The Armagh Observatory Business Plan 2008/2009

Business Plan for Period 2008 April 1 to 2009 March 31

Prepared by the Director

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Executive Summary

Organization and Funding The Armagh Observatory is the oldest scientific institution in Northern Ireland, the longest continuously operating astronomical research institute in the UK and Ireland. There is a fluctuating population of some 20–25 academic staff which at the end of 2007 comprised 6 Research Astronomers and 18 other academic staff (including the director, several PDRAs and around a dozen PhD students), as well as 3 core research and 4.5 core grounds and administrative support staff. In addition the Observatory has an active visitors programme, hosting an average of around 15 temporary academic visitors from abroad each year who typically come for 1–3 weeks, and a further 4 PhD students are co-supervised by Observatory staff but based elsewhere.

The group operates on the international stage and is underpinned by core funding from DCAL. The total expenditure of the Observatory is in excess of £1M per year, of which approximately three-quarters is directed towards research: in 2006/2007, for example, £106.4k was spent on administration and corporate governance; £148.8k on buildings and grounds; and £782.6k on research and related outreach projects. Core DCAL funding has averaged approximately £660k per year over the last six years, whilst over the same period the DCAL has provided additional funding averaging around £150k per year in response to competitive bids for additional support for research, education and public outreach, technical equipment and infrastructure projects. The balance of income is made up primarily by external grants, which in recent years have averaged around £235k per year. In addition, the in-kind cost of the use by Armagh Observatory staff of UK central facilities has averaged a further £430k per year over the past ten years.

Research Infrastructure and Activity In order to carry out their work, staff require access to the highest level of technical equipment, continuously updated, including approximately 50 workstations and peripherals, and a computer cluster comprising 25 dual-processor work nodes and one master node with a total of 50 GB memory. The Observatory's high-quality technical equipment is complemented by a Library and Archives that is one of the premier specialist collections of its kind in the UK and Ireland. The archives contain a unique and growing collection of historic books and manuscripts, as well as scientific instruments, clocks and other artefacts related to the development of astronomy over more than two hundred years.

The meteorological archive contains the longest continuous daily climate series from a single site in the UK and Ireland. The climate station has been continuously maintained since 1795, with readings currently taken every day at 09:00 (GMT). Calibration of these data has enabled researchers and government departments to use the Armagh series for reports and research into global warming. This is a subject of significant strategic importance for Northern Ireland as we move into an era of rapid climate change. The Armagh Observatory's climate record provides a long historical baseline against which to judge how Northern Ireland's climate is responding to climate change world-wide.

The Observatory carries out front-line astronomical research in three key areas of astrophysics: Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics. These fields encompass the dynamical structure, evolution and origin of objects in the outer solar system; comparative planetology and meteor physics; the use of spacecraft such as SoHO, TRACE and Hinode, to study fundamental questions such as how the Sun's outer atmosphere is heated, what drives the solar wind and the Sun's variable magnetic activity (and its effect on climate); and a wide range of detailed investigations into the formation and evolution of stars, taking into account factors such as mass loss through stellar winds, stellar oscillations, stellar magnetic fields and extreme chemical abundances, and the impact of binarity (two stars orbiting closely around one another) on our understanding of the evolution of stars and galaxies. In particular, our multi-strand multi-wavelength approach to the discovery of ultra-compact binaries will provide crucial input for understanding the first detected gravitational wave events. These individual research programmes (and others not mentioned) together encompass the Observatory's long-term research function; they typically have lead times of a year or two and require up to 3–5 years for completion.

Outreach and Visitor Numbers In addition to its primary research function, the Armagh Observatory undertakes an active programme of Science in the Community, supported in the last two years by the Skills and Science funding package. Recent innovative projects have included construction of the Human Orrery (the first such exhibit in the world to be laid out with precision); involvement in the Royal Society's "Living with a Star" exhibition and related International Heliophysical Year (IHY) activities; organizing the first Cross-Border Schools Science Conference; and creating the first International Phenology Garden in Northern Ireland. Partly as a result of our active engagement with the community, the Observatory has regularly attracted more than 300 mass-media citations to its work per year; its web-sites attract more than 1.5 million unique e-visitors annually from around the world; and more than 40,000

people per year visit the landscaped Grounds and Astropark. The trends of some of these performance indicators are shown in Table 1 (see p.4).

Performance The Armagh Observatory has enjoyed considerable success during the past year, and indeed over a much longer time, with the overwhelming majority of key performance indicators exceeding prior-year targets and on ascending trajectories. The trends in the Observatory's performance are summarized in Table 1, Figure 1 (see p.3) and Figure 2 (see p.11), and Table 3 (see p.10).

Over the past number of years, as described in Section 1 (p.5), the Observatory has made very significant contributions to Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics. It is developing new research programmes in each of these areas, as well as other projects, which will be completed over the next 3–6 years.

Objectives for 2008/2009 The Armagh Observatory is a vibrant international research institute which plays a full role in international astronomy whilst developing and promoting the rich heritage of Northern Ireland astronomy and presenting an attractive and positive image of Northern Ireland on the international stage. The principal Business Plan objectives for 2008/2009 are to:

- obtain external grants and funding to support new research projects;
- strengthen the Observatory's research capacity and capability in Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics, by recruiting 3–4 PhD students and providing a high-quality research environment to facilitate the advanced training of such students at the beginning of their astronomical careers, and by playing a full role together with other academic partners in plans to upgrade NIRAN, and through this the Observatory's connection to the Internet (currently 10 Mbps); and
- advance plans for the design of a new Library, Archives and Historic Scientific Instruments building, partial funding for which has been provisionally identified within the DCAL indicative Capital budget from 2010/2011.

In addition, the Observatory plans to maintain its currently very active programmes of education and public outreach, and of Science in the Community, and to play a leading role in various public events both locally (e.g. contributing to the tercentenary of the birth of the Observatory's founder, Archbishop Richard Robinson) and on the island of Ireland (e.g. in co-organizing the Ninth European Symposium for the Protection of the Night Sky, to be held in Armagh from 17–20 September 2009), and farther afield (e.g. by playing a full and active UK-and-Ireland role in the International Year of Astronomy 2009).

Funding The issue of underfunding of the Armagh Observatory has been drawn to the attention of senior management and the DCAL repeatedly over the past number of years. At the beginning of 2008/2009 the Observatory faced what appeared to be an unprecedented situation in all its nearly 220-year history: that is, for the first time the announced grant-in-aid from the DCAL and the Observatory's Reserves were together insufficient to enable the Observatory to plan to the end of the financial year. The risk was not new: it had been brought to the attention of the DCAL frequently in the previous year and the problem had formed the basis for the CSR request for a sufficient step-increase in the Observatory's baseline funding (both Resource and Capital) to support the Observatory's core function of research in astronomy and related sciences. By significantly reducing outgoings for 2008/2009 (e.g. by one staff member volunteering to work part-time for the year and deferring some items of expenditure to future years, where possible), and with the support of an additional £35k transferred from the Armagh Planetarium and the commitment of a further £60k from the DCAL in-year, this critical risk has receded for another year and the Observatory is able to project a balanced budget for 2008/2009. This balanced budget, submitted to the DCAL on 2008 April 6 and subsequently approved for operational purposes, is shown in Table 4. Nevertheless, it should be emphasized that the funding difficulty identified as part of the CSR request for the present planning period remains, and strenuous efforts should be made to resolve the projected funding difficulties for 2009/2010 et seq.

