

COLLEGE OF COMPUTER, MATHEMATICAL, AND NATURAL SCIENCES

ODYSSEY

BLACK HOLES

SUPERMASSIVE
Guardians of the Galaxies

ODYSSEY

Editor: Abby Robinson

Editorial Associates:
Rachel Bender, Mary Kearney
and Matthew Wright

Designer: Loretta Kuo

DEPARTMENTS

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Department of Atmospheric
and Oceanic Science
(formerly Meteorology)
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Dear Friends,

As you read this letter, another exciting and highly productive semester has come to a close. At our May commencement, the college awarded more than 1,100 degrees and graduated its first cohort of students in the Integrated Life Sciences honors program. You can read more on page 18 about our commencement speaker, University System of Maryland Regents Professor of Physics Sylvester James Gates Jr., his wife, and his twin son and daughter, who both graduated with their bachelor's degrees from our college this spring.

Over the past few months, we have celebrated the achievements of many students in the college who earned nationally competitive awards: a senior received a Rhodes Scholarship (read more on page 21), another senior received a Fulbright Scholarship, three juniors received Goldwater Scholarships, three sophomores received Hollings Scholarships from the National Oceanic and Atmospheric Administration, an alumnus received a Soros Fellowship to attend medical school, and a total of nine students and alumni received National Science Foundation Graduate Research Fellowships.

This spring, the state confirmed its financial support for the Brendan Iribe Center for Computer Science and Innovation and selected the design firm HDR Architecture. Thanks to the hard work of many faculty members, staff members and students, we

have completed our planning of the innovative research, education and collaboration spaces in the building, which we anticipate breaking ground on next spring. Construction is also progressing along Campus Drive on the Edward St. John Learning and Teaching Center, which will feature collaborative learning environments and new chemistry instructional laboratories when it opens in 2017.

Across campus in the new Physical Sciences Complex, a group of astronomy faculty members continue their efforts to identify and study supermassive black holes. The more we learn about these matter-hungry cosmic juggernauts, the closer we get to understanding the nature of matter and the origin of the universe. You can read more on page 4 about our astronomers' efforts to uncloak these massive beasts.

As always, we thank you—our alumni and friends—for your collective support, which moves us ahead and ensures that our college remains at the forefront of research and education.

A handwritten signature in blue ink that reads "Jayanth R. Banavar". The signature is fluid and cursive.

Jayanth Banavar

Dean

College of Computer, Mathematical,
and Natural Sciences

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ON THE COVER

TWO EXTRA SPIRAL ARMS THAT GLOW IN X-RAY, OPTICAL AND RADIO LIGHT ARE SEEN IN THIS COMPOSITE IMAGE OF GALAXY NGC 4258. THE SUPERMASSIVE BLACK HOLE AT THE CENTER OF NGC 4258 IS ABOUT 10 TIMES LARGER THAN THE ONE IN THE MILKY WAY AND IS CONSUMING MATERIAL AT A FASTER RATE, POTENTIALLY INCREASING ITS IMPACT ON THE EVOLUTION OF ITS HOST GALAXY.

*Image by NASA/CXC/
JPL-Caltech/STScI/NSF/
NRAO/VLA*





BLACK HOLES

SUPERMASSIVE
Guardians of the Galaxies

By Matthew Wright
Illustration by ESA/ATG Medialab

BLACK HOLES

are the darkest and most mysterious objects in the known universe. In casual conversation, they serve as a stand-in for any unseen force capable of making things disappear. Tell your friends you lost a sock in the dryer or can't find your keys, and they might well invoke a black hole as the guilty party.

It is easy to understand why black holes have this reputation. After all, they are so massive and dense that not even light can escape their immense gravitational pull. Any matter that wanders too close is irreversibly drawn past the black hole's event horizon—the point beyond which it is impossible for anything to escape. The gravitational field of a black hole is so powerful it can bend light and warp the fabric of space and time.

But black holes are so much more than matter-hungry cosmic juggernauts. Although their relatively small size makes them very tricky to study, especially at large distances, black holes hide key details about the nature of matter and the origin of the universe.

"We now know that black holes are a ubiquitous component of galaxies," says Suvi Gezari, an assistant professor of astronomy at the University of Maryland who tracks the evolution of black holes over time. "These exotic manifestations of strong gravity are so powerful, the physics alone is a compelling area of study. The largest of them most likely shape the evolution of their host galaxies and go through their own distinct phases of development."

The largest black holes Gezari refers to are supermassive black holes, which can reach 10 billion times the mass of the sun. At least

one of these behemoths is believed to occupy the center of every massive galaxy, where they can exert a strong influence on their host galaxy's size, shape and life history. Those who have seen the 2014 blockbuster movie *Interstellar* will have some idea of the forces at play, as a supermassive black hole played a key role in that film's plot. Supermassive black holes have been spotted in several dozen nearby galaxies—including Earth's own Milky Way.

Smaller black holes exist (See "The Smaller Cousins of Supermassive Black Holes," page 10), but supermassive black holes are particularly tantalizing targets for research, largely because of their suspected role in the evolution of galaxies. These giant black holes are also thought to be the perfect natural laboratories to study gravitational waves and may one day yield further secrets about the nature of gravity.

The more scientists learn about these massive beasts, the closer they get to understanding the origin of the universe and the nature of matter itself. And UMD astronomers are leading the way, with a group of researchers dedicated to finding and demystifying supermassive black holes.

TRACKING GHOSTS

Nowadays, astronomers are quite confident that black holes exist. But that was not always the case. An object that is totally dark is terribly difficult to confirm, let alone study.

The idea of black holes first surfaced when Albert Einstein published his theory of general relativity in 1915. Although Einstein

was initially quiet on the subject, his theory implied the existence of "dark stars" in purely mathematical terms: any object with sufficiently high mass and density would be expected to create a staggeringly powerful gravitational field. According to some accounts, the very idea made Einstein uncomfortable, and for decades the concept sat on the proverbial shelf.

Then, in the early 1970s, observational technology caught up with theory. One of the first key discoveries was Sagittarius A* (pronounced "A-star"), a powerful source of radio emissions situated near the center of the Milky Way. For years, astronomers struggled to explain this object, which is now widely accepted to be the Milky Way's supermassive black hole.

"There's almost nothing feeding Sagittarius A* at the moment. It's starving, the poor thing," says Sylvain Veilleux, an astronomy professor at UMD. "While our galaxy's central black hole isn't very exciting now, it was probably a lot more interesting in the past."

A LIGHT IN THE DARKNESS

Luckily, when black holes consume matter they become active, and a spectacular show ensues. When astronomers search for active supermassive black holes at the centers of distant galaxies, they are looking not for the black hole itself, but for telltale evidence of the black hole's dining habits.

Active supermassive black holes have a large "accretion disk" of matter—mostly gas—which is drawn toward the black hole.

THE "FIRST" BLACK HOLE

The term "black hole" first surfaced in the 1960s, coined by theoretical physicist John Archibald Wheeler, who also mentored some of the biggest names in black hole research—including UMD's own Charles Misner, professor emeritus of physics. In 1972, the stellar mass object Cygnus X-1 was recognized as the first potential black hole discovery, based in part on its intense X-ray emissions. Debate on Cygnus X-1's status continued for nearly two decades—fueling a famous friendly wager between Stephen Hawking and Kip Thorne—but by the early 1990s the astronomy community had widely accepted it as a true black hole. ■



**"THERE'S
ALMOST
NOTHING FEEDING
SAGITTARIUS A*
AT THE MOMENT.
IT'S STARVING, THE
POOR THING."**

—SYLVAIN VEILLEUX

As the gas becomes more densely packed, it produces friction on an epic scale. This friction sets off some impressive fireworks, emitting radiation across the entire electromagnetic spectrum.

This explosive dance between a central supermassive black hole and its accretion disk creates an active galactic nucleus. The most energetic active galactic nuclei are quasars, which are the brightest objects in the known universe. Finding these objects is not exactly easy, but technology and methodology have advanced by leaps and bounds over the last several decades.

"One of the main areas of my research is to find how many active galactic nuclei are there, in what type of galaxies they are located and what effect they seem to have on their host galaxies. Theorists can take it from there," says Richard Mushotzky, an astronomy professor at UMD. To distinguish an active nucleus from any of a number of other bright objects in the sky, one needs to rely on a combination of three main sources of evidence. The first is X-ray emission.

"Almost all active galaxies are luminous X-ray sources. Once you get to a certain luminosity—about a billion times that of the sun—the object is always an active black hole," Mushotzky explains.

Second, there are also key differences between the spectrum of the light emitted by active galactic nuclei and by stars and more typical celestial objects.

"The nature of the light that a quasar emits is very different. If a star emits red, green and blue, you can think of a quasar as emitting maroon, chartreuse and puce," Mushotzky says.

A third line of evidence is radio wave emission, which enabled the detection and study of Sagittarius A* decades ago. But only some quasars are strong radio sources. Others are referred to as "radio quiet," making the first two sources of evidence all the more important.

All told, more than 100,000 active galactic nuclei have been identified to date.

Gezari, Veilleux, Mushotzky and other UMD colleagues have had a hand in some of these discoveries. But the hunt continues, and each new discovery provides another chance to ask some big questions. One of the most compelling questions is also one of the most basic: How, exactly, do these giants exist?

AN EXISTENTIAL PUZZLE

Light from the most distant quasars has been traveling for a very long time, meaning that many of these objects existed as early as a billion years after the Big Bang. (The universe is around 13.8 billion years old.) The very existence of supermassive black holes that early raises some huge questions. According to standard model physics, the early universe should not contain any one object—let alone many of them—with that much mass. Simply put, a billion years is not long enough for anything to have grown so big.

"It's as weird as seeing a bunch of eggs that are bigger than the chicken that laid them," says Gezari. "We see a lot of supermassive black holes out there, but not enough time has passed for them to accrete. There must have been some very big seeds to produce them."

Much like a water main has a maximum capacity, and thus can only carry a certain amount of water per second, all black holes have a built-in "speed limit" that defines how quickly they can collect matter. Sir Arthur Stanley Eddington first described this limit in the context of massive stars, long before black holes were definitively known to exist, but the concept applies to any body that exerts a

strong gravitational field.

