BBC

BRITAIN'S NEXT ASTRONAUT IS READY FOR SPACE

#230 JULY 2024

Sky at Night

THE UK'S BEST-SELLING ASTRONOMY MAGAZINE

IMPACT ON JUPITER

30 years on: How comet Shoemaker–Levy sent Earth a dramatic warning

MISSION ON THE EDGE: INTO THE UNKNOWN WITH NEW HORIZONS

THE UK PARALYMPIAN OPENING ACCESS TO ORBIT

TOUR THE MAJESTIC MILKY WAY AT ITS BEST | THE HUNT FOR DARK MATTER DEEP BENEATH YORKSHIRE | VAONIS VESPERA II SMART TELESCOPE ON TEST

Mission into the UNKNOWN

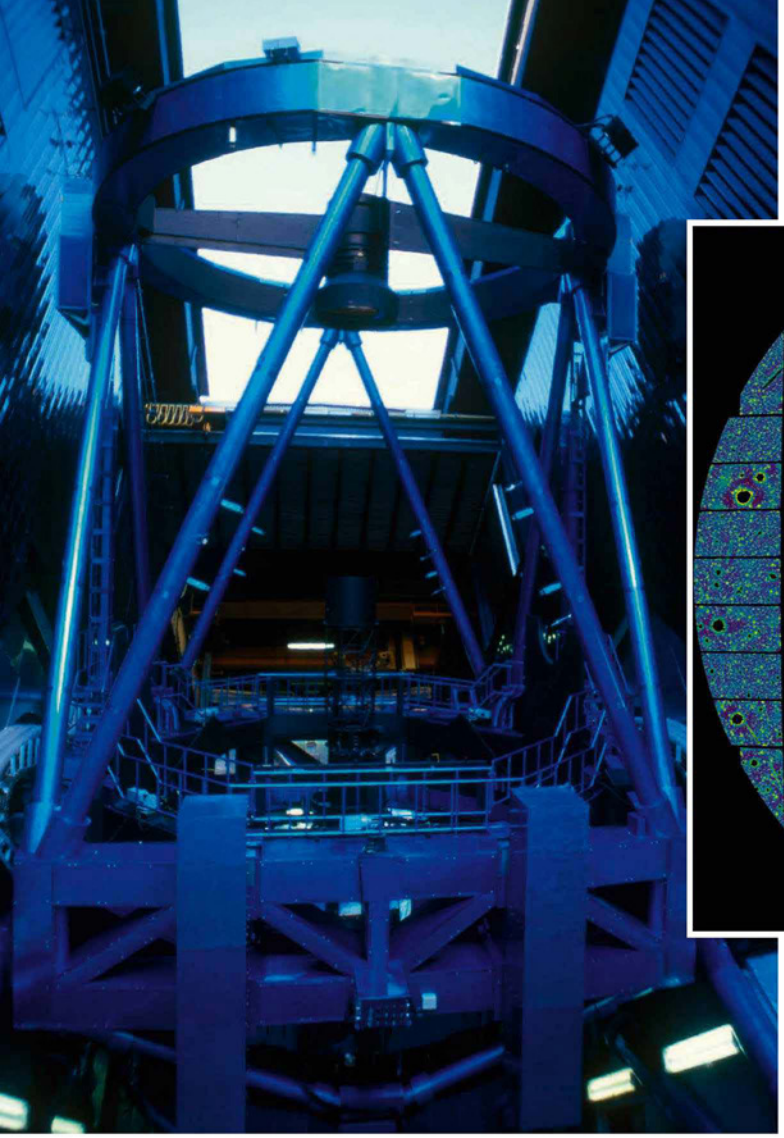
For the last 18 years, New Horizons has been flying to Pluto and beyond. But how do scientists run a mission at the darkest, uncharted fringes of our Solar System? **Ezzy Pearson** finds out

