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Citizen Scientists Discover Five-Planet System

LORI DAJOSE

Caltech Strategic Communications

This article is adapted from a story that was originally published online at [caltech.edu](#).

Caltech staff scientist Jessie Christiansen is a founder of a citizen-scientist project called Exoplanet Explorers.

In its search for exoplanets—planets outside of our solar system—NASA's Kepler telescope trails behind Earth, measuring the brightness of stars that may potentially host planets. The instrument identifies potential planets around other stars by looking for dips in the brightness of the stars that occur when planets cross in front of, or transit, them. Typically, computer programs flag the stars with these brightness dips, then astronomers look at each one and decide whether or not they truly could host a planet candidate.

Over the three years of the K2 mission, 287,309 stars have been observed, and tens of thousands more roll in every few months. So how do astronomers sift through all that data?

Enter the Exoplanet Explorers citizen scientist project, developed by UC Santa Cruz astronomer Ian Crossfield and Caltech staff scientist Jessie Christiansen. Exoplanet Explorers is hosted on Zooniverse, an online platform for crowdsourcing research.

"People anywhere can log on and learn what real signals from exoplanets look like, and then look through actual data collected from the Kepler telescope to vote on whether or not to classify a given signal as a transit, or just noise," says Christiansen. "We have each potential transit signal looked at by a minimum of 10 people, and each needs a minimum of 90 percent

of 'yes' votes to be considered for further characterization."

In early April, just two weeks after the initial prototype of Exoplanet Explorers was set up on Zooniverse, it was featured in a three-day event on the ABC Australia television series Stargazing Live. In the first 48 hours after the project was introduced, Exoplanet Explorers received over 2 million classifications from more than 10,000 users. Included in that search was a brand-new dataset from the K2 mission—the reincarnation of the primary Kepler mission, ended three years ago. K2 has a whole new field of view and crop of stars around which to search for planets. No professional astronomer had yet looked through this dataset, called C12.

Back in California, Crossfield and Christiansen joined NASA astronomer Geert Barentsen, who was in Australia, in examining results as they came in. Using the depth of the transit curve and the periodicity with which it appears, they made estimates for how large the potential planet is and how close it orbits to its star. On the second night of the show, the researchers discussed the demographics of the planet candidates found so far—44 Jupiter-sized planets, 72 Neptune-sized, 44 Earth-sized, and 53 so-called Super Earth's, which are larger than Earth but smaller than Neptune.

"We wanted to find a new classification that would be exciting to announce on the final night, so we were originally combing through the planet candidates to find a planet in the habitable zone—the region around a star where liquid water could exist," says Christiansen. "But those can take a while to validate, to make sure that it really is a real planet and not a false alarm. So, we decided to look

for a multi-planet system because it's very hard to get an accidental false signal of several planets."

After this decision, Barentsen left to get a cup of tea. By the time he returned, Christiansen had sorted the crowdsourced data to find a star with multiple transits and discovered a star with four planets orbiting it. Three of the four planets had 100 percent "yes" votes from over 10 people, and the remaining one had 92 percent "yes" votes. This is the first multi-planet system of exoplanets discovered entirely by crowdsourcing.

After the discovery was announced on Stargazing Live, Christiansen and her colleagues continued to study and characterize the system, dubbed K2-138. They statistically validated the set of planet signals as being "extremely likely," according to Christiansen, to be signals from true planets. They also found that the planets are orbiting in an interesting mathematical relationship called a resonance, in which each planet takes almost exactly 50 percent longer to orbit the star than the next planet further in. The researchers also found a fifth planet on the same chain of resonances, and hints of a sixth planet as well. A paper describing the system has been accepted for publication in *The Astronomical Journal*.

This is the only system with a chain of unbroken resonances in this configuration, and may provide clues to theorists looking to unlock the mysteries of planet formation and migration.

"The clockwork-like orbital architecture of this planetary system is keenly reminiscent of the Galilean satellites of Jupiter," says Konstantin Batygin, assistant professor of planetary science and Van Nuys Page Scholar, who

was not involved with the study. "Orbital commensurabilities among planets are fundamentally fragile, so the present-day configuration of the K2-138 planets

Caltech postdoctoral scholar Erik Petigura; Joshua Schlieder of NASA Goddard; Courtney Dressing of UC Berkeley; Andrew Vanderburg of Harvard; Sarah



Artist's visualization of the K2-138 system, the first multi-planet system discovered by citizen scientists. The central star is slightly smaller and cooler than our sun. The five known planets are all between the size of Earth and Neptune; planet b may potentially be rocky, but planets c, d, e, and f likely contain large amounts of ice and gas. All five planets have orbital periods shorter than 13 days and are all incredibly hot, ranging from 800 to 1800 degrees Fahrenheit.

Image courtesy of NASA/JPL-Caltech/R. Hurt (IPAC)

clearly points to a rather gentle and laminar formation environment of these distant worlds."

"Some current theories suggest that planets form by a chaotic scattering of rock and gas and other material in the early stages of the planetary system's life. However, these theories are unlikely to result in such a closely packed, orderly system as K2-138," says Christiansen. "What's exciting is that we found this unusual system with the help of the general public."

The paper is titled "The K2-138 system: A Near-Resonant Chain of Five Sub-Neptune Planets Discovered by Citizen Scientists." In addition to Christiansen, Crossfield, and Barentsen; other coauthors include Chris Lintott, Campbell Allen, Adam McMaster, Grant Miller, Martin Veldthuis of the University of Oxford; Thomas Barclay of NASA Goddard and the University of Maryland; Brooke Simmons of UC San Diego;

Allen and Zach Wolfenbarger of the Adler Planetarium; Brian Cox of the University of Manchester; Julia Zemiro of the Australian Broadcasting Corporation; Caltech Professor of Astronomy Andrew Howard; John Livingston of the University of Tokyo; Evan Sinukoff of the Australian Broadcasting Corporation and the University of Hawai'i at Manoa; Timothy Catron of Arizona State University; Andrew Grey, Joshua Kusch, Ivan Terentev, and Martin Vales of Zooniverse as part of the University of Oxford; and Martti Kristiansen of the Technical University of Denmark. Funding was provided by the NASA Science Mission Directorate, Google, the Alfred P. Sloan Foundation, NASA, the National Science Foundation, the U.S. Department of Energy, the Japanese Monbukagakusho, the Max Planck Society, and the Higher Education Funding Council for England.

