BritGravII
Second British Gravity Meeting
School of Mathematical Sciences, Queen Mary, University of London
Mon/Tue, June 10/11, 2002

The second of the annual BritGrav meetings on current research in Gravitational Physics in Britain took place at the School of Mathematical Sciences of Queen Mary, University of London on June 10/11, 2002. We tried to maintain the two good practices established at Southampton last year (see Carsten Gundlach’s report at [arXiv:gr-qc/0104062]); namely allowing short talks of equal duration and keeping the participants’ expenses to a minimum. We were also able, with support from the groups below, to provide partial financial support for the younger participants.

Altogether 95 participants took part, including a good number from research institutions outside Britain (namely, France, Sweden, Russia, Spain, Austria, USA, Portugal, Ireland, Germany, South Africa, Canada and Poland). There were a total of 47 talks — of 12 minutes duration each — over these two days. These included 1 talk by an undergraduate finalist, 15 talks by PhD students and 11 talks by postdoctoral researchers. The sessions were roughly grouped into the following categories: Classical General Relativity, Mathematical Studies, Quantum Gravitation, Quantum Theory on Curved Spacetimes, Alternative Models, Relativistic Astrophysics, Numerical Methods, and Other Topics.

Below is the list of the abstracts of all the talks, in alphabetical order, submitted by the authors. The references to the electronic preprints at [arXiv.org](http://arXiv.org) have been added where they exist.

The BritGravII meeting was kindly supported financially by the London Mathematical Society, the Institute of Physics Mathematical and Theoretical Physics Group, the Institute of Physics Gravitational Physics Group, the scientific journal [Classical and Quantum Gravity](http://www.iop.org/journals/cqg) and the School of Mathematical Sciences, Queen Mary, University of London.

The BritGravIII meeting is to be organised by Robin Tucker of the Department of Physics at the University of Lancaster and held in September 2003. All enquiries should be directed to him electronically at R.Tucker@lancaster.ac.uk.

Henk van Elst and Reza Tavakol, Astronomy Unit, Queen Mary, University of London

Submitted abstracts

1. Anderson, Edward
   (eda@maths.qmul.ac.uk, Astronomy Unit, Queen Mary, University of London)

   **The 3-space approach to relativity: results**
   We show how 3 branches of gravitational theory arise from the 3-space approach: general relativity, arbitrary supermetric strong gravity and a conformal theory of gravity [1,2,3]. We show then how inclusion of vector fields in the general relativity branch leads to electromagnetism and Yang-Mills theory [1,4]. The technique used throughout is an exhaustive extension of Dirac’s generalized Hamiltonian formalism [4,5]. We finally comment on work in progress contrasting our matter results in general relativity with Kuchar’s hypersurface formulation (which, in contrast to the 3-space approach, presupposes 4-geometry) [6].

   [1] J. Barbour, B.Z. Foster and N. O’Murchadha, [arXiv:gr-qc/0012089](http://arXiv.org/abs/gr-qc/0012089) (accepted by Class. Quantum Grav.), [2] J. Barbour and N. O’Murchadha, [arXiv:gr-qc/9911071](http://arXiv.org/abs/gr-qc/9911071), [3] E. Anderson, [arXiv:gr-qc/0205118](http://arXiv.org/abs/gr-qc/0205118), [4] E. Anderson and J. Barbour, [arXiv:gr-qc/0201092](http://arXiv.org/abs/gr-qc/0201092) (accepted by Class. Quantum Grav.), [5] P.A.M. Dirac, Lectures in Quantum Mechanics (Yeshiva University, NY 1964), [6] K. Kuchar, J. Math. Phys 17, 777, 792, 801 (1976); J. Math. Phys. 18, 1589 (1977).
2. Arminjon, Mayeul  
(arminjon@hmg.inpg.fr, Laboratoire “Sols, Solides, Structures”, CNRS, Grenoble, France)  

**Asymptotic PN approximation and the point-particle limit in a scalar theory of gravitation**  
To test celestial mechanics in an alternative theory based on just a scalar field, an ”asymptotic” PN scheme has been developed: Applying the usual method of asymptotic expansions for a system of PDE’s, all fields are expanded in powers of the field-strength parameter $\lambda$ - not merely the gravitational field as in the standard PN scheme. This gives separate equations at each order in $\lambda$. By integrating these local equations inside the bodies, one gets equations of motion for the mass centers. The good separation between bodies is exploited by introducing another small parameter $\eta$ and truncating the equations of motion with respect to $\eta$. The point particle limit is defined by assuming that the size of all bodies but one shrinks with a small parameter $\xi$. The equation of motion obtained thus contains a structure-dependent term and does not coincide with the equation of motion for a test particle in the field of the massive body. This follows from using the asymptotic scheme and presumably holds true for GR.  

arXiv.org: [gr-qc/0202029](http://arxiv.org/abs/gr-qc/0202029)  

