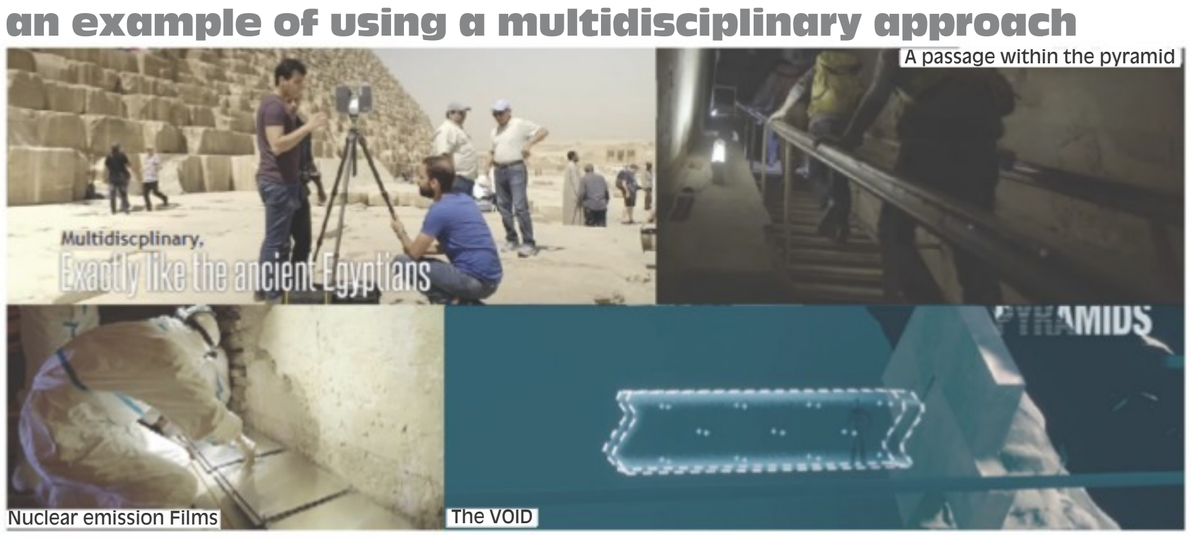
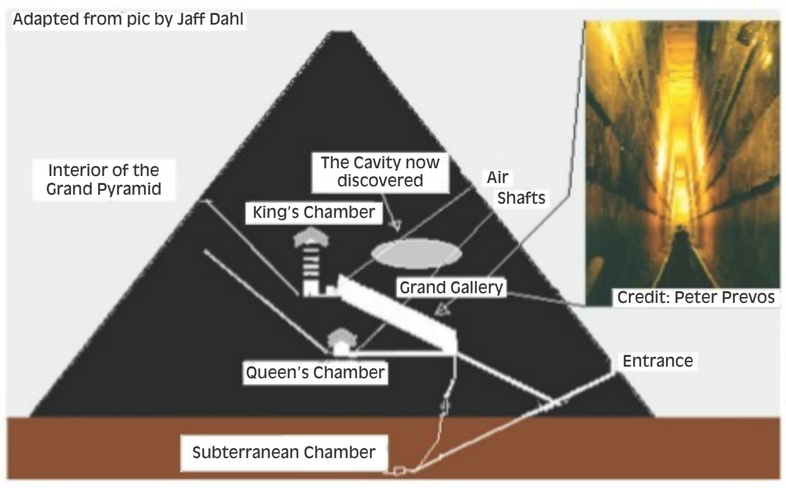
Secret chamber in Cheops' pyramid

An archaeologist using muons to probe pyramids is an example of using a multidisciplinary approach





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Locating hidden spaces within large earth and stone constructions like pyramids presents unique challenges. Even X rays, which the dentist uses to detect cavities, or other methods we are familiar with, cannot be used to peer into a six million tonne stone pyramid.

