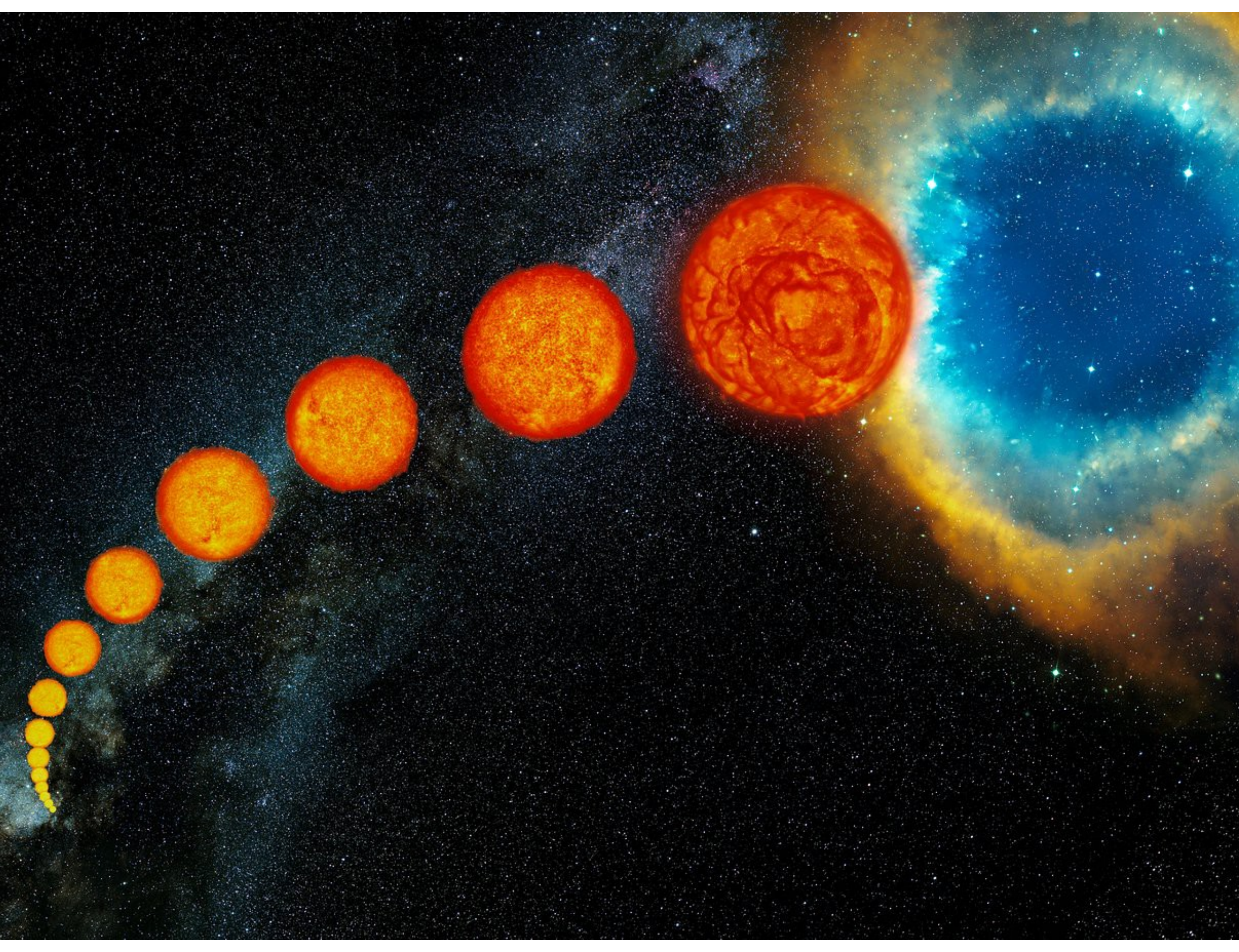
The Lifecycle of the Sun

We Talk Physics

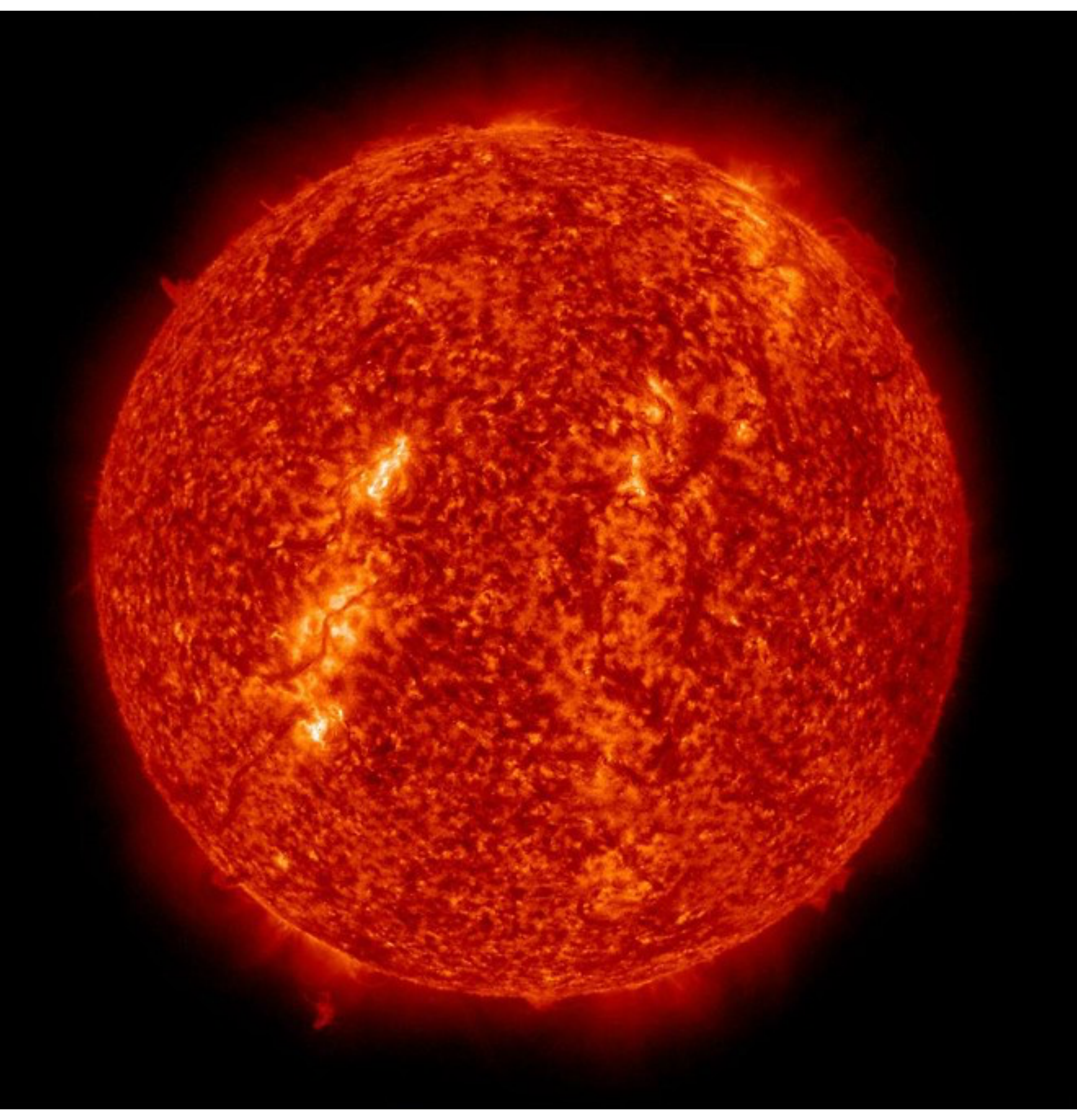


Credit: ESO/S. Steinhöfel

How did our Sun come to be? Where did it come from, and what will happen to it long after we are gone?

The story of our Sun begins roughly 4.5 billion years ago when it was born from clouds of gas and dust known as the interstellar medium. The gas clouds, primarily composed of hydrogen gas, eventually grow sufficiently large that its inward gravitational force overcomes its outward gas pressure, leading to collapse. During this collapse, a large amount of gravitational energy is released, leading to a significant increase in temperature — so significant that fusion via the pp chain reaction is triggered inside the star.

The Sun is now on the so called main sequence, where it will remain for the majority of its life, slowly — **the timescales on which stellar astrophysics operates are incomprehensibly long compared to human timescales** — converting hydrogen in its core into helium for roughly 10 billion years. Every second, the Sun burns up its hydrogen fuel and produces enough radiative energy to sustain itself against the unrelenting pull of gravity. If we were able to capture all the energy radiated by the Sun for even one second, we would have enough to supply all the world's energy needs (based on 2019 usage) half a million times over.



Credit: NASA/SDO

After the hydrogen reserves in the core are consumed, the Sun rapidly moves through a series of evolutionary stages. As the Sun turns off the main sequence, fusion via the pp chain stops, but the central temperature is sufficiently high that hydrogen continues to burn in a shell around the degenerate helium core. **The Sun grows in size, becoming large enough to consume the Earth.