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NEWSLETTER OF
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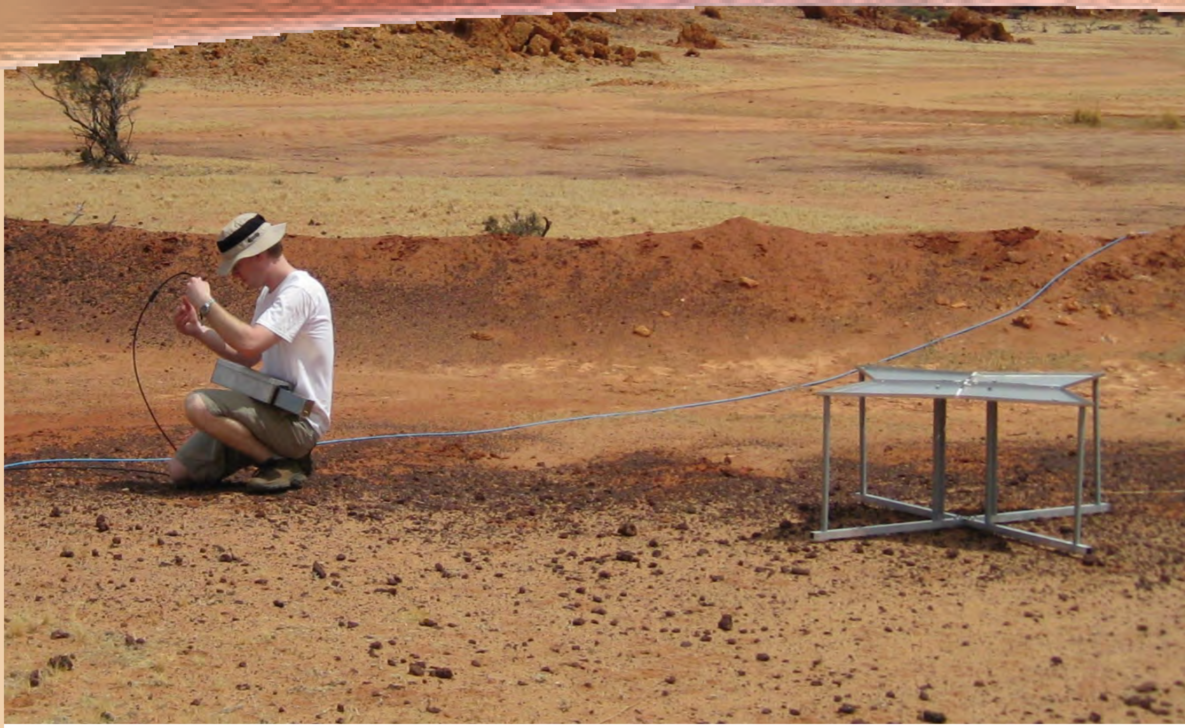
SESE Source



THIS ISSUE

REMINDER

The Ravi DeFilippo Field Camp Scholarship fund has been created to pay the costs of one ASU student to take our Field Geology II (Field Camp) course. The fund has been growing steadily all semester and has about $19k, however, it needs to have $25k to be an endowed fund and support a scholarship off the interest. Thanks to all of you who have given. If you have not given, please consider supporting this scholarship.

Donate online by clicking **HERE.**

Opening a new window into the early universe

By Nicole A. Cassis

Thirteen billion years ago our universe was dark. There were neither stars nor galaxies; there was only hydrogen gas left over after the Big Bang. Eventually that mysterious time came to an end as the first stars ignited and their radiation transformed the nearby gas atoms into ions. This phase of the universe's history is called the Epoch of Reionization (EoR), and it is intimately linked to many fundamental questions in cosmology. But looking back so far in time presents numerous observational challenges. ASU's Judd Bowman and Alan Rogers of Massachusetts Institute of Technology have developed a small-scale radio astronomy experiment designed to detect a never-before-seen signal from the early universe during this period of time, a development that has the potential to revolutionize the understanding of how the first galaxies formed and evolved.

"Our goal is to detect a signal from the time of the Epoch of Reionization. We want to pin down when the first galaxies formed and then understand what types of stars existed in them and how they affected their environments," says Bowman, an assistant professor in SESE.

Bowman and Rogers deployed a custom-built radio spectrometer called EDGES to the Murchison Radio-astronomy Observatory in Western Australia to measure the radio spectrum between 100 and 200 MHz. Though simple in design – consisting of just an antenna, an amplifier, some calibration circuits, and a computer, all connected to a solar-powered energy source – its task is highly complex. Instead of looking for early galaxies themselves, the experiment looks for the hydrogen gas that existed between the galaxies. Though an extremely difficult observation to make, it isn't impossible, as Bowman and Rogers have demonstrated in their paper published in *Nature* on Dec. 9.

