Fifth Australasian Conference on General Relativity and Gravitation

ICRANet International Year of Astronomy Program

The Sun, the Stars, the Universe and General Relativity

University of Canterbury
Christchurch, New Zealand

15–18 December, 2009

Conference Programme

Time	Wednesday 16 Dec	Thursday 17 Dec	Friday 18 Dec
8:30am	Registration open	-	-
8:50 - 9:00	Opening remarks	-	-
9:00 - 9:40	Ju	Scott	Inta
9:40 - 10:20	Brewin	Manchester	Wiltshire
10:20 - 10:50	coffee break	coffee break	coffee break
10:50 - 11:10	Stefszky	Threlfall	Schaefer
11:10 - 11:30	Pandey	Barry	Mattsson
11:30 - 11:50	Scholtz	Watanabe	Smale
11:50 - 12:10	Abreu	Howard	Heisenberg
12:10 - 12:30	Ong	Whale	Sigismondi
12:30 - 2:00	lunch break	photo; lunch break	lunch break
2:00 - 2:40	Visser	Frauendiener	Titarchuk
2:40 - 3:00	Cianfrani	Lewis	Kerr
3:00 - 3:20	Neupane	Svarc	Geralico
3:20 - 3:40	Farajollahi	Kofron	Fackerell
3:40 - 4:10	coffee break	coffee break	coffee break
4:10 - 4:40	Norton	Ahluwalia	Anderson
4:40 - 5:10	Kovar	Dariescu	Tiglio
5:10 - 5:30	Petrasek	Schritt	Close; prize award
5:30 - 5:50		Beckwith	
5:30pm	ASGRG BG meeting		
6:15pm	Dinner, Physics 701	Banquet, from 7pm	
7:30pm	**Public lecture C3**	Ilam Homestead	

ABSTRACTS

Wednesday 16 December

9:00 - 9:40 *Plenary talk*

Towards the Southern Hemisphere Gravitational Wave Detector: Technology, the Science Case for AIGO and Recent Progress

Li Ju *(University of Western Australia)*

Collaborators: ACIGA

A southern hemisphere gravitational wave detector of sensitivity comparable to Advanced LIGO and VIRGO greatly improves the worldwide gravitational wave detector array. It creates a dramatic improvement in angular resolution, improves the statistical confidence of candidate events and enables improved discrimination against noise. This enables better distance estimates for inspiral events, allowing unambiguous optical identification of host galaxies for about 25% of neutron star binary inspiral events. AIGO is proposed to be similar to Advanced LIGO in optical configuration. The isolation and suspension systems will be down- selected from the stiff Advanced LIGO design and the soft systems developed at Gingin. The project is planned as an international collaboration. This talk will summarise the science benefits of AIGO and report the current status of the AIGO proposal, proposed international collaborations partners and management plan.

9:40 - 10:20 *Plenary talk*

Non-standard Computational Methods in Numerical Relativity

Leo Brewin *(Monash University, Australia)*

Despite the success of finite difference methods in numerical relativity it should be noted that other techniques do exist and should be explored. These range from the familiar finite element and spectral methods to the more exotic methods such as discrete differential forms and lattice methods. In this talk I will provide an overview of these non-standard approaches to numerical relativity. I will focus on the computational issues and provide a brief survey of past successes (and limitations) of these methods.

10:50 - 11:10

Optical Squeezing for Next Generation Interferometric Gravitational Wave Detectors

Michael S Stefszky *(Australian National University)*

Collaborators: Sheon Chua, Conor Mow-Lowry, Benjamin C Buchler, Kirk McKenzie, Sheila Dwyer, Ping Koy Lam and David E. McClelland

The injection of squeezed states of light will improve the shot-noise limited sensitivity of operational gravitational-wave interferometers. This will potentially allow a detector to operate at design sensitivity with lower laser power or improve the noise performance of a detector operating at full power. The Centre for Gravitational Physics at the ANU has designed and fabricated the optical parametric oscillator (OPO), the crucial component of a squeezed light source, for likely use in a test experiment on the 4 km LIGO H1 interferometer, after the S6 run and before the Advanced LIGO build. The gain in detection sensitivity and the interaction between the interferometer and squeezer of a full-scale gravitational-wave interferometer will be investigated. The results showing the performance of the planned LIGO H1 Squeezing OPO, including the latest low frequency (100Hz 10kHz) squeezing data, will also be presented.

11:10 - 11:30

An $f(R)$ Theory of Gravity Motivated by Gravitational Waves

Sadanand Pandey *(Unitech, Lae, Papua New Guinea)*

Gravitational waves are an inevitable consequence of Einstein theory of gravitation but they are not conformally flat as electromagnetic waves. It requires to modify Einstein theory to obtain conformally flat gravitational waves. So we attempted to modify Einstein theory by taking Lagrangian a polynomial in R without associating it with scalar field or mesonic field or so. Some of the consequences of this theory are also discussed.

11:30 - 11:50

On Asymptotically Flat Solutions of Einstein's Equations Periodic in Time

Martin Scholtz *(Institute of Theoretical Physics, Charles University, Prague, Czech Republic)*

Collaborators: Jiri Bicak, Paul Tod

By an argument similar to that of Gibbons and Stewart, but in a different coordinate system and less restrictive gauge, we show that any weakly-asymptotically-simple, analytic vacuum or electrovacuum solutions of the Einstein equations which are periodic in time are necessarily stationary.

