National Aeronautics and Space Administration

goddard tech trends

A New Frontier in X-ray Astronomy?

Volume 4 | Issue 4 | Summer 2008

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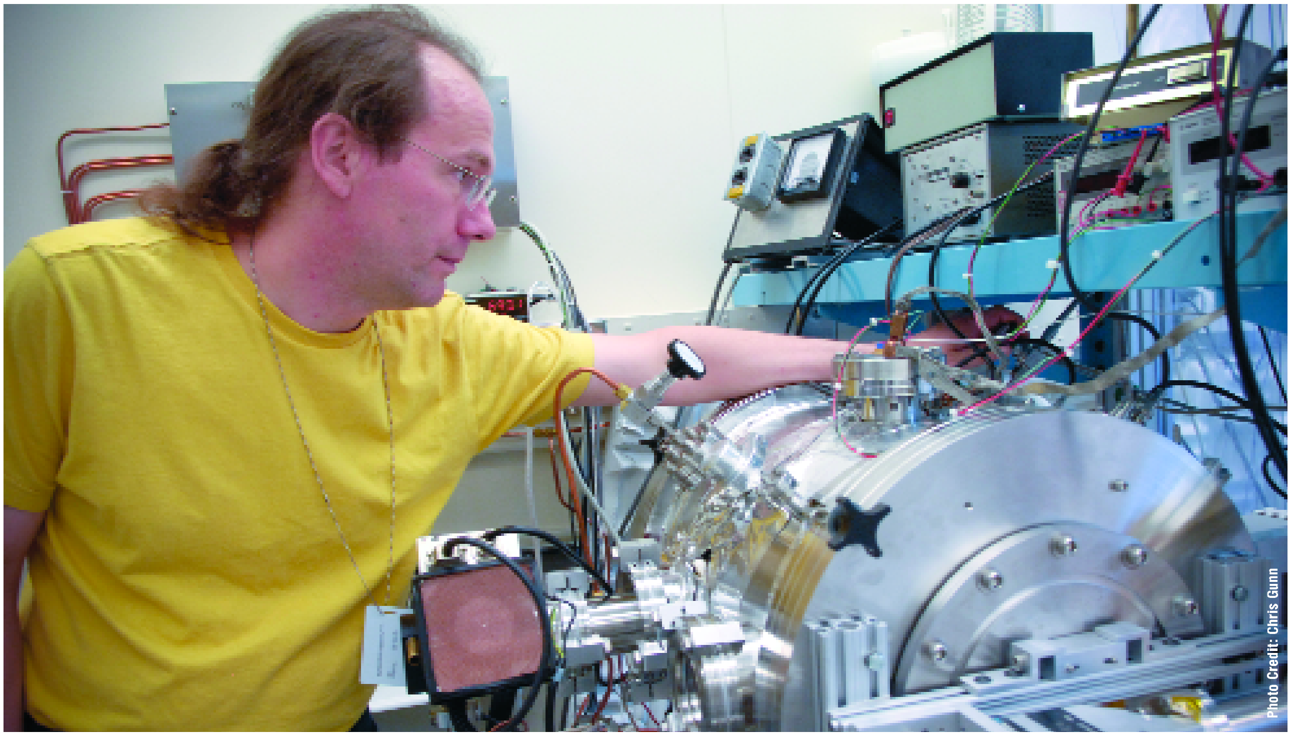
Opening a New Frontier in X-ray Astronomy

Goddard Team Wins Phase-A Study Award for Possible SMEX Mission



Goddard scientist Phil Deines-Jones (pictured here) and his colleague, Kevin Black, used Goddard R&D funding to develop the world's first time-projection chamber polarimeter, which could fly on the proposed Gravity and Extreme Magnetism SMEX mission if NASA selects it as one of two Small Explorers next year. Deines-Jones and Black will begin testing the prototype this summer.

A Goddard-led team now has a shot at building the world's first telescope dedicated to measuring the polarization of high-energy X-ray light.

NASA recently selected Goddard's Gravity and Extreme Magnetism SMEX (GEMS) team to receive $750,000 to carry out a detailed mission concept study, which is due this fall. Of the six missions selected for Phase-A studies, the Agency will select two next year for full development under the Small Explorer (SMEX) program. One of the two could launch as early as 2012.

