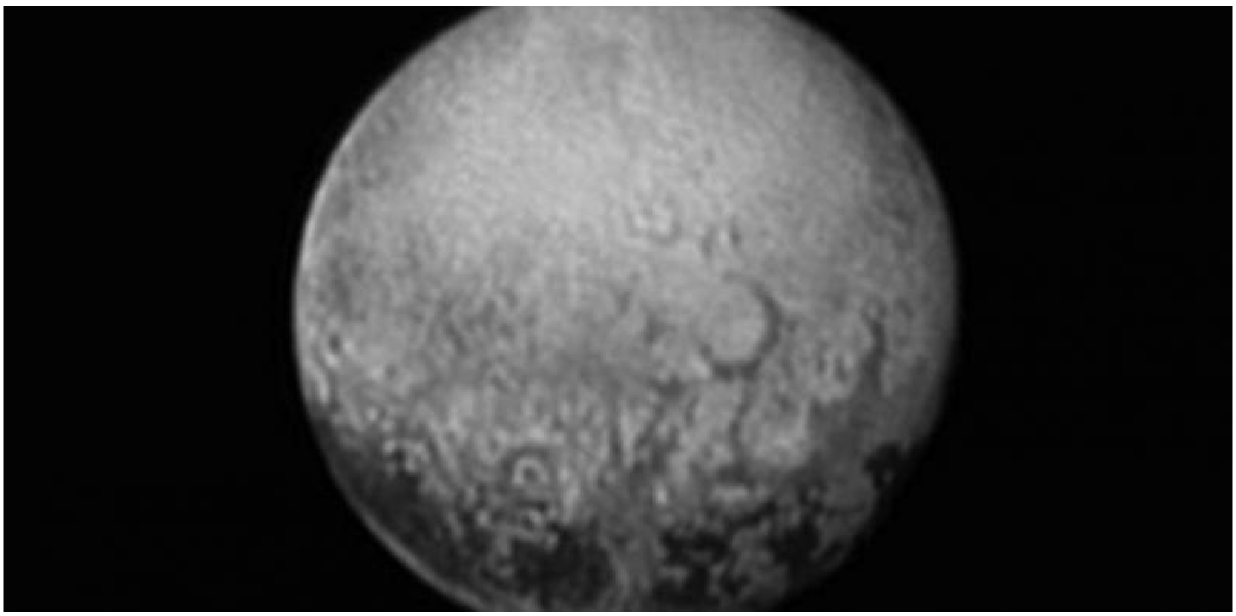
Pluto and its collision-course place in our solar system

July 13 2015, by Jonti Horner And Jonathan P. Marshall



New Horizons' look at Pluto's Charon-facing hemisphere reveals intriguing geologic details that are of keen interest to mission scientists. This image was taken on July 11, 2015, when the spacecraft was 4 million km from Pluto. Credit: NASA/JHUAPL/SWRI

There are just hours to go now before the New Horizons Spacecraft will tear past Pluto on Tuesday July 14 (about 10pm AEST), giving us our first closeup view of the enigmatic dwarf planet.

As it flies past, the seven instruments on board will capture every moment of their fleeting encounter.

Over the months that follow, that data will trickle back to Earth, providing vital new clues to help piece together the story of our solar system's formation and evolution.

But what do we already know about Pluto and its place in our solar system?

Most science is generally experimental in nature. If you want to find out how something works, you can hit it with a hammer, boil it in a test tube or make it run through a complicated maze - you get the idea.

Astronomy, by contrast, is an observational science. We can't really experiment (except through clever use of computers). Instead, we gather observations and use them to piece together the story of how, when, why, and where something happened.

So the universe is a crime scene, and astronomers are the detectives examining the clues left behind. Pluto, and its brethren in the space beyond the planets, are particularly important clues for astronomers studying our solar system's past.

Pluto - a celestial oddball

In the years since it was discovered in 1930, astronomers have learned a great deal about Pluto. It's turned out to be a very unusual object.

It is highly reflective, exuding a tenuous atmosphere when closest to the sun. In addition, it has a family of satellites, including the behemoth Charon, a little over 1,200km in diameter it is just over half Pluto's size.

