// MATTERS OF GRAVITY

The newsletter of the Topical Group on Gravitation of the American Physical Society

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Contents

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Editorial

The next newsletter is due September 1st. This and all subsequent issues will be available on the web at `http://www.oakland.edu/physics/Gravity.htm` All issues before number **28** are available at `http://www.phys.lsu.edu/mog`

Any ideas for topics that should be covered by the newsletter, should be emailed to me, or Greg Comer, or the relevant correspondent. Any comments/questions/complaints about the newsletter should be emailed to me.

A hardcopy of the newsletter is distributed free of charge to the members of the APS Topical Group on Gravitation upon request (the default distribution form is via the web) to the secretary of the Topical Group. It is considered a lack of etiquette to ask me to mail you hard copies of the newsletter unless you have exhausted all your resources to get your copy otherwise.

David Garfinkle

Correspondents of Matters of Gravity

- John Friedman and Kip Thorne: Relativistic Astrophysics,
- Bei-Lok Hu: Quantum Cosmology and Related Topics
- Gary Horowitz: Interface with Mathematical High Energy Physics and String Theory
- Beverly Berger: News from NSF
- Richard Matzner: Numerical Relativity
- Abhay Ashtekar and Ted Newman: Mathematical Relativity
- Bernie Schutz: News From Europe
- Lee Smolin: Quantum Gravity
- Cliff Will: Confrontation of Theory with Experiment
- Peter Bender: Space Experiments
- Jens Gundlach: Laboratory Experiments
- Warren Johnson: Resonant Mass Gravitational Wave Detectors
- David Shoemaker: LIGO Project
- Stan Whitcomb: Gravitational Wave detection
- Peter Saulson and Jorge Pullin: former editors, correspondents at large.

Topical Group in Gravitation (GGR) Authorities

Chair: David Garfinkle; Chair-Elect: Stan Whitcomb; Vice-Chair: Steve Detweiler. Secretary-Treasurer: Gabriela Gonzalez; Past Chair: Dieter Brill; Delegates: Alessandra Buonanno, Bob Wagoner, Lee Lindblom, Eric Poisson, Frans Pretorius, Larry Ford.

GGR program at the APS meeting in Denver

David Garfinkle, Oakland University garfinkl-at-oakland.edu

We have an exciting GGR related program at the upcoming APS "April" meeting (actually May 2-5) in Denver. Our chair-elect Stan Whitcomb did an excellent job of putting together this program. At the APS April meeting there will be several invited sessions of talks sponsored by the Topical Group in Gravitation (GGR). The large number of sessions sponsored by GGR means that our Topical Group has become one of the most important units at this meeting: only the Divisions of Astrophysics, Particles and Fields, and Nuclear Physics have a larger presence at the April meeting. In addition, there will be plenary talks on gravitational topics, and several of the invited sessions sponsored by other APS units are likely to be of interest to GGR members.

2009 is the 400th anniversary of Galileo's telescope, and this meeting emphasizes new ways of looking at the universe. Plenary talks include:

First Results from Fermi/GLAST Peter Michelson (Stanford University)
Merging Black Holes Joan Centrella (NASA/Goddard)
Nature's Highest Energy Messenger: Pierre Auger Observatory
James Cronin (Univ. of Chicago)

The invited sessions sponsored by GGR are as follows:

Merging Galaxies
(joint with DAP)
Stelios Kazantzidis Fueling of Black Holes in Galaxy Mergers
Marta Volonteri Cosmological Growth of Black Holes
Alberto Vecchio Probing Black Hole Mergers with LISA

Numerical simulations of coalescing compact objects: black holes and neutron stars
(joint with DCOMP)
Yosef Zlochower Status of Black Hole-Black Hole Simulations and Applications
Yuk Tung Liu Status of Neutron Star-Black Hole Simulations and Applications
Luciano Rezzolla Status of Neutron Star-Neutron Star Simulations and Applications

