DUBLIN INSTITUTE FOR ADVANCED STUDIES

DIAS

School of Cosmic Physics

Annual Report for the School of Cosmic Physics for the year ending 31 December 2000

SUMMARY

DIAS School of Cosmic Physics Annual Report 2000

The quinquennial external review of the School took place in February. The new parallel cluster was officially launched in November. Extensive work was put into the development of School and Institute strategy documents throughout the year.

In the ***Astrophysics Section*** considerable effort was put into refining the calibration of the data from the Ultra Heavy Cosmic Ray Experiment and removing systematic effects. The work on cosmic rays in the atmosphere, and the resultant health implications for commercial aircraft flight, continued and received a boost with the awarding of a further EU contract to continue the studies through the period of solar maximum. A notable result in the star formation group was the development by Lery and coworkers of a global model for outflows from young stars which appears to offer a number of advantages over the conventional ones. This theoretical work was backed up by ground based and HST observational studies, including the first optical spectra of a jet from a young star obtained with the space telescope. An interesting application of the involutional symmetry of the ideal gas Euler equations to the simulation using high power laser implosion facilities of supernova remnants was discovered and published.

Galactic nuclei, evolving stellar populations and massive stars constituted the main research focus for the ***Astronomy Section*** in Dunsink Observatory. As in recent years, the emphasis has been on high-energy (X-ray) observational data. The nuclear and stellar population contributions to the total X-ray output were studied for several individual galaxies (such as M32, NGC 3147, NGC 4552). A substantial computer simulation programme that evaluates the X-ray emission of an evolving stellar population was advanced and can soon be applied to extragalactic star formation regions. Individual massive stars were investigated and the class properties of certain Wolf-Rayet type stars were determined. The exploitation of Archival Research assumed a larger scale during the year. The Optical Monitoring Camera for the INTEGRAL satellite was largely completed and is ready for launch. The Open Nights at Dunsink Observatory keep attracting school groups and members of the general public. Restoration work has been carried out for some of the historical instruments in Dunsink.

Research in the ***Geophysics Section*** mainly concentrated on studies offshore in the Rockall Trough, and onshore in southeast and southwest Ireland. In the RAPIDS III project the quality of the large volume of data is very high and modelling of the four profiles continued with preliminary whole crustal models on two of the profiles completed. Of particular note from the deep-tow sidescan sonar project, TRIM, was a detailed study of an extensive population of carbonate mounds. A theoretical model was developed which predicts the observed size and shape distribution of the population, and allows an age profile to be determined. Onshore, inversion of the seismic data in the LEGS experiment revealed the structure of the Leinster Granite and provided the first detailed information on the seismic response of Caledonian granites. A 3-D model for the crust of southwest Ireland was developed using off-line seismic data from the VARNET project and our existing gravity data. Further afield, data acquisition in the Hawaiian Plume experiment continued throughout the year.

ANNUAL REPORT
SCHOOL OF COSMIC PHYSICS, 2000

Annual Report of the Governing Board of the School of Cosmic Physics for the year ending 31 December 2000 adopted at its meeting on 30 April 2001

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l STAFF, SCHOLARS AND ASSOCIATES

Senior Professors: L.O'C. Drury (Director), A.W.B. Jacob, E.J.A. Meurs.

Professors: A. Thompson, D. O'Sullivan, T.P. Ray.

Assistant Professors: P.W. Readman, B.M. O'Reilly (contract basis), I. Elliott (with retrospection to 01 July 98).

Research Assistants: Three vacancies.

Experimental Officers: T.A. Blake, B.D. Jordan, J.Walsh (computer manager, contract basis).

Visiting Scientists: B. Austin (Hydrosearch), D. Bartlett (National Radiological Protection Board (NRPB), UK), P. Basford (Pasminco), C.J. Bean (Department of Geology, UCD), P. Beck (Austrian Research Center (ARCS), Austria), S. Bennett (Department of Geology, TCD), E. Benton (University of San Francisco, USA), J-F Bottollier (Institute for Nuclear Safety and Protection (IPSN), France), N. Buttimore (Dept of Mathematics, TCD), J. Chamberlain (Phillips Petroleum), M. Critchley (ERA/Maptec), O. Dardis (UCD), C.J. Davis (Joint Astronomy Center, Hawaii), A.L. Densmore (Department of Geology, TCD), V. Dwarkadas (University of Sydney, 17 May – 15 June), J.N. González Pérez (Istituto de Astrofisica de Canarias), Th. de Graauw (SRON, Groningen, NL), C. Jarlskog (CERN, Switzerland), F. Kennedy (CAPTEC, Ireland), T. Lagrange (CERN, Switzerland), L. Lindborg (Swedish Radiation Protection Institute (SSI), Sweden), U. Locatelli (University of Milan), K.-H. Mack (Istituto di Radio Astronomia, Bologna), R. Mundt (Max Planck Institute for Astronomy, Heidelberg), M. Murphy (University of New South Wales, Australia), R. Pasqualli (Department of Geology, TCD), W.E.A. Phillips (Department of Geology, TCD), D. Praeg (UCD), J. Schutte (GFZ Potsdam), C. Solla (Department of Geology, TCD), L. Tommasino (Agenzia Nazionale per la Protezione dell'Ambiente (ANPA), Italy), U. Schrewe (Physikalisch Technische Bundesanstalt (PTB), Germany), P.M. Shannon (Department of Geology, UCD), M.I. Wilkinson (Institute of Astronomy, Cambridge, UK), I. Woelbern (GFZ Potsdam, 13-23 June), L. Yun (Astronomical Observatory, Lisbon), W. Zeilinger (Institute of Astronomy, Vienna).

Technical and Clerical Staff: A. Byrne, A.M. Callanan, E. Clifton, P. Daly, W. Dumpleton, E. Flood, A. Grace-Casey, C.M. Horan, S. Ledwidge (part-time job-sharing basis from 01 October), L. Quigley, M. Smyth, H. Sullivan, G. Wallace, (two vacancies).

Scholars: M. Carr, O. Carroll (from 01 October), J. Cunniffe, J. Donnelly, G. Fennell (from 01 October to 31 December), J.A. Hodgson, M. Landes (until 31 March), K. McGrane (without stipend), F. McGroarty (from 01 October), L. Norci (from 17 January), A. O'Brien (without stipend, until 30 June), V.Unnithan (without stipend, until 31 March), Z. Zang (until 30 June), D. Zhou.

Project Supported Positions: S. Annibaldi (Turbulent Fusion Plasmas), F. Bacciotti (European Space Agency Fellow, until 30 September), R. Butler (University College Galway, until 28 January), T. Lery (Enterprise Ireland), F. McGroarty (DIAS/Enterprise Ireland, from 01 October), G.D. Mackenzie (RAPIDS III), E. Parizot (TMR Astroplasmaphysics Network, until 31 August).

Professores Emeriti: H.A. Brück (to 04 March)*, T. Kiang, T. Murphy.

Research Associates: C.J. Bean (UCD), D. Corcoran (UL), T. Downes (TCD/DCU), P. Duffy (UCD), A.J. Keane (ITB), R. Keary (GSI), A. Lawrence (Edinburgh), B. McBreen (UCD), J. Makris (Hamburg), P. Morris (British Antartic Survey), N.P. Murphy (BP), F. Murtagh (QUB), W.E.A. Phillips (TCD), V.F. Polcaro (IAS, Frascati), C. Prodehl (Karlsruhe), P.M. Shannon (UCD), M. Wilkinson (Oxford).

Project Students: E. Doherty (TCD, from 01 October to 31 December).

Vacation Students: C. Heverin (UCD, until 14 April), S.T.F. Jacob (TCD, until 14 April).

*H.A. Brück died on 04 March 2000.

2 RESEARCH ACTIVITIES IN THE ASTROPHYSICS SECTION

2.01 Strange transport in electrostatic drift wave turbulence

S V Annibaldi and L Drury with G Manfredi (Nancy), K Hopcraft (Nottingham) and R Dendy (Culham)

The anomalous transport of test particles in the Hasegawa-Mima model of drift wave turbulence was studied numerically. In addition to the electrostatic potential obtained by solving the Hasegawa-Mima equation, other auxiliary fields, in particular the Weiss field which measures the relative importance of shear and vorticity, were used in analysing the particle transport. Trapping vortices and zonal flow patterns similar to those observed in planetary atmospheres were found depending on the parameters used. Finite Larmor radius effects have been included and shown to strongly inhibit transport when the Larmor radius of the test particle is comparable to the size of the dominant structures.

These studies show strongly non-diffusive transport in certain parameter regimes. Some of these characteristics can be reproduced by random walk models with power law fluctuating step numbers. Analytical investigations of such models showed that they can produce power-law tails when the underlying process is isotropic, but that if the walk is biased they give exponential decay except in the bias direction where again there is a power-law tail.

2.02 Spherical box models of particle acceleration.

L Drury and E Parizot

The so-called "box model" for particle acceleration at shocks, originally developed for planar shocks to allow a simple treatment of such effects as synchrotron losses, has been extended to a time-dependent spherical version suitable for use in discussing particle acceleration in supernova remnants. Remarkably, an approximate analytical integration of the equations is possible. The resulting theory substantially clarifies a number of questions concerning the shape and position of the upper cut-off to the accelerated particle energy spectrum.

2.03 Implosion-explosion duality applied to the laboratory simulation of astrophysical systems.

L Drury with T Mendonca (Lisboa)

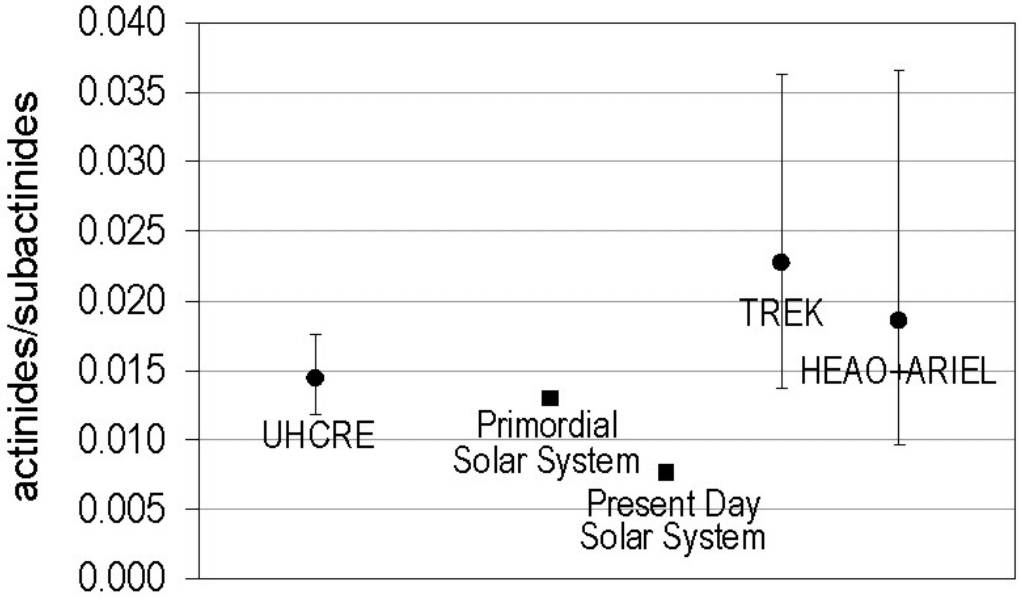
A possible application of the remarkable involutional symmetry of ideal Eulerian gas dynamics (see last year's report) to the laboratory simulation of supernova remnants using laser implosion facilities was discussed. With a suitably constructed static target, and appropriately tailored implosion drive, it should be possible to simulate the interaction of highly structured explosion ejecta hitting an ambient medium. All the purely gas dynamical effects such as instabilities, turbulence and shock formation will be exactly reproduced, including the geometrical effects of spherical divergence, as long as the equation of state can be well approximated by a polytrope of exponent 5/3.

