Space News Update

— September 17, 2019 —

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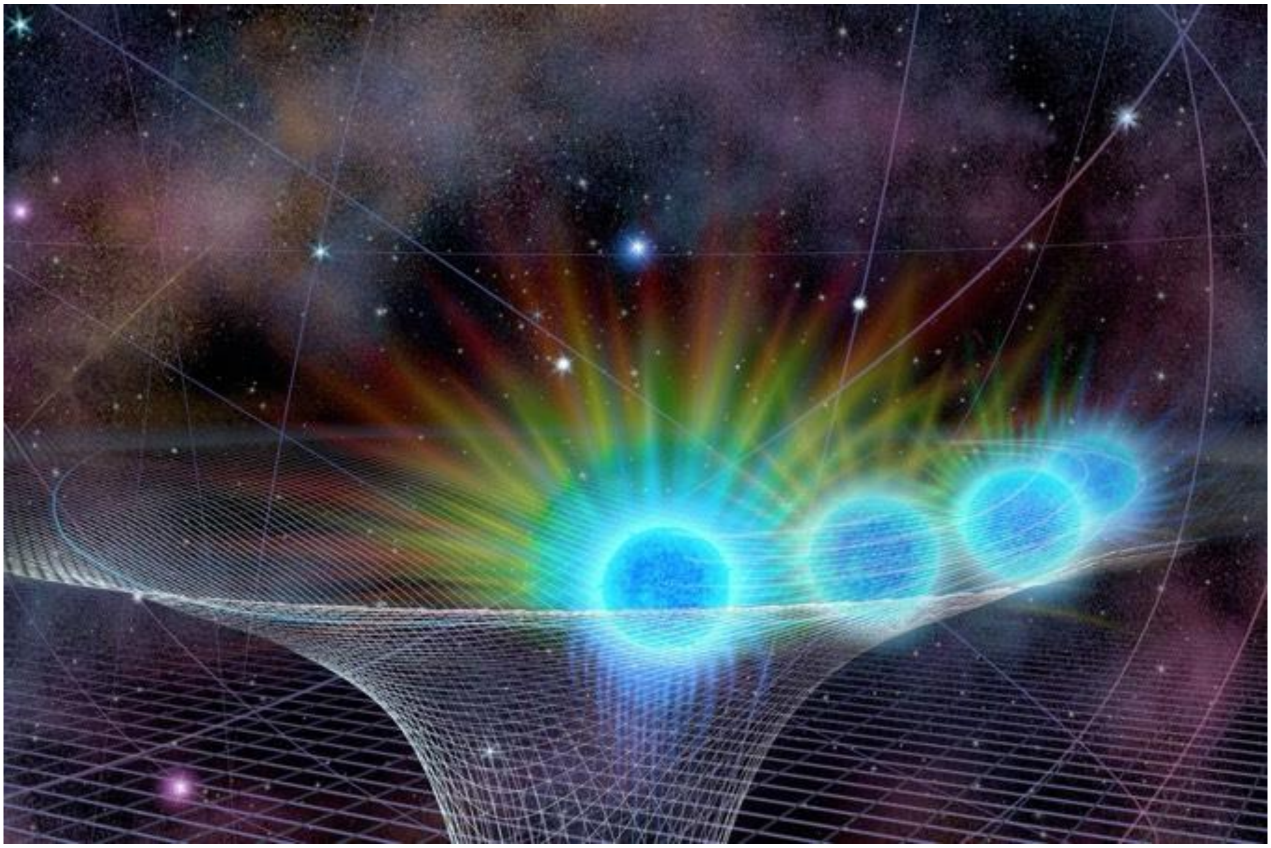
In the News

Departments

1. Black Hole at the Center of Our Galaxy Appears to be Getting Hungrier



A rendering of the star S0-2 orbiting Sagittarius A, the supermassive black hole at the heart of the Milky Way. Gas pulled away by the black hole as S0-2 made a close flyby last year could be powering recent outbursts. Image: Nicolle Fuller/National Science Foundation*

The enormous black hole at the center of our galaxy is having an unusually large meal of interstellar gas and dust, and researchers don't yet understand why.

"We have never seen anything like this in the 24 years we have studied the supermassive black hole," said Andrea Ghez, UCLA professor of physics and astronomy and a co-senior author of the research. "It's usually a pretty quiet, wimpy black hole on a diet. We don't know what is driving this big feast."

A paper about the study, led by the UCLA Galactic Center Group, which Ghez heads, is published today in Astrophysical Journal Letters.

The researchers analyzed more than 13,000 observations of the black hole from 133 nights since 2003. The images were gathered by the W.M. Keck Observatory in Hawaii and the European Southern Observatory's Very Large Telescope in Chile. The team found that on May 13, the area just outside the black hole's "point of no return" (so called because once matter enters, it can never escape) was twice as bright as the next-brightest observation.

They also observed large changes on two other nights this year; all three of those changes were "unprecedented," Ghez said.

The brightness the scientists observed is caused by radiation from gas and dust falling into the black hole; the findings prompted them to ask whether this was an extraordinary singular event or a precursor to significantly increased activity.

“The big question is whether the black hole is entering a new phase — for example if the spigot has been turned up and the rate of gas falling down the black hole ‘drain’ has increased for an extended period — or whether we have just seen the fireworks from a few unusual blobs of gas falling in,” said Mark Morris, UCLA professor of physics and astronomy and the paper’s co-senior author.

