A Newsletter from the Kavli Institute for Theoretical Physics at UC Santa Barbara

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Why Care About Type Ia Supernovae?

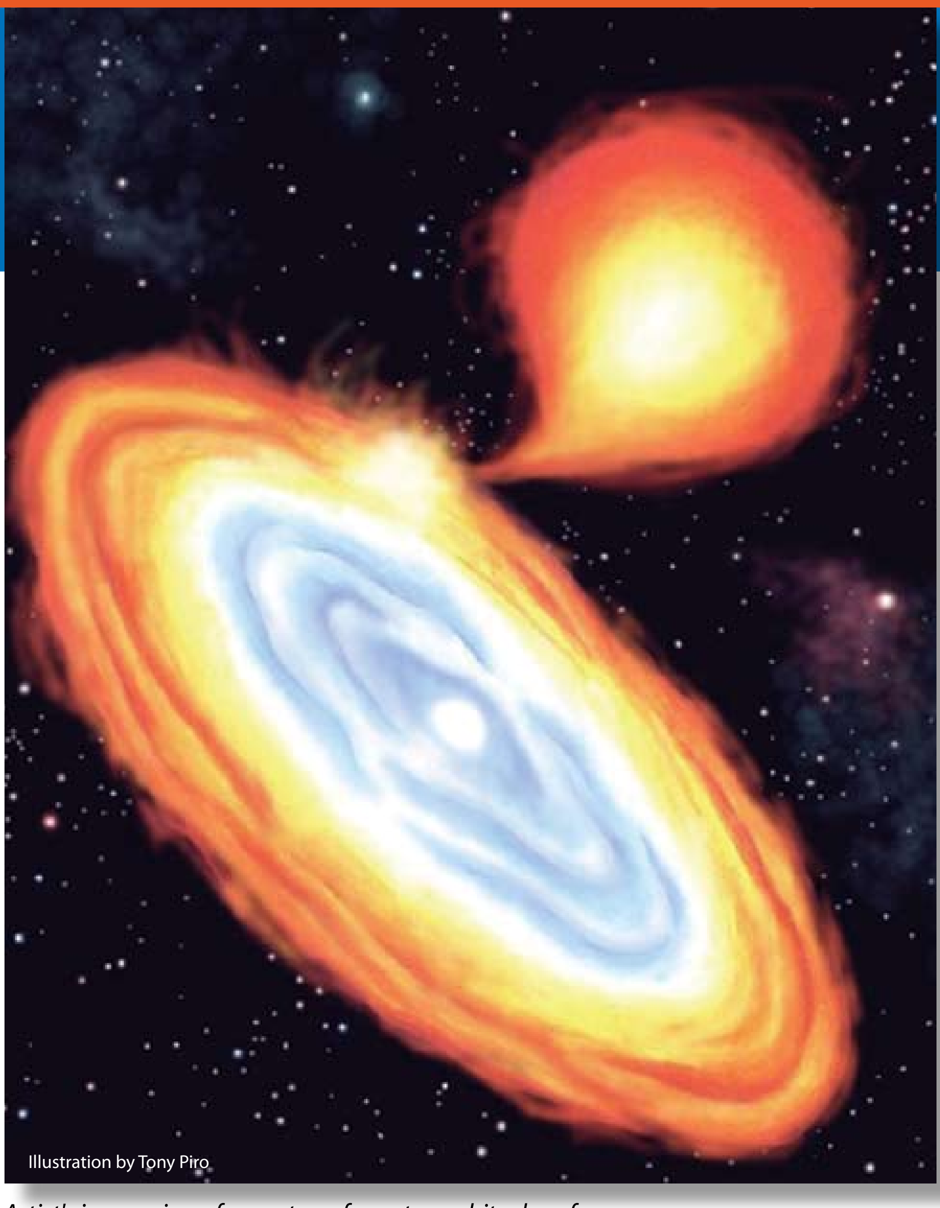

Illustration by Tony Piro

Artist's impression of mass transfer onto a white dwarf.

IN APRIL OF 1006 occurred the brightest stellar event so far in recorded history, visible for months at a time, on and off, for years afterward. According to Cairo astrologer Ali ibn Ridwan, "its brightness was a little more than that of the quarter of the Moon."

Almost exactly a thousand years later, astrophysicists and astronomers gathered at the Kavli Institute for Theoretical Physics in Santa Barbara to try better to understand the phenomenon exemplified by the 1006 event. That spectacular phenomenon—most probably the thermonuclear explosion of an elderly star known as a "white dwarf"—is called a "type Ia supernova."

Such events occur close enough to be visible to an unaided observer on Earth about once every 200 years. As rare as they seem from the vantage of this planet, type Ia supernovae are quite common occurrences in the universe as a whole, with an estimated rate of one per second, according to astrophysicist Lars Bildsten, KITP permanent member and an organizer of the program "Accretion and Explosion: The Astrophysics of Degenerate Stars" (Jan. 29 to June 1, 2007).

There is a tradition at the KITP of blackboard luncheon talks on Mondays. Typically, two or three programs addressing very different scientific issues and attracting very different types of physicists run concurrently at the KITP. For the Monday blackboard talks, a presenter from one program pitches the talk so that scientists attending the other programs can readily grasp key questions perplexing colleagues in the presenter's program.

Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics, another of the four supernova program organizers, ended her blackboard talk (on the dynamics of two possible star pairings conjectured to lead to Ia supernova events) by asking rhetorically, "Why care?" and herself answering, "Cosmology."

This kind of supernova is the tool used by two teams of astronomers in the mid to late 1990s to make inadvertently what is surely one of the most momentous discoveries of the century. They found that the expansion rate of the universe is speeding up when most folks (including them) who had even thought about the expansion formulated by Hubble and Humason in 1929, thought it was slowing down.

That finding in turn means that something counteracting the force of gravity, which is exerted by matter both ordinary (baryonic) and dark (yet to be identified), has to account for the speeding up, and that

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From the Heart

"CARDIAC DYNAMICS," a month-long, KITP mini-program held in the summer of 2006, brought together physicists, cardiologists, and biomedical scientists and engineers for interdisciplinary collaboration on the application of techniques of non-linear dynamics to understanding the sub-set of cardiac arrhythmias that are potentially fatal.

When the lower, bigger chambers of the human heart—the ventricles—quiver or fibrillate, death almost always ensues unless a defibrillator is applied to halt the fatal process. Ventricular fibrillation generally follows a regime of rapid rhythm or ventricular "tachycardia" (not to be confused with the heart "flutter" people typically sense as an arrhythmia, which pertains to the upper, smaller chambers or atria).

In the United States, more than half the sudden deaths due to cardiac disease follow directly from ventricular tachycardia and fibrillation. The only efficient method currently available to prevent cardiac death is to deliver a huge electrical shock to the fibrillating heart, wiping out the vortices that cause fibrillation. However, these shocks may irreversibly damage heart tissue.

"Developing a fundamental understanding of the mechanisms that trigger and maintain life-threatening cardiac arrhythmias is crucially important for designing anti-arrhythmic therapies that successfully reduce mortality," according to the proposal submitted by mini-program organizers.

Ventricular tachycardia and fibrillation represent extremely complicated non-linear patterns in both space and time that are "multi-scale" problems, encompassing a

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INSIDE...

Scholars Program Infuses Vitality Into Research Efforts Of Physicists Who Mostly Teach Undergraduates

"COMING TO SANTA BARBARA as a KITP scholar is like joining a brotherhood in a place of worship. To physicists it is as Jerusalem is to the Jews or as Mecca is to Muslims with [KITP director] David Gross as custodian of the Holy Shrine," said Eugene Chudnovsky, whose duties as a physics professor at the City College of New York (CUNY) focus principally on the teaching of many, many undergraduates.

In language plainer, but less gender-specific than Chudnovsky's, though nonetheless appreciative, Donna Sheng of Cal State University, Northridge, said, "Being a KITP scholar was an exciting learning experience for me. It provided me a best chance to work as a real researcher like others from a research university."

Carlos Ordonez, a physics professor at the University of Houston, said, "Being able to spend time at KITP is giving me a wonderful opportunity to be where the action is in theoretical physics, which will have a very positive impact on my research and personal life in manifold ways. I dearly thank KITP for this."

Established for theoretical physicists such as Chudnovsky and Sheng and Ordonez, the KITP Scholars Program, funded by the National Science Foundation (NSF), aims "to support the research efforts of faculty at U.S. colleges and universities that are not major research institutions," according to the mission statement. "Applicants from non-Ph.D.-granting institutions and from institutions with greater emphasis on teaching (as measured, for example, by teaching load) are particularly encouraged."

The one other certain requirement of applicants is the demonstration of "ongoing research activity."

"Ten years ago, when I came to the KITP as director," said David Gross, "I wanted to start a program for theoretical physicists who are endeavoring to continue a research career while working at institutions whose principal mission is teaching undergraduates.

