**Research Corporation Science Profiles, 2009:**

**10 Young Scientists Tell Their Stories**

**By Ford Burkhart**

**In Tiny Pores, a Big Challenge to Analytical Chemistry**

Our cells’ portals are smart indeed. They can recognize incoming molecules, like proteins, bind to just the right one and grant entry as needed. That skill helps keep us alive. Such a passageway, called a nuclear pore complex, is in essence a powerful hole in the wall, one that really knows its molecular biology.

For Lane Baker, that’s a model well worth translating from nature to synthetic systems.

Baker, an analytical chemist at Indiana University, plans to study how to create technology that would work in much the same way as the NPC’s in our cells.

The synthetic portal would be smart and selective, with what Baker compares to a Velcro-like lining, just strong enough to briefly cling to the protein molecule, long enough to recognize its chemistry and usher it inside. Each of our cells has about 2,000 such portals, and they can conduct business about 1,000 times a second.

In his lab at the University of Indiana, Baker hopes to combine ideas from analytical chemistry and bioscience with practical insights from his days on a farm in Missouri to improve our understanding of biological pores like the NPC.

Applications might be found in creating sensors or separation technologies in which an opening the size of a protein molecule, about 10 nanometers (a human hair is perhaps 3,000 times as wide as a nanometer), can exert chemical control on what passes through. The portal could provide a selective membrane to separate out, say, a small molecule of a drug in an industrial process. Ultimately these holes could be contained in small portable devices and could be operated with low power and very simple read-out electronics.

“For me, it’s a conceptually simple idea,” said Baker, an assistant professor of chemistry at Indiana University. “It’s a hole in a wall, with the ability to recognize what’s moving through it. We want that hole to do some work for us.”

In any living organism, such surface openings they carry out a lot of its survival chores. A protein can create such an opening in a cell membrane, which can let essentials pass in and out, or can signal events outside and let the cell talk to the environment.

“We are trying to make such holes that are synthetic by adapting ideas from the living organism to the artificial material,” Baker said.

Baker grew up on family farm in central Missouri and tried a range of fields, from biology to physics to medicine. “Then one day a light came on,” he said. “All those fields can show how things work, but none of them explains things at the deeper, practical level that chemistry provides.”

In doctoral work at Texas A. & M., Baker says he fell in love with electrochemical sensors. “I knew as an undergraduate that I liked instruments and building things. At A. & M. I learned the molecular side, how to let molecules do the work.”

In postdoctoral work at the Naval Research Laboratory in Washington, he began work with semiconductors using solid state physics. “We were doing scanning probe microscopy, looking at semiconductor wafers, silicon chips,” he said, referring to the scanning tunneling microscope, a device that can read a surface at the atomic level. Then, during a second post doctoral fellowship, at the University of Florida in Gainesville, he began to put together all those fields. “I was studying nanopores, and I realized I could combine my experience with scanning probes in my work on these pores.”

Now, in his work at Simon Hall, Indiana’s flagship multidisciplinary science center, Baker is trying to, in essence, cut out pieces of the proteins from a natural pore and make them work in synthetic pores.

Ideally, each pore will be selective, specific to certain kinds of molecules, like a membrane protein. “We’ve taken some first steps, but we don’t yet have the level of control we need to do everything we’d like to do,” Baker said.

One day, such a synthetic pore could be able to pull out one molecule at a time from a sample for analysis. “If you put a drop of blood on a membrane, and the pore lets you look for one molecule, one protein at a time, you can determine if that molecule is there, and you can estimate the concentration,” Baker said. “Then you can take it a step further, you can start to think: What else it is interacting with? This is where it really gets interesting.”

Perhaps not so far removed from that Missouri farm, the goal is still to get some work done, with some essentially simple ideas.

=

**Mutagenesis: The Dark Side of the Amazing DNA Repair Shop**

Imagine a marvelous “DNA Repair Shop” where the crew could keep the beast running, no matter the pings, clicks and clacks. Sounds good at first – the old machine keeps going and going, copying DNA for a new generation, but it has a dark side.

Penny Beuning, a chemical biologist at Northeastern University in Boston, knows the harm that might result when cell mechanisms slip up, and then keep on copying DNA containing an error. At worst, the harm can include diseases like cancer.

Our cells must fix up our DNA many times a day, after the daily bruising we inflict on our genes. Many times a day, our cells’ most precious cargo, our genome, gets battered and scrambled − by the chemicals we eat or breathe in, our exposure to the sun’s ultraviolet light, even the byproducts of normal metabolism.

“All of that is constantly damaging our DNA,” Beuning said. “But most of us stay healthy. Our cells have a powerful way to restore the DNA information to how it was before the damage was done.”

