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IMAGING DETECTORS: Innovative CMOS circuitry helps detectors resist radiation damage

Scientists at Rochester Institute of Technology (RIT) and the University of Rochester (both Rochester, NY) have been awarded $592,000 from the NASA Planetary Instrument Definition and Development Program to design, build, and test, in collaboration with NASA scientists, an imaging detector specifically for use in harsh extraterrestrial environments.

Goals for the device include smaller size, less power consumption, and more radiation tolerance than technology currently in use. Achievement of these goals will lead to lower mission costs and greater scientific productivity, notes Donald Figer, director of the Rochester Imaging Detector Laboratory (RIDL) at RIT and lead scientist on the project. “But, ultimately, radiation immunity is the focus,” he says.

High-energy particles permeate space and can damage electronics by disrupting sites in the crystal lattice of a semiconductor, Figer explains. Once damaged, the material has a higher dark current and a greater probability of trapping photogenerated charge. Together, these effects reduce the sensitivity of a detector, ultimately limiting mission lifetime. One possible solution would be to add heavy shielding to block radiation, but the resulting costs in weight, and potentially in thermal mass, would be prohibitive.

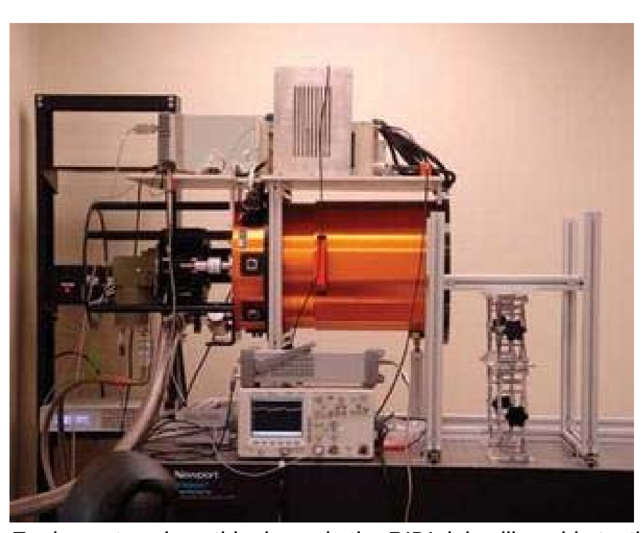
Figer’s team has set out to develop a new detector design based on a marriage of beneficial qualities from CCD and CMOS detectors. CCD detectors, which are most often used for space missions, offer very low noise, but the desirable noise performance is gradually degraded by radiation damage. While CMOS detectors offer intrinsically higher radiation resistance than CCDs, they start out with a relatively high read noise.

CMOS devices tend to have higher radiation resistance because the photogenerated charge is read out immediately from each pixel, rather than receiving prolonged radiation exposure while clocking across an entire CCD prior to readout. Therefore, the Rochester design uses low-power CMOS circuits arranged in high-density packaging within individual pixels to further enhance radiation resistance.

“The effects of radiation are vastly reduced because of a number of features of our design,” Figer says. “First, we convert charge in a pixel at that pixel, rather than transferring it across thousands of other pixels, as in a CCD. Second, our measurement is purely differential. So a charge hit by radiation can be easily identified as a huge, sudden spike in the signal and removed in real time. Note that in a CCD, once a pixel is hit, its signal for that exposure is worthless. Finally, because our circuit is highly differential, it is not subject to long-term voltage drifts due to radiation damage.”

The researchers achieve CCD-comparable read-out noise by sampling the signal using a sigma-delta analog-to-digital (A/D) circuit with a feedback path that restores charge to the charge-collection node. The new detector is based on a patented technology invented by Zeljko Ignjatovic and colleagues at the University of Rochester, and commercialized through Signal Sciences (Rochester, NY).

So far, the team has fabricated and measured performance in early design prototypes. The researchers expect to ultimately achieve read noise on the order of 0.3 electrons, less than a third of the noise of current CCD technology, and power consumption of 0.88 nW per pixel, three orders of magnitude less than CCDs and more than one order of magnitude less than current CMOS technology.



Equipment such as this dewar in the RIDL lab will enable testing of the overall system to determine how the sensors hold up in cryogenic environments. (Courtesy of Rochester Institute of Technology)
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During the course of the three-year project the device will be tested at the RIDL, a new facility established to develop detector technologies for next-generation ground-based and space telescopes (see figure). In addition to Ignjatovic, Figer’s team includes Zoran Ninkov from RIT, Melissa McGrath from NASA Marshall Space Flight Center (Huntsville, AL), and Shouleh Nikzad from NASA Jet Propulsion Laboratory (Pasadena, CA).

