Feature Article

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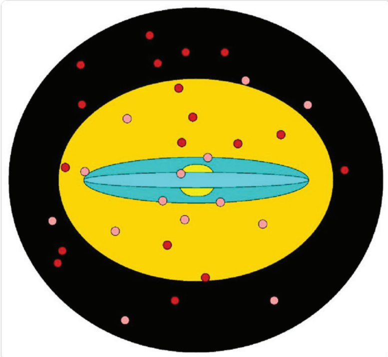
Gayandhi's childhood was spent travelling around the Middle East and South East Asia with her family. She migrated to Australia in 1994, which is where she grew up. After enjoying a summer vacation at the Siding Springs Observatory in Coonabarabran, she chose observational astronomy as her professional career. Gayandhi obtained her PhD in Astronomy from Mount Stromlo Observatory, part of the Australian National University. She is currently an ESO fellow based in Garching, where she works with the User Support Department. Outside the office she is the busy mother of two little boys.

Despite decades of study into galaxy formation, we still have only a crude picture of how galaxies like our own Milky Way came to exist. Much detail on the physical scenarios is still missing and understanding it requires the joint effort of observations, theories, and complex numerical simulations. The newly developed technique of chemical tagging offers the possibility to reconstruct the original building blocks of our Galaxy, thereby providing an observational tool to develop the sequence of events that led to the Milky Way as we see today.

How did our Galaxy form?

The Milky Way is a spiral disk galaxy, with several distinguishing components which are the results of different formation and evolutionary processes. These parts are seen in other spiral galaxies, and are not unique to the Milky Way. The major components include the dark matter halo, which is thought to have assembled first, initiating and driving the galaxy formation process; the stellar halo, which is the oldest stellar component of the Galaxy and hosts most of the very massive and dense globular clusters; the central bar which is also referred to as the bulge when the Galaxy is viewed edge-on from the side; and the stellar disk, which can be split into two sub-disks – thin and thick disks. The stellar disk is the defining component of all spiral galaxies including the Milky Way. Therefore understanding how the galactic disk formed is fundamental to understanding galaxy formation. That said, the disk is also the most difficult component to study as it is constantly evolving, undergoing numerous evolutionary processes, with new stars being formed and mixed into the background field.



A schematic diagram of the Milky Way today, showing its main components. The black region represents the dark matter halo. In yellow is the old stellar halo containing the oldest stars in the Galaxy. The disk is represented in blue, with the thick disk in dark blue and thin disk in light blue. In the centre in light yellow is the bulge and the small red dots represent the distribution of dense globular clusters in the Milky Way.
Image credit: De Silva, G., (2006), PhD Thesis, Australian National University.

A currently popular model for galaxy formation is one of hierarchical aggregation, where smaller independent structures join forces to form the larger structures. Within this hierarchical structure formation model, the details of the formation and evolution of our Galactic disk is poorly understood, due to the complexity of the factors involved.

Chemical Tagging the Galactic Disk

Ubiquitous throughout the disk and woven through the background field stars are star clusters which represent the birth sites of stars. These disk star clusters are referred to as galactic or open clusters. However, open clusters lead a life of uncertainty between survival and disruption. Most open cluster stars will dissolve and disperse into the Galaxy's background, like children in a family growing up and eventually leaving home. Therefore most bound star clusters that we see today are young cluster, such as the Pleiades.

Infrared image of the Milky Way taken by the DIRBE instrument on board the Cosmic Background Explorer (COBE) satellite. Image credit: NASA Goddard Space Flight Center and the COBE Science Working Group.

However, a few old open clusters also exist in the disk. These rare old open clusters can be regarded as fossil structures and are witnesses of the formation history of the Galactic disk. Studying the chemical properties of these old fossils show that all stars within the cluster share the same chemistry, meaning that the member stars have the same signature in the form of chemical abundance patterns. This chemical signature acquired at birth is preserved within the stars throughout their lives, except in particular cases such as binaries, variables or very massive stars. Most other stars should retain their original chemical signature despite their travels around the Galaxy. Therefore we can use this chemical signature as a tag to identify the origin of a given star in the Galaxy. This technique is now referred to as chemical tagging.