Pluto's orbit is distinctly non-circular, or eccentric. At its closest to the sun (a distance of 4.44 billion km), Pluto passes within the orbit of Neptune, while at its most distant it lies almost three billion kilometres further away.

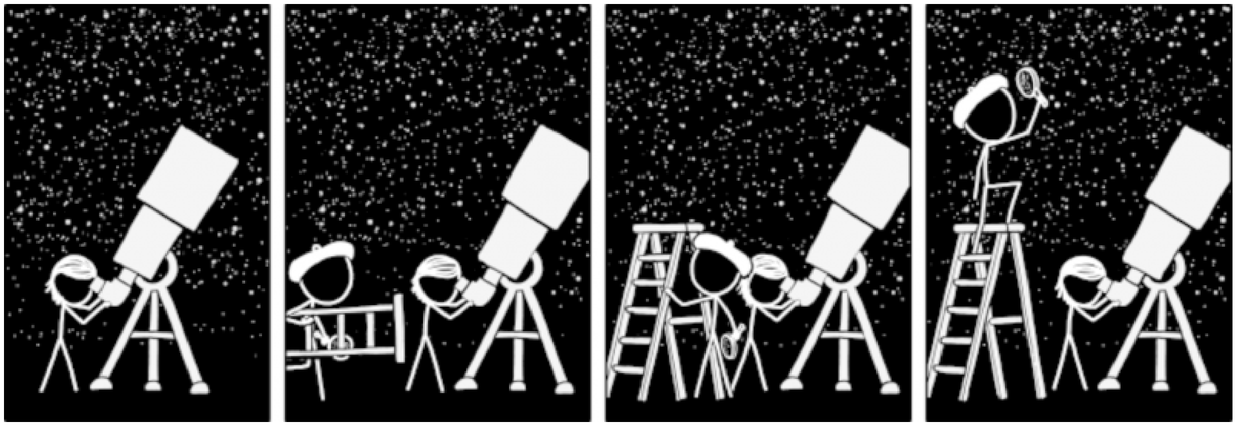
Pluto's orbit is also tilted, or inclined, by about 17 degrees to the plane of the solar system. Pluto wanders both far above and far below the other planets during each 248-year orbit.

The oddities don't end there. Crossing paths with Neptune, you might expect Pluto to eventually come close to that planet, potentially even crashing into it. But it avoids such a fate due to something called a mean-motion resonance.

Pluto's orbit takes around 50% longer than that of Neptune's (164 years). Pluto therefore completes two full laps of the sun in around the time it takes Neptune to complete three. This prevents close encounters between Pluto and Neptune. Every time Pluto crosses Neptune's orbit, Neptune is elsewhere.

It works like this: on the first orbit, Pluto beats Neptune to the point their orbits cross, and the two avoid a collision by a huge distance. By the time Pluto completes another orbit, Neptune has completed one and a half, meaning that it now precedes Pluto, and a collision is again avoided. After another Plutonian year, the two return to where they started, and the dance begins again.

Because Neptune completes three orbits in the time Pluto completes two, we say that they are trapped in 3:2 mean-motion resonance. And it is this resonance that is key to our understanding the solar system's formation.



Astronomy, an observational science, places astronomers in the role of detectives trying to disentangle the universe around us. Credit: xkcd, CC BY-NC-SA

Pluto and planet formation

Our current best theory is that the solar system formed from a gas and dust-rich protoplanetary disk - much like those observed around young stars in the Orion nebula.

For planets, dwarf planets and other assorted debris to form in such an environment, the disk has to be dynamically cold – in other words, as flat as a pancake.

In that scenario, the tiny fragments of dust and ice in the disk collide at such slow speeds that they can stick together, rather than smashing one another apart.

Fast forward uncounted collisions over a few tens of millions of years and a planetary system is born.

This is a surprisingly successful model and matches the clues we observe better than any of its rivals. But, at first glance, Pluto's peculiar orbit seems to contradict the story. If Pluto formed that way, why does it now move on such an eccentric and inclined orbit?

And Pluto isn't alone. We now know of a large population of objects beyond Neptune's orbit, many of which are also trapped in resonance with Neptune, and move on inclined and/or eccentric orbits. They're certainly not what you might expect of a population born from a thin, cold disk of material.

And so we have a clue, in the form of the eccentricities and inclinations of Pluto and the other Plutinos. But what does it portend?

