

ASTROPHYSICS

Echoes from an old outburst

are normally found on the cell's surface and lining the inside of some vesicles. The authors found that other vesicle-damaging pathogenic bacteria such as *Listeria monocytogenes* and *Shigella flexneri* are also decorated by galectins soon after infection. Moreover, osmotic damage of cytoplasmic vesicles in the absence of bacteria also resulted in the recruitment of galectins to the damaged vesicles. On the basis of their observations, the researchers conclude that galectins can act as sensors of non-specific danger by detecting host sugar molecules that are exposed on damaged vesicle membranes.

Although it has been speculated² that damaged SCVs serve as a signal to target bacteria for autophagy, Thurston and colleagues' work provides much-needed insight into the mechanistic details. Their results show that, when the microbes try to escape into the cytoplasm by disrupting the vesicles, host sugar molecules are exposed. Cytoplasmic galectin 8 then functions as a danger receptor: it binds to the exposed carbohydrates and recruits NDP52, which further attracts LC3 and autophagy machinery to the damaged compartment, thus triggering antibacterial autophagy soon after infection.

But the authors also show that recruitment of galectin 8 to damaged vesicles is a general danger response. Whether autophagy is also activated by galectin 8 in any other situations in which a cellular organelle is disrupted needs to be further investigated. Other galectins are recruited to damaged cytoplasmic vesicles such as SCVs, but at present their role in cellular defences to infection is unclear.

Is sugar exposure the only signal required to detect damaged SCVs? Most likely not, because NDP52 is only one of the three adaptors required to target S. Typhimurium to autophagy. So, the mechanisms that regulate recruitment of p62 and optineurin to damaged SCVs, and the ways by which the three adaptors cooperatively regulate antimicrobial autophagy, are exciting questions for future studies. ■

Ju Huang and John H. Brumell are in the Cell Biology Program, Hospital for Sick Children, Toronto, Ontario M5G1X8, Canada. **J.H.B.** is also in the Department of Molecular Genetics and Institute of Medical Science, University of Toronto. e-mails: juh@sickkids.ca; john.brumell@sickkids.ca

1. Thurston, T. L. M., Wandel, M. P., von Muhlinen, N., Foeglein, Á. & Randow, F. *Nature* **482**, 414–418 (2012).
2. Birmingham, C. L. et al. *J. Biol. Chem.* **281**, 11374–11383 (2006).
3. Kageyama, S. et al. *Mol. Biol. Cell.* **22**, 2290–2300 (2011).
4. Huang, J. et al. *Proc. Natl Acad. Sci. USA* **106**, 6226–6231 (2009).
5. Shahnazari, S. et al. *Cell Host Microbe* **8**, 137–146 (2010).
6. Zheng, Y. T. et al. *J. Immunol.* **183**, 5909–5916 (2009).
7. Thurston, T. L. M. et al. *Nature Immunol.* **10**, 1215–1221 (2009).
8. Wild, P. et al. *Science* **333**, 228–233 (2011).
9. Cemina, M., Kim, P. K. & Brumell, J. H. *Autophagy* **7**, 341–345 (2011).

Almost two centuries after the eruption of one of the most massive binary systems in our Galaxy, light reflected from its surroundings has been detected. The observations challenge traditional models for the eruption. SEE LETTER P.375

NOAM SOKER & AMIT KASHI

Extremely massive stars — at least a hundred times more massive than the Sun — are rare astrophysical objects. Historically, they were thought to influence their environment through their luminosity (equivalent to that of several million Suns) and through the explosion, or supernova, that marks the end of their life. On page 375 of this issue, Rest *et al.*¹ describe an analysis of light echoes from the nineteenth-century 'Great Eruption' of η Carinae, one of the most massive two-star systems in the Milky Way. The work strengthens previous claims that such stars have a third mechanism by which to release mass and energy into their environment.

From 1838 to 1858, η Carinae was in a continuous state of energetic outburst². At the time, however, there was no equipment available with which to record its spectrum. The spectrum of an astrophysical source, such as a star or galaxy, can be thought of as its fingerprints: it provides information about the source's temperature, density, velocity and chemical composition.

In an impressive piece of observational work, Rest and colleagues¹ return, almost two centuries later, to the 'crime scene' of η Carinae's eruption and take its fingerprints. The prime suspect in the case is the least massive star of the binary system, the companion, which stole mass from the more massive and more evolved 'primary' star. The primary itself was in an unstable phase during the 20-year period of the eruption. The crime scene is the ambient dust that reflects light from the eruption. This reflected light has taken longer to reach Earth than light following a straight path and not crossing the dust, and so has arrived there only recently — this is why the phenomenon is termed a light echo.

