Institute for Pure and Applied Mathematics, UCLA
Annual Progress Report for 2021-2022
Award # 1925919
August 4, 2022

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EXECUTIVE SUMMARY

This report covers our activities from June 12, 2021 through June 10, 2022 (which we refer to as the reporting period). This report includes the 2021 summer research programs (RIPS and GRIPS). The 2022 summer programs are underway at the time of reporting and will be included in the next annual report.

IPAM held two long programs in the reporting period:

- Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy (September 13 - December 17, 2021)
- Advancing Quantum Mechanics with Mathematics and Statistics (March 7 - June 10, 2022)

IPAM held the following workshops in the reporting period:

- Quantum Numerical Linear Algebra (January 24 - 27, 2022)
- Calculus of Variations in Probability and Geometry (February 7 - 11, 2022)
- Mathematics of Intelligences (February 14 - 18, 2022)

Furthermore, the following public lecture was organized during this period:

- Green Family Lecture Series: “From the Possibility to the Certainty of a Supermassive Black Hole” (October 25, 2021) by Andrea Ghez

During the reporting period, IPAM hosted the following special events and conferences:

- Number Theory Event for Undergraduate Students (October 16 - 17, 2021)
- Blackwell-Tapia Satellite Conference (November 19 - 20, 2021)
- A Celebration for Women in Mathematics, year 2022 (May 12, 2022)

IPAM typically offers two reunion conferences for each IPAM long program; the first is held a year and a half after the conclusion of the long program, and the second is held one year after the first. Due to the unprecedented crisis posed by the COVID-19 pandemic, a number of reunion

conferences scheduled during 2019-20 and 2020-21 reporting periods were postponed. During the current reporting period, we were able to bring together these cohorts for an opportunity to reconnect and reflect on collaborations that followed since they attended the long programs. We were able to convene reunion conference for the following cohort in Lake Arrowhead:

- Big Data Meets Large-Scale Computing Reunion Conference I (December 12 - 17, 2021)
- Quantitative Linear Algebra Reunion Conference II (December 12 - 17, 2021)
- Geometry and Learning Reunion Conference I (December 12 - 17, 2021)
- Machine Learning for Physics Reunion Conference I (June 5 - 10, 2022)
- Mathematical Challenges and Opportunities for Autonomous Vehicles Reunion Conference (June 5 - 10, 2022)

The following reunion event took place at IPAM:

- Hamilton-Jacobi PDEs Reunion Conference I (January 5 - 21, 2022)

RIPS Los Angeles convened as planned and in-person. GRIPS Sendai 2021 took place virtually. Due to safety concerns, RIPS Singapore and GRIPS Berlin were cancelled. This report includes two 2021 student research programs:

- Research in Industrial Projects (RIPS) in LA
- Graduate-level RIPS (GRIPS) in Sendai

A. PARTICIPANT LIST

A list of all participants in IPAM programs will be provided to NSF in electronic form (Excel). The list will include participants for programs whose start dates fall between June 12, 2021 through June 10, 2022.

B. FINANCE SUPPORT LIST

A list of participants that received support from IPAM will be provided to NSF in electronic form (Excel). The list includes all funded participants of programs that occurred between June 1, 2021 through May 31, 2022.

C. INCOME AND EXPENDITURE REPORT

Grant # DMS 1925919:
This table shows appropriations and expenses for June 1, 2021 through May 31, 2022 for grant #1925919.

	A	B	C	D	E	F
			A-B=C		B+D=E	A-E=F
Budget Category	Appropriation Year 2	Actual Expenses	Balance	Encumbered Expenses as of May 2022	Total & Encumbered Expenses at May 2022	Encumbered Balance as of May 2022
A. Operations Fund	$2,003,333	$1,616,331	$387,002	$188,401	$1,804,731	$198,602
B. Participant Costs	$1,900,000	$1,303,209	$596,791	$126,342	$1,429,552	$470,448
C. Indirect Costs	$1,096,667	$857,638	$239,029	$0	$857,638	$239,029
Totals	$5,000,000	$3,777,178	$1,222,822	$314,743	$4,091,921	$908,079

IPAM received an appropriation of $5,000,000 each for first two years of the grant. Initially, due to the COVID-19 epidemic, IPAM activities were fully an online format until June 2021. After June 2021, participants could choose to participate in-person or remotely, rendering in-person participation highly dependent on COVID surges and travel disruptions. Although online programs lowered our Participant Support Costs due to optional participant travel, IPAM was still able to aggressively recruit in-person participants, thus spending at healthy levels.

During Year 2, Operational Costs (e.g., salaries, benefits, equipment, supplies) were steady at $1,804,731. Participant Support Costs (e.g., stipends, travel, housing, and subsistence for the scientists working on IPAM Programs) were at a healthy level of $1,429,552. Indirect Costs rates are based on current facilities and administrative cost rates negotiated with the Federal

government and the University of California. IPAM's work is conducted at an on-campus location which is subject to a 56% facilities and administrative cost rate. Indirect costs are not applied to equipment and participant support costs.

Registration fees for NSF-supported conferences are accounted for as program income. IPAM charges modest registration fees primarily to discourage non-serious registrations. Registration fees for workshops are $75 for faculty and government/military participants, $100 for industry participants, $50 for post-doctoral scholars and $25 for graduate students. During this reporting period, the in-person workshop registration fees collected were approximately $20,000 and waived for online programs. All program income collected is spent entirely on participant support expenses.

D. POSTDOCTORAL PLACEMENT LIST

IPAM appointed three postdoctoral Scholars during the reporting period. Funded by the Simons Foundation, the postdocs participated in the long programs.

Li Li
Li actively participated in the 2021 fall long program *Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy.* In the Spring, he continued his research with UCLA faculty as well as a future postdoctoral advisor at UC Irvine. After completing his postdoctoral research at IPAM, he will continue his postdoc in UC Irvine.

Zhimeng Ouyang
Zhimeng actively participated in the 2021 fall long program *Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy.* She also collaborated with UCLA faculty in the Fall and in the Spring. After completing her postdoctoral research at IPAM, she will join the University of Chicago as a Dickson Instructor and NSF postdoc.

Kevin Stubbs
Kevin served as a core participant in IPAM's 2022 spring long program *Advancing Quantum Mechanics with Mathematics and Statistics*. In the Fall of 2021, he collaborated with members of the UCLA mathematics department. He contributed to the 2022 student research program *Research in Industrial Projects (RIPS)* in LA as an academic mentor. After completing his postdoctoral research at IPAM, he will continue his postdoc in UC Berkley.

E. MATH INSTITUTE DIRECTORS' MEETING REPORT

Mathematical Sciences Institutes Directors (MIDs) Virtual Meeting

April 29, 2022
9:10-1:00pm PT
Dial-in https://msri.zoom.us/j/93605549887
Meeting ID: 964 0402 0254

Participating
AIM:
Estelle Basor
Brian Conrey

IAS:
Akshay Venkatesh

ICERM:
Brandon Hassett
Caroline Klivans
Ulrica Wilson

IMSI:
Kevin Corlette
Bo Hammer
Doug Simpson

IPAM:
Christian Ratsch
Dima Shlyakhtenko
Parama Sigurdsen

MSRI:
Helene Barcelo
David Eisenbud
Tatiana Toro

NSF:
Marian Bocea
Stefaan De Winter

Pedro Embid
Yiliya Gorb
Judy Huixia Wang
Joanna Kania-Bartoszynska
David Manderscheid
Andrew Pollington
Junping Wang
Henry Warchall

AGENDA
9:10-9:30 welcome, Introductions and Approval of 2021 Minutes
9:30-9:50 David Manderscheid: DMS updates
9:50-10:00 break

10:00-10:08 AIM updates (6 minutes + 2 mins Q&A, including update on recent/upcoming changes)
10:08-10:14 IAS updates (4 mins + 2 mins Q&A)
10:14-10:20 ICERM updates (4 mins + 2 mins Q&A)
10:20-10:26 IMSI updates (4 mins + 2 mins Q&A)
10:26-10:32 IPAM updates (4 mins + 2 mins Q&A)
10:32-10:38 MSRI updates (4 mins + 2 mins Q&A)

Discussion Items

10:45-11:00 NSF branding
11:00-11:10 Could the NSF give some updates/info on its AI Research Institutes program?
11:10-11:25 Open discussion: COVID-19 pandemic effects on expenditures
11:25-11:40 Open discussion: return of in-person events at the institutes

11:40-11:50 Break

11:50-12:10 Potential broadening of Institutes' engagement with the Mathematical Sciences Community

Individual and Open Discussion

12:10-12:30 Breakout rooms with individual institutes (no minutes kept)
12:30-12:50 Open discussion

13:00 meeting ends

MINUTES
Minutes from April 2021 meeting were approved unanimously.

9:15AM - 9:45AM DAVID MANDERSCHEID: DMS UPDATES
New DMS division director David Manderscheid provided highlights on recent developments at the NSF Division of Mathematical Sciences (DMS). A NSF strategic plan was released with new emphasis on impacts through technology. The 2022 budget request included a 20% increase for NSF but current Congressional budget provides 4% growth. It is not yet clear how this will be distributed at the Mathematical and Physical Sciences Directorate level, which includes four other divisions: astronomy, physics, chemistry, and the material division. Most likely there will be a flat budget for DMS of roughly 250 million. The fiscal year 2023 appropriation request to President Biden is once again 20%. It remains to be seen how it plays out in Congress, with the midterm elections coming up in fall 2022.

The Math Institutes are an extremely important part of DMS's portfolio -- a good percentage of the $250M, roughly 10%, goes to the institutes. The institute model is gaining attention at the office of the Director. The Committee of Visitors Report to the NPS advisory committee in the fall of 2020 included many positive questions about institutes, asking if they could be replicated in the other sciences.

To retain this momentum of this support, the institutes are asked to report about the highlights of things they have been implementing research and education wise. Assistant Director, Sean Jones, is a very strong supporter of the institutes; the institutes are encouraged to provide the body of evidence of their impact to sustain this support.

Manderscheid is planning to visit several of the institutes in the near future.

Manderscheid gave some highlights of new high priority NSF programs:

Funds for postdocs (at the level of MPS) to develop the scientific community, especially in the times of COVID.

ASCEND is a program for postdoctoral fellowships, mostly aimed at people from underrepresented minority groups.

LEAPS is a program that is aimed at people from mostly underrepresented minority groups, who are at non-R1 institutions as assistant professors to help them get their research career started.
DMS puts an increasing emphasis on collaborations. There has been a Dear Colleague letter initiative for collaboration between the Director of Biological Sciences and Social Sciences for

IHBEM (Including Human Behavior and Epidemiological Models) to incorporate human behavior in epidemiological models to understand vaccine reluctance during COVID, for example. Another area of application can be gun violence and climate change.

A further major program is joint with Simons Foundation focusing on theory and mathematics in biology. This is a winner takes all competition for a five-year $50 million institute. Half the funds are coming from Simons and the other half coming from NSF, split equally between biological sciences and DMS. There is the possibility of renewal for another five-year period.
There is also focus on AI and applications. Research around automated theorem proving and theorem checking is gaining a lot of traction as well.

There is a lot of interest around computer science within NSF and from industry. Microsoft and Amazon are both interested in possibly providing funding.

Request to the Institutes: The Simons Foundation has been a very strong supporter of the mathematical and other sciences. But there are other foundations out there too. One shouldn't just rely on the Simons Foundation, just as one shouldn't rely just on NSF. If the institutes have other foundations that might be interested in partnering, it could be enhanced by NSF being a part of that. Obvious candidates: Keck or Schmidt.

Q&A
Dima (IPAM): How much of AI Institute program is associated with Computer Science? What about mathematics of the foundational aspects of AI?

Judy (NSF): AI does occupy a very important place, and this is also one of the priority areas that MPS is paying attention to. There have been some internal discussions regarding AI in different areas, including science areas covered by MPS. Nothing has been decided yet and feedback is welcome.

David Eisenbud (MSRI): Can the PIs be from industry or do they have to be from universities?

Judy (NSF): they do not have to be from universities. Regarding funding and eligibility, MPS have to look if there are any restrictions to certain organization.

Junping (NSF): currently DMS is co-funding two institutions. We are pushing to get more mathematics involvement in the AI Institutes.

Dima (IPAM): it was mentioned before the possibility of having an informal site visit. How do we proceed with this? Should ask our program contact?

David Manderscheid clarified that he is planning to visit institutes, and if any wish to arrange informal mid-grant cycle visits in addition, they should be in touch with their program officers.

9:55AM - 10:40AM INSTITUTE UPDATES

AIM:
Brian Conrey (AIM): AIM is back in person after 2 virtual years. Success in using virtual office environ/ment Sococo during pandemic for online AIM Research Communities. These promote long-term collaborations through regular virtual meetings of a group of 50-70 people each with a virtual "office", akin to a workshop in slow motion.

Developed a partnership with AMS involving joint math meetings. AIM will participate in the prize sessions and will give out the Alexanderson Award. Other plans of note include organizing special sessions and having receptions for the math circles, community teacher circles, and students' circles. Much of the foundational work was done on the last couple of years when everything was virtual; things now are starting to get back in person, and AIM has a whole suite of activities.

Several well-received initiatives for mathematicians and for teachers, students, parents, and public included programs like Math Mondays, Global Math Project, festivals, and classroom visits, both remote and in person. AIM is also advertising to departments and inviting their involvement.
AIM will move to Caltech in about a year. Exact date is not available yet. AIM will be housed on the 8th floor of Caltech Hall formerly the Millikan Library. Through this transition, AIM will remain completely independent. The space is being remodeled and will be provided rent free for exclusive use of AIM.

AIM will partner with Caltech to bring over 800 weeklong visitors per year. While AIM's outreach programs have a national focus, working with people in that LA area will be highly impactful. Future partners will include the Southern California Network of math teacher circles and IPAM. Also, there is BEAM LA and the Art of Problem Solving is in San Diego

Q&A
Joanna Kania-Bartoszynska (NSF): will AIM be part of Caltech more than physically? Will AIM NSF proposals be submitted through Caltech?

Brian Conrey (AIM): we will have Caltech privileges on campus. We will invite some Caltech faculty to the Scientific Board. It is possible that future deputy directors or directors of AIM will come from the Caltech faculty. Proposals will be submitted through AIM.

IAS:

Akshay Venkatesh (IAS): IAS has returned to normal operations. IAS's special year this year is on fluid mechanics and symplectic geometry. In the previous academic year, 66 of the 87 invited came in person, and this year all but 2 did.

COVID impacts: low percentage of female applicants (17% last year, 20% this year, both well below historical averages). This is has been discussed with the other institutes. Also, there have been intrusions on Zoom talks by non-mathematicians asking too many questions. A registration system to restrict access is being considered.

Q&A

Joanna Kania-Bartoszynska (NSF): why did COVID impact the number of applications from women?

Akshay Venkatesh (IAS): We don't fully understand mechanism, but it's something the other Institutes have also seen.

Brandon Hassett (ICERM): ICERM saw a large difference in in-person attendance of male and female participants during one of its workshops during the Omicron surge in the winter. ICERM provided a lot of flexibility and only men came in person. There was a very marked gender bias in the decisions whether to travel or not.

