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Astronomy & Physics Weekly News

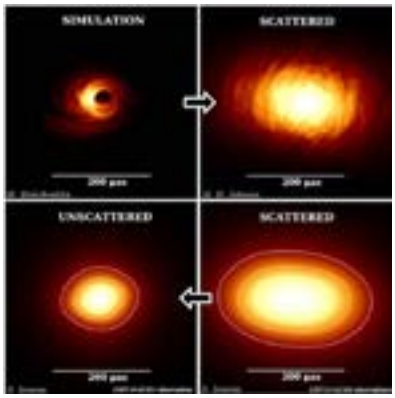
Dept. of Applied Physics & Astronomy - University of Sharjah
Compiled by Dr. Ilias Fernini

Top News

IT Support Issam Jami

Design by Mohamed Bakir

Radio jets from the Milky Way's black hole could be pointing right at Earth



This image shows different views of Sagittarius A*. The top two images are simulations of its scattered and unscattered light, while the bottom two show real images taken by a telescope array. S. Issaoun, M. Mościbrodzka, Radboud University/ M. D. Johnson, CfA

By blocking out scattered light, astronomers were able to study our central black hole's powerful radio jet — which might be looking right at us.

We've spent decades trying to decode our supermassive black hole, but crucial clues could've been in front of us all along.

Using an array of 13 radio telescopes, astronomers from the Max Planck Institute were able to home in on Sagittarius A* (pronounced A-star), the region that houses the Milky Way's supermassive black hole. And once they'd cleared out the noise of scattered light that surrounds it, they found that the powerful radio emission that blasts from the black hole is coming from just a tiny area, which could be aimed right at Earth. The research was published Monday in The Astrophysical Journal and, if confirmed, could shed new light on Sgr A* and its radio jets.

Black Hole Blasts

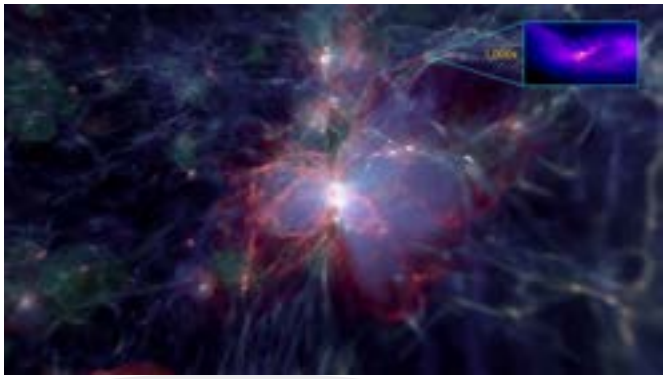
Supermassive black holes are pretty common in our universe, sitting at the hearts of most large galaxies. Their strong gravitational fields allow them to suck in and obliterate objects that get too close to them. And while they absorb most of this celestial matter, a small fraction escapes the black hole and blasts back out into space. These emissions, known as jets, emit radio waves and travel at nearly the speed of light.

And even though we can detect some of Sgr A*'s radio emissions from Earth, studying it is easier said than done. There's a cloud of hot gas that sits between Earth and Sgr A*. And this interstellar gas scatters the jets' light, making it hard to clearly pinpoint radio waves from the black hole.

Glaring Beam

But recently, a team of researchers were able to isolate this radio emission using very long baseline interferometry — a technique that combines multiple telescopes to create a massive, extremely powerful one. Using 13 radio telescopes from around the world ...Read More...

Supermassive Black Holes Likely Born in 'Halos' of Dark Matter



A 30,000-lightśyear-wide region from a supercomputer simulation called the Renaissance Simulation centered on a cluster of young galaxies that generate radiation (white) and metals (green) while heating surrounding gas. A dark matter halo just outside this heated region forms three supermassive stars (inset), each of which is over 1,000 times the mass of our sun. These giant stars quickly collapse into massive black holes and, over billions of years, eventually form supermassive black holes. Credit: Advanced Visualization Lab, National Center for Supercomputing Applications

The birth story of the universe's first supermassive black holes is getting a rethink.

Researchers have generally thought that the seeds of these pioneering behemoths sprouted in areas awash in ultraviolet radiation streaming from neighbor galaxies. This radiation inhibited the formation of normal stars, freeing up material for eventual incorporation into black holes, the idea goes.

