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Ohio State

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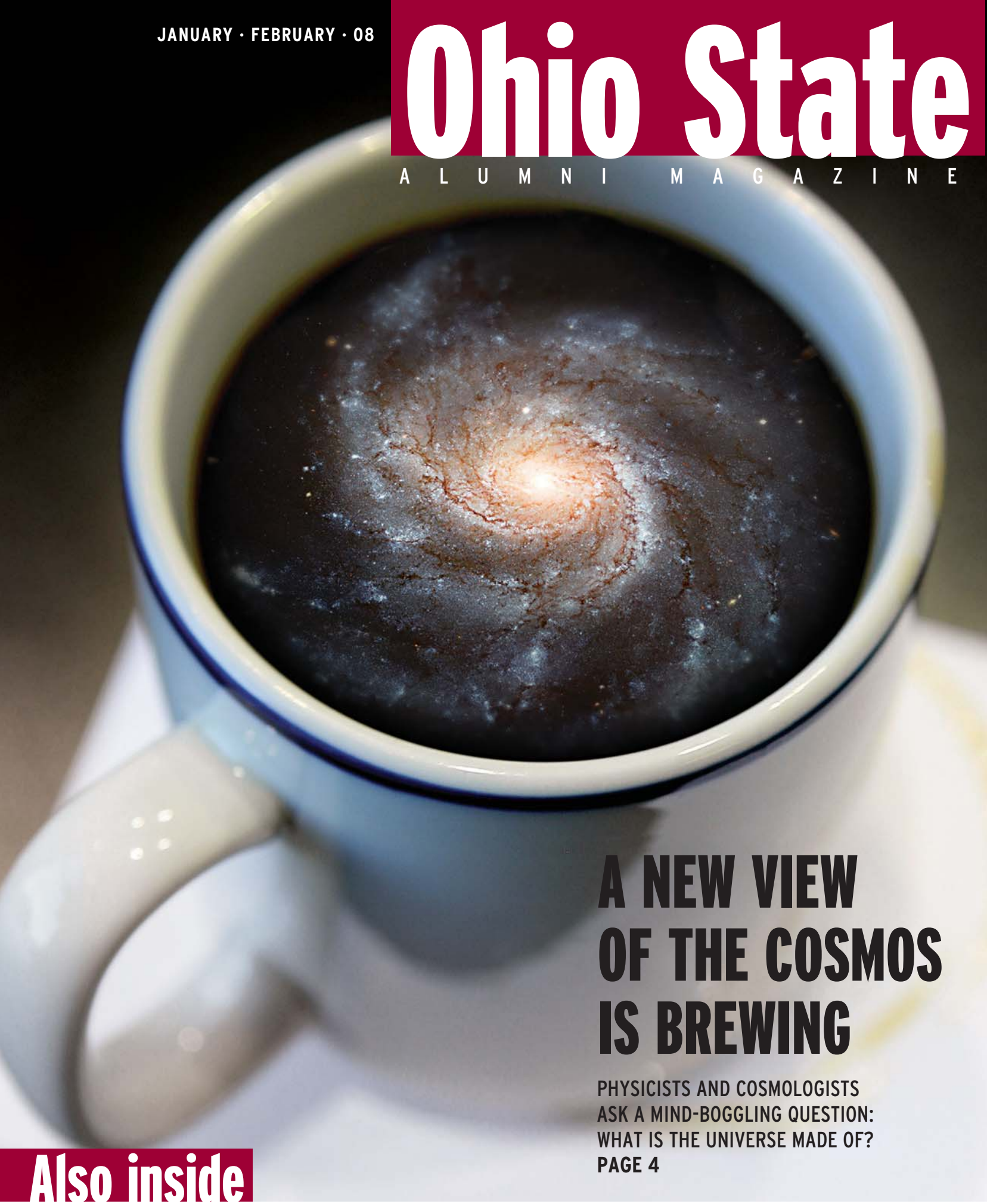

A NEW VIEW OF THE COSMOS IS BREWING

PHYSICISTS AND COSMOLOGISTS ASK A MIND-BOGGLING QUESTION: WHAT IS THE UNIVERSE MADE OF?
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Photo illustration by **RICK HARRISON**

Cosmic Quest

Fueled by out-of-this-world curiosity, millions of dollars, and **a lot of coffee** (see page 8)—Ohio State researchers are reaching for the stars. By **PAM FROST GORDER.**

As we look to the night sky, our eyes naturally seek out the bright spots—the stars, the galaxies, the other brilliant celestial objects, blazing on their background of deepest black. That black, our eyes tell us, is nothing, a void.