Women and Minorities in Multi-Messenger Astronomy of Gamma-Ray Bursts
(joint with DAP, COM and CSWP)
Laura Cadonati Gamma-Ray Burst Observations with LIGO
Enrico Ramirez-Ruiz Triggering Gamma-Ray Bursts
Ignacio Taboada Neutrino Messages from Gamma Ray Bursts

Panel Discussion: Women and Minorities in Gravity: Science and Career Paths
(joint with DAP, COM and CSWP)
Andrea Lommen Pulsar Timing and Gravitational Waves
Fotini Markopoulou Challenges in Quantum Gravity
Steve McGuire Materials Science in LIGO

Spanning the Gravitational Wave Spectrum
Vuk Mandic Gravitational wave astronomy using LIGO
Guido Mueller LISA - the other new window to the universe
Frederick Jenet Pulsar Timing to Search for nanoHz Gravitationa Waves

The Scientific Legacy of John Wheeler
(joint with FHP)
Kenneth Ford John Wheeler, 1933-1959: Particles and Weapons
Kip Thorne John Wheeler, 1952-1976: Black Holes and Geometrodynamics
Wojciech Zurek John Wheeler, 1976-1996: "Law Without Law" and Quantum Information

Precision Measurements in Gravity
Nergis Mavalvala Beyond the quantum limit in gravitational wave detectors
William Weber LISA Pathfinder: testing the limits of pure geodesic motion for gravitational wave observation in space
Michael Watkins The GRACE Mission

Developments in Quantum Gravity
James Hartle Einstein Prize Talk
Laurent Freidel TBD
Robert Wald TBD

In addition, there are a number of other invited sessions that will be of interest to some GGR members:

New Facilities in Particle Astrophysics I (DAP)
Frank Krennrich AGIS-the Advanced Gamma-ray Imaging System
Joel Bregman Science Drivers for the International X-ray Observatory
Zeljko Ivezic LSST: the physics of the dark universe

New Facilities in Particle Astrophysics II (DAP)
Stephan Meyer Probing Inflation with Cosmic Microwave Background Polarization
Jonathan Grindlay EXIST: Surveying Black Holes from the Early Universe to Local Galaxies
Thomas Prince LISA: Using Gravitational Waves to Observe the Universe

Early Science from the Fermi Gamma-Ray Space Telescope (DAP)
Charles A. Meegan Fermi Observations of Gamma-Ray Bursts
James Chiang Fermi/LAT Observations of the Extragalactic Gamma-Ray Sky
Troy A Porter Highlights of Galactic Scientific Results from the Large Area Telescope

New Eyes on the Universe I (DAP)
Stefan Westerhoff New Results from the Pierre Auger Observatory
Martin Israel TIGER: Progress in Determining the Sources of Galactic Cosmic Rays
Todor Stanev Recent Progress and New Puzzles in Cosmic Ray Physics

New Eyes on the Universe II (DAP)
Simon Swordy The VERITAS gamma-ray observatory: Recent observations and status
John Pretz Milagro's Survey of the TeV Gamma-Ray Sky
Teresa Montaruli Recent Results from IceCube

Dark Matter (DPF)
Andrew Hime A DEAP & CLEAN Program for the Direct Detection of Dark Matter
Mark Pearce Recent Results from PAMELA
Dan Hooper The Hunt for Dark Matter

Frontiers in Computational Astrophysics (DCOMP)
Chris Fryer Stellar Core Collapse
Tiziana di Matteo The Interplay between Galaxy Evolution and Supermassive Black Hole Growth
Jonathan McKinney Accretion Flows around Compact Objects

Computational Astrophysics of Disks: From Black Holes to Planets (DCOMP)
Charles Gammie Relativistic Magneto-Hydrodynamics and Black-Hole Accretion
Marina Romanova MHD Simulations of Disk-Star Interaction
Richard H. Durisen Radiative Hydrodynamics of Protoplanetary Disks and the Origin of Giant Planets

