

ASTRONOMY BEHIND THE HEADLINES
A podcast for Informal Science Educators
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Episode 12: SCIENCE FROM THE MOON
with Dr. Jack Burns, University of Colorado at Boulder

Credits:

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Begin transcript:

HOST CAROLYN COLLINS PETERSEN: Welcome to *Astronomy Behind the Headlines*, a production of the Astronomical Society of the Pacific.

October 8th is International Observe the Moon Night. The theme this year is “What does the Moon mean to you?”

Our neighbor in space has always fascinated us, both culturally and scientifically. Humans first set foot on its dusty surface beginning in 1969. Six of 11 *Apollo* missions landed astronauts on the Moon to do a variety of science experiments, which still go on today. For example, the *Apollo* lunar laser ranging experiment still exists, and scientists aim lasers at reflectors on the Moon to measure its distance from Earth. The Lunar Reconnaissance Orbiter, LRO, has sent back highly detailed images showing the locations of those first missions and the science lab equipment that was so much a part of humanity’s first steps off our home planet.

Scientists continue to explore the Moon, to understand its physical structure, and they plan to use it for future research in astrophysics and cosmology. Dr. Jack Burns, of the University of Colorado's Lunar University Network for Astrophysics Research (LUNAR), joins us to talk about lunar exploration and some exciting work his team is planning to do from the surface of the Moon.

Dr. Burns, welcome to *Astronomy Behind the Headlines*.

DR. JACK BURNS: Well, thank you Carolyn. It's great to be with you.

HOST: Those gorgeous LRO images clearly show us our first manned "labs" on the Moon. Tell us what kind of science we got from the *Apollo* missions.

DR. BURNS: Sure, happy to do that, because there really was a treasure trove of science that came back from the Moon. We may not always remember that as much as just the exploration. But, basic things like, for example, the samples brought back from the Moon really confirmed the scenario in which the Moon was formed as the result of a collision between a Mars-sized object some four and a half billion years ago with the Earth. And, the Moon coalesced out of the debris from that collision, so it's sort of half a large asteroid and half of Earth. Before *Apollo*, we really didn't know which of several models formed the Moon.

Apollo also had a seismic network on the surface, so we were able to probe the lunar interior because the moonquakes are formed very differently than earthquakes. The moonquakes mainly come from tidal stresses from the Earth, because it's not geologically active.

And, we also set up a series of what are called "retro-reflectors" which are basically highly polished mirror surfaces on the Moon, where we continue to shine lasers from the Earth and measure the distance between the Earth and the Moon very, very accurately. Today, we can get to accuracies approaching a millimeter. That's important because it allows us to produce unprecedented constraints on gravitational physics—particularly testing the theory of General Relativity, which continues to hold up well, but also looking for where General Relativity may break at some point in the future.

And, it also is the only way that we can currently constrain the interior of the Moon, and it's how we've come to learn just in recent years that the Moon probably has a fluid core.

There's a whole range of interesting science that continues right through to today.

HOST: There's another Earth-based mission with the same name—APOLLO—that also studies the Moon. Tell us about that. (*NOTE to listeners: APOLLO is the Apache Point Observatory Lunar Laser-ranging Operation*).

Dr. Burns: Yes, that is the follow-on to the retro-reflectors that were left by the *Apollo* astronauts. The APOLLO uses the 3.5-meter telescope at Apache Point in southern New Mexico. It's led by Tom Murphy, who's a member of our team, and Tom uses the much larger aperture of the Apache Point telescope to be able to get better signals coming back from the Moon.

So, just recently, for example, he had a very fascinating discovery, he was able to do reflections of the *Lunakhod 1* spacecraft, which had been lost for forty years. He was able to recover that, and that provides a new station on the Moon that we didn't have previously available, and that is going to be a great bonus for us to further constrain the interior of the Moon.

HOST: Let's talk about the recently launched Gravity Recovery and Interior Laboratory—or GRAIL. What will the GRAIL mission tell us about the Moon?

DR. BURNS: Well, GRAIL is going to be unique, because it's two satellites that are going to be in orbit of the Moon, and they use radio techniques to measure their separation very, very accurately. The reason that's important is that any small perturbations in their separations are due to gravity changes on the Moon. So, they're going to be able to map the gravitational field of the Moon, not just the surface, but deep into the interior of the Moon. That's important because it will allow us to understand further details on how the Moon formed, how it coalesced, the transition between the crust and the mantle and then into the core of the Moon.

HOST: I've also read that scientists are also going to use GRAIL to look at a theory that there may have been two early Moons orbiting Earth at one time, and that they coalesced to form our current Moon.

Dr. Burns: Possibly, because that's very interesting. That's one of the things I talk about all the time—one of the remaining mysteries is, why is the near side of the Moon look SO different from the far side? The near side has all of these maria, smooth regions and the far side has all of these highlands. And, so one recent theory is that the Moon actually formed from a couple of large pieces of debris. GRAIL, by mapping the gravitational field, could look for the remnants of that debris. The principal investigator of that mission is indeed going to look very carefully at those data to try to test that model.

