

Preview of Award 1066293 - Annual Project Report

Cover

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Accomplishments

* What are the major goals of the project?

The primary major goal of the Aspen Center for Physics is to nurture cutting-edge research in physics and related disciplines by providing a unique physical and scientific environment ideally suited for stimulating interactions, collaborations and innovation.

An additional major goal is to conduct public outreach at all levels, from children to the general public, to increase understanding of and interest in physics, and to encourage young people in pursuing careers in STEM. The value of these outreach activities is enhanced by the fact that Aspen attracts visitors from all over the world both in winter and in summer, so that the Center's outreach has a broad national and even international impact.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: In summer 2012, the Aspen Center for Physics hosted 522 leading international researchers from a broad range of institutions around the world. A total of 553 researchers participated in the winter 2013 conferences.

The summer scientific programs emphasize open problems at the cutting edge and the format is designed to maximize informal interactions within each area and cross-fertilization between different areas. This is accomplished by a program of informal workshops spanning a wide range of physics and related disciplines, with two or three workshops running concurrently, combined with small working groups and visits by individuals. The Summer Workshops are selected from the proposals received from the international physics community by a committee of General Members of the ACP, with the goal of selecting timely and exciting topics which will attract the most outstanding researchers. The titles and organizers of the 2012 Summer Workshops are listed in a separate pdf file; topics included results from the LHC/Higgs; Massive Stars and Gamma-Ray Bursts; Correlated Electron Systems; and Stochastic Flows.

Of the 59 organizers of the summer workshops, only 2 are General Members of the ACP and 2 are Honorary Members of the ACP.

The quality of the researchers in the summer programs at the Center is ensured by a competitive admissions process. In summer 2012, the 522 participants were selected from 940 applicants. Special attention was paid to including junior researchers (76 assistant professors, 120 postdocs, and a few particularly outstanding senior graduate students). In addition, each workshop is required to have a member of the organizing committee who is the Diversity coordinator, and a member of the ACP's Diversity Committee serves on the Admissions Committee, with the result that 97 participants (18.6%) were female and 15 (almost 3%) from small universities (fewer than 3 physics PhDs annually). Participants need not be affiliated with a specific workshop: 13 different small working groups (57 physicists in total) were hosted, together with 70 physicists who applied primarily to undertake Individual research. We note that only 47 of the 522 summer participants were ACP General Members.

The physics ideas under discussion in the summer workshops are disseminated to the ACP participants in other sub-fields through a colloquium held weekly at the Center for Physics, presented by a participant in an ongoing workshop. These colloquia also facilitate cross-disciplinary collaboration. The titles and speakers of the summer 2012 colloquia are reported in an attached file (Physics_colloquium.pdf).

The purpose of the Winter Conferences is to respond rapidly to breaking developments in areas of current interest in physics and interdisciplinary research. These one-week winter conferences, like the summer workshops, are selected from proposals received from the international physics community by a committee of ACP General Members. The high profile and level of interest in organizing this conferences is evidenced by the fact that of the total of 30 organizers of the 2013 Winter Conferences, none was a General Member or an Honorary Member of the ACP. These conferences, with up to 100 participants each week, have a full schedule of formal presentations, geared to dissemination of the latest results, complementary to the summer program's focus on unsolved problems. The full list of winter conferences held in 2013 is included in an attached file; the topics covered cutting-edge physics across many fields. The quality of participants is ensured by a competitive admissions procedure conducted by the organizers of each conference, with the additional goal of encouraging junior participants (including graduate students) and diversity. Of the 2013 winter participants, 94 (17%) were women.

In both summer 2012 and winter 2013, the Aspen Center for Physics continued to develop its increasingly rich and visible public outreach program. In both summer and winter, a series of public lectures is offered to introduce the public to the most exciting directions of current physics research, as well as to issues concerning science policy. These lectures are subsequently broadcast on public television, accompanied by separate interviews with the lecturers. The lectures and interviews are freely available on the internet for viewing in a video archive accessible through the ACP website. In the winter, the public lecture is preceded by a Physics Cafe, during which selected physicists from the winter conference engage the public in a conversational Q & A session. In the summer, the public lectures are complemented by more informal Dialogues, which are get-togethers where leading researchers discuss their current research in a relaxed setting in which questions and discussions between the speaker and the audience are strongly encouraged. Also in the summer, the 'Physics is for Kids' Family Barbeques feature an informal lecture, often accompanied by demonstrations and/or hands-on activities, by a physicist from the summer program. In Summer 2012, in honour of the 50th Anniversary of the founding of the ACP, we also held two Public Symposia, with a panel of physicists. The full listings of these series of events are given in an attached pdf file

(summer2012_winter2013outreach.pdf).