Nuclear Physics Connections with Astrophysics/Cosmology (DNP)
Sanjay Reddy Matter Under Extreme Conditions and Its Role in Explosive Astrophysical Phenomena
Paul Stankus Quark-Gluon Plasma: The Stuff of the Early Universe
Jorge Piekarewicz Neutron Stars and the PREX Experiment

Nuclear Physics in Astrophysics - From Stars to Stellar Explosions (DNP)
Dave Arnett Bethe Prize Talk: The Physics of Stars
D. Andrew Howell Dimming Metals: the Effect of Progenitor Metallicity on the 56Ni Yield and Luminosity of Type Ia Supernovae
Remco Zagers Test of Weak Reaction Rates of Importance for Late Stellar Evolution Using Charge-Exchange Reactions

Precision Measurements Impacting Cosmology (GPMFC)
Adam Reiss The Hubble Constant from the Hubble Space Telescope, Version 2.0
Maxim Pospelov Interacting dark energy in the lab: can we detect it?
Eric Adelberger Tests of Lorentz invariance using spinning electrons and the moon

we hear that ...

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Jim Hartle is this year's winner of the APS *Einstein Prize* for Gravitational Physics.

Robert Caldwell, Steven Carlip, Chris Fryer, David Garfinkle, John Hughes, Vassiliki Kalogera, Frank Krennrich, Pablo Laguna, Eric Poisson, Norna Robertson, James Ryan and Michael Zucker have been elected Fellows of the American Physical Society.

Hearty Congratulations!

400 years ago

David Garfinkle, Oakland University garfinkl-at-oakland.edu

In a departure from our usual "100 years ago" format, we note that 400 years ago Galileo first used a telescope for astronomy. In celebration of this monumental event 2009 has been designated the international year of astronomy.

The 24th Texas Symposium on Relativistic Astrophysics

Scott Hughes, Massachusetts Institute of Technology sahughes-at-mit.edu

The Texas Symposium on Relativistic Astrophysics was held in Vancouver, British Columbia, December 8th–12th of 2008. This was the 24th Texas meeting; the first was December, 1963 in Dallas, Texas. The impetus for the first meeting was the discovery that certain odd radio sources were cosmological, implying that they were extremely luminous. It quickly became clear that gravitational energy release was a likely explanation for these sources (now called "quasars"), and so the meeting brought together researchers in relativity, theoretical astrophysics and observational astronomy. This is a report on the plenary talks at Texas XXIV.

Virginia Trimble of UC Irvine reminded us of the meeting's history in her talk "A Remarkable Achievement: Texas at 45." This was a comprehensive overview of milestones reported at past Symposia (e.g., pulsars in 1968, Hawking radiation in 1972, the Hulse-Taylor pulsar in 1974, supernova 1987a in 1988). Virginia punctuated her talk by describing problems getting speakers from various countries (e.g., Vitaly Ginzburg was prevented from attending Texas I), issues with funding (one year the conference was funded by Motorola, hoping for a tie-in with their "Quasar" televisions), and the slowly but (at least recently) steadily increasing number of women speaking and organizing the meeting.

The remainder of Day 1's plenary talks focused on recent observations and facilities. Shri Kulkarni of Caltech began by reviewing gamma-ray bursts. He first described successes of the recent past, such as confirmation that most bursts are cosmological, and the discovery that "long soft" bursts emit in narrow jets. Shri noted that there are clouds on the horizon: Models explaining bursts are becoming somewhat baroque, needing to invoke multiple jets and repeated shocks. Finally, he described evidence that "short hard" bursts come from a distinct population than the long soft bursts. The emerging picture indicates that short hard bursts are related to stellar remnants rather than massive star collapse.

