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Redshift into Focus

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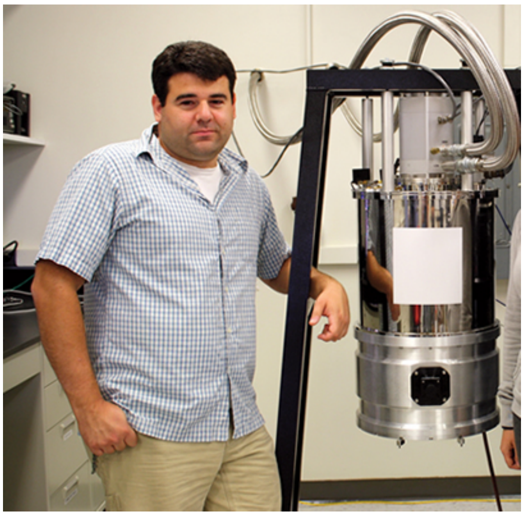
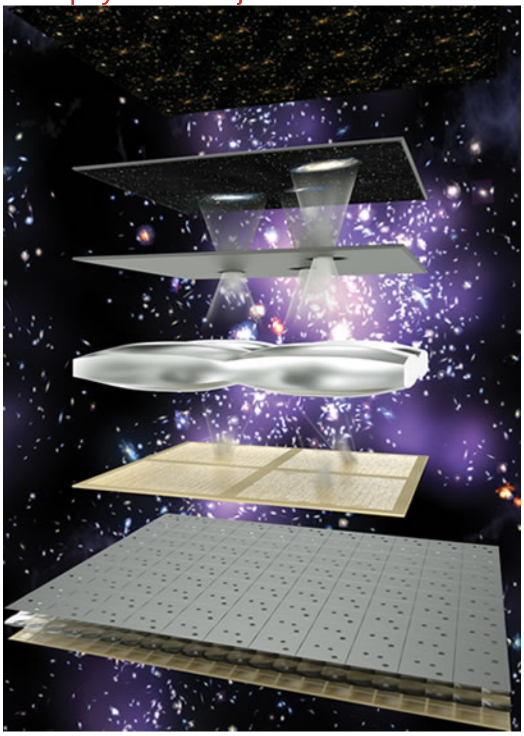
Astrophysicists are designing a detector that could accelerate our understanding of Dark Energy and reveal new stellar energies



Astrophysicist Benjamin Mazin stands next to an MKID detector.



Microwave Kinetic Induction Detector (MKID)
Artist?s (Peter Allen) concept of a Superconducting Multobject Spectrograph (SuperMOS). As described by Benjamin Mazin, ?The light from the telescope

passes through a metal mask in the focal plane that contains holes drilled at the known locations of astronomical objects. The light from the object passes through the hole, but the light from neighboring objects and sky background is rejected. A reimaging system focuses the light that gets through the mask onto a large plate scale MKID array positioned behind it, providing low resolution optical through near-IR spectroscopy. This allows the light from a single object to be mapped to a single MKID, allowing scaling to a very large number of simultaneous objects.?

Redshift into Focus

By scanning at a low resolution, a revolutionary new detector developed by UCSB astrophysicists could accelerate our understanding of Dark Energy and the Universe

BY SONIA FERNANDEZ

Call it a wide shot on the universe: Microwave Kinetic Induction Detectors (MKID), a technology being developed by UC Santa Barbara astrophysics [2] assistant professor Benjamin Mazin [3] and an international team of colleagues, promises to give astronomers a new ? and markedly more efficient ? way to measure the light given off by celestial entities such as galaxies and supernovae.

?One of the hardest things in astronomy is figuring out what to look at. The sky is pretty big,? Mazin said, aptly summarizing one of the key problems faced by astronomers and astrophysicists. You almost can?t see the forest for the trees ? or, in this case, the Universe for the stars.

With the increasing sensitivity of astrophysical instrumentation, it?s possible to discover galaxies billions of light years away, but it has proven difficult ? and expensive ? to get detailed information on these faint sources.

?Using low resolution spectroscopy, MKID technology [4] will be incorporated into instruments that can return spectra of billions of galaxies instead of the millions one gets with traditional multi-object spectroscopy,? said Mazin. It has the potential to save countless hours by allowing scientists to look at a broad brush picture of the sky and then hone in on the elements of interest.

?It?s a leap of a factor of 1,000 in the number of sources you can take spectroscopic data on,? he said. ?It opens up this massive new parameter space.?

Mazin and his lab, which includes postdoctoral scholars Danica Marsden and Gerhard Ulbricht; and graduate students Seth Meeker, Eric Langman, Matt Strader, and Paul Szypryt are the only group in the world that is working with optical UV and near infrared superconducting detectors for astronomy. Other researchers ? including Mazin?s grad school mentors and MKID pioneers Jonas Zmuidzinas and Sunil Golwala at Caltech [5], and Rick LeDuc at the Jet Propulsion Laboratory [6] ? have used MKID with success in the sub-millimeter wavelength ranges.

