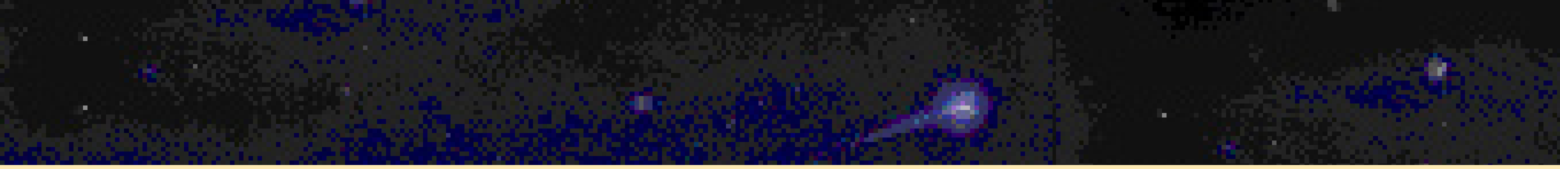
For dozens of UNH physicists and students,

Space Rocks!

By Rachel M. Collins '81

In a wooden hut atop the 6,288-foot peak of New Hampshire's Mount Washington, three banks of tubes, each one an inch in diameter and three feet long, are surrounded by layers of lead and paraffin. Inside, the small gas-filled brass tubes of the neutron detector spark briefly as they detect a cosmic ray entering the Earth's atmosphere.



OVERLEAF: Space scientists pictured are (clockwise from lower left) Amitava Bhattacharjee, Jim Connell, Jim Ryan, Lynn Kistler, Terry Forbes, Eberhard Möbius and Roy Torbert. Illustration by Bill Cigliano.

Fifty years ago, the late UNH physics professor John "Jack" Lockwood built this detector and drove up Mount Washington in an open-roof Jeep to install it. And ever since, it has been steadily and reliably transmitting data on cosmic rays—charged particles from outer space—back to scientists at UNH.

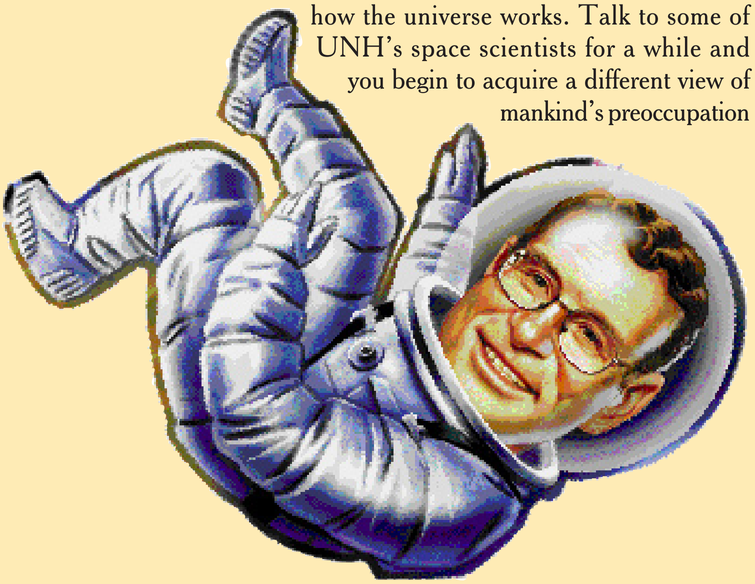
Approximately 445,300,000 miles away, on the far side of the Sun, the Ulysses spacecraft is heading toward its fly-by of Jupiter. It, too, is collecting data and sending it back to UNH. It also has proved reliable and steady: This is the third time the plucky satellite has made the trip since it was launched in 1990. Six other NASA satellites with UNH experiments aboard are also in orbit, all beaming back a wealth of valuable data.

When he created the Mount Washington detector in 1955, Lockwood probably had no idea that it would be the start of a space science program now noted worldwide. "When the U.S. had the capability to put a satellite in orbit," says Berrien Moore III, director of the UNH Institute for the Study of Earth, Oceans, and Space, "we had the ability to put instrumentation on that satellite." During the past half-century, UNH has been a part of nearly 30 NASA missions, including a dozen in the 1990s alone. Currently, 27 faculty members, 10 research scientists, 25 engineers and dozens of undergraduate and graduate students study space weather, solar flares, cosmic rays and the workings of plasma.