This speed limit bears Eddington's name and is a balance between two competing forces: the gravity drawing matter toward a black hole and the outward radiation pressure generated by this process.

"If we look at quasars that formed not long after the Big Bang, we find objects on the order of billions of solar masses," says Christopher Reynolds, an astronomy professor at UMD whose work straddles the line between observation and theory. "So it seems the universe might have had a 'race' to make supermassive black holes within the first few billion years. It turns out this is quite hard. They would have to grow at the Eddington limit for the entire early history of the universe."

Such a scenario is difficult to explain, largely because it is hard to model how a stand-alone black hole could be fed with enough matter to maintain the Eddington limit for that long. So, astronomers have looked for other explanations. It's possible that supermassive black holes are byproducts of galaxy formation, seeded by giant central stars that collapsed and formed smaller black holes. Sitting at the center of a young, turbulent host galaxy might provide such a "seed" with enough raw material to grow bigger and quickly reach the Eddington limit.

Reynolds is leading an effort to simulate black hole seeding as a principal investigator on a National Science Foundation-funded project called the Theoretical and Computational Astrophysics Network (TCAN). With nodes at UMD, Georgia Tech and Yale, TCAN researchers are harnessing the significant computing power available at these institutions to run complex computer models of the accretion process.

"We plan to make models of these huge gas balls to see if they do actually form supermassive black holes," Reynolds explains. "It's not a given that they will. The high levels of energy could blow them apart. There are lots of ways the process could go wrong, actually."



Plasma jets

Plasma jets

ANATOMY OF AN ACTIVE BLACK HOLE

ACTIVE
GALACTIC
NUCLEUS

Large-scale galactic winds/outflow

Small-scale radiation-driven winds

Accretion disk

The Smaller Cousins of Supermassive Black Holes

It can be tough to imagine the scale of black holes. They contain a lot of matter, but their extreme density means they do not take up much space. A black hole is defined by its event horizon, which has

a linear and predictable 1:1 relationship with its mass; for every solar mass, the radius of a black hole's event horizon expands by 1 kilometer.

To put this in perspective: if Earth was compressed to the density of a black hole, its event horizon would occupy about as much space as a single grape. This example is largely hypothetical, however. Although some have suggested the existence of "micro" black holes, they have not yet been documented with any certainty.

The minimum mass of known black holes is about three to five times the mass of our own sun. Much like the grape-sized Earth example above, all that mass is crammed into a mind-bendingly small package: a black hole with the mass of five suns would create an event horizon small enough to fit within Washington, D.C.'s Capital Beltway.

These small black holes are called stellar mass black holes, which reach a maximum of a couple dozen times the mass of our sun. Most are the corpses of dead stars, which spent all of their fuel and collapsed under the weight of their own gravity. C.V. Vishveshwara, Ph.D. '68, physics, was the first to prove the stability of black holes formed in this way.

Astronomers suspect the existence of slightly larger black holes, known as intermediate-mass black holes. Direct evidence for these mid-sized objects of several hundred solar masses has been in short supply. But in late 2014, Dheeraj Pasham, M.S. '10, Ph.D. '14, astronomy, and Astronomy Professor Richard Mushotzky published a paper in the journal *Nature* that described one of the first likely candidates.

"Despite lots of study, there is still not 100 percent certainty that intermediate-mass black holes exist. I'm in the camp that believes the answer is yes," says Mushotzky. "It's really hard to figure out. Some candidates have properties that are consistent with black holes, but in other ways they don't behave like black holes at all. Whatever we discover, it will be really weird, which makes things exciting." ■

STELLAR MASS
BLACK HOLES
5-25 solar masses

INTERMEDIATE-MASS
BLACK HOLES
100-100,000 solar masses

SUPERMASSIVE
BLACK HOLES
1,000,000-10,000,000,000
solar masses

GREATER THAN THE SUM OF ITS PARTS

Some astronomers argue that simple accretion, even for a prolonged time at or near the Eddington limit, still does not adequately account for supermassive black holes. Instead, an alternate theory suggests that smaller black holes formed by accretion at the centers of young galaxies long ago. Then, some of these galaxies merged together, combining their central black holes to form larger black holes. This process continued, leading to progressively larger black holes that eventually reached supermassive status.

Galaxy mergers are known to happen. Combine that with the assumption that every galaxy has a black hole at its center, and this scenario starts to make a lot of sense.

"Small galaxies merge to form bigger ones, so it is reasonable to think that the black holes will merge as well," says Gezari. "But so far as we know, there is only one supermassive black hole at the center of most galaxies, and evidence for two or more black holes has been difficult to find."

Gezari and graduate student Tingting Liu recently published a study in *The Astrophysical Journal Letters* documenting what they believe to be a pair of supermassive black holes at the center of a large galaxy named PSO J334.2028+01.4075. If they are correct, this black hole "binary" most likely represents the final stage of a galaxy merger. The black holes are very close together—closer than anyone has seen before—leading the researchers to suspect that the two black holes are gravitationally bound to one another.

If this is the case, it is likely that the two giant black holes will soon merge to become one—possibly within the next 20 years or so.

Confirming a black hole merger would lend a lot of weight to the idea that supermassive black holes formed in the same way, from a series of black hole mergers beginning shortly after the Big Bang.

"Previously, we were only able to look at one picture of the system, one moment frozen in time, like a single snapshot," Liu explains. Now, with the advent of new data collection techniques, such as the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS1) survey that provided the researchers with their data, Liu says, "we're looking at a movie of how these systems evolve."

A GALACTIC THERMOSTAT

Regardless of how they form, it's clear that supermassive black holes have a close bond with their host galaxies. One of the newest and most exciting areas of black hole research aims to understand the precise nature of this relationship. It is quite likely that these monster black holes are a major influence, strongly modifying the dynamics and evolution of the entire system.

"Galaxies and supermassive black holes are all wrapped up together, a lot like an ecosystem," adds Mushotzky. "It's not something you can separate out easily."

A single, curious observation has driven much of the research in this area: in nearly every galaxy where a supermassive black hole has been observed, astronomers have seen a tight correlation between the mass of the black hole and the mass of the galaxy. The bigger the galaxy, the more massive the black hole at its center.

This is likely not a coincidence. A supermassive black hole's extraordinary energy output would almost certainly have far-reaching effects on the matter surrounding it. Many quasars have been observed shooting powerful, focused jets of plasma from their centers that reach hundreds of light years outside their home galaxies. Some of these jets are so luminous they can be detected billions of light years away, but it is not entirely clear whether and how the jets might affect the galaxy itself.

Focused jets are not the only powerful energy blasts produced by quasars. In 2011, Veilleux and David Rupke, Ph.D. '04, physics, were the first to describe winds that carry huge loads of gas and dust out beyond the edges of a galaxy. The study, published in *The*

AGENTS OF EXPLORATION



Amy Reines

Some great careers emerge in unexpected ways. Amy Reines, B.S. '98, astronomy, didn't set out to study science, instead starting off as a business major. Reines changed her major after getting hooked on Grace Deming's Astronomy 101 class. After completing a couple of master's degrees and founding a startup in math tutoring, she earned a Ph.D. in astronomy from the University of Virginia in 2011. "I unexpectedly found a supermassive black hole in a dwarf starburst galaxy and that completely changed my research focus," Reines says. Following her doctoral studies, Reines was awarded a NASA Einstein Fellowship at the National Radio Astronomy Observatory and began a NASA Hubble Fellowship at the University of Michigan last year.



R. Brent Tully

In 1977, shortly after accepting a position at the University of Hawaii, R. Brent Tully, Ph.D. '72, astronomy, published a landmark paper with J. Richard Fisher, Ph.D. '72, astronomy, which proposed a relationship between the masses of galaxies and their luminosities. The Tully-Fisher relation, which remains a standard tool for astronomers, has enabled the measurement of distances between Earth and far-flung galaxies. "When I started graduate studies in 1964, I saw immediately that astronomy was wide open," Tully says. "Little was known and the competition was limited." Tully has published numerous catalogs of nearby galaxies, and in 2014 shared the Gruber Foundation Cosmology Prize for discoveries regarding the structure of our universe, governed by an invisible gravitational component—what we now call dark matter.



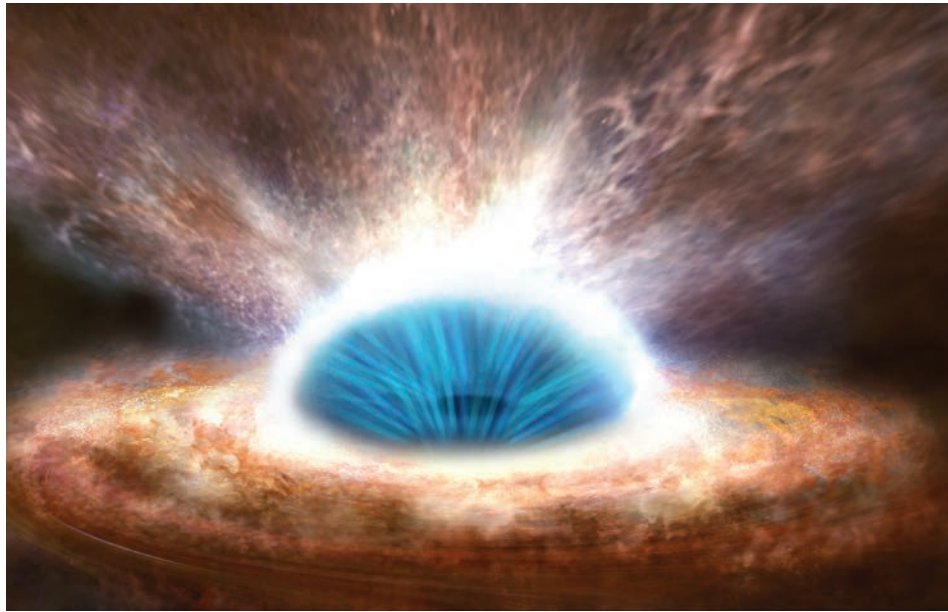
KwangHo Park

KwangHo Park, Ph.D. '12, astronomy, is deeply involved in the study of black hole origins. Now a postdoctoral researcher at Georgia Tech, he participates in the Theoretical and Computational Astrophysics Network and models the growth of supermassive black holes. His main concern is how active galactic nuclei balance the forces of gas accretion in "brightest cluster galaxies," home to the most massive black holes in the universe. "I hope we can get a better answer to one of the biggest mysteries," Park says. "How do massive black holes form and grow in both the early and present-day universe?"



