

White Dwarfs and Revelations

When a star runs out of fuel, it can collapse into an extremely hot and dense body known as a white dwarf. **Simon Joyce** explains how these distant dead stars have led us to a new understanding of the universe.

Men willingly believe what they wish

Over 400 years ago Shakespeare wrote Julius Caesar, which includes the famous line “I am constant as the Northern Star.” This was based on the fact that Polaris, the Northern Star, does not appear to move during the course of a night due to it being directly above the Earth’s axis of rotation. All the other stars appear to move in a circle as the Earth rotates. However, since the time of the ancient Greeks it had been thought that the Earth stayed still and the stars rotated as they were attached to the great celestial sphere. From before the time of Julius Caesar right up to the time of Shakespeare, the stars were considered permanent and unchanging entities. This was a logical assumption as the stars do not appear to change from one night to the next. Applying this theory and measuring the relative positions of all the stars would mean that we could produce a complete map of the universe which would be correct for all time.



Time lapse photo. Only Polaris at the centre appears not to move.

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One of the strangest things about science is that the more we understand about a subject, the more striking the small details that don’t quite fit our interpretation become. At a similar time as Shakespeare was writing, the astronomer Tycho Brahe was performing the most accurate measurements of the relative positions of the stars that had ever been made. In 1577 he observed that a new star had appeared in the sky which had never been seen before. This was the first evidence that stars actually change. However, we now know that Tycho observed the death of a star as opposed to the birth of a new star. Importantly, this one new point of light was evidence that the universe does not work in the way that we had believed for thousands of years. Rather than being permanent, stars undergo various stages of development as they follow a life cycle. We now know that stars are formed from collapsing gas clouds, live a long lifetime of stable nuclear burning, and then die when they run out of fuel.



Comparison of the size of a white dwarf (Sirius B) and the Earth



Artists’ impression of Sirius A and its much smaller companion Sirius B

“That’s no moon”

In the case of Sirius, a few years after Bessel died, the star that Bessel had predicted was finally directly observed. The star is too faint to be seen without a powerful telescope. The bright star we can see is called Sirius A and the companion star predicted by Bessel is Sirius B – a white dwarf, so called due to its small size and white hot glow. The existence of this star was a great puzzle because it was measured to be a similar size to Earth, yet it contained as much mass as the Sun. No one had theorized that an object of this nature could exist, especially since the star is composed of material 3000 times denser than anything found on Earth. It would be impossible to lift up even a pin head composed of this material. This strange material turned out to be the answer to what is left over after a star has died. A tiny point of light had evolved our understanding of the nature of the universe.

“Bessel proposed that an unseen star was orbiting Sirius and causing this strange movement”

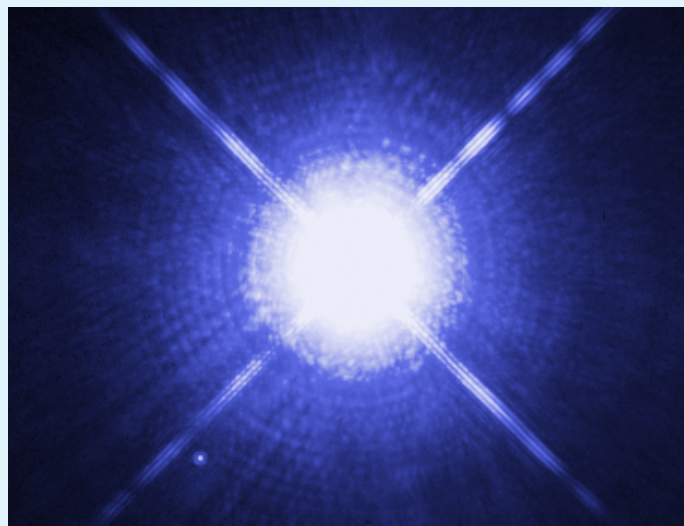
This poses the question; what is left behind after the death of a star? A clue came from observations of Sirius, the brightest star in the night sky. In 1844, the astronomer Friedrich Bessel was making very precise measurements of stars. By this time, it was known that the stars are not fixed points in a giant celestial sphere as was imagined by Aristotle. Instead, stars travel through space, although this movement is very difficult to detect due to the vast distances involved. Imagine watching an ant from several miles away and trying to determine how far it has walked. Astronomers had been observing Sirius for over 100 years trying to detect this movement. What Bessel noticed was that Sirius did not move in a straight line as predicted. It wobbled back and forth over a period of about 50 years. Only extremely accurate measurements over a period of decades allowed the detection of this movement. Based on these observations, Bessel proposed that an unseen star was orbiting Sirius and causing this strange movement.

“The existence of numberless visible stars can prove nothing against the existence of numberless invisible ones.” (Bessel 1844).

