EARTH SCIENCE Haiti quake surprise leaves looming threat **p.1018**

STEM CELLS Anonymous group rattles community with image-fraud claims **p.1020**

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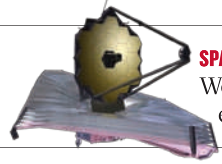


SPACE Will the James Webb Space Telescope eat NASA? **p.1028**

T. DICKINSON

Comet Hartley 2 (right), shrouded by a glow of ionized gas, glides across a starry backdrop.

ASTRONOMY

Glimpsing a comet's heart

As comet Hartley 2 comes into close view, researchers are lining up with questions.

BY ADAM MANN

By now, the scenario is familiar: a distant light in the spacecraft's cameras becomes a fuzzy blob, which brightens and grows until the craft is suddenly plunging through an ionized fog. Enveloped in haze, the camera spies a dark, frozen lump — the elusive nucleus of a comet, one of the strangest and least understood bodies in the Solar System.

Since a battery of probes whizzed past comet Halley in 1986, the nuclei of four different comets have been successfully imaged and studied during fly-bys (see 'A gallery of surprises'). But rather than building up a simple and satisfying stereotype of what comets are like, these encounters have revealed a surprisingly diverse array of features and processes. If all goes well, on 4 November, the cometary repertoire will grow by one more, when the NASA spacecraft EPOXI passes within 700 kilometres of comet Hartley 2 (see 'How to catch a comet').

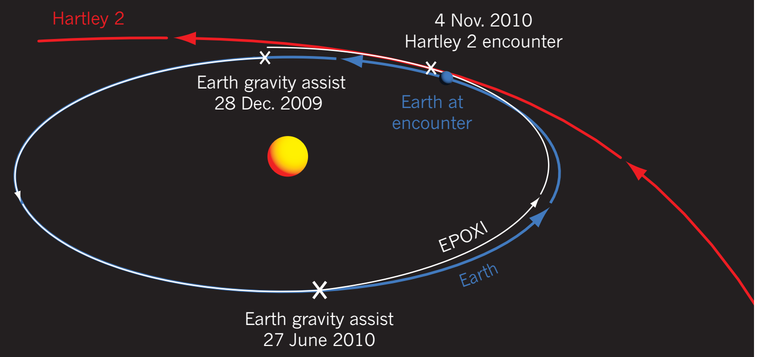
"It seems like every time we go to a new comet, we discover new phenomena," says Lori Feaga, an astronomer at the University of Maryland in College Park, who is on the mission's science team.

In the annals of cometary exploration, EPOXI is already a hero. Formerly known as Deep Impact, in 2005 it flung a projectile at the nucleus of comet Tempel 1 and studied the plume of debris ejected by the impact. Since then, it has been on course to Hartley 2 as part of the Deep Impact Extended Investigation (DIXI). During the five-year cruise it trained its camera on distant stars to search for signs of transiting exoplanets in a project called the Extrasolar Planet Observation and Characterization (EPOCh) investigation. A mash-up of acronyms gives the mission its current name.

Hartley 2 has already tantalized researchers with behaviour unlike anything seen at other comets, says principal investigator Michael A'Hearn, an astronomer at the University of Maryland who also led the Deep Impact encounter. Observing its target in September, the spacecraft discovered that Hartley 2's production of cyanogen — a byproduct ▶

HOW TO CATCH A COMET

Two close encounters with Earth set NASA's EPOXI spacecraft on course for its rendezvous with comet Hartley 2.



of cyanides — increased fivefold over an eight-day period and then slowly returned to average. Such outgassing events on comets are usually violent and accompanied by dust, but this event was not, and the EPOXI team is still arguing about how to interpret the finding, A'Hearn says.

Anita Cochran, an astronomer at the University of Texas in Austin who studies Hartley 2 with ground-based telescopes, adds that the comet's nucleus, 1 kilometre in diameter, is putting out as much water vapour as Tempel 1, which has nearly ten times the surface area. She suspects that unlike larger comet nuclei with their isolated jets of gas and dust, Hartley 2's entire surface may seethe with outgassing. EPOXI scientists hope to learn why.

Such contrasts in appearance and behaviour challenge the notion that comets have a single, shared history. In the most general sense, they are understood to be accretions of frozen volatiles and rocky debris left over from the formation of the outer Solar System — fossils that preserve crucial information about the environment from which the outer planets emerged. With each close encounter, however, the picture becomes more complex.

The Stardust mission, for example, which collected material as it passed through the tail of comet Wild 2 in 2004 and brought the samples to Earth, found minerals that could only have been produced at high temperatures. This has led researchers to wonder if some comets were formed closer to the Sun than previously believed.

Deep Impact, for its part, identified 60 circular depressions on comet Tempel 1 that look like impact craters, says A'Hearn. But the Sun's heat sublimates roughly half a metre of surface each time the comet completes an orbit, which should have quickly erased these marks. Another process must account for the depressions, according to A'Hearn.

The surface of Tempel 1 also showed what looked like cryo-volcanic flows, in which warmer, softer ice from the interior of the comet had apparently been extruded onto the frozen surface. "This seemed to indicate that some comet nuclei are active in their interiors," says Michael Belton, an emeritus astronomer at Kitt Peak National Observatory in Arizona. Belton and other researchers are developing theories to explain how cryo-volcanism could arise on such small, cold bodies.

Over the next five years, new missions are likely to add even more complexity to the cometary picture. In February 2011, the Stardust mission — rebranded NExT — is scheduled to revisit Tempel 1 to see how it looks five years after inspection by Deep Impact. Three years later, Europe's Rosetta mission should reach comet Churyumov–Gerasimenko, and become the first spacecraft to orbit a comet nucleus and deposit a lander on its surface.

After that, comet science, which has flourished in recent years, could enter a lull without new missions to drive new discoveries. Such missions could be inherently more difficult and expensive than before— involving feats such as boring into a comet's nucleus — or take far longer to run. On the wish-list would be a journey to the comet reservoirs beyond Neptune's orbit to look at comets that are less altered from their pristine condition by successive passages near the Sun.

But comets remain a highly prized data source for many researchers. "NASA's stated goal is to explore the Solar System, which means you don't just go to the Moon and to Mars, you also explore unknown places," says David Jewitt, an astronomer at the University of California, Los Angeles. And comets, he says, "are really unknown places". ■

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For a slideshow of comet images see:
go.nature.com/wavtpz

A GALLERY OF SURPRISES

Four close encounters have yielded big differences among comets.

HALLEY (1986)

The first and largest (16 km) comet nucleus to be imaged, Halley showed bright jets and a nearly coal-black surface.

BORRELLY (2001)

Borrelly's patchy appearance hinted at variations in surface composition. Looking for ice, researchers found a warm, dry surface.

WILD 2 (2004)

Dust from the oddly pitted nucleus contained minerals that seemed to have formed nearer to the Sun than expected for a comet.

TEMPEL 1 (2005)

The best-imaged nucleus so far, Tempel 1 showed signs of cryo-volcanism and exposed ice. A probe found a surface fluffier than snow.

ESA/MPAE, LINDAU; NASA/JPL; NASA/JPL-CALTECH/UMD