Although team members will not speculate on their chances of winning, they nonetheless are optimistic.

"I think our mission will fly eventually because it explores a new frontier in X-ray astronomy," said Jean Swank, who is leading the mission, along with Deputy Principal Investigator Keith Jahoda. "I hope it is now. It would help us better understand the results of other X-ray missions."

Never-Before-Obtained Measurements

Although the observatory would study a variety of high-energy objects, its greatest contribution likely will be in what it can reveal about black holes.

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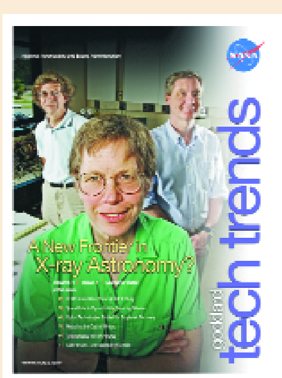


About The Cover:

A Goddard-led team now has a shot at building the world's first telescope that would measure the polarization of X-ray light. NASA Headquarters awarded $750,000 to Goddard's Gravity and Extreme Magnetism SMEX team to carry out a detailed mission concept study. Of the six missions selected for Phase-A studies, the Agency will select two for full development under the Small Explorer program. The team includes Principal Investigator Jean Swanks (center), Deputy Principal Investigator Keith Jahoda (left), and scientist Kevin Black (right). Phil Deines-Jones, another scientist, is not pictured.

Photo Credit: Chris Gunn

SpaceCube to Debut in Flight Demonstration

Hybrid Computer to Fly on Hubble Servicing Mission

While astronauts carry out the complicated task of rendezvousing with and grappling the bus-sized Hubble Space Telescope during the fourth and final servicing mission this fall, a small hybrid computer will execute the same exacting maneuvers in a simulation to test whether computers can do the work of humans.

As the real docking unfolds, algorithms installed on the SpaceCube computer will pretend that they are autonomously controlling the Shuttle's docking with the observatory.

"The astronauts will be controlling the real docking, but SpaceCube's docking algorithms will be running in parallel behind the scenes," said Thomas Flatley, a Goddard technologist who is using Internal Research and Development (IRAD) funds to develop science applications for the technology. "If the algorithms work well, we may be able to use them to do automatic computer-controlled dockings in the future."

Developed by Goddard technologists John Godfrey, Dave Petrick, and others on the Hubble Space Telescope Relative Navigation System, SpaceCube is a small, hybrid computer system that provides 15 to 25 times the processing power of a typical Rad750 flight processor used on most command, data, and handling flight computers. Making it even more attractive is SpaceCube's use of commercial-grade components, which are significantly less expensive than those that have been "radiation-hardened" for space flight.

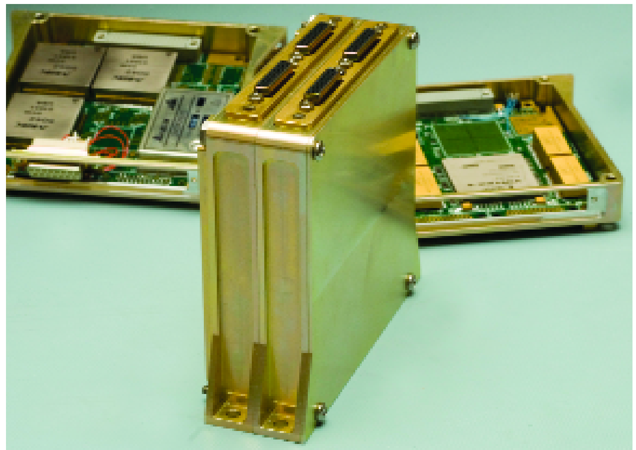
The Hubble servicing mission is the first space-based demonstration of the technology, Flatley said. Should it perform as Flatley expects, its potential to revolutionize NASA's command, data, and handling needs is enormous, he added.

Onboard Data Reduction

For future missions, the technology's most important contribution could be in on-board data reduction and product generation.

Future NASA missions are expected to generate enormous quantities of raw data that will easily overwhelm onboard data-storage systems. "If data processing could be performed on the spacecraft itself, then only the final data products would have to be stored," Flatley said. "This could allow an instrument to collect 10 to 50 times more data without increasing onboard storage capabilities."

