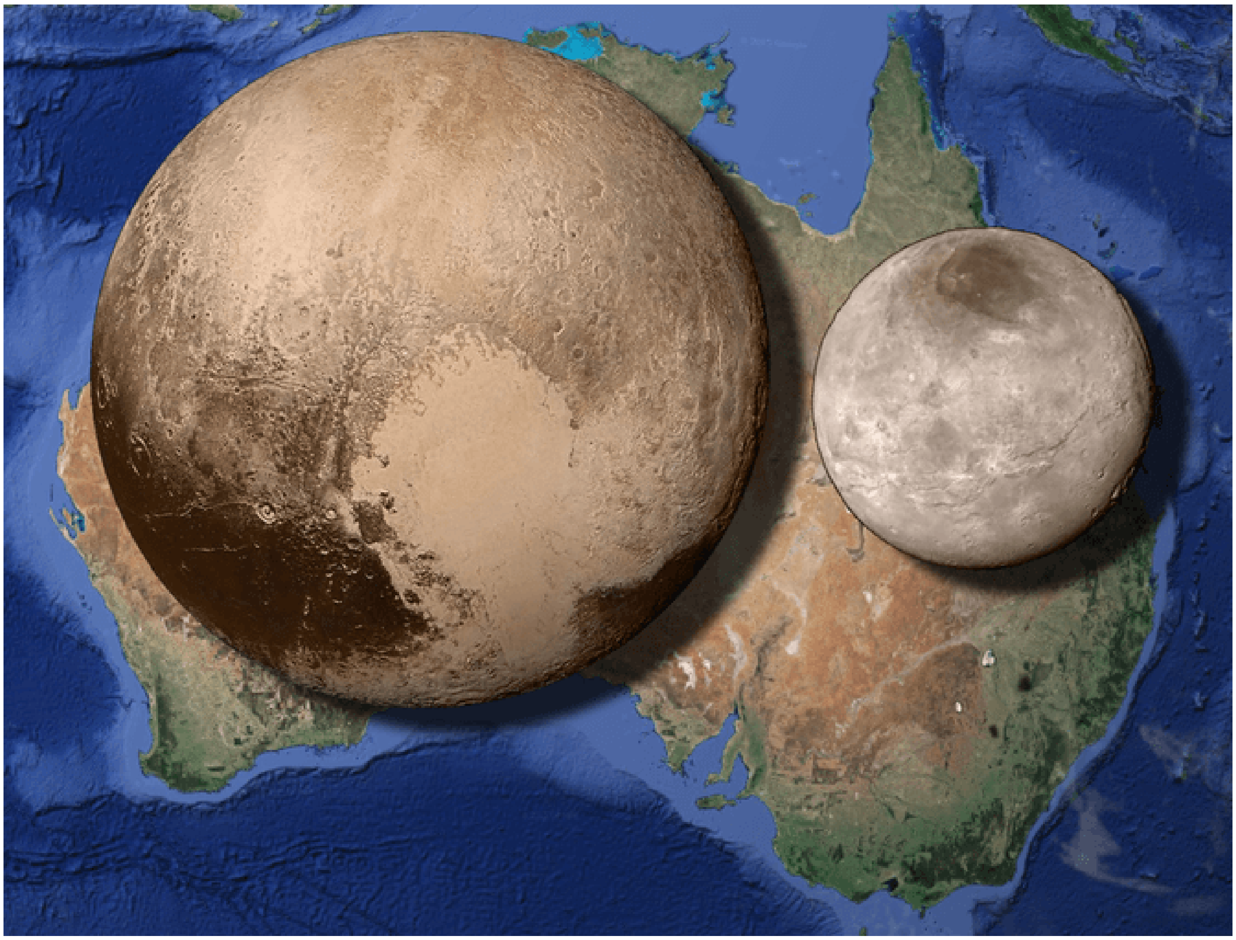
What flows on Pluto?

August 20 2015, by Helen Maynard-Casely



Pluto and its moons (Charon, Nix and Hydra) scaled next to Australia. Credit: NASA/Andy Casely, CC BY-SA