"I thought that it was a pity that some of our students who are educated in theoretical physics who don't end up at research universities, but at teaching institutions have such a difficult time pursuing a research career. Many, in fact, choose not to continue careers in higher education or even industry, but leave the profession for Wall Street."

That disaffection, Gross said, "seems an enormous waste of resources."

He said that he took his cue for establishing the KITP Scholars Program from mathematicians, who have a history of combining research with a career in undergraduate teaching. Mathematics, like theoretical physics, does not require extensive and expensive laboratory facilities in order to do research, but access to an intellectually stimulating and supportive environment.

Each KITP scholar award funds a total of three round trips to Santa Barbara and up to six weeks of local expenses, to be used over a period of up to three years. To date 24 scholars have been selected, and it is expected that seven more will be chosen this year.

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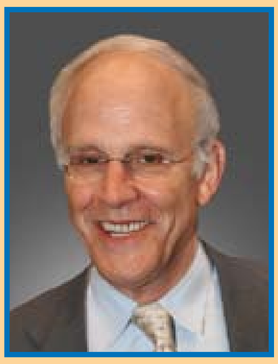
From the Director



Tony Mastres

AT THE END OF MAY, the Kavli Institute for Theoretical Physics China (KITPC) was inaugurated in Beijing in a ceremony at the Great Hall of the People. We extend our hearty congratulations to our sister institution, which in many ways is modeled after the KITP here in Santa Barbara.

This modeling is no surprise since I was asked two years ago to help the Institute for Theoretical Physics in Beijing (which was founded one year before the ITP was founded in Santa Barbara) to reform and extend their scope of operations in accordance with China's decision to invest vast resources in the development of basic science and technology.

Not surprisingly, the advice of the International Advisory Committee that I put together was to follow the lead of the KITP by initiating programmatic activity that would bring world-class scientists to China from around the world to work together on research problems in leading areas of physics and closely related subjects.

In a remarkably brief period of two years, our Chinese colleagues and we on the International Advisory Committee worked together to fashion a new institute, which Fred Kavli was generous enough to support, along with a second institute in Beijing (the Kavli Institute for Astrophysics and Astronomy).

Though our sister institution is in many ways modeled after the KITP, it has an additional, important pedagogical mission aimed at enriching the physics education for China's young people. The KITPC aims to run short-term schools on specific topics as well as create and administer allied, educational programmatic efforts.

We welcome the Kavli Institute for Theoretical Physics China to the growing constellation of Kavli institutes and look forward to mutually beneficial collaborations.

David Gross

Heart CONTINUED FROM PAGE 1

range of dynamics from the operation of ion channels in a single cell to the wave movement of ion channel operation in tissue (from cell to cell) to the beating of the heart itself over a lifetime.

The physics approach to the problem of cardiac dynamics is through the study of excitable media that can form spiral waves.

One important aspect of cardiac dynamics is akin to the behavior of a forest fire that burns vegetation in a moving, wave-like pattern. The forest cannot re-burn—another wave of fire cannot propagate—until the forest has re-grown. That necessary period of recovery when a wave cannot be propagated is characteristic of non-linear excitable media. Anomalous spacial variation in such regions can initiate wave patterns leading to fatal cardiac arrhythmias.

The month-long program in 2006 followed from a four-month KITP program on "Pattern Formation in Physics and Biology" in the fall of 2003 that devoted one week" to cardiac dynamics. Written feedback on that experience showed that the cardiologists especially appreciated and were stimulated by the questions the physicists raised, according to "Pattern Formation" program organizer and physicist Eberhard Bodenschatz of the Max Planck Institute of Biophysical Chemistry in Göttingen, Germany.

Bodenschatz also served as an organizer of the 2006 "Cardiac Dynamics" mini-program. Its other organizers included biomedical engineer Emilia Entcheva, State University of New York, Syracuse; physiologist Robert Gilmour, College of Veterinary Medicine, Cornell University, Ithaca; physicist Alain Karma, Northeastern University, Boston; and physicist Valentin Krinsky, CNRS Institute for Non-Linearity, Nice, France.

In conjunction with the mini-program, Karma, gave a public lecture for the Friends of KITP and the community. That lecture, "Ways of the Heart: Taming Cardiac Fibrillation," is available through the KITP web site at www.kitp.ucsb.edu by following the links from "Talks" at top through "Public Lectures" under the alternate title "Bringing Order to Chaotic Hearts."

Karma and Gilmour also co-authored an article, "Nonlinear Dynamics of Heart Rhythm Disorders," which appeared in the March 2007 issue of *Physics Today*. The authors note, "This article grew out of an interdisciplinary workshop on cardiac dynamics hosted in July 2006 by the Kavli Institute for Theoretical Physics in Santa Barbara, California, and supported by NSF, the Burroughs Wellcome Fund, and DARPA."

Nell Campbell

Participants in "Cardiac Dynamics" mini-program

Scholars Program CONTINUED FROM PAGE 1

"We have been pleasantly surprised by the large number of excellent and highly qualified scientists who maintain research careers at teaching institutions throughout the country," said Gross. "Every year we typically have twice as many applicants as we can choose, and the number of new applicants continues to grow from year to year, so there is quite a large population out there whom we are serving by this program."

Scholars are encouraged to time their visits to coincide with programs and conferences particularly advantageous to their research pursuits. Each scholar is assigned a KITP permanent member as a resource for research support and guidance.

Gross describes the program as a "morale booster for scientists who otherwise can be somewhat isolated either in the small departments of colleges or in institutions where faculty colleagues no longer pursue research at the edge."

Said Arjendu Pattanayak of Carleton College in Minnesota, "One of the things I've realized about myself is that I do a lot of my thinking by talking about it, but that I also need a lot of alone time. That's hard to do in the context of a small college atmosphere for two reasons—the teaching load means there's little 'down time,' and the small faculty size means that there is a lack of other scientists in my field (or graduate students and post-docs). KITP is a great place for that kind of interaction. I spent an intense few hours talking to an experimentalist—Vladan Vuletic [MIT]—on one trip that helped me greatly clarify what I was doing."

"If more people could take advantage of career opportunities such as the KITP Scholars Program affords," said Gross, "it would enormously benefit teaching institutions since these are incredibly qualified people who would make excellent teachers and could introduce young undergraduates to science as it is really performed."

William Putikka of Ohio State University in Columbus explained how the KITP Scholars Program had benefitted him professionally, "From my point of view, the most important thing is recognition from the larger community of physics. Faculty positions with heavier teaching loads generally make it more difficult to win recognition at the national level (grants, awards, *etc.*), so it is nice to have something targeted at this population. This kind of recognition carries considerable weight with other local faculty and the university administration."

Said Gross, "We hope to encourage young people and to promote the idea that there are such opportunities in addition to staying at a top research university and trying to be exactly like their graduate advisors." He noted that "The KITP Scholars Program addresses the needs of physicists who really like teaching and prefer to be at a teaching college."

The KITP Scholars have, of their own accord, gone on to "self-organize" or form a support network aided by a one-week mini-program held four years ago, which attracted about 30 participants from primarily undergraduate teaching institutions.

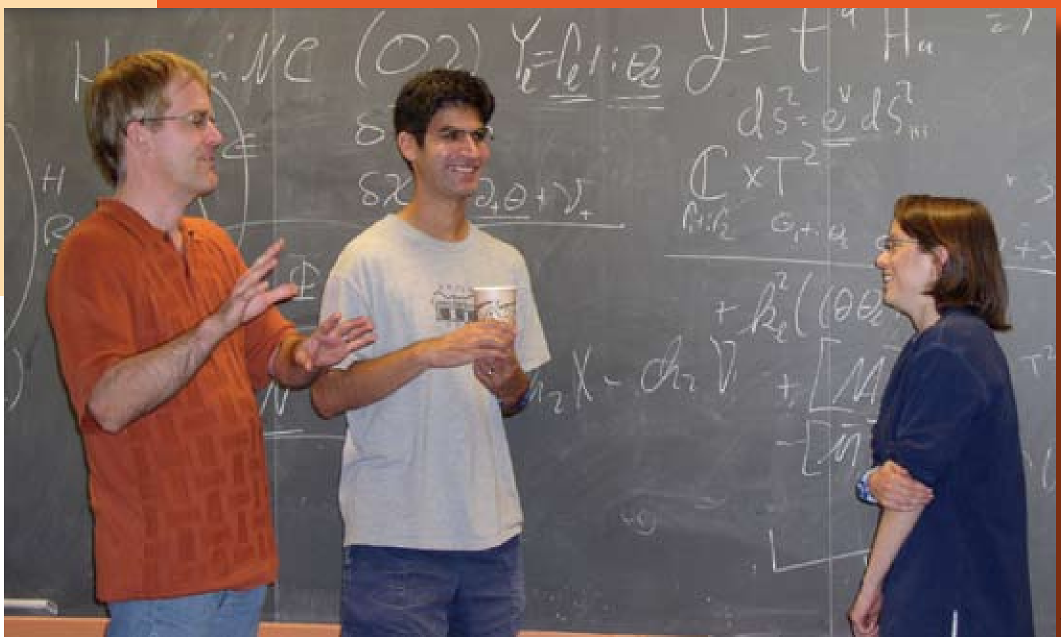
The experience of that program in turn led to efforts to create a nation-wide organization to promote the interests of this population of physicists. The KITP is sponsoring a two-week workshop this summer from July 16 to 27 to enable scholars to establish that organization.

