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Composite photo of the May 2022 total lunar eclipse as seen in Colorado

Credit: JILAn Annika Ekrem

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Research Highlights

Feature Articles

A Surging Glow in a Distant Galaxy Could Change the Way We Look at Black Holes

Something strange is afoot in the galaxy known as 1ES 1927+654: In late 2017, and for reasons that scientists couldn't explain, the supermassive black hole sitting at the heart of this galaxy underwent a massive identity crisis. Over a span of months, the already-bright object, which is so luminous that it belongs to a class of black holes known as active galactic nuclei (AGN), suddenly grew a lot brighter—glowing nearly 100 times more than normal in visible light.

Now, an international team of astrophysicists, including scientists from CU Boulder, may have pinpointed the cause of that shift. The magnetic field lines threading through the black hole appear to have flipped upside down, causing a rapid but short-lived change in the object's properties. It was as if compasses on Earth suddenly started pointing south instead of north.

The findings, published May 5 in *The Astrophysical Journal,* could change how scientists look at supermassive black holes, said study coauthor Nicolas Scepi.

“Normally, we would expect black holes to evolve over millions of years,” said Scepi, a postdoctoral researcher at JILA, a joint research institute between CU Boulder and the National Institute of Standards and Technology (NIST). “But these objects, which we call changing-look AGNs, evolve over very short time scales. Their magnetic fields may be key to understanding this rapid evolution.” Scepi, alongside JILA Fellows Mitchell Begelman and Jason Dexter, first theorized that such a magnetic flip-flop could be possible in 2021.

The new study supports the idea. In it, a team led by Sibasish Laha of NASA's Goddard Space Flight Center collected the most comprehensive data yet on this far-away object. The group drew on observations from seven telescope arrays on the ground and in space, tracing the flow of radiation from 1ES 1927+654 as the AGN blazed bright then dimmed back down.

The observations suggest that the magnetic fields of supermassive black holes may be a lot more dynamic than scientists once believed. And, Begelman noted, this AGN probably isn't alone.

“If we saw this in one case, we'll definitely see it again,” said Begelman, professor in the Department of Astrophysical and Planetary Sciences (APS). “Now we know what to look for.”

An Unusual Black Hole

Begelman explained that AGNs are borne out of some of the most extreme physics in the known universe. These monsters arise when supermassive black holes begin to pull in huge amounts of gas from the galaxies around them. Like water circling a drain, that material will spin faster and faster the closer it gets to the black hole—forming a bright “accretion disk” that generates intense and varied radiation that scientists can view from billions of light-years away.

Those accretion disks also give rise to a curious feature: They generate strong magnetic fields that wrap around the central black hole and, like Earth's own magnetic field, point in a distinct direction, such as north or south.

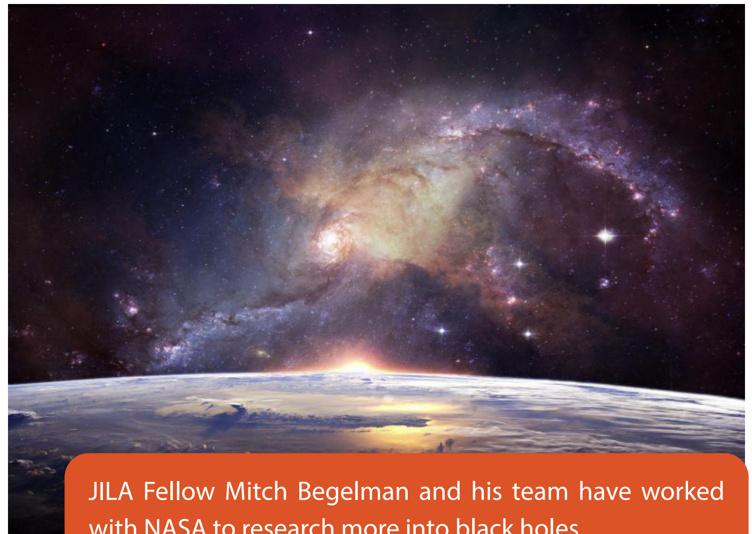
“There's increasingly evidence from the Event Horizon Telescope and other observations that magnetic fields might play a key role in influencing how gas falls onto black holes,” said Dexter, assistant professor in APS. Which could also influence how bright an AGN, like the one at the heart of 1ES 1927+654, looks through telescopes.

By May 2018, this object's surge in energy had reached a peak, ejecting more visible light but also many times more ultraviolet radiation than usual. Around the same time, the AGN's emissions of X-ray radiation began to dim. "Normally, if the ultraviolet rises, your X-rays will also rise," Scepi said. "But here, the ultraviolet rose, while the X-ray decreased by a lot. That's very unusual."

Turning on Its Head

Researchers at JILA proposed a possible answer for that unusual behavior in a paper published last year. Begelman explained that these features are constantly pulling in gas from outside space, and some of that gas also carries magnetic fields. If the AGN pulls in magnetic fields that point in an opposite direction to its own—they point south, say, instead of north—then its own field will weaken. It's a bit like how a tug-of-war team tugging on a rope in one direction can nullify the efforts of their opponents pulling the other way.

With this AGN, the JILA team theorized, the black hole's magnetic field got so weak that it flipped upside down. "You're basically wiping out the magnetic field entirely," Begelman said.



JILA Fellow Mitch Begelman and his team have worked with NASA to research more into black holes

Image Credit: Pixabay, Open Commons Images

In the new study, researchers led by NASA set out to collect as many observations as they could of 1ES 1927+654.

The disconnect between ultraviolet and X-ray radiation turned out to be the smoking gun. Astrophysicists suspect that a weakening magnetic field would cause just such a change in the physics of an AGN—shifting the black hole's accretion disk so that it ejected more ultraviolet and visible light and, paradoxically, less X-ray radiation. No other theory could explain what the researchers were seeing.

The AGN itself quieted down and returned to normal by summer 2021. But Scepi and Begelman view the event as a natural experiment—a way of probing close to the black hole to learn more about how these objects fuel bright beams of radiation. That information, in turn, may help scientists know exactly what kinds of signals they should look for to find more weird AGNs in the night sky.

"Maybe there are some similar events that have already been observed—we just don't know about them yet," Scepi said.