John Mulchaey

For some, the tug of supermassive black holes can be felt in a more figurative sense. John Mulchaey, Ph.D. '94, astronomy, studied active galaxies and supermassive black holes as a doctoral student. Positions as a postdoctoral researcher and then a staff astronomer at the Carnegie Observatories saw him shift his research focus to how galaxies evolve and change over time. Recently, Mulchaey returned to his roots and the study of supermassive black holes: "I'm very excited about a new project where we will search for these black holes in the smallest galaxies we know of," Mulchaey says. He'll balance this research program along with his responsibilities as director of the Carnegie Observatories, a promotion made official in April 2015.



THIS ARTIST'S CONCEPT SHOWS HOW THE SUPERMASSIVE BLACK HOLE AT THE CENTER OF IRAS F11119+3257 GATHERS SURROUNDING MATTER FROM A DISC (ORANGE) AND PUSHES IT AWAY IN A POWERFUL WIND (BLUE), WHICH POWERS A LARGE-SCALE GALACTIC OUTFLOW OF MOLECULAR GAS (REDDISH PURPLE).

Astrophysical Journal Letters, showed that these winds act like a cosmic leaf blower, clearing out large amounts of star-forming gas and thus shutting down star formation in the best-studied case to date, the galaxy Markarian 231.

"We have been finding that these winds are common. They're very important and carry a lot of mass," Veilleux explains. "In some cases, up to 1,000 solar masses worth of material blows out every year in these winds."

It was immediately clear that these winds controlled Markarian 231's evolution and development, and it seemed obvious that the supermassive black hole at the galaxy's center was responsible. But the researchers wanted confirmation.

In 2015, Veilleux, Reynolds and several UMD colleagues published a paper in the journal *Nature* that presented powerful evidence to explain this link. The supermassive black hole at the center of a galaxy named IRAS F11119+3257 emits small-scale radiation-driven winds from its accretion disk. These winds, in turn, directly power the galaxy-scale winds that clear out the galaxy's supply of star-forming gas.

"This is the first galaxy in which we can see both the wind from the active galactic nucleus and the large-scale outflow of molecular gas at the same time," says the paper's lead author Francesco Tombesi, an assistant research scientist in UMD's Department of Astronomy with a joint appointment at NASA's Goddard Space

Flight Center.

"It's the first opportunity to see the connection between these two phenomena," Tombesi continues. "It's also among the first observational evidence to confirm that supermassive black holes can influence the entire galaxy, including the stars and the interstellar medium."

But this mode of constant, highly energetic activity is not the only way supermassive black holes are believed to control their host galaxies. Theory suggests that black

black hole would need a signal to sense when it's time to clear out excess gas and thus turn off the star-forming process. Conversely, the black hole also needs a signal to let it know when the job is done and balance has been achieved once again.

"When a black hole is in maintenance mode, how does the feedback actually work? We don't yet have a good explanation for how the black hole knows how much energy to put out," Reynolds explains. "How does the feedback loop get the message to shut down?"

This is an important question."

"GALAXIES AND SUPERMASSIVE BLACK HOLES ARE ALL WRAPPED UP TOGETHER, A LOT LIKE AN ECOSYSTEM."

—RICHARD MUSHOTZKY

holes might also become intermittently active in short bursts, thus controlling the rate of star formation at a finer scale. These pulses of galactic wind would clear out just enough star-making gas to bring the mass balance of the galaxy back into line before shutting down once again. Astronomers call this process "feedback."

Much like a thermostat will turn on your home's air conditioner only when it receives a signal that the rooms are too warm, the

are members of the scientific oversight group for ASTRO-H, which is set to go into orbit before April 2016. ASTRO-H will give astronomers an unmatched view of X-ray-emitting objects throughout the universe, and active galactic nuclei are at the top of the priority list.

"ASTRO-H will have better spectroscopy than ever before, giving us better glasses with which to see," says Mushotzky. "It will tell us much more about what is happening very

LOOKING AHEAD

The study of supermassive black holes continues to make huge leaps, and UMD astronomers are helping lead the way. A major technological advance will be the launch of ASTRO-H, a next-generation X-ray satellite telescope built by the Japan Aerospace Exploration Agency (JAXA) in collaboration with NASA. Mushotzky and Reynolds

A HAWC Eye on the High-Energy Sky

near the black hole and how the accretion disk and black hole influence one another. It's a very exciting time."

In 2022, the Large Synoptic Survey Telescope is expected to come online in northern Chile. This instrument will survey a huge swath of the night sky and could potentially pinpoint the locations of millions of undiscovered quasars, thousands of which could be powered by binary supermassive black holes.

Further into the future, better instruments could also reveal more about the weirder, more theoretical aspects of black hole physics. Stephen Hawking has proposed the idea that black holes could "leak" radiation and strange, as-yet unknown particles. The very idea flies in the face of the classic notion that nothing can escape a black hole's event horizon.

Finding evidence for such a phenomenon could provide a long-sought bridge between standard-model physics and quantum physics. The most powerful particle accelerator on Earth, the Large Hadron Collider (LHC), is currently the best tool available to address such questions. It recently began its second run with the goal of producing particles of dark matter. But one day, with the right technology, perhaps supermassive black holes could help expand physicists' knowledge of matter and energy.

"A supermassive black hole can spit out matter at nearly the speed of light. Black holes might be nature's most efficient particle accelerators," Reynolds says. "We're very proud of the LHC, but nature can accelerate particles at way higher energy than anything we can produce here on Earth."

Further down the line, Sagittarius A* might yet have another moment in the spotlight. The Milky Way is on a collision course with the nearby Andromeda galaxy. One day, the two supermassive black holes could form a binary much like the one that Liu and Gezari described in early 2015.

"But don't worry," Gezari says reassuringly. "We have about 4 or 5 billion years to go before that happens." ■

Active galactic nuclei are among the most energetic phenomena in the known universe. These bright objects produce radiation across the entire electromagnetic spectrum, including high-energy gamma rays and cosmic rays that can easily reach Earth from distant active galaxies.

The High Altitude Water Cherenkov (HAWC) Gamma-Ray Observatory, located 13,500 feet above sea level on the slopes of Mexico's Volcán Sierra Negra, is the newest tool available to visualize active galactic nuclei and other high-energy targets such as supernovae and neutron star collisions. Construction of HAWC is now complete, and the milestone was marked with an inaugural event at the observatory March 19-20, 2015.

"HAWC truly is the only observatory of its kind and will give us a clearer picture than ever before of the high-energy wonders of the universe," says Jordan Goodman, professor of physics at the University of Maryland. The project is a joint collaboration between the United States and Mexico, and Goodman leads a team of UMD physicists that has managed construction of the observatory since 2011.

Each of HAWC's 300 detectors is a huge tank containing 50,000 gallons of ultrapure water with four light sensors anchored to the floor. When gamma rays or cosmic rays reach Earth's atmosphere they set off a cascade of charged particles, and when these particles reach the water in HAWC's detectors, they produce a cone-shaped flash of light known as Cherenkov radiation. The effect is much like a sonic boom produced by a supersonic jet, because the particles are traveling slightly faster than the speed of light when they enter the detectors.

The light sensors record each flash of Cherenkov radiation inside the detector tanks. By comparing nanosecond differences in arrival times at each light sensor, scientists can reconstruct the angle of travel for each particle cascade. The intensity of the light indicates the primary particle's energy, and the pattern of detector hits can distinguish between gamma rays and cosmic rays. Occupying an area equivalent to more than three football fields,



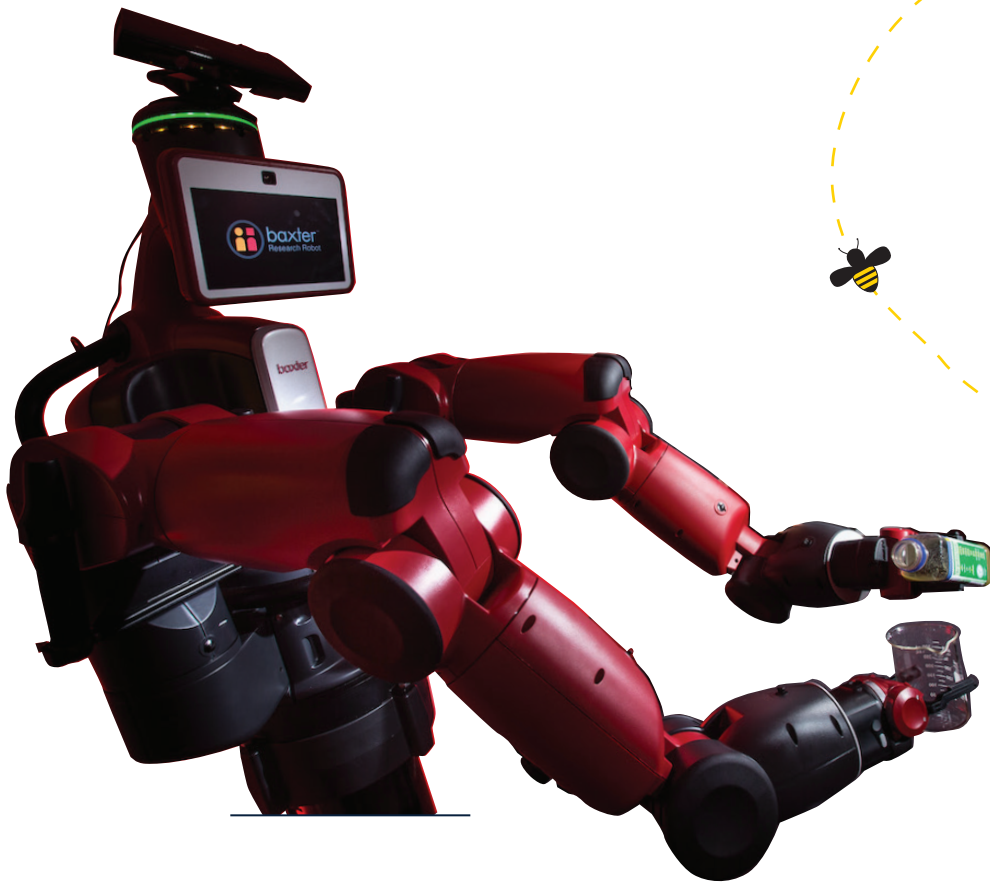
THIS VIEW OF THE HAWC OBSERVATORY WAS TAKEN FROM THE SLOPES OF VOLCÁN SIERRA NEGRA. ITS NEIGHBOR, PICO DE ORIZABA, IS THE HIGHEST PEAK IN MEXICO AND IS VISIBLE IN THE BACKGROUND.

