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1 Introduction

The School is generally strong in central areas of pure and applied mathematics and in mathematical statistics—see Appendix A. Pure Mathematics, in particular, is listed amongst the University of Sydney’s “Institutional Research Strengths”—see Appendix B. In addition, several new areas of strength are emerging—see Appendix C.

Each member of staff is a member of a Research Group. These Groups were formed to promote and encourage the research effort through common-interest activities.

There are currently 4 Research Groups, with the largest one, Pure Mathematics, having a subgroup structure:

- Applied Mathematics
- Nonlinear Mathematics
- Pure Mathematics
  - Algebra
  - Analysis
  - Categories and Combinatorics
  - Computational and Discrete Mathematics
  - Geometry and Topology
- Statistics.

After listing the members of the School, we describe the research highlights for 2001, dividing them according to the separate groups and subgroups. We then describe the activities of the groups in greater detail. Several members of staff are active in research into mathematical education, and their activities are then described. We then describe our other research activities, listing postgraduate degrees awarded, honours and vacation students, and seminars and meetings.


2 Members of School

Professors
John Joseph Cannon, MSc PhD
Edward Norman Dancer, BSc ANU PhD Camb., FAA
Gustav Isaac Lehrer, PhD Warw. BSc, FAA (currently Senior Research Fellow)
John Robinson, BSc Qld. PhD
Eugene Seneta, MSc Adel. PhD A.N.U., FAA

Readers
Donald I. Cartwright, PhD Ill. BSc
Jonathan A. Hillman, BSc W.Aust. AM Harv. PhD A.N.U.
King-Fai Lai, BSc Lond. MPhil PhD Yale

Associate Professors
Christopher J. Durrant, MA PhD Camb.
Terence M. Gagen, BSc Qld. PhD A.N.U.
William G. Gibson, MSc Cant. PhD N.S.W.
Robert B. Howlett, BA PhD Adel.
Ronald W. James, BSc PhD
Charles C. Macaskill, BSc PhD Adel.
Malcolm P. Quine, MSc Lond. PhD A.N.U.
Donald E. Taylor, MSc Monash DPhil Oxf.
Neville C. Weber, MSc PhD

Director of First-Year Studies

Senior Lecturers
Peter W. Buchen, PhD Camb. BSc
Koo-Guan Choo, BSc Nan. MSc Ott. PhD Br Col.
Christopher M. Cosgrove, BSc PhD
David Easdown, BA A.N.U. PhD Monash
Roger W. Eyland, PhD Camb. MSc
David J. Galloway, BA PhD Camb.
Hugh C. Luckock, BSc Auck. PhD N’cle (UK)
Gordon P. Monro, BSc Monash PhD Brist.
Mary R. Myerscough, DPhil Oxf. BSc
Nigel R. O’Brian, MA Camb. PhD Warw.
M. Shelton Peiris, DipMath MSc Peradeniya PhD Monash
Mary C. Phipps, MSc
James N. Ward, BSc PhD (on secondment)
Karl H. Wehrhahn, BSc Alta PhD
Lecturers
Sandra C. Britton, BSc N.S.W. MA
Howard D’Abrera, PhD Calif. BSc
Daniel Daners, PhD Zurich
Humphrey Gastineau-Hills, MSc PhD
Jenny Henderson, DipEd Flin. MSc
David J. Ivers, BSc PhD
Andrew P. Mathas, BSc MSc PhD Ill.
Alexander I. Molev, Diploma PhD Moscow
Adrian M. Nelson, PhD Lond. BSc
Marc Raimondo, MSc DipStats PhD Paris
Rosemary S. Thompson, BSc A.N.U. PhD

Associate Lecturers
Michael Stewart, BSc MA

Senior Research Fellows
Professor Gustav Isaac Lehrer, PhD Warw. BSc
Ruibin Zhang, BSc Shandong PhD Tas.

Postdoctoral Fellows
Stephen G. Lack, BSc PhD Cam.
Joost van Hamel, PhD Amsterdam
Shusen Yan, MS South China Uni. Tech. PhD Wuhan Inst.

Senior Research Associates
Scott P. Contini, BSc Purdue MSc Georgia MSc Wisc.
Claus Fieker, Diplom Düsseldorf PhD Tech. Univ. Berlin
Leslie Farnell, MA PhD Oxf. DipEd Canberra
David R. Kohel, BSc Texas A& M PhD Berkeley
Laurentiu Paunescu, MSc Bucharest PhD
Allan Steel, BSc
William R. Unger, BSc PhD
Nanhua Xi, BSc Huaihua Inst. MSc PhD East China Normal

Research Associates
Geoffrey Bailey, BSc
Volker Gebhardt, Diplom Erlangen PhD Essen
Quingguang Huang, MSc Shandong PhD U.N.E.
Paulette Lieby, BSc Northern Territory University PhD NTU
Benjamin M.S. Martin, BSc Otago PhD London
Jane Sexton, BSc PhD Qld.

Senior Research Assistants
Bruce Cox, BSc
Research Assistants
Anne O’Kane, BA MPhil
Nicole Sutherland, BSc Macquarie
Ben Smith, BSc
Greg White, BSc

Visiting Professors
Richard Cowan, BSc, GradDip (OR), PhD U.N.S.W.
Nick Fisher, BSc MSc, PhD North Carolina, DSc
Graeme Bryce Segal, DPhil Oxf. BSc

Emeritus Professors
Gregory Maxwell Kelly, BA PhD Camb. BSc, FAA
Gordon Elliott Wall, BSc Adel. PhD Camb., FAA
Peter Robert Wilson, BA MSc Melb. PhD, FRAS

Honorary Reader
Tzee-Char Kuo, BS Natnl Taiwan PhD Chic.

Honorary Associate Professors
Edward D. Fackerell, MSc PhD
John J. Mack, MA Camb. BSc PhD
Robert F.C. Walters, MSc Qld. PhD A.N.U.
Denis E. Winch, MSc PhD, FRAS

Honorary Senior Lecturer
W. Barrie Fraser, BSc ME Cant. SM PhD Harv.
3 Research highlights in 2001

3.1 Applied:

Research activities in Financial Mathematics under the leadership of Buchen continued in 2001 with 3 new research students starting projects. These include Ho-Shon who began an MSc on pricing two asset rainbow options, Bertram studying self-similar, long-memory stock price models and Geninsson who started a project on stochastic volatility models. Rodolfo continued his research on developing theoretical and computational models for American (early exercise) options and Kyng has switched the emphasis of his research to pricing Asian options. Buchen made significant progress in developing a new methodology for pricing a large class of exotic options using the method of images coupled with arbitrage free static hedging. PhD student Otto Konstandatos is continuing this development with application to pricing non-standard barrier and lookback options.