Other co-authors on the new study included researchers from the University of Maryland, Baltimore County in the U.S.; Instituto de Astrofísica de Canarias in Spain; Inter-University Centre for Astronomy and Astrophysics in India; Technion in Israel; Space Telescope Science Institute in the U.S.; National Institute for Astrophysics in Italy; Roma Tre University in Italy; National Autonomous University of Mexico; University of Florence in Italy; and the University of Birmingham in the United Kingdom.

Sibasish Laha, Eileen Meyer, Agniva Roychowdhury, Josefa Becerra Gonzalez, J. A. Acosta-Pulido, Aditya Thapa, Ritesh Ghosh, Ehud Behar, Luigi C. Gallo, Gerard A. Kriss, Francesca Panessa, Stefano Bianchi, Fabio La Franca, Nicolas Scepi, Mitchell C. Begelman, Anna Lia Longinotti, Elisabeta Lusso, Samantha Oates, Matt Nicholl, and S. Bradley Cenko. " A Radio, Optical, UV, and X-Ray View of the Enigmatic Changing-look Active Galactic Nucleus 1ES 1927+654 from Its Pre- to Postflare States." The Astrophysical Journal, 931 (1): 1-5: 10.3847/1538-4357/ac63aa. (2022)

Written by Dan Strain, Writer for CU Boulder Strategic Relations and Communications

Creating A Two-Step Dance for Lasers

Lasers have not only fascinated scientists for decades, but they have also become an integral part of many electronic devices. To create scientific-grade lasers, physicists try to control the temporal, spatial, phase, and polarization properties of the laser beam's pulse to be able to manipulate it. One of these properties is called the orbital angular momentum (OAM), and its phase, or shape, swirls as the doughnut-shaped laser beam travels through space. There are two types of OAM, spatial (S-OAM) and spatial-temporal (ST-OAM). S-OAM describes the angular momentum of the laser beam that is parallel to the light source's propagation direction. In contrast, ST-OAM has angular momentum that moves in a motion perpendicular to the light source's propagation direction, which creates a time component to the momentum [1, 2]. Because of these differences, ST-OAM is more difficult to study due to this time component. According to senior scientist Dr. Chen-Ting Liao: "The problem is that ST-OAM is very difficult to see or measure. And if we can't see or measure this easily, there's no way we can fully understand and optimize it, let alone use it for potential future applications." To try to overcome this difficulty, a collaboration led by Dr. Liao and other researchers, including JILA Fellows Margaret Murnane and Henry Kapteyn, worked out a method to image and better analyze ST-OAM beams. Their work was subsequently published in ACS Photonics and featured on the cover [3].

A Two-Step System

"Our overarching goal was: How do we get a very simple, straightforward way to characterize and measure these kinds of light pulses?" Liao said. To develop their imaging method, the team of researchers first looked at how S-OAM beams were imaged. "People measure S-OAMs by using a cylindrical lens [a concave shaped lens which enlarges light at a single point], which can form special patterns to reveal the S-OAM's shape," explained graduate student and the paper's first author, Guan Gui. "So, our idea was initially inspired by the traditional method in spatial OAMs and we adapted that to the spatial-temporal OAM."

As ST-OAMs have both a spatial and a temporal (time) component to the laser beam's angular momentum, the process to image the beam's structures was more complicated than just using a cylindrical lens, due to the constraints of the time component. To solve this problem, Gui, Liao, and their team had an idea. "The idea is that we only need two optical elements in this very simple yet powerful method," added Liao. "The first one is a grating, and the second one is a cylindrical mirror." Like the two-step dance that uses two steps to move the dancers, this method used two different components to resolve the ST-OAM into images that could be analyzed in space and in time.

The first component the beam interacts with is a grating, or a time equivalent analyzer, which converts the time component of the ST-OAM into other quantitative for calculation and analysis. "We use a grating which maps the time domain information into the spectral domain [this changes the time component into a spatial one with different laser beams]," Liao elaborated, "That's why we get this rainbow-like light." From there, the beam's rainbow spectra move into a cylindrical (non-spherical) mirror, a space-equivalent analyzer. This analyzer helps to break up the shape of the laser. "After we disperse the light into different colors using the grating," said Liao, "we use a cylindrical mirror that breaks the symmetry of the structured laser pulse. So, in this case, we can map out both the spatial-temporal information." The researchers did this by converting the time component into a spectral component, and then breaking up the spectral structure to analyze the laser pulse. The raw images created by this process could reveal the presence or absence of the ST-OAM. According to Liao, the striped patterns in the raw images can indicate the sign (positive or negative) and the space-time topological charge numbers (quantitative descriptors of the shape of the ST-OAM) as well. The positive or negative charge told the researchers which direction the ST-OAM was rotating. This new imaging system not only gave the researchers a better understanding of the structures of the ST-OAM but created a method giving immediate initial results.

Using 3D Structured Light

Excited by this new technique, the researchers realized it would help in multiple applications. “Thanks to our method, we can easily find the imperfections in the ST-OAM and better characterize it,” added Gui. “Measuring imperfections is important in research—it not only provides practical approaches toward perfections, but sometimes, these imperfections can also carry extra information that researchers are interested in. For example, these imperfections might reveal how ST-OAM light interacts with materials.” Liao and collaborators also saw potential opportunities for their new method in microscopy and imaging. “When people do microscopy and imaging, they use 2D structured light to enhance their images, such as structured illumination and super-resolution microscopy,” he said. “In our case, we are exploring the potential of ST-OAM in terms of better 3D imaging.” The researchers are hopeful others will utilize their methods to discover more information about ST-OAM.

After publishing in ACS Photonics, the researchers were notified that their paper was chosen for an ACS Editor's Choice award and was also selected to be featured on the journal cover. Papers are chosen for this award based on nominations. The team was delighted by the news. As Gui said: “I am very excited that our research got recognized by the community—it can be very helpful to this field. I'm also grateful for the people who worked together on this project. Our team always starts a project by discussing what is important and beneficial to the community, and these discussions help cultivate ideas than can solve a problem.”

