Beyond Pluto

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NASA mission control has already steered New Horizons toward its final destination

TOP: NASA/JOHNS HOPKINS UNIVERSITY APL/SWRI/STEVE GRIBBEN; DROP INS: MICHAEL SOLURI; FAR LEFT: NASA/JOHNS HOPKINS UNIVERSITY APL/SWRI

WITH Pluto rapidly shrinking from view, NASA's New Horizons probe is slipping further into a vast unexplored wilderness known as the Kuiper belt. This great frigid expanse beyond the gas giant Neptune is home to millions of icy bodies, known as Kuiper belt objects, many of which are thought to be pristine remnants from the birth of our planetary neighbourhood some 4.6 billion years ago.

As the world continues to gawp at breathtaking images of the Kuiper belt's most famous inhabitant, Pluto, the plucky little probe that snapped them is about to embark on one last fly-by. It won't be easy: New Horizons's latest target is much smaller than the dwarf planet and there is uncertainty about its exact position. But if all goes to plan, this valedictory mission could yet be the most revealing phase of an awe-inspring journey.

"The Kuiper belt is a truly key population for understanding how the solar system evolved after the planets formed," says Michele Bannister of the University of Victoria in Canada, who works on the Outer Solar System Origins Survey – a project to map the Kuiper belt from Earth to get a handle on how it formed. By capturing the first close-up views of one of its smaller inhabitants, New Horizons's final act before it falls silent could help rewrite the history of our cosmic neck of the woods.

This last assignment is far from an afterthought. In fact, the visit to a second Kuiper belt object was something the New Horizons team thought about from the outset, says John Spencer of the Southwest Research Institute in Boulder, Colorado, who is part of the planning team for the extended mission. "Back when the spacecraft was still being designed in 2002, we were thinking pretty seriously about what we would need to do."

Most importantly, the probe's designers made sure it would have sufficient fuel reserves to fire up the thrusters that would steer it towards another Kuiper belt object. "If we couldn't change course we would have no ability to get close to anything other than by the incredibly unlikely chance that we would just happen to breeze right by something," says Spencer.

The big question, though, was exactly what to aim for. Although estimates suggest there are hundreds of thousands of icy bodies in the Kuiper belt (see "Welcome to the boonies," page 36), the challenge was to discover objects within reach of New Horizons.

With Spencer at the helm, the search team started scanning the far reaches of the solar system in 2004, using the Subaru telescope in Hawaii. They wanted to check there was nothing large and interesting enough to warrant a tweak to the Pluto fly-by schedule. There was not. So two years later, when New Horizons was launched on its epic voyage, it carried enough fuel to explore a small portion of the Kuiper belt, but its post-Pluto destination was still unknown.

By 2011, with New Horizons set on a specific path, the team had a much narrower section of sky to scour, in the constellation Sagittarius. But now there was a fresh obstacle: it would be difficult to pick out faint objects against the myriad Milky Way stars in the background. "We were quite concerned by late 2013," says Spencer. "We'd had three years of searching and we were finding it very challenging to look in the very dense star fields."

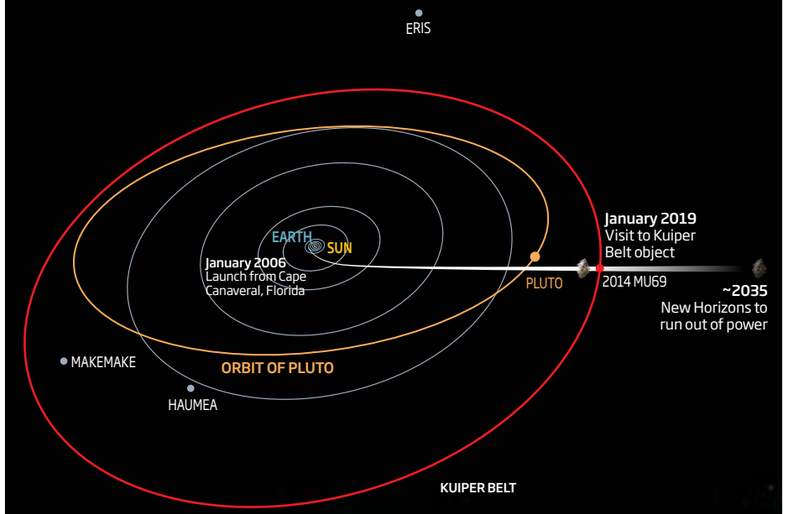
Eventually the group managed to discover some 50 Kuiper belt objects lurking in front of this sparkling backdrop. Unfortunately, all of them lay beyond the range of the outbound New Horizons. "I think the closest one that we found would have required about 50 per cent more fuel than we actually had in the tank," says Spencer. "We knew we were getting down to the ballpark of where we needed to be, but we certainly hadn't got what we needed at that point. That was why we turned to Hubble."