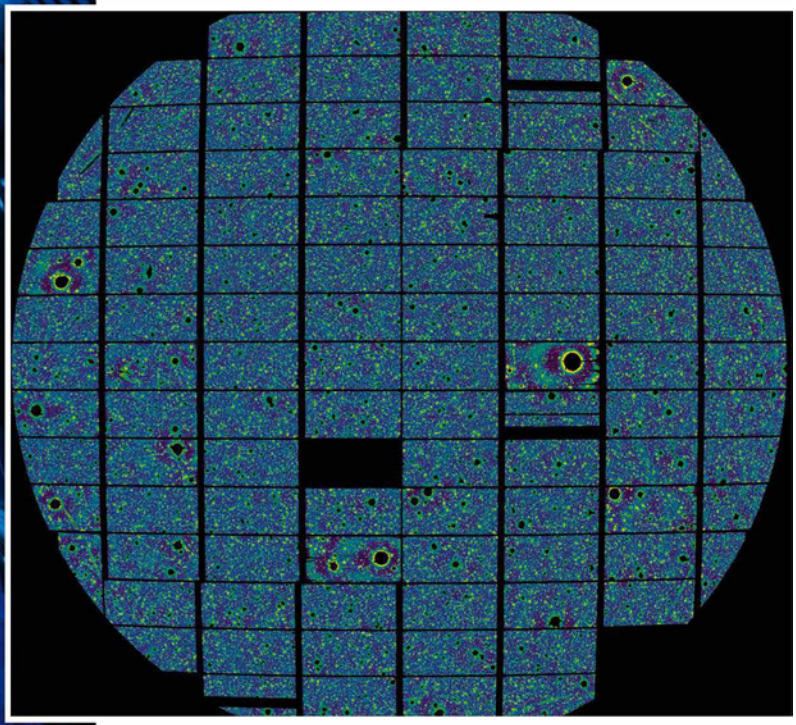
Far on the outskirts of our Solar System lies the diminutive dwarf planet Pluto. Ever since its discovery in 1930, it's held a special place in the hearts of space fans the world over. This month on 23 July, the planet will be at opposition, directly opposite the Sun from Earth, and just four days later it makes its closest approach to our planet. Even then, however, it's a dim and distant cousin of our Solar System family, an incomprehensible 5.8 billion kilometres (3.6 billion miles) away.

It's difficult to grasp such vast distances, which is why at these scales scientists use Astronomical Units (AU), where 1 AU is around 150 million kilometres (93 million miles). Pluto resides in a ring of icy objects beyond the orbit of Neptune, beginning 30 AU from the Sun, called the Kuiper Belt. Astronomers have tried to study this distant region from Earth as best as they can, but even at their closest, our most powerful telescopes see individual objects only as dots moving against the background stars. And so the Belt remains largely unknown, shrouded in mystery at the very edge of our vision. That is until NASA's New Horizons began its epic exploration behind the veil. ▶

ILLUSTRATION: NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

Remote control: hurtling through the far-distant Kuiper Belt, intrepid New Horizons is still doing great science





▲ Spotting Kuiper Belt objects for the mission to hone in on is no easy task. This image from just one night of observations shows a hunting ground crowded with countless stars

◀ Scientists peer ahead using the 8.2-metre optical Subaru Telescope in Hawaii to plan New Horizons' next steps

▶ New Horizons is the one brave traveller that is venturing far into this distant region, sailing through the Kuiper Belt for over a decade. The probe is best known for its fly-bys of Pluto and fellow Kuiper Belt object (KBO) Arrokoth, but the mission is not done yet. Every year, it travels 3 AU further into the darkness. In October this year, it will pass the 60 AU mark, and with power and fuel reserves expected to last until 2050, it promises to continue bringing a light to the region for many years to come.

The biggest hope for the mission is the possibility of finding another Kuiper Belt object for a third fly-by.

"There's only one criterion for a fly-by target," says Alan Stern, principal investigator of New Horizons, "– that it be close enough to our trajectory that we can get there with the remaining fuel on board."

Flying blind

The New Horizons team are scouting the path ahead of their spacecraft with the 8.2-metre-wide Subaru Telescope on Mauna Kea in Hawaii. Using its widefield camera, the team take deep images of the region of sky that New Horizons is flying through. By comparing these from night to night, astronomers can look for KBOs moving slowly across the background stars. A search in 2020 uncovered 100 new KBOs, though unfortunately no suitable candidates were found.