2.04 The Ultra Heavy Cosmic Ray Experiment (UHCRE) on the LDEF Mission

A. Thompson, D. O'Sullivan, J. Donnelly and L.O'C. Drury with K.-P. Wenzel (ESTEC)

In the total sample of UHCRE events accumulated to date, the charge assignment error for individual cosmic ray events in the actinide region was estimated to vary from about ±1.5e to about ±2.5e. During the year, a programme was initiated to refine the UHCRE charge spectrum further, especially in the actinide region, with the ultimate objective of measuring the thorium/uranium ratio with sufficient confidence for astrophysical significance. This programme involves the utilisation of further calibration exposures with beams of ultra-heavy ions in detector plates containing cosmic ray actinide events in order to identify possible systematic errors. In particular, it involves the experimental derivation of correction factors for small systematic differences in signal from etch to etch in relevant UHCRE detector plates from the many etches employed during the entire period of UHCRE data extraction. In addition, a general review of the entire UHCRE data base was undertaken and areas for verification, further measurement or further analysis were identified. Furthermore, a re-examination of the track response model (the relationship between signal strength and ionisation) was pursued. The overall charge resolution is, consequently, expected to improve with a final UHCRE charge spectrum scheduled for the end of 2001. It should be emphasised that the UHCRE data base contains the only statistically significant sample of cosmic ray actinides in existence at present.

The current UHCRE value for the relative abundance of cosmic ray actinides, defined as $(Z \geq 88)/(74 \leq Z \leq 87)$, is $0.0144 \pm 0.0031/0.0026$. This value is consistent with propagated primordial solar system material and



Observed and derived actinide relative abundances (Z>87)/(73<Z<88).
The UHCRE results are consistent with origin in normal interstellar gas and dust.

hence supports the view that the origin of the cosmic ray material is predominantly normal interstellar gas and dust. During the year, updated UHCRE results for the ultra heavy cosmic ray spectrum were presented at the 33rd COSPAR Scientific Assembly and at the 20th International Conference on Nuclear Tracks in Solids.

2.05 The KLEM Project

A. Thompson and L. Drury with G. Bashindzhagyan et al (Moscow State University), J. Adams (NASA Marshall Space Flight Center), M. Simon (University of Siegen, Germany), A. Chilingarian (Yerevan), N. Egorov et al (Zelenograd, Russia), J. Procureur (CENBG Nuclear Research Center, France) and O. Saavedra (Torino University, Italy)

The basic objective of the KLEM Project is to directly measure the elemental energy spectra of very high energy (10^{11}–10^{16}eV) cosmic rays using a large aperture lightweight detector system in Earth orbit. As pointed out in last year's Annual Report, it is not economically feasible to achieve this scientific goal by conventional means (ie using an ionisation calorimeter) because the mass required to be deployed in Earth orbit would be very large (at least 50 tonnes). An alternative approach, using a kinematic technique, is to measure the primary particle energy by determining the angular distribution of secondaries produced in a target layer using silicon microstrip detector technology. An instrument based on this approach (KLEM) has been designed which, due to its light weight, can have a large aperture allowing a dramatically increased exposure factor and enabling the direct measurement of cosmic ray nuclei to be extended up to and through 10^{16} eV. During the year, considerable progress was made in the overall project and in the development of the instrument, with the support of the Russian Space Agency (Rosaviacosmos). It is planned to begin construction of a small prototype (KLEM-1, 0.16m^2 collecting area, less than 70kg weight and less than 90W power consumption) in 2001 with launch in 2004. The full scale instrument, with a collecting area of 4m^2 and a three-year exposure with launch currently scheduled for 2008, is expected to identify at least 25 particles with E>10^{16} eV.

A significant development, towards the end of the year, was the decision to extend the project to include a low energy cosmic ray instrument, UHIS (Ultra Heavy Isotope Spectrometer), to be inserted in the KLEM target. The UHIS device has a modular structure and utilises sets of silicon detectors of various thickness. The scientific objective of UHIS is to measure the fluxes of ultra heavy cosmic ray isotopes with Z > 30 and to investigate the composition of Solar and Anomalous cosmic ray components. The plan is to combine the two research programmes (KLEM and UHIS) into one (by incorporating the UHIS scientific package as part of the KLEM instrumentation) with the common name of NUCLEON. Such integration significantly decreases the total cost of programme accomplishment. The small scale NUCLEON prototype (NUCLEON-1) will thus consist consists of two parts, the high-energy KLEM-1 device and the low energy UHIS-1 instrument, which is mounted in the KLEM-1 target. The NUCLEON Project has been included in the Russian Federal Space Research Programme under "Fundamental Space Investigations".

During the year KLEM presentations were made at the Space Technology and Applications International Forum (STAIF-2000), the American Physical Society April Meeting 2000, the 33rd COSPAR Scientific

Assembly and the 17th European Cosmic Ray Symposium.

2.06 Cosmic Radiation in the Earth's Atmosphere

D. O'Sullivan, E. Flood and D. Zhou

Work on finalising data from the IRMA-2 project was continued and analysis was completed for publication by midyear. The DIAS contribution to this work included linear energy transfer measurements and associated radiation doses for the Dublin-New York, Milan-Los Angeles, Milan-Tokyo and Rome-Rio Janeiro subsonic routes, and the London-New York Concorde route. Charge spectra of $Z \geq 2$ nuclei were also determined on some of these routes. Comparison of data with the FLUKA Monte Carlo code and the LUIN code were undertaken with the final results. The main achievements of the IRMA-2 project were the measurement of neutron, proton and heavy nuclei spectra at aircraft altitudes and a detailed determination of radiation dose rates as a function of altitude and latitude for subsonic and supersonic air routes during solar minimum.

A proposal (DOSMAX) to continue the work under the EC 5th Framework Programme for the duration of solar minimum period 2000-2003, which was submitted in Oct 1999, with D. O'Sullivan as European Co-ordinator, was successful and DIAS was informed in February. The proposal was one of only three funded from a total of 37 proposals submitted under the Sources of Natural Radiation Category. Funding of 869,381 Euros was awarded for a 42-month duration starting on 01 July 2000 with a contribution of 198,296 Euros for DIAS. The team includes DIAS, ANPA (Italy), ARCS (Austria), CERN, IPSN (France), NRPB (UK), PTB (Germany) and SSI (Sweden).

Work started immediately with calibration of new detectors at the CERN reference field in July and successful discussions with Aer Lingus, British Airways, Czech and French Airlines, as well as NASA, resulted in a planned programme of exposures for DIAS detectors over the next three years. Special arrangements were made to launch detectors at very short notice during the onset of significant solar activity. In September successful exposures of DIAS detectors to high energy neutrons and protons took place at the Svedberg Laboratory in Uppsala. DIAS detectors were also exposed to heavy ions at the HIMAC accelerator in Japan.

To date preliminary measurements have already been made on a number of routes and calibration is at an advanced stage. Comparison of data with computer code predictions, including the new EPCARD code developed in the IRMA-2 project, is continuing.

2.07 Space Weather

D. O'Sullivan

D. O'Sullivan was appointed to the European Space Agency's Working Team on Space Weather in April. Space weather is defined as conditions on the sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence space borne and ground based technology and can endanger human life and health. The team's brief is to put forward a case for a European Space Weather Service. At present Europe depends on US and Japan for expertise and data. D. O'Sullivan was appointed Topic Leader for the area of Astronaut and Aircrew safety and his sub-group authored a report which was submitted to ESA in December.

2.08 A New Global Model for Outflows from Young Stars

T. Lery and T.P. Ray with A. Frank (Rochester University, New York), R.N. Henriksen (Queen's University, Ontario, Canada), J. Fiege (McLennan Laboratories, University of Toronto) and F. Bacciotti (Arcetri Astrophysical Observatory, Florence)

Powerful, highly collimated jets, surrounded by bipolar molecular outflows, are commonly observed near Young Stellar Objects (YSOs). In the usual theoretical picture of star formation, the jet is ejected from a magnetised accretion disk and the molecular outflow is driven either by the jet or by a wider wind coming from the disk. Lery et al, however, have put forward an alternative global flow model. According to their scenario, in addition to a central accretion-ejection engine driving the jet, in-falling matter that follows a circulation pattern around the central object powers the molecular outflow. The jet does not necessarily entrain this material.

They have reported, for the first time, solutions for the three different parts of this self-similar model, i.e. the jet, the in-falling envelope and the circulating matter that eventually forms the molecular outflow. Observational and physical consequences of this new global self-similar MHD model for flows around YSOs have been presented. Lery et al have shown that the model produces a heated pressure-driven outflow with magneto-centrifugal acceleration and collimation. Without pressure, only deflection can be observed in the circulation model, and there is no gain in velocity of the flow or in energy. On the other hand, when the gas is heated, more energetic outflows can be produced. The presence of the magnetic field and rotation induces anisotropies that help collimation and acceleration.

This new picture of the accretion/outflow phase provides a possible explanation for many observed properties of YSO outflows, the most important being the high mass molecular outflows from massive proto-

stars. It also allows us to sketch an evolutionary sequence for the changing environment of a young star. It is suggested that this global model may apply to both low and high mass stars, where circulation and accretion-ejection may be of different relative importance.

2.09 Near-Infrared Spectroscopy of Proto-Stars

T.P. Ray with C.J. Davis (Joint Astronomy Center, Hawaii), L Desroches (University of Victoria, Canada) and Colin Aspin (Gemini Science Office, Oxford)

Infrared echelle spectroscopy is a powerful diagnostic of dynamic activity in the immediate vicinity of optically obscure young stars. In particular H_2 and Br γ observations probe the orthogonal processes of outflow and in-fall respectively.

Ray et al have discovered high-velocity H_2 emission lines in the extended lobes of nine outflows and, more importantly, complex H_2 line emission *within a few hundred Astronomical Units of their sources*. They have compared these "Molecular Hydrogen Emission-Line" regions, or MHELs, to optical Forbidden Emission-Line regions (FELs) observed in classical T Tauri and some Herbig Ae/Be stars. Like the FELs, both low and high-velocity components are observed in H_2, with blue-shifted velocities of the order of 5-20 kms^{-1} and 50-150 kms^{-1} respectively. As in the case of FELs, low velocity components are more common than high velocity components in MHEL regions. Ray et al found high velocity H_2 components were spatially more offset from their exciting sources than corresponding low velocity components, again as is the case of optical FELs. The MHEL regions (which are in all cases blue-shifted) are thought to be associated with the collimation zones of outflows.

Br γ emission was detected towards four of the embedded young stars observed (SVS 13, IRAS 04239+2436, HH 34-IRS and GGD 27(1)) as well as towards the T Tauri star AS 353A. These lines are all broad and symmetric, the line peaks being blue-shifted by about 30 kms^{-1}. The profiles found are typical of the permitted hydrogen line profiles observed in many T Tauri stars, and probably derive from magneto-sonic accretion flows. No red-shifted absorption features (i.e. inverse P-Cygni profiles) were observed in any of the sources, however. Although predicted by accretion models, no dependence on line width with inclination angle of the system (to the line of sight) was found. Moreover no Br γ was detected in any of the extended flow lobes. Instead, Br γ emission was seen to be confined to the source and to be spatially unresolved along the flow axis.

2.10 Hubble Space Telescope Observations of Stellar Jets

F. Bacciotti and T.P. Ray with R. Mundt (Max Planck Institute for Astronomy, Heidelberg) and J. Eislöffel (Karl Schwarzchild Observatory, Tautenburg)

Although stellar jets have been recognized as an essential element of the star formation process, the mechanisms regulating their acceleration and initial collimation are not yet fully understood. In order to investigate the "central engines" of young stars with as high an angular resolution as possible (<0.1˝), a programme of spectroscopic imaging of a small sample of optically visible young stars has been undertaken using the Hubble Space Telescope (HST). The observing phase is now complete (since December) and the data are currently being analysed.

DG Tauri was the initial target for this programme and *the spectra obtained were the first optical spectra of a jet from a young star obtained from space*. The extraordinary richness of the HST datasets has provided important information on the physics of the acceleration/collimation region close to the source. For example, it has become clear that the flow is denser and more collimated at higher velocities: something that has been suspected on the basis of theory but confirmed for the first time by these observations. Moreover the refined 2-D maps of physical parameters in the initial section of the flow (electron temperature, ionisation fraction, etc) have been derived and analysed. Any viable theory for jet collimation and acceleration must explain such maps.

