UNC | COLLEGE OF ARTS AND SCIENCES
Physics and Astronomy

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FALL 2018

OPTICAL IMAGING CAPTURES CELL AND NANOPARTICLE MOVEMENT

Pictured left to right: Cassandra Houston, Amy Oldenburg, Ruofei Bu, Jack Vincent, Hillel Price, Kelsey Oeler, Lin Yang, Jessica Barrick, Ben Levy, and Santosh Balakrishnan.

Placing your hand over a flashlight at night, you observe a warm, red glow. This occurs because red and near-infrared photons are less absorbed by tissue, penetrating more deeply. Exploiting this effect, researchers in the Coherence Imaging Lab (CIL), directed by Amy Oldenburg, use low-coherence interferometry to "optically range" where near-infrared photons are reflected (scattered) inside tissue, analogous to radar. The scattering positions indicate tissue structures, allowing reconstruction of detailed 2- and 3-dimensional maps (optical coherence tomograms, OCT) inside tissue at the micrometer scale.

Importantly, these tomograms contain optical phase information that is sensitive to nanoscale motions of cellular components and nanoparticle probes. To capture these tiny and fast motions, CIL researchers have constructed a state-of-the-art, "parallelized" OCT system, recently described in Optics Letters. The parallelized system scans a line-focused beam across the tissue surface (as opposed to a point-focus), enabling imaging at frame rates of 5 kiloHertz. This allows researchers to capture nanoscale motions inside tissues, including:

- nanoparticle diffusion to measure tissue pore sizes
- intracellular motion of migrating cancer cells
- magnetically-activatable cells in marine animals

The new capability afforded by parallelized OCT is enabling an exciting new generation of collaborations between the CIL and biological and medical researchers.

Faculty Spotlight

Amy Nicholson came to UNC-Chapel Hill in 2017 from the University of California, Berkeley, where she was a postdoctoral research assistant. Nicholson's research interests are in quantum physics, the study of the universe at the levels of atoms and subatomic particles, such as quarks and gluons. She specializes in lattice quantum chromodynamics (Lattice QCD), a numerical method to calculate physically observable quantities. She is particularly interested in understanding how properties of protons and neutrons emerge from the underlying theory of QCD, and how these properties lead to the formation of nuclei shortly after the Big Bang and within stars. She also calculates quantities that are important for understanding experimental searches for new physics beyond the currently accepted Standard Model of particle physics, to answer questions about the origin of matter in the Universe and the nature of dark matter.

WHAT'S INSIDE

FROM THE **CHAIR**

"What do Walt Disney Studios sell?" The question was asked by the host of a recent live radio talk show that I was fortunate to attend. I thought I knew the answer to that one: movies. But he continued with, "No! Disney sells magical dreams for everyone." He then said, "What does Harley-Davidson sell?" I thought, at least I can answer this one: motorbikes, of course. He exclaimed, "No! Harley-Davidson sells a feeling of freedom in a life choked full with responsibilities. Harley-Davidson sells rebellion." This was getting interesting. He continued with, "What do social media sell?" Finally, a straightforward answer, I thought: connectivity with family and friends?! He announced "No! Social media sell you!"

After the show, an uncomfortable question slowly started to form in my mind, a question that is anathema to most of my colleagues in the department: What do we sell? It is a fair question to ask in academia, considering the renewed emphasis university administrators place on industry applications, entrepreneurship, and spin-off companies. "What are the most important things professors actually do?" My next thoughts were: we sell an education! But what does that mean, exactly? Maybe we sell a degree?! Wait, that is a terrible answer!

Let me try again: we sell marketable skills, for the benefit of society. I started to like this answer better. We do indeed sell to our students a broadening of their intellectual horizon. We provide them with mental tools to produce creative ideas so that they can succeed in their professional lives. Let's try to be more specific. A good analogy is the relationship between a coach and an athlete who wants to build muscle. Professors are like coaches. They certainly do not sell muscle. The athlete must earn the muscle. Coaches educate athletes, by sharing the expertise they acquired during their own careers. Coaches also share recommendations for being creative and thereby enable athletes to succeed.

At a fundamental level, we sell an experience to our students that most of them will never have again in their lives: the opportunity for serious exploration of highly complicated intellectual problems, in a diverse environment where curiosity and discovery are at the heart of meaning.

