Berkeley Center for Cosmological Physics
Annual Report
2008

GENERAL INFORMATION

BCCP website: http://bccp.lbl.gov/
BCCP office location: UC Berkeley, Physics Department, 437 Old LeConte, University of California, Berkeley, CA 94720

VISION AND PLAN FOR BCCP AND TEACHERS' ACADEMY

Over the past year, BCCP has been assembling a world-class team of researchers to unravel the physics describing the history and fate of the universe. Created in December 2007 with seed money from the Moore Foundation, BCCP is becoming a major component of UCB's vision and direction for the 21st century study of cosmology.

The emergence of precision cosmology in the last decade will continue to have a revolutionary impact on our view of the universe. In theory and observation, Berkeley has a unique combination of people and projects. Our research covers the earliest epochs of the universe to the present. Berkeley has been the pioneer and leader in this area and will continue its leadership role with the Center for Cosmological Physics.

The BCCP mission is to understand the laws that govern how the universe came to be the way it is, and its future, through a series of research programs designed to define and carry out the necessary observations and experiments. BCCP will attack the fundamental questions in cosmology in a transformative atmosphere where seasoned physicists drawn from UCB and LBNL collaborate with the exceptionally talented young researchers BCCP is attracting.

A companion mission of the Center is to harness the excitement and benefits of its work, to motivate private support, and to implement related state-of-the-art teacher education and public outreach programs, in recognition of the long-term interdependency of world-class research capabilities and strong science and math education at every level. BCCP will help prepare teachers and students in science and stimulate their passion to pursue careers in science, engineering and mathematics.

STRATEGY:

Our mission question/statement: WHAT PHYSICAL LAWS DESCRIBE THE UNIVERSE? This question guides our programs of Research, Education, and Outreach.
BCCP asks the fundamental questions that create the foundation of an accurate, reliable model of the cosmos, and then compares the implications of the model against observations. One takes the simplest possible model consistent with the data, and then asks - What happens when we add to or change that model? Are the changes consistent with observation and theory? A "flow down" research plan adaptively leads to the desired increased understanding by doing the following: (1) Producing the Minimum Straightforward Standard Model of cosmology (MSSM); (2) Defining the major unanswered questions of the MSSM; (3) Developing a road map to answer those questions; and (4) Continuing and augmenting existing research programs or add needed new ones.

The Center's first order of business is to lead to a new level of understanding of the universe by a program to answer the key questions in cosmology:

- Did inflation happen? How?
- What is dark matter?
- What is dark energy?
- What generated the matter-antimatter asymmetry?
- Are there other relics to be found (e.g. cosmic strings)?
- Do fundamental constants vary?
- What other exotic forces might come into play?

A prime portion of this effort is to recruit outstanding young students (graduate and undergraduate) and extraordinary postdocs by offering them prestigious fellowships. Our first two pairs of postdoctoral BCCP Fellows came as the best of more than one hundred qualified applicants. This is the kind of talent we can recruit because of the existence of the Center and the Moore Foundation funding.

Areas of current multi-disciplinary postdoctoral research include: (1) integrated analyses of existing cosmological data to further elucidate the regimes and behavior of dark matter and dark energy which together comprise 96% of the energy density of the universe; (2) study of the eras of inflation (early Big Bang) and re-ionization (first stars) using radiation from the cosmic microwave background, red-shifted Lyman Alpha emissions, and gravitational lensing; and (3) probe of dark matter galactic halos and the growth of large scale structure using weak gravitational lensing effects in Hubble Space Telescope's COSMOS data surveys of galaxies. Future plans include increasing the current number of postdoctoral researchers from four to ten.

The Center will host a series of workshops and long-term visiting experts in computation, theory, and experiment. To more effectively disseminate this rapidly advancing field to graduate and postdoctoral students and harness their great interest and excitement, focused exposure on key topics is necessary. Annual conferences will be provided on the basics, the current status and new findings, and the anticipated results and developments in the field. Significant time will be allocated for discussions with leaders in the field and for international networking.

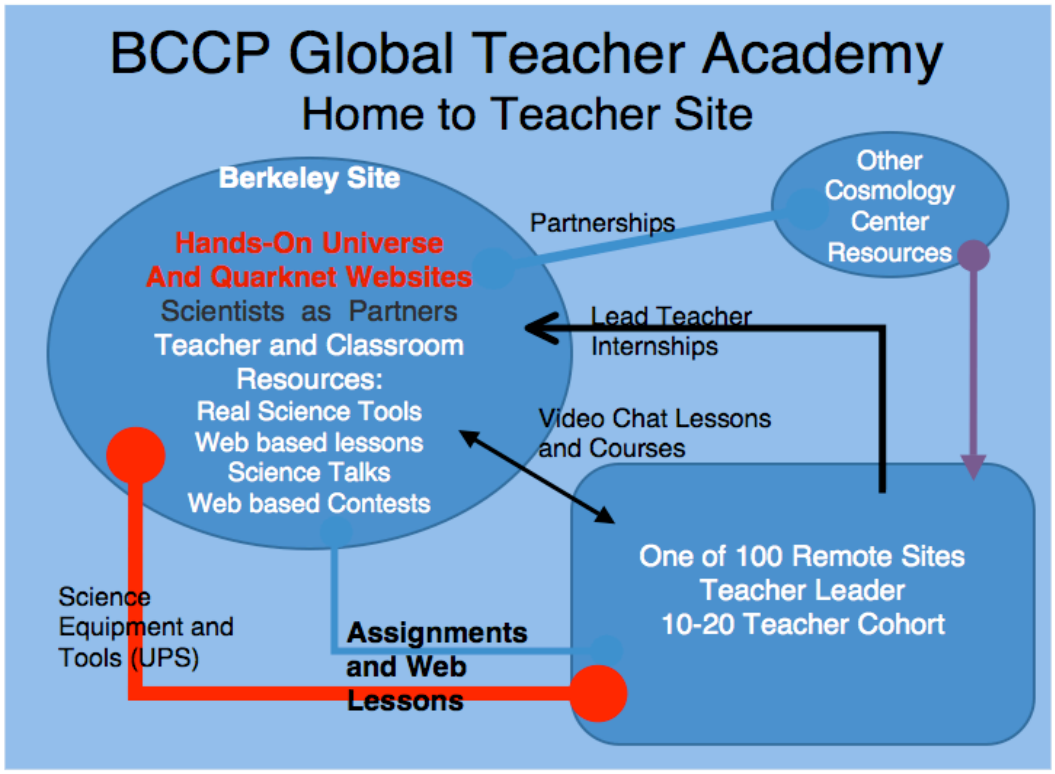
In parallel, the Center brings the excitement of active science to the community, developing education and outreach activities that include graduate students and Center postdoctoral fellows. Links to high school programs will train the next generation to understand and appreciate the role of science in our world. BCCP has established a teacher-focused academy that represents a model for 21st century science education and outreach. This academy will develop, support, evaluate, and disseminate innovative strategies for science and engineering education with cosmology as the unifying theme. Teachers and students of all ages will engage in programs and activities to discover their place in the universe through science and engineering education. They will develop an understanding of the origin, structure, and evolution of the universe, and share their knowledge with other students and the public.

