MATTERS OF GRAVITY

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

Number 8 **Fall 1996**

Contents

Editor

Jorge Pullin

Center for Gravitational Physics and Geometry
The Pennsylvania State University
University Park, PA 16802-6300
Fax: (814)863-9608
Phone (814)863-9597
Internet: `pullin@phys.psu.edu`
WWW: `http://www.phys.psu.edu/PULLIN`

Editorial

Not much to say in this editorial except that the newsletter is now produced in LaTeX, this will allow us to generate automatically an html version of it and better distribute it through the World Wide Web to the TeX/Postscript impaired. By the way, the html version is really something: every occurrence of an email address, preprint archive reference or web page is hotlinked, so you can click and surf. It also led to one of the worst Sundays in my life: getting LaTeX to do what you want is difficult enough without having to plan ahead your LaTeX code to be readable by an "intelligent translator program" (LaTeX2html by Nikos Drakos, a wonderful tool).

As usual I wish to again remind people that suggestions for authors/topics for the newsletter are very welcome.

We wish to say good bye and thanks a lot to Peter Michelson and welcome Warren Johnson as correspondent for bar-type gravitational wave detectors.

The next newsletter is due February 1st. If everything goes well this newsletter should be available in the gr-qc Los Alamos archives under number gr-qc/9609008. To retrieve it send email to gr-qc@xxx.lanl.gov (or gr-qc@babbage.sissa.it in Europe) with Subject: get 9609008 (numbers 2-7 are also available in gr-qc). All issues are available in the WWW:
`http://vishnu.nirvana.phys.psu.edu/mog.html`
A hardcopy of the newsletter is distributed free of charge to the members of the APS Topical Group on Gravitation. 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

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
- Richard Isaacson: 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

April 1997 Joint APS/AAPT Meeting

CALL FOR PAPERS (0th announcement):

The 1997 Joint American Physical Society/American Association of Physics Teachers Meeting will be held April 18-21 1997 in Washington, DC. This meeting will feature invited sessions sponsored by the Topical Group in Gravitation (GTG) as well as the GTG annual business meeting. The Ligo Research Community will also hold its meeting here. This year the GTG will organize approximately two focus sessions with invited and contributed talks on specific topics of interest to the GTG membership. The details of the focus sessions will be made available as soon as possible on the APS Meetings and GTG Web pages:
`http://www.aps.org/meet/meetcal.html`
`http://vishnu.nirvana.phys.psu.edu/tig/`

Contributed papers are also welcomed from MOG readers on (1) experiments and observations related to the detection and interpretation of gravitational waves, (2) experimental tests of gravitational theories, (3) computational general relativity, (4) relativistic astrophysics, (5) theories of the gravitational field, solutions to the field equations, and properties of solutions, (6) classical and quantum cosmology, and (7) quantum gravity.

The abstract deadline (see `http://www.aps.org/meet/meetcal.html`) is not yet posted but will probably be around the end of the year. To submit an abstract, APS but not GTG membership is required (an APS member may submit an abstract for a non-member).

See the section on electronic submission of abstracts at
`http://www.aps.org/meet/index.html`.

GEO600

Buildings and trenches finished; Installation of vacuum tube beginning
K. Danzmann
University of Hannover
kvd@mpqgrav2.amp.uni-hannover.de

GEO600 is a laser interferometric gravitational wave detector with 600 m long arms being built in the small town of Ruthe, near Hannover, Germany. It is designed and constructed by a British-German Collaboration comprising the research groups from University of Glasgow (Jim Hough), University of Cardiff and Albert-Einstein-Institut (Bernard Schutz), and University of Hannover and Max-Planck-Institut für Quantenoptik (Karsten Danzmann).

The objective is to use advanced technology right from the beginning and to achieve a sensitivity not too far from first generation LIGO and VIRGO. GEO600 will serve as a testbed for second generation detector concepts and possibly take part in the first round of coincidence observations. GEO600 is a somewhat smaller instrument, but is meant to be very flexible and can be built on a short time-scale. Because the detector is not designed to be extensible in length, the total capital cost of the project can be kept to about 7 M$.

Groundbreaking for GEO600 was in September 1995. Due to an unusually cold winter, construction was delayed for several month. But this month the buildings and the trench for the submerged vacuum tube were finished. The vacuum tube has a diameter of 60 cm and is of an unusual but cost-effective design that has been proposed by Roger Bennett from Rutherford Appleton Laboratory. We are using a wall thickness of only 0.8 mm and the tube is stiffened by a continuous corrugation of about 1 inch amplitude that runs along the whole length of the tube. No bellows are thus required to take up the thermal expansion. The tube is suspended inside the trench by a wire pendulum from rollers running along a rail. The vacuum tube is manufactured in 4 m long segments that are delivered to the site, welded to the rest of the tube in the eastern end building and then pushed into the trench. Welding and installation of the tube on the site are beginning in the first week of September.

More information about GEO600 can found at our web site
`http://www.geo600.uni-hannover.de`

Update on Black Hole Microstates in String Theory

Gary T. Horowitz, UC Santa Barbara
gary@cosmic.physics.ucsb.edu

Last January, Strominger and Vafa (hep-th/9601029) showed that the Bekenstein-Hawking entropy of a static five dimensional extreme black hole was precisely reproduced by counting states in string theory with the same mass and charge (for macroscopic black holes). This touched off an explosion of interest and in the next few months, this agreement was shown to hold for near extremal as well as extremal, four and five dimensional black holes, including rotation. I wrote a review of these developments in April (gr-qc/9604051). What I would like to do here is summarize some of the progress since then.

Perhaps the most important new development is a calculation by Das and Mathur (hep-th/9606185) showing that the *rate* of Hawking radiation from a near extremal black hole agrees with the string theory prediction based on interactions between the microstates. The fact that the spectrum is thermal with the same temperature as the black hole is not a surprise, given that it was already known that the entropy as a function of energy was the same in the two systems. However, the fact that the overall coefficient agrees is highly nontrivial and quite remarkable. This result has implications for the black hole information puzzle. Recall that in string theory, there is a length scale l_s set by the string tension. Newton's constant is related to this length and the string coupling g by $G = g^2 l_s^2$ (in four dimensions). At weak coupling, $g \ll 1$, an extreme black hole is described by a flat space configuration of objects known as D-branes. A near extremal black hole is described by an 'excited state' of D-branes. In this description, there is no analog of the event horizon and the emission from excited D-branes is manifestly unitary. The apparent thermal nature of the radiation arises from the large number of degress of freedom, just like an ordinary hot object. At strong coupling, the gravitational field becomes stronger and one obtains a near extremal black hole. The fact that the rate of Hawking evaporation from this black hole agrees with the string calculation is further evidence that radiation from near extremal black holes is also unitary.

In another development, there has been a great increase in the class of solutions for which the Bekenstein-Hawking entropy has been shown to agree with the counting of string states. Previously, it was shown that for black holes depending on a finite number of parameters (including mass, charges and angular momentum) the entropy as a function of these parameters was reproduced by counting states of D-branes at weak string coupling. Recently with Don Marolf, we extended this to the case where the solution depends on arbitrary *functions* (hep-th/9605224, hep-th/9606113).

