

## Earth & Space

# The Star That Wouldn't Die

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This Break was edited by Max Caine, *Editor-in-chief* - TheScienceBreaker

### ABSTRACT

*A star that seems to have exploded multiple times is defying all theories about stellar deaths.*

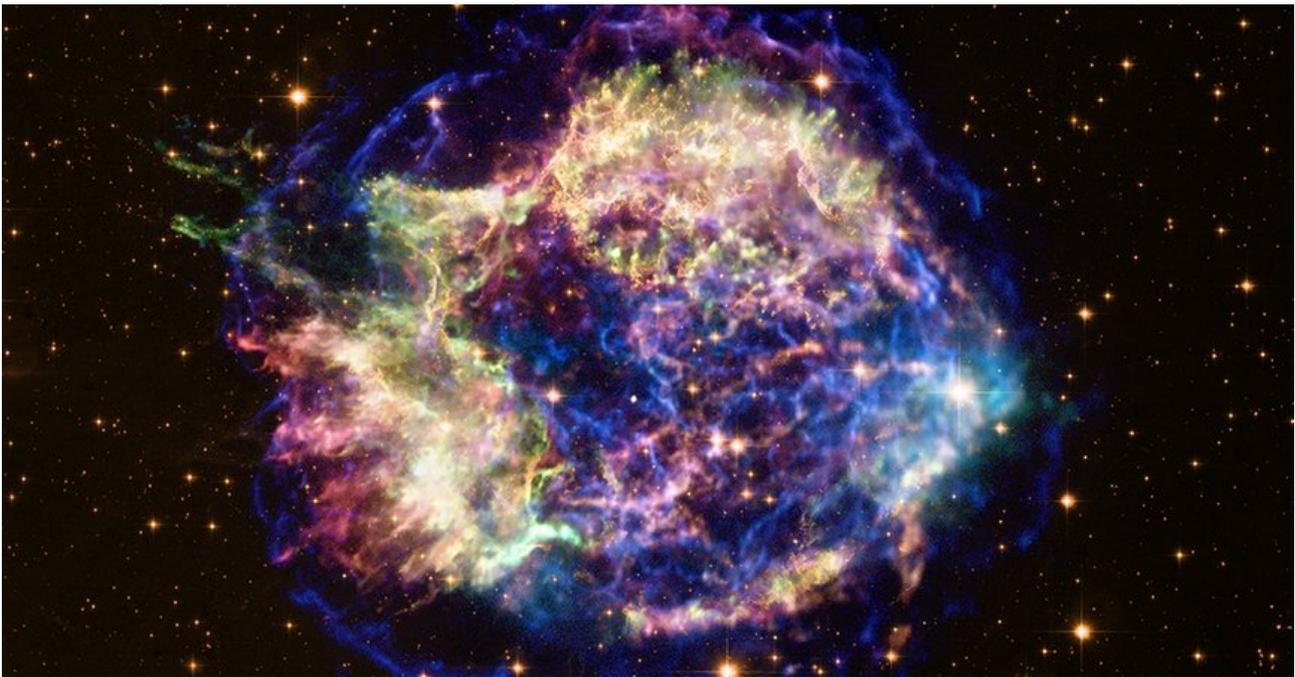


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Stars might seem eternal, but, like people, they are born, evolve and eventually die. A star will spend most of its life converting hydrogen into helium, a [nuclear fusion process](#) that produces energy which the star uses to hold itself up against its own gravity and to produce the light and heat that make it shine. Eventually, hydrogen will run out, fusion will fizzle, and the star will start to collapse under its own weight. As the star collapses, its core gets hotter and denser, until at some point the conditions for fusing helium into carbon and oxygen ignite that process, halting the collapse. Stars about 10 times more massive than our sun and larger, will go on to successive episodes of collapse and fusion of heavier elements, until they reach iron. Fusing iron into

heavier elements no longer produces any energy, so at that stage the star is done for. It will collapse until the core is so dense that it forms a neutron star. The rest of the star bounces off the dense core and explodes in what is called a supernova. With tens of solar masses of material flying off at thousands of km/s, supernovae are some of the most energetic events in the Universe. For a period of a few months they can be as bright as billions of suns, outshining the entire galaxy in which they reside.

Though supernovae are relatively rare (about one star will explode as a supernova every 100 years per galaxy), modern telescopes using wide field digital cameras can image hundreds of thousands of

galaxies per night, finding about one new supernova every hour. Thousands of such explosions have been studied in detail and several different types of supernovae have been identified. The most common type is the explosion of so-called red-supergiant stars – 10-20 solar-mass stars, made mostly of leftover hydrogen from their outer layers. These stars explode in what are called Type II-P supernovae which remain bright for about three months and then fade away for ever.

In September of 2014, the 48-inch telescope at the [Palomar observatory](#) in California was searching for supernovae as part of a several year-long project called the intermediate Palomar Transient Factory (iPTF). One of the supernovae it discovered, dubbed iPTF14hls, initially seemed uninteresting as it was already fading, having passed its peak luminosity earlier in the year while the telescope was not looking. However, the telescope kept monitoring iPTF14hls, and several months later we noticed it start to get bright again. This kind of behavior is very unusual for a supernova, so we took a spectrum of it's light – splitting it into a rainbow to check the composition, temperature and velocities of the exploding material. To our surprise, the spectrum looked like that of a typical Type II-P supernova, at about one month after explosion. But iPTF14hls was

already several months into its explosion, and it was getting brighter instead of fainter.

iPTF14hls went on to fade and re-brighten at least four more times over the course of two years, all the while presenting the spectrum of a Type II-P evolving in slow motion (600 days after it was discovered, the spectrum looked exactly like that of a 60-day old Type II-P supernova). When we looked back in the archives we found that the same Palomar telescope had imaged the galaxy which hosted iPTF14hls already in 1954. To our surprise there appeared to be a supernova at the same position as iPTF14hls in that image – 60 years ago.

A supernova that fades and brightens five times, has the spectrum of a normal supernova 10 times younger, and had exploded at least once 60 years before - all of this is unprecedented and extremely puzzling. None of these properties can be coherently explained by any existing supernova theory.

Three years after its discovery, iPTF14hls continues to shine, though it is now finally fading for what appears to be the last time. This single star, which seems to have somehow exploded multiple times, is forcing us to re-think our theories about massive stars, their violent evolution and their explosive deaths.