At the time, that seemingly put to rest any hope of another fly-by, as the Kuiper Belt was thought to only extend out to 50 AU, and New Horizons sailed past that limit in 2021.

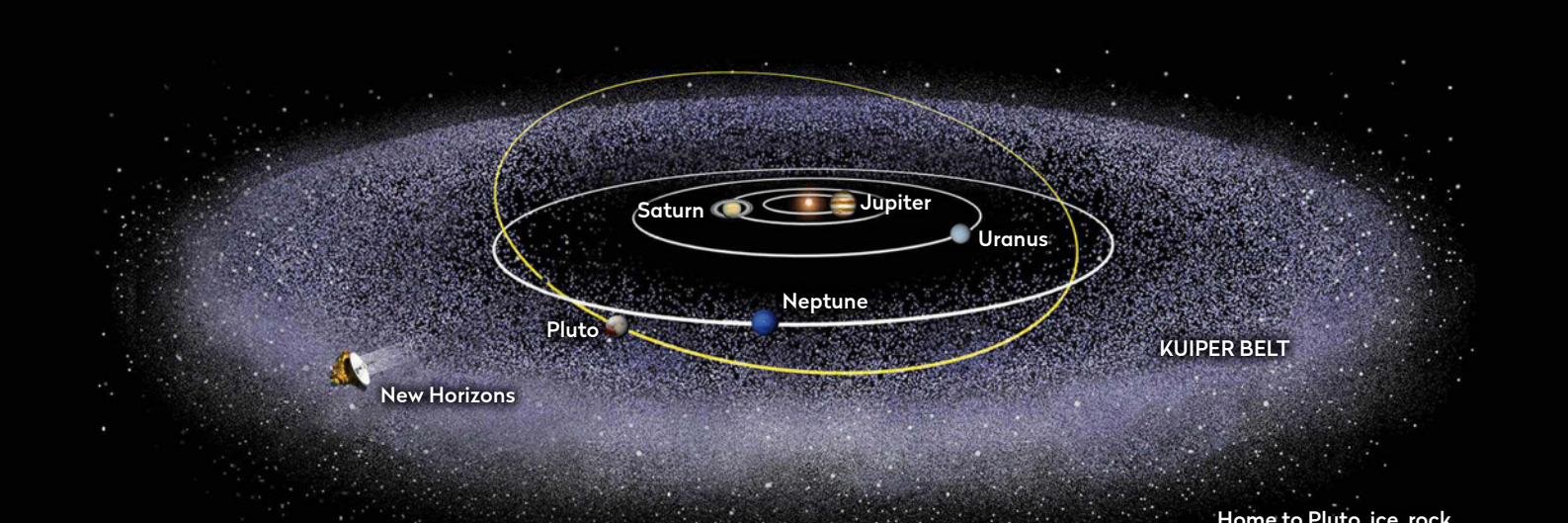
◀ Are we there yet? The Student Dust Counter Instrument detects microscopic particles hitting New Horizons, telling it whether it's still in the thick of the Kuiper Belt

"That was as far out as we could see," says Stern. "After about 50 AU it appeared that there's a desert of objects. The question always was: is that a Kuiper cliff, where that's the end of it and after that there's nothing? Or is it a Kuiper trough, where there's simply a desert crossing and then you see more Kuiper Belt? Because our telescopes couldn't see much further back then, we didn't know the answer."

The further New Horizons sailed beyond this supposed edge, though, the more apparent it became that the Belt wasn't quite done yet.

"Our ground-based surveys using the Subaru Telescope detected a whole bevy of objects much further out than we ever expected," said Stern. "We've already found a dozen objects way beyond where we expected to find them. And that's probably just the tip of the iceberg."