11:50 - 12:10

Kodama Time

Gabriel Abreu *(Victoria University of Wellington, NZ)*

Collaborators: Matt Visser

In a general (3+1)-dimensional spherically symmetric spacetime, a preferred time coordinate is introduced by applying the Clebsch decomposition theorem to the Kodama vector. Then a preferred coordinate system is constructed for the time-dependent metric tensor. However certain ambiguities arise when the time-dependent metric is studied, such as the time-dependent redshift factor, and the time-dependent surface gravity. Nevertheless, by building a set of radial null geodesics, it is possible to define and calculate a notion of "bulk gravity" that generalizes the usual "surface gravity" and is valid throughout the entire spacetime geometry.

12:10 - 12:30

Faster than Light

Yen C Ong *(National University of Singapore)*

We study the properties of Alcubierre drive and its many variants, all of which are spacetimes with features reminiscent of the fictional "warp drive" capable of faster than light (FTL) travel. We also explore these FTL drives in curved spacetime backgrounds.

2:00 - 2:40 *Plenary talk*

Who's Afraid of Lorentz Symmetry Breaking?

Matt Visser *(Victoria University of Wellington, NZ)*

Is Lorentz symmetry truly fundamental? Or is it just an "accidental" low-momentum emergent symmetry? Opinions on this issue have undergone a radical mutation over the last few years. Historically, Lorentz symmetry was considered absolutely fundamental — not to be trifled with — but for a number of independent reasons the modern viewpoint is more nuanced. What are the benefits of Lorentz symmetry breaking? What can we do with it? Why should we care?

2:40 - 3:00

SU(2) Hamiltonian Structure in the Holst Formulation of Gravity

Francesco Cianfrani *(ICRA, University of Rome "Sapienza", Italy)*

Collaborators: Giovanni Montani

It is outlined the relevance for Quantum Gravity of inferring a kinematical SU(2) gauge structure in a generic Lorentz frame. Then, the analysis of Hamiltonian constraints is performed in vacuum and in presence of matter fields. SU(2) Gauss constraints are shown to arise even though no restriction of the local Lorentz frame takes place.

3:00 - 3:20

Non-singular Warped Compactifications and the Quest for a Realistic Cosmology

Ishwaree Neupane *(University of Canterbury, NZ)*

In this talk I discuss about the recent attempts, difficulties and prospects of explaining the cosmic inflation and the current acceleration of the universe (attributed to cosmological vacuum energy) using explicit cosmological solutions of five- and ten-dimensional warped supergravity models. These solutions correspond to the dimensional reduction to 4 dimensions of the 10D supergravity models, where the spacetime is a warped product of a six-dimensional Einstein space and dS_4.

3:20 - 3:40

Phantom Crossing in Brans-Dicke Cosmology

Hossein Farajollahi *(University of Guilan, Rasht, Iran)*

In this talk, we consider FRW cosmology in the generalized Brans-Dicke cosmology. We consider a time dependent Brans-Dicke parameter omega, and show the equation of state parameter can cross over -1, and investigate its bouncing condition.

4:10 - 4:40

On Calculating Self-force for Radiating Systems

Andrew Norton *(Max Planck Institute for Gravitational Physics, Germany)*

The self-force on a radiating system can be calculated by considering energy-momentum balance across a worldtube that encloses the system. For example, such tube-based calculations have been done in a curved background spacetime for the electromagnetic self-force on a point-like charge (DeWitt and Brehme 1960, Hobbs 1968) and for the gravitational self-force on a point-like mass (Mino, Sasaki and Tanaka 1997). Until recently, however, all tube-based self-force calculations have followed the steps taken in Dirac's 1938 calculation of the electromagnetic self-force for the classical radiating electron. In particular, they have invoked a "classical mass renormalization" as the radius of the worldtube goes to zero. This step is mathematically ill defined and physically nonsensical. It involves the subtraction of divergent quantities and ascribes an infinite negative "bare mass" to the system. Nevertheless, it gives the right answer! I shall explain why, by showing how tube-based self-force calculations can be done properly, that is, for systems of finite size and without invoking a mass renormalization.

The talk is based on published results (Class. Quantum Grav. 26 (2009) 105009), but if time permits I shall also describe some recent applications and examples.

4:40 - 5:10
Influence of Cosmological Constant on Physics near Black Holes
Jiri Kovar *(Silesian University, Opava, Czech Republic)*
Collaborators: Zdenek Stuchlik, Petr Slany

Data from a wide variety of independent cosmological tests indicate that more than 70% of energy content of the Universe is in the form of so-called 'dark energy', which can be well represented by the repulsive cosmological constant in Einstein's equations. It is well known that cosmological constant strongly influences expansion of the Universe, leading finally to an accelerated stage. In our work, we have studied possible effects of cosmological constant in astrophysically motivated problems, investigating properties of test-particle motion, spinning test-particle motion and perfect fluid configuration in the black-hole Schwarzschild-de Sitter solution of Einstein's equations and in the black-hole and naked-singularity Kerr-de Sitter solutions.