This has parallels with the modern theories of dark matter and dark energy. We can observe and predict the effects, but we don’t know exactly what the cause of those effects is.

“[Stars] live a long lifetime of stable nuclear burning, and then die when they run out of fuel”

White dwarfs are a glimpse into our solar system’s future. They are what is left behind after stars have used all of their fuel and collapsed under the force of gravity. We have progressed from thinking we live in an eternal and unchanging universe to one where even the stars themselves will one day fade away. Unlike most of the stars we can see with the naked eye, white dwarfs no longer generate heat via nuclear fusion. These stars still give off light as the cooling process takes billions of years. It is the fate of our galaxy to eventually be populated only by stellar remnants like these fading white dwarfs. Until relatively recently (only 124 million years ago), Sirius B was a star brighter than our Sun. To dinosaurs on Earth, the star would have appeared brighter than Venus in the sky. The death of this star created the nearest white dwarf to Earth.



“White dwarfs are a glimpse into our solar system’s future”

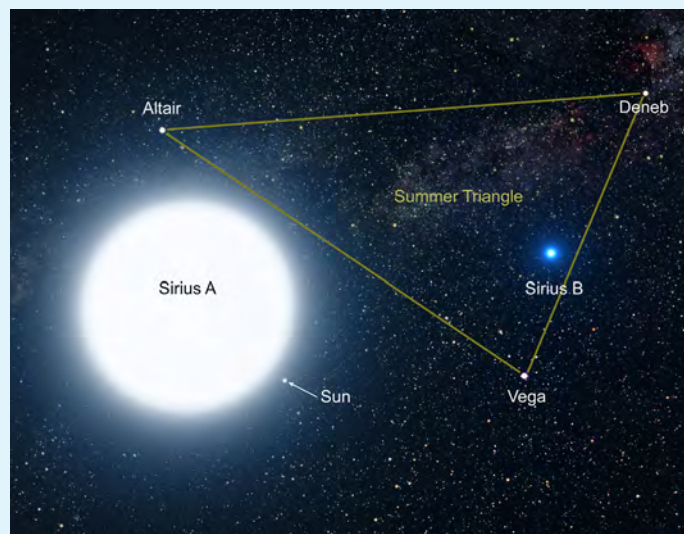
Despite the vast improvement in telescopes since the time of Bessel, observations of white dwarfs remain a challenge. I am using observations of Sirius B and other white dwarfs taken with the Hubble Space Telescope. The HST is a huge improvement over the instruments available to Bessel. Nevertheless, a large part of my work is focused on understanding the systematic problems which can affect the results. For example, the motion of the HST as it orbits the Earth introduces a shift in the wavelength of the measured light and I had to develop a method for removing this shift from the data. I was then able to calculate the mass of Sirius B using the spectroscopic or the gravitational red-shift method (see box). Our collaborators are using a third method called astrometry to measure the orbit and then derive the mass. We have found that our measurements of the mass of Sirius B made using the three different methods do not exactly match. This may indicate another missing piece in our understanding of physics, or in our understanding of the methods involved in making the measurements. Either way, finding the solution could prove to have important implications for the way we study stars and may even alter our view of the universe once again.

Sirius B is the small dot on the bottom left. It is dwarfed by its massive companion Sirius A (Bond H.E. Journal of Physics conference series, 2009)

Shifting focus

Sirius B now provides an excellent opportunity for scientific study. A key part of our work is the measurement of the mass of Sirius B along with several other white dwarfs. They provide an opportunity to test theories such as general relativity and quantum mechanics. The best method to test these theories is to determine if they can provide correct predictions in extreme conditions – such as the high density environment of a white dwarf. For example, quantum mechanics predicts that white dwarfs should have some very strange behaviour. Normal stars and planets are bigger the more matter they have. But with white dwarfs, the more matter they have, the smaller they are. This is exactly what we see. Sirius B is a high-mass white dwarf, but it is actually much smaller than low mass white dwarfs.

“A key part of our work is the measurement of the mass of Sirius B... to test theories such as general relativity and quantum mechanics”



Artist impression of how the Sun would appear to an observer in the Sirius system

Three ways to weigh a star

Spectroscopic

When we observe the spectrum of a white dwarf we see dark lines caused by the absorption of certain wavelengths of light in the atmosphere of the star. It's a bit like shining a torch through a cloud. The shape and depth of these dark lines depends on the mass of the white dwarf.

Gravitational red-shift

The same absorption lines used in the spectroscopic method also get shifted to longer wavelengths by the gravity of the white dwarf. This is equivalent to the Doppler effect where soundwaves change to lower pitch as an ambulance drives away from us. The stronger the gravity, the more the lines are shifted. So if we measure how much the lines are shifted, we can calculate what mass and radius the white dwarf must have to cause that shift.