This mission component will take advantage of BCCP's innovative research culture to promote four objectives:

- Education and training future scientists, engineers and computer scientists.
- Education and professional development of pre-college teachers.
- Motivation of students to pursue careers in science and technology.
- Promotion of public understanding of cosmology.

Education and Outreach Strategies:

- Provide research opportunities that are fully integrated with education and outreach activities
- Fellowships for graduate students and postdoctoral scholars
- Research Assistance positions for undergraduates and teachers
- Visiting researchers and scholar positions combining research and educational activities



OVERVIEW Center Administration

During this first year, a small administrative staff has been organized to support Center activities. Regular staff meetings were conducted to plan events and monitor Center activities. One focus of activity has been recruitment. A committee was formed to conduct the search for an Executive Director. A nationwide search yielded a strong pool of applicants, and leading candidates were brought to the Center for extensive interviews. A top candidate, Lucia Ortega-Villasana was identified and the recruitment process is being finalized.

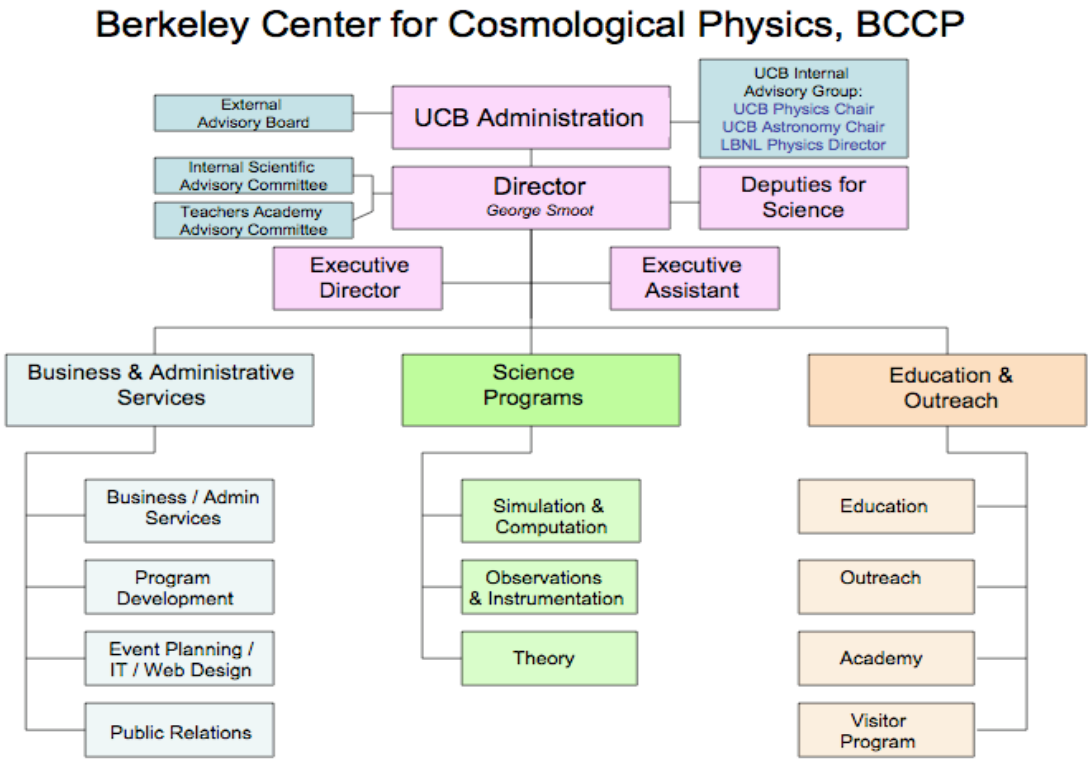
For the Center Fellow searches, the staff assisted a search committee consisting of the Center's leading scientists. Over 100 applications from an international pool of young scientists were received in both the first and second year. The Center Fellow selection was extremely competitive.

Staff also provided support for the Center's educational and promotional activities as well as financial monitoring and budget projections.

Over the past year, while waiting for finalization of an Executive Director hire, staff has initiated some outreach and fund-raising efforts with short brochures and the BCCP website. The brochures, compiled with assistance from William Green, UC Berkeley Physics Development Officer Maria Hjelm, Rosemary Nocera, Dr. Anthony Spadafora, Melissa Barclay, Matisse Roach and Dianna Attia were handed out at UC Berkeley's Cal Day in April 2008.

LBNL's Creative Services created a BCCP logo with some input by staff.

With William Green as consulting attorney, BCCP staff worked on a draft business plan for BCCP. Anthony Spadafora produced a draft governance plan, which includes an overview of BCCP.



The internal advisory committees have been constituted from a group of Berkeley professors and staff and the External Advisory Board empanelled including Professor Leon Lederman (Nobel Laureate in Physics and leading educator of the Illinois Academy; in 1989 helped to organize a Teachers' Academy for Mathematics and Science, designed to retrain 20,000 teachers in the Chicago Public Schools in the art of teaching science and mathematics.) and other persons with appropriate science and education credentials as well as those with contacts for additional resources.

