UNIVERSITY OF CAMBRIDGE

Isaac Newton Institute for Mathematical Sciences

Annual Report for 1993-94

July 1995

ISAAC NEWTON INSTITUTE
FOR
MATHEMATICAL SCIENCES

Annual Report for 1993-94

Cover Photograph and Interior of Institute (p.24):J Austin

DIRECTOR'S REPORT

After the frenetic activity of setting up the Newton Institute, launching it and dealing with initial teething problems, the Institute has now settled down to a more stable mode. The second full year of operation saw another four successful programmes continuing our emphasis on a broad coverage of interdisciplinary activities. In addition to mathematicians of all types, we have involved engineers, biologists, computer scientists, physiologists and physicists. The unique contribution of the Institute lies in this universal approach.

We passed one essential hurdle when the SERC rolling grant was carried forward (by the new EPSRC). The review committee gave the Institute the highest possible grading.

Our relations with industry will be significantly enhanced by a new joint venture with Hewlett-Packard which will establish a link with their new Basic Research Institute in Mathematical Sciences. It will also bring tangible benefits to the Institute in terms of computer hardware.

Our international links are being further strengthened with increasing support from the European Union and new opportunities in Japan and elsewhere. Our international reputation is now fully established and the many visitors we have had from all over the world are our best ambassadors.

The Leverhulme Trust awarded a substantial grant to aid scientists from the former Soviet Union and Eastern Europe to participate in the work of the Newton Institute.

As a flagship for mathematics in Cambridge, we are the starting point for the ambitious development of a 'Mathematical Campus' on the adjacent site. In particular, the Institute has helped to foster links between Pure and Applied Mathematics.

Peter Goddard, the first Deputy Director and prime mover in the establishment and development of the Institute, retired at the end of September 1994 on taking up the Mastership of St John's College. He leaves behind a thriving Institute, a tribute to his judgment, perseverance and dedication. We welcome Professor John Wright from the University of Reading as his successor.

Michael Atiyah

INTRODUCTION

The fundamental purpose of the Newton Institute is to foster research in the Mathematical Sciences of the highest international standing, Mathematical Sciences being interpreted extremely broadly.

The Director, Sir Michael Atiyah, is advised on scientific policy by a committee of distinguished scientists, the Scientific Steering Committee. All of its members, apart from the Director, are external to Cambridge.

The range of sciences in which mathematics plays a significant part is, of course, too large for an Institute of modest size to cover adequately. The Scientific Steering Committee has to make difficult choices when assessing which research programmes to recommend. Many proposals of great scientific merit and timeliness are received. One of the aims of the Newton Institute is to break down the barriers which arise from the departmental structure of most universities. A major consideration when judging the appropriateness of a proposed research programme is the extent to which it is "interdisciplinary". Usually this will involve bringing together research workers with very different backgrounds and expertise.

Even the design of the building, with no corridors and all offices opening off central meeting areas, encourages visiting researchers to interact fruitfully.

The Institute's current method of working is to run parallel six-month research programmes from January to June and from July to December, that is four programmes each year.

Research in mathematics, as in many other sciences, tends to consist of major breakthroughs, with rapid exploitation of new ideas, followed by long periods of consolidation. For the Newton Institute to be an exciting and important world centre it has to be involved with the breakthroughs rather than the consolidation.

The UK Scientific Community is served by the Newton Institute in two major ways. First, UK experts are given the opportunity to work and collaborate with the best overseas workers in their field over an extended period. Secondly, other UK scientists, particularly young people, are encouraged to visit the Institute to be introduced to exciting new research developments by some of the world's greatest mathematical scientists.

1. FOUNDING OF THE INSTITUTE

The inauguration of the Institute on 3 July 1992 was the culmination of four years' preparation. For a number of years and for a variety of reasons, a need had been felt for a UK national institute in theoretical physics and mathematics. Efforts had been made outside Cambridge to initiate such a development but little concrete progress had been made. A crucial advantage which made the development seem feasible to the group which started to develop the project in Cambridge in June 1988 was the possible availability of "pump-priming" financial support from Cambridge Colleges.

After some preliminary planning, tentative approaches for funding were made to St John's College and Trinity College in October 1988. In March 1989 St John's agreed in principle to construct a building on land the College owned at Clarkson Road in West Cambridge to house a Mathematical Sciences Research Institute. The building would be provided rent free for the first five years, subject to satisfactory evidence being received that funds to meet the running costs of the Institute for that period would be available from other sources, and subject to the rental value of the building being no more than about £150,000 per year.

The proposed institute had been conceived from the start as a national institute covering the whole broad range of the mathematical sciences. It was therefore decided to approach various appropriate national bodies. An important opportunity for this was provided by the retreat organised by the London Mathematical Society (LMS) in May 1989 at the Isle of Thorns which was attended by representatives from the Edinburgh Mathematical Society, the Institute of Mathematics and its Applications, the Royal Statistical Society, a number of different universities and Professor AFM Smith (then Chairman of the Science and Engineering Research Council Mathematics Committee). Those present (voting as individuals) passed a motion "that the mathematicians present at the Retreat welcome with enthusiasm the creation of the Institute for Mathematical Sciences in Cambridge, along the lines proposed by the Cambridge Committee". Following this, the backing of the principal learned societies concerned with the mathematical sciences was obtained.

In June 1989 the Trustees of the Isaac Newton Trust, established by Trinity College, indicated that the Trust would provide £200,000 per annum for five years towards the running costs of the Institute provided that additional funding of at least double this amount (exclusive of the rent being provided by St John's) was forthcoming from other sources. Sir Michael Atiyah, who joined the Committee in May 1989, suggested that adopting the name *The Isaac Newton Institute for Mathematical Sciences* would be highly appropriate in view of the Institute's proposed breadth through pure mathematics, theoretical physics and the other mathematical sciences.

The earliest date by which the Institute could open was constrained by both the time necessary to select and organise the first research programmes and by the time required for the planning and construction of the building. Both of these considerations pointed to July 1992 as the date for inaugurating the Institute's scientific work.

Financial support from the Science and Engineering Research Council (SERC) had to be a vital aspect of the Institute's finances, both for the financial backbone it would provide directly and because it provided a testimony of the value of the Institute to the mathematical community through the peer review process. Informal approaches were made to the Mathematics Committee of the Science Board of the SERC starting in April 1989. The SERC decided that proposals to realise a national institute should be sought from UK universities. Five proposals, from Cambridge, Edinburgh (Edinburgh and Heriot-Watt Universities), London, Oxford and Warwick, were selected for further consideration. Presentations were made in London by representatives of those short-listed in November 1989 to a committee reporting to the Mathematics Committee of the SERC. In December the Mathematics Committee recommended the funding of the Cambridge proposal.

This was confirmed early in 1990 with a "rolling" grant of about £500,000 per year for the first four years.

Early in 1990, Sir Michael Atiyah was appointed Master of Trinity College. This cleared the way for him to become the first Director of the Institute.

The award of the SERC grant, together with the financial support provided by LMS, NM Rothschild and Sons and others, meant that all the conditions attached to the grants from St John's and Trinity had been satisfied, and so the Institute could now definitely be established. Other generous contributions to setting-up costs came from Apple UK; Cambridge University Press; Princeton University Press; Springer-Verlag and other publishers; Christ's, Gonville and Caius, Emmanuel and Jesus Colleges; the Nuffield Foundation; Sun Microsystems and the University of Cambridge. Further details are given in section 7a below.

A report proposing the establishment of the Institute as part of the University of Cambridge and setting out its constitution was prepared and approved by the University on 2 November 1990, formally establishing the Institute retrospectively from the previous 1 October. The Report appointed Professor Goddard as Deputy Director of the Institute from 1 October 1991 and established a Management Committee and Scientific Steering Committee (see below).

Scientific planning began in earnest in the summer of 1990. A call for proposals was issued and the Scientific Steering Committee met for the first time in October. From the 23 proposals it received, it recommended the Director to select as the first programmes, to start in July 1992, *Low Dimensional Topology and Quantum Field Theory* and *Dynamo Theory*.

By the time the Institute opened in July 1992, the eight programmes for the first two years were at active stages of preparation with invitations to participants issued for nearly all of the first year and much of the second.

The official opening of the building had to wait till 30 October 1992 when the Chancellor of the University, HRH The Duke of Edinburgh, came to the Institute and met many of the visiting members.

2. NEW DEVELOPMENTS AND SUMMARY 1993–1994

The Institute began its second year of operation in July 1993 with parallel programmes on *Computer Vision* and *Random Spatial Processes*, followed in January by parallel programmes on *Geometry and Gravity* and *Cellular Automata, Aggregation and Growth*. All four programmes had a broad mixture of participants from different disciplines with *Computer Vision* drawing on a particularly wide range of scientists including psychologists, robotics engineers, statisticians and biologists.

As well as the long-term participants in these programmes, large numbers of mathematical scientists were attracted to the workshops, conferences and lectures held at the Institute throughout the year.

2.1 Young Scientists: We were particularly pleased that many younger scientists took part in the work of the Institute in 1993/94 and we have monitored their participation. The Institute sees it as an important part of its policy to encourage the participation of young scientists, particularly those at post-graduate and post-doctoral level. The Gabriella and Paul Rosenbaum Foundation generously donate the sum of $70,000 per annum to enable one young American scientist to attend each programme. This scheme was initially established for three years but we have made strenuous efforts to effect its renewal with the result that it will now continue at least to the end of July 1997. It has been highly successful, not only from the point of view of the people supported, but also because through it other young scientists have become aware of the Institute and decided to attend its programmes.

Younger scientists who are staying for any length of time are encouraged to apply for the status of "Affiliated Participant", sponsored by a visiting member which, although it cannot promise an office because of lack of space, entitles them to be in the Institute at any time day or night, use of the library and specified use of computers. They are welcome, of course, to attend all lectures and seminars. Indeed the attendance of young people is a regular feature of all the Institute's activities and this is strongly encouraged in the Institute's publicity.

Young scientists attending the *Cellular Automata, Aggregation and Growth* NATO ASI/EC conference in June 1994

In addition, we hold a number of conferences and workshops which are specifically aimed at more junior scientists and which the majority of young participants are fully-funded to attend. These include NATO Advanced Study Institutes (ASIs). We held two during 1993/94, one in July 1993 as part of the *Random Spatial Processes* programme and one in June 1994 as part of the *Cellular Automata, Aggregation and Growth* programme. Both were very well attended.

The Newton Institute has also set up a number of Euroconferences with funding from the European Union (EU)'s Human Capital and Mobility Fund. These too are specifically targeted at younger people. The Euroconference scheme takes place in academic institutions throughout Europe and the Newton Institute is particularly pleased to have secured funding for two series of such conferences to date. In line with the grant conditions, funded participation is limited to young (usually under 35)

people from EU countries, with efforts being made to achieve as wide a spread as possible. Those from the disadvantaged areas of the EU are particularly encouraged to attend.

Euroconferences are a concentrated period of activity lasting between several days and two weeks during which there are both formal lectures and opportunities for young people to discuss their work. The timetable is scheduled so that there is free time during the day for more mundane activities such as going to the bank and at least one social event takes place during each conference. Longer conferences may even include a day trip such as the tour of Suffolk villages which was part of the *Cellular Automata, Aggregation and Growth* summer conference. Two Newton Institute Euroconferences took place during 1993/94. The first formed part of the *Geometry and Gravity* programme in March 1994 and the second was a joint Euroconference with the *Cellular Automata, Aggregation and Growth* NATO ASI.

Many young scientists also attended the series of lectures given by Professor Hawking and Professor Sir Roger Penrose on the *The Nature of Space and Time* which were held in Lady Mitchell Hall and again formed part of the *Geometry and Gravity* programme. We are currently making applications for further funds which will enable us to offer extra support to young scientists.

2.2 Hewlett-Packard: Negotiations with Hewlett-Packard took place throughout this academic year with the result that Hewlett-Packard decided to give generous support to the Institute by donating powerful workstations and associated equipment and by establishing a Hewlett-Packard Senior Research Fellowship at the Newton Institute. The workstations were donated in July 1994 and the Fellowship established from January 1995, hence both will be discussed in more detail in the 1994/95 Annual Report.

The Newton Institute is pleased to be associated with the new Hewlett-Packard Basic Research Institute in Mathematical Sciences (BRIMS) in Bristol and looks forward to a long and fruitful co-operation between BRIMS and the Newton Institute. The inauguration of BRIMS took place at the Newton Institute in October 1994 and this event will also be discussed in more detail in next year's Annual Report.

2.3 Leverhulme Trust: The Leverhulme Trust also announced its first grant to the Newton Institute in 1993/94. The Institute identified the funding of participants from Eastern Europe and the former Soviet Union as being a very important part of its provision. Such scientists are often distinguished but are unable to raise their own funds to visit other academic institutions. Accordingly, the Institute made an application in which it asked the Leverhulme Trust to provide part-funding to cover travel and subsistence payments for participants from Eastern Europe and the former Soviet Union from July 1994 over a period of three years, together with associated additional costs. The total amount requested was £55,000 *pa* to provide thirty-seven and a half person-months of subsistence expenses at about £1,000 per month, £6,000 in travel expenses and £11,500 in additional costs. This would provide fifteen Visiting Fellowships if the average stay were two and a half months as expected. The Trust awarded this amount in full and the grant will begin in July 1994.

2.4 Office of the Year Award: The Institute's building won the Du Pont Award for Innovation at the 1993 Office of the Year awards which were organised by the Association of Facilities Managers and the Institute of Facilities Management. This endorsed our belief in the quality and originality of the Institute's building. The design is highly successful and continues to work well, attracting many favourable comments from short and long-stay participants.

2.5 Princeton University Press Series: The first lectures in the Princeton University Press/ Newton Institute lecture series were given during 1993/94 and are due to be published in 1995.

Professor Steven Zucker gave a course of three lectures on *Computational Vision and Biological Perception* in November 1993 which were well-received.

Professor Sir Roger Penrose and Professor Stephen Hawking gave alternate lectures on *The Nature of Space and Time* during April and May 1994, with the very last lecture being a debate between the two. Such was the demand to attend these lectures that the majority were held in Lady Mitchell Hall which has a much higher capacity (500) than the Newton Institute. The debate was held at the Institute and close-circuit TV was installed to enable those who could not obtain a seat in the lecture theatre to watch in the Institute's building. Princeton University Press also arranged for the lectures to be professionally recorded by Anglia TV and an edited version may well become available on video.

2.6 Cambridge University Press Series: Publications agreed with Cambridge University Press were also advanced during 1993/94. The first book, *Solar and Planetary Dynamos*, edited by MRE Proctor, PC Matthews and AM Rucklidge, was published and at least four others were in advanced stages of preparation.

2.7 Visits Made to other UK Universities: Scientists visiting the Newton Institute are encouraged to visit other UK universities during the course of their stay and a paragraph has been added to the standard invitation letter to emphasise this point. Information about current Newton Institute visitors, together with contact numbers, is also available on the World Wide Web. Visiting members of the Institute have given over 120 seminars in departments outside Cambridge. This is an increase on the previous figure of 100. UK universities at which visiting members have talked include Aberdeen, Bristol, Durham, Edinburgh, Imperial College, King's College London, Leeds, Newcastle, Nottingham, Oxford, Queen Mary and Westfield College, Sheffield, Stirling, Surrey, Sussex, Swansea and Warwick as well as the HP Research Centre in Bristol and the CIBA Foundation Symposium in London. In many cases, there will have been talks in more than one department.

2.8 Staffing: As a result of experience gained in the first year, and because of increasing numbers of conferences and workshops, some changes were made in Institute staffing levels and job descriptions.

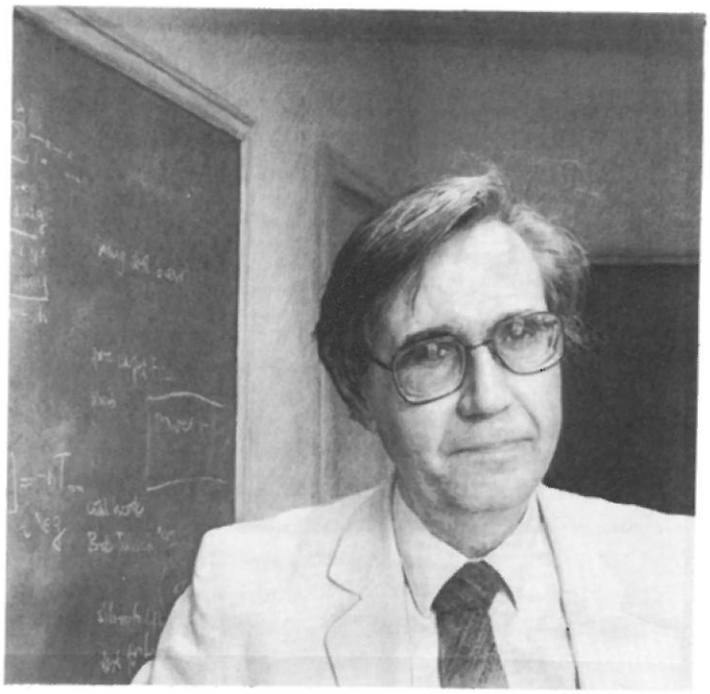
2.9 SERC/EPSRC: In the autumn of 1993 the rolling grant given by the SERC was due to be reviewed. The Institute therefore submitted a new application form and was informed of an official review visit. That visit took place in November 1993. Shortly afterwards the SERC was replaced by several more specialised research councils. The recommendations from the review body resulted, however, in the rolling SERC grant being renewed and taken over by the Engineering and Physical Sciences Research Council (EPSRC). Application will also be made to the Particle Physics and Astronomy Research Council (PPARC) at the time of the next EPSRC review.

2.10 Institute Finances: The Institute's finances remain robust in the short term but are heavily dependent on substantial support for running costs provided by the Newton Trust and on generous rent subvention given by St John's College. When these come to an end considerable difficulties will ensue unless adequate replacement funding for infrastructure is obtained from elsewhere.

The Institute is grateful for financial support received in 1993/94 from the EPSRC, The Newton Trust, St John's College, NM Rothschild and Sons, Centre Nationale de Recherches Scientifiques (CNRS), the Daiwa Anglo-Japanese Foundation, the Gabriella and Paul Rosenbaum Foundation, the Prudential, NATO (for advanced study institutes), the European Community Human Capital and Mobility Scheme (Euroconferences), the LMS, the Institute of Physics, Jesus College, the Cambridge Philosophical Society and a number of private individuals.

2.11 Professor Peter Goddard: Professor Goddard, Deputy Director throughout the Institute's

fledgling years, announced that he would be leaving on 30th September 1994, and in February 1994 was elected Master of St John's College from 1st October 1994.



Peter Goddard. *Drawing: Bob Tulloch, 1992*; reproduced by kind permission of the Master and Fellows of St John's College

3. MANAGEMENT AND STAFF

3.1 Management: The management of the Institute is the responsibility of the Management Committee. This has been modified slightly in 1993/94 to include a representative of the School of Technology and an EPSRC rather than an SERC representative. The Committee now consists of the Director, the Deputy Director, the Heads of DAMTP and DPMMS, five persons appointed by the General Board of the Faculties (of whom one is nominated by the Council of the School of Physical Sciences, one is nominated by the Faculty Board of Mathematics and one is nominated by the School of Technology), a Chairman appointed by the General Board, one person appointed by each of St John's College, Trinity College and the EPSRC and one additional person co-opted at the discretion of the committee.

The membership of the Management Committee at 30 June 1994 was:

Professor PV Landshoff	General Board *Chairman*
Sir Michael Atiyah, OM, PRS	Director
Professor A Baker, FRS	Trinity College
Professor JH Coates, FRS	Head DPMMS
Professor DG Crighton, FRS	Head DAMTP
Professor AP Dowling	School of Technology
Mr J Farrow	EPSRC
Professor P Goddard, FRS	Deputy Director
Professor FP Kelly, FRS	co-opted
Professor Sir Martin Rees, FRS	CSPS
Dr GA Reid	St John's College
Dr PMH Wilson	Faculty of Mathematics
Professor JDM Wright	General Board
Professor Sir Christopher Zeeman, FRS	General Board

Dr Neil Viner (SERC) also served on the Committee during 1993/94.

During the year 1993/94 the Management Committee met once during each University term (on 8th November, 7th March and 3rd June). At these meetings it received reports on the Institute's finances, facilities, publicity, housing arrangements and fund-raising efforts. It approved the scientific programmes which the Director proposed to it on the advice of the Scientific Steering Committee and it received the minutes of that Committee. It was responsible for recommending to the General Board elections to Rothschild Visiting Professorships on the advice of the Director and Deputy Director. It received regular detailed reports on the progress of planning for those programmes which had been approved and final reports on those programmes which had been completed.

3.2 Staff: Sir Michael Atiyah remains Director of the Newton Institute but other changes have taken place during the past year, the most significant of which was the announcement by Professor Peter Goddard of his decision to resign as Deputy Director. A long and careful search for a successor culminated in the appointment of Professor John Wright to take over on that date.

At the end of the first full year of operation it was easier to assess exactly which staff were needed and how the duties should be divided. It was recognised that the post of Administrator was an extremely busy one which needed additional support. Thus Lynne Stuart was upgraded from Principal Secretary to Administrative Assistant in the Director's Office in July 1993 in order that she could take on more of that rôle. It was also felt that more consistent assistance with financial management was necessary and hence Sarita Haggart took up her position as full-time Accounts Clerk at the beginning of the same month. Ann Cartwright became the new Institute Administrator on 1st September 1993, replacing Ken Smith. Computing was also identified as a key area which

was under-resourced in terms of personnel. Thus Mustapha Amrani was appointed as Computer Assistant from 1st January 1994. Janey Marsters resigned as Conference and Programme Secretary at the end of May 1994 to be replaced by Florence Leroy in August 1994.

The Institute would not have survived without a wide variety of extra helpers who were called upon to assist at particularly busy times to provide cover or additional help and support. In 1993/94 these included Lindsay Abbott; Caroline Bardy; Ian Farquharson; Kate Gibbons; Michael Goddard; Julie Godfrey; Philip Greenwood; Sallie Hage; Florence Leroy; Wanda Lewcun; Carrie Marshall; Michael Sekulla; Alison Suter; William Tunstall-Pedoe and Peter Wren.

The present staff of the Institute consists of:

Director	Sir Michael Atiyah OM, PRS
Deputy Director (to 30/9/94)	Professor P Goddard FRS
(from 1/10/94)	Professor J Wright
Institute Administrator	Ms A Cartwright
Administrative Assistant	Ms LA Stuart
Computer Systems Manager	Mrs HM Strudwick
Computing Assistant	Dr M Amrani
Librarian	Mrs M Allen
Housing Officer	Ms W Abbott
Accounts Clerk	Miss S Haggart
Secretary	Ms F Leroy
Receptionist	Miss T Hibbitt
Catering Assistant	Miss T Secker

The Director and Deputy Director were supported in 1993/94 by two Assistant Directors, Dr Pelham Wilson and Dr Noah Linden. Dr Wilson was Assistant Director until 1st October 1994. The Institute is grateful for all his work on its behalf.

3.3 Evaluation: In order to seek ways of improving its management and administrative procedures, the Institute continues to collect information and monitor its performance and achievements in various ways. It collects biographical information on its visiting members. It gets each visiting member to complete a general questionnaire, requesting an evaluation of and comments on the Institute's facilities, staff support, financial provision and coffee, lunch and tea arrangements. Visiting members are also asked to fill out a housing questionnaire. Conference participants are now also asked to complete a questionnaire requesting evaluation and comments on conference organisation, scientific content, lunch arrangements and accommodation arrangements. The results of all these questionnaires are collated and discussed at regular staff meetings, together with suggestions for changes and problems which have emerged. Where possible, improvements have been made. This is seen as a continuing process. The numbers of younger scientists attending lectures and seminars at the Institute is also monitored (although this relies upon them signing in at reception or registering as affiliated participants), as are talks given by visiting members in other academic institutions. Numbers of women attending the Institute are recorded too. Each visiting member is required to write a report on his or her stay, giving details of work done and useful interactions during the visit and each fills in a form indicating publications which are likely to arise out of his or her visit. These are followed up at regular intervals until publication details are received. On the whole the reports of visiting members have been positive and often very enthusiastic. A selection is quoted here:

I found my stay at the Newton Institute to be excellent—certainly one of the best research visits I

have had.

I found the architecture of the building very appropriate for the kind of joint work mathematicians like to do. The staff is very co-operative and friendly. The computer and library facilities are appropriate.

It's been one of the most enjoyable and profitable times I have spent anywhere... I sincerely hope that the INI will continue to exist and be run in a similar style. I'm sure that I am not alone in saying that the staff support and architectural design both contributed significantly to the ability of the scientists to devote their full attention to collaborative research.

The two months I spent at the Newton Institute have brought me closer to the scientific community of the UK than anything else in my professional life so far.

The Newton Institute has a unique atmosphere where people work hard with feeling no stress. It is thus much easier to progress and to collaborate in such exceptional conditions. I enjoyed my stay very much and I am thankful to all the staff that made things as easy as possible. All the people working for the Institute have always been extremely helpful.

I have enjoyed this excellent programme enormously. I have never in my career been so stimulated for so long, which the seven publications I wrote in six months bear witness to.

The staff derive considerable satisfaction from such comments but they are far from complacent and are constantly striving to improve the Institute as a stimulating environment for research.

3.4 Visit to the Institute of Theoretical Physics (ITP) in Santa Barbara and Mathematical Sciences Research Institute (MSRI) in Berkeley: Professor Peter Goddard (Deputy Director), Ann Cartwright (Institute Administrator) and Lynne Stuart (Administrative Assistant) visited ITP from 16 March to 19 March 1994, attending the inauguration of their new building and MSRI from 21 March to 22 March 1994 to study different methods of running institutes. Whilst there they interviewed the majority of the staff at ITP, including the retiring Administrator who had worked there for fourteen years. At MSRI they talked only to senior staff because there had recently been many changes of personnel.

Their main conclusions from these visits can be summarised thus:

a. *Academic Staff.* Both ITP and MSRI have a number of full-time academic staff involved in administration, two in the former case and three in the latter. All expect to spend fifty per cent of their time on research.

b. *Funding.* Both ITP and MSRI get the majority of their funding from a single source and so do not need to fundraise to the same extent as the Newton Institute. This means less work at several levels of the organisation although the Newton Institute prefers not to be entirely dependent on one source of funding.

c. *Housing.* ITP and MSRI Housing Officers put participants in contact with the landlords or agents of suitable properties. Neither Institute rents properties to sub-let to participants as does the Newton Institute. Although the latter is more labour-intensive, local conditions mean it would be virtually impossible to do otherwise and offer a service at all.

d. *Visiting Members.* ITP has permanent members and postdoctoral fellows. MSRI has visiting members who are not attached to any particular programme and postdoctoral fellows. Limitations of physical space mean that this would be extremely difficult at the Newton Institute.

e. *Programme Structure and Conferences.* Although the ITP programme structure is similar, there are many less conferences and workshops than at the Newton Institute. MSRI, whose range of activities is not as large as the Newton Institute operates a different programme structure with one year-long programme and a series of shorter programmes, thus offering greater flexibility, which results in fewer topics being treated in depth.

f. *Management.* ITP does not have a management committee. All management is conducted through senior staff. MSRI has a management committee which is totally independent of the University of California. In some ways this generates extra work, particularly in the area of finances, where it also leaves the Institute more vulnerable. On the other hand, autonomy and the lack of bureaucracy could be used positively to provide additional flexibility.

g. *Scientific Advisory Committees.* The scientific advisory committees of both ITP and MSRI differ from that of the Newton Institute in the way they function. Proposals are invited by ITP at annual intervals the ITP committee develops and encourages these proposals almost independently of the Director. The MSRI committee does not specifically ask for proposals. It initiates and develops these itself to an even greater extent.

h. *Administrative Staff.* ITP has a number of long-term student helpers who are used on a regular basis to supplement the work of permanent staff. This helps to alleviate some of the administrative burden and is especially useful for holiday cover.

4. PROGRAMME STRUCTURE AND ORGANISATION

4.1 General: The Institute adopted the pattern, for its early years at least, of having two six-month research programmes running at any one time, four per year and this was the pattern followed in 1993/94. Participants are characterised as either long-stay (8 days or more) or short-stay (7 days or less). Long-stay participants are also known as visiting members. Numbers quoted refer to long-stay participants unless otherwise stated. Each programme had an average of 18 to 23 participants in residence at any one time, and the Institute had between 40 and 50 visiting members staying for two weeks or more. The total number of participants in a programme was between 48 and 67. In addition, there were 576 short-stay participants across the four programmes. The statistics for those programmes which took place in 1993/94 are given in the following table:

Programme	*Visiting Members*	*Average Stay (days)*	*Average Occupancy*
Computer Vision	58	50	18
Random Spatial Processes	55	61	20
Geometry and Gravity	67	55	23
Cellular Automata, Aggregation and Growth	48	70	20

During its second year of operation the Institute has seen an overall increase in the number of visiting scientists. These have included over 220 visiting members (a slight increase on the previous year), staying between two weeks and six months, about two months on average. Nearly 75% of these were from overseas compared to 80% the previous year. Within the four programmes there have been a total of 24 workshops, periods of more intense activity on specialised topics or pedagogical activities which involved an additional 370 participants. In addition, the programmes themselves attracted a large number of scientists who made short visits, including about 200 who stayed for only a few days (compared to 95 short-term visitors in 1992/93).

Professor Alain Connes in discussion with Professor Gary Horowitz during the *Geometry and Gravity* programme

The visiting members are listed in §9.1 and a chart showing the periods of their visits is given in §9.2. A breakdown of numbers by nationality is given in §9.3 and a graph showing the age distribution of visiting members is shown in §9.4. The median is 39 years with an interquartile range of 33 years to 46 years. For workshops and short-stay visits the age profile is younger. Detailed biographical records have not been compiled for all short-stay participants, but an age survey at a typical large workshop produced a median age of 37 years with an interquartile range of 29 years to 44 years.

The scientific planning for each programme is the responsibility of a team of three or four organisers. The choice of organisers is made so as to reflect the intended scope of the programme.

Programme Structure and Organisation

Programmes are selected about two years before they are scheduled to begin. The first task of the organisers is to identify leading workers who are willing to commit themselves to participating in the programme for an appreciable period. A wider group can then be approached in successive tranches. In the period between 18 and 6 months before the programme starts, the budget for subsistence and travel will be committed in this way. Naturally, there will be subsequent changes and withdrawals due to unforeseen circumstances, leaving flexibility in the budget to enable some invitations to be issued just before and during the programme.

A typical structure for a programme is to begin with some more pedagogical activity, to have two or three more specialised workshops towards the middle of the programme, focussing on particular aspects of the programme or closely related areas, and perhaps to end with some more general meeting summarising the state of the art. Such a model is not rigidly imposed and programmes vary quite considerably in their actual structure. In addition to the workshops, etc, which serve to widen the participation in the programmes, the organisers are strongly encouraged to organise less formal special days, short meetings or intensive lecture series, which can attract daily or short-term visitors, so further increasing the impact of the Institute on the UK mathematical community. As we have seen above, this policy was more successfully pursued in the second year of operation than the first.

All of this is against the background of regular series of seminars in each programme. During the year July 1993 to June 1994, there were over 770 lectures and seminars given in the Institute, an increase of 120 on the previous year. A list of these seminars, which perhaps more than anything else illustrates the scope of the Institute and the intensity of its activities, is given in §9.6. In addition, visiting members are also encouraged to go to other UK universities to give lectures and seminars. In 1993/94 the total number of lectures and seminars given elsewhere was 120. Again, this was an increase on the previous year's total (see §2.7).