The Summer 'Physics is for Kids' Family Barbeques and the Physics Cafes are co-hosted by the Aspen Science Center (ASC). The ASC is a non-profit organization, based in Aspen, and was founded 'to bring science into our lives in a compelling way and use the power of good science to create a better future for all of us'. The collaboration between the ACP and the ASC is very fruitful, with ACP providing the physics experts and the ASC providing outreach experience and hands-on experiments for the BBQs. Furthermore, last summer we together (ASC and ACP) initiated the Aspen Science Fair, which proved to be a huge success. This one-day event (08/12/12) drew a crowd of approximately 800 people to interact with, and learn from, many local scientific not-for-profit organizations and physicists.

The interactions between the ACP and local high school students have been strengthened by the recent introduction of the 'go-fer' program at ACP, whereby the ACP asked teachers of advanced physics classes to recommend their students as 'go-fers' at the ACP during the summer months. ACP hosted six such students in 2012 and expects twice this many in 2013. The students do not just undertake (paid) mundane tasks such as making coffee; the ACP also arranges one-on-one meetings for them with physicists who are working in an area of the student's special interest or who are from a university to which the student may apply. The high-school students leave the Center with greater enthusiasm for furthering their science education.

In 2012, we initiated two additional new outreach activities. The first is a monthly radio program on physics, broadcast on KDNK, a local community access station. This is aimed at high school students, and features a participating physicist being interviewed by past or current high-school 'go-fers'. This format allows the students to gain a deeper appreciation for who physicists are and what they do, and to encourage them to envisage themselves as physicists.

Second, the ACP and ASC also initiated a star-gazing event (June 20, 2012), with participating astrophysicists explaining the physics behind the glorious night skies of Aspen. Daryl Haggard, Romeel Dave, Jarita Holbrook, Emily Levesque, Loyal Durand, Bernice Durand, Nial Tanvir and Charles L. Steinhardt engaged approximately 150 members of the public with the astrophysics of stars and galaxies. The experience was enhanced by stories from "Spellbinders".

Specific Objectives: The specific objectives identified as essential to reaching the goal of the Aspen Center for Physics to nurture cutting-edge physics include:

- (1) to free researchers from the usual constraints and distractions of their home institutions by the smooth administration of the logistics and facilities of the Center;
- (2) to create each week, in both summer and winter, a community of outstanding researchers with related interests and complementary expertise;
- (3) to encourage free discussion within this community to identify the most important unsolved problems and to explore creative ideas;
- (4) to strengthen existing collaborations between researchers from different institutions and to promote the formation of new collaborations;
- (5) to choose summer colloquium speakers who can clearly convey the ideas and importance of the work in their area to their nonspecialist fellow participants at the Center, and
- (6) to stimulate and energize the passion for science that drives the most inspiring and

successful researchers, mentors and teachers.

The specific objective identified as essential to reaching the goals of the Aspen Center for Physics to outreach to the public is to recruit public lecturers, dialogue hosts and kids' barbeque speakers who combine a record of outstanding accomplishment in their field with the gift of making science come alive for the layperson.

Significant Results:

The major scientific results from the activities supported under this NSF grant are the 349 peer-reviewed research papers resulting from participation in the ACP programs, published during this reporting period and citing this NSF grant. These are reported as a pdf file in the 'Products' section of this report.

Highlights include (note the paper number is from the pdf file of refereed publications):

paper #51: T. Bensby et al. "Chemical evolution of the Galactic bulge as traced by microlensed dwarf and subgiant stars. V. Evidence for a wide age distribution and a complex metallicity distribution function". *Astronomy & Astrophysics*, 549:A147 (2013)

This paper takes advantage of the (rare) magnification of the light from stars like the Sun, but located close to the Galactic Center, by stars much closer in distance to the Sun (microlensing). This magnification means that these intrinsically faint stars can be studied in unprecedented detail, revealing much about the central 'bulge' of the Milky Way Galaxy. Our Galaxy, the Milky Way, is a template for disk galaxy formation in general and these findings of a complex age and chemical enrichment history are far-reaching.

The abstract reads, in part: Based on high-resolution spectra obtained during gravitational microlensing events we present a detailed elemental abundance analysis of 32 dwarf and subgiant stars in the Galactic bulge. Combined with the sample of 26 stars from the previous papers in this series, we now have 58 microlensed bulge dwarfs and subgiants that have been homogeneously analysed. The results from the microlensed bulge dwarf stars in combination with other findings in the literature, in particular the evidence that the bulge has cylindrical rotation, indicate that the Milky Way could be an almost pure disk galaxy. The bulge would then just be a conglomerate of the other Galactic stellar populations (thin disk, thick disk, halo, and ...?), residing together in the central parts of the Galaxy, influenced by the Galactic bar.

paper #72: Premala Chandra, Piers Coleman, and Rebecca Flint, "Hastatic order in the heavy-fermion compound URu₂Si₂," *Nature* 493, 621 (2013)

This paper reports the identification of the hidden order in the heavy fermion compound URu₂Si₂ (URS). This work was begun at ACP in summer 2011, with authors P. Coleman, R. Flint and P. Chandra identifying a benchtop test of the nominal valence of the U-ion which provide an important constraint on theoretical descriptions of URS (paper #127). In the work of summer 2012, resulting in the present paper, the authors proposed an order parameter for URS showing consistency with previous experiments with predictions for new ones.