PROMOTIONAL EVENTS

On December 4, 2007, BCCP launched the announcement of the new Center with a panel hosted by Professor George Smoot, UC Berkeley Chancellor Birgeneau, Professor Saul Perlmutter, and Dean of Physical Sciences Mark Richards. Representatives from local news agencies such as ABC, CBS, Chron4 News, *San Francisco Chronicle, San Francisco Business Times, Daily Californian*, and physicsworld.com covered the event.

Over the past year, BCCP Director Dr. George F. Smoot, along with BCCP staff and researchers have participated in various promotional events to promote BCCP, raise its visibility, and recruit potential donors for BCCP. Other outreach programs include The Global Teachers' Academy, student/teacher workshops, and development of online science courses.

In April 2008, BCCP participated in UC Berkeley's 140th Cal Day Event. BCCP set up a booth with the Physics Department and other UC Berkeley departments and research units. More than 80,000 participants attended, which created high visibility for BCCP.

Professor Smoot has also presented a number of talks and attended various seminars where he has brought visibility to BCCP. He discussed the new Center and distributed BCCP brochures. Among these include:

December 16-20, 2007 - Cambridge, England event with Stephen Hawking
December 31, 2007 -January 12, 2008, 2008 Indian Science Congress, India
February 13, 2008, Anna McPherson Lectures in Physics, McGill University, Canada
February 29 – March 7, 2008 – Honeywell, Nobel Lecture, Pune India
March 19-20, 2008 – Kilby Foundation Broadcast and reception, Dallas, Texas
March 20-22, 2008 – Vanderbilt University
March 30-April 1, 2008 – Illinois Institute of Technology
April 6, 2008 – SISSA, Trieste and University of Udine, Italy
April 7-8, 2008 – Ninth International Symposium Frontiers, Italy
April 9, 2008 – Physical Research Laboratory, India
April 14-21 – FEST, SISSA, Italy
April 21-22 – University of Rijeka Science Festival
April 22-24 – University of Oxford, England - Halley Lecture

BERKELEY FACULTY and RESEARCH STAFF

Berkeley already had a large contingent of faculty and research staff working directly on cosmology and related fields. This contingent has many activities including theory, observation, instrumentation development and computation. During this period these efforts have continued to grow assisted by the University and BCCP, particularly through its postdoctoral fellow and graduate student programs.

Cosmology Theory

Noticeably our theoretical staff of Professors Martin White, Chung Pei Ma, and staff Bob Cahn, Joanne Cohn, Eric Linder have been augmented by the addition of Professor Uros Seljak and the theoretical postdoctoral fellows. Related high energy astrophysicists include Eliot Quataert, Jonathon

Arons, Eliot Bloom, and students and post docs. We have also augmented the Cosmology Computation Center and other related areas of cosmology.

CMB Experiment and Data Analysis

With staff Reese Baird, Julian Borrill, Christopher Cantalupo, Bruce Grossan, Bill Holzapfel, Ted Kisner, Adrian Lee, Paul Richards, George Smoot and Helmut Spieler who have recently been augmented by Sara Ricciardi and Federico Stivoli.

Dark Matter, Neutrino Astrophysics

Buford Price, Stuart Klein, Kevin Lesko, and Bernard Sadoulet have major ongoing experimental efforts.

Large Scale Structure

Marc Davis and David Schlegel have major observational programs which have been augmented by postdoctoral fellows and graduate students.

Supernovae

Greg Aldering, Alex Filippenko, Gerson Goldhaber, Don Groom, Alex Kim, Michael Levi, Peter Nugent, Carl Pennypacker, Saul Perlmutter, Natalie Roe and Mark Strovink along with many post docs and students work on Supernovae and dark energy observational programs.

Particle Theory

Rafael Bousso, Mary K. Gaillard, Ori Ganor, Lawrence Hall, Petr Horava, and Hitoshi Murayama are some of the many particle theory faculty participate in the cosmology center and also the Center for Theoretical Physics with many post docs and students.

POSTDOCTORAL FELLOWS:

Dr. Anze Slosar: BCCP Fellow

Thanks to the great research opportunities at the Berkeley Center for Cosmological Physics, during his first fellowship year, Anze has authored or coauthored six published papers and submitted a further six. Of those papers he was the first author on three. There were two main thrusts in his work. First, he worked on development of a new exciting technique for constraining the non-Gaussianity from the large-scale structure data. The culmination of this work was a paper published in the *Journal of Cosmology and Astroparticle Physics* in which he and other collaborators put constraints on the local non-Gaussianity parameter fnl from the large-scale structure. These constraints are comparable to the best constraints derived from the cosmic microwave background. Second, he contributed to the Galaxy Zoo project, a citizen science project aimed at visually classifying galaxies from the Sloan Digital Sky Survey. He constructed the main data reduction pipeline for the project and analyzed the data to produce the first chiral correlation function of galaxy spins. Finally, he tutored two visiting students: Erminia Calabrese from the University of Rome, coauthored (together with George Smoot and Alessandro Melchiorri) a paper about lensing of the cosmic microwave background published in *Physical Review D* and Katarina Markovic from the University College London, with whom we are in the final stages of writing of a paper about constraining the warm dark matter models from the shear power spectra.

