Astronomy

Chance discovery sheds light on exploding stars

Frederick M. Walter

A rare event has been identified in a brief detection of X-rays. Serendipity only pays off when you know what to do with it, and researchers have used the finding to verify a long-standing theory about a class of exploding star. **See p.248**

Even with the increasing amount of data archived in all-sky surveys, astronomical discovery still relies heavily on serendipity. Theory can guide the process (and sometimes lead it astray), but there is no 'standard model' for the Universe and everything in it, so progress is often driven by the unexpected. It takes a good observer to see something unusual and interpret it as noteworthy. On page 248, König *et al.*[1] have turned serendipity into success by correctly characterizing X-rays, detected in just 35.8 seconds, as the product of an exploding white dwarf – thus contributing to our understanding of the physics of these stars.

The detection came from eROSITA, an instrument that scans a swathe of the sky for X-ray emissions every four hours from an orbit around Earth's L2 point, which also hosts the James Webb Space Telescope's orbit. L2 is shorthand for the second of Earth's five Lagrange points; these are areas in which the gravitational pulls of the Sun and Earth are balanced by the centripetal acceleration due to the satellite's orbit, so that the satellite remains there.

eROSITA takes six months to build up an image of the X-ray sky, and before the joint German–Russian mission was interrupted by Russia's invasion of Ukraine, it had completed four full scans. These data allow us to study how X-ray sources vary on timescales from seconds to years.

König *et al.* recognized that a very bright X-ray source, which was detected only once, in a single scan on 7 July 2020, coincided in space and time with the outburst of the classical nova YZ Reticuli (ref. 2). From this, they inferred that a decades'-old prediction[3] about the physics of such novae was correct.

Classical novae are runaway thermonuclear reactions (essentially, hydrogen bombs) that occur on the surfaces of white dwarf stars – the cinders that remain after low-mass stars have spent their nuclear fuel. White dwarfs are inert bodies with masses close to that of the Sun, packed into volumes comparable to that of Earth. Their densities are around one million times that of ordinary matter.

When a white dwarf in a binary system gains mass by accreting matter from its companion star (Fig. 1), the immense pressure at the base of the added hydrogen layer forces the gas into a state in which its pressure is set by the quantum properties of its electrons, rather than by the thermal pressure. This means that the accreted hydrogen does not expand, even though its temperature continues to increase. A thermonuclear reaction occurs when this layer becomes hot enough to trigger fusion reactions.

Because fusion rates increase extremely rapidly with temperature, and because increasing the temperature does not relieve the pressure, the reaction quickly gets out of control. The star's immediate response is to blow off much of the accreted layer, increasing its radius enormously and relieving the pressure.

In 1990, the runaway reaction was predicted[3] to produce a bright flash when the blast from the explosion reaches the photosphere (the outer layer of the white dwarf). At this point, the star shines at the highest possible luminosity, known as the Eddington luminosity, because the outward acceleration of its material due to radiation pressure matches its inward acceleration due to gravity. Before the accreted layer can be ejected, and when its radius is close to that of the white dwarf, the object's temperature will be several million degrees[3]. But it will cool rapidly so that the emitted electromagnetic radiation moves out of the X-ray frequency band as the radius increases at several thousand kilometres per second. The nova becomes visible to the naked eye some hours to a few days later, when the temperature has decreased and the emitted radiation moves to optical frequencies.

Later, days to months after the explosion, the expanding ejected layer becomes so dilute that soft X-rays (those with energies of less than one kiloelectronvolt) can pass through it. In principle, this should make the surface of the white dwarf visible again, because it is still radiating at around the Eddington luminosity. But the flash of soft X-rays had never been seen – until now.

Astronomical observation demands patience, but it also requires savvy interpretation. On observing a brief flash of X-rays in the eROSITA data, König *et al.* realized that it coincided with the position and expected timing of the outburst from YZ Reticuli, providing long-awaited verification of the 1990 prediction.

