

# DUBLIN INSTITUTE FOR ADVANCED STUDIES

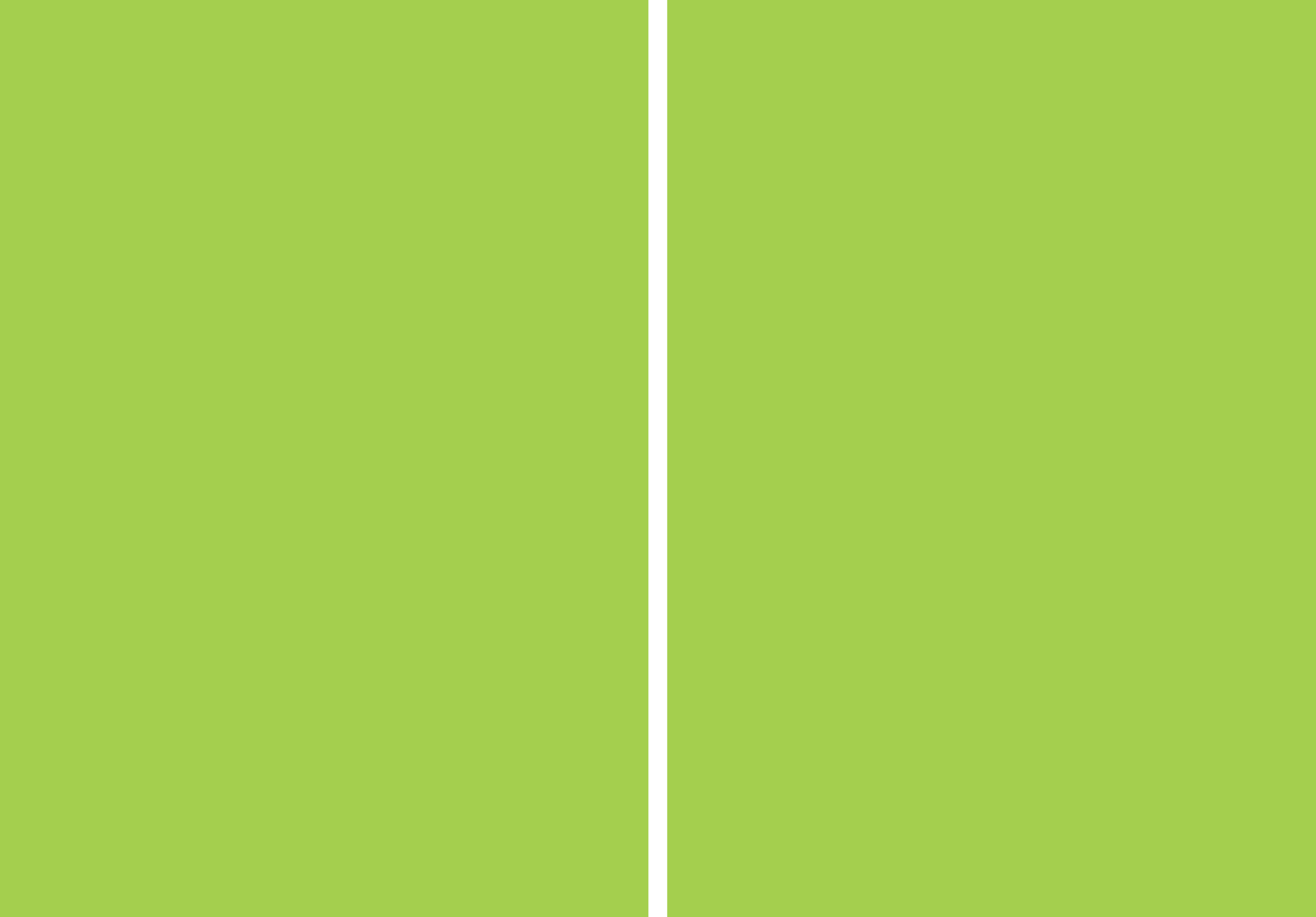
Institiúid Ard-Léinn Bhaile Átha Cliath

Research Report 2006

DUBLIN INSTITUTE FOR ADVANCED STUDIES

RESEARCH REPORT 2006





# Contents

## School of Celtic Studies

<b>1 Research Work</b>	<b>XX</b>
1.1 Taighde/Research	XX
1.2 Meamram Paipéar Ríomhaire/Irish Script on Screen (ISOS)	XX
1.3 Tionscnamh Bibleagrafaíochta/Bibliography project	XX
1.4 Eagarthóireacht/Editing	XX
1.5 Foilsitheoireacht/Publishing	XX
1.6 Díolachán leabhar/Sale of books	XX
1.7 Foilseacháin/Publications	XX
1.8 Leabharlann/Library	XX
1.9 Imeachtaí/Events	XX
1.10 Léachtaí (foireann agus scoláirí)/Lectures (staff and scholars)	XX
1.11 Cúrsaí in ollscoileanna Éireannacha/Courses in Irish universities	XX
1.12 Scrúdaitheoireacht sheachtarach, srl./External examining etc.	XX
1.13 Na meáin chumarsáide agus aithne phoiblí/Media and public awareness	XX
1.14 Coistí seachtracha/Outside committees	XX
1.15 Governing Board of the School of Celtic Studies	XX
1.16 Cúairteoirí agus Comhaltáí/Visitors and Associates	XX

## School of Cosmic Physics – Astronomy and Astrophysics

<b>1. General</b>	<b>XX</b>
<b>2. Research Work</b>	<b>XX</b>
2.1 Astronomy and Astrophysics Activities	XX
2.1.1 TeV Gamma-Ray Astronomy	XX
2.1.2 Magnetic Field and Mass Modelling of DR21(OH)	XX
2.1.3 Magnetic Fields in High-Mass Star-Forming Regions	XX
2.1.4 Magnetic Fields in Low-Mass Star-Forming Regions	XX
2.1.5 Establishing the Direction of Rotation in Circumstellar Discs	XX
2.1.6 Numerical Simulations of Stellar Jets	XX
2.1.7 Development of a Parallel, Adaptive Mesh Refinement Code for MHD Simulations of Astrophysical Fluids	XX
2.1.8 Understanding the Structure of Passive Circumstellar Disks	XX
2.1.9 Study of the Properties of Dust in the Interstellar Medium	XX
2.1.10 Developing New Techniques for the Determination of Extinction Maps	XX
2.1.11 Structure and Kinematics of Shell Galaxies	XX
2.1.12 NAHUAL: a High-resolution Spectrograph for the 10.4-m Gran Telescopio Canarias	XX
2.1.13 Plasma Simulations of Relativistic Collisionless Shocks	XX



2.1.14	Earliest Stages of Star Formation	XX
2.1.15	Clustered Star Formation	XX
2.1.16	Resistive Magneto-hydrodynamic (MHD) Jet Launching Models	XX
2.1.17	Parametric Study of Jet Propagation in Young Stellar Objects (YSOs)	XX
2.1.18	Comparison of Numerical MHD Codes	XX
2.1.19	Physics of Shock Waves	XX
2.1.20	Magnetic Fields in Molecular Outflows	XX
2.1.21	Stellar X-Ray Hardness Ratios	XX
2.1.22	Blazar Monitoring	XX
2.1.23	Echelle Spectroscopy of Runaway Stars	XX
2.1.24	Simulations of Runaway Star Production	XX
2.1.25	Space Dosimetry	XX
2.1.26	Swift Satellite Observations of GRBs	XX
2.1.27	Gamma Ray Bursts: REM Telescope Observations	XX
2.1.28	K-Corrections for Various Supernova Types	XX
2.1.29	High Resolution Echelle Spectroscopy of GRB Afterglows	XX
2.1.30	High Resouion Studies of Outflow Activity in Brown Dwarfs and T Tauri Stars	XX

**3. National and International Projects ..... XX**

3.1	Irish Centre for High-End Computing	XX
3.2	The Mid-Infrared Instrument (MIRI) for the James Webb Space Telescope	XX
3.3	JETSET	XX

**4. Miscellaneous ..... XX**

4.1	Lecture Courses	XX
4.2	Public Outreach	XX
4.3	Dunsink Observatory	XX
4.4	Observatory House, Dunsink	XX
4.5	School of Cosmic Physics Seminar Series	XX

**5. Travel including External Seminars ..... XX**

**6. Publications ..... XX**

6.1	Refereed Journals	XX
6.2	Refereed Books	XX
6.3	Non-Refereed Books and Journals	XX
6.4	Electronic Circulars	XX

**School of Cosmic Physics - Geophysics**

**1. General ..... XX**

**2. General Geophysics Activities ..... XX**

2.1	CHIGI - Irish Geoscience Graduate Programme proposal	XX
2.2	TOPO-Europe/EuroArray	XX
2.3	AfricaArray	XX
2.4	Joint Inversion of Electromagnetic and Seismic Data	XX

<b>3. Electromagnetic Activities</b> .....	<b>XX</b>
3.1 SAMTEX (Southern African Magnetotelluric Experiment) .....	XX
3.2 ISLE-MT .....	XX
3.3 PICASSO .....	XX
3.4 3D MT Modelling/Inversion .....	XX
3.5 Marine EM .....	XX
3.5.1 Malin Sea Survey .....	XX
3.5.2 Galway Survey .....	XX
3.6 Other .....	XX
3.6.1 Cork EM Survey .....	XX
3.6.2 Birr Castle Resistivity Survey .....	XX
3.6.3 INDEPTH .....	XX
3.6.4 LEMI-417s .....	XX
3.6.5 Other and General .....	XX
<b>4. Seismological Activities</b> .....	<b>XX</b>
4.1 Hades (Hatton Deep Seismic) .....	XX
4.2 RAPIDS 4 (Rockall and Porcupine Irish Deep Seismic) and PIMS (Porcupine Irish Margins) .....	XX
4.3 ISLE (Irish Seismological Lithospheric Experiment) .....	XX
4.4 EAGLE (Ethiopian-Afar Geoscientific Lithospheric Experiment) .....	XX
4.5 TRIM (TOBI Rockall Irish Margins) .....	XX
4.6 Seismic Network and Irish Earthquakes .....	XX
4.6.1 DIAS Network .....	XX
4.6.2 DSB .....	XX
4.6.3 VAL .....	XX
4.6.4 NEAMTWS .....	XX
4.7 Other .....	XX
<b>5. Geodynamic Modelling</b> .....	<b>XX</b>
<b>6. Collaboration with Wider Research Community</b> .....	<b>XX</b>
6.1 Visits to other Laboratories by Section members .....	XX
6.2 Visitors to the Section .....	XX
6.3 Other Collaborative Activities by Section Members .....	XX
<b>7. Public Outreach</b> .....	<b>XX</b>
<b>8. Training Undertaken</b> .....	<b>XX</b>
<b>9. Short Courses/Workshops</b> .....	<b>XX</b>
<b>10. Miscellanea</b> .....	<b>XX</b>



# School of Theoretical Physics

<b>1 Report on Research Work.....</b>	<b>XX</b>
1.1 Work by Senior Professors and Collaborators.....	XX
1.1.1 Anderson Localisation and Nanotubes.....	XX
1.1.2 Bose-Hubbard Model with Disorder.....	XX
1.1.3 Large Deviations for Random Walks.....	XX
1.1.4 Quantum Coding.....	XX
1.1.5 Quantum Entanglement.....	XX
1.1.6 The Asymmetric Exclusion Process.....	XX
1.1.7 Bethe Ansatz.....	XX
1.1.8 Integrable Quantum Field Theories.....	XX
1.1.9 Vanishing Theorems.....	XX
1.1.10 Maya Epigraphy.....	XX
1.1.11 Fuzzy Physics.....	XX
1.1.12 Fuzzy Physics and Monte Carlo Simulations.....	XX
1.2 Independent Work by Fellows.....	XX
1.2.1 Integrable Models: Baxter-Bazhanov-Stroganov T-Model.....	XX
1.2.2 Integrable Models: Aharonov-Bohm Effect on the Poincare Disk.....	XX
1.2.3 Integrable Models: Point Interactions in One Dimension and Holonomic Quantum Fields.....	XX
1.2.4 Exactly Solvable Models of One-Dimensional Many Particle Stochastic Processes.....	XX
1.2.5 String Theory and Supersymmetric Gauge Theories.....	XX
1.2.6 Theory of Elementary Particles.....	XX
1.3 Independent Work by Research Scholars and Students.....	XX
1.3.1 The Gross-Pitaevskii Formula and Bose-Einstein Condensation.....	XX
1.3.2 Destabilization of Multi-Fuzzy Spheres at a Distance.....	XX
1.3.3 $N = 4$ Super Yang Mills.....	XX
1.3.4 Quantum Information.....	XX
1.3.5 Gravity Theories on Non-Commutative Plane.....	XX
1.3.6 Regularizing NC QFTs.....	XX
1.3.7 Fuzzy and SUSY Fuzzy Physics.....	XX
1.3.8 Collective Excitations of Non-Commutative CP1 Solitons.....	XX
1.3.9 Vector Bundles over the Non-Commutative 3-Sphere.....	XX
1.3.10 Quantum Hall Effect in Graphene and Edge Physics.....	XX
1.3.11 Quantum Information Theory.....	XX
1.3.12 Non-Commutative Vector Bundles.....	XX
1.3.13 Flag Manifolds.....	XX
1.3.14 Lie Algebras.....	XX
1.3.15 Non-Commutative Geometry.....	XX
1.3.16 Fuzzy Physics.....	XX
1.3.17 Lattice Field Theory.....	XX
1.3.18 Exact Renormalization Group.....	XX
1.3.19 Drinfeld Twist and General Relativity with Fuzzy Spaces.....	XX
1.3.20 Quantization of Flag Manifolds and their Supersymmetric Extensions.....	XX
1.3.21 Fuzzy Toric Geometries.....	XX
1.4 Work by Research Associates.....	XX
1.4.1 The Quantum Hall Effect.....	XX
1.4.2 Non-Commutative Geometry.....	XX
1.4.3 Higher Dimensional Field Theories.....	XX

<b>2 Publications</b> .....	<b>XX</b>
2.1 Communications of the Dublin Institute for Advanced Studies, Series A. ....	XX
2.2 Papers in Refereed Journals. ....	XX
2.3 Papers in Conference Proceedings. ....	XX
2.4 Theses and other Publications. ....	XX
2.5 Preprints. ....	XX
<b>3 Programme of Scholarly Events</b> .....	<b>XX</b>
3.1 Lectures Organised by The School. ....	XX
3.1.1 Seminars Organised by the Theoretical Particle Physics Group. ....	XX
3.2 Symposia, Conferences, Workshops Organised. ....	XX
<b>4 Presentations at Conferences or Seminars</b> .....	<b>XX</b>
4.1 Talks and Papers Presented. ....	
<b>5 Collaboration with the Wider Research Community</b> .....	<b>XX</b>
5.1 National. ....	XX
5.2 International. ....	XX
<b>6 Participation in Outside Committees</b> .....	<b>XX</b>
<b>7 Attendance at External Conferences, Workshops, Meetings and Lectures</b> .....	<b>XX</b>
7.1 Conferences/Workshops/Scientific Meetings Attended. ....	XX
7.2 Lectures and Organisational Meetings Attended. ....	XX
<b>8 Research Grants/External Funds Secured</b> .....	<b>XX</b>
<b>9 Honours/Awards/Special Achievements Received</b> .....	<b>XX</b>
<b>10 Public Awareness Activities</b> .....	<b>XX</b>
10.1 Public Lectures. ....	XX
10.2 Contribution to the Media. ....	XX

# School of Celtic Studies

## 1 Research Work

**Annual report of the Governing Board of the School of Celtic Studies for the year ending 31 December 2006 adopted at its meeting of 29 March 2007.**

### Staff and Scholars

Senior Professors: Liam Breatnach (Director) Fergus Kelly,

Máirtín Ó Murchú (until 12 November) Pádraig Breatnach (from 5 December)

Professors: Malachy McKenna, Pádraig Ó Macháin.

Assistant Professors: Aoibheann Nic Dhonnchadha, Michelle O Riordan (Publications Officer).

Bibliographer: Alexandre Guilarte

Dialectologist: Brian Ó Curnáin.

Bergin Fellow: Roisín McLaughlin, Clodagh Downey (from 1 August)

Scholars: Jenifer Ní Ghrádaigh, (to October) Nicholas Evans, (to October) Eoghan Ó Raghallaigh, Brent Miles, Nora White, Gordan O Riain.

Assistant Librarians: Charlotte Dillon (to October), Órla Ní Chanainn, Margaret Kelly (from November).

School Administrator: Eibhlín Nic Dhonncha

Technical Staff : ISOS: Anne Marie O'Brien,

IT support: Andrew McCarthy (part-time), Stephen McCullagh (part-time)

### 1.1 Taighde/Research

#### Dialect Studies

Brian Ó Curnáin continued his work on the Irish of Galway and Connaught, and carried out field-work in central Connemara. He continued video recording of children between the ages of three and six years who have a command of the Irish language

in Connemara. He also continued on his monograph of *The Irish of Iorras Aithneach, County Galway*, made final corrections and prepared it for publication. Malachy McKenna continued his work on *The Irish of Rann na Feirste: a phonemic study*. He completed a draft of an article entitled 'An index to the Rann na Feirste material in *The linguistic atlas and survey of Irish dialects*' for publication in *Celtica* 25, and began checking it. Máirtín Ó Murchú continued work on the Gaelic of West Perthshire.

#### Textual editions

Fergus Kelly worked on edition of a Legal Treatise attributed to Giolla na Naomh mac Aodhagáin († 1309), and on an Old Irish text on legal disputes within marriage (*Corpus Iuris Hibernici* i 144.5-150.16).

Roisín McLaughlin prepared her book entitled *Studies in Early Irish Satire* for publication. She was awarded her PhD in Early Irish from Trinity College Dublin for her Thesis entitled *A Critical Edition of Mittelirische Verslehren III*.

Visiting Professor Mark Scowcroft continued his work on an edition of the second recension of *Lebor Gabála Éirenn*. Visiting Professor Nancy Stenson worked on a series of grammar/exercise books for learning Irish, and an article on changing meanings of the verb 'faigh' in Modern Irish.

Research scholar Nora White began work on a new edition of *The Rule of Mo Chutu*.

#### Historical studies

Research scholar Jenifer Ní Ghrádaigh continued her ongoing research into the architecture of twelfth-century Clonmacnoise and its patrons, artistic connections between Ireland and Europe in the twelfth century, iconographic significance of architectural and sculptural features, and the position of the *saer* 'wright' in early Irish law.

Research scholar Nicholas Evans continued on early medieval Irish and Scottish chronicles.



Research scholar Eoghan Ó Raghallaigh continued working toward his doctorate on his thesis entitled *An edition of bardic poems from the Nugent Manuscript*. He also continued to work on the forthcoming corpus of bardic poetry for the HEA-funded Irish-Scottish Academic Initiative.

Research scholar Brent Miles began work on editions of two Middle Irish texts on the subject of classical Troy and Thebes, and he continued work on a book on classical learning in medieval Ireland, which is his principal project.

Michelle O Riordan finalised work on her book *Irish Bardic Poetry and Rhetorical Reality* and submitted it to Cork University Press for publication in 2007.

Clodagh Downey began a project to create editions and translations of the entire works of the Middle Irish poet, Cúán ua Lothcháin. She completed an edition and translation of the poem beginning '*Trí croind Éirenn oiregdha*'. She also prepared and delivered a paper on early Irish traditions relating to the birth of an important Munster ancestor figure and began work on an article on the Cycles of the Kings for a collection of essays on the History of Irish Manuscript Literature.

### Cataloguing of manuscripts

Pádraig Ó Macháin began work on correcting and preparing for publication William Mahon's catalogue of Irish Manuscripts in Villanova University, Pennsylvania. Aoibheann Nic Dhonnchadha carried out research on Early Modern Irish medical manuscripts.

### 1.2 Meamram Paipéar Ríomhaire/Irish Script on Screen (ISOS)

The Irish Script on Screen project completed work on the 14th century manuscript in the Royal Irish Academy, in January and July/August. Work also began, at the request of the Academy, on a trial digitisation of the Domhnach Airgid manuscript. The ISOS website is now averaging 2 million visits per annum, and 800,000 requests for pages per annum. On 7th October, ISOS organised and hosted a seminar by Dr Peter Robinson of the Institute for Textual Scholarship and Electronic Editing, University of Birmingham. The seminar discussed the subject of electronic editions of texts, and the future of mass digitisation. The attendance, which numbered sixty, was drawn mainly from the scholarly and archival communities.

### 1.3 Tionscnamh Bibleagrafaíochta/ Bibliography project

Alexandre Guilarte continued work leading to the completion of the fourth volume of the bibliography. During this year the aim has been to adapt the style and terminology of the bibliography to the criteria that will be observed henceforth, and to advance towards the clearing of the thirty-year backlog of scientific literature, focusing primarily on periodical academic publications. Coinciding with this year's Tionól, an up-to-date version of BILL IV has been published on the School of Celtic Studies website – [www.celt.dias.ie](http://www.celt.dias.ie)

### 1.4 Eagarthóireacht/Editing

Fergus Kelly: Co-editor of *Celtica* 25. He carried out editorial work on Alexander Falileyev, *Welsh Walter of Henley*, and on Díaz y Díaz, *De Ordine Creaturarum*.

Malachy McKenna: Co-editor of *Celtica* 25.

Liam Breatnach: Co-editor of *Ériu* 56. He carried out editorial work on Elmar Ternes, *The Phonemic Analysis of Scottish Gaelic*.

Aoibheann Nic Dhonnchadha: (with Pádraig Ó Macháin), *An Linn Bhui: Iris Ghaeltacht na nDéise* imleabhar 10.

Michelle O Riordan: Arranged for reprinting School of Celtic Studies publications.

Pádraig Ó Macháin: Completed editorial work on William Mahon, *Catalogue of Irish manuscripts in Villanova University, Pennsylvania*. Co-editor of *An Linn Bhui: Iris Ghaeltacht na nDéise* imleabhar 10. He edited *Ossory, Laois and Leinster* Volume 2.

Roisín McLaughlin continued working on editions of *Mittelirische Verslehren III* and *In Lebor Ollaman*. Studies in Early Irish Satire is due for publication in 2007.

Clodagh Downey completed edition and translation of poem beginning '*Trí croind Éirenn oiregdha*'. Transcribed and collated poem beginning '*A fhir áin iadas in tech*' from eleven manuscripts.

### 1.5 Foilsitheoireacht/Publishing

As one of its statutory functions, in addition to research and publication by its own staff, the School provides for the assessment, editing, and publishing of books and papers by outside scholars. The following books were published in 2006:

Elmar Ternes, *The Phonemic Analysis of Scottish Gaelic*, xvi + 167 pp. ISBN 1 85500 206 X.



Alexander Falileyev, *Welsh Walter of Henley*, Medieval and Modern Welsh Series volume xii, xci + 225 pp. ISBN 1 85500 183 7.

### Reprints

The following reprints were seen through the press by the School's Publications Officer, Michelle O Riordan:

Cecile O'Rahilly (ed.), *Tain Bó Cúailnge: Recension 1*. (F 2.13)

Wolfgang Meid (ed.), *Táin Bó Fraich* (F 5.22)

D. Simon Evans *A Grammar of Middle Welsh* (H 2.0)

Seán Mac Airt (ed.), *The Annals of Inisfallen* (G 5)

### 1.6 Díolachán leabhar/Sale of books

Promotion of publications was effected by the School Administrator, Eibhlín Nic Dhonncha, through advertising in *Books Ireland*, *National Concert Hall Annual Brochure*, *Comhar*, *Saol*, *Foinse*, *Books Ireland*, *Lá*, *Conradh na Gaeilge: Clár Seachtain na Gaeilge*, *An tOireachtas: Clár na Féile*, *Lámhleabhar An Choláiste Ollscoile*, *Baile Átha Cliath*, *Library News*, and various articles in national and international newspapers. Also publication catalogue distributed at various Book Fairs in Ireland and abroad.

### 1.7 Foilseacháin/Publications

Liam Breatnach: 'Satire, Praise and the Early Irish Poet', *Ériu* 56 (2006) 63-84.

Clodagh Downey: 'Trí croind Éirenn oiregdha' to appear in *Éigse*.

Nicholas Evans: Entries on 'Legendary history, Pictish', 'Legendary history, Scottish Gaelic', 'Scottish king-lists', 'The Chronicle of the Kings of Alba', 'Bridei son of Maelchon', 'Bridei son of Billi', in *Celtic culture: a historical encyclopedia*, ed. John T. Koch, ABC-CLIO Inc., Santa Barbara, California.

Fergus Kelly: 'Audacht Morainn', 'Senchas Már', 'Triads of Ireland', 'Wisdom literature, Irish', in *Celtic culture: a historical encyclopedia*, ed. John T. Koch, ABC-CLIO Inc., Santa Barbara, California.

Jenifer Ní Ghrádaigh: 'My dear Pickwick' – James Graves' early sketchbooks and his development as an antiquarian', in *Ossory, Laois and Leinster 2* (2006) pp. 96-122. 'Scattery Island's forgotten Romanesque', *Archaeology Ireland*, Vol. 20 No. 4 (Winter 2006) pp.26-30. 'A legal perspective on the saer and workshop practice in pre-Norman Ireland', in R. Moss, ed., *Proceedings of the 5th International Conference of Insular Art* [forthcoming]. 'Locked up, locked in, always looking for doorways', in *Lost and Found*, vol. 2, ed. J. Fenwick [forthcoming].

Aoibheann Nic Dhonnchadha: 'The medical school of Aghmacart, Queen's County' *Ossory Laois and Leinster 2* (2006) pp. 11-43

Pádraig Ó Macháin: 'Seanmóintí Déiseacha san *Irisleabhar*', *An Linn Bhuí* 10 (2006) 141-50. 'General Sherman and Fr Shearman', *Ossory, Laois and Leinster 2* (2006) 218-22. 'Scribal practice and textual survival: the example of Uilliam Mac Mhurchaidh', *Scottish Gaelic Studies* 22 (2006) 95-122. Book Reviews in *Éigse* 35 (2005 – [published 2006]) 159-68.

Brent Miles: 'Irish evidence for shared sources of classical mythology in Anglo-Saxon England and medieval Ireland', in *Insignis Sophiae Arcator. Essays in Honour of Michael W. Herren on his 65th Birthday*, ed. G.R. Wieland, C. Ruff and R.G. Arthur (Turnhout, 2006).

Eoghan Ó Raghallaigh: 'A poem to Aodh Buidhe and Alasdair Mac Domhnaill of Tinnakill, Queen's County' in *Ossory, Laois and Leinster, 2* (2006).

Michelle O Riordan: 'Ireland 1600-1800', forthcoming in *Palgrave History of Ireland* (expected in 2007).

Nora White: 'Compert Mongáin and three other early Mongán tales' *Maynooth Medieval Irish Texts series*, Vol. 5 (2006)

### 1.8 Leabharlann/Library

There were over 180 acquisitions of core titles in Celtic Studies, including monographs, research reports, festschrifts and conference proceedings. Additional publications were supplied through long-established standing orders. The library appreciates the Institute's publications exchange partners and is grateful for the various books received from generous donors.

The library added one new title to its journals list, which now exceeds 130 current titles. *The Journal of the Australian Early Medieval Association* was the latest title added to the collection.

Staff borrowed over 250 books from the library. Through the inter-library loan service a further 79 monograph titles and 17 serial articles were supplied to staff. The library made its facilities available to 53 recorded external visitors from Ireland and abroad including visitors from Finland, Belgium, Wales, Czech Republic, United States of America, Greece and Austria. Bibliographic and information requests were answered by library staff, in person, via correspondence and over the telephone. Further progress was made in the current and retrospective cataloguing of the collection.

## 1.9 Imeachtaí/Events

### Statutory Public Lecture

This year's Statutory Public Lecture was delivered by Professor Professor Pádraig Ó Riain, National University of Ireland, Cork. The title of the lecture was 'The Book of Glendalough: A Continuing Investigation. It was delivered as part of the Tionól 2006, in The National University of Ireland, Belfield, Dublin on Friday 17th November to a large audience (circa 110).

### Other Lectures

On Thursday 6th April the School of Celtic Studies hosted the Myles Dillon Memorial Lecture. The lecture, 'Linguistic connections between India and Ireland', was given by Dr. Jürgen Uhlich, of Trinity College, Dublin to a large audience (circa 130, calculated on the basis of the number of handouts distributed).

On Saturday 7th October the School of Celtic Studies hosted a one day Digital Seminar on matters relating to digital editions and textual scholarship. The seminar was conducted by Dr Peter Robinson from the Institute for Textual Scholarship and Electronic Editing, University of Birmingham, in England.

### Tionól 2006

The School's annual conference, Tionól 2006, was organised by Professor Pádraig Ó Macháin, assisted by Eibhlín Nic Dhonncha, and took place on the 17th and 18th November. Over the two days, a total of eighteen papers were delivered by scholars representing ten institutions. The attendance at sessions of the Tionól reached ninety persons.

The following is a list of speakers and papers:

Sharon Arbuthnot (University of Cambridge) 'Medieval Etymology: Knives, Scone and Skene.'

Jacopo Bisagni (NUI Galway) 'The earliest manuscripts of *Amrae Coluimb Chille*.'

Peter McQuillan (University of Notre Dame) '*Suairc* and *Duairc* part 2: the eighteenth century.'

Immo Warntjes (NUI Galway) 'A newly discovered Irish computus containing Old Irish terminology.'

Máirín Ní Dhonnchadha (NUI Galway) 'The identity of the speaker and the author of *Aithbe damsá bés mora*.'

Brent Miles (School of Celtic Studies) 'Text, Commentary, Play: identifying learned imitation in Irish heroic saga.'

Richard Glyn Roberts (NUI, Dublin) '*Madwaith Hen Gyrys o Iâl*: the sources of the Medieval Welsh proverb collections.'

Paul Russell (University of Cambridge) 'Fragments of early Irish glossaries: an introduction to the Early Irish Glossary Project (EIGP) and Database (EIGD).'

Mícheál Ó Flaithearta (University of Utrecht) 'Sanasaíocht an fhocail *sionnach* "fox".'

Tadhg Ó Dúshláine (NUI Maynooth) 'Critique Uí Chorcóra ar chonclúid *Chaoine Airt Uí Laoire*.'

Caoimhín Breatnach (NUI, Dublin) 'The composition of the *Liber flavus Fergusiorum*.'

Brian Ó Dálaigh (NUI Maynooth) 'Mícheál Coimín: Jacobite, Protestant and Gaelic poet.'

Pádraic Moran (NUI Galway) 'The pronunciation of Greek in early medieval Ireland'

G.R. Isaac (NUI Galway) 'The name of Ireland in Irish and Welsh.'

Karen Jankulak (University of Wales, Lampeter) 'Adjacent saints' dedications between Cornwall and Brittany.'

Julianne Nyhan (NUI Cork) 'Establishing the relative sophistication of the ordering systems used in the major glossaries of Medieval Ireland.'

Eoin Mac Cárthaigh (Trinity College, Dublin) 'Does *binne* rhyme with *file*?'

Gerald Manning (NUI, Galway) 'On the treatment of the poets and ecclesiastics in *Míadshlechteae*.'

### Seminars

Liam Breatnach held a weekly seminar on a Middle Irish poem on Scandinavian Dublin, as well as a seminar on early Irish law.

Roisín McLaughlin gave a weekly seminar on *Mittelirische Verslehren III*.

### 1.10 Léachtaí (foireann agus scoláirí)/ Lectures (staff and scholars)

Liam Breatnach: 'Poets and Their Poetry in Early Mediaeval Ireland', Centre of Medieval Studies, University of Utrecht; October 2006.

'A Text on Ecclesiastical Succession', Comhdháil Lae ar Léann na Gaeilge 3/Irish Studies One-Day Conference 3. Léann Lámhscríbhinní Loháin/ The Louvain Manuscript Heritage, UCD; December 2006.

Clodagh Downey: 'Some challenges to reading and editing medieval Irish poetry', The Challenges of Manuscript-based Research Workshop, NUI, Cork; September.

'Purple reign – the naming of Conall Corc', VIII Symposium of Societas Celtologica Nordica, Helsinki; September. 'Cúán ua Lothcháin and the transmission of early Irish history' Mícheál Ó Cléirigh Institute for the Study of Irish History and Civilisation, University College Dublin; October.

Nicholas Evans: 'The calculation of Columba's arrival in Britain in Bede's *Ecclesiastical History* and the Pictish king-lists', Conference of Irish Medievalists, Kilkenny; June. 'Ideology, literacy, and matriliney: approaches to Medieval texts of the Pictish past', International Medieval Congress, Leeds; July.

Fergus Kelly: 'The early Irish law of evidence', Centre for Advanced Welsh and Celtic Studies, University of Wales, Aberystwyth; February. 'Legal disputes within marriage', Jesus College, Oxford; February. 'An Introduction to Brehon law', Law Society of Ireland, Blackhall Place; May. 'Early Irish land-law' Law Society of Ireland, Blackhall Place; May. 'Litigation in early Irish law' Law Society of Ireland, Blackhall Place; May. 'Brehon law in modern times: conclusion' Law Society of Ireland, Blackhall Place; June. 'An overview of current progress in early Irish legal studies', School of Law, National University of Ireland, Dublin; November.

Brent Miles: 'Text, commentary, play: identifying learned imitation in Irish heroic saga' Tionól, School of Celtic Studies; November.

Malachy McKenna: 'The structure of Modern Irish; sentences and sounds', Congress on the Celtic Languages, Ulster Folk Museum; November.

Jenifer Ní Ghrádaigh: 'From new orders to new order: religion, politics and the Anglo-Norman invasion' Hunt Museum Liberal Arts Course; February. 'Politics, Patronage and Workshop: Analyzing Romanesque Clonmacnoise' UCLA Celtic Colloquium

Seminar; May. 'Devenish round tower: a depiction of the evangelists in twelfth-century Ireland?' VIII Symposium of Societas Celtologica Nordica, Helsinki; September.

