UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Academic Program Review Self-Assessment

Department of Physics

October 4th, 2023

Academic Program Review Self-Assessment

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I. Strategy

a. Vision, Mission, and Aspirations

We strive to continue making Illinois Physics one of the best places in the world to carry out Physics research and to promote education and training in Physics and related fields. We offer a friendly, inclusive, and collaborative environment in which to work, with broad resources for faculty, researchers, students, and staff, giving all department members ample room and opportunity to freely develop their creativity and to succeed in innovation and learning. Urbana-style research fosters close collaboration between theorists and experimentalists in a climate of camaraderie, respect, and inclusiveness.

In research we want to be known nationally and internationally for taking on and solving the most challenging problems in Physics and for providing foundational scientific support for collaborative research with our partners in other Grainger College of Engineering (GCOE) departments and research units across campus.

Academically, we want to be known for our innovative, evidence-based approach to teaching that succeeds in educating and training the largest numbers of Physics majors and non-majors in the country at the highest standard of academic excellence.

In our interactions, we want to sustain and propagate the unique camaraderie and supportiveness of the faculty, staff, and students that have emerged as part of our core culture. We strive to offer an open and inclusive environment to all, resulting in a deep sense of community and belonging for department members from all backgrounds.

In service, we want to be seen as excellent citizens in our own department, college, and campus and as impactful leaders in the United States and international Physics communities.

b. Goals and Assessment

Our goal is to be outstanding in everything we choose to do. Our metrics for assessing that for each area in which we participate are to be competitive for the top people and the most attractive funding opportunities, to be able to address the most exciting and important challenges as they arise, and to set the agenda for advancing Physics

research and education. For educational outcome we assess the success of our alumni in academia, in the corporate world, and in government. In measuring our success in research, we count quantitative parameters such as publication output, research expenditures, and rankings as well as qualitative indicators such as scientific leadership positions held by faculty, awards, and honorary appointments. In evaluating our success in educational outcomes, we count factors such as time-to-degree, retention rate, exit interviews, job placement, starting salaries, and alumni giving.

Key goals for the next 5 years include:

1. **Improving curriculum and teaching capacity:**

   a. Physics will continue to improve and update its evidence-based curriculum, including the development of new teaching technologies. These efforts will strengthen our leadership in Physics Education Research and secure the academic and career placement success of our students. In recent years the average starting salary of Illinois Physics graduates with a bachelor's degree has increased from $59,000 in 2017–2018 to $85,500 in 2020–2021, a 45% increase (with inflation-adjusted, 34%). The data are taken from Illinois Success, a campus survey of alumni placement and career success. For comparison, the AIP 2023 fall salary data show a national average of about $70,000 for starting salaries for Physics bachelor's graduates in the private sector focusing on STEM work.

   b. Improvements in curriculum and innovation in teaching technologies will create the basis for further increases in teaching capacity to support the expected growth in student enrollments from new programs in the GCOE and in LAS without compromising excellence in students' educational outcomes. By FY26, we expect 200 additional students for the introductory course series Physics 211–214, originating from new degree programs in Astronomy, Bio Engineering, and Civil Engineering and joint degrees between Computer Science and Physics. These added students will grow the number of students taking introductory courses in Physics to more than 3,000 each semester.

   c. The department will complete the launch of a new upper-division Biophysics laboratory, while carrying out an $800k modernization of the suite of existing upper-division laboratories. These facilities improvements will create teaching capacity in upper-division teaching laboratories for the anticipated increase in enrollment and introduce a set of modern quantum optics experiments. The additional capacity in upper-division laboratories will eliminate a current bottleneck restricting the number of Physics majors.

   d. Physics will acquire scheduling control from campus of the 2 large capacity Loomis Laboratory lecture halls, LL141 and LL151 This change gives us the ability to schedule high-enrollment upper-division lectures in LL151, which is important as increasing student numbers in several courses will exceed the maximum capacity in current lecture rooms. For example, the enrollment in the senior quantum mechanics course series has reached 90 students/semester; both PHYS 486 and PHYS 487 are taught every semester.

2. **Growing academic programs**:

   Physics will increase the enrollment of Physics majors from 500 to 700 students by FY29. This enrollment bump will be accomplished both by increasing the Physics major enrollment and by starting new applied degree programs: CS + Physics in Fall 24 (with 100 students by FY29), Data Science + Physics in Fall 25 (with 60 students by FY29). We are also starting 2 professional master's programs. A MEng in

Instrumentation and Applied Physics started in August 2023 with 13 students and will expand to 40 students in FY29. A MEng in QIS will start in Fall 25, with 20 students by FY29.

3. **Building an inclusive community:**

Physics has made progress with gender equity and the participation of students and physicists from underrepresented groups in some areas. For faculty, the fraction of female faculty has doubled to 27% over the past 10 years (AIP average: 16% in 2014), while the fraction of faculty from underrepresented minorities has remained constant at 8% (AIP average: 5.3% in 2012). In the same period, the number of female graduate students in the department has increased from about 16% to 29% (AIP average: 20% in 2019), and the number of graduate students from underrepresented minorities from about 4% to 12.6% (AIP average: 4.8% in 2019). However, Physics has not been able to increase the representation of undergraduate women, 16%, or African American undergraduate students, 1.6%. Both numbers remain well below the AIP averages of 22% and 3.1%, respectively. The department has seen a moderate increase of students who identify as Hispanic or Latinx, from about 4% to 7.1 % (AIP average: 10.9% in 2018) over the past 10 years.

To further increase the **diversity of our faculty**, we rely on campus-wide and college-level training for search committee members, for A&P committee members, and for members of the department leadership. The most impactful tools for increasing faculty diversity are the campus programs for Target of Opportunity hires (TOP) and dual career hires (DCAC).

The **graduate program** will continue on its current successful track of increasing diversity and inclusion. Principal components continue to be holistic admission without reliance on the GRE; bridge program-like arrangements for students applying from colleges not preparing students for graduate courses at Illinois; continued aggressive recruitment at targeted conferences, such as the APS March Meeting, SACNAS, the NSBP Conference; a bridge program with Fisk University for students interested in Computational Biology; strong mentoring through the Physics Graduate Office (which will be strengthened with a new graduate advisor to support the Associate Head for Graduate Studies); and participation in externally and internally funded programs providing fellowships, evaluations/training, and/or planning assistance.