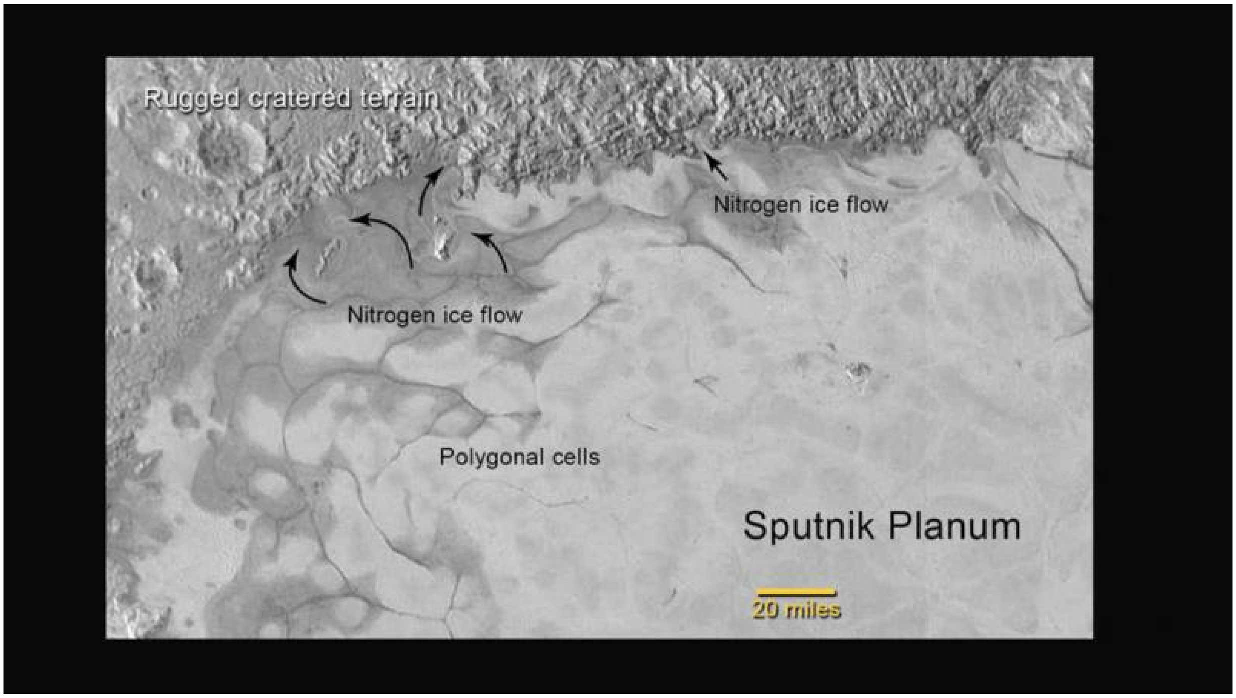
It's now been over a month since the New Horizons spacecraft flew by one of the last unknown outposts of our solar system and although we've only just seen a trickle of the data it collected, it has all been rather exciting. Over the next 14 months New Horizons will stare unblinkingly back at Earth transmitting its data over the slowest internet connection in the solar system.

Amongst the mountains, strange terrain and young surface that we've already interpreted for the Plutonian surface, those reviewing the images have picked out what they believe to be nitrogen or methane flows on the surface. Contrasting that with the other major finding of 3000 m water-ice mountains on Pluto – does it leave you wondering why ice can form mountains on Pluto, but methane flows?

Perhaps this is all a bit obvious, both nitrogen and methane we're pretty used to being gas, and solid water ice is an everyday thing – so it's not too far to stretch the imagination and think that, when solid, ice will be stronger than solid nitrogen and methane. But if we contrast that to the place on Earth where we do have a water-ice landscape, amongst our poles, these areas are very much shaped by the flow of water ice. So, I'm going to play the five-year-old here and ask the perpetual, why?

A sunny day on Pluto will be about 44 K (about -229 °C), and at that temperature water, methane and nitrogen are all resolutely solid. However, it's the way that these materials arrange their atoms into a solid that gives away why they flow or not.

Are we all familiar with the crystal structure of ice? It's hexagonal, and that's what gives us the beautiful six sided snowflakes that we are used too. Part of the reason that ice takes up that structures under the conditions of Earth (and indeed the surface of Pluto) is the way that the hydrogen atoms in each water (H_2O) 'stick' to the oxygen atom in the next molecule.



Flows of surface material identified in the northern region of Pluto's Sputnik Planum. These border onto the great ice mountains that New Horizon's also discovered. Credit: NASA/JHUAPL/SwRI

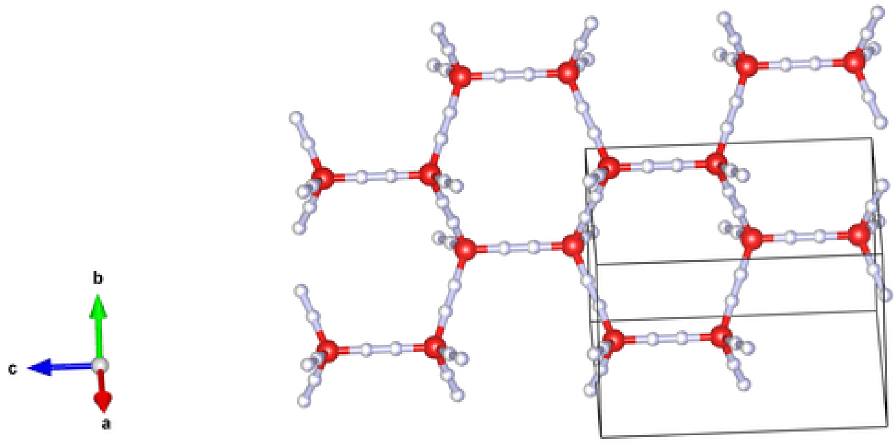
Known as the 'hydrogen' bond, the interaction between hydrogen and oxygen atoms in water still puzzles scientists to this day, and is the main reason for some of the special properties of ice. One of which is making it really strong, especially at 44 K. At these temperatures ice is held together by a rigid framework of water molecules held together by hydrogen bonds, like a steel frame supporting a skyscraper. This means you can build mountains.