But scientists at Ohio State's new Center for Cosmology and Astro-Particle Physics tell us something different: that the void contains dark matter and streams of equally invisible high-energy particles. They tell us that a force called dark energy roams there, working to tear the universe apart.

"Once we discover [what the universe is made of], it'll lead to even more questions."

–Terry Walker, professor of physics and director of the Center for Cosmology and Astro-Particle Physics

The multimillion-dollar question

In 2005, Ohio State announced a program called Targeted Investment in Excellence (TIE). The university was going to invest $100 million in a small number of research programs that had the potential to significantly impact their fields.

Terry Walker, a professor of physics, and David Weinberg, a professor of astronomy, drew together a group of Ohio State colleagues to craft a TIE proposal that began with a bold question: "What is the universe made of?"

Their contention: with Ohio State's expertise in cosmology (the study of the structure and evolution of the universe) and astro-particle physics (the study of high-energy particles and the role they play in shaping the universe), the university was poised to join an elite group of institutions around the country that could examine the question as it should be examined.

The proposal won $5.2 million in TIE funds over five years, and the Center for Cosmology and Astro-Particle Physics (CCAPP) was born.

Mysteries of the universe

CCAPP comprises more than 20 faculty researchers from physics and astronomy. They're all working to answer the same big question, but from slightly different angles.

And so far, they're all discovering the same thing: the normal matter we know of—the "stuff" made of protons, neutrons, and electrons—is only a tiny portion of the universe, about 5 percent.

That 5 percent accounts for all the stars in all the galaxies—everything bright and visible to the human eye—as well as dark objects such as planets and interstellar dust that don't cast light of their own, but that we can see because of light shining on them. The other 95 percent of the universe is dark matter and dark energy.

It's the dark stuff that will determine the universe's fate. Dark matter, which comprises 25 percent, exerts the gravity that holds

Booster rocket

Ohio State's explorations into outer space have received a boost in the form of a $20 million gift, the second largest in the university's history.

"The discoveries that result . . . may even help us to understand the very nature of our existence," said President E. Gordon Gee in announcing the anonymous gift last October.

The gift will fund student fellowships and two faculty chairs named for men known for their interest in exploration:

- The **Thomas Jefferson Chair** will support a professor in the College of Mathematical and Physical Sciences studying within the Center for Cosmology and Astro-Particle Physics or the Planetary Studies Initiative. Specifically, the researcher's work will concentrate on the search for extra-solar planets with the potential to support life.
- The **John Glenn Chair** will support a faculty member in the College of Engineering. The researcher will study propulsion technologies for orbital payload delivery, interplanetary transport, and power systems for space travel or for moon or planetary bases.

The gift also will create the Space Exploration Research Fund to provide fellowships to support research by students studying science or allied fields to advance space exploration.

In keeping with Jefferson and Glenn's commitment to public service, the holders of their namesake chairs will be encouraged to mentor a student or postdoctoral researcher in the university's John Glenn School of Public Affairs. ■

our galaxies together. And dark energy, the remaining 70 percent, does just the opposite: it's pushing the normal matter away in all directions and speeding the expansion of the universe.

It's possible that ultimately, dark energy may stretch the universe so far that normal matter will no longer hold together. But there's no need for immediate concern: that cold fate, should it come to pass, would be billions of years away.

Elite company

Even if CCAPP researchers discover the answer to their big question, it won't have a direct application to everyday life. So why pursue it?

To the scientists, the reason is simple. Wanting to get to the bottom of mysteries is human nature. We don't know what most of the universe is made of, and not knowing is simply unacceptable.

