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Feature Article

Joana possesses impressive academic credentials, with experience in physics, mathematics and astronomy. She has worked as an explainer in planetariums and is involved in a social project centred on the diffusion of free software in schools.

Stars are formed in large clouds of gas and dust that are scattered throughout the cosmos. But how much of this process do we really understand? Is it the same for all stars? Are they produced one at a time? Is there anything that still puzzles astronomers? Using state of the art observatories and venturing away from visible light wavelengths, all these questions and many more besides can now be answered.

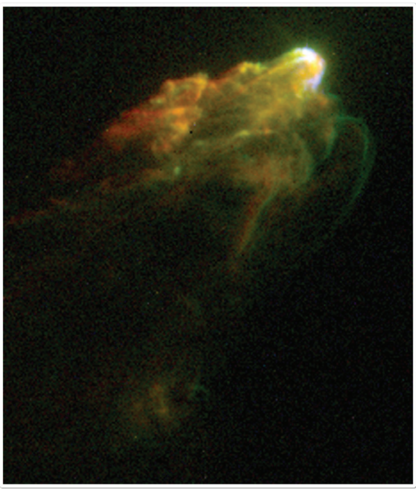
Stellar nurseries

Stars are formed in large clouds made up of vast amounts of gas and dust called giant molecular clouds, or GMCs for short. These all found all over our Galaxy, as is the case with most of the galaxies in the Universe. The formation process appears to be the same for all stars, with small, albeit significant differences depending on the final stellar mass. Under the action of gravity, turbulence and magnetic fields, the dust and gas begin to gather to form protostars that will grow in size as the material continuously accretes from the cloud to the star-to-be. The temperature and pressure in the centre of the protostar progressively increases until a point when it is hot enough to ignite the fusion of hydrogen, the most abundant element in the Universe, and in GMCs in particular. These nuclear reactions then become the main source of energy of the now adult star.

Stars are born in clouds of gas and dust, like the famous Eagle Nebula.
Image credit: Jeff Hester and Paul Scowen (Arizona State University), and NASA/ESA.

Stars like our Sun

The exact understanding of each step for the formation of individual stars differs according to their mass. Low-mass stars, like our Sun, take a considerable amount of time to reach adulthood, allowing them to be studied in detail. Over the years, astronomers drew a consistent picture that seems to apply to all low-mass stars, in which a small portion of the cloud gathers in the form of a cocoon around the protostar from which it grows. This cocoon, or envelope, then evolves into a flat disk, from which the star continues to grow, although at a slower rate. During this process the young protostar develops outflows from its poles in a direction perpendicular to the disk, that helps the rotating material from the disk to slow down and "fall" into the central star. As the outflows impact the surrounding cloud, they produce bright and colourful shocks forming the beautiful Herbig-Haro objects.



Young stars can emit high-speed jets of material. These were only discovered 20 years ago.
Image credit: J. Hester (Arizona State University), the WFPC 2 Investigation Definition Team, and NASA/ESA.

Deeper understanding

Massive stars form more rapidly and evolve into adulthood while still completely embedded in their thick cocoons, so they emerge from the cloud already fully formed. For this reason, the understanding of their formation mechanism has remained elusive for many years. Several theories involving, for example, the coalescence of smaller stars to form one more massive star have been proposed. But nowadays, based on better and deeper observations and crucial theoretical development, it is generally accepted that massive stars form in roughly the same manner as their low-mass counterparts, with accretion from an envelope and later a disk as the primary growth mechanism of the central seed or protostar. Their winds are naturally stronger and more energetic, causing a tremendous impact on the neighboring lower-mass stars and the left-over cloud.

Peering through the dust

Although it could in principle, star formation does not occur in isolation - rather than producing one star at the time, GMCs produce clusters of a few tens to over ten thousand stars spanning the entire spectrum of stellar masses. Interestingly, regardless of the number of stars formed or of the external conditions of the cloud, the percentage of stars of any given mass seems to be constant in all known star forming regions, as if nature followed always the same recipe for star formation. This is still a puzzle to astronomers today as it is not easy to envision a process potentially responsible for such a high degree of homogeneity over

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such a wide range of cluster masses, but the answer is slowly emerging from the constant technical improvement of the observing facilities.

During their first million year, star clusters are invisible to traditional telescopes (those working in visible light, the light our eyes are sensitive to) because the newly born stars are still inside the cloud, heavily obscured by the circumstellar and ambient dust. Only in the late '80s, with the advent of telescopes sensitive to infrared light, were the first young clusters ever observed, as infrared radiation can pierce more effectively through the obscuring dust than the visible light. Since then, and mainly in the last 10 years, telescopes bearing increasingly more advanced detectors have made it possible to study the early stages of star formation. As the massive stars begin to form and ignite their powerful winds, the gas and dust still left in the cloud are blown away and the cluster reveals itself in visible light. This happens around an age of 5 to 10 million years, a blink of an eye for astronomical standards.

Infrared radiation penetrates gas and dust, letting special telescopes obtain outstanding views of young stars.
Image credit: Joana Ascenso.

Finding pieces of the puzzle

My job as an astronomer is to contribute to the understanding of these star forming regions using state-of-the-art observations in the near- and mid-infrared. Being a remote science, the understanding of light, be it in the form of photographs or spectra, is crucial. A simple picture can tell a rich and enlightening tale of the star formation process, and its thorough analysis can be of invaluable importance for finding the missing pieces of the puzzle and putting them in the appropriate context. I am especially interested in the study of the global properties of star clusters - why different clusters share so many similarities, where in a cluster planets form and how they survive the presence of the destructive massive stars, or whether and why massive stars appear to concentrate on the cluster cores -, and, more recently, in the study of dark clouds, the precursors of stars and clusters.

Star clusters provide more than just pretty pictures; the information gained from studying them is very important for astronomers.
Image credit: Joana Ascenso

As technology evolves, we will be able to probe the most difficult and unknown episodes of star formation - those that occur in the earliest of ages, deep inside the cloud and that were up to now hidden from our view and discovery. A myriad of telescopes providing unprecedented quality and coverage of the electromagnetic spectrum are soon to be completed, making these very interesting times for the study of star formation. Soon, it will be possible to study the obscure processes occurring inside the clouds in great detail, in a promise to revolutionise our theories of the mysterious formation of stars and planets from giant clouds of gas and dust. I have no doubt Galileo would be thrilled and inspired had he lived to see our days.

This feature article was written as part of the Cosmic Diary Cornerstone project for the International Year of Astronomy 2009. To find out more, check out www.cosmicdiary.org and www.astronomy2009.org.