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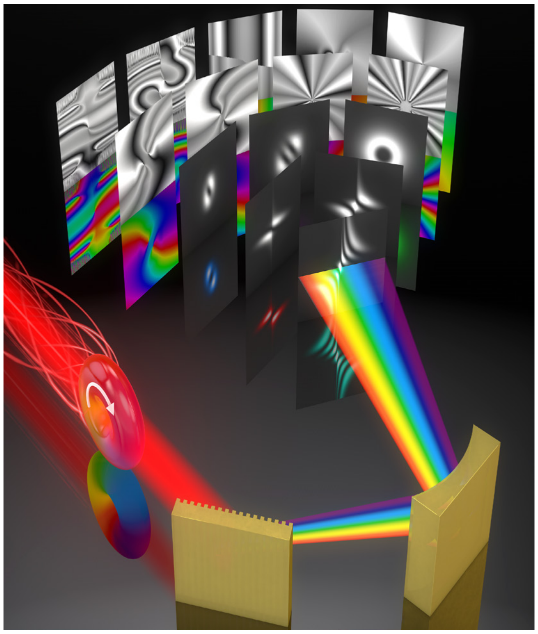

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Written by Kenna Hughes-Castleberry

Above: A rendering of the method used by the researchers to image the ST-OAM using a combination of a grating and a cylindrical lens.

Image Credit: Steven Burrows/Kapteyn and Murnane Laboratories

Quantum Information and Snowflakes

Qubits are a basic building block for quantum computers, but they're also notoriously fragile—tricky to observe without erasing their information in the process. Now, new research from CU Boulder and the National Institute of Standards and Technology (NIST) may be a leap forward for handling qubits with a light touch.

In the study, a team of physicists demonstrated that it could read out the signals from a type of qubit called a superconducting qubit using laser light—and without destroying the qubit at the same time.

The group's results could be a major step toward building a quantum internet, the researchers say. Such a network would link up dozens or even hundreds of quantum chips, allowing engineers to solve problems that are beyond the reach of even the fastest supercomputers around today. They could also, theoretically, use a similar set of tools to send unbreakable codes over long distances.

The study, published June 15 in the journal *Nature*, was led by JILA, a joint research institute between CU Boulder and NIST. "Currently, there's no way to send quantum signals between distant superconducting processors like we send signals between two classical computers," said Robert Delaney, lead author of the study and a former graduate student at JILA.

Quantum computers, which run on qubits, get their power by tapping into the properties of quantum physics, or the physics governing very small things. Delaney explained the traditional bits that run your laptop are pretty limited: They can only take on a value of zero or one, the numbers that underly most computer programming to date. Qubits, in contrast, can be zeros, ones or, through a property called "superposition," exist as zeros and ones at the same time.

But working with qubits is also a bit like trying to catch a snowflake in your warm hand. Even the tiniest disturbance can collapse that superposition, causing them to look like normal bits.

In the new study, Delaney and his colleagues showed they could get around that fragility. The team uses a wafer-thin piece of silicon and nitrogen to transform the signal coming out of a superconducting qubit into visible light—the same sort of light that already carries digital signals from city to city through fiber-optic cables.

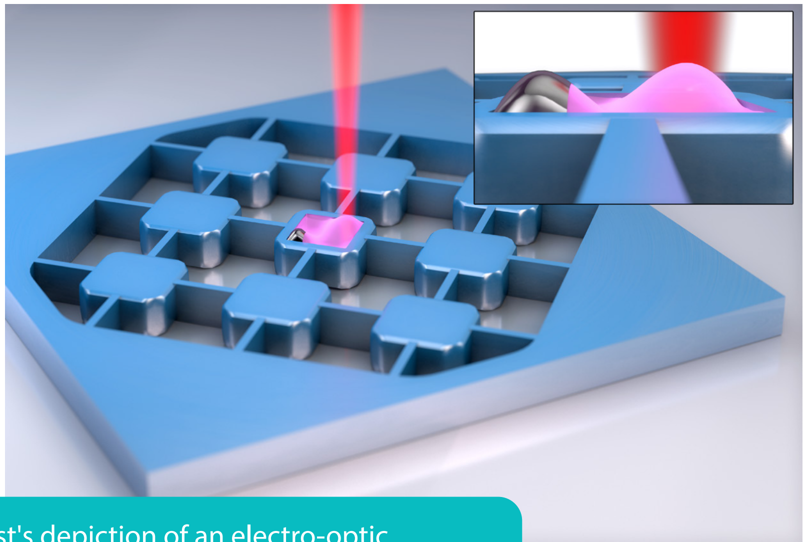
"Researchers have done experiments to extract optical light from a qubit, but not disrupting the qubit in the process is a challenge," said study co-author Cindy Regal, JILA fellow and associate professor of physics at CU Boulder.

Fragile Qubits

There are a lot of different ways to make a qubit, she added. Some scientists have assembled qubits by trapping an atom in laser light. Others have experimented with embedding qubits into diamonds and other crystals. Companies like IBM and Google have begun designing quantum computer chips using qubits made from superconductors.

Superconductors are materials that electrons can speed around without resistance. Under the right circumstances, superconductors will emit quantum signals in the form of tiny particles of light, or "photons," that oscillate at microwave frequencies. And that's where the problem starts, Delaney said.

To send those kinds of quantum signals over long distances, re-



Artist's depiction of an electro-optic transducer, an ultra-thin wafer that can read out the information from a superconducting qubit.

Image Credit:
Steven Burrows/Regal and Lehnert Groups

searchers would first need to convert microwave photons into visible light, or optical, photons—which can whiz in relative safety through networks fiberoptic cables across town or even between cities. But when it comes to quantum computers, achieving that transformation is tricky, said study co-author Konrad Lehnert.

In part, that's because one of the main tools you need to turn microwave photons into optical photons is laser light, and lasers are the nemesis of superconducting qubits. If even one stray photon from a laser beam hits your qubit, it will erase completely.

"The fragility of qubits and the essential incompatibility between superconductors and laser light makes usually prevents this kind of readout," said Lehnert, a NIST and JILA fellow.

Secret Codes

To get around that obstacle, the team turned to a go-between: a thin piece of material called an electro-optic transducer.

Delaney explained the team begins by zapping that wafer, which is too small to see without a microscope, with laser light. When microwave photons from a qubit bump into the device, it wobbles and spits out more photons—but these ones now oscillate at a completely different frequency. Microwave light goes in, and visible light comes out

In the latest study, the researchers tested their transducer using a real superconducting qubit. They discovered the thin material could achieve this switcheroo while also effectively keeping those mortal enemies, qubits and lasers, isolated from each other. In other words, none of the photons from the laser light leaked back to disrupt the superconductor. "Our electro-optic transducer does not have much effect on the qubit," Delaney said.