But a new study suggests that another phenomenon was perhaps more important in suppressing this type of star formation — the rapid growth of "halos" of dark matter, the mysterious stuff that makes up most of the material universe (and is so named because it neither absorbs nor reflects light).

"In this study, we have uncovered a totally new mechanism that sparks the formation of massive black holes in particular dark-matter halos," study lead author John Wise, an associate professor in the Center for Relativistic Astrophysics at the Georgia Institute of Technology, said in a statement.

"Instead of just considering radiation, we need to look at how quickly the halos grow," Wise added. "We don't need that much physics to understand it — just how the dark matter is distributed and how gravity will affect that. Forming a massive black hole requires being in a rare region with an intense convergence of matter."

Wise and his colleagues came to this conclusion after analyzing supercomputer simulations of the early universe's evolution. These simulations revealed 10 dark matter halos that harbored only gas clouds, despite being so massive that they should have become stellar ...Read More...

Our solar system's formation was a lot messier than you think

The early solar system was a violent place: it wasn't just asteroids, but whole planets that veered on strange courses. NASA

When most of us learn about the solar system, it seems like a pretty well-ordered place. Our Sun formed first, about five billion years ago, and the planets appeared a little later. As a very general trend, these planets grew larger and less dense the farther from the Sun they formed.

But this story leaves out the chaotic dynamics and frenetic reshuffling that occurred when our solar system was young. Nature may like order eventually, but that order evolves out of pure chance. Our solar system may be settled down now, but in its youth, it was a wild place.
Creating order out of chaos

The basic story does sound ordered. Any star system begins as a vast disk of gas with a baby star forming in the center. The star absorbs the vast majority of the material in this disk, but there's some left over. Those remnants coalesces into dust grains, which become pebbles, which become boulders and eventually planets. Meanwhile, the young star is turning on and starting to shine, creating a solar wind that starts to blow out the leftover gas. Only heavy materials are left near the star, leading to small, dense planets close by. Physics also tells us these closer planets have smaller orbits, limiting the amount of material they can encounter and nab with their growing gravitational bulk. Farther out, gas giants can form, sucking in large amounts of hydrogen and helium gas. And beyond that, you find the snow line, where ices can exist without being melted or baked away by the Sun's heat. These get incorporated into the ice giants.

That sounds very tidy and quaint, a cosmic "just-so story", if you will. But the solar system is more messy and more complex than that. There's the Kuiper Belt and Oort Cloud for example, swaths of detritus that aren't collected into any one object. Mars is suspiciously tiny, and why is there an asteroid belt in the middle of the solar system anyway?

We also know that Earth was struck by some monstrous object in its early history, though where it came from is still a mystery. In any case, that planet-sized impactor gave us a Moon — which turns out to be helpful in all kinds of ways. But it certainly wasn't destined ...Read More...

Ancient lunar craters reveal Earth's own impact history

An image of the Moltke crater taken from Apollo 10. One new study has revealed new details about impact craters on Earth by studying lunar craters. Wikimedia Commons

Lunar Impact Craters
By studying the scars left from long-gone, violent lunar impacts, scientists have revealed new details about the history of impacts on Earth.

Because the Moon is so close to the Earth, it's thought that impacts there correspond to impacts and craters left on our own world. "The Moon and Earth are very close neighbors. The population of impactors that would hit the Moon would also hit the Earth," study author Sara Mazrouei of the University of Toronto said in an email. "Therefore, they should have both experienced a similar history in terms of impact cratering."

And by observing the Moon's many craters, her research team discovered that about 290 million years ago, the rate of crater-forming impacts on the Moon increased dramatically. That implies that more space rocks were also striking Earth at the time.

Earth's Impact History
The results also give insights into the time period before this sudden increase happened. Earth has few impact scars dating to between 300 million and 650 million years ago. Researchers had assumed that our planet's erosion processes had simply erased any evidence of these ancient craters over time. But Mazrouei and her team's work implies erosion wasn't to blame — there were simply fewer impacts during this earlier time.

Erosion likely did play a role in wiping away craters that formed before 650 million years ago, her team also found.