At its best, the repair kit is rather like a built-in system-restore button, which sets everything right most of the time. However, a few random mutations, accidental changes that occur when DNA is being copied, can be useful to allow cells and organisms to evolve.

Beuning is an expert in a newly identified part of our DNA repair team called translesion polymerases. Many questions remain about why and how these players, named only in 2001, jump in to help with the process of copying damaged DNA.

“Are these tools enzyme-specific for a certain type of damage?” Beuning asks, “Or just able to copy any crazy structure that doesn’t seem to belong?”

Several kinds of enzymes patrol our DNA for errors and fix some of them. They regularly scan our tangled spiral staircase called the DNA double helix, focusing mostly on the areas with genes that keep us alive, but staying alert for the slightest glitch anywhere else.

Replicating damaged genes could lead to harmful outcomes beyond cancer, like the cell degeneration that occurs in Alzheimer’s or Huntington’s disease. Specific enzymes can jump in and rebuild the genes in a damaged stretch of the helix, and they usually succeed, or we’d soon die. How that works has been studied intensively for at least 40 years, but much is still unknown.

How we fix chemical damage to the six billion units, called bases, in our DNA recipe book is a vast area of biology, one involving questions about cancer, aging and the structural changes in genes that get passed on – known as mutagenesis. What we know is, we fix enough of the glitches so that life – that is, the production of new essential proteins – can continue.

Our cells’ proofreaders can spot any mistake, a wrong pattern, and other enzymes can insert the correct sequence, copying it from the other side of the helix.

Beuning is expanding the frontiers of research in this subfield of molecular biology. Her focus is on those vigilant proofreaders. There are more of them than was thought.

Her laboratory’s recent work has shown that even within a cell, multiple enzymes can compete for access to the damaged DNA. It’s not entirely clear how the cell picks the winner. Meanwhile, in other circumstances, the enzymes are extremely specific.

Another aspect of her work examines the structures and interactions of protein machines that make all of this possible. Beuning and her team discovered that one of the DNA copying enzymes binds to single-stranded DNA using a highly unusual “passive” mode, which likely plays a role in how all of the different enzymes compete for the DNA.

Beyond those benchmarks, Beuning is pressing on, blending chemistry with genetics and physiology in a basement lab at Hurtig Hall, the heart of chemistry at Northeastern. Early in her career, Beuning set out to learn the secrets of how cells maintain their information quality, in everything from yeast and bacteria to advanced animals, like humans. In post doctoral study at MIT, she began to study how the errors are spotted and how our cells repair them.

Beuning’s journey through research itself has been far from typical. She grew up in a small town in Minnesota called Avon, which, for her, evokes Garrison Keillor’s “A Prairie Home Companion.” “I certainly didn’t know people with Ph.D.’s,” she recalls. But teachers advised her to make the leap to Macalester College in St. Paul where she studied chemistry and math.

“I spent all my free time in the lab,” she recalls. “It was the greatest thing ever.” A professor told her that she could be paid to do that in graduate school. “You’re joking?” she replied. Before long she was doing a doctoral dissertation in chemistry at the University of Minnesota, on transfer RNA, or tRNA, the molecules that link up an amino acid sequence with the correct information in DNA.

“I wanted to learn more of the biology, to learn what I didn’t know,” she said. That part was filled in during her MIT post doctoral research. “I studied genetics and physiology, the new things I wanted to learn,” she said, “and now I am in a position to couple genetics and biochemistry.”

As a first-generation college graduate, she is devoted to helping the next generation, with emphasis on recruitment and training of women in science programs. “When I look back, I see that some people encouraged me to reach as high as I can reach,” she said. “That made a huge difference.”

**=**

**Reading Glasses for the Cosmos**

Observing dark matter, the unseen stuff that makes up most of the universe, takes some ingenuity. Mike Gladders has a few creative suggestions.

This mysterious matter is called “dark” because it doesn’t interact with light. But you can observe its giant fingerprints across the cosmos ― in the form of distortions it causes as gravity from huge clusters of galaxies and dark matter bend nearby light on its way toward Earth. Gladders will take a new tack by seeking answers among the most massive objects in the universe, galaxy clusters.

The huge tug of gravity from any immense distant object can become a sort of lens, altering light waves like a pair of reading glasses. Gladders’ research focuses on that effect, called gravitational lensing. If you know what to expect without the distortion, you can calculate whatever was making it happen.

“Gravity almost acts like an optic, or a lens, would,” said Gladders, an assistant professor of astronomy at the University of Chicago. “The gravity in this case is caused by the mass of huge clusters of galaxies, which are mostly dark matter.”

Dark matter has baffled physicists and astronomers since the 1930s when its presence was inferred by calculations to explain the motions of the galaxies within galaxy clusters. While no one yet understands dark matter, there are plenty of competing theories, and Gladders plans to help sort them out.