"The repulsive gravity of dark energy is the most puzzling mystery of all," Weinberg said. "It's as if you walked outside and tossed a baseball in the air, and instead of falling back to the Earth, the ball just continued to go up and up, all the way out of sight. You'd want to know why."

Science magazine named the discovery of dark energy and the later confirmation of that discovery its "Breakthrough of the Year" in 1998 and 2003. NASA, the National Science Foundation, the Department of Energy, and the National Academies all say the question of what the universe is made of is one of their research priorities. Several elite research universities—including the University of Chicago, Stanford University, the Massachusetts Institute of Technology, and the University of California, Berkeley—are daring to probe the question with dedicated programs and institutes. Ohio State has now joined that list.

Initial accomplishments

CCAPP pays for young graduate students, postdoctoral researchers, and professors to visit the university for a few days or weeks at a critical early time in their careers. Even if they can't solve a particular research problem during their visit, they can get a good start on it. And they get something more: the experience of being part of the Ohio State group dynamic.

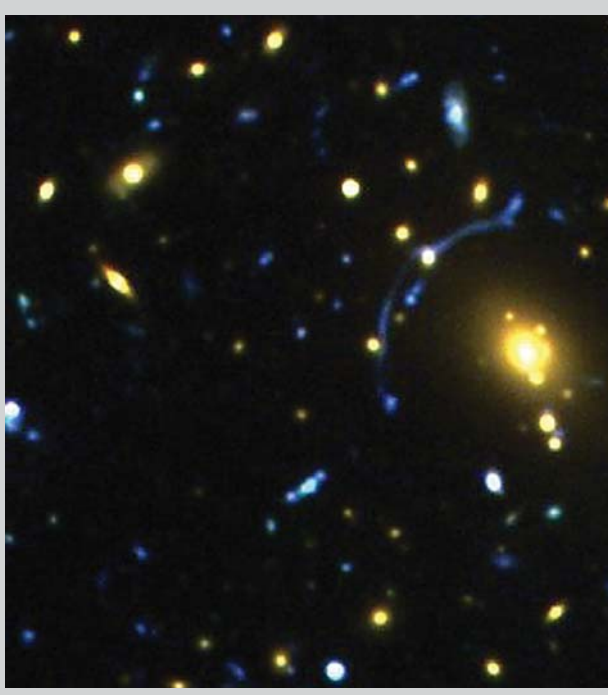
"We want to make it a badge of accomplishment," said Walker, who is the director of CCAPP. "We want people to come through Ohio State because it's the best place to be, and they can put it on their resume. And it's close to that now. It's a big deal for people to come here because of the things they accomplish."

To that end, CCAPP is budgeting about 30 percent of its funding to support visitors, workshops, and seminars. Another 30 percent will double the number of postdoctoral researchers now in the program, and the remaining 40 percent will fund the research and development of new experiments.

One year into CCAPP's existence, Walker can list accomplishments in all three areas. The program has hosted more than 50 visitors and run four workshops with some 200 participants. It has hired three postdoctoral researchers from some of the most prestigious institutions in astronomy, and plans to hire several more this year.

The university has joined the Dark Energy Survey Collaboration, an international effort to determine the properties of dark energy. CCAPP is providing funding and postdoctoral research support for the project.

CCAPP members are also collaborating on the Sloan Digital Sky Survey, the largest sky-mapping project ever undertaken, for which Weinberg is the scientific spokesperson. Others are working on detectors for the Pierre Auger Observatory in Argentina that will identify cosmic rays, the most energetic particles in the universe. And CCAPP faculty and students are



"It's as if you tossed a baseball in the air, and instead of falling back to the Earth, the ball just continued to go up and up. You'd want to know why."

–David Weinberg, professor of astronomy

Photo by RICK HARRISON

making use of the Large Binocular Telescope in Arizona, in which Ohio State also is a partner institution. (See "To catch a cluster," below.)

The projects may appear to have little in common. But untold numbers of subatomic particles resulted from the Big Bang 14 billion years ago, and infinitely more particles stream from exploding stars today. Some of the particles could account for dark matter, or help scientists understand the physics behind dark energy.

