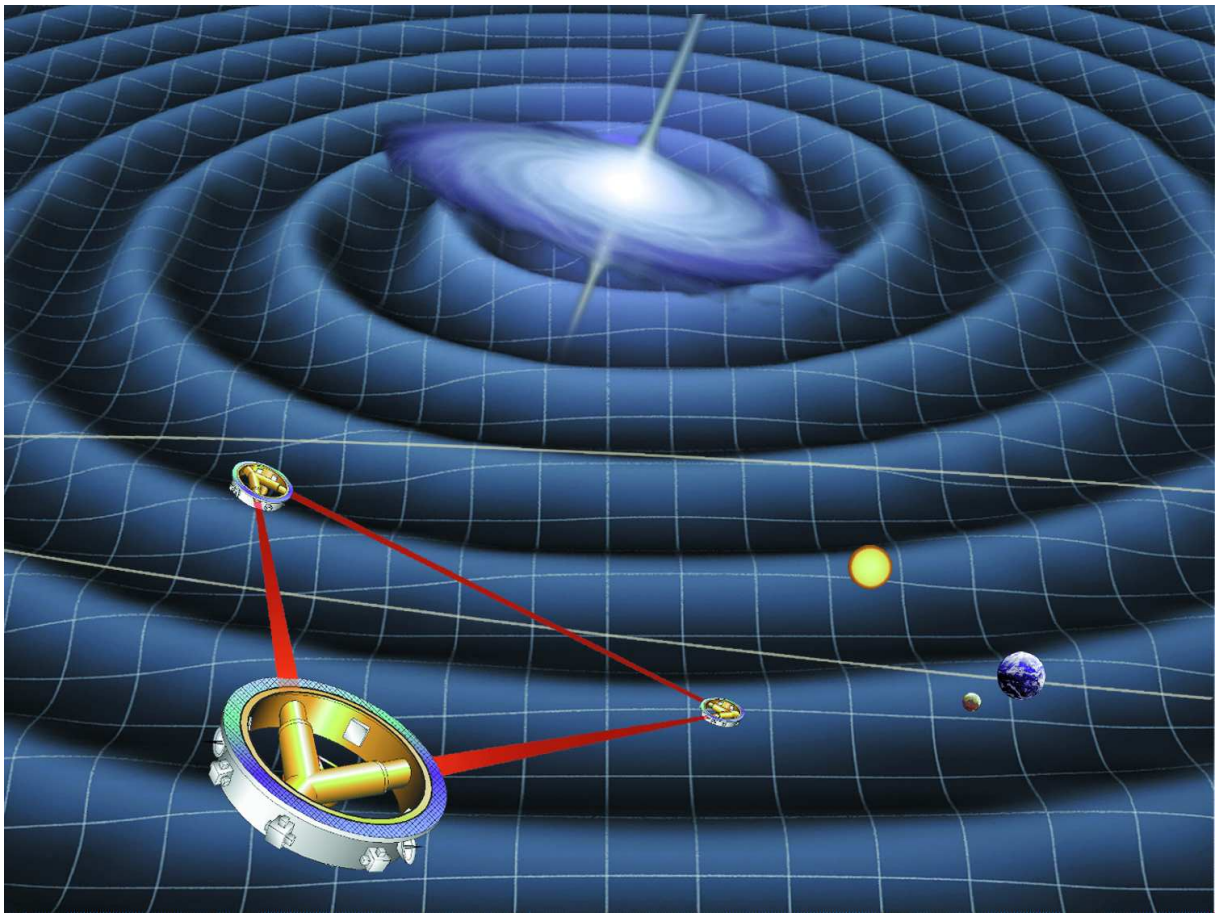
Newsletter of the Gravitational Physics Group of the Institute of Physics

August 2005



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Group web page:

`http://groups.iop.org/GP/`

The artist's image on the cover page was taken from the web site of the Jet Propulsion Laboratory (`http://lisa.jpl.nasa.gov/gallery2.html`).