One does not usually expect a solution with an event horizon to depend on arbitrary functions, since the 'no-hair' theorems show that stationary black holes are characterized by only a few parameters. If one tries to add a wave to the spacetime, it either falls down the hole, or radiates to infinity. However it turns out that extremal black strings, i.e. one dimensional extended objects with an event horizon, are different (Larsen and Wilczek hep-th/9511064). They can support traveling waves of arbitrary profile. These waves affect the horizon area and the distribution of momentum along the black string. By counting states of D-branes with the same momentum distribution as the black string, one finds perfect agreement with the Bekenstein Hawking entropy for all wave profiles (hep-th/9605224, hep-th/9606113).

An outstanding open question is to extend these results to black holes which are far from extremality. There are indications that we are getting close to taking this important next step.

LIGO project status

Stan Whitcomb, Caltech
stan@ligo.caltech.edu

Construction continues to move forward rapidly at both LIGO sites (Hanford Washington and Livingston, Louisiana). At the Hanford site, construction of 8 kilometers of concrete foundations which will support the beam tubes has been completed. The final survey of the foundation along the two arms indicates that they are straight and level with an accuracy of 1.5 cm. Our Architect/Engineering contractor (Ralph M. Parsons Co.) completed the final design for the buildings. A contract with Levernier Construction Inc of Spokane Washington for the building construction was signed, and work is now underway. At the Louisiana site, the main activity is the rough grading (earthwork to level the site and to build up a berm on which the LIGO facility will be built). This work has gone more slowly than expected due to heavy rains, but is now nearing completion.

The vacuum system is also moving forward. Chicago Bridge and Iron, the company building the LIGO beam tubes (which connect the vertex and ends of the two arms), is installing its fabrication equipment in a facility near the Hanford site. They are preparing for full production of the LIGO beam tubes and plan to begin installation by fall of this year. The final design of the vacuum chambers and associated equipment which will be in the located in the buildings has been completed. Our contractor for this effort, Process Systems International, is now building the first large chambers.

The design of the LIGO detectors is accelerating, with most detector subsystems well into the preliminary design phase. Orders have already been placed for the fused silica that will be used for the test masses and other large optics. LIGO's decision to switch its baseline interferometer design to Nd:YAG lasers operating 1.06 microns has led to a development contract with Lightwave Electronics Corporation to develop a 10 W single frequency laser; first results from this development are expected near the end of the year.

In the R&D program, the 40 m interferometer has been converted to an optically recombined system as the first step toward recycling. The signal extraction and control topology in the recombined configuration is similar to that planned for the full-scale interferometers; a prime objective of this effort was to compare these signals with the results of modeling and in particular to study the problem of lock acquisition. At MIT, optical phase noise at the level of 10^{-10} rad Hz$^{-1/2}$ are being investigated with a 5 m long suspended interferometer. This interferometer, initially configured as a simple Michelson, has now been converted to a recycled configuration. The increase in effective power due to recycling is approximately a factor of 500, leading to nearly 100 W incident on the beamsplitter. A detailed characterization of the noise is presently underway.

As an additional means of communicating up-to-the-minute information about LIGO, we have initiated a monthly newsletter. It can be accessed through our WWW home page at `http://www.ligo.caltech.edu`.

The Hamiltonian constraint in the loop representation of quantum gravity

John Baez, UC Riverside
jbaez@math.ucr.edu

For some time now, the most important outstanding problem in the loop representation of quantum gravity has been to formulate the Wheeler-DeWitt equation in a rigorous way by making the Hamiltonian constraint into a well-defined operator. Thomas Thiemann recently wrote four papers aimed at solving this problem (gr-qc/9606088, 89, 90, 91) which have caused quite a bit of excitement among those working on the loop representation. In this brief introduction to his work and the history leading up to it, I will not attempt to credit the many people to whose work I allude; detailed references can be found in his papers.

An interesting feature of Thiemann's approach is that while it uses the whole battery of new techniques developed in the loop representation of quantum gravity, in some respects it returns to earlier ideas from geometrodynamics. Recall that in geometrodynamics *á la* Wheeler and DeWitt, the basic canonically conjugate variables were the 3-metric q_{ab} and extrinsic curvature K^{ab}. The idea was to quantize these, making them into operators acting on wavefunctions on the space of 3-metrics, and then to quantize the Hamiltonian and diffeomorphism constraints and seek wavefunctions annihilated by these quantized constraints. In particular, if H denotes the Hamiltonian constraint, a physical state ψ should satisfy the Wheeler-DeWitt equation

$$H\psi = 0. \tag{1}$$

However, this program soon became regarded as dauntingly difficult for various reasons, one being that H is not a polynomial in q_{ab} and K^{ab}: it contains a factor of $(\det q)^{1/2}$. Experience had taught field theorists that it is difficult to quantize non-polynomial expressions in the canonically conjugate variables.

In the 1980's Ashtekar found a new formulation of general relativity in which the canonically conjugate variables are a densitized complex triad field E^a_i and a chiral spin connection $A^i_a = \Gamma^i_a - iK^i_a$, where Γ^i_a is built from the Levi-Civita connection of the 3-metric and K^i_a is built from the extrinsic curvature. As their names suggest, E^a_i and A^i_a are analogous to the electric field and vector potential in electromagnetism.

At first glance, in terms of E^a_i and A^i_a the Hamiltonian constraint appears polynomial in form. This greatly revived optimism in canonical quantum gravity. However, in this new formalism one is really working with the *densitized* Hamiltonian constraint $\tilde{H}$, which is related to the original Hamiltonian constraint by $\tilde{H} = (\det q)^{1/2} H$. Thus in a sense the original problem has been displaced rather than addressed. It took a while, but it was eventually seen that many of the problems with quantizing $\tilde{H}$ can be traced to this fact (or technically speaking, the fact that it has density weight 2).

A more immediately evident problem was that because E^a_i is complex-valued, the corresponding 3-metric is also complex-valued unless one imposes extra 'reality conditions'. The reality conditions are easy to deal with in the Riemannian theory, where the signature of spacetime is taken to be $++++$. There one can handle them by working with a *real* densitized triad field E^a_i and an SU(2) connection given by $A^i_a = \Gamma^i_a + K^i_a$. In the physically important Lorentzian theory, however, no such easy remedy is available.

Despite these problems, the enthusiasm generated by the new variables led to a burst of work on canonical quantum gravity. Many new ideas were developed, most prominently the loop representation. In the Riemannian theory, this gives a perfectly rigorous way to construct the Hilbert space on which the Hamiltonian constraint is supposed to be an operator: the Hilbert space $L^2(\mathcal{A})$ of square-integrable wavefunctions on the space $\mathcal{A}$ of SU(2) connections. The idea is to work with graphs embedded in space, and for each such graph to define a Hilbert space of wavefunctions depending only on the holonomies of the connection along the edges of the graph. One then forms the union of all these Hilbert spaces and completes it to obtain the desired Hilbert space $L^2(\mathcal{A})$.

It turns out $L^2(\mathcal{A})$ has a basis of 'spin networks', given by graphs with labellings of the edges by representations of SU(2) — i.e., spins — as well as certain labellings of the vertices. One can quantize various interesting observables such as the area of a surface or the volume of a region of space, obtaining operators on $L^2(\mathcal{A})$. Moreover, the matrix elements of these operators have been explicitly computed in the spin network basis.