These mountains don't flow like on Earth because it's too cold. Glaciers on Earth move in a number of ways, one of which is by the 'creep' of defects in the structure of the ice. This can only happen if the water molecules have enough energy to vibrate a little – which they don't really have at the chilly condition of Pluto.

So ice is strong. But methane has hydrogen in it (CH_4) so why can't it form hydrogen bonds to make it strong? The issue here is that methane has too many hydrogen atoms, and they take up all the 'stickyness' of the carbon atom in the middle. This means that the structure of methane is pretty simple. We all remember the fun we had in ball pools at children? If your ball pool was square and, for a moment, didn't have a ton of kids playing in it the balls would arrange themselves in a structure we call 'close packing'. And that's the structure that solid methane forms. The methane molecules are unable to stick to any of its neighbours, so find themselves spinning about. If you 'rotationally disorder' a tetragonal methane molecule it ends up looking a lot like a sphere – like the balls in your pool! The only force that is holding them together is the weak Van de Waals interaction, sort of like gravity for atoms.

This means that solid methane is quite like jelly! We actually called it a plastic solid because if you prod it, it won't return to its original shape. And because there's no framework holding the methane molecules together then even at the frozen temperatures of Pluto it can flow.

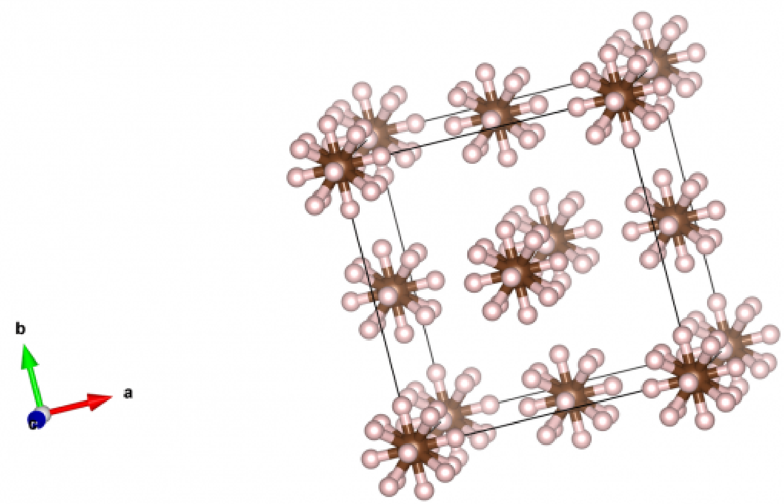
Nitrogen is pretty similar to methane – in its solid forms it forms molecules of pairs of nitrogen atoms. These N_2 pairs also spin making them pack like spheres and again forming a plastic solid.



The wonderful hexagonal structure of water ice - this is what’s found in your freezer. Here I’ve drawn in the hydrogen bonds so you can see how all the water molecules connect to each other. The molecules themselves look like they have too many hydrogen, that’s because this structure shows how they are constantly flipping positions - you’ll only find hydrogen (the white spheres) in those spots half of the time. This image was generated from structure #1008748 in the Open Crystallography database. Credit: Helen Maynard-Casely

Though we've known the structures of solid ice, methane and nitrogen for quite some time, there are still some complications that need to be investigated. One of which is how these materials mix together. Water mixed with 'gas' molecules like nitrogen and methane can formed caged materials called clathrates. And the possibilities of solids that are a mixture of nitrogen and methane have only just started to be probed.

So you can see that even in 'icy' materials there is a range of physical properties, and its very likely that the contrast between these will shape the landforms on worlds like Pluto. We've had hundreds of years for geoscientists on Earth to understand how our terrestrial surface has been shaped, now's the time for the icy geologists to ply their trade off-world.



The crystal structure of solid methane when cooled to 44 K. You don't see the 'normal' tetrahedrons of the methane molecule because the molecules are rotating and acting like spheres. This picture was generated from a crystal structure model #5900000 in the Open Crystallography database. Credit: Helen Maynard-Casely

This story is published courtesy of The Conversation *(under Creative Commons-Attribution/No derivatives).*

Source: The Conversation