ICERM

Brandon Hassett (ICERM): ICERM has been transitioning from mostly virtual to mostly in-person over the last year. All activities are either in-person or are available in person. Last summer undergraduate program was in person, which required some effort. For the past year, ICERM allowed people to freely choose between in-person and remote attendance, and in-person percentages responded to health conditions. In January, 85% of the speakers were virtual; currently, over 90% are in-person.

ICERM expects a busy summer, including additional long-term visitors from spring and fall 2020 programs that did not yet meet in person. There will be a social justice program in the summer running in parallel with a summer ICERM program, and in parallel with two three-week reading programs. There is also a larger than usual cohort of postdocs.

There has been a lot of experimentation with new types of programs. For hybrid programs, in consultation with the Boards, the goal is to have a critical mass of in-person participants to achieve networking benefits. Also experimented with two-step programs: a short concentrated week followed by a long-period of on-line collaboration, followed by an in-person capstone.

Q&A

Joanna Kania-Bartoszynska (NSF): were the postdocs at the institute?

Brandon Hassett (ICERM): the majority of the postdocs were, but there were some cases where postdocs were affiliated scientifically with past programs, e.g., postdocs that were connected with nonlinear algebra program, or computational combinatorial algebraic geometry program. And in those cases, their mentors were not on site.

Pedro Embid (NSF): when you talk about hybrid and the critical mass of people in-person, do you have a percentage in mind?

Brandon Hassett (ICERM): we have discussed this with both our Scientific Board and the Board of Trustees. Currently, for an in-person workshop, we will allow 20% of the speakers to be invited with the intention that they would only come virtually, and we want 80% of the speakers to actually be in-person. We recognize that in some cases the individuals who are essential to the success of a program cannot be convinced to travel and so we don't want to close the door completely. But we want that when someone looks at the slate of speakers that the majority of the people that are there will be people that they can actually interact with over coffee breaks. Those informal interactions are quite important. One of the disadvantages of this approach is we often don't know whether people who are supposed to be in-person will be so with 100% reliability. We will learn and adjust, but that is the thinking right now.

IMSI

Kevin Corlette (IMSI): IMSI is in its second full year of operation, the first with an in-person component. IMSI ran their first long program in the fall, on distributed solutions to complex societal problems. It addressed problems of modeling populations of agents which have some capacity to assess and predict the behavior of other members of the population. There were 7 workshops over the course of the program, 2 of those were virtual. One of them ended up being a replacement for a workshop where the organizers were only interested in in-person activities. It was replaced it on short notice with a different workshop with some tutorial lectures on three different themes. The other workshops were all hybrid to varying degrees. A minority of the speakers were in-person.

In the winter, IMSI ran 3 workshops, on private AI, on multi-scale microbial communities, and on the mathematics of soft matter. Because of the Omicron surge, two of the workshops were fully virtual. The third workshop had a relatively small group in-person of organizers, speakers, and postdocs, with the rest of the audience virtual. For every event, up until recently, it was necessary to ask for permission from the university and give them an estimate of how many people would be in-person etc., which made planning challenging.

Spring is closer to what will hopefully be normal operations. There are currently approximately 20 long term visitors in residence, or about 80% capacity, in the long program on decision making and uncertainty. There are 7 embedded workshops in the program, 3 of which already happened and the fourth is starting next week. These workshops were held mostly in-person, although a significant fraction of the audience has been online.

Looking forward IMSI has three workshops coming up in summer: one on data value with focus on markets; one on mathematical methods for quantum hardware; and the third on Gaussian processes.

IMSI is also hosting the AI+ Science Summer School in collaboration with the Data Science Institute at the University of Chicago. It will focus on several themes, including AI for geosciences and climate modeling, AI guided search in chemistry and molecular biology, and AI guided experimental design.

A long program on confronting global climate change is scheduled for the Fall. In addition, there will be a collaboration on a Trustworthy AI Summit, which will include panels on topics such as AI and the scientific method, and the fourth industrial revolution. Some of the organizers are part of a group that is putting in a proposal in the AI Research Institutes competition.

Q&A
Joanna Kania-Bartoszynska (NSF): How do you like your new building?

Kevin Corlette (IMSI): I like it quite well. We are looking forward to the site visit near the end of May from the NSF.

IPAM
Dima (IPAM): IPAM's programs are being held in-person since last June, starting with a reunion conference and in-person undergraduate RIPS program. The Fall long program on gravitational waves was at 70-75% capacity. Currently, IPAM is out of office space with double-occupancy offices, i.e., back to normal.

All of the IPAM workshops are run in hybrid format which works well for the interactions during the talk. What is missing for remote participants are interactions after talks, e.g. over tea. So far IPAM has not constrained the number of remote speakers or remote participants, but we are planning to cap the number of remote speakers at around 20% (i.e., 4-5 in a 25 speaker workshop), to ensure more interaction.

Thanks to Simons Foundation funding, IPAM now runs a postdoctoral program (3 postdocs per year this year and next year).

COVID protocols: UCLA provides weekly (or more frequent) saliva-based PCR tests for our participants, and we test everyone who comes to IPAM with a rapid test. IPAM had had several cases at the peak of Omicron.

Partnerships: IPAM is a partner of the Challenge Institute for Quantum Computation (CIQC) that spans a partnership between Berkeley, UCLA, Caltech, the Simons Institute, and IPAM. At UCLA, CIQC started a professional master's program in quantum science and are setting up an internship track for that. IPAM's RIPS program and the graduate level RIPS serve as a model. IPAM and CIQC are also co-organizing a winter school together. Topics related to CIQC will be featured in a long program taking place in about a year.

For long programs, IPAM started hosting Zoom recruitment events, where organizers give a short mathematical introduction to the program. This is recorded, but there's live participation also. The organizers answer questions about who they would like to see participate, what skill-sets will be needed, and why it is interesting, and directorate members answer questions about mechanics of application and participation.

IPAM participated in several satellite events, including the Blackwell Tapia conference and the upcoming celebration of Women in Mathematics Day.

Reminder: the LatMath conference was postponed to July 7 through 9.

Q&A

Joanna Kania-Bartoszynska (NSF): I am curious about your impressions about the postdocs. Was it an enhancement to have postdocs, or was it more trouble than it was worth? Is that something you would want to continue, or is the jury's still out?

Dima (IPAM): we want to at least interview the postdocs. Our first crop is finishing up their year right now. So, we would want to do exit interviews. And this will be a big part of the assessment of whether it makes sense for us going forward.

Helene Barcelo (MSRI): you said you mentioned that you were doing zoom event for interested people in the program. Do you know if this had an impact on the ratio of application from underrepresented groups and from women?

Dima (IPAM): we don't know yet. We have just done this three weeks ago. So, we are still assessing to see if the application numbers have picked up. We did have a healthy number of people joining in.

David Eisenbud (MSRI): how do you get them to come to the zoom meeting?

Dima (IPAM): we have advertised it to mailing lists that we had available to us. Going forward, we will be more organized about this. It is an evolving project.

MSRI:
David Eisenbud (MSRI): MSRI held had a jumbo program on random matrices in the fall. This semester, there is one on analysis in geometry of random shapes; and on complex dynamics that's been very active.

After year and a half of virtual programs, it is clear that people just love being back together. MSRI is now running full workshops which are going well. There are many precautions: testing, contact tracing, masks, outdoors eating. There hasn't been any transmission within the building but members reported approximately one case per week.

Collaborations: MSRI has a long-standing collaboration with the American Math Society involving Congressional briefings; two are this year. There is also a multi-year collaboration with the Chicago Mercantile Exchange. MSRI gives an annual prize in quantitative finance and economics. Nancy Stokey is the winner this year.

The newest collaboration is a joint graduate program with IBM research. MSRI will have a meeting with IBM Research in Yorktown Heights on business and science trends that will change the world in the next 50 years.

The National Math festival was spread out over a semester virtually last year.

Helene Barcelo (MSRI): MSRI will be having 13 graduate schools this summer: 2 at MSRI itself, 3 at MSRI's partner, St. Mary's College in Moraga. The other 8 summer schools are throughout the world with various partnerships with including PCMI, Oxford, a research institute in Crete etc. This creates some challenges, since there surely will be COVID cases among 400+ students being sent around the world this summer.

MSRI is planning a one-month reunion for the programs from March 2020 that was cut short. One of those will happen in Mexico. The other one will be at MSRI mid-July -- mid-August. It's on number theory. MSRI will also hold their usual six-week REU program. There will also be the ADJOINT program, a year-long program for African diaspora mathematicians that starts with a two-week workshop.

MSRI also has a research program for women in mathematics; it brings a group of researchers for two weeks at MSRI and these will be throughout the summer.

David Eisenbud (MSRI): two more updates -- May 18 MSRI will be going public with a big announcement related to its endowment campaign. The other major change is that David Eisenbud will retire from the directorship on August 1 and Tatiana Toro will take over.
Tatiana Toro (MSRI): Pleased to say we have been working together since the fall to guarantee that this will be a smooth transition.

MSRI will start its 40th year celebration on May 18. The goal is to have a yearlong celebration with some small events and then a large event in the spring of 2023 with reunions for each decade.

Q&A
Dima (IPAM): I just wanted to say we will miss a lot working with you, David. It's been wonderful to get to know you.

10:45AM – 12:35PM DISCUSSION ITEMS

NSF BRANDING
Joanna Kania-Bartoszynska (NSF): NSF is asking everyone to acknowledge NSF support during talks, in papers, and on their websites, or at any events that are happening because of the funding given by NSF. The logo can be downloaded from this link: https://www.nsf.gov/policies/logos.jsp Institutes are being asked to put this logo on their newsletters, and any published material or communications about NSF supported activities. The office of Legislation and Public Affairs is tasked with making sure that this is happening. NSF have asked all our PIs on individual grants to do this. This also applies to the institutes supported by the NSF.

David Manderscheid (NSF): NSF wants to ensure that the public understands the purpose of the National Science Foundation, with its almost $10 billion budget. Some of the institute web sites prominently feature the logo; others less so. Please make sure you have it prominently featured, make sure that the public knows the institutes are supported by the NSF. The office of Legislative and Public Affairs, which is the organization within NSF that is responsible for this initiative, reports to the Office of the Director and this directive is coming from the top.

Henry Warchall (NSF): as you know, the NSF is not allowed to lobby Congress. The only way that NSF can get Congress to give NSF more money is by request from the general community. So, this branding is actually directly tied to the NSF budget and also a recognition of the things that NSF funding has accomplished.

COVID-19 PANDEMIC EFFECTS ON EXPENDITURES
Marian Bocea (NSF): spending has been lagging behind due to the pandemic. That is to be expected. We would like to know your thoughts on what's going to happen going forward. Do you

plan to support more participants in events that will happen? Once in-person becomes possible, do you plan to think about a no-cost extension?

Brandon Hassett (ICERM): ICERM projects steep growth in staff and administrative costs due to the need to retain and attract staff, especially for on-site work. There is also inflationary pressure on the participant support side, including costs for rentals and airfare. ICERM just increased its reimbursement guidance by 25%. It is not clear which of these items (administrative or participant costs) will dominate in the medium term.

Dima (IPAM): IPAM also has seen a lot of inflationary pressures, most prominently in the area of shorter-term rentals. IPAM was substantially under spending in the first couple of years of the grant. However, much of this underspending is likely to be absorbed by activities postponed from 2020-21, as well as higher inflationary costs, and a large surplus at the end of the grant cycle is not anticipated.

Joanna Kania-Bartoszynska (NSF): The NSF is used to this, but the division of grants and contracts may ask institutes about their spending plans. Large balances with no spending plan will be of concern to us. Costs of bringing in visitors and the administrative costs all seem to be going up. But there is certain amount of resistance when the administrative costs are the majority of the award. This is something that institutes need to keep in mind because while of course administrators are making it possible for visitors to come, we want the lion share of the money to go to the visitors.

Helene Barcelo (MSRI): do you have a percentage split of what you'd like to see in grant budget? Such as 60% on the participant and 40% on staff?

Joanna Kania-Bartoszynska (NSF): NSF will not comment on something like this.

Marian Bocea (NSF): to clarify, NSF doesn't take it easy moving funds away from participants. To make that kind of change, it needs to be requested to NSF. If any of the institutes are considering this, the best is to contact the Program Officer first and if everything makes sense, then submit a formal request for re-budgeting and for reallocating funds from participant support.

RETURN OF IN-PERSON EVENTS AT THE INSTITUTES

Dima (IPAM): There is enthusiasm for bringing back in-person activities as much as possible. However, travel is an inconvenience and involves some degree of risk to health. IPAM had an in-person only reunion events last December at the UCLA Lake Arrowhead Conference center which were well-attended despite the COVID surge. However, a number of people could not come because of health concerns, visa issues, etc.

Joanna Kania-Bartoszynska (NSF): how challenging did you find the hybrid events? I've been attending our staff meetings as a zoom participants last couple of times with people in the room and we don't really see anybody's face, who is sitting in the room. The communication between the online people and the on-site people is hard. The online people can chat or they see each other's faces on the screen. People in the room can talk amongst each other. But connecting the two groups is a challenge.

Brandon Hassett (ICERM): for hybrid meetings to work, the person chairing or moderating needs to make a very active effort to involve both communities on an equal basis. We need a session chair that will alternate between asking questions in the Zoom audience and asking questions from the in-person audience. I think it's difficult, and we really hesitate to put burdens on the people who show up in-person to force them to involve virtual participants in everything that they do. And this is one reason why we don't actively encourage participants to be virtual.

David Eisenbud (MSRI): So far, my impression of the hybrid situation is that it's in some ways the third best choice between in-person, virtual, and hybrid.
Helene Barcelo (MSRI): I think that keeping on the hybrid for the workshops and seminars is important because those who enter isolation because of COVID can remain engaged. Hybrid may also play a role in equity providing access to activities to people who otherwise could not come.

Bo Hammer (IMSI): Hybrid allows some equity of access, as Helene pointed out. However, while this is necessary, there is a concern of whether it's the same quality of experience, particularly outside of the talks. It is hard to positively compare online experience with the experience of being in residence for 10 weeks, experiencing interactions outside of formal sessions, which is when the magic often happens. In that way, it's an open question as to how somebody participating virtually can benefit in the same way. At the same time, having the technology that enables hybrid participation possibly provides access to people who might not otherwise ever be able to come regardless of COVID. For example, faculty in HBCUs or minority serving institutions have heavy teaching loads and limited funding, making participation difficult. So, at least providing a hybrid experience would enable them to partially participate versus not being here at all. I think it's an open question worth some research to see impact on equity, whether the hybrid mode enables or makes it worse in the end through unintended consequences.

Ulrica Wilson (ICERM): I would worry about our reactions to underrepresented groups not coming in person. I worry that our response is to create what we all consider less than optimal ways to participate. I know nobody intends this to happen, but these things creep up over time. And so, what does equity look like? I think there are opportunities with hybrid but I worry about settling in on that.

David Manderscheid (NSF): I would echo that and I want to add something else: social science literature says that if you know somebody, it's much easier to connect via zoom or during a hybrid event later on than if you don't know somebody. So, the importance for all people, but especially for those who already feel marginalized, of having in-person opportunities, and for us to make sure we provide those opportunities. I think it's true for all people but particularly for those people who haven't had the opportunity previously.