Published in refereed journals:

1. Lintott, Chris J., Schawinski, Kevin, Slosar, An_e, Land, Kate, Bamford, Steven, Thomas, Daniel, Raddick, M. Jordan, Nichol, Robert C., Szalay, Alex, Andreescu, Dan, Murray, Phil, Vandenberg, Jan. "Galaxy Zoo: morphologies derived from visual inspection of galaxies from the Sloan Digital Sky Survey." *Monthly Notices of the Royal Astronomical Society*, Volume 389, Issue 3, pp. 1179-1189. 09/2008
2. Fogli, G. L., Lisi, E., Marrone, A., Melchiorri, A., Palazzo, A., Rotunno, A. M., Serra, P., Silk, J., Slosar, A. "Observables sensitive to absolute neutrino masses." *Physical Review D,* vol. 78, Issue 3, id. 033010, 08/2008
3. Land, Kate, Slosar, An_e, Lintott, Chris, Andreescu, Dan, Bamford, Steven, Murray, Phil, Nichol, Robert, Raddick, M. Jordan, Schawinski, Kevin, Szalay, Alex, Thomas, Daniel, Vandenberg, Jan. "Galaxy Zoo: the large-scale spin statistics of spiral galaxies in the Sloan Digital Sky Survey." *Monthly Notices of the Royal Astronomical Society*, Volume 388, Issue 4, pp. 1686-1692. 08/2008
4. Slosar, An_e, Hirata, Christopher, Seljak, Uro_, Ho, Shirley, Padmanabhan, Nikhil. "Constraints on local primordial non-Gaussianity from large scale structure." *Journal of Cosmology and Astroparticle Physics*, Issue 08, pp. 031 (2008). 08/2008
5. Gordon, Christopher, Land, Kate, Slosar, An_e. "Determining the motion of the Solar system relative to the cosmic microwave background using Type Ia supernovae." *Monthly Notices of the Royal Astronomical Society*, Volume 387, Issue 1, pp. 371-376. 06/2008
6. Calabrese, Erminia, Slosar, Anze, Melchiorri, Alessandro, Smoot, George F., Zahn, Oliver. "Cosmic Microwave Weak lensing data as a test for the dark universe." *Physical Review D*, vol. 77, Issue 12, id. 123531. 06/2008
7. Palazzo, A., Cumberbatch, D., Slosar, A., Silk, J. "Sterile neutrinos as subdominant warm dark matter." *Physical Review D*, vol. 76, Issue 10, id. 103511. 11/2007
8. Land, Kate and Slosar, An_e. "Correlation between galactic HI and the cosmic microwave background." *Physical Review D*, vol. 76, Issue 8, id. 087301. 10/2007

Submitted to refereed journals:

1. Slosar, Anze, Land, Kate, Bamford, Steven, Lintott, Chris, Andreescu, Dan, Murray, Phil, Nichol, Robert, Raddick, M. Jordan, Schawinski, Kevin, Szalay, Alex, Thomas, Daniel, Vandenberg, Jan. "Galaxy Zoo: Chiral correlation function of galaxy spins."
Submitted to *MNRAS*.
2. Slosar, Anze. "Optimal dataset combining in f_nl constraints from large scale structure." Submitted to *JCAP*.
3. Bamford, Steven P., Nichol, Robert C., Baldry, Ivan K., Land, Kate, Lintott, Chris J., Schawinski, Kevin, Slosar, Anze, Szalay, Alexander S., Thomas, Daniel, Torki, Mehri, Andreescu, Dan, Edmondson, Edward M., Miller, Christopher J., Murray, Phil, Raddick, M. Jordan, Vandenberg, Jan. "Galaxy Zoo: the independence of morphology and colour."
Submitted to *MNRAS*:
4. Schawinski, Kevin, Lintott, Chris J., Land, Kate, Bamford, Steven, Thomas, Daniel, Raddick, M. Jordan, Nichol, Robert C., Slosar, An_e, Szalay, Alex, Andreescu, Dan, Murray, Phil, Vandenberg, Jan. "Galaxy Zoo: A sample of blue early-type galaxies at low redshift."
5. Lintott, Chris J., Schawinski, Kevin, Van Arkel, Hanny, Land, Kate, Bamford, Steven, Thomas, Daniel, Raddick, M. Jordan, Nichol, Robert C., Slosar, An_e, Szalay, Alex, Andreescu, Dan, Murray, Phil, Vandenberg, Jan. "Galaxy Zoo: 'Hanny's Voorwerp', a quasar light echo?"

Conference proceedings:

1. Lintott, Chris, Schawinski, K., Land, K., Slosar, A., Szalay, A., Bamford, S., Nichol, R., Thomas, D., van den Berg, J., Murray, P., Raddick, J., Andreescu, D., and Galaxy Zoo team. "Preliminary Results from Galaxy Zoo: The Sloan by Eye." American Astronomical Society, AAS Meeting #211, #142.01; *Bulletin of the American Astronomical Society*, Vol. 39, p.994. 12/2007
2. Raddick, Jordan, Lintott, C. J., Schawinski, K., Thomas, D., Nichol, R. C., Andreescu, D., Bamford, S., Land, K. R., Murray, P., Slosar, A., Szalay, A. S., Vandenberg, J. and Galaxy Zoo team. "Galaxy Zoo: An Experiment in Public Science Participation." American Astronomical Society, AAS Meeting #211, #94.03; *Bulletin of the American Astronomical Society,* Vol. 39, p.892. 12/2007
3. Raddick, Jordan, Lintott, C., Bamford, S., Land, K., Locksmith, D., Murray, P., Nichol, B., Schawinski, K., Slosar, A., Szalay, A., Thomas, D., Vandenberg, J., Andreescu, D. "Galaxy Zoo: Motivations of Citizen Scientists." American Astronomical Society, AAS Meeting #212, #40.01; *Bulletin of the American Astronomical Society*, Vol. 40, p.240, 12/2007.

Dr. Oliver Zahn: BCCP Fellow

During Oliver Zahn's first year as Center Fellow, he joined three experimental collaborations at Berkeley that have measured and are aiming to measure properties of the cosmic microwave background (CMB) temperature and polarization anisotropy. They are the South Pole Telescope (SPT), the APEX-SZ experiment, and the PolarBear telescope. For APEX-SZ, Oliver Zahn is leading the effort to constrain the small angular scale power spectrum owing to the so-called Sunyaev-Zel'dovich effects produced by scattering of the primordial CMB photons off free electrons post reionization of the universe. For the South Pole Telescope, Oliver is helping in the angular power spectrum measurement and the cluster mass function determination, and is leading the efforts to detect the kinetic Sunyaev-Zel'dovich effect (due to peculiar motion of galaxy clusters) as well as gravitational lensing of the CMB.
Oliver Zahn is also working on a number of theoretical projects. One paper develops a novel technique to simulate both the source distribution and large-scale morphology of neutral and ionized hydrogen during the Epoch of Reionization (EoR) at redshifts 15-6. Oliver's scheme is orders of magnitude faster than previous radiative transfer simulations without sacrificing accuracy notably. In a second project, Oliver is investigating the impact of gas-related secondary anisotropies in the CMB, in particular the Sunyaev-Zel'dovich effects, on the recovery of the large scale structure induced gravitational lensing.