From spectral analyses of light echoes from η Carinae's eruption, Rest *et al.* deduce that the temperature of the gas ejected during the outburst was about 5,000 kelvin. This temperature, the authors say, is lower than that expected from conventional eruption models — in which the outflow of the eruption is in the form of a strong stellar wind. They further argue that such a temperature fits best with a hydrodynamic eruption mechanism. One possible model³ for a hydrodynamic eruption

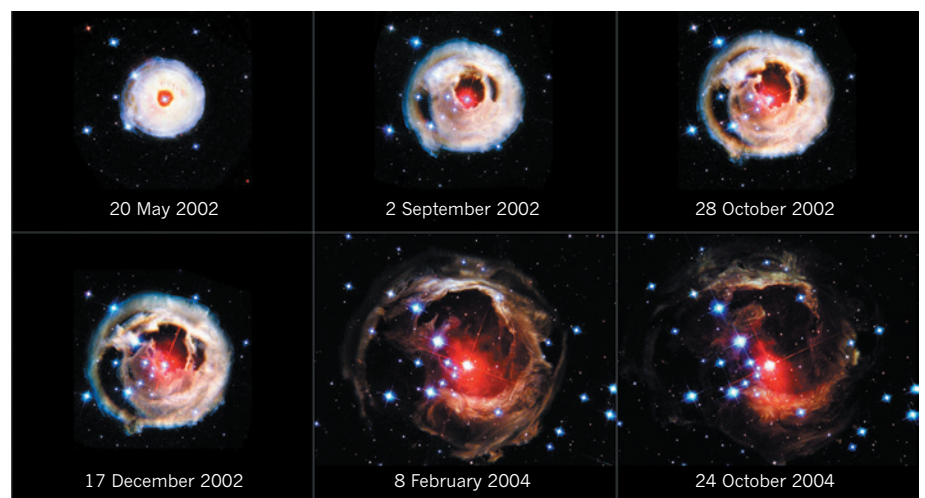


Figure 1 | V838 Monocerotis' light echoes. The six panels show a time sequence of light echoes from the 2002 eruption of the star V838 Monocerotis, as light from the eruption reached and illuminated the star's dusty surroundings, at increasing distances from the star, and travelled to Earth. The star itself is not resolved, but it is located at the centre of the structures in these images. The eruption of V838 Monocerotis and that of the nineteenth-century eruption of the two-star system η Carinae studied by Rest and colleagues¹ have some common properties, despite the different nature of the erupting stars.

NASA, ESA & Z. LEVAY (STSC)

involves mass transfer from the primary to the companion.

According to this binary model, during the 20-year Great Eruption, the companion would have accreted matter in the form of gas in an amount equivalent to several times the mass of the Sun. A huge amount of gravitational energy would have been released during this accretion process, which would have been the main energy source of the Great Eruption. Furthermore, some of the mass accreted by the companion would have been blown by the companion itself in two opposing directions, leading to the shaping of the Homunculus bipolar nebula, which is now observed to surround the binary system. Most of the mass in the nebula was blown directly by the primary star. The present masses of the primary and companion may be up to 170 and 80 times that of the Sun, respectively³.

During the Great Eruption, η Carinae experienced two bright peaks in luminosity, in 1838 and in 1843 (refs 4, 5). Rest *et al.*¹ find that the echoes' light curves — graphs of their intensity as a function of time — are consistent with these peaks. The time difference between the two peaks corresponds to the orbital period of the binary system around 1840; at present, the orbital period is five and a half years^{3,4,6}. The peaks themselves occurred when the two stars were closest together in their elliptical orbit around each other. Rest and colleagues' analysis of the echoes' spectra and light curves lends some support to an eruption model in which energy comes from mass transfer that is triggered at the stars' closest approach.

The temperature of about 5,000 K and the occurrence of two strong peaks (two weaker peaks are recorded historically at around 1849 and 1854) are reminiscent of the eruptive event⁷ that the star V838 Monocerotis experienced in 2002 (Fig. 1). One popular model for this eruption posits⁸ that a low-mass star of about half the mass of the Sun was destroyed in a merger with a star about six times more massive than the Sun. The accretion of gas from the low-mass star onto the surface of the more massive star would have been the energy source of the eruption. As in the case of η Carinae, the star that accreted mass is a non-evolved star such as the Sun: it is at an evolutionary stage during which nuclear-fusion reactions of hydrogen still occur in its centre.