Some thought has been given as to whether the structure of four six-month research programmes each year should be varied, eg by having some two- or three-month research programmes. Some topics, whilst not justifying a full six-month programme, might make excellent subjects for a two- or three-month one. It would also help the Institute cover a wider range of the mathematical sciences.

A further possible variation is that of the 'fatter' or more major programme which could take place alongside two or more shorter and more minor programmes. A more diverse pattern could present greater logistical difficulties and, in the case of shorter programmes, some problems where Visiting Fellowships and Professorships were designed for participants staying for longer periods and there could be too much overlap with the work of other British Institutes. It has therefore been decided to proceed with caution in this direction by experimenting first with minor programme variations in late 1996.

4.2 Scientific Steering Committee: The Director is advised on the scientific work of the Institute and, in particular, on the selection of programmes by the Institute's Scientific Steering Committee. This Committee has undergone minor changes since the reorganisation of the research councils and now consists of the Director, three persons appointed by the General Board (GB) on the recommendation of the EPSRC, one person recommended by the General Board on the recommendation of the Particle Physics and Astronomy Research Council (PPARC), two persons appointed by the General Board on the recommendation of the LMS, six persons appointed by the General Board after consultation with the Councils of the Schools of the University and national scientific bodies (the Royal Society, the Royal Society of Edinburgh, the Royal Statistical Society, the Institute of Physics, the Royal Academy of Engineering, the Institute of Mathematics and its Applications and the Edinburgh Mathematical Society) and one additional person co-opted at the discretion of the Committee.

The membership of the Committee on 30 June 1994 was:

Professor Sir Christopher Zeeman, FRS	Oxford University	GB *Chairman*
Sir Michael Atiyah, OM, PRS	Newton Institute	Director
Professor JM Ball, FRS	Heriot-Watt	LMS
Professor MV Berry, FRS	Bristol	GB
Professor J-M Bismut	Orsay	GB
Professor GA Gehring	Sheffield	GB
Professor TJ Pedley	Leeds	GB
Professor BD Ripley	Oxford	EPSRC
Professor AFM Smith	Imperial College	EPSRC
Professor JT Stuart, FRS	Imperial College	EPSRC
Professor CTC Wall, FRS	Liverpool	LMS

Professor VI Arnold, Professor PG Burke, Professor IG Halliday and Professor DJ Wallace were members of the Committee from 1991 to 1993. The Committee is required to meet once per year but in practice meets twice per year, once in the Spring and once during the Autumn term.

4.3 Programmes: The Scientific Steering Committee perceives its rôle as involving both the consideration of proposals received and the stimulation of proposals in the areas of mathematical sciences which it considers to be potentially particularly suitable for the Institute. The Institute advertises its willingness to receive proposals in a variety of ways which have included the annual distribution of a poster containing a "Call for Proposals" to over 500 departments and institutions concerned with the mathematical sciences in the UK and abroad. At meetings the Committee regularly considers in which areas it should stimulate proposals and the Director, the Deputy Director or individual Committee members then assume responsibility for taking action in particular areas.

The Institute began its scientific work in July 1992 with its first two programmes, on *Low-dimensional Topology and Quantum Field Theory* and *Dynamo Theory*; since then, six further programmes on *L-functions and Arithmetic*, *Epidemic Models*, *Computer Vision*, *Random Spatial Processes*, *Geometry and Gravity* and *Cellular Automata, Aggregation and Growth* have been completed. On the advice of the Scientific Steering Committee, the following programmes have now been selected for 1994–96:

July to December 1994

Topological Defects
Symplectic Geometry

January to June 1995

Exponential Asymptotics
Financial Mathematics

July to December 1995

Semantics of Computation
From Finite to Infinite Dimensional Dynamical Systems

January to June 1996

Dynamics of Complex Fluids
Computer Security, Cryptology and Coding Theory

4.4 Scientific Policy: It is the intention of the Scientific Steering Committee that the Newton Institute should be devoted to the Mathematical Sciences in the broad sense. The range of sciences in which mathematics plays a significant part is, of course, too large for an Institute of modest size to cover adequately. In making the necessary choices important principles are that no topic is excluded *a priori* and that scientific merit is to be the deciding factor. One of the main purposes of the Newton Institute is to overcome the normal barriers which are presented by departmental structures in Universities. In consequence, a main criterion in judging the "scientific merit" of a proposed research programme is the extent to which it is "interdisciplinary". Usually this will involve bringing together research workers with very different backgrounds and expertise. There must, however, be a clear common ground on which all can focus and each programme has to have a substantial and significant mathematical content and a broad mathematical/scientific base. A further main criterion should be that the subject area is in the forefront of current development.

Because of the wide base of support for the Newton Institute in the research councils and elsewhere, the Institute's programmes should as far as possible represent an appropriate balance between the various mathematical fields. Such considerations, however, are secondary to the prime objective of having high quality programmes. If there are no exciting developments, actual or potential, in a particular field, it would be wrong to run a programme simply to maintain a balance.

Details of forthcoming programmes are listed below:

Symplectic Geometry **July to December 1994**

Organisers: SK Donaldson (Oxford), D McDuff (Stony Brook), D Salamon (Warwick), CB Thomas (Cambridge).

Surfaces known as symplectic manifolds arise in many branches of pure and applied mathematics, for example they provide the natural framework in which to discuss classical mechanics. There has been dramatic progress in recent years in understanding their properties drawing on results from many disciplines, including differential geometry and topology, global analysis and the theory of partial differential equations. The programme will bring together mathematicians from all these fields together with theoretical physicists with the aim of further developing the theory for example by exploiting the parallelism between Yang-Mills theory in four dimensions (which was originally constructed by physicists to describe the strong nuclear force between elementary particles) and symplectic geometry in spaces of arbitrary even dimension.

Topological Defects **July to December 1994**

Organisers: AJ Bray (Manchester), TWB Kibble (Imperial), RS Ward (Durham).

Topological defects appear in a vast array of physical situations, from cosmic strings which occur in unified field theories of elementary particles at the highest energies, to vortices which occur in superfluids at temperatures approaching absolute zero. These defects exhibit remarkably similar behaviour, whether it be the breaking and joining of cosmic strings or of superfluid vortices or the evolution of a network of defects in a liquid crystal. By bringing together experts in field theory, cosmology, condensed-matter physics and high-energy particle theory, the programme aims to exploit common themes and thus further the study of topological defects in each of these contexts.

Exponential Asymptotics **January to June 1995**

Organisers: MV Berry (Bristol), CJ Howls (Bristol), MD Kruskal (Rutgers), FWJ Olver (Maryland).

Although quantities which are exponentially small are important and arise frequently in applications, until recently the mathematical literature about them has been sparse. Now there is an upsurge in interest in the subject and a central new concept (*resurgence*) has emerged which describes how small exponentials are responsible for the divergences of asymptotic series. Resurgence enables the divergent tails to be decoded (for example by resummation) to yield these exponentials. New mathematical techniques are being developed as well as new areas of application, for example pattern formation in fluids, chaos in classical and quantum mechanics, and even philosophy. The aim of the programme is to foster a common culture, based on the recognition that (as with chaos in the 1970s) the problems being studied are essentially the same despite differences of language and approach.

Financial Mathematics **January to June 1995**

Organisers: MHA Davis (Imperial), SD Hodges (Warwick), I Karatzas (Columbia), LCG Rogers (QMW).

Since no-one has yet found a way to make sure money on the financial markets, we are led to conclude that the prices of various financial assets should be regarded as random processes. In the last 15–20 years, there has been an enormous explosion in the range and volume of derivative securities traded (a derivative security is a financial instrument whose price depends on the behaviour of the prices of other assets). These derivative securities offer the buyer a means of protecting against the risk inherent in the random fluctuations of asset prices, but the financial institutions selling them need to know how to price them, and how to hedge them. This has stimulated the application of mathematics to a broad range of such questions: How should one model these processes? How should we estimate these models? How should one use the models to deduce prices and to decide trading strategies? Major applications of probability, statistics, stochastic optimal control, partial differential equations, numerical analysis and simulation result, in addition to the questions of economic theory which arise. The practical importance of this application area is hard to overstate; as one example, trading in just one class of derivatives, interest-rate swaps, grew from nothing in 1981 to $3000 billion ten years later.

Semantics of Computation **July to December 1995**

Organisers: S Abramsky (Imperial), G Kahn (INRIA Sophia-Antipolis), JC Mitchell (Stanford), AM Pitts (Cambridge).

Advances in hardware have enabled a huge expansion of the capabilities and uses of computer systems. The challenge of effectively engineering the software of these systems has led Computer Scientists to identify fundamental principles for structuring computational tasks, such as the use of *procedures* (ie breaking down large programming tasks into smaller blocks), and of *concurrency* (many tasks being performed simultaneously, possibly by separate units). These principles have been embodied in programming languages, and methods for reasoning about such constructs have been developed. The attempt to provide rigorous foundations for these developments has resulted in a rich mathematical theory of the semantics of computation. While striking successes have been achieved, there are major challenges to refine the current framework for semantics in order to deal with the subtle issues which arise, for example, in combining concurrency and procedures. The programme will bring together mathematicians, theoretical computer scientists, language designers and software engineers, with the aim of enhancing the interactions between these overlapping

communities, and thus furthering the interplay between foundational work and advanced language design and software technology.

From Finite to Infinite Dimensional Dynamical Systems **July to December 1995**

Organisers: P Constantin (Chicago), JD Gibbon (Imperial), J Hale (Georgia), CT Sparrow (Cambridge).

The non-linear behaviour of dynamical systems is of great and continuing interest in mathematics and throughout the sciences. Although work in this area was originally stimulated by attempts to understand high dimensional systems such as the weather, much of the effort focussed on non-linearities in low dimensional systems for which the proofs and numerical experiments are much easier. More recently, progress has been made towards clarifying the relationship between low and high dimensional systems (including infinite dimensional ones). Some of these results show that infinite dimensional systems (PDEs for example) can be effectively finite dimensional, whilst others attempt to describe truly infinite dimensional behaviour. What these recent developments have in common is that they combine the topological approach, which has been so successfully applied to low dimensional systems, with classical analytic methods. The programme will bring together experts in both finite and infinite dimensional systems, and aims to make progress in such areas as spatio-temporal chaos, attractors in infinite dimensional systems, and others where experimental and numerical results suggest that both topological and analytic theories play important rôles.

Dynamics of Complex Fluids **January to June 1996**

Organisers: TCB McLeish (Leeds), JRA Pearson (Schlumberger Cambridge Research), K Walters (Aberystwyth).

Many fluids of industrial, biological and environmental importance (eg molten plastics, salad dressings, whole blood, sinovial fluid, fluidised sediments) respond in a complicated fashion when deformed. The reasons for this complexity can be traced back to their molecular structure and to the hydrodynamic forces acting between molecules. The programme will bring together experts who seek to relate flow behaviour to structure and those who seek to predict flow fields of such fluids in complex geometries, with particular reference to polymer melts, polymer solutions, liquid crystals and colloidal suspensions. This involves modelling on a wide range of length (and associated time) scales, ie from molecular dynamics to large scale continuum mechanics. Most of the mathematical problems that arise involve non-linear differential, integro-differential or integral equations; a full range of analytical and numerical techniques has to be employed to obtain solutions.

Computer Security, Cryptology and Coding Theory **January to June 1996**

Organisers: RJ Anderson (Cambridge), PG Farrell (Manchester), P Landrock (Århus), RM Needham (Cambridge).

Over the past twenty years, the quest for dependable computer systems has fuelled rapid advances in cryptology and coding theory. Cryptology is used to secure electronic transactions, while coding theory has facilitated many recent advances in radio-based communications. These techniques are central to designing distributed systems which will perform reliably despite the presence of noise and of malicious attacks, and there is a growing interaction between them at the theoretical level. Practical aspects are also important, and incorporating cryptographic and coding techniques into systems turns out to be much more complex than was first anticipated; this has led to interest in formal methods of verification and in robustness principles. By bringing together mathematicians, computer scientists and engineers working in these related fields, the programme aims to further both the theoretical and the engineering aspects of the art.

5. FACILITIES

5.1 Building: The Institute's building contains two seminar rooms with flexible seating (the larger, Seminar Room 1, holding between ninety-six and one hundred and fifty people and the smaller, Seminar Room 2, between thirty-six and fifty) a library, thirty offices (eighteen double and twelve single), a General Office (for administration), offices for the Institute Administrator and the Deputy Director and common areas. For use in the seminar rooms, the Institute possesses four GBI 5000 overhead projectors, three Kodak Carousel 35mm slide projectors and a GEC CRT projector (mounted onto the ceiling in Seminar Room 1) which can project European and USA videos (in PAL, SECAM and NTSC formats) and the output, in monochrome or colour, from a SunSPARC station, an HP, a Macintosh Quadra or a PC. In each seminar room there are six chalk boards and two overhead projector screens. In Seminar Room 1 there is also a central screen which can be raised and lowered automatically from the lectern. It can be used for the CRT projector, one or two slide projectors (which can be controlled from the lectern) or an overhead projector.

The library, seminar rooms and administrative offices are grouped around a ground-floor common area and the scientists' offices which are on the mezzanine and galleried first and second floors, surround the mezzanine common area. Throughout the building there are places for discussion grouped around chalkboards. As with the rest of the Institute's facilities, the building has been designed with a view to quickness of assimilation, which is of prime importance given the relatively short average stay of participants compared with the members of a normal university department.

The originality and effectiveness of the design of the Newton Institute building was formally recognised when it was awarded the Du Pont Award for Innovation at the 1993 Office of the Year Awards. The award was presented to Lynne Stuart by the Duke of Gloucester at a ceremony held in London on 18 November 1993. The cut-glass decanter which she received on behalf of the Institute is now on display in the library. The award generated welcome publicity for the Institute and for its architects, Annand and Mustoe.

Lynne Stuart receiving the Du Pont Award for Innovation from the Duke of Gloucester. *Photo: Bill Mason Photography*

In October 1993 the latter made a donation to the Institute of a bust of the Director, Sir Michael Atiyah, sculpted by David Annand, brother of the architect and a distinguished artist, using the cold cast bronze technique. The bust was unveiled by the Chairman of the Management Committee at a ceremony on 8th October attended by members of the local press, visitors, staff and the Management Committee.

Some minor improvements were made to the building in 1993/94. A switch was installed in the lift to ensure that the doors could be kept open for long enough to allow a wheelchair user to enter easily.

A removable ramp has been made for visitors in wheelchairs who wish to go directly from the car park into Seminar Room 1. The ramp is installed on request.

Concern was felt that the cycle path which runs alongside the Institute between our building and Wolfson Court was potentially hazardous as there were no warning signs to either motorists or cyclists at the point where cars cross the path on entry to the Institute car park. A series of temporary signs were erected by the Institute until permanent signs were erected by St John's College.

At a meeting to inform the Institute's neighbours about the proposed development of the Clarkson Road site to include facilities for the DAMTP and the DPMMS, it transpired that the most significant criticism of the present building is the high level of external lighting. The Institute is experimenting with these lights in order to achieve an acceptable but safe level.

Most of the "snagging" of the building has now been completed. Major items included the re-lining of the lift shaft and replacement of the screen outside the library. Some minor woodwork and other items are still outstanding.

Future plans for the Institute include the possibility of extending the building by utilising the loft space to create additional rooms, particularly for computer use. The essential character of the building will not be lost but the extra space generated could be used both for offices for scientists and for a computer room.

The Institute is currently examining the question of food provision for participants at lunchtimes. Limitations are imposed because of the kitchen facilities. The provision of hot food is not possible at the moment and more adequate refrigeration is necessary to provide a better range of cold food. Meanwhile, various microwave meals and cup-a-soups are left out for participants to purchase overnight and at weekends, and cereal and milk are available at breakfast time. A range of chocolates, sweets, crisps and fresh fruit is also provided for purchase and high-quality coffee and tea are always available from our 'Flavia' machines.

5.2 Computing Facilities

Of the four programmes running at the Institute last year, *Computer Vision* and *Random Spatial Processes* made particularly heavy use of the Institute's computing resources. In particular, they had a greater requirement for "number-crunching" facilities than any of the previous programmes. It was anticipated that this demand would continue to rise and it was therefore decided to upgrade all the Sun workstations in participants' offices to 12 MB of RAM. The IPC workstation, *bohr*, was upgraded to 64 MB of RAM, to provide scope for memory-hungry programs to be run within the Institute.

The proposed donation of new computer equipment by Hewlett-Packard meant that, in addition, the Institute's computer base would be supplemented by nine high-speed, relatively powerful workstations, having high-resolution graphics monitors, as well as a much more powerful workstation with high processor speeds and a large amount of RAM. It was decided, therefore, to withdraw a number of the older Sun workstations which had been purchased second-hand by the Institute, removing the memory from them and installing it in some of the newer Sun computers. Additionally, several of the Sun workstations were to be converted to run as *X*-terminals, with a Hewlett-Packard workstation acting as a server, to make more efficient use of their capacity.

A number of items of software on the Unix network have been upgraded, including *Mathematica*, *Glim* and *OpenWindows*. We are continuing to support *Sunview* which is Sun's original windowing system and which a number of participants are still more familiar with than the *X*-windows systems.

The arrival of Dr Mustapha Amrani, our new Computing Assistant, in January was most welcome, providing first-line support to users and designing really usable front ends for many of the administrative database programs. In addition, a number of new databases and associated programs have

been written, and the whole front-end system has been made more coherent. An on-line information system has also been provided for the administrative computer network to enable the administrative staff to access on-screen, and thus more quickly, much of the information currently supplied in paper form, eg telephone/office lists, seminar lists. Administrative staff have been making use of the system for some time and are finding it much easier to use by means of the menu-driven applications now provided.

The Novell network, which is of vital importance to the administrative system of IBM compatibles and Macintosh machines, is heavily used. Thus, in 1994/95 we will both increase our network licence and at the same time upgrade to the next version of Novell 3.1.

Information about the Institute, including seminar information, lists of visitors, etc, is now available by means of "anonymous ftp". This allows people from outside the Institute, who do not necessarily normally have access to our computer system, to download the relevant information to their own local computer. In parallel with this, we have also installed a "gopher" system which makes it possible to display the information on-screen without the need to download the individual files. Activity on both systems is logged and they are fairly heavily used. The information provided is monitored by members of staff, who also suggest new information to be included on these services. Seminar lists are automatically copied into the relevant directories, and an automatic checking system notifies staff if the lists are out of date. A future development in this line is the provision of a World Wide Web page about the Newton Institute.

A new printer has been installed in the General Office which has built-in networking capabilities, so that has been configured to provide direct printing facilities to each Unix host on the academic network independent of the printing service for the Novell network. This has reduced the traffic through our Novell fileserver and further improved the speed of printing within the General Office. Additionally, it can print at a resolution of 800 dots per inch, has three paper trays and can be used to print on to A3, which is extremely useful for the production of posters. The printer previously in the General Office has now been installed on the Second Floor to provide a printing facility for people nearby.

A new Macintosh computer, a Quadra 650 with internal CD-ROM drive, has also been purchased to act as a desktop publishing workstation. It has been linked to the colour scanner/printer to enable the speedy production of leaflets about the Institute. For example, it was used successfully to produce brochure information for the American trip by the Deputy Director and Administrators.

During April, it was noticed that there had been a spate of unauthorised access to the computers within DAMTP. From there, entry was gained successfully to the University's Central Unix Service, the DPMMS, and the Newton Institute. Immediate steps were taken in all these institutions to tighten up security measures. The presence at the Institute of so many people from outside Cambridge meant that it was not possible to disconnect our computer systems from the Internet for more than a day at a time, whereas the mathematics departments remained disconnected for more than one week. However, during those periods of disconnection we were able to install new security patches to the kernels of the file servers and workstations. In addition, new passwords were issued to all users together with more detailed guidelines about the setting of passwords.

5.3 Library

The number of monographs currently held in the library stands at just under 3200 and a catalogue of nearly all of these is available online via the University Library's Online Public Access Catalogue, which can be accessed from the terminal in the library, in the offices of the participants or remotely. In cataloguing the monographs thought has been given to the future developments for the library. The titles and holdings of serials are also on this system and can be accessed similarly.

Over the period 1993/1994 nearly 450 loans were recorded. A commonly used rule of thumb states that for every loan transaction there are four other transactions taking place in the library, so this would make the number of transactions in the library over the last year roughly 1800.

The library was heavily used by affiliated participants, particularly from the *Geometry and Gravity* programme. Their use of the library was reviewed but no major changes implemented. Photographs are now taken of all such students in order to be able to ensure that some degree of control can be kept on library use.

A new facility in the library is the display of preprints and reprints relevant to the programmes.

The archive of publications of past participants is maintained in the library where copies of many are deposited. Details are updated regularly and automatically sent to the Institute's ftp system.

The Institute's first publications appeared this year. The first book in our Cambridge University Press series was entitled *Solar and Planetary Dynamos*, edited by MRE Proctor, PC Matthews and AM Rucklidge.

5.4 Housing

The Institute provides housing for its participants in eleven flats (at Mordell Court, Chesterton High Street) and a listed building containing six study bedrooms (at 1 Chapel Street), all situated about a mile and three quarters from the Institute and rented from St John's College, and an average of fourteen other dwellings (mostly private houses and flats).

For a single person, prices vary from £15 to £18 per night, with accommodation ranging from single study bedrooms sharing bathroom facilities, to self-contained one-bedroom flats. For accompanied participants, prices range from £20 to £26 per night for those coming with one other person, and from £24 to £27 per night for those coming with larger families. In each case prices reflect the size of the property and the length of stay.

All the accommodation that the Institute has arranged is fully-furnished and of good quality, and the rent charged includes council taxes and maintenance costs but not telephone, electricity or gas charges. The prices reflect the fact that, in order to be able to guarantee accommodation for its relatively short-stay members, the Institute often has to rent properties for periods when they will be unoccupied and the rent must cover these voids. The rent charge must bear a sensible relation to the subsistence allowances the Institute pays, currently £30 per day. This allowance is primarily designed to cover the accommodation and basic food costs for a single person. It should also cover the cost of accommodation for a participant accompanied by his or her family, though not in this case the food costs as well.

In practice, taking into account the Christmas break, it is difficult to get occupancy rates much above two hundred and eighty days per year. The housing office is in effect a small business with an annual turnover of £150,000 which has to run at very close to zero margin, neither making a substantial profit nor being an appreciable drain on the Institute's finances.

5.5 Publicity

Information about the Institute, including seminar information, lists of visitors, etc is now available by means of "anonymous ftp". This allows people from outside the Institute who do not necessarily normally have access to our computer system, to run a file transfer programme by which means they can download the relevant information to their own local computer. To access this information it is necessary to `ftp` to:

`newton.newton.cam.ac.uk`

entering `ftp` as the user name and your usual email address as the password. All of the information is contained in the directory `pub` and the directories below that. The directory `pub/programmes` contains newsletters and charts and lists of expected participants in present and future programmes. The directory `pub/seminars` contains the seminar lists. The directory `pub/general` contains the list of current visiting members with telephone numbers and office assignments, their accommodation addresses in Cambridge, the Institute's General Information booklet, travel information and information on how to submit proposals for future programmes. Much of this information is updated automatically at regular intervals from the Institute's databases. In parallel with `ftp`, we have also installed a "gopher" system which runs on the same principle but is menu-driven and displays the information on screen without the need to download the individual files. Activity on both systems is logged and they are both heavily used. Institute information will shortly appear on the World Wide Web. The home page will be

`http://www.newton.cam.ac.uk`

The Institute sends weekly mailouts both through conventional means and by electronic means to publicise its programmes and seminars. Special mailouts are undertaken for conferences and special events and the Institute is currently expanding and revising all its mailing lists.

Following on the Du Pont Award for Innovation, highly complimentary articles appeared in a wide variety of publications which included *Centrepiece Magazine*; *Premises and Facilities Management* and *Facility and Design Management*. The award was also mentioned in *The Times* and the *Cambridge Evening News*.

Further publicity was generated by the lectures given by Professor Stephen Hawking and Professor Sir Roger Penrose in April and May 1994 as part of the *Geometry and Gravity* programme. As a result of these, articles appeared in the *New York Times Magazine* and elsewhere. A publication from Princeton University Press (PUP) will follow and we were also very grateful to PUP for commissioning high-quality videotapes of the lectures, extracts from which can be used in future Institute promotional material.

5.6 Merchandise

The Institute has continued to sell *Fermat's Last Theorem* T-shirts throughout the year and has also added T-shirts for the *Random Spatial Processes*, *Cellular Automata, Aggregation and Growth* and *Geometry and Gravity* programmes, the latter being designed by Professor Hawking and selling in large numbers. In addition, we have produced an Institute pen as well as the Institute postcards already on sale. Any profits are used to support the Institute's activities. Future projects include Institute mugs and Institute Christmas cards.

Interior of the Isaac Newton Institute

6. FUND-RAISING AND GRANT AID

6.1 SERC/EPSRC Rolling Grant

a. *Original Grants.* The rolling grant awarded by the SERC on the basis of the competition held in 1989 consisted of two components, a *Visiting Fellowship Grant (VFG)* to provide subsistence and travel costs for participants, and a *Special Research Grant (SRG)* to provide contributions to the setting-up costs of the Institute and to the recurrent 'core' costs of the Institute's research programme through the provision of salaries for organisers and key participants. To these was subsequently added a third *Direct Costs Grant (DCG)* grant to contribute (following the dual research support transfer from the universities' funding councils to the research council) to the administrative costs of the Institute, by providing 60% of the salary of the Administrator and the salaries of the Principal Secretary (subsequently upgraded to Administrative Assistant) and the Conference and Programme Secretary.

b. *Rolling Mechanism.* The original grants were awarded for a four-year period with a review to take place before the end of the first two years, with the intention that they should be replaced with new grants which would then run for four years with a start date two years after the original one. This process could then continue at two year intervals, so that the horizon would then be extended from the two years remaining to a new four-year horizon. At each two-yearly review, a case can be made if appropriate for changes in resources allocated for the coming two years and a case has to be made for the resources requested for the two years beyond that into which the grant will be extended.

c. *Review Dates.* In order to enable the *SRG* to make a contribution to the setting-up costs of the Institute the start date of the grants was set as 1 January 1992, six months before the Institute began operation. The date by which the review had to take place was set as 31 December 1993. An application was made in September 1993 for increased resources for the second two-year period, ie the calendar years 1994 and 1995, in the form of the cost of upgrading the Principal Secretary to Administrative Assistant and and the cost of an Assistant Computer Officer, and for an extension into the third two-year period, ie the calendar years 1996 and 1997. The review panel visited the Institute on 16 November 1993, reporting to the SERC Mathematics Committee in December. Because of the need to consult other Boards and Committees, the grant could not be announced before March nor given a start date before 1 March 1994. It is understood that it is the intention of EPSRC that the next review should begin with the submission of an application by the Institute in September 1995, with a review panel visiting the Institute in October or November and a new grant beginning on 1 March 1996.

d. *The Award.* The review panel recommended support in full for the application made in September 1993 for extension of the rolling grant but the Mathematics Committee, whilst largely accepting the report, felt it had to cut back the award by £60k over the four-year period. The original award had contained contributions of 7.5% from the Engineering Board, 6.25% from the Astronomy and Planetary Science Board (APSB) and 5% from the Nuclear Physics Board (NPB), the bulk coming from the Science Board under which the Mathematics Committee sat. In consequence approaches were made within SERC to their successors, the Engineering and Technology Board and the Particle, Space and Astronomy Board for contributions to fund the increased resources for 1994 and 1995 and for the extension into 1996 and 1997. The Engineering and Technology Board agreed but the Particle, Space and Astronomy Board suggested that, following the reorganisation of research councils from 1 April 1994, requests for additional support could best be handled by direct application to the new Particle Physics and Astronomy Research Council (PPARC). They therefore declined to provide a contribution to the increased resources requested or the extension beyond 1995 but

their commitment for 1994 and 1995 will of course be honoured. In view of this the Mathematics Committee has made further funds available to enable the award to continue at its present level until the next review date (1 March 1996). Thus the Institute was granted a substantial sum of money which will enable it to maintain its activities at current levels.

6.2 Hewlett-Packard: Towards the end of the 1993/94 year, Hewlett-Packard very generously offered to make a very considerable donation of computer equipment to the Institute, consisting of one high-speed, high-resolution graphics computer with very large disk capacity to act as a 'number-crunching' machine, and capable of handling symbolic manipulation packages (eg *Mathematica*) and graphics with ease; nine fast workstations with high resolution monitors and large disk capacity which have ten times more memory than SPARCstation 1/1+ machines and processors running nine times faster than our fastest desktop Sun; operating system, manuals and cabling for all the above; one Deskjet 1200 colour PostScript general printer and one colour plotter for plotting graphical output. The approximate total value of the donation is £350,000. Hewlett-Packard also wish to fund a Senior Hewlett-Packard Research Fellow at the Institute. We expect the person to be in post from January 1995.

6.3 Isaac Newton Trust: The Isaac Newton Trust continued to provide the Institute with £200,000 *pa* as a contribution to overheads. This support is vital to the continued existence of the Institute. In addition, the Isaac Newton Trust made a contribution of £10,000 towards the salary of the Library and Information Officer.

6.4 St John's College: St John's College donated the sum of £150,000 to the Institute in 1993/94, being the second instalment (of five) of its funding to offset against the rent of the Newton Institute building.

6.5 NM Rothschild and Sons: The money donated by NM Rothschild and Sons in 1992 to be used for the salary of Rothschild Distinguished Visiting Professors over a five-year period was spent in 1993/94 on Professor David Mumford (Harvard University) on the *Computer Vision* programme and Professor James Hartle (University of California, Santa Barbara) and Professor Shing-Tung Yau (Harvard) on the *Geometry and Gravity* programme, and associated costs.

6.6 Leverhulme Trust: During 1993/94 a successful application was made to the Leverhulme Trust for £165,000 over three years, beginning in July 1994. This money will be spent on subsistence and travel costs for scientists from Eastern Europe and the former Soviet Union, together with associated additional costs.

6.7 Centre Nationale de Recherches Scientifiques (CNRS): Members of the CNRS visited the Institute for the purposes of assessment during the year 1993/94. The organisation continues to donate the sum of 400,000FF to the Newton Institute towards subsistence and travel costs for French participants (in particular those from CNRS laboratories) and associated costs.

6.8 Gabriella and Paul Rosenbaum Foundation: The Institute received the second instalment of a three-year grant from the Gabriella and Paul Rosenbaum Foundation. The $ 70,000 given funds the salary of one young American scientist on each of the Institute's four programmes. This year the recipients were Dr Jitendra Malik on the *Computer Vision* programme; Dr Tom Mountford on the *Random Spatial Processes* programme; Dr Iddo Yekutieli on the *Cellular Automata, Aggregation and Growth* programme and Dr Arlen Anderson on the *Geometry and Gravity* programme. The grant has been extended for a further two years.

6.9 EU: Applications were made to the European Union's Human Capital and Mobility Fund for Euroconferences to enable the Institute to fund a series of conferences primarily aimed at young people. The first conference series which covers the years 1993/94 and 1994/95 was awarded

60,000 ecu in subsidy to spend on four conferences and the second series, which covers the years 1994/95 to 1996/97, has been awarded 90,000 ecu for eight conferences.

6.10 NATO Advanced Study Institutes (ASIs): Applications were made to NATO by the organisers of the programmes on *Random Spatial Processes* and *Cellular Automata, Aggregation and Growth* for support to fund conferences under the NATO ASI programme. Again, these were largely aimed at young scientists. Both of these applications were successful, the former being awarded the sum of £48,852 and the latter being awarded £47,170.