Peter Michelson of Stanford then discussed early results from the Fermi Gamma-ray Telescope. Formerly known as GLAST (the Gamma-ray Large Area Space Telescope), it was renamed to salute Enrico Fermi's contributions to astrophysics, and to acknowledge the role of international collaboration in its development. Fermi has already gathered 100 times as many photons as EGRET, the previous all-sky gamma-ray monitor. One exciting result is the discovery of a pulsar in the supernova remnant CTA1. No remnant had been seen there before; this appears to represent a pulsar which only emits in gamma rays. Future surveys will look for dark matter annihilation, a prime mission goal.

Day 1 concluded with Paul Sommers of Penn State discussing the Pierre Auger cosmic ray observatory. Pierre Auger consists of two sets sets of Cerenkov detectors: A (completed) site in Argentina, with 1600 tanks spread over 3000 km^2, and a (planned) site in Colorado with 4400 tanks spread over 8000 km^2. The southern site has important science results, including confirmation of cosmic ray depletion above the GZK (Greisen-Zatsepin-Kuzmin) cutoff, and an apparent correlation with active galactic nuclei for rays with energy above $\sim 57 \times 10^{18}$ eV. Unfortunately, the correlation appears strongest with AGN that are not well covered by the southern hemisphere site. Paul was eager to develop the northern site to improve sky coverage.

Day 2 began with Manuela Campanelli of the Rochester Institute of Technology describing "Binary Black Hole Simulations," giving an overview of the explosion of activity in numerical relativity in the past few years. Manuela focused on recent physics results, describing the outstanding overlap between numerical waveforms and analytic techniques, as well as describing what we have learned about mass and spin evolution, and recoil imparted by gravitational-wave emission. Sterl Phinney of Caltech then described "Relativistic Astrophysics with Gravitational Waves." Sterl reviewed how gravitational waves can be used to formulate interesting strong-field gravity tests, probe the nature and abundance of compact objects, and answer questions in stellar evolution and stellar dynamics. He concluded by noting that many of these issues will be answered most clearly by coordinating future gravitational-wave observations with telescope observations in all bands, an appeal this audience was well positioned to hear.

From compact objects we moved into cosmology. Henk Hoekstra of Leiden told us about "Weak Lensing by Large-scale Structure," one of the most promising techniques for weighing large groups of matter. The challenge here is to back out the ellipticity imposed by lensing shear on galaxy images in the presence of a galaxy's intrinsic shape, pixellation, blurring, and noise. Statistics makes it possible: A field of galaxies lensed by some structure will have common lensing shear; other contributions should average out in a well-defined sense. Wendy Freedman then discussed "The Cosmic Distance Scale." Her talk primarily described how recent measurements have improved our knowledge of the distance to Cepheid variable stars in not-too-distant galaxies. Recall that Cepheids vary in luminosity with a fixed period-luminosity relation. By measuring the period of a distant Cepheid, we learn its absolute magnitude. From its measured apparent magnitude, we then learn its distance. Improving our knowledge of the first "rung" on the cosmic distance ladder has a great impact on *all* distances. This work is largely responsible for pinning down the Hubble constant to the roughly 10% accuracy we use today.

Eiichiro Komatsu of the University of Texas opened Day 3 speaking on "Non-gaussianity in the Cosmic Microwave Background." This was a prize lecture, celebrating Eiichiro's win of the 2008 Young Scientist Prize from the International Union of Pure and Applied Physics. The talk made it clear that this was a well-deserved prize; Eiichiro gave an engaging, entertaining, and informative summary of how non-gaussianity can arise and imprint itself on the CMB. He demonstrated that the CMB is Gaussian to better than 0.1% — in many ways a more stringent constraint than our limits on spatial flatness. Christof Pfrommer of CITA then described "High Energy Astrophysics in Galaxy Clusters." Chris's talk made it clear that clusters are extremely complicated objects. He made an excellent case that they will be interesting targets for observing campaigns with Fermi; they should also be excellent targets for low-frequency radio arrays, since cluster gas will be shocked. His talk introduced many of us to the German word "gischt," the foam on top of a cresting wave, which he used to describe emission from a shock front.