Aoibheann Nic Dhonnchadha: 'Winifred Wulff (1895-1946): Beatha agus Saothar' Léachtaí Cholm Cille, Ollscoil na hÉireann, Maigh Nuad; April.

Brian Ó Curnáin: 'The linguistic sociology of Irish' Comhdháil Teangeolaíocht na Gaeilge X' Glasgow University; 'Locality and orality; sociolinguistics, geolinguistics and higher register' Orality and Text in the Gaelic World Colloquium, Edinburgh University, Scotland.

Pádraig Ó Macháin: 'Ireland's manuscript heritage', Abbeyleix; June. 'Digitising Irish manuscripts' National University of Ireland, Cork; September. 'Scríobhaithe, eagarthóirí agus malairtí mallaithe' Ollscoil na hÉireann, Corcaigh; Meán Fómhair. 'Litriocht Ghaelach na nDéise sa 19ú haois', Tionól an Fhómhair, Dungarvan; September. 'The iconography of exile; Fearghal Óg Mac an Bhaird in Louvain', Irish Studies One-Day Conference (The Louvain Manuscript Heritage) National University of Ireland, Dublin; December.

### 1.11 Cúrsaí in ollscoileanna Éireannacha/ Courses in Irish universities

Nicholas Evans tutored first-year History at National University of Ireland, Dublin.

Fergus Kelly gave a weekly lecture on 'Early Irish law', to second and third year students, School of Irish, Trinity College Dublin (Hilary term).

Malachy McKenna gave two courses i Scoil na Gaeilge, Trinity College Dublin: 'Canúintí na Nua-Ghaeilge' and 'Gaeilge Uladh'.

Jenifer Ní Ghrádaigh gave a ten week course for 3rd and 4th year students in the National College of Art and Design, Dublin: The Politics of the past in Irish Art, c.1750-1916.

Eoghan Ó Raghallaigh gave a course on Palaeography to 4th year undergraduates in Roinn na Gaeilge, Trinity College, Dublin.

Michelle O Riordan gave a MA Seminar Course: *Bardic poetry* in the National University of Ireland Galway. She also gave a Faculty and Students seminar on *Bardic poetry* in the National University of Ireland Galway.

### 1.12 Scrúdaitheoireacht sheachtarach, srl./ External examining etc.

Liam Breatnach: External examiner, Department of Old and Middle Irish, NUI Maynooth. External assessor for Trinity College, Cambridge, and in the Department of Celtic Languages and Culture, University of Utrecht.

Fergus Kelly: external examiner, Department of Celtic languages and literatures, Harvard University (PhD thesis); School of Irish, Trinity College Dublin (PhD thesis); External referee, Faculty of Historical and Cultural Studies (Celtic Archaeology), University of Vienna (Habilitationsschrift thesis)

### 1.13 Na meáin chumarsáide agus aithne phoiblí/ Media and public awareness

#### Website of the School of Celtic Studies

The school of Celtic Studies website ([www.scs.dias.ie](http://www.scs.dias.ie)) continued to develop under the direction of Professor Pádraig Ó Macháin and Andrew McCarthy.

#### Television and radio

Pádraig Ó Macháin took part in various interviews throughout the year on Raidió Teilifís Éireann and Raidió na Gaeltachta. He also performed book launches in Waterford (February) and Johnstown, Co. Kilkenny (August).

### 1.14 Coistí seachtracha/Outside committees

Jenifer Ní Ghrádaigh: Honorary General Secretary of the Royal Society of Antiquaries of Ireland.

Michelle O Riordan: Member of the Ralahine Utopian Studies Workshop UCL; Medieval Society and a member of the Cork Historical and Archaeological Society.

Aoibheann Nic Dhonnchadha: Ball de Choiste Náisiúnta Léann na Gaeilge, Acadamh Ríoga na hÉireann. Member of An Coiste Leabharlainne, Coláiste na Rinne, Rinn Ó gCuanach, Dún Garbhán. Advisor to manuscript project in outside academic Institutions. Advisor to Dr Laura Nuvoloni, Department of Mss, British Library, compiler of new catalogue description of BL Ms. Harl. 546 (16th cent. medical manuscript).

### 1.15 Governing Board of the School of Celtic Studies

Professor Anders Ahlqvist (Chairman)  
Professor Angela Bourke  
Professor Máire Herbert  
Professor Liam Mac Mathúna

Professor Dónall Ó Baoill  
Dr Nollaig Ó Muraíle  
Professor Ruairí Ó hUiginn  
Dr Katharine Simms  
Professor Liam Breatnach  
Professor Fergus Kelly  
Professor Máirtín Ó Murchú (until November)  
Professor Pádraig Breatnach (from December)

The Board met four times in 2006: 9 March, 17 May, 17 August and 16 November.

### 1.16 Cuairteoirí agus Comhaltaí/ Visitors and Associates

#### Visiting Professors

Professor Eric Hamp (University of Chicago)  
Professor Mark Scowcroft (Catholic University of America)  
Professor Nancy Stenson (University of Minnesota, USA)  
Professor Markku Filppula (University of Joensuu, Finland)  
Professor Neil McLeod (Murdoch University, Western Australia)  
Professor James McCloskey (University of California, Santa Cruz)  
Professor Melita Cataldi (University of Turin, Italy)  
Professor Erich Poppe (Philipps University, Hamburg, Germany)  
Professor Tomás Ó Cathasaigh (Harvard University, USA)  
Professor Johani Klemola (University of Tampere, Finland)  
Professor Elmar Ternes (University of Hamburg)

#### Research Associates

Dr Gwenllian Awbery, University of Wales, Cardiff (1990)  
Dr John Carey, National University of Ireland, Cork (1990)  
Professor Thomas Charles-Edwards, University of Oxford (1990)  
Professor Toshio Doi, Nagoya Women's University (1991)  
Professor David N. Dumville, University of Aberdeen (1989)  
Professor D. Ellis Evans, University of Oxford (1990)  
Professor William Gillies, University of Edinburgh (1989)



Professor Geraint Gruffydd, Centre for Advanced Welsh and Celtic Studies, Aberystwyth (1989)

Professor Eric P. Hamp, University of Chicago (1989)

Dr Anthony Harvey, Royal Irish Academy (2004)

Professor Michael Lapidge, University of Cambridge (1988)

Professor Donald MacAulay, University of Glasgow (1989)

Professor James McCloskey, University of California, Santa Cruz (2004)

Professor Toshitsugu Matsuoka, Hosei University, Tokyo (1991)

Dr Martin McNamara, MSC, Milltown Institute of Theology and Philosophy (1989)

An tOllamh Tomás Ó Con Cheanainn, Ollscoil na hÉireann, Baile Átha Cliath (1991)

An tOllamh Donnchadh Ó Corráin, Coláiste na hOllscoile, Corcaigh (1991)

An tOllamh Ruairí Ó hUiginn, Ollscoil na hÉireann, Má Nuad (1999)

Professor Pádraig Ó Néill, The University of North Carolina at Chapel Hill (1990)

Dr Brynley F. Roberts, National Library of Wales, Aberystwyth (1990)

Professor R. Mark Scowcroft, Catholic University of America (1990)

Professor Richard Sharpe, University of Oxford (1988)

Professor Robert L. Thomson, University of Leeds (1991)

Professor Calvert Watkins, Harvard University (1990)

Professor Morfydd Owen, Centre for Advanced Celtic and Welsh Studies (2003)

Dr Tom O'Loughlin, University of Wales, Lampeter (2003)

Dr Thomas O'Loughlin (University of Wales, Lampeter)

Jonathan Wooding (University of Wales, Lampeter)

Dr Jacqueline Borsje (University of Utrecht, The Netherlands)

Father Chrysostom (Koutloumous Monastery, Greece)

Karen Jankulak (University of Wales, Lampeter)

Sharon Arbuthnot (Cambridge University)

Micheál Ó Flaitheartaigh (University of Uppsala)

Paul Russell (Cambridge University)

Peter McQuillan (University of Notre Dame)

### Scoláirí Cuairte / Visiting Scholars

Overseas scholars (apart from those listed above under Visiting Professors) who availed of library and research facilities are included in the following list. In addition to these, the School accords library and research facilities to Irish-based scholars when it holds materials which are lacking in the scholars' own institutions and in the major libraries in Dublin.

# School of Cosmic Physics – Astronomy and Astrophysics

## 1. General

### Personnel

Celine Combet, Agueda Gras-Velazquez, and Gareth Murphy successfully defended their PhD theses in the area of star formation. Drs Fabio de Colle and Jose Gracia took up their posts as JETSET postdoctoral fellows. Dr. Dirk Froebrich left at the end of October after appointment as a lecturer in the star formation group in the University of Kent. Professor Felix Aharonian joined the permanent staff of the Astronomy and Astrophysics Section from the Max Planck Institute for Nuclear Physics in Heidelberg.

## 2. Astronomy and Astrophysics Research Activities

### TeV Gamma-Ray Astronomy

*F. Aharonian and L. Drury*

The HESS system of imaging atmospheric telescopes continued to have a very successful year with a large number of new results reported. Among the highlights were the publication of detailed observations of a second well-resolved shell-type supernova remnant, the so-called “Vela junior” remnant RXJ0852.0-4622. While in many respects (brightness, spectrum etc) very similar to the remnant RXJ1713-3946 studied earlier there are also interesting differences. In particular the morphology of Vela junior indicates that the emission comes from a rather thin spherical shell with thickness less than 10% of the radius, whereas in RXJ1713-3946 the emission region is considerably more extended radially. It is tempting to relate this to different evolutionary stages of the two objects. Other highlights were the detection of diffuse emission from the Galactic centre ridge region, rapid time-variability in the flaring emission of an extra-galactic blazar, many detections of pulsar wind nebulae, strong 3.9 day orbital modulation in the emission of the Galactic micro-quasar LS5039 and a surprisingly tight limit on the amount of extra-galactic infra-red background light.

### Magnetic Field and Mass Modelling of DR21(OH)

*R. L. Curran, J. L. Collett (University of Hertfordshire),  
J. W. Atkinson (UH), and A. Chrysostomou (UH)*

The plane-of-the-sky magnetic field of the massive star-forming region DR21(OH) has been observed using submillimetre imaging polarimetry. The polarimetry indicates an ordered field, which has an East-West direction. There is a decrease in polarisation with increasing total intensity, consistent with either the field becoming tangled within the core, or the dust grains becoming less well aligned to the magnetic field. Naïve Chandrasekhar & Fermi field strength estimates lead to an estimated plane-of-the-sky strength of  $\sim 1$  mG across the ridge of gas and dust to the North of the main core. The mass-to-flux ratio for a cylindrical model was analysed, and it was found that there is no critical limit, meaning that filaments cannot collapse without limit, irrespective of the strengths of gravity and the initial magnetic field. Mass modelling in the form of Bonner-Ebert (BE) spheres and Penston-Larson (PL) infall models has been carried out – whilst it has been proved that BE spheres do not represent a good way of establishing the static/dynamic nature of a core, they are, along with the PL infall models, very useful as a means of characterising the cores in a way that is both useful to the observational and theoretical communities.

### Magnetic Fields in High-Mass Star-Forming Regions

*R. L. Curran & A. Chrysostomou (University of Hertfordshire)*

The process of high-mass star formation is not nearly as well understood as that of low-mass stars. Recently, the favoured method of high-mass star formation has been a ‘scaled-up’ version of the low-mass process (rather than the coalescence of low-mass stars). The magnetic field plays an important role in this process, providing (it is thought) support to the cloud initially, then, once the support begins to fail, allowing collapse, the magnetic field is also responsible for driving and collimating the jets and outflows, thus removing the excess angular momentum. This is currently the largest sample of high-mass star-forming regions observed using submillimetre-imaging polarimetry. This



method traces the plane-of-the-sky magnetic field morphology throughout these regions. Analysis of this sample reveals that there is no single magnetic field morphology responsible during the star-forming process. A decrease in polarisation percentage with increasing total intensity is observed in all but the youngest objects, suggesting that these younger objects are either less centrally condensed, or have less tangling of the magnetic field at the centre of the cores.

### Magnetic Fields in Low-Mass Star-Forming Regions

*R. L. Curran & A. Chrysostomou (University of Hertfordshire)*

Submillimetre imaging polarimetry is being used to analyse the plane-of-the-sky magnetic field in low-mass star forming regions, with an aim of understanding the role played by the field in this process. The majority of isolated low-mass stars either form as singles or binary systems (as opposed to high-mass star formation, which generally takes place in clusters). This should lead to less complex magnetic field morphologies in these low-mass cores, making interpretation of the observed polarimetry patterns less difficult. However, isolated low-mass star-forming regions are much fainter in the submillimetre than their high-mass counter-parts, and so many more observations are required to build enough signal-to-noise.

### Establishing the Direction of Rotation in Circumstellar Discs

*R. L. Curran, E. T. Whelan & T. P. Ray*

Circumstellar discs play a fundamental role in star and planet formation. The central protostar gains a significant fraction of its mass by accretion through the disc. Also – in many generally accepted models – it is the disc, threaded by open magnetic field lines that launch the observed jets and outflows centrifugally, thus removing the excess angular momentum and preventing the protostar from reaching break-up velocity. It is, however, only just becoming possible to test these theories observationally. By observing the CO  $v = 2-0$  bandhead – a known tracer of these discs – for a sample of T-Tauri stars, it should be possible to establish the sense of rotation of the discs. Furthermore, comparison of the measured displacements with the locations predicted will test current circumstellar disc theory. A pilot programme has commenced using the United Kingdom Infrared Telescope and the initial data is currently being analysed.

### Numerical Simulations of Stellar Jets

*F. De Colle, J. Gracia, A.C. Raga, P. Kajdic, A. Esquivel, J.Canto' (UNAM) and T. Downes (DCU)*

This group are currently working on comparisons between observations and theoretical models and on numerical aspects of jet simulations. Also, in collaboration with J. Gracia, they are beginning a parametric study of jet propagation in YSOs (see below).

In a study led by Esquivel they discuss the Herbig-Haro jet HH30 that shows a chain of aligned knots, pointing towards what appears to be a highly fragmented “head”. The question that they address is whether or not a 4-period variable velocity ejection (suggested by a recent paper) results in a leading working surface with the high fragmentation of the “head” of the HH 30 jet. In order to do this they computed a 3D, radiative jet simulation. It was found that their simulation does produce a leading working surface with a striking resemblance to the head of HH 30. It then appears to be clear that the variable ejection implied by the chain of knots close to the HH 30 source has a direct effect on the head of the jet, producing the highly fragmented observed structure. This is the first time that such a connection has been proven for an HH outflow.

In another work led by Raga, they have studied the effect of resolution on numerical simulations of jets computing 3 adaptive grid simulations with different resolutions. It is seen that successively more complex structures are obtained for increasing numerical simulations. While the detailed structure of an internal working surface depends on resolution, the predicted emission line luminosities (integrated over the volume of the working surface) are surprisingly stable. This is very good news for the comparison of simulations of radiative jet with observations of HH objects.

Finally over the last decades, a relatively large number of papers have presented numerical simulations of radiative jets, using very different ways to compute the cooling (ranging from a parameterised cooling function to a detailed treatment of chemical structure). Implementing different cooling and looking at the results from numerical simulations, the group are addressing the question of what kind of cooling is necessary to predict the flow structure and emission properties of radiative jets.



### Development of a Parallel, Adaptive Mesh Refinement Code for MHD Simulations of Astrophysical Fluids

*F. De Colle, A.C. Raga (UNAM)*

An MHD adaptive mesh refinement parallel code is currently under development. This code is based on the more recent techniques ("Godunov method") for the integration of the MHD equations and on different methods to maintain the divergence of the magnetic field closed to zero during the calculations. The adaptive mesh refinement is implemented both on one grid and on multi-grids. The parallelization is obtained using MPI. The code allows for the possibility of including more physics: external gravity, thermal conduction, heating and cooling terms. The uniform mesh version of the code has been recently applied to the study of a broad range of astrophysical problems: supernova remnant propagation, dynamics of HII regions (including some limited treatment of the radiative transfer), solar coronal loops and finally to the study of the solar wind interaction with Mars.

### Understanding the Structure of Passive Circumstellar Disks

*F. De Colle and R. Rafikov (CITA, Canada)*

Hydrostatic equilibrium structure and spectral energy distributions (SEDs) of externally irradiated circumstellar disks are often computed on the basis of the two-temperature approximation of Chiang & Goldreich. These calculations have been refined by using more realistic vertical temperature profiles; profiles that go beyond the two-temperature approximation. In this way analytical expressions for the vertical density and pressure profiles at every point in the disk can be determined as well as the shape of the disk surface. Armed with these analytical results, the full radial structure of the disk is calculated and it is demonstrated that it favourably agrees with the more refined numerical calculations. A simple and efficient way can then be used to calculate the SED based on this approximation to the disk's thermal structure. Resulting SED provide very good matches (especially at short wavelengths) to the more detailed (but also more time-consuming) SED calculations making use of the full frequency- and angle-dependent radiation transfer in the disk.

### Study of the Properties of Dust in the Interstellar Medium

*C. del Burgo, L. Cambr esy (Strasbourg Observatory)*

A study has been made of the spatial distribution and the properties of the warm and cold components of big dust grains using optical extinction and far-infrared emission maps in the translucent cloud LDN 1780 (del Burgo & Cambr esy 2006). The cold component is concentrated in the innermost/densest regions of the cloud, it is well correlated with the integrated  $^{13}\text{CO}$  ( $J=1-0$ ) line tracing molecular gas at densities of  $10^3 \text{ cm}^{-3}$  and it is surrounded by the warm component. The colour temperatures of the warm and cold component are  $\sim 25$  and  $16.5 \text{ K}$  (assuming a power-law emissivity  $\beta=2$ ), respectively. A good correlation was found between the H $\alpha$  emission and the extinction of the cloud and a ratio  $I_{\nu}(\text{H}\alpha)/A_{\nu} = 2.2 \pm 0.1 \text{ Rayleigh mag}^{-1}$  was derived. The H $\alpha$  emission of the diffuse local background of LDN 1780 is consistent with the ionization from OB stars of the Galactic mid-plane and the Scorpius-Centaurus OB association. In the cloud itself, the very good correlation between the H $\alpha$  and extinction for a wide range of column densities is interpreted as being due to the presence of a source of ionization that can penetrate very deep into the cloud. The possibility of this result being due to ionization from  $\sim 100 \text{ MeV}$  cosmic rays is discussed.

### Developing New Techniques for the Determination of Extinction Maps

*C. del Burgo, D. Froebrich (DIAS, Kent)*

Some techniques to determine the dust extinction law in the Galaxy from broad-band photometry have been developed. Using star counts, colour excess and a combination of both methods the near-infrared extinction power-law  $\alpha$  (assumed extinction  $A_{\lambda} \propto \lambda^{-\alpha}$ ) and its error has been determined. These methods have been applied to the Two Micron All Sky Survey (2MASS) data to derive maps of  $\beta$  and extinction in the near infrared for the small cloud IC1396W (Froebrich & del Burgo 2006). Colour excess maps are generally converted to extinction maps assuming a constant value of  $\alpha$ , the same observed in the diffuse Interstellar Medium (ISM). Conversely, it was noted that a proper determination of  $\alpha$  is required to transform colour excess values into extinction since significant  $\alpha$  variations can be found in translucent and dense clouds. These methods have also been applied to study the properties of dust in the molecular cloud complex LDN 134, where variations in the dust grain size distribution are found (del Burgo 2006).



### Structure and Kinematics of Shell Galaxies

*C. del Burgo, G. Sikkema, R. Peletier, E. A. Valentijn (KI, Groningen),  
D. Carter (Liverpool JM University), M. Balcells (IAC, Spain)*

A study of a few shell ellipticals using high resolution ACS optical data from the Hubble Space Telescope (HST) has been carried out. Shell galaxies are good candidates to test theories of elliptical galaxy formation. Shells are faint stellar features that are believed to provide evidence of a merger event. The optical colours V-I of the shells and the underlying galaxies have been determined. The deep HST observations allow the detection of shells very close to the nuclei of the galaxies and faint dust features. All galaxies show out of dynamical equilibrium dust features. The merger model seems to describe the shell distributions best.

### NAHUAL: a High-resolution Spectrograph for the 10.4-m Gran Telescopio Canarias

*C. del Burgo, E. Martin (IAC, Spain, PI of Nahual),  
E. Guenther (Tautenburg, Germany) et al.*

The project Nahual (**N**ear-infrared **H**igh-resolution **S**pectrograph for **P**lanet Hunting) is intended to develop a high-resolution infrared spectrograph for the 10.4-m "Gran Telescopio Canarias" telescope in the Spanish Observatorio del Roque de los Muchachos. The main scientific objective of the project is the detection of extra-solar planets around ultra-cool objects. This is an international project led by the Instituto de Astrofísica de Canarias (IAC) with the participation of research institutes in Germany, Ireland, Italy and Portugal. CdB leads the Irish consortium that involves so far DIAS and NUI Maynooth. In the last Nahual workshop (Dornburg, June 2006) each institute identified the instrumental tasks to develop in the project. It is planned to participate in the development of the general optics of the instrument, and particularly in the grating deployment mechanism, the slit deployment mechanism and the acquisition camera. Recently, a proposal has been submitted to the Spanish Ministry of Education and Science in order to get some funding for the project.

### Plasma Simulations of Relativistic Collisionless Shocks

*L. Drury and M. Dieckmann (Ruhr-University Bochum)*

Particle in cell (PIC) simulations of the relativistic collision of two magnetised plasma slabs have been carried out to study the process of collisionless shock formation under conditions appropriate to gamma-ray burst source models. Unlike other

studies, which have generally focused on external shock models and the spontaneous generation of magnetic fields by the Weibel instability, this work has considered the collision of already magnetised slabs. This should be more applicable to the so-called internal shocks thought to be responsible for much of the fine-structure in the burst emission. Rapid formation of a strong shock is observed along with significant acceleration of both protons and electrons. The calculations were performed using the CosmoGrid share of ICHEC computational resources.

### Earliest Stages of Star Formation

*D. Froebrich, Schmeja (Potsdam), M. Smith (Kent),  
R. Klessen (Potsdam)*

During the earliest stage of star formation (Class 0) protostars gain most of their final mass. This group have investigated how well current models are able to predict the observational properties of those objects. Numerically derived mass accretion rates from gravo-turbulent simulations were combined with an evolutionary model of the envelope structure to obtain model evolutionary tracks of Class 0 objects for the three main observables (envelope mass, bolometric temperature and luminosity). A three dimensional Kolmogorow-Smirnow test was then applied to quantify the agreement between model predictions and observation. Monte-Carlo methods were used to constrain free model parameters. In general a rather small agreement (70%) of models and observations was found. However, one can conclude from their investigations that star formation is in essence a localised and stochastic process, governed in the majority of regions by turbulence rather than by ambipolar diffusion and that the Class 0 phase lasts between 20 and 60 thousand years (Froeblich, Schmeja, Smith, Klessen).

### Clustered Star Formation

*D. Froebrich, C. Raftery (TCD), A. Scholz (Toronto)*

Most stars form in clusters, embedded in clouds of gas and dust. This group used star counts in the 2MASS point source catalogue to obtain a complete sample of all star clusters in the Galactic Plane with  $|b| < 20^\circ$ . 1788 cluster candidates were identified (86 known globular clusters, 681 known open clusters and 1021 new cluster candidates). For all objects radial star density profiles were fitted to obtain the size, stellar density and number of stars in the cluster. Those properties were then used to obtain a measure to classify the new candidates in their sample. This led to a number of very good candidates for so far unknown globular clusters in our Galaxy. A study of the

spatial distribution of all clusters revealed that about half of our new candidates are indeed new open clusters. Further we find that star clusters are clustered on scales of 0.7degrees. This corresponds to an increased probability to find cluster pairs on spatial scales of 10-25pc, i.e. about the size of molecular clouds.

### **Resistive Magneto-hydrodynamic (MHD) Jet Launching Models**

*J. Gracia and M. Cemeljic (University of Athens)*

It is generally accepted, that MHD processes play an important role in the initial formation, acceleration and collimation of jets from accretion disks. While ideal MHD is in principle sufficient to describe these processes in the actual jet, non-ideal MHD cannot be neglected in the accretion disk. Global models of accretion and jet launching must therefore necessarily include magnetic resistivity. Building on previous analytical and numerical studies, this project aims to understand the influence of non-ideal MHD on jet launching emphasizing the effect of resistive heating.

### **Parametric Study of Jet Propagation in Young Stellar Objects (YSOs)**

*J. Gracia, F. De Colle*

MHD jet propagation can easily be understood in terms of a few dimensionless parameters, namely the density contrast between the external medium and the jet beam, and the magnetic Mach number of the jet beam. This simple analysis assumes, that the toroidal components of the magnetic and velocity field vanish. On the other hand, theoretical MHD models postulate non-vanishing toroidal components, at least close to the launching region. Further, observations seem to indicate, that jets might retain an azimuthal velocity component up to large spatial distances. A parametric study including non-vanishing azimuthal components has been initiated. We expect, that jet propagation will depend on the fraction of toroidal versus poloidal components of the respective fields as well.

### **Comparison of Numerical MHD Codes**

*F. De Colle, J. Gracia and T. Lery*

The purpose of this project is to define and set-up a series of standard tests for MHD astrophysical codes. The ultimate goal would be to be able to provide tests for the wider community as a reference for MHD code developers in the area. We would like to be able to apply our different codes to a real common problem of jet propagation and ejection. This would help us to understand and estimate the intrinsic error present in the simulations

presented in the literature. In December an international workshop was organized in Dublin as part of this project.

### **Physics of Shock Waves**

*S. Leygnac*

Jets emitted by young stellar objects propagate in the interstellar medium with high velocities. The interaction of the jet with the interstellar matter creates shock waves, named Herbig-Haro objects. The accurate modelling of some of these shocks demands the inclusion of radiation in hydrodynamics models. But the actual modelling takes into account the shape of the shock only in an approximate way. Calculations and observations of laboratory shocks with characteristics comparable to the astrophysical shocks have shown that one-dimensional (1D) models are not sufficient to describe a curved shock. S. Leygnac has therefore developed 3D models to improve the modelling of astrophysical shocks. The complete description of the problem requires the inclusion of radiation, atomic physics and magneto-hydrodynamics. He is extending his previous numerical models with stationary radiative transfer to full 3D geometry. These calculations are made possible using code optimised to run in a parallel computing environment.

### **Magnetic Fields in Molecular Outflows**

*A. Lim, R. L. Curran and T.P. Ray*

MHD models (axi-symmetric and full-3D) of molecular outflows are being developed for the purpose of producing simulated polarised emission from the dust and CO in molecular outflows. These will be compared with existing polarimetric observations of star-forming regions and also used as a basis for application for observing time on the SMA in the upcoming semester (and in the future, ALMA).

Alignment of the dipole moments of dust and molecules with an ambient magnetic field results in partial polarisation of the emission from these components of the ISM. From this emission it will be, for the first time, possible to determine the magnetic field in stellar jets/molecular outflows – only within the last year has it become possible to observe the polarised emission at the resolution required to resolve the structure of the magnetic field in molecular outflows from young stellar objects (YSOs). However, these observations only yield the plane-of-the-sky component of the field, summed along the line-of-sight, hence a number of field morphologies may be consistent with any given observed polarisation pattern. Without detailed modelling, it is not clear what these field morphologies are.



A modified version of the Reefa adaptive-mesh MHD code will be used to conduct a series of simulations of the propagation of a stellar jet into magnetised media in which the field strength varies both quantitatively and morphologically. From each of these simulations the polarised emission maps will be calculated, these can then be used to constrain the field morphologies that are inferred from observations.

### Stellar X-ray Hardness Ratios

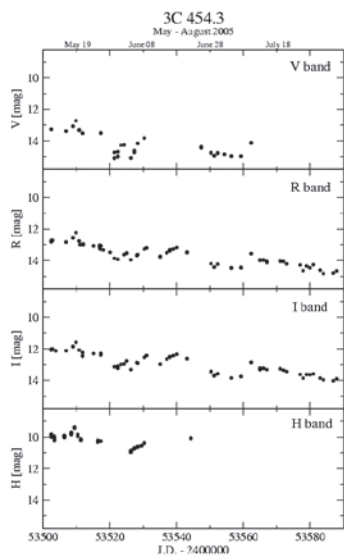
*E.J.A. Meurs, L. Norci (DCU), P. Casey (NUIM)*

X-ray hardness ratios, providing a measure for the spectral characteristics of X-ray sources, were re-assessed for a sample of bright OB stars. While the same overall result was obtained as before, this has provided an interesting enlargement of the number of stars included in this study.

### Blazar Monitoring

*E.J.A. Meurs, P. Ward, S. Vergani, L. Norci (DCU), the REM collaboration*

Non-GRB observations with the automatic REM Telescope have yielded monitoring data for several blazars (certain highly variable, luminous active nuclei of galaxies). The blazars included here, such as PKS0537-441, 3C454.3 and PKS2155-304, had been selected for study by virtue of being also known high energy emitters. The blazars mentioned here were particularly noticeable in our observations as cases that have exhibited high amplitude maxima or flares.



The brightness variation of the blazar 3C454.3 in 2005. On 19 May 2005 this object reached a historical maximum, more than a magnitude brighter than has been observed so far. The brightness has subsequently been decaying over the next couple of months.

### Echelle Spectroscopy of Runaway Stars

*C. O'Maoileidigh, E.J.A. Meurs, L. Norci (DCU), C. Rossi (University of Rome "La Sapienza")*

Blaauw (1993) discusses a tendency for O type runaway stars to have elevated helium abundance and rotational velocity, in comparison to their non-runaway counterparts. For the supernova in a binary scenario, elevated helium abundance and rotational velocity are a natural consequence of mass transfer to the companion star prior to the supernova explosion of the primary. It has been pointed out for example by Maeder (1987) that stars born with high rotation rates could exhibit affected chemical composition, perhaps also producing elevated helium abundances. However, it is not obvious then why generally the non-runaway stars avoid the domain occupied by ejected stars so completely. Therefore, we seek to increase the body of rotational velocity determinations for known runaways in order to have a much larger sample from which to draw conclusions. From two observing weeks, using the 1.52 m Cassini telescope at Loiano Observatory in Italy in May 2006 and in October 2006, we obtained echelle spectra of  $\sim 30$  runaway stars which had no rotational velocity previously recorded and a number of spectra for a few cases with previous (though often conflicting) estimates for comparison. The data reduction for this material was well advanced by the end of the year.

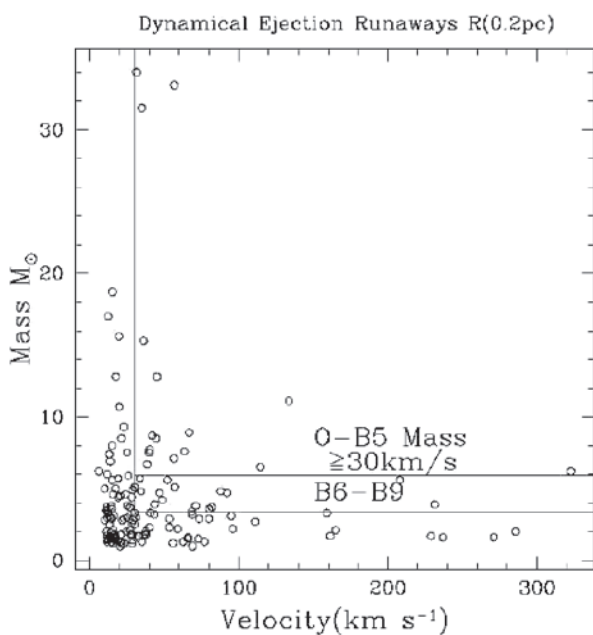
### Simulations of Runaway Star Production

*C. O'Maoileidigh, E.J.A. Meurs, L. Norci (DCU), M. Wilkinson (IoA, Cambridge)*

Runaway stars are ejected due to gravitational encounters at an early dense phase in the life of a stellar cluster. As the cluster expands and evolves this mechanism becomes less effective and it is expected that the supernova in a binary mechanism takes over as, after a few million years, the more massive stars begin to end their lives in supernova explosions, ejecting their companions from the system. The goal of this project is to produce a model which incorporates both scenarios for runaway star production. To do this we use an N-body code to study cluster dynamics and we investigate the details of binary evolution paying particular attention to supernova characteristics such as natal kick velocities.

The computer code employed is Sverre Aarseth's Nbody6 code, running on a purpose built GRAPE computer. Further work was carried out during an EARA(EST) fellowship at IoA, Cambridge over the Summer. By the end of the year this included runs with

50%, 75% and 100% binaries, initially mass segregated, Plummer distributed (as opposed to a homogeneous uniform sphere), various initial virial ratio values, ranges of semi-major axis distribution for initial binaries, populations with 45, 450 and 4500 stars, and mass transfer included. This amounts to approximately 800 simulations in total (each run-set consists of 20 simulations), which are next to be analysed and interpreted.



Runaway stars (velocities  $>30\text{km/s}$ ) produced in a simulation of a dense stellar group.

