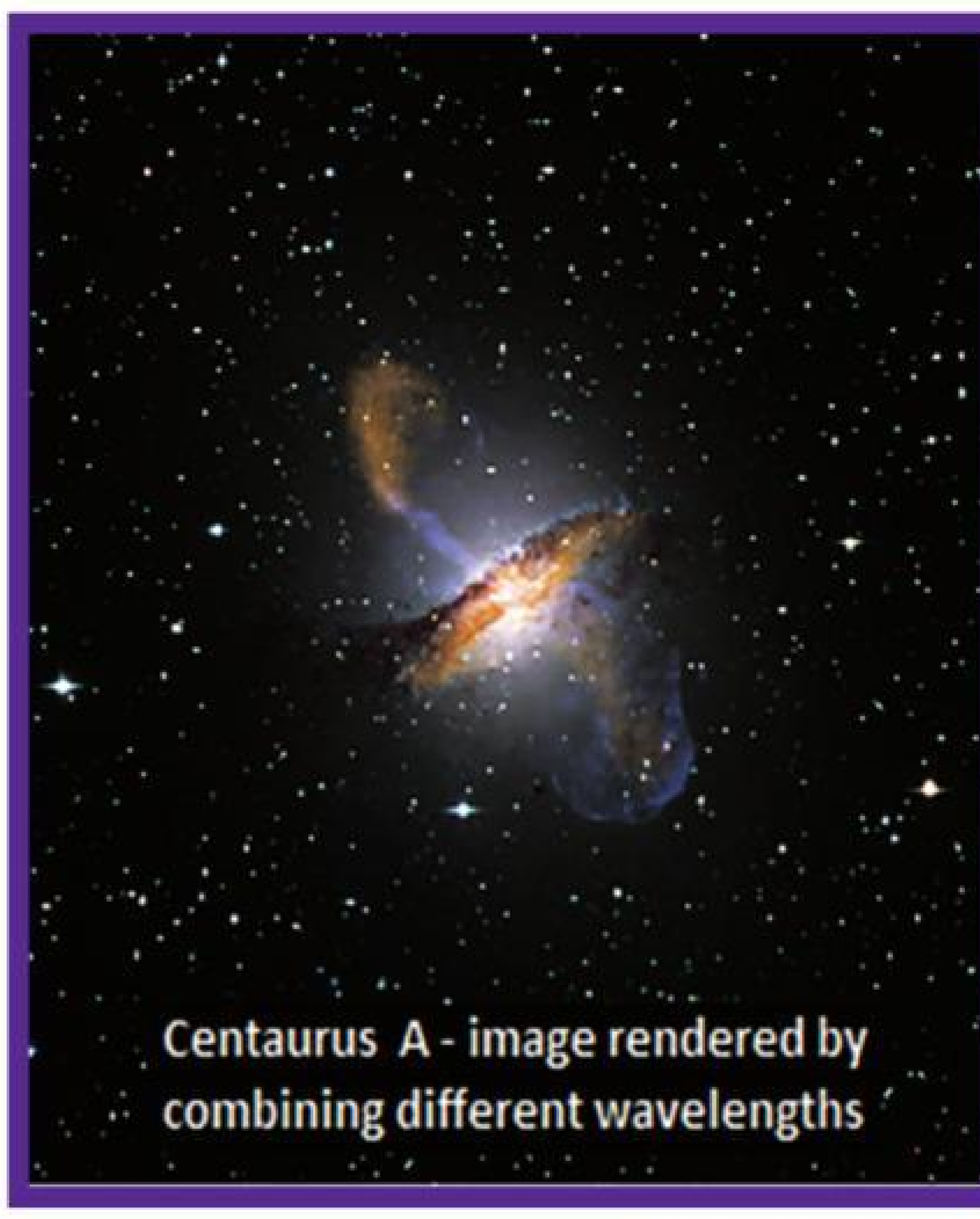
