

Science Focus

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**THE NEW
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SPECIAL
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THE HUNT FOR **PLANET 9**

How we'll find the most mysterious
object in our Solar System

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Beyond Neptune, a handful of small worlds are moving in harmony. Astronomers think they might be dancing to the tune of a third world lurking in the darkness, one that's four times bigger than Earth and significant enough to be named our Solar System's ninth planet. Now they think they know exactly where to look for it...

by COLIN STUART

Look up at the night sky and find the famous three stars of Orion's Belt. Then extend the line between them up and to the right towards the constellation of Taurus, The Bull. Halfway between them sits a small patch of otherwise unremarkable sky that could well be home to one of the most famous finds in astronomical history – a ninth planet orbiting the Sun. It isn't every day a new planet is discovered in the Solar System. In fact, by one measure, it has only happened twice before in all of human history with Uranus (1781) and Neptune (1846). All the other planets have been known since antiquity and were never really 'discovered'. Objects such as Ceres (the largest

asteroid) and Pluto were once deemed part of the planet club, but have since had their membership revoked. William Herschel, Urbain Le Verrier, Johann Gottfried Galle and John Couch Adams are the only astronomers to ever find a new planet that is still considered as such.

That elite list may soon be about to grow. CalTech astronomers Mike Brown and Konstantin Batygin are among the frontrunners to join it. Back in 2016 they went public with the radical notion that the roll call of planets orbiting the Sun isn't finished. They had noticed a handful of small

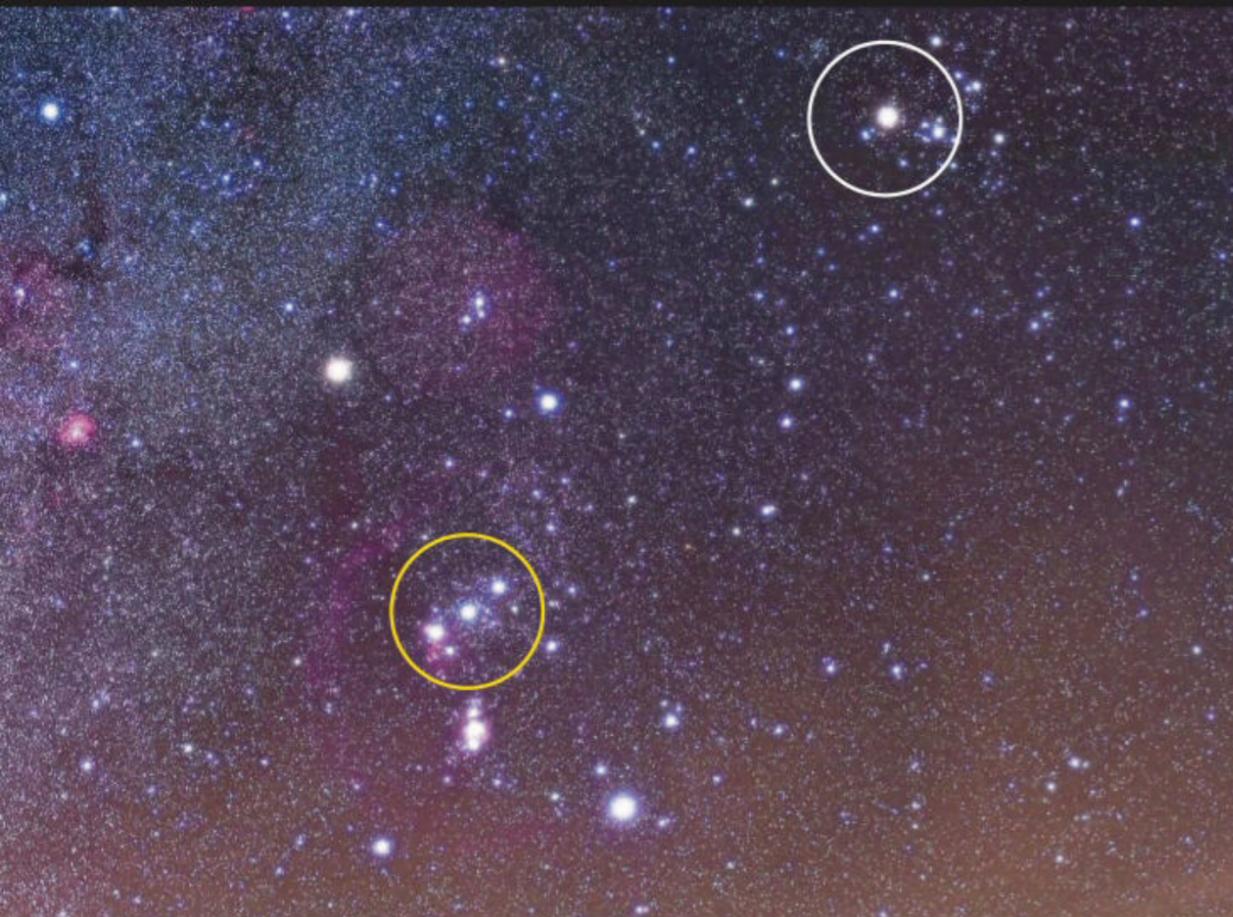
worlds beyond Neptune behaving mysteriously, and considered that perhaps a ninth planet could account for their strange motion. "We were confident that another planet could explain the features of the outer Solar System," says Batygin. They've been scouring the sky for this object, but so far it has escaped them. For now, this potential world goes by the moniker of Planet Nine. If and when it is discovered, it will be named after a Roman or Greek deity, just like the other planets.

