BERKELEY CENTER *for*
COSMOLOGICAL PHYSICS

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CONTENTS

THE BERKELEY CENTER FOR COSMOLOGICAL PHYSICS

Founded in 2007, the Berkeley Center for Cosmological Physics (BCCP) is an integrated research and education physics think tank nested within the University of California, Berkeley (UCB) and Lawrence Berkeley National Laboratory (LBNL). The Moore Foundation's support of this science-based, results-driven organization has created significant and measurable impact over a period of 24 months. This progress and fiscal report for program year 2009 presents a summary of BCCP's distinct initiatives that are moving towards large-scale outcomes.

BCCP has three primary areas of focus — research, education, and global partnerships — and seeks the full integration of research and education within its global cosmology research network.

Professor George Smoot founded BCCP in 2007 after winning the Nobel Prize in physics. The prize recognized his 1992 discovery of tiny temperature fluctuations in the cosmic microwave background — the radiation left over from the Big Bang. Determined to build an advanced research center to study the origins, evolution, and future of the universe, Professor Smoot donated a significant portion of his Nobel Prize funds to launch this startup, and he has motivated others to give of their time, effort, talent, and expertise. As required by the foundation, match dollars of $1 million are evidenced in Appendix A of this report. The generous support received from the Gordon and Betty Moore Foundation remains a valuable contribution — over the last 24 months, it has allowed for strategic leveraging of staffing and resources. BCCP continues to benefit from Dr. Smoot's Nobel Prize. Dr. Smoot travels around the globe, speaking about his vision for 21st-century cosmology research and education at science conferences, corporate seminars of research and development, research institutions, and informal science education centers — and even through the entertainment industry.

This progress report describes how BCCP and the Gordon and Betty Moore Foundation, together, continue to assemble a world-class team of researcher who are unraveling the physics describing the history and fate of the Universe while collaborating with global partners in Paris and Korea. Additional activities associated to BCCP include the development of a Global Teachers Academy (BCCP GTA), updates related to BCCP post doctoral fellows, graduate students, seeds and incubations for the next generation of cosmology-related programs, sabbatical visitors, winter cosmology school, global partnerships, staffing, development, and business operations.

OUR VISION, MISSION, AND GOALS

During this reporting period, BCCP organized strategic discussions between staff from Lawrence Berkeley National Laboratory and UC Berkeley for the purpose of establishing a clear vision, mission, and organizational goals associated to its research and education activities.

Vision. BCCP researchers will explore new frontiers in cosmology, gravitation, and astrophysics to create a framework of knowledge that transcends national boundaries and benefits generations to come. The result will be discovery and understanding of the physics necessary to explain our universe quantitatively to an unprecedented level of accuracy.

Mission. BCCP aims to unravel the physics behind the history and structure of the universe, and to strengthen research and education by forging cosmological discoveries that will create a 21st-century model for the study of cosmology.

Goals. In support of BCCP's vision and mission, we have established the following goals:

- Create a framework of cosmology that defines the most critical ideas, experiments, and observations necessary for distinguishing and narrowing the possible descriptions of the universe.
- Develop highly trained scientists in a cutting-edge field that encompasses the use of mathematics, high-energy physics, technology, and other cross-disciplinary fields.
- Instigate landmark research in the field of cosmology.
- Implement middle school and high school educational outreach and teacher development nationally and globally that enhances public awareness, scientific literacy and interest in the fields of science, technology, engineering, and math.

FRONTIER-SCIENCE RESEARCH

The Center continues to successfully evolve and develop, building its business plan and activities around frontier-science research that will lead to a new level of understanding of the universe. BCCP has focused on understanding the origin and evolution of the universe through a series of programs to define the observations, experiments, concepts, and simulations needed to answer the key fundamental questions in cosmology. Bringing together experimentation, computation, and theory, BCCP continues to move toward creating a foundation of an accurate, reliable model of the cosmos, and then comparing the implications of the model against observations — thus opening new horizons and expanding our knowledge of the universe. BCCP research programs are addressing the following major questions:

- What is dark energy, and how is it causing the expansion of the universe to accelerate?
- How did space-time come into being early in the universe?
- What is dark matter, and how does it relate to fundamental symmetries in the early universe?
- Why is there an excess of matter over antimatter in the current universe when they were in equal abundance at very early times?

While developing the framework of necessary and optimum observational and experimental cosmology programs, BCCP has begun to seed and incubate these next generation programs. The first of these include:

1) *BOSS (Baryon Oscillation Spectroscopic Survey).* BCCP most recently hired cosmologists who are world leaders on the newest approach to dark energy measurements: Baryon Acoustic Oscillations (BAO). By studying the clustering of galaxies, we can detect the imprint of the density, or sound, waves that were "frozen in" as the cosmic plasma of the early universe cooled – the

same acoustic phenomena that produced the anisotropies that we see in the Cosmic Microwave Background (CMB). Moreover, by comparing the structure in the CMB with that seen in the distribution of galaxies in the nearer universe, we obtain a measurement of the properties of dark energy causing the recent cosmic acceleration. This gives a new window on the phenomenon, which is independent of the one using supernovae, providing a complementary way of understanding the history of the universe and what drives it. The Center's scientists are developing a new project that can make a dramatic step forward in BAO dark energy measurements. The survey is designed to obtain spectra of 1.5 million galaxies at $z<0.7$, and 160,000 quasars for the BAO signal at much higher redshifts. This is a prime example of work that BCCP is incubating to cross the hurdles and deliver demonstrations necessary to establish the project for full funding.

2) *POLARBEAR (Cosmic Microwave Background Polarization) and PLANCK.* BCCP scientists are at the forefront of CMB instrumentation developments. We have instruments running on several cutting-edge experiments, including the PLANCK satellite and the South Pole Telescope that is arguably taking the best current data of small angular scale anisotropies. The PLANCK satellite was launched on May 14, 2009. Dr. Smoot has been involved in PLANCK since its inception, and he is a senior member of the project. POLARBEAR is undergoing construction and will eventually observe from the high Atacama Desert in Chile, with even better sensitivity although over a smaller area of sky. The ambitious goal of this work is to search for the signature of gravity waves from the inflationary era of the universe 10^-35 s after the Big Bang at energies of 10^16 GeV. This is the epoch when our actual space and time become macroscopic out of quantum fluctuations. Such a discovery would teach us about the universe at the very beginning of time at energy scales that probe fundamental physics beyond the reach of particle accelerators. This is a critical step in efforts to map the entire history of the universe. POLARBEAR and PLANCK are clear examples of novel projects that — with the help of strategic

seed funding — would allow a new field to develop. These projects illustrate the diverse capabilities of BCCP, including:

a) *CMB experience in the Department of Physics;*

b) *Experience with large detector systems;*

c) *Parallel supercomputing expertise at NERSC;*

d) *Electromagnetic design expertise at RAL; and*

e) *The micro fabrication facilities in Berkeley's electrical engineering program.*

3) *JDEM (Joint Dark Energy Mission) Satellite.* This is a joint mission between the Department of Energy and NASA. The collaboration of the two agencies will ultimately lead to sufficient resources to have three strong probes of the dark energy and accelerating universe: gravitational lensing, supernovae, and baryon acoustic oscillations. Together they allow us to test the validity of Einstein's General Relativity theory on cosmic scales while also independently observing dark energy. However, with two agencies involved, timing and coordination can be difficult and the path to a satellite mission as mapped out does not allow for studies outside the nominal critical path. This single-minded approach means that some key science topics cannot be included unless there is room to explore them in a less rigid fashion. Several key projects of the JDEM satellite are now unfunded, and strategic seed funding could allow BCCP to accomplish science that might not otherwise be included in the mission design. As we did in the 1990s with the landmark Center for Particle Astrophysics (which then led to some of the most important cosmology work of the following years), Berkeley can play a critical role. BCCP is a more nimble body that can ensure JDEM delivers the science of interest to the whole community, conducting studies and tradeoffs that fall in between agencies.

4) *The Legacy Supernova Calibration Program.* All of the major programs proposed for the next decade that use supernovae to study dark energy will require a novel supernova calibration program. These include the dramatic example

of the JDEM satellite project supernova probe and the Nearby Supernova Factory, a key element of JDEM that demonstrated the basic steps required. Our next task will be to design and develop a project that will scale up this work to reach the numbers and precision needed. The Center's scientists in this field (the leaders of the Supernova Cosmology Project, JDEM, and the Nearby Supernova Factory) are now beginning work on this next step. Like mapping the trajectory of a ball (that forms a parabola when gravity is uniform and an ellipse when it is not) documenting the brightness of supernova in the universe to map the history of cosmic expansion will inform our understanding of time, space, and behavior of gravity.