HAWC is able to "see" these events in relatively high resolution.

To envision how the detectors work, Goodman suggests imagining your computer keyboard as a detector array, with each key representing one tank. Now, approach the keyboard with an open hand at an angle. This represents the cascade of charged particles. The heel of your hand will strike a few keys first, followed by more keys in a defined order as you flatten your palm across the keyboard.

"Someone else would be able to determine exactly where your hand came from based solely on the order of key presses," Goodman explains. "HAWC works the same way, with multiple detectors arrayed over a defined space."

From its perch atop the highest accessible peak in Mexico, HAWC will have 15 percent of the sky within its sights at any given time. As the earth rotates, so too will HAWC's field of vision, meaning that HAWC will see up to two-thirds of the sky every 24 hours. The team has a variety of science goals, and spotting and studying new active galactic nuclei is at the top of the list. ■



Robots Learn to Use Kitchen Tools by Watching YouTube Videos

Imagine having a personal robot prepare your breakfast every morning. Now, imagine that this robot did not need any help figuring out how to make the perfect omelet, because it learned all the necessary steps by watching videos on YouTube. It might sound like science fiction, but scientists have just made a significant breakthrough that will bring this scenario one step closer to reality.

Researchers at the University of Maryland Institute for Advanced Computer Studies (UMIACS) are developing robotic systems that are able to teach themselves. Specifically, these robots are able to learn the intricate grasping and manipulation movements required for cooking by watching online cooking videos. The robots can “think” for themselves, determining the best combination of observed motions that will allow them to efficiently accomplish a given task.

“Others have tried to copy the movements. Instead, we try to copy the goals. This is the breakthrough,” says Yiannis Aloimonos, UMD professor in computer science and UMIACS.

This approach allows the robots to decide for themselves how best to combine various actions, rather than reproducing a predetermined series of actions. Once a robot has learned a “vocabulary” of actions, it can then string actions together in a way that achieves a given goal. In fact, this is precisely what distinguishes this work from previous efforts.

Aloimonos and Cornelia Fermüller, an associate research scientist at UMIACS, envision a future in which robots tend to the mundane chores of daily life while humans are freed to pursue more stimulating tasks.

“We are trying to create a technology so that robots eventually can interact with humans,” says Fermüller. ■

Nation’s Beekeepers Lost 40 Percent of Bees in 2014-15

Beekeepers across the United States lost more than 40 percent of their honey bee colonies during the year spanning April 2014 to April 2015, according to the latest results of an annual nationwide survey conducted by the Bee Informed Partnership.

While winter loss rates improved slightly compared to last year, summer losses—and consequently, total annual losses—were more severe. Commercial beekeepers were hit particularly hard by the high rate of summer losses, which outstripped winter losses for the first time in five years, stoking concerns over the long-term trend of poor health in honey bee colonies.

“We traditionally thought of winter losses as a more important indicator of health, because surviving the cold winter months is a crucial test for any bee colony,” says Dennis vanEngelsdorp, an assistant professor of entomology at the University of Maryland and project director for the Bee Informed Partnership. “But we now know that summer loss rates are significant, too. This is especially so for commercial beekeepers, who are now losing more colonies in the summer compared with the winter. Years ago, this was unheard of.”

This is the ninth year of the winter loss survey and the fifth year to include summer and annual losses in addition to winter loss data. More than 6,000 beekeepers from all 50 states responded to this year’s survey. All told, these beekeepers are responsible for nearly 15 percent of the nation’s estimated 2.74 million managed honey bee colonies. Estimates of the total economic value of honey bee pollination services range between \$10 billion and \$15 billion annually. The survey was conducted by the Bee Informed Partnership in collaboration with the Apiary Inspectors of America, with funding from the U.S. Department of Agriculture. ■

Customized Soap Bubbles Set to Transform Drug and Vaccine Delivery

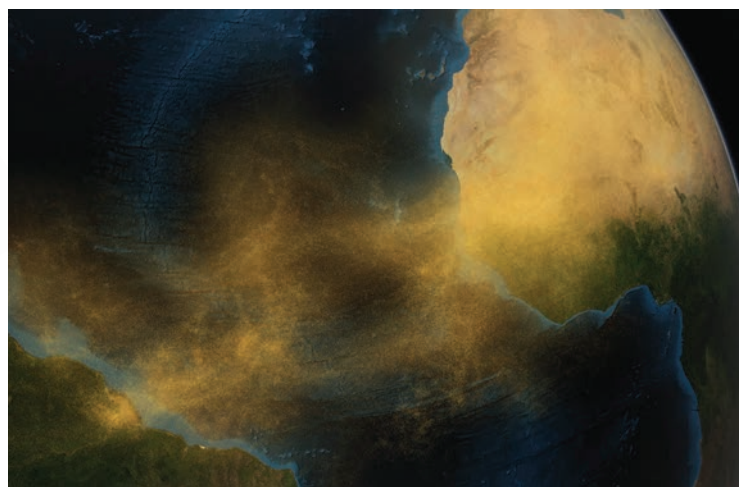
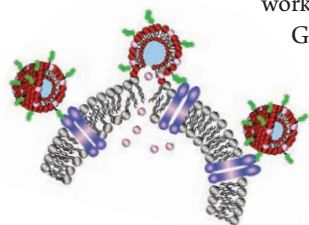
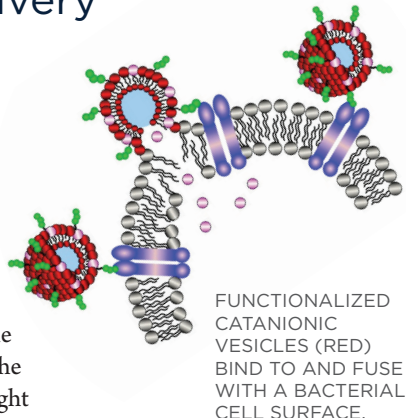
When Philip DeShong and Daniel Stein began tagging soap bubbles with biomolecules that trick the body into mistaking the capsules for disease-causing cells, they had no idea this technology would one day be poised to change the way drugs and vaccines fight bacteria, viruses and cancer.

“We have created a technology platform that allows us to make drug and vaccine delivery vehicles that have previously been very difficult to prepare,” says DeShong, a University of Maryland chemistry and biochemistry professor. “If someone provides us with an antigen, it is possible for us to formulate it into a vaccine, purify it and have 1,000 doses ready within 72 hours.”

DeShong and UMD Cell Biology and Molecular Genetics Professor Stein founded the College Park, Md.-based startup company SD Nanosciences in 2007 to commercialize the technology, which is the basis for four pending patents.

The researchers have developed vaccines against the bacterium responsible for gonorrhea and against the pathogen that causes the potentially lethal disease tularemia. Both vaccines produced high levels of protective antibodies in mice. The latter was tested in collaboration with Stefanie Vogel, B.S. '72, Ph.D. '77, microbiology, professor of microbiology and immunology at the University of Maryland School of Medicine.

Because the technology is flexible, cost effective and highly efficient, it is drawing a lot of attention from both public and private funders. In May 2014, the researchers received \$1 million from MedImmune, the global biologics research and development arm of AstraZeneca, to further test and evaluate their technology for vaccine delivery. In October 2014, the scientist duo received a Maryland Innovation Initiative award of \$150,000 from the Maryland Technology Development Corporation to continue their work developing vaccines against Gram-negative bacteria. ■



THIS CONCEPTUAL IMAGE DEPICTS DUST FROM THE SAHARAN DESERT CROSSING THE ATLANTIC OCEAN TO THE AMAZON RAINFOREST IN SOUTH AMERICA.

Massive Amounts of Saharan Dust Fertilize the Amazon Rainforest

The Sahara Desert and the Amazon rainforest seem to inhabit separate worlds. The former is a vast expanse of sand and scrub stretching across the northern third of Africa, while the latter is a dense green mass of humid jungle covering northeast South America. And yet, they are connected: every year, millions of tons of nutrient-rich Saharan dust cross the Atlantic Ocean, bringing vital phosphorus and other fertilizers to depleted Amazon soils.

For the first time, scientists have an accurate estimate of how much phosphorus makes this trans-Atlantic journey: 22,000 tons per year, which roughly matches the amount that the Amazon loses from rain and flooding. This phosphorus accounts for just 0.08 percent of the 27.7 million tons of Saharan dust that settles in the Amazon every year.

“We know that dust is very important in many ways. It is an essential component of the Earth system. Dust will affect climate and, at the same time, climate change will affect dust,” says Hongbin Yu, an associate research scientist at the Earth System Science Interdisciplinary Center, a joint center of the University of Maryland and NASA’s Goddard Space Flight Center.

Yu and his colleagues analyzed dust transport estimates based on data collected by a NASA satellite between 2007 and 2013. Year by year, the pattern is highly variable. There was an 86 percent change between the highest amount of dust transported in 2007 and the lowest in 2011.

Although the seven-year data record is too short to make conclusions about long-term trends, it is an important step toward understanding how dust and other windborne particles, or aerosols, behave as they move across the ocean.

“This is a small world, and we’re all connected together,” Yu says. ■



Deep Time, Deep Foundations

Ann Wylie's Years at Maryland Leave a Lasting Mark

Since Ann Wylie's arrival at the University of Maryland in 1972 as an assistant professor, she has seen a lot of changes. And she has been instrumental in helping many of the changes take place.