Jomaa and Macaskill refined a method for solving the Poisson equation in an irregular domain. Macaskill and Gray worked with Zhang on a University Sesquicentenary R and D Scheme supported project on spontaneous ignition of an assembly of self-heating packages inside a shipping container. Professor David Dritschel, University of St Andrews, visited for 3 weeks to conduct collaborative work with Macaskill and Schaerf on applications of the CASL method in geophysical fluid dynamics.

The solar physics group (Durrant, McCloghan, Turner, Wilson) has continued its study of the evolution and reversals of the Sun’s high-latitude and polar magnetic fields during Cycle 23, using both synoptic maps of the large-scale fields obtained from the National Solar Observatory at Kitt Peak and high resolution mosaics obtained at the Big Bear Solar Observatory. The study concerns the relationship between the evolution of the large-scale patterns and the emergence of both small and large-scale flux at high-latitudes. Simulations of the large-scale patterns using the flux-transport equation have been compared with observations in order to test models of the emerging flux. Wilson visited the Big Bear Solar Observatory, CA, and the High Altitude Observatory, CO, (HAO) in April-May, 2001. Galloway conducted research into magnetohydrodynamic waves in the convection zone of the Sun, and the limiting effect of the Lorentz force on the growth of magnetic fields in astrophysical fast dynamos. Galloway and colleagues from the School of Physics also investigated models for reconnection processes in solar flares.

The geomagnetic and geodynamo group continued work on geomagnetic data analysis and dynamo theory for the Earth. Ivers completed and benchmarked a pseudo-spectral dynamically-consistent spherical shell dynamo code, which forms the basis of a computational laboratory for dynamo studies. Ivers, Stening (UNSW), Turner and Winch used signal processing techniques to analyse the longitudinal behaviour of the equatorial electrojet in magnetic data from the Danish satellite oersted. Bachtiar and James began a large computational investigation of the possibility of supporting magnetic dynamos in conducting spheres by purely planar flows.

Fraser continued his work continues on the “Indian rope trick”, the stability of other parametrically excited systems, and also on the application of nonlinear elastic rod theory to yarn twisting dynamics in various textile yarn manufacturing machinery. He made collaborative research visits to the Technical University of Budapest, the University of Bristol, and University College London.
3.2 Nonlinear:

- **Dancer** was one of the organizers of a very successful semester-length program (January –July) on nonlinear partial differential equations at the Newton Institute in Cambridge. He also gave one of the main lectures at international mathematical meetings in Rome and Sherbrooke (Canada). He continues to work on differential equations and nonlinear analysis.

- **Myerscough** worked on modelling of self-organization of social insect communities, especially honeybees. With Melissa Cox, she completed work on modelling the effects of individual variation on foraging efficiency in honeybees. In collaboration with Dr Ben Oldroyd of the School of Biological Sciences and Sonia Graham, she worked on task allocation models. In collaboration with Dr Madeleine Beekman she started work on mathematical modelling of hygienic behaviour in bees. In December she presented a paper on foraging at a workshop on Organisation of Social Insects, held at the Isaac Newton Institute in Cambridge.

Colonies of social insects such as ants, bees and termites, are made up of a large number of individuals. Each colony works as a unit to find food, construct a home and rear brood. Yet each individual in the colony has limited information about the colony needs and only a comparatively limited repertoire of behaviours. Mathematical models enable the effect of individual behaviours on the whole colony to be examined quickly and easily and so are a very useful tool in exploring how such insect colonies self-organise. Last year Dr Myerscough researched the effect of individual variation on colony-wide foraging efficiency; how insects self-allocate tasks; and the individual behaviours in bees which enable the colony to dispose of diseased brood and so remain healthy. This work is pursued in collaboration with the Bee Lab, headed by Dr Ben Oldroyd in the School of Biological Sciences and supported by an ARC Project Grant to Drs Oldroyd and Myerscough.

3.3 Algebra:

The symmetry inherent in the laws of physics motivated Lie’s nineteenth century investigation of continuous transformation groups, leading to the development of the branch of mathematics now known as Lie Theory. The algebraic structures associated with Lie theory are of central importance in mathematics, having applications in many areas: geometry, topology, analysis, mathematical physics. Much of the research conducted by members of the Algebra Group is in this general area.

In 2001 **Mathas** classified the tilting modules of the cyclotomic $q$-Schur algebras; these are an important class of modules which give information about decomposition multiplicities. In addition, together with Ariki he classified the Iwahori-Hecke algebras of type $B$ which have finite representation type and with James he proved an intriguing comparison formulae for decomposition numbers of Hecke algebras and Schur algebras at different roots of unity.

**Zhang** continued research on quantum groups and supersymmetry. With Scheunert he worked on a Hopf algebraic formulation of Lie supergroups and related geometries, obtaining a realization of the irreducible integrable representations of the general linear supergroup on sections of algebraic versions of homogeneous supervector bundles.
Zhang and Lai investigated quantum group actions, in particular, multiplicity free actions, on non-commutative associative algebras, and derived Howe dualities between quantum groups associated with the classical Lie algebras.

Lai studied $p$-adic modular forms and with Mark Kisin gave a construction of the canonical subgroup using tubes of Berthelot and proved the compactness of the $U_p$ operators. He was writing a book on the geometrical theory of modular forms with Zhao Chun-Lai of Peking University.

Lehrer’s research included investigation of the action of unitary reflection groups and other finite groups on algebraic varieties (like moduli spaces) and associated cohomology spaces, over the complex field and over fields of nonzero characteristic. In particular, he proved, with Mark Kisin, an “equivariant comparison theorem”, which reduces the determination of abstract cohomology actions to concrete combinatorial problems. With John Graham he also investigated representations of diagram algebras and affine Hecke algebras, which led to the determination of decomposition numbers for certain “standard modules”.