In order to emphasise the influence of the cosmological constant, we have compared our results with the related ones when cosmological constant is zero. All the mentioned problems have been presented in terms of the standard general relativistic approaches, such as Carter's equations, effective potential, Papapetrou equation of motion, general relativistic Euler equation, etc. The test-particle and fluid properties have been treated also in the framework of the optical reference geometry allowing introduction of inertial forces in the intuitive natural Newtonian way. For circular this approach seems to be more convenient in comparison with the standard general relativistic ones. Moreover, we have shown that in some particular cases in the Schwarzschild-de Sitter spacetimes, especially in the test particle motion and adiabatic perfect fluid tori investigations, it is possible to employ even the pseudo-Newtonian approach, based on appropriately chosen gravitational potential within the Newtonian physics. The differences between the pseudo-Newtonian and general-relativistic results can be considered as negligible in most of the investigated problems, such as determination of the marginally bound and stable circular orbits, shapes, masses, central densities, temperatures and pressures of the adiabatic tori.

5:10 - 5:30
Equatorial Circular Orbits in the Kerr-Newman-de Sitter Spacetimes
Martin Petrasek *(Silesian University, Opava, Czech Republic)*
Collaborators: Petr Slany, Zdenek Stuchlik

We consider the influence of the cosmological constant on the character of the geodetical equatorial circular orbits in the rotating and charged Kerr-Newman black-hole and naked-singularity spacetimes. Conditions for the existence of geodesics are determined. Significant limits such as static radius, circular photon orbits are presented. We discuss existence, orientation and stability of the equatorial circular orbits. In the Kerr–Newman de Sitter spacetime geometry the existence of two static radii implies different situations in both plus– and minus–family circular orbits in comparison with the Kerr–de Sitter spacetimes. Especially in the naked singularity case, existence of the so called plus–family orbits is now restricted by the rotational parameter from above. Also, for some values of charge, cosmological parameter and rotational parameter, minus-family orbits exists not only between the outer static radius and minus-family circular photon orbit but also between the inner static radius and minus-family circular photon orbit.

Public Lecture

Cracking the Einstein Code

Roy P Kerr *(University of Canterbury, NZ; and ICRANet, Italy)*

In 1963 three hundred astronomers, astrophysicists and general relativists met in Dallas to try to explain Quasars. These newly discovered objects were extremely distant and therefore had to be enormously powerful, but no known process of conventional science was able to generate anything like the energies observed. The only hope was gravitational collapse, but the standard non-rotating Black Hole model of Schwarzschild was not enough. These Quasars were continuing to pour out incredible amounts of energy, and this could not come from inside an event horizon. Furthermore, all objects rotate, even if just slightly, and it was not clear that a rotating star could even collapse to a black hole.

In a short talk at this first Texas conference Roy Kerr announced that he had found a solution for a rotating body, and that this could represent the final gravitational field for a rotating Black Hole. Within a few years it was proved that this solution - the Kerr geometry - is unique. A Black Hole is defined completely by its mass, its spin and its electric charge. As John Wheeler was to say: *"Black Holes have no hair"*.

Although no energy can escape from the Black Hole, it was soon realised that enormous amounts of gravitational energy can be released by an accretion disc of matter around it. It appears that all galaxies have a supermassive Black Hole at their centres and that these may have played a starring role in the creation of galaxies in the early universe.

In this lecture Professor Kerr will recount the story of rotating Black Holes, from their discovery in 1963, to present observations of supermassive Black Holes of millions - even billions - of solar masses in the centres of galaxies.

BIOGRAPHICAL SKETCH: Roy Kerr is Emeritus Professor at the University of Canterbury, and Yevgeny Lifschitz Professor at ICRANet, Italy. Born in 1934 in Kurow, and educated at the Universities of Canterbury and Cambridge, he discovered the "most important exact solution of Einstein's equations" while at the University of Texas in 1963. In 1971 he returned to the University of Canterbury as Professor of Applied Mathematics, and served as Head of the Department of Mathematics for much of the 1980s. Since his retirement in 1993 the Kerr geometry has become increasingly important in astrophysics, as technological advances have revealed rotating black holes to be key to the life cycle of the Universe. Roy is now much in demand as a public speaker. He has received the Hector Medal (1982) and the Rutherford Medal (1993) of the Royal Society of NZ, the Hughes Medal (1984) of the Royal Society London, and the Marcel Grossmann Award (2006).

Thursday 17 December

9:00 - 9:40   *Plenary talk*
Encoding Cosmological Futures with Conformal Structures
Susan M Scott   *(Australian National University)*
Collaborators: Philipp A Höhn

It has long been a primary objective of cosmology to understand the apparent isotropy in our universe and to provide a mathematical formulation for its evolution. A promising school of thought for its explanation is quiescent cosmology which already possesses a mathematical framework, namely the definition of an isotropic singularity, but only for the initial state of the universe. A complementary framework is therefore necessary to also describe possible final states of the universe. Our new definitions of an anisotropic future endless universe and an anisotropic future singularity, whose structure and properties differ significantly from those of the isotropic singularity, offer a promising realisation for this framework. The combination of the three definitions together then provides the first complete formalisation of the quiescent cosmology concept.