What do they hope to learn? Nothing less than how the universe works. Talk to some of UNH's space scientists for a while and you begin to acquire a different view of mankind's preoccupation with Earth. It turns out it's a big place out there. What we normally think of as space—planets, moons, stars, comets, supernovas—is less than 1 percent of the universe. All the rest is a new, almost entirely unexplored frontier.

Space Traffic Cop

There are so many satellites in orbit above the Earth's equator that companies that want to launch a satellite have to get permission first from North American Aerospace Defense Command.



Space physics is a young field because until recently, humans were earth-bound. That began to change after Robert Goddard launched the world's first liquid-fueled rocket in 1926, and by the 1960s, launch vehicles were available to put experiments both in the Earth's upper atmosphere and in deep space. The data these instruments collect will not only help scientists explain some of the most fundamental questions of physics but may help to solve some of our most pressing problems, including a source of cheap, clean energy.

Beyond Plasma TVs

Ask most people to define the word *plasma*, and they'll probably mention blood transfusions or a kind of TV screen. To space scientists, *plasma* means only one thing: the fourth state of matter. Plasmas, which constitute almost all of space, are tricky and unpredictable. They can behave like fluids but they exhibit bizarre, hard-to-understand behaviors.

To better understand plasmas in general and a strange, little-understood phenomenon called "reconnection" in particular, space physicist Roy Torbert, director of UNH's Space Science Center, and his team members will be building four identical instruments for NASA's Magnetospheric Multiscale Mission. The $38 million grant—the biggest single grant ever awarded at UNH—is part of a huge, $400-million international project to put four satellites in the magnetosphere, where space meets the Earth's ionosphere.

The four satellites, scheduled for launch in 2013, will fly together in a tightly coordinated formation to take measurements of what happens when the Earth's magnetic field is hit by the highly charged particles—called the solar wind—that stream out from the Sun. One of the goals of the project is to unravel the hows and whys of reconnection.

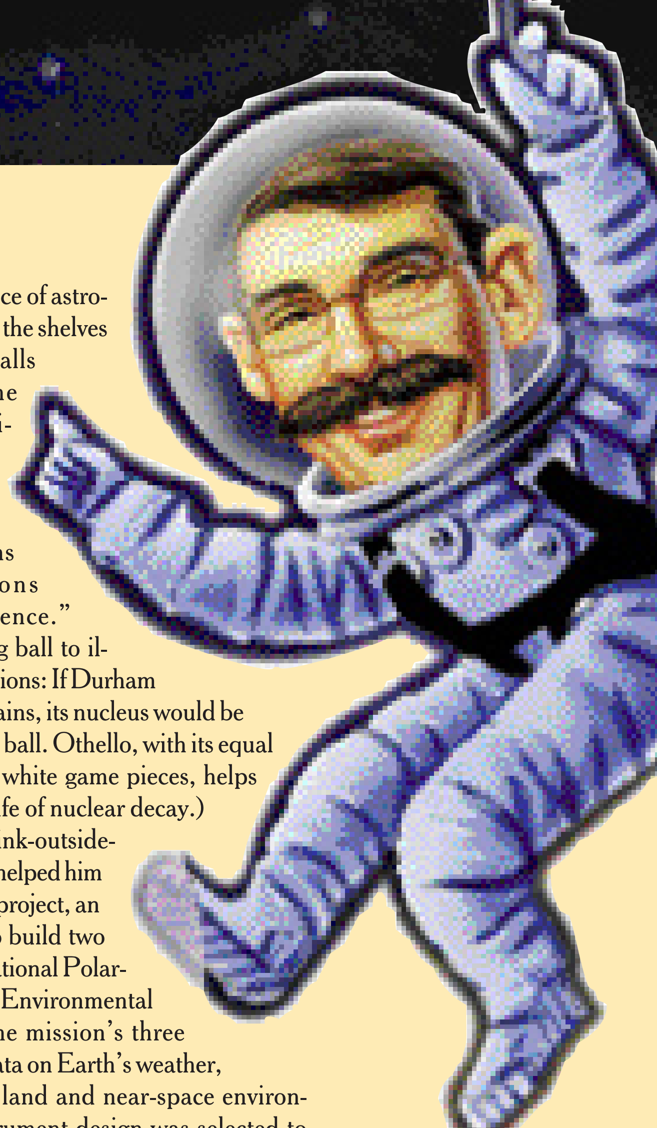
A rough analogy to describe reconnection goes like this. Imagine holding an onion out a car window as you drive along the highway. (Don't try this at home, says Torbert.) The onion represents Earth with its surrounding magnetic field lines; the air streaming past represents the solar wind. On a normal car ride, the air rushes by the onion, which is none the worse for wear. Now imagine a different car ride where magnetic energy in the air streaming past transforms the outer layers of onion skin into something hot and fluid (think hot lava); on the back side of the onion, it reverts to onion skin. This conversion of magnetic energy into mechanical energy and back again as the solar wind surges over the Earth's magnetic fields—reconnection—was thought to be impossible until experiments aboard spacecraft in the '70s and '80s showed it was indeed occurring. On the Sun, reconnection is thought to be responsible for solar flares and the much larger coronal mass ejections, and scientists believe it also occurs near black holes and pulsars.

