# MATTERS OF GRAVITY

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

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# Editorial

Given that relativity is about to be 100 years old, we decided to add a section "100 years ago" where we will reprint (if copyright allows) famous papers from 100 years ago. We start with a paper by Lorentz from 1904.

I want to encourage the readership to suggest topics for articles in MOG. In the last few issues articles were solicited by myself. This is not good for keeping the newsletter balanced. Either contact the relevant correspondent or me directly.

The next newsletter is due February 1st. All issues are available in the WWW:
`http://www.phys.lsu.edu/mog`

The newsletter is 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.

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

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# Topical Group in Gravitation (GGR) Authorities

# Message from the Chair

Jim Isenberg, University of Oregon jim-at-newton.uoregon.edu

Albert Einstein was born $125\frac{1}{2}$ years ago in Ulm, Germany. A little over 25 years later, Einstein published three epic papers which set the course for much of theoretical physics for the twentieth century (and beyond). One of them introduces special relativity, one of them proposes a new "quantum" model for understanding the photoelectric effect, and the last describes a statistical mathematical model for understanding Brownian motion.

Einstein's may be the most familiar face on the planet, and unlike his main competitors (Osama bin Laden, Saddam Hussein, Mao, Castro, and Michael Jackson), just about everyone likes him. If you tell someone that you work on Einstein stuff, you get a much friendlier reaction than if you say that you study differential equations or do LIGO data analysis. Einstein has been used successfully to sell computer supplies, bagels, nuclear weapons, national aspirations, IQ tests, healthcare, and board games.

This coming year, we should capitalize on our Einstein connection and use him to sell gravitational physics, both within the scientific community and out in public. The UN is helping: With Einstein in mind, it has officially declared 2005 to be the "International Year of Physics" (2004 is the "International Year of Rice"). The APS is responding: It has a number of programs planned, some kicking off this October, and it has encouraged us to organize a special evening of talks on gravitational physics at next April's meeting. The public news media will likely be interested in Einstein and the centennial of the 1905 papers as well; and if our local media isn't, we should tell them about it. In doing so, we can convey to them and to the public some of the joy and satisfaction we get in studying general relativity and gravity. And we can tell people about how dramatically this area of scientific research has developed in recent years. The Speaker's Bureau, which has been organized through the GGR in cooperation with other groups, should help with this public mission. Its goals and operation are described by Richard Price elsewhere in this issue of MOG.

A key purpose of the topical group is to tell people about gravitational physics, get them interested in it, and encourage fresh talent to enter the field. Einstein, though over 125 years old, should be a big help this year in achieving this goal.

# We hear that...

Jorge Pullin, LSU pullin-at-lsu.edu

• Bryce DeWitt is this year's winner of the *Einstein Prize* of APS.

Hearty congratulations!

# THE TGG WYP Speakers Program

Richard Price, University of Texas at Brownsville rprice-at-physics.utah.edu

Your Executive Committee felt that the topical group has a special relationship to the 2005 International Year of Physics. Einstein is the spur for WYP, and Einstein is ours. We sponsor the Einstein prize, don't we? And Einstein, after all, would have been a TGG member. As Chairman Jim points out in his message, there will be enhanced interest in Einstein, and in Einstein physics in the WYP. Our topical group has the experts in the physics, so the decision was made, almost two and a half years ago, to share our expertise with the world; the TGG WYP Speakers program was started.

The TGG WYP task force, Chairman Jim, Jennie Traschen and myself, set up a program to connect speaker requests with appropriate speakers. (Speakers on the right subject who can speak at the right technical — or nontechnical – level.) The program, costing nothing, is well within the TGG budget. The administration is carried out by a staff member, Danka Mogilska, of the University of Texas at Brownsville (my new home). The requesting group sends in, by mail, email, or webform, a request with all the information, and Danka looks for a suitable speaker close enough so that negligible travel is involved. If a candidate speaker is found, then the speaker is invited to contact the requesting group. In this way, the inconvenience to the speakers is minimized.

It appears to others also now, that such a speakers program is a good idea. The WYP effort of the Forum on the History of Physics, under the leadership of Virginia Trimble, is quite naturally very interested in the Einstein connection in the WYP. A month ago, they joined with us in the Speakers program. We can now offer experts on Einstein as well as on his physics. Very recently we also established a tie to the Division of Astrophysics. This is so recent, in fact, that details have not been worked out. It is likely that they will provide a different kind of service (in which they pay travel funds!), but it will be useful to have a central administration for all these speakers.

Early on, the Executive Committee selfishly decided that our priority in the Speakers program would be undergraduate institutions, colleges that have potential gravity physics grad students. It appears at present that prioritization is necessary. Requests began rolling in at the end of July, and there are many we will not be able to fill.

You can see our website by going to the APS website (www.aps.org) and following the WYP link to the Speakers Program, or you can go directly to

http://www.phys.utb.edu/WYPspeakers/REQUESTS/howto.html

It should be a long, but interesting year.

# Gravity Probe B is launched from Vandenberg AFB

Bill Hamilton, Louisiana State University hamilton-at-phys.lsu.edu

April 20, 2004 marked the end of the beginning phases for the Gravity Probe B experiment with the launch of the experiment aboard a Delta II rocket from Vandenberg AFB. This experiment has had an extraordinarily long gestation period as initial discussions between Bill Fairbank, Leonard Schiff and Bob Cannon at the Stanford men's swimming pool in 1958 combined with Francis Everitt joining the effort in 1962 culminated in the launch in 2004. Now, as Francis said after the launch, the real work begins.

Gravity Probe B is an elaborate package that is designed to directly demonstrate two effects. The first, the geodetic effect, measures the precession of a gyroscope orbiting the earth. If a perfect gyroscope is placed in a free falling orbit around a massive object the angular momentum of the gyroscope will be connected with the orbit through parallel transport. Since the space-time is curved the geometry of the orbit is not Euclidean. As Everitt put it at the press conference before the launch: "If the orbit were perfectly circular its circumference would be just a couple of centimeters less than $\pi$ times the orbital diameter." Thus the gyro angular momentum exhibits a precession in the plane of the orbit. The second effect, the Lense-Thirring precession, results from the dragging of the orbital inertial frame by the rotating earth. This precession can be made to be perpendicular to the geodetic precession if the orbit is polar.

The predicted precessions are very small. The geodetic precession is calculated to be 6614.4 milliarcseconds per year; the frame dragging precession is supposed to be 40.9 milliarcseconds per year. These incredibly small precession angles required the development of many new technologies. The experiment's orbit has to be continuously corrected for drag, i.e. it must be a zero g orbit. The gyroscopes need to be perfect spheres to eliminate the torques due to gravitational gradients and techniques had to be developed to make them and to measure their orientation without inducing torques. A technique needed to be developed to maintain a fixed direction in inertial space and a whole new type of telescope was developed to sense this direction and couple it to the gyroscopes. All of this means that literally hundreds of people have been involved in, or have contributed to, various aspects of the GPB spacecraft.

Not everyone who came or who tried to come was able to see the launch because, in the best tradition of Gravity Probe B, there were delays. The original launch of 6 December 2003 had to be postponed to rework some grounding problems in the experimental control unit. It was then scheduled for Saturday, 17 April 2004. Most of us who had tickets already were able to change them to the later date. NASA had been very explicit that we had to have official letters of invitation to attend and they were reissued for the later date. On 7 April we were informed that the launch was postponed for two days, until Monday, 19 April because of a short circuit in the launch tower. Everyone I talked to said that they just decided that it was "this time for sure" and that they weren't going to change their tickets.