9:40 - 10:20   *Plenary talk*
Detection of Gravitational Waves with Pulsar Timing
Richard N Manchester   *(Australia Telescope National Facility, CSIRO)*

Millisecond pulsars have extremely stable periods and small perturbations in the observed periods due to gravitational waves (GW) passing over the Earth and the pulsar can in principle be detected. Observations of just a few pulsars can only ever put a limit on the strength of GW in the Galaxy, but a positive detection can be made with observations of many pulsars spread across the celestial sphere, a so-called *Pulsar Timing Array* (PTA). PTAs are sensitive to GW with frequencies in the nano Hertz range and hence are complementary to ground– and space–based laser–interferometer systems. The Parkes Pulsar Timing Array (PPTA) project has been timing 20 millisecond pulsars for about four years with steadily improving technology and similar PTA systems are under development in North America (NANOGrav) and Europe (EPTA). These PTAs should detect predicted levels of the stochastic GW background from binary super-massive black holes in the cores of distant galaxies in 5–10 years. Failure to detect this GW background will have a significant impact on merger models for the growth of galaxies and their central black holes and on models for cosmic-string formation in the early Universe.

10:50 - 11:10
The Conformal Structure of FRW Space-times
Philip A Threlfall   *(Australian National University)*
Collaborators: Susan M. Scott

We will consider the Friedmann-Roberston-Walker (FRW) space-times in the context of conformal relationships. Recently there has been a lot of interest in the different types of singularities that the FRW space-times admit, namely Big Bangs, Big Crunches, Big Rips, Sudden Singularities and Extremality Events. We present a discussion and comparison of these singularities in relation to the generic conformal singularities defined by Höhn and Scott, [1] namely the Isotropic Past Singularity (IPS), Isotropic Future Singularity (IFS), Anisotropic Future Singularity (AFS), Future Isotropic Universe (FIU) and the Anisotropic Future Endless Universe (AFEU).

[1] Scott and Höhn, "Encoding cosmological futures with conformal structures", Classical and Quantum Gravity, vol. 26, 2009.

11:10 - 11:30

A Topology for the Abstract Boundary Construction of Space-time

Richard Barry *(Australian National University)*

Collaborators: Susan M. Scott

The abstract boundary construction produces a boundary for an n-dimensional manifold in such a way that this boundary is independent of any particular embeddings. In effect, this is done by considering all possible embedding of a manifold. This boundary then allows for various types of boundary points, such as 'singularities' and 'points at infinity' to be defined. Due to the way in which the abstract boundary is constructed, it is of particular importance to understand how boundary points of one embedding are related to boundary points of another embedding. A topology which encapsulates some of this information would therefore be highly useful, and would aid in the construction of 'optimal embeddings' of space-times, i. e. , embeddings of space-times that clearly display all of their important physical features, like singularities. A possible topology that exhibits this behaviour, and its properties, will be discussed.

11:30 - 11:50

Electrodynamics Around Schwarzschild and Reissner-Nordstrom Black Holes

Maya Watanabe *(Monash University, Australia)*

Collaborators: Anthony Lun

In 1927, Copson found an exact fundamental solution for an electric charge outside a Schwarzschild black hole using Hadamard's methods in isotropic coordinates. The solution has various interpretations, one of which was expounded by Linet in 1976. Linet interpreted the solution as representing two electric charges of equal strength and sign, one lying inside and one lying outside the event horizon of a Schwarzschild black hole. In the same regard, it is possible to reinterpret the solution to represent two electric charges of opposite sign lying inside and outside the horizon. We use Copson's solution to construct this scenario and study the electrodynamics of this electric dipole situation. Further we generalize the solution to look at the Reissner-Nordstrom case and consider the possible electrodynamical processes around non-rotating, charged and uncharged black holes. We find that our solution reduces to the Schwarzschild black hole when the charge outside the black hole is placed on the horizon.

11:50 - 12:10

Relativistic Causal Boundaries in Singular Space-times

Ecaterina Howard *(Macquarie University, Australia)*

Black holes harbor space-time singularities of infinite curvature, where classical physics, causality and future predictability break down. The singularity theorems state that a space-time which satisfies reasonable energy and causality conditions but also contains a trapped surface, must lead to a singularity, seen as causal geodesic incompleteness. Event horizons are key diagnostics for the presence and properties of black holes. The issue of the stability of the Cauchy horizon from future null infinity is discussed. In my talk I outline a few recent achievements and open questions in our understanding of the causal nature of singularities. I address several key problems concerning the future Cauchy development, break-down criteria and local/global sufficient conditions for the horizon stability. Finally, I discuss new points concerning the space-time causal boundaries and conformal boundary extensions for time oriented Lorentzian manifolds.

