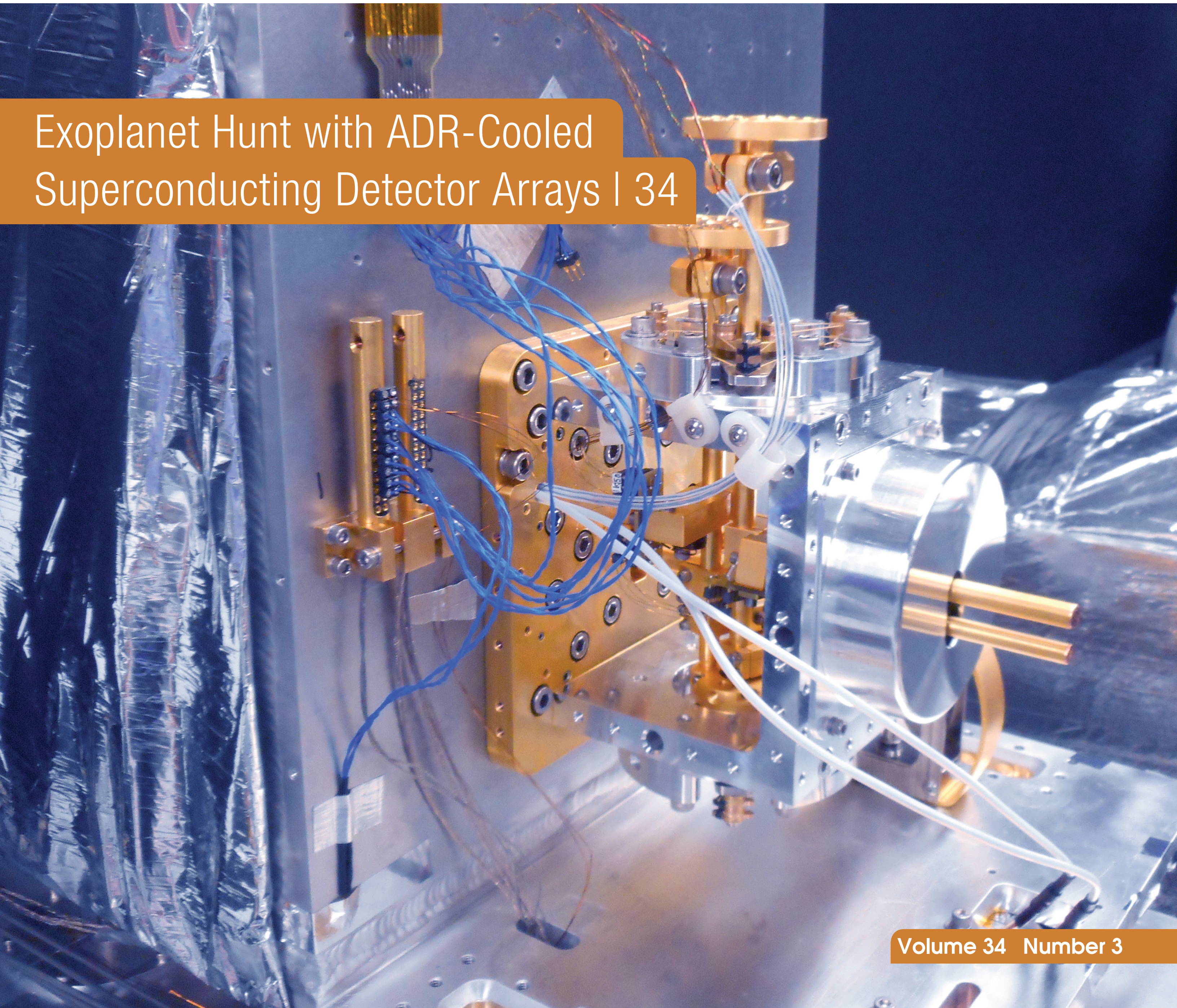
Cold Facts INTERNATIONAL

The Magazine of the Cryogenic Society of America, Inc.

