BritGrav12, Southampton, 3/4 April 2012

Participants and talks, final version

Participants giving talks

1. **Simon Gentle, Durham**: A soliton menagerie in AdS

   I will discuss charged scalar solitons in asymptotically global AdS4 spacetimes. Regular and horizon-free, these solutions have a rich phase space and exhibit critical behaviour as a function of Lagrangian parameters. I will demonstrate how such solitons can generically be blown up to coincide with the zero-temperature limit of charged hairy black branes.

2. **Elizabeth Winstanley, Sheffield**: Non-abelian dyons in anti-de Sitter space

   In asymptotically flat space, su(2) Einstein-Yang-Mills black holes and solitons are restricted to have a non-trivial magnetic gauge field only. This is not the case in asymptotically anti-de Sitter space, where dyonic black holes and solitons are possible, having non-trivial electric and magnetic parts of the gauge field. We revisit the su(2) dyons originally found by Bjoraker and Hosotani, as well as considering black hole and soliton solutions of the Einstein-Yang-Mills equations with su(3) gauge group. We focus on the rich structure of the phase space of solutions.

3. **John Miller, Oxford**: Primordial black holes and dark matter?

   Several recent papers have discussed the possibility that the dark matter of the universe might be in the form of microscopic black holes formed at very early times. This talk presents a plausible mechanism for producing these.

4. **Mark Roberts**: Galactic rotation and string theory

   The unique spherically symmetric metric which has vanishing weyl tensor, is asymptotically desitter, and can model constant galactic rotation curves is presented. Two types of field equations are shown to have this metric as an exact solution. The first is palatini varied scalar-tensor theory. The second is the low energy limit of string theory modified by inclusion of a contrived potential.

5. **Michael Fil'chenkov, People's Friendship University (Moscow)**: A space-time foam contribution to the universe's initial perturbations

   Fluctuations at the early Universes de Sitter stage give rise to initial perturbations being observed via CMB temperature anisotropy. The latter was shown to depend on the potential barrier in the tunneling approach for the Universes birth from nothing Loop quantum cosmology (LQC) corrections to the pre-de-Sitter potential energy have proved to be of importance for the initial density perturbations. Thus, the space-time foam described by LQC should be taken into account, while estimating the initial perturbations in the early Universe.

6. **Clemens Hanel, Vienna**: Generalized hyperbolicity in the context of nonlinear distributional geometry

   We show generalized hyperbolicity, i.e. the well-posedness of the Cauchy problem, for normally hyperbolic PDEs in case of a Lorentzian metric of low regularity. We therefore employ the framework of generalized functions in the sense of Colombeau to model low regularity spacetimes. The main technical tools used herein are higher order energy estimates. This existence and uniqueness result is in particular intended as starting point for tackling quasilinear equations via linearization and an iterative scheme. Finally, we give an outlook on the study of Einsteins equations within this framework.

7. **Susan Nelmes, Durham**: Phase transition and anisotropic deformations of neutron star matter

   The Skyrme model is known to be a low energy, effective field theory for QCD and when coupled to a gravitational field provides an ideal semi-classical model to describe neutron stars. In this talk we explore how a Skyrme crystal solution can be used to construct minimal energy neutron star configurations, in particular by allowing the crystal to be strained anisotropically.

8. **Barry Wardell, University College Dublin**: Self-consistent orbital evolution of a particle around a Schwarzschild black hole

   The motion of a charged particle is influenced by the self-force arising from the particle's interaction with its own field. In a curved spacetime, this self-force depends on the entire past history of the particle and is difficult to evaluate. As a result, all existing self-force evaluations in curved spacetime are for particles moving along a fixed trajectory. In this talk I will describe how this longstanding limitation has been overcome and present fully self-consistent orbits and waveforms of a scalar charged particle around a Schwarzschild black hole.

9. **Anna Heffernan, University College Dublin**: Applications of a high order coordinate expansion of the singular field

The self field of a charged particle has a component that diverges at the particle. We use both coordinate and covariant approaches to compute an expansion of this singular field for generic geodesic orbits in Schwarzschild spacetime for scalar, electromagnetic and graviational cases. We find the agreement of both approaches and give, as an application, the calculation of previously unknown regularisation parameters. In this so-called "mode-sum regularization" approach, each mode of the field is finite, while their sum diverges. The sum may be rendered finite and convergent by the subtraction of "regularization parameters". Higher order parameters lead to faster convergence in the mode-sum.

10. **Christian Krüger, Southampton**: Thermal g-modes in young neutron stars

    Non-barotropic neutron stars allow for g-modes, whose driving force may be due to a composition or a temperature gradient. For this study—the aim of which is to include more physics in the neutron star model than in previous studies—we take thermal pressure into account on top of a cold, realistic and modern equation of state including composition and study its effect on the various oscillation modes in the framework of general relativistic perturbation theory. We also investigate how the effect of temperature gradually decreases as the neutron star cools over time.