The recently restructured Physics Diversity Committee has focused its activities on increasing **diversity in undergraduate programs**. In this effort the committee closely collaborates with the Office for Undergraduate Studies in Physics, the Physics Education Research group, the GCOE and, externally, the AIP TEAM-UP initiative. We highlight 4 initiatives here (more details can be found in Section V):

a. TEAM-UP: The Illinois TEAM-UP team completed all phases of the AIP-administered program and has established a shared goal of doubling the enrollment of African American students by 2030. Initial TEAM-UP funding will be used to assess the climate for African American students in our department. Currently, we are responding to an invitation of the TEAM-UP Together Partners (AAPT, AAS, AIP, APS, and SPS) and will submit a TEAM-UP EXCEL grant proposal that will define and finalize our plans for reaching our enrollment goals for African American students.

b. Scholarships: In recent years the GCOE has offered to incoming classes about 240 scholarships for women, 110 scholarships for students from underrepresented minorities, and 95 scholarships for students from low-income backgrounds. Physics has 2 department-level fellowships that are offered to prospective students from underrepresented groups. The department has designated fundraising for

student scholarships as the top priority of the Physics advancement efforts in support of recruiting students from underrepresented groups and from low-income families.

c. With the help of the Heising-Simons Foundation, Physics inaugurated Nadya Mason as the first Rosalyn Yalow Professor in May 2022. Rosalyn Yalow is the second female Illinois Physics graduate student who earned her PhD in 1945. Yalow shared the 1977 Nobel Prize in Physiology or Medicine for her invention of the radioimmunoassay technique. The Yalow Professorship will support our outreach to prospective female students. In September 2023, Physics received approval from the Chancellor to rename the 300-seat lecture hall, LL141, in Yalow's name. All GCOE students are taking PHYS 211 and PHYS 212 in the Yalow Auditorium; we believe Yalow will be an outstanding role model for female Physics students. A campus historical marker honoring Yalow will be placed at the external entrance, and the foyer outside LL141 will be updated with a historical display in honor of Rosalyn Yalow. The department will also initiate a Rosalyn Yalow scholarship for female undergraduate students.

d. The department will expand outreach programs to high school students. Expanded programming will focus on GCOE-administered high school summer programs in STEM, including "Young Scholars," a summer research program for high school students from underrepresented minorities initiated by Physics, as well as the Illinois Physics and Secondary Schools Partnership Program (IPaSS), initiated and run by the Physics Education Research group.

4. **Strengthening research:**

Future faculty hiring and investments in research infrastructure will focus on strengthening 5 strategic pillars of our research effort:

a. Condensed Matter Physics (CMP) and Institute for Condensed Matter Theory (ICMT). In Spring '23 we hired 1 CMP experimentalist and 2 CMP theorists. We presently have an active search for a CMP experimentalist and will prioritize hiring in CM for the next 4 years to restore our recently lost top ranking in Condensed Matter Physics. In the most recent *US News* graduate rankings, Illinois CMP is ranked #5.

b. Physics will continue its investments in and leadership of the Illinois Quantum Information Science and Technology Center (IQUIST). IQUIST was launched in 2018 by Physics faculty with $15M support from the college and campus. This interdisciplinary research center is a college initiative that is administratively located in the Materials Research Lab. IQUIST is composed of 66 faculty from Computer Science, Electrical and Computer Engineering, Materials Science and Engineering, Mathematics, Chemistry, Physics, Philosophy, Computer Science, Mechanical Science and Engineering, Aerospace Engineering, Business Administration, and the National Center for Supercomputing Applications, with 40 postdocs and 170 graduate students. Its research grant portfolio exceeds $100M. Investments in IQUIST will strengthen our research efforts and rankings in AMO (#13), CM (#5), and Quantum Physics (#12). Investments needed include additional research support personnel and faculty hires in QIS theory.

c. Physics will continue investments in research groups associated with the Illinois Center for Advanced Studies of the Universe (ICASU). ICASU aims at leadership in synergistic Physics at the interface between Astrophysics, Gravitation, High-Energy, and Nuclear Physics. ICASU currently has 34 faculty members from Physics, Astronomy, Mathematics, NCSA, Computer Science, and Philosophy.

The total portfolio of research grants secured by ICASU faculty since the start of the institute in 2019 is $51M. 33 postdocs and 122 graduate students are associated with ICASU. Investments in ICASU will strengthen our research efforts and rankings in Cosmology/Relativity/Gravity, Particle, and Nuclear Physics (#6). Particle Physics was briefly ranked #14 in 2022. Investments needed for ICASU include support for postdocs for interdisciplinary work and faculty positions in its core research areas (Astrophysics, Cosmology, Gravitation, High-Energy, and Nuclear Physics).

d. Physics will seek to strengthen the Biophysics group, ranked #5, with 2 faculty hires in the next 4 years. Biophysics research at Illinois is carried out in close collaboration between Physics, Biophysics, Chemistry, Biochemistry, Cell and Developmental Biology, and Microbiology. A new $30M NSF Science and Technology Center for "Quantitative Cell Biology," led by Chemistry at Illinois and hosted by the Beckman Institute, succeeds the NSF Center for the Physics of Living Cells (2009–2022).

e. An important focus will be investments in our graduate program and graduate curriculum. IQUIST and ICASU faculty are updating the graduate curriculum with content related to Quantum Information Science and topics at the intersection between Particle, Nuclear, and Gravitational Physics. With 334 graduate students, Illinois Physics currently has the largest program in the US. Graduate students are at the core of our research effort. The large class of graduate students is necessary to sustain the growth of our research effort (research expenditures have increased by 75% since 2017 to $40.7M) and to teach over 4,500 majors and non-majors each semester. In addition to conducting research in the Physics department, a strong Physics background is valuable in other fields: 27 of our graduate students work with advisers or co-advisors from 8 other departments in the GCOE and LAS; these 22 external faculty advisors hold affiliate appointments in Physics. An important goal, and significant challenge, for the department is to adjust support for graduate students in response to inflationary demands in light of budgetary pressures. In FY22 the teaching assistant budget reached $3.4M.

c. Opportunities and Emerging Trends

IQUIST, starting in 2018, and ICASU, founded in 2019, position us well to take advantage of opportunities arising in Quantum Information Science and Technology as well as from gravitational wave detection, multi-messenger astronomy, and resulting opportunities at the intersection of Gravitation, Nuclear, and Particle Physics. The efforts in IQUIST and ICASU greatly benefit from our long experience with collaborative, interdisciplinary science. The unique location of Physics in the GCOE enables close collaboration between Physics and other Engineering units, providing a fertile environment for creative ideas and innovation. IQUIST actively collaborates with QIS efforts in Chicago and will further strengthen Illinois' presence in the Chicago Metropolitan region. The 2018 National Quantum Initiative Act elevates investments in Quantum Science as a national priority; continued investment in this space seems likely.