Lehrer accepted invitations to speak at several major international conferences. Specifically, he gave plenary addresses at

- a Stuttgart conference marking Brauer’s 100th anniversary,
- a Tokyo international meeting on Quantum Groups and algebraic groups,
- a Bielefeld international meeting on representation theory,
- a conference in Gregynog (Wales) in honour of J.A. Green and commemorating the work of Issai Schur,

as well as a 1-hour talk at an algebraic groups meeting in Oberwolfach, and invited addresses at Essen and at the Freiburg-Basel-Strasbourg Mathematics Colloquium.

3.4 Analysis:

- Cartwright worked on the harmonic analysis of groups associated with trees and buildings, and on random walks on buildings. In joint work with W. Woess (Graz), he applied spherical harmonic analysis of buildings of type $A_n$, and described the asymptotic behaviour of “isotropic” random walks on such buildings. These results were described in a talk to an international conference in Vienna. He completed joint work with P. Solé (Lille) and A. Zuk (Lyon), on “Ramanujan complexes”, which are simplicial complexes with certain extreme spectral properties. He worked with M. Voit (Tübingen) on positive definite spherical functions associated with buildings. He also worked with J. Kupka (Monash) on a problem in number theory.
3.5 Categories:

Category theory is a recent branch of mathematics originating in algebraic topology, but rapidly establishing connections with algebra, logic, algebraic and differential geometry, computer science, and mathematical physics. Category theory is particularly suited to providing conceptual frameworks for areas of mathematical research and scholarships. The Australian Category Seminar, which meets at the University of Sydney and Macquarie University, is a world centre of research in Category Theory.

Some highlights in 2001 include:

- The paper of Lack on *A Quillen model structure for 2-categories*, to be published in *K-Theory*. This studies in details certain homotopy-theoretic aspects of the study of 2-categories, using the framework for homotopy theory developed by Quillen.

- The work of Lack and Bunge (McGill University, Montréal) on a van Kampen theorem for toposes. This considers an abstract 2-category of spaces equipped with a notion of covering, and then studies van Kampen theorems for the resulting fundamental groups (defined à la Chévalley). The theorems are proved using Grothendieck’s theory of descent. In the main example the 2-category of spaces is the 2-category of Grothendieck toposes (defined over an arbitrary base topos).

- The paper *The extensive completion of a distributive category* of Cockett (University of Calgary) and Lack, published in *Theory and Applications of Categories*. A category is distributive if it “satisfies the equation $A \times (B + C) = A \times B + A \times C$” in a certain precise sense. Such categories have proved to be important in computer science. The slightly stronger condition of extensivity is more geometric, and is typical of categories of (unpointed) spaces. In this paper, it is shown how to “freely” turn a distributive category into an extensive one.

- The paper $\mathcal{V}$-Cat *is locally presentable or locally bounded if $\mathcal{V}$ is so*, of Kelly and Lack. This is part of a general program to study properties of a monoidal category $\mathcal{V}$ inherited by the category $\mathcal{V}$-Cat of categories enriched over $\mathcal{V}$. In this case the properties in question are related to the “solution set conditions” of Freyd’s adjoint functor theorem.

- The paper *A note on actions of a monoidal category* of Janelidze (Georgian Institute of Mathematics, Tbilisi) and Kelly. This studies the relationship between monoids (in a monoidal category) and monads; a monad on a category $\mathcal{C}$ is a monoid in the monoidal category of endofunctors of $\mathcal{C}$, and is a way of encoding algebraic structure borne by objects of $\mathcal{C}$. The main results include sufficient conditions for the existence of certain adjoint functors between categories which have large hom-sets, so that Freyd’s adjoint functor theorem can not be applied.
3.6 Computational mathematics: Magma

The Computational Algebra Group is concerned with the discovery and application of algorithmic methods in algebra, number theory and algebraic geometry. A major aspect of the work of the group is the development of the Magma Computer Algebra system which is used by mathematicians in more than 40 different countries.

Cannon and Holt (Warwick) developed an algorithm for determining the automorphism group of a general finite group. While there were already effective algorithms for special classes of groups, the Cannon-Holt algorithm represents the first effective algorithm that applies to arbitrary finite groups. A slight variation of the automorphism group algorithm may be used to determine when two groups are isomorphic. The isomorphism problem is one of the most fundamental questions that arises in computational group theory. Unger discovered an algorithm for computing the soluble radical and radical quotient of a matrix group (given by a base and strong generating set) thereby generalizing work of Holt. This is the first step in applying the powerful trivial Fitting paradigm to computing with such groups. Unger also used the trivial Fitting paradigm to devise a very elegant and fast algorithm for computing the chief series of a permutation group.

Gebhardt developed a new method for determining the normal form of an element of an infinite polycyclic group which is often much faster than the traditional approach. This immediately provides a faster method for multiplying elements in such groups. In a joint project with Eick (Kassel) he worked on the development of an algorithm for computing polycyclic quotients of finitely presented groups. The idea is to achieve better performance by exploiting the polycyclic group structure so as to reduce the complexity of Groebner bases computations.

A scheme for computing with Groebner bases over general Euclidean rings has been implemented within Magma by Steel. The ability to compute Groebner bases allows us to solve systems of polynomial equations. While implementations of Groebner basis techniques are widely available for polynomial rings defined over fields, this is the first facility developed for the much more general class of polynomial rings defined over Euclidean rings. Since Euclidean rings include the integers, such a facility has many applications.

Algorithms for solving very large sparse linear systems have been developed by Steel. Such linear systems arise in many contexts in computer algebra, and a variety of algorithms have been developed to handle the different kinds of systems efficiently. As a first application the sparse equation solver was integrated with sieving code developed by Thomé (École Polytechnique) in order to provide the means for solving Discrete Logarithm problems in very large finite fields $GF(2^n)$. The Thomé code recently set a world record for computing discrete logarithms in characteristic 2.

A number field is a finite degree extension of the field of rational numbers. The class group associated with a number field is one of its most important invariants and a great deal of effort has been expended over the last decade in discovering more efficient ways to construct it. Significant advances have been made recently by Fieker and Hess. As a result, Fieker was able to determine the class group of a field of degree 50 arising in a question of John Coates. (The calculation took 80 days). He was also successful in determining a related property (the $S$-units) for a number field of degree 37 thereby allowing Bill McCallum (Arizona) to construct an important example illuminating aspects of Galois cohomology of number fields. Hess, Fieker
and Sutherland generalized number field algorithms for computing with relative extensions so that they apply to algebraic function fields.