A nationally recognized mineralogist and economic geologist, Wylie has never been one to take the prescribed route. She left her home in Midland, Texas at a time, she says, when no one left Texas, to go to Wellesley College and later Columbia University. Wylie became the first woman faculty member in Maryland's Department of Agronomy, and was also the first female faculty member in the Department of Geology when it was created in 1973.

After more than two decades on the faculty at Maryland, Wylie began to take on leadership positions—most recently senior vice president and provost—and helped propel the university into the ranks of top research and teaching institutions. She was named the university's Outstanding Woman of the Year in 2012, and last year, she became the first geology faculty member to receive the President's Medal.

After 42 years at the University of Maryland, Wylie retired last fall. She recently talked with Odyssey about her career, how she's seen the university change and what she hopes for the university's future.

Is geology something you always planned to study?

My grandfather was the chief geologist for Philips Petroleum. I went to college as a mathematics major, but I lost interest. I took a course in geology, in honor of my grandfather, and I found it extraordinarily interesting, so I switched my major to geology.

Was your career goal always to become a professor?

I always wanted to teach, but I thought I would teach high school students. When I was getting my Ph.D. at Columbia University, I chose laboratory work over field study and discovered that I loved research as well as teaching. When I graduated, my husband and I moved to Washington, D.C., because I thought I could get a job at the Bureau of Mines or the Geological Survey. I didn't even get an interview at the Geological Survey! But the University of Maryland hired me, and I never looked back. As a professor, I always felt like I was giving students a gift. Most young people have no idea about the world that they live in, so when you begin to point things out, you raise their awareness of the world and enrich their lives.

How have things changed for women in science since you began your career?

It's night and day. I never experienced what many women in my generation did—having to take a job well beneath them—but women in the sciences were just not taken seriously in the 1970s. Many were relegated to being lab technicians. I'm proud to see an abundance of women in geology today, and I believe they have equal opportunities for jobs.

What drew you to administration?

I love the University of Maryland. I always kept myself involved in the life of the university. As a female professor in the sciences, I served on a lot of committees, and I liked that. Except for a two-year period when I was the associate dean for research of the Graduate School, I spent 27 years as a faculty member before I entered higher education administration, first as associate dean, then as associate provost, assistant president and chief of staff, vice president for administrative affairs, and senior vice president and provost. I

immediately took hold of the jobs. I had been at the university so long and had seen so much of the university that I really understood how it worked from the bottom to the top, and the issues that were important to faculty, staff and students.

You've been involved in a lot of changes here. What accomplishment are you the most proud of?

Of the things I think I played a small role in, I'm the most proud of the transformation of the University of Maryland to a first-tier institution. When I was named associate provost in 2000, I took on issues I thought were standing in the way of our university being excellent. For instance, I worked with the University Senate to begin to change some of our academic standards to improve our students' academic achievements and graduation rates. We didn't just wait for good students to come, we made sure we were accepting and graduating the best and brightest students. One thing I've seen over and over is that people rise to the expectations that are set for them. Achieving and maintaining excellence is an ongoing process that has been extraordinarily rewarding for me.

What advice do you have for geology majors?

Geology is a marvelous major. This field provides excellent training as a general problem solver. The skills you will learn in how to formulate hypotheses and manage and analyze data can be applied to any problem in your life. Geology also gives you a perspective on human life. Humans have only been around for the blink of an eye, whereas Earth has been around for a long time, and it's always changing. As a result, geologists are gifted with the sense of deep time.

What's next for you?

I've almost finished writing a book on the history of the Catoclin Mountains, which includes trail guides. I spend time hiking and playing golf. I am writing review papers, and I serve on the scientific advisory board of the National Stone, Sand and Gravel Association. I also continue to work with the geology department to help engage alumni with their alma mater. ■ —ELLEN TERNES

“Geologists are gifted with the sense of deep time.”



1973
WYLIE IS UMD'S FIRST FEMALE GEOLOGY FACULTY MEMBER



2008
WYLIE SERVES AS VP FOR ADMINISTRATIVE AFFAIRS



2012
WYLIE, PICTURED WITH UMD PRESIDENT LOH, IS NAMED THE UNIVERSITY'S OUTSTANDING WOMAN OF THE YEAR



2014
WYLIE IS THE FIRST GEOLOGY FACULTY MEMBER TO RECEIVE THE UMD PRESIDENT'S MEDAL

A Family Affair

Gates Twins Graduate and Move on to Doctoral Studies

A college graduation is a big deal for any family. Proud relatives and friends travel from far and wide to celebrate the new graduate's achievements and maybe make a few suggestions for the future.

But for twin siblings Delilah Gates and Sylvester Gates III, graduates of the University of Maryland Class of 2015, their commencement on May 22 held a couple of unusual and exciting twists.

For starters, not everyone gets the chance to graduate alongside a brother or sister in the same ceremony. Sibling rivalry might have guided some twins to attend separate schools. But for physics and mathematics double major Delilah and biological sciences major Sylvester, who sometimes stop short of finishing each other's sentences, attending the same university seems to have been a natural fit.

But that's only part of the story: Delilah and Sylvester also had the rare honor of knowing their commencement speaker personally. Their father, Sylvester James Gates Jr., addressed the College of Computer, Mathematical, and Natural Sciences' bachelor's, master's and doctoral graduates at this year's ceremony.

Gates is a University System of Maryland Regents Professor, Distinguished University Professor and John S. Toll Professor of Physics at UMD. Their mother, Dianna E. Abney, joined her husband on stage for the duration of the event. Abney is an accomplished pediatrician and health officer for the Charles County, Md. Department of Health in southern Maryland.

"You would think I had encouraged Sylvester and Delilah to study science, but



THE GATES FAMILY (L-R): DIANNA ABNEY, DELILAH, SYLVESTER AND JIM.

that's not the case at all. I wanted them to study finance, so they can take care of their mother and me when we retire!" says the elder Gates, who is called Jim by family and friends. He cracks just enough of a smile to let on that he is joking, and is justifiably proud of his children's accomplishments. Sylvester is quick to call out his father's ruse.

"I don't believe them," Sylvester says. "They'll never retire. They're workaholics!"

Not surprisingly, their parents' drive has left quite an impression on Delilah and Sylvester, who will both begin Ph.D. programs in the fall.

Delilah will study physics at Harvard University, but not before continuing research she began here at UMD. In collaboration with her father and several colleagues from the Army Research Laboratory, she has

co-authored three papers on adinkras—a type of mathematical symbol that describes relationships in supergravity and supersymmetry.

Sylvester will study molecular cancer biology at Duke University. He spent the summers of 2013 and 2014 at the Broad Institute of MIT and Harvard, and studied a protein suspected to play a role in leukemia and other cancers. He'll get something of a head start on his Ph.D. work when he begins his research rounds in July.

Both twins considered other schools for their undergraduate studies, but ultimately decided that UMD was the best choice. The close proximity to home was just an added bonus.

"We had spent so much time here as kids, it felt like a second home anyway," says Delilah. ■ —MATTHEW WRIGHT



#OUTWORK ON AND OFF THE COURT

VARUN RAM CELEBRATES MARYLAND'S WIN OVER VALPARAISO IN THE TERPS' FIRST NCAA TOURNAMENT GAME SINCE 2010.

Varun Ram starts every day by checking his planner, the pre-smartphone kind that requires writing by hand everything he needs to do that day. With a schedule like Ram's and his drive to accomplish big goals, Ram considers his planner pretty much indispensable.

A member of the Maryland men's basketball team who graduated this spring with a 3.9 GPA in biological sciences, Ram's days at Maryland were filled with hours of studying, practice and training. And Ram loved every minute of it, in the classroom and on the court.

Ram's path from his Columbia, Md., home to College Park wasn't a direct one. Ram liked Maryland's academic possibilities from the start, but there was something else driving him—his love of basketball. The five-foot-nine guard was on a high school club team that finished third in the nation in tournament play, but Ram figured there was no way he would make the Terps team he has loved since he was a kid.

He accepted an offer to play at Trinity College in Connecticut, but only after making a promise to his mother, a toxicologist for the Environmental Protection Agency, and to his

father, an IT programming manager for the National Weather Service. "All parents aren't supportive of things outside of academics," Ram says. "My parents instilled in me the drive to do well, no matter what I did, and they knew I loved basketball. But I had to promise my mother I would get all A's."

Ram earned the A's, and he played ball, but after his freshman year, he realized he really wanted to be at Maryland for the academics. "A big university like Maryland has so many more opportunities for biological sciences majors," Ram says.

Ram understood his basketball career might be over if he transferred to Maryland, but, thanks to a good word from his Trinity coach, the Terps let him try out. In the two weeks he waited to hear if he'd made the cut, Ram kept practicing. "I thought, until the coach tells me no, I'm not going to quit."

When Maryland basketball coach Mark Turgeon called to tell him he was on the team, Ram says, "It changed my life. It still blows my mind that I'm playing for Maryland." Two years later, Ram played his first minutes in a home game, and then started in the BB&T Classic.

Ram matched up against starting point guard Melo Trimble in practice. He says the

team mindset was to work together to do whatever they needed to win.

This year, in his first NCAA Tournament appearance, Ram entered the close game in the final seconds and smacked the ball away from a Valparaiso player to secure Maryland's win. A celebration exploded around him—teammates mobbed him, cameras surrounded him and reporters asked to interview him. Ram's name became the top trending topic on Twitter. He was profiled on ESPN.com and by the *New York Post* and *The Washington Post*.

"Varun has a great attitude and provides terrific energy every day, whether at practice or during a game," says Turgeon. "He has a relentless work ethic and is a tremendous student who has been an invaluable member of our basketball team."

Off the court, Ram roomed with classmates he met in an organic chemistry study group three years ago. "I even got my roommates to do a planner," he laughs.