Herbert Bernstein of Hampshire College in Massachusetts, who has spearheaded that effort to organize, recalled a chance conversation with three other physicists that took place during a summer workshop on quantum information in Cambridge, England. "Noting that we all taught at liberal arts colleges (and internally marveling at how incredibly good the others were—really smart scientists who had done something important), I quipped that 'We should help support each other by forming LARPA—Liberal Arts Research Physicists Association.'

"And lo and behold, two of the four professors from that chance encounter (myself and Don Spector [Hobart and William Smith Colleges, Geneva, N.Y.]) are organizers of a workshop at KITP this summer whose express purpose is to support theorists at undergraduate institutions in America and to form an organization to institutionalize such support!"

Peter Malinowski

String Phenomenology Revs Up in Anticipation Of LHC Turn on



Charmien Carrier

"String Phenomenology" program organizers, Joe Lykken, (l) of Fermilab, and Shamit Kachru and Eva Silverstein of Stanford

STRING THEORY, initially conceived in the late 1960s to explain the strong force that traps quark triplets in protons and neutrons, is no longer all that "new."

With the discovery of the correct theory of the strong interactions in 1973, string theory became a backwater of particle physics for a decade until Michael Green of Cambridge University and John Schwarz of the California Institute of Technology discovered that string theory could incorporate both quantum mechanics and general relativity. That discovery set off a sustained exploration of the dazzling intellectual terrain opened by the string/brane approach to a theory of fundamental physical reality, which has now gone on for more than 20 years.

To some observers, both lay and scientist, the intellectual terrain opened by the theory has seemed to stretch out in directions and dimensions ever further from ordinary observations of reality. And, accordingly, string critics have on and off for almost two decades pointed to how developments have taken place solely in the heads of theorists whose feet have strayed from the path of experiment.

That disjunction between theory and experiment is what makes the program "String Phenomenology," which ran at the KITP from Aug. 7 to Dec. 15, 2006, seem to some an incarnate oxymoron.

"'Phenomenology,'" explained program organizer Gordon Kane, "is a term that applies in physics only to particle physics. In the other fields of physics," said Kane, "there are experimentalists and there are theorists. Only in particle physics is there a further distinction among theorists who incline either towards phenomenology or towards formalism."

Accelerator facilities collide particles, and the aftermath of the collisions is recorded via detectors. In order to "read" that data, phenomenologists first have to convert the theory of, say, a quark into its signature in the detector. So phenomenologists are in particle physics the middlemen between experiment and theory.

Kane characterizes the newly emerging role of phenomenology in string theory as the attempt to connect the theory to nature.

"A few years ago, almost nobody would allow that there was something called 'string phenomenology,'" said Kane. "What people said then was, 'Until you figure out string theory, you can't do phenomenology.' Now I think that is exactly opposite of what will happen. I think we'll figure out string theory by doing phenomenology."

After more than two decades of theory development, finally there are nearing completion facilities whose experimental results can be used to guide the theory—the Large Hadron Collider (LHC), set to turn on soon at CERN, in Geneva, Switzerland, and the Planck Satellite soon to be launched by the European Science Agency (ESA) to explore further the cosmic microwave background radiation and the newly discovered changes in the expansion rate of the universe. Interestingly, both these grand efforts to probe deeper into fundamental reality are based, not in the United States, but in Europe.

The KITP "String Phenomenology" program was designed to enable participants to anticipate the results of these experiments and ask how what is seen might relate to string theory and vice versa.

Supersymmetry

Data to issue from experiments conducted at the LHC are expected to determine whether low energy supersymmetry (SUSY) exists or not. "Low energy" is relative here to the colossal energies that pertained in the early universe because the TeV (trillion electron volt) energy-scale of the particles accelerated at the LHC will exceed by an order of magnitude energies achieved in previous accelerator experiments.

Almost as old as string theory, supersymmetry is an idea that emerged in the early 1970s from hints coming from early efforts at string theory. It requires extra, quantum dimensions of space (not to be confused with the extra spatial dimensions of string theory). These quantum dimensions are characterized by anti-commuting numbers (*i.e.*, *ab* is not equal to *ba*, but rather *-ba*), whereby every fermion has a bosonic super-partner and vice versa. Or, to put it another way, for every one of our known particles, such as the quark and electron and photon and neutrino, there exists a more massive super-partner (respectively, "squark," "selectron," "photino," and "sneutrino").

According to supersymmetric theories, half the particles have so far been discovered. And, notably, the lightest supersymmetric particle(s) to which all the others would decay at the low energies of our world and present universe—the neutralino—is one of the strongest candidates for the dark matter that astrophysicists have discovered makes up most of the matter in the universe.

Supersymmetry also enables the unification of the three forces of quantum mechanics—the electromagnetic and the weak (already unified in the electroweak theory) and the strong—with each other and with gravity. At high enough energies and at short enough distances, gravity, which is (relative to the other forces in our everyday world) extraordinarily weak, becomes as strong as the other three forces. Each of the forces then is a low energy manifestation of one force.

If Kane is an expert on and long-time enthusiast for supersymmetric theories, another "String Phenomenology" program organizer, Eva Silverstein, has a career-long interest in the complicated problem of supersymmetry breaking.

The world as we know it is not supersymmetric, so for supersymmetry to have existed, it had to have been broken somehow in relation to some energy scale. The question is whether that scale is as low as the TeV scale of the Large Hadron Collider.

Silverstein, whose research has focused, among other areas, on understanding the compactifications of the extra spatial dimensions that string theory requires, is "eagerly awaiting the LHC results on physics at the TeV scale."

So far, efforts to understand how the extra dimensions of string theory are curled up or compactified have mostly centered on Calabi-Yau manifolds, which accord with low-energy supersymmetry. Silverstein has been working on a less supersymmetric class of compactifications.

Whatever the verdict rendered by experiment at the LHC on low-energy SUSY, string theorists such as Silverstein benefit because they acquire a sense of direction for the theory. It is almost as if she and kindred string theorists have said, "If low-energy SUSY is discovered, that's great! But if it isn't, then what space-shape could account for those extra dimensions?" In other words, the anticipation of experimental findings—whatever the outcomes—itself spurs theoretical research, and that impetus is the glory of this new string phenomenology.

Other space-shapes

Seated in her office during the program, Silverstein said, "I am enjoying the KITP now because of the presence of a lot of expertise in the study of more generic compactification manifolds than people normally study. People have almost exclusively focused on Calabi-Yau manifolds, which involve turning off the leading terms in the potential energy that you obtain from a more generic starting point in string theory.

"But looking from a so-called top-down point of view, we try to see if string theory in itself leads to a preference for any particle kind of low energy physics. If we take that point of view, then we need not make too many assumptions from the start, and most spaces that could be shapes for the extra dimensions of string theory are not Calabi-Yau, but spaces with more curvature, and," she adds, "those with some negative curvature are by far the most generic among the possible geometries. This study is really interesting both for the potential application to low energy physics obtained from such compactifications and for the description of space and time that is different from naive general relativity or point particle geometry.

"This interpretation of a string theory in extra dimensions is what's new," she said, and admits that "It is not yet translating into an observable signature, but these kinds of things have a way of doing so after you understand them."

Participants in the "String Phenomenology" program frequently used a metaphor to describe the state of string theory research. They talked about "living near the lamppost or not"—*i.e.*, working where there is enough light to enable seeing what has mostly already been seen, but being kept, by the safety of the lighted way, from getting lost in the greater, dark surrounding terrain, where likely the answers lie.

Kane added an old twist to the new metaphor, "There is a joke about the drunk who looks under the lamppost for the keys to his car. He knows he dropped the keys elsewhere, but prefers to look where there's light."

In addition to Kane of the University of Michigan and Silverstein of Stanford University, other organizers of the program included Michael Dine of the University of California at Santa Cruz, Shamit Kachru of Stanford, Joe Lykken of Fermilab, and Fernando Quevedo of Cambridge.

Polchinski Receives Prestigious Heineman Prize

Kevin Barron

JOSEPH POLCHINSKI, a permanent member of the Kavli Institute for Theoretical Physics, has been named 2007 recipient of the prestigious Dannie Heineman Prize for Mathematical Physics. He shares the prize with Juan Maldacena of the Institute for Advanced Study in Princeton.