“We will ask how the lens acts to distort the background images in the sky,” he said. “Then we can say, ‘This is what you’d expect given this amount of dark matter.’ At a minimum you eliminate some of the competing models, and perhaps one will come to the fore.”

Imagine you were an optometrist and someone asked you to calculate the strength of a certain pair of glasses. You could test them and calculate the prescription. “That’s what we do with these gravitational lenses,” Gladders said.

The goal is to find just the right kind of clusters. “Clusters are rare,” Gladders said. “And those that exhibit lensing are even rarer, and really hard to find.”

To search for galaxy clusters that act as gravitational lenses, you have to start by finding a large number of galaxy clusters. Gladders does this by an analysis of large galaxy catalogs, searching for sometimes subtle overdensities in the galaxy distribution that mark the clusters. The largest such source catalog is the noted Sloan Digital Sky Survey, which contains information on some 250 million objects. The second largest such catalog is Gladders' own Red-Sequence Cluster Survey, comprising roughly 150 million objects, some of them more than a million times fainter than the faintest objects that you can see by eye. Gladders will start with such a list of individual galaxies, and reduce this to the 50,000 or so really promising clusters of galaxies. From there, the task is to generate a list of the few hundred gravitational lenses lurking in this vast set of data. “These are visually spectacular objects,” Gladders said. “They have a real discovery aspect to them.”

Gladders is a regular at the world’s top observatories. He has visited the Magellan telescopes at Las Campanas Observatory, in the remote Andean foothills of Chile, more than 30 times. Getting there is a privilege and a feat, taking months of preparation. So when his last visit overlapped his teaching of the “Astronomy and Astrophysics of Stars” class at Chicago, Gladders simply lectured from Chile by an Internet hookup.

He was able to share with students the joy of doing astronomy 18 hours a day, on three or four hours of sleep and lots of coffee, running the telescope, taking data, modifying the program. “When it’s cloudy one night, you have to figure how to get two nights of work done the next night,” he said. “I still enjoy it, the fascinating moments on a mountaintop, in a control room, with banks of computers. There’s a mystical quality to the experience, staring at the night sky, figuring out deep questions you’ve been asking for years. As I prioritize things, that ranks above almost anything else.”

Gladders was born in Southampton, England, and studied briefly at the University of Victoria, in Canada, before he was thrown out, for poor grades. “This can teach students that sometimes you can fall down and get back up,” he said. He worked at geophysics for the oil industry in Calgary until he was readmitted to college. He moved on to a Ph.D. at the University of Toronto, and became a fellow at The Carnegie Observatories in Pasadena, California, and then joined the University of Chicago.

Astronomers need big samples for robust tests of their models. "A few years ago the total known sample of lenses was just a few handfuls of objects,” he said. “We are now finding hundreds of these objects.”

As to direct measurement, Gladders said, some astronomers have high hopes for the Large Hadron Collider, the new accelerator under the Swiss-French border. “The LHC may reveal the dark matter particle”.

“If not,” he added, “then maybe astronomical tests are the only way.”

**=**

**Tuning a Magnet, Making Rainbows**

Turning clear water to any color at the touch of a button suggests an alchemist’s wizardry, but Yadong Yin makes it a routine event in his materials chemistry lab.

The feat by Yin, an assistant professor of chemistry at the University of California, Riverside, involves subjecting ordinary iron oxide particles – the kind that cover a floppy disk to record data – to a magnetic field. The magnet secures the particles in an array of photonic crystals. Those arrays can split light into various colors, and how they are arranged determines what colors are reflected.

Yin’s nanoparticles can self-assemble into colloidal crystals – with periodic structures analogous to their atomic or molecular counterparts -- of any color. In other experiments, similar crystals reflected light only with a fixed color, or wavelength. Yin’s range of colors is a wide and fully reversible optical response to magnets.

The applications fall into a category called optical microelectromechanical systems.

“You could use the technique in any display where you need to change the color of the material with a magnet,” Yin said. “You could make a board with that material, and on the back you would have electromagnets. As you vary the strength of the field, you will see different colors from the front.”

“We can produce one color at a time as we move the magnet over the solution,” Yin said.

And for his next feat, Yin hopes to apply fundamental chemistry to achieve these effects with different solvents. “Alcohol and mineral oil, for example, don’t let us organize the colors in the same way,” he said. “My research focus will address that issue, trying to put the materials in right order.”

The potential applications spin off in many directions, including making high-security documents with invisible photonic marks, fiber optics, sensors, or making inexpensive reflective displays useful on warning signs.