"Once we understand more about reconnection, we'll be able to predict space weather," says Torbert, referring to the solar storms that can wreak havoc with power grids on Earth and take out the communications and weather satellites that orbit the Earth's equator. He points out that one of the biggest hurdles currently facing manned flights to other planets—like Mars—is the threat of radiation from these solar storms, which can kill astronauts unless they have enough advance notice to seek shelter in a lead- or water-lined hideaway.

Understanding reconnection will also help scientists who are trying to confine plasmas in order to produce fusion energy—an inexhaustible, environmentally friendly and safe alternative to both nuclear energy and fossil fuels. Plasmas are notoriously hard to confine, and the sudden and unpredictable release of energy—in other words, reconnection—is the last thing a fusion power plant operator wants.

This is not the first time that Torbert and his team have built instruments that can study reconnection: They designed and built detectors for a project called Cluster, which, like their new project, had four satellites to give a three-dimensional view of particle behavior. Cluster was launched from French Guiana in 1996. As the team watched on a live satellite feed in Durham, the French-built rocket exploded 43 seconds after lift-off, flinging the charred remnants of the satellites into a mangrove swamp. "It was unbelievable to watch a decade's worth of work blow up," Torbert recalls. But NASA determined the project was too important to give up, and four years later, team members held their breath as Cluster II was launched—this time successfully—with UNH-built instruments on board.

Like most of UNH's space scientists, Torbert teaches physics classes while working with fellow researchers on numerous satellite projects. "One of the strengths of space science at UNH is that because the researchers here have a history of collaboration with each other and a history of successful missions, UNH is held in high regard," he says. "That helps us when it comes to winning new grants and attracting talented people from top programs."



A Very Good Year

In the Morse Hall office of astrophysicist Jim Connell, the shelves contain ping pong balls and the board game Othello. It's not evidence of Connell's hobbies—they're props for his Physics 444 class on "Myths and Misconceptions About Nuclear Science." (He uses a ping pong ball to illustrate atomic dimensions: If Durham were an atom, he explains, its nucleus would be the size of a ping pong ball. Othello, with its equal number of black and white game pieces, helps him explain the half-life of nuclear decay.)

It was this same think-outside-the-box mentality that helped him win the center's latest project, an $8 million contract to build two instruments for the National Polar-orbiting Operational Environmental Satellite System. The mission's three satellites will collect data on Earth's weather, atmosphere, oceans, land and near-space environment; Connell's instrument design was selected to measure high-energy charged particles.

One day, exasperated with a physics problem, Connell went outside for a walk. A naval history buff, he began thinking about battleships and how their armored sides were built at an angle to give the ship extra protection—incoming shells would have to travel farther to penetrate the hull. "The same principle applies to particle detectors," says Connell, who realized that if he mounted three detectors in a row, each at a different angle, he would be able to triangulate the particles' direction from space.

Yet another new project—making 2005 a very good year indeed for UNH space science—is a $5 million grant awarded by NASA to space physicists Eberhard Möbius and Marty Lee to create an instrument for the Interstellar Boundary Explorer mission. Möbius and Lee will be helping to build extremely sensitive cameras to capture images of atoms at the point where the solar wind collides with the edge of the solar system beyond Pluto.