To help realize that goal, Flatley is using IRAD funds to develop a variety of computer algorithms that would give the spacecraft's data-handling system the ability to process memory-intensive raw data into less weighty images and other products.



Developed by Goddard technologists, SpaceCube is a small, hybrid computer system that provides 15 to 25 times the processing power of a typical Rad750 flight processor. It will be demonstrated for the first time in space during the Hubble servicing mission.

Future Flight Opportunities

SpaceCube also has potential to dramatically decrease the cost of spacecraft missions.

Today, spacecraft engineers overcome the ill effects of radiation on electronic components, such as computer processors, through the use of "radiation-hardened" hardware. Although these specially built components work well in space, they are very expensive to produce. One application-specific integrated circuit, for example, can cost as much as $1 million to produce.

SpaceCube, however, is equipped with radiation-tolerant circuits, which means that while they can withstand the harsh space environment, they are nonetheless prone to radiation-induced "upsets." However, by employing special mitigation software techniques, SpaceCube can find and computationally correct these errors. Flatley will get his chance to demonstrate the capability in space next year when SpaceCube flies as part of a Naval Research Laboratory experiment on NASA's Express Logistics Carrier, an attached payload on the International Space Station.

Despite the technology's huge potential, Flatley conceded that it might be unsuitable for some spacecraft applications. Computer systems needed for risk-intolerant applications, such as providing oxygen inside human habitats on the Moon, for example, may always require true radiation-hardened devices and/or "super redundancy," he said. "Our goal is to see how far we can go." ◆

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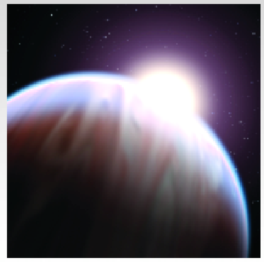
SPECIAL REPORT: NEXT-GENERATION ASTRONOMY MISSIONS

Earlier this year, NASA selected 19 science teams to conduct year-long studies of new concepts for next-generation astronomy missions. The Astrophysics Strategic Mission Concept Studies will play a role in what the National Research Council recommends as the priorities in its upcoming Astronomy and Astrophysics Decadal Survey. Although Goddard personnel are serving on 11 of the selected teams, this issue of Goddard Tech Trends showcases some of the optics technologies that Center scientists and engineers are investigating for four of the proposed missions.



Distinguishing Fireflies Next to a Lighthouse

Goddard Technologists Study Optics Technologies for Exoplanet Discovery

Goddard scientist Rick Lyon has been working on potential missions and technologies to find planets around other stars since the late 1980s. Only recently has he begun to believe that NASA may actually fly a planet-finding mission in his lifetime.

"This is the closest it's come to being real," he said.

Lyon and other Goddard scientists and engineers have joined teams studying optics technologies for three possible exoplanet missions: the Extrasolar Planetary Imaging Coronagraph (EPIC), the New Worlds Observer (NWO), and the eXtrasolar Planet Characterization (XPC) mission.

The possibility of a mission devoted to planet finding is tantalizing, especially to those interested in ratcheting up a science that began 13 years ago when astronomers found and confirmed the existence of the first planet outside the solar system. Since then, scientists have confirmed nearly 300, mostly Jovian-type gas giants.

Which science missions garner favor is still an open question. Whatever the approach, Goddard scientists hope their participation in the studies will position the Center to eventually build the telescopes and the starlight-suppression technologies needed to discern a planet orbiting a star up to hundreds of light-years away — a challenge that Goddard scientist Mark Clampin likens to "trying to distinguish a firefly next to a lighthouse."

Nulling Coronagraph

The visible nulling coronagraph (VNC) is a promising technology for directly detecting and characterizing Jupiter-sized gas giants, one of EPIC's science goals. Under this concept, the VNC would be coupled to a single telescope to inteferometrically suppress starlight and increase the contrast of the circumstellar region surrounding the star. This would allow astronomers to image the planet.

This year, the EPIC team received Internal Research and Development funding to demonstrate the VNC in a vibration-isolated vacuum tank. The aim is to make sure the technology can achieve a stable level of contrast in white light. "We're going to get the required contrast this year," said Petar Arsenovic, lead technologist for the Center's Optics Branch. "This technique is certainly possible."

