Who *Really* Discovered the First Exoplanet?

Two Swiss astronomers got a well-deserved Nobel for finding an exoplanet, but there's an intriguing backstory

By Josh Winn

The year 1995, like 1492, was the dawn of an age of discovery. The new explorers, instead of using seagoing vessels to discover continents, use telescopes to discover planets revolving around distant stars. Thousands of these extrasolar planets, a term usually shortened to "exoplanets," have been found, including a few potentially Earth-like worlds, along with bizarre objects that bear no resemblance to any of the planets in our solar system.

Two of these exoplanet explorers, Michel Mayor and Didier Queloz, were recently awarded half of the Nobel Prize in Physics for the discovery they made in 1995. My colleagues and I are united in our admiration for their pioneering work, and in our pride to be continuing what they began.

But there is something peculiar about the Nobel Prize citation. It says: "for the discovery of an exoplanet orbiting a solar-type star." Shouldn't it say the *first* exoplanet? After all, hundreds of astronomers have discovered *an* exoplanet. I've helped find a few. Even high school students and amateur astronomers have discovered them. Did the Nobel Committee make a typographical error?

No, they did not, and thereby hangs a tale.

Just as it is problematic to decide who discovered America (Christopher Columbus? John Cabot? Leif Erikson? Amerigo Vespucci, whose name is the one that stuck? Those who came on foot from Siberia tens of thousands of years ago?) it is difficult to say who discovered the first exoplanet. There are at least five credible contenders, and it's fun and fascinating to consider the merits of each case. So, let's pretend we are on the Nobel Committee, charged with picking the winner.

First, though, we need to understand the mindset of pre-exoplanet astronomers. They expected all planetary systems would resemble our own solar system. Not in every detail, but at least in a few important respects: the orbits of the planets are nearly circular and lie in the same plane, with the giant planets (like Jupiter) on the outside, and the rocky planets (like Earth) much closer to the star.

Over the centuries, astronomers developed a theory for planet formation that explained why those patterns should be universal, as inevitable consequences of the physical processes that occur within the swirling vortex of material that surrounds a newborn star. I am tempted to describe the theory, but I'll spare you the details, because the early exoplanet discoveries showed this theory is wrong, or at least incomplete. All you need to know is that this expectation was deeply entrenched.

You also need to know how to detect exoplanets. The first thing you might try is pointing a telescope at a star and looking for fainter objects circling around it. This turns out to be nearly impossible: planets are much too faint. Instead, the first exoplanets were detected by observing the *motion* of the star.

Children are taught that planets revolve around the sun, but that's a little white lie. In reality, the sun and planets revolve around the center of mass of the entire solar system. If you built a scale model of the solar system laying on a flat disk, the center of mass is where you could balance the disk on your fingertip. The sun is the most massive component of the solar system, so it is always close to the center of mass, but it does shuffle around a little. The planets around a distant star should cause the star to move, too. And that gives astronomers a way to find them, using *the Doppler effect.*

Whenever a moving object emits waves—such as sound or light waves—the length between waves is compressed in the forward direction, and stretched in the reverse direction. For sound, wavelength determines pitch, explaining why an ambulance's siren drops in pitch as it speeds by. For light, wavelength determines color. When a star moves toward us, its light will appear ever-so-slightly bluer, and when the star recedes, it reddens. We're talking about changes of a few parts per million, or less, which is why you need specialized astronomical equipment to detect them.

We're just about ready to review the candidates for the discoverer of the first exoplanet, but there's one more thing. We should decide in advance what we mean by *discover*. This will turn out to be important.

A dictionary definition is "to obtain knowledge for the first time." Okay, but what is *knowledge*? For that we turn to a philosophy textbook, in the chapter on epistemology, where we learn that knowledge is *justified true belief*. Our task, then, is to identify the first person to have a justified true belief in the existence of an exoplanet.

Because it must be *true*, we need not discuss all the false starts and spurious claims that tarnished the reputation of planet hunters for decades. By requiring it be *justified*, we set aside the lucky guessers. In 1953, Philip K. Dick wrote a story set on a planet around the star Proxima Centauri, and in 2017, astronomers detected such a planet, but Philip K. Dick did not discover the planet.

Our briefing is now complete, and we can welcome the contenders into the ring, in chronological order.

In 1979, Gordon Walker and a few colleagues at the University of British Columbia began searching for planets. He was the world's preeminent authority in precise Doppler observations. He designed his survey on the premise that all planetary systems resemble the Solar System. The biggest signals—and, given the limitations of his equipment, the only signals he had any chance of detecting—would come from giant planets, similar to Jupiter, which takes 12 years to go around the sun. Which meant that Walker needed to commit to a very long-term project.

