Astronomy

A planet transiting a stellar grave

Steven Parsons

Evidence has been found of a planet circling the smouldering remains of a dead star in a tight orbit. The discovery raises the question of how the planet survived the star's death throes — and whether other planets also orbit the remains. See p.363

In the past few decades, the number of planets discovered beyond our Solar System has increased rapidly, and current estimates are that around one-third of all Sun-like stars host planetary systems[1]. Given that the Milky Way contains around ten billion Sun-like stars, there are likely to be billions of planets in our Galaxy. All of these planet-hosting stars will eventually die, leaving behind burnt-out remnants known as white dwarfs. What becomes of the stars' planetary systems when this happens is unclear, but in some cases it is thought that planets will survive and remain in orbit around the white dwarf[2]. On page 363, Vanderburg *et al.*[3] report the discovery of a planet that passes in front of (transits) the white dwarf WD 1856+534 every 1.4 days. Their work not only proves that planets can indeed survive the death of their star, but might offer us a glimpse of the far future of our own Solar System.

Sun-like stars fuse hydrogen into helium in their cores, producing copious amounts of energy that they use to support themselves against gravitational collapse. Stars are born with huge reserves of hydrogen, but eventually this supply is exhausted. The Sun has burnt through roughly half of its hydrogen supply. When this runs out, in five billion years, the Sun — and, by extension, the rest of the Solar System — will undergo a fundamental change.

When only a small amount of hydrogen remains, fusion will continue in a shell around the Sun's core. This will cause the outer envelope of the Sun to swell to an enormous size. At its maximum extent, the surface of the Sun might reach all the way to Earth's orbit, engulfing Mercury, Venus and, potentially, Earth itself. The Sun will then start to rapidly eject its outer envelope into interstellar space. The decreasing mass of the Sun will cause the other planets to move outwards, away from the Sun, to conserve angular momentum. When the last of the envelope is ejected, the Sun's core will be revealed: a smouldering, Earth-sized white dwarf that will slowly cool for the rest of time.

In this scenario, it is clear that the closest planets to the Sun are likely to be engulfed and destroyed. However, Mars, the asteroid belt and all the gas-giant planets will probably survive and stay in altered orbits around the Sun's remains. More broadly, we might expect many white dwarfs to host remnant planetary systems. Indeed, there has been growing evidence of this in the form of asteroids that have wandered too close to white dwarfs and then been torn apart by intense gravitational forces[4]. Debris from these asteroids rains down onto the surfaces of many white dwarfs, whereupon we can detect it[5]. However, until now, no planet in orbit around a white dwarf had been detected directly.

Enter Vanderburg *et al.*, who used data collected by NASA's Transiting Exoplanet Survey Satellite (TESS) mission to detect the periodic dimming of the white dwarf WD 1856+534. This dimming is caused by a planet passing between the white dwarf and Earth. Because white dwarfs are so small, the planetary transit is very 'deep': 56% of the white dwarf's light is blocked, compared with the typical 1–2% that is blocked by gas-giant planets around normal stars. In the case of WD 1856+534, the transiting planet is similar in size to Jupiter, and therefore has a diameter about ten times that of the white dwarf (Fig. 1).

In principle, such a deep transit should be easy to detect, so it might seem odd that such systems have escaped discovery for so long. However, the small size of white dwarfs also means that the transits are brief, lasting just 8 minutes in this case (compared with several hours for normal stars). Therefore, finding these planets requires white dwarfs to be both rapidly and constantly monitored — something that has become possible only in the past decade, thanks to missions such as TESS and NASA's Kepler (see ref. 6, for example).

The shape of the transit of WD 1856+534 gives us a good idea of the radius of the orbiting planet, but Vanderburg *et al.* were unable to place strong constraints on the planet's mass. Using infrared data, they calculate an upper limit of 14 times the mass of Jupiter. This confirms that the orbiting object is indeed a planet (rather than a failed star), but the unknown mass makes it impossible to tell whether the planet has been fundamentally altered by the death of its host star. A mass

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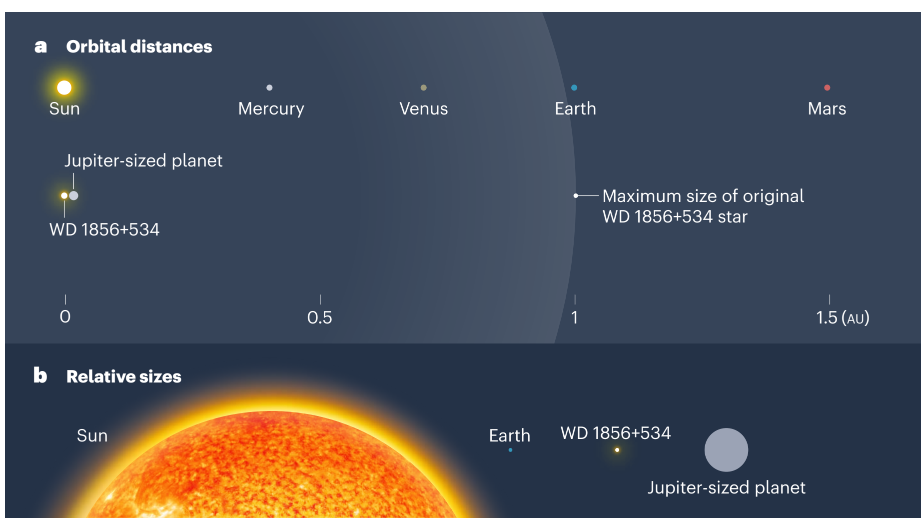