## Space Dosimetry

*D. O'Sullivan and E. Flood*



The Matroshka experiment (see Figure), recovered from the Space Station late in 2005 was analysed during the year. The investigation's main focus is on measuring the radiation dose on human organs in Earth orbit during extra-vehicular activity when humans are exposed to the full rigours of cosmic radiation

and solar particle events. Half of the DIAS data was shared with Johnson Space Center at Houston and analysis was done jointly. The Matroshka team, headed by the German Space Agency, met at Oxford in September to discuss the early results obtained by all experimenters and D O'Sullivan presented the DIAS/JSC preliminary results. Overall, the Matroshka data has shown up non trivial differences in dose measurements made by different instruments and it is possible that the very lengthy exposure of 21 months in extreme radiation conditions caused problems for some of the detectors. These differences are being investigated further. The DIAS/JSC data show that the maximum doses were found at a number of locations on the trunk of the phantom and that the eye and stomach locations received the least. The Matroshka-2 mission which is investigating exposures inside the Space Station was due to be returned to earth in September but is now delayed until March 2007.

Analysis of the data from the 'Return to Flight' mission of the Space Shuttle (STS-114) in July 2005 was completed. Excellent agreement was found between the results obtained by the tissue equivalent proportional counter (TEPC) and the nuclear track detectors. A combination of these two detector types may be the best choice for future long-term missions to Mars.

The DOBIES experiment which is a DIAS collaboration with the Belgian Nuclear Research Centre and the Czech Academy of Sciences was eventually launched from Baikonur on September 18th and recovered from Earth orbit on September 28th. Analysis of the experimental data, which aims to study the effects of cosmic radiation on model bacteria in Space. This work has important applications in the preparation for long-term human space flights where bacterial mutations could cause significant problems for crews. Analysis started in November and will continue until 2007. Dr Filip Vanhavere of the Belgian Research Centre visited DIAS for preliminary discussions.

## Swift Satellite Observations of GRBs

*S. Vergani, E.J.A. Meurs, G. Tagliaferri, and the Brera Observatory Swift team*

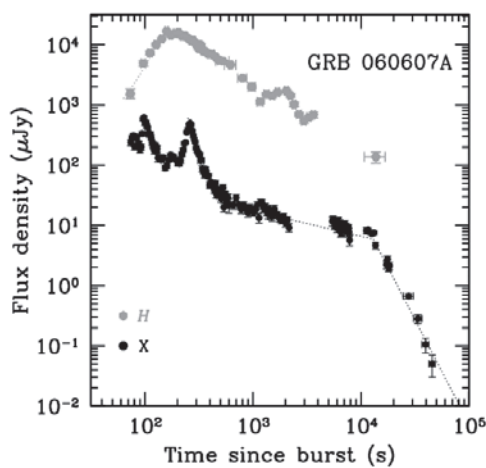
The successful Swift Satellite has become the main source of GRB detections. Contributions are made to the operation of the satellite and the subsequent data reduction, thanks to collaborating with the Brera Observatory Swift team as Burst Advocate (S. Vergani). The latter activity includes also responsibility for the Swift follow-up and the scientific analysis related to any particular GRB since its detection, the analysis of



Swift X-ray data and dissemination of the results. In addition, the whole Swift GRB sample is being analysed homogeneously, together with some of the astronomers at Brera Observatory, to investigate the Spectral Energy Distribution (SED) of the bursts. This allows testing of afterglow models, the difference between the X-ray and optical afterglows, and the dust properties along the line of sight to the bursts.

### Gamma Ray Bursts: REM Telescope Observations

*S. Vergani, P. Ward, E.J.A. Meurs, L. Norci (DCU), S. Covino, D. Malesani, A. Moretti, et al. (Brera Observatory)*



The near-infrared light curve of GRB060607A (grey symbols, H-filter), showing onset of afterglow, peaks 165 seconds after the start of the burst and subsequent decay. The black symbols refer to X-ray measurements.

Throughout the year, the night observing schedule of the REM Telescope has been managed, and the performance of the telescope monitored, by this group during several week-long periods. REM is a robotic telescope designed primarily to observe Gamma Ray Bursts (GRBs), autonomously and within seconds after the burst. In the case of a GRB alert, quick data reduction is carried out and image frames are analysed for any fading transient objects that may be GRB afterglows. Results are directly reported to the GCN Circulars. Several photometric measurements of afterglows were obtained; a couple of these were actually discovered by REM.

The REM Near-InfraRed light curves of GRB060418 and GRB060607A show a clear detection of the onset of the afterglow and its subsequent decay as predicted by the standard fireball forward shock model. It has therefore been possible for the first time to obtain a direct determination of the initial fireball Lorentz factor, finding a value of about 400, in agreement with the GRB theoretical models of highly relativistic shells.

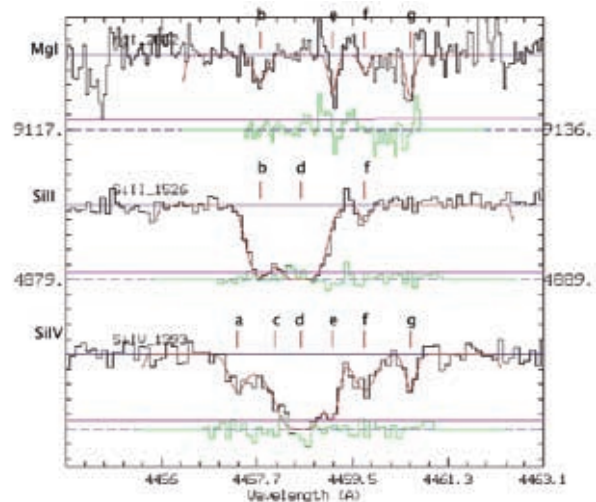
### K-corrections for Various Supernova Types

*P. Ward, E.J.A. Meurs*

For the purpose of assessing possible supernova contributions to the light curves of GRB afterglows, we have been developing so-called K-corrections for supernovae. The K-correction accounts for the effects of cosmological expansion on the emission properties of astronomical objects. In that way, observed light curves can be interpreted properly. Our K-corrections were derived first for one particular type of supernovae, type Ia, and will next be expanded to cover other types of supernovae.

### High Resolution Echelle Spectroscopy of GRB Afterglows

*P. Ward, S. Vergani, E.J.A. Meurs, L. Norci (DCU), F. Fiore, V. D'Elia, S. Piranomonte (Rome Observatory)*

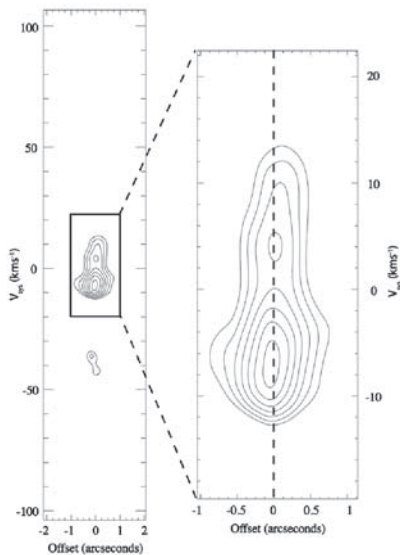


MgI, SiII and SiIV absorption components in the highest redshift system of the GRB050922C afterglow

During the year, high quality spectra were analysed for the bright GRB afterglows of GRB050730 and GRB050922C. In both cases, several absorption systems appeared to be present; the highest redshift system matches the host galaxy redshift and is thought to be associated with the GRB itself, while the other absorption systems are due to intervening material along the line of sight. Concentrating on the highest redshift system for each of these two GRB afterglows, several components can be recognized. The analysis of these components indicates a very complex burst environment, with some of the components closer to the GRB site than others. Similar data for yet another burst, GRB060607A, were obtained in multiple exposures. These are currently being analysed with the aim to study early absorption line variability of this GRB.

## High Resolution Studies of Outflow Activity in Brown Dwarfs and T Tauri Stars

E. Whelan, T.P. Ray, F. Bacciotti (Arcetri Observatory),  
R. Jayawardhana (Toronto) and P. Garcia (Porto)



A position velocity diagram of the 2MASS1207-3932 bipolar outflow in the [O I]  $\lambda$ 6300 line. The blue and red-shifted lobes are detected at radial velocities of  $-8/+4 \text{ km s}^{-1}$  respectively (with respect to the systemic velocity).

Work is continuing in the new field of outflows driven by young brown dwarfs (BDs). This group discovered the first BD outflow in 2005 as reported in *Nature*. Their findings not only show close parallels between young BDs and Classical T Tauri stars, (progenitors to stars like our Sun) but also highlights the robustness of the outflow mechanism in astrophysics across an enormous mass range: from  $10^{8-9}$  solar masses in the case of active galactic nuclei (AGN) down to 0.07 solar masses for BDs. Since this initial work, observations of a second BD 2MASS1207-3932 (a 24 Jupiter mass object) have been taken with UVES on the ESO Very Large Telescope. These observations reveal a T Tauri-like bipolar outflow driven by this young BD, making it the *smallest mass galactic object* with an outflow. It is now apparent that the primary requirement for an outflow/jet is a magnetised accretion disk. Hence this new discovery raises the possibility that young giant planets, with disks, could also launch outflows. Further observations of BDs with the VLT have been requested and granted.

A second on-going project involves using the OASIS spectro-imager on the William Herschel Telescope to obtain high spatial resolution spectra of the micro-jets from a number of classical T Tauri stars. To date 2D spectra of the jets from DG Tau and

RW Aur has been obtained. This data has allowed us to not only do proper motion studies but also to investigate the detailed morphology and kinematics of the jets. The next step in the analysis will be to map, using spectral diagnostic tools, the excitation conditions within the jet launch region as both a function of velocity and distance along the jet.

## 3. National and International Projects

### Irish Centre for High-End Computing

L. Drury

The Irish Centre for High-End Computing (ICHEC) was established with the aid of a capital grant from the CosmoGrid project and in return CosmoGrid has access to 40% of the ICHEC resources. There is a very close working relationship between ICHEC and CosmoGrid with the Dublin staff of ICHEC being based in DIAS. In June 2006 the founding Director of ICHEC, Dr. Andy Shearer, stepped down and Luke Drury assumed the responsibilities of acting director on a temporary basis while a new Director was being sought by an international search. By the end of the year a candidate had been identified and negotiations with the Director Designate were begun. An application to SFI for continuation funding to allow operation through to mid-2008 was successful.

### The Mid-Infrared Instrument (MIRI) for the James Webb Space Telescope

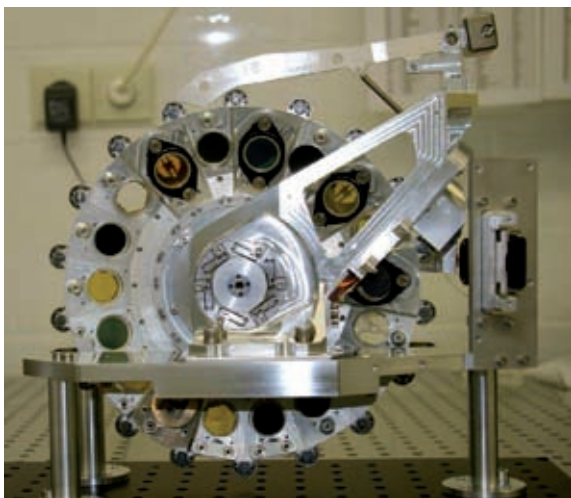
T.P. Ray and E. Flood

The James Webb Space Telescope programme is proceeding according to plan with much of the hardware already manufactured: for example the mirror segments. Those of us involved in the project were delighted with the news that Dr. John Mather, Project Scientist, was awarded the Nobel Prize in Physics with George Smoot for their work on the microwave background radiation.

The Mid-Infrared Instrument (MIRI) structural model (SM) passed all required tests, e.g. vibration and thermal, and the decision was made to go ahead with production of the Verification Model (VM). The MIRI Critical Design Review (CDR) was held in ESTEC, Noordwijk in December with a large number of ESA and NASA Review Board members present. No major problems were identified by the independent assessors. The University of Reading, under contract from DIAS, completed its imaging filter



and spectrometer dichroic manufacturing programme. One dichroic (beam-splitter) for the Mid-Infrared Instrument (MIRI) has been re-manufactured with higher-grade cadmium selenide to improve its transmission properties. The latter was paid for by a separate contract from the University of Stockholm. A number of filters were shipped to CEA, Saclay for integration into the Verification Model Filter Wheel Assembly (see Figure).



The MIRI Filter Wheel Assembly for the Verification Model (VM) in CEA, Saclay. The infrared filters, manufactured by the University of Reading under contract to DIAS, have been placed into the wheel.

It has been decided that NASA, ESA and the Canadian Space Agency (CSA) will hold their review of the James Webb Space Telescope in Dublin in 2007 from June 11-14. Over 300 people are expected to attend including representatives of the main US and European contractors, e.g. Northrop Grumman and Astrium. The venue will be the Royal Hospital Kilmainham.

## JETSET

*T.P. Ray, T. Lery, E. Flood, E. Whelan, F. de Colle, and J. Gracia*



Participants at the JETSET School on High Angular Resolution Observations held on Elba Island, Italy in September.

All 17 Experienced Researcher (ER) and Early Stage Researcher (ESR) posts in the JET Simulations, Experiment and Theory (JETSET) Marie Curie network have now been filled. T.P. Ray is the network coordinator; E. Whelan Scientific Administrator and E. Flood General Administrator. The first JETSET Science Meeting and School was held in Villiard de Lans, with the support of the Laboratoire d'Astrophysique de Grenoble, on the theme of *Jets from Young Stars: Models and Constraints*, from 9-13 January 2006. JETSET's first periodic report on activity and spending (to the end of February 2006) was submitted to Brussels and approved. The second JETSET Science Meeting and School was then held on Marciana Marina, Elba Island, Italy, from 4-8 September with the theme *High Angular Resolution Observations*. Local support came from the Osservatorio Astrofisico di Arcetri, one of the JETSET partners. A contract to publish the lectures from the school in the series *Lecture Notes in Physics* was arranged with Springer-Verlag.

## 4. Miscellaneous

### Lecture Courses

**T.P. Ray** gave courses on galaxy dynamics, the interstellar medium and New Topics in Astrophysics in Trinity College Dublin.

### Public Outreach

**D. Froebrich** delivered a public talk in Vanderbilt University Nashville, What Do Astronomers Do? on 28th June.

**E. J. A. Meurs** gave a talk to a primary school in Swords on 8th June and one to the Astro2 Society in NUIM entitled "Kicking Neutron Stars through the Galaxy" on 24th October. He also contributed to the Annual Exhibition of Astronomy Ireland on 2nd December and started a pilot programme (with Castleknock Community College) to assist secondary schools in using the Faulkes Telescopes. The latter are two 2-m robotic telescopes stationed in Hawaii and Australia.

**D O'Sullivan** delivered a talk at the Alchemist Cafe entitled 'Cosmic Rays and Space Travellers: A Safe Combination?' His work was included in the Royal Irish Academy book entitled 'Flashes of Brilliance' published in March 2006. He gave two extended interviews on radio. On Dec 7th he spoke on the RTE programme 'Quantum Leap' outlining his work on cosmic radiation and aircrew and on the same day he spoke on FM2 on the recent announcement by NASA to return to the Moon, and outlined his present research, and lunar research he undertook during the Apollo Lunar programme, in the late sixties and early seventies.



### Dunsink Observatory

The ever-popular Open Nights for the general public were organized twice monthly in January through to March and in October – December with the assistance of members of the Astronomy and Astrophysics Section. In addition there have been a number of special evenings arranged for students from both local secondary schools and universities that took on roughly the same format as the Open Nights. These evenings were composed of short talks on the Solar System, the history of the observatory and research currently being carried out within DIAS. In addition there was a 20-30 minute talk by either an internal or external speaker. The public/students were then taken to the South Dome where the use of telescopes, types of telescope and – weather permitting – what can be seen through the telescope at the time (in 2006 this was usually the Moon or Saturn) were described and explained.

### Observatory House, Dunsink

An attempt by a mobile telephone company to install antennae on Observatory House in Dunsink Observatory was successfully averted. It is to be noted that Observatory House, the main building at Dunsink, is a listed building.

### School of Cosmic Physics Seminar Series

The series of joint seminars in the school were organised by M. Moorkamp (Geophysics), D. Froebrich (Astronomy & Astrophysics) and from October onwards by J. Gracia (Astronomy & Astrophysics)

January 20th Max Moorkamp (DIAS), Modern Programming Languages and Free Software in Scientific Computing

January 27th, Jeremy Yates (University College London), Dust and Molecules in High Mass Star Formation Regions: Local and Distant

February 3rd, Fabio de Colle (DIAS), The Structure of Circumstellar discs

February 10th, Colin Brown (National University of Ireland, Galway), Some Considerations on the Visualisation of Magnetotelluric Array Data

February 17th, David Malone (National University of Ireland, Maynooth), Time in the Modern World

March 3rd, Cian Crowley (Trinity College Dublin), Mass-loss from Red Giant Stars: An Ultraviolet Perspective

March 10th, Dmitry B. Avdeev (DIAS), 3-D MT Inverse Problem: How We Numerically Solve It and First Results

March 24th, Dirk Froebrich (DIAS), Making Stars - How well do we understand it?

March 31st, Stephane Dudzinski & John Allman (DIAS), Presentation of the Current Computer Structure and Services in DIAS

April 7th, C.K. Rao (DIAS), Magnetotelluric Studies across Iapetus Suture Zone in Ireland (An Overview of ISLE-MT Work at DIAS)

April 28th, Rachel Curran (DIAS), An Introduction to Polarimetry: Mapping Magnetic Fields in Star-forming Regions

May 2nd, Adele Manzella (University of Pisa), Geothermal Exploration

May 2nd, Juanjo Ledo (University of Barcelona), MT Observations of the Rheology of the Lower Crust

May 12th, Sierd Cloetingh (University Amsterdam), Intra-plate Deformation and Neotectonic Controls on Europe's Continental Lithosphere

May 19th, Emma Whelan (DIAS), An Introduction to Brown Dwarfs in Star Forming Regions

May 26th, Steve Jones (Trinity College Dublin), Crustal Flow Beneath Iceland: Implications for Mantle Plumes, Continental Tectonics and Climate

June 6th, David Maurin (INFN Turin), Dark Matter, Super-Symmetric Matter and Antimatter, What's the Matter?

June 23rd, Paul Ward (DIAS), Gamma Ray Bursts - Probing Burst Environments in High Redshift Galaxies

June 29th, Céline Combet (DIAS), Theoretical Studies of Flows Around Forming Stars

July 13th, Tetsuzo Seno (University of Tokyo), Dehydration of Warming Serpentinized Forearc mantle: Implications for Exhumation of HP/UHP Metamorphic Belts and Plate Boundary Formation

July 26th, Steven S. Vogt (Lick Observatory) Finding Planets Around Nearby Stars: An Update on the California-Carnegie Exoplanet Survey



July 26th, Emanuele Spitoni (University of Bologna), Ballistic Models for Galactic Fountains in Spiral Galaxies

July 27th, Jonathan Mackey (Harvard-Smithsonian Center for Astrophysics), Galaxy Alignments and Their Effect on Weak-Lensing Measurements

September 15th, Dave Carter (Liverpool John Moores University), The ACS Coma Cluster Survey

September 18th, Chris J. Davis (Joint Astronomy Centre), High-mass Star Formation in DR21/W75 - the Big Picture Courtesy of WFCAM, SPITZER and SCUBA

October 9th, Michel Koenig (Laboratoire LULI), Recent Laboratory Astrophysics Experiments at LULI

October 10th, Michael Burton (University of New South Wales and Armagh Observatory), An overview of Astronomy in Antarctica

October 24th, Linda Sparke (University of Wisconsin), Bars in Bars and Rings Round Stars

October 27th, Linda Podio (Osservatorio Astrofisico di Arcetri), Recipes for Stellar Jets: from Optical/Infrared Diagnostics to High Resolution Spectro-astrometric Analysis

November 9th, Susanna Vergani (DIAS), Direct Gamma-ray Burst Fireball Lorentz Factor Measurement through REM Early Afterglow Observations

November 10th, Ron M. Clowes (University of British Columbia), The Canadian Lithoprobe Project - Multidisciplinary Earth Science Studies Reveal the evolution of a Continent

November 17th, Graziano Ferrari (Storia Geofisica Ambiente), Robert Mallet and His Laboratory

November 11th, Mark Muller (DIAS), The Seismic Structure of the Ultra-slow Spreading Southwest Indian Ridge: Constraints on Mantle Melting and Crustal Accretion Processes at Mid-ocean Ridges

December 19th, Dirk Froebrich (University of Kent), 2MASS, Faith and Patience - Looking for the Needle in the Haystack  
Subtitle: The Search for Unknown Milky Way Globular Clusters in 2MASS data

## 5. Travel including External Seminars

**F. Aharonian** Organiser of the Gamma Ray and Neutrino Session at the 23rd Symposium on Relativistic Astrophysics, Melbourne, 11-15 December;

**R. Curran** JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January 2006; ASGI Spring Meeting, University College Cork, 4 May; JETSET School and Meeting on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September;

**F. De Colle** Talk at JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January 2006; MPI and OpenMP course, Manno (Switzerland), 23-25 August; JETSET School and Meeting on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September; Scientific collaboration with Dr. Roman Rafikov, CITA (Toronto, Canada), 12-18 November; Scientific collaboration with Dr. Alex Raga, Instituto de Ciencias Nucleares, Mexico City, 12 September–21 November; Scientific collaboration with Drs. Jane Arthur & Will Henney, CryA, Morelia, Mexico, 25-26 October;

**C. del Burgo** Talk at the ASGI Spring Meeting, University College Cork, 4 May 2006: Nahual: a High Resolution NIR Spectroscopy Instrument for the biggest Optical-NIR Telescope in the World; Seminar in the UCD School of Physics Colloquium Series, 12 May: Nahual: What Can We Do With a High-Resolution Spectrograph?; Collaborative visit to the Strasbourg Observatory to work with Laurent Cambrésy on dust properties, 13-20 May; Seminar at the Strasbourg Observatory, 19 May: The Far-Infrared Signature of Dust in the ISM, from Diffuse to Dense Regions; Collaboration with the FEOS star formation group, Universidad Autonoma de Madrid and LAEFF, Villafranca 30 May; Talks at the 3rd Nahual Meeting, 19-21 June, Dornburg/Saale, Thuringia, Germany: "Polarimetric Options" and "Studies of Dust"; Collaboration with the FEOS star formation group, Universidad Autonoma de Madrid and LAEFF, Villafranca 26 July and 4 October; Virtual Observatory Meeting, Villafranca, 9 October; Collaborative visit to the Kapteyn Astronomical Institute, University of Groningen, to work with Adjunct Prof. Reynier Peletier on the shell galaxy project, 25 November-3 December;

**L. Drury** Visit to Heidelberg for discussions with F. Aharonian on KM3 project, 6-7 March; Invited talk at APS meeting, Dallas, 22-25 April; Hess Meeting, Berlin 4-5 May; Invited talk at conference, Barcelona,

4-8 June; HESS Collaboration Meeting, Montpellier, 17-22 September; HPCx Workshop, Edinburgh, 4-5 October; Fachbeirat review of MPIK, Heidelberg, 9-12 October; CTA Meeting, Utrecht, 5-7 November;

**S. Dudzinski** FOSDEM System Administration Conference, Brussels, 24-25 February; Grid Workshop, Paris, 27-28 April; Sane System Administration Conference, Delft, Holland, 15-19 May;

**E. Flood** JETSET Meeting and School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January 2006; JETSET Meeting and School on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September;

**D. Froebrich** JETSET Meeting and School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January 2006; Visit to Canterbury for collaboration work with M. Smith and to deliver a seminar: Star Formation in Small Clouds, 18-20 Jan; Visit to Heidelberg for collaboration work with S. Wolf (MPIA) and R. Klessen (ITA) and to deliver a seminar: Large-scale Extinction Mapping, 18-21 April; Talk at the ASGI Spring Meeting, University College Cork: 2MASS Selected Star Clusters with  $|b| < 20^\circ$ , 4 May; Work at the Thuringian State Observatory, Tautenburg and delivering a seminar: Large-scale Extinction Mapping, 29 May – 2 June; Observing trip, Hawaii, and collaborative work with C. Davis in the JAC and seminar in the JAC: Large-scale Extinction Mapping, June 23-July 07; University of Kent, 26-28 July; EPoS Conference, Ringberg Castle, Bavaria, including a talk: Protostellar Evolution – Confronting Models and Observations, 27 August – 1 September;

**J. Gracia** Talk at the 7th Enigma Meeting, Ydra, Greece, 8-10 May: “Synthetic Synchrotron Emission Maps from Simple MHD Configurations”; JETSET School and Meeting on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September; Talk at MHD Code Comparison Workshop, Dublin, 7-8 December: “The MHD code Nirvana”;

**T. Lery** Attending and giving a lecture at the JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January; Visit to CEA, Paris, 6-7 March; Visit to CDS, Strasbourg, 3-4 April; IST-Africa 2006, Pretoria, South Africa, 1-6 May; Global Grid Forum, Tokyo, 9-12 May; Grid Day, Brussels, 29-30 May; HEALTH-Grid 2006, Valencia, 5-7 June; Visit to CEA, Paris, 8-9 June; Attending EU-ICT-Bio Workshop, Brussels, 29-30 June; Celine Combet PhD thesis defence, Paris, 5-8 July; Visit to SAADA Team, Strasbourg, 31 August - 01 September; JETSET Meeting and School on High

Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September; HET Meeting, Amsterdam, 18 September; Grid EU meeting, Brussels, 19-20 September; e-IRG EU meeting, Helsinki, 3-6 October; HET meeting, Zurich, 10-11 October; Peer Review Conference, Prague, 12-13 October; HET meeting, Frankfurt, 16-17 October; SIRENE meeting, Helsinki, 19 October, HET meeting, Brussels, 26 October; Super-Computing 2006, Tampa, USA, 11-18 November; HET meeting, Zurich, 27 November; SIRENE meeting, Stockholm, 29 November; HET meeting Frankfurt, 12 December;

**S. Leygnac** Poster with S. O’Sullivan and T. Lery, JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January: Radiation in YSO Jets and Shocks; Talk at the Postdoc Researchers Day at Luth, Observatoire de Paris-Meudon, Meudon, France, March 2006: Shock Diagnostics of Protostellar Jets;

**E.J.A. Meurs** Visit to Astrophysics Centre Porto University, 19-25 February, seminar “On the supernova origin of runaway stars”; Observing run Loiano Observatory (Italy), 30 April – 7 May; Meeting on REM Telescope and Swift collaboration, Brera Observatory, Merate (Italy), 5 May; Collaboration Rome Observatory, 7-16 May; National Committee for Astronomy and Space Science meeting, RIA, 25 May; Work visit, Astronomical Institute Anton Pannekoek, University of Amsterdam, 16 July – 5 August, seminar “William R. Hamilton: Observatory Director and Mathematician”; National Committee for Astronomy and Space Science meeting, UCD, 31 August; ASGI Fall meeting, UCD, 31 August; Presentation of ESA’s Cosmic Vision Programme, Enterprise Ireland, 11 September; Discussions ESO, 25-28 September; Observing run Loiano Observatory (Italy), 9-17 October; Talk “High energy emission from supermassive black holes in the nuclei of the nearest galaxies”, DCU/NPCST, 27 October; Working visit ESO, 20-23 November, seminar “A REM Telescope measurement of the GRB fireball Lorentz factor and VLT-UVES views of circumburst material”; National Committee for Astronomy and Space Science meeting, Enterprise Ireland, 7 December; Astrophysics Colloquium in honour of Brian McBreen, UCD, 18-19 December, talk “Results with the REM Telescope and high-resolution GRB afterglow spectroscopy”;

**G. Murphy** ASGI Spring Meeting, University College Cork, 4 May; JETSET School and Meeting on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September;



**C. O'Maoileidigh** Working visit, IoA Cambridge, 20-26 February; 36th Saas Fee Advanced Course on "First Light in the Universe", Les Diablerets (Switzerland), 3-8 April; Observing run Loiano Observatory (Italy), 29 April – 7 May; Working visit to University of Rome "La Sapienza", 8-12 May; EARA (EST) Fellowship, IoA Cambridge, 12 June – 14 September; Summer School on "Astrophysical N-body simulations and stellar dynamics", IoA Cambridge, 30 July – 11 August; Observing run Loiano Observatory (Italy), 9-16 October;

**D O'Sullivan** Talk in Trinity College Dublin, 1 February: Radiation Hazards in Space and in the Upper Atmosphere; Talk at the 11th Workshop on Radiation Monitoring for the International Space Station at St Peter's College Oxford, 6-8 September: The DIAS/JSC Preliminary Results from the Matroshka-1 Mission; Talk at the 10th International Symposium on Radiation Protection at Coimbra University, Portugal Sept 17-Sept 23: The DIAS/JSC Results from the Space Shuttle Atlantis Mission STS-114;

**T. P. Ray** Attending as coordinator and giving a lecture at the JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-11 January; MIRI Steering Committee, Brussels, 13 January; Invited Seminar, Dublin City University, 9 February; Physical Sciences Committee, Royal Irish Academy, 7 March; Media Course, Carr Communications, 8 March; Invited Seminar, University of Exeter, 10 March; MERLIN Steering Committee, Jodrell Bank, 22 March; MIRI European Consortium Meeting, Copenhagen, 3-5 May; Giving an invited talk in the University of Bristol, 25 May; MERLIN Time Allocation Group, Jodrell Bank, 1 June; Attending as session organiser, Early Stages of Star Formation, Ringberg Castle, Bavaria, 27 August -1 September; Attending as coordinator to the JETSET Meeting and School on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September; Invited talk, Workshop in honour of J. Dyson, University of Leeds, 20 September; MIRI National Programme Managers Meeting, Amsterdam, 10-11 October; Invited Lecture for Maths Week, National Irish Museum, Dublin, 18 October; MERLIN Time Allocation Group, University of Hertfordshire, 14 November; Launch 7th EU Framework Programme, Royal Hospital Kilmainham, 15 November; MERLIN Steering Committee, Jodrell Bank, 20 November; Physical Sciences Committee, Royal Irish Academy, 5 December; MIRI Critical Design Review Board, ESTEC, Noordwijk, 6-7 December;

**S. Vergani** Training for Swift X-Ray Telescope data analysis, Brera Observatory, INAF-Merate (Italy), March—May; 36th Saas Fee Advanced Course on "First Light in the Universe", Les Diablerets

(Switzerland), 3-8 April; Poster presentation "REM observations of GRB060418: the fireball Lorentz factor determination", at "Swift and GRBs: Unveiling the relativistic universe", San Servolo (Venice) 5-9 June; Swift Burst Advocate duty and collaboration, Brera Observatory, INAF-Merate and INAF-Monte Porzio (Rome), July; ASGI Fall meeting, talk "Direct GRB fireball Lorentz factor measurements through REM early afterglow observations", UCD, 31 August; Swift Burst Advocate duty and collaboration, Brera Observatory, INAF-Merate (Italy), September; Talk "Direct GRB fireball Lorentz factor measurements through REM early afterglow observations", DCU/NPCST, 27 October; Presentation to "Italian Swift Meeting", Brera Observatory, INAF-Merate (Italy), 29-30 November; Talk "Direct GRB fireball Lorentz factor measurements through REM early afterglow observations" at "5th Mt Stromlo Symposium: Disks, Winds and Jets – from Planets to Quasars", Mt Stromlo Observatory, Canberra, 3-8 December; Poster presentation "GRB afterglow onset observations and initial fireball Lorentz factor measurement", at XXIII Texas Symposium on Relativistic Astrophysics, Melbourne University, 11-15 December;

**P. Ward** 36th Saas Fee Advanced Course on "First Light in the Universe", Les Diablerets (Switzerland), 3-8 April; ASGI Spring meeting, UCC, 3-4 May; Poster presentation "UVES/MLT High resolution spectroscopy of Gamma Ray Bursts afterglows" at "Swift and GRBs: Unveiling the relativistic universe", San Servolo (Venice) 5-9 June; Royal Astronomical Society meeting on "Recent developments in the study of Gamma Ray Bursts", London, 18-20 September;

**E. Whelan** Poster with T. P. Ray, JETSET School on Jets from Young Stars: Models and Constraints, Villard-de-Lans (France), 9-13 January; ASGI Spring Meeting, University College Cork, 4 May; Collaborative work with NUI, Galway, 17-20 July; Talk at the Autumn ASGI Meeting UCD, Dublin, September: Outflow Activity from Brown Dwarfs; Talk at the JETSET School and Meeting on High Angular Resolution and Interferometric Techniques Applied to Jets, Marciana Marina, Elba, Italy, 4-8 September: Outflow Activity in Brown Dwarfs.