Modeling the Effects of Wastewater Injection

ROBERT PERKINS

Caltech Strategic Communications

This article is adapted from a story that was originally published online at [caltech.edu](#).

Earth scientists develop a model to estimate the largest possible quake in a given location that could be caused by the disposal of water used in hydraulic fracturing.

Hydraulic fracturing, or "fracking," is a petroleum-extraction procedure in which millions of gallons of water (as well as sand and chemicals) are injected deep into underground shale beds to crack the rock and release natural gas and oil. According to the United States Geological Survey, fracking itself does not typically trigger earthquakes. Instead, the increased risk for seismicity is more strongly linked with the subsequent injection of the wastewater from fracking and other oil-extraction processes into massive disposal wells that are thousands of feet underground.

Previous attempts to model the relationship between injection of wastewater and the triggering of earthquakes suggested that the maximum magnitude of the seismic activity induced in this way would be proportional to the volume of the fluids injected. However, this interpretation fails to account for the fact that earthquakes can grow beyond the area impacted by fluid pressure, says Jean Paul Ampuero, professor of seismology at Caltech

and co-author of a new study on the topic that appears in the journal *Science Advances* on December 20.

Combining theory and computer simulations of dynamic earthquake ruptures, Ampuero and his colleagues developed a model that explains how the size of injection-induced earthquakes depends on not only the volume of fluid being injected but also the energy stored

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THE CALIFORNIA TECH

Caltech Y Column

CALTECH Y

The Caltech Y Column serves to inform students of upcoming events and volunteer opportunities. The list is compiled by Katherine Guo from information given by the Caltech Y and its student leaders.

Founded by students in 1916, the Y was organized to provide extracurricular activities planned and implemented by students as an opportunity to learn leadership skills and discover themselves. The mission of today's Y remains the same—to provide opportunities that will prepare students to become engaged, responsible citizens of the world. The Y seeks to broaden students' worldviews, raise social, ethical, and cultural awareness through teamwork, community engagement, activism, and leadership. More information about the Caltech Y and its programs can be found at <https://caltechy.org>. The office is located at 505 S. Wilson Avenue.

Upcoming Events

Costa Rica Alternative Spring Break Trip

Saturday, March 17th through Sunday, March 25th (9 days) | Cost: \$950

Applications Due: by Noon on November, 22nd

The Caltech Y is excited to seek applicants for our 2017 Alternative Spring Break trip to Costa Rica. Join other Caltech students for a conservation focused spring break trip this year. On the Costa Rica trip we will be working with a host organization OSA Conservation www.osaconservation.org – which is dedicated to protecting the globally significant biodiversity of Costa Rica's Osa Peninsula. Don't miss out on this fantastic opportunity to explore another part of our planet and make a tangible difference in the world.

Trips fees include transportation, lodging, and most food. The Costa Rica Alternative Spring Break trip is coordinated by the Caltech Y and has been made possible thanks to generous funding from the Frank and Elsie Stefanko Fund, the George Housner Fund, Caltech Student Affairs, and the Caltech Y. Spaces are limited.

Visit http://caltechy.org/programs_services/areas/asb/ for applications and more information.

The Caltech Y Social Activism Speaker Series presents:

Solving Climate Change: From Policy to Personal

Thursday | November 30th | 4:00 to 6:00 PM | Location: TBD

The Caltech Y Social Activism Speaker Series is hosting a panel with members of the Citizens' Climate Lobby, a non-partisan volunteer organization dedicated to national policy to address climate change.

Climate change is one of the most pressing issues facing humanity. While the impacts of emissions up to now will be felt potentially for decades, significant policy changes are required in the immediate future to address greenhouse gas emissions and reverse the warming

trend in the long term. Passing legislation to deal with this pressing issue however, remains a problem. CCL campaigns for the passage of a Carbon Fee and Dividend bill designed to tax carbon emissions and return carbon dioxide to its pre-1990s levels. This discussion will feature a panel of CCL members from a variety of backgrounds each of whom will bring their perspective to this issue. Each panel member will talk about their views and then take questions from the audience.

Presentations are intended to introduce one perspective in order to stimulate thought and to provide a forum for respectful dialogue and examination. The views expressed by speakers are solely those of the speakers. Presentations do not necessarily reflect the opinion of the California Institute of Technology or the Caltech Y and should not be taken as an endorsement of the ideas, speakers or groups.

Decompression 2.0

Friday | December 1st | 3:00 to 5:00 PM | Center for Student Services

We made the move... Decompression is now an end of the week stress reliever with activities, snacks and entertainment. Don't go into finals week stressed out. Join us at the end of class week for a little break before studying. A variety of drinks and snacks, entertainment and activities will be provided.