It would work best in daylight, with refracted light, or with a light source in the dark, since it is all based on reflection. Very strong sunshine will provide the brightest colors.

“You could put the particles on a bank note, embed them in the paper, and people would not see the color, but if you ran it over a magnet under it, it would appear as a security feature,” Yin said.

In China, where Yin was born on a farm in Jiangsu, near Shanghai, his family encouraged his science work. Although his parents had only an elementary school education, they recognized Yin’s talents, and his usefulness. “They knew I liked to disassemble stuff as a child,” he said. “Anything mechanical or electronic I would take apart, a radio, an old alarm clock. They were my playthings.” Now, when he returns to China, his parents have a to-do list. “My dad is always waiting, keeping the things that were broken in my absence.”

In high school in Jiangsu, he chose chemistry when a teacher told him, “With chemistry, it is easier to find an industry job.’’ Not true, he discovered. “And I didn’t feel excited about chemistry then. At that point, we had no chance to do experiments.”

He won a place at the University of Science and Technology of China, in Hefei, Anhui Province, and received his B.S. and M.S. degrees in applied chemistry there, graduating a year early by hard work, he says, and went on to receive his Ph.D. at the University of Washington.

At USTC, he managed to not only master the art of experiments but also to publish several papers. “In quite good journals,” he adds. With that on his C.V., he sent an e-mail to his future adviser in Seattle and asked for a chance to study and work in his lab. “He said, O.K., come,” Yin recalls.

Yin was a postdoctoral researcher at UC Berkeley and then a staff scientist at the Lawrence Berkeley National Laboratory before joining UC Riverside in 2006.

These days he enjoys telling old Chinese stories to his daughter Jessica. Her favorite is a classic from the 1500s about the monk who traveled west along the Silk Road to learn about Buddhism, with three disciples, one of them a wise monkey, and a dragon prince. They appear in different and amazing forms, and there’s a fair amount of magic. But no rainbows in a drop of water. That’s just chemistry.

=

**Flashing Mysteries, Milliseconds in Length**

In a quiet expanse of West Virginia hills, the biggest excitement on many days may be the latest news about a new kind of neutron star.

Somewhere between Morgantown, W. Va., and Charlottesville, Va., about an hour from the nearest Wal-Mart, world-class astronomers are scanning the radio sky for elusive data that might challenge Einstein’s theories about our galaxy and indeed the entire cosmos.

A leader of those galactic detectives, Duncan Lorimer, an assistant professor of physics at West Virginia University, abandons the main campus each summer for a lush and very dark corner of the Appalachian countryside called Green Bank where he works with the world’s largest fully steerable dish. There, at the National Radio Astronomy Observatory, he is searching for transient radio sources in the sky.

In the fall, he’s back on campus sharing his enthusiasm with WVU students, high school scholars and anyone else who will listen.

One recently discovered class of such objects is the rotating radio transients, RRATs or, informally, “rats.” “We look for things not seen very often, things that are difficult to detect, and then for only a few milliseconds,” Lorimer said one summer evening. “Some will repeat. Some will not.” The RRATs hint at more than they actually reveal. “We don’t really know much about them,” Lorimer said. “That’s part of the mystery.” This class of neutron stars was identified by their distinctive bursts, unlike other pulsars, which blip away steadily.

Lorimer has been studying white dwarfs, neutron stars and black holes, collectively known as “compact objects,” since 1991. Most of this research involves looking for and studying neutron stars which are observable with radio telescopes as pulsars. While working as a research associate at the Arecibo observatory, Puerto Rico, the world’s largest radio telescope, he met his wife, Maura McLaughlin, then an Astronomy graduate student from Cornell, which runs the Arecibo observatory. She is now also an assistant professor of physics at WVU, and they are among the world’s top experts on the RRATs, which are thought to be a class of rotating neutron stars.

Lorimer’s enthusiasm itself pulses like a galactic entity.

Lorimer titled his proposal for a 2009 Cottrell award “Bursts, Flickers and Cosmic Flashers: Exploring the Transient Radio Sky.” The proposal was inspired by a discovery that Lorimer and collaborators made in 2007 while searching archival radio observations for more RRATs. “We were looking at some data taken on the Large and Small Magellanic Clouds which are satellite galaxies to the Milky Way,” he explained, “and quite unexpectedly we detected a very bright burst of radio waves of completely unknown origin.”

Despite repeated attempts to detect the source again, no further bursts have been seen.

He says his observation suggests that this is the prototype of a new class of astronomical objects that could originate from well beyond the Milky Way. Lorimer proposes to search for similar events and try to understand their origin.

“One possibility is that they are the radio signals caused by coalescing neutron stars in distant galaxies, but the mystery is far from settled,” Lorimer added.