LONG-DISTANCE RELATIONSHIP

Planet Nine's suggested existence is based on observations over the last decade with telescopes big enough to peer into the murky environs beyond the eight known planets. Studying this under-explored wilderness is a real challenge. We only see thanks to reflected sunlight, and for these trans-Neptunian objects (TNOs) that light has to undergo quite a journey. The odyssey starts at the Sun, then travels out to a distance of more than 4,500,000,000km, before bouncing off an object and making the return trip to the Earth almost all the way back to the start. That light is also fading all the while, making it very faint and requiring a big telescope to collect it. Take the 600-kilometre-wide object known as 2012 VP113. It sits 80 times further from the Sun than the Earth, meaning the light we see reflected from it is around 40 million times dimmer than normal sunlight. Despite travelling at 300,000 kilometres per second, light takes nearly a day to cover the full distance from the Sun to VP113 and back to the Earth.

It was the discovery of VP113 by astronomers Scott Sheppard and Chad Trujillo in 2014 that first flagged up the possibility of an undiscovered

"WE WERE CONFIDENT THAT ANOTHER PLANET COULD EXPLAIN THE FEATURES OF THE OUTER SOLAR SYSTEM"



planet. They are another team currently hunting down Planet Nine. Closer scrutiny of VP113's path around the Sun showed that it shared orbital characteristics with another TNO called Sedna. The angle at which they approach the Sun is eerily similar. Our best theories of Solar System formation say that for each object this tilt should be random. So the fact that these two objects match arouses suspicion. "They're like the fingerprints and broken glass of a crime scene," says Megan Schwamb from the Gemini Observatory in Hawaii and co-discoverer of several TNOs. "Who did it?". One explanation is to point the finger at a ninth planet, whose gravity is pulling on these objects and organising their orbits. To be doing that it would have to be several times the mass of the Earth. It wouldn't be the first time we've found a new planet this way. After Uranus was discovered, discrepancies in its orbit were put down to the tug of another planet even further out. Sure enough, when astronomers calculated where this planet would be they discovered Neptune. Now teams of astronomers including Brown, Batygin, Sheppard and Trujillo are trying to do the same with Planet Nine.

HIDE AND SEEK

So far the planet remains stubbornly out of view, but the search has cemented the evidence that it is really there. In the process of trawling the outer Solar System, astronomers have uncovered new TNOs. We now know of 14 objects clustered together more than 230 times further from the Sun than the Earth. This includes an object nicknamed The Goblin, discovered by a team of astronomers including Sheppard and announced in October 2018. It's a 300-kilometre-wide TNO on a highly elongated 40,000-year loop around the Sun. The more of these objects that we find sharing similar tilts, the stronger the case for Planet Nine becomes.