Thiemann's approach applies this machinery to Lorentzian gravity by exploiting the interplay between the Riemannian and Lorentzian theories. As in the Riemannian theory, he takes as his canonically conjugate variables a real densitized triad field E_i^a and an SU(2) connection A_a^i. This automatically deals with the reality conditions. He also takes as his Hilbert space the space $L^2(\mathcal{A})$ as defined above, since it turns out that this space is acceptable for the Lorentzian theory as well as the Riemannian theory. Then, modulo some important subtleties we discuss below, he quantizes the Hamiltonian constraint of Lorentzian gravity to obtain an operator on $L^2(\mathcal{A})$. Interestingly, it is crucial to his approach that he quantizes H rather than the densitized Hamiltonian constraint $\tilde{H}$. This avoids the regularization problems that plagued attempts to quantize $\tilde{H}$.

How does Thiemann quantize the Hamiltonian constraint? First, in the context of classical general relativity he derives a very clever formula for the Hamiltonian constraint in terms of the Poisson brackets of the connection A_a^i, its curvature F_{ab}^i — analogous to the magnetic field in electromagnetism — and the total volume V of space. (For simplicity, we assume here that space is compact.) Using the trick of replacing Poisson brackets by commutators, this reduces the problem of quantizing the Hamiltonian constraint to the problem of quantizing A_a^i, F_{ab}^i, and V. As noted, V has already been successfully quantized, and the resulting 'volume operator' is known quite explicitly. This leaves A_a^i and F_{ab}^i.

Now, a fundamental fact about the loop representation — at least as currently formulated — is that the connection and curvature do not correspond to well-defined operators on $L^2(\mathcal{A})$, even if one smears them with test functions in the usual way. Instead, one has operators corresponding to parallel transport along paths in space. Classically we can write a formula for A_a^i in terms of parallel transport along an infinitesimal open path, and a formula for F_{ab}^i in terms of parallel transport around an infinitesimal loop. However, in loop representation of the quantum theory one cannot take the limit as the path or loop shrinks to zero length. The best one can do when quantizing A_a^i and F_{ab}^i is to choose some paths or loops of finite size and use parallel transport along them to define *approximate* versions of these operators. This introduces a new kind of ambiguity when quantizing polynomial expressions in A_a^i and F_{ab}^i: dependence on arbitrary choices of paths or loops.

So, contrary to the conventional wisdom of old, while the factors of $(\det q)^{1/2}$ in the Hamiltonian constraint are essential in Thiemann's approach, the polynomial expressions in A_a^i and F_{ab}^i introduce problematic ambiguities! In short, Thiemann really constructs a large family of *different versions* of the Hamiltonian constraint operator, depending on how the choices of paths and loops are made. However, by making these choices according to a careful method developed with the help of Jerzy Lewandowski, the ambiguity is such that two different versions acting on a spin network give spin networks differing only by a diffeomorphism of space. Mathematically speaking we may describe this as follows. Let $L \subset L^2(\mathcal{A})$ be the space of finite linear combinations of spin networks, and let L/Diff be the space of finite linear combinations of spin networks modulo diffeomorphisms. Then Thiemann obtains, for any choice of lapse function N, a smeared Hamiltonian constraint operator

$$\hat{H}(N) \colon L \to L/\mathrm{Diff}, \tag{2}$$

independent of the arbitrary choices he needed in his construction.

Since these operators $\hat{H}(N)$ do not map a space to itself we cannot ask whether they satisfy the naively expected commutation relations, the 'Dirac algebra'. However, this should come as no surprise, since the Dirac algebra also involves other operators that are ill-defined in the loop representation, such as the 3-metric q_{ab}. Thiemann does check as far as possible that the consequences one would expect from the Dirac algebra really do hold. Thus if one is troubled by how arbitrary choices of paths and loops prevent one from achieving a representation of the Dirac algebra, one is really troubled by the assumption, built into the loop representation, that q_{ab}, A^i_a, and F^i_{ab} are not well-defined operator-valued distributions. Ultimately, the validity of this assumption can only be known through its implications for physics.

Thiemann's approach to quantizing the Hamiltonian constraint is certainly not the only one imaginable within the general framework of the loop representation. (Indeed, his papers actually treat two approaches, one yielding a formally Hermitian operator, the other not.) As soon as his work became understood, discussion began on whether it gives the right physics, or perhaps needs some modification, or perhaps exhibits fundamental problems with the loop representation. The quest for a good theory of quantum gravity is far from over. But at the very least, Thiemann's work overturns some established wisdom and opens up exciting new avenues for research.

International conference on gravitational waves: Sources and Detectors

Valeria Ferrari and Maria Alessandra Papa, Università di Roma
valeria@roma1.infn.it

The Conference was held on March 19-23 1996 in Cascina (Pisa) near the site where the VIRGO interferometer is now under construction. It was attended by 120 physicists plus a sociologist who is "keeping under observation" the scientific community involved in the search of gravitational waves. The aim of the Conference was to gather the efforts of the theoreticians and the experimentalists working in the field and stimulate future work on the phenomenology of GWs in close connection with the experiments.

On the theoretical side, the sources of GWs have been the subject of several talks. Inspiralling compact binaries have been discussed by L. Blanchet, who showed that, in order to extract significant information from VIRGO and LIGO observations, the radiation field and the internal dynamics of the binary system must be evaluated including post-newtonian corrections at least up to third order. E. Gorgoulhon and S. Bonazzola have discussed how efficiently a magnetic dipole moment of a rotating neutron star can induce distortions in the axial symmetry with consequent emission of GWs. Other mechanisms which may be responsible for axial symmetry breaking (such us Chandrasekhar-Friedman-Schutz instability, MacLaurin-Jacobi transition and crust defects) have also been reviewed. K. Kokkotas has shown that from the detailed knowledge of the spectrum of the quasi-normal modes of a compact star one can infer the values of its mass and radius and have indications on its internal structure. Great interest have received the estimates of the relic stochastic GW background spectrum provided by inflationary cosmology in the framework of string theory, which have been presented by G.Veneziano and R. Brustein. They suggest that, depending on the constraints of the theory, the predicted power spectra may be detectable. Another kind of stochastic GW background due to cosmological supernovae explosion, has been evaluated (D. Blair $z \geq 2$, and A. Di Fazio-V.Ferrari $4 \leq z \leq 8$), and it emerges that it may be competitive with the string background in the VIRGO-LIGO bandwidth.

Fully relativistic numerical codes for gravitational collapse and coalescing compact objects have been shown to be in progress.

The status of the experiments was discussed both in plenary talks and workshops. A number of resonant bars are actually taking data as well as the TENKO-100 interferometer in Japan. The quoted sensitivities to a pulse of GWs for the resonant experiments are:
EXPLORER (Geneva, Cern) $h \sim 6 \cdot 10^{-19}$,
NAUTILUS (Frascati LNF, Roma), $h \sim 6 \cdot 10^{-19}$,
NIOBE (Perth, UWA) $h \sim 6 \cdot 10^{-19}$,
TENKO-100 (ISAS Japan) $\tilde{h} \sim 10^{-19} \frac{1}{\sqrt{Hz}} @100Hz$, and $\tilde{h} \sim 5 \cdot 10^{-19} \frac{1}{\sqrt{Hz}} @1kHz$.
AURIGA (Legnaro LNL, Padova) started the cryogenic tests and will soon be operational.