These abstract thoughts do have practical relevance. Remember the olive tree story in my last letter, which illustrated the relationship between basic research and applications. For example, take my research, which is in stellar nuclear fusion, which hardly sounds that it would ever lend itself to any practical purposes. But we need to be innovative in our basic research to succeed and to stay ahead of our competition. Just over the past two year, one of my graduate students developed a new computational method to analyze pulse-height spectra, which could also be applied to the detection of smuggled radioactive material. Another student of mine developed an interesting procedure of loading helium atoms into solid materials, which could also be interesting for radioactive waste storage. In both cases, we developed these methods for basic science experiments, but they could result in products of practical relevance further down the road. These are not exceptional cases, by any means, and many of my colleagues will tell you similar stories.

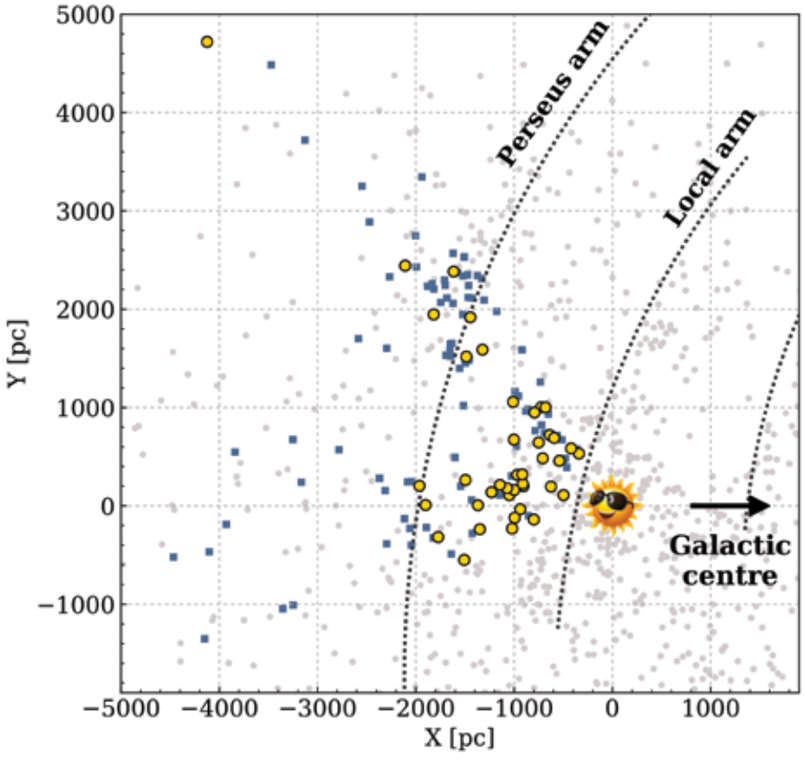
I am sure that the present edition of the newsletter will grab your attention. I encourage you, again, to share with me your stories and impressions. We are proud of our alumni and friends!

Best wishes,

Christian Iliadis
Chair, UNC-CH Physics & Astronomy

IN THE LAB

Graduate student Rohan Isaac has become a spectroscopic jack-of-all-trades as he studies the relationships among crystal structure, vibrational modes, and electronic transport in organic semiconductors. A student in Professor Laurie McNeil's lab, he grows crystals of compounds such as anthracene-pyromellitic dianhydride, a charge-transfer compound made of stacks of alternating donor and acceptor organic molecules. These materials can be used in a variety of technologies, including solar cells, photosensors, and lightweight electronics. Rohan uses resonant Raman spectroscopy to extract the coupling between the electronic and vibrational states in his crystals, and then collaborates with Professor Andrew Moran in the UNC Chemistry Department to do transient absorption spectroscopy of the excited states (electron-hole pairs, or excitons). He is looking for evidence of singlet-triplet fission, in which one exciton with antiparallel spins splits into two such species with parallel spins. This phenomenon would boost the efficiency of solar cells made from the material. Rohan also uses ground-state optical absorption, fluorescence, and infrared absorption spectroscopies to supplement his primary measurements. Combining his experimental results with density functional theory calculations carried out by collaborators at Georgia Tech, Rohan hopes to obtain a complete picture of these fascinating materials by the time he graduates in 2019.



NOW YOU SEE ME: NEWLY DISCOVERED STELLAR CLUSTERS IN THE SOLAR NEIGHBORHOOD

The Cosmostatistics Iniative (COIN), an international collaboration that consists of experts in astrophysics, statistics and machine learning, has discovered 41 new groups of stars known as "open clusters" in a nearby region of the Galaxy, towards the direction of the Perseus spiral arm.

Open clusters are groups of stars composed of dozens up to several thousand members born in the same region. The cluster members share common properties, like age, distance from the Sun, and velocity, and are distributed all over the Galactic disk. Since the early 1800s, astronomers have shown great interest in these systems as they reveal important information about the way stars form and evolve and even about the structure of the Milky Way itself.

