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

Great news are rocking our field of research. Two new NSF-funded Physics Frontiers Centers, one of them in gravitational wave physics and another in cosmology. A new privately funded institute devoted to fundamental physics including gravity is created in Canada. LIGO, TAMA and GEO are collecting data. A big grid computing project will deliver computational resources unheard of in the past. Several members of our community honored. You can read about it all here, in Matters of Gravity!

An editorial note: the article by Seiji Kawamura was originally signed "Seiji Kawamura and the TAMA collaboration", similarly the article by Stan Whitcomb was signed "Stan Whitcomb reporting for the LIGO Laboratory and the LIGO Science Collaboration". I shortened them to keep in line with usual MOG practice.

Otherwise not much to report here. If you are burning to have Matters of Gravity with you all the time, the newsletter is now available for Palm Pilots, Palm PC's and web-enabled cell phones as an Avantgo channel. Check out `http://www.avantgo.com` under technology→science. The next newsletter is due February 1st. If everything goes well this newsletter should be available in the gr-qc Los Alamos archives (`http://xxx.lanl.gov`) under number gr-qc/yymmnnn. To retrieve it send email to gr-qc@xxx.lanl.gov with Subject: get yymmnnn (numbers 2-17 are also available in gr-qc). All issues are available in the WWW:
`http://www.phys.lsu.edu/mog`
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.

If you have comments/questions/complaints about the newsletter email me. Have fun.

Jorge Pullin

We hear that...

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Jürgen Ehlers will receive the 2002 Max Planck Medal of the German Physical Society. The medal is given by the Society for outstanding acheivements in theoretical physics from worldwide nominations and is widely regarded as its the highest international honor. It was instituted in Jnue 1929 to mark the 50th anniversary of Planck's doctorate. The first two recipients were Planck and Einstein. Ehlers will receive the prize in March 2002 during a special ceremony at the annual meeting of DFG.

Gary Horowitz, Bei-Lok Hu and *David Shoemaker* have been made Fellows of the American Physical Society.

Hearty congratulations!

Correspondents

- John Friedman and Kip Thorne: Relativistic Astrophysics,
- Raymond Laflamme: 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
- Riley Newman: Laboratory Experiments
- Warren Johnson: Resonant Mass Gravitational Wave Detectors
- Stan Whitcomb: LIGO Project
- Peter Saulson: correspondent at large.

Center for Gravitational Wave Physics, a new NSF Physics Frontier Center

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On August 15 the National Science Foundation created at Penn State the Center for Gravitational Wave Physics as part of its new Physics Frontier Centers program.

As described by the Foundation, the goal of the Physics Frontier Center (PFC) program is to support timely, aggressive, and forward-looking research with the potential to lead to fundamental advances in physics. This new Center is one of only three funded by the Foundation in the first round of Physics Frontier Center funding. The mission of the Center for Gravitational Wave Physics is to help crystallize and develop the emerging discipline of gravitational wave phenomenology: the astrophysics and fundamental physics that gravitational wave observations — in all wavebands — enable.

Research at the Center will focus on interdisciplinary problems at the interface of general relativity, gravitational waves, astrophysics and detector design:

- Astrophysics and gravitational waves: problems of source calculations, astrophysical modeling of sources and their populations, and interpretation of observations,
- General relativity and gravitational waves: testing relativity and developing numerical and analytic tools needed for detailed studies of sources (e.g., numerical relativity and radiation reaction),
- Detector design studies: how target science — the sources one wants to detect or the science one wants to do — constructively influences the design of advanced gravitational wave detectors.

The Center for Gravitational Wave Physics is a community resource, meant to support and encourage research in gravitational wave phenomenology. An important component of the Center is a major, international visitors program. Center funding is available to host visitors or groups of visitors who wish to become involved in gravitational wave phenomenology research or focus attention on specific problems. Visits, supported by the Center, from weeks to months are possible, and limited funding is available to support sabbatic visitors.

In addition, the Center will host frequent focus sessions, workshops and conferences on critical gravitational wave phenomenology problems. Focus sessions, which last for just a few days, typically address a single, narrowly defined problem on which it is thought substantial progress can be made through concentrated effort by experts. Workshops, like the recent Gravitational Wave Phenomenology Workshop (described elsewhere in this volume), last from a few days to a week are broader meetings, aimed at discussion and accessible to non-experts and new-comers to the field. Conferences, such as the forthcoming Fourth International LISA Symposium, are larger and longer affairs, whose purpose is to consolidate work in preparation for future efforts.

The recent Gravitational Wave Phenomenology Workshop, held on 6–8 November 2001, was the first workshop sponsored by the new Center. Forthcoming focus sessions include

- Astrophysical Initial Data Problem: (29–30 March 2002) Posing Astrophysically relevant initial data for numerical relativity investigations of binary black hole or neutron star coalescence. Organized by Greg Cook and Pablo Laguna.

- WORK-BENCH: (Spring 2002) Present use and future development of the `bench` program for advanced interferometric detector design. Organized by Sam Finn, Gabriela González, David Shoemaker, Robin Stebbins and Ken Strain.