As well as confirming a theory, this serendipitous discovery makes two new inferences possible. The first is an estimate of the exact time of the thermonuclear reaction. The time lag between the reaction and the beginning of the brightening at optical frequencies informs

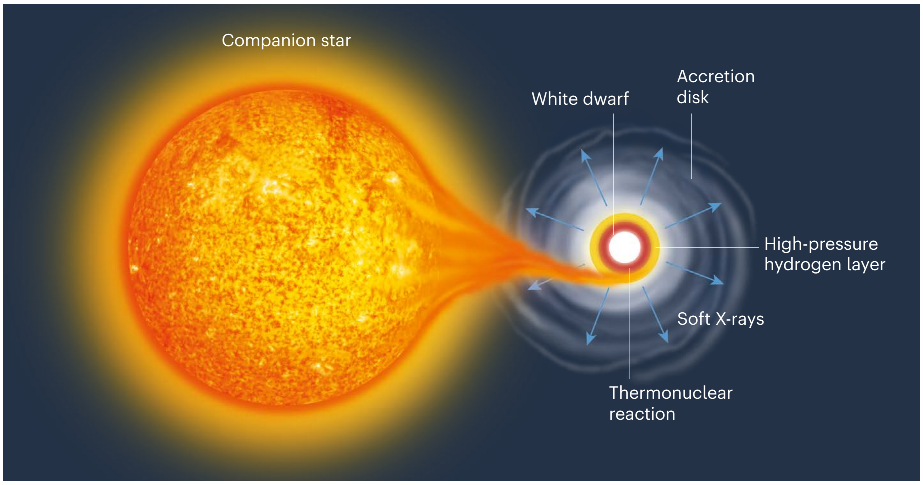

Figure 1 | The onset of a nova explosion. As a white dwarf star accretes hydrogen from a companion star (not to scale), the pressure and temperature in the accumulated layer increase, but the gas does not expand. As the temperature continues to increase, a runaway thermonuclear reaction is triggered. Some of the energy released contributes to ejection of the outer layers of the white dwarf, resulting in a nova (not shown) that eventually becomes visible to the naked eye. However, it was previously predicted[3] that some of the energy released in the explosion immediately leaks through the accreted layer, and would be detectable as a soft (low-energy) X-ray flash. König and colleagues[1] have now verified this prediction.

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us of the dynamics of the expanding photosphere. And the temperature of the surface at the time of the explosion constrains the mass of the white dwarf.

The lesson from this observation is that a brief, unexpected detection can allow an astute team to figure out that a rare event has occurred and capitalize on it. Lest it sound too easy, the X-ray source was actually too bright for the detector, which was severely affected by 'pile-up' – photons arrived faster than the detector could count them. This severely complicated the data analysis. But by overcoming the problem, König and colleagues have filled a gap in our understanding of how classical novae occur. And all this from 35.8 seconds in the cross hairs.

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Origins of life

A possible path towards encoded protein synthesis

Claudia Bonfio

How did the biological machinery for protein synthesis evolve from simple chemicals on ancient Earth? Experiments suggest an intriguing role for modified RNA nucleotides in directing stepwise peptide synthesis. **See p.279**

DNA and RNA serve as the primary information carriers that make up the genetic material of living cells – which puts nucleic acids such as these at the heart of most theories of the origins of life. In particular, the 'RNA world' hypothesis posits that self-replicating RNA molecules acted both as information carriers and as catalysts for biochemical processes before DNA and proteins evolved. However, this hypothesis does not explain why, how and when proteins replaced RNA to become the largest and most diverse class of catalyst in modern cells. On page 279, Müller *et al.*[1] report findings that suggest how RNA could have directed the emergence of proteins on early Earth.

The interplay between RNA and proteins remains central to arguably the most fundamental cellular process: translation. This involves biomolecular machines called ribosomes – themselves composed of RNA and protein components – that use sequences encoded by messenger RNAs as templates for protein synthesis (Fig. 1a). Ribosomes recognize codons (triplets of nucleotides) in mRNA sequences, and induce them to bind to complementary sequences in transfer-RNA molecules. The bound tRNA carries the amino acid specifically encoded by the codon. This amino acid is attached to the nascent protein chain by the ribosome, and the translation cycle begins again as the ribosome moves on to decode the next codon in the mRNA.