Publications:

1) K.Smith, O.Zahn and O.Dore. "Detection of Gravitational Lensing in the Cosmic Microwave Background." *Phys. Rev. D* 76, 043510 (2007) arXiv:0705.3980
2) D.Babich, A.Benson, O.Zahn, D.Stark. "The Effect Of Inhomogeneous Reionization On The Spectral Properties Of Massive Galaxies." 2007. *AAS*, 211, #111.06
3) A.Lidz, O.Zahn, M.McQuinn, M.Zaldarriaga and L.Hernquist. "Detecting the Rise and Fall of 21 cm Fluctuations with the Murchison Widefield Array." *Astrophys. J.*, 680, 962 (2008) arXiv:0711.4373
4) Y.Mao, M.Tegmark, M.McQuinn, M.Zaldarriaga and O.Zahn. "How accurately can 21 cm tomography constrain cosmology?" *Phys. Rev. D* 78, 023529 (2008) arXiv:0802.1710
5) E.Calabrese, A.Slosar, A.Melchiorri, G.F.Smoot and O.Zahn. "Cosmic Microwave Weak lensing data as a test for the dark universe." *Phys. Rev. D* 77, 123531 (2008) arXiv:0803.2309
6) A.Lidz, O.Zahn, S.Furlanetto, M.McQuinn, L.Hernquist and M.Zaldarriaga. `"Probing Reionization with the 21 cm-Galaxy Cross Power Spectrum." arXiv:0806.1055

7) N.W. Halverson et al. (APEX-SZ collaboration). “Sunyaev-Zel'dovich Effect Observations of the Bullet Cluster (1E 0657-56) with APEX-SZ." arXiv:0807.4208

Dr. Tristan Smith: BCCP Fellow

Tristan Smith’s research lies at the interface between cosmology and gravity. Gravity has always occupied a unique place among the fundamental forces of nature. As the `universal force' it plays an essential role in the evolution of the Universe, from the big bang to today. As the only known force that cannot be written within a consistent quantum theory its underlying nature is expected to help elucidate the complete `theory of everything.’ As the weakest force it allows information to come to us from events occurring at energy scales approaching the Planck scale. Tristan Smith’s research concentrates on using novel probes in order to address questions concerning the dynamics of inflation, the nature of dark energy, observational signatures of string-inspired modifications to general relativity, and the fundamental symmetries of gravity (such as parity and Lorentz invariance).

Primordial gravitational-wave backgrounds provide an unparalleled window into physical processes occurring at energy scales as high as the Planck scale. In particular, the gravitational-wave background might allow us to infer fundamental properties of the processes that produce such backgrounds, such as inflation. To this end, along with Marc Kamionkowski and Asantha Cooray, Tristan Smith has studied how the direct detection of the inflationary gravitational-wave back- ground (IGWB) would enable a probe of the fundamental nature of the inflationary epoch (3).

This work has shown how direct observations of the IGWB will allow us an unprecedented view into the mechanisms behind inflation and that there is a good chance the IGWB will be observable in BBO. However, it is possible that a non-standard expansion history could complicate interpretations of the physical significance of the amplitude and slope of the directly observed IGWB. In future research he plans to address these issues and quantify how well we may be able to remove degeneracies with a non-standard expansion history (4).

In addition to this, along with George Smoot and his student Noel Swanson, Tristan has begun a study in order to explore how well one might use pulsar timing arrays in order to detect and measure the properties of gravitational waves. Currently, pulsar timing arrays are the most sensitive probe of gravitational waves (6) and their sensitivity is expected to increase by several orders of magnitude with the construction of the Square Kilometer Array (SKA) radio telescope which plans to be in full operation by 2020. Many groups have explored how to use pulsar timing measurements in order to place limits on stochastic gravitational wave backgrounds. However, less work has focused on identifying how to use this data to explore other sources of gravitational waves such as short duration bursts and polarized backgrounds. We plan to articulate how best to use this data in order to extract as much information about gravitational waves as possible.

The study of alternative theories to general relativity has recently gained a lot of interest because of the observation that the expansion of the Universe is accelerating. Many explanations for the accelerated expansion rely on proposing a new source of stress-energy within the context of general relativity (such as a cosmological constant or a scalar field). Alternatively, the observed accelerated expansion might indicate a breakdown of general relativity. Along with Adrienne Erickcek, Marc Kamionkowski, and Takeshi Chiba, he has shown that certain gravity theories [known as f(R)-gravity] that have the potential to explain the current epoch of accelerated expansion, under a particular set of conditions, severely violate observations of gravity within the solar system (7). Their work has made it clear that it is the non-linear behavior of the theory as well as its behavior on cosmological scales that allows it to pass solar system tests.

This non-linear behavior gives f(R) gravity some unique observational consequences. In particular, measurements comparing the bending of light around an object and the object's mass yields a determination of a parameter denoted PPN. In general relativity PPN = 1.