6.11 Prudential Distinguished Fellowship: This year's instalment of £25,000 from the Prudential Corporation was the second of three, given to be spent on distinguished visiting fellows and associated costs. In 1993/94 the recipients of Prudential awards were Professor Henrik Flyvbjerg; Dr Tim Halpin-Healy and Dr Michael Moore. All three attended the *Cellular Automata, Aggregation and Growth* programme.

6.12 LMS: LMS awarded the sum of £10,000 *pa* to the Institute for five years beginning in 1992/93. This money is to fund subsistence and travel costs for short-term UK participants.

6.13 DAIWA Anglo-Japanese Foundation: The sum of £10,000 was awarded to the Institute by the Daiwa Foundation to fund the participation of Japanese scientists in the Institute's programmes.

6.14 Institute of Physics Fellowship: The Institute received the second £10,000 instalment (of five) of its grant from the Institute of Physics which is given to support a visiting physicist from Eastern Europe. The recipient of the fellowship was Dr Janos Kertész, Deputy Director of the Institute of Physics at the Technical University in Budapest who attended the *Cellular Automata, Aggregation and Growth* programme.

6.15 Jesus College: Jesus College contributed £5,000 towards running costs as it has pledged to do for the first five years of the Institute's operation.

6.16 Cambridge Philosophical Society: The Cambridge Philosophical Society funds four bursaries of £250 each per Institute year to enable young (under 35) scientists to attend the Institute's programmes. In 1993/94 unspent funds were also carried forward from the previous year and hence six bursaries were awarded in total. The recipients of these awards were: Dr Nicola Ferrier *Computer Vision*; Dr Ben Hambly, Dr Alison Etheridge and Dr Terence Chan *Random Spatial Processes* and Dr Timothy Newman and Dr Martin Evans *Cellular Automata, Aggregation and Growth*.

7. FINANCES

The grants given and expenditure incurred on establishing the Institute are summarised in Table 7a below. Grants for recurrent costs are also summarised in Table 7b.

Table 7c, prepared in connection with the fundraising for the Institute gives a picture of the funds which are necessary for the Institute to continue to operate at the best possible level. EPSRC funding, through a "rolling grant", is assured until 31 December 1997 and is to be reviewed for the second time in the autumn of 1995. It will then be considered for extension for a further two years to 31 December 1999 and the resources provided for 1996 and 1997 will be reviewed. The subvention of the rent (by £150k *pa*) provided by St John's College and the grant of £200k *pa* from the Newton Trust will last until June 1997.

Table 7a—Setting-Up Costs

Donations		**Expenditure**	
Apple UK	108,000	Audio Visual Aids	27,743
Books (Individuals)	232,000	Consumables	16,000
Books (Organisations)	25,000	Computing Equipment	409,086
Cambridge University	121,000	Furniture & Equipment	139,727
Cambridge Colleges	140,000	Library	305,930
Individuals	17,221	Office Equipment	40,437
London Math Soc	20,000	Inauguration	5,704
Nuffield Foundation	57,298	Security Systems	15,715
SERC	100,000	Staff Costs	84,644
Sun Microsystems	213,000		
Interest	11,467		
Total	£1,044,986	Total	£1,044,986

Apple UK donated computer equipment worth £108,000.

Donations of books and journals worth about £232,000 were received from individuals. Donations of money totalling £17,221 were also received.

Donations of books and journals were received from Cambridge University Press, London Mathematical Society, Princeton University Press, Springer-Verlag and other organisations, totalling about £25,000 in value.

Grants of £5,000 from Christ's College, £30,000 from Emmanuel College, £100,000 from Gonville and Caius College were received towards the costs of establishing the Institute. Jesus College gave a grant of £5,000 *pa* for 5 years.

The London Mathematical Society provided a grant of £20,000 towards establishing the Institute. This was part of a larger grant of £70,000, the remainder to be paid over 5 years.

The Nuffield Foundation provided a grant of £57,298 to meet the salary costs of the Deputy Director and some secretarial and other support during the setting-up period.

A grant of £100,000 was received from the SERC towards the cost of establishing the Institute, £70,000 for computing equipment and £30,000 for the library.

Sun Microsystems donated computer equipment worth about £213,000.

A grant of £100,000 was received from the University of Cambridge towards the cost of furniture and equipment for the building. A further grant of £21,000 was provided out of anticipated income

from the UFC associated with the Institute.

Table 7b—Grants for Recurrent Costs

SERC/EPSRC	£568k
Isaac Newton Trust	£210k
St John's College	£150k
NATO	£96k
NM Rothschild & Sons	£67k
CNRS	£47k
Rosenbaum Foundation	£47k
European Union	£28k
Prudential Corporation plc	£25k
Institute of Physics	£10k
London Mathematical Society	£10k
Daiwa Anglo-Japanese Foundation	£10k
Jesus College	£5k
Cambridge Philosophical Society	£1.5k

Table 7c Future Funding Needs

Notes		91–92	92–93	93–94	94–95	95–96	96–97	97–98
	BUILDING							
1	Setting-up cost	£234k						
2	Rent		£184k	£184k	£184k	£184k	£184k	£184k
3	Overheads		£27k	£23k	£28k	£29k	£29k	£30k
	Total Need	£234k	£211k	£207k	£212k	£213k	£213k	£214k
4	*Funding secured*	*£234k*	*£211k*	*£207k*	*£212k*	*£213k*	*£213k*	*£60k*
	Funding Need: building							**£154k**
	EQUIPMENT							
5	Computers	£409k	£105k	£122k	£122k	£125k	£128k	£131k
6	Books	£306k	£18k	£27k	£27k	£28k	£28k	£29k
7	Consumables		£63k	£71k	£70k	£72k	£74k	£75k
	Total Need	£715k	£186k	£220k	£219k	£225k	£230k	£235k
8	*Funding secured*	*£715k*	*£186k*	*£220k*	*£219k*	*£214k*	*£200k*	£165k
	Funding Need: equipment					**£11k**	**£30k**	**£70k**
	POSTS							
9	Core posts	£85k	£227k	£212k	£245k	£277k	£284k	£291k
10	Visiting posts		£541k	£538k	£560k	£574k	£588k	£603k
	Total Need	£85k	£768k	£750k	£805k	£851k	£872k	£894k
11	*Funding secured*	*£85k*	*£768k*	*£750k*	*£805k*	*£832k*	*£788k*	*£695k*
	Funding Need: posts					**£19k**	**£84k**	**£199k**
	Total Annual Funding Need					**£30k**	**£114k**	**£423k**
	Cumulative Total Need					**£30k**	**£144k**	**£567k**

NOTES:

1. The setting up costs include fitting out, furniture, office equipment and audio-visual equipment.

2. Funds have been secured to rent the building for the first five years from 1 July 1992.

3. Overhead contributions include amounts paid to the University of Cambridge in respect of heat, lighting, maintenance etc.

4. Includes £750k from St John's College towards the first five years' rent, and grants of £121k from the SERC and £100k from Gonville and Caius College.

5. Includes the cost of maintaining and renewing the hardware and software necessary for the first class computing and electronic communication system which is essential for the Institute.

Finances

6. The Library needs to maintain a collection of the most important texts and the key journals over a broad range of the mathematical sciences.

7. Consumables includes items not subsumed under other headings including stationery, publicity materials, telephones, postage, faxes etc.

8. Computer workstations have been donated by Hewlett-Packard, Sun Microsystems and Apple UK; software has been donated by NAG, Claris and Wolfram Research. Over 4000 books and journals have been donated by a large number of publishers and individual members of the mathematical community. Emmanuel, Jesus and Christ's Colleges have made grants.

9. Core posts include the Deputy Director and administrative staff and the Hewlett-Packard Senior Research Fellow from January 1995.

10. Visiting posts include the research programme organisers, visiting professorships and fellowships, as well as basic subsistence allowances for most of the 220 scientists who come as visiting members of the Institute each year.

11. Funding has been obtained as follows:

Institute of Physics	£50k over 5 years
Prudential Corporation plc	£100k over 4 years
NM Rothschild & Sons	£333k over 5 years
Isaac Newton Trust	£1050k over 5 years
London Mathematical Society	£70k over 5 years
CNRS	£200k over 5 years
Rosenbaum Foundation	£225k over 5 years
Daiwa Anglo-Japanese Foundation	£26k over 2 years
SERC/EPSRC	£3239k over 6 years
Hewlett-Packard	£490k over 5 years
Leverhulme Trust	£165k over 3 years

8. PROGRAMME REPORTS

Programme 5: COMPUTER VISION — July to December 1993

Report from the Organisers

A Blake (Oxford), D Mumford (Harvard), BD Ripley (Oxford).

Introduction. This programme brought together researchers from a wide range of disciplines, principally mathematics, statistics and engineering, but also computer science, psychology and various biological sciences. (The organisers are from departments of engineering science, mathematics and statistics.) Computer vision is an inter-disciplinary area, but it is not a well-defined academic subject, and sub-communities work in different 'universes' attending separate conferences, publishing in separate journals and so forth. One of the main aims of the programme was to break down some of these barriers and explore in depth the potential impact of mathematical and statistical methodology within computer vision, and we believe that our success at this is the major achievement of the programme.

Computer vision has developed rapidly in the last two decades. It developed originally as an engineering discipline to tackle practical problems in several areas: visual navigation of mobile robots and road vehicles, hand-eye coordination in assembly robots, quality inspection of manufactured goods and automated analysis of medical images. David Marr, from many perspectives the founder of the area, was the first to seek systematically analogies between the solutions of these problems by computer and their solutions in an animal brain. The field is somewhat split between those who take biological vision as their model and want to describe the brain's algorithms and those who seek direct engineering solutions to the practical problems of vision. The involvement of mathematicians and statisticians has been relatively recent but substantial contributions have already been made, and sufficient computing power is now available to enable theoretical approaches to be developed into feasible computational algorithms. Thus theoretically founded methods can be expected to have increasing importance in the future, and this programme has been very timely in influencing the future directions and coherence of the subject of computer vision.

Organisation. Since the subject to be covered is so broad, we decided to structure the six-month period rather precisely. Sixteen weeks were allocated to specific topics (see the table below) and each was allocated to one or two week-organisers who were asked to arrange the lecture programme for that week and ensure that there was enough introductory material, often in the form of one or two short courses. We aimed at 8 hours of lectures per week (but the pressure to let everyone speak who had something significant to add usually resulted in about 12 hours per week). This structure was widely advertised several months in advance.

Four of these topics were designated as workshops, which were advertised even more widely and had more intensive programmes of around 20 lectures. However, many of the topics attracted visitors from the UK for the week, so several weeks had over 40 people in attendance. We had intended to organise *software challenges*, but this proved to be too ambitious, partly because of the limited hardware available at the Institute and partly from the difficulty in establishing standards and comparing software with divergent goals. However, in the areas of two out of the four planned challenges — real-time visual tracking and model-based vision — software from Oxford and from Rochester was installed and demonstrated.

Schedule of topic weeks.

Week	Topic	Week Organiser(s)
July 5–9	Active Vision I	R Brockett, CM Brown
July 12–16	Computational Geometry and Robotic Path-Planning	JM Brady
July 19–23	Active Vision II — WORKSHOP	A Blake, D Terzopoulos
July 26–30	Computational Approaches to Analysis of Multiple Views	O Faugeras, T Huang
Aug. 2–6	Psychophysics of Motion and Binocular Stereo	K Nakayama
Aug. 16–20	Biology of Vision	D van Essen
Aug. 23–27	Object Recognition I — WORKSHOP	J Mundy
Sept. 6–10	Object Recognition II	S Geman
Sept. 13–17	Surface Geometry	J Koenderink
Sept. 20–24	Wavelets and Pyramid Architectures	P Burt, S Mallat
Oct. 18–22	Statistical Methods in Vision — WORKSHOP	PJ Green
Oct. 25–29	Speech Recognition and relations to Vision	S Roukos, J Bridle
Nov. 1–5	Statistical Basis of Learning and Classification	BD Ripley
Nov. 8–12	Reinforcement Learning and Adaptive Control	A Barto
Nov. 22–26	Texture Segmentation and Classification	J Malik, K Conradsen
Nov. 29–Dec. 3	Geometry-driven Diffusion and Image Segmentation — WORKSHOP	D Mumford

One motivation for choosing this structure was the realisation that as many leading workers in computer vision are running 'labs' and are heavily dependent on grant/industrial funding, they would only be able to visit Cambridge for periods of 1–4 weeks. (Several people visited twice, and long-term visitors returned home for short periods of administration and grant review.) Our structure enabled us to attract researchers for those topics which particularly interested them or to which we particularly wanted their contributions.

Several special lectures were targeted at a less specialist audience. Steven Zucker gave the Princeton University Press series of six lectures on

Computational Vision and Biological Perception

and David Mumford gave the annual Marr lecture on

What does the brain have to compute in order to see?

a version of which was also given in Edinburgh. During the workshop on *Statistical Methods in Vision* papers by three of the participants were read to the Research Section of the Royal Statistical Society in London:

BD Ripley: *Neural Networks and Related Methods for Classification.*

U Grenander and MI Miller: *Representations of Knowledge in Complex Systems.*

There was one joint discussion session with the parallel programme, Random Spatial Processes, and considerable cross-attendance and informal interaction.

Attendance. Eight people attended throughout the programme, six for around three months, sixteen for 4–8 weeks, and there were 73 recorded one week visits. (We estimate another 100 people attended for one or more weeks, without specific invitations.)

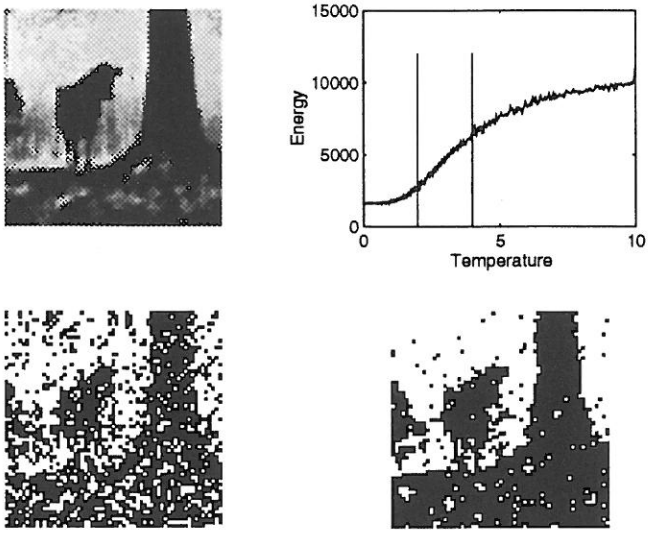
There was extensive attendance by younger UK workers, especially from the main UK groups at Oxford and Sheffield. Many Cambridge scientists from the Engineering and Biological Departments

were regular participants. Unfortunately many senior UK researchers found it difficult to come for more than very short visits.

Highlights. Our impressions are that the main impact of the computer vision programme has been at the conceptual level; it has led to much wider (and more widespread) understanding of the possible theoretical bases for computer vision. Central to this has been the rôle of Bayesian statistical inference, which has recurred throughout the programme, often in topics unsuspected by the organisers!

Hierarchical Bayesian inference has occurred in many of the topic weeks, in which 'layered' abstractions of a visual scene are used as levels of interpretation. For example, when viewing a human face we may wish to factor out the effects of lighting and viewpoint (equivalently, of 'pose') before considering a family of template faces to identify individual faces by name. Methods developed in speech, expert systems and genetics are now available to compute 'optimal' estimates within such hierarchical structures by far-reaching extensions of dynamic programming. Some ideas have already been implemented in computer vision (for instance in object recognition and in reinforcement learning), but the latest techniques developed by statisticians will now be applied within the computer vision community.

Object Recognition was a recurring theme, not only in the weeks specifically dedicated to this, but in the majority of other weeks. This topic both highlighted the divergence between 'camps' involved in the development of very different techniques and the promise if these can be integrated. These range from the use of polynomial invariant theory, to searching in a space of random diffeomorphisms, to exploiting curvature and non-linear shape diffusion based on curvature. It is very striking that although pure mathematics has developed geometric theories ranging from topology to differential geometry to algebraic geometry, none of these seems to capture the intuitive notion of 'shape' and what we mean when we say two shapes are 'similar'. In our week on surface geometry, we even sought to include the insights of a sculptor (John Willats) in describing shape. The range of algorithms developed for object recognition reflects this search for modeling the diverse things similarity of shape includes.



Top left: Input image. Top right: Energy as a function of temperature during the annealing process. Bottom left: An intermediate stage at a relatively high temperature in the construction of foreground/background by annealing. Bottom right: A lower temperature stage. The temperatures of two samples are marked by the vertical lines in the graph: note that they delineate the steepest part of the curve – the 'phase transition' in this example.

What have we learned from biological vision? Several unifying themes in computer vision have been developed using strongly evidence from and intuition based on the study of biological vision. We mention three of these. One is the idea that the appropriate vision front-end is a multiscale wavelet-like filter bank, extracting local spatial frequency features and analogous to simple and complex cell responses on the brain area V1. The ubiquity of this theme, from algorithms for stereo and motion computation to texture segmentation was striking. A second is the need to

separate the computation of local edges, eg by filters, from that of extended edges or contours. Both the neurophysiology of V1 and V2 and the psychophysics of the Gestalt school suggest that extended edges represent a higher stage of processing. Finally, the existence of massive feedback pathways in the brain has been linked generally with statistical models in which a very complex prior is used and specifically with the idea of fitting flexible templates. On the other hand, we saw some very useful algorithms which seem as un-biological as propellers for flight. Examples include the use of invariant theory for object recognition and the characterisation of faces using principal curvatures obtainable from laser range data, but probably not from ordinary images.

Statistical filtering and control. Another of the potentially productive links reinforced during the programme has been between active vision/robotics and control theory. This was evident particularly during the first three weeks and the "reinforcement learning" week in November. Roger Brockett was particularly influential in disseminating theories of stochastic estimation and control and expanding on potential applications in motion modelling. The dynamic programming theme recurred in the context of reinforcement learning, with particular application to learning direct sensory-motor couplings.

Output. The main success of our programme will be in establishing a coherent theoretical view on computer vision. The workshop has heavily influenced the following books which have been planned and/or substantially written during the programme:

A Blake: *Visual Contour Tracking*

CM Brown, D Terzopoulos: *Real Time Vision.* (Drawn from the weeks on active vision.)

J Malik, R Cipolla, P Perona, A Zisserman: *Vision: Principles, Models and Applications.*

D Mumford, A Yuille, P Belhumeur: *Computer Vision*

BD Ripley, NL Hjort: *Pattern Recognition and Neural Networks.*

S Zucker: *Computational Vision and Biological Perception,* Princeton University Press.

which can in turn be expected to influence the future of computer vision as a subject. There will be many other publications, impossible to assess as yet. Many of the long-term participants, while resident here, also traveled and lectured outside of Cambridge, to a wide variety of departments. These include lectures at Oxford, London, Edinburgh, Leeds, Liverpool and Stirling in the UK, INRIA (Nice), Tübingen and Heidelberg on the continent. While it is always difficult to engage in extensive software development while on leave, several projects were successfully carried out with the Institute computer base and with special-purpose vision equipment brought in. These include:

Belhumeur and Mumford: *Genetic algorithm style minimisation procedures*

Blake and Isard: *Linking stochastic estimation with template models*

Brown: *Lattice predictors*

Cipolla and Giblin: *Geometry of silhouettes in motion*

Oliensis: *Structure from motion algorithms*

Tiwari: *Path-planning, Face image analysis*

Weiss and Giblin: *Algorithms for visual analysis of surface geometry*

Programme 6: RANDOM SPATIAL PROCESSES July to December 1993

Report from the Organisers

MT Barlow (UBC, Vancouver), GR Grimmett (Cambridge), H Kesten (Cornell).

Introduction

The theory of random spatial processes has been born out of a need to understand the evolution of complex stochastic systems living in a space normally of finite dimension. This programme aimed at making progress on some of the hardest problems presently under scrutiny, namely, to understand the structure of phase transitions in probabilistic systems, to comprehend the natures of pure phases and the rôle of the number of dimensions, to study geometrical properties of evolving processes, as well as to model and solve concrete problems arising in related areas of scientific research.

In the past two decades there have been studied a great variety of models involving the interaction of a large (or infinite) number of particles, and often exhibiting phase transition. Many of these models have been inspired by statistical physics. While such models may differ considerably in detail, a number of general tools have been developed. One aim of the programme was to acquaint young researchers with these tools. A second aim was to bring together more senior researchers who are already familiar with various parts of this 'machinery' in order to make further substantial progress by combined efforts.

Most of the best researchers worldwide in the field contributed to the success of the programme by visiting for substantial periods. Attempts were made to guide progress by having periods of focus on different aspects, with specialist contributions from groups originating in different countries. There were about 55 long-term visitors in all, with an average stay of 2 months. During the months July–August there were many U.S. visitors, with a more European mix subsequently. All active UK probabilists were welcome, and most of them visited, at least for short periods.

The programme opened in July with a NATO Advanced Study Institute entitled 'Probability Theory of Spatial Disorder and Phase Transition' (G Grimmett, director). Around 120 individuals showed up at this 11 day meeting, from a multiplicity of countries. The principal speakers delivered two talks each, being expositions of recent progress and areas ripe for future research. This superb ASI was attended by at least 28 UK scientists, many of whom were less than 30 years old.

Activity related to material expounded at the ASI continued throughout August. In September there was a successful week devoted to 'Stochastic methods in partial differential equations', for which many experts attended specially (J Norris, M Barlow, G Grimmett, organisers). Once again, UK participation was high. The third and final meeting, on 'Metastability and hydrodynamic limits for interacting particle systems', took place in November (H Kesten, organiser); this was a concentrated research symposium devoted largely to the dynamics of evolving processes.

In between these three meetings, we pursued a programme of 2–4 seminars or expository talks per week. This more tranquil timetable enabled participants to interact and to reflect. Almost always (in the daytime) one could find participants discussing scientific problems in the common area of the Institute. Various groups of researchers attained the critical point of fruitful collaboration, and good progress was made on a variety of topics (see below). A number of these collaborations have resulted already in preprints, and many more articles are in the pipeline.

In addition to the funding arranged through the Newton Institute budget, we benefited from the substantial grant of around $ 48,000 from NATO, as well as ancillary sums from the National Science Foundation, the London Mathematical Society, and the Cambridge Philosophical Society.

Some people took part in discussions with members of the parallel programme on Computer Vision.

Scientific Programme

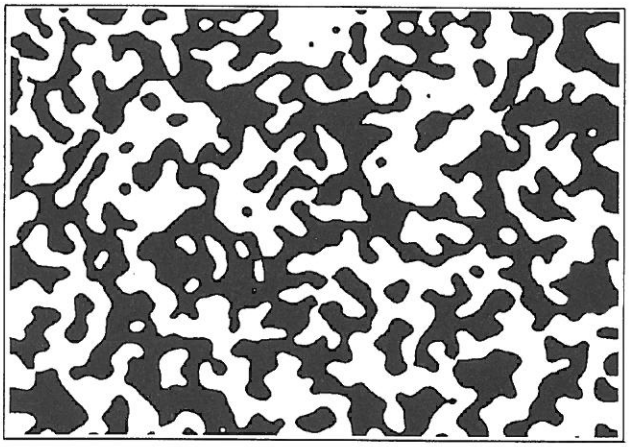
A variety of closely related major themes have been pursued.

Large deviations in statistical physics. The sophisticated large deviations machinery of R Dobrushin and S Shlosman has many principal applications to interacting systems. These include the study (with R Kotecky) of the shape of the critical droplet in the two-dimensional Ising model, and the verification in this case of the famous Wulff construction (work continues in three dimensions). Also dependent on methods from the theory of large deviations is the ongoing programme of R Dobrushin and some of his students to derive higher order hydrodynamic equations. Typically these are equations involving a small parameter ϵ representing the local density of an evolving system of particles. Whereas the usual 'Euler' hydrodynamic equations give a good approximation for times of order $O(\epsilon^{-1})$ only, the nth order Navier–Stokes equations are useful for times as large as $O(\epsilon^{-n})$.

Metastability and time-evolution. The energy function of a system generally has many minima. A system which spends a long time near a local minimum before flipping to a global minimum is sometimes said to be metastable. There are substantial mathematical difficulties in studying metastability for complex interacting systems, and a major part of the programme was devoted to this general area. Outstanding progress has been made on metastability for the Ising model, and various groups were brought together to discuss and report (R Schonmann, E Olivieri, F Martinelli, E Scoppola, H-T Yau, and others).

One now has quite good estimates of how long it takes for a d-dimensional Ising model on a finite box, evolving under Glauber dynamics, to change from 'all minus-spins' to the plus-state. The parameters involved are the size of the box, the strength of the magnetic field, and the temperature; one usually works at low temperatures and small magnetic fields. One may measure the distance between the state of the system and the plus-state using various norms. Several participants explored the relations between such estimates and their dependence on the mixing properties of the Ising model.

There are also major problems of a similar nature for the Ising model on the infinite space $\mathbb{Z}^d$. These were attacked also by participants in the programme, but are not yet well understood.



In this cellular automaton, each site progressively changes its colour in agreement with the majority of its neighbours. Clustering (or self-organisation) occurs swiftly, as illustrated here after three updates with random initial colours. (Figure by David Griffeath)

Movement of interfaces. A new type of problem has arisen in the study of dynamical models whose stationary state is given by the Ising model. Such questions are closely related to metastability and to hydrodynamic limits of systems in 2 or more dimensions. A specific problem of this nature concerns the way the boundary of a growing droplet of plus-spins moves inside a set of minus-spins, when an Ising system evolves under Glauber dynamics from 'all minus' to the plus-state. In certain regimes this movement may

be described as 'motion by mean curvature' (A De Masi, E Presutti). Another example (in one dimension) is the motion of the interface in Glauber dynamics for an Ising system with Kac potential (after an appropriate limit has been taken). In this case one may show the existence of travelling waves (A De Masi, E Presutti).

Similar issues arise in the study of the shock wave experienced by one-dimensional exclusion processes and other nearest-neighbour attractive systems (P Ferrari). The position of the wave-front may be observed by positioning a special particle there. The movement of this particle is then observed, and various results may be obtained, including laws of large numbers, central limit theorems, as well as information about solutions to the macroscopic equation arising in the hydrodynamic limit.

Statistical physics. Many models of statistical physics pose first-class challenges to the probabilist, and we mention here several areas under this heading. First, progress has been made on understanding the nature of phase transitions for spin glasses (M Aizenman, A Gandolfi, M Keane, C Newman). For such mathematical models the phenomenon of frustration poses a major difficulty, and a similar problem arises in studying hard-core models (J van den Berg, R Dobrushin, H-O Georgii).

An important model from statistical physics involves Schrödinger-type equations with random potentials, and sometimes other random coefficients. One of the main questions here is to determine conditions on the potentials and energy values for which these equations have localised eigenfunctions. M Aizenman and S Molchanov have given greatly simplified proofs of some known results, and have proved new results implying that localisation occurs in a variety of regimes. M Aizenman gave two lectures on his method during the NATO conference.

Quantum systems were the subject of investigation by several participants. For example, A Mazel and Y Suhov studied the phase diagram and ground states of a quantum system with a generalised hard-core interaction.

A topic of burgeoning interest amongst physicists and probabilists is the study of repulsive and attractive random walks and Brownian motion, and self-avoiding walks (T Hara, Y Higuchi, G Slade, B Tóth, E Bolthausen). We heard several lectures on this. The lace expansion is a major tool here (see below).

Lace expansions. In the context of percolation and polymer models such as the self-avoiding walk, a major component of understanding phase transition and dimension-dependence is to prove existence of the critical exponents characterising the behaviour of various quantities of interest near the critical point. Although much non-mathematical and numerical work has been done in this direction, rigorous proofs of existence of critical exponents have only begun to appear in recent years. This problem is dimension-dependent, and currently rigorous results have been obtained only above the upper critical dimensions, respectively four, six, and eight for the self-avoiding walk, percolation, and lattice animals (branched polymers). This work, due primarily to T Hara and G Slade and continued during the programme, is based on the application of an expansion method known as the lace expansion. It remains a major challenge to prove existence of critical exponents in lower dimensions.

Ising/Potts models. The Ising model in two dimensions has a beautiful geometry which varies as a function of temperature and external field. Y Higuchi has continued his successful project to understand the geometry of single-spin clusters. Partially related is the problem of proving weak mixing (J van den Berg, A Gandolfi, Y Higuchi, R Schonmann).

D Abraham and C Newman described their work on weighted surface models with an Ising interaction, and on related questions about the geometry of 'Peierls contours'.

Potts models have been studied extensively. In addition to the work of J.Cardy and G Grimmett (see below), we were fortunate to be visited twice by R Kotecky, who explained the detailed application of Pirogov–Sinai contour theory to Potts models.

Interacting particle processes. A standard model for the spread of infection is the contact process. This is the simplest of a class of 'threshold' models, in which each point becomes infected at a rate which depends on the states of its neighbours. T Liggett explained how the ergodic structure of such processes in one dimension depends on the numerical value of the critical point of the contact process, and how to calculate this value to the desired accuracy.

The random-cluster model is a process of stochastic geometry which generalises the Potts model. J Cardy described beautiful conjectures for the conformal invariance of two-dimensional Potts models at criticality; it may be many years before such conjectures (which may be applied also to crossing probabilities of random-cluster processes) are verified rigorously. G Grimmett explored level-set representations and time-evolutions for random-cluster models, in an attempt to understand the phenomenon of first and second order phase transitions.

T Mountford, our Rosenbaum Fellow, worked on a variety of interacting particle processes. One fine result of his is a Poisson limit theorem for the output from queues in series; his solution to this old problem in queueing theory uses ideas developed for exclusion processes.

Growth models. Models of stochastic growth are relevant to several areas of applied science, including cancer research, epidemiology, crystal growth, and so on. Various visitors reported on different aspects of the rigorous theory. G Lawler described progress and open problems for diffusion-limited aggregation (DLA), a process studied also by M Barlow and E Perkins on trees. K Alexander and M Penrose have worked on processes which accrete into spanning trees. H Kesten, C Newman, R Pemantle, Y Peres, and M Piza have proved elegant bounds for the fractal-like structure of the boundary of a certain growth process; interesting questions remain unanswered for this problem. J Hammersley continued his work on understanding the nature of holes created within the boundary of an Eden cluster, using in part Monte Carlo simulation.

Tree processes. When crystalline lattices are too hard, the physicist and probabilist migrate to a tree. Trees are often regarded as infinite-dimensional analogues of crystalline lattices. Models which are too difficult to analyse on finite-dimensional spaces are sometimes tractable on trees, owing to the absence of loops. Such solutions for trees then serve as guides to what may be expected in high but finite dimensions. Until a few years ago, one considered typically only *regular* trees. R Lyons, R Pemantle, and Y Peres have shown that many problems are tractable on completely general trees, including finding critical values for Ising and percolation processes. Under investigation now are various properties of random walks on trees. For example, criteria for recurrence and transience have been found, properties of harmonic measure on the boundary of the tree are known (in the transient case), and there are intriguing comparisons between polar sets (sets which are not hit by a random walk) on different Galton–Watson trees (R Lyons, R Pemantle, Y Peres).

In another direction, examples have been constructed (by I Benjamini and H Kesten) of trees on which one can see all sequences of 0s and 1s in an independent percolation process, starting from a prescribed finite number of vertices.

Finally in this section we mention the work of M Barlow and E Perkins on diffusion-limited aggregation (DLA) on trees (see above).