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Planetary 3-D Roadmaps

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ROCHESTER, N.Y., May 16, 2008 – A team of researchers at Rochester Institute of Technology (RIT) led by scientist Donald Figer, are developing an image detector that is out of this world. The new Lidar (light detection and ranging) imaging detector uses light, instead of radio waves, to measure distance and other features of celestial bodies.

In conjunction with MIT's Lincoln Laboratory, RIT's Imaging Detector Laboratory (RIDL) is creating the optical/ultraviolet imaging Lidar detector with the hope that it will provide 3-D location information for planetary surfaces. These "roadmaps" will provide robots, astronauts and engineers details about atmospheric composition, biohazards, wind speed and temperature. Information like this could help land future spacecraft and more effectively navigate roving cameras across a Martian or lunar terrain.


The Lidar imaging detector unit.

The devise will consist of a 2-D continuous array of light sensing elements connected to high-speed circuits.

"The imaging Lidar detector could become a workhorse for a wide range of NASA missions," says Figer, RIT professor and director of the RIDL. "It could support NASA's planetary missions like Europa Geophysical Orbiter or a Mars High-resolution Spatial Mapper."

Lidar works by measuring the time it takes for light to travel from a laser beam to an object and back into a light detector. The new detector can be used to measure distance, speed and rotation. It will provide high-spatial resolution topography as well as measurements of planetary atmospheric properties – pressure, temperature, chemical composition and ground-layer properties. The devise can also be used to probe the environments of comets, asteroids and moons.

The team, consisting of Figer, Zoran Ninkov and Stefi Baum from RIT and Brian Aull and Robert Reich from the Lincoln Laboratory, will apply Lidar techniques to design and fabricate a Geiger-Mode Avalanche Photodiode array detector. The devise will consist of an array of sensors hybridized to a high-speed readout circuit to enable robust performance in space. The radiation-hard detector will capture high-resolution images and consume low amounts of power.

The imaging component of the new detector will capture swaths of entire scenes where the laser beam travels. In contrast, today's Lidar systems rely upon a single pixel design, limiting how much and how fast information can be captured.

"You would have to move your one pixel across a scene to build up an image," says Figer. "That's the state of the art Lidar right now. That's what is flying on spacecraft now, looking down on Earth to get topographical information and on instruments flying around other planets."

The Lidar imaging detector will be able to distinguish topographical details that differ in height by as little as one centimeter. This is an improvement in a technology that conflates objects less than one meter in relative height. The Lidar that is currently used could confuse a boulder for a pebble, an important detail when landing spacecraft.

"You can have your pixel correspond to a few feet by a few feet spatial resolution instead of kilometer by kilometer," Figer says. "And now you can take Lidar pictures at fine resolutions and build up a map in hours instead of taking years at comparable resolution with a single image."

The imaging Lidar detector will be tested at RIDL in environments that mimic aspects of operations in NASA space missions.

In addition to planetary mapping, imaging Lidar detectors will have uses on Earth, such as remote sensing of the atmosphere for both climate studies and weather forecasting, topographical mapping, biohazard detection, autonomous vehicle navigation, battlefield friend/foe identification and missile tracking, to name a few.

RIT's $547,000 Lidar program is funded by NASA, and includes a potential $589,000 phase for fabrication and testing.

For more information, visit: www.rit.edu .

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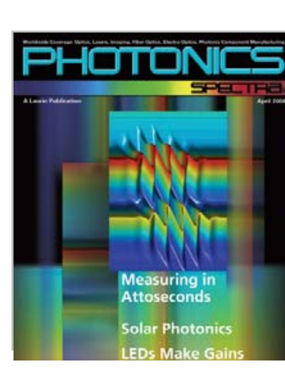

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Detector Resists Radiation

ROCHESTER, N.Y., Aug. 15, 2007 -- An imaging detector promises to revolutionize future NASA planetary missions with technology that could withstand the harsh radiation environments in space.

Scientists from Rochester Institute of Technology (RIT) and University of Rochester (UR) won $592,000 from the NASA Planetary Instrument Definition and Development Program to design, build and test a detector that should be resilient against radiation damage. The lightweight device will be smaller and consume less power than technology currently in use. The novel readout circuitry design will give the device a radiation tolerance not possible in standard optical detectors.