A very active topic in algebraic geometry is the study of surfaces. In order to formulate conjectures about the possible behaviours of surfaces, researchers have been compiling tables of different types of surface. In a major effort, Brown and Reid (Warwick) constructed a Magma database of all $K3$ surfaces having codimension up to 4 and more restricted classes of surfaces in higher codimension. A previous determination of the surfaces for codimensions 2, 3 and 4 each represented a PhD. The new list includes some surfaces that had been missed in previous classifications but more importantly, by having the information in the form of a computer database and providing tools for interrogating it, it has far greater utility than previous lists. Early experimentation indicates a wealth of new geometrical phenomena which will impact on the study of surfaces and especially 3-folds over the next few years. A design for an advanced version of the database was developed by Lieby.

A database containing all of the best-known binary linear codes of length up to 256 was constructed by Cannon, Grassl (Karlsruhe) and White. This is the first time that a database explicitly containing each of the codes has been constructed. Many codes in the database had previously been theoretically predicted, without ever having been constructed. The database contains over 32,000 codes and has been made available to the coding theory community as part of the Computer Algebra system Magma. Such a database represents a valuable resource for coding theorists and is already in wide use.

An algorithm that tests a graph for being planar and which runs in linear time devised by J. Boyer and W. Myrvold has been implemented in Magma by Lieby together with McKay (ANU). If the graph happens to be planar a planar embedding is found. The algorithm is very fast and may be applied to graphs having thousands of vertices. In joint work with Diana Combe (UNSW) and Bill Palmer, Unger found a new group-valued signing of a balanced incomplete block design (a Bhaskar Rao design) over $A_4$.

3.7 Geometry and Topology:

The members of the Geometry and Topology subgroup use algebra to study curves, surfaces and their higher dimensional analogues. These are the natural geometric settings in which to study the qualitative behaviour of problems depending on many variables. Hillman and his students concentrate on the interaction of the fundamental group with Poincaré duality in dimensions 3 and 4, while Paunescu and Kuo study singularities of spaces defined by polynomial equations. In August Hillman made two monographs available through the School web site, *Four-manifolds, Geometries and Knots* and *Algebraic Invariants of Links*, representing the culmination of work begun in 1996. The sustained collaboration of Paunescu with the Japanese and French singularity theorists continued, with visits of three Japanese mathematicians to Sydney and a visit by Paunescu to Marseille and Chambery. Michael Kemp joined the group as a new PhD candidate, and is working on the determination of which nonorientable Seifert fibred 4-manifolds admit geometric structures in the sense of Thurston.
3.8 Statistics:

- GENERALISED LINEAR MODELS. Weber and Courtney continued their investigation of the erratic behaviour of conditional likelihood and maximum likelihood estimators for the shape parameter in the negative binomial distribution. Work with Warton on common slope tests for errors-in-variables models was completed and will be published in the Biometrical Journal.

- ESTIMATING FUNCTIONS/TIME SERIES. Peiris’s joint work with Thavaneswaran (University of Manitoba) on application of estimating functions to estimation of nonlinear time series models and the analysis of ARMA type time series models with infinite variance innovations was published in Mathematical and Computer Modelling, International Journal of Modelling and Simulations and Metrika.

- CURVE ESTIMATION AND INVERSE PROBLEMS. Raimondo visited Stanford University (in August) to work with Johnstone on inverse estimation from scale-space dependent data. The work has been submitted to the Annals of Statistics. Raimondo and Tajvidi (who visited Sydney in September) have been working on robust smoothing methods using wavelet transforms. Particular feature of their approach is to use Extreme Value Theory in the wavelet domain. This collaboration led to a published paper in InterStat as well as a submitted paper to Statistica Sinica.

4 Applied

Members

Staff  Peter Buchen, Chris Durrant, Dave Galloway, David Ivers, Ron James, Hugh Luckock, Charlie Macaskill, Rose Thompson.

Honorary appointments  Greg Cave, David Edelman, Barrie Fraser, Matthew Hardman, Michael Kelly, Philip Loh, Jane Sexton, Emeritus Professor Peter Wilson, Denis Winch.

Visitors  David Dritschel (University of St Andrews), S. Malin, M. Marchenko, Harvinder Sidhu (Australian Defence Force Academy), Bill Spence (Queen Mary and Westfield College), Harold Zirin (Tokyo Science University).

Postgraduate students

Alhaji Bachtiar, MSc. Topic on Numerical investigation of the planar flow antidynamo theorem. Supervisor: James.


Igor Geninson, PhD. Topic on Stochastic volatility models. Supervisor: Buchen.
Kevin Ho-Shon, MSc. Topic on *Two-asset rainbow options*. Supervisor: Buchen.

Ziad Jomaa, PhD. Topic on *Coherent vortices in geophysical fluid dynamics*. Supervisor: Macaskill.

Otto Konstandatos, PhD. Topic on *Pricing exotic options*. Supervisor: Buchen.

Timothy Kyng, PhD. Topic on *Pricing Asian options*. Supervisor: Buchen.


Karl Rodolfo, PhD. Topic on *American options*. Supervisor: Buchen.

Timothy Schaerf, PhD. Topic on *Vortex dynamics on the beta plane*. Supervisors: Macaskill, Ivers.

Jon Turner, PhD. Topic on *Satellite magnetic data analysis and the Australian magnetic field*. Supervisor: Ivers.

Lei Zhang, Msc. Topic on *Spontaneous combustion in arrays of containers*. Supervisors: Macaskill, Gray.

### 4.1 Publications

#### Journal articles


#### Encyclopaedia Entries

Conference articles and abstracts

1. AA Bachtiar and RW James (2001), *Numerical investigation of the planar flow antidynamo theorem*, presented (Bachtiar) at the ANZIAM NSW Branch Conference, November, The Entrance.


4.2 Grants held

1. Stump DH (University of Queensland) and Fraser WB, ARC Project Grant, $36,941: The application of nonlinear rod theory to DNA supercoiling.

2. Winch DE, Ivers DJ, Stening RJ (University of New South Wales), ARC Project Grant, $40,864: New global and regional analyses of satellite magnetic data.
3. Ivers DJ, Turner JPR, Winch DE, AGSO, $30,000, Analysis of magnetic data over the Australian region.


