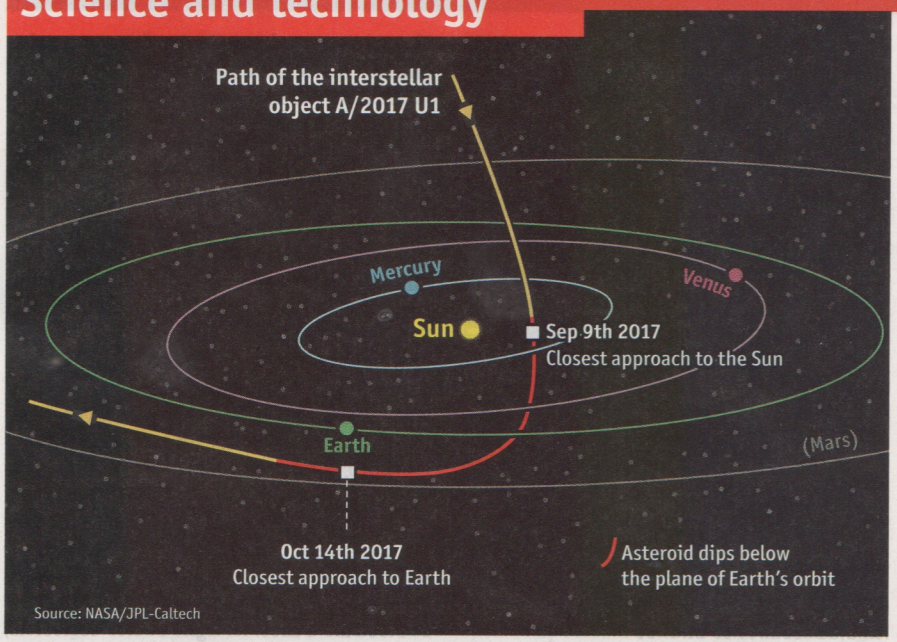

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Interstellar travel (I)

Rendezvous with Rama

The first visitor from another solar system has just been spotted

AEONS ago, perhaps long before Earth itself existed, a hunk of rock circling a star somewhere in the Milky Way was thrown out of its orbit so violently that it was ejected from its natal system. Thus began a journey that would, in time, take it within an astronomical hair's breadth of humanity's home planet. On October 19th this visitor was spotted by Rob Weryk of the University of Hawaii in pictures produced by Pan-STARRS 1, a telescope on Haleakala. It thus became the first interstellar interloper into Earth's solar system to be spied by astronomers.

Its origin is clear from its speed. When spotted, it was travelling at 25.5km per second. That is too fast for it to have a closed, elliptical orbit around the Sun. Nor could its velocity have been the result of an encounter with a planet giving it an extra gravitational kick, for it arrived from well above the ecliptic plane, close to which all the Sun's planets orbit. Dr Weryk's object, now named A/2017 U1 (the "A" stands for asteroid), thus almost certainly arrived from interstellar space.

Observations from other telescopes have confirmed A/2017 U1's extrasolar origins. After swinging around the Sun, as the diagram shows, it passed about 25m km below Earth on October 14th, before speeding back above the ecliptic plane. It is now heading out of the solar system towards the constellation of Pegasus, at a speed of 44km per second.

Sci-fi buffs may find this tale familiar. One of the great works of 20th-century science fiction, "Rendezvous with Rama", by Arthur C. Clarke, starts similarly. Rama, as the object in the novel is dubbed, turns out to be an uncrewed alien spacecraft, 54km long. It, too, arrives from the void, loops around the Sun, and vanishes into the distance again. Sadly, A/2017 U1 is no spacecraft. It is a rock about 400 metres across. But it still has an interesting story to tell.

Hello and goodbye

Models of planet formation suggest that interstellar objects such as A/2017 U1 are likely to be icy rocks known as comets, formed on the periphery of distant solar systems, rather than dry rocks, known as asteroids, dislodged from such systems' interiors, which are places where any comet-like volatiles will have been driven off by the heat of their parent stars. Indeed, A/2017 U1 was first classified as a comet. But the absence of a tail of gas and dust, produced when comets fly close to the Sun, and analysis by Alan Fitzsimmons of Queen's University in Belfast of sunlight reflected from its surface, suggest that surface is mostly rock.