The Armagh Observatory does not lightly request additional funding. Rather, it is a highly successful organization which with adequate funding for its needs is in a good position to make very significant contributions to the aims and objectives of the Northern Ireland government. The requested additional funding in years 2 and 3 of the planning period will enable the Observatory to discover new facts about the Universe and pursue new research projects, often in collaboration with other leading astronomical groups on the international stage. In addition, it will facilitate the development of new public outreach

projects as part of its Science in the Community programmes, and enable the Observatory to lay a strong foundation for explaining, exploiting and preserving the unique heritage in Armagh of more than two hundred years of astronomy. Thus, the provision of a sufficiency of funding for the Armagh Observatory to carry out its work will enable Armagh Observatory staff, as they have done in the past, to continue to achieve key DCAL targets and promote a positive image of Northern Ireland on the international stage, together with all the economic and societal benefits that entails.

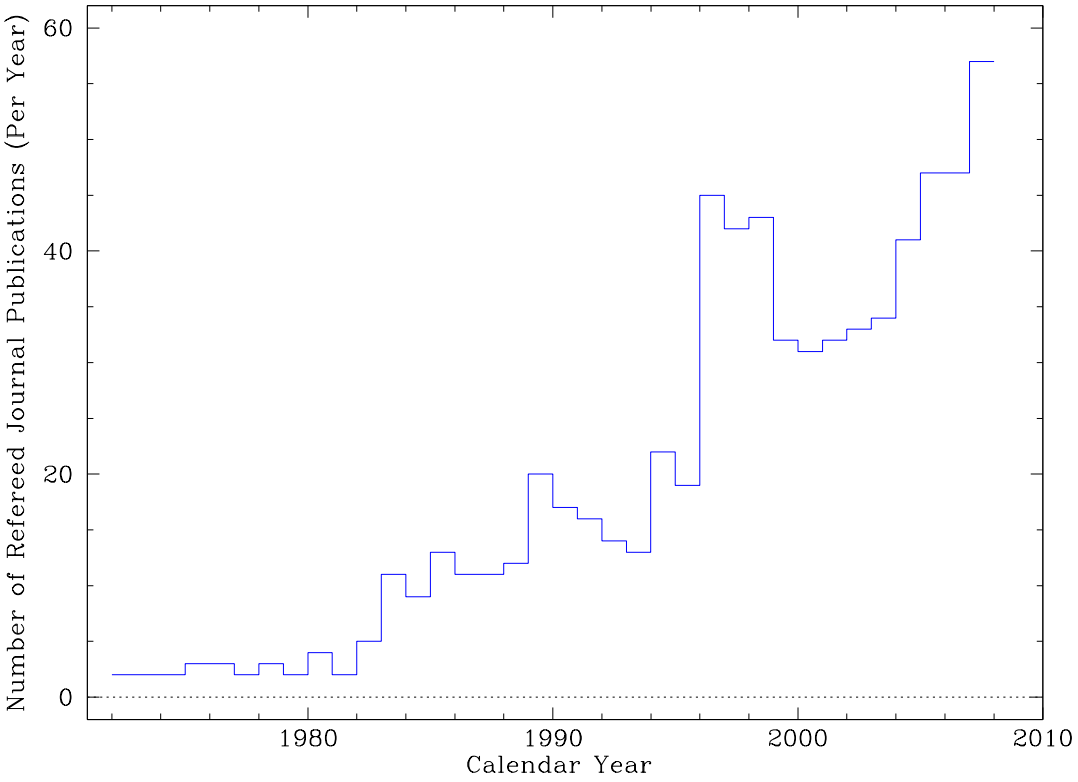

Figure 1: The number of refereed journal papers published by Armagh Observatory staff over the past thirty-five years for comparison with Key PI "Refereed Publications" illustrated in Figure 2 and Tables 1 and 3. Note how the Observatory's productivity has increased by a factor of approximately five during a period when the total funding in cash terms (i.e. making no allowance for inflation) has only doubled, a remarkable achievement.

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Calendar Year	DCAL Grant-in-Aid (£000s)				External Grant Income (£000s)		Refereed Scientific Journal Publications		Distinct e-Visitors (000s)		Identified Media Citations		RAE Grade	Days Absence Per Person Per Year	
	Core Revenue	Core Capital	Additional Funding	Total	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Actual	Target
1992	374.0	83.3	0	457.3			14						4		
1993	399.0	46.0	0	445.0	35.0		13								
1994	369.5	33.6	22.5	425.6	58.0		22				11				
1995	412.5	56.0	0	468.5	172.0		19				14				
1996	424.0	56.0	7.4	487.4	264.0		45				47		4	0.4	
1997	428.0	37.7	7.5	473.2	275.0		42		66		109			3.8	
1998	418.0	25.0	0	443.0	195.0		43		80		147			0.3	
1999	452.0	6.5	0	458.5	293.0	200	32	30	134	100	238	100		0.5	
2000	452.0	6.5	80.0	538.5	212.0	200	31	30	174	100	235	100		0.3	
2001	466.0	7.5	240.0	713.5	221.3	200	32	30	318	200	302	100	4	1.8	
2002	616.0	7.5	110.0	733.5	305.7	230	33	32	354	350	267	200		0.2	
2003	660.0	6.5	115.0	781.5	270.4	250	34	32	470	370	226	200		0.4	
2004	660.0	6.0	218.0	884.0	239.4	250	41	32	576	500	284	200		0.4	
2005	660.0	6.5	125.0	791.5	207.9	200	47	35	1012	400	349	200		0.4	13
2006	660.0	6.5	144.5	811.0	163.2	200	47	40	1539	1200	301	200		0.2	12
2007	660.0	6.5	202.5	869.0	200.0	300	57	45	1585	1800	325	250		0.5	11
2008	**817.0**	**25.0**	**95.0**	**937.0**		**300**		**50**		**1800**		**250**			**10**
2009	**817.0**	**25.0**	**162.5**	**1004.5**		**300**		**50**		**1800**		**250**			**10**
2010	**817.0**	**25.0**	**205.5**	**1047.5**		**300**		**50**		**1800**		**250**			**10**

Notes to Table of Historic Key Performance Indicators:

1. Financial figures refer to the corresponding financial year, so that Core Revenue funding for 2008 refers to the core revenue funding received in cash terms during 2008/2009 and so on. All other figures are per calendar year.
2. Total DCAL grant-in-aid received in cash terms during each financial year is broken down into Core Revenue, Core Capital and Additional Funding (both Revenue and Capital). In prior years the latter represents additional funding provided by the DCAL in response to competitive bids from the Observatory to support specific in-year projects and other activities (e.g. during 2006/2007 and 2007/2008 this included £125k and £175k for Skills and Science activities). The figure for 2008/2009 (£95k) is made up of £35k from the Planetarium and an additional £60k from the DCAL. **For future years it represents the required step-increase in core funding for the remaining two years of the three-year planning period**.
3. Figures for External Grant Income refer to external grant income received in cash terms during each financial year.
4. The Table includes the Absence Record for Armagh Observatory staff, defined as the ratio S/N, where S is the total number of days lost due to staff absence per calendar year, and N is the total number of staff in post at the end of the corresponding year. The Observatory's results are many times better than the best recorded in any government department; for example, DCAL absence targets for 2005/2006, 2006/2007 and 2007/2008, which refer to the percentage of working days lost, are 5.8%, 5.3% and 5.0%. Assuming 220 working days in a year, these targets correspond respectively to $S/N = 12.8$, 11.7 and 11.0.
5. Targets and/or requirements for calendar year 2008 or financial year 2008/2009 and beyond are expressed in round figures.