The state of the art for the interferometric antennas, VIRGO, LIGO, GEO600, and TAMA, has been reported and the following expected sensitivities have been quoted:
VIRGO: $\tilde{h} \sim 10^{-21} \frac{1}{\sqrt{Hz}} @10Hz$, and $\tilde{h} \sim 3 \cdot 10^{-23} \frac{1}{\sqrt{Hz}} @500Hz$.
LIGO: $\tilde{h} \sim 2 \cdot 10^{-23} \frac{1}{\sqrt{Hz}}$ in a bandwidth of $\sim 200Hz$.
GEO600: $\tilde{h} \sim 4 \cdot 10^{-23} \frac{1}{\sqrt{Hz}}$ (depending on bandwidth)
TAMA: $\tilde{h} \sim 8 \cdot 10^{-23} \frac{1}{\sqrt{Hz}} @300Hz$ in a bandwidth of $\sim 300Hz$.

Doppler tracking experiments and upper limits on the emission of GWs in the range of $10^{-4} - 10^{-1} Hz$ have been reviewed by Luciano Iess. The sensitivity of LISA to GWs from various binary systems (WD-WD, BH-BH, WD-BH, MBH-MBH etc) and to GWs of cosmological origin, has been discussed, together with the planning of the experiment, by Peter Bender. From his graphs LISA's sensitivity should range between $\tilde{h} \sim 10^{-21} \frac{1}{\sqrt{Hz}} @ 10^{-4} Hz$, and $\tilde{h} \sim 10^{-23} \frac{1}{\sqrt{Hz}} @ 10^{-1} Hz$.

Data analysis for extracting GW-signals from present and future data, has focused essentially on the study of filtering procedures for single detectors and for different kinds of networks. These two issues have been discussed in talks regarding the use of APE1000 to detect coalescing binaries and pulsars parameters (A.Vicere'), the search of monocromatic and stochastic GWs with NAUTILUS and EXPLORER (P.Astone), the estimate of chirp parameters (I.M.Pinto), the signal deconvolution for a multimode spherical detector (E.Coccia), the cross-correlation of data from several bars (S. Vitale), the use of bar-interferometer networks for pulse detection (B. Schutz), and the use of local arrays of small resonators for high frequency detection (S.Frasca).

12th Pacific Coast Gravity Meeting - Karel Kuchař fest

Richard Price, University of Utah
rprice@mail.physics.utah.edu

Near the end of March, at the University of Utah, there were two relativity meetings that were loosely associated, at least in timing, and which made for an interesting juxtaposition. On Thursday, March 21 was "KKfest," a one day conference honoring the 60th birthday of Karel Kuchař. It was followed by the two days of the twelfth Pacific Coast Gravity Meeting. The latter is a meeting centered on young people; all talks are contributed, and each speaker, first year student or Nobel laureate, gets 15 minutes. The KKfest, by contrast, consisted of six invited talks, by "the establishment." A banquet on Friday evening honored Karel Kuchař, but was attended by almost all the PCGM12 participants. Almost 100 people attended! And the crossover was not limited to the banquet. Almost all participants in each conference attended the other conference. It gave the venerable sages of the KKfest a chance to be energized by the enthusiasm of those starting out in the field; at the KKfest the young people of PCGM12 got a first hand contact with some of the history of the ideas in our field.

The speakers during the day of KKfest were Jiri Bičák, Bryce DeWitt, Petr Hájíček, Jim Hartle, Claudio Teitelboim, and Jim York. All their talks gave a historical perspective on modern issues, and on the influence on Karel Kuchař's contributions. Talks in the KKfest covered some exact solutions and black hole thermodynamics, but the main focus, of course, was quantum gravity. Here reviews were given and recent ideas were reported in the canonical approach, the covariant approach, and generalized quantum mechanics.

The Pacific Coast Gravity meeting had 54 talks (!) by presenters from 22 institutions. (The Pacific coast was analytically extended to include, for example, Ireland.) The breadth of the topics showed the recent breadth of our field. There were, on the one hand, talks on knot polynomials (Jorge Pullin) and intermediate topologies (Don Marolf). On the other there were reports on the low frequency satellite tracking gravitational wave experiment (John Armstrong), and on light baffles for the LIGO beam tube (Kip Thorne).

As in the past, Doug Eardley donated a prize to be awarded for the best graduate student presentation. When given no choice but to point to a single name, an impartial international jury pointed to the name Shawn Kolitch of UC Santa Barbara.

Any short list of the most interesting presentations at PCGM would be incomplete, but would include a reversal of a recent result, and a verification of a longstanding one. Gary Horowitz (UCSB) reported computations of black hole entropy from string theory. Previously such calculations had been claimed to imply that extreme black holes had zero entropy. The correction of a technical error in those calculations has led to new results which show that entropy for extreme holes is related to horizon area exactly the same as for moderate holes. Paul Anderson (Wake Forest) reported on a careful study of a gravitational geon. His results completely confirmed the claims in the classical paper by Brill and Hartle. Another talk that stimulated much buzzing in the hallways was the claim by Thomas Thiemann (Harvard) that a finite theory results if a real connection is used for the Ashtekar variables.

At the Friday evening banquet the key speaker was John A. Wheeler who applauded Karel Kuchař's contributions, character and culture and read some of the words of Vaclav Havel about the nature of our pursuit of answers. A gentle roast followed and was enjoyed by all, or perhaps by all but one.

First International LISA Symposium

Robin Stebbins, JILA/University of Colorado
stebbins@jila.colorado.edu

The First International LISA Symposium was held at the Rutherford Appleton Laboratory in Chilton, 9-12 July 1996. The symposium highlighted the scientific opportunities of gravitational wave detection in space. The symposium was further enriched by poster sessions, technology demonstrations, a full-scale mockup of a LISA spacecraft, laboratory tours and a delightful dinner cruise on the Thames with live jazz! The main oral sessions are summarized below. Selected papers from the symposium are scheduled to appear in the March 1997 issue of Classical and Quantum Gravity. Mike Sandford, the scientific and local organizing committees, and the RAL staff are to be commended for putting together such a stimulating and pleasant symposium.

In the overview session, Rudiger Reinhard (ESA) described the status of LISA in ESA's Horizons 2000 Plus Programme, and Karsten Danzmann (Hannover), Bill Folkner (JPL) and Koos Cornelisse (ESTEC) described the current baseline LISA mission. Kip Thorne (Caltech) described a menagerie of dark, extremely relativistic objects in the Universe which might be discovered with a low-frequency gravitational wave detector in space, and the insight into gravitation theories to be gained from them. Martin Rees (Cambridge) surveyed the available information on massive black holes and gave a very positive assessment of the likelihood of detection of signals from various scenarios.

The sources session focused on astrophysical systems which could produce low-frequency gravitational waves likely to be detected by LISA. Frank Verbunt (Utrecht) reviewed the state of observational knowledge about binaries systems consisting of main sequence stars and/or compact objects which could give rise to detectable signals. Steinn Sigurdsson (Cambridge) described the capture of low-mass black holes by massive black holes in galactic cusps. Alberto Vecchio (MPI/Potsdam) reported on signals from coalescing massive black holes. Curt Cutler (Penn State) showed that LISA could only identify the source of signals from coalescing massive black holes if there was some supplementary optical indication. Pete Bender (JILA) described a revised estimation of the confusions limit from galactic and extragalactic binaries. I. Pinto (Salerno) described the spectrum of signals from insular clusters.