JAN HALASKA/ALAMY STOCK PHOTO, NASA/JOHNS HOPKINS APL/SOUTHWEST RESEARCH INSTITUTE/SUBARU TELESCOPE, NASA/LASP, THE JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY, EUGENDOBRIC/ISTOCK/GETTY IMAGES



Home to Pluto, ice, rock, comets and dwarf planets, the Kuiper Belt circles the outer Solar System like a puffed-up doughnut

The Kuiper Belt

Our Solar System is surrounded by a ring of icy space rocks

The Kuiper Belt is believed to be made up of the icy leftovers from the Solar System's formation. It gets its name from Gerard Kuiper, who published a paper in 1951 speculating on the presence of objects in the space beyond Pluto, though astronomer Kenneth Edgeworth had previously mentioned similar objects too.

The icy fragments are spread out over a huge, doughnut-shaped region. It's thought that in the early days of the Solar System, the belt could have contained a mass 10 times that of Earth. At some point in the next few hundred million years, however, the gas giants shifted in their orbits, creating gravitational chaos throughout the Solar System.

This resulted in a huge number of KBOs being ejected from the Belt, and now only around 0.1 Earth masses remains. Even though the Solar System is a lot more stable today, objects are occasionally flung out of the Belt. Those which are sent on trajectories towards the inner Solar System appear to us as short-period comets.

The Kuiper Belt isn't unique to our Solar System. Similar structures, known as debris discs, have been seen in many other planetary systems. These tend to be less compact than ours, and some stars even appear to host two nested Kuiper Belts that are much dustier than ours. In fact, if our belt was around another star, it wouldn't contain enough dust for us to detect it.

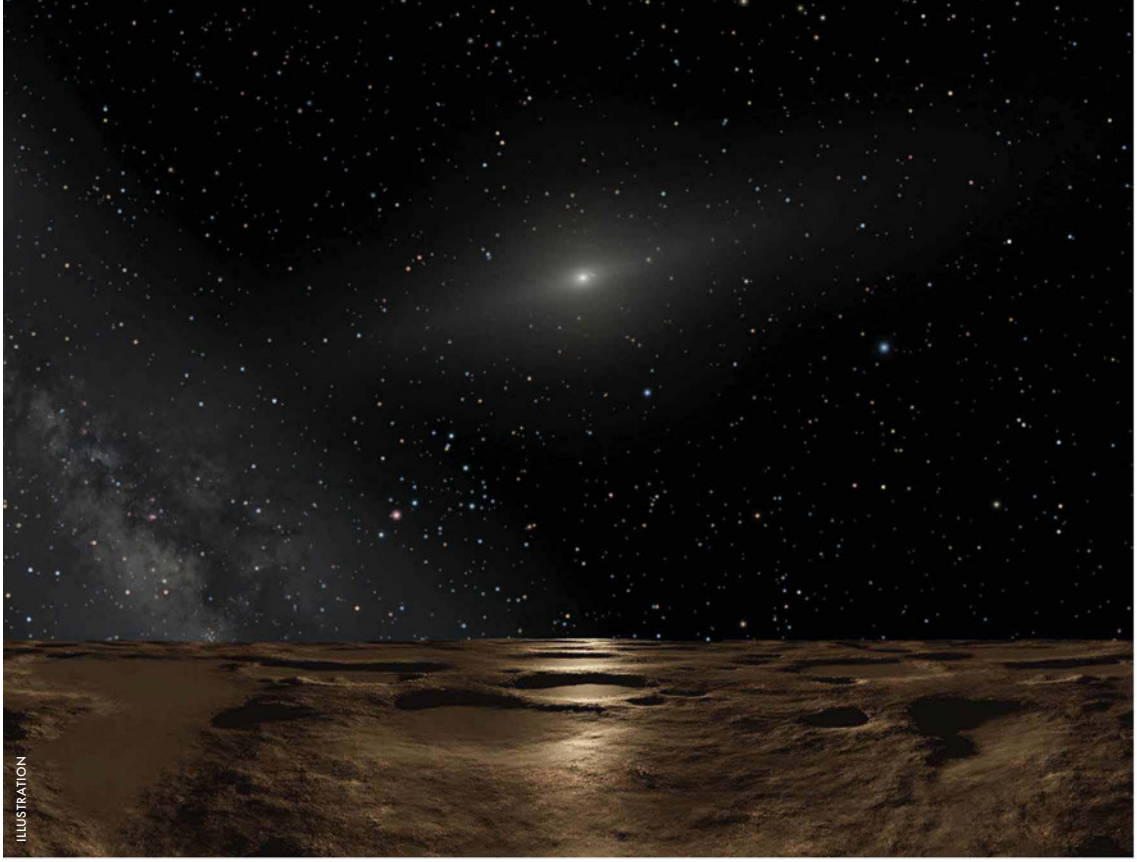
At the same time, New Horizons itself was looking at its surroundings, trying to find any sign it was leaving the Kuiper Belt, with the help of its Student Dust Counter (SDC) instrument.