The launch activities were a virtual Woodstock of old gravitational physicists. NASA's official visitor's headquarters was in the small town of Buellton. It was there that the press conferences were staged and it was from there that buses were scheduled to take people out to the launch site. A number of people, many of those from Stanford, stayed nearer to the

Vandenberg gates at Lompoc. I saw people that I hadn't seen in 15 or 20 years. There were several NASA briefings at the Marriott in Buellton. The powers-that-be had been thoughtful enough to invite the children of Leonard Schiff and Bill Fairbank to see the launch and to participate in the briefings.

On Monday morning, 19 April, a vast fleet of buses appeared in front of the Marriott and hauled us all out to the official viewing site. We discovered that we couldn't see the rocket on the launch site at all: it was hidden behind a small hill. We did have television monitors underneath a big tent and loud speakers connected to launch control but there was no view of the launch tower. A number of us with binoculars and absolutely no knowledge speculated about just what things visible on the horizon might be the launch tower. We all took pictures of the horizon and each other and eagerly listened to the countdown until t= -3 when it was announced that the winds aloft were too high and the launch would be postponed until tomorrow: Tuesday 20 March.

The delay was unfortunate for a number of the prospective viewers because of class commitments or plane reservations. Several had to leave. Some of us with rental cars decided to scout the area to see if there was a better viewing spot. We found a place behind the weather station where the launch tower was in full view at a distance of about 4 km and we were told that the weather station personnel would hook up a loud speaker to listen to mission control. Talking to old time Vandenberg personnel at a party for the invitees hosted by Brad Parkinson reinforced the desirability of this spot.

The next morning we drove to our newfound viewing site and, by the time of the launch, were sharing it with about 250 other people including many past and present members of the Stanford team. Rumors were passed about the reason for the previous day's delay, the prevalent one being that there had been a checksum error in loading the wind profile into the guidance system. Knowledgeable people spoke about the reasons for various gas ventings from the rocket. Finally when the count got to t=0 there was a tremendous cloud of smoke from the solid rocket boosters and the vehicle began to rise above the tower. It took fewer than 3 minutes until the rocket was completely out of sight, leaving only a trail of smoke in the sky. My main impression from the launch was that the brightness of the rocket's flame was much greater than anything I could have imagined from what I had seen of launches on television. The other impression, of course, was of how many people's work had gone into this project to get it this far and how much more there still was to do.

As an experimentalist I am sometimes accused of being over-awed by technology. GPB is, to me, much more than a technological demonstration. It is an attempt to measure, directly, things that we now believe we know. We didn't know these things when the experiment started. We still don't have direct measurements of them. This experiment is a direct measurement in an environment we believe we understand. I can only be amazed at the persistence of the Stanford team and Francis Everitt. It took more than 40 years to develop the technology and methodology to make these measurements. In a year we should have a firmer foundation for our theoretical speculations.

At this writing the experiment is working well. To check on its progress look at http://einstein.stanford.edu.

# Questions and progress in mathematical general relativity

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Maxwell's equations are vitally important for describing the physical universe but raise very few serious questions mathematically. There is considerable mathematical interest in the global behavior of wave maps but there is little evidence that wave maps play a direct role in modeling important physical phenomena. One of the very few field equation systems which is both a vital tool for modeling physics and a very rich source of serious research problems in math is that of Einstein.

From a mathematical point of view, the study of Einstein's equations lies in the realm of geometric analysis, which analyzes PDEs (partial differential equations) that involve structures from differential geometry. For some of the PDEs of geometric analysis, such as the minimal surface equation and the harmonic map equation, the PDE system is elliptic (potential-like); for others, like Ricci flow and mean curvature flow, the PDEs are parabolic (heat-like) ; while for still others, such as wave maps and Yang-Mills, the PDEs are hyperbolic (wave-like). Interestingly in the case of Einstein's equations, there are aspects of all three types: the Einstein constraints are essentially elliptic, the full system is essentially hyperbolic, and when certain ansatze are applied (such as that of Robinson-Trautman) parabolic analysis is called for. As a consequence of this feature, the mathematical study of the Einstein equation system intersects with a much wider variety of areas in geometric analysis than does that of most other geometric analysis PDEs.

Rather than attempting any sort of an overview, I want to focus now on a number of mathematically interesting questions which have arisen from the study of Einstein's equations. In almost all of them there has been substantial progress in recent years.

**Positive Mass and the Penrose Inequality**: It is relatively straightforward to define an integral quantity which measures the mass of an isolated gravitational system. One of the most intensely pursued questions of mathematical GR during the 1960's and 1970's was whether one could prove that such a quantity is either positive or zero, and zero if and only the spacetime is flat. A theorem to that effect was proven finally in 1979 by Schoen-Yau [1] and in 1981 by Witten [2] independently. Since then, interest has shifted to showing that if a spacetime contains black holes, then the mass must be greater than or equal to a quantity involving the square root of the areas of the horizons (the "Penrose Inequality"). Two very innovative proofs of this conjecture, *for the time symmetric case* (initial data with vanishing extrinsic curvature), have been produced in recent years by Bray [3] and by Huisken-Ilmanen [4]. One would very much like to extend this work to the non time symmetric case; this appears to be very difficult. We note that in the time symmetric case, the question can be analyzed purely in terms of Riemannian geometry. This is not true of the more general case.

**Shielding Gravitational Effects**: In Maxwell's theory, a conductor can be used to mask from the view of outside observers many of the details of a charge configuration. Since there are no known negative masses in gravitational physics, it has long been thought that there are no such conductor-like objects for shielding from external view the details of a mass or gravitational field configuration. The elliptic character of the Einstein constraints has reinforced this conjecture. Recent work on the gluing of solutions of the Einstein constraints now belies this idea. In particular the work of Corvino-Schoen [5,6] shows that for essentially any asymptotically Euclidean initial data for Einstein's equations, one can cut out the region outside of some ball and replace it by a smooth extension which, some finite distance out, is exactly data for the Schwarzschild or Kerr solution. The interior details are lost to observers who are far enough away. The gluing results of Chrusciel-Isenberg-Mazzeo-Pollack [7,8] allow other quite surprising joins of disparate sets of initial data. One finds as a consequence of their work that a given region may contain an arbitrary number of wormholes without affecting at all the gravitational fields some distance away from the region. All of these gluing results exploit the underdetermined nature of the Einstein constraint equations (more fields than equations). There is likely much more that can be done to exploit this feature. In particular, one would like to know if it allows one to always extend a given solution of the constraints on a ball to an asymptotically Euclidean solution on $R^3$. This question plays a role in the Bartnik approach to defining the "quasilocal mass"of a given region.