The session on gravitational theories and numerical relativity began with a talk by Richard Matzner (Texas) on the computation of waveforms from the coalescence of black hole binary systems. Leonid Grishchuk (Cardiff) offered an explanation of cosmic background anisotropies based on relic gravitational waves, and noted existing observational support. Ewald Muller (MPI/Garching) described the gravitational wave generation in the inner core and the outer convective region of a type II supernova. Gerhard Shafer (MPI/Jena) discussed how alternate theories of gravitation might be checked with LISA.

Updates were given by on the VIRGO Project by Francesco Fidecaro (Pisa), on GEO 600 by Harald Luck (MPI/Hannover), on LIGO by David Shoemaker (MIT), on the TAMA Project by Keita Kawabe (Tokyo) experiments. Construction is proceeding well on all of these ground-based interferometers. Bruno Bertotti (Pavia) reviewed past attempts to detect gravitational waves by spacecraft tracking and previewed plans for the Cassini mission. Guido Pizzella (Rome) summarized the current and expected performance of resonant detectors. Stefano Vitale (Trento) analyzed the sensitivity of two resonant detectors, and two resonant detectors and an interferometer, to an isotropic, stochastic background. M. Cerdonio (Padova) reported performance of AURIGA when cooled to 140 mK.

The next session delved into gravitational wave signal extraction and data analysis. Robin Stebbins (JILA) outlined the challenges of extracting astrophysical information from the many and varied gravitational wave signals likely to be in LISA data. Michael Peterseim (Hannover) examined the angular resolution obtainable with various signal parameters. Roland Schilling (MPI/Garching) analyzed the response function of LISA above 10 mHz where the wavelength is shorter than the armlength. Giacomo Giampieri (QMC) discussed the anisotropy of the stochastic background caused by galactic binaries, as seen by LISA. Oliver Jennrich (Hannover) reported on the polarization resolution which LISA could obtain. Bill Folkner (JPL) described the onboard signal processing planned for in the LISA mission. L. Milano (INFN) simulated the application of matched filters to search for binary signals in VIRGO data.

The final session of the conference addressed enabling technologies for gravitational wave detection. Sheila Rowan (Glasgow) reported on the performance of prototype monolithic fused quartz suspensions for ground-based interferometers. Paul McNamara (Glasgow) described a laboratory demonstration of weak light phase-locking, a requirement for LISA. Dan DeBra (Stanford) reviewed drag-free satellite technology, both flown and future. M. Rodrigues (ONERA) explained the LISA accelerometer design. Clive Speake (Birmingham) analyzed two designs for capacitive sensing circuits for the dominant noise source, and showed that LISA goals can be achieved with either design. Yusuf Jafry (ESA) reported on a simulation of cosmic ray charging of the LISA proof mass done with the GEANT code. And P. Rottengatter (LZH) reported on the successful intensity and amplitude stabilization of Nd:YAG lasers for use in LISA. Dave Robertson (Glasgow) described the LISA optics and limiting noise sources in the optical measurement. Walter Winkler (MPI/Garching) gave an analysis of the far-field effects of LISA transmitting a truncated Gaussian beam. Wei-Tou Ni (Taiwan) described the ASTROD mission for performing several relativistic tests in solar orbit, and technology development activities to support fundamental physics missions. Dan DeBra read a paper submitted by S. Marcuccio (Centrospacio) reporting on recent tests and development of the Field Emission Electric Propulsion (FEEP) thrusters planned for LISA.

Schrödinger Institute Workshop on Mathematical Problems of Quantum Gravity

Abhay Ashtekar, Penn State
ashtekar@phys.psu.edu

A 2-month workshop was held at the Erwin Schrödinger International Institute for Mathematical Sciences in Vienna during July and August, '96. It was jointly organized by Peter Aichelburg and myself.

There were 23 participants from outside Austria, mostly young physicists who have been working on various aspects of quantum gravity. In addition, about a dozen faculty and students from Vienna actively participated in the seminars and discussions. While the focus of this effort was on non-perturbative quantum general relativity, there were several experts from string theory, supergravity, quantum cosmology, quantum field theory, as well as mathematical physics in a broad sense of the term. Unfortunately, there was a rather severe desk-space limitation in July and so the workshop had to make do without the participation of a number of experts who had time-constraints of their own. There were two weekly "official seminars" which were widely announced –one entitled "fundamental issues", and the other "advanced topics". They enhanced the scientific interaction between workshop participants and the local physics and mathematics community. In addition, there were "discussion seminars" (the remaining) three days a week. The afternoons were left open for further informal discussions (and real work!).

On the scientific front, the workshop elevated the subject to a new level of maturity. It enabled the participants to take stock of a number of areas to obtain a global picture of issues that are now well-understood and also opened new directions for several other key issues. Because of the space limitation, I will restrict myself here only to a few illustrative highlights. A more detailed discussion of the (July) activities can be found in John Baez's "This Week's Finds" series, weeks 85-88 (`http://math.ucr.edu/home/baez/twf.html`) which also contains many references. A Schrödinger Institute pre-print containing abstracts of seminars will be available early October. Further information on the workshop as well as pre-prints of research carried out during the workshop can be obtained from the Schrödinger Institute home page `http://www.esi.ac.at/ESI-Preprints.html`).

In the list that follows, the names in parenthesis refer to people who gave seminars or led discussions (although almost everyone present made significant contributions to all the discussions).

Quantum Hamiltonian constraint. (Hans-Jürgen Matschull, Jorge Pullin, Carlo Rovelli, Thomas Thiemann)
Quantum geometry. (AA, Jerzy Lewandowksi, Renate Loll, Thiemann)
Lattice methods and skeletonization in loop quantum gravity. (Loll, Michael Reisenberger)
Super-selection rules in quantum gravity. (AA, Lewandowski, Donald Marolf, Jose Mourão, Thiemann)

Degenerate metrics: extensions of GR. (Ted Jacobson, Lewandowski, Matschull)
Global issues, Hamiltonian formulations. (Fernanado Barbero, Domenico Giulini)
Mathematical issues in quantum field theory and quantum gravity. (John Baez, Matthias Blau, Herbert Balasin, Rodolfo Gambini, Mourao, Marolf)
Exactly soluble midisuperspaces. (AA, Hermann Nicolai)

Lessons from low dimensional gravity. (AA, Giulini, Lewandowski, Marolf, Mourao, Thiemann, Strobl).

Black-hole entropy. (Jacobson, Kirill Krasnov, Marolf, Rob Myers, Rovelli)
Topological quantum field theories (Baez, Reisenberger)
String duality, conformal field theories (Jürgen Fuchs, Krzysztof Meissner, Myers, Strobl)
Foundations of quantum mechanics and quantum cosmology (AA, Giulini, Jonathan Halliwell, Franz Embacher)

If participants were to single out one topic that generated most excitement, it would probably be the regularization of the Hamiltonian constraint by Thiemann (gr-qc/9606088, 89, 90, 91). This has significantly deepened our understanding of the mathematical problems underlying quantum dynamics of general relativity. (For details, see Baez's article in this issue.) However, a number of important problems remain. In particular, during the workshop it was realized that these regularized quantum constraints have the feature that they strongly commute not only on diffeomorphism invariant states (which is to be expected physically) but also on a rather large class of states which are not diffeomorphism invariant (which is alarming from a physical viewpoint). A related potential difficulty is with the semi-classical limit: it is not clear if all the quantum constraints, taken together, admit a sufficient number of semi-classical states. Analogous calculations in 2+1 dimensions indicate that the appropriate semi-classical sector *does* exist. In 3+1 dimensions, further work is needed. This will no doubt be an area of much research and new effort in the coming year.