However, in f(R) gravity the value of PPN depends on the strength of the gravitational field around that object. Current lensing surveys, such as the Sloan Lens ACS (SLACS) survey, provide us with observations that may allow us to test whether PPN assumes a universal value or not thereby testing

such alternative gravity theories as f(R) gravity. In ongoing work, he will explore how well such surveys can test the universality of the value of PPN (8).
Besides providing an explanation for the recent epoch of accelerated expansion, modifications to the Einstein-Hilbert action are expected since quantized general relativity is non-renormalizable.
One common feature of these modifications is to introduce parity violation into the gravitational sector. In work done in collaboration with Adrienne Erickcek, Robert Caldwell, and Marc Kamionkowski, Smith has looked at how they may detect parity violation by probing the gravitomagnetic field applicable to the rotating Earth (9). Two current experiments seek to measure this field: LAGEOS has measured it to within 10% of its general relativitistic value and Gravity Probe B will attempt to measure it to at least this accuracy.
In related work Smith has investigated how the post-Newtonian equations of motion depend on an unspecified gravitomagnetic field. Using the fact that any alternative gravitational Ampere's law must respect mass conservation he has been able to derive a general form that the gravitomagnetic field can take. Using these results he has found the expressions for the secular changes in the inclination, argument of pericenter, and line of nodes applicable to binary systems for a generalized gravitomagnetic field (10). This framework allows for a more complete analysis of gravitomagnetic effects in these systems, especially the recently discovered double pulsar system, PSR J0737-3039A B (11).

References:

[1] D. N. Spergel et al. (WMAP) *A. J. Sup*. 170, 377 (2007).
[2] universe.nasa.gov/program/bbo.html
[3] T. L. Smith, M. Kamionkowski, and A. Cooray, Phys. Rev. D, 73, 023504 (2006);
T. L. Smith, H. V. Peiris, and A. Cooray, *Phys. Rev. D*, 73, 123503 (2006);
T. L. Smith, M. Kamionkowski, and A. Cooray, [arXiv:0802.1530], *Phys. Rev. D,* in press.
[4] T. L. Smith, in preparation.
[5] T. L. Smith, E. Pierpaoli, and M. Kamionkowski. *Phys. Rev. Lett.* 97, 021301 (2006).
[6] S. Detweiler, ApJ 234, 1100 (1979).
[7] A. L. Erickcek, T. L. Smith, and M. Kamionkowski. *Phys. Rev. D*, 74R, 121501 (2006);
T. Chiba, T. L. Smith, and A. L. Erickcek. *Phys. Rev. D*, 75, 124014 (2007).
[8] T. L. Smith, in preparation.
[9] T. L. Smith, A. E. Erickcek, R. R. Caldwell, and M. Kamionkowski. *Phys. Rev. D*, 77, 024015 (2008).
[10] T. L. Smith, in preparation.
[11] A. G. Lyne et al., *Science*, 303, 1153 (2004).

Dr. Jeremy Tinker: BCCP Fellow

In the coming year Jeremy Tinker will complete projects on both cosmological parameter estimation and galaxy formation. Jeremy Tinker is using a combination of two different statistics from the final data release of the Sloan Digital Sky Survey to constrain Omega_m and sigma_8; the two point correlation function of galaxies and the galaxy content of clusters found within the survey. The former probes the spatial distribution of all galaxies while the latter isolates galaxies in a narrow range of dark matter halo mass. Using a model for galaxy bias known as the halo occupation distribution, the combination of these two statistics breaks the degeneracy between cosmology and bias to generate constraints on the aforementioned parameters that are competitive with current CMB constraints.

Concurrently, Jeremy Tinker will use a combination of observed clustering measurements and dark matter N-body simulations performed by Prof. Martin White to test the proposed mechanisms for the

creation of the red sequence of galaxies--those galaxies that have stopped forming stars and exhibit spheroid morphologies. Current theories predicts that these galaxies are formed by mergers or accretion onto massive halos, but whether these theories can reproduce the distribution of red galaxies seen in voids--where mergers are rare and accretion is nonexistent--is an open question that Jeremy

Tinker will address. If there are not enough mergers in under-dense regions to account for the observed population of red galaxies in voids, a new method of halting star formation in dark matter halos must be found.

Dr. Alexie Leauthaud: Chamberlain Fellow

Since Alexie Leauthaud arrived at LBNL in October 2007, she has attended several conferences and given several seminar/conference talks (UBC Nov 2007, Ensenada March 08, SNAP meeting May 2008, UVIC June 2008). Alexie attended and gave a presentation at a cluster workshop at MPE at the end of July 2008. Alexie participated in the Teachers' Academy workshop at the end of July. Since October 2007, Alexie has made the following progress in her work:

1) Great progress has been made on correcting CTE (Charge Transfer Efficiency) effects in COSMOS data and in SNAP CCD data. We have made preliminary tests showing that we can remove CTE to about 90%. We hope to make new weak lensing catalogs for COSMOS by Sep 2008. These catalogs should have greatly reduced systematics. Two papers in preparation are associated with this work

2) Alexie has used the weak gravitational technique to study the masses of galaxy groups and clusters in the COSMOS data-set. In particular, this work looks at the evolution of the Lx-M200 relation. Alexie submitted this paper at the end of August.

Publications for 2008

1) Ilbert, O. et al. 2008, COSMOS Photometric Redshifts with 30-bands for 2-deg2, arXiv0809.2101I
2) Gabor, J. M. et al. 2008, AGN Host Galaxy Morphologies in COSMOS, arXiv0809.0309G
3) Caputi, K. I. et al. 2008, The Optical Spectra of 24 micro-m Galaxies in the COSMOS Field. I. Spitzer MIPS Bright Sources in the zCOSMOS-Bright 10k Catalog, ApJ, 680, 939-961
4) Faure, C. et al. 2008, First Catalog of Strong Lens Candidates in the COSMOS Field, ApJs, 176, 19-38

Dr. Reiko Nakajima: Postdoctoral Scholar

Reiko has primarily worked on the Supermassive Cluster project, along with Co-I Dr. Rachel Mandelbaum at IAS. The primary purpose of this project is to calibrate the intrinsic scatter in the relation between the X-ray and gravitational lensing observables in massive galaxy clusters, so that it may be used in characterizing the evolution of Dark Energy through cluster counting. This will be achieved through precision weak lensing mass estimates of the target 20 massive clusters.