5) *Center for Cosmology Computing Initiative.* Although cosmology has now matured to the point that we can make significant progress in understanding key physics questions by constructing high-precision experiments, designing and executing such experiments requires a new level of theoretical, analytic, and computational sophistication that is almost unprecedented in astrophysical measurements. The exciting projects thus appear to have a somewhat different characteristic than previous astronomy projects: the data are complex enough that those theorists who understand the details of the data are often needed to participate in the analysis. Moreover, sophisticated computing capabilities are needed by both the experimentalists and the theorists. Typically, the analysis of these observational data now takes longer than the experiment itself! The experimental and the theoretical — the data analysis and the simulations — are in fact tightly interwoven in today's cosmology. Many of the key questions in cosmology rely on subtle signals in the data and require theoretically sophisticated approaches to data analysis and interpretation. Simulations are required both as event generators for modeling the analysis pipelines and as the theoretical predictions themselves. Numerical simulations are indispensable in investigating how the universe evolved from the minute primordial fluctuations into the highly nonlinear web of galaxies and clusters observed today. Fellowships for postdoctoral experts and a large

multi-processor cluster are essential for bridging the current gap between national centers and smaller desktop computers. Computational problems on these intermediate scales are often the center of innovative research, whose development would be inefficient and laborious at the national computing centers.

6) *EoR (Epoch of Reionization)*. The goal of the EoR experiment is to directly detect emission from hydrogen during the epoch of reionization — the period just after the "dark ages" when stars are beginning to form and reheat the hydrogen and the modern universe is just beginning. There may be more than one epoch of reionization as recent WMAP and high redshift quasars are beginning to inform us. Our next steps are to develop a prototype two-element radio interferometer and testing to see what level of backgrounds and instrumental issues need to be overcome.

MULTIDISCIPLINARY RESEARCHERS AND STUDENTS

Over a period of 24 months, BCCP has attracted the talent of postdoctoral researchers, graduate students, numerous undergraduate students, and more than 45 scientists, and it engaged more than 100 researchers from around the world in its first annual cosmology conference in January 2009. **There is a now a core group of seven outstanding postdoctoral fellows (five funded by Moore and two funded from other sources),** enabling a critical mass of scholars who have begun to flourish and interact with outstanding senior researchers from Berkeley, Korea, and France, as well as with select graduate and undergraduates students. **On an annual basis, BCCP continues to recruit outstanding young students and extraordinary postdocs by offering them prestigious fellowships and a dynamic research environment at Berkeley.** As a result of George Smoot's international appointments (presented below in our Global Partnerships section), there is also strong interaction with the Laboratory of Nuclear and High Energy Physics at

the University of Paris VI and VII in France, and the Institute for the Early Universe at EWHA Woman's University in Seoul, South Korea.

Areas of current multidisciplinary 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 reionization (first stars) using radiation from the cosmic microwave background, redshifted 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 the Hubble Space Telescope's COSMOS survey.

BCCP POSTDOCTORAL FELLOWSHIPS

Future plans include increasing the current number of postdoctoral researchers from five to ten. Recruitment for BCCP's eighth postdoctoral researcher was launched in September 2009.

Dr. Anže Slosar

Anže Slosar is very excited about the forthcoming BOSS experiment, which began commissioning in August 2009. He wants to use the data from the BOSS experiment to constraint the properties of the dark energy at very high redshifts, which is in the early stages of evolution of the universe. In most standard models, the dark energy is completely negligible in the early universe, but observations of light from distant quasars can actually tell us if this is indeed the case or if nature holds new surprises for us. To this end, Slosar and his collaborators

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Dr. Oliver Zahn

During Dr. Zahn's first two \years at BCCP, he has joined three experimental collaborations that measure fluctuations in the Cosmic Microwave Background temperature and polarization. In addition, he has co-authored 19 journal articles on various topics in cosmology, most of which have already appeared in peer-reviewed journals. The experimental groups he has joined as a member are the APEX-SZ experiment, the South Pole Telescope (SPT), and PolarBear. Thus far, his work has focused on APEX-SZ and SPT. On APEX-SZ, he has worked with Christian Reichardt on measuring the angular power spectrum, a measure of fluctuations in the CMB, due to clusters and point sources. A bolometric array of ultra-sensitive detectors operating at 150 GHz, APEX-SZ has surveyed about 10 square degrees of the sky since 2005 with an angular resolution of 1 arcmin. A relatively deep and homogeneous 1 square degree region was chosen for the power spectrum analysis. I implemented a pseudo-Cl pipeline using SZ signal simulations created from a large N-body+Gas simulation, and noise simulations created from difference maps of various sets of scans of the experiment. Using pre-existing numerical tools from other experiments. The result is a ~3 sigma detection of excess power beyond the damping tail, the first such measurement at 150 GHz, as well as an upper limit on the amplitude of matter fluctuations on large cosmological scales. Through a joint parameter fit I interpreted this as a first detection of infrared source power in the CMB. The publication will appear in a few weeks. Most recently he has worked on inferring cosmological parameters from the SPT. While it has a similar detector technology to APEX-SZ, SPT is a dedicated survey observing from the South Pole, and it has achieved far larger sky coverage of 200 square degrees during its first full science observations season (2008). Furthermore, SPT also observes at three frequencies, 90, 150, and 220 GHz simultaneously. He implemented a Monte-Carlo Markov-Chain code to explore the multi-parameter space with two different point source populations, Sunyaev-Zel'dovich (SZ) effect owing to clusters of galaxies, primary CMB fluctuations, using the multi-frequency information. The preliminary results are a breakthrough 5-sigma detection of the SZ power spectrum amplitude, which allows to place a ~2% error on the amplitude of matter fluctuations. He expects to publish the power spectrum results in the next few weeks. He is presently working on the 2009 data, which have sufficiently low noise and large sky coverage to allow first-ever detections of the kinetic SZ effect.

Dr. Zahn's next longer-term goal is to develop a pipeline to detect gravitational lensing of the cosmic microwave background in the CMB using an optimized four-point estimator. While SPT's 2009 data in theory easily allow for such a detection, systematical uncertainties due to scanning pattern and beam asymmetry are making the construction of a practical algorithm challenging. Dr. Zahn also plans to get involved in PolarBear now that data collection has started. This is a polarization sensitive bolometric experiment currently observing in eastern California in two frequency bands in order to detect a stochastic background of gravitational waves from inflation and to push the field of CMB lensing one step further. These two endeavors are tightly related since a high S/N detection of inflationary gravity waves through the B mode polarization pattern in the CMB will require cleaning of lensing-induced B modes. Among the next generation of polarization experiments, APEX-SZ has the unique ability to measure both regimes, with its small beam of 4 arc-minutes and large sky coverage of 100 square degrees. In addition to his heavy involvement in interpreting CMB data, he has also been working on various theoretical projects with collaborators at Princeton and Harvard. One paper will quantify the effects of real-life instrumental systematics on the attempts to measure CMB lensing and gravity wave. In addition he is also working with Wayne Hu at the University of Chicago on systematic issues in lensing reconstruction caused by the presence of the thermal and kinetic Sunyaev-Zel'dovich effects. There are also problems with systematic biases of the standard estimators for CMB lensing that arise even in the absence of the SZ effects, which we aim to correct. These theoretical investigations will lay the groundwork for the systematics-assessment of the SPT lensing measurement. Furthermore, he is in the process of completing a paper related to his PhD field of interest of cosmological reionization. For the first time, he is exploring the degree of similarity between two different radiative transfer codes developed by his co-authors as well as two analytic algorithms developed by Dr. Zahn to describe the large scale distribution of ionized gas. He ran all these algorithms on the same large scale N-body simulation of the cosmic web during reionization. These simulations have significantly larger dynamical range than past simulations of reionization, and for the first time resolve the smallest galactic sources responsible for the process, as well as spanning 140 co-moving Megaparsec. In addition, the work makes forecasts for the redshifted 21 cm signal resulting from these simulations. In a separate project with collaborators at Princeton and UCLA, they have devised a semi-analytic scheme to establish halo catalogues that can, in

combination with the analytic reionization schemes, yield accurate descriptions of the large-scale distribution of sources and the ionization fronts they create. They do so with orders of magnitude less computational expense than full N-body simulations while increasing the dynamical range, while giving a highly accurate description of the distribution of the HII regions. All these results will be of immediate relevance to one of the first high-redshift 21 cm experiments built here at Berkeley, PAPER, for planning its scanning strategy, among other experiments being build e.g. in Australia and Europe.