The team hasn't gotten to the point where it can transmit actual quantum information through its microscopic telephone booth. Among other issues, the device isn't particularly efficient yet. It takes about 500 microwave photons, on average, to produce a single visible light photon.

The researchers are currently working to improve that rate. Once they do, new possibilities may emerge in the quantum realm. Scientists could, theoretically, use a similar set of tools to send quantum signals over cables that would automatically erase their information when someone was trying to listen in. Mission Impossible made real, in other words, and all thanks to the sensitive qubit.

Robert D. Delaney, Maxwell D. Uremy, Sarang Mittal, Benjamin M. Brubaker, Johnathan M. Kindem, Peter S. Burns, Cindy Regal, and Konrad Lehnert. "Superconducting-qubit readout via low-backaction electro-optic transduction." Nature, 606 (1): 489-493. (2022).

Written by Dan Strain, Writer for CU Boulder Strategic Relations and Communications

Connecting Microwave and Optical Frequencies through the Ground State

The process of developing a quantum computer has seen significant progress in the past 20 years. Quantum computers are designed to solve complex problems using the intricacies of quantum mechanics. These computers can also communicate with each other by using entangled photons (photons that have connected quantum states). As a result of this entanglement, quantum communication can provide a more secure form of communication, and has been seen as a promising method for the future of a more private and faster internet.

Quantum computers manipulate qubits (quantum bits) of information in order to solve problems. As qubits are quite fragile, any environmental noise in the system can render them unreadable. Often, superconducting qubits are used for quantum computing and are designed to operate at specific frequencies, called microwave frequencies, which have low energy. In order for these superconducting qubits to work, they need to be kept at very low temperatures. The systems that cool the qubits to low temperatures are extraordinarily difficult to scale up in size, posing a significant challenge to long-distance quantum communication systems. To override this problem, JILA Fellow Cindy Regal and her research group collaborated with JILA and NIST fellow Konrad Lehnert and his research group to create a special transducer that can translate information from microwave frequencies into optical photons, which don't require low temperatures.

In order to supply the energy needed to promote these microwave signals to higher optical frequencies, any such transducer requires a strong laser. Unlike their previous devices and other competing technologies, their new transducer was not affected by this laser light, giving the entire system less environmental noise. Previous work from both teams had already decreased the noise in the previous system, but with their new transducer, the environmental noise was decreased even further. The researchers published their results in *Physical Review X* in tandem with a separate paper on connecting the transducer with superconducting qubits in *Nature* (a separate article about the *Nature* paper was written by the University of Colorado Boulder's Strategic Relations and Communications writer Daniel Strain).

Optical Versus Microwave

Optical photons oscillate at very high frequencies (hundreds of trillions of cycles per second), and so have higher energy than photons wiggling at microwave frequencies. With this higher energy, optical frequencies yield various benefits to quantum communication because they can work at a wider range of temperatures and at longer distances. In order to harness these benefits, the researchers developed a transducer that could transform microwave frequencies from the superconducting qubit into optical frequencies, or light. The transducer performed this transition using a mechanical membrane that connects the microwave and optical systems together within a cold refrigerator. The transducer thus connected the superconducting circuit to an optical cavity, where photons could bounce around. According to graduate student Maxwell Urmey of the Regal group:

The transducer developed by the Lehnert and Regal research groups uses side-banded cooling to convert microwave photons to optical photons

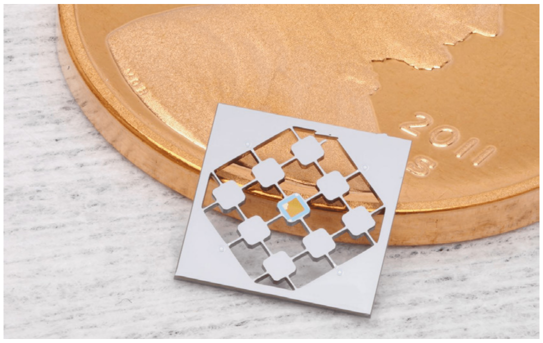
Image Credit: NIST

"The mechanically vibrating membrane can talk to both the optical cavity [containing the photons] and superconducting circuit, so we're able to transduce from microwave to optical frequencies and back."

Urmey also explained how the transducer would route information: "You'd want to start with your superconducting quantum computer, and then send a signal from it to the transducer, which would then convert that signal to light. You could then transmit that signal at room temperature, and detect it, ultimately with the capability to generate long-distance entanglement." The researchers set out to fine-tune the transducer in order to reduce the noise within the context of this setup.

More Robustness and Less Noise

In designing their transducer, the researchers used a special membrane made with a silicon nitride component to better fine tune the robustness of the system. "We designed a phononic crystal structure [designed to control and direct sound waves], which essentially isolates this floppy membrane from the substrate in which it sits," elaborated Sarang Mittal, a graduate student in the Lehnert group. "That substrate, which is a silicon chip, can also have modes that can couple to your signals. You can isolate the motion of the membrane from the motion of the substrate by designing a series of what looks like blocks and tethers. That improves our quality factor, which is easiest to think about as the number of times an excitation can bounce around in the resonator before it leaves. So, our quality factor in this paper is something like 107. So, if we put some energy into the mechanical element in the membrane, it could bounce around 10 million times before it gets lost." This improved quality can help improve quantum communications by protecting the system from environmental noise.



By fine-tuning their transducer design, the researchers were able to lower the amount of environmental noise, making the system even more robust. "If you're converting some information between these two frequency domains, you want to make sure you don't add a lot of other random stuff to it," Mittal said. "That would pollute the signal and ruin what's quantum about it." As much of the noise in the transducer comes from random extra photons, lowering the number of these photons can lower the noise. As Mittal added, "Many of the improvements we made lowered the noise from 34 additional photons in our last paper to three and a half in this paper."

The device was so well isolated that the researchers were able to reach the vibrational ground state with laser cooling. This process is analogous to how a laser cools atoms and ions. This ground-state cooling was applied specifically to the mechanical membrane of the transducer, within the phononic crystal design. "In order to ground-state cool the membrane mode, we take advantage of the excellent optical mode control of this device and crank up the laser power," said Urmey. The researchers found that they could use a higher laser power without introducing more noise to the system. Previous studies had not been able to achieve this result, suggesting that the new transducer design could have big implications for future quantum devices. The team was excited by the abilities of their new transducer, and hope to continue fine-tuning it for even better quality and efficiency. The results of this study push brings the reality of a working quantum network one step closer, highlighting the potential of future technologies that exploit fundamental details of quantum physics.