In Biophysics, the department intends to use expanding opportunities in Quantitative Cell Biology (QCB) and the new $30M NSF STC for QCB to strengthen its Biological Physics group. Progress in the field rests on wide and close interdisciplinary collaboration, one of Illinois' core strengths.

In High-Energy Physics, we have started to work closely with Fermi National Accelerator Laboratory on future dark matter experiments. Additionally, we have identified significant opportunities for workforce development in Accelerator Physics and Instrumentation R&D. This effort will increase the presence of Illinois Physics in Metropolitan Chicago.

d. Peers

Our strategic thinking is grounded, in part, through comparisons with our peers. Table I.1 lists academic data for 2021–2022 for the top dozen departments in the country, as most recently ranked by *U.S. News*, out of the nearly 750 indexed by the AIP. Illinois is one of only three public universities represented in this group. Specialties where Illinois is ranked by U.S. News include Condensed Matter (#5), Living Systems (#5), Nuclear (#6), Quantum (#12) and Atomic-Molecular-Optical (#13), where peers in each group are generally drawn from top-25 departments. We continually strive to strengthen our contributions across these areas. In general, we regard these rankings as one indication that we have strong impacts in the subfields represented in our department, on a par with the best in the country.

Institution	USNWR ranking	# Faculty	BS degrees awarded	BS degrees per faculty	Intro physics enrollment	Total Grad students	*# of Intro students/ faculty*	*Undergrads/ grad student*	*Grads/ faculty*
MIT	1	80	66	0.83	776	291	*9.7*	*3.6*	*3.6*
Stanford	1	47	27	0.57	619	206	*13.2*	*3.5*	*4.4*
Caltech	3	48	27	0.56	260	153	*5.4*	*2.4*	*3.2*
Harvard	3	59	53	0.90	480	247	*8.1*	*2.8*	*4.2*
Princeton	3	39	26	0.67	418	131	*10.7*	*4.0*	*3.4*
UC Berkeley	3	63	100	1.59	2632	263	*41.9*	*11.5*	*4.2*
Cornell	7	51	54	1.06	2149	173	*42.1*	*13.7*	*3.4*
U Chicago	7	53	67	1.26	812	222	*15.3*	*4.9*	*4.2*
Columbia	9	36	34	0.94	777	103	*21.6*	*8.7*	*2.9*
UC Santa Barbara	9	60	149	2.48	1766	210	*29.4*	*11.2*	*3.5*
UIUC	**9**	**60**	**134**	**2.23**	**2813**	**317**	***46.9***	***10.6***	***5.3***
Yale	9	37	36	0.97	796	146	*21.5*	*6.4*	*3.9*
Average		52.8	64.4	1.17	1191.5	205	*22.6*	*7.1*	*3.9*

Table I.1: Number of Physics faculty, BS degrees awarded, and degrees/faculty in 2021–2022 at US News World Report Top-10 ranked Physics departments in the US (USNWR, AIP Physics Rosters 2022). The last 3 columns are derived from AIP data: the number of students taking intro courses per faculty, the total number of undergraduates per graduate student, and the number of graduate students per faculty. We estimate the (total number of undergraduate students) as (the intro Physics enrollment) + (4 x BS degrees awarded) using the AIP data.

Table I.1 illustrates the scale of the Illinois Physics educational program. The department awards 2.23 bachelor's degrees/faculty/year, 1.9 times more than the average among peers and 3.7 times more than the average (0.6 BS/faculty/year) for all PhD-granting Physics programs in the US. The department has the largest Physics graduate program in the country. The number of undergraduate students (non-majors and majors) per faculty is the highest among peers, and the number of graduate students per faculty member is the highest in the country. The delivery of Physics education at the largest scale with the highest standards of academic rigor at Illinois has been made possible through the innovations of our PER group and their successful implementation in the Physics curriculum.

e. Key Challenges

The age structure of the faculty, resulting in 19 faculty departures over the past 5 years, combined with the impact of the pandemic realignment, with 11 staff departures in 2020 and 2021, led to significant challenges in restructuring faculty and staff without negatively impacting research and teaching missions. The transition in faculty and staff was complicated by the extraordinary constraints on the university budget during the pandemic and the transition between budget models resulting in significant budget planning uncertainties.

However, the strong commitment to excellence in the GCOE and in the Office of the Provost made it possible for Physics, with significant deficit spending, to hire 17 new, early, and mid-career faculty, strategically strengthening IQUIST and ICASU. These investments have led to a 75% increase in the department's research expenditures, rising to $40.7M in FY23, and have brought about a noticeable rejuvenation of the department. Simultaneously, Physics has hired 6 specialized faculty members (teaching and research professors) who significantly strengthen our capacity to successfully staff and teach the largest Physics undergraduate classes in the country. Finally, Physics was able to fill 10 of the 11 vacant staff positions, with 1 search still being open, based on the positive work environment for staff in Physics and active hiring and recruitment initiatives of Physics HR and the Assistant Head of Administration Jennifer Jorstad.

In Condensed Matter, faculty departures included 5 members of the National Academy of Sciences. The departure of several highly regarded colleagues has contributed to the loss of Illinois' top ranking in Condensed Matter. The Condensed Matter ranking is highly important reputationally and directly impacts Physics' ability to attract the best students and faculty from around the world. In response, the GCOE supported 3 strong hires in CM in Spring '23 (arriving in January and August 2024), approved a Condensed Matter experiment search for FY24, and committed to additional searches in CM experiment for the coming years.

II. Academic/Student Experience

a. Undergraduate Academic/Student Experience

Q1. Undergraduate Enrollment Trends: As of the Fall '23 semester, our undergraduate Physics program has 495 majors, of which 257 (52%) are Illinois residents, 103 (21%) are non-residents, and 135 (27%) are international students. Enrollment has grown over the last 20 years (Figure II.1), nearly doubling in size since 2004. Today, Illinois Physics is one of the 4 largest programs in the nation, generating >2.2 physics Bachelor degrees per full-time faculty per year (a total of 134 in 2022), well above the national median of 0.6 at Ph.D. granting departments and above that of all other top-10 US Physics programs, with the exception of UC-Santa Barbara (see Table I.1). Female students make up 16% (80 women) of Illinois Physics majors. Currently 7.1% (35 students) of our undergraduates identify as Hispanic/Latinx, and 1.6% (8) as Black. As shown in Figure II.2, undergraduate demographics have remained consistent over the last 5–6 years, with a moderate increase in Hispanic/Latinx students. However, all 3 percentages continue to lag behind national averages of 22%, 10.9%, and 3.1%, respectively. In the Big-10, schools of comparable size, Illinois typically graduates the largest number of Black and Hispanic students.