- Radiation Reaction: (Spring 2002) Implementing practical schemes for computing the gravitational waveforms, especially from extreme mass ratio binary systems. Organized by Warren Anderson, Patrick Brady, Eanna Flanagan and Sam Finn.

- Numerical Relativity: (24–29 June 2002) Jointly sponsored with the Institute for Mathematics and its Applications (IMA), this workshop will bring together the numerical relativity and the mathematicians working in numerical analysis, scientific computation, partial differential equations and geometry for an intense but informal discussion aimed at bringing new ideas and techniques into the numerical relativity, and propelling applied mathematicians with relevant skills and interest into numerical relativity. Organized by IMA director Doug Arnold, Abhay Ashtekar and Pablo Laguna.

- Stellar Populations: (Fall 2002) What — and how — can we learn about stellar populations from gravitational wave observations? Organized by Vicky Kalogera, Martin Rees and Sam Finn.

- Massive black hole coalescence: (Fall 2002) Massive black holes are presumed to coalesce in the cores of interacting galaxies, and these coalescence events are potentially important gravitational wave sources for LISA. Present theoretical estimates of the coalescence rates give timescales much longer than suggested by indirect observational evidence. What's missing from our understanding? Organized by Steinn Sigurdsson and Ramesh Narayan.

- Numerical Relativity and Gravitational Wave Data Analysis: (Fall 2002) Numerical relativity has much to offer to the analysis and interpretation of gravitational wave observations. This focus session will bring these two communities together to foster a greater understanding of how numerical relativity can aid in gravitational wave data analysis and interpretation. Organized by Bernd Brügmann, Sam Finn and Pablo Laguna.

Forthcoming workshops hosted by the Center include the Fourth Capra Meeting on Radiation Reaction in General Relativity, which will follow immediately on the heels of the radiation reaction focus session, and the second Gravitational Wave Phenomenology Workshop, tentatively planned for Spring 2003. Forthcoming conferences hosted by the Center include the Fourth International LISA Symposium, which will be held 19–24 July 2002.

The core, resident faculty of the Center for Gravitational Wave Physics are Abhay Ashtekar, Sam Finn (Director), Peter Meszaros, Pablo Laguna (Associate Director), Steinn Sigurdsson and Alex Wolszczan. In addition, the Center for Gravitational Wave Physics non-resident faculty members, who are expected to visit frequently, are Warren Anderson, Mario Diaz and Joseph Romano (University of Texas, Brownsville); Patrick Brady (University of Wisconsin, Milwaukee); Matt Choptuik (University of British Columbia); Eanna Flanagan (Cornell

University); Gabriela Gonzalez, Jorge Pullin and Joel Tohline (Louisiana State University); Richard Price (University of Utah); Robin Stebbins (Goddard Spaceflight Center); and Ken Strain (University of Glasgow).

All Center activities are open to the broad scientific community, whose participation will be supported through the Center's visitor program. For more information on the opportunities provided by the Center please contact `CGWP@Gravity.Phys.PSU.Edu` or see the Center's web site (presently under construction) at `http://cgwp.phys.psu.edu`

Perimeter Institute for Theoretical Physics

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Perimeter Institute for Theoretical Physics opened its doors this past September in Waterloo, Ontario, Canada. Pi, as we call it, is an independent, privately endowed institute, which will specialize in fields having to do with fundamental physics. This naturally includes several fields in which relativists work including quantum gravity, cosmology and string theory.

This year Pi opened with 3 researchers (long term positions equivalent to faculty), two associates, who have appointments also in a new Institute of Quantum Computing (IQC) founded simultaneously at the University of Waterloo, four postdocs and 5 students. (For the names and much other information please see `http://www.perimeterinstitute.ca`). The scientific staff is being recruited primarily from outside Canada. Next year we expect to have around 7 researchers, 10 postdocs, plus visitors and students. There is also an active visitors and seminar programs, with an average of 2 new visitors arriving each week (for details see `http://www.perimeterinstitute.ca/news_fr.htm`).

There is already quite a lively atmosphere, and the visitor to Pi will usually find several informal discussions and collaborations under way throughout the building. In January alone we had seminars by Stephon Alexander (London), Giovanni Amelino-Camelia (Rome), Daniel Gottesman (Berkeley), Ted Jacobson (Maryland), Robert Laughlin (Stanford), Seth Major (Hamilton), Hendryk Pfieffer (Cambridge) and Maxim Pospelov (Victoria), who presented their work on a range of topics in quantum gravity, quantum phase transitions, black hole physics, Planck scale phenomenology and quantum information theory.

The plan is to grow over six years to 40 resident scientists, plus visitors, students, associates and affiliates (the latter are people whose primary appointments are in nearby universities.) The fields of emphasis for this first stage are quantum gravity, including but not limited to string theory and foundations of quantum mechanics including quantum information theory. In later years other fields of theoretical physics will be added.