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Celebrating JILA's 60th Anniversary

This year, JILA celebrates its 60th anniversary. Officially established on April 13, 1962, as a joint institution between the University of Colorado Boulder and what was the National Bureau of Standards (NBS) at the time and is now the National Institute of Standards and Technology (NIST), JILA has become a world leader in physics research. Its rich history includes three Nobel laureates, groundbreaking work in laser development, atomic clocks, underlying dedication to precision measurement, and even competitive sports leagues. The process of creating this science goliath was not always straightforward and took the dedication and hard work of many individuals.

The idea for JILA came from a 1958 meeting of the International Astronomical Union in Moscow. Dr. Lewis Branscombe, a founding member and the head of the atomic physics department of the NBS proposed an institution for laboratory astrophysics to co-founder, and professor of astrophysics at CU Boulder, Dr. Richard Thomas. As Branscombe was directly funded by the government, and Thomas by the university, they realized that the best option for such an institution would be a joint establishment between the two entities. Together with the third founding member, Dr. Michael Seaton, a theorist at University College London, they toured nine universities in 1960 and 1961 to find a suitable home for the institution. Finally, the trio settled on CU Boulder as the location for their new institution. This was in part due to the President of the university at the time, Quigg Newton, who was supportive of their cause.

In April of 1962, JILA was founded, standing for the Joint Institute of Laboratory Astrophysics. Laboratory astrophysics was of particular interest to the International Astronomical Union as it focused on topics ranging from studying the Sun's visible light spectrum to developing retroreflecting mirrors.

Trying to find a building on the campus to house JILA, CU Boulder's Chief Financial Officer Leo Hill worked with both the NBS and National Science Foundation to pay rent for two floors of the old State Armory building. The NBS also provided funds for laboratory equipment. JILA began construc-

Groundbreaking ceremony for the new JILA laboratory wing and the 10-story office tower, February 25, 1965. (l—r) Lewis Branscomb, Chair of JILA; Donald Hornig, Science Advisor to President Lyndon Johnson; Joseph Smiley, CU President; and Robert Huntoon, Director of the Institute for Basic Standards at NBS.
Credit: University of Colorado Publications Service

Close up of entrance to the old State Armory Building, JILA's first home on the University of Colorado campus. Credit: JILA

tion for its own building shortly after, with the first part, the B-wing, completed in 1966, and the JILA tower finished in 1967. JILA added two more wings to its building, the S-wing (dedicated in 1988), and the X-wing in 2011. There are plans for further expansion with a Y-wing to be built, but nothing is currently in process.

Setting up in the Old Armory building, the JILA scientists (by the early 1960s there were seven scientists at JILA) established several rules that would help JILA function properly. These rules centered around leadership, funding, and fellowships. It was negotiated that with JILA's creation, the NBS would provide instruments and laboratories, while CU Boulder would provide researchers and land for the institution. With its unique agreements and roles, JILA's institute was relatively free to make its own way scientifically. In 1961, CU Boulder's Board of Regents approved the title of professor adjoint for any NBS faculty who taught classes at the University. This further solidified the connection between the university and the NBS and made it easier for JILA to attract new scientists.

One of these scientists was Dr. John "Jan" Hall, who was an expert in laser systems and who had previously worked at the NBS location in Washington DC. Though JILA was created during the height of the space race, with the idea being to help the U.S. win this race, Hall helped move JILA in a new direction with laser development. JILA still had ties to astrophysics and astronomy, such as developing lunar lasers for the space race, but the times were changing, and JILA was broadening its research focus to other topics.

By the late 1960s into the 1970s, JILA's fields were expanding to include laser physics, atomic physics, and others. Hall, at the helm of this shift, helped develop the first high-precision lasers at JILA. His work on these systems would later garner him a Nobel Prize in Physics in 2005.

The 1970s brought a deeper sense of community within JILA, as it was described as a "fun, fast, and free-spirited place." It was during this time that, along with rafting or ski trips, JILAns also created their own sports leagues, including softball and volleyball. In 1974, JILA elected its first female chair, Katharine Gebbie. Gebbie would later move over to NIST and become their Chief of Quantum Physics Division in 1988, but before she did, she helped recruit and support other female JILA Fellows in JILA. The fields of study within the institution also diversified, as in 1977, the NBS changed the name of their JILA division to the "Quantum Physics Division," predicting the role that quantum physics would play in JILA's future.

In the 1980s, JILA was beginning to modernize with the help of the early internet. Thanks to JILA fellow Judah Levine and colleagues the Automated Computer Time Service was brought online, accessible through dial-up modems. This was a monumental first step in modernizing time transfer, as users had access to atomic clock time. By 1988, JILA's population consisted of more than 200 people, including that the National Bureau of Standards (NBS) became the National Institute of Standards and Technology (NIST), changing its infrastructure and goals.

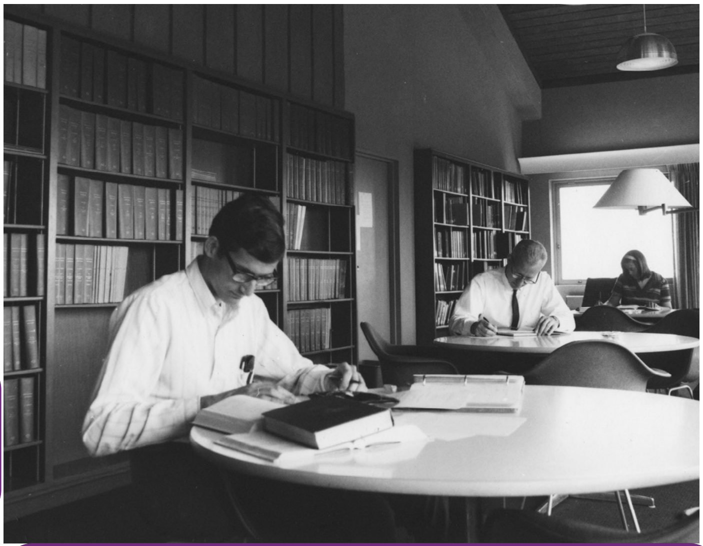
More breakthroughs occurred in the 1990s, as JILA once more shifted its mission to reflect NIST's mandate for developing precision measurement, and educating graduate students in future technology. In 1994, JILA had become more than its previous name implied, and dropped the definition of its acronym as the Joint Institute of Laboratory Astrophysics in acknowledgement of the broader scope of science conducted there. In 1995, Nobel-prize winning research was performed by JILA Fellows Carl Weiman and Eric Cornell, as they discovered the Bose-Einstein-Condensate (BEC), a special state of matter helpful for studying quantum dynamics. Nineteen ninety-six brought the 500th Fellows' meeting, as well as diversity initiatives to make the community more inclusive.