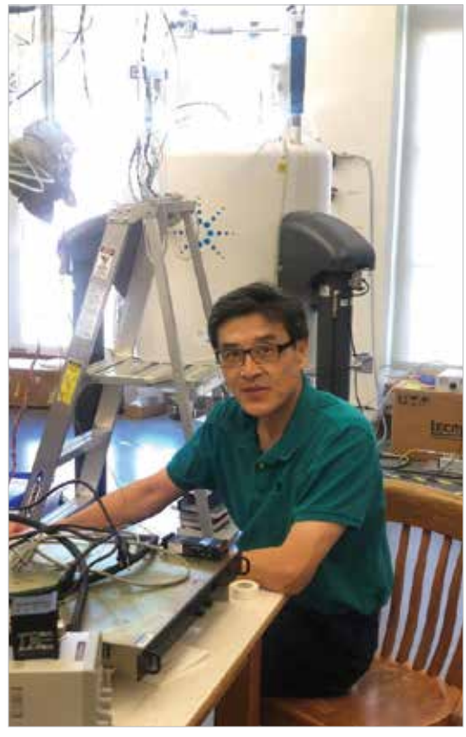
The new results are based on Gaia satellite data, which provided velocities and distances for billions of stars in our Galaxy. The COIN collaboration, chaired by Dr. Rafael S. de Souza (UNC-Chapel Hill) has developed a fully automated algorithm, which combines machine learning and statistical techniques in order to spot potential clusters by studying stellar positions and velocities.

All these newly discovered star clusters are found within about 6000 light years from the Sun. Although we thought that we knew our neighborhood well enough, this result challenges the status quo and leaves ample room for additional discoveries.

Dr. Rafael is a researcher in the department of Physics & Astronomy at UNC-Chapel Hill and an expert in the use of cutting-edge statistical models to untangle scientific puzzles. Together with the department chair, Christian Iliadis, he recently developed a statistical sound nuclear physics model to probe the nuclear reaction rates occurring during the Big Bang.

PHYSICS CORNER

Supported by a grant from the US Army Research Office, Professors Yue Wu and Alfred Kleinhammes, together with their students, undertook the investigation of liquid-liquid phase transitions in metallic melts. Just like graphite and diamond are both made of pure carbon, liquids of identical composition could also assume different phases. However, these liquid phases are very difficult to recognize due to the lack of obvious symmetry differences. We found a novel approach to solve this problem using high-temperature (up to 1500°C) nuclear magnetic resonance techniques. With this approach, liquid-to-liquid phase transitions are revealed in various systems including those of crucial technological and commercial importance. This discovery points out a new way of making better materials through controlling the phases of the melt. They also performed work on developing contrast agents for tracking fluid flow. This work, supported by the Advanced Energy Consortium, has led to recent field tests in Texas where contrast agents were injected along with the fracking fluid to map out the fluid flow. This is not only important for the oil and gas industry but also for people concerned about the environmental impact of fracking.



STAFF NOTES

Three staff members were recognized for their contributions to the department with achievement awards at the close of 2017. Instrument Shop Supervisor Phil Thompson earned the Donna Braxton Staff Excellence award, while Administrative Support Associate Jean Baldwin earned Team Player of the Year. Alisa Demao, Administrative Support Specialist, received the Personal Achievement Award. Anyone – staff, faculty or student – can nominate a staff member for the annual awards, which were inaugurated in 2014 to recognize superior service. The recognition comes with a monetary bonus. The awards are announced at the department's holiday party each December. The 2017 winners will serve with faculty representatives on the awards committee that chooses the 2018 recipients.

Cassandra Houston

Cassandra, Biophysics Administrative Assistant, became a Certified Research Administrator (CRA) in June 2018. CRA designation is granted by the Research Administrators Certification Council to individuals who have demonstrated the knowledge and experience necessary to serve as an administrator of professional and sponsored research programs. Before taking the four-hour exam, Cassandra completed a 12-week preparation course and one-day test review.

The department has recognized two new staff members since fall of 2017: Executive Assistant to the Chair Janice Jackson and Accounting Technician Patina Herring.

Janice Jackson

Janice worked for the Commonwealth of Virginia for eleven years with the Halifax County Soil & Water Conservation District. Her work is very similar which has made her transition effortless. "I enjoy working with the department and I am thankful to be a part of the UNC family."

Patina Herring

Patina has previously worked with the UNC system, but never on the UNC Chapel Hill campus, which she considers beautiful. What do Small Business, TV, and Bursar's office have in common? They are places where Patina worked in the UNC system. Her current accounting responsibilities use many of the same systems but in a different area. As a UNC Chapel Hill graduate and native of North Carolina she is a Tar Heel.