3. Barbour, Julian  
(julian@platonia.com, Banbury)  

**The 3-space approach to relativity: motivation**  
In a recent paper, ‘Relativity without relativity’, Barbour, Foster and O’Murchadha have presented a new approach to relativity and gauge theory based entirely on three-dimensional concepts. My talk will motivate this 3-space approach and show how it has the potential to clarify difficult conceptual issues in quantum gravity, ease some of the technical difficulties, and perhaps lead to a viable scale-invariant generalization of general relativity.  

arXiv.org: [gr-qc/0012089](http://arxiv.org/abs/gr-qc/0012089), [gr-qc/9911071](http://arxiv.org/abs/gr-qc/9911071)  

4. Bonnor, William  
(100571.2247@compuserve.com, School of Mathematical Sciences, Queen Mary, University of London)  

**Closed timelike curves**  
Closed timelike curves (CTC) occur in general relativity, raising the question of time travel and its associated paradoxes. They are usually dismissed on the grounds that the spacetimes in which they arise are non-physical. However, this is not so in all cases.  

I argue that relativists ought seriously to consider the significance of CTC.  

5. Carr, Bernard  
(B.J.Carr@qmul.ac.uk, Astronomy Unit, Queen Mary, University of London)  

**Tolman–Bondi collapse in scalar-tensor theory as a probe of gravitational memory**  
In cosmological models with a varying gravitational constant, it is not clear whether primordial black holes preserve the value of $G$ at their formation epoch. We investigate this question by using the Tolman–Bondi model to study the evolution of a background scalar field when a black hole forms from the collapse of dust in a flat Friedmann Universe. Providing the back reaction of the scalar field on the metric can be neglected, we find that the value of the scalar field at the event horizon very quickly assumes the background cosmological value. This suggests that there is very little gravitational memory.  

arXiv.org: [astro-ph/0112563](http://arxiv.org/abs/astro-ph/0112563)  

6. Docherty, Peter  
(Thepdocherty@btopenworld.com, Department of Mathematical Sciences, University of Loughborough)
A disintegrating cosmic string
We present a simple sandwich gravitational wave of the Robinson–Trautman family. This is interpreted as representing a shock wave with a spherical wavefront which propagates into a Minkowski background minus a wedge. (i.e. the background contains a cosmic string.) The deficit angle (the tension) of the string decreases through the gravitational wave, which then ceases. This leaves an expanding spherical region of Minkowski space behind it. The decay of the cosmic string over a finite interval of retarded time may be considered to generate the gravitational wave.

arXiv.org: gr-qc/0204085

7. Dolby, Carl
(dolby@ariadne.physics.ox.ac.uk, Theoretical Physics, University of Oxford)
Radar time, simultaneity, and QFT for arbitrary observers in gravitational backgrounds
An approach to fermionic QFT in gravitational and electromagnetic backgrounds will be presented, which allows a consistent particle interpretation at all ‘times’. The concept of radar time (popularised by Bondi in his work on k-calculus) provides a suitable observer dependent foliation of spacetime, hence allowing this interpretation to be applied to an arbitrarily moving observer. A number operator results, which depends only on the observers motion and the background present (not on any choice of coordinates or gauge), and which generalises Gibbons’ definition to non-stationary spacetimes. This operator is non-local on small scales, but is ‘effectively local’ on scales larger than the Compton wavelength of the particle concerned. Applications of this construction to spatially uniform electric fields, accelerating observers, and simple cosmologies will be presented.

arXiv.org: hep-th/0103228, gr-qc/0104077

8. Dowker, Fay
(f.dowker@qmul.ac.uk, Department of Physics, Queen Mary, University of London)
The deep structure of spacetime
A brief review of the causal set approach to quantum gravity.

9. Edgar, Brian
(bredg@mai.liu.se, Mathematics Department, University of Linköping, Sweden)
Applications of dimensionally dependent identities
Dimensionally dependent identities are tensor identities which are valid only in some dimension(s). As well as providing a unifying derivation of familiar, but apparently unrelated identities, they are important tools for a systematic treatment — in different dimensions — of such topics as invariants of the Riemann tensor, and properties of super-energy tensors.

arXiv.org: gr-qc/0105066, gr-qc/0202092

10. Fil’chenkov, Michael
(fil@crosna.net, Institute of Gravitation and Cosmology, Peoples’ Friendship University of Russia, Moscow, Russia)
Quantum birth of a universe with rotation
Of importance is the question of rotation of the early Universe despite the observational angular velocity is now negligible, if exists. Integrating Raychaudhuri’s equation for a homogeneous multicomponent universe with rotation, we obtain a Friedmann-like equation. Quantizing the latter gives Wheeler–DeWitt’s equation. Energy levels of the pre-de-Sitter universe as well as a tunnelling factor for the birth of a rotating universe are calculated. Black-body radiation and de Sitter’s vacuum do not take part in the rotation of the Universe. The tunnelling factor proves to depend on the angular momenta of matter components. The general problem of the origin of rotation
in astronomy is discussed in connection with its possible cosmological nature as well as the existing
formulae for angular momenta of astronomical objects. The quantum primordial rotation may
affect a further classical evolution of the Universe, generating the observable angular momenta of
galaxies.

