Tiny planet-finding mirrors borrow from Webb Telescope playbook

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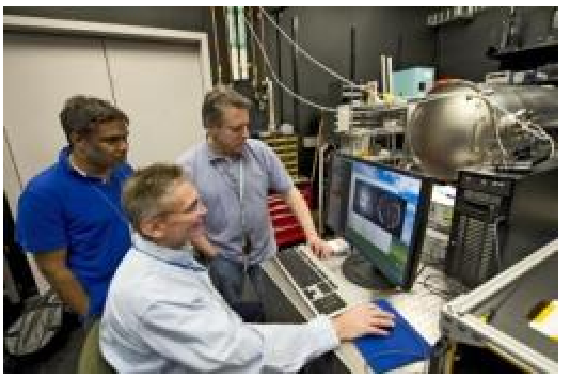

The Visible Nulling Coronagraph (VNC) combines an interferometer with a coronagraph to image and characterize Jovian-size planets. In this photo, Goddard scientists Rick Lyon (foreground) and Udayan Mallik (left), who are joined by Pete Petrone (right), an employee of Sigma Space Corporation in Lanham, Md., are monitoring the progress of wavefront control using the VNC, which is operating inside a vacuum tank. Credit: NASA/Chris Gunn

NASA's next flagship mission — the James Webb Space Telescope — will carry the largest primary mirror ever deployed. This segmented behemoth will unfold to 21.3 feet in diameter once the observatory reaches its orbit in 2018.

A team of scientists at NASA's Goddard Space Flight Center in Greenbelt, Md., now is developing an instrument that would image and characterize planets beyond the solar system possibly from a high-altitude balloon has borrowed a page from the Webb telescope's playbook. It has created an infinitely smaller segmented mirror that currently measures less than a half-inch in diameter and promises to revolutionize space-based telescopes in the future.

The multiple mirror array (MMA), now being developed by the Berkeley, Calif.-based Iris AO, Inc., under a NASA Small Business Innovative Research grant, is one of the enabling technologies on the Visible Nulling Coronagraph (VNC), a hybrid instrument combining an interferometer with a coronagraph — in itself a first. In laboratory tests, the VNC has proven that it can detect, image, and characterize likely targets. "Nearly all the technologies are completed or are on track," said Principal Investigator Rick Lyon of NASA Goddard, who, with his colleague, Mark Clampin, began working on the VNC more than three years ago.

As a result of that progress, the team hopes to apply the technology to a balloon-borne instrument called the Big Balloon Exoplanet Nulling Interferometer (BigBENI), which Lyon believes could be ready for operations as early as 2016. Carried on a gondola attached to a high-altitude balloon, the VNC-equipped BigBENI would be able to suppress starlight and increase the contrast of Jupiter- and ultimately Earth-sized planets.

The science that BigBENI could perform is compelling, Lyon added. At 135,000 feet — the altitude at which NASA balloons fly — Lyon estimates he could detect and image at least eight science targets in less than five hours and an additional six in about 20 hours. "BigBENI offers a nearer-term way to image planets" and search for specific chemicals that might indicate the presence of life — a long-sought science goal.

Mirror Array Central to Capability

Such a capability is due in large part to the tiny mirrors, Lyon said. "MMA is a legacy of the Webb telescope," he added. "Segmented mirrors are the future, not only for traditional observing missions like Webb, but also for non-traditional uses, like the one we've developed for planet finding. No other coronagraph has segmented mirrors."

Under the VNC/BigBENI concept — whose development NASA currently supports through several technology-development programs — starlight collected by a primary mirror or telescope travels down the instrument's optical path to the first of two beamsplitters within each arm of the VNC interferometer. The MMA is located in only one arm. A second beamsplitter recombines the beams into two output paths known as the "bright" and "dark" channels. The starlight passes to the bright and the planet light to the dark.

Because MMA is a mirror image of the telescope, it can see wavefront and amplitude errors caused by vibration, dust, and turbulence that prevent the light from being perfectly focused as it's collected. The MMA not only senses those errors, but also corrects them.

Algorithms that Lyon developed calculate errors in the telescope's wavefront and instruct MMA's 169 tiny nano-size segments — each measuring the width of three human hairs and perched atop tiny finger-like devices — to piston, tip, and tilt up to thousands of times per second to precisely correct the distortions and then cancel the starlight in the dark channel. A second technology, the spatial filter array, passively acts in concert with the MMA to further correct both amplitude and wavefront errors.

Combined, these technologies allow the mirror array to create an internal coronagraph to suppress starlight and increase the contrast of the circumstellar region surrounding a star, thereby allowing scientists to detect planets and dust disks. BigBENI's mirror array would contain 313 segments, Lyon said.

Applications Abound

While unique in its application as a coronagraph, MMA and its associated wavefront-sensing-and-control technologies, hold great promise for other applications, including medical imaging, LASIK eye surgery, and even military gun sights, Lyon said. But for NASA, the benefit lies in being able to fly less expensive telescopes.

"Ultimately with this technology, you can get away with a low-cost, low-risk primary mirror," Lyon said. In contrast, Webb's much larger segmented mirror was expensive to build. Technicians carefully constructed the mirror segments to an exact optical prescription and then mounted them on a mechanism that positions each to perfect alignment, much like the tiny fingers on MMA.

To assure a perfect focus, however, the Webb telescope will first image a target. After ground controllers have analyzed the image with multiple algorithms, they then can send commands to tweak the mirrors' alignment. This compares with MMA's ability to perform up to thousands of wavefront calculations per second, position the mirror segments, and then maintain a tight alignment — all from onboard the instrument.

"The idea is can we come up with something that is up to hundreds of times more precise than the Webb telescope's wavefront control? I think we can. We're doing it now in a standard lab. If you can do wavefront sensing and control fast enough, which we've proven, you can get away with a not-so-great telescope," Lyon said.

Provided by NASA's Goddard Space Flight Center