After receiving his bachelor's degree in May, Ram had another year of basketball eligibility. He plans to return in the fall to Gary Williams Court and the University of Maryland to begin graduate school, where the odds are pretty certain he'll have his planner within reach. ■ —ELLEN TERNES

Focusing on Diversity in Computer Science

Over the past nine years, the percentage of female computer science majors at the University Maryland has increased from 7 to 16 percent. To continue this upward trajectory, the university launched the Maryland Center for Women in Computing in 2014. The center is supported by the university's Department of Computer Science, Institute for Advanced Computer Studies, and College of Computer, Mathematical, and Natural Sciences.

"The Maryland Center for Women in Computing has a very important mission—to offer programs designed to increase the number of students from currently underrepresented groups who choose to enter computing fields and programs to help them be successful and remain excited about the field," said the center's director Jandelyn Plane, a senior lecturer in the Department of Computer Science.

The center operates programs to reach K-12 teachers and students, and creates initiatives on campus for female graduate and undergraduate students studying in all areas of computing. The center helps prepare high school students for the CyberPatriot competition. In the center's three-year middle school program, Computer Science Connect, students gain solid programming experience, along with foundational algorithmic, cryptologic and mathematical skills, and an awareness of cybersecurity and safety.

In October 2014, the center received \$90,000 from the Building Recruiting And Inclusion for Diversity initiative to support its activities, which are also funded by philanthropic gifts and research grants. The funding enabled UMD to send more than 30 students and faculty members to the Grace Hopper Celebration of Women in Computing.

"We also plan to use the funding to create courses that are attractive for non-majors, including one that involves some programming, but emphasizes data analysis and what electronic tools can do to help you solve problems in your discipline," said Samir Khuller, the Elizabeth Stevenson Iribe Chair of Computer Science. ■

Bay Area Terps Connect

In March, over 200 University of Maryland alumni and guests living in California's Bay Area gathered for a networking reception at the Computer History Museum. Guest speaker Brendan Iribe, alumnus and co-founder and CEO of Oculus VR, shared his thoughts on the transformational impact of technology over time and his reasons for giving the university \$31 million to create the Brendan Iribe Center for Computer Science and Innovation. Students in the university's Quality Enhancement Systems and Teams (QUEST) program—who traveled to Silicon Valley during spring break to visit businesses and learn firsthand about design, innovation and quality—also attended the reception. ■



SEVENTH GRADERS SHAROLYN HYSON (LEFT) AND ELISKA PEACOCK DEMONSTRATE HOW TO PROGRAM LEGO ROBOTS AS PART OF COMPUTER SCIENCE CONNECT.



MEETHU MALU, COMPUTER SCIENCE GRADUATE STUDENT, PRESENTS HER RESEARCH ON WEARABLE DEVICES FOR PEOPLE WITH MOTOR IMPAIRMENTS.



JAN PLANE, DIRECTOR OF THE MARYLAND CENTER FOR WOMEN IN COMPUTING, WITH DAUGHTER ANGELISA, B.S. '15, COMPUTER SCIENCE.



BRENDAN IRIBE (CENTER), CO-FOUNDER AND CEO OF OCULUS VR, WITH UMD QUEST UNDERGRADUATES AT THE BAY AREA ALUMNI NETWORKING RECEPTION.

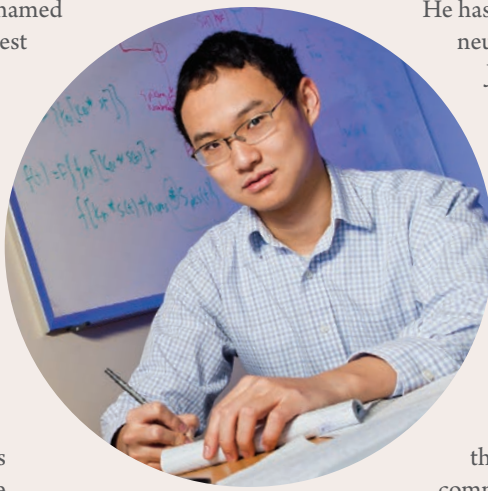
Fang Cao Named Rhodes Scholar

Senior biological sciences major Fang Cao was named a 2015 Rhodes Scholar, winning the world's oldest and most prestigious award for international study. He is the second Rhodes Scholar in university history; the first was Thomas McMillen, B.S. '74, biochemistry.

Cao will use the scholarship to pursue a master's degree in pharmacology at the University of Oxford in England. His long-term plans include a career in medicine and public health policy.

"My desire to become a physician and advocate dedicated to improving health care opportunities for underserved communities across America fueled my interest in the Rhodes Scholarship," said Cao. "I'm thankful to all of the wonderful mentors, teachers and advisers I've met since I stepped onto the University of Maryland campus who helped me earn this prestigious award."

Cao was the first UMD student to be awarded both Goldwater and Truman Scholarships. In addition, he was the recipient of a Howard Hughes Medical Institute undergraduate research fellowship, a National Institutes of Health (NIH) intramural training research award and an NIH exceptional summer intern award.



FANG CAO

He has conducted molecular and computational neuroscience research in the laboratories of Jeffrey Smith at NIH and Daniel Butts in UMD's Department of Biology.

As a member of the Integrated Life Sciences program in the Honors College, Cao founded a program at a local high school to tutor disadvantaged minority students in college-level biology. Thanks to the program, the school saw a marked improvement in the students' average AP biology exam score. Inspired by these results, Cao founded a second tutoring program at the school to help students obtain their high school diploma and consider attending community and four-year colleges. The program now boasts 35 UMD students serving as mentors.

"We worked with the teachers to understand past failures with tutoring initiatives, sat in on classes to observe student behavior and developed new approaches, such as biology Jeopardy, to get the students excited about the material," said Cao. "I thought I could contribute to improving educational opportunities for those who are less fortunate. ■"

College Celebrates Brit Kirwan's 50 Years at Maryland and Awards Him Top Honor

In early March, the Department of Mathematics celebrated the 50-year anniversary of William E. "Brit" Kirwan's arrival at the University of Maryland.

Kirwan, who officially retired as chancellor of the University System of Maryland on July 1, arrived as an assistant professor of mathematics in 1964. He became chair of the Department of Mathematics in 1977 and then went on to be vice president for academic affairs and provost, before becoming president of the university for 10 years. After 34 years in College Park, Kirwan spent four years as president of The Ohio State University before returning to serve for 12 years as Maryland's chancellor.

During a daylong conference, mathematicians and educators from around the world visited College Park to honor Kirwan's achievements. Speakers included Princeton University Professor Charles Fefferman, B.S. '66, mathematics; Vanderbilt University Professor Edward Saff, Ph.D. '68, mathematics; University of Michigan Professor Peter Duren; University of California, Los Angeles Professor Emeritus Mark Green; University of Texas at Austin Professor Uri Treisman; and Bar Ilan University Professor Emeritus and former UMD Professor Lawrence Zalcman.

As part of the celebration, Kirwan was awarded the 2015 Circle of Discovery award from the College of Computer, Mathematical, and



(L-R) MATHEMATICS CHAIR SCOTT WOLPERT, BRIT KIRWAN, CMNS DEAN JAYANTH BANAVAR.

Natural Sciences. He was honored "for his service to the mathematics community, the State of Maryland and the nation as a recognized authority on critical issues in higher education including diversity, access, affordability, economic impact, college athletics reform and gender equity."

The Circle of Discovery honors the college's most notable faculty members and alumni for their visionary leadership and outstanding research. ■

Math Whiz
wins
Wall Street

+++



After realizing that a job at a structural engineering firm would not be the right fit for him, Ali Hirsra could have switched to electrical engineering or become a doctor.

But two professors changed his life course, helping the man who would become a Wall Street pro discover the possibilities math offered a dedicated worker with a creative and insightful mind.

Today, Ali Hirsra, M.A. '97, Ph.D. '98, applied mathematics, is managing partner at Sauma Capital and an adjunct professor at Columbia University. He has helped investment firms protect their assets, patented methods for post-trade allocations, and written books and journal articles that guide future financiers.

Hirsra emigrated from Iran at the age of 25, coming to the University of Maryland largely because he had missed a language test required by another school. He fell in love with the university and his classmates quickly, taking as many math courses as possible, even though his first Maryland degree would be in civil engineering (M.S. '93).

Though he had hoped to launch his own construction business, Hirsra realized this career did not suit his "high-energy" persona. He decided instead to work on a master's degree in applied mathematics because it would give him options in engineering, biology or the rapidly changing field of computer science.

He still remembers vividly how nervous he was when Mathematics Professor Jeffery Cooper sent him to meet with Smith School of Business Professor of Finance Dilip Madan, M.A. '71, Ph.D. '75, mathematics; Ph.D. '72, economics.

"I was literally in love with mathematics," recalls Hirsra. "But I got so scared at that first meeting. I didn't really know anything about the mathematics of finance field."

Though intimidated by Madan's line of questioning, Hirsra made up his mind: he would prove himself a top-notch candidate.

Once in the graduate program, Hirsra gave selflessly as a graduate assistant, spearheading study groups outside of his required commitment. He worked on two dissertations (one with Madan and a second with Computer Science Professor Howard Elman), developing algorithms for complex mathematical models to help explain what drives sudden jumps in commodity and stock prices.

"It was a great collaboration," says Madan. "We would discuss problem formulation at an abstract level, and a few weeks later Ali would present fully worked-out solutions, complete with graphs, comparisons and convergence speeds. It was clear he would be going places, given the level of his focus, determination and sheer energy."

Among the places Hirsra has gone? Banc of America Securities, Morgan Stanley and Caspian Capital Management. As a frequent conference speaker, he still runs into Madan often. The two will sit together after a long day of presentations and dig into the details of one another's latest mathematical problems.

"He shows me how much I still have to learn," says Hirsra, who is also a member of University of Maryland College Park Foundation's board of trustees. "I can show him a three-page proof and he will reduce it to a three-line solution."

Hirsra credits Madan and Elman with helping him break into Wall Street, even though he didn't have the Ivy League degree some employers thought of as essential at the time.

"I still use what I learned from them," Hirsra says. "Dilip taught me how to use mathematics in financial applications, and Howard taught me how to build scalable and efficient algorithms."

Hirsra cut his teeth as a quantitative analyst, or "quant," determining equations and creating pricing engines and options for trading and risk management. By 2004, he moved to the buy side as a quant trader. The self-proclaimed "math geek" had to find his footing again.