An international team from institutes in France, Japan and Egypt, report, in the journal *Nature* that while X rays or conventional radiation cannot penetrate the material of the pyramid, elementary atomic particles, created in the upper atmosphere by cosmic rays, are uniquely suited. Muon showers hence helped a group of archaeologists, physicists and civil engineers to show that the Great Pyramid of Giza, famous for its internal passages and chambers, has yet another chamber, comparable in size and unknown so far.

The Great Pyramid, also known as the Pyramid of Khufu or the Pyramid of Cheops, nearly 140 metres tall and 230 metres at the base, is a marvel of accurate engineering and sheer scale, for something built over 4,500 years ago. A remarkable feature about its measurements is that the ratio of the perimeter to the height (170/280 royal cubits) is within 0.05 per cent of the value of two times Pi (or the ratio of the perimeter of a circle to its diameter).

The pyramid consists of 2.3 million blocks, with 5.5 million tonnes of limestone and 8,000 tonnes of granite, some of the granite blocks being 80 tonnes in weight.

As shown in the picture, the entrance to the pyramid is through a descending, interior passage and then an ascent, leading to the Queen's Chamber, the Grand Gallery and the King's Chamber.

There has been much research and conjecture about the purpose and intention of these different passages and spaces and the suspicion and belief that there were yet more cavities to be found. As most parts are inaccessible, different kinds of probes and robotic devices have been used to follow narrow channels and to probe for cavities in the rock. There has been probing with radar and there have been studies of microgravity to detect voids, in the same way that gravity scans show deposits of ores underground. But were crowned with little success till the present studies with penetrating radiation using muons — elementary particles that arise from cosmic rays.

The muon is an elementary particle that is like the electron in its charge and spin but has over 200 times the mass. It is unstable and rapidly decays, usually into a normal electron and a pair of very light, neutral particles, called neutrinos, which carry away the energy that represents the difference in mass. Because of its greater mass, however, the muon suffers less deflection by other charges or fields and hence does not lose energy by radiation during deflection, which happens with lighter charged particles. The muon hence penetrates deeper into dense materials than other charged particles. Radiation like radar, X rays or gamma rays is anyway rapidly absorbed.

Muons arise in high energy nuclear reactions or as secondary products of the interaction of cosmic rays with atomic nuclei in the earth's atmosphere. As the interactions are of high energy, the heavy muon particles created continue to move towards the earth at nearly the speed of light. Relativistic effects make time to pass more slowly for the muon and it covers large distances before it decays. Muons are thus found not only to reach the surface of the earth, but survive to a good depth within, and down to the beds of oceans.

In this way, muons can pass through much of the rock that composes the pyramid and when they emerge, they can be detected with the help of their decay products. Nevertheless, muons do get deflected or absorbed in their passage through the rock and the numbers detected vary according to the mass of rock that the muons have passed through. This is the principle behind using muons to look for voids in rock, and cosmic ray muons for scanning a large structure like a pyramid.

The quest for cavities in the Grand Pyramid with muons was first undertaken in the 1960s and the detector was the spark chamber, a stack of metal plates filled with a gas that gets ionised if a charged particle passes through. The effort, however, failed to detect cavities, perhaps due to inadequacies of the equipment. Current muon detectors have been effective in investigating volcanoes, in the inhospitable interior of the Fukushima reactor, for detecting contraband, interiors of heritage buildings and in archaeology. In using muons with a structure like Cheops' Pyramid, of course, only cosmic ray muons can be used. Cosmic ray muons are limited to one direction, and there is need for long periods for data collection.

The present search for cavities, known as the Scan Pyramids mission, started in 2015 with "nuclear emission films" — developed by the Nagoya University — as the detector. These are photographic films on both sides of a plastic sheet and provide fine grained detection with directional information. Sheets, about a foot square, were laid on in eight-square-metre-wide panels in the Queen's Chamber and an adjoining niche, with the axis of the King's Chamber and the Grand Gallery running in between. The positions were changed periodically and observations were made over several months. The results showed areas of higher muon flux in places where expected because of the voids of the King's Chamber and the Grand Gallery. While this validated the procedure, it was interesting that the muon flux indicated yet another void, nearly the same size as and parallel to the Grand Gallery.