The team has continued to observe the area and will try to settle that question based on what they see from new images.

“We want to know how black holes grow and affect the evolution of galaxies and the universe,” said Ghez, UCLA’s Lauren B. Leichtman and Arthur E. Levine Professor of Astrophysics. “We want to know why the supermassive hole gets brighter and how it gets brighter.”

The new findings are based on observations of the black hole — which is called Sagittarius A*, or Sgr A* — during four nights in April and May at the Keck Observatory. The brightness surrounding the black hole always varies somewhat, but the scientists were stunned by the extreme variations in brightness during that timeframe, including their observations on May 13.

“The first image I saw that night, the black hole was so bright I initially mistook it for the star S0-2, because I had never seen Sagittarius A* that bright,” said UCLA research scientist Tuan Do, the study’s lead author. “But it quickly became clear the source had to be the black hole, which was really exciting.”

One hypothesis about the increased activity is that when a star called S0-2 made its closest approach to the black hole during the summer 2018, it launched a large quantity of gas that reached the black hole this year.

Another possibility involves a bizarre object known as G2, which is most likely a pair of binary stars, which made its closest approach to the black hole in 2014. It’s possible the black hole could have stripped off the outer layer of G2, Ghez said, which could help explain the increased brightness just outside the black hole.

Morris said another possibility is that the brightening corresponds to the demise of large asteroids that have been drawn in to the black hole.

No danger to Earth

The black hole is some 26,000 light-years away and poses no danger to our planet. Do said the radiation would have to be 10 billion times as bright as what the astronomers detected to affect life on Earth.

Astrophysical Journal Letters also published a second article by the researchers, describing speckle holography, the technique that enabled them to extract and use very faint information from 24 years of data they recorded from near the black hole.

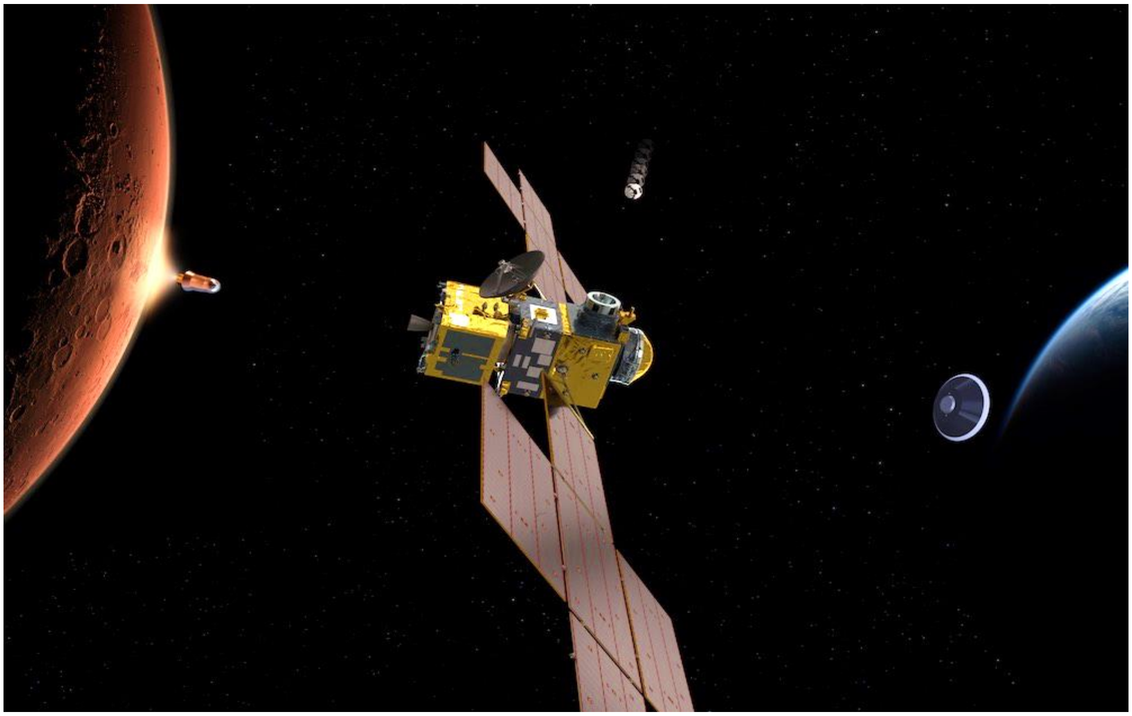
Ghez’s research team reported July 25 in the journal Science the most comprehensive test of Einstein’s iconic general theory of relativity near the black hole. Their conclusion that Einstein’s theory passed the test and is correct, at least for now, was based on their study of S0-2 as it made a complete orbit around the black hole.

Ghez’s team studies more than 3,000 stars that orbit the supermassive black hole. Since 2004, the scientists have used a powerful technology that Ghez helped pioneer, called adaptive optics, which corrects the distorting effects of the Earth’s atmosphere in real time. But speckle holography enabled the researchers to improve the data from the decade before adaptive optics came into play. Reanalyzing data from those years helped the team conclude that they had not seen that level of brightness near the black hole in 24 years.

“It was like doing LASIK surgery on our early images,” Ghez said. “We collected the data to answer one question and serendipitously unveiled other exciting scientific discoveries that we didn’t anticipate.”