This artist's concept shows the proposed New Worlds Observer and its giant sunshade, which would fly in formation with the telescope to block starlight and help reveal the presence of planets within a star's habitable zone.

Starshade

NWO and XPC, on the other hand, would look for planets that lay within the habitable zones of their parent stars — planets that could possibly support life. Although the two missions vary in many ways, both would employ a large deployable occulter or starshade. It would fly in formation with the telescope, separated by millions of meters.

"The arrangement of NWO's flower-shaped starshade and telescope in the starshade's geometric shadow allows planets as close as about 50 milli-arcseconds from the star to be imaged with little interference from the star's light," said Doug Leviton, who is serving on the NWO team. With this technology, NWO would directly image exoplanets and spectrally characterize them to look for evidence of water, oxygen, and methane, which are indicators of life.

XPC also would fly an internal coronagraph, a telescopic attachment that would assist in blocking direct light from a star so that the telescope could resolve orbiting planets and perhaps look for signatures of life.

"Any of these methods will in principle work, but how realistic are they in terms of cost, technology readiness, and risk?" Lyon said. "How do you perform the integration and testing? That's the purpose of these studies," Lyon said. "Which approach is the lowest risk, build-able within a defined budget and schedule, and provides the most value to NASA, the science community, and the public?" ◆

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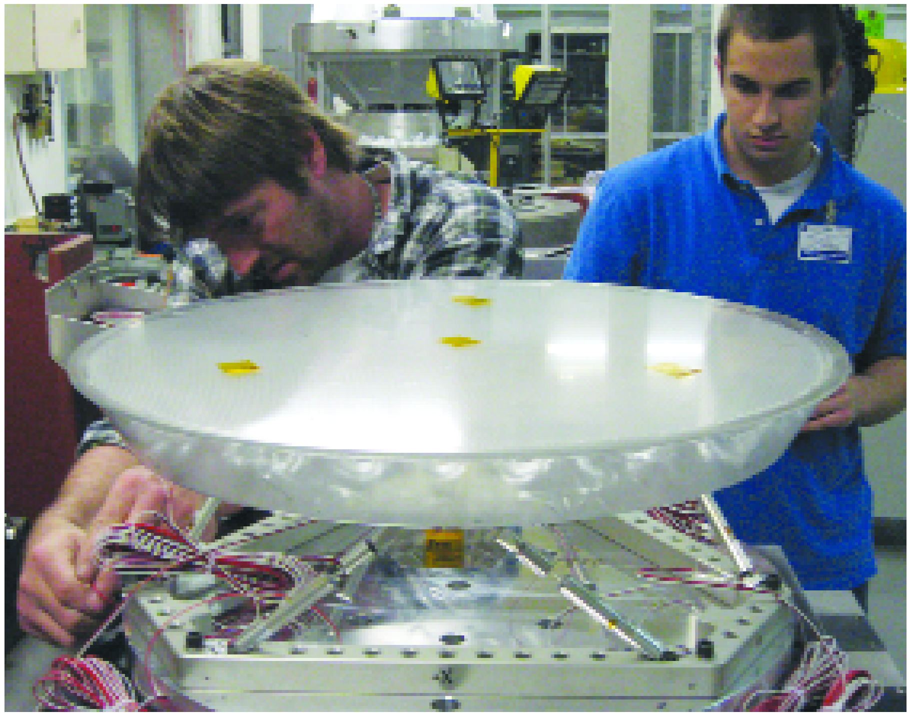
A Next-Generation Challenge: Reducing the Cost of Building Large Mirrors

NASA's latest ultraviolet/optical telescope concept — a potential successor to the Hubble Space Telescope — could discover the existence of life-bearing, Earth-like planets in our galaxy and give scientists insights into how the universe develops over time. But it can't be built unless engineers figure out how to build a less expensive primary mirror.

"We need to bring down the costs of mirrors," said Goddard technologist David Content, who is now investigating optics requirements for the proposed Advanced Technology Large-Aperture Space Telescope (ATLAST), one of the 19 mission concepts NASA is funding under the Astrophysics Strategic Missions Concept Studies.