11. **Alex Nielsen, Albert Einstein Institute (Potsdam)**: Compact binary coalescence parameter estimations

    We examine the parameter accuracy that can be achieved by advanced ground-based detectors for binary inspiralling black holes and neutron stars. We use the 2.5 PN spinning waveforms of Arun et al.. Our main result is that the errors are noticeably different from existing 2PN studies for aligned spins. We also examine several regions of parameter space relevant to expected sources and the impact of simple priors. While the masses can be determined more accurately, the individual spins are measured less accurately compared to previous work at lower PN order. A combination of the spins is measurable to higher accuracy and we examine what this can tell us about spinning systems.

12. **Michael Pürrer, Cardiff**: An efficient iterative method to reduce eccentricity in numerical-relativity simulations of compact binary inspiral

    We present a new iteration method to reduce eccentricity in black-hole-binary simulations. Given reasonably low eccentricity starting momenta we evolve puncture initial data numerically for 4 orbits and construct improved initial parameters by comparing the inspiral with post-Newtonian calculations. Our method is the first to be applied directly to the gravitational-wave (GW) signal, rather than the orbital motion and is thus less prone to gauge effects. We can reach eccentricities below 0.001 in one or two iteration steps. We find that this is well below the requirements for GW astronomy in the advanced detector era. Our method can be readily adapted to any compact-binary simulation with GW emission, including black-hole-binary simulations that use alternative approaches, and neutron-star-binary simulations. We also comment on the difference between the eccentricities calculated from the orbital motion and the GW signal.

13. **Steven Kerr, Nottingham**: Fermionic spinfoam models and TQFTs

    One can attempt to define the functional integral for quantum gravity through a discretisation procedure. The result is often referred to as a spinfoam model. These models often suffer from a dependence on the particular discretisation procedure one chooses. Also, matter, and in particular fermions, are absent in such models. We take the point of view that the matter is crucial; that one should not try to quantise just the gravitational field, but also the matter fields at the same time. In a theory of fermions minimally coupled to a gauge field, an appropriate action for the gauge field is induced after integrating out the fermions. Hence we take the fermions to be more fundamental, and focus on minimally coupled fermionic theories. We also take independence of the model on the discretisation procedure to be a vital guiding principle. Theories with this property are sometimes called Topological Quantum Field Theories (TQFTs). We have constructed a one dimensional, minimally coupled fermionic TQFT, whose details will be presented. Naturally one would like to do something similar in higher dimensions, and this is the subject of current investigations.

14. **Matthew Hewitt, Sheffield**: Vacuum polarisation on the brane for a higher dimensional black hole spacetime

    For an ADD braneworld we study the Hartle-Hawking vacuum for a massless, conformally coupled scalar field external to the horizon of a Schwarzschild-Tangherlini black hole. Taking our universe to be a 4D brane within this system we explicitly calculate the renormalized value of the autocorrelation function of the field, $\langle \phi^2 \rangle_{\rm ren}$, on the brane inside a bulk constructed of four (Schwarzschild spacetime) to eleven dimensions and discuss the associated numerical complications. It has been shown in four dimensions that the analytic component of $\langle \phi^2 \rangle_{\rm ren}$ is a good approximation for the total value and we demonstrate whether this holds in the higher dimensional cases.

15. **Lucy Keer, Southampton**: Neutron star oscillations from starquakes

    Glitches - sudden increases in spin rate - are observed in many neutron stars. One mechanism that has been proposed to account for these is the starquake model, in which glitches are triggered by a loss of strain in the solid crust of the star. Starquakes can be expected to excite some of the oscillation modes of the neutron star, which means that they are of interest as a source of gravitational waves. We describe a model that we are developing to calculate the change in the properties of the star during a starquake, in order to work out how the star oscillates after the glitch.

16. **Michael Hogg, Southampton**: Superfluid instabilities of r-modes in differentially rotating neutron stars

    Superfluid hydrodynamics affects the spin-evolution of mature neutron stars, and may be key to explaining pulsar glitches. However, most models for this phenomenon exclude the global instability required triggers this event. In this paper we discuss a mechanism that may fill this gap. We establish that small scale inertial r-modes may become unstable in a superfluid neutron star that exhibits a rotational lag, expected to build up due to vortex pinning as the star spins down. Somewhat counter-intuitively, this instability, which should be generic in superfluid systems with strong coupling, arises due to the dissipative vortex-mediated mutual friction. We discuss the nature of this superfluid instability for a simple incompressible model, allowing for entrainment coupling between the two fluid components. We also analyse the damping effect of shear viscosity, which should be efficient at small scales, arguing that it will not be sufficient to completely suppress the instability in astrophysical systems.