“All these benefits will lead to lower mission costs and greater scientific productivity,” said Donald Figer, director of the Rochester Imaging Detector Laboratory at RIT and lead scientist on the project, in an RIT press release. “But ultimately, radiation immunity is the focus.”

Figer’s team includes Zeljko Ignjatovic from UR, Zoran Ninkov from RIT, Melissa McGrath from NASA Marshall Space Flight Center and Shouleh Nikzad from NASA Jet Propulsion Laboratory.

“Our detector captures images directly in the digital domain at the pixel level rendering subsequent signal transmission less susceptible to cosmic radiation environment,” said Ignjatovic, assistant professor of electrical and computer engineering.

The new detector is based on a technology created by Ignjatovic and his colleagues at UR in which each pixel reads and converts its signal from analog to digital immediately upon capture. Standard optical detectors lack this capability. Instead, signals must travel along a line of sensors to reach a readout circuit. This wastes energy and leaves the signal vulnerable to radiation damage that degrades the circuit over time.

“Radiation-tolerant detectors are a critical need for NASA in the continued exploration of the solar system,” said McGrath, chief scientist in the Science and Mission Systems Office at NASA Marshall Space Flight Center.

Stefi Baum, director of the Chester F. Carlson Center for Imaging Science at RIT, said, “In space astronomy and planetary missions, detectors are frequently the critical pacing item. By developing detectors with greatly reduced noise properties and greatly enhanced tolerance to radiation damage -- the chief lifetime limiter of detectors in space -- the collaboration should dramatically improve the reach in sensitivity and lifetime of the missions to explore and understand the nature of the planets with which we share our solar system.”

Testing the overall system will determine how the sensors hold up in cryogenic environments in which the detector is cooled to very low temperatures, imitating conditions in space. The device will be tested at RIT's Rochester Imaging Detector Laboratory, a new facility to develop detector technologies for next-generation ground-based and space telescopes.

The imaging detector under development will boast a dynamic range and greater short wavelength sensitivity. Figer said the detector could become a key technology for future planetary missions in the most severe radiation environments. The technology could figure heavily in missions under consideration for NASA’s Discovery, Mars Exploration and New Frontiers programs.

It might someday be used to capture hyperspectral imaging from a platform orbiting the outer planets or their satellites. Cameras looking down on Europa could take a picture of every wavelength at every pixel.

“We could use that information to figure out if there are lakes of water on Europa or hydrocarbons on Titan,” Figer said. “We can figure out the composition of a surface without having to land on it, which we might want to do 10 years later. Then we would know where to land.”

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Mystery Of Quintuplet Stars In Milky Way Solved

ScienceDaily (Aug. 18, 2006) — For the first time, scientists have identified the cluster of Quintuplet stars in the Milky Way's galactic center, next to the super massive black hole, as massive binary stars nearing the end of their life cycle, solving a mystery that had dogged astronomers for more than 15 years.

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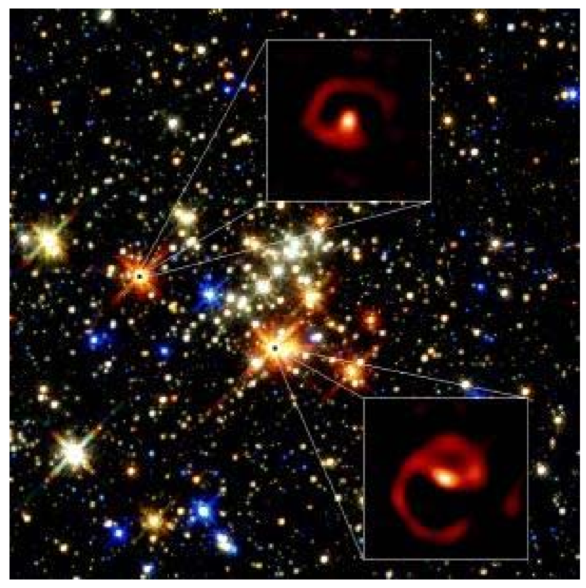

A Yin and Yang in the Galactic Center. High-resolution infrared images of the dusty pinwheel nebulae are shown inset overlaid on a Hubble Space Telescope image of the Quintuplet cluster. Each of the five bright red stars is now thought to be a pinwheel nebula. (Image Credit: Peter Tuthill (Sydney U.), Keck Observatory, Donald Figer (RIT))

The nature of the stars was not entirely clear until now. In a paper published in the Aug. 18 issue of Science, co-authors Peter Tuthill of the University of Sydney and Donald Figer of Rochester Institute of Technology show that the Quintuplet cluster consists of young massive binary stars that produce large amounts of dust. Their data reveal that five bright red stars are nearing the end of their "short" lives of approximately 5 million years. These quickly evolving stars burn fast and bright, but die younger than fainter stars, which live for billions of years. The study captures the Quintuplet stars just before disintegrating in supernovae explosions.