Measure-valued diffusions are continuum limits of branching walks, and serve as models for the spatial distribution of a population whose members branch, die, and move. The two fundamental processes in the field, the Fleming–Viot process (FV) and super Brownian motion (SBM) (also known as the Dawson–Watanabe process) are related by the fact (discovered by A Etheridge, P March, and E Perkins) that FV is just SBM conditioned to have constant mass. Although these processes take values in spaces of non-atomic measures, it is possible to follow the histories of the individuals which make up the population. P Donnelly described a simple way of doing this, while JF LeGall outlined another, and D Dawson and E Perkins a third. The individuals in SBM evolve and move independently, but for more realistic models one wishes to allow interactions between individuals and the whole population (eg particles move away from densely populated regions), or between populations (for models of competing species, say). E Perkins described a 'stochastic calculus' which enables a variety of models with interactions to be built from SBM, while P March (in joint work with D Dawson) has obtained resolvent estimates which allow Stroock–Varadhan perturbation methods to be applied to the FV process. Such work was expounded and investigated by a substantial group of visitors (A Greven, T Shiga, etc) during the programme, and was central to the September meeting.

Stochastic partial differential equations. The rigorous study of random fields indexed by a continuum rather than a lattice is in its infancy, one-dimensional and Gaussian cases aside. Stochastic partial differential equations, by which a well understood random field such as white noise is transformed infinitesimally into some more general field, offer a way forward, currently an active area of research worldwide. This was represented in the September meeting and the associated discussions by the work of J Norris, R Tribe, J Walsh, and others, as were many of the other connections between continuum random processes and partial differential equations, for example in travelling waves (J Biggins, Y Suhov). However a rigorous theory of continuum limits of critical lattice systems is still a long way off, if not impossible in general.

Professor Claude Kipnis: We regret to report the death of one of the participants on the *Random Spatial Processes* programme. Professor Claude Kipnis died in his Cambridge residence of an acute myocardial infarction at the beginning of September 1993.

Programme 7: GEOMETRY AND GRAVITY — January to June 1994

Report from the Organisers

GW Gibbons (Cambridge), SW Hawking (Cambridge) and CJ Isham (London).

Introduction: The aim of this programme was to bring together geometers and physicists interested in Problems in Classical and Quantum Gravity. In addition to classical differential geometry there has arisen over the past few years the important mathematical subject variously called "non-commutative differential geometry" or the "quantised calculus". Developed originally by mathematicians the subject is now being taken up by physicists especially as an alternative to the Kaluza-Klein procedure for obtaining descriptions of matter in terms of the geometry of an extended spacetime.

In addition to these purely mathematical areas there has been a remarkable resurgence of interest of late in the foundations of quantum mechanics and its relevance for studies of the early universe—quantum cosmology. New ways of looking at the nature of spacetime and their relevance for quantum theory are also at the heart of Twistor theory and this viewpoint has stimulated a number of important developments within differential geometry and gauge theory.

Finally the subject of gravitational collapse and the quantum properties of black holes continues to offer deep challenges to our understanding of fundamental physics and provides much of the physical motivation behind our attempts to quantise gravity.

Programme Structure: With these four main areas in mind the organisers decided to structure the programme in terms of four main sub-programmes:

Mathematical Foundations (Jan–March)

Twistor Theory (April–June)

Quantum Cosmology (March–May)

Black Hole Physics (May–June)

Long-Term Participation: The overall cohesion of the programme was maintained by the presence throughout the 6-month period of the organisers and James Hartle and Gary Horowitz. Both the latter have extremely broad interests and their presence for the entire six-month period (Hartle as Rothschild Professor for part of it) contributed enormously to the success of the programme. Also present for the entire six-month period were Arlen Anderson (Rosenbaum Fellow) and Ben Harms.

Other Activities: In addition to the main activities a number of small workshops and a major review conference were held during the six months. The conference, supported in part by funds from the EU, was entitled *Classical and Quantum Gravity* (28–31 March) and was a four-day Survey Meeting. The speakers were partly taken from among the participants, and about half were invited specially. The meeting was extremely well attended both by people from the UK and from the EU. The level of the talks was accessible to a broad mathematical audience and a large number of students and post-doctoral workers were present.

At a more technical level mini workshops were held on *Membranes and Higher Dimensional Extended Objects* (21–23 March), *Closed Timelike Curves and Black Holes* (11–15 April), *Black Holes* (6–9 June), *Twistors* (8–14 June) and *Strings* (23–27 May) and a one-day meeting on Saturday 7 May at which members of the Editorial Board of Classical and Quantum Gravity spoke on their recent research. In association with the programme Professor J Charap organised a workshop on the *Geometry of Constrained Dynamical Systems* (15–18 June).

Mathematical Foundations: This sub-programme began with ten lectures by S-T Yau (Rothschild Professor) on *Non-linear Equations* and *Geometry and Gravity*. Professor Yau's lectures covered classical genĕral relativity (the positive mass theorem and the properties of minimal surfaces) and also the applications of algebraic geometry to string theory—especially to the as yet imperfectly understood phenomenon of *mirror manifolds*. Professor Yau's lectures were followed by a series of lectures by Professor A Connes on the *Quantised Calculus*. Professor Connes developed the general theory, and gave some applications to the standard model of particle physics. Professor Connes was present for the entire three months of the sub-programme. During his stay he was able to extend his work to cover the Einstein action. He also worked with Rovelli on the problem of time in quantum cosmology from the point of view of the algebraic approach to quantum theory. Other participants (Madore, Dubois-Viollette, Machir) developed various aspects of the formalism of non-commutative differential geometry to the point where concrete physical models are beginning to emerge.

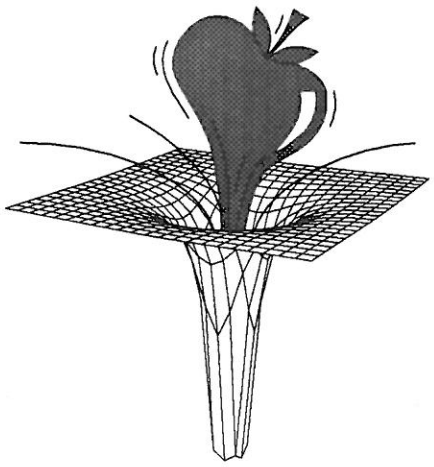
Quantum Cosmology: The central interest of this sub-programme were the various approaches to *Decoherent Histories* developed by Griffiths, Omnes, Gell-Mann, Hartle and others. All four were present at the Institute for part of the programme. A regular seminar was held in which Hartle,

Isham and Halliwell led the discussions. One notable development was the work of Isham (and Linden) who were able to relate the general scheme of Gell-Mann and Hartle to a generalisation of the quantum logic which incorporates ideas from temporal logic.

The study week on *Closed Timelike Curves* proved extremely valuable in providing a challenge to attempts being made, such as the Hartle-Gell-Mann scheme, to generalise the basic quantum-mechanical framework. It identifies what must be sacrificed and what may be retained in the present theory. There was some agreement that one could have either unitarity or linearity but not both.

Twistor Theory: This sub-programme was fortunate in being able to attract most of the leaders in this field, including of course Sir Roger Penrose whose knighthood was announced during his stay at the Institute. A high proportion of the participants working on Twistor theory were able to attend for the entire three months and progress was made on generalising the non-linear graviton construction to general, non self-dual gravitational fields and to the relation between the Penrose transform and the Radon transform. The Twistor Week attracted a large number of twistor theorists from within the UK.

Black Hole Physics: In addition to the long standing debate about whether quantum coherence is maintained during quantum processes involving black holes there was extensive discussion of the possibility—relaxed for some time but now at the centre of attention—that charged black holes (magnetic or electric) may be pair-created by sufficiently strong external electromagnetic fields. Analysing this possibility has produced many new insights into the quantum physics of black holes and gave rise to much discussion. Another topic of increasing importance is the relationship between black holes and superstring states. This has become more pressing because of recent developments—due in part to Sen—which relate, via so-called S-duality—the properties of string states at strong coupling to those of soliton states, such as Yang-Mills BPS monopoles, at weak coupling. There were several discussions of how this phenomenon might carry over to the situation where gravitational fields are taken into account. This work raises both mathematical and physical challenges and exchanges between mathematicians like Yau and Segal on the one hand and string theorists like Harvey and Gauntlett on the other provided to be extremely valuable.



The design for the *Geometry and Gravity* programme T-shirt, by Simon Gill based on an idea by Stephen Hawking

Another topic which received extensive attention was the significance in string theory of the singularities of classical relativity. There is now mounting evidence that not all classical spacetimes with singularities should be considered singular in string theory. A related question relates to the idea of "duality": that physics at very small and very large distances may be related by a symmetry of string theory.

Public Lecture Programme: In addition to the usual regular seminar programme and workshops two of the participants—Stephen Hawking and Roger Penrose—delivered three public lectures on the theme of *The Nature of Space and Time*. In the lectures, which are to be published by Princeton University Press, Hawking and Penrose were able to survey their own individual approaches to the

various problems raised by the existence of spacetime singularities, the need to quantise gravity, the nature of a possible gravitational entropy and its relevance for our understanding of the Big Bang. These lectures were extremely popular and attracted large audiences. They culminated in a debate—held in the Institute, during which the two protagonists were able to restate their respective positions and contrast them with the opposite viewpoint. It may be anticipated that the stimulus that their efforts have produced will continue to provoke discussion among students and others in the future. They clearly established that the ultimate aims of quantum gravity are not merely to solve technical problems, important as these are, but also to address some of the most fundamental questions about the nature of the universe and the laws that govern it.

Programme 8: CELLULAR AUTOMATA, AGGREGATION AND GROWTH January to June 1994

Report from the Organisers

B Derrida (Ecole Normale Supérieure), AJ McKane (Manchester), ER Speer (Rutgers).

Introduction. As the behaviour of statistical mechanical systems in thermal equilibrium becomes increasingly well understood, much activity among theoretical physicists and mathematicians interested in statistical physics has focused in recent years on the behaviour of nonequilibrium systems, and in particular on problems of the growth. The advent of large-scale computer simulations has also contributed to the huge increase of scientific activity in this area. The problems of interest are typically modeled as systems of very large number of microscopic objects which evolve according to very simple dynamical rules of a local character, and one is interested in the statistical properties of the system at a macroscopic scale.

The goal of the programme in Cellular Automata, Aggregation and Growth was to bring together scientists, primarily physicists and mathematicians, who have worked in and contributed to this field, and to encourage interactions among them. The high quality of the participants, the amount of collaborative effort which ensued, and the enthusiasm shown by the participants in their final reports all testify to the degree to which these goals were met. Nine participants stayed for the entire six months of the programme, fifteen others stayed for at least two months, and more than twenty visited for shorter periods.

Scientific activities were scheduled with a view toward promoting the goal of interaction and collaboration. A twice weekly seminar was used as a vehicle for participants, particularly those recently arrived, to introduce their work to others; this seminar also provided an opportunity to bring to Cambridge, or to the Institute from other parts of Cambridge, scientists working in the areas of interest of the programme. A series of short meetings was designed to introduce participants systematically to some of the major topics of the programme, and to reach out to U.K. scientists at Cambridge and other institutions. The programme ended with a NATO Advanced Study Institute on Scale Invariance, Interfaces and Non-equilibrium Dynamics, organised by M Droz, AJ McKane, J Vannimenus and D Wolf.

We wish to express our appreciation to the Director, Deputy Director, and Institute staff for the excellent support which they gave to the programme.

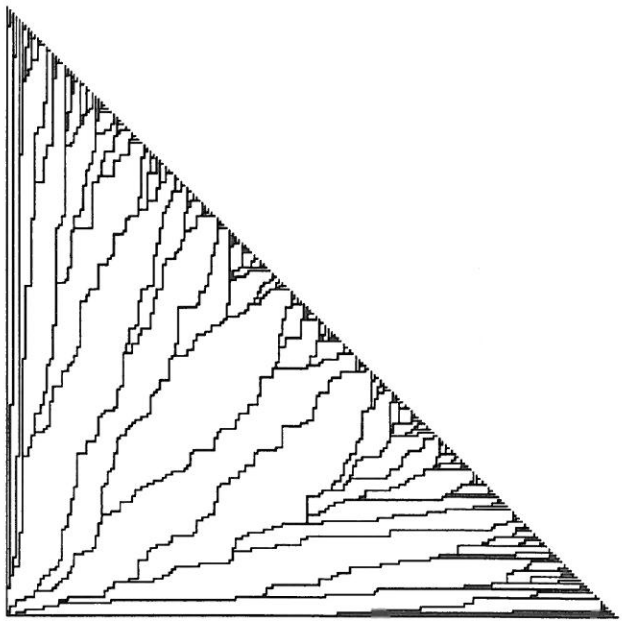
Areas of Scientific Activity: The topic of the meeting and the interest of the participants spanned rather broad areas of physics and mathematics, and many collaborations were initiated. It is convenient to describe these scientific activities in terms of a number of specific sub-areas.

Kinetic roughening and the KPZ equation: This was one of the most active areas represented; participants working on these problems included Edwards, Halpin-Healy, Kardar, Kertész, Krug,

Moore, Tang, and Wolf. In particular, Kertész and Wolf (with E Somfai) obtained results on long range temporal correlations in nucleation events during layer by layer growth. Moore obtained an exact solution of the KPZ in all dimensions higher than four.

Coarsening phenomena: It emerged from the meeting held on coarsening, and in particular from the review talks there of Alan Bray, that for this problem many of the fundamental dynamical principles, the self-similarity structure, and the scaling relations are now fairly well understood. On the other hand, several collaborations among participants in the programme have produced additional progress in this area. Bray, Derrida, and Godreche discovered that certain quantities relevant to coarsening phenomena—for example, the number of unflipped spins, as a function of time, in an Ising or Potts model started from a random initial condition and evolving with Glauber dynamics—decay with a power law having a nontrivial exponent; they also solved exactly a related deterministic model in one dimension. For the stochastic dynamics, several approaches have been developed to determine the exponents exactly, in particular by Dhar and Hakim. Kertész and Ramaswamy found multiple time scales and logarithmically slow coarsening in a two-species asymmetric exclusion model.

Asymmetric exclusion models and exact solutions: As the programme developed, a great deal of discussion and collaborative effort grew out of work over the past several years, by Derrida and collaborators, on exact solutions for certain one-dimensional driven diffusive systems called asymmetric exclusion models. In these solutions, exact formulas for the steady state measure of these systems are obtained as particular matrix elements, or as traces, of products of infinite dimensional matrices. These solutions played an important rôle in the discussion of shocks and fronts at the short meeting devoted to that subject. Moreover, during the programme Derrida, Evans, and Mallick extended these methods to calculate the exact diffusion constant in one such model. Schütz also obtained results on these models, using a somewhat different algebraic approach. At the moment there is hope that these techniques can be pushed to obtain further results, but that question is certainly not settled.



A directed polymer "river basin": the solution of a global optimisation problem closely related to interface growth; from *Kinetic Roughening Phenomena, Stochastic Growth, Directed Polymers, and All That* by T Halpin-Healy and Y-C Zhang.

Work took place also on some related models in which exact solutions are, at least at the moment, not obtainable. Evans, Godreche, and Mukamel studied a one dimensional, two species asymmetric exclusion model, in a system with open boundaries, in which there is a rather surprising broken symmetry; in general, such symmetry breaking does not take place in one dimensional equilibrium systems (at least those with short range interactions), so the nonequilibrium nature of the model is critical here. Kertész and Ramaswamy studied several two dimensional versions of the driven asymmetric exclusion process.

Self organised criticality: This area, while perhaps not as active as a few years ago, still presents interesting questions. One of these is to determine just what behaviours of a system should be

characterised as SOC and what properties of the system are required to give rise to this behaviour; these questions played a major rôle in Grinstein's lectures to the NATO Institute, and motivated Flyvbjerg's derivation of a particularly simple SOC system, the "self organised critical pinball machine." Another area of activity is the application of SOC concepts to biological and evolutionary models; Bak and Flyvbjerg, and Derrida and Flyvbjerg with J De Boer, AD Jackson, and T Wettig, obtained results in this area. Speer returned to one of the original SOC models, obtaining results on conservation laws in the directed sandpile model of Dhar and Ramaswamy.

A question which remains open is the relation of SOC models for sandpiles with behaviour of actual granular materials. Several talks at seminars and at the NATO meeting were devoted to experimental work in this area.

Reaction-diffusion systems: Reaction-diffusion systems, and the formation of fronts in such systems, were discussed in seminars by Cardy and Droz, and by Chopard at the NATO Institute. Droz and McKane were able to show the equivalence of the two existing methods for obtaining a field-theoretic description of these systems. Newman obtained results on some novel effects in reaction-diffusion systems in dimension two.

Behaviour of fronts: We have discussed above the work in the programme on shocks and fronts as motivation for and application of exact solutions of asymmetric exclusion models, and on fronts in reaction-diffusion systems. In separate work, Dekking and Speer studied the shape of fronts in the more abstract probabilistic setting of the minimal displacement of a branching random walk.

Disordered systems: The visit of Kardar seemed to be a focus for several collaborations in the area of disordered systems. Derrida and Kardar developed a position-space renormalisation group scheme for the study of a branched directed polymer in a random medium, modeling the interface of a Potts model in the presence of random bonds. Dhar, Kardar and Tang studied the depinning transition of interfaces from impurities, focusing on anisotropic depinning potentials, which they conjecture lead to new universality classes of depinning.

Diffusion limited aggregation: Seminars on diffusion limited aggregation and Laplacian growth, describing the current experimental and theoretical status and some new directions of attack, were presented by Ball, Couder, Halsey, Hakim, and Yekutieli. Yekutieli continued his work on a model of branched growth defined on abstract tree graphs.

Field theoretic and other continuum methods: Several collaborations have been formed in which field theoretic methods are used to study non-equilibrium statistical mechanical behaviour. Dickman, Grinstein, and Livi have used these methods to examine the critical properties of contact processes with many absorbing states. Domany, Grinstein, and Livi worked on damage spreading in more general interacting particle systems; they believe that their methods will show that the static critical behaviour is that of ordinary directed percolation. McKane and Zia used path integral techniques to calculate the statistics of one-dimensional interfaces. Blum and McKane, motivated by work of Schwartz and Edwards on the KPZ equation, studied variational approaches to stochastic processes, especially those for which detailed balance does not hold. McKane worked with participants in the programme on Geometry and Gravity on the use of standard nonequilibrium statistical mechanics techniques in studying quantum decoherence.

Cellular Automata: Work was carried out in a variety of unrelated areas of cellular automata research. Chaté presented a seminar describing rather surprising collective behaviour of certain cellular automata in high (four, five and six) dimensions. The source of this behaviour is not clear at the moment, and Chaté and Tang began a collaboration to see if it can be reproduced by a systematic mean-field-like approximation. Goldenfeld and McKane studied the problem of

modeling quantum systems by cellular automata; an extensive review of literature led them to conclude that there are fundamental difficulties with all previous work in this area. Speer and Steif initiated a rigorous study of a deterministic cellular automaton, the threshold voter model, in a region of parameter space in which now rigorous results are currently available.

Short Meetings: Various short meetings were organised as part of the programme.

3–4 February: *Dynamics of Phase Ordering and Other Coarsening Phenomena.*
A one and a half day meeting with three review talks by A Bray and talks on current work by N Goldenfeld, V Hakim, and I Yekutieli.

3–4 March: *Kinetic Roughening*
A one and a half day meeting with two review talks by T Halpin-Healy and talks on current work by S Edwards, L Tang, and D Wolf.

23 March: *Fronts and Shocks:*
An afternoon meeting with talks by M Droz, J Krug, E Speer, and H Spohn.

21–22 April: *Diffusion Limited Aggregation* A one and a half day meeting with two review talks by R Ball and talks on current work by J Earnshaw, T Halsey, and I Yekutieli.

12–13 May: *Self-organised Criticality*
A one and a half day meeting with two review talks by D Dhar and talks on current work by P Bak, J-P Bouchaud, and H Flyvbjerg.

25 May: *Cellular Automata:*
An afternoon meeting with talks by J Hemmingsson, R Livi, and A Toom.

1 June: *Spitalfields Day*
A one day meeting with talks by B Derrida, D Dhar, H Flyvbjerg, and R Zia.

20–30 June: *Scale Invariance, Interfaces and Non-Equilibrium Dynamics*
A NATO Advanced Study Institute with talks by B Chopard, Y Couder, S Edwards, H Flyvbjerg, G Grinstein, V Hakim, I Jánosi, M Kardar, J Krug, J Rajchenbach, L Sander, M Siegert, K Sneppen, D Wolf, and R Zia.

9. APPENDICES

9.1 NATIONALITIES AND COUNTRIES OF RESIDENCE OF VISITING MEMBERS

Programme: Computer Vision

Participant	Nationality	Country of Residence	Home Institution	Visits
Amit, Y	Israel	USA	Department of Statistics, University of Chicago	22 Aug - 10 Sep, 1 Oct - 15 Oct,
Bajcsy, R	USA	USA	Department of Computer Sciences, University of Pennsylvania	19 Jul - 30 Jul,
Barlow, HB	UK	UK	Physiological Laboratory, University of Cambridge	9 Aug - 20 Aug,
Belhumeur, PN	USA	USA	Robotics Laboratory, Harvard University	9 Jul - 27 Aug, 19 Oct - 2 Dec,
Blake, A	UK	UK	Department of Engineering Science, University of Oxford	5 Jul - 17 Dec,
Brockett, RW	USA	USA	Department of Applied Science, Harvard University	1 Jul - 30 Jul,
Brown, C	USA	USA	Department of Computer Science, University of Rochester	5 Jul - 18 Aug,
Cipolla, R	UK	UK	Department of Engineering, University of Cambridge	5 Jul - 1 Oct,
Conradsen, K	Denmark	Denmark	Technical University of Denmark	4 Nov - 5 Dec,
Cooper, DB	USA	USA	Department of Engineering, Brown University	21 Aug - 15 Sep,
Cox, IJ	UK	USA	NEC Research Institute, Princeton	26 Jul - 6 Aug,
Ferrier, NJ	UK	UK	Department of Engineering Science, University of Oxford	4 Jul - 31 Jul, 9 Aug - 13 Aug, 29 Nov - 3 Dec,
Forsyth, D	South Africa	USA	Department of Computer Science, University of Iowa	2 Aug - 29 Aug,
Frigessi, A	Italy	Italy	Laboratorio di Statistica, Venezia	18 Oct - 29 Oct,
Geiger, D	USA	USA	Siemens Corporate Research, Princeton	6 Sep - 17 Dec,
Geman, D	USA	USA	Department of Mathematics, University of Massachusetts	22 Aug - 28 Aug, 5 Sep - 11 Sep,
Geman, S	USA	USA	Department of Applied Mathematics, Brown University	14 Aug - 12 Sep, 25 Oct - 26 Nov,
Giblin, PJ	UK	UK	Department of Pure Mathematics, University of Liverpool	12 Jul - 25 Sep, 29 Nov - 3 Dec,
Gidas, B	USA	USA	Department of Applied Mathematics, Brown University	29 Nov - 6 Dec,
Graffigne, C	France	France	Mathématiques, Université de Paris-Sud	16 Oct - 30 Oct,
Green, PJ	UK	UK	Department of Mathematics, University of Bristol	17 Oct - 23 Oct, 1 Nov - 5 Nov, 8 Nov - 12 Nov,
Hallam, J	UK	UK	Department of Artificial Intelligence, University of Edinburgh	19 Jul - 30 Jul, 30 Aug - 10 Sep, 1 Nov - 12 Nov,
Huang, TS	USA	USA	Beckman Institute, University of Illinois	4 Jul - 10 Jul, 19 Jul - 27 Jul,

9.1 Visiting Members

Kay, JW	UK	UK	Department of Computing and Mathematics, University of Stirling	18 Oct - 22 Oct,
Kimia, BB	Canada	USA	Department of Engineering, Brown University	29 Nov - 3 Dec,
Kübler, O	Germany	Switzerland	Institut für Kommunikationstechnik, ETH, Zürich	16 Aug - 20 Aug, 29 Nov - 3 Dec,
Longuet-Higgins, HC	UK	UK	Experimental Psychology Laboratory, University of Sussex	26 Jul - 6 Aug,
Mackay, DJC	UK	UK	Department of Physics, University of Cambridge	18 Oct - 25 Nov,
Malik, J	India	USA	Computer Science Division, University of California	15 Jul - 5 Dec,
Manduchi, R	Italy	USA	Department of Electrical Engineering, University of California	19 Sep - 21 Oct,
Mayhew, JEW	UK	UK	AI Vision Research Unit, University of Sheffield	5 Jul - 17 Dec,
Maybank, SJ	UK	UK	GEC Marconi Hirst Research Centre	26 Jul - 30 Jul, 23 Aug - 27 Aug, 6 Sep - 10 Sep, 18 Oct - 22 Oct, 1 Nov - 5 Nov, 29 Nov - 3 Dec,
Morel, J-M	France	France	CEREMADE, Université de Paris-Dauphine	2 Dec - 4 Dec,
Mumford, D	USA	USA	Department of Mathematics, Harvard University	15 Jul - 15 Dec,
Mundy, JL	USA	USA	GEC Research and Development Center, New York	19 Jul - 27 Aug,
Nakayama, K	USA	USA	Department of Psychology, Harvard University	1 Aug - 7 Aug,
Neal, RM	Canada	Canada	Department of Computer Science, University of Toronto	28 Oct - 12 Nov,
Nicholls, GK	New Zealand	UK	Department of Statistics, University of Oxford	22 Nov - 3 Dec,
Oliensis, J	USA	USA	Department of Computer Science, University of Massachusetts	5 Jul - 1 Oct,
Perona, P	Italy	USA	Caltech, Pasadena	25 Oct - 5 Nov, 21 Nov - 3 Dec,
Pollick, FE	USA	USA	ATR Human Information Processing Research Laboratory, Kyoto	26 Jul - 6 Aug,
Porrill, J	UK	UK	AI Vision Research Unit, University of Sheffield	26 Jul - 29 Oct, 20 Jul - 22 Jul,
Ripley, BD	UK	UK	Department of Statistics, University of Oxford	4 Jul - 17 Dec,
Sapiro, G	Uruguay	Israel	Department of Electrical Engineering, Technion, Israel	19 Jul - 23 Jul, 12 Sep - 17 Sep, 29 Nov - 3 Dec,
Shiota, T	Japan	Japan	Department of Mathematics, University of Kyoto	22 Nov - 6 Dec,
Sparr, AG	Sweden	Sweden	Department of Mathematics, University of Lund	13 Sep - 25 Sep,
Spiegelhalter, DJ	UK	UK	MRC Biostatistics Unit, Cambridge	18 Oct - 22 Oct, 1 Nov - 5 Nov,
Szeliski, R	Canada	USA	Digital Equipment Corporation, Cambridge, Massachusetts	19 Jul - 30 Jul, 6 Sep - 24 Sep,
Tannenbaum, A	Israel	USA	Department of Electrical Engineering, University of Minnesota	12 Sep - 17 Sep, 28 Nov - 4 Dec,
Terzopoulos, D	Canada	Canada	Department of Computer Science, University of Toronto	17 Jul - 1 Aug,

9.1 Visiting Members

Tiwari, S	India	USA	Department of Mathematics, University of Wisconsin	4 Jul - 17 Dec,
Van Gool, L	Belgium	Belgium	ESAT-M12, University of Leuven	19 Jul - 31 Jul, 22 Aug - 28 Aug, 28 Nov - 4 Dec,
Weiss, RS	USA	USA	Department of Computer Science, University of Massachusetts	22 Aug - 18 Sep,
Weinshall, D	Israel	Israel	Institute of Computer Science, Hebrew University of Jerusalem	5 Jul - 6 Aug, 22 Aug - 26 Aug,
Werman, M	Israel	Israel	Institute of Computer Science, Hebrew University of Jerusalem	4 Jul - 29 Jul, 22 Aug - 6 Sep,
Yuille, AL	UK	USA	Division of Applied Sciences, Harvard University	3 Jul - 24 Sep, 5 Oct - 17 Dec,
Zisserman, A	UK	UK	Department of Engineering Science, University of Oxford	4 Jul - 10 Dec,
Zucker, SW	USA	Canada	Department of Electrical Engineering, McGill University	1 Sep - 17 Dec,

Programme: Random Spatial Processes

Participant	Nationality	Country of Residence	Home Institution	Visits
Abraham, DB	UK	UK	Department of Theoretical Physics, University of Oxford	1 Jul - 14 Aug, 29 Aug - 12 Sep, 5 Nov - 3 Dec,
Aizenman, M	USA	USA	Department of Physics, University of Princeton	1 Jul - 31 Jul,
Alexander, KS	USA	USA	Department of Mathematics, University of Southern California	4 Jul - 13 Aug,
Andjel, ED	Argentina	France	Mathématiques Informatique Mécanique, Université de Provence Provence	1 Sep - 30 Sep,
Barlow, MT	UK	Canada	Department of Mathematics, University of British Columbia	1 Jul - 30 Dec,
Benjamini, I	Israel	Israel	Department of Mathematics, Cornell University	4 Oct - 29 Oct,
BenArous, G	France	France	Département de Mathematiques, Université de Paris-Sud	12 Sep - 18 Sep,
Bolthausen, E	Switzerland	Switzerland	Institut für Angewandte Mathematik, Universität Zürich	13 Sep - 24 Sep,
Chayes, J	USA	USA	Department of Mathematics, University of California	4 Jul - 16 Jul,
Chan, T	Australia	UK	Department of Actuarial Mathematics, Heriot-Watt University	19 Sep - 25 Sep,
Dawson, DA	Canada	Canada	Department of Mathematics and Statistics, University of Carleton, Ottawa	12 Sep - 24 Sep,
De Masi, A	Italy	Italy	Dipartimento di Matematica, Università de l'Aquila	1 Sep - 14 Nov,
Dobrushin, RL	Russia	Russia	Institute for Information Transmission Problems, Moscow	10 Sep - 30 Nov,
Donnelly, PJ	Australia	UK	School of Mathematical Sciences, QMW College, London	18 Oct - 22 Oct, 12 Sep - 17 Sep, 1 Nov - 12 Nov,
Ferrari, PA	Italy	Brazil	Instituto de Matemática e Statística, Universidade de Sao Paulo	5 Jul - 31 Dec,

