ASTRONOMY

A new molecular factory

Sun Kwok

Carbon-rich stars are known to be prolific producers of molecules. Against expectations, astronomers have identified an old, oxygen-rich star that can also synthesize a chemically varied molecular cocktail.

For 30 years, astronomers' favourite star in the search for molecules was a nearby, old, carbon-rich star called CW Leo. This star produces such a variety of molecules that it constitutes a veritable 'molecular factory'. On page 1094 of this issue, Ziurys *et al.*[1] describe how they have discovered another stellar molecular factory that is almost as prolific. VY Canis Majoris (VY CMa) is a cool, old star like CW Leo, and like CW Leo it is in our Galactic neighbourhood. But it is different in one crucial respect: it is rich in oxygen. Apparently, then, oxygen-rich stars can also produce a wide variety of molecules when they are near the ends of their lives.

Most people think of stars as sources of light. But since the early 1970s, and the development of infrared and microwave astronomy, stars have also proved to be sources of matter. We now know that old stars generate strong stellar winds that eject material from the parent star into interstellar space. Because many heavy elements are synthesized by nuclear processes in the interior of old stars, stellar winds are a major avenue for feeding those elements into the interstellar medium.

What kinds of matter are in the stellar winds? In addition to atomic nuclei, it turns out that the stellar winds have very rich chemical contents. Spectroscopic observations at millimetre and submillimetre wavelengths have resulted in the detection of more than 60 types of molecule. These include inorganic molecules (for example, CO, SiO, SiS, NH_3, AlCl), organic molecules (C_2H_2, CH_4, H_2CO, CH_3CN), radicals (CN, C_2H, C_3, HCO^+), rings (C_3H_2) and chains (HC_5N, HC_7N)[2]. The winds are dispersing fast, so the formation processes must take place on timescales as short as hundreds of years.

Conventional wisdom suggests that if oxygen is more abundant than carbon, most of the carbon atoms in the wind of VY CMa should be locked up in the CO molecule, a simple and stable molecular species that forms in the atmosphere of the star. Given the lack of available carbon atoms, an oxygen-rich star is not expected to have the chemical versatility of a carbon-rich star and is therefore much less likely to have a chemically rich molecular content.

So it comes as a surprise that Ziurys *et al.*[1] announce seven newly discovered molecules in the stellar wind of VY CMa. Not only is the production of these increased numbers of molecules a feat in itself[1], but the variety of molecules is striking as well. Among the seven are molecules containing sulphur (NS), phosphorus (PN), silicon (SiS) and even metals (NaCl, or salt). Phosphorus is of particular interest because this element has an essential role in the biochemistry of life, in spite of its low abundance in the cosmos. The authors' discovery also reveals unexpected physical complexity. They found the molecular ion HCO^+, even though it is not expected to be present in the low-temperature, neutral environment of a cool star.

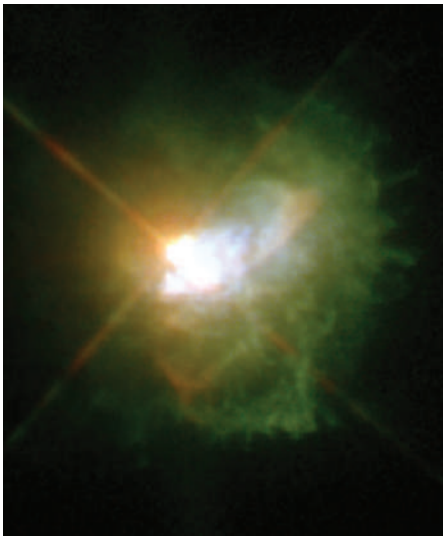

Figure 1 | Stellar performance. This colour-composite picture of VY CMa consists of separate images, taken in blue, green, red and near-infrared light, obtained with the Hubble Space Telescope (HST) Wide Field and Planetary Camera 2. The image reveals complex circumstellar ejecta, with arcs, filaments and knots of material formed by the massive outflows created during several outbursts. As Ziurys *et al.*[1] recount, the observed emission from different molecular species can be traced to the different optical features. (Composite image created from HST data taken by R. Humphreys.)

The molecules in VY CMa were identified through their rotational transitions. When a molecule decays to a lower rotational state, having been excited by collisions or radiation to a higher rotational state, it emits microwaves at specific wavelengths. Modern spectrometers can have high spectral resolution, so different molecular species can be uniquely identified by the wavelengths of the observed spectral lines. Because the observed line wavelengths are shifted by the velocities of the emitting gas, as a result of the Doppler effect, Ziurys *et al.* were also able to derive the kinematic structures of the different components of the winds from the emission profiles of lines. Imaging of VY CMa by the Hubble Space Telescope has shown that the winds have complicated morphologies (Fig. 1), and the origin of the different molecules can be traced to different morphological features[3]. So these observations can also be used as probes to help elucidate the physics of the winds.

Our interest in old stars is not confined to the molecules they may be producing. In the gas phase, molecules are in turn believed to be the building-blocks of more complex inorganic and organic solids that consist of hundreds of atoms. These solids have been detected by infrared spectroscopy through their vibrational modes. Planetary nebulae, the descendants of old red-giant stars such as CW Leo, have been seen to contain carbonaceous compounds with both ring and chain structures typical of complex organic substances[4]. The detection of additional gas-phase molecules will help us draw a more complete picture of chemical synthesis in stars.

Ziurys and colleagues' report[1] shows that there is much more to be learnt about the use of old stars as laboratories for studying interstellar chemistry. How do these stars manage to make complex molecules in the extreme low-density environment? Do physical shocks, radiation or even grain-surface chemistry contribute to the molecular-formation process? What chemical pathways lead from the simple gas-phase molecules to complex organic solids? And what roles do these molecules have in the enrichment of the Galaxy and maybe even the early Solar System? Such questions have broad implications beyond astronomy and chemistry — winds from old stars will be an enticing target of observations for some time to come. ■

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3. Humphreys, R. M., Helton, L. A. & Jones, T. J. *Astron. J.* **133,** 2716–2729 (2007).
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Robert Cahn (1924–2007)

Robert Cahn, who died on 9 April 2007, was a much-valued and prolific contributor to *Nature*, and to News & Views in particular. His articles first appeared in the mid-1960s, and ranged widely across the discipline of materials science. The July issue of *Nature Materials* includes a full obituary by A. Lindsay Greer, which is freely available at http://dx.doi.org/10.1038/nmat1941

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