The HST data shows that the ionisation fraction rises rapidly in the jet close to the star (≤ 1˝), to reach a plateau and then slowly decreases following a recombination curve. In the same region the temperature falls by a factor 2-3 and the total density drops by one to two orders of magnitude. These results provide strong constraints on any proposed models for the formation of jets from young stars. Partial ionisation appears to be a dominant feature in the beams of such jets, and must be properly taken into account. For example, it may introduce important differences in the modelling of magnetized jets, due to collisions between charged particles and neutrals. Several theoretical groups are currently investigating how partial ionisation affects a jet. In addition the observations indicate that the gas is in a non-equilibrium ionisation state and that the ionisation appears to be produced at the very beginning of the jet by an unknown mechanism. Thereafter it decouples from the thermal conditions, probably as a consequence of rapid expansion. Several possible mechanisms to generate the partial ionisation at the base of the flow are currently being investigated including oblique shocks, turbulent boundary layers, and heating by ambipolar diffusion. This last mechanism has been analysed in detail in collaboration with D. Galli and C.

Chiuderi of the Arcetri Astrophysical Observatory (Florence).

Another very important result derived from analysing the Hubble spectra is the first tentative evidence for rotation in an outflow close to a star. Rotation is of fundamental importance in the modelling of jets and in understanding the interplay between accretion and ejection of matter in their generation. Canonical models, in fact, invoke the simultaneous action of magnetic and centrifugal forces in a rotating star/disk system threaded by open magnetic field lines (this is the so-called "magneto-centrifugal" acceleration mechanism). The Hubble data indicate azimuthal flows speeds, in the case of DG Tauri, of around 8 kms^{-1} at distances of 30-40 AU from the central outflow axis. Such a result *is consistent* with magneto-hydrodynamic disk wind models.

3 RESEARCH ACTIVITIES IN THE GEOPHYSICS SECTION

3.01 LEGS (LEinster Granite Seismics)

J.A. Hodgson, P.W. Readman and B.M. O'Reilly with P.S. Kennan (UCD)

The Leinster Granite is one of the largest Caledonian batholiths in Europe. This project is attempting to define the geometry of the granite, which is an important factor in an understanding of its origin and emplacement mechanism. During this year detailed modelling and interpretation of the seismic data collected during the experiment performed in 1999, as well as some gravity modelling of existing DIAS gravity data, was undertaken. The emphasis has been on modelling the entire crustal and upper mantle structure and the relationship this has to the structure of the granite. Detailed inversion of the seismic data revealed that the granite has a layered, or sheeted, type of structure extending to a maximum depth of five kilometres. This is somewhat less than had previously been thought. A sub-surface extension to the southwest was found, consistent with the observed Bouguer anomaly in the area. These results have provided the first detailed information on the wide-angle seismic response of granites within the Caledonian orogenic belt. When combined with additional information available on the structural geology and geochemistry of the granite they will provide a greater understanding of how such large bodies are developed and emplaced, and how their formation is linked to the development of large-scale orogenic belts.

The long length of the seismic lines, in particular the one running roughly along the axis of the granite, together with the large number of seismic records obtained from the experiment has allowed the structure of the lower crust and upper mantle to be modelled in considerable detail over much of the length of the axial line. The crustal thickness averages about 30 km, similar to that found in our previous experiments elsewhere onshore Ireland, and in Britain. One notable feature is a significant thinning of the crust to about a thickness of 28 km beneath the main granite body. The origin of this feature is not understood at this stage but it is clearly spatially related to the presence of thickened granite. Within the mid-crust a series of inclined features are interpreted as evidence of deep-seated faults. Further gravity modelling is planned and should further constrain the structural models so far developed. The graduate student working on the project, James Hodgson, has started writing his Ph.D. thesis and expects to finish next year.

3.02 Gravity (Investigation of onshore sediment transport routes)

P.W. Readman and B.M. O'Reilly with colleagues from TCD

This project, lead by A. Phillips (Geology Department, TCD), to trace the path of possible Tertiary river channels across Ireland continued during the year. The research assistant employed in TCD has compiled what eventually has turned out to be a very extensive catalogue of existing bore-hole data for the Irish Midlands. This has been fully integrated into a GIS system together with other types of data, in particular the DIAS gravity data. Interpretation of this combined dataset has taken place during the year and is continuing. The new gravity data collected in 1999 has been processed and integrated with our existing data and used to help locate the possible channels. Further work, including some exploratory drilling and more gravity work is planned.

3.03 VARNET (VARiscan NETwork)

A.W.B. Jacob, M. Landes, B.M. O'Reilly and P.W. Readman with colleagues from UCD and University of Karlsruhe

The main effort during the year was in 3-D modelling of the seismic data collected during this project, augmented by 3-D modelling of the gravity data. New 3-D seismic processing software developed by John Hole at USGS, Menlo Park, was tested and implemented, and a 3-D gravity modelling programme was modified to run in DIAS. Although the VARNET experiment was not designed as a 3-D experiment, the large number of shots and the resulting 'fan'-shot geometry provides sufficient ray coverage for semi-quantitative 3-D seismic modelling to be attempted for the region to the south of the Shannon Estuary and for its feasibility to be assessed. The results have shown there to be a significant degree of lateral inhomogeneity over the region. Two high velocity zones of 6.4-6.6 km s^{-1} were found beneath Dingle Bay and the Kenmare

River. These may be associated with major east-west trending Variscan features. The origin of another high velocity zone dominating the Munster Basin is however less certain, although its existence is at least partially confirmed by the 3-D gravity work. The Killarney-Mallow Fault Zone was seen to have a 20 km band of rather uniform velocities of about 6.1 km s^{-1} associated with it. The Moho surface was modelled on the basis of PmP reflections and found to rise from about 32 km under the Shannon Estuary to around 27-28 km towards the coast. Significant correlations exist with magnetotelluric measurements in the area undertaken by the Applied Geophysics Unit at UCG as part of this project.

3.04 AIRS (Atlantic Irish Rockall Survey)

K. McGrane, P.W. Readman and A.W.B. Jacob with V. Unnitham and P.M. Shannon (UCD)

The AIRS project formally finished in September 1999 although some interpretation of the GLORIA (Geologic LOnge Range Inclined ASDIC) sidescan data has continued since then. In addition, analysis of marine gravity data was carried out using traditional potential field and 2-D and 2.5-D modelling techniques, and an assessment of the Euler deconvolution technique was undertaken for two profiles for which there are existing seismic models from the earlier RAPIDS II project. The results indicated that a major NW-SE trending lineament within the Rockall Basin reflects pronounced variations in crustal structure and sedimentary thickness. These thickness variations are interpreted as the effects of cross-basin faulting along a fault zone defined by the lineament. Transverse gravity lineaments to the north of this feature are also interpreted as major cross-basin fault zones.

The final report for the project was completed, along with a GLORIA processing manual and quick guide. A Marine Resource Series publication was also prepared for the Marine Institute

3.05 TRIM (TOBI Rockall Irish Margins)

P.W. Readman, B.M. O'Reilly and A.W.B. Jacob with P.M. Shannon (UCD)

The interpretation of the TRIM deep-tow (TOBI - Towed Ocean Bottom Instrument) sidescan data was refined during the year and final versions of the interpretation maps were completed and digitised. Detailed testing of the interpretation of the data was undertaken using the large gravity corer dataset released to the investigators by members of the Rockall Studies Group. The data from 330 individual core samples were examined, classified in detail and correlated with the interpretation based on the TOBI sidescan acoustic response and the 3.5 kHz profiler data. This confirmed both detailed and regional aspects of the interpretation and broadened our understanding of slope processes along the margins of the Rockall Trough. In addition, an assessment of slope failure hazards in the area was undertaken using these results and a knowledge of the seismic hazards west of Ireland based on our seismic network (see later).

Sonar backscatter and the character of the 3.5 kHz profiler data change systematically along the eastern margin. This variation is due to changes in sedimentological facies which reflect variations in glacially controlled mass wastage processes. Glacial influences are overwhelming in the north where a large glacio-marine sedimentary wedge is developed. Canyons are conspicuously absent and slope gradients are lowest along this part of the continental margin, while further south they are more common where the margin becomes progressively starved of sediments. The change in morphology of the canyon systems to the south may reflect an older age for their inception. Large-scale submarine fan complexes are also developed which are probably comprised of stacked Pleistocene sediment sequences related to the advance and retreat of glaciers across the continental slope. Along the southernmost part of the margin where an extensive region of rock outcrop is present, the sediment input is lowest and the margin is most starved.

Some preliminary work in correlating the sidescan data with deeply penetrating, but lower resolution, seismic profiling data from selected regions of the Rockall Basin was undertaken with other members of the Rockall Studies Group. The results of these preliminary studies are encouraging and indicate that this type of approach could produce valuable information on the Cenozoic development of the basin and the geological history of slope-failure processes in such a deep-water basin.

The very high resolution of the sidescan data allowed specific aspects of oceanographic processes to be focussed upon. In particular, a detailed study of a carbonate mound population on the northwest shoulder of the Porcupine Bank was carried out. An analytical model for the growth of the population which incorporated biological and current flow processes was developed. This model was shown to predict the frequency distribution of mound sizes and elongations for the entire population of about 140 mounds. It also allows an age structure for the mound population to be determined, but this has yet to be rigorously tested with independent data.

It is expected that future work will involve similar more focussed studies which emphasise specific features and processes that have been identified from the sidescan investigation. This future work may involve collaboration with researchers working in related fields, and will be based on other types of oceanographic and geophysical data.

3.06 RAPIDS III (Rockall and Porcupine Irish Deep Seismics)

A.W.B. Jacob and G.D. Mackenzie with P.M. Shannon (UCD) and colleagues from the University of Hamburg

In early 1999, the RAPIDS 3 project acquired four wide-angle reflection/refraction seismic profiles within the Irish sector of the Rockall Trough. The aim of the project is to provide a constraint on crustal and sedimentary geometries in the region and to improve the understanding of the tectonic evolution of the Irish continental margin. The project is funded as part of the Petroleum Infrastructure Programme (PIP) sponsored by a consortium of oil companies, the Rockall Studies Group (RSG).

Throughout the year (2000), data processing and 2-D travel-time modelling has continued on all four profiles with initial results being presented at two international conferences. One week was spent in Hamburg in June re-processing some of the data at GeoPro GmbH. Preliminary P wave velocity models have been completed for the sedimentary succession on three of the four profiles while preliminary whole crustal models were completed on two of the profiles. Typically a sedimentary succession of 4–5 km thick is modelled consisting of three main seismic packages (each containing a number of local units). These are generally flat lying in the centre of the Rockall Basin pinching out to the basin margins where significant structural complexities are observed. The sedimentary succession is thought to be of Late Palaeozoic to Recent age. A crust, approximately 30 km thick, consisting of three layers, and similar to that observed beneath Ireland, is modelled beneath the Porcupine and Rockall Highs. This thins considerably beneath the centre of the basin where the Moho is observed at about 12 – 15 km depth. Beneath the Rockall trough the crust appears to consist of one, or at maximum two, layers.

3.07 Teleseismic Study of the Hawaiian Plume

A.W.B. Jacob, G. Wallace, C. Horan, L. Quigley and T.A. Blake with R. Kind and Ingo Woelbern from GFZ Potsdam and colleagues in the University of Hawaii

Although geochemical and gravity measurements indicate the existence of a vigorous mantle plume beneath Hawaii, there is a lack of direct seismic evidence which would enable the modelling of the physics of the plume to be undertaken. The current project aims to do this and good progress has been made with data gathered in the first nine months of the deployment. What appears to be present is a relatively narrow but hot plume. The upper part of the plume is now better defined and the shallow (about 130 km below the surface) low-velocity zone under Hawaii itself is being modelled in greater detail. It has been found to extend further to the southwest than an earlier study had indicated.

In June we sadly learnt of the death in a swimming accident of one of the station minders, Stanley Bucacas. Mr. Bucacus was a science teacher at Kekaha Elementary School on Kauai, and now Jim Denny has kindly agreed to take over the station at Kekaha. During October routine maintenance on the seismic recording stations in Hawaii was carried out and the station at Hana was closed down. In November, Ellen McNulty replaced Georgiana Young and she now arranges the collection of disks in Hawaii for shipment to Dublin. An information pack consisting of a booklet and CDROM explaining the project was prepared and distributed to all the station minders (landowners/teachers). This included background information, some sample waveform data of events recorded by the Hawaii stations, and software to view the events. The project has now been extended and is planned to run until the end of April 2001.