Relativistic Astrophysics: a summer school at Bad Honnef

Hans-Peter Nollert, Penn State
nollert@phys.psu.edu

Modern astrophysics is unthinkable without the input of general relativity. Therefore, the German Astronomical Society (Astronomische Gesellschaft) joined forces with the 'Gravitation and Relativity Theory' section of the German Physical Society (DPG) in organizing this school on selected topics in relativistic astrophysics, such as gravitational lensing, gravitational waves, neutron stars and collapsing binaries, and accretion phenomena. The school took place in the physics center of the Deutsche Physikalische Gesellschaft in Bad Honnef from August 19 to 23 1996.

Jürgen Ehlers brought the lectures off to a great start with his comprehensive overview over the basic concepts of general relativity, with emphasis on physical interpretation, on astrophysical relevance, especially for lensing and gravitational radiation, and on the initial value problem for time evolution calculations. He found ways to help even old experts in the field see many things in a new light.

Peter Schneider discussed gravitational lensing: its history in the context of astrophysics, the basic concepts and the wealth of information that can be gained from observations of weak lensing: Mass profiles of galaxies, dark mass concentration, mean distribution of galaxies, even the Hubble constant - and much more. With new telescopes soon becoming operational, he foresees a bright future for his field.

Joachim Wambsganss described the searches for microlensing events. He presented the theoretical background and an overview over the history of the MACHO, EROS, and OGLE projects. The search for dark matter objects, for binaries and planets is the main objective in studying galactic microlensing events. About three times as many events as expected are observed in the galactic bulge, but fewer than expected towards the large Magellanic cloud. A preliminary conclusion states that the galactic halo almost certainly does not consist of brown dwarfs. The focus of attention for extragalactic events is on the determination of size and brightness profile of the sources, and on the detection of compact objects for the lenses and the determination of their masses.

Ute Kraus discussed theory and consequences of light deflection near neutron stars. Geometric effects, such as increased visibility of the star's surface, can have drastic effects for the pulse profiles of radiation emitted on or near the surface of the star. Since her main concern were light curves of X-ray pulsars, it is sufficient to consider photon trajectories in a Schwarzschild metric. In addition to the geometric effects, changes of photon energy and intensity radiation have to be taken into account.

Karsten Danzmann's guide on "How to build a GEO600 interferometric gravitational wave detector in your back yard with spare change found under your couch cushions" covered every aspect from using recycling to make your laser light go further, to reducing noise of nearby tractors, to the proper way of welding the vacuum tubes. If you can spare a little more, go for LISA, the heavenly version - you'll be first on the block to have one, and you will be guaranteed a variety of spectacular sources, such as coalescence of massive black holes anywhere in the universe, or white dwarf binaries.

Ed Seidel reported that the Grand Challenge community is getting ready to tackle a new challenge: the fully relativistic, three dimensional treatment of the merger of neutron star binaries. The plan is to use post-Newtonian techniques for the pre-coalescence phase, and then take the results of this as initial data (at a separation of about $8M$) for the general relativistic hydrodynamical calculation. The relativistic field equations will be even more difficult to handle than the hydrodynamic equations, requiring the development of suitable algorithms, of adaptive mesh techniques, finding the best gauge conditions, and an effective use of parallel algorithms.

Heinz Herold discussed the effects of various equations of state and of rapid rotation on the equilibrium state of neutron stars. The structure equations can be solved using a variational principle in the form of a minimum surface problem. The numerical treatment is based on a finite element discretization. It turns out that higher mass models allow higher angular velocities. The deformation of the surface of the star was visualized using isometric embedding (for its internal geometry) or ray-tracing (for a view from the outside).

An excursion to the Drachenfels, a nearby hill featuring ancient ruins of a fortress, a grand view over the Rhine river, and a restaurant, provided some welcome diversion for the participants on Tuesday afternoon.

Instabilities of rotating stars can be quite frightening: **Lee Lindblom** pointed out that in principle, every star, even the earth, shows rotational instability. Luckily, they are usually countered by dissipative effects. Using a Newtonian two-potential technique, he found that the balance may be in favor for the instabilities in the case of neutron stars. However, it is not clear if they can prevail in a relativistic context, since they will be damped by gravitational radiation. At least for realistic equations of state, they may turn out not to be an issue.

Hans-Peter Nollert discussed treating collisions of black holes and neutron stars without the help of supercomputers. He pretended that the two colliding bodies are like a perturbation of the single final object: $1 + 1 \approx 1$. The gravitational radiation emitted during and after the collision can then be obtained from linear equations. For black holes, the comparison with the full numerical calculations is remarkably good. He wishes he could do the same trick for neutron stars - if only a good fairy would take care of the initial conditions...

Whatever the central source of a gamma ray burster actually is, there has to be a fireball - unless gamma ray bursters are local, i.e. less than 200pc away. With this premise, **Peter Mészáros** gave theoretical explanations for many observed features of these elusive objects, based on the expansion of the fireball and the dissipation of its energy.

Harald Riffert provided the necessary ingredients for a model of thin accretion disks around black holes: Solve the gas dynamics in the equatorial plane of a Kerr background metric, build the energy-momentum tensor from an ideal fluid, viscous stress, and radiation flux, assume the disk to be stationary and rotationally symmetric, with velocities dominant in the ϕ direction. Integrating over the height of the disk, the vertical structure equations decouple from the radial part. The radial disk structure can be solved analytically, and the vertical equations have the same form as in the Newtonian case. The resulting model spectra can be fit to the UV-soft X-ray continuum of AGN.

When it comes to rapidly rotating relativistic systems, most work has concentrated on black holes and neutron stars, with little attention payed to other systems. **Jim Ipser** studied rapidly rotating accretion disks around compact objects, using a quasinormal mode analysis for perturbations of a simple equilibrium model. As a clever trick, he uses the perturbed Euler equation to eliminate the velocity perturbations. Relying on the Cowling approximation eliminates the metric perturbations, resulting in a single equation for a potential-like fluid variable. Taking into account frame dragging, his model provides a possible source for quasi-periodic oscillations in black hole X-ray binaries, giving a counter-argument to the objection that sources showing QPO's cannot be candidates for black holes.

Are quasars supermassive black holes or star clusters at the centers of galaxies? After reviewing an impressive collection of observational data, **Max Camenzind** favored the black hole scenario. In order to explain the central machine providing the power and accelerating the observed jets, magnetic fields are required. Consequently, the magnetohydrodynamics of disks in the background field of rapidly rotating stars was the topic of the second part of his lecture.

Fred Rasio presented a three dimensional Newtonian treatment of the merger phase of binary neutron star coalescence, using smoothed particle hydrodynamics. A Newtonian treatment is interesting in its own right: The hydrodynamics contain enough challenging physics, and they dominate the dynamics of the merger. The results can thus serve as preliminary estimates for the gravitational radiation emitted during the merger. When fully numerical codes become available, the Newtonian results can serve as a test case. In the future, nuclear physics, strong relativistic effects, and turbulent viscosity should be included for a more realistic treatment.

Pablo Laguna studied the evolution of matter in curved spacetime, using a smoothed particle approach on a fixed relativistic background. The SPH simulation reproduces the results of length scale estimates if the artificial viscosity is suitably adjusted. In particular, he examined the tidal disruption of stars by massive black holes. This scenario can be regarded as the fuelling process of active galactic nuclei: A dense star cluster in the vicinity of a central, supermassive black hole provides the necessary raw material.