Pack It In, Pack It Out

Early explorations left so much debris in space, which is dangerous to current missions, that all parts of a spacecraft now must either stay attached or burn up in the atmosphere.

“We've been good at measuring charged particles, but it's a challenge for a camera to measure a neutral atom,” Möbius says. “Essentially, we're building Geordi's visor,” he jokes, referring to the blind Star Trek character Geordi La Forge whose futuristic sunglasses allow him to see better than his fellow shipmates.

As the solar system moves through our galaxy, it encounters something called the interstellar medium: In it are particles released both by the explosions of novas and supernovas and the stellar winds from other stars. Our solar system travels through space in a huge magnetic bubble called the heliosphere, which serves as Earth's first line of defense from dangerous cosmic rays (the other two are the Earth's magnetic field and its atmosphere). Launched in 2008, the satellite will travel in a highly elliptical orbit that will allow it to produce the first map of the heliosphere's boundary; it will also capture neutral interstellar gas. “Now we will be getting at the real thing,” says Möbius. “We want to study the raw material out of which stars and planets are formed. It's the only place we can get our hands directly on this interstellar gas.”

Switcheroo

Every 11 to 12 years, the Sun reverses its magnetic poles: north becomes south, and vice versa. Earth, too, has reversed its poles in the past, and will do so again—every 100,000 years or so.

Beepers, Balloons and Contraband

So many graduate students have worked with astrophysicist Jim Ryan on his gamma ray and cosmic ray projects that he has a shelf full of their black hard-bound theses. The Compton Gamma Ray Observatory, launched in 1991 with four UNH-built instruments aboard, orbited Earth 51,658 times and sent back many dissertations' worth of data before NASA decided five years ago to crash the observatory, after one of its gyroscopes failed, in a remote part of the Pacific Ocean.

Every minute of every day for those nine years, Ryan kept a beeper either on his belt or next to his bed to alert him when the observatory detected a cosmic gamma ray burst. When his beeper went off, Ryan would rush to the phone to alert astronomers before the burst disappeared. “There would be one every two to three weeks, and always in the middle of the night,” says Ryan, laughing.

There are two sources of gamma ray bursts, according to Ryan. One is hypernovas, clusters of incredibly massive stars that emit an enormous burst of radiation when they die. The other is thought to come from collisions between neutron stars, which are stars that have collapsed under their own weight.

Ryan is now working on several new projects, including Groundwinds, a close-to-Earth mission that will study how wind travels in the first 15 to 18 miles of our atmosphere. Using huge balloons, the experiment will illuminate small patches of the atmosphere with short bursts of a laser, allowing telescopes on the ground to get a snapshot of the wind's speed by observing a change in color called the Doppler effect. “Our lack of knowledge of the wind on a global scale is a big limiting factor in our ability to predict weather,” he says.

A neutron camera that Ryan is building for a future NASA mission turns out to have an unanticipated application for homeland security. Under a three-year, $750,000 grant from the U.S. Department of Energy, Ryan and his team are re-engineering their space-based instrument to detect contraband radioactive material at train stations, truck stops, ports and border crossings. “The neutrons coming from radioactive, fissionable material—plutonium, uranium—are all right smack in the same energy range as those we're looking to detect close to the Sun,” he says. And, to locate radioactive contraband, he adds, “what you need is a sensitive, small, lightweight, low-power detector, which is just what we've been working on for the past year and a half.”

Too New for Textbooks

In July 1969, when man first landed on the moon, Lynn Kistler watched the event on television with her grandfather, Adolf Busemann. A German aerodynamicist who, like Wernher von Braun, was brought to the United States after World War II to help with

the American rocket program, Busemann pioneered the theory of angled wings on planes for high-speed flight. From her grandfather—as well as her father, an aeronautical engineer in the space program and her mother, a math major—Kistler inherited her enthusiasm, love of science and sense of humor. She can remember her grandfather singing an "Annie Get Your Gun" song with new lyrics: "There's no business like *flow* business, like no business I know!"