The pair of theoretical physicists is cited "For profound developments in Mathematical Physics that have illuminated interconnections and launched major research areas in Quantum Field Theory, String Theory, and Gravity."

Administered jointly by the American Physical Society (APS) and the American Institute of Physics, the Heineman Prize was established in 1959 to recognize outstanding research in the field of mathematical physics. The prize was awarded at the annual APS meeting held in 2007 in April in Jacksonville, Fla.

Polchinski, the principal discoverer of D-branes and their properties, is widely recognized as one of the leading field and string theorists of his generation.

String theory affords the best approach to date to a grand theory that encompasses gravity and the other three forces described by the Standard Model of particle physics (the electromagnetic, weak and strong forces). Strings and branes are the essential structures in string theory.

Instead of being only one-dimensional like strings, branes can have any dimensionality, including one. One-dimensional branes are called "D1 branes or D strings." So there are essentially two types of strings—the "heterotic" string or "F" (for "fundamental") string, which physicists knew about prior to Polchinski's 1995 discovery, and the "D string," or one-dimensional brane.

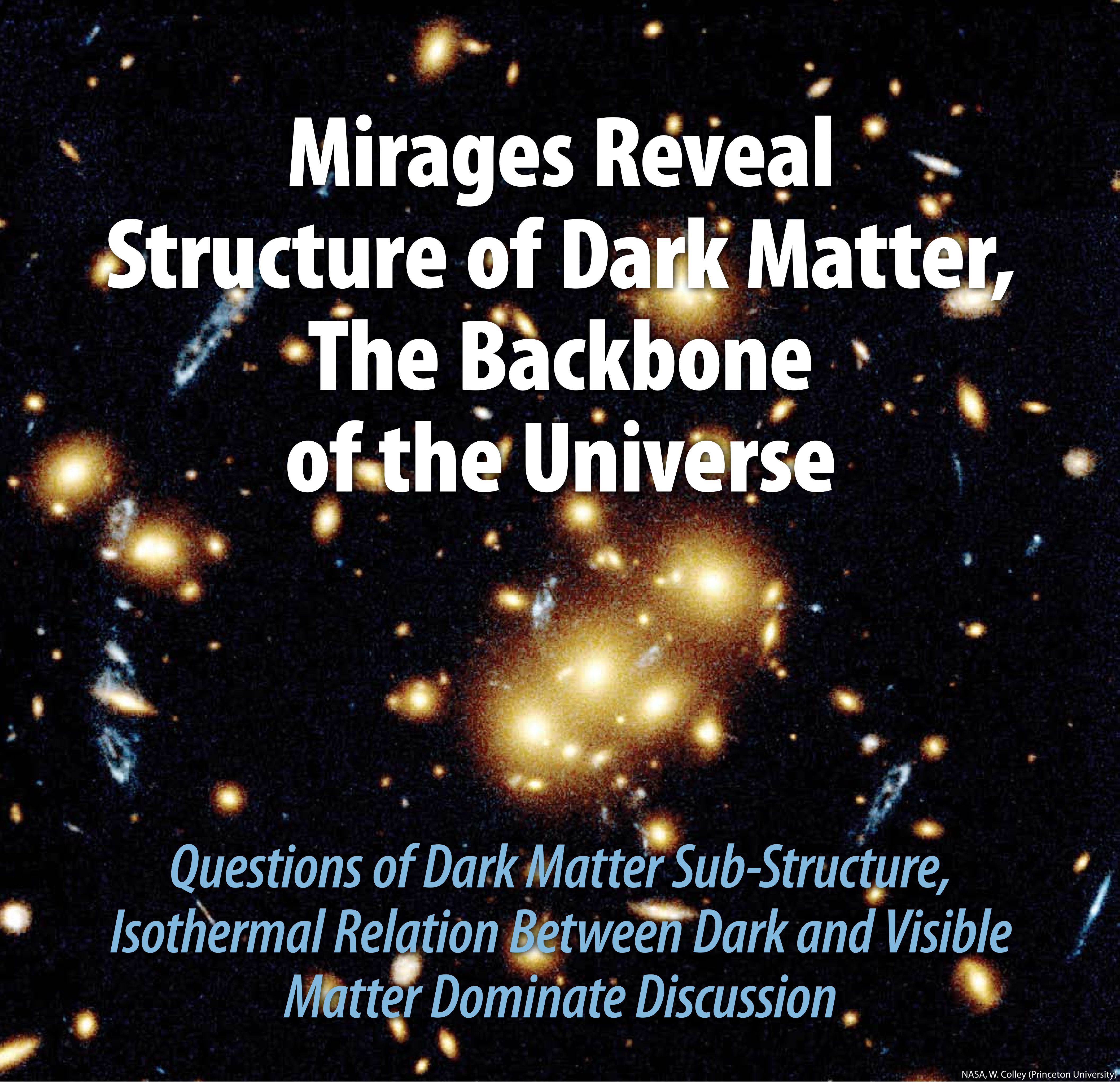
Polchinski is the author of a two-volume text on string theory, which is already a classic in the field.

The native New Yorker received a BA degree from the California Institute of Technology in 1975 and his PhD from Berkeley in 1980. After two two-year stints as a research associate, first at the Stanford Linear Accelerator (SLAC) and then at Harvard, Polchinski joined the faculty at the University of Texas at Austin as an assistant professor in 1984. He advanced to associate professor there in 1987 and to professor in 1990. He accepted his professorial appointment at Santa Barbara in 1992.

Recipient of an Alfred P. Sloan Fellowship from 1985 to 1989, Polchinski was elected a fellow of the American Physical Society in 1997 and a member of the American Academy of Arts and Sciences in 2002 and the National Academy of Sciences in 2005.

Mirages Reveal Structure of Dark Matter, The Backbone of the Universe

Questions of Dark Matter Sub-Structure, Isothermal Relation Between Dark and Visible Matter Dominate Discussion



NASA, W. Colley (Princeton University)

The central yellow spheres are galaxies in a cluster whose mass is a million billion times that of our Sun. The blue smears arrayed circularly around the periphery—an Einstein ring—are multiple images of a background object whose light path has been affected by the cluster. That effect requires much more mass—in dark matter—than can be accounted for by the radiant matter.

ENGLISH SPEAKING astrophysicists call the phenomenon "gravitational lensing"; the French call it "*mirage gravitationnel*." The plainer English nomenclature focuses on cause; the more suggestive French, on effect.

The phenomenon itself is a vivid example of Einstein's Theory of General Relativity in action. A massive object, such as a galaxy, between an observer on planet Earth and a distant light source acts like a "lens" parceling and bending the light from the distant source such that the Earth observer sees two or more or even a ring of images of the same distant source. The multiplicity of the images is the "mirage."

The gravity of the massive intervening object curves Spacetime so that the shortest distance is a curved route in the apparent flat, Euclidean space for the observer (in reality a straight line in curved Spacetime). Because the light from the distant source is parceled by and around the intervening "lens," the multiple images of the same distant object arrive at different times on earth—even as much as a year or two apart.

That time discrepancy in the arrival of images provides a key for understanding the structure of the universe.

That relationship between technique and structure was the subject of a KITP program "Applications of Gravitational Lensing: Unique Insights into Galaxy Formation and Evolution," from Sept. 18 to Nov. 2, 2006, and conference the week of Oct. 3. The program attracted 50 participants; the conference, 120.

When gravitational lensing was first discovered in the late 1970s, astronomers hailed the phenomenon as a "natural telescope," with emphasis on the enabling observation of the distant light source. In time it became apparent that the routes of the multiple images also mapped out the gravitational fields of the intervening objects, and those fields were a powerful indicator of the presence and the extent of "dark matter" because the visible matter could not begin to account for the gravitational fields.

Dark matter makes up 25 percent of the stuff in the universe though what it is remains unknown. The visible or "baryonic" matter—which radiates and which we can therefore see as stars and galaxies and all the stuff we know about on planet Earth—accounts for about four to five percent of the mass in the universe. The rest is something called "dark energy," discovered inadvertently in recent surveys of distant supernovae (the subject of another KITP program and articles in this newsletter) and supported by observations of large-scale structure and the microwave background.

"Dark energy" may or may not be synonymous with the cosmological constant, a term designated by "λ" (the Greek letter lambda), which Einstein introduced into his equations for General Relativity in order to counteract the force of gravity and therefore to maintain a static universe, and which he abandoned when the universe was shown to be not static, but expanding. Physicists have, if anything, less understanding of dark energy than of dark matter.

So 95 to 96 percent of what makes up the universe is a mystery.

Though physicists don't know what the dark stuffs are, they do know how much of each there is, and the consensus that has emerged about the percentages of the three primary constituents is called "precision cosmology."