Partial data were obtained at Kitt Peak National Observatory (KPNO) and Multi Mirror Telescope (MMT), and a preliminary analysis on the lensing has been completed. Further scheduled MMT observation time should complete the imaging for gravitational lensing; we have submitted a proposal to KPNO to complete the 5-band photometry, for purposes of obtaining photometric redshifts. The X-ray observation and analysis is complete through archival data. In addition, Reiko is working on other observational cosmology projects with Prof. Uros Seljak and Prof. Marc Davis. She has participated in the Physics In and Through Cosmology Teacher-Student Workshop.

1) G.M. Bernstein and R. Nakajima 2008, Multipole Formulae for Gravitational Lensing Shear and Flexion, arXiv:0807.1931 submitted to ApJ

GRADUATE STUDENT SUPPORT

Jessica Kirkpatrick

Jessica Kirkpatrick is a fourth year PhD candidate in the Physics Department at UC Berkeley. She is currently researching techniques described by Jeffrey Newman (Pittsburgh) to calibrate redshift distributions of photometric data, using cross-correlations between photometric and spectroscopic data. She plans to use the Sloan Digital Sky Survey (SDSS) Luminous Red Galaxies (LRGs) catalog to test this technique.

She is collaborating with Alexia Schultz (Princeton) on this project and is supervised by David Schlegel. Jessica is also one of two coordinators for the Society for Women in the Physical Sciences (SWPS), a student organization which aims to provide a supportive and connected community for the women in the physical sciences at Berkeley. SWPS runs a mentorship program, does outreach and volunteer work with schools, holds career and educational workshops, meets with visiting speakers, and puts on department-wide social events.

Eric Huff

Since joining BCCP in January, Eric has been working on cosmological applications of weak gravitational lensing. Most of this work has gone into producing for lensing analysis a high-quality 250 square degree coadded of the sky using Sloan Digital Sky Survey imaging. Once complete, he will be in a position to directly measure the clustering of dark matter on larger scales than ever before. Just as importantly, this analysis will prove a useful field test for methods to be employed in future lensing measurements drawing on data from much-anticipated ground-based surveys such as Pan-Starrs and the Large Synoptic Survey Telescope.

In addition to this, he is working on a measurement of the properties of dark matter halos using weak gravitational lensing in COSMOS data, and on developing new methods that may improve the sensitivity of lensing experiments.

VISITOR/SABBATICAL SUPPORT

Janna Levin, Professor, Columbia University
Carlo Baccigalupi, Scientist, SISSA, Trieste, Italy
Francesca Perrotta, Scientist, SISSA, Trieste, Italy
Federico Stivoli, Postdoctoral researcher, SISSA, Trieste, Italy
Simona Mei, Professor, University of Paris
Laurie Kerrigan, High School teacher, Mercy High School, San Francisco
Erminia Calabrese, Graduate student, University of Rome “La Sapienza”
Eric Gawiser, Assistant Professor, Rutgers University
William Green, PhD, Lawyer, MBA
Niayesh Ashfordi, Researcher, Perimeter Institute
Lucia Guaita, Graduate student, Rutgers University
Melody Wolk, Graduate student, Ecole Normale Superieure de Cachan, France
Katarina Markovic, Undergraduate student, University College, London, England
Ixandra Achitouv, Graduate student, University of Paris, Diderot, France

EDUCATIONAL PROGRAMS

Teachers' Workshops – Science Education through and in Cosmology

The Teachers' Academy is an integral part of BCCP which is directed at assisting and inspiring middle and high school science and math teachers by bringing them into contact with cutting edge cosmology research. A sample of the educational material can be found at UniverseAdventure.org. The Teachers' Academy effort has been active for two years and was preceded by a period of development and planning as well as trying different approaches. We have planned to make the impact wide reaching though the development of courses, lessons and web based resources delivered through the Internet. A key component of this strategy is to create a technology rich teacher training center that provides instruction and teacher training through partner organizations and leadership teachers. A good model of this type of activity can be seen in the BCCP web site coverage of an HOU workshop for teachers in Kenya delivered from Berkeley Lab by a local HOU teacher trainer. In July of 2007 the first workshop to establish the curriculum for this component was held at Berkeley. The Physics in and Through Cosmology workshop for teachers and high school students was captured and can be reviewed at the following web site: http://bccp.lbl.gov/Academy/workshop.html and http://bccp.lbl.gov/Academy/workshop2.html The second workshop was held July of 2008 and included Physics In and Through the Large Hadron Collider Science.

Winter School – Essential Cosmology for the Next Generation – January 12-19, 2009

Held in Los Cabos, Mexico

Co-hosted by Berkeley Center for Cosmological Physics, Advanced Institute for Cosmology, Mexico and Universe Cluster, Munich

Seminar topics will include (also available on webcast):

* Secondary Anistropies in the CMB (SZ, ISW, etc.)
* Large Scale Structure
* Acceleration of the Universe (mapping, e.g. supernovae, and dark energy theory)
* Simulations of Structure and Backgrounds (including visualization)
* Dark Matter (astrophysical, terrestrial, neutrinos)

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Selected speakers and courses:

George Smoot (University of California, Berkeley *Plenary presentations*), John Carlstrom (University of Chicago *Plenary presentations*), Carlos Frenk (University of Durham, UK *Simulation/Visualization*), Wayne Hu (University of Chicago *CMB Secondary Anisotropies),* Eric Linder (University of California, Berkeley *Dark Energy*), Chung-Pei Ma (University of California, Berkeley *Dark Matter*) and Simon White (Max Planck Institute, Germany *Large Scale Structure*)

BCCP First Year Staff

Rollie Otto

Starting in 2007, Rollie Otto, who had recently retired as Head of the Center for Science and Engineering Education, began working with BCCP to establish a teacher academy that represents a twenty-first-century model for cosmology education and outreach. Rollie and George developed a vision to create *A Global Cosmology Education Academy* where teachers and students of all ages around the world will engage in programs and activities to discover their place in the universe through science and engineering education. This model teacher–focused academy will develop, support, evaluate, and disseminate innovative strategies for science and engineering education with cosmology as the unifying theme. In support of the start up of the Academy, Rollie created and coordinated a summer workshop entitled, "Physics In and Through Cosmology" for outstanding high school students and their teachers. These workshops, which took place in the summers of 2007 and 2008, were designed to develop and test curricular materials for the Global Cosmology Education Teacher Academy. The workshop lectures and instructional activities along with student videos are posted on the BCCP web site.