To reach their conclusions, the researchers estimated the ages of 111 young, large lunar impact craters using infrared satellite images of the Moon's surface. This let them determine the thermal properties of their material in these craters, and reveal the crater's age.

However, the astronomers say it's still a mystery as to why impact rates dramatically increased 290 million years ago.

"An idea is that it is due to a breakup in an asteroid family," Mazrouei said. "When asteroid families ...Read More...

Earth's Oldest Rock Found on the Moon

Rock fragment from Earth via the Moon.

Scientists discover what may be Earth's oldest rock in a lunar sample returned by the Apollo 14 astronauts. The research about this possible relic from the Hadean Earth was published in the journal Earth and Planetary Science Letters.

An international team of scientists associated with the Center for Lunar Science and Exploration (CLSE), part of NASA's Solar System Exploration Research Virtual Institute, found evidence that the rock was launched from Earth by a large impacting asteroid or comet.

This impact jettisoned material through Earth's primitive atmosphere, into space, where it collided with the surface of the Moon (which was three times closer to Earth than it is now) about 4 billion years ago. The rock was subsequently mixed with other lunar surface materials into one sample.

The team developed techniques for locating impactor fragments in the lunar regolith, which prompted CLSE principal investigator Dr. David A. Kring, a Universities Space Research Association (USRA) scientist at the Lunar and Planetary Institute (LPI), to challenge them to locate a piece of Earth on the Moon.

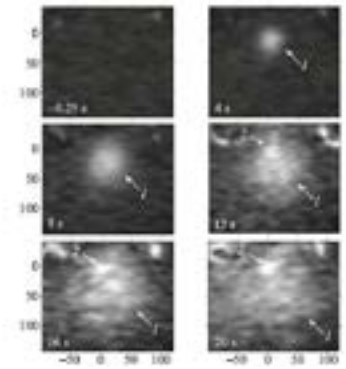
Led by research scientist Jeremy Bellucci and Professor Alexander Nemchin, team members working at the Swedish Museum of Natural History and Curtin University in Australia rose to the challenge. The result of their investigation is a 2 gram fragment of rock composed of quartz, feldspar, and zircon, all commonly found on Earth and highly unusual on the Moon.

Chemical analysis of the rock fragment shows it crystallized in a terrestrial-like oxidized system, at terrestrial temperatures, rather than in the reducing and higher temperature conditions characteristic of the Moon.

"It is an extraordinary find that helps paint a better picture of early Earth and the bombardment that modified our planet during the dawn of life," says Dr. Kring.

It is possible that the sample is not of terrestrial origin, but instead crystallized on the Moon, however ..Read More...

Scientists explain formation of lunar dust clouds



Photographs of the region where the meteoroid collides at the point (0, 0) with the surface of the Moon taken at 0.25 s before the collision and at 4, 8, 12, 16, and 20 s after the collision. The axes present distances in kilometers. Arrows 1 and 2 indicate the fast large and slow small dust clouds, respectively.

Physicists from the Higher School of Economics and Space Research Institute have identified a mechanism explaining the appearance of two dusty plasma clouds resulting from a meteoroid that impacted the surface of the Moon. The study was published in JETP Letters.

The collision of a meteoroid with the surface of the Moon greatly changes the properties of the surrounding dusty plasma system by throwing a large quantity of lunar soil-regolith debris - dust particles measuring 10-100 microns - into the otherwise relatively unsullied exosphere.

In 2015, astronomers at the Garden Observatory in Gordola (Switzerland) observed a similar phenomenon when they recorded an optical flash resulting from a meteoroid impacting the Moon. An international group of scientists using data from astronomical observations concluded that a fairly large and fast-moving meteoroid hadimpacted the Moon, raising two clouds of unknown composition.

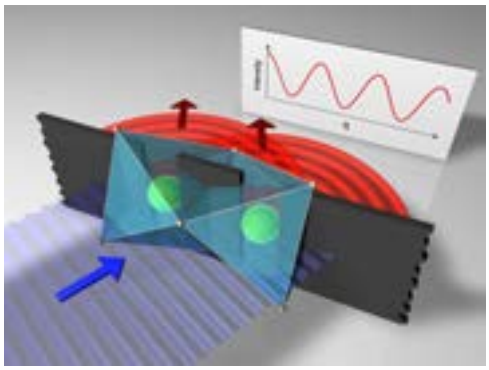
Russian researchers from the Higher School of Economics, Space Research Institute (IKI), Moscow Institute of Physics and Technology, Sternberg Astronomical Institute, and Far Eastern Federal University determined that a meteoroid's collision with the surface of the Moon produces a shock wave that throws up regolith fragments and droplets of molten material into the surrounding free space.