Table 1: Trends of Armagh Observatory performance indicators (PIs) versus calendar year. Table last updated 2008 July 31.

1 Organization and Research Environment

The Armagh Observatory is the oldest scientific institution in Northern Ireland (NI), one of the few non-university groups to participate in the Research Assessment Exercise (RAE). There is a fluctuating population of some 20–25 academic staff which at the end of 2007 comprised 6 Research Astronomers and 18 other academic staff (including the director, several PDRAs and around a dozen PhD students), as well as 3 core research and 4.5 core grounds and administrative support staff. For full details, see Table 2. In addition the Observatory has an active visitors programme, hosting an average of around 15 temporary academic visitors from abroad each year who typically come for 1–3 weeks, and a further 4 PhD students are co-supervised by Observatory staff but based elsewhere.

Year	Research Astronomers	Other Academic Research Staff	Core Research Support	Core Grounds and Admin.	External/Visitors and Others	Total
1998	5	17	3	5	4	34
1999	5	18	3	4	4	34
2000	5	16	3	4	5	33
2001	6	14	3	4	4	31
2002	5	14	3	5	3	30
2003	5	14	3	5	3	30
2004	5	18	3	5	4	35
2005	3	16	3	5	3	30
2006	3	16	3	5	4	31
2007	6	18	3	5	5	37

Table 2: The number of Armagh Observatory staff present in various categories at the end of each calendar year.

Technical equipment is excellent; the Observatory's access to the Southern African Large Telescope (SALT) encourages high-level contact with other organizations and collaboration with South Africa, and staff frequently obtain time on international telescopes, both ground-based and in space. The group has internationally recognized expertise in the growing field of polarimetry.

The Observatory is underpinned by core funding from DCAL, provided as part of a single joint grant to the Armagh Observatory and the Armagh Planetarium. The total expenditure of the Observatory is in excess of £1M per year (see Table 4, p.14), of which approximately three-quarters is directed towards research: in 2006/2007, for example, £106.4k was spent on administration and corporate governance; £148.8k on buildings and grounds; and £782.6k on research and related outreach projects. Core DCAL funding has averaged approximately £660k per year over the last six years, whilst over the same period the DCAL has provided additional funding averaging around £150k per year in response to competitive bids for additional support for research, education and public outreach, technical equipment and infrastructure projects. The balance of income is made up primarily by external grants, which in recent years have averaged around £235k per year. In addition, the in-kind cost of the use by Armagh Observatory staff of UK central facilities has averaged a further £430k per year over the past ten years.

1.1 Research Environment

Staff require access to the highest level of technical equipment, continuously updated, including approximately 50 workstations and peripherals, and a computer cluster comprising 25 dual-processor work nodes and one master node with a total of 50 GB memory. The Observatory is a gateway to grid computing via GridIreland and has a dedicated Internet connection to the Joint Academic Network (JANET) provided under the auspices of the Northern Ireland Regional Area Network (NIRAN), which links Northern Ireland to JANET through two 2.5 Gbps circuits hosted at Queen's University Belfast. NIRAN provides the Observatory with significant technical expertise and access to an exceptionally reliable Internet service (greater than 99.97% reliability in the last year), although funding constraints currently limit the Observatory's total bandwidth to 10 Mbps.

The Observatory's high-quality technical equipment is complemented by a Library and Archives that is one of the premier specialist collections of its kind in the UK and Ireland. The Library contains long runs of all the major astronomical journals as well as certain climatological journals, and a comprehensive

selection of conference proceedings, textbooks and other material covering astronomy, physics, mathematics and related sciences. The archives contain a unique and growing collection of historic books and manuscripts, as well as scientific instruments, clocks and other artefacts related to the development of astronomy over more than two hundred years.

The meteorological archive contains the longest continuous daily climate series from a single site in the UK and Ireland. The climate station has been continuously maintained since 1795, with readings currently taken every day at 09:00 (GMT). Calibration of these data has enabled researchers and government departments to use the Armagh series for reports and research into global warming. This is a subject of significant strategic importance for Northern Ireland as we move into an era of rapid climate change. The Armagh Observatory's climate record provides a long historical baseline against which to judge how Northern Ireland's climate is responding to climate change world-wide.

In recent years the Observatory has implemented a rolling programme of improvements to the main Grade A Listed building, historic telescopes and telescope domes, supported by funding from the DCAL and other bodies (e.g. the Heritage Lottery Fund) totalling c.£700k since 2001. An important new Capital project is construction of a new Library, Archives and Historic Scientific Instruments building. This has received indicative support from the DCAL; it will provide a high-quality lecture theatre suitable for holding workshops and public events, additional office space, and rooms to conserve and display on a rotating basis the Observatory's fascinating and unique historic material.

Finally, in addition to its primary research function, the Armagh Observatory also undertakes an active programme of Science in the Community, supported in the last two years by the Skills and Science funding package. Recent innovative projects have included construction of the Human Orrery (the first such exhibit in the world to be laid out with precision); involvement in the Royal Society's "Living with a Star" exhibition and related International Heliophysical Year (IHY) activities; organizing the first Cross-Border Schools Science Conference; and creating the first International Phenology Garden in Northern Ireland. In addition, staff regularly supervise school work-experience and undergraduate summer and final-year projects; assist school students with Faulkes Telescope projects; organize a biennial Schools Lecture in association with the Robinson Lecture; and promote astronomy through public lectures and the mass-media. Partly as a result of this active engagement with the community, the Observatory has regularly attracted more than 300 mass-media citations to its work per year; its web-sites attract more than 1.5 million unique e-visitors annually from around the world; and more than 40,000 people per year visit the landscaped Grounds and Astropark. The trends of some of these performance indicators are shown in Table 1 (p.4).

1.2 Research Areas

The three principal research themes are Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics.

The Observatory's research in Solar-System Science encompasses the dynamical structure and evolution of objects in the outer solar system; the new field of comparative planetology, including the irregular satellite systems of the outer planets and time-critical phenomena such as satellite mutual events and meteor showers on other planets; and the effects over geological time-scales of comet, asteroid and meteoroid impacts on the Earth. These fields play a key role in planet formation and solar-system cosmogony, provide a basis for understanding exo-planetary systems, and help us understand Earth's place in the Universe.

In Solar Physics, the Observatory is involved in space missions such as SoHO, TRACE, Hinode, and Stereo. Our research exploits data from these and other facilities and is aimed at fundamental questions such as how the corona is heated, how the solar wind is driven, and what drives the Sun's variable magnetic activity. The latter affects Earth through a still poorly understood Sun-climate connection.

The Observatory's research in Stellar and Galactic Astrophysics is providing a detailed understanding of the formation and evolution of stars when factors such as mass loss through radiatively driven stellar winds, the effects of magnetic fields, stellar oscillations, and extreme abundances are taken into account. Around half of all stars have a stellar companion. We have a parallel strand to understand the evolution of stellar binaries and the detailed physical processes, such as accretion, which occur in interacting systems.