1 Chairman's welcome

Contributed by David Wands, Chair of GPG

Welcome to the first newsletter from the IoP Gravitational Physics Group!

The Gravitational Physics Group of the Institute of Physics was established five years ago with the aim of providing a common forum for research across a broad range of topics that contribute to our understanding of gravity.

100 years after Einstein revolutionised our notion of space and time, the subject is more vibrant than ever before and central to developments in fundamental physics. New laser interferometers such as GEO and LIGO offer the tantalising prospect of directly detecting gravitational waves as predicted by Einstein's theory of relativity. These experiments have begun the challenging task of sifting through the experimental noise in search of astronomical signals. And many researchers are already working towards the launch of the LISA experiment into space which is expected to really begin the era of high signal-to-noise gravitational wave astronomy, opening up a new window on our Universe.

At the same time gravity is playing an increasingly central role in attempts to create a unified theory of all fundamental interactions. String theorists previously dealt with the embarrassment of unseen extra dimensions by wrapping them up so they were too small to be accessible. But some are now daring to explore at least some of these new dimensions raising the possibility that extra dimensions could be revealed in future experiments, either in high-energy collisions such as at CERN's Large Hadron Collider, or in high precision tests of Newtonian gravity on sub-millimetre scales, or with gravitational wave detectors.

Traditionally the gravitational physics community has been divided into distinct camps of experimentalists or theorists, but the emergence of more and more empirical tests and applications of gravitational theory has begun to break down some of these divides. The Gravitational Physics Group aims to bring these diverse groups together and provide a common voice for the subject.

We have done this principally by organising and supporting meetings on gravitational physics and supporting the attendance of members at major international meetings, such as GR17 last year in Dublin. In the last year we have organised a dark energy meeting at Sheffield (November 2004), and a joint meeting with the mathematical and theoretical physics group on quantum gravity in Durham (July 2005). We also co-organised a meeting at the Royal Astronomical Society in London (December 2004) on gravitational lensing. Our AGM was a half-day meeting at the Institute of Physics in London with talks from Sheila Rowan and Bob Bingham on the search for gravitational waves and experimental tests of gravity.

Our modest budget from the IoP means that by ourselves we can only organise a small number of meetings. But we are also able to offer some support to meetings organised by others, such as the annual BritGrav meeting, especially aimed at enabling IoP members and students to attend.

We welcome suggestions for topics for meetings; even better we welcome volunteers to organise meetings! The success of the group rests not just with the

committee (we will do our best!) but also with the membership. If you think there are aspects of gravitational physics that we should be representing, please get involved. In particular a healthy group needs a regular circulation of the committee membership and we will be looking for new committee members at our AGM early next year. Please contact me or any of our committee members if you'd like to know more about getting involved.

Our budget from the Institute of Physics is determined in large part by how many members we have. So please encourage others to join the IoP today and sign up as members of the Gravitational Physics Group! The membership fee is only £12 for PhD students, and this will be paid automatically by EPSRC for the students they fund.

Details of how to join are given at the end of this newsletter!

There are many benefits to joining, including free delivery of the Institute's monthly magazine *Physics World*, discounted subscription to IoP journals and books and even career advice!

Please help us to make the Gravitational Physics Group an effective forum for representing the whole community and spread the word about the exciting developments in gravity!

2 Forthcoming meetings

2.1 Joint IoP/RAS LISA meeting

Jointly with the Royal Astronomical Society the Gravitational Physics Group is sponsoring a two-day meeting in London on the proposed ESA-NASA space-based gravitational wave detector, LISA, on 12/13 January 2006. The programme for the meeting will include discussions of both LISA and LISA Pathfinder and will comprise a range of mainly invited talks from international figures in the relevant research fields. Over the next few months further details will be available via the Royal Astronomical Society Monthly meetings web page:

`http://www.ras.org.uk/html/ras_meetings.html`

2.2 BritGrav V

The fifth British Gravity Meeting will take place from 20th–23rd September 2005 in St. Catherine's College, Oxford. It will be hosted by the CCLRC Rutherford Appleton Laboratory, with additional support from the Gravitational Physics Subgroup of the IoP and Classical and Quantum Gravity. More details are available on the web site:

`http://www.sstd.rl.ac.uk/britgrav5/`

3 Recent meetings

3.1 New directions in Numerical Relativity

Contributed by Carsten Gundlach, University of Southampton

The conference 'New directions in numerical relativity' took place at the University of Southampton on 18 and 19 August 2005. It had been organised by Carsten Gundlach (Southampton) and Helmut Friedrich (AEI Golm) as a satellite meeting of the Newton Institute programme on Global problems in mathematical relativity.

The meeting was attended by 46 researchers, 18 of which had come from the Newton Institute programme. This included 10 of the 12 speakers. 7 participants including 2 speakers were from Southampton. Almost all participants were housed in a hall of residence on campus, which allowed for useful interactions over meals and in the evening. All talks were invited, in a format of 45 minutes plus 15 minutes for discussion.

There was a good mixture of talks from the continuum mathematical side (Frauendiener, Friedman, Sarbach, Stewart), finite differencing theory (Calabrese, Kreiss, Reula) and talks centered on simulations (Choptuik, Garfinkle, Hawke, Lehner, Pretorius). There were lively discussions.

The conference package including accommodation and meals was covered by sponsorship for all participants, and some participants also received sponsorship for their travel expenses. NI members were sponsored by the NI. The majority of other participants were sponsored by an EU grant held by the organisers of the main NI programme (Chrusciel, Friedrich and Tod). One Russian participant and one British PhD students were sponsored by the LMS.

The IOP has given 300 pounds in sponsorship, and this has been assigned for sponsoring the conference package and travel expenses of John Stewart (invited speaker, Cambridge), and the conference package of Jonathan Thornburg (AEI Golm). Both could not have been sponsored under the terms of the other sponsors.

The NI web page of the meeting is

`http://www.newton.cam.ac.uk/programmes/GMR/gmrw01.html`

and the web page with a record of the talks is

`http://www.maths.soton.ac.uk/ cg/satellite/`

3.2 8th Capra Meeting on Radiation Reaction

Contributed by Leor Barack, University of Southampton

The *Capra* meetings are international annual gatherings of theorists working on the problem of radiation reaction in General Relativity. Previous meetings were held in Southern California (in 1998, at a ranch donated to Caltech by former Caltech alumnus, Hollywood director Frank Capra), Dublin, Caltech, Potsdam (Germany),

Penn State, Kyoto, and Brownsville (Texas). The Capra meetings focus on the study of radiation reaction and self interaction ("self force") in curved spacetime, especially in the context of the general relativistic two-body problem. This problem relates to several important open theoretical issues in Classical Relativity, including the notion of a "point particle" in curved spacetime, the consequences of the failure of the Huygens principle, the regularization of the gravitational self-force, and the quest for a description of the self-force effect consistent with the principle of equivalence. The recent interest in this problem has been strongly driven by the prospects of detecting low frequency gravitational waves with the Laser Interferometer Space Antenna (LISA)—a joined ESA-NASA mission scheduled for launch around 2013. One of the most interesting sources for LISA will be the inspiral of compact objects into supermassive black holes in galactic nuclei. During the last year of inspiral a typical source will send us hundreds of thousands of gravitational-wave cycles. Searching these signals in the data steam of LISA will be extremely challenging from the data analysis point of view, and will require to have at hand accurate theoretical waveform templates. To generate such templates it is necessary to have accurate knowledge of the orbital evolution, which, in turn, requires the inclusion of self-force effects. There has been a remarkable progress on this problem over the last few years, much through the work of the Capra community.