Lorimer, born in Darlington, in northeast England, received his Ph.D. studying neutron stars using radio astronomy at the University of Manchester, home of the Jodrell Bank Observatory. He did post doctoral study at the Max-Planck Institute for Radio Astronomy in Germany, and then was a staff scientist at the Arecibo Observatory. He was back at Manchester with a fellowship from the Royal Society when he was part of the team credited with the discovery of the RRATs, which were announced in 2006.

“There’s a lot of interest in looking for more of these elusive transient radio sources,” Lorimer said, and that’s what he intends to do as a Cottrell award winner. The stakes are high. Using telescopes, archives and the latest research tools, Lorimer’s work could help probe theories of gravity and general relativity.

“It is possible that gravitational wave signals are associated with these transient radio bursts,” he said, “and the detection of these could open up a whole new window on the Universe.”

**=**

**Superconducting Qubits and (Maybe) Quantum Computing**

For a decade or so, physicists have made headlines with talk of a new, powerful quantum computer, one that could solve problems with undreamed of complexity. Reactions have ranged from optimistic to skeptical.

For Robert McDermott, an assistant professor of physics at the University of Wisconsin, that goal is at best a point on a distant horizon, but giant steps have been accomplished.

“We are a long way from realizing a computer large enough to do something practical,” McDermott said. “We have moved toward that goal, but there’s still no guarantee that we will get there. Meanwhile, however, we’re learning much about the quantum mechanics of nanoscale systems.”

McDermott is running experiments that are part of a global effort to guide the eventual construction of such a computer, based on nanoscale units called quantum bits, or qubits. The curious qubit has the freedom to assume, in computer language, both a zero and a one and some other states, or superpositions, as well, simultaneously. If that is not strange enough, for the outsider, quantum mechanisms also have a property called “entanglement,” by which a change in an atom can be teleported with precision to a separate atom some distance away.

“We can take advantage of quantum superpositions and entanglement,” McDermott said. “I am an experimentalist, and my interest is in how to build a computer that operates quantum mechanically.”

McDermott’s approach makes use of superconducting circuits, somewhat like the circuits on a silicon chip in a conventional computer. The superconducting circuits incorporate special metals, in which electricity flows without resistance, along with layers of dielectric materials -- ones that cannot conduct electricity. The circuits exploit a phenomenon called the Josephson Effect, the result when two superconductors, divided by an insulating barrier, form tunnels for electrons to move across that barrier. To function properly, these circuits must be maintained at a very low temperature: around 20 millikelvin, about 100 times colder than outer space. To achieve these low temperatures, researchers use a machine called a dilution refrigerator, which cools with helium isotopes. McDermott and his students assembled such a cooling system from parts fabricated in the physics department’s machine shop.

A key problem that is central to McDermott’s work is decoherence: the degradation of the quantum state of the qubit. While the bits in an ordinary computer stay put, at zero or one, and retain your data, in a quantum computer that won’t happen. “In microseconds, all the quantum information is lost,” McDermott said. “We need to find a way to extend coherence times, by improving the materials of the qubit circuit.”

McDermott hopes to help explain the deeper fundamental physics of such decoherence. “It would be great to reduce decoherence to a level where we could build a quantum computer on a large scale,” he said. While some projects have achieved a scale of two or three qubits, a useful computer would require maybe 1,000 qubits or more to solve the problems we cannot solve with today’s computers.

As for applications, quantum computers would excel at factorization of large numbers, McDermott said, which has implications for cryptography. Potential spin-offs of this work include the realization of improved detectors based on superconductors. For example, McDermott’s research may help improve a type of ultrasensitive detector known as a SQUID, for superconducting quantum interference device. SQUIDs have been applied to such varied tasks as measurement of the magnetic fields generated by the brain, and astrophysical searches for subtle gravity waves from outer space.

Meanwhile, just getting a quantum mechanics computer up to the needed qubit levels is one of his major goals. And, says McDermott, “That’s still a long way off.”

**=**

**Einstein’s Cosmic Ripples: Pursuing the Elusive Waves of Gravity**

Maura McLaughlin is searching the northern sky hoping to detect something that has so-far eluded astrophysicists: the gravity ripples in space-time predicted by Einstein but not yet found.

Those subtle waves have been calculated, conceptualized, theorized about and even blueprinted in detail over nearly 100 years, but despite the use of increasingly sensitive detectors no one has actual seen them, so far. McLaughlin is on the case, with a new approach. She’s in no rush. If it takes 5, 10 or 20 years, fine. Nothing ranks higher on the “to do” list for modern physics. Observing gravitational waves, or GWs, would cast light on the collapse of stars, the birth of black holes and the Big Bang itself.