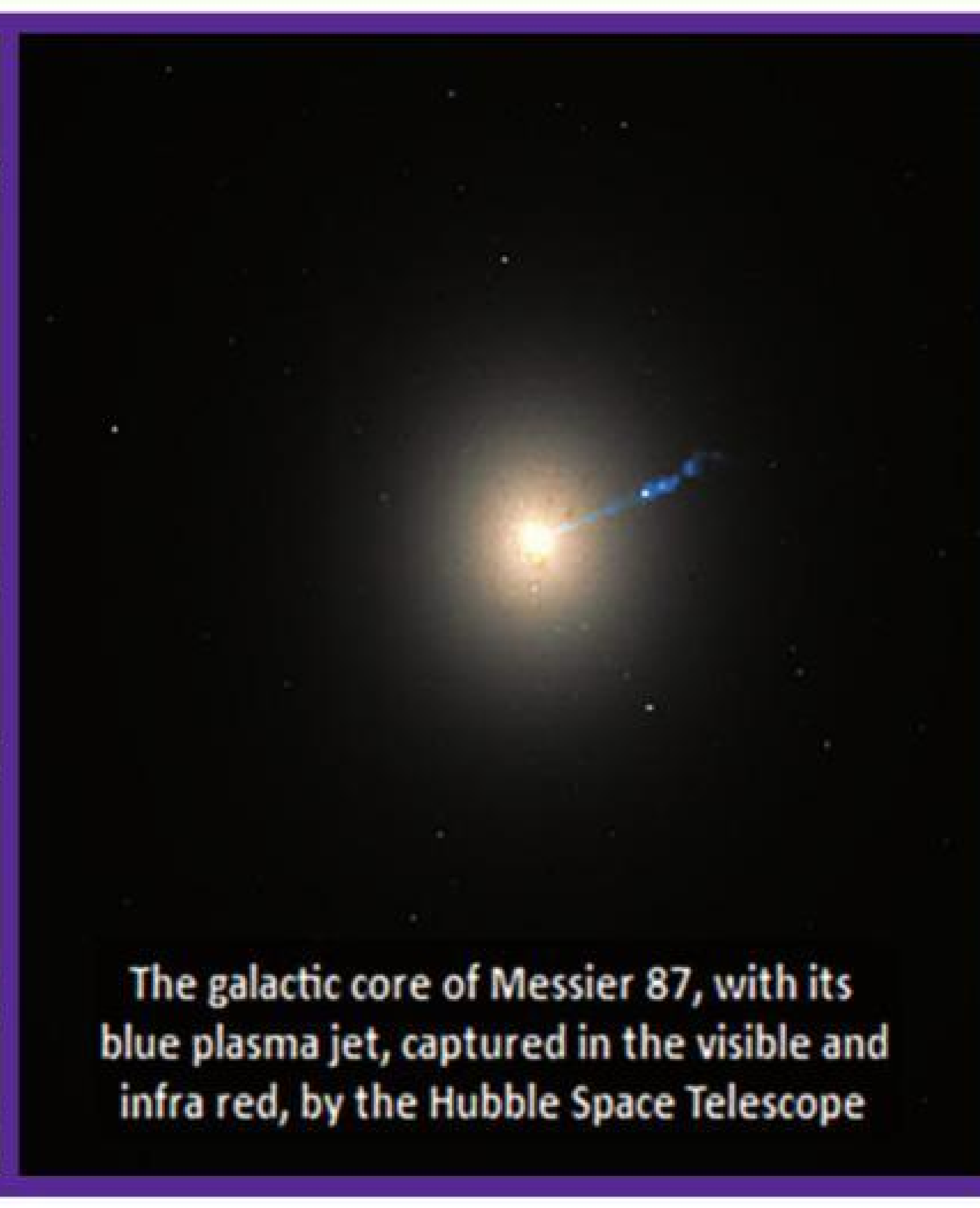
Taking a closer look