A second detection method consisted of four layers of panels of scintillator bars, developed by the KEK particle accelerator establishment in Japan. This method was deployed for many months, the *Nature* report says, and it identified the same void, consistent with the results of the first method. A third method, developed by the Atomic Energy Research organisation, CEA, at Saclay, near Paris, employs a pattern of gas detectors whose output is amplified and processed by built-in electronics. The 3D image created by this method also confirms the new cavity discovered by the Nagoya University arrangement.

A large, new void detected with high confidence by three different muon detection technologies and three independent analyses constitutes a breakthrough in the understanding of Khufu's Pyramid and its internal structure, says the paper in *Nature*. "While there is currently no information about the role of this void, these findings show how modern particle physics can shed new light on the world's archaeological heritage," it says.

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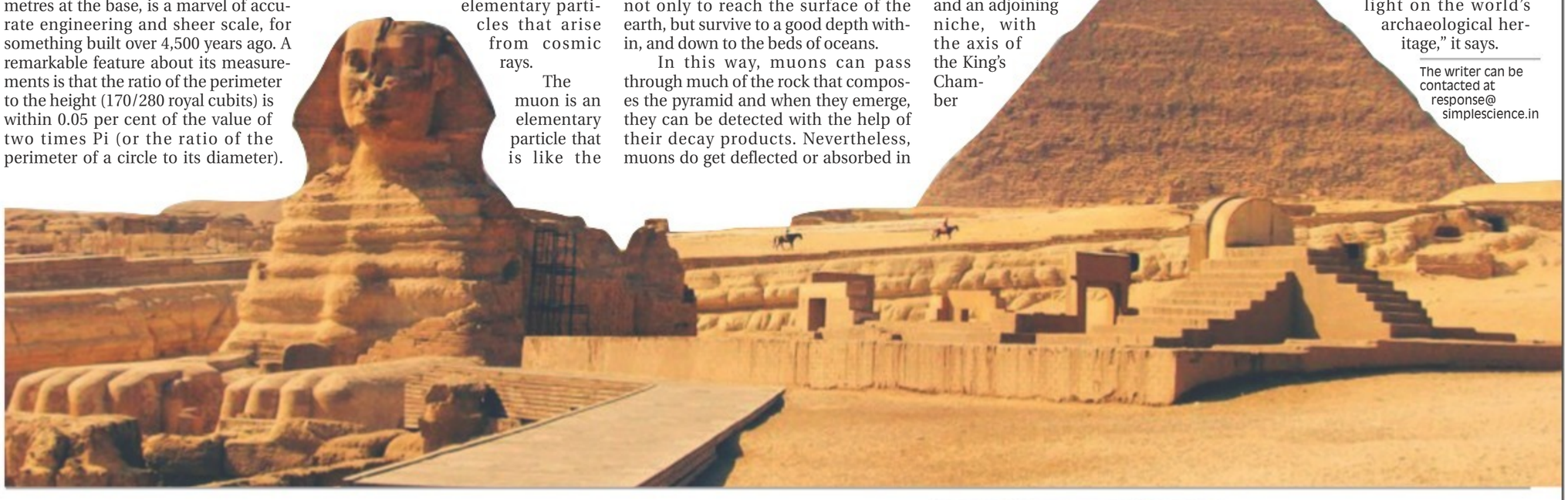

Cosmic martyrs

On the 60th anniversary of Laika's journey into the unknown, here's what happens to all the dogs, monkeys and mice sent into space

Ham (left) the first chimpanzee in space and a Russian dog is prepared for lift off.

TOM BATCHELOR

Laika's last moments on earth were spent strapped into a windowless Soviet rocket awaiting lift off. The stray dog had enjoyed a meteoric rise to fame in 1957, having been plucked from a Moscow street, hastily trained and blasted into space. That ill-fated mission resulted in Laika overheating and dying five hours into the flight.