Reinhard Genzel of the Max-Planck-Institut for Extraterrestrial Physics then brought us up to date on "The Galactic Center." He primarily focused on his group's work using the Very Large Telescope in Cerro Paranal, Chile (with much credit also given to his main competitor, Andrea Ghez's group at UCLA). He now reports the mass of the presumed black hole at the center of our galaxy as $3.95 \pm 0.06 \times 10^6\, M_\odot$, with most of the error due to uncertainty in our knowledge of the distance to the galactic center (needed to convert angular motions to physical motions). This work requires resolution of tens of milliarcseconds. Reinhard described plans to get to *micro*arcsecond resolution using optical interferometry at the Very Large Telescope. Day 3 concluded with a provocative talk by Craig Hogan, now at Fermilab, entitled "What's wrong with cosmology?" It appeared in the program as "What's wrong with *concordance* cosmology?", but Craig decided to push things a little further. He cautioned the audience not to become too enamoured of various "isms," such as "fundamentalism" (only the deepest truths matter!), "giantism" (if a 10 meter telescope is good, a 100 meter telescope is better!), and "futurism" (10 years from now, data from X will revolutionize this subject!). It was a fun way to conclude before our free afternoon.

Day 4 began with Cliff Will of Washington University telling us about "Testing general relativity: A 30-year perspective and a view of the future." The perspective part of the talk referred to the fact that Texas IX occurred almost exactly 30 years earlier in Munich. That meeting featured the first presentation of the $\dot{P}$ measurement from PSR 1913+16, with many concluding that testing general relativity was done. This viewpoint was quickly overthrown by work on fifth forces (which rose and fell in the 1980s), string theory, extra dimensions, Lorentz violation, dark matter and dark energy. Cliff noted that future tests are likely to be astronomical in nature, pointing to work on imaging accretion disks around black holes, ever more precise mapping of orbits, gravitational-wave astronomy, and cosmology. Ingrid Stairs of the University of British Columbia then described "The Double Pulsar," PSRJ0737-3039. In introducing her, Bill Unruh thanked whoever it was that prayed for this object, and suggested that they keep at it. Much of J0737's magic is due to the serendipitous alignment of the binary to our line of sight: The pulsars eclipse one another over their 2.4 hour orbit. This allows us to formulate tests that are far more stringent than those encountered for almost any other astronomical objects. For example, the Shapiro delay due to pulses from one pulsar passing near the other agrees with GR to within 0.05%. The eclipsing geometry also lets us map the magnetosphere of one of the neutron stars as pulses from the other are affected by it.

We concluded this day with a pair of talks on cosmology. Andrew Liddle of the University of Sussex spoke on "Inflation," reviewing the subject and describing how well it is constrained at present. A particular point of interest is the index characterizing the spectrum of scalar perturbations. Inflation predicts n_S slightly less than 1. Andrew emphasized that, though the data currently indicates $n_S \simeq 0.96$, one cannot really state with great confidence that $n_S \neq 1$. Tom Abel of Stanford then told us about "Cosmic Reionization." This talk was largely motivated by upcoming low-frequency radio observations which will make 3-D tomographic maps of hydrogen ionization in early structure formation. Much like the cosmic microwave background, these maps will trace the density and distribution of matter, but do so over a range of redshifts rather than at a single epoch. Tom showed us that simulations of structure growth can now trace matter evolution from a nearly isotropic initial density field to produce protostars of a just a few Jupiter masses, covering 23 orders of magnitude in density.