This year's meeting—the eighth in the series—took place July 11-14th in Abingdon, Oxfordshire. Organised jointly by the Southampton Relativity Group (N. Andersson, L. Barack, K. Glampedakis) and the Centre for Fundamental Physics at RAL (R. Bingham), the meeting was hosted at RAL's *Cosener's house*—a conference facility situated at a picturesque Thames side in the grounds of the medieval Abbey of Abingdon. 41 researchers attended the meeting this year, 21 of whom represented foreign institutes (in the US, Canada, Japan, France, Italy, Ireland and Israel). Of the 20 British attendants, 5 were graduate students and 5 were postdocs, representing 5 Universities (Birmingham, Cambridge, Cardiff, Lancaster and Southampton). In keeping up with the Capra tradition, the atmosphere in the meeting has been kept open, relaxed, and informal. The scientific agenda included contributed talks, each allocated an overall 1-hour time slot, of which at least 15 minutes were to be reserved for questions and discussion. The topics covered by the speakers ranged from issues in the fundamental formulation of self forces in curved spacetime, through advances in black hole perturbation theory, to actual computations of the self force on particles in black hole orbits. The last part of the meeting focused on detection aspects and data-analysis strategies for extreme-mass-ratio inspirals.

The meeting opened with a user-friendly "self-force primer" by Steve Detweiler (Gainsville). Eric Poisson (Guelph) followed with a talk on the metric of tidally distorted black holes, and Warren Anderson (Milwaukee) presented results from an analytic computation of the local tail contribution to the gravitational self force. Leor Barack (Southampton) concluded the first day with a talk on his Lorenz-gauge formulation of black hole perturbation theory, with applications to self force calculations. In the second day of the meeting, Dong-Hoon Kim (Gainsville) presented his calculation of the "regularization parameters" necessary for calculating the gravitational self-force on particles in circular orbits around Schwarzschild black holes.

Steve Detweiler then showed how these can be used to deduce some gauge-invariant self-force effects for such orbits. Hiroyuki Nakano (Osaka City Univ.) next explained how to derive the regularization parameters for generic orbits in Schwarzschild, and was followed by Waratu Hikida (Kyoto), who presented first results from calculations of the scalar self-force for eccentric orbits. Sophiane Aoudia (Nice) discussed the calculation of the regularization parameters in the case of a particle plunging radially into a black hole. A fully-numerical approach to the problem was introduced by Carlos Sopuerta (Penn State), who presented first results from time-domain finite-element numerical simulations of extreme-mass-ratio inspirals.

The third day of the meeting was opened by Carlos Lousto (Brownsville) with a talk on recent progress on the problem of reconstructing the metric perturbation in black hole spacetimes. This was followed up by Bernard Whiting (Gainsville), who discussed further ideas on how one might go about reconstructing the metric perturbation in Kerr spacetime, and by Larry Price (Gainsville) who presented a useful Maple toolkit for carrying out calculations in the GHP approach to Kerr perturbations. Eran Rosenthal (Guelph) wrapped up this part of the meeting with a talk on regularization of the second-order self force.

In opening the final, "detection aspects" part of the meeting, Jonathan Gair (Cambridge) presented work done to develop a set of "quick and dirty" approximate waveforms for extreme-mass-ratio inspirals, which had been used to scope out data-analysis issues. Norichika sago (Osaka) reviewed the underlying formalism for an alternative set of approximate waveforms, based on a strong form of adiabaticity assumption and a time-averaging procedure. A numerical code for calculating such adiabatic waveforms was presented by Steve Drasco (Cornell) at the beginning of the last day of the meeting. He argued that such waveforms are likely to be sufficiently accurate to enable detection of extreme-mass-ratio inspirals with LISA, but perhaps not accurate enough to allow full extraction of system parameters. Next, Kostas Glampedakis (Southampton) presented a formalism that could be used to quantify deviations from Kerr geometry, as encoded in the waveforms from extreme-mass-ratio inspirals. Jonathan Gair then discussed the challenges and work done on developing data-analysis techniques for searching over inspirals in the LISA data stream. Gareth Jones (Cardiff) described a search method based on an algorithm for identifying "clusters and ridges" on a time-frequency spectrogram. Alberto Vecchio and Alexander Stroeer (Birmingham) presented a data analysis scheme for detecting interacting white-dwarf binaries, with lessons for detection of extreme-mass-ratio inspirals. Finally, Charles Wang (Aberdeen) discussed the consequences of photons interacting with gravitational waves from compact objects.