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Dr. Tristan Smith

During Dr. Smith's first year as a Center Fellow, he has pursued various new ways to test our understanding of gravitational physics. One of the most important and fascinating predictions of Einstein's theory of general relativity is the existence of gravitational waves. These are ripples in space-time that travel through the universe in much the same way as water waves radiate away from a stone thrown into a pond. Although the effects of gravitational waves have been seen indirectly through observations of binary pulsar systems, the direct detection of gravitational waves remains a central goal in gravity research today. Many gravitational wave detectors have been built around the world (including two in the United States). In addition to these ground-based detectors, there are new efforts to use the exquisite precision of the timing of pulsar pulses to detect gravitational waves. Besides the exciting prospect of directly verifying the existence of gravitational waves, the ability to observe the universe in this new "light" will undoubtedly reveal new and completely unexpected aspects of the universe. In forthcoming work, along with Professor George Smoot and his student Noel Swanson, Dr. Smith has developed a new way to use observations of binary pulsar systems (as opposed to isolated pulsars) in order to directly detect gravitational waves. In addition to this they have found that the original (and often cited) derivations of the effects of gravitational waves on pulsar timing are not as rigorous as they should be especially given the importance of detecting gravitational waves. Along with Swanson, Dr. Smith has rigorously derived the effects

of a gravitational wave on the frequency of pulses from pulsars in three distinct ways and is the first to highlight the extent to which the standard derivation fails. Their work opens the way to using future observations of pulsars in order to both detect gravitational waves as well as test our basic understanding of gravitational physics in its most extreme and subtle aspects.

Besides pursuing these new tools to detect gravitational waves and confirm a central predication of Einstein's theory of general relativity, Dr. Smith has been active in looking for new ways to test our basic understanding of gravitational physics. In particular, the observation that the expansion of the universe is accelerating is by far the most pressing question in theoretical cosmology today. Many attempts to explain this observation within the context of Einstein's theory of general relativity have been put forth. In addition to these explanations, it is important to consider the possibility that the accelerated expansion is actually an indication that the predictions of general relativity are wrong and that these observations are pointing us towards a new understanding of how gravity works. To this end Dr. Smith has worked with several collaborators on articulating the predictions of various theories of gravity that are capable of explaining the observed accelerated expansion. In a recent paper Dr. Smith used observations of strong gravitational lensing around galaxies in order to place constraints on several specific gravity theories. These constraints are competitive with other tests of gravity both within the solar system and on the largest observable scales within the universe. He is currently working on improving these tests by including measurements of time-delays in light signals around these same galaxies in order to break degeneracies inherent in these measurements that were articulated in his most recent paper. Besides coming up with new ways to test our understanding of gravity, along with Dr. Eric Linder, Dr. Smith has been working on new theories of gravity that can account for the observed accelerated expansion. These new theories present some novel and interesting aspects especially when it comes to their predictions for how objects move in response to a gravitational force.

Publications:

1) "Testing gravity on kiloparsec scales with strong gravitational lenses." Tristan L. Smith, arXiv:0907.4829, Submitted to the Physical Review.

2) "The inflationary gravitational-wave background and measurements of the scalar spectral index." Tristan L. Smith, Marc Kamionkowski, Asantha Cooray, Physical Review D, 78, 083525 (2008)

3) "The effects of Chern-Simons gravity on bodies orbiting the Earth." Tristan L. Smith, Adrienne L. Erickcek, Robert R. Caldwell, Marc Kamionkowski, arXiv:0708.0001, Physical Review D, 77, 024015 (2008).

4) "Solar System constraints to general f(R) gravity." Takeshi Chiba, Tristan L. Smith, Adrienne L. Erickcek, Physical Review D, 75, 124014 (2007)

5) "Solar System tests DO rule out 1/R gravity." Adrienne L. Erickcek, Tristan L. Smith, Marc Kamionkowski, Physical Review D, 74, 121501 (2006)

6) "Non-Gaussian Covariance of CMB B-modes of Polarization and Parameter Degradation." Chao Li, Tristan L. Smith, Asantha Cooray, Physical Review D, 75, 083501 (2007)

7) "A new cosmic microwave background constraint to primordial gravitational waves." Tristan L. Smith, Elena Pierpaoli, Marc Kamionkowski, Physical Review Letters, 97, 021301 (2006)

8) "Deciphering inflation with gravitational-waves: cosmic microwave background polarization vs. direct detection with laser interferometers." Tristan L. Smith, Hiranya V. Peiris, Asantha Cooray, Physical Review D, 73, 123503 (2006)

9) "Average Extinction Curves and Relative Abundances for QSO Absorption Line Systems at 1 < z_abs < 2." Donald G. York et al., MNRAS, 367, 945-978 (2006)

10) "Direct detection of the inflationary gravitational-wave background." Tristan L. Smith, Marc Kamionkowski, Asantha Cooray, Physical Review D, 73, 023504 (2006)

Dr. Jeremy Tinker

Jeremy Tinker is working on the analysis of galaxy clustering statistics, both in the local universe and at high redshift. The questions that can be addressed with galaxy clustering are myriad; his work is directed both at using galaxy clustering to constrain cosmological parameters and at gaining fundamental insight into the processes that govern galaxy formation. Together with fellow BCCP postdoc Alexie Leathaud, Tinker will use the structure within the Cosmic Evolution Survey (COSMOS) to measure the evolution of both the galaxies within the survey and the dark matter the lies underneath the luminous objects. In order to understand galaxy evolution, one must first understand the relationship between dark matter and galaxies. Because dark matter dominates the mass of the universe, this relationship will determine much of the physics that drives galaxy formation. Clustering analysis provides a direct mapping between galaxies and dark matter — it tells us which galaxies occupy what dark matter halos. By measuring this correspondence over the redshift range of the COSMOS survey, roughly out to z=1 (over 7 billion years of the history of the universe), Dr. Tinker will determine the growth and star formation of the entire population of galaxies in the survey. A complementary aspect of this analysis involves mapping the evolution of the dark matter itself. High-mass halos within COSMOS can be detected through their X-ray emission. For these rare systems, the relationship between galaxies can be determined explicitly. Given these data, there is only one cosmology that can explain the number of galaxies within the X-ray systems and the overall level of galaxy clustering within the survey. This analysis provides a direct measurement of the growth of structure over half the history of the universe. These data will provide constraints on models of dark energy and modified gravity that seek to explain the accelerated expansion of the universe.

Currently, Dr. Tinker is finishing projects to implement these ideas in the local universe through measurements of galaxies and galaxy clusters in the Sloan Digital Sky Survey (SDSS). Covering nearly one-fourth of the sky, SDSS provides unprecedented precision. With these data, Tinker will constrain the present day cosmology to an accuracy that is competitive with current cosmic microwave background results.

Publications:

1) "Extending Recovery of the Primordial Matter Power Spectrum." Jaiyul Yoo, David H. Weinberg, Jeremy L. Tinker, Zheng Zheng, Michael S. Warren, Astrophysical Journal, 698, 967, (2009)

2) "Collapse Barriers and Halo Abundance: Testing the Excursion Set." Ansatz Brant Robertson, Andrey Kravtsov, Jeremy Tinker, Andrew Zentner, Astrophysical Journal, 696, 636 (2009)

3) "Interpreting the Clustering of Distant Red Galaxies." Jeremy Tinker, Risa Wechsler, Zheng Zheng, accepted to the Astrophysical Journal.

4) "The Clustering of MgII Absorption Systems at z=0.5 and Detection of Cold Gas in Massive Halos." Jean-Rene Gauthier, Hsiao-Wen Chen, Jeremy Tinker, Astrophysical journal, 702, 50 (2009)

5) "On the Redshift Evolution of MgII Absorption Systems." Jeremy Tinker & Hsiao-Wen Chen, accepted to the Astrophysical Journal.

6) "What Does Clustering Tell Us About the Buildup of the Red Sequence?" Jeremy Tinker & Andrew Wetzel, submitted to the Astrophysical Journal.