But Sputnik 2's launch — 60 years ago — was a defining moment in the history of space exploration; only the second time a spacecraft had been launched into Earth's orbit, and the first time a living creature had been on board.

While Laika may have been a trailblazer in orbiting the Earth, animals were being employed in the name of space exploration more than a decade earlier. Russian and American scientists have long used animals to test the limits of their ability to send living organisms into space — and return them unharmed.

The first sent into outer space were fruit flies blasted to an altitude of 68 miles inside a re-fashioned Nazi V2 rocket in 1947. In the years that followed, Nasa sent several monkeys, named Albert I, II, III, IV, into space attached to monitoring instruments. All of them died. It was not until the flight of a monkey named Yorick (accompanied by 11 mice) in September 1951 that scientists could claim to have sent a primate into space and returned it back to Earth alive.

Following the success of that flight, the experiments became more elaborate. On one mission, two white mice — Mildred and Albert — were placed inside a rotating drum allowing them to float during the period of weightlessness. Closely watching these tests were Soviet scientists, who began sending mice, rats and rabbits of their own as one-way passengers on low-level orbits.

But to gather the necessary information to design a cabin fit for a human astronaut, they also turned to stray dogs. On 15 August 1951, Dezik and Tsygan were launched, becoming the first canine suborbital astronauts.

Several more embarked on similar, suborbital flights until stray mongrel Laika — dubbed Muttnik — was picked up from the street and trained for her Earth-orbiting mission. "It harks back to a time when people knew very little about the space," Martin Barstow, director of the Leicester Institute of Space and Earth Observation, said of Laika's mission.

He told The Independent: "They didn't know if people could survive in space. It was very much a pathfinder. It was a precursor to Yuri Gagarin's flight in 1961. They were testing their capsule technology, testing the oxygen supply, whether or not radiation might have harmed it and whether it could have survived the mission."

Adilya Kotovskaya, a 90-year-old Russian biologist who helped train Laika, speaking on the 60th anniversary, said, "Those nine orbits of Earth made Laika the world's first cosmonaut — sacrificed for the sake of the success of future space missions."

"We chose strays because they are more resourceful and less demanding."

The first animals to reach outer space and return alive were a pair of dogs — Belka and Strelka — who blasted off on 19 August 1960, returning a day later. In 1968 the Soviet Union sent a spacecraft to orbit the moon carrying two tortoises, wine flies and mealworms. Frogs, cats and spiders have followed. But once humans landed on the moon in 1969, the role of animals began to fade.

Attention — and controversy — has only recently returned to the use of animals in 21st century space exploration and in particular, the bid to send humans to Mars. A major risk to astronauts attempting to reach the red planet is the high level of radiation, so US, European and Russian space agencies have considered testing the effect on monkeys before sending humans to Mars.

An effigy of Laika

Boris Lapin, director of the Sochi Institute of Medical Primatology, said monkeys and humans "have approximately identical sensitivity to small and large radiation doses". "It is better to experiment on the macaques, but not on dogs or other animals," he said.

Professor Barstow said there was "no chance" that dogs would be tested on in future space missions. The largest creatures in the International Space Station's laboratory are likely to be small insects, he said. "We're a bit more alert to the nuances of whether or not you should test anything on animals these days.

"And putting animals in space is not a lot different to testing cosmetics on them. When and if you do it, it has to be under controlled circumstances. It is a different era now.

"We know a lot about radiation and how it affects humans and animals. The issue of radiation for a trip to Mars is more about understanding what the doses will be and testing protection systems and I don't see why you would need to use animals to test and verify that. We are much more sophisticated in the ways we measure and test that now." The Caenorhabditis elegans worm is the latest animal set to reach space, chosen because it has similar nerve, muscle and digestive systems to humans. The worms will reach the International Space Station in just over a year as part of the Molecular Muscle experiment.