Those fragments and hardened molten droplets rise above the surface of the Moon, interact with the electrons in the solar wind and solar radiation and take on an electrical charge.

Two dusty plasma clouds form as a result - one composed of regolith fragments and a second of hardened droplets of molten material. The differing characteristics of the two clouds make it possible to observe them separately.

Scientists have calculated the main characteristics of the clouds - the speed at which they expand, the size, number density, and electrical charge of the particles in each, and so on. The calculations and observational data matched. It was found that a cloud formed by ...Read More...

Classic double-slit experiment in a new light



An intense beam of high-energy X-ray photons (violet) hits two adjacent iridium atoms (green) in the crystal. This excites electrons in the atoms for a short time. The atoms emit X-ray photons which overlap behind the two iridium atoms (red) and can be analyzed as interference images. Credit: Markus Grueninger, University of Cologne

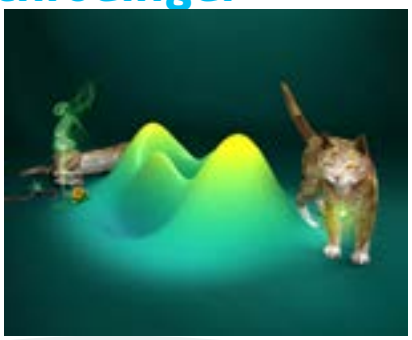
An international research team led by physicists from the University of Cologne has implemented a new variant of the basic double-slit experiment using resonant inelastic X-ray scattering at the European Synchrotron ESRF in Grenoble. This new variant offers a deeper understanding of the electronic structure of solids. Writing in Science Advances, the research group have now presented their results in a study titled "Resonant inelastic X-ray incarnation of Young's double-slit experiment."

The double-slit experiment is of fundamental importance in physics. More than 200 years ago, Thomas Young diffracted light at two adjacent slits, thus generating interference patterns (images based on superposition) behind this double slit. Thus, he demonstrated the wave nature of light. In the 20th century, scientists have shown that electrons or molecules scattered on a double slit show the same interference pattern, which contradicts the classical expectation of particle behaviour, but can be explained in quantum-mechanical wave-particle dualism. In contrast, the researchers in Cologne investigated an iridium oxide crystal ($Ba_3CeIr_2O_9$) by means of resonant inelastic X-ray scattering (RIXS).

The crystal is irradiated with strongly collimated, high-energy X-ray photons. The X-rays are scattered by the iridium atoms in the crystal, which take over the role of the slits in Young's classical experiment. Due to the rapid technical development of RIXS and a skilful choice of crystal structure, the physicists were observed the scattering on two adjacent iridium atoms, a so-called dimer.

"The interference pattern tells us a lot about the scattering object, the dimer double slit," says Professor Markus Grueninger, who heads the research group at the University of Cologne. In contrast to the classical double-slit experiment, the inelastically scattered X-ray photons provide information about the excited states of the dimer, in particular their symmetry, and thus about the dynamic physical properties of the solid. ...Read More...

An entangled atom-light state realizes a paradoxical thought experiment by Erwin Schrödinger



Dead and alive: Schrödinger's cat is entangled with an atom. If the atom is excited, the cat is alive. If it has decayed, the cat is dead. In the experiment, a light pulse represents the two states (peaks) and may be in a superposition of both, just like the cat. Credit: Christoph Hohmann, Nanosystems Initiative Munich (NIM)

An old thought experiment now appears in a new light. In 1935 Erwin Schrödinger formulated a thought experiment designed to capture the paradoxical nature of quantum physics. A group of researchers led by Gerhard Rempe, Director of the Department of Quantum Dynamics at the Max Planck Institute of Quantum Optics, has now realized an optical version of Schrödinger's thought experiment in the laboratory. In this instance, pulses of laser light play the role of the cat. The insights gained from the project open up new prospects for enhanced control of optical states, that can in the future be used for quantum communications.

