## Astronomy

# When is a star a superstar?

*from C. Martin Gaskell*

How massive and luminous can a star be? The traditional upper limit to the mass of a stable main-sequence star is about 60 times that of the Sun, but superstars with masses thousands of times greater than this have been seriously considered for the power sources in quasars (or at least as possible progenitors of the supermassive black holes currently favoured as these power sources). The object R136a in the Large Magellanic Cloud has been claimed to be such a superstar. The latest observations[1], however, show that it is not a single object but a small compact cluster of bright stars, some of which nonetheless have a luminosity that exceeds that of the brightest known star in our Galaxy.

The dominant feature of the Large Magellanic Cloud — an irregular companion galaxy to our own Milky Way — is a gigantic region of star formation, visible to the naked eye, and known as 30 Doradus (the name comes from the 1712 star catalogue of John Flamsteed, the first astronomer royal). This nebula — often called the Tarantula — is the biggest region of star formation in our local group of galaxies. It is over 3,000 light years across and contains half a million solar masses of gas. In its centre are some extremely bright stars, dominant among which is HD38268. More commonly known as R136 (it was number 136 in a list of stars published by the Radcliffe observatory[2] in 1960), it is putting out enough ultraviolet radiation to ionize almost the entire Tarantula nebula.

What is R136? Studies at the beginning of the century showed it to have the spectrum of a very hot O star. In 1973, N. R. Walborn suggested that it was not one star but a small compact cluster of very luminous stars[3]. He argued that compact systems of a handful of bright stars within a light year or so were often found in the very centres of giant star-forming regions. The four stars known to amateur astronomers as the Trapezium, in the Orion nebula, are the nearest example. Walborn argued that if a system like the Trapezium were transported to the distance of the Large Magellanic Cloud, it would resemble a single star on photographs. Further work showed that R136 does have several components[4] but two groups suggested that the brightest component (R136a) was a single massive superstar with a mass of 2,000 – 4,000 solar masses[4,5]. Such a star would be very interesting as it would far exceed the conventional upper limit to the masses of normal stars. This limit, first derived by A. S. Eddington[6], and named after him, occurs because the intensity of radiation becomes so great that radiation pressure exceeds gravity. R136a is in fact losing mass at an enormous rate: Cassinelli, Mathis and Savage estimate it loses the equivalent of the entire mass of the Sun in 3,000 years[5].

Better spatial resolution was needed to see if R136a is indeed a single superstar. The resolution of photographs taken by telescopes from the Earth's surface is set by turbulence in the atmosphere, and the very best photographs of R136a, taken in Chile, have a resolution of 0.7 arcseconds[7]. It was C. E. Worley, of the US Naval Observatory, who realized that R136a had already been resolved by visual micrometer measurements made 60 years ago[8,9] but overlooked by modern spectroscopists. Worley, himself, made further visual observations in 1983 and published the results in a one page paper[10] (perhaps the last time anyone will publish a visual micrometer observation of a double star in the *Astrophysical Journal Letters*). Worley's observations confirmed that R136a is actually two stars separated by 0.49 arcseconds with one ($R136a_1$) being twice as bright as the other ($R136a_2$). $R136a_1$, if a single star, would still be a very impressive object of perhaps 750 solar masses[7]. But is it a single star?

The issue has finally been settled by G. Weigelt and G. Baier using the technique of holographic speckle interferometry[1]. From 8,000 short-exposure pictures of R136, taken with the Danish 1.5 m telescope at the European Southern Observatory, they were able to reconstruct the true image of R136a because of the presence of the point sources R136b and R136c in the same field (holographic reference stars). Their conclusion is that $R136a_1$ is actually a double star with a 0.10 arcsecond separation, and that there are at least 8 stars within a circle 1 arcsecond in diameter. Weigelt and Baier have therefore shown that R136 is indeed a complex of stars, much like the Trapezium in Orion, as Walborn had suggested.

Although nobody now believes 30 Doradus contains a 2,000 solar mass superstar, R136a remains highly interesting. Its three brightest components are each probably of more than a hundred solar masses, brighter than any star in our Galaxy. Many questions about the birth, life and death of such stars remain. □


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## Embryology

# Interacting systems in amphibia

*from Hugh Woodland and Elizabeth Jones*

AMPHIBIAN embryos have long been a favourite experimental material for embryologists because their large size and independent development makes them particularly amenable to techniques like microinjection and grafting. They are therefore particularly suitable for finding out how the variety of cells in the very early embryo differentiate. This kind of information is virtually non-existent for *Drosophila*, another developmental system much in favour at the moment. *Drosophila* work relies mainly on mutants and those available affect higher orders of pattern, rather than the basic events of cytodifferentiation. Thus, although the power of genetics cannot be applied to the amphibians, they still have a very important place in embryological research. Moreover, new life has very recently been injected into the study of amphibian embryology by the introduction of cloned DNA and antibody reagents which distinguish particular types of differentiation.

Until now, it has been necessary to rely on purely morphological criteria for identifying tissues in amphibian embryos and, in many kinds of experiment, tissues may be very abnormal and their identification hard to justify, especially to those without extensive histological experience. Sometimes, as where cell division is blocked with agents that disrupt the cytoskeleton, the correct morphology of the tissue could not possibly appear. Cloned DNA molecules or antibodies (mostly prepared from *Xenopus* embryos) are being introduced to circumvent these problems. The DNA gives very accurate quantitative information but, since nobody has yet developed a viable method of *in situ* hybridization for early stages of amphibian development, spatial information is limited. The reverse is true of antibodies, which may readily be used for the immunohistological staining of sections.

How are the main tissues of the embryo generated? At the time of nervous system formation, all vertebrates have the structure shown in Fig. 1*c*. The considerable