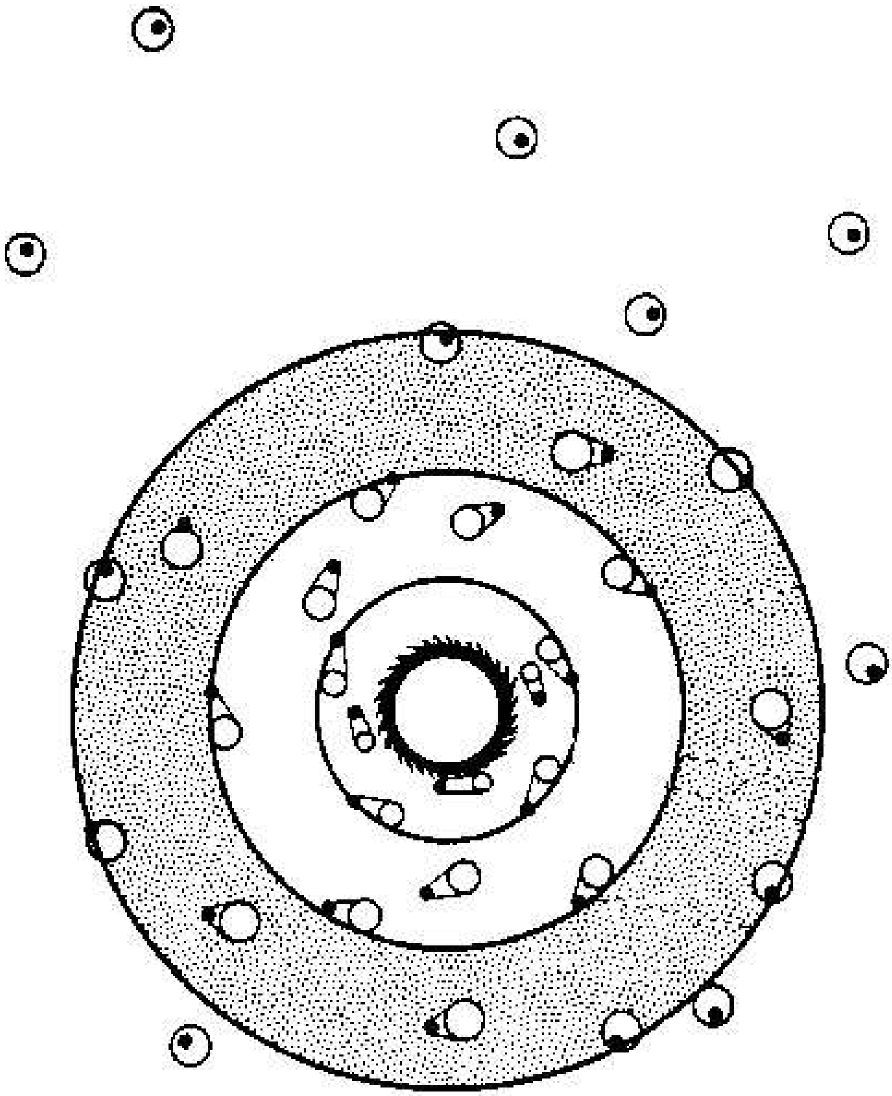
— Kerr Fest —

Black Holes in Astrophysics, General Relativity and Quantum Gravity



University of Canterbury, Christchurch, New Zealand

26–28, August, 2004

Who's going to crack that Einstein equation? Me! Roy Kerr - age 2, Kurow

Contents

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Overview:
Roy Kerr and the spin on black holes

In 1963 the New Zealand mathematician Roy Kerr achieved something that had eluded scientists for 47 years — he found the solution of Einstein's equations which describes the space outside a rotating star or black hole. Kerr's solution has been described as *"the most important exact solution to any equation in physics"*.

Shortly after Einstein wrote down his gravitational field equations in 1915, Karl Schwarzschild found a solution which describes a non-rotating spherical star or black hole. However, it is known that all stars rotate, and that Schwarzschild's solution is at best an approximation. Kerr's achievement of finding an exact solution for the rotating case — something many had doubted could be done - was therefore a revolution in astrophysics. Stephen Hawking describes events as follows [1]:

> "*In 1963, Roy Kerr, a New Zealander, found a set of solutions of the equations of general relativity that described rotating black holes. These "Kerr" black holes rotate at a constant rate, their size and shape depending only on their mass and rate of rotation. If the rotation is zero, the black hole is perfectly round and the solution is identical to the Schwarzschild solution. If the rotation is non-zero, the black hole bulges outward near its equator (just as the earth or the sun bulge due to their rotation), and the faster it rotates, the more it bulges. So, to extend Israel's result to include rotating bodies, it was conjectured that any rotating body that collapsed to form a black hole would eventually settle down to a stationary state described by the Kerr solution. In 1970 a colleague and fellow research student of mine at Cambridge, Brandon Carter, took the first step toward proving this conjecture. He showed that, provided a stationary rotating black hole had an axis of symmetry, like a spinning top, its size and shape would depend only on its mass and rate of rotation. Then, in 1971, I proved that any stationary rotating black hole would indeed have such an axis of symmetry. Finally, in 1973, David Robinson at Kings College, London, used Carter's and my results to show that the conjecture had been correct: such a black hole had indeed to be the Kerr solution.* "

The significance of the Kerr solution has perhaps been most eloquently summarised by the legendary astrophysicist S. Chandrasekhar (Nobel laureate, 1983) [2]:

> "*In my entire scientific life, extending over forty-five years, the most shattering experience has been the realization that an exact solution of Einstein's equations of general relativity, discovered by the New Zealand mathematician, Roy Kerr, provides the absolutely exact representation of untold numbers of massive black holes that populate the universe. This shuddering before the beautiful, this incredible fact that a discovery motivated by a search after the beautiful in mathematics should find its exact replica in Nature, persuades me to say that beauty is that to which the human mind responds at its deepest and most profound.*"

Over the 41 years since its discovery the Kerr solution has been pivotal in deepening our understanding of astrophysics and gravitation. Many new effects arise in the Kerr solution - a rotating object drags space with it, in a way which would not be possible in Newton's theory. The rotation of Kerr black holes has been shown to be a possible explanation for some of the most violent and energetic phenomena in the universe, such as the supernovae producing gamma ray bursts, and jets in active galactic nuclei.