How could translation have emerged on prebiotic Earth? Chemical processes have been discovered that can drive the non-encoded stepwise elongation of peptides (short chains of amino acids)[2]. Moreover, peptide-bond formation directed by an RNA template in the absence of a ribosome has been reported[3], involving single nucleotides loaded with amino acids. But processes that enable encoded protein synthesis without ribosomes have remained elusive.

DNA and RNA mainly consist of just four 'canonical' nucleotides, each of which contains a specific base: adenine, guanine, cytosine and either thymine (in the case of DNA) or uracil (RNA). However, DNA and RNA also commonly include non-canonical nucleotides, which are modified versions of the canonical ones. Among their key cellular roles, these modified nucleotides participate in translation by stabilizing and diversifying the tertiary (3D) structures of tRNAs, and by coordinating base pairing of tRNAs with mRNA[4]. For example, the non-canonical nucleotide N^6-threonylcarbamoyladenosine (t^6A) is an essential and universally evolutionarily conserved nucleotide responsible for decoding codons whose first nucleotide contains adenine.

The ubiquity of non-canonical nucleotides suggests that they were present early on during the emergence and evolution of life. Previously published work[5] from the same research group as that of Müller *et al.* showed that modified nucleosides (non-canonical nucleotides that lack a phosphate group), including those in which the bases have amino acids attached, could have been synthesized alongside canonical ones, starting from simple molecules thought to have been readily available on early Earth. However, if modified and unmodified nucleosides were indeed mixed together before the advent of life, how could RNA sequences predominantly consisting of

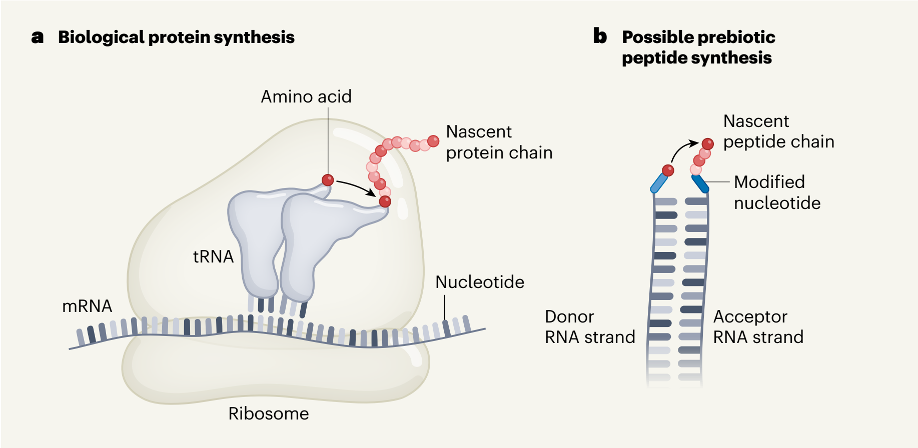

Figure 1 | A plausible evolutionary precursor to biological peptide-synthesis machinery. a, In the biological process of translation, a protein–RNA complex called the ribosome uses messenger RNAs as templates for protein synthesis. Ribosomes recognize codons (triplets of nucleotides) in mRNA sequences and induce them to bind to complementary sequences in transfer-RNA molecules. The bound tRNA carries the amino acid specifically encoded by the codon. This amino acid is transferred by the ribosome to elongate the nascent protein chain, which is attached to a second tRNA bound to the mRNA. **b,** Müller *et al.*[1] report a chemical system in which an RNA duplex promotes peptide synthesis. A modified nucleotide on the 'donor' strand can be loaded with an amino acid, which is then transferred to extend a nascent peptide on a modified nucleotide on the 'acceptor' strand of the duplex. This system could have formed on prebiotic Earth to act as a starting point for the evolution of ribosomal peptide synthesis.

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