11. Gaburov, Evghenii
(eg35@leicester.ac.uk, Department of Physics and Astronomy, University of Leicester)

**Anisotropic black holes in Einstein and brane gravity**
We consider exact solutions of Einstein equations defining static black holes parametrized by off-
diagonal metrics which by anholonomic mappings can be equivalently transformed into some
diagonal metrics with coefficients being very similar to those from the Schwarzschild and/or
Reissner–Nördstrom solutions with anisotropic renormalizations of constants. We emphasize that
such classes of solutions, for instance, with ellipsoidal symmetry of horizons, can be constructed
even in general relativity theory if off-diagonal metrics and anholonomic frames are introduced
into considerations. Such solutions do not violate the Israel’s uniqueness theorems on static black
hole configurations because at long radial distances one holds the usual Schwarzschild limit. We
show that anisotropic deformations of the Reissner–Nördstrom metric can be an exact solution on
the brane, re-interpreted as a black hole with an effective electromagnetic like charge anisotropi-
cally induced and polarized by higher dimension gravitational interactions.

arXiv.org: hep-th/0108065

12. Garcia-Islas, Juan Manuel
(jm.garcia-islas@maths.nottingham.ac.uk, School of Mathematical Sciences, University of Not-
ttingham)

**Observables in 2+1 dimensional Euclidian quantum gravity**
A new set of observables is defined in the framework of 2+1 dimensional quantum gravity. This is
studied using the Turaev–Viro model which is the deformed version of the Ponzano–Regge model,
as it uses the powerful methods of quantum groups. The expectation values of our new observables
turn out to be related with relativistic spin network invariants. Moreover, when considering some
particular examples it appears that we can obtain some relationships with a rational conformal field
theory in the form of identities.

13. García-Parrado Gómez-Lobo, Alfonso
(wtbagaoa@lg.ehu.es, Departamento de Física Teórica e Historia de la Ciencia, Universidad del
País Vasco, Bilbao, Spain)

**Causal relationship: a new tool for the causal characterization of Lorentzian manifolds**
We define a new kind of relation between two diffeomorphic Lorentzian manifolds called *causal
relation*, which is any diffeomorphism characterized by mapping every future vector of the first
manifold onto a future vector of the second. We perform a thorough study of the mathematical
properties of causal relations and prove in particular that two given Lorentzian manifolds may
be causally related only in one direction. This leads us to the concept of causally equivalent
Lorentzian manifolds as those mutually causally related. This concept is more general and of a
more basic nature than the conformal relationship, because we prove the remarkable result that a
conformal relation $f$ is characterized by the fact of being a causal relation of the *particular*
kind in which both $f$ and $f^{-1}$ are causal relations. Another important feature of causally equivalent
Lorentzian manifolds is that there is a one-to-one correspondence between their respective future
(and past) objects. This clearly indicates that the causal equivalence is the right definition capturing
the *causal indistinguishability* of Lorentzian manifolds. Further, it is possible to introduce a partial
order in the set of Lorentzian manifolds providing a classification of classes of spacetimes in terms
of their causal properties.
A parallel study for embedded hypersurfaces in Lorentzian manifolds is also carried out, which together with the concept of asymptotically isocausal spacetimes, allows us to attach a causal boundary to some spacetimes. Explicit examples will be presented.

arXiv.org: math-ph/0202005

14. Griffiths, Jerry
(J.B.Griffiths@lboro.ac.uk, Department of Mathematical Sciences, University of Loughborough)

The initial value problem for colliding plane waves: the nonlinear case
A general method is presented for constructing solutions for colliding plane pure gravitational or mixed gravitational and electromagnetic waves with distinct wavefronts which propagate initially into a Minkowski background. This method enables us in principle to construct the solution in the wave interaction region directly in terms of initial data that are specified on two null characteristics. This is achieved by reducing the characteristic initial value problem to some simple linear integral “evolution” equations. The method presented for solving these equations arises from a general monodromy transform approach. This makes use of the fact that the symmetry reduced Einstein or Einstein–Maxwell equations (which are equivalent to the hyperbolic Ernst equations) can be reformulated as linear integral equations. These can be constructed in terms of “dynamical” monodromy data for solutions of an associated linear problem on the spectral plane. It is shown that such an approach can be generalized to solutions with nonanalytical behaviour of fields on null characteristics as is required for colliding waves with distinct wavefronts. Using a number of examples, it is demonstrated how the method presented can be used in practice to solve this nonlinear characteristic initial value problem for colliding plane waves.