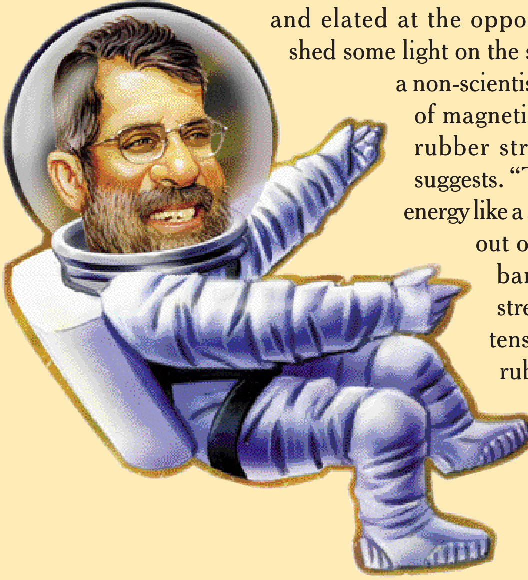
Since arriving at UNH in 1990, Kistler has worked on projects studying aurora, ionized particles and reconnection, and she's building an instrument for Stereo, a two-satellite project to study coronal mass ejections on the Sun; UNH's $7 million part of the mission is headed by Antoinette "Toni" Galvin.

A part of the team that built an experiment for the Cluster missions, Kistler analyzes the data Cluster II transmits back to Earth. And she is in the process of proposing a detector for a new NASA mission called the Radiation Belt Storm Probe. The radiation belts are bands of energetic electrons and protons trapped in circular orbits around the Earth; the particles are energetic enough to damage satellites.

"The stuff we do is a part of space science you don't really learn," Kistler says. "It's so new that it's not what they concentrate on in college—it isn't in the textbooks yet. And yet understanding the effects of these particles is critical in our technology-dependent world."

Close, But No Cigar—Yet

Not all space scientists at UNH build instruments that fly in space. Amitava Bhattacharjee, who holds the Peter T. Paul Chair of Space Science, uses mathematics and computer simulation to try to make sense of what the experimentalists discover. As a space plasma physics theorist, he seems positively delighted to tackle tough problems like reconnection, "dusty" plasmas and turbulence, and elated at the opportunity to shed some light on the subject for a non-scientist. "Think of magnetic fields as rubber strings," he suggests. "They carry energy like a sling made out of a rubber band. If you stretch it, the tension in the rubber band is converted into the speed of the stone." While discoveries in plasma science have led to breakthroughs such as the process the semiconductor industry uses to make miniaturized silicon chips, scientists like Bhattacharjee are quick to note that practical applications are not what primarily drives space or plasma physics. "I will not make a causal connection that because of magnetic reconnection research, you can produce better plasma TVs—that would be too tenuous," Bhattacharjee says. "What I can say, though, is that it's the mindset that makes us ask why things work the way they do, and try to answer fundamental questions, that may result eventually, in an unplanned way, in producing something that might actually be useful to people."



Northern Ionized Particles

The aurora, those luminous, flickering lights high in the northern (and southern) night skies, are electrons and ionized particles from space, slipping along the lines of the Earth's magnetic fields.

Fellow theorist Terry Forbes agrees. "The main reason I do this is not for practical reasons—otherwise I'd be an engineer—it's the intrigue of finding out these phenomena," says Forbes, who studies solar flares and coronal mass ejections, and with Bhattacharjee, recently received a $375,000 grant from the National Science Foundation to study reconnection.

Solar flares were first observed in 1859 by English astronomer Richard Carrington, and they still defy explanation. "But we're getting closer," says Forbes. One of the reasons for recent progress is the pictures of the Sun taken by telescopes aboard space observatories. "For a long time, all we had were images of the surface of the Sun," he notes. "We didn't realize it was a more complex structure. If it's invisible to you, you have no hope of getting it right."

Forbes and Bhattacharjee spend a lot of time collaborating with colleagues like Torbert as they design space instruments. "We tell him [Torbert], 'If that's the case then this should happen,'" Forbes says. "'If that didn't happen, think again.'"

Bhattacharjee believes that it's a great time to be working in space physics, and an even better time to be a young person starting out in the field. "Look at the whole gamut of observational information that we have now. That was totally unavailable to someone like me when I started out," he says. "We're at a very exciting stage right now, and I think even greater things will occur in the next 25 years." ~

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