It’s a matter of nailing down the explanation of Einstein’s four-dimensional space-time, by detecting the distortions in that force of gravity that he theorized are set off by violent events like the collision of stars perhaps as distant as 300 million light-years, or several thousand galaxies, away.

McLaughlin, an assistant professor of physics at West Virginia University, and her team use pulsars as their starting point in the remote hills of West Virginia, home of the Green Bank Telescope. With pulsar measurements taken there, and with the Arecibo telescope in Puerto Rico, they believe they can one day detect GWs. McLaughlin and her team are surveying the radio skies from Green Bank and from Arecibo Observatory in Puerto Rico, the largest telescope in the world. They aim to detect more millisecond pulsars, which are incredibly precise celestial clocks. Gravitational waves will produce correlated disturbances in the arrival times of pulsars which can be detected by high-precision observations.

This is a different approach from that of two American observatories that make up the nearly $300 million experiment called LIGO, begun in the 1990’s, in central Washington and among the pines of Louisiana. LIGO, which stands for the Laser Interferometer Gravitational-Wave Observatory, hopes to detect gravity waves at the two distant sites, thus ruling out an earthquake or other local effect. Each lab sends laser beams down two identical arms that form a giant V in the countryside at each site. The beams travel 2.5 miles to mirrors, then home again. LIGO hopes a GW – a tiny movement indeed, much smaller than the nucleus of an atom - will rattle and stretch the arms, putting them out of sync, which a detector will record. So far, though, no waves.

“We think the waves exist, but it has always been an indirect measure,” McLaughlin said. “We can observe stars that are in orbit around each other, and see that their orbits are shrinking and getting closer together in time. That’s exactly in line with what Einstein predicted, and that’s all good. The next step is detecting the gravity waves directly.”

As a GW passes, the light travel times between Earth and all the pulsars will change slightly. “If we can measure these disturbances, we should be able to see this wave passing, this ripple in space time,” McLaughlin said. “But it’s tricky, because it’s a very small effect.”

McLaughlin became hooked on science as a schoolgirl in Oreland, Pa., reading science fiction, the works of Isaac Asimov, and the writings of the astronomer Carl Sagan and the physicist Stephen Hawking. “That got me interested,” she said. She was at Penn State in the early 1990s when her career choice was settled by a research project at the Arecibo Observatory. “That was pretty cool,” she says.

At Cornell, she earned her doctorate in physics, working on pulsars, and then moved on to the University of Manchester as an NSF math and physical sciences distinguished research fellow and as a postdoctoral research associate. She joined WVU in 2006.

The significance of detecting GWs is hard to overestimate. “It’s a big deal, like a Nobel Prize-winning big deal, and would bring a massive increase in our understanding of the universe,” McLaughlin said. “As we learn about sources of gravity waves, we will know about objects we can’t see with visible light. We will gain a new window on the universe.”

**=**

**Rethinking the Stellar Soup: Turbulence among the Stars**

For centuries, astronomers underestimated the vitality of the vast galactic soup between the stars. Now, with new tools to observe the galaxies and new models of their behavior, we are getting a picture of a wild and unexplained scene filled with fountains of hot gases exploding and cooling down into clumps that may give birth to new stars.

Snezana Stanimirovic, an assistant professor of astronomy at the University of Wisconsin-Madison, is among the leaders in bridging the two main ways of studying the stuff between the billions of stars – direct observations and astrophysical models.

Using data from the Arecibo radio telescope, the world’s largest, she is helping paint a richly detailed panorama of one of the liveliest components of space, the thin atmosphere called the interstellar medium, or ISM.

“What’s interesting is that the interstellar medium makes stars, and then at end of their lives the stars return their matter and energy back into that medium,” she said. “It’s very dynamic. And it’s essential for galaxies, for their evolution, and for how the galaxies behave and interact with their neighbors.”

Stanimirovic studies how the galactic clouds form and morph into stars, in turn shaping the evolution of galaxies like our own Milky Way, and the next-door Small Magellanic Cloud, all of them alive with big gravitational forces and little understood turbulence.

“This turbulence is something we don’t understand well,” she said. “We know it affects many astrophysical processes, especially star formation. A lot of recent models using numbers and theoretical assumptions have simulated the interstellar medium. Some are starting to include information about turbulence. However, we still need to test how well the simulated spectra match the observations.

“By comparing observations and simulations we are trying to understand all the essential physics that needs to be included in the models. We are not there yet.”

Stanimirovic, pronounced stani-MEE-ro-vitch, was born in Serbia, then Yugoslavia, and studied at Belgrade University and at the University of Western Sydney at Nepean, in Australia, and did post doctoral work at the Arecibo Observatory, in Puerto Rico, and at the University of California, Berkeley.