One explanation is that over many millennia cosmic rays have transformed the icy, volatile chemicals that would be expected to stream off a comet into more stable compounds. Another is that the Sun is not the first star A/2017 U1 has chanced upon, and that the volatile materials have been boiled off by previous stellar encounters. Or it could be that the object actually was dry to begin with—perhaps once orbiting its parent star in an equivalent of the solar system's asteroid belt and then having been ejected by an encounter with a Jupiter-like planet.

Another puzzle is why nothing like A/2017 U1 has been seen before. Theories of planet formation suggest such objects should be a reasonably common sight. Perhaps the theories are wrong. Or it could be that these interstellar visitors have been overlooked in the past, and that there will be a spate of such sightings in future.

The proof that interstellar wanderers like A/2017 U1 really do exist also touches on the question of how life got going on Earth in the first place. Though most researchers think it evolved *in situ* from non-living chemicals, a few favour the idea that this evolution happened elsewhere and that living things, in the form of bacteria, were carried to Earth fully formed, inside objects of this sort.

Whether life could survive such a journey is moot. Outer space has a temperature close to absolute zero, is full of harmful radiation and is of course a vacuum. But some forms of life are remarkably resilient, even to these sorts of extremity. Experiments that may shed some light on the matter are being planned as part of efforts to send unmanned, miniature space probes to stars close to the solar system (see next article).

As to the rock itself, it surely deserves a more memorable name than the one it sports at the moment. And a quick look at the list of existing asteroid names instantly suggests one. Perhaps in expectation of a discovery like this, the International Astronomical Union, which approves such names officially, has not yet called an asteroid "Rama". How about it, chaps? ■

Interstellar travel (II)

Life in the fast lane

Yuzhe Studio

SANTA BARBARA

The first voyager to another star may be a nematode or a tardigrade

SPACE is cold. So, when launching dogs for early space missions, Soviet rocket scientists chose strays like Laika that had survived on the streets during Moscow's freezing winter. Today, in contrast, some researchers working on an ambitious effort to dispatch craft to Alpha Centauri, the nearest solar system to Earth's, see the chill of space not as a hindrance to sending life from one such system to another, but rather as a way to do just that.

Alpha Centauri is an attractive target. It is a cluster of three stars and at least one planet that is only about four light-years away. With money from NASA, America's space agency, and others, the Experimental Cosmology Group at the University of California, Santa Barbara, is designing a system, called Project Starlight, that proposes to use a powerful laser beam to push fleets of lightweight spacecraft, each the size of a DVD, to a fifth of the speed of light.

Even at that blistering velocity, though, a journey to Alpha Centauri would last more than 20 years. And, with a maximum weight of no more than a small coin, these starchips, as they have been dubbed, could not carry enough food, oxygen and waste-removal apparatus to keep even minuscule creatures alive that long. Unless, that is, those creatures could travel in suspended animation, frozen by the chill of space.

This looks possible. A microscopic nematode worm, *Caenorhabditis elegans*, which is much studied and well understood by biologists, can be frozen for years and yet, within minutes of thawing in a drop of warm water, begin to squirm, eat and reproduce as if no time had passed.

If people are going to send spacecraft to the nearest stars, then Philip Lubin, who is in charge of Project Starlight, would like some living creatures to go along for the ride, Laika-like, to see what happens to them. Dr Lubin's team has begun designing miniature chambers in which the frozen worms could travel, be revived with heat from plutonium, a starchip's source of power, and be monitored with tiny cameras and other sensors, data from which would be beamed back to Earth. Joel Rothman, who is in charge of this part of the project, which is called Terrestrial Biomes in Space, points out the advantages for such work that *C. elegans* possesses.

For a start, the worms are hardy. Some of the specimens in Dr Rothman's laboratory have been in suspended animation at -70°C for 33 years. Others are descendants

An ambassador to aliens?

of animals that orbited Earth as part of *Columbia*'s last, fatal, mission, in 2003. Though this space shuttle's disintegration on re-entry killed its human crew, the nematodes survived.