Caltech Y Explore LA Series The Broad Museum

Sunday | December 3rd | 2:30 PM | Cost: \$5 | Transportation Included

Sign-up starting Thursday, 11/16 at the Caltech Y

Join us on a visit to The Broad with the Caltech Y! The Broad is a contemporary art museum founded by philanthropists Eli and Edythe Broad. Designed by Diller Scofidio + Renfro in collaboration with Gensler, the museum is home to 2,000 works of art from the Broad collection, which is among the most prominent holdings of postwar and contemporary art worldwide, and presents an active program of rotating temporary exhibitions and innovative audience engagement. The 120,000-square-foot building features two floors of gallery space and is the headquarters of The Broad Art Foundation's worldwide lending library, which has actively loaned collection works to museums around the world since 1984. With in-depth representations of influential contemporary artists like Jean-Michel Basquiat, Barbara Kruger, Cy Twombly, Ed Ruscha, Kara Walker, Christopher Wool, Jeff Koons, Joseph Beuys, Jasper Johns, Cindy Sherman, Robert Rauschenberg, and more, plus an ever-growing representation of younger artists, The Broad enriches, provokes, inspires, and fosters appreciation of art of our time. This offer is for students only; however, students purchasing tickets are permitted to purchase tickets for up to one guest each – and that guest can be a non-student. Explore LA is coordinated by the Caltech Y. The Caltech Y is located in the Tyson House 505 South Wilson (Bldg. 128).

The Caltech Y Social Activism Speaker Series is hosting a panel with members of the Citizens' Climate Lobby, a non-partisan volunteer organization dedicated to national policy to address climate change.

Climate change is one of the most pressing issues facing humanity. While the impacts of emissions up to now will be felt potentially for decades, significant policy changes are required in the immediate future to address greenhouse gas emissions and reverse the warming

Caltechlive!

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SATURDAY, JANUARY 27, 2018 • 4 PM

Beckman Auditorium • \$10 (general admission)
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Life: Challenges of Life

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Discussion Leader: **Christopher Spalding**

Caltech Geological & Planetary Sciences Ph.D. Student

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Mentors for L.I.F.E

Volunteer times: 2:45 - 5:00 PM at various locations in Pasadena

Stressed out by school? Step outside the Caltech bubble and mentor tweens who've yet to even consider college. Things you could do: Build a baking soda and vinegar volcano, read a book aloud, play sports or board games, teach the alphabet of another language, do a craft. Having a mentor makes an at-risk student 55% more likely to attend college, 78% more likely to volunteer regularly, and 130% more likely to hold a leadership position. Interested? If you have 180 seconds, you can watch this video and be inspired. If you have an hour a week, you can mentor someone and be their inspiration. If you feel unqualified, don't worry. Ultimately, mentoring is about being a consistent, dependable friend—not a surrogate parent or psychiatrist.

To get started, contact noelle@caltech.edu.

Hathaway Sycamores

Every Monday | 5:45 - 8:00 PM | Highland Park

Volunteer at Hathaway Sycamores, a group that supports local underprivileged but motivated high school students. There are a variety of ages and subjects being tutored. The service trip includes about 40 minutes of travel time and 1.5 hours of tutoring. Transportation is included.

For more info and to RSVP email Elisabeth at egallmei@caltech.edu. Eligible for Federal Work Study.

Scientists Design Bacteria to Reflect “Sonar” Signals for Ultrasound Imaging

WHITNEY CLAVIN

Caltech Strategic Communications

This article is adapted from a story that was originally published online at caltech.edu.

New technology may one day allow doctors to image therapeutic bacterial cells in patients.

In the 1966 science fiction film *Fantastic Voyage*, a submarine is shrunk down and injected into a scientist's body to repair a blood clot in his brain. While the movie may be still be fiction, researchers at Caltech are making strides in this direction: they have, for the first time, created bacterial cells with the ability to reflect sound waves from inside bodies, reminiscent of how submarines reflect sonar to reveal their locations.

The ultimate goal is to be able to inject therapeutic bacteria into a patient's body—for example, as probiotics to help treat diseases of the gut or as targeted tumor treatments—and then use ultrasound machines to hit the engineered bacteria with sound waves to generate images that reveal the locations of the microbes. The pictures would let doctors know if the treatments made it to the right place in the body and were working properly.

“We are engineering the bacterial cells so they can bounce sound waves back to us and let us know their location the way a ship or submarine scatters sonar when another ship is looking for it,” says Mikhail Shapiro, assistant professor of chemical engineering, Schlumberger Scholar, and Heritage Medical Research Institute Investigator. “We want to be able

to ask the bacteria, ‘Where are you and how are you doing?’ The first step is to learn to visualize and locate the cells, and the next step is to communicate with them.”

The results will be published in the January 4 issue of the journal *Nature*. The lead author is Raymond Bourdeau, a former postdoctoral scholar in Shapiro's lab.

The idea of using bacteria as medicine is not new. Probiotics have been developed to treat conditions of the gut, such as irritable bowel disease, and some early studies have shown that bacteria can be used to target and destroy cancer cells. But visualizing these bacterial cells as well as communicating with them—both to gather intel on what's happening in the body and give the bacteria instructions about what to do next—is not yet possible. Imaging techniques that rely on light—such as taking pictures of cells tagged with a “reporter gene” that codes for green fluorescent protein—only work in tissue samples removed from the body. This is because light cannot penetrate into deeper tissues like the gut, where the bacterial cells would reside.

Shapiro wants to solve this problem with ultrasound techniques because sound waves can travel deeper into bodies. He says he had a eureka moment about six years ago when he learned about gas-filled protein structures in water-dwelling bacteria that help regulate the organisms' buoyancy. Shapiro hypothesized that these structures, called gas vesicles, could bounce back sound waves in ways that make them distinguishable from other types of cells. Indeed, Shapiro and his colleagues