In recent years a wealth of new astronomical observations has provided strong evidence for the existence of rotating Kerr black holes. Most impressively, it has recently been shown from observations of matter falling into the supermassive black hole in the centre of our own galaxy that it must be rotating at close to half of the maximum rate allowed by the Kerr solution [3].

In future, the Kerr solution – and its numerical generalizations to describe neutron star and black hole mergers – will have a great role to play in understanding signatures of gravitational waves which we hope to detect over the next decade or two.

In the year of Roy Kerr's 70th birthday, we therefore believe it is timely to hold this Symposium to review these exciting recent advances and pay tribute to Roy and tremendous impact that his solution has had on astrophysics, general relativity and quantum gravity.

References

[1] S.W. Hawking, *A Brief History of Time* (Bantam Books, 1988), chapter 6.

[2] S. Chandrasekhar, *"Shakespeare, Newton, and Beethoven"*, Ryerson Lecture, University of Chicago, 1975; reprinted in S. Chandrasekhar, *"Truth and Beauty"*, (University of Chicago Press, 1987)

[3] R. Genzel et al., Nature **425** (2003) 934.

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Programme

All talks, unless otherwise indicated, are in Lecture Theatre 031, basement level Maths and Computer Sciences Building.

THURSDAY 26 August

8:30–9:20	Registration (Foyer, basement level, Maths building)
9:20–9:30	Opening remarks (David Wiltshire)
9:30–9:40	Official welcome (Roy Sharp, Vice-Chancellor)
	PLENARY TALKS (Morning Chair: David Wiltshire)
9:40–10:30	Brandon Carter [CNRS, Paris-Meudon, France] *Global and local problems with Kerr's solution*
10:30–11:10	Coffee
11:10–12:00	Maurice van Putten [LIGO / MIT, USA] *The endpoint of binary evolution: Singlets, doublets? Triplets!*
12:00- 1:30	Lunch
1:30–2:20	Gary Horowitz [U California, Santa Barbara, USA] *Higher dimensional generalizations of the Kerr black hole*
	CONTRIBUTED TALKS (Afternoon Chair: Anthony Lun)
2:20–2:45	Ishwaree Neupane [U Canterbury, New Zealand] *Anti-de Sitter/de Sitter correspondence and twisting S-branes*
2:45–3:10	Michael Kuchiev [UNSW, Australia] *Reflection from the horizon of black holes*
3:10–3:35	Victor Flambaum [UNSW, Australia] *Reflection on the horizon and absorption of scalar particles by black holes*
3:35–4:05	Coffee
4:05–4:30	Gabriela Slezakova [U Waikato, New Zealand] *Geodesics of Kerr black holes*
4:30–4:55	Stephen Fletcher [Monash U, Australia] *Novikov coordinates for the Kerr spacetime*
5:15–6:15	**Welcome Reception** (Room 701, 7th floor, Physics and Astronomy building)
	PUBLIC LECTURE (Lecture Theatre C1)
8:00–9:00	Fulvio Melia [U Arizona, USA] *The supermassive black hole at the centre of our galaxy*

FRIDAY 27 August

PLENARY TALKS (Morning Chair: Matt Visser)

9:00–9:50	Josh Goldberg [Syracuse U, USA] *Gravity and general relativity*
9:50–10:40	Susan Scott [ANU, Australia] *Can the Milky Way be weighed using Earth-based interferometry?*
10:40–11:10	Coffee
11:10–12:00	Andy Fabian [IOA, U Cambridge, UK] *Effects of strong gravity on X-ray spectra: observational evidence for Kerr black holes*
12:00–1:30	Lunch
1:30–2:20	Steve Carlip [U California, Davis, USA] *Horizon constraints and black hole entropy*

CONTRIBUTED TALKS (Afternoon Chair: Susan Scott)

2:20–2:45	Joey Medved [VUW, New Zealand] *The quantum Kerr black hole*
2:45–3:10	Stuart Wyithe [U Melbourne, Australia] *Formation and evolution of early super-massive black holes*
3:10–3:35	Andrew Melatos [U Melbourne, Australia] *Gravitational waves from X-ray millisecond pulsars with a polar magnetic mountain*
3:35–3:45	Group photo (assemble steps at MCSC main door)
3:45–4:15	Coffee
4:15–4:40	Andrew Moylan [ANU, Australia] *Visualisation in the Kerr space-time using GR work bench*
4:40–5:05	Sung-Won Kim [Ewha Women's University, Korea] *The Kerr metric and rotating wormhole*
5:05–5:30	Anthony Lun [Monash U, Australia] *On continued contraction of a rotating dust cloud to form a Kerr black hole*

SPECIAL TALK

5:30–6:00	Roy Kerr [U Canterbury, New Zealand] *Reminiscences: a personal spin on black holes*
7:00 for 7:30 pm	**Banquet** (University Staff Club, Ilam Homestead)

SATURDAY 28 August

	PLENARY TALKS	(Morning Chair: Robert Bartnik)
9:00–9:50	David Robinson [Kings College, London, UK] *Four decades of black hole uniqueness theorems*	
9:50–10:40	Remo Ruffini [ICRA, U Rome, Italy] *The ergosphere and dyadosphere of black holes*	
10:40–11:10	Coffee	
11:10–12:00	Zoltan Perjés [KFKI, RMKI, Budapest, Hungary] *The behaviour of principal null directions of a black hole under perturbations*	
12:00–12:50	Matt Visser [VUW, New Zealand] *Near horizon geometry for generic rotating black holes*	
12:50–1:00	Closing remarks	
1:15–5:15 (approx)	**Excursion** Lunch, scenic drive and visit to Rutherford's Den, and Canterbury Ring Laser	

Details of Social Events

WELCOME RECEPTION, Thursday 26 August

Drinks and finger food will be served. As this will not be a full meal, we are organising restaurant bookings (fixed menu meals to be in time for Public Lecture) at 6:30pm in the Indian and Chinese restaurants close to campus.