**Cosmic Censorship and the Nature of Singularities**: The Hawking-Penrose singularity theorems indicate that singularities (in the sense of geodesic incompleteness) generically occur in solutions of Einstein's equations , but they say little about the nature of these singularities. Roughly speaking, one expects the singularities to be characterized either by curvature blowup or by the breakdown of causality (marked by the formation of a Cauchy horizon). The Strong Cosmic Censorship Conjecture (SCC) suggests that curvature blowup occurs generically, and Cauchy horizons develop only in very special cases. Proving SCC is a big challenge, requiring detailed knowledge of how solutions evolve generically. There has, however, been progress in proving the conjecture in limited families of solutions, defined by the presence of symmetries. The most recent work in this direction, done by Ringstrom [9] proves that SCC holds for the class of Gowdy solutions on the torus. One of the key steps used by Ringstrom (as well as his predecessors) is the verification that the Gowdy solutions are velocity dominated near the singularity. This approach may be useful for certain less specialized families of spacetimes which also appear to be velocity dominated, like the polarized solutions with $U(1)$ symmetry, While more general families of solutions are likely to not have this property, numerical studies indicate that they may be oscillatory in the BKL sense, and the challenge now is to verify this, and use it to prove SCC.

The very recent work of Dafermos [10] on the stability of the Cauchy horizons found in the Reissner-Nordstrom solutions (spherically symmetric charged black holes) is also relevant to the question of SCC. Interestingly, he finds stability for certain differentiability classes of perturbations, but not for others. Further development of this approach should be very useful

The Weak Cosmic Censorship Conjecture (WCC), which is *not* a consequence of SCC, concerns a very different question: If a singularity develops as a result of collapse in an asymptotically flat solution, does an event horizon generally develop and cover it from view by observers at infinity? As with SCC, WCC is a conjecture concerning the behavior of *generic* solutions, not every solution. While interest in this question is strong, there have not been any important recent results relevant to WCC.

**Long Time Behavior of Solutions and Stability**: For any nonlinear hyperbolic PDE system with a well-posed Cauchy problem, one of the questions of primary interest is whether one can characterize those initial data sets for which solutions exist for all (proper) time. Since singularities do generically develop, one cannot expect long time existence in both time directions; but there is no reason to expect singularities in both directions. For a system as nonlinear as Einstein's equations, long time existence is a very difficult problem. As a first step towards its study, one approach is to investigate the stability of long time existence about solutions like Minkowski space for which it is known to hold. Some years ago, Christodoulou and Klainerman [11] showed that indeed Minkowski space is stable in this sense. The recent works of Klainerman-Niccolo [12] and of Lindblad-Rodnianski [13] prove roughly the same result, but with stronger control of the asymptotic properties of the spacetimes, with different choices of gauge, and with the use of techniques which are much simpler. One would like to extend these results to Schwarzschild and to Kerr, but there is to date no progress in this direction.

Andersson and Moncrief [13] have studied the stability of long time existence for a different sort of spacetime: They have proven stability for the expanding, spatially compact spacetimes one obtains by compactifying the constant negative curvature hyperboloids in the future light cone of the origin in Minkowski spacetime. It is not known what the spacetime developments of the perturbed data do in the contracting direction toward the singularity, but in the future direction, they find that in fact the perturbed spacetimes asymptotically approach the flat spacetimes from which they have been perturbed. Similar stability results have been obtained by Choquet-Bruhat and Moncrief [14] for expanding $U(1)$ symmetric spacetimes, and it is intriguing to speculate that for rapid enough expansion, stability of long time existence is a general feature.

Another line of research related to the long time behavior of solutions focuses on determining which sets of asymptotically Euclidean initial data develop into spacetimes which can be conformally compactified so as to include the familiar "scri" structure at null infinity. Until recently, the only spacetimes known to have this complete structure were stationary. Combining the gluing work of Corvino-Schoen discussed above with Friedrich's [15] work on the generation of scri from sufficiently small initial data on an asymptotically hyperbolic spacelike surface, one now knows that there are non stationary, radiating solutions with a complete scri. The recent work of Kroon [16] shows that the nature of scri can, for general spacetimes, become quite complicated (including "polyhomogeneous" behavior.)

Finally, we note that one approach towards obtaining long time existence for a hyperbolic system is to try to reduce the level of regularity (number of derivatives) needed to prove well-posedness, and then find a conserved norm compatible with that level of regularity. Klainerman-Rodnianski [17] and Smith-Tataru [18] have focused on this approach, and have managed to prove well-posedness for data with the metric in the Sobolev space $H^{2+\epsilon}$, and the extrinsic curvature in $H^{1+\epsilon}$. The first group is working very hard to remove the $\epsilon$.

There are a number of other very interesting areas of mathematical study of the Einstein equations, including work to establish an initial value-boundary value formulation of the system, efforts to understand and parameterize non constant mean curvature solutions of the Einstein constraint equations, attempts to obtain an analytical understanding of the critical solutions found in Choptuik's numerical studies of gravitational collapse, and continued studies of the "static stars are spherical" conjecture. There is every expectation that the recent record of progress in this area will continue for some time to come.

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# Summary of recent preliminary LIGO results

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The LIGO Lab and the LIGO Scientific Collaboration (LSC) continue to interweave detector commissioning and data taking with data analysis and the presentation and publication of scientific results. In the Spring 2003 issue of *Matters of Gravity*, Gary Sanders summarized the status of the LIGO detector commissioning effort leading up to the first Science Run (S1) and recapped the preliminary "upper-limits" results that Albert Lazzarini had reported at the AAAS meeting in Denver. In last Fall's issue, Stan Whitcomb reported on the completion of a second LIGO data taking run, S2. In the intervening year, the LIGO Scientific Collaboration has published a sequence of five major articles that culminate the work on the S1 data set [1-5], as well as numerous conference proceedings and technical reports [6]. We also completed another two-month science run (S3) in early January of 2004. In this note, I would like to briefly recap the published S1 results, as well as summarize the preliminary S2 and S3 results that were presented at the Denver APS meeting in May and the Dublin GR17 meeting in July.

The data analysis effort within the LSC is currently divided among four groups reflecting four distinct source types: the Inspiral Upper Limits Group, the Stochastic Background Upper Limits Group, the Pulsar (continuous waves) Upper Limits Group and the "Burst" Upper Limits Group. When the groups were formed some years ago, the qualifier "upper-limits" was included in the group name to reflect the fact that the sensitivity of the instrument during the early running would likely lend itself to only setting upper limits on flux strength and population models. However, as the sensitivity of the detectors has improved, each group has begun to set their sites on true detections, and thus the use of the qualifier is falling by the way-side.

However, the first article [1] to wind its way through both the internal LSC review[1] and the external peer-review process was not an astrophysical paper originating from within the analysis groups. Rather, the first paper gave a detailed description of the configuration and performance of the LIGO detectors and the British-German GEO detector during the 17 day S1 data run in August and September of 2002. This "detector" paper was then followed by "upper-limits" papers from each of the four search groups. Although the final astrophysical results in these four papers do not challenge any existing theories, they do present complete analyses which show how to search *real* data for small gravitational wave signals and how to translate those searches into astrophysical limits.

The presentation of the preliminary S2 and S3 results at the APS and GR meetings followed a pattern similar to the S1 publications: a summary presentation describing the status of the detectors was followed by a talk from each of the four analysis groups. Although the results are summarized below, we invite everyone to take a look at the vu-graphs that were presented [7]. The central feature of the summary talk was to show the dramatic improvement

[1]Most of us in gravitational physics have written papers in small collaborations and know the difficulties of negotiating with our colleagues about the precise content of the paper: imagine scaling this process to an author list with over 300 people!

in detector sensitivity over the last few years. Figure 1 shows that the commissioning efforts are paying off, and the detector is nearing the design sensitivity.