"For 50 years," said program/conference organizer and UCSB physicist Tommaso Treu, "the name of the game has been measuring those parameters. Now that we know how much, we want to know what that means."

"We have a model that seems to work, but that looks very crazy," said organizer Leon Koopmans of Kapteyn Astronomical Institute, Groningen University in the Netherlands.

That model is called "lambda CDM": "lambda" represents the dark energy, which may or may not be the same as the cosmological constant; and "CDM" stands for "Cold Dark Matter."

Since five to six times as much of the universe appears to be made up of dark matter in comparison to the visible gas, stars, and galaxies, the theoretical astrophysicists who model the universe via computer simulations focus on dark matter basically to the exclusion of visible matter. (Currently, simulations of the formation and evolution of structure in the universe work with a base unit of 10^8 solar masses.)

"Dark matter is the backbone of galaxy formation," asserted Treu. "Galaxies form into dark matter haloes, so if you do not understand dark matter, you cannot understand galaxy formation."

And since dark matter doesn't shine, it can only be "observed" gravitationally through lensing or dynamics (motion).

The idea behind the program was to bring the simulators of galaxy formation

Center are program organizers Leon Koopmans (l) and Tommaso Treu with program participants, at left, Raphael Gavazzi, UCSB physics postdoc, and Sherry Suyu, KITP Fellow and Caltech graduate student, and, at right, Adam Bolton (l), Harvard-Smithsonian Center for Astrophysics fellow, and Phil Marshall, UCSB physics postdoc and Tabasgo Fellow.

and evolution together with the experts on gravitational lensing.

What Koopmans and Treu did in organizing the program/conference was, in some sense, to scale up to the community level their personal and collaborative experiences. Said Koopmans, "I started in lensing and moved to galaxy formation, and Tommaso moved in the opposite direction. He started in galaxy formation—studying these galaxies from their light point of view, not only from their mass point of view. Our experiences gave us the idea of bringing together these communities that historically have been quite distinct."

Interactions between the simulators and the lensers focused particularly on two issues: the dark matter sub-structure and the isothermal relationship between dark and visible matter on scales of galaxies and also the larger clusters of galaxies.

One of the principal issues with the lambda CDM model for galaxy formation and evolution is that it works so well for simulating large-scale structure, but appears problematic for smaller scales.

"Gravitational lenses also operate on the scale of clusters of galaxies," explained Koopmans. "Hundreds of galaxies come together into one big structure that is very massive and that itself acts as a lens for background objects, which are seen as very spectacular long arcs, for example."

"We see these arc features," said Treu, "a lensed object in the background that is stretched by the whole cluster. Those features indicate that there is much more mass in the cluster than you can see. We then infer how much dark matter there is and how it's distributed. And it is distributed differently than the luminous matter. Dark matter spreads out more in a halo-like structure."

Whence dark satellites?

"One of the most exciting issues is whether there is some sub-structure in the dark matter too. It is predicted," said Treu, "but still needs to be found, and lensing is one way of doing this."

"Pure dark matter simulations yield," said Koopmans, "many dark matter clumps, not just in clusters of galaxies, but also in galaxies. We don't see these sub-structures in the light, so the question arises: Do these dark matter clumps not have the stars or gas in them, which would make them visible to us? Or do these dark matter clumps not exist? And if they don't, that's a problem for our CDM model because those sub-structures are its strong prediction."

"Our Milky Way," said Treu, "is part of what we call the local group, which includes Andromeda and the Magellanic Clouds. If you count how many satellites there are to the local group, there are very few. We don't see them, or haven't yet. So at the end of the '90s, a huge crisis emerged: How come galaxies like the local group don't exhibit satellites in the halo as predicted? The simulations predict 10 to 100 times more. An amount 100 times more is not something you can shuffle away.

"Here is where lensing comes in. These things should be there; if we get our act together and find a way to observe them, we'll find them. And that's what we tried to do here at the KITP by bringing the communities together—collaborate on approaches to the problem that can be implemented by individual researchers afterwards.

"Then," said Treu, "there is another side to this story; the universe is made of these strange galaxies. There is a simple sea of dark matter and dark energy, and a whole zoo-full of different galaxies. But the galaxies come in only a small range of sizes. They have some scaling relationship, so that if they have a certain mass, they can only have a certain size. Why is that the case?"

Said Koopmans, "If you look at these galaxies, certain relations among the observables emerge, such as how bright they are, how big they are, how massive. These relations are extremely tight, and you see them in these very massive elliptical galaxies and in spiral galaxies. And these relations are very strongly affected by how the dark matter would be distributed around the galaxies. So this tells us that somehow what we observe is following a very tight relation that is dependent on how the dark matter is distributed. So there is a very close coupling between what the dark matter is doing and what the gas and stars are doing.

"The simulations are getting better as our computers get better," said Koopmans, "but it is extremely hard in this whole picture of the cold dark matter and hierarchical formation to find extremely tight relations–you find them approximately, but you never find them as tight as we are observing them."

Bulge-halo conspiracy

"After sub-structure," said Treu, "the second most exciting part of this program is what Leon and I like to call the 'bulge-halo conspiracy.' Imagine you have a galaxy, and you can measure by a miracle (in this case gravitational lensing with something else) the run of the density of mass with respect to radius. The galaxy is dense in the center and becomes less and less dense outwards. With lensing you can measure the total mass density profile because you don't care if it's stars or dark matter. The surprising thing is that no matter what you do, it looks like the dark matter and the luminous matter conspire to form what we call an 'isothermal mass profile.'"

"In other words," clarified Koopmans, "if you add up the stars and gas and dark matter, the density profile is the same for these elliptical galaxies as for spiral galaxies. You don't see much of a difference. If you look at the more massive galaxies, you see lots of differences between how their light is distributed, but somehow the dark matter compensates in such a way that the density profile stays the same."

Said Treu, "The law is extremely simple. The density is proportional to one over the radius squared."

The dark matter complements the baryonic matter so that the same relationship pertains?

"Yes," said Treu, "the sum of the two miraculously always ends up looking like this, so the two affect each other. There is some kind of fundamental structure, and the two adjust to each other somehow. Sometimes that relationship is called the 'attractor,'" said Treu.

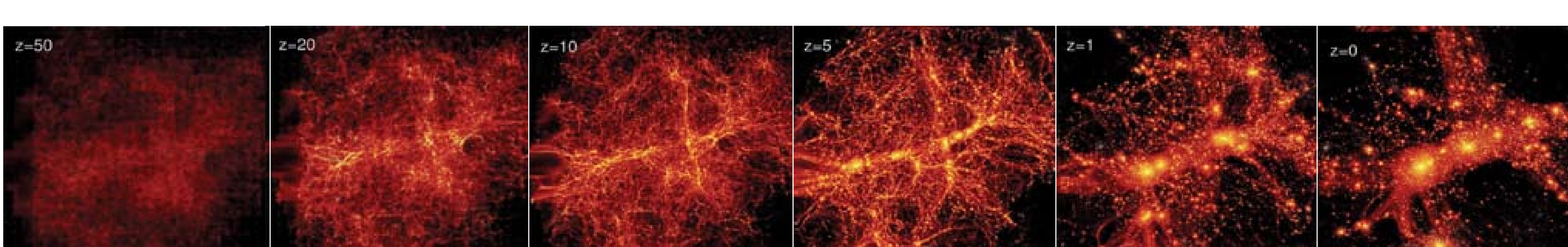
"This is an unexplained phenomenon," said Koopmans.

"What happened here in this program," said Treu, "is that we grappled with two big ideas—the substructure and the isothermal relationship. Communities, who don't traditionally talk much to each other, did. It was a big success."