"At Morgan Stanley, I was helping the firm not lose money; I had not developed strategies for making money," Hirsra says. "I learned you have to be able to sleep on a big bet. You could make or lose tons over a short period and lose your job over it. It is nerve wracking, but exciting."

Hirsra's approach is to gather knowledge from as many sources as possible, including statisticians, linguists and even philosophers.

"There are so many factors at play: politics, a housing crisis, international factors," Hirsra says. "A day later, the best equations won't be right."

Even with his financial and academic success, the husband, and father of a six-year-old son, remains humble. He loves sharing what he has learned with students. Hoarse after a three-hour lecture, he brags about master's students with the potential to become top-notch researchers. He hopes to offer them the same supportive, yet challenging, learning environment his Maryland professors did years ago.

Madan says he is not surprised Hirsra would continue teaching after so much investment success, but he still admires his friend's commitment and focus.

"Many people wander through their lives, taking charge of some things for some time, but then there are slippages and leaks," says Madan. "Not with Ali." ■ —KIMBERLY MARSALAS

TERPAHOLICS Can't Stop Giving

Some aspiring doctors at the University of Maryland are lucky enough to find themselves in the Kensington, Md., office of Dr. Philip Schneider, B.S. '79, biochemistry, shadowing one of the Washington area's top spine surgeons and asking him for professional advice.

In a high-poverty, largely minority high school a few miles away, a younger group of students is just as lucky to work with Schneider's wife, Joyce, B.A. '79, criminology, a volunteer dedicated to getting them into college.

Last year, the couple furthered their commitment to local students by establishing an endowed scholarship for first-generation college students with financial need who enroll in the College of Computer, Mathematical, and Natural Sciences at the University of Maryland. Preference will be given to students from Maryland's Montgomery County.

"We've given lots of gifts over the years to the university, maybe in smaller amounts, but kind of all over the place," says Dr. Schneider, president of Montgomery Orthopedics and a member of the University of Maryland College Park Foundation's board of trustees. "What we really liked about this opportunity is that we could shape the gift, and it will be matched by the university in perpetuity."

The Schneiders' \$50,000 gift created a TerpStart scholarship, part of a two-year matching initiative launched by the university. Spendable income generated by TerpStart scholarships will be matched by the university annually, forever.

The Schneiders met at Maryland and never really left. Committed athletic boosters, they attend every home football game and most basketball games. If you see the



THE SCHNEIDER FAMILY (L-R): PHILIP, RACHEL, JOYCE AND JONATHAN.

"People look at Montgomery County and see the 'haves,' but there is another part to the county where there are quite a few 'have-nots.'"

"Terpaholics" banner flying over their six-parking space tailgate—twice named "best tailgate" by the Division of Student Affairs—you've found them. The couple routinely hosts 75 to 200 friends, family members and students with food and festivities to match their fanaticism.

"It's been a great way over 35-plus years to stay connected and to show our kids that the University of Maryland's a great place," says Dr. Schneider. "And we like having the students come by and talk with us about their future careers."

Dr. Schneider was an Omicron Delta Kappa member and student government treasurer who followed his father into medicine, beginning at Maryland and finishing with his M.D. at Howard University. He serves as medical director of the Holy Cross Hospital Spine Center in Silver Spring, Md., and occasionally lectures on campus for the biology,

and chemistry and biochemistry departments.

Mrs. Schneider was the first in her family to attend college. She spent years in corporate America before taking a break to raise the couple's two children. Daughter Rachel is now a certified public accountant, and son Jonathan, B.A. '13, government and politics and economics, works for a consulting firm.

Mrs. Schneider founded a children's museum and became an "all-purpose volunteer." She says much of her work now is about helping others access services like education.

"People look at Montgomery County and see the 'haves,' but there is another part to the county where there are quite a few 'have-nots,'" she says.

The Schneiders hope their latest gift to Maryland brings about more recognition of the need in Montgomery County.

"We'd like to start a trend," says Dr. Schneider. ■ —KIMBERLY MARSELAS

FACULTY & STAFF HIGHLIGHTS

Three faculty members were awarded 2015 Sloan Research Fellowships in recognition of distinguished performance and unique potential to make substantial contributions to their field.

- **Jacob Bedrossian**, mathematics
- **Mohammad Hafezi**, Joint Quantum Institute
- **Vladimir Manucharyan**, physics

Mikhail Anisimov, Institute for Physical Science and Technology, and **Michael Raupp**, entomology, received 2015 University System of Maryland Regents' Faculty Awards for excellence in research, scholarship, and creative activity, and for excellence in public service, respectively.

John Benedetto, mathematics, was named fellow of the American Mathematical Society for his contributions to theoretical and applied harmonic analysis, and for editorial service, mentoring and professional leadership.

Gretchen Campbell, Joint Quantum Institute, received the 2015 Maria Goeppert Mayer Award from the American Physical Society for her contributions to the study of superfluidity in atomic gas Bose-Einstein condensates, including creating the first closed circuit atomtronic devices.

Paul Julienne, Joint Quantum Institute, received the 2015 William F. Meggers Award from The Optical Society.

Eugenia Kalnay, atmospheric and oceanic science, was elected to the American Academy of Arts and Sciences. She also received the 2015 Joanne Simpson Mentorship Award from the American Meteorological Society.

Jonathan Katz, computer science, and **Zhanqing Li**, atmospheric and oceanic science, were awarded Humboldt Research Awards from the Alexander von Humboldt Foundation.

Ved Lekic, geology, was awarded a Packard Fellowship for Science and Engineering from the David and Lucile Packard Foundation. In 2014, 18 promising early-career scientists and engineers received the fellowship.

Charles Misner, physics, and collaborator Stanley Deser (Brandeis), were awarded the

2015 Einstein Medal by the Albert Einstein Society for important contributions to general relativity.

Christopher Monroe, physics, was awarded the 2015 Arthur L. Schawlow Prize in Laser Science by the American Physical Society for pioneering research in the use of lasers to realize the elements of quantum information processing with trapped atomic ions.

Catherine Plaisant, University of Maryland Institute for Advanced Computer Studies, was elected to the Association for Computing Machinery Special Interest Group on Computer-Human Interaction Academy for her pioneering work in human-computer interaction and information visualization.

Edward Redish, physics, received the Excellence in Physics Education Award from the American Physical Society.

Herman Sintim, chemistry and biochemistry, was awarded a 2015-2016 Sigma Xi Distinguished Lectureship.

Ian Spielman, Joint Quantum Institute, received the I.I. Rabi Prize in Atomic, Molecular and Optical Physics, awarded to recognize and encourage outstanding research in atomic, molecular and optical physics by investigators who have held a Ph.D. for 10 years or less.

Aravind Srinivasan, computer science, was elected fellow of the Association for Computing Machinery for his contributions to algorithms, probabilistic methods and networks.

Eitan Tadmor, mathematics, was awarded the 2015 Peter Henrici Prize for original, broad and fundamental contributions to the applied and numerical analysis of nonlinear differential equations and their applications in areas such as fluid dynamics, image processing and social dynamics.

Lai-Xi Wang, chemistry and biochemistry, was named fellow of the American Association for the Advancement of Science for distinguished contributions to the field of carbohydrate chemistry and glycobiology.

Ellen Williams, physics, was confirmed by the U.S. Senate as director of the Advanced

Research Projects Agency-Energy, which aims to advance high-potential, high-impact energy technologies that are too early in development for private-sector investment.

Peter Yoon, Institute for Physical Science and Technology, was elected fellow of the American Physical Society in recognition of his contributions to fundamental kinetic plasma turbulence theory and for numerous research contributions in magnetospheric, solar and interplanetary plasmas. ■

IN MEMORIAM

Alfred Boyd, chemistry and biochemistry, died December 5. Boyd joined the faculty in 1957 and retired in 2003, but continued teaching courses until 2006.

Eugenie Clark, biology, died February 25. Known as the "shark lady," Clark joined the zoology faculty in 1968 and officially retired in 1992, continuing to teach until 1999.

John Corliss, biology, died December 21. Corliss served as Department of Zoology chair for 18 years. In his honor, the International Society of Protistologists presents an annual award to a member of the society for an outstanding paper in ciliate systematics.

John Horváth, mathematics, died March 12. Horváth's career spanned the transition from the early years of analysis in the first half of the 20th century to modern mathematics as we know it today.

Eugene Rasmusson, atmospheric and oceanic science, died March 22. A member of the National Academy of Engineering, he is best known for his pioneering study of the observed structure of ocean-atmosphere variations in the tropical Pacific that underpin what is now popularly known as El Niño.

Linda Zappasodi, chemistry and biochemistry, died June 11. During her 16 years in the department, Zappasodi directed facility operations and renovations and safety projects. ■

ALUMNI HIGHLIGHTS

Three alumni were awarded 2015 Sloan Research Fellowships.

- **Michael Schatz**, M.S. '08, Ph.D. '10, computer science, is associate professor in Cold Spring Harbor Laboratory's Simons Center for Quantitative Biology.
- **Andrew Snowden**, B.S. '04, mathematics, is assistant professor of mathematics at the University of Michigan.
- **Cole Trapnell**, B.S. '05, mathematics and computer science; Ph.D. '10, computer science, is assistant professor of genome sciences at the University of Washington.

Three alumnae were named fellow of the American Physical Society.

- **Karen Byrum**, M.S. '85, physics, a physicist at Argonne National Laboratory, was elected for her contributions in advancing a complimentary experimental approach for studying dark matter by including cosmic gamma rays, and for contributions in developing new technologies for triggering and photodetection.
- **Elizabeth Hays**, Ph.D. '04, physics, an astrophysicist at NASA's Goddard Space Flight Center, was elected for her discovery of high-energy gamma-ray flares from the Crab Nebula in Fermi data and her major contributions to the success of Fermi.
- **Ana Maria Rey**, Ph.D. '04, physics, an associate professor of physics at the University of Colorado Boulder and a research fellow at JILA, was elected for her pioneering research on developing fundamental understanding and control of novel quantum systems, and finding applications for a wide range of scientific fields, including quantum metrology and the emerging interface between atomic, molecular and optical physics; condensed matter; and quantum information science.

