The Big Eye

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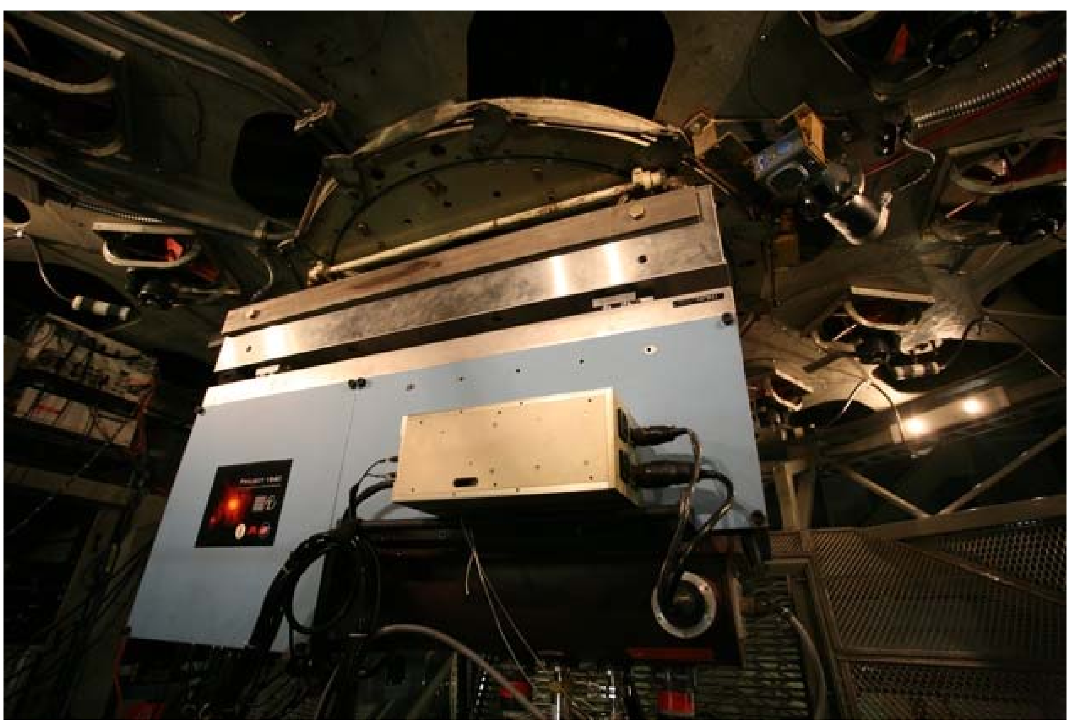
Project 1640 Sifts Through Starlight to Reveal New Worlds

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, a 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.



The Project 1640 instrument mounted at the focus of the 200-inch Hale telescope. (AMNH/B. R. Oppenheimer)

“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."

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THE PALOMAR OBSERVATORY DOCENT CORNER

George Ellery Hale, MIT and Cal Tech

by Mike Bertin, MIT '63, July 2012

I often begin my tours of the Hale telescope by asking our guests to look up at the dome of the 200 inch telescope and telling them that I call this building "the Cathedral of Astronomy'. The great cathedrals of Europe were soaring structures, inviting the faithful to cast their eyes to the heavens and marvel at the mysteries of creation. This lovely art deco building, observatory dome invites astronomers who come to Palomar Mountain, and all our visitors, to do the same, but to gaze through the prism of science.

We often don't know whose vision it was that brought about the building of great cathedrals in France, Spain, or Italy, but we know whose vision it was that brought about the construction of the cathedral of astronomy -- George Ellery Hale. Hale's name is not well known today, but he was the most important solar astronomer at the start of the 20th century, and he built the world's largest telescope four times -- first a 40 inch refractor at Yerkes Observatory in 1897, then the 60 inch reflector at Mount Wilson in 1908, the 100 inch Hooker Telescope at Mount Wilson in 1917, and finally the 200 inch telescope at Palomar. Hale died before his final accomplishment was complete, but when the telescope was dedicated in 1948 it was named in his honor.