Source: UCLA Return to Contents

2. NASA, ESA Officials Seek Formal Approvals for Mars Sample Return Mission



Artist's concept of a Mars sample return mission, including a U.S.-built Mars Ascent Vehicle (left), a European-built Earth Return Orbiter (center), and a NASA-provided Earth Entry Vehicle (right). Credit: ESA/ATG medialab

After crystallizing a partnership to retrieve samples from the surface of Mars and return them to Earth, NASA and European Space Agency officials are seeking government funding commitments before the end of this year to carry out a multibillion-dollar robotic mission that could depart Earth with a pair of rocket launches as soon as 2026.

The Mars sample return mission, if approved, would pick up rock and soil samples collected by NASA's Mars 2020 rover set for launch next year. The specimens would come back to Earth for detailed analysis in terrestrial laboratories, yielding results that scientists say will paint a far clearer picture of the Martian environment — today and in ancient times — than possible with one-way robotic missions.

A preliminary signal of support came earlier this year came in the White House's fiscal year 2020 budget request, which proposed $109 million for NASA to work on future Mars missions, including a sample return. That's after NASA received $50 million to study the sample return effort in 2019.

"The 2020 budget, the president's recommended budget, included Mars sample return as a recommendation that we begin working on," said Lori Glaze, director of NASA's planetary science division, in a presentation Sept. 10 to the National Academies' Committee on Astrobiology and Planetary Sciences. "We don't know the status of that through congressional funding yet because we don't have an appropriations bill yet, but we're hopeful that there will be some appropriations there so we can move out on this activity."

NASA unveiled a strategy to pursue a "lean" lower-cost Mars sample return mission in 2017, a plan Glaze said would allow scientists to get their hands on fresh samples from the Martian surface as soon as possible.

But even a lean Mars sample return mission will cost billions of dollars. When asked at the Sept. 10 meeting, Glaze said NASA's cost estimate for a Mars sample return mission is "still pretty rough at this point" and she said she was reticent to give a specific number.

"Keep in mind, we're looking at a collaborative approach, which helps," she said. "It's in the kind of $2.5 to $3 billion (range). And that number is for the U.S. side, the launch of the lander, (it) does not include the fetch rover, that's ESA-provided. On the Earth Return Orbiter, it's ESA-provided, but it carries a U.S. payload capture system and re-entry system."

Senior NASA leaders in July approved preliminary plans for the Mars sample return mission put together over the last two years, including roles for the U.S. space agency, ESA, and individual NASA centers, Glaze said. NASA and ESA signed a "statement of intent" in April 2018 to jointly work on a Mars sample return program.

"There would also be opportunities for commercial participation in various aspects, as well as additional international participation," Glaze said.

"Hopefully, by the end of the calendar year, we'll know what the congressional appropriation is for NASA, and whether or not that includes funding for Mars sample return," Glaze said. "And also, in November, ESA has their ministerial meeting coming up, where they hopefully get the permission to move out and move forward with Mars sample return on their side."

The meeting of European government ministers, set for Nov. 27-28 in Seville, Spain, will approve funding for ESA programs over the next few years. Among other space research projects, ESA will propose to government ministers a budget to kick-start development of the European elements of a Mars sample return mission.

Mars sample return missions have been studied for decades, but the concepts have never moved into full-scale development.

"Finding an affordable solution is going to be key if we are going to be able to ultimately move this forward, and not just make it another study," said Jim Watzin, director of NASA's Mars exploration program at NASA Headquarters.

Beyond any funding provided by Congress in NASA's 2020 budget, agency officials hope for a more firm commitment for Mars sample return from the Trump administration in the White House's fiscal year 2021 budget request, potentially including authority to officially kick off full-scale development.

"The president will submit his budget request for fiscal year '21, typically in the February timeframe, and that's when we would hear whether or not the administration has made the decision to support sample return, and in what timeframe from a budgetary perspective," Watzin said.

NASA officials describe the sample return effort as a "campaign" sustained over more than a decade with at least three separate launches from Earth, beginning next July with the liftoff of the Mars 2020 rover from Cape Canaveral on top of a United Launch Alliance Atlas 5 rocket.

The Mars 2020 rover will land on the Red Planet in February 2021 at Jezero Crater, the location of an ancient dried-up river delta where water and sediments flowed into a basin billions of years ago.

The sophisticated rover carries its own miniature laboratory, with instruments to study Martian geology and search for organic molecules at finer scales than achievable by any prior mission. It also carries a weather station, a ground-penetrating radar and a technology demonstration payload to convert carbon dioxide in the Martian atmosphere into oxygen, a pathfinder for human explorers to live off the land.

But a primary goal of the Mars 2020 rover will be to collect up to 43 hermetically-sealed tubes of core samples drilled from Martian rocks. Some of the tubes, each about the size of a pencil, will be retrieved by a fetch rover launched in the next phase of the Mars sample return campaign.

"The studies have prepared both agencies to make a very informed decision around the end of 2019, and from my perspective, this is huge progress," Watzin said. "I think we've got a really strong team in place, and everybody is really hopeful that we'll get the support on both the east side and the west side of the Atlantic to proceed."

Assuming formal approvals in the coming months, NASA and ESA officials say the sample retrieval mission could depart Earth with a pair of launches in 2026. Mars launch opportunities come every 26 months, but not all interplanetary windows are favorable for the departure of a round-trip mission, Watzin said.

"When you look at the round-trip aspects of going to and from Mars, propulsion demands are enormous," Watzin said in July. "The physics for launching and leaving a planet, both here on Earth and on Mars, cannot support an every 26-month opportunity like we've been used to. There are a couple of opportunities where the energetics are manageable with a reasonable budget and reasonable technology, and the rest of the opportunities require the invention of new things. And a limited cost and affordable approach means that the invention of new things had to be restricted on any approach that we took.