** The degenerate core does not expand as it heats up, and so it is during this stage that the helium core flash occurs; when the temperature becomes incredibly high, a runaway nuclear reaction occurs in the Sun, and for a few seconds it produces as much energy as the entire Milky Way. The degeneracy of the core is eventually lifted, and helium begins burning in the core of the Sun.

It is here that heavier metals like carbon and oxygen are produced (astronomers refer to anything other than hydrogen and helium as metals!). This portion of a star's lifetime is the helium analogue to the main sequence, but far shorter. When the helium fuel in the Sun's core is eventually depleted, the Sun begins to burn helium in a shell around the core, which is now inactive. This helium burning is hot enough that a shell of hydrogen around the helium shell also burns. Interestingly, the product of hydrogen burning is helium, which is the fuel used by the inner helium burning shell. As a result, the outer shell periodically fuels the inner shell, causing helium shell flashes, which are observable as thermal pulsations that take place over thousands of years.

It is thought that these flashes are (at least partly) responsible for the Sun losing significant amounts of mass. **Most of the gas in the outer parts of the Sun — enriched with the metals created in the earlier stages of the Sun's life — is ejected outwards, supplying the material for new stars to form in a new cycle.** The emitted gas glows brightly as it is ionized by the radiation from the central star, which is now just the hot, inert, carbon-oxygen core that remains of the Sun. Slowly but surely, the central star, known as a white dwarf, cools over hundreds of billions of years into darkness.

Credit: NASA, ESA, HEIC, and The Hubble Heritage Team (STScI/AURA)