Work on refining and streamlining the data processing and archiving procedures necessary to cope with the large volumes of data that this project generates continued during the year. Direct data download from the USGS data loggers on the Big Island of Hawaii was started, with assistance from J. Luetgart of the USGS, of data recorded at the Hawaiian recording sites KHU, UXL and STC. All data from the project is currently archived on DLT magnetic tape in duplicate and stored in different locations for security reasons.

3.08 The Seismic Network (DNET, ENET, DSB and VAL)

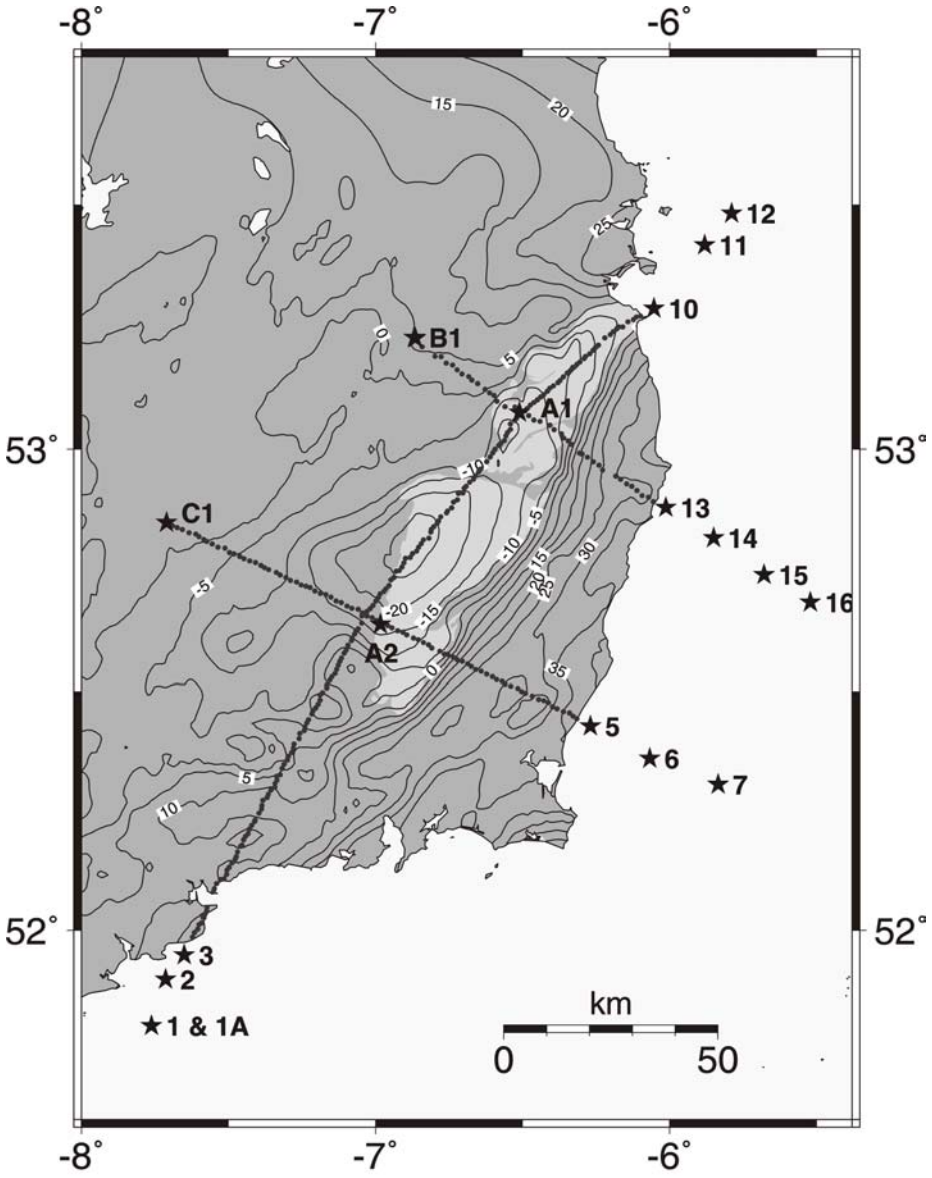
A.W.B. Jacob, T.A. Blake, G. Wallace, C. Horan and L. Quigley

In April the seismometers and amp-mods were removed from the pits at the ECP (Carnsore Point) and ECB (Carrickbyrne) stations. It is planned to install a digital recording station at ETA (Tara Hill). Bob Miller, who had taken care of the seismic station at Carnsore Point since ENET was established in the late seventies, died on 06 July.

Recorded events

Two onshore events occurred in Ireland during the year but there were no felt reports for either of them. The first event was near Midleton, Co. Cork on 18 May and the second occurred near New Ross, Co. Wexford on 19 October. There were events in the Irish Sea on 17 February, 20 May, 29 September and 09 October. On 11 September an event was recorded in the Rockall Trough with a magnitude 2.7 M_L.

The largest onshore event in the UK occurred in Warwick, Warwickshire on 23 September, and had a magnitude of 4.2M_L and a felt intensity of +V. No damage or injuries were reported. A number of smaller



Location of the LEGS seismic lines. Bouguer anomaly contours and the granite outcrop (lighter shading) also shown.

events (< 2.8 M_L) occurred in Scotland and Wales. The North Sea / Norwegian Coast area was active with events in February (3.3 M_L), May (3.6 M_L), August (4.5 M_L), October (3.9 M_L) and December (4.2 M_L and 4.6 M_L).

There were number of significant earthquakes during the year. Perhaps the most destructive, resulting in many casualties occurred in Southern Sumatera, Indonesia on 04 June. Having a magnitude of 8.0 Ms, at least 103 people were killed and over 2000 were injured. The other large events which were felt in the epicentral areas occurred in Sulawesi, Indonesia, 04 May, 7.5 Ms; N. Ankara, Turkey, 06 June, 6.1 Ms; Iceland, 17 and 21 June, both 6.6 Ms; Sakhalin Islands, Russia, 04 August, 7.1 Ms; W. Honshu, Japan, 06 October, 6.8 Ms; Caspian Sea, 25 November, 6.3 Ms and 06 December, 7.2 Mw.

Requests for general information on earthquakes, volcanoes etc. were received from schoolchildren. There were more specific requests from engineers (both private and public sector) and students from 3rd level colleges. Students from DIT Bolton Street (Computer and Surveying Departments) obtained assistance for their research projects through discussion with Section members and use of the School of Cosmic Physics library.

Broadband station at Valentia Meteorological Observatory

In February a PC for seismic data processing was installed at the Valentia Observatory and instruction given to M. O'Mahony and T. Sullivan in the use of the system. DIAS staff continued to provide technical support with visits in March and September. Data from the station at Valentia is being archived with the DIAS network data.

Broadband digital seismic station DSB
Major repair work was completed on the DSB station during the year after faults developed on several of the circuit boards. J. Schutte, from Potsdam spent four days in August on the repairs which were successfully completed. The station data continues to be both sent to Potsdam and archived on CDROM in DIAS.

4 RESEARCH ACTIVITIES IN THE ASTRONOMY SECTION

4.01 IRAS galaxies at high energies

E.J.A. Meurs, J. Cunniffe and L. Norci with A. Antonelli (Rome Observatory, Monte Porzio), K. Koyama and H. Awaki (Kyoto)

Spectral analyses covering the 1--10 keV (X-ray) region of the electromagnetic spectrum can in many instances establish the relative importance of two components that often contribute to the total X-ray output of galaxies: stellar evolution products and hidden active nuclei. These components are particularly relevant to be investigated for so-called IRAS galaxies, in which strong starformation takes place. The spectral analyses for a selection of IRAS galaxies have been progressing during the year, using data from the ASCA and SAX satellite observatories. The detailed investigation of one particular IRAS galaxy (NGC 3147) was continued. Three separate observations obtained with the ROSAT satellite High Resolution Imager were aligned and superposed in order to achieve better signal-to-noise and the data from the ROSAT and SAX satellites were checked for any temporal variability. The earlier conclusion that most of the X-ray emission from this galaxy is to be ascribed to starburst activity remains unchanged.

4.02 Searching for active cores in Local Group galaxies

Z. Zang and E.J.A. Meurs

Several points regarding the extensive search for high-energy signatures of active central cores in the closest galaxies were finalized. The idea behind this project is that in members of the Local Group of galaxies immediately around the Milky Way any such active cores can be revealed down to lower luminosities than can be reached for galaxies farther away. Our survey of Local Group members has indicated that only in four of the largest systems in the Group signs of nuclear activity can be found, judged from X-ray observations; these four are candidate massive Black Holes. For one of these, the Andromeda Nebula satellite M32, a new high-resolution X-ray observation was examined. The same X-ray source extension could be established for M32 that had enabled us to interpret this source as a possible weakly active nucleus.

4.03 Long-term variability of nuclear X-ray sources in galaxies

J. Cunniffe and E.J.A. Meurs

Data reduction work continued on the elliptical galaxy NCG 4552, which had shown an increase in brightness of a factor five followed by a decay back to its previous level in Hubble Space Telescope ultra-violet data, during the ROSAT PSPC observation period June 1990 -- October 1994. This may have been the result of the disruption of a star on a close flyby of the galactic nucleus. The stellar debris is expected to fuel a central massive Black Hole, which would notably lead to an increase of X-ray emission due to a short-term accretion disk being formed and high-energy radiation being visible for this duration. After analysis of data from the ROSAT satellite, this work has now been extended to cover also available data from the ASCA, EXOSAT and Einstein satellites. A particular effort has been put into separating a possibly variable unresolved component in the nucleus from a non-varying extended component associated with the body of the galaxy. Indications for a mild variability of the central component have been found.

A broad-based search for other such stellar disruption events has started as an automated archival research project. Data from the ROSAT, EXOSAT, Einstein and ASCA satellites are retrieved and analysed for a sizeable sample comprising the brightest galaxies (to magnitude 13). The central region of the programme galaxies naturally constitutes the focus of interest.

4.04 Opposite quasars

E.J.A. Meurs with E. Doherty (TCD)

Quasars are among the most luminous objects in the Universe that can be seen till the greatest observable distances. They constitute therefore valuable cosmological probes. One cosmological theory dealing with a multiply connecting Universe suggests that distant objects may be visible in two approximately opposite direction on the sky. Since one case of such an opposite pair of quasars had been mentioned in the literature as possible support for this theoretical hypothesis, a more general search for opposite pairs of quasars was undertaken. Using existing catalogues of quasars, 52 candidate pairs emerged. These can be used for example for a study of their spectra, to look

for any special spectral feature that both objects have in common and that would increase the likelihood that they belong together.

4.05 Interpretation of X-ray Hardness Ratios for galaxies

M. Carr and E.J.A. Meurs

For many sources detected with the ROSAT PSPC (Position Sensitive Proportional Counter) there are not enough counts to make reliable spectra (minimum of around 1000 counts required). As an alternative to spectra one may calculate two hardness ratios (HRs), defined as ratios of photons in selected softer and harder bands of the spectra. Unfortunately it is not possible to calculate directly from these hardness ratios the amount of line-of-sight absorbing material (N_H), which is a quantity of interest when studying the Large-Scale distribution of galaxies in the Universe. As a tool for obtaining the quantity of N_H from Hardness Ratio plots, spectra are modelled for galaxies (assuming power law spectra) with a range of values of absorbing material N_H and photon index γ. These simulations yield a well defined grid of points for N_H and γ values for a diagram of HR1 versus HR2. HRs calculated from observations can then be compared with the grid of HRs to determine, or set limits on, the amount of N_H present. This grid is being applied to data from the near and far side of Voids in the Large Scale structure of galaxies to search for evidence of processed gas in the Voids. This application is currently being extended to ROSAT data on a basic selection of galaxies in general.