During the 1970s, JILA staff and scientists were fond of wild and creative Halloween costumes.
Credit: JILA

The 1990s was also an important decade for laser physics at JILA. By 1997, JILA identified seven fields of physics that researchers were studying: atomic physics, chemical physics, materials physics, optical physics, molecular physics, precision measurement, and astrophysics. Laser physics was an underlying study in many of these fields. In 1999, JILA Fellows Margaret Murnane and her husband Henry Kapteyn created what was then the fastest tabletop laser system. That same year, Fellows Jan Hall and Jun Ye developed the first optical frequency comb laser, a tool used by researchers to study optical physics. With these important developments, JILA was quickly establishing a reputation as a world leader in physics research. This reputation boosted JILA's success, as, by the late 1990s, the institution was producing 5–10% of the nation's new Ph.D. graduates

Woodbury Hall on the University of Colorado at Boulder Campus. In September 1963, JILA expanded into two and a half floors of this building.
Credit: University of Colorado

Aerial view of the newly completed JILA tower situated on the University of Colorado at Boulder campus, 1967.
Credit: University of Colorado Publications Service



JILA scientists studying in the library on the 10th floor of the JILA tower.
Credit: JILA

in atomic, molecular, and optical (AMO) physics.

The success continued into the 2000s, as three Nobel Prizes were awarded to JILA Fellows during the decade. In 2001, Eric Cornell and Carl Weiman were awarded the Nobel Prize in Physics for their work in 1995 on the BEC. The State of Colorado established March 6th as “Carl Weinman and Eric Cornell day” to honor the scientists. A few years later in 2005, Jan Hall also received the Nobel Prize in Physics for his work on laser systems and for developing the first optical frequency comb. JILA also added biophysics as a new field of study, which was helped by the addition of JILA Fellow Thomas Perkins, who worked in this area.

Three JILA Fellows were honored during the 2010s by being selected by then-President Obama to fill important leadership positions within scientific governing groups, including the White House Office of Science and Technology Policy. These Fellows included Carl Weinman, Margaret Murnane, and Carl Lineberger. JILA also celebrated its 50th birthday on April 13th, 2012.

Since then, JILA Fellows have received many prestigious scientific awards and grants. The decades of graduate students and postdoctoral researchers who have worked at the institution have gone on to lead successful careers and scientific efforts for other institutions around the world. JILA has also helped spawn many spin-off companies, including 12 companies based in Colorado. These companies range in their products and technology and include companies such as ColdQuanta, Hall Stable Lasers, High Precision Devices, KM Labs, Vescent, to name a few.

With 60 years of scientific research and groundbreaking discoveries, and many successful scientific careers launched, and hundreds of lives impacted, it is no surprise that JILA continues to be a global leader in physics research and a pillar within the scientific community. As JILA celebrates its 60th anniversary this year, we look not only to past accomplishments but also to the future, excited to be carrying on such a rich and fulfilling legacy.

