New Camera to Help Search for Life Outside Our Solar System

W. M. Keck Foundation grant supports development of ultra-sensitive camera

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EVANSTON, Ill. --- A Northwestern University research team has been awarded a $1 million grant from the W. M. Keck Foundation to develop a fast, ultra-sensitive camera that could be the first to directly image light reflected by planets outside our solar system and help scientists in their search for life on Earth-like exoplanets.

Hooman Mohseni, who invented the technology upon which the camera will be based, is the principal investigator on the grant and will lead the detector and camera development. He is a professor of electrical engineering and computer science in the McCormick School of Engineering and Applied Science and a member of the Center for Interdisciplinary Exploration and Research in Astrophysics (CIERA).

The Northwestern researchers will design, create and test a completely new camera that operates in the near infrared range of the light spectrum, with far better sensitivity and utility than existing light detector technologies. Using such a camera on a telescope offers the promise of directly imaging planets about 100 times fainter than those imaged by current technology.

The Keck Foundation's grant will count toward **We Will. The Campaign for Northwestern**, a $3.75 billion University-wide fundraising effort announced in 2014.

"The Keck award will push this technology to its limit and a whole new performance level," Mohseni said. "Our very challenging goal is to produce ultra-small structures -- as small as a virus -- on this bio-inspired detector to get the light sensitivity we need to image planets outside our solar system."

Nearly 2,000 exoplanets, or extrasolar planets, have been discovered so far, but because of limitations in imaging systems, most have only been detected indirectly. The innovative Northwestern imaging technology -- inspired by the light detection mechanism of the rods in the human eye -- would be used to image potentially habitable planets as well as provide new observations to help astronomers better understand how our solar system and other planetary systems developed.

The first imaging target outside our solar system will be Jupiter-sized planets located in the habitable

zone. (The habitable zone, also known as the Goldilock's Zone, is a region around a star where conditions are not too hot and not too cold, but just right for possible life.)

The prototype camera would be combined with other sophisticated technology on the Subaru Telescope in Hawaii, one of the premier imaging telescopes in the world, to directly image these extrasolar gas giants in reflected light. This achievement would be a first.

"Our technology has the potential to allow a paradigm shift in how sensitive these cameras can be," said Melville Ulmer, a member of the research team. He is a professor of physics and astronomy in the Weinberg College of Arts and Sciences and a member of CIERA and will lead the integration of the camera with telescopes.

"When taking a thousand images a second of the sky, you are not getting much light per exposure, so you need a sensitive device that also works fast," Ulmer said. "This is what the Keck Foundation has funded us to develop. Keck's support will enable us to do some really cool work."

Mohseni has been working on light sensor technology since 2004, making a "semiconductor" version of the human eye rod cells -- the first bio-inspired light detector. He then incorporated the detector into a camera, which most recently has been shown to be approximately 100 times more sensitive than existing technology.

"The level of control we need to achieve a highly uniform grid of ultra-small nanostructures with near-perfect atomic control -- giving us the desired light sensitivity -- is beyond the reach of current technology," Mohseni said. "However, we have a lot of new insights and novel approaches to achieve this goal."

The third member of the team is Olivier Guyon, one of the world's leaders in using optics to image exoplanets and a Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) Project Scientist. He will lead the testing of the camera on the Subaru Telescope, an 8.2-meter optical-infrared telescope at the summit of Mauna Kea, Hawaii.

A decade ago, most astronomers assumed that potentially habitable planets could not be imaged with telescopes from the ground. Thanks to significant technology advancements and the upcoming generation of extremely large telescopes (now under construction), instruments capable of imaging these planets now are possible.

"Exoplanets are notoriously challenging to image: they are much fainter than and very close to the stars they orbit," Guyon said. "Fast, sensitive detectors are absolutely essential for this imaging challenge. We are developing and validating one of the last missing technologies required to search for life outside our solar system."

If the new camera performs well on the Subaru Telescope, the next step will be to use the technology on one of the new extremely large telescopes, such as the Thirty Meter Telescope, which would provide even better imaging capabilities.

This combination of forces offers the possibility of imaging Earth-like planets -- potentially habitable rocky planets located in the habitable zone. (The Subaru Telescope is not large enough to detect Earth-sized planets.)

The promise of the new near infrared camera derives from Mohseni's bio-inspired electron injectors, a technology whose sensitivity capabilities geometrically increase as the size of the injectors decreases.

The camera also promises to revolutionize medical imaging (e.g., deep tissue optical coherence tomography), 3-D imaging (e.g., for self-driving vehicles) and photon-number resolving (e.g., for scalable quantum computing).

The project, titled "A Novel Near-Infrared Camera System for Breakthroughs in Astrophysics and Beyond," advances a key goal of Northwestern's strategic plan: to discover creative solutions.

The W. M. Keck Foundation was established in 1954 by William Myron Keck, the founder of The Superior Oil Company. The foundation supports pioneering research and the development of new technologies in science and engineering, high-risk basic medical research with transformative potential and undergraduate education in designated states.

Support raised as part of **We Will. The Campaign for Northwestern** will help realize the transformational vision set forth in Northwestern's strategic plan and solidify the University's position among the world's leading research universities. For more information, visit wewill.northwestern.edu.

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