## 6. Publications

### Refereed Journals

Agudo, I., ... Gracia, J. and 13 co-authors, Testing the inverse-Compton catastrophe scenario in the intra-day variable blazar S5 0716+71. II. A search for intra-day variability at millimetre wavelengths with the IRAM 30m telescope, *Astronomy and Astrophysics*, **456**, 117

- Aharonian, F., ... Drury, L., and 105 co-authors, HESS Observations of the Galactic Center Region and Their Possible Dark Matter Interpretation, *Physical Review Letters*, **97**, 221102
- Aharonian, F., ... Drury, L., and 104 co-authors, First detection of a VHE gamma-ray spectral maximum from a cosmic source: HESS discovery of the Vela X nebula, *Astronomy and Astrophysics*, **448**, L43
- Aharonian, F., ... Drury, L., and 105 co-authors, Observations of the Crab nebula with HESS, *Astronomy and Astrophysics*, **457**, 899
- Aharonian, F., ... Drury, L., and 103 co-authors, Discovery of very high energy  $\gamma$ -ray emission from the BL Lacertae object H 2356-309 with the HESS Cherenkov telescopes, *Astronomy and Astrophysics*, **455**, 461
- Aharonian, F., ... Drury, L., and 101 co-authors, Evidence for VHE  $\gamma$ -ray emission from the distant BL Lac PG 1553+113, *Astronomy and Astrophysics*, **448**, L19
- Aharonian, F., ... Drury, L., and 100 co-authors, Discovery of very-high-energy  $\gamma$ -rays from the Galactic Centre ridge, *Nature*, **439**, 695
- Aharonian, F., ... Drury, L., and 100 co-authors, A low level of extragalactic background light as revealed by  $\gamma$ -rays from blazars, *Nature*, **440**, 1018
- Aharonian, F., ... Drury, L., and 97 co-authors, The H.E.S.S. Survey of the Inner Galaxy in Very High Energy Gamma Rays, *Astrophysical Journal*, **636**, 777
- Aharonian, F., ... Drury, L., and 99 co-authors, A detailed spectral and morphological study of the gamma-ray supernova remnant RX J1713.7-3946 with HESS, *Astronomy and Astrophysics*, **449**, 223
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- Cerqueira, A. H., Velázquez, P. F., Raga, A. C., Vasconcelos, M. J., and De Colle, F., Emission lines from rotating proto-stellar jets with variable velocity profiles. I. Three-dimensional numerical simulation of the non-magnetic case, *Astronomy and Astrophysics*, **448**, 231
- Ciardi, A., ... Lery, T. and 12 co-authors, 3D MHD Simulations of Laboratory Plasma Jets, *Astrophysics and Space Science*, 526
- Ciardi, A., Lebedev, S. V., Stehle, C., and Lery, T., Laboratory models for astrophysical jets, *Journal de Physique IV*, **133**, 1043
- Combet, C., Lery, T., and Murphy, G. C., Transit Flow Models for Low- and High-Mass Protostars, *Astrophysical Journal*, **637**, 798
- Davis, C. J., Nisini, B., Takami, M., Pyo, T.-S., Smith, M. D., Whelan, E., Ray, T. P., and Chrysostomou, A., Adaptive-Optics-Assisted Near-Infrared Spectroscopy of SVS 13 and Its Jet, *Astrophysical Journal*, **639**, 969
- De Colle, F. and Raga, A. C., MHD simulations of radiative jets from young stellar objects, H $\alpha$  emission, *Astronomy and Astrophysics*, **449**, 1061
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- Dieckmann, M. E., Drury, L., and Shukla, P. K., On the ultra-relativistic two-stream instability, electrostatic turbulence and Brownian motion, *New Journal of Physics*, **8**, 40
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- Froebrich, D. and Del Burgo, C., Extinction techniques and impact on dust property determination, *Monthly Notices of the Royal Astronomical Society*, **369**, 1901
- Froebrich, D., Schmeja, S., Smith, M. D., and Klessen, R. S., Evolution of Class 0 protostars: models versus observations, *Monthly Notices of the Royal Astronomical Society*, **368**, 435
- Fuhrmann, L., ... Meurs, E., ... Ward, P. and 18 co-authors, A rapid and dramatic outburst in Blazar 3C 454.3 during May 2005: Optical and infrared observations with REM and AIT, *Astronomy and Astrophysics*, **445**, L1



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Meurs, E.J.A., Fabbiano, G. (Eds), Populations of High Energy Sources in Galaxies, Proceedings of the 230th Symposium of the International Astronomical Union, Cambridge University Press

### Non-Refereed Books and Journals

Dieckmann, M. E., Drury, L., and Shukla, P. K., On The Ultra-relativistic Two-stream Instability, Electrostatic Turbulence And Brownian Motion, Cosmic Particle Acceleration, 26th meeting of the IAU, Joint Discussion 1, 16-17 August, 2006, Prague, Czech Republic, JD01, #50, 1

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# School of Cosmic Physics – Geophysics

## 1. General

The year saw Geophysics decrease with the departure of two important scientists working on the HADES project, namely Laurent Gernigon and Celine Ravaut. Both were successful at being awarded IRCSET Fellowships. Laurent decided not to accept his, and left for a position in the Geological Survey of Norway. Celine would liked to have stayed, but problems with getting permission to hire her caused a delay in excess of a year, and in the interim Celine chose to leave for a position also in Norway.

Also, the Fellowship terms of Drs. D. Avdeev, C.K. Rao and U. Weckmann ended in the year, and they all returned to their home institutions in Russia, India and Germany respectively.

Dr. Mark Muller started his PostDoctoral Fellowship on the SAMTEX project, and Dr. Franz Hauser started as a contract researcher on the HADES project.

## 2. General Geophysics Activities

### 2.1. CHIGI – Irish Geoscience Graduate Programme Proposal

During 2006 the Committee of Heads of Irish Geoscience Institutes (CHIGI) constituted itself and met for the first time. The All-Ireland committee comprises the Heads of Earth Science at NUIG, TCD, and UCC, the Head of Geophysics at DIAS, and the Directors of the Geological Surveys of Ireland and of Northern Ireland. The committee meets on an irregular basis to consider cross-cutting issues of significance to the geoscience community.

The major activity of CHIGI in 2006 was building the case for an All-Ireland approach to graduate geoscience education, culminating in a proposal for an Irish Geoscience Graduate Programme (IGGP) to IRCSET for funding under the Exploratory Grants for Graduate Research Education programmes (GREP). This proposal was not successful for Exploratory Grant funding. However in the Government's National Development Plan 2007-2013 under the Geoscience Sub-Programme there is a commitment on the part of Government to develop incorporated island-wide networked teaching resources.

### 2.2. TOPO-Europe/EuroArray

TOPO-Europe was accepted in November, 2006, as a European Science Foundation EUROCORES programme. EuroArray will provide the lithospheric imaging component of TOPO-Europe.

#### Public Outreach:

- Article published in *Irish Times* by Dick Ahlstrom on *Crust in Carpathians thinnest on Continent* describing TOPO-Europe and the research work of the School's 2006 Statutory Public Lecturer, Professor Sierd Cloetingh, of Vrije University, Amsterdam (Netherlands), 11 May.

#### Publication:

- Cloetingh, S., P. Bogaard, P.A. Ziegler, F. Wenzel, O. Heidbach, W. Spakman, H. Thybo, A.G. Jones, H.-P. Bunge, P.A.M. Andriessen, E. Burov, L. Matenco, G. Bada, G. Peters, R.T. van Balen, C. Faccenna, R. Carbonell, J. Gallard, R.A. Stephenson, I. Artemieva, S. Sliupa, A. Soesso, O. Oncken, Z. Ben-Avraham, A.M. Friederich, J. Mosar, and the TOPO EUROPE Working Group, 4-D topographic evolution of the intra-plate regions of Europe: a multidisciplinary approach linking geology, geophysics and geotechnology, *Global Planet. Change*, in review.

#### Presentation:

- Jones, A.G., H. Thybo, and P. Maguire, 2006. EuroArray: A programme for the 4D study of the Assembly of the European Continent. **Invited** paper at: European Geosciences Union General Assembly 2006, Vienna, Austria, 2-7 April.

### 2.3. AfricaArray

In discussions with the AfricaArray principles, Jones was asked to try to secure funding for a seismological observatory in Zamia. He visited Zambia in April, and had fruitful discussions with the Chief Geophysicist of the Geological Survey of Zambia. However, little progress has been made in convincing IrelandAid to support Third



Level education in Africa. DIAS is contributing to AfricaArray by providing technical support to the University of the Witwatersrand Geophysical Field School held annually in June/July.

#### Workshop:

- AfricaArray workshop, Johannesburg, South Africa, 13-14 July.

## 2.4. Joint Inversion of Electromagnetic and Seismic Data

*M. Moorkamp, A.G. Jones, with Professor D. Eaton (Univ. Western Ontario, Canada)*

One of the objectives of the ISLE-MT project was to develop a joint-inversion algorithm for magnetotelluric (MT) and seismic receiver function data. The acquisition of co-located MT and seismic data at each site made this project an ideal candidate for this new approach and promised new insights into the structure of the Earth. However, due to limited and noisy seismic events, noisy MT data, and highly complex Earth, co-located seismic and MT data from other areas have been considered. As a first-step to initiate this work, one-dimensional approaches were used, with a genetic algorithm search for models that satisfied both sets of data.

Genetic algorithms are a class of stochastic optimisation algorithms that use mechanisms similar to biological evolution. They have been shown to be well suited for the solution of multi-objective optimisation problems. In comparison with traditional linearized methods they can escape local minima and do not just yield a single output model, but a range of output models, that display the trade-off between fitting the datasets. This additional information can help to assess in how far the underlying assumptions for the inversion process are valid. These advantages come at the cost of a much higher number of function evaluations, i.e., forward modelling calculations. For our purposes this is not a great concern, because both seismic and electric model responses can be calculated in fractions of seconds.

Tests with synthetic data show that the genetic algorithm is successful at finding an appropriate model for realistic synthetic input data. The result of the next step, inversion of real data collected during the ISLE and ISLE-MT experiments is shown in Figure 2.4.1. We obtain a realistic joint model for seismic velocities and resistivities. The Moho depth of 28 km and lithosphere-asthenosphere boundary at 110 km both agree with results from earlier studies.

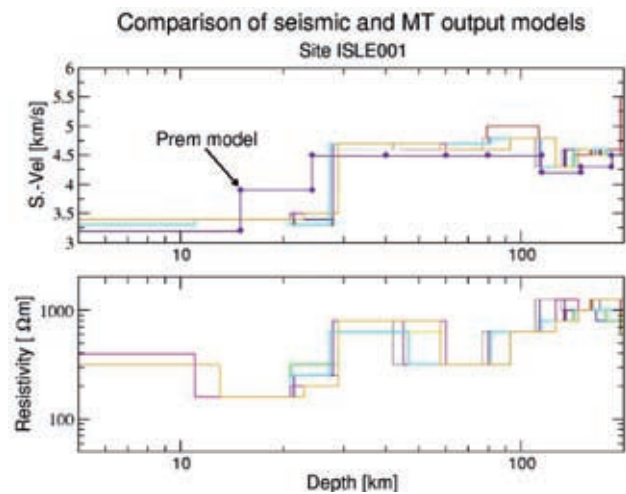


Figure 2.4.1: Joint inversion models of data from a site in southern Ireland. The model marked "Prem" is the global standard 1D velocity model of the Earth.

In order to see in how far Ireland is different from other regions we compare the obtained model with joint inversion models from the Slave Craton, northwestern Canada. The previously observed correlation between seismic and electrical interfaces in the Slave Craton motivated the joint inversion project in Ireland. As can be expected for an old cratonic region both Moho-discontinuity and lithosphere-asthenosphere boundary are deeper than in Ireland. In the Slave Craton the Moho is well resolved by both datasets because of the absence of a shallow conductor and a pronounced decrease in resistivity below the discontinuity.

Two joint inversion models A and B are shown in Figure 2.4.2. The differences between the two models are minor. Note that the Central Slave Mantle Conductor, discovered by Jones et al. (2001, 2003), is well defined in the MT data, and the region is a shear wave low velocity zone of a reduction of  $\sim 0.2$  km/s. There is the suggestion of resistivity and velocity increases at  $\sim 150$  km depth, which is the graphite-diamond stability depth. An increase in resistivity would be consistent with lack of a graphite conducting phase in the lower lithosphere; the actual resistivity of that layer is virtually unresolved as it lies between two more conducting layers (see, e.g., Jones, 1999). The lithosphere-asthenosphere boundary is well-defined in the MT data, with a resistivity decrease at  $\sim 220$  km, consistent with petrological results, but the corresponding velocity interface indicates a velocity *increase*, rather than decrease. However, the shear wave velocities within the lower layers are poorly resolved.

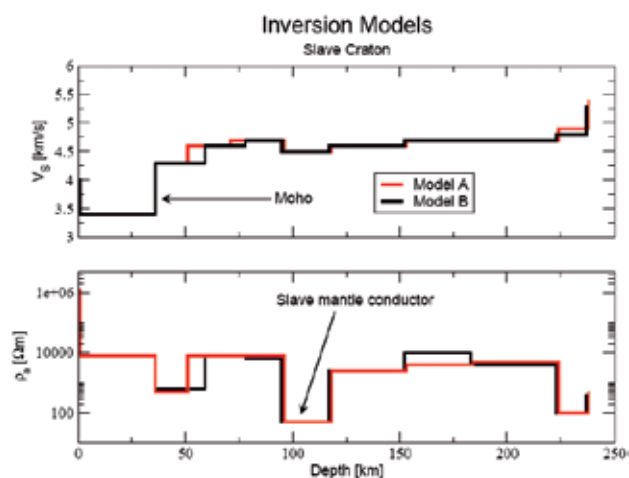


Figure 2.4.2: Joint inversion of RF and MT data from a site on the Slave craton in northwestern Canada. Note identification of the Central Slave Mantle Conductor.

### Presentations:

- Jones, A.G., and M. Moorkamp, 2006. Are seismic velocities and electrical conductivities reconcilable? Contributed paper at: American Geophysical Union Fall Meeting, San Francisco, USA, 11–15 December.
- Moorkamp, M., C.K. Rao and A.G. Jones, 2006. Inverting receiver-function and MT-data with a genetic algorithm. Contributed paper at: 49th Annual Irish Geological Research Meeting, University College Cork, Cork, Ireland, 24-26 February.
- Moorkamp, M., A.G. Jones, and C.K. Rao, 2006. Joint inversion of MT and seismic receiver function data using a genetic algorithm, Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Moorkamp, M., A.G. Jones, and C.K. Rao, 2006. Using a genetic algorithm to assess data compatibility in joint inversion. Contributed paper at: American Geophysical Union Fall Meeting, San Francisco, USA, 11–15 December.

### Proposal:

- Pre-proposal submitted to SFI RFP2007 competition by A.G. Jones to continue and advance joint inversion of seismic and MT data accepted for submission as a full proposal.

## 3. Electromagnetic Activities

### 3.1. SAMTEX (Southern African Magnetotelluric Experiment)

A.G. Jones, X. Garcia, M. Muller, M. Hamilton, M. Miensoopust, with Geophysics staff and colleagues from Woods Hole Oceanographic Institution (U.S.A.), the University of Witwatersrand (South Africa), the Council for Geosciences (South Africa), Geological Survey of Botswana, Geological Survey of Namibia, DeBeers (South Africa), Rio Tinto Mineral Exploration (UK and Botswana) and BHP-Billiton

Broadband (BBMT) and long period (LMT) MT data have been acquired on three phases of acquisition on the SAMTEX (Southern African Magnetotelluric experiment) project since October 2003 in South Africa, Botswana and Namibia at the sites shown in Figure 3.1.1. The BBMT data were acquired every 20 km, on average, except for sites located within the Witwatersrand Basin, using up to nine Phoenix MTU-V5 systems simultaneously.



The SAMTEX project saw completion of Phase III during the Spring of 2006 with successful acquisition at an astonishing number of sites, shown in the gray squares in Figure 3.1.1. SAMTEX now has data from over 550 sites in an area of over a million square kilometres (Figure 3.1.1), making it the largest regional MT survey ever conducted.

Typical examples of good data and noisy data are shown in Figures 3.1.2a and 3.1.2b respectively. The most difficult noise source was from the DC trains that ran parallel to the profile in the middle section, and from the DC power systems in the diamond mines. Coherent noise contributions were observed for over 100+ km, taking the form of steps in the e-fields (as power was supplied to the engines) and spikes in the h-fields when observed by the coils, which record dB/dt.

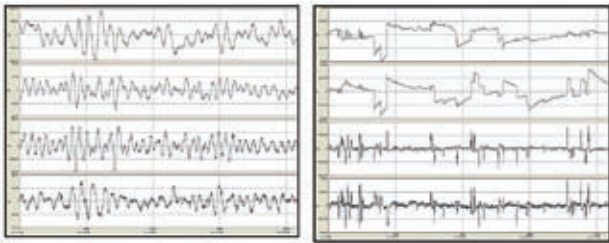


Figure 3.1.2: MT times series from SAMTEX sites. Time segment is just over 8 minutes long (12,000 points). Traces are Ex, Ey, Hx, Hy from top to bottom. (a) Example of good quality data. (b) Example of poor quality data. The noise source for these data was the DC trains.

Standard time series processing schemes using modern, multi-site-correlation, robust approaches are poorly successful at retrieving high-quality interpretable responses from sites contaminated by high levels of particularly DC noise. Various research directions are being explored to try to deal with this problem.

A preliminary model of the data from the main NE-SW 1350-km-long profile crossing the Kaapvaal Craton, from the Zimbabwe border to within 200 km of Cape Town is shown in Figure 3.1.3. This model is representative of many different models produced by different SAMTEX members using various subsets of the data.

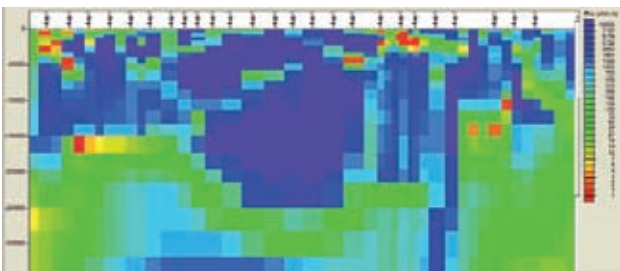


Figure 3.1.3: Preliminary model of the LMT data from the main NW-SW profile crossing the Kaapvaal Craton. NE is to the right and SW to the left.

The model fits for the northernmost 1/3 of the sites are poorer than for the other sites. The overarching robust result is the difference in lithospheric thickness between the sites on the Namaqua-Natal Mobile Belt (NNMB) and those on the Kaapvaal Craton (KC). The sites on the NNMB exhibit a lithospheric thickness of the order of 150 km, and the kimberlites are non-diamondiferous. In contrast, in the centre of the KC lithospheric thickness is 250 km or greater, and there are no known kimberlites. The transition between the two is the region beneath the Kimberley-Koffiefontein-Jagersfontein diamondiferous kimberlite trend. This spatial relationship between thin, transitional and thick lithosphere is best viewed in 3D perspective (Figure 3.1.4).

One particular aspect that we are exploring using the SAMTEX dataset is the relationship between seismic and electrical anisotropy of the crust and lithospheric mantle. This is the primary research focus of scholar Mark Hamilton, and the initial results were published in a special volume devoted to Continental Anisotropy. The electrical anisotropy results from the main profile are compared to seismic anisotropy, determined using SKS splitting, in Figure 3.1.5.

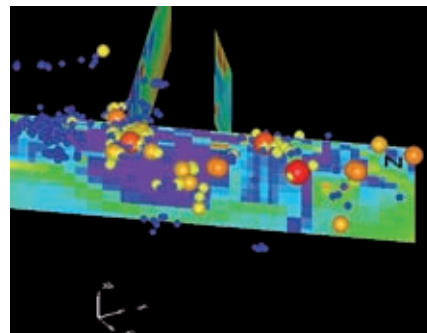


Figure 3.1.4: Model of the main profile (Figure 3.1.3) showing association with known kimberlite pipes. Blue spheres are non-diamondiferous kimberlite pipes, whereas yellow to red spheres are diamondiferous kimberlite pipes, and the size and colour of the sphere indicates the diameter of the pipe.

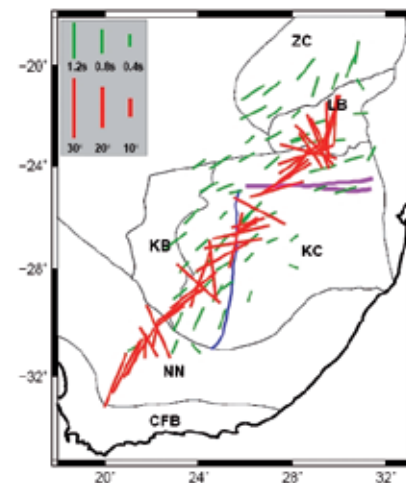


Figure 3.1.5: Electrical more conductive directions (in red), scaled by maximum phase difference, for the lithospheric upper mantle, and the shear-wave-splitting results (both high and low quality results plotted in green, but sites with no detectable splitting omitted) from Hamilton et al. (2006). ZC: Zimbabwe craton. KC: Kaapvaal craton. LB: Limpopo Belt. NN: Namaqua-Natal mobile belt. CFB: Cape Fold Belt. KB: Kheis and Proterozoic fold and thrust Belt. Blue line: the N-S trending Colesburg Magnetic Lineament (CML). Purple lines: the E-W trending Thabazimbi-Murchison Lineament (TML).

BHP-Billiton joined the consortium, which enables financially a fourth Phase of acquisition. Plans are for acquisition along the dashed orange lines on Figure 3.1.1, likely in January-March, 2008 after the end of the sunspot minimum.



### Workshop:

- SAMTEX interpretation workshop, Dublin, 17-19 October. Academic, government and industry attendees came from Ireland, U.K., and South Africa.

### Short Course:

- *African Geodynamics*: Two day Short Course presented by Professor Colin Reeves of International Institute for Geo-Information Science & Earth Observation (ITC), Netherlands, on 28-29 November. Academic, government and industry attendees came from Ireland, U.K., and South Africa.

### Publications:

- Hamilton, M., A.G. Jones, R.L. Evans, S. Evans, S. Fourie, X. Garcia, A. Mountford, J.E. Spratt, and the SAMTEX Team, 2006. Anisotropy structure of the lithosphere derived from magnetotelluric and seismic shear-wave splitting analyses in southern Africa, *Physics of the Earth and Planetary Interiors*, **158**, 226-239.

### Presentations:

- Evans S.F., A.G. Jones, R. Evans X. Garcia, S. Fourie, and A. Mountford, 2006. The Southern African Magnetotelluric Experiment (SAMTEX): Progress and preliminary interpretations. Contributed paper at: Australian Society of Exploration Geophysicists Annual General Meeting, Melbourne, Australia, 2-6 July.
- Evans, R.L., A.G. Jones, X. Garcia, M. Hamilton, S. Evans, S. Fourie, J. Spratt and the SAMTEX Team. The electrical lithosphere beneath the Kaapvaal Craton: Links to kimberlites. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Hamilton, M., A.G. Jones, R.L. Evans, S.F. Evans, C.J.S. Fourie, A. Mountford, X. Garcia, J. Spratt, and the SAMTEX MT team, 2006. Magnetotelluric studies across the Kaapvaal craton in southern Africa. Contributed paper at: 49th Annual Irish Geological Research Meeting, University College Cork, Cork, Ireland, 24-26 February.
- Hamilton, M., A.G. Jones, R.L. Evans, S.F. Evans, C.J.S. Fourie, X. Garcia, A. Mountford, J. Spratt, and the SAMTEX MT team. A comparison of seismic and electrical anisotropy over the southern African region. British Geophysical Association Postgraduate Meeting, Edinburgh, Scotland, 31 August - 1 September

- Hamilton, M.P., A.G. Jones, R.L. Evans, S.F. Evans, C.J.S. Fourie, and the SAMTEX team, 2006. Comparison of electrical and seismic anisotropy of southern Africa. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Hamilton, M.P., A.G. Jones, R.L. Evans, S.F. Evans, C.J.S. Fourie, A. Mountford, T. Ngwisanyi, D. Hutchins, X. Garcia, M.R. Muller, J. Spratt, M. Miensopust, and the SAMTEX MT Team. A comparison of electrical and seismic anisotropy across the southern African region. Contributed paper at: American Geophysical Union Fall Meeting, San Francisco, USA, 11-15 December.
- Jones, A.G., and the SAMTEX team, 2006. Electromagnetic imaging of the Kaapvaal Craton, South Africa – Status Report. Contributed paper at: Canadian Geophysical Union Annual Meeting, Banff, Alberta, Canada, 14-17 May.
- Jones, A.G., X. Garcia, M. Hamilton, M. Miensopust, M. Muller, J. Spratt, R. Evans, A. Chave, S. Fourie, E. Stettler, R. Stettler, J. Cole, H. Ngwisanyi, D. Hutchins, S. Evans, D. Hatch, A. Mountford, E. Cunion, and the SAMTEX team, 2006. SAMTEX (Southern African Magnetotelluric Experiment): Overview and First Results. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Miensopust, M., A.G. Jones, M. Muller, M. Hamilton, X. Garcia, J. Spratt, R. Evans, S. Evans, A. Mountford, C. Fourie, D. Hutchins, H. Ngwisanyi and the SAMTEX team. Lithospheric studies of major Archean cratons and their Proterozoic bounding belts in southern Africa using MT. British Geophysical Association Postgraduate Meeting, Edinburgh, Scotland, 31 August - 1 September
- Muller, M., Webb, S., Jones, A., Hough, T., Kowalczyk, P., Evans, R., Fourie, C., Hatch, D., Mountford, A. and the SAMTEX team. Crustal imaging of the Archaean Witwatersrand Basin and Vredefort Dome, South Africa, using broadband magnetotellurics. 18th Electromagnetic Induction Workshop, El Vendrell, Spain, 18-22 September.
- Muller, M.R., M.P. Hamilton, S.F. Evans, A.G. Jones, R.L. Evans, X. Garcia, A. Mountford, C.J.S. Fourie, D. Hutchins, T. Ngwisanyi, T. and the SAMTEX team. Constraints on the lithospheric evolution of the Rehoboth and Kaapvaal cratons, Southern Africa, from broadband magnetotellurics. American Geophysical Union Fall Meeting, San Francisco, USA, 11-15 December.

### 3.2 ISLE-MT

C.K. Rao, M. Moorkamp, A.G. Jones

The complete set of ISLE-MT sites acquired in 2004 and 2004 field campaigns is shown in Figure 3.2.1. During 2006 the PostDoctoral Fellowship of Dr. C.K. Rao was extended by four months in order to complete the initial modelling and interpretation, and to advance progress on modelling and interpretation of the complete ISLE-MT dataset. Dr. Rao returned to the Indian Institute of Geomagnetism in May, but continues to model and interpret the ISLE-MT dataset.

A paper describing the results of the interpretation from a NNW-SSE profile in eastern Ireland across the Iapetus Suture Zone was accepted in early 2007. The final modelling result is shown in Figure 3.2.2. The model highlights an undulating high conductivity layer, of thickness 10-15 km and resistivity 2-5 W.m, at middle to lower crustal depths interpreted as sulphide-bearing graphitic sediments deposited between the converging continents of Laurentia and Avalonia during the closure of the Iapetus Ocean. The sediments underwent sinistral, transpressional deformation during convergence, and movements along the faults transported the sediments to depths of 5-10 km forming the U-shaped conductor beneath the centre of the profile correlative with the inferred location of the Iapetus Suture Zone. Two high resistivity blocks identified above the U-shaped conductor are interpreted as Caledonian granite bodies, and likely relate to late Caledonian igneous activity.

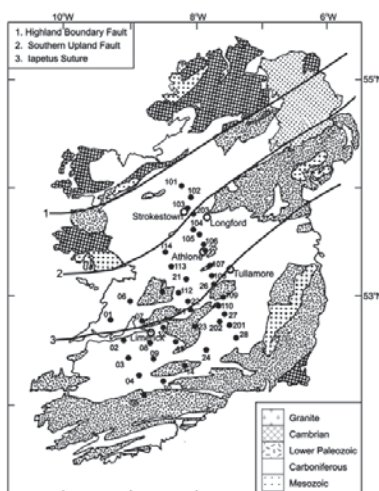


Figure 3.2.1: ISLE-MT site locations across the Iapetus Suture Zone (labelled 3)

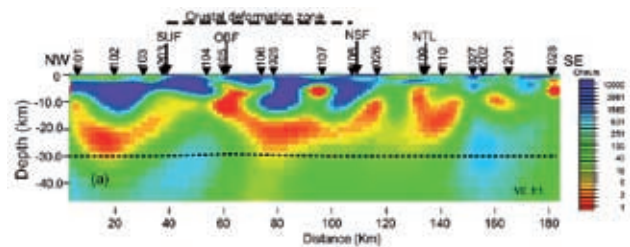


Figure 3.2.2: Resistivity model from the main NNW-SSE profile in eastern Ireland across the Iapetus Suture Zone (see Figure 3.2.1).

#### Publication:

- Rao, C.K., A.G. Jones, and M. Moorkamp, 2007. The geometry of the Iapetus suture zone in central Ireland deduced from a magnetotelluric study, *Physics of the Earth and Planetary Interiors*, in press.

#### Presentations:

- Moorkamp, M., A.G. Jones, and C.K. Rao, 2006. Processing magnetotelluric time series with adaptive filters and neural networks. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Rao, C.K., A.G. Jones, and M. Moorkamp, 2006. Electromagnetic imaging of crustal structure across the Iapetus Suture zone in Ireland. Contributed paper at: 49th Annual Irish Geological Research Meeting, University College Cork, Cork, Ireland, 24-26 February.
- Rao, C.K., A.G. Jones, and M. Moorkamp, 2006. Crustal structure deduced from MT studies across Iapetus Suture zone in Ireland. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Rao, C.K., A.G. Jones, and M. Moorkamp, 2006. A magnetotelluric study across the Iapetus suture zone in Ireland: Preliminary results of 3D forward modelling. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.

### 3.3. PICASSO

A.G. Jones, X. Garcia, and J.-P. Schmoldt, with colleagues from the University of Barcelona and other Iberian and Moroccan universities, plus Dr. R.L. Evans (Woods Hole Oceanographic Institute, U.S.A.) and other U.S., Spanish, and other European scientists



The PICASSO project – for Program to Investigate the Cause of the Alboran-Atlas System convective Overturn – is an international, multi-disciplinary project to study the complex tectonics of the Africa-Europe collision in the western Mediterranean, with attendant east-west extension and possible subduction or delamination beneath the Alboran Sea.

The PICASSO consortium is seeking funding from a variety of sources, including the U.S. National Science Foundation, the European Science Foundation under the aegis of TOPO-Europe/EuroArray, and the individual science foundations of Europe, including a successful proposal to Science Foundation Ireland in January 2006 for Irish participation. Seismological instrumentation will be provided by the IRIS/PASSCAL instrumentation facility, the European instrumentation facility at the German GeoForschungsZentrum Potsdam (GFZ), from a proposal submission to Spanish funding sources, and from individual institutions and national governments, including DIAS's own sixteen (16) broadband portable seismic systems.

Magnetotelluric leadership and instrumentation will be provided principally by DIAS and the MT group at the University of Barcelona (UB), with other European, and possibly U.S., institutions taking part.

An approximate experimental plan for the seismic profiling component proposed to the Continental Dynamics programme of the National Science Foundation in November, 2006, is shown in Fig. 3.3.1. This plan is subject to change depending on the successes of the proposal to the NSF.

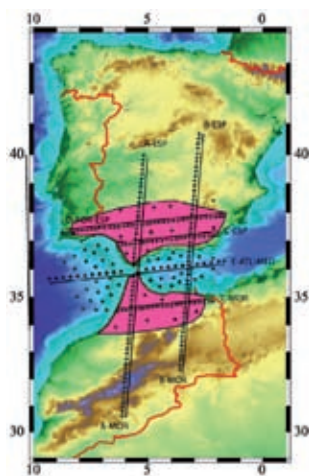


Figure 3.3.1: PICASSO proposed NSF profiles

The MT component being proposed by DIAS and UB involves three inter-related components; (1) acquisition along the main

N-S profile (profile A-ESP and A-MOR in Fig. 3.3.1), (2) acquisition along three new profiles across the Atlas mountains, and (3) acquisition at specific locations across the Betics to complement existing data. Additional ocean-bottom seismic and magnetotelluric measurements are expected to be proposed by appropriate groups in Europe and the U.S.A.

To date, the competition for the studentship resulted with an offer going to Jan-Philippe Schmoldt of Germany, who will finish his Diplom in February, 2007 and join DIAS at that time. A second studentship, funded by a DIAS internal scholarship, will be advertised in Spring, 2007, to start in September, 2007.

The first phase of fieldwork will occur in Autumn, 2007, and is a profile from Madrid to Gibraltar. The second phase of fieldwork, scheduled for Autumn, 2008, is the continuation of this profile into Morocco across the Atlas mountains.

#### Proposals:

- Proposal submitted by Jones to SFI RFP2006 competition to fund an EM component of PICASSO. Proposal funded at a level of €160,000 for 3 years.
- Proposal submitted to the U.S. National Science Foundation for PICASSO involvement by U.S. scientists, including undertaking an EM survey in the Mediterranean (Rob Evans lead).

### 3.4. 3D MT Modelling/Inversion

*D. Avdeev, A. Avdeeva*

In 2006 we have been working on acceleration and validation of the prototype of three-dimensional (3D) magnetotelluric (MT) inversion, which is subject of our ongoing research.

For the period of 1 January - 31 May 2006, we developed a parallel implementation of 3D electromagnetic (EM) modelling solution based on the volume integral equation approach. This forward modelling is an essential part of our inversion. The key time-consuming part of this forward problem solution is the discrete 2D convolution routine. We chose to parallelize this routine, since we demonstrated that another time-consuming part of the solution, calculation of the Green matrices, takes less wall time, especially for large-scale 3D models. To understand to what extent our new implementation improves performance of 3D EM forward modelling code, we compared it with the serial x3d implementation by Avdeev et al. (1997, 2002). On both distributed and shared memory clusters our implementation

allowed the solution to be reasonably accelerated. As an example, acceleration of 7 times was achieved with 16 processors. Further work will be concentrated on adapting this parallel implementation for the 3D EM inversion.

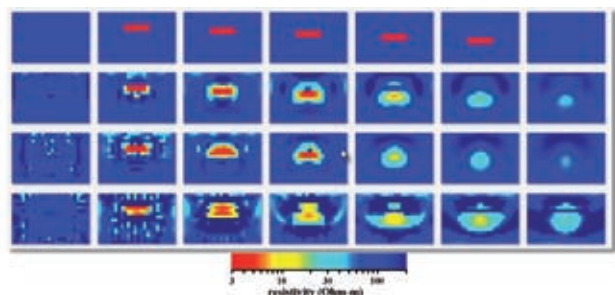


Figure 3.4.1: Results of the inversions. Each row of panels presents seven horizontal (x-y) slices of the model starting from 150 m (left) to 750 m (right) depth (z). 1st row corresponds to the true model; 2nd row – to the result of the inversion with use of the stabilizer and with gradually diminishing regularization parameter; 3rd row – to the result of the inversion when we restart the inversion every 20 iterations and without use of the stabilizer, and the last row corresponds to the result of the inversion without use of the stabilizer, but with limits imposed on conductivities.