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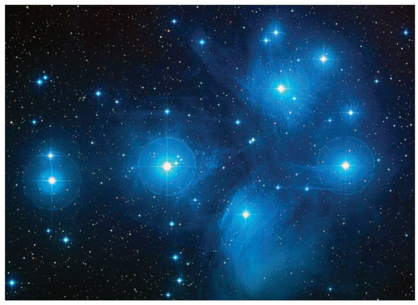
Untangling our Milky Way Galaxy

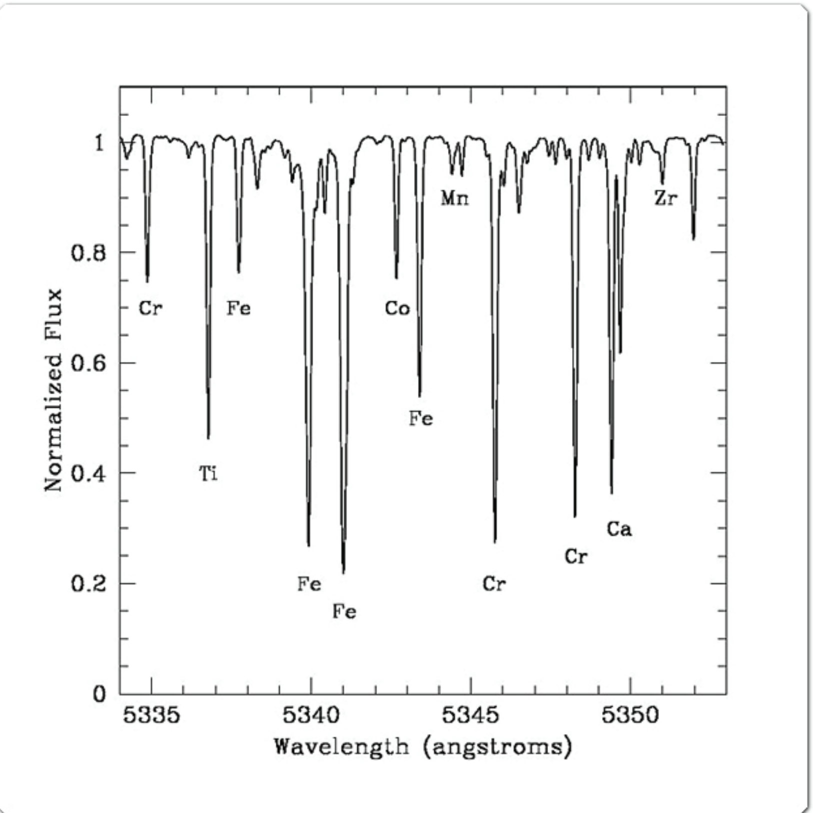
While members of most star clusters have now dispersed into the field background, we can use the chemical tagging technique to trace them back to their original birth site, thereby reconstructing the lost fossil clusters of the Milky Way disk. To study the chemical signatures we require high quality spectra. Instruments such as the Ultraviolet and Visual Echelle Spectrograph (UVES) available at the 8m Very Large Telescope (VLT) and the High Resolution Echelle Spectrograph (HiRes) available on the 10m Keck telescope, provide the high resolution and high signal data that is required to measure very accurate elemental abundances. The abundances of numerous elements can be measured from the absorption line features in the spectra in order to establish the stars' chemical signature.



The well known Pleiades cluster is a young open cluster with an age of about 100 million years. As the cluster travels around the Galaxy, its member stars will eventually disperse into the Galaxy background.
Image credit: Digitized Sky Survey.

Tracing the Solar family

Just like DNA can be used to trace the ancestors of one's family tree, the chemical tagging technique can be used to recover the original family members of our Sun. Although our Sun is now a single star, it was born in a star cluster. The other siblings which are now located elsewhere in the Galaxy can be traced by looking for their unique chemical signature. Finding other stars that share the exact same chemical make-up as the Sun is one of the goals of chemical tagging.



A region of the solar spectrum with several elemental line features. By measuring the depth of the absorption lines astronomers can derive the abundance of the different elements.
Image credit: Observed with UVES on the VLT.

The long term goal of chemical tagging is to reconstruct the ancient building blocks of the Galactic disk. By reconstructing these original clusters we will get insights into the formation and evolutionary processes, such as the rate of star formation, or possible accretion of smaller external galaxies. This will enable us to develop a sequence of events of how the Milky Way came to be as we see today. The currently available instrumentation on ground-based telescopes are able to provide data on the nearby regions of the disk. They are not sufficient to perform large-scale chemical tagging of the entire Galactic disk.

This field of research will be greatly boosted by the upcoming Gaia mission of the European Space Agency. Gaia is set to be launched by 2012 and will provide data for about one billion stars in our Galaxy. There is much to look forward to in the future.

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.