"The SDC registers impacts on the spacecraft from microscopic dust particles," explains Stern. "Those particles are created by collisions between KBOs, or other processes that cause them to shed material. What you'd expect is that when you leave the Kuiper Belt, the number of dust impacts dramatically plummets. All of the mathematical models from the 2000s and 2010s indicated our dust detector should start to see that decline somewhere around 2020.

"Well, it's 2024 and there's been no sign of decline. In fact, we're seeing more."

Choosing the next target

All the indicators point towards an expanded population of KBOs ahead of the spacecraft, perhaps even as far out as 100 AU, hidden beyond the limits of our current observatories. Luckily, these limits will soon be pushed back by two new telescopes, the Vera Rubin Observatory and the Roman Space Telescope, which should both be in operation by the end of 2027. Both of these will peer deeper into the gloom, seeking out even more potential KBOs. ▶



ILLUSTRATION

◀ **Living on the edge: the Sun is just a glimmer out where New Horizon roams. The piano-sized probe is currently 8.7 billion kilometres (5.4 billion miles) away**

"Because the sky is so dark out there way beyond the middle Solar System, we're able to probe the Cosmic Optical Background"

▶ "It's a needle in a haystack problem," says Stern. "But we're searching very hard. The spacecraft has the power to operate until the year 2050, but operations for a fly-by require more power, so we can only do fly-bys until 2040 or maybe 2041. That's a long time."

Even if there is no other target for a potential fly-by, there is still much scientific work for New Horizons to do. It is one of only three spacecraft to have seen the outermost reaches of our Solar System and to have been able to call back home with what it has found.

"The last ones to come out this way were the Voyagers," explains Stern. "They were built in the '70s. Our spacecraft was built in the 21st century. Our particle and plasma spectrometers are orders of magnitude more capable."

The mission is currently investigating three main scientific fields: planetary science, astrophysics and heliophysics.

"In the planetary science bucket, we're observing Kuiper Belt objects as we pass them by. Not at close enough range to see their geology, but close enough to study their surface properties and to search for satellites," says Stern.

In addition to Pluto and Arrokoth, New Horizons has observed 36 other KBOs using its Long-Range Reconnaissance Imager (LORRI), essentially a 8.2-inch reflecting telescope. While the aperture is similar to what an amateur astronomer might have in their back garden, LORRI has two major advantages: it's much closer to its targets than our Earth-based telescopes and it's able to view these KBOs from several different angles as it flies past.

"They're very tiny and very softly lit by the Sun out there," says Stern. "Only New Horizons can study how their brightness varies as they rotate."

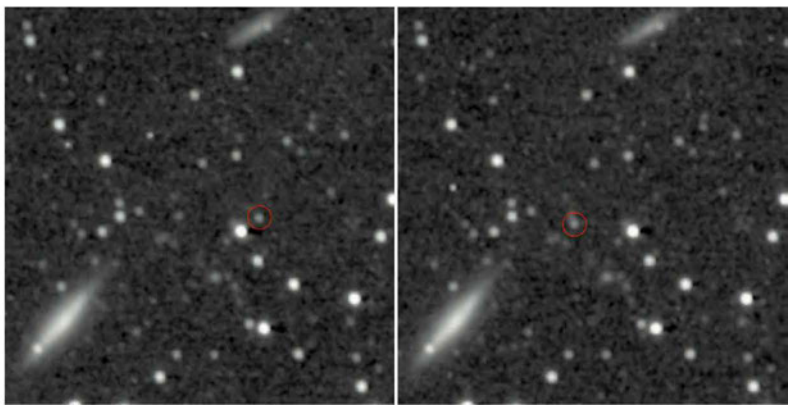
As well as revealing information about their shape and rotation rates, studying how the light reflects off the KBOs from different angles can also reveal details of their surface characteristics, such as roughness and albedo.