9.1 Visiting Members

Gandolfi, A	Italy	Italy	Facolta di Scienze, Universitá de Torino	8 Jul - 15 Dec,
Georgii, HOF	Germany	Germany	Mathematisches Institut, Universität München	27 Sep - 14 Oct,
Greven, A	Germany	Germany	Institut für Mathematische Stochastik, Georg-August-Universität Göttingen	13 Sep - 25 Sep,
Grimmett, GR	UK	UK	Department of Pure Mathematics and Mathematical Statistics, University of Cambridge	1 Jul - 31 Dec,
Hambly, B	Australia	UK	Department of Mathematics and Statistics, University of Edinburgh	12 Sep - 24 Sep,
Hara, T	Japan	Japan	Department of Applied Physics, Tokyo Institute of Technology	3 Jul - 14 Aug,
Higuchi, Y	Japan	Japan	Department of Mathematics, University of Kobe	1 Jul - 15 Dec,
Keane, M	USA	Netherlands	Delft University of Technology	1 Jul - 30 Sep, 19 Oct - 29 Oct, 27 Nov - 14 Dec,
Kesten, H	USA	USA	Department of Mathematics, Cornell University	1 Jul - 30 Dec,
Kipnis, CP	France	France	CEREMADE, Université de Paris-Dauphine	24 Aug - 13 Sep,
Kotecky, R	Czechoslovakia	Czechoslovakia	Department of Theoretical Physics, Charles University, Prague	25 Oct - 27 Nov,
Landim, C	USA	USA	Courant Institute of Mathematical Sciences, University of New York	7 Nov - 14 Nov,
Lawler, GF	USA	USA	Department of Mathematics, Duke University	3 Jul - 29 Aug,
Liggett, TM	USA	USA	Department of Mathematics, University of California at Los Angeles	4 Jul - 4 Aug,
Martinelli, F	Italy	Italy	Dipartimento di Matematica, Universitá di Roma	28 Oct - 28 Nov,
Martin-Löf, A	Sweden	Sweden	Department of Mathematical Sciences, University of Stockholm	1 Jul - 31 Jul, 7 Nov - 19 Nov,
March, P	USA	USA	Department of Mathematics, Ohio State University	12 Sep - 17 Sep,
Mountford, TS	UK	USA	Department of Mathematics, University of California at Los Angeles	1 Jul - 15 Dec,
Newman, CM	USA	USA	Courant Institute of Mathematical Sciences, University of New York	1 Jul - 22 Aug,
Norris, JR	UK	UK	Department of Pure Mathematics and Mathematical Statistics, University of Cambridge	1 Jul - 15 Dec,
Olivieri, E	Italy	Italy	Dipartimento di Matematica, Universitá di Roma	28 Oct - 28 Nov,
Pardoux, E	France	France	Laboratoire de Mathématiques, Université de Provence	24 Aug - 18 Sep,
Pemantle, R	USA	USA	Department of Mathematics, University of Wisconsin	4 Jul - 15 Jul, 31 Jul - 29 Aug,
Penrose, MD	UK	UK	Department of Mathematical Sciences, University of Durham	3 Jul - 31 Aug,
Perkins, EA	Canada	Canada	Department of Mathematics, University of British Columbia	12 Sep - 24 Sep,
Peres, Y	Israel	USA	Department of Mathematics, Yale University	4 Jul - 20 Jul,
Petritis, D	Greece	France	Institut de Recherche Mathématique, Université de Rennes	23 Nov - 9 Dec,
Picco, P	France	France	Centre National de la Recherche Scientifique, Marseille	31 Oct - 13 Nov,
Presutti, E	Italy	Italy	Dipartimento di Matematica, Universitá di Roma	1 Sep - 28 Nov,

Schonmann, RH	Brazil	USA	Department of Mathematics, University of California at Los Angeles	2 Jul - 9 Sep, 8 Nov - 19 Nov,
Scoppola, E	Italy	Italy	Instituto di Fisica, Universitá di Roma	8 Nov - 19 Nov,
Shiga, T	Japan	Japan	Department of Applied Physics, Tokyo Institute of Technology	8 Sep - 28 Sep,
Shlosman, SB	Russia	Russia	Institute for Information Transmission Problems, Moscow	5 Oct - 26 Nov,
Sidoravicius, V	Lithuania	Brazil	IMPA, Rio de Janeiro	1 Sep - 19 Sep,
Slade, GD	Canada	Canada	Department of Mathematics and Statistics, McMaster University	1 Jul - 15 Dec,
Steif, JE	USA	Sweden	Department of Mathematics, Chalmers University of Technology	12 Sep - 19 Sep,
Suhov, YM	Russia	UK	Department of Pure Mathematics and Mathematical Statistics, University of Cambridge	1 Jul - 31 Dec,
Toth, B	Hungary	Hungary	Institute of Mathematics, Hungarian Academy of Sciences	7 Nov - 25 Nov,
Van den Berg, J	Netherlands	Netherlands	Centre for Mathematics and Computer Science, Amsterdam	1 Aug - 30 Nov,
Walsh, JB	USA	Canada	Department of Mathematics, University of British Columbia	9 Sep - 18 Sep,

Programme: Geometry and Gravity

Participant	Nationality	Country of Residence	Home Institution	Visits
Aichelburg, PC	Austria	Austria	Institut für Theoretische Physik, Universität Wien	14 Feb - 6 Mar,
Alvarez, E	Spain	Spain	Departamento de Fisica Teorica, Universidad Autonoma de Madrid	11 Apr - 21 Apr,
Anderson, A	USA	USA	Blackett Laboratory, Imperial College	1 Jan - 30 Jun,
Ashtekar, AV	USA	USA	Center for Gravitational Physics, Pennsylvania State University	2 Jun - 30 Jun,
Bailey, TN	UK	UK	Department of Mathematics, University of Edinburgh	1 Apr - 30 Jun,
Brady, PR	Eire	UK	Department of Physics, University of Newcastle	28 Mar - 31 Mar, 11 Apr - 15 Apr,
Bugajska, KM	Canada	Canada	Department of Mathematics, York University, Toronto	8 Feb - 8 May,
Carlip, SJ	USA	USA	Department of Physics, University of California at Davis	22 Jun - 30 Jun,
Carter, B	UK	France	Observatoire de Paris-Meudon	19 Feb - 23 Apr,
Clarke, CJS	UK	UK	Department of Mathematics, University of Southampton	28 Mar - 31 Mar, 11 Apr - 12 Apr, 14 Apr - 14 Apr,
Connes, A	France	France	Institute des Hautes Etudes Scientifiques, Bures-sur-Yvette	10 Jan - 31 Mar,
De Alwis, SP	Sri Lanka	USA	Department of Physics, University of Colorado	16 May - 29 Jun,
Dowker, F	UK	USA	Department of Physics, University of California at Santa Barbara	2 Mar - 31 May,
Dowker, JS	UK	UK	Department of Physics, University of Manchester	28 Mar - 31 Mar, 11 Apr - 15 Apr,

9.1 Visiting Members

Dubois-Violette, M	France	France	Laboratoire de Physique Théorique, Université de Paris	28 Feb - 11 Mar,
Eastwood, MG	UK	Australia	Department of Pure Mathematics, University of Adelaide	1 Apr - 30 Jun,
Ellwood, DA	UK	France	Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette	6 Jan - 31 Mar,
Garriga, J	Spain	UK	Department of Applied Mathematics and Theoretical Physics, University of Cambridge	21 Mar - 23 Mar, 28 Mar - 31 Mar,
Gauntlett, J	USA	USA	Enrico Fermi Institute, University of Chicago	15 Apr - 30 Jun,
Gell-Mann, M	USA	USA	Sante Fe Institute	19 Mar - 26 Mar, 31 Mar - 6 Apr,
Gibbons, GW	UK	UK	Department of Applied Mathematics and Theoretical Physics, University of Cambridge	1 Jan - 30 Jun,
Giulini, DJW	Germany	Germany	Fakultät für Physik, Albert Ludwigs Universität	6 Mar - 2 Apr,
Halliwell, JJ	UK	UK	Blackett Laboratory, Imperial College	28 Mar - 27 May,
Harms, BC	USA	USA	Department of Physics and Astronomy, University of Alabama	1 Jan - 20 Jun,
Hartle, JB	USA	USA	Department of Physics, University of California at Santa Barbara	14 Jan - 31 Jan, 7 Jun - 30 Jun,
Harvey, J	USA	USA	Enrico Fermi Institute, University of Chicago	5 Jun - 29 Jun,
Hawking, SW	UK	UK	Department of Applied Mathematics and Theoretical Physics, University of Cambridge	1 Jan - 30 Jun,
Hayward, SA	UK	UK	Department of Mathematical Studies, University of Southampton	28 Mar - 31 Mar, 11 Apr - 15 Apr,
Hoppe, J	Germany	Germany	Institut für Theoretische Physik, Universität Karlsruhe	1 Jan - 31 Mar,
Horowitz, G	USA	USA	Department of Physics, University of California at Santa Barbara	13 Jan - 28 Jun,
Hull, CM	UK	UK	Department of Physics, QMW College, London	23 May - 27 May, 22 Jun - 26 Jun,
Hu, BL	USA	USA	Department of Physics, University of Maryland	28 Mar - 7 Apr, 16 May - 26 May,
Isham, CJ	UK	UK	Blackett Laboratory, Imperial College	1 Jan - 30 Jun,
Kallosh, RE	Russia	USA	Department of Physics, Stanford University	16 Mar - 1 Apr,
Kay, BS	UK	UK	Department of Mathematics, University of York	8 Feb - 9 Feb, 28 Mar - 31 Mar, 11 Apr - 15 Apr,
Klimčík, C	Czechoslovakia	Czechoslovakia	Nuclear Centre, Charles University, Prague	1 Jan - 22 Jan, 30 Jan - 12 Feb, 13 Mar - 26 Mar,
Kodama, H	Japan	Japan	Uji Research Center, Yukawa Institute, University of Kyoto	1 Mar - 30 Jun,
Kuchař, KV	USA	USA	Department of Physics, University of Utah	27 Mar - 1 Jun,
Laflamme, R	Canada	USA	Los Alamos National Laboratory	1 Apr - 13 May,
LeBrun, CR	USA	USA	Department of Mathematics, SUNY at Stony Brook	2 May - 30 Jun,
Madore, J	Canada	France	Laboratoire de Physique Théorique, Université de Paris	1 Feb - 20 Mar, 27 Mar - 31 Mar,
Mason, LJ	UK	UK	Mathematical Institute, University of Oxford	16 Apr - 30 Jun,

9.1 Visiting Members

McCarthy, PJ	UK	UK	School of Mathematical Sciences, QMW College, London	7 Mar - 25 Mar, 28 Mar - 31 Mar,
Michor, PW	Austria	Austria	Institut für Mathematik, Universität Wien	28 Feb - 11 Mar,
Ortin, T	Spain	UK	Department of Physics, QMW College, London	28 Mar - 31 Mar, 11 Apr - 15 Apr,
Paz, JP	Argentina	Argentina	Department of Physics, University of Buenos Aires	2 May - 30 May,
Penrose, R	UK	UK	Mathematical Institute, University of Oxford	25 Apr - 22 Jun, 28 Mar - 29 Mar,
Perry, MJ	UK	UK	Department of Applied Mathematics and Theoretical Physics, University of Cambridge	4 Jan - 30 Jun,
Politzer, HD	USA	USA	Caltech, Pasadena	9 Apr - 17 Apr,
Preskill, J	USA	USA	Caltech, Pasadena	1 Jun - 23 Jun,
Pullin, J	Argentina	USA	Center for Gravitational Physics, Pennsylvania State University	28 Mar - 4 Apr,
Rovelli, C	Italy	USA	Department of Physics, University of Pittsburgh	15 Jan - 13 Feb,
Simon, J	USA	USA	Department of Physics, University of Maryland	10 Apr - 17 Apr,
Singer, MA	UK	UK	Department of Mathematics, University of Edinburgh	4 May - 30 Jun,
Smolin, L	USA	USA	Center for Gravitational Physics, Pennsylvania State University	18 May - 3 Jun,
Stelle, K	UK	UK	Blackett Laboratory, Imperial College	21 Mar - 23 Mar, 28 Mar - 31 Mar, 10 May - 17 Jun,
Strominger, A	USA	USA	Department of Physics, University of California at Santa Barbara	6 Jun - 25 Jun,
Susskind, L	USA	USA	Department of Physics, Stanford University	1 Jun - 28 Jun,
Tod, KP	UK	UK	Mathematical Institute, University of Oxford	28 Mar - 31 Mar, 12 Apr - 15 Apr, 8 Jun - 10 Jun, 13 Jun - 14 Jun,
Tseytlin, A	Russia	UK	Blackett Laboratory, Imperial College	28 Mar - 31 Mar, 18 Apr - 24 Apr,
Tucker, R	UK	UK	Department of Physics, University of Lancaster	28 Mar - 31 Mar, 21 Mar - 24 Mar,
Vickers, J	UK	UK	Department of Mathematics, University of Southampton	28 Mar - 31 Mar, 11 Apr - 15 Apr,
Wald, RM	USA	USA	Enrico Fermi Institute, University of Chicago	21 Mar - 1 Apr,
Ward, RS	UK	UK	Department of Mathematical Sciences, University of Durham	1 Apr - 30 Jun,
Woodhouse, NMJ	UK	UK	Wadham College, University of Oxford	2 May - 10 Jun,
Yau, ST	USA	USA	Department of Mathematics, Harvard University	3 Jan - 31 Jan, 1 May - 30 Jun,

9.1 Visiting Members

Programme: Cellular Automata, Aggregation and Growth

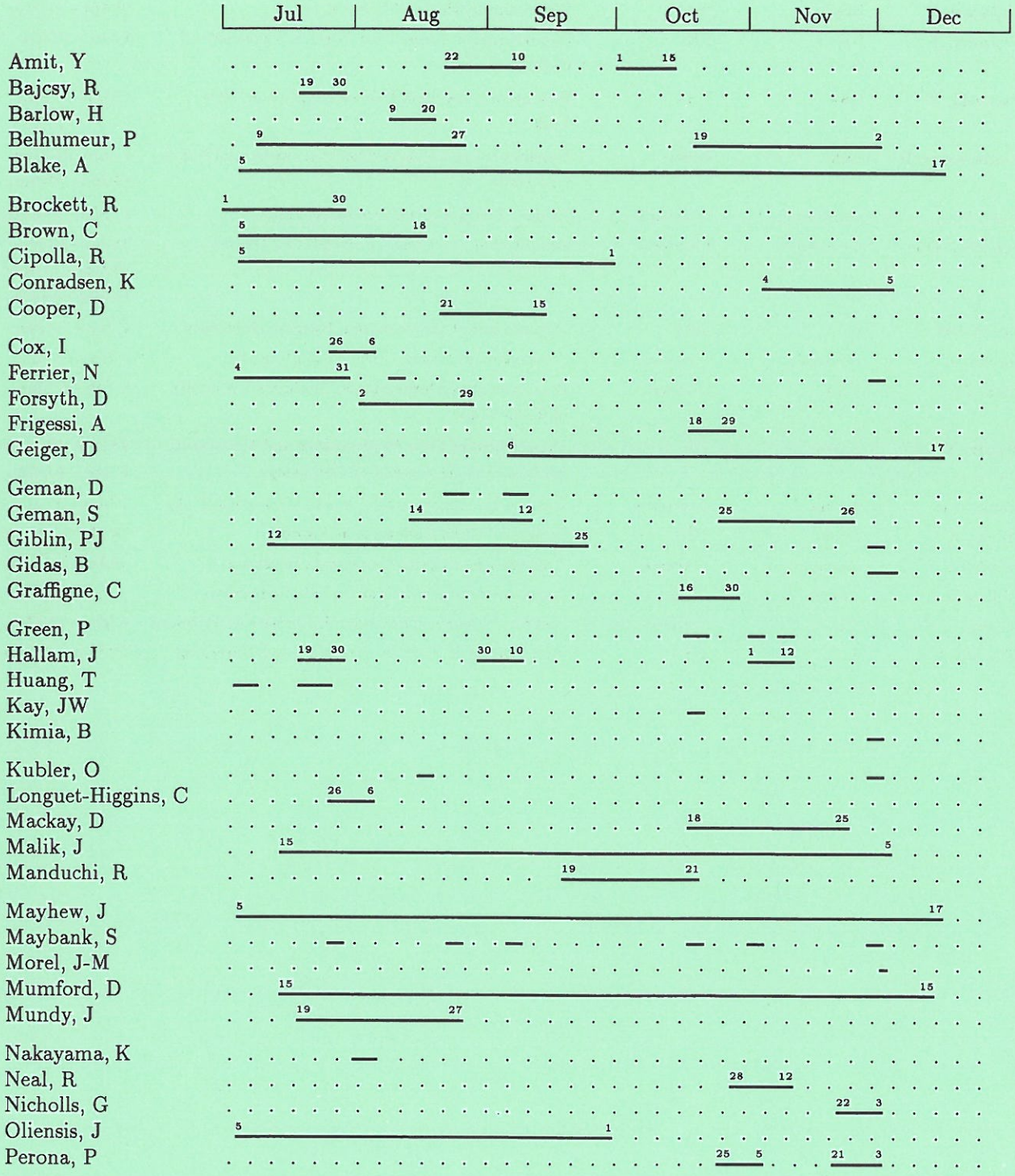
Participant	Nationality	Country of Residence	Home Institution	Visits
Abraham, DB	UK	UK	Department of Theoretical Physics, University of Oxford	29 Mar - 30 Mar, 15 Jun - 30 Jun,
Bak, P	Denmark	USA	Department of Physics, Brookhaven Laboratory	15 Jan - 22 Jan, 1 May - 31 May,
Blum, T	USA	UK	Department of Theoretical Physics, University of Manchester	4 Jan - 30 Jun,
Bray, AJ	UK	UK	Department of Physics, University of Manchester	4 Jan - 31 Mar,
Chaté, H	France	France	Service de Physique de l'Etat Condensé, Saclay	4 Apr - 16 May,
Dekking, FM	Netherlands	Netherlands	Department of Mathematics, Delft University of Technology	10 Jan - 30 Jan,
Derrida, B	France	France	Laboratoire de Physique Statistique, ENS	1 Jan - 30 Jun,
Dhar, D	India	India	Tata Institute of Fundamental Research, Bombay	15 Apr - 30 Jun,
Dickman, R	USA	USA	Department of Physics and Astronomy, City University of New York	7 Jun - 29 Jun,
Domany, E	Israel	Israel	Weizmann Institute of Science, Israel	25 May - 30 Jun,
Droz, M	Switzerland	Switzerland	Département de Physique Théorique, Université de Genève	15 Mar - 14 Apr,
Dudarev, S	Russia	UK	Department of Materials, University of Oxford	19 Jun - 30 Jun,
Evans, MR	UK	France	Laboratoire de Physique Statistique, ENS	4 Jan - 1 Mar,
Fisher, DS	USA	USA	Department of Physics, Harvard University	30 May - 3 Jun,
Flyvbjerg, H	Denmark	Denmark	Niels Bohr Institute, Copenhagen	4 Jan - 30 Jun,
Godrèche, C	France	France	Service de Physique de l'Etat Condensé, Saclay	13 Feb - 14 May, 14 Jun - 19 Jun,
Goldenfeld, N	UK	USA	Department of Physics, University of Illinois at Urbana	3 Jan - 10 Feb,
Gray, LF	USA	USA	School of Mathematics, University of Minnesota	9 Mar - 31 Mar,
Grinstein, G	Canada	USA	IBM Watson Research Center	3 May - 30 Jun,
Hakim, V	France	France	Laboratoire de Physique Statistique, ENS	4 Jan - 30 Jun,
Halpin-Healy, T	USA	USA	Department of Physics, Barnard College, Columbia University	8 Jan - 30 Jun,
Hwa, T	USA	USA	Institute of Advanced Study, University of Princeton	16 Jun - 30 Jun,
Kardar, M	Iran	USA	Department of Physics, MIT	28 Feb - 4 Mar, 28 Mar - 15 Apr,
Kertész, J	Hungary	Hungary	Institute of Physics, Technical University of Budapest	2 Jan - 7 Apr, 24 May - 30 Jun,
Koukiou, F	Greece	France	Département de Physique, Université de Cergy-Pontoise	7 Apr - 22 Apr,
Krug, J	Germany	Germany	Institut für Festkörperforschung, Jülich	14 Mar - 13 Apr,
Lebowitz, JL	USA	USA	Department of Mathematics, Rutgers University	5 Jun - 11 Jun,
Livi, R	Italy	Italy	Dipartimento di Fisica, Università di Bologna	1 May - 30 Jun,
Maes, CDT	Belgium	Belgium	Institute of Theoretical Physics, University of Leuven	1 Mar - 31 Mar,
Mallick, K	France	France	Département de Mathématiques, ENS	2 Feb - 18 Feb, 4 Apr - 24 Apr,

9.1 Visiting Members

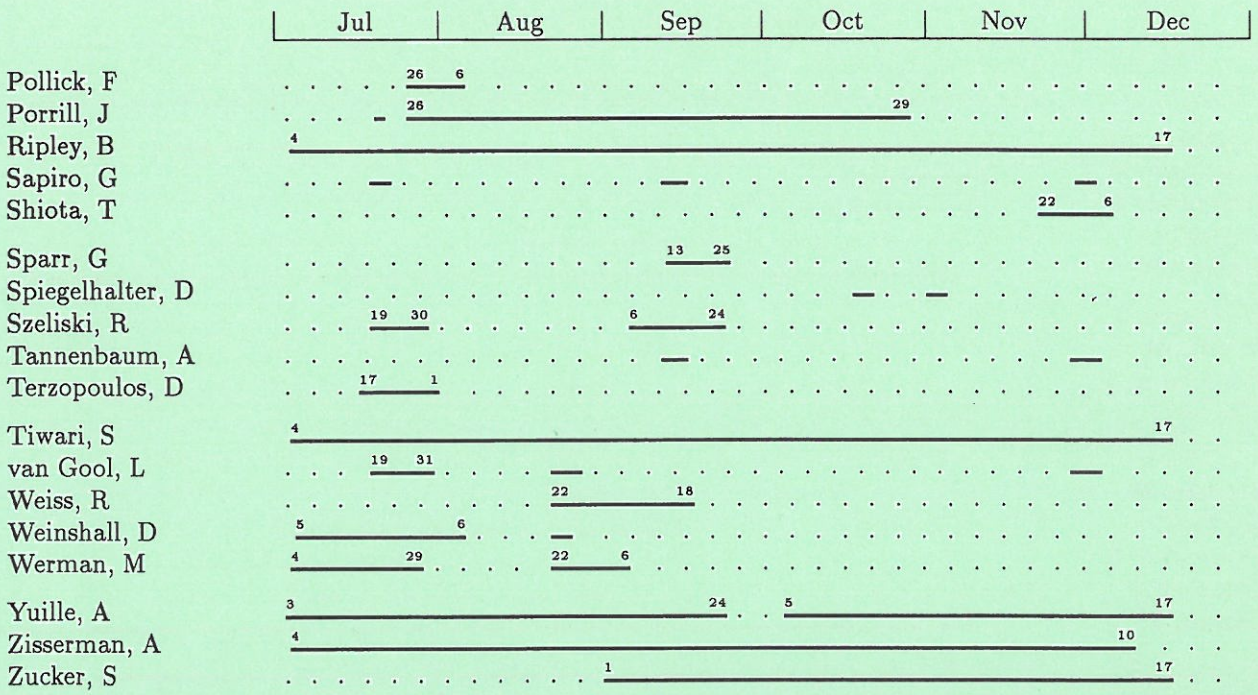
McKane, AJ	UK	UK	Department of Physics, University of Manchester	1 Jan - 30 Jun,
Moore, MA	UK	UK	Department of Physics and Astronomy, University of Manchester	1 Jan - 30 Jun,
Mukamel, D	Israel	Israel	Weizmann Institute of Science, Israel	19 Apr - 30 Jun,
Newman, T	UK	UK	Department of Theoretical Physics, University of Oxford	5 Apr - 30 Apr,
Paczuski, M	USA	USA	Brookhaven National Laboratory, Upton, New York	1 May - 31 May,
Ramaswamy, R	India	India	Department of Physical Sciences, Jawaharlal Nehru University	1 Jan - 27 Mar, 19 Jun - 30 Jun,
Rost, M	Germany	Germany	Institut für Festkörperforschung, Jülich	23 Mar - 29 Mar,
Schuetz, GM	Germany	Germany	Department of Physics, University of Oxford	31 Jan - 28 Feb, 23 Mar - 29 Mar, 11 May - 14 May,
Speer, ER	USA	USA	Department of Mathematics, Rutgers University	1 Jan - 30 Jun,
Spohn, H	Germany	Germany	Theoretische Physik, Universität München	6 Mar - 9 Apr,
Steif, JE	USA	Sweden	Department of Mathematics, Chalmers University of Technology	6 Feb - 6 Mar,
Suhov, YM	Russia	UK	Department of Pure Mathematics and Mathematical Statistics, University of Cambridge	28 Feb - 12 Mar, 5 Apr - 15 Jun,
Tang, L-H	China	Germany	Institut für Theoretische Physik, Universität Köln	1 Mar - 30 Jun,
Toom, A	USA	USA	Incarnate Word College, San Antonio	14 May - 30 Jun,
Wolf, DE	Germany	Germany	Theoretische Physik, Universität Duisburg	13 Feb - 16 Apr,
Yekutieli, I	Israel	USA	Department of Mathematics, Yale University	1 Jan - 30 Jun,
Zhang, Y-C	China	Switzerland	Institut Physique Theorique, Université de Fribourg	6 May - 15 May,
Zia, RKP	USA	USA	Department of Physics, Virginia State University	29 May - 30 Jun,