The meeting ended with a day of talks on cosmology. Sean Carroll of Caltech opened by describing "Dark forces and dark energy." Noting that this territory has been very well covered in various venues recently, Sean quickly jumped to the punchline: Our universe appears to be dominated by a cosmological constant, and the bulk of its matter appears to be non-baryonic. Sean described various mechanisms and theories to explain these features, but noted that many alternates end up introducing as many problems as they solve. His advice was just to do the observations and experiments and not pay too much attention to theoretical objections. Jonathan Feng of UC Irvine followed this by discussing "Dark matter candidates and signals." Jonathan emphasized, much as Sean did, that there is an enormous range of possibilities, with very few constraints. He described the various experiments that aim to directly detect dark matter particles, and gave a brief summary of recent observations (DAMA's annual modulations; the positron excess seen by the PAMELA and ATIC satellites) which *may* be related to dark matter. Unfortunately, it is hard to find a model which explains *all* of these data! Phil Hopkins of UC Berkeley then told us about "Quasars, Feedback, and Galaxy Formation." This was a true gastrophysics talk, examining the ways in which quasars are fueled, how their output acts back on their host galaxy ("feedback"), and what this implies for the evolution of galaxy structure and quasar luminosity function with cosmic time.

Lawrence Krauss, now at the University of Arizona, wrapped up the meeting with "The Future of the Universe and the Future of Cosmology," or "Our Miserable Future." He was quite pessimistic about ever understanding dark energy. Though detection of only a tiny deviation from a pure Λ universe would immediately falsify the cosmological constant hypothesis, we are unlikely to be able to measure a tiny deviation. He made the interesting observation that if the cosmological constant hypothesis is correct, then we are evolving toward deSitter's static universe: Everything beyond a relatively nearby horizon will move out of causal contact. Future cosmologists (who he described as "lonely and ignorant ... but dominant") will have no need to develop "cosmology" as we now know it, since the whole universe will just be our galaxy. These cosmologists will be led, by the best data available to them, to a totally incorrect fundamental model of the universe — a point he suggests we bear in mind when examining our data today.

In her opening remarks, Virginia Trimble noted that when the first Symposium was proposed, Engelbert Schucking asked his co-organizers, "What the hell is *relativistic astrophysics*?" Judging by the talks presented here in Vancouver, it appears to be astrophysics in which general relativity plays a crucial role. It's worth recalling the concluding remarks of Tommy Gold at the first Texas meeting: "... here we have a case ... that the relativists with their sophisticated work were not only magnificent cultural ornaments but might actually be useful to science! ... It is all very pleasing, so let us hope that it is right. What a shame it would be if we had to go and dismiss all the relativists again." Texas XXIV shows that there's not much danger of such dismissal anytime soon. I'm looking forward to Texas XXV.

Loop Quantum Cosmology Workshop

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Loop quantum cosmology (LQC) is a non-perturbative quantization of symmetry reduced spacetimes, based on loop quantum gravity. In recent years it has emerged as a promising arena for quantum gravity of simple yet rich models, offering interesting physical implications. These include insights on the resolution of spacelike singularities and ramifications of quantum gravity on the physics of the very early universe. The LQC workshop at the Institute of Gravitation and the Cosmos at Penn State was the first such meeting in this field. It was a 3-day event, October 23-25, 2008, bringing more than 40 participants including many LQC experts and young researchers together under the same roof. A highlight of this workshop was its attendance and talks by experts from other fields who provided insights from an interdisciplinary perspective. The meeting took place in an academically stimulating atmosphere with a large number of open discussions during the talks and in special discussion sessions.

There were a total of 21 talks including three reviews on LQC; some were of a longer duration (45 minutes to 1 hour) and others, shorter seminars (30 minutes). The workshop was divided into different themes for each day. On the first day it focused on the nature of spacetime near classical singularities and homogeneous models in LQC. Day 2 dealt with quantization of inhomogeneous models, effects of quantum geometry on quantum fields and effective equations. Day 3 focused on physical implications and phenomenological models. An important part of the schedule were the daily focused discussion sessions (90 minutes each). These sessions were also used for very short voluntary talks by the participants.