Seeing in the dark

New Horizons has another advantage that helps with the astrophysics part of its science remit, in that it is beyond the faint fog created by light reflecting off dust in the inner Solar System.

"Because the sky is so dark out there way beyond the inner and middle Solar System, we're able to probe something called the Cosmic Optical Background much more sensitively than has ever been done before," says Stern.

▼ **Dwarf planet Quaoar ('Kwa-war'), imaged with the LORRI instrument in July 2016 from 14 AU away**



ADOLF SCHALLER/GETTY, NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE X 3, LAUER ET AL./ASTROPHYSICAL JOURNAL 2021

A tale of two fly-bys

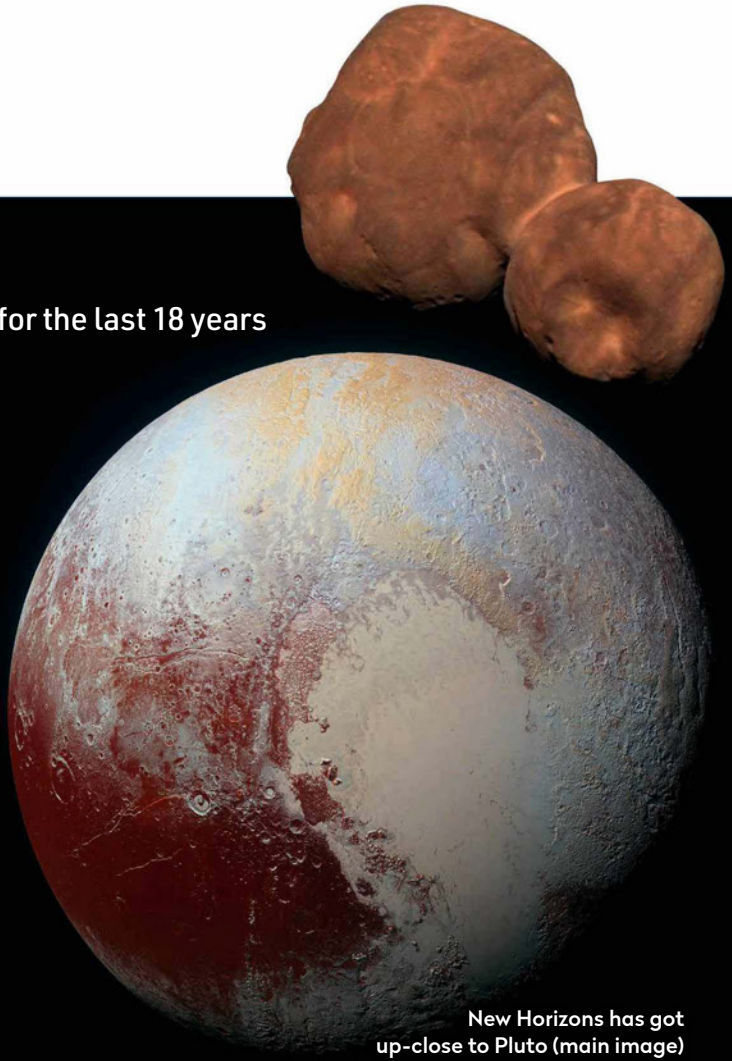
New Horizons has been travelling through space for the last 18 years

New Horizons launched from Cape Canaveral, Florida, on 19 January 2006. A year later, it flew past Jupiter, using the planet's gravity to boost its speed to 84,000km/h (52,000mph). It still took the spacecraft over nine years to travel the five billion kilometres (three billion miles) to Pluto.