Her initial focus was the Small Magellanic Cloud, a dwarf galaxy 200,000 light years away, but she expanded her study to include our own Milky Way, taking a hard look at the substantial gravity interactions between the two neighbors.

Interstellar medium is quite different in the two galaxies, Stanimirovic said. “We are still trying to establish how this affects star formation,” she said. “There is a lot of theory that cloud formation depends on galactic environments. The amount of metals in the atmosphere is important for how the clouds fragment. We are still trying to establish the links between cloud and star formation. The story is still evolving.”

Her work takes spectra and images of atomic hydrogen and translates them into statistical functions that can be compared with predictions from numerical models.

“You compare what you measure using a radio telescope with what the models predict that ISM should look like. If the model doesn’t match the observation, you may need to include one or more ingredients in the model,” she said. “You keep going until you pin down what’s going on.”

From the start, Stanimirovic was thinking big. As a girl in a mountain town in Yugoslavia called Surdulica, she read books by Carl Sagan and whatever other astronomy she could find. At the end of high school, one big exam screened all the students in the country for just five places in astronomy at Belgrade University. If she failed, she recalled, she would settle for a less competitive subject ― like theoretical math, numerical math or theoretical physics. At the three-hour exam in June in a large theater in Belgrade, she recalls, “I just went in and did well, and I got it.” That October, her classes began.

A few years later, she was studying the ISM for her PhD thesis at the Australia Telescope Compact Array, doing interferometry, a method that allows extremely fine detail images of the ISM, and working with the Parkes Observatory. Both are in New South Wales.

That theme has continued at Arecibo, where she has found that the ISM looks remarkably different in the Milky Way from what she found in the Small Magellanic Cloud. “It’s amazing,” she said. “You study a far away galaxy in the universe, and then step back into our own, and you are so limited in how to explain the complexity and diversity of what you see.”

She believes the Small Magellanic Cloud can serve as a stepping stone to study of distant galaxies. But more powerful tools are needed, Stanimirovic says, and she looks forward to working with one in particular, the ASKAP. That stands for Australian Square Kilometer Array Pathfinder, a powerful radio telescope consisting of 36 antennas, expected to be able to pull in more information than any device in the history of astronomy, to be ready by 2013.

“Just imagine that,” she said. “We will be one step closer to the future.”

=

**Synthesizing Molecules of Red Wine’s Superingredient**

An ingredient in red wine and grape skins called resveratrol is one popular explanation of the French Paradox: despite high intake of fats, relatively few heart attacks. Resveratrol is used by grapes and some 70 other plants throughout the world to fashion hundreds of other molecules that appear to have important health benefits.

With some original thinking, Scott Snyder, a synthetic organic chemist at Columbia University, is seeking to find ways to mirror what plants do naturally – manufacture those complex molecules called oligomers. He hopes to better understand their behavior and the uses of this ancient ingredient in a wide range of diseases and other modern applications.

Resveratrol and the molecules made from it, it turns out, are made by plants to defend against pathogens, primarily fungal infections. In mice, however, they appear to extend the aging process and aid against tumors ,and in humans, there are high hopes that they can do everything they do in mice and even help ward off heart trouble. Snyder’s work may expand our knowledge of how they work and may defend our bodies against other diseases, like H.I.V. The molecules he and his students are creating may one day help protect against bird flu or serve as insecticides.

“Nature makes these compounds not to cure human disease but to allow the producing organism to survive,” Snyder says. “They take resveratrol and use it like a Lego set, putting two or three or even ten together to make dozens of natural products all at once. Our goal was to figure out how we could create these structures one at a time so we could study them further.”

That’s the really tricky part, Snyder says, the problem of controlled synthesis.

Learning how won’t come quickly, but Snyder’s lab is well on the way. If you look at the 500 or so chemicals in grapes that add up to red wine and account for its subtle variations in taste and color, there’s only one polyphenol that is unique to red wine that is not found in appreciable quantities in white wine and grape juice, and that’s resveratrol. That, says Snyder, was one anomaly worth studying.

Here’s another. Of the 700 complex molecules made from resveratrol that have been isolated from plants, nearly all result from predictable patterns of chemical reactivity; 10 or so of these structures, however, don’t fit chemists’ expectations, and had been regarded largely as synthetic anomalies, something that went off track. “They were the black sheep members of the family,” Snyder says.

“But they pointed us to a different way to begin this synthesis,” Snyder says.

After six months of false starts in his lab and building on 30 years of failed attempts by other chemists to solve the same problem, Snyder realized that the key clues resided in those anomalies. To get to the synthesis of compounds made from resveratrol, he knew he had to create an original molecule to serve as a new starting point for a vital series of reactions. “We shifted our approach and started looking at the odd balls, playing with different ideas for what they were indicating that starting point could be,” he says.