"So we have two opportunities that we've seriously looked at, and they span from '26 to '29 in various shapes and forms," Watzin said.

The European Space Agency will provide a fetch rover, which will arrive on Mars aboard a U.S.-built lander and then drive off the stationary platform to pick up samples collected by the NASA Mars 2020 rover. After gathering the sample tubes, the fetch rover will return the specimens to the NASA lander and transfer the materials into a mechanism to be loaded aboard a U.S.-built Mars Ascent Vehicle.

The fetch rover and Mars Ascent Vehicle will arrive on Mars aboard the same lander. The rocket will loft the payload into orbit around Mars to rendezvous with a European-made Earth Return Orbiter, the spacecraft that will return the samples to Earth. The U.S. lander and European fetch rover, including the NASA-provided Mars Ascent Vehicle, would launch on a U.S. rocket in 2026. A few months later, the Earth Return Orbiter and a U.S. re-entry vehicle would lift off on a European launcher.

If the sample return missions launch in 2026, the Mars 2020 rover itself could still be operating when they arrive at the Red Planet. That could give scientists a backup option to transfer the samples into the Mars Ascent Vehicle, in case the fetch rover encounters problems.

"Having an early opportunity for sample return allows us to use Mars 2020 as a player in this," Watzin said. "We have the operational option of holding tubes on Mars 2020 as a contingency against any snafu with the fetch rover, and we have the fetch rover picking up tubes that have been dropped as a contingency against Mars 2020."

In July, ESA released an invitation for European industry to submit proposals to build the Earth Return Orbiter. Airbus Defense and Space received a study contract from ESA last year to begin designing systems for a fetch rover, building on Airbus's experience in building the European ExoMars rover set for launch next year, named Rosalind Franklin.

NASA engineers continue evaluating solid-fueled and hybrid propulsion options, including two-stage and single-stage variants, for the Mars Ascent Vehicle.

NASA will also supply the re-entry capsule to deliver the samples back to Earth's surface. After release from the European return craft, the capsule will target landing in the Utah desert in 2031.

Engineers plan to return the samples without a parachute. Instead, the armored entry vehicle will crash into the ground at high speed.

Watzin said drop tests show the samples will still be in good condition after a high-speed landing, and the tubes flying on the Mars 2020 rover were designed with the no-chute return in mind.

NASA is concerned about the risk extraterrestrial samples might pose to humans and Earth's environment, so the entry capsule would have to be designed to withstand a parachute failure.

Designing the mission without a return parachute will also save weight on the spacecraft.

"The lowest mass entry vehicle is going to be with only those systems you absolutely have to have," Watzin said. "For those reasons, we went without (a parachute in our design). We know we have to prove it."

If approved for a launch target in 2026, the Mars sample return mission would be NASA's next flagship-class science mission after the Mars 2020 rover and the Europa Clipper probe, set for launch in 2020 and 2023, respectively.

Source: Spaceflight Now Return to Contents

3. NASA Kennedy to Develop Tech to Melt Moon Dust, Extract Oxygen

The Gaseous Lunar Oxygen from Regolith Electrolysis (GaLORE) project team won an internal award to develop a device that will melt lunar regolith and turn it into oxygen. Credits: NASA

A team at NASA's Kennedy Space Center in Florida is planning to develop a device that will melt lunar regolith — the dirt and dust on the Moon made from crushed rock — and turn it into oxygen. Advancing technologies to use space-based resources is important to sustainable lunar exploration under the agency's Artemis program, and will support future exploration into the solar system, including Mars.

The Gaseous Lunar Oxygen from Regolith Electrolysis (GaLORE) project team won an internal award to develop the melting technology. Regolith on the Moon is made from oxidized metals like iron oxide, silicon oxide and aluminum oxide. GaLORE is advancing technology to heat the regolith to more than 3,000 degrees Fahrenheit and flow electricity through the molten material. This will cause a chemical reaction that splits the regolith into gaseous oxygen and metals.

"After landing the first woman and next man on the Moon by 2024, NASA needs technologies that use lunar materials to achieve our secondary goal — sustainable human lunar exploration — to prepare us for long-duration human missions to Mars," said Kevin Grossman, a materials science expert and GaLORE project lead at Kennedy's Swamp Works. "Although the Moon has no atmosphere, oxygen exists on the Moon in the form of metal oxide powder. Extracting usable oxygen can be done with electrolysis, but technology gaps stand in the way of realizing its full potential for space applications."

The process of passing an electric current through a liquid is called electrolysis. This practice is commonly demonstrated in high school chemistry classes and used widely in various industries on Earth, but things like electrolysis react differently on another world.

There are a few challenges, Grossman noted. First, the high temperatures and presence of iron in the soil creates extremely corrosive conditions. Second, operating on the Moon requires an instrument design that can withstand extreme conditions and run autonomously.

"Our goal is to solve some of these challenges and get NASA one step closer to an automated mass production of oxygen on the Moon," said Grossman. "We could use the oxygen for astronaut life support as well as an oxidizer for fuel. We could use the metal for infrastructure and to 3D print vehicles and tools for sustaining and expanding human presence there."