Using advanced imaging techniques on the world's biggest telescope at the W.M. Keck Observatory in Hawaii, the scientists captured the stars at the highest attainable resolution for the instrument, far exceeding the capability of the Hubble Space Telescope, which imaged the cluster a decade ago. The extra-resolution gives scientists a new glimpse of the dust plumes surrounding the stars and the swirling spirals Tuthill likened to pinwheels when he identified the first one in 1999 elsewhere in the galaxy.

"Only a few pinwheels are known in the galaxy," Figer says. "The point is, we've found five all next to each other in the same cluster. No one has seen anything like this before."

According to Figer, the swirling dust in pinwheel stars is key to the presence of the most evolved massive stars and points to the presence of pairs of stars. The geometry of the plume allows scientists to measure the properties of the binary stars, including the orbital period and distance.

"The only way that pinwheels can form is if they have two stars, swirling around each other. The stars are so close that their winds collide, forming dust in a spiral shape, just like water sprayed from a garden hose of a twirling sprinkler," Figer says. "A single star wouldn't be able to produce the dust and wouldn't have the spiral outflow."

An earlier study by Figer in 1996 claimed the Quintuplet cluster consists of evolved massive stars that produce dust. Figer's research could not be confirmed until now with the use of the Keck telescope.

"If you want to understand star formation, you have to understand if they are forming alone or if they have partners," Figer says. "The answer gives us a clue as to whether stars form alone or with companions."

Adapted from materials provided by Rochester Institute of Technology.

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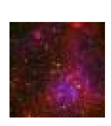

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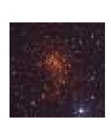

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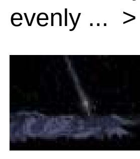

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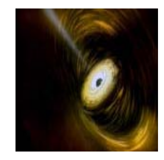

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New Imaging Detectors Could Take Snapshots From Deep Space

Rochester NY (SPX) Aug 16, 2007
by Staff Writers

Snapshots from space may someday confirm the presence of lakes and oceans on Europa-one of Jupiter's moons-and on other planetary bodies. Imaging detectors that capture information from every wavelength in the electromagnetic spectrum could detect the presence of liquid methane or hydrocarbons, the stew that just might sustain microbial life forms.

An imaging detector under development by a team of scientists from Rochester Institute of Technology and University of Rochester promises to revolutionize future NASA planetary missions with technology that could withstand the harsh radiation environments in space.

The team won $592,000 from the NASA Planetary Instrument Definition and Development Program to design, build and test a detector that should be resilient against radiation damage. The lightweight device will be smaller and consume less power than technology currently in use. The novel readout circuitry design will give the device a radiation tolerance not possible in standard optical detectors.

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"In space astronomy and planetary missions, detectors are frequently the critical pacing item," adds Stefi Baum, director of the Chester F. Carlson Center for Imaging Science at RIT. "By developing detectors with greatly reduced noise properties and greatly enhanced tolerance to radiation damage-the chief lifetime limiter of detectors in space-the collaboration should dramatically improve the reach in sensitivity and lifetime of the missions to explore and understand the nature of the planets with which we share our solar system."

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The detector might someday be used to capture hyperspectral imaging from a platform orbiting the outer planets or their satellites. Cameras looking down on Europa could take a picture of every wavelength at every pixel. "We could use that information to figure out if there are lakes of water on Europa or hydrocarbons on Titan," Figer says. "We can figure out the composition of a surface without having to land on it, which we might want to do 10 years later. Then we would know where to land."