Dr. Sudeep Das

Sudeep Das joined BCCP in September 2009 after a one-year stint as a postdoctoral fellow at Princeton University. He received his Ph.D. from Princeton in November 2008 under the supervision of Professor David Spergel. His research revolves around the physics of the Cosmic Microwave Background (CMB) and its interaction with the large-scale structure (LSS) in the universe. Dr. Das is specifically interested in the gravitational lensing of CMB by the intervening structure, which is a powerful probe of Dark Energy and neutrino mass. His thesis focused on exploring this effect through theoretical calculations and high-resolution simulations. He has studied how the combination of CMB lensing and weak lensing of galaxies can be used to probe the geometry of the universe (Das and Spergel, 2009a), and

how the theories put forward for "explaining" an apparently anomalous Cold Spot in the CMB map from the WMAP satellite can be tested via their CMB lensing signatures (Das and Spergel, 2009b). With his colleagues, he has shown that galaxy bias information extracted with CMB lensing can be combined with upcoming redshift surveys to test General Relativity on cosmological scales (Acquavia, Hajian, Spergel and Das, 2008). He has also helped in showing how the lensing information from a futuristic CMB experiment will help break cosmological parameter degeneracies (Smith et al 2009). Dr. Das was among the first to develop an algorithm for simulating the effect of CMB lensing on large sky patches, respecting the curvature of the sky (Das and Bode, 2008). Over the past two years, Dr. Das has become deeply involved in the Atacama Cosmology Telescope Project (ACT), a six-meter telescope in Chile specially designed to measure the CMB anisotropies with unprecedented resolution and sensitivity. His lensing simulation has been incorporated into the data analysis pipeline of ACT (Sehgal, Bode, Das et al. 2009). With Amir Hajian and David Spergel, Dr. Das has developed a novel approach to the problem of measuring the power spectrum of the CMB from data on small sky patches – a problem relevant to ACT and all high-resolution CMB experiments (Das, Hajian and Spergel, 2009). This method improves over existing methods by optimizing the information recovery from CMB maps at small angular scales. Side by side with developing the theory of this method, Sudeep has led the development of software for power spectrum analysis for small-scale CMB experiments. Currently, he is heavily involved in the estimation of the power spectrum from the ACT maps. Recently, he has also become interested in the physics of the Lyman-alpha forest and its synergies with CMB experiments. He and his colleagues have shown that it is possible to measure the cross-correlation of the Lyman-alpha flux with CMB lensing using upcoming surveys (Vallinoto, Das, Spergel and Viel, 2009). Such measurements will shed light on neutrino mass and Dark Energy.

Over the coming months, Dr. Das will mainly concentrate on the problem of extracting the CMB lensing signal from ACT maps, and separating it from other secondary anisotropies. This will be one of the very first attempts at isolating the lensing signal from CMB maps alone. He will also continue his theoretical line of investigation. His current theoretical projects include investigating the cosmological information that can be extracted from combing CMB maps from the Planck satellite with infrared and sub-mm galaxy surveys, like Hershel.

He is also interested in the lensing signatures of alternative theories of the cosmic acceleration. Sudeep is also looking forward to starting successful collaborations with BCCP scientists to widen the scope of his research.

Publications:

1) "Simulations of the Microwave Sky." Neelima Sehgal, Paul Bode, Sudeep Das, Carlos Hernandez-Monteagudo, Kevin Huffenberger, Yen-Ting, Jeremiah P. Ostriker, Hy Trac, arXiv:0908.0540v2The Atacama Cosmology Telescope (ACT): Beam Profiles and First SZ Cluster Maps, A. D. Hincks, V. Acquaviva, P. Ade, P. Aguirre , M. Amiri, J. W. Appel, L. F. Barrientos, E. S. Battistelli, J. R. Bond, B. Brown, B. Burger, J. Chervenak , S. Das , M. J. Devlin et al., arXiv:0907.0461v2 (2009)

2) "Lenses in the forest: cross-correlation of the Lyman-alpha flux with CMB lensing." Alberto Vallinotto, Sudeep Das, David N. Spergel, Matteo Viel, Physical Review Letters, 103, 091304 (2009)

3) "CMBPol Mission Concept Study: Gravitational Lensing." Kendrick M. Smith , Asantha Cooray , Sudeep Das, Olivier Dore, Duncan Hanson, Chris Hirata, Manoj Kaplinghat, Brian Keating, Marilena LoVerde, Nathan Miller, Graca Rocha, Meir Shimon, Oliver Zahn, arXiv:0811.3916v1 (2009)

4) "Measuring Distance Ratios with CMB-Galaxy Lensing Cross-correlations." Sudeep Das and David N. Spergel, Physical Review D, 79, 043509 (2009)

5) "CMB Lensing and the WMAP Cold Spot." Sudeep Das and David N. Spergel, Physical Review D, 79, 043007 (2009)

6) "Efficient Power Spectrum Estimation for High Resolution CMB Maps." Sudeep Das, Amir Hajian, and David N. Spergel, Physical Review D, 79, 083008 (2009)

7) "Next Generation Redshift Surveys and the Origin of Cosmic Acceleration." Viviana Acquaviva, Amir Hajian, David N. Spergel, and Sudeep Das, Physical Review D, 78, 043514 (2008)

8) "A Large Sky Simulation of the Gravitational Lensing of the Cosmic Microwave Background." Sudeep Das and Paul Bode, The Astrophysical Journal 682 (2008)

9) "Testing a new analytic model for gravitational lensing probabilities." Sudeep Das and Jeremiah P. Ostriker, Astrophysical Journal 645 (2006)

Dr. Alexie Leauthaud, Chamberlain Fellow

Alexie Leauthaud probes the dark universe via measurements of weak gravitational lensing — the deflection of light from distant galaxies by intervening gravitational potentials. This is a purely geometrical effect, free from astrophysical biases and sensitive to all mass regardless of its baryonic or dark form. Mounting observational evidence for dark matter and dark energy represent a challenge to the standard model of particle physics and General Relativity's prediction for the behavior of gravity on large scales. Gravitational lensing techniques have a uniquely dual ability to probe both the growth of structure (which is dominated by the distribution of dark matter) as well as the geometrical distance-redshift relation (which traces the expansion history of the universe and can thus distinguish between a cosmological constant and more esoteric forms of dark energy). Given that all of existing scientific knowledge concerns the baryons, determining the nature of dark matter and dark energy is widely viewed as one of the most outstanding problems in physics.

Alexie's current work is focused on lensing measurements with COSMOS, the largest contiguous HST survey to date (cosmos.astro.caltech.edu). In particular, she is interested in using the galaxy-galaxy lensing technique in order to probe the relation between galaxies and the dark matter halos in which they reside.

Publications:

1) "Pixel-Based Correction for Charge Transfer Inefficiency in the Hubble Space Telescope Advanced Camera for Surveys." Massey et al. 2009, MNRAS in Press Giodini et al. 2009.

2) "Stellar and Total Baryon Mass Fractions in Groups and Clusters Since Redshift 1, ApJ, 703 Gabor et al. 2009.

3) "Active Galactic Nucleus Host Galaxy Morphologies in COSMOS, ApJ, 691, 705-722

Submitted Publications:

1) "Galaxy-galaxy lensing in the COSMOS survey: form and evolution of the mass-luminosity Relation." Leauthaud et al. 2009, submitted to ApJ.

2) "The effects of Charge Transfer Inefficiency (CTI) on galaxy shape measurements." Rhodes, et al. submitted to ApJ Capak et al. 2009.

3) "Spectroscopy of luminous z>7 galaxy candidates and sources of contamination in z>7 galaxy searches arXiv:0910.0444. Kovac et al. 2009.

Dr. Reiko Nakajima, Postdoctoral Scholar

Dr. Nakajima's main area of research is in the study of dark matter distribution in the universe. She is continuing her work on weak gravitational lensing around massive galaxy clusters. By carefully measuring the distortion in the shapes of the galaxies (which is due to the high concentration of dark matter that encompass these clusters), she intends to obtain an accurate measurement of the total mass in these clusters. A direct measurement of dark matter mass is not possible except for this gravitational lensing effect; this project will be the first to obtain a precise measurement of individual cluster masses, which will in turn yield a better constraint on cosmological large scale structure growth. This project involves observational data from Subaru Telescope in Hawaii and Multimirror Telescope (MMT) and Kitt Peak National Observatory (KPNO) in Arizona. Other observational projects by Dr. Nakajima include inspecting the average mass distribution around less massive concentration of dark matter, such as that of individual galaxies. This study will help constrain cosmological large scale structure and contribute to the galaxy information under the cosmological context, by connecting the easily observable galaxy to the extended dark matter distribution around it. This project involves observational data from the Sloan Digital Sky Survey (SDSS).