Dima (IPAM): we asked people why they participate remotely or in person. Some can't participate because they're sick during the conference. Some people give completely different reasons. We have very rarely had people cite that their teaching prevents them from coming. Usually it's because they are "busy". But these are also the types of participants that do not really contribute to a good workshop. In 99% of the cases, one watch the identical talk by the same person on YouTube, and get exactly as much out of it. So, in some sense, we're wasting a slot in a workshop for a person who could have much more interaction and much more impact.

Also, institutions tend to treat zoom conferences very differently when their employees go there in person: while it's been a long-established practice to cover for colleagues who are gone to conferences, this does not extend to virtual events. Virtual participation also leaves the person open to more distractions. I think the technical issue of the hybrid format can be solved but there are all these kinds of societal things including communication between people that just are not there yet.

Joanna Kania-Bartoszynska (NSF): this is anecdotal, but when we invite panelists, there were some women that we asked to come to the panel, they said it was easier for them to come because it was hybrid. But then, when asked again later, they said, I really cannot do it virtually. If I was coming in-person, I could leave my duties behind, but it's harder to cover teaching and the kids still need to be fed, the dog needs to be walked and so on.

Kevin Corlette (IMSI): Coming in person is not as much of an opportunity to get away from responsibilities at home as it used to be. We get regular requests from people who are here in-person for space where they can teach their classes remotely.

Estelle Basor (AIM): This is something that hasn't happened before, but we have participants who want to go in to breakout room and do a zoom session with their class which breaks up their week in a workshop.

BROADENING INSTITUTES' ENGAGEMENT

Junping (NSF): Could there be something along the line of having a partnership between the institutes and minority serving institutions, or primarily undergraduate institutions? We just want to throw something on the table for discussion. We would like to grow some partnership between

Institutes so that they can increase recruitment and retention of faculty and provide more opportunities for faculty and students.

David Manderscheid (NSF): The goal is to collectively getting people involved that wouldn't ordinarily get involved in research in the sciences. Priority right now at NSF is to bring people from institutions that traditionally don't get large amounts of funding from the NSF, with emphasis on R2, minority serving institutions.

David Eisenbud (MSRI): There's been a development of this kind over time, which certainly could be expanded. One of the earliest such matters was Blackwell Tapia conference which we started originally with Cornell University, but then other Institutes were interested. And I think that was really the origin of the what's now the math institutes diversity committee.
Brandon Hassett (ICERM): I think that these small-scale collaboration activities, they do reach people that might not otherwise be engaged in research. I don't know whether this can be scaled more, but this is probably the part of our activities that most engages non-R1 faculty.

Tatiana Toro (MSRI): I had a conversation with David Spergel about six months ago about a program at the Kavli Institute for Theoretical Physics. They bring undergraduates from minority serving institutions or non-traditional institutions to an internship program. Students are brought to work with the people at the KITP, and somebody takes responsibility and they really are integrated into the group. They get to see what the research is, what type of projects there are. I was thinking that if we got together and we would be willing to bring students to work with the participants who are long term visitors to institutes. That might be a way to impact some of the students and will be offering something different. This will be for graduate students. I understand many non-R1 institutes don't have graduate programs. Maybe we could think of ways to have undergrads come and visit also, but get them involved in what we're doing.

David Manderscheid (NSF): we are doing that right now with national labs, sending money to national labs for internships of this sort. This is something that would sit and play very well at NSF.

Helene Barcelo (MSRI): Do we know what is the intention behind this effort in the sense that do we know why it is? I mean, why the NSF? How will success be measured?

David Manderscheid (NSF): That's a very good question. I think there're threefold reasons: First, broadening the scientific base and broadening support for scientific research. Second, there are mechanisms that are being discussed to enhance research and infrastructure of these institutions, not just support for the faculty. And third is the question of workforce, building the scientific workforce.

Dima (IPAM): We have tried what we call a buyout, which is where we send money to the institution of participants to get them out of teaching and enable them to come for the length of the long program for a person from a primarily undergraduate or minority serving institution. We anticipate that after going back to their institution, they can increase their impact by bringing ideas from the IPAM program home.

Henry Warchall (NSF) via chat:
Programs in the other 4 NSF MPS Divisions:
https://beta.nsf.gov/funding/opportunities/partnerships-research-and-education-materials-prem
https://beta.nsf.gov/funding/opportunities/partnerships-research-and-education-physics-prep
https://beta.nsf.gov/funding/opportunities/partnerships-astronomy-astrophysics-research-and-education-paare
https://beta.nsf.gov/funding/opportunities/partnerships-research-and-education-chemistry-prec

In 3 of the 4 MPS programs, proposals are to be submitted by a minority-serving institution; the programs do not furnish supplements to the host Centers.
Bo Hammer (IMSI): it seems like there's some capacity building that needs to happen in the southeast and the South in particular in the context of NSF missing millions priority. I'm wondering if there's a way for the institutes to take our show on the road and hold workshops in partnership with minority serving institutions in regions that don't currently have Institutes. That could be one way to begin building capacity in regions that don't currently have institutes.
Junping (NSF): Action items:

- Possible schemes or mechanisms to switch or enable certain partnerships.
- to get feedback on whether this should be a collective effort from all the institutes, or whether it should be done individually by each institute.
- And what type of methods do you want to see from the NSF in terms of funding.

Brian Conrey (AIM): there are precedents to getting all the institutes working together, with supplementary grants. If there were supplementary grants offered so each institute figured out what they can do, that would make sense. Also have some kind of program that cut across what everybody is doing, whether it's workshops, or some kind of meeting, or something that everybody could be involved in. That might be worthwhile.
Brandon Hassett (ICERM): all the math Institutes have quite independent and active Scientific Advisory Boards that have a large impact. How are we going to know how our resources are allocated, and what programs are being run? It's premature to discuss the mechanics, but I know that this has been sort of a complicating factor when we discussed collaborative projects in the past with other schools.

12:10PM - 12:30PM BREAKOUT ROOMS WITH INDIVIDUAL INSTITUTES (NO MINUTES KEPT)

12:30PM - 12:50PM OPEN DISCUSSION

2023 MIDS meeting will be on April 28-29, 2023 hosted by IMSI.

12:38pm PM meeting adjourned.

F. PARTICIPANT SUMMARY

In this report, we are reporting on participants of programs that took place between June 12, 2021 through June 10, 2022. We have included the participants of the reunion conference. This report does not include the participants of our RIPS/G-RIPS 2022 summer programs which will be captured in the next reporting cycle.

Also note that we do not collect RSVPs or participants data for "Public Lectures".

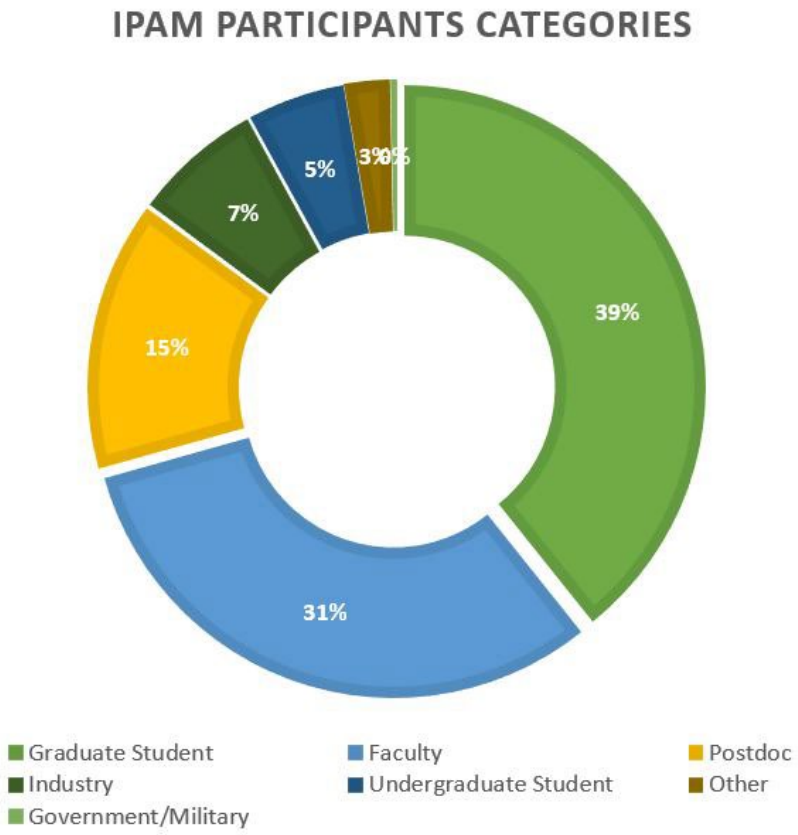
Table F: All Participants' Gender and Ethnicity by Program Type (June 12, 2021 through June 10, 2022)

Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Long Programs	109	26	106	2	0	9	96
Public Lectures	-	-	-	-	-	-	-
Reunion Conferences	113	26	110	0	6	10	106
Special Events and Conferences	39	18	35	1	9	12	34
Student Research Programs	213	68	199	0	13	10	204
Workshops	1982	468	1891	24	27	143	1644
Summer Schools	48	10	43	0	0	3	40
Total	**2504**	**616**	**2384**	**27**	**55**	**187**	**2124**
Percent of No. Reporting:		26%	95.21%	1.27%	2.59%	8.80%	
	All underrepresented ethnic groups:				*269*	*12.66%*	

There were 1,320 unique participants for this same period. (Some of the participants attended more than one program, usually multiple workshops within a long program.) Out of those reporting gender, 26% were women. Out of those who reported ethnicity, 14% of unique participants were members of an underrepresented ethnic group.

It is worth noting that starting fall 2021, IPAM made a strong move to transition back to in-person programs, supplemented by a virtual component.

The majority of IPAM participants were faculty and graduate students. See the chart below for the percentage of participants in each category.



G. POSTDOCTORAL PROGRAM SUMMARY

363 postdocs participated in IPAM's programs during the reporting period (June 12, 2021 - June 10, 2022). Nine postdocs participated in IPAM's student research programs. See table G.

Table G: Postdocs' Gender and Ethnicity by Program Type (June 12, 2021 - June 10, 2022)

Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Long Programs	27	3	26	0	0	2	23
Public Lectures	-	-	-	-	-	-	-

Table G: Postdocs' Gender and Ethnicity by Program Type (June 12, 2021 - June 10, 2022)							
Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Reunion Conferences	16	2	16	0	0	3	16
Special Events and Conferences	1	1	1	0	1	0	1
Student Research Programs	9	4	9	0	0	0	7
Workshops	299	55	286	0	0	25	247
Summer Schools	11	2	11	0	2	0	11
Total	**363**	**67**	**349**	**0**	**3**	**30**	**305**
Percent of No. Reporting:		19%	96.14%	0.00%	0.98%	9.84%	
	All underrepresented ethnic groups:				*33*	*10.82%*	

H. GRADUATE STUDENT PROGRAM SUMMARY

As with previous years, a robust number of graduate students participated in IPAM's workshops and long programs during the reporting period, as well as in Graduate-level RIPS. A few participated in RIPS-LA as academic mentors. Graduate students often find a compelling thesis topic at an IPAM program, and also frequently make contacts that lead to their first jobs. See table H for further breakdown.

Table H: Graduate Students' Gender and Ethnicity by Program Type (June 12, 2021 - June 10, 2022)							
Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Long Programs	35	11	35	1	0	3	33
Public Lectures	-	-	-	-	-	-	-
Reunion Conferences	19	5	19	0	1	2	18
Special Events and Conferences	2	0	2	0	2	0	2
Student Research Programs	30	7	30	0	4	1	29
Workshops	874	217	849	0	16	61	736

Table H: Graduate Students' Gender and Ethnicity by Program Type (June 12, 2021 - June 10, 2022)							
Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
	23	3	22	12	0	2	21
Total	**983**	**243**	**957**	**13**	**23**	**69**	**839**
Percent of No. Reporting:		25%	97.36%	1.55%	2.74%	8.22%	
	All underrepresented ethnic groups:				*105*	*12.51%*	

I. UNDERGRADUATE STUDENT PROGRAM SUMMARY

Typically, undergraduate students participate in RIPS-LA, RIPS-Singapore, and RIPS Projects Day. However, we saw a number of undergraduate students attend other programs at IPAM during the reporting period.

Table I: Undergraduate Students' Gender and Ethnicity by Program Type (June 12, 2021 - June 10, 2022)							
Program Type	Total Participants	Gender		Underrepresented Ethnic Groups			
		Female	No. Reporting Gender	Amer. Indian	Black	Hispanic	No. Reporting Ethnicity
Special Events and Conferences	23	11	22	1	3	9	22
Student Research Programs	108	51	102	0	3	9	108
Total	**131**	**62**	**124**	**1**	**6**	**18**	**130**
Percent of No. Reporting:		50%	94.66%	0.77%	4.62%	13.85%	
	All underrepresented ethnic groups:				*25*	*19.23%*	

J. PROGRAM DESCRIPTION

STUDENT RESEARCH PROGRAM: Graduate Research in Industrial Projects for Students (G-RIPS) Sendai 2021. JUNE 14 - AUGUST 6, 2021.

Graduate-Level Research in Industrial Projects for Students (GRIPS) offers graduate level students in mathematics and related disciplines the opportunity to work on industry-sponsored by Germany. Students from the U.S. and the host country get to work on cross-cultural teams on

research problems designed by industrial sponsors. The projects are of serious interest to the sponsor and offer a stimulating challenge to students; most involve both analytic and computational work. At the end of the program, the teams present the results of their work and prepare a final report. IPAM encourages the U.S. students to publish and/or present their research at conferences in the year following the program. English is the only language required for participation.

8 U.S. students participated in G-RIPS Sendai in 2021 together with 8 Japanese students. Each team consists of 2 US students and 2 Japanese students. The program was organized as a virtual program this year. The format worked quite well. The students worked during their respective daylight hours, and met almost every day between 4 pm and 6 pm PDT (which is 7 pm – 9 pm EDT, and 8 am – 10 am JST). We used Sococo, Zoom, and Slack to facilitate the interactions. Each team had one academic mentor, who is a Japanese junior faculty at Tohoku University. In addition, we were supporting two U.S.-based "co-mentors", who had been added to the program to help with difficulties that are associated with the time difference. In addition to the research activities, the students participated in weekly cultural classes, language classes, and additional social activities. While the students were not able to visit Japan in the summer of 2021, we anticipate that all G-RIPS students will participate in a special research symposium at Tohoku University in March 2022, and that they will present the G-RIPS results at that symposium. The students worked on projects that were sponsored by some of the most important companies in Japan. This year, the list of industrial partners included Toyota (more precisely, F-MIRAI, that is supported by Toyota), NEC, and Mitsubishi (2 projects). At the end of the program, each team presented the results of their work orally and in a written report.