12:10 - 12:30

Two New Conditions for the Occurrence of Krolak Strong Curvature

Ben Whale *(Australian National University)*

It is sometimes stated that the only reason for believing that singularities occur in gravitational collapse is the singularity theorems [1, 2, 4]. Given this, investigating the physical consequences of singularity theorems is an important part of understanding gravitational collapse and singularity formation. Tipler and Krolak's strong curvature conditions provide a link between the sometimes very geometric assumptions of singularity theorems and physical behaviour. Unfortunately the Krolak [3] and Tipler [5] conditions make statements about geodesic divergence at every point along a geodesic, while the singularity theorems make a statement only about the geodesic divergence at a single point on a geodesic. If one wishes to use the Krolak and Tipler conditions to describe physical behaviour in singularity formation we need to overcome this difference. We give two necessary and sufficient conditions for a timelike geodesic to satisfy the Krolak strong curvature condition in terms of the geodesic divergence from a single point. These results are the first step towards providing a concrete path to linking the formation of singularities in gravitational collapse to curvature behaviour.

[1] Bizon, P., E. Malec, and N. O. Murchadha, Trapped surfaces due to concentration of matter in spherically symmetric geometries. Classical and Quantum Gravity, 1989. 6(7), p. 961-976.

[2] Hawking, S. W., Comments on cosmic censorship. General Relativity and Gravitation, 1979. 10: p. 1047 - 1049.

[3] Krolak, A., A proof of the cosmic censorship hypothesis. General Relativity and Gravitation, 1983. 15: p. 99-104.

[4] Schoen, R. and S. -T. Yau, The existence of a black hole due to condensation of matter. Communications in Mathematical Physics, 1983. 90: p. 575 - 579.

[5] Tipler, F. J., Singularities in conformally flat spacetimes. Phys. Lett., 1977. A64(1): p. 8-10.

2:00 - 2:40 *Plenary talk*

Conceptual Issues in Numerical Relativity

Joerg Frauendiener *(University of Otago, Dunedin, NZ)*

Numerical relativity has seen a great development in the previous five years. In particular, the binary black hole problem has been treated in a quite remarkable and satisfactory way. This talk will present some of the methods used and the results achieved. Furthermore, there will be a discussion of the tacit assumptions underlying the mathematical model of the physical situation and their consequences in the numerical treatment. It turns out that asymptotic flatness imposes a condition, which is very difficult to implement numerically. Some possible alternatives are discussed.

2:40 - 3:00

Numerical Differential Geometry: GRworkbench

Benjamin R Lewis *(Australian National University)*

Collaborators: Susan M. Scott

We will present several demonstrations of GRworkbench. This is a software package we have developed for exploring the properties of space-times, numerically performing experiments, and producing visualisations. This software was designed to enable the researcher to visually explore the global properties of a space-time in a coordinate-independent manner.

3:00 - 3:20

Geodesics in Impulsive Vacuum Spacetimes with a Cosmological Constant

Robert Svarc *(Charles University, Prague, Czech Republic)*

Collaborators: Jiri Podolsky

The influence of expanding spherical impulsive gravitational waves, propagating in Minkowski, de Sitter and anti-de Sitter universe, on geodesics is studied. The refraction formulae which identify the positions and the velocity vector inclination of free test particles on both sides of the impulse are derived. These results are visualized in the case of the impulsive wave generated by a snapping cosmic string.

3:20 - 3:40

Accelerated Objects in General Relativity

David Kofron *(Charles University, Prague, Czech Republic)*

Collaborators: Jiri Bicak

The boost-rotation symmetric spacetimes are the only explicit solutions of Einstein's equations which represent finite moving object and are asymptotically flat. Employing the Ehlers frame theory we construct their Newtonian limits and provide specific examples (such as charged C-metric). The Newtonian limits correspond to the fields of classical point (charged) masses undergoing uniform acceleration in classical mechanics. We also consider special-relativistic limits of charged rotating C-metric obtaining thus "accelerated electromagnetic magic field" of two oppositely accelerated charged relativistic discs.

4:10 - 4:40

The Ghost of Pauli: Implications of Energy Conservation in Neutrino Oscillations

D. V. Ahluwalia *(University of Canterbury, NZ)*

Collaborators: D. Schritt

Insistence on the conservation of energy led Pauli to conjecture the existence of neutrinos. The data that has since accumulated adds a new twist to the story. Neutrinos neither carry a definite mass, nor a definite energy, and as a consequence oscillate from one flavour to another. Each flavour has a different energy expectation value. Neutrino oscillations thus raise a fundamental question, how is energy conserved when a neutrino of one flavour oscillates to another flavour? To resolve this paradoxical situation, we here propose a conjecture that the neutrino mixing matrix must be such that in the oscillation process the energy expectation values enjoy flavour independence. This conjecture turns out to be very powerful. Using the existing data, it suggests that either neutrinos have interactions that go beyond those expected from the standard model, or there must exist sterile neutrinos.

4:40 - 5:10
5-Dimensional Toy Model for Particle Confinement in Spatially-Warped Einstein Universe
Ciprian and Marina-Aura Dariescu *(Faculty of Physics, Al. I. Cuza University of Iasi, Romania)*

The present paper deals with massless fermions evolving in a 5D spacetime, with $S^3 \times R$ four-dimensional slices. After solving the Gordon and Dirac-type equations, we consider the direct interaction introduced by the Yukawa coupling and analyze the confinement mechanism of chiral fermions. It turns out that only the left modes are exhibiting the tendency of confinement. However, the behavior is clearly depending on the values of the quantum number m. In the cases corresponding to $m = 1$ and $m = -1$, once the coupling constant is increasing, these left-handed modes become more and more dominant in the brane.