CONFERENCE BANQUET, Friday 27 August

This dinner in honour of Professor Roy Kerr will be held in the historic Ilam Homestead (Staff Club), 87 Ilam Road. (Peter Jackson's film *Heavenly Creatures* was filmed on location here in 1994.) A cash bar will be available from 7.00pm, with dinner commencing at 7.30pm. Wine will be provided on each table, and soft drinks can be ordered for those who do not drink alcohol. Other alcoholic beverages (beer, spirits) should be purchased from the cash bar downstairs by 8pm. Tickets ordered for the banquet are in your registration packet.

EXCURSION, Saturday 28 August

The Canterbury Ring Laser at Cashmere is the world's largest Sagnac interferometer, routinely measuring variations in the Earth's rotation (earthquakes, movement of the rotation axis induced by tidal torques etc) with a sensitivity of 5-10 billionths of the Earth's rotation rate. The effect of Lense-Thirring frame dragging by the Earth – which of course reaches its greatest manifestation in the Kerr black hole – is one to two orders of magnitude smaller than our present sensitivity, at 0.5 billionths of the basic rotation rate of the Earth.

The excursion will begin with lunch at the Arts Centre (old university campus) where delegates may also visit Ernest Rutherford's Den, followed by a scenic drive along the Port Hills crater rim from Sumner to Victoria Park and the Cashmere Cavern. (We split into two groups for the Cavern visit.) The bus will depart Creyke Road bus stop, opposite the Engineering School. Delegates will need to purchase their own lunches.

Abstracts

Special Talk

Roy P. Kerr (Emeritus Professor, Department of Mathematics and Statistics, University of Canterbury, NZ)

Reminiscences: A personal spin on black holes

(5:30–6:00 pm, Friday 27th)

Roy has been presented with the above title by the conference organisers with the brief that he captivate us for half an hour with a historical ramble in his laconic style through events just over 40 years ago which led to the discovery of what has been called by many "the most important solution of Einstein's equations".

Public Lecture

Fulvio Melia (Department of Physics, University of Arizona, USA)

The supermassive black hole at the centre of our galaxy

(8:00 pm, Thursday 26th – Lecture Theatre C1)

In the past, they were recognized as the most destructive force in nature. Now, following a cascade of astonishing discoveries, supermassive black holes have undergone a dramatic shift in paradigm – these objects may have been critical to the formation of structure in the early universe, spawning bursts of star formation and planets. As many as 300 million of them may now be lurking through the vast expanses of the observable cosmos. The most accessible among them appears to be lurking at the centre of our galaxy. In this talk, we will examine the evidence that has brought us to this point, and we will see why the astrophysical community is now looking with great anticipation to the imminent breakthroughs that will permit us to see the shadow of a black hole within this decade.

Plenary Talks

Steve Carlip (Physics Department, University of California, Davis, USA)
Horizon constraints and black hole entropy
(1:30–2:20 pm, Friday 27th)

To ask a question about a black hole in quantum gravity, one must restrict initial or boundary data to ensure that a black hole is actually present. For two-dimensional dilaton gravity, and probably a much wider class of theories as well, the imposition of a "stretched horizon" constraint alters the algebra of symmetries at the horizon, introducing a central term. Standard conformal field theory techniques can then then be used to obtain the asymptotic density of states, reproducing the Bekenstein-Hawking entropy. The microscopic states responsible for black hole entropy can thus be viewed as "would-be pure gauge" states that become physical because the symmetry is altered by the requirement that a horizon exist.

Brandon Carter (Observatoire de Paris, Meudon, France)
Global and local problems with Kerr's solution
(9:40–10:30 am, Thursday 26th)

In view of the current vogue for higher dimensional analogues — of doubtful relevance to reality — the unquestionable physical importance of Kerr's original 4-dimensional metric needs to be reiterated. What Kerr originally sought was an asymptotically flat Einstein metric with type D Weyl tensor, but what he found turned out to be a solution also for other interesting problems, characterised by alternative local conditions: as well as the Kerr-Schild ansatz, these include a succession of progressively more sophisticated separability properties that are interpretable in terms of the presence of a Killing–Yano tensor. However, what made the Kerr metric so important is the global property of being a solution — and indeed (as subsequent work has by now fairly rigorously established) the most general solution — of the equilibrium problem for an isolated uncharged black hole. Much modern astrophysical work is based on the presumption that Kerr's solution really does apply to what are prudently describable as "black hole candidates", but there is still no firm observational evidence for what, if confirmed, would finally establish that the validity of Einstein's theory is not restricted to the weak field regime.

Andy Fabian (Institute of Astronomy, University of Cambridge, UK)
Effects of strong gravity on X-ray spectra: observational evidence for Kerr black holes
(11:10 am –12:00, Friday 27th)

The X-ray spectra of accreting black holes, both in active galactic nuclei and stellar mass sources, often show a broad skewed iron emission line. The red wing of the line is predominantly due to gravitational redshift and in some cases indicates that the emission originates from only 2 to 3 gravitational radii. Large light bending effects at such small radii affect the variability in a manner consistent with observation. The data provide strong evidence for rapidly spinning, Kerr, black holes. Recent data and future prospects will also be discussed.

Joshua Goldberg (Department of Physics, Syracuse University, USA)

Gravity and general relativity

(9:00–9:50 am, Friday 27th)

Cosmological observations suggest possible modifications or breakdown of general relativity at the classical or phenomenological level. Some of these will be discussed.