5. Melrose D(Physics), Galloway DJ, IREX, $10,000, Cosmic Magnetic Fields.


5 Nonlinear

5.1 Members

Staff Chris Cosgrove, Norman Dancer, Daniel Daners, Les Farnell, Bill Gibson, Quingguang Huang, Gordon Monro, Mary Myerscough, Nigel O’Brian, Shusen Yan.

Honorary appointments Clare Chapman, Simon Davis, Ted Fackerell, Emeritus Professor Brian Gray, Joachim Hempel.

Visitors Peter Clarkson (University of Kent), E. Crooks, Yihong Du (University of New England), Nalini Joshi(University of Adelaide), Philip Maini (Oxford), Marta Mazzocco (Oxford University), J. B. McLeod (University of Pittsburgh), B. Ruf (University of Milan), Anthony Weston (Akron), Nicholas Witte (University of Melbourne), W. Zou.

Postgraduate students


Hossein Farajollahi, PhD. Topic on Time and observables in GR. Supervisor: Luckock.

Greg Lemon, PhD. Topic on Physiological processes in single cells. Supervisor: Gibson.


Ruxue Yu, PhD. Topic on \textit{Application of topological degree theory to PDEs}. Supervisor: Dancer.

Peter Zeitsch, PhD. Topic on \textit{Lie-B"acklund symmetries in linear hyperbolic PDEs}. Supervisor: Cosgrove.

5.2 Publications

\textbf{Journal articles}


### Conference articles and abstracts


### Grants held

1. **Gibson WG**, Bennett MR (Department of Physiology, University of Sydney), ARC Project Grant, $65,573: Computation of exterior currents and potentials for neurons, muscle fibres and arteries.
2. **Dancer EN**, ARC Project Grant, $53,005: *Bifurcations and secondary bifurcations for ordinary and partial differential equations.*

6 Algebra

6.1 Members

**Staff**  David Easdown, Terry Gagen, Joost van Hamel, Jenny Henderson, Bob Howlett, King-Fai Lai, Gus Lehrer, Ben Martin, Andrew Mathas, Alex Molev, Bill Palmer, Don Taylor, Nanhua Xi, Ruibin Zhang.

**Honorary appointments**  Geoff Ball, Don Barnes, Jerome Blair, Clare Coleman, Diana Combe, Sue Evans-Riley, Ben Martin, Brett McElwee, Leanne Rylands, Tim Wall.

**Visiting professor**  Professor Graeme Segal, Oxford University.

**Visitors**  Stephen Bigelow (University of Melbourne), Bill Casselman (University of British Columbia), Ngo Bau Chau (University of Paris Nord), Shun-Jen Cheng (National Taiwan University), R. Delbourgo, Stephen Donkin (Queen Mary and Westfield College), J. Fontaine (University of Paris-Sud), Vyacheslav Futorny (University of São Paulo), Professor Paul Gérardin, (University of Paris VII). Rod Gover (University of Auckland), John Graham (University of Birmingham), Ian Grojnowski (Cambridge University), Richard Kane (University of Western Ontario), Anatol Kirillov (Nagoya University), Mark Kisin, Gunter Malle (University of Kassel), Jean Michel (University of Paris VII), L. Peng, Eric Ragoucy (Université de Savoie), P. Sorba, Tonny Springer (University of Utrecht), Helena Verrill (Cambridge University), P. Wang, Z. Wang, Sigrid Wortmann (University of Heidelberg), Xiaoping Xu (Hong Kong University of Science and Technology), Y. Yin, Chun-Lai Zhao (Peking University).

**Postgraduate students**

Noelle Anthony, PhD. Topic on *Embedding the singular braid monoid into the braid group.* Supervisor: Easdown.

Sacha Blumen, PhD. Topic on *Quantum supergroups.* Supervisor: Zhang.


Mark Hopkins, PhD. Topic on *Quantum groups and Yangians.* Supervisor: Molev.


Christopher Macneikan, PhD (completed in 2001). Topic on *Equivalent cohomology of toral complements*. Supervisor: Lehrer.

Krishnasamy Muraleedaran, MSc. Topic on *Parabolic subgroups in unitary reflection groups*. Supervisor: Taylor.

Leah Ratliff, PhD. Topic on *Alternating Hecke algebras*. Supervisor: Mathas.


### 6.2 Publications

#### Journal articles


**Conference articles and abstracts**


**6.3 Grants**

1. **Lehrer GI**, ARC Project Grant, $91,944: Geometric themes in the representation theory of groups and algebras.

2. **Lehrer GI**, Australian Senior Research Fellowship, $110,177: Geometric aspects of the representation theory of algebraic structures.

3. **Zhang R**, Australian Senior Research Fellowship, $79,733: Quantum groups, noncommutative geometry and applications.

**7 Analysis**

**7.1 Members**

**Staff**  Sandra Britton, Donald Cartwright, K.-G. Choo, Roger Eyland, Adrian Nelson.

Dai Feng, Garth Dales (University of Leeds), James Byrnes (University of Massachusetts), Constantinos Karanikas (University of Thessaloniki), Ferenc Moricz (University of Szeged).

**7.2 Publications**

**Journal articles**


Conference articles and abstracts


2. Sharma MD, Brew A, New P and Britton S (2001) Do students in the Faculty of Science transfer mathematical skills between subject areas? The Vice-Chancellor’s Showcase of Scholarly Inquiry in Teaching and Learning, Showcase of Scholarly Inquiry in Teaching and Learning, — (ed.), —, The Institute for Teaching and Learning, 36.


8 Categories

8.1 Members

Staff Humphrey Gastineau-Hills, Steve Lack, Karl Wehrhahn.

Honorary appointments Amitavo Islam, Max Kelly, Rowan Kemp, Mike Johnson, Professor Ross Street, Shu-Hao Sun, Bob Walters, Henry Weld.

Visitors Marta Bunge (McGill University), Aurelio Carboni (Università dell’Insubria), George Janelidze (Georgian Institute of Mathematics), Bachuki Mesablishvili (Georgian Institute of Mathematics).

