Look Into the Heavens, Look Into the Past

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Imagine stepping out onto a balcony at night and look at the sky. There are no clouds or dirty air, and you can see many stars, nebulae, planets, and galaxies! You might think about how beautiful the sky is! However, you can see not only the beautiful starry sky but also the history of our universe. Why? Because light has a limited velocity. We perceive light as being transmitted instantly, but since its velocity is 300,000 km/s, there is a delay between its emission and its arrival to us. For example, it takes 8 minutes for light to travel from the Sun to Earth! (Technically, we use the unit “light year (lyr)” as a distance in which light takes 1 year to travel.) Remember this fact and look at the sky again. Among many stars, many galaxies are millions of lyrs away from Earth (unfortunately, we cannot see them with the naked eye because they are so faint). In other words, galaxies show us their past shape! That is why I mentioned that

you can feel the history of the universe. If you look at a faraway galaxy, you can see a past landscape of the universe.

According to this principle, many astronomers explore the history of the universe by observing galaxies. The James Webb Space Telescope (JWST) has enabled us to observe the universe from over 13 billion years ago. This technical advance and ongoing exploration have raised new questions in astronomy. Specifically, “What is the origin of heavy elements?” For a long time, it has been believed that heavy elements (elements whose atomic number is larger than 2), produced by the nucleosynthesis process of hydrogen and helium gas in stars, were dispersed by supernovae (explosion of stars when they ‘die’). However, JWST observation revealed that many galaxies in the past showed different heavy element abundance ratios from those produced by supernovae’s dispersion [1]. Therefore, astronomers suggest that several candidate stars and processes may contribute to these unusual elemental abundances. That is my interest “Which factors play a critical role in galactic chemical evolution?” I am currently investigating this enigma through galactic simulation using a supercomputer.

Let me talk about my background that led me to this research topic. Since I was young, I have had a keen interest in space. In my childhood, my favorite celestial object was the Andromeda galaxy because it is the largest system visible to the naked eye in the sky. After learning a bit about galaxies in elementary school, my interest grew because I found galaxies, which produce stars, planets, and heavy elements (e.g. materials of our body), mysterious. As a junior student, I participated in a workshop and analyzed JWST data. During this workshop, I examined the “color” of distant galaxies to determine their elementary abundance. How? The principle is straightforward: Each element emits unique colored light. By calculating the strength or faintness of each color, we can reveal the abundance ratio of each component. Through this experience, I was impressed by our ability to calculate the chemical data of distant objects. After the workshop, I read a paper about the strange chemical abundance ratio of distant galaxies mentioned above, and I wanted to address this question. However, because a galaxy is a chaotic system that includes many kinds of stars, I thought using simulation would be a good way to explore what happens in galactic evolution. Now I am conducting a galactic simulation that includes the effect of stars, dark matter (unknown substances!), and gas to observe how heavy element abundances increased in past galaxies.

Three suspects may produce a unique galactic chemical abundance. The first and the second are certain types of stars named Wolf-Rayet stars and Supermassive stars (whose weight is over 10,000 times heavier than the Sun!). And the third one is a tidal disruption event (an event in which a black hole disrupts a star due to its gravity) [2]. When I was a child, I learned from books that supernovae disperse heavy elements, so I thought supernovae were our origin. However, the latest observation and my research in galactic simulation reveal that heavy elements were dispersed by another process among the three. If that is the case, our understanding of the universe will be dramatically shifted. Many textbooks would be revised! Many astronomers around the world observe the sky and calculate to uncover the true history of the universe. From just faint light from distant galaxies, we can explore the long history of the universe, and eye-opening discoveries may emerge. This is an interesting and exciting thing in astronomy. Nowadays, many high-resolution telescopes such as JWST and TAO open windows to the distant (e.g. past) universe. We are currently experiencing a paradigm shift. Luckily, we can be a witness of it. Why not become part of this vision of humankind's exploration of the universe?

References

[1] [2] Isobe, Yuki, et al. "JWST Identification of Extremely Low C/N Galaxies with

[N/O]≳ 0.5 at z∼ 6–10 Evidencing the Early CNO-cycle Enrichment and a Connection with Globular Cluster Formation." *The Astrophysical Journal* 959.2 (2023): 100. [**arXiv:2307.00710**]

Graphics are cited from いらすとや.

I used ChatGPT and Grammarly to correct grammar.

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