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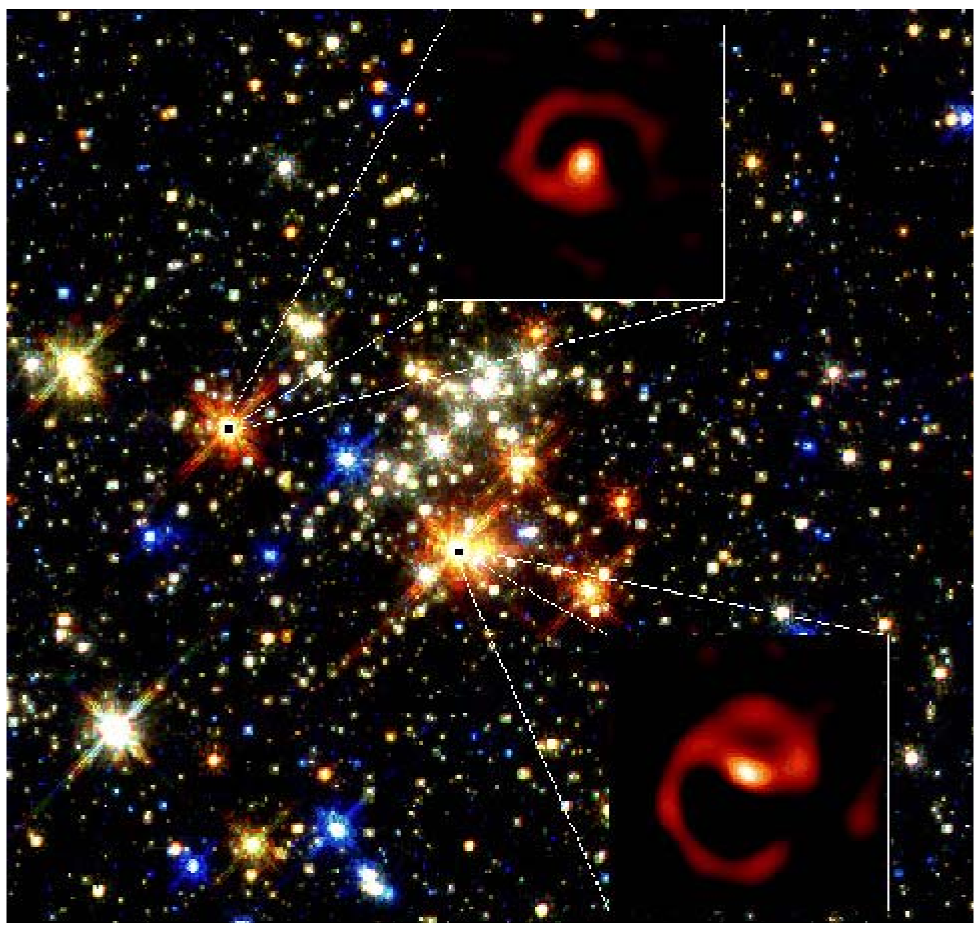
Quintuplet stars sport "pinwheels"

Dusty spirals reveal binary stars in the massive Quintuplet cluster.

Francis Reddy



Dusty spirals around two of Quintuplet's red stars reveal each to be a binary. *Keck Observatory / Peter Tuthill and Don Figer* [larger image]

August 17, 2006

The discovery of dusty pinwheels around two stars in the Milky Way's Quintuplet cluster reveals each contains a pair of stars instead of just one. The finding puts to rest debate among astronomers over the nature of these dust-cocooned stars.

A team led by Peter Tuthill, an astrophysicist at Australia's University of Sydney, investigated the cluster's brightest stars using the giant telescope at Keck Observatory in Hawaii. Quintuplet, named for its five prominent red stars, is one of our galaxy's most massive clusters. But its brightest stars have been hard to view in detail because they're quite distant — about 26,000 light-years away — and each is wrapped in a light-reddening shroud of dust. Quintuplet holds many Wolf-Rayet stars — a type thought to be the immediate precursors of supernovae.

"Only a few pinwheels are known in the galaxy," says team member Don Figer, an astronomer at the Rochester Institute of Technology in New York. "We've found five all next to each other in the same cluster."

The astronomers obtained cluster images with the greatest resolution yet, but they were unable to penetrate completely the stars' dusty shroud. Nevertheless, the new images allowed the team to see that the dust forms spirals. The geometry of the plume allows scientists to measure the properties of the binary stars, including orbital period and distance.

Tuthill and team member John Monnier of the University of Michigan at Ann Arbor had seen this before. In 1999, they identified dust pinwheels around two other Wolf-Rayet stars (WR 104 and WR 98a). The spiraling dust forms when a Wolf-Rayet star's violent outflow, called a stellar wind, collides with a similar outflow from an orbiting companion star. The interacting winds create the spiraling dust stream.

Quintuplet's stars show the same type of spiral, which tells researchers each is actually two or more stars and demonstrates that Quintuplet's most massive members are smaller than previously thought. The findings will appear in Friday's issue of the journal *Science*.