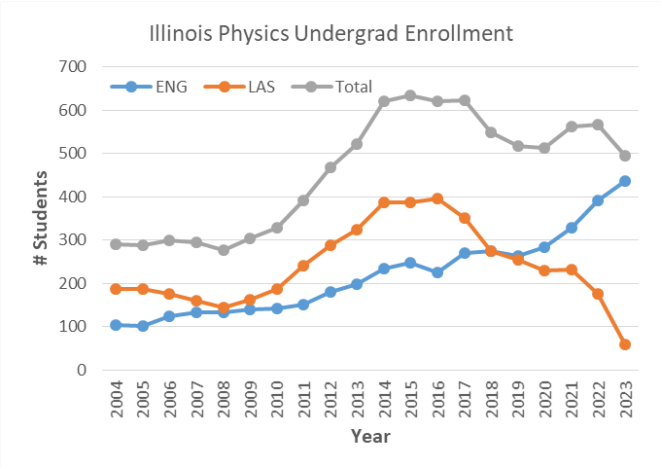

Figure II.1. *Enrollment of Illinois Physics Undergrad Students by Year. LAS (red), ENG (blue), and total enrollment (gray) from 2004 to 2023 (UIUC DMI data).*

Illinois Physics majors have historically been split between several degrees offered in the College of Liberal Arts and Sciences (LAS; Figure II.1, orange curve) and the Grainger College of Engineering (GCOE; Figure II.1, blue curve). In Spring '21 a restructuring proposal was approved to consolidate the different Physics programs. Starting in Fall '22, our students were admitted into the single "Physics" Bachelor of Science degree in GCOE. Benefits of program restructuring include improved student cohesion, greater and guaranteed

student access to GCOE resources (including diversity programs and targeted scholarships for admissions), streamlined operations, and improved revenue for the department through the recovery of differential tuition that had previously gone to LAS. Students in the LAS Physics programs (totaling 59 in Fall '23) have been given the choice to transfer into GCOE or continue in LAS until graduation. We expect to retire these LAS degrees fully by 2025.

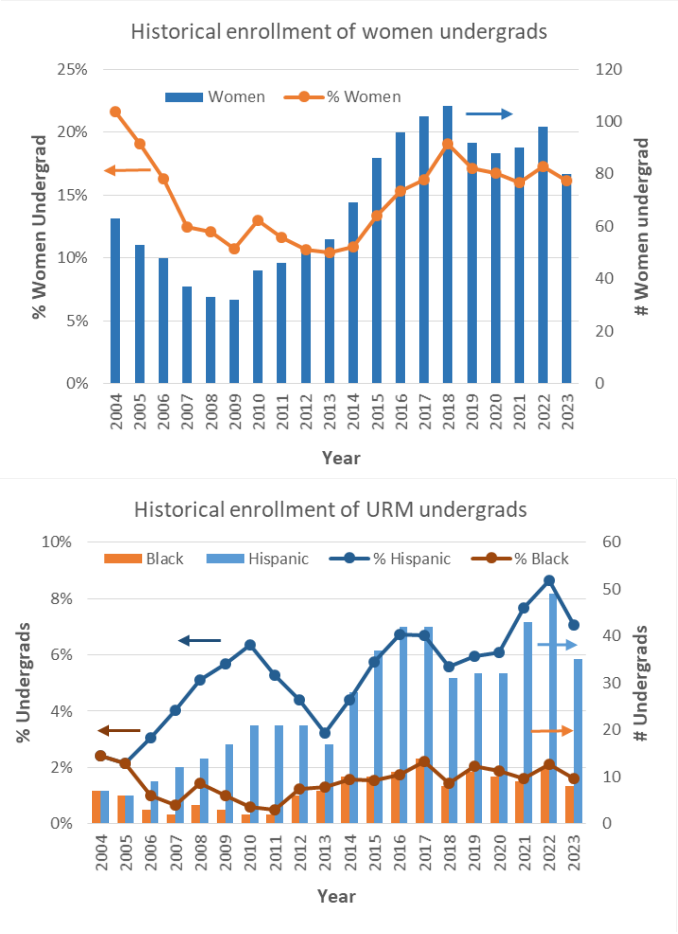

Figure II.2. *Number (blue) and percentage (orange) of women undergrad students by year (top). Number (light blue/orange) and percentage (blue/red) of Latinx/Black undergrads by year (bottom) (UIUC DMI data).*

a. *Instruction*. Today the Physics department teaches over 4,500 undergraduates each semester, close to 3,000 through the introductory Physics sequences PHYS 101/102 (algebra-based Mechanics & Heat/E&M and Modern Physics) and PHYS 211/212/213/214 (calculus-based Mechanics/E&M/Thermal/Quantum). The majority of students in the 21X courses are enrolled in Engineering degrees; only a small fraction are Physics majors (in Fall '23, ~3% out of ~2800). Our introductory Physics course enrollment is one of the largest in the nation, higher than that of any other top-10 US Physics program (see Table I.1). Teaching Physics at this scale without compromising quality requires significant departmental resources, including 18 faculty instructors and 80–90 TAs each semester. We maintain educational excellence at this scale by employing the many curricular innovations developed by the PER group. One example is the iOLab, a hand-held measurement device that replaces the traditional Physics lab setup, which was deployed in the PHYS 101/102 and 211/212 sequences in the last 3 years. The shift to iOLabs, coupled with a move of the introductory course labs into dedicated space in the Campus Instructional Facility (CIF), has helped relieve space and equipment constraints in Loomis. These developments will allow our introductory courses to meet the increased enrollment in the College of Engineering, which is expected to grow by 150 students by Fall '25.

b. *Future challenges*. The University of Illinois recently adopted an Integrated and Value-Centered Budget (IVCB) model. One feature of this model is to incentivize departments to increase their number of majors. For example, under this model, each additional Physics major increases the department's revenue by $14,000. Calculated as $12,000 + (12 credits x $200), the first $12,000 is based on the student declaring as a Physics major; the remaining $2,400 assumes the student enrolls for 12 credits of Physics each year. Hence, each Physics major brings more than $55,000 to the department's revenue over their 4-year career. The IVCB model makes the number of Physics majors an important factor in determining the state portion of the department's budget.