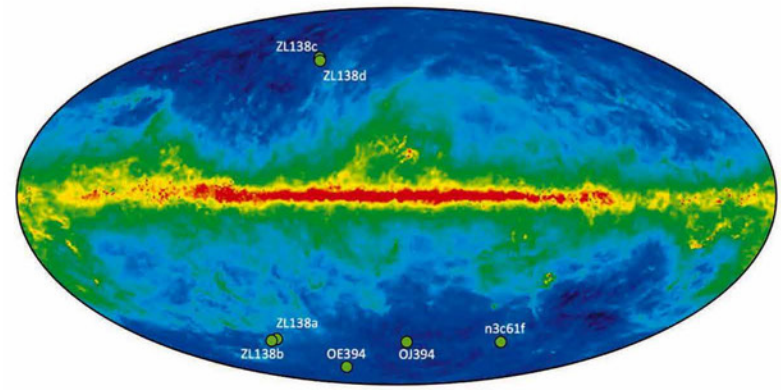
On 14 July, the spacecraft passed just 12,500km (7,800 miles) away from Pluto and its moons Charon, Styx, Nix, Kerberos and Hydra. Despite the speed at which it whipped past the planet, New Horizons was able to conduct detailed observations. Pluto was unveiled as a complex world with a jumble of different terrains, including a wide heart-shaped region of bright nitrogen ice called Tombaugh Regio, after Clyde Tombaugh who discovered Pluto.

Even before the Pluto encounter, the New Horizons team had looked for other potential fly-by targets, eventually narrowing in on 2014 MU69, nicknamed Ultima Thule and later named Arrokoth. New Horizon flew 3,500km (2,200 miles) past the object on 1 January 2019, when they were 43.4 AU from the Sun. The images revealed Arrokoth to be a double-lobed object, around 32km (22 miles) long and surprisingly red in colour – most likely due to the mixture of organic chemicals contained within its icy form.

The information gleaned from these short encounters with two very different objects has helped planetary scientists shape our understanding of the Kuiper Belt – and left them crossing their fingers that they may still add a third to the roster.



New Horizons has got up-close to Pluto (main image) and Arrokoth (top) so far



▲ **With the light and dust pollution of the inner Solar System in its rear-view mirror, the probe is free to isolate the Cosmic Optical Background. To date it's been able to identify seven new light sources in the distant Universe**

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press

The Cosmic Optical Background is the combined visible light from the stars in all the galaxies beyond our Milky Way, as well as from the brightly glowing accretion discs around black holes.

The New Horizons team used LORRI to measure the background back in 2023, as well as assessing the Cosmic Ultraviolet Background using the Alice ultraviolet spectrometer. The results of both are still being studied, but will eventually be used to identify how many galaxies there are in the Universe beyond those we can see individually.

Finally, New Horizons is currently journeying through the outer edge of the heliosphere, the extended atmosphere of the Sun, a bubble created by its magnetic field and the solar wind.

"Presently we're approaching something called the termination shock, which is the first milestone of leaving the heliosphere and proceeding into interstellar space," explains Stern. "We expect to start crossing the termination shock possibly as soon as three years from now."

The termination shock marks the point where solar wind particles begin to slow down as the Sun's influence begins to interact with the surrounding interstellar medium. The Voyager probes previously passed the termination shock when they were around 90 AU from the Sun. A few years later, they crossed into interstellar space completely, at a distance of 120 AU. As the Voyager probes were built with little knowledge of what they would find in the region, they lacked the instruments to fully explore the solar wind particles they found.

But their loss was New Horizons' gain, and it has been well equipped for the task. The spacecraft is expected to head into interstellar space sometime in the 2040s, where its instruments will be able to measure the flow of particles in the region, revealing how our heliosphere supports itself against the flow of the interstellar medium.

After that, we'll just have to wait and see what New Horizons finds as its journey continues outward into the distant dark of interstellar space, beyond the edge of our Solar System.