



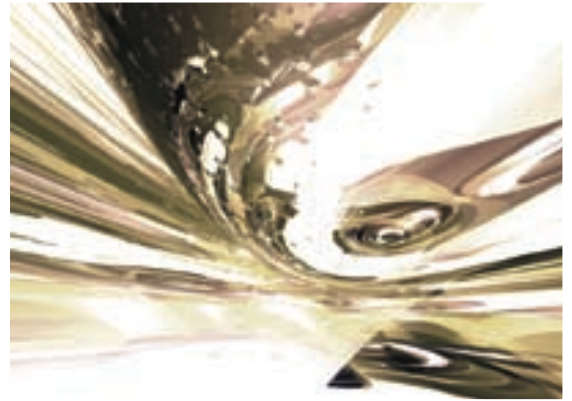
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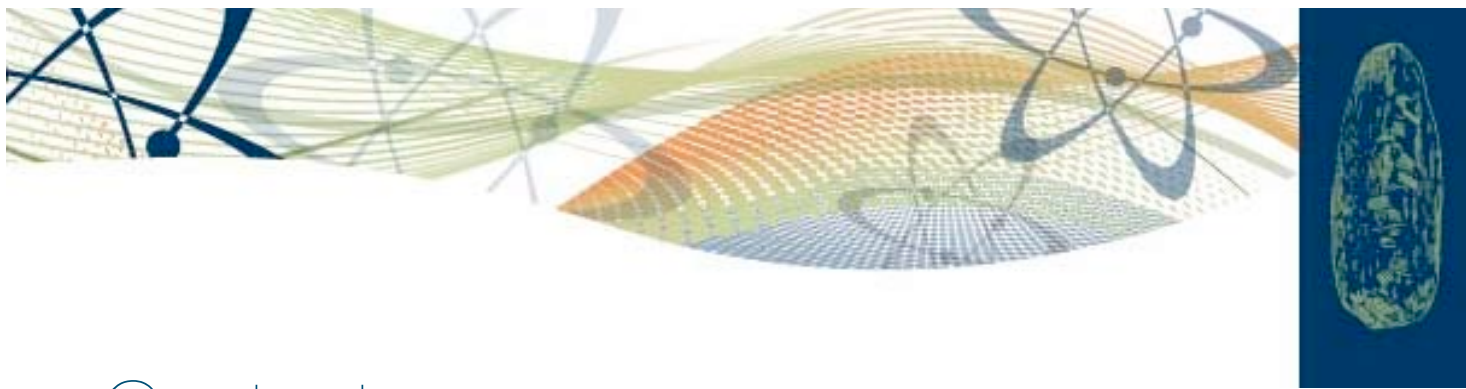
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Dublin Institute for Advanced Studies

Research Report 2007





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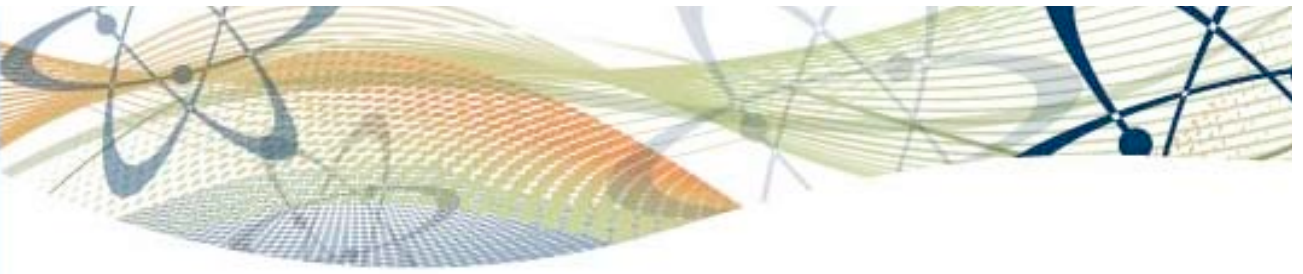
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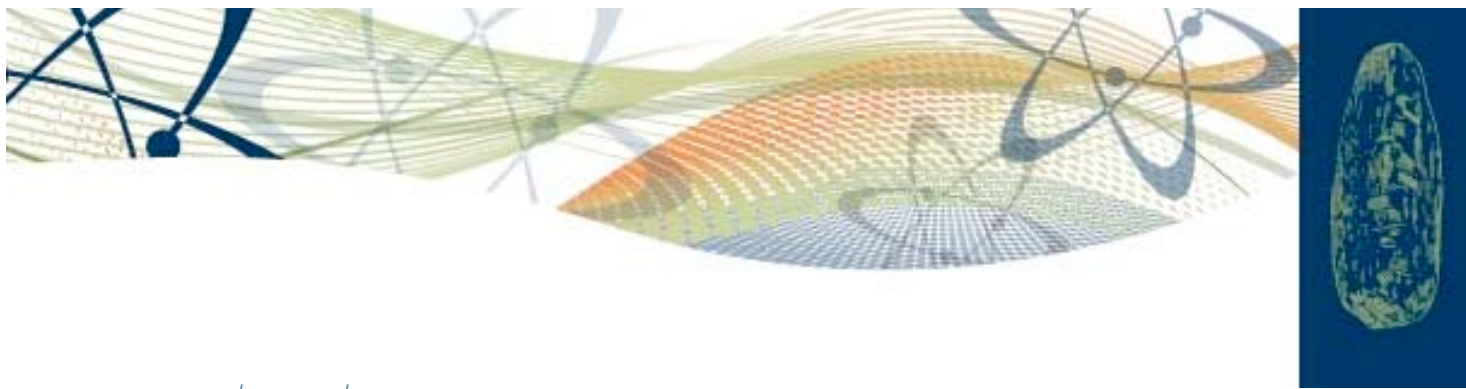
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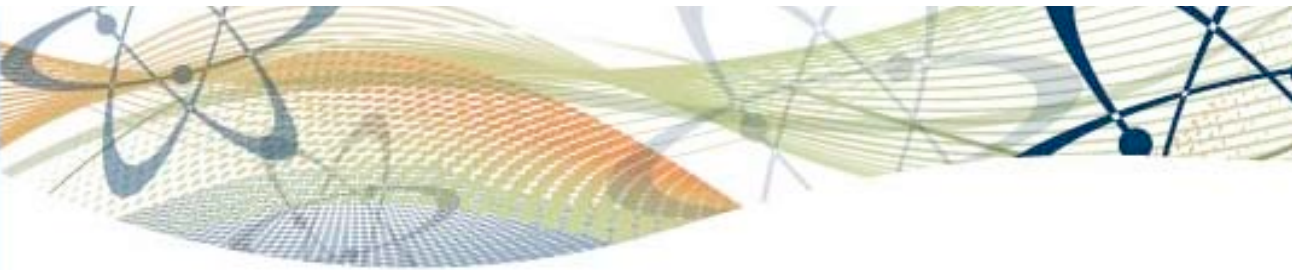


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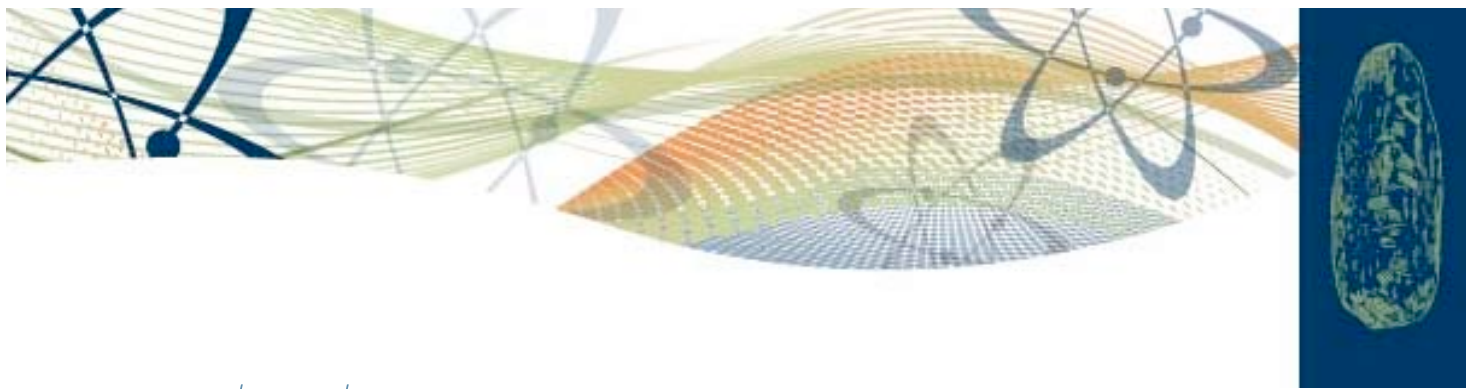
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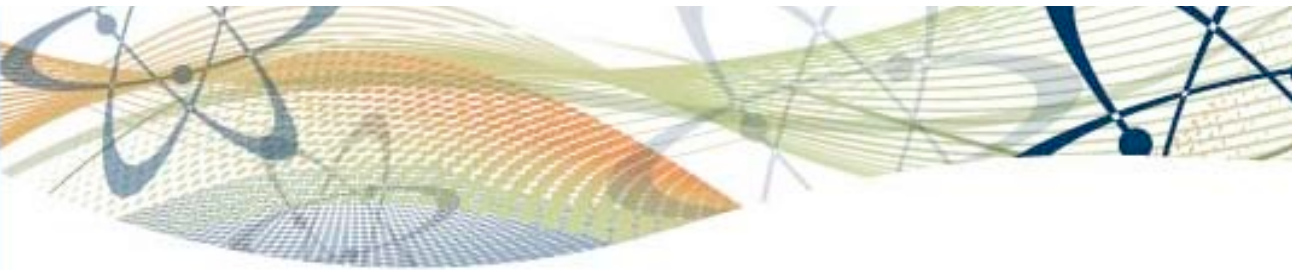


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# School of Celtic Studies

Annual report of the Governing Board of the School of Celtic Studies for the year ending 31 December 2007 adopted at its meeting of 28 February 2008.

## 1 Research Work

### Foireann agus Scoláirí/Staff and Scholars

Senior Professors: Liam Breatnach (Director to 29 March), Fergus Kelly (Director from 29 March),

Pádraig Breatnach

Professors: Malachy McKenna, Pádraig Ó Macháin

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

Bibliographer: Alexandre Guilarte

Dialectologist: Brian Ó Curnáin

Bergin Fellows: Roisín McLaughlin, Clodagh Downey

Scholars: Eoghan Ó Raghallaigh (to 30 September), Brent Miles, Nora White, Gordon Ó Riain, Freya Verstraten (from 1 October)

Librarian: Margaret Kelly

Library Assistant: Órla Ní Chanainn

School Administrator: Eibhlín Nic Dhonncha

Technical Staff : ISOS: Anne Marie O'Brien, John O' Brien (employed as leave replacement)

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 carried out field-work in north and west Conamara. He also made progress with his monograph on the Irish of An Caisleán Gearr and Baile Chláir. He maintained communication with Séamas Ó Direáin regarding his work on *A survey of spoken Irish in the Aran Islands, Co. Galway* which is being prepared for submission to the School of Celtic Studies. He advised the Librarian in the Royal Irish Academy on the recordings of Gaeilge Wilhelm Dögen that were made in 1930. Malachy McKenna continued his work on *The Irish of Rann na Feirste: a phonemic study*, and made regular field-trips to Rann na Feirste in connection with this project.

#### Textual editions

Liam Breatnach continued with his edition of the Old Irish

law-text *Córus Bésnai*.

Pádraig A. Breatnach worked on the seventeenth-century Irish manuscript repertories from St. Anthony's College, Louvain, as well as on Irish chronicle poems by Dubhthach Ó Duibhgeannáin. In addition, he carried out research into the poems on the O'Donnells 1200-1600, the Irish apocryphal texts, and redactive methodologies in seanchas poetry. Clodagh Downey continued her research on the poetic corpus of the Middle Irish poet, Cúán ua Lothcháin.

This involved consultation and transcription of the many manuscripts containing this poetry, edition and collation of these transcriptions, and preliminary work on the translation and annotation of the texts.

Fergus Kelly worked on an 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 144.5-150.16*).

Roisín McLaughlin finalised her book *Early Irish Satire* for publication in 2008. She also continued work on editions of *Mittelirische Verslehren III and of In Lebor Ollaman*.

Gerald Manning (Post-doctoral IRCHSS Fellow) carried out preliminary work on an edition of the law-text *Uraicecht Becc*.

Brent Miles completed an edition of a Middle Irish retelling of the Theban Cycle entitled *Riss in Mundtuirc*, and began work on an edition of a Middle Irish history of Troy entitled *In Tres Troí*. He also continued work on a book on the connection between medieval Irish classical studies and Irish heroic saga.

Gordon Ó Riain continued work on editions of poems by Maol Eachlainn na nUirsgéal Ó hUiginn towards his doctorate.

Nora White continued work on a new edition of 'The Rule of Mochuta'.

#### Historical studies

Michelle O Riordan continued her research in bardic poetry and in the political poetry of the seventeenth century.

Freya Verstraten submitted her PhD thesis 'The Anglicisation of the Gaelic Irish nobility c. 1169 – c. 1366' to Trinity College, Dublin.

#### Cataloguing of manuscripts

William Mahon's catalogue of Irish Manuscripts in Villanova University, Pennsylvania, was published under the general



editorship of Pádraig Ó Macháin.

Aoibheann Nic Dhonnchadha continued her preparation of a catalogue of the Irish medical manuscripts in the Library of Trinity College Dublin.

### 1.2 Tionscnamh Leabhar Breac/Leabhar Breac Project

Professor Liam Breatnach initiated a team project which will provide a diplomatic edition of the *Leabhar Breac*, in both printed and digitised form. The team currently consists of Clodagh Downey, Roisín McLaughlin, Brent Miles, Nora White, and Gordon Ó Riain.

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

The Irish Script on Screen project (ISOS) continues to make steady progress under the direction of Professor Pádraig Ó Macháin. The use and popularity of the project is reflected in the number of visits to the website ([www.isos.celt.dias.ie](http://www.isos.celt.dias.ie)) recorded during 2007: the total number amounting to 2,116,865 hits.

Demands on ISOS in other areas are also increasing. In addition to the regular flow of users' queries that were dealt with concerning ISOS and Irish manuscripts in general, during the year the project facilitated the provision of images for varied uses such as an exhibition in Santiago de Compostella, publications in scholarly journals, and an American television documentary.

Digitising work was concentrated in the Russell Library, NUI Maynooth, up to May 2007, when the first phase of a digital project involving the Maynooth collection of Irish manuscripts was completed. The opportunity was taken during this period to add an amount of catalogue material to the website, with hyperlinks to the digital images. This work is still in progress. The processing of all digitised material to date is now backed up on tape and hard-disk. A number of meetings took place during the year between ISOS and the representatives of prospective future partners.

### 1.4 Tionscnamh Bibleagrafaíochta/Bibliography project

Alexandre Guilarte continued his work on the fourth volume of the *Bibliography of Irish Linguistics and Literature*, with the inclusion of further material from academic periodicals in the field of Irish Studies. At the same time the features of 'eBILL', its online version, have been revised in order to improve end-user performance, and its contents brought up-to-date on a

continuing basis.

### 1.5 Eagarthóireacht/Editing

Liam Breatnach: Co-editor of *Ériu* 57.

Pádraig A. Breatnach: Editor of Proceedings of Comhdháil Lae ar Léann na Gaeilge 3: (with Caoimhín Breatnach, Meidhbhín Ní Úrdail) *Léann lámhscríbhinní Lobháin: The Louvain manuscript heritage*, Éigse Publications 1 (Dublin 2007) (204 pp) (Series Editor: P. A. Breatnach). Editor of *Éigse: A Journal of Irish Studies*, vol. XXXVI (in progress). Fergus Kelly: Co-editor of *Celtica* 25.

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

Aoibheann Nic Dhonnchadha: Comh-eagarthóir, *An Linn Bhúí: Iris Ghaeltacht na nDéise*, imleabhar 11.

Pádraig Ó Macháin: completed editorial work on William Mahon, *Catalogue of Irish manuscripts in Villanova University, Pennsylvania*. Comh-eagarthóir, *An Linn Bhúí: Iris Ghaeltacht na nDéise*, imleabhar 11.

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

### 1.6 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 2007:

Brian Ó Curnáin, *The Irish of Iorras Aithneach, Co. Galway*, 4 vols. ISBN 978 1 85500204 3

Malachy McKenna and Fergus Kelly (ed.) *Celtica* 25, ISSN 0069 1399; ISBN 978 1 85500 208 1

William Mahon, *Catalogue of Irish Manuscripts in Villanova University, Pennsylvania*, ISSN 0791 1890; ISBN 978 1 85500 199 2.

### Reprints

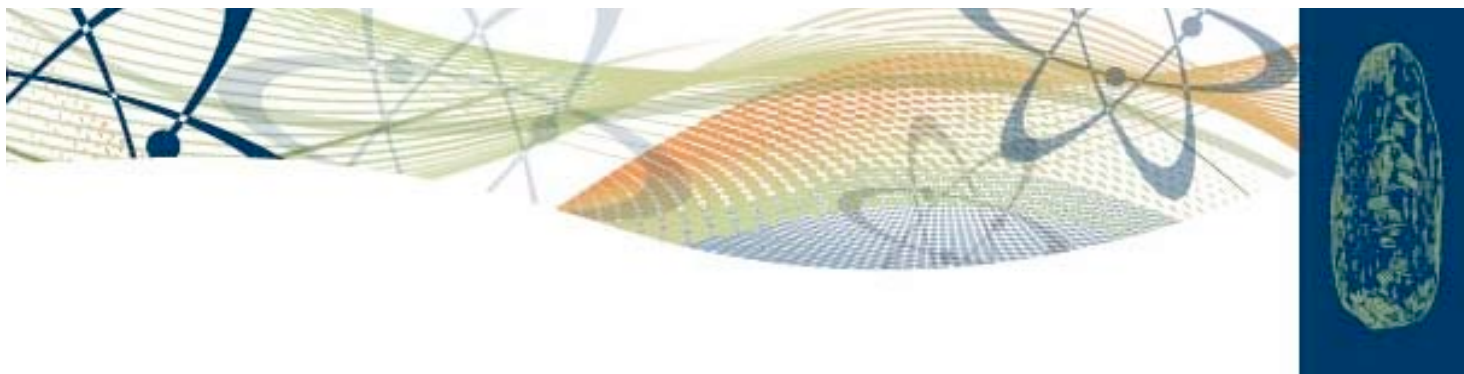
The following reprints were seen through the press by the School's Publications Officer, Michelle O Riordan:

R. I. Best and M. A. O'Brien (ed.), *The Book of Leinster* Vol. IV (B 3.2.4)

J. Vendryes, *Lexique étymologique de l'irlandais ancien: lettres RS* (E 4.5.3)

Kuno Meyer (ed.), *Fianaigeacht* (F 3.15)

Sir Ifor Williams (ed.), *Armes Prydein: The Prophecy of Britain, from the Book of Taliesin* (H 2.6)



### 1.7 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.

### 1.8 Foilseacháin/Publications

Liam Breatnach: 'A Verse on Succession to Ecclesiastical Office', in *Léann lámhscríbhinní Lobháin: The Louvain manuscript heritage* (ed. Pádraig A. Breatnach, Caoimhín Breatnach, Meidhbhín Ní Úrdail), Éigse Publications 1 (Dublin 2007) 32-41. 'Varia: 1. An Old Irish gloss on *Cáin Lánamna*. 2. An instance of do-maisi in the Irish Gospel of Thomas. 3. An Old Irish attestation of *suacht* in *Féilire Óengusso*', *Ériu* 57 (2007) 155-63.

Pádraig A. Breatnach: 'Repertoria manuscriptorum Collegii S. Antonii', in *Léann lámhscríbhinní Lobháin: The Louvain manuscript heritage*. Éigse Publications 1 (Dublin 2007) 3-20. 'Crisis in the universities: the impact on the humanities', *Studies: An Irish Quarterly Review*, vol. 96, no. 384 (Winter 2007) 391-406.

Fergus Kelly: 'Onomatopoeic interjections in Early Irish', *Celtica* 25, 88-107. Review of T.M. Charles-Edwards, *The chronicle of Ireland* (Liverpool University Press, 2006), *Celtica* 25, 270-71. Review of Jacques Lacroix, *Les noms d'origine gauloise: la Gaule des activités économiques* (Éditions Errance, Paris 2005), *Celtica* 25, 271-4. Review of Michelle Comber, *Native evidence of non-ferrous metalworking in Early Historic Ireland* (British Archaeological Reports: International Series 1296, Oxford 2004), *Celtica* 25, 274-7. Review of Rachel Bromwich, *Trioedd Ynys Prydein: the triads of the Island of Britain* (third edition, University of Wales Press, Cardiff 2006), *Celtica* 25, 277-8.

Malachy McKenna: 'An index of the Rann na Feirste material in *The linguistic atlas and survey of Irish dialects i and iv*', *Celtica* 25, 108-142.

Roisín McLaughlin: *Early Irish Satire* (forthcoming).

Michelle O Riordan: *Irish Bardic Poetry and Rhetorical Reality* (Cork University Press), launched at the Institute on 29 June.

Clodagh Downey: 'Purple Reign – the naming of Conall Corc', for the proceedings of Societas Celtologica Nordica

symposium. 'The life and work of Cúán ua Lothcháin' for the 2008 edition of journal *Ríocht na Midhe*.

Gordon Ó Riain: 'Dán réitigh le Conchobhar ruadh Mac Con Midhe (†1481)', *Léann Lámhscríbhinní Lobháin: The Louvain Manuscript Heritage*, (ed. P. A. Breatnach, Caoimhín Breatnach, Meidhbhín Ní Úrdail, Dublin 2007) 54-75.

Freya Verstraten: 'Images of Gaelic lordship in Ireland, c. 1200 – c. 1400', in *Lordship in medieval Ireland: image and reality* (ed. Linda Doran and James Lyttleton, Dublin 2007) 47-74. Review of *The Deeds of the Normans in Ireland. La Geste des Engleis en Yrlande. A new Edition of the Chronicle Formerly Known as The Song of Dermot and the Earl*, ed. Evelyn Mullally (Dublin 2002), *Celtica* 25, 292-3. Review of J. F. Lydon, *The lordship of Ireland in the middle ages* (2nd ed.; Dublin 2003) *Celtica* 25, 293-5.

Aoibheann Nic Dhonnchadha: 'The "Book of the O'Lees" and other medical manuscripts and astronomical tracts', in *The Royal Irish Academy Library Treasures* edited by Siobhán Fitzpatrick (forthcoming)

Pádraig Ó Macháin: 'Teagasc an Athar de Bhál', *An Linn Bhui* 11, 97-131. 'A crosántacht for Uilliam Búrc', *Celtica* 25, 175-94. 'The iconography of exile: Fearghal Óg Mac an Bhaire in Louvain', in *Léann lámhscríbhinní Lobháin: the Louvain manuscript heritage*, (ed. Pádraig A. Breatnach, Caoimhín Breatnach, Meidhbhín Ní Úrdail, Dublin 2007) 76-111. 'Two documents relating to Ó Conchubhair Donn', *Ériu* 57 (2007) 113-19.

Eoghan Ó Raghallaigh: Review of *Éigse: a journal of Irish Studies* (ed. Pádraig A. Breatnach) vols. 31 (1999), 32 (2000) in *Celtica* 25, 285-8.

### 1.9 Leabharlann/Library

Heritage online was launched in February. The online catalogue can now be searched by staff members from their office pc via the intranet within the School. The library management system was upgraded twice during the year and two new modules were installed. The library intranet website was also launched in February. The library intranet site contains links to Heritage online, electronic resources, useful links and general library information.

Current and retrospective cataloguing continued.

Acquisitions continued in subject areas relevant to the research needs of the School. Regular updates on recent accessions and current periodicals were issued and research and bibliographic queries from members of the School



and from visitors were dealt with. Inter-library loans were ordered, consulted and returned to the lending Institution. Statistics on library users and queries were kept on a daily basis. During the Summer two students were given work experience by the School. Stephanie Rousseau and Maureen Quinn both worked on ongoing library projects and made considerable progress. The Special Collection and the Map Collection were both indexed and standardised on the library management system (Heritage) and retrospective cataloguing was carried out. In September the Librarian Margaret Kelly made a presentation to the Governing Board of the School of Celtic Studies outlining progress made to date and possible areas for future growth. A library security system was acquired in order to further enhance the security of the library collection. The full installation and set-up of this system will be carried out in early 2008.

Margaret Kelly attended two seminars towards continuing professional development: *Shifting Sands: Experiencing Change in the Library and Information Environment* (April, National Library of Ireland) and *An Ghaeilge sa Leabharlann: Promoting the Use of Irish in Libraries* (November, Mercer's Hotel). The Library Assistant Orla Ní Chanainn attended a course entitled *Disaster Planning for Libraries* (October, Trinity College Library).

### 1.10 Imeachtaí/Events

#### Statutory Public Lecture

This year's Statutory Public Lecture was delivered by Dr Katharine Simms, Trinity College, Dublin. The title of the lecture was 'The Nature and Function of Bardic Poetry: An Introduction to the DIAS Bardic Poetry Database'. It was delivered as part of the Tionól 2007, in Trinity College, Dublin, on Friday 16 November to an audience of around 100.

#### Other Lectures

On Friday 18 May the School of Celtic Studies hosted the Second Myles Dillon Memorial Lecture. The lecture, 'The Neighbours of Celtic: Family or Friends? The Relationship between Celtic, Italic and Germanic Revisited' was given by Professor Peter Schrijver, University of Utrecht. The attendance numbered approximately 110.

#### Tionól 2007

Tionól 2007 was held on 16 and 17 November under the directorship of Professor Pádraig Ó Macháin and assisted by

Eibhlín Nic Dhonncha, School Administrator.

An unprecedented number of papers were offered this year. Twenty papers were presented, in Irish and English, over the two days on subjects that ranged from prehistory to modern topics. The speakers represented a total of 14 individual academic institutions, and came from the United States of America, Sweden, Wales, England, Canada, Brittany, Germany as well as Ireland. The popularity of the Tionól was reflected also in the high attendance over the two days. The average attendance recorded was 90.

#### The following is a list of speakers and papers:

Kicki Ingridsson (NUI, Galway) 'Suicide and death of grief in early Irish literature'.

Aaron Griffith (University of Vienna) 'The distribution of the *Notae Augentes* in the Old Irish Glosses: a case of the animacy hierarchy'.

Graham Isaac (NUI, Galway) 'The relative chronology of sound changes from Proto-Indo-European to Common Celtic'.

Anthony Harvey (Royal Irish Academy) 'Disunderstanding' in Hiberno-Latin: a seventh-century technique for generating new vocabulary.

Morfydd Owen (Bryn Eithin, Aberystwyth) 'The vocabulary of the Welsh medical texts'.

Nora White (School of Celtic Studies, DIAS) 'The rule of Mochuta'.

Fergus Kelly (School of Celtic Studies, DIAS) 'Cauldron imagery in a legal passage on judges (CIH 1307.38-1308.6)'.

Julianne Nyhan (NUI, Cork) 'Emerging electronic research infrastructures for Irish lexicography'.

Diarmuid Ó Sé (UCD) 'The grammatical status of the "Autonomous Verb" in Irish'.

Peter McQuillan (University of Notre Dame, Indiana) 'Towards the contextualization of seventeenth- and eighteenth-century Irish poetry'.

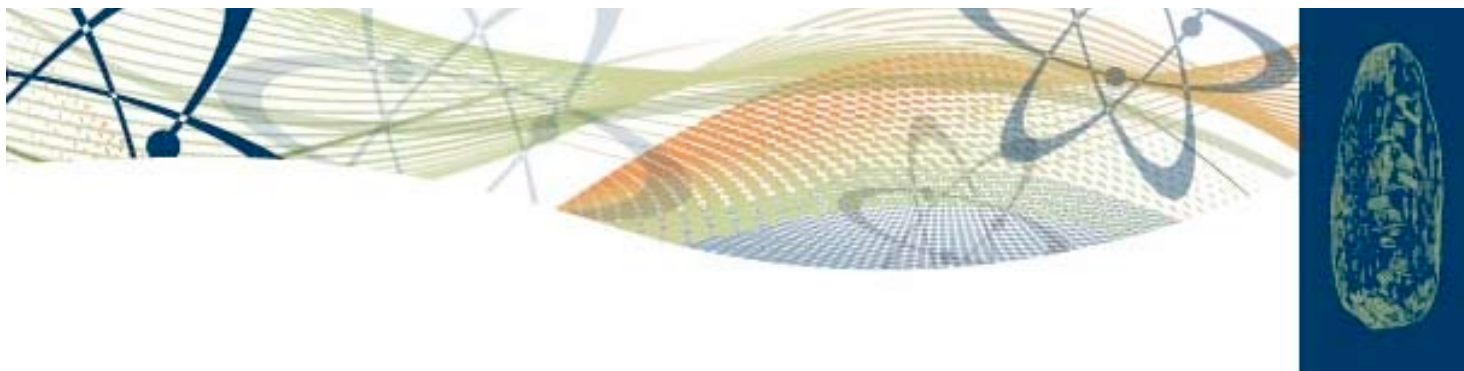
Liam Mac Amhlaigh (Froebel College of Education, Dublin) 'An examination of seventeenth- and eighteenth-century Irish lexicographers'.

Ríonach Uí Ógáin (UCD) 'Cailín Deas Crúite na mBó'.

Brent Miles (School of Celtic Studies, DIAS) 'Full Cycle: *In Tres Troí* and the conclusion to the Irish History of Troy'.

Jenny Rowland (UCD) 'The maiming of horses in *Branwen*'.

Dáibhí Ó Cróinín (NUI, Galway) 'The newly-discovered Whitley Stokes collection in the Albertina University-Library



in Leipzig’.

Kim McCone (NUI, Maynooth) ‘Celts, Galatians and Gauls: the etymology of Greek *Keltoi*, *Galatai* and Latin *Galli*’.

Eva Guillourel (University of Rennes, France) ‘An approach of behaviours regarding death and religion in Brittany through the analysis of *Gwerziou*’.

Matthias Egeler (Oxford University) ‘Death, wings and divine devouring: possible Mediterranean affinities of Irish battlefield demons’.

Donnchadh Ó Corráin (NUI, Cork) ‘Why compose on your back in the dark? Druidry or science?’

Aidan Breen (Trinity College, Dublin) ‘Cultural Contacts between Ireland, Britain and the Eastern Mediterranean in the Pre-Islamic Period, c.460-650’.

### Seminars

Liam Breatnach concluded his series of seminars on a Middle Irish poem on Viking Dublin, and gave a seminar on a Middle Irish poem of advice to a student. He also conducted a seminar on Early Irish Law consisting of readings from a variety of Old Irish law-texts.

Pádraig A. Breatnach held a weekly seminar on ‘Poems on the O’Donnells (1200-1600)’.

Roisín McLaughlin held a weekly seminar on the Middle Irish Metrical Tract *Mittelirische Verslehren III*.

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

Liam Breatnach: ‘An ceathrú Leibhéal: Taighde agus Scoláireacht’, Comhdháil ar Léann na Gaeilge sna hOllscoileanna, Acadamh Ríoga na hÉireann, (24 Feabhra).

Pádraig A. Breatnach: ‘Athruithe san ollscolaíocht: dushlán do Léann na Gaeilge’, Comhdháil ar Léann na Gaeilge sna hOllscoileanna, Acadamh Ríoga na hÉireann, (24 Feabhra).

‘Repertoria mancriptorum Collegii S. Antonii’, Louvain Summer School Lobbhain/Leuven 400’, Louvain Institute for Ireland in Europe, Leuven (23 May).

‘Redactive methodologies in the transmission of early modern Irish historical verse’, 13th International Congress of Celtic Studies, Bonn University; July. ‘An tAthair Bonaventura Ó Dochartaigh OFM († 1680) agus sealúchas lámhscríbhinní Choláiste San Antaine’, Comhdháil ‘Lobbhain/Louvain 1607-2007’, Scoil na Gaeilge, Ollscoil na hÉireann, Gaillimh (13 Deireadh Fomhair).

Clodagh Downey: ‘Sruth Segsa agus sruith éicse – Cúán

ua Lothcháin and the Boyne’, 21st Irish Conference of Medievalists, Mary Immaculate College, Limerick (June).

‘Corop suthain ar n-ardri – the poetic life and afterlife of Máel Sechnaill Mór mac Domnaill’, 13th International Congress of Celtic Studies, Bonn University, (July).

Fergus Kelly: ‘A legal Treatise attributed to Giolla na Naomh Mac Aodhagáin’, School of Irish, Trinity College Dublin, (18 January).

‘Early Irish law and society’, Faculty of History, Moscow State University, (10 April). ‘Marriage and divorce in Early Christian Ireland’, Faculty of History, Moscow State University, (12 April)

Early Irish Farming: the documentary evidence’, Faculty of History, Moscow State University, (13 April). ‘Triads in Early Irish literature, Smolny Institute, St Petersburg State University, (19 April).

‘Evidence in Early Irish law’, Royal Society of Antiquaries of Ireland, (26 April). ‘Early Irish law’, Glendalough Visitor Centre, (10 July).

‘*Crimthann* “fox” and other Early Irish formations in *-than(n)*, *-then(n)*’, 13th International Congress of Celtic Studies, Bonn University, (10 July). ‘Cauldron imagery in a legal passage on judges (CIH 1307.38-1308.6)’, Tionól, School of Celtic Studies, (November).

Brent Miles: ‘Full Cycle: In Tres Troí and the Conclusion to the Irish History of Troy’, Tionól, School of Celtic Studies, Dublin. (November).

‘Epic Similes and the Development of Formulaic Comparison in Middle Irish Prose’, 13th International Congress of Celtic Studies, Bonn University, (July).

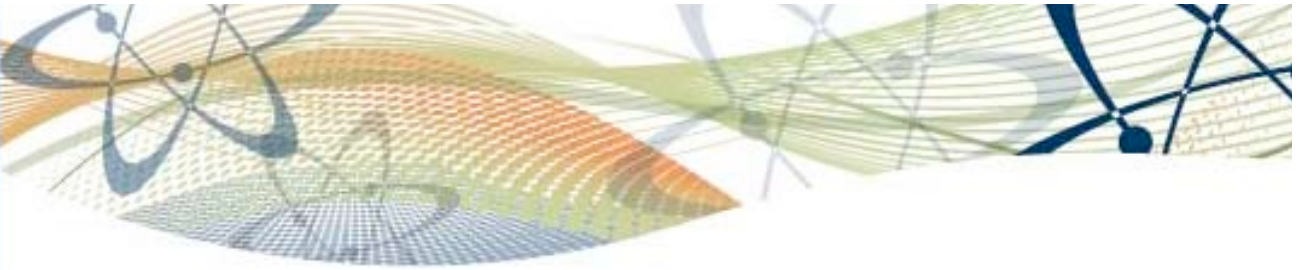
Malachy McKenna: ‘The structure of Modern Irish; sentences and sounds’, Congress on the Celtic Languages, Ulster Folk Museum (November).

Roisín McLaughlin ‘I sin Aracept ro tinoiled’: a reference to a lost Aracept in Laud 610? 13th International Conference of Celtic Studies, Bonn University (July)

Aoibheann Nic Dhonnchadha: ‘The Medical texts in Harley 546: a discussion of their sources’. Paper read at British Library Symposium: ‘Healing and the Harley Collection: Medieval Medical Manuscripts revealed’, Warburg Institute, London (July).

‘Lámhscríbhinní leighis na Gaeilge, 1400-1650’: lecture given to Daonscoil na Mumhan in Coláiste na Rinne, Rinn Ó gCuanach, Co. Waterford (August).

Brian Ó Curnáin: ‘Traditional and non-traditional Irish and language death in Co. Galway’ guest speaker Department of Celtic, University of Glasgow. ‘Nontraditional and reduced acquisition of Irish in the Conamara Gaeltacht’, 13th International Congress of Celtic Studies (July). ‘Nua-iasachtaí i nGaeilge Iorras Aithneach, Condae na Gaillimhe’,



Comhdhail Teangeolaíocht na Gaeilge XI, Ollscoil na hÉireann, Má Nuad.

Pádraig Ó Macháin: 'Eóghan Ruadh and Fearghal Óg: two Mac an Bhaird poets in exile', Louvain400 conference, Irish Institute, Louvain (24 May). "One glimpse of Ireland": the manuscript of Fr. Nicolás (alias Fearghal Dubh) Ó Gadhra OSA', Irish Europe: Language, Text and Culture. 1600-1640. NUI Maynooth (15 September). 'Among friends and enemies: Irish poets in Louvain', Ireland and Europe in the Seventeenth Century, Royal Irish Academy (28 September). 'Collections of Bardic verse in the Low Countries', UCD Michéal Ó Cléirigh Seminar (2 November).

Michelle O Riordan: 'Imeacht na nIarlaí: fairsinge agus buaine na hinsinte fileata'. Scoil Mherriman (26-28 Eanáir). "Dána an turas trialltar sonn"--- páirt de scéalaibh agus d'imtheachtaibh Uí Néill nuair a dh'fhág sé Éire', Léachtaí Cholm Cille (30-31 Márta). 'Beannacht ar anmain Éireann': Ireland's soul died with the departure of the Earls? Irish Post-Medieval Archaeology Group (IPMAG) in Rathmullan, Co. Donegal (27-29 April).

Freya Verstraten: 'Was there a Gaelic Irish 'Middle Nation'?', Conference 'The first English Empire?', Trinity College, Dublin (15 September).

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

Clodagh Downey presented a seminar for the M.Phil. in Early Irish, School of Irish, Trinity College Dublin, on 'Cath Cairn Chonaill: the Battle of Carn Conaill'.

Brian Ó Curnáin: léachtóir páirt-aimseartha in Acadamh na hOllscolaíochta Gaeilge, Ollscoil na hÉireann, An Cheathrú Rua, Co. na Gaillimhe, don Chúrsa MA sa Phleanáil Teanga. Michelle O Riordan: 'A Survey of Irish Literature' for the Irish Studies Module, First-year Bachelor in Arts and Theology, Mater Dei Institute of Education, Dublin City University.

Malachy McKenna: dhá chúrsa i Scoil na Gaeilge, Coláiste na Tríonóide, Baile Átha Cliath: 'Bunfhoghraíocht na Nua-Ghaeilge' agus 'Gaeilge Uladh'.

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

Liam Breatnach: external examiner for Early and Medieval Irish, National University of Ireland, Maynooth.

Fergus Kelly: external examiner, University of Helsinki (PhD thesis).

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

#### Website of the School of Celtic Studies

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

#### Television and radio

Brian Ó Curnáin took part in various interviews on RTÉ, TG4, and Raidió na Gaeltachta in connection with his book *The Irish of Iorras Aithneach, Co. Galway*. He took part in an interview with Raidió na Gaeltachta to discuss the publication *Aistí ar an Nua-Ghaeilge in ómós do Bhreandán Ó Buachalla* (curtha in eagar ag A. Doyle agus S. Ní Laoire).

Michelle O Riordan took part in various short interviews with TG4 and Raidió na Gaeltachta during the year.

Aoibheann Nic Dhonnchadha participated (at the request of CELT, UCC) as interviewee in an article entitled 'Putting medical history online', by Eoin Burke-Kennedy, in Health Supplement, Irish Times (September).

### 1.15 Coistí seachtracha/Outside committees

Liam Breatnach: was nominated as Local Chairman of the Organising Committee of the 14th International Congress of Celtic Studies, to be held in Maynooth in 2011.

Pádraig A. Breatnach: Ball de Choiste Náisiúnta Léann na Gaeilge, Acadamh Ríoga na hÉireann. Gairmeoir na Comhdhála 'Athruithe san ollscolaíocht: dúshlán do Léann na Gaeilge', Acadamh Ríoga na hÉireann, 24 Feabhra. The Librarian Margaret Kelly was appointed to the committee of the Academic and Special Libraries Section of the Library Association of Ireland [www.libraryassociation.ie](http://www.libraryassociation.ie). She is also a member of the working group for Library Ireland Week 2008. Aoibheann Nic Dhonnchadha: Ball de Choiste Náisiúnta Léann na Gaeilge, Acadamh Ríoga na hÉireann.

### 1.16 Bord Rialúcháin Scoil an Léinn Cheiltigh/ Governing Board of the School of Celtic Studies

Professor Anders Ahlqvist (Chairman)

Professor Angela Bourke

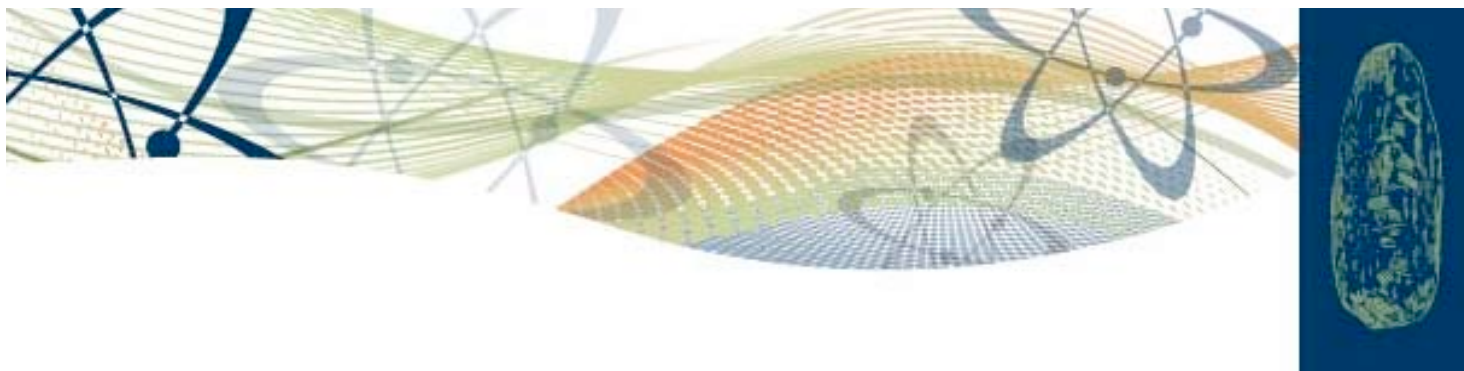
Professor Máire Herbert

Professor Liam Mac Mathúna

Dr Eilís Ní Dheá

Professor Dónall Ó Baoill

Dr Nollaig Ó Muraíle



Professor Ruairí Ó hUiginn  
 Dr Katharine Simms  
 Professor Liam Breatnach  
 Professor Fergus Kelly  
 Professor Pádraig A. Breatnach

The Board met four times in 2007: 29 March, 18 May, 27 September, 15 November.

### 1.17 Cuairteoirí agus Comhaltai/Visitors and Associates

#### Visiting Professors

Professor Markku Filppula (University of Joensuu, Finland)  
 Professor Melita Cataldi (University of Turin, Italy)  
 Professor Tomás Ó Cathasaigh (Harvard University, USA)  
 Professor Thomas Charles-Edwards (Jesus College, Oxford, UK)  
 Professor Johan Corthals (University of Hamburg, Germany)  
 Professor Peter Schrijver (University of Utrecht)  
 Professor Pádraig Ó Néill (The University of North Carolina at Chapel Hill)

#### Visiting IRCHSS Research Fellow

Dr Caoimhín Breatnach (University College Dublin)

#### Research Associates

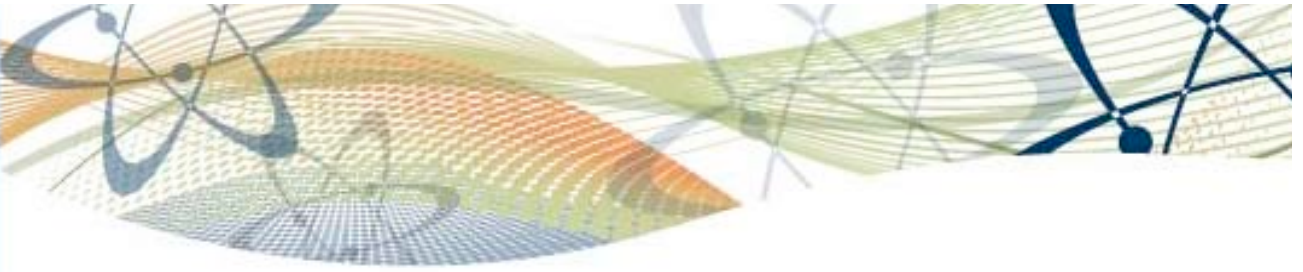
Dr Gwenllian Awbery, University of Wales, Cardiff (1990)  
 Dr John Carey, National University of Ireland, Cork (1990)  
 Professor Thomas Charles-Edwards, University of Oxford (1990)  
 Professor Toshio Doi, Nagoya Women's University (1991)  
 Professor David N. Dumville, University of Aberdeen (1989)  
 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)  
 Dr Martin McNamara, MSC, Milltown Institute of Theology and Philosophy (1989)  
 Professor Toshitsugu Matsuoka, Hosei University, Tokyo (1991)

An tOllamh Tomás Ó Con Ceanainn, 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)  
 Dr Tom O'Loughlin, University of Wales, Lampeter (2003)  
 Professor Pádraig Ó Néill, The University of North Carolina at Chapel Hill (1990)  
 Dr Morfydd Owen, Bryn Eithin, Aberystwyth (2003)  
 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 Calvert Watkins, Harvard University (1990)

#### 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.

Dr Thomas O'Loughlin (University of Wales, Lampeter)  
 Dr Jacqueline Borsje (University of Amsterdam, The Netherlands)  
 Father Chrysostom (Koutloumous Monastery, Greece)  
 Riitta Latvio, (University of Helsinki, Finland)  
 Nicholas Evans (Glasgow University, Scotland)  
 Aaron Griffith (University of Vienna, Austria)  
 Anton A. Elkhov (Moscow State University, Russia)  
 Piero de Gennaro, (University of Turin, Italy)  
 Aidan Breen (University of Massachusetts, Boston, USA)  
 Ranke de Vries, (Utrecht University, The Netherlands)  
 Matthias Egeler, (Jesus College, Oxford, UK)  
 Tatyana Mikhailova (Moscow State University, Russia)



# School of Cosmic Physics - Astronomy and Astrophysics

## 1 Highlights

In 2007 the combined Astronomy and Astrophysics Section has:

- published over 60 refereed publications including papers in *Science* and *Nature*;
- reported the detection of a second jet from a brown dwarf, this time of very low mass (24 Jupiter masses);
- published an estimate of the initial Lorentz factor of a GRB from observations of the starting time of the optical afterglow emission;
- seen evidence from X-ray observations of rapid acceleration in SNRs;
- hosted two major international meetings (JWST and HEPRO);
- secured 9.5MEuro under PRTL cycle 4 for the e-INIS proposal;
- negotiated the purchase of the national capability computing service machine with the support of the HEA and HEAnet and in partnership with the universities, RCSI, DIT and the Tyndall Institute;
- taken on 3 new postdocs and 3 students;
- submitted two PhD theses;
- initiated enhanced outreach activities in Dunsink;
- published another book in the JETset lecture notes series;
- been included in the preparatory phase EU proposal for KM3NeT;
- moved into new offices in number 31 Fitzwilliam place with an internal 10GB fibre-optic data ring and modern fire-suppressed server room.