9.2 CHART OF VISITS 1993–94

Computer Vision

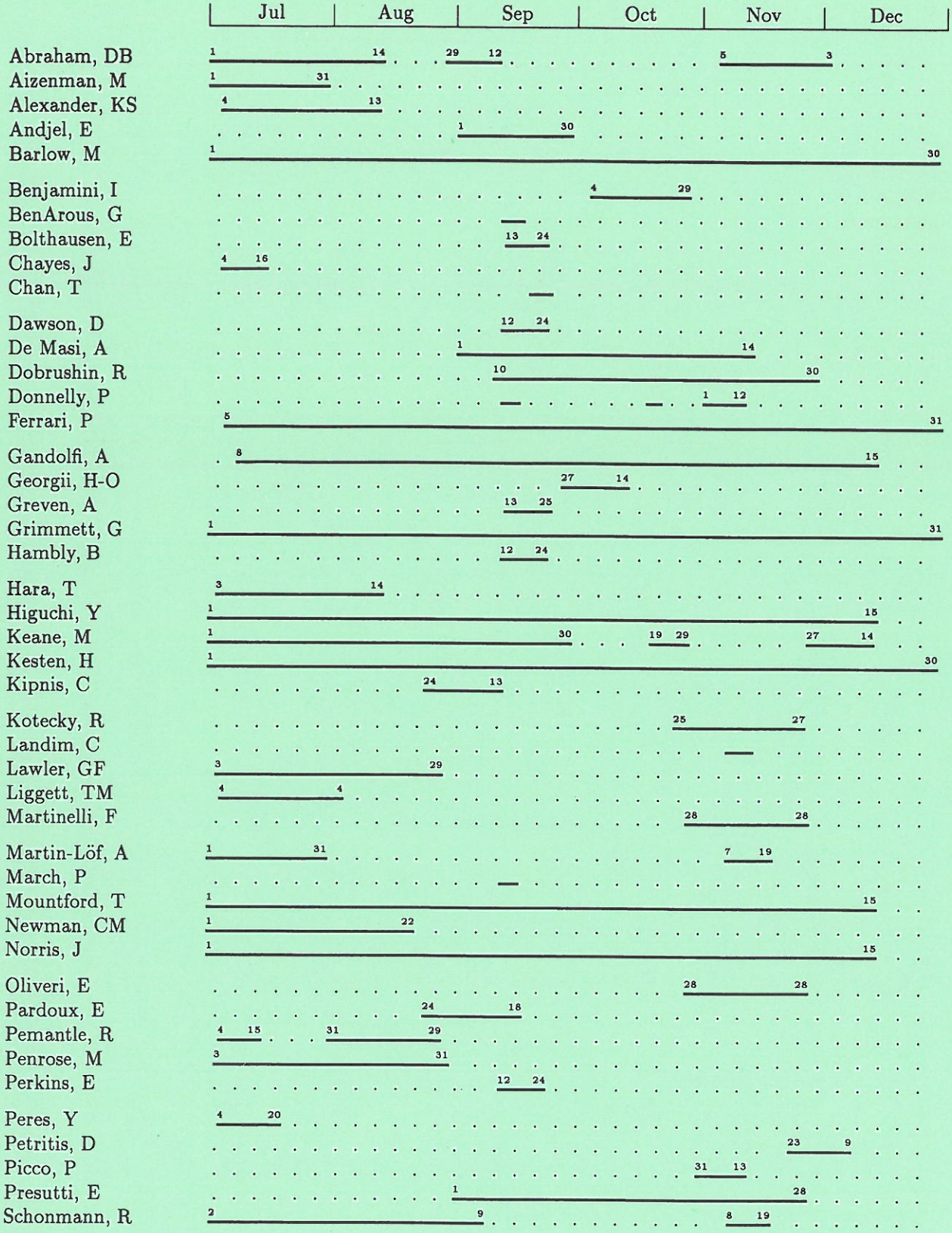


9.2 Chart of Visits 1993–94

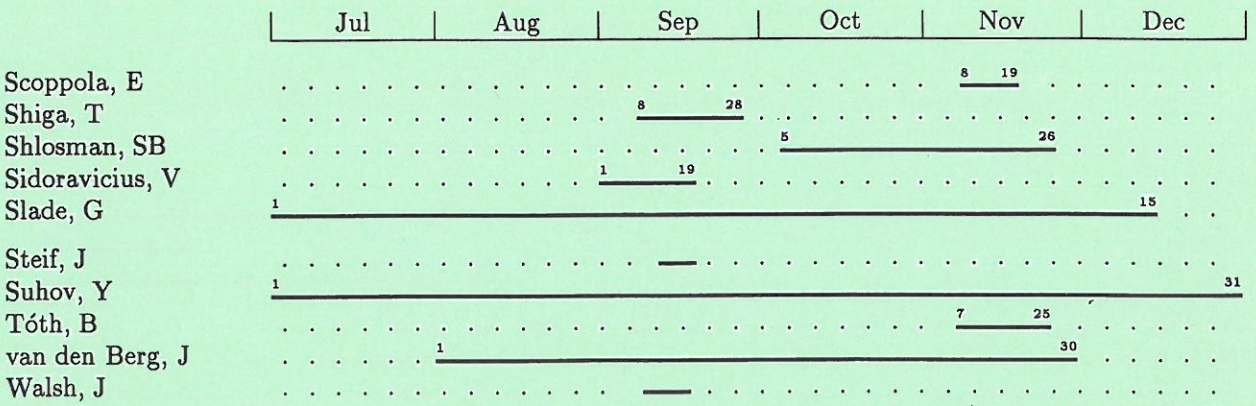


9.2 Chart of Visits 1993–94

Random Spatial Processes

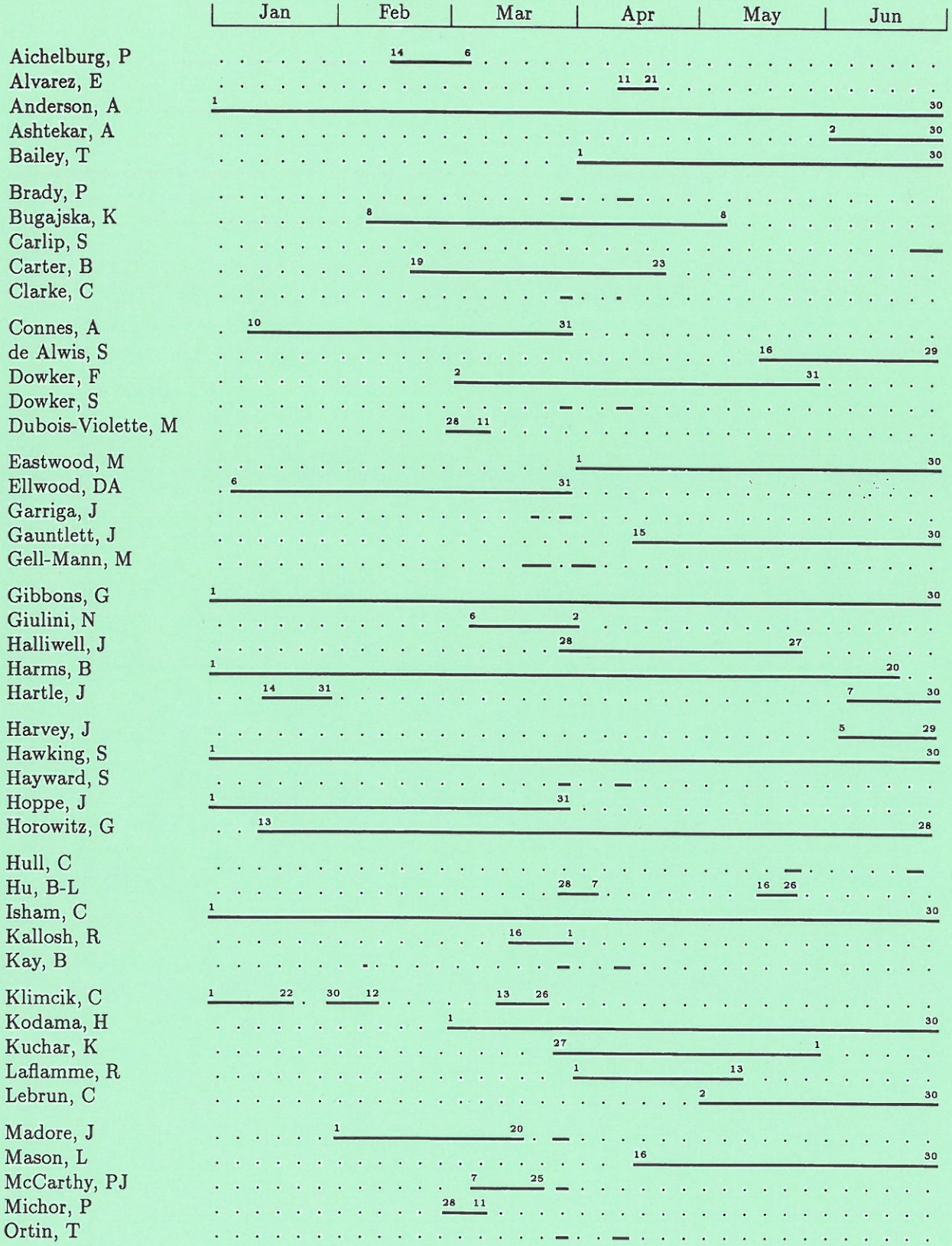


9.2 Chart of Visits 1993–94

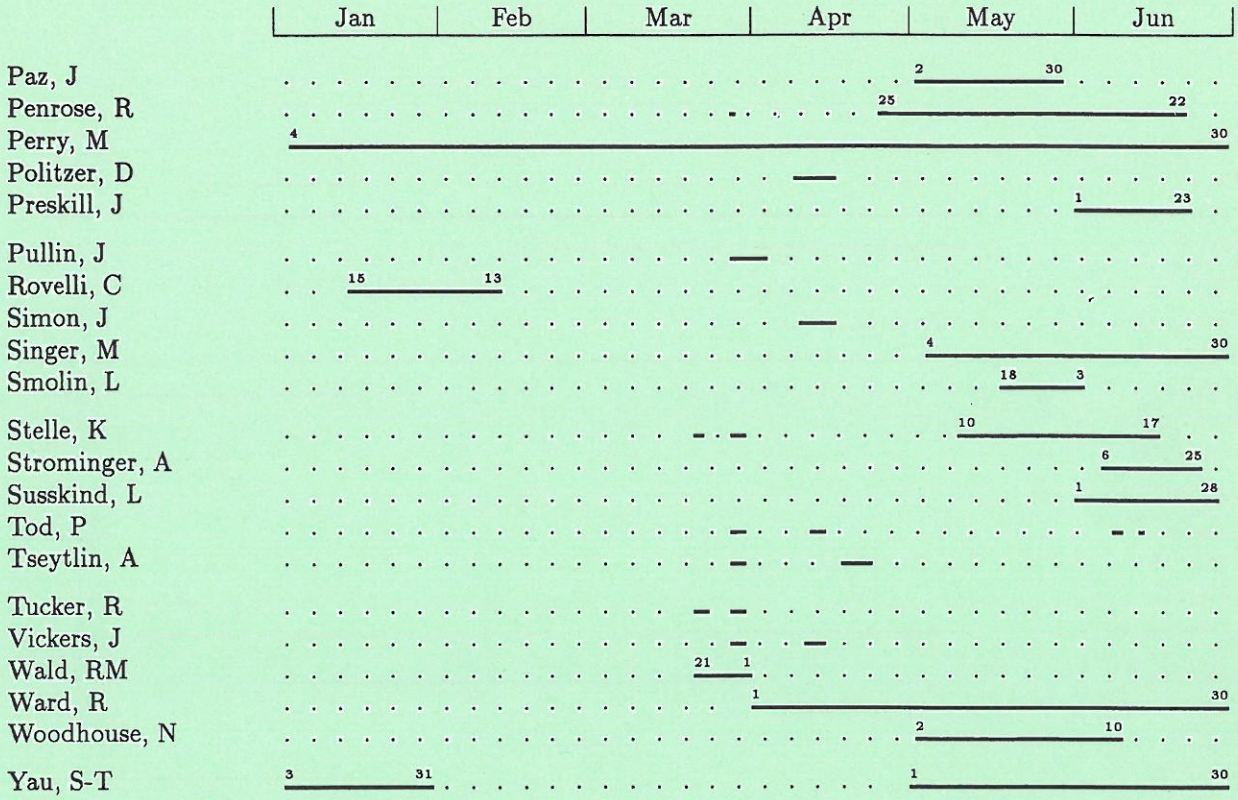


9.2 Chart of Visits 1993–94

Geometry and Gravity

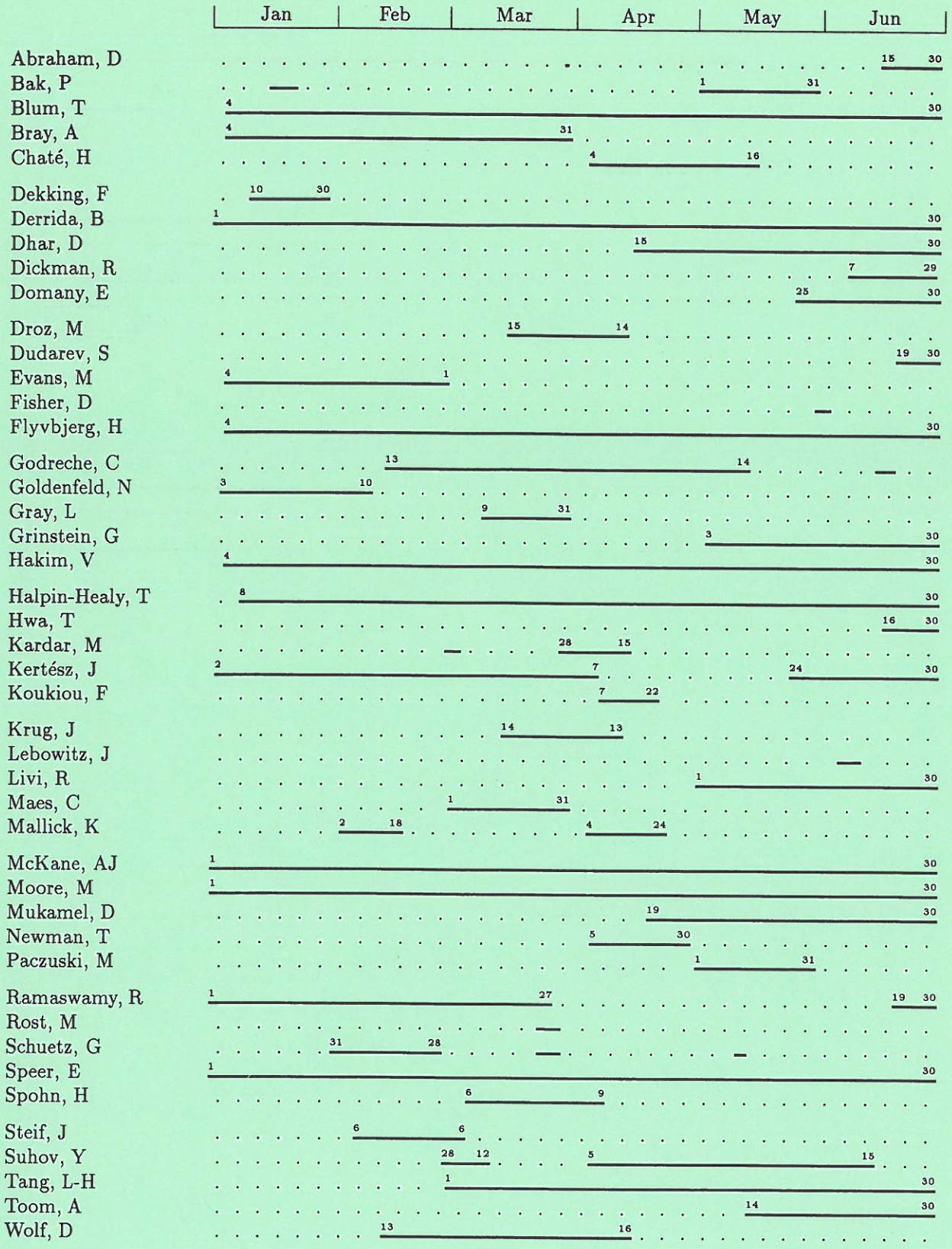


9.2 Chart of Visits 1993–94

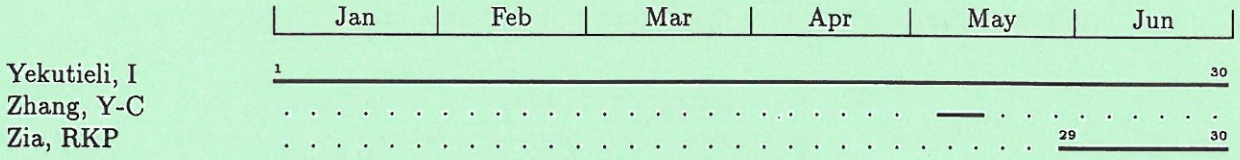


9.2 Chart of Visits 1993–94

Cellular Automata, Aggregation and Growth



9.2 Chart of Visits 1993–94



9.3 NATIONALITY AND COUNTRY OF RESIDENCE

Country	Visiting Members		Workshops
	Residents	Nationals	Residents
Argentina	1	3	0
Australia	1	3	0
Austria	2	2	1
Belgium	2	2	7
Brazil	2	1	0
Canada	9	11	1
China	0	2	1
Czech Republic	2	2	3
Denmark	2	3	3
Eire	0	1	3
Finland	0	0	3
France	20	13	34
Germany	10	10	35
Greece	0	2	2
Hungary	2	2	1
India	2	4	4
Iran	0	1	1
Israel	6	9	2
Italy	8	12	19
Japan	5	5	7
Lithuania	0	1	0
Netherlands	3	2	18
New Zealand	0	1	0
Norway	0	0	3
Portugal	0	0	3
Russia	2	6	7
Singapore	0	0	1
South Africa	0	1	1
Spain	1	3	10
Sri Lanka	1	0	0
Sweden	3	2	6
Switzerland	4	2	10
Turkey	0	0	1
UK	56	57	325
USA	81	61	64
Uruguay	0	1	0
Total	225	225	576

9.4 CUMULATIVE FREQUENCY GRAPH OF AGES OF VISITING MEMBERS

9.5 PAPERS PRODUCED BY PARTICIPANTS

Abraham DB, Newman TJ, Schuetz GM — RSP
Non-equilibrium dynamics of finite interfaces

Abraham DB, Latremoliere F — RSP
Corner spontaneous magnetisation in the planar Ising ferromagnet

Aizenman M — RSP
The localization transition on Bethe lattices

Albeverio S, Zhou X — RSP
Gaussian behaviour of a modified Domb-Joyce model in $d \geq 4$ dimensions

Alexander K — RSP
Simultaneous uniqueness of infinite clusters in stationary random labelled graphs

Alexander K — RSP
Approximation of subadditive functions and convergence rates in limiting-shape results

Altmann M — EPI
Susceptible infected-removed epidemic models with dynamic partnerships

Altmann M — EPI
The deterministic limit of infectious disease models with dynamic partners

Altmann M, Morris WM — EPI
A clarification of the mixing model

Anderson A, Halliwell J, Linden N — GGR
Holes in general relativity

Anderson A — GGR
Unitarity in the presence of closed timelike curves

Anderson A — GGR
Towards not quantizing the gravitational field

Anderson A — GGR
An elegant solution of the N-body Toda system

Anderson A — GGR
The quantum action: Schwinger's action principle revisited

Anderson A — GGR
Coupling classical and quantum variables

Andjel E, Schinazi R — RSP
A complete convergence theorem for an epidemic model

Ashtekar A, Varadarajan M — GGR
A striking property of the gravitational Hamiltonian

Ashtekar A, Lewandowski J, Marolf D *et al* — GGR
Coherent state transforms on the space of connections

Ashtekar A — GGR
A manifestly gauge invariant approach to quantum gauge theories

Ashtekar A, Lewandowski J — GGR
Differential geometry on the space of connections

Ashtekar A, Lewandowski J — GGR
Projective techniques and functional integration for gauge theories

Bailey NTJ — EPI
An improved hybrid HIV/AIDS model geared to specific public health data and decision-making

Bailey NTJ — EPI
HIV/AIDS: Core group dynamics and public health action

Bailey NTJ — EPI
Prediction and validation in the public health modelling of HIV/AIDS

9.5 Papers Produced by Participants

Bailey NTJ — EPI
Operational modelling of HIV/AIDS to assist public health control

Bailey T, Eastwood M, Singer M — GGR
The Penrose transform for non-holomorphic correspondences

Bailey T, Eastwood M, Mason L *et al* — GGR
Complex analysis and the Fuuk transform

Bailey T, Eastwood M, Mason L — GGR
The Radon and Fourier transforms as real analogues of the Penrose and twistor transforms

Bajcsy R — CVI
A commentary on Jeannerod's "Representing brain neural correlates of motor intention and imagery"

Bak P, Flyvbjerg H, Sneppen K — CAG
Can we model Darwin?

Barma M, Ramaswamy R — CAG
Field-induced transport in random media

Baumann G, Jánosi IM, Wolf D — CAG
Particle trajectories and segregation in a two-dimensional rotating drum

Beardsley P, Zisserman A, Murray D *et al* — CVI
Navigation using affine structure from motion

Becker N, Shao Q — EPI
A transmission model for a disease with some fatalities

Belhumeur P, Mumford D, Yuille A — CVI
On vision

Belitsky V, Ferrari P — RSP
Hydrodynamic limits of a model of annihilating deterministic particles

Benjamini I, Pemantle R, Peres Y — RSP
Martin capacity for Markov chains and random walks in varying dimensions

Besag J, Green P, Higdon D *et al* — CVI
Bayesian computation and stochastic systems

Bienenstock E — CVI
A model of neocortex

Blake A — CVI
Improbable views

Blake A, Curwen R, Zisserman A — CVI
A framework for spatio-temporal control in the tracking of visual contours

Blake A — CVI
A theory of planar grasp

Blake A, Sinclair D — CVI
Isoperimetric normalisation of planar curves

Blake A, Isard M — CVI
Learning to track lip-movements

Blake A, Isard M — CVI
Phase-space tuning for a visual contour tracker

Blake A, Isard M — CVI
Three-dimensional position, attitude and shape input using video tracking of hands and lips

Blake A — CVI
Visual contour tracking

Blum T, McKane A — CAG
Variational schemes in the Fokker-Planck equation

9.5 Papers Produced by Participants

Brassesco S, De Masi A, Presutti E — RSP
Brownian fluctuations of the instanton in the $d = 1$ Ginzberg-Landau equation with noise

Brydges DC, Slade G — RSP
The diffusive phase of a model of self-interacting walks

Bushnell CJ, Henniart G — LFN
Local tame lifting for $GL(n)$

Cairns A — EPI
Primary component analysis of epidemic models

Cardy J, Mussardo G — LDT
Universal properties of self-avoiding walks from two-dimensional field theory

Carlip S — GGR
Statistical mechanics of the three-dimensional black hole

Carter B — GGR
Equations of motion of a stiff geodynamic string or higher brane

Chakrabarti SK, Rosner R, Vainshtein SI — DYN
Possible role of massive black holes in the generation of galactic magnetic fields

Cipolla R, Perona P, Zisserman A *et al* — CVI
Graduate textbook on computational vision

Clune T, Knobloch E — DYN
Pattern selection in three-dimensional magnetoconvection

Colmez P — LFN
Fonctions zêta p-adiques en $s = 0$

Corrigan E — LDT
Knot physics

Crivelli M, Felder G, Wieczerkowski C — LDT
Topological representations of $U_q(SL_2(\mathbb{C}))$ on the torus and the mapping class group

Da Costa G — LDT
Lattice models and BV type relations

Darmon H, Granville A — LFN
On the equations $z^m = F(x, y)$ and $Ax^p + By^q = Cz^r$

Date E, Okado M — LDT
Calculation of excitation spectra of the spin model related with the vector representation of the quantized affine algebra of type $A_n^{(1)}$

De Alwis S — GGR
Quantum dilaton gravity in two dimensions

De Boer J, Derrida B, Flyvbjerg H *et al* — CAG
A simple model of self-organized biological evolution

De Masi A, Orlandi E, Presutti E *et al* — RSP
Glauber evolution with Kac potentials: I. Mesoscopic and macroscopic limits, interface dynamics

De Masi A, Gobron T, Presutti E — RSP
Travelling fronts in non local evolution equations

De Zoysa A, Carter R, Mendis KN — EPI
Mathematical simulations of transmission blocking vaccine strategies for "P. Vivax" malaria

De Zoysa A — EPI
Quantitative analysis of "P. Vivax" malaria transmission with special emphasis on transmission blocking immunity

Dekking FM, Speer E — CAG
On the shape of the wavefront in branching random walk

9.5 Papers Produced by Participants

Derrida B, Bray A, Godrèche C — CAG
Non-trivial exponents in the zero temperature dynamics of the one-dimensional Ising and Potts models

Derrida B, Evans M, Godrèche C — CAG
Exact diffusion constant for one-dimensional asymmetric exclusion models with open boundaries

Derrida B, Evans M — CAG
Exact steady state properties of the one dimensional asymmetric exclusion model

Derrida B, Flyvbjerg H, Jackson A *et al* — CAG
A simple model of self-organised biological evolution

Derrida B, Bray A, Godrèche C — CAG
Non-trivial algebraic decay in a soluble model of coarsening

Dhar D — CAG
Spatial organisation in a dissipative model of sandpiles

Di Francesco P, Zuber J-B — LDT
Fusion potentials: I

Dickman R — CAG
Numerical study of a field theory for directed percolation

Dobrushin R, Shlosman S — RSP
Droplet condensation in the Ising model: a moderate deviation point of view

Dobrushin R, Blinovskii V — RSP
Large deviations for piece-wise homogeneous random walk

Dobrushin R, Pechersky J — RSP
Large deviations for processes with independent increments on infinite interval

Dobson AP, Hudson PJ — EPI
Microparasites: observed patterns in wildlife

Domany E — CAG
Directed percolation and damage spreading

Donnelly P — RSP
Match probability calculations for multi-locus DNA profiles

Dowker F — GGR
On the consistent histories approach to quantum mechanics

Droz M, McKane A — CAG
Equivalence between Poisson representation and Fock space formalism for birth-death processes

Dubois-Violette M, Michor P — GGR
The Frölicher-Nijenhuis bracket for derivation based non-commutative differential forms

Eastwood M, Gindikin SG, Wong H — GGR
Holomorphic realization of J-cohomology and constructions of representations

Eguchi T — LDT
$c = 1$ Liouville theory perturbed by the black hole mass operator

Eguchi T — LDT
Two-dimensional black hole and the $c = 1$ Liouville theory

Enqvist K, Shukurov A, Sokoloff D *et al* — DYN
The neutrino mass and the origin of galactic magnetic fields

Evans M, Foster D, Godrèche C *et al* — CAG
Spontaneous symmetry breaking in a one-dimensional driven diffusive system

Evans M, Kawahigashi Y — LDT
Quantum symmetries of operator algebras

Fairlie D, Nuyts J — LDT
A fresh look at generalized Veneziano amplitudes

9.5 Papers Produced by Participants

Fearn DR, Kuang W — LDT
Resistive instability in the absence of critical levels

Felder G, Wieczerkowski C — LDT
Conformal blocks on elliptic curves and the Knizhnik-Zomolodchikov-Bernard equations

Ferrari PA — RSP
Behaviour of a second-class particle in the rarefaction front for the asymmetric simple exclusion process

Ferrari PA — RSP
Recent results on shocks and second-class particles for the asymmetric simple exclusion process

Ferrari PA, Fontes L, Kohayakawa Y — RSP
Invariant measures for a two species asymmetric process

Ferrari PA, Kesten H, Martínez S — RSP
R-positivity, quasi-stationary distributions and ratio limit theorems for a class of probabilistic automata

Ferrier N, Rowe S, Blake A — CVI
Real-time traffic monitoring

Flyvbjerg H, Holy TE, Leibler S — CAG
Stochastic dynamics of microtubules: a model for caps and catastrophes

Flyvbjerg H, Sneppen K, Bak P *et al* — CAG
Evolution as a self-organised critical phenomenon

Flyvbjerg H, Fygenson D, Leibler S *et al* — CAG
Bulk nucleation of microtubules

Flyvbjerg H — CAG
A very simple self-organised critical system

Flyvbjerg H, Bak P, Jensen M *et al* — CAG
A theory of macro-evolution

Flyvbjerg H — CAG
Self-organised critical pin-ball machine

Flyvbjerg H, Bak P, Jensen M *et al* — CAG
A self-organised critical model for evolution

Forsyth D, Mundy J, Zisserman A *et al* — CVI
Using global consistency to recognise Euclidean objects with an uncalibrated camera

Friedlander JB, Granville A — LFN
Smoothing "smooth" numbers

Friedlander S, Vishik MM — DYN
On stability and instability criteria for MHD

Gailitis A — DYN
Magnetic field generation by axisymmetric flows of conducting liquid in a spherical stationary conductor cavity

Gauntlett J — GGR
S-duality and the spectrum of magnetic monopoles in heterotic string theory

Gervais JL, Saveliev MV — LDT
W-geometry of the Toda systems associated with non-exceptional simple Lie algebras

Gibbons G, Kallosh R — GGR
Topology, the Gauss-Bonnet theorem and the entropy of dilaton black holes

Giblin P, Cipolla R — CVI
Following cusps

Giblin P, Cipolla R — CVI
Frontier points

9.5 Papers Produced by Participants

Giblin P, Zisserman A — CVI
Profiles of surfaces in computer vision

Giblin P, Pollick F, Rycroft J — CVI
Recovery of an unknown axis of rotation from the profiles of a rotating surface

Giblin P, Pollick F — CVI
Profiles under circular motion

Giblin P, Weiss R — CVI
Epipolar fields on surfaces

Gilbert A, Otani NF, Childress S — DYN
Simple dynamical fast dynamos

Gilbert A — DYN
A cascade interpretation of Lundgren's stretched spiral vortex model for turbulent fine structure

Ginzburg V — DYN
An embedding $S^{2n-1} \to \mathbb{R}^{2n}$, $2n-1 \geq 7$, whose Hamiltonian flow has no periodic trajectories

Goto Y — LFN
Arithmetic of weighted projective surfaces over finite fields

Granville A — LFN
Integers, without large prime factors, in arithmetic progressions. II

Granville A, Sun Z-W — LFN
Values of Bernouilli polynomials

Gray L — CAG
Convergence to equilibrium and a strong law for the motion of restricted interfaces

Gray L, Speer E — CAG
Toom interface

Green P, Grenander U, Miller M — CVI
Representations of knowledge in complex systems

Green P — CVI
Statistical aspects of medical imaging (editorial)

Green P — CVI
Contribution to discussion of paper by Grenander and Miller, RSS Ordinary meeting, 20 October 1993

Green P — CVI
Markov chain Monte Carlo in image analysis

Greenhalgh D, Dietz K — EPI
Some bounds on estimates for the basic reproductive ratio R_0 derived from the age-specific force of infection

Grimmett G — RSP
Percolative problems

Grimmett G — RSP
The random-cluster model

Grimmett G — RSP
Stochastic random-cluster process and the uniqueness of random-cluster measures

Grimmett G, Bollobás B, Janson S — RSP
The random-cluster model on the complete graph

Grimmett G — RSP
Comparison and disjoint-occurrence inequalities for random-cluster models

Grinstein G — CAG
Self-organised criticality

Grinstein G — CAG
Systems with infinite numbers of absorbing states

9.5 Papers Produced by Participants

Grinstein G — CAG
Damage spreading in nonequilibrium systems

Grinstein G — CAG
Power law correlations in systems with coherent periodic oscillations

Guilini D — GGR
Diffeomorphism group of three-manifolds

Hakim V, Rappel W-J — CAG
Noise induces periodic behavior in the globally-coupled complex Ginzberg-Landau equation

Hakim V — CAG
Shapes and dynamics of Laplacian growth

Hallam J — CVI
Hybrid problems need hybrid solutions? Tracking and controlling toy cars

Halpin-Healy T — CAG
Stochastic growth, kinetic roughening phenomena, random energy landscapes, and all that: aspects of multidisciplinary statistical mechanics

Hambly B — RSP
On constant tail behaviour for the limiting random variable in a supercritical branching process

Hammersley J — RSP
Fractal dynamics of Eden clusters

Hammersley J, Mazzarino G — RSP
Properties of large Eden clusters in the plane

Hara T, Slade G — RSP
The self-avoiding walk and percolation critical points in high dimensions

Hara T, Slade G — RSP
Mean-field behaviour and the lace expansion

Harms B, Leblanc Y — GGR
Black objects in the gauge theory of p-branes

Harris M — LFN
Cohomological realisation of supercuspidal representations of $GL(n)$

Hartle J, Gell-Mann M — GGR
Equivalent sets of histories and multiple quasiclassical domains

Hartle J — GGR
Quasiclassical domains in a quantum universe

Hartle J — GGR
Spacetime information

Hartle J, LaFlamme R, Marolf D — GGR
Conservation laws in the quantum mechanics of closed systems

Hartle J, Miller W — GGR
Signature of the simplicial supermetric

Hartle J, Williams R — GGR
Simplicial mini superspace IV: Solutions on product triangulations

Harvey J — GGR
S-duality and the spectrum of magnetic monopoles in heterotic string theory

Hasibeder G — EPI
When susceptible and infective human hosts are not equally attractive to mosquitoes: a generalisation of the Ross model

Hasibeder G — EPI
Comments on heterogeneity: aspects in mathematical epidemiology

Hawking S, Horowitz G, Ross S — GGR
Entropy, area, and black hole pairs

9.5 Papers Produced by Participants

Heath-Brown DR
A mean value estimate for real character sums LFN

Heath-Brown DR
The Hardy Littlewood circle method for quadratic and cubic forms LFN

Heesterbeek JAP, Roberts MG
Threshold quantities for infectious diseases in periodic environments EPI

Hida H
p-adic ordinary Hecke algebras for $GL(2)$ LFN

Higuchi Y
Exponential decay of the cluster size distribution for ferromagnetic Ising percolation RSP

Higuchi Y, Toth B
Limit theorems for the so-called reinforced random walk RSP

Higuchi Y
Exponential decay of the cluster size distribution for the two-dimensional Ising percolation RSP

Hoppe J
Some classical solutions of relativistic membrane equations in four space-time dimensions GGR

Hoppe J
Surface motions and fluid dynamics GGR

Horowitz G, Tseytlin A
On exact solutions and singularities in string theory GGR

Horowitz G
A new test of cosmic censorship GGR

Horowitz G, Hawking S, Ross S
Black hole pair annihilation GGR

Horowitz G, Gibbons G, Townsend P
Resolving singularities in higher dimensions GGR

Hudson HM, Ma J, Green J
Fisher's method of scoring in statistical image reconstruction: comparison of Jacobi and Gauss-Seidel iterative schemes CVI

Hudson PJ, Dobson AP
Macroparasites: observed patterns in wildlife EPI

Ihara Y, Matsumoto M
On Galois actions on profinite completions of braid groups LFN

Isham C, Linden N
Quantum temporal logic and decoherence functionals in the histories approach to generalised quantum theory GGR

Isham C, Linden N, Schreckenberg S
The classification of decoherence functionals: an analogue of Gleason's theorem GGR

Jacquez JA
Role of primary infection in epidemics of HIV infection in gay cohorts EPI

Kay J, Phillips W
Activation functions, computational goals and learning rules for local processors with contextual guidance CVI

Keane M, Smorodinsky M, Solomyak B
Cantor criticality RSP

Kent J, Mardia KV, Rabe S
Face description from laser range data CVI

Kertész J, Ramaswamy R
Pattern formation in two-dimensional traffic models and related systems CAG

Kertész J, Somfai E, Wolf D — CAG
Correlated island nucleation in layer-by-layer growth

Kertész J, Ramaswamy R — CAG
Coarsening in a driven diffusive systems with two species

Kesten H, Schonmann RH — RSP
On some growth models with a small parameter

Kesten H — RSP
Branching random walk with a critical branching part

Kimia B, Tannenbaum A, Zucker S — CVI
Non-linear shape approximation via the entropy scale space

Klimčik C, Tseytlin A — GGR
Propagation of strings in the null orbifolds

Kodama H — GGR
Description of quantum dynamics of totally constrained systems in an extended state space

Kodama H, Fiujita Y — GGR
Influence of cooling flow and galactic motion on the iron distribution in clusters of galaxies

Kolyvagin V — LFN
On the modular hypothesis and Fermat's last theorem

Kolyvagin V — LFN
Fermat equation over cyclotomic fields

Kotecky R, Olivieri E — RSP
Shapes of growing droplets: a model of escape from a metastable phase

Kotecky R, Chayes L, Shlosman S — RSP
Aggregation and intermediate phases in dilute spin systems

Kotecky R, Martinelli F, Mazel A — RSP
The rate of approach to equilibrium for three-dimensional Ising model

Krug J, Dobbs HT — CAG
Current-induced faceting of crystal surfaces

Krug J — CAG
Turbulence and generic scale invariance

Kuchař K — GGR
Friedmann universe as a parametrized harmonic oscillator

Kuchař K, Romana J — GGR
The role of time in quantum collapse

Kuchař K, Brown D — GGR
Dust in quantum gravity

Kuzanayan K, Sokolov D — DYN
On the parametric resonance in thin disk galactic dynamo

Károlyi A, Kertész J — CAG
Hydrodynamic cellular automata for granular media

Laflamme R, Gregory R — GGR
The stability extremally charged black string from string theory

Langer P, Zucker S — CVI
A computational model of spatially varying illumination

Laumon G — LFN
Sur la cohomologie à supports compacts des variétés de Shimura pour $GSF(4)$

Lawler G — RSP
Random walks, harmonic measure and Laplacian growth models

Le Gall J-F, Perkins E, Taylor S — RSP
The packing measure of the support of super-Brownian motion

LeBrun C — GGR
Anti-self-dual metrics and Kähler geometry

LeBrun C, Ye Y-G — GGR
Complex contact transformations and quaternionic geometry

LeBrun C, Mason L — GGR
Twistors, Zoll manifolds and projective structures

LeBrun C, Singer M — GGR
Electro-gravitational instantons and complex deformation theory

LeBrun C — GGR
Fano manifolds, contact structures, and quaternionic geometry

Liggett T — RSP
Improved upper bounds for the contact process critical value

MacKay D, Takeuchi R — CVI
Interpolation models with multiple hyperparameters

MacKay D, Peto L — CVI
Smoothing within a hierarchical probabilistic model, with applications to language modelling

Maes C, Giacomin G, Lebowitz J — CAG
Ground state percolation in lattice gases

Malik J, Rosenholtz R — CVI
Recovering surface curvature and orientation from texture distortion: a least squares algorithm and sensitive analysis

Malkus WVR — DYN
Energy sources for planetary dynamos

Mardia KV, Little JA — CVI
Image warping using derivative information

Mardia KV, Rabe S, Kent J — CVI
Statistics, shape and images

Martinelli F — RSP
On the two-dimensional Ising model in the phase coexistence region