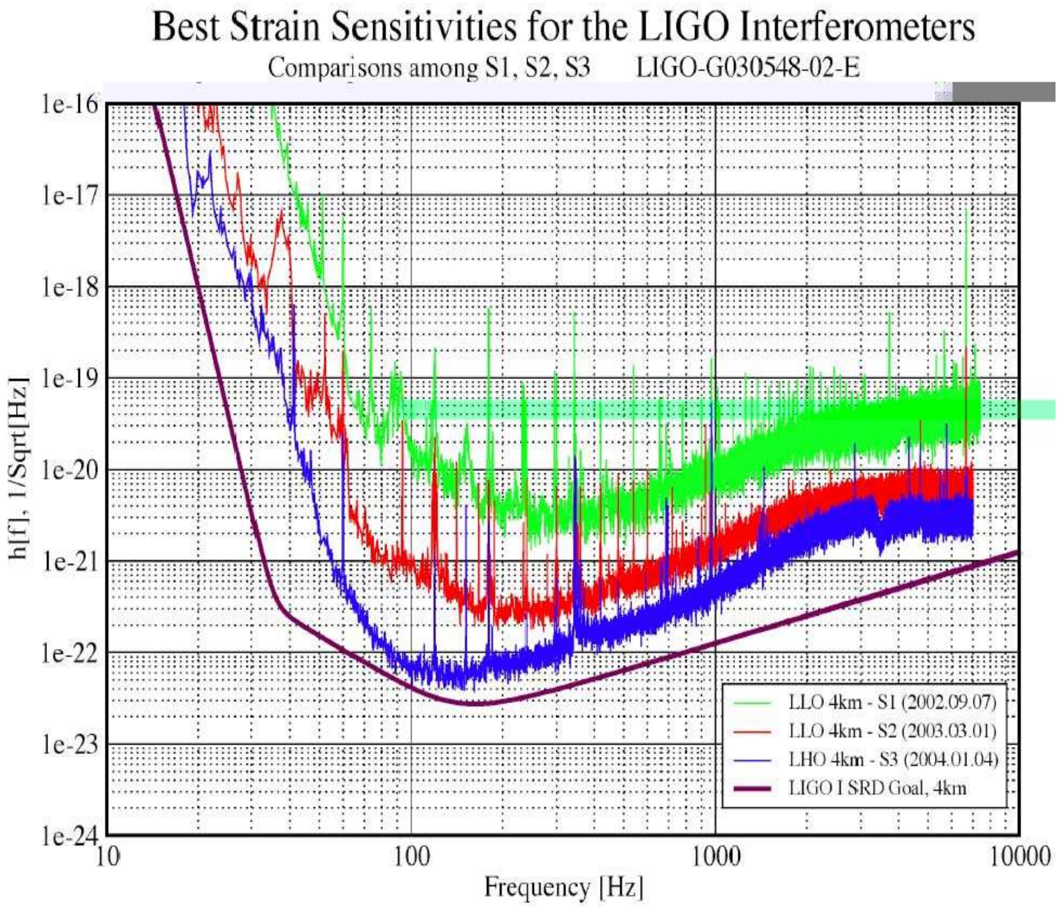


Figure 1: Best Strain Sensitivities for the LIGO Interferometers. LHO refers to the Hanford Observatory. LLO refers to the Livingston Observatory.

In the published S1 analysis [2], the Burst Group took on the daunting task of limiting the rate and strength of poorly modeled burst sources of gravitational waves. [It is hard to look for something when you don't know what it looks like.] The primary result of this analysis was to quantify an excluded (or low probability) region in the rate versus signal strength plane. Although a similar analysis is being repeated with the more sensitive S2 and S3 data, the Burst Group has also added a new type of search to the mix: a "triggered" burst search. Some preliminary results from this search were presented at the APS and the GR17 meetings. During S2 an especially strong $\gamma$-ray burst (GRB 030329) popped off nearby ($z = 0.1685$). The data from the two Hanford detectors were cross correlated in a 180 second interval surrounding the arrival time of the burst. [Unfortunately the Livingston and GEO detectors were off-line during the burst.] This was compared to a threshold set by a similar analysis conducted on data taken well away from the burst arrival time. Although no gravitational wave burst was detected, a strain upper limit of $h_{rss} \approx 6 \times 10^{-21}\mathrm{Hz}^{-1/2}$ was set.

The Inspiral Group searched for non-spinning binary neutron star inspirals in 236 hours of S1 data [3]. Unfortunately, the sensitivity of the instruments only allowed them to see inspirals within a portion of the Milky Way Galaxy. The group used a "loudest event" statistic to determine the upper limit on the event rate of neutron star coalescences. The published

S1 paper gives a ninety-percent confidence limit on the event rate of binary neutron star coalescences as

$$R_{S1} < 1.7 \times 10^2 \text{ per year per MWEG} .$$

Here, MWEG means Milky Way Equivalent Galaxy. During the S2 run the instrument was considerably more sensitive and could see beyond the Galaxy. For example, the Livingston Detector, could reach M31. However, because the group is beginning to look beyond simply setting upper limits and toward a possible detection, they have modified their analysis pipeline accordingly. Only coincident data (when two or more interferometers were operating) was included in their upper limit. This reduced the "live time" to about 355 hours and therefore reduced the upper limit that might have been attained had they analyzed the "singles" S2 data in the same way they analyzed the S1 data. Nevertheless, an improved preliminary upper limit of

$$R_{S2} < 50 \text{ per year per MWEG}$$

was obtained.

As the Inspiral Analysis Group moves forward, they will be casting a broader net and include searches for binary black holes with masses greater than $3M_{\text{Sun}}$. Searching for these signals presents a special challenge as neither the waveforms or the population models are well known. They will also be looking for inspiraling massive halo objects (MACHOs) with masses in the range of $0.2 - 1.0M_{\text{Sun}}$. The MACHO search presents a different challenge as the template waveforms for these low mass systems spend much longer in the LIGO sensitivity band than do the neutron star binaries.

In analyzing the S1 data [4], the Pulsar Analysis Group used two very different techniques to perform a search aimed at setting an upper limit on the ellipticity of PSR 1939+2134: a Bayesian time-domain search and a frequency-domain search. Several features of this search are worth noting. First, a directed search at a pulsar with known frequency and sky location is less computationally intensive than a search for unknown pulsars in a broad region of the sky or in a broad frequency band. Second, during S1, both GEO and LIGO were operating, and therefore the results combine information from both detectors. Third, the fact that two different analysis methods arrived at essentially the same results instills confidence in the implementation of both methods. The result is a bound on the ellipticity of this pulsar of $\epsilon_{S1} < 2.9 \times 10^{-4}$.

Using the S2 data, the Pulsar Analysis Group has now applied the "time domain" search method to 28 known isolated pulsars with good timing data. In the case of PSR 1939+2134, this analysis has improved the upper limit on the ellipticity by about an order of magnitude. A full list of the ellipticity bounds should be published soon. The Pulsar Analysis Group also has ambitious plans for doing wide parameter space searches to look for unknown pulsars.