"According to Schrödinger's idea, it is possible for a microscopic particle, such as a single atom, to exist in two different states at once. This is called a superposition. Moreover, when such a particle interacts with a macroscopic object, they can become 'entangled', and the macroscopic object may end up in superposition state. Schrödinger proposed the example of a cat, which can be both dead and alive, depending on whether or not a radioactive atom has decayed – a notion which is in obvious conflict with our everyday experience," Professor Rempe explains.

In order to realize this philosophical gedanken experiment in the laboratory, physicists have turned to various model systems. The one implemented in this instance follows a scheme proposed by the theoreticians Wang and Duan in 2005. Here, the superposition of two states of an optical pulse serves as the cat. The experimental techniques required to implement this proposal – in particular an optical resonator – have been developed in Rempe's group over the past few years.

A test for the scope of quantum mechanics

The researchers involved in the project were initially skeptical as to whether it would be possible to generate and reliably detect such quantum mechanically entangled cat states with the available technology. ...Read More...

New technology uses lasers to transmit audible messages to specific people

Credit: CCO Public Domain

Researchers have demonstrated that a laser can transmit an audible message to a person without any type of receiver equipment. The ability to send highly targeted audio signals over the air could be used to communicate across noisy rooms or warn individuals of a dangerous situation such as an active shooter.

In The Optical Society (OSA) journal Optics Letters, researchers from the Massachusetts Institute of Technology's Lincoln Laboratory report using two different laser-based methods to transmit various tones, music and recorded speech at a conversational volume.

"Our system can be used from some distance away to beam information directly to someone's ear," said research team leader Charles M. Wynn. "It is the first system that uses lasers that are fully safe for the eyes and skin to localize an audible signal to a particular person in any setting."

Creating sound from air

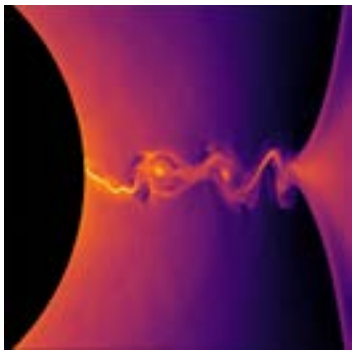
The new approaches are based on the photoacoustic effect, which occurs when a material forms sound waves after absorbing light. In this case, the researchers used water vapor in the air to absorb light and create sound.

"This can work even in relatively dry conditions because there is almost always a little water in the air, especially around people," said Wynn. "We found that we don't need a lot of water if we use a laser wavelength that is very strongly absorbed by water. This was key because the stronger absorption leads to more sound."

One of the new sound transmission methods grew from a technique called dynamic photoacoustic spectroscopy (DPAS), which the researchers previously developed for chemical detection. In the earlier work, they discovered that scanning, or sweeping, a laser beam at the speed of sound could improve chemical detection.

"The speed of sound is a very special speed at which to work," said Ryan M. Sullenberger, first author of the paper. "In this new paper, we show that sweeping a laser beam at the speed of sound at a wavelength absorbed by water can be used as an efficient way to create sound." ...Read More...

How to escape a black hole: Simulations provide new clues about powerful plasma jets



This visualization of a general-relativistic collisionless plasma simulation shows the density of positrons near the event horizon of a rotating black hole. Plasma instabilities produce island-like structures in the region of intense electric current. Credit: Kyle Parfrey et al./Berkeley Lab

Black holes are known for their voracious appetites, binging on matter with such ferocity that not even light can escape once it's swallowed up.

Less understood, though, is how black holes purge energy locked up in their rotation, jetting near-light-speed plasmas into space to opposite sides in one of the most powerful displays in the universe. These jets can extend outward for millions of light years.

New simulations led by researchers working at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and UC Berkeley have combined decades-old theories to provide new insight about the driving mechanisms in the plasma jets that allows them to steal energy from black holes' powerful gravitational fields and propel it far from their gaping mouths.

The simulations could provide a useful comparison for high-resolution observations from the Event Horizon Telescope, an array that is designed to provide the first direct images of the regions where the plasma jets form.