2021 SPONSORS	PROJECT DESCRIPTION
F-MIRAI (Toyota)	Design for next-generation mobility service in suburban areas
	Design for next-generation mobility service in suburban areas
Mitsubishi	Development of a mapping space for intuitive teleoperation with heterogeneous devices of multiple types
	Optimization of wireless base station placement as an essential foundation for our future IoT society
NEC	Annealing machine application to artificial neural networks

Mitsubishi (Project A)

Industrial partner: Advanced Technology R&D Center of Mitsubishi Electric Corp. Mitsubishi Electric Corp., founded in 1921, is an electronic and electric equipment manufacturer developing products and solutions in widely diverse fields, including home appliances, industrial equipment, and space technologies. The Advanced Technology R&D Center was established to support the business of Mitsubishi Electric Group through the development of a broad scope of projects covering both basic and new advanced technologies. The main research themes include power electronics, mechatronics, satellite communications, next generation key devices, system solutions for electric power, transportation, factory automation, and automobiles.

Project title: Development of a Mapping Space for Intuitive Teleoperation with Heterogeneous Devices of Multiple Types

Project description: The goal of this project was consideration of a method for selecting a subspace that is intuitive and capable of handling multiple types of edge devices with different structures, referring to an earlier study. Although an inductive approach based on statistics is also possible, we would like to consider a deductive approach based on knowledge of dynamical systems and nonlinear mapping. Although an earlier report described mappings between heteromorphic hands, the subject matter of this project is not necessarily limited to mapping robotic hands. Because we possess several devices, including robot hands, we intend to conduct experiments with them and to specify the edge devices after selection.

MITSUBISHI (Project B)

Project title: Optimization of wireless base station placement as an essential foundation for our future IoT society

Project description: The purpose of the project was creation of an efficient and reliable optimization algorithm to ascertain the positions and directions of wireless base stations to reduce the costs and time for designing wireless systems. The optimization algorithm accepts the spatial distribution of radio signal strength (RSS) to evaluate the cost function. The G-RIPS team was asked to provide a propagation model that can predict the RSS. Participants can change the propagation model input parameters such as the base station position, direction, transmitting power, and the design environment geometry. Then, the propagation model predicts RSS considering the transmission loss which occurs when radio waves pass through walls and when multiple reflections of radio waves occur on the wall.

F-MIRAI (TOYOTA) Project

Industrial Partner: Toyota Motor Corporation and University of Tsukuba
Toyota will lead the way to the future of mobility, enriching lives worldwide with the safest and most responsible ways of moving people. In the near future, cars are expected to connect with people and communities and to perform in new roles as part of human social infrastructure. New domains of service such as AI, autonomous driving, robotics, and connected cars are becoming especially important. Toyota aims to reach the ultimate goal of sustainable mobility, creating a mobile future society full of smiles. Toyota and the University of Tsukuba have jointly established the R&D center for strategic frontiers in social planning (F-MIRAI), which advances toward Society 5.0 through the development of infrastructure for future communities and the formation of industrial centers through long-term collaborative action.

Project title: Design for next-generation mobility service in suburban areas

Project description: This goal of this project was to design Mobility-as-a-Service (MaaS) for practical cases for the campus of University of Tsukuba through analyses of person-trips and

other related datasets. The present major transportation modes around the university are private cars, buses, bicycles, and walks. The services accompanied with mobility around the campus are various, ranging from education, health care, and nursing care, to childcare. Participants were expected to estimate the overall transportation demand to optimize those services through analyses of available datasets, and to build a mathematical model as a system-of-systems based on some of the following perspectives. All can be considered with automated vehicles.

NEC Project

Industrial partner: NEC Corporation.
NEC (https://www.nec.com), founded in 1899, is now particularly addressing the development of solutions for society that will help resolve many issues the world is facing and which will engender the creation of a brighter and more prosperous society. Through co-creation initiatives with many different stakeholders, including customers, business partners, private individuals, government agencies, and international institutions, NEC is actively devising new business models to create social value by harnessing our extensive information and communication technology (ICT) assets.

Project title: Annealing machine application to artificial neural networks

Project description: The project's goal was to achieve the first application of a large annealing machine, NEC's system composed of SX-Aurora TSUBASA and software for an annealing algorithm, to the neural network training process, in particular Boltzmann machines (BMs). If their application is successful, the team would then be asked to demonstrate the benefits and shortcomings of this approach and how it might accelerate standard approaches. Students were asked to develop an algorithm to run BMs using the potential of NEC's annealing machine. Students had a unique experience because the system has not been released and because its hardware, SX-Aurora TSUBASA, is a very high performance vector super computer.

Comments from our participant survey:

"It gave me exposure to real world/industrial applications of mathematics."

"It has prepared me far more than what academic coursework has provided."

"Reminded me how much I enjoy operations research and mathematics as a whole."

"I really enjoyed the program."

"I think this program did really well considering it was in an online format. I do not think much should change, but I think that communication with our international counterparts is limited compared to if we were in-person. As a result, there were some (minor) challenges in explaining concepts, elaborating on specific code, etc. Nevertheless, I think this program was done well and I hope it becomes in-person in the future."

STUDENT RESEARCH PROGRAM: Research in Industrial Projects for Students (RIPS) Los Angeles 2021. JUNE 21 - AUGUST 20, 2021.

The Research in Industrial Projects for Students (RIPS) Program provides an opportunity for talented undergraduates studying math, computer science, and related disciplines to work in teams on a real-world research projects proposed by sponsors from industry or the public sector. The student team, with support from their academic mentor and industry mentor, will research the problem and present their results, both orally and in writing, at the end of the program. The REU program is nine weeks. IPAM provides each undergraduate student with a stipend of $3,500. IPAM organizes two RIPS cohorts every year: one at the UCLA campus in Los Angeles, and another in Singapore.

In a typical year, round-trip travel and accommodations costs are covered by IPAM. Students also receive a meal allowance and a stipend, and conference support to present their research. These terms apply to U.S. participants recruited by IPAM.

Due to the unprecedented global outbreak of COVID-19, our partners in Singapore made the difficult decision to cancel hosting RIPS in 2021.

37 students participated in RIPS 2021.

2021 SPONSORS	PROJECT DESCRIPTIONS
Aerospace Corp.	Multi-hypothesis tracking of space objects and targets
Air Force Research Laboratory	Deconvolution of temporally under-resolved image sequence for coupled systems
AMD	Accelerating scientific applications with deep neural networks
Aquatic	Statistical forecasting of intraday stock returns in quantitative trading
Google	Improve the efficiency of security protections within Ads Data Hub, focusing on strategies to improve and measure the protections of those difference constraints
GumGum	Ad viewability predictor model
HRL	Understand the start-up behavior from a frozen coolant heat pipe
LLNL	Investigating a new Monte Carlo algorithm for the random cluster model
IBM	Space/time tradeoffs in quantum computing

Project 1: Aerospace Corp.
Routing of information in dynamic networks is a challenging problem due to large design space and complex objectives. The ever-growing demand for efficient and reliable transfer of information among the nodes of the network imposes additional constraints. Common approaches to this problem, often generic and based on static network assumptions, are not able to capture constantly changing networks and high-load dynamic conditions that appear in modern-day space communication systems.

Students will use a reinforcement learning-based tool for dynamic network routing taking advantage of state-of-the-art machine learning techniques. The proposed implementation will be compared against classical implementations in terms of average delivery time for packets and load requirements.

Desired Skills: Students would ideally have a background and experience in Python Programming, Communication Networks, Machine Learning and Optimization Concepts.

Project 2: Air Force Research Laboratory

Cross maps are typically constructed between different observables of a coupled nonlinear system by exploiting time-delay embedding. They typically lead to optimal reconstructions as the amount of data collected increases. The goal here is to reconstruct multiple high speed current signals taken from different locations within a coupled plasma system; however, if the signal to noise ratio is poor, the reconstructions can fail to converge towards perfect reconstruction either because of true noise or additional unresolved dynamics present in the signal. Students will work on a state based sampling method recently developed and will consider an unstructured grid. The convergence behavior of this unstructured approach as the number of samples and cells is increased will be explored first for a simple chaotic ODE, the Lorenz system. The method will then be applied to a pair of experimental signals from a Hall Effect thruster experiment that has already been shown to produce high quality cross map reconstructions. The applicability of the approach to real experimental measurements will then be evaluated.

Desired skills: Students would ideally have a background and experience in Python/Matlab ; Secondary desired skills: Differential Equations, Numerical Methods (ODE Integrators/Convergence Metrics/etc.), Statistics (Pearson Correlation, Nonparametric Density Estimation), Dynamical Systems Theory, Control Theory.

Project 3: Alibaba

How to best match products to consumers? This is a large-scale mathematical optimization problem for finding the best allocation between demands and supplies. For instance, for product recommendation, we need to present diversified and well-selected assortments on web pages in order to maximize consumer engagement (e.g., clicks, purchases, dwell time). Meanwhile, there are inventory and other business constraints that limit the total numbers and the frequencies of product deliveries. The underlying task is, therefore, to globally maximize consumer engagement while satisfying all the inventory constraints.

Students will have access to the sponsor's general-purpose mathematical solver and are expected to develop problem decomposition and stochastic sampling techniques and try them on a large test dataset.

Desired skills: Students would ideally have a background and experience Python, Stochastic analysis.

Project 4: Aquatic

Trading strategies based on quantitative analysis rely on mathematical computations and number crunching to identify trading opportunities. The team will research the current state of the art Coordinate Descent (CD) and/or Alternating Direction Method of Moments (ADMM) or another competitive method and modify the algorithm to optimize its performance on two sample optimization problems arising in automated securities trading.

Desired skills: Students would ideally have a background and experience in applied numerical optimization and computer science. The team will benefit from experience in Python to prototype and C/C++ to optimize performance.

Project 5: AMD

Ray tracing is a technique for rendering images whereby the path of light from different sources is traced across the pixels in an image and the interaction of the light paths with objects in the scene is simulated. Ray tracing has been used for many years in rendering images, especially in films. While the results of ray tracing can lead to very realistic looking images, ray tracing is a computationally intensive task. As such, rendering images in real time using ray tracing has not been feasible. However, emerging GPU architectures are beginning to support ray tracing algorithms in hardware, enabling real-time ray tracing. This project seeks to study the emulation of ray tracing in images using machine learning.

This project explores common frameworks and algorithms in generative modeling, with the objective of building models that automatically generate images that appear to have been rendered using ray tracing. The results of this study will be applicable to any rendered image of a three-dimensional scene.

Desired skills: Students would ideally have a background and experience in Machine Learning, Programming in Python in Linux environments.

Secondary desired skills: Programming with C++; Tensorflow, CAFFE2, PyTorch; Numerical mathematics, Numerical Linear Algebra; Applied mathematics; Optimization.

Project 6: Google LA

The goal of this project is to develop metrics to evaluate customer success when accessing a list of queries on a database, in the presence of late-arriving data. The students will also explore techniques the customer can use to increase their success according to those metrics, and develop alternative differential privacy techniques. Techniques such as adding noise to a customer's query result may satisfy customer needs while adequately protecting privacy.

Desired skills: Students would ideally have a background in statistics, programming, modeling and simulation.

Project 7: HRL

Additive manufacturing has the potential to drastically alter the design and fabrication of functional materials. The goal of this project is to develop high throughput software for analyzing datasets from two experimental techniques to detect defects in such materials. The defect correlation analysis that we envision would make use of computer vision (on static images/volumes), feature engineering (e.g. volume averaging, incorporating lumped parameter heat transfer models, interpolation schemes), and machine learning classification algorithms available in existing software frameworks (e.g. Keras, PyTorch, Scikit-learn) to develop software aiding in the analysis of existing and future datasets.

Desired skills: Students would ideally have a background and experience in programming (e.g. Python), basic statistics, basic physics (e.g. diffusion, heat transfer).

Project 8: LLNL

Many optimization problems are time dependent, for example, optimizing the shape of a car or an airfoil to minimize drag. These applications traditionally involve sequential time marching both forward and backward in time. Unfortunately, the traditional simulation approach of sequential time marching is becoming a bottleneck as computer architectures must increasingly rely on higher concurrency to provide greater peak performance.

This project investigates the performance of a new parallel time integration solver for time dependent constrained optimization problems. It is a project in scientific computing and numerical analysis. Some basic understanding of partial differential equations, non-linear dynamics, discretization, and numerical algorithms is desirable.

Desired skills: Students would ideally have experience in programming in C or C++.

Project 9: AMD (G-RIPS)

QMCPACK is a quantum Monte Carlo code that leverages stochastic integration to solve the weak formulation of the Schrödinger equation. Solutions to Schrödinger's equation describe not only molecular, atomic, and subatomic systems, but also macroscopic systems, and is used to predict electronic structure of chemical, physical, and materials problems of interest. The QMCPACK application is expected to scale to the entire machine. To ensure application readiness at this unprecedented scale, this project will identify the key compute kernels in QMCPACK and explore methods for accelerating them. Objectives of this project include: Identify key performance elements of QMCPACK, optimize key kernels for performance at exascale, accelerate key kernels using machine learning, and potentially, publication of the methods and results.

Note: G-RIPS is partially supported by an IRES grant from NSF’s Office of International Science and Engineering.

Comments from our participant survey and correspondence:

"I will be starting my PhD studying quantitative methods at University of Wisconsin-Madison this coming Fall. Thank you so much for hosting the RIPS program back in 2020 when the COVID first started and not canceling the program. I cannot stress enough how much the program developed my skills. It helped tremendously in my own development and in my graduate application process. I am excited to participate in RIPS again this coming summer in (hopefully) Singapore."

"RIPS allowed me to widen my network in both industry and academia and to interact with top researchers at UCLA. This is an invaluable experience."

"Very highquality program"

SUMMER SCHOOL: Mathematics of Topological Phases of Matter. AUGUST 29 - SEPTEMBER 3, 2021.

Organizing Committee:
Colleen Delaney (University of California, Santa Barbara (UCSB))
Michael Freedman (Microsoft Research)
Matthew Hastings (Microsoft Research)
Zhenghan Wang (Microsoft Research)

The application of topology to physics has become an integral part of a second quantum revolution in the sciences. The discovery of topological insulators and progress towards topological superconductors realizing non-abelian statistics has moved topological phases of matter onto the center stage in the interaction of topology and physics beyond the quantum Hall effect. While topological physics has been intensively investigated by physicists for the last few decades, the mathematical theory lags far behind. One challenge is formulating the right definition of topological phases of matter, which is closely related to the notoriously difficult problem of finding a rigorous mathematical formulation of quantum field theory.

In this summer school, we focused on two relatively mature foundational topics, and two new directions in the mathematics of topological phases of matter.

The mathematical theory of topological phases of matter is well established in two settings – in two spatial dimensions where they are modeled by topological quantum field theories (TQFTs) and modular tensor categories (MTCs), and for the special case of symmetry protected topological phases (SPTs) that are classified in any spatial dimension by generalized cohomology theories including group cohomology for bosonic SPTs and K-theory for fermions. For these two topics, the relation between a physical model and a well-developed field of math is very tight.

Two emerging directions under active development that are challenging the existing mathematical paradigm for topological phases are fractons and quantum cellular automata (QCA). Theories describing phenomena in topological physics can be distinguished by whether they are "additive" like K-theories, or "multiplicative" ones like MTCs and fractons, but

interestingly QCA can be either depending on whether they are free or interacting. Fractons too defy our current understanding of topological phases, and it is still an open question if they have continuous limits and if so, whether or not they are also beyond quantum field theories.

We invited experts in both mathematics and theoretical physics to cover each topic from both sides. Speakers also covered current research in these fields.