Technicians at the Wallops Flight Facility prepare the corrugated mirror before a recent environmental test.

Under the study effort, Content is leading a Goddard optics team examining designs, including a possible 8-meter, monolithic primary mirror or a segmented, 16-meter primary mirror. Overall, the study team includes engineers from other NASA Centers, the Space Telescope Science Institute, industry, and academia.

At this point, mirror construction for either size remains a showstopper. "Today it costs about $4 million per square meter to build a primary mirror," Content said. "That means an 8-meter primary mirror would cost about $200 million. At those prices, you've just priced yourself out of the running."

But Content believes a potential solution is within reach.

Supported in part by the Innovative Partnerships Program and previous Goddard Internal Research and Development funding, Content has been working with ITT Space Systems to advance the technology-readiness level of the company's "corrugated mirror." This technology starts with five thin sheets of glass — front and back plates and three intermediate layers. The intermediate layers are molded and fused to the outer plates to efficiently support the front of the mirror at many points. The end result is a lighter, less costly mirror that takes a fraction of the time to produce.

Traditional mirror-making techniques are dramatically different. Typically in the construction of a large mirror or a piece of a segmented mirror — similar to the ones Content and his team are investigating for ATLAST — technicians would begin with a solid blank of glass and remove almost all of it to reduce its weight. They then would polish the glass to meet an exact optical prescription. "With ITT's approach, we're building up, rather than taking away," Content said.

Although still in the testing phases, Content is optimistic that the technology could reduce mirror-construction costs by a factor of three to 10 and satisfy the light-gathering needs of future NASA astronomy missions.

Last summer, Content and his team ran environmental tests on a half-meter-wide mirror segment. It survived, advancing the technology's readiness to a level four. Another test is scheduled for this summer. If the mirror survives that test, the technology becomes an attractive solution for nearer-term missions, Content said.

"We're not at a level where we can carry out a system-level demonstration, but I do think there is a future here," Content said. ◆

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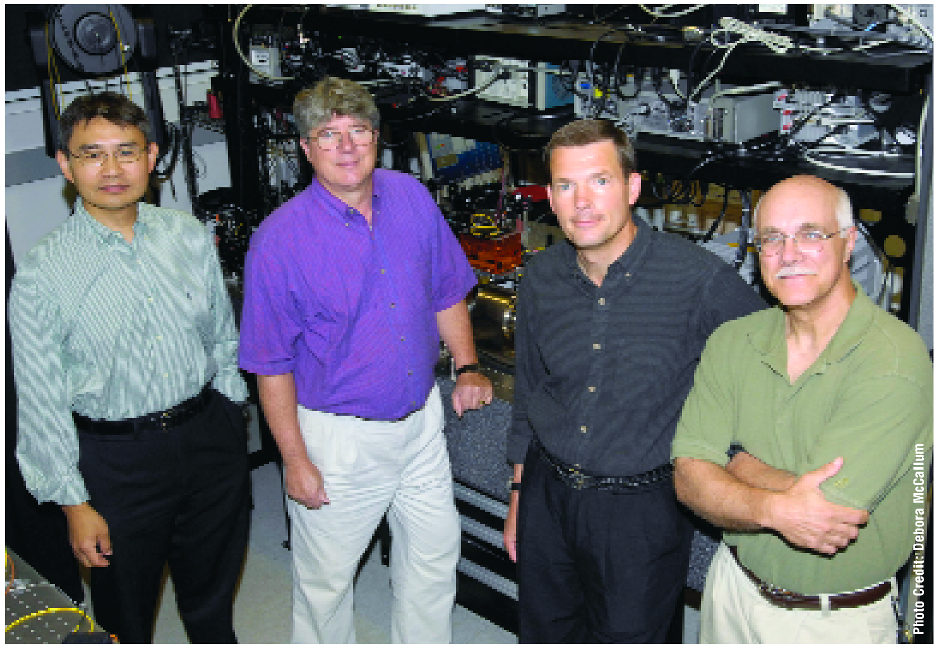
Goddard Technologists Win $11.2 Million to Continue Earth-Observing Instrument Concepts



Goddard technologists (from left to right) Tony Yu, Bill Heaps, Bill Abshire, and Chuck McClain won Instrument Incubator Program funding to advance the technology-readiness levels of different Earth-observing instruments.