From June we have been working, on a validation of the prototype of 3D MT inversion on synthetic datasets. Our 3D MT inverse problem solution is based on a limited-memory quasi-Newton (QN) method with simple bounds. To validate the robustness of this solution we developed various implementations, which differ according to the type of regularization used. The first implementation uses the simple bounds, imposed on the conductivities of the cells, and the second exploits the Tikhonov-type stabilizer with a gradually diminishing regularization parameter. Using these two approaches we invert a realistic synthetic MT impedance dataset calculated for a tilted conductive dyke embedded in a uniform half-space. As can be seen from Figure 3.4.1, the second approach works significantly better, allowing the true model to be recovered from the synthetic dataset much faster. In addition we obtain a smoother final model using this approach.

#### Publications:

- Avdeev, D.B., 2006. 3-D EM forward modeling using integral equations, in *Electromagnetic Sounding of the Earth's Interior*, Ed. V. Spichak, Methods in Geochemistry and Geophysics, **40**, 147–159, Elsevier, Amsterdam.
- Avdeev, D.B., 2006. EM modeling, forward, in *Encyclopedia of Geomagnetism and Paleomagnetism*, Eds. D. Gubbins and E. Herrero-Bervera, Springer.

- Avdeev, D.B., and A.D. Avdeeva, 2006. A rigorous three-dimensional magnetotelluric inversion, *PIER*, **62**, 41-48.
- Avdeev, D.B., and A.D. Avdeeva, Three-dimensional magnetotelluric inversion using a limited-memory QN optimization, *Geophysics* (under second review).
- Avdeeva, A.D., and D.B. Avdeev, 2006. QN inversion of large-scale MT data, in *PIERS 2006 Cambridge Proceedings*.
- Avdeeva, A.D., and D.B. Avdeev, 2006. A limited-memory quasi-Newton inversion for 1-D magnetotellurics, *Geophysics*, **71**, 191-196.

#### Presentations:

- Avdeev, D.B., and A.D. Avdeeva, A rigorous three-dimensional magnetotelluric inversion, PIERS, Cambridge, USA, 26-29 March.
- Avdeev, D.B., and A.D. Avdeeva, 3-D MT inversion using quasi-Newton optimization, International Conference "Tikhonov and Contemporary Mathematics," Moscow, Russia, 19-25 June.
- Avdeev, D.B., and A.D. Avdeeva, 3-D MT inversion: first tests using synthetic data, 18th IAGA WG 1.2 Workshop on Electromagnetic Induction in the Earth, El Vendrell, Spain, 17-23 September.
- Avdeeva, A.D., and D.B. Avdeev, A limited-memory quasi-Newton method for magnetotelluric inversion, IGRM Conference, UCC, Cork, Ireland, 24-26 February.
- Avdeeva, A.D., and D.B. Avdeev, QN inversion of large-scale MT data, PIERS, Cambridge, USA, 26-29 March.
- Avdeeva, A.D., and D.B. Avdeev, A parallel implementation of 3-D EM forward modelling, 18th IAGA WG 1.2 Workshop on Electromagnetic Induction in the Earth, El Vendrell, Spain, 17-23 September.
- Avdeeva, A.D., and D.B. Avdeev, Limited-memory quasi-Newton magnetotelluric inversion as an example of optimization problem in geophysics, Winter Symposium, DIAS, Dublin, Ireland, 14-15 December.



### 3.5 Marine EM

*X. Garcia, A.G. Jones, together with R.L. Evans (WHOI)*

#### 3.5.1. Malin Sea Survey

A marine survey, funded under the Petroleum Infrastructure Program (PIP), was carried out in July in the Malin Sea area. The objectives of the survey were to provide acoustic and electromagnetic data from the Malin Sea for geohazard related studies in a pockmark field. Additionally a groundtruthing programme, using both bottom sampling and video footage, was to be carried out to understand better the nature of these features. Due to the bad weather conditions during the first days of the survey, we also surveyed Lough Swilly (Co. Donegal). A total of thirteen lines of EM data were collected, and in November we held an interpretation workshop at the offices of the Geological Survey of Ireland.

A towed EM system built at the Woods Hole Oceanographic Institution was used to measure the electrical conductivity distribution at a depth of around 20 m below the seafloor along profiles, and thus we are able to provide maps of physical properties and integrate them with other available geophysical and geological data. Measured conductivities are readily transformed into porosities using Archie's law. The presence of gas and changes in sediment facies is expected to increase or decrease the conductivity of the seafloor. To first order, the presence of gas within the sediments framework will act as an electrical insulator, decreasing conductivity (also porosity) by several orders of magnitude. However, the degree to which the bulk conductivity will be increased by the gas phase depends on the gas concentration and how it is distributed between grains. Decreases in conductivity can also be caused by carbonate cementation and pore water freshening.

The towed EM system (TEM) was built at WHOI, but based on a design developed by the Geological Survey of Canada. The system is dragged along the seafloor at speeds of 1-2 knots and makes measurements of the electrical conductivity approximately every 10m along track. The system has a CTD sensor mounted in the transmitter and so provides continuous measurements of bottom water salinity and temperature, which are important as the system traverses regions of fluid expulsion. On board the Celtic Voyager a USBL system was mounted on the transmitter to add accurate (<1 m) positioning of the TEM system.

The raw data collected consists of 3 measurements of magnetic field amplitude and phase on each of three receivers. Data from each receiver are separately converted into apparent porosities

by finding the best fitting equivalent half-space resistivity to the data and converting this value to porosity using an empirical relationship (Archie's law). The three apparent porosity values are essentially averages over different depths of seafloor. The closest receiver is 4m behind the transmitter and averages over about 2m of seafloor. The furthest receiver is 40m behind and provides information to a depth of about 20m. As the system is towed and measurements are made on each receiver, profiles of apparent porosity are built up.

The data were displayed on board in real time as amplitudes and phases of the magnetic fields and also as apparent porosities calculated from the best fitting half-space. EM showed raised apparent porosities as the system was getting into the pockmarks and a decrease of 5 to 10 porosity percentage while the system was within it. Figure 3.5.1.1 shows the apparent porosities measured in the vicinity of pockmark II (its surface expression roughly depicted in black). There is a clear drop of porosities within the pockmark. We have also observed a good correlation between class classification from multibeam and EM porosities. These results will improve as we obtain results from the groundtruthing survey.



Figure 3.5.1.1: Map of apparent porosities showing a zoom around pockmark 2. The black line shows an outline of the pockmark. Top: map of the upper 6 m (13 m receiver). Bottom: map of the upper 20m (40 m receiver).

#### 3.5.2. Galway Survey

The proposal submitted by Prof. Colin Brown (NUIG), Xavier Garcia (DIAS), Rob Evans (WHOI) and Xavier Monteys (GSI) was partially funded. This project will map Galway Bay in an unprecedented way acquiring EM, bathymetry and seismic data, and also collect grab samples, gravity and piston cores,



vibrocores and also water samples. The goals of this survey are twofold: map the Bay to study its glacial history and also map channels responsible for groundwater discharges, an event that can pose serious environmental problems.

Full funding for ship time to acquire geophysical data has been obtained from the INFOMAR project and also has been increased to 5 days. This survey will happen in mid February. The coring will be realized later during the year using the Celtic Explorer, also under the umbrella of the INFOMAR project.

#### Proposals

- Submitted proposal to build towed EM system to the Infomar project (rejected)
- Proposal being prepared that will be submitted to oil companies working in Ireland to carry out an EM survey on the Porcupine basin. The goal is to study the thermal history of the basin and its tectonic origin. This is done in collaboration with Kerry Key and Steve Constable from Scripps and Rob Hardy (TCD).

#### Presentations:

- Garcia, X., A.G. Jones, C. Brown, and X. Monteys, 2006. Update on the development of a marine EM research group in Ireland. Contributed paper at: 49th Annual Irish Geological Research Meeting, University College Cork, Cork, Ireland, 24-26 February.
- Garcia, X., X. Monteys, R. Evans, and B. Kelleher, 2006. Geohazard identification and early reconnaissance for hydrocarbon potential using marine electromagnetic and high frequency acoustic methods. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.

#### Reports:

- Garcia, X., and X. Monteys, 2006. Geohazard identification in the Malin Sea – CV06\_EM\_GEOH – Preliminary interpretation of towed EM data from Malin sea in the vicinity of pockmark 2, December.
- Monteys, X., and X. Garcia, 2006. Geohazard identification in the Malin Sea - CV06\_EM\_GEOH cruise report, August.

### 3.6. Other

#### 3.6.1. Cork EM Survey

*L. Collins, J.E. Spratt, A.G. Jones, with B. Higgs (UCC) and J. Ledo, E. Falgas (U Barcelona)*

In collaboration with B. Higgs (UCC), a Control Source Magnetotelluric (CSMT) survey was carried out in and around the Cork city area in July with the aim to find the depth of buried glacial valleys. The StrataGem Electromagnetic Imaging System was used, on loan from the University of Barcelona. E. Falgas from UB came for the week to work the system. This was the first time this equipment was used in Ireland and it was a learning experience. The initial results look very promising and more processing and analysis needs to be done.

#### 3.6.2. Birr Castle Resistivity Survey

*L. Collins, A.G. Jones, J.E. Spratt*

#### Presentation:

- Collins, L., J.E. Spratt, A.G. Jones, 2006. Looking down to look up. 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.

#### 3.6.3. INDEPTH

*A.G. Jones, J.E. Spratt, together with Professor M. Unsworth (University of Alberta)*

Planning continues for INDEPTH-IV activities. The main phase of fieldwork will now most likely be in Summer, 2008.

#### Presentation:

- Unsworth, M.J., A.G. Jones, W. Wenbo, G. Marquis, S. Gokarn, and B. Denghai, 2006. Crustal rheology of the Tibetan Plateau Inferred from magnetotelluric data. Contributed paper at: Western Pacific Geoscience Meeting, Beijing, 24-27 July.

#### 3.6.4. LEMI-417s

In June the group received delivery of eight long period magnetotelluric systems, LEMI-417s, manufacturer by Dr. Valery Korapanov of the Lviv Centre of Institute of Space Research in the Ukraine. The instruments were acceptance tested in Ireland, then sent to the Helsinki Magnetic Observatory for final calibration in August and September.



Subsequently, four of them were sent to Italy to acquire data as part of a geothermal energy project based in Tuscany led by Dr. Adele Manzella of the Institute of Geosciences and Earth Resources in Pisa. First results from the field processed data are shown in Figure 3.6.4.1, where excellent quality MT responses out to periods in excess of 30,000 s (over 8 hours) were achieved with only two weeks of recording.

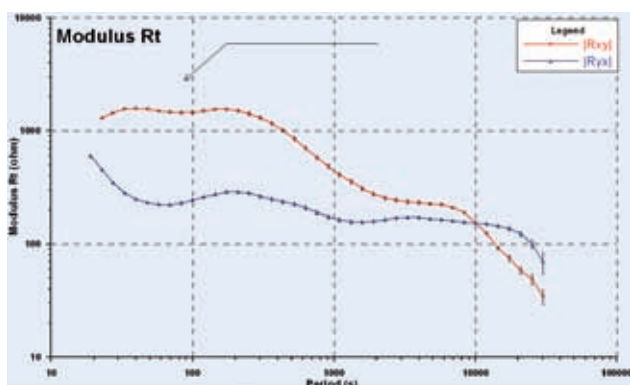


Figure 3.6.4.1: Long period MT data recorded by a LEMI-417 at a site in Tuscany

### 3.6.5. Other and General

#### Research:

- C.K. Rao and X. Garcia, Modelling and inversion of data from the Bhima Basin MT Survey, India.

#### Publications:

- Jones, A.G., 2006. Electromagnetic interrogation of the anisotropic Earth: Looking into the Earth with polarized spectacles. *Physics of the Earth and Planetary Interiors*, **158**, 281-291.
- Jones, A.G. and X. Garcia, 2006. Electrical resistivity structure of the Yellowknife River Fault Zone and surrounding region. In *Gold in the Yellowknife Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project*, published by Geological Association of Canada, Mineral Deposits Division, Special Publication No. 3, Chapter 10, 126-141.
- Queralt, P., A.G. Jones, and J. Ledo, 2007. Electromagnetic imaging of a complex ore body, three-dimensional forward modelling, two-dimensional inversion, sensitivity tests and down-mine measurements. *Geophysics*, in press.

#### Presentations:

- Garcia, X., 2006. *Uses of electromagnetic methods in Ireland*. Presentation to Geological Survey of Ireland.
- Garcia, X., and A.G. Jones, 2006. Processing of AMT data using the Wavelet transform. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Garcia, X., and C.K. Rao. Conductivity images of Proterozoic basin (Bhima), Southern India. 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Jones, A.G., 2006. The Electric Earth: Understanding Earth processes from deep-probing electromagnetic imaging. **Invited** seminar to: South African Geophysical Association, The School of Geoscience, The University of the Witwatersrand, Johannesburg, South Africa, 14 March.
- Jones, A.G., 2006. Information about the Earth from deep-probing electromagnetic studies. **Invited** seminar to: Geological Society of Zambia, Geology Department, University of Zambia, Lusaka, Zambia, 4 April.
- Jones, A.G., 2006. Geophysics in Canada - Quo Vademus? **Invited** dinner address at: Canadian Geophysical Union Annual Meeting, Banff, Alberta, Canada, 14-17 May.
- Jones, A.G., and I.J. Ferguson, 2006. Analysis of POLARIS MT data from the Slave Craton, Northwest Territories, Canada. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.
- Spratt, J., J. Craven and A.G. Jones, 2006. Re-analysis and modelling of MT data from the Nechako Basin, British Columbia, Canada. Contributed paper at: 18th EM Induction Workshop, El Vendrell, Spain, 17-23 September.

#### Proposal:

- Pre-proposal submitted to SFI RFP2007 competition by X. Garcia and A.G. Jones to undertake a detailed AMT/MT/CSMT survey of the unstable flank on the island of La Palma (Canary Islands) accepted for submission as a full proposal.

## 4. Seismological Activities

### 4.1. HADES (Hatton Deep Seismic)

*P.W. Readman, B.M. O'Reilly, C. Ravaut, A. Chabert with Professor P.M. Shannon (UCD)*

Work on the transverse lines across the Hatton Ocean-Continent margin was extended to include analysis of profile P1, located predominantly over oceanic crust. Considerable effort was also directed at assessing the reliability and resolution of the tomography model using a comprehensive set of checkerboard tests and convergence analysis. This was particularly focussed on the lower crust at the ocean-continent boundary where the presence of a lower crustal velocity anomaly appears that it may represent two connected magmatic bodies, one on the ocean side and one on the continental side of the boundary. The seismic velocity model derived from the first-arrival traveltimes inversion for part of profile P1 spanning the Hatton Continental Margin is shown in Figure 4.1.1. As the depth resolution of tomography model extends only to about 15-20 km, the depth to the Moho was defined by a forward modelling approach using PmP arrivals (reflected from the Moho interface) and a velocity model interpolated from the first-arrival traveltimes tomography model.

The model along the axis of the Hatton Basin (Profile P3) shows considerable detail in the sedimentary layers and upper crust with several structural highs separating sedimentary sub-basins. The sedimentary sequence is simpler than that previously determined in the Rockall Trough and the possible reasons for this are being investigated. Three crustal layers are defined consistent with a weaker extension regime than we have determined for the Rockall Trough. The new seismic models are being integrated with other geophysical datasets, in particular vertical seismic reflection recently data collected in the Hatton Basin (involving DIAS/UCD scientists) as part of the Irish National Seabed Survey, and gravity/magnetic data. First publications are being prepared.

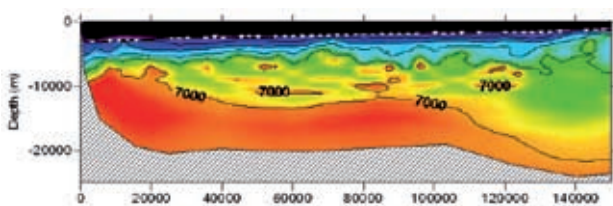


Figure 4.1.1: Seismic velocity section over the Hatton Continental Margin: detail from the first-arrival traveltimes tomography image, HADES Profile P1.

Celine Ravaut spent two weeks in February/March at Laboratoire Géosciences Azur, Villefranche-sur-mer to investigate the possibility of applying full-waveform inversion to the Hades data. The results were promising and future work was planned in collaboration with Stéphane Operto.

#### Presentations:

- Chabert, A., Ravaut, C., Readman, P.W., O'Reilly, B.M., Shannon, P.M. and Gernigon, L. Crustal structure of the Hatton Basin (North Atlantic) from a wide-angle seismic experiment. 49th Annual Irish Geology Research Meeting, Cork, 24-26 February.
- Chabert, A., Ravaut, C., Readman, P.W., O'Reilly, B.M., Shannon, P.M. Crustal structure of the Hatton Basin (Northwest Atlantic) from a wide-angle seismic experiment. European Geosciences Union General Assembly, Vienna, 2-7 April.
- Chabert A., C. Ravaut, P.W. Readman, B.M O'Reilly, P.M. Shannon. Structure et évolution du Bassin d'Hatton (Atlantique Nord) à partir de données de sismique grand-angle et de sismique réflexion. Institut de Physique du Globe de Paris, Congrès des Doctorants (IPGP), Paris, France, 24-27 April.
- Chabert, A., Crustal structure of the Hatton Basin (North Atlantic) from wide-angle and reflection seismic data. British Geophysical Association Post-Graduate Research Meeting, Edinburgh, 31 August - 1 September.
- Chabert, A., Ravaut, C., Readman, P.W., O'Reilly, B.M. and Shannon, P.M. Crustal structure of the Hatton Basin (North Atlantic) from wide-angle and reflection seismic data. American Geophysical Union Fall Meeting, San Francisco, USA, 11-15 December.
- Ravaut, C., Readman, P.W., O'Reilly, B.M. and Shannon, P.M. Quantitative seismic imaging of the crust by frequency-domain full-waveform inversion. 49th Annual Irish Geology Research Meeting, Cork, 24-26 February.
- Ravaut, C., Readman, P.W. Operto, S. O'Reilly B.M. and Shannon, P.M. Wide-angle seismic imaging of the West Hatton Continental Margin: Preliminary results from combined traveltimes and full-waveform inversion. European Geosciences Union General Assembly, Vienna, 2-7 April.



- Ravaut, C., Chabert, A., Readman, P.W., O'Reilly, B.M., Shannon P.M. and Gernigon, L. A Wide-Angle Seismic Study of the Hatton Continental Margin, European Association of Geoscientists and Engineers 68th Conference and Exhibition, Vienna, 12-15 June.
- Readman, P.W., O'Reilly, B.M., Shannon, P.M., Hauser, F., Makris, J., Ravaut, C., Chabert, A. and Gernigon, L. New high-resolution marine wide-angle seismic profiles along the Hatton Continental Margin and in the Porcupine Basin, west of Ireland: a case study. 30th European Seismological Commission Meeting and 13th European Conference on Earthquake Engineering, Geneva, 3-8 September.

#### Reports:

- Ravaut, C., Readman, P.W., O'Reilly, B.M. and Shannon, P.M. Wide-angle seismic profile across the Hatton Continental Margin. Report submitted to the Petroleum Infrastructure Programme.
- Gernigon, L., Shannon, P.M., Readman, P.W. and O'Reilly, B.M. Geological interpretation and synthesis of the Irish and Hatton margins. Report submitted to the Petroleum Infrastructure Programme.
- Chabert, A., Readman, P.W., O'Reilly, B.M. and Shannon, P.M. Wide-angle seismic profile in the Hatton Basin. Report submitted to the Petroleum Infrastructure Programme.

#### Short Course attended:

- A short course (DISC "education days") in London on seismic reflection interpretation given by K. Markfurt (seismic attributes) and E. Robien (migration techniques) was attended by C. Ravaut and A. Chabert during March.

## 4.2. RAPIDS 4 (Rockall and Porcupine Irish Deep Seismic) and PIMS (Porcupine Irish Margins)

*B.M. O'Reilly, P.W. Readman and F. Hauser with Professor P.M. Shannon (UCD)*

The RAPIDS 4 crustal/upper mantle model across the Porcupine Arch was finalised and the results published. A new related project - PIMS (Porcupine Irish Margins) - was started in March. This involves correlating the crustal model developed for the Porcupine Basin flanks in the RAPIDS 4 experiment with the high resolution whole crustal models from the VARNET (Variscan network) experiment in southwest Ireland and the offshore BIRPS

(British Institutions Reflection Profiling Syndicate) deep vertical reflection data. The current work is using data recorded by our land instruments from a recent offshore seismic experiment in the Porcupine Basin to identify and model the intra-crustal reflectors as seen on the VARNET and BIRPS profiles. We have found that the best approach is to use forward ray-tracing techniques because due to the shot-receiver configuration (i.e. sea shots recorded with onshore stations) none of the PIMS-profiles are reversed.

#### Publication:

- O'Reilly, B.M., Hauser, F., Ravaut, C., Readman, P.W. and Shannon, P.M. Crustal thinning, mantle exhumation and serpentinisation in the Porcupine Basin, offshore Ireland: Evidence from wide-angle seismic data. *Journal of the Geological Society, London*, **263**, 775-787.

#### Presentations:

- Hauser, F., O'Reilly, B.M., Readman, P.W. and Shannon, P.M. The RAPIDS4 wide-angle seismic experiment in the Porcupine Basin: Evidence for mantle exhumation and serpentinisation. Irish Geology Research Meeting, Cork, 24-26 February.
- Hauser, F., O'Reilly, B.M., Readman, P.W. and Shannon, P.M. A wide-angle experiment in the Porcupine Basin: Evidence for mantle exhumation and serpentinisation. European Geosciences Union General Assembly, Vienna, 2-7 April.
- Readman, P.W., O'Reilly, B.M., Shannon, P.M., Hauser, F., Makris, J., Ravaut, C. Chabert, A. and Gernigon, L. New high-resolution marine wide-angle seismic profiles along the Hatton Continental Margin and in the Porcupine Basin, west of Ireland: a case study. 30th European Seismological Commission Meeting and 13th European Conference on Earthquake Engineering, Geneva, 3-8 September.
- O'Reilly, B.M. and Readman, P.W. Linkages between Irish and Canadian North Atlantic Basins. A brief presentation to the North Atlantic Petroleum Systems Research Workshop at the Exploring Atlantic Ireland 2006 Conference, Dublin, 8-9 November.

#### Report:

- Hauser, F., O'Reilly, B.M., Shannon, P.M. and Readman, P.W. Wide-angle seismic profile in the Porcupine Basin. Report submitted to the Rockall Studies Group of the Petroleum Infrastructure Programme.

### 4.3. ISLE (Irish Seismological Lithospheric Experiment)

*P.W. Readman, V.C. Do and B.M. O'Reilly with Geophysics staff, and colleagues from the University of Karlsruhe*

Data collection for the ISLE project continued throughout the year. Some stations that had been deployed for more than 2 years were retrieved and several new stations were deployed, primarily in the northwest and southeast of the country to improve the geographical coverage, particularly with a view to further investigations that are planned for the data collected during ISLE. Further analysis of the SKS/SKKS splitting results confirmed the preliminary results by a more thorough search and assessment of suitable events, extending back to 1994 and 1998 for the permanent stations DSB and VAL respectively. The variation with back-azimuth cannot be explained by any reasonable model that confines the anisotropy to the upper 200 km of mantle and we conclude from further Fresnel zone considerations that there is a deep source in the oceanic (Atlantic) mantle.

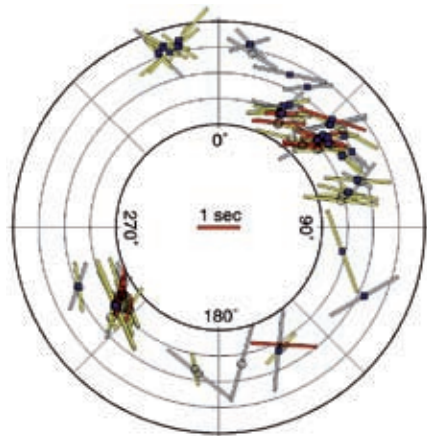


Figure 1.3.1: Some shear-wave splitting results from the ISLE project. Vectors show fast polarization directions with length proportional to delay times, plotted at true epicentral source distances (outer circle is 160o) and back-azimuths. Note the major difference in directions from east Asia (at ~45o) and South America (~230o).

The results (Figure 4.3.1) indicate that the anisotropy within the crust and mantle of the western Eurasian plate is considerably more complex than previously thought, and the project has raised new questions. The possible contribution to the observed anisotropy from the crust was investigated using our previously collected data from a controlled source wide-angle seismic experiment in southwest Ireland (VARNET – VARiscan NETWORK). The results clearly indicate that the contribution from the crust, using the S<sub>g</sub> phase for the upper crust and S<sub>mS</sub> for the

lower crust is relatively minor (delay times up to 0.2 s at most, compared to 1.2 s from the splitting measurements).

Collaboration with our Karlsruhe colleagues on the receiver function study has continued with further work on the S-to-P receiver functions being brought to publication stage. Collaboration with NUI Galway was initiated to investigate joint inversion of teleseismic arrival times and gravity data. A student at Galway will develop code, written by Christel Tiberi (Université de Paris 6), that has been used in a project in the Baikal rift zone. The method has the potential to increase the resolution and refine the results of a tomographic inversion alone.

Van Chuong Do completed his PhD in September 2006.

#### Publications:

- Do, V.C., Readman, P.W., O'Reilly, B.M. and Landes, M. 2006. Shear-wave splitting observation across southwest Ireland, *Geophysical Research Letters* **33**, L03309, doi: 10.1029/2005GL024496.
- Landes, M., Ritter, J.R.R., O'Reilly, B.M., Readman, P.W. and Do, V.C., 2006. A N-S receiver function profile across the Variscides and Caledonides of SW Ireland. *Geophysical Journal International*, **166**, 814-824.
- Landes, M., Ritter, J.R.R. and Readman, P.W. 2007. Proto-Iceland Plume caused by thinning of Irish lithosphere. *Earth and Planetary Science Letters*, in press.

#### Thesis:

- Do, V.C. A study of seismic anisotropy in Ireland. PhD dissertation submitted to University College Dublin.

#### Presentations:

- Do, V.C., Readman, P.W. and O'Reilly, B.M. Deep-source anisotropy revealed from shear-wave splitting measurements in southwest Ireland. Irish Geology Research Meeting, 24-26 Cork, February.
- Do, V.C., Readman, P.W., O'Reilly, B.M. and Hauser, F. Investigation of crustal and upper mantle anisotropy in southeast Ireland using teleseismic shear-wave splitting and onshore refraction data analysis. Workshop meeting on Seismic anisotropy and geodynamics of the lithosphere-asthenosphere system, T\_e\_t, Czech Republic, 17-21 June.



- Do, V.C., Readman, P.W. and O'Reilly, B.M., Deep-source anisotropy revealed from shear-wave splitting results from southwest Ireland. 30th European Seismological Commission Meeting and 13th European Conference on Earthquake Engineering, Geneva, 3-8 September.

#### Proposal:

- Pre-proposal submitted to SFI RFP2007 competition by P.W. Readman to apply advanced receiver function methods to the ISLE dataset was accepted for submission as a full proposal.

#### 4.4. EAGLE (Ethiopian-Afar Geoscientific Lithospheric Experiment)

*B.M. O'Reilly with G.R. Keller (UTEP) and P.K.H. Maguire (University of Leicester) and the EAGLE Working Group*

The paper on the crustal and upper mantle structure of the Northern Main Ethiopian Rift using the tomographic and forward modelling methods appeared in a Special Publication of the Journal of the Geological Society, London. The paper presents results from the EAGLE controlled source seismic experiment and provides an interpretation of crustal and upper mantle models, derived using forward and tomographic modelling techniques. The magmatic and geodynamic implications for understanding the development of an embryonic volcanic continental margin, currently undergoing lithospheric breakup, south of the Afar triple junction are discussed in detail. The results have an important bearing in understanding the processes that have caused lithospheric processes globally.

#### Publication:

- Maguire, P.K.H., Keller, G.R., Klemperer, S.L., Mackenzie, G.D., Keranen, K., Harder, S., O'Reilly, B.M., Thybo, H., Asfaw, L. and Amha, M. 2006. Crustal structure of the Northern Main Ethiopian Rift from the EAGLE controlled survey; a snapshot of incipient lithospheric breakup. In: Yigu, G., Ebinger, C.J. and Maguire, P.K.H. (eds) *The Afar Volcanic Province within the East African Rift System*. Geological Society, London, Special Publications 29, 269-291

#### 4.5. TRIM (TOBI Rockall Irish Margins)

*B.M. O'Reilly and P.W. Readman with P.M. Shannon and G. Elliot, University College Dublin*

Analysis of the TRIM TOBI (Towed Ocean Bottom Instrument) data from the eastern side of the Rockall Trough continued during 2007 in collaboration with colleagues in the School of Geological Sciences at UCD to study, in particular, the development of major submarine canyon systems (Figure 4.5.1) and their development, and sedimentation processes. Slope failure features, submarine turbidite fan systems and bottom current processes in the northeast Atlantic were compared with similar features found elsewhere in the North Atlantic region (i.e. the UK Norwegian and Labrador margins). Global palaeoclimate change from the late Pleistocene to the current Holocene period was concluded to have been the main forcing mechanism in instigating major episodes of submarine fan sedimentation during glacial periods, rather than crustal tectonics. Along-slope bottom current processes prevailed during climatically warmer periods when the main North Atlantic thermohaline circulation system was strongest. One paper was published, and another is in press describing this work.



Figure 4.5.1: Example of TOBI interpretation from the eastern side of the Rockall Trough, showing two large canyon systems. Red lines indicate canyon axes and ridges and green areas indicate sediment aprons.

**Publications:**

- Elliot, G.M., Shannon, P.M. Haughton, P.D.W., Praeg, D. and O'Reilly, B.M. 2006. Mid- to Late Cenozoic canyon development eastern margin of the Rockall Trough, offshore Ireland. *Marine Geology* 229, 113-132.
- O'Reilly, B.M., Readman, P.W. and Shannon P.M. 2007. Shelf to slope sedimentation processes in the northeast Atlantic, off NW Ireland, and the impact of Plio-Pleistocene glaciations. *Marine Geology*, in press.

**4.6. Seismic Network and Irish Earthquakes**

*T. Blake, G. Wallace, C. Horan, L. Collins*

**4.6.1. DIAS Network**

DIAS initiated - and is funding when possible - the ad hoc development of a regional seismic network since 1978. A supplementary budget is now required if the network is to be developed to acceptable international standards. From an already failing seismic network DIAS continues to supply important waveform data to the international seismological community. DIAS personnel collect the data disk every week.

The DIAS Regional Seismic Network records seismic events (local, regional and teleseismic earthquakes), quarry blasts and other supersonic events. All earthquake parameter data recorded is shared internationally with our seismological partners through the International Seismological Commission (ISC) and with our European partners at The European and Mediterranean Seismological Centre (EMSC).

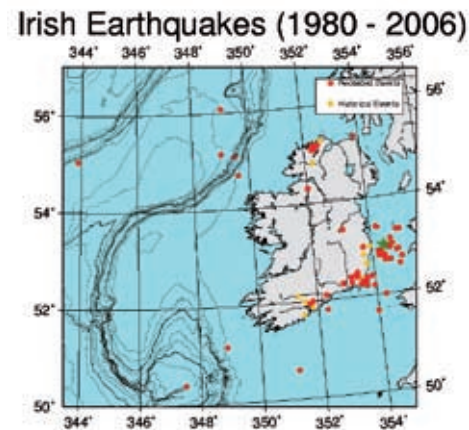


Figure 4.6.1.1

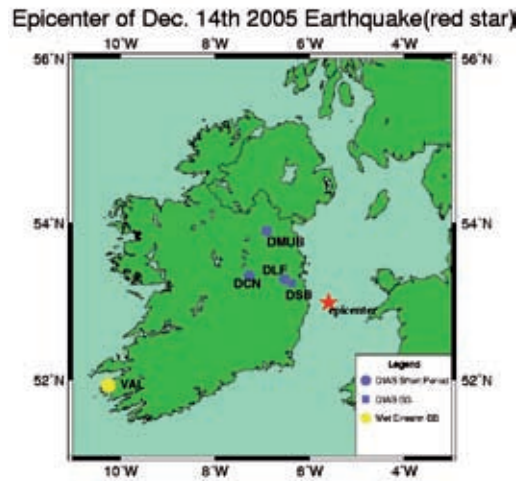


Figure 4.6.1.2

Figure 4.6.1.1 shows the instrumentally recorded earthquakes (red dots) and the historical earthquakes (from folklore, and manuscripts, yellow dots) that have occurred in and around Ireland up to the end of 2006. Figure 4.6.1.2 is a map of the Regional DIAS Seismic Network and the location of the earthquake off Wicklow Head in Dec 14th 2005 which measured 2.8 ML Local Magnitude on the Richter Scale. Figure 4.6.1.3 shows the regional events recorded by the seismic array from January-November, 2006.

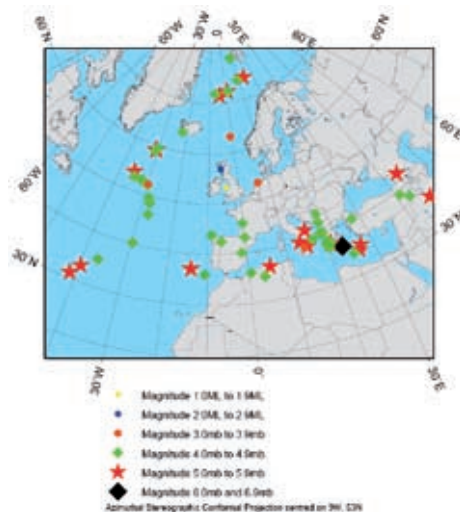


Figure 4.6.1.3: Regional events (out to 30° radial distance) recorded by the seismic network from January-November, 2006.