Martin-Löf A — EPI
The final size of a nearly critical epidemic, and the first passage time of a Wiener process to a parabolic barrier

Martin-Löf A — EPI
Diffusion approximation for a nearly critical s-i-s epidemic

Maslov S, Paczuski M — CAG
Scaling theory of depinning in the Sneppen model

Mason L — GGR
Self-duality on split signature

Mason L, LeBrun C — GGR
On the Blaschke conjecture

Mason L, Bailey T, Eastwood M — GGR
Twistor theory and the Radon transform

Maybank S — CVI
Finite dimension filters

Mazel A, Suhov Y — RSP
Ground states of a Boson quantum lattice model

Metz JAJ, Van den Bosch J — EPI
Velocities of epidemic spread

Miller T, Zucker S — CVI
Computation in neural cliques: biological consistency implies computational tractability

9.5 Papers Produced by Participants

Moore MA — CAG
Energy barriers for flux line crossing

Moore MA — CAG
The vortex glass scaling exponent

Moore MA, Blum T, Doherty JP — CAG
Glassy solutions of the Kardar-Parisi-Zhang equation

Moorhouse T, Ward RS — GGR
Numerical twistor procedure for solving a nonlinear field equation

Morris WM, Dean L — EPI
Effect of sexual behaviour change on long term HIV-prevalence among homosexual men

Morris WM, Kretzschmar M — EPI
Concurrent partnerships and transmission dynamics in networks

Mountford T — RSP
A coupling of infinite particle systems

Mountford T — RSP
Exponential convergence of sub-critical attractive reversible nearest particle systems

Mountford T, Prabhaker B — RSP
On weak convergence of departures from an infinite series of queues

Mukamel D — CAG
Asymmetric exclusion model with two species: spontaneous symmetry breaking

Mukamel D — CAG
Droplet dynamics in an asymmetric exclusion model

Mukamel D — CAG
Spontaneous symmetry breaking in one-dimensional driven diffusive systems

Mundy J, Zisserman A — CVI
Applications of invariance in computer vision

Mundy J, Liu J, Zisserman A — CVI
Repeated structures: image correspondence constraints and three-dimensional structure recovery

Nayak SK, Ramaswamy R — CAG
Melting of $(Ar\text{-}Xe)_{13}$ clusters: surface-core effects

Neal RM — CVI
Priors for infinite networks

Newman C — RSP
Disordered Ising systems and random cluster representations

Norris JR — RSP
Twisted sheets

Olivieri E, Scoppola E — RSP
Markov chains with exponentially small transition probabilities: first exit problem from a general domain. I. The reversible case

Pardoux E, Buckdahn R — RSP
Backward SDEs driven by Levy processes and related integro-partial differential equations

Pauwels E, Fiddelaers P, Van Gool J — CVI
Geometry-driven curve evolution

Pemantle R — RSP
Maximum variations of total risk

Pemantle R — RSP
Sharpness of second moment criteria for branching and tree-indexed processes

Penrose M — RSP
Self-avoiding walks and trees in spread-out lattices

9.5 Papers Produced by Participants

Popa S — LDT
Free-independent sequences in type II_1 factors and related problems

Prasad D, Ramakrishnan D — LFN
Symplectic root numbers of two-dimensional Galois representations: an interpretation

Proctor M — DYN
Lectures on instability in the presence of symmetry

Razumov AV, Saveliev MV — LDT
Differential geometry of Toda systems

Ribet KA — LFN
Wiles proves Taniyama's conjecture; Fermat's last theorem follows

Ripley BD — CVI
Choosing network complexity

Ripley BD — CVI
Network methods in statistics

Ripley BD — CVI
Flexible non-linear approaches to classification

Ripley BD — CVI
Comment on: Neural networks, a review from a statistical perspective, by Bing Cheng and D.M. Titterington

Ripley BD, Hjort NL — CVI
Pattern recognition and neural networks

Roberts MG, Heesterbeek JAP — EPI
The dynamics of nematode infections of farmed ruminants

Sattenspiel L — EPI
Structured epidemic models and the spread of measles on Dominica, West Indies

Schonmann R — RSP
Theorems and conjectures on the droplet-driven relaxation of stochastic Ising models

Schuetz GM — CAG
Duality relations for asymmetric exclusion processes

Shapiro L, Zisserman A, Brady JM — CVI
Motion from point matches using affine epipolar geometry

Shiga T — RSP
Measure-valued branching diffusions: immigrations, excursions and limit theorems

Sidoravicius V, Kipnis C — RSP
CLT for the rescaled dynamics of a tagged particle in the interacting Ornstein-Uhlenbeck process

Sidoravicius V, Prescutti E — RSP
Long-time behaviour of a charged particle interacting with an ideal gas

Singer M — GGR
Remarks on the period mapping for four-dimensional conformal structures

Singer M, Murray MK — GGR
Non-integral hyperbolic monopoles and their spectral curves

Singer M, LeBrun C — GGR
Electro-gravitational instantons and complex deformation theory

Smolin L — GGR
A strong coupling expansion for quantum gravity

Smolin L — GGR
Canonical quantization of the Bianchi model

Smolin L — GGR
The strange quark mass and the cosmological natural selection hypothesis

9.5 Papers Produced by Participants

Sneppen K, Bak P, Flyvbjerg H *et al* CAG
Evolution as a self-organized critical phenomenon (macro-evolution/punctuated equilibrium/self- organization/criticality)

Soward A DYN
On the role of stagnation points and particle paths in a two-dimensional flow fast dynamo model

Soward A DYN
Phase mixed rotating magnetoconvection and Taylor's condition. I. Amplitude equations

Soward A DYN
Phase mixed rotating magnetoconvection and Taylor's condition. II. Travelling pulses

Soward A DYN
Phase mixed rotating magnetoconvection and Taylor's condition. III. Wave trains

Sparr G CVI
A common framework for kinetic depth, reconstruction and motion for deformable objects

Speer E CAG
Conservation laws in a directed sandpile model

Stinchcombe RB, Schuetz GM CAG
Operator algebra for stochastic dynamics and the Heisenberg chain

Suhov Y, Vvedenskaya N RSP
The limiting departure flow in an infinite series of queues I

Suhov Y RSP
The limiting departure flow in an infinite series of queues II

Tang L-H, Kardar M CAG
Driven depinning in an anisotropic medium

Tang L-H, Chaté H, Grinstein G CAG
Phase diffusion in quasiperiodic cellular automata

Tang L-H CAG
Dynamical surfaces

Toom A CAG
Simple one-dimensional interaction systems with super-exponential relaxation times

Toth B RSP
"True" self-avoiding walks with generalized bond repulsion on $\mathbb{Z}$

Vainshtein SI, Du Y, Sreenivasan KR DYN
Sign-singular measure and its association with turbulent scalings

Vainshtein SI, Sreenivasan KR, Pierrehumbert RT *et al* DYN
Scaling exponents for turbulence and other random processes and their relationships with multifractal structure

Vainshtein SI, Sreenivasan KR DYN
Kolmogorov's $\frac{4}{5}$th law and intermittency in turbulence

Vainshtein SI DYN
On the generation of magnetic flux and fractal properties

Van Gool L, Moons T, Ungureanu D *et al* CVI
The characterisation and detection of skewed symmetry

Van Gool L, Moons T, Pauwels E *et al* CVI
Vision and Lie's approach to invariance

Van den Berg J, Gandolfi A RSP
A triangle inequality for covariances of binary FKG random variables

9.5 Papers Produced by Participants

Van den Berg J — RSP
An improved lower bound for the critical activity of the hard-square lattice gas model

Van den Berg J — RSP
Disagreement percolation and mixing properties of Gibbs measures

Van den Bosch F, Zadoks JC, Metz JAJ — EPI
Continental expansion of plant disease: a survey of some recent results

Vaughan R — LFN
The use of additive number theory of numbers without large prime factors

Velasco-Hernandez JX — EPI
A model for Chagas disease involving transmission by vectors and blood transfusion

Ward RS — GGR
Discrete A_n Toda field equations

Whelan J — GGR
Spacetime alternatives in relativistic particle motion

Wolf D — CAG
Correlated nucleation in molecular beam epitaxy

Wolf D — CAG
Computer simulation of molecular beam epitaxy

Woodhouse N — GGR
Self-duality and integrability

Wytzes-Allen M — STA
A woolcomber's guide to the stars

Xu G — CVI
Segmentation and optical flow for multiple rigid motions via recovery of epipolar geometry

Yekutieli I — CAG
Self-diffusion and "visited" surface in the droplet condensation problem

Yekutieli I — CAG
A model of branched growth

Yuille A — CVI
Bayesian decision theory and psychophysics

Zeitlin V, Kambe T — DYN
Two-dimensional ideal magnetohydrodynamics and differential geometry

Zhang K — LFN
On coupling between the Poincaré equation and the heat equation

Zhang S — LFN
On the 3-part of Birch and Swinnerton-Dyer conjecture

Zia RKP, Blum T — CAG
An introduction to the statistical mechanics of driven-diffusive systems

Zisserman A, Forsyth D, Mundy J *et al* — CVI
Three-dimensional object recognition using invariance

Zisserman A — CVI
A case against epipolar geometry

'CVI', 'RSP', 'GGR' or 'CAG' indicate that the author(s) were participants in the *Computer Vision*, *Random Spatial Processes*, *Geometry and Gravity* or *Cellular Automata, Aggregation and Growth* programmes; 'LDT', 'DYN', 'LFN' or 'EPI' indicate that the author(s) were participants in the *Low Dimensional Topology and Quantum Field Theory*, *Dynamo Theory*, *L-functions and Arithmetic* or *Epidemic Models* programmes which took place in 1992/93 but the papers were not published until 1993/94; 'STA' indicates that the author(s) were members of the Institute staff.

9.6 SEMINARS AND LECTURES

July 1993 – June 1994

T Liggett	*Survival and coexistence in interacting particle systems I*	05/07/93	RSP*
B Derrida	*Mathematical problems in the theory of disordered systems*	05/07/93	RSP*
F Den Hollander	*Scaling for a random polymer*	05/07/93	RSP*
M Keane	*Ergodic theory of spatial processes I*	05/07/93	RSP*
R Carpenter	*Biological gaze control: overview*	06/07/93	CVI*
B Derrida	*Exact results in asymmetric exclusion models*	06/07/93	RSP*
D Griffeath	*Self-organization in cellular automata I*	06/07/93	RSP*
R Carpenter	*Case study: active vision*	06/07/93	CVI*
R Brockett	*Kalman filtering*	06/07/93	CVI*
Y Peres	*The percolation approach to capacity and multiple points for Brownian motion*	06/07/93	RSP*
M Keane	*Ergodic theory of spatial processes II*	06/07/93	RSP*
D Griffeath	*Self-organization in cellular automata II*	07/07/93	RSP*
R Brockett	*Linear quadratic Gaussian control principles*	07/07/93	CVI*
G Grimmett	*Percolation and related models I*	07/07/93	RSP*
R Daniel	*Practical control system design*	07/07/93	CVI*
R Schonmann	*Critical droplets and metastability in stochastic Ising models I*	07/07/93	RSP*
F Comets	*High temperature Sherrington-Kirkpatrick model and stochastic calculus*	07/07/93	RSP*
G Grimmett	*Percolation and related models II*	08/07/93	RSP*
K Glover	*H^∞ control principles*	08/07/93	CVI*
R Schonmann	*Critical droplets and metastability in stochastic Ising models II*	08/07/93	RSP*
C Brown	*The problem of delay: experiments with positive feedback control*	08/07/93	CVI*
D Weir	*Active vision at GEC*	08/07/93	CVI*
G Papanicolaou	*Convection enhanced diffusion I*	08/07/93	RSP*
T Liggett	*Survival and coexistence in interacting particle systems II*	08/07/93	RSP*
G Papanicolaou	*Convection enhanced diffusion II*	09/07/93	RSP*
R Brockett	*Feedback linearization control*	09/07/93	CVI*
J Chayes	*Self-organized criticality and singular diffusion*	09/07/93	RSP*
C Brown	*Cognitive gaze control: Bayes nets and decision theory*	09/07/93	CVI*
A Klein	*Multiscale analysis in disordered systems*	09/07/93	RSP*
R Kotecky	*Geometric representation of lattice models and large volume asymptotics*	09/07/93	RSP*
B Zegarlinski	*Disordered spin systems: some results and problems*	11/07/93	RSP*
E Scoppola	*Metastability for Markov chains: a general procedure based on renormalisation group ideas*	11/07/93	RSP*
M Menshikov	*Constructive methods in Markov chain theory*	11/07/93	RSP*
C Newman	*Disordered Ising systems and random cluster representations I*	12/07/93	RSP*
P Ferrari	*Shocks in exclusion processes with drift*	12/07/93	RSP*
S Shlosman	*Ising model and large deviations I*	12/07/93	RSP*
K Alexander	*Spanning forests, invasion percolation and optimal paths to infinity in percolation methods*	12/07/93	RSP*
S Schlosman	*Ising model and large deviations II*	13/07/93	RSP*

9.6 Seminars and Lectures July 1993 – June 1994

M Aizenman	*The localization transition for random operators I*	13/07/93	RSP*
M Brady	*Introduction to path planning and sensor guided control*	13/07/93	CVI*
H Kesten	*First-passage percolation and the problem of shape*	13/07/93	RSP*
M Piza	*Fluctuations in first-passage percolation*	13/07/93	RSP*
S Cameron	*Search methods for path planning*	14/07/93	CVI*
M Aizenman	*The localization transition for random operators II*	14/07/93	RSP*
G Slade	*Mean-field behaviour and the lace expansion I*	14/07/93	RSP*
A Maclean	*Using snakes for path planning*	14/07/93	CVI*
S Cameron	*Non-holonomic path planning for wheeled vehicles*	14/07/93	CVI*
G Lawler	*Random walks, harmonic measure and Laplacian growth models I*	14/07/93	RSP*
B Nachtergaele	*Stochastic geometric aspects of quantum spin states*	14/07/93	RSP*
M Brady	*Sensor guided control of the AGV and path planning for the robot head*	15/07/93	CVI*
A Kupiainen	*Renormalization group ideas for random walks and PDEs*	15/07/93	RSP*
J Manyika	*Sensor data fusion and decision theoretic control*	15/07/93	CVI*
G Slade	*Mean-field behaviour and the lace expansion II*	15/07/93	RSP*
G Lawler	*Random walks, harmonic measure and Laplacian growth models II*	15/07/93	RSP*
C Newman	*Disordered Ising systems and random cluster representations II*	15/07/93	RSP*
Y Peres	*Speed of random walk and dimension of harmonic measure on Galton-Watson trees*	19/07/93	RSP
J Porrill	*Active vision at AI Vision Research Unit at Sheffield*	20/07/93	CVI*
D Murray	*Controlling the Yorick stereo head*	20/07/93	CVI*
D Terzopoulos	*Dynamic models for recursive shape and motion estimation*	20/07/93	CVI*
A Blake	*Control of scale in curve tracking*	20/07/93	CVI*
R Curwen	*Parallel implementation of curve trackers*	20/07/93	CVI*
G Sullivan	*Traffic surveillance using model-based vision*	21/07/93	CVI*
J Malik	*Applications of tracking to traffic monitoring*	21/07/93	CVI*
J Hallam	*Model cars: an experiment in real-time intelligent control*	21/07/93	CVI*
J Mayhew	*Active vision at AI Vision Research Unit: the adaptive control and self-calibration of a 4 d.o.f. stereo camera head*	21/07/93	CVI*
R Bajcsy	*Cooperating behaviours: discrete dynamic events*	21/07/93	CVI*
R Cipolla	*Uncalibrated stereo hand-eye coordination*	21/07/93	CVI*
M Taylor	*Grasping three-dimensional objects using an active viewer*	21/07/93	CVI*
C Taylor	*Generation and fitting of trainable flexible templates*	22/07/93	CVI*
A Yuille	*Theoretical and experimental advances in deformable templates*	22/07/93	CVI*
L Shapiro	*Tracking moving heads*	22/07/93	CVI*
D Tock	*Tracking drivers' eyes*	22/07/93	CVI*
R Szeliski	*Robust shape recovery from occluding contours using a linear smoother*	22/07/93	CVI*
D Hogg	*Fusing two views using object motion*	22/07/93	CVI*
D Aldous	*Hammersley's process and its hydrodynamical limit*	23/07/93	RSP
C Longuet-Higgins	*Ambiguous surfaces*	26/07/93	CVI*
S Maybank	*Critical sets for lines and points*	26/07/93	CVI*
T Huang	*Feature-based motion estimation*	26/07/93	CVI*
O Faugeras	*Ambiguous sets of lines for motion estimation from three views*	27/07/93	CVI*
P Giblin	*Recovery of surfaces from profiles under rotation with unknown axis*	27/07/93	CVI*

9.6 Seminars and Lectures July 1993 – June 1994

M Werman	*From image sequences for computer graphics and geometric modelling*	27/07/93	CVI*
A Martin-Löf	*The final size of a nearly critical epidemic and a first passage time problem*	27/07/93	RSP
S Maybank	*Reconstructions for minimal data sets*	27/07/93	CVI*
C Longuet-Higgins	*SVD for compacting para-perspective image sequence data in the manner of Tomasi and Kanade*	27/07/93	CVI*
O Faugeras	*Affine and projective reconstruction from a pair of uncalibrated cameras*	28/07/93	CVI*
R Szeliski	*Recovering three-dimensional shape and motion from image streams using nonlinear least squares*	28/07/93	CVI*
L Shapiro	*Structure and motion with an affine camera*	28/07/93	CVI*
P Beardsley	*Projective structure from motion*	28/07/93	CVI*
D Weinshall	*The linear acquisition of similarity and affine invariant shape from noisy sequences of images*	28/07/93	CVI*
O Faugeras	*Camera geometry*	29/07/93	CVI*
O Faugeras	*E- and F-matrixes, Sturm and Kruppa*	29/07/93	CVI*
R Horaud	*Hand-eye calibration*	29/07/93	CVI*
G Lawler	*Slowly recurrent sets and loop-erased walk in d-dimensions*	30/07/93	RSP
J Porrill	*Geometry of binocular stereopsis with vergence*	02/08/93	CVI*
T Hara	*Lower bounds on the connective constant of self-avoiding walks*	02/08/93	RSP
D Weinshall	*On polar disparity*	02/08/93	CVI*
J Gårding	*More on polar disparity*	02/08/93	CVI*
J Malik	*On disparity gradients*	02/08/93	CVI*
K Nakayama	*Tutorial on psychophysics of vision I*	03/08/93	CVI*
B Rogers	*Psychophysics of stereopsis*	03/08/93	CVI*
K Nakayama	*Tutorial on psychophysics of vision II*	03/08/93	CVI*
K Nakayama	*Tutorial on psychophysics of vision III*	04/08/93	CVI*
J Frisby	*Stereo-texture interactions*	04/08/93	CVI*
W Freeman	*Modelling the statistics of the world as seen by the eye*	04/08/93	CVI*
K Nakayama	*Tutorial on psychophysics of vision IV*	05/08/93	CVI*
A Derrington	*Some simple failures of human motion perception*	05/08/93	CVI*
K Alexander	*Boundary fluctuations in first-passage percolation*	06/08/93	RSP
M Penrose	*Spread-out continuum percolation*	09/08/93	RSP
N Bingham	*Some application of large deviation theory*	11/08/93	RSP
R Pemantle	*Discrete potential theory for Markov chains and an application of potential theory to Galton-Watson trees*	13/08/93	RSP
R Schonmann	*For two-dimensional lattice spin systems weak mixing implies strong mixing*	16/08/93	RSP
D van Essen	*Principles of neural architecture and function*	16/08/93	CVI*
D van Essen	*Subcortical and early cortical processing*	17/08/93	CVI*
J Robson	*An interpretation of image representation in primary visual cortex*	17/08/93	CVI*
D van Essen	*Higher visual processing*	17/08/93	CVI*
F Heitger	*Modelling V2 and gestalt grouping*	18/08/93	CVI*
H Barlow	*Neural coding*	18/08/93	CVI*
D van Essen	*Visual attention: computational models and psychological tests*	18/08/93	CVI*

J Malik	*Simple cells, complex cells and contour cells: what algorithms do they support?*	19/08/93	CVI*
D O'Carroll	*Higher order visual processing in flying insects*	19/08/93	CVI*
A Sillito	*The role of cortico-fugal feedback in central visual function*	19/08/93	CVI*
D Mumford	*Modelling the feedback circuits in the brain*	19/08/93	CVI*
M Keane	*Cantor criticality*	20/08/93	RSP
J Mundy	*Object recognition: introduction*	23/08/93	CVI*
J Mundy	*An overview and history of object recognition*	23/08/93	CVI*
Y Higuchi	*Two-dimensional Ising percolation*	23/08/93	RSP
S Ullman	*An overview of model-based recognition*	23/08/93	CVI*
J Mundy	*Interpretation tree and pose clustering*	23/08/93	CVI*
S Ullman	*Alignment*	23/08/93	CVI*
J Mundy	*Curved object recognition*	24/08/93	CVI*
J Porrill	*Object recognition in TINA*	24/08/93	CVI*
T Moons	*Invariant characteristics of articulated objects*	24/08/93	CVI*
R Poppelstone	*Pose determination using symmetry groups*	24/08/93	CVI*
D Cooper	*The role of statistics in recognition*	24/08/93	CVI*
J Mundy	*Invariant methods in recognition*	25/08/93	CVI*
S Ullman	*Comments on invariant methods*	25/08/93	CVI*
C Rothwell	*A recognition system based on invariants*	25/08/93	CVI*
D Forsyth	*Recognizing extruded and algebraic surfaces*	25/08/93	CVI*
A Zisserman	*Invariants of three-dimensional symmetric objects*	25/08/93	CVI*
J Mundy	*Multiple-view invariants*	26/08/93	CVI*
L Stark	*Object classes based on function*	26/08/93	CVI*
A Evans	*Object recognition using neural networks*	26/08/93	CVI*
A Shashua	*Does intensity play a role in recognition?*	26/08/93	CVI*
S Ullman	*Object recognition in the future I*	26/08/93	CVI*
J Mundy	*Object recognition in the future II*	26/08/93	CVI*
T Mountford	*An old fool and his coupling*	27/08/93	RSP
J van den Berg	*Disagreement percolation and uniqueness of Gibbs measures*	01/09/93	RSP
P Ferrari	*Poisson approximation for the departure from a system with infinitely many queues*	03/09/93	RSP
S Geman	*Object recognition: introduction*	06/09/93	CVI*
U Grenander	*Ramblings on pathology patterns*	06/09/93	CVI*
D Abraham	*An application of percolation to random surfaces*	06/09/93	RSP
S Geman	*Discussion on recognition of multiple objects in complex scenes*	07/09/93	CVI*
Y Amit	*Graphical methods for image matching*	08/09/93	CVI*
B Ripley	*Classifying galaxies and worms in images*	08/09/93	CVI*
A Blake	*Motion- and shape-selective contours*	09/09/93	CVI*
R Weiss	*Local search for verification of model matching*	09/09/93	CVI*
S Zucker	*Shape models*	10/09/93	CVI*
C Kipnis	*From gradient to nongradient in exclusion processes*	10/09/93	RSP
D Mumford	*Recognition of faces and leaves and defining similar shapes*	10/09/93	CVI*
J Walsh	*Stochastic two-point boundary value problem*	13/09/93	RSP*
R Tribe	*Long-time behaviour of another white noise heat equation*	13/09/93	RSP*
Y Suhov	*Random branching processes and travelling wave solutions for coupled KPP equations*	13/09/93	RSP*

J Koenderink	*Topographic representation*	13/09/93	CVI*
A Sznitman	*Aspects of Brownian motion in a Poissonian potential*	13/09/93	RSP*
R Szeliski	*Particle representation*	13/09/93	CVI*
T Shiga	*Measure-valued branching diffusions: excursions, immigrations and limit theorems*	13/09/93	RSP*
S Zucker	*Surfel representation*	13/09/93	CVI*
E Perkins	*Measure-valued diffusions with singular interactions*	14/09/93	RSP*
J Koenderink	*Ecological optics of surfaces*	14/09/93	CVI*
E Pardoux	*Backward SDEs and quasilinear PDEs and variational inequalities*	14/09/93	RSP*
N Gonchasruk	*On a class of quasilinear stochastic differential equations of parabolic type*	14/09/93	RSP*
P Giblin	*Projection to lines and planes*	14/09/93	CVI*
J Norris	*Two-parameter diffusions*	14/09/93	RSP*
P March	*Resolvent estimates for Fleming-Viot operators*	14/09/93	RSP*
J Le Gall	*A new random process and its connections with PDEs*	15/09/93	RSP*
J Koenderink	*Natural parts of surfaces*	15/09/93	CVI*
A Etheridge	*Representations of superprocesses*	15/09/93	RSP*
I Porteous	*Robust geometry of surfaces*	15/09/93	CVI*
D Mumford	*What's ON a face*	15/09/93	CVI*
J Steif	*The critical threshold voter automaton*	15/09/93	RSP
P Donnelly	*Discrete constructions for measure-valued diffusions*	16/09/93	RSP*
J Koenderink	*Geometry of pictorial relief*	16/09/93	CVI*
D Dawson	*Quasi-equilibria in a hierarchical Fleming-Viot model*	16/09/93	RSP*
J Willats	*A sculptor's perspective*	16/09/93	CVI*
M Van den Berg	*Heat content, Minkowski dimension and capacitory density*	16/09/93	RSP*
E Davies	*Analysis on some bounded locally Euclidean manifolds*	16/09/93	RSP*
W Kendall	*Probability and gradient estimates for harmonic maps*	16/09/93	RSP*
E Bolthausen	*On self-attracting random walks*	17/09/93	RSP*
J Biggins	*Spatial branching processes and the KPP equation and its neighbours*	17/09/93	RSP*
G BenArous	*Langevin dynamics for spin glasses*	17/09/93	RSP*
A Greven	*On systems with a large number of interacting components*	20/09/93	RSP
P Burt	*A framework for multi-resolution image analysis*	20/09/93	CVI*
S Mallat	*Multi-resolution, wavelets and local frequency decompositions*	20/09/93	CVI*
S Mallat	*Orthonormal wavelets for image processing*	21/09/93	CVI*
P Burt	*Pyramid applications for image processing*	21/09/93	CVI*
J Hammersley	*Fractal dynamics of Eden clusters*	22/09/93	RSP
P Burt	*Pyramid applications to computer vision*	22/09/93	CVI*
S Mallat	*Multiscale edge detection*	22/09/93	CVI*
J Daugman	*Gabor wavelets in mammalian vision and pattern recognition applications*	23/09/93	CVI*
E Andjel	*The exclusion process with a finite number of particles*	24/09/93	RSP
F Kelly	*Loss networks*	27/09/93	RSP
P Hall	*Statistical estimation of fractal properties*	29/09/93	RSP
H Georgii	*Large deviations for Gibbsian point random fields with super-stable interactions*	04/10/93	RSP
I Benjamini	*λ_1 and the Liouville property*	06/10/93	RSP

9.6 Seminars and Lectures July 1993 – June 1994

M Rees	*Understanding cosmic evolution: progress, hype and prospects*	11/10/93	INS
M Barlow	*DLA on the binary tree*	13/10/93	RSP
P Green	*Bayesian image analysis*	18/10/93	CVI*
D Spiegelhalter	*Graphical models and exact calculations*	18/10/93	CVI*
P Green	*Emission tomography and EM algorithms*	18/10/93	CVI*
H Huppert	*Volcanoes: how they work*	18/10/93	INS
P Green	*Markov chain Monte Carlo in image problems*	19/10/93	CVI*
M Miller	*Inference in parametric spaces of varying dimension*	19/10/93	CVI*
B Ripley	*Galaxy deconvolution and recognition*	19/10/93	CVI*
C Graffigne	*Segmentation algorithms*	19/10/93	CVI*
J Kay	*Edge-preserving image restoration*	19/10/93	CVI*
D Titterington	*Parameter estimation in image models*	20/10/93	CVI*
C Jennison	*Multiple site updates in image estimation*	20/10/93	CVI*
T Kaijser	*On couplings of random systems with complete connections*	20/10/93	RSP
A Baddeley	*Stochastic geometry and high level vision*	21/10/93	CVI*
C Jennison	*Subpixel resolution and edge fitting*	21/10/93	CVI*
D Phillips	*Hierarchical templates and tracking via MCMC*	21/10/93	CVI*
A Frigessi	*Informative priors in remote sensing*	21/10/93	CVI*
P Donnelly	*Genealogical processes in population genetics*	22/10/93	RSP
J Bridle	*Overview of automatic speech recognition*	25/10/93	CVI
J Bridle	*Signal processing and acoustic modelling for automatic speech recognition*	25/10/93	CVI
J Bridle	*Hidden Markov theory and basic algorithms*	25/10/93	CVI
J Bridle	*Whole-word connected speech recognition*	26/10/93	CVI
S Roukos	*Large vocabulary issues/decision-tree based methods*	26/10/93	CVI
S Zucker	*Computational vision and biological perception I. The visual cortex and edge detection*	26/10/93	INS
A Gandolfi	*Greedy lattice animals*	27/10/93	RSP
S Roukos	*Statistical language models for automatic speech recognition*	27/10/93	CVI
M Brooke	*Lip reading and talking-head graphics*	27/10/93	CVI
S Della Pietra	*Introduction to maximum entropy and exponential models*	28/10/93	CVI
B Ripley	*Applicability of speech techniques in vision: a discussion*	28/10/93	CVI
S Della Pietra	*Maximum entropy continued*	28/10/93	CVI
S Zucker	*Computational vision and biological perception II. Grouping and the geometry of curve inferencing*	28/10/93	INS
S Della Pietra	*Growing overlapping decision trees*	29/10/93	CVI
J Cardy	*Conformal invariance, the Potts model and percolation*	29/10/93	RSP
S Della Pietra	*Language translation by statistical means*	29/10/93	CVI
B Ripley	*Overview of neural nets and classification trees*	01/11/93	CVI
D Spiegelhalter	*Belief nets I: introduction*	01/11/93	CVI
R Dobrushin	*Gibbs fields from physics through mathematics to all sciences*	01/11/93	INS
D Spiegelhalter	*Belief nets II*	02/11/93	CVI
B Ripley	*Neural networks for classification*	02/11/93	CVI
R Neal	*The Bayesian approach to accommodating complex models and its Monte Carlo implementation*	02/11/93	CVI
D MacKay	*Issues in Bayesian adaptive modelling*	02/11/93	CVI