Figure 1 | Comparison between the inner Solar System and a white-dwarf system. Vanderburg *et al.*[3] report that a Jupiter-sized planet orbits the white dwarf WD 1856+534. **a**, The orbit is extremely small — the planet is roughly 20 times closer to the white dwarf than is Mercury to the Sun. The white dwarf was previously a giant star, the outer envelope of which once extended well beyond the planet's orbit. This raises the question of how the planet arrived in its current orbit. All distances are in astronomical units (AU), and the size of the giant star is shown to scale; the sizes of the other stars and planets are not shown to scale. **b**, The relative sizes of the Sun and Earth, and of WD 1856+534 and its orbiting planet, are shown here for comparison.

and radius measurement for this planet would enable us to compare it with similar planets orbiting Sun-like stars, possibly revealing any changes that the planet has undergone in the past. Unfortunately, it seems highly unlikely that the mass will be determined precisely any time soon. This is because WD 1856+534 is too cold to produce any absorption features in its spectrum that could be analysed to determine the white dwarf's radial velocity, a measurement that is typically used to calculate the masses of orbiting planets.

One of the biggest questions to emerge from Vanderburg and colleagues' study is how the planet ended up so close to the white dwarf. The planet is located just 4 solar radii from the white dwarf (or roughly 20 times closer to the white dwarf than Mercury is to the Sun). Assuming that the inner planetary system was swallowed by the expanding star, it seems extremely unlikely that the planet has always been this close to its star.

Vanderburg *et al.* suggest two possible explanations. The first is that the planet avoided destruction by tearing off the outer layers of the expanding star when it was engulfed. The second is that several distant planets survived the death of the star, but their altered orbits caused them to interact with each other — whereupon the observed planet was thrown towards the white dwarf by another planet. This latter explanation seems the most likely, and offers the tantalizing prospect of detecting additional planets in this system in the future. Given that WD 1856+534 is only 25 parsecs (82 light years) from Earth, the gravitational effects of any further planets on the white dwarf could be detectable by missions such as the European Space Agency's Gaia space observatory. This system therefore opens up an entirely new field of exoplanetary research.

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Tumour biology

How cancer invasion takes shape

Karolina Punovuori & Sara A. Wickström

Skin cancers resulting from distinct mutations have characteristic tissue forms and different disease outcomes. Analysing the architecture of benign and aggressive tumours reveals how mechanical forces drive these patterns. **See p.433**

The interplay between form and function is a cornerstone of biology, and the dismantling of normal tissue organization is a hallmark of many diseases. A long-standing question is whether changes in tissue architecture are merely a by-product of destructive diseases such as cancer, or whether they actively influence disease progression. Distinct types of skin cancer are driven by specific genetic abnormalities and give rise to distinctive tumour shapes. However, how these structures arise, and whether their specific forms affect the different outcomes of benign and malignant cancers, has been unclear. On page 433, Fiore *et al.*[1] report an analysis of skin cancer in mice that uncovers some of the key principles involved.

The skin's outer region, called the epidermis, is made of layers of epithelial cells. Down in the basal layer at the bottom of the epidermis, stem cells divide to self-renew their population and to generate cells of the suprabasal layers above, each layer of which represents a further-differentiated state. The final stage of differentiation generates a layer of dead cells on the skin's surface, which are continually shed. The constant need to replace these dying cells creates high demand for the basal stem cells to divide and produce differentiated cells. Owing to their potency and long lifetime, these stem cells, which frequently acquire cancer-causing mutations, are the cells of origin for two common types of skin cancer. One is basal cell carcinoma (BCC), a benign tumour that does not usually spread into other tissues, and the second is squamous cell carcinoma (SCC), which is more aggressive and invasive[2,3].

Fiore and colleagues engineered mouse embryonic skin cells to express cancer-causing mutations. A mutation in the gene *SmoM2* that activates the Sonic Hedgehog signalling pathway produced 'budding' skin conformations, characteristic of BCC (Fig. 1). By contrast, a mutation in the gene *HRas* that causes hyperactivity in the RAS–MAPK pathway generated skin 'folds' similar to those found in SCC. Both types of mutation caused cancer cells to proliferate faster than did their surrounding normal cells, but the mechanical properties of the tumour environment differed profoundly between the two tumour types.

Using an impressively broad selection of methods and combining theoretical and experimental approaches, Fiore *et al.* demonstrated that the two cancer-promoting mutations had different effects on the production, turnover and stiffness of the basement membrane. This is a thin layer of specialized extracellular matrix material that separates the epidermal cells from the rest of the skin, such as the adjacent compartment below called the dermis. The authors report that the BCC-like tumours actively produced and remodelled the basement membrane, and the resulting extracellular matrix had low stiffness and was malleable in its response to forces generated by the cancer cells. By contrast, the SCC-like cells produced less basement membrane, and the absence of remodelling made the underlying extracellular matrix comparatively stiffer.

As the BCC-like tumour expanded, the compressive forces exerted by the rapidly dividing and thus crowded pool of cancer cells caused buckling of the epidermis and basement membrane, resulting in the growth of tumour buds. However, in SCC-like tumours, the same type of force generated by proliferation and cellular crowding exerted towards the stiffer basement membrane did not result in such tissue deformation, and instead the tumour formed wave-like folds. Importantly, Fiore and colleagues report that experimentally altering the basement membrane to mimic high remodelling forced a switch from the formation of tumour folds to buds.

The authors observed specific differences between the two tumour types in the distribution of the actin and myosin protein machinery that generates cellular contractility and tension: the BCC-like cells exhibited high tension at the cellular boundary between the cancer and the neighbouring healthy tissue, however,

Correction
Owing to an editorial error, an earlier version of this article attributed the Kepler mission to the European Space Agency, rather than to NASA.