Libby Jackson, human spaceflight and microgravity programme manager at the UK Space Agency, told The Independent the experiment "will look at how these worms age in space and how their muscles are affected by weightlessness". "This could help scientists understand the molecular mechanisms responsible for muscle-wasting conditions, such as muscular dystrophy, which could improve the lives of people on Earth," she added.

Julia Baines, science policy adviser at animal rights group Peta, said, "Animals aren't astronauts and, unlike human volunteers, can't give their consent to being the subjects of experiments or to risking their lives on a frightening mission into the unknown.

"Laika, the first animal to be launched into orbit, died from overheating and panic in the tiny spacecraft — all alone and in severe pain."

In 2010, under mounting pressure from animal rights campaigners, Nasa announced it was shelving a plan to conduct radiation experiments on squirrel monkeys. The European Space Agency also ruled out further primate tests, saying it did not see "any need or use" for them.

But reports suggest Russia is also moving ahead with plans for primate experimentation. Nasa argues that without testing in the early days of space exploration, Soviet and American programmes "could have suffered great losses of human life".

"These animals performed a service to their respective countries that no human could or would have performed," the agency said, "They gave their lives and their service in the name of technological advancement, paving the way for humanity's many forays into space."

The independent

PLUS POINTS

This is the universe

The universe is so vast it's almost impossible to picture what it might look like crammed into one field of view.

But musician Pablo Carlos Budassi managed to do it by combining logarithmic maps of the universe from Princeton and images from Nasa. He created the image above that shows the observable universe in one disc.

Our sun and solar system are at the very centre of the image, followed by the outer ring of our Milky Way galaxy, the Perseus arm of the Milky Way, a ring of other nearby galaxies like Andromeda, the rest of the cosmic web, cosmic microwave background radiation left-over from the big bang, and finally a ring of plasma also generated by the big bang.

Logarithms help us make sense of huge numbers, and in this case, huge distances. Rather than showing all parts of the universe on a linear scale, each chunk of the circle represents a field of view several orders of magnitude larger than the one before it. That's why the entire observable universe can fit inside the circle.

Budassi got the idea after making hexaflexagons for his son's birthday one year.

The independent

Black hole jets

Scientists have moved a step closer to understanding nature's own *Star Wars*-like Death Star beams — ultra powerful jets of energy that shoot out from the vicinity of black holes. The study has been investigating the mysterious cosmic phenomena — known as relativistic jets — by measuring how quickly they switch on and shine brightly once they are launched.

In the research published in *Nature Astronomy,* the international team of scientists show how they used precise multi-wavelength observations of a binary system called V404 Cygni — consisting of a star and a black hole closely orbiting each other, with the black hole feeding off matter from the star that falls through the disc — to throw light on this hotly debated phenomenon. Professor Vik Dhillon, from the University of Sheffield's department of physics and astronomy said, "One of the best ways of observing a black hole is in a binary system, where the black hole is in orbit with a star and pulling gas from it. Some of this gas doesn't fall into the event horizon of the black hole, but is instead ejected in the form of a jet emanating from close to the black hole.

"Our observations have demonstrated that the rapidly varying optical light we see comes from this jet, only about 40,000 km above the black hole, allowing us to test theoretical models of how black hole jets are believed to form."

V404 Cygni is located about 7,800 light years away in the constellation of Cygnus, and weighs as much as about nine of our suns put together. The research team captured the data in June 2015 when V404 Cygni was observed radiating one of the brightest "outbursts" of light from a black hole ever seen — bright enough to be visible to small telescopes used by amateur astronomers, and energetic enough to tear apart an Earth-like planet if properly focused.

The research, which was led by the University of Southampton, included the universities of Sheffield, Oxford, Cambridge and Warwick, in the UK, as well as universities in Italy, Spain, France, USA, Canada, Netherlands, Switzerland, India, Germany and the United Arab Emirates.