Publications:

1) "Improved Constraints on the Gravitational Lens Q0957+561. I. Weak Lensing." Reiko Nakajima, Gary M. Bernstein, Ross Fadely, Charles R. Keeton, Tim Schrabback (2009)

2) "Improved Constraints on the Gravitational Lens Q0957+561. II. Strong Lensing." Ross Fadely, Charles R. Keeton, Reiko Nakajima, Gary M. Bernstein (2009)

BCCP GRADUATE STUDENTS

Jessica Kirkpatrick

Jessica Kirkpatrick is working on quasar target selection for the Baryon Oscillation Spectroscopic Survey (BOSS) on the Sloan Telescope. She is using a likelihood estimator for selecting QSOs from SDSS photometry. Jessica is also using SDSS-II data as well as BOSS commissioning data to reconstruct photometric redshift distributions using a cross correlation technique outlined in Newman 2008.

Eric Huff

The distribution of matter in the universe on very large scales — the "cosmic web" of filaments and voids — encodes much of what can foreseeably be measured about the nature of dark matter and dark energy. Because most of the matter in this distribution is invisible, we can map it only with indirect methods.

The images of very distant galaxies are minutely distorted as light from these galaxies passes through the gravitational influence of the cosmic web on its way to our telescopes; these distortions are very small in amplitude, but coherent over much greater distances than any of the physical effects that determine the intrinsic properties of galaxies. By measuring statistical correlations in the shapes and orientations of very large numbers of

galaxies in modern sky surveys, it is possible to reconstruct the distribution of dark matter in the universe. Measurements of this effect, termed weak gravitational lensing, are the only known way to directly map out the invisible component of the universe. As a technique, weak gravitational lensing is still in its infancy. The signal is small and very difficult to measure, and most existing sky surveys are either too small, too insensitive, or lack sufficient image quality to detect a lensing signal on large scales at high significance. By combining many repeated scans of a large patch sky made by the Sloan Digital Sky Survey, Eric is constructing a data set capable of making a competitive, scientifically interesting weak lensing measurement on the largest scale to date with the intent to publish the key measurements over the course of the next year.

VISITOR/SABBATICAL SUPPORT

The Center is currently providing support to the following educators:

- Professor Eric Gawiser, Rutgers University
- Professor Kim Griest, University of California San Diego
- Dr. Jorge Luis Cervantes Cota, Advanced Institute of Cosmology, Mexico

WINTER SCHOOL: ESSENTIAL COSMOLOGY FOR THE NEXT GENERATION

The winter school/conference on essential cosmology for the next generation attracted 100 graduate students, postdocs, and researchers from January 12–16, 2009. The meeting combined high-impact lecture courses with state-of-the-art plenary talks and participant discussion sessions to explore and advance cosmology research and interdisciplinary training.

One of the most popular aspects involved the student research poster competition. The meeting was jointly organized by the Berkeley Center for Cosmological

Physics, the Instituto Avanzado de Cosmologia of Mexico, and the Excellence Cluster Universe of Munich, Germany. A public lecture by Professor Smoot (with parallel Spanish translation) drew several hundred locals, including 300 schoolchildren. While developing the framework of necessary and optimum observational and experimental cosmology programs, BCCP has begun to seed and incubate these next generation programs. The first of these include: BCCP and IAC have organized the next winter school for January 11–15, 2010 and drawn a new round of world-class course lecturers from MIT, the Institute for Advanced Study, Institute for Physics and Mathematics of the Universe in Japan, and Sussex University in the U.K. Main topics include the physics of cosmic microwave background polarization spectra and non-Gaussianity, large-scale structure surveys ongoing and in the future, and theoretical interpretation and experimental analysis of the latest data. We will repeat the successful interactive format and train a new group of students and postdocs. The courses and plenary talks are put on video and archived for webcasting — the 2009 lectures received more than 3,000 viewings on YouTube and are an invaluable resource benefiting students and teachers at underserved institutions.

GLOBAL PARTNERSHIPS

BCCP has key partners around the world who will contribute and share innovative resources and scientific information and are committed to coordinated Global Teachers Academy activities and outreach. With a focus on research and education collaborations, Professor Smoot has received appointments as the director of two separate centers of cosmology: 1) Institute for the Early Universe, EWHA Woman's University, Seoul, South Korea and, 2) Paris Center of Cosmological Physics, University Pierre and Marie Curie (Paris VI), Paris, France. The following are BCCP collaborators:

- Institute for the Early Universe, EWHA Woman's University, Seoul, Korea
- Incheon University, Incheon, Korea
- University Pierre and Marie Curie (Paris VI), Paris, France
- University Denis Diderot (Paris VII), Paris, France

- Instituto Avanzado de Cosmologia, Mexico

BCCP GLOBAL TEACHERS ACADEMY

A key component is the Berkeley Center for Cosmological Physics is the BCCP Global Teachers Academy (BCCP GTA). The BCCP GTA promotes and supports STEM education reform. Over a period of six months, the BCCP has attracted the interest of private community foundations and Fortune 100 corporations that are interested in supporting Professor Smoot's vision for science education reform. BCCP has invited a group of distinguished prospects to join the BCCP in its educational initiatives at the local, national, and global level. They include: S. D. Bechtel, Jr., Foundation, IBM Global Community Initiatives, Google, Target, Wal-Mart and Symantec. BCCP also has direct links to international research partnerships and global astronomy and physics education communities (Global Hands on Universe, European Global Hands on Universe and Contemporary Physics Education Project), whose members work to bring the "real world" of science, technology, engineering, and mathematics to classrooms around the world. These education partners are prepared to assist in the referral of teachers to the academy. Three significant advancements toward a fully funded and functioning BCCP GTA were accomplished in 2009:

1) The establishment of a template for a 21st-century teacher professional development model.

2) The identification of several large key teacher networks that view the BCCP GTA as fully aligned with their goals for reforming science technology, engineering, and mathematics (STEM) in their K-12 school districts.

3) The BCCP GTA has attracted the attention of corporations and foundations with large international STEM education outreach efforts. BCCP GTA is working to establish collaborations and partnerships at the local and international level.

4) BCCP held its third "Physics in and Through Cosmology Workshop" with a number of new dimensions being added.

5) Rollie Otto, the director for BCCP Education Outreach and the Global Teachers Academy, was invited to join the National Academy of Engineering panel looking at K-12 Engineering Education in the United States. As an invited speaker, he presented findings and recommendations to the NAE panel at a conference of California STEM educators and leaders jointly hosted by the California Council on Science and Technology and the National Academy of Engineering. The report calls for fully integrated STEM education in our K-12 schools and is gaining the attention of national STEM education policy makers. The BCCP GTA will be a model for this full integration, the use of information technology, and global teacher and student exchanges.

Global Teachers Academy – Workshop Summer 2009. The LBNL Physics Division and the Berkeley Center for Cosmological Physics hosted its third Physics in and Through Cosmology Workshop for QuarkNet Leadership teachers and their students. The workshop was held July 7–17 at the Berkeley Lab. Seven teachers participated: five of the seven active QN leadership teachers and two new teachers. Also participating were 23 high school students and five UC Berkeley undergraduate students supported through the Cal Teach (teacher preparation) program. Teachers represented public and private high schools in the greater San Francisco Bay Area. Students were nominated by their teachers and invited to attend the workshop. The diversity of student participants (seven young women and 16 young men, and no underrepresented minorities) was less than in the past due to limited support for recruitment.

The daily workshop format consisted of hands-on warm-up activities related to specific Cosmology concepts; talks by Supernova Cosmology and LHC scientists, postdocs and graduate students; presentations and lessons by participating teachers related to the day's theme: and project-based activities. Five groups, consisting of one or two QuarkNet Leadership teachers, four or five students, and one Cal Teach undergraduate were formed for the two weeks

and asked to produce a final report related to the famous scientist or key telescope/particle physics experiment. The daily themes were 21st Century Cosmology, Astronomy, Particle Physics, Cosmic Rays Detectors (Field Trip), Plank and CMB, Dark Energy, Dark Matter, LHC and Higgs, and Neutrinos.

Several innovations were introduced this year. A two way audio, video link was established for George Smoot's talk with students in a workshop at DUSEL. Facebook was used during the workshop for the deposit of pictures, comments and dialog within the five working groups during the workshop. A software program, INSPIRATION for concept mapping was used for assessment of student knowledge. Students and teachers were expected to utilize have their computers open and connected to the internet at all times and to freely use Google and other search engines

BRANDING AND MESSAGE

Branding and Marketing Firm: In the spring of 2009, BCCP contracted the services of the branding firm Peterson, Skolnick and Dodge (PS&D). PS&D has extensive experience in higher education marketing, branding, and admissions and philanthropy communications. PS&D has been fortunate to work with many UC clients over the years. And while each institution has clear distinctions, this firm was selected by BCCP as result of its considerable experience in understanding what makes research and education special — appealing to key constituencies.