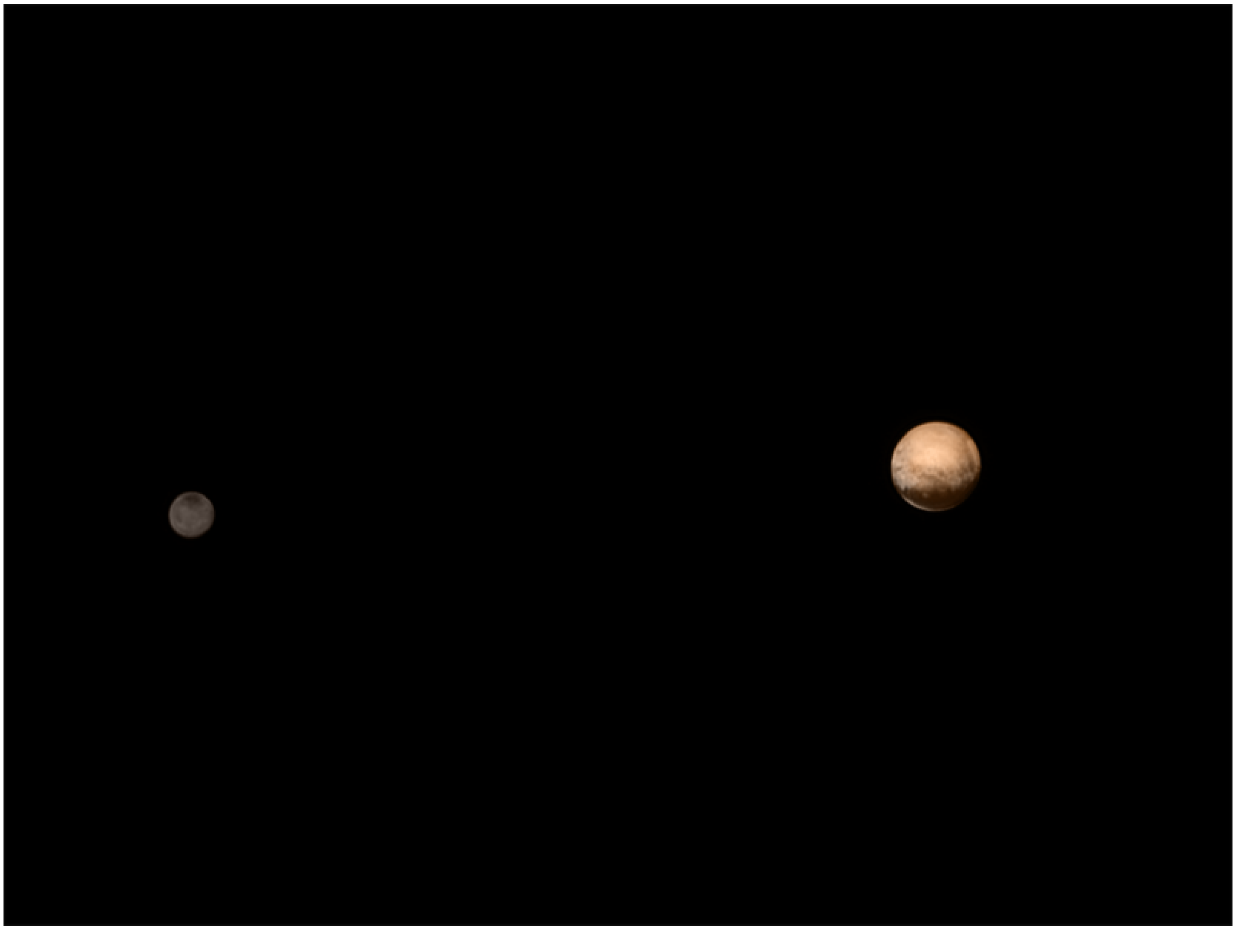
Pluto as the yardstick of migration

As our models of planet formation have become more sophisticated, the simple picture that our planets formed on their current orbits has been overturned.

Based on the evidence frozen in to the solar system's small body populations, we now think that Jupiter, Saturn, Uranus and Neptune migrated as they grew, spreading out to reach their current dispersed architecture.