A search through the S1 data for a stochastic background of gravitational waves has also been completed and published [5]. The basic idea is to cross-correlate data from two detectors with the appropriate range of time lags. The result for the Hanford-Livingston cross correlation is a bound on $\Omega_{gw} h_{100}^2 < 23 \pm 4.6$ in the frequency band $64 - 265$Hz, where $\Omega_{gw}$ is the energy density per logarithmic frequency interval divided by the energy density required to close the universe, and $h_{100}$ is the Hubble constant in units of 100km/sec Mpc. At the GR17 meeting, a preliminary S2 result of $\Omega_{gw} h_{100}^2 < 0.018(+0.007, -0.003)$ in the frequency band $50 - 300$Hz was presented. Based on sensitivity estimates from the S3 noise curves, we expect to be able to place a bound of roughly $5 \times 10^{-4}$ in the same frequency band.

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- *Analysis of First LIGO Science Data for Stochastic Gravitational Waves.* Phys.Rev. D69 (2004) 122004.
- In addition to [1-5], there have also been numerous conference proceedings and technical articles that have appeared. Most can be found by searching for the LIGO Collaboration at http://www.slac.stanford.edu/spires/hep/search/index.shtml.
- http://www.ligo.org/ → Observational Results.


## 100 Years ago

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In 1904 H. A. Lorentz published the paper “Electromagnetic phenomena in a system moving with any velocity less than that of light” in Proceedings of the Academy of Sciences of Amsterdam. The paper is reprinted in its English version in the Dover book “The principle of relativity”. A scan of this version is available in

http://www.phys.lsu.edu/mog/100

# Einstein 125

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The German Physical Society celebrated Einstein's 125th birthday in Ulm, his birthplace, through a conference. Since the membership of the Society is very large —according to the organizers, it is the largest Physical Society worldwide— they have to divide their annual meetings into sections. This meeting brought together sections on General relativity Gravitation, History of Physics and Mathematical Physics.

The conference was inaugurated by the German President, Johannes Rau on March 14th, the day Einstein was born. There was a delightful evening lecture entitled "Einstein's Impact on Theoretical Physics of the 21st Century" by Professor C.N. Yang. Although he is now 81 and had flown to Germany from Hong Kong just the day before, there was not the slightest trace of jet-lag or fatigue. He started out by saying that in his view, Einstein was by far the greatest scientist of the 20th century and characterized his work by *Depth, Scope, Imagination, Persistence, and Absolute Independence*. Then, in his usual crisp style, he summarized the continuing impact of Einstein's creative contributions, particularly, his "obsessions with unified field theory". Professor Yang sharply disagreed with the view that this work was misguided or futile. Specifically, he explained that three key themes in contemporary physics originate in that work: Geometrization of physics; non-linearity of laws of Nature; and the role of topology in physics.

This lecture was followed by a surprise: a musical event featuring Paul Einstein on violin and Siegfried Räbblen on Piano. Paul, a great grandson of Einstein's is a musician living in the south of France and played on Einstein's violin. The piece was a Mozart Sonata, K304, written in 1778. It is the only instrumental work Mozart wrote in E-minor and its poignancy reflects Mozart's reaction to the news of his mother's death. It was Einstein's favorite.

Three days starting Monday, March 15th were devoted to the scientific part of the conference. The program on General Relativity and Gravitational Physics was organized by Claus Kiefer, the Chair of the Section, in consultation with other office bearers. Plenary talks were given by Abhay Ashtekar (Gravity, Geometry and the Quantum: Building on Einstein's Legacy); Gerhard Huisken (Geometrical Concepts in General Relativity); Hermann Nicolai (Cosmological Billiards); Asher Peres (Quantum information and Relativity Theory) and Cliff Will (Was Einstein Right?). In addition, there were several parallel sessions on gravitational physics which featured invited talks by Martin Bojowald (Quantum Cosmology); Christian Fleishhack (Loop Quantum Gravity: Progress and Pitfalls); and Domenico Giulini (The Thin-Sandwich problem: A Status Report), as well as a number of contributed talks by others. In addition to scientific talks, there was parallel session on "Einstein and the Arts" and a plenary lecture by Arthur Miller, comparing Einstein's and Picasso's views on space and time, in particular, simultaneity.

The city of Ulm had commissioned a special opera, *Einstein, die Spuren des Lichts* (Einstein and the traces of light) from Dirk D'Ase, the Composer in Residence in Vienna for this occasion, with libretto by Joachim Stiller. The conference participants were treated to a special performance on the evening of Tuesday, March 16th. The city has also organized a year-long exhibit to celebrate the 125th birthday. There were several interesting items in the exhibit. The one I found most moving was the desk that Einstein used in the Berne Patent office —it was just sitting there, unprotected. One could touch it, even open the drawers. Alas, there were no forgotten, left-over papers from 1905!

# The 7th Eastern Gravity Meeting

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The seventh annual Eastern Gravity meeting took place on the lovely campus of Bowdoin College in Brunswick, Maine from June 11-12, 2004. Approximately thirty relativists participated in the conference.

In the first session, talks of the current status of evolving binary black hole orbits in the fully-non-linear regime were discussed. Gregory Cook (Wake Forest University) started the meeting by relating the current state of efforts to generate astrophysically realistic initial data for black-hole binaries. In particular, he discussed the consequences of different boundary conditions on the data. Ulrich Sperhake (Penn State) presented evolutions using dynamical excision with fixed mesh refinement and the BSSN-formulation. He pointed out that there are still difficulties in evolving a boosted black hole with moving excision regions; nonetheless, he has been able to evolve black holes with boosted velocities of 0.4c for 120M. Wolfgang Tichy (Penn State) showed numerical simulations of a black hole binary quasi-circular orbit also using BSSN and fixed mesh refinement. He emphasized the importance of using the gauge to keep the apparent horizons in a fixed location long enough to evolve one orbital time period. Carlos Sopuerta (Penn State) ended this session with a new effort to model Extreme-Mass-Ratio Binaries numerically using finite elements. To date they have successfully completed a toy-model using scalar gravity.

The second morning session focused on binaries of a black-hole and a companion star. The first talk was given by Monica Skoge (student at Princeton) a former undergraduate student at Bowdoin. She illustrated a numerical method for the construction of quasi-equilibrium models of black hole-neutron star binaries, concentrating the the construction of such binaries in Newtonian gravity. Thomas Baumgarte (Bowdoin College) continued, focusing on the relativistic version of the problem. In their preliminary work, they located the onset of tidal disruption in this fully relativistic framework in the extreme-mass-ratio regime. Pablo Laguna (Penn State) presented gravitational waves from stellar disruptions by super-massive black holes. He showed that quadrupole gravitational waves emitted during the tidal disruption process are described reasonable well (within $\approx 5\%$) by a point particle approximation even in the strong encounter case. Finally Sasa Ratkovic (graduate student at SUNY at Stony Brook) ended the session with a report on how different equations of state for the companion (either quark or neutron star) may result in a detectable difference in the gravitational wave signatures. These results are based on a pseudo-general relativistic potential that incorporates post-Newtonian corrections.

The third session concerned mostly quantum cosmology. Seth Major (Hamilton College) started off with a discussion on the consequences of a quantum cosmology arising from quantum geometry. Building on the work of Martin Bojowald, he presented the solution to the Lorentzian Hamiltonian constraint for isotropic loop quantum cosmology coupled to a massless scalar field. David Craig (Hamilton College) discussed decoherent histories formulations of quantum theory and described applying these ideas to construct a consistent quantum theory of recollapsing homogeneous universes, the Bianchi IX cosmological models. Michael Pfenning (U.S. Military Academy) gave a brief introduction to the quantum weak energy inequalities and showed ways the quantum inequalities can by used to constrain the magnitude of the Casimir vacuum energy density both above and below. Daniel Cartin (Naval Academy Preparatory School) followed recent work by Bojowald and others that looked at cosmological models in terms of loop quantum gravity and applied these methods to Bianchi I LRS spacetimes.

