Pulsars

Good evening, I'm Rosie Richardson and the discovery I've decided to focus on is pulsars.

(next slide) Stars have a life cycle, called the main sequence. It starts with a massive cloud of dust and gas (containing a lot of hydrogen) known as a nebula which gravity pulls together. As the mass falls together it gets hot. A star is formed when it is hot enough for the hydrogen to fuse together to make helium. This fusion process releases energy, which keeps the core of the star hot. From here a star will either become one like our sun, called a main sequence star or a larger star called a massive star. The development of a star now depends on its size. For a main sequence star, all of the hydrogen will at some point be used up and larger elements will have been made. Now, these larger atoms will fuse together and the star begins to expand into a red giant. Eventually, fusion stops at which point a smaller star contracts due to gravity. It becomes smaller and cools, and is called a white dwarf.

However, for larger stars, the story's a lot less peaceful. It continues fusing heavier and heavier elements and expands and heats up to form a red supergiant. This heat generates a lot of pressure which keeps the star from collapsing under gravity. However, the fuel eventually runs out so the pressure drops extremely quickly. Gravity pushes in on the star and it collapses creating enormous shock waves that cause the other layer of the stars to explode. This leaves behind a very dense core that can either become a black hole or a neutron star. Most neutron stars are observed as pulsars *(next slide)*

Pulsars are rotating neutron stars observed to release pulses of radiation at regular intervals ranging between milliseconds and seconds. Pulsars have very strong magnetic fields which funnel jets of particles out along the two magnetic poles. These accelerated particles produce very powerful beams of light. Often, the magnetic field is not in line with the spin axis of the star, so those beams of particles and light are swept around as the star rotates. When the beam crosses our line of sight, we see a pulse – basically, we see pulsars turn on and off as the beam sweeps over Earth.

Pulsars are kind of like lighthouses. A lighthouse emits a beam of light that sweeps across the sky. Even though the light is constantly shining, you only see the beam when it is pointing towards you. *(next slide)*

The first pulsar was observed on November 28, 1967, by Jocelyn Bell Burnell and Antony Hewish, when Bell Burnell was a research student of Hewish. They observed pulses separated by 1.33 seconds that came from the same location in the sky. In looking for explanations for the pulses, the short period of the pulses ruled out most astrophysical sources of radiation, such as stars, and they also ruled out a human source.

When observations with another telescope confirmed the emission, it eliminated any sort of error with the instruments. At this point, Bell Burnell said that she and Hewish "did not really believe that we had picked up signals from another civilization, but obviously, the idea had crossed our minds and we had no proof that it was an entirely natural radio emission." Even so, they nicknamed the signal LGM-1, for "little green men". *(next slide)*

The discovery of pulsars was recognised in 1974 with a Nobel Prize, but Bell Burnell herself didn't receive it. Instead, it was awarded to Hewish and another astrophysicist Martin Ryle. Many other astrophysicists criticised the fact that Bell Burnell didn't receive the Prize including Sir Fred Hoyle. In 1977, Bell Burnell responded to the controversy saying, "I believe it would demean Nobel Prizes if they were awarded to research students, except in very exceptional cases, and I do not believe this is one of them."

However, she hasn't been completely overlooked. *(next slide)* Adding to her already considerable collection of awards and honours, in 2018, Bell Burnell was given the Special Breakthrough Prize in Fundamental Physics, for "fundamental contributions to the discovery of pulsars, and a lifetime of inspiring leadership in the scientific community." This prize is one of the most lucrative in the world and the money received from it is more than twice the amount given to Nobel Prize winners. Bell Burnell gave the entire £2.3 million to set up a fund helping female, minority and refugee students to become physics researchers which is now known as the "Bell Burnell Graduate Scholarship Fund." *(next slide)*

It's also possible to see pulsars in culture. German-born British composer Max Richter has written a piece inspired by the discovery of the first pulsar, CP1919, called "Journey (CP1919)". The sound of a pulsar was also used by English indie band Arctic Monkeys, in the video for their song "4 Out of 5". Finally, and most notably, English post-punk band Joy Division used an image of CP1919's radio pulses on the cover of their 1979 debut album "Unknown Pleasures." *(next slide)*

Beyond their cultural impact, pulsars have applications in the real world and are used by scientists in research. For example, the light emitted by pulsars carries information about them and what is happening inside them. That means pulsars give scientists information about the physics of neutron stars, which are one of the densest materials in the universe. Under such incredible pressure, matter behaves in ways not seen before in any other environment in the universe. The strange state of matter inside neutron stars is what scientists call "nuclear pasta". Sometimes, the atoms arrange themselves in flat sheets, like lasagna, or spirals like fusilli, or small nuggets like gnocchi.

Pulsars are also useful because of the precision of their pulses, which means they are thought to be the most accurate natural clocks in the universe. As a result, scientists can watch for changes in the pulses that could indicate something happening in the space nearby. This method was used to find exoplanets. In fact, the first planet outside Earth's solar system ever found was orbiting a pulsar. Because pulsars move through space while releasing pulses regularly, scientists can use them to calculate cosmic distances. The changing position of a pulsar means the light it emits takes a longer or shorter time to reach Earth. Thanks to pulsars, scientists have now made the most accurate distance measurements of cosmic objects to date. Over 40 years since pulsars were discovered, we are still finding more applications for them.