A beautiful new building is planned, designed by the architectural firm of Saucier and Perrott, who were chosen after a competition. The building was designed after extensive consultations with scientists and we believe will provide the most hospitable and welcoming atmosphere that exists for doing theoretical physics, in a visually stunning setting (see `http://www.perimeterinstitute.ca/news_fr.htm`).). The building will be on the side of Silver Lake, next to Waterloo Park, and a short walk from both the University of Waterloo and the newly invigorated downtown core of the city of Waterloo. While Pi will be primarily a residential institute, there will be conferences, workshops and the like held in the building, as well as cultural activities such as concerts and lectures on science for the public. The first Pi public lecture was given in October by Roger Penrose, and drew an audience that was twice the capacity of the lecture hall.

Presently we are located in a beautiful old red stone building in the center of Waterloo. The building features a large informal interaction area with, we believe, the only bar in the world with wall-to-wall black boards (called by popular acclaim the hbar).

Waterloo is in the heart of the fastest growing region in Canada, and is a center for high tech industry as well as home to two universities. Those of us who have just moved here have been very pleased to find ourselves in a sophisticated, youthful, growing and diverse city. Toronto, which is one of the most exciting cities culturally in North America, and is also the worlds most ethnically diverse city, is a bit more than an hour away by car, bus and train. The Toronto International airport is 45-50 minutes away.

The Institute was founded by Mike Lazaridis, founder and co-Ceo of Research in Motion and several friends, who are contributing an endowment of $120 million (Canadian). The Institute is governed primarily by its scientific staff, with oversight from a Scientific Advisory Committee (SAC) of renowned senior theoretical physicists. As in private universities, there is a board of directors, but scientific decisions are primarily the purview of the scientific staff with oversight by the SAC. While independent, the institute has negotiated already or has under discussion a complex set of relationships with the University of Waterloo and other universities in Southern Ontario and Canada. These relationships include cross appointment of researchers, associates, affiliates and joint projects. The internal scientific governance is democratic and non-hierarchical; there is no scientific director and there are no heads of groups. While this condition was mandated by the founders, it was also discussed extensively among the scientists and advisory committee, and a number of models and examples were studied before arriving at the present structure. We believe that history shows that the scientific institutes and departments that maintain themselves at the highest level of quality for the longest time are those run on relatively non-hierarchical and democratic lines.

But just as important as money, bricks, offices, networks and computers is spirit, philosophy and culture. We are designing Pi with the hope that it will remain perpetually youthful, dynamic and flexible, a home to important research on the frontiers of physics, even when it is no longer young. Pi scientists are chosen to be not only scientific leaders in their fields, but dynamic, risk taking, open and ambitious people, who are interested in work done outside their specializations and are open to new ideas and competing research programs. They must also be people who respect other people, communicate easily and honestly, prefer working in a non-hierarchical and democratic setting and are interested in being involved in the adventure of building a new scientific institute.

Of course, in the end, the only measure of success of a new institute is the quality of the science that is done there, sustained over many years. At present, all that can be said is that Pi is off to a very good start, and we hope to see and host many members of the gravitational physics community here over the next few years. Watch this space.

For more information regarding seminars and visitors and information about postdoctoral, visiting and long term positions see `http://www.perimeterinstitute.ca/news_fr.htm`).

Detector and Data Developments within GEO 600

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It is not the landscape that makes Ruthe, near Hannover, Germany, an exciting place. The site of the British-German GEO-600 gravitational wave detector is a peaceful and relaxed placed. Unlike Hanford and Livingston, which host its larger LIGO brethren, there is no danger of earthquakes or wildfires, radioactivity is low, and alligators have not been seen around for a very long time.

GEO is the first medium-scale interferometer to enter in operation in Europe. By mid 2002, GEO plans to achieve its full sensitivity. Although GEO's armlength is only 600 meters, compared to LIGO 4 km, it features advanced mirror suspensions and optics which, by the way, are planned to be incorporated into advanced LIGO. The use of such advanced technology makes GEO design sensitivity almost comparable to initial LIGO, and therefore it has reasonable chances of detecting gravitational waves (especially from compact binary inspirals, neutron stars and supernova events). Moreover, GEO will be unique among the first interferometers in being able to operate in narrow-band mode which will give it a better sensitivity to continuous, nearly periodic signals than the larger projects (LIGO and the French-Italian VIRGO) would have in the selected band.

While getting closer to completion, 2001 has been an intensive year for GEO. Detector and environmental data have been produced continuously throughout the year. GEO generates on the order of 50 GBytes of data per day, which are stored using a data format fully compatible with LIGO and VIRGO. In addition, GEO and LIGO have become partners: they have signed full reciprocal data exchange agreements, GEO is part of the LSC (LIGO Scientific Collaboration), and they are jointly developing data analysis software. Besides, GEO is building four different computer clusters at AEI-Golm, Birmingham, Cardiff and Hannover where the different data analysis tasks are to be performed.

In February 2001, a workshop took place in Ruthe and gave the main kick to GEO Detector Characterization (DC) activities. Those who attended realized that the site is cold in winter, especially if you need to walk to the next building equipped with facilities, which highlights the enthusiasm experimentalists are putting in bringing the interferometer to work. Later on, in June, another GEO-DC workshop took place, but this time at AEI-Golm. On that occasion, the need of the DC-Robot, as an efficient automated system to characterize the data, and its interaction with a database were pushed forward.