STAFF MILESTONES

In the past six months, the department has recognized four staff member milestone:

25 YEARS OF STATE SERVICE

Steve Medlin
Specialty Trades Technician

20 YEARS OF STATE SERVICE

Cliff Tysor
Specialty Trades Technician

5 YEARS OF STATE SERVICE

Maggie Jensen
Graduate Affairs Coordinator

Greg Smith
Human Resources Manager

STUDENT SPOTLIGHT

- **John Dupuy** (MS 2018) accepted a position with RedHat in Raleigh, North Carolina.
- **Christopher Frazer** (PhD 2018) accepted a position with Applied Physics Lab, Baltimore, Maryland.
- **Robert Call** (PhD 2018) accepted a position at Norfolk Academy, Norfolk, Virginia.
- **Charlie Bonfield** (MS 2018) accepted a position at Digitalsmiths.
- **Michael Hoffman** (PhD 2017) accepted a position at Digitalsmiths

COSMS NEWS

This past spring the CoSMS Institute continued its distinguished visitor program by hosting Dr. Clifford Johnson, Professor of Physics & Astronomy at the University of Southern California. As part of the NC Science Festival and in conjunction with the Morehead Planetarium, Dr. Johnson gave the Douglass Hunt Lecture on the subject of Black Holes, Time & Space. Dr. Johnson serves as a science advisor to Marvel superhero movies and is known for his writing and drawing of graphic novels that communicate science to the public. CoSMS recently completed a design concept study to convert space on the west side on the second floor of Phillips Hall to host CoSMS events and advance its mission of uniting scientist to advance our understanding of the universe. As shown in the figure, this converted space would allow the Institute to host workshops, visitors, facilitate interactions and help advance its dual mission to communicate the excitement of this science to the general public.

Stay updated with the latest news and events!

Check out webpage at cosms.unc.edu for upcoming events, or email cosms@unc.edu to request being added to our listserv.

UNC PHYSICS & ASTRONOMY

Facts

In 2018, there were **84 graduate students** and nearly **230 physics majors** in the department.

UNC Physics Department has made a systematic effort to actively address diversity and women's representation among its faculty. Nationally, the percentage of women professors in physics is less than 10%. In our department, the **percentage of female faculty is 26%.**

The Physics & Astronomy Department welcomed **Research Associate Professor Christy Inscoe, Professor Robert Janssen** and **Assistant Professor Andrew Mann** to the faculty this year.

Joaquín Drut, newly promoted Associate Professor and Melchor Fellow, **received the 2018 Hettleman Prize for Artistic and Scholarly Achievement by Young Faculty,** which recognizes the achievements of outstanding junior tenure-track faculty or recently tenured faculty.

Tamara Branca was promoted to Associate Professor with tenure effective January 2019.

Professor Reyco Henning receives the 2018 Carlyle Sitterson Award for Teaching First-Year Students, which was established to recognize excellence in teaching first-year students by a tenured or tenure track faculty member.

Teaching Assistant Professor Jennifer Weinberg-Wolf received the 2018 Tanner Award for Excellence in Undergraduate Teaching, which was established to recognize excellence in inspirational teaching of undergraduate students, particularly first- and second-year students.

Professor Christian Iliadis has been named the J. Ross Macdonald Distinguished Professor of Physics and Astronomy.

The UNC Physics & Astronomy Department hosted a **"Science is Awesome Day"** for approximately 300 fourth graders from three schools in the Chapel Hill-Carrboro City Schools District.

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GREETINGS FROM CHAPEL HILL!

Hi there! My name is Amberly Nardo, and I am thrilled to be working with Physics and Astronomy on behalf of the College of Arts and Sciences Foundation to help the department accomplish its goals. I work with fellow UNC alumni and friends of the university to raise private funding that allows the Chair, Professor Christian Iliadis, to make strategic improvements in the department as well as provide direct student support. With many exciting projects on the horizon, private philanthropy has and will continue to play a critical role in the department's ability to maintain its stature of excellence. For gift options, including multi-year pledges, stock donations or planned gifts, please do not hesitate to contact me. I hope to meet many of you in the year ahead.

Amberly Nardo
Assistant Director of Development
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The Department of Physics and Astronomy Excellence Fund helps enhance our world-class programs in research and education by supporting visiting speakers, providing seed fundsfor new instrumentation, and expanding research experiences for our students.

Gifts of any size will greatly increase our ability to support outstanding faculty and students.

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Thank you!