He also had to hope that Jupiter-like planets are common, because he was only able to monitor about 20 stars. To expand his search, he would need more support from the Telescope Time Allocation Committee, which was not forthcoming. Walker wrote later: "It is quite hard nowadays to realize the atmosphere of skepticism and indifference in the 1980s to proposed searches for [extrasolar] planets. Some people felt that such an undertaking was not even a legitimate part of astronomy."

Despite this obstacle, by 1988 he had detected the signal of a Jupiter-mass planet that circles around a star named Gamma Cephei every 2.7 years. So, does Walker win the prize? Did he have a true and justified belief in the planet's existence?

Well, it was *true*: the planet's existence was definitively confirmed in 2003. The problem is whether the belief was *justified* in 1988. Walker's signal stood out clearly from the noise, but he still worried he was being fooled. The Doppler signal might be caused by something else besides a planet. Maybe the 2.7-year pattern was from the star's rotation, rather than motion. The sun rotates once a month, but Walker thought Gamma Cephei was a giant star, which could be rotating much more slowly.

In a 1992 paper, based on this concern, Walker backed away from the claim that the signal from Gamma Cephei represented a planet. But as it turns out, the star had been misclassified. It's not a giant star. Walker had been fooled into worrying he was fooling himself. His caution was natural, given the atmosphere of skepticism bordering on hostility. Maybe it is best to say that Walker detected the planet but did not quite discover it.

That brings us to our next contender, David Latham, of the Smithsonian Astrophysical Observatory. In 1989, he and his collaborators reported an intriguing Doppler signal around a star called HD 114762. The signal was crystal clear. Its characteristics were compatible with orbital motion, and incompatible with rotation.

This would seem to be a slam-dunk discovery. Indeed, HD 114762 is included in NASA's comprehensive database of exoplanets, logged with 1989 as the year of discovery. That's six years before Mayor and Queloz.

So, why won't Latham be shaking the hand of the King of Sweden? Because at the time, Latham's accomplishment was not *perceived* as a planet discovery. There were some weird things about the putative planet.

First of all, the orbit is not close to being circular. It's an ellipse with one dimension twice as long as the other—quite unlike the planets of the Solar System. Second, the planet is 11 times more massive than Jupiter, which seemed outlandish. In fact, the planet could be even more massive, because the Doppler method only tells us the planet's *minimum possible* mass. That's because the star moves in all three dimensions, but the Doppler effect only arises from one of those dimensions: the motion toward or away from the observer.

Finally, the orbit seemed way too small for a giant planet. It's less than a tenth of the size of Jupiter's orbit. According to the theory of planet formation, giant planets should never form so close to the star. That's the domain of small, rocky planets.

Latham thought it could be a planet, but some of his team members (and most other astronomers) thought that was a stretch. Their 1989 paper only mentions the possibility of a planet by way of speculation. More likely, they wrote, it was a brown dwarf, a sort of failed star that never ignited nuclear fusion reactions.

Today, though, none of the "peculiarities" of HD 114762 are considered peculiar at all. We know that a few percent of sunlike stars have a giant planet with a small, highly elliptical orbit. And some of them do have masses as high as 10 or even 20 times that of Jupiter.

Latham has a good claim to be the first to discover an exoplanet, but this is only from our retrospective view. The claim was *true,* and amply *justified* by the data. But at the time, it was not *believed,* because of the prejudice that planets should look and act like the planets in the solar system.

What came next was a stunning surprise. In 1992, Aleksander Wolszczan and Dale Frail announced the discovery of two planets, comparable in mass to the Earth, using a variation on the Doppler method. The evidence was watertight and convincing. The stunning thing was that the star is not an ordinary star like the sun; it's a *pulsar*.

Pulsars are among the most exotic things in the universe. They are remnants of supernova explosions, which take place when a massive star runs out of nuclear fuel and becomes unstable. A pulsar packs the mass of the entire sun into a ball only 20 kilometers across, making it so dense that with one false move it would collapse and become a black hole. Also, it can spin around hundreds of times per second, and spew forth radio waves, x-rays and lethal doses of radiation.

How should we score this candidate for the First Exoplanet? The claim was true and justified. It was believed and is still believed by the astronomical community. The only hang-up was whether the objects orbiting the pulsar should qualify as *planets*.

To that point, the astronomers' working definition of a *planet* was an object with a mass too small to be a star or a brown dwarf. The pulsar discovery forced a more careful appraisal. Maybe the word *planet* should be reserved for objects orbiting a normal star, not a zombie star. (Now you understand why the 2019 Nobel citation refers to "an exoplanet *around a solar-type star.*")

Some astronomers insisted that *planets* must form within the swirling vortex of material surrounding a young star. That's not where the pulsar's companions came from. Presumably, they formed after the supernova explosion, because they couldn't have survived the catastrophic blast of energy. Maybe some of the exploding material ended up falling back down and started orbiting the pulsar, and the planets formed out of that material. A serious problem with any formation-based definition, though, is that there is no universally agreed-upon theory for the formation of "normal" planets, either.