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"This gas would have emitted a radio line at a wavelength of 21 cm – stretched to about 2 meters by the time we see it today, which is about the size of a person," explains Bowman. "As galaxies formed, they would have ionized the primordial hydrogen around them and caused the radio line to disappear. Therefore, by constraining when the line was present or not present, we can learn indirectly about the first galaxies and how they evolved in the early universe." Because the amount of stretching, or redshifting, of the 21 cm line increases for earlier times in the Universe's history, the disappearance of the inter-galactic hydrogen gas should produce a step-like feature in the radio spectrum that Bowman and Rogers measured with their experiment.

Radio measurements of the redshifted 21 cm line are anticipated to be an extremely powerful probe of the reionization history, but they are very challenging. The experiment ran for three months, a rather lengthy observation time, but a necessity given the faintness of the signal compared to the other sources of emission from the sky.

"We carefully designed and built this simple instrument and took it out to observe the radio spectrum and we saw all kinds of astronomical emission but it was 10,000 times stronger than the theoretical expectation for the signal we are looking for," explains Bowman. "That didn't surprise us because we knew that going into it, but it means it's very hard to see the signal we want to see."

The low frequency radio sky is dominated by intense emission from our own galaxy that is many times brighter than the cosmological signal. Add to that the interference from television, FM radio, low earth orbit satellites, and other telecommunications radio transmitters (present even in remote areas like Australia's Outback) and it is a real challenge. Filtering out these troublesome foreground signals is a principal focus of instrument design and data analysis techniques. Fortunately, many of the strongest foregrounds have spectral properties that make them possible to separate from the expected EoR signals.

After careful analysis of their observations, Bowman and Rogers were able to show that the gas between galaxies could not have been ionized extremely rapidly. This marks the first time that radio observations have directly probed the properties of primordial gas during the EoR and paves the way for future studies. "We're breaking down barriers to open an entirely new window into the early universe," Bowman says.

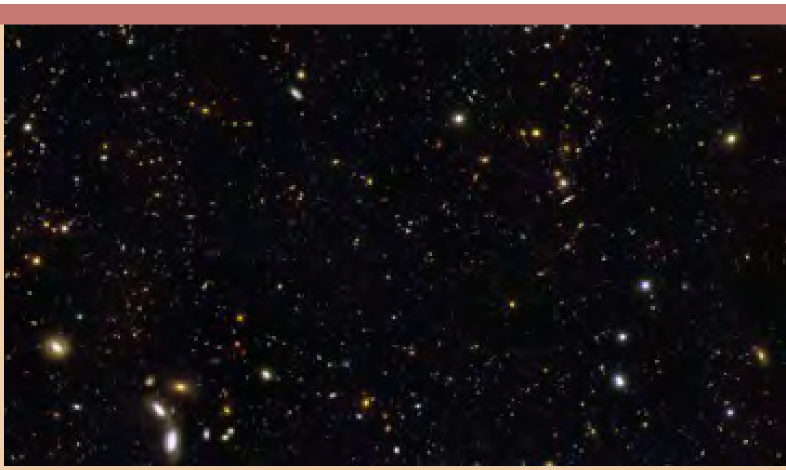
The next generation of large radio telescopes is under construction right now to attempt much more sophisticated measurements of the 21 cm line from the EoR. Bowman is the project scientist for one of the telescopes called the Murchison Widefield Array. According to him, the most likely physical picture for the EoR looked like a lot of bubbles that started percolating out from galaxies and then grew together – but that idea needs to be tested. If lots of galaxies all put out a little bit of radiation, then there would be many little bubbles everywhere and those would grow and eventually merge like a really fizzy and frothy foam. On the other hand, if there were just a few big galaxies that each emitted a lot of radiation then there would have been only a few big bubbles that grew together.

"Our goal, eventually, is to make radio maps of the sky showing how and when reionization occurred. Since we can't make those maps yet, we are starting with these simple experiments to begin to constrain the basic properties of the gas and how long it took for galaxies to change it," explains Bowman. "This will improve our understanding of the large-scale evolution of the universe."