On top of this, for a creature composed of fewer than 1,000 cells, *C. elegans* can manifest quite complex behaviour. Individuals will, for example, wriggle toward good smells and away from unpleasant ones. They can, like rats and pigeons, be trained to turn left (or right) in a maze if that is the path that leads routinely to food. And such learned behaviours continue even after an animal has been in suspended animation for decades.

As a backup to *C. elegans* Dr Rothman's laboratory is also studying another group of potential starchip travellers—waterborne micro-animals called tardigrades (pictured) that, when cold and dehydrated, can withstand suspended animation for at least a century and perhaps millennia. These "water bears", as they are also known, resist radiation as well as temperatures and pressures, low and high, that would kill nearly all other animals.

The Terrestrial Biomes in Space team thus hopes, if starchips ever do fly, to learn how years of travel through cosmic cold and radiation, and acceleration to a significant fraction of the speed of light, affect life. Once awoken near Alpha Centauri, will the creatures recall behaviour learned on Earth? Will they reproduce, hatch, grow and die differently from their Earth-bound counterparts? The answers may help reveal what might happen to bigger creatures, such as humans, on long star treks.

Some worry about these aims. They fear earthly organisms might contaminate alien worlds. Catherine Conley, in particular, is critical of the idea of putting them on starchips, lest they damage another realm. Dr Conley is the head of NASA's Planetary Protection Office. In light of her concerns, and those of others, NASA's bounty does not extend to paying for the Terrestrial Biomes in Space side of Project Starlight.

In truth, animals are unlikely to contaminate anything. They have to eat, and unless their destination is furnished with living creatures made of molecules more or less identical to those of life on Earth, they will starve. Moreover, if a starchip did encounter a planet, then its near-luminal impact velocity would create an explosion with a yield of about a kilotonne, blasting it into plasma in nanoseconds.

Dr Conley's fears, however, are not unwarranted in the case of creatures that do not need to eat other living things—bacteria that can photosynthesise or extract energy from minerals, for example. Some, indeed, think that life itself may spread around the universe in this way, on rocks that travel from one star system to another. Until recently, there has been no sign of such rocks. But (see previous story) one has just entered the solar system. ■

Egyptology

Pyramid selling

Yuzhe Studio

A new chamber has been detected in the Great Pyramid of Giza

ANCIENT Egypt has held the world in thrall for so long that some of those once enthralled are now ancient history themselves. Well-to-do Romans of the early Empire, for instance, would tour the place to look at antiquities older to them than the Colosseum is to a tourist today. Yet Egypt keeps secrets still. Its royal tombs, both those underground and the skyward-reaching pyramids, are rife with stories of hidden chambers. And, in the most famous tomb of all, the Great Pyramid of Giza, one such has just been shown to be real.

It was discovered by Kunihiro Morishima of Nagoya University, in Japan, and his colleagues. They searched not by the time-honoured archaeological techniques of digging with trowels and knocking down walls with hammers, but by muon tomography—an esoteric way of looking inside ▸▸

things using the fallout from cosmic rays that have hit Earth's atmosphere. Muons are heavy kin to electrons. They are able to penetrate solid matter to some degree, but are eventually absorbed by it. By measuring the absorption rate of muons travelling in different directions through a large object, such as a pyramid, it is possible to work out if there is an empty space within. By suitable triangulation, it is then possible to work out where that empty space is. And this, as they describe in a paper in *Nature*, is what Dr Morishima and his colleagues have done for the Great Pyramid.

The pyramid itself, the last-standing of the Seven Wonders of the Ancient World, was built around 2560BC by Khufu, a pharaoh better known in the West by his Hellenised name, Cheops. Several of its internal chambers, including the Queen's chamber, the King's chamber and the Grand Gallery, were robbed in antiquity, and excavated more systematically in the 19th and 20th centuries by various archaeologists. But there has always been a suspicion that, in such a huge pile of stone, more chambers exist—perhaps unplundered.

To look for such chambers Dr Morishima and his colleagues deployed three sorts of muon detector in various places in and around the pyramid. One type were nuclear emulsion films. These are photographic films which capture the tracks of muons passing through them. The second were scintillator hodoscopes. These are made of material that gives off light as a muon passes—again allowing its path to be followed. The third type of instrument, micropattern gaseous detectors, follow the passage of muons from the trails of ionised gas they leave behind.