The workshop started with opening remarks by Abhay Ashtekar (Penn State) who welcomed all participants and gave a brief introduction about the progress in the field. He stressed the importance of distinguishing between results which have been rigorously proved and established from those which are preliminary in nature. The morning session on the first day was on *Classical Singularities* in which Beverly Berger (National Science Foundation) gave a review of various mathematical and numerical results on the approach to singularities in classical general relativity, obtained by different groups in recent years. She pointed out that there is ample emerging evidence in support of the BKL conjecture. Adam Henderson (Penn State) then reported on a formulation of the BKL conjecture that is well-adapted to LQC. Frans Pretorius (Princeton) discussed recent results on Ekpyrotic/Cyclic models which show that the ultra stiff equation of state for the radion field suppresses the chaotic mixmaster behavior near the big bang. These results indicate that spacetime near the big bang singularity may be homogeneous. The afternoon session focused on *Homogeneous Loop Quantum Cosmology* in which Abhay Ashtekar gave a review, summarizing various recent developments on singularity resolution. He also gave an update on new results which include a quantum bounce at the Planck scale in inflationary models. In this session, Edward Wilson-Ewing (Penn State) presented the first consistent loop quantization of Bianchi-I spacetime and discussed emerging exciting physics which shares the feature of quantum bounce with isotropic models. In the discussion session, Frans Pretorius stressed exchange of ideas between LQC and Ekpyrotic models to achieve singularity resolution in the latter.

On the second day, the morning session focused on *Inhomogeneous Loop Quantum Cosmology*. Jerzy Lewandowski (Warsaw University) gave a review of results on the effects of quantum geometry on quantum fields. Alejandro Corichi (UNAM, Morelia) and Guillermo A. Mena Marugan (IEM (CSIC), Madrid) gave short reviews of the Fock and Hybrid quantizations of the Gowdy models respectively. The afternoon session talks were on the *Effective Equations* in which Martin Bojowald (Penn State) gave an overview of one of the approaches to obtain effective dynamics. The discussion session on the second day featured two short talks on very interesting results. The first one by Victor Taveras (Penn State) was on modifications to Friedman dynamics in LQC. The second talk was by Tomasz Pawlowski (IEM (CSIC), Madrid) who presented results using effective dynamics in the Hybrid quantization of Gowdy models. He discussed numerical simulations performed by the Madrid group which show the presence of a quantum bounce in the presence of inhomogeneities.

The final day of the workshop focused on *Loop quantum gravity phenomenology, Inflation and CMB*. Parampreet Singh (Perimeter) gave a review of recent results obtained by different groups and discussed fate of singularities using effective dynamics in LQC. Mairi Sakellariadou (Kings College) gave an overview of the numerical results obtained from lattice refinement techniques. This was followed by a talk by William Nelson (Kings College) on phenomenological aspects of these techniques in dark energy models. The afternoon session featured short talks on preliminary results on issues inspired by loop quantum gravity. These included effects on cosmological perturbations (Michal Artymowski (Warsaw University) and Gianluca Calcagni (Penn State)) and implications of treating the Barbero-Immirzi parameter as a field (Nico Yunes (Princeton)). In this session Tirthabir Biswas (Penn State) presented ideas to obtain a scale invariant spectrum of perturbations using the string gas mechanism. In the concluding session, participants discussed various new results presented during the workshop, assessed what has been achieved so far and open directions which need to pursued in the near future.

The workshop dinner took place in the Nittany Lion Inn, one of the historic hotels of the United States. Participants used this warm occasion to discuss the possibilities to organize another workshop focused on LQC in near future. External experts commented that the workshop was a wonderful opportunity to get updates and clarifications on recent developments. Because of the emphasis on discussions, younger participants found it especially rewarding. Online proceedings are available at
`http://www.gravity.psu.edu/events/loop_quantum_cosmology/proceedings_lqc.shtml`