Topology plays a vital role in our understanding of phases of matter and their phase transitions, quantum entanglement, and quantum computing. The discovery of topological materials is a milestone in physics that has been celebrated by several Nobel prizes. But the mathematics of topological phases is still in its infancy. We trust that this summer school laid the foundations for further development.

Comments from our participant survey:

"The talks by mathematicians were great and I learn some interesting things from them."

"I am still trying to learn more about the physics side of this topics and this was a great environment to do so"

"The best part of the summer school was meeting other participants, both mathematicians and non-mathematicians. It made the whole week worthwhile."

"I appreciate the support since I know that IPAM did their best to help me make the most of this school even when childcare support is in general not available. Thank you a lot!"

"This was my first IPAM workshop, and I was extremely impressed. It was a fantastic workshop overall. I also appreciated the COVID safety measures."

LONG PROGRAM: Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy. SEPTEMBER 13 - DECEMBER 17, 2021.

Organizing Committee:
Manuela Campanelli (Rochester Institute of Technology)
Marco Cavaglia (Missouri University of Science and Technology)
Jose Antonio Font (University of Valencia)
Igor Rodnianski (Princeton University)
Susana Serna (Universitat Autònoma de Barcelona)
Gunther Uhlmann (University of Washington)

The field of Relativistic Astrophysics has recently witnessed a major revolution with the historical Nobel-Prize-winning observation of Gravitational Waves (GWs) from a binary black hole merger and the first GW observation of the merger of two neutron stars. The latter was followed by electromagnetic detections from the ground and space triggering an unprecedented

multi-instrument observational campaign. These detections have led to the beginning of GW astronomy and the era of multi-messenger astrophysics.

The scientific impact of the existing GW observations in fundamental physics, astronomy, astrophysics, nuclear physics, and cosmology is already extraordinary. In the next few years, with the significant increase of available GW data driven by the continuous upgrades of current detectors and by the incorporation of additional GW facilities to the global network, this impact will multiply. Processing and interpreting the anticipated huge number of forthcoming GW detections will pose a significant challenge and will require close interaction between mathematical modelers, waveform developers, numerical relativists, data analysts and theoretical and observational astrophysicists.

On the one hand, progress in multi-messenger astrophysics is driven by observations with increasingly more sensitive telescopes, high-energy neutrino detectors, and GW detectors on Earth and in space. On the other hand, another major element of advance is provided by the theoretical studies of Einstein's General Relativity equations to explain those observations. Modern theoretical astrophysics relies on mathematical properties of the initial conditions for the evolution of the General Relativity equations and numerical simulations to improve the understanding of the dynamics of astrophysical systems.

The aim of this program was to connect efforts of the mathematical and physical sciences communities to address the latest advances and new challenges on the understanding of multi-messenger astronomy. The IPAM program comprised of four workshops, each addressing a different topic: the generation of catalogs of waveform templates; the discussion of the mathematical modeling of the equations governing strong relativistic systems; parameter estimation of astrophysical sources of gravitational waves; and the state of the art of big data and deep learning techniques for GW data analysis.

Comments from our participant survey:

"The resources were great and the environment to work was amazing"

"The program was excellent, and I am absolutely glad I joined it. My only suggestion would be that it might be helpful to have a larger portion of postdocs/ junior academics in order to make the working groups more productive. Thank you so much for everything!"

"I actually loved the program and greatly appreciate being invited. Thank you"

"Thank you for the incredible conference! It was the best one I have attended."

"I would like some days to have longer blocks to discuss/work with colleagues but I understand this was a summer school and maybe that is to the main aim. The Staff was great, thank you!"

WORKSHOP: Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy Tutorials. SEPTEMBER 14 - 21, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

The program opened with several days of tutorials that provided an introduction to major themes of the entire program and the four workshops. The goal was to build a foundation for the participants of this program who have diverse scientific backgrounds.

Comments from our participant survey:

"I found the mathematics talks very interesting, probably the most interesting for me, even though they might not have been so immediately related to the workshop topic. Perhaps a bit harder to understand for physicists who might not have encountered some of the maths terms."

"It was a nice mix of topics!"

"Thank you to everyone for your friendliness and readiness to help."

WORKSHOP: Computational Challenges in Multi-Messenger Astrophysics. October 4 - 8, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

Organizing Committee:
Miguel Ángel Aloy (University of Valencia)
Manuela Campanelli (Rochester Institute of Technology)
Marco Cavaglia (Missouri University of Science and Technology)
Philippe G. LeFloch (Sorbonne University, Paris)
Luciano Rezzolla (Johann Wolfgang Goethe-Universität Frankfurt)
Susana Serna (Autonomous University of Barcelona)

Computational relativistic astrophysics and numerical relativity face a number of challenges following the first detection of binary black holes and binary neutron stars: high Lorentz factors, strong and dynamical gravitational fields, uncertain equations of state, magnetic fields, radiative and dissipative effects, large dynamical ranges, solutions of constrained hyperbolic systems. The likely gravitational signals produced after the collapse of massive stellar cores offer unique probes of the dynamics of newly-born compact stellar remnants. Predicting source dynamics of future detections of gravitational wave signals is important to understand the physics of these events in the current and next-generation earth-based gravitational-wave detectors and essential to achieve design sensitivity in future space-based detectors. The goal of this workshop was to bring together mathematical modelers in general relativity, astrophysicists, and experts in numerical relativity to discuss open issues to improve current approaches to build increasingly more accurate gravitational wave templates that allow to identify future detections.

This workshop included a poster session.

While this workshop was offered in-person, participants were given the option to register and attend talks virtually.

Comments from our participant survey:

"Thank you for organizing the workshop in person. I was looking forward to meet colleagues again after so long. It was wonderful to interact and discuss our research in person in a place like IPAM."

"The workshop was extremely well organized, and very productive. Congratulations to you and your team! One minor suggestion to help you further improve the hybrid-workshops: please make a microphone available to the local audience in all sessions. Sometimes their questions were difficult to hear by online speakers, and this would help improve the communication and encourage more questions."

"Well done! I truly enjoyed the workshop and IPAM's environment."

"Very satisfied with the workshop. Through virtual mode, I can able to connect remotely. It has given a feast to my knowledge throughout the week. Thank you for the wonderful workshop."

"I thank a lot to the IPAM for making the workshop happening under the current circumstances. Staffs are super friendly and helpful, I would like to thank Roland, especially."

"There is almost half a day of time difference between Indian standard time and Pacific time. I had to manage with the lecture recordings. The texhnical team did an amazing job of making the lectures available the very next day."

"The hybrid format worked very well. I was surprised how well it went. The raising hand robot is fantastic! And it seems that it was helpful for the sessions chairs. I would have liked to see who was connected remotely. I know that many colleagues and friends were planning to attend but I didn't know who was there until this weekend that I got some emails from them. The hybrid format worked well but I hope it evolves to a more in person audience and speakers format. I don't think I'll travel again for a workshop in which more than 60% of the presentations are virtual."

"Best of both worlds!"

"The IPAM workshop is exactly in the form that I wishes to be. It has long time for discussion reserved, the allocated time for speakers is 50 mins, which are justly nice to summarize the big issues for a selected important issues for this workshop."

"Excellent technical setups. Much better than most other online workshops I attended recently."

"Very helpful and interesting"

WORKSHOP: Mathematical and Numerical Aspects of Gravitation. OCTOBER 25 - 29, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

Organizing Committee:
Lydia Bieri (University of Michigan)
Matthew Choptuik (University of British Columbia)
Mihalis Dafermos (Princeton University)
Anne Franzen (Technical University of Lisbon)
Antonio Marquina (University of Valencia)
Igor Rodnianski (Princeton University)
Gunther Uhlmann (University of Washington)

Ever since general relativity's birth in 1915, mathematics has had a profound impact on the way the theory has been understood: Examples over the years include Hilbert's variational formulation, Noether's early theorems on conservation laws, Choquet-Bruhat's foundational well-posedness theorem and the hyperbolicity of the equations, Bondi's concept of null infinity and gravitational waves, the incompleteness theorems of Penrose and the black hole concept, the positive energy theorem of Schoen and Yau, and the nonlinear stability of Minkowski space proven by Christodoulou and Klainerman. In more recent years, the power of numerics has added additional insights to our mathematical picture, particularly after Pretorius's 2004 breakthrough allowing for the numerical simulation of binary black hole systems. Today, research on mathematical and numerical aspects of general relativity constitute two vibrant fields which have become very influential in the wider mathematics and physics communities. The two fields have many points of contact: Some common goals shared by both rigorous mathematical analysis and numerics include understanding the formation of black holes in gravitational collapse, their non-linear stability, and their interaction with other black holes in binary systems or other scattering processes. In their practical application to astrophysics, the two fields often play complementary roles: Numerics generates the templates which play an important part in interpreting gravitational wave detections by LIGO and VIRGO, while rigorous mathematical analysis has introduced subtle new concepts, like Christodoulou memory, which may play an important role in the next generation of detectors. Another common goal of both rigorous mathematics and of numerics, of interest to theoretical physics, is to understand generic spacetime singularities, so as to resolve in particular the celebrated weak and strong cosmic censorship conjectures of Penrose. As singularities probe the limits of the theory, a resolution of these conjectures may shed light on various attempts to transcend general relativity. Other recent problems which have brought together mathematics and numerics include work on asymptotically anti-de Sitter spacetimes, and well-posedness for alternative theories of gravity, both of interest in high energy physics. There is also recent activity on inverse problems. This workshop gathered mathematicians, theoretical physicists, and numerical analysis developers to discuss these and other issues.

IPAM organized a Women's Luncheon during this workshop, which was well attended. Professor Andrea Ghez joined the luncheon and as an invited guest.

While this workshop was offered in-person, participants were given the option to register and attend talks virtually.

Comments from our participant survey:

"I am very glad there was the virtual option to attend and the talks were recorded, otherwise I would not have been able to attend. I am pleased with the ease of accessing the talks, and the speakers were very good."

"Overall you IPAM folks are doing a great job given the hybrid format! Thanks for all your work and dedication"

WORKSHOP: Source inference and parameter estimation in Gravitational Wave Astronomy. NOVEMBER 15 - 19, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

Organizing Committee:
Katerina Chatziioannou (California Institute of Technology)
Jose Antonio Font (University of Valencia)
Patricia Schmidt (University of Birmingham)
Salvatore Vitale (Massachusetts Institute of Technology)

Gravitational-wave (GW) observations offer a unique opportunity to study astrophysical and cosmological sources that are difficult to access through electromagnetic observations. Inferring the sources' properties from their GW signal is one of the key objectives of GW data analysis. The planned improvements in the sensitivity of the ground-based detectors and future space-based observatories, however, bring unique computational and mathematical challenges to the inference problem including long-duration signals, high signal-to-noise ratios, increased parameter dimensionality and overlapping signals. These challenges must be overcome to fully exploit the scientific potential of GW observations. The goal of this workshop was to connect statisticians, computer scientists, and GW astrophysicists to discuss the current state-of-the-art approaches to parameter estimation in GW astrophysics, and to identify the open issues to enable fast and reliable inference for different GW sources, including modelled and un-modelled signals, for the current and planned GW observatories.

This workshop included a poster session.

While this workshop was offered in-person, participants were given the option to register and attend talks virtually.

Comments from our participant survey:

"The overall program was really good, I enjoyed and learned a lot and now know that through discussions itself, one can enhance his/her knowledge to a great extent!!! Thank you for this opportunity!!!!"
"I really enjoy this workshop! Except for the nice talks, it was organized quite well! The talks on the day were focused on 1 topic. Each day started with a 15min introduction and ended with a panel discussion. It makes the talks easy to follow and understand."

"The Zoom setup (audio, video, hand-raising robot) worked very well."

"The hand-raising robot was a neat addition."

"The robot with raising hand is super!"

"Since I attended in person, I did not use the recordings or zoom links, but I have encouraged my own students and postdocs to look at the recorded talks that are related to their own research projects. I think having those talks recorded is a really valuable resource. I plan to go back and watch some of them again."

"The staff were amazing. In particular, I really appreciated all of the work Neli Petrosyan did to stay in contact with the speakers before the workshop. There were so many helpful emails reminding us about lodging, reimbursement, scheduling, etc. She is great!"

"The workshop was great!!! Hoping to have more such workshops in the future!!!"

"Great workshop!"

"Thank you for allowing me to be a part of the workshop!"

"Patricia and Katerina did a great job organizing this workshop. Getting the whole group back together after the pandemic was not easy for them. Thanks for that. It was great to see everybody and having everyone presenting."

"The hybrid set up is impressive. The person taking care of the microphones, camera, Zoom, etc, was very efficient. He did a great job during the week. Thanks for that! I'm vegan and the variety and quality of food was far from being healthy. Almost no fruit for a couple of days. I expected more from a California site, but thanks for offering food."

"This workshop was particularly well designed, with the talks by topics split into different days etc."

WORKSHOP: Big Data in Multi-Messenger Astrophysics. NOVEMBER 29 - DECEMBER 3, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

Organizing Committee:
Marco Cavaglia (Missouri University of Science and Technology)
Peter Couvares (California Institute of Technology)
Gabriela González (Louisiana State University)
Ik Siong Heng (University of Glasgow)
Antonio Marquina (University of Valencia)

Detection of gravitational waves requires the operation of very sophisticated detectors producing large amounts of data. The sensitivity of the gravitational-wave detectors to astrophysical signals is limited by the noise associated with the instruments themselves and their environment. Invaluable astrophysical information is buried in data sets that may be too large or complex to be analyzed with traditional data-processing techniques.

To make the analysis of gravitational-wave detector data more efficient it becomes increasingly more important to characterize and mitigate the detector noise sources, as well as find more powerful ways to extract information from the detector data. Methods for the analysis of gravitational-wave detector data range from standard signal processing algorithms to novel machine learning algorithms. This workshop focused on the development of these techniques for a more efficient handling of gravitational-wave data sets, reduction of detector noise, identification of astrophysical signals and increase in detection confidence. It brought together astrophysicists, mathematicians, and statisticians working on the state-of-the-art data analysis.

While this workshop was offered in-person, participants were given the option to register and attend talks virtually.

Comments from our participant survey:

"I found every lectures really interesting, and also inspiring for my own research"

"In this session the talks were mostly by non-mathematicians. But those that were pitched from a math standpoint were accessible to someone like me who is not a professional mathematician."

"Briana was very helpful and attentive. Thank you!."

"Briana was very attentive and efficient."

"Thank you for letting me participate in this workshop. I look forward to more in person meetings."

"Thanks to IPAM for hosting this workshop."

"Great talk by Marco Cavaglia. Very entertaining and didactic."

WORKSHOP: Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy Culminating Retreat at Lake Arrowhead. DECEMBER 12 - 17, 2021.

Part of the Long Program "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy"

The culminating workshop was organized by the organizing committee of the long program. The final workshop in the long program, "Mathematical and Computational Challenges in the Era of Gravitational Wave Astronomy" which was held at Lake Arrowhead Conference Center, provided an opportunity for the program's core participants to report on their work during the past three months and to discuss future projects. Many of the collaborations and interactions that were formed during the program had a chance to deepen.

REUNION CONFERENCE: Big Data Meets Large-Scale Computing Reunion Conference I. DECEMBER 12 - 17, 2021.

