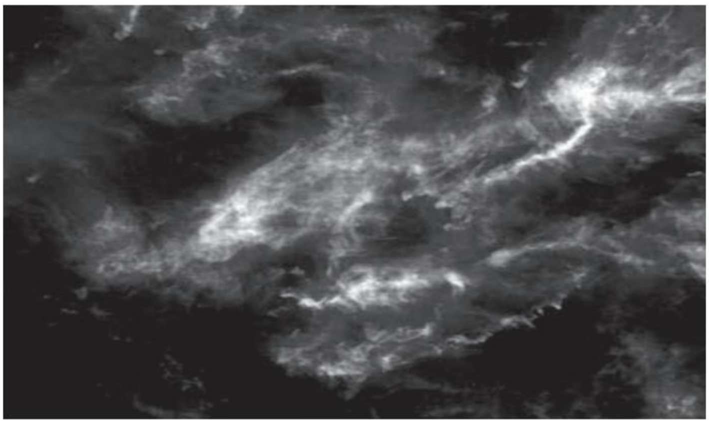
3. Gravitational Collapse: The core undergoes a gravitational implosion. Once gravity becomes dominant, the collapse progresses largely "

The collapse of molecular cloud cores occurs in free-fall, from the inside out, and is dependent on the core's density. Higher density leads to faster collapse, with typical molecular cloud cores having densities of up to a million molecules per cubic centimeter and collapsing within a million years or so. However, despite the abundance of dense cores observed throughout the Galaxy, there seems to be a mechanism preventing the rapid formation of protostars from all cores simultaneously. Factors such as core rotation and internal turbulence likely act as inhibitors, allowing only a few cores to approach the brink of collapse at any given time.

In the absence of inhibiting factors, the Jeans scenario would result in an endless cycle of fragmentation and condensation, eventually leading to the formation of protoplanets. However, this outcome is averted as new mechanisms come into play to halt further breakup. These mechanisms arise from the core itself. Initially transparent to its own infrared radiation, the core eventually reaches a density where it interacts with emergent photons, causing it to heat up. The thermal energy accumulated within the warm core then prevents free-fall collapse and regulates the contraction rate based on the core's luminosity.

This phase, known as Mediated Contraction, involves the conversion of gravitational energy from infalling material into thermal energy within the protostellar core. Angular momentum plays a crucial role in this contraction process. As the core contracts, any initial rotation is amplified until the core reaches its gravitational limit. To exceed this limit, the core must shed some of its angular momentum. Astronomers generally agree that the most effective way to achieve this is by breaking up the core into a binary system consisting of two smaller rotating cores orbiting their mutual centre of mass. Another approach to reduce angular momentum is by transferring mass away from the protostellar core.





