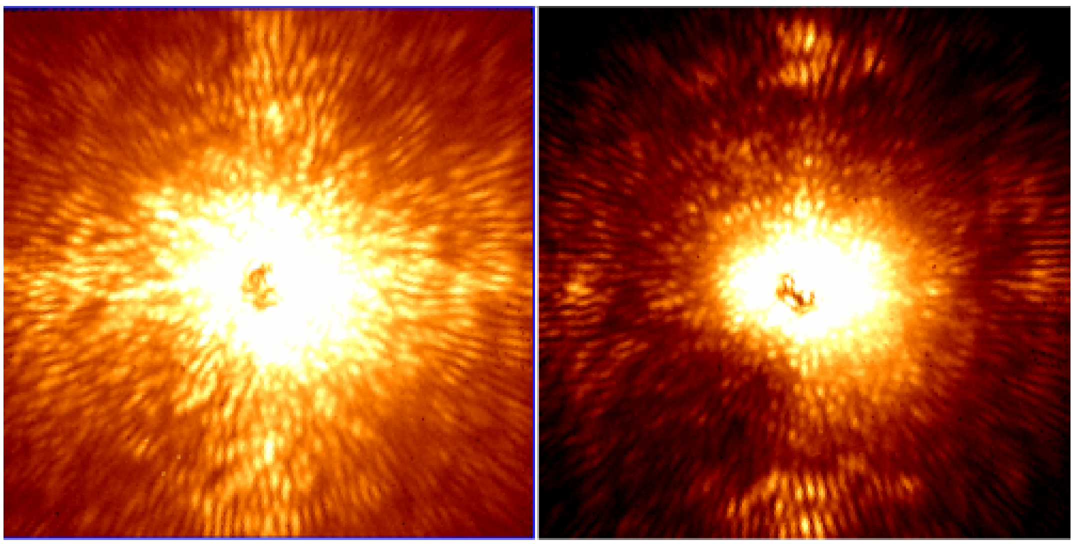
New instrument sifts through starlight to reveal new worlds

July 5 2012



This figure shows two images of HD 157728, a nearby star 1.5 times larger than the sun. The star is centered in both images, and its light has been mostly removed by the adaptive optics system and coronagraph. The remaining starlight leaves a speckled background against which fainter objects cannot be seen. On the left, the image was made without the ultra-precise starlight control that Project 1640 is capable of. On the right, the wavefront sensor was active, and a darker square hole formed in the residual starlight, allowing objects up to 10 million times fainter than the star to be seen. Images were taken on June 14, 2012, with Project 1640 on the Palomar Observatory's 200-inch Hale telescope. Credit: Courtesy of Project 1640

An advanced telescope imaging system that started taking data last month is the first of its kind capable of spotting planets orbiting suns outside of our solar system. The collaborative set of high-tech instrumentation and software, called Project 1640, is now operating on the Hale telescope at the Palomar Observatory in California after more than six years of development by researchers and engineers at the American Museum of Natural History, the California Institute of Technology, and the Jet Propulsion Laboratory (JPL). The project's first images demonstrating a new technique that creates extremely precise "dark holes" around stars of interest were presented today at the International Society for Optics and Photonics (SPIE) Astronomical Telescopes and Instrumentation meeting in Amsterdam by Ben R. Oppenheimer, an associate curator in the Museum's Department of Astrophysics and principal investigator for Project 1640.

Although hundreds of planets are known from indirect detection methods to orbit other stars, it's extremely difficult to see them directly in an image. This is largely because the light that stars emit is tens of millions to billions of times brighter than the light given off by planets.

"We are blinded by this starlight," Oppenheimer said. "Once we can actually see these exoplanets, we can determine the colors they emit, the chemical compositions of their atmospheres, and even the physical characteristics of their surfaces. Ultimately, direct measurements, when conducted from space, can be used to better understand the origin of Earth and to look for signs of life in other worlds."