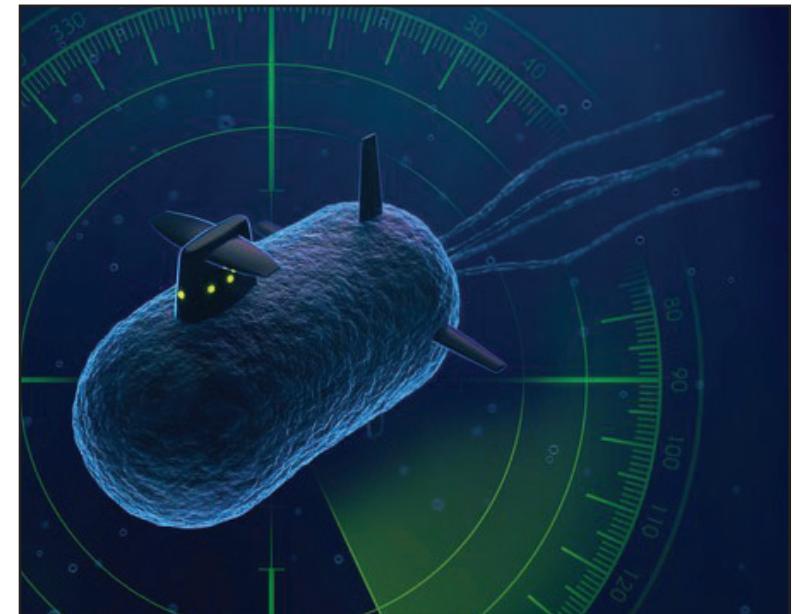
demonstrated that the gas vesicles can be imaged with ultrasound in the guts and other tissues of mice.

The team's next goal was to transfer the genes for making gas vesicles from the water-dwelling bacteria into a different type of bacteria—*Escherichia coli*, which is commonly used in microbial therapeutics, such as probiotics.

“We wanted to teach the *E. coli* bacteria to make the gas vesicles themselves,” says Shapiro. “I've been wanting to do this ever since we realized the potential of gas vesicles, but we hit some roadblocks along the way. When we finally got the system to work, we were ecstatic.”

One of the challenges the team hit involved the transfer of the genetic machinery for gas vesicles into *E. coli*. They first tried to transfer gas-vesicle genes isolated from a water-dwelling bacterium called *Anabaena flos-aquae*, but this didn't work—the *E. coli* failed to make the vesicles. They tried again using gas-vesicle genes from a closer relative of *E. coli*, a bacterium called *Bacillus megaterium*. This didn't succeed either, because the resulting gas vesicles were too small to efficiently scatter sound waves. Finally, the team tried a mix of genes from both species—and it worked. The *E. coli* made gas vesicles on their own.

The gas vesicle genes code for proteins that act like either bricks or cranes in building the final vesicle structure—some of the proteins are the building blocks of the vesicles while some help in actually assembling the structures. “Essentially, we figured out that we need the bricks from *Anabaena flos-aquae* and the cranes from



Artwork of a bacterial cell made to look like a submarine. In the same way that submarines reflect sonar and reveal their location, bacteria have been engineered to reflect sound waves and reveal their location in the body.

Image courtesy of Barth van Rossum for Caltech

Bacillus megaterium in order for the *E. coli* to be able to make gas vesicles,” says Bourdeau.

Subsequent experiments from the team demonstrated that the engineered *E. coli* could indeed be imaged and located within the guts of mice using ultrasound.

“This is the first acoustic reporter gene for use in ultrasound imaging,” says Shapiro. “We hope it will ultimately do for ultrasound what green fluorescent protein has done for light-based imaging techniques, which is to really revolutionize the imaging of cells in ways there were not possible before.”

The researchers say the technology should be available soon to scientists who do research in animals, although it will take

many more years to develop the method for use in humans.

The *Nature* study, titled “Acoustic reporter genes for noninvasive imaging of microbes in mammalian hosts,” was funded by the National Institutes of Health, the Canadian Institute of Health Research, the Burroughs Wellcome Fund, the Packard Fellowship, the Pew Scholarship, the Heritage Medical Research Institute, the National Science Foundation, and the Natural Sciences and Engineering Research Council of Canada. Other Caltech authors include research technician Audrey Lee Gosselin, graduate students Anupama Lakshmanan, Arash Farhadi, Sripriya Ravindra Kumar, and former undergraduate student Suchita Nety (BS '17).

Scientists Design Model to Measure Quakes Caused By Fracking

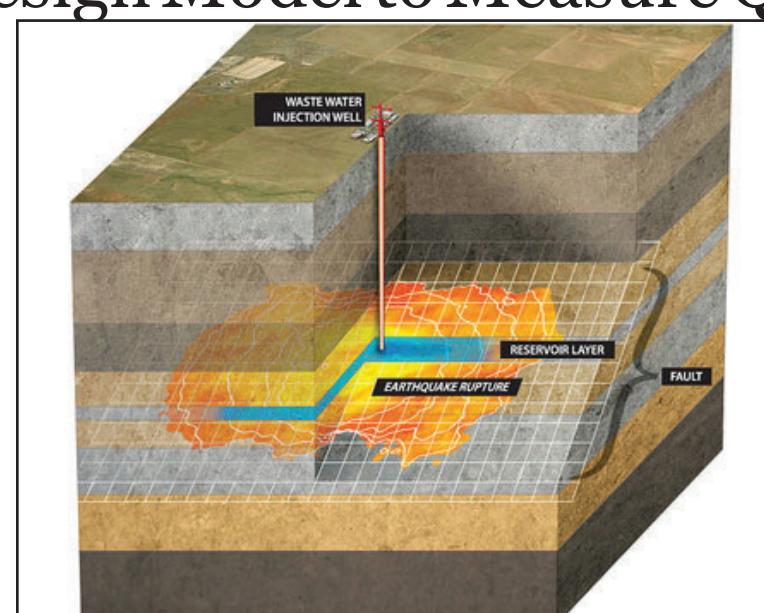
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on nearby faults. The result is a model that quantifies the distance that an earthquake can propagate beyond an injection site—which in turn predicts the maximum magnitude of an induced seismic event.

“Earthquakes induced by human activities involving underground injection of fluids or gas are a growing concern, a hazard that needs to be controlled in order to develop a safer and cleaner energy future,” Ampuero says.

This induced seismicity has been the subject of significant research in recent years and is also attracting researchers who, like Ampuero, are primarily interested in unraveling the physics of natural earthquakes. “This may be the closest researchers will ever get to a large-scale controlled earthquake experiment,” Ampuero says. For the new work, Ampuero teamed up with Martin Galis, postdoctoral researcher at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia.