Our high number of majors (and phase-out of LAS Physics degrees) over the last 2 years has contributed to achieving a balanced budget for the first time in recent history. We plan to increase enrollments further

to 600 over the next 2 years. However, as highlighted in a recent APS report, for the first time in 20 years we are now seeing a decrease in the number of Physics majors across the country. Demographic trends suggest the situation will get significantly worse over the next 5 years through a predicted 15% decline in the college-age population. Indeed, the most recent admissions cycle suggests that we have currently saturated the market of Physics majors. Two new degree programs combining Physis with computer and data science seek to overcome this limitation.

Q2. Undergraduate Initiatives and Their Desired Effect: We believe one major barrier to reaching a wider pool of applicants is the perception that a Physics degree is primarily intended for students who want to continue on to graduate degrees. Given the strong job market in STEM fields, this perception can significantly reduce the attractiveness of the Physics degree, disproportionately so for students from underrepresented minorities. Beyond highlighting the career opportunities available with a BS in Physics, the department is creating 2 new degrees: Computer Science (CS) + Physics and Physics + Data Science (DS). These degrees directly target students who are interested in Physics but also want to ensure that their degree provides a clear path to a high-paying job.

a. **CS + Physics.** The Illinois CS + Physics program is designed to meet the increasing needs for a trained workforce in both Computation and Physics. This collaboration between CS and Physics provides an innovative, blended program for students interested in the intersection between Computing and Physics and in acquiring the skills to develop and implement quantitative models of physical systems. The curriculum includes all of the introductory Physics courses, the Physics technical core (Classical Mechanics, Electromagnetic Fields, and Quantum Mechanics), and 2 Computational Physics courses. In addition, CS + Physics majors take 32 credits from the CS program, giving them a strong foundation in Data Structures, Software Development, and Numerical Methods. Graduates from the program will be well-prepared for careers in Computational Physics, Finance, Quantum Information Sciences, and traditional programming.

   CS + Physics students will benefit from the significant infrastructure within GCOE for placing CS students in highly competitive jobs. Students will also be able to continue their graduate school education in either Computer Science or Physics. We anticipate significant demand for this degree as it provides students with a passion for Physics and problem-solving with a clear path to industry. The program will also benefit from being advertised both on the Physics website and on the CS website, which attracts over 16,000 applicants each year. The inaugural class will begin in Fall ’24, with an initial target enrollment of 25 students/year. Since this is a joint degree with Computer Science, each student will contribute 50% of a Physics major in revenue. However, beyond the direct budgetary impact, this program can play an important role in changing the culture within the department, opening more direct connections with and pathways to industry for all students in the department.

b. **Physics + DS.** The Physics + DS degree is scheduled to begin in Fall ‘25 and will build on the success of CS + Physics. Students in this program will learn techniques to analyze large and complex datasets. A distinguishing feature of this program will be its sharp focus on the data-rich physical sciences as the domains in which modern artificial intelligence (AI) and machine learning (ML) will be taught. Like the CS + Physics program, the curriculum will include a core set of Physics courses, with an additional 32 credits of Data Science courses. It will similarly provide clear pathways into academic or private-sector positions. In contrast to CS + Physics, the Physics + DS program will not have the same capacity constraints and its budget model will provide Physics with 100% credit for the major. A challenge for the Physics + DS degree will be attracting majors, since it will not have the benefit of the visibility provided by the CS department.

Ultimately, we hope that the addition of these 2 new degrees will have multiple benefits. First, they will satisfy the increasing need to train physicists in modern computational and data science approaches. Second, they will increase undergraduate enrollments by providing an attractive option for students looking for pathways into industry careers. Other departments in the GCOE, in particular CS, see a large surplus of qualified applicants, and we believe there is a large and diverse pool of talented students for whom these new degrees could be attractive. As a part of the College of Engineering, the Department of Physics is ideally positioned to be a top choice for students interested in Physics, but also prioritizing a clear career path with their undergraduate degree.

Q3. Undergraduate Program Professional Development:

a. **Undergraduate coursework.** The Physics curriculum provides our majors with a rigorous foundation in Physics and Mathematics but also prepares them for a wide variety of technical and professional careers, including graduate study in Physics or closely related fields. Elective options in topics as diverse as "Computational Physics" (PHYS 246), "Quantum Information" (PHYS 370), "Teaching Physics" (PHYS 394), "Research-Grade Laboratory Experiments" (PHYS 403), and "Experimental Biophysics" (PHYS 407), to name a few, are offered each year for students looking to explore different specializations. Students can select from several program tracks to earn a foundation in other fields while earning their Physics degree. Pre-defined tracks include Astrophysics, Biophysics, Computational Physics, Nuclear Physics, Business, Pre-Med, Pre-Law, and Graduate Study. With departmental approval, students can also create customized tracks based on their career goals and interests.

   All first-year Physics majors are required to take the undergraduate orientation course, "Physics Careers" (PHYS 110), which provides students with the critical information, resources, and tools needed to be successful in the program. Faculty, student, and alumni panels are invited to class to discuss research and career opportunities. The course works to reduce the perception that Physics is primarily for students continuing on to graduate school, exposing students to the wide range of career options available with a Physics BS. Later in the undergraduate program, "Communicating in Physics" (PHYS 496) teaches valuable writing and oral communication practices and standard conventions for Physics talks, abstracts, journal articles, and figures and, more broadly, for effectively communicating science to general audiences.

b. **Mentoring.** All first-year students are assigned peer mentors through the orientation course (PHYS 110), providing them with an opportunity to connect with other undergraduate Physics majors. As a required assignment for PHYS 110, student mentors work with their mentees in crafting a 4-year academic plan, which they submit to their academic advisor. All majors are also matched to a faculty mentor for all 4 years in the program. Faculty hold informal meetings with their mentees each semester to discuss academics, research, graduate school, and career opportunities.

c. **Undergraduate research.** The large research program in Illinois Physics benefits students by providing them with many opportunities for undergraduate research. Each semester, about 50–60 students carry out independent research in Physics laboratories; many do so for academic credit (PHYS 497), although significant numbers receive stipends depending on funding availability in their research labs. Several mechanisms are in place to facilitate connections between students looking for research opportunities and faculty: (i) PHYS 110, which provides an overview of Illinois Physics research and invites a faculty panel to promote research opportunities in their labs; (ii) a "Research Readiness" web portal that helps match student interest, experience, and academic history with faculty requirements and available projects; and

(iii) the Undergraduate Research Symposium, which allows research groups to present their work and advertise research opportunities. This highly successful symposium is now regularly attended by more than 80 undergraduates and has grown to incorporate lab tours.