Neptune, in particular, was a great wanderer, with some models suggesting it formed between one and two billion kilometres closer to the sun than we currently observe it. But how can we tell?

The answer? Pluto's peculiar orbit and those of the Plutinos.



Pluto and Charon, as imaged by New Horizons on July 8, 2015. Credit: NASA-JHUAPL-SWRI

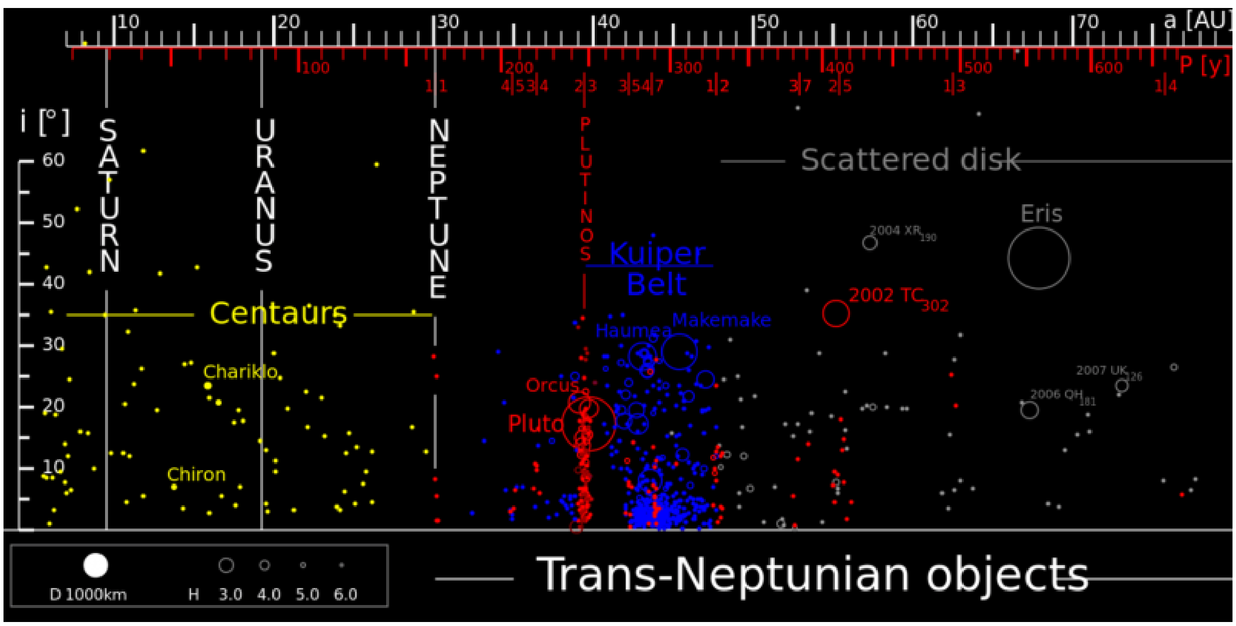
The evidence for Neptune's great journey

As the planets formed, with Neptune much closer to the sun than it is today, there was a wealth of debris (planetesimals) further out. As Neptune fed, devouring the material closest to it, it scattered material inward from this trans-Neptunian region and, in the process, began to drift outwards.

As Neptune moved, so did the location of its resonances. Objects were captured as the planet swept outwards, forced to move in lockstep with the giant.

As it travelled further, Neptune ensnared more objects. Once caught, few escaped, and the rest were carried inexorably outwards, swept ahead of the giant planet. As they were pushed, the force driving them acted to excite their orbits, increasing their eccentricities and their inclinations.

Eventually, Neptune's migration all but ceased, and the population of Plutinos was frozen to that we observe today - the clue that reveals the magnitude of Neptune's rapid outward march.