Gary T. Horowitz (Physics Department, University of California, Santa Barbara, USA)

Higher dimensional generalizations of the Kerr black hole

(1:30–2:20, Thursday 26th)

Motivated by string theory, I will describe black hole solutions in more than four spacetime dimensions. In this case there are higher dimensional generalizations of black holes such as black strings. I will start with non-rotating solutions and discuss the instability of certain black strings and the recently discovered phase diagram for black holes and black strings. I will then discuss rotating solutions. In five dimensions, in addition to rotating black holes with horizon topology S^3, there are rotating black ring solutions which have topology $S^1 \times S^2$. These are qualitatively new objects in which the horizon is a ring supporting itself against collapse by rotation. Charged generalizations of these solutions have also been found.

Zoltan Perjés (Research Institute for Particle and Nuclear Physics, Budapest, Hungary)

The behaviour of principal null directions of a black hole under perturbations

(11:10–12:00 am, Saturday 28th)

Perturbations of the most general black hole states described by the Kerr metric have been studied by many researchers in the past decades. In many cases, such as in the works of Chandrasekhar, Detweiler, Teukolsky, Chrzanowski and Ori, the Newman–Penrose tetrad method has been employed for both the unperturbed quantities and for the small perturbations. In these works, a tacit assumption is initially made that all quantities belonging to the perturbed space-time, such as the spin coefficients and the Weyl spinor components are of equal order of magnitude. This implies that quantities which vanish for the Kerr metric are infinitesimal and all other quantities differ in an infinitesimal term from their values in the Kerr metric. The validity of this assumption is scrutinized here by taking into account the behaviour of observable quantities under perturbations. Former work of Christian and Sachs shows how the principal null directions can be observed by the reception of light signals. We show that the smooth behaviour of principal null directions under perturbations is incompatible with the notion that the components of the perturbed Weyl spinor are of like order. Hence we conclude that either the smooth behaviour of certain physical observable under perturbations must be given up, or the basic tenet of perturbative approaches to black holes, i.e., the equality of orders of magnitude has to be abandoned.

David C. Robinson (Mathematics Department, King's College, London, UK)

Four decades of black hole uniqueness theorems

(9:00–9:50 am, Saturday 28th)

The history and development of the uniqueness theorems for equilibrium black holes will be reviewed. Research from the 1960's until the present day will be surveyed and its mathematical and physical implications will be discussed.

Remo Ruffini (ICRA and University of Rome, Italy)

The ergosphere and dyadosphere of black holes

(9:50–10:40 am, Saturday 28th)

The work of Roy Kerr is today fundamental for approaching issues of relativistic astrophysics as diverse as the Gravity Probe B mission of NASA around our planet earth, the Binary X-Ray sources in our galaxy, the active galactic nuclei in the cosmos. No astrophysicist can work on these issues without daily recalling Kerr's work. Essential to the utilization of the Kerr solution has been the separability of the Hamilton Jacobi equation by Brandon Carter. I recall how starting from the work of Carter, by introducing with Wheeler an effective potential technique and the concept of "ergosphere", we obtained the Christodoulou-Ruffini energy mass formula of the black hole. The concept of extractable energy of a Black Hole, implied by this formula, plays today the fundamental role in understanding the energy source of gamma ray bursts (GRBs). The basic energetics of GRBs needs the introduction of the novel concept of a "dyadosphere" of a Black Hole. Reasons are given why the occurrence of a dyadosphere within the ergosphere of a Kerr black hole can be the key factor in understanding the astrophysics of jets in micro-quasars and active galactic nuclei.

Susan M. Scott (Centre for Gravitational Physics, Australian National University, Canberra)

Can the Milky Way be weighed using Earth-based interferometry?

(9:50–10:40, Friday 27th)

It was recently claimed that the mass of the Milky Way can be measured using a small 10 cm Michelson-type interferometer located on the surface of the Earth. Using the Kerr metric to model the Earth located in the gravitational field of the Galactic centre, light travel times were calculated along the orthogonal directions of the interferometer arms. The difference in travel times was proportional to the Galactic mass and the size of the effect was claimed to be measurable.

We have investigated the claim, both analytically and computationally, and found it to be an artifact of the simplifying assumptions employed in the analysis. The physical situation pertaining to the claim has been modeled in a numerical experiment in GRworkbench, an ongoing project in visual, numerical General Relativity at The Australian National University, without the necessity of making any simplifying assumptions. An accurate estimate of the effect for the Milky Way, the Sun and the Earth has been obtained.

Maurice H.P.M. van Putten (LIGO, Massachusetts Institute of Technology, USA)
The endpoint of binary evolution: Singlets, doublets? Triplets!
(11:10 am–12, Thursday 26th)

We discuss the nucleation and evolution of black holes in core-collapse of massive stars in binaries. With low probability, the newly formed black hole remains centered and matures into a high-mass rotating black hole, if the binary is compact. Type Ib/c supernovae are associated with the parent population of de-centred events, wherein the black hole leaves the core prematurely. All de-centred events should produce a single short burst in gravitational radiation. Centered events are predicted to produce a second, long burst in gravitational radiation powered by a luminous black hole, representing a triplet gamma ray burst–supernova–gravitational wave burst. These signatures are of interest to the gravitational-wave experiments LIGO, VIRGO and TAMA, and provide a method for calorimetric evidence for Kerr black holes.

Matt Visser (School of Mathematical Sciences, Victoria University of Wellington, NZ)
Near horizon geometry for generic rotating black holes
(12:00–12:50 pm, Saturday 28th)

A popular explanation for the microscopic origin of Bekenstein's black hole entropy is the conjecture that this entropy can be ascribed to a collection of (1+1) dimensional conformal field theories that reside at the horizon, and defined on the two-plane perpendicular to the horizon. If this is to be the case, then the Einstein equations must force the Ricci curvature to possess a high degree of symmetry at the horizon. We test this hypothesis by working directly with the spacetime geometry for a generic rotating black hole — constrained only by the existence of a stationary non-static Killing horizon, and with otherwise arbitrary matter content — to show that the Einstein tensor block diagonalizes on the horizon. This is a specific example of an "enhanced symmetry" that manifests only at the horizon itself.