Four Goddard technologists have won nearly $11.2 million in NASA Headquarters funding to further develop new Earth-observing instruments that would gather measurements needed to understand global climate change.

The NASA Science Mission Directorate selected James Abshire, Anthony Yu, Charles McClain, and William Heaps to receive funding under its 3-year Instrument Incubator Program (IIP), which is designed to reduce the risk of innovative instrument systems needed for future science missions. All four principal investigators used Goddard Internal Research and Development (IRAD) resources to initiate work on their concepts.

"If we didn't have IRAD, I don't think we could have put together this proposal," McClain said, after learning of his IIP award. "It was pretty critical." Abshire agreed: "The support from the Goddard IRAD was a key factor in our start and in some key technical areas."

All the instruments respond to needs outlined by the National Research Council (NRC) in its first-ever Decadal Survey of Earth-observing missions. Released in 2007, the report urged NASA to enhance its network of environmental spacecraft by funding 15 new Earth-observing missions between 2010 and 2020.

The instruments address a variety of problems. Both Abshire and Heaps are developing different laser techniques for measuring carbon dioxide — a leading greenhouse gas in the atmosphere. Both would satisfy requirements of the NRC-proposed Active Sensing of CO2 Emissions over Nights, Days, and Seasons mission.

"Emissions of carbon dioxide increase every year," Heaps explained. Yet, the amount in the atmosphere does not jibe with the emitted levels. That means an unknown sink — typically oceans, plants, and other organisms that use photosynthesis to remove carbon from the atmosphere — exists and isn't being accounted for in computer modeling. "It's important to know where it is," Heaps said. "It might be something we could do more of to reduce carbon-dioxide levels."

Yu, meanwhile, is developing a swath-mapping space laser altimeter that would measure precisely how long it takes for photons in a laser pulse to hit the ground, reflect, and travel back to the instrument, thereby providing topographic and vegetation data.

Unlike other laser altimeters, however, Yu is hoping to create an instrument that would produce at least 16 laser spots, each measuring only 5 meters in diameter. The smaller the laser "footprint," the more detailed the data gathered. And with multiple laser beams, the instrument would allow simultaneous measurements over a larger geographic area. Yu said the IIP was a step toward realizing the ultimate Lidar Surface Topography mission goal of 1,000-beam swath mapping of the Earth's surface.

And McClain is developing a next-generation ocean radiometer that would measure marine photosynthesis, which is key to the carbon cycle and the ocean food chain. His concept, called the Ocean Radiometer for Carbon Assessment, builds on the work Goddard scientists and engineers pioneered in the development of other ocean color sensors, particularly the Sea-viewing Wide Field-of-view Sensor and the Moderate-resolution Imaging Spectroradiometer.

During the 3 years, the technologists plan to fine-tune their instrument concepts and ultimately test their devices from an aircraft platform. ◆

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The Story of Life…As Recorded in a Rock

Goddard biogeochemist Jennifer Eigenbrode, who is an expert at detecting organic compounds in rocks, is using R&D funds to develop a simplified sample-processing method that could be applied to a robotic chemistry lab.

The quest to discover whether Mars ever hosted an environment friendly to microscopic forms of life will begin with renewed vigor in 2010 when a Mini Cooper-sized robot touches down and begins scooping up, processing, and analyzing soil and rock samples to detect the presence of organic compounds.

Without question, the Mars Science Laboratory (MSL) will be one of the most complicated and capable missions ever landed on the surface of another planet, said Jennifer Eigenbrode, a biogeochemist who is working with the Goddard team building one of MSL's onboard chemical-processing labs, the Sample Analysis at Mars (SAM) instrument suite.

SAM will carry out the initial search for organic compounds on Mars, relying on scorching heat to process the samples. SAM's gas chromatograph and spectrometers will then analyze the resulting gases for potential biomarkers. "SAM should detect organic carbon if it is present, regardless of its chemistry," Eigenbrode said.

But, there is a catch.

"Heat breaks carbon bonds, resulting in the loss of certain chemical information," she said. "If SAM discovers an environment rich in organics, we will have compelling scientific reasons to develop more sophisticated tools that can determine if these are life or non-life processes. In that case, what we'll need is a robotic laboratory that offers the capabilities and flexibility of an Earth-based organic geochemistry laboratory," Eigenbrode said.