## 2 Staff

*Senior Professors* Luke Drury, Evert Meurs

*Professors* Felix Aharonian, Tom Ray

*Emeritus Professors* Denis O'Sullivan, Alex Thompson, Ian Elliott, Tao Kiang

*Schrodinger Fellows* Andy Lim, Carlos del Burgo, Masha Chernyakova (from 1 April)

*EU Marie Curie Fellow* Stefano Gabici (from 1 Oct)

*IRCSET Fellow* Paul Dempsey (from 1 Oct)

*SFI-funded Researchers* Rachel Curran, Linda Podio (from 17 Dec)

*Visiting Scientists* Peter Duffy (on sabbatical from UCD), Mark

Dieckmann (Norköping University, Sweden)

*Hamilton Scholars* Sean Delaney (from 17 Sep), Jonathan Mackey, Denys Malyshev (from 15 Oct), Colin Melody (to 31 Oct), Elisa Nichelli (from 30 Apr), Susanna Vergani, Paul Ward (to 31 Oct)

*Summer Student Interns* Paul Dawson (11 Jun – 03 Aug), Sara-Jane Doogan (29 May – 13 Sep), Lynda Fennell (11 Jun – 31 Aug), Barry Whelan (5 – 29 Jun)

*Experimental Officer* (IT support unit) Stephane Dudzynski  
*Senior Technical Officer* (Dunsink Observatory) Mike Smyth  
*Technical Officers* Anne Grace, Hilary O'Donnell, Eileen Flood  
*Secretarial and Reception* Carol Woods (to 27 Apr), Phyllis Daly, Iwona Pelcer (from 17 Oct), one vacancy

*Groundsman* (Dunsink Observatory) Thomás Mac Grioffa  
*CosmoGrid project positions* Anna Avdeeva (student), Thibaut Lery (project scientist, to 22 Jan), Conor Masterson (project scientist, 22 Jan to 13 Jul), Anne Shaw (project administrator), Sebastian Leygnac (researcher, to 31 Oct), David Golden (IT system administrator, to 14 Apr), Phillipe Grange (IT system administrator, from 03 Sep), S Wang (researcher, seconded to Met Eireann), Tadashi Yamasaki (researcher, to 30 Jun)

*JETSET project positions* Emma Whelan (academic administrator), Jose Gracia (researcher), Fabio de Colle (researcher)

## 3 Research Reports

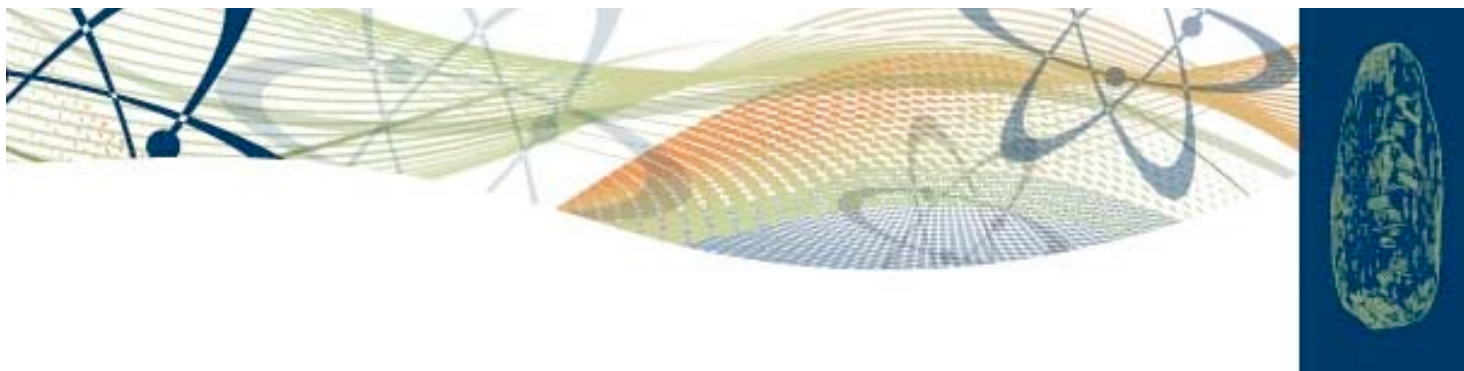
### 3.1 Interstellar Dust and Near-Infrared spectroscopy

#### 3.1.1 Shells in elliptical galaxies

*C. del Burgo, D. Carter, G. Peletier, M. Balcells and E. Valentijn*

Two papers have been published on a sample of six shell galaxies based on Hubble Space Telescope observations (Sikkema, Carter, Peletier, Balcells, del Burgo & Valentijn 2007, *A&A*, 467, 1011) and Spitzer data of NGC 5982 (del Burgo, Carter & Sikkema 2008, *A&A*, 477, 105). A figure of the last paper was selected as cover of the journal. The distribution of dust traced by optical obscuration and infrared emission has been studied. HST data gauge small amounts of dust in the central regions of the sample, while the Spitzer data reveals the presence of a much bigger amount of cold dust forming a central disk in NGC 5982. In this galaxy shells are detected for the first time from mid-infrared emission and two new external shells are discovered (del Burgo et al. 2008). A prominent shell has been analysed revealing its





blue V-I and [3.6]-[4.5] colours with respect to the underlying galaxy. Spitzer data of a few shell galaxies are also being studied.

### 3.1.2 Interstellar medium of the Milky Way

*C. del Burgo with D. Froebrich (U Kent), G. Murphy (Grenoble), M. Smith (U Kent), J. Walsh (TCD)*

A large-scale extinction map of the Galactic Anticentre from 2MASS has been published (Froebrich, Murphy, Smith, Walsh & del Burgo 2007, MNRAS, 378, 1447) based on the techniques developed in Froebrich & del Burgo (2006, MNRAS, 369, 1901). Next year CdB will work on the analysis of the near-infrared colours and far-infrared emission in the cloud complexes that are identified in the mentioned Galactic Anticentre map. In addition, he plans to analyse the anomalous emission detected in a few dust clouds with Prof. Rafael Rebolo and collaborators (IAC, Spain).

### 3.1.3 Integral Field Spectroscopy of Galaxies

*C. del Burgo with Dr. Evencio Mediavilla (IAC, Spain) and Dr. Santiago Arribas (DAMIR, Spain)*

A collaboration has been initiated to perform research on the circumnuclear regions of nearby normal and active galaxies from Integral Field Spectroscopy (IFS). IFS studies of shell galaxies have been continued in collaboration with Prof. Dave Carter (Liverpool, UK) and Dr. Marc Balcells (IAC).

## 3.2 High energy processes in Binary Systems

### 3.2.1 On the origin of TeV radiation in LS 5039

*F. Aharonian, D. Khangulyan (MPIK, Heidelberg), V. Bosch-Ramon (MPIK, Heidelberg)*

The recent detections of TeV gamma-rays from compact binary systems show that relativistic outflows (jets or winds) are sites of effective acceleration of particles up to multi-TeV energies.

The aim of this study was to explore the conditions of acceleration and radiation of ultrarelativistic electrons in LS 5039, the gamma-ray emitting binary system for which the highest quality TeV data are available. Assuming that the gamma-ray emitter is a jet-like structure, detailed numerical calculations of the energy spectrum and light curves has been performed accounting for the acceleration efficiency, the location of the accelerator, the speed of the emitting flow, the inclination angle of the system, as well as specific features related to anisotropic inverse Compton

(IC) scattering and pair production. The accelerator should not be deep inside the binary system unless one assumes a very efficient acceleration rate. Within the IC scenario both the gamma-ray spectrum and flux are strongly orbital phase dependent, therefore the physical properties of the source can be constrained only by observations capable of providing detailed energy spectra for narrow orbital phase intervals ( $\ll 0.1$ ).

### 3.2.2 Modeling the interaction of relativistic and nonrelativistic winds in the binary system PSR 1259-63/SS2883. I. Hydrodynamical limit

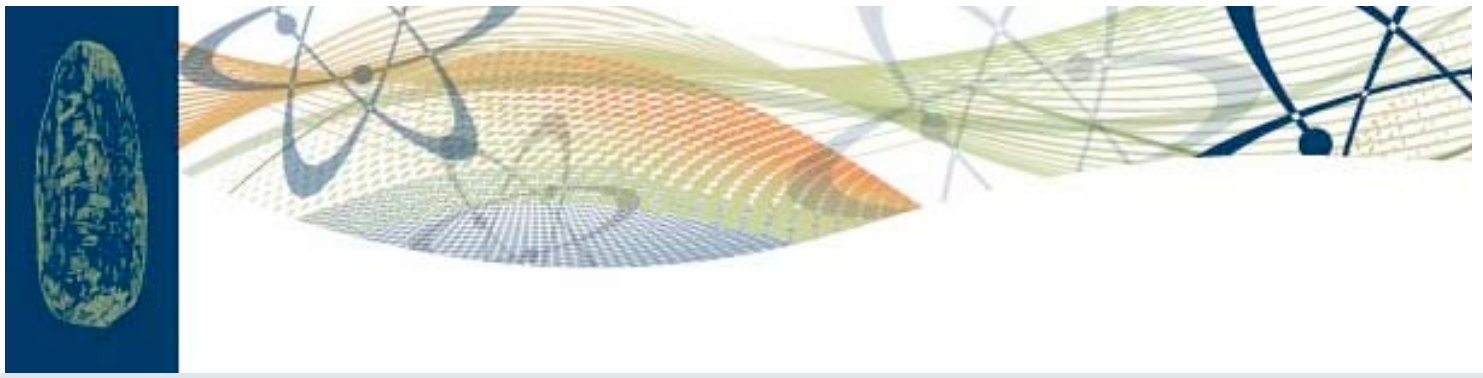
*F. Aharonian, D. Khangulyan (MPIK, Heidelberg), S. Bogovalov (Moscow Engineering Physics Institute), D. Koldoba and G. Ustyugova (Keldysh Institute of Applied Mathematics, Moscow)*

Detailed hydrodynamical studies have been conducted to study properties of the flow produced when a relativistic wind interacts with a nonrelativistic wind. In binary systems this scenario can be realized at collision of pulsar and stellar winds. The numerical calculations show that the wind collision could result in formation of an "unclosed" (at spatial scales comparable to the binary system size) pulsar wind termination shock even when the stellar wind ram pressure exceeds significantly the pulsar wind kinetic pressure. Moreover, the post-shock flow propagates in a rather narrow region, with very high bulk Lorentz factor ( $\sim 100$ ). Interestingly, no magnetic field is required for formation of the ultrarelativistic bulk motion – the plasma acceleration is related to adiabatic losses, and thus has pure hydrodynamical origin. The obtained results offer a new interpretation for the orbital modulation of radio, X-ray and gamma-ray signals detected from binary pulsar PSR 1259-63/SS2883.

### 3.2.3 TeV light curve of PSR B1259-63/SS2883

*F. Aharonian, D. Khangulyan (MPIK, Heidelberg), S. Hnatic (MPIK, Heidelberg), S. Bogovalov (Moscow Engineering Physics Institute)*

The evolution of the energy spectra of relativistic electrons under different assumptions about the acceleration and energy-loss rates of electrons, and the impact of these processes on the light curve of Inverse Compton gamma-rays have been studied. It is demonstrated that the observed by HESS TeV gamma-ray light-curve of the binary pulsar PSR



B1259-63/SS2883 can be explained (i) by adiabatic losses which dominate over the entire trajectory of the pulsar with a significant increase towards the periastron or (ii) by the ‘early’ (sub-TeV) cut-offs in the energy spectra of electrons due to the enhanced rate of Compton losses close to the periastron. The calculated spectral and temporal characteristics of the TeV radiation provide conclusive tests to distinguish between these two working hypotheses. The Compton deceleration of the electron-positron pulsar wind contributes to the decrease of the non-thermal power released in the accelerated electrons after the wind termination, and thus to the reduction of the IC and synchrotron components of radiation close to the periastron. Although this effect alone cannot explain the observed TeV and X-ray light curves, the Comptonization of the cold ultrarelativistic wind leads to the formation of gamma-radiation with a specific line-type energy spectrum. While the HESS data already constrain the Lorentz factor of the wind,  $\gamma \leq 10^6$ , future observations of this object with GLAST should allow a deep probe of the wind Lorentz factor in the range between  $10^4$  and  $10^6$ .

### 3.2.4 A Rotating Hollow Cone Anisotropy of TeV Emission from Binary Systems

*M.Chernyakova & A. Neronov (ISDC)*

Gamma-ray-loud binary systems are a newly identified class of sources in which either accretion onto the compact object or interaction of an outflow from the compact object with the wind and radiation from a massive companion star leads to the production of very high energy (VHE)  $\gamma$ -ray emission. The VHE  $\gamma$ -ray emission from the  $\gamma$ -ray-loud binaries is variable on the orbital period (or shorter) timescale. This implies that the emission region is located close to the binary system, in a highly inhomogeneous and anisotropic particle and photon background produced by massive companion star.

The  $\gamma$ -ray emission from such a region should have a characteristic rotating hollow cone anisotropy; i.e., most of the photons are emitted at a certain angle with respect to a symmetry axis directed radially away from the massive star. Orbital motion of the emission region around the massive star leads to the rotation of the emission cone and to the appearance of maxima in the orbit-folded light curve in the VHE band. The phases of the maxima and their width put constraints on the geometry of the system. For the case of LS 5039 we found that its TeV lightcurve can be interpreted in a straightforward way, in terms of this model, and that if

the source of the electrons is located close to the compact object (pulsar case), then the inclination of the orbit should be rather high,  $i > 40^\circ$ . Contrary, if the inclination of the binary orbit is small, the observed TeV  $\gamma$ -ray emission is produced far from the compact object (e.g. in jet).

### 3.2.5 Compactified pulsar wind nebula model of gamma-ray loud binary LSI +61 303

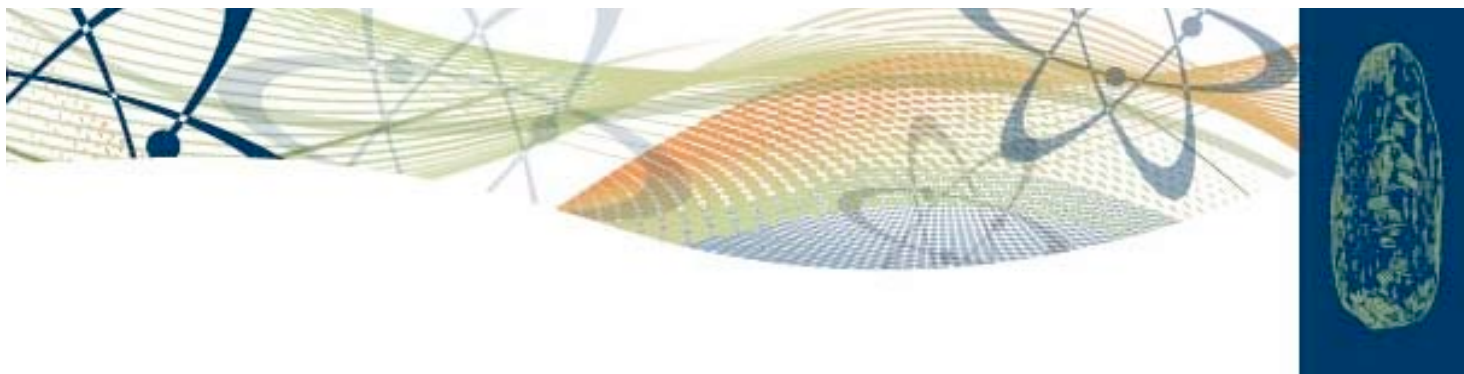
*M.Chernyakova, A. Neronov (ISDC), A. Zdziarski (Copernicus, Poland)*

LSI +61 303 is one of the three currently known  $\gamma$ -ray-loud X-ray binaries. The nature of the compact source is not known, but similarity of the spectral energy distribution of the source to the one of PSR B1259-63, powered by the rotational energy of the young pulsar makes it interesting to apply the ‘pulsar model’ to the LSI +61 303 as well. If the activity of LSI +61 303 is powered by a young pulsar, the radio-to- $\gamma$ -ray emission is generated in the course of collision of relativistic pulsar wind with the wind from companion star. Different physical processes determine cooling of high-energy particles at different distances from Be star. This leads to an onion-like structure in which the region of dominance of Coulomb losses is embedded into the region of dominance of inverse Compton (IC) losses which is, in turn, situated inside the region of dominant synchrotron loss. The density and inhomogeneity of the stellar wind determine the speed of escape of the high-energy particles injected in the region of pulsar/stellar wind interaction. Anisotropy of the stellar wind leads to the dependence of the escape speed on the orbital phase and, as a consequence, to the variations of the relative importance of Coulomb, IC, and synchrotron losses along the orbit. Such model explains the puzzling behaviour of radio, X-ray and  $\gamma$ -ray lightcurves of the system (shifts of the maxima from the periastron, shifts between the maxima of X-ray and radio lightcurves, shifts of the maxima from orbit to orbit).

### 3.2.6 Unusual bright state of the X-ray pulsar 4U0352+309/X Persei Be/X-ray binary

*M.Chernyakova, A.Lutovinov (IKI), S. Tzygankov (IKI)*

4U0352+309/X Persei is a Be/X-ray binary, consisting of a X-ray pulsar 4U0352+309 and a Be star companion optically identified with the star X-Persei. Contrary to other Be/X-ray binaries there is no clear correlation between the X-ray and optical flares from the system, though this can be related to



the fact that X-ray data were much more sparse than optical ones until the launch of the RXTE observatory. In order to understand the physical properties governing the system we study the 1996-2007 ASM/RXTE lightcurve along with the available PCA/RXTE, INTEGRAL and optical data from this period.

### 3.3 Synchrotron radiation of young SNRs

#### 3.3.1 Extremely fast acceleration of cosmic rays in a supernova remnant

*F. Aharonian, Y. Uchiyama, T. Tanaka, T. Takahashi and Y. Maeda (ISAS, Tokyo)*

Galactic cosmic rays (CRs) are widely believed to be accelerated by shock waves associated with the expansion of supernova ejecta into the interstellar medium. A key issue in this longstanding conjecture is a theoretical prediction that the interstellar magnetic field can be substantially amplified at the shock of a young supernova remnant (SNR) through magnetohydrodynamic waves generated by cosmic rays. Based on the Chandra observations of RXJ1713.7-3946, we revealed remarkable brightening and decay of X-ray hot spots in the shell of this young SNR on a one-year timescale. This rapid variability shows that the X-rays are produced by ultrarelativistic electrons through a synchrotron process and that electron acceleration does indeed take place in a strongly magnetized environment, indicating amplification of the magnetic field by a factor of more than 100. The X-ray variability also implies that we have witnessed the ongoing shock-acceleration of electrons in real time. Independently, broadband X-ray spectrometric measurements of RXJ1713.7-3946 indicate that electron acceleration proceeds in the most effective ('Bohm-diffusion') regime. Taken together, these two results provide a strong argument for acceleration of protons and nuclei to energies of 1PeV( $10^{15}$  eV) and beyond in young supernova remnants.

#### 3.3.2 Analytical solutions for energy spectra of electrons accelerated by nonrelativistic shock-waves in shell type supernova remnants

*F. Aharonian, V. Zirakashvili (IZMIRAN, Troitsk)*

Recent observations of hard X-rays and very high energy gamma-rays from a number of young shell type supernova remnants indicate the importance of detailed quantitative studies of energy spectra of relativistic electrons formed via diffusive shock acceleration accompanied by intense

nonthermal emission through synchrotron radiation and inverse Compton scattering. The aim of this work was derivation of exact asymptotic solutions of the kinetic equation which describes the energy distribution of shock-accelerated electrons for an arbitrary energydependence of the diffusion coefficient. Methods: The asymptotic solutions at low and very high energy domains coupled with numerical calculations in the intermediate energy range allow analytical presentations of energy spectra of electrons for the entire energy region. Results: Under the assumption that the energy losses of electrons are dominated by synchrotron cooling, the exact asymptotic spectra of electrons without any restriction on the diffusion coefficient have been derived. We also obtained simple analytical approximations which describe, with accuracy better than ten percent, the energy spectra of nonthermal emission of shock-accelerated electrons due to the synchrotron radiation and inverse Compton scattering. The results can be applied for interpretation of X-ray and gamma-ray observations of shell type supernova remnants, as well as other nonthermal high energy source populations like microquasars and large scale synchrotron jets of active galactic nuclei.

### 3.4 Particle acceleration and gamma-ray production in the vicinity of black holes

#### 3.4.1 Production of TeV Gamma Radiation in the Vicinity of the Supermassive BlackHole in the Giant Radio Galaxy M87

*F. Aharonian, A. Neronov (INTEGRAL Science Data Centre, Versoix)*

Although the giant radio galaxy M87 harbors many distinct regions of broadband nonthermal emission, the recently reported fast variability of TeV gamma-rays from M87, on a timescale of days, strongly constrains the range of speculations concerning the possible sites and scenarios of particle acceleration responsible for the observed TeV emission. A natural production site of this radiation is the immediate vicinity of the central supermassive black hole (BH). Because of its low bolometric luminosity, the nucleus of M87 can be effectively transparent for gamma-rays up to an energy of 10 TeV, which makes this source an ideal laboratory for the study of particle acceleration processes close to the BH event horizon. We critically analyze different possible radiation mechanisms in this region and argue that the observed very high energy gamma-ray emission can be



explained as the inverse Compton emission of ultrarelativistic electron-positron pairs produced through the development of an electromagnetic cascade in the BH magnetosphere. Through detailed numerical calculations of acceleration and radiation of electrons in the magnetospheric vacuum gap it is demonstrated that the “pulsar magnetospherelike” scenario can satisfactorily explain the main properties of the TeV gamma-ray emission from M87.

### 3.4.2 Variable VHE gamma-ray emission from non-blazar AGNs

*F. Aharonian, F. Rieger (MPIK, Heidelberg)*

The observation of rapidly variable very high energy (VHE) gamma-rays from non-aligned active galactic nuclei (AGNs), as reported from M87, proves challenging for conventional theoretical acceleration and emission models. We re-examine the centrifugal acceleration of particles by rotating jet magnetospheres in the vicinity of accreting supermassive black hole systems and analyze the energy constraints imposed for highly underluminous systems. Applications are presented for conditions expected to be present in the radio galaxy M87, assuming accretion onto the central black hole to occur in an advection-dominated (ADAF) mode. We show that for a highly underluminous source like M87, centrifugally accelerated electrons may reach Lorentz factors up to  $\gamma \sim (10^7 - 10^8)$ , allowing inverse Compton (Thomson) upscattering of sub-mm disk photons to the TeV regime. Upscattering of Comptonized disk photons results in a flat TeV spectrum  $L_\nu \propto \nu^{\alpha_c}$  with spectral index  $\alpha_c \simeq 1.2$ . The characteristic variability time scale is of the order  $r_L/c$ , which in the case of M87 corresponds to  $\simeq 1.7$  d for a typical light cylinder radius of  $r_L \simeq 5r_s$ . Centrifugal acceleration could thus provide a natural explanation for the challenging VHE emission features in M87. Our results suggest that some advection-dominated accreting (non-blazar) AGNs could well be observable VHE emitting sources.

## 3.5 Relativistic jets in AGN

### 3.5.1 Off-Axis Emission from Relativistic Plasma Flows

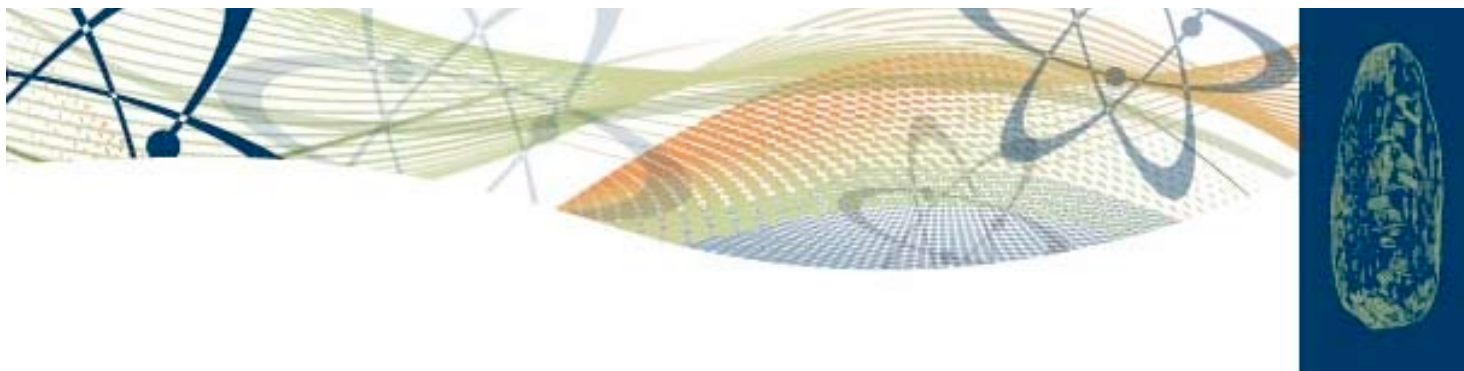
*F. Aharonian, E. Derishev and V.I. Kochanovsky (Institute of Applied Physics, Nizhny Novgorod)*

There is no universal law describing how the spectra and luminosity of synchrotron and inverse Compton radiation from relativistic jets change with increasing observation angle. Instead, the physics of particle acceleration leaves pronounced imprints in the observed spectra and allows for a freedom in numerous modifications of them. The impact of these effects is the strongest for high-energy radiation and depends on the details of the particle acceleration mechanism(s). Thus, the observed impact is sensitive to the models' details, and one can use that sensitivity to discriminate between various (but maybe rather similar) models. Generally, the beam patterns of relativistic jets in the GeV-TeV spectral domain are much wider than the inverse Lorentz factor. The off-axis emission in this energy range appears to be brighter and has a much harder spectrum and a much higher cutoff frequency compared to the values derived from Dopplerboosting considerations alone. The implications include the possibility of explaining highlatitude unidentified EGRET sources as off-axis but otherwise typical relativistic jet sources, such as blazars, and the prediction of GeV-TeV afterglow from transient jet sources, such as gamma-ray bursts. The phenomenon of beam pattern broadening may have a strong impact on the high energy neutrino emission.

### 3.5.2 Formation of hard VHE gamma-ray spectra of blazars due to internal photon-photon absorption

*F. Aharonian, D. Khangulyan (MPIK, Heidelberg), L. Costamante (Stanford University)*

The energy spectra of TeV gamma-rays from blazars, after being corrected for intergalactic absorption in the Extragalactic Background Light (EBL), appear unusually hard, a fact that poses challenges to the conventional models of particle acceleration in TeV blazars and/or to the EBL models. A natural solution of this problem could be internal absorption of gamma-rays caused by interactions with dense narrow-band radiation fields in the vicinity of compact gamma-ray production regions. This process can lead to the formation of gamma-ray spectra of an almost arbitrary hardness. If so, this would allow significant relaxation of the current tight constraints on particle acceleration and radiation



models, although at the expense of enhanced requirements to the available nonthermal energy budget. The latter, however, is not a critical issue, as long as it can be largely compensated by the Doppler boosting, assuming very large ( $\geq 30$ ) Doppler factors of the relativistically moving gamma-ray production regions. The suggested scenario of formation of hard gamma-ray spectra predicts detectable synchrotron radiation of secondary electron-positron pairs which might require a revision of the current “standard paradigm” of spectral energy distributions of gamma-ray blazars. If the primary gamma-rays are of hadronic origin related to  $pp$  or  $p\gamma$  interactions, the “internal gamma-ray absorption” model predicts neutrino fluxes close to the detection threshold of the next generation high energy neutrino detectors.

### 3.6 Multiwavelength studies of TeV gamma-ray sources

#### 3.6.1 TeV Gamma-Ray Emission of a PWN in the Galactic Center?

*F. Aharonian, J. Hinton (University of Leeds)*

The intense Compton cooling of ultrarelativistic electrons in the Klein-Nishina regime in radiation-dominated environments, such as that found in the Galactic center, may result in radically different electron spectra than those produced by synchrotron cooling. We explore these effects and their impact on the X-ray and gamma-ray spectra produced in electron accelerators in this region in comparison to elsewhere in our Galaxy. We calculated the broadband emission expected from the newly discovered pulsar wind nebula G359.95-0.04 and the possible relationship of this X-ray source to the central TeV gamma-ray source HESS J1745-290.

#### 3.6.2 XMM-Newton Observations Reveal the X-Ray Counterpart of the Very High Energy Gamma-Ray Source HESS J1640-465

*F. Aharonian, S. Funk and O. Reimer (University of Stanford), J. Hinton (University of Leeds), W. Hofmann (MPIK, Heidelberg), G. Pühlhofer and S. Wagner (LSW, Heidelberg)*

X-ray observations of the as of yet unidentified very high energy gamma-ray source HESS J1640-465 have been proposed with the aim of establishing a counterpart of this source in the keV energy range, and identifying the mechanism responsible for the VHE emission. The 21.8 ks XMM-Newton observation of HESS J1640-465 in 2005 September represents a significant

improvement in sensitivity and angular resolution over previous ASCA studies in this region. These new data show a hard-spectrum X-ray-emitting object at the centroid of the H.E.S.S. source, within the shell of the radio supernova remnant (SNR) G338.3-0.0. This object is consistent with the position and flux previously measured by both ASCA and Swift XRT, but is now shown to be significantly extended. We argue that this object is very likely the counterpart to HESS J1640-465, and that both objects may represent the pulsar wind nebula of an as of yet undiscovered pulsar associated with G338.3-0.0.

#### 3.6.3 XMM-Newton observations of HESS J1813-178 reveal a composite Supernova remnant

*F. Aharonian, S. Funk and O. Reimer (University of Stanford), J. Hinton (University of Leeds), Y. Moriguchi and Y. Fukui (Nagoya University), W. Hofmann (MPIK, Heidelberg), G. Pühlhofer and S. Wagner (LSW, Heidelberg)*

X-ray and 12CO(J=1-0) observations of the TeV gamma-ray source HESS J1813-178 have been analyzed with the aim of understanding the origin of the gamma-ray emission. High angular resolution X-ray studies of the VHE gamma-ray emission region are performed using 18.6 ks of XMM-Newton data, taken on HESS J1813-178 in October 2005. NANTEN12CO(J=1-0) data are used to search for correlations of the gamma-ray emission with molecular clouds which could act as target material for gamma-ray production in a hadronic scenario.

The NANTEN 12CO observations show a giant molecular cloud of  $2.5 \times 10^5$  solar masses in the vicinity of HESS J1813-178. The X-ray data show a highly absorbed ( $nH = 10^{23} \text{ cm}^{-2}$ ) non-thermal X-ray emitting object exhibiting a compact core and an extended tail towards the north-east, located in the centre of the radio shell-type SNR G12.82-0.02. The central object shows morphological and spectral resemblance to a Pulsar Wind Nebula and therefore it is likely that this object is a composite SNR. In order to connect the core X-ray emission to the VHE gamma-ray emission electrons have to be accelerated to energies of at least 1 PeV. This supports the plerionic origin of highest energy electrons.



### 3.6.4 Potential neutrino signals from Galactic gamma-ray sources

*F. Aharonian, S. Kelner (MPIK, Heidelberg), A. Kappes and C. Stegmann (University of Erlangen-Nuremberg), J. Hinton (University of Leeds)*

A certain fraction of TeV gamma-ray sources discovered by HESS in the galactic disk are believed to be of hadronic origin, and hence they are potential sources of high energy neutrinos. The neutrino flux of these sources can be estimated with good accuracy. Using the energy spectra and source morphologies measured by H.E.S.S., together with recent parameterisations of pion production and decay in  $pp$  interactions, the signal and background rates expected from these sources have been calculated for the proposed  $1\text{km}^3$  scale neutrino detector in the Mediterranean Sea (KM3NeT). It appears that at energies above 1 TeV the brightest gamma-ray sources can initiate in KM3NeT neutrino events with rates comparable to the background rate from atmospheric neutrinos (a few events per year). Thus these sources can be marginally detected by KM3NeT, after several years of continuous operation, provided that the contributions of gamma-rays of leptonic (inverse Compton) origin to the gamma-ray fluxes detected by HESS are negligible.

## 3.7 Star Formation

### 3.7.1 Automatic Pipeline from Jet Simulations to Synthetic Observations

*J. Gracia, JETSET Collaboration*

Numerical simulations and observations cannot be compared directly. While the former describes the plasma in terms of physical quantities such as density, pressure, magnetic field and velocity, the latter observes only photon flux as a function of frequency. Translating numerical simulations into synthetic observations is a highly non-trivial task. In principle, the JETSET collaboration possess all the necessary skills to bridge this gap, however it is scattered over a number of nodes. The goal of this project is to produce a set of tools for processing model simulations, leading to synthetic spectra which can be directly compared with observations. This requires assembling various inputs and know-how from individual members of the collaboration, defining interfaces between the different tools and rewriting them in a consistent manner within a single code. A prototype implementation of the pipeline was completed.

### 3.7.2 Extending radially self-similar MHD models by introducing an outer disk radius

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

One geometrical limitation of self-similar MHD models for jets is the non-existence of an intrinsic scale. The jets formally extend to radial infinity. The aim of this project is to investigate numerically, how imposing an outer radius of the jet, i.e. cutting off the analytical solution at arbitrary radii, affects the topology and structure, the stability and ability to explain observations of a radial self-similar analytical solution.

### 3.7.3 Resistive MHD Jet Launching Models

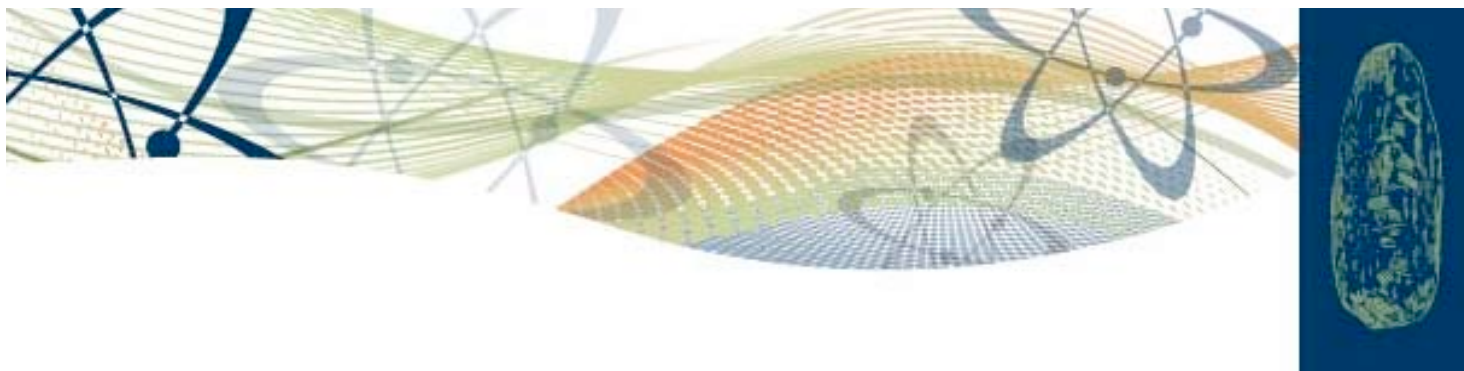
*J. Gracia and M. Cemeljic (University of Athens)*

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. Preliminary results seem to indicate, that at low values of resistivity the numerical results coincide very well with the ideal models. Only, an additional (resistive) heating is observed along the flowlines. However, above a critical resistivity value, the flow completely changes character and becomes intrinsically time-dependent, i.e. no steady-state solutions were found. We are currently investigating if this is a numerical artifact, and, if real, what is the relationship of the time-scale for variability to the flow parameters.

### 3.7.4 On the Origin of Knots in YSO Jets

*F. De Colle, J. Gracia, G. Murphy (LAOG Grenoble)*

Jets from young stars normally consist of chains of knots, Herbig-Haro (HH) objects, with some periodicity in their spatial distribution, corresponding to changes in ejection from the protostar/disk system on timescales around 10 yrs. We have studied different possibilities for the origin of the HH objects and, using simple analytical arguments, we have shown that a periodic or quasi-periodic variation in the stellar magnetic field produces a variation in the ejection velocity of the outflow from the star-disk system, large enough to generate the observed knots.



### 3.7.5 Diagnostics of inhomogeneous stellar jets

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

We have studied the effects of projection and beam convolution on the determination of the physical parameters (electron density and temperature, and hydrogen ionization fraction) of stellar jets. Additionally, we applied standard tomographic techniques to reconstruct the values of the parameters across the HH30 jet, obtaining in this way a three dimensional picture of the observed jet. The jet presents larger gradients in density in comparison to those determined from previous studies, and a reasonable decrease in temperature along the axes of propagation.

### 3.7.6 Development of a photoionization/MHD code

*F. De Colle, W. Henney (UNAM, Mexico), J. Arthur (UNAM, Mexico), G. Mellema (Stockholm University)*

We have developed a photoionization code as a hybrid of the Mezcalt code (developed by F. De Colle) with the C2Ray code (by G. Mellema). The code is currently being used to run three dimensional radiation MHD simulations of photoionized globules and the formation and expansion of HII regions in turbulent magnetized molecular clouds. Additionally, the AMR version of the MHD code was parallelised during a six weeks visit to CINECA (Bologna, Italy), including a simple strategy to handle load balancing.

### 3.7.7 Outflow activity in brown dwarfs

*E. Whelan and T.P. Ray*

Early in 2007 we reported, using the technique of spectro-astrometry, the discovery of the second brown dwarf (BD) with an outflow. The BD in question, 2MASS1207-3932, is a  $24M_{\text{JUP}}$  object hence it is now *the lowest mass galactic object* with a known outflow. ESO also released a press release describing this result (See Figures 1 and 2). A further 30 hours of ESO VLT observing time was granted to continue this work: 25 hours to obtain more spectra and 5 hours for imaging. Analysis is currently underway. A 3rd outflow from the BD ISO Cha 217 has already been identified. Using FORS 1 on the VLT we will attempt to directly image a number of these outflows for the first time.

### 3.7.8 Spectro-astrometry as a probe of the inner regions of young stellar objects

*E. Whelan, L. Podio and T.P. Ray*

We are using the specialised technique of spectro-astrometry to search for outflow components in emission lines from young stars. This method can also be used to identify dust holes in their surrounding disks on a couple of AU scales. To continue this work MIKE spectra (from the Magellan 8m telescope) is being analysed of the classical T Tauri star RU Lupi. The idea here is to see how the size of dust hole changes in different permitted emission lines ( $H\alpha$ ,  $H\beta$ ,  $H\gamma$ ). In addition, observing time was granted in December to study a sample of T Tauri and Herbig Ae/Be stars using UIST on the United Kingdom Infrared Telescope (UKIRT). Due to bad weather only 30% of the project was completed during the run, however, the observations still remain in the queue and will be completed. Linda Podio, a new IRCSET Fellow, joined the group in December and is a collaborator for this project. In addition 11 hours of ESO time has been granted to observe near-infrared permitted lines with ISAAC on the VLT.

### 3.7.9 Large-scale outflows from classical T Tauri stars

*T.P. Ray, F. McGroarty (Maynooth) and D. Froebrich (University of Kent)*

We have examined the environment of a number of evolved low-mass young stars, i.e. classical T Tauri stars, to see if they are capable of driving parsec-scale outflows. These stars - CW Tau, DG Tau, DO Tau, HV Tau C and RW Aur were previously known to drive only small-scale outflows of a few hundredths of a parsec. We discovered that they drive outflows of 0.5 pc-1 pc, based on the morphology and alignment of newly discovered and previously known HH objects with these sources and their jets. A cross-correlation method was used to determine the proper motions of the HH objects in these five outflows (HH 220, HH 229, HH 702, HH 705 and HH 826 - HH 835) which in turn allows us to confirm their driving sources.



Figure 1: Artist's impression of the DIAS discovery of a bipolar outflow from the brown dwarf 2MASS1207-3932, published by ESO as a press release. This is the lowest mass galactic object with a jet.

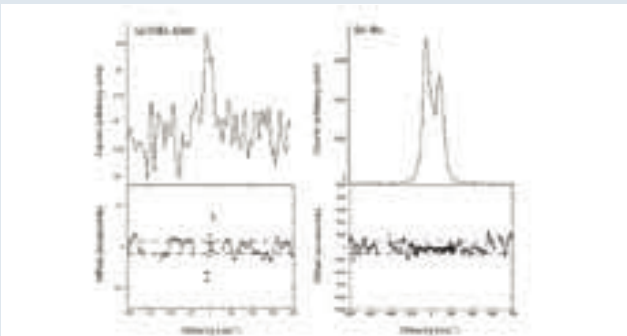


Figure 2: Offset velocity diagrams in the vicinity of the [O I]  $\lambda$ 6300 and H $\alpha$  lines of the brown dwarf 2MASS1207-3932. Data have been averaged by 3 pixel rows in the spatial direction centred on the continuum. Note the continuum has not been subtracted. The green dashed lines delineate the  $\pm 1 \sigma$  error envelope for the centroid position of the continuum. No offsets are measured in the H $\alpha$  line as expected, ruling out the possibility of spectro-astrometric artifacts. The large offsets, in the vicinity of the forbidden [O I] line and on either side of the continuum, are due to the bipolar outflow. The H $\alpha$  emission is largely dominated by accretion and thus coincides with the source.

Tangential velocities of HH objects at large distances from their origin are currently poorly known so these proper motions will allow us to determine how outflow velocities change with distance from their source. We found tangential velocities of typically  $200 \text{ km s}^{-1}$  for the more distant objects

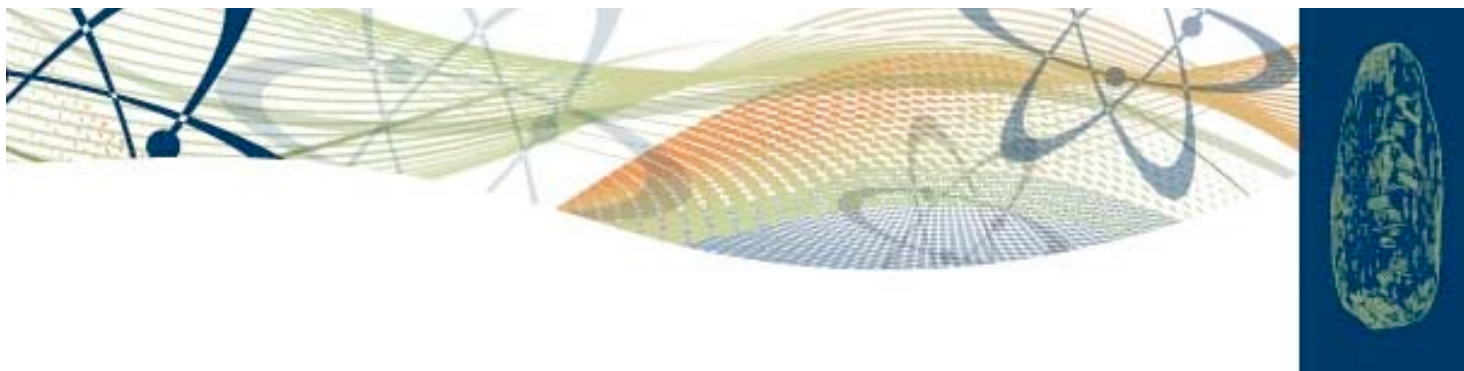
in these outflows. Surprisingly, similar tangential velocities were found for the jets. This leads us to suggest that either the outflow velocity was much higher  $10^3$  years ago when the more distant objects were ejected and that these objects have decelerated to their current velocity or that the outflow velocity at the source has remained approximately constant and the more distant objects have not undergone significant deceleration due to interactions with the ambient medium. Numerical simulations are needed to help decide between these scenarios.

### 3.7.10 Investigating the transport of angular momentum from embedded young stellar objects

*T.P. Ray, A. Chrysostomou (University of Hertfordshire), C.J. Davis (Joint Astronomy Center, Hawaii), F. Bacciotti (Arcetri), B. Nisni (Rome Observatory), J. Eisloffel (Tautenburg Observatory) and H. Takami (Subaru)*

In this pilot study, we have examined molecular jets from the embedded Class I sources, HH 26 and HH 72, to search, for the first time, for kinematic signatures of jet rotation from young embedded sources. High resolution long-slit spectroscopy of the H $_2$  1-0 S(1) transition was obtained using VLT/ISAAC, position-velocity (PV) diagrams constructed and intensity-weighted radial velocities transverse to the jet flow measured. Asymmetric PV diagrams were seen for both objects which a simple empirical model of a cylindrical jet section shows could in principle be reproduced by jet rotation alone. Assuming magneto-centrifugal launching, the observed HH 26 flow may originate at a disk radius of 2-4 AU from the star with the toroidal component of the magnetic field dominant at the observed location, in agreement with magnetic collimation models. We have estimated the angular momentum transported by the HH 26 jet and shown that it already amounts to 70% of the angular momentum that has to be extracted from the disk for accretion to proceed at the observed rate. The results of this pilot study suggest that jet rotation may also be present at early evolutionary phases and supports the hypothesis that they carry away excess angular momentum, thus allowing the central protostar to increase its mass.





### 3.7.11 Searching for Jet Rotation with the Hubble Space Telescope

*T.P. Ray, D. Coffey and F. Bacciotti (Arcetri), and J. Eislöffel and J. Woitas (Tautenburg Observatory)*

We have continued our study using the Hubble Space Telescope Imaging Spectrograph (STIS) at optical and near-ultraviolet (NUV) wavelengths to investigate rotation in young stellar object jets. Results were presented for the approaching jet from DG Tau, CW Tau, HH 30, and the bipolar jet from TH 28. Systematic asymmetries in Doppler shift were detected across the jet, within 100 AU from the star. At optical wavelengths, radial velocity differences were typically  $(10-25) \pm 5 \text{ km s}^{-1}$ , while differences in the NUV range were consistently lower, at typically  $10 \pm 5 \text{ km s}^{-1}$ . Results were interpreted as possible rotation signatures. Importantly, there is agreement between the optical and NUV results for DG Tau. Under the assumption of steady magnetocentrifugal acceleration, the survey results lead to estimates for the distance of the jet footpoint from the star, and give values consistent with earlier studies. Therefore, if indeed the detected Doppler gradients trace rotation within the jet, then under the assumption of steady MHD ejection, the derived footpoint radii support the existence of magnetized disk winds.

However, since we do not resolve the innermost layers of the flow, we cannot exclude the possibility that there also exists an X-wind or stellar wind component.

### 3.7.12 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 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. However, these observations only yield the plane-of-

the-sky component, 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 which are inferred from observations.

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

*R.L. Curran and 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 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.

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

*R.L. Curran and 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 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, 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.

### 3.7.15 Establishing the Direction of Rotation in Circumstellar Discs

*R.L. Curran, E.T. Whelan, T.P. Ray, D. Coffey (Arcetri), F. Bacciotti (Arcetri), and P. Garcia (University of Porto)*

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.

### 3.7.16 Homogeneous Reduced Polarimetry Data from the JCMT

*R.L. Curran and B. Matthews (Herzberg Centre for Astrophysics, Canada)*

In the past, it has been found that polarimetry data is especially susceptible to data reduction methods. Rachel Curran has previously analysed various data reduction techniques for SCUBA polarimetry taken with the JCMT. Using the data reduction of Curran & Chrysostomou 2007, all polarimetry map data in the JCMT archive have been downloaded, and reduced. This reduced data has since been re-entered into the archive, allowing for the first time a fully reduced, homogeneous data set available to the public from the JCMT. Such a data set allows for direct comparisons to be made between data of different objects, taken at different times, for different projects.

## 3.8 Extragalactic Jets

### 3.8.1 MHD models and synthetic synchrotron emission maps for the M87 jet

*J. Gracia, S. Bogovalov (State University of Moscow), K. Tsinganos (University of Athens)*

We have calculated self-consistent MHD models for the jet of M87. The model consists of two distinct zones: an inner relativistic outflow, which we identify with the observed jet, and an outer cold disk-wind. While the former does not self collimate efficiently due to its high effective inertia, the latter fulfills all the conditions for efficient collimation by the magnetocentrifugal mechanism. Given the right balance between the effective inertia of the inner flow and the collimation efficiency of the outer disk wind, the relativistic flow is magnetically confined into a well collimated beam for a wide range of parameters and matches the measurements of the opening angle of M87 over several orders of magnitude in spatial extent.