15. Grumiller, Daniel
(grumil@hep.itp.tuwien.ac.at, Institute for Theoretical Physics, Vienna University of Technology, Austria)

Virtual black hole phenomenology from 2d dilaton theories
Equipped with the tools of (spherically reduced) dilaton gravity in first order formulation and with the results for the lowest order S-matrix for s-wave gravitational scattering, new properties of the ensuing cross-section are discussed. We find CPT invariance, despite of the non-local nature of our effective theory and discover pseudo-self-similarity in its kinematic sector. After presenting the Carter–Penrose diagram for the corresponding virtual black hole geometry we encounter distributional contributions to its Ricci-scalar and a vanishing Einstein–Hilbert action for that configuration. Finally, a comparison is done between our (Minkowskian) virtual black hole and Hawking’s (Euclidean) virtual black hole bubbles.

arXiv.org: gr-qc/0111097, gr-qc/0105034

16. Hall, Graham
(g.hall@maths.abdn.ac.uk, Department of Mathematical Sciences, University of Aberdeen)

Sectional curvature in general relativity
Let \((M, g)\) be a space-time, let \(p \in M\) and let \(T_pM\) be the tangent space to \(M\) at \(p\). Let \(F\) be a non-null 2-space at \(p\) spanned by \(u, v \in T_pM\). Define, in a standard notation, the sectional curvature of \(F\) by

\[
\sigma_p(F) = \frac{R_{abcd} F^{ab} F^{cd}}{2g_{[a}g_{d]}F^{ab}F^{cd}} \quad (F_{ab} = 2u_{[a}v_{b]}).
\]

This definition depends only on \(F\) and not on the spanning pair \(u\) and \(v\). Now define a real valued function \(\sigma\) on the set of all non-null 2-spaces at all points of \(M\) according to \(\sigma(F) = \sigma_p(F)\) if \(F\) is a non-null 2-space at \(p\).

A detailed study of the function \(\sigma\) can be carried out and reveals that given that \(\sigma_p\) is not a constant function for any \(p\) and that \((M, g)\) is not a conformally flat plane-wave, then the function \(\sigma\) uniquely
determines the metric $g$ from whence it came. In particular, for nowhere flat vacuum space-times, the metric $g$ and the sectional curvature function $\sigma$ are in one-to-one correspondence. Thus the sectional curvature function could be used as an alternative field variable for general relativity, at least in the vacuum situation.

The sectional curvature function can also be used to describe symmetries on $M$, and the Petrov type and energy momentum tensor type at each point of $M$ can be recovered from it.

17. **Henson, Joe**
(j.j.henson@qmul.ac.uk, Department of Physics, Queen Mary, University of London)

**What are the “observables” of quantum gravity?**
A brief discussion of what the different approaches to quantum gravity hope will be the most general sorts of questions they can answer. An explanation of why the problem has a well defined meaning and possible solution in the casual set approach.

18. **Jones, David Ian**
(D.I.Jones@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)

**Numerical implementation of a local radiation reaction**
In this talk I will present the results of a linear Newtonian hydrodynamics code in which the dissipative effect of gravitational wave emission is modelled using a local force. The force itself is that derived via post-Newtonian methods by Blanchet, Damour and Schafer, who eliminated the high time derivatives found in other formulations by introducing a number of Poisson-like equations. It is hoped that by testing this method in the linear regime it can then be easily extended and used with confidence is the non-linear one.

19. **Konkowski, Deborah**
(dak@usna.edu, US Naval Academy, Annapolis, Maryland, USA)

**Definition and classification of singularities in GR: classical and quantum**
After briefly reviewing the definition and classification of classical singularities in general relativistic spacetimes, I will give a definition of a quantum singularity in a spacetime following the pioneering work of G. Horowitz and D. Marolf. Examples of classically singular spacetimes which do and do not have quantum singularities will be given. If time permits I will present results on quasiregular spacetimes [Konkowski, D.A. and Helliwell, T.M. (2001), Gen. Rel. Grav. 33, 1131] and static cylindrically-symmetric spacetimes [work in progress].

20. **Lambert, Paul**
(p.e.lambert@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)

**The constraint algebra of the $2+2$ Ashtekar Hamiltonian**
In this talk I present the results of applying the Dirac–Bergman algorithm to a $2+2$ (double null) Lagrangian based on self-dual 2-forms described in [1]. The use of Ashtekar variables results in polynomial constraints. The first class constraint algebra forms a Lie algebra. I will then give some discussion of the geometrical meaning of the first class constraints. This work provides the first stage of a canonical quantisation procedure for the Einstein equations.

[1] R.A. d’Inverno and J.A. Vickers $2+2$ decomposition of Ashtekar variables Class. Quantum Grav. 12, 753 (1995).

21. **Lazkoz Saez, Ruth**
(wtplasar@lg.ehu.es, Departamento de Física Teórica e Historia de la Ciencia, Universidad del País Vasco, Bilbao, Spain)

**Newtonian limit of boost-rotation symmetric spacetimes**
Boost-rotation spacetimes are believed to describe particles in hyperbolic motion. We study the
Newtonian limit of those spacetimes within the context of Cartan–Friedrich frame theory and provide general results concerning conditions of the existence of the limit of the corresponding time and space-metrics, connection are Riemann tensor. This leads to a clear identification of the Newtonian potential of those boost-rotation spacetimes admitting such limits and in particular of some examples.