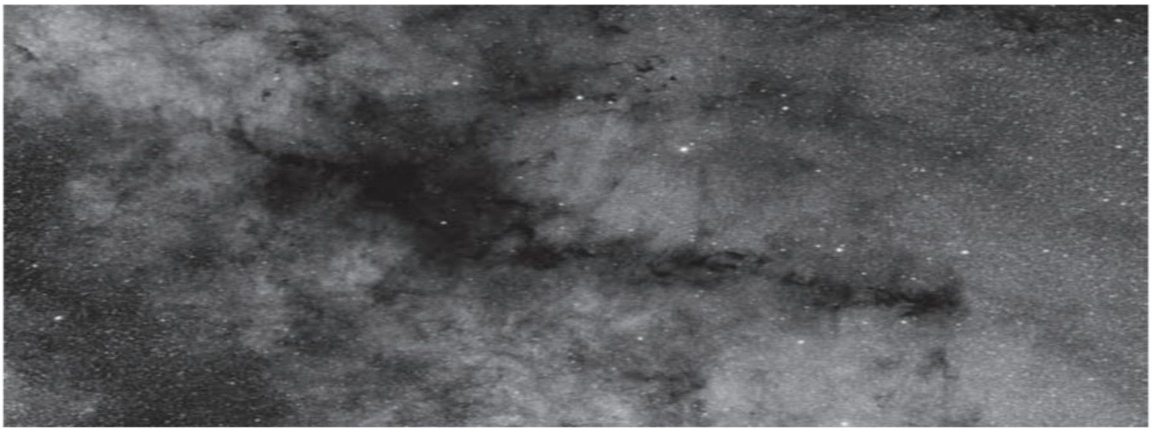
CO Emission

To facilitate the formation of a protostar, a process known as the shrinking core mechanism occurs, involving the formation of a rotating disk of material around the growing protostar. This disk, called an accretion disk, serves as a reservoir for storing excess angular momentum and facilitates the transfer of material from the core's outer envelope to the protostar. Additionally, rotating mass can be shed through the emission of bipolar jets along the rotational axis of the core. For this mechanism to be effective, the outflowing jets must also possess significant rotational motion.

The contraction of the core presents another challenge—the need to dissipate its magnetic field. As the core collapses, the magnetic field that traverses it intensifies, becoming a resistance to further collapse. While the magnetic field primarily affects charged particles (ions), it hampers the overall contraction process. Astrophysicists have developed a concept called ambipolar diffusion to address this issue. Ambipolar diffusion describes how charged and neutral particles exchange energies, allowing the neutrals to gradually drift inward past the magnetically fixed ions.

The overall picture depicts a core undergoing preferential collapse along directions influenced by its rotation and magnetic field. New material accretes around the equatorial region, while excess material is expelled along the rotational axis in the form of jets. The rate of contraction is regulated in accordance with the core's ability to radiate away gravitational energy. Consequently, a protostar emerges, powered solely by gravitational contraction. Initially, the protostar remains obscured by residual gas and dust, with its spectrum dominated by infrared light emitted by the dust, which re-radiates the internal luminosity. Astronomers refer to such infrared-dominated protostellar sources as Young Stellar Objects (YSOs) of spectral Class 0.

Competitive Accretion is another process wherein neighbouring cores contend for unbound material in their vicinity. Turbulence within the cloud plays a significant role as cores interact and compete for available resources. Detailed animations showcasing this phenomenon are truly remarkable.