The following message was created and has been formally integrated into BCCP's publications, web site, and collaterals:

"The Remarkable Journey — Heroic ideas in Cosmology.

"As humans we have always yearned to understand the universe and our place in it. That yearning is reflected in the ancient heroic myths about the creation of the universe that are part of the peoples and cultures around the world. Today, we are tantalizingly close to new breakthroughs in our understanding of the cosmos—thanks to "heroic ideas" in cosmology.

"Today's "heroic ideas" in cosmology are part of a long tradition of scientific curiosity, determination, and perseverance leading to great intellectual discoveries dating back to the earliest stargazers, and to Copernicus and Galileo. As was true in the Copernican revolution, the results of today's cosmology research will transform our thinking, our science, our technology, and our deepest understanding of what it is to be human in the universe.

"We need heroes of another kind to keep us on this path. We need 'heroic' supporters, visionaries who will invest in the next great breakthrough, in the next generation of scientists, and in science education that can level the playing field and inspire students from every community across America. I invite you to learn more, go deeper, and consider joining us on our quest. We promise a remarkable journey."

Creative Design Firm: BCCP retained the services of the design firm Alterpop to create logos that would represent the organization's research and education identity. The identity design has placed BCCP's "face forward" on its web site, proposals, information decks, pamphlets, business cards, letterhead, and other material. In April 2009, BCCP leadership selected a logo to match its brand and message.

The firm is currently working on a "collateral" logo to identify the Global Teachers Academy, and is also creating the organization media standards for design, media, and marketing materials.

Web Site Redesign: BCCP staff has interviewed three Internet firms and has selected the services of F5 Interactive to begin the process for development of a new web site. This web site will support information related to research, publications, collaborations, funders, events, a video library of presentations, and general contact information. The site will be representative of cutting-edge frontier science. It is anticipated that this project will develop over time since many locations throughout the site will not only be developed to inform but also to interact with BCCP staff, services, and programs. A section will be entirely dedicated to media including chat forums, blog links, and videos in order to share the latest on research and education. BCCP is exploring collateral opportunities for our web site and anticipated technology-based services that will support our 21st-century academy with corporations that include Google, IBM, and Symantec.

FUND DEVELOPMENT

Within just 24 months, BCCP has raised $2.5 million in grants and matching funds from UC Berkeley, and $5 million in endowments. Establishing a common set of messages for the Center's funding campaign is critical to its successful preparation and execution that will dramatically impact its ability to coordinate strategies for federal relations and to bring in new partners and investors to participate in the development of the Center programs of research, education, and long-term sustainability. BCCP has coordinated its fundraising activities with UC Berkeley's University Relations division (Vice Chancellor Scott Biddy's office). Key activities include:

1) Coordination with University Relations staff on prospects (individual, corporate, and foundations);

2) Research and vetting of relevant prospects;

3) Strategy approach development;

4) Proposal preparation and review; and

5) Involvement of UCB leadership, including Chancellor Birgeneau, Nobel Laureate George Smoot, Vice Chancellor Scott Biddy and key UCB alumni.

Over a period of six months, BCCP has developed a BCCP brochure, poster, and information deck (see Appendix B). The brochure, in its final phase of development, provides information related to our history, mission, vision, research, global collaborations and global teachers academy. Opportunities to support the BCCP are outlined throughout the pamphlet. This information will also be coordinated with our BCCP web site redesign. Priority areas of funding are: endowment, research, education, and operations. Other opportunities to build unrestricted funding via sponsorship of our annual conference, videos, and education workshops are in the development stage.

BCCP notes the following target audiences for investment and partnership:

Primary Audience

- National and international science and education community
- Frontier-science researchers in the fields of cosmology, astrophysics, theoretical physics, astronomy, and particle physics
- Global partners: other centers of cosmological research and education
- Federal agencies: Department of Energy, Department of Science, National Science Foundation

Secondary Audience

- National corporations that focus on science, space science, technology, communication, or engineering products and/or services that have a local and international presence as well as philanthropic foundations or community giving programs.
- National and local private or community foundations that have a giving focus in the areas of science, research, endowments, or science education.
- Individuals of high wealth who have an interest or have invested in science, technology, or engineering with a focus on astronomy, technology, or cosmology.
- UC Berkeley alumni who majored in STEM fields and who are in positions of leadership with a private business or corporations.
- UC Berkeley graduate and undergraduate students of George Smoot, and other individuals interested in cosmology, astronomy, and/or physics.

In developing the BCCP's fund development campaign activities and expenses, we are in the process of evaluating the staff and consultants needed to effectively and successfully manage the BCCP funding campaign. As part of this analysis, it has been agreed by leadership that it would prove advantageous to have the BCCP's executive director drive the funding model. Until additional funds are raised, BCCP will tap into operations and business support through LBNL and UCB staff.

Funding Goal

The overall fundraising goal for the campaign is $11.5 million over a period of three years.

Funding Model

The funding model targets corporations, foundations, and individual donors — all of which must be tapped into to raise this level of funding — and is divided into four categories: 1) donors who are already giving to BCCP; 2) prospects who are already engaged with BCCP but not yet giving; 3) new prospects; and 4) federal relations. The funding model is not meant to reflect exact dollar goals; rather, it reflects the mix of expected funding sources and will help guide how efforts should be prioritized.

OBJECTIVES	EXISTING FUNDER	EXISTING PROSPECT	NEW PROSPECT	TOTAL $ AMOUNT	TOTAL %
Individuals			$2.5 million	$2.5 million	22%
Foundations	$2.5 million		$1.5 million	$ 4.0 million	34%
Corporations		$2.5 million		$2.5 million	22%
Government			$2.5 million	$2.5 million	22%
Total $ Amount	$2.5 million	$2.5 million	$6.5 million	$11.5 million	100%
Total Percentage	22%	22%	56%	100%	

Notes: This model is meant to reflect the expected mix of funding sources and help guide where efforts should be prioritized. It is not meant to be a micro financial goal-setting model or to dictate that we meet these numbers specifically.

BCCP has launched fundraising activities including prospect identification, research, vetting strategies, cultivation meetings, letters of intent, and proposal submissions. Based on its current budget, which consists of funding from the Moore Foundation, match dollars, and assigned endowments, the following core needs that drive the fundraising have been identified:

1) BCCP Global Teachers Academy: Staffing, program operations, technology and cyber support tools, evaluation, administration.

2) BCCP Postdoctoral Research: Research staff support, supervisory staff, funding to support research activities, collaborative partners, equipment, facilities, travel, education.

3) BCCP Cosmology For the Next Generation Conference: Sponsorship support for postdoctoral attendees (international), speakers, conference venue, videotaping, posting of cosmology school presentation on web, dissemination of presentations to global cosmology community.

4) BCCP Web Site: Sponsorship support for cutting-edge web site that will present the latest in cosmology research to international cosmology community, development of media site that will be utilized by researchers, teachers and students, web-based tools associated with BCCP GTA.

5) General Operational Support: Support for executive and administrative staff, development activities, and general operations.

6) Endowment: Long-term support for BCCP.

As of May 1, 2009, BCCP has submitted approximately $2 million in proposals and letters of intent. The primary focus of its prospect cultivations has been with Fortune 100 corporations. More than 23 national corporations have been identified and are in various phases of cultivation. Proposal invitations have been made to BCCP from Honeywell Corporation, Symantec, Wal-Mart, and Target. Early cultivation and exploration of potential relationships are under way with Google, IBM, GE Foundation, Intel, and Motorola. Cultivations and

submission for private and community foundations include the S. D. Bechtel, Jr., Foundation and the Margoes Foundation. Early exploration is under way with the Stuart Foundation, Marin Community Foundation, and the Annenberg Foundation. In addition, University Relations has identified individual prospects and is developing internal strategies for approach and cultivation.