An electronic version of all talks given in the meeting is available online:

`http://www.sstd.rl.ac.uk/capra/`

The organizers acknowledge the generous financial support of RAL and the IoP Gravitational Physics Group.

3.3 Future Surveys of Dark Energy

Contributed by Rob Crittenden, University of Portsmouth

The University of Portsmouth hosted a one-day meeting on 'Future Surveys of Dark Energy' on June 21st 2005 with support from the gravitational physics group. The purpose of the meeting was to discuss various future surveys which hope to probe the nature of 'dark energy,' the generic term for the matter (or alternative gravitational physics) which is thought to be responsible for causing the expansion of the Universe to accelerate. The meeting followed immediately after a Sloan Digital Sky Survey (SDSS) collaboration meeting, and brought together the UK community with many participants from around the world, including the US, Japan and Korea.

Over the next decade, the expansion history of the Universe will be explored in many ways, including supernovae surveys, the cosmic microwave background and observations of large scale structure and gravitational lensing at high redshifts. In addition to discussing ongoing experiments, such as the Supernovae Legacy Survey (SNLS) and the SDSS SN survey, the participants debated various proposed experiments, including the Dark Energy Survey (DES), lensing projects like PanSTARRS and DarkCam, the Wide Field Multi-Object Spectrograph (WFMOS) and the Square Kilometer Array (SKA). The meeting was first of its kind to bring together the whole UK dark energy community with an aim to help coordinate the UK efforts in exploring the origin of the mysterious acceleration.

The overheads for all the talks can be found at the website:

`http://sdss2005.info/darkenergy/agenda.htm`

3.4 Theory and Experiment in Quantum Gravity

Contributed by Elizabeth Winstanley, University of Sheffield

Quantum gravity is a wide-ranging subject, with many different theoretical approaches and the exciting possibility of probing quantum gravity phenomenology in the near future. The aim of this meeting was to give an overview of current research in at least some areas of quantum gravity, both theoretical and experimental. The talks were pedagogical in nature and accessible to PhD students, and the meeting informal, with plenty of time for discussion. The meeting was held in the Ogden Centre for Fundamental Physics, University of Durham, from 7-8th of July 2005, and organized by Ruth Gregory (Durham) and Elizabeth Winstanley (Sheffield).

The first day began with three talks on theoretical approaches to quantum gravity. Fay Dowker (Imperial College London) gave an introduction to the concept of causal sets and the new construction of swerves for particle paths on a causal set; John Barrett (Nottingham) reviewed current research in spin foams and the latest developments in $3 + 0$-dimensional quantum gravity; and Bernard Kay (York) introduced the theory of quantum field theory in curved space, and its applications to the Casimir effect and black hole radiation. The second session of the first day was devoted to higher dimensions and branes. Tony Padilla (Oxford) explained the particular features of brane world gravity, and focussed on the idea of braneworld

holography; and Christos Charmousis (Orsay) covered higher derivative (particularly Lovelock) gravity, and its importance for $4 + N$-dimensional spacetimes. The first day ended with a talk by Panagiota Kanti (Durham) on the Hawking radiation of higher-dimensional brane black holes.

The second day began with cosmology: Ian Moss (Newcastle-upon-Tyne) spoke about quantum effects in brane cosmology, and the role of boundary conditions in Horava-Witten theory. Ivonne Zavala (Boulder) brought us up-to-date with developments in brane inflation in string theory. Then the emphasis changed to experimental areas: Joy Christian (Oxford) explored the forthcoming experimental possibilities of probing the Planck scale with cosmogenic neutrinos, and Giles Hammond (Birmingham) introduced the new experiments testing the Casimir force and the inverse square law at short range.