But there are alternative explanations. The leading one is that these copycat orbits are nothing more than observational bias. There are thought to be millions of TNOs out there that we haven't found yet, all with random orbits. It could just be a fluke that we've happened upon the handful that do share similar paths around the Sun. If this were true, Planet Nine would be a figment of our ◀

TOP: The five confirmed dwarf planets in our Solar System and their moons. From left to right: Pluto; Eris; Makemake; Ceres; Haumea

MIDDLE: The region of sky between Orion's Belt (yellow circle) and Taurus (white circle) is the search area for Planet Nine

BOTTOM: Artist's impression of Planet Nine

FAMOUS OBJECTS BEYOND NEPTUNE



SEDNA

Discovered by Mike Brown, Chad Trujillo and David Rabinowitz in 2003, Sedna was one of the objects that forced astronomers to re-evaluate Pluto's planethood. It takes 11,400 years to orbit the Sun, crawling along at an average speed of just one kilometre per second. Sedna will make its closest approach to the Sun in 2075–2076, providing a once in an 11,400-year opportunity to get the best view of this world named after the Inuit goddess of the sea.



2012 VP113

This object is often nicknamed 'Biden' after Joe Biden, who was the US vice-president at the time of its discovery at the Cerro Tololo Inter-American Observatory in Chile. At 600 kilometres wide, astronomers believe its pink colouration is due to the way cosmic radiation has shaded its surface, which is made of water and/or methane ice. It doesn't get as close to the Sun as Sedna, nor as far away. Sedna and Biden were the original basis for the Planet Nine idea.

◆ imaginations. But in January 2019 Brown and Batygin published new research attempting to quantify how likely this is based on the latest TNO discoveries. Their answer? Just 0.2 per cent. "That's our most conservative estimate," says Batygin. A ninth planet, they claim, is the only existing explanation for what we see in the outer Solar System.

SCOURING THE SKIES

That doesn't mean finding it is easy. All searches so far have failed to spot the planet. The hunt is not helped by the fact that there are only a handful of telescopes in the world capable of seeing it. Not only do you need a large aperture telescope to collect the faint light, you also need one equipped with a camera with a wide field of view. Brown is using the 8.2-metre Subaru telescope in Hawaii to hunt for it, while Batygin is busy crunching the numbers. "The search area is 800 square degrees of sky," says Brown. That's

about the same as 3,200 full Moons. A telescope with a narrow view would just take too long to cover this vast expanse.

It's not a two-dimensional patch of sky either, but three-dimensional. We also don't know Planet Nine's exact distance from the Sun. If it is near it will be brighter and if it's further away it will be dimmer. When it comes to the brighter end, Brown says they've already covered nearly all of the sky where it might be hiding without success. "That's surprising to me," he says. "That would have been the most reasonable guess of what Planet Nine would be like."

The findings are all the more unexpected when Batygin's latest computer modelling is taken into account. "We've performed thousands of new computer simulations in the last 18 months," he says, all to understand more about where Planet Nine could be. According to Batygin, the upshot of those calculations is that "Planet Nine is smaller in all parameters by a factor of two ◆

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GETTY IMAGES



THE GOBLIN

Named because it was discovered close to Halloween, The Goblin was first observed on 13 October 2015 using the Mauna Kea Observatory in Hawaii. It took three years to track it in sufficient detail to pin down its orbit and announce the discovery to the public. The Goblin's highly elongated orbit carries it from roughly twice Pluto's distance from the Sun all the way out to 30 times further than that. It's about as bright as one of Pluto's smaller moons.