Achieving that next level of sophistication on a robotic laboratory operating millions of miles from home won't be easy. But that's what Eigenbrode has set out to do.

Using Internal Research and Development funding, Eigenbrode is now developing a chemical-processing method that would combine some of the many different steps researchers use in laboratories on Earth to process and study organic compounds to learn more about their evolution. "No single technology identifies all molecular components because they have different chemistries. If organics are present on Mars and elsewhere, they likely include complex compounds, which require additional processing to find them."

Making her job more complex is the fact that such an in-line methodology doesn't currently exist for Earth laboratories. Researchers must follow multiple steps when preparing samples for analysis. However, should Eigenbrode find the right combination of steps that could be applied easily

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X-ray Astronomy... Continued from page 1

The mission would provide never-before-obtained measurements of how fast black holes spin and how their spin rates affect the curvature of space-time. It also would reveal aspects of how black holes consume and eject matter — data that no other X-ray mission has been able to collect to date.

"This is an important subject in understanding the development of the universe," Swank said. Although black holes consume copious amounts of matter that orbit too close to their event horizons — the area where the gravitational pull is so strong that nothing can escape — they also eject X-ray-emitting matter back into the universe. "Repopulating space with matter is part of the balance. It plays a key role in the evolution of galaxies," Swank said. "GEMS will be able to tell us the shapes of the emitting matter better than existing missions can."

Polarimetry Offers Best Approach

Polarimetry is the best way to obtain this information. Most forms of electromagnetic radiation, including X-rays, radio, and visible light, are a chaotic mixture of waves vibrating in all directions, up and down, side to side, or at any angle perpendicular to the direction from which the wave originated. This is known as unpolarized radiation.

However, if a wave passes through certain materials or is reflected from a surface, like the accretion disk around a black hole, it will vibrate mainly in one direction. This makes it easier to track its origin and its behavior as it interacts with gravitational or magnetic fields. Therefore, measuring polarized X-rays can reveal the geometry of matter as it's ejected from a black hole, determining whether the matter is confined to a flat disk, puffed into a sphere, or expelled in a jet. No currently available imaging technique can provide the same information.

Until now, the measurement has been impossible to perform, hampered by poor instrument sensitivity and difficulty capturing enough X-ray photons to measure their polarization.

With support from Goddard's Internal Research and Development program and other NASA R&D funding, however, Goddard scientists Phil Deines-Jones and Kevin Black developed a new technique for measuring X-ray polarization, building the world's first time-projection chamber polarimeter. Its design allows the capture of more X-ray photons and it measures more precisely their polarization. The polarimeter would be placed at the focus of a grazing-incidence X-ray telescope similar to those on the Japanese-U.S. mission, Suzaku. Goddard's Peter Serlemitsos and Yang Soong would provide the mirrors.

Black and Deines-Jones have built a flight-like prototype of their polarimeter and expect to finish environmental testing this summer before the team submits its Phase-A report. "It's the most sensitive technique that anyone knows of for doing this type of science," Deines-Jones said. "It's also a unique Goddard capability. We want to make discoveries with it." ◆

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Story of Life... Continued from page 7

to a next-generation instrument, NASA then would have the ability to identify a much larger variety of compounds and perhaps get a more complete picture of how life, if it existed in the first place, evolved over time, she said.

"We know that life interacts with its environment," she said. Fossil fuels, after all, formed from prehistoric plants, animals, and microorganisms that died, decomposed into organic materials, and became buried under layers and layers of mud, rock, and sand 300 million years ago. "If life evolved here, it could have evolved elsewhere. What we want is a record of life and the most direct way to track these organisms is in the organic molecules in rock samples. What we need are the tools with which to do the search." ◆

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Goddard Tech Trends

Goddard Tech Trends is published quarterly by the Office of the Chief Technologist at the Goddard Space Flight Center in Greenbelt, Md. The newsletter describes technology developments at Goddard and explains how they are helping NASA to achieve its missions. If you want more information about Goddard technology, contact the Chief Technologist. If you wish to be placed on the newsletter distribution list, contact the editor.

NP-2007-10-853-GSFC (revised 4/08)

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