Another effort, largely invisible to outsiders, is the analysis of GEO data. With the aim of gaining a better understanding of the detector behavior and its environment, data from environmental monitors, e.g., seismometers, magnetometers, and, of course, from the detector itself are being analyzed. As the the detector status has been progressing, data analysis activities have turned more complex and organized. After the summer, different subgroups focused their attention to the commissioning of different detector subsystems. Of particular interest was the GEO engineering run that took place in October 15-18, 2001. The mode-cleaners were in almost final configuration and the Michelson was locked on mid fringe with no power recycling. This run was a success, shift scheme and data transfer Ruthe-Hannover-AEI were exercised, and the long term behavior of the whole system was tested.

As in any other project, GEO has overcome many hardships, some of them unexpected. At the end of October, data acquisition at the north-end station was interrupted for several days because mice had eaten too many optical fibers. This time, new fibers with a 40 year guarantee of mouse-proofness were ordered to give us the upper hand in the fight.

From November onwards, a big effort was devoted to lock the Michelson on a dark fringe and incorporating the power recycling cavity. In parallel, a deep analysis of the detector subsystems (geophones, laser power, magnetometers, mode-cleaners, etc) has taken place. To keep track of the detector and data acquisition status, GEO detector database is available via a web interphase. This includes also signal descriptions, calibration information, data viewer, and two electronic labbooks (GEO-600 and GEO-DC) actively used by both experimentalists and theorists.

It is worth mention, although not being a gravitational wave detection, GEO first astronomical observation has already occurred. The geomagnetic storm due to two fast moving coronal mass ejections on November 22, 2001, was observed in the GEO magnetometers as expected in November 24 data.

The last thing I want to mention and most exciting one, is the coincidence run with LIGO. Both LIGO and GEO detectors were on operation from December 28th until January 14th. The run was a great success. GEO had a duty cycle of about 80%. For some days the power-recycled interferometer was in lock for more than 95% of the time. The longest continuous lock segment was of 3h 48min. Monday 14th was a day for celebration in Ruthe with all the operators and people that participated in the shifts. We really got very good data!

During the run other events took place. For example, on January 2nd, the waves from an earthquake near Australia (Vanuatu Islands, magnitude 7.1 on the Richter scale) hit GEO. The interferometer lost lock, but it was realigned and locked automatically from then on. Almost all the earthquakes worldwide, with a magnitude bigger than 4.5, can be seen on our seismometer data but often do not influence the detector output so much. In the data (e.g., from the feedback to the intermediate masses) we can clearly see the influence of the moon with a period of 12.4h, and our magnetometers continue recording information of the Sun-Earth environment. With the gravitational wave data taken from this coincidence run we hope to be able to set astrophysical upper limits on different gravitational wave sources.

Pay attention to the next Matters of Gravity edition, I am sure there will be plenty of news from the gravitational wave community.

Grid Physics, the Virtual Data Grid, and LIGO

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Between 28 December 2001 and 14 January 2002, the three largest interferometric gravitational-wave detectors in the world were listening for signatures of cataclysmic astrophysical events in our Galaxy and beyond. For many involved in the LIGO (Laser Interferometer Gravitational-wave Observatory) project, this was an event of grand proportions which demonstrated that we are truly on the brink of gravitational-wave astronomy. Yet the data run was just the beginning. About 13 Terabytes of data was recorded and will be analyzed over the coming months. Scaling these numbers to full scale scientific operations, the experiment will generate several hundreds of Terabytes of data per year.

The variety of sources which could produce gravitational waves call for a variety of search techniques to be applied to the data stream. For example, searches for stochastic background gravitational waves require minimal computational power–a standard desktop workstation is good enough–yet, the search must access the data from all the detectors. At the other end of the spectrum of computational requirements are searches for continuous signals from spinning neutron stars. These signals are extremely weak, and require coherent accumulation of signal-to-noise for long periods of time; this introduces the need to account for earth-motion-induced Doppler shifts and internal evolution of the sources. Thus, the variety of signals and their weakness lead to an analysis problem which can use essentially infinite computing resources.

But the computational requirements are only half the story. LIGO computing facilities and scientific users reside at many different national and international centers and universities. For the LIGO Scientific Collaboration (LSC) [1], therefore, accessing these large datasets and performing an efficient analysis on them requires a dynamically distributed computational infrastructure, including tools to manage storage, migration and replication of data, job control, and cataloging of the many data products. The LIGO Data Analysis System handles these problems on a scale consistent with the LIGO-I mission, however *Grid Computing* [2] provides a new computational infrastructure to extend and enhance current capabilities to a level consistent with the expected requirements.

LIGO is only one of several physics experiments expecting to generate vast amounts of data which must be carefully analyzed using complex algorithms requiring enormous computational power. For this reason several LSC member institutions, including California Institute of Technology (CIT), The University of Texas at Brownsville (UTB), and University of Wisconsin–Milwaukee (UWM), are participating in a multi-experiment project, sponsored by the National Science Foundation, to build the first Petabyte-scale computational grid environment for data intensive experiments. The Grid Physics Network (GriPhyN) [9] project is a collaboration of both experimental physicists and information technology researchers. Driving the project are unprecedented requirements for geographically dispersed extraction of complex scientific information from very large collections of measured data, flowing from four experiments in high-energy and nuclear physics (two large hadron colliders at CERN, CMS and ATLAS [3]), gravitational waves (LIGO [4]) and astronomy (the SDSS project [5]). To meet these requirements, GriPhyN researchers will develop the Virtual Data Toolkit (VDT) containing basic elements to construct the first Global Petascale Virtual Grid.