4.06 High-energy studies of starforming regions in extragalactic context

L. Norci and E.J.A. Meurs

Many types of starforming regions are encountered among the extragalactic objects. Recently it has become possible to study such regions at X-rays with appreciable spatial and spectral resolution. At these high energies interesting information can be retrieved about the evolving stellar population and its interaction with the ambient Interstellar Medium. A novel approach to interpreting such data is the development of a population synthesis computer programme that monitors the X-ray active phases for each individual star (and each binary) while the stellar population evolves.

Several computational improvements were made to the population synthesis programme. The description of the important evolved stages of massive stars was updated by incorporating the latest stellar evolution scenarios. The simulation of binary systems was added to the programme and a start was made with including their special evolution histories. Tests have been run on the stellar population of the giant starforming region 30 Doradus in the Large Magellanic Cloud, using published observational data; various possible conditions for the starforming process were established.

4.07 The Einstein EMSS galaxy clusters

L. Norci and E.J.A. Meurs with H. Böhringer, R. Treumann, W. Voges (MPE, Garching) and H. Ebeling (Hawaii)

During the Einstein X-ray satellite Extended Medium Sensitivity Survey, 835 serendipitous sources have been detected, of which 105 were recognised as clusters of galaxies. The ROSAT All Sky Survey offers for the first time the opportunity of a direct evaluation of the extension and shape of the X-ray emitting region. This allows sensible measurements of the source extension and the background contribution. In particular, the EMSS cluster sample contains several distant clusters with low brightness distributions for which the definition of extension and background are crucial for flux determination.

The catalogue of the EMSS clusters has been updated including recent literature and the determinations of source morphology, energy flux and luminosity as well as spectral Hardness Ratios have been adjusted accordingly. An extensive literature search was carried out in order to check for any apparent source components that could be due to foreground or background objects.

4.08 Studies of WO stars

L. Norci with V.F. Polcaro, R. Viotti (IAS, Frascati) and C. Rossi (Istituto Astronomico Universita' di Roma)

Among the massive stars, the Wolf-Rayet stars represent an advanced stage of evolution, generally believed to be descending from the luminous and massive O stars. Notable emission lines signifying the atomic elements N, C or O have led to subtypes WN, WC and WO. The prevalence of these spectral emission lines is connected with the production of these elements by nucleosynthesis in the stellar interiors. Generally these stars exhibit very strong winds from their surfaces and experience correspondingly high mass loss.

On-going work on the spectral classification of WC and WO stars focussed on the contribution of the element helium (He) to one speecific spectral feature. The blend at 465 nm consists of lines of CIII and CIV, with an additional He line that increases in strength over the WC and WO spectral classes, as the stellar temperature increases. Together with line width data the observed behaviour can be related to different height layers in the stellar winds from these stars where the emission lines are formed. Other aspects of the spectral classification of WC and WO stars that were investigated refer to the influence of binarity and of

metallicity of the stellar population in which they occur.

The likely X-ray emitting system BD+37^o ~1160/4U ~0515+38 was examined with X-ray data from the EXOSAT and ROSAT satellites. The EXOSAT data yield a detection that provides a much smaller error box than the original data for this source from the Uhuru satellite and confirm the star BD+37^o ~1160 as optical counterpart. As optical spectra indicate, this is a new Be/X-ray system. The ROSAT data do not give a detection, confirming the transient nature of the source. The X-rays would be emitted when a companion Neutron Star (or possibly White Dwarf) passes in its orbit close to the optical star and interacts with circumstellar material (disk, shell, wind).

Another example of an advanced evolutionary stage of a massive star was studied with the variable star BC Cygni. This is a red supergiant, a class of stars about which relatively little is known. The red supergiants represent a crucial stage in the evolution of massive stars preceding the Wolf-Rayet and Supernova phases, according to the most recent stellar models experienced by stars with initial masses between 10 and 40 solar masses. For masses below 20 solar masses the stars end up as type II Supernovae; above this mass will end their lives as type Ib/Ic Supernovae, after passing through a Wolf-Rayet phase. A start was made with examining the group's optical spectra of this star, in order to look for evidence of so-called s-elements as recently had been discovered in another star of this type. The s-elements are products of nuclear reactions by which neutrons are added to atomic nuclei. With spectra available for another couple of red supergiants, an interesting comparison can be made in one of these cases with a similar type object that occurs in a substantially older cluster of stars and accordingly probably is an object of smaller mass.

4.09 The origin of runaway stars

E.J.A. Meurs, G. Fennell and L. Norci

Some of the young massive stars appear to have left their places of birth at great speed, as "runaway" stars. This may have been caused either by being part of a binary system of which one member exploded as Supernova or by strong gravitational interactions with other massive stars during an early stage shortly after their birth when they were very close together. If they are post-Supernova binaries, then the expectation is that they are accompanied in many cases by the Neutron Star that was formed at the explosion. Analysis of high-energy data, which should reveal the presence of such condensed companions, has been extended to include a completer coverage of known runaway stars for which ROSAT data are available. Also for this enlarged sample, no evidence is found for the anticipated X-ray sources corresponding to Neutron Stars. Whether this implies that gravitational ejection from dense stellar groups is the more likely mechanism for producing the runaway stars or that other factors are of influence (for example more frequent break-up of binaries during Supernova explosion than currently assumed) is not yet clear at this moment.

4.10 Optical Monitoring Camera for INTEGRAL (the INTErnational Gamma-Ray Astrophysical Laboratory)

B.D. Jordan, M. Smyth and E.J.A. Meurs with B. McBreen (UCD) and F. Quilligan (UCD)

The Electrical Ground Support Equipment (EGSE) for the Optical Monitoring Camera (OMC) onboard the ESA INTEGRAL satellite was returned to Dublin from Madrid to carry out modifications to the "house-keeping" system. The modifications included a monitor for four extra thermistor probes installed in the OMC telescope sunshield. This work involved redesigning and replacing the current sources for all of the temperature probes. A 500 Watt D.C. power supply was provided to power the focal plane and baffle heater elements and instrument cover independently of the spacecraft power supply during tests of the Qualification and Flight models.

A cable "break-out box" was built at Dunsink to facilitate external monitoring of voltage and current characteristics for each signal and supply line to the Focal Plane Assembly. The break-out box includes special connectors and a high-speed digital oscilloscope to enable the detection and recording of electrical glitches and "out of spec" signal levels. The completed equipment was delivered to INTA, Madrid, in October and integrated with the imaging Electrical Ground Support Equipment. After inspection and acceptance tests the equipment was reinstalled in the INTA clean room laboratory and was used for the acceptance tests of the OMC Qualification and Flight models.

A revised edition of the full documentation set for the CCD, the Focal Plane Assembly, the imaging EGSE and the house-keeping EGSE was prepared and submitted to the INTEGRAL documentation library.

5 FACILITIES

5.1 Computers and Network

Astronomy Section An underground fibre optic cable was laid between Dunsink House and the Observatory main building. The cable is terminated in an eight port Ethernet hub to provide access to the Dunsink LAN for the computers installed in the main building. A colour ink jet printer and scanner were installed in the Dunsink

computer room and are available for general use. The LAN server, Ethernet switch, UPS and modems have been mounted in an equipment rack and relocated to a "server room" on the ground floor of Dunsink House. Major damage to the LAN and the telephone system occurred during a thunderstorm in May. The Ethernet switch, modems and several Ethernet interface cards had to be replaced. Extensive repairs to the telephone system were carried out. New lightning barriers have been fitted to the external telephone and modem lines.

Astrophysics Section and Geophysics Section The radio link to HEAnet continued to give very reliable service throughout the year. Internally, as described last year, it is clear that the network needs upgrading. Surveys were carried out and estimates obtained in preparation for a switch from old coaxial to modern UTP cabling throughout number 5 Merrion Square; this was then included as a capital item in the estimates submitted for 2001.

The existing stock of PCs and workstations was maintained and slightly expanded during the year. This involved the routine replacement of failing monitors, power supplies and fans as required as well as the installation of two new 73GB discs to provide additional storage capacity and replace old discs which were showing sporadic errors. A high capacity HP4500 laser colour printer was installed as the main colour printer for A4 output. In addition two new laptops, a LCD projector and a high-end graphics workstation (a SGI Octane2) were purchased.

The major event of the year was the construction of a new Beowulf cluster with 32 processors housed in 16 dualprocessor rack-mounted machines. Tests revealed that performance under the FreeBSD operating system was about 10\% better than under Linux or Solaris and that peak performance was 10GFlops making it the fastest research system routinely available in Ireland. The system was officially switched on by the Minister for Science and Technology, Noel Treacy TD, as part of national science week. The old Beowulf cluster machines were reused, partially as a development and testing system, and partially as emergency replacements for servers in administration and Dunsink.

On the software side there were numerous upgrades to standard packages, including major upgrades to GCC and LaTeX. The astronomical package AIPS++ was installed for a summer student. Security continues to be a major area of concern; all supported OSs required security patches during the year. The new Windows 2000 operating system was installed on one PC. First impressions were generally favourable, but problems were experienced with the driver software for a HP scanner and with the Netscape web browser. A solution to the scanner problem was eventually found and posted on the net.

5.2 Nuclear Track Equipment

Comprehensive solid state nuclear track detector (SSNTD) preparation and etching facilities were maintained throughout the year in Track Lab #3. These facilities were optimised to the requirements of the final stages of the LDEF/UHCRE programme and for the continuation of the IRMA work. During April, an uninterruptible power supply (UPS) was installed in Track Lab #3 to protect critical operations in the event of power outages. The equipment selected was an APC (American Power Conversion) Smart-UPS XL type SU2200XLINET unit with two additional battery packs, type UXBP48, to provide extended-run power protection. During a mission critical etching application (typically running over five days) the etch tank monitoring computer plus agitation motor plus temperature control system consume a total of 735 watts and the UPS equipment can provide this power for more than ten hours. The effectiveness of this UPS system since installation has been excellent.

Etching equipment was maintained and serviced as necessary during the year. A new pumping system for sodium hydroxide solutions was installed. Replacement sub-systems or components for Etch Tank #1 included a new contact-thermometer unit and new agitation drive mechanisms. The high precision temperature control system was refurbished. Temperature stability continued to be better than $\pm$ 0.005 °C.

The six Leitz-ASL track measuring microscope stations, the Nikon-Heidenhain track measuring microscope station and the six Nikon stereo scanning microscope systems were also maintained and upgraded as necessary during the year. In particular, the fine focus displacement mechanism on one of the Leitz-ASL stations in Track Lab #2 was reconditioned and the upper optical components of another Leitz-ASL station were refurbished. In addition, a Nikon stereo scanning microscope system in Track Lab #2 was completely overhauled.

5.3 La Palma Observatory

5.3.1 La Palma Advisory Committee (LPAC)

No meetings of the La Palma Advisory Committee (LPAC) were held during the year.

5.3.2 Observing runs in 2000

No observing runs (PATT or otherwise) were supported financially during the year.

6 SEMINARS, COLLOQUIA, LECTURES

6.1 Statutory Public Lecture

M.A. Khan (Department of Geology, University of Leicester) delivered the Annual Statutory Public Lecture for the School of Cosmic Physics. The lecture was entitled *Rift Valleys – Do they fall, or are they pushed?* and took place at Trinity College Dublin (Ussher Theatre, Arts Block) on 15 November. Following the example set last year, this lecture was included in the programme for the National Science Week.

6.2 Seminars and Open Lectures in the School

C. Davis (Joint Astronomy Center, Hilo, Hawaii): *Serpens – the Big Picture. Wide-Field Observations of Star Formation in a Dark Cloud*, 13 January.

V. Dwarkadas (University of Sydney): *The Evolution of Supernova Remnants in Circumstellar Wind-blown Bubbles*, 30 May.

J.N. González Pérez (Instituto de Astrofisica de Canarias): *The Canary Island Blazar Monitoring Program: Variability Characteristics of OJ287*, 31 October.

T. Lery (DIAS): *Infall-Accretion-Ejection, how do they coexist during star formation?*, 02 November.

K-H. Mack (IRA Bologna): *Aspects of source evolution studies: Selected examples of recent results and on-going work on large extragalactic surveys*, l6 October.