It is important to note that the new model only predicts the



Wastewater injected in an underground reservoir layer crossed by a fault triggers an earthquake. The earthquake rupture grows larger than the zone pressurized by water injection.

Image courtesy of Galis et al., and Thomas Willard/Caltech Graphic Resources

maximum possible magnitude of an earthquake rather than what the earthquake magnitude will actually be, the researchers say. It defines upper limits based on the amount of pent-up energy in the earth's crust prior to fluid injection.

The new model offers insight into natural earthquakes, creating a framework for understanding what causes earthquakes to stop shaking. Earthquakes can be triggered by the pressure and disturbance caused

by fluid injection, but they may grow beyond the zone immediately impacted by the wastewater injection by tapping into tectonic energy that is already stored nearby. As is the case for induced seismicity, natural earthquakes can start in small areas of the earth's crust where that energy is concentrated. How large they grow is determined by the amount of energy in surrounding regions.

The paper is titled “Induced seismicity provides insight into why earthquake ruptures stop.” Ampuero and Galis's co-authors include Paul Martin Mai of KAUST and Frédéric Cappa of the Université Côte d'Azur in Nice and Institut Universitaire de France in Paris. Funding came from the National Science Foundation, KAUST, and the Agence Nationale de la Recherche in France.

This is the second study this month from Ampuero that offers new insight into earthquake science. On December 1, Ampuero and colleagues from Centre national de la recherche scientifique in Paris found that it is possible to observe disturbances in the earth's gravitational field almost instantly after an earthquake, raising the potential for the use of these disturbances as part of an early-warning system. (These disturbances travel at the speed of light, while the fastest seismic waves of an earthquake propagate at several kilometers per second, which means that monitoring the disturbances could potentially improve existing early-warning systems by seconds or even minutes.)

Ampuero and his colleagues found that seismometers in China and South Korea picked up perturbations in the earth's gravitational field during the 9.1 Tohoku earthquake in Japan in 2011 via signals that appeared as tiny accelerations on seismometers more than a minute before the ground beneath the seismometers started to shake.

DON'T PUT IT OFF!

Coping with procrastination

A free workshop for all Caltech students

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And again on Friday, January 12th @ 12:00

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SPORTS

THE CALIFORNIA TECH

JANUARY 16, 2018

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Kawashima jump starts bench at Chapman

GOCALTECH.COM

Actual Sports Content Editor

ORANGE, Calif. (Jan. 8, 2017) – Senior wing David Kawashima came off the bench to lead the Caltech men's basketball team in scoring at Chapman University (4-1 SCIAC) on Monday evening in a game where all 10 Beavers scored baskets.

Kawashima led the Beavers with an evenly distributed 12 points in 20 minutes to provide his team with a spark off the bench. He shot an efficient 6-for-7 and played a key role in the Beavers shooting nearly 50-percent from the field (49.1 percent). Sophomore guard Alec Andrews, additionally put together another respectable all-around line out of the starting point guard spot. He scored 11 points and added a team-high six rebounds and five assists in 32 minutes of action. He also converted on both of his free throws

in a game where the Beavers got to the free throw line more than in their last two games combined. They also shot 70 percent as a team, 10 percent above the season average.

The Beavers put 45 points on the host Panthers in the second half for their most significant scoring half of the season. Outscoring Chapman by one point in the final 20 minutes after a first half where the home team led by 15 ultimately resulted in defeat, but the second-half numbers cannot be ignored. Caltech got to the free throw line 16 times and sophomore forward Ross Carter stuck out with seven points, converting on both of his field goal attempts and both of his free throw attempts. Both teams spent the majority of the half jockeying for position, and thus neither team managed to gain a significant upperhand on the other, in spite of the varied scoring.



This looks like a Nike ad - ahhh and the swoosh is so perfectly positioned for it too!

-gocaltech.com

Schneider bounces back at Oxy



I didn't know you could parkour off of another human. Look at that air!

-gocaltech.com

GOCALTECH.COM
Actual Sports Content Editor

EAGLE ROCK, Calif. (Jan. 10, 2017) – Freshman forward Spencer Schneider came through with another plus-50 percent shooting game as the Caltech men's basketball team pushed first-place host Occidental College on Wednesday evening.

Schneider dumped in a team-best 17 points on 6-of-11 shooting and contributed seven rebounds, four assists and two blocks. The freshman got better as the game wore on, as 11 of his points came in the second half. Sophomore guard Alec Andrews keyed the Beavers' first half effort with 10 of his 12 points to keep the Beavers just three points behind their SCIAC adversaries heading

into the second half. Senior wing David Kawashima, like Andrews scored 12 points but scored seven of them in the second half.

The second half featured a fast start for the home team, but the Beavers caught up quickly, nearly erasing a 13-point deficit with a 13-2 run in the game's final 10 minutes. Caltech held Oxy without a field goal from the nine-minute mark on and strung together 10 consecutive defensive stops to keep the hosts in check. By game's end, the Beavers had nearly pulled even with the Tigers in shooting percentage and outshot the hosts from beyond the arc by 12 percent. The visitors eventually closed the gap to just two points, and though they were unable to finish the win it illustrates a marked improvement from the two teams' initial meeting back in November.