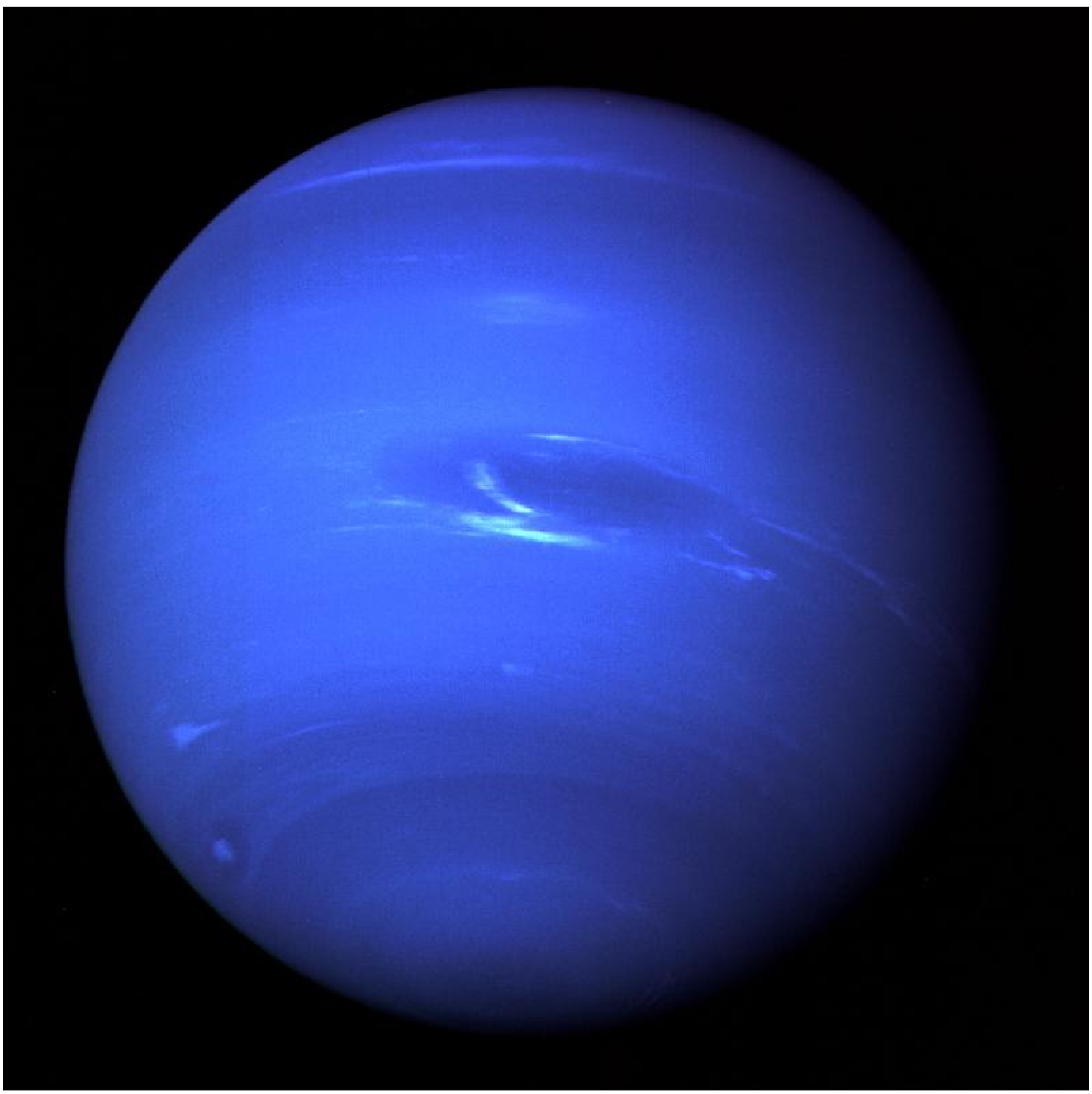


The inclination of orbits of the solar system’s small bodies, outward from Saturn’s orbit. Credit: Wikimedia, CC BY-SA

A well travelled enigma

This brings us back to Pluto. From its orbit, and its link to Neptune, we can tell that Neptune must have formed closer to the sun and then moved outwards.

That also means that Pluto must have formed closer to the sun than its current orbit. We can estimate where it formed, to some degree, based on its current excitement.



Neptune's Great Dark Spot and its companion bright smudge as captured by Voyager 2. Credit: NASA

And this is where we come to the hero of the hour - the New Horizons spacecraft. The measurements the probe makes in the coming hours as it passes Pluto should give us an independent measure of where it formed, adding a vital new clue to the mix.

Will it support our theories, or will we have to start again from scratch? We will have to see what the data reveals, and that's part of the beauty and thrill of the observational detective missions such as these.

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