The virtual data concept aims to unify the view of data in the distributed Grid environment. It will not matter if the data is raw or processed, or if it was generated from an hadron collider experiment or a gravitational-wave detector. The virtual Grid will enable data access and archival at nodes distributed around the globe while storing meta-data which make the data self-describing. The VDT developed by GriPhyN will be deployed on the Grid to directly manage these fundamental virtual data objects instead of complex data pipelines. In the case of LIGO, the VDT will be capable of executing deep searches for gravitational waves using many machines distributed around the world, while making the results available to the scientists in a transparent fashion. Once deployed, the Grid tools currently under development will significantly enhance scientists' ability to carry out the necessary analysis of LIGO data. In fact, prototype data replication tools (being developed by Scott Koranda at UWM) are already moving data from the archive at Caltech onto spinning disks at UWM for analysis using the UWM system.

GriPhyN is not the only data grid project, although it is one of the largest and probably most advanced in the world. Similar projects are now active in Europe and Asia. In September, the NSF announced the additional award of $13.65M over five years to a consortium of 15 universities and four national laboratories to create the International Virtual Data Grid Laboratory [6,7] (iVDGL). The iVDGL, to be constructed in partnership with the European Union, Japan, Australia and eventually other world regions, will form the world's first true *Global Grid*. The iVDGL will provide a unified computational resource for major scientific experiments in physics, astronomy, biology, and engineering. The iVDGL will therefore serve as a unique computing resource for testing new GriPhyN computational paradigms at the Petabyte scale and beyond. Management of the iVDGL is integrated with that of the GriPhyN project. The international partners are investing more than $20M around the world to build computational sites as part of the consortium. Moreover, the NSF award of iVDGL is matched by $2M in university contributions, plus funding for Computer Science Fellows by the UK e-Science Programme [10]. Of this total award, $2.11M will go to universities affiliated with the LIGO Laboratory to develop Grid Computing centers at the three GriPhyN/LSC institutions (CIT, UWM and UTB) and at Pennsylvania State University (PSU).

A significant challenge for science in the 21st century is data management and analysis. Just as large database technology has revolutionized the commercial world as the backbone of many information intensive enterprises, so virtual data, Grid computing and transparent access to a world of computing resources will revolutionize science in the coming decade.

References:

[1] LIGO Scientific Collaboration web site:
`http://www.ligo.caltech.edu/LIGO_web/lsc/lsc.html`.

[2] The Computational Grid is described in the book "The Grid : Blueprint for a New Computing Infrastructure" edited by Ian Foster and Carl Kesselman – Morgan Kaufmann Publishers (1998) ISBN 1-55860-475-8. Many more references can be found at the following web site:
`http://www.aei-potsdam.mpg.de/~manuela/GridWeb/info/grid.html`.

[3] CMS and ATLAS are two large hadron colliders at CERN, the world's largest particle physics center near Geneva in Switzerland (see web site:
`http://www.griphyn.org/info/physics/high.html` .)

[4] The Laser Interferometer Gravitational-wave Observatory web site:
http://www.ligo.caltech.edu.

[5] The Sloan Digital Sky Survey (SDSS) project is the most ambitious astronomical survey project ever undertaken. The survey will map in detail one-quarter of the entire sky, determining the positions and absolute brightnesses of more than 100 million celestial objects. It will also measure the distances to more than a million galaxies and quasars. Apache Point Observatory, site of the SDSS telescopes, is operated by the Astrophysical Research Consortium (ARC). (see web site at: http://www.sdss.org/sdss.html)

[6] The International Virtual Data Grid Laboratory web site:
http://www.ivdgl.org.

[7] The Outreach Center of the Grid Physics Network web site:
http://www.aei-potsdam.mpg.de/~manuela/GridWeb/main.html.

[8] The Grid Physics Network web site: http://www.griphyn.org.

[9] e-Science is an equivalent project to iVDGL in the UK (see web site at:
http://www.e-science.clrc.ac.uk/).

1000 hours of data taken on TAMA300 and the first lock of the recycled TAMA300

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The TAMA project, the Japanese effort for detecting gravitational waves using the 300m laser interferometer (TAMA300), took an unprecedented 1000 hours of data in the summer of 2001. Just recently the power recycling system was implemented in TAMA300, and the recycled interferometer was successfully locked.