Source: NASA

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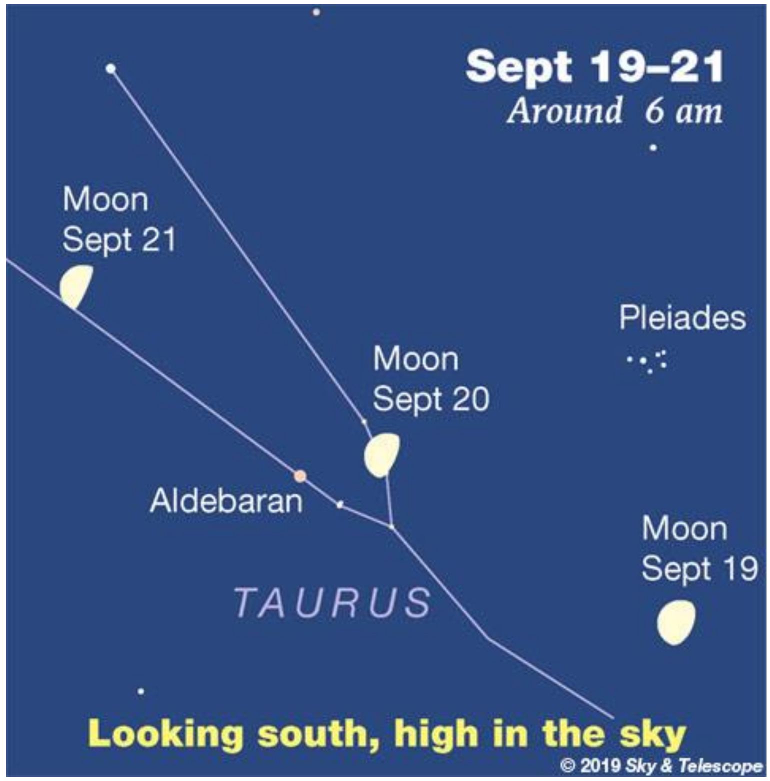
The Night Sky



The waning Moon now crosses Taurus, high in the sky as dawn begins to brighten (which is not necessarily at 6 a.m.; that depends on your location in your time zone).

Tuesday, Sept. 17

• You know the season is changing; we've reached the time of year when, just after nightfall, Cassiopeia has already climbed a little higher in the northeast than the Big Dipper has sunk in the northwest. Cas reigns high in early evening during the chilly fall-winter half of the year. The Big Dipper takes over for the milder evenings of spring and summer.

Almost midway between them stands Polaris. It's currently a little above their midpoint.

Wednesday, Sept. 18

• This is the time of year when the rich Cygnus Milky Way crosses the zenith in early evening (for skywatchers at mid-northern latitudes). The Milky Way extends straight up from the southwest horizon, passed overhead, and runs straight down to the northeast.

Thursday, Sept. 19

• In the west off to the Big Dipper's left, bright Arcturus, the "Spring Star," shines a little lower at nightfall each week. From Arcturus, the narrow kite-shaped pattern of Bootes extends 24° to the upper right.

• If you're up before dawn Friday morning, you'll find the waning gibbous Moon high with Aldebaran near it, as shown above.

Friday, Sept. 20

• These moonless evenings are a good time to bring out your binoculars and try for the unusually small, compact open cluster NGC 7160 in the rich center of Cepheus, now high in the north — as Matt Wedel tells in his Binocular Highlight, with finder chart, in the center of the September *Sky & Telescope*.

Saturday, Sept. 21

• Last-quarter Moon (exact at 10:41 p.m. Eastern Daylight Time). Tonight the Moon rises around midnight daylight-saving time, depending on your location. Watch for it to clear the east-northeast horizon lower right of Capella and lower left of the Pleiades.

By the first sign of Sunday's dawn the Moon shines high in the southeast, now with Orion to its lower right and Gemini to its lower left. How often do you examine the Moon with your telescope when the Moon is its late-night waning phases? To most of us, the waxing Moon of evening is much more familiar — when lunar mountains and crater walls cast their shadows in the opposite direction.

• Summer's not quite over yet! The September equinox this year comes at 3:50 a.m. September 23rd EDT.

Source: Sky and Telescope

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ISS Sighting Opportunities (from Denver)

Date	Visible	Max Height	Appears	Disappears
Tue Sep 17, 8:19 PM	1 min	19°	11° above S	19° above SSE
Wed Sep 18, 7:32 PM	3 min	13°	10° above SSE	10° above ESE
Wed Sep 18, 9:07 PM	2 min	27°	10° above WSW	27° above WSW
Thu Sep 19, 8:18 PM	4 min	73°	10° above SW	36° above ENE
Fri Sep 20, 7:30 PM	6 min	38°	11° above SSW	10° above ENE
Fri Sep 20, 9:09 PM	1 min	26°	20° above WNW	26° above NW

Sighting information for other cities can be found at NASA's Satellite Sighting Information

NASA-TV Highlights (all times Eastern Time Zone)

September 18, Wednesday

- 4 p.m. – Video file of the International Space Station Expedition 61-62 crew's pre-launch activities at the Baikonur Cosmodrome in Kazakhstan (Skripochka, Meir, Almansoori), which includes material recorded from Sept. 10-18 – Johnson Space Center via Baikonur, Kazakhstan (Media Channel)

Watch NASA TV online by going to the NASA website.