In the second part of this work, we present synthetic synchrotron emission maps for our MHD models. In principle the two-zone model can reproduce the morphological structure seen in radio observations, as central-peaked profiles across the jet close to the source, limb-brightening further down the jet, and a bright knot close to the position of HST-1. However it is difficult to reconcile all features into a single set of parameters.

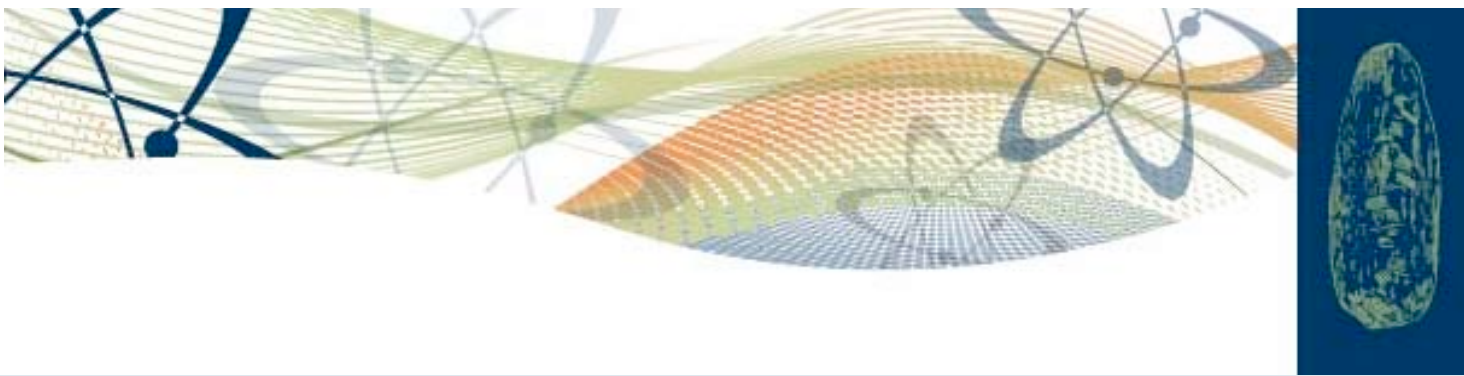
## 3.9 Gamma Ray Burst studies

### 3.9.1 REM Telescope observations

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

The arrangement by which groups participating in the REM Telescope project participated as Duty Scientists for several week-long periods ceased to be in force in 2007. Now with a centralized management of the REM observations, again a number of Gamma Ray Burst (GRB) afterglows was detected throughout the year.

The publication of the initial fireball Lorentz factor determination, which could be derived from the early afterglow onset detection for the two bursts GRB060418 and GRB060607A, led to Press Releases by the European Southern Observatory and by Dublin City University. The lightcurves of the two short bursts GRB050724 and GRB070707 (see Fig. 3) were studied, along with their host galaxy properties. Though short, both these bursts feature lightcurves that have been well monitored.



### 3.9.2 Modelling of supernova contributions to GRB afterglow lightcurves

*P. Ward, E.J.A. Meurs, C. Rebelo (Porto)*

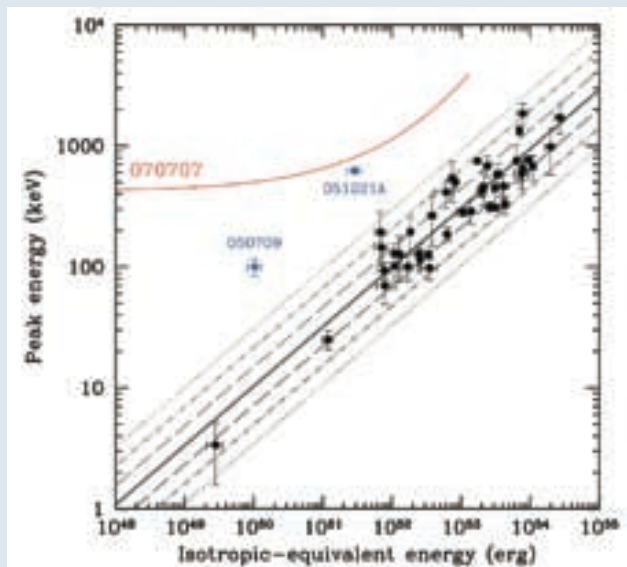


Figure 3: The red curved line represents the position of the short burst GRB070707 as a function of the (unknown) redshift, in a plot showing the 'Amati' relationship between isotropic and peak energies.

In order to model supernova contributions to the lightcurves of Gamma Ray Burst (GRB) afterglows, we have extended our determination of so-called K-corrections. The K-correction accounts for the effects of cosmological expansion on the emission properties of astronomical objects. This is important for GRBs as they are often found at cosmological redshifts (i.e., distances). The K-corrections were derived previously for type Ia supernovae, now they have been expanded to cover all known supernova types (see Fig. 4).

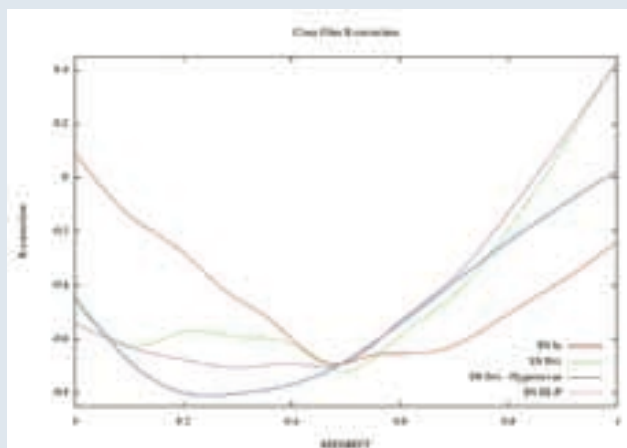


Figure 4: Cross-filter K corrections (in magnitudes) for different supernova types, over the redshift interval  $0 < z < 1$

The set of K-corrections thus obtained was then applied to model the possible contributions by different supernova types to a number of GRB afterglow lightcurves that have exhibited late-time re-brightenings. In this way we can assess which supernova types may explain the observed afterglow lightcurve bumps and which ones cannot do this. Overall, the supernova type Ic (which is often taken as a default choice) comes mostly out on top. But some other types can on the other hand not always be ruled out, in particular types Ia. This is interesting, as the peak emission of types Ia is dominated by Nickel production, which is thought to be also produced in type Ic supernovae associated with GRBs.

### 3.9.3 Swift satellite observations of GRBs

*S. Vergani, E.J.A. Meurs, the Brera Observatory Swift team*  
The Swift satellite kept detecting Gamma Ray Bursts (GRBs) regularly. Contributions to the operation of the satellite, by way of Burst Advocate were made by S. Vergani. Multiwavelength studies were carried out for two bursts, GRB060418 and GRB070311. GRB060418 exhibits a huge early time X-ray flare, which phenomenologically shows similarities to the prompt  $\gamma$ -ray emission. For GRB070311, the prompt emission, early afterglow and late re-brightening may all be ascribed to externally shocked material.

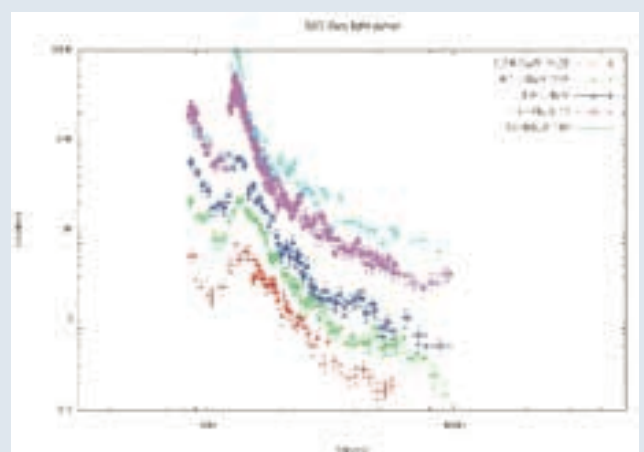
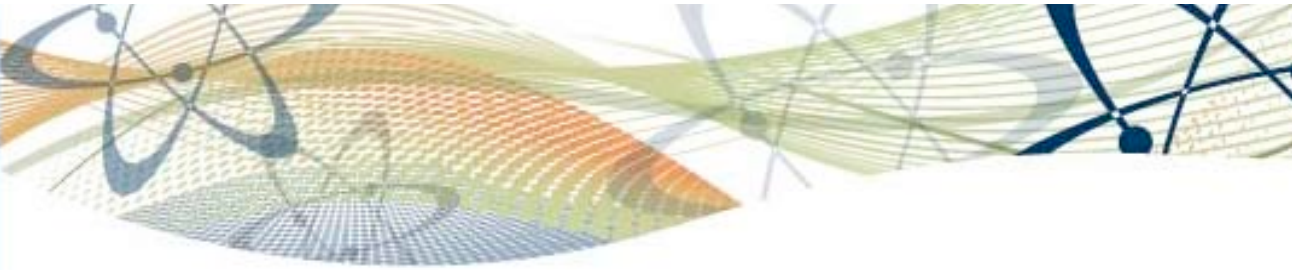


Figure 5: X-ray lightcurves of GRB060418 in different energy bands, as reported in the legend (with an added factor giving a vertical displacement with respect to the 1.0-1.3 keV data, for clarity). The plot shows a pulse that is narrower in the high-energy (hard) bands and with a peak time that occurs later in the soft bands. This is reminiscent of what is observed for the prompt emission  $\gamma$ -ray pulses.



### 3.9.4 High resolution echelle spectroscopy of GRB afterglows

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

High-resolution echelle spectroscopy is a relatively new and exciting tool for GRB astronomy. Sometimes data are obtained only minutes after a burst has occurred, which is important because of the transient nature and decreasing brightness of the afterglows. The echelle spectroscopy highlights the presence of intervening material along the line of sight, in the immediate surroundings of a burst as well as in separate intervening systems.

Echelle spectra for GRB050922C display a complex absorption system at the redshift of the host galaxy, with 7 components. The identification of multiple fine structure transitions allows for a constraint on the ionisation mechanisms involved. Also, for the first time we could identify which components are associated with the medium surrounding the burst and which are associated with the host galaxy. In addition, through the detection of MgI we can determine which components are closest to the GRB site. The redshift system of the host galaxy of GRB060607A, at a redshift of 3.074, shows little complexity; just CIV and SiIV are detected (apart from Ly $\alpha$ , see Fig. 6). By far the most complex system is one of the intervening systems, at  $z=2.933$ , which shows a great number of absorption features. It is possible that the burst occurred at the edge of a galaxy and as a result there was not as much galactic material in the line of sight. Another possible reason for the uncomplicated nature of the absorption system of the host is the ejection of the progenitor from the rich starforming region in which it was born.

## 3.10 Runaway star studies

### 3.10.1 Production mechanisms

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

OB runaway stars are massive, early-type, high-velocity stars which have been ejected from their parent birthplaces. Two mechanisms offer plausible explanations for these objects. A supernova occurring in a binary system can often result in the system becoming unbound and the companion star being released from the system with a velocity comparable to its orbital velocity. On the other hand, close gravitational interactions between two or more stars can result in

dynamical ejection of one or more of the stars as they are being flung from the system with a high velocity. Both of these mechanisms have been shown to exist in nature; however, which mechanism dominates the production of OB runaways is still unknown.

An extensive set of Nbody simulations was completed in order to explore the parameter space relevant to the production of runaway stars, such as initial cluster density, binary fraction, binary binding energy, etc. The dynamical ejection mechanism was investigated using a sophisticated Nbody code, Aarseth's Nbody6 programme, which simulates gravitational encounters between stars in a realistic cluster environment, including many other cluster properties and details relating to stellar evolution. The initial conditions of star clusters in general are unknown, but also there exists a wide variety of clusters with different properties, such as mass, size, density, etc. Thus, a range of cluster conditions was studied in order to determine how the rate of ejection of massive stars is altered within these varying environments. Several effects were considered: low, intermediate and high stellar densities; initial binary populations; initial binary binding energies; primordial mass segregation; gas expulsion; population size; and stellar mass distributions. Subsequently, a set of population synthesis routines was employed in order to study the supernova in a binary ejection mechanism in detail. The implications of the natal kick velocity, given to the neutron star at explosion, on our runaway population were considered. The number of ejections changes as a result of different initial binary separation ranges. From the velocity dispersion of binaries ejected via this supernova in a binary mechanism we give evidence that the applied natal kick velocity distribution is bimodal, with lower kicks being applied to binaries which subsequently become Be/X-ray binaries and higher kicks to binaries which become OB supergiant X-ray binaries.

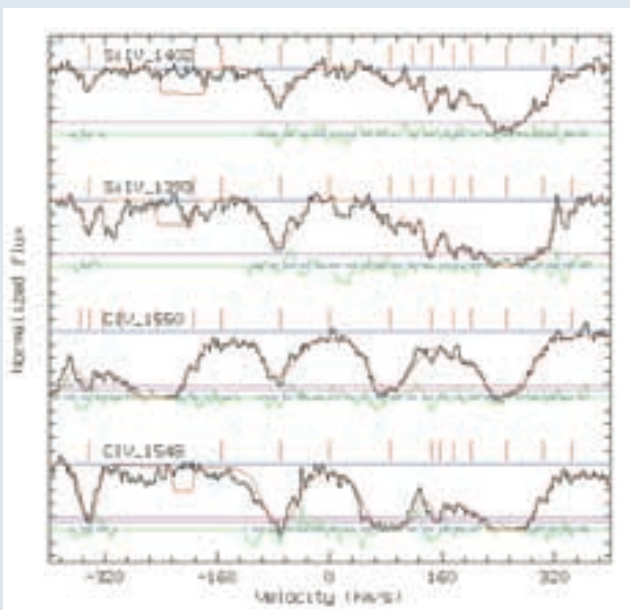
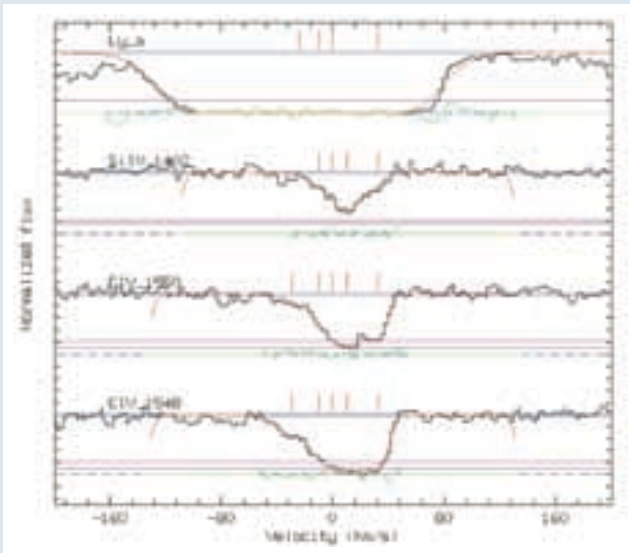
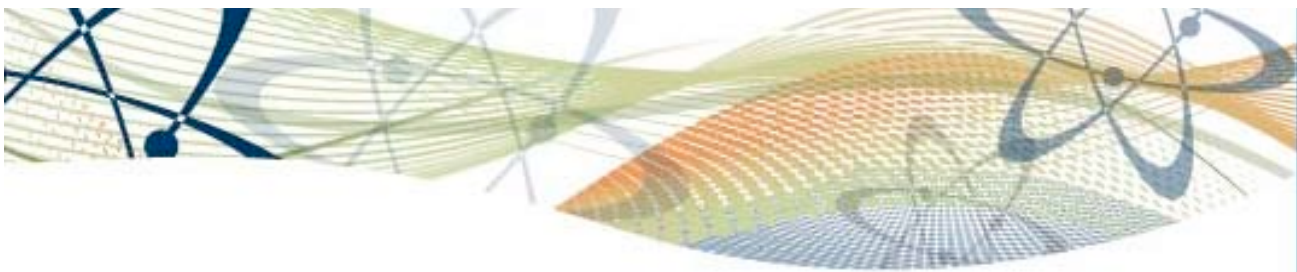


Figure 6: Top: Absorption features found in GRB060607 at  $z=3.074$   
 Bottom: The intervening absorber at  $z=2.933$  with more complex absorption features.

From a consideration of mass transfer from the primary star to the companion prior to the supernova explosion we find that nearly all O and only 30% of B star runaways are likely to be observed as Blue Stragglers with respect to their parent clusters. It is also suggested that 15% of runaways ejected via this mechanism may be so-called Thorne-Zytkow objects (stars where a companion neutron star has spiralled in and occupies their centres). The statistics of binary runaways created via either mechanism allow to consider the observational implications of these results.

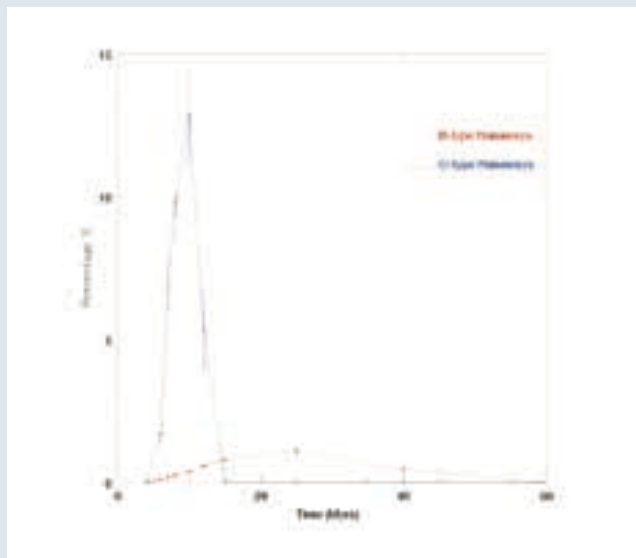


Figure 7: The percentage of runaway stars ejected via the supernova in a binary scenario, with respect to time.

### 3.10.2 Echelle spectroscopy of runaway stars

*C. O'Maolaidigh, E.J.A. Meurs, L. Norci (DCU), C. Rossi and V.F. Polcaro (Rome)*

Blaauw suggested in 1993 that excess rotation in runaway stars may be an indicator of close binary evolution as increased rotational velocity is a natural consequence of mass transfer to the companion star prior to the supernova explosion of the primary star. The implication is that the runaways were ejected via the supernova in a binary scenario. Following this, we determined rotation rates for 38 OB runaways and added these values to the database of runaways with known rotation velocities, thus extending the body of such data by 20%. The results confirm Blaauws conclusion that O-type runaways show excess rotation rates suggesting that the majority of O-type runaways is ejected via the supernova in a binary scenario. The B-type runaways show no excess rotation with respect to the rotation velocity of typical B stars, therefore the majority of B-type runaways is likely to have been dynamically ejected.



### 3.11 X-ray astronomy

#### 3.11.1 Stellar hardness ratios

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

Following our earlier, statistical result that the X-ray hardness ratios of stars (which provide a measure for the spectral characteristics of X-ray sources) vary chiefly as a result of interstellar absorption, we have embarked on a star-by-star evaluation of X-ray versus optical data. This is to demonstrate the inferred effect of line-of-sight absorption in much greater detail. To support the interpretation of the observational data, we have extended earlier work on the dependence of the X-ray hardness ratios on emission and absorption processes, featuring greater parameter ranges than investigated previously. A web-based tool that will allow to determine emission and absorption characteristics for X-ray sources from their hardness ratios is in preparation.

#### 3.11.2 Young stellar clusters

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

The high-energy emission from very young stellar clusters may be modelled without encountering difficulties due to the intricacies introduced by close-binary evolution. We have started a project to analyse X-ray data for several very young stellar clusters and to compare the results with model calculations for these clusters. For a start, we are analysing two such clusters, NGC346 in the Small Magellanic Cloud and the Galactic Super Star Cluster Westerlund 1. To support these investigations, we are preparing a master list of Super Star Clusters that will be made available on the World Wide Web.

### 3.12 General Theory

#### 3.12.1 Particle Acceleration by Multiple Parallel Shocks

*P. Dempsey, J. Tammi (UCD) and P. Duffy (UCD)*

Using both numerical and semi-analytical techniques we are examining particle acceleration in multiple parallel relativistic shocks. The non-relativistic results have been known for sometime and by extending these results to the relativistic limit we hope to apply them to the internal shock models of gamma-ray bursts.

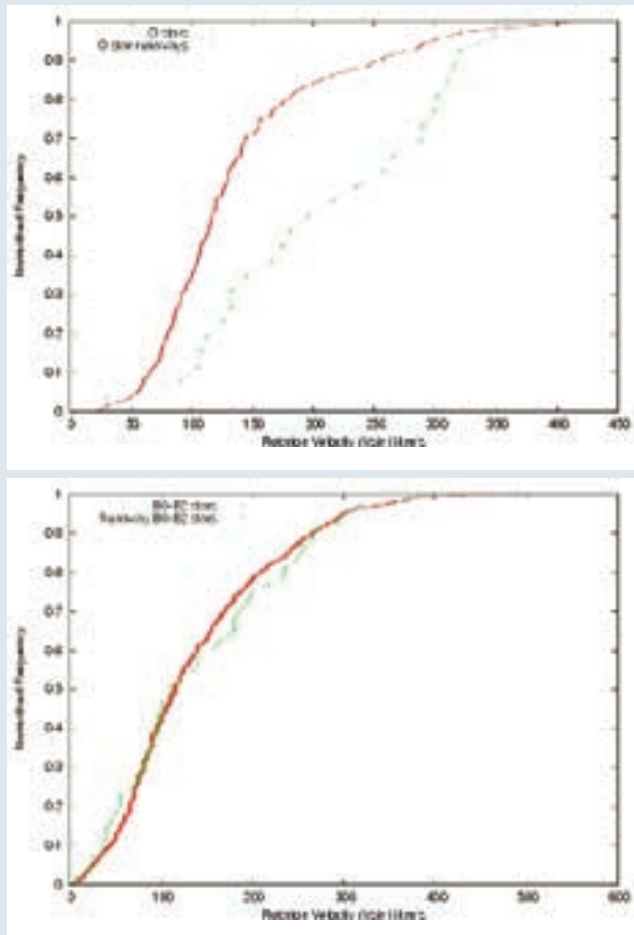
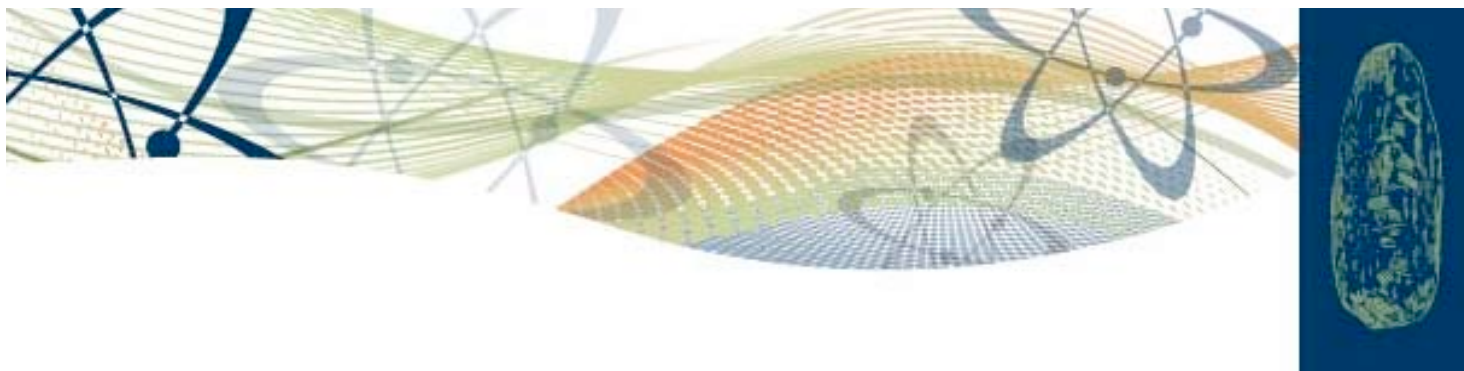


Figure 8: Cumulative distribution functions of rotation velocity, for normal (red) and runaway (green) O stars (top) and B0-B2 stars (bottom).

#### 3.12.2 Approximate Analytic Solutions to Relativistic Shock Acceleration

*P. Dempsey, J. Kirk (MPIK Heidelberg)*

Keshet & Waxman (2005) produced a simple formula for the power law index of particles accelerated at shocks of arbitrary velocity. While their formula fits previous values very well, their derivation contains several errors and their method fails to produce a pitch angle distribution that is consistent with previous numerical and semi-analytical work. By making certain analytical approximations we have produced power law indices that are close to those previously calculated, while simultaneously obtaining pitch angle distribution which agree with those found in early semi-analytic work.



### 3.12.3 PIC simulations of relativistic shock formation

*M. Dieckmann and L. Drury*

The plasma processes responsible for shock formation in the case of relativistic flow speeds are complex and can only really be studied using particle in cell simulations. Studies to date have mainly used a reflection geometry in which an incoming plasma flow is “reflected” off a solid wall at one end of the simulation box. While this is a very convenient way to set up a shock simulation it is equivalent to the collision of two plasma streams of equal density. The physically more relevant case of unequal densities has been little studied. Previous work has also focussed mainly on the case of weak initial magnetic fields. In this work we consider shocks forming from the interaction of magnetised clouds of unequal density. The magnetic field is shown to strongly suppress the filamentation instabilities seen in the weak-field case and allows the use of 1-D simulations to complement and study in more detail aspects of the 2-D simulations. Strong electromagnetic structures are seen, involving both electric and magnetic fields, and are associated with fast electron energisation.

### 3.12.4 Radiative Processes in the Interstellar Medium

*J. Mackey, and A. Lim*

As part of J. Mackey's Ph.D. programme we have been developing a modular Magneto-Hydrodynamics (MHD) code with optional radiative transfer, with a view to studying various radiative effects in the interstellar medium. The JETSET School on “Numerical MHD and Instabilities” in January 2007 was a very useful introduction to the methods we have used. A parallel MHD code on a uniform grid has been developed and tested on the ICHEC computing cluster ‘Walton.’ The radiative transfer module is currently in development/testing, and we anticipate using our code during 2008 to study a number of astrophysical situations, including photo-evaporation of gas clouds in planetary nebulae, radiation from young stars, and radiative precursors of jets.

### 3.13 Space Dosimetry

*D O’Sullivan with Johnson Space Center, Houston*

The first phase of the Matroshka-1 project was completed during the year and results were prepared for submission to Nature. The Matroshka experiment measured for the first time the doses experienced by astronauts from the

various components of ionising radiation in space on the surface and internal organs of a human like phantom located outside the International Space Station. This allowed the simulation of extra vehicular activity by an astronaut. The results show a steep gradient from the uppermost layer of the skin to the deep organs with a ratio of about 20 to 1. The skin dose at about 1mGy/d is the greatest followed by the dose rate at the eye. With the exception of the breast and salivary glands, the dose rates for other organs such as the kidneys, pancreas, esophagus, lungs, brain, heart etc, are in the range from 0.2 to 0.3 mGy/d. In total, values were determined for 24 organs. Although several international track detector groups participated in the project, only the DIAS/JSC data has been selected for the first major publication due to difficulties with the interpretation of all other track results.

The DOBIES experiment continued during 2007 and analysis of the detectors flown on the Soyuz Mission 13S in Sept 2006 was completed. The objective of the experiment was to investigate how bacteria cope with space flight conditions such as reduced gravity, space radiation and other environmental extremes. The detectors were located in the Zvezda service module in association with several bacterial cultures. The preliminary results which were reported at an international meeting in Delft in July, showed how reference dose values can be provided for comparing biological samples located at different positions on the ISS or flown on different missions. The values of dose equivalent measured were about 580 micro Sievert per day, some 40% higher than that obtained on a previous flight. The increase is consistent with the solar cycle variation. Further work awaits the launch of the European Columbus Laboratory. A launch due to take place in December was postponed and is now scheduled for February 2008. This mission will also carry an further extension of the Matroshka work.

## 4 International Collaborations

### 4.1 HESS, HESS-II and CTA

The HESS (High Energy Stereo System) collaboration of which DIAS is a member continued to produce a stream of new discoveries and has established ground-based TeV astronomy as a genuine new astronomical window allowing us for the first time to see the extreme non-thermal universe. This success was recognised by the award of the Descartes prize for European Collaborative research to the collaboration



at a ceremony in Brussels on March 7th (see Fig. 9)  
 The HESS-II project aims to extend the HESS system with an additional large telescope located at the centre of the existing four telescope system. Preliminary engineering work was completed during the year.



Figure 9: The Award Certificate for the Descartes Prize 2006 announced on 7 March 2007 in Brussels

A joint initiative by the HESS and MAGIC collaborations, as well as other interested individuals and institutes, was launched in 2006 to plan for a large Cherenkov Telescope Array (CTA) project which would be the natural successor to the HESS, MAGIC and VERITAS collaborations. Unlike the existing projects this would be run as a public observatory and not an experimental collaboration. Luke Drury, in collaboration with Alessandro de Angelis, was convener of the “Physics Working Group for CTA” until March 2007 and coordinated the first draft of the “physics case for CTA” document. An application, coordinated by Heidelberg and with DIAS as a partner, was submitted to the EU for an FP7 design study in May.

#### 4.2 JETSET

*T.P. Ray, JETSET Network Coordinator*

In 2007 the Jet Simulations, Experiment and Theory (JETSET) network had two schools and associated science meetings:

1. *Numerical MHD and Instabilities*, including a special session dedicated to visualization techniques and virtual reality in Sauze D.Oulx near Turin in January
2. *From Models to Observations and Experiments* in Ponta Delgada, San Miguel Island, in the Azores in June

In both cases approximately 60-80 people attended. During 2007, the JETSET network had its mid-term review in the Azores coinciding with the fifth school. The review, by the European Commission, was conducted over one day.



Figure 10: The JETSET School in Sauze d'Oulx near Turin in January 2007

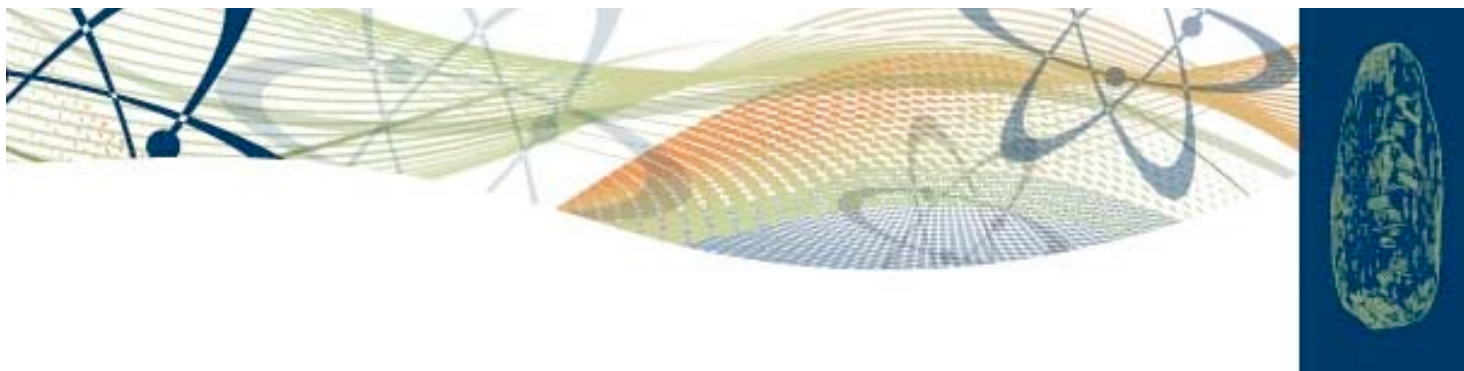
It involved presentations by the network scientists, early stage researchers (ESRs) and experienced researchers (ERs) directly employed under the contract. The Commission representative also held private sessions with the ERs and ESRs so they could express their views confidentially on the network. In July the Commission reported that “the network is working in an excellent manner and provides a stimulating environment for young researchers in a challenging and topical area of astronomy (as was clear from the lively discussions).00. The network thus passed its mid-term review with flying colours.

Judging by the extensive mid-term report (submitted in April to the EC), the network has produced a very large number of joint publications and observing campaigns using facilities such as the ESO’s VLT, Magellan, IRAM, the Plateau de Bure Interferometer, etc. In addition applications have also been submitted to utilise current or future space missions including Spitzer and Herschel (due for launch in 2008).

The next school (the sixth) and JETSET science meeting will be on *High Performance Computing in Astrophysics* in NUI, Galway. It is jointly being organised by DIAS and NUI Galway’s Department of Physics.

All ESR and ER positions are currently filled and it should be noted that there was only one change in personnel (at the University of Athens node) since the inception of the network. The latter vacancy was quickly filled. Finally it is also worth





noting that all ESRs are currently on course to complete their PhDs within the lifetime of the network (scheduled to finish in January 2009).

### 4.3 KM3NeT

*F. Aharonian and L. Drury*

DIAS, mainly in the person of Professor Felix Aharonian, was invited to participate in the FP6 design study for a deep underwater neutrino telescope to be located in the Mediterranean sea, KM3NeT, coordinated by Professor Uli Katz of the University of Erlangen. The accession of DIAS to the collaboration was formally announced at the general assembly of the KM3NeT consortium held in the Nestor Institute, Pylos, Greece, from 16th to 18th April.

### 4.4 MIRI

*T. Ray*

The Mid-Infrared Instrument (MIRI) on board the James Webb Space Telescope (JWST) consists of an imager (including a four-quadrant coronagraph phase mask), a low-resolution spectrometer (with  $R \approx 100$  for wavelengths  $5\mu\text{m} \leq \lambda \leq 10\mu\text{m}$ ) and an intermediate resolution integral field spectrograph ( $R \approx 3000$  for  $5\mu\text{m} \leq \lambda \leq 28\mu\text{m}$ ) cryogenically cooled to 7K using a NASA supplied cooling system. The European Consortium is supplying the MIRI optics while the focal plane detectors are the responsibility of the US (primarily the Jet Propulsion Laboratory in Pasadena). The Dublin Institute for Advanced Studies (DIAS) is part of the MIRI European Consortium. DIAS, as its contribution to the hardware, supplied the long wavelength filters for the imager and beam-splitters for the intermediate resolution spectrograph. As the filters and beamsplitters were manufactured in batch mode, DIAS has effectively delivered not only the hardware required for the demonstration and verification models (DM and VM respectively) but also the flight model (FM). Delivery Review Boards (DRBs) are currently in progress for these items and final sign off is expected in January 2008.

Transmission of these multi-layer filters (see Fig. 11) has proven to be excellent (typically 60-80%) and in most cases 10% better than spec. Obviously this will significantly reduce exposure times for a given signal to noise and save expensive telescope resources.

MIRI is a complex instrument as it utilises not only imaging

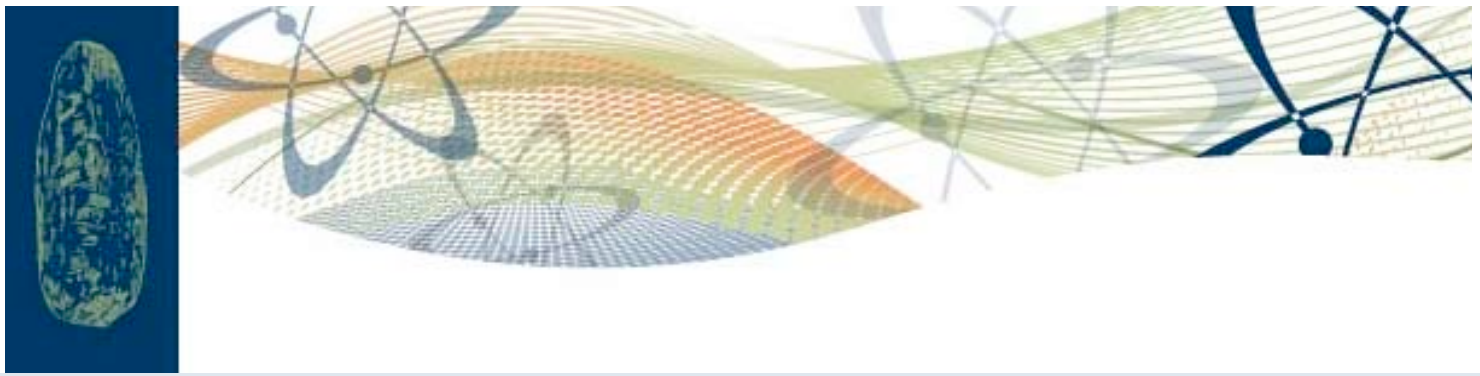
modes but also integral field unit spectroscopy. While the overall plan for data processing is now more or less clear, the process whereby the necessary software is developed is only now being put in place. In any event, the MIRI Consortium has taken the decision that this will be done by a distributed team of software engineers. Obviously this will require a clear and organised structure to ensure success.

In particular it is envisaged that:

- A common development plan is agreed upon and maintained
- Issues that impact on other sub-teams are directly communicated to the whole team
- A basic common development environment will be in place for flight model (FM) testing similar to the mission environment
- There will be open access to software resources for all parties involved
- A Configuration Control system is in place for all phases of development



Figure 11: Mid-infrared filters, supplied by the Dublin Institute for Advanced Studies, that were used to populate the MIRI verification model (VM) filter wheel in the CEA, Saclay



At this stage, the Consortium intend to agree on a common development environment, with the Space Telescope Science Institute (STScI), at the first MIRI Software Summit which is scheduled for early next year.

The MIRI Software Team will be located (alphabetically) in the University of Arizona, Commissariat l'nergie Atomique (CEA), DIAS, ATC (Edinburgh), University of Leiden, University of Leuven, Max Planck Institute for Astronomy in Heidelberg (MPIA), Rutherford Appleton Laboratory, Stichting Astronomisch Onderzoek Nederland (SRON) and STScI (Baltimore).

Negotiations are ongoing with Enterprise Ireland for an extension of our PRODEX funding to cover the period 2008-2013 and, in particular, to fund two software engineers based at DIAS who will play a fundamental role in developing MIRI software, in particular to support its spectroscopy modes.

#### 4.5 NAHUAL

*C. del Burgo*

CdB is a co-PI of NAHUAL, a near-infrared (0.9 - 2.5  $\mu\text{m}$ ) high-resolution spectrograph ( $R=65000$ ) for the 10.4m GRANTECAN telescope on the Observatorio Roque de Los Muchachos (La Palma, Spain). NAHUAL is developed in the framework of an international collaboration led by the Instituto de Astrofísica de Canarias (IAC, Spain) with the participation of research centres in Germany, Italy, Portugal and Ireland. CdB leads the Irish team, which is working on the general optics and the grating mechanism, the acquisition camera and the polarimetric mode. NAHUAL will be mainly aimed at searching for extrasolar planets of a few times the Earth mass. I am currently working on the comparison of models with high resolution spectroscopy of brown dwarfs obtained with NIRSPEC (Hawaii, USA). We have obtained a grant for personal and performance expenses for the development of NAHUAL. Also we have recently got a grant for the project RoPACS. The main goal of RoPACS is the study of extra-solar planets around cool stars.

#### 4.6 REM

*E. Meurs*

The Rapid Eye Mount (REM) Telescope is a robotic telescope with the principal aim to provide quick follow-up observations of Gamma Ray Bursts detected by satellite -ray observatories.

The telescope has a 60 cm diameter mirror, is located at La Silla (Chile), and carries Near-InfraRed as well as optical cameras. The REM project is led by Brera Observatory in Milan-Merate (Italy), with Irish participation by DIAS and UCD. When not just observing Gamma Ray Bursts, the REM Telescope carries out a variety of monitoring observations. In this way, several blazars are being followed in time (blazars are a class of highly variable, luminous active nuclei of galaxies). The blazars studied here are notorious for being also known high-energy emitters. Results were obtained notably for blazars that exhibited high amplitude maxima or flares during our observations (see Fig. 12)

Other types of object that we have been monitoring with the REM Telescope include Luminous Blue Variables in the Magellanic Clouds and a special sub-class of Be stars that is characterized by warm dust.

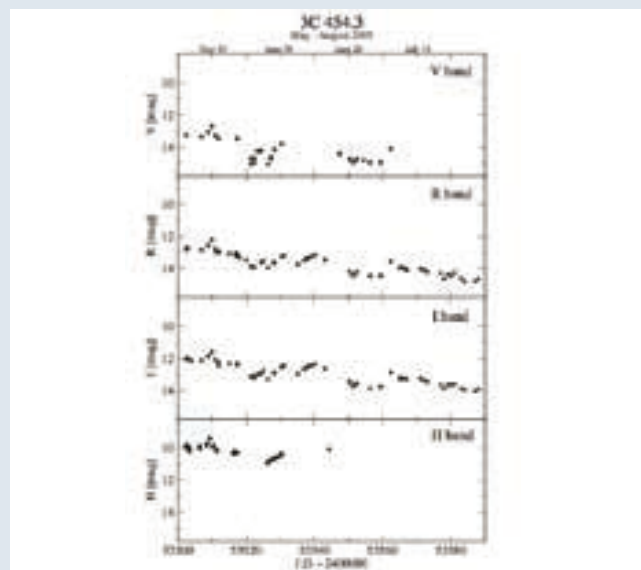
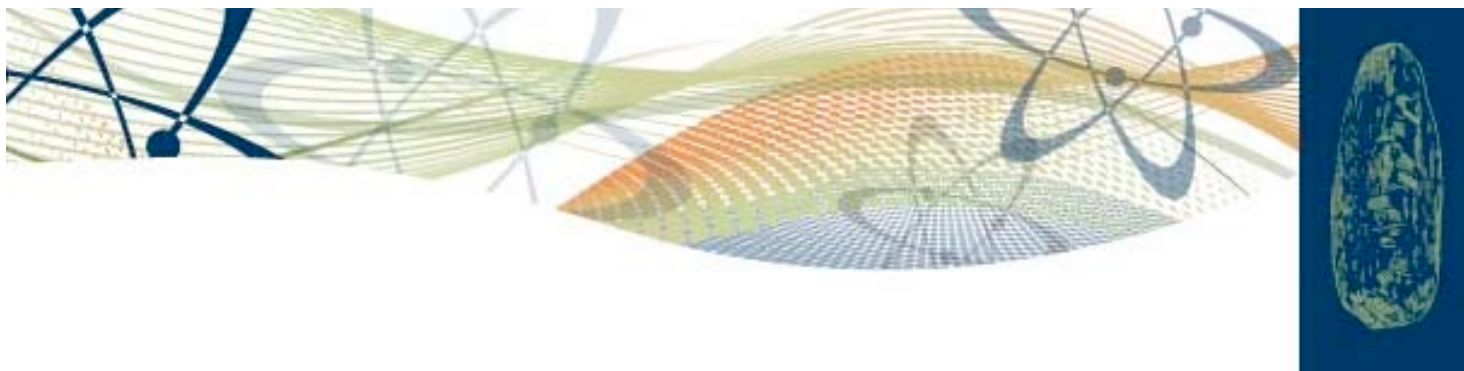


Figure 12: The brightness variation of the blazar 3C454.3 in 2005. On 19 May 2005 this object reached a historical maximum, more than a magnitude brighter than had been observed previously. The brightness subsequently decayed the next couple of months.

#### 4.7 ROTSE

*F. Aharonian*

The Robotic Optical Transient Search Experiment (ROTSE) is dedicated to observation and detection of optical transients with an emphasis on prompt afterglows of gamma-ray bursts (GRBs). The ROTSE-III program involves establishing fully automated, robotic telescopes in sites around the world to facilitate uniform, rapid follow-up of celestial transient



events. The wide field of view and the fast response of the HESS telescopes provides measurements which cannot be performed by conventional telescopes. The ROTSE telescopes are installed at four locations including the site close to Mt. Gamsberg, Namibia, and in collaboration with the HESS project.

#### 4.8 Echelle spectroscopy of bright GRBs

*E. Meurs*

In a collaboration led by Rome Observatory (Italy), high-resolution echelle spectroscopy is obtained as a means to study the immediate surroundings of Gamma Ray Bursts.

### 5 Contributions to the national e-Infrastructure

#### 5.1 e-INIS

Building on the success of the Programme for Research in Third Level Institutions (PRTL) cycle 3 project CosmoGrid (which played a major role in establishing the Irish Centre for High-End Computing, ICHEC) the school through the Institute submitted a two-component proposal to the Higher Education Authority under PRTL-4. The first part, e-INIS, was a collaborative programme to develop an integrated national e-Infrastructure and the second, e-PSI, was an institutionally-led e-science programme building on the infrastructure. Unfortunately, while e-INIS was highly praised by the reviewers and funded, the e-PSI programme was regarded as less coherent and failed to get funding.

#### 5.2 Blue Gene

For a number of years there has been an intensive debate about the need for Ireland to make a strategic investment in enabling true capability (as distinct from capacity) computing. In this context, and in discussions with the Higher Education Authority and other interested parties, the Institute offered to make resources from the CosmoGrid project available for this purpose. The seven universities and other major research institutions all strongly supported this and an understanding was reached that if we acquired a high-performance system to be run as a national service, they would subscribe to this at a level which would cover the recurrent running costs, estimated at 57K per institution per year. The HEA agreed to the reallocation of funding on condition that the system would be hosted in the HEAnet national hosting centre

and operated by the Irish Centre for High-End Computing (ICHEC). On this basis an EU public procurement exercise was carried out by HEAnet on behalf of DIAS, ICHEC and the academic community for "Purchase of a Supercomputer". This process ultimately resulted in the selection of IBM and its BlueGene architecture as the recommended vendor and a Blue Gene system consisting of one rack of L and one rack of P was ordered and installed by the end of the year. As part of the deal IBM will also provide 4 person-years of scientific support to Irish research groups and guaranteed access to the large deep-computing facilities of IBM. The original objective was to make a strategic investment opening up the possibility of true high-capability computing to Irish researchers. This has been achieved. Groups can experiment and test codes on the L, do production runs on the P, and then if necessary obtain access to some of the most powerful machines on the planet. Looking to the future the Blue Gene acquisition gives us a number of very valuable things:

- it demonstrates in a very concrete way that the academic sector can come together under the leadership of the Institute and contribute to the implementation of national strategic objectives;
- it gives the Institute a strong link to a major industrial partner in IBM;
- most importantly, it enables us to push the boundaries of computational science as applied to Cosmic Physics.