The final session of the day started with a discussion on self-force effects on the ISCO of Schwarzschild by Steve Detweiler (University of Florida). The self-force effects, from a scalar field, have been calculated for a particle in a circular orbit of the Schwarzschild geometry. Such effects change the radius and orbital frequency of the innermost stable circular orbit. Steve Drasco (graduate student at Cornell) computed gravitational waveforms, and asymptotic fluxes of energy and angular momentum produced by a spin-less point particle moving along an arbitrary bound geodesic of a Kerr black hole accurate to the first order in the mass ratio of the two bodies. Etienne Racine (graduate student at Cornell) presented a surface integral derivation of post-1-Newtonian translational equations of motion for a system of arbitrarily structured bodies, including the coupling to all the bodies' mass and current multipole moments.

The second day of the conference started with Charles Evans (University of North Carolina) presenting a means of specifying exact outgoing-wave boundary conditions in time domain calculations with the boundary at a finite distance from the isolated source. He applied the method to the cases of a flat-space three-dimensional wave equation and Schwarzchild. Ian Morrison (undergraduate, Bowdoin College) described the effects of differential rotation on the maximum mass of Neutron Stars with nuclear equations of states. He finds that the maximum mass increases above the limit for non-rotating stars by about 50%. David Garfinkle (Univ. of Guelph/Perimeter Institute) showed the results for the numerical simulation of the approach to the singularity in a general (no symmetry) vacuum spacetime, results support the BKL conjecture; namely, as the singularity is approached spatial derivatives become negligible and at each spatial point the dynamics becomes that of a homogeneous, oscillatory spacetime. Steven Liebling (Long Island University) discussed his use of non-gravitating, nonlinear models in three dimensions using a distributed adaptive mesh refinement framework to investigate the threshold behavior as a step in developing the infrastructure to model the gravitational field equations.

The final session of the meeting began with Munawar Karim (St. John Fisher College) who presented his work on a compact (10cm) gravitational wave detector. Eanna Flanagan (Cornell) discussed how, when a source emits a burst of gravitational waves, different observers will measure different net changes in the angular momentum of the source, an effect related to the phenomenon of gravitational wave memory. Douglas Sweetser presented a Rank 1 Unified Field Theory. He contends that it may be possible to quantize the 4D field equations using two spin fields: spin 1 for EM and spin 2 for gravity. R.L. Collins (retired, The Univ. Texas at Austin) presented his case for a scalar alternate to GR based on Mass-metric relativity. He contends that the Gravity Probe B will potentially invalidated one of these theories of gravity.

On behalf of the participants, congratulations again to Steve Drasco for winning the Best Student Talk award. All the students gave outstanding talks, congratulations to each of them. Our thanks to Thomas Baumgarte and Bowdoin College for organizing a well run, enjoyable meeting and reception. Greg Cook has volunteered to host the 8th Eastern Gravity meeting next year at Wake Forest University in North Carolina, date to be announced.

# 2004 Aspen winter conference on gravitational waves and their detection (GWADW)

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The 2004 Aspen Winter Conference on Gravitational Waves and their Detection (GWADW) was held at the Aspen Center for Physics, Aspen, Colorado, Feb. 15-21, 2004. The subtitle was “Advancing Gravitational Wave Detectors: Pushing the Quantum Limits”. The special goal of this workshop was to consider novel Gravitational Wave detectors beyond the concepts used in Advanced LIGO and other future interferometers and bars. Particular emphasis was placed on various methods that approach and exceed the quantum limit, as, for example, with Quantum Non Demolition (QND).

As usual for the Aspen conferences, each day of the workshop consisted of about six hours of scheduled talks and discussion as well as scheduled workshop interactions. The nature of the housing, with all participants living and dining under the same roof, at the Aspen Meadows, encouraged extensive opportunities for informal scientific exchange. In addition, a public lecture was given on Wednesday, February 18, 2004 at the Wheeler Opera House by Mark Coles (NSF), entitled , “The Universe... Live and in concert”.

The opening session, chaired by Nergis Mavalvala and entitled, “Pushing the Quantum Limits” , set the tone for the workshop. It started with a talk by Nergis on “Quantum Noise, Quantum Correlations and the Standard Quantum Limit in GW Interferometers” . This was followed by provocative talks by Yanbei Chen on “Various Ways of Beating the Standard Quantum Limit”, and by T. Corbitt who discussed “A Quantum noise simulation network”. These talks stimulated lots of discussion in the auditorium, on the slopes and at dinner.

Following a discussion by Richard Matzner on “Constrained Evolution: Concepts and New Results” , in a short session on Relevant Astrophysical Sources, the subject of Techniques Addressing Quantum Noise occupied the next few sessions. Ric DeSalvo discussed the virtues of going underground in “Mining for Gravitational Waves”. Incidentally, Going Underground is one of the two subtopics for the 2005 GWADW Meeting in Aspen. K. Somiya proposed an “RF Readout scheme to Overcome the SQL”, In the first of two talks on Squeezed Light, R. Schnabel discussed a “Demonstration of Squeezed Light at Sideband Frequencies below 100kH and T. Corbitt informed us about “A Ponderomotive Squeezed Vacuum Source”.

Sessions on The Status of Existing Detectors followed. M. Cerdonio told us about “Wideband Operation of Upgraded Auriga’, A. Gretarsson reported on the staus of LIGO, B. Willke on the status of GEO 600, E. Tournefier on the status of Virgo, and S. Sato reported both on the status of TAMA and of a data taking run. A series of talks on next generation detectors followed. Advanced LIGO was discussed by D. Ottaway, and K. Kuroda informed us about the current staus of LCGT and CLIO. B. Willke discussed Lasers for Advanced Interferometers and M. Cerdonio reported on progress on the feasibility of DUAL. At this point, late Wednesday, Feb. 18, Stan Whitcomb led a discussion on what should drive the rest of the workshop. Such a discussion has become a feature of this very interactive workshop, and resulted in the talks that were eventually scheduled for the Summary session on Saturday morning. Norna Robertson reported on the suspension design for Advanced LIGO and R.

DeSalvo discoursed on “Bodies in Motion’.

A session on LISA followed. M. Tinto told us about a scheme for optimal filtering of LISA data, R. Spero discussed ST7 Interferometer Development, and M. te Plate described the LISA Test Package (LTP), the Optical Bench system, and the LTP Inertial Sensor System.

Inasmuch as we are finally taking data, Stan Whitcomb reported on results from LIGO and GEO Science runs. E. Majorana then talked on “Suspended Mirror Control: Learning through Virgo Experience”. The next few sessions were devoted to advances in critical areas, and to lowering the sensitivity floor. These included some more LISA oriented talks such as given by D. Shaddock, who talked about the LISA Optical Bench, and a round table organized by A. Ruediger on “One-Arm Locking of LISA”. The participants, in addition to Ruediger, were D. Shaddock, I. Thorpe, and M. Tinto. RSE was another important subject. Beyersdork talked about implementing RSE via polarization control, S. Kawamura talked about the current status of the 40m Detuned RSE Prototype, and K. Somiya updated us on RSE in Japan.