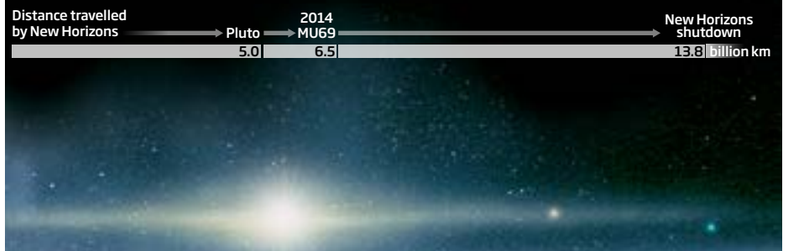
The Hubble Space Telescope promised more detailed images. But first the team had to prove to Hubble bosses that they stood a good chance of discovering potential targets, and then they had to sift though an avalanche of data. "It was nerve-racking," says Spencer, "but mostly it was just kind of exhilarating."

In 2014, the team finally struck gold: two Kuiper belt objects, 2014 PN70 and 2014 MU69, both of which would be within New Horizons's reach. The amount of fuel required to steer a course towards the former would have left precious little for precision manoeuvres around the object, compromising the ›

Final fly-by

Before it falls silent forever, the New Horizons probe is heading deep into the Kuiper belt for one last mission: a close encounter with a pristine remnant from the early days of the solar system – 2014 MU69





JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE/JHUAPL/SWRI

WELCOME TO THE BOONIES

We suspected there were frozen badlands beyond the planets long before we saw them. In 1951, astronomer Gerard Kuiper made a strong case for the existence of a vast swathe of icy bodies beyond Neptune's orbit. It wasn't until 1992, however, that astronomers spotted something other than Pluto out there. It was the first real evidence of an immense ring of debris at the outermost edges of the solar system – a region now known as the Kuiper belt.

Astronomers have since discovered roughly 1500 Kuiper belt objects orbiting between 4.5 and 7.5 billion kilometres from the sun. And yet we've barely scratched the surface. We know that most of them are tens of kilometres across but there are a few larger bodies out there, including Pluto and its largest moon Charon. The dwarf planet Eris, for instance, appears to be almost the same size as Pluto, and might have similar geological activity. The region is also thought to be the source of most short-period comets, which take less than 200 years to orbit the sun.

But our best estimates suggest this planetary wasteland should contain hundreds of thousands of icy bodies – remnants from the solar system's early days – and we know almost nothing about all but a handful of them. "We are still pretty ignorant about many aspects of the Kuiper belt," says Wes Fraser of Queen's University Belfast, UK. "For one thing, we don't know much about what they are made of. They must have some sort of rock inside, but what is it?"

The Kuiper belt holds secrets about how the planets formed and how our planetary neighbourhood evolved. It might even provide insights into why Pluto didn't make it to planet status, says Fraser.

Trouble is, the region is so distant that even with space telescopes it has been difficult to get to know its inhabitants. No wonder planetary scientists are so excited by the prospect of a close encounter with one of them (see main story).

mission's scientific objectives, says Spencer. "So it was a fairly straightforward choice in the end." New Horizons would go to 2014 MU69.

The team is hoping that NASA will officially sign off on the extended mission to 2014 MU69, a decision that won't be made until late next year. But Spencer and his colleagues have already commanded the four engine burns needed to send the probe in the direction of its post-Pluto target, currently roughly 1.5 billion kilometres from the dwarf planet (see diagram, left).

Assuming the extended mission gets the nod, when the spacecraft visits 2014 MU69 in January 2019, we can expect to see an object very different from Pluto. Measurements of its brightness suggest it is between 30 and 40 kilometres across – far smaller than the 2370-kilometre-wide dwarf planet. It is also expected to be irregularly shaped and covered with craters, says Spencer. And as a member of the "cold classicals" group, which move in relatively circular orbits compared with other Kuiper belt objects, it should be reddish in hue.

Just as with Pluto, New Horizons's encounter with 2014 MU69 will be fleeting, and its instruments will have to work flat out to gather data on their icy quarry. "We'll be using our infrared spectrometer to map the composition of the surface and the ultraviolet spectrometer to look for any signs of an atmosphere," says Spencer. "We don't expect to see an atmosphere on something this small but we sure will be ready for surprises."