Staff regularly obtain time on internationally recognized telescopes and satellites, including the European Southern Observatory Very Large Telescopes (c.250 hours), the Isaac Newton Group telescopes on La Palma (several weeks), radio telescopes such as the Very Large Array (USA) and the Australia Telescope Compact Array (160 and 50 hours respectively) and the intercontinental Very Long Baseline Interferometer (12 hours) and Giant Metrewave Radio Telescope (India), and space telescopes such as XMM-Newton and Chandra (270 ksec), SoHO (300 hours), TRACE (90 hours) etc. In addition, the

Observatory is a founder member of the UK SALT Consortium, which with DCAL support provides access to SALT (South Africa), one of the largest optical telescopes in the world.

Solar-System Science The trans-Neptunian region plays a key role in all modern theories of the origin of the solar system, and our investigations have helped substantially to redefine our understanding of comets, asteroids and trans-Neptunian objects (TNOs). Observatory staff have pioneered the use of polarimetry with large telescopes to characterize the surfaces of TNOs and obtained the first polarimetric observations of a Centaur and a TNO; they have discovered a new class of dynamically stable 'outer' TNO not gravitationally scattered by Neptune; and demonstrated the fundamental role of the Oort cloud in determining the flux of comets through the planetary system. This work highlights the importance of understanding the Oort cloud as the primary source of Centaurs and short-period comets, as well as its key role in determining the flux of cometary near-Earth objects (NEOs), crucial for the long-term future of civilization. In our theoretical work we develop and apply state-of-the-art numerical integration codes to the evolution of large numbers of particles for time-scales up to the age of the solar system.

In the field of comparative planetology, Observatory staff led the team that detected the first Uranian mutual event, and play a major role in international programmes to refine the orbits of planetary satellites using the phenomenon of so-called 'mutual events'. These time-critical observations provide positional information with a precision otherwise only possible with spacecraft, allowing models of the satellites' mutual gravitational interactions and internal tidal dissipation to be refined. Theoretical work addresses the slow, self-induced orbital diffusion in the newly discovered families of irregular satellites around Jupiter and Saturn. Staff also play a leading international role in the prediction and modelling of meteor showers on other planets. This has implications for the detection of meteors from orbiters or landers, and the production of organic material from fireballs in the Martian atmosphere.

Research on the impact of comets, asteroids and meteoroids on the Earth focuses on the role of these bodies in driving the evolution of life (e.g. through the mass-extinction of species) and causing environmental change (e.g. through global warming/cooling). This has implications for many other fields and directly confronts the conventional paradigm that the Earth and other planets evolve independently of their near-space celestial environment. In addition to studying the origin of the NEOs that crater the Earth, Armagh Observatory staff have led international progress in meteor physics. For example, they provided observational verification of their 1999 prediction of the 2006 Leonid meteor outburst, and have developed new modelling techniques to predict the structure and evolution of meteoroid streams and hence when dense dust trails run into planets.

Solar Physics The Observatory's research in Solar Physics focuses on interpreting multi-waveband observations of the Sun's active outer atmosphere, modelling the highly variable emission to determine fundamental plasma properties, and identifying the interrelationships between different observed phenomena. Recent achievements include pioneering work on interpreting small-scale dynamic phenomena; the discovery of bi-directional jets at coronal-hole boundaries; magnetic field extrapolation modelling applied to coronal bright points; and the first spectroscopic evidence of plasma condensation in a coronal loop. The work addresses the question of how energy is transported through the solar atmosphere to the corona and solar wind via transient magnetohydrodynamic (MHD) phenomena such as jets, spicules, blinkers and waves.

Physical processes which must be considered include the effects of electron-density-dependent ionization, time-dependent ionization, and non-Maxwellian electron-velocity distributions. An important new result is that spectral lines formed at similar temperatures can react very differently to increasing activity owing to electron-density-dependent ionization, a process not generally included in the coronal approximation.

Research in this area has applications to other areas of astronomy including the properties of the Sun as a star, research on other cool stars and studies of stellar atmospheres, and the effects of solar variability on the Earth and therefore how variations in the Sun affect climate.

Stellar and Galactic Astrophysics Research in this area applies cutting-edge observational, theoretical and modelling techniques to the study of stars of all types and at all stages of evolution. Recent achievements include the first large systematic surveys of magnetic fields in pre-main-sequence and main-sequence stars in open star clusters, leading to new understanding of the origin and time-evolution of stellar magnetic fields; the first detailed time-evolution of the physical parameters of a stellar flare; the discovery of pulsed non-thermal radio emission from a brown dwarf; establishing the importance of binarity in the evolution of extreme helium stars; determining, with ULTRACAM, the best light curves for rapidly pulsating subdwarf B stars; demonstrating the importance of nickel in determining the edge

of the instability strip; discovering the most compact binary systems known to date, with implications for the number of gravitational wave detections by LISA and other observatories; the most definitive study of the origin of X-rays from magnetic interacting binary systems, using the X-ray space telescope XMM-Newton; the discovery, using polarimetry, of accretion discs around intermediate-mass pre-main-sequence stars; and the discovery that mass-loss rates from Wolf-Rayet stars depend on the photospheric iron abundance, providing a clue to the metallicity bias of long-duration Gamma-Ray Bursts (GRBs).

In addition, spectroscopic techniques are used to investigate stars with peculiar atmospheric abundances, and asteroseismology to probe below a star's visible surface. Polarimetry explores the link between magnetic fields, stellar evolution and the inhomogeneous distribution of exotic elements in early-type stars, testing diffusion theories of how radiation and magnetic fields concentrate certain elements within a star's atmosphere.

Other work includes studies of radiative transport in stellar atmospheres; the hydrodynamics of radiatively dominated stellar atmospheres and winds; the impact of binarity on the origin of extreme helium stars; the discovery and evolutionary investigations of ultra-compact white-dwarf binaries; the origin and evolution of massive stars in different cosmic environments; the origin of the first stars in the Universe; the progenitors of GRBs and supernovae; galaxy population synthesis studies; and studies of radio emission from ultra-cool substellar objects such as brown dwarfs and how this informs understanding of radio emission from cool stellar objects such as M dwarfs.

Other Programmes Armagh Observatory staff also study the accretion of interplanetary dust and meteoroids on the Earth; the use of Armagh's 212-year long daily meteorological series for studies of global climate change; the effects of clouds and solar variability on global warming; and the history of astronomy (e.g. the 2007 Lindsay Centennial Symposium). Recent key achievements have been the calibration of the meteorological archive and demonstrating the importance of clouds for climate change. These examples illustrate the breadth of research interests in this small but vibrant international research group.

1.3 Research Plans for 2008/2009 and Beyond

Armagh Observatory staff have an international lead in Oort cloud modelling, cometary dynamics and meteoroid stream research, and in the use of polarimetry to characterize the surface properties of TNOs. In solar physics we are extending our leadership in modelling and interpreting transient, fine-scale solar features; and in Stellar and Galactic Astrophysics the group has an international lead in fields such as asteroseismology as applied to oscillations of low-mass early-type stars, evolution of the chemical composition of magnetic and non-magnetic early-type stars, polarimetric studies of stellar magnetic fields, the detection of electron-cyclotron maser emission from ultra-cool dwarfs, the observation and modelling of ultra-compact binaries, and theoretical modelling of solar-composition and extremely low-metal massive and supermassive stars.

Projects in these areas use the latest space-based and ground-based instrumentation and modelling techniques, and many demonstrate the synergy of overlapping research themes and techniques: for example, the detection of electron-cyclotron maser emission from ultra-cool dwarfs and ultra-compact binaries; the use of polarimetry in solar-system science and stellar astrophysics; the discovery of stars with short-period oscillations in surveys for ultra-compact binaries; and the emission of X-rays in compact binaries and stars.