Palomar Observatory is owned and operated by Cal Tech. But the founder of Palomar, George Ellery Hale, was an 1890 graduate of MIT. As an MIT graduate myself, and the longest serving docent in the public outreach program, I've taken a lot of kidding about my MIT pedigree. Last February, I had lunch in Pasadena with Andy Boden, Deputy Director for Caltech Optical Observatories, whose special responsibility is Palomar. After lunch Andy took me to the campus book store to buy me a gray T-shirt. On the front it had the stylized "MIT" logo of my alma mater. But on the back, touché, it said, "Because not everyone can go to Caltech" with a little palm tree tucked in along with the text. On the other hand I try to give as good as I get. Several times when Cal Tech students are brought to the observatory by their professors I wear my MIT sweatshirt to the event. As the docents are introduced I slowly open my outer jacket, revealing the MIT logo. As I'm doing this I tell them they've been lured off the campus so a team of students from MIT can once again steal the Cal Tech Fleming cannon. This Spanish American War cannon has sat in front of the Fleming House dorm on the Cal Tech Campus since the Vietnam Era, when Cal Tech students stole it from a military prep school[1,2].

In the early morning of March 28, 2006, when Cal Tech students are still sleeping, but MIT students are already hard at work, a crew of "movers" [MIT students !] absconded with the cannon, presenting phony work orders to the Caltech security guards who challenged them as they were removing it. The cannon was displayed on the MIT campus, adorned with a huge replica of the MIT ring (affectionately called "the brass rat" -- ask me to show you mine when I'm giving you a tour) and a white flag of surrender[3].

That spring a group of MIT women (and one smart guy) posed in bikinis with the cannon[3]. It was a great "hack" as pranks at MIT are known. But it was all in fun, and late in April a team of Cal Tech students and Cal Tech Alumni at MIT stole the cannon back. In its place, they left miniature cannon under glass and a note signed by the Fleming House president[4] -- they had reclaimed their legacy.

The ties between Cal Tech and MIT are much deeper than sophomoric pranks and rivalries for the honor of being the finest technical university in the world. The trail goes back to George

Ellery Hale. At MIT he met his lifelong friends, his classmate Harry Goodwin, and his chemistry instructor, Arthur Noyes. Goodwin was the best man at George Hale's wedding, and after MIT and for the rest of his life Hale consulted with Goodwin and Noyes whenever he had to make a major decision. By 1904 Hale was living in Pasadena, building the Mount Wilson Observatory and doing solar astronomy. In 1907, when MIT sought a new president, Noyes, on behalf of the MIT trustees, approached Hale to take the job. Hale turned down his old friend. Hale wanted to do research, not oversee a university. Noyes himself served as acting president of MIT from 1907 to 1909. Hale maintained close ties with MIT after graduation, returning often to speak there and writing to The Tech, the MIT student newspaper. For example, in a 1910 letter he urged physics grads at MIT to consider jobs at the new physics labs and observatories then being built. And in 1920 Hale turned the tables on Noyes. He invited Noyes to head the new Gates Chemical Lab at Cal Tech[5]. Noyes couldn't resist Hale and he became a major influence on the educational philosophy and the development of Caltech.

In 1907, at the suggestion of a Pasadena neighbor Hale became a member of the board of trustees of the obscure Throop Polytechnic Institute, which had been founded in 1891[6]. After WWI Hale helped bring Nobel Laureate Robert Millikan (who measured the charge of the electron) to Pasadena. Hale had known Millikan when both were young professors at the University of Chicago. Hale, Millikan, and Noyes helped re-invent Throop as the modern Cal Tech. There were strong MIT influences in the new university in Pasadena. Not the least of these are the mascots of Cal Tech and MIT -- both are beavers. The beaver appears prominently on the very recognizable MIT class ring -- hence the name Brass Rat.

Connections between MIT and Cal Tech remain strong today. Many bright young men and women spend part of their education, graduate or undergraduate, or their careers, at one school and then the other. One of Cal Tech's most famous faculty members, Richard Feynman, was MIT class of 1939. And there are many others. For me, being in a small way connected with the excellence of MIT and Cal Tech is the reward for being a Palomar docent. And I'm sure the kidding will continue -- in both directions.

There are two busts of George Ellery Hale on public display. One is in the lobby of the Hale Telescope dome, welcoming visitors, whether astronomers or not, from all over the world. The other is on the Cal Tech Campus, gazing east and up toward Mount Wilson. I have seen both. You may notice that on both busts the nose is shiny. They say that some people rub Hale's nose for good luck. That may be true.

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