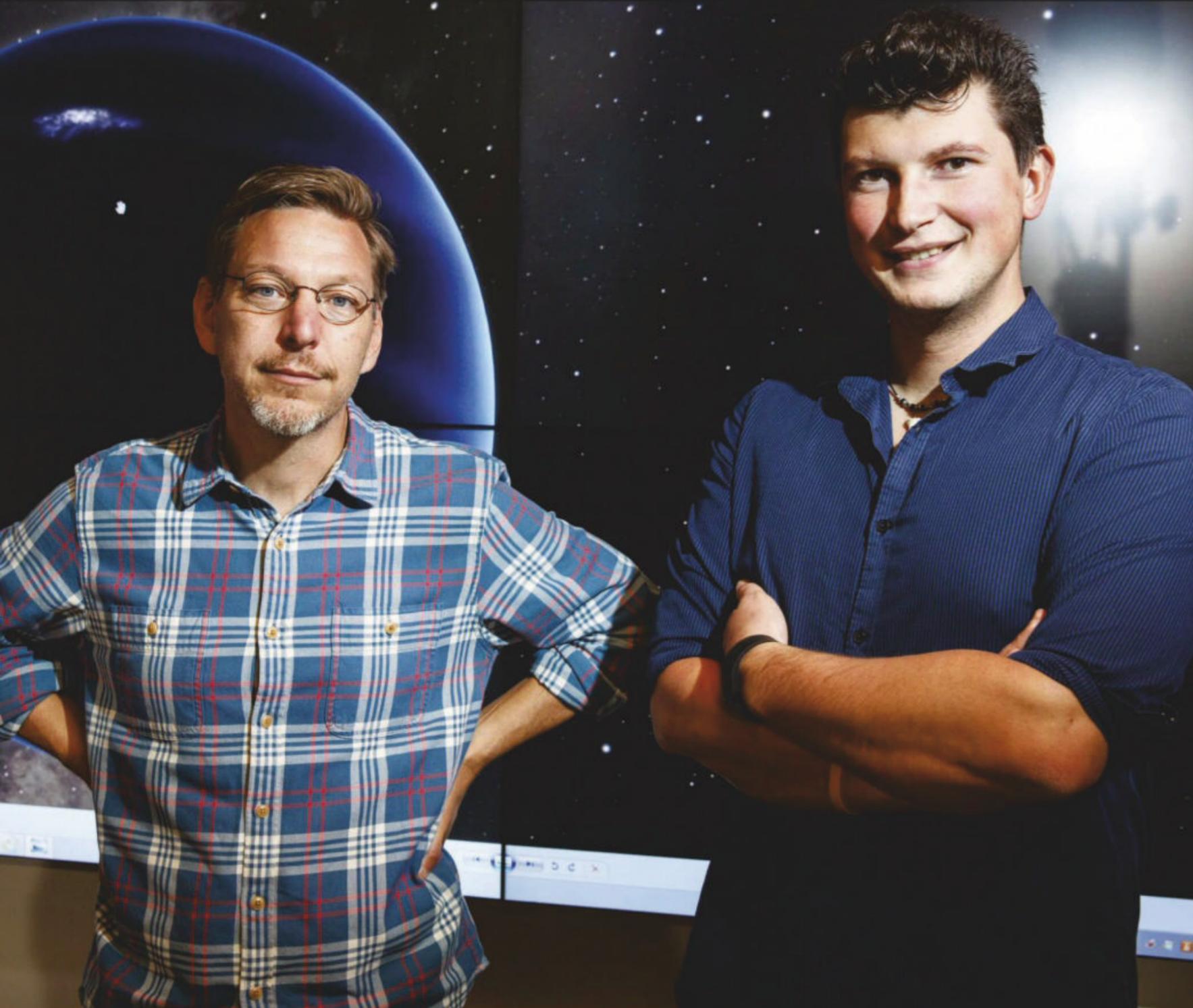
FAROUT

Astronomers like to keep things simple where they can, as illustrated by the nickname of this object found on 10 November 2018. A name like FarOut marks that, at the time of its discovery, it was the furthest object ever found in the Solar System. Unfortunately this won't be its official name. Looking back at older photographs actually shows that FarOut had been captured before in 2015 and 2017. Like VP113, it appears to be pinkish in colour.