Haleftiras huge from deep in Oxy duel

GOCALTECH.COM

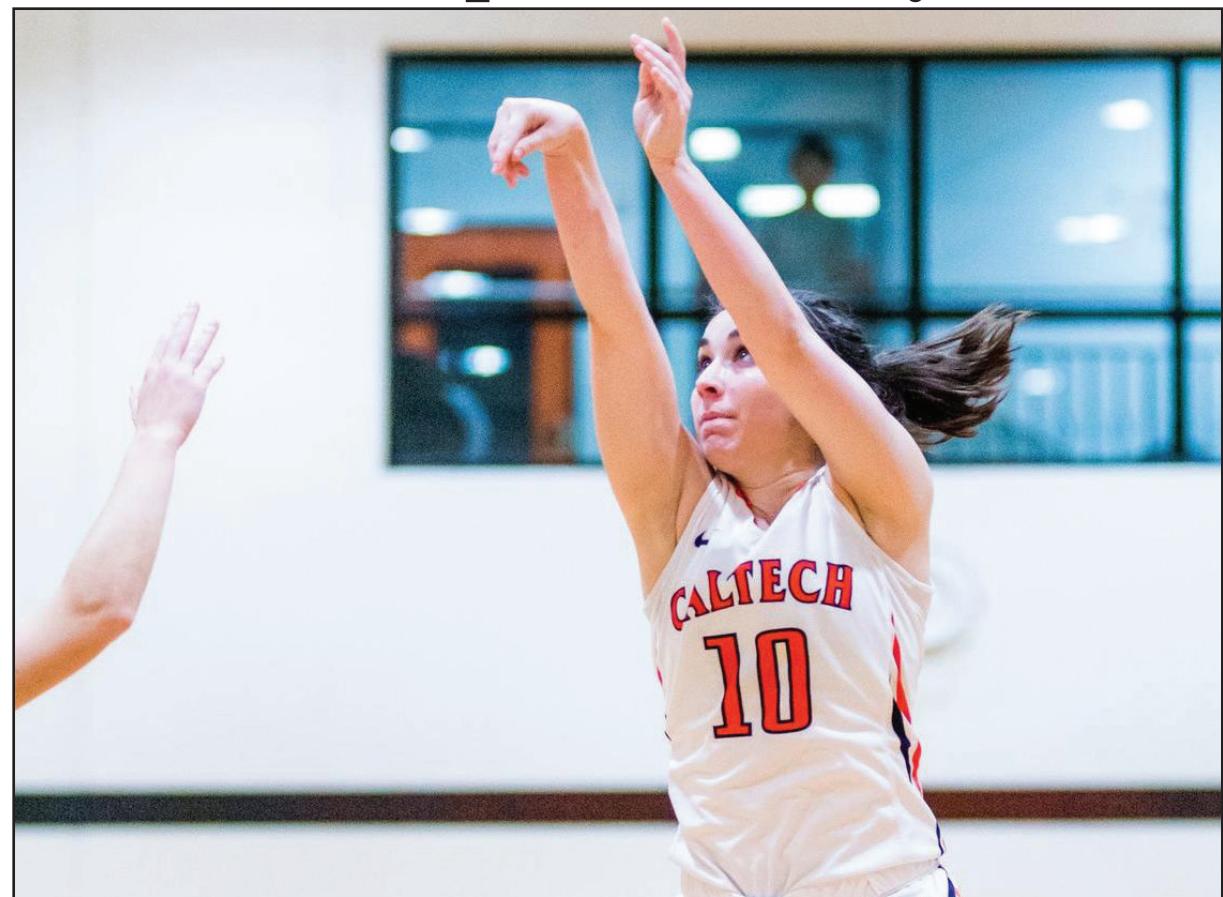
Actual Sports Content Editor

PASADENA (Jan. 11, 2017) – Junior guard Nika Haleftiras shot 50-percent from the three-point line and helped put the Caltech women's basketball team in a position to win against visiting Occidental College on Wednesday evening.

Haleftiras came up big with a 4-for-8 night from three, en route to 16 points and three rebounds in 37 minutes of action. Two of the junior's three's came in the third quarter and had an essential part in digging the Beavers out of a 10-point hole. Her second three-pointer of the quarter cut the Tigers' lead to just one point and set her team up to potentially steal the game in the fourth quarter. Her final three-pointer of the game helped silence a brief Oxy run and give Caltech the confidence to challenge for the win in the game's final two minutes, marking the third consecutive game in which the team has done so. The lead changed just once (after the Beavers jumped out to a 4-0 lead in the first quarter) but the Tigers led by as many as 16 points early in the second quarter, which the Beavers cut to as little as one point thanks to Haleftiras and company.

While the Tigers ultimately held off the Beavers, the hosts managed to outrebound

the significantly larger visiting team and outshot them by a slim margin. Sophomore guard Samantha D'Costa played a role in these numbers, scoring 23 points to go along with 12 rebounds for her fifth double-double of the season. She also came away with two steals and two blocks to make up another impressive all-around performance. Junior center Elizabeth Eiden also came down with 12 rebounds and blocked three shots, furthering her status as the conference's leading shot blocker. Like the aforementioned Haleftiras, sophomore guard Grace Peng also scored 16 points and led her team with four assists.



GUUUURRRLLL this is a beautiful photo. You should be a hand model - look at that flick of the wrist. 10/10.

-gocaltech.com

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THE CALIFORNIA TECH

ANNOUNCEMENT:

VICE PROVOST, CHIEF DIVERSITY OFFICER, AND PROFESSOR OF ENGLISH CINDY WEINSTEIN HOLDS REGULAR OFFICE HOURS AS AN OPPORTUNITY FOR UNDERGRADUATE STUDENTS, GRADUATE STUDENTS, AND POSTDOCS TO MEET FOR DISCUSSIONS PERTAINING TO THE COUNCIL ON UNDERGRADUATE EDUCATION; CALTECH ACCREDITATION; THE STAFF AND FACULTY CONSULTATION CENTER; STUDENT-FACULTY PROGRAMS; THE CENTER FOR TEACHING, LEARNING, AND OUTREACH; THE CALTECH DIVERSITY CENTER; AND THE CALTECH LIBRARIES.

THERE ARE FOUR 15-MINUTE APPOINTMENTS AVAILABLE PER OFFICE HOUR. SIGN UP AT THE OFFICE OF THE VICE PROVOST IN PARSONS-GATES ROOM 104, BY PHONE AT 626-395-6339, OR BY EMAIL TO DLEWIS@CALTECH.EDU. WE LOOK FORWARD TO HEARING FROM YOU!