#### 4.6.2. DSB

Waveform data quality from DSB (the German GeoFON station operated by DIAS) continued to be good and the data are archived in both GFZ Potsdam and in DIAS. Data are downloaded directly to GFZ via 56k modem and are available via internet usually within an hour (although this has on occasion been over two hours). The data can be seen online at this address: [http://www.gfz-potsdam.de/geofon/gfn\\_liveseis.html](http://www.gfz-potsdam.de/geofon/gfn_liveseis.html). DIAS personnel collect the DAT tape of the data every 4 weeks.

Figure 4.6.2.1 is a seismogram of the largest earthquake recorded by our seismic station DSB in 2006. This earthquake occurred in the Kuril Islands region of the North Pacific on Nov 15th and measured 8.3 Magnitude on the Richter Scale.

Ongoing discussion took place during the year as to how best download data from DSB in realtime. Such options as satellite, fibre optic and wireless were discussed. There was a systems failure with the hard disk at station DSB. This was replaced by GEOFON with the latest model SEISCOMP, a data communication module for data download. This has been working satisfactorily since its installation.

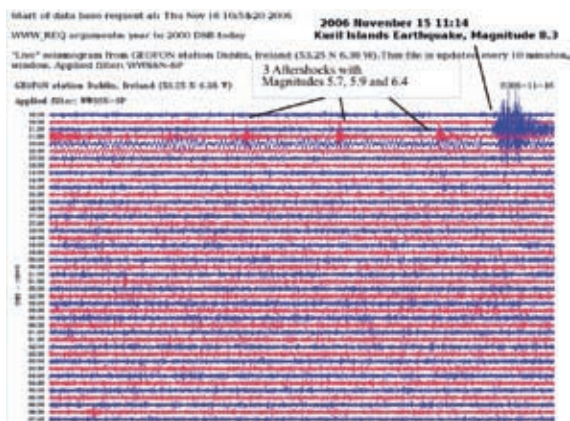


Figure 4.6.2.1: Largest earthquakes recorded in 2006 by DSB

#### 4.6.3. VAL

The development of the seismic recording station VAL in Met Eireann Observatory in Valentia, Co Kerry, was discussed during the year. It is intended that the data transfer from station Val will be upgraded to online realtime data transfer in the near future. Application has been made to Telecom Eireann to install a broadband connection to facilitate this development.

A Memorandum of Understanding was signed between the Section and Met Eireann outlining future seismological cooperation between DIAS and Met Eireann for the Valentia station.

#### 4.6.4. NEAMTWS

Discussions were held with GSI regarding our participation in the North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS), and the Irish Government's tsunami warning system initiative. GSI is the Irish representative in this group which represents among other aspects, DIAS' interests in monitoring, on a continuous, real-time basis, seismological and other geophysical data in an array across the whole island of Ireland.

##### Short Course:

- SeismicHandler Software: One day Short Course presented by Dr. Klaus Stammler of Erlangen Seismic Observatory on 29 October. DIAS and Irish academic attendees.

##### Public Outreach:

- Article published in Irish Times by Alison Healy on Call for Irish tsunami warning system describing DIAS's attempts to have established an Irish National Seismic Network, 231 January.
- Information and seismograms of December 04 Sumatra and recent Pakistan events were sent to all ISLE station minders and landowners. Information and seismograms of December 04 Sumatra event were also sent to the manager of Kerry Geopark Project.
- T. Blake presented a lecture to transition year students at Loreto College, Crumlin, entitled "Earthquakes in Ireland, how and why we record them", 18 May.
- T. Blake was interviewed by RTE Radio and Radio FM104 regarding tsunamis and their possible effects on Ireland. He also did radio interviews for Local Radio in Donegal and BBC Northern Ireland regarding earthquakes in and around Ireland.

##### Publications:

- Beazley, T., Reading our Shaking Earth, Into the Premier Division, Science Spin, **18**, 23-25.
- Blake, T.A., 2006. Measuring Irelands Earthquakes, Irish Mining and Quarrying Society Journal, Extractive Industry Ireland, 78-81.



## 4.7 Other

### Robert Mallet:

- Meetings took place with colleagues from Italy and the Italian Embassy in Ireland regarding the plans to celebrate in 2010 the bicentenary of the birth of Robert Mallet a famous Irish scientist and engineer. These meetings coincided with the official launch in the Italian Embassy in Dublin of a 2 volume book by Dr Graziano Ferrari on the work of Robert Mallet on the Great Neapolitan Earthquake of December 1857.

### Proposal submissions:

- Pre-proposal submitted by P.W. Readman to the SFI RFP2007 competition: "Lithospheric and upper mantle anisotropy structure around Ireland from receiver function studies" accepted for submission as a full proposal.
- Pre-proposal submitted by P.W. Readman to the SFI RFP2007 competition: "Forward modelling and inversion techniques for large high-resolution wide-angle seismic datasets" not accepted for submission as a full proposal.
- Pre-proposal submitted by B.M. O'Reilly to the SFI RFP2007 competition: "The hypothesis of kinematic coherence within the Mesozoic extensional basin system in the North Atlantic and its implications for styles of deformation" not accepted for submission as a full proposal.
- Pre-proposal submitted by B.M. O'Reilly to the SFI RFP2007 competition: "Seismic investigations of the Convective Alboran Sea Overtun System" not accepted for submission as a full proposal.

### Presentation:

- V. Raileanu, J. Ritter, M. Radulian, M. Martin, A. Bala, F. Hauser, M. Popa and C. Ionescu. Crustal and lithospheric structure within and around the Vrancea seismogenic zone, Romania. European Geosciences Union (EGU) General Assembly 2005, Vienna, Austria, 2-7 April.

### IRCSET fellowship:

- Problems raised by the Departments of Education and Finance with IRCSET Postdoctoral fellowships awarded to the Institute continued from September 2005 through to October 2006. Celine Ravaut had been awarded a fellowship beginning in October 2005 to study "Quantitative seismic

imaging of the Hatton Continental margin using frequency-domain full-waveform inversion" working with P.W. Readman and B.M. O'Reilly in collaboration with Géosciences Azur in Nice, France and with members of Cosmosgrid group. Unfortunately as a result of these difficulties she finally decided to take up another research position in Norway.

## 5. Geodynamic Modelling

*T. Yamasaki, J. Sheehan, B.M. O'Reilly and P.W. Readman*

There has been further study of grain-size-related rheological weak zones as a possible controlling influence on the mode of lithospheric extension, and a paper describing some of this work was completed and published during the year. Localized deformation in volcanic passive margins brought about by magmatic underplating has also been investigated, particularly in relation to the conjugate volcanic passive margin in the northeastern Atlantic, Vøring and northeastern Greenland margins. Apparent inward deformation migration has been observed in these margins. The prior numerical model has successfully reproduced outward migration of deformation associated with the thermal cooling in the deformed region. However, magmatic underplating model proposed in this study can predict the inward migration of localized deformation, depending on the initial crustal structure, extensional velocity, and the features of underplating (see Fig. 5.1). This study is being prepared to submit the special volume of the Geological Society of London. The TEKTON code was parallelized by John Sheehan, but the increase in computational speed by about a factor of 2-3 was somewhat disappointing. A finite element routine to solve the heat advection/diffusion equation is being developed and will be fully coupled with the evolving strain field. A visit to Vrije University, Amsterdam was made in October to establish a collaboration with the long established Analogue and Computational Modelling Groups led by Sierd Cloetingh and Dimitrios Sokoutis. A plan was formulated for longer visits of 1 and 3 months by Tadashi Yamasaki and John Sheehan to carry out analogue modelling experiments relevant to the development of the entire North Atlantic. Additional cooperation and sharing of expertise will involve numerical modelling of rheological effects applied to the North Atlantic region and Central Europe (Transylvanian and Pannonian Basins). During October Tadashi Yamasaki and John Sheehan attended a 2-day course given by the Netherlands Research School of Sedimentary Geology on the fundamentals of Analogue Modelling.

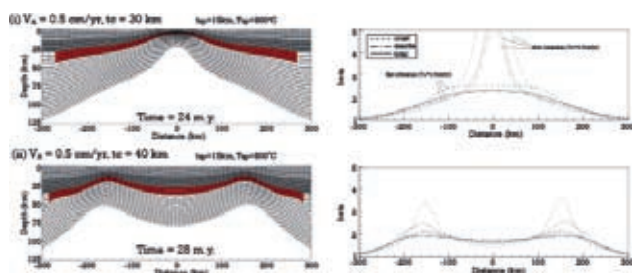


Figure 5.1: Deformed grids of finite element model including magmatic underplating with the thickness of 15 km and temperature of 800 deg, and stretching factors of crust and mantle. Extensional velocity  $V_x$  is 0.5 cm/yr. The initial crustal thickness is (i) 30 km and (ii) 40 km, respectively.

#### Publications:

- Yamasaki, T., O'Reilly, B.M. and Readman, P.W., 2006. A rheological weak zone intensified by the post-rift thermal relaxation as a possible origin of strain localization associated with the reactivation of rifting. *Earth and Planetary Science Letters*, **248**, 119-131.
- Yamasaki, T., 2007. Role of strain hardening in cessation of rifting at constant tectonic force. *Earth and Planetary Science Letters*, in revision.

#### Presentations:

- Sheehan, J., Rheology and the Porcupine Basin. Irish Geology Research Meeting,, Cork, 24-26 February.
- Yamasaki, T. and Gernigon, L. Style of lithospheric extension influenced by magmatic underplating. European Geosciences Union General Assembly, Vienna, 2-7 April.
- Yamasaki, T. Extensional deformation of the lithosphere controlled by the rheological heterogeneity prior to and/or during extension. 2nd CSAG Workshop, Vrije University, Amsterdam, 9-10 November.
- Yamasaki, T. and Gernigon, L. Magmatic underplating as a possible origin of deformation localization during lithospheric extension. American Geophysical Union Fall Meeting, San Francisco, 11-15 December.

## 6. Collaboration with Wider Research Community

### 6.1. Visits to other Laboratories by Section Members

- Professor Alan Jones, one week at the University of Barcelona hosted by Professors Juanjo Ledo and Pilar Queralt, 21-27 February.
- Dr. Celine Ravaut, two weeks at Laboratoire Géosciences Azur, Villefranche-sur-mer, February-March.
- Mr. Mark Hamilton, one month at Woods Hole Oceanographic Institution hosted by Dr. Rob Evans, 3 May – 1 June.
- Dr. Brian O'Reilly, Dr. Tadashi Yamasaki and Mr. John Sheehan, one week at Vrije University, Amsterdam, hosted by Professors Sierd Cloetingh and Dimitrios Sokoutis, 19-22 June.
- Mr. John Sheehan, seven weeks at Vrije University, Amsterdam, hosted by Professors Sierd Cloetingh and Dimitrios Sokoutis, 12-13 October and 14 November - 22 December.
- Dr. Tadashi Yamasaki, 6 weeks at Vrije University, Amsterdam, hosted by Professors Sierd Cloetingh and Dimitrios Sokoutis, 11 October – 17 November.
- Mr. Max Moorkamp, one month at the University of Western Ontario hosted by Professor David Eaton (Honorary Professor at the School of Cosmic Physics), November-December.

### 6.2. Visitors to the Section

- Dr. Franz Hauser, January - February.
- Dr. Celine Ravaut, January - September.
- Professor Tetsuzo Seno, Earthquake Research Institute, University of Tokyo, 12-14 July.
- Christel Tiberi, Dr. Eve Daly and Mr. J-P O'Donnell to discuss possible collaboration, 28 August.
- Dr. Klaus Stammler, Erlangen Seismic Observatory, 27-30 September.
- Mr. J.-P. O'Donnell, NUI Galway, 1-27 October.

- Mr. Jim Craven, Geological Survey of Canada, Ottawa, 27-29 September.
- Dr. Chris Hatton, De Beers, Johannesburg, South Africa, 16 October – 5 November.
- Dr. Sue Webb, U. Witwatersrand, Johannesburg, South Africa, 16-19 October.
- Professor David Thomson, Queen's University, Kingston, Ontario, Canada, 23-27 October.
- Professor Ron Clowes, University of British Columbia, Canada, 9-12 November.

### 6.3. Other Collaborative Activities by Section Members

- A new collaboration with Professor Sierd Cloetingh and his group at the Vrije University, Amsterdam, was initiated to work on analogue/numerical modelling of lithospheric-scale tectonics.
- Collaboration with the University Karlsruhe continued on the analysis of receiver functions and tomography from the ISLE data. We also collaborated in a research grant application to Deutsche Forschungsgemeinschaft for a seismic/gravity investigation on S-type granites.
- Cooperation with Stéphane Operto (Laboratoire Géosciences Azur, Villefranche sur mer) was started by Celine Ravaut on the further development and application of full waveform inversion code to our offshore seismic data. Depending on the success of a current grant application we hope that this will continue, along with continued collaboration with Celine Ravaut, now at Sintef, Norway.
- Collaboration with Eve Daly and J.-P. O'Donnell from the School of Earth and Ocean Sciences, NUI Galway, was initiated to investigate joint inversion of teleseismic arrival times and gravity data.
- Collaboration with Professor Pat Shannon at UCD continued with sidescan sonar and offshore seismic studies.
- Collaboration with University of Texas at El Paso (Randy Keller) and University of Leicester (Peter Maguire) was continued on the EAGLE data.
- Collaboration with Dr. Bettie Higgs from University College Cork and Ester Falgas from University Barcelona was initiated to carry out a Control Source Magnetotelluric (CSMT) survey to find buried glacial valleys in and around the Cork city area. We plan to continue this activity in 2007 since initial results look very promising.
- Collaboration initiated between the MT groups in Ireland (DIAS), Spain (University of Barcelona) and Italy (Institute of Geosciences and Earth Resources in Pisa). Under this Irish-Spanish-Italian MT (ISI-MT) collaboration plans are being made for a survey of Sicily in Spring, 2007.

## 7. Public Outreach

- Article published in *Irish Times* by Alison Healy on *Call for Irish tsunami warning system* describing DIAS's attempts to have established an Irish National Seismic Network, 23 January.
- Article published in *Irish Times* by Dick Ahlstrom on *Crust in Carpathians thinnest on Continent* describing TOPO-Europe and the research work of the School's 2006 Statutory Public Lecturer, Professor Sierd Cloetingh, of Vrije University, Amsterdam (Netherlands), 11 May.
- Information and seismograms of December 04 Sumatra and recent Pakistan events were sent to all ISLE station minders and landowners. Information and seismograms of December 04 Sumatra event were also sent to the manager of Kerry Geopark Project.
- T. Blake presented a lecture to transition year students at Loreto College, Crumlin, entitled "Earthquakes in Ireland, how and why we record them", 18 May.
- T. Blake was interviewed by RTE Radio and Radio FM104 regarding tsunamis and their possible effects on Ireland. He also did radio interviews for Local Radio in Donegal and BBC Northern Ireland regarding earthquakes in and around Ireland.

## 8. Training Undertaken

- First Aid Course, Red Cross, Johannesburg, South Africa, 15-16 February: M. Muller.
- Summer of Applied Geophysical Experience (SAGE), New Mexico, USA, 21 June - 13 July : M. Miensopust.
- Webmaster Course, Dublin, 20 March to 8 September: L. Collins.



- LEMI-417 design and operation course, 9-17 June: G. Wallace.
- WinGLink training course, Milan, Italy, 20-22 November: X. Garcia, M. Miensopust, M. Muller.

## 9. Short Courses/Workshops

- SAMTEX Workshop on MT Data Modelling: 17-19 October. Attendees came from Ireland, U.K., and South Africa.
- *SeismicHandler Software*: One day Short Course presented by Dr. Klaus Stammler of Erlangen Seismic Observatory on 29 October. DIAS and Irish academic attendees.
- *African Geodynamics*: Two day Short Course presented by Professor Colin Reeves of International Institute for Geo-Information Science & Earth Observation (ITC), Netherlands, on 28-29 November. Academic, government and industry attendees came from Ireland, U.K., and South Africa.

## 10. Miscellanea

### L. Collins

- Webmaster, MTNet ([www.mtnet.info](http://www.mtnet.info))

### X. Garcia

- Presented lecture on electrical and electromagnetic methods to undergraduate students at Trinity College Dublin.
- Advisor on Marine EM methods to Providence Resource, Inc.
- Webmaster, MTNet ([www.mtnet.info](http://www.mtnet.info))

### A.G. Jones

- Editorial Board, *Earth, Planets & Space*.
- Associate Editor, *Journal of Geophysical Research*.
- Acting Editor, Special issue of *Physics of the Earth and Planetary Interiors* devoted to Continental Anisotropy.
- Adjunct Professor, Syracuse University, Syracuse, NY, USA.
- Adjunct Professor, Queen's University, Kingston, Ontario, Canada.
- Adjunct Professor, NUI Galway, Ireland.
- Visiting Professor, Trinity College Dublin, Ireland.

- Honorary Professor, University of Leicester, UK.
- Visiting Scientist, Geological Survey of Canada.
- Member, Committee of Heads of Irish Earth Science Institutes.
- Webmaster, MTNet ([www.mtnet.info](http://www.mtnet.info))

### M. Muller

- Honorary Research Associate, University of the Witwatersrand, Johannesburg, South Africa.

### B.M. O'Reilly

- Member, Editorial Board, *Irish Journal of Earth Sciences*.
- Member, Intermargins Steering Committee.

### P.W. Readman

- Member, Consultative Committee of the Geological Survey of Ireland.
- Titular Member, European Seismological Commission.
- Member, Marine Institute Third Level Liaison Committee.
- Research Associate, UCD

# School of Theoretical Physics

## 1 Report on Research Work

### 1.1 Work by Senior Professors and Collaborators

#### 1.1.1 Anderson Localisation and Nanotubes

(T.C. Dorlas, J.V. Pulé & C. Dobrovolny)

The collaboration with Prof. Joe Pulé (UCD) and Christophe Dobrovolny on Anderson localisation in an armchair nanotube was finally completed. Pastur's method as extended by Schulz-Baldes to quasi one-dimensional systems was used, to compute the two lowest Lyapunov exponents of the armchair nanotube, to second order in the disorder strength. This work will be published in the proceedings of the conference in honour of the late Professor John Lewis, [06-10].

#### 1.1.2 Bose-Hubbard Model With Disorder

(T.C. Dorlas, L. Pastur & V. Zagrebnov)

The Bose-Hubbard model, first introduced by Fischer et al. in 1987, is currently very popular for describing Bose-Einstein condensation in an optical lattice.

A long-range-hopping version of this model was solved completely a few years ago, together with J.B. Bru. Last year a study of the same model but with disorder was initiated in a collaboration with Leonid Pastur (Kharkov) and Valentin Zagrebnov (Marseille). Again, a variational expression for the pressure can be derived. A detailed analysis of this expression in a variety of cases has revealed interesting new behaviour due to the disorder. In particular it was found that, in contrast with the free Bose gas, where the disorder enhances condensation, in this model the disorder can suppress condensation at and near certain fractional densities. On the other hand, the suppression of condensation at integer densities in the absence of disorder can be lifted. The figure illustrates some of these phenomena. It represents the critical inverse temperature as a function of the density for several values of the disorder parameter.

This work has been completed this year, and was published in [2].

#### 1.1.3 Large Deviations For Random Walks

(T.C. Dorlas & S. Adams)

The Feynman-Kac representation of Bose gas on a lattice with interaction expresses the pressure in terms of an expectation w.r.t. a symmetrised collection of random walks. The corresponding measure has been little studied (an exception is a paper by T.C. Dorlas a few years ago, but that was more limited in scope). A number of large deviation results for this measure was proven. This may have applications to certain models of a Bose gas. The result proved in an earlier paper is derived as a special case. These results are reported in [06-16] and have been submitted to Ann. Henri Poincaré.

#### 1.1.4 Quantum Coding

(T.C. Dorlas, N. Datta & C. Morgan)

Work on quantum coding theory in collaboration with Dr. Nilanjana Datta (Cambridge) has progressed significantly this year. A new proof of the Holevo-Schumacher-Westmoreland theorem (analogue of Shannon's channel coding theorem) was found which uses a quantum version of the Feinstein lemma. This work was presented (by N.D.) at the 2006 IEEE International Symposium on Information Theory in Seattle [06-02]. It was published in the proceedings [29]. This work led to the group considering an extension of this theorem to channels with memory. The extension to channels with short-term memory is technical but straight-forward. However, we discovered that this had already been done by Kretschmann and Werner, using different methods. A class of examples of channels with long-term memory was then considered. The simplest such class has the form:

$$\mathbb{C}^{(n)}(\frac{1}{2}(n)) =$$

$$\prod_{i=1}^n \mathbb{C}^{(i)}$$

$$\mathbb{C}^{(i)}$$

$$\mathbb{C}^{(i)}(\frac{1}{2}(n));$$

where the  $\mathbb{C}^{(i)}$  are completely positive maps  $\mathbb{C}^{(i)} : B(H) \rightarrow B(K)$  and



$f_i > 0$  with  $\sum_{i=1}^P f_i = 1$ . It was proven that the capacity of this type of channel is given by

$$C(\mathcal{C}) = \sup$$

$$\sum_{j \in H} p_j \log \frac{1}{p_j}$$

$$\text{subject to } \sum_{j \in H} p_j = 1,$$

where the supremum is over all finite ensembles  $\{p_j\}_{j \in H}$  of states  $|j\rangle$  on  $H$  with probabilities  $p_j$ , and  $\mathcal{C}$  denotes the Holevo quantity. This work has been submitted [06-15]. Work on more general channels with long-term memory is in progress.

Together with a Ph.D. student (Ciara Morgan) the Holevo expression for the capacity of a memoryless channel is being studied more closely. We were able to cast it in a different form involving a supremum over measures. This suggests links with Statistical Mechanics which will be further investigated. Work also started on calculating an explicit expression for the capacity of the amplitude-damping channel.

### 1.1.5 Quantum Entanglement

(T.C. Dorlas & A. Guesquiere)

Together with another Ph.D. student (Anne Guesquiere) a study has been undertaken of the decay of entanglement of two particles, initially in a Gaussian entangled state, due to the interaction with a heat bath. This work is in progress.

### 1.1.6 The Asymmetric Exclusion Process

(T.C. Dorlas & V.B. Priezzhev)

The collaboration with V. B. Priezzhev concerning the exact solution of this model on a ring was continued. The model had been solved previously on an infinite line by Schütz, but for the understanding of the approach to equilibrium the ring geometry is more appropriate. Previously, Priezzhev had introduced a modification of the Bethe Ansatz method which allows an exact solution of the problem on a ring. However, the resulting equations are rather complicated and it is not a straightforward exercise to derive explicit expressions for physical quantities from these. In fact, even the simple fact that the total probability of all configurations at time  $t > 0$  equals 1, is not trivial to prove. This normalisation of the total probability was proved last year. The Bethe Ansatz expression for the probability that the last particle reaches the end of the interval in time  $t$  given an initial configuration where all  $P$  particles are

positioned in the first  $P$  sites of the lattice was evaluated. The asymptotics of this expression were analysed. The result was reported in [06-34] last year. The referees pointed out that the resulting expression can in this specific case in fact be calculated more easily. We verified this claim and also corrected some mistakes in the asymptotic analysis. The paper will shortly be resubmitted.

### 1.1.7 Bethe Ansatz

(T.C. Dorlas)

An SFI grant was secured for the study of the Bethe Ansatz solution of quantum spin models, in particular the Heisenberg spin chain. This solution (first obtained by Bethe in 1931) involves a number of assumptions which have not been proven, the most intriguing of which being the 'string hypothesis'. This says that the solutions of the Bethe Ansatz equations occur in sets of  $n$ -tuples of complex numbers with equal real parts in the thermodynamic limit. It is proposed to reformulate the Bethe Ansatz equations directly in this limit in the form of a single nonlinear equation for a set of measures. This was successfully done in the case of the nonlinear Schrödinger model, but the case of the Heisenberg chain is much more difficult.

### 1.1.8 Integrable Quantum Field Theories

(W. Nahm, D. Zagier & S. Ni Chiagáin)

Two-dimensional integrable theories have gotten new importance because of a surprising connection with string theory. Strings on Anti-de-Sitter space are classically integrable, and accumulated evidence suggests that this integrability persists after quantisation. Moreover, AdS/CFT duality relates the corresponding string spectrum to the scaling dimensions of gauge theory operators. In perturbation theory, the latter are related to energy levels in an integrable lattice model. In spite of the integrability, a complete solution is not yet in sight however, even though there have been several hundred publications in this area. One probably must find a new mathematical structure for systems of finite size which generalises the Yangian symmetry of infinitely extended systems.

When the size of a compactified integrable system tends to zero, one often finds a conformally invariant theory. My major observation was that the generalised Yangian symmetry should survive in this limit. This led to a precise mathematical conjecture relating algebraic K-theory and modular forms. In collaboration with Don Zagier, director of the Max-Planck-

Institute for Mathematics at Bonn, this idea passed extensive testing in 2006. Zagier now refers to it as Nahm's conjecture, which in mathematical parlance means that it has an excellent chance of being true. Zagier and I had given related talks at a Les Houches Winter School in 2003. After inclusion of much of the new material, our contributions are due to be published by Springer in: *Frontiers in Number Theory, Physics and Geometry*, P. Cartier et al. eds. Unfortunately, some important material could not be included due to publication deadlines.

The PhD thesis of my student Sinead Ni Chiagain concerns the same topic. She handed in her thesis in December. Zagier agreed to be external examiner and a student of Zagier who also works on these problems will probably accept a position at UCD, with much potential for collaboration. Sinead's work concerned a class of examples where the relation with Yangian representation theory is manifest. She set out to solve certain systems of algebraic equations for an arbitrarily large rectangular matrix of variables. As conjectured by Kirillov and Reshetikhin, we could show that the variables can be written as characters of irreducible representations of Yangians based on D-type Lie algebras. Sinead found the expected number of solutions for which all variables become rational linear combinations of roots of unity, and we proved that there are no other solutions. The proof is contained in Sinead's thesis, but not yet submitted to a journal.

### 1.1.9 Vanishing Theorems

(W. Nahm & F. Laytimi)

Work with Fatima Laytimi on vanishing theorems for positive vector bundles over algebraic manifolds was continued. The group studied how the vanishing conditions change, when positivity constraints of various strictness are imposed on the vector bundles and proved a general theorem to this effect. Somewhat simplified it states the conditions on  $p, q$  for which the cohomology groups  $H^p(X; S^q E)$  vanish, when  $E$  is ample, for varying  $m$ . The paper is essentially ready, but not yet on the net.

### 1.1.10 Maya Epigraphy

(W. Nahm)

A paper on the longest inscription at the important Maya city of Yaxchilan was published [3]. This inscription is of great historical importance, but large parts of it are heavily eroded or even completely destroyed. Moreover, a few stone blocks

have been scrambled. In 1997 it was shown that the highly structured nature of the text allows a decipherment of most of the inscription. Simon Martin later pointed out that an irregularity in the text had been overlooked, however. Based on his discovery we could make much further progress. This concerns the completion of the king list, the reconstruction of the chronology of the site, with dates for several of its rulers, and the reconstruction of the events in an interregnum period of ten years. It turned out that a rival government had been set up by Piedras Negras, the major rival of Yaxchilan further down the Usumacinta river. This rival government had dynastic legitimacy, and for many years there was an uneasy truce, until the Yaxchilan king eliminated it by military means.

### 1.1.11 Fuzzy Physics

(Denjoe O'Connor)

The principal line of research pursued in 2006 continued to be the exploration of field theory in its matrix regularized form known as "fuzzy field theory". Fuzzy field theories are field theories where the algebra of functions of a manifold is replaced by a suitable matrix algebra, with matrix dimension  $N$ , and the Laplace-Beltrami operator by a suitable double commutator Laplacian mapping matrices to matrices of the same dimension. The triple of Matrix algebra, norm  $\langle F|F \rangle = \text{Tr} N (F|F)$  and Laplacian defines the geometry of the fuzzy space.

The "fuzzy approach" provides a regularization of field theory (and hopefully string theory) that is well adapted to the non-perturbative study of both commutative and noncommutative field theories including those with chiral fermions. It is also well suited to the study of supersymmetric models as it is possible to truncate the theory to a finite number of degrees of freedom while retaining the exact supersymmetry. The ingredients are then a graded matrix algebra, where the matrix entries now contain both commuting and anti-commuting (or Grassmann) entries and the trace over matrices is replaced by a supertrace.

At the level of the classical Euclidean action, the method naturally preserves most of the fundamental symmetries of the theory in question, though these can be broken spontaneously. A continually increasing number of fuzzy spaces is now available including all flag and superflag manifolds (see Saemann and Murray [06-21]) as well as a further large class of algebraic varieties (see Saemann [06-24]).



A new construction of fuzzy CPN in a manner that allows one to access all noncommutative equivariant complex vector bundles over fuzzy CPN has been given (see [06-18]). The construction allowed us to give a simplified construction of polarization tensors on  $S^2$  that generalizes to CPN, identify Laplacians and natural non-commutative covariant derivative operators that map between the modules that describe noncommutative vector bundles. Curiously as part of the construction it was possible to construct composite oscillators that obey a Heisenberg algebra on an appropriate reduced Fock space.

It is planned to explore the K-theory associated with these constructions in the coming months. As part of this process David Evans of Cardiff gave us an introductory set of lectures.

## 1.2 Independent Work by Fellows

### 1.2.1 Integrable Models: Baxter-Bazhanov-Stroganov $\zeta^2$ -Model

(O. Lisovyy)

A representation of the row-to-row transfer matrix of the Baxter-Bazhanov-Stroganov  $\zeta^2$ -model for  $N = 2$  in terms of an integral over two commuting sets of Grassmann variables was found. Using this representation, transfer matrix eigenvectors were explicitly calculated and normalized. It was also shown how form factors of the model can be expressed in terms of determinants and inverses of certain Toeplitz matrices. [11].

### 1.2.2 Integrable Models: Aharonov-Bohm Effect On The Poincaré Disk

(O. Lisovyy)

The formal quantum Hamiltonian of a charged particle on the Poincaré disk in the presence of an Aharonov-Bohm magnetic vortex and a uniform magnetic field were studied. It was shown that this Hamiltonian admits a four-parameter family of self-adjoint extensions. The density of states and the resolvent of this hamiltonian for natural values of the extension parameters were calculated using Sommerfield-type integral representations for the radial waves on the hyperbolic disk. [06-35].

### 1.2.3 Integrable Models: Point Interactions In One Dimension And Holonomic Quantum Fields

(O. Lisovyy)

A family of quantum fields, associated to  $\delta$ -interactions in one dimension were studied. These fields provide the simplest example of the holonomic quantum fields of M. Sato, T. Miwa and M. Jimbo. Corresponding field operators belong to an infinite-dimensional representation of the group  $SL(2;R)$  in the Fock space of ordinary harmonic oscillator. Form factors of such fields and their correlation functions were computed, which are related to the determinants of Schrödinger operators with a finite number of point interactions. It was also shown that these determinants coincide with  $\zeta$  functions obtained through the trivialization of the  $\det \alpha$ -bundle over a Grassmannian associated to a family of Schrödinger operators. [12].

### 1.2.4 Exactly Solvable Models of One-Dimensional Many Particle Stochastic Processes.

(A. Povolotsky)

The solution of the master equation for the totally asymmetric exclusion process with parallel update has been obtained on the infinite line with fixed initial configuration. The result is presented in simple determinant form. [14] & [15].

The technique of the summation over the spectrum of the evolution operator of the totally asymmetric exclusion process with parallel update on the ring is developed. As a result the expression for the transition probability from one arbitrary configuration to another for arbitrary time is obtained. This will be published next year.

### 1.2.5 String Theory And Supersymmetric Gauge Theories

(C. Roemelsberger)

Research was carried out into string theory and supersymmetric gauge theories and also on counting BPS operators in  $N = 2$  supersymmetric quiver gauge theories. The study of hydrodynamics and AdS/CFT was also undertaken.

### 1.2.6 Theory of Elementary Particles

(O.W. Greenberg, Ireland-United States Fulbright Scholar)

The development of models of generations of quarks and leptons was pursued. A schematic model of generations was put forward. [06-36].



### 1.3 Independent Work by Research Scholars and Students

#### 1.3.1 The Gross-Pitaevskii Formula and Bose-Einstein Condensation

(S. Adams)

The main result is the temperature dependent Gross-Pitaevskii variational formula for the so-called Hartree model in the large particle limit, where the interaction is scaled such that the system is dilute. The corresponding study of the large time limit, which is interpreted as zero-temperature limit, for finite number of particles and the large particle limit in the product ground state resulted in publications. [8] & [9].

#### 1.3.2 Destabilization of multi-fuzzy spheres at a distance

(S. Bal)

The IIB matrix model is one of the proposals for a non-perturbative construction of string theory. It is a large  $N$  reduced model of ten-dimensional supersymmetric Yang-Mills theory where spacetime emerges dynamically.

There is a simpler class of matrix models where the space-time and matter dynamically emerge. These are non-commutative gauge theories on the fuzzy sphere which is a simple compact noncommutative manifold. The geometry emerges as a minimum action configuration but only for some parameter values.

A multifuzzy sphere system can be described by a block diagonal representation of matrices in a matrix model corresponds to a multi D-brane system in string theory. Though the overall matrix is traceless, the individual blocks in a block diagonal representation do not need to be traceless and the value of the trace of these blocks gives the space time coordinate of the center of the fuzzy sphere corresponding to the block. These systems also have supersymmetric analogues.