FARFAROUT

FarOut didn't hold its crown as a record breaker for long. In February 2019 a team led by Scott Sheppard announced the discovery of an object even further out – nicknamed FarFarOut. This time it is 140 times further from the Sun than Earth (or 21 billion kilometres). Both objects have been found so recently that their orbits are still being determined to see if they support the Planet Nine theory.



Mike Brown (left) and Konstantin Batygin (right) are searching the skies for objects beyond Neptune, including Planet Nine

HEAD IN THE CLOUDS:
The Subaru Telescope on top of
Hawaii's Mauna Kea is being used to
search the skies for Planet Nine



“NATURE HAS NO OBLIGATION TO YOU. LOOK AT GRAVITATIONAL WAVES – THEY TOOK 100 YEARS TO FIND”

• compared to our original estimates”. Its orbital period is now thought to be 10,000 years rather than 20,000. It is five times the mass of the Earth, not 10. Despite being smaller, its shorter orbit would make it about two and half times brighter than the original 2016 estimates.

THE NET IS CLOSING

So how come Brown still hasn't found it, despite trawling the whole area at the brighter end? “We don't know its albedo and that's the key parameter,” says Brown. An object's albedo is a measure of how much sunlight its surface reflects back into space. “It could either be a super-cloudy, bright object or a dark ice ball covered in junk with a low albedo.” The fact it hasn't been found yet suggests it is the latter. If a dull surface is making it dimmer, finding Planet Nine will take more time. “We've covered about 50 per cent of the sky in that range,” he says.

So the net is closing, but it is a laborious process. “The main difficulty is sustaining such an intense search for many years,” says Brown. Planet Nine's predicted position out between Orion's Belt and Taurus is both a blessing and curse. Orion is part of the winter sky, which means that astronomers are restricted to searching for it during that season. In the summer it is part of the daytime sky and therefore undetectable. On the plus side, winter nights are longer, but the emphatic downside is that in recent years the winter weather in Hawaii has been horrendous. Batygin recalls one occasion where he was driving up the volcano to the telescope with hailstones the size of golf balls slamming into the car. On another occasion the weather looked clear, but Brown arrived at the telescope to find the door to the telescope was frozen shut. “We've had every sort of obstacle you can imagine,” says Brown. Other roadblocks have included volcanic eruptions, earthquakes and sulphur dioxide fumes. “It's frustrating,” he says. “[I'd] like to find it and move on to something else.” With winter now over, this season is done and the search will have to wait until the Earth moves back round to the favourable

side of the Sun. Batygin sums it up nicely: “Nature has no obligation to you,” he says. “Look at gravitational waves – they took 100 years to find.”

Hopefully we won't have to wait quite that long. If the current searches fail, there's hope on the horizon in the form of the Large Synoptic Survey Telescope (LSST). Currently under

construction in Chile, its 3.2 billion pixel camera will be capable of photographing an area of sky the size of 49 full Moons at once. It's due to start operation in 2022. Even if it doesn't find Planet Nine right away, it is expected to discover hundreds of new TNOs. If their orbits also share the tell-tale alignment, then that would both strengthen the case for Planet Nine and point astronomers towards where to find it. According to Schwamb, the Planet Nine hypothesis is an answerable question. “It is not going to be a mystery forever,” she says.

A deeper puzzle is how Planet Nine got there in the first place. How does a planet five times the mass of the Earth end up marooned up to 20 times further from the Sun than Neptune? The most likely explanation is it formed in the inner Solar System with the other eight planets, before some event threw it out into the depths of space. Even before astronomers found evidence for Planet Nine, computer simulations of the Solar System's formation were hinting at a missing planet. Starting with five giant planets resulted in a Solar System that looks more like ours today than those that started with just four. The only trouble was that there was no other evidence that this extra planet ever existed. Yet if the current frenzy of activity confirms the existence of Planet Nine, it is almost certainly this missing world. Its discovery would mean more than just another planet on the list: it could be the key to understanding why our Solar System looks the way it does today. **SF**

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