Contributed Talks

Victor Flambaum (School of Physics, University of New South Wales, Australia)
Reflection on the horizon and absorption of scalar particles by black holes
(3:10–3:35 pm, Thursday 26th)

Quantum scattering of particles by black holes is governed by two different processes. One of them, which is well known, is due to those processes that take place outside the horizon; it is often called the greybody factor. Another one is related to the recently discovered effect of reflection on the horizon. This quantum phenomenon is due to those effects that take place strictly on the horizon. The present work shows that the reflection on the horizon has a very strong qualitative impact on the absorption cross section. The classical work of Unruh (1976) showed that the absorption cross section for low energy particles equals the area of the horizon. However, the reflection on the horizon reduces this cross section, making it zero in the infrared limit (i.e. for very low energies). This effect diminishes ability of black holes to accumulate matter, which may have numerous implications. For example, it may be very important during formation of small primordial black holes. It is argued that the effect has a general bearing, it should manifest itself for different impact particles and different black holes, including the Kerr rotating black holes.

Reference

[1] M.Yu. Kuchiev and V.V. Flambaum, *Scattering of scalar particles by a black hole*, Phys. Rev. **D** (2004) accepted for publication; gr-qc/0312065.

Steven J. Fletcher (School of Mathematical Sciences, Monash University, Australia)
Novikov coordinates for the Kerr spacetime
(4:30–4:55 pm, Thursday 26th)

By referring to the geodesic equations we demonstrate a simple method for deriving Novikov's freely falling coordinates for the Schwarzschild spacetime. We extend the method to show that it is also possible to introduce Novikov type coordinates for the Kerr spacetime. After analyzing the geometry of the freely falling surfaces of constant specific energy we discuss their significance as possible boundary surfaces for rotating collapsing clouds of dust.

Sung-Won Kim (Department of Science Education, Ewha Women's University, Seoul, Korea)

The Kerr metric and rotating wormhole

(4:40–5:05 pm, Friday 27th)

The rotating wormhole is developed in most stationary and axially symmetric spacetime. The freedom to cast the metric into spherical polar coordinates is used for obtaining the proper rotating wormhole model. The geometrical properties of this model is discussed in the context of the Kerr black hole.

Michael Kuchiev (School of Physics, University of New South Wales, Australia)

Reflection from the horizon of black holes

(2:45–3:10 pm, Thursday 26th)

Usually it is presumed that any particle that approaches the event horizon of a black hole crosses the horizon quite smoothly and then stays inside. However, it has been argued recently [1–3] that this physical picture holds only in the classical approximation. Quantum corrections amend it qualitatively, making possible the reflection on the horizon. In other words, any particle that approaches the horizon can bounce back in the outside world. The reflection is strong for low energy particles, which makes black holes almost perfect reflectors in the infrared region. The effect of reflection shares its physical origins with the Hawking radiation phenomenon, they both rely on quantum processes that take place in the strong gravitational field strictly on the event horizon. The effect is bound to produce a number of consequences, including physics of the Kerr black holes.

References

[1] M.Yu. Kuchiev, *Reflection, radiation and interference for black holes,* Phys. Rev. **D** (2004) scheduled for the June issue; gr-qc/0310051.

[3] M.Yu. Kuchiev, *Reflection from black holes and space-time topology*, Europhys. Lett. 65 (2004) 445-451; gr-qc/0310134.

[3] M.Yu. Kuchiev, *Reflection from black holes*, gr-qc/0310008.

Anthony W.C. Lun (School of Mathematical Sciences, Monash University, Australia)

On continued contraction of a rotating dust cloud to form a Kerr black hole

(5:05–5:30 pm, Friday 27th)

We construct in comoving coordinates an exact solution of a contracting rotating dust solution, which joined smoothly onto the Kerr metric. The solution evolves to form a Kerr black hole. When the angular momentum parameter, a, is set to zero, the solution reduces to the classical collapsing dust solution of Oppenheimer and Snyder.

Joey Medved (School of Mathematical Sciences, Victoria University of Wellington, NZ)

The quantum Kerr black hole

(2:20–2:45 pm, Friday 27th)

A long time ago, Bekenstein argued, on heuristic grounds, that a quantized black hole should have a discrete and uniformly spaced area spectrum. Notably, there has since been many rigorous calculations in support of these arguments. Nonetheless, there has been very little progress in generalizing this notion to a Kerr (rotating) black hole. In this talk, I will review a paper in which we did, after all, derive the Kerr area spectrum and, moreover, cast it in a form that complies perfectly with Bekenstein's mandate.

A. Melatos and D.J.B. Payne (School of Physics, University of Melbourne, Australia)

Gravitational waves from X-ray millisecond pulsars with a polar magnetic mountain

(3:10–3:35 pm, Friday 27th)

The hydromagnetic structure of a neutron star accreting symmetrically at both magnetic poles is calculated numerically as a function of accreted mass, starting from a centered magnetic dipole and evolving through a quasistatic sequence of two-dimensional Grad-Shafranov equilibria. Our calculation is the first to solve self-consistently (by respecting flux freezing) for the distribution of accreted matter and magnetic flux as a function of stellar latitude. We find that $10^{-5}M_{\rm solar}$ must be accreted before the magnetic field is distorted enough to appreciably reduce the magnetic dipole moment, well above earlier estimates of $10^{-10}M_{\rm solar}$. Moreover, the magnetic field is compressed locally up to 10^3 times its initial strength, deforming the crust significantly and creating a sizable, inclined mass quadrupole (epsilon $\sim 10^{-7}$ for $10^{-1}M_{\rm solar}$ accreted — a polar magnetic mountain. We predict the amplitude of the gravitational wave signal from objects undergoing magnetic field burial by accretion, principally X-ray millisecond pulsars, and calculate their evolution in the spin period-magnetic moment plane. We also investigate related processes that affect the evolution of the mass quadrupole and hence the gravitational wave signal: detachment of magnetic bubbles above $10^{-4}M_{\rm solar}$, disruption of the distorted magnetic field by hydromagnetic (Parker and interchange) instabilities, sinking of the magnetic mountain, and relaxation by Ohmic diffusion.