Even though the scientists are imaging what are considered relatively nearby stars—those no more than 200 light years away—an extraordinary level of precision is needed to produce accurate results.

"Imaging planets directly is supremely challenging," said Charles Beichman, executive director of the NASA ExoPlanet Science Institute at the California Institute of Technology. "Imagine trying to see a firefly whirling around a searchlight more than a thousand miles away."

Project 1640 is based on four major instruments that image infrared light generated by stars and the warm, young planets orbiting them. The instruments are now in operation and producing some of the highest-contrast images ever made, revealing celestial objects 1 million to 10 million times fainter than the star at the center of the image.

The core of this technical advance is the coordinated operation of: the world's most advanced adaptive optics system, built at Caltech and JPL, which can manipulate light by applying more than 7 million active mirror deformations per second with a precision level better than 1 nanometer—about 100 times smaller than a typical bacterium; a coronagraph, built at the Museum, which optically dims the star but not other celestial objects in the field of view; a spectrograph built by a team from the Museum and Cambridge University that records the images of other solar systems in a rainbow of colors simultaneously; and a specialized wavefront sensor built by a team at JPL that is imbedded in the coronagraph and senses imperfections in the light path at a precision of a nanometer.

Although the coronagraph creates an "artificial eclipse" inside Project 1640, blocking the extremely bright light emanating from the star, about half of a percent of that light remains in the form of a bright speckled background superimposed on the solar systems of interest. Each of these speckles can be hundreds of times brighter than the planets and must be controlled with exquisite precision.

Project 1640, however, has now demonstrated a technique that can darken the speckles far beyond any previous capability, in effect carving a dark square in the speckle background centered on the star. The dark region can only be created by measuring and controlling distortions in the distant star's light, caused by traveling through the atmosphere and optics, at the 5-nanometer level (a small fraction of the wavelength of light). Previously, the dark hole created by the Project 1640 technique had only been observed in controlled laboratory conditions. Now, the effect on an actual star has been observed through a telescope.

"High-contrast imaging requires each subsystem perform flawlessly and in complete unison to differentiate planet light from starlight," said Richard Dekany, the associate director for instrumentation at Caltech Optical Observatories. "Even a small starlight leak in the system can inundate our photodetectors and pull the shroud back down over these planets."

Now that the full system is working, the researchers have started a three-year survey, during which they plan to image hundreds of young stars.

"The more we learn about them, the more we realize how vastly different planetary systems can be from our own," said Jet Propulsion Laboratory astronomer Gautam Vasisht. "All indications point to a tremendous diversity of planetary systems, far beyond what was imagined just 10 years ago. We are on the verge of an incredibly rich new field."

The planets orbiting these bright stars in Project 1640's scope are likely very large, on the order of the size of Jupiter, and too hot for life to exist, though it's possible that other planets in these systems, or their moons, could harbor life. One of the biggest research potentials of the new project is to unlock knowledge about what the architectures of solar systems say about our own planet.

"In order to understand the origin of Earth, we need to understand the origin of planets in general," said Lynne Hillenbrand, an astronomy professor at the California Institute of Technology. "How do they form, how do they evolve? How does our solar system with both gas giant and rocky small planets compare to others? These are questions that are very important to humanity."

More information: Research papers:

B.R. Oppenheimer et al, "Project 1640: the world's first ExAO coronagraphic hyperspectral imager for comparative planetary science," 8447-72, Proc. SPIE Astronomical Telescopes and Instrumentation.

C. Zhai et al, "A first order wavefront estimation algorithm for P1640 calibrator," 8447-259, Proc. SPIE Astronomical Telescopes and Instrumentation.

J. E. Roberts et al, "Results from the PALM-3000 high-order adaptive optics system," 8447-34, Proc. SPIE Astronomical Telescopes and Instrumentation

T.N. Truong et al, "Design and implementation of the PALM-3000 real-time control system," 8447-87, Proc. SPIE Astronomical Telescopes and Instrumentation.

Provided by American Museum of Natural History