HOST: During *Apollo 16*, I recall that astronauts used a far-ultraviolet telescope to observe objects like the Milky Way, galactic clusters, and Earth's atmosphere. Those were the first serious astrophysical observations done from the Moon. You and a group of scientists at nearly two dozen institutions and companies in the U.S. and Europe are now proposing the Moon as a platform for continued astrophysical research. So, tell us about that.

DR. BURNS: We are. We're planning to undertake several new kinds of observations from the Moon, taking advantage of its unique capabilities. The first is, we're working to place a new generation of these retro-reflectors on the Moon, and with these more active sensors, we believe that we can measure the Earth-Moon distance now down to accuracies of close to ten microns. So, that's just mind-boggling to think of that Moon-Earth distance. With that, we can really differentiate now between models of gravity, between what Einstein proposed and some of what are called the "non-metric models". That's very exciting, because we expect at some point General Relativity will break, because we know it's not the final model. The final model also has to incorporate elements of quantum physics.

So, that's one of the things we want to do. The other is—the Moon is an important natural resource in that its far side, which always faces away from the Earth, is the only place in the inner solar system that is truly radio quiet at low frequencies—at frequencies below the FM, below 100 megahertz. That is, from a cosmology

perspective, for understanding the early universe, that is one of the parts of the electromagnetic spectrum that we are eager to probe because it's going to open up the very universe for the first time, allow us to see the first stars, the first galaxies collapsing at time periods of anywhere from about a hundred to four hundred million years after the Big Bang. And, actually, the first black holes, in galaxies, too. They produce x-rays, they heat the surrounding medium, and we will see the residue of that in the radio spectrum. Just to remind you, the universe as a whole is 13.7 billion years old, so this is very early in its history.

Those same radio telescopes, either in orbit, or particularly on the surface of the Moon, we're going to use to study the Sun at frequencies below 10 megahertz, so very low frequencies. And, the Sun has never been studied at those wavelengths. That's important because in times when there's a lot of solar activity, things called coronal mass ejections—large, pieces of plasma are sent out from the Sun and they shock the interplanetary medium and create high-energy particles. They knock out our satellites, they affect the power grids on the Earth, and they can be deadly to future astronauts traveling interplanetary space. So, these radio telescopes on the Moon will be the first to be able to map these regions and to serve as an early warning of these kind of energetic events that come regularly from the Sun. These low-frequency telescopes will allow us to measure for the first time the ionosphere of the Moon. The Moon has a very, very thin ionized atmosphere, but it's never really been measured very well.

HOST: How do you envision all of these plans playing out?

Dr. Burns: One of the issues that we are focusing on in our center is the overlap between science and exploration. We think in returning to the Moon and then going to asteroids, going to the moons of Mars, that we're going to see a unification for the first time between science and exploration. When you're exploring a body like the Moon, it's really looking at the geology, looking at the physics, looking at the astronomy opportunities. And so, that's very exciting.

So, the technologies that we're developing to deploy some of these radio telescopes, for example, I think are going to be driven by a combination of robots operated directly by astronauts, either in orbit or on the surface of the Moon. And, that's an exciting new

development, because with *Apollo*, we didn't have the computer technology and the robotics to be able to do that. The next generation of explorers are going to have—they're going to bring their "pets" along with them. In this case, it's going to be intelligent robots who are going to go out, they're gonna sample—the geologists, the astronomers, the physicists are going to tell them what to do and understand the data in real time, and then send them on their missions, and then come back and interact with them in a new way that's going to be exciting for the future of exploration.

HOST: So, your group—in both its science and its outreach—is working to excite that next generation of lunar explorers.

Dr. Burns: Oh, that's very much a part of it, because, those of us that grew up in the early days of the space program and with *Apollo*, we still carry that excitement with us. But, the current generation hasn't lived through that. And so, exciting them not only to the kinds of science that *Apollo* was able to do, but this next step, with these new technologies, new ways of being able to do some virtual reality from the Moon—we're going to be able to involve kids and the general public in real time to drive rovers on the Moon, to participate with the astronauts as they're exploring, putting out these pieces of scientific equipment. So, it's going to be very different than *Apollo*, but getting the public and the students excited about doing that is a real challenge for us now.

HOST: It sounds like a fascinating future for astrophysics research on the Moon. Dr. Burns, thank you for joining us on *Astronomy Behind the Headlines*. It has been a pleasure having you.

DR. BURNS: It was enjoyable for me as well. Thank you, Carolyn.

HOST: If you'd like to learn more about past, current, and future science research involving the structure of the Moon, its evolutionary history—and its use as an astrophysics platform, point your browser to www.astrosociety.org/abh. Thanks for listening!

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