Many students continue to work in research groups over the summer. In some cases, these students are directly supported by the research groups they work with, but in other cases Physics offers them support in the form of scholarships from generous donor gifts. Typically, 20–25 research awards are selected from faculty nominations submitted each spring. Physics also offers a number of named undergraduate awards to incentivize and recognize excellence in research as well as academics, outreach, and writing.

d. **Other professional development opportunities.** All Physics majors have access to professional development resources and programs in GCOE. (i) Engineering Career Services (ECS) holds yearly career fairs and on-campus interviews with employers. ECS also provides services such as 1-on-1 career advising, resume writing workshops, and mock interviews. Physics has begun to work closely with ECS to ensure that Physics majors are well-served by their programs. (ii) International Programs in Engineering (IPENG) provides study-abroad opportunities with partner institutions, allowing our majors to take courses abroad that automatically transfer into their degrees. The PHYS 110 orientation introduces all first-year students to these programs. Within the department, the Undergraduate Office also serves as an information hub for advertising to our majors other professional development opportunities (career, research, conferences, etc.) on campus and beyond.

Q6. Undergraduate Student Learning Objectives: By the completion of their degree program, a student earning a Bachelor of Science in Physics will be able to:

a. Define and use fundamental principles of Physics as defined and used by scientists and engineers.

1. Identify which fundamental principles should be applied to a specified situation.
2. Identify the tools used by scientists and engineers to use fundamental physical principles to solve problems.
3. Apply Physics problem-solving tools to known and novel problems.

b. Analyze quantitative and qualitative data.

1. Design and execute Physics experiments to answer open-ended questions.
2. Develop mathematical models to extract Physics results from numerical data.
3. Communicate, verbally and in writing, both experimental and theoretical results.

c. Participate in cooperative groups to design, practice, and communicate Physics and Physics-related information to themselves and the community.

1. Develop Physics and Mathematics-related problem-solving skills through participation in cooperative learning groups.
2. Design and execute Physics experiments/research projects in a collaborative setting.
3. Document, report, and present experimental results.

Academic Program Review Self-Assessment

Q7. Evaluation of Undergraduate Learning Objectives: The Department of Physics assessment plan uses both direct and indirect tools to assess Physics student outcomes. The direct assessment includes:

a. Informal Early Feedback: Students in each major-specific course are invited to participate in a survey to help the department and instructors evaluate students' understanding of the course's learning objectives, outcomes, and goals.

Evaluation of Direct Student Learning and Other Summative Learning Assessments: Final examinations (i.e., questions and student work) are collected for evaluation of learning outcomes, as well as the mastery of the outcomes by students. Anonymized student work is used for the evaluation.

1. Summary reports of the above are made available to instructors and the department leadership. Indirect assessment tools include enrollment numbers, demographic information, and degree completion rates. Regular feedback from the Physics Student Advisory Board (PhySAB) meeting weekly with the associate head for undergraduate studies; student surveys; and campus-level data, such as the Chancellor's Senior Survey, are also used to assess learning objectives.

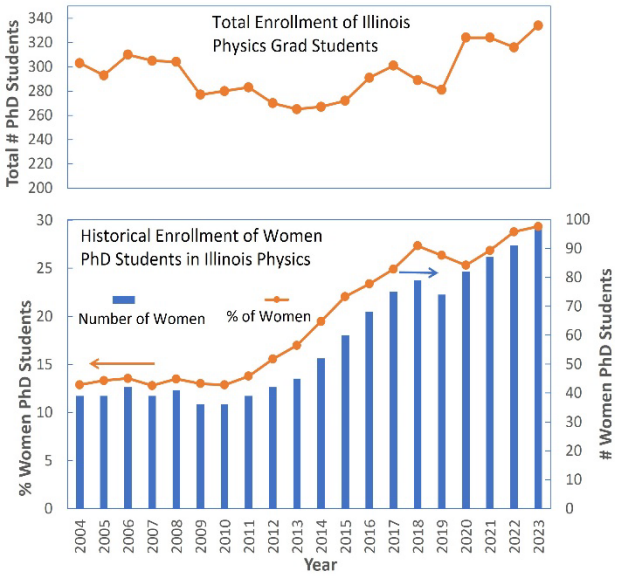

Figure II.3 (top) Total Enrollment of Illinois Physics Grad Students by Year. (bottom) *Number (blue) and percentage (orange) of women graduate students enrolled in the Illinois Physics PhD program, 2004–2023 (UIUC DMI*

2. The Undergraduate Office, with assistance from the Undergraduate Studies Committee, regularly evaluates degree program requirements, chokepoints in degree completion progression, course updates and revisions, and desirable new courses. In recent years this information has been used to identify needs for Computational Physics courses; standardize syllabi in the Physics technical core; and grow capacity in advanced lab courses, a bottleneck for degree completion. The status of the Learning Outcomes Assessment is reported annually to campus.

3. Physics relies on Illinois Success, a campus survey of alumni career success, for its analysis of alumni placement data and as input to evolving curricular needs for Physics students.

b. PhD Program Academic/Student Experience

Q1. Grad Program Enrollment Trends: As of Fall '23, the Illinois Physics graduate student enrollment is 334, including 188 (56%) domestic students and 146 (44%) international students. Over the past 20 years, the total graduate student enrollment has remained relatively flat, fluctuating slightly in the range between roughly 270 and 334 graduate students (Fig. II.3, top). This range is primarily governed by the number of research opportunities that have been available to Illinois Physics grad students. Female grad students currently make up 29.3% (98 women) of PhD students in Illinois Physics, which is an increase from 14.6% (38 women) in our program in Fall '11 (Fig. II.3, bottom). The percentage of domestic Black and Hispanic/Latinx students currently in our PhD program is 9.0% (30 students), an increase from the 2% of historically underrepresented domestic

students in our program in 2004 (Fig. II.4). Currently, 12.6% (42 students) of all Illinois Physics PhD students identify as Hispanic/Latinx or Black. Since 2020, 26% (36 women) and 6% (8 students) of Illinois Physics PhD graduates were women and historically underrepresented students, respectively.