A cosmic perspective was provided by **Andreas Tammann**, who reviewed observations determining the Hubble constant. Since measurements of redshifts are generally undisputed, most of his talk concentrated on determining cosmic distances. He used SNe Ia supernovae calibrated by cepheids, the Virgo cluster, and field galaxies. Including independent methods such as growth of supernovae shells, gravitational lenses, or fluctuations of the microwave background, he arrived at a value of $H_0 = 55 \pm 10$. He warned the audience to be critical of headlines which will soon appear in popular newspapers, claiming that a new distance determination of the Fornax cluster in the southern hemisphere leads to $H_0 = 73$, since this value may be based on improper identification of distances. He discussed estimates for the age of the universe, which he puts at $12.5 - -15 \times 10^9$ yrs, compatible with his favored value of H_0.

Michael Soffel reviewed experiments relating to gravity: Is there a fifth force (pronounced dead), does the gravitational constant depend on time (not to within one part in 10^{11}), and what is its numerical value (the worst known physical constant)? He discussed the weak equivalence principle, the Einstein EP, and the strong EP. All are very well confirmed by various experiment; improved measurements are desirable with respect to some quantizations of gravity, which might cause tiny deviations ($10^{-11} - -10^{-15}$). With regard to general relativity, he discussed perihelion advance, light deflection, timing delay, and the Lense-Thirring effect.

The proceedings of the school will be published by Vieweg in early 1997.

The organizers, Hanns Ruder, Harald Riffert, and Hans-Peter Nollert for the Astronomische Gesellschaft and Friedrich Hehl for the Deutsche Physikalische Gesellschaft, wish to acknowledge the generous financial support from the WE-Heraeus Foundation which made this school possible.

We wish to point out that the names of the organizers of last year's school on "Relativity and scientific computing", Friedrich Hehl and Roland Puntigam for the Deutsche Physikalische Gesellschaft and Hanns Ruder for the Astronomische Gesellschaft, were inadvertently left out of the report on this school in the last issue of Matters of Gravity.

Intermediate binary black hole workshop at Caltech

Lee Samuel Finn, Northwestern
lsf@marlowe.astro.nwu.edu

Since late 1993, a wide collaboration of relativists have been engaged in an effort to solve numerically for the final inspiral and coalescence of a binary black hole system. A quantitative understanding of black hole binary coalescence is needed to complete our solution of the relativistic Kepler problem, whose beginnings (in a nearly Newtonian binary undergoing slow, adiabatic inspiral) and endings (in a quiescent, single Kerr black hole) are already understood separately. The gravitational radiation arising from this final stage of binary inspiral/coalescence may also be detectable in the interferometric detectors now under construction; thus, the waveforms predicted by these calculations may play an important role in the associated data analysis.

To connect the initial and final states of the relativistic Kepler problem, or to use the predicted waveforms to learn something of the character of an observed coalescing binary, it is necessary that the initial data for the numerical calculation be firmly related to a binary system involving two distinct black holes of definite mass and spin in an orbit of certain energy and orbital angular momentum. Herein lies two problems:

1. Numerical calculations of coalescence so tax the anticipated computing resources expected to be available with next generation supercomputers that the numerical initial data must be imposed no earlier than $\sim 4\pi$ orbital phase before coalescence. At this separation the binary systems total mass cannot be resolved into the individual black hole masses, nor can the systems total angular momentum be usefully resolved into black hole spins and orbital angular momentum.

2. The techniques used to evolve a binary from large separation, where its character (component masses and spins, orbital energy and angular momentum) can be described in Newtonian terms, to small separations, where the fully numerical evolution can begin, become increasingly suspect as the separation decreases; thus, either extensions to existing methods or entirely new methods must be found to continue the evolution of a binary system to the point where fully numerical methods can take over.

To highlight the urgency of these problems, the Binary Black Hole Grand Challenge Alliance sponsored a one-day meeting at Caltech on 27 July 1996. This meeting, hosted by the Caltech Relativity Group, brought together, in person or by teleconference from Cardiff and Potsdam, many of the experts in the fields of post-Newtonian binary evolution calculations and numerical relativity for a discussion of these problems and possible approaches to their solution.

The meeting began with an overview by Richard Matzner, principal-investigator of the Binary Black Hole Grand Challenge Team, on the project status, followed by a presentation by Takashi Nakamura on the on-going efforts in Japan to approach the same problem. Discussion then turned, with presentations by Nakamura, Sasaki and Wiseman, and by Seidel and Matzner, to the second question described above: what is the minimum separation for which existing post-Newtonian methods can give reliable results for a symmetric black hole binary, and what is the maximum separation at which the numerical calculations can begin if they are to carry the evolution reliably through coalescence to the final state of a single, perturbed black hole?

Several proposals were discussed for bridging the gap between the ending point of the reliable perturbative techniques used for the adiabatic inspiral and the fully numerical techniques being pursued for the coalescence. Two of these proposals convey the range of options discussed. Steve Detweiler described very promising work, just nearing completion, on a post-Minkowskii approximation scheme for iteratively constructing *spacetimes* (not spacetime slices) that satisfy the full field equations to fixed order in G. On the other hand, Kip Thorne suggested that an adiabatic approximation to the field equations be sought that would allow the numerical solution to be carried out from larger separations. One element of this approximation, which would deal with the "dynamics" associated with the motion of the black holes through the coordinate grid used in the numerical calculations (but not the dynamics associated with the physical propagation of radiation), is the use of a coordinate system that co-rotates with the binary. Such a coordinate system introduces a light-cylinder, where the character of the coordinates change (some of the coordinates becoming light-like as one crosses the cylinder), and there was considerable discussion over the difficulties of handling this transition region, posing boundary conditions, and identifying the other components of the adiabatic approximation.

The discussion then turned briefly to the problem of identifying the numerical initial data for the coalescence calculations with a binary evolved from large separations. Here, again, discussion covered the full range of possibilities. Larry Kidder discussed a method under investigation with Sam Finn where the multipolar decomposition of the spatial metric and extrinsic curvature on a near-zone two-sphere surrounding the binary in the numerical initial data slice is compared to an identical decomposition of a similar slice through, *e.g.,* a post-Newtonian spacetime. In the restricted context of binary black hole initial data and a point-mass binary post-Newtonian spacetime, intuition suggests that agreement of the moments with $\ell < \ell_{\max}$ suggests that the evolution of the numerical initial data represents an approximate continuation of the binary system evolved by post-Newtonian (or other) means from large separation, and that this approximation should become better as $\ell_{\max}$ increases. The principle concern, voiced by Kip Thorne, is the identification of a prescription that identifies unambiguously equivalent two-spheres and multipole moments in the numerical initial data slice and the post-Newtonian spacetime. On the other hand, Lee Lindblom suggested that if the evolution scheme used for the early, adiabatic inspiral could be made sufficiently accurate (*i.e.,* satisfy the constraints with sufficiently small residuals) at small separation, that a slice through the resulting spacetime could be used directly for as initial data for the fully numerical evolution, thus eliminating the "seam" that Kidder and Finn were attempting to sew.