Over the next 3–6 years the Observatory plans to exploit its leading international position in these fields and to capitalize on growing world interest in each of these principal research themes. A selection of specific projects, spanning each of the Observatory's key research themes, is identified below; they illustrate the vibrancy of its current research profile and demonstrate the ability to conduct world-class science for years to come.

Solar-System Science Future projects include theoretical investigations of the dynamical evolution of new classes of TNO in the Edgeworth-Kuiper belt and inner Oort cloud, also extending our understanding of the Oort cloud to include spiral-arm and molecular cloud perturbations over the age of the solar system. This will inform our understanding of comets in interstellar space and of 'Oort clouds' around exo-planetary systems.

We will also use polarimetry to investigate the surface properties of comets and other distant objects and search for pre-biotic materials in comets and other objects.

New dynamical studies will address the two orders of magnitude discrepancy between the observed and predicted number of Halley-type asteroids, essential for understanding the NEO impact hazard, and

high-precision modelling of cometary/NEO dust trails will be used to predict the time-dependence of their close approaches to Earth. The group is involved in various space missions and future planetary proposals such as Marco Polo (ESA), and studies of meteoroid-stream formation and evolution will provide the first reliable meteor forecasts for *in situ* studies on other planets, providing key input for the international EuroPlaNet initiative.

Solar Physics Future work aims to exploit the wealth of data from current (and future) solar observatories, and especially our expertise in using coordinated space and ground-based observations and in coronal seismology. NASA's Solar Dynamics Observatory mission, flagship of the 'International Living with a Star' programme, will be launched in January 2009. It will enable the solar atmosphere to be studied globally and with a combination of spatial and temporal resolution far better than previously achieved.

With a cadence an order of magnitude better than previous missions, these new observations will especially benefit the emerging field of coronal seismology: the study that uses complex coronal-plasma oscillations to infer the physical state of the plasma in ways that complement those based on spectroscopy alone.

In addition, the Solar Physics group plans to undertake new MHD modelling of the different transient phenomena in the solar atmosphere; studies of the effects of non-Maxwellian electron-velocity distributions in the production of model spectra; and to extend this new knowledge of solar physics to improve our understanding of other cool stars and the impact of solar variability on climate change.

Stellar and Galactic Astrophysics Future work involves quantifying the evolutionary pathways for Type Ia supernovae used as cosmological distance indicators; understanding the predominantly wind-driven evolution of massive stars as a function of metallicity, with implications for understanding GRBs and the earliest stars in the Universe; broadening our work in asteroseismology; using polarimetry to detect stellar magnetic fields; and developing new galaxy population models using state-of-the-art stellar atmosphere models and opacity codes. Our multi-strand-wavelength approach to the discovery of ultra-compact binaries will provide crucial input for understanding the first detected gravitational wave events; and observations of electron-cyclotron maser emission will provide new insight into this important physical process, observed in solar system objects, ultra-cool brown dwarfs and ultra-compact X-ray binaries.

2 Business Plan Outturn 2007/2008

The key tasks for the prior year were to (1) complete the Observatory's RAE submission; (2) complete the planned Skills and Science activities for the period; and (3) develop a Business Case for the new Library, Archives and Historic Scientific Instruments Building.

The pressure to provide a suitably secure, modern long-term storage space for the nationally significant Armagh Observatory Library and Archives, and to ensure that the material contained therein can be properly curated and displayed on a rotating basis in the best possible setting, increases with every year that passes.

Both key tasks (1) and (2) have been completed in the year under review, but the third item was completed only in part. Following the provision of a detailed case for support to the DCAL at the beginning of the period, towards the end of 2007 an indication was received from the DCAL that it might in principle be able to provide partial Capital support for a new Library building. Nevertheless, the lack of any additional research development funds during the year made it impossible for the Observatory to procure the necessary external support to finalize plans for the new Library building and so develop a fully costed Business Case for the new exhibition and storage facility. This important matter is therefore deferred to another year, pending additional funding.

In addition to these key tasks, the principal objectives during 2007 and Financial Year 2007/2008, and the corresponding outturns may be summarized as follows:

- maintain and expand existing high-quality research programmes — **done**: a record 57 refereed journal publications published during 2007;
- obtain grants and additional external funding to support new research projects — **done**: £200.0k external grant income received;
- prepare for the Research Assessment Exercise (RAE 2008), which has a census date 2007 October 31, and make a high-quality RAE submission — **done**: RAE Return submitted prior to the end-November 2007 deadline;

Calendar or Financial Year	Rate of Return Key PI 'A'		Admin. Efficiency Key PI 'B'		Staff Absence Key PI 'C'		Refereed Publications Key PI 'D'	
	Actual (%)	Target (%)	Actual (%)	Target (%)	Actual (d/p/yr)	Target (d/p/yr)	Actual (per year)	Target (per year)
2004 or 2004/2005	19.9		6.6		0.4		41	32
2005 or 2005/2006	18.1		7.4		0.4		47	35
2006 or 2006/2007	19.0	20.0	10.3	10.0	0.2	12.0	47	40
2007 or 2007/2008	20.7	20.0	7.7	8.8	0.5	11.0	57	45
2008 or 2008/2009		**21.5**		**8.2**		**10.0**		**50**

Table 3: New key performance indicators agreed with the DCAL during 2006. The first column denotes the calendar or financial year. The percentage Rate of Return (Key PI 'A') corresponds to the ratio of total external income to total income per financial year; Admin. Efficiency (Key PI 'B') represents the ratio of the total expenditure of the Observatory on governance and administration to total expenditure, again per financial year; Staff Absence (Key PI 'C') denotes the average number of days absence per person per calendar year (d/p/yr); and Refereed Publications (Key PI 'D') denotes the number of refereed journal papers produced by Observatory staff in each calendar year.

- promote and develop the Armagh Observatory Grounds and Astropark, and widen access to astronomy at Armagh by expanding the Observatory's Education and Public Outreach (EPO) programme — **done**: a record of more than 40,000 visitors to the Observatory Grounds and Astropark during 2007, more than twice as many as in 2005; and
- progress plans for a new Library, Archives and Historic Scientific Instruments Building — **done in part**: see above.

The trends of the various key performance indicators that together represent the sum of these principal strategic objectives are summarized in Figure 2 (p.11), while other relevant material is presented in Table 1 (p.4). Table 3 illustrates the corresponding trends for the four new Key Performance Indicators (Key PIs) introduced by the DCAL halfway through 2006.

These Tables and Figures demonstrate that the Armagh Observatory has achieved considerable success during the past year 2007/2008. The appointment of three early-career Research Astronomers during 2006/2007 to replace those that had left or retired during previous years, has brought the total number of such senior research staff to six — the same as in 2001 — and has provided the Observatory with a strong body of high-quality research staff for the future.

2.1 New Key PIs

For reference, we provide brief definitions and comments upon the four new Key PIs introduced by the DCAL halfway through 2006. Thus, we have:

A **"Rate of Return"**: the ratio of total external income as a percentage of total income per financial year following resource accounting rules. In recent years, this ratio (which takes no account of the Observatory's significant use of external facilities) has averaged around 20%. In general, a high value is better.

We note that when the cost of the use of UK national and international facilities is included, the overall rate of return on DCAL investment in scientific research at Armagh is very much larger than even these very good figures.