Andrew Moylan (Dept of Physics, Faculty of Science, Australian National University, Canberra)

Visualisation in the Kerr space-time using GRworkbench

(4:15–4:40 pm, Friday 27th)

The GRworkbench software, an ongoing project at The Australian National University, facilitates visualisation of, and numerical computation in, exact solutions to the Einstein field equation. Space-times, such as the Kerr black hole solution, are defined by the metric components as a function of position on one or more charts, together with the maps between the charts. GRworkbench is then able to perform numerical operations, such as integration of the geodesic equation, by automatically computing any required quantities which are dependent on the metric and its derivatives. Objects in four-dimensional space-times are visualised by projecting them under arbitrary transformations to a three-dimensional visualisation space, which is then viewable by the user from any position and angle.

Ishwaree P. Neupane (Department of Physics and Astronomy, University of Canterbury, NZ)

Anti-de Sitter/de Sitter correspondence and twisting S-branes

(2:20–2:45 pm, Thursday 26th)

We compute the conserved quantities for some classes of anti-de Sitter and de Sitter black hole spacetimes in diverse dimensions. The quantities in de Sitter spacetime match with those in anti-de Sitter black hole spacetime but when the horizon of the latter is a Euclidean (hyperbolic) space. This led us to conjecture that de Sitter holography is mapped to an anti-de Sitter space whose boundary is a constant negative curvature manifold; the latter space normally breaks the supersymmetry as does its de Sitter counterpart.

We also present some smooth time dependent supergravity solutions that correspond to analytic continuations of Kerr black holes.

Gabriela Slezáková (Department of Mathematics, University of Waikato, NZ)

Geodesics of Kerr black holes

(4:05–4:30 pm, Thursday 26th)

A geodesic is a curve such that its tangent is transported parallel with it. I shall explain how geodesics are classified, describe a method of finding solutions of equations by which geodesics are governed, and illustrate orbits derived on the basis of these solutions. Equatorial geodesics of all three types of the Kerr black holes will be considered ("slow Kerr": $a < M$, "extreme Kerr": $a = M$, and "fast Kerr": $a > M$), and a few examples of orbits out of equator will be presented, too.

Stuart Wyithe (School of Physics, University of Melbourne, Australia)

Formation and evolution of early super-massive black holes

(2:45–3:10 pm, Friday 27th)

The most massive black-holes known reside in the centers of massive galaxies, and weigh as much as 1–10 billion solar masses. Accretion onto these super-massive black-holes is thought to power quasars, which are seen throughout most of the history of the universe. The most distant quasars known imply that some super-massive black-holes had already formed within the first billion years after the big-bang. A picture is now emerging where super-massive black-hole growth at these early epochs proceeds via accretion and coalescence within the context of a standard hierarchically merging cold dark matter universe. This picture naturally explains the observed abundance and luminosity distribution of high redshift quasars, as well as the properties of their spatial clustering. Of particular interest is the result that clustering statistics suggest that super-massive black-hole mass depend on the depth of the potential well in which it formed.

Curriculum Vitae: Roy P. Kerr

PERSONAL INFORMATION

Born:	Kurow, New Zealand	16 May 1934
Married:	Joyce Marie	1955-84
Married:	Margaret Anne	1984-
Children:	Susan Marie	b. 8 July 1959; d. 11 December 1966
	Robin Anne	b. 21 January 1963
	Christopher Martin	b. 20 January 1966
	Patrick Seamus Gordon	b. 13 August 1983
	Sarah Jane Margaret	b. 13 December 1985

EDUCATION

School	St Andrews College	Dux	1950
		University Entrance Scholarship	1950
University	**Canterbury U.**	M.Sc.	1951-54
		Senior Scholarship	1953
		Cook Memorial Prize	1955
	Cambridge U.	Ph.D.	1955-59
		Sir Arthur Sims Scholarship	1955-57

PRESENT POSITION

Professor Emeritus (Retired)	Canterbury U.	1993-

PAST POSITIONS HELD

Research Associate	Syracuse U.	1958-60
Research Physicist	ARL, WPAFB, Dayton, Ohio	1960-63
Associate Professor	U. Texas, Austin	1963-67
Full Professor	U. Texas, Austin	1967-71
Professor	Canterbury U.	1971-83
Head of Department	Canterbury U.	1983-91
Head, International Research Group,	National Academy of Sciences, KFKI, Budapest	1991-93
Professor	Canterbury U.	1992-93

AWARDS

Fellow	Royal Society of N.Z.	1976
Hector Medal	Royal Society of N.Z.	1982
Hughes Medal	Royal Society of London	1984
Rutherford Medal	Royal Society of N.Z.	1993

GRADUATE STUDENTS

D. Farnsworth	U. Texas at Austin	1966
G. C. Debney	U. Texas at Austin	1967
M. Mezzino	U. Texas at Austin	1971
R. Wilson	U. Texas at Austin	1971
G. J. Weir	Canterbury U.	1976
W. D. Halford	Massey U.	1977

PUBLICATIONS

1. *"On the Spherically Symmetric Solutions in Moffat's Unified Field Theory"*,
Nuovo Cim. **X8**, 789 (1958).

2. *"The Lorentz-covariant Approximation Method in General Relativity - I"*,
Nuovo Cim. **X13**, 469 (1958).

3. *"The Lorentz-covariant Approximation Method in General Relativity - II, The Second Approximation"*,
Nuovo Cim. **X13**, 492 (1959).