Finally, Richard Price described on-going work with Andrew Abrahams, Jorge Pullin and other collaborators on "naive" application of perturbation theory to black hole coalescence. Following-up on earlier work by Abrahams and Cook, Abrahams, Price, Pullin and collaborators use either the Zerilli equation for Schwarzschild perturbations or the Teukolsky equation for perturbations of Kerr to evolve the highly perturbed single black holes that exist immediately following the formation of a single event horizon in a binary black hole coalescence. Doing so, they have found a remarkable and unexpected agreement with the radiated energy of the fully numerical simulation. This work suggests that, for at least some purposes, the validity of black hole linear perturbation theory may extend far into the regime traditionally considered a large perturbation.

Quantum Gravity in the Southern Cone

Rodolfo Gambini, Universidad de la Republica, Montevideo, Uruguay
rgambini@fisica.edu.uy

The idea of this meeting was to bring together international researchers in quantum gravity with researchers from the area of the Southern Cone of South America. The workshop was attended by 85 participants and took place in Punta del Este, Uruguay on April 10-12 1996.

The plenary lectures included Esteban Calzetta speaking about Stochastic behavior in field theories and semiclassical gravity, Jim Hartle on quantum cosmology and quantum mechanics, Marc Henneaux on cohomological methods in field theory, Gary Horowitz on black hole entropy in string theory, Carlos Kozameh on Fuzzy spacetimes, Karel Kuchař on quantum collapse, Juan Pablo Paz on decoherence, Jorge Pullin on knot theory and the dynamics of quantum gravity, Carlo Rovelli on black hole radiation and entropy in loop quantum gravity and Lee Smolin on quantum spin networks and quantum gravity.

There were afternoon sessions including talks by

Max Bañados, Mario Castagnino, Alfredo Dominguez, Hugo Fort, Fabian Gaioli, Jose Maluf, Hugo Morales Técotl, Viktor Mostepanenko, Javier Muniain, Mike Ryan, Victor Tapia, Ranjeet Tate, Thomas Thiemann, Luis Urrutia,

and posters by

Daniel Armand-Ugon, Diego Dalvit, Cayetano Di Bartolo, Rafael Ferraro, Fabian Gaioli, Edgardo Garcia Alvarez, Fernando Lombardo, Daniel Sforza.

The conference was generally well received by the participants and attracted a lot of coverage by the Uruguayan media. A second edition of the conference will be organized in Bariloche, Argentina, in January 1998.

Report on the Spring APS Meeting

Beverly Berger, Oakland University
berger@vela.oakland.edu

The Gravitation Topical Group (GTG) made its official debut at the APS–AAPT Meeting in Indianapolis, 2–5 May 1996. Traditionally, this meeting has enjoyed significant participation by the Divisions of Astrophysics (DAP), Particles and Field (DPF), and Nuclear Physics. Decades ago, there were also several sessions on gravitational physics. This participation had declined over the years but, with the formation of the GTG, has now experienced a strong revival. The GTG sponsored a well-attended invited session with talks by Cliff Will ("Gravitational Waves and the Death-Dance of Compact Stellar Binaries"), Fred Raab ("Progress Toward a Laser Interferometer Gravitational Wave Observatory"), Ho Jung Paik ("Spheres—Omni-directional Multi-mode Gravitational Wave Antennas for Next Generation"), and Matt Choptuik ("Critical Phenomena in Gravitational Collapse"). There were also two joint invited sessions. The first with the Topical Group on Fundamental Constants and Precision Measurements (FCTG) featured talks by Francis Everitt ("From Cavendish to the Space Age: Some Thoughts on the History of Precision Measurements"), Jim Faller ("Precision Measurements with Gravity"), Riley Newman ("New Measurements of G"), and Paul Worden ("Testing the Equivalence Principle in Space"). This session was so successful that FCTG and GTG will co-sponsor another session at the 1997 Spring Meeting. The other joint session with DAP focused on neutron stars with talks by Peter Meszaros ("Neutron Star Models and Gamma Ray Bursts"), Dong Lai ("Learning about Neutron Star from Coalescing Compact Binaries and Radio Pulsar Binaries"), John Friedman ("General Relativistic Instabilities of Neutron Stars"), and Charles Meegan ("Observations of Gamma Ray Bursts"). There were also a number of contributed papers that were divided among three sessions: Numerical Relativity, Black Holes, and Cosmology (chaired by Matt Choptuik), Gravity Experiments and Theory (chaired by Fred Raab), and Gravitation Theories (chaired by David Garfinkle). The GTG also held its first business meeting at the conference. In addition to these official GTG activities, there was other evidence of the vitality of gravitational physics. A special plenary session of the APS featured Kip Thorne's Lilienfeld Prize Lecture ("Black Holes, Gravitational Waves, and Quantum Non-Demolition") while a joint Division of Particles and Fields-DAP session on Particle Astrophysics included an invited talk by Barry Barrish ("The Detection of Gravitational Waves"). Finally, this interest in LIGO provided a backdrop for the meeting of the LIGO Research Community which will also participate in the 1997 Meeting.

Details and abstracts can be found at `http://www.aps.org/BAPSMAY96/index.html`. For those who could not attend the meeting, the minutes are given below.

Minutes for Business Meeting of Topical Group on Gravitation

Executive Committee members present: Berger, Thorne, Bardeen, Parker, Raab, Shoemaker, Finn. Absent: Ashtekar, Isenberg, Wald

The meeting was called to order at approximately 5 pm by Beverly Berger.

Beverly Berger introduced the officers of the topical group and gave a brief description of the membership statistics. The topical group currently has approximately 300 members, significantly above the minimum level of 200 members required to form and maintain such a group. It was noted that there are approximately 150 people who signed the petition requesting formation of the topical group but are not yet members. Efforts will be made to bring these people into the group's membership. The membership is comprised of approximately equal numbers of theoretical and experimental investigators.

The status of committees was reported. The nominating committee, chaired by David Shoemaker, will begin to prepare for election of a vice-chair and two executive-committee members this autumn. The Fellowship Committee, chaired by Abhay Ashtekar, is currently considering nominations for APS Fellowship.

A report was given on the state of the group's finances (as provided by Jim Isenberg). Income, principally from membership fees, totalled $1417. Expenses, associated with printing and mailing the newsletter, "Matters of Gravity", totalled $943. This leaves a balance of $473 in the Treasury. The issue of potential cost savings by using electronic distribution of "Matters of Gravity" was raised. Members in attendance voiced agreement with Isenberg's suggestion that future distributions of the newsletter would be done electronically as far as possible, provided that members could still opt for a paper copy if electronic access presented problems. Members would be contacted by e-mail concerning whether they want electronic or paper copies of the newsletter in future. Attendees at the meeting were asked for suggestions of how these funds might be used to good effect. Suggestions were made that something to encourage student participation, either through support for attending meetings or an award, might be a good use for funds.

Beverly Berger advised the audience that organizing future meetings would be an important issue in the near future. The precise details were not yet clear, because the first Meetings Committee of APS to involve the Topical Group on Gravitation would only meet later in the week. Anticipating that our small topical group would get only a few meetings slots at the next April meeting, the general sentiment supported splitting those slots with other groups that had shared interests. This had worked well at this meeting and was thought to provide better exposure with limited speaking slots. The issue of joint sponsorship of gravitational physics meetings that already occur on a periodic basis was raised, but further work was needed to identify what the APS rules are in this area.

Beverly Berger Adjourned the meeting at approximately 5:40 pm.

Minutes submitted by Fred Raab fjr@ligo.caltech.edu, (with slight revisions by Beverly Berger).