CENTER ADMINISTRATION

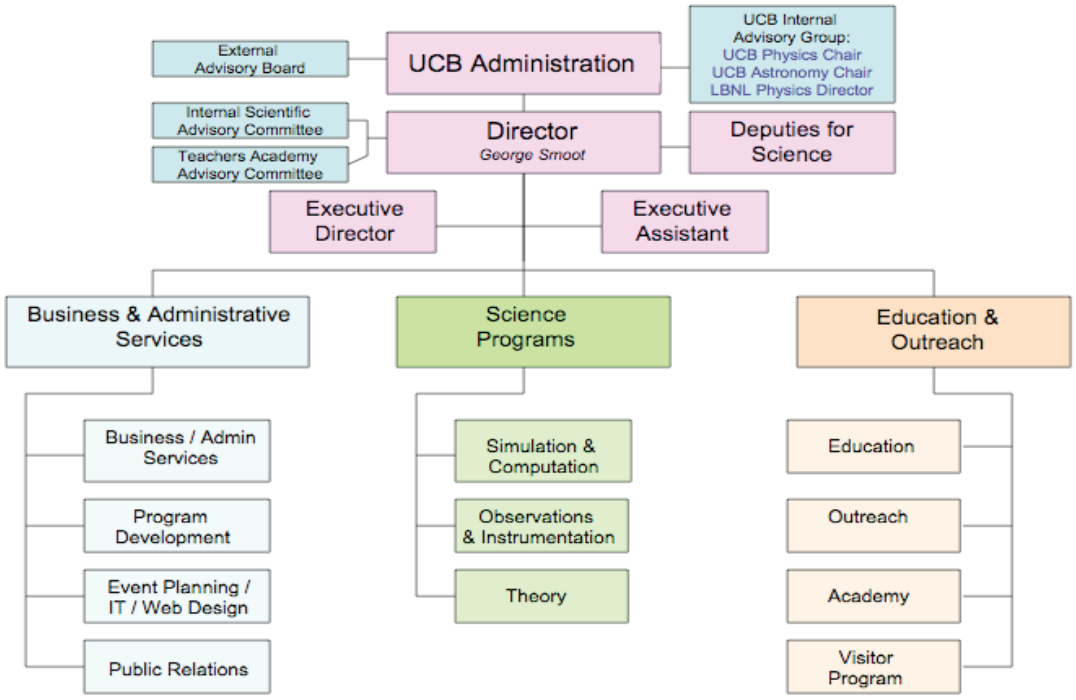
A strong business plan that includes operations, development, and long-term sustainability has been coordinated with UC Berkeley's University Relations division, the Office of Research, and Lawrence Berkeley National Laboratory.

Center staffing and partners. BCCP's key leadership includes:

- George Smoot, Founder and Center Director
- Lucia Ortega Villasana, Executive Director
- Eric Linder, Deputy Director
- Rollie Otto, Education Outreach and Global Teachers Academy Director
- Matisse Roach, Executive Assistant

In addition, staff from UC Berkeley's Department of Physics and LBNL's Physics Division provide in-kind support and resources associated to business operations, human resources, finance, and accounting. There are also key science and education leaders in the supernova cosmology program and the supercomputing center at UC Berkeley and Lawrence Berkeley Laboratory. Other key collaborators at the University and the community include nationally recognized outreach programs such as Cal Teach, a recipient of a National Math and Science Initiative award for increasing the number and quality of pre-service STEM teachers, and the Chabot Space and Science Center. The following organizational chart presents internal administration of the center. Activities associated to external advisory committees are in development.

The Berkeley Center for Cosmological Physics (BCCP)



Staffing

BCCP staffing has expanded since its first year of implementation. Roles and functions of key staff from UC Berkeley and Lawrence Berkeley National Laboratory, as well as select consultants, is outlined below. Most noted, BCCP did select and appoint the executive director, Lucia Ortega Villasana, who joined BCCP on November 1, 2009, and has focused her work on development and fundraising activities. Mrs. Ortega Villasana has an extensive background in federal, state, and corporate and foundation relations, and more than 14 years of experience in developing centers of research and education in the University of California system.

Activities associated to BCCP business and development administration are shared by UC Berkeley and Lawrence Berkeley National Laboratory. Staff meetings are held on a regular basis. Members of the staff are coordinating the business model with the funding model in order to meet the long-term research, education, and operational needs of the center as well as its sustainability plan. **The following table presents all relevant staff and their roles in BCCP.**

STAFFING and CONTRIBUTORS		
	Staff and Contributing Members	**Role**
BCCP		
LBNL	George Smoot	Founder and Director
UCB	Lucia Ortega Villasana	Executive Director – Development and Marketing – Corp, Foundation, Individual. Renewals and Prospect activity/Local, national and international.
UCB	Eric Linder	Deputy Director
UCB	Rollie Otto	Director of Educational Outreach
LBNL	Matisse Roach	Executive Assistant
UCB	Rosemary Nocera	Media and Web Site
UCB	Anze Slosar	BCCP Postdoc
UCB	Oliver Zahn	BCCP Postdoc
UCB	Sudeep Das	BCCP Postdoc
UCB	Jeremy Tinker	BCCP Postdoc
UCB	Tristan Smith	BCCP Postdoc
UCB	Alexie Leauthaud	Chamberlain Fellow
UCB	Reiko Nakajima	Postdoctoral Fellow
UCB Physics Division		
UCB	Carol Dudley	Recruitment and Personnel
UCB	Norma Ridayavedra	Travel and Purchasing
UCB	Maria Hejlm	Marketing and Development
UCB	Kathy Lee	HR Processing
UCB	Computing and Support	Technical Services
UCB University Relations		
UCB	Assistance Vice Chancellor David Blinder	Development of Strategies and Coordination with key UR staff
UCB	Jennifer Cutting	Major Gifts Director/Individuals
UCB	Office of Corporate & Foundation Relations	Research and Prospect Vetting
UCB	University Relations Support Services	Proposal Review and Assistance
Lawrence Berkeley National Lab		
LBNL	Anthony Spadafora	Operations and Business Development
LBNL	Diana Attia	Human Resource and Personnel Management
Other Key Contributors		
	William Green	Strategic Planning Activities
	Alterpop	Creative Design Services
	Peterson, Skolnick and Dodge	Brand and Messaging
	F5 Interactive	Web Redesign

HONOREE DOCTORATE DEGREES, APPOINTMENTS, AND AWARDS

Professor Smoot continues to receive recognition for his accomplishments and success. His status and the level of excellence he brings to BCCP is recognized around the world. The following outlines his most recent appointments, awards and presentations:

Appointments and Awards:

- Honorary Professor of Graduate University of Chinese Academy of Sciences Institute of Physics CAS (Beijing, China), November 14, 2008
- Rector Magnifico Doctor Honoris Causa — por la Universidad Miguel Hernandez de Elche al Alicante, Spain November 28, 2008
- Oersted Medal Award 2009 — American Association of Physics Teachers, February 14, 2009, Chicago, IL.
- Director, Institute for the Early Universe, EWHA Woman's University as a Distinguished Fellow of the EWHA Academy for Advanced Studies, Beijing, China, January 2009
- In March 2009, Professor Smoot accepted a directorship with the EWHA Woman's University in Seoul, South Korea, and formed a partnership with the University of California, Berkeley and the EWHA Woman's University to create a memorandum of understanding between both organizations.
- In June 2009, Professor Smoot accepted an appointment at the Centre for Astroparticle Physics and Cosmology, University of Paris, France.

PROMOTIONAL EVENTS

In July 2008 Professor Smoot was a contestant on the CBS/FOX Network television game show "Are You Smarter Than A Fifth Grader?" The appearance allowed him the opportunity to briefly discuss his work in science and highlight the Nobel Prize for millions of viewers nationwide. The showed aired on September 18, 2009. Professor Smoot also made a cameo appearance on CBS's Emmy Award-nominated comedy "The Big Bang Theory" in February 2009. The show is a weekly sitcom about four scientists. Since the television show began airing in 2005, two of Professor Smoot's science posters have been used as props for the set. The posters display his discoveries, making them a great way to promote science and his contributions to the field of science.

Over the past year, Professor Smoot and other BCCP staff and researchers have participated in various promotional events to raise the Center's 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 2009, BCCP participated in UC Berkeley's Cal Day event. BCCP set up a booth with the Physics Department and other UC Berkeley departments and research units. More than 84,000 participants attended, generating high visibility for BCCP.