5:10 - 5:30
Self-interacting Fermionic Dark Matter with Axis of Locality
Dimitri Schritt *(University of Canterbury, NZ)*
Collaborators: D. V. Ahluwalia, Cheng-Yang Lee

We here provide further details on the construction and properties of mass dimension one quantum fields based on Elko expansion coefficients. We show that by a judicious choice of phases, the locality structure can be dramatically improved. In the process we construct a fermionic dark matter candidate which carries not only an unsuppressed quartic self-interaction but also a preferred axis. Both of these aspects are tentatively supported by the data on dark matter.

5:30 - 5:50
Snyder Geometry, Loop Quantum Gravity and Brane Worlds
Andrew W Beckwith *(American Institute of Beam Energy Propulsion, USA)*

In Loop Quantum Gravity (LQG) the entropy of Standard Model black holes is of order 10^{89}, with pronounced implications for the classical singularities of general relativity. Recent papers in LQG, which the author was exposed to at the 12th Marcel Grossman conference, assumed that big bounce replaced the singularity conditions of Hawking, Ellis, and others. In particular, Marco Valerio Battisti [*Phys. Rev.* **D 79** *(2009) 083506*] uses Snyder geometry to find a common basis in which to make a limiting approximation to derive either braneworld or LQG conditions for cosmological evolution. The heart of what Battisti works with is a deformed Euclidean Snyder space.

We will use this result explicitly to establish criteria for information transfer from a prior to a present universe. In this way one may, on falsifiable experimental grounds, determine whether minimal spatial uncertainty requirements for space time can distinguish between LQG and brane world scenarios. The tie in with entropy and information processing comes in via order of magnitude estimates of the minimum informational content needed to preserve continuity of basic physical laws between our present and a past cosmos. Continuity would be preserved in physical laws if the fundamental physical constants of nature remain invariant.

Friday 18 December

9:00 - 9:40   Plenary talk

Catching a Wave: Interesting Science Discovered en Route to the Detection of Gravitational Waves using Ground-based Laser Interferometers

Ra Inta   *(Australian National University)*

It is difficult to be a member of the gravitational physics community and not be aware of the large laser-based gravitational wave (GW) observatories forming the LIGO-Virgo network. Although they have not yet made a positive direct detection, they have already established useful limits on GW emission by a range of astrophysical objects and systems.

Here I will present an update on the LIGO-Virgo observatories, what they are intended to achieve, and what they have achieved to date. Not only have the observatories themselves undergone substantial upgrades, but the data analysis community is also continuously maturing, developing more sophisticated and sensitive search methods. I will describe some of the more recent and interesting work in the four main categories expected to yield detection, those from burst, compact binary coalescence, stochastic and continuous GW sources. Finally I will discuss some aspects of the future of the LIGO-Virgo project.

9:40 - 10:20   Plenary talk

Dark Energy Without Dark Energy

David L Wiltshire   *(University of Canterbury, NZ)*

Below scales of about $100/h$ Mpc our universe displays a complex inhomogeneous structure dominated by voids, with clusters of galaxies in sheets and filaments. The coincidence that cosmic expansion appears to start accelerating at the epoch when such structures form has prompted a number of researchers to question whether dark energy is a signature of a failure of the standard cosmology to properly account, on average, for the distribution of matter we observe. Several ideas have been put forward, with much debate and controversy. I will discuss the debate and the key issues which involve both the change to average cosmic evolution from backreaction, and the solution to the "fitting problem", How do our own observations relate to average quantities when the variance of local geometry becomes significant? I suggest that properly understanding these issues yields a viable cosmology, in which dark energy is recognized as a mis-identification of gravitational energy gradients associated with inhomogeneous structures, purely in general relativity with matter obeying the strong energy condition. A number of quantifiable and testable predictions will be presented, and present and future observational prospects discussed.

10:50 - 11:10

Nonlinear Integrated Sachs-Wolfe Effect

Bjoern M Schaefer   *(ARI Heidelberg, Germany)*

I present a number of results concerning the nonlinear integrated Sachs-Wolfe effect as a secondary CMB anisotropy, in particular the non-Gaussian signal and its detectability, and the contamination of the angular spectrum of the linear ISW-effect.

11:10 - 11:30
Cosmic Acceleration from Structure Formation
Teppo Mattsson *(University of Canterbury, NZ)*

The cosmological structure formation has been proposed as the culprit for why the expansion of the universe seems to have accelerated. I discuss the physical interpretation of some models that support this idea at a quantitative level.

11:30 - 11:50
Supernovae Ia and Model Dependence
Peter Smale *(University of Canterbury, NZ)*

Hubble diagrams of high redshift Type Ia supernovae clearly show deviation from an Einstein-de Sitter cosmological model. In the context of FLRW cosmology, this deviation can be accommodated by including a dark energy component in the energy density. In the inhomogeneous cosmological model of Wiltshire (2007), this effect is explained as an illusion brought about by the situation of observers within wall regions that separate voids. Fitting supernovae Ia observations to this model is problematic, however, since FLRW assumptions are built into the supernovae Ia data calibration process. This talk will discuss this issue.