17. **Stephanie Erickson, Southampton**: A conservation law formulation of nonlinear elasticity in relativity for NS crust shattering

    Tidal shattering of neutron star crusts is expected to play a role in the dynamics of binary neutron star mergers, giving rise phenomena such as energetic gamma-ray bursts. For this reason, we have developed a general relativistic conservation-law formalism for nonlinear elasticity; this 4 allows us to use high-resolution shock-capturing methods to resolve strong shocks. We hope to use this formalism to simulate the evolution of discontinuities in the crust of a neutron star caused by shattering and refreezing of the crust, thus illuminating the role this process may play in the evolution of a binary neutron star system.

18. **Adam Pound, Southampton**: The equation of motion of a small compact body

    In order to extract physical parameters from the waveform of an extreme-mass-ratio binary, one requires a highly accurate description of the motion of the smaller body in the binary. I show how to derive the equation of motion of a small, compact body moving in an arbitrary vacuum spacetime. My method is based on matched asymptotic expansions, in which I calculate a general solution to Einstein's equation in a small region surrounding the body. Taking the small body to be approximately spherical and non-rotating (e.g., a perturbed Schwarzschild black hole), I find the equation of motion through second order in the body's mass. In this case, the motion is found to be geodesic in a certain locally defined regular geometry satisfying Einstein's equation at second order.

19. **Wynn Ho, Southampton**: Revealing the physics of r-modes in low-mass X-ray binaries

    We consider the astrophysical constraints on the gravitational-wave-driven r-mode instability in neutron stars in low-mass x-ray binaries. Simple theoretical models indicate that many of these systems reside inside the r-mode instability region. However, this is in clear disagreement with expectations, especially for the systems containing the most rapidly rotating neutron stars. The inconsistency highlights the need to reevaluate our understanding of the many areas of physics relevant to the r-mode instability.

20. **Carl Kent, Sheffield**: Scalar field Hadamard renormalisation in pure AdS_n with a general coupling

    Expectation values of operators that are quadratic in quantised fields (and/or their derivatives) are formally divergent when evaluated at the same space-time point. This poses a fundamental problem for the interpretation of quantum field theories (QFTs), as the classical analogues of such objects represent physical observables. The simplest class of such objects is the vacuum expectation value of quadratic field fluctuations, more commonly referred to as the renormalised 'vacuum polarisation' of the field. Traditionally, renormalisation methods are employed in QFTs to remove such divergent behaviour and to restore physical meaning to the affected objects. Hadamard renormalisation is a particularly elegant technique as it results from a mathematically rigorous theorem.* * * *We have recently studied the propagation of neutral scalar fields generally coupled to pure AdS_n. In this talk I will cover the Hadamard renormalisation of the vacuum polarisation of this theory. I will also highlight the simplifying effects of the symmetries of AdS_n on the calculation along the way.q

21. **Sam Dolan, Southampton**: Gravitational self-force calculations with time-domain schemes

    A community effort is underway to model the motion and gravitational-wave signature of the Extreme Mass-Ratio Inspiral (a compact mass in a strong-field orbit about a supermassive black hole). In the self-force approach, the compact mass generates a metric perturbation which leads to a back-reaction on the motion, which may be interpreted as the effect of a gravitational self-force (GSF) deflecting the motion away from a geodesic of the background spacetime. Accurate time-domain (rather than frequency-domain) schemes are needed for "self-consistent evolutions", whereby the motion is corrected by the GSF at each time step. But practical problems are encountered in time-domain formulations. In particular, I will demonstrate that the linearized Einstein equations in Lorenz gauge (formulated as a constraint-damped Z4 system) are susceptible to gauge modes which show linear-in-time growth. I will propose a particular "generalized" Lorenz gauge which offers a way forward, and I will describe some recent progress.

22. **Eoin Condron, Dublin City University**: Cosmic censorship and the collapse of a scalar field in cylindrical symmetry

    We model the collapse of the scalar field in self-similar cylindrical symmetry, with an initial regular axis. Previous work determined full solutions to the field equations up to the past null cone of the scaling origin, which is a regular singular point of the system. We now present partial solutions to the system in the region beyond the past null cone of the origin and discuss the issue of cosmic censorship relative to this model of collapse. Solutions are shown to be analytic in a neighbourhood of this point and are approximated in this neighbourhood using truncated series. In some cases, these approximations lead to global solutions being obtained.

