Life and fate of a star

Jonathan Freundlich

The warm light of the Sun that basks the Earth has enabled life to bloom on our planet. Our fate is inevitably tied to the fate of our star.

A gaseous structure

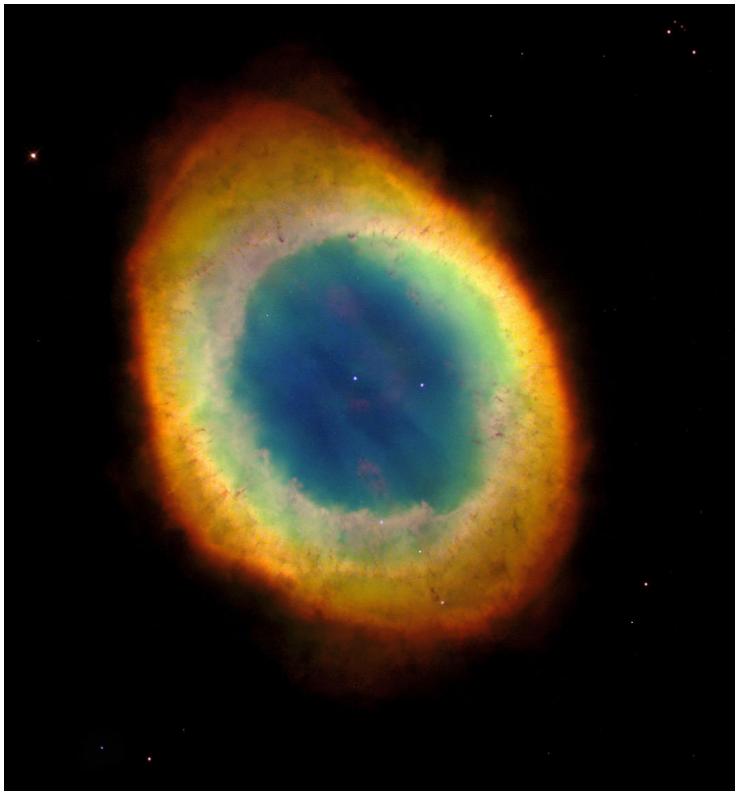
The Sun is an incredibly hot sphere of gas, mainly made of hydrogen, and the temperature in its core can reach millions of degrees. In this unbearable furnace, hundreds of millions of tons of hydrogen atoms fuse together each second to form heavier elements like helium through powerful nuclear reactions. These fusion reactions are very energetic and emit the intense light that would blind you if you were to stare at the Sun for too long.

Unlike the Earth, a star is made of gas and has no definite boundary: a falling object would never hit any ground! Gravity pulls the gas particles together, until the gas is too dense to contract anymore. The closer to the center, the higher the pressure and the denser it gets. The nuclear fusion reactions, that make the Sun shine, take place in its very center, where density and temperature are the highest.

The evolution of the Sun

Our Sun was born about five billion years ago from a giant gaseous cloud mostly made of hydrogen. The cloud contracted because of its gravitational pull, and temperature and pressure became so high that the nuclear fusion reactions started. But these reactions slowly drain the available hydrogen reservoir. In another five billion years, the core of our Sun will run out of fuel as its hydrogen will have been consumed to form helium atoms. The nuclear reactions will stop.

There will still be some hydrogen around the core though. So when pressure and temperature increase again, this hydrogen will start to fuse, and the Sun will become even more luminous than before! Such a star is called a red giant star because its outer layers expand dramatically. At that stage, the Sun will be so big it will engulf the Earth's orbit!



The Ring Nebula as seen by the Hubble Space Telescope. CREDIT: THE HUBBLE HERITAGE TEAM (AURA/STSCL/NASA)

Eventually, the outer layers of the Sun will be ejected away from the dense core and all nuclear fusion reactions will stop. The exposed core will slowly cool down without the power supply of the nuclear reactions. Such a remnant is called a white dwarf, and there is notably a faint white dwarf in the middle of the Ring Nebula. The Ring Nebula is the glowing remain of a star like our Sun. The outer layers of the star were ejected four thousand years ago, and their fading red glow is now slowly moving away from the white dwarf. The stellar remnant still emits some ultraviolet light, which bathes the central area of the nebula. This is how the future of our Sun may look like.

Life on Earth will become impossible during the last stages of our Sun's lifetime. But there is still a lot of time before that and humanity will hopefully have moved away from the vicinity of the Sun by then!

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ASTROPHYSICAL SERIES

- Thermonuclear weapons use uncontrolled but powerful hydrogen fusion reactions like in the stars
- The international ITER project currently being built in the South of France aims at achieving controlled nuclear fusion for the first time. Its completion is expected around 2027
- At the end of the red giant phase of the Sun, nuclear fusion reactions should produce carbon and oxygen atoms from the helium of the core. Heavier elements only form in more massive stars
- Stars much more massive than the Sun may explode as supernovae at the end of their lives and result in neutron stars and black holes instead of white dwarfs