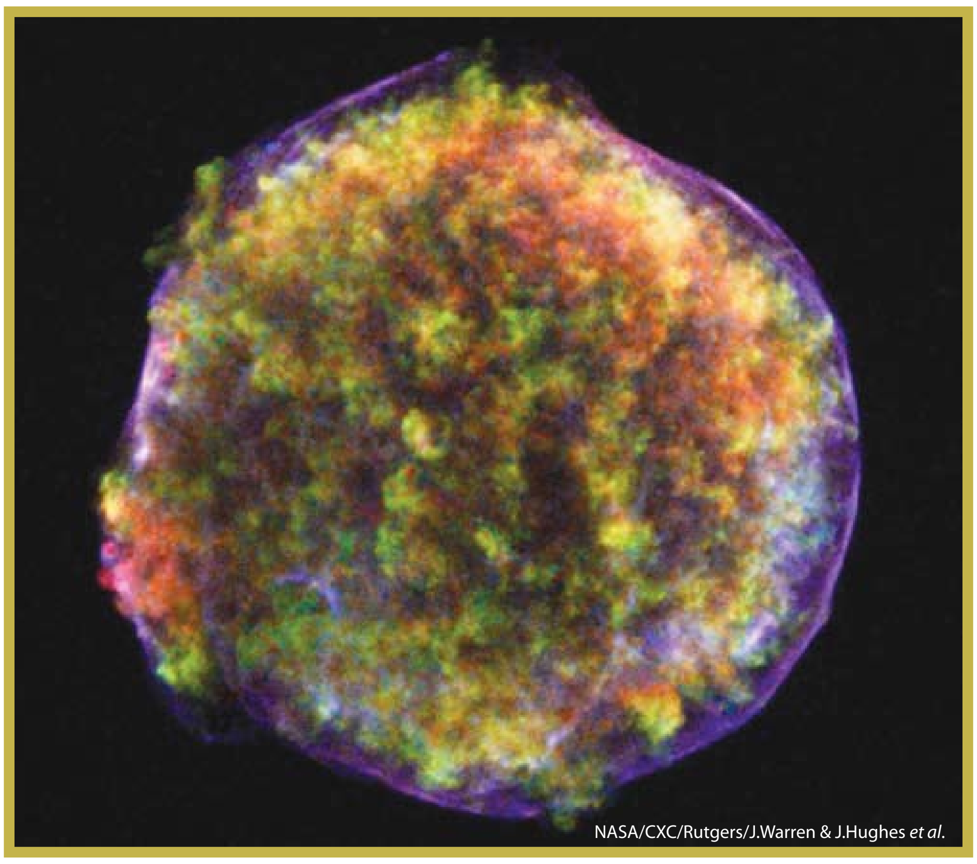
The "bullet" cluster—a composite x-ray lensing image depicts collision of two merging sub-clusters, whereby the weakly interacting dark matter (blue) keeps on going, while the atoms (red) interact strongly. This shows that normal matter cannot account for all the gravity of the cluster, but dark matter is needed.

"Indeed," added Koopmans, "I think how successful was reflected by the large turnout at the conference—120 participants!"

In addition to Koopmans and Treu, the other organizers of the program included Chung-Pei Ma of Berkeley, Ben Moore of the University of Zurich, and Peter Schneider of the Argelander-Institut für Astronomie in Bonn.



Simulation of the growth of structure with arrow of time going from left to right



Left: Tycho's supernova remnant (Chandra)

Stellar End Products: White Dwarfs, Supernovae, Neutron Stars, Black Holes

Degenerate Star Program Participants Grapple With Many Open Questions

WITH STARS, it would seem, size matters. It is the necessary but not absolute determinant of their ends: (1) whether they expire in a thermonuclear explosion like the supernovae type Ia or (2) collapse and explode like the supernovae types Ib and II or (3) just quietly cool for eternity like the typical white dwarf.

Collapsing cores are the fate of stars eight times or more massive than the sun (the more massive the star, the faster its evolution). The residue of a supernova type II core collapse is either a neutron star or a black hole. Neutron stars are much smaller but much denser than white dwarfs.

The rest of the stars, including the Sun, burn up and degenerate into white dwarfs, which are about the size of the Earth. Late in their life cycle, these stars expand into what are called "red giants" (larger [hence "giants"] but cooler [hence "red"] as seen from Earth); and then the outer envelope puffs away leaving a little more than half the original mass. (See image below).

So there are enormous numbers of white dwarfs in the universe, but the only ones we can observe are nearby in our own Milky Way Galaxy because these objects are dim. So all direct information about white dwarfs is based on observations of the way they look and behave in the present (since proximity of source to observer determines the age of light in the universe).

One out of every 100 white dwarfs will supernova; the question for participants in the KITP 2007 degenerate star program and conference is why this particular white dwarf of the many? What determines the Ia supernova fate?

It would seem to be coupling—the orbiting of one star around another. Program organizer Rosanne Di Stefano focuses on two pairing possibilities: either two white dwarfs or a white dwarf and a companion star. Still most pairs do not a supernova make, so the big question is what distinguishes the rare pair which do supernova? For a white dwarf to supernova it has to gain matter somehow from somewhere, and the best, if not the only, way now under serious scientific consideration is from a companion star.

While traveling by ship from India to England to pursue graduate work, Subrahmanyan Chandrasekhar (awarded a Physics Nobel Prize in 1985 for his theoretical insights into the gravitational collapse of stars) worked out the quantum mechanical implications of the stellar endgame.

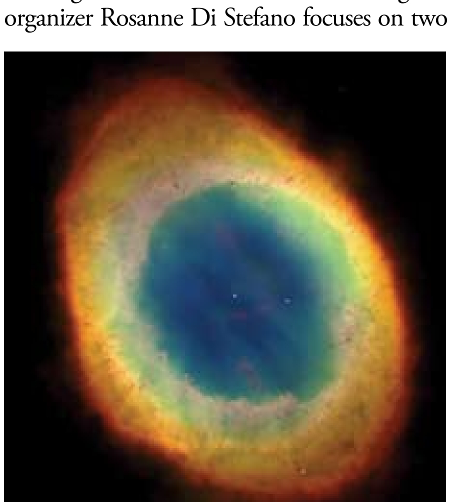
White dwarfs are small and dense. In the end-stages of their evolution, what holds up the star remnant (*i.e.*, counteracts the contracting force of gravity) is degenerate electron pressure. Electrons, long-since stripped from atoms, cannot as fermions occupy the same state, so there is a limit to the extent to which electrons can, in effect, be squeezed together in space. Chandrasekhar worked out the largest mass that can be supported by electron degeneracy.

Theorists hypothesize that mass added to the white dwarf from a companion will overwhelm the degenerate electron pressure and trigger the Ia supernova explosion.

The process whereby the matter from one star (be it degenerate or not) is accreted by the other in such a way as to trigger the supernova chain reaction is, according to Di Stefano, "complex and not well understood."

Craig Wheeler, the current president of the American Astronomical Society and a degenerate star program organizer, has been engrossed in the study of supernovae, especially the thermonuclear exploders, for three decades. "We have made a lot of progress in the past 30 years," he said, "but some of the central issues such as 'How do you get a white dwarf into the place where it can explode?' have been a problem all along and are still a problem.

"What this conference is all about is the nature of the companion star," said Wheeler referring to the greater gathering of supernova aficionados the week of March 19 in the midst of the four-month-long program. "All the chess pieces are on the board," said Wheeler, "but we just don't know how nature plays the game.



Young white dwarf at the center of ejected matter

"It turns out that the easiest place to look for that companion star is Tycho's supernova," said Wheeler of the explosion whose brilliant aftermath was witnessed by the Danish astronomer Tycho Brahe in 1572. [Image to the left shows how we see it today in x-rays.]

Wheeler explains that observers have looked for the hypothetical companion star unloosed from gravitational interaction with the now incinerated white dwarf. That companion should, he said, be found "whizzing off. One of the things we heard here," said Wheeler, "was a report by Brian Schmidt from Australia [Mount Stromio Observatory]. He looked at all other stars that could be candidates for the former companion, and he hasn't been able to identify anything."

Schmidt's findings led Wheeler to wonder about the preferred binary model of healthy companion and white dwarf. "Can that model," pondered Wheeler, "assimilate that lack of evidence, even contradiction?"

Observations of the aftermath of Tycho's supernova provided another interesting challenge to the standard Ia supernova model. The week before the conference, program participant Carles Badenes of Rutgers issued a preprint, which considered the question of how dense the gas is into which the supernova exploded.

"It looks like ordinary interstellar medium gas," said Wheeler, pointing out that that observation contradicts a frequently invoked picture in which excess material is blown out of the binary system by a wind. That picture predicted that the surrounding region would have been evacuated by the wind, "but Carles is saying that's not true," said Wheeler. "There appears to have been no prior evacuation before the thermonuclear explosion."

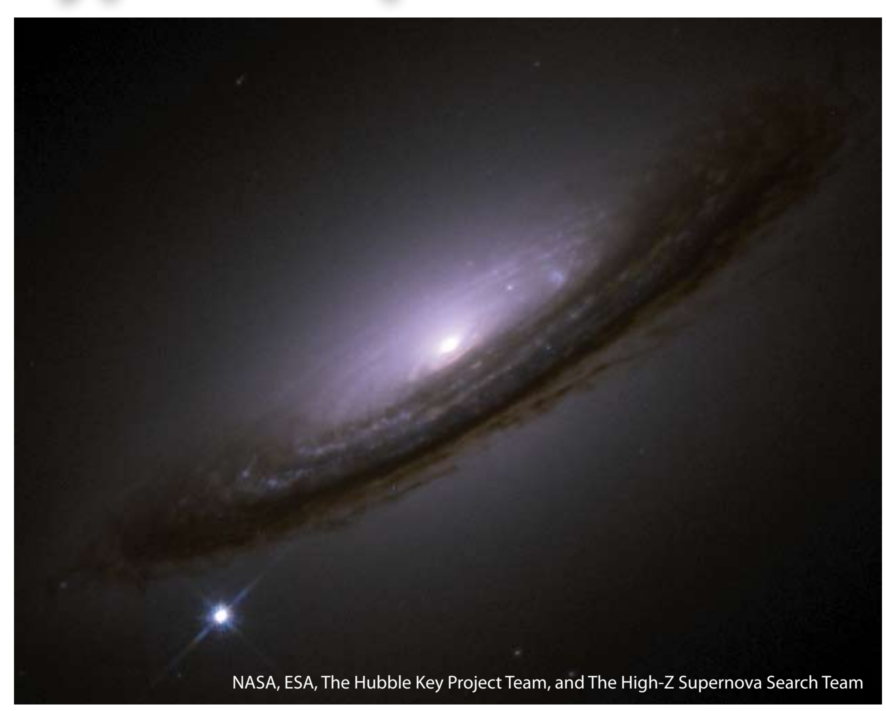
One ironic outcome of the degenerate star program and conference is the realization of how much more needs to be known about the tools—type Ia supernovae—that have themselves revealed so much about the nature of the universe.

