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Harrison Tasoff

Snapping A Space Shot

The search for life on planets beyond our solar system has long been the purview of science fiction, but a UC Santa Barbara team supported by the Heising-Simons Foundation is now building the technology to do just that.

Over the last three decades astronomers have discovered more than 4,000 planets outside our solar system, called exoplanets. All but a few of these have been detected indirectly, by measuring the tiny effects they have on the light we receive from their host stars. These effects are so minute that they can only be measured with state-of-the-art, precision instruments.

Even with such instrumentation, mounted on the best observatories in the world, these indirect methods are best at finding planets that are rather close to their host stars, usually a small fraction of the Earth-Sun distance. What's more, larger planets have stronger signals than smaller ones. Hence, small, rocky planets similar to Earth and Mars are far harder to detect than gas giants similar to Jupiter and Saturn.

"As a result of this observational bias, there are very few examples of detected Earth-like planets," said physics professor Benjamin Mazin, whose lab is leading UC Santa Barbara's portion of the new effort.

The search for signs of extraterrestrial life will require not only detecting small, rocky planets, but also harvesting their light to look for biosignatures. These are chemical or physical presences that suggest life may be present.

“Measuring the atmospheric composition of rocky exoplanets for biosignatures calls for a new observational method,” Mazin said. That new method is direct imaging, the high-tech equivalent of taking a photograph of another solar system.

Importantly, direct imaging will enable scientists to investigate the chemical composition of exoplanets’ atmospheres using spectroscopy. Essentially, the researchers take the light that is passed through a planet’s atmosphere and split it into its constituent wavelengths, exactly as a prism breaks up sunlight into a rainbow. The colors present and absent indicate what chemicals the light interacted with, some of which could be biosignatures such as molecular oxygen.

This is all well and good, however exoplanets are extremely difficult to image directly for a slew of reasons. The stars that these potentially habitable worlds orbit are more than one million times brighter than they are. That starlight also gets distorted by the Earth’s atmosphere and the highly complex chain of mirrors, lenses and filters in a modern telescope. The glare often overwhelms the planetary light, Mazin explained.

"Taking a picture of a nearby solar system is one of the most technologically challenging things we do in astronomy, mainly because Earth’s atmosphere royally messes up the picture,” he said. “It’s like trying to take a picture through a windshield that’s getting blasted with rain."

On top of these challenges is distance. These systems are so far away that angle in the sky between a typical star and its planet is smaller than the angle a flu virus held at arm’s length takes up in your field of view. This tiny star-to-planet apparent separation puts the planet where the glare from the errant starlight is most intense.

The Mazin lab is part of a multi-university team of astronomers that the Heising-Simons Foundation is investing in to advance direct imaging technologies. The goal is to develop instrumentation sensitive enough to detect and characterize temperate, Earth-sized planets around nearby, low mass stars from ground-based observatories.

This team has expertise in disciplines ranging from ultra-sensitive light detectors and adaptive optics (which remove most of the distortion created by Earth’s atmosphere) to the design of starlight suppression systems and advanced imaging algorithms.

UC Santa Barbara has developed a powerful new kind of superconducting photon sensor, called an MKID, and has integrated these detectors with the 8-meter Subaru Telescope in Hawaii. The university will use Heising-Simons funding to develop the data processing algorithms needed to turn MKID data into scientific discoveries. The team also will work to use the fast stream of MKID data to improve the adaptive optics at high speed.

“I feel there is no more compelling problem to work on,” Mazin said. “Learning about nearby planets tells us a lot about ourselves and our place in the universe."

The Heising-Simons Foundation is a family foundation based in Los Altos and San Francisco, California. The foundation works with its many partners to advance sustainable solutions in climate and clean energy, enable groundbreaking research in science, enhance the education of our youngest learners and support human rights for all people.

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.