M. Murphy (University of New South Wales, Australia): *Does the fine structure constant vary in spacetime?*, 21 March.

L. Norci (Dunsink Observatory, DIAS): *The EMSS clusters in the ROSAT All Sky Survey*, 2l November.

M. Wilkinson (IoA, Cambridge): *The masses of the dark halos of the Milky Way and Andromeda Galaxies*, 13 April.

W. Zeilinger (Institute of Astronomy, Vienna): *Physical properties of barred galaxies: the kinematical behaviour of multi-component systems*, 25 January.

In the series of informal internal seminars at Dunsink Observatory, the following talk was scheduled during the year:

G. Fennell (TCD), *An X-ray examination of runaway stars*, 12 July

6.3 Presentations to Scientific Meetings

S V Annibaldi: *Non-Gaussian Transport in Strong Plasma Turbulence* (poster paper), International Workshop "Chaotic Transport and Complexity", Carry le Rouet, France, 26-30 June.

T.A. Blake: *DIAS regional seismic network: Patterns of seismicity*, Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February.

J. Donnelly: *The Relative Abundance of Actinides in the Cosmic Radiation*, The 33rd COSPAR Scientific Assembly, Warsaw, Poland, 16-23 July; *The cosmic ray actinide charge spectrum derived from a 10m^2 array of solid state nuclear track detectors in earth orbit*, The 20th International Conference on Nuclear Tracks in Solids, Portoroz, Slovenia, 28 August – 01 September.

L Drury: Invited talk, *Diffusive shock acceleration in SNRs*, Gamma-2000 International Symposium on High Energy Gamma-Ray Astronomy, Heidelberg, Germany, 26-30 June; Two lectures, *Particle acceleration in astrophysics* and *Cosmic Rays in the Galaxy*, NATO Advanced Study Institute, Predeal, Romania, 27 August - 03 September.

J.A. Hodgson: *Geophysical modelling of the Leinster Granite*, Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; *Results of a wide-angle study of the Leinster Granite*, Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; *A wide-angle study of SE Ireland and the structure of the Leinster Granite*, American Geophysical Union 2000 Fall Meeting (FM2000), San Francisco, 15-19 December.

A.W.B. Jacob: *A detailed receiver function study of the Hawaiian Plume conduit*, American Geophysical 2000 Fall Meeting (FM2000), San Francisco, 15-19 December.

M.A. Khan: *The lithospheric structure of the Kenya Rift as revealed by wide-angle seismic measurements*, The first Stephan Mueller conference of the European Geophysical Society (EGS), "From Continetal Breakup to Collision", Grand Nirvana Hotel, Dead Sea, Israel, 11-16 June; *The deep structure of the Kenyan Rift from seismic, gravity and MT measurements*, The 31st International Geological Congress, Rio de Janeiro, Brazil, 06-17 August.

M. Landes: *VARNET-96: 3-D inversion of upper crustal seismic refraction data, SW Ireland*, Irish Geological Research Meeting, Cork, 25-27 February; *VARNET-96: A window on the Upper Palaeozoic*

evolution of southwest Ireland, Irish Geological Research Meeting, Cork, 25-27 February; *A model for Caledonian crustal intraplating, granite generation and syn-tectonic emplacement in SW Ireland*, Irish Geological Research Meeting**,** Cork, 25-27 February.

T. Lery : *Structure and Stability of MHD Jets*, Similarities and Universality in Relativistic Flows, Mykonos, Greece, 01-05 October; *A New YSO Outflow Model, Jet Simulations and Their Emission*; Emission Lines from Jet Flows, Isla Mujeres, 13- 17 November; *MHD Jets from Keplerian Rotators*, Emission Lines from Jet Flows, Isla Mujeres, Mexico, 13-17 November.

G.D. Makenzie: *RAPIDS 3: A wide-angle seismic study of the Rockall Trough*, The XXVII General Assembly of the European Seismological Commission, Lisbon, 10-15 September; *The structure of the Rockall Trough from wide-angle seismic profiling*, American Geophysical Union 2000 Fall Meeting (FM2000), San Francisco, 15-19 December.

E.J.A. Meurs: Two contributions, *An X-ray examination of runaway stars* and *Simulations of the X-ray output of evolving stellar populations*, Conference on "The influence of binaries on stellar population studies", Brussels, Belgium, 20-26 August.

L. Norci: *The HMXRB System BD+37^{o} ~1160/4U ~0515+38*, The 33rd COSPAR Scientific Assembly, Warsaw, Poland, 16-23 July; *WC/WO stars: a quantitative analysis of the influence of binarity and metallicity*, Conference on "The influence of binaries on stellar population studies", Brussels, Belgium, 20-26 August.

B.M. O'Reilly: *Slope instability features in the Rockall Trough, offshore Ireland*, Irish Geological Research Meeting, Cork, 25-27 February; *Carbonate mounds on the Porcupine Bank imaged with TOBI sidescan sonar*, ACES Workshop, Galway, 23 July; *Growth pattern of a carbonate mound population on the Eastern margin of the Rockall Trough, Offshore Ireland*, American Geophysical Union 2000 Fall Meeting (FM2000), San Francisco, 15-19 December.

D. O'Sullivan: *Investigation of Cosmic Rays and their Secondaries at Aviation Altitudes*, The 20th International Conference on Nuclear Tracks in Solids, Portoroz, Slovenia, 31 August; *Astronauts and Aircrew*, ESA Space Weather Workshop, ESTEC, Noordwijk, Holland, 12 December.

E. Parizot: *Galactic Cosmic Rays and the Light Elements*, The ISSI meeting on "The Astrophysics of Galactic Cosmic Rays", Bern, Switzerland, 15-19 May; *LiBeB production in Superbubbles and associated gamma-ray lines*, The 9th European and 5th Euro-Asian Astronomical Society Conference (JENAM 2000), Moscow, Russia, 29 May - 03 June.

T.P. Ray: *The Early Stages of Star Formation*, Alexander von Humboldt Foundation Meeting, Trinity College Dublin, 24 - 26 March; *Exploring the Central Engines of Young Stars*, Emission Lines from Jet Flows, Isla Mujeres, Mexico, 13-17 November.

P.W. Readman: *A proposed palaeo-valley trending north-west across Ireland of greater antiquity and normal to a Neogene tectonic activity and normal to a Neogene palaeo-drainage pattern*, Geological Society of London, Petroleum Group, "Exhumation of Circum-Atlantic Continental Margins: Timing, Mechanisms and Implications for Hydrocarbon Exploration", London, 13-14 June; *Changes in slope failure style along the eastern margin of the Rockall trough revealed by TOBI sidescan sonar*, American Geophysical Union 2000 Fall Meeting (FM2000), San Francisco, 15-19 December.

J. Walsh: *The design, construction and aims of the new DIAS parallel cluster*, Spring meeting of the Irish Association for High Performance Computing, UCC, Cork, 08 May.

Z. Zang: *An X-ray Search for Active Cores in Local Group Galaxies*, Astronomical Science Group of Ireland (ASGI) Spring Meeting, University College Dublin, 31 March.

6.4 External Seminars

S V Annibaldi: *Evidence for Stange Kinetics in Hasegawa-Mima Turbulent Transport*, Risoe National Laboratory, Risoe, Denmark, 18 January 2000; *Non-Gaussian Transport in Strong Plasma Turbulence*, Culham Science Centre, Culham, UK, 16 August 2000.

F. Bacciotti: *HST Spectroscopy of DG Tauri*, Armagh Observatory, 21 September.

L Drury: Colloquium, *The connection between interstellar dust and cosmic rays*, Forschung Zentrum, Karlsruhe, Germany, 09 May; Gentner seminar, *Prospects for the laboratory smulation of SNR physics*, Heidelberg, Germany, 10 May; Repeat seminar, *The connection between interstellar dust and cosmic rays*, Evora, Portugal, 23 May; Astrophysics seminar, *Interpreting the Cosmic Ray Composition*, Durham, England, 14 June;

T. Lery: *A New Model for Star Formation*, Observatoire de Paris, Meudon, France, 17 March; *Importance of the Magnetic Field During AGB and PN Phases*, GRAAL, Universite de Montpellier, 19 March; *Star Formation*, Observatoire de Lyon, 07 April; *Star Formation*, Observatoire de Marseille, 09 April; *Magnetic Fields in Astrophysics*, Institut d'Astrophysique Spatiale, Orsay, 19 May; Star Formation, Queen's University, Ontario, Canada, 21

June; *Formation of Planetary Nebulae*, Laboratoire d'Astrophysique de Montpellier, France, 11 October.

E.J.A. Meurs: *An X-ray search for active cores in Local Group galaxies*, Istituto di Radio Astronomia, Bologna, Italy, 10 January; *An X-ray search for active cores in Local Group galaxies*, Istituto di Astrofisica Spaziale, Italy, 12 January.

E. Parizot: *LiBeB nucleosynthesis and energetic particles*, Service d'Astrophysique, Saclay, France, 22 March; *LiBeB and Galactic chemical evolution*, DASGAL, Meudon, France, 23 March; *LiBeB nucleosynthesis and particle acceleration in superbubbles*, Institut de Physique Nucleaire d'Orsay, Orsay, France, 24 March.

T. Ray: *HST Imaging and Spectroscopy of Young Stars*, Department of Physics and Astronomy, University of New South Wales, Sydney, Australia, 07 April; *Early Days in the Life of a Star*, Department of Physics, University of Wollongong, New South Wales, Australia, 19 April.

6.5 Lecture Courses

L. Drury, E.J.A. Meurs and L. Norci together with colleagues from UCD and SPCM: Joint course of eight hours on *Topics in High-energy Astrophysics* at TCD during Michaelmas term.

E.J.A. Meurs: Lecture course of nine hours on *Stellar Dynamics* at TCD during Hilary term; Course of eight hours on *Physics of Galaxies* at TCD during Hilary Term. Guidance provided for 4th year TCD physics student.

L. Norci: Course of nine lectures on *Stellar Structure and Evolution* in TCD during Hilary term.

T.P. Ray: Lecture Course on the *Interstellar Medium* to Senior Sophister (final year) students at the Department of Physics, TCD, during Hilary Term.

L. Drury: Lecture Course 343 (*Astrophysical Gas Dynamics*) at the Department of Mathematics, TCD, during Michaelmas term.

6.6 Popular Lectures

I. Elliott: Presentation on *Teaching Junior Certificate Astronomy*, H.Dip.Ed. course, UCD, 15 February; *The History of Dunsink*, lecture to the Meath Archaeological Society, 04 June; *Celestial Fireworks*, lecture at the Millennium Festival of Science, Derry, 23 September; *The Fascination of Astronomy*, lecture to the Quest Group, Rathmines, 14 December.

G. Mackenzie: *Impact Cratering*, The Stirling Astronomical Society, Stirling, Scotland, 05 May.

E.J.A. Meurs: *The expanding view of our Universe during the 20th century*, Irish Astronomical Society, 21 February; *The expanding view of our Universe during the 20th century*, Tullamore Astronomical Society, 05 March.

D. O'Sullivan: *Science and Society*, the second in a series of six lectures at the Svedberg Laboratory, University of Uppsala, Sweden, 16 September.

T.P. Ray: *What Lies Between the Stars and Us?*, Millennium Cosmos Weekend, Tullamore, County Offaly, 04 March; *Exploring the Interstellar Medium*, Irish Astronomical Society, Dublin, 20 March; *How Stars and Planets Are Made*, Science Outreach Programme, University of New South Wales, Sydney, Australia, 14 April; *Exploring Other Worlds*, Presidential Address, Trinity Astronomical Society, Trinity College Dublin, 17 October.

7 LAUNCHES, ORGANISATION OF MEETINGS AND PUBLIC FACILITIES

7.1 Launch of New Parallel Cluster

The new UMa parallel cluster was officially switched on by the Minister for Science, Technology and Commerce, Noel Treacy TD, at a ceremony on 17 November in 5 Merrion Square. The Director of the School paid tribute to the vision, ability and enthusiasm of the former and current experimental officers in the Astrophysics section, Wai Ming Tai and John Walsh, without whom the cluster could not have been built. Two research associates of the School, C. Bean from UCD and T. Downes from DCU gave short presentations on the significance of the new cluster for their research. The Minister congratulated the School on its work and expressed the view that it should be more widely known.

7.2 Irish Astronomical Staff Meetings

Observational astronomical staff in Ireland met again twice during the year at Dunsink Observatory to discuss possible future observational facilities for Ireland. These meetings were held on 22 February and 05 December.