The reunion conference was organized by the original long program organizing committee. This was the first reunion conference for participants of the fall 2018 long program "Big Data Meets Large-Scale Computing." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

Comments from our participant survey:

"This is a good program for interdisciplinary research."

"My interests in machine learning, high performance computing, and data analytics, and in how these come together, greatly increased as a result of the talks I heard at the IPAM workshops in this long program."

"the long program helped to broaden my understanding of big data which will be an important area I will need to understand better for future roles."

"The influence is great and allows me to continue my research career."

"Since the long program, I have started several small projects with colleagues in machine learning to better understand how these methods can be used in conjunction with computational mathematics for simulation."

"The collaboration with people from numerical analysis stimulated me again to look into physics applications, i.e. on quantum computing."

REUNION CONFERENCE: Quantitative Linear Algebra Reunion Conference II. DECEMBER 12 - 17, 2021.

Note: bibliographic data for this program was collected in May 2021 and was reported to the NSF in last year's report.

The reunion conference was organized by the original long program organizing committee. This was the second reunion conference for participants of the spring 2018 long program "Quantitative Linear Algebra." It was a timely get-together to continue some of the collaborations that were started during the long program and at the first reunion. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

Comments from our participant survey:

"There are strong technical barriers to studying operator algebras. The participants of the IPAM Long Program in Quantitative Linear Algebra included a strong group of specialists in this field. Access to this community of support helped me to establish both professional connections and foundational research perspectives that are now the basis for many of my collaborative efforts as an early career mathematician. Given the lack of fellow graduate students studying operator algebras at my home institution, participation in this IPAM Long Program gave me both access and a sense of belonging to this research community."

"I have published two papers based in part on my collaboration with other researchers attending the program."

"it was also very interesting at the reunions to hear about the research in other programs"

REUNION CONFERENCE: Geometry and Learning Reunion Conference I. DECEMBER 12 - 17, 2021.

Note: Due to COVID-related postponement of reunions this reunion

The reunion conference was organized by the original long program organizing committee. This was the first reunion conference for participants of the spring 2019 long program "Geometry and Learning from Data in 3D and Beyond." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

Comments from our participant survey:

"My participation in the IPAM Long Program certainly was a plus in my application for my current job, albeit that I can use its technical contents in my job tasks only to a very minor extent. Beyond that, since GL2019 I stay in regular touch with three of its core participants, all of whom

have completed their PhD meanwhile. Moreover, I had and have infrequent e-mail contact with a few more GL2019 participants."

REUNION CONFERENCE: Hamilton-Jacobi PDEs Reunion Conference I. JANUARY 5 - 21, 2022.

The reunion conference was organized by the original long program organizing committee. This was the first reunion conference for participants of the spring 2020 long program "Hamilton-Jacobi PDEs." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

WORKSHOP: Quantum Numerical Linear Algebra. JANUARY 24 - 27, 2022.

Organizing Committee:
Aram Harrow (Massachusetts Institute of Technology)
Lin Lin (University of California, Berkeley (UC Berkeley))
Thomas Vidick (California Institute of Technology)
Nathan Wiebe (University of Toronto)

With the rapid development of quantum computers, a number of quantum algorithms have been developed and tested on both superconducting qubits based machines and trapped-ion hardware. The recent development of quantum algorithms has significantly pushed forward the frontier of using quantum computers for performing a wide range of numerical linear algebra tasks, such as solving linear systems, eigenvalue decomposition, singular value decomposition, matrix function evaluation etc. While many quantum algorithms aim at future fault-tolerant quantum architecture, some of such numerical linear algebra algorithms have already demonstrated promise for being implemented on near term quantum devices. This workshop brought together leading experts in quantum numerical linear algebra, to discuss the recent development of quantum algorithms to perform linear algebra tasks for solving challenging problems in science and engineering and for various industrial and technological applications.

Due to increased infection rates at the time, the workshop was held in remote format. The program included a virtual poster session.

Comments from our participant survey:

"Thanks for the amazing workshop!"

"Thanks for giving me the chance to attend the workshop. It is really helpful for me."

"Great workshop. I learned a lot! Thank you!"

"I found this workshop to be very well-organized. The selection of speakers was excellent and the format really helped facilitate discussions. The IPAM staff communicated clearly and did an amazing job making sure everything ran smoothly."

WORKSHOP: Calculus of Variations in Probability and Geometry. FEBRUARY 7 - 11, 2022.

Organizing Committee:
Steven Heilman (University of Southern California)
Alina Stancu (Concordia University)
Elisabeth Werner (Case Western Reserve University)

Recently, the techniques from calculus of variations have been extensively used to tackle isoperimetric-type inequalities in Euclidean space. In particular, progress was made on a number of newly emerged questions in geometric probability theory. Understanding these questions will shed light on how symmetry and structure influence various families of isoperimetric-type inequalities.

This circle of ideas has been used in Riemannian geometry for decades in the fields of geometry and probability such as hypercontractive inequalities and their interactions with curvature. Recently, these ideas have found new applications.

Conversely, questions motivated purely by differential geometry, such as mean curvature flow, are ameliorated by studying isoperimetric-type problems with respect to the Gaussian measure. This connection was evidenced by Huisken's monotonicity formula and studies of singularities in mean curvature flow. The above isoperimetric-type questions have tight connections in theoretical computer science and social choice theory — appearing e.g. in the computational hardness for MAX-CUT and in the Majority is Stablest Theorem. The interplay of geometry and probability appears also in recent breakthrough developments on the KLS-conjecture, itself an isoperimetric-type problem for arbitrary Euclidean convex sets.

In summary, a few different communities of researchers have an interest in similar problems, perhaps without realizing the common intersection of interests. This workshop proposed to bring together these disparate fields to discuss these related questions, and to share insights and problems.

While this workshop was offered in-person, participants were given the option to register and attend talks virtually.

This workshop included a poster session.

Comments from our participant survey:

"Great selection of speakers."

"This was probably the most interesting conference I remember !! Literally could not miss one talk, all so interesting!"
"All was great and you guys were well organized. Thank you for such a great workshop and hospitality."
"Grad students usually have courses during the regular term time so traveling to attend conferences far away is nearly impossible. The hybrid mode is very useful in this case."

WORKSHOP: Mathematics of Collective Intelligence. FEBRUARY 15 - 19, 2022.

Organizing Committee:
John Baez (University of California, Riverside (UC Riverside))
Pranab Das (Elon University)
Jessica Flack (Santa Fe Institute)
Jacob Foster (University of California, Los Angeles (UCLA))
Alison Gopnik (University of California, Berkeley (UC Berkeley))
Max Kleiman-Weiner (Common Sense Machines)
Lakshminarayanan Mahadevan (Harvard University)
Josh Tenenbaum (Massachusetts Institute of Technology)

All known intelligent systems are collectives. Individual organisms are collectives of cells, which develop, heal, sense, and act. Groups of human and non-human animals use a range of mechanisms to coordinate their behavior across space and time, from flocks and swarms to organizations, institutions, and cultural traditions. Deep learning—the dominant approach to artificial intelligence—gains its power from combining simple units into complex architectures; many contemporary architectures (e.g., GANs) combine multiple learners, and multi-agent settings are a critical research frontier for AI, especially settings that integrate human and artificial agents.

These examples imply that a scientific understanding of intelligence must fundamentally grapple with collective intelligence—in a much broader sense than typical usage of the term would suggest. A variety of mathematical and computational models have been developed to explain and design intelligent behavior in particular collectives. Several mathematical fields source the ideas used to build and understand these models, from dynamical systems, statistical mechanics, network science, and random matrix theory to information theory, optimization, Bayesian statistics, and game theory–even applied category theory, in recent years. It remains unclear, however, whether we have the right mathematical language to provide a unified, abstract account of collective intelligence–or whether such a language is even possible! This workshop brought together leading experts who study and model collective intelligence, as well as those who seek to understand such models. Its goal was to explore the advantages and disadvantages of existing modeling frameworks; to find collective implementations of models of individual cognition; to expand the systems and settings understood as manifesting collective intelligence; and to grow the community of researchers who study the mathematical foundations of collective intelligence.

Comments from our participant survey:

"Kudos to Breana Musella and the organizational staff who made the whole process incredibly smooth and enjoyable despite the challenges of the pandemic. Rich Bartlebaugh was a constant, attentive supporter of the tech and, thanks to him we had a glitch-free event. (In my experience that is almost unique!) Yvette King has been communicative and easy to work with on the financial front. And Selenne Banuelos did an excellent job conveying the leadership team's goals, interests and concerns both in regard to this workshop and a potential long program. While it is quite unusual to offer what may seem a fulsome review of the team, I feel it is really worth noting that this was an exceptionally easy and enjoyable process -- superior in some ways to any academic workshop or conference experience I have had. Thank you all very much!"

"uploading each day of lecture videos is very helpful for remote users"

"I was attending from India (13 hours time difference), but it is a very small inconvenience. I would not have been able to participate in person. My sincere thanks to the organizers for accommodating online participants.."

"Great!"

LONG PROGRAM: Advancing Quantum Mechanics with Mathematics and Statistics.
MARCH 7 - JUNE 10, 2022.

Organizing Committee:
Eric Cances (École Nationale des Ponts-et-Chaussées)
Maria J. Esteban (CNRS and Université Paris-Dauphine)
Giulia Galli (University of Chicago)
Lin Lin (University of California, Berkeley (UC Berkeley))
Alejandro Rodriguez (Princeton University)
Alexandre Tkatchenko (University of Luxembourg)

Quantum mechanics is the fundamental theory of fields and matter and it is arguably the most successful and widely applicable theory in the history of physics. Quantum mechanics is widely used today to describe low and high energy phenomena. This includes studying molecules and solids throughout biology, chemistry and physics, and even the determination of constitutive relations in engineered mesoscale structures.

The aim of this program was to pave the way towards practical and error-controlled quantum-mechanical calculations with tens of thousands (or even millions) of quantum particles. This IPAM program was based on the premise that by systematically analyzing the structure and topology of Hilbert spaces of different systems and methods, as an interdisciplinary community we can overcome the bottlenecks of existing approximations, and move towards quantum multiscale methods based on Hilbert space embedding, model order reduction, and complementary mathematical and statistical techniques. This program brought together physicists, mathematicians, chemists, engineers, and computer scientists interested in pushing the boundaries of theory and methods based on quantum mechanics.

The program hosted a special discussion on Quantum Mechanics at the Moiré Scale

Comments from our participant survey:

"Everything was amazing. Not a very constructive comment but it's the truth!"

"The time in between workshops was the most unique and valuable part of the program, but the workshops were also quite informative."

"Just two comments:
1) It might be a better idea in the future to limit the Long Program to 3 big workshops instead of 4 as this gives enough time to the core members to collaborate on their own. Otherwise, as things stand, the program is a bit too hectic (in my opinion) which might make it a bit difficult for participants to collaborate on their projects.
2) IPAM already did this but I think an even bigger effort can be made to convince more senior people to stay at the institute for longer periods of time and not just to attend workshops and leave the next day."

"I formed a collaboration with an awesome chemist and I'm excited to be working on a paper together with them!"

"This was a great and highly beneficial program. Thank you!"

"Overall the programme seemed less dense and more relaxed than previous ones I've attended. I appreciated this very much. Maybe it was due to Covid, but I hope it will continue this way. Also - personally, I enjoyed the ad hoc workshops almost more than the formal ones."

"The IPAM directors and staff are amazing. Everyone from Christian, Dima, and Selena to Roland, Ginger, Breanna, Sabrina and Rich. Incredible job! Please take a bow!"

"Very pleasant and productive stay. New collaborations, new topics of research...for the coming years."

WORKSHOP: Advancing Quantum Mechanics with Mathematics and Statistics Tutorials. MARCH 8 - 11, 2022.

Part of the Long Program "Advancing Quantum Mechanics with Mathematics and Statistics"

The program opened with four days of tutorials that provided an introduction to major themes of the entire program and the four workshops. The goal is to build a foundation for the participants of this program who have diverse scientific backgrounds.

Comments from our participant survey:

"I think that the in person nature of the workshop greatly improved the quality of the workshop."

“The robotic hand raising for virtual participants was awesome!”

“Kieran's intro talk was especially good -- he worked hard to keep things pedagogical.”

“Almost uniformly across the board these were advanced talks that went completely over the heads of current Ph.D. students / anyone that didn't already know about the topics. This doesn't mean the workshop was bad --- I mean, a lot of the point of IPAM is to just generate exposure to cutting-edge research topics, so a certain amount of confusion is inevitable. Moreover, the participants were really really friendly, so I honestly had a great time. But for a week of "tutorials", these were conspicuously not really tutorials.”

“Staff are lovely, the opportunities for hanging out and meeting potential collaborators are really special.”

“Thanks for putting this on! Despite a bit of exhaustion at the lectures (okay, admittedly I'm pretty picky), I had a great time. Mainly I appreciated being able to meet such lovely folks and have frank conversations with them over coffee outside the venue :)”

WORKSHOP: Multiscale Approaches in Quantum Mechanics. MARCH 28 - APRIL 1, 2022.

Part of the Long Program “Advancing Quantum Mechanics with Mathematics and Statistics”

Organizing Committee:
Eric Cances (École Nationale des Ponts-et-Chaussées)
Maria J. Esteban (CNRS and Université Paris-Dauphine)
Giulia Galli (University of Chicago)
Lin Lin (University of California, Berkeley (UC Berkeley))
Alejandro Rodriguez (Princeton University)
Alexandre Tkatchenko (University of Luxembourg)

This workshop set the stage and define research directions for the rest of the program. The idea is to achieve a healthy mix between researchers developing quantum theories and methods on different spatial and temporal scales (from field theory to continuum), providing a forum to discuss the advances in multiscale modeling in quantum mechanics and pave the way to stronger coupling between existing methods and completely novel quantum approaches. The main question is: how to integrate existing quantum methods at different levels of accuracy and efficiency, reduce their weaknesses, improve their applicability, explore limiting behaviors, and enable quantum calculations on much larger scales? For example, electronic orbitals obtained from density-functional theory calculations are being increasingly used in many-body Green’s function theories, explicitly correlated methods, quantum impurity models, quantum embedding theories, and quantum computation of electronic structure. Such synergies provide a way to approach the exact solution of the Schroedinger equation, in addition to significantly accelerating the cost of explicit many-body calculations. On a much larger spatial scale, multiscale coupling

of approximate many body Hamiltonians with Maxwell's equations allows unifying microscopic and continuum treatments of van der Waals and Casimir interactions, eventually making it possible to push the boundaries of such calculations to macroscopic systems.

This workshop included a poster session.

Comments from our participant survey:

"I have learned many things from the workshop. It was really fantastic to me. I enjoyed the lectures specially on DFT."

"Online is always a little challenging but the format did a great job of making it work. One improvement would be more direct communication with the online audience. We could hear that some things being discussed in the room, but could not hear what they were."

"I really enjoy it, keep on doing it this way! Alfred."

"I wanted to commend the people controlling the camera for zooming in on the blackboard when it was being used. It made me feel included as an online participant."

"Technically the hybrid talks were set up very well. But there were too many of them."

Re staff support: "Very helpful and very responsive. Thanks a lot!"