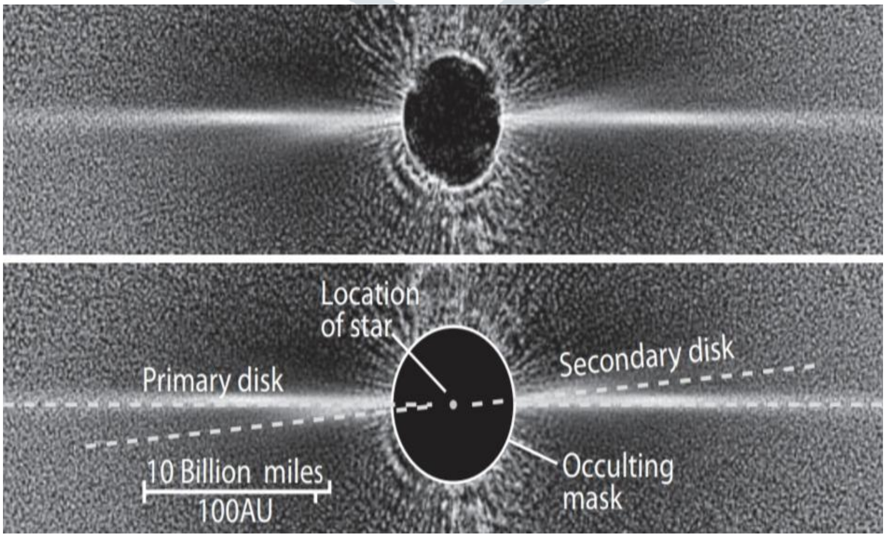


Trapezium Cluster Initial Mass Function

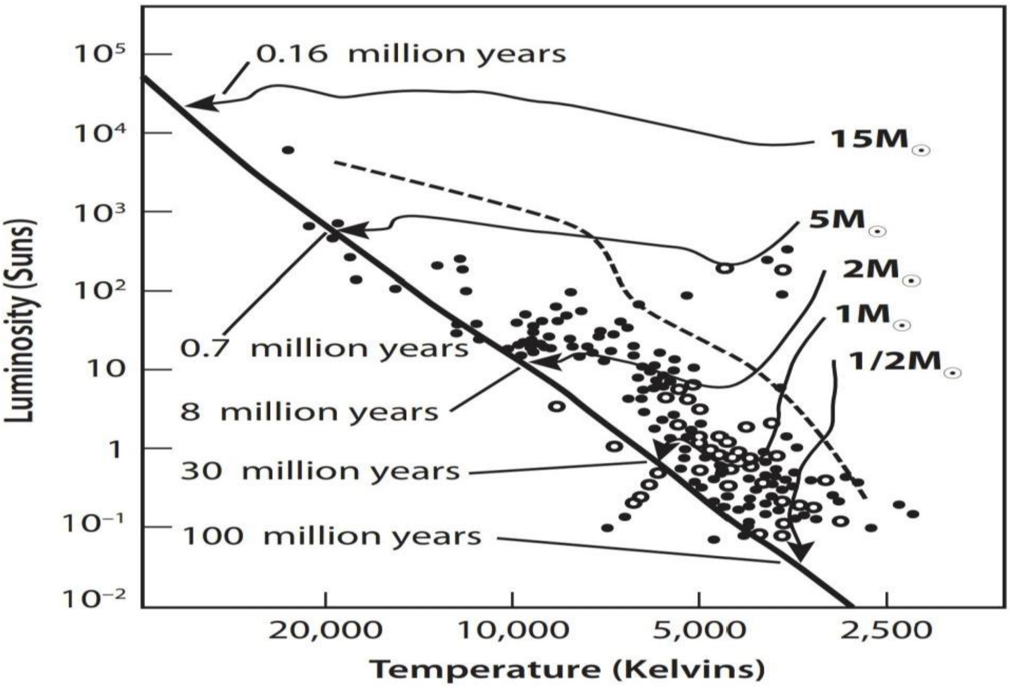
Observing the dynamic scenes of chaotic motion and competitive accretion, reminiscent of the skater's game 'crack the whip,' one can discern winners and losers. Remarkably, some newly formed stars are completely expelled from the stellar cloud.

As protostars and their surrounding accretion disks gradually stabilize, their spectral emissions begin to shift towards higher photon energies and shorter infrared wavelengths. At this stage, we can glimpse through the core and detect the light emitted by the accretion disk itself. The inner region of the dusty disk, located closest to the protostar, exhibits the highest temperature, resulting in emissions at the shortest infrared wavelengths. Astronomers can track this evolution by studying the resultant infrared spectra.