As a result, they ended up revealing the structure of a new building-block that could reach the desired outcome, the controlled synthesis of compounds built from resveratrol. Snyder and his team have now applied they same lesson to achieve the synthesis of other important bioactive molecules from nature as well.

“The moral of the story is, don’t dismiss an anomaly. Find a way to use it,” says Snyder, who has been doing science since childhood. In Buffalo, N.Y., his father was a biochemist who made Scott feel at home in the lab; his mother was a mathematician. In high school, he was one of 20 finalists selected in 1995 to compete as representative for the United States in the International Chemistry Olympiad and was a semi-finalist in the Westinghouse Science Talent Search. He was then a top chemistry major at Williams College, received a Ph.D. at Scripps Research Institute, and was a postdoctoral fellow at Harvard in the laboratory of a Nobel Laureate.

Millennia ago, plants made the compounds like resveratrol because of evolutionary pressure to survive. Now, on the fifth floor of legendary Havemeyer Hall where Nobel Prize winning ideas in chemistry are almost old hat, Snyder’s lab seeks to harness those eons of evolution and adapt them in ways that may point to groundbreaking applications.

=

**Synthetic Chemistry, Ethics and a Little Pixie Dust**

Rory Waterman calls himself an ethical chemist. He explains that he’s on the trail of best catalyst to make important reactions play out without waste. And for him, eliminating waste is a matter of ethics.

He works on a key frontier for the synthetic inorganic chemist, in the booming field called organometallics, which shares the tricks of organic and inorganic chemistry and much more.

Catalysts have been speeding up reactions in chemistry since, well, perhaps Thomas Jefferson and Ben Franklin. Back then, catalysts were crucial at the dawn of American industry, creating bonds with carbon and all the elements central to mining and manufacturing.

Waterman’s work, in the chemistry department at the University of Vermont, is on a whole new plane, involving the newest challenges in organometallic chemistry. His goal is chemical bonds that will avoid costly waste.

“Our overall method is to develop catalytic reactions, those that use a small amount of an additive,” he said. “In essence, this is chemical pixie dust. You sprinkle in a catalyst and it makes a reaction that was slow or difficult a lot easier.” Waterman admits he’s no expert on pixie dust, but his lab is on the leading edge of designing new uses for catalysts and efficient ways to recover them when their work is done.

Waterman’s focus is catalysts used with a group of metals that includes phosphorus and its neighbors in the Periodic Table of Elements, a step up in difficulty from catalysts that bond with nitrogen and oxygen. “The methods don’t broadly exist for these molecules,” he said.

The phosphorus molecules have interesting electrical properties, he says, and could play roles in LED displays, for example. “But to use these molecules, it’s now quite wasteful,” Waterman says. “It’s a kind of social justice issue.”

In the Periodic Table, elements are grouped into blocks, based on the behavior of their electrons. The group that Waterman works with is called p-block elements. He focuses on a location that contains heavier p-block elements, like nitrogen, phosphorus and arsenic.

A few years ago, Waterman’s lab made a discovery about arsenic, finding how to produce a specific reaction that goes by the hefty name of Alpha arsenidene elimination. They came up with improved methods to achieve that difficult set of reactions.

“We now hope to push that reactivity to phosphorus,” he said, “to see if the process works for heavier elements. If it does, we want to push it up to that level.”

What will it take to achieve that? “I wish I knew,” Waterman said with a laugh. “From the arsenic chemistry, now we will try to emulate that for phosphorus. All options are open. We’ll do it from a variety of angles, in hopes of getting that event to occur in a single complex, or system.”

Transition metals, those that fall between two important groups in the Period Tables, are among the best friends of the synthetic chemist. Waterman hopes to build his catalysis reactions using models that involve transition metals like iridium and zirconium. “We’re going to look at a variety of different ways, a multipronged approach.”

If he succeeds, industry will no doubt be watching. “We will be far closer then to the applications that we foresee,” he says. “We will try, in house, to build these molecules, but it will all be of interest to industry.”

In his undergraduate work at the University of Rochester, Waterman worked on paramagnetic metalloproteins. “Then I discovered I liked to make things, so I moved to synthetic chemistry.” He received his Ph.D. at the University of Chicago and did postdoctoral study at UC Berkeley.

It took a sophomore class in organic chemistry to hook him. “I thought, What a spectacular idea!” he recalled. “I went from organic chemistry to organometallo chemistry. Things only got better.”

Recently his parents visited him at his home in Burlington, bringing a chemistry set from their basement that they thought he’d recognize. “They thought I had played with it,” he said. “Not so. Didn’t know it was ever there.” Whatever he missed, he’s been filling in the gaps, from organometallics to ethics to pixie dust.