Written by Kenna Hughes-Castleberry

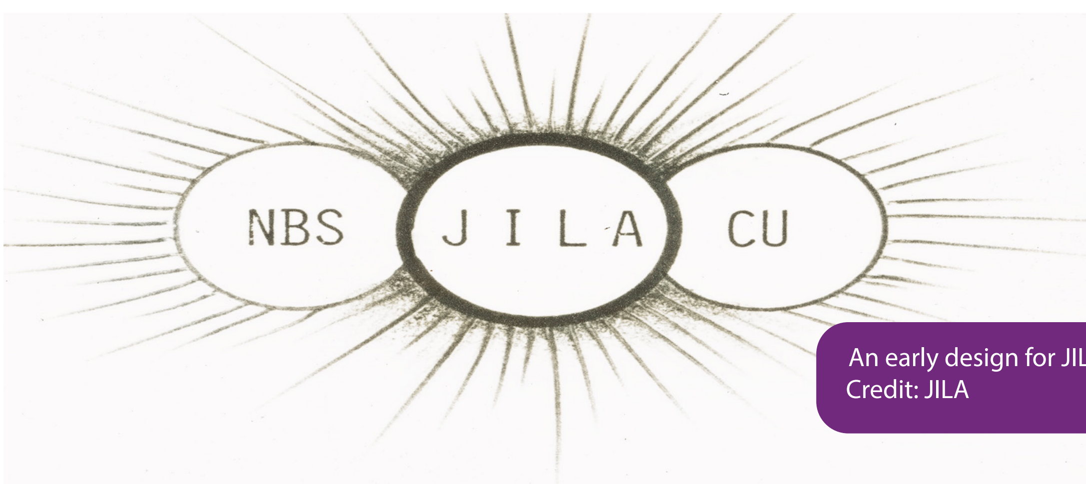
A Visual History of JILA

A note from the Editors

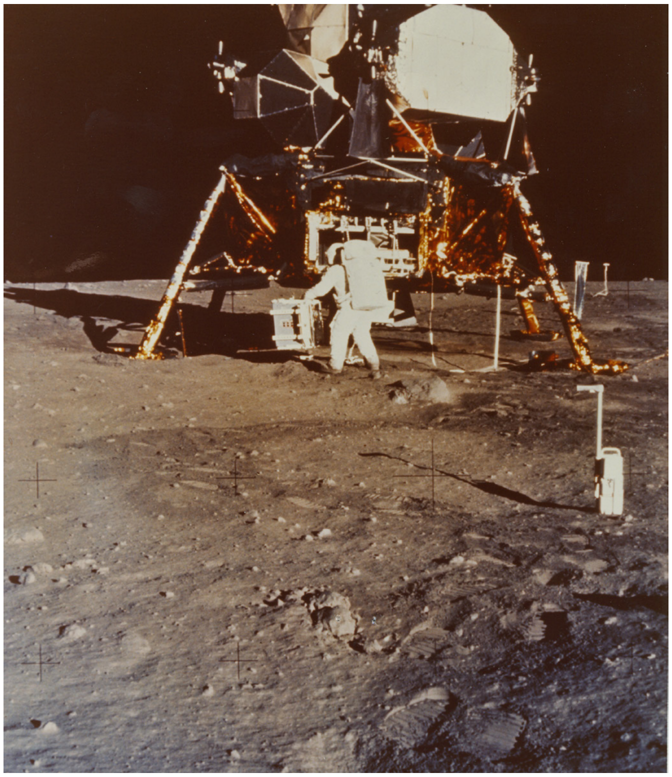
It is difficult to summarize the rich history of an institution like JILA in just a few pages. That's why pictures can often do more justice to describing the atmosphere and the research. Here we present a brief visual history of JILA for that very reason, hoping to encapsulate the depth of JILA's long legacy.

Above: The foundation of JILA's tower building, circa 1960s
Credit: JILA

Right: A picnic from 1962, one of the first gatherings in JILA's history
Credit: JILA

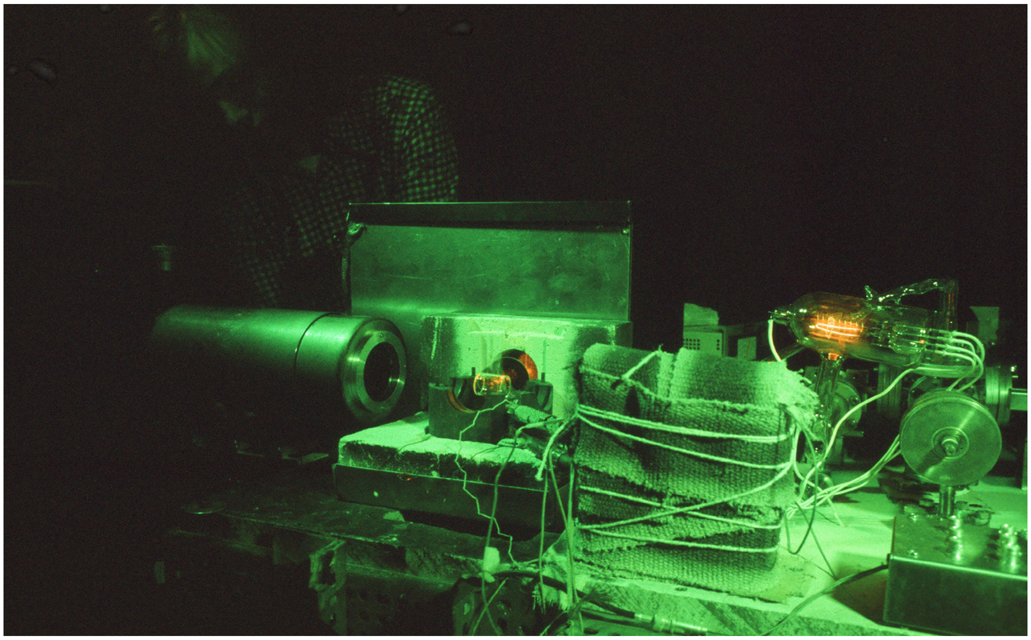


An early design for JILA's logo, circa 1975
Credit: JILA



Left: An astronaut works on placing a lunar-laer ranger onto the moon. This ranger is part of a larger experiment which several JILA fellows worked on during the 1960s, including JILA Fellow Jim Faller.
Credit: JILA

Above: The first female Chair elected to JILA, Katherine Gebbie, works in her office. Circa 1980
Credit: JILA



Left: A laser apparatus set up used by several JILA Fellows. Circa 1988.
Credit: JILA

JEDI Projects: Values Project

How does a scientific institution define what it is? Many scientific institutions use core values or phrases to help guide their visions. JILA is currently undergoing the process of identifying and defining its core values.

JEDI (JILA Excellence in Diversity and Inclusivity) is a group within JILA working to take the lead on this project and are working with the JILA community to define JILA's core values.

JILA consultant Regan Byrd has begun this process by training individuals as community leaders to help groups within the community define the values that they would like JILA to have. These groups of JILAns will then combine values and vote on the ones that best define JILA. The values project is slated to be finished in September.

Written by Kenna Hughes-Castleberry

Life After JILA

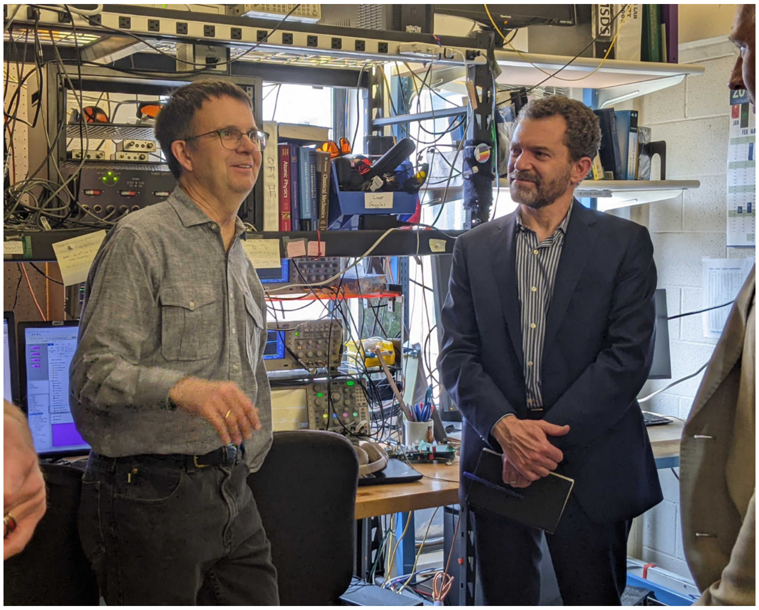
Rabin Paudel, a Data Scientist at Intel, speaks on his time at JILA
Image Credit: Rabin Paudel