Postgraduate students

8.2 Publications

Journal articles


8.3 Grants


2. Lack, SG, Australian Postdoctoral Fellowship, $61,087: The algebra of categories with structure.

9 Computational Algebra

9.1 Members

**Staff** Geoff Bailey (Research Associate), John Cannon, Scott Contini (Senior Research Associate), Bruce Cox (Senior Research Assistant, part-time), Claus Fieker (Senior Research Associate), David Kohel (Senior Research Associate), Paulette Lieby (Research Associate), Anne O’Kane (Research Assistant, part-time), Nicole Sharp (Research Assistant), Ben Smith (Research Assistant, part-time), Allan Steel (Senior Research Associate), Bill Unger (Senior Research Associate), Volker Gebhardt (Research Associate), Greg White (Research Assistant, part-time).

** Visitors** Gavin Brown (University of Warwick), Jon Carlson (University of Georgia), David Bayer (Columbia), Nils Bruin (Simon Fraser University), Bettina Eick (University of Kassel), Pierrick Gaudry (Ecole Polytechnique), Katharina Geissler (TU Berlin), Willem de Graaf (Utrecht), Martine Girard (Leiden), Florian Hess (TU Berlin), Juergen Klueners (Heidelberg),...
Axel Kohnert (University of Bayreuth), Dimitri Leemans (Université Libre Brussels), Scott McCallum (Macquarie University), Scott Murray (University of Chicago), Graham Norton (University of Queensland), Eamonn O’Brien (Auckland) Sebastian Pauli (CICMA, Montreal), Miles Reid (University of Warwick), Colva Roney-Dougal(QMW, London), Josef Schicho (RISC-Linz), William Stein (Harvard University), Emmanuel Thome (Univ. P. & M. Curie, Paris), Helena Verrill (Copenhagen), Paul Zimmermann (INRIA, Nancy).

Honorary appointments  Arjen Lenstra, John Mack.

Postgraduate students

- Paul Hunter, PhD. Topic on Class field theory and its applications to abelian varieties. Supervisor: Kohel.
  - Allan Steel, PhD. Topic on Asymptotically-fast matrix algorithms. Supervisor: Cannon.

9.2 Publications

Journal articles


Conference articles and abstracts

9.3 Grants held

1. Cannon JJ, Pohst ME (Technische University of Berlin), ARC Project Grant, $61,296: Effective methods in class field theory.

2. Cannon JJ, ARC Project Grant, $63,399: A cohomological approach to computing the fundamental invariants of a finite group.


10 Geometry and Topology

10.1 Members

Staff Jonathan Hillman, Laurentiu Paunescu.

Honorary appointments Tzee-Char Kuo.

Visitors Professor Jon Berrick (Singapore) Dr. Toshi Fukui, Dr. Shuzo Izumi, Dr. Satoshi Koike (Hyogo), Professor Steven Yau (Illinois-Chicago)

Postgraduate students


Michael Kemp, PhD. Topic in Geometric structures on Seifert fibred 4-manifolds. Supervisor: Hillman.

10.2 Publications

Journal articles


Conference articles and abstracts


10.3 Grants held

1. **Kuo TC**, ARC Project Grant, $88,388: *Applications of blow-analytic equisingularity theory*.

11 Statistics

11.1 Members

**Staff**  Howard D’Abrero, Shelton Peiris, Mary Phipps, Malcolm Quine, Marc Raimondo, John Robinson, Eugene Seneta, Michael Stewart, Neville Weber.

**Honorary appointments**  Wen Dai.

**Visitors**  Professors Richard Cowan, Nick Fisher, Andrezj Kozek (Macquarie University), Nader Tajvidi (Lund University), Iain Johnstone (Stanford University), Sergei Zuyev (University of Strathclyde).

**Postgraduate students**

Kingsley Agho, PhD. Topic in *Asymptotic approximations for finite samples*. Supervisor: Robinson.


11.2 Publications

Books


Chapters in Books


3. **Phipps MC** Categorical Data for Health researchers The chapter appeared in ‘Health Research’, Oxford University Press. (Edited by C Berghlud).


Journal articles


Conference articles and abstracts

1. **Raimondo M.** Odysse de la Statistique, June 2001/Paris/Self-similarity and wavelets.


12 Research in Mathematics Education

Research in Mathematics Education is carried out by many members of the School, some of whom are organized into SUTMEG: the Sydney University Tertiary Mathematics Education Group.

12.1 Members of SUTMEG

Geoffrey Ball, Sandra Britton, Barrie Fraser, Terry Gagen, Bill Gibson, Stephen Goulter, Jenny Henderson.

12.2 Publications

Conference articles and abstracts


12.3 Unpublished presentations

2. Britton S, 4-unit HSC marking, North Sydney Region Maths Association HSC examiners’ meeting, March.


12.4 Grants held

1. Britton S, Ivers D, James R, Macaskill C, Teaching Improvement Fund Grant, University of Sydney, $10,000, Web-based mathematics service courses.

13 Postgraduate degrees awarded

PhD


14 Honours students

- Edmund Campbell, Hons I, Applied Mathematics. Some sufficient conditions for cooperation to exist in iterated prisoner’s dilemma. Supervisor: Ivers.


### 15 Vacation scholars

The school offers undergraduates who are gifted in mathematics the opportunity to undertake a study/research project during the summer vacation. The vacation scholarship program is
intended primarily for students completing their third year mathematics or statistics courses, and planning on continuing their studies in these fields. However, applications from exceptional first or second year students may be considered. The purpose of the program is to introduce students to mathematical research. The project of each successful candidate is supervised by a member of staff of the School.

In the 2001/2002 summer, the following students held Vacation Scholarships:

- **Michael Carmody.** Project on *Coxeter groups*. Supervisor: Howlett.
- **Mark Hertzberg.** Project on *Divergent asymptotic series*. Supervisor: Joshi.
- **Hai Trung Ho.** Project on *p-adic numbers*. Supervisor: Lai.
- **Jock McOrist.** Project on *Orthogonal polynomials*. Supervisor: Joshi.
- **Max Skipper.** Project on *Numerical Simulation of a Simple Limit-Order Market*. Supervisor: Luckock.
- **Alan Stapledon.** Project on *Differential topology*. Supervisor: Paunescu.
- Brett Witty (University of Queensland). Project on *Conjugacy classes of maximal tori in real reductive groups*. Supervisor: Van Hamel.

### 16 Seminars

Further details, often including abstracts, may be found on the School’s web site.

**Joint colloquia**  Held alternately at the University of Sydney and the University of New South Wales. Organisers: Dr Donald Cartwright and Dr Hendrik Grundling (UNSW).