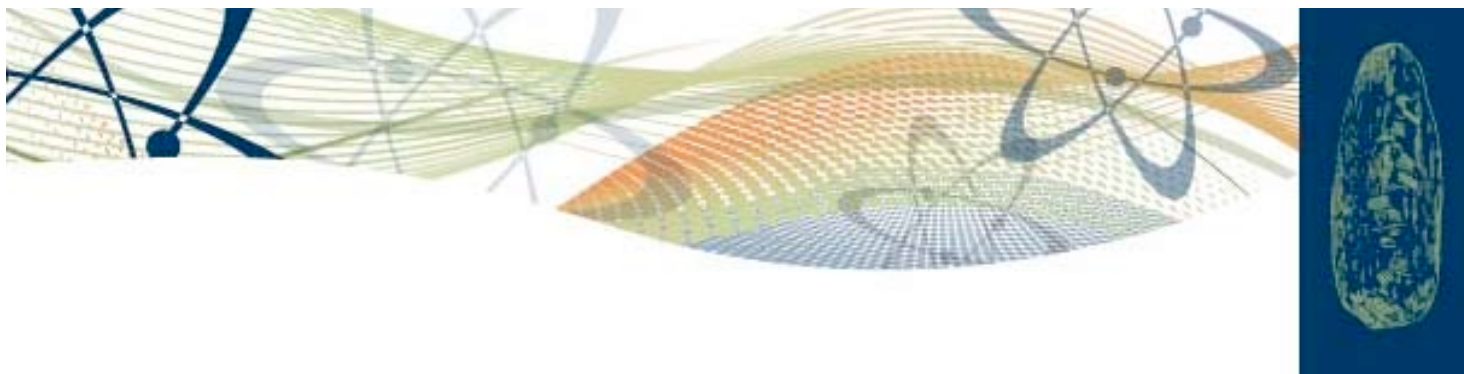
Figure 13: The IBM Blue Gene/P in the National Hosting Centre



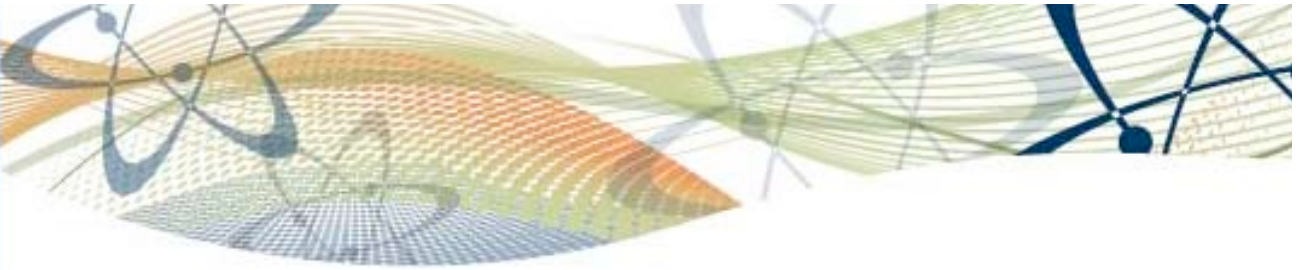
## 6 Publications

### 6.1 Refereed publications

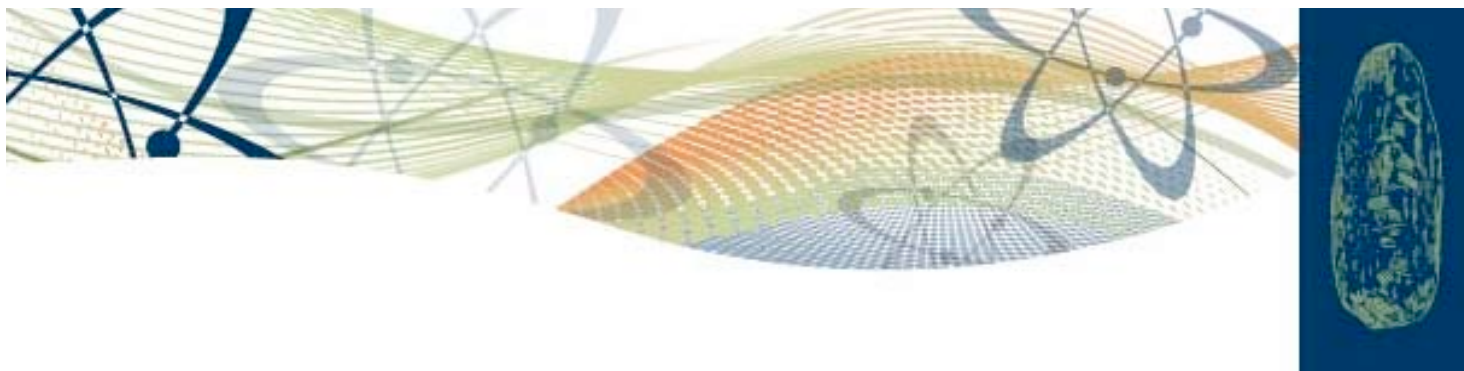
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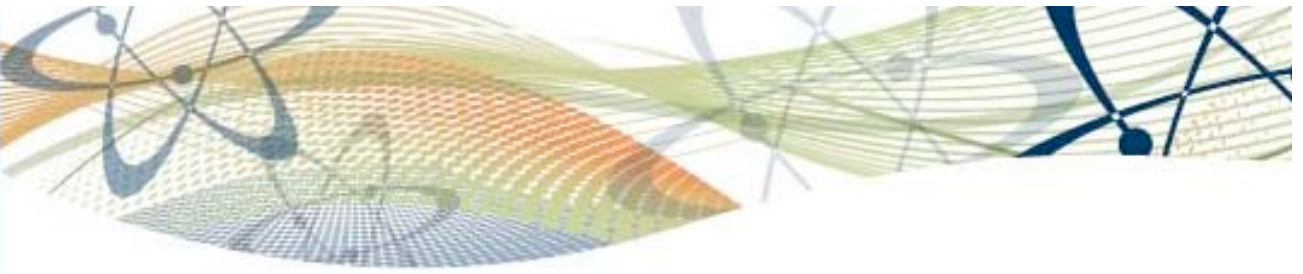
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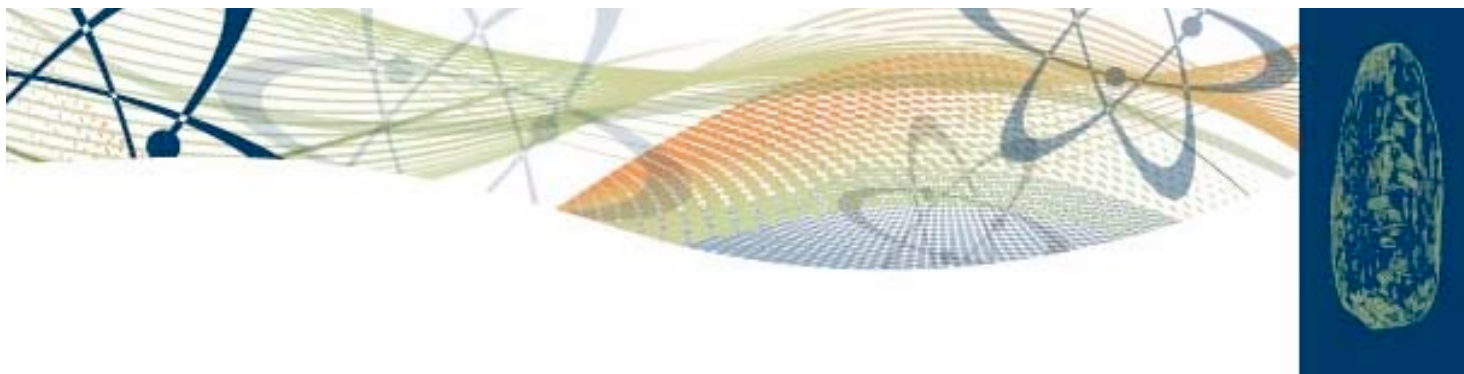
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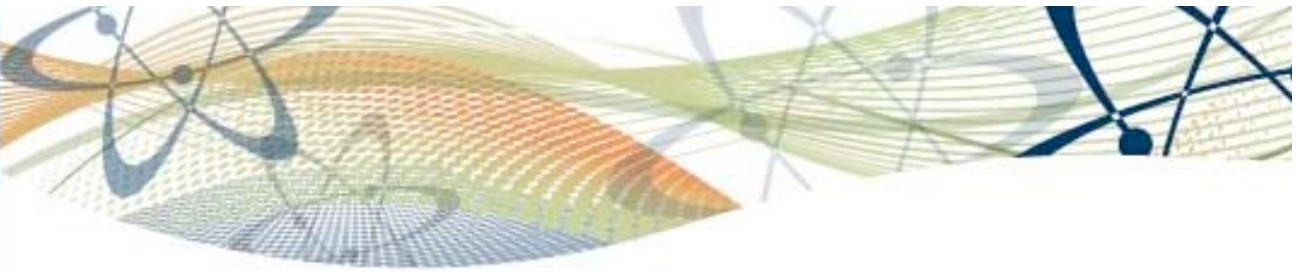


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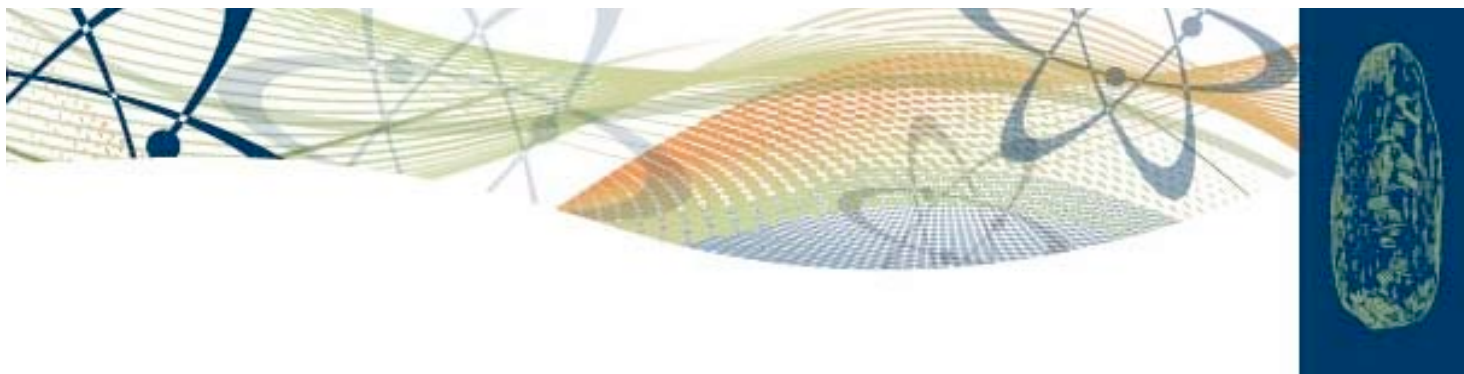




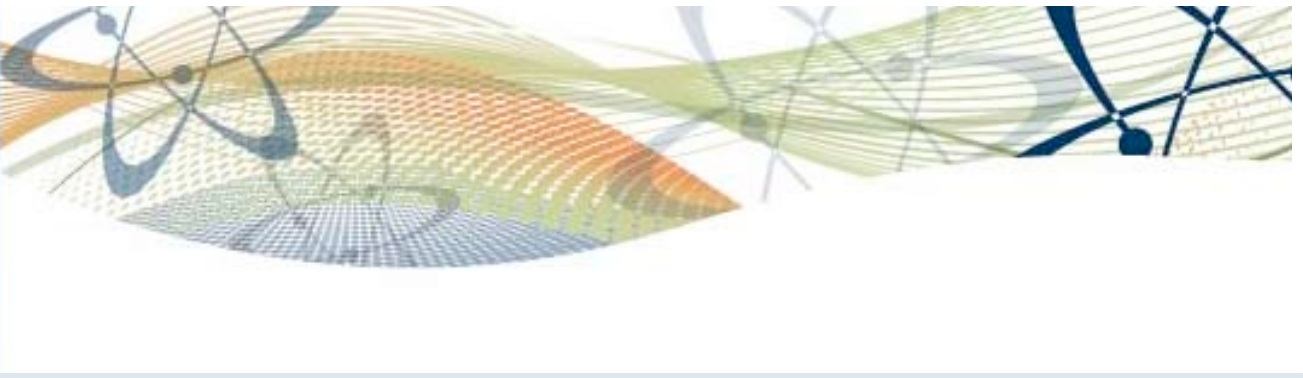
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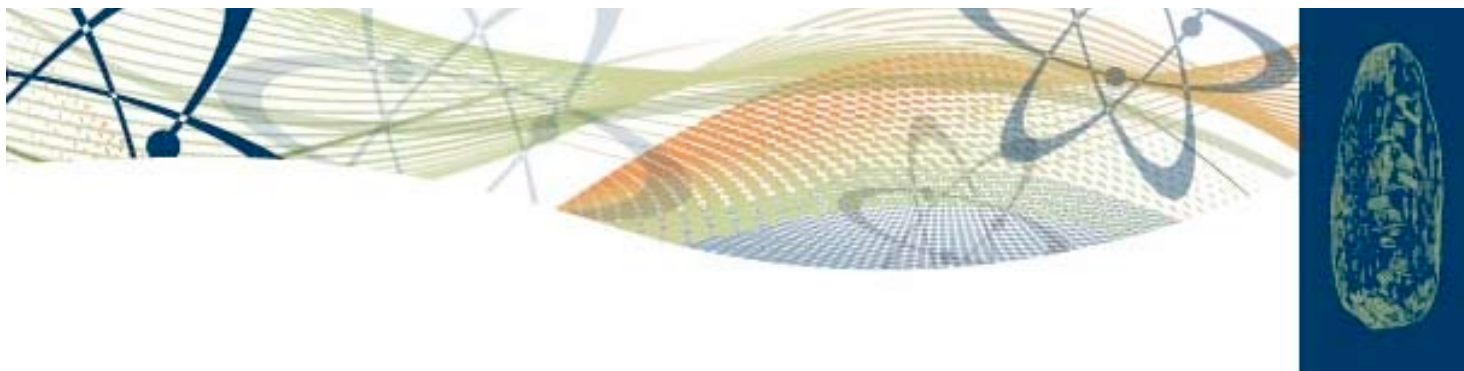
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  2. Blasi, Pasquale, Gabici, Stefano, & Brunetti, Gianfranco: Gamma rays from clusters of galaxies *arXiv:astro-ph/0701545*
  3. Piranomonte, S., D'Elia, V., Ward, P., Fiore, F., & Meurs, E. J. A.: UVES/VLT High Resolution Spectroscopy of Gamma Ray Burst Afterglows *arXiv:astro-ph/0701563*
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  7. Aharonian, Felix: Galactic Sources of High Energy Neutrinos *arXiv:astro-ph/0702680*
  8. Amato, Elena, Blasi, Pasquale, & Gabici, Stefano: Kinetic approaches to particle acceleration at cosmic ray modified shocks *arXiv:0705.3723*
  9. Funk, S., Hinton, J. A., Pühlhofer, G., Aharonian, F. A., Hofmann, W., Reimer, O., & Wagner, S.: XMM-Newton Observations Reveal the X-Ray Counterpart of the Very High Energy Gamma-Ray Source HESS J1640-465 *arXiv:astro-ph/0701166*
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  14. The HESS collaboration: An Exceptional Very High Energy Gamma-Ray Flare of PKS 2155-304 *arXiv:0706.0797*
  15. Gabici, Stefano & Aharonian, Felix A.: Searching for Galactic Cosmic-Ray Pevatrons with Multi-TeV Gamma Rays and Neutrinos *arXiv:0705.3011*
  16. H. E. S. S. Collaboration: M. Lemoine-Goumard, Aharonian, F., Degrange, B., Drury, L., & Schwanke, U.: H.E.S.S. observations of the supernova remnant RX J0852.0-4622 *arXiv:0709.4621*
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  22. Rea, N., Nichelli, E., Israel, G. L., Perna, R., Oosterbroek, T., Parmar, A. N., Turolla, R., Campana, S., Stella, L., Zane, S., & Angelini, L.: Very deep X-ray observations of the anomalous X-ray pulsar 4U0142+614 *arXiv:0707.3363*
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  25. Neronov, A. & Aharonian, Felix A.: Production of TeV Gamma Radiation in the Vicinity of the Supermassive Black Hole in the Giant Radio Galaxy M87 *arXiv:0704.3282*
  26. Tammi, Joni & Dempsey, Paul: Particle acceleration by multiple parallel shocks *arXiv:0712.1749*
  27. Gracia, J., Bogovalov, S., & Tsinganos, K.: MHD models and synthetic synchrotron maps for the jet of M87 *arXiv:0712.2734*



28. Rieger, F. M. & Aharonian, F. A.: Variable VHE gamma-ray emission from non-blazar AGNs *arXiv:0712.2902*
29. Neronov, A. & Chernyakova, M.: A Rotating Hollow Cone Anisotropy of TeV Emission from Binary Systems *arXiv:0711.3085*

## 7 Invited talks

- **Luke Drury**

1. First International GLAST symposium, Stanford USA, 5-8 Feb, "TeV gamma-ray sources and GLAST"
2. 3rd Belief Brainstorming Workshop, Dublin, 17-18 May, "The e-INIS vision"
3. TeVPA'07, Venice, Italy, 27-31 Aug, "The Next Generation of ground-based gamma-ray telescopes"
4. HEAnet annual conference, Kilkenny, 15-16 Nov, "e-INIS building the Irish National e-Infrastructure"

- **Evert Meurs**

- **Felix Aharonian**

1. Astrophysical Implications of Very High Energy Gamma-Ray Observations with HESS, Max-Planck Institut fuer Radioastronomy, Bonn, Germany, January 26, 2007 (Astronomy Colloquium)
2. Very high energy gamma ray sources, University of Leiden, Leiden, Holland, February 15, 2007 (Astronomy Colloquium)
3. Recent results from HESS, MIT, Cambridge, USA, March 13, 2007 (Astrophysics Colloquium)
4. Supernova Remnants and Pulsar Driven Nebulae, Harvard University, Cambridge, USA, March 15, 2007 (Harvard-Smithsonian Astrophysics Center Colloquium)
5. Ground Based Gamma Ray Astronomy: Status and Perspectives, CALTECH, Pasadena, March 21, 2007 (Astronomy Colloquium).
6. Next generation ground-based gamma-ray detectors: scientific motivations, potential and perspectives, Stanford University, USA, May 10, 2007 (ACKS Seminar)
7. Exploring the TeV sky with HESS, Roma Astronomical Observatory, National Institute for Astrophysics, Italy, June 19, 2007
8. Origin of cosmic rays, invited (plenary) talk at the Conference on "Ultra-high energy cosmic rays,

neutrinos and photons", Pennsylvania State University, May 2007

9. On the potential and objectives of ground based gamma ray astronomy, invited talk, at the Workshop on "The light of the dark: solving the mysteries of the Universe" Villa Mondragone, Frascati, June 2007
10. The Very High Energy Gamma Ray Sky, invited (plenary) talk at the "JENAM07" (Joint European and National Astronomy Meeting), Yerevan, Aug 2007
11. Future of High Energy Gamma ray Astronomy, invited (plenary) talk at the "10th ICATPP Conference on Astroparticle, Particle, Space Physics, Detectors", Como, October 2007
12. The TeV Universe, invited talk at the Symposium on "High Energy in Space", Palermo, October 2007

- **Tom Ray**

1. JETSET School and Workshop: Numerical MHD and Instabilities Visualization Techniques and Virtual Reality, Sauze d'Oulx, Turin, Italy, January 8-13, 2007
2. Lindsay Symposium, Armagh Observatory, January 26
3. University of Wales, Cardiff, March 21
4. IAU Symposium 243: Star-Disk Interaction in Young Stars, Grenoble, 21-25 May
5. Hellenic Astronomical Conference, Thassos, Greece, 13-15 September

- **Carlos del Burgo**

1. The infrared signature of dust in the interstellar medium of galaxies, Departamento de Astrofisica Molecular e Infrarroja (DAMIR), Instituto de Estructura de la Materia (CSIC), Madrid, Spain, December

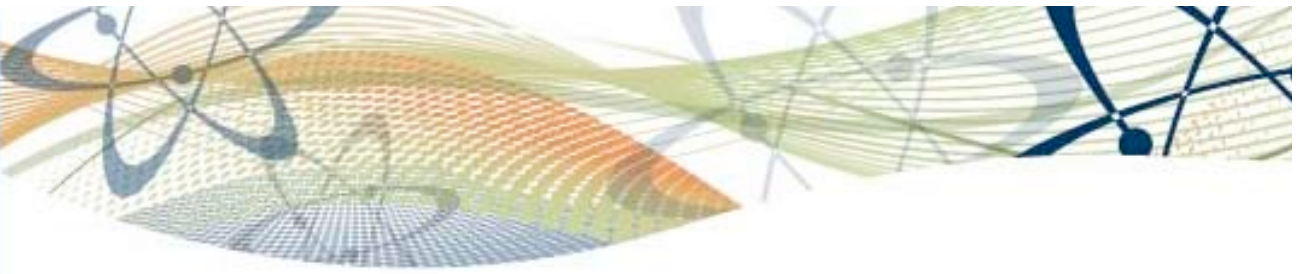
## 8 External Funding

- **Luke Drury**

1. PRTL-3 CosmoGrid, until end of year
2. PRTL-4 e-INIS, from September
3. IRCSET, one postdoc

- **Felix Aharonian**

1. EU FP6 Design Study KM3NeT
2. SFI RFP, two postgrads
3. EU Marie Curie fellowship



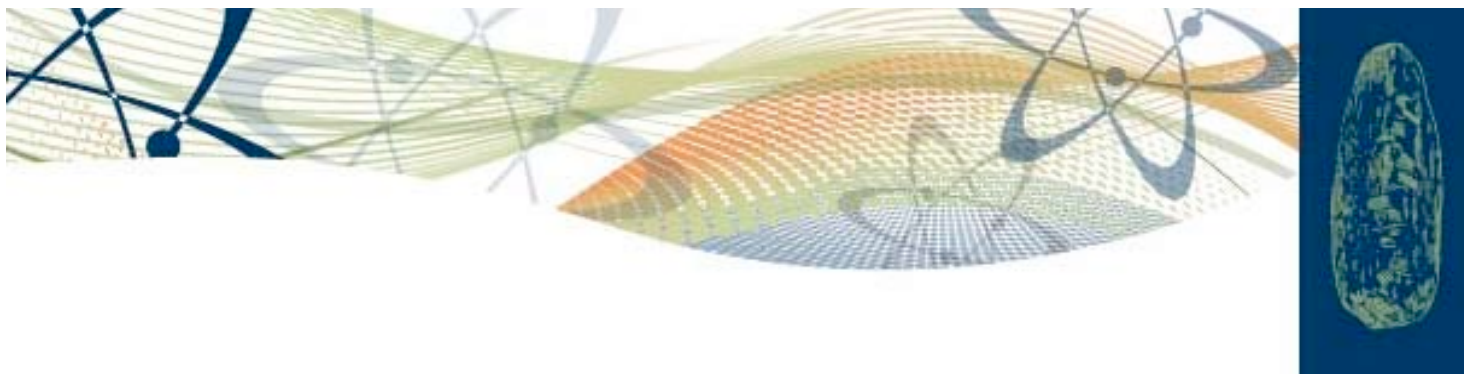
- **Tom Ray**
  1. EU Research Training Network JETSET
  2. PRODEX MIRI
  3. SFI RFP, one postdoc and one postgrad
  4. IRCSET, one postdoc
- **Carlos del Burgo**
  1. co-I on proposal of PI Eduardo Martin, project: AYA2007-67458, "Detection of exoplanets using high spectral resolution spectrographs in big telescopes" funded with 0.5MEuro over three years.

## 9 Community Service

- **Luke Drury:**
    1. invited by NUI,G to be a member of the ICHEC oversight board;
    2. invited to serve as chairman of the interview panel for the NUI travelling studentships;
    3. member of the H.E.S.S. Collaboration Board;
    4. member of the KM3NeT consortium.
  - **Felix Aharonian**
    1. Co-PI of the ROTSE project;
    2. Member of the H.E.S.S. Collaboration Board
    3. Member of the Consortium of the KM3NeT
    4. Member of ARGOS X - a member of the proposal team "Argos-X: A Panoptic X-ray Observatory (a project submitted to NASA)
    5. Member of the working group "Science with NeXT" (Japanese next generation Xray mission)
    6. chair of the PhD theses defense Committee on Astrophysics (University of Barcelona)
    7. member of the PhD theses defense Committee on Physics (Oxford University)
    8. Lectures in University College Dublin "Introduction to High Energy Gamma Ray Astrophysics" (a course of 6 lectures for final-year students)
    9. Member ("Principal Scientist/Professor") of the Heidelberg Graduate School of Fundamental Physics at the University of Heidelberg
    10. External scientific member of the MPIK in the High Energy Astrophysics Group
    11. Co-director of LEA - European Associated Laboratory on High Energy Astrophysics (jointly supported by CNRS and MPG)
    12. member of the European Astronet Infrastructure Roadmap Panel A: "High energy, astro-particle
  - **astrophysics and gravitational waves"**
  - 13. member of the group of referees for the ESA's Cosmic Vision 2015-2025 proposals
  - 14. peer reviewer of proposals within the frameworks of the ESF (European Science Foundation, NWO (the Dutch research council), DPG (Deutsche Physikalische Gesellschaft), ANR (Agence Nationale de la Recherche), ICREA (Catalan Foundation for Research and Innovation), Swiss National Science Foundation ("Mathematics, Natural and Engineering Sciences), NSERC (Natural Sciences and Engineering Research Council of Canada).
  - 15. an Editor of the International Journal of Modern Physics D
- **Evert Meurs:**
    1. member of the RIA Astronomy and Space Science Committee;
    2. member of the Joint Management Committee, Armagh Observatory and Planetarium.
    3. edited a National Plan for Astronomy in Ireland to support the case for membership of the European Southern Observatory
  - **Tom Ray**
    1. Co-PI of the MIRI project;
    2. Chairman of the e-MERLIN Steering Committee (Steering committee for national radio astronomy facilities in the UK);
    3. External Expert EU Framework 7 Programme;
    4. Member of the Herschel Observatory Time Allocation Committee;
    5. PhD Thesis Defense Committee, University of Hertfordshire;
    6. Member of the Physical and Chemical Sciences Committee, Royal Irish Academy

## 10 Public Outreach

The normal programme of Open Nights recommenced in October and was supplemented by a number of special events. In addition the Irish Astronomical Society were facilitated by being allowed use Dunsink for their meetings while their normal meetings rooms were being refurbished. Tom Ray took over (on a temporary six-month) basis as Public Outreach Coordinator for the School.



Date	Event	Time	Principal Speaker
17 Sep	IAS Group Meeting	19:00	Terry Moseley
3 Oct	Open Night	20:00	Deirdre Kelleghan
15 Oct	IAS Group Meeting	19:00	Michael O'Connell
16 Oct	Hamilton Walk	13:00	NUIM
17 Oct	Open Night	20:00	Dr Mohsen Shadmehri (DCU)
23 Oct	CBS Swords	19:00	Astronomy in Schools
7 Nov	International Ladies Association	19:30	Prof Tom Ray

#### Science week 2007

12 Nov	Bray schools & teachers	19:00	Dr Carlos del Burgo
13 Nov	West Dublin schools	19:00	Dr Peter Duffy
14 Nov	South Dublin schools	19:00	Dr Rachel Curran
15 Nov	St Ciaran's Kells	10:00	Dr Mohsen Shadmehri
	Our Lady's Templeogue	19:00	Dr Emma Whelan
19 Nov	IAS Group meeting	19:00	Deirdre Kelleghan
21 Nov	Open Night	20:00	Dr David Malone
28 Nov	TCD Physics Society	19:00	Dr Rachel Curran
3 Dec	IAS Group meeting	19:00	Derek Heatly
4 Dec	ISTA Branch meeting	19:00	Multiple speakers
5 Dec	Open night	20:00	Dr Brian Espey
19 Dec	Open night	20:00	Dr Dirk Froebrich

The following assisted regularly in running the above events: Clare Raftery, Nicola Meenan, Orna Nicholl (TCD students); Tomas Griffin, Denys Malishev, Paul Dawson, Luke Drury, Ann Grace, Eileen Flood, Hilary O'Donnell, Mike Smyth (DIAS); Deirdre Kelleghan, Robin Moore, Val Dunne (IAS).

Architecture students from UCD (Mark Costello) and DIT Bolton street (Bronagu Page, Brendan FitzPatrick, Flow O Droma, Dan Shanahan) visited Dunsink as part of student projects in conservation studies.

Three talks on astronomy for CETNS primary school (Castleknock Educate Together National School), for fourth, fifth and sixth classes were given by Prof E. Meurs.

#### 10.1 Statutory Public Lecture

The JWST project scientist, Professor John Mather, Nobel Physics Laureate of 2006, gave the School's Statutory Public Lecture, on 14th June in the Clinton auditorium, UCD, to a full house. There was a lively discussion with the public after the talk.

## 11 Conferences Organised

### 11.1 High Energy Phenomena in Relativistic Outflows



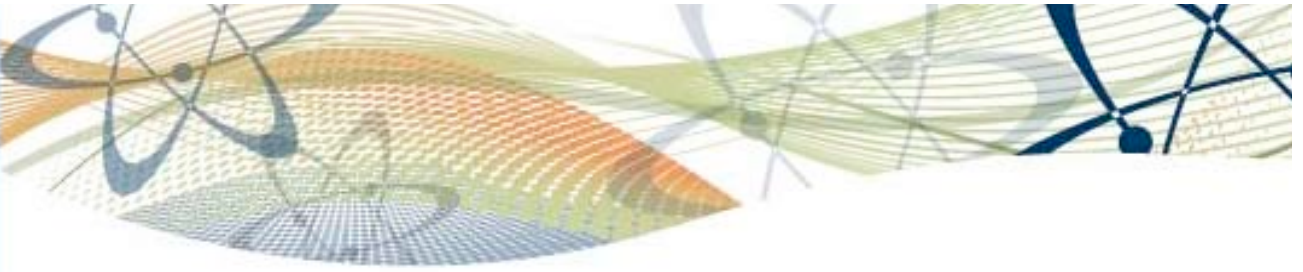
Figure 14: Participants of the HEPRO workshop before the conference dinner in the TCD dining hall

This workshop, which ran for the week from Monday 24 to Friday 28 September 2007, was devoted to the comprehensive discussion of recent theoretical and phenomenological developments concerning the interpretation of high energy phenomena related, in one way or another, to objects containing relativistic winds and jets. The meeting attracted an excellent list of speakers and participants including such world-class scientists as Peter Meszaros, Andy Fabian, Jonathan Arons and Ari Koenigl. In total 116 participants registered for the five day event (see Fig. 14). Originally it had been intended to hold the meeting in Burlington Road, but due to pressure of numbers it was moved to the Joly lecture theatre in TCD which proved an excellent venue.

Local logistics, including a trip on the Wednesday afternoon to the Boyne valley, were handled in house and the conference ran within budget. The Proceedings will be published in a special issue of the International Journal of Modern Physics D. Local organising committee: Felix Aharonian, Luke Drury, Tom Ray, Peter Duffy, Hilary O'Donnell. Scientific Organising Committee: Felix Aharonian, Katherine Blundell, Paolo Coppi, Luke Drury, Peter Duffy, Peter Meszaros, Josep M. Paredes, Tom Ray, Gustavo E. Romero, Guy Pelletier, Marek Sikora, Marco Tavani. The presentations are available online at: <http://www.dias.ie/~pdempsey/HEPROpdfs/index.html>.

### 11.2 JWST meeting

From June 11th to the 13th some 300 NASA, ESA and Canadian Space Agency (CSA) personnel, along with prime



contractors, and instrument scientists, met in the Royal Hospital Kilmainham to review progress with the JamesWebb Space Telescope (JWST) scheduled for launch in 2013. The meeting was held at the invitation of the Dublin Institute for Advanced Studies who are involved in building the Mid-Infrared Instrument (MIRI), one of the four main instruments on board JWST.



*Figure 15:* Full-scale model of the James Webb Space Telescope at the Royal Hospital Kilmainham where NASA, ESA and the CSA reviewed the project.

The project is progressing well and is currently not only on schedule but within budget. JWST when launched will replace the very successful Hubble Space Telescope but unlike Hubble it will be placed beyond the Moon (at the second Lagrange point) to keep its instruments passively cooled to 47K. MIRI itself, because of its operating wavelengths, will be cryogenically cooled to 7K using liquid helium.

To launch the meeting, and to attract public interest, a full-scale model of the JWST was brought to Dublin (see Fig. 15) for six weeks. The model was built by Northrop Grumman (the projects main contractors) but it was erected and disassembled by a team of FÁS trainees under supervision. The model attracted a lot of interest from the public not only after featuring on the front page of the Irish Times but also in TV and radio programmes such as the RTE News, Pat Kenny and Drive Time.

The JWST project scientist, John Mather, Nobel Physics Laureate of 2006, gave a joint Royal Irish Academy/DIAS

public lecture on 12th June in the Edmund Burke Theatre (TCD) and the School's Statutory Public Lecture on 14th June in UCD. On both occasions, John lectured to full houses.

Sponsorship (approximately 100K Euro) was very kindly provided for the event from a number of bodies including Enterprise Ireland, FÁS, Omega Air, An Post and Discover Science and Engineering. FÁS also provided manpower, as previously mentioned, to erect and disassemble the model. Finally ESA sent a 10:1 scale model of the launch vehicle (the Ariane V rocket), which was placed in the Baroque Chapel of the Royal Hospital Kilmainham (see Fig. 16).



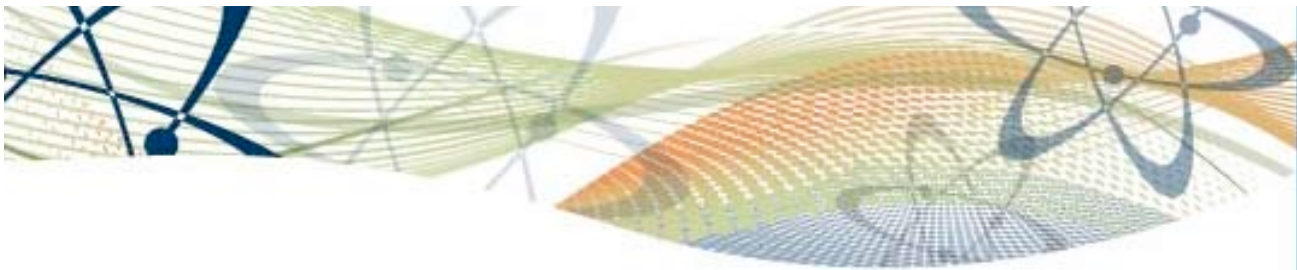
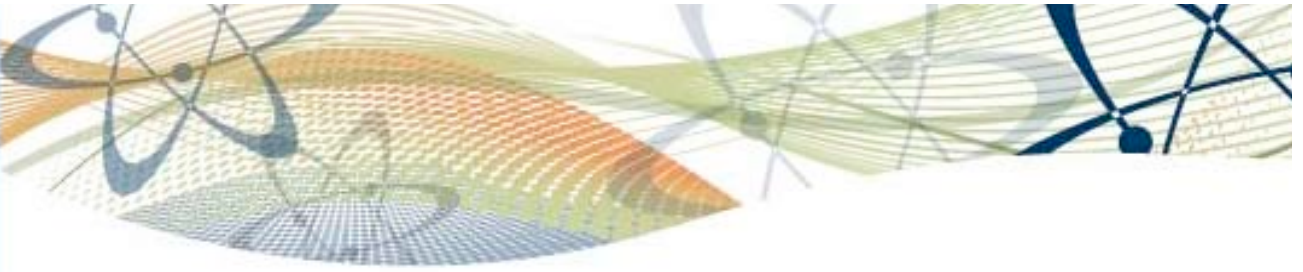


Figure 16: Children enjoying a day out in the RHK at the Ariane V Rocket Model in the Baroque Chapel



# School of Cosmic Physics - Geophysics

## 1 General

### 1.1 Personnel Highlights

The personnel highlight of 2007 was the successful hiring on Dr. Sergei Lebedev as Assistant Professor of Seismology after a search requiring two competitions. Professor Lebedev will move to DIAS from Utrecht in February, 2008.

The year saw a change of students who started with Alan Jones. Max Moorkamp submitted his thesis and successfully defended it in September. Max stayed at DIAS for five months as a Post-Doctoral Scholar. Mark Hamilton submitted his thesis, and then left DIAS for industry in mid-November. Anna Avdeeva submitted her thesis in December, and it will be examined in January, 2008. In addition, Van Do Chuong, who had left the School in November, 2006 for a position in industry, successfully defended his thesis in April.

CosmoGrid Fellow Dr. Tadashi Yamasaki left in the Summer to take up a fellowship in the numerical and analogue modelling laboratory of Professor Sierd Cloetingh at the Vrije Universiteit of Amsterdam.

Finally, during the year Professor Sierd Cloetingh was appointed an Honorary Professor in the School of Cosmic Physics, by the Governing Board, in recognition of his contributions with regard to analogue modelling of tectonic processes by Dr. Tadashi Yamasaki and school scholar John Sheehan during extended visits to Amsterdam.

### 1.2 Research Highlights

There were a number of research highlights during 2007. On the European front, TOPO-EUROPE was accepted by the European Science Foundation as a new EUROCORES theme programme, and a call for preliminary Coordinated Research Projects resulted in 45 proposals. Of those, 23 were invited for submission in the call for full CRP proposals in September, and Section members were involved in two. Results of the CRP proposals will be announced in 2008. TOPO-EUROPE is becoming the largest pan-European geoscience project ever undertaken, and scientists in almost all European countries are involved. More information can be obtained from the ESF web site: <http://www.esf.org/activities/eurocores/programmes/topo-europe.html>

On the international front, the Section continued its involvement with AfricaArray (<http://africaarray.psu.edu/>) through supplying a mentor, SAMTEX SFI-funded Scholar Marion Miensopust, to the University of the Witwatersrand for

its annual Geophysical Field School, held in June. Attempts at securing Irish funding to support permanent seismic stations in African countries continued.

The first paper from the Southern African Magnetotelluric Experiment (SAMTEX), Hamilton et al., published in 2006, discussed and compared seismic and electrical anisotropy of the lithosphere (upper rigid plate to 150-250 km) in South Africa. A new model was developed by School Scholar Mark Hamilton and Professor Alan Jones to explain anisotropy sensed by seismic shear waves that passed through the core (SKS) that will be presented at conferences in 2008.

Research was completed by SFI-funded Scholar Max Moorkamp and Professor Alan Jones in the joint inversion of seismic P-wave receiver functions (PRF) and magnetotelluric (MT) responses, and published in Moorkamp et al. (2007). During Moorkamp's Post-Doctoral Scholarship, this research was extended to include joint inversion of surface waves as well as PRFs and MT responses. A grant proposal to SFI by Jones to extend this work further by including anisotropic layers was successful, and searches begun for the Scholar and Post-Doctoral Fellow.

The Irish Seismological Lithosphere Experiment Phase I (ISLE1) was completed, and a grant proposal to SFI by Peter Readman for an extension to central and northern Ireland, especially to investigate upper mantle anisotropy by a variety of seismic techniques including anisotropic receiver functions and surface waves, was successful.

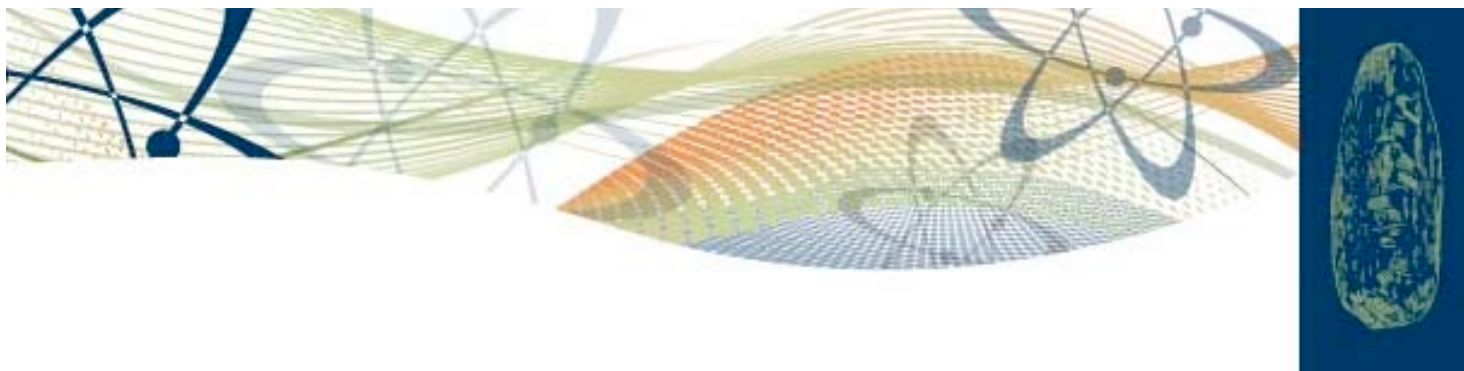
The technical problems encountered in the first phase of the analogue basin modelling experiments were solved after a further visit to Vrije University by John Sheehan.

The interpretation of seismic reflection data from the Hatton region, collected as part of the Irish National Seabed Survey Geological in association with the Petroleum Infrastructure Programme, was undertaken and integrated with potential field modelling along the reflection profiles.

Funding was secured by Brian O'Reilly by PIPCo/RSG to work on Irish deep-water Basin margins.

Investigation of sedimentation processes on the glaciated eastern margin of the Rockall Trough using data from the TRIM survey was completed and a paper published in *Marine Geology*.

Following the exploratory workshop during 2006, DIAS was invited to participate in the North Atlantic Petroleum Systems Assessment (NAPSA) programme visit to Memorial University,



Newfoundland, where two invited presentations were given by Brian O'Reilly on reconstructing early Mesozoic extension in the North Atlantic, and an overview of the group's research activities to petroleum exploration. Six posters were also presented.

### 1.3 Productivity synopsis of Professorial staff members

The synopsis of the productivity, students supervised and funding raised during 2007 of the Section's Professorial staff are listed in the below table. Full details are given in this Annual Report.

	Jones	O'Reilly	Readman
Published papers	6	1	2
Submitted papers in review	4	2	0
PhDs submitted	3	1*	1*
Students supervised	5	3*	3*
External funding raised	€778.1K	€90.0K	€113.3K
Invited presentations/seminars	7	2	0

### 1.4 New external funding received in 2007

#### 1.4.1 SFI proposals funded:

Section members submitted a total of six pre-proposals to Science Foundation Ireland's Research Frontiers Programme for the 2007 competition (RFP2007), of which three were invited to proposal stage. Of those three, two were successful

1. A proposal by Jones to continue and extend the work of Max Moorkamp and Jones on the Joint Inversion of Seismic and Electromagnetic Data with a focus on anisotropy of the lithospheric mantle. This was funded for three years at €191,500, which is the full funding requested, and will support a Post-Doctoral Fellow (2 years) and a Graduate Scholar (3 years).
2. A proposal by Readman to continue and extend the ISLE experiment into central and northern Ireland, with a focus on anisotropy of the mantle. This was funded for three years at €113,000, which is the full funding requested, and will support a Graduate Scholar (3 years).

In addition, Jones received €20,000 as a Supplement Award for his SAMTEX project funded by SFI in the RFP2005 competition. This supplement is for funding towards the

fourth phase of SAMTEX data acquisition planned for early-2008.

#### 1.4.2 Other funding received

BHP-Billiton joined the SAMTEX consortium and paid the industry support contribution of €130,000 to cover access to the SAMTEX data from all four phases of acquisition. On behalf of the Heads of Geoscience University Departments, Jones put in a proposal for funding the Irish Geoscience Graduate Programme (IGGP) to the Griffith Geoscience Research Awards Scheme of the Department of Communications, Energy and Natural Resources. The Griffith Scheme is named after Richard Griffith, the celebrated geologist and engineer, who lived from 1784 to 1878 (94 years) and produced the first geology map of all of Ireland. The award was for €416,000 over a seven year period. Further details of the IGGP are given below.

A proposal by Brian O'Reilly for a three-year project to investigate structure in the Porcupine Basin and adjoining Irish Continental Platform was partly funded by PIPCo/PSG to a level of 90,000 Euro for one year, to focus on the transition from the Platform to basin region.

### 1.5 Proposals submitted

#### 1.5.1 SFI pre-proposals submitted to RFP2008 competition

A total of eight (8) pre-proposals were submitted by Section members in September, 2008, to Science Foundation Ireland's Research Frontiers Programme for the Research Frontiers Programme for 2008 (RFP2008). Of these eight, three have been invited to full proposal stage, one by Jones and two by Lebedev, and they will be submitted in January, 2008 with the outcome known by late-April.

#### 1.5.2 SFI Equipment Call Proposals

Two proposals were submitted under SFI's Equipment Call in 2007, and neither was successful.

#### 1.5.3 SFI Supplement Grant Requests

Jones submitted a Supplement Grant Request to SFI to augment the SAMTEX RFP2005 grant. €48,000 was requested, and an award of €20,000 was granted.



#### 1.5.4 Other proposals

The Griffith proposal to initiate the IGGP (see above) was successful with a seven year award totalling €416,000/ Max Moorkamp's proposal to HPC Europe for funding to spend one month with Dr. Sergei Lebedev in Utrecht was successful, and Moorkamp spent October in Utrecht. During this time Moorkamp initiated including surface wave data into the Joint Inversion of seismic and MT data.

Jones and Lebedev led a Common Research Project (CRP) proposal to TOPO-EUROPE EUROCORES for LABTOP – Lithosphere-Asthenosphere Boundary Topography across West and Central Europe – from the Eastern European Craton to the American Massif. The preliminary CRP was invited to full proposal stage, and was submitted in September, 2007 and the outcome will be announced in 2008.

Jones is the Principal Investigator (PI) of an Individual Project (IP) submitted as part of a Common Research Project (CRP) proposal to TOPO-EUROPE EUROCORES called TOPO-MED – Plate re-organization in the western Mediterranean: lithospheric causes and topographic consequences, led by Professor Rinus Wortel of the University of Utrecht. The preliminary CRP was invited to full proposal stage, and was submitted in September, 2007 and the outcome will be announced in 2008.

## 2 General geophysics activities

### 2.1 CHIGI – Irish Geoscience Graduate Programme

*A.G. Jones*

One of the first products of the Committee of Heads of Irish Geoscience Institutes ([www.chigi.ie](http://www.chigi.ie)), is the concept of an Irish Geoscience Graduate Programme (IGGP). The IGGP is planned to become a virtual graduate programme for All-Ireland (North and South) within which graduate students will receive advanced training in both specialised and broad-ranging geoscience topics from the academic experts across Ireland. The award was for €416,000 over a seven year period, and is to fund a Co-ordinator for the first two years, and an Administrator for the following five years. The role of the Co-ordinator is to establish the IGGP with the first courses being presented in September, 2009.

### 2.2 TOPO-Europe/EuroArray

*A.G. Jones*

TOPO-EUROPE is destined to become the largest pan-European programme ever undertaken. It is uniting the efforts of hundreds of scientists in almost all European countries in an effort to understand the controls of mantle dynamics on surface topography. TOPO-EUROPE was accepted in 2007 as a EUROCORES initiative, with the greatest number of countries signing on. Total of 47 Outline CRPs (Coordinated Research Projects) received, which is the greatest number ever, with 23 going to full proposal stage. Three outline CRPs submitted with co-PIs Jones and Professor Sergei Lebedev. Two of these – LABTOP (Jones as lead co-ordinator) and TOPO-MED went forward to full CRP proposal stage.

#### Publication:

Cloetingh, S.A.P.L., P.A. Ziegler, P.J.F. Bogaard, P.A.M. Andriessen, I.M Artemieva, G. Bada, R.T. van Balen, F. Beekman, Z. Ben-Avraham, J.-P. Brun, H.P. Bunge, E.B. Burov, R. Carbonell, C. Facenna, A. Friedrich, J. Gallart, A.G. Green, O. Heidbach, **A.G. Jones**, L. Matenco, J. Mosar, O. Oncken, C. Pascal, G. Peters, S. Sliampa, A. Soesoo, W. Spakman, R.A. Stephenson, H. Thybo, T. Torsvik, G. de Vicente, F. Wenzel, M.J.R. Wortel, and the TOPO-EUROPE Working Group, 2007. TOPO-EUROPE: The geoscience of coupled deep Earth-surface processes. *Global and Planetary Change*, 58, 1-118.