22. Louko, Jorma  
(Jorma.Louko@nottingham.ac.uk, School of Mathematical Sciences, University of Nottingham)  
**Thermal effects with a locally bifurcate Killing horizon**  
Thermal effects in quantum field theory on spacetimes with a bifurcate Killing horizon, such as nonextremal black holes or Rindler space, are usually attributed to the existence of two causally disconnected ‘exterior’ regions separated by the horizon. We discuss the situation in spacetimes that have a local analogue of a bifurcate Killing horizon and just one ‘exterior’ region. Thermal effects are then no longer exact but emerge approximately in certain limits, including the limits of late and early times.

**arXiv.org:** [hep-th/0002111], [gr-qc/9906031], [gr-qc/9812056], [hep-th/9808081], [gr-qc/9802068]

23. Martin, Nigel  
(gnnmartin@cix.compulink.co.uk)  
**The unambiguous speed of light**  
This paper observes that the field equations of relativity, in the form \( T = G \), represent a reasonable generalisation of the definition of mass in the light of an assumption that the local speed of light is constant. The hope is that this allows relativity to be explained without compromise to a less mathematical audience, building up logically from ideas that will be familiar to any ordinary well educated person.

24. Martin-Garcia, José  
(J.M.Martin-Garcia@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)  
**Self-similarity in the Vlasov–Einstein system**  
The Vlasov–Einstein system describes the evolution of a statistical ensemble of non-interacting particles coupled to gravity through their average properties. It is the only system where ‘critical phenomena in gravitational collapse’ have not been found. In this talk we address this problem, restricting the study to the simpler case of massless particles. Only one of the two key ingredients for criticality is present: there are self-similar solutions, but they cannot be codimension-1 stable.

**arXiv.org:** [gr-qc/0112009]

25. Matteucci, Paolo  
(p.matteucci@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)  
**Multisymplectic derivation of 2 + 2 Hamiltonian dynamics**  
Multisymplectic geometry, which stems from some pioneering work of De Donder and Weyl in the early 1930s, has recently come back into vogue owing to an innovative approach to quantization proposed by Kanatchikov. Unlike the ADM approach, where dynamics is described in terms of the infinite-dimensional space of fields at a given instant of time, in the multisymplectic formalism dynamics is phrased in the context of the finite-dimensional space of fields at a given event in space-time. The 2+2 formalism developed by d’Inverno, Stachel and Smallwood, which is particularly suited to many situations in General Relativity, lies exactly in between the two approaches, and, whereas its relationship with the former is well-known, there is reason to believe that only a correct understanding of its connection with the latter will provide full insight into its geometry.
26. **Mena, Filipe**  
(fmena@math.uminho.pt, Departamento de Matematica, Universidade do Minho, Braga, Portugal)  

**Initial data and spherical dust collapse**  
We study the role of the initial data in the final state of collapse in Lemaître–Tolman–Bondi models. In connection to the cosmic censorship conjecture we study the existence of null radial geodesics which emanate from the central singularity. We consider stability aspects of the black hole and naked singularity solutions.  

**arXiv.org:** [gr-qc/0002062, gr-qc/010808](http://arxiv.org/abs/gr-qc/0002062, gr-qc/010808)  

27. **Mukohyama, Shinji**  
(mukoyama@schwinger.harvard.edu, Department of Physics, Harvard University, Cambridge (MA), USA)  

**Brane cosmology driven by the rolling tachyon**  
Brane cosmology driven by the tachyon rolling down to its ground state is investigated. We adopt an effective field theoretical description for the tachyon and Randall–Sundrum type brane world scenario. After formulating basic equations, we show that the standard cosmology with a usual scalar field can mimic the low energy behavior of the system near the tachyon ground state. We also investigate qualitative behavior of the system beyond the low energy regime for positive, negative and vanishing 4-dimensional effective cosmological constant \( \Lambda_4 = \kappa_5^4 V(T_0)^2 / 12 - |\Lambda_5| / 2 \), where \( \kappa_5 \) and \( \Lambda_5 \) are 5-dimensional gravitational coupling constant and (negative) cosmological constant, respectively, and \( V(T_0) \) is the (positive) tension of the brane in the tachyon ground state. In particular, for \( \Lambda_4 < 0 \) the tachyon never settles down to its potential minimum and the universe eventually hits a big-crunch singularity.  

**arXiv.org:** [hep-th/0204084](http://arxiv.org/abs/hep-th/0204084)  

28. **Nerozzi, Andrea**  
(andrea.nerozzi@port.ac.uk, Institute of Cosmology and Gravitation, University of Portsmouth)  

**Relativistic irrotational fluids: 3D simulations in Schwarzschild metric**  
Irrotational fluids constitute an interesting topic in astrophysics since the Euler equations reduce in this case to a non-linear scalar field equation. Exact solutions for irrotational fluids accreting onto black-holes have been found in literature in the further approximation of the fluid sound speed being equal to the speed of light, the equation being in this case linear. I present in my talk some 3D numerical simulations for matter accreting onto a Schwarzschild black hole, in the non-linear regime in which no constraint is imposed on the fluid sound speed.  