Community News

Congratulations to SESE alum John Hernlund, winner of the 2010 Jason Morgan Young Scientist Award. This AGU award is given every year to an outstanding young tectonophysicist who is within six years of receiving her/his Ph.D. Hernlund graduated from UC Los Angeles in 2006, was a postdoc at IPG in Paris and University of British Columbia through 2009, and is now a research fellow at UC Berkeley. He received his B.S. in Geology from ASU in 2000. His work has had much influence and impact on understanding the structure and evolution of the deep mantle, particularly as related to the post-perovskite phase and the dynamics of melting in the deep mantle and the concept of a basal magma ocean. Hernlund was highlighted in the Nov. 2009 issue of the *SESE Source*.

We would like to welcome our newest member to the SESE community: Elizabeth Jane Frus, born on Thursday, Dec. 2 to Becky Mathews Frus and Adam Frus. Rebecca is a SESE graduate student focusing on earth science educational research.



In honor of Hubble Space Telescope's twentieth anniversary, The New Yorker published a gallery of "The Best NASA Photographs of 2010." One of the many photos included was an image that ASU played a hand in processing. Slide number seven is an image that SESE's Rogier Windhorst, Seth Cohen, Matt Mechtley, and Michael Rutkowski helped process that shows more than 12 billion years of cosmic history. Such a detailed view of the universe has never before been assembled with this much of color, clarity, accuracy, and depth. Click **here** to see this image and others.

The hunt for the lunar core

By Nicole A. Cassis

The Moon, Earth's closest neighbor, has long been studied to help us better understand our own planet. Of particular interest is the lunar interior, which could hold clues to its ancient origins. In an attempt to extract information on the very deep interior of the Moon, a team of NASA-led researchers applied new technology to old data. Apollo seismic data was reanalyzed using modern methodologies and detected what many scientists have predicted: the Moon has a core.

According to the team's findings, published Jan. 6 in the online edition of Science, the Moon possesses an iron-rich core with a solid inner ball nearly 150 miles in radius, and a 55-mile thick outer fluid shell.

"The Moon's deepest interior, especially whether or not it has a core, has been a blind spot for seismologists," says Ed Garnero, a professor in SESE. "The seismic data from the old Apollo missions were too noisy to image the Moon with any confidence. Other types of information have inferred the presence of a lunar core, but the details on its size and composition were not well constrained."

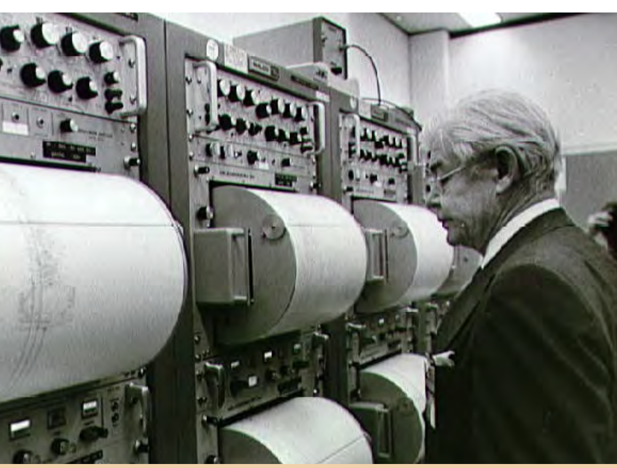
Sensitive seismographs scattered across Earth make studying our planet's interior possible. After earthquakes these instruments record waves that travel through the interior of the planet, which help to determine the structure and composition of Earth's layers. Just as geoscientists study earthquakes to learn about the structure of Earth, seismic waves of "moonquakes" (seismic events on the Moon) can be analyzed to probe the lunar interior.

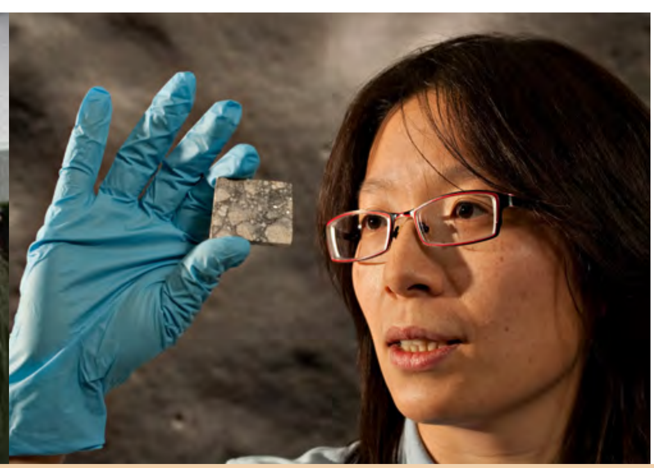
When Garnero and his graduate student Peiying (Patty) Lin heard about research being done to hunt for the core of the Moon by lead author Renee Weber at NASA's Marshall Space Flight Center, they suggested that array processing might be an effective approach, a method where seismic recordings are added together in a special way and studied in concert. The multiple recordings processed together allow researchers to extract very faint signals. The depth of layers that reflect seismic energy can be identified, ultimately signifying the composition and state of matter at varying depths.