- For example, during the ten-year period 1996–2005 inclusive, the total DCAL income received was £6.30M; the total external grant and other income was £2.60M; and the total cost of the use of UK national and international facilities was £4.30M. Thus, the average rate of return on DCAL investment over this period was 41%, a figure that increases to 110% when the cost of the Observatory's use of UK central facilities is included.

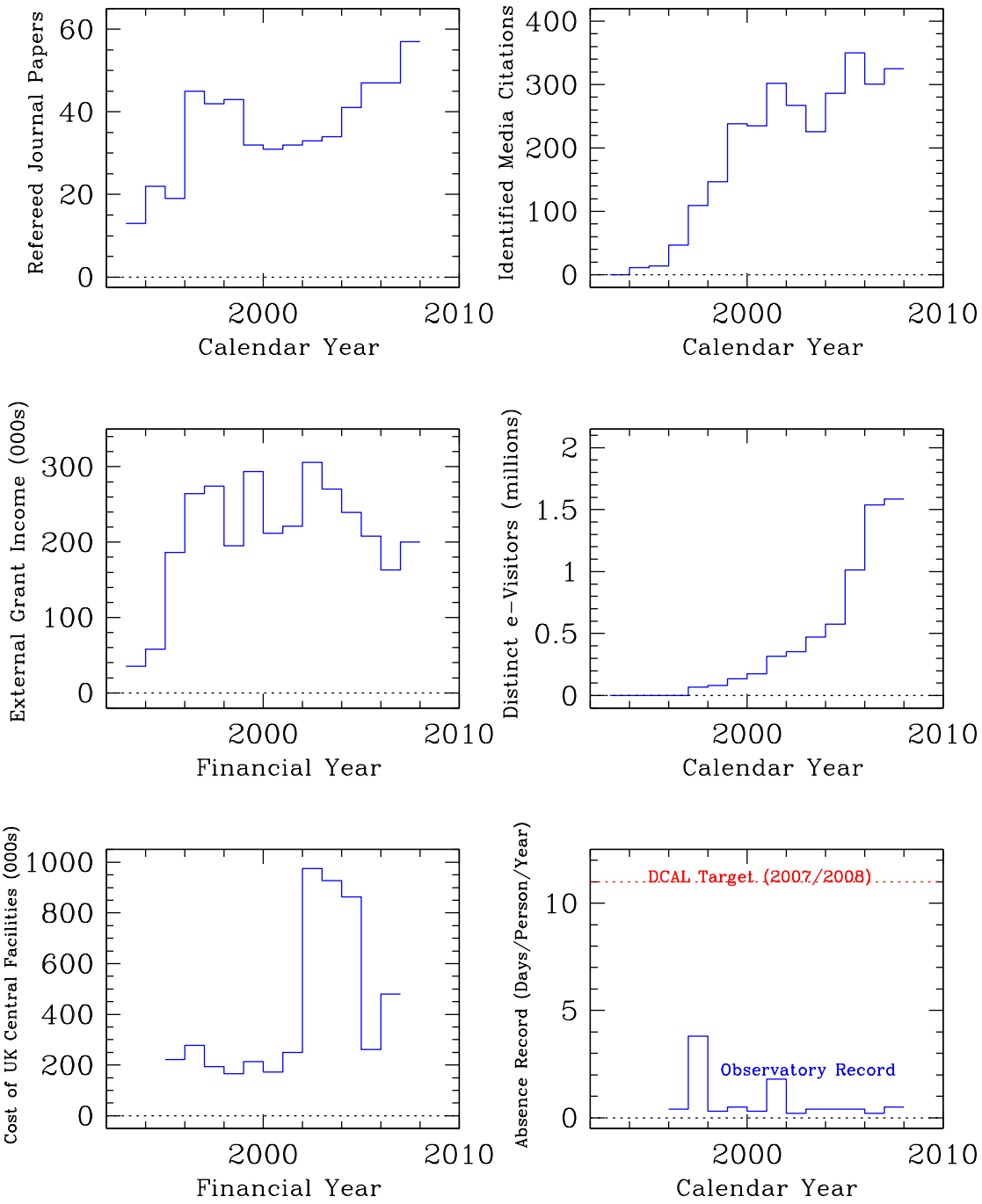

Figure 2: Histograms showing the trends of various performance indicators for the Armagh Observatory during the past fifteen years. The different panels show the number of refereed journal publications per calendar year; the amount of external (i.e. non-DCAL) grant income (£000s) received in cash terms per financial year; the cost of UK Central Facilities (telescopes etc.) used by Observatory staff per financial year, ignoring the significant additional cost of non-UK international facilities; the number of identified mass-media citations to the Observatory, its staff and their work during per calendar year; the number of Distinct e-Visitors (DEVs), in millions, to the Observatory web-sites per calendar year; and the rate of staff absence per calendar year (days per person per year), compared with the DCAL target for 2007/2008.

This demonstrates the very significant added value provided by the Armagh Observatory on DCAL investment in research astronomy at Armagh, a result which is reflected in the equally significant impact of the Armagh Observatory on the national and international stage.

B: **"Administrative Efficiency"**: the ratio of total governance and administration costs as a percentage of total expenditure per financial year. This provides a measure of the efficiency of the Armagh Observatory in delivering a high-quality astronomical service at the lowest reasonable cost. A low value is better.

In recent years, governance and administration costs have averaged around 10% or less, another statistic demonstrating the very high cost-effectiveness of DCAL support for astronomical research at Armagh. There is no scope for improving this figure except by growing the total volume of the Observatory's research.

- In recent years, approximately 70% of the Observatory's total running costs are research-related, the balance (around 20%) being attributable to the cost of buildings, grounds and estates costs, a very low figure considering that the Observatory is a Grade A listed building located in approximately 14 acres of attractively landscaped parkland (the Armagh Observatory Grounds and Astropark), which is open to the public 365 days per year and managed and developed by Observatory staff.

C: **"Staff Absence"**: the average number of days absence per person per calendar year (days per person per year). A low value is better.

It is well known that the rate of staff absence is a sensitive proxy for the loyalty, commitment, motivation and morale of staff (or, conversely, for issues relating to poor staff relations, stress at work, and low morale). The Armagh Observatory staff's exceptional performance in this regard, sometimes under quite difficult circumstances, should be applauded. The average number of days absence per staff member per year over the past ten years is 0.50.

- This is many times better than the best absence record reported by any Government department over the same period (see bottom right-hand panel of Figure 2).

D: **"Refereed Publications"**: the number of scientific papers published per calendar year in refereed scientific journals. In general, a high value is better.

A high number of refereed publications demonstrates a high volume of quality scientific outputs, but the absolute quality of each publication is a further important factor that must also be taken into account. Thus, we do not plan to increase the number of refereed journal publications indefinitely, but encourage staff also to focus on raising the quality and impact of their individual work.

- This is one reason why the Armagh Observatory participates in the periodic Research Assessment Exercise (RAE), a UK-wide assessment in which the Observatory has achieved a Grade 4 in each of the past three RAEs (1992, 1996 and 2001), corresponding to a minimum quality of at least a national/international standard.

At the end of 2007 the Observatory successfully completed a return to the most recent RAE (RAE 2008). Whereas participation in the RAE has brought significant additional 'RAE' research income into the university sector, the Armagh Observatory has never obtained any financial benefit from the RAE.

Referring again to Table 1 (p.4), we note that the value for External Grant Income for 2007/2008 is significantly higher than that for the prior year (2006/2007), demonstrating that this figure is again on an ascending trajectory despite the very difficult climate for receipt of external grants.