29. **Nolan, Brien**  
(Brien.Nolan@dcu.ie, Dublin City University, Ireland)  

**Generalized solutions for shell-crossing singularities**  
We derive generalized solutions of Einstein’s equations for spherically symmetric dust-filled space-times which admit shell-crossing singularities. In the marginally bound case, the solutions are weak solutions of a conservation law which is equivalent to the field equation in this case. In the non-marginally bound case, the equations are solved in a generalized sense involving metric functions of bounded variation. The solutions are not unique to the future of the shell-crossing singularity, which is a shock wave in the present treatment; the metric is bounded but not continuous.  

30. **Patel, Mohammed**  
(mpatel@maths.abdn.ac.uk, Department of Mathematical Sciences, University of Aberdeen)  

**Projective symmetry in conformally flat perfect fluid spacetimes**  
Following a study of projective symmetry in FRW models, it is shown that the only conformally flat, perfect fluid spacetimes admitting such symmetry are essentially (locally) of the FRW type.
31. **Pfenning, Michael**  
(mjp11@york.ac.uk, Department of Mathematics, University of York)  

**Quantum inequalities for the electromagnetic and Proca fields in hyperbolic spacetimes**  
It has been known for some time that all of the classical energy conditions in general relativity can be violated by quantum fields. Thus, the energy density can become arbitrarily negative. This can lead to unobserved phenomena such as violations of the second law of thermodynamics, repulsive gravity and the creation of spacetimes with closed timelike curves. Fortunately, quantum field theory also places strict limits on negative energies. Where as the pointwise energy density may become arbitrarily negative, weighted time averages, known as quantum inequalities, are bounded below. I will present recent results which prove that such inequalities exist for spin one fields in globally hyperbolic spacetimes.

32. **Polnarev, Alexander**  
(A.G.Polnarev@qmul.ac.uk, Astronomy Unit, Queen Mary, University of London)  

**Response of a spaceborn gravitational antenna to solar oscillations**  
The possibility of observing very small amplitude low frequency solar oscillations with the proposed laser interferometer space antenna LISA is investigated. For frequencies below 0.0002 Hz the dominant contribution is from the near zone time dependent gravitational quadrupole moments associated with the normal modes of oscillation. For frequencies above 0.0003 Hz the dominant contribution is from gravitational radiation generated by the quadrupole oscillations. The low order solar quadrupole pressure and gravity oscillation modes have not yet been detected above the solar background by helioseismic velocity and intensity measurements. The estimates of the amplitudes needed to give a detectable signal on a LISA type space laser interferometer imply surface velocity amplitudes on the sun of the order of 1-10 mm/sec in the frequency range 0.0001-0.0005 Hz. Such surface velocities are below the current sensitivity limits on helioseismic measurements. If modes exist with frequencies and amplitudes in this range they could be detected with a LISA type laser interferometer.  

[arXiv.org](https://arxiv.org/abs/astro-ph/0103472)

33. **Prix, Reinhard**  
(R.Prix@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)  

**Adiabatic oscillations of non-rotating superfluid neutron stars**  
I present results concerning the linear adiabatic oscillations of non–rotating superfluid neutron stars in Newtonian gravitation. A two–fluid model is used to describe the superfluid neutron star, where one fluid consists of the superfluid neutrons, while the second fluid contains all the co-moving constituents (protons, electrons). I show numerical results which indicate the doubling of all ”acoustic” modes (f- and p- modes), and confirm the absence of g–modes in these superfluid models. The properties of these two–fluid modes change as functions of the coupling by entrainment, and one generally finds avoided mode-crossings. The oscillations of normal-fluid neutron stars are recovered as a special case simply by locking the two fluids together. In this effective one-fluid case we find the usual singlet f- and p- modes, and we also recover the expected g-modes of stratified neutron star models. The presence or absence of g-modes could therefore give a direct observational indication of superfluidity in neutron stars.  

[arXiv.org](https://arxiv.org/abs/astro-ph/0204520)

34. **Re, Virginia**  
(Virginia.Re@port.ac.uk, Institute of Cosmology and Gravitation, University of Portsmouth)  

**How to invariantly characterize non-linear black hole perturbations**  
The aim of this work is to introduce a characterization of a non linearly perturbed black-hole
spacetime in vacuum, using an approach based on the Weyl curvature scalars. The physical background is the Bondi–Sachs metric. This metric describes an axisymmetric non-rotating spacetime and, from a purely physical viewpoint, it can be considered as a “perturbation” of a spherical black-hole described by the Schwarzschild metric. Our purpose is to characterize this non linear perturbations using the Weyl scalars. The Bondi metric is Petrov type I, that is the most general case in which no particular physical characteristic emerges, unless it is possible to fall in one of the so-called standard forms for Petrov type I. From this point of view, the physically interesting case is the one in which the scalars $\Psi_1$ and $\Psi_3$ are equal to zero, because they represent only gauge fields. In order to obtain this, we use the three classes of rotations for the tetrad vectors. Once obtained the rotated non zero scalars $\Psi_0$, $\Psi_2$, $\Psi_4$, the aim is to explicitly calculate them at each point of the spacetime using the Bondi code in order to get an invariant characterization of the curvature throughout the spacetime.

