Gazing at the remains of stars in the night sky

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There are faint lights in the sky, they are named stars. Long ago, humans wondered about those stars. People looked up at the sky, and from the shining stars in the night sky, they wove many stories and myths. The stars also served as guideposts, helping the people of ancient times. But the star was not only a point of light. Galileo Galilei made his own telescope and observed the sky. He realized there are many types of stars, moons, planets, suns, star clusters, and galaxies. Many types of celestial bodies crowded the sky, shining brightly.

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However, the light from these celestial bodies was not solely visible; it also included various forms of electromagnetic radiation invisible to the naked eye. In the late 19th century, Wilhelm Conrad Röntgen discovered X-rays, which are not visible to the eyes. In 1912, Victor Franz Hess fond cosmic rays, which comes from outer space, outside of the earth. The cosmic rays are somewhat containing a lot of energy and come from everywhere in the sky. In 1962, Ricardo Giacconi made the first observation of a star using X-rays. Then found a lot of celestial bodies are emitting x-rays.

X-rays cannot pass through the atmosphere, so to observe them, we must go to space. However, humans cannot live and be active in space for long periods of time, so we must send telescopes to observe the stars instead. A lot of telescopes have been sent to space. The most popular space telescope is the Hubble Space Telescope, but it cannot observe X-rays. Each space telescope (and other telescopes) has its own visible range, and the Hubble Space Telescope can

only observe visible light. The most famous X-ray observing telescope is the Chandra X-ray Observatory, a satellite over 20 meters in length!

Until recently, many stars have been observed, and many things have been discovered. We can determine the abundance of elements in galaxies. We can now observe the remnants of radiation from the Big Bang, which is known as cosmic background radiation. However, the origins of cosmic rays and elements remain uncertain. The key to understanding this mystery is X-ray observation.

It is said that the origin of cosmic rays must be the supernova remnants (SNRs for short). SNRs are the remains of the supernova explosion. When a star (like our sun!) ends its life, sometimes a large explosion occurs, which is the supernova explosion. The supernova explosion is so bright that it can be easily seen from Earth. The bright star (which had exploded!) suddenly appears in the sky and often astonished people in ancient times. The oldest record of a supernova explosion is from 185 CE by Chinese astronomers.

Elements can only be created by nuclear fusion reactions, and this process requires a lot of energy, so the elements were created in the center of the star. However, even in the center of the star, elements heavier than iron could not be created. A supernova explosion is so massive that it emits more energy than ten times the energy which the sun emits in its lifetime. Thus, many elements heavier than iron are believed to have been formed by supernova explosions. Therefore, by investigating the SNRs, we can gain a deeper understanding of the origin of matter.

It is important to observe these supernova explosions because we can’t reproduce their procedure. However, a supernova explosion is a rare and sudden event, and it presents a lot of difficulties to observe these supernova explosions directly. What we can only observe in detail are the remnants left from a supernova explosion, which are SNRs. SNRs are beautiful and dynamic celestial bodies. There are a lot of types of SNRs, and none of them are the same. SNRs are merely the remnant of the supernova, but they have a lot of energy, and their properties vary by their age, size, and material.

I love SNRs because they are beautiful and are key to understanding the origin of matter. SNRs are not just beautiful celestial bodies; they hold many mysteries. When a supernova

explosion occurs, a lot of energy is emitted as shock waves. These shock waves expand, even tens of thousands of years after the event, creating the massive structure of SNRs. This shock wave somehow accelerates electrons, meaning the electrons absorb a lot of energy from these shock waves. It is said that the energetic structure of the shock wave front accounts for this electron acceleration. And it is believed that this event is the source of cosmic rays, though the process remains uncertain. I want to uncover these mysteries.

Revealing the physics of SNRs can also provide a deep understanding of high energy physics like plasma physics. Plasma is a hot, ionized gas where electrons are separated from atoms. SNRs contain a lot of plasma, and this plasma is actively reacting. Plasma physics is important because it can be applied to many fields of physics and technology such as nuclear fusion reactors. Through a nuclear fusion reactor, elements lose a small amount of their mass. And mass has a lot of energy as Einstein found (as you know, E=mc^2!). So, energy can be extracted from matter through nuclear fusion reactions. But nuclear fusion reactions are highly energetic and unstable. One way to stabilize nuclear fusion reactors is to use a magnetic field to control the plasma inside the reactor. Nuclear fusion reactors emit a lot of energy, so they are expected to be a cutting-edge technology to solve the energy problem.

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