New chemical clues shine a light on galactic evolution

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Researchers use atomic data to measure distinct cosmic elements

In a new study, a team of astronomers has identified wavelengths of light that could be useful for tracing the chemical evolution of the universe.

Using computational modeling to simulate how electrons interact with manganese ions — an element produced during stellar explosions called supernovae — researchers predicted how different environmental conditions could produce types of observable light called emission lines.

They found that certain emission lines were extremely sensitive to changes in the temperature and density of the surrounding nebula, meaning they could be useful tools for analyzing rapidly expanding objects like supernova remnants and other large gas clouds, said Anil Pradhan, co-author of the study and a professor of .

Anil Pradhan

“If we understand the chemical composition of galaxies, we can learn more about the chemistry of stars and their elements,” said Pradhan. “That will eventually lead to understanding the evolution of the universe and the composition of everything within it.”

The study was recently published in *The Monthly Notices of The Royal Astronomical Society.*

Stellar explosions play a crucial role in the formation of heavy elements like iron and other metals, which are essential to the evolution of stars, planets and other cosmic objects. Manganese is a key element because its abundance increases over time, meaning that researchers can use it as a cosmological clock to learn more about how galaxies evolve.

“Space and time are related, so measuring manganese abundances can grant us insight into the ever-expanding nature of the universe,” said Pradhan. “By combining this emission line data with other known facts on important elements like oxygen and sulfur, we may be able to view some of the earliest observable epochs in the history of the universe.”

Still, depending on their strength, faint emission lines can be extremely difficult and time-consuming to detect. To overcome these limitations, Pradhan and his colleagues employed powerful computing systems to model the behavior of more than 700 potential emission lines using atomic physics calculations that would otherwise have taken years to complete.

Though their work is still theoretical, the findings suggest that once paired with real-life astronomical observations, these conclusions could even be used to predict the conditions of other types of complex space environments, said Pradhan. Moreover, understanding manganese’s role in the cosmos could help scientists predict the universe’s chemical future.

“We’re getting better and better at capturing energy that reveals the shape of the universe,” said Pradhan. “This work joins astrophysics, atomic physics and plasma physics together, and we’re on the cusp of discovering many brand new processes.”

The team plans to verify their data using the James Webb Space Telescope and other ground-based observatories specialized in detecting chemical variations across time and space. The results from this work will also be made publicly available so that researchers can compare their datasets with novel atomic analyses, laying the foundation for similar chemical discoveries.

This work was supported by the National Science Foundation and partially carried out at the Ohio Supercomputer Center. Co-authors include Sultana Nahar from Ohio State and first author Zher Samak from Al-Aqsa University in Gaza, Palestine.

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