Both endeavors require physicists who normally work with particle accelerators or particle detectors—devices that are buried deep within the ground—to team up with astronomers who are gazing through telescopes pointed at the sky. "The techniques that both groups use are directly applicable to these problems, and they have to work together," Walker said.

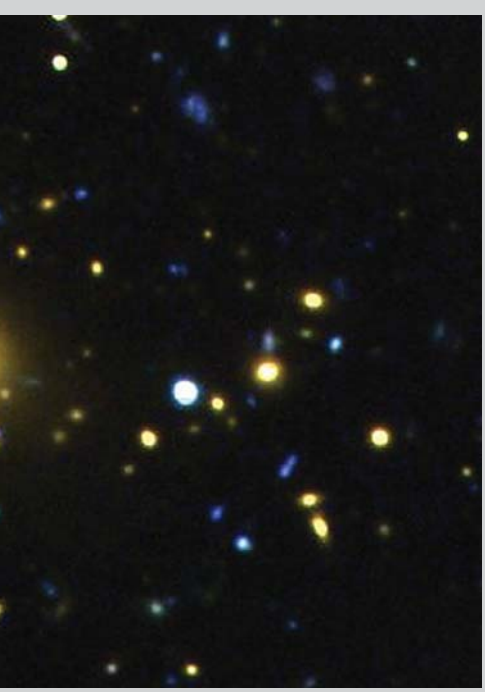
Theory and practice

If two CCAPP researchers can be considered emblematic of cosmology and astroparticle physics, it's Smita Mathur and John Beacom. Though their areas of study are very different, they both relate to the search for dark matter.

Mathur, an associate professor of astronomy, studies quasars, which are galaxies with massive black holes in the center. Quasars are billions of years old and are among the most distant objects in the universe.

Mathur is trying to understand what happens inside quasars. And because quasars shine so brightly, she also is able to use them to take X-ray images of matter surrounding our local group of galaxies. She's not looking for dark matter, exactly, but she has discovered trails of hot gas that may provide a kind of road map to its location. CCAPP recently provided matching funds for her to hire a postdoctoral researcher to help continue the project.

While Mathur is an observational astronomer—she uses telescopes to study the universe—Beacom, an associate professor of physics and astronomy, is a theorist. His work centers on the neutrino, a subatomic particle formed in the nuclear reactions that make stars shine. Neutrinos are high-energy particles, but they don't interact much with normal matter. Even though countless neutrinos burrow through our planet every second,



To catch a cluster

How many blue arcs do you see?

Sure, the two large arcs near the center left are easy to spot. But there are at least 60 other tiny arcs scattered throughout this image, which Paul Martini captured with the Large Binocular Telescope (LBT) last May.

The image is of a cluster of galaxies called Abell 611, one of the most massive such groups in the universe. Martini, an assistant professor of astronomy, and his colleagues are using the LBT in their quest to discover what the universe is made of.

The arcs are stretched-out images of other galaxies that are shining from behind Abell 611, Martini explained. The phenomenon happens because the cluster is so massive, its gravity bends the light waves emanating from the galaxies and scatters the light around the image, similar to the way a glass sun-catcher hanging in a window bends and scatters light.

Ohio State is one of five international partners building the LBT on Mount Graham in Arizona. Although the telescope is not yet fully functional, researchers are already scanning the heavens with it. When complete, it will be the world's largest telescope on a single mount and offer 10 times the resolution of the Hubble Space Telescope. ■ **PFG**

The power of caffeine

Ohio State's CCAPP researchers, those who study the mysteries of dark matter and dark energy, initially were drawn together by dark energy of a different kind—the kind that's brewing right now in a coffeepot on the fourth floor of McPherson Laboratory.

One by one on a chilly October morning, professors and students file into a conference room, cup of brew in hand. Some are astronomers. Some are physicists. Some are clearly not quite awake. But by the time their discussion is under way, it's obvious that serious business is happening here.

An article from a scientific journal appears on a screen at the front of the room. It might concern research that originated at Ohio State, or it might be from anywhere else in the world. Suddenly, students are arguing with professors. Professors are arguing with each other. Voices are raised. Arms are waved in emphasis. The room explodes in laughter. Somewhere in the middle of it all, a consensus is reached.