Professor Smoot has also presented a number of talks and attended various seminars, fostering increased global visibility for BCCP. He discussed the Center and promoted all of the great work that it is producing in science. Among these include:

- September 4, 2008 — Chabot Space & Science 125th Anniversary Gala, Oakland, CA
- November 7–16, 2008 — Nobel Laureates "Harmony and Development of Human Beings," Beijing, China
- September 23–30, 2008 — Hypatia for Alejandria Teacher's Association, Orihuela, (Alicante) Spain
- December 16–19, 2009 — University of EWHA, Seoul, Korea

- January 12–19, 2009 — BCCP's "Essential Cosmology for the Next Generation," Los Cabos, Mexico
- January 16–19, 2009 — Rome Science Festival, "Universe and Space Explorations"
- February 12–16, 2009 — American Association of Physics Teachers Oersted Medal, Chicago, IL
- March 4–14, 2009 — Bridges Dialogues Towards A Culture of Peace, Thailand and Malaysia
- March 15, 2009 — University of VII, Paris, France
- May 6–10, 2009 — The Planck Launch, Kourou, French Guiana
- May 19–20, 2009 — Honeywell Technical Symposium, Glendale, AZ
- May 28–29, 2009 — Physics of the Standard Model of the Universe: Colegio de Espaia, Paris, France
- July 10–12, 2009 — "SciFoo Camp" Friends of O'Reilly," Santa Clara, CA
- July 13–15, 2009 — Singular University, Mountain View, CA
- July 15–21, 2009 — BCCP/Global Teachers Academy "Teachers for Summer Workshop," Berkeley, CA
- July 17–23, 2009 — Frontiers of Cosmology in Antarctica/Solar Eclipse, Beijing, China and Suzhou, China
- September 29, 2009 — City of Paris University, Nuit Blanche, "Exploration 360"
- September 30, 2009 — Paris-Berkeley Dark Energy Workshop, University of Paris 6 & 7 CMB, "Cosmology"
- October 2, 2009 — University, Marmar & Polytechnic University Istanbul, "Cosmology"

- October 14, 2009 — Embassy of Italy in Paris, Embassy of Italy in Paris, "World Status and Education"
- October 15, 2009 — Institute of France, Institute of France, "Comments on Induction of New Members"
- October 16, 2009 — Universite de Paris 6, Universite de Paris 6, "Advanced Cosmology and Progress"
- October 19, 2009 — Accademia Museum, Venice, Accademia, "Leonardo and Modern Science and Art"
- October 21, 2009 — Chalonge School Torino Italy, University of Turin & Chalonge School, "CMB Cosmology"
- October 21, 2009 — Piedmonte Regional Government Italy, Palacio - Public Events, "Modern Cosmology"
- October 23, 2009 — Mayan Skies - El Universo del Maya world premier, Instituto Polytechnic National Planetaria, "Maya Skies & Modern Cosmology"
- October 23, 2009 — Mayan Skies - El Universo del Maya world premier, Instituto Polytechnic National Planetaria "Maya Skies and Modern Education"
- October 26, 2009 — Congress Nacional Fisica - Plenary Talk 1st, Mexican Physical Society, "Cosmology Today"
- October 30, 2009 — Observatoire de Paris, Observatoire de Paris, "Advances in Cosmology"

CONCLUSION

Together, BCCP and the Gordon and Betty Moore Foundation continue to assemble a world-class team of researchers who are unraveling the physics describing the history and fate of the universe while collaborating with partners around the world. BCCP is successfully building its future in science and education, and continues to send a global message that it is a premier center of research and education. Prime examples of its success in research are associated with the science programs BCCP is incubating. Through the combined talent of Dr. Smoot, the BCCP postdoctoral team of researchers, and the global collaborators in Korea, France, and Mexico, BCCP will create the next generation of cosmology-related programs. BCCP enjoys a competitive process for recruitment and selection of its postdoctoral team, receiving more than 150 applicants from top institutions of education and research around the world. In 2009, BCCP successfully linked to the international scientific astrophysics and cosmology research community. Additionally, BCCP is pleased to launch its second Winter School — with the theme of "Essential Cosmology for the Next Generation" — to take place in January 2010.

With America's focus on STEM education reform, BCCP's education-outreach team and staff have enhanced the design for the BCCP Global Teachers Academy programs and are successfully creating an educational model that is attracting corporations, foundations, and government interest. The use of real science information and data, technology, and web-based tools will enhance the science and math skills of middle and high school teachers, increase classroom success, and inspire students to learn more about the field of cosmology. Collaborations with global education organizations of physics, cosmology, astronomy, and astrophysics such as the Chabot Space and Science Center, Quarknet, Hands on the Universe, European Hands on the Universe, and International Hands on the Universe has increased opportunities for BCCP to collaborate at the local, national, and international level. BCCP has forged strong connections with teachers and students throughout the Bay Area, the U.S., and internationally in Korea, China, France, and Japan. These activities will ultimately develop an international cohort of scientists, teachers, and students, and will serve as a model that levels the

playing field for America's students. This activity has peaked the interest of U.S.-headquartered companies with national and international presence such as Honeywell, Google, Symantec, IBM, and Target. Whether incubating the next generation of cosmological programs or exploring the joint development of new educational platforms for academic networking with Google or IBM, BCCP and Moore are making great strides.

BCCP and Moore are on the threshold of an exciting new era in scientific, astrophysics, cosmology research, and science education reform. We continue to appreciate the Moore Foundation's generous contribution to our goals.

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GORDON AND BETTY MOORE FOUNDATION
THE PRESIDIO OF SAN FRANCISCO
P.O. BOX 29910
SAN FRANCISCO, CA 94129-0910

CUMULATIVE
FINANCIAL REPORT

UCB File No.	**91922**
Report Type	**Interim**

Principal Investigator:	**Smoot, George F**
Title:	**Berkeley Center for Cosmological Physics**

Award No.	**1621**
Period: From-	**Nov. 15, 2007**
To-	**Sept. 30, 2009**

RECEIPTS:

UNEXPENDED BALANCE at	**Nov. 15, 2007**	**$0.00**
Cash received during the period		**$1,001,250.00**
STIP Interest Income		**$27,578.06**
Total Cash Available		**$1,028,828.06**

EXPENDITURES:		**Budgeted Amount**	**Actual Expense**	**Balance**	
Salaries/Wages		**$988,680.00**	**$550,358.31**	**$438,321.69**	
Employee Benefits		**$211,320.00**	**$104,851.94**	**$106,468.06**	
Educational Programs/Misc Expenses		**$102,578.06**	**$90,504.91**	**$12,073.15**	
Travel/Visitor Support		**$60,000.00**	**$47,822.74**	**$12,177.26**	
Total Direct Costs		**$1,362,578.06**	**$793,537.90**	**$569,040.16**	
Indirect Costs at	**12.50%**	**$166,875.00**	**$99,192.27**	**$67,682.73**	
Total Expenditures		**$1,529,453.06**	**$892,730.17**	**$636,722.89**	**$892,730.17**
UNEXPENDED BALANCE at	**Sept. 30, 2009**				**$136,097.89**

Esther Chang

10/12/2009

Prepared by: Esther Chang, Award Analyst **Date**
Phone: 510-643-6724; Fax: 510-643-8997
e-mail: estherc@berkeley.edu

cc: Smoot, George F

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DEPARTMENT OF PHYSICS
366 Le Conte Hall #7300
TEL: 510/642-7166
FAX: 510/643-8497

October 23, 2009

To Whom It May Concern:

Re: Matching funds, Gordon and Betty Moore Foundation Grant, Berkeley Center for Cosmological Physics (BCCP)

I am writing to confirm receipt of matching funds that were reported in the September 26, 2007 letter from Executive Dean Mark A Richards to Roslyn C. Kartychak.

1) $500,000 was received from the campus on June 19, 2007 in the form of an allocation of Chancellor's Office Income, fund number 69799.
2) Physics Professor and Nobel Laureate George F Smoot made a personal donation of $500,000 for the BCCP. These funds were received October 9, 2007 and were established as an endowment, #W6043, The Center for Cosmological Physics Fund.

In addition to these funds, the following matching funds have been received by the campus or are in progress:

1) The Thomas C. and Alison Schneider Chair in Physics, designated for Cosmology
   Pledged: $1 million in December 2007
   Paid to date: $490,875 on December 31, 2007
2) The Michael Garland Chair in Physics, designated for Cosmology
   Pledged: $1 million in March 2008
   Paid to date: $250,000 - $204,000 on April 23, 2008 and $46,000 on June 18, 2008
3) Gary Bengier for Alex Filippenko's Palomar Transient Finder Project
   Pledged: $120,000
   Paid to date: $80,000 - $40,000 on March 3, 2008 and $40,000 on March 3, 2009

Sincerely,

Claudia Ayala Lopez
Director of Administration
Department of Physic

Cc: Chair Frances Hellman
Professor George F. Smoot
Executive Director Lucia Ortega Villasana