35. Roberts, Mark
(mdrobertsza@yahoo.co.uk, Wonersh Park)

**The rotation and shear of a string**

Whether a string has rotation and shear can be investigated by an analogy with the point particle. Rotation and shear involve first covariant spacetime derivatives of a vector field and, because the metric stress tensor for both the point particle and the string have no such derivatives, the best vector fields can be identified by requiring the conservation of the metric stress. It is found that the best vector field is a non-unit accelerating field in $x$, rather than a unit non-accelerating vector involving the momenta; it is also found that there is an equation obeyed by the spacetime derivative of the Lagrangian. The relationship between membranes and fluids is looked at.

arXiv.org: [hep-th/0204236](http://arxiv.org/abs/hep-th/0204236)

36. Santano-Roco, Miguel
(M.Santano-Roco@lboro.ac.uk, Department of Mathematical Sciences, University of Loughborough)

**The characteristic initial value problem for colliding plane waves: The linear case**

The physical situation of the collision and subsequent interaction of plane gravitational waves in a Minkowski background is a well-posed characteristic initial value problem in which the initial data is specified on the two null characteristics that define the wavefronts. In this talk, there will be analysed how the Abel transform method can be used in practice to solve this problem for the linear case in which the polarization of the two gravitational waves is constant and aligned. There will also be shown how the method works for some known solutions, where the problems arise in other cases, and how the problem can always be solved in terms of an infinite series if two initial spectral functions can be determined.

arXiv.org: [gr-qc/0206075](http://arxiv.org/abs/gr-qc/0206075)

37. Singh, Dinesh
(d.singh@lancaster.ac.uk, Department of Physics, University of Lancaster)

**Scattering of spinning test particles by plane gravitational and electromagnetic waves**

The Mathisson–Papapetrou–Dixon (MPD) equations for the motion of electrically neutral massive spinning particles are analysed, in the pole-dipole approximation, in an Einstein–Maxwell plane-wave background spacetime. By exploiting the high symmetry of such spacetimes these equations are reduced to a system of tractable ordinary differential equations. Classes of exact solutions are given, corresponding to particular initial conditions for the directions of the particle spin relative to the direction of the propagating background fields. For Einstein–Maxwell pulses a scattering cross section is defined that reduces in certain limits to those associated with the scattering of scalar and Dirac particles based on classical and quantum field theoretic techniques. The relative
simplicity of the MPD approach and its use of macroscopic spin distributions suggests that it may have advantages in those astrophysical situations that involve strong classical gravitational and electromagnetic environments.

arXiv.org: gr-qc/0203038

38. Sopuerta, Carlos F
(carlos.sopuerta@port.ac.uk, Institute of Cosmology and Gravitation, University of Portsmouth)

Two-parameters non-linear spacetime perturbations
An underlying fundamental assumption in relativistic perturbation theory is that there exists a parametric family of spacetimes that can be Taylor expanded around a background. The choice of the latter is crucial to obtain a manageable theory, so that it is sometime convenient to construct a perturbative formalism based on two (or more) parameters. The study of perturbations of rotating stars is a good example: in this case it may be convenient to treat the axisymmetric star using a slow rotation approximation (expansion in the angular velocity), so that the background is spherical. We analyse the gauge dependence of non-linear perturbations depending on two parameters, derive explicit higher order gauge transformation rules, and define gauge invariance in this context.

39. Steele, Christopher
(Christopher.Steele@maths.nottingham.ac.uk, School of Mathematical Sciences, University of Nottingham)

Relativistic spin networks
I will discuss Relativistic Spin Networks based on the representation theory of the four dimensional rotation group. I will present recent work on the asymptotics of the Riemannian 4-simplex, extending work of Barrett and Williams [1]. Some numerical results will be explained using stationary phase calculations.

[1] The asymptotics of an amplitude for the 4-simplex John W. Barrett, Ruth M. Williams gr-qc/9809032.

40. Tucker, Robin
(r.tucker@lancaster.ac.uk, Department of Physics, University of Lancaster)

The LASSO project
It is proposed to explore the interaction of weak gravitational fields with slender elastic materials in order to assess the viability of achieving enhanced sensitivities for the detection of gravitational waves with frequencies between $10^{-4}$ and 1 Hz.

The aim is the design of novel gravitational antennae in interplanetary orbit. The implementation of these ideas would be complimentary to existing programmes of gravitational wave research but exploiting a current niche in the frequency spectrum.

