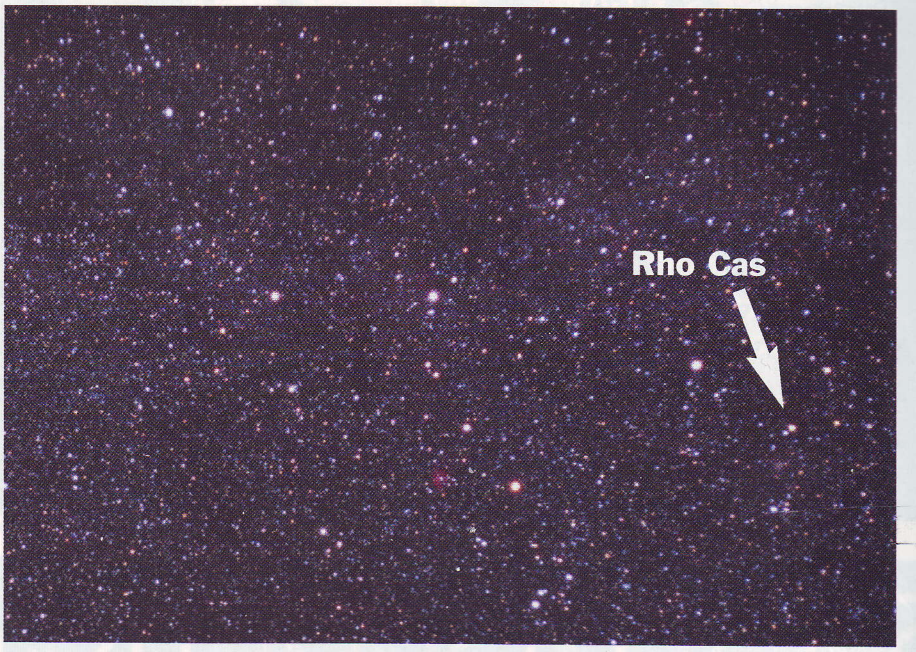
When stars g

The swirling hydrogen gas on the surface of the star Rho Cassiopeia is turbulent at best; a seething, frothing mass, normally radiating at a temperature of 7,000 Kelvin. Keith Cooper **explains what happens when, periodically, Rho Cassiopeia's turbulence gets the better of it.**

The onset of an eruption is signaled when gas begins to swirl and fall in towards the centre of the star. The pressure rises, compressing and heating the gas, causing the star to brighten briefly. Essentially, the star is coiling up like a spring on a trampoline and, within months, it bounces back.

In the summer of the year 2000 hydrogen gas measuring ten thousand Earth masses was blasted out from the surface of Rho Cas, the largest surface eruption ever observed on a star. A shock wave of material now encircles the star that could form a planetary nebulae around Rho Cas similar to the Homunculus Nebula around the star Eta Carinae. During the eruption Rho Cas' surface temperature dropped three thousand degrees to a relatively cool 4,000K, and already the star's surface is recoiling again, perhaps preparing for an even bigger eruption. Welcome to the explosive life of a hypergiant.



The constellation of Cassiopeia, home of the hypergiant Rho Cas. Image: Nik Szymanek.

Rho Cas belongs to a rare breed of stars known as 'hypergiants', of which only twelve are known to exist in the Galaxy, and only seven are 'yellow hypergiants' like Rho Cas. These stars are extremely luminous. Indeed, Rho Cas is five hundred thousand times more luminous than the Sun and, even at a distance of ten thousand light years, it can be detected by the naked eye in the constellation of Cassiopeia.

Heading for the void

Placing yellow hypergiants on the Hertzsprung–Russell diagram is difficult as they do not easily fit into the previously accepted stellar models. Some theorists speculate that they could be some kind of evolved star, between the red supergiant phase and the blue supergiant phase. All the known yellow hypergiants seem to heading for what is known as the 'Yellow Evolutionary Void', where the atmospheres of the hypergiants reach a comparatively more settled state. The problem for astronomers is that due to the rarity of these stars, the individual steps on the path to this void have yet to be seen. Very little is known about the stellar mechanics involved, or even whether hypergiants can actually reach the Void before they blow themselves apart in a supernova event, all of which makes the recent mass-ejection of Rho Cas crucial in studies of this type of star.

Hypergiant stars must lose sufficient mass to cross the Void boundary, which is what Rho Cas has been doing, not only in the year 2000 but also back in 1946, when astronomers observed a similar eruption. Then an eruption caused the star to alter from an F–Class to an M–Class, dropping in temperature by 2,000 degrees. The eruption in 2000 was even bigger. Because we see the star as it was ten thousand years ago, if we can take the last two eruptions as being typical of the star, Rho Cas could have already ejected so much material that the star has all but dissipated into the glowing relic of a cool, billowing cloud of hydrogen gas. On each eruption the star is jettisoning one tenth of a solar mass, and in the space of ten thousand years it will undergo two hundred eruptions. In total, if each eruption is similar in size, this will accumulate to the equivalent of twenty solar masses ejected from the star.