Partnerships with established Hands-On Universe and Quarknet programs are a key component of the Global Cosmology Education Academy. Rollie developed a diagram (see page 3) showing the conceptual framework for global teacher education using web tools and centered at the Berkeley Lab.

Diana Attia

Diana Attia, the General Sciences Business Manager, supported, managed and coordinated some of the BCCP administrative and personnel issues with UC Berkeley Physics Department staff. She worked closely with management to draft initial organizational charts of BCCP Center staff and functions. Of significant importance was the recruitment effort for the Executive Officer position. She drafted the initial position description, ensured all parties concurred with content and worked with UCB to post and track applicants. She worked with management to formulate interview questions and coordinated interview schedules with committee members and UCB HR staff. She phone-screened applicants and selected the top candidates for interviews. The interview committee met with several candidates and made their recommendation to BCCP Director. She also secured excellent administrator support for the BCCP Director and continues to supervise and in some cases over-see administrative and personnel issues. She attended monthly BCCP planning meetings and ensured assigned action items were completed.

Melissa Barclay

In addition to the abovementioned editorial assistance with Cal Day Brochures, Physics Grant Assistant Melissa Barclay has been a main contact person in handling the grant administration and business aspects of BCCP. Initially, she was responsible for liaising with the Physics Department during the Moore Foundation grant submittals. Since then, she has been monitoring the grant's budgetary expenditures and working with Dr. Spadafora in producing monthly and annual budgetary reports and projections, and developing a budget and spending plan pending the arrival of the Center Executive Officer. She has provided budget reports for review by Dr. Smoot and others at periodic meetings of BCCP. In addition, she dealt with issues related to the new hires of postdoctoral scholars: submitting job postings to American Astronomical Society and UC Berkeley, and compiling and tracking those postdoctoral applicants by downloading and uploading their applications and letters of recommendation on a twiki site for the Postdoctoral Search Committee's review.

Once the postdoctoral scholars were hired, she was a point person for the many questions regarding their transition to Berkeley. Among other things, this included guest processing at LBNL, managing office space issues such as telephones and computer usage, assistance with payroll and personnel matters, processing of relocation expenses and travel reimbursements, and procurement of computers and other research supplies.

William Green

Bill Green, a former Visiting Scientist at Berkeley Lab's cosmology group, assisted in BCCP's strategic planning activities, including the development of a draft business plan, a draft governance plan, and the formulation of development goals. Bill assisted in creating copy in materials used for BCCP fundraising and outreach.

Maria Hjelm

Maria Hjelm, development officer for the Physics Department, assisted in the set up of BCCP and the outline of the development plan for the Center. Maria participated and helped organize several events for BCCP.

Matisse Roach

Brings years of progressive experience as an Executive Assistant to the BCCP Director combined with many years of expertise in Production Operations Management, Business Development, and Innovative Leadership, as well as Contract Negotiation. Matisse works on confidential correspondence, spreadsheets and presentation materials, coordinates monthly BCCP Prospect Strategy Meetings, performs a full range of administrative duties, including management of heavy calendaring, on-site/off-site meeting coordination, produces meeting agendas, processes travel vouchers, coordinates domestic and international travel for the Director and focuses on business imperatives and successfully meets deadlines.

Anthony Spadafora

Dr. Anthony Spadafora, currently Chief of Staff to LBNL Director Steven Chu produced a draft governance plan, which includes an overview of BCCP. Tony was also responsible for putting into place many of the procedures and policies and work with Professor Smoot and Melissa Barclay to develop a budget and spending plan pending the arrival of the Center Executive Officer.

Rosemary Nocera - Multimedia Director

• Website design and maintenance - graphic design, written material, photography, and videography for BCCP and BCCP Teacher Academy websites. Currently working with Drupal open source web content management to create more dynamic, interactive websites.
• Print Graphics: Design and fabrication of multimedia presentations and visual/poster displays. Created BCCP poster and flyer for Campus Cal Day.
• Education and Outreach: Planning and development of community/educational outreach programs emphasizing public awareness and appreciation for science. Assisted in planning and implementation of the BCCP cosmology workshop for students and teachers. Advised students on creating scripts for science videos. Filmed and edited videos for posting on the BCCP website and YouTube. Creating a series of video interviews with BCCP postdocs, grad students, and Cosmology Workshop speakers. Developed the concept of having an online student science video competition on YouTube. After reviewing presentation formats for scientific research, she is currently developing a more effective multimedia online presentation medium for scientists through Drupal.

BCCP: The Future

BCCP looks forward to a bright future which combines active science within a university and research setting of senior scientists, graduate students and Center postdoctoral fellows and the wider community developing education and outreach activities. The model of science education such as the Teachers Academy and other educational outreach programs for the next generation of young people will help them to understand and appreciate the role of science in the 21st century. We hope to make a wide reaching impact, inspiring young people though the development of courses, lessons and web based resources delivered through the Internet and the teacher training center.

We look forward to breakthroughs occurring in BCCP's quest to answer the key open questions in cosmology, which demands the unparalleled knowledge-based creativity the Center is generating. In a think-tank atmosphere, BCCP is combining efforts of theoretical, computational and observational physicists and a promising new generation of post-doctoral researchers into creative cross-functional teams. Their combined talents, experience, and passion will generate the higher level of thought needed to define the physics of the universe.

We are especially enthusiastic about our first annual meeting of the Winter School--with the theme of "Essential Cosmology for the Next Generation"--to take place in Mexico, in January 2009 which will link BCCP more strongly with the international scientific astrophysics and cosmology research community.

BCCP is located in one of the most exciting and creative scientific centers in the world: the Bay Area. Home to four research universities, two important government laboratories, and several science museums, BCCP will partner with these institutions and present our findings to an eager public. We are on the threshold of an exciting new era in scientific, astrophysics and cosmology research, and BCCP is excited to be part of that event. We appreciate the Moore Foundation's contribution to our goals.