4. Dr. Daniel Daners (University of Sydney). *The Dirichlet Problem on Varying Domains*. March 9 at UNSW.

5. Professor Michael Cowling (UNSW). *Conformal and contact mappings on nilpotent Lie groups*. March 16 at Sydney.
6. Dr. Leanne Rylands (University of Western Sydney). *The standard modules for simple Lie algebras*. March 30 at UNSW.

7. Professor Sandy Grabiner (Pomona College). *Convolution Algebras on $\mathbb{R}^+$*. April 6 at Sydney.

8. Professor Amnon Ne’eman (Australian National University). *Determinants, $K_1$ and derived categories*. April 27 at UNSW.


10. Dr Gavin Brown (University of Sydney). *Big Gorenstein rings and flips of complex three-folds*. May 11 at UNSW.


12. Professor William McCallum (University of Arizona). *The Brauer Group and Rational Points on Curves*. May 25 at UNSW.


14. Professor Rob Donnelly (Murray State University). *Picturing Representations of Semisimple Lie Algebras*. August 3 at UNSW.

15. Professor Robin Chapman (University of Exeter). *Alternating Sign Matrices and Tournaments*. August 10 at UNSW.


17. Professor Robin Chapman (University of Exeter). *Combinatorial proofs of $q$-series identities*. August 24 at UNSW.


19. Professor Graeme Segal (Oxford University). *Loop groups, the Verlinde algebra and $K$-theory*. September 14 at UNSW.


**Algebra** Organiser: Dr Andrew Mathas

1. Miles Reid (University of Warwick). *Birational geometry and graded rings*. January 5.


3. Xiaoping Xu (Hong Kong University of Science and Technology). *Non-graded Infinite Dimensional Simple Lie Algebras*. January 17.


15. **Chris Macneikan**. *The cohomology of toral complements*. June 1.


17. **Don Barnes**. *Cohomology of F-excentric modules of a soluble Lie algebra*. June 15

18. **Andrew Mathas**. *The representation type of Hecke algebras of type B*. June 22


22. **Andrew Mathas**. *Tilting modules for cyclotomic Schur algebras*. August 3.


30. **Ben Martin**. *Conjugacy classes in a reductive subgroup of a reductive group*. October 19.


**Applied** Organiser: Associate Professor Charlie Macaskill.


2. Professor John Perram (University of Southern Denmark). *Non-linear dynamical systems in the undergraduate physics curriculum*. March 7.

3. **Dr Ted Fackerell**. *GPS, Descartes, the Princess of Bohemia and the Tripos*. March 14.


5. A/Prof. Peter Harrowell (School of Chemistry, University of Sydney). *To Cross a Crowded Room: the Mathematics of Cooperativity*. April 4.

6. Dr Bill Spence (Queen Mary College, University of London). *Topological Holography*. April 11.

8. Prof Tony Roberts (University of Southern Queensland). *Holistic discretisation illuminates and enhances the numerical modelling of differential equations*. April 27.


10. **Dr Hugh Luckock**. *Modelling the Continuous Double Auction*. May 16.

11. Dr Glenda Wardle (School of Biological Sciences, University of Sydney). *Why delay reproduction? A matrix projection model and graph theory approach to problems in life history evolution*. May 23.

12. Prof Peter Robinson (School of Physics, University of Sydney). *Neurophysical Modelling of Brain Dynamics*. May 30.


15. **Dr Barrie Fraser**. *Whirling Strings and Spinning Yarns*. September 12.


17. Dr Marta Mazzocco (Oxford University). *Classical solutions of PVI*. October 12.


19. Professor David Dritschel (University of St Andrews). *A new twist on the numerical simulation of fluid flows*. October 17.


**Category Theory**  Held alternately at the University of Sydney and Macquarie University. Organisers: Dr Stephen Lack and Dr Daniel Steen (Macquarie).


12. **Steve Lack.** *V-Cat is nice when V is.* March 7 at Macquarie.


19. **Max Kelly.** *Comments on free bicompletions.* April 11 at Sydney.


22. **Max Kelly.** *The new Barr preprint on derived functors without projectives.* May 2 at Macquarie.

23. **Steve Lack.** *A Quillen model structure for 2-categories.* May 16 at Macquarie.


34. **Steve Lack.** *Symmetric spectra.* July 4 at Sydney.

35. Michael Batanin. *Contractible multitensors of higher dimensional structures.* July 11 at Macquarie.

36. Robert Colomb. *Application of category theory to information systems design.* July 11 at Macquarie.


40. **Steve Lack.** *Limits for partial map categories.* August 1 at Sydney.

41. Workshop (including talks by Kelly, Lack, and Street). August 8 at Macquarie.

42. Marta Bunge (McGill University). *Path-linearizable categories.* September 5 at Macquarie.

43. Ross Street (Macquarie University). *Weak omega-categories.* September 5 at Macquarie.

44. Ross Street (Macquarie University). *\(L^1\).* September 12 at Macquarie.

45. Marta Bunge (McGill University). *A comparison theorem for two types of single universes.* September 12 at Macquarie.


47. **Steve Lack.** *A Quillen model structure for \(V\)-categories.* September 26 at Sydney.


49. Marta Bunge (McGill University). *The fundamental group of a (universal) branched covering in topos theory.* October 10 at Sydney.

50. Daniel Steffen. *A cartesian closed category of games and take-back strategies, cont..* October 17 at Macquarie.


55. **Steve Lack.** *Extensivity for 2-categories*. November 7 at Sydney.

56. **Steve Lack.** *A van Kampen theorem for toposes*. November 14 at Macquarie.

57. Marta Bunge (McGill University). *Locally path simply connected toposes and their fundamental groupoids*. November 14 at Macquarie.


59. **Max Kelly.** *Why local boundedness is a useful notion*. November 28 at Macquarie.


**Computational Algebra**  Organiser: David Kohel.


15. Nils Bruin (Simon Fraser University). *Bounding the rank of an elliptic curve.* June 14.


17. Miles Reid (University of Warwick). *Graded rings, K3 surfaces,...* June 19.


**Statistics**  Organisers: Associate Professor Malcolm Quine and Dr Shelton Peiris.


4. Dr Lars S Jermiin (School of Biological Sciences, University of Sydney). *Comparative Genomics in a Post-Genomic Era.* April 6.

5. Professor Sergei Zuyev (Strathclyde University). *Fractal and aggregate tessellations.* April 20.

6. **Dr Marc Raimondo.** *Constant versus Changing Self-Similarity Index.* May 11.