This two-day meeting was attended by over 60 people, including many graduate students. The organizers would like to thank the Mathematical & Theoretical Physics and Gravitational Physics Groups of the Institute of Physics for financial support.

4 LISA and LISA Pathfinder

Contributed by Diana Shaul, Imperial College London

LISA is the keystone gravitational wave (GW) mission of ESA and NASA, planned for launch around 2014. LISA will be the first GW space observatory, sensitive to the low frequency (0.1mHz-0.1Hz) signals expected from both the most powerful GW sources in the Universe, mergers of supermassive black holes in distant galaxies, and the most predictable, galactic binary star systems.

LISA will basically act as a giant Michelson interferometer in space. It will consist of 3 spacecraft, flying in an equilateral triangle formation, of 5 million km side length. At the heart of each spacecraft will be 4 cm gold-platinum cubes (test masses), that will act as the interferometer end mirrors. To reach its target sensitivity, these test masses must be, in essence, free-falling. Realisation of this level of isolation is the most difficult design challenge for LISA. To ensure that this challenge will be met, a technology demonstration mission, LISA Pathfinder (LPF)—previously known as SMART-2—is planned for launch in 2009.

Two instruments will be flown on LPF: the LTP, provided by ESA and the DRS, provided by NASA. Each instrument will basically consist of 2 test masses, separated by about 30cm, and a laser system, which will enable the relative motion of the test masses, and the critical residual acceleration levels, to be measured. At the moment, the Flight Model of LTP is being built by teams across Europe.

The UK has had a strong involvement in LTP development from the start. The University of Birmingham is providing the Phase Measurement System, which will use the signals from quadrant photodiodes, on which the laser light is incident, to determine the separation of the test masses and their position relative to the spacecraft. The team at the University of Glasgow is building the Flight Model Interferometer, having already successfully completed the first demonstration of

interferometry, at the LPF target sensitivity. Imperial College London is building the Charge Management System—essential to minimise disturbances associated with the build up of charge due to cosmic rays and solar particles, on the isolated test masses—and have already provided an Engineering Model (EM) capable of the achieving the necessary discharge levels. The Rutherford Appleton Laboratory, in collaboration with Glasgow, has assembled a prototype optical bench and provided a fully functional EM test mass caging system.

With this work on the technological side ongoing, ESA is turning its attention to the formidable task of data analysis for LISA, and earlier this year issued a call for letters of interest for participating in the data analysis development and planning process. LISA will be an almost omni-directional detector, and the raw data stream from LISA will contain the superposition of both gravitational wave signals and instrumental artefacts. This means that the accuracy with which one signal is extracted can limit the identification of others. Developing methods to untangle LISA's complex signals is not a task that can wait—we must have tried and tested methods in place, prior to launch, to maximise the return on our investment in LISA. Identifying signals in real-time will enable follow up electromagnetic observations of transient signals—with a 'heads up' from LISA, we will be able to turn our telescopes in time to watch supermassive black holes, as they coalesce!

The inter-reliance of the data and indeed, the disciplines, which are key to LISA's success: instrumental design and characterisation, data analysis and source modelling, mean that by its very nature, LISA must be a collaborative effort. Encouraged by PPARC, UK groups have recently organised themselves into a coherent force: LUKC (the LISA UK Collaboration), convened by Professor Mike Cruise of the University of Birmingham. The rationale behind the formation of LUKC is to coordinate the input from UK universities and institutes, working in collaboration, to bring their expertise in instrumentation, theory, data analysis and data handling to the benefit of the project, maintaining, and building on the strong UK role in LISA.