The abstract reads: The development of collective long-range order by means of phase transitions occurs by the spontaneous breaking of fundamental symmetries. Magnetism is a consequence of broken time-reversal symmetry, whereas superfluidity results from broken gauge invariance. The broken symmetry that develops below 17.5 kelvin in the heavy-fermion compound URu₂Si₂ has long eluded such identification. Here we show that the recent observation of Ising quasiparticles in URu₂Si₂ results from a spinor order parameter that breaks double time-reversal symmetry, mixing states of integer and half-integer spin. Such 'hastatic' order hybridizes uranium-atom

conduction electrons with Ising $5f(2)$ states to produce Ising quasiparticles; it accounts for the large entropy of condensation and the magnetic anomaly observed in torque magnetometry. Hysteric order predicts a tiny transverse moment in the conduction-electron 'sea', a colossal Ising anisotropy in the nonlinear susceptibility anomaly and a resonant, energy-dependent nematicity in the tunnelling density of states.

paper #196: J. Kearney, A. Pierce, and N. Weiner, "Vectorlike fermions and Higgs couplings," *Phys. Rev. D*, 86(11):113005 (2012)

This paper is one of several exploring the consequences of the discovery of a Higgs-like particle at the LHC, naturally much discussed during the Summer 2012 workshops. It has already received 37 citations.

The abstract reads: New vectorlike fermions that mix with the third generation can significantly affect the τ and b Yukawa couplings. Consistent with precision electroweak measurements, the width of the Higgs boson to $\tau\tau$, bb can be reduced by $O(1)$ with respect to the Standard Model values. In the case of the b quark, a reduced width would result in an enhanced branching ratio for other final states, such as $\gamma\gamma$. New leptons can also substantially modify the Higgs boson branching ratio to photons through radiative effects, while new quarks can contribute to gg fusion. The combined effect can be as much as a factor of two on the branching ratio to $\gamma\gamma$. The new quarks and leptons could be light, which would allow discovery at the LHC. In the case of significant suppression of $h \rightarrow \tau\tau$, searches for new leptons decaying to τ -rich final states, perhaps in association with Higgs bosons, are motivated.

paper #247: P. Mehta and D. J. Schwab, "Energetic costs of cellular computation." *Proceedings of the National Academy of Science* 109:17978–17982 (2012)

This paper investigates the consequences of the fundamental link between information and thermodynamics, which means that even the simplest cells need to expend energy to learn about their environment. For example, bacterial spores must sense environmental conditions in order to know when to germinate, and thus must expend energy (exceeding the Landauer bound) even in their state of 'suspended animation'. Mehta and Schwab calculate the energy required for a simple cell to estimate the concentration of a substance in its environment, and demonstrate that information gathering mechanisms must be constrained by the energetic costs of their operation.

The abstract reads: Cells often perform computations in order to respond to environmental cues. A simple example is the classic problem, first considered by Berg and Purcell, of determining the concentration of a chemical ligand in the surrounding media. On general theoretical grounds, it is expected that such computations require cells to consume energy. In particular, Landauer's principle states that energy must be consumed in order to erase the memory of past observations. Here, we explicitly calculate the energetic cost of steady-state computation of ligand concentration for a simple two-component cellular network that implements a noisy version of the Berg–Purcell strategy. We show that learning about external concentrations necessitates the breaking of detailed balance and consumption of energy, with greater learning requiring more energy. Our calculations suggest that the energetic costs of cellular computation may be an important constraint on networks designed to function in resource poor environments, such as the spore germination networks of bacteria.

Key outcomes or Other achievements: From excerpts of the exit reports of individual participants, we present evidence of the Center's continued success in achieving its specific objectives and more broadly in reaching its major goals.

(1) The Center is successful in freeing researchers from the distractions of their home

institutions to concentrate on challenging scientific problems or major projects.

Fabian Walter: I found the peace and quiet to concentrate on a major review that I am currently preparing for the Annual Reviews in Astronomy and Astrophysics, the leading review journal in Astrophysics. I made major progress with this review which would simply not have been possible elsewhere, away from 'real life' and related duties/distractions.

Lei-Han Tang; I was working on a manuscript on regulation of metabolic flow in *E. coli*. This is some work I wished to complete for some time but it only became possible with the peace and leisure on the grounds of ACP.

Sang Chul Kim: It turned out that I got the crucial idea for the solution for one of the two problems I solved during my stay during a hike, and not while sitting in the office. This might indicate that an exceptional environment is a 'promoter' for scientific work.