Physics professor Terry Walker and astronomy professor David Weinberg have sat in on the daily ritual for years. In fact, at one point the "Astronomy Morning Coffee" and other informal collaborations had become so routine, they began to take the close relationship between their departments almost for granted.

But visitors to the university had taken notice—including two external review committees. Academic departments are always under review, and in this case, two groups of scientists from peer institutions visited Ohio State in order to evaluate the Department of Physics and the Department of Astronomy. The reviewers were struck by the collaborations they saw.

"The astrophysics group here is unusual because half of us sit in the physics department and half of us sit in astronomy. It's actually one of our strengths," Walker said.

The fact that the two departments could sit down over coffee and have a free exchange of ideas meant that they already had something special going,

the reviewers said. The university needed only to set up a formal center to create something extraordinary. That's what eventually became CCAPP.

There's something about the culture at Ohio State that lends itself to such big endeavors, Weinberg said. It was he who, upon joining the university in 1995, founded the astronomy department's coffee klatches.

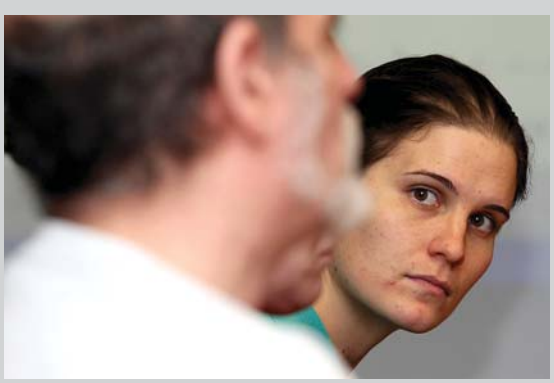
The gathering originally was meant to replicate similar ones at institutions such as Princeton and Cambridge. But the discussions quickly became more boisterous and broader in their subject matter than anywhere else. They grew into something uniquely Ohio State.

Every day, a volunteer picks a handful of scientific journal articles that have been posted to a Web archive operated by Cornell University. Faculty and students discuss the merits of each article.

If an article was written by someone at Ohio State, that person is expected to describe his or her work to the group. Then it's everybody else's job to pick it apart. In that way, the Morning Coffee is like an even more nail-biting version of the rigorous peer review that determines what is published in scholarly journals.

Students are expected to hold their own in the discussions, and they're also expected to challenge professors, another characteristic that sets the event apart from those at other institutions. ■ **PFG**

Photos by RICK HARRISON



Morning coffee and lively conversation draw students and professors to a McPherson Laboratory conference room.

scientists capture only a few of them each day in specially designed underground detectors.

Beacom reconstructs what happens in the hidden neighborhoods around exploding stars and black holes, where neutrinos are created and dark matter lurks. He has developed ways for scientists to trace neutrinos detected on Earth back to the violent events that spawned them. "It's like forensics from a billion light years away," he said.

It's too early to know if CCAPP will find the answer to its grand question, "What is the universe made of?" Walker knows one thing for sure, though. "Once we discover what it is, it'll be new physics," he said. "And it'll lead to even more questions." ■

Learn more:
www.physics.ohio-state.edu/~astro/ccapp

See page 26 for more about Smita Mathur.

Targeted Investment in Excellence

10 ways to change the world

The Targeted Investment in Excellence initiative is an ambitious effort to support research projects that have the potential to enhance Ohio State's national and international prominence. The university is allocating $50 million in funding to 10 projects over five years. The participating colleges will match the funding for a total investment of $100 million.

This is the third in a series highlighting each TIE project.

Advanced Materials Initiative
Center for Clean, Sustainable Energy
Center for Cosmology and Astro-Particle Physics
Climate, Water, and Carbon Program (see *OSAM,* May/June 2007)
Mathematical Biosciences Institute
Micro-RNA Project
Music, Media, and Enterprise Program
Population and Health Initiative
Public Health Preparedness Program (see *OSAM,* November/December 2007)
Translational Plant Sciences Initiative

Learn more: oaa.osu.edu/tie