23. **David Bruschi, Nottingham**: Entanglement, cavities, metrology and more

    We propose a scheme to analyze how relativistic motion of cavities affects entanglement between modes of quantum bosonic or fermionic fields contained within. We consider scenarios with two cavities, one of which undergoes some "general" trajectory; in this case we analyze the effects of motion on the entanglement initially present between modes in the two boxes and find that in general entanglement is degraded. We also consider scenarios where one cavity follows some general trajectory and in this case we analyze the entanglement between different modes of the field contained inside: we find that entanglement is created. Surprisingly, we also find that, given special trajectories, (arbitrarily) high entanglement can be generated. Entanglement degradation between modes in two different $\sim 10m$ cavities can become observable for massless traverse photons of optical wavelength at accelerations of $\sim 1g$. Our results indicate that gravity might affect quantum information tasks.

24. **Lee Hodgkinson, Nottingham**: Static, stationary and inertial Unruh-DeWitt detectors on the BTZ black hole

    We examine an Unruh-DeWitt particle detector coupled to a scalar field in three-dimensional curved spacetime. We first obtain a regulator-free expression for the transition probability in an arbitrary Hadamard state, working within first-order perturbation theory and assuming smooth switching, and we show that a well-defined instantaneous transition rate is recovered in the sharp switching limit. We then analyse the response for a massless minimally coupled field in the Hartle-Hawking vacua on the Bañados-Teitelboim-Zanelli black hole, under both transparent and reflective boundary conditions. A selection of stationary and freely-falling detector trajectories are examined, including the co-rotating trajectories, for which the response is shown to be thermal. Analytic results in a number of asymptotic regimes, including those of large and small mass, are complemented by numerical results in the transition regimes. The boundary condition at infinity is seen to have a significant effect on the response.

25. **Sarah Chadburn, Durham**: Cosmic Superstrings in Warped Spacetime

    Brane inflation, an inflationary model based in string theory, may result in the production of cosmic superstrings. It is thought that these strings may persist into present times, and be detectable via their gravitational wave signal. We consider the effects of the warped extra dimensions present in brane inflationary models on the dynamics of cosmic strings. Notably, we conclude that we do not necessarily expect them to be localized at the bottom of a warped throat, as is commonly assumed, but to have significant motion in the internal dimensions.

26. **Christian Lübbe, Leicester**: Radiation fluid space-times and non-linear stability

    I will talk about recent work with J.A. Valiente-Kroon (QMUL). We consider space-times whose matter model is a radiation fluid (trace-free perfect fluid). We use the conformal Einstein field equations to analyse the stability of future conformal infinity.

27. **Ernesto Nungesser, Albert Einstein Institute (Potsdam)**: Future asymptotics in some homogeneous models

    I will present some results concerning the future non-linear stability of the Einstein-Vlasov system with Bianchi A symmetries and future directions.

28. **Laura Rhian Pickard, UCL**: Gravitational waves from eccentric binary systems.

    I will present calculations of the expected gravitational wave signals for numerous known eccentric binary systems and discuss the general effect of orbital parameters on gravitational wave spectra. I use these expected signals to construct a luminosity function for gravitational waves from eccentric binaries of different classes in the Galaxy, and compare this to the X-ray luminosity function of the Galaxy.

29. **Victor Ambrus, Sheffield**: Rotating fermions

    We consider thermal states of Dirac particles as seen by an observer rotating with a constant angular velocity about a fixed axis. Our analytic results show that the energy density in thermal states diverges as an inverse power of the distance from the speed of light surface, i.e. the surface at which co-rotating particles move with the speed of light. Enclosing the system in a cylindrical box inside or on the speed of light surface cures this divergence, but brings about the Casimir divergece. An asymptotic analysis of our implementation of the MIT bag model shows that the renormalised vacuum expectation value of the energy density diverges as an inverse power of the distance from the bounding surface.

Participants not giving talks

30. **Prakash Sarnobat, PS3 Consultancy**
31. **Hugo Ferreira, Nottingham**
32. **Leor Barack, Southampton**
33. **Carsten Gundlach, Southampton**
34. **Ian Hawke, Southampton**
35. **Ian Jones, Southampton**
36. **Tim Lemon, Southampton**
37. **John Muddle, Southampton**
38. **Cesar Merlín González, Southampton**
39. **Niels Warburton, Southampton**
40. **Stuart Wells, Southampton**
41. **José Ricardo Oliveira, Nottingham**
42. **Pau Figueras, Cambridge**
43. **James Vickers, Southampton**
44. **Nils Andersson, Southampton**
45. **Brien Nolan, Dublin City University**
46. **Wahiba Toubal, Sheffield**
47. **Sara Tavares, Nottingham**
48. **Chris Kavanagh, University College Dublin**
49. **Patrick Nolan, University College Dublin**
50. **Nigel Martin**
51. **Adrian Ottewill, University College Dublin**