Selma de Mink: In the US people are so driven by the next deadline for grants applications that we are always in a hurry. Really taking the time to sit down, think and fully discuss the many aspects of a particular problem with expert colleagues has become a very rare event. Aspen really provides the opportunity to do this. Maybe only for a few intense weeks of the year, but that is enough for the start of high-quality papers that have a real impact.

(2) The Center creates each week, in both summer and winter, a community of outstanding researchers with related interests and complementary expertise.

Hannah Arnold: The 25 climate scientists attending my workshop were joined for much of the time by two groups of astrophysicists. It was clear from discussion with my astrophysical colleagues and through attendance at the weekly cross-disciplinary talks that astrophysics and climate physics share many of the same problems. It was therefore very interesting to find out how physicists in a different field tackled our shared problems.

(3) The atmosphere and organization of the Center encourage free discussion within this community to identify the most important unsolved problems and to explore creative ideas;

Alexei Filipenko: Most conferences and meetings are far too full of lectures, one after the other, the entire time. The more relaxed atmosphere at Aspen provides the opportunity for extended, in-depth discussions that often lead to real progress. If there were no Aspen Center, I would argue strongly for the establishment of something very similar!

Andrea Stolte: I particularly enjoyed the open-minded atmosphere and the flexibility to discuss and talk with people, in contrast to the otherwise strict conference structure. The ACP's atmosphere clearly fostered discussions and spontaneous gettogethers about topics that are more basic and much more intense than is possible during usual meetings. Particularly enriching was the mix of scientists from different groups that would not normally gather during special topic conferences.

Tobias Baldauf: I appreciate the Center's dedication to blackboard talks. Having to write on the blackboard forces the speaker to slow down and to reduce information, i.e. plots, to the essence. This allows the audience to follow the speaker's ideas and to come up with suggestions or critical remarks during the talk. The talks during our workshop were always very interactive and I had the impression that this interactive atmosphere encourages people to discuss ideas rather than only presenting results that are ready for publication. I think that this discussion of ideas is very important in a

time where every researcher is measured by the number of publications and where there is a lot of competition between groups. I appreciate the open discussion of unsolved problems in the field.

(4) The Center is successful in strengthening existing collaborations between researchers from different institutions and in promoting the formation of new collaborations.

Scott Dodelson: The first two weeks here was with a new Working Group. The five of us met daily and developed plans for two important projects: the effects of baryons on weak lensing and the ability of spectroscopic surveys to mitigate systematics in lensing surveys. Both of these are hot topics, important to upcoming surveys, and we feel our Working Group will make a major contribution with these projects. There is simply no way this could have happened without Aspen: none of us are in the same place; I did not even know one of the people in our group [just her work], and the project evolved over the two weeks because of our frequent blackboard-based discussions. There were no powerpoint talks or lectures. It was simply 5 people trying to figure stuff out. Again, without Aspen, this would not have happened.

Roberto Capuzo-Dolcetta: During the 3 weeks, various collaborations began and the beautiful thing was that often these collaborations were born during some hiking on one of the many trails around.

(5) to choose summer colloquium speakers who can clearly convey the ideas and importance of the work in their area to their nonspecialist fellow participants at the Center.

John Berlinsky: I got a lot out of Ashvin Vishwanath's colloquium in the first week and I found Zohar Komargodski's colloquium truly awe inspiring.

Meigan Aronson: I would also like to say that the colloquium that week, delivered by Chandra Varma, was outstanding. A central problem in physics is that there is almost no interchange between the worlds of high energy physics and condensed matter physics, and this talk dealt with the parallel discoveries of the Higgs boson that were made 40 years apart in the two fields. It is a fascinating expose.

(6) The experience of working at the Center stimulates and energizes the passion for science that drives the most inspiring and successful researchers, mentors and teachers.

Kentaro Nagamine: These two weeks were the most fruitful weeks of this year in terms of my study. The university faculty like me often get frustrated for not having enough free time to read papers during the semester due to teaching and other duties. Just reading papers that I had to read, and thinking about it in Aspen is very gratifying moment. I was a bit exhausted this year after 6 yrs of being junior faculty, but I was re-energized again here in Aspen (in terms of research).

John J Eldridge: I have recently started a new academic position at the University of Auckland. I am the only astronomer at that location so have been a bit isolated. It wasn't until I arrived at Aspen and started to talk to my colleagues that I hadn't seen for some time did I realise what I'd been missing. During the two weeks I had so many conversations about astrophysics and other matters that I felt reinvigorated about science and ready to get on with the work of discovery.

Jill Naiman: My experience at the Aspen Center was exactly how I thought being a scientist would be like when I was a kid. Even group lunch outings quickly became great opportunities to talk science, even with our mouths were full. When I got back

home my advisor revealed to me that the reason he suggested I apply to an Aspen workshop was to motivate me to stay in academia, and I have to say, it worked! I've never been more motivated to progress on my thesis and projects I started at Aspen.