14. Dr Bai Zhidong (National University of Singapore). *Inestimability of association parameter based on a broken sample.* December 17.

**SUTMEG** Organisers: Sandra Britton and Jenny Henderson


**17 Meetings**

**Sydney Statistics Conference** The annual Sydney Statistics Conference was held (joint with the UNSW and Macquarie University) on February 14, 8.30am to 5.30pm in Carslaw room 275. Program committee: Shelton Peiris (chair), Estate Khmaladze, Andrzej Kozek. The speakers were:

1. **Neville Weber.** The Asymptotic Behaviour of Estimators for the Shape Parameter of the Negative Binomial Distribution.

2. Andrzej Kozek and Dr. Jiying Yin, (Macquarie University) On Gauss quadratures and on Partial Cross Validation in nonparametric regression estimation.


6. Peter Hall (Australian National University). Data tuning.

7. Malcolm Quine and Andrew Hayen. Areas of components of the typical Voronoi polygon in a homogeneous Poisson process in the plane.


Appendix A: Research Strengths of the School.

The School is generally strong in central areas of pure, applied and statistical mathematics.

- **Algebra.**
  The group is recognised as a world centre for research in representation theory of algebraic groups and related algebraic structures, including Lie algebras, Hecke algebras, Schur algebras, quantum groups, Yangians and reflection groups. Other areas of strength include group theory, including Coxeter groups and braid groups, as well as finite groups and semigroups, formal languages and algebraic combinatorics.

- **Analysis.**
  Analysis on buildings and groups which act on them, automorphic forms, p-adic modular forms and crystalline cohomology.

- **Applied Mathematics.**
  Financial mathematics, geomagnetism (in particular satellite data analysis), geophysical fluid dynamics, wave propagation in random media, combustion modelling, ultrasound acoustics and biomedical mathematics, solar and astrophysics.

- **Computational algebra.**
  The research of this internationally recognised group spans the theoretical, algorithmic, and computational sides of mathematics, including cryptography. The present emphasis is on group theory, commutative algebra and algebraic geometry.

- **Geometry and Topology.**
  The group studies the algebraic topology of low-dimensional manifolds and singularity theory and associated areas of algebraic geometry. They are known internationally for their work in 2-knots.

- **Non-linear Analysis.**
  The group studies the theory of nonlinear partial differential equations, where there is a particularly strong group, population models and explicitly solvable nonlinear equations and Painlevé equations.

- **Statistics.**
  Asymptotic approximations applied in theoretical statistics, in some related probability limit theorems and in applied probability and stochastic processes.

- **Computational and Theoretical Neurology.**
  Mathematical modelling of neurophysiological systems. This is a joint program with M. Bennett in Physiology.
Appendix B: Institutional Research Strengths.

**Pure Mathematics.** At the University of Sydney Pure Mathematics represents one of the university’s major areas of research strength, with a large and vigorous group of researchers, who have individually and collectively made contributions which are responsible for the considerable international profile of the university in this area. Although they are by no means the only themes pursued to international standards of excellence, we single out three major ones as those where the impact of the School’s members has been particularly significant:

- **Algebraic and Geometric Theory of Representations.**
- **Nonlinear differential equations.**
- **Computational Algebra.**
20 Appendix C: Emerging Research Strengths.

- **Cryptography and Coding:**
  In recent years tools developed by the Computational Algebra Group have found major applications to cryptography and coding theory. The group recently commenced a research project on problems associated with the construction and cryptanalysis of Public Key Cryptosystems. For example, in the area of elliptic curve (EC) cryptography, attention has focussed on fast generation of cryptographically secure curves. This work has been sufficiently successful that the giant European telecommunications company, Deutsche Telekom, is considering awarding the group a research contract to produce curves needed for a planned “smart” card system. On the theoretical side, Florian Hess and two co-workers created international interest recently when they showed that an important class of EC cryptosystems had a serious weakness. In coding theory, the interests of the group lie in the construction of good error-correcting codes, especially using algebraic geometry (AG-codes). The main people involved include John Cannon (cryptography and coding theory), David Kohel (Senior Research Associate) (number-theoretic cryptography and coding theory) and Claus Fieker (Research Fellow) (construction of AG-codes). The group will be further strengthened following the appointment of the Sesqui Lecturer in Cryptography.

- **Statistical applications in Biology and Medicine:**
  Problems in neurobiology are being considered by several members of sta (Robinson, Quine, Stewart) and have attracted international collaboration (Holst (Stockholm), Chiu (Hong Kong), Molchanov (Glasgow)). These involve estimation techniques, error detection problems, asymptotic methods for mixture model inference, and stochastic models applied to neurotransmitter release and linear growth models, which can also be used as a model for the splitting of DNA strands. Raimondo is applying wavelet methods to DNA sequences and working on cough sounds for detecting asthma. Work is in progress on categorical analysis in medicine (Seneta, Phipps) and in errors in variable models (Weber).

- **Financial Mathematics and Interdisciplinary Modelling:**
  Financial Mathematics is attracting outstanding students in ever-increasing numbers. The Financial Modelling group comprises sta members (Buchen, Luckock, O’Brian); Research Associates (Edelman, Kelly); and six research students. Recently direct links with industry have been forged through the establishment of the Sydney Financial Mathematics Workshop with sponsorship from the National Australia Bank and Q-Group Australia. This workshop attracts both practitioners and academics, who meet monthly to discuss developments at the highest level. Members are regular contributors to Financial Mathematics seminars and conferences. In future Financial Mathematics should have an expanded teaching and research profile. Modelling has always been the key central theme in Applied Mathematics at Sydney, but in the past mainly concentrated in the traditional areas of Relativity and Cosmology, Geophysics, Solar Physics, Elasticity and Fluid Mechanics. In recent times activities have increased in Biomathematics, including Biomedical Mathematics, Neurobiology and NMR Spectroscopy (Myerscough, Thompson, Durrant, Gibson) and Combustion Modelling (Macaskill). Recent projects have included collaborative work with the Departments of Biology, Physics, Physiology, Biochemistry, as well as ADFA, Macquarie University, and the Sugar Research Institute (Queensland). These activities illustrate an increasing recognition of the importance of modelling in many areas other than Applied Mathematics, and the need for an interdisciplinary approach.