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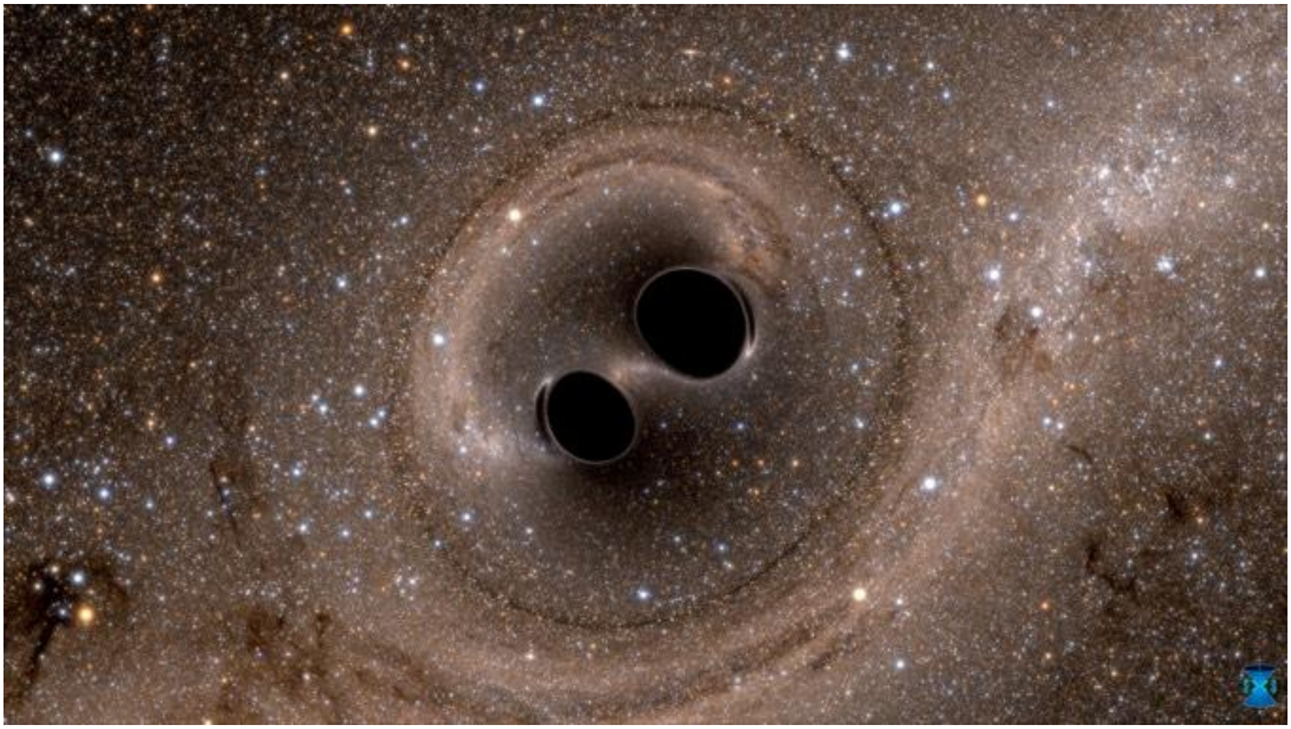
Space Calendar

- Sep 17 - AI4Copernicus Day: Artificial Intelligence & Earth Observation, Namur, Belgium
- Sep 17-20 - Next Generation VLA Workshop, Mitaka, Japan
- Sep 17-20 - Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference, Maui, Hawaii
- Sep 17-20 - The Physical Society of Japan 2019 Autumn Meeting: Elementary Particle Physics, Nuclear Physics, and Cosmic Rays/Astrophysics, Yamagata, Japan
- Sep 17-21 - Conference: The Modern Physics of Compact Stars and Relativistic Gravity 2019 (MPCS2019), Yerevan, Armenia
- Sep 18 - Asteroid 26732 Damianpeach Closest Approach To Earth (1.082 AU)
- Sep 18 - Asteroid 6312 Robheinlein Closest Approach To Earth (1.163 AU)
- Sep 18 - Asteroid 443 Photographica Closest Approach To Earth (1.299 AU)
- Sep 18 - Asteroid 8925 Boattini Closest Approach To Earth (1.343 AU)
- Sep 18 - Keck All-sky Precision Adaptive-optics (KAPA) Science Team Meeting, Los Angeles, California
- Sep 18 - Lecture: The Geological History of the Moon from the Perspective of Unopened Apollo Samples, Tucson, Arizona
- Sep 18 - Colloquium: A VLA Polarimetric Study of the Galactic Center Radio Arc, Sydney, Australia
- Sep 18-19 - 13th ESPI Autumn Conference - European Space Diplomacy, Vienna, Austria
- Sep 18-19 - Virtual Workshop: Astrovirology
- Sep 18-25 - Workshop on Quantum Geometry, Field Theory and Gravity, Corfu, Greece
- Sep 19 - Lecture: It Broke! Stories of How we Fixed It, Pasadena, California
- Sep 19 - Lecture: The Music of Stars, Newcastle upon Tyne, United Kingdom
- Sep 19 - Colloquium: The Quantum Black Hole - How Exotic Physics May Enter, Princeton, New Jersey
- Sep 19 - 2019 AMOS Dialogue in Maui, Maui, Hawaii
- Sep 19 - Colloquium: What have we learned about binary neutron stars since the discovery of GW170817?, Ithaca, New York
- Sep 19-20 - International Conference on Geomagnetic Storms and Space Weather (ICGSSW 2019), Paris, France
- Sep 19-20 - 1st Bermuda Space Sustainability Workshop, Hamilton, Bermuda
- Sep 19-20 - Keck Science Meeting 2019, Los Angeles, California
- Sep 19-21 - 7th Annual Giant Magellan Telescope (GMT) Community Science Meeting: The Cosmic Baryon Cycle - Impact on Galaxy Evolution, Carlsbad, California
- Sep 19-24 - Conference: Mapping Central Regions of Active Galactic Nuclei, Guilin, China
- Sep 20 - Amor Asteroid 2019 RP2 Near-Earth Flyby (0.022 AU)
- Sep 20 - Aten Asteroid 297418 (2000 SP43) Near-Earth Flyby (0.068 AU)
- Sep 20 - Aten Asteroid 2015 SD Near-Earth Flyby (0.081 AU)
- Sep 20 - Lecture: It Broke! Stories of How we Fixed It, Pasadena, California
- Sep 20 -Program: Utilise the Power of Space to Transform your Business on Earth, Daresbury, United Kingdom
- Sep 20-22 - Workshop on β-decay and Charge-exchange Reactions for Nuclear-astrophysics, Hong Kong

