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Tracing the history of the Milky Way

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We all ? even those of us who live in rural areas ? live in a great city, one made of stars, our Milky Way galaxy. You can even see it on a dark night away from city lights, a vast, dense cloud of billions of stars that arches from horizon to horizon.

It wasn?t until 1923 when astronomer Edwin Hubble and others discovered that hazy nebulae that observers had been looking at for hundreds of years were not actually within our own galaxy, but were galaxies in their own right. Now we know there are hundreds of billions of galaxies in the universe.

Our own was born some 12.3 billion years ago, about one to three billion years after the Big Bang itself.

We are learning more and more, especially in the last ten years or so, about how the Milky Way formed and evolves. Like other spiral galaxies, our Milky Way has several distinct structural components that probably appeared at different stages in its formation process. The stars belonging to each component have distinct chemical compositions, and they move through the galaxy in distinctive ways. Such differences hold important clues about how the Milky Way formed and develops.

Stellar motions through the galaxy can be influenced by a variety of processes, just as comets and asteroid orbits can be changed abruptly by encounters with other bodies. A lot can be determined about galaxy formation by how these motions are influenced.

By contrast, chemical composition of a star?s outer layers is, for the most part, preserved from birth. Thus, chemical abundance ? the amounts of various chemical elements seen in the spectra of stellar atmospheres ? can provide a clearer picture of what happened in the past. Chemical composition of stars is a kind of fossil record of what happened in the past.

Studies of the kinetic and chemical properties of stars is how we learn about galaxy formation and development. Such studies will take a giant leap forward when the European Space Agency?s Gaia satellite launches in a few years. Gaia will census the distances, motions, chemical compositions and many other properties of stars halfway across the galaxy.

But those who study our galaxy aren?t waiting for Gaia. Ambitious surveys using ground and space-based telescopes are underway and new discoveries are reported almost daily. What follows is a quick summary of some of those discoveries.

Stars are not only sources of light and heat, they are the factories where most chemical elements are produced. We now know that only a few species, such as hydrogen, helium, deuterium, helium and lithium were synthesized during the Big Bang, while almost everything else has been manufactured since then inside stars.

A star?s death is important because it is then that most of the chemical elements produced during its life are ejected into the interstellar medium as the gas that exists between stars. These elements are then mixed with the gases already present, and they increase the interstellar medium?s overall metallicity ? its percentage of chemical elements heavier than hydrogen and helium.

We?re talking here about carbon, sodium, potassium ? the very elements out of which we are made. We literally would not be here unless an earlier generation of stars had not lived out their lives and died, producing the materials for making new stars and planets.

The Milky Way galaxy can be described as a flattened disk of gas and stars with a bulge at the center. The bulge and the disk are both surrounded by a spherical halo made of old stars, globular clusters, and still-mysterious dark matter.

By analyzing the abundance ratios in stars belonging to the halo, the bulge and the disk, astronomers already have seen clear indications that in the halo and the bulge, star formation peaked in the distant past and has been very inefficient afterward. By contrast, stars have formed at a less intense but almost constant rate in our galaxy?s thin disk.

There are many pieces of evidence that our galaxy did not evolve in a ?closed box,? sufficient unto itself, with no new material being incorporated since the initial formation event. In 1994 a dwarf spheroid galaxy that is effectively merging with our galaxy was discovered. Other accretion debris is being found in our galaxy?s halo in the course of several ongoing surveys.

Our galaxy?s central bulge is difficult to observe, as it is almost entirely hidden from view by dust in the Milky Way?s mid-plane. The data now available show that metal abundances range widely among bulge stars, but that the bulge is dominated by old stars. However, new stars formation has been observed and suggests that element-rich gas may have been pushed toward the bulge.

The thinking now is that star formation happened fast and furiously when the Milky Way was very young, then halted for a few billions years when gas density fell off, then picked up again. Our own sun has about five billion years left in its life span.

Galaxy formation is complex, and we are still missing many of the pieces needed to complete the puzzle. Some questions will be answered by Gaia?s exploration in the near future. With Gaia we will actually be able to leave the sun?s neighborhood and get, for the first time, data on chemical abundances throughout the disk and halo of the Milky Way.