However, Rho Cas is a huge star, and will be rapidly using up all the hydrogen within its core. The helium flash will come quickly, as will death through supernova explosion, which may indeed already have happened. Therefore, the probability of Rho Cas evolving into the Yellow Evolutionary Void is low, if that was ever possible in the first place. As such, Rho Cas is now the number one suspect to be the next supernova in the Galaxy.

The Yellow Evolutionary Void is aptly named, for at present it does seem to be a void, absent of any stars. One star that has come close to it is the star HR 8752, which is teetering upon the edge of the Void. At this particular stage in a hypergiant's life, stars approaching the Void show increased activity, with regular variations in temperature and density inversions which may

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The William Herschel Telescope on La Palma was used to study Rho Cassiopeia. Image: Nik Szymanek

account for some of the instability. HR 8752 is also shedding mass, though not quite as spectacularly as Rho Cas.

As astronomers become more aware of these stars, spectroscopic analysis of them over the coming years could begin to clear up the muddy waters that surround their existence. More crucially, it may assist in solving one of the enduring problems in stellar astrophysics – why there are no stars with luminosities over a million times that of the Sun.

The astronomers who observed the Rho Cas eruption, led by Alex Lobel of the Harvard-Smithsonian Centre for Astrophysics, calculated how much mass had been ejected by using spectroscopy. The eruption had altered Rho Cas' spectra markedly, and a computer model that matched the new spectra gave the astonishing figure of ten thousand Earth masses ejected from the star. Furthermore, the spectroscopic analysis showed dark bands in the optical spectra, indicating the formation of molecules of titanium-oxide in Rho Cas' expanding atmosphere that did not usually exist there. The same bands were also seen in 1946, and are a symptom of the dimming and cooling of the star during its eruption. The shockwave that blasted out the ejected hydrogen was pushing the gas away from the star in a shell moving at four times the speed of sound.

It is therefore no surprise that there are no stars with luminosities of one million solar luminosities or more because they simply don't hang around long enough for astronomers to detect them. Higher mass and higher luminosity stars have short lifetimes as it is, and if they keep erupting like Rho Cas has, they'll be around for an even shorter period. We are fortunate that there are several good candidates for observation – Rho Cas, Eta Carinae, HR 8752 and P Cygni amongst others – just at a time when we have developed equipment sensitive enough to examine these stars in great detail.

If astronomers do finally see one of them explode, it will be the closest supernova to the Earth since the star that exploded to create the Crab Nebula in 1054, and it will yield an amazing amount of information regarding supernovae in general. It may also clear up other riddles, such as whether gamma ray bursts really do originate from extremely massive stars going nova.

In that case, perhaps it is fortunate that we are not too close to any of these stars when they get hyper.

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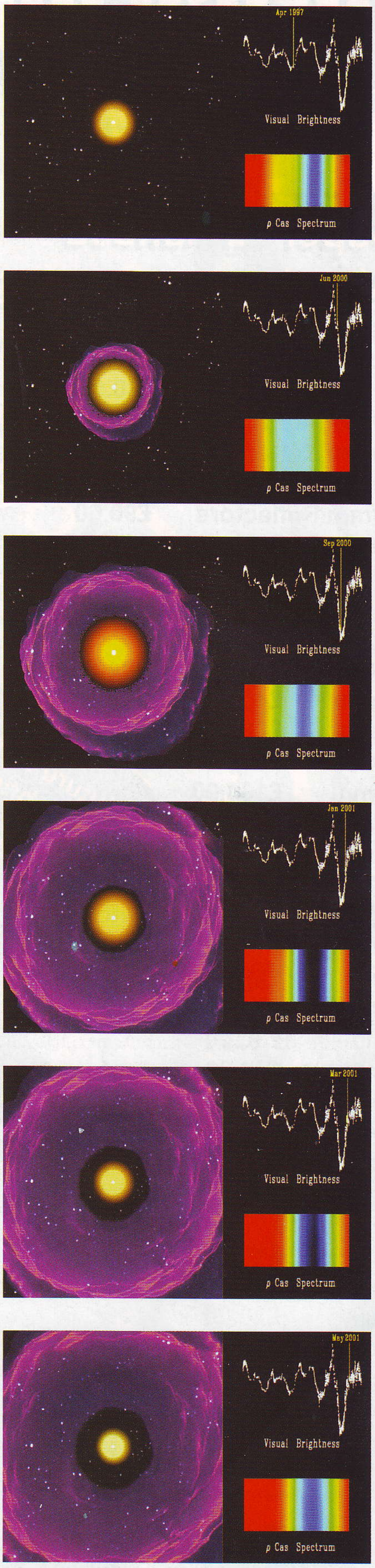

A science team led by Alex Lobel watched Rho Cas develop dark bands in its optical spectrum. The last time this happened was during 1946 when the star's atmosphere 'chilled' to 3000K. Image sequence courtesy: Alex Lobel and the Harvard-Smithsonian Center for Astrophysics.