The telescope will enable new views of the black hole at the center of our own Milky Way galaxy, as well as detailed views of other supermassive black holes.

"How can the energy in a black hole's rotation be extracted to make jets?" said Kyle Parfrey, who led the work on the simulations while he was an Einstein Postdoctoral Fellow affiliated with the Nuclear Science Division at Berkeley Lab. "This has been a question for a long time."

Now a senior fellow at NASA Goddard Space Flight Center in Maryland, Parfrey is the lead author of a study, published Jan. 23 in Physical Review Letters, that details the simulations research.

The simulations, for the first time, unite a theory that explains how electric currents around a black hole twist magnetic fields into forming jets, with a separate theory explaining how particles crossing through a ...Read More...

Mystery orbits in outermost reaches of solar system not caused by 'Planet Nine'

Kuiper Belt's ice cores. Credit: ESO/M. Kornmesser

The strange orbits of some objects in the farthest reaches of our solar system, hypothesised by some astronomers to be shaped by an unknown ninth planet, can instead be explained by the combined gravitational force of small objects orbiting the Sun beyond Neptune, say researchers.

The alternative explanation to the so-called 'Planet Nine' hypothesis, put forward by researchers at the University of Cambridge and the American University of Beirut, proposes a disc made up of small icy bodies with a combined mass as much as ten times that of Earth. When combined with a simplified model of the solar system, the gravitational forces of the hypothesised disc can account for the unusual orbital architecture exhibited by some objects at the outer reaches of the solar system.

While the new theory is not the first to propose that the gravitational forces of a massive disc made of small objects could avoid the need for a ninth planet, it is the first such theory which is able to explain the significant features of the observed orbits while accounting for the mass and gravity of the other eight planets in our solar system. The results are reported in the Astronomical Journal.

Beyond the orbit of Neptune lies the Kuiper Belt, which is made up of small bodies left over from the formation of the solar system. Neptune and the other giant planets gravitationally influence the objects in the Kuiper Belt and beyond, collectively known as trans-Neptunian Objects (TNOs), which encircle the Sun on nearly-circular paths from almost all directions.

However, astronomers have discovered some mysterious outliers. Since 2003, around 30 TNOs on highly elliptical orbits have been spotted: they stand out from the rest of the TNOs by sharing, on average, the same spatial orientation. This type of clustering cannot be explained by our existing eight-planet solar system architecture and has led to some astronomers hypothesising that the unusual orbits could be influenced by the existence of an as-yet-unknown ninth planet.

The 'Planet Nine' hypothesis suggests that to account for the unusual orbits of these TNOs, there would have to be another planet, believed to be about ten times more massive than Earth, lurking in the distant ...Read More...

Astronomers use split images of quasars to produce a new estimate of the Hubble constant

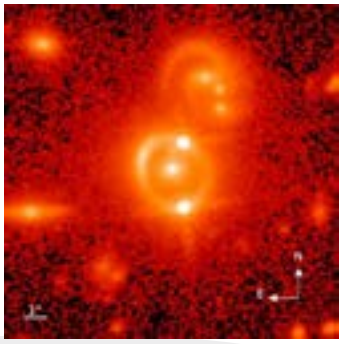


Image from the Hubble Space Telescope of a doubly imaged quasar. Credit: NASA Hubble Space Telescope, Tommaso Treu/ UCLA, and Birrer et al

The question of how quickly the universe is expanding has been bugging astronomers for almost a century. Different studies keep coming up with different answers—which has some researchers wondering if they've overlooked a key mechanism in the machinery that drives the cosmos.

Now, by pioneering a new way to measure how quickly the cosmos is expanding, a team led by UCLA astronomers has taken a step toward resolving the debate. The group's research is published today in Monthly Notices of the Royal Astronomical Society.

At the heart of the dispute is the Hubble constant, a number that relates distances to the redshifts of galaxies—the amount that light is stretched as it travels to Earth through the expanding universe. Estimates for the Hubble constant range from about 67 to 73 kilometers per second per megaparsec, meaning that two points in space 1 megaparsec apart (the equivalent of 3.26 million light-years) are racing away from each other at a speed between 67 and 73 kilometers per second.