We also note that the number of Distinct e-Visitors has continued to grow, the value for 2007/2008 (1.6 million) again being a record; and the number of identified media citations (325 noted) is also very significantly higher than the target of 250, highlighting the significant impact of the Armagh Observatory on both the regional and international scale. The exceptionally good absence record has already been noted.

3 Objectives for 2008/2009

The Armagh Observatory is a vibrant international research institute which plays a full role in international astronomy whilst developing and promoting the rich heritage of Northern Ireland astronomy and presenting an attractive and positive image of Northern Ireland on the international stage. The principal Business Plan objectives for 2008/2009 are to:

- obtain external grants and funding to support new research projects;
- strengthen the Observatory's research capacity and capability in Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics, by recruiting 3–4 PhD students and providing a high-quality research environment to facilitate the advanced training of such students at the beginning of their astronomical careers, and by playing a full role together with other academic partners in plans to upgrade NIRAN, and through this the Observatory's connection to the Internet (currently 10 Mbps); and
- advance plans for the design of a new Library, Archives and Historic Scientific Instruments building, partial funding for which has been provisionally identified within the DCAL indicative Capital budget from 2010/2011.

In addition, the Observatory plans to maintain its currently very active programmes of education and public outreach, and of Science in the Community, and to play a leading role in various public events both locally (e.g. contributing to the tercentenary of the birth of the Observatory's founder, Archbishop Richard Robinson) and on the island of Ireland (e.g. in co-organizing the Ninth European Symposium for the Protection of the Night Sky, to be held in Armagh from 17–20 September 2009), and farther afield (e.g. by playing a full and active UK-and-Ireland role in the International Year of Astronomy 2009).

Funding The issue of underfunding of the Armagh Observatory has been drawn to the attention of senior management and the DCAL repeatedly over the past number of years. At the beginning of 2008/2009 the Observatory faced what appeared to be an unprecedented situation in all its nearly 220-year history: that is, for the first time the announced grant-in-aid from the DCAL and the Observatory's Reserves were together insufficient to enable the Observatory to plan to the end of the financial year. The risk was not new: it had been brought to the attention of the DCAL frequently in the previous year and the problem had formed the basis for the CSR request for a sufficient step-increase in the Observatory's baseline funding (both Resource and Capital) to support the Observatory's core function of research in astronomy and related sciences. By significantly reducing outgoings for 2008/2009 (e.g. by one staff member volunteering to work part-time for the year and deferring some items of expenditure to future years, where possible), and with the support of an additional £35k transferred from the Armagh Planetarium and the promise of a further £60k to be provided from the DCAL in-year, this critical risk has receded for another year and the Observatory is able to project a balanced budget for 2008/2009. The resulting budget, submitted to the DCAL on 2008 April 6 and subsequently approved for operational purposes, is shown in Table 4. Nevertheless, it should be emphasized that the funding difficulty identified as part of the CSR request for the present planning period remains, and strenuous efforts should be made to resolve the projected funding difficulties for 2009/2010 et seq. (cf. Tables 1 and 4).

The Armagh Observatory does not lightly request additional funding. Rather, it is a highly successful organization which with adequate funding for its needs is in a good position to make very significant contributions to the aims and objectives of the Northern Ireland government. The requested additional funding in years 2 and 3 of the planning period will enable the Observatory to discover new facts about the Universe and pursue new research projects, often in collaboration with other leading astronomical groups on the international stage. In addition, it will facilitate the development of new public outreach projects as part of its Science in the Community programmes, and enable the Observatory to lay a strong foundation for explaining, exploiting and preserving the unique heritage in Armagh of more than two hundred years of astronomy. Thus, the provision of a sufficiency of funding for the Armagh Observatory to carry out its work will enable Armagh Observatory staff, as they have done in the past, to continue to achieve key DCAL targets and promote a positive image of Northern Ireland on the international stage, together with all the economic and societal benefits that entails.