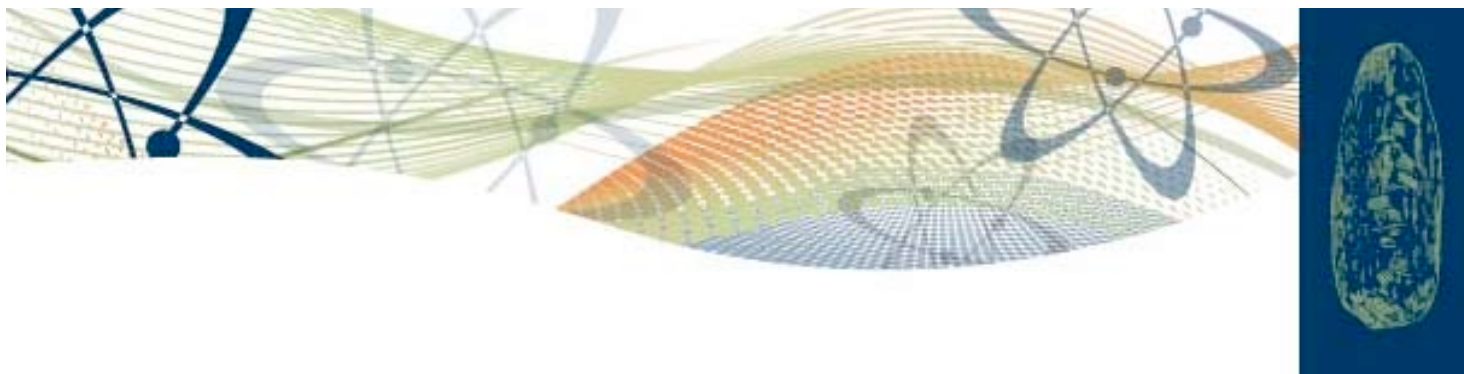
#### Presentations:

**Jones, A.G.**, H. Thybo and P. Maguire, 2007. EuroArray: A proposal for imaging Europe in 4D by installation of an infrastructure to enable co-ordinated acquisition of teleseismic, MT, GPS and other geoscientific data across Europe. PICASSO MT Group Workshop, Barcelona, Spain, 16 February.

**Jones, A.G.**, and the TOPO-EUROPE Team, 2007. TOPO-EUROPE: Monitoring the changing Earth we live on. Irish Geological Research Meeting, University of Ulster Coleraine, United Kingdom, 24-25 February.

**Jones, A.G.**, M. Moorkamp, and M.P. Hamilton, 2007. Structures and geometries in the continental lithosphere: Insights from joint inversion and co-operative interpretation of seismic and electromagnetic data. Invited presentation, TOPO-Europe session, European Geosciences Union meeting, Vienna, Austria, 16-20 April.

Jones, A.G., M. Moorkamp, and M.P. Hamilton, 2007. Imaging the continental lithosphere using seismic and electromagnetic methods. TOPO-EUROPE Annual Workshop, Rome, Italy, 3-4 May.



### 2.3 AfricaArray

A.G. Jones

AfricaArray is a unique project with the dual aims of increasing geophysical education and enhancing research infrastructure within Africa. Jones is attempting to secure Irish funding to support seismic stations in African countries. DIAS made its usual contribution to AfricaArray through Marion Miensopust acting as a mentor on the AfricaArray Geophysical Field School organized by the University of the Witwatersrand.

Presentation:

Jones, A.G., M.R. Muller, M.P. Hamilton, and the SAMTEX Team, 2007. SAMTEX results: insights from co-operative interpretation of seismic and electromagnetic data. Invited keynote presentation at AfricaArray Annual Workshop, University of the Witwatersrand, Johannesburg, South Africa, 17-18 July, 2007.

### 2.4 Joint inversion of electromagnetic and seismic data

M. Moorkamp, A.G. Jones

Joint inversion of different data is the key to reducing acceptable model space in a significant manner. The initial work of Moorkamp and Jones was published this year (see Figure 2.4), and extensions to it were made by Moorkamp in his Ph.D. thesis and as a consequence of the HPC Europe award to Moorkamp that funded his one month visit to Dr. Sergei Lebedev, then at the University of Utrecht.

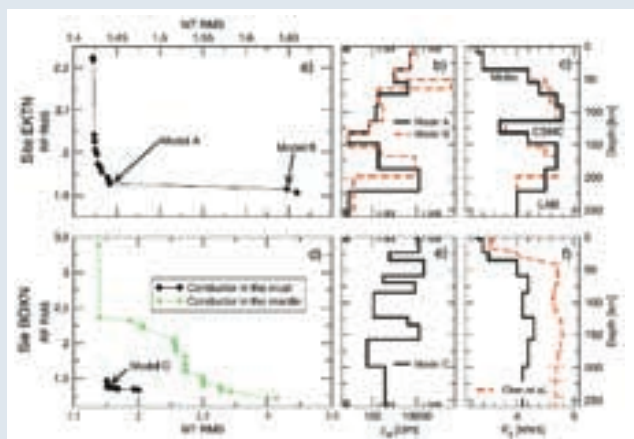


Figure 2.4: Representative joint inversion models and trade-off curves for sites BOXN and EKTN on the Slave Craton in northern Canada. For site EKTN we show two representative models that illustrate the differences between different parts of the trade-off curve. For site BOXN we show the dependence of the trade-off curves on the location of the first conductor. Only for a crustal conductor a joint model can explain the two data sets. We plot the optimum model together with the surface wave results by Chen et al. [2007].

In March the Section held the first St. Patrick's Geophysical Workshop with a focus on New Developments in Joint Inversion of Geophysical Data. Nineteen participants came from DIAS, from other Irish academic institutions, from Europe and from North America. ([http://homepages.dias.ie/~mm/workshop\\_2006.html](http://homepages.dias.ie/~mm/workshop_2006.html))

Proposal:

Jones submitted proposal to Science Foundation Ireland's RFP2007 competition to continue research in joint inversion of seismic and MT data, which was successful at the requested level of €191,000. A Post-Doctoral Fellow and a Ph.D. student are being sought.

Ph.D. Thesis:

Max Moorkamp submitted his Ph.D. thesis at the beginning of August and it was examined at the end of September at the NUI, Galway where Moorkamp was registered. The external examiner was Professor Laust Pedersen of the University of Uppsala. The examining committee were very impressed with the work of Moorkamp, and accepted the thesis with only minor typographical corrections required.

Publication:

**Moorkamp, M., A.G. Jones** and D.W. Eaton, 2007. Joint inversion of teleseismic receiver functions and magnetotelluric data using a genetic algorithm: Are seismic velocities and electrical conductivities compatible? *Geophysical Research Letters*, 34, L16311, doi: 10.1029/2007GL030519.

Presentations:

**Jones, A.G., M. Moorkamp,** and **M.P. Hamilton**, 2007.

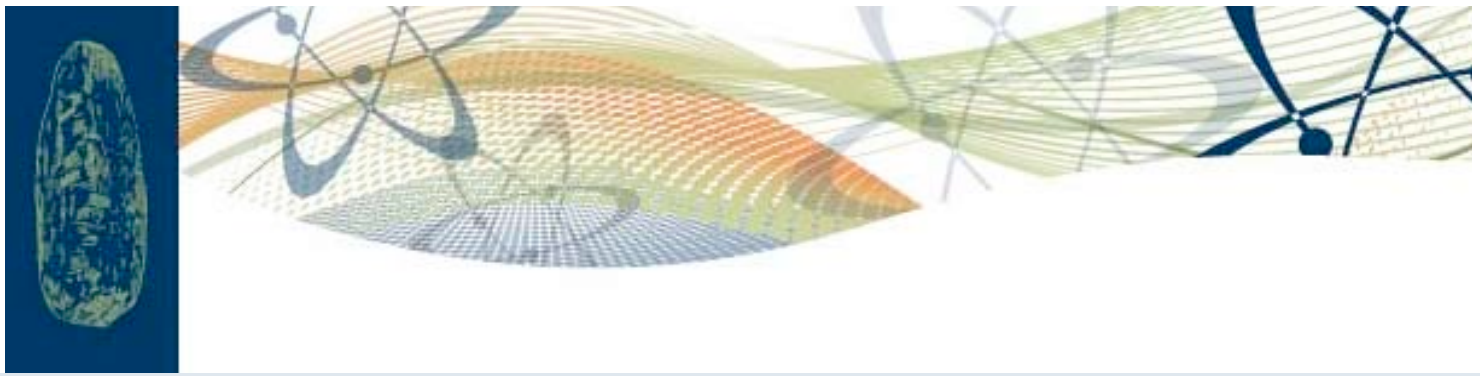
Structures and geometries in the continental lithosphere: Insights from joint inversion and co-operative interpretation of seismic and electromagnetic data. Invited presentation, European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Moorkamp, M., A.G. Jones** and D.W. Eaton, 2007.

A lithosphere-scale relationship between electrical conductivity and seismic velocity in the Slave Craton? European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Jones, A.G., M. Moorkamp,** and **M.P. Hamilton**, 2007.

Imaging the continental lithosphere using seismic and electromagnetic methods. TOPO-EUROPE Annual Workshop, Rome, Italy, 3-4 May.



**Moorkamp M., A.G. Jones,** and D.W. Eaton, 2007. Joint inversion with a genetic algorithm: Finding a model and assessing compatibility. Contributed paper at: 22nd Colloquium on Electromagnetic Depth Research, Decin, Czech Republic, 1-5 October.

### 3 Electromagnetic activities

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

*A.G. Jones, X. Garcia, M. Muller, M. Hamilton, M. Miensopust*

There was no data acquisition for the SAMTEX project in 2007, giving an opportunity to complete the processing of all of the data from Phases I, II and III. Some of the data are still causing difficulties because of the high distortion from DC train lines and mine electricity supplies – these will require the development of new tools as the existing ones are insufficient. The main result obtained to date is the imaging, using approximate methods, of resistivity structure at various depths. The map for a depth of 200 km is shown in Figure 3.1.1, and a strong correlation with deep resistivity and the surface outline of the Archean Kaapvaal Craton is apparent.

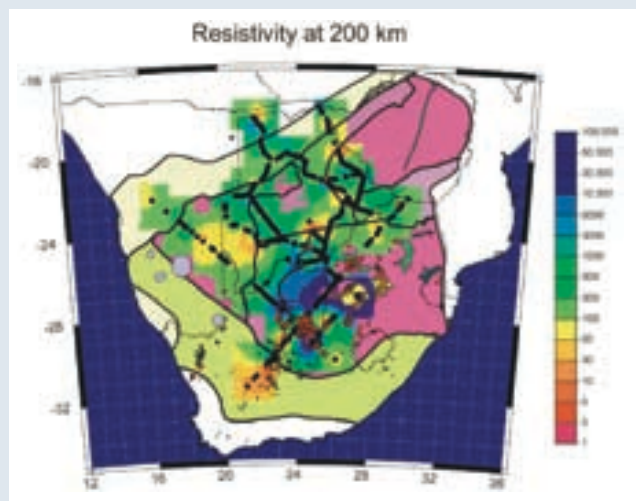


Figure 3.1.1: Resistivity image at a depth of 200 km with diamondiferous (red circles) and non-diamondiferous (black dots) kimberlites marked.

SFI-funded Post-Doctoral Fellow Mark Muller focussed on developing a model for the Namibian profiles, particularly over the enigmatic “Rehoboth Terrane”, thought by some to be an Archean craton. Muller also focussed on preparing for

the Phase IV fieldwork programme, to take place in January to May, 2008. This fieldwork would be the most challenging, with acquisition in the Central Kalahari Game Reserve – an area almost as large as the island of Ireland but without any facilities or services at all and with thick sand cover limiting driving to 20 km/h in places.

DIAS Scholar Mark Hamilton continued to analyse the SAMTEX data for electrical anisotropy, and compared the results found with seismic anisotropy from SKS. The comparison at lithospheric depths is shown in Figure 3.1.2. A new model for interpreting SKS anisotropy was developed that combined aspects of the “Silver” model, which ascribes all the observed anisotropy to fossil, frozen-in anisotropy within the lithospheric mantle, and the “Vinnik” model, which ascribes all the anisotropy to asthenospheric flow.

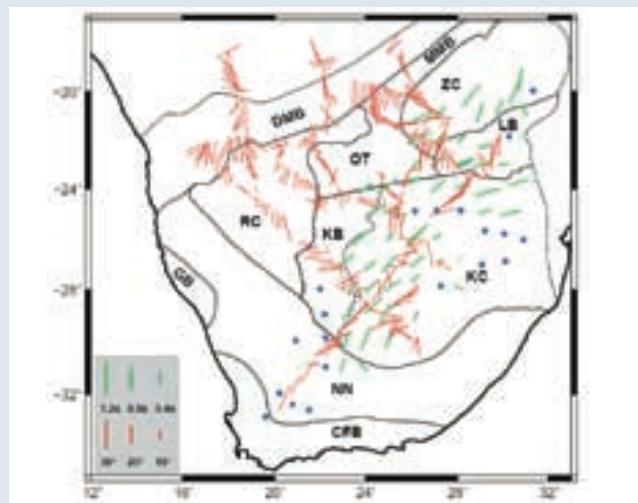
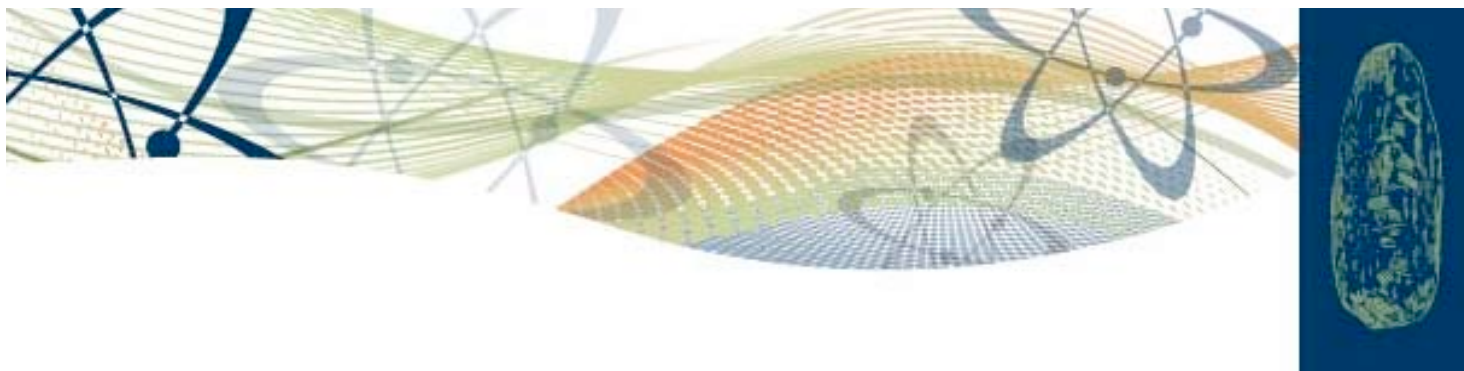


Figure 3.1.2: Electrical anisotropy of the lithospheric mantle (red bars) compared to seismic anisotropy (green bars). In both cases the length of the bar denotes the strength of anisotropy.

SFI-funded Scholar Marion Miensopust focussed on processing and analysing data from the profile that crossed over the Zimbabwe craton, the so-called ZIM line, and initiated two-dimensional (2D) modelling of the responses. In addition, Miensopust started to work on three-dimensional modelling and inversion in collaboration with Dr. Colin Farquharson of Memorial University of Newfoundland, Canada.

#### Ph.D. Thesis:

Mark Hamilton completed his Ph.D. thesis in November and submitted it to the University of the Witwatersrand for examination.



Presentations:

**Hamilton, M.P., A.G. Jones, R.L. Evans, M.R. Muller, M. Miensopust, C.J.S. Fourie, T. Ngwisanyi, D. Hutchins, S.F. Evans, A. Mountford, and the SAMTEX MT Team, 2007.** Electrical and seismic anisotropy properties over Southern Africa. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Hamilton, M.P., A.G. Jones, M.R. Muller, M.P. Miensopust, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007.** Electrical and seismic anisotropy of the southern African lithosphere. Presented at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October, 2007.

**Jones, A.G., M. Moorkamp, and M.P. Hamilton, 2007.** Structures and geometries in the continental lithosphere: Insights from joint inversion and co-operative interpretation of seismic and electromagnetic data. **Invited presentation**, European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Jones, A.G., M.P. Hamilton, M. Miensopust, M.R. Muller, R.L. Evans, C.J.S. Fourie, T. Ngwisanyi, D. Hutchins, S.F. Evans, A. Mountford, and the SAMTEX team, 2007.** Lithospheric structure of Southern Africa deduced from the Southern African MT Experiment (SAMTEX) project. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Jones, A.G., 2007.** Deep probing electromagnetic studies of cratons in southern Africa compared and contrasted with the results from the Slave and Superior cratons. Invited seminar presented at Department of Earth and Ocean Sciences, UBC, Vancouver, Canada. 28 June.

**Jones, A.G., M.R. Muller, M.P. Hamilton, and the SAMTEX Team, 2007.** SAMTEX results: insights from co-operative interpretation of seismic and electromagnetic data. **Invited keynote presentation** at AfricaArray Annual Workshop, University of the Witwatersrand, Johannesburg, South Africa, 17-18 July, 2007.

**Jones, A.G., M.R. Muller, M.P. Miensopust, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007.** Southern African Magnetotelluric Experiment (SAMTEX):

Project overview and regional results. **Invited keynote presentation** at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October, 2007.

**Jones, A.G., M.R. Muller, M.P. Miensopust, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007.** Southern African lithospheric structures and geometries imaged by SAMTEX: Clues to Archean tectonic processes.

**Invited presentation** at Fall American Geophysical Union meeting, San Francisco, USA, December 2007

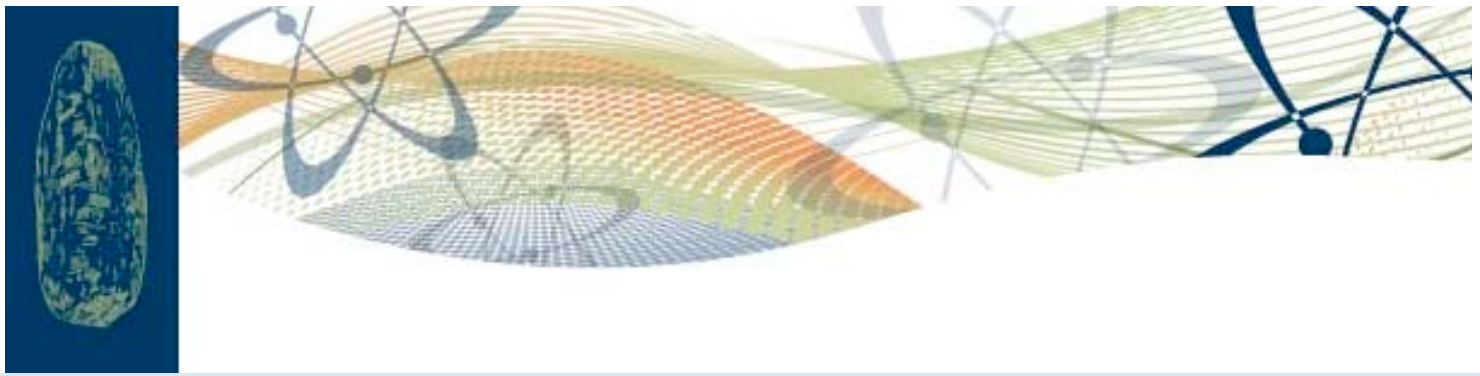
**Miensopust M.P., A.G. Jones, M.R. Muller, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007.** Effects of the chosen strike angle on the two-dimensional modeling of magnetotelluric data. Contributed paper at: 22nd Colloquium on Electromagnetic Depth Research, Decin, Czech Republic, 1-5 October.

**Miensopust, M.P., A.G. Jones, M.R. Muller, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007.** Magnetotelluric profile across the Zimbabwe craton. Presented at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October, 2007.

**Miensopust, M.P., C.G. Farquharson and A.G. Jones, 2007.** Three-Dimensional Forward Modeling of Magnetotelluric Data Over Cratonic Lithosphere and Attendant Geological Structures: Case Study of the Zimbabwe Craton. AGU Fall Meeting, San Francisco, 10-14 December, 2007

**Muller, M.R., A.G. Jones, R.L. Evans, C. Hatton, M.P. Hamilton, M. Miensopust, A. Mountford, C.J.S. Fourie, D. Hutchins, T. Ngwisanyi and the SAMTEX team, 2007.** Constraints from broadband magnetotellurics and mantle xenolith geochemistry on lithospheric thickness and stabilisation age of the Rehoboth Terrane, southern Africa. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Muller, M.R., A.G. Jones, M.P. Miensopust, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F.**



Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007. Deep electrical resistivity structure of the Kaapvaal and Rehoboth Terranes, Southern Africa, from broadband magnetotellurics, and implications for Archaean and Proterozoic lithospheric evolution. Presented at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October, 2007.

**Spratt, J.E., A.G. Jones, M.R. Muller, M.P. Miensopust, M.P. Hamilton, X. Garcia,** R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team, 2007. Structural directions and dimensionality of the Damara Mobile Belt and neighbouring terranes. Presented at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October, 2007.

Reports:

**Muller, M.R.,** 2007. SAMTEX Phases I, II, and III: Data acquisition, processing and current interpretation results. Non-scientific progress report written to meet commitments to and requirements of government sponsors.

**3.2 ISLE-MT (Ireland Lithosphere Experiment – MT)**

*A.G. Jones, M. Moorkamp*

The ISLE-MT project concluded during the year with Moorkamp completing his Ph.D. thesis. Initial results from the main N-S profile crossing the lapetus suture zone showed extensive lateral variations in electrical resistivity (Figure 3.2). Dr. C.K. Rao is leading the final paper, but for personal reasons this is delayed.

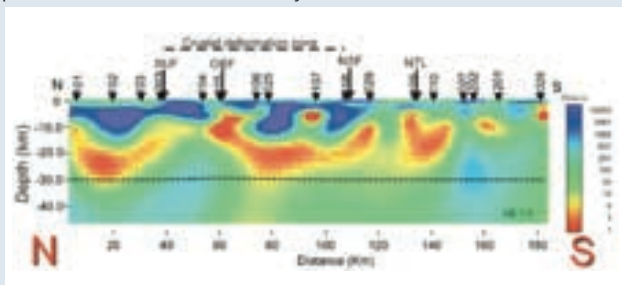


Figure 3.2: Geo-electric section across the lapetus Suture Zone in central Ireland obtained from 2-D inversion of MT (TE and TM) and TZ data; SUF, Southern Uplands Fault; OBF, Orlock Bridge Fault; NSF, Navan Silvermines Fault; NTL, Navan Tipperary Lineament. The crustal deformation zone and depth to the Moho from seismic refraction studies are shown with a dashed line on top and in the middle of the section, respectively.

Publication:

Rao, C.K., A.G. Jones, and M. Moorkamp, 2007. The geometry of the lapetus suture zone in central Ireland deduced from a magnetotelluric study. *Physics of the Earth and Planetary Interiors*, 161, 134-141.

**3.3 PICASSO (Programme to Investigate Convecting Alboran Sea System Overturn)**

*A.G. Jones, J.-P. Schmoldt*

The first phase of PICASSO fieldwork took place in September to November, 2007. Magnetotelluric data were acquired at twenty-six broadband MT (BBMT) sites and at twenty-one long period MT (LMT) sites. The site locations and an apparent resistivity pseudo-section are shown in Figure 3.3. Very strong lateral variation is apparent in the electrical structure going from South (left) to North (right). This variation will be modelled in 2008.

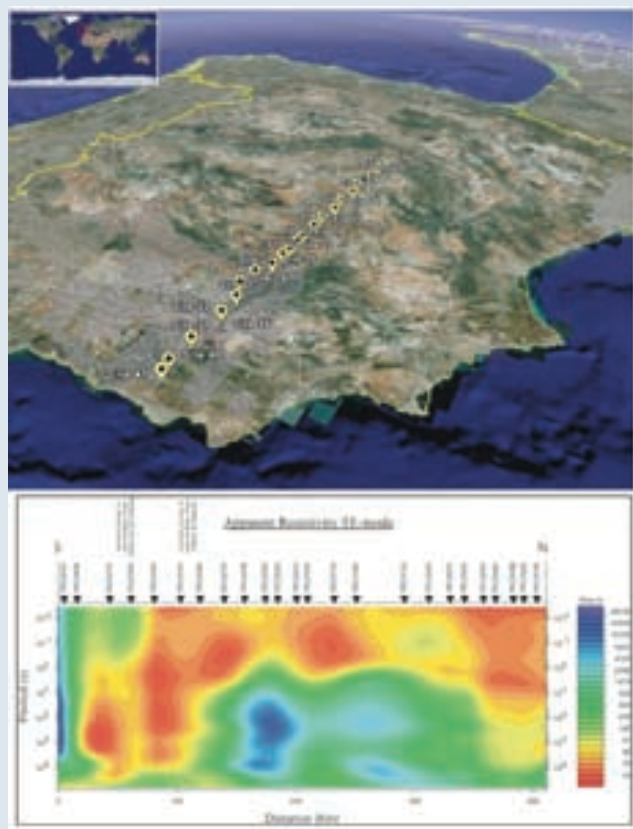
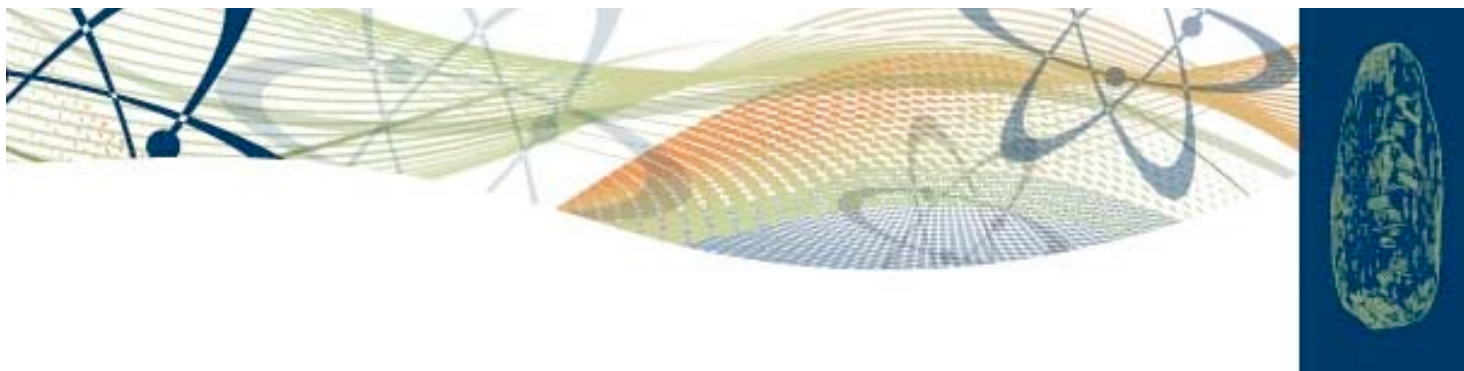


Figure 3.3: Top: Locations of PICASSO MT sites in Spain. Bottom: Apparent resistivity pseudo-section from South (left) to North (right) showing very strong lateral variation in electrical resistivity.





### 3.4 3D MT modelling/inversion

#### 3.4.1 3D MT Inversion

A. Avdeeva

The three-dimensional MT inversion research by CosmoGrid-funded Ph.D. Scholar Anna Avdeeva concluded in 2007 with submission of her thesis in mid-December. It will be examined in late-January, 2008.

##### Presentations:

**Avdeeva, A.D.**, D.B. Avdeev, 3D MT Inversion with a Limited-Memory QN Method: Confirmation of Robustness, 23rd International Review of Progress in Applied Computational Electromagnetics, ACES, Verona, Italy, 19-23 March.

**Avdeeva, A.D.**, Numerical Studies on 3D Modelling and Inversion: Work in Progress, Earthquake Research Institute, University of Tokyo, Japan, 12 June.

**Avdeeva, A.D.**, D.B. Avdeev, Three-dimensional Magnetotelluric Inversion Using quasi-Newton Minimization, 4th International Symposium on Three-Dimensional Electromagnetics, Freiberg, Germany, 27-30 September.

**Avdeeva, A.D.**, M. Commer, G.A. Newman, Hydrocarbon Reservoir Detectability Study for Marine CSEM Methods: Time-Domain versus Frequency-Domain, SEG International Exposition and 77th Annual Meeting in San Antonio, Texas, USA, 23-28 September.

#### 3.4.2 3D MT Modelling and Inversion

*M. Miensopust and A.G. Jones*

Miensopust and Jones initiated a programme of research into comparing three-dimensional magnetotelluric forward codes and testing out available inversion codes. Miensopust visited Dr. Colin Farquharson of the Memorial University of Newfoundland, Canada, during August.

A DIAS workshop on 3D MT Inversion is being planned as the 2nd St. Patrick's Geophysical Workshop to be held in Dublin in mid-March prior to St. Patrick's Day. Test models and data are being prepared by Miensopust and Jones, together with Professor Pilar Queralt, of the University of Barcelona, who spent three months as a Visiting Scientist to the Section in October to December.

##### Presentation:

**Miensopust, M.P.**, A. Martí and **A.G. Jones**, 2007. Inversion of synthetic data using WSINV3DMT code.

Contributed paper at: 4th International Symposium on Three-Dimensional Electromagnetics, Freiberg, Germany, 27-30 September.

Martí, A., **M.P. Miensopust**, **A.G. Jones**, P. Queralt, J. Ledo, and A. Marcuello, 2007. Testing dimensionality of inverted models responses using WSINV3DMT code. Contributed paper at: 4th International Symposium on Three-Dimensional Electromagnetics, Freiberg, Germany, 27-30 September.

**Miensopust, M.P.**, and **A.G. Jones**, 2007. Testing of the 3D inversion routine engine - the used 3D forward algorithm - by comparison with 2D forward modelling results. Contributed paper at: 4th International Symposium on Three-Dimensional Electromagnetics, Freiberg, Germany, 27-30 September.

### 3.5 Marine EM

The Marine EM programme continued under the leadership of Schrödinger Fellow Dr. Xavier Garcia. There were two specific activities, namely the Malin Sea project and the Galway Bay project, as well as general presentations.

##### Presentations:

**Garcia, X.**, A.D. Chave and J.H. Filloux, 2007. A Permanent Seafloor Geomagnetic Observatory. Second International Workshop on Marine Technology, MARTECH'07. Vilanova i la Geltrú, Barcelona.

**Garcia, X.**, X. Monteys, R.L. Evans and B. Kelleher, 2007. Geohazard identification and early reconnaissance for hydrocarbon potential using Marine Electromagnetic and High Frequency Acoustic methods. Seabed mapping workshop 2007. Dublin, 2007.

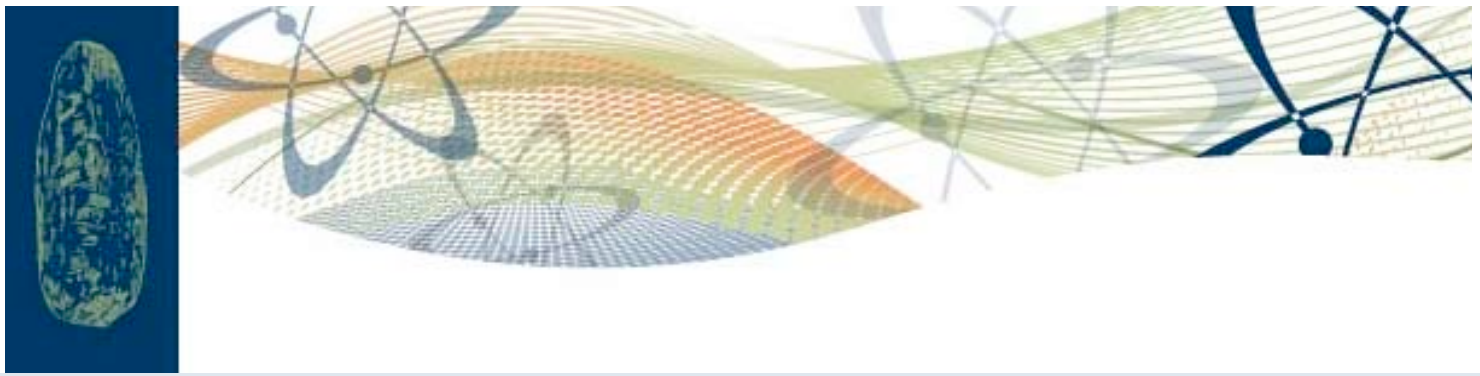
**Garcia, X.**, 2007. INSS/INFOMAR Integration of Datasets: EM technology. **Invited talk**, Seabed mapping Workshop 2007. Dublin.

**Garcia, X.**, **A.G. Jones**, X. Monteys and R.L. Evans, 2007. Overview of activities of the Marine EM group at DIAS. British Geophysical Association "New Advances in Geophysics" Conference, "New Techniques and Discoveries in Marine Geophysics", Feb 8-9.

#### 3.5.1 Malin Sea project

*X. Garcia*

Funding was obtained to acquire a 25 to 30 m piston core in the Malin Sea, providing a unique record of the Holocene



and the necessary constraints for the geophysical data. Cores were to have been obtained in October but due to bad weather conditions two attempts to obtain them were aborted. Plans are in place to try again in 2008. The map of apparent porosity obtained from the controlled-source electromagnetic experiment is shown in Figure 3.5.1, and the spatial correlation between the regions of low porosity and a known pockmark is obvious.

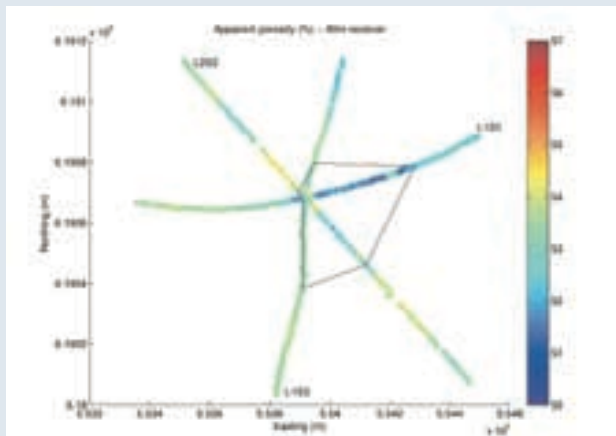


Figure 3.5.1: Map of apparent porosities with 40 m receiver showing a zoom around pockmark 2. The black line shows an outline of the pockmark.

#### Presentations:

- Garcia, X.**, X. Monteys, R.L. Evans and B. Kelleher, 2007. Geohazard identification and early reconnaissance for hydrocarbon potential using marine electromagnetic and high frequency acoustic methods. EGU General Assembly, Vienna.
- Garcia, X.**, R.L. Evans, and X. Monteys, 2007. Using Controlled Source EM Methods to Constrain Physical Properties of the Uppermost Seafloor: An Example of Instrumentation and a Case Study from a Gas Pock-Mark Offshore Ireland. **Invited talk**, EAGE 69th Conference and Exhibition. London.
- Garcia, X.**, R.L. Evans and X. Monteys, 2007. Using Controlled Source EM Methods to Constrain Physical Properties of the Uppermost Seafloor: An Example of Instrumentation and a Case Study from a Gas Pock-Mark Offshore Ireland. Second International Workshop on Marine Technology, MARTECH'07. Vilanova i la Geltrú, Barcelona.

#### 3.5.2 Galway Bay project

*X. Garcia*

Over 50 m of cores have been acquired under INFOMAR project in Galway Bay. Chemical and physical analyses of cores have been completed at NOC (Southampton, UK) and WHOI (USA).

#### **3.6 Other**

##### 3.6.1 LAPIS (La Palma Internal Structure)

*X. Garcia, A.G. Jones, J.E. Spratt*

A pilot MT survey was undertaken on La Palma in July to study the potential for catastrophic collapse of the flank of the Cumbre Vieja volcano that is modelled to pose an extreme tsunami hazard for the northern Atlantic.

##### 3.6.2 INDEPTH (InterNational DEep Profiling of Tibet and the Himalaya)

*A.G. Jones*

During 2007 negotiations took place between Chinese scientists, led by Dr. Wei Wenbo of the China University of Geosciences Beijing, Professor Martyn Unsworth, of the University of Alberta, Canada, and Professor Alan Jones of DIAS. These negotiations concerned a fourth phase of data acquisition under the InterNational DEep Profiling of Tibet and the Himalaya (INDEPTH) programme, INDEPTH4, which will be focussed on the northern edge of the Tibetan Plateau with profiles crossing the Kunlun and Altyn Tagh faults.

##### Proposal:

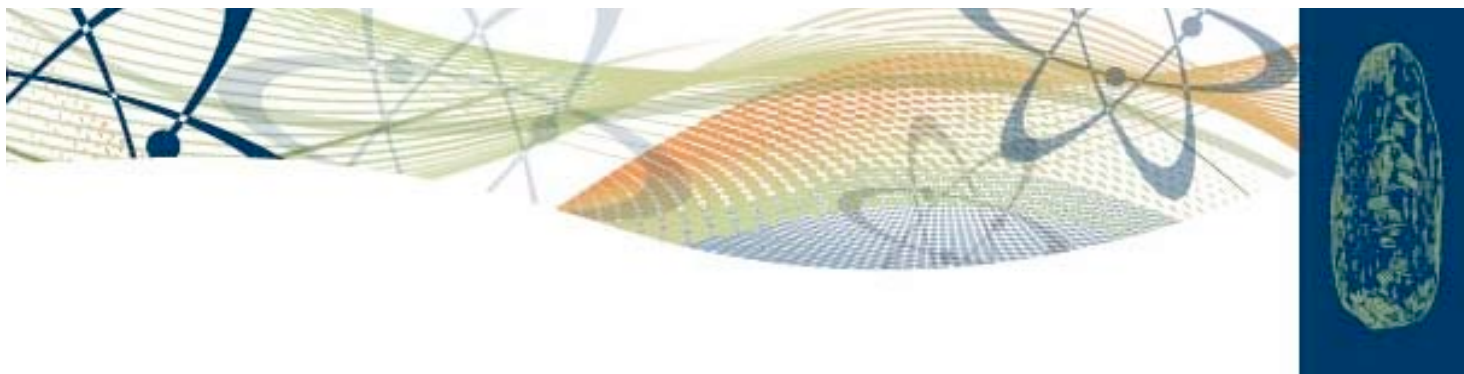
Jones submitted a pre-proposal to SFI's RFP2000 competition, and was invited to full proposal stage. The full proposal will be submitted in January, 2008, and will augment the NSF-funded effort through funding Irish-based scientists and student to work full-time on INDEPTH4 data.

##### Publication:

Wei, W., S. Jin, G. Ye, M. Deng, H. Tan, M. Unsworth, J. Booker, A.G. Jones and S. Li, 2007. Features of faults in the central and northern Tibetan plateau based on results of INDEPTH (III)-MT. *Frontiers in the Earth Sciences in China*, 1, 121-128.

##### Presentation:

Unsworth, M., W. Wenbo, A.G. Jones and B. Denghai, 2007. Crustal and upper mantle rheology of the Tibetan plateau: New constraints from magnetotelluric data. 22nd Himalaya-Karakoram-Tibet Workshop, Hong Kong SAR, China, 22-25 May.



### 3.6.3 Other and General

Other publications and presentations by EM group members of the Section are listed below.

#### Publications:

- Garcia, X.** and **A.G. Jones**, 2007. Robust processing of magnetotelluric data in the AMT dead-band using the Continuous Wavelet Transform. *Geophysics*, in revision.
- Eaton, D.W., F. Darbyshire, R.L. Evans, H. Grütter, **A.G. Jones**, and X. Yuan, 2007. The elusive lithosphere-asthenosphere boundary (LAB) beneath cratons. *Lithos*, submitted.
- Jones, A.G.**, R.L. Evans and D.W. Eaton, 2007. Velocity-conductivity relationships for mantle mineral assemblages in Archean cratonic lithosphere based on extremal bounds. *Lithos*, submitted.
- Lezeata, P., A.D. Chave, **A.G. Jones**, and R.L. Evans, 2007. Source field effects in the auroral zone: Evidence from the Slave craton (NW Canada). *Physics of the Earth and Planetary Interiors*, **164**, 21-45.

Queralt, P., **A.G. Jones**, and J. Ledo, 2007. Electromagnetic imaging of a complex ore body: three-dimensional forward modeling, sensitivity tests and down-mine measurements. *Geophysics*, **72**, 85-95.

Spratt, J., **A.G. Jones**, V. Jackson, L. Collins, and A. Avdeeva, 2007. Lithospheric geometry of the Wopmay Orogen from a Slave Craton to Bear Province Magnetotelluric Transect. *Journal of Geophysical Research*, submitted.

#### Presentations:

**Jones, A.G.**, 2007. Knowledge of the continental lithosphere from electromagnetic studies. Invited keynote presentation at Continental Lithosphere Workshop, Merrickville, Ontario, Canada, 7-10 March.

## 4 Seismological activities

### 4.1 HADES (Hatton Deep Seismic)

*P.W. Readman, B.M. O'Reilly, A. Chabert*

The model for the axial profile (see Figure 4.1.1) within the Hatton Basin was completed and integrated with the results from profiles across the Hatton Continental Margin. Particular emphasis was placed on prominent  $P_mP$  reflections to define the velocity structure of the lower crust and the depth to

the crust-mantle-boundary. The models were integrated with interpretations of re-processed high-resolution vertical reflection profiles (Figure 4.1.2), recently collected within the Hatton Basin as part of the Irish National Seabed Survey.

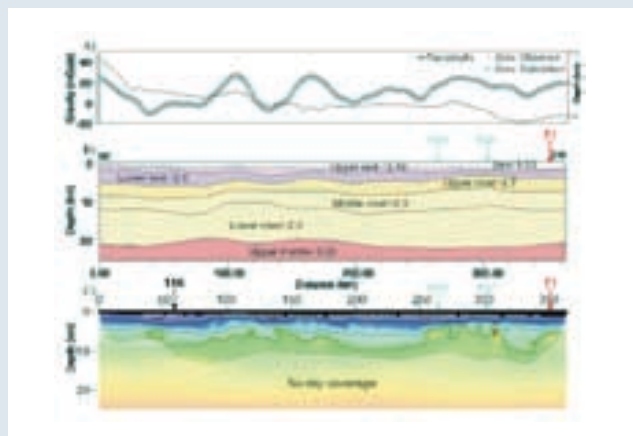


Figure 4.1.1: Gravity model for HADES profile P3. (a) Circles show the observed gravity anomaly variation; blue curve is calculated from the model shown in (b); black line is bathymetry; (c) shows the velocity model derived from first arrival traveltimes tomography.

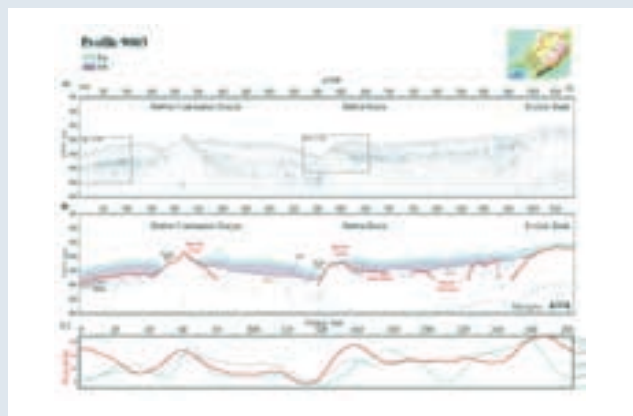
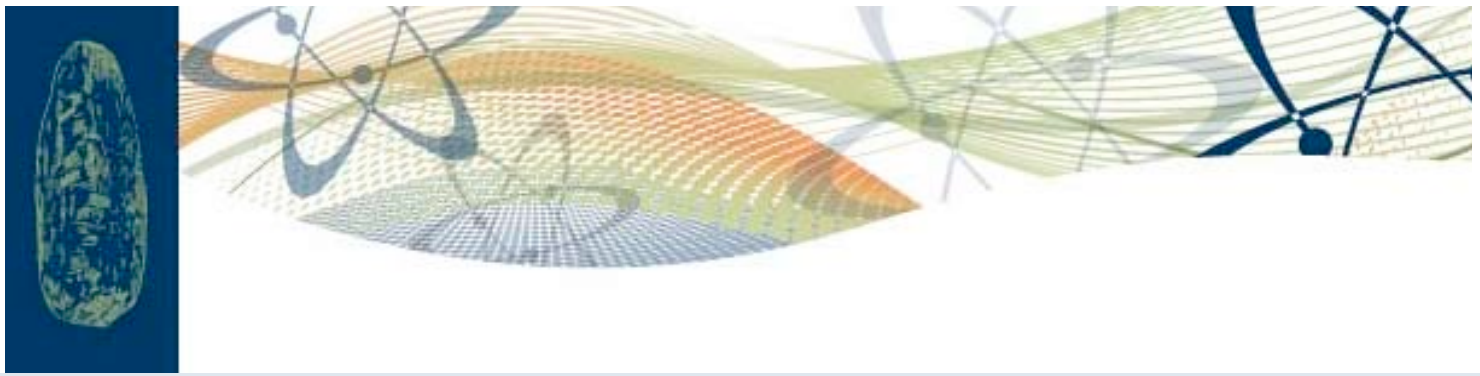


Figure 4.1.2: An example of a processed seismic section across the Hatton Basin (GSI/ISPSG Profile 9003) with interpretation. Lowest figure shows the variations of (red line) free-air gravity anomaly derived from satellite altimetry (Sandwell and Smith 1997) and (blue line) magnetic anomaly (from the compilation of Verhoef et al. 1996).

Gravity modelling of these seismic reflection lines provided additional constraints on the deep structure of the Hatton Basin. These models show a stretched crust in the basin of 14 to 16 km in thickness, compared to the nearly 30 km thick crust under the Rockall Bank and about 25 km under the Hatton Continental Margin. The sedimentary sequence in the basin varies from 2.5 to 3 km in thickness, which is



slightly thinner than interpreted using the wide-angle seismic data along the HADES axial profile.

Gravity modelling of the HADES profiles (Figure 4.1.1) also allowed a better definition of those parts of the velocity models which are not well constrained by the wide-angle data (i.e. middle and lower crust and depth to Moho near the edges of the profiles).

Ph.D. Thesis:

Anne Chabert completed a first draft of her PhD thesis.

Presentations:

**Chabert, A., C. Ravaut, P.W. Readman, B.M O'Reilly,** P.M. Shannon. Wide-angle seismic imaging of the Hatton Basin (North Atlantic). 50th Annual Irish Geological Research Meeting, School of Environmental Sciences, University of Ulster, Coleraine, Northern Ireland, 23-25 February

**O'Reilly, B.M., Readman, P.W., Gernigon, L., Ravaut, C., Chabert, A.** and Shannon, P.M., Basin analysis and wide-angle seismic modelling offshore Ireland. Poster presentation at the NAPSA Workshop, Memorial University, 24-26 July.

**Readman, P.W., O'Reilly, B.M., Ravaut, C.** and **Chabert, A.** Wide-angle seismic imaging of the Hatton Continental Margin: results from travel-time tomography. Invited Poster presentation at the NAPSA Workshop, Memorial University, 24-26 July.

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

*B.M. O'Reilly, P.W. Readman, F. Hauser*

The PIMS project involves linking the onshore crustal structure of Ireland to the crustal model developed for the Porcupine Basin during the RAPIDS4 experiment. Processing of the large amount of seismic (airgun) data gathered in 2004, during the onshore/offshore experiment (in collaboration with GEOMAR, see Figure 4.2.1) indicates, that seismic energy propagates to distances often exceeding 150 km. Detailed attention was focussed on integrating onshore crustal structure with the known offshore structure of the Porcupine Basin. This required a re-evaluation of the VARNET models, developed previously. The approach taken was to include shear wave energy as an additional constraint on the structure and seismic properties of the crust. Results from this work were surprising and unexpected. A new model for

the composition of the entire crust in a region straddling the lapetus Suture Zone in southwest Ireland was developed.