"Array processing methods can enhance faint, hard-to-detect seismic signals by adding seismograms together. If seismic wave energy goes down and bounces off of some deep interface at a particular depth, like the Moon's core-mantle boundary, then that signal "echo" should be present in all the recordings, even if below the background noise level. But when we add the signals together, that core reflection amplitude becomes visible, which lets us map the deep Moon," explains Lin, who is also one of the paper's authors.

The team found the deepest interior of the moon to have considerable structural similarities with the Earth. Their work suggests that the lunar core contains a small percentage of light elements such as sulfur, similar to light elements in Earth's core – sulfur, oxygen and others.

"There are a lot of exciting things happening with the Moon, like Professor Mark Robinson's LRO mission producing hi-res photos of amazing phenomena. However, just as with Earth, there is much we don't know about the lunar interior, and that information is key to deciphering the origin and evolution of the Moon, including the very early Earth," says Garnero.





Far left: In the Mission Control Center at Houston seismic tracings made by seismometers left on the Moon during earlier Apollo lunar landing missions are viewed. Credit: NASA. Left: Nearly 40 years later, Lin and Garnero are applying modern Earth-based seismology techniques to learn more about the Moon. Here Lin holds Northwest Africa 5000, a lunar meteorite in the collection of the ASU Center for Meteorite Studies. Credit: Tom Story/ASU.

Lonely robots map land and seas — without humans

By Matthew C. Button

Srikanth Saripalli has been working on autonomous navigation for robotic vehicles for more than a decade. As an assistant professor at ASU since 2008 he has lead collaborations with undergraduates on several vehicles such as a helicopter and submarine vehicles that can map its surroundings and explore unknown areas without the direct aid of a human controller. Essentially Saripalli has been perfecting algorithms that allow these robots to "fly" and "swim" all by themselves. His research is potentially useful in far-off space explorations where direct control from earth may be difficult or inefficient. During his time at the Mobility and Robotics section at NASA/JPL he developed similar algorithms for the aerial exploration of Titan, the largest of Saturn's moons. *SESE Source* had a chance to speak to Saripalli and look a little deeper into his current projects at ASU, projects that have sparked the interest of 3TV who produced a recent broadcast about his work.

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SESE Source: So, most of your work has focused on creating autonomous robots without need for human direction, what's wrong with humans?

Saripalli: [Laughs] There is nothing wrong with humans, robots are primarily aids to humans, and these autonomous tasks we want them do are part of the three d's: dirty, dull, or dangerous – things nobody wants to do…You can look at autonomy on a kind of slide rule where at one end there is full autonomy and at the other there is the simple dolly, with a human and a joystick.

SESE Source: You have been working on a system that would allow a robotic helicopter to navigate itself without the use of GPS, has GPS gone wrong?

Saripalli: No, GPS is a very useful tool and it is ubiquitous but there are a lot of places where there is no GPS, such as Mars or the Moon or underwater.

SESE Source: Where do you get the parts for this helicopter, and how do you put it all together?

Saripalli: Most of the robots are made from off the shelf parts we order them from catalogues. Undergrads usually build and write the basic programming.

SESE Source: Exactly what kind of sensors do these robots use?

Saripalli: Inertial sensors, gyros, LIDAR, depending on their environment.

SESE Source: How do you come up with these algorithms and conceive these systems for navigation?

Saripalli: Mostly it comes from previous projects. And lots and lots of testing, you know the finished product looks cool and impressive but actually programming the robot, and running is hard work and can be dull.

SESE Source: All of this talk about autonomy and robotic independence sounds a lot like Artificial Intelligence (AI), what's the difference?

Saripalli: Embodiment I suppose. With robotics we aren't just interested with a robot's programming and autonomy, but also the mechanism and physical embodiment. They are certainly related and there definitely is overlap.

SESE Source: So you've been letting a helicopter fly all on its own, have you had many crashes during the extensive testing regiments?

Saripalli: Not at ASU. I've seen something like 50 crashed helicopters; toward the beginning they were frequent, a few a year, but I've actually been one year without a crash, quite a streak.

Saripalli mentored a group of students from the University of Maryland and ASU, which took first place in the 2010 Revolutionary Aerospace Systems Concepts Academic Linkage Competition. The contest involved their construction of a possible lunar vehicle that could act as a realistic moon-ready assistant to astronauts' exploration of the moon. The final rover was an impressive feat for Saripalli for which he was very proud of his undergraduates. ASU has many ways students interested in robotics can find involvement, including a robotics team for senior level students looking to challenge themselves in creating these mechanical aids.