STUDENT OFFICE HOURS FOR WINTER TERM 2018:

1/17/18 WEDNESDAY 11:00 A.M.-12:00 P.M.
 1/23/18 TUESDAY 9:00 A.M.-10:00 A.M.
 2/15/18 THURSDAY 9:00-10:00 A.M.
 2/21/18 WEDNESDAY 11:00 A.M.-12:00 P.M.
 2/27/18 TUESDAY 10:00-11:00 A.M.
 3/8/18 THURSDAY 11:00 A.M.-12:00 P.M.
 3/12/18 MONDAY 10:00-11:00 A.M.
 3/19/18 MONDAY 10:00 A.M.-11:00 A.M.

ARC Minutes 1.14.2018

Present: Kavya Sreedhar, Amrita Rhoads, Michael Yao, Ryan Han, Allison Tang, Vaishnavi Shrivastava, Vibha Vijayakumar, Matthew Zeitlin, Alejandro Lopez, Erika Salzman

Minutes submitted by: Allison Tang and Shreya Ramachandran

1. Programming

- a. Student Faculty Lunches (SFLs): 2 SFLs per term, more students
- b. Course Compliments: combine with Take a Prof Out to Lunch, more often
- c. Software Seminars: Mathematica, 1/24 or 1/31, Wednesday 4pm
- d. Research List: met with Candace from SFP, list released after SURF deadline
- e. UG+Grad Student Research Seminars: talk to GSC Academics Chair, send out signup form; ~10min talks, 1 talk per term
- f. Course Concerns: Donut adding more functionalities to feedback form
- g. Ombuds Training: Thursday 1/18

2. Projects

- a. Continued TQFR Revamp discussion

3. Miscellaneous

- a. PS12 vs. PS141b: PS141b won in the survey
- b. New term: new projects or ideas always welcome. Elections coming up

ARC Tip of the Week: Deans' Tutors are available to help with you courses!

The ARC website at arc.caltech.edu has more information about what the ARC does if you are interested. We meet every Sunday at 11am in SAC13 and our meetings are open to everyone! If you have any questions, please feel free to email ksreedha@caltech.edu.

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CROSSWORD

ASCIT Minutes

Meetings are every week in SAC 13

ASCIT Board of Directors Meeting

Minutes for January 12, 2017. Taken by Dana He.

Officers Present: Sakthi Vetrivel, Kavya Sreedhar, Rachael Morton, Alice Zhai, Dana He

Guests: Ann Chou, Chen Chang, Chris Dosen, Sean Yu

Call to Order: 4:06 pm

President's Report (Sakthi):

- Went to Faculty Board Meeting to talk about Caltech Campaign.
- Prefrosh Yield Committee had their first meeting.
- Midnight Donuts will be on February 12th.
- Would like to renovate ASCIT screening room.

Officer's Reports:

V.P. of Academic Affairs (Kavya):

- Working on tracking ARC expenses for this year. Has used 32% of the budget this year. Tom Mannion is now funding Student-Faculty lunches.
- ARC minutes are now in the Tech and a link will be sent out to join the mailing list.
- CS 21 is being recorded for course capture.
- Planning a software seminar for the next few weeks.
- Creating research list for professors looking for student researchers during the school year.
- Looking into having undergraduate and graduate students present about their own research to help other students also looking into get into research.
- CS department is looking to hire new lecturer.
- Math boot camp course has about 50 people and is going well.

V.P. of Non-Academic Affairs (Rachael):

- Sending out frosh rotation survey to see how frosh feel about rotation.
- Bechtel meetings are happening weekly with COUCH, staff and faculty groups. Decision to come out in February. Will need to discuss house leadership structure (6 PAs). Will need metrics to measure success.

Director of Operations (Sara):

- Not in attendance.

Treasurer (Sarah):

- Most refunds have been returned or are going through Judy. We are able to refund in cash (under \$100) like normal again.

- Puzzle Hunt Club requesting \$500-1000 for puzzle event on Sunday the 28th. Expecting 30-40 people, possibly more. Advertising through emails. Money would mostly be used for cost of food.

Social Director (Alice):

- Yesterday was Trivia Night which went pretty well. Attendance was around 20-25. Will continue having Trivia Night about once a term.
- Next Saturday is Six Flags trip. Will send out survey tomorrow to sign up. First come, first serve. Will have a bus for transportation.
- Got 50 tickets for Cirque du Soleil. Transportation provided, unsure about cost.
- Meeting with Tom Mannion to do floor plan for ASCIT formal.

Secretary (Dana):

- Nothing to report.

If anyone has any questions or concerns about a section of the minutes please email the appropriate officer. We are happy to answer any questions.