7.3 Dunsink Open Nights, Visitor Facilities and Public information

The interactive Visitors' Facility in Dunsink Observatory was actively used throughout the year for

demonstrations to groups (from schools and otherwise) and to visitors generally. Open Nights for the general public were held twice monthly during the winter half year, led by W. Dumpleton. Members of the Irish Astronomical Society provided organizational support on these evenings. Information services included, amongst other issues, viewing data for satellites, background to various celestial phemomena and precise timings for sunrise and sunset, Lighting Up Times, beginnings of seasons and changes between winter time and summer time.

The same thunderstorm in May that had caused damages to the Dunsink LAN and modems also affected the Exhibition Room control computer in the Observatory main building. All of the interfaces, transducers and remote control light switches for the control computer were replaced. The interconnecting cable harness from the control box to the computer was also replaced.

As a contribution to Science Week Ireland 2000 in November, the James South Refractor was on view to the public for several mornings and afternoons during that week.

8 EXTERNAL WORK

8.1 Astrophysics Section

S V Annibaldi: Concentrated Advanced Course on Le'vy processes, Centre for Mathematical Physics and Stochastics, University of Aarhus, Denmark, 24-28 January; Collaboration meeting (J.J. Rasmussen, V. Naulin et al), Risoe National Laboratory, Risoe, Denmark, 17-20 January; Collaboration meetings (K.I. Hopcraft), Theoretical Mechanics Division, School of Mathematical Sciences, University of Nottingham, Nottingham, UK, 03-07 April and 22-25 October; Collaboration meeting (R.O. Dendy and G. Manfredi), Culham Science Centre, Culham, UK, 14-18 August.

F. Bacciotti: Workshop on P Cygni, Armagh Observatory, 22 August; Collaborative Work on Star Formation, Armagh Observatory, 21 September.

J. Donnelly: The 33rd COSPAR Scientific Assembly, Warsaw, Poland, 16-23 July; The 17th European Cosmic Ray Symposium (ECRS2000), Lodz, Poland, 23-28 July; The 20th International Conference on Nuclear Tracks in Solids, Portoroz, Slovenia, 28 August – 01 September.

L Drury: APP Network meeting, Rowton Castle, England, 31 January - 03 February; Management Committee meeting, Armagh, 01 March; Collaboration with T. Mendonça, IST, Lisbon, Portugal, 04-09 March; Third International Conference on Laboratory Astrophysics with Intense Lasers, Houston, Texas. 28 March - 04 April; Collaboration with J. Kirk plus midterm review of network, MPI für Kernphysik, Heidelberg, Germany, 06-13 May; Colloquium, Forschung Zentrum, Karlsruhe, Germany, 09 May; Gentner seminar, Heidelberg, Germany, 10 May; ISSI (International Space Science Institute) workshop on "Astrophysics of galactic cosmic rays", Berne, Switzerland, 14-21 May, APP (AstroPlasmaPhysics) Network meeting plus seminar, Evora, Portugal, 21-25 May; Management Committee meeting, Armagh, 02 June; Discussions with the Durham gamma-ray astronomy group plus astrophysics seminar, Durham, England, 14 June; HESS consortium meeting plus gamma-2000 international symposium, Heidelberg, Germany, 24 June - 01 July; Invited talk, Heidelberg, Germany, 27 June; Secondment to CEA Saclay (minus two weeks holiday), 05 July - 24 August; NATO Advanced Study Institute, Predeal, Romania, 27 August - 03 September; NOC meeting for Hamburg ICRC, Hamburg, Germany, 13-15 September.

E. Flood: DOSMAX Meeting and Detector Calibration Exposures at CERN, 27 July - 01 August; Calibration Exposures at the Svedberg Laboratory, Uppsala, Sweden, 13-19 September.

T. Lery: Observatoire de Paris Meudon and University of Marseille, France, 23 March – 08 April; Star Formation project, Kingston, Ontario, Canada and Rochester University, New York, USA, 17 June - 11 July; CNRS School on Star Formation and Young Star Physics, Aussois, France, 16-22 September; Similarities and Universality in Relativistic Flows (SURF 2000), Mykonos, Greece, 29 September – 08 October; Emission Lines from Jet Flows, Isla Mujeres, Mexico, 13-17 November.

D. O'Sullivan: Institute of Physics Meeting, London, 19-22 January; Institute of Physics, Spring Weekend Meeting, Adare, Limerick, 14-16 April; Space Weather Meeting, Nice, France, 25-30 April; ESA Space Weather Working Team meeting, Noordwijk, Holland, 04-06 July; DOSMAX Meeting and Exposures at CERN, Switzerland, 26 July - 01 August; The 20th International Conference on Nuclear Tracks in Solids, Portoroz, Slovenia, 26 August - 09 September; Calibration Exposures at the Svedberg Laboratory, Uppsala, Sweden, 13-19 September; Space Weather Working Team meeting, Paris, France, 11-14 November; Space Weather Working Team meeting, Noordwijk, Holland, 11-14 December .

E. Parizot: APP network workshop, Rowton, UK, 30 January –03 February; ISSI meeting on "The Astrophysics of Galactic Cosmic Rays", Bern, Switzerland, 15-19 May; The 9th European and 5th Euro-Asian Astronomical Society Conference (JENAM 2000), Moscow, Russia, 29 May - 03 June.

T.P. Ray: Joint Irish Telescope Initiative, Armagh Observatory, 28 January; Alexander von Humboldt Foundation Meeting, Trinity College Dublin, 24-26 March; Department of Physics and Astronomy, University of New South Wales, Sydney, Australia, 01 April – 07 May; Department of Astronomy, University of Cardiff, Wales and PATT, Swindon, England, 06–11 June; International Astronomical Union General Assembly and IAU Symposium 202, University of Manchester, England, 06-20 August; Astronomical Science Group of Ireland, Queen's University Belfast, 08 September; Thesis examination, Department of Astronomy, University of Cardiff, Wales, 02-03 November; Emission Lines from Jet Flows, Isla Mujeres, Cancun, Mexico, 13-17 November; Irish Radio Telescope Proposal, Birr, 20 December.

J. Walsh: Spring meeting of the Irish Association for High Performance Computing, University College Cork, 08 May; System Administrators Network two day conference, Maastrict, Holland, 23-25 May.

8.2 Geophysics Section

T.A. Blake: Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; The XXVII General Assembly of the European Seismological Commission, Lisbon, Portugal, 10-15 September; American Geophysical Fall Meeting (AGU FM2000), San Francisco, 15-19 December.

J.A. Hodgson: Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; The XXVII General Assembly of the European Seismological Commission, Lisbon, Portugal, 10-15 September; American Geophysical Fall Meeting (AGU FM2000), San Francisco, 15-19 December.

C. Horan: Gravity tutorial at Dublin Institute for Technology, Bolton Street, Dublin, 14 March; Survey Ireland Conference, Malahide, Co. Dublin, 11-12 May.

A.W.B. Jacob: The XXVII General Assembly of the European Seismological Commission, Lisbon, Portugal, 10-15 September; Hawaii project discussions, Potsdam, Germany, 12-14 December.

M.A. Khan: The 31st International Geological Congress, Rio de Janeiro, Brazil, 06-17 August.

M. Landes: Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February.

K. McGrane: Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February.

G. Mackenzie: Valenetia Meteorological Observatory, 02-04 February; Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; RSG (Rockall Studies Group) Technical Forum, Dublin, 29 March; RAPIDS-3 data processing, Hamburg, Germany, 12-16 June; The XXVII General Assembly of the European Seismological Commission, Lisbon, Portugal, 10-15 September; American Geophysical Fall Meeting (AGU FM2000), San Francisco, 15-19 December.

B.M. O'Reilly: Seminar on The Irish Seabed Survey, Geological Survey of Ireland (GSI), Beggars Bush, Dublin, 20 January; European Science Foundation Workshop, EUROMARINS, Sitges, Barcelona, Spain, 26-29 February; Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; RSG (Rockall Studies Group) Technical Forum, Dublin, 28-29 March; Geological Society of London, Workshop on Atlantic Continental Margins, London, 13-14 June; ACES Workshop, Galway, 23 June; Reflections and Soundings: 40 years of Geophysics in Africa and Ireland, Galway, 23-24 June; RSG (Rockall Studies Group) Meeting on rock drill locations, Dublin, 26 July; ERDAS Users Group Meeting, Cambridge, England, September 19-20; Seabed Survey Seminar, Dublin, 17 November; Porcupine Studies Group Meeting, University College Dublin, 05 December; American Geophysical Fall Meeting (AGU FM2000), San Francisco, 15-19 December.

L. Quigley: Valentia Meteorological Observatory, 02-04 February, 07-08 March and 27-29 September; Survey Ireland Conference, Malahide, Co. Dublin, 11-12 May; GIS Ireland meeting (IRLOGI), Malahide, Co. Dublin, 17 October; Hawaii fieldwork, 23 October - 11 November.

P.W. Readman: Seminar on The Irish Seabed Survey, Geological Survey of Ireland (GSI), Beggars Bush, Dublin, 20 January; Irish Geological Research Meeting (IGRM-43), Cork, 25-27 February; RSG (Rockall Studies Group) Technical Forum, Dublin, 28-29 March; Geological Society of London, Workshop on Atlantic Continental Margins, London, 13-14 June; ACES Workshop, Galway, 23 June; Reflections and Soundings: 40 years of Geophysics in Africa and Ireland, Galway, 23-24 June; RSG (Rockall Studies Group) Meeting on rock drill locations, Dublin, 26 July; ERDAS Users Group Meeting, Cambridge, England, September 19-20; Seabed Survey Seminar, Dublin, 17 November; Porcupine Studies Group Meeting, University College Dublin, 05 December; American Geophysical Fall Meeting (AGU FM2000), San Francisco, 15-19 December.

G. Wallace: Hawaii fieldwork, 23 October - 11 November.

8.3 Astronomy Section

E.J.A. Meurs: Osservatorio Astronomico di Roma, Rome, 16 May - 03 June; Conference on "The influence of binaries on stellar population studies", VU

Brussels, Belgium, 20-26 August; Osservatorio Astronomico di Roma, Rome, 10-27 September.

L. Norci: Istituto di Astrofisica Spaziale, Rome, 12-22 March; Astronomical Science Group of Ireland (ASGI) Spring Meeting, UCD, 31 March; Conference on "The influence of binaries on stellar population studies", VU Brussels, Belgium, 20-26 August.

B. Jordan: OMC (Optical Monitoring Camera) and OMC Electrical Ground Support Equipment (EGSE) and non-conformance review meeting, INTA, Madrid, 09-11 February; Delivery and acceptance test of modified Electrical Ground Support Equipment, INTA, Madrid, 19-21 July; Delivery and acceptance test of OMC Flight Model and Delivery Review Board meeting, INTA, Madrid, 09-12 October; Meeting of Irish radio telescope group, Birr, 20 December.

I.Elliott: Astronomical Science Group of Ireland (ASGI) Spring Meeting, UCD, 31 March; ASGI Autumn Meeting, Queen's University, Belfast, 08 September; Physics Teaching Fair, CERN, Geneva, 06-10 November.

J. Cunniffe: Workshop "Observing with INTEGRAL", The INTEGRAL Science Data Centre, Les Diablerets, Switzerland, 27 March - 01 April; Astronomical Science Group of Ireland (ASGI) Autumn Meeting, Queen's University, Belfast, 08 September.

M. Carr: Astronomical Science Group of Ireland (ASGI) Spring Meeting, UCD, 31 March; European Space Agency Summer School "Extragalactic Astronomy and Cosmology from Space", Alpbach, Austria, 18-27 July; ASGI Autumn Meeting, Queen's University, Belfast, 08 September.

Z. Zang: Astronomical Science Group of Ireland (ASGI) Spring Meeting, UCD, 31 March.

9 MISCELLANEA

L.O'C. Drury continued to serve as Vice-Chairman of the *Commission on Cosmic Rays* of the International Union of Pure and Applied Physics and as the DIAS representative on the National Committee for Astronomy and Space Science of the Royal Irish Academy.