Astrometric

Sirius A and B are in a binary and they orbit around each other once every 50 years. Careful observations over the last 150 years have allowed us to calculate what mass the two stars must have to produce the observed orbit.

Simon Joyce is a 2nd year PhD student in the Department of Physics & Astronomy. His work on white dwarfs is done in collaboration with Martin Barstow and Sarah Casewell (University of Leicester), Jay Holberg (University of Arizona) and Howard Bond (Pennsylvania State University).

My life as a part-time PhD researcher in Law

Undertaking a PhD is tough work. Now imagine studying part-time whilst living across the Atlantic Ocean and running your own legal firm. Law PhD student **Marcelo Henrique Lapolla Andrade** writes how he handles these conditions and how his research can improve the legal system in Brazil.

I started my PhD in Leicester back in 2015. After a thorough search for schools that allow part-time distance learning, I found that the University of Leicester had it all: a programme designed for distance learners; a great reputation in law with highly respected academic staff, the pleasant environment of the city; the courteous citizens, and not to mention the best football team in the country! These aspects all convinced me that I had made the right decision.

Climbing the academic ladder

Prior to starting this PhD, I had recently finished my Masters at Mackenzie Presbyterian University in Brazil, which focused on antitrust law – regulations on the conduct of companies regarding fair competition for consumers – and earned a separate postgraduate Master of Laws (LLM) degree on U.S. Law at Washington University in St. Louis, United States. Thus, aiming for a higher degree in the United Kingdom – with its old and widely respected legal system – was not only my dream, but also a natural step in terms of my educational development.

Since I started the program, I have visited the campus twice; to attend the graduate conference and to take part in training sessions. Being on campus is always a great opportunity to use the library facilities and to meet my supervisors in person – though our online meetings have proven to be quite productive and made me confident that the distance will not be an issue that will affect my research.

A working knowledge

Alongside the difficulty of studying for my PhD at a distance, my professional life is very busy here in Brazil. I own a law firm with over 100 employees. As such, finding a practical research topic would make my efforts in taking on a PhD twice as useful; for myself and for Brazilian legislation. It was in handling my clients' interests and problems that I identified what I believed to be a gap in our legal system; the absence of a specific provision in current Brazilian legislation regulating one's duty to mitigate another party's losses, known worldwide as the 'mitigation doctrine'.

The basic idea of the mitigation doctrine is simple; you must take reasonable steps to limit your losses even if they were caused by another. For example, if a supplier of bricks fails to deliver the bricks

to a construction company on the date agreed in their contract, the construction company must take reasonable steps to limit the losses caused by the late delivery – by perhaps obtaining bricks from a different supplier and/or assigning other tasks to its employees so that they do not sit idly while being paid. The practical effect of this is that a court will refuse to order the brick supplier to compensate any loss that the construction company could have avoided through taking reasonable steps. The doctrine is usually supported by reference to notions of good faith and economic efficiency in the use of resources.

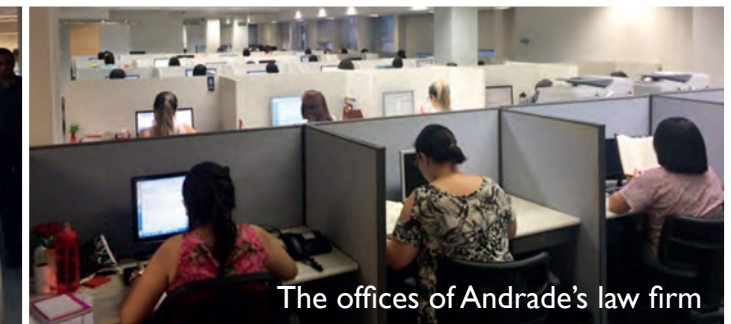
“Finding a practical research topic would make my efforts in taking on a PhD twice as useful: for myself and for Brazilian legislation”

Shedding light on Brazilian law

Building on this background, the first goal of my thesis is to compare the mitigation doctrine to various existing principles of Brazilian law which can affect the compensation of losses. Here I aim to demonstrate that the existing principles leave significant gaps in the law. The second goal is to research how other jurisdictions have filled these gaps by developing a mitigation doctrine and to investigate how they apply this doctrine to law. Finally, as the conclusion, I will come up with a proposal for the most adequate provision to be added to the Brazilian legal framework.

So far, I am very happy with the support I am getting from the University. This includes the IT team, various staff across the university and – of course – my supervisors. I am doing my best to enjoy every single moment of it and working really hard to achieve something I will be very proud of.

Marcelo Henrique Lapolla Andrade is a PhD student studying Commercial Law at the Leicester Law School in the University of Leicester.



The offices of Andrade's law firm