What ended up happening is that astronomers got comfortable referring to Wolszczan and Frail's objects as planets. But the pulsar planets were treated as freaks, and the search for more of them has turned out to be barren and unproductive. Only one other pulsar is known to have a planet, and even in that case, the evidence is not as secure.

That brings us to 1995. Michel Mayor and Didier Queloz, two astronomers from the Geneva Observatory in Switzerland, had been improving the Doppler technique. Earlier, Mayor had helped Latham observe his star. Then, he and his student, Queloz, decided to go planet hunting themselves. They had a near-monopoly on a telescope in France, which allowed them to monitor more stars than Walker or Latham.

One of their stars, a sunlike star named 51 Pegasi, was moving to-and-fro with an amplitude of 50 meters per second, and a period of only 4.2 days. The signal implied the existence of a planet with a minimum mass in between that of Saturn and Jupiter. That was a mass that made astronomers comfortable. Less comfortable was the orbital distance: only one twentieth of the distance from the Earth to the Sun.

That, insisted many theorists, was no place for a giant planet. Being so close to the star, the object orbiting 51 Peg is heated to thousands of degrees. Mayor and Queloz had discovered what would come to be known as a "hot Jupiter," a type of planet presumed to be impossible in the prevailing theory of planet formation.

The astronomical community was skeptical, not only because of the contradiction with their expectations but also given the checkered history of the field. Some were concerned that the Doppler shifts were from stellar pulsations, rather than orbital motion; maybe the surface of 51 Peg was bulging out, then sinking back with a regular rhythm.

Over the next few years, however, all these concerns were put to rest. This was the real deal. Planet formation theory had to be updated.

Mayor and Queloz, then, were the first to hold a *justified true belief* in the existence of an object that everyone agrees is an exoplanet around a sunlike star. Just as importantly, the discovery of 51 Peg had the same effect as the first sighting of an unexplored and seemingly boundless continent. The exponential growth in planet discoveries, and in the number of scientists working in this area, began in 1995. That's why the Nobel Committee thought Mayor and Queloz deserved the scientific spotlight (and a half million dollars).

Putting on my pedant's hat, though, I will note that the claim that 51 Peg is a planet was not 100 percent justified. Remember, the Doppler method only reveals the orbiting body's *minimum* mass—the true mass could be larger. Much larger, if its orbit happens to be perpendicular to our line of sight. While this would require a very unlikely coincidence, it was conceivable at the time that the companion of 51 Peg is actually a brown dwarf. In fact, it is a planet. The true mass was eventually measured with a different technique that relies on detecting the planet's own light, but not until 2015.

The *first* exoplanet for which the mass was measured without ambiguity is named HD 209458b. In that case, the planet's orbit happens to carry it directly in front of the star, causing a miniature eclipse. That's what eliminates the usual uncertainty regarding the orbit's orientation. The eclipses were detected in 1999 by two competing groups, one led by David Charbonneau and the other by Gregory Henry. But while this was technically a more definitive discovery, by this time in history the astronomical community had stopped doubting the discoveries of 51 Peg and other, similar objects.

Pedantry aside, it's also worth noting that, despite all the false starts, detecting exoplanets was one of those rare and wonderful occasions when a project turned out to be *easier* than anticipated. Usually, Murphy's Law prevails: everything is harder and takes longer than you expect. What made things easier in this case was the existence of hot Jupiters, a gift from nature that nobody expected. Hot Jupiters produce the biggest Doppler signals, and they can be detected and confirmed with only a few weeks' worth of data; no need to wait decades, as Walker had thought would be necessary.

In fact, it's not quite true that *nobody* expected hot Jupiters. In 1956, Otto Struve wrote a short paper pointing out that the precision of Doppler measurements had become good enough to detect massive planets, but only if they existed in tiny orbits. Setting aside the question of how such a planet might have formed, he realized there is no law of physics that forbids such planets from existing. His paper might have ignited a whole new area of astronomy, but in fact, it languished in obscurity. The planet around 51 Peg probably could have been discovered in the early 1960s, or surely by Walker in the 1980s, had he been able to observe more stars.

I try to remember this story when I am suffering from excessive pessimism. Even if a field has been tarnished by previous claims that turned out to be wrong, even if other talented people have tried before, even if theorists tell you that your idea is farfetched—there may still be a truly spectacular phenomenon waiting to be discovered.

Josh Winn is an astronomer at Princeton University who studies the geometry of exoplanetary systems, and recorded a 24-lecture series about exoplanets for The Great Courses.