A.W.B. Jacob retired as Chairman of the National Committee for Geodesy and Geophysics of the Royal Irish Academy, and continued as convenor and as a member of that committee. He also continued as a Research Associate of University College Dublin.

E.J.A. Meurs advised the Trinity Astronomy and Space Society as Honorary President. He further served on the National Committee for Astronomy and Space Science of the Royal Irish Academy and as Chairman on the La Palma Advisory Committee.

D. O'Sullivan continued to serve as Chairman of the Institute of Physics in Ireland until 16 April, when he presided over the annual Spring Meeting at Adare in Co Limerick.

P.W. Readman was elected as Secretary to the National Committee for Geodesy and Geophysics of the Royal Irish Academy. He also continued as a Research Associate of University College Dublin.

T.P. Ray served as the DIAS representative on the RIA *National Committee for Physics* and as a member of the *MERLIN Time Allocation Group* within the Panel for Allocation of Telescope Time (PATT). In addition he was elected President of the Trinity College Astronomical Society.

D. O'Sullivan was elected an Honorary Fellow of the International Nuclear Track Society for his contribution to nuclear track physics and its application to cosmic radiation, at a special ceremony in Portoroz, Slovenia, in August.

I. Elliott continued as a member of the National Committee for Science and Engineering Commemorative Plaques and as a member of the Science and Technology Committee of the Royal Dublin Society. He also continued as Chairman of the Irish Science Centres Association Network which held meetings in Birr (14 April) and at the National Botanic Gardens in Glasnevin (07 October).

D. O'Sullivan continued as chairman of the Ireland-CERN campaign committee initiated by the Royal Irish Academy. Several meetings took place with senior civil servants and others early in the year and close contact was maintained with CERN staff including the Director General. A document outlining a case for Ireland's membership of CERN was presented to the Director of the Office of Science and Technology (OST) at a meeting with his colleagues in May. A further meeting took place in October and this was attended by CERN representatives and representatives of OST, Forfas, IDA and Enterprise Ireland. Discussions and exchange of information are continuing.

In the Astrophysics Section D. Zhou successfully defended his PhD thesis (see section 10.3). The external examiner was L. Tommasino (Agenzia Nazionale per la Protezione dell'Ambiente (ANPA), Rome, Italy).

B. Jordan represented Dunsink Observatory at the funeral of Prof. H. Brück in Edinburgh, 11 March.

J.A. Hodgson won an "Outstanding Student Presentation Award" at the American Geophysical Union Fall Meeting (AGU FM2000, San Francisco, 15-19 December) for his presentation *A wide-angle study of SE Ireland and the structure of the Leinster Granite*.

D. O'Sullivan was invited by V. Perelygin of Dubna, Russia, to be the co-ordinator of a FSU-European proposal to INTAS, following a series of communications and a meeting in August in Portoroz. The document which was drafted and finalised at DIAS was submitted in October and proposes a search for super heavy elements (Z≥110) in nature using nuclear tracks in meteoric crystals, following the very significant advances in super heavy element production at Dubna in the last year or two. Successful proposals will be announced in Feb 2001.

I. Elliott's talk on "Exploring Space and Time" in the Thomas Davis series of lectures on "Science and Technology at the end of the 20th Century", originally broadcast on 03 May 1999, was repeated on RTE Radio-1 on 16 October. He also gave two interviews about Dunsink on Desmond McGuinness' local history programme on Phoenix FM; these were broadcast in October.

Dunsink Observatory prepared and manned a stand at an annual Science Fair of Enterprise Ireland in Leopardstown.

I. Elliott served as secretary to the National Steering Committee for Physics on Stage, a year-long programme under the auspices of CERN, ESA and ESO to identify innovative methods of teaching physics. The programme involved educators from 22 European countries and culminated in a Physics Teaching Fair at CERN, 06 -10 November. Ireland contributed a well-received musical performance by a group of seven physics students. In addition, eight delegates from Ireland participated in the presentations and workshops.

C. Horan continued to give a Gravity Practical and Tutorial to Geo-Surveying students at Dublin Institute for Technology, Bolton Street (14 March).

L. Quigley continued to edit *Survey Ireland* and the *Institute of Irish Surveyors News (IIS News).*

The Shortt Free Pendulum Slave Clock was restored to working order by J. Daly, B. Jordan and W. Dumpleton. The Master Pendulum leaf spring suspension mechanism had been damaged when the clocks were dismantled during building alterations. G. Daly has fabricated a replacement spring and restoration of the Master Pendulum is ongoing.

E. Whelan, Physics Department, TCD, was supervised by T.P. Ray from September to December for her final year astrophysics project using radio interferometer data from the Very Large Array (VLA) Archive.

Five Transition Year pupils spent a week each at Dunsink Observatory as part of their Work Experience programmes.

C. Townsend (Transition Year Student) worked with T.P. Ray on data conversion from 22 May – 02 June.

On 15 December, Mr Frank Prendergast, Head of the Department of Geomatics, DIT, Bolton Street, determined the position of the dome on the main building at Dunsink using a hand-held GPS receiver. The geodetic co-ordinates relative to the Ireland 1965 Datum are 53º 23' 13.7" N ± 0.5", 6º 20' 15.5" W ± 0.3".

An RTE television crew visited Dunsink on 10 May to film scenes involving the comedian Brendan O'Carroll, a native of Finglas.

I. Elliott prepared 16 certificates of Lighting-up Time and other astronomical information for legal purposes. Routine information on the positions of the Sun and Moon was supplied to architects, sporting organisations and film companies.

As a safety measure, OPW laid down heavy stone boulders around the perimeter of the paddock next to Dunsink House.

10 PUBLICATIONS

10.1 Refereed Publications

S V Annibaldi, G Manfredi, R O Dendy and L O'C Drury: *Evidence for strange kinetics in Hasegawa-Mima turbulent transport*, Plasma Physics and Controlled Fusion, Vol 42, pp L13-L22 (2000).

S. Appl, T. Lery and H. Baty: *Current-driven Instabilities in Astrophysical Jets. Linear Analysis*, Astron. Astrophys., Vol. 355, pp 818-828 (2000).

F. Bacciotti, R. Mundt, T.P. Ray, J. Eislöffel, J. Solf and M. Camezind: *Hubble Space Telescope STIS Spectroscopy of the Optical Outflow from DG Tauri: Structure and Kinematics on Sub-arcsecond Scales*, Astrophys. J. Letters, Vol. 537, pp L49-L52 (2000).

V.M. Costa, M.T.V.T. Lago, L. Norci and E.J.A. Meurs: *TTauri stars: the UV/X-ray connection*, Astron. Astrophys., Vol 354, pp 621-635 (2000).

K. Cunha, V.V. Smith, E. Parizot and D.L. Lambert: *Light-Element Abundance Patterns in the Orion Association. I. Hubble Space Telescope Observations*

of Boron in G Dwarfs, Astrophys. J., Vol 543, pp 850-860 (2000).

C.J. Davis, A. Chrysostomou, H. E. Matthews, T. Jenness and T.P. Ray: *Submillimeter Polarimetry of the Protostellar Outflow Sources in Serpens with the Submillimeter Common-User Bolometer Array*, Astrophys. J. Letters, Vol. 530, pp L115-L118 (2000).

M E Dieckmann, K G McClements, S C Chapman, R O Dendy and L O'C Drury: *Electron acceleration due to high frequency instabilitites at supernova remnant shock* , Astron. Astrophys., Vol 356, pp 377-388 (2000).

L.O'C. Drury and J.T. Mendonça: *Explosion Implosion Duality and the Laboratory Simulation of Astrophysical Systems*, Physics of Plasmas, Vol 7, pp 5148-5152 (2000).

J. Eislöffel, R. Mundt, T.P. Ray and L. F. Rodrìguez: *Collimation and Propagation of Stellar Jets*, Protostars and Planets IV (University of Arizona Press), eds. V. Mannings, A.P. Boss and S.S. Russell, pp 815-840 (2000).

A. Frank, T. Lery, T.A. Gardiner, T.W. Jones, and D. Ryu: *The Propagation of Magneto-Centrifugally Launched Jets: I*, Astrophys. J., Vol 540, pp 342-361 (2000).

W. Geissler, T. Plenefisch, R. Kind, K. Klinge, H. Kämpf, A. Bouškova, V. Nehybka, Z. Skácelová and B. Jacob: *The Moho strucure in the western Eger Rift: a receiver function experiment*, Studia geoph. et geod., Vol 44, pp 188-194 (2000).

M. Landes, C. Prodehl, F. Hauser, A.W.B. Jacob and N.J. Vermeulen: *VARNET-96: influence of the Variscan and Caledonian orogenies on crustal structure in SW Ireland*, Geophys. J. Int., Vol 140, pp 660-676 (2000).

T. Lery, H. Baty and S. Appl: *Current-driven Instabilities in Astrophysical Jets. Non Linear Development*, Astron. Astrophys., Vol 355, pp 1201-1208 (2000).

T. Lery and A. Frank: *Structure and Stability of Keplerian MHD Jets*, Astrophy. J., Vol. 533, pp 897-910 (2000).

E.J.A. Meurs: *Prospects for extragalactic research with big telescopes*, Irish Astron. J., Vl 27, pp 35-36 (2000).

D. O'Sullivan: *Cosmic Rays and Their Influence on Aircrew*, Radiation Research, Vol 2, pp 713-718 (2000).

D. O'Sullivan, D. Bartlett, R. Grillmaier, W. Heinrich, L. Lindborg, H. Schraube, M. Silari, L. Tommasino and D. Zhou: *Investigation of Radiation Fields at Aircraft Altitudes*, Radiation Protection Dosimetry, Vol 92 (Nos 1-3), pp 195-198 (2000).

S. O'Sullivan and T.P. Ray: *Numerical Simulations of Steady and Pulsed Non-adiabatic Magnetised Jets from Young Stars*, Astron. Astrophys., Vol 363, pp 355-372 (2000).

E. Parizot: *Superbubbles and the Galactic evolution of Li, Be and B*, Astron. Astrophys., Vol 362, pp 786-798 (2000).

E. Parizot and L. Drury: *Bimordal production of Be and B in the early Galaxy*, Astron. Astrophys. Vol 356, pp L66-L70 (2000).

T.P. Ray: *The Environment of Young Stars*, Laser Guide Star Adaptive Optics for Astronomy (Kluwer Academic Publishers, Dordrecht), eds. N. Ageorges and C. Dainty, pp 263-284 (2000).

T.P. Ray: *What Drives Molecular Outflows from Young Stars?*, Astrophys. Space Science, Vol 272, pp 115-125 (2000).

V. Unnithan, P.M. Shannon, A.W.B. Jacob, P.W. Readman and R. Keary: *Reconnaissance survey of the Irish continental shelf/shelf edge (AIRS '96)*, Marine Resource Series, No. 12, 33pp (2000).

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11 REVIEW AND STRATEGIC PLANNING

11.1 External Review

It is the policy of the School of Cosmic Physics Board to commission an external evaluation of the work of the School by an expert panel every five years, to coincide roughly with the handing over from one Board to the next. Such a quinquennial review was due in 2000 and took place on 07 and 08 February under the Chairmanship of Prof Malcolm Longair from the University of Cambridge. The other members of the expert review group were Professor Jacqueline Bergeron, European Southern Observatory; Professor Roger Davies, University of Durham; and Prof Nicholas Kusznir, University of Liverpool. The group were generally complimentary about the work of the School, but expressed serious concern about accommodation and staffing problems as well as a lack of clear leadership. They strongly advocated the development of a more active, strategic and science-driven approach to the management of the School. The full report is attached as an appendix to this annual report.

11.2 Strategic Planning

A considerable amount of time was devoted during the year to the discussion of strategy. The first strategic plan of the school, produced in 1999, was recognised as unsatisfactory in many ways although it did provide a useful starting point. At Institute level a facilitator was employed by Council to help prepare an overall Institute strategy. In parallel with this the School, following the strong recommendation of the Longair review, worked on a detailed School Strategy which was science driven and set out clear goals and benchmarks for the next five years. These discussions took much of the year, but by December a consensus had been reached within the School on the science objectives for the next five years and, although details still had to be resolved, the outline of an overall Institute strategy within which the School strategy could be implemented was beginning to take shape.