STAR DEATH, STAR BIRTH

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Ken Tapping, 4th June, 2024

In the year 1054, observers around the world noticed a new star in the sky. Over days it brightened until it was visible during the day, and then, over the ensuing months, it faded to invisibility. Today, telescopes reveal an expanding cloud of gas. In the core of that cloud is a strong radio source and a pulsar, the remains of the star, compressed down to a diameter of a few kilometres, rotating rapidly and radiating beams of radio waves and X-rays. That expanding cloud is now known as the Crab Nebula. It lies some 6500 light years away. The event the ancient astronomers observed was a supernova, the collapse and explosion of a dying giant star.

In the years after the Second World War, many countries built radio telescopes. They showed bright radio emission from the Milky Way, and a number of bright sources. The Crab Nebula was one of them. Back then most radio telescopes were huge dishes, like the 75-metre diameter dish at Jodrell Bank, UK. These could determine the direction the signals were coming from, and by scanning them to and fro, make radio maps of the sky. However, these big dishes weren't big enough to see structural details in those sources.

Today things have changed. Although it is still technically very difficult to make large, single dish radio telescopes, we can make far bigger radio telescopes out of large numbers of small, relatively cheap antennas. Thanks to modern signal processing and imaging techniques, we can make radio images of large areas of the sky with better detail than the human eye or even many optical telescopes can achieve. What these technical developments are showing us is stunning. We now have "radio eyes" and can see how the sky would look if we could see radio waves instead of light.

Where our optical telescopes would show black space, stars and maybe a wisp or two of cloud, the radio view shows huge, complex clouds and other structures. There are particularly dense clouds where new planetary systems are forming. Most of this material has been around since the beginning of the universe. Scattered in these clouds we see the remains of numerous exploded stars. Some of these remains, such as the Crab Nebula, have complex shapes. However, many are more or less spherical bubbles, voids with glowing skins. When the star exploded, it blew away the surrounding cloud material, which piled up against the surrounding cloud, forming the glowing shell. Sometimes we see a pulsar or some other remnant of the dead star in the middle.

Supernovas are endings, but they are also beginnings. That expanding shell of material ejected by the exploding star contains the waste products from a lifetime of energy production, which includes all the elements from the lightest to iron. In the explosion all the heavier elements were produced. This material goes out and mixes with the clouds, providing the raw materials for planets and people. The explosions also cause something else. They can destabilize clouds, making them collapse to form new stars and planets.

Those clouds exist in an environment of magnetic fields, radiation pressure from stars and the interplay of weak gravitational fields. As long as these more or less cancel out, the clouds remain, slowly changing shape over time, maybe for millions of years. However, if that balance is disturbed by causing a little bit of a cloud to increase in density, that concentration starts to gravitationally pull in other material, leading to a local collapse and the formation of new stars and planetary systems. An ideal agent to make these density enhancements and local compressions of the cloud material is the supernova explosion. Without them the universe would be very different.

Just before dawn, look for Mars low in the dawn glow, and Saturn a bit higher and further to the west. The Moon will be New on the 6th.

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