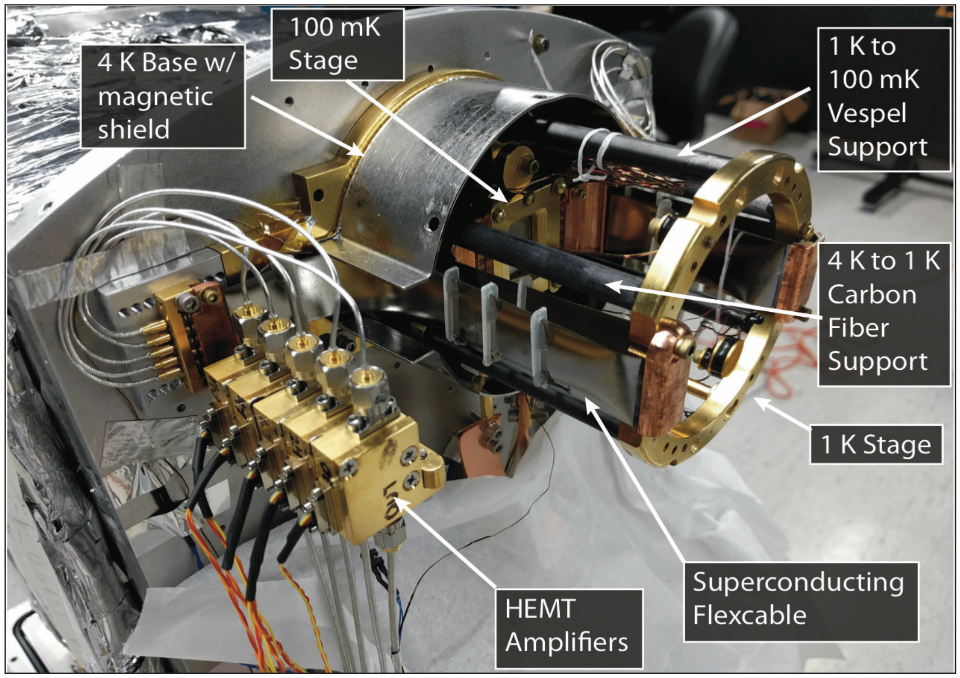


Exoplanet Hunt with ADR-Cooled Superconducting Detector Arrays | 34

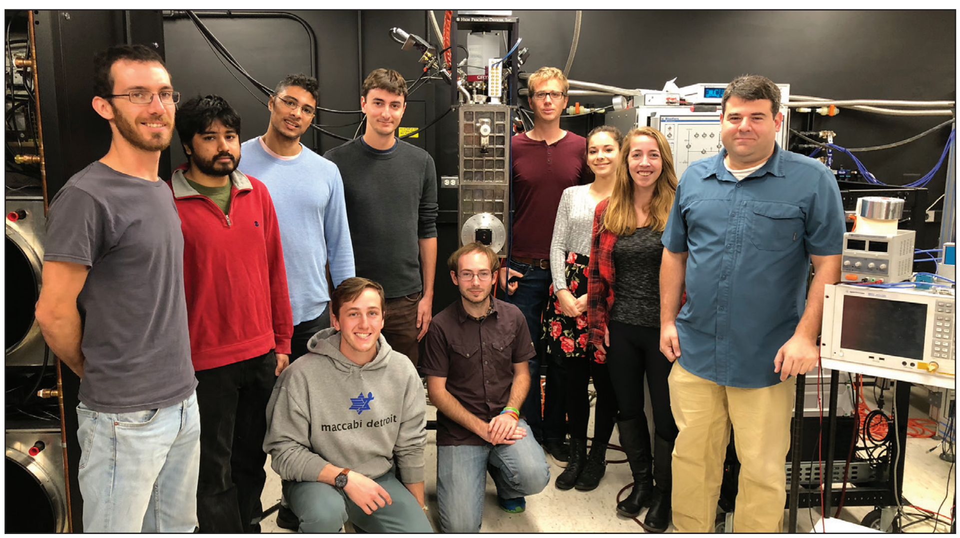
34

Volume 34 Number 3

Researchers Hunting Exoplanets with Superconducting Arrays



A look inside the DARKNESS cryostat. *Image: Mazin*



The astronomy team working with Dr. Mazin (right). *Image: Mazin*

The key to revealing the exoplanets tucked away around the universe may just be locked up in the advancement of Microwave Kinetic Inductance Detectors (MKIDs), an array of superconducting detectors made from platinum sillicide and housed in a cryostat at 100 mK.