The progenitor of η Carinae's eruption seems to fall into a varied group of systems that undergo eruptions powered by impulsive mass accretion onto non-evolved stars. The accreting stars can be very massive, as for η Carinae; five to eight times as massive as the Sun, as for V838 Monocerotis; or Sun-like stars. This heterogeneous group of progenitors might also include dying red-giant stars. Accretion of mass from a dying red-giant star onto a Sun-like star over a time span of 5–50 years could

lead to eruptions and shape some bipolar planetary nebulae. Red-giant stars are Sun-like stars in a late phase of evolution, during which they become very bright and large. Planetary nebulae are the last moment of a Sun-like star's glory: they are beautiful shining clouds of gas and dust that last for 100,000 years. The nebulae are formed from gas that was once part of the outer shells of the red-giant star. Some of these planetary nebulae are known to have been formed over a short period of time, and have a structure that is not unlike that of η Carinae. One example of such nebulae is the bipolar planetary nebula NGC 6302 (ref. 9).

As Rest and colleagues¹ mention, a few more years of data are required to improve the echoes' light curves and to test their consistency with the historical observations. This will definitely help to nail down the origin of the eruption event, to find out whether it was triggered by mass transfer to the companion or by some as-yet-undetermined eruptive event in the primary itself, as proposed by some traditional models. Although it has been studied for more than a century, η Carinae still holds

several secrets. In the coming years, it is hoped that observations with modern telescopes will shed more light on this intriguing binary system. ■

Noam Soker is in the Department of Physics, Technion, Haifa 32000, Israel. **Amit Kashi** is in the Department of Physics and Astronomy, University of Nevada, Las Vegas, Las Vegas, Nevada 89154–4002, USA. e-mails: soker@physics.technion.ac.il; kashia@physics.unlv.edu

1. Rest, A. *et al.* *Nature* **482**, 375–378 (2012).
2. Davidson, K. & Humphreys, R. M. *Annu. Rev. Astron. Astrophys.* **35**, 1–32 (1997).
3. Kashi, A. & Soker, N. *Astrophys. J.* **723**, 602–611 (2010).
4. Smith, N. & Frew, D. J. *Mon. Not. R. Astron. Soc.* **415**, 2009–2019 (2011).
5. Humphreys, R. M., Davidson, K. & Smith, N. *Publ. Astron. Soc. Pacif.* **111**, 1124–1131 (1999).
6. Damiani, A. *Astrophys. J.* **460**, L49–L52 (1996).
7. Bond, H. E. *et al.* *Nature* **422**, 405–408 (2003).
8. Soker, N. & Tylenda, R. *Mon. Not. R. Astron. Soc.* **373**, 733–738 (2006).
9. Szyszka, C., Zijlstra, A. A. & Walsh, J. R. *Mon. Not. R. Astron. Soc.* **416**, 715–726 (2011).

STRUCTURAL BIOLOGY

Ion channel in the spotlight

When expressed in neurons, channelrhodopsin proteins allow the cells' electrical activity to be controlled by light. The structure of one such protein will guide efforts to make better tools for controlling neurons. SEE ARTICLE P.369

OLIVER P. ERNST & THOMAS P. SAKMAR

Imagine taking a pigment from the eyespot (the light-receptive organelle) of a motile, photosynthetic alga and putting it into the neuron of a living mouse. Now imagine exciting the pigment using laser light and seeing a reproducible effect of this stimulus on the behaviour of the mouse. It sounds unbelievable, but this is the basis of optogenetics — the combination of optical techniques and genetic engineering that allows light to control an organism's physiology and behaviour¹.

The algal eyespot pigments that facilitate optogenetics are proteins called channelrhodopsins (ChRs), and they can be thought of as light-activated, nanometre-scale electrodes. When expressed in cells *in vitro* or *in vivo*, ChRs target the cell membrane and are bound to a chromophore — a kind of molecular antenna that absorbs light. Illumination of the ChR rapidly causes a flow of cations across the membrane. The resulting electrical current then gradually turns off and the ChR

'recovers', whereupon the whole process can be repeated. But the precise mechanism for how light opens the channel gate and how the gate closes is not known. On page 369 of this issue, Kato *et al.*² report a high-resolution X-ray crystal structure of a genetically engineered ChR, and use it to propose an explanation for how the isomerization of its chromophore causes pore opening.

Although the behaviour of motile algae has been studied for decades, it wasn't until 2002 that an eyespot pigment of the alga *Chlamydomonas reinhardtii* was identified³ as the light-activated protein channelrhodopsin 1. Three years later, ChRs were expressed in mammalian neurons and used to facilitate the light-induced stimulation of the cells' activity⁴. Subsequent bioengineering of ChRs, enabling optical control of cells on the millisecond timescale, together with the development of systems for delivering genes to specific cell types, boosted the rapidly growing field of optogenetics⁵. Since then, the use of this technology has grown exponentially, with no signs of its popularity waning.