During the observation period, the interferometer was remarkably stable: it held lock continuously for more than 20 hours several times, and the overall duty cycle was 86%. The observational functions of the detector had been drastically improved for this data run: a newly-developed automatic re-locking system of the whole interferometer worked reliably, a newly-established quick look system helped us to find any unusual behavior of the interferometer as well as the data taking system, and a newly-implemented medium-speed data acquisition system (64 channels) supplemented the existing high-speed and low-speed data acquisition system (100 channels) for recording important detector information. As for the sensitivity of the detector, it had been improved around 100 Hz by a factor of 10 compared with the sensitivity obtained in the summer of 2000, resulting in a significant improvement of the sensitivity to chirps from heavier-mass binary coalescence. The best strain sensitivity of $5x10^{-21}\mathrm{Hz}^{-1/2}$ around 1 kHz remained the same as before.

During the above-mentioned data run, the interferometer was operated without the power recycling system. Since then we have begun implementing recycling in TAMA300. Around the end of 2001 the recycled interferometer was finally locked for a few seconds for the first time in the history of TAMA300! The lock has been made more and more robust by reactivating the alignment control system for the test masses and by adjusting all the servo systems carefully. As of Jan. 23, 2002, TAMA300 with recycling can hold lock for up to 46 minutes continuously. We will continue to stabilize the lock of the interferometer as well as to improve the sensitivity of the detector.

Please have a look at our home page for more details, `http://tamago.mtk.nao.ac.jp`

LIGO Takes Some Data!

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Many members of the LIGO Scientific Collaboration (LSC) spent The final days of 2001 and the early days of 2002 at the LIGO observatories in Hanford, Washington, and Livingston, Louisiana, participating in the seventh LIGO engineering run (E7). Unlike previous LIGO engineering runs which focused on characterizing the interferometers and improving their reliability, the goal of E7 was to provide data for a first end-to-end test of the data analysis pipeline, to test data acquisition and archiving, gain experience with round-the-clock interferometer operation and detector monitoring.

For two weeks teams of scientists and operators attempted to keep the three LIGO interferometers locked and taking data. Although the LIGO interferometers still have a long way to go to reach their design sensitivity, the data recorded during E7 will provide LSC scientists with the real interferometer data needed for perfecting and tuning their gravitational wave search algorithms. In addition to the three LIGO interferometers, we were fortunate to have the GEO-600 interferometer near Hanover, Germany and the Allegro bar-detector at Louisiana State University operating in cooperation with LIGO during much of the run.

To maximize the overlap of the lock times among the interferometers each LIGO interferometer was operated in a configuration that minimized the risk of down time. The 2 km interferometer at Hanford was operated in its final power-recycled mode. Because the commissioning of the 4 km interferometers at Hanford and Livingston has been scheduled to lag that of the 2 km instrument, their power-recycling mode is not yet reliable enough for extended data taking. The 4 km instruments were therefore operated in a non-recycled mode to improve overall lock-time.

The E7 run, like previous runs, was an occasion for large number of LSC scientists to participate actively in the operation of the interferometers and to perform other scientific activities at the observatories. Monitoring programs ran continuously to help the operators and scientists keeping tabs on the current interferometer status, and preliminary analysis of the data collected during the E7 run took place using the LIGO Data Analysis Systems (LDAS) at the sites. In addition, off site analysis occurred on smaller selected data sets at Caltech and MIT. In the end, over 13 TB of data from nearly 8000 interferometer and environmental channels had been collected and archived.

The three interferometers were individually locked for ∼60-70% of the run, with the majority of that time (∼40-60% of the total) in locked segments long enough for meaningful analysis (more than 15 minutes). The total time with all three interferometers locked was 140 hours (∼34%), out of which 71 hours (∼18%) represent segments longer than 15 minutes. Considering the early stage in the commissioning, we are rather pleased with this performance.

LIGO is funded by the National Science Foundation under Cooperative Agreement PHY–9210038. This work is a collaborative effort of the Laser Interferometer Gravitational-wave Observatory and the institutions of the LIGO Science Collaboration.

More information about LIGO can be found at: `http://www.ligo.caltech.edu`.

LIGO-T020016-00-D

Quantum gravity: progress from an unexpected direction

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Over the last few of years, a new candidate theory of quantum gravity has been emerging: the so-called "Lorentzian lattice quantum gravity" championed by Jan Ambjorn [Niels Bohr Institute], Renate Loll [Utrecht], and co-workers [1]. It's not brane theory (string theory), it's not quantum geometry (new variables); and it's not traditional Euclidean lattice gravity. It has elements of both the quantum and the geometric approaches; and it is sufficiently different to irritate partisans of both camps.

Quantum gravity, the as yet unconsummated marriage between quantum physics and Einstein's general relativity, is widely (though perhaps not universally) regarded as the single most pressing problem facing theoretical physics at the turn of the millennium. The two main contenders, "Brane theory/ String theory" and "Quantum geometry/ new variables", have their genesis in different communities. They address different questions, using different strategies, and have different strengths (and weaknesses).

Brane theory/ string theory grew out of the high-energy particle physics community, and views quantum physics as paramount [2]. The consensus feeling in the brane community is that to achieve the quantization of gravity they would be willing to take quite drastic steps, to mutilate the geometrical foundations of general relativity and if necessary to *force* general relativity to fit into the brane framework. In contrast, the general relativity community views the geometrical nature of Einstein's gravity as sacrosanct, and would by and large be quite willing to do a little drastic surgery to the foundations of quantum physics if they felt it unavoidable [2]. "Lorentzian lattice quantum gravity" does a little of both: it adopts some aspects of each of these approaches, and violates other cherished notions of these two main candidate models.