The dynamics of slender structures, several km in length, are ideally suited to analysis by the simple theory of Cosserat rods. Such a description offers a clean conceptual separation of the vibrations induced by bending, shear, twist and extension and the coupling between eigen-modes due to tidal accelerations can be reliably estimated in terms of the constitutive properties of the structure. The detection of gravitational waves in the 1 Hz region would provide vital information about stochastic backgrounds in the early Universe and the relevance of super-massive black holes to the processes that lead to processes in the centre of galaxies.

arXiv.org: gr-qc/0112004

41. Valiente Kroon, Juan Antonio
(jav@aei-potsdam.mpg.de, Albert–Einstein–Institut, Golm, Germany)
Early radiative properties of the developments of time symmetric, conformally flat initial data

Using a representation of spatial infinity based in the properties of conformal geodesics, the first terms of an expansion for the Bondi mass for the development of time symmetric, conformally flat initial data are calculated. As it is to be expected, the Bondi mass agrees with the ADM at the sets where null infinity “touches” spatial infinity. The second term in the expansion is proportional to the sum of the squared norms of the Newman–Penrose constants of the spacetime. In base of this result it is argued that these constants provide a measure of the incoming radiation contained in the spacetime. This is illustrated by means of the Misner and Brill–Lindquist data sets.

42. Vera, Raúl
(r.vera@qmul.ac.uk, School of Mathematical Sciences, Queen Mary, University of London)

Generalisation of the Einstein–Straus/Oppenheimer–Snyder models to anisotropic settings

We study the possibility of generalising the Einstein–Straus model to anisotropic settings, by considering the matching of locally cylindrically symmetric static regions to the set of $G_4$ on $S^3$ locally rotationally symmetric (LRS) spacetimes. We show that such matchings preserving the symmetry are only possible for a restricted subset of the LRS models in which there is no evolution in one spacelike direction. These results are applied to spatially homogeneous (Bianchi) exteriors where the static part represents a finite bounded interior region without holes. We find that it is impossible to embed finite static strings or other locally cylindrically symmetric static objects (such as bottle or coin-shaped objects) in reasonable Bianchi cosmological models, irrespective of the matter content. Furthermore, we find that if the exterior spacetime is assumed to have a perfect fluid source satisfying the dominant energy condition, then only a very particular family of LRS stiff fluid solutions are compatible with this model.

Finally, given the interior/exterior duality in the matching procedure, our results have the interesting consequence that the Oppenheimer–Snyder model of collapse cannot be generalised to such anisotropic cases.

arXiv.org: gr-qc/0205011

43. Villalba, Victor
(villalba@th.physik.uni-frankfurt.de, Institut für Theoretische Physik, Johann–Wolfgang–Goethe Universität, Frankfurt am Main, Germany)

Creation of scalar and Dirac particles in the presence of electromagnetic fields in cosmological backgrounds

We compute the density of scalar and Dirac particles created by a cosmological background in the presence of homogeneous electromagnetic fields. In order to compute the rate of particles created we apply a quasi-classical approach. The idea behind the method is the following: First, we solve the relativistic Hamilton–Jacobi equation and, looking at its solutions, we identify positive and negative frequency modes. Second, after separating variables, we solve the Klein–Gordon and Dirac equations and, after comparing with the results obtained for the quasi-classical limit, we identify the positive and negative frequency states and compute the Bogoliubov coefficients. We discuss the influence of electromagnetic fields on the particle creation process in some homogeneous cosmological models.

arXiv.org: gr-qc/0112006

44. Waters, Thomas
(thomas.waters2@mail.dcu.ie, Dublin City University, Ireland)

Stability of Cauchy horizon in Vaidya space-time

We examine scalar radiation impinging on the Cauchy horizon in the Vaidya space-time, and dis-
cover that an observer crossing the horizon measures a finite flux. We also examine the stability of the horizon with respect to linear gravitational perturbations.

45. Watts, Anna
(alw1@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)

**Stability of differentially rotating neutron stars**
Previous studies have shown the oscillations of neutron stars to be a promising source of gravitational waves. The majority of these studies have considered uniformly rotating stars. Neutron stars are however likely to be born rotating differentially. Differential rotation complicates the stellar model as it introduces singularities into the dynamical equations that give rise to corotation points and a continuous spectrum. We present results from a simple model that highlights the key features of the oscillations of a differentially rotating star, including possible new instabilities.

46. Weeks, Richard
(rhw101@york.ac.uk, Department of Mathematics, University of York)

**The physical graviton two-point function in de Sitter spacetime**
The graviton two-point functions in de Sitter spacetime have been calculated in various gauges. Most of them grow as the distance between the two points becomes large. (The growth is usually logarithmic.) Although it has been shown that such growth does not translate into gauge-invariant correlation functions which increase with distance, it will still be interesting to find a graviton two-point function without this behaviour. In this work we calculate the physical graviton two-point function in the coordinate system with $S^3$ spatial sections which covers the whole spacetime. This two-point function appears not to grow as a function of the two-point distance.

47. Williams, Rhiannon
(R.L.Williams@maths.soton.ac.uk, Faculty of Mathematical Studies, University of Southampton)

**A characteristic approach to perturbed Kerr black holes**
In preliminary work, we have developed a numerical code for evolving the Regge–Wheeler equation governing black hole perturbations in Schwarzschild spacetime. Boundary problems are avoided in an evolution over the entire exterior spacetime by matching ingoing and outgoing compactified null hypersurfaces. Following this, we have used the characteristic approach to evolve the 3D wave equation in axisymmetric flat space. This work is now extended to perturbations in Kerr spacetime by evolving the Teukolsky equation on compactified null hypersurfaces.