11:50 - 12:10
Cluster Formation in Lagrangian Perturbation Theory
Lavinia Heisenberg *(Institute for Theoretical Astrophysics, University of Heidelberg, Germany)*
Collaborators: Matthias Bartelmann

One of the most important fields of research in modern cosmology is the understanding of the formation of structure in the Universe. In recent years there has been a lot of observational progresses and beside that the numerical simulations became important. Most of those numerical simulations concentrated on the simulation of the collisionless dark matter component, which drives the dynamical evolution on the largest scales, using particle methods. The main topic of this talk will be about my investigations of the clustering of dark matter halos and of their merging history in a Lagrangian framework. For the numerical implementation based on the PINOCCHIO algorithm I am using a higher order Lagrangian perturbative description of the gravitational dynamics of the cosmological large-scale structure and the influence of dark energy on the formation dynamics. I follow the formation and evolution of individual dark matter halos by triaxial gravitational collapse in a given field realisation and determine their growth and merging history numerically. The properties of the halo population are of fundamental importance for understanding the formation and evolution of galaxy clusters at high redshifts and their observational implications. [Collaborator, Matthias Bartelmann]

12:10 - 12:30
Measuring Solar Diameter with Baily Beads: From Watts to Kaguya's Lunar Profiles
Costantino Sigismondi *(ICRA, University of Rome "Sapienza", Italy and Nice University, France)*
Collaborators: M. Soma, D. Herald

The variations of the solar diameter smaller than 1 part over 10000 are very difficult to be detected unambiguously. One of the most promising methods is the use of Baily's beads during central solar eclipses (total and annular), and it can be applied also to old observations.

Recently the lunar profiles computed from the Japanese mission Kaguya become available, and we compare the first results on the computation of solar diameter during the annular eclipse of September 2006 obtained with Watts and Kaguya's data.

2:00 - 2:40 *Plenary talk*

Determination of Black Hole Masses in Galactic Black Hole Binaries

Lev Titarchuk *(University of Ferrara, Italy; and NASA Goddard Space Flight Center, USA)*

Collaborators: Nikolai Shaposhnikov

I present a study of correlations between X-ray spectral and timing properties observed from a number of Galactic Black Hole (BH) binaries during hard-soft state spectral evolution. We analyze 17 transition episodes from 8 BH sources observed with Rossi X-ray Timing Explorer (RXTE). Our scaling technique for BH mass determination uses a correlation between spectral index and quasi-periodic oscillation (QPO) frequency. In addition, we use a correlation between index and the normalization of the disk "seed" component to cross-check the BH mass determination and estimate the distance to the source. In fact, the index-normalization correlation also discloses the index-mass accretion rate saturation effect given that the normalization of disk "seed" photon supply is proportional to the disk mass accretion rate. We present arguments that this observationally established index saturation effect is a signature of the bulk motion (converging) flow onto black hole which was early predicted by the dynamical Comptonization theory. We apply our scaling technique to determine BH masses and distances for Cygnus X-1, GX 339-4, 4U 1543-47, XTE J1550-564, XTE J1650-500, H 1743-322 and XTE J1859-226. Good agreement of our results for sources with known values of BH masses and distance provides an independent verification for our scaling technique.

2:40 - 3:00

Canonical Forms for Stationary Axisymmetric Solutions

Roy P Kerr *(University of Canterbury, NZ; and ICRANet, Italy)*

The Lewis-Papapetrou-Ernst formulation of the field equations for stationary axisymmetric metrics has been standard for several decades. This has generated many new solutions for quadrupole sources but these have been so complicated that the metrics have not always been calculated from the Ernst potentials. It will be shown that theses metrics are not nearly as complicated as thought provided that a suitable representation is used.

3:00 - 3:20

Kerr-Schild Ansatz Revised

Andrea Geralico *(ICRA, University of Rome "Sapienza", Italy)*

Collaborators: D. Bini, Roy P. Kerr

The Kerr-Schild ansatz is revised by treating Kerr-Schild metrics as "exact linear perturbations" of Minkowski space, being expressed as a linear superposition of the flat spacetime metric and a squared null vector field multiplied by some scalar function. Based just on this linearity property an alternative derivation of the Kerr solution is presented by distinguish in the Einstein as well as energy momentum tensors the contributions of different orders, i. e. powers of the scalar function, then solving separately each individual set of field equations. The basic assumption in the original derivation of Kerr solution was that the null congruence is both geodesic and shear free. This condition is relaxed in the present treatment, where the field equations are solved without any assumption. It turns out that the congruence must be anyway geodesic and shear free as a consequence of third and second order equations.

3:20 - 3:40

Investigating Symmetry Groups of 1 Killing Vector Equations.

Ted Fackerell *(retired from University of Sydney, Australia)*

I investigate symmetry groups for the 1-Killing vector vacuum Einstein equations, looking also at which CA packages are helpful. In particular, I look at how knowledge of a Lie pseudogroup of invariance may be used in integrating the equations.