"I was attending from 2am - 10am locally, which made concentration a bit hard. I probably would have asked more questions if I was there live. Nevertheless, it worked well."

"Was run well. A little more direct communication with online participants might have improved things, since we could not hear the room so well. By the end it was better because chairs repeated questions and information to us."

"It's great to be here at IPAM!"

WORKSHOP: Model Reduction in Quantum Mechanics. APRIL 11 - 15, 2022.

Part of the Long Program "Advancing Quantum Mechanics with Mathematics and Statistics"

Organizing Committee:
Eric Cances (École Nationale des Ponts-et-Chaussées)
Garnet Chan (California Institute of Technology)
Robert DiStasio (Cornell University)
Maria J. Esteban (CNRS and Université Paris-Dauphine)

This workshop focused on three fundamental aspects.

The first one was the rigorous mathematical derivation of reduced models from reference quantum models in some regimes such as the semiclassical limit, adiabatic limit, thermodynamic limit, and high/low density limit. New approaches have been developed in the past two decades, which lead to successful mathematical derivations of reduced models in a number of settings. However, in many settings the mathematical relations between reference and reduced models and the domain of validity of the latter still have to be clarified.

The second aspect was concerned with effective interactions. Interactions between elementary particles typically have very simple functional form such as the Coulomb potential between two charged particles. However, upon solving the many-particle quantum mechanical equations, complex and intricate interactions emerge. The understanding and systematization of such interactions between composite objects provides a pathway to better understand quantum mechanics itself and constitutes the basis for developing coarse-grained approaches to describe interactions in large quantum systems.

The third aspect was about simplified quasiparticle or collective mode descriptions of complicated quantum states, using one-particle spin-orbitals, plasmons, phonons, polarons, or excitons. Such objects are embedded in finite or infinite dimensional Hilbert spaces defined by the basis set utilized to expand the many-body wavefunction. Recently, many interesting efforts have been dedicated to analyzing and visualizing quantum states in Hilbert spaces, as well as to map and embed Hilbert spaces between different quantum systems. Such mapping and embedding of Hilbert spaces brings out novel insights into the intricate nature of quantum fluctuations and should ultimately allow to develop better and more reliable approximations for solving complex quantum systems.

This workshop included a poster session.

Comments from our participant survey:

“The support by IPAM is generous in all respects. This is the important "fuel" that keeps a good workshop running - if I ask for a ball pen, say, the answer would be "Here you have three in different colors plus a pencil." Also, the catering offered for breakfast, coffee breaks, and the initial reception is excellent.”

“I really enjoyed it, it's so great! Alfred.”

“I think it is great as it is - just don't change it! Cheers, Volker Bach.”

“Excelllent workshop, please include short courses for Ph.D. students.”

“It was really professional, Rich did a great job! I don't really see much room for improvement....”

Re challenges due to different time zones: “I was physically present so it wasn't an issue for me but I can certainly see that it would be difficult for people in Europe, for instance, to attend talks taking place after 15:00 LA time. Having said this, I think the organisers did their best to make

the workshops accessible to participants in other time zones and I don't see what else can be done to improve the situation....”

Re if anything should be changed: “No, except that I wish that nothing be changed! cheers, Volker Bach.”

WORKSHOP: Large-Scale Certified Numerical Methods in Quantum Mechanics. MAY 2 - 6, 2022.

Part of the Long Program “Advancing Quantum Mechanics with Mathematics and Statistics”

Organizing Committee:
Giulia Galli (University of Chicago)
Laura Grigori (Institut National de Recherche en Informatique Automatique (INRIA))
Lin Lin (University of California, Berkeley)
Yvon Maday (Université de Paris VII et Université de Paris VI (Pierre et Marie Curie))

Simulating very large quantum systems require new numerical methods and algorithms. Such simulations indeed lead to solving linear and nonlinear systems of equations and eigenvalue problems, that are characterized by high dimensionality, large ranks (for tensor problems), and extreme scale. They must exploit massive parallelism in both space and time and rank-reduction methods, through deterministic or stochastic approaches, optimized data structures, and minimize communication. It is also key to have tools at hands to assess the quality of the simulation results. Error analysis is of major relevance in the simulation of quantum systems, but to date, it has received less attention than in other fields such as fluid or structure dynamics. The error between the exact and computed values of a given physical quantity of interest (QOI), e.g. the dissociation energy of a molecule, has several origins: a model error (resulting from the choice of a computationally tractable, but not extremely accurate, model, e.g. Kohn-Sham with B3LYP functional), a discretization error (resulting from the choice of a finite basis set), an algorithmic error (due to the choice of stopping criteria in Self-Consistent Field and other iterative algorithms), an implementation error (due to possible bugs or uncontrolled round-off errors), a computing error (due to random hardware failures). Quantifying these different sources of errors is key for two reasons. First, guaranteed estimates on these five components of the error would allow one to supplement the computed value of the QOI returned by the numerical simulation with guaranteed error bars (certification of the result). Second, this would allow one to choose the parameters of the simulation (approximate model, discretization parameters, algorithm and stopping criteria, data structures?) in an optimal way in order to minimize the computational effort required to reach the target accuracy (error balancing). Since molecular simulation consumes a massive amount of CPU time in scientific research centers worldwide, this would have a major impact on the use of scientific computing resources.

IPAM organized a Women’s Luncheon during this workshop, which was well attended.

Comments from our participant survey:

"It is very nice to have the presentations accessible quickly after the talks. I would propose to have a written discussion for each talk, to include better the remote participants. Maybe a slack channel for each talk?"

WORKSHOP: Monte Carlo and Machine Learning Approaches in Quantum Mechanics. MAY 23 - 27, 2022.

Part of the Long Program "Advancing Quantum Mechanics with Mathematics and Statistics"

Organizing Committee:
Kieron Burke (University of California, Irvine (UCI))
David Ceperley (University of Illinois at Urbana-Champaign)
Marivi Fernández-Serra (SUNY Stony Brook)
Anatole von Lilienfeld (University of Basel)
Anatole von Lilienfeld (University of Basel)
Jonathan Weare (New York University)

Quantum mechanics has strong connections with probability theory and statistics. Quantum problems can be formulated in terms of Feynman's imaginary-time path integrals, which maps some quantum partition functions onto classical ones which are then amenable to statistical sampling techniques. New statistical learning approaches are emerging that aim to account for the appropriate quantum physics by virtue of their architecture. Considering these recent developments, we brought together people interested in quantum systems and machine learning techniques. Specific topics included topological phases, the sign problem, boundaries between classical and quantum statistics, entanglement, methods to parameterize the phase (or nodes) and amplitude of many-body wavefunctions, statistical approaches to functional approximation in DFT, and auxiliary field techniques. Generally speaking, this workshop addressed new opportunities for statistical learning techniques which enable us to extend the reach and overcome the limitations of Monte Carlo and other methods as applied to the modeling and understanding of quantum systems. The goal was to highlight examples where quantum and statistical methods enhance each other.

This workshop included a poster session.

While this workshop was offered in-person, participants were offered the option to register and attend talks virtually.

Comments from our participant survey:

"IPAM is always the best place to gather with the best scientists in the community. They"

"I have no suggestions so far. Maybe the only thing I may have to say is to broaden the topic of the workshop. For instance, the topic of Monte Carlo could have been treated in relation too ther topics ranging from Field Theory, Statistical Physics to quantum computing. I think this would have added value to the workshop, though I am very happy with the workshop itself because I

got to know a lot about other methods like Variational and Quantum Montecaro which I haven't used much before."

"Happy hour was great, this was my favorite workshop so far."

WORKSHOP: Advancing Quantum Mechanics with Mathematics and Statistics Culminating Workshop at Lake Arrowhead. June 5 - 10, 2022.

Part of the Long Program "Advancing Quantum Mechanics with Mathematics and Statistics"

The culminating workshop was organized by the organizing committee of the long program. The final workshop in the long program, "Advancing Quantum Mechanics with Mathematics and Statistics," which was held at Lake Arrowhead Conference Center, provided an opportunity for the program's core participants to report on their work during the past three months and to discuss future projects. Many of the collaborations and interactions that were formed during the program had a chance to deepen.

REUNION CONFERENCE: Machine Learning for Physics and the Physics of Learning Reunion Conference I. JUNE 5 - 10, 2022.

The reunion conference was organized by the original long program organizing committee. This was the first reunion conference for participants of the fall 2019 long program "Machine Learning for Physics and the Physics of Learning." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

REUNION CONFERENCE: Mathematical Challenges and Opportunities for Autonomous Vehicles Reunion Conference 1. JUNE 5 - 10, 2022.

The reunion conference was organized by the original long program organizing committee. This was the first reunion conference for participants of the fall 2020 long program "Mathematical Challenges and Opportunities for Autonomous Vehicles." It was a timely get-together to continue some of the collaborations that were started during the long program. Presentations were given by all participants, with plenty of time between talks for discussions and collaborations.

OUTREACH ACTIVITIES, 2021-2022

MATHFest XXXI: OCTOBER 1 - OCTOBER 2, 2021 (Virtual)

The 2021 Undergraduate MATHFest was held on Friday, October 1 through Saturday, October 2, 2021. The program was held virtually on the Zoom platform. The program featured undergraduate student poster and oral presentations, information about graduate school,

networking and Problem Time! The organizers are the members of the NAM Program Committee: Rhonda Fitzgedrald (Vice-President and Committee Vice-Chairperson) Brittany Mosby (Committee Vice-Chairperson and Region C Member). RIPS Program Director, Susana Serna represented IPAM at the event. Additionally, IPAM advertised its RIPS (undergraduate) and GRIPS (graduate) programs through minority institutions and organizations.

SPECIAL EVENT: PUNDiT: (P)racticum for (Und)ergraduates (i)n Number (T)heory.
OCTOBER 16 - 17, 2021.

Organizing Committee:
Caleb Ashley (Boston College)
Edray Goins (Pomona College)

"PUNDiT: (P)racticum for (Und)ergraduates (i)n Number (T)heory" was a 2-day intensive program which showcased number theory broadly interpreted at the introductory level. A goal of this program was to expose Southern California students traditionally underrepresented in number theory (such as women and underrepresented minorities) to the beauty of the subject.

The Practicum was introductory in nature and no prior number theory coursework was assumed. Familiarity with Calculus and Linear Algebra while helpful, was not a requirement. The Practicum was designed for students who had completed minimal coursework in upper-division mathematics courses.

PUNDiT took place on Saturday October 16 and Sunday October 17, and featured four types of events:

- Tutorial: Two faculty members rotated to give three lectures over two days to introduce Riemann Surfaces.
- Problem Sessions: Two graduate students coordinated a series of three hour-long group-work sessions where students worked on problems meant to supplement the tutorials.
- Expository Talks: Four experts in number theory gave one-hour introductory presentations on various topics.
- Panel Discussions: There were panels on "Opportunities in Number Theory for Undergraduates" and "Opportunities at the NSF-Math Institutes for Undergraduates".

Tutorial #1: From Pendula to Elliptic Curves (Edray Goins)

Tutorial #2: Riemann Surfaces: number, function theory, and geometry (Caleb Ashley)

Tutorial #3: Character varieties: moduli, Markov equation, and Jabberwocky (Caleb Ashley)

Comments from our participant survey:

"Hi, I wanted to say thank you to all the organizers and staff for the amazing activity and effort. Also, thank you for the opportunity to participate. It was an amazing learning experience, which encourage me to increase my math knowledge and to consider applying to grad school. Also, the exposition to research opportunities as undergrads was an amazing part of the event…"

"I don't think I had that met that many minorities also doing math back at Caltech. It was great to get to know people like me who are also into math."

"Please keep doing stuff like this. It's motivating to know that math can become diverse and there's people similar to oneself passionate about the same thing. At the same time, it's also motivating to know there's all this available opportunities during the summer that make me look forward to it. This is very relevant since, from talking to upperclassmen and people of my class, I feel math often gets dropped and changed for something more applied since there is a lack of awareness for programs like the ones mentioned in this program that make you feel like you are actually doing something instead of just hitting books."

"I loved my time at PUNDiT! Thank you for inviting me to the lectures."

"Amazing!!!"

"The topics and lectures were amazing. Although they were a little bit elevated compared to my math level, this gave me the push to learn more about the topic.

"I enjoyed each of the lectures. However, I thought the lectures on Riemann Surfaces, "Prime Time Math", and Arithmetic Geometry were the most intriguing.."

"It was nice to see there's math I like and don't like so much. It gave me a much better focus on what I am trying to achieve."

"It's nice to have something to look forward to in the future and know I can already start realizing a research career in mathematics."

"As someone who didn't initially know too much about the math community and its research areas, I found the program to be quite insightful. Overall, I highly enjoyed interacting with everyone."

PUBLIC LECTURE: Green Family Lecture: "From the Possibility to the Certainty of a Supermassive Black Hole" by Dr. Andrea M. Ghez. OCTOBER 25, 2021.

Abstract:
Learn about new developments in the study of supermassive black holes. Through the capture and analysis of twenty years of high-resolution imaging, the UCLA Galactic Center Group has moved the case for a supermassive black hole at the center of our galaxy from a possibility to a certainty and provided the best evidence to date for the existence of these truly exotic objects. This was made possible with the first measurements of stellar orbits around a galactic

nucleus. Further advances in state-of-the-art of high-resolution imaging technology on the world's largest telescopes have greatly expanded the power of using stellar orbits to study black holes. Recent observations have revealed an environment around the black hole that is quite unexpected (young stars where there should be none; a lack of old stars where there should be many; and a puzzling new class of objects). Continued measurements of the motions of stars have solved many of the puzzles posed by these perplexing populations of stars. This work is providing insight into how black holes grow and the role that they play in regulating the growth of their host galaxies. Measurements this past year of stellar orbits at the Galactic Center have provided new insight on how gravity works near a supermassive hole, a new and unexplored regime for this fundamental force of nature.

Speaker Bio:
Andrea M. Ghez, professor of Physics & Astronomy and Lauren B. Leichtman & Arthur E. Levine chair in Astrophysics, is one of the world's leading experts in observational astrophysics and heads UCLA's Galactic Center Group. Best known for her ground-breaking work on the center of our Galaxy, which has led to the best evidence to date for the existence of supermassive black holes, she has received numerous honors and awards. In 2020 she became the fourth woman to be awarded the Nobel Prize in Physics, sharing one half of the prize with Reinhard Genzel (the other half was awarded to Roger Penrose). She is the first woman to receive a Crafoord prize in any field, received the Bakerian Medal from the Royal Society of London, a MacArthur Fellowship, and was elected to the National Academy of Sciences, the American Academy of Arts & Sciences, and the American Philosophical Society.
Ghez earned her B.S from MIT in 1987, and her PhD from Caltech in 1992 and has been on the faculty at UCLA since 1994.

This lecture was part of the Green Family Lecture Series and was attended by about 200 people. It was open to the public. Registration was not required, so no participants are reported.

SPECIAL EVENT: Blackwell-Tapia Satellite Conference. NOVEMBER 19 - 20, 2021. (Primary organizer: MSRI)

MSRI and the Mathematical Science Institutes Diversity Initiative (MSIDI) hosted the 2021 *Blackwell-Tapia Conference* (rescheduled from Fall 2020) held simultaneously at four locations nationwide. IPAM served as one of the four locations. The conference celebrated the 2020 Blackwell-Tapia prize winner, Tatiana Toro (University of Washington), who has been announced as the next Director of MSRI, effective August 2022.