On the one hand, "Lorentzian lattice quantum gravity" has grown out of the lattice community, itself a subset of the particle physics community. In lattice physics spacetime is approximated by a discrete lattice of points spaced a finite distance apart. This "latticization" process is a way of guaranteeing that quantum field theory can be defined in a *finite* and *non-perturbative* fashion. (Indeed currently the lattice is the *only* known non-perturbative regulator for flat-space quantum field theory. This technique is absolutely essential when carrying out computer simulations of quantum field theories, and in particular, computer simulations of quarks, gluons, and the like in QCD.) In addition to these particle physics notions, "Lorentzian lattice quantum gravity" has strongly adopted the geometric flavour of general relativity; it speaks of surfaces and spaces, of geometries and shapes.

On the other hand, "Lorentzian lattice quantum gravity" has irritated both brane theorists and general relativists (and more than a few lattice physicists as well): It does not have, and does not seem to require, the complicated superstructure of supersymmetry and all the other technical machinery of brane theory/ string theory. (A critically important feature of brane theory/ string theory which justifies the amount of time spent on the model is that in an appropriate limit it seems to approximate key aspects of general relativity; and do so without the violent mathematical infinities encountered in most other approaches. Of course, there is always the risk that there might be other less complicated theories out there that might do an equally good job in this regard.) Additionally, "Lorentzian lattice quantum gravity" irritates some members of the relativity community by not including *all* possible 4-dimensional geometries: The key ingredient that makes this Lorentzian approach different (and successful, at last in a lower-dimensional setting) is that it to some extent enforces a separation between the notions of space and time, so that space-time is really taken as a product of "space" with "time". It then sums over the resulting restricted set of (3+1)-dimensional geometries; not over all 4-dimensional geometries (that being the traditional approach of the so-called Euclidean lattice quantum gravity).

Technically, Lorentzian lattice quantum gravity restricts the sum over 4-dimensional geometries to cover only that subset of 4-dimensional geometries compatible with the existence of 3+1 space+time dimensions. (The condition used is a discretized version of stable causality; in the sense of the existence of a global time function.) The result of this topological/ geometrical restriction is that the model produces reasonably large, reasonably smooth patches of spacetime that look like they are good precursors for our observable universe. (Euclidean lattice quantum gravity, and variants thereof such as Matrix theory, have an unfortunate tendency to curdle into long thin polymer-like strands that look nothing like the more or less flat spacetime in our immediate vicinity; Quantum geometry based on new variables likewise encounters technical difficulties in generating an approximately smooth manifold in the low-energy large-distance limit.)

The good news is that once reasonably large, reasonably flat, patches of spacetime exist, the arguments leading to Sakharov's notion of "induced gravity" almost guarantee the generation of a cosmological constant and an Einstein–Hilbert term in the effective action through one-loop quantum effects [3]; and this would almost automatically guarantee an inverse-square law at very low energies (large distances). The bad news is that so far the large flat regions have only been demonstrated to exist in 1+1 and 2+1 dimensions — the (3+1)-dimensional case continues to pose considerable technical difficulties.

All in all, the development of "Lorentzian lattice quantum gravity" is extremely exciting: It is non-perturbative, definitely high-energy (ultraviolet) finite, and has good prospects for an acceptable low-energy (infra-red) limit. It has taken ideas from both the quantum and the relativity camps, though it has not completely satisfied either camp. Keep an eye out for further developments.

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Gravitational-wave phenomenology at PennState

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During a few surprisingly warm days in early November 2001, 86 keen gravitational-wave scientists gathered at the State College Days Inn for the first annual Gravitational Wave (GW) phenomenology workshop. The event was an excellent celebration of the recently funded Physics Frontier Center — the talks were of extremely high standard, and there were numerous fruitful discussions.

Talks were given on topics covering most areas relevant for gravitational-wave physics. In fact, I think the meeting is well described as a serious attempt at figuring out what "gravitational-wave phenomenology" might actually mean... The Tuesday morning started off with a session on astrophysics. Peter Meszaros provided an update on gamma-ray bursts and the possible connection to GWs. Particularly interesting here is the fact that there no longer seems to be an "energy crisis": The energy released generally seems to be within one order of magnitude of 10^{51} ergs. Tony Mezzacappa told us about the most recent simulations of core collapse supernovae. He easily convinced us that this is a very hard problem, involving plenty of "dirty" and not very well understood physics. Although he was not very optimistic about being able to do fully relativistic calculations in the near future, he indicated significant progress on understanding the stabilizing influence of multidimensional radiation transport. Basically there now seems to be a consensus in the collapse community: Supernovae simply don't explode! Joan Centrella rounded off the morning session with a nice talk covering the range of issues from source modeling to data analysis. She highlighted recent results that indicate that the dynamical bar-mode instability in rapidly spinning neutron stars may be much longer lived than was thought a couple of years ago. This could be very good news for observations!