The stability of these systems was studied by expanding the action around a classical background to one-loop in the interaction between fuzzy spheres in the bosonic and supersymmetric cases.

The system has an instability when the surface of the spheres touch each other. On the other hand, for a large-distance between the spheres case, it is seen that there is still an attractive force between the two fuzzy spheres.

The supersymmetric Chern Simons Yang Mills model has also been studied. The two fuzzy sphere system there has similar behavior, except there are some extra zero modes.

Research on these topics will be continued into the next reporting period.

#### 1.3.3 $N = 4$ Super Yang Mills

(F. Dolan)

Work has commenced on two topics in  $N = 4$  super Yang Mills since arriving in October. This is a very special quantum field theory in that it enjoys conformal symmetry and supersymmetry and is thought to have an identical description (in some precise sense) to a super string theory via the AdS/CFT correspondence.

One such topic concerns a certain four point correlation function and how it behaves beyond leading order in a large  $N$  (of gauge group  $SU(N)$ ) expansion and in the strong coupling limit of  $N = 4$  super Yang Mills. This is a so-called chiral four point function and its explicit form has been found at  $O(1=N^2)$  using the AdS/CFT correspondence (relating, in this regime, a gravity theory in an AdS space to a conformal field theory on the boundary -  $N = 4$  super Yang Mills). One may use an analysis in terms of operator mixing, anomalous dimensions and conformal partial wave expansions to make predictions for the four point function at  $O(1=N^4)$ . Through such an analysis, a very concise and neat expression for this function but without a knowledge of anomalous dimensions at  $O(1=N^4)$  was found. Unfortunately attempting to compute this function by the usual techniques employed in the AdS/CFT correspondence is at present a prohibitively difficult problem. Nevertheless, a non-trivial prediction both for the four point function and anomalous dimensions at next to leading order merits further consideration.

The other topic researched is the computation of finite  $N$  partition functions for fields transforming in the adjoint representation of the gauge group  $SU(N)$  in  $N = 4$  super Yang Mills. The initial focus has been on free field theory partition functions since the techniques employed may be useful for interacting theory ones. Such partition functions may be written down generically in terms of certain non-trivial integrals over  $SU(N)$ . The usual technique one uses to evaluate these integrals in the large  $N$  limit is via saddle point methods, however it has been shown how one may use certain theorems on symmetric polynomials to recover equivalent results (and an exact result for the half BPS case for any  $N$ ). It is also possible to give explicit



solutions for low  $N$  cases for an arbitrary number of fields. These results have an interesting interpretation from an enumerative combinatoric perspective and extend some formulae in that area of the mathematics literature.

### 1.3.4 Quantum Information

*(A. Ghesquire)*

Work has been pursued on the decoherence arising in a Gaussian two-particle system. The case of the system decohering without outside influence was investigated. Afterwards, with the help of G.W.Ford and R.F.O'Connell, and of the independent oscillator model that they described, the system was subjected to a heat bath and the resulting effects studied. A decoherence time for the system was obtained. Studies of quantum information with continuous variables are currently in progress, as well as an attempt at obtaining a curve showing the evolution of the entanglement entropy.

### 1.3.5 Gravity Theories on Noncommutative Plane

*(S. Kürkçüoğlu, A.P. Balachandran, K.S. Gupta & T.R. Govindarajan)*

Dr. Kürkçüoğlu has collaborated with Professors A.P. Balachandran (Syracuse University), K.S. Gupta (Saha Institute, Kolkata, India) and T.R.Govindarajan (IMSC, Chennai, India) on the formulation of lower dimensional gravity theories on noncommutative (NC) spaces. This research has been motivated by the recent developments due to Chaichian et al. and Aschieri et al., who reported that a so-called "twisted" Poincaré and diffeomorphism symmetry is consistent with field theories on NC spaces. To be more precise, Chaichian and Aschieri demonstrated that both the Poincaré and the diffeomorphism group act as an automorphism on the algebra of functions over the NC space, if the coproduct associated with these symmetries is suitably deformed.

The collaborators recognized that these developments open possibilities for many interesting developments. One such being the study of gravity in NC spaces, already pursued to get the NC version of the Einstein-Hilbert action. However, due to the complicated nature of this action new physics is hard to extract. Thus Dr. Kürkçüoğlu and his collaborators considered that new physics could be probed first in lower dimensional gravity theories.

Gravity in two dimensional spacetime has many interesting features. It can be formulated as a gauge theory, and in the

presence of a dilaton field it has a black hole solution. It presents a less complicated setting for testing new ideas. Thus, Dr. Kürkçüoğlu and his collaborators considered that it is practically advantageous to study the formulation of gravity theories on the noncommutative plane to gain some insight into the physics involved in such models.

In this regard, the collaborators have succeeded in formulating a twisted generally covariant, NC gauge theory of  $1+1$  dimensional gravity. It has been verified that this theory has the commutative AdS<sub>2</sub> space as a solution. In a certain contracted limit of the gauge group the NC version of the dilaton gravity theory has also been obtained. It is known that the latter has a black hole solution, and studies of the collaborators have shown that it too is a solution for their NC theory. [10].

The collaborators conceive this study as a first step in a long term research program. Within this program it has been foreseen that a range of related problems could be studied. Dr. Kürkçüoğlu has initiated preliminary investigations directed at the addition of matter sources, where there are some preliminary indications that novel results will emerge. In the next stage, a plan to make a survey study of NC  $2+1$  gravity in terms of suitable NC Chern-Simons theories is in order. Also in this context, producing concrete results on noncommutative deformations of BTZ black holes is another objective of the collaborators.

Together with the study of gravitation on the fuzzy sphere, which is described below, this collaboration is also viewed as an effort to study the NC gravity in a systematical manner.

### 1.3.6 Regularizing NC QFTs

*(S. Kürkçüoğlu, M. Panero & T.R. Govindarajan)*

In collaboration with Professor T.R. Govindarajan (IMSC, Chennai, India) the one loop structure of noncommutative QFT's was studied using the techniques of nonlocal regularization.

The nonlocal regularization technique is a Poincaré-invariant regularization scheme which yields an effective, nonlocal theory for energies below a cut-off scale, and it has been successfully applied to various field theories in the literature. The researchers considered the general features and the peculiar advantages of this regularization scheme for theories defined in noncommutative spaces. The investigation was focused on the particular case where the noncommutativity parameter is inversely proportional to the square of the ultraviolet

cut-off, via a dimensionless parameter  $\epsilon$ . The perturbative corrections at one-loop order for a scalar theory with quartic interactions were worked out. It was found that the signature of noncommutativity appears in  $\epsilon$ -dependent terms. The researchers also elaborated on the implications of this approach, which avoids the problems related to UV-IR mixing, from the perspective of the Wilson renormalization program. The results are published in [7].

### 1.3.7 Fuzzy and SUSY Fuzzy Physics

*(S. Kürkçüoğlu, A.P. Balachandran & S. Vaidya)*

During this year Dr. Kürkçüoğlu and his collaborators Professor A.P. Balachandran from Syracuse University and Dr. S. Vaidya from IISc Bangalore India, have completed the revision of the 2005 preprint of their book on fuzzy physics. The book reviews the developments that have happened in the past decade or so in the field of fuzzy and supersymmetric fuzzy physics. It covers the geometrical aspects of fuzzy spaces, as well as the theory of scalar, spinor and gauge fields on fuzzy spaces. The projective module approach to construct fuzzy solitons is also covered with examples. Since it has been placed in the preprint archive arxiv, it has received very encouraging feedback from the scientific community. In the light of this feedback the authors have revised the book during the year 2006. The revision process has been completed and the book is due to be published by World Scientific publishing company.

### 1.3.8 Collective Excitations of Non-commutative CP1 Solitons

*(S. Kürkçüoğlu, A.P. Balachandran & K.S. Gupta)*

During Summer 2006, Professor A.P. Balachandran (Syracuse University), Professor K. S. Gupta (Saha Institute, Kolkata, India) and Dr. Kürkçüoğlu started to explore the collective excitations of CP1 solitons on the noncommutative plane as well as those of the associated topological terms. The researchers first reviewed the formulation of CP1 solitons on the noncommutative plane and elaborated on some new features, such as an alternative definition of their topological charge. By making the global symmetries of the solitons time-dependent, the collective excitations of the NC Berry phase  $S_{Berry}$  and the Chern-Simons SCS terms have been investigated. Subsequently, the canonical quantization of the resulting systems from these topological terms are performed. From the quantization of the CP1 action together with SCS the spectrum of total angular momentum for the NC CP1 soliton is obtained and its similarity with that

of the corresponding commutative theory is discussed. The consequences and potential applications of these results in the context of QH systems are being investigated.

### 1.3.9 Vector Bundles over the Non-commutative 3-Sphere

*(S. Kürkçüoğlu)*

Dr. Kürkçüoğlu has very recently initiated studies in constructing deformations of  $SU(2)$  fibrations over the noncommutative three sphere  $S^3_\mu$ . The latter belongs to a class of noncommutative spaces constructed by Connes and Landi  $S^3_\mu$  and is constructed as follows. One starts with the algebra of functions on  $A(R^4)$  on  $R^4$ . As  $T^2$  has an action on  $A(R^4)$  it follows from the work of Rieffel, and Connes and Landi that the pointwise product on  $A(R^4)$  can be deformed to a noncommutative product and hence one has  $A(R^4_\mu)$  with the deformation parameter  $\mu$ .  $S^3_\mu$  is obtained by taking the quotient of  $A(R^4_\mu)$  by the two-sided ideal generated by the appropriate central element. Currently, Dr. Kürkçüoğlu is formulating the noncommutative vector bundles associated with the irreducible representations of  $SU(2)$  as projective modules associated to coequivariant maps from the representation space of  $SU(2)$  to the fiber bundle  $S^3_\mu \times S^3_\mu$ . The next step planned in this research is the application of the results of this construction to study the structure of Skyrmions on  $S^3_\mu$ .

### 1.3.10 Quantum Hall Effect in Graphene and Edge Physics

*(M. Leitner, M. Gruber & W. Nahm)*

M. Leitner continued her research in October returning after nine months maternity leave. This research concerns the quantum field theory of charged fermions in two space dimensions, which recently turned out to be essential for the understanding of graphene. This material has great promise in information technology, perhaps even for quantum computing.

The experiments on this new material display an unusual "half integer" Quantum Hall effect. It has been argued (Nature 438, November 2005) that the deviation from integrality is due to the zero mass of the particles. Work on massive Dirac fermions, previously mentioned in 2005, shows however that this is not decisive. Instead, the crucial point is the invariance of the low energy effective quantum field theory under a Lorentz group (with a maximal velocity of  $c=300$ ) and the geometry of the latter. The topicality of the subject had been ignored by the referees of Phys. Rev. Lett. The introduction was rewritten, stressing the relevance for graphene and the paper submitted



to ATPM in July. The main result has been accepted with some changes.

In two space dimensions, spontaneous edge currents are predicted for edge devices in the absence of both an external magnetic and electric field, when time and space inversion symmetries are broken by magnetic impurities in the material. For rather general boundary conditions imposed on the half plane, the net edge current has been calculated [13]. Depending on the choice of boundary condition, it is proportional to the internal voltage (the width of an occupied gap energy interval over the particle's charge) or to zero, respectively, in natural units. The group wondered whether this promising result actually has a chance of becoming of practical importance. For instance, contributions from the bulk (by states with energies in the bulk spectrum) might dominate and mask the switch of the edge current. The calculation yields a bulk current, parallel to the edge, which is exponentially suppressed in the interior but quadratically divergent at the boundary. This result is unphysical and needs to be understood.

### 1.3.11 Quantum Information Theory

*(C. Morgan)*

Quantum error correction and quantum data compression are two important techniques in Quantum Information Theory. Quantum error correcting codes are applied to information to protect it from the effects of noise when the information is sent over a noisy channel. This resilience is achieved with the particular encoding of the quantum states, adding redundancy to the information.

Quantum data compression allows states from a redundant quantum source to be compressed, such that the fidelity, which provides a measure of the faithfulness of the input and output states, approaches its maximum.

Some fundamental concepts relating to both quantum error correction and quantum data compression have been examined, with particular interest in the fidelity for a general channel subject to arbitrary errors. Work is currently concentrated on finding a maximiser of the quantum mutual information for a quantum channel. The capacity of a channel is given by the maximisation of the mutual information and can be interpreted as the amount of information that can be sent reliably over the channel. Obtaining the maximiser for classical information transmitted over a quantum channel has been the main focus.

This transmission is achieved by encoding the information as quantum states and the Holevo-Schumacher-Westmorland theorem provides an expression to calculate the capacity using a discrete set of input states. It has been shown that for a discrete pure state ensemble, it is sufficient to consider (at most)  $d^2$  states, for the maximisation of the mutual information of a system of dimension  $d$ . Proving this result for states on continuous state space was concentrated on.

### 1.3.12 Non-commutative Vector Bundles

*(S. Murray, B.P. Dolan, I. Huet & Denjoe O'Connor)*

Non-commutative vector bundles over fuzzy CPN were constructed along with the corresponding covariant derivatives. This employed a novel composite oscillator technique, which simultaneously gave a generalization of the Schwinger-Jordan construction to any representation of  $su(n)$ . The work was carried out with Brian P. Dolan, Idrish Huet and Denjoe O'Connor and released as a DIAS Preprint [06-18]. Some research was also conducted on spinor bundles over CPN using this approach and relating it to previous methods. This has yet to be finalized.

### 1.3.13 Flag Manifolds

*(S. Murray & C. Saemann)*

An outline of the generalization of the above work to a more general class of manifold, namely flag manifolds was presented with Christian Saemann and released as a DIAS Preprint [06-21]. Using the Plücker coordinate and coherent state description, fuzzy versions of the algebra of functions on these spaces in both operatorial and star product language were constructed. This was extended to certain supersymmetric cases; in particular, fuzzy versions of Calabi-Yau supermanifolds were found.

### 1.3.14 Lie Algebras

*(S. Ni Chiagáin)*

Certain integrable models are described by pairs  $(X; Y)$  of ADET Dynkin diagrams. At high energy these models are expected to have a conformally invariant limit. The  $S$ -matrix of the model determines algebraic equations, whose solutions are mapped to the central charge and scaling dimensions of the corresponding conformal field theory. The equations of the  $(D_m; A_n)$  model was studied and all solutions were found explicitly using the representation theory of Lie algebras and related Yangians. These mathematically rigorous results are in agreement with the

expectations arising from physics.

The overlap between certain  $q$ -hypergeometric series and modular functions was also investigated. A particular class of  $r$ -fold  $q$ -hypergeometric series, denoted  $f_{A;B;C}$  was studied. Here  $A$  is a positive definite, symmetric,  $2 \times 2$  matrix,  $B$  is a vector of length 2, and  $C$  is a scalar, all three with rational entries. It turns out that for certain choices of the matrix  $A$ , the function  $f_{A;B;C}$  can be made modular. The corresponding values of  $B$  and  $C$  were calculated. It is expected that functions  $f_{A;B;C}$  arising in this way are characters of some rational conformal field theory. This has been shown to be true in at least one case.

### 1.3.15 Non-Commutative Geometry

(*M. Panero*)

Non-commutative geometry has a number of applications in various areas of physics, including string theory, quantum gravity, and the theory of the Quantum Hall effect. A well-known phenomenon occurring in non-commutative field theory is the mixing of ultra-violet and infra-red (UV/IR) degrees of freedom: this has a number of important physical consequences, which are of great interest both from the theoretical and phenomenological point of view.

Work has been completed, which is focused on a perturbative approach to quantum field theories in non-commutative space-time, using a non-local regularization; this approach provides a direct connection between the high-energy dynamics and the renormalization group approach due to Wilson.

### 1.3.16 Fuzzy Physics

(*M. Panero, Denjoe O'Connor and students*)

The fuzzy space approach provides an elegant, mathematically well-defined regularization scheme for quantum field theory, and provides a potential tool for non-perturbative studies of different physical models, both in the non-commutative case or in the commutative limit. This approach allows a natural representation of physical fields as matrices of finite dimension.

A comprehensive study of the scalar field theory with quartic interactions on the fuzzy sphere has been pursued: this work has highlighted a number of physical aspects relevant to the model. Monte Carlo simulations have been run, using a novel and efficient algorithm devised for this study, and the numerical results have been successfully compared with the theoretical

predictions in different physical regimes.

Also, numerical simulations of a supersymmetric model have been performed, using the fuzzy sphere as a regularization scheme for the theory. The phase structure and various observables of physical interest have been investigated.

### 1.3.17 Lattice Field Theory

(*M. Panero*)

Numerical simulations of lattice field theory have been performed, studying various aspects of the confinement problem in Quantum Gauge Theory. In particular, the main issues addressed are:

- the effective string picture for confinement
- the Nambu-Goto effective model as a phenomenological description for interfaces in lattice field theory.

### 1.3.18 Exact Renormalization Group

(*O. Rosten*)

Research is currently under way into the Exact Renormalization Group (ERG), which is essentially the continuum version of Wilson's RG. For a given field theory, the basic idea of the ERG is the implementation of a momentum cutoff,  $\mu$ , in such a way that the physics at this scale is described in terms of parameters relevant to this scale. The effects of the modes above  $\mu$ , which have been integrated out, are encoded in Wilson's effective action,  $S_\mu$ . The ERG (or flow) equation determines how  $S_\mu$  evolves with  $\mu$ , thereby linking physics at different energy scales and so providing access to nonperturbative physics. A long term aim of the work is to use the ERG to understand the low energy domain of QCD, which is of course one of the most pressing problems in theoretical physics.

Two important steps have recently been taken in this direction. First, work was completed describing how to use the formalism to compute the expectation values of gauge invariant operators in QCD [16]. A particular novelty of the approach is that manifest gauge invariance is maintained at all stages: no gauge fixing is necessary.

In a complimentary work [06-22] it was discovered that the full, nonperturbative expression for these expectation values can be remarkably simplified. This is just as well – the price of manifest gauge invariance is that the formalism is subject to significant



complication. Nevertheless, this work provides evidence (building on earlier developments) that these complications can be to a large extent removed, when performing actual calculations. Whilst the simplifications found are very encouraging, it is still the case that further simplification would be highly desirable. Trying to find out whether this is possible comprises an important strand of the current work.

In a very recent development, progress has begun on the setting up of a collaboration to numerically solve the flow equation (in some approximation scheme). Rather than dealing with the maximally complicated QCD, it is planned to start by looking at QED in three dimensions. Not only is this problem simpler, but it is important: QED in three dimensions is believed to be an effective description of certain high temperature superconductors. Finally, the process of supersymmetrizing the construction has begun. Since much more is known about the nonperturbative domain of the supersymmetric cousins of QCD, than of QCD itself, this could provide a useful setting in which to better understand the nonperturbative aspects of the formalism. It is also hoped that this work will lead to collaborations with others at DIAS on related areas.

### 1.3.19 Drinfeld Twist and General Relativity with Fuzzy Spaces

(C. Saemann & S. Kırkçüoğlu)

In this project, a simplified formula for the star product on CPnL, which enabled the group to define a twist element suited for discussing a Drinfeld twist like structure on fuzzy complex projective spaces, was given. The existence of such a twist has several consequences for field theories on fuzzy spaces, some of which were discussed in the publication [06-09]. As expected, it was found that the twist of the coproduct is trivial for the generators of isometries on CPnL. Furthermore, the twist allowed one to define a covariant tensor calculus on CPnL from the perspective of the standard embedding of CPn in flat Euclidean space. That is, a representation of a truncated sub-group of the diffeomorphisms on CPn on the algebra of functions on CPnL was found. Using this calculus, an Einstein-Hilbert action on the fuzzy sphere, which is invariant under twisted diffeomorphisms was eventually written down.

### 1.3.20 Quantization of Flag Manifolds and their Supersymmetric Extensions

(C. Saemann & S. Murray)

In the resulting publication [06-21] the description of flag manifolds in terms of Plücker coordinates and coherent states was reviewed. Using this description, fuzzy versions of the algebra of functions on these spaces in both operator and star product language were constructed. The main focus here was on flag manifolds appearing in the double fibration underlying the most common twistor correspondences. After extending the Pluecker description to certain supersymmetric cases, the appropriate deformed algebra of functions on a number of fuzzy flag supermanifolds was obtained. In particular, fuzzy versions of Calabi-Yau supermanifolds were found.

### 1.3.21 Fuzzy Toric Geometries

(C. Saemann)

A construction of fuzzy spaces which approximate projective toric varieties was found. The construction uses the canonical embedding of such varieties into a complex projective space: The algebra of fuzzy functions on a toric variety is obtained by a restriction of the fuzzy algebra of functions on the complex projective space appearing in the embedding. Several explicit examples for this construction in a resulting publication are given [06-24]. In particular, fuzzy weighted projective spaces as well as fuzzy Hirzebruch and del Pezzo surfaces were presented. As the construction is actually suited for arbitrary subvarieties of complex projective spaces, large classes of fuzzy Calabi-Yau manifolds are easily obtained and fuzzy K3 surfaces and fuzzy quintic three-folds were commented on. Besides enlarging the number of available fuzzy spaces significantly, evidence for the conjecture that the fuzzification of a projective toric variety amounts to a quantization of its toric base was found.

## 1.4 Work by Research Associates

### 1.4.1 The Quantum Hall Effect

(B. Dolan & Cliff Burgess)

Work continued on the collaboration with Cliff Burgess of McMaster University University, Hamilton, Ontario, Canada on duality and the modular group in the quantum Hall effect. The role of the modular group in quantum Hall systems consisting of more than one components, such as bi-layers, spin degenerate monolayers and graphene is currently being developed.

### 1.4.2 Non-Commutative Geometry

(B. Dolan)

Work has been carried out on non-commutative geometry in the context of gravity, in particular in non-commutative black-holes.

### 1.4.3 Higher Dimensional Field Theories

(D.H. Tchrakian)

The following general areas of research were pursued: Higher dimensional field theories, including dimensional descent; Abelian and non Abelian gauged Higgs and Skyrme field theories, including their gravitating cases; Special emphasis on higher curvature Yang-Mills and gravitational terms, as well as inclusion of (negative) cosmological constant. Specific problems tackled are outlined below.

A model for the U(1) gauged Skyrminion in 3 + 1 dimensions was found in [21]. The study of finite mass solutions in Einstein-Yang-Mills systems in higher dimensions was continued, and completed the case with negative cosmological constant. The study of soliton/antisoliton chains in 3 + 1 dimensions was continued in particular to solutions of a symmetry breaking Goldstone model. Instanton/antiinstanton solutions to the 4 + 0 dimensional SU(2) Yang-Mills system were constructed [24]. A study was carried out of gravitating gauge field systems in all 4p dimensions, whose gravitational part consists of higher order gravitational terms of order 2p in the Riemann curvature [23]. The AdS<sub>4</sub> gravitating SU(2) Yang-Mills system descending from 11 dimensional supergravity was studied and the classical solutions in the bulk were constructed [25]. An analysis of a conformally coupled gravity/scalar model on the 3 dimensional boundary was also attempted.

## 2 Publications

### 2.1 Communications of the Dublin Institute for Advanced Studies, Series A.

- [1] S. Adams: Mathematical Statistical Mechanics. *Communications of the Dublin Institute for Advanced Studies Series A* **30** (2006) 1-90.

### 2.2 Papers in Refereed Journals

- [2] T. C. Dorlas, L. A. Pastur & V. A. Zagrebnoy: Condensation in a disordered infinite-range hopping Bose-Hubbard model. *J. Stat. Phys.* **124** (2006) 1137-1178.

- [3] W. Nahm: New readings on hieroglyphic stairway 1 of Yaxchilan. *Mexicon* **28** (2006) 28-39.
- [4] Denjoe O'Connor & B. Ydri: Monte Carlo simulation of a NC gauge theory on the fuzzy sphere. *JHEP* **0611** (2006) 016.
- [5] M. Caselle, M. Hasenbusch and M. Panero: On the effective string spectrum of the tridimensional Z(2) gauge model. *JHEP* **01** (2006) 076.
- [6] M. Caselle, M. Hasenbusch and M. Panero: High precision Monte Carlo simulations of interfaces in the three-dimensional Ising model: a comparison with the Nambu-Goto effective string model. *JHEP* **03** (2006) 084.
- [7] T.R. Govindarajan, S. Kürkcüoğlu & M. Panero: Nonlocal regularisation of noncommutative field theories. *Modern Physics Letters A* **21** (2006) 1851-1863.
- [8] S. Adams, J.B. Bru & W. König: Large deviations for trapped interacting Brownian particles and paths. *Ann. Prob.* **34** (2006) 1340-1422.
- [9] S. Adams, W. König & J.B. Bru: Large systems of path-repellent Brownian motions in a trap at positive temperature. *Electronic Journal of Probability* **11** (2006) 460-485.
- [10] A. P. Balachandran, T. R. Govindarajan, K. S. Gupta & S. Kürkcüoğlu: Noncommutative two dimensional gravities. *Class. Quant. Grav.* **23** (2006) 5799.
- [11] O. Lisovyy: Transfer matrix eigenvectors of the Baxter-Bazhanov-Stroganov  $z^2$ -model for  $N = 2$ . *J. Phys.* **A39** (2006) 2265-2285.
- [12] O. Lisovyy: Point interactions in one dimension and holonomic quantum fields. *Letts. Math. Phys.* **77** (2006) 63-81.
- [13] M. Leitner & M. Gruber: Spontaneous edge currents for the Dirac equation in two space dimensions. *Letts. Math. Phys.* **75** (2006) 25-37.
- [14] A.M. Povolotsky & V.B. Priezzhev: Determinant solution for the totally asymmetric exclusion process with parallel update. *Stat. Mech.* (2006) P07002.
- [15] A.M. Povolotsky & J.F.F. Mendes: Bethe Ansatz solution of discrete time stochastic processes with fully parallel update. *J. Stat. Phys.* **123** (2006) 125-166.



- [16] O. Rosten: General computations without fixing the gauge. *Phys. Rev.* **D 74** (2006) 125006.
- [17] B. Dolan:  $N = 2$  Supersymmetric Yang-Mills and the Quantum Hall effect. *IJMPA* **21** (2006) 4807-4821.
- [18] B. Dolan: Duality in supersymmetric Yang-Mills and the Quantum Hall effect. *Mod. Phys. Lett.* **A21** (2006) 1567-1585.
- [19] B. Dolan: Meromorphic Scaling Flow of  $N=2$  Supersymmetric  $SU(2)$  Yang-Mills with Matter. *Nucl. Phys.* **B737** (2006) 153-175.
- [20] E. Radu & D. H. Tchrakian: No hair conjecture, nonabelian hierarchies and anti-de Sitter spacetime. *Phys. Rev.* **D 73** (2006) 024006.
- [21] V. Paturyan, E. Radu & D. H. Tchrakian: Spinning  $U(1)$  gauged Skyrmions. *Phys. Lett.* **B 632** (2006) 109-113.
- [22] V. Paturyan, E. Radu & D. H. Tchrakian: Solitons and soliton-antisoliton pairs of a Goldstone model in  $3 + 1$  dimensions. *J. Phys.* **A 39** (2006) 3817-3828.
- [23] E. Radu, C. Stelea & D. H. Tchrakian: Features of gravity-Yang-Mills hierarchies in  $d$ -dimensions. *Phys. Rev.* **D 73** (2006) 084015.
- [24] E. Radu & D. H. Tchrakian: Self-dual instanton and nonself-dual instanton-antiinstanton solutions in  $d = 4$  Yang-Mills theory. *Phys. Lett.* **B 636** (2006) 201-206.
- [25] R.B. Mann, E. Radu & D. H. Tchrakian: Nonabelian solutions in  $AdS_4$  and  $d = 11$  supergravity. *Phys. Rev.* **D 74** (2006) 064015.

### 2.3 Papers in Conference Proceedings

- [26] F.G. Flores, Denjoe O'Connor & X. Martin: Simulating the scalar field on the fuzzy sphere. *Proceedings of Science* **LAT2005** (2005) 262.
- [27] J. Medina, W. Bietenholz, F. Hofheinz & Denjoe O'Connor: Field Theory Simulations on a Fuzzy Sphere - an Alternative to the Lattice. *Proceedings of Science* **LAT2005** (2005) 263.
- [28] M. Panero: Quantum field theory in a non-commutative space: Theoretical predictions and numerical results on the fuzzy sphere. *Proceedings of the O'Raiferthaigh Symposium on Non-Perturbative and Symmetry Methods in Field Theory, June 22-24, 2006, Budapest, Hungary.*
- [29] N. Datta and T.C. Dorlas: A quantum version of Feinstein's lemma and its application to channel coding. *Proc. of Int. Symp. Inf. Th. ISIT 2006, Seattle*, (2006) 441-445.

### 2.4 Theses and other publications

- [30] J. Medina: Fuzzy scalar field theories: numerical and analytical investigations. *Ph.D. thesis, April 2006, Cinvestav, Mexico City.*
- [31] N. Datta & T.C. Dorlas: Source coding in quantum information theory. *Encyclopedia of Mathematical Physics*, (eds.), Elsevier 2006, 609{617.
- [32] T.C. Dorlas: Schrödinger's scientific work. *DIAS Website* 2006.
- [33] T. C. Dorlas: Translation of Schrödinger's article in *Die Naturwissenschaften*, 23, 1935: "Die gegenwärtige Situation in der Quantenmechanik." *DIAS Website* 2006.

### 2.5 Preprints

#### DIAS-STP-

- [06-01] M. Caselle, M. Hasenbusch & M. Panero: High precision Monte Carlo simulations of interfaces in the three-dimensional Ising model: a comparison with the Nambu-Goto effective string model.
- [06-02] N. Datta & T. C. Dorlas: A quantum version of the Feinstein lemma and its application to channel coding.
- [06-03] A. P. Balachandran, T. R. Govindarajan, K.S. Gupta & S. Kürkçüoğlu: Noncommutative two dimensional gravities
- [06-04] T. C. Dorlas, L. A. Pastur & V. A. Zagrebnoy: Condensation in a disordered infinite-range hopping Bose-Hubbard model.
- [06-05] T.R. Govindarajan, S. Kürkçüoğlu & M. Panero: Nonlocal regularisation of noncommutative field theories.
- [06-06] A.M. Povolotsky & V.B. Priezzhev: Determinant solution for the totally asymmetric exclusion process with parallel update.
- [06-07] O. Lisovyy: Point interactions in one dimension and holonomic quantum fields.
- [06-08] O. Lisovyy: Transfer matrix eigenvectors of the Baxter-Bazhanov-Stroganov  $z^2$ -model for  $N = 2$ .



- [06-09] S. Kürkçüoğlu & C. Saemann: Drinfeld twist and general relativity with fuzzy spaces.
- [06-10] C. Dobrowolny, T.C. Dorlas & J. V. Pulé: Lowest Lyapunov exponents for the armchair nanotube.
- [06-11] M. Panero: Numerical simulations of a non-commutative theory: the scalar model on the fuzzy sphere.
- [06-12] M. Panero: Quantum field theory in a non-commutative space: theoretical predictions and numerical results on the fuzzy sphere.
- [06-13] B. Dolan: Modular symmetry and fractional charges in  $N = 2$  supersymmetric Yang-Mills and the quantum Hall effect.
- [06-14] B. Dolan: Duality in supersymmetric Yang-Mills and the quantum Hall effect.
- [06-15] N. Datta & T.C. Dorlas: Coding theorem for a class of quantum channels with long-term memory.
- [06-16] S. Adams & T.C. Dorlas: Asymptotic Feynman-Kac formulae for large symmetrised systems of random walks.
- [06-17] B.P. Dolan, K.S. Gupta & A. Stern: Noncommutative BTZ Black hole and discrete time.
- [06-18] B. Dolan, I. Huet, S. Murray & Denjoe O'Connor: Noncommutative vector bundles over fuzzy CPN and their covariant derivatives.
- [06-19] O.J. Rosten: General computations without fixing the gauge.
- [06-20] A. Hanany & C. Römelberger: Counting BPS operators in the chiral ring of  $N = 2$  supersymmetric gauge theories or  $N = 2$  brane surgery.
- [06-21] S. Murray & C. Saemann: Quantization of flag manifolds and their supersymmetric extensions.
- [06-22] O.J. Rosten: Universality from very general nonperturbative flow equations in QCD.
- [06-23] B. Dolan: The quantum Hall effect in graphene: emergent modular symmetry and the semi-circle law.
- [06-24] C. Saemann: Fuzzy toric geometries.
- [06-25] B. Dolan & C. Burgess: Duality, the semi-circle law and quantum Hall bilayers.
- [06-26] E. Radu & D. H. Tchrakian: No hair conjecture, nonabelian hierarchies and anti-de Sitter spacetime.
- [06-27] V. Paturyan, E. Radu & D. H. Tchrakian: Spinning  $U(1)$  gauged Skyrmons.
- [06-28] V. Paturyan, E. Radu & D. H. Tchrakian: Solitons and soliton-antisoliton pairs of a Goldstone model in  $3 + 1$  dimensions.
- [06-29] E. Radu, C. Stelea & D. H. Tchrakian: Features of gravity-Yang-Mills hierarchies in  $d$ -dimensions.
- [06-30] E. Radu & D. H. Tchrakian: Self-dual instanton and nonself-dual instanton-antiinstanton solutions in  $d = 4$  Yang-Mills theory.
- [06-31] R.B. Mann, E. Radu & D. H. Tchrakian: Nonabelian solutions in  $AdS_4$  and  $d = 11$  supergravity.
- [06-32] Denjoe O'Connor & B. Ydri: Monte Carlo simulation of a NC gauge theory on the fuzzy sphere.
- [06-33] Denjoe O'Connor, J.A. Santiago & C.R. Stephens: An analytic equation of state for Ising-like models.
- [06-34] T.C. Dorlas & V.B. Priezzhev: Finite-time current probabilities in the asymmetric exclusion process on a ring.
- [06-35] O. Lisovsky: Aharonov-Bohm effect on the Poincaré disk.
- [06-36] O.W. Greenberg: A schematic model of generations.