Said program organizer Robert Kirshner, one of the primary users of type Ia supernovae for cosmology, "How you get to the point of explosion is still pretty mysterious, and even after doing a good job of gathering the learned people from around the world who work on this stuff, I think the conclusion is we still don't know which are the stars that are on this path and how they are going to get there. We want to know the bio of these things; that story is not clear. There is plenty more to do."

For Kirshner, the observer, the key development of the program/conference has been getting the white dwarf experts, especially their observers, together with the supernova experts—two communities, he says, which were not well acquainted prior to the KITP program and conference.

He points out that the Sloan Sky Survey, a mapping of objects in a quarter of the universe, recently multiplied the number of known white dwarfs by a factor of 10 from roughly 1,000 to 10,000, thereby providing white dwarf observers with a plethora of new opportunities for the kind of in-depth follow-up that will lead to the more complete "bio of these things," that will in turn provide new approaches to the questions that have energized the program's participants.

Type Ia Supernovae CONTINUED FROM PAGE 1



Supernova 1994D in Galaxy NGC 4526 from HubbleSite.org

something, termed "dark energy," turns out to make up 70 percent of the stuff in the universe.

Because Ia supernovae are so intrinsically bright (The death throes of one star as bright as the billions of stars that make up a galaxy! See image above.), these supernovae can be seen from very far away and from very long ago.

The key cosmological time pinpointed by the supernovae is about five billion years ago, according to another of the program's organizers Robert Kirshner, the Harvard astronomer who led one of the two supernovae search teams that discovered the accelerating expansion and its origin in dark energy.

The universe began to expand 14 or 15 billion years ago. Five billion years ago—at a redshift of 0.5—the expansion rate turned from slowing down to speeding up. Until 10 years ago, no one had ever thought five billion years ago was a special time for the universe. It is about the same time, incidentally, that our Sun came into being and the solar system formed.

Bildsten, the theorist whose research focuses on the astrophysics of the supernovae themselves, and Kirshner, the observer for whom supernovae are tools, conceived the degenerate star program because, as DiStefano pointed out, these death stars have of late revealed if not exactly "new heavens, new earth," then a radically new way of looking at them.

The lingering question is whether the billions-of-year-old supernovae occur in a similar context and are themselves enough similar to the nearby and more recent supernovae that have been well studied (if not well understood) to warrant the assumptions of similarity that make supernovae such powerful tools for cosmology.

Thermonuclear Explosions Cause Most Heated of Discussions

KITP's Resident Astrophysicist Describes Fusion Reactions

NASA and H. Richer (U. of British Columbia)

AS AN ORGANIZER of the program on degenerate stars, KITP permanent member Lars Bildsten represents the participants who are particularly interested in the explosions of carbon-oxygen white dwarfs.

As Bildsten said, "Some participants don't care at all about the objects themselves, they just want to use them. We want to understand them. We would like to understand these astrophysical events as well as any others that are occurring that are indicators of accretion and explosion on white dwarfs.

"Historically," said Bildsten, "there are two types of supernovae—the ones [type I] with no hydrogen in their spectra and the ones [type II] with hydrogen in their spectra. Type Ia supernovae exhibit spectral lines of silicon and calcium—very heavy elements; you don't see hydrogen or helium. We think their origin is the complete incineration of a white dwarf from what was probably a solar mass of carbon and oxygen to mostly the most stable nucleus you can make out of incinerating that material–nickel 56."

The energy for supernovae II comes from the gravitational energy released in the collapse of a stellar core to a neutron star that sends out a shock that disrupts the envelope and that engenders the supernova, said Bildsten. By contrast, the origin of the type Ia supernova energy is completely thermonuclear, coming from the fusion of carbon to nickel 56.

With supernovae Ia there exists an empirical relationship between the peak brightness and the decline rate, he explains. The brighter the supernova, the slower will be its decline; and conversely the dimmer the supernova, the more rapid will be its decline. This key relationship, called "the Phillips relationship" after its discoverer (program participant Mark Phillips of Las Campanas Observatory, Chile), enabled supernovae Ia to be used as tools for cosmology. In other words, the shape of the light curve tells observers whether they are looking at a bright or dim supernova so that their assessment of its distance is independent of the apparent brightness of the object; otherwise, dimmer ones could look further away (relative to bright ones) than they really are.

"This Phillips relation is still not understood theoretically," said Bildsten. "We don't really know what the controlling parameter is. We think most of the brighter ones may be more successful at incinerating most of the white dwarf. So the simplest scenario is that they all have roughly the same mass, but differ in terms of how much nickel they make. If they have a lot of nickel, they are bright; if they have less radioactive heating, they are faint. What nobody can do is explain the rapid decay of the ones that fade fast."

Nickel is crucial to brightness because we do not see the actual explosion, but days later the cloud of radioactively decaying nickel; so, the reasoning goes, the more nickel, the brighter the supernova.

To recapitulate, some white dwarfs detonate (though unclear how) and set off a chain reaction in which carbon and oxygen isotopes fuse to form radioactive nickel 56. The fusion energy then overcomes the gravitational energy and unbinds the white dwarf, and all the stuff just leaves the scene at the rate of 10,000 kilometers per second. Days later the brilliant glow we see from earth is the radioactive nickel decaying to radioactive cobalt 56, which in turn visibly decays to stable iron 56.

In addition to tools for cosmology, supernovae Ia provide another service of making about two-thirds of the iron in the universe.

The carbon-oxygen white dwarf is the endpoint for most stars, which have converted hydrogen to helium and helium to carbon and oxygen. Incidentally, the carbon so key to life molecules comes not from supernovae Ia, but from supernovae II (the core collapsers). The thermonuclear explosion of type Ia's converts all the carbon to magnesium and then to nickel, so there is no carbon left to seed the intergalactic medium for the formation of more stars and solar systems and life forms.

"We would like to know," said Bildsten, "whether the origin of supernovae Ia depends on the kind of galaxy they are in." Elliptical galaxies harbor only old stars; and because all the stars are old, they are also comparatively low mass (since the more massive a star the shorter its life). Observers see no type II supernovae in elliptical galaxies though they do see supernovae Ia. In spiral galaxies, where star formation is vigorous and young stars abound, both types of supernovae are observed. The supernovae Ia seen in elliptical galaxies tend to be less bright than the supernovae Ia seen in spirals.

"What has become clear in only the last two or three years," said Bildsten, "is that all evidence points to the rate of those supernovae popping off in a young stellar population knowing about the young stars." In other words, where there is a vigorous star formation rate, there is a vigorous type Ia rate.

"Those supernovae might well have a different path to explosion than the ones in ellipticals," said Bildsten. "But if there are two different populations," he asked, "why should they all lie on the same Phillips relationship? There are data now that seem to point to two paths depending on what kinds of star are around to make these events. At high redshifts [*i.e.* the greater the redshift, the further away and the longer ago the object] vigorous star formation occurs, and there are very few aged stars; so we would think that at high redshifts, we are mostly seeing the bright ones. If they obey the same relationship that is seen nearby, then everything is okay," said Bildsten, meaning the use of supernovae Ia as tools for cosmology. "But that's not my problem.

"What we are trying to do in the program is to have a critical discussion of this path to ignition. How do these things explode?"

Though the trigger is unclear, what seems to be clear is that additional mass is required and the only source is from another star.

Bildsten emphasizes, "The carbon fuses as a function of rising density, not rising temperature. This density effect is the real cold fusion!" he exclaims.

Astrophysicists call the effect "pycnonuclear" burning from the Greek "*pyknos*," meaning "dense."