Source: JPL Space Calendar Return to Contents

Food for Thought

First 'Overtones' Heard in the Ringing of a Black Hole



A frame from a computer simulation illustrating two black holes in the process of spiraling in toward each other before merging in a gravitational "space quake." Image: SXS, the Simulating extreme Spacetimes (SXS) project

By listening for specific tones in the gravitational waves of black hole mergers, researchers are putting Albert Einstein's theories to new tests.

When two black holes collide, they merge into one bigger black hole and ring like a struck bell, sending out ripples in space and time called gravitational waves. Embedded in these gravitational waves are specific frequencies, or tones, which are akin to individual notes in a musical chord.

Now, researchers have detected two such tones for the first time in the "ringdown" of a newly formed black hole. Previously, it was assumed that only a single tone could be measured and that additional tones, called overtones, would be too faint to be detected with today's technologies.

"Before, it was as if you were trying to match the sound of a chord from a guitar using only a single string," says Matthew Giesler, a graduate student at Caltech and second author of a new study detailing the results in the September 12 issue of *Physical Review Letters*. Giesler is lead author of a related paper submitted to *Physical Review X* about the technique used to find the overtones.

The results, which were based on reanalyzing data captured by the National Science Foundation's LIGO (Laser Interferometer Gravitational-wave Observatory), have put Albert Einstein's general theory of relativity to a new kind of test. Because merging black holes experience crushing gravity, studies of these events allow researchers to test the general theory of relativity under extreme conditions. In this particular case, the researchers tested a specific prediction of general relativity: that black holes can be fully described by just their mass and rate of spin. Yet again, Einstein passed the test.

"This kind of test had been proposed long before the first detection, but everybody expected it would have to wait many years before detectors would be sensitive enough," says Saul Teukolsky (PhD '73), the Robinson Professor of

Theoretical Astrophysics at Caltech and advisor to Giesler. "This result shows that we can start carrying out the test already with today's detectors by including the overtones, an unexpected and exciting result."

LIGO made history in 2015 when it made the first-ever direct detection of gravitational waves, 100 years after Einstein first predicted them. Since then, LIGO and its European-based partner observatory, Virgo, have detected nearly 30 gravitational-wave events, which are being further analyzed. Many of these gravitational waves arose when two black holes collided, sending quivers through space.

"A new black hole forms out of a violent astrophysical process and thus is in an agitated state," says Maximiliano (Max) Isi (PhD '18), lead author of the *Physical Review Letters* study, now at MIT. "However, it quickly sheds this surplus energy in the form of gravitational waves."

As part of Giesler's graduate work, he started to investigate whether overtones could be detected in current gravitational-wave data in addition to the main signal, or tone, even though most scientists believed these overtones were too faint. He specifically looked at simulations of LIGO's first detection of gravitational waves, from a black hole merger event known as GW150914.

During the end-phase of the merger, a period of time known as the ringdown, the newly merged black hole is still shaking. Giesler found that the overtones, which are loud but short-lived, are present in an earlier phase of the ringdown than previously had been realized.

"This was a very surprising result. The conventional wisdom was that by the time the remnant black hole had settled down so that any tones could be detected, the overtones would have decayed away almost completely," says Teukolsky, who is also a professor of physics at Cornell University. "Instead, it turns out that the overtones are detectable before the main tone becomes visible."

The newfound overtones helped the researchers test the "no hair" theorem for black holes—the idea that there are no other characteristics, or "hairs," needed to define a black hole other than mass or spin. The new results confirm that the black holes do not have hairs, but scientists suspect that future tests of the theory, in which even more detailed observations are used to probe black hole mergers, may show otherwise.

"Einstein's theory could break down if there are quantum effects at play," says Giesler. "Newton's theory of gravity passes many tests where gravity is weak, but completely fails when it comes to describing gravity at its most extreme, like when it comes to trying to describe merging black holes. Similarly, as we eventually probe the signal from black holes with increasing accuracy, it is possible that even general relativity might someday fail the test."

Over the next few years, planned upgrades to LIGO and Virgo will make the observatories even more sensitive to gravitational waves, revealing additional hidden tones.

"The bigger and louder an event, the more likely LIGO can pick up these overtones," says Alan Weinstein, a professor of physics at Caltech and a member of the LIGO Laboratory, who is not associated with this study. "With LIGO's first detection of gravitational waves, we confirmed predictions made by general relativity. Now, by searching for overtones, and even fainter signals called higher-order modes, we are looking for deeper tests of the theory, and even potential evidence of the theory breaking down."