## 3 Programme of Scholarly Events

### 3.1 Lectures Organised by The School

- R. Dijkgraaf (Universiteit van Amsterdam) *Gauge theories and free fermions*. 22 November
- P. Duclos (CPT, CNRS, Marseille) *Three quantum charged particles interacting through delta potentials* 29 August
- D. Evans (Cardiff University) *K Theory*. Series of four lectures 6-10 November
- S. Fredenhagen (ETH, Zurich) *Permutation D-branes*. 27 January



- A. Konechny (Rutgers University) *On boundary renormalization group flows in two dimensions*. 27 January
- J.P. Luminet (Laboratoire Univers et Théories de l'Observatoire de Paris, Meudon, France) *Cosmic topology and CMB data*. 3 February
- H. Schulz-Baldes (University of Erlangen-Nuernberg, Germany) *Random matrix theory beyond the Wigner ensemble*. 7 April
- E. Sharpe (Utah University) *Compactifications of string theories*. 27 January
- T. Wiseman (Harvard University) *Super Yang-Mills and black holes*. 27 January
- T. Jonsson (University of Iceland, Reykjavik) *Random walks on random combs and trees*. 9 March
- D. Leites (Stockholm University) *How to construct Lie algebras? (Towards the super analog of the Kostrikin-Shafarevich conjecture)*. 30 November
- P. Majumdar (Saha Institute of Nuclear Physics, Calcutta, India) *Quantum black holes: entropy and thermal stability*. 27 July
- R. Manvelyan (Technische Universität Kaiserslautern, Germany & Yerevan Physics Institute, Armenia) *The quantum trace anomaly of the higher spin currents in Ads(4)*. 14 September

### 3.1.1 Seminars Organised by The Theoretical Particle Physics Group

- R. Banerjee (S.N. Bose National Centre for Basic Sciences, Kolkata, India) *Gauge symmetry in noncommutative gauge theories*. 12 October
- H.W. Braden (Edinburgh University) *Monopoles and an identity of Ramanujan*. 18 May
- T. Brown (Queen Mary University) *Correlators, probabilities and topologies in N=4 SYM*. 14 December
- M. Chaichian (University of Helsinki, Finland) *Concept of twist symmetry and its implications to noncommutative quantum field and gauge theories*. 31 August
- F.A. Dolan (Cambridge University) *N = 4 Superconformal characters and Yang Mills partition functions*. 7 September
- A. Gerasimov (ITEP, Moscow & Trinity College Dublin) *On an interpolation of special functions*. 25 May
- O.W. Greenberg (University of Maryland) *A schematic model of generations of quarks and leptons*. 26 October
- K.S. Gupta (Saha Institute of Nuclear Physics, Kolkata, India) *Quasinormal modes of black holes*. 20 April
- J. Guven (ICN UNAM, Mexico) *Tethered membranes: conformal invariance in biophysics*. 12 December
- J.L. Jaramillo (Laboratoire Univers et Theories de l'Observatoire de Paris, Meudon, France) *Quasi-local black hole horizons in numerical relativity: a quasi-equilibrium case*. 4 May
- R. Manvelyan (Technische Universität Kaiserslautern, Germany & Yerevan Physics Institute, Armenia) *Conformal coupling of the scalar field with gravity in higher dimensions*. 2 November
- N. O'Connell (University College Cork) *Duistermaat-Heckman measure for Coxeter Groups*. 7 December
- D. Parashar (Warwick University) *Coloured quantum groups and Yang-Baxter operators*. 30 March
- T. Quella (King's College, London) *Strings on supergroups - a free fermion resolution*. 1 June
- H. Römer (Freiburg University, Germany) *Currents and energy-momentum tensor and ultralocality*. 2 March
- O.J. Rosten (University of Southampton) *General computation without fixing the gauge*. 5 September
- D. Tong (DAMTP, Cambridge) *D-branes in field theory*. 23 February
- P. Vitale (Università Federico II & INFN, Naples, Italy) *Twisted conformal symmetry in noncommutative two-dimensional quantum field theory*. 23 March
- A. Winter (University of Bristol) *State discrimination with post-measurement information*. 29 November
- B. Ydri (Badji Mokhtar-Annba University, Algeria) *Monte Carlo simulation of NC gauge field on the fuzzy sphere*. 14 June

### 3.2 Symposia, Conferences, Workshops organised

The **13th Irish Quantum Field Theory Meeting** was held on 12th and 13th May. The following lectures were delivered.

- B. Durkan (Trinity College Dublin) *Monopoles with Dirac singularities.*
- C. Ford (Trinity College Dublin) *Moduli of doubly periodic instantons.*
- S. Frolov (MPI/AEI Potsdam) *The  $AdS(5) \times S^{**5}$  superstring in light-cone gauge.*
- E. Jennings (Trinity College Dublin) *Spin asymmetries in proton antiproton interactions.*
- S. Keegan *Algebraic K-theory and partition functions in conformal field theory.*
- B. Kreuzler (MIC Limerick) *Derived categories - a simple singular example.*
- J. Maldacena (IAS, Princeton) **O’Raifeartaigh Speaker** *QCD, strings and black holes: the large  $N$  limit of field theories and gravity.*
- J. Maldacena (IAS, Princeton) **O’Raifeartaigh Speaker** *Giant magnons.*
- S. Murray (DIAS & National University of Ireland, Maynooth) *Spinors on fuzzy CPN.*
- D. O’Brien (Trinity College Dublin) *Helicity amplitudes and antiproton polarisation.*
- A. Ozer (Trinity College Dublin) *Lunin-Maldacena deformations with three parameters.*
- M. Peardon (Trinity College Dublin) *Simulation technology for lattice QCD.*
- E. Radu (National University of Ireland, Maynooth) *Nonabelian solitons, hairy black holes and AdS/CFT.*
- C. Saemann *Matrix models and D-branes in twistor string theory.*

The second series of **John Lewis Lectures** were delivered by Professor S.R.S. Varadhan (Courant Institute, New York). The lecture series is jointly organised between the Dublin Institute for Advanced Studies and the Hamilton Mathematics Institute at Trinity College Dublin with generous donation by Corvil Networks. The following lectures were delivered:-

- *Random walks in a random environment, basic issues.* 15 May
- *Issues related to large deviations.* 16 May
- *Connections to homogenization.* 18 May

#### A **Workshop on Fuzzy Physics and Noncommutative Geometry** was held from 12th until 20th June. The following

lectures were delivered in the mornings and discussion groups met in the afternoons.

- P. Presnajder (Comenius University, Bratislava, Slovakia) *A Fuzzy Version of Minkowski Space.*
- R. Szabo (Herriot-Watt University, Edinburgh, UK) *Quiver Gauge Theory and Noncommutative Vortices.*
- J. Hoppe (Royal Institute of Technology, Stockholm, Sweden) *Fuzzy Riemann Surfaces.*
- B. Ydri (Badji Mokhtar University, Annaba, Algeria) *Phase Structure of Noncommutative Gauge Theory on the Fuzzy Sphere.*
- A.P. Balachandran (Syracuse University, Syracuse, NY, USA) *Twisted Co-products and Quantum Field Theory.*
- S. Vaidya (Indian Institute of Science, Bangalore, India) *Noncommutative QED.*
- W. Nahm *Integrable theories and their conformal limits*
- D. Kochan(Comenius University, Bratislava, Slovakia) *Odd Poisson Structure’s and Supergeometry.*

The **Winter Symposium** was held on 14th and 15th December. Lectures were given as follows:

- M. Hynes (Director, IRCSET) *Supporting mathematics research: an IRCSET perspective.*
- W. Greenberg (Univ. of Maryland & DIAS) *How quarks got color: a participant view.*



- A. O'Farrell (National University Ire-land, Maynooth)  
*Aspects of reversibility.*
- J. Vala (National University Ireland, Maynooth)  
*Topological quantum computation.*
- P. Lynch (University College Dublin)  
*Energy spectra from entropy principles.*
- A. Povolotsky  
*Exact solution for discrete time asymmetric exclusion process.*
- A. Avdeeva (School of Cosmic Physics, DIAS)  
*Limited-memory quasi-Newton magnetotelluric inversion as an example of an optimization problem in geophysics.*
- C. Römelberger  $N = 2$  brane surgery.
- A. Solomon (The Open University)  
*Positive aspects of dissipation.*
- A. Raftery (Univ. of Washington & Czech Academy of Sciences, Prague) *Statistical inference for deterministic mathematical models.*

#### Statutory Public Lecture

The Statutory Public Lecture held over from 2005 was delivered by Professor J.P. Luminet (Directeur de Recherches au CNRS, Observatoire de Paris) on The shape of the universe, on 1 February in Trinity College Dublin.

The Statutory Public Lecture was delivered by Professor S.R.S. Varadhan (Courant Institute of Mathematical Sciences, New York) on Randomness, chance and probability, on 17 May in University College Dublin, Belfield.

## 4 Presentations at Conferences or Seminars

### 4.1 Talks and Papers Presented

#### T.C. Dorlas:

- Talk "Faithful transmission of quantum information" at NUI Maynooth. 10 February.
- Seminar talk "Quantum information and quantum coding" at University of Wales, Swansea. 10 March.
- Talk "A quantum version of Feinstein's theorem and its application to channel coding" given by collaborator Dr. Nilanjana Datta at the International Symposium on Information Theory, Seattle. 9-14 July.

- Seminar "Quantum coding theorem for a convex combination of memoryless channels" at The Quantum Information Theory Department, Cambridge. 1 November.
- Talk "Optimal coding of classical messages for a quantum channel with memory" at the "Open Systems Days", a two-day meeting about open systems in Marseille, CPT. 9-10 November.

#### W. Nahm:

- Talk "Quantum Field Theory and Mathematics" at 25th Anniversary of the MPIM, Bonn. 1-5 April.
- Talk "Lochlainn O'Raifeartaigh's legacy" at O'Raifeartaigh Symposium on non-perturbative and symmetry methods in field theory" Budapest. 22-24 June.
- Talk "TBA (Thermodynamic Bethe Ansatz)" at Exactly solvable systems in quantum field theory"York. 10-11 August.

#### Denjoe O'Connor:

- Talk "The phase diagrams of some fuzzy field theories" at Workshop on "Noncommutative Geometry" Bratislava, Slovakia. 12 July.
- Talk "Quantal Random Walks" at Imperial College, London. 22 September.

#### S.Bal:

- Talk "Dynamical generation of gauge group in matrix model" was delivered at the following institutes/universities.  
Institute of Mathematical Sciences, Chennai, India  
Department of Physics, Indian Institute of Technology, Chennai, India  
Department of Physics, Indian Institute of Technology, Mumbai, India  
Department of Physics, Delhi University, Delhi, India  
Department of Physics, Indian Institute of Technology, Kanpur, India  
Department of Physics, Indian Institute of Technology, Guwahati, India  
S.B. Bose National Centre for Basic Sciences, Kolkata, India  
Saha Institute for Nuclear Sciences, Kolkata, India.  
10 April -13 May.

**O.W. Greenberg:**

- Talk “The discovery of color in particle physics: a personal perspective” was delivered at the following institutes/universities.  
University of Bergen. 6 October.  
Chalmers Institute of Technology, Goteborg. 11 October.  
University of Oslo. 16 October.  
Universita di Roma, La Sapienza. 29 November.  
University of Durham. 7 December.  
University of Bristol. 13 December.  
Université Catholique de Louvain &  
Université Libre de Bruxelles. 21 December.
- Talk “Quantum statistics in three space dimensions” delivered at Symposium in honour of the 60th birthday of Jon Magne Leinaas. University of Oslo. 14 October.
- Talk “A schematic model of generations of quarks and leptons” was delivered at the following institutes/universities.  
University of Bergen. 9 October.  
Chalmers Institute of Technology, Goteborg, 12 October.  
Frascati Accelerator Division, Istituto Nazionale di Fisica Nucleare. 30 November.  
University of Bristol. 13 December.
- Talk “Observable consequences of the generation structure of quarks and leptons”. Université Libre de Bruxelles. 20 December

**S. Kürkçüoğlu:**

- Invited talk “Waves in noncommutative spacetimes” at International Conference on “Noncommutative Geometry and Quantum Physics” S.N. Bose National Centre for Basic Sciences, Kolkata, India. 4-10 January.

**O. Lisovyy:**

- Lecture “Exact solution for the operator of spin field in the Ising model on a finite lattice” at Bogolyubov lectures dedicated to 40th anniversary of the Institute for Theoretical Physics, Kyiv, Ukraine. 20 January.
- Seminar “Tau functions and isomonodromic deformations” at the Department of Mathematics of the University Lyon-I,

Lyon, France. 7 April.

- Lecture “Painlevé VI and isomonodromic deformations of the Dirac equation” at 6th meeting “Integrable systems and quantum field theory” Peyresq, France. 10{25 June.

**C. Morgan:**

- Poster on “Fidelity of a general error for quantum error correction” at Gordon Research Conference on Quantum Information, Il Ciocco, Italy. 7-12 May.

**S. Murray:**

- “Fuzzy Physics” at British Universities Summer School in Theoretical Elementary Particle Physics (BUSSTEPP 2006), University of Edinburgh. 28 August - 8 September.

**M. Panero:**

- Invited talk: “A comparison of effective string predictions and numerical results in the confined phase of Abelian lattice gauge theories” at Regensburg University, Germany. 12 January.
- Invited talk: “Comparing numerical results and effective string predictions in the confined phase of Abelian lattice gauge theories” at Liverpool University. 18 January.
- Invited talk: “Interfaces in lattice gauge theory” at Wales University, Swansea. 13 October.

**A. Povolotsky:**

- Poster presentation “Determinant solution for the totally asymmetric exclusion process with parallel update” at Non-Equilibrium Dynamics of Interacting Particle Systems Workshop, Isaac Newton Institute for Mathematical Sciences, Cambridge. 27 March - 7 April.

**C. Saemann:**

- Invited talk: “Twistors, supersymmetric gauge theory and string theory” at EMPG, Edinburgh. 24 May.

## 5 Collaboration with the Wider Research Community

### 5.1 National

#### Lecture Courses and Workshops

**T.C. Dorlas:**

- Course for undergraduates on Quantum Computing and Information (Academic year 2005-2006).
- The Winter Symposium was organised in collaboration with the IMS, on 14-15 December.

**W. Nahm:**

- Course for undergraduates on Integrable Lattice Models (Academic year 2005-2006).
- Helped organise the 13th Irish Quantum Field Theory Meeting held 12-13 May.
- Organiser (With B. Dolan (NUIM), S. Shatashvili (TCD) and J. Vala (NUIM)) of an International Conference on "Topological Quantum Computing" to be held in Dublin, September 2007. This will be the first conference on this topic in Europe. The participation of several leading researchers as international coorganisers and advisors was obtained.

**Denjoe O'Connor:**

- Helped organise the 13th Irish Quantum Field Theory Meeting held 12-13 May.
- Helped organise the Workshop on Fuzzy Physics and Noncommutative Geometry held 10-20 June.

**A. Povolotsky:**

- Series of seminars on Exactly solvable stochastic processes
- Series of seminars on Theory of symmetric functions Staff Acting as External Supervisors

**W. Nahm:**

- Ph. D. Student (University of Bonn, Germany) Defended 9-16 July.

**Denjoe O'Connor:**

- Ph.D. supervisor for Julieta Medina (Cinvestav, Mexico) Defended April.
- Ph.D. supervisor for Rodrigo Delgadillo Blando (Cinvestav, Mexico)
- Ph.D supervisor for Fernando Garcia Flores (Cinvestav, Mexico)

- Ph.D. supervisor for Idrish Huet Hernandez (Cinvestav, Mexico)

**Staff Acting as External Examiners****T.C. Dorlas:**

- External referee on the interview committee for examining the thesis of James Borg entitled "Random Schrödinger Operators with Magnetic Vortices", University College Dublin, April.

**Denjoe O'Connor:**

- External examiner for Stephen Watterson, Ph. D. Thesis T.C.D., 30 March.

**Research Associates**

- AT&T: N. Duffield
- DCU: E. Buffet, J. Burzlaff, E. O'Riordan
- DIT: T. Garavaglia, D. Gilbert, M. Golden, B. Goldsmith, P Houston, E. Prodanov
- Intern. Centre For Theoretical Physics, Trieste : J. Chela-Flores
- IT, Carlow: D. O Sé
- IT, Tallaght: N. Gorman
- Ludwig-maximilians-universität München: I.Sachs
- Meteorological Service: P. Lynch
- NUI, Cork: N. O'Connell, M. Vandyck
- NUI, Galway: J. Burns, M.J. Conneely, M.P. Tuite
- NUI, Maynooth: M. Daly, B. Dolan, D. Heffernan, C. Nash, A. O'Farrell, J.A. Slevin, D.H. Tchrakian
- Open University: A.I. Solomon
- Oxford University: R.G. Flood
- TCD: P.S. Florides, J. Miller, D. Weaire
- Universiteit Leiden: F. Freire
- UCD: A. Ottewill, J.V. Pulé, W. Sullivan, P. Watts
- UL: S. O'Brien

- Unaffiliated: G.M. O'Brien, D. Ó Mathuna

## 5.2 International

### W. Nahm:

- Acted as a referee for "Special Research Group of the German Research Society" Hamburg. 6-7 April.
- Member of the International Panel for the Evaluation of Research at the Institute for Studies in Theoretical Physics and Mathematics (IPM) in Tehran, 14-16 April.

### Denjoe O'Connor:

- Member of International Advisory board of the Central European Joint Programme of Doctoral studies in Theoretical Physics (<http://umbriel.phy.hr/cejp/>).

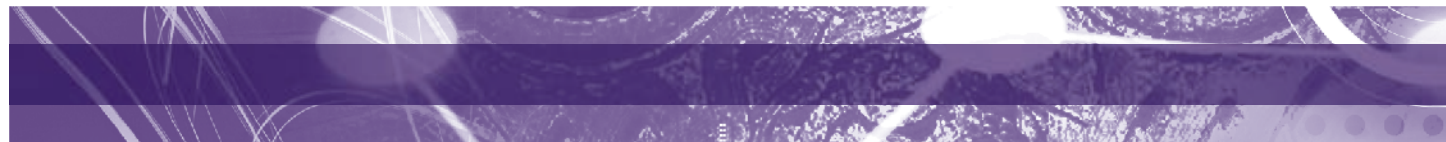
### Visiting Researchers

#### Short visits (up to one week):

- W. Bietenholz (Humboldt University, Berlin) 8-12 March
- H. Braden (University of Edinburgh) 18-19 May
- T. Brown (University of London) 13-14 December
- M. Chaichian (Helsinki University) 29 August - 1 September; 5-8 September
- R. Dijkgraaf (University of Amsterdam) 22 November
- F. Dolan (DAMTP, Cambridge) 4-9 September
- D. Evans (University of Cardiff) 5-10 November
- J. Guven (Mexico) 10-13 December
- J.L. Jaramillo (Observatoire de Paris) 3-6 May
- T. Jonsson (University of Iceland) 8-11 March
- B. Kreussler (MIC, Limerick) 11-13 May
- D. Leites (Max-Planck-Institute, Leipzig) 27 November - 2 December
- J.-P. Luminet (CNRS, France) 1-4 February
- J. Maldacena (IAS Princeton) 12-14 May
- P. Majumdar (SAHA, India, Oxford & Sussex) 24-29 July
- N. O'Connell (UCC) 7-9 December
- D. Parashar (Warwick University) 29 March - 1 April
- T. Quella (King's College, London) 31 May - 6 June
- A. Rafferty (Czech Academy of Sciences, Prague & University of Washington) 14-17 December
- O. Rosten (University of Southampton) 5-8 September
- A. Solomon (Open University & Paris) 13-15 December
- D. Tong (University of Cambridge) 21-24 February
- P. Vitale (INFN, Italy) 21-24 March
- J. Volkholz (Humboldt University, Berlin) 5-12 March
- A. Winter (University of Bristol) 28-30 November

#### Long visits:

- S. Bal 3 January - 31 August
- A.P. Balachandran (Syracuse University) 8-23 June
- R. Banerjee (S.N. Bose Centre, Kolkata, India) 27 September - 31 October
- P. Duclos (CNRS, Luminy, Marseille) 20-30 August
- G.W. Ford (University of Michigan) 29 May - 29 June
- F. Freire (Universities Utrecht & Leiden) 10-23 July
- O.W. Greenberg (University of Maryland) 3 September - 31 December
- K.S. Gupta (Saha Institute of Nuclear Physics, India) 5-25 April
- S. Kürkçüoğlu (University of Hannover) 1 November - 12 December
- F. Laytimi (University Lille) 11-29 May
- R. Manvelyan (Yerevan, Armenia) 10-26 September
- R.F. O'Connell (Louisiana State University) 28 May - 5 August
- V.B. Priezzhev (JINR, Dubna) 13 October - 2 November
- H. Roemer (Freiburg University) 23 February - 14 March
- H. Schulz-Baldes (University Erlangen, Germany) 5-13 April



- V.V. Sreedhar (Indian Institute of Technology, Kanpur)  
2 May - 2 August
- S.R.S. Varadhan ( Courant Institute, New York) 10-23 May
- V. Zagrebnov (Marseille) 1-11 March

#### Research Visits by School Staff

##### T.C. Dorlas:

- Research visits to Statistical Laboratory, University of Cambridge. 9-14 January; 19-23 February; 7-10 May; 22-30 June; 17-22 September; 1-3 November.
- Research visit to Centre de Physique Théorique, Marseille. 6-11 June.

##### Denjoe O'Connor:

- Research visit to Cinvestav, Mexico and visit to UNAM, Mexico 1-30 April.

##### S. Adams:

- Research visit to University of Leipzig 2-14 February; 6-13 March; 27 March - 2 April; 8-14 April.
- Research visit to University of Leipzig. 6-13 March; 27 March - 2 April; 8-14 April.
- Research visit to Warwick University. 7-20 June.
- Research visit to MPI, Leipzig. 15-21 May; 23 June - 12 July; 1-2 September; 16-27 September.
- Research visit to Roma Tor Vergata, Rome II University. 15 October - 12 November.

##### S. Bal:

- Research visits to the following Institute of Mathematical Sciences, Chennai, India  
Department of Physics, Indian Institute of Technology, Chennai, India  
Department of Physics, Indian Institute of Technology, Mumbai, India  
Department of Physics, Delhi University, Delhi, India  
Department of Physics, Indian Institute of Technology, Kanpur, India  
Department of Physics, Indian Institute of Technology,

Guwahati, India  
S.B. Bose National Centre for Basic Sciences, Kolkata, India  
Saha Institute for Nuclear Sciences, Kolkata, India.  
10 April - 13 May.

##### R. Delgadillo Blando:

- Research visit to University F. Rabelais, Tours, France. 10-24 April.

##### S. Kürkçüoğlu:

- Research visit to Middle East Technical University, Ankara, Turkey. 24-31 July.

##### O. Lisovyy:

- Research visit to the Department of Mathematics of the University Lyon-I, Lyon, France. 6-10 April.

##### A. Povolotsky:

- Research visit to the Bogoliubov Laboratory of Theoretical physics, Joint Institute for Nuclear Research, Dubna, Russia. 21-31 December.

## 6 Participation in Outside Committees

##### W. Nahm:

Member of the Royal Irish Academy Committee for Mathematical Sciences. The committee met on November 7.

## 7 Attendance at External Conferences, Workshops, Meetings and Lectures

### 7.1 Conferences/Workshops/Scientific Meetings Attended

##### T.C. Dorlas:

- Colloquium at University of Wales, Swansea. 9-11 March.
- International Symposium on "Information theory", Seattle. 9-14 July 2006.
- "Open Systems Days" Marseille. 9-10 November.



**W. Nahm:**

- 25th Anniversary of MPIM, Bonn. 1-5 April.
- "LOR 2006, O'Raifeartaigh symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 22-24 June.
- "Exactly solvable systems in quantum field theory" York. 10-11 August.

**Denjoe O'Connor:**

- LOR 2006, O'Raifeartaigh symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 22-24 June.
- "WNG06, International workshop on non-commutative geometry" Comenius University, Bratislava, Slovakia. 24 June - 14 July.
- "Causal sets" Imperial College, London. 19-22 September.

**S. Adams:**

- "Stochastics 2006" Frankfurt University. 14-20 March.
- EU-MULTIMAT conference, Cambridge. 21-26 March.
- Spring school in Rome "Mathematics and materials" University of Rome. 2-7 April.
- "Stochastic and atomistic aspects of elasticity" workshop, TU-Berlin. 25-27 May.
- "Spatial random processes and statistical mechanics" workshop, Mathematisches Forschungsinstitut Oberwolfach, Germany. 3-10 September.
- LMS Meeting & workshop "Analysis and stochastics of growth processes". 11-15 September.
- "Microscopic approaches to elastic and surface tension functionals" workshop, Roma Tor Vergata, Rome II University. 16-26 October.

**S. Bal:**

- Workshop "Introduction to high performance computing" organised by ICHEC. 10-11 October.

**F. Dolan:**

- The UK Annual Theory Meeting, Durham. 18-20 December.

**A. Ghesquire:**

- "Physics education -a new wave" Institute of Physics Spring Weekend Meeting, Bundoran, Co. Donegal. 31 March - 2 April.
- Gordon Research Conference on "Quantum information science" Il Ciocco, Italy. 7-12 May.

**S. Kırkçuoğlu:**

- "International conference on noncommutative geometry and quantum physics" S.N. Bose National Centre for Basic Sciences, Kolkata, India. 4-10 January.
- "XIII Irish quantum field theory meeting 2006" Dublin Institute for Advanced Studies. 12-13 May.
- "Fuzzy physics and non-commutative geometry workshop" Dublin Institute for Advanced Studies. 6-20 June.
- "LOR 2006, O'Raifeartaigh Symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 22-24 June.

**O. Lisovyy:**

- 6th meeting "Integrable systems and quantum field theory at Peyresq" Peyresq, France. 10-25 June.

**C. Morgan:**

- Four workshops on "Introduction to quantum optics and applications" UCD. 13 February - 20 March.
- "Physics education -a new wave" Institute of Physics Spring Weekend Meeting, Bundoran, Co. Donegal. 31 March - 2 April,
- Gordon Research Conference on "Quantum information science" Il Ciocco, Italy. 7-12 May.

**S. Murray:**

- "XIII Irish quantum field theory meeting 2006", Dublin Institute for Advanced Studies. 12-13 May.
- "LOR 2006, O'Raifeartaigh Symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 22-24 June.

- "WNG06, International workshop on non-commutative geometry" Comenius University, Bratislava, Slovakia. 24 June - 14 July.
- 36th British Universities Summer School in Theoretical Elementary Particle Physics (BUSSTEPP 2006), University of Edinburgh. 28 August - 8 September.

#### M. Panero:

- "Lattice field theory collaboration meeting" Turin University, Turin, Italy. 3-8 May.
- "XIII Irish quantum field theory meeting 2006" Dublin Institute for Advanced Studies. 12-13 May.
- "Fuzzy physics and non-commutative geometry workshop" Dublin Institute for Advanced Studies. 6-20 June.
- "LOR 2006, O'Raifeartaigh symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 21-23 June.
- "WNG06, International workshop on non-commutative geometry" Comenius University, Bratislava, Slovakia. 25 June - 11 July.

#### A. Povolotsky:

- "Nonequilibrium dynamics of interacting particle systems workshop" Isaac Newton Institute, Cambridge. 26 March - 8 April.
- "Nucleation theory & application" JINR, Dubna. 12-30 April.

#### O. Rosten:

- "The Andrew Chamblin memorial conference" Trinity College, Cambridge. 13-15 October.
- The UK Annual Theory Meeting, Durham. 18-20 December.

#### C. Saemann:

- "LOR 2006, O'Raifeartaigh symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 21-23 June.
- "WNG06, International workshop on non-commutative geometry" Comenius University, Bratislava, Slovakia. 25 June - 11 July.

#### T. Tchrakian

- LOR 2006, O'Raifeartaigh symposium on non-perturbative and symmetry methods in field theory" KFKI Research Institute, Budapest, Hungary. 22-24 June.

## 7.2 Lectures and Organisational Meetings Attended

#### T.C. Dorlas:

- Lecture by Prof. Catherine Morawetz, Trinity College Dublin. 3 May.
- Series of John Lewis lectures by Prof. S. R. S. Varadhan. 15, 16 & 18 May.
- Statutory Public Lecture by Prof. S. R. S. Varadhan. 17 May.
- Meeting with Dr. Robert Hunt, Deputy Director, Newton Institute, Cambridge. 27 June.
- Meeting with the Dr. Conor O'Carroll, concerning Graduate Schools. 30 August.
- Meeting with Prof. Jan-Karel Lenstra, Director of the "Centrum voor Wiskunde en Informatica" Amsterdam. 13 October.
- Afternoon of lectures in honour of Prof. Ph.-A. Martin, Lausanne. 10 November.

#### A. Ghesquiere

- Quantum error correcting subsystems by David W. Kribs (Department of Mathematics and Statistics, University of Guelph, Ontario, Canada). NUI, Maynooth. 24 July.
- Entanglement, purity and energy of discrete and continuous variable quantum states by Derek McHugh (Research Center for Quantum Information, Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia). NUI, Maynooth. 18 August.
- Simulating higher transcendental mathematical functions with quantum mechanics by Professor Jason Twamley (Physics Department, Macquarie University, Sydney, Australia). NUI, Maynooth. 12 September.
- The off-shell symmetry algebra of the light-cone AdS<sub>5</sub> × S<sup>5</sup> superstring by Gleb Arutyunov (Utrecht). TCD. 27 November.

- Nanoscale magnetism – From the limits of magnetic storage to spin currents in quantum antiferromagnets by Dr Hans-Benjamin Braun (School of Physics, University College Dublin). NUI, Maynooth. 1 December.

#### O. Lisovyy:

- Bogolyubov lectures dedicated to 40th anniversary of the Institute for Theoretical Physics, Kyiv, Ukraine. 18-20 January.

#### C. Morgan:

- Low density parity check codes by Dr. Marcus Greferath (University College Dublin). Dublin City University. 30 March.
- Quantum error correcting subsystems by Dr. David Kribs (University of Guelph, Canada). NUI, Maynooth. 24 July.
- Entanglement, purity and energy of discrete and continuous variable quantum states by Dr. Derek McHugh (Research Centre for Quantum Information, Slovakia). NUI, Maynooth. 18 August.

#### S. Murray:

- Attended weekly Dublin Theoretical Physics Colloquium, Trinity College Dublin.

#### M. Panero:

- Attended John T. Lewis Lectures by Prof. S. R. S. Varadhan, (Courant Institute, New York). 15,16 & 18 May.

## 8 Research Grants/ External Funds Secured

#### T.C. Dorlas:

- Research Frontiers Programme 2006. Project Title: *Mathematical Analysis of the Bethe Ansatz Solution of Spin Models*. Amount awarded: €114,000 over 3 years.
- Ulysses grant for collaboration with France, together with Profs. J. V. Pulé, V.A. Zagrebnoy and P. Duclos.

#### Denjoe O'Connor:

- 2003-2006: Basic Research Grant from Enterprise Ireland for €189,000. This grant has been extended for one year to 2007.
- 2004-2006: An Embark Initiative Postdoctoral Fellowship to Seçkin Kürkcüoğlu funded by IRCSET for a period of three

years with effect from 1 October.

- 2005-2007: An Embark Initiative Post-doctoral Fellowship to Subrata Bal funded by IRCSET for a period of two years with effect from 1 October.
- 2006-2008: An Embark Initiative Post-doctoral Fellowship to Oliver Rosten funded by IRCSET for a period of two years with effect from 1 October 2006.
- 2006-2008: An Embark Initiative Post-doctoral Fellowship to Frances Dolan funded by IRCSET for a period of two years with effect from 1 October 2006.
- 2002-2006: Subnode of EU Research Training Network €33,000.
- 2006-2010: Node for Research Training Network in Noncommutative Geometry (EU-NCG) The total contract is for €2,800,000.
- 2006-2007: Simulations of Field Theories in Noncommutative Spaces (bep00010) on the HLRN computer system in Germany

#### C. Morgan:

- Ongoing three year Research Demonstratorship with the School of Mathematical Sciences, University College Dublin.

#### S. ni Chiagain:

- Ongoing three year IRCSET scholarship.

## 9 Honours/Awards/ Special Achievements Received

#### W. Nahm:

- Enrolled as a member of the Royal Irish Academy, 12 May.

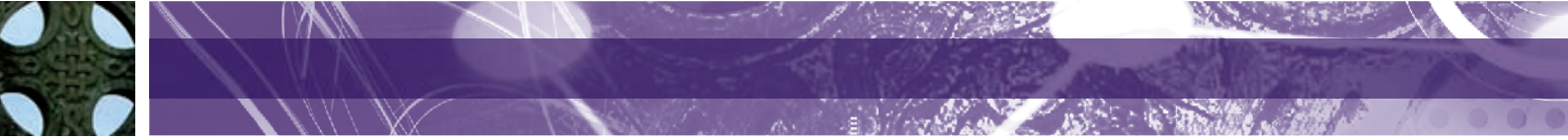
## 10 Public Awareness Activities

### 10.1 Public Lectures

#### T. Dorlas:

- Public Lecture "How to solve Sudoku by computer" Dunsink during Science Week. 13 November.

### 10.2 Contribution to the Media



**W. Nahm & M. Leitner:**

- An article entitled *Looking beyond the silicon age* was published in *The Irish Scientist* 2006.