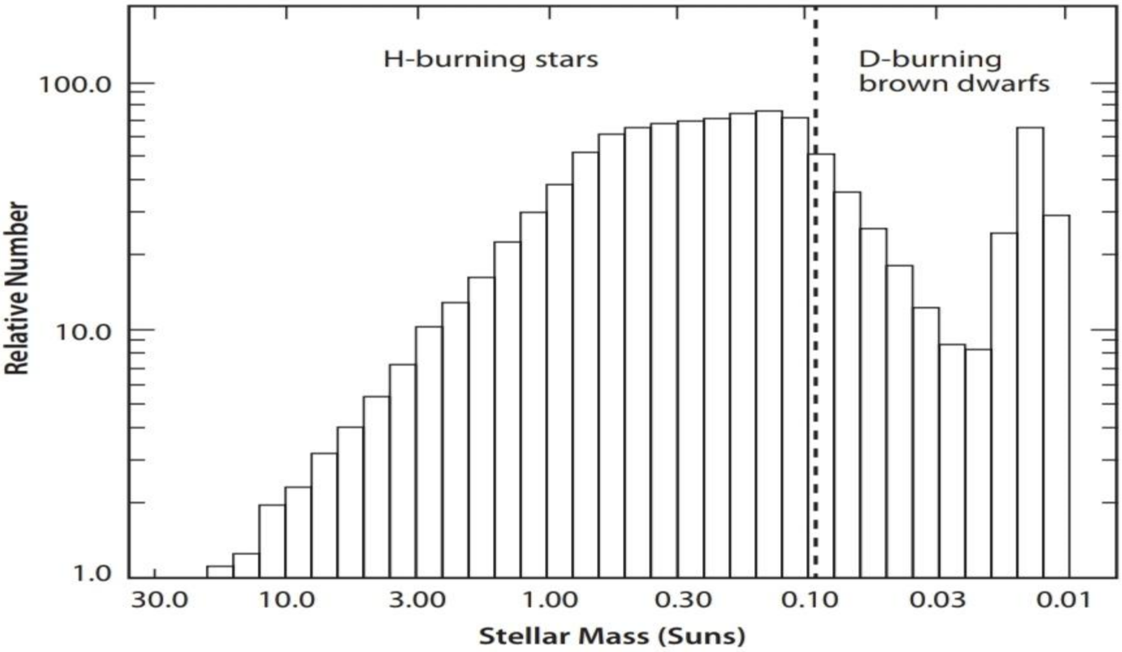
Once the young stellar object (YSO) becomes visible at near-infrared wavelengths, it is classified as a spectral Class I object. The YSO is still considered a protostar, with its luminosity solely powered by the infall and accretion of matter. In addition, some of these YSOs exhibit intense X-ray emission. This energetic radiation is believed to arise from the YSO's accreting disk and outflowing winds, associated with vigorous magnetic activity. In fact, one of the most effective methods for identifying YSOs among other stellar sources within a molecular cloud is through their X-ray emissions.



Disk clearing occurs when the YSO's winds and radiation eliminate any residual matter from its vicinity. These winds can be extremely powerful, reaching velocities of several hundred km/s (or millions of km/hr), and the mass-loss rates can be on the order of 10-5 times that of the Sun per year—equivalent to shedding two Earths annually, or a mountain range every second. However, these intense exhalations cannot continue indefinitely, as the star would eventually disperse itself completely within approximately 100,000 years. In the process of planet formation within the disk, the newly formed planets play a role in clearing the surrounding material. These planets gather and disrupt any gas and dust along their orbital paths, creating annular gaps within the disk. These gaps then modify the spectrum of the emerging light. When a gap is positioned close to the star, the absence of the hottest materials leads to a deficit of emission at shorter wavelengths.