*** What opportunities for training and professional development has the project provided?**

The project does not include formal training or professional development activities. However, the ACP programs bring together physicists at all stages of their careers. In particular, during the summer program, postdoctoral researchers and junior faculty interact with more experienced senior researchers in shared offices and at the lunch table as well as in the organized talks and discussions, benefiting from informal advice, and from the personal relationships and collaborations thus formed. This is described in more detail in the Impacts section on human resources. In summer 2012, 23% of the participants were postdocs, 14.5% were assistant professors and 36.6% of the participants were 'first-timers'.

*** How have the results been disseminated to communities of interest?**

The results of the research undertaken by visiting physicists at the ACP have been disseminated to the international physics community through the 349 peer-reviewed journal articles listed in the pdf file under 'Products'.

During the Summer program, the background and context of the physics problems being discussed at the workshops and progress made are disseminated to the other Summer participants through weekly colloquia held at the ACP. The list of colloquia from Summer 2012 is given in an attached pdf file (Physics_colloquium.pdf).

The dissemination of activities at the Center through outreach has been described above in the Major Activities section, and in the attached file (summer2012_winter2013outreach.pdf). In addition to the live events, films of the public lectures and TV interviews with the public lecturers are the outreach activities are made available in a video archive on the internet, and interviews with participating physicists are broadcast monthly on a local radio station.

This outreach included several activities involving local high school students, recently developed and initiated with the aim of strengthening their interest in learning and careers in physics. ACP asked teachers of advanced physics classes to recommend their students as possible 'go-fers' at the ACP, during the summer months. ACP hosted six such students in 2012 (and expects twice this many in 2013). The students do not just undertake (paid) mundane tasks such as making coffee; the ACP also arranges one-on-one meetings for them with physicists who are working in an area of the student's special interest or who are from a university to which the student may apply. The high-school students leave the Center with greater enthusiasm for furthering their science education. We also initiated a new activity: a monthly radio program on physics, broadcast on KDNK, a local community access station. This broadcast is aimed at high school students, and consists of a participating physicist being interviewed by high-school students recommended by their physics teachers. The questioners are tasked with investigating the research undertaken by the physicist being interviewed and to base their questions on their findings. This format allows the student interviewers and audience to gain a deeper appreciation for who physicists are and what they do, with the hope that they can envisage themselves as physicists.

*** What do you plan to do during the next reporting period to accomplish the goals?**

ACP plans another summer of stimulating and topical workshops across many sub-fields of physics, complemented by cutting-edge Winter conferences.. The schedules of these are as follows:

Summer 2013 Workshops:

Individual Research 5/26-9/15

Working Groups 5/26-9/15

Physics of Functional Biological Assemblies: Pushing, Pulling and Sensing 5/26-6/30

Lattice Gauge Theory in the LHC Era 5/26-6/16

The Origins of Stellar Clustering: From Fragmenting Clouds to the Build-Up of Galaxies 5/26-6/16

The Obscured Universe: Dust and Gas in Distant Starburst Galaxies 5/26-6/16

The Next Decade of Weak Lensing Science 6/16-7/7

Disorder, Dynamics, Frustration and Topology in Quantum Condensed Matter 6/16-7/21

Mathematics of Superconformal Field Theory 7/7-8/4

The Milky Way as a Laboratory for Galaxy Formation 7/21-8/11

Optical Lattice Emulators and Beyond 8/4-8/25

Implications of LHC Higgs-Like Signals 8/11-9/1

Dark Matter in Galaxies, the LHC and Direct and Indirect Searches: Are We Near the End of the Road? 8/18-9/15

Multi-Component Many-Body Systems 8/25-9/15

Astrophysical Mechanisms of Particle Acceleration and Escape from the Accelerators 9/1-9/15

2014 Winter Conferences

Unconventional Order in Strongly Correlated Electron Systems 1/5-11

Beyond Quasiparticles: New Paradigms for Quantum Fluids 1/12-18

Frontiers in Particle Physics: From Dark Matter to the LHC and Beyond 1/18-24

Active Fluids: Bridging Complex Fluids and Biofluids 1/27 - 2/2

Unveiling The Formation of Massive Galaxies - Theoretical and Observational Challenges 2/2-8

Advances in Quantum Algorithms and Computation 3/9-14

New Perspectives on Thermalization: Condensed Matter, Quantum Information, QCD and String Theory 3/16-22

The Aspen Center for Physics also plans to continue its established outreach activities.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
2012summerworkshops_2013winterconfs.pdf	List of 2012 Summer workshops (titles and organizers) and 2013 Winter Conferences (titles and organizers).	Rosemary Wyse	06/25/2013
summer2012_winter2013outreach.pdf	Detailed listing of the established on-going series of outreach events, for summer 2012 and winter 2013	Rosemary Wyse	06/25/2013
Physics_colloquium.pdf	List of Physics Colloquia, Summer 2012	Rosemary Wyse	06/25/2013

Products

Journals

Books

Book Chapters

Thesis/Dissertations

Conference Papers and Presentations

Other Publications

ACP Participants (7/1/12). *See attached files for listing of publications.* 3 attached files, peer-reviewed, preprints and book chapters.