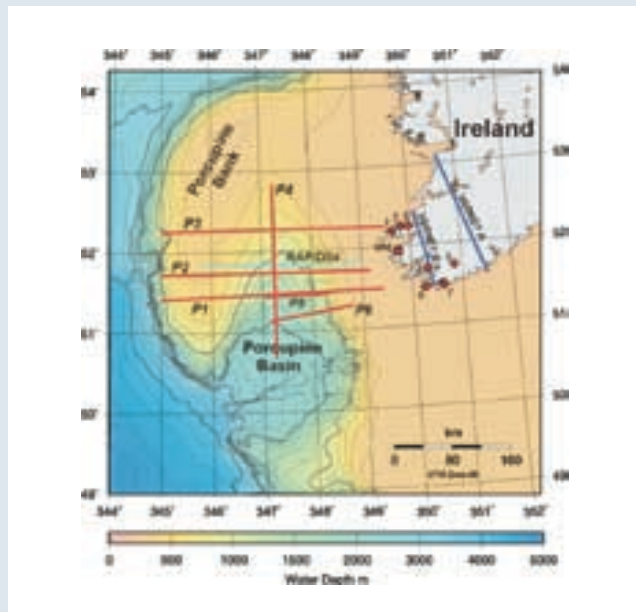


Figure 4.2.1: Location map of the GEOMAR wide-angle profiles across the Porcupine Basin. Also shown are the RAPIDS4 profile and the VARNET lines A and B. DIAS short-period onshore stations shown as red diamonds. VAL broadband station shown as a red square.

Many global studies at the laboratory to the whole crustal scale indicate that seismic wave velocities are sensitive to the mineralogy of the continental crust. Variations in the compressional ( $V_p$ ) and shear ( $V_s$ ) wave velocities observed during the controlled source wide-angle seismic experiment (VARNET) were used to derive the distribution of Poisson's ratio ( $\sigma$ ) and to predict the bulk composition of the crust. The range in  $V_p$  and  $\sigma$  encountered throughout the crust is highly sensitive to bulk silica content ( $\%SiO_2$ ). The results demonstrate that the crust is unusually felsic compared to that found globally (Figure 4.2.2). Moreover, the lower (10 km) of crust has a bulk silica content of ~64%, which is much greater than is considered typical of a mafic lower crust. Independent geochemical and petrophysical measurements from mid to lower crust granulite facies xenoliths from the Irish Midlands agree remarkably well with the controlled source seismic results. The combined results have implications for crustal accretion and growth processes.

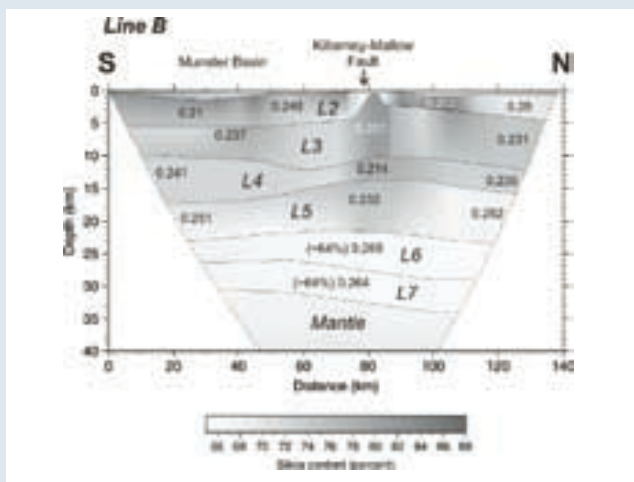
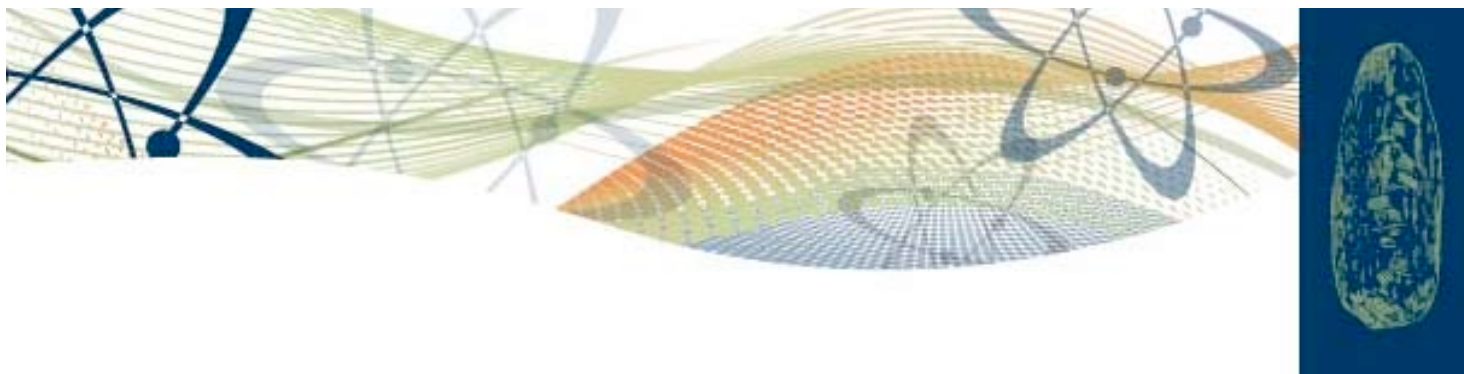


Figure 4.2.2: The chemical constitution of the crust of southwest Ireland in terms of silica content (shown as grey-scale) as derived from variations in Poisson's ratio.

Proposal:

O'Reilly submitted a long-term proposal to extend this work to investigate the detailed structure in the Porcupine Basin and adjoining Irish Continental Platform. This was partly funded by PIPCo/PSG at a reduced level of 90,000 Euro to provide funding for a senior post-doctoral researcher for one year to focus on the transition region from Platform to Basin.

Presentations:

**Hauser, F., B.M. O'Reilly and P.W. Readman.** The Porcupine Irish Margins Project: First data examples from an onshore/offshore seismic experiment in SW Ireland. 50th Annual Irish Geological Research Meeting, School of Environmental Sciences, University of Ulster, Coleraine, Northern Ireland, 23-25 February

**Hauser, F., B.M. O'Reilly, P.W. Readman and V.C. Do,** H.-M. Rumpel, 2007. S-wave and density structure along two wide-angle lines in SW-Ireland. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**Hauser, F., O'Reilly, B.M. and Readman, P.W.,** 2007. Shear wave velocity structure in southwest Ireland from VARNET controlled-source seismic data. Poster presentation at the NAPSA Workshop, Memorial University, 24-26 July.

**O'Reilly, B.M., F. Hauser, P.W. Readman and P.M.** Shannon. Seismic evidence for mantle exhumation and serpentinisation in the Porcupine Basin. 50th Annual Irish Geological Research Meeting, School of Environmental Sciences, University of Ulster, Coleraine, Northern Ireland,

23-25 February

**O'Reilly, B.M., Hauser, F., Readman P.W.** and Shannon, P.M., 2007. Seismic evidence for mantle exhumation and serpentinisation in the Porcupine Basin. Poster presentation at the NAPSA Workshop, Memorial University, 24-26 July.

**Readman, P.W., F. Hauser, B.M. O'Reilly, V.C. Do** and H.-M. Rumpel, 2007. Constraints on crustal structure in SW-Ireland from shear-wave refraction and density data. 50th Annual Irish Geological Research Meeting, School of Environmental Sciences, University of Ulster, Coleraine, Northern Ireland, 23-25 February.

**Readman, P.W. and O'Reilly, B.M.,** 2007. Regional Mesozoic basin development along the Irish continental margins: constraints from potential field modelling. Poster presentation at the NAPSA Workshop, Memorial University, 24-26 July.

**4.3 ISLE (Irish Seismological Lithospheric Experiment)**

*P.W. Readman, B.M. O'Reilly*

Data collection continued during 2007 with a view to future receiver function and tomographic investigations as part of the newly funded Irish Seismological Upper Mantle Experiment (ISUM). A new study on crustal anisotropy in southwest Ireland was instigated using controlled source seismic data from the VARNET project. This study will investigate relationships between tectonic fabrics in the crust and the propagation of differently polarised S-waves.

The joint inversion study of seismic and gravity data in collaboration with J. P. O'Donnell and Dr Eve Daly (NUIG Galway) and C. Tiberi (Université Pierre et Marie Curie-Paris 6) produced first preliminary results. The initial study used 1936 P/PKPdf cross-correlated relative travel-time residuals derived from 276 events recorded by the ISLE data over a three-year period from September 2003. Analysis indicates a change of the order of 1 second from faster to slower arrivals moving from north to south across the Iapetus Suture Zone (Figure 4.3). Synthetic testing and analysis was started with preliminary results to be presented at the European Geosciences Union Meeting in April 2008.

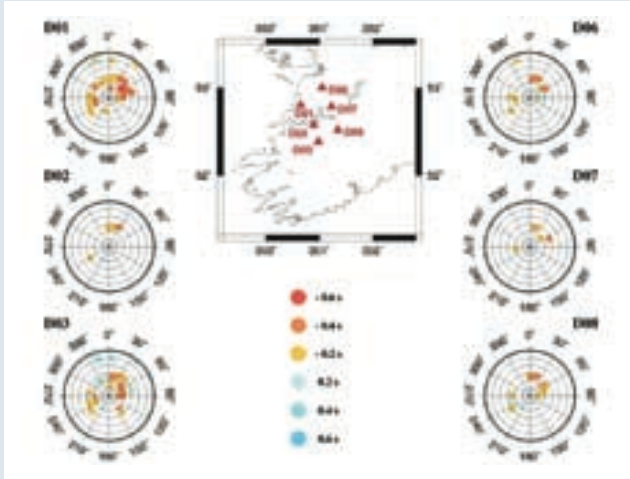
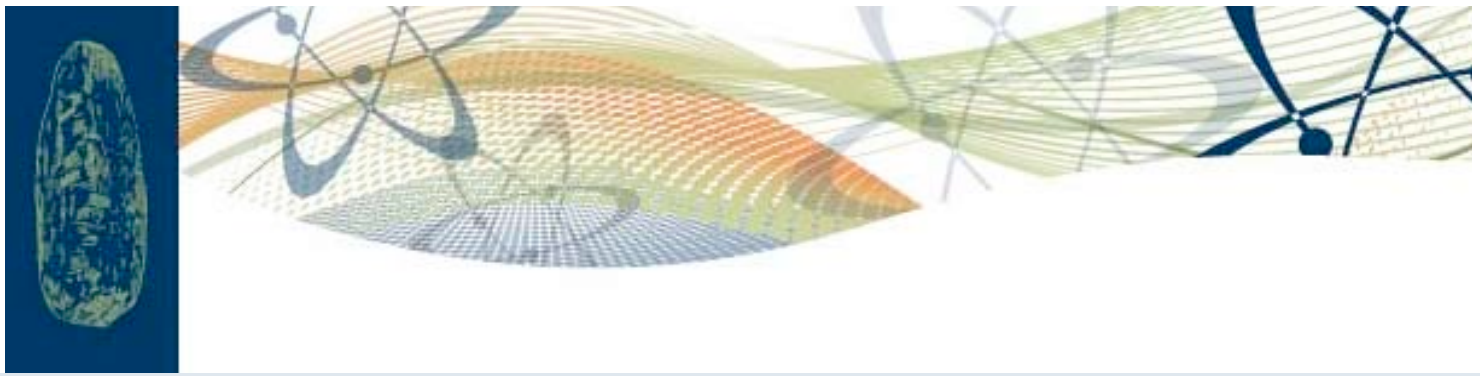


Figure 4.3: Example of azimuthal distribution of P-wave traveltimes residuals for data from some of the ISLE stations

Results from the S receiver function study were published and suggest a change in lithospheric properties towards northeast Ireland that is spatially associated with the intensity of Cenozoic volcanic activity.

Proposal:

Proposal submitted to Science Foundation Ireland for RFP2007 to continue on ISLE data with a focus on upper mantle anisotropy around Ireland. Proposal funded at requested level of €113.30K, including funding for a PhD student.

Publication:

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*, 255, 32-40.

Presentation:

Ritter, J.R.R., Landes, M., Wawerzinek, B., Readman, P.W., O'Reilly, B.M. and Do, V.C. Lithosphere-Asthenosphere System Underneath Ireland. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

Do, V.C., Readman, P.W., O'Reilly, B.M. and Hauser, F. Shear-wave splitting results from southwest Ireland: Deep-source anisotropy revealed. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

**4.4 TRIM (TOBI Rockall Irish Margins)**

*B.M. O'Reilly, P.W. Readman*

A paper exploring Plio-Pleistocene sedimentation processes on the eastern margin of the Rockall Trough was published in *Marine Geology*. The paper principally considers climatic

controls on deep-water sedimentation in the northeast Atlantic. There was interaction with other researchers in using the TRIM data for other investigations. A brief study considering the use of TRIM sidescan data in mapping deep-water benthic habitats was carried out with the Irish Marine Institute. The possibility of integrating high resolution INSS (Irish National Seabed Survey) bathymetric data with deep towed TOBI sidescan imagery, to enhance understanding of the geological and sedimentological history of the Irish Atlantic margins, was also discussed. Shallow gas hydrate deposits are known to occur in Arctic and sub-tropical regions of the North Atlantic. However, there is no documented evidence for hydrate occurrences west of Ireland or Britain. The possibility of detecting hydrate deposits, using wide-angle seismic reflections recorded during the HADES and RAPIDS experiments, was investigated in collaboration with the National Oceanographic Centre in Southampton. Results so far are inconclusive, because of the low frequency nature of the seismic source.

Publication:

**O'Reilly, B.M.**, Shannon, P.M. and **Readman, P.W.**, 2007. Shelf to slope sedimentation processes and the impact of Plio-Pleistocene glaciations in the northeast Atlantic, west of Ireland. *Marine Geology*, 238, 21-44.

Presentations:

Elliott, G.M., Shannon, P.M., Haughton, P.D.W., Praeg, D., **O'Reilly, B.M.**, 2007.

Mid to Late Cenozoic evolution of a sediment starved slope system: the Rockall Trough, west of Ireland. European Geosciences Union meeting, Vienna, Austria, 16-20 April.

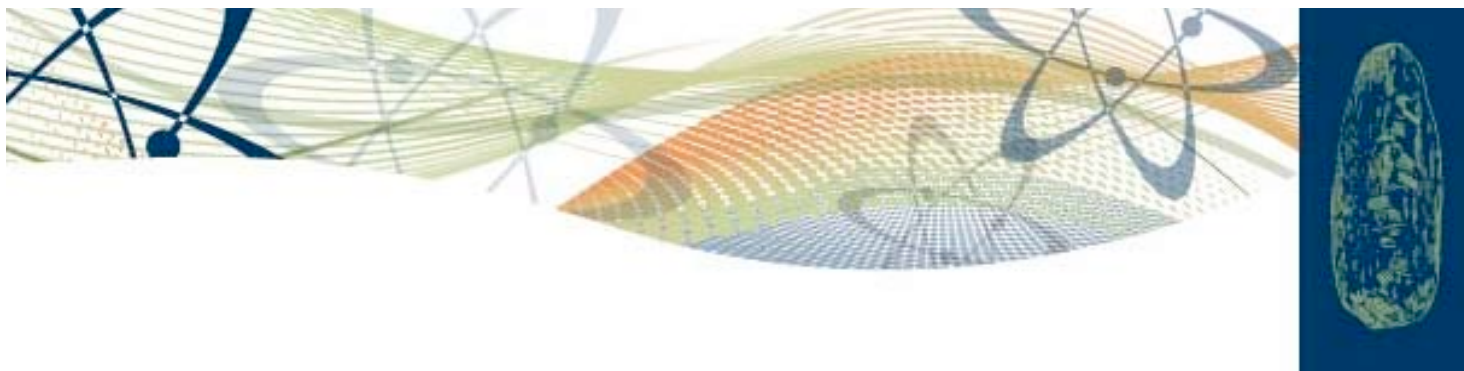
**O'Reilly, B.M.** and **P.W. Readman**. Cold-water coral ecosystem development in the NE Atlantic: evidence for strong coupling with Pleistocene and Holocene climate change. Poster presentation at the NAPS Workshop, Memorial University, 24-26 July.

**4.5 Seismic Network and Irish Earthquakes**

**4.5.1 Irish Seismic network**

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

2007 saw moves by the observatory group towards implementing a modern seismic network for Ireland. Through the installation of a Seedlink server and with upgrades at both DSB in the Dublin Mountains and VAL in Valentia, data is now returned in realtime to DIAS.



#### 4.5.2 *Tsunami Warning System*

A.G. Jones, T. Blake

The case for a Tsunami Warning System (TWS) for Ireland continued to be built, with a modern seismic network as a core component. Jones, as a member of the TWS Technical Working Group of the Interdepartmental TWS Committee, met with the visiting InterGovernmental Oceanographic Commission in early-July. In their report on the plans for an Irish TWS, the IOC stated that:

*Given the inadequacy of the existing national seismic network to contribute to the NEAMTWS, the proposed RT instrumentation upgrade is strongly supported and it should ensure long-term maintenance capabilities.*

#### Presentations:

- Blake: Presentation on DIAS Seismic Network at ORFEUS Workshop, Bucharest.
- Blake: Presentation to Students at Dublin City University on "Shake Rattle and Roll, Getting to grips with Earthquakes, An Irish Perspective, Dec 12th 2007.

### 5 Geodynamic modelling

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

Two visits to Professor Dimitrios Sokoutis at Vrije University, Amsterdam were made during the first (February-March) and second part of the year. The first involved general training and the design of the analogue experiments to test ideas regarding extensional deformation of the lithosphere and development of sedimentary basins (Figure 5.1). Initially these were unsuccessful due to the relative novelty of the problem addressed. The return visit by John Sheehan, in October to December 2007, to study the influence of weak zones on lithospheric rifting was highly successful. Various technical difficulties in setting up the analogue models were overcome and significant results were obtained. These results indicate that extreme strain focussing can occur in continental crust if substantial heterogeneities in strength are present in the sub-crustal mantle lithosphere (Figure 5.2). In all three analogue models were completed in Amsterdam and two models, using a centrifuge apparatus, were also completed in Florence. Numerical simulations are already underway for comparison with the analogue results.

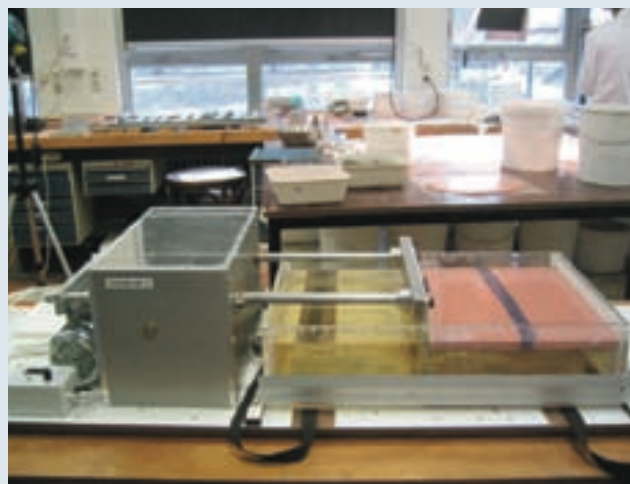


Figure 5.1: Experimental setup for analogue experiments. This shows a model in the course of construction. The purple coloured layer is a weak zone within the mantle (in this case). Further layers for the crust are then placed on top of this. The model is then extended by means of the piston shown.

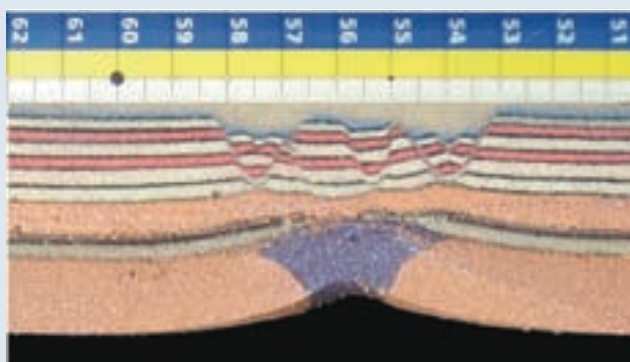
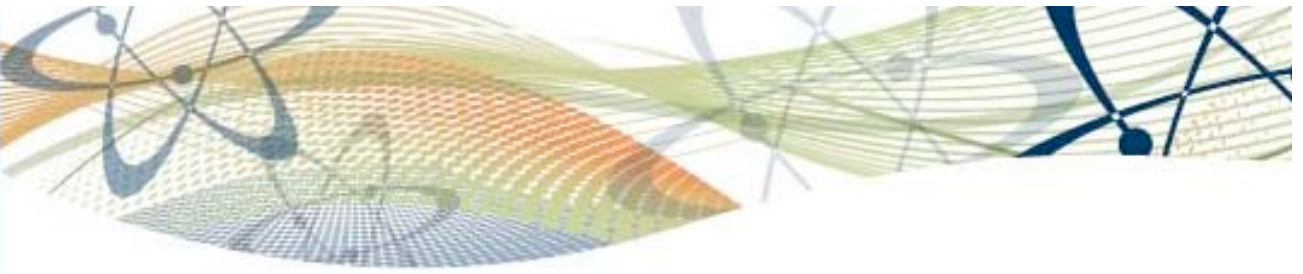


Figure 5.2: An example of a vertical section cut through the model after extension. In this model the weak zone had originally extended up to the base of the brittle mantle.

#### Publications:

**Yamasaki, T.**, Miura, H., Nogi, Y. Flexural uplift of the Transantarctic Mountains controlled by rheological structure beneath the Antarctica. Submitted to *Geophysical Journal International*.

**Yamasaki, T.** and Gernigon, L. Magmatic underplating as a possible origin of deformation localization during lithospheric extension. Submitted to *Special Publication of Geological Society of London*.



## 6 Collaboration with wider research community

### 6.1 Visits to other laboratories by Section members

- Avdeeva: Visit to Tokyo University, Japan, August.
- Garcia: Visit Barcelona Center for Subsurface Imaging (BCSI), November
- Jones: Collaborative visit to University of Barcelona, February.
- Jones: Collaborative visit to Geological Survey of Canada, June.
- Miensopust: Visited University of Barcelona, January.
- Miensopust: Visited U. Witwatersrand and take part as an instructor in the Geophysical Field School, June/July.
- Muller: Visit U. Witwatersrand to for collaboration with co-researchers S. Webb and R. Hart on Vredefort Dome. Also collaborate with De Beers consultant C. Hatton on lithosphere thickness determinations from MT data. Both visits Johannesburg, October.
- O'Reilly: Visit to Memorial University, Newfoundland, July.
- Sheehan: Two visits to Vrije University, Amsterdam, February-March and October-December.

### 6.2 Visitors to the Section

- Dr. Alan Chave, Woods Hole Oceanographic Institution, 21-25 March.
- Dr Sarah Bennetti, Irish Marine Institute, 11-12 June.
- Professor Gordon Cooper, The University of the Witwatersrand, 28 January – 4 February.
- Professor Fiona Darbyshire, University de Quebec a Montreal, 25 March – 20 April.
- Dr Rob Evans, Woods Hole Oceanographic Institution, date TBD.
- Dr. Chris Hatton, Consultant to De Beers, date TBD.
- Dr Keith Lambkin, Senior Scientist Valentia Met Station Caherciveen Co Kerry, 12-13 November.
- J.-P. O'Donnell, NUI Galway, two extended visits during the year.
- Dr. Joachim Ritter, University of Karlsruhe, late February.
- Ms. Sue Webb, The University of the Witwatersrand, date TBD.

### 6.3 Collaborative Activities by Section members

- UCD: ISLE, TRIM
- NUIG: Marine EM, ISLE, ISLE-MT

- MI: Marine EM
- Met Eireann: Valentia
- GFZ (Germany): DSB
- Karlsruhe: ISLE
- UB (Spain): PICASSO, 3D MT inversion
- GSC (Canada): Nechako, Bathurst high-res EM, Churchill deep MT
- UWO (Canada): Joint inversion, seismology
- WHOI (USA): Marine EM, EM processing
- Vrije U (Netherlands): Rheological modelling
- CGS (RSA), GSB (Botswana), GSN (Namibia): SAMTEX
- Wits (RSA): SAMTEX, AfricaArray
- UTM (Spain): Marine EM
- Repsol (Spain): Marine EM

## 7 Public outreach

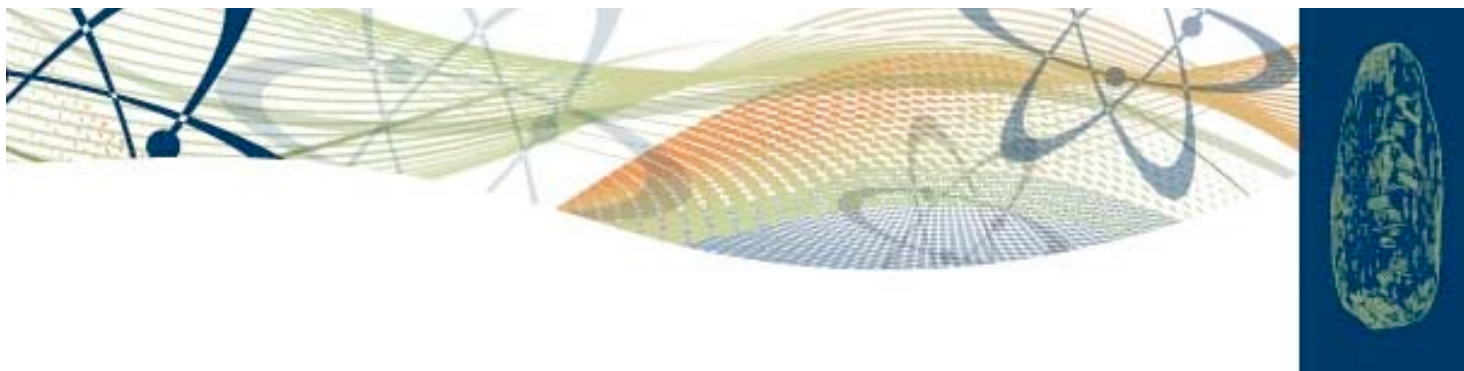
The Outreach efforts of the School focussed on primary and secondary school pupils.

T. Blake initiated a Secondary Schools Outreach Programme on Earthquakes. Two secondary schools received talks to their transition year students about earthquakes.

However, the most important Outreach programme ever initiated by the Geophysics Section is the "Seismology in Schools" programme. Seismology in Schools started in the U.S.A. over a decade ago, and now over 100 schools have their own seismometers and are connected to each other through the internet. An new scheme is running in Italy, and the U.K., through the British Geological Survey, started an equivalent scheme. DIAS was invited to become involved and to try to roll out a Seismology in Schools programme in Ireland.

Blake attended the launch of the "Seismology in Schools" programme at the Institute of Physics, in London, May 30th 2007, and the Section decided to initiate a pilot effort by purchasing four of the BGS-designed seismometers and involving schools in the Dublin region on a rotating basis. On November 21st T. Blake made a presentation to the Directors of the Educational Centres across Ireland, and the Directors enthusiastically endorsed the project and decided to purchase thirty-four (34) seismometers from their own resources. In addition, the Geological Survey of Ireland put in an order for a further four more. Thus in 2008 the Section must roll out this programme to over 40 schools instead of the 2 originally planned.





## 8 Short Courses/Workshops

*Image Processing*, One-day Short Course presented by Professor Gordon Cooper (The University of the Witwatersrand) on 30 January.

*Wavelets*, Two-day Short Course presented by Professor Gordon Cooper (The University of the Witwatersrand) on 31 January – 1 February.

*Seismology in the Investigation of Earth's Crust and Upper-Mantle*, Two-day Short Course presented by Dr. Mark Muller (DIAS) on 20-21 February.

*New Developments in Joint Inversion*, 3-day workshop to be held in DIAS on 14-16 March.

*Statistics*, Three-day Sort Course presented by Dr. Alan Chave (WHOI) on 21 – 23 May.

*Seismology in Schools*, One day training day given by Dr Paul Denton BGS for 14 teachers who wished to implement the seismology in schools programme, Merrion Square, Dec 7th 2007

## 9 Miscellanea

### *T. Blake*

- *Radio Interviews*: RTE Radio 1 Drive Time programme, May 24th 2007, Interview on potential treat to Ireland from large earthquakes in Atlantic.
- RTE Radio 1 Seascapes Programme Thursday Aug 2nd 2007, Interview on Tsunamis, possible treats to Ireland.
- RTE Radio 1 interview Drive Time programme following earthquake in Peru, Aug 16th 2007

### *X. Garcia*

- Presented lecture on electrical and electromagnetic methods to undergraduate students at Trinity College Dublin.

### *A.G. Jones*

- Editorial Board, *Earth, Planets & Space*.
- Associate Editor, *Journal of Geophysical Research*.
- Adjunct Professor, Queen's University, Kingston, Ontario, Canada.
- Adjunct Professor, NUI Galway, Ireland.
- Visiting Professor, Trinity College Dublin, Ireland.
- Honourary Professor, University of Leicester, UK.
- Visiting Scientist, Geological Survey of Canada.
- Member, Committee of Heads of Irish Earth Science Institutes (CHIESI).
- Member, Consultative Committee to the Geological Survey of Ireland.
- Member, Life, Earth and Environmental Sciences committee of the European Science Foundation.

### *M. Moorkamp*

- Course on scientific computing in C++

### *M. Muller*

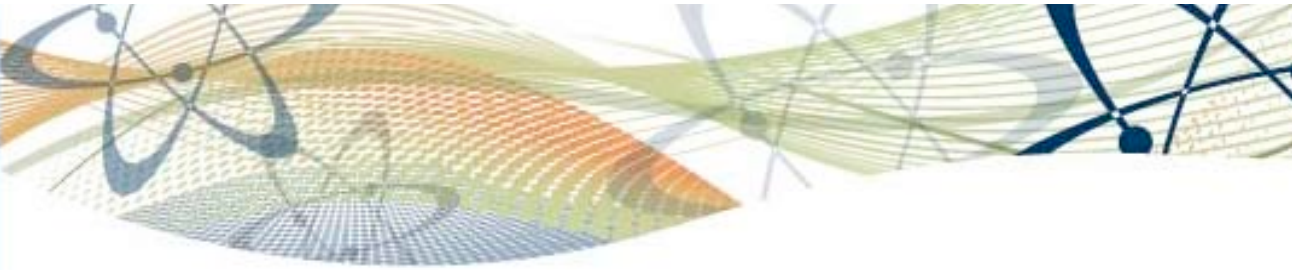
- Honorary Research Associate, University of the Witwatersrand, Johannesburg, South Africa.

### *B.M. O'Reilly*

- Member, Editorial Board, Irish Journal of Earth Sciences.
- Member, Internargins Steering Committee.
- Invited to Irish National Roundtable event for GTR-H, "Investment in Geothermal Energy", 3 April 2007, Dublin.

### *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.
- Invited to EU Marine Green paper "Towards a future maritime policy for the Union" Stakeholder Conference, 6 March, Dublin.
- Invited to Irish National Roundtable event for GTR-H, "Investment in Geothermal Energy", 3 April 2007, Dublin.



## 10 Productivity

### 10.1 Publications by Section members

The publications of all academic staff members and scholars for 2007 are listed below.

*Cloetingh, S.A.P.L., P.A. Ziegler, P.J.F. Bogaard, P.A.M.*

*Andriessen, I.M Artemieva, G. Bada, R.T. van Balen, F. Beekman, Z. Ben-Avraham, J.-P. Brun, H.P. Bunge, E.B. Burov, R. Carbonell, C. Facenna, A. Friedrich, J. Gallart, A.G. Green, O. Heidbach, **A.G. Jones**, L. Matenco, J. Mosar, O. Oncken, C. Pascal, G. Peters, S. Sliupa, A. Soesoo, W. Spakman, R.A. Stephenson, H. Thybo, T. Torsvik, G. de Vicente, F. Wenzel, M.J.R. Wortel, and the TOPO-EUROPE Working Group, 2007. TOPO-EUROPE: The geoscience of coupled deep Earth-surface processes. *Global and Planetary Change*, **58**, 1-118.*

**Garcia, X.** and **A.G. Jones**, 2007. Robust processing of magnetotelluric data in the AMT dead-band using the Continuous Wavelet Transform. *Geophysics*, in revision.

*Eaton, D.W., F. Darbyshire, R.L. Evans, H. Grütter, **A.G. Jones**, and X. Yuan, 2007. The elusive lithosphere-asthenosphere boundary (LAB) beneath cratons. *Lithos*, accepted subject to minor revision.*

**Jones, A.G.**, R.L. Evans and D.W. Eaton, 2007. Velocity-conductivity relationships for mantle mineral assemblages in Archean cratonic lithosphere based on extremal bounds. *Lithos*, submitted.

*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*, **255**, 32-40.*

*Lezeata, P., A.D. Chave, **A.G. Jones**, and R.L. Evans, 2007. Source field effects in the auroral zone: Evidence from the Slave craton (NW Canada). *Physics of the Earth and Planetary Interiors*, **164**, 21-45.*

**Moorkamp, M.**, 2007. Comment on 'The magnetotelluric phase tensor' by T. Grant Caldwell, Hugh M. Bibby and Colin Brown. *Geophysical Journal International*, **171**, 565-566.

**Moorkamp, M., A.G. Jones** and D.W. Eaton, 2007.

*Joint inversion of teleseismic receiver functions and magnetotelluric data using a genetic algorithm: Are seismic velocities and electrical conductivities compatible? *Geophysical Research Letters*, **34**, L16311, doi: 10.1029/2007GL030519.*

**O'Reilly, B.M.**, P.M. Shannon, and **P.W. Readman**, 2007.

*Shelf to slope sedimentation processes and the impact of Plio-Pleistocene glaciations in the northeast Atlantic, west of Ireland. *Marine Geology*, **238**, 21-44.*

*Queralt, P., **A.G. Jones**, and J. Ledo, 2007. Electromagnetic imaging of a complex ore body: three-dimensional forward modeling, sensitivity tests and down-mine measurements. *Geophysics*, **72**, 85-95.*

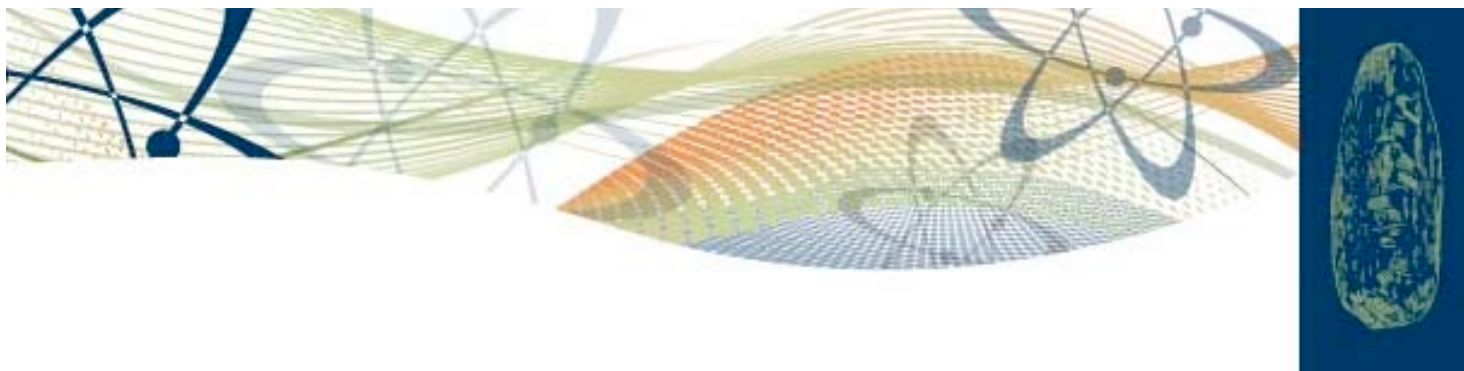
**Rao, C.K., A.G. Jones**, and **M. Moorkamp**, 2007. The geometry of the lapetus suture zone in central Ireland deduced from a magnetotelluric study. *Physics of the Earth and Planetary Interiors*, **161**, 134-141.

**Spratt, J., A.G. Jones**, V. Jackson, **L. Collins**, and **A. Avdeeva**, 2007. Lithospheric geometry of the Wopmay Orogen from a Slave Craton to Bear Province Magnetotelluric Transect. *Journal of Geophysical Research – Solid Earth*, submitted.

**Yamasaki, T.**, Miura, H., Nogi, Y. Flexural uplift of the Transantarctic Mountains controlled by rheological structure beneath the Antarctica. *Geophysical Journal International*, submitted.

**Yamasaki, T.** and Gernigon, L. Magmatic underplating as a possible origin of deformation localization during lithospheric extension. *Tectonophysics*, submitted.

*Wei, W., S. Jin, G. Ye, M. Deng, H. Tan, M. Unsworth, J. Booker, **A.G. Jones** and S. Li, 2007. Features of faults in the central and northern Tibetan plateau based on results of INDEPTH (III)-MT. *Frontiers in the Earth Sciences in China*, **1**, 121-128.*



## 10.2 Theses defended

V.C. Do, *A study of seismic anisotropy in Ireland. Defended on 27th April 2007 at University College Dublin. External examiner: Professor Michael Kendall, University of Bristol.*

M. Moorkamp, *Joint Inversion of Magnetotelluric and Receiver Function Data. Defended on 14th September at the National University of Ireland, Galway. External examiner: Professor Laust B. Pedersen, University of Uppsala.*

## 10.3 Invited Presentations

**Garcia, X., R.L. Evans, and X. Monteys.** *Using Controlled Source EM Methods to Constrain Physical Properties of the Uppermost Seafloor: An Example of Instrumentation and a Case Study from a Gas Pock-Mark Offshore Ireland. Invited presentation, EAGE 69th Conference and Exhibition. London.*

**Garcia, X., X. Monteys, R.L. Evans, and B. Kelleher.** *Geohazard identification and early reconnaissance for hydrocarbon potential using Marine Electromagnetic and High Frequency Acoustic methods. Invited presentation, Seabed mapping workshop 2007. Dublin, 2007.*

**Garcia, X.** *INSS/INFOMAR Integration of Datasets: EM technology. Invited presentation, Seabed mapping workshop 2007. Dublin, 2007.*

**Jones, A.G.,** 2007. *Knowledge of the continental lithosphere from electromagnetic studies. Invited keynote presentation at Continental Lithosphere Workshop, Merrickville, Ontario, Canada, 7-10 March.*

**Jones, A.G., M. Moorkamp, and M.P. Hamilton,** 2007. *Structures and geometries in the continental lithosphere: Insights from joint inversion and co-operative interpretation of seismic and electromagnetic data. Invited presentation, TOPO-Europe session, European Geosciences Union meeting, Vienna, Austria, 16-20 April.*

**Jones, A.G.,** 2007. *Deep probing electromagnetic studies of cratons in southern Africa compared and contrasted with the results from the Slave and Superior cratons. Invited*

*seminar presented at Department of Earth and Ocean Sciences, UBC, Vancouver, Canada. 28 June.*

**Jones, A.G.,** 2007. *Early Earth tectonics: Results from deep-probing electromagnetic studies on Archean cratons. Invited seminar, Department of Geology, University of Leicester, 11 October.*

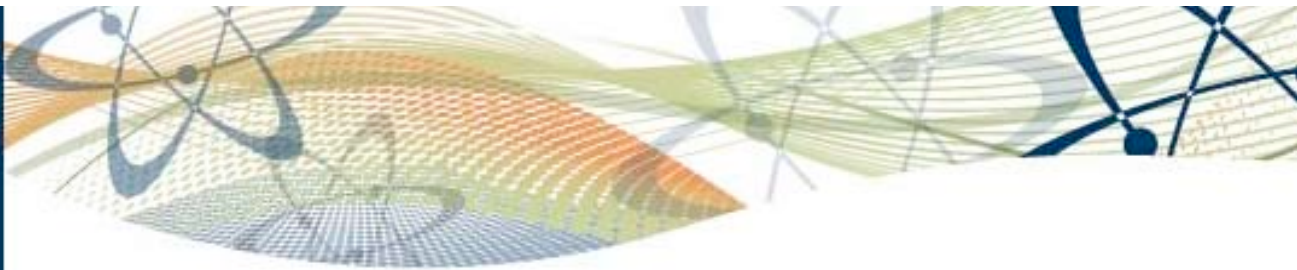
**Jones, A.G., M.R. Muller, M.P. Hamilton, and the SAMTEX Team,** 2007. *SAMTEX results: insights from co-operative interpretation of seismic and electromagnetic data. Invited keynote presentation at AfricaArray Annual Workshop, University of the Witwatersrand, Johannesburg, South Africa, 17-18 July.*

**Jones, A.G., M.R. Muller, M.P. Miensoopust, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team,** 2007. *Southern African Magnetotelluric Experiment (SAMTEX): Project overview and regional results. Invited keynote presentation at Southern African Geophysical Association conference, Wild Coast, South Africa, 24-26 October.*

**Jones, A.G., M.R. Muller, M.P. Miensoopust, M.P. Hamilton, J.E. Spratt, X. Garcia, R.L. Evans, S.F. Evans, A. Mountford, W. Pettit, P. Cole, T. Ngwisanyi, D. Hutchins, C.J.S. Fourie, and the SAMTEX Team,** 2007. *Southern African lithospheric structures and geometries imaged by SAMTEX: Clues to Archean tectonic processes. Invited presentation at American Geophysical Union Fall meeting, 10-14 December.*

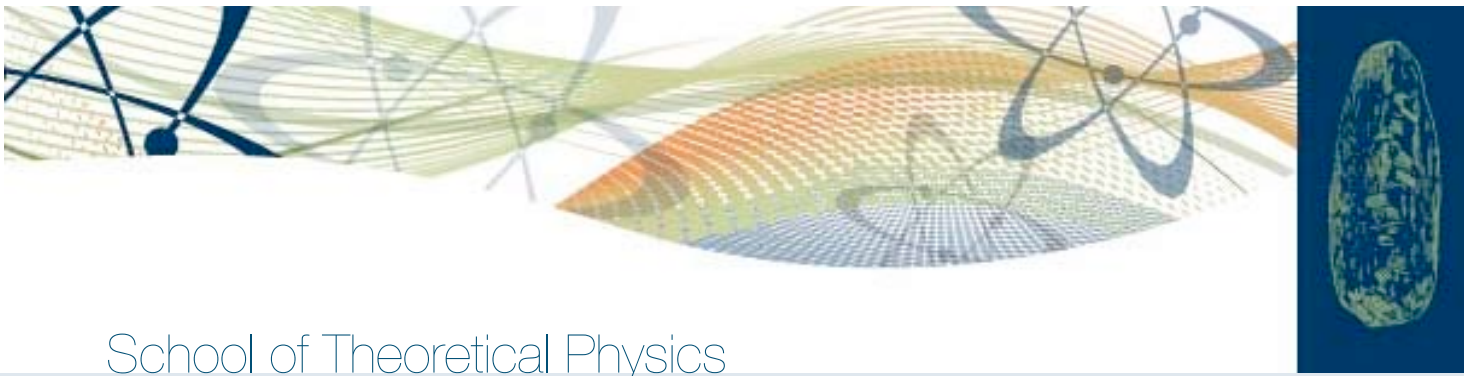
**O'Reilly, B.M.** *An overview of research activities in DIAS relevant to petroleum exploration along the conjugate continental margins of NW Europe and eastern Canada. Invited presentation at the NAPSA Workshop, Memorial University, 24-26 July.*

**O'Reilly, B.M.** *Reconstructing early Mesozoic extension in the North Atlantic: a preliminary first step in understanding linkages between basin assemblages offshore Ireland and Newfoundland. Invited keynote presentation at the NAPSA Workshop, Memorial University, 24-26 July.*



## School of Cosmic Physics Research Projects 2007

<b>Projects</b>	<b>Opening Balance 2007 €</b>	<b>Receipts 2007 €</b>	<b>Applied as Income 2007 €</b>	<b>Closing Balance 2007 €</b>
Gamma Ray Bursts	21,841	40,003	24,261	37,583
<b>tfl Astronomy</b>	<b>21,841</b>	<b>40,003</b>	<b>24,261</b>	<b>37,583</b>
Astro Plasma Physics	3,000	0	3,000	0
Dos Max	14,317	0	484	13,833
PRTLl-CosmoGrid	2,581,550	3,328,108	4,368,302	1,541,356
Nam Conference	17,218	0	0	17,218
Jet 4 (Central Engines...stars)	95,133	(980)	55,612	38,542
Jetset	52,912	1,746,068	1,713,385	85,594
Dobies	0	6,045	3,770	2,275
KVM3Net	0	25,000	14,090	10,910
SFI Felix GNM	0	63,500	13,700	49,800
SFI Cores to Disks	0	23,149	0	23,149
Cosmic Ray Origin	0	89,039	15,461	73,578
E-Inis -PRTLl Cycle 4	0	710,000	667	709,333
NGST Project	(1,257)	109,094	122,628	(14,791)
Jonathon Mackay -IrcSet Postgrad	528	24,003	27,365	(2,833)
Paul Dempsey - IRCSET Fellow	0	0	9,137	(9,137)
Linda Podio -IRCSET Fellow	0	0	1,474	(1,474)
<b>tfl Astrophysics</b>	<b>2,763,401</b>	<b>6,123,026</b>	<b>6,349,075</b>	<b>2,537,352</b>
Hades Project/c Ravaut	40,933	21,780	37,760	24,953
Nabask	15,490	0	0	15,490
Isle-MT	2,733	0	2,733	0
Samtex	135,995	0	1,895	134,100
SFI Samtex	79,416	48,476	85,515	42,377
Geo External Funds	0	21,517	8,951	12,566
SFI Joint RFP	0	69,067	0	69,067
Irish Geoscience Graduate Programme	0	41,108	0	41,108
SFI Isle 2 Preadman	0	56,700	423	56,277
SFI Picasso	39,195	58,566	100,315	(2,554)
Marem SFI -X Garcia/NUIG	0	0	5,507	(5,507)
<b>tfl Geophysics</b>	<b>313,762</b>	<b>317,214</b>	<b>243,099</b>	<b>387,877</b>
<b>Total Cosmic Physics</b>	<b>3,099,004</b>	<b>6,480,243</b>	<b>6,616,435</b>	<b>2,962,812</b>
<b>Applied to the accounts in 2007</b>			<b>6,616,435</b>	
<b>Capital Investment 2007</b>			<b>(2,661,030)</b>	
<b>Applied as Income to the accounts in 2007</b>			<b>3,955,405</b>	



# School of Theoretical Physics

## 1 Report on Research Work

### 1.1 Work by Senior Professors and Collaborators

#### 1.1.1 Bose-Hubbard Model

(T.C. Dorlas & S. Adams)

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. A new derivation of this solution was found in collaboration with a former Scholar, S. Adams. This derivation is more satisfactory and is based on a  $C^*$ -algebraic formalism developed by Petz, Raggio and Verbeure for the case of quantum lattice systems. Some small errors in the work with Bru were also corrected. A variational formula for the translation-invariant version of the Bose-Hubbard model was also obtained. This work was published this year in [4].

#### 1.1.2 Quantum Coding

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

Work on quantum coding theory in collaboration with Dr. Nilanjana Datta (Cambridge) has further progressed this year. An extension of the Holevo-Schumacher Westmoreland theorem to a class of channels with long-term memory of the form

$$\Phi^{(n)}(\rho^{(n)}) = \sum_{i=1}^M \gamma_i \Phi_i^{\otimes n}(\rho^{(n)}), \quad (1.1)$$

where the  $\Phi_i$  are completely positive maps  $\Phi_i: \mathcal{B}(\mathcal{H}) \rightarrow \mathcal{B}(\mathcal{K})$  and  $\gamma_i > 0$  with  $\sum_{i=1}^M \gamma_i = 1$  was started last year and completed in the beginning of this year. It was proved that the capacity of this type of channel is given by

$$C(\Phi) = \sup_{\{p_j, \rho_j\}} \left[ \bigwedge_{i=1}^M \chi(\{p_j, \Phi_i(\rho_j)\}) \right],$$

where the supremum is over all finite ensembles  $\{p_j, \rho_j\}$  of states  $\rho_j$  on  $\mathcal{H}$  with probabilities  $p_j$ , and  $\chi$  denotes the Holevo quantity. It was then extended to the case of entanglement-assisted capacity for the same class of channels in collaboration with Y. Suhov: see [07-08]. During an extended visit to Cambridge, the classical capacity of a much more general class of channels was derived.