Q3. Grad Program Professional Development:

a. **Graduate coursework.** First-year graduate students typically take 2 to 3 courses per semester and prepare for the qualifying exam. Courses commonly taken by grad students in their first year include PHYS 580/581 ("Quantum Mechanics" I/II), PHYS 508/509 ("Mathematical Methods" I/II), PHYS 505 ("Electricity and Magnetism"), and PHYS 504 ("Statistical Physics"). First-year grad students are also required to take PHYS 596 ("Graduate Physics Orientation"), which offers basic instruction in scientific writing, scientific presentation, research collaboration, scientific ethics, the use of scientific resources, etc. Students interested in more advanced instruction in scientific writing, scientific presentation, and proposal writing can take PHYS 595 ("Communicating Scientific Research"), which has been offered each spring semester since 2012. Physics grad students also have a survey course requirement, which is satisfied by completing 2 advanced graduate-level courses in any of the following: Biophysics, Nuclear and Particle Physics, Astrophysics, Quantum Optics and Information, Atomic Physics, or Condensed Matter Physics. Second-year grad students typically enroll in 1 or 2 advanced courses each semester to prepare for research. After the second year, most students take mostly research credits, perhaps taking an occasional "Research Topic" (PHYS 598) course.

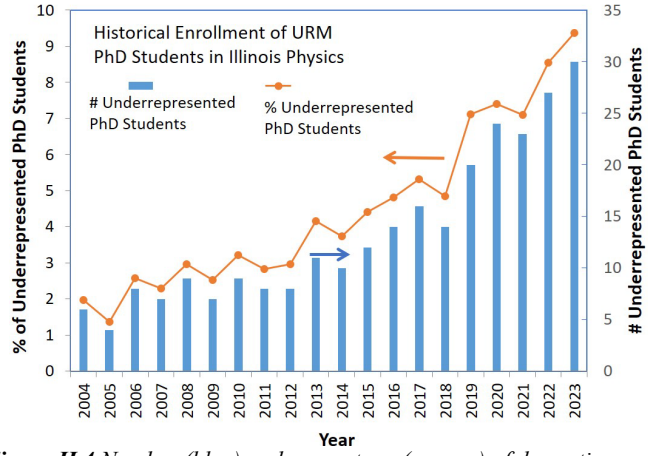

Figure II.4 *Number (blue) and percentage (orange) of domestic Black and Hispanic/Latinx students enrolled in the Illinois Physics PhD program, 2004–2023 (UIUC DMI data).*

b. **Graduate teaching instruction.** Most first-year grad students start as teaching assistants (TA) while investigating research opportunities in different groups. TA training for all new teaching assistants begins the week before fall semester with a "boot camp," during which experienced TAs share best practices and provide feedback as new TAs engage in various teaching scenarios. TA training continues throughout the first year, and each introductory Physics course is assigned an experienced "Mentor TA" who helps to train new TAs.

b. **Graduate research.** PhD students generally transition into research groups sometime during their first year in the program. To help students transition into research groups, the first-year course PHYS 596, "Graduate Physics Orientation," offers research presentations by faculty members interested in taking on research students. The Illinois Physics Grad Office also runs a Physics Graduate Student Blog, which posts advertisements for faculty research openings as well as academic announcements, fellowship and job opportunities, etc. First-year students are expected to identify a research group by the summer after their first year, but the transition to research groups typically happens at different stages for different students, with roughly 50% starting research by the end of their first semester, 10% starting at the beginning of their first year, and nearly 100% starting by the summer after their first year.

c. **Other professional development opportunities.** In addition to course and teaching instruction, a yearly Graduate Fellowship Workshop and a Graduate Fellowship Pre-Competition offer basic training in

proposal writing to students interested in submitting NSF, DOE, or other graduate research fellowship applications. Since 2011, Illinois Physics grad students have received 33 NSF Grad Research Fellowships, 5 NDSEG Grad Fellowships, and 2 DOE Grad Fellowships. The Grad Office also offers other professional development resources for Illinois Physics graduate students, including (i) a Physics Graduate Student Blog with posts about research, job, and professional development opportunities; (ii) a graduate student travel award program that provides Physics grad students with funding to present their research and network at conferences; (iii) a Physics Careers Seminar series, discussed in more detail below; and (iv) a summer internship program. The Illinois Physics department also supports several student organizations that foster community, provide leadership and mentoring opportunities, and create a positive climate for Illinois Physics graduate students. These groups include (i) the Physics Graduate Student Association, which runs social events, a graduate student colloquium, and the Science at the Market outreach activity; (ii) Illinois-GPS, a Physics grad student mentoring group for Physics undergrads; (iii) Illinois Graduate Peer Mentoring, a graduate peer mentoring group for first-year grad students; (iv) Women and Gender Minorities in Physics, which hosts retreats and social events; and (v) a Graduate Student Diversity Committee. Our PhD program also participates in the Illinois Sloan Center for Exemplary Mentoring, which provides mentoring and professional development resources for Black and Hispanic/Latinx PhD students in STEM departments.

Q4. Graduate Student Job Placement: The graduation rate for Illinois Physics graduate students since 2004 has been approximately 85%, which is significantly higher than the 60% national average graduation rate for Physics PhD programs. Our graduation rate for students receiving either PhDs *or* terminal MS degrees is 96%. From the beginning of record-keeping in 2011, 87% of Illinois Physics PhD students have either graduated (or are still progressing in our program if they joined recently). The Physics Grad Office maintains a job placement database of the 665 Illinois Physics PhD students who have graduated between 2005 and 2023. Historically, Illinois Physics has a 94% job placement rate for PhD students immediately upon graduation, with 54% of PhD students taking postdoctoral positions, 33% of PhD students taking positions in industry, and 12% of PhD students taking positions in national labs (see Fig. II.5). A detailed summary of the companies and institutions that have employed Illinois Physics PhD students is made available to our grad students to help them identify employment and networking opportunities for jobs and internships. A Physics Careers Seminar series—in which 5-7 Illinois Physics PhD alumni are invited each semester to talk about their careers—is also offered to make Physics grad students aware of their diverse career options. The Physics Careers Seminar series has hosted over 130 alumni speakers since 2012. The Illinois Physics Grad Office also runs a summer internship program for interested PhD students, supporting 2 students each summer to work at local companies such as Inprentus. More than 60 Illinois Physics PhD students have participated in internships in the past 8 years. Finally, the department also maintains an Illinois Physics LinkedIn network to help current graduate students network with PhD alumni for potential jobs and internships.