4. *"The Lorentz-covariant Approximation Method in General Relativity - III, Einstein-Maxwell Fields"*, Nuovo Cim. **X13**, 673 (1959).

5. *"On the Quasi-static Approximation in General Relativity"*,
Nuovo Cim. **X16**, 26 (1960).

6. *"Some Applications of the Infinitesimal Holonomy Group to the Petrov Classification of Einstein Spaces"*, (with J.N. Goldberg), J. Math. Phys. **2**, 327 (1961).

7. *"Einstein Spaces with Four Parameter Holonomy Groups"*, (with J.N. Goldberg),
J. Math. Phys. **2**, 332 (1961).

8. *"Scalar Invariants and Groups of Motions in a V_n with Positive Definite Metric Tensor"*,
Tensor **12**, 74 (1961).

9. *"Scalar Invariants and Groups of Motions in Four Dimensional Einstein Spaces"*,
J. Math. Mech. **12**, 33 (1963).

10. *"The Gravitational Field of a Spinning Mass as an Example of Algebraically Special Metrics"*, Phys. Rev. Lett. **11**, 237 (1963).

11. *"Asymptotic Properties of the Electromagnetic Field"* (with J.N. Goldberg),
J. Math. Phys. **5**, 172 (1964).

12. *"A new Class of Vacuum Solutions of the Einstein Field Equations"* (with A. Schild),
Atti del Congregno Sulla Relativita Generale: Galileo Centenario, (1965).

13. *"Some Algebraically Degenerate Solutions of Einstein's Gravitational Field Equations"* (with A. Schild), Proc. Symp. Appl. Math. **17** (1965).

14. *"Homogeneous Dust Filled Cosmological Solutions"* (with D. Farnsworth),
J. Math. Phys. **7**, 1625 (1966).

15. *"Solutions of the Einstein and Einstein-Maxwell Field Equations"* (with G.C. Debney and A. Schild), J. Math. Phys. **10**, 1842 (1969).

16. *"Einstein Spaces with Symmetry Groups"* (with G.C. Debney),
J. Math. Phys. **11**, 2807 (1970).

17. *"Diverging Type-D Metrics"* (with G.J. Weir),
Proc. Roy. Soc. London **A 355**, 31 (1977).

18. *"Singularities in the Kerr-Schild Metrics"* (with W.B. Wilson),
Gen. Rel. Grav. **10**, 273 (1979).

19. *"Einstein Spaces and Homothetic Motions: I"* (with W.D. Halford), J. Math. Phys. **21**, 120 (1980).

20. *"Gravitational Fields in General Relativity"* in *"Spacetime and Geometry"*, the A. Schild memorial volume, Univ. of Texas Press, 102 (1982).

21. *"A General Theorem on Gravitational Metrics in Prolate Spheroidal Coordinates"*, Proc. CMA Aust. Nat. Univ. **19**, 196 (1988).

22. *"A Simplified Representation of Stationary Axially Symmetric Metrics"* (with W.B. Wilson), in *Proc. Fifth Marcel Grossmann Conf.*, Ed. R. Ruffini, 507 (1989).

23. *"On Stationary Axially-Symmetric Gravitational Metrics of Rational Type"*, Atti del Convegno Int. Fisica Matematica Classica e Relativita, 144 (1990).

24. *"Einstein Vacuum Field Equations with a Single Non-null Killing Vector"* (with E.D. Fackerell), Gen. Rel. Grav. **23**, 861 (1991).

25. *"Relativity Today: Proceedings of the Fourth Hungarian Relativity Workshop"* (edited with Z. Perjés), (Akadémiai Kiadó, Budapest, Hungary, 1994).

Guest Book

We have placed a Guest Book online at the website, so that those who cannot make it to the Symposium can send their messages to Roy. Here are messages received as of the time of printing.

Dear Roy, I'm really sorry not to be with you to celebrate your achievements, and your attainment of 'years of discretion'! It is wonderful that we now know that there are zillions of 'Kerr solutions' throughout the cosmos. I'm glad that my colleague Andy Fabian will be there – he's done more than anyone to firm this evidence up. All good wishes. Martin Rees
Martin Rees UK
– Friday, August 13, 2004 at 20:40:33 (NZST)

Greetings to the Lord of the confocal parabolic(?) Rings on this major event! All we earthlings are duly grateful for the many papers made possible by your own; some of us — such as the undersigned — are still trying to find an easy way to understand one of them! It has been a long time since we met in this hemisphere, but I remember the good old days when GR was young (again) and the living was – if not easy– at least always rewarding! Happy big birthday, Stanley
Stanley Deser ⟨`deser@brandeis.edu`⟩ *USA*
– Saturday, August 14, 2004 at 06:37:57 (NZST)

Dear Roy, I have enormous respect and enthusiasm for your contributions to mathematical physics. I wish I could be in New Zealand to celebrate your birthday with you. My warm wishes for a great celebration amidst good friends. Kip
Kip Thorne ⟨`kip@tapir.caltech.edu`⟩ *USA*
– Saturday, August 14, 2004 at 10:19:39 (NZST)

Dear Roy, You know that your solution is the main point of my scientific activity. But it is really connected with all branches of the modern physics: from Cosmos to Superstrings up to Planckian scale. I wish you good health and long years of further activity. It is a very great pity that I will not be able to see you now, but maybe you will be able to visit Moscow. It would be fine, and I could try to do my best for such a visit. Please accept my heartiest congratulations on the occasion of your Jubilee. Yours, Alexander
Alexander Burinskii ⟨`bur@ibrae.ac.ru`⟩ *Russia*
– Tuesday, August 17, 2004 at 21:57:01 (NZST)

Dear Roy, Congratulations on your birthday and for making it possible for so many people to enjoy learning about the extraordinary properties of a metric that you liked to call 'spinning Schwarzschild'. Best wishes
John D. Barrow UK
– Friday, August 20, 2004 at 01:22:07 (NZST)