Status = OTHER; Acknowledgement of Federal Support = Yes

Technologies or Techniques

Nothing to report.

Patents

Nothing to report.

Inventions

Nothing to report.

Licenses

Nothing to report.

Websites

Title: <http://www.aspenphys.org/>

URL: This is the home page of the Aspen Center for Physics and contains links to all of the

Description: NSF-supported activities, both for the public and for physicists. The web pages were thoroughly revamped and updated in 2012.

Other Products

Product Type: Audio or Video Products

Description: Clifford Johnson, a General Member of the Aspen Center for Physics and Professor of Physics at the University of Southern California, created a short video describing the history and present activities of the ACP. This is available through the ACP website <http://www.aspenphys.org/aboutus/index.html>.

Other: Audio or Video Products

Product Type: All public lectures are videoed and shown on local television. Links to the videos are

Description: given on the ACP website next to the listing of the lecture.

Other: **Supporting Files**

Filename	Description	Uploaded By	Uploaded On
OtherPublications.pdf	List of preprints and conference proceedings	Karin Rabe	06/28/2013
Books-and-Book-Chapters.pdf	List of books and book chapters	Karin Rabe	06/28/2013
JournalPublications.pdf	List of papers published in refereed journals	Rosemary Wyse	06/28/2013

Participants**Research Experience for Undergraduates (REU) funding****What individuals have worked on the project?**

Name	Most Senior Project Role	Nearest Person Month Worked
Rosemary F Wyse	PD/PI	1
Karin M Rabe	Co PD/PI	1

What other organizations have been involved as partners?

Nothing to report.

Have other collaborators or contacts been involved? Y

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The research and resulting findings of the participants in the ACP programs cover all subfields of physics, including astrophysics and biological physics. Thus the impacts on the discipline of physics, broadly defined, are many and varied. Arguably the most important impact made on the base of knowledge and technique in physics is the cross-fertilization of ideas achieved through the informal discussions fostered by the summer programs at ACP, with simultaneous workshops in diverse topics. Established techniques from one field of physics can, and do, find novel applications in another. Inter-institutional and international collaborations were created and/or strengthened during summer 2012, as described in participants' exit reports.

The fostering of interactions across subfields of physics was illustrated in summer 2012 by the workshop on Disorder, Algorithms and Complexity. The purpose of this workshop was to evaluate recent progress and consideration of outstanding problems in computational complexity and Monte Carlo algorithms. A notable characteristic of this workshop was the interdisciplinary attendance. Participant comments include:

Horacio Castillo: I learned about the state of the art in studies of algorithms and complexity, particularly regarding boolean satisfiability and related problems. I have started working in this area earlier this year, and my interaction with other workshop participants has given me a much better grasp of the state of the field and the interesting questions that are open. I'd like to remark that the environment at the Center has been very favorable in fostering spontaneous and productive discussions. Over the years, my previous stays at the Center have been particularly fruitful in generating germs of future projects, and it appears likely that the same will happen with this one.

Daniel Stein: This visit to Aspen was particularly useful. I was a participant in the workshop on Disorder, Algorithms, and Complexity, which was expertly organized and brought together some of the very best people in the fields of interest. Both the formal talks and the informal discussions were lively, interesting, and productive.

Other workshops bring together researchers from a variety of specializations relevant to a particularly important problem or set of problems in physics. In summer 2012 this was exemplified by the workshop Evolution of Massive Stars and Progenitors of GRBs. The purpose of the workshop was to bring together leaders in the two complementary subdisciplines of gamma-ray bursts and massive stellar evolution to improve mutual understanding, share recent results and identify future collaborative lines of research that could shape the goals of these two communities.

Emily Levesque (co-organizer): A number of people told me that they left with new collaborators, contacts, and project ideas, and in many cases these collaborations served to finally combine people working in separate but very complementary areas of gamma-ray burst and stellar astronomy. One organizer commented upon his departure that it was among the "best two weeks of my scientific career". Based on this success we definitely plan to hold future workshops that continue bringing these sub-fields together!

Another mode in which research interactions are developed is by sequencing or overlapping two or more workshops on topics with common threads. Two examples from summer 2012 are the concurrence of the Evolutionary Dynamics workshop and the Disorder, Algorithms and Complexity workshop, and the overlapping of the Gauge Theory workshop and the Spin-Orbit Physics workshop. Three excerpts from relevant exit reports follow.