An astronomy team led by Dr. Benjamin Mazin at the University of California Santa Barbara is using MKID arrays for research on two telescopes, the Hale telescope at Palomar Observatory near San Diego and the Subaru telescope located at the Maunakea Observatory on Hawaii. Mazin began work on MKIDs nearly two decades ago while working under Dr. Jonas Zmuidzinas at Caltech, who co-pioneered the detectors for cosmic microwave background astronomy with Dr. Henry LeDuc at JPL.

Mazin has since adapted and advanced the technology for the direct imaging of exoplanets. With direct imaging, telescopes detect light from the planet itself, recording either the self-luminous thermal infrared light that young—and still hot—planets give off, or reflected light from a star that bounces off a planet and then towards the detector.

Researchers have previously relied on indirect methods to search for exoplanets, including the radial velocity technique that looks at the spectrum of a star as it's pushed and pulled by its planetary companions; and transit photometry, where a dip in the brightness of a star is detected as planets cross in front of the disk of the star.

There are several Earth-based telescopes that use other direct imaging techniques, including SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch) and GPI (Gemini Planet Imager), both in Chile. The primary advantage of using MKIDs over conventional detectors, according to Mazin, is the absence of read noise and dark current, and a fast readout time, the equivalent of a couple thousand frames per second. The arrays also have the ability to determine the wavelength and arrival time of every photon, information important for distinguishing a planet from scattered or diffracted light called speckles. "Using the time information of the photon arrival time, combined with built-in spectroscopy and the zero read noise that the MKIDS provide, allows us to do a better job of suppressing the background and detecting the planets," he says.

The MKID detectors—called DARKNESS (DARK-speckle Near-infrared Energy-resolved Superconducting Spectrophotometer) at Palomar and MEC (MKID Exoplanet Camera) at Maunakea—act as both science cameras and focal-plane wave-front sensors, measuring the light and then sending a signal back to a mirror that can form into a new shape 2,000 times a second. The process cleans up atmospheric distortion that causes stars to twinkle by suppressing the starlight and enabling higher contrast ratios between the star and the planet.

The instruments use Adiabatic Dilution Refrigerators (ADRs) provided by HPD (CSA CSM) to reach 100 mK. "At Subaru, where our MEC instrument is stationary, we have a Cryomech (CSA CSM) pulse tube that gets us to about 4 K and then an ADR that takes us down to 100 mK. On DARKNESS, we use a liquid helium/liquid nitrogen-cooled ADR because there wasn't an easy way to get the hoses from the pulse tube to where the instrument rests."

In both cases, the ADRs have to last about 12 hours so the team doesn't have to recycle the magnet during the night. Mazin says the team undertook a lot of cryogenic engineering in order to get the heat load on the low temperature stage down below a microwatt, involving the development of niobium-titanium-based flex cables—to bring the microwave signals down with a very low heat load—and custom infrared blocking filters to prevent thermal infrared backgrounds from heating up the detectors.

The team also uses dilution refrigerators in its lab for MKID materials research below 100 mK. Mazin says the team can make an array in about three or four days, allowing the researchers to update the arrays used on the telescopes between runs. With DARKNESS, that's only a few times a year, but the MEC instrument on Subaru will be permanently mounted, allowing for more research time.

Preliminary results from the MKID detectors are promising, according to Mazin. "We're hoping that the combination of the resolution, the more advanced control techniques and the photon arrival time information is going to allow us to reduce the contrast floor from about 10^{-6} that researchers get on conventional instruments down to the 10^{-7} or 10^{-8}, where we'll be able to start seeing planets in reflected light from their stars instead of just their self-luminous thermal infrared."

In the next five to ten years, Mazin wants to push for contrast ratios that allow the team to detect Jupiter-mass planets. He says that goal is reasonable even with the limitations of current 8- to 10-meter telescopes on the ground. His long-term goal involves developing a PSI (Planetary System Imager) for TMT (Thirty Meter Telescope), a project set for development either in Hawaii or the Canary Islands. "Going from an 8-meter to a 30-meter telescope is something like an improvement of 200 in your ability to detect planets," Mazin says. "So, as soon as that telescope is built we expect things to open up and we'll be able to look at planets that are much closer to their stars than we can now."

There is also a more remote possibility of spaceborne missions. Plans for two of the telescope missions NASA is considering for the 2030s—LUVIOR and HabEx—call for direct imaging solutions. The challenge for Mazin's team, he says, is finding a way to actually test the technology in space. "There's a long way to go before all the barriers to getting these detectors in space are overcome, but it's something that my lab is working on and we'll have to see." ■