Do black holes become different when they grow larger?



Centaurus A - image rendered by combining different wavelengths



The galactic core of Messier 87, with its blue plasma jet, captured in the visible and infra red, by the Hubble Space Telescope

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A spectacular discovery of modern astronomy is the black hole, a collapsed star that grows so dense that it holds back the light it should emit. But, does the nature of black holes change when they grow?

The idea of the black hole, as we understand it, arose from Albert Einstein's General Theory of Relativity and the notion that a large mass should crush itself by gravity, so that close packed matter bends the surrounding space, and even light cannot escape. The idea has been developed over the last century and observatories have detected many such objects. And the effort is to view their features, to see if they are in keeping with what theory says.

A team of scientists from the Netherlands, Germany, Poland, Italy, Spain, different parts of the United States, Canada, Chile, Japan, Taiwan, China and Australia, writing in the journal, *Nature Astronomy*, draw on current work, to find that the nature of black holes remains basically unchanged even when they grow to very large dimensions. It is further to a breakthrough of 2017, when a worldwide collaboration of radio telescopes created a visual rendition of the region around one of the largest black holes known. The team writing in the journal describes the latest findings, of 2021, that the appearance of an intermediate-size black hole is largely the same.

The idea of a black hole was first proposed in the 18th century, when light was considered to consist of material particles, the "corpuscu - lar theory". This, of course, was discarded when light was recognised as an electromagnetic wave. Thinking about the nature of such waves, however, led Einstein to find that energy, mass and gravitation were properties of space itself — a conclusion dramatically verified when the rays of light from distant stars were seen to be bent by gravity when they grazed past the Sun.

The result was the return of the black hole, now understood as the fate of a star that starts with a mass more than certain times that of our Sun, finally to collapse into itself. The force of gravity at the surface creates a boundary, the "event horizon", beyond which nothing that happens within the star can be detected. The effect of the high gravitational force, however, is that matter in the vicinity of the collapsed star is powerfully attracted, to stream in and feed the black hole, which grows to become more massive.

The way a black hole can be detected, in fact, is with the help of radiation from this matter whirling round to crash into the black hole, which, itself, did not emit any light. With this method, and another, of the gravitational effect of bending starlight that came from behind the black hole, a great many black holes have been discovered. While many are modest sized, as a star that is 1.4 times the mass of the Sun could become a black hole, a great many are thousands, even billions of times the mass of the Sun. The largest black holes are known as supermassive black holes (SMBH) and it is believed that there is an SMBH at the centre of all galaxies. An object called "Sagittarius A", named so because it is in the Sagittarius constellation, is considered to be the one at the centre of the Milky Way.

Although the surroundings of black holes can be made out in optical telescopes, details are not possible. Because of the great distances, any detail survives only in long wavelength radiation, radio waves. Images in radio waves cannot be formed with ordinary telescopes but need radio antennas. And to capture images in long wavelengths we need telescopes with very large apertures. Radio telescopes hence usually consist of an array of antennas located over an area of many kilometres, and the arrangement is called Very Long Baseline Interferometry (VLBI).

Now, whether in radio waves or visible light, it is radiation of shorter wavelengths that yield the sharpest images. The sharpest images formed by radio telescopes are hence the ones formed by the radiation of wavelengths of the order of centimetres, as opposed to waves with wavelength in metres. Obtaining such images, however, calls for radio telescopes with even larger apertures, and for that, there are collaborations of telescopes spread countrywide, or over groups of countries. And the largest is the Event Horizon Telescope (EHT), a worldwide network of synchronised radio telescopes. The network of telescope arrays works like a telescope with a lens (or reflector) as large as the Earth.

It was the EHT that announced in 2019 the imaging, which was from 2017, of the SMBH at the centre of Messier 87 (also known as Virgo A), a supergiant galaxy with many trillion stars in the constellation, Virgo. This was possible because EHT has the capacity to detect the radiation of wavelength down to millimetres. At that wavelength, the resolution of images can be as fine as a lightday, or 30 billion kilometres (which is excellent resolution for an object 53 million light years away).

The images of the "jets" of ionised particles around M87 were highly consistent with the predictions based on the General Theory of Relativity. M87, however, is one of the most massive black holes known, and it does not follow that what has been seen would hold for less massive black holes, where the accretion of matter is less vigorous. The team writing in *Nature Astronomy* hence turned their attention to Centaurus A, a black hole of intermediate mass, in the constellation Centaurus. At only 55 million solar masses, compared to 6.5 billion of M87, Cen A accumulates matter only at a fraction of the rate of M87.

Cen A, as one of the nearest active radio galaxies, has been extensively studied. The galaxy, however, lies to the south of the galactic plane and is outside what most VLBI arrays, which are in the Northern Hemisphere, can reach. And the few that can, have been able to work only at longer, centimetre wavelengths, explains Michael Janssen, the leader of the research team. It is thanks to EHT that radio telescope arrays in the south, like Atacama Large Millimetre Array and Atacama Pathfinder Experimental Telescope, in Chile, and the South Pole Telescope, in Amundsen-Scott South Pole Station, Antarctica, became available.