Atmosphere or not, getting up close and personal with 2014 MU69 should help to reveal whether Pluto was formed from such objects and could help to address fundamental questions about how planets form.

According to our best theory, planets are born out of protoplanetary discs – great whirls

The New Horizons probe is about the size of a baby grand piano

SCOTT ANDREWS/GETTY

of dust and gas spinning around the midriff of a young star. The material comes together to form small clumps, which pull in more material thanks to their modest gravity. Soon you have the beginnings of planets, known as planetesimals, and eventually planets.

Objects like 2014 MU69, as residents of a region that has remained largely undisturbed since the early days of the solar system, are thought to be the ancient leftovers from this planet-forming process. "We would very much like to know what processes formed the primordial planetesimals – the original building blocks of the planets – and 2014 MU69 is the closest we have yet come to flying by one of these," says planetary astronomer Alex Parker, also at the Southwest Research Institute, who helped discover 2014 MU69.

Its relatively undisturbed location far from the sun – what Parker calls its "deep-freeze orbit" – has helped to preserve it as a time capsule. So this mystery chunk should tell us about the processes by which it was formed and how its ilk helped to build the planets.

Scars of violence?

If New Horizons observes fresh impact craters, for example, it may reveal something about the formation of bodies like Pluto. Any newish pockmarks will have uncovered material from below the surface of 2014 MU69 – stuff that hasn't been altered by cosmic rays, say, or ultraviolet radiation. That should allow us to figure out its composition, says Spencer. "We can compare that to what we expect objects like Pluto to have been made of."

Such observations could also help to solve another great mystery: how the solar system came to be arranged in its particular way. Current models suggest that the gas giants were once bunched up much more tightly than they are today, encircled by a substantial disc of planetesimals. Then something destabilised this cosy arrangement, hurling the planets into their present-day positions. The outer disc was shaken up too, although some of it endured to form the Kuiper belt.

Scientists have run many simulations of this period, and yet precisely how this process played out remains a conundrum. Was it a violent upheaval or a more gentle migration? To answer that, we need to know exactly how massive the disc of planetesimals was before the gas giants migrated. And here is where 2014 MU69's craters could help.

"In a way the craters actually preserve a reflection of the amount of mass that was around these objects at some point," says Wes Fraser of Queen's University Belfast, UK. The idea is that if an object is riddled with scars, that would suggest there were once lots of objects around to crash into it, whereas if an object has only a few craters, it was probably surrounded by fewer objects. By studying the sizes and numbers of craters in New Horizons's images, scientists should get a better idea of the mass of the disc. And by feeding that back into current models, they should get a clearer picture of how the solar system evolved into what we see today.

For Bannister and her colleagues at the Outer Solar System Origins Survey, the fly-by could also provide context for their studies of the orbits and surface compositions of distant Kuiper belt objects. "We can finally match together what we see from Earth only as a tiny point of light with the actual ices and hydrocarbons that cover its surface," she says. And although 2014 MU69 will undoubtedly be the centre of attention during this post-Pluto mission, the team behind New Horizons will also study other objects the probe glimpses.

As for the little probe itself, once it has completed its work in the Kuiper belt, it will glide ever further into the outer reaches of the solar system. It will continue to send back data, including measurements of the solar wind – the stream of charged particles flowing from our star – until its radioactive power source runs out, probably in the mid-2030s.

Regardless of when we lose touch, New Horizons's fate is set. With the Kuiper belt frontier traversed, it will drift off into the Milky Way – its precious data stored on Earth and its journey into darkness complete. ■

Will Gater is an astronomy journalist based in Somerset, UK

WHERE SPACECRAFT GO TO DIE

Once New Horizons has slipped past its latest target in the Kuiper belt, its course will whisk it deep into the Milky Way. It will follow an armada of space probes that have sailed into quiet retirement or crashed into violent oblivion.

Like New Horizons, the two Voyager spacecraft – which toured the outer planets in the 1970s and 1980s – are heading for interstellar space. And data returned by Voyager 1 has led some to argue that it has already left our solar system.

Others have gone out with a bang. The Galileo probe to Jupiter was commanded to plummet into the gas giant so as not to litter the planet's moons with earthly debris. And the Rosetta mission, currently hovering around the comet 67P Churyumov-Gerasimenko, will be deliberately crashed into its icy quarry next year. A similar fate awaits Cassini, due to plunge into Saturn in 2017.

A few spacecraft are lucky enough to retire on the planet they went to see. When the adventures of the Mars rovers Opportunity and Curiosity eventually come to an end, for instance, they will sit motionless on the Red Planet's surface, slowly gathering ochre dust as the Martian breeze swirls around them.

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