These channels are of the form

$$(\Phi^{(n)})(\phi)(A) = \sum_{i_1, \dots, i_n \in I} \gamma_{i_1} q_{i_1 i_2} \dots q_{i_{n-1} i_n} (\Phi_{i_1} \otimes \dots \otimes \Phi_{i_n})(\rho_{\phi_n}),$$

where  $(q_{ij})_{i,j \in I}$  is the transition matrix of a general Markov chain with finite state space  $I$ , and  $(\gamma_i)_{i \in I}$  is an equilibrium distribution for this chain. It was proved in [07-21] that the classical capacity of a channel of this type is given by

$$C(\Phi) = \lim_{n \rightarrow \infty} \sup_{\{p_j(n), \rho_j(n)\}} \left[ \bigwedge_{C \in \mathcal{C}} \bar{\chi}_C^{(n)}(\{p_j(n), \rho_j(n)\}) \right]$$

Here  $\mathcal{C}$  runs over the set of *communicating classes* of the Markov chain, and  $\bar{\chi}_C^{(n)}(\{p_j(n), \rho_j(n)\})$  is a Holevo-type expression for the Markov chain restricted to the class  $\mathcal{C}$ .

Together with a Ph.D. student (Ciara Morgan) the Holevo expression for the capacity of the amplitude-damping channel was studied and an explicit expression for the (product-state) capacity was obtained. This led further to the construction of an example of a channel with long-term memory of the type (1.1) where the capacity is not given by the minimum of the capacities of the individual CPT maps  $\Phi_i$ . It is intended to extend this study to the case of a periodic channel.

#### 1.1.3 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.

#### 1.1.4 Bethe Ansatz

(T.C. Dorlas & M. Samsonov)

Together with Dr. Maxim Samsonov, the study of the Bethe Ansatz solution of quantum spin models, in particular the Heisenberg spin chain was begun. 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 thermo dynamic limit.



It is proposed to reformulate the Bethe Ansatz equations directly in this limit in the form of a single non-linear equation for a set of measures. This was successfully done in the case of the non-linear Schrödinger model, but the case of the Heisenberg chain is much more difficult. In fact, work started with the easier, but nonetheless non-trivial problem of the rigorous proof of the Bethe-Ansatz solution of the classical six-vertex model. This model is closely related to the Heisenberg chain in that the Bethe Ansatz equations are in fact the same! The difference is that only a restricted set of solutions, namely those corresponding to the ground state of the Heisenberg chain, is relevant for the six-vertex model. Two cases were treated: those where the interaction parameter  $\Delta$  takes values in the intervals  $(0; 1)$  and  $(-\infty, -1)$ . In these cases, the Bethe-Ansatz equations can be written in a variational form with a functional which is convex. This work is currently in the process of being completed.

#### 1.1.5 Discrete Feynman Integral

(T.C. Dorlas & E. Thomas)

While in Cambridge, work commenced on a rigorous version of the Feynman integral or a single particle on a lattice. Contrary to the continuous case, there is a genuine vector-valued measure associated with this integral. This work is in collaboration with Prof. Erik Thomas (Groningen) and is not yet finished, though a draft manuscript was written.

#### 1.1.6 Lecture Notes on Relative Entropy

(T.C. Dorlas)

Also while in Cambridge, considerable progress was made with a set of lecture notes on "Relative Entropy on  $\mathcal{B}(\mathcal{H})$ ". The main idea of these notes is that the most important aspects of quantum relative entropy do not need the technically difficult Tomita-Takesaki theory needed in the cases of general Von Neumann algebras. The notes include an extended appendix on operator theory and operator algebras. A chapter on applications has yet to be written, but it is hoped that the manuscript can be finished before summer 2008.

#### 1.1.7 Partition Functions and q-Hypergeometric Series

(W. Nahm, D. Zagier & S. Zwegers)

Conformal field theories which have integrable deformations with purely elastic scattering seem to have partition functions of a simple q-hypergeometric form. Their terms are quotients

with a q-deformed factorial as denominator and a numerator given by exponentiating an inhomogeneous quadratic form. The homogenous part of the latter is given by the scattering matrix of the deformed theory. Conversely, most of the modular invariant functions of the form just described seem to come from conformal field theories and it seems of interest to classify them. It is a long standing conjecture that for any quadratic form which yields modular forms in the way described a certain dual quadratic form also yields a modular form. This is a generalization of level rank duality which arose in the context of the study of the Langlands program. The conjecture has a perturbative and a nonperturbative part, since deviations from modular behaviour may be of inverse power law type or may be exponentially suppressed. In the past year the perturbative part of the conjecture was proven. More generally, the perturbative series for arbitrary quadratic forms was related to the series for its dual. The relation implies that vanishing in one case implies vanishing in the other. Further work along these lines is going on in discussions with Zagier and his former student Sander Zwegers, who recently obtained a permanent position at UCD.

#### 1.1.8 Discrete Hirota Equations

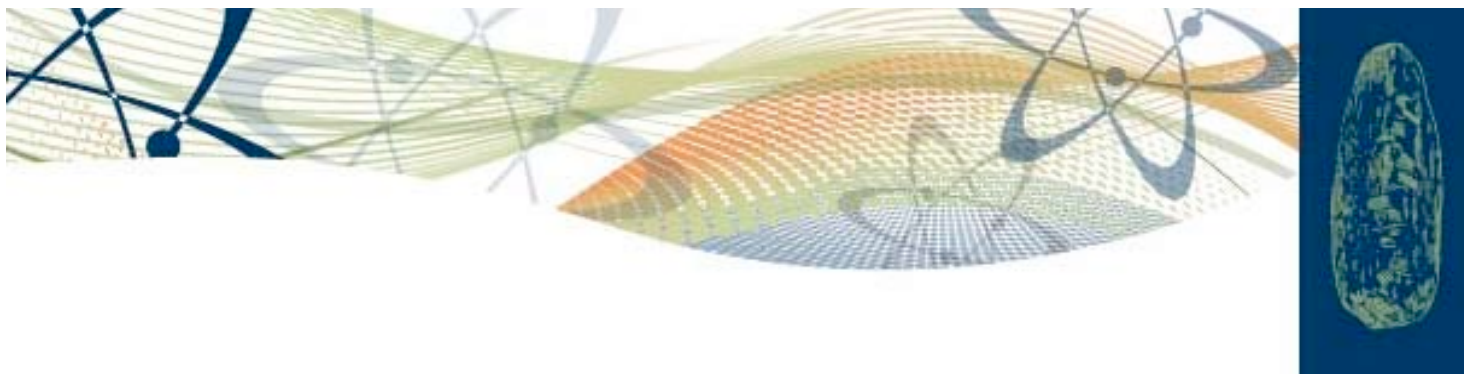
(W. Nahm & S. Keegan)

The discrete Hirota equation is an important integrable system, which turned out to have unexpected relations to quantum field theory. In the context of the PhD thesis of my student Sinéad Keegan it was shown how to relate calculations concerning the modular invariance of certain q-hypergeometric series to the Hirota equations. In its original form the equations related to Lie algebras  $A_r$ , but  $D_r$  is equally important. One has algebraic equations for an infinite family of variables  $z_{in}$ , where  $i$  goes from 1 to  $r$  and  $n$  takes arbitrary integral values. For the  $A$ -case a complete solution was presented in the thesis, but for the  $D$ -case only the result for  $i = 1$  could be derived. After obtaining her PhD, Sinéad went to Oxford to study financial mathematics. The work was completed using new methods, which also allow for a simplified solution in the  $A$ -case.

#### 1.1.9 Knot Polynomials

(W. Nahm, S. Gukov & Zagier)

During a joint visit with S. Gukov, UCSB to Zagier in Bonn, calculations of the modular properties of knot invariants



related to Chern-Simons theories with complex gauge groups were worked on. The approach was somewhat experimental and yielded very intriguing but still poorly understood results. They seem to be related to the perturbative expansions of q-hypergeometric partition functions mentioned above, with the figure-of-eight knot related to the simple quadratic form  $-n^2$ .

### 1.1.10 Fuzzy Physics

*(Denjoe O'Connor)*

The principal line of research pursued in 2007 continued to be the exploration of field theory in its matrix regularized form known as "fuzzyfield theory". Fuzzyfield 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  $\langle F/F \rangle = \frac{Tr}{N} (F^\dagger F)$  and Laplacian defines the geometry of the fuzzy space.

The approach "fuzzy" provides a regularization of field theory (and hopefully string theory) that is well adapted to the non-perturbative study 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 as well as a further large class of algebraic varieties.

### 1.1.11 Fuzzy Scalar Field Theory as a Multitrace Matrix Model

*(Denjoe O'Connor and C. Sämann)*

An analytical approach to scalarfield theory on the fuzzy sphere based on considering a perturbative expansion of the kinetic term was developed. This expansion allows one to integrate out the angular degrees of freedom in the hermitian matrices encoding the scalarfield. The remaining model depends only on the eigenvalues of the matrices and corresponds to a multi trace hermitian matrix model. Such a model can be solved by standard techniques as e.g. the saddle-point approximation. The perturbative expansion up to second order is evaluated and the one-cut solution of the saddle point approximation in the large  $N$  limit is presented. This approach was applied to a model which has been proposed as an appropriate regularization of scalarfield theory on the plane within the framework of fuzzy geometry.

### 1.1.12 A Universal Dirac Operator and Noncommutative Spin Bundles over Fuzzy Complex Projective Spaces

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

A universal Dirac operator for noncommutative spin and spin<sup>c</sup> bundles over fuzzy complex projective spaces is presented. An explicit construction of these bundles is given, which are described in terms of finite dimensional matrices, calculate the spectrum and explicitly exhibit the Dirac eigenspinors. To our knowledge the spin<sup>c</sup> spectrum for  $CP^n$  with  $n \geq 3$  is new.

### 1.1.13 Geometry in Transition: A Model of Emergent Geometry

*(R. Delgadillo-Blando, Denjoe O'Connor & B. Ydri)*

A three matrix model with global  $SO(3)$  symmetry containing at most quartic powers of the matrices was studied. An exotic line of discontinuous transitions with a jump in the entropy was found, characteristic of a 1st order transition, yet with divergent critical fluctuations and a divergent specific heat with critical exponent  $\alpha = 1/2$ . The low temperature phase is a geometrical one with gaugefields fluctuating on a round sphere. As the temperature increased the sphere evaporates in a transition to a pure matrix phase with no background geometrical structure. Both the geometry and gaugefields are determined dynamically. It is not difficult to invent higher dimensional models with essentially similar phenomenology. The model presents an appealing picture of a geometrical phase emerging as the system cools and



suggests a scenario for the emergence of geometry in the early universe.

#### 1.1.14 Probing the Fuzzy Sphere Regularisation in Simulations of the $3d \lambda\phi^4$ Model

(W. Bietenholz, J. Medina & Denjoe O'Connor)

The  $3d \lambda\phi^4$  model by discretising the Euclidean time and representing the spatial part on a fuzzy sphere was regularized. The latter involved a truncated expansion of the field in spherical harmonics. This yielded a numerically tractable formulation, which constituted an unconventional alternative to the lattice. In contrast to the  $2d$  version, the radius  $R$  plays an independent rôle. The phase diagram in terms of  $R$  and the cutoff was explored, as well as the parameters and coupling  $\lambda$ . The phases of disorder, uniform order and non-uniform order were identified. The result to the phase diagrams of the  $3d$  model on a non-commutative torus, and of the  $2d$  model on a fuzzy sphere were compared. Our data at strong coupling reproduce accurately the behaviour of a matrix chain, which corresponds to the  $c = 1$ - model in string theory. This observation enables a conjecture about the thermodynamic limit.

### 1.2 Independent Work by Fellows

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

(A. Povolotsky)

The determinant expression for the time dependent transition probabilities in the totally asymmetric exclusion process with parallel update on a ring has been obtained. To this end, the method of summation over the roots of Bethe equations based on the multidimensional analogue of the Cauchy residue theorem has been developed. This method has been applied to construct the resolution of the identity operator from the generalized eigenvectors of the evolution operator, which has been useful for calculation of the matrix elements of its powers. As a by-product the generating function of the joint probability distribution of particle configurations and the total distance travelled by the particles has been obtained.

#### 1.2.2 Quantum Hall Systems

(J.K. Slingerland & P. Bonderson)

Research was carried out on topological phases in condensed matter physics and on topological quantum computation. In particular a new physical explanation of conductance plateaux in fractional quantum Hall systems, in the second Landau level was studied, proposing trial wave functions for the electronic ground states of all observed conductance plateaux in this Landau level, as well as predicting others which may emerge with better sample quality and lower temperatures. This resulted in a preprint co-authored with P. Bonderson [07-24].

#### 1.2.3 Anyon Models

(J.K. Slingerland & P. Bonderson)

Work on a catalogue of anyon models (unitary braided tensor categories) as well as more general unitary tensor categories of up to 6 objects was carried out. A program to solve the consistency conditions for such models, the pentagon and hexagon equations was written, and a preprint with P. Bonderson is in preparation. This should be of interest to physicists working on topological systems, especially for the application to topological quantum computation, which requires the detailed data on braiding and tensor recoupling produced by the program, but should also be of interest to mathematicians as a source of (counter)-examples in the theory of tensor categories.

#### 1.2.4 Transitions between Topological Phases

(J.K. Slingerland, F.A. Bais & J. Pachos)

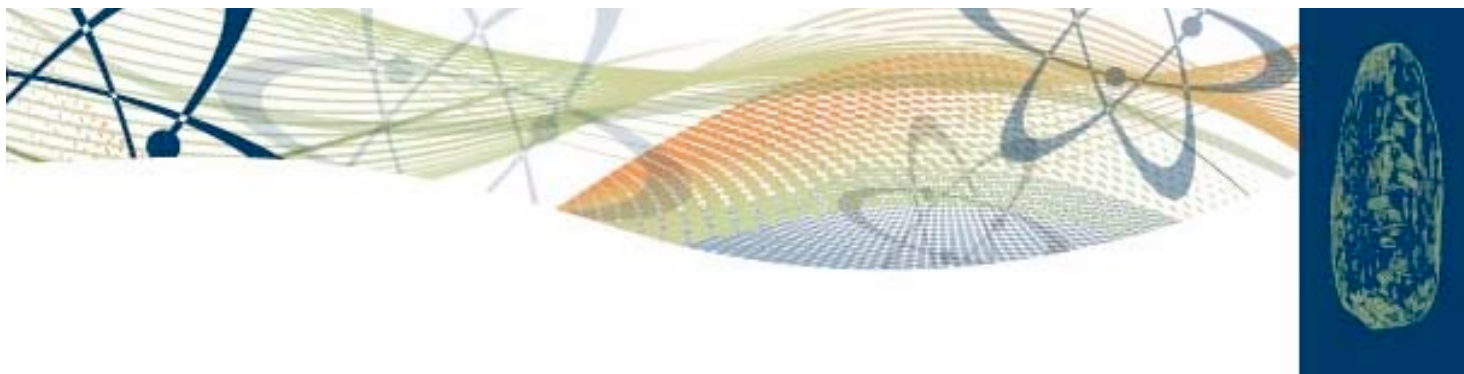
With F.A. Bais (University of Amsterdam), work continued on the characterisation of phase transitions between topological phases induced by the condensation of bosonic quasiparticles. This has led to interesting connections with constructions in conformal field theory such as the coset construction and the conformal embedding. Some work in a similar direction, with J. Pachos (University of Leeds), was also initiated.

#### 1.2.5 Magnetic Monopoles

(J.K. Slingerland, L. Kampmeijer, F.A. Bais & B.J. Schroers)

Work was carried out on magnetic monopoles in gauge theories where the gauge group is broken to a residual non-Abelian group. This is joint work with L. Kampmeijer and F.A. Bais (University of Amsterdam) and B.J. Schroers





(Heriot-Watt University). One of the results is the identification of a set of fundamental monopole charges such that all monopoles can be seen as smooth deformations of monopoles that are constructed by patching together spatially separated fundamental monopoles. A publication is in preparation.

### 1.3 Independent Work by Research Scholars and Students

#### 1.3.1 Scattering of $\delta$ -Interacting Particles

(P. Abramski)

Work commenced in the area of scattering of  $\delta$ -interacting particles, the specific sub-area of interest being the completeness of wave functions for the system of arbitrary number of identical particles. Such a wave function should satisfy to the corresponding Schrödinger equation describing the scattering process. Preliminary study of the subject amounted to consideration of the cases of interaction between two particles with different shapes of attracting or repulsive interacting potentials. Of particular importance for further study is the case of 3 particle  $\delta$ -interaction. In order to obtain a clear interpretation of wave functions for this case in each scattering region, the system of particles is represented as a combination of waves reflected and transmitted through the region borders. A universal rule for the calculation of the amplitudes of these waves in arbitrary region of scattering was also obtained. Further generalisation should give an adequate result for the case of an arbitrary number of particles.

#### 1.3.2 Instability of Intersecting Fuzzy Spheres

(S. Bal)

The stability of a multi fuzzy sphere configuration representing many fuzzy spheres in dimensionally reduced Yang-Mill-Chern-Simons models with and without supersymmetry was studied. The one loop effective action around these configurations was calculated and it was found that the intersecting fuzzy spheres are unstable in all the models considered. It was seen that the concentric fuzzy spheres with different radii, which are identified with the 'tHooft-Polyakov monopoles, are perturbatively stable in the Bosonic model and in the  $D = 10$  supersymmetric model.

#### 1.3.3 Higher gauge groups on Fuzzy Sphere

(S. Bal)

A matrix model to describe a gauge theory on fuzzy sphere was studied.

A methodology to study this model non perturbatively was developed. From the degeneracy of the eigenvalues of gaugefields  $D_a$ , a generation of  $U(2)$  and  $U(3)$  gauge groups in regions of the phase space were found. It was seen that the eigenvalue distribution of  $D^2$  follows Wigner semicircular distribution in these cases. This model is being studied to investigate the phase structure and extract more information about noncommutative  $U(2)$  and  $U(3)$  gauge theory on fuzzy sphere. This might help addressing issues related to UV-IR mixing in noncommutative gauge theories in future.

#### 1.3.4 Superconformal Partition Functions

(F. Dolan)

New methods for computing and analyzing freefield partition functions in conformal Yang Mills theories were obtained employing symmetric polynomial techniques. In particular, a method was found for obtaining the leading large  $N$  contributions to partition functions with wide applicability and which is easier to apply in many cases than more standard approaches such as saddle point methods.

This method also gives a procedure for finding finite  $N$  corrections, which is a significant improvement over more standard techniques where finite  $N$  corrections can be difficult to obtain.

General formulae for counting certain BPS operators in the freefield limit of superconformal Yang Mills theories were obtained using symmetric polynomial techniques. Asymptotic formulae for counting BPS operators in the chiral ring of certain superconformal Yang Mills theories were found. These formulae provide for extensions to the well known Hardy-Ramanujan and Meinardus formulae.

#### 1.3.5 The Superconformal Index

(F. Dolan)

Formulae for the superconformal index for  $\mathcal{N} = 1$  superconformal theories were found using q-series identities. These formulae prove and extend certain formulae first proposed by Christian Romelsberger using Seiberg duality. Matching of the superconformal index for a wide range of Seiberg dual theories was thus proved and for certain large



$\mathcal{N}$  limits extended to Kutasov-Schwimmer dual theories. This represents very non-trivial tests of  $\mathcal{N} = 1$  supersymmetric dualities and gives non obvious connections between partition functions for  $\mathcal{N} = 1$  superconformal field theories and q-series.

### 1.3.6 Evolving a Two-Particle System Using a Master Equation Approach

(A. Ghesquiére)

The case under study is that of a two particles system with gaussian wavefunction coupled to a heat bath. In order to evolve the system, a master equation approach was considered using the Quantum Brownian Motion Master Equation (see Phys. Rev. **A 53** (1996) 2633). A one-particle system was evolved and its Von Neumann entropy calculated. A solution to the master equation for a two-particle case was calculated in the case where the particles belong to different heat baths. The entanglement will be estimated using an entanglement measure known as the negativity. A new master equation is being derived for the case where the two-particles belong to the same heat bath.

### 1.3.7 Non-commutative Geometry

(I. Huet)

The field of research is centered in the area of noncommutative geometry and its applications to physics. In particular the main field of study is fuzzy geometry and its differential structures. Fuzzy geometry has potential applications in quantum field theory, more specifically the work is in quantum electrodynamics, which formulation in the noncommutative geometry setting is still not clear.

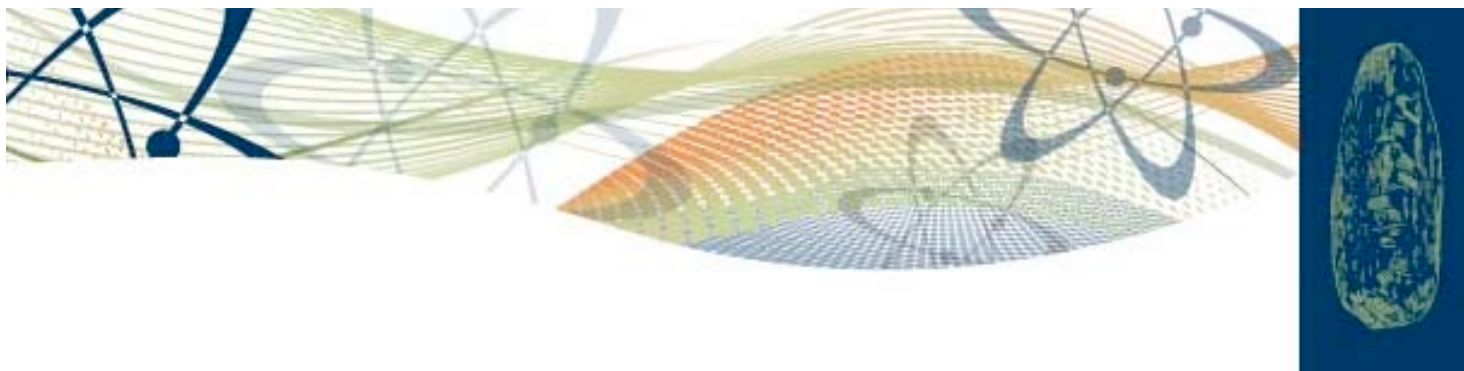
### 1.3.8 Quantum Hall Effect for a Two-Dimensional Relativistic Electron Gas

(M. Leitner & W. Nahm)

Work continued on the quantum Hall effect for a two-dimensional relativistic electron gas in a material with broken time reversal symmetry. In part this was made necessary by the referee's objections to the paper *Zero field Hall effect in  $(2 + 1)$ -dimensional QED*, submitted to ATMP in 2006. The relationship between local physics (Dirac sea) and the low energy description of graphene (an atomic monolayer of graphite) was worked out. The discussion of why the ground state over the momentum space torus  $T^*$  does not define a proper line bundle but is a generalisation with non-integer

Chern number was improved on. Due to the infinite volume of the covering space  $\mathbb{R}^2$ , the degeneracies of the one-particle states involved are densely distributed over the  $T^*$  so that ambiguities occur already infinitesimally. Furthermore, no two fibers to different base points can be embedded into one overall Hilbert space. While the scalar product of the respective ground states diverges, its phase and thus the holonomy around a closed path on  $T^*$  is still well-defined, which yields the Hall conductivity. In presence of an exterior magnetic field of finite strength  $B$ , each Landau level contributes  $\sigma_H = 1$  (in natural units). Letting  $B \rightarrow 0$ , which does not influence the total Hall-conductivity, the infinitely many one-level contributions sum up to  $\pm 1/2$ , in agreement with the  $\zeta$  function regularisation.

The finite size corrections to the Hall conductivity are now better understood. The only previous explicit study of this effect needed more complicated geometries (genus  $\geq 2$ ), as the effect vanished on the torus. This was unfortunate since it meant that the effect is unlikely to be observable. In discussions with Werner Nahm, however, it was found that in the situation without an external magnetic field the argument by Avron, Seiler, and Zograf (PRL **73**, (1994) 24) breaks down. The system is translationally invariant so that different boundary conditions  $\vec{k}, \vec{k}'$  in  $T^*$  are not gauge equivalent. Since the position operator inherited from  $\mathbb{R}^2$  is incompatible with periodic boundary conditions, the Kubo-formula for the torus geometry can be derived only if the constant electric field  $\vec{E}$  is defined in a time dependent way. Since the boundary condition enters the Hamiltonian in the shape of a gaugefield, one is led to identify  $E_i t = k_i / e$  ( $e$  the electron charge) and so to interpret  $k_i$  as a magnetic (Aharonov-Bohm like) flux through the  $i$ -th fundamental cycle of the position space torus. Now  $\vec{k}$  draws on  $T^*$  a geodesic in time, which means that the Hall-conductivity becomes time dependent and should vary periodically for rational slope, similarly as in the AC Josephson effect. A joint publication on this observation is planned with Werner Nahm. At present the experimental accessibility of the prediction is being considered. Work would need to be done with systems of very few (less than 10) electrons, but recent research indicates that currents can be defined even in such a situation.



### 1.3.9 Quantum Information Theory

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

A measure of the amount of classical information remaining in a state that has been sent over a noisy quantum channel is known as the Holevo quantity. The capacity of a channel is given by the maximisation of this quantity over an ensemble of input states, and can be interpreted as the amount of information that can be sent reliably over the channel. The group focused on obtaining the maximiser for classical information transmitted in the form of product states over noisy quantum channels. In this case the fact that the capacity is given by the maximum of the Holevo quantity is known as the Holevo-Schumacher-Westmoreland (HSW) Theorem. The problem of determining this maximiser in the case of the amplitude damping channel was considered in particular and the capacity of this channel was evaluated. It is known in general that the maximising ensemble can always be assumed to consist of at most  $d^2$  pure states if  $d$  is the dimension of the state space, but it was shown that in the case of the amplitude damping channel, the maximum is in fact obtained for an ensemble of two pure states.

The product state capacity of a convex combination of memory less channels was shown by N. Datta and T.C. Dorlas (2007) to be given by the supremum of the minimum of the corresponding Holevo quantities. A convex combination of a depolarising channel and an amplitude damping channel was considered and it was shown that in this case the corresponding product state capacity does not in fact equal the minimum of their product state capacities. It was also shown that in the case of a convex combination of depolarising or amplitude damping channels, the capacity is given by the minimum of the respective capacities.

Currently, the group is testing a theorem relating to periodic channels using the amplitude damping and depolarising channels mentioned above. Later it is planned to focus on a class of error correcting codes widely used in classical information theory known as low-density parity check codes. It is anticipated that a parity check code can be generated using the states which achieved capacity for the amplitude damping and depolarising channels.

### 1.3.10 Non-commutative Spin Bundles

(S. Murray)

Noncommutative spin and spin<sup>c</sup> bundles over the fuzzy complex projective spaces were constructed along with

a universal Dirac operator simultaneously valid on all these bundles. Sections were described in terms of infinite dimensional matrices. Dirac eigenspinors and their eigenvalues were given explicitly and the spectrum was found to be a truncation of the continuum result for the known cases. Mapping to the continuum complex projective spaces led to a new continuum formulation of spinors and the new result of the spin spectrum for complex dimension greater than two.

### 1.3.11 Exact Renormalization Group

(O. Rosten)

The primary focus of this year's research has been expanding the scope of the research performed, using previous research as a basis. The general area of the research is the Exact Renormalization Group (ERG), which is essentially the continuous version of Wilson's Renormalization Group (RG). Subsequent to 2007, the direction of the research was almost exclusively in the direction of gaugefield theories. Now, however, the themes have been broadened with the added bonus that discoveries made by doing this seem likely to facilitate progress in the original direction.

### 1.3.12 Nonrenormalizable Trajectories

(O. Rosten)

The main project of 2007 was investigating ERG trajectories which are nonrenormalizable, in the Wilsonian sense. An interesting question to ask of such trajectories is, given some fixed starting point in parameter space, how the effective action at the effective scale,  $\Lambda$ , changes as the bare scale (and hence the duration of the flow down to  $\Lambda$ ) is changed. When the effective action satisfies Polchinski's version of the Exact Renormalization Group equation, it was proven, directly from the path integral, that the dependence of the effective action on the bare scale, keeping the interaction part of the bare action fixed, is given by an equation of the same form as the Polchinski equation but with a kernel of the opposite sign. It was then investigated whether similar equations exist for various generalizations of the Polchinski equation. Using nonperturbative, diagrammatic arguments it was found that an action can always be constructed which satisfies the Polchinski-like equation under variation of the bare scale. For the family of flow equations in which the field is renormalized, but the blocking functional is the simplest allowed, this action is essentially identified with the effective



action at  $\Lambda = 0$ . This does not seem to hold for more elaborate generalizations.

## 1.4 Cosmological Perturbation Theory

(O. Rosten)

A considerable widening of the scope of the research was achieved when a proposed application of the ERG to cosmological perturbation theory in Matarrese and Pietroni, JCAP **0706** (2007) 026, arXiv:astro-ph/0703563 and arXiv:astro-ph/0702653 was noticed to constitute a misnomer. Rather, it was realised that, once Matarrese and Pietroni had instructively cast this classical problem into path integral form, the evolution equation then derived comes about as a special case of considering how the generating functional responds to variations of the primordial power spectrum. This clarified the approach of Matarrese and Pietroni and will hopefully lead to some new research directions.

### 1.4.1 Scalar Field Theory

(C. Saemann)

During this year, research was concentrated on developing an analytical approach to scalarfield theory on the fuzzy sphere. Eventually, this approach was based on considering a perturbative expansion of the kinetic term, which in turn allows for integrating out the angular degrees of freedom in the hermitian matrices encoding the scalarfield. The remaining model depends only on the eigenvalues of the matrices and corresponds to a multitrace hermitian matrix model. Such a model can be solved by standard techniques as e.g. the saddle-point approximation.

### 1.4.2 Einstein Supergravity

(C. Saemann & M. Wolf)

Generalizing the twistorial description of Einstein supergravity to the cases  $N > 2$  was examined, together with Martin Wolf, Imperial College London. This approach might shed new light on the conjectured finiteness of  $N = 8$  supergravity. As a first step, one has to generalize a procedure called "de-gauging" for higher number of supercharges. In this procedure, off-shell Einstein supergravity is obtained by explicitly breaking the R- and Weyl symmetry in off-shell conformal supergravity.

### 1.4.3 Exact Renormalization Group

(C. Saemann & O. Rosten)

Exact renormalization group (ERG) techniques were applied to a recently proposed modification of scalarfield theory on noncommutative  $\mathbb{R}^4$ , together with Oliver Rosten. This model is conjectured to be free of the usual UV/IR-mixing problems and in fact, it is believed to be fully renormalizable. It would be very interesting to have a nonperturbative proof for the renormalizability of this theory, and such a proof might be provided in the future by ERG methods.

### 1.4.4 Spin Chain and Vertex Models

(M. Samsonov)

Work was carried out on the mathematical analysis of spin chain and vertex models. A rigorous proof of the completeness of Bethe ansatz states in the  $\mathfrak{6}$ -vertex model was investigated. An analysis of the thermodynamic limit of the  $\mathfrak{6}$ -vertex model, existence and uniqueness of the solutions of the thermodynamic Bethe ansatz equation for any  $\Delta \in \mathbb{R}$  was undertaken.

## 1.5 Work by Research Associates

### 1.5.1 The Quantum Hall Effect

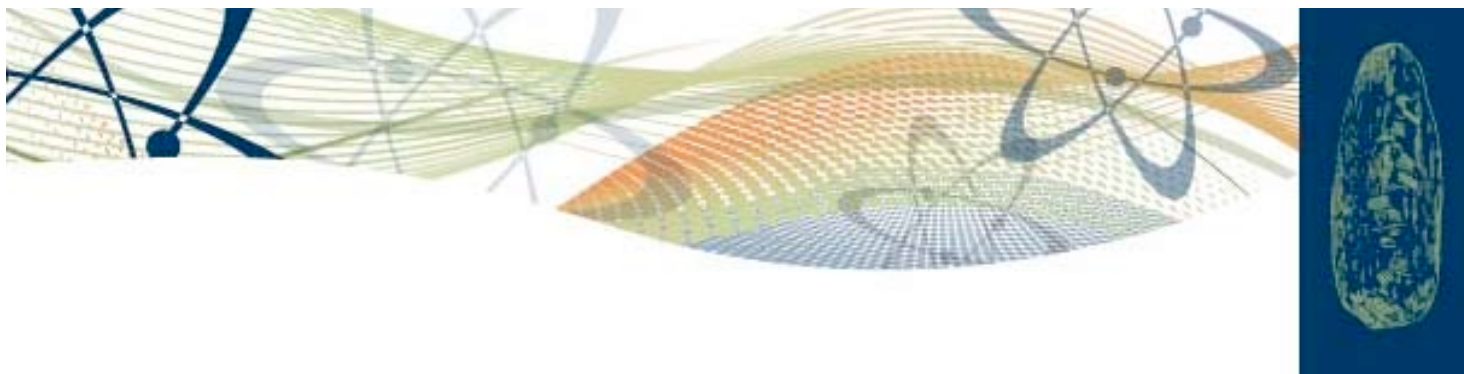
(B. Dolan & Cliff Burgess)

An ongoing collaboration with Cliff Burgess (Perimeter Institute, Waterloo, Canada and McMaster University, Hamilton, Ontario, Canada) on duality and the modular group in the quantum Hall effect continued. Work proceeded on developing 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. It is hoped that a prediction for a hierarchical structure for the fractional quantum Hall effect in graphene will be tested experimentally in the near future.

### 1.5.2 Non-Commutative Geometry

(A. Balachandran, B. Dolan, C. Nash, D. O'Connor, P. Presnajder, A. Stern & K. Gupta)

A programme to develop closed matrix algebras approximating compact manifolds, one aim of which is numerical computation, has continued and been extended to cover complex quadrics. A concise formulation of line and spinor bundles over fuzzy  $CP^n$  has been developed. Work is proceeding to further extend the analysis to



supersymmetric matrix algebras, focusing at the moment on the supersymmetric fuzzy sphere.

### 1.5.3 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 listed below.

The study continued 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. (Completed). The study continued of static gravitating Yang-Mills-Higgs systems in all  $4p$  dimensional spacetime, whose gravitational and YM parts consist of higher order terms of order  $2p$  in the Riemann and curvatures. (Ongoing). The study of finite mass solutions in Einstein-Yang-Mills systems featuring a Chern-Simons term, in  $4 + 1$  dimensions. (Ongoing). The study of finite static solutions in a  $SU(2)$  Yang-Mills-Higgs system featuring a Chern-Simons term, in  $2+1$  dimensions. (Ongoing). Extended the study of solitons-antisoliton chains to  $3+1$ ,  $4+1$  and  $5+1$  dimensions, to solutions to a symmetry breaking Goldstone model. (Completed). Constructed bi-azimuthal solutions to the  $SU(2)$  Yang-Mills system interacting with the dilaton in  $4+1$  dimensions. (Completed). Constructed bi-azimuthal solutions to the  $SU(2)$  Yang-Mills system interacting with the gravity in  $4 + 1$  dimensions. (Completed). Explored the possibility of constructing non Abelian Hopfions in  $3 + 1$  dimensions. (Preliminary stage).

## 2 Publications

### 2.1 Books

- [1] W. Nahm: Conformal Field Theory and Torsion Elements of the Bloch Group. *Frontiers in Number Theory, Physics and Geometry II*, P. Cartier et al. eds., Springer January 2007, p. 67-132.

### 2.2 Papers in refereed journals

- [2] N. Datta and T.C. Dorlas: Coding theorem for a class of quantum channels with long-term memory. *J. Phys.* **A 40** (2007) 1{18.
- [3] T.C. Dorlas and V.B. Priezzhev: Finite-Time Current probabilities in the asymmetric exclusion process on a ring. *J. Stat. Phys.* **129** (2007) 787{805.
- [4] S. Adams and T. C. Dorlas:  $C^*$ algebraic derivation of the variational formula for the pressure of the infinite-range-hopping Bose-Hubbard Model. *J. Math. Phys.* **48** (2007) 103304.
- [5] Denjoe O'Connor, J.A. Santiago & C.R. Stephens: An analytic equation of state for Ising-like models. *J. Phys.* **A 40** (2007) 901.
- [6] Denjoe O'Connor & C. Saemann: Fuzzy scalar field theory as a multitrace matrix model. *JHEP* **0708** (2007) 066.
- [7] B.P. Dolan, I. Huet, S. Murray & Denjoe O'Connor: Noncommutative vector bundles over fuzzy  $CP^N$  and their covariant derivatives. *JHEP* **07** (2007) 007.
- [8] B. Dolan & C. Burgess: Duality, the semi-circle law and quantum Hall bi-layers. *Phys. Rev.* **B 76** (2007) 155310.
- [9] B. Dolan: The quantum Hall effect in graphene: emergent modular symmetry and the semi-circle law. *Phys. Rev.* **B 76** (2007) 113406.
- [10] B.P. Dolan, K.S. Gupta & A. Stern: Noncommutative BTZ Black hole and discrete time. *Class. Quant. Grav.* **24** (2007) 1647-1655.



[11] B. Dolan: Modular symmetry and fractional charges in  $N = 2$  super symmetric Yang-Mills and the quantum Hall effect. *SIGMA* **3** (2007) 010.

[12] S. Kurkcuglu and C. Saemann: Drinfeld twist and general relativity with fuzzy spaces. *Class. Quant. Grav.* **24** (2007) 291.

[13] M. Panero: Numerical simulations of a non-commutative theory: the scalar model on the fuzzy sphere. *JHEP* **05** (2007) 082.

[14] A.M. Povolotsky & V.B. Priezzhev: Determinant solution for the totally asymmetric exclusion process with parallel update II. Ring geometry. *J.Stat. Mech.* (2007) P08018.

[15] O.J. Rosten: Universality from very general nonperturbative flow equations in QCD. *Phys. Lett.* **B 645** (2007) 466.

[16] Y. Brihaye, E.Radu & D. H. Tchrakian: Einstein-Yang-Mills solutions in higher dimensional de Sitter spacetime. *Phys. Rev.* **D 75** (2007) 024022.

[17] R. Manvelyan & D. H. Tchrakian: Conformal coupling of the scalarfield with gravity in higher dimensions and invariant powers of the Laplacian. *Phys. Lett.* **B 644** (2007) 370-374.

[18] E. Radu, Ya. Shnir & D. H. Tchrakian: Particle-like solutions to the YangMills-dilaton system in  $d = 4 + 1$  dimensions. *Phys. Rev.* **D 75** (2007) 045003.

[19] E. Radu & D.H. Tchrakian: Goldstone models in  $D+1$  dimensions  $D = 3; 4; 5$  supporting stable and zeros topological charge solutions. *Physica* **A 40** 1012910153.

[20] E. Radu, Ya. Shnir & D. H. Tchrakian:  $d = 4 + 1$  gravitating nonabelianfields with bi-azimuthal symmetry. *Phys. Lett.* **B 57** 246-254.

[21] Y. Brihaye, E. Radu and D.H. Tchrakian: AdS<sub>5</sub> rotating non-Abelian black holes. *Phys. Rev.* **D 74** (2007) 024022.

## 2.3 Papers in conference proceedings

[22] C. Dobrovolny, T.C. Dorlas and J.V. Pulé: Lowest Lyapunov exponents for the armchair nanotube. *Markov Processes & Related Fields* **13** (2007) 331{390.

[23] B. Dolan: Duality in supersymmetric Yang-Mills and the quantum Hall effect. *Proceedings of the 33rd International Conference on High Energy Physics, Moscow, 2006, Ed. A. Sissakian, G. Kozlov and E. Kolganova, World Scientific, (2007)*

[24] T. Tchrakian: Monopoles in all dimensions. *Memorial Volume for A.Zamolodchikov, eds. R. Poghosyan and H. Babujian, Humboldt-Kolleg Meeting Nor Hamberd{Tbilisi, October 2007.*

## 2.4 Theses and other publications

### 2.4.1 Theses

[25] I. Huet: Laplacian and Dirac operator on  $CP^N_{\mathbb{F}}$  Ph.D. thesis, Cinvestav, Mexico City.

[26] J. Fitzpatrick: The Fermion Doubling Problem in Quantum Field Theory. M.Sc. thesis, UCD.

[27] M. Allen: The Schwinger Model on the Fuzzy Sphere. M.Sc. thesis, UCD.

[28] S.R. Walsh: Exposition on the Causal Set Approach to Quantum Gravity. M.Sc. thesis, UCD.

[29] S. Keegan: Algebraic K-Theory and Partition Functions in Conformal Field Theory. Ph.D. thesis, UCD

### 2.4.2 Other Publications

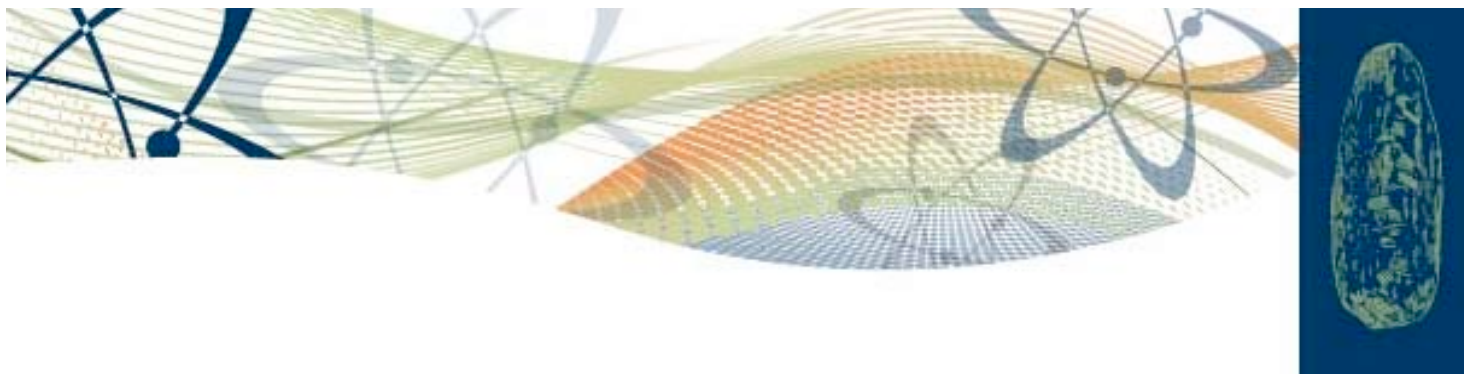
[30] T.C. Dorlas: History of the School of Theoretical Physics 1950-present.

[31] T.C. Dorlas: Translation of: "On Einstein's gas theory" by E. Schrödinger.

## 2.5 Preprints

### DIAS-STP-

[07-01] Y. Brihaye, E.Radu & D. H.Tchrakian: Einstein-Yang-Mills solutions in higher dimensional de Sitter spacetime.



[07-02] R. Manvelyan & D. H. Tchrakian: Conformal coupling of the scalarfield with gravity in higher dimensions and invariant powers of the Laplacian.

[07-03] E. Radu, Ya. Shnir & D. H. Tchrakian: Particle-like solutions to the Yang-Mills-dilaton system in  $d = 4 + 1$  dimensions.

[07-04] D.H. Tchrakian: Dirac-Yang monopoles and their regular counterparts.

[07-05] F. Dolan: Counting BPS operators in  $N = 4$  symmetry. [07-06] E. Radu & D.H. Tchrakian: Goldstone models in  $D + 1$  dimensions  $D = 3; 4; 5$  supporting stable and zeros topological charge solutions.

[07-07] E. Radu, Ya. Shnir & D. H. Tchrakian:  $d = 4 + 1$  gravitating nonabelianfields with bi-azimuthal symmetry.

[07-08] N. Datta, Y. Suhov & T.C. Dorlas: Entanglement assisted classical capacity for a class of quantum channels with long-term memory.

[07-09] S. Keegan: Algebraic K-theory and partition functions in conformalfield theory.

[07-10] A.M. Povolotsky & V.B. Priezzhev: Determinant solution for the totally asymmetric exclusion process with parallel update II. Ring geometry.

[07-11] Denjoe O'Connor & C. Saemann: Fuzzy scalarfield theory as a multitrace matrix model.

[07-12] E. Radu, D.H. Tchrakian & Y. Yang: Spherically symmetric selfdual Yang-Mills instantons on curved backgrounds in all even dimensions.

[07-13] C. Römelberger: Calculating the superconformal index.

[07-14] T.C. Dorlas & W. Skrypnik: Three order parameters in quantum XZ spin-oscillator models with Gibbsian ground states.

[07-15] S. Adams & T.C. Dorlas:  $C^*$ - algebraic approach to the Bose-Hubbard model.

[07-16] Denjoe O'Connor & C. Saemann: A multitrace matrix model from fuzzy scalarfield theory.

[07-17] O.J. Rosten: Sensitivity of non-renormalizable trajectories to the bare scale.

[07-18] O.J. Rosten: A comment on the path integral approach to cosmological perturbation theory.

[07-19] B.P. Dolan, I. Huet, S. Murray & Denjoe O'Connor: A universal Dirac operator and noncommutative spin bundles over fuzzy complex projective spaces.

[07-20] T. Azuma, S. Bal & J. Nishimura: The instability of

intersecting fuzzy spheres.

[07-21] N. Datta & T.C. Dorlas: Classical capacity of quantum channels with general Markovian correlated noise.

[07-22] R.D. Blando, Denjoe O'Connor & B. Ydri: Geometry in transition: a model of emergent geometry.

[07-23] J. Medina, W. Bietenholz & Denjoe O'Connor: Probing the fuzzy sphere regularization in simulations of the 3d  $\phi^4$ .

[07-24] P. Bonderson & J.K. Slingerland: Fractional Quantum Hall hierarchy and the second Landau level.

[07-25] S.M. Khoroshkin, I.I. Pop, M. Samsonov, A.A. Stolin & V.N. Tolstoy: On some Lie bialgebra structures on polynomial algebras and their quantization.