Combining the results of these approaches revealed a void inside the pyramid some 30 metres long, with about the same volume (800 cubic metres or so) as the Grand Gallery. Its centre is 40-50 metres north of the Queen's chamber. Muon tomography is a low-resolution technique, so the exact shape of this void—or even whether it is actually several smaller voids in proximity to one another—remains to be determined. But it is clearly a large space.

How to examine it in more detail also remains to be determined. Drilling into such an important monument to get at the newly discovered void is out of the question. Camera probes inserted into shafts within the pyramid that are unsafe for human entry have found things that may or may not be unopened doors, but none would debouch directly into the newly discovered space. Muon tomography is not, at the moment, sensitive enough to see such shafts, so unknown ones would not have shown up on Dr Morishima's survey. Presumably there is, somewhere in the pyramid, a corridor of some sort that leads to the new void. But that is still on the list of unrevealed Ancient Egyptian secrets. ■

Palaeontology

Mother knows best

Mammoth society seems to have been like that of modern elephants

ELEPHANTS live in social groups of up to a dozen, led by a matriarch. At least, they do if they are not mature males. But once a male becomes sexually potent, he leaves his native band and sets up shop by himself. The only males present in these groups are therefore juveniles. This arrangement is common to all living species of elephant (of which there are either two or three, depending on which taxonomist you ask). But elephant biologists would like to know if it was also true of extinct elephant species. And for one of those, the mammoth, this week sees the publication of data suggesting that it was.

One advantage elephants gain from living together is that the groups are repositories of information that gets handed down the generations—for example, what parts of a home range are best avoided, because they are dangerous. Males may not have time to learn of all these hazards (for elephants may range over tens of thousands of square kilometres) before they start living alone. It is no surprise, therefore, that males are much more likely than females to fall victim to natural traps, such as boiling-hot springs and sinkholes. If that were also true of mammoths, it would be evidence that they had a similar social system to that of modern elephants. Patricia Pecnerova and Love Dalen of the Museum of Natural History in Stockholm, Sweden, therefore decided to investigate the matter. They have published their results in *Current Biology*.

Ms Pecnerova and Dr Dalen knew from past work that some of the best-preserved mammoths in the world's fossil collections were thought to have died in mudflows or fallen into pools where they drowned. Moreover, when the skeletons of these beasts were studied, their morphology suggested that almost all of them were male. Paired with studies of fossilised footprints left behind by mammoths when they walked over soft ground, this evidence suggested that female mammoths did, indeed, travel in groups with their young, while adult males were solitary. But, though suggestive, these studies were not large enough to be compelling. The two researchers therefore sought to collect further evidence.

They worked with a team of colleagues to examine the remains of as many mammoths as they could get their hands on. The specimens they looked at came from river basins, coastlines and lake shores, where they had been redeposited after being eroded from frozen sediments and then washed downstream. Though not pristine, these fossils were numerous. In total, the team obtained the remains of 98 animals.

Rather than guess from the bones what sex their owners had been, Ms Pecnerova and Dr Dalen turned to DNA analysis. This showed 66 specimens to be male and 29 to be female (three were unsexable). That clearly suggests a preservation bias in the fossil record—and, since animals that get buried in hot springs, marshes, crevasses and sinkholes are much more likely to be preserved for posterity than those that die in the open air, the data confirm the inference drawn from the well-preserved specimens, that male mammoths walked alone, and suffered as a result. ■

All for one and one for all

Military drones

Back to the unicopter

Why design an unmanned helicopter from scratch, when you can adapt an existing, manned one?

IN THE future, the skies of cities may belong to aerial drones. These are spider-like devices with four or more propellers (thus often known as quadcopters, hexacopters, octocopters and so on) that provide both lift and thrust. The hope is that autonomous, self-guided versions of these will deliver anything from pizzas to passengers from door to door without being held up by terrestrial traffic jams.

Delivering goods, and particularly people, to and from a battlefield is, though, a bit different. Aircraft have to be hardened against enemy action, and also need the capacity to transport large payloads. A flying spider is unlikely to cut the mustard. Instead, Lockheed Martin, the maker of one of the world's best-known military helicopters, the Black Hawk, is working on a drone with those specifications—made from a Black Hawk helicopter.

