Marcus Chown
When our Sun was young

What gets hotter as it loses heat? asked Lewis Carroll. The answer is the Sun. It's all down to the Sun being a ball of gas held together by gravity. Robbed of heat, gas particles fly about more sluggishly, sapped of the ability to push outwards against gravity. Consequently, gravity crushes the ball smaller. And, when a gas is squeezed, it gets hotter, as anyone who has squeezed the air in a bicycle pump knows. But the real situation is more complicated. Something is replacing the Sun's heat just as fast as it is lost to space.

In the 20th century, astronomers realised the "something" is nuclear reactions in the Sun's core, which transform hydrogen, the lightest element, into helium, the second lightest. Helium, being heavier than hydrogen, sinks to the centre of the Sun, becoming compressed and heating up. The upshot is that the Sun still gets hotter as it loses heat – which creates a big problem. When the Earth was born 4.55 billion years ago, the Sun should have been about 30 per cent fainter. Our planet should have been frozen solid. However, evidence contradicts this. Geologists have found ancient rocks that could have formed only in the presence of liquid water. And biologists have found fossil bacterial colonies called stromatolites from about 3.5 billion years ago. Like their modern counterparts off the coast of Western Australia, they lived in shallow coastal water. The fact that the youthful Sun was too feeble to prevent the young Earth from freezing yet the young Earth evidently did not freeze is called the "faint young Sun paradox". It was first recognised as a puzzle in 1972 by the astronomers George Mullen and Carl Sagan.

Many solutions have been suggested. For instance, the radioactive elements uranium, thorium and potassium – whose decay keeps the Earth's interior hot today – would have kept the interior even hotter in the past when they were more active. In fact, uranium would have been "enriched" enough with the "bomb isotope" uranium-235 to have created natural nuclear reactors, like the one that operated in what is now Gabon in central Africa 2 billion years ago. Unfortunately, enhanced radioactive heating would have been insufficient to keep the Earth from freezing. Another possibility is that the newborn Earth was swaddled in a super-thick blanket of greenhouse gases like carbon dioxide and methane. But it is hard to imagine a scenario that could keep the Earth warm enough for long enough.

What makes the proposed solutions even shakier is they work only for the Earth. The faint young Sun paradox is exacerbated by evidence from Martian rovers which have found that Mars – so far from the Sun that it gets about half the sunlight of the Earth – had oceans, lakes and rivers during its first billion years. One solution that might simultaneously explain how both the Earth and Mars remained unfrozen is that we have got the Sun wrong and it was actually as luminous when it was born as it is today. The luminosity of a star increases with its mass, so a more massive Sun would do the trick. In fact, because the heat a planet would receive goes up as a high-power of the mass of the Sun, the Sun need only be four to five per cent more massive than today to be 30 per cent brighter. But how then did the Sun lose its baby fat?

The Sun is continually losing matter via the "solar wind" at a rate of about a 100 trillionth of its mass each year. To shed four to five per cent of its mass, it would have to have shed mass at a rate about 300 times faster than today for its first two or three billion years of life. Most astronomers think this implausible. But now an astronomer in the US has looked at it afresh. It is hard to measure the stellar winds of young sun-like stars. But we can observe how fast they spin. And sun-like stars start off spinning very fast – about once every few days – and end up spinning sluggishly like the Sun – about once every 26 days. Such a slowdown happens because such stars have magnetic field lines extending radially from surfaces like the spokes of a wheel. And matter streams outwards along them. The effect of this is exactly like a spinning ice skater extending her arms and as a result turning more slowly.

Controversially, Petrus Martens of Georgia State University in Atlanta thinks the spin-down of some young Sun-like stars implies they are losing mass at roughly the right rate to solve the faint young Sun paradox. So, has the puzzle been solved? Well, it has persisted for almost half a century and every previous solution has been shot down. Who is to say whether there will be more twists before the puzzle is finally put to bed? ●