Mazin is also working with other research groups at UCSB, including professors Crystal Martin [7] and Tommaso Treu [8]. Treu?s research team is tracking observations as part of the Brightest of Reionizing Galaxies [9] (BoRG) survey using the Hubble Space Telescope. They made news earlier this year when the project spotted the most distant galaxy protocluster ever observed, developed at an estimated 600 million years after the Big Bang. For the astronomy layperson, this is very young on the timeline of the origins of the Universe.

Off campus, Mazin is collaborating with UCLA?s Infrared Instrumentation Lab, Caltech, Yale Astronomy, and University of Illinois, to build two detectors called Mega-*z* and Giga-*z*. When hooked up to powerful telescopes, both instruments will allow scientists to observe and measure two of the most intriguing phenomena in astrophysics: Dark Energy and the related accelerating expansion of the Universe. At UCSB, Treu and Martin are also collaborators on Giga-*z*.

The ?*z*? in Mega-*z* and Giga-*z* represents the astronomical term for redshift?a Doppler-effect phenomenon that occurs as light sources move father away from the observer and shift towards the longer-wavelength red end of the spectrum. Mega-*z*, which is currently in the proposal stage, is planned for installation at the Keck Observatory [10] 10 meter telescopes in Hawai?i to measure the redshifts of a million very faint galaxies.

Dark Energy is another mystery that MKIDs could help illuminate. A hypothetical mass-energy that dominates three quarters of the universe, Dark Energy is credited for the universe?s accelerating expansion.

?We know the universe?s expansion has been accelerating. That?s something that was discovered a decade ago by Hubble,? said Mazin. It was the Hubble Space Telescope observation that galaxies that are constantly moving away from the observer, and from each other due to the constant expansion of the universe, that won Saul Perlmutter, Brian P. Schmidt, and Adam G. Riess the 2011 Nobel Prize [11]. ?It totally changed the way people look at the universe.?

?While astronomers and astrophysicists now know something weird is going on out there,? said Mazin, ?we?re only slightly closer to understanding it, and it doesn?t look like it will be the kind of thing that physics experiments in the lab are going to have the power to probe.?

Enter Giga-*z*, a far more ambitious instrument, which would be able to detect the redshift of billions of galaxies. By looking at the galaxies? angular correlation function, astrophysicists will be able to determine their distances from one another.

?When you do that, you find that there?s a scale built into the expansion and structure of the universe, imprinted by inflation. It?s a scale of 150 co-moving megaparsecs,? Mazin said. Using a technique called Baryon Acoustic Oscillation (BAO) as a ruler, and then observing how that scale changes over time, astronomers can get a measurement of the rate of change of the universe?s expansion. This, Mazin said, could give astronomers more information about Dark Energy, helping to identify the physics behind it.

What makes Mega-*z* and Giga-*z* unique is the built-in spectral resolution of the MKIDs, which allows the use of direct lens-coupled, aperture mask spectroscopy as opposed to the more conventional, expensive, and complicated fiber-fed spectroscopy. Fiber-fed instruments can take the spectra of about 5,000 galaxies at a time, while the MKID devices can measure 100,000, or a million at a time, a far more efficient use of the telescope, said Mazin.

?The wavelength coverage also extends to the near infrared,? he added, ?which is extremely important for observations of high redshift galaxies.? The low-resolution aspect also allows scientists to measure some of the physical properties of the galaxy, including the stellar population, stellar ages, metallicities, and redshift.

?It?s broad brush astronomy but we?ll be doing it on 1,000 times more galaxies than anything else has done. That is where the real power comes in,? said Mazin.

Mazin and his colleagues are seeking the funds to build the approximately $3 million Mega-*z* instrument?a much smaller pricetag compared to a conventional fiber-fed instrument at $100 million. Should they get the funding, said Mazin, the Mega-*z* will take about three or four years to build. Once built, it?s headed for the Keck telescope for about 20 to 30 nights of observation over a two-year period.

?Then we would have a big science team work on extracting as much science as we can from these observations, and that science is going to be very broad,? Mazin said. Galaxy evolution, active galactic nuclei, and subluminous dwarf galaxies around the Milky Way are all part of the research, said Mazin, with spectroscopy that goes deeper than the current magnitude of the faintest surveys. ?We?ll be looking at galaxies with i-band magnitude between 24 and 26.?

They?ve already assembled a prototype called ARCHONS, the ARray Camera for Optical to Near-IR Spectrophotometry, a simpler version of Mega- and Giga-*z*. The team has tested it at Caltech?s Palomar telescope [12] and the Lick Observatory [13] in the Diablo Range near San Jose.

In the optical and near-infrared ranges, Mazin said he predicts MKIDs becoming a standard replacement for charge-coupled device (CCD)-based instruments for many applications in the next few decades.

?This technology will completely revolutionize astronomy,? said Omer Blaes [14], chair of the Physics [15] department at UCSB. ?Right now most astronomers use CCDs, the same detectors in digital cameras. The detectors aren?t sensitive to different energies. These MKIDs will both sense the photons and measure their energy simultaneously. You can measure rapidly variable sources all with a simple detector.?

Mazin credits his ?coming of age? as an astronomer in this era of precision cosmology as the inspiration for using this novel way of observing the universe.

?It brought up some very interesting questions and pointed out that between Dark Matter and Dark Energy we have 96 percent of the universe that we don?t understand. There?s still a ton of work to do and I?m happy to be part of it,? he said.

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