Four alumni received National Science Foundation Graduate Research Fellowships.

- **Taarika Babu**, B.S. '13, biochemistry, attends graduate school at Johns Hopkins University.
- **Prachi Bagadia**, B.S. '12, biological sciences; B.A. '12, english, attends graduate school at the Washington University in St. Louis.
- **Joseph Pennington**, B.S. '12, biological sciences and biochemistry, attends graduate school at Florida State University.
- **Rishi Sugla**, B.S. '13, geology, attends

graduate school at the University of California, San Diego, and Scripps Institution of Oceanography.

In recognition of their many accomplishments, the college's 2015 Distinguished Alumni awardees were honored on April 10.

- **Brian Crawford**, B.S. '76, biochemistry, is president of the American Chemical Society Publications Division.
- **David DeWitt**, M.S. '92, Ph.D. '94, meteorology, is director of the National Oceanic and Atmospheric Administration's Climate Prediction Center.
- **Jordan Goodman**, B.S. '73, M.S. '75, Ph.D. '78, physics, is a professor of physics at the University of Maryland.
- **Robert Hanisch**, M.S. '78, Ph.D. '81, astronomy, is director of the Office of Data and Informatics at the National Institute of Standards and Technology.
- **Julius Hyatt**, B.S. '80, zoology, is co-owner and oral maxillofacial surgeon at the Maryland Center for Oral Surgery.
- **Georgette Kiser**, B.S. '89, mathematics, is chief information officer at The Carlyle Group.
- **Philip Piccoli**, Ph.D. '92, geology, is a senior research scientist in geology at the University of Maryland.
- **Stefanie Vogel**, B.S. '72, Ph.D. '77, microbiology, is a professor of microbiology and immunology at the University of Maryland School of Medicine.
- **Wayne White**, B.S. '80, entomology, is vice president at American Pest.
- **Shayan Zadeh**, M.S. '02, computer science, is co-founder of Zoosk and Gear Zero.

Zvi Band, B.S. '06, computer science, CEO of Contactually, was named a Tech Titan by Washingtonian magazine.

Craig Carlson, Ph.D. '94, marine-estuarine-environmental sciences, received the 2015 G. Evelyn Hutchinson Award from the Association for Sciences of Limnology and Oceanography for accurately mapping variation in dissolved organic carbon and linking it to the dynamics of microbial communities. Carlson is chair of the Department of Ecology, Evolution and Marine Biology at the University of California, Santa Barbara.

Akiva Cohen, B.S. '85, microbiology; M.S. '89, zoology, received a MERIT award from the National Institutes of Health.

A concussion and traumatic brain injury (TBI) expert, he has been investigating the use of an amino acid-based dietary therapy to mitigate TBI long-term effects. Cohen works at The Children's Hospital of Philadelphia.

Arati Dasgupta, B.S. '73, M.S. '76, Ph.D. '83, physics, was awarded fellowship to the Washington Academy of Sciences for outstanding achievements and contributions in the field of plasma physics. Dasgupta works at the Radiation Hydrodynamics Branch of the Plasma Physics Division at the Naval Research Laboratory.

Sam Droege, B.S. '80, biological sciences, was featured in the November-December issue of *Audubon* magazine. The article focused on Droege's pilot program to survey North America's wild bee population. Droege is a biologist at the U.S. Geological Survey's Patuxent Wildlife Research Center.

Aliza Licht, B.S. '96, biological sciences, senior vice president global communications at Donna Karan International, authored the book "Leave Your Mark," which gives personal and professional guidance to people beginning their career.

Willie May, Ph.D. '77, chemistry, was confirmed as under secretary of commerce for standards and technology and director of the National Institute of Standards and Technology.

Mary Ann Ottinger, Ph.D. '77, zoology, was named fellow of the American Association for the Advancement of Science for distinguished contributions to the field of neuroendocrinology. Ottinger is associate vice president for research at the University of Houston (UH) and associate vice chancellor for research for the UH system.

DJ Patil, M.A. '99, Ph.D. '01, applied mathematics, was appointed chief data scientist for the White House. Patil will work on the Obama administration's precision medicine initiative. (Read more on page 28.) ■

ALUMNI NOTES ARE WELCOME.

PLEASE SEND THEM TO ODYSSEY, CMNS DEAN'S OFFICE, UNIVERSITY OF MARYLAND, 2300 SYMONS HALL, COLLEGE PARK, MD 20742. SEND INFORMATION BY FAX TO 301.314.9949 OR BY EMAIL TO MKEARNEY@UMD.EDU.

Entrepreneurial Roller Coasters



SAMIR KAUL

In April, **Samir Kaul**, M.S. '97, biochemistry, returned to College Park to speak with students and faculty members about his career as a venture capitalist. A founding general partner at Khosla Ventures since 2006, Kaul invests mostly in renewable energy, clean technology, food and agriculture, and life science innovations.

Kaul told a crowd of more than 100 people about several companies he has invested in at Khosla. One company launched a healthier and more affordable mayonnaise, another developed a biopsy-free tumor sequencing test that tracks tumor genomics in real time, others created solid-state batteries and LEDs.

He shared some of the personal and professional ups and downs he has experienced in his life. Kaul also offered the audience a few pieces of advice, which he uses to help stay grounded:

- Be a missionary, not a mercenary.
- Have faith in your conviction.
- Find time for yourself.
- Have fun, life is short.

Prior to joining Khosla, Kaul invested in early-stage biotechnology companies at Flagship Ventures and conducted research at Craig Venter's Institute for Genomic Research. He received his bachelor's degree in biology from the University of Michigan and an MBA from Harvard Business School. ■

STUDENT HIGHLIGHTS

Three graduate students were named Achievement Rewards for College Scientists (ARCS) Scholars.

- **Adam Greeley**, atmospheric and oceanic science
- **Rachel Lee**, physics
- **Deepali Sengupta**, neuroscience and cognitive science

Three undergraduates were among the 260 Barry Goldwater Scholars selected from a field of 1,206 students nominated nationally this year.

- **Shane Falcinelli**, biological sciences
- **Nathan Ng**, physics, mathematics and economics
- **Iowis Zhu**, biological sciences and biochemistry

Three undergraduates received National Oceanic and Atmospheric Administration Ernest F. Hollings scholarships.

- **Jose Gabriel Almarino**, biological sciences
- **Kelsey Malloy**, atmospheric and oceanic science
- **Jonathan Seibert**, atmospheric and oceanic science, and computer science

Five students received National Science Foundation Graduate Research Fellowships. *Graduate students:*

- **Ruilong Hu**, neuroscience and cognitive science
- **Madhvi Venkatraman**, biological sciences

Undergraduate students:

- **Daniel Farias**, computer science, mathematics and electrical engineering, will attend graduate school at the University of California, Berkeley, in electrical engineering.
- **Michael Mandler**, chemistry and biological sciences, will attend graduate school at Harvard University in organic chemistry.
- **Rafael Setra**, mathematics and electrical engineering, will attend graduate school

at Stanford University in electrical engineering.

Cell biology and molecular genetics graduate student **Alicia Bowen** received the 2014 Winifred Burks-Houck Graduate Student Leadership Award from the National Society for the Professional Advancement of Black Chemists and Chemical Engineers.

Biological sciences major **Fang Cao** was named a 2015 Rhodes Scholar, and will pursue a master's degree in pharmacology at Oxford University. Cao was also selected as the University Medalist for the May 2015 commencement. (Read more on page 21.)

Computer science graduate student **Snigdha Chaturvedi** was awarded a 2015 IBM Ph.D. Fellowship.

Computer science major **Jeremy Krach** placed third in the 2014 IBM Master the Mainframe Contest, which involved learning how to use, maintain and design applications on a mainframe computer.

Geology graduate student **Alex Lopatka** was awarded a 2015 National Science Foundation East Asia and Pacific Summer Institute grant to conduct stable isotope analyses on fossil corals at the National Institute of Water and Atmospheric Research in Auckland, New Zealand.

Evguenia Morgun, a biological sciences major, has been awarded a 2015-16 German Academic Exchange Service (DAAD) Study Scholarship to conduct research in Germany. She will work toward developing a gene therapy approach for the treatment of a rare and fatal neurodegenerative disorder.

Chemistry major **Brandon Ng** was awarded a 2015-16 Fulbright U.S. Student Grant to Israel to investigate the use of nanotechnology to treat multiple myeloma in Israel. ■

COMMENCEMENT 2014



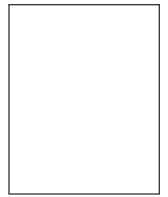
RAY O. JOHNSON

Ray O. Johnson, former senior vice president and chief technology officer of the Lockheed Martin Corp., gave the commencement address at the College of Computer, Mathematical, and Natural Sciences' December 2014 ceremony. Johnson is also a member of the college's Board of Visitors. ■



COLLEGE OF
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Alumnus DJ Patil Named U.S. Chief Data Scientist

In February, DJ Patil, M.A. '99, Ph.D. '01, applied mathematics, was named deputy chief technology officer for data policy and chief data scientist at the White House. In these roles, Patil will help shape policies and practices to help maximize the nation's return on its investment in data.

Specifically, he will help the United States acquire, process and leverage data in a timely fashion to create efficiencies, enable transparency, provide security and foster innovation. Patil will focus first on precision medicine.

"Medical and genomic data provides an incredible opportunity to transition from a 'one-size-fits-all' approach to health care towards a truly personalized system, one that takes into account individual differences in people's genes, environments, and lifestyles in order to optimally prevent and treat disease," says Patil, who shares credit for coining the term "data science."

Prior to joining the White House, Patil was vice president of product at RelateIQ, which was acquired by Salesforce. He also previously held positions at LinkedIn, Greylock Partners, Skype, PayPal and eBay. Prior to his work in the private sector, Patil worked at the Department of Defense, where he focused on fields like social network analysis to help anticipate emerging threats to the United States. As a graduate student at Maryland, Patil used open data sets published by the National Oceanic and Atmospheric Administration to make major improvements in numerical weather forecasting. ■



Photo by Chris Usher