Now, with the help of such resources, the team had data from Cen A at 10 times shorter wavelengths and 16 times sharper resolution, to enable imaging of structures at the lightday scale. The team reports that characteristic jet structures, or streams of matter flowing into the Cen A resemble the jets imaged with M87 "remarkably well". And further, the team could locate where the SMBH should lie, with respect to the structures seen, and it appears that the boundary of the core should be visible at about four times shorter wavelengths.

The main conclusion, however, is that the environment of charged particles in motion around the largest black holes is similar to that around intermediate-size black holes, and modest black holes, like the one at the centre of our own galaxy.

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PLUS POINTS

Rare sight

Images of a glass octopus with transparent skin have been captured by marine scientists exploring seamounts in the Pacific Ocean, giving researchers a rare glimpse of the elusive sea creature.

The octopus, known as *Vitreledonella richardi*, has only a few visible features — its optic nerve, eyeballs and digestive tract — and has been rarely filmed, despite scientists knowing of its existence for more than 100 years. Due to a lack of live footage, researchers have been forced to study the animal by analysing specimens found in the gut contents of predators.

Marine scientists aboard a research vessel for the Schmidt Ocean Institute, an oceanographic research group, captured two sightings of the octopus during their expedition near the Phoenix Islands Archipelago. The researchers spent 34 days conducting high-resolution seafloor mapping of more than 30,000 square kilometres and video exploration of five additional seamounts.

"Working with scientists and local researchers, this expedition is a remarkable example of the frontiers of science and exploration that we are able to support," Jyotika Virmani, executive director of the Schmidt Ocean Institute, said in a statement on the trip, "Live-streaming the dives gives us a glimpse of rarely seen and fascinating creatures such as the transparent glass octopus. By providing this platform to further the understanding of our ocean, we trigger the imagination while helping to push forward scientific insights and the protection of our underwater world."

The research team's underwater robot, named SuBastian, also captured footage for the first time of a rare whale shark that is thought to be more than 40 feet in length. In addition, scientists witnessed unusual marine behaviour, such as crabs stealing fish from one another, during their 21 expedition dives — which totalled more than 182 hours of exploration on the seafloor.

—The independent

Snore secrets

Proof of who snores the loudest and advice on how to stop it may finally be coming to families thanks to Artificial Intelligence developed by researchers at the University of Sheffield in the United Kingdom.

The AI, developed by Guy Brown and Ning Ma from the University's Speech and Hearing Research Group, can monitor snoring levels and identify sleep disorders such as sleep apnoea. The technology is being commercialised through a new app – SoundSleep — available on iOS devices and soon to be available on Android.

Sleep apnoea causes a person's breathing to stop and start while they sleep and they may also make gasping, snorting or choking noises, wake up a lot and/or snore loudly. Without treatment the condition can lead to high blood pressure, a higher chance of having a stroke, depression, mood swings, difficulty concentrating at school or work and an increased risk of having a serious accident due to tiredness.

Sleep disorders such as sleep apnoea are usually diagnosed in specialist sleep clinics, but these can be expensive and also disruptive for patients as they usually have to wear a range of devices that can feel uncomfortable or invasive. Travelling to sleep clinics has also become more difficult for some patients due to Covid restrictions.

Ma, research fellow in the University of Sheffield's department of computer science, said, "Getting a good night's sleep is a problem that affects lots of people. We understand that finding that secret to a good night's sleep can seem stressful and confusing, so what we are trying to do with our research is use the latest, state-of-the-art Artificial Intelligence to help people get to the bottom of what is preventing them from getting a good night's sleep as easily as possible."

To access the SoundSleep app, visit *https://soundsleep.info/*

FORGOTTEN REVOLUTIONARY

Emmy Noether faced sexism and Nazism – 100 years later her contributions to ring theory still influence modern mathematics

TAMAR LICHTER BLANKS

When Albert Einstein wrote an obituary for Emmy Noether in 1935, he described her as a "creative mathematical genius" who — despite "unselfish, significant work over a period of many years" — did not get the recognition she deserved. She made ground-breaking contributions to mathematics at a time when women were barred from academia and when Jewish people like herself faced persecution in Nazi Germany, where she lived.

This year marks the 100th anniversary of Noether's landmark paper on ring theory, a branch of theoretical mathematics that is still fascinating and challenging mathematicians like me today.

I remember the first time I learned about Noether and the surprise I felt when my professor referred to the brilliant ring theorist as "she." Even though I am a woman doing mathematics, I had assumed Noether would be a man. I was surprised at how moved I was to learn she was a woman, too.