Meeting Adjourned: 4:28 pm

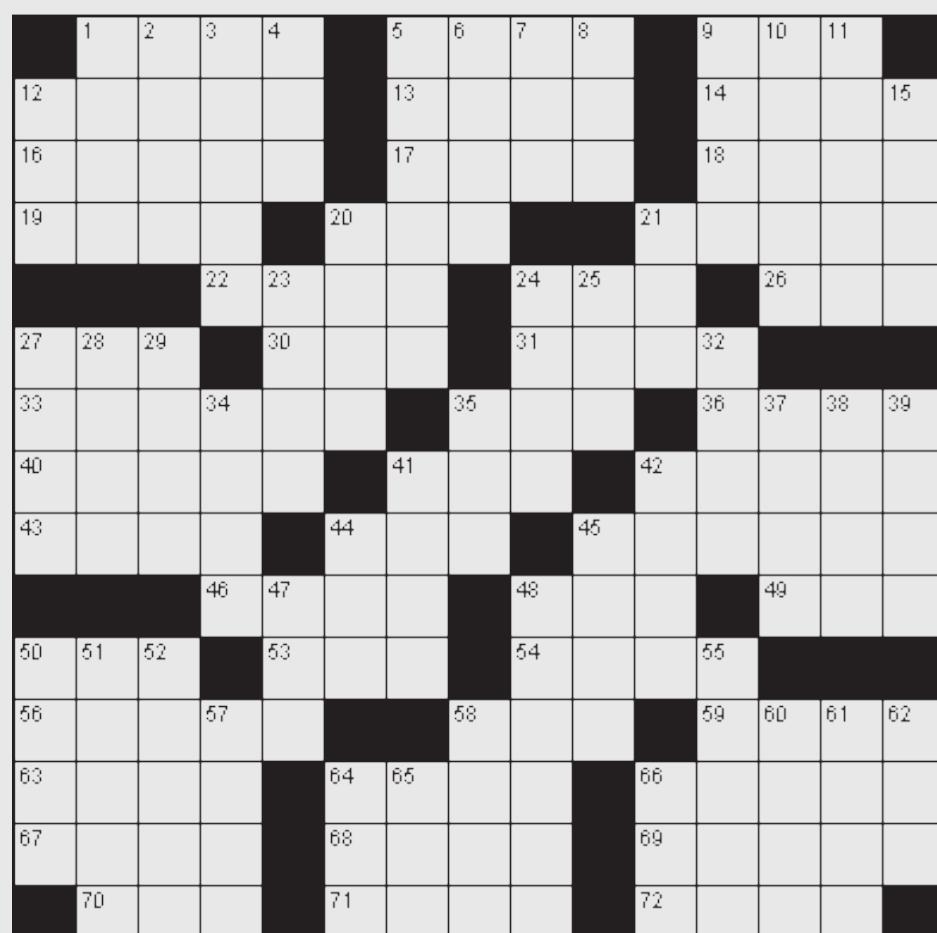
Crossword

Across

- Subdivisions of a play
- Be lazy or idle
- Division of geological time
- Oddity
- Qualified to do things well
- Marsh hen
- Circular coral reef
- Portrayal
- Leporid mammal
- Dome-shaped shrine
- Staining substance
- Sentry positions
- Observed
- Large body of water
- Tackiness
- Peculiar
- Annoy
- Friendly nation
- Closer
- Not in operation
- Fiend
- Supply food ready to eat
- Veneration
- Thick woolen fabric
- Panache
- Transgression
- Thawed
- Alpine lift
- Ardent follower and admirer
- Cunning
- Flow back or recede
- Frozen
- Concludes
- Vernacular
- Pig pen
- Type of star
- Direct attention on something
- Surfeit
- Unit of weight for precious stones
- System of exercises
- Shout
- Imperial decree
- Encountered
- Manufacture
- Accessory
- Motor vehicle
- Harvest
- Roofing material
- Ancient Roman god
- Voice box
- Musical instrument
- Each and every one
- Professional charge
- Reverberation
- Cook with dry heat
- Artery
- Feline
- Trial
- Cervid
- Buddy
- At any time
- Secure
- Fairy
- One time only

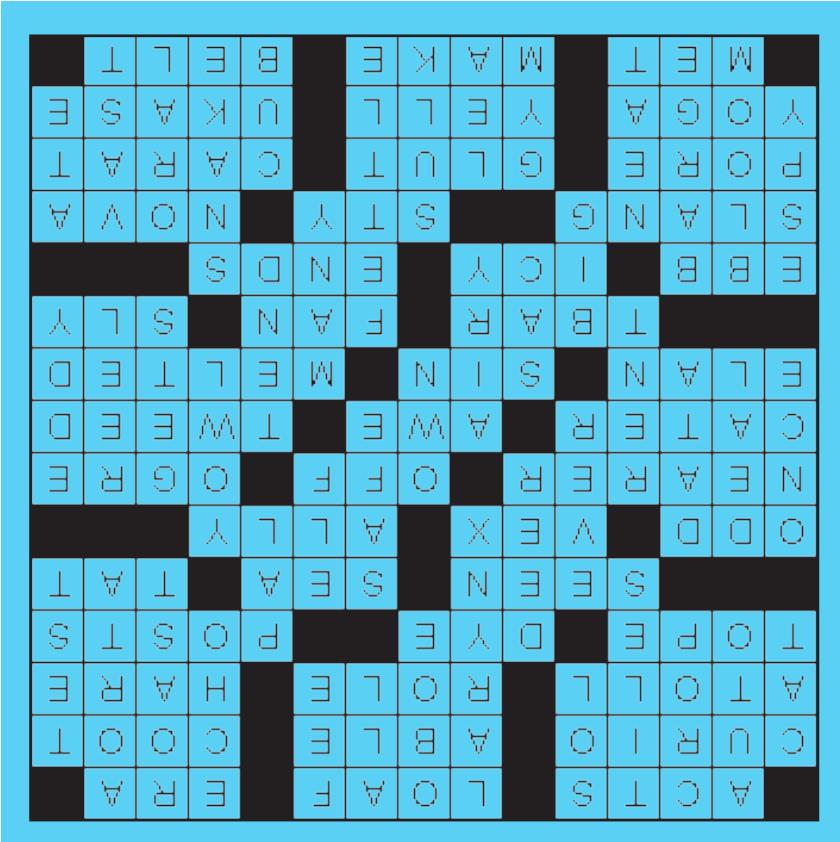
Down

- Information
- Caterwaul
- Let for money
- Possess
- Obtains
- Spool
- Miniature whirlpool
- Ethereal
- Look after
- Pouch
- Large but indefinite number
- Prominent
- Physical fitness
- Catch sight of
- Flower
- Flatbottom boat
- Ophidian
- Orderly
- Brood
- Unwritten
- Immense
- Consumed
- Athletic facility, in short
- Pasture
- Young bear



HUMOR

Answers to current crossword (pg 7)



-<http://puzzlechoice.com>

The California Tech

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