4:10 - 4:40

Spherical Black Holes in Cosmological and Other Fluid Backgrounds: An Overview

Malcolm Anderson *(Universiti Brunei Darusslam)*

A longstanding problem in classical general relativity concerns the embedding of a non-rotating (spherical) black hole in a cosmological background. It is well known that the only static solutions of the Einstein equations describing a spherical black hole in a cosmological background are the Schwarzschild-de Sitter and Schwarzschild-anti-de Sitter metrics. But there exists in addition a large class of non-static solutions, which includes the McVittie [1] and generalised McVittie [2] metrics, the Sultana-Dyer solution [3], a family of self-similar metrics due to Saida, Harada, Maeda and Nozawa [4, 5], and the Clifton solutions [6].

In this talk I will review the history of the problem of what are often called "dynamical black holes", and discuss in particular a recent dispute between Bachichev at al. [7] and Gao et al. [8] over the claim that the mass of a black hole can be reduced as a result of the accretion of phantom energy (that is, a fluid with $p/\rho < -1$).

[1] McVittie GC (1933), Mon. Not. R. Astr. Soc. 93, 325.
[2] Faraoni V and Jacques A (2007), Phys. Rev. D76, 063510.
[3] Sultana J and Dyer CC (2005), Gen. Rel. Grav. 37, 1349.
[4] Saida H, Harada T and Maeda H (2007), Class. Quant. Grav. 24, 4711.
[5] Nozawa M and Maeda H (2008), Class. Quant. Grav. 25, 055009.
[6] Clifton T (2006), Class. Quant. Grav. 23, 7445.
[7] Babichev E, Dokuchaev V and Eroshenko Yu (2004), Phys. Rev. Lett. 93, 021102.
[8] Gao C, Chen X, Faraoni V and Shen Y-G (2008), Class. Quant. Grav. D78, 024008.

4:40 - 5:10

Modeling Non-linearities in the Ringdown of Colliding Black Holes

Manuel Tiglio *(University of Maryland, USA)*

Collaborators: David Brizuela, Frank Herrmann, Jose Maria Martin Garcia, Enrique Pazos

I will present a new covariant and gauge invariant formalism for arbitrary second order perturbations of (non-rotating) black holes. Next I will discuss a numerical implementation of such formalism and studies of the gravitational radiation generated by self-coupling of linear perturbations. Finally, I will review some ongoing comparisons with full non-linear simulations of colliding black holes. One of the goals of this ongoing effort is to gain further insights in the late stages of colliding black holes and its analytical modeling. A second motivation comes from the possibility of LISA being able to detect a second ringdown mode.

EATERIES

Eateries are within a short walking distance of the campus (refer to the maps provided).
The Main Restaurants and Takeaway Cafes are listed below:

- **University of Canterbury Staff Club, Ilam Homestead**
  It is located across the Ilam Road, opposite to the UCSA (refer to maps provided). *Due to end of term functions, the Staff Club is open for lunch til Wednesday 16 only this week. On Thursday and Friday delegates will have to go elsewhere.*

  The Club provides a range of luncheon at reasonable prices in the upstairs dining room. The first floor has bar facilities to members/guests. The bar is comfortably furnished with lounges. Also available are a range of newspapers and periodicals for guest's and member's use.

- **Indian Spices**:
  Location: Adjacent to the University Bookshop (refer to maps provided)
  It is at the shortest distance from the lecturer/conference hall. This restaurant serves both Indian and Chinese cuisines.

- **Tandoori Palace: Indian Cuisine**:
  Location: 71 Ilam Road (towards Riccarton Road off the Campus)

  It is about a 5-minute walk from the Erskine building/lecture hall. Tandoori Palace has a good reputation for serving typical Indian cuisines (Nan and Tandoori).
  Opening Hours: 12:30 – 2:00pm, 4:30 pm – 8:00 pm

- **Foo San: Yam Cha**
  Chinese Delight/Asian Cuisine
  Location: Corner of Ilam Road and Rountree Street
  Foo San has a good reputation for serving typical Chinese cuisines at reasonable prices.

There are a few more restaurants and cafes within the campus premises. **Reboot**, a small sandwich and coffee bar is located on level 1 of the Erskine building, conveniently for delegates. Many small cafes and restaurants – such as a noodle bar – are inside the UCSA (University of Canterbury Student Association) building complex, **Cafe 101** (in the Commerce Building) and **Cafe 360** (in the James Height, the basement of the Central Library).

The University of Canterbury is a 10-minute drive from the Christchurch city center and is easily accessible by bike or public transportation (about 20-minutes to the city exchange/center).

SHOPPING CENTRES/SUPERMARKETS

For participants staying at Bishop Julius Hall (90 Waimairi Road) the closest supermarket is *Countdown* at 361 Riccarton Road. It takes about 10 minutes to reach there from the Bishop-Julius Hall. Many other small shops and banks are close by at *Upper Riccarton / Bush Inn Shopping Centre.*

For participants staying at Academy Motor Lodge (62 Creyke Road) the closest supermarket is *New World* at 23 Memorial Avenue. It takes about 10 minutes to reach there from the Academy Lodge (refer to maps provided). (There is a short back-street route via a walkway from Barlow Street off Creyke Road.) A few other small shops are close by at *Fendalton Mall.*