The four host sites were:

- Mathematical Sciences Research Institute (MSRI): Berkeley, California
- Institute for Pure and Applied Mathematics (IPAM): Los Angeles, California
- Institute for Mathematical and Statistical Innovation (IMSI): Chicago, Illinois
- Institute for Advanced Study (IAS): Princeton, New Jersey

Held every other year, the conference and prize honor David Blackwell, the first African-American member of the National Academy of Science, and Richard Tapia, winner of the

National Medal of Science in 2010, two seminal figures who inspired a generation of African-American, Native American, and Latino/Latina students to pursue careers in mathematics. The Blackwell-Tapia Prize recognizes a mathematician who has contributed significantly to research in his or her area of expertise, and who has served as a role model for mathematical scientists and students from underrepresented minority groups or has contributed in other significant ways to addressing the problem of under-representation of minorities in math.

The conference included scientific talks, poster presentations, panel discussions, ample opportunities for networking, and the awarding of the Blackwell-Tapia Prize. Participants were invited from all career stages and represented institutions of all sizes across the country, including Puerto Rico.

Participation data was collected by MSRI and are not included in this report.

SPECIAL EVENT: A Celebration for Women in Mathematics, year 2022. May 12, 2022. (Primary organizer: MSRI)

MSRI organized the *Celebration of Women in Mathematics, year 2022* which was aimed at graduate students, with a focus on "How to Build a Career in Math". It was a hybrid workshop, with online and in-person activities at satellite institutions. The UCLA Mathematics department and IPAM served as one of the satellite locations. IPAM directors were members of the satellite organization committee and served as mentors in the planned events. IPAM also provided material support.

Participation data was collected by MSRI and are not included in this report.

K. PROGRAM CONSULTANT LIST

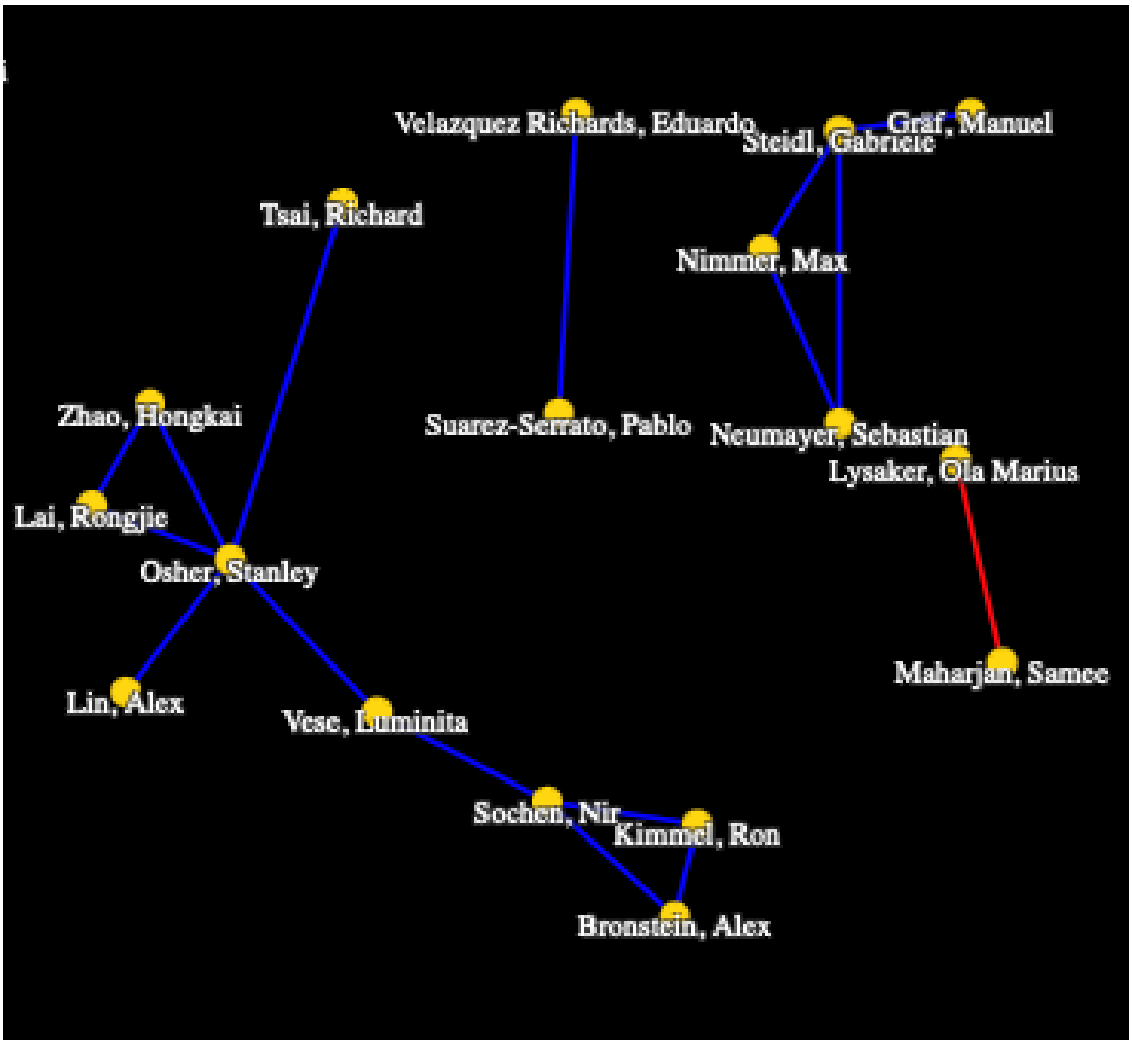
IPAM consulted a variety of scholars and practitioners in the scientific planning of its programs. The list below includes program organizers for the programs that took place during this reporting period or upcoming programs for which organizing committees have begun meeting. The list excludes IPAM's scientific staff (directors) and members of IPAM's Science Advisory Board and Board of Trustees, who are listed in "Section O, Committee Membership". On occasion, IPAM scientific staff and Board Members are organizers of workshops and long programs, and are therefore included in the list below.

Last Name	First Name	Institution Name
Aloy	Miguel Ángel	University of Valencia
Ashley	Caleb	Boston College
Baez	John	University of California, Riverside (UC Riverside)
Bieri	Lydia	University of Michigan
Buhmann	Joachim	ETH Zurich

Last Name	First Name	Institution Name
Campanelli	Manuela	Rochester Institute of Technology
Cances	Eric	École Nationale des Ponts-et-Chaussées
Cavaglia	Marco	Missouri University of Science and Technology
Choptuik	Matthew	University of British Columbia
Dafermos	Mihalis	Princeton University
Das	Pranab	Elon University
Delaney	Colleen	Indiana University
Esteban	Maria J.	CNRS and Université Paris-Dauphine
Flack	Jessica	Santa Fe Institute
Font	Jose Antonio	University of Valencia
Foster	Jacob	UCLA
Franzen	Anne	Instituto Superior Técnico
Freedman	Michael	Microsoft Research
Galli	Giulia	University of Chicago
Goins	Edray	Pomona College
González	Gabriela	Louisiana State University
Harrow	Aram	Massachusetts Institute of Technology
Hastings	Matthew	Microsoft Research
Heilman	Steven	University of Southern California (USC)
Heng	Ik Siong	University of Glasgow
Kleiman-Weiner	Max	Common Sense Machines
LeFloch	Philippe G.	Sorbonne University, Paris
Lin	Lin	UC Berkeley
Maday	Yvon	Université de Paris VII (Denis Diderot) et Université de Paris VI (Pierre et Marie Curie)
Mahadevan	L	Harvard University
Rezzolla	Luciano	Johann Wolfgang Goethe-Universität Frankfurt
Rodnianski	Igor	Princeton University
Rodriguez	Alejandro	Princeton University
Serna	Susana	Universitat Autònoma de Barcelona
Stancu	Alina	Concordia University
Tenenbaum	Josh	Massachusetts Institute of Technology
Tkatchenko	Alexandre	University of Luxembourg
Uhlmann	Gunther	University of Washington
Vidick	Thomas	California Institute of Technology
Wang	Zhenghan	Microsoft Research
Weare	Jonathan	New York University
Werner	Elisabeth	Case Western Reserve University
Wiebe	Nathan	University of Toronto

L. PUBLICATIONS LIST

This report includes publications that resulted from the spring 2019 long program. The list was compiled automatically and represent collaborations between program members which were published in the year of the program or later. These publications were entered into the project reports "Products" form in Research.gov. We chose not to include pre-prints. We confirmed that the publications in this report were not reported in our previous annual reports. The program resulted in at least one new collaboration (see red edge in the graph below), while existing collaborations continued.



M. INDUSTRIAL AND GOVERNMENTAL INVOLVEMENT

We have significant involvement of industry and government labs in our summer program, Research in Industrial Projects for Students (RIPS)-Los Angeles. Companies and other organizations sponsor research projects and one or more representatives of the organization interact with the student team. Many of them are listed as participants of RIPS and RIPS Projects Day.

IPAM received grants and gifts during this period from government and military agencies to support specific programs, including:

- Los Alamos National Laboratory: $10,000 (For Latinx program support)
- IRES grant through NSF-OISE supports GRIPS-Berlin (9/1/2018-8/31/2021; $121,140)
- NSF Mathematical Sciences Institutes Diversity Initiative – Latinx in the Mathematical Sciences (9/15/19-8/31/22; $106,515)

We seek the advice of government and industry by recruiting corporate and government leaders to serve on our Science Advisory Board and Board of Trustees. See section O for a complete list of members and their affiliations.

Out of all of IPAM's participants during this reporting period, 8 held positions in government or military organizations, such as Lawrence Livermore National Laboratory, NASA - Marshall Space Flight Center, National Cancer Institute, National Institute of Standards and Technology, and Sandia National Laboratories. One of our program speakers came from government or military labs.

Participants also included industry representatives, such as Alibaba, Amazon, AMD, Aquatic Capital, Facebook, Google, GumGum, HRL, IBM, Microsoft Research, and more. Sixteen program speakers were from the industry and private sector.

N. EXTERNAL SUPPORT

In addition to the funding listed in Table N below, IPAM receives substantial in-kind financial support from UCLA. The Director's entire salary/benefits and administrative stipend are paid directly by UCLA. The Director of Special Projects is released from two courses at the cost of replacing him by a junior person academic. IPAM is not charged for the use of its centrally located building, maintenance, or custodial care. Also, UCLA offers IPAM centralized administrative support, technology, recreational facilities, and public health guidance for COVID safety, though it is difficult to quantify such support monetarily.

The table shows other funding received by IPAM from June 1, 2021 through May 31, 2022.

Table N: Other Funding Support	2022
Federal Funding	
*NSF-Collaborative Research MSIDI	$106,515
*NSF-IRES Track 1 - GRIPS Berlin	$121,140
Sub-total	$227,655
Support from Foundations and Endowments	
Simons Foundation - Post Doctoral Scholars	$357,408
*Simons Foundation	$207,573
Berland Foundation	$12,000
IPAM's 20th Anniversary	$4,750
IPAM Director's Endowment Fund	$6,350
Sub-total	$588,081
UCLA Funding	
Dean Physical Sciences	$287,540
Vice Chancellor for Research	$161,553
Sub-total	$449,093
Industrial Affiliates and Other Support	
Aerospace	$28,000
Aquatic	$28,000
HRL	$28,000
Google, Inc	$28,000
Los Alamos National Laboratory	$10,000
GumGum	$28,000
IBM	$28,000
Sub-total	$178,000
Others	
Other Donors	$16,400
Sub-total	$16,400
TOTAL	$1,459,229

* These funds are not new appropriations, but are utilizing no-cost extension options and reflect balances as of June 2021

O. COMMITTEE MEMBERSHIP

IPAM's committees include the Board of Trustees and Science Advisory Board. The members during the reporting period are listed below. The IPAM directors are *ex officio* members.

Board of Trustees, 2021-22 Membership

Name	Institution	Department or Title
David Balaban	Navican	Vice President
Katy Börner	Indiana University Bloomington	Distinguished Professor of Engineering and Information Science
Russel Caflisch	New York University	Director, Courant Institute
Brenda Dietrich	Cornell University	Professor
Katherine Ensor	Rice Univeristy	Noah G. Harding Professor of Statistics
Diana Farrell	Independent	
James Gidney	The Aerospace Corporation	Director, Navigation and Geopositioning Systems Department
Edray Goins	Pomona College	Professor
Alfred Hales	Center for Communications Research West	
Tyler Kleykamp	Georgetown University	Fellow, State Chief Data Officer Network
Monique Miller	Euclidean Capital	Head of Investment Strategy
Nancy Potok (Chair)	NAPx consulting	CEO
C. Matthew Snipp	Stanford University	Professor, School of Humanities and Sciences
Tina Sung	Partnership for Public Service	Vice President, Government Transformation
Costis Toregas	George Washington University	Director, Cyber Security and Privacy Research Institute
Mariel Vazquez	UC Davis	Professor, Department of Mathematics

Science Advisory Board, 2021-22 Membership

Name	Institution	Department or Title
Brenner, Michael	Harvard University	Professor of Applied Mathematics

Name	Institution	Department or Title
Brown, Emery	MIT/Harvard Medical School	Professor of Medical Engineering and of Computational Neuroscience
Candes, Emmanuel	Stanford University	Barnum-Simons Chair in Mathematics and Statistics
Clementi, Cecilia	FU Berlin	Einstein Professor of Physics
Dwork, Cynthia	Harvard University	Gordon McKay Professor of Computer Science
Ellenberg, Jordan	Uni. of Wisconsin-Madison	John D. MacArthur Professor of Mathematics
Green, Mark	UCLA	Professor Emeritus
Hittinger, Jeffrey	Lawrence Livermore Nat. Lab.	Director of the Center for Applied Scientific Computing
Jones, Peter	Yale University	Professor of Mathematics
Kenyon, Richard	Yale University	Erastus L. DeForest Professor of Mathematics
Lin, Xihong	Harvard University	Henry Pickering Walcott Professor and Chair of the Department of Biostatistics
Meyers, Lauren Ancel	University of Texas at Austin	Cooley Centennial Professor in Biology and Statistics
Müller, Klaus-Robert	Technische Universität Berlin	Chair of the Machine Learning Group
Parrilo, Pablo	MIT	Professor of Electrical Engineering and Computer Science
Tao, Terence	UCLA	Professor of Mathematics and James and Carol Collins Chair at UCLA
Tchetgen Tchetgen, Eric	Wharton School, U Penn	Family President's Distinguished Professor and Professor of Statistics
Thiffeault, Jean-Luc	Uni. of Wisconsin – Madison	Professor of Mathematics
Tibshirani, Ryan	Carnegie Mellon University	Associate Professor in the Departments of Statistics and Machine Learning
Trevisan, Luca	Bocconi University	Professor of Computer Science
Wilkinson, Amie	University of Chicago	Professor of Mathematics
Witten, Daniela	University of Washington	Professor of Statistics and Biostatistics