Fifteen years ago at a program on exploding stars at the KITP, two of the current participants, Ed van den Heuvel and Ken Nomoto, wrote a paper together, which matched then fresh, soft x-ray satellite-based observations with a model they proposed of a white dwarf in a very particular kind of binary. That paper "Accreting White Dwarf Models for CAL 83, CAL 87 and Other Ultrasoft X-ray Sources in the LMC" [*i.e.*, "Large Magellanic Clouds"] has become a classic in the field, according to Bildsten, and still provides the basis for the preferred ignition scenario today because it describes the mechanism for white dwarfs that become massive enough through accretion to overcome the degenerate electron pressure counteracting gravity, to contract, and to ignite.

"Many of us," said Bildsten, "have been working on alternative ignition scenarios because this one is so weird."

All the program/conference organizers independently observed how "very contentious" were the discussions on how the explosion happens. Bildsten counted, "Five scenarios in terms of binaries that give you different kinds of triggers and probably would have different kinds of explosions."

Apparently, the more models, the hotter the discussion gets?

"At a very fundamental level, there are huge holes in our understanding," comments Bildsten.

Nell Campbell

Standing, Edward van den Heuvel (l) and Lars Bildsten; seated, Rosanne Di Stefano (l), Robert Kirshner, and Craig Wheeler

Secondary School Teachers Sample Stellar Treats

Nell Campbell

Teachers Jennifer Adams (l), Clayton, Missouri; Gail Van Ekeren, Kiluaea, Hawaii; and Nick Nicastro, Holden, Massachusetts

On March 17 the Kavli Institute for Theoretical Physics hosted its annual conference for secondary school science teachers from throughout the United States. The topic was "Forging the Elements and Probing the Universe With Stars."

The conference, coordinated by KITP permanent member and astrophysicist Lars Bildsten, tapped the scientific talent on hand for the four-month-long spring program on "Accretion and Explosion: The Astrophysics of Degenerate Stars."

The morning talks focused on stellar fundamentals: Bildsten described the astrophysics of "The Life of a Star" and Hendrik Schatz of Michigan State University explained the processes of "Forging the Elements During Stellar Death."

The afternoon sessions looked at how dying stars function as probes for astronomers. Edward van den Heuvel of the University of Amsterdam spoke about the core collapsing supernovae in a talk entitled "Gamma-Ray Bursts: Probes of Star Formation in the Early Universe." Speaking from experience, Harvard astronomer Robert Kirshner explained "Cosmic Acceleration Revealed by Exploding Stars."

Serving as moderators for the lively question and answer sessions following the talks were Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics in the morning and Craig Wheeler of the University of Texas at Austin in the afternoon.

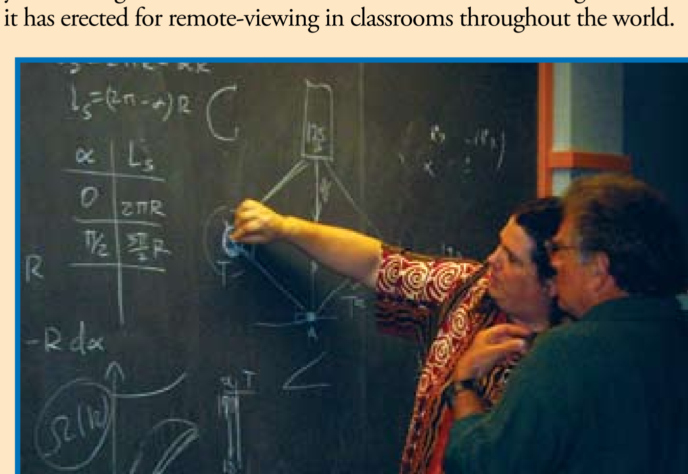
Before the luncheon break KITP director David Gross acted as facilitator of a "Town Hall Discussion," which focused on how to turn more young people on to science. The teachers stressed the conflict inherent in teaching creatively and teaching to standardized test-taking.

Nell Campbell

Simon Raab, member of the KITP Director's Council, addresses teachers.

This Teachers Conference featured two novel events, likely to be repeated:

- Video conferencing with the Exploratorium in San Francisco enabled Bay-area secondary teachers to participate without traveling to Santa Barbara.
- The teachers who did make the trip had an opportunity during the day after the conference to engage in an extraordinary new educational venture at the Santa Barbara-based Las Cumbres Observatory Global Telescope Network (www.lcogt.net). This private observatory is enabling teachers and their students to commandeer a global network of small telescopes it has erected for remote-viewing in classrooms throughout the world.



Craig Kunimoto

Secondary school teachers collaborate at KITP

Kavli Institute for Theoretical Physics
UC Santa Barbara
Santa Barbara, CA 93106-4030

ONGOING & UPCOMING

For Physicists…

PROGRAMS

Strongly Correlated Phases in Condensed Matter and Degenerate Atomic Systems
Jan. 29 – June 15, 2007
Immanuel Bloch, Victor Gurarie, Deborah Jin, Yong Baek Kim, Leo Radzihovsky, Peter Zoller

Accretion and Explosion: The Astrophysics of Degenerate Stars
Jan. 29 – June 1, 2007
Lars Bildsten, Rosanne Di Stefano, Robert Kirshner, Craig Wheeler

Biological Switches and Clocks
July 2 – Aug. 10, 2007
Reka Albert, Albert Goldbeter, Peter Ruoff, Jill Sible, John Tyson

Theoretical Physicists at Primarily Undergraduate Institutions
July 16 – 27, 2007
Herbert Bernstein, Donald Spector
Mini-program

Star Formation Through Cosmic Time
Aug. 6 – Dec. 7, 2007
Tom Abel, Alyssa Goodman, Chris McKee, Paolo Padoan

Moments and Multiplets in Mott Materials
Aug. 13 – Dec. 14, 2007
Leon Balents, Matthew Fisher, Daniel Khomskii, George Sawatzky, Oleg Tchernyshyov

Nonequilibrium Dynamics in Particle Physics and Cosmology
Jan. 14 – March 21, 2008
Juergen Berges, Lev Kofman, Laurence Yaffe

Physics of the Large Hadron Collider
Feb. 4 – June 6, 2008
Csaba Csaki, Tao Han, JoAnne Hewett, James Wells

Anatomy, Development, and Evolution of the Brain
March 3 – April 25, 2008
Ken Kosik, Alexi Koulakov, Greg Lemke, Sara Solla, Sam Wang

Physics of Climate Change
April 28 – July 11, 2008
Jean Carlson, Gregory Falkovich, John Harte, Brad Marston, Ray Pierrehumbert

Dynamo Theory
May 5 – July 18, 2008
Chris Jones, Daniel Lathrop, Steven Tobias, Ellen Zweibel

CONFERENCES

Star Formation, Then and Now
Aug. 13 – 17, 2007
Tom Abel, Alyssa Goodman, Chris McKee, Paolo Padoan

Motterials: Spin, Orbital, and Lattice Physics Near the Mott Transition
Sept. 10 – 14, 2007
Matthew Fisher, Daniel Khomskii, George Sawatzky, Nicola Spaldin, Oleg Tchernyshyov

Nonequilibrium Phenomena in Cosmology and Particle Physics
Feb. 25 – 29, 2008
Juergen Berges, Lev Kofman, Laurence Yaffe

Frontiers of Climate Science
May 5 – 9, 2008
Jean Carlson, Grisha Falkovich, John Harte, Brad Marston, Ray Pierrehumbert

Anticipating Physics at the Large Hadron Collider
June 2 – 6, 2008
Csaba Csaki, Tao Han, JoAnne Hewet, James Wells

Magnetic Field Generation in Experiments, Geophysics and Astrophysics
July 14 –18, 2008
Chris Jones, Daniel Lathrop, Steven Tobias, Ellen Zweibel

For details of programs go to our website: http://www.kitp.ucsb.edu/activities/

For Friends of KITP…

SEE WEB SITE:
www.kitp.ucsb.edu/community/friends_upcoming_events.php


Derek Westen

Guests enjoy a special evening with renowned Harvard astronomer and author of The Extravagant Universe, *Robert P. Kirshner, hosted by Beth and Derek Westen, and sponsored by the Kavli Institute for Theoretical Physics. On a separate occasion, Kirshner gave a public lecture at the KITP on "Einstein's Blunder Undone: The Discovery of Cosmic Acceleration."*

For information about events and membership, contact Charmien Carrier at (805) 893-6349 or charmien@kitp.ucsb.edu.
For other Friends queries, contact Sarah Vaughan, Director of Development and Community Relations at (805) 893-7313.

KITP Director's Council

The Director's Council is made up of leaders in fields other than physics, but with an interest in physics, who meet several times a year to provide the KITP leadership with invaluable support and advice. Chaired by John Mackall, the Council also includes Joe Alibrandi, David L. Brown, Virginia Castagnola-Hunter, K.C. Cole, Michael Ditmore, Fred Gluck, Gus Gurley, James Knight, Stuart Mabon, Simon Raab, and Derek Westen.

For profiles go to: http://www.kitp.ucsb.edu/community/director.html.