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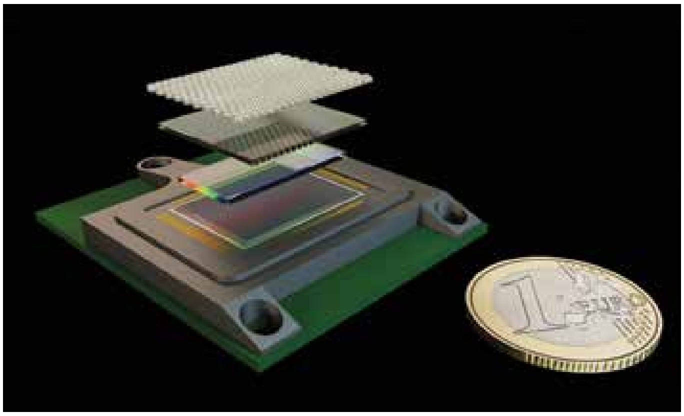
Exoplanet Earth: An Ultimate Selfie to Find Habitable Worlds



The LOUPE mission instrument (here with a 1-euro coin for scale) includes layers of liquid crystals that will continuously collect and analyze photons of light reflecting off the entire Earth disk. Credit: Jens Hoeijmakers

Twenty-five years after we discovered the first world orbiting another star, our exoplanet catalog numbers 4,301 and climbing. However, only about 51 exoplanets have been truly seen. This small collection of directly imaged worlds comprises a variety of stellar objects, from failed stars known as brown dwarfs to young Jupiter-like gas giants to the odd hellish lava world.

Each observed exoplanet was picked out from the glare of a nearby sun because of its extreme size, orbit, or temperature. Collecting light from more Earth-like planets remains beyond the reach of today's telescopes. The necessary technological refinement is only a matter of time, however, and the payoffs could be significant.

The Potential in Planetary Pixels

At Delft University of Technology in the Netherlands, researchers have been investigating what artificial intelligence (AI) algorithms could "see" within the light bouncing off more homelike exoplanets. Astrophysicist Dora Klindžić is particularly interested in light polarization—the orientations in which photons vibrate.

Polarimetry has long precedence in planetary science. In the 1970s, NASA's James Hansen used it to reveal that Venus's clouds were made of sulfuric acid. More recently, the Gemini Planet Imager in Chile conducted polarimetry surveys of the protoplanetary disks surrounding newly formed stars to directly image and measure the composition of any young gas giants.

Klindžić believes that the fingerprints of more terrestrial surface features are also being broadcast in the vibrating photons that rockier exoplanets reflect out into space. "If we have a planet which has clouds, liquid water, continents, snow, and ice, each one of these types of reflecting surfaces is going to be discernible in the polarization of light," she said.

Last year another team at Delft proposed a distinct color signature for polarized light bouncing off an imagined ocean exoplanet. However, Klindžić reasoned, if scientists are looking for signs of life, algorithms to analyze these planetary pixels need training on our only known living planet. This analysis means taking polarimetry off Earth to provide a whole-planet perspective. Klindžić is targeting the Moon as the ideal vantage point. Her new paper, published in *Philosophical Transactions of the Royal Society* in collaboration with colleagues at Leiden Observatory and the company cosine remote sensing, presents the LOUPE mission—the Lunar Observatory for Unresolved Polarimetry of the Earth (bit.ly/observing-exoplanets).

The mission will take what Klindžić describes as "the ultimate Earth selfie." Likely to resemble an unresolved pale blue dot, the selfie will contain all the polarimetric information coming off Earth's illuminated disk—a continuous stream of photons whose vibrations are shaped by their reflection off that familiar patchwork of weather systems, oceans, continents, and ice sheets, all rotating in and out of view. If an AI tool can learn to extract such surface and atmospheric features, scientists could characterize similar signatures from exoplanet light.

For a mission with such lofty aims, LOUPE is a modest instrument. A coin-sized spectropolarimeter weighing a few hundred grams, its key components are liquid crystals, like those in a laptop screen. These crystals will count Earth-reflected photons while characterizing their wavelength and polarization. Because of Earth's brightness in the Moon's sky, a stationary wide-field lens will avoid the need for any mechanical point and focus system. This lens will keep weight and power requirements low, allowing LOUPE to piggyback on a future rover or lander or even on the planned lunar Gateway space station.

Looking at Earth in a New Light

Klindžić is not alone in looking to Earth to better understand worlds far beyond. At NASA's Jet Propulsion Laboratory, Jonathan Jiang is training his own AI on simulated exo-Earth pixels based on the photon flux data collected by the DSCOVR satellite. At the University of Colorado Boulder, Allison Youngblood used the Hubble Space Telescope to explore the earthshine reflected off the Moon during a blood moon eclipse. She detected ultraviolet signals of atmospheric ozone, a potential biosignature.

"Polarimetry provides many more details than traditional imaging or spectroscopy. So even though direct imaging of Earth-sized planets is several decades away, it really is the future for exoplanet characterization. I think it's important to do experiments like LOUPE now, when the telescopes that will directly image exoplanets are still being designed," said Youngblood.

The Delft team is building LOUPE prototypes with a 2022 launch window in mind and an eye on proposed coronagraphic telescopes, such as the Nancy Grace Roman Space Telescope, which will mechanically block starlight to reveal orbiting exoplanets. Klindžić also points to polarimetry instruments planned for NASA's Habitable Exoplanet Observatory and Large UV/Optical/IR Surveyor mission concepts and believes LOUPE's benchmark signal for an archetypal Earth could help these missions bring some distant, but perhaps familiar, worlds into focus.

"We are looking at ourselves to know others," Klindžić said.

By **James Romero** (@mrjamesromero), Science Writer