### 3 Programme of Scholarly Events

#### 3.1 Lectures Organised by The School

V.A. Rubakov (Institute for Nuclear Research Russian Academy of Sciences, Moscow & Honorary Adjunct Professor, NUI Maynooth) *Introduction to cosmology* (Series of Lectures) 3,4 & 8,9 May

Y. Suhov (University of Cambridge) *Malliavin measures, SLE and CFT*. 2 May

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

- N. Akerblom (Max-Planck-Institut für Physik, München) *Aspects of D-instantons in intersecting D-brane models*. 27 September

- P. Bonderson (Microsoft Research, Station Q, Santa Barbara) *Probing non-Abelian statistics in the fractional quantum Hall effect*. 20 September

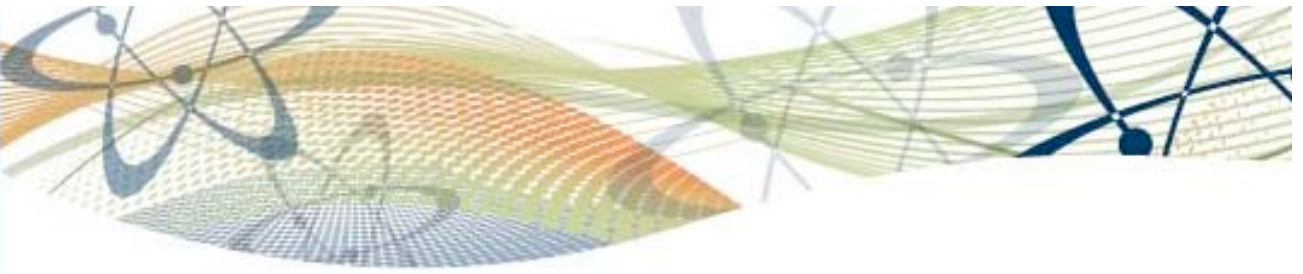
- M. Crocce (Institut de Ciències del'Espai) *Renormalized perturbation theory: a new approach to gravitational clustering*. 12 October

- T. Curtright (University of Miami) *Quasi-hermitian Liouville theory*. 27 June

- M. Douglas (Rutgers University) *Recent developments in the landscape of string theory*. 30 January

- J. Gray (Institut d'Astrophysique de Paris) *Perturbative anti-brane potentials in heterotic M-theory*. 8 February

- O.W. Greenberg (Department of Physics, University



of Maryland) *Experimental signatures for a model of generations of quarks and leptons*. 17 January

- J. Guven (University of Mexico) *How paper folds: bending with local geometrical constraints*. 17 December
- Yang-Hui He (Oxford) *Quivers, syzygies and plethystics*. 15 February
- M. Ihl (University of Texas at Austin) *RHIC and AdS/CFT*. 8 March
- B. Julia (Ecole Normale Supérieure, Paris) *From self-dual gravity to dual gravity with a cosmological constant*. 1 March
- Y. Kimura (Queen Mary College) *Branes, anti-branes and Brauer algebra in gauge-gravity duality*. 23 November
- K. Nishijima (Helsinki) *Emergence of the second generation in particle physics*. 25 September
- J. Pachos (Leeds University) *Graphene with geometrically induced vorticity*. 16 October
- E. Rabinovici (The Hebrew University) *Little Hagedorn holography*. 3 May
- D. Rideout (Imperial College, London) *Entropy bound from discrete quantum gravity*. 15 March
- M. Samsonov *Affine twists*. 29 March
- J. Shock (Sanriago de Compostela) *AdS/CFT with flavour in electric and magnetic backgrounds*. 6 December
- S. Simon (Alcatel-Lucent, Bell Labs) *The unexpected physics of modern wireless communication: replicas, diffusions and supersymmetry for fun and profit*. 6 September
- H. Steinacker (Universität Wien) *Localization for Yang-Mills on the fuzzy sphere*. 25 January
- N. Suryanarayana (Imperial College, London) *Towards a microstate counting of susy black holes in AdS(5)*. 22 February
- J. Teschner (DESY) *On the spectrum of the Sinh-Gordon model infinite volume*. 29 November
- S. Uhlmann (Universität Jena) *Ward identities for invariant group integrals*. 1 February
- M. Volkov (Université de Tours) *Super-conducting vortices in gaugefield theory*. 18 January
- M. Wolf (Imperial College London) *Twistors and integrability of super Yang-Mills theories*. 19 April

### 3.1.2 Seminars Organised by T.C. Dorlas's Group

- P. Abramski *Explicit formulas for the spectral density function of the one-dimensional Schrödinger operator in the case of step-function potential*. 15 November
- A. Povolotsky *Theory of reflection groups* Series of seminars. March - April.
- J.K. Slingerland *Topological storage and protection of quantum information using Kitaev's toric code*. 4 & 11 October
- M. Samsonov *Introduction to Lie Algebras*. Course of Lectures starting 18 October.

### 3.2 Symposia, Conferences, Workshops organised

The O'Raifeartaigh Memorial Lecture was delivered on 11 May by Professor V. Rubakov (Institute for Nuclear Research of the Russian Academy of Sciences, Moscow) at the IQFT07 -14th Irish Quantum Field Theory Meeting held in Galway. The lecture was entitled *Anomalous baryon number non-conservation: ups and downs*. The third series of **John Lewis Lectures** were delivered by Professor Ya. Sinai (Princeton). The lecture series is jointly organised by the Dublin Institute for Advanced Studies and the Hamilton Mathematics Institute at Trinity College Dublin with generous donation from Corvil Networks. The following set of lectures were delivered and focused on the following topic:

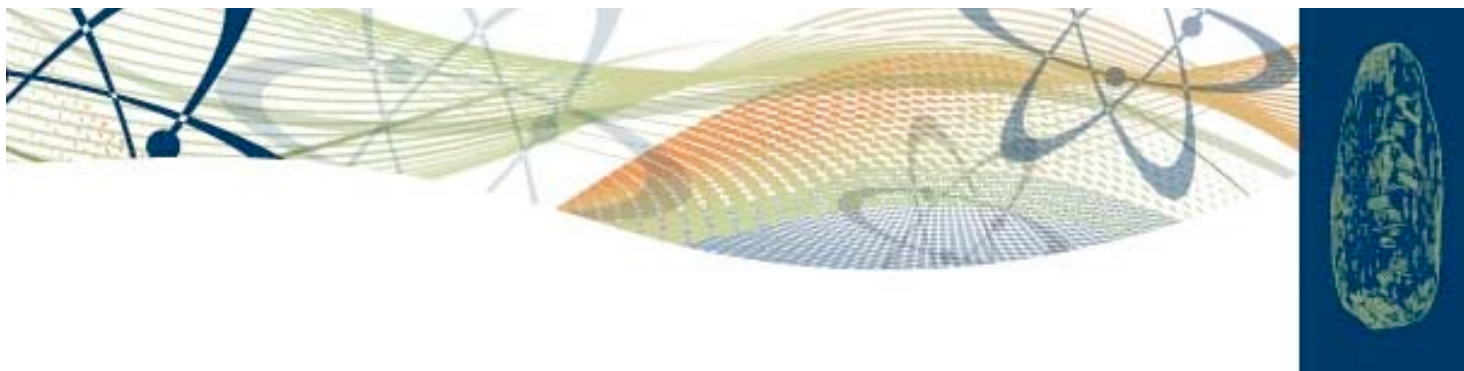
- *Blow-ups in Navier-Stokes systems and renormalisation group theory* 24, 25 and 30 May.

#### A Workshop on Mathematical Analysis of Quantum

**Systems** was held from 2-4 April. The following lectures were delivered.

- J.-B. Bru (Vienna) *Flow equations for operators and non-autonomous evolution equations*.
- P. Duclos (Marseille) *On the skeleton method*.
- G. Friesecke (Munich) *Mathematical aspects of van der Waals forces*.
- F. Germinet (Cergy-Pontoise) *A new concentration estimate and application to universal occurrence of Anderson localization*.
- O. Lisovyy (Tours) *Aharonov-Bohm effect on the Poincaré disk*.
- Ph.-A. Martin (Lausanne) *Some new aspects of the Casimir effect: the saga of a factor 1/2*.





- T. Matsui (Fukuoka, Japan) *Entanglement and Haag duality.*
- B. Nachtergaele (Davis-CA) *New applications of Lieb-Robinson bounds.*
- C.A. Pillet (Marseille) *Transport in quasi-free fermionic systems.*
- A. Povolotsky *The asymmetric exclusion process with parallel update. Formulae for the transition probabilities.*
- M. Samsonov *An approach to construction of affine Drinfeld twists.*
- W. Skrypnik (Kiev) *Order in lattice spin-oscillator systems with Gibbsian ground states.*
- A. Stolin (Goteborg) *Classification of quantum groups.*
- Y. Suhov (Cambridge) *Anderson localisation for multi-particle random lattice Schrödinger operators.*
- A. Suto (Hungary) *Finding crystalline ground states.*
- F. Theil (Warwick) *Long-time justification of the gainless homogeneous Boltzmann equation.*
- A. Verbeure (Leuven) *BEC: the condensate equation.*
- J. Yngvason (Vienna) *The TF limit for rapidly rotating Bose gases in anharmonic traps.*
- V. Zagrebnov (Leuven) *About the BEC in some random models.*
- D. Spisso (National Institute of Nuclear Physics, Naples) *Electrostatics using the fuzzy sphere.*
- C. Saemann *Simulations and multi-trace matrix models.*
- A.P. Balachandran (Syracuse University, N.Y.) & F. Lizzi (National Institute of Nuclear Physics, Naples) *Phenomenology and twisted symmetries.*
- M. Schlichenmaier (University of Luxembourg) *Quantization of Kaehler Manifolds.*
- P. Presnajder (Comenius University, Bratislava) *Non-commutative twistor spaces.*
- Denjoe O'Connor *The status of super-symmetric models.*
- S. Majid (Queen Mary College, University of London) *Fuzzy  $\mathbb{R}^3$ .*
- O. Rosten *Renormalisation, non-commutative geometry and exact RG.*

**An International Workshop on Fuzzy Physics and Non-commutative Geometry 2007** was held from 5-16 June.

The following lectures were delivered:-

- S. Majid (Queen Mary College, University of London) *Noncommutative harmonic analysis, sampling theory and the Duflo map in 2+1 quantum gravity.*
- M. Panero (Universitaet Regensburg, Germany) *Numerical results for the non-commutative scalar model.*
- R. Szabo (Heriot-Watt University, Edinburgh) *Two-dimensional noncommutative gauge theories.*
- C. Speckner (University of Wuerzburg, Germany) *Noncommutative standard model.*
- M. Schlichenmaier (University of Luxembourg) *Berezin-Toeplitz quantization of compact Kaehler manifolds.*
- H. Steinacker (Universitaet Wien, Austria) *Spontaneously generated fuzzy extra dimensions and fermions.*

Informal discussions led by various participants were as follows:-

- A.P. Balachandran (Syracuse University, NY) *Twisted Symmetry.*

An International Workshop on Topological Quantum Computing organised jointly by School of Theoretical Physics, DIAS, Department of Mathematical Physics, NUIM and School of Mathematics, Trinity College Dublin was held from 10-14 September. The following lectures were delivered:-

- W. Kang *Experimental investigation of Quantum Hall interferometers.*
- S. Simon *Landau level mixing and braiding statistics / bulk-edge coupling in the 5/2 interferometer.*
- K. Shtengel *Probing non-Abelian statistics in the fractional Quantum Hall effect.*
- P. Bonderson *Interferometry with non-Abelian anyons.*  
A. Stern *Proposed experiments to detect non-abelian quantum states.*
- N. Bonesteel *Random chains of interacting non-Abelian quasiparticles.*
- R. Mosseri *Geometrical approach to  $SU(2)$  navigation with Fibonaccianyons.*
- S. Sachdev *Superconductors with topological order.*
- V. Pasquier *Quantum Hall effect and orthogonal polynomials.*
- D. Haldane *Generalized Pauli principle for Read-Rezayi non-Abelian Quantum Hall states.*
- K. Schoutens *Bipartite entanglement entropy in Quantum Hall states.*
- S. D. Sarma *Realistic topological quantum computation.*
- S. Bais *Topological symmetry breaking by Bose*



condensates.

- C. Nayak *Broken symmetry and topological order at  $\nu = 5/2$ .*
- M. Freedman *Measurement-only (topological) quantum computation.*
- P. Fendley *Finding Fibonacci.*
- J. Slingerland *Finding and solving Anyon models.*
- M. Troyer *Stability of topological phases.*
- B. Whaley *Quantum loop gases and topological quantum computation.*
- G. Misguich *Topological order in quantum dimer models.*
- S. Bravyi *Measurement-based quantum computation with Kitaev's toric code states.*
- I. Arad *Quantum algorithms and universality with non-unitary representations of the braid group: applications to the Jones polynomial and the q-state Potts model.*
- V. Korepin *Entanglement in spin chains.*
- N. Cooper *Towards Non-Abelian phases in ultracold atomic gases.*
- J. Pachos *Anyonic statistics from entangled states.*
- DIAS Seminar: M. Freedman *Positivity of three manifold pairings.*
- Public Lecture: M. Freedman *How Topology will save Moore's law: Quantum computation via exotic states of matter.*

The 13th Annual Schrödinger Lecture was given by Professor Jörg Schmiedmayer, Vienna on Atom Chips: Integrated Circuits for Matter Waves. This lecture was organized by the Austrian Embassy, the School of Physics at TCD and DIAS and was held on 5 December.

The Winter Symposium was held on 13th and 14th December. Lectures were given as follows:

- B. Dolan (NUIM) *The quantum Hall effect and modular symmetry.*
- B. Guilfoyle (IT Tralee) *Lagrangian curves on spectral curves of monopoles.*
- O. Murphy (Irish Applied Mathematics Teachers' Association) *Applied maths. in Ireland - where is it going?*
- V. Skachek (Claude Shannon Institute, UCD) *Linear-programming decoding of error-correcting codes.*
- J. Charpin (University of Limerick) *Non Newtonian fluids and spin coating.*
- A. Povolotsky *Totally asymmetric exclusion process*

*with parallel update. Determinant formulas for transition probabilities.*

- O. Rosten *An introduction to the exact renormalization group.*
- W. Nahm *Number theory, quantum fields and Blue Gene.*
- L. Drury *An overview of the IBM Blue Gene system.*
- J. Coleman (TCD) *High yield production of graphene.*

#### Statutory Public Lecture

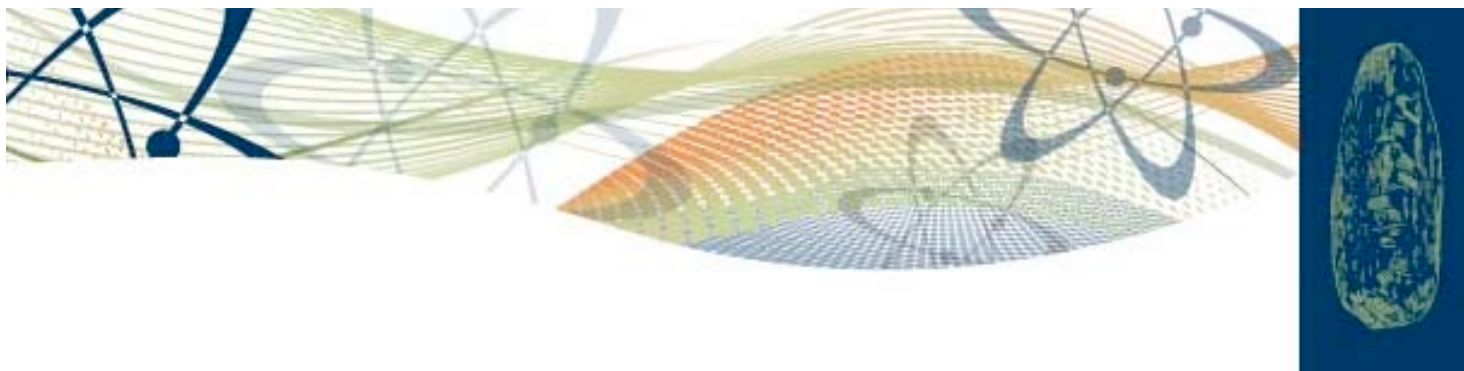
The Statutory Public Lecture on *Wizardry with light: freeze, teleport, and go!* was delivered by Professor Lene Hau (Harvard University) on 16 May in Trinity College Dublin.

## 4 Presentations at Conferences or Seminars

### 4.1 Talks and Papers Presented

T.C. Dorlas:

- Talk "Generalisation of the HSW Theorem" at the "All-Island Conference on Quantum Information Science and Technology", Maynooth, 19-20 April.
- Talk "Variational expressions for the Bose-Hubbard Model" at conference on "Analysis and Stochastics in Quantum Many-Body Systems", Leipzig, 17-19 May.
- Talk "The HSW Theorem for quantum channels with long-term memory" at the conference on "Large Quantum Systems", Warwick, 11-15 June.
- Colloquium talk "Quantum Information Theory" at Groningen University, 27 September.
- Seminar talk "Quantum channels with memory" at Imperial College (Inst. for Math. Sciences), 1 November.
- Seminar talk "The discrete Feynman integral" at Cambridge Statistical Laboratory, 13 November.
- Seminar talk "The discrete Feynman integral" at Warwick University, 14 November. W. Nahm:
- Talk "Modular functions and Hirota equations" at Max-Planck-Institute for Mathematics, Bonn, 6 March.
- Colloquium Talk "Finite size corrections to the thermodynamic Betheansatz" at School of Mathematics, Trinity College Dublin, 19 November. Denjoe O'Connor:
- Talk "Random tilings, melting crystals, and two-dimensional fermions" at Irish Quantum Field Theory Meeting, NUI Galway, 12 May.
- Talk "Dirac operators on Fuzzy spaces" at "Aspects of



Membrane Dynamics", Stockholm, 20 June.

- Talk "Random tilings and lattice Dirac operators" at Workshop on "Non-commutative Geometry", Bratislava, Slovakia, 12 July.
- Talk "Geometry in transition: A model of emergent geometry" at Europe Science Foundation Workshop on "Non-commutative Quantum Field Theory", ESI Vienna, 27 November.

*F. Dolan: 23*

- Talk "Counting BPS operators in  $\mathcal{N} = 4$  SYM", at 14th Irish Quantum Field Theory Meeting, Galway, 11-12 May.
- Talk "Counting BPS operators in  $\mathcal{N} = 4$  SYM", at University of Parma, Italy, 2-6 July.

*A. Ghesqui re*

- A poster presentation "Evolving a density matrix: a master equation approach", at the conference "Noise, Information and Complexity at Quantum Scale", Erice, Sicily, 4-10 November.
- A presentation "Introduction to Master Equations", at an informal meeting with the Topological Quantum Computing group, National University of Ireland, Maynooth, 17th December.

*I. Huet:*

- Talk "Noncommutative vector bundles over fuzzy  $CP^N$  and their covariant derivatives" at 14th Irish Quantum Field Theory Meeting, NUI Galway, 11-12 May.

*M. Leitner*

- Talk "Graphene electronics and quantumfield theory in 2+1 dimensions" at the Mini-Symposium on "Topological Quantum Computation" at NUI Maynooth, 6 January.
- Talk "L'effet Hall   champ z ro dans l'electrodynamique quantique de 2+1 dimensions", University of Tours, 24 May.
- Talk "Zerofield Hall effect in 2 + 1 dimensional QFT" Physikalisch-Technische Bundesanstalt (PTB), Braunschweig (Germany), 29 October.

*C. Morgan:*

- A poster presentation "Finding a maximiser for quantum mutual information", at the conference "Noise, Information and Complexity at Quantum Scale" Erice, Sicily, 4-10 November.

*A. Povolotsky:*

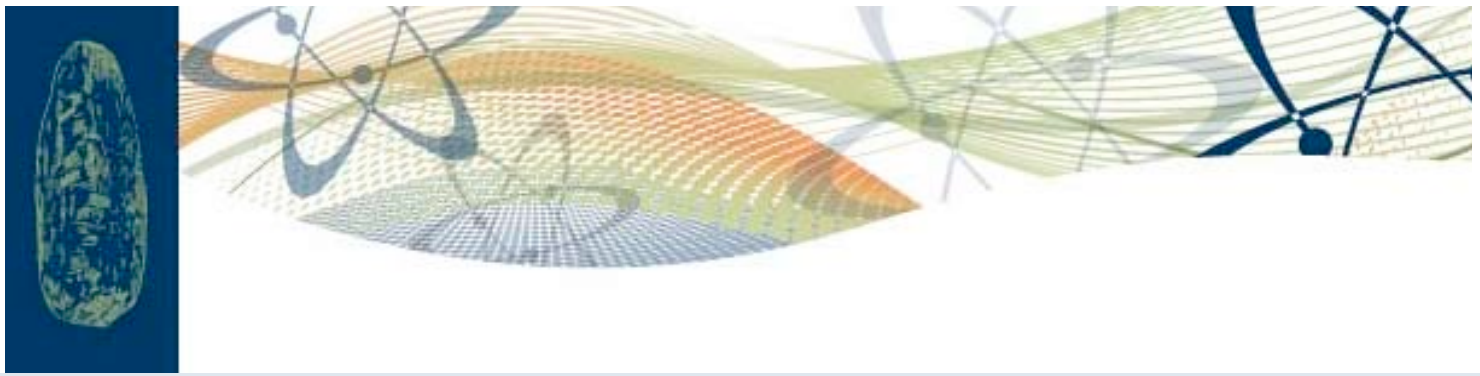
- Talk "Determinant solution for the asymmetric exclusion process with parallel update" at the "International Workshop Classical and Quantum Integrable Systems ", Dubna, Russia, 21-26 January.
- Seminar "The asymmetric exclusion process with parallel update" at University of Tours, Tours, France, 20 June.
- Determinant solution for the totally asymmetric exclusion process with parallel update", Poster presentation at the conference "Statphys23", Genova, Italy, 9-13 July.
- Talk "Totally asymmetric exclusion process with parallel update" at the conference "Fluctuation and dissipation phenomena in driven systems far from equilibrium", at Max Planck Institute for Complex Systems, Dresden, 16-18 July.

*O. Rosten:*

- Talk "Sensitivity of nonrenormalizable trajectories to the bare scale" at Workshop on "Renormalisation Group and Effective Field Theories", Durham, 27-29 September.
- Seminar Talks "Invariants of the Exact RG", at Uuniversity of Southern California, University of California Los Angeles, Los Alamos National laboratory, May - June.

*C. Saemann:*

- Talk "On the phase diagram of fuzzy scalarfield theory" at Workshop on "Non-Commutativity and Physics", Bayrischzell, 13 May.
- Talk "On the Phase Diagram of Fuzzy Scalar Field Theory", Imperial College, London, 17 May.
- Talk "Fuzzy scalarfield theory as a multitrace matrix model" at Workshop on "Supersymmetries and Quantum Symmetries (SQS'07)" BLTP, JINR, Dubna, 31 July.
- Talk "Matrix models in twistor string theory" at the conference "Twistor, Strings and Scattering Amplitudes", Durham, 23 August.



*M. Samsonov:*

- Talk "r-matrices and Drinfeld twists" at conference "Symmetry in Nonlinear Mathematical Physics", Kiev, Ukraine, 24-30 June.

*J.K. Slingerland:*

- Talk "Finding and solving Anyon models" at International Workshop on "Topological Quantum Computing", Hamilton Mathematics Institute, Trinity College, Dublin, 10-14 September.
- Talk "Interferometry with non-Abelian anyons", University of Leeds, 5-6 November.
- Talk "Fractional Quantum Hall hierarchy and the second Landau level", at Mini-Symposium on "Topological Quantum Computation", Max Planck Institut für Quantenoptik, Garching, 10-11 December.
- Talk "Fractional Quantum Hall hierarchy and the second Landau level" at Microsoft Station Q, University of California, Santa Barbara, 17-20 December.

## 5 Collaboration with the Wider Research Community

### 5.1 National Lecture Courses and Workshops

*W. Nahm*

- The School of Mathematics (TCD), the Department of Mathematical Physics (NUIM) and the School of Theoretical Physics jointly held an International Workshop on Topological Quantum Computing (TQC 2007) at the Hamilton Mathematics Institute at TCD, 10-14 September with W. Nahm as one of the local organizers. Most of the internationally leading experts gave talks, in particular Mike Freedman, mathematician and Fields medal winner, who now works at Microsoft Station Q on the development of a quantum computer and Steve Simon from Alcatel-Lucent. During the conference the European participants decided to make joint applications for a European project in this area with central hub at our School.

*Denjoe O'Connor:*

- Helped organise Workshop on Fuzzy Physics and Noncommutative Geometry held 5-16 June.

### Staff Acting as External Supervisors

*W. Nahm:*

- Ph.D. supervisor for Sinead Keegan (UCD, Dublin)

*Denjoe O'Connor:*

- 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)
- M.Sc. supervisor for Johathan Fitzpatrick (UCD, Dublin)
- M.Sc. supervisor for Michael Allen (UCD, Dublin)
- M.Sc. supervisor for Stephen R. Walsh (UCD, Dublin)

### Staff Acting as External Examiners

*T.C. Dorlas:*

- External referee on the interview committee for examining the thesis of Motohisa Fukuda entitled "Additivity conjectures in quantum information theory" at Cambridge University, 25 June.

*W.Nahm:*

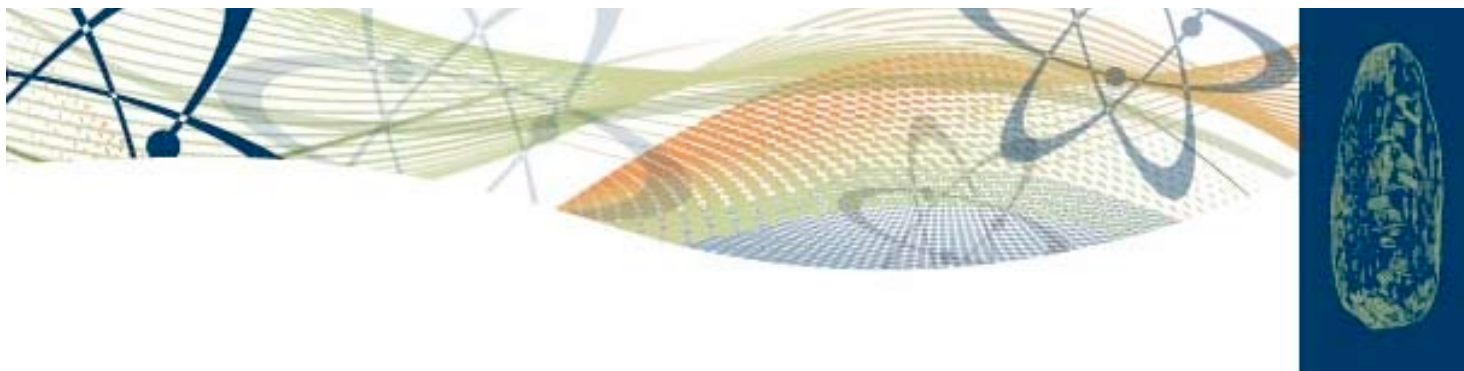
- External Examiner for the M. Sc. thesis "Singular Monopoles" by Brian Durcan, TCD.

*Denjoe O'Connor:*

- External Examiner for Ph.D. resubmission of Stephen Watterson 2007.
- External Examiner for Ph.D. thesis "Nonperturbative Studies of Quantum Field Theories on Noncommutative Spaces" by Jan Volkholz, Humbolt Universität zu Berlin.

### Research Associates

- AT&T: N. Duffeld
- DCU: E. Buffet, J. Burzlaff, E.O'Riordan
- DIT: T. Garavaglia, D. Gilbert, M.mGolden, 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, J. Vala
- OPEN UNIVERSITY: A.I. Solomon
- OXFORD UNIVERSITY: R.G. Flood
- TCD: P.S. Florides, J. Miller, I. Sachs, 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:*

- Participated on review panel and external examination of Max Planck Institute for Mathematics, Bonn, Germany, 22-24 June.
- Attended Review Panel of the German Research Society for Proposals of Graduate Colleges (Analysis, Geometry and String Theory, University of Hannover; Mathematics for Fluids and Images, University of Saarland; Mathematical Structures in Modern Quantum Physics, University of Göttingen), 18 September.
- Attended meeting for selection of visitors at Max Planck Institute, Bonn, Germany, 6-7 December.

### *T.C. Dorlas:*

- Referee of a European grant application in the ERC's Starting Grant funding scheme.

### *Denjoe O'Connor:*

- Member of International Advisory board of the Central European Joint Programme of Doctoral studies in Theoretical Physics.

### *Visiting Researchers*

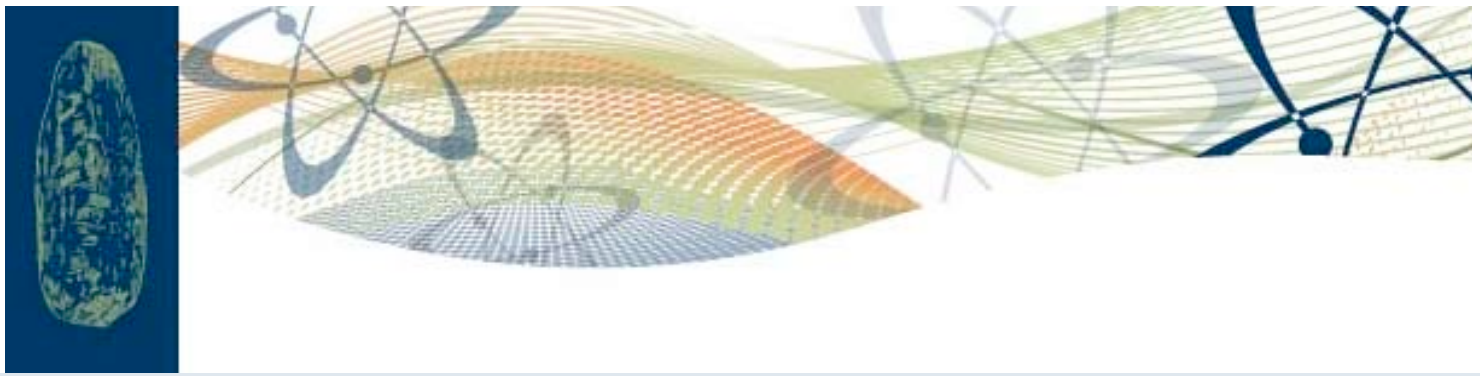
#### *Short visits (up to one week):*

- N. Akerblom (Max Planck Institute, Munich) 26-29 September.
- W. Bietenholz (DESY Zeuthen, Germany) 26-27 June.
- H.M. Croce (Institut de Ciències de l'Espai) 11-13 October.
- T. Curtright (Miami, Florida) 26-28 June.
- M. Friedman (Microsoft, CNSI UCSB) 10-14 September.
- J. Gray (Inst. d'Astrophysique de Paris) 7-9 February.

- J. Guven (University of Mexico) 17-19 December.
- Y.-H. He (University of Oxford) 15-17 February.
- M. Ihl (University of Texas) 5-9 March.
- B. Julia (Lab. de Phys. Theor. de l'ENS, (CNRS)Paris) 28 February - 2 March.
- Y. Kimura (University of London) 20-23 November.
- T. Michoel (University of Ghent) 5-8 April.
- B. Nachtergaele (University of California, Davis) 3-7 April.
- V.S. Nemani (Imperial College, London) 19-23 February.
- K. Nishijima (University of Tokyo) 24-28 September.
- J. Pachos (University of Leeds) 14-16 October.
- D. Rideout (Imperial College, London) 13-17 March.
- T. Roska (Hungarian Acad. of Science & Pázmány University, Budapest) 26 October.
- J. Shock (University of Santiago de Compostela) 6-8 December.
- K. Shtengel (University of California, Riverside) 16-23 September.
- W. Spitzer (University of Nuremberg, Erlangen) 4-7 April.
- H. Steinacker (University of Vienna) 24-27 January.
- J. Teschner (DESY, Germany) 27-30 November.
- S. Uhlmann (University of Jena) 31 January - 2 February.
- M. Volkov (University of Tours) 15-19 January.
- M. Wolf (University of Aberdeen & Australia) 16-21 April.
- V.A. Zagrebnev (Marseille) 16-26 August.

#### *Long visits:*

- P. Bonderson (Microsoft Station Q, Santa Barbara) 16-24 September
- V. Duclos (Univ. Sud Toulon Var, France) 21-30 August.
- D.E. Evans (Cardiff University) 20 August - 3 September.
- G.W. Ford (Michigan University) 8-25 June.
- O.W. Greenberg (University of Maryland) 1-18 January.
- G. Immirzi (Università di Perugia) 5 February - 14 March.
- R.F. O'Connell (Louisiana State University) 28 May - 28 July.
- V.B. Priezzhev (JINR, Dubna) 27 August - 10 September.
- E. Radu (NUI, Maynooth) 2 April - 14 May.
- V.A. Rubakov (Russian Academy of Sciences, Moscow & Honorary Adjunct Professor, NUIM) 2-13 May.
- S. Simon (Bell Labs., New Jersey) 9-17 September.
- Ya. Sinai (Princeton University) 21 May - 2 June.
- Y. Suhov (University of Cambridge) 28 April - 8 May.



## Research Visits by School Staff

### *T.C. Dorlas:*

- Research visit to the Joint Institute of Nuclear Research, Dubna (Russia), 7-15 February.
- Research visit to the Max Planck Institute for Mathematics in the Sciences, Leipzig, 4-10 March.
- Research visits to Statistical Laboratory, University of Cambridge, 29 April- 5 May; 25-29 June; 31 July - 2 August.
- Visit to the Centre de Physique Théorique in Marseille for research collaboration with Profs. P. Duclos, J. V. Pulpe, and V. A. Zagrebnov on the Ulysses project "A mathematical analysis of quasi-particles and transport in carbon nanotubes II", 2-8 July.
- Extended (4 months) visit to the Statistical Laboratory, Cambridge, 5 September - 20 December.
- Visit to Imperial College, London, 1 November.
- Visit to Warwick University, 14 November.

### *W. Nahm*

- Research visit to Max Planck Institute for Mathematics, Bonn, 3-10 March.
- Research visit to University of Lille 1, 2-15 May; 18-27 May.

### *Denjoe O'Connor:*

- Research visit to Cinvestav, Mexico, 24 March - 1 April.

### *F. Dolan:*

- Research visit to University of Parma, Italy, 2-6 July.
- Visiting post-doctoral researcher at University of Southampton, 22-26 September, 13 October - 31 December.

### *S. Keegan*

- Research visit to University of Edinburgh, 31 January - 1 February.
- Research visit to University of Augsburg, 14-17 May.

### *M. Leitner*

- Research visit to University of Lille 1 and University of Tours, 2-27 May.
- Visited Physikalisch-Technische Bundesanstalt (PTB), Braunschweig (Germany), 29-30 October.

### *C. Morgan:*

- Visited T.C. Dorlas during his sabbatical to University of Cambridge, 29 October - 2 November.

### *S. Murray:*

- Research visit to University of Edinburgh, 31 January - 1 February.
- Visiting Junior Schrödinger Fellow at The Erwin Schrödinger International Institute for Mathematical Physics, Vienna, Austria, 1 August - 30 September.

### *A. Povolotsky:*

- Research visit to the Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, Russia, 1 January - 12 February.
- Research visit to University of Tours, 18-23 June.

### *C. Romelsberger*

- Research visit to CERN, Switzerland, 13-28 January.
- Research visit to Imperial College, London, 31 January - 1 February.
- Research visit to Amsterdam, 11-14 March.
- Research visit to University of the Basque Country, Spain, 14 March - 24 June, 24 June - 31 August.

### *O. Rosten:*

- Research visit to University of Graz, 23-26 January.
- Research visit to University of California, 16 April - 11 May.
- Research visit to University of California Santa Barbara, 28 May - 8 June.

### *C. Saemann*

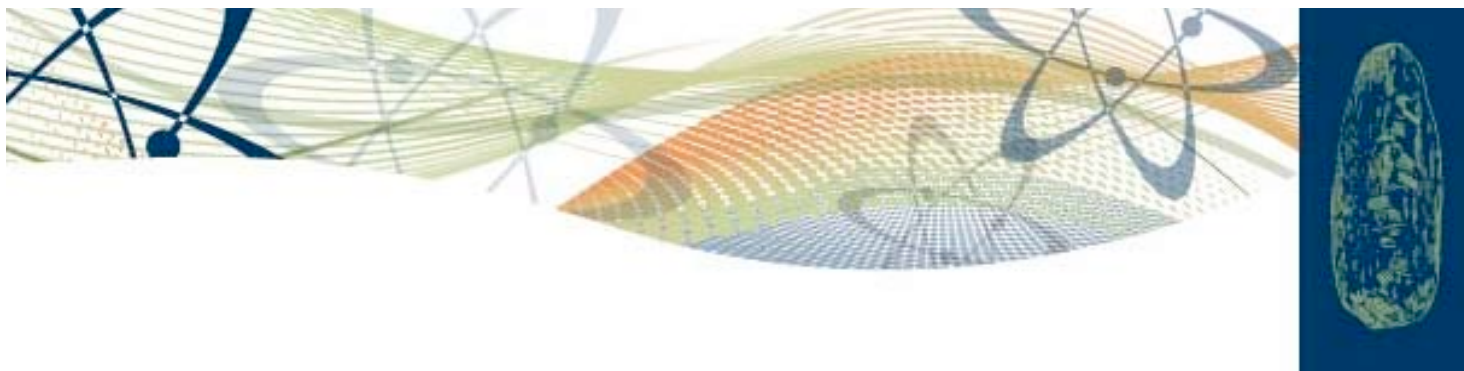
- Research visit to Imperial College, London, 15-18 May.

### *M. Samsonov*

- Research visit to Chalmers Institute of Technology, Sweden, 16-23 May.
- Research visit to Kiev, Ukraine, 22 June - 10 July.

### *J.K. Slingerland:*

- Visit to University of Leeds, 5-6 November.
- Research visit to Institute for Theoretical Physics, University of Amsterdam, Amsterdam, 6-7 December.
- Research visit to University of California, Riverside, 13 December.
- Visit to Microsoft Station Q, University of California, Santa Barbara, 17-20 December.



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

### 6.1 Conferences/Workshops/Scientific Meetings

#### Attended

*T.C. Dorlas:*

- All-Island Conference on "Quantum Information Science and Technology", Maynooth. 19-20 April.
- "Open Systems Days", Leipzig. 18-19 May.
- "Large Quantum Systems", Warwick, 11-15 June.
- Colloquium at University of Groningen, 27-28 September.

*W. Nahm:*

- Conference in Hamilton Mathematics Institute, TCD, 10-15 April.

*Denjoe O'Connor:*

- "Irish Quantum Field Theory Meeting", University College, Galway, 11-12 May.
- "Workshop on Fuzzy Physics and Non-commutative Geometry", DIAS, 5-16 June.
- Workshop "Aspects of Membrane Dynamics", Royal Institute of Technology, Stockholm, 18-22 June.
- Workshop on "Non-commutative Geometry", Bratislava, Slovakia, 2-14 July.
- Workshop held at Erwin Schrödinger Institute, 26-30 November.

*S. Bal:*

- "International Workshop on Fuzzy Physics and Non-commutative Geometry", DIAS, 5-16 June.
- "International Workshop on Topological Quantum Computing", TCD, 10-14 September.
- Winter Symposium, DIAS, 13-14 December.

*F. Dolan:*

- "Gauge Field and Strings Workshop", Isaac Newton Institute, University of Cambridge, 3-10 April.
- "Irish Quantum Field Theory Meeting", University College, Galway, 11-12 May.
- "12th Claude Itzykson Meeting", Ecole Normale Supérieure, Paris, 17-23 June.
- Conference, Cambridge, 17-22 September.
- "International Workshop on Fuzzy Physics and Non-commutative Geometry", Dublin Institute for

Advanced Studies, 5-16 June.

- UK Annual High Energy Theory Meeting, Durham University, 17-19 December.

*A. Ghesquiére:*

- "Mini-Symposium on Topological Quantum Computation", N.U.I. Maynooth, 6-7 January.
- All-Island Conference on "Quantum Information Science and Technology", N.U.I. Maynooth, 19-20 April.
- Summer School on "Quantum Information and Control (QUIC)", N.U.I. Maynooth, 27-31 August.
- "Noise, Information and Complexity at Quantum Scale", Erice (Sicily), 4-10 November.

*I. Huet:*

- 14th Irish Quantum Field Theory Meeting, NUI Galway, 11-12 May.
- International Workshop on "Fuzzy Physics and Non-commutative Geometry", Dublin Institute for Advanced Studies, 5-16 June.

*M. Leitner*

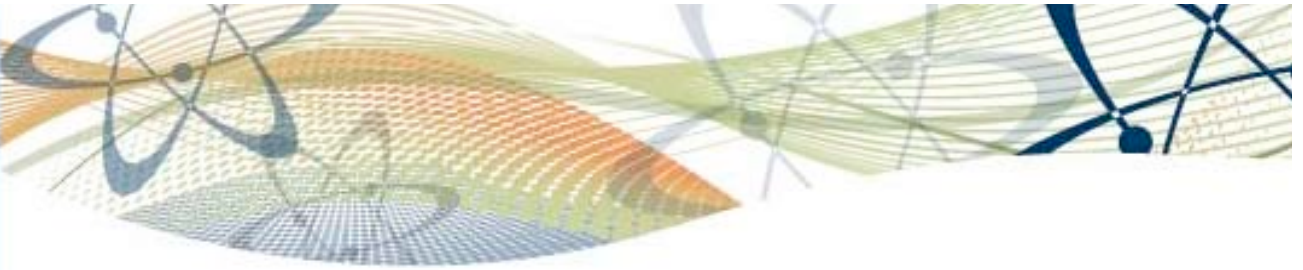
- Conference in Hamilton Mathematics Institute, TCD, 10-15 April.

*C. Morgan:*

- "Mini-Symposium on Topological Quantum Computation", N.U.I. Maynooth, 6-7 January.
- "All-Island Conference on "Quantum Information Science and Technology", N.U.I. Maynooth, 19-20 April.
- 2007 IEEE International Symposium on "Information Theory", Acropolis Congress and Exhibition Centre, Nice, France, 24-29 June.
- Summer School on "Quantum Information and Control (QUIC)", N.U.I. Maynooth, 27-31 August.
- "Noise, Information and Complexity at Quantum Scale", Erice (Sicily), 4-10 November.

*S. Murray:*

- Conference "Non-commutative Space time Geometries", University of Eastern Piedmont at Alessandria, Italy, 26-31 March.
- "Bayrischzell Workshop on Non-commutativity and Physics", Bayrischzell, Germany, 11-14 May.
- International Workshop on Fuzzy Physics and



Non-commutative Geometry”, Dublin Institute for Advanced Studies, 5-16 June.

- Workshop on Non-commutative Geometry”, Comenius University, Bratislava, Slovakia, 25 June -13 July.
- UK Annual High Energy Theory Meeting, Durham University, 17-19 December.

*A. Povolotsky:*

- "International Workshop Classical and Quantum Integrable Systems", Dubna, Russia, 21-26 January.
- Conference "Mathematical Analysis of Quantum Systems", Dublin Institute for Advanced Studies, 2-4 April.
- Workshop "Statistical Physics and Logarithmic Conformal Field Theory", Dubna, Russia, 1-12 June.
- Conference "Statphys23", Genova, Italy, 9-13 July.
- Conference "Fluctuation and Dissipation Phenomena in Driven Systems far from Equilibrium", Max Planck Institute for Complex Systems, Dresden, 16-18 July.
- "Winter Symposium", Dublin Institute for Advanced Studies, 13-14 December.

*C. Romelsberger:*

- RTN Winter School on "Strings, Supergravity and Gauge Theories", CERN, Switzerland, 15-19 January.
- Conference "Strings '07", Madrid, Spain, 25-29 June.
- Workshop "Strings '07", Benasque, Spain, 1-13 July.

*O. Rosten:*

- International Workshop on "Fuzzy Physics and Non-commutative Geometry", Dublin Institute for Advanced Studies, 5-16 June.
- Workshop on "Renormalisation Group and Effective Field Theories", Durham, 27-29 September.
- European Science Foundation Workshop "Non-commutative Quantum Field Theory", Erwin Schrödinger Institute, Vienna, 26-29 November.
- UK Annual High Energy Theory Meeting, Durham University, 17-19 December.

*C. Saemann:*

- RTN Winter School on "Strings, Supergravity and Gauge Theories", CERN, Switzerland, 15-19 January.
- Workshop on "Non-Commutativity and Physics", Bayrischzell, Germany, 11-14 May.

- Workshop on "Non-commutative Geometry", Bratislava, Slovakia, 29 June- 8 July.
- "Supersymmetries and Quantum Symmetries (SQS'07)", BLTP, JINR, Dubna, Russia, 29 July - 4 August.
- "Twistors, Strings and Scattering Amplitudes", Durham, 19-25 August.

*M. Samsonov:*

- "Symmetry in Nonlinear Mathematical Physics", Kiev, Ukraine, 24-30 June. J.K. Slingerland:
- International Workshop on "Topological Quantum Computing", Hamilton Mathematics Institute, Trinity College, Dublin, 10-14 September.
- Mini-Symposium on "Topological Quantum Computation", Max Planck Institut für Quantenoptik, Garching, 10-11 December.
- Station Q Fall Meeting”, Microsoft Station Q, University of California, Santa Barbara, 14-16 December.

## 6.2 Lectures and Organisational Meetings Attended

*T.C. Dorlas:*

- Series of John Lewis lectures by Prof. Ya. Sinai. 23, 25 & 30 May.
- Statutory Public Lecture by Prof. L. Hau-Vestergaard. 16 May.

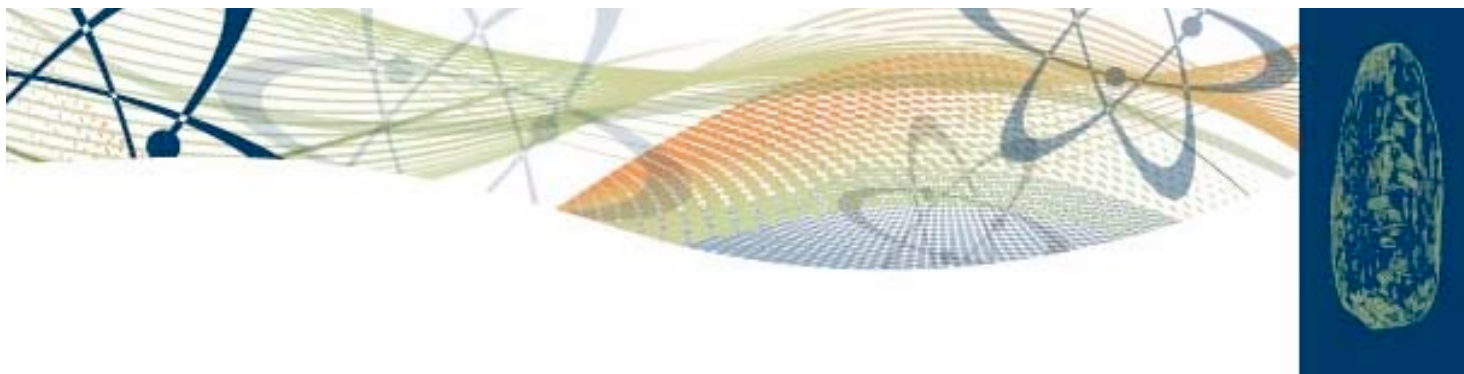
*I. Huet:*

- "Introduction to cosmology", lectures by V. Rubakov, May.
- "Lie algebras", lectures by M. Samsonov

*C. Morgan:*

- "Introduction to mutually unbiased bases" by R.Gow (UCD), Claude Shannon Institute Algebra Seminar, UCD, 5 February.
- "On channel capacities" by C. King (Northeastern University, Boston), UCD, 15 May.
- "Characterisation results on weighted minihypers and on linear codes meeting the Greisner bound" by L. Storme (University of Ghent, Belgium), Claude Shannon Institute Algebra Seminar, UCD, 19 December.





## 7 Research Grants / External Funds Secured

*T.C. Dorlas:*

- Small grant SECOQC and FET/QIPC \SCALA"(£2000) to support extended visit to Cambridge.

*Denjoe O'Connor:*

- 2007-2011: Node of Marie Curie Research Training Network €233, 652.73.
- 2003-2007: Basic Research Grant from Enterprise Ireland for €189,000.
- 2006-2008: 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 Postdoctoral 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.
- 2007-2009: An Embark Initiative Post-doctoral Fellowship to Babar Qureshi funded by IRCSET for a period of two years years with effect from 16 December 2007.
- 2006-2007: Simulations of Field Theories in Noncommutative Spaces (bep00010) on the HLRN computer system in Germany

*C. Morgan:*

- UCD Seed Funding Scheme, Travel and accommodation costs for participation at "Noise Information and Complexity at Quantum Scale Conference 2007". Amount: €1300.

## 8 Honours/Awards/Special Achievements Received

**A. Ghesqui re:**

- Awarded The Hamilton Medal from Dublin Institute for Advanced Studies, February.

*C. Morgan:*

- Awarded The Hamilton Medal from Dublin Institute for Advanced Studies, February.

*S. Murray:*

- Awarded The Hamilton Medal from Dublin Institute for Advanced Studies, February.

## 9 Public Awareness Activities

### 9.1 Articles

*T. Dorlas:*

- A short history of the School of Theoretical Physics was written for publication on the School's website.