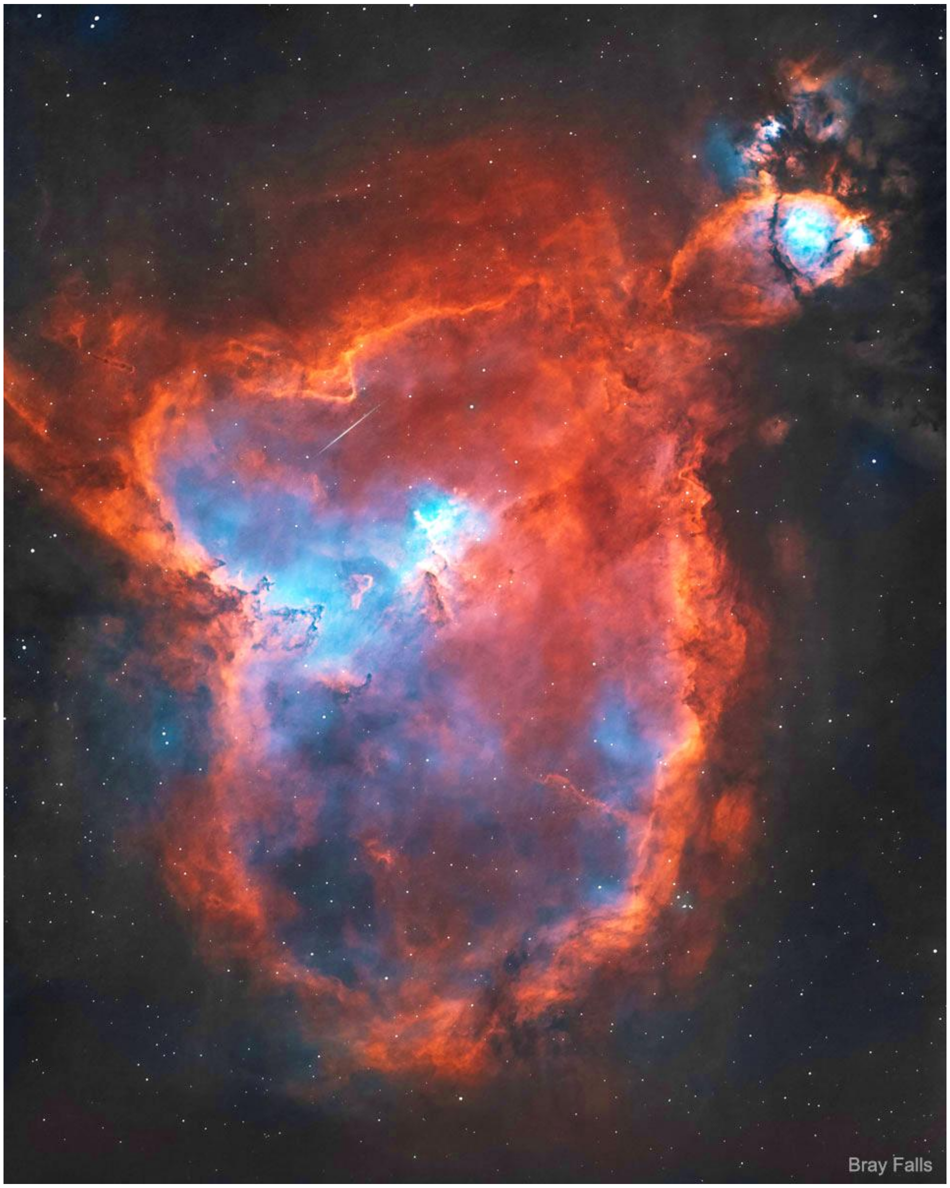
Says Isi, "Little by little, black holes will shed their mysteries, revolutionizing our understanding of gravity, space, and time."

The *Physical Review Letters* study, titled, "Testing the no-hair theorem with GW150914," was funded by NASA, LIGO, the National Science Foundation, the Simons Foundation, and the Sherman Fairchild Foundation. Other authors include Will Farr (BS '03) of the Flatiron Institute and Stony Brook University, and Mark Scheel, a research professor of physics at Caltech.

The study submitted to *Physical Review X*, titled, "Black hole ringdown: the importance of overtones," was funded by the Sherman Fairchild Foundation, NSF, LIGO, and Caltech. Other authors include Mark Scheel.

Source: California Institute of Technology Return to Contents

Space Image of the Week



IC 1805: The Heart Nebula

Image Credit & Copyright: Bray Falls

Explanation: What energizes the Heart Nebula? First, the large emission nebula dubbed IC 1805 looks, in whole, like a human heart. The nebula glows brightly in red light emitted by its most prominent element: hydrogen. The red glow and the larger shape are all powered by a small group of stars near the nebula's center. In the center of the Heart Nebula are young stars from the open star cluster Melotte 15 that are eroding away several picturesque dust pillars with their energetic light and winds. The open cluster of stars contains a few bright stars nearly 50 times the mass of our Sun, many dim stars only a fraction of the mass of our Sun, and an absent microquasar that was expelled millions of years ago.

The Heart Nebula is located about 7,500 light years away toward the constellation of Cassiopeia. Coincidentally, a small meteor was captured in the foreground during imaging and is visible above the dust pillars. At the top right is the companion Fishhead Nebula.

Source: NASA APOD Return to Contents