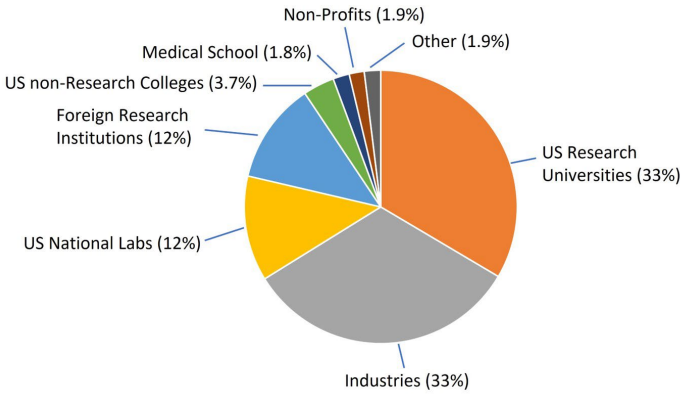

Figure II.5 *Initial job placement distribution of 665 Illinois Physics PhD graduates from 2005-2023.*

Q6. Graduate Student Learning Objectives: The learning objectives of Illinois Physics graduate students are to obtain a firm foundation in core Physics, Math, and current Physics research topics; learn to design and conduct original experiments, model physical phenomena; analyze and interpret data; learn to work

collaboratively with diverse teams; develop facility with the concepts, techniques, and literature associated with the student's specific research subfield; learn to teach and mentor others effectively; learn to communicate scientific topics effectively both to specialists in the student's research subfield and to non-specialists; know and practice professional and scientific ethical responsibilities; and develop the ability to identify important scientific problems.

Q7. Evaluation of Learning Objectives: Grad student preparation in foundational Physics is evaluated in part using a required qualifying exam—which tests 4 key areas: Classical Mechanics, Electricity and Magnetism, Quantum Mechanics, and Statistical Physics. The qualifying exam is normally taken at the beginning of a PhD student's second year. Promotion to PhD candidacy after the qualifying exam involves a holistic evaluation of each student's research progress, first-year coursework performance, and qualifying exam score. If a student's research progress and prior coursework has been strong, poor performance in a particular section of the qualifying exam is generally remediated with additional course requirements to bolster the student's preparation in that area of Physics. Preparation for research is further evaluated as part of the preliminary exam—normally taken in the student's third or fourth year—which consists of a 15-page paper and a research presentation that describes the PhD student's thesis research proposal. The preliminary exam is evaluated by a faculty committee.

The effectiveness of our TA training is reflected in the large number of teaching assistants selected on the "Teachers Rated as Excellent" list each semester by the UIUC Center for Teaching and Learning.

Finally, all Illinois Physics graduate students go through an annual evaluation process, consisting of (i) required evaluations by the Associate Head for Graduate Programs that consist of a summary of each graduate student's progress toward the PhD and recommendations for when relevant academic requirements should be met; (ii) required self-evaluations of each student's academic, research, and degree progress during the past year; and (iii) in-person meetings between each student and their research advisor to discuss research and degree progress. Post-prelim students are also required to meet annually with the chairs of their thesis committees to update their chairs on research progress.

Spotlight: Illinois Physics Master of Engineering (MEng) Programs Academic/Student Experience
Described immediately below, Physics also currently has 2 Master of Engineering professional master's programs in development or progress.

Q1. Enrollment: The "Instrumentation and Applied Physics" MEng program offers a 2-semester, project-based curriculum that mixes laboratory, classroom, and field work as a means of teaching students to take collaborative projects from conception and design through planning, prototyping, calibration, analysis, and documentation. This MEng program has an inaugural Fall '23 cohort of 13 students. A second Physics-based MEng program expected to start in Fall '25 is in development and focuses on Quantum Information.

Q3. Professional Development: All professional development opportunities available to Illinois Physics PhD students (described above) are also available to MEng students.

Q4. Job Placement: Job placement information is not yet available for the MEng programs.

Q6 & Q7. Learning Objectives and Evaluation: Learning objectives and evaluation are not yet available for the future MEng program in QIS. The MEng in Instrumentation and Applied Physics has just begun. Currently, we have insufficient experience for evaluation. However, the learning objectives ask that students:

1. Be able to conceive, propose, plan, and execute technical projects using a wide range of laboratory tools, instrumentation, and analysis techniques.
2. Understand the physics and experimental techniques underlying measurement instruments and tools.
3. Develop the ability to work collaboratively with a diverse team.
4. Be able to organize activities in a technical project, using standard project management tools.
5. Learn to consider the tradeoffs associated with technology down-elects.
6. Be able to analyze measurement data and draw supportable conclusions, including the use of deep learning and machine learning techniques in the analysis of complex data sets drawn from fields that include Physics, Medicine, and Agriculture.
7. Develop the ability to communicate—both orally and in writing—to present technical topics effectively to specialists and non-specialists.
8. Develop an understanding of basic business principles and practices.

III. Research

The research carried out by the Physics department scales from the smallest objects in the universe to the largest and covers everything in-between. The 56 tenure-system faculty members are almost evenly split between theoretical research and experimental research. The research efforts comprise 7 groups: Astrophysics-Relativity-Cosmology (ARC), Atomic-Molecular-Optical (AMO), Biophysics, Condensed Matter Physics, High-Energy Physics, Nuclear Physics, and Physics Education Research. Historically, Illinois Physics has been known for its world-class Condensed Matter group, and this recognition has helped us to invest in solidifying other research efforts. Physics has wide-ranging collaborative efforts within the department and between departments and other institutions. These collaborations are anchored by a number of institutes (ICASU, ICMT, IQUIST) and federal funding centers (DOE EFRC, NSF MRSEC, NSF QLCI). Furthermore, Physics research efforts have been translated to inform the broader community through (1) reoccurring outreach events: a science booth at the Urbana Farmer's Market, "Saturday Physics for Everyone" lectures, "Astronomy on Tap" gatherings, "WhysGuy" science outreach TV segments; (2) STEAM performances: *Quantum Voyages*, *Quantum Rhapsodies*, the Art-Science Festival, *The Joy of Regathering*; and (3) and the operation of the world's first science-based "escape room," LabEscape, which is open to the public. Collectively, these outreach efforts have engaged tens of thousands of people over the past 5 years. By any metric—publications, awards, funding, society and national academy members, DEI efforts, outreach—Illinois Physics has been extremely productive and successful.

a. Group Research Efforts

Astrophysics, Relativity and Cosmology Group (ARC)

The Astrophysics, Gravitation, and Cosmology group in Illinois Physics studies the largest scales in the Universe, from stars and black holes in our Milky Way to the cosmic microwave background and the first galaxies. Research in these areas includes experimental, theoretical, mathematical, and computational work. Areas of focus include plasma astrophysics and accretion disks around black holes (Gammie); numerical relativity for compact objects and binaries in and outside of general relativity (Shapiro, Tsokaros, Witek); analytical relativity for compact objects and binaries, and tests of general relativity with gravitational wave data (Yunes); cosmological