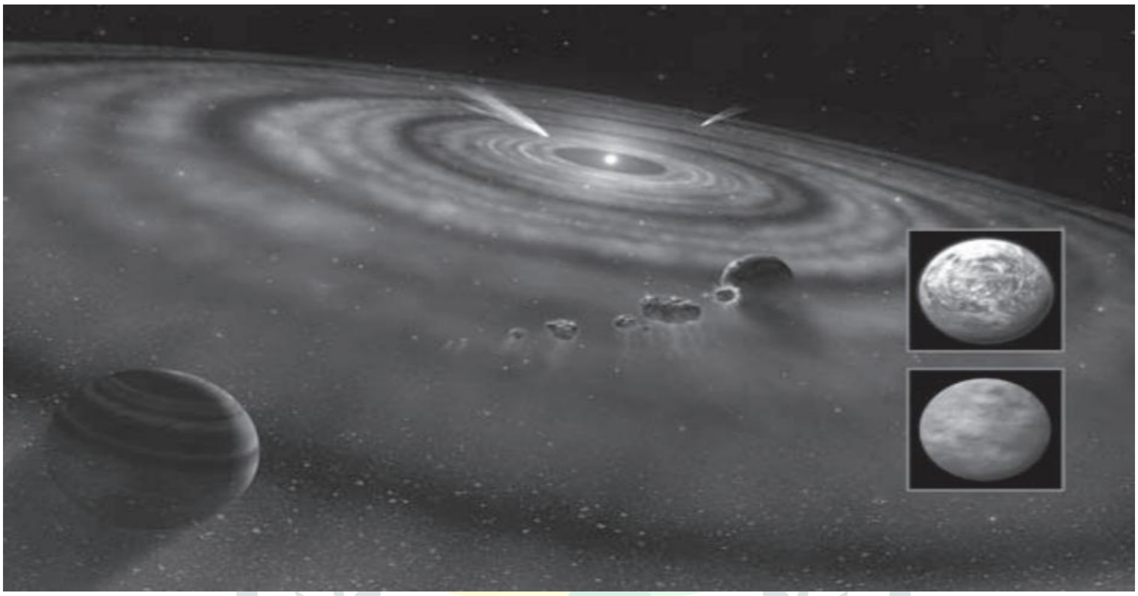


While human lifetimes may seem lengthy, they are still small when compared to the H-burning lifetimes of their main-sequence counterparts. The remnant disk surrounding each Pre-Main Sequence (PMS) star is no longer composed of its original gas and dust content. Instead, it consists of debris resulting from intense collisions among the previously formed planets. One prominent example of such a debris disk can be observed in the Bet a Pictoris system (refer to figure 6.4). PMS stars accompanied by debris disks signify the final stage of their developmental process. These systems exhibit no infrared excess in their spectra due to the



limited amount of dust available to absorb and re-emit the star's radiation. They are identified by their distinct characteristics of H-alpha, X-ray, and radio emissions, earning them the designation of Class III Young Stellar Objects (YSOs).

We can also consider the scenario where entire families of stars are formed together. Surprisingly, this is not an uncommon phenomenon. In fact, it is believed that the majority of stars originate as part of multiple systems. Some of these systems, such as binaries and more complex clusters, are clearly bound by mutual gravitational forces. Others, like the T-Tauri associations found in nearby molecular clouds or the OB associations discovered farther away, are more loosely distributed. These newly formed groups of stars hold significant value for astronomers, as they still retain a majority of their original stellar members. This allows them to serve as comprehensive snapshots of the stellar demographics present in star-forming regions.



Through meticulous measurements of stellar luminosities and spectral types within clustered regions, astronomers have derived reasonably accurate estimates of each star's mass. When these data are plotted in the form of a histogram, the resulting frequency distribution of stellar masses exhibits a characteristic shape (refer to figure 6.5). This distribution, known as the Initial Mass Function (IMF), provides insights into the probability of forming a star with a particular mass. It appears that stars with masses ranging from 0.1 to 0.6 times that of the Sun are most commonly produced. Some scientists propose that this preference for certain masses is influenced by the thermal pressures within the star-forming clouds. It is believed that an equilibrium exists between the internal pressures within the cloud cores and the external pressures exerted by the surrounding inter-core medium. In relatively small molecular clouds like Taurus or the Pipe Nebula near the galactic center, the ambient pressures favor the formation of cloud cores with masses several times that of the Sun. Accounting for a star-forming efficiency of approximately 25 percent, such cores would naturally give rise to stars within the observed sub-solar mass range.

Conclusion

Stars go through a remarkable lifecycle, undergoing various transformations based on their mass. Massive stars, for instance, culminate in spectacular events such as supernovae, giving rise to neutron stars or black holes. On the other hand, average stars, like our sun, experience a more tranquil finale as they evolve into white dwarfs, surrounded by a dissipating planetary nebula. It is intriguing to note that despite their differing sizes, all stars adhere to a uniform seven-stage cycle, commencing as a gas cloud and concluding as a remnant.

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