Her inspiring story is one that not many people know.

A rare woman in mathematics

Noether was born in 1882 in Erlangen, Germany. Her father was a mathematics professor, but it must have seemed unlikely to a young Noether that she would follow in his footsteps. At the time, few women took classes at German universities, and when they did, they could only audit them. Teaching at a university was out of the question.

But in 1903 — a few years after Noether graduated from a high school for girls — Erlangen University started to let women enrol. She signed up and eventually earned her doctorate in mathematics there.

That doctorate should have been the end of Noether's mathematical career. At the time, women were still not allowed to teach at universities in Germany. But she stuck with mathematics anyway, staying in Erlangen and unofficially supervising doctoral students without pay.

In 1915, she applied for a position at the prestigious University of Göttingen. The dean at the university, also a mathematician, was in favour of hiring Noether, although his argument was far from feminist. "I think the female brain is unsuitable for mathematical production," he wrote, but Noether stood out as "one of the rare exceptions."

Unfortunately for Noether, the Prussian Ministry of Education would not give the university permission to have a woman on their faculty, no matter how talented. Noether stayed in Göttingen anyway and taught courses listed under the name of a male faculty member.

During those years, she kept doing research. While she was still an unofficial lecturer, Noether made important contributions to theoretical physics and Einstein's Theory of Relativity. The university finally granted her lecturer status in 1919 — four years after she applied.

A revolution in ring theory

In 1921, only two years after becoming an official lecturer, Noether published revolutionary discoveries in ring theory that mathematicians are still pondering and building upon today. Her work in ring theory is the main reason that I, like many mathematicians today, know her name.

Ring theory is the study of mathematical objects called rings. Despite the name, these rings have nothing to do with circles or ring-shaped objects — theoretical or otherwise. In mathematics, a ring is a set of items you can add, subtract and multiply and always get another object that is in the set.

A classic example is the ring known as Z. It is made of all the integers — positive and negative whole numbers like 0, 1, 2, 3, -1, -2, -3 and so on — and it is a ring because if you add, subtract or multiply two integers, you always get another integer.

There are infinitely many rings, and each one is different. A ring can be made of numbers, functions, matrices, polynomials or other abstract objects — as long as there's a way to add, subtract and multiply them.

One reason rings are so interesting to mathematicians is that often it is possible to tell something is a ring, but it's difficult to know much about the specifics of that particular ring. It's like seeing a croissant at a fancy bakery. You know you are looking at a croissant, but you might not know whether it's filled with almond paste, chocolate or something else altogether.

Instead of focusing on one ring at a time, Noether showed that a whole class of easy-to-identify rings all share a common internal structure, like a row of houses with the same floor plan. These rings are now called Noetherian rings, and the structure they share is like a map that guides the mathematicians who study them.

Noetherian rings show up all the time in modern mathematics. Mathematicians still use Noether's map today, not just in ring theory, but in other areas such as number theory and algebraic geometry.

Escape from Nazi Germany

Noether published her famous ring theory paper and other important results in mathematics while she was a lecturer in Göttingen from 1919 to 1933. But in the spring of 1933, the University of Göttingen received a telegram: Six faculty members — including Noether — had to stop teaching immediately. The Nazis had passed a law barring Jews from professorship.

Noether's response, it seems, was calm. "This thing is much less terrible for me than it is for many others," she wrote in a letter to a fellow mathematician. But she was out of a job, and no university in Germany could hire her.

Help came from the United States. Bryn Mawr, a women's college in Pennsylvania, offered Noether a professorship through a special fund for refugee German scholars. She accepted the offer and, as a professor at Bryn Mawr, she mentored four younger women — one doctoral student and three postdoctoral researchers — in advanced mathematics.

Noether's time at Bryn Mawr was, tragically, short. In 1935 she had surgery to remove a tumour and died unexpectedly four days later.

At Noether's funeral, mathematician Hermann Weyl compared her sudden passing to "the echo of a thunderclap." In her short life, she shook up mathematics. She kept teaching and learning even when women and Jews were not welcome. One hundred years later, Noether's mathematical genius and "unbreakable optimism" are qualities to admire.

The writer is a doctoral candidate in mathematics, Rutgers University, United States. This article first appeared on www.theconversation.com