Turning existing helicopters into drones is not a new idea. Northrop Grumman's RQ-8 Fire Scout, used for reconnaissance in Afghanistan by America's navy, and now being developed for mine hunting and fighting off swarms of small boats, is a modification of the Schweizer 330SP light-utility helicopter. The Kaman K-MAX, a heavy-lifting drone which the country's marine corps tested in Afghanistan for delivering cargo, is a modified version of the Kaman K-1200. A civilian version is now available, for firefighting. And since 2004 Boeing has been flying an unmanned demonstrator version of its H-6 Little Bird, a military-reconnaissance helicopter.

All these aircraft, however, are controlled by ground-based pilots. Lockheed's intention is to build an autonomous craft—one that can sense and avoid obstacles and identify safe landing sites without human assistance. The project, sponsored by DARPA, America's main military-research agency, is known as Matrix. So far, Matrix has been used only as a co-pilot. But, if all goes well, the first helicopter able, in theory, to fly by itself will take off early next year. Though it will not be put to such a test immediately, the intention is that Matrix will eventually take over everything.

Matrix includes several sorts of sensor, so the helicopter can see for itself. It has what Lockheed describes as a supercomputer to interpret input from these sensors and to make decisions based on that input. It also has servo-controlled devices which operate the machine's flight controls.

The main sensor is a form of LIDAR, the laser equivalent of radar. LIDAR is part of the equipment of driverless cars, but the Matrix version is more powerful. It can detect objects hundreds of metres away. Also, as Chris Van Buiten, vice-president of Sikorsky Innovations, the part of Lockheed running the project, observes, a helicopter must deal with three dimensions, not two, and is likely to be travelling faster than a car. It may, for instance, be flying at over 250kph at low level in what he terms "obstacle-rich terrain", with trees, power lines and buildings, as well as other aircraft to avoid—not to mention enemy fire.

Black Hawk up

Mr Van Buiten is cagey about the other sensors Matrix uses, but says they include various cameras and conventional radars. Presumably, the system will also have digitised terrain maps that will both assist navigation and permit it to spot changes in geographical features that may be the result of enemy activities. As to the flight-controlling servos, these are built into the aircraft itself. Matrix is not like PIBOT, a humanoid robotic flight-control system being designed by engineers in South Korea, which sits in an unmodified pilot's seat and manipulates unmodified controls.

The sensors' rapid reactions—milliseconds rather than the two seconds or so a human pilot takes to assess and respond to an unexpected hazard—should make the unmanned system safer than such a pilot. It will take time to reach that level, but Matrix should, almost from the beginning, be able to take the aircraft over and fly it solo in case of an emergency. If the engine were to fail, for example, it would scan the ground below for the best landing spot and touch down there without human assistance. It will also be able to detect whether the pilot has fallen unconscious and, if so, fly the helicopter safely.

The plan is to expand these sorts of features, moving steadily from assisting the pilot to flying the aircraft autonomously. And though there are what Mr Van Buiten calls "gnarly technical problems" to be overcome, he says the biggest challenge is building trust. Not only passengers, but also pilots and regulators need to have confidence in the safety of Matrix before it can be fully autonomised.

Mr Van Buiten cites a precedent for such trust-building—a recovery system which Lockheed installed in F-16 fighter jets. If an F-16 pilot passes out during a violent manoeuvre, this automatically brings the aircraft into a straight and level flight path. That has already prevented several crashes, shifting pilots' attitudes from indifference to "I want that on board my fighter".

The airframe being used for the first tests is one of the oldest models of Black Hawk, a UH-60A from 1980. This was chosen to demonstrate the ease with which an aircraft can be upgraded. Once the modified aircraft is airborne, it will be a matter of accumulating thousands of hours of reliable operation while steadily expanding the range of tasks that the automated controls can carry out unaided in increasingly challenging environments. Then, from Lockheed's point of view, it will be ready for testing by the armed forces.

Warfare, however, is not the only potential market for Matrix. Mr Van Buiten says the technology may also see early use servicing offshore oil and gas platforms, permitting them to be resupplied in all weather conditions, without risking pilots. Fortunately for those who find even quadcopters noisy and irritating, pizza delivery is not on Lockheed's menu. ■

Look! No hands...