LUKC have sent a comprehensive letter, in response to ESA's call, reflecting their interest in the areas highlighted (and a few others besides!). The themes that have been addressed are:

- Stellar mass binaries (coordinated by A. Vecchio, University of Birmingham)
- Massive black hole binaries (coordinated by B. Sathyaprakash, Cardiff University)
- Extreme mass-ratio inspirals (coordinated by N. Andersson, University of Southampton)
- Stochastic signals analysis (coordinated by J. Romano, Cardiff University)
- Cosmology (coordinated by A. Jaffe, Imperial College London)
- Unmodelled sources (coordinated by G. Woan, University of Glasgow)

- Global data analysis (coordinated by G. Woan, University of Glasgow)
- Multi-band astronomy (coordinated by G. Branduardi-Raymont, MSSL)
- Data quality and characterisation (coordinated by T. Sumner, Imperial College London)
- Instrument and mission simulation (coordinated by A. Freise, University of Birmingham)
- Solar, cosmic ray and environmental physics (coordinated by T. Sumner, Imperial College London)
- Data and processing centre (coordinated by P. Allan, RAL)

At the moment, LUKC includes research groups from 14 institutions.

5 An Industrial Perspective on Gravitational Physics Research

Contributed by Vaughan Stanger, BAE Systems Advanced Technology Centre

The reader may be forgiven for wondering precisely how gravitational physics is relevant to a defence company such as BAE Systems. In fact, we have been in the business of countering gravity for many years, the Harrier VTOL aircraft being perhaps the most obvious example. More recently, BAE Systems funded a research programme called Greenglow, which supported leading British academics researching topics in gravitational, quantum and electromagnetic physics that might one day lead to novel power and propulsion systems. Although Greenglow came to a planned end in 2004 the company maintains a general interest in such topics, not only because of what they might ultimately deliver in terms of fundamental capability, e.g. radically new propulsion systems for aircraft, but also the more prosaic spin-offs that might happen en route. For example, researchers at Glasgow University are investigating the use of so-called 'squeezed light' to improve the sensitivity of their laser interferometry apparatus, which is designed to detect gravitational waves from astronomical sources. Squeezed light was the subject of an ATC review of emerging technology as long ago as 2002. At the time we noted that electro-optic sensors might benefit from the use of squeezed local oscillators. Participation in the Gravitational Physics Group therefore helps BAE Systems maintain a watching brief on this and other research topics of interest to the company.

In my role as GPG Industrial Liaison Office, I hope to foster awareness in UK industry of the leading edge technologies that are being developed to support experimental R&D projects in academia.

6 Cosmic Visions for Fundamental Physics

Contributed by Diana Shaul, Imperial College London

How did our Universe end up the way it is? How did the extreme conditions that existed after the Big Bang conspire to make it how it is? Why did the expansion of the Universe accelerate in that instant after the Big Bang? Why has it started to accelerate again, now? What is dark energy? What is dark matter? It is quite shocking to realise that, even in our 21st century knowledge based society, we do not have any stock answers to such fundamental questions about our own existence—the questions at the very heart of fundamental physics.

In 2004, the European Space Agency (ESA) received a tremendous response from European fundamental physicists to its Call for Themes for Cosmic Vision 2015-2025: the plan for the ESA Science Programme for the decade 2015-2025.

Earth is a noisy environment where gravity restricts the scope of experiments that can be carried out. Free of these constraints, scientists have suggested a wide array of imaginative, sensitive tests to find out more about our Universe. For example, can we detect very small scale deviations from the laws of physics as we understand them? Will these challenge general relativity and quantum theory in the way that Newtonian physics was once challenged? Will we be able to perceive a structure in space itself if we look on small enough scales?

An opportunity to explore the laws of physics in extreme conditions, beyond the reach of an Earth based laboratory is afforded to space based astronomy missions. A new-generation space-based X-ray observatory could allow us to see the hot gas on the very edge of a black hole, to probe gravity and the physics of matter in this environment. LISA-like gravitational-wave observatories in space will give us direct and detailed observations of black holes, and may enable us to see the universal gravitational wave background, which was produced a moment after the Big Bang. Simultaneous X-ray and gravitational wave observations will give us the opportunity to measure the redshift-distance relation so precisely that the time-dependence of the dark energy could be studied.