In other talks, P. Beyersdorf talked about Technical Noise in QND and R. Mittleman discussed progress in the important LIGO Livingston Seismic Upgrade. M. Rakhmanov talked about how to measure the Dynamic responses of the LIGO 4 km Fabry-Perot Arm Cavities. Y. Aso discussed the Suspension Point Interferometer.

The workshop concluded with a discussion of “Important Questions” raised during the Wednesday morning discussion led by Whitcomb. W. Johnson explored the use of Bigger Masses and R. DeSalvo examined the role of Gravity Gradients. F. Vetrano had the last word in his discussion of the role of Atom Interferometry.

# Fifth LISA Symposium

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LISA Symposia are held every two years, with the venue alternating between the U.S. and Europe. The latest one—the Fifth International LISA Symposium—was held at ESTEC (The Netherlands) on July 12-15, 2004. Oliver Jennrich was the main organizer, and it was attended by about 180 scientists.

About 80 talks and almost 30 posters were presented over the course of this 4-day meeting. Almost all the talks are now available on-line at

http://www.rssd.esa.int/index.php?project=SP&page=LISA%20Symposium.

The Proceedings will be published in a special issue of *Classical and Quantum Gravity*.

The first day was devoted to LISA Pathfinder, a technology demonstrator mission that will test key LISA technologies, especially the inertial sensing and and drag-free control. Also, several different kinds of thrusters (FEEPS, colloidal thusters, cold gas) will be employed, to help determine the best choice for LISA. LISA Pathfinder will carry two instruments: the European LISA Test Package (LTP) and the U.S. Disturbance Reduction System (DRS). Work on both sides of the Atlantic appears to be proceeding smoothly towards LISA Pathfinder's scheduled launch in 2008.

Tuesday morning was devoted to status reviews from the major ground-based detectors (both bars and interferometers). The rest of the meeting was then devoted to sessions on LISA instrumental work, astrophysical sources, modeling and simulation, and LISA data analysis.

The instrumental talks described significant progress on many fronts, including the interferometry, test-mass charging and discharging, self-gravity gradients, and the thrusters. The theoretical talks mainly dealt with coalescences of massive ($\sim 10^6 M_\odot$) black holes, inspirals of stellar-mass compact objects into massive black holes (including the radiation reaction problem), and the problem of "fitting out" as many short-period galactic binaries as possible (important since confusion noise from these binaries will actually dominate LISA's noise curve in the low-to-mid-frequency range).

From the sessions on simulations and data analysis, a couple talks were essentially advertisements for new LISA-related websites. I'm happy to use this space to help propagate that information. M. Vallisneri and J. Armstrong have developed a software package called *Synthetic LISA* for generating synthetic LISA time series, i.e., for computing the TDI responses to gravitational waves and for adding noise with the predicted spectrum. This is available at http://www.vallis.org/syntheticlisa/. A similar package called *The LISA Simulator* has been built by N. Cornish, L. Rubbo, and O. Poujade; it is available at http://www.physics.montana.edu/lisa/. Another relatively new site is the *Mock LISA Data Archive* ( http://astrogravs.nasa.gov/docs/mlda/), which contains a collection of simulated data for different source classes, to be used in developing and benchmarking data analysis algorithms.

I'll conclude by mentioning that the Symposium took place under a bit of a cloud, politically. U.S. President Bush's new Vision for NASA (announced in Jan.'04) involves a re-prioritization of NASA activities, with more emphasis on manned missions (leading eventually to astronauts on Mars) and less on space science. To help free up money for the manned program, the budget for the *Beyond Einstein* program was cut back significantly: the LISA schedule was delayed by one year, Constellation-X was delayed two years, and the Einstein Probes (like the Dark Energy Probe) were eliminated from the budget completely. However, despite these developments, knowledgeable insiders generally opined that LISA enjoys sufficient support, both from Congress and within NASA, that further budget tightening for science would probably just lead to further delays, as opposed to LISA's cancellation.

# GR17

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GR17, the 17th International Conference on General Relativity and Gravitation, took place in the Royal Dublin Society convention centre, Dublin, Ireland from July 18th-23rd this summer. This conference series, held under the auspices of the International Society on General Relativity and Gravitation provides a forum for a triennial review of all areas of research in gravitation, as well as an opportunity to look forward to and plan for future challenges. This report can only give a very brief flavour of the content of the conference. The proceedings will be published next year by World Scientific and in the meantime, abstracts and links to some talks are available at the conference website http://www.dcu.ie/~nolanb/gr17.htm (please note that www.gr17.com will not be in operation from late 2004 on). The conference was attended by just under 700 scientific delegates.

The organization of the GRn conferences is in the hands of a Scientific Organizing Committee, whose principal remit is to select plenary speakers and workshop chairs, and a Local Organizing Committee who handle organizational aspects. For GR17 these were chaired by Curt Cutler (AEI, Golm) and Petros Florides (Trinity College Dublin) respectively.

The conference was opened on the morning of Monday 19th July by Her Excellency Mrs Mary McAleese, President of the Republic of Ireland, who delivered a well received address mentioning the contributions of John Lighton Synge to relativity and William Rowan Hamilton to physics generally. She also exhorted the audience to make the most of the week's opportunities to learn and discuss and to leave Dublin with a renewed commitment to their vocation as scientists. Petros Florides presented Mrs McAleese with copies of books by Stephen Hawking, Roger Penrose and Kip Thorne to mark the occasion, which prompted her to comment that she had never been given so much homework in her life. The opening also included the presentation by the (outgoing) Society president Bob Wald to Eanna Flanagan of the Xanthopoulous Award and a memorial lecture on JL Synge by Petros Florides. Ted Newman spoke briefly about the life and contribution to relativity of Peter Bergmann, who passed away since the last GR meeting.

There were 16 plenary lectures and 19 workshops at GR17. The former number represents a slight reduction on the number at GR16 held in Durban: this was done to allow more time for informal discussion. The 19 workshops were divided between afternoon parallel sessions and two evening poster sessions. The promise - and subsequent appearance - of a glass or two of wine during the poster sessions led to their being very well attended, with discussions only dying down as RDS staff began turning off the lights.

The SOC attracted an exceptional list of plenary speakers to GR17. The scientific content of the conference was initiated by Sterl Phinney (Caltech), who spoke about what we hope to learn about astrophysics and relativity from the LISA mission, as well as what subsequent missions may tell us about cosmology and the early universe. Piotr Chruściel (Tours) gave a review of key results in Mathematical Relativity since GR16, focusing on global properties of the (vacuum) Einstein equations. Don Marolf spoke about the current status of the conjectured AdS/CFT correspondence of string theory, as well as its more controversial generalizations to other quantum theories of gravity.

Barry Barish (LIGO/Caltech) reviewed the status of the worldwide network of gravitational wave observatories and the scientific data currently being generated, and spoke about the prospects for the future of gravitational wave detection by this network. John Baez (UC Riverside) gave an expository talk on spin networks, spin foams and loop quantum gravity, highlighting the theory's successes in accounts of black hole entropy and the big bang. Miguel Alcubierre (Mexico City) had the unenviable task of reviewing recent progress in numerical relativity, both in terms of the theoretical framework (hyperbolic formulations, gauge choices, boundary conditions) and astrophysical simulations.

