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This is the End!

12.1 The Death of the Sun

Our star has been considered as a god throughout the many centuries of human existence. It was Ra for the Egyptians, Helios for the Greeks, Sol Indiges and Sol Invictus for the Romans, Inti for South America's Incas, and something else in each of the ancient cultures. Now, in this last chapter, a name will be needed for the necrology of the Sun. Perhaps, Sol would be appropriate, like the ancient Roman Sun god Sol Invictus. An important name for an important star. As previously mentioned, our star was born in an interstellar cloud of dust and gas. Such is the nursery of all stars, including "Sol." Stellar nurseries are abundant in the many galaxies of the Universe. All stars are born in the same way (Fig. 12.1).

Sol is now in the middle stage of its life, and like everything in the Universe, it is finite and will eventually die, a natural ending for all evolving beings. Nothing lasts forever, and that includes the Sun. It will die when all its helium has been used up, at which point it will shrink and become a white dwarf, blasting its outer layers into space and leaving what is misleadingly known as a "planetary nebula." This is a much-abridged description of the death of such an important star as Sol, life-giver to all the inhabitants of planet Earth. But humans will not be present to witness its death because most astronomers estimate that our Sun has probably five to six billion years left to live, while others estimate even longer before it dies. At any rate, we are talking about a very, very long time, so humanity is not going to witness this disaster. Although we cannot predict that for sure, it seems likely that by then humanity will be long gone.

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Fig. 12.1 Stellar nursery. Acrylic paint on canvas and stars in fused glass. In this painting, I imagined a goddess taking care of new born stars

Astrophysicists can say fairly precisely how the death of our star will come about. It will eject a large mass of gas, called the envelope, into space, revealing only the core of the star. At this point, the nuclear fuel which kept the Sun alive will run out, and our star will die. But before this, it will go through different stages and transformations. In five billion years from now, it will become a red giant, and this is when the core of the Sun will shrink and the outer layers will expand, engulfing the nearby planets. Mercury and Venus will thus be destroyed. The Earth should survive the destructive force of the Sun, but it will no longer be inhabitable.

Indeed, the online publication ScienceAlert suggests that humans have only one billion years left to live comfortably on Earth, since the Sun gets brighter and hotter by about 10% every billion years. This means that, even a billion years from now, there is a real possibility that life on Earth will have come to an end. With such enormous heat, everything will burn, the oceans will evaporate, and the surface will become too hot for any possibility of supporting life. But the Sun will continue the transformations leading up to its death.

From a red giant it will become a white dwarf, and after exhausting all its fuel, it will expel its outer material, and create a so-called "planetary nebula." Only the hot core of the star will remain. At this point it will become a very hot white dwarf, at a temperature of 100 000 K. From there, it will very gradually cool down over the following billion years. Its mass will shrink to half of the previous mass of the Sun, but it will be 200 times as dense. A white dwarf is among the densest objects in space, surpassed only by neutron stars and black holes. According to NASA, the gravity on the surface of a white dwarf would be some 350 000 times as strong as we feel here on Earth. So, a person weighing 68 kg on Earth would weigh over 22 million kg on the surface of a white dwarf.[1]

At this final point, our dear Sol would in no way resemble the Sun god adored by so many different human cultures. Eventually, after its death, Sol will turn into a "planetary nebula," a kind of solar corpse. So, now, it looks like the biography of the Sun is definitely finished, and, as in the old movies, all that remains to say is "THE END"! (Fig. 12.2).

12.2 Not Quite!

Actually, it's not quite the end yet, because, as scientists always point out, energy does not just disappear: it transforms. So, there are more questions to be asked. What happens to the stellar remnants, and to the transformation of the Sun? The answers to those questions belong to cosmology and theoretical physics.

Horst Stöcker, Professor Laureatus for theoretical physics at the Goethe University Frankfurt, the Frankfurt Institute for Advanced Studies (FIAS), and the GSI Helmholtz Centre for Heavy Ion Research, explains how our Sun

[1] Scientists think there might be a crust 50 km thick below the atmosphere of a white dwarf, and it may be that, at the bottom, we would find a crystal lattice of carbon and oxygen atoms. Scientists even compare such a carbon–oxygen white dwarf with a very large diamond! But at that point, who could possible care how many diamonds could be found at the center of a white dwarf.