Marija Vucelja: This summer I had the wonderful opportunity to participate in two programs organized by the Aspen Center for Physics: Disorder, Algorithms and Complexity and Evolutionary Dynamics and Information Hierarchies in Biological Systems. Participation in both programs has broadened my scientific horizons and shaped my understanding on the future course of developments in these fields. In particular I feel that through talks and discussions I managed to deepen my knowledge of population genetics and evolution. Now I have a clearer view of the possible role of a statistical physicist, like myself, in understanding biological evolution.

Matthew Fisher (Spin-Orbit Physics workshop): I had several very interesting discussions with some of my string/particle theory colleagues from the "other program", especially Anton Kapustin (about phases with "soft" Goldstone modes), with Igor Klebanov about general issues (concerns) in the AdS/CFT construction of (the putative) finite density phases of correlated electrons and with Steve Shenker about various issues in discrete gauge theory. These inter-disciplinary discussions are precisely the kind of interactions that are greatly facilitated by the relaxed environment in Aspen, and rarely

if ever occur in other settings.

Michael Green (Gauge Theory workshop): Of more general benefit was my interaction with condensed matter physicists in the Spin Orbit Physics in Correlated Electron Systems program. The close connections between our fields were demonstrated by the extremely fruitful common sessions between the two programs.

Another important impact of workshops is the bringing together of experimentalists and theorists to focus on cutting-edge problems in a particular field. observers and theorists in astrophysics, experimentalists and theorists in condensed matter, and especially timely, high-energy experimentalists and phenomenologists for discussion of results from the LHC. Excerpts from exit reports follow.

Yehuda Ben-Zion: My participation in the workshop Large Fluctuations and Collective Behavior in Solids at the Aspen Center for Physics during July 29 - August 12, 2012, has been highly rewarding professionally and personally. The broad perspectives of the participants and wide range of theoretical and observational results were stimulating and inspiring.

Christopher Hill: As the deputy physics coordinator for the CMS experiment at CERN (2012- 2014), I oversee all the physics analyses being carried out at the LHC. It has been useful this week to get feedback on these searches and measurements from the many theorists in attendance this week. Likewise, it has also been fruitful to discuss ideas for new analyses that are as yet not being done.

Kenji Kadota: One of the big advantages for the Aspen workshop is that I could interact not only with the theorists but also the people who are involved with the actual data analysis of the on-going experiments. I can get the opportunities to see those people at a conference, but the conference schedule is typically pretty tight filled with so many talks whole day. So the relaxed schedule in a friendly atmosphere in Aspen was definitely of big help for me to interact with many world-class researchers.

Michael Garcia: The confluence of people allows observers and theorists to meet and explore new ideas, something that simply does not happen at other venues.

What is the impact on other disciplines?

Scientists whose primary disciplines are outside physics are increasingly participating in the programs at ACP. The 2013 winter conference program included "Single Molecule Biophysics." The summer 2012 program included two workshops with an impact on biology. The purpose of the 'Physics of Behavior' workshop was to explore how physical constraints define the strategies and biological machinery that living systems use to shape their behavior in the dynamic, noisy, and resource-limited physical world. The participants came from diverse departments including Electrical Engineering, Bioengineering, Biomedical Engineering, Center for Learning and Memory, Center for Memory and Brain, Computational Neurobiology, Neuroscience, Biochemistry, Molecular Biology, Cell Biology, Physiology, Organismal Biology and Anatomy, and Integrative Genomics as well as Physics. Indeed, fully 50% (16/32) of the participants in that workshop were from departments without 'physics' in the name. Similarly, the workshop "Evolutionary Dynamics and Information Hierarchies in Biological Systems" attracted 32 participants to explore the information hierarchies and their influence on the mechanisms that allow organisms to interact, adapt, survive, reproduce and evolve. Almost 2/3 (20/32) of these participants were from departments other than physics or applied physics.

In addition, the summer 2012 workshop, "Stochastic Flows and Climate Modeling," brought together leading researchers from applied mathematics, atmosphere and ocean dynamics and climate science as well as from physics and astronomy.

Comments from exit reports relating to the impact of these programs include:

Andre Brown: "The Physics of Behavior is at a very early stage and we are still defining what it means and what the central questions are. It is difficult to put a finger on, but the many informal interactions and group discussions that I have had during this time have convinced me that there is something new and different in this community's analysis of behavior and that it will develop as a field in very exciting directions. I think it's great that the Center has provided support to this small but growing community at the earliest stages of development."

Mark Nelson: "The Physics of Behavior workshop focused on surveying and defining an emerging area of cross-disciplinary interaction between physics and behavioral biology. Talks spanned the gamut from single-celled organisms (bacteria), small multicellular organisms with less than 1000 cells (the nematode worm, *C. elegans*), to complex organisms with millions to

trillions of cells, such as insects, fish, birds, and mammals. The breadth of coverage was really a strong point of the workshop. It gave me a deeper appreciation of the tight dynamic couplings between "brain", body and environment across many orders of magnitude in spatial and temporal scale.