The afternoon session was focussed on key problems in relativity. Saul Teukolsky discussed whether numerical relativity was "on the right track". The question was motivated by the fact that LIGO (and other detectors) are due to come online and there still are no "accurate" template signals for black-hole mergers. However, as Saul made clear, there has been a lot of progress recently. In particular, our understanding of the fundamental lack of stability of the ADM formalism has been much improved. The one issue of major importance that must ultimately be faced was also discussed. Namely, how to formulate "astrophysical" initial data. This is a very difficult problem, which requires serious attention. Abhay Ashtekar discussed recent work on isolated black-hole horizons. He outlined an exciting scheme wherein the properties of individual black holes may be evaluated in the vicinity of the horizon. If this idea could be implemented numerically, it could prove of tremendous use for black-hole excision etcetera. During the following coffee break, the main topic of discussion was Saul Teukolsky's slides: The general consensus was that they must have come out in the wash, and that he would be well advised to use permanent ink next time... The day ended with a talk by Eanna Flanagan on the radiation reaction problem. The main challenge still concerns the general binary orbital evolution in the Kerr spacetime. How are we supposed to deal with the Carter constant? Kip Thorne commented that the issue is becoming crucial as LIGO is only 5 months away. But when he then asked what people in the community were doing about it Eanna was saved by the bell (as the firealarm went off!).

In the evening Kip gave one of his vintage public lectures on gravitational waves. It was extremely well attended and clearly a very popular event.

The Wednesday began with another astrophysics session. Vicky Kalogera discussed the constraints that the several different binary pulsars pose on the general stellar population, and how this relates to observable GWs from inspiraling binaries and gamma-ray bursts. She pointed out that GW observations could challenge current stellar evolution models, eg. by finding black holes with masses above $15 - 20M_{\odot}$. Steinn Sigurdsson followed this with a discussion of stochastic GW backgrounds, both primordial and astrophysical. He discussed the fact that GW has an "Olber's paradox" in that the summed strain from all sources is not divergent. Recent estimates by Sterl Phinney were discussed at length. These suggest that it is because LIGO has difficulty seeing point sources that there can't be a significant astrophysical background. If you see plenty of sources, the background will swamp the detector. Given the number of galactic stellar binaries this could provide a severe problem for LISA, and people are now thinking hard about how accurately one can hope to filter out the strongest binary signals from the LISA data stream in order to unveil the primordial background. The morning session finished by Alex Wolszczan describing how the radio technology is improving towards the point where one should be able to detect GWs from relativistic binaries. This would require measurements of the pulse arrival time to μs precision. Alex suggested that this might a serious possibility on the 5 year timescale.

The afternoon was mysteriously labeled "interface". First, Joel Tohline gave an overview of hydrodynamical simulations of various relevant scenarios; close binary merger, bar-mode and r-mode instabilities. These simulations provide an impressive demonstration of large scale numerics leading to new insights about the detailed physics. Various codes have now reached the level of reliability where one can probe the truly nonlinear regime for quite realistic scenarios. I find that extremely exciting! Finally, Sam Finn gave the last proper talk of the day. He discussed how GW observations could provide tests of general relativity. As he put the question: "Is there any value added by testing the theory in the dynamical sector?". Sam provided three cases that would provide very useful information: Binary inspiral for inferring the mass of the graviton as well as mapping the actual black-hole spacetime, and black-hole ringdowns for providing unequivocal evidence of the presence of black holes. The day ended with a round-table discussion of GW phenomenology. The consensus seemed to be that we should take this to mean "the use of GW to explore astrophysics", which makes a lot of sense.

In the evening we were treated to a banquet at the Nittany Lion Inn. It was a memorable event, with several entertaining speeches describing Richard Isaacson's role in supporting gravity research (in view of his retirement from NSF).

The talks on the final day concerned detector technology. Massimo Cerdonio summarized that status of existing bar detectors and described possible future advances in technology. Most exciting here is the prospect for dual spheres, which would in principle provide acoustic broadband instruments with sensitivity in the kHz regime. Alessandra Buonnanno provided a peak into the future of advanced interferometers. A main issue for future generations concerns beating the standard quantum limit. Alessandra described this problem and discussed how one could hope to how to beat it. Robin Stebbins described the modeling plan for the LISA mission. Appropriately he ended the talks of the meeting on a high note by pointing out that 75% of all large scale NASA mission have failed. This is a thought too terrible to contemplate...

Kip Thorne closed the meeting with a succinct summary of the various talks, thus putting everything in context. He concluded his overview by wishing the new PFC luck in the future, and I would like to second that here. The meeting was an exciting one, and the organizers deserve a lot of credit. Not only did they provide a pleasant atmosphere, they also left plenty of time for discussions in the busy program. This should serve as a good example for organizers of future meetings: Get people debating and you will have a great couple of days.

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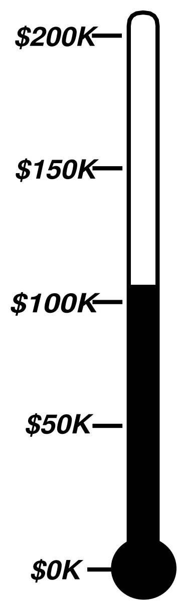

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