"The Hubble constant anchors the physical scale of the universe," said Simon Birrer, a UCLA postdoctoral scholar and lead author of the study. Without a precise value for the Hubble constant, astronomers can't accurately determine the sizes of remote galaxies, the age of the universe or the expansion history of the cosmos.

Most methods for deriving the Hubble constant have two ingredients: a distance to some source of light and that light source's redshift. Looking for a light source that had not been used in other scientists' calculations, Birrer and colleagues turned to quasars, fountains of radiation that are powered by gargantuan black holes. And for their research, the scientists chose one specific subset of quasars—those whose light has been bent by the gravity of an intervening galaxy, which produces two side-by-side images of the quasar on the sky. Light from the two images takes different routes to Earth. When the quasar's brightness fluctuates, the two ...Read More...

Special Read:

Prolonged spaceflight could weaken astronauts' immune systems

Credit: CC0 Public Domain

NASA hopes to send humans to Mars by 2030 on a round-trip mission that could take up to three years—far longer than any human has ever traveled in space. Such long-term spaceflights could adversely affect certain cells in the immune systems of astronauts, according to a new study led by University of Arizona researchers.

"What NASA and other space agencies are concerned about is whether or not the immune system is going to be compromised during very prolonged spaceflight missions," said Richard Simpson, senior author and associate professor of nutritional sciences at the UA. "What clinical risks are there to the astronauts during these missions when they're exposed to things like microgravity, radiation and isolation stress? Could it be catastrophic to the level that the astronaut wouldn't be able to complete the mission?"

Simpson and his team of researchers at the UA, the University of Houston, Louisiana State University and NASA-Johnson Space Center, studied the effects of spaceflights of six months or more on natural killer cells, or NK cells, a type of white blood cell that kills cancerous cells in the body and prevents old viruses from reactivating.

"Cancer is a big risk to astronauts during very prolonged spaceflight missions because of the exposure to radiation," Simpson said. "[NK-cells] are also very important to kill off virally infected cells. When you're in the space station, it's a very sterile environment—you're not likely to pick up the flu or a rhinovirus or some community-type infection—but the infections that are a problem are the viruses that are already in your body. These are mostly viruses that cause things like shingles, mononucleosis or cold sores; they stay in your body for the rest of your life, and they do reactivate when you're stressed."

Scientists compared blood samples of eight crewmembers who completed missions to the International Space Station with healthy individuals who remained on Earth. Blood samples were taken before launch, at several points during the mission and after the astronauts' return to Earth.

The results showed that NK-cell function is impaired in astronauts as compared with pre-flight levels and ground-based controls. At flight day 90, NK-cell cytotoxic activity against leukemia cells in vitro was reduced by approximately 50 percent in International Space Station crew members.

"When we look at the function of the astronaut samples during flight compared to their own samples before they flew, it goes down. When we compare them to controls who stayed on Earth, it still goes down," Simpson said. "I don't think there's any doubt that NK-cell function is decreasing in the spaceflight environment when analyzed in a cell culture system."

The effect appears to be more pronounced in first-time astronauts, as opposed to those who have already been in space.

"Serendipitously, we found that half our crew members had flown before, and the other half hadn't," Simpson said. "So we were able to just split them in half to see if there was an effect, and there was. The 'rookies' had greater drops in NK-cell function compared to the veterans." ..Read More...

This Week's Sky at a Glance - Jan. 26 - Feb. 01, 2019

Jan. 28	Mo	01:11	Last Quarter
Jan. 30	We	06:46	Mercury Superior Conj.
Jan. 31	Th	03:54	Moon-Jupiter: 3° S
		21:36	Moon-Venus: 0.1° S

Amazing Images From Sunday's Total Lunar Eclipse as Observers Spy Impact Flash

.....But it was actually a flash near the limb of the Moon that caught many an observer's eye. The event occurred around 4:41:43 UT on January 21st, under half a minute into totality. Discussion of the impact flash across Twitter sent many an observer (including myself) scrambling to look back over images and video... unfortunately, we had snapped stills just a minute prior to and after the event! Fortunately, lots of video was running featuring the eclipse worldwide, and soon, several videos confirmed the event. ...Read More...

Amateur astronomer Christian Fröschlin of the Netherlands captured this amazing still image of the impact, which appeared on one of the 9,000 images he made of the eclipse. Christian Fröschlin