Gaurav Arya: "The Evolutionary Dynamics and Information Hierarchies in Biological Systems workshop, first of all, allowed me to discuss at length several new ideas with the participants. Specifically, I enjoyed my discussions with Alexander Morozov, Michael Biehl, Sergei Grigoryev, and Karsten Rippe. Discussions with Alexander allowed us to formulate a new computational strategy for examining the effects of nucleosome positioning on the internal structure of the 30-nm fiber, which my graduate student is currently pursuing. My discussions with Michael, my office mate, introduced me to the fascinating topic of neural networks. The discussions have allowed me to think of new and innovative ways for tackling the problem of recovering chromatin conformation from interaction frequency maps. Sergei and Karsten gave me valuable feedback on some of the research I presented during the workshop and provided me new biological systems to examine. The Aspen workshop format is a fantastic idea that allows physicists to discuss research in very friendly, informal, and unrestricted settings."

Nicholas Cowan: "Since most of the participants were fluid dynamicists and Earth climate modellers, the Climate Modeling workshop was very much a mind-expanding experience for me (a trained astrophysicist)."

What is the impact on the development of human resources?

The ACP programs bring together physicists at all levels and facilitate interactions between them, for example through shared offices. This can, and does, create new life-long collaborations and friendships. In summer 2012, 76/522 were assistant professors and 120/522 were postdoctoral fellows. We actively seek first-time applicants and in summer 2012, 191/522 had not participated in prior years. In addition, 56/522 participants were NOT faculty members at universities, but rather staff members at government laboratories, observatories and industrial laboratories, and thus the junior researchers could discuss non-university careers. We include three excerpts from the exit reports of junior participants:

David Curtin: I only finished my PhD last year, and I was very excited to join the 'adult' high energy theory community as a postdoc, part of which I always understood to be attending the Aspen Workshop. I was not disappointed. My three weeks there were a tremendously productive and enjoyable time. I strengthened connections with other physicists I already knew and met many whose work I was familiar with but who I'd never had a chance to meet or get to know properly. Science, like all endeavors, relies crucially on these human connections we build with our fellow researchers, and I felt like Aspen was invaluable in helping me link up with members of our community.

Marija Vucelja: This fall I will be applying for Assistant Professor jobs. The discussions I had here at Aspen, have had a tremendous influence on my research statement. A couple of publications are in progress because of the new and old collaborations.

J. Kelly Holley-Bockelman: I've attended Aspen summer workshops since I was a postdoc -- maybe seven years now if I've counted right -- and each time has been meaningful for my career in different ways. This time, I came as a harried untenured professor, who needed some quiet time away from her research team to think about some of her new results, who needed to advertise her research in order to get those coveted citations, and who needed to solidify some connections with potential collaborators. The ACP workshop provided all that.

The ACP actively encourages women and under-represented minorities to participate, and indeed requires that one member of the organizing committee of each workshop or conference be identified as responsible for ensuring diversity in the applicant pool for that workshop/conference. In addition, there is a separate Diversity Committee of the governing body (the General Members) of the ACP. The percentage of women in summer 2012 (18.6%) represents an increase over summer 2011 (17%). It is hoped that the success in increasing participation at the Center will help to increase participation in the physics community.

Bernice Durand, an Honorary Trustee of the ACP, graciously hosted a weekly lunch for all the women participants. This is an ideal forum for networking, exchanging experiences, and discussing work-life balance. Comments from exit reports include:

Daryl Haggard: I appreciated Bernice Durand's weekly luncheon for the center's female participants. We had lively discussions, in particular how to engage younger women (even teenagers) in science and how to portray our femininity in

what are still male-dominated fields.

Elizabeth Simmons: I attended three lunches for women physicists at the home of Bernice Durand. As usual, the discussions about physics, the physics community, dual career issues, and women in the news were lively and thought-provoking. These lunches are a wonderful addition to the ACP experience, as they bring together women of all fields and generations.

Stephanie Palmer: It was so useful to sit and chat with other female faculty members as we navigate some of the challenges particular to our gender in our fields, but also to reflect on how far things have come since, say, Bernice first visited Aspen.

What is the impact on physical resources that form infrastructure?

Nothing to report.

What is the impact on institutional resources that form infrastructure?

Nothing to report.

What is the impact on information resources that form infrastructure?

Nothing to report.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

The outreach activities of the ACP reach beyond the academic world and aimed to improve public appreciation and knowledge of cutting-edge physics (e.g. the Public Lectures), and knowledge of physicists and how they think and work (the informal Dialogues and Physics Cafes).

Changes

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.