Dear Roy, Happy birthday ! We have never met. But I have been influenced by your achievement in unveiling the Kerr metric since my postdoc days in Austin in the early seventies. There I heard stories about you and the discovery from the late Alfred Schild. And who can work on black holes without bumping all the time into your blessed solution? Just a few years back two of my graduate student showed me how one can deduce classically that black hole entropy has to be proportional to black hole area just from the elementary properties of

the Kerr metric. There is scarcely a result in gravitation theory which can compare to your metric it in manifold uses—black hole physics, astrophysics, quantum gravity—you name it. I wish we could have met at this august occasion. But all the same, my best wishes to you for many happy returns, good health and continued scientific productivity. Jacob D. Bekenstein
Jacob D. Bekenstein ⟨bekenste@vms.huji.ac.il⟩ *Israel*
– Saturday, August 21, 2004 at 01:01:53 (NZST)

Dear Roy, I wish you an happy birthday. I was so happy to share with you the living room of our two apartments in Cochin last February! It was nice to meeting you also in Bangalore. I hope that the conference will be very nice for you, and wish you all the best for the coming years. Sincerely yours, Luc Blanchet
Luc Blanchet ⟨blanchet@iap.fr⟩ *France*
– Tuesday, August 24, 2004 at 01:42:44 (NZST)

Dear Roy, Happy birthday! It will soon be half–a–century since we were colleagues together at Cambridge. You may recollect that we even wrote a paper together on deriving equations of motion from GR. I believe that we did meet again after Cambridge at some conference, but the time and its location escape my memory. Your black hole solution was a great discovery. I hope you have a successful Fest and that this finds you in good health. Best Regards, John.
John Moffat ⟨jmoffat@perimeterinstitute.ca⟩ *Canada*
– Tuesday, August 24, 2004 at 04:53:09 (NZST)

Dear Roy, Congratulations on your having reached a significant age milestone. Congratulations also for the recognition and honors you have won. When I met you at Wright Field, I did not realize you were about to describe the fate of all the stars in the universe. Sorry I cannot be at the Kerr Fest in person. With best wishes, Louis Witten
Louis Witten ⟨witten@physics.uc.edu⟩ *USA*
– Tuesday, August 24, 2004 at 06:06:02 (NZST)

Participants

Peter Adshead	University of Canterbury, Christchurch, NZ
Frank Andrews	Carter Obervatory, Wellington, NZ
Robert Bartnik	University of Canberra, Australia
Petarpa Boonserm	Victoria University of Wellington, NZ
Steve Carlip	University of California at Davis, USA
Benedict Carter	University of Canterbury, Christchurch, NZ
Brandon Carter	CNRS, Paris-Meudon, France
Celine Cattoen	Victoria University of Wellington, NZ
Chang-Kui Duan	Chongqing UPT, China; and University of Canterbury, Christchurch, NZ
Guntar Elepans	Wellington, NZ
Natalie Elepans (née Kerr)	Wellington, NZ
Andy Fabian	IOA, University of Cambridge, UK
Victor Flambaum	University of New South Wales, Sydney, Australia
Stephen Fletcher	Monash University, Melbourne, Australia
Adam Gillard	University of Canterbury, Christchurch, NZ
Joshua Goldberg	Syracuse University, USA
Scott Green	University of Canterbury, Christchurch, NZ
Niels Gresnigt	University of Canterbury, Christchurch, NZ
Dean Halford	Massey University, Palmerston North, NZ
Marilyn Head	Wellington, NZ
Stephanie Hickford	University of Canterbury, Christchurch, NZ
Gary Horowitz	University of California at Santa Barbara, USA
William Joyce	University of Canterbury, Christchurch, NZ
Roy Kerr	University of Canterbury, Christchurch, NZ
Sung-Won Kim	Ewha Women's University, Seoul, Korea
Michael Kuchiev	University of New South Wales, Sydney, Australia
Ben Leith	University of Canterbury, Christchurch, NZ
Yiing Leong	University of Canterbury, Christchurch, NZ
Stephano Liberati	SISSA, Trieste, Italy
Keiran Lond	University of Canterbury, Christchurch, NZ
Anthony Lun	Monash University, Melbourne, Australia
Luz Maria Sanchez	University of Canterbury, Christchurch, NZ
Damien Martin	Victoria University of Wellington, NZ
Joey Medved	Victoria University of Wellington, NZ
Andrew Melatos	University of Melbourne, Australia
Fulvio Melia	University of Arizona, USA
Andrew Moylan	Australian National University, Canberra, Australia
Ishwaree Neupane	University of Canterbury, Christchurch, NZ
Alex Nielsen	University of Canterbury, Christchurch, NZ
Andrew Norton	University of Technology, Sydney, Australia

Hiroshin Okamura	Kogakuin University, Tokyo, Japan
Zoltan Perjés	KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary
Lydia Philpott	Australian National University, Canberra, Australia
Angus Prain	University of Canterbury, Christchurch, NZ
Giles Reid	University of Canterbury, Christchurch, NZ
David Robinson	King's College London, UK
Remo Ruffini	ICRA, University of Rome, Italy
Susan Scott	Australian National University, Canberra, Australia
Marni Sheppeard	University of Canterbury, Christchurch, NZ
Gabriela Slezáková	University of Waikato, Hamilton, NZ
Ewan Stewart	KAIST, Seoul, Korea; and University of Canterbury, Christchurch, NZ
Rob Taylor	Auckland, NZ
Maurice Van Putten	LIGO / Massachusetts Institute of Technology, USA
Matt Visser	Victoria University of Wellington, NZ
Marsha Weaver	University of Canberra, Australia
Silke Weinfurtner	Victoria University of Wellington, NZ
Graham Weir	IRL, Lower Hutt, NZ
Karl Wette	Australian National University, Canberra, Australia
Ben Whale	Australian National University, Canberra, Australia
Angela White	Australian National University, Canberra, Australia
David Wiltshire	University of Canterbury, Christchurch, NZ
Stuart Wyithe	University of Melbourne, Australia