Dust devils on Mars

By Matthew C. Button

Twisting about on the surface of Mars, formed from the deep red dust of the planet, dust devils rage over the planet's surface. Dust devils are vortexes that form from the surface upward, which vacuum loose sediment and inject dust into the atmosphere. They are common on Earth, especially in the heated surface of many of the Arizonian deserts. Recent Mars Spirit Rover pictures also reveal hundreds of active dust devils trailing over the surface of the planet. SESE's Ronald Greeley and his students have been examining martian dust devils for several years with a combination of field and laboratory experiments that seek to teach us more about the twisters that vacuum the dustiest planet, Mars.

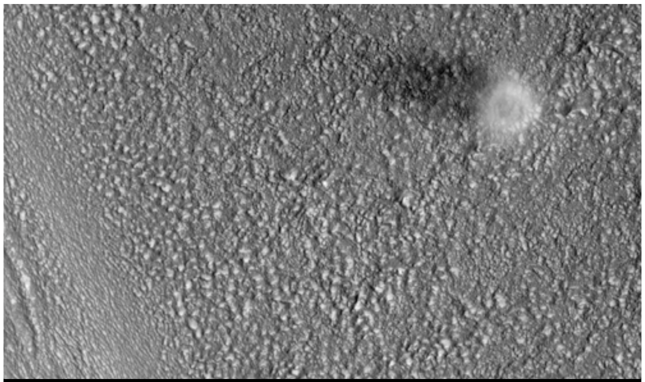
Tornadoes typically form at height in the air and extend down to the surface, whereas dust devils originate at the surface and extend upward. Dust devils look much like tornadoes to the untrained eye but they are in fact very different. Smooth surface, lack of vegetation, low pressure and surface heat come together to make Mars a plentiful site of dust devil activity.

One of the curious ways scientists can observe the movement of these twister-type phenomena is to study the tracks left behind on the surface by dust devils. Looking at the collective directions of the dust devils has revealed seasonal movement of the dust around the planet.

"We have compiled thousands of pictures of dust devils from lander and orbiter observations and from that we examine the role of dust devils; we can look at their tracks and compare them with predicted wind patterns to understand how they alter the surface," Greeley explains.

Collectively, dust devils actually put enough dust in the atmosphere to cool the planet's atmosphere. This cooling then prevents the formation of more dust devils by retarding surface heating, and as a result the dust can then fall back to the surface. This cycle of injecting dust in warm periods and then cooling and settling the dust on the surface is pivotal in understanding the seasons on the Red Planet. This dust cycling repeatedly covers old dust devil tracks and forms new tracks, such that the data must be captured before the tracks disappear.

Studies of dust devils on Earth help to understand those on Mars. Dust devils are observed on Earth by driving trucks with mounted sensors into naturally occurring devils, the desert version of storm-chasers. However, Mars conditions need to be mimicked to check the Earth-derived observations. To do this, Greeley uses his simulator at NASA Ames Research Center that creates the same atmospheric conditions of Mars within a sealed chamber. The small tracks and dust piles in this lab-sized "twister" system are effective tools as the larger versions on Mars. The versions have the same vortex structure and leave the same track ripples as their Mars counterparts and are instrumental in understanding the direction and speed of the more intense and vastly larger Mars dust devils.



This image taken by the Hi-Rise camera aboard NASA's Mars Reconnaissance Orbiter catches a dust devil blowing across the martian surface. Credit: NASA/JPL/University of Arizona.

"We aren't just looking at their formations to understand Mars' geology, or rover operations, but also so that we can also understand what's called forward contamination," Greeley says.

Forward contamination is what might happen if the rovers, satellites, or other spacecraft take bacteria or chemicals from Earth to Mars and contaminate its surface. Knowing the wind patterns and where contaminants will end up is critical in such cases.

Regardless of understanding the role of the martian twisters and their effect on the seasons, the movement of particles by wind has become a greatly important facet of Mars exploration.

In addition to the NASA Mars rover team, Greeley is currently part of the European Space Agency's orbital imaging of Mars as a co-investigator on a specialized German camera that allows scientist to see the dust devils in motion.

"This allows us to measure the speed of the dust devils. It's the only system that can allow us to see motions from orbit and we can couple much of what we see on the ground with these satellite observations," Greeley explains.

Be it from orbit or wind tunnel, rover or telescope, scientists work to shed more light onto the conditions of the red planet, which like ASU is a home to devils, not of the sun, but of the sand.