9.6 Seminars and Lectures July 1993 – June 1994

S Zucker	*Computational vision and biological perception III. Cliques of neurons and visual accuracy*	02/11/93	INS
G Slade	*Attractive and repulsive walks*	03/11/93	RSP
D Bell	*Dempster/Schafer methodology for handling uncertainty in spatial reasoning*	03/11/93	CVI
D Wolpert	*Stacked generalization*	04/11/93	CVI
A Dawid	*Computational developments for networks*	04/11/93	CVI
A Gammerman	*PRESS - probabilistic reasoning expert system shell*	04/11/93	CVI
S Zucker	*Computational vision and biological perception IV. Neuronal metabolism, colour and texture*	04/11/93	INS
R Dobrushin	*Fluctuations of boundaries of droplets*	05/11/93	RSP
R Dobrushin	*The hydrodynamical equations of Navier-Stokes level*	08/11/93	RSP*
A De Masi	*Travelling fronts for Glauber dynamics with a magnetic field and Kac interactions*	08/11/93	RSP*
B Toth	*Anomalous diffusion of self-repelling random walks*	08/11/93	RSP*
B Ripley	*What have we learned? Mathematical theories of generalization*	08/11/93	INS
F Martinelli	*On the stochastic two-dimensional Ising model in the phase transition region*	09/11/93	RSP*
S Shlosman	*Annealed spin systems and the Fisher renormalization group*	09/11/93	RSP*
A Barto	*An introduction to reinforcement learning*	09/11/93	CVI*
A Barto	*Reinforcement as adaptive optimal control*	09/11/93	CVI*
S Zucker	*Computational vision and biological perception V. Temporal cortex, object recognition and shape categories*	09/11/93	INS
D Abraham	*Stochastic dynamics of Dobrushin interface lattice gas model*	09/11/93	RSP*
E Olivieri	*Metastability and nucleation for general stochastic Ising models*	10/11/93	RSP*
P Ferrari	*Annihilating particle systems and automata*	10/11/93	RSP*
T Prescott	*Adaptive local navigation*	10/11/93	CVI*
C Landim	*Hydrodynamical limit for space inhomogeneous asymmetric zero-range processes*	10/11/93	RSP*
T Mountford	*Bootstrap percolation*	10/11/93	RSP*
R Kotecky	*Influence of boundaries on states in finite volumes*	11/11/93	RSP*
E Scoppola	*Graph methods and renormalization for Markov chains*	11/11/93	RSP*
A Barto	*Theoretical aspects of reinforcement learning algorithms based on dynamic programming*	11/11/93	CVI*
C Watkins	*Q-learning and animal learning*	11/11/93	CVI*
N Temperley	*The cluster theory approach to metastability of a liquid*	11/11/93	RSP*
H Yau	*Scaling limit of the asymmetric simple exclusion process*	11/11/93	RSP*
R Schonmann	*A simple model for crystal growth*	12/11/93	RSP*
E Presutti	*Time asymptotics of a reaction diffusion equation with a small noise*	12/11/93	RSP*
A Barto	*Issues for application, animal learning and neuroscience*	12/11/93	CVI*
O Penrose	*Metastability and the analytically continued free energy*	12/11/93	RSP*
P Whittle	*Polymer models and the Potts model*	15/11/93	RSP
J Coates	*Fermat's last theorem*	15/11/93	INS
E Presutti	*Critical fluctuations in Glauber dynamics*	17/11/93	RSP
J Malik	*Overview and examples*	22/11/93	CVI*
F Martinelli	*On a logarithmic Sobolev inequality for Gibbs measures*	22/11/93	RSP

9.6 Seminars and Lectures July 1993 – June 1994

P Perona	*Texture segmentation*	22/11/93	CVI*
D Mumford	*What does the brain have to compute in order to see?*	22/11/93	INS*
E Olivieri	*Renormalization group pathologies and finite size conditions*	23/11/93	RSP
A Yuille	*The coupled-membrane model for texture segmentation*	23/11/93	CVI*
K Conradsen	*Case studies in texture analysis I*	23/11/93	CVI*
K Conradsen	*Case studies in texture analysis II*	23/11/93	CVI*
J Carstensen	*Co-occurrence matrices and applications*	24/11/93	CVI*
B Ripley	*Statistical pattern recognition*	24/11/93	CVI*
J Gårding	*Shape from texture I*	25/11/93	CVI*
J Malik	*Shape from texture II*	25/11/93	CVI*
A Gandolfi	*On Talagrand's method of isoperimetric inequations*	29/11/93	RSP
B Romeny	*Foundations of linear scale space*	29/11/93	CVI*
T Lindeberg	*Scale selection and blob analysis*	29/11/93	CVI*
M Barlow	*Analysis in fractal media*	29/11/93	INS
P Perona	*Anisotropic diffusion*	30/11/93	CVI*
T Shiota	*Regularization and corner detection*	30/11/93	CVI*
G Gerig	*Vector-valued diffusions*	30/11/93	CVI*
L Alvarez	*Axiomatic approach to multi-scale analysis and evolution of curves*	30/11/93	CVI*
W Niessen	*Implementation of four scale-space schemes*	30/11/93	CVI*
L van Gool	*Parallel implementations*	30/11/93	CVI*
D Mumford	*Overview of energy approaches*	01/12/93	CVI*
S Mitter	*Minimization of energy functionals*	01/12/93	CVI*
D Petritis	*The low temperature phase diagram on Penrose and more general quasi-periodic lattices*	01/12/93	RSP
N Nordstrom	*Relationship between the energy formulation and diffusions*	01/12/93	CVI*
J Morel	*Existence and regularity of minimum energy solutions*	01/12/93	CVI*
D Geiger	*Relations with statistical physics*	01/12/93	CVI*
B Romeny	*Covariant formalism and nonlinear scale-space*	01/12/93	CVI*
P Leaci	*Perspectives from the De Giorgi school on free boundary problems*	01/12/93	CVI*
S Pizer	*Objects and geometry of scale space*	02/12/93	CVI*
G Gerig	*Applications to medical imaging*	02/12/93	CVI*
L van Gool	*Coupled nonlinear diffusion for early vision*	02/12/93	CVI*
J Weber	*Segmentation of optical flow based on three-dimensional motion and diffusion*	02/12/93	CVI*
S Pizer	*Variable conductance diffusion via pattern recognition*	02/12/93	CVI*
R Whitaker	*Embedded snakes: energy minimizing blobs*	02/12/93	CVI*
B Kimia	*Entropy scale space for shape*	02/12/93	CVI*
A Bangham	*Sieve filtering*	02/12/93	CVI*
P Perona	*Asymmetrically biased diffusions for image normalization and quantization*	02/12/93	CVI*
S Tavaré	*Random combinatorial structures and the Ewens sampling formula*	06/12/93	RSP
A Pece	*Direct and inverse processing in the visual system*	06/12/93	CVI
A Horridge	*The vision of bees and its invariances*	07/12/93	CVI
S Yau	*Nonlinear equations, geometry and gravity I*	04/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity II*	04/01/94	GGR

S Yau	*Nonlinear equations, geometry and gravity III*	05/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity IV*	05/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity V*	06/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity VI*	06/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity VII*	07/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity VIII*	07/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity IX*	10/01/94	GGR
S Yau	*Nonlinear equations, geometry and gravity X*	10/01/94	GGR
R Ramaswamy	*Sand pile models and defects*	11/01/94	CAG
D Sherrington	*Complexity and order parameter flows in neural dynamics*	12/01/94	CAG
A Connes	*Quantized calculus and applications I*	13/01/94	GGR
A Connes	*Quantized calculus and applications II*	13/01/94	GGR
H Flyvbjerg	*Physics of soap froths*	17/01/94	INS
A Connes	*Quantized calculus and applications III*	18/01/94	GGR
N Goldenfeld	*Renormalization group and structural stability for PDEs and travelling waves*	18/01/94	CAG
A Connes	*Quantized calculus and applications IV*	18/01/94	GGR
F Dekking	*Travelling waves for nonlinear operators*	19/01/94	CAG
A Connes	*Quantized calculus and applications V*	20/01/94	GGR
A Connes	*Quantized calculus and applications VI*	20/01/94	GGR
J Hoppe	*The dynamics of relativistic membranes*	24/01/94	GGR
J Hartle	*Quantum mechanics and quantum cosmology*	24/01/94	INS
A Connes	*Quantized calculus and applications VII*	25/01/94	GGR
A Connes	*Quantized calculus and applications VIII*	25/01/94	GGR
J Kertész	*Kinetic roughening with quenched disorder*	25/01/94	CAG
N Hitchin	*Einstein metrics with self-dual Weyl tensor*	25/01/94	GGR
M Evans	*Exact results on asymmetric exclusion and relation to growth*	26/01/94	CAG
A Connes	*Quantized calculus and applications IX*	27/01/94	GGR
A Connes	*Quantized calculus and applications X*	27/01/94	GGR
C Klimĉi'k	*Duality invariant class of exact string backgrounds*	31/01/94	GGR
N Manton	*Dynamics of solitons*	31/01/94	INS
A Connes	*Quantized calculus and applications XI*	01/02/94	GGR
A Connes	*Quantized calculus and applications XII*	01/02/94	GGR
J Girard	*Linear logic*	01/02/94	*
A Connes	*Quantized calculus and applications XIII*	03/02/94	GGR
A Connes	*Quantized calculus and applications XIV*	03/02/94	GGR
A Bray	*Introduction to the dynamics of phase ordering I*	03/02/94	CAG*
A Bray	*Introduction to the dynamics of phase ordering II*	03/02/94	CAG*
A Bray	*Introduction to the dynamics of phase ordering III*	04/02/94	CAG*
N Goldenfeld	*Scaling and universality in cell dynamic models for phase ordering and crystal growth*	04/02/94	CAG*
I Yekutieli	*Models of domain growth and coarsening*	04/02/94	CAG*
V Hakim	*Growth and competition of needles in a Laplacian field*	04/02/94	CAG*
C Rovelli	*Non-perturbative quantum gravity in the loop representation*	07/02/94	GGR
M Alexander	*Simple models of walking, running and jumping*	07/02/94	INS
G Schuetz	*Non-abelian symmetries of stochastic processes*	08/02/94	CAG

9.6 Seminars and Lectures July 1993 – June 1994

M Schwartz	*Nonlinear deposition*	09/02/94	CAG
B Kay	*Quantum field theory on spacetime with horizons and the KMS condition*	09/02/94	GGR
A Connes	*Quantized calculus and applications XV*	10/02/94	GGR
A Connes	*Quantized calculus and applications XVI*	10/02/94	GGR
P D'Eath	*Bosonic physical states in $N = 1$ supergravity*	14/02/94	GGR
G Horowitz	*Gravitational collapse: from black holes to naked singularities*	14/02/94	INS
T Blum	*Replica approach to directed polymers*	15/02/94	CAG
B Palmer	*Conformal minimal surfaces*	15/02/94	GGR
R Stinchcombe	*Evaporation deposition models*	17/02/94	CAG
J Madore	*Physics and non-commutative geometry*	21/02/94	GGR
T Halpin-Healy	*Kinetic roughening phenomena*	21/02/94	INS
J Steif	*Phase transition for cellular automata*	22/02/94	CAG
R Ball	*Models of self-similar crack growth*	23/02/94	CAG
D Ellwood	*Pushouts of C^*-algebras*	28/02/94	GGR
C Isham	*The challenge of quantum gravity*	28/02/94	INS
T Halpin-Healy	*KPZ primer I*	03/03/94	CAG*
T Halpin-Healy	*KPZ primer II*	03/03/94	CAG*
K Bugajska	*From symplectic structure to space-time*	03/03/94	GGR
D Wolf	*Correlated noise and anomalous scaling*	04/03/94	CAG*
L Tang	*Kinetic roughening at a driven depinning transition*	04/03/94	CAG*
S Edwards	*Statistics of surfaces under deposition*	04/03/94	CAG*
M Dubois-Violette	*Non-commutative differential calculus, symplectic geometry and quantum mechanics*	07/03/94	GGR
A Connes	*Non-commutative geometry and particle physics*	07/03/94	INS
C Godrèche	*Blockage transition in a two-dimensional system*	08/03/94	CAG
H Jensen	*The fate of the elastic string in a random environment*	09/03/94	CAG
P Michor	*The Frölicher-Nijenhuis bracket for derivation based non-commutative differential forms*	10/03/94	GGR
J Cardy	*Field theory and renormalization group for reaction diffusion processes*	15/03/94	CAG
C Maes	*Percolation in some correlated models of statistical mechanics*	16/03/94	CAG
H Levine	*A new look at continuum approaches to DLA*	18/03/94	CAG
M Tonin	*Twistor-like formulation of supermembranes*	21/03/94	GGR*
R Tucker	*Geometrical variations for stiff membranes in curved spaces*	21/03/94	GGR*
G 't Hooft	*Nature as an information processing machine: joint CAG/GGR seminar*	21/03/94	GGR*
R Percacci	*Target space duality in p-branes*	22/03/94	GGR*
R Khuri	*Black p-branes in four-dimensional string theory*	22/03/94	GGR*
J Hoppe	*Integrable membranes and fluid dynamics*	22/03/94	GGR*
L Gary	*Equilibrium behavior on particle systems interfaces*	22/03/94	CAG
P Townsend	*Global structure of p-brane solitons*	22/03/94	GGR*
U Lindstrom	*The zero tension limit of strings and membranes*	22/03/94	GGR*
J Garriga	*Covariant perturbations on membranes*	22/03/94	GGR*
I Bakas	*Infinite symmetries in string theory*	23/03/94	GGR*
B Carter	*Classical dynamics of a brane complex*	23/03/94	GGR*

9.6 Seminars and Lectures July 1993 – June 1994

P Schaller	*Remarks on supermembranes in four dimensions*	23/03/94	GGR*
M Droz	*Fronts and pattern formation in reaction diffusion system*	23/03/94	CAG*
H Spohn	*Shock fluctuations in stochastic lattice gas models*	23/03/94	CAG*
J Krug	*Disorder-induced unbinding and shock fluctuations*	23/03/94	CAG*
E Speer	*Microscopic structure of shocks: the Burgers equation and the asymmetric exclusion process*	23/03/94	CAG*
J Hartle	*Generalized quantum theory and the quantum theory of spacetime*	28/03/94	GGR*
C Isham	*Quantum logic and the generalized quantum theory of Gell-Mann and Hartle*	28/03/94	GGR*
R Penrose	*Twistor theory: aims and achievements*	28/03/94	GGR*
K Kuchař	*In quantum collapse, ask which bell it is that tolls*	29/03/94	GGR*
J Madore	*Non-commutative differential geometry*	29/03/94	GGR*
T Damour	*Theoretical implications of experiments on gravity*	29/03/94	GGR*
C Clarke	*Lorentz geometry: causality and singularities*	30/03/94	GGR*
J Stewart	*What can computers tell us about general relativity*	30/03/94	GGR*
S Hawking	*Loss of quantum coherence with closed timelike curves*	30/03/94	GGR*
G Gibbons	*Solitons and gravity*	30/03/94	GGR*
R Kallosh	*Supersymmetry and gravity*	30/03/94	GGR*
G Horowitz	*The impact of superstring theory on general relativity*	31/03/94	GGR*
B Kay	*Quantum field theory in a curved spacetime: future directions*	31/03/94	GGR*
J Halliwell	*Information theory and gravity*	31/03/94	GGR*
H Spohn	*Bulk diffusivity of lattice gases close to criticality*	05/04/94	CAG
T Newman	*Exact results for a model of interface growth*	06/04/94	CAG
D Deutsch	*Quantum computation and closed timelike curves*	11/04/94	GGR*
J Simon	*Unitarity and closed timelike curves*	12/04/94	GGR*
F Koukiou	*The mean field theory of directed polymers in random media and spin glass models*	12/04/94	CAG
J Hartle	*Path integrals and closed timelike curves*	12/04/94	GGR*
S Hawking	*Quantum coherence and closed timelike curves*	13/04/94	GGR*
H Chaté	*Collective behaviour in spatially extended dynamical objects*	13/04/94	CAG
D Politzer	*Simple examples of closed timelike curves*	13/04/94	GGR*
A Lahiri	*A toy model of black hole thermodynamics*	14/04/94	GGR*
B Kay	*Misner space and F-locality*	14/04/94	GGR*
S Rosenberg	*Testing closed timelike curves causality violation*	14/04/94	GGR*
M Cassidy	*Nonlinearity with closed timelike curves*	14/04/94	GGR*
R Laflamme	*Stability of charged strings and p-branes*	14/04/94	GGR*
T Ortin	*Time symmetric initial data sets in dilaton gravity*	15/04/94	GGR*
J Dowker	*Geometric entropy*	15/04/94	GGR*
C Gundlach	*Isaacson expansion in quantum cosmology*	18/04/94	GGR
E Alvarez	*On non-abelian duality*	20/04/94	GGR
R Ball	*Introduction to diffusion limited aggregation I*	21/04/94	CAG*
R Ball	*Introduction to diffusion limited aggregation II*	21/04/94	CAG*
T Halsey	*Diffusion limited aggregation as branched growth*	22/04/94	CAG*
J Earnshaw	*Scaling in colloidal aggregation*	22/04/94	CAG*
I Yekutieli	*Asymptotics of diffusion limited aggregation*	22/04/94	CAG*
	SSC Meeting	24/04/94	

9.6 Seminars and Lectures July 1993 – June 1994

V Frolov	*Wavefunction of a black hole and the dynamical origin of entropy*	25/04/94	GGR
S Hawking	*The nature of space and time I: classical theory*	25/04/94	GGR*
D Mukamel	*Selection in non-equilibrium systems*	26/04/94	CAG
M Moore	*Flux lines and pinning in high-temperature superconductors*	27/04/94	CAG
R Penrose	*The nature of space and time II: structure of space-time singularities*	27/04/94	GGR*
S Hawking	*The nature of space and time III: quantum black holes*	29/04/94	GGR*
R Ward	*Self-dual Einstein as two-dimensional field theory*	02/05/94	GGR
R Penrose	*The nature of space and time IV: space-time and quantum theory*	02/05/94	GGR*
G Grimmett	*Probabilistic aspects of the Potts model*	03/05/94	CAG
M Paczuski	*Field theory of a model of self-organised criticality*	04/05/94	CAG
S Hawking	*The nature of space and time V: quantum cosmology*	04/05/94	GGR*
A Anderson	*Coupling classical and quantum variables*	05/05/94	GGR*
R Penrose	*The nature of space and time VI: the twistor view of space-time*	06/05/94	GGR*
M MacCallum	*Roughening up Scri*	07/05/94	GGR*
J Friedman	*QFT on space-time with closed timelike curves and on non-time-orientable space-times*	07/05/94	GGR*
G 't Hooft	*Dynamics of the black hole horizon*	07/05/94	GGR*
D Kramer	*On radiative solutions in general relativity*	07/05/94	GGR*
S Hawking	*The nature of space and time VII: debate*	09/05/94	GGR
R Omnès	*Philosophical consequences of the interpretation of quantum mechanics by consistent histories*	10/05/94	GGR*
D Dhar	*Introduction to self-organized criticality I*	12/05/94	CAG*
L Mason	*Quasi-local mass, Hamiltonians and positive energy*	12/05/94	GGR*
D Dhar	*Introduction to self-organized criticality II*	12/05/94	CAG*
P Bak	*Is life a self-organized critical phenomenon?*	13/05/94	CAG*
J Bouchaud	*Some phenomenological ideas for the statics and dynamics of sandpiles*	13/05/94	CAG*
H Flyvbjerg	*Self-organized critical pin-ball machine*	13/05/94	CAG*
J Gauntlett	*$SL(2,\mathbb{Z})$ duality and soliton theory*	16/05/94	GGR
R Livi	*Defects in a coupled map system*	17/05/94	CAG
J Paz	*Decoherence, chaos and the classical limit*	17/05/94	GGR*
H Flyvbjerg	*Stochastic dynamics of microtubules*	18/05/94	CAG
H Kodama	*Alternative treatment of the quantum Hamiltonian constraint*	19/05/94	GGR*
L Smolin	*The Cherns-Simons functional as a time-function in canonical gravity*	23/05/94	GGR
B Lian	*Algebra, cohomology and quantum operators*	23/05/94	GGR*
A Klemm	*Mirror symmetry on Calabi-Yau spaces*	24/05/94	GGR*
A Toom	*Cellular automata with super-exponential relaxation times*	25/05/94	CAG*
R Livi	*Cellular automata modelling of immune networks*	25/05/94	CAG*
J Hemmingsson	*On global quasiperiodicity in cellular automata*	25/05/94	CAG*
T Ortin	*$SL(2,\mathbb{R})$ duality and supersymmetry*	26/05/94	GGR*
A Albrecht	*Locating information in quantum systems*	26/05/94	GGR*
G Segal	*L^2 cohomology of monopole moduli spaces*	27/05/94	GGR*
M Green	*A discussion of open issues in string theory*	27/05/94	GGR*
P D'Eath	*Finiteness of $N = 1$ supergravity with supermatter*	30/05/94	GGR

9.6 Seminars and Lectures July 1993 – June 1994

D Fisher	*Collective transport in random media*	31/05/94	CAG
R Zia	*American football, barber poles and clouds: pattern formation in a noisy cellular automaton*	01/06/94	CAG*
D Dhar	*The Abelian cellular automaton model of sandpiles*	01/06/94	CAG*
B Derrida	*Exact steady states of systems out of equilibrium: asymmetric exclusion models*	01/06/94	CAG*
H Flyvbjerg	*Dynamics of froths and foams*	01/06/94	CAG*
J Gauntlett	*Pair creation of black holes*	06/06/94	GGR*
J Preskill	*Black hole theory dynamics in two dimensions*	06/06/94	GGR*
L Susskind	*Gedanken experiments and black hole complementarity*	06/06/94	GGR*
J Harvey	*S-duality in heterotic string theory*	07/06/94	GGR*
D Mukamel	*Symmetry breaking in one dimension driven diffusive systems*	07/06/94	CAG
S Hawking	*Pair creation and annihilation of black holes*	07/06/94	GGR*
G Horowitz	*Pair creation of large black holes*	07/06/94	GGR*
J Lebowitz	*Asymptotic behavior of densities and spatial structure in diffusion limited two particle reactions*	08/06/94	CAG
M Eastwood	*Holomorphic realisations of representations*	08/06/94	GGR*
S De Alwis	*Time and black holes*	08/06/94	GGR*
M Singer	*A "period mapping" for four-dimensional conformal manifolds*	08/06/94	GGR*
P Tod	*Some solutions of the Boyer-Finley equation*	09/06/94	GGR*
S Merkulov	*Twistor theory and fundamental geometries*	09/06/94	GGR*
C LeBrun	*Anti-self-dual manifolds and Kähler geometry*	09/06/94	GGR*
L Susskind	*Strings, horizons and complementarity*	09/06/94	GGR*
R Horan	*A vanishing theorem for quaternionic-Kähler manifolds*	09/06/94	GGR*
R Ward	*Numerical twistors*	10/06/94	GGR*
L Mason	*Self-duality in split signature and the inverse scattering transform*	10/06/94	GGR*
T Bailey	*A CR Penrose transform*	10/06/94	GGR*
R Penrose	*Twistors for vacuum spacetimes*	13/06/94	GGR*
L Mason	*Further remarks on twistors for vacuum spacetimes*	13/06/94	GGR*
L Hughston	*Quantum measurement and stochastic differential geometry*	13/06/94	GGR*
N Woodhouse	*Twistor theory of the Painlevé equations*	13/06/94	GGR*
C LeBrun	*Quaternionic-Kähler manifolds*	14/06/94	GGR*
A Hodges	*Twistor diagrams*	14/06/94	GGR*
R Dickman	*Critical phenomena at the edge of extinction*	14/06/94	CAG
M Eastwood	*Twistor theory and the X-ray transform*	14/06/94	GGR*
M Singer	*Non-integral hyperbolic monopoles*	14/06/94	GGR*
M Banados	*Central charges in the canonical realization of asymptotic symmetries in non-abelian Chern-Simons theory*	15/06/94	GGR*
I Barashenkov	*Topological Chern-Simons vortices from the constrained Hamiltonian formalism*	15/06/94	GGR*
G Clément	*Classical solutions of gravitating Chern-Simons electrodynamics*	15/06/94	GGR*
D Tchrakian	*Exponentially localised instantons*	15/06/94	GGR*
J Figueroa-O'Farrill	*Homological obstructions to gauging sigma models*	15/06/94	GGR*
G Papadopoulos	*Solitons and the geometry of massive sigma models*	15/06/94	GGR*
C Fosco	*Canonical structure of the nonlinear sigma model in a polynomial formulation*	15/06/94	GGR*
A Ashtekar	*A manifestly gauge-invariant approach to quantum gauge theories*	16/06/94	GGR*

J Mouraô	*Integration theory on the space of connections modulo gauge transformations: projective techniques*	16/06/94	GGR*
L Garay	*Path integration in Ashtekar variables*	16/06/94	GGR*
J Pons	*Evolutionary laws, initial conditions and gauge fixing in constrained systems*	16/06/94	GGR*
G Fischer	*Light-cone formulation of gauge theories*	16/06/94	GGR*
L Lusanna	*Hamiltonian constraints and Dirac's observables: from relativistic particles towards field theory and general relativity*	16/06/94	GGR*
R De Pietri	*Gauging kinematical and internal symmetry groups for extended system: the Galilean one-time and two-times harmonic oscillator*	16/06/94	GGR*
G Longhi	*On the harmonic interaction of three relativistic point particles*	16/06/94	GGR*
O Coussaert	*Symmetry of the (2+1) dimensional black holes*	16/06/94	GGR*
H Kastrup	*Spherically symmetric gravity as a completely integrable constrained system*	16/06/94	GGR*
N Manojlović	*Quantization of the gravitational solitons*	16/06/94	GGR*
M Talon	*The R-matrix of the Calogero model*	17/06/94	GGR*
G Rybkin	*Batalin-Fradkin-Vilkovisky approach for gauge-invariant systems with closed algebra*	17/06/94	GGR*
J Gomis	*Anomalies, WZ terms and field-antifield formalism*	17/06/94	GGR*
J Barbour	*Time and the interpretation of the Hamiltonian constraint in canonical gravity*	17/06/94	GGR*
J Greensite	*Transfer matrix quantization of general relativity, and the problem of time*	17/06/94	GGR*
J Roca	*W-symmetry and the rigid particle*	17/06/94	GGR*
V Nesterenko	*Pure geometrical treatment of singular Lagrangians with higher derivatives*	17/06/94	GGR*
M Plyushchay	*Dirac versus reduced phase space quantization for systems having no gauge conditions*	17/06/94	GGR*
R Tucker	*Classical and quantum aspects of degenerate metric fields*	17/06/94	GGR*
A McKane	*Transition rates and stationary probability distributions in systems without detailed balance*	17/06/94	CAG
F Brandt	*BRS-cohomology in two and higher dimensional gravitational theories*	17/06/94	GGR*
J Nelson	*Quantisation of $(2+1)$ dimensional gravity for $g=1$ and $g=2$*	17/06/94	GGR*
P Tuckey	*Geometry of time-dependent constraints*	18/06/94	GGR*
M Henneaux	*New results on local BRST cohomology in gravity*	18/06/94	GGR*
H Müller-Kirsten	*Collective coordinates and BRST transformations*	18/06/94	GGR*
D Sorokin	*Geometry of fermionic constraints in superstring theories*	18/06/94	GGR*
L Dolan	*BRST and new superstring states*	18/06/94	GGR*
S Lyakhovich	*Second class constraint problem in the framework of Hamiltonian BRST theory*	18/06/94	GGR*
J Krug	*Statistical mechanics of growth processes I: scale invariance from competitive growth*	20/06/94	CAG*
V Hakim	*Shape and dynamics of Laplacian growth I: physical examples, simple shapes and selection by capillary effects*	20/06/94	CAG*
B Chopard	*Cellular automata modelling of pattern formation I: introduction, modelling of physical systems, examples*	20/06/94	CAG*

9.6 Seminars and Lectures July 1993 – June 1994

G Grinstein	*Generic scale invariance and self-organised criticality I: introduction to generic scale invariance*	20/06/94	CAG*
J Krug	*Statistical mechanics of growth processes II: kinetic roughening I: fundamentals*	21/06/94	CAG*
B Chopard	*Cellular automata modelling of pattern formation II: from micro- to macroscopic: the FHP model of a fluid*	21/06/94	CAG*
G Grinstein	*Generic scale invariance and self-organized criticality II: models of self-organised criticality*	21/06/94	CAG*
M Siegert	*Non-equilibrium ordering dynamics and pattern formation I: modern theories of phase ordering*	21/06/94	CAG*
J Krug	*Statistical mechanics of growth processes III: kinetic roughening II: aspects of KPZ theory*	22/06/94	CAG*
B Chopard	*Cellular automata modelling of pattern formation III: from micro- to macroscopic: $A + B \rightarrow 0$ reaction-diffusion process*	22/06/94	CAG*
A Strominger	*A possible resolution of the black hole information puzzle*	22/06/94	GGR
G Grinstein	*Generic scale invariance and self-organized criticality III: experimental tests of self-organised criticality*	22/06/94	CAG*
B Chopard	*Cellular automata modelling of pattern formation IV: growth processes in reaction-diffusion systems, Liesegang patterns*	22/06/94	CAG*
J Krug	*Statistical mechanics of growth processes IV: turbulence and interfaces*	23/06/94	CAG*
V Hakim	*Shape and dynamics of Laplacian growth II: dynamics in two dimensions and conformal mapping*	23/06/94	CAG*
J Rajchenbach	*Recent experimental results on granular media I: general features of granular systems*	23/06/94	CAG*
M Siegert	*Non-equilibrium ordering dynamics and pattern formation II: numerical simulations of phase ordering*	23/06/94	CAG*
K Sneppen	*Minimal SOC: intermittent dynamics of interfaces and evolution*	24/06/94	CAG*
V Hakim	*Shape and dynamics of Laplacian growth III: fractal growth and stochastic models*	24/06/94	CAG*
J Rajchenbach	*Recent experimental results on granular media II: experiments in two-dimensional granular systems*	24/06/94	CAG*
R Zia	*Statistical mechanics of driven diffusive systems I: critical and generic singularities in a driven Ising lattice gas*	24/06/94	CAG*
M Kardar	*Fluctuating lines: randomness, depinning and non-equilibrium effects I: anisotropy and depinning of a line in two dimensions*	25/06/94	CAG*
D Wolf	*Computer simulation of driven systems I: submonolayer morphology in molecular beam epitaxy*	25/06/94	CAG*
R Zia	*Statistical mechanics of driven systems II: phase transitions in variants of the Katz-Lebowitz-Spohn model*	25/06/94	CAG*
L Sander	*Pattern and scaling in the growth of thin films*	25/06/94	CAG*
Y Couder	*Experiments on pattern formation: from stable fronts to fractal structures I*	27/06/94	CAG*
M Kardar	*Fluctuating lines: randomness, depinning and non-equilibrium effects II: anisotropy and depinning of a line in three dimensions*	27/06/94	CAG*
N Hitchin	*Monopole and instanton moduli spaces*	27/06/94	GGR
S Edwards	*Field theories for deposition*	27/06/94	CAG*

M Siegert	*Non-equilibrium ordering dynamics and pattern formation III: pattern formation in molecular beam epitaxy*	27/06/94	CAG*
Y Couder	*Experiments on pattern formation: from stable fronts to fractal structures II*	28/06/94	CAG*
D Wolf	*Computer simulation of driven systems II: correlations in layer-by-layer growth*	28/06/94	CAG*
J Rajchenbach	*Recent experimental results on granular media III: segregation*	28/06/94	CAG*
D Wolf	*Computer simulations of driven systems III: modelling of granular materials*	28/06/94	CAG*
Y Couder	*Experiments in pattern formation: from stable fronts to fractal structures III*	29/06/94	CAG*
M Kardar	*Fluctuating lines: randomness, depinning and non-equilibrium effects III: nonlinear dynamics of a moving flux line*	29/06/94	CAG*
H Flyvbjerg	*A very simple self-organized critical system*	29/06/94	CAG*
I Jánosi	*Population dynamics of coupled map lattices*	29/06/94	CAG*
D Wolf	*Computer simulation of driven systems IV: heap formation and segregation*	30/06/94	CAG*
M Kardar	*Fluctuating lines: randomness, depinning and non-equilibrium effects IV: nonlinear relaxation of drifting polymers*	30/06/94	CAG*

'CVI', 'RSP', 'GGR' or 'CAG' indicate that the seminar is within the *Computer Vision*, *Random Spatial Processes*, *Geometry and Gravity* or *Cellular Automata, Aggregation and Growth* programmes; 'INS' denotes an Institute seminar. An asterisk indicates that the seminar took place within a workshop