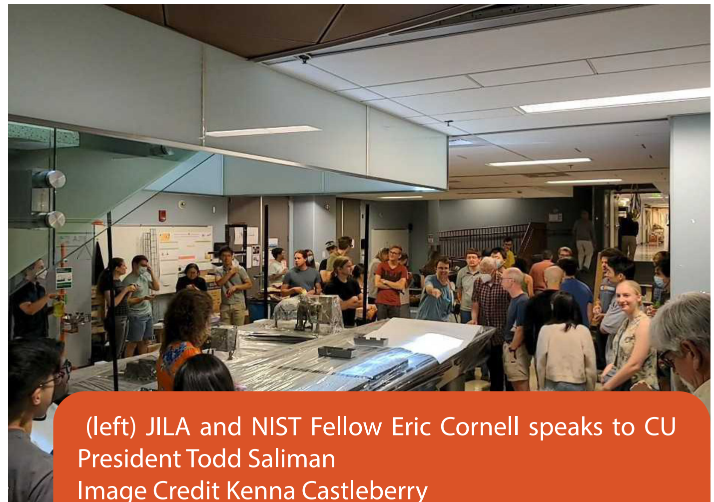
Most, if not all, JILA alumni have found that their time at JILA has signficiantly and positively impacted their careers. Whether through working on cutting-edge research or networking with others, most JILA alumni have left the institution with essential skills needed for their future successes. This is the case for Dr. Rabin Paudel, who was a Senior Applications Engineer at Cymer/ASML, which is a Dutch multinational company that makes photolithography equipment used by semiconductor chipmakers. Since the writing of this article, Paudel has now started a new position at Intel Corporation.

It was more than a decade before this job that Paudel arrived at JILA. "I started my graduate program in physics at JILA in 2010," Paudel explained. "I worked in the lab of the late professor JILA Fellow Debbie Jin and got my Ph.D. in 2017. For my graduate thesis, I studied strongly interacting Fermi gases using a novel probing technique with Laguerre-Gaussian optical beams. I also built a new generation of Fermi gas experiments from an empty lab space (which is now part of JILA and NIST Fellow Eric Cornell's strongly interacting Bose gas experiment)." Using the scientific knowledge and research techniques he learned, Paudel transitioned from academia to a career within the technology industry.

While Paudel has recently switched jobs, he still credits JILA with influencing his career success "Even though my current job is not directly in the field of quantum Fermi gases, my time at JILA has profoundly impacted my career," he said. "On the technical side, the ways you learn to design experiments, think about metrology, and approach troubleshooting challenges at JILA have strongly prepared me to work in the semiconductor industry." Paudel has also seen JILA influence his methods of analysis. "On the strategic side, I also learned to think with a holistic approach to any problems, not just specific short-term strategies, and think how things impact a big picture."

Written by Kenna Hughes-Castleberry





(left) JILA and NIST Fellow Eric Cornell speaks to CU President Todd Saliman
Image Credit Kenna Castleberry

(right) JILA celebrates the Summer Solstice in the X-Wing basement
Image Credit: JR Raith

News

University of Colorado President Todd Saliman visited JILA this past May and toured the laboratories at the invitation of JILA and NIST Fellow Eric Cornell. His visit was due to an invitation from JILA and NIST Fellow Eric Cornell to tour his laboratories. President Saliman viewed two of Cornell's laboratories, looking at several laser systems the researchers use to study electrons and other particles. Cornell, for his part, was delighted to explain his research and introduced his entire laboratory team to President Saliman. The President was amazed by not only Cornell's research but the team, ranging from recently graduated undergraduates to post-doctoral researchers. President Saliman asked Cornell about the impact of his research on both scientific discovery and his work mentoring students and researchers in his laboratory.

JIlA celebrates the Summer Solstice on June 21. The solstice happens twice a year, and in the summer, marks the longest daylight hours and shortest nighttime hours for the season. JILA's X-wing was designed to capture the Sun's light at the moment of the summer solstice in its basement floor. At 12:57 pm on June 21, JILAns gathered to watch the sun's rays move along the X-Wing basement floor, celebrating the event with food and laughter.

Awards

Two JILA graduate students were awarded this year's Richard Nelson Thomas Award for Graduate Students in Astrophyiscs. This award is given annually in honor of Dr. Richard Nelson Thomas, a founding member of JILA and an astrophysics researcher. This year, graduate students Tyler McMaken and Lia Hankla received the award. McMaken studies under the mentorship of JILA Fellow Andrew Hamilton, and focuses on black hole dynamics, looking at how quantum field theory and general relativity work in tandem on this phenomena in the galaxy. Similarly, Hankla also studies black holes under JILA Fellow Jason Dexter's mentoring. Her research focuses on plasma (hot gas) interacting with the black holes.

JILA and NIST Fellow Jun Ye has been distinguished as one of the 2022 Fellows for the U.S. Department of Defense's Vannevar Bush Fellowship. This highly competitive Fellowship is named in honor of Dr. Vannevar Bush, who directed the Office of Scientific Research and Development after World War II. In line with Dr. Bush's vision, the Fellowship aims to advance transformative, university-based fundamental research. For the FY 2022 competition, more than 300 white papers were received.

University of Colorado Boulder

National Institute of Standards and Technology
U.S. Department of Commerce

About JILA

JILA was founded in 1962 as a joint institute of CU-Boulder and NIST. JILA is located at the base of the Rocky Mountains on the CU-Boulder campus in the Duane Physics complex.

JILA's faculty includes two Nobel laureates, Eric Cornell and John Hall, as well as two John D. and Catherine T. MacArthur Fellows, Margaret Murnane and Ana Maria Rey. JILA's CU members hold faculty appointments in the Departments of Physics; Astrophysical & Planetary Science; Chemistry; Biochemistry; and Molecular, Cellular, and Developmental Biology, as well as in the School of Engineering.

The wide-ranging interests of our scientists have made JILA one of the nation's leading research institutes in the physical sciences. They explore some of today's most challenging and fundamental scientific questions about quantum physics, the design of precision optical and x-ray lasers, the fundamental principles underlying the interaction of light and matter, and processes that have governed the evolution of the Universe for nearly 14 billion years. Research topics range from the small, frigid world governed by the laws of quantum mechanics through the physics of biological and chemical systems to the processes that shape the stars and galaxies. JILA science encompasses eight broad categories: Astrophysics, Atomic & Molecular Physics, Biophysics, Chemical Physics, Laser Physics, Nanoscience, Precision Measurement, and Quantum Information Science & Technology.

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