Wednesday morning saw the Gravity Research Funded session, chaired by Louis Witten. GRF provides funding for each GRn conference to invite speakers whose interests and expertise are in areas that are tangential to or slightly outside general relativity. Thus the audience at GR17 had the opportunity to hear Sir Martin Rees (Cambridge) speak about black holes in active galactic nuclei, Jim Peebles (Princeton) present a detailed critical review of the $\Lambda-$CDM cosmological tests and John Preskill (Caltech) introduce the theory of and prospects for quantum computing.

Preskill took to the stage again on Wednesday afternoon, when Stephen Hawking (Cambridge) presented his proposed solution of the black hole information paradox. Preskill jointly chaired the session with Kip Thorne, who is the third party to a bet (Thorne & Hawking vs. Preskill) on the issue. The event, introduced by Petros Florides, attracted a lot of media attention and so the scientific audience was joined by numerous members of the fourth estate to witness Hawking - but not Thorne - concede the bet and to watch Preskill wave his prize (an encyclopedia of baseball, from which information can be extracted at will) triumphantly over his head. (This correspondent was greatly amused by media reporting on the shenanigans, with references to an "audience of Dublin boffins" being stunned by Hawking's confession that he "got the hole thing wrong". GR17 was referred to as the "brains Olympics" - in which case Preskill's parody of Olympian glory was spot on.)

Back at the science end of things, Eric Poisson (Guelph) spoke first on Thursday morning on the gravitational self-force (he began by asking where all the TV cameras had gone). Licia Verde (Pennsylvania) reviewed the implications for cosmology of the first year WMAP data, and promised that the second year data would be available "soon". Joseph Polchinski (UCSB) spoke about recent work that shows that certain superstrings populating the early universe could expand to cosmic scales today and be a significant source of gravitational waves.

The first of the Friday morning lectures was given by Lars Bildsten (KITP, UCSB), who spoke about recent advances in relativistic astrophysics (sensitive X-ray astronomy; solar black hole masses; data from PSR 0737-3039) and mentioned the consequent challenges for theorists and the gravitational wave detection community. Nergis Mavalvala (MIT) talked about the current status of advanced gravitational wave detector technology, and how this is now showing the way to a quantum-limited interferometer. The final plenary lecture was given by David Langlois (IAP, Paris) who reviewed the implications of the braneworld scenario for gravitation and cosmology. The focus was on the standard braneworld picture of our 4-d world resident in a 5-d bulk.

It is impossible to mention individually any of the large number of oral and poster presentations made in the workshops, but note that the conference book of abstracts is available online (see url above). Close to 600 (different) abstracts were submitted in all, amounting to some

400 talks and 200 posters. There were two public lectures held during the week. Kip Thorne spoke on Monday night about what we will learn from the new science of gravitational wave astronomy, and Roger Penrose spoke on Friday night, giving his personal opinions on some popular contemporary physical theories which he categorized under the headings "Fashion, Faith and Fantasy". Other business during the week included the election of the new GRG Society officers; Cliff Will succeeds Bob Wald as president.

Astonishingly for Dublin, delegates encountered only one day of rain, allowing us to have lunch and coffee in the RDS grounds most days and enjoy what passes for good weather here. We look forward to even more sunshine at GR18 in Sydney in 2007.

# Loops and Spinfoams

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The "Loops and Spinfoams" conference was held in Luminy, Marseille, France, on May 3 to 7, 2004. Aim of the conference was to make the point on the loop approach to quantum gravity.

Participation has been much higher than expected: more than a hundred participant, including a large number of young researchers and students. Discussion has been intense and the atmosphere friendly and very lively.

The conference was articulated in thematic days, focused on: (i) Canonical loop quantum gravity, (ii) the spinfoam formalism, (iii) applications, and (iv) related approaches. The program was developed in 45 presentations of different lengths, too many for illustrating them here individually. Very ample time was left for questions and for discussion, a format that has proven effective and has been appreciated by the participants.

The overall picture of the research in nonperturbative quantum gravity that has emerged is encouraging. The loop approach, with its rich variety of versions and formalisms, is still incomplete, and a large number of issues remain open. But there is a large common ground in the variety of points of view. A general understanding on how to formulate background independent quantum field theory exists and yields to a credible hypothesis of solution to the quantum gravity puzzle. In addition, loop quantum gravity is finding an increasing spectrum of applications.

A general discussion during the last morning has been based on a list of questions proposed by the audience. The list of these questions (quite interesting, and requested by many) can be found from my home page http://www.cpt.univ-mrs.fr/˜rovelli. Pictures of the conference can be found in http://perimeterinstitute.ca/activities/scientific/cws/marseille.cfm. Publication of proceedings has been suggested and is being considered.

The weather, uncharacteristically grey during the first days, has cleared up for the free afternoon, allowing the participants to spread along the sea and in the marvelous wilderness of Marseille's "Calanques".

# 20th Pacific coast gravity meeting

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The 20th Pacific Coast Gravity Meeting (PCGM20) was held at the California Institute of Technology, Pasadena, on March 26 and 27, 2004. Faithful to its tradition, this was an informal and relaxed regional meeting where all participants who wished to speak had a chance to engage a welcoming audience for all of twelve intense minutes. As always, the aim was to foster communication and understanding among gravitational physicists with different backgrounds. The conference was organized by the writer of this report with the invaluable help of JoAnn Boyd and Yanbei Chen, and with the wise and benign oversight of Kip Thorne.

This year's meeting was graced by the enthusiastic participation of more than 80 researchers, 45 of which gave talks. The first day began with a session on gravitational-wave astrophysics, with Shane L. Larson, Rick Jenet, Rafael Araya-Gochez, Marc Favata, Sherry Suyu, and Geoffrey Lovelace; the next session, on ground-based interferometers, was animated by Patrick Sutton, Jan Harms, Yi Pan, Akira Villar, Peter Shawhan, and Szabolcs Marka. Vladimir Braginsky opened the afternoon with a charming talk on the "Adolescent Years of Experimental Physics;" he was followed by more theoretical talks, by Alfonso Agnew, Ivan Avramidi, William Pezzaglia, Jack Hohner, Steve Giddings, Belkis Cabrera-Palmer, Henriette Elvang, Keith Copsey, and James Dunham. In the evening, the weary participants found refreshment(s) at an animated party at Kip Thorne's house.

The second day began on (or near) cosmology, with talks by Zoltan Perjes, Dominic Clancy, Jim Isenberg, Lior Burko, and Donald Marolf; it continued on research relevant to LISA, with Teviet Creighton, Naoki Seto, Daniel Bambeck, Seth Timpano, Louis Rubbo, and Jeff Crowder. The afternoon sessions dwelt on numerical relativity, with Harald Pfeiffer, Mark Scheel, Robert Owen, Ilya Mandel, Luisa Buchman, and Frans Pretorius; and the meeting closed with Mihai Bondarescu (delivering Pavlin Savov's talk), Richard Price, David Meier, Craig Hogan, Gary Horowitz, and Martin Kaplan. The titles of all talks can be seen on the PCGM20 website, www.tapir.caltech.edu/pcgm20.

Fifteen students competed for the award for the best student presentation, previously known as the Jocelyn Bell Burnell prize, and now sponsored by the APS Topical Group on Gravitation, which was awarded jointly to Henriette Elvang (University of California, Santa Barbara), and Louis Rubbo (Montana State University, Bozeman).

The next PCGM will be held at the University of Oregon, Eugene, most probably on March 25 and 26, 2005. Watch out for the announcement.