Fig. 12.2 White dwarf. In this painting, I imagined how the Sun could shrink into compact object called a white dwarf. Oil paint on canvas with bright metallic fused glass

and the other stars finally die. Once the nuclear fuel in a star is exhausted, it will become either a white dwarf, a neutron star, or a black hole. This represents the final stage in the evolution of any star. Our own star, being a low to intermediate mass star, will return most of its mass to interstellar space and become a white dwarf. Ninety-five percent of the stars in the Milky Way will become white dwarfs. In the case of a massive star, the stellar remnant is initially a proto-neutron star. During its evolution—stellar evolution is the process by which a star changes over the course of time—neutrinos are

produced abundantly in the nuclear reaction. In these stages, they can easily escape from the star, but when the core collapses, the neutrinos trapped inside can cause a violent explosion and the star becomes a supernova. In some cases, when the explosion fails, or does not manage to expel enough mass, the process continues, until the gravitational collapse results in a black hole.

The mass lost by stars plays an important role for stellar evolution, and also in the chemical evolution of our galaxy. According to Professor Stöcker, the mechanism of mass loss of evolved stars is not yet fully understood.

So, the Sun will disappear from the sky in that way, but astrophysicists mention the encouraging fact that it will continue to exist in some sense through its interaction with matter in the Universe. Energy does not just disappear. It gets transformed. In that case, it will still be there as a kind of invisible ghost, as the white dwarf slowly fades away.

It turns out that the smallest stars take longer to fade away, because they burn slowly, and can live up to 100 billion years. This is somewhat paradoxical, because it is much longer than the current age of the Universe. The lifetime of a star depends on its mass, and can range from a few billion years for the massive ones, to trillions of years for the least massive, which may still be around at the very end of the Universe.

It's not easy to grasp the concept of the unlimited conservation of energy. Is energy really immortal? Some physicists hypothesize that the energy can gradually decrease until it becomes very faint, thereby decreasing in quality the dynamic of the cosmos, gradually spreading out, but never lost. Others imagine the end of the Universe to be an ocean of photons. The ultimate fate of the cosmos is unknown, of course, but there is plenty of speculation. Maybe, there will not be much left besides cold, dark space stretching into the void, and certainly no trace of our dearest Sol.

But there is an interesting cosmological model called conformal cyclic cosmology (CCC), proposed by theoretical physicist and mathematician, Roger Penrose, a recent Nobel laureate, and his colleague Vahe Gurzadyan. In 2001, Penrose suggested that the end of the Universe might be the beginning of a new one. The model accepts the expansion of the Universe until the complete dissolution of all matter and the absorption of all light by black holes. At that point, what remains will be similar to the initial condition of the gravitational singularity. According to the CCC model, the Universe would go through infinitely many cycles, called aeons. Every infinite future of spacetime represents a repetition of the previous one, identified with the

singularity of the Big Bang. The CCC model, as Penrose affirms, is based on studies of the cosmic background radiation and on waves which have been discovered in the residual material of previous universes. So, the final state of the Universe could be the beginning of another.

Sir Roger Penrose's theory is somehow comforting! An infinite cycle of repeating universes could mean that the end of time is not an end but a beginning of aeons of galaxies, stars like our own, and life.

A cyclic cosmology was also proposed by physicist Paul Steinhardt of Princeton University in 2001. He described a Universe exploding into existence, not once, but repeatedly over time. Penrose's theory is different, because the final state of his Universe tends to a cold and disordered emptiness, where the notion of time starts to lose meaning. There is the same entropy (disorder) that there was before the Big Bang, the cause being the evaporation of black holes.

The Hindu religion has believed in such a cyclic universe for at least five thousand years. For Hindus, humans are also recycled, through reincarnation of the soul. But perhaps this is just wishful thinking, a search for eternal life. Professor Penrose is a physicist and mathematician, and explains the cyclic cosmology through science, not as a consequence of blind faith.

I conclude this biography of the Sun with my own personal kind of wishful thinking. I hope that this is not the end, and that the stars, the galaxies, even our own Sun will come back through eternal cycles of death and rebirth, again and again. So, to conclude this book, the final words "The End" will not be necessary (Fig. 12.3).

Fig. 12.3 It's not the end. Painted glass