Last Up-date 2008 July 31	2010/2011 Budget £k	2009/1010 Budget £k	2008/2009 6th April Budget £k	2007/2008 Actual £k	2006/2007 Actual £k	2005/2006 Actual (Restated) £k	2004/2005 Actual £k
Income							
DCAL recurrent grant paid							
DCAL recurrent grant paid	817.0	817.0	817.0	660.0	660.0	660.0	660.0
Re-allocation of DCAL recurrent grant from Planetarium	0.0	0.0	35.0	0.0	0.0	0.0	0.0
Additional in-year recurrent grant	0.0	0.0	60.0	0.0	4.6	90.0	94.0
Total DCAL recurrent grant paid	817.0	817.0	912.0	660.0	664.6	750.0	754.0
DCAL capital grant							
Capital grant paid	25.0	25.0	25.0	6.5	6.5	6.5	6.0
Capital grant deferred	0.0	0.0	0.0	0.0	-1.9	0.0	0.0
Additional in-year capital funds paid	0.0	0.0	0.0	27.5	15.0	35.0	123.8
Total DCAL capital grant paid	**25.0**	**25.0**	**25.0**	**34.0**	**19.6**	**41.5**	**129.8**
DCAL Additional Restricted Funds							
Miscellaneous restricted funding	0.0	0.0	0.0	0.0	13.3	21.9	74.0
New Library, Archives and Historic Scientific Instruments Building	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Net Skills and Science Funding	0.0	0.0	0.0	173.0	124.9	0.0	0.0
Pension deficit (Note: not shown as grant not yet announced)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total DCAL additional restricted funds	**0.0**	**0.0**	**0.0**	**173.0**	**138.2**	**21.9**	**74.0**
External Grants and Other Restricted Funds							
New Library, Archives and Historic Scientific Instruments Building	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grants and other restricted funds received	233.7	234.9	182.9	200.0	163.2	207.9	239.4
Grants and other restricted funds deferred	0.0	0.0	-1.2	-17.3	-23.2	-63.0	-22.5
Grants and other restricted funds released	3.0	4.2	37.4	24.5	36.4	22.5	9.5
Total	**236.7**	**239.1**	**219.1**	**207.2**	**176.4**	**167.4**	**226.4**
Miscellaneous Other Income	**7.9**	**7.8**	**11.7**	**19.5**	**16.5**	**12.9**	**11.0**
Total Income	**1086.6**	**1088.9**	**1167.8**	**1093.7**	**1015.3**	**993.7**	**1195.2**
Expenditure							
Research and Research Support Costs							
Capital equipment from DCAL capital grant	25.0	25.0	25.0	6.5	6.5	6.5	6.0
Appropriation of DCAL recurrent grant for capital equipment	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Additional capital equipment from in-year DCAL funds	0.0	0.0	0.0	27.5	13.1	35.0	30.0
Capital equipment funded by external grants and other income	0.0	3.0	9.6	0.0	6.6	1.2	21.6
New Library, Archives and Historic Scientific Instruments Building	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Contribution to SALT operating costs	10.1	9.5	3.2	0.5	11.0	0.0	37.0
Other SALT/UKSC expenses	1.5	1.5	1.5	0.1	0.2	1.7	0.5
ARTI project	0.0	0.0	0.0	0.0	0.0	3.5	0.0
Miscellaneous conferences and research infrastructure	0.0	0.0	0.0	0.0	0.0	0.0	21.9
Salaries of permanent research and research support staff	617.6	578.9	549.8	506.5	348.7	381.5	392.5
Salaries of fixed-term research and research support staff	97.0	94.0	84.0	101.9	74.9	82.1	116.3
Salary of Archivist	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Student maintenance grants	105.2	94.6	100.1	111.9	107.3	116.4	100.8
Research staff costs allocated to Skills & Science	0.0	0.0	0.0	-56.5	-20.9	0.0	0.0
Student maintenance grants allocated to Skills & Science	0.0	0.0	0.0	-82.5	-40.3	0.0	0.0
Student fees	11.0	10.5	10.0	9.3	9.3	11.9	9.3
Former Director's pension supplement	2.4	2.3	2.2	2.0	2.0	2.0	2.0
Core travel and subsistence from DCAL funds	30.0	30.0	25.0	23.3	20.3	22.9	23.5
Travel and subsistence from external grants and other income	23.2	22.9	42.5	28.5	22.1	22.4	10.2
STFC Summer School	0.0	0.0	0.0	20.4	0.0	0.0	0.0
Visitors programme	12.0	24.0	10.0	1.5	3.3	8.0	9.2
Conferences	1.5	0.0	1.0	0.0	1.2	0.0	1.3
Hosting meetings and lectures	1.5	1.5	1.0	2.4	1.2	0.4	0.8
Royal Society Solar Exhibit	0.0	0.0	0.0	1.5	0.0	0.0	0.0
Release of taxation provision	0.0	0.0	0.0	0.0	0.0	0.0	-21.1
JANET access costs	50.0	50.0	36.0	25.9	19.4	25.2	29.9
Core computer consumables from DCAL funds	16.0	14.0	12.0	12.5	18.5	12.8	15.2
Computer consumables funded by external grants and other income	0.0	0.0	10.0	1.0	3.1	1.3	0.6
Library, archives and historic instruments	35.0	35.0	30.0	24.5	46.0	31.8	33.4
Publications	0.7	0.7	0.7	1.9	0.3	0.8	2.3
UK entertaining	0.1	0.1	0.1	0.1	0.0	0.5	0.4
Advertising and promotions	0.5	0.5	0.5	0.3	1.1	1.2	0.8
Public Understanding of Science	5.0	15.0	5.0	1.7	0.0	0.0	0.0
Historic books/instruments	0.0	0.0	0.0	0.0	0.9	0.0	0.0
North/South Schools Conference 2007 / Lindsay Meeting 2007 over-provision	0.0	0.0	0.0	-2.0	0.0	0.0	0.0
Agency staff costs (meteorological records)	6.0	6.0	0.0	0.0	0.0	0.0	2.7
Pension deficit (Note: not shown as deficit not yet announced)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Losses and Special Payments	0.0	0.0	0.0	0.0	1.9	0.0	0.0
Total research and research support costs	1051.3	1019.0	959.2	770.7	657.7	769.2	847.1
Skills & Science							
Direct costs							
Leaflets	0.0	0.0	0.0	0.0	2.1	0.0	0.0
Direct salaries	0.0	0.0	0.0	35.8	28.6	0.0	0.0
North/South Schools Conference 2007 / Lindsay Meeting 2007	0.0	0.0	0.0	0.0	9.3	0.0	0.0
Equipment	0.0	0.0	0.0	0.0	23.4	0.0	0.0
Travel & subsistence	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumables	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Re-allocation of core costs							
Student maintenance grants/fees	0.0	0.0	0.0	82.5	40.3	0.0	0.0
Research staff student supervision costs	0.0	0.0	0.0	56.5	20.9	0.0	0.0
Total Skills and Science costs	0.0	0.0	0.0	174.8	124.9	0.0	0.0
Buildings, Buildings Refurbishment and Grounds Costs							
Buildings, domes and telescopes project funding (DCAL and EHS)	0.0	0.0	0.0	0.0	13.1	21.9	42.3
DDA and other capital costs	0.0	0.0	0.0	0.0	0.0	0.0	90.3
Salaries of grounds and meteorological records support staff	42.1	40.6	39.0	37.0	35.6	34.8	30.1
Salaries of cleaning and security staff (shared with the Planetarium)	0.0	0.0	0.0	1.8	6.0	6.0	4.5
New Library, Archives and Historic Scientific Instruments Building Estates Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agency Cleaning Costs	5.8	5.5	5.2	2.5	0.0	0.0	0.0
Cleaning consumables	1.7	1.6	1.5	0.9	0.7	1.4	4.5
Service contracts and professional fees	6.7	6.6	6.5	4.3	5.6	16.2	7.5
Central procurement costs	2.0	2.0	2.0	1.4	6.6	0.0	0.0
Property repairs and grounds	35.0	34.0	20.0	24.1	43.2	16.9	38.8
Heat, light, power	33.5	31.5	29.0	29.1	26.6	26.6	19.8
Insurance	10.0	10.0	10.0	9.5	11.1	13.0	13.6
Rates	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Buildings, Buildings Refurbishments and Grounds Costs	137.1	132.1	113.5	110.9	148.8	137.1	251.7
Administration and Corporate Governance Costs							
Salaries of administrative and administrative support staff	71.6	68.5	67.1	62.7	60.2	52.1	52.9
Management Committee/Board of Governors	2.0	1.5	1.0	0.7	0.8	0.4	1.1
Internal audit	3.5	3.5	1.8	1.8	1.8	1.5	2.0
External audit	4.0	3.9	3.8	4.2	3.7	3.2	3.4
Legal fees	0.0	0.0	0.0	0.0	0.0	-1.2	2.0
Staff training	2.0	2.0	2.0	0.3	1.5	0.9	1.2
Recruitment	1.0	1.0	1.0	0.8	10.4	0.7	0.9
Stationery	2.6	2.5	2.5	2.1	2.7	3.3	2.9
Post and telephone	4.5	4.5	4.7	5.2	5.6	4.7	5.6
Printing	1.5	1.5	1.5	0.5	0.6	0.6	0.0
Office and miscellaneous equipment	3.0	3.0	3.0	2.9	4.5	2.6	1.8
General expenses	5.0	5.0	4.0	5.7	4.7	4.0	4.2
Other professional fees (Actuary, SELB, VLA, EEF)	3.0	3.0	3.0	0.9	9.8	0.0	0.0
Bank interest and other charges	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Total Administration and Corporate Governance Costs	103.7	99.9	95.4	87.8	106.4	72.8	78.0
Net Pension Costs	0.0	0.0	0.0	18.0	8.0	38.0	0.0
Total Expenditure	1292.1	1251.0	1168.1	1162.2	1045.8	1017.1	1176.8
Surplus/-Deficit (Before Pension Costs)	**-205.5**	**-162.1**	**-0.3**	**-50.5**	**-22.5**	**14.6**	**18.4**

Table 4: The budget for the Business Plan 2008/2009, last updated 2008 July 31, with costs for the new Library building zeroed and actuals replacing projections for 2007/2008.

4 Alignment of Armagh Observatory and Government Objectives

The letter from the DCAL (2008 January 18) advising the Observatory of the draft indicative allocation from the CSR, namely a share of the total joint funding of £1,300k (Resource) and £50k (Capital), requested that the DCAL's draft Public Service Agreements (PSAs) should also be considered in the Business Plan. The five DCAL PSAs are listed below, together with an indication of how the Armagh Observatory makes major contributions to most, if not all, of them.

This itemized list is then followed by a summary of how the Observatory's work contributes to both these and other PSAs in the Northern Ireland Programme for Government, and then by a slightly broader discussion of how