Whatever data we glean from the missions ESA selects, one thing is certain: our efforts to ensure that we are ready for launch will force us to develop new technologies with wider applicability, such as better gyroscopes and improved ways to observe the Earth.

It is envisioned that this exciting Cosmic Vision program will be divided into 3 slices in time—each slice with an equal allocation of funds, and a call for proposals. The call for proposals for the 1st slice is expected to be during the 1st half of 2006—so start drafting those proposals now—this is an opportunity we cannot afford to miss!

The next ESA council meeting at ministerial level will be in December 2005. In this meeting, the annual budget of the science programme for the next 5 years will be agreed. To enable the Cosmic Visions program to be implemented, an increase of around 2.4% in the level of resources is needed. Without this increase, we will not have a fundamental physics space program during the 2015-2025 timeframe.

However, with the right investment, Europe will have the opportunity to take the lead in this exciting new space-based research field.

Our questions may appear simple, but the easiest sounding questions are often the most fundamental. The answers are out of our reach on Earth yet must be at the heart of our existence. We must take this opportunity to ask our questions in space, knowing that the journey towards their answers will be an education in itself.

7 Treasurer's report

Contributed by Diana Shaul, Imperial College London

The Group receives an annual allocation from the IoP, made up of two parts: a basic allocation and an additional amount that increases as a function of membership levels. Our total allocation for this year was £2,586.

We will be supporting six meetings this year compared to last year's five. We try to encourage student participation and most of the £2,700 that we have set aside for the meetings will go towards student support.

We spent about £550 on this year's AGM, and had the privilege of hearing two great talks, from Professor Bob Bingham of RAL and Dr Sheila Rowan of Glasgow University.

Committee expenses have totalled about £360 this year, to date. We try to keep these expenses down, for example, by discussing issues via email, where we can.

Each year, we also try to leave a healthy balance to carry forward to the next year, to guarantee that we will be able to offer meeting support, and to cope with contingencies.

This year, the amount we have spent/allocated to date comes to £3,603.17 (similar to last year's total expenditure of £3,612.55). Our total income this year (including the balance brought forward from 2004) was £5,642.79. This means we should have around £2000 to carry forward to next year and with your continued support, we can look forward to an exciting schedule for 2006! (Please see overleaf for a tabulated financial statement).

IoP Gravitational Physics Group Financial Statement 2005				
Income				
Balance brought forward from 31/Dec/04	£3,056.79			
Basic allocation	£1,500.00			
Additional allocation (increases with number of Group members)	£1,086.00			
Total	£5,642.79	compared with	£6,669.34	for last year
Expenses				
Meeting support	£2,700.00	compared with	£2,588.38	for last year
AGM	£541.93	compared with	£786.27	for last year
Group expenses & sundries	£361.24	compared with	£237.90	for last year
Total (to date)	£3,603.17	compared with	£3,612.55	for all of last year
This leaves a balance of	£2,039.62	at	15/09/2005	

8 Contact details

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To find out more about the Group

- You can visit out internet site:

  `http://groups.iop.org/GP/`

- Or you can email the Group Secretary Elizabeth Winstanley:

  `E.Winstanley@sheffield.ac.uk`

To contribute to the next newsletter

If you would like to contribute an article to the next newsletter please email Ian Jones at

`D.I.Jones@soton.ac.uk`

9 How to join

For those already members of the IoP

- The easiest way to join the Gravitational Physics Group is to go to:

  `http://members.iop.org/login.asp`

- After logging in (using your membership number), click on 'Your Groups' and then it is straightforward to add/remove groups.

- For IoP members without web access, the simplest way to join a group is to amend your membership renewal form. Alternatively, write to the following address:

  Membership Department,
  The Institute of Physics,
  76 Portland Place,
  London.
  W1B 1NT

- Note that students do not pay for the first group they join!

For those who are not members of the IoP

- If you would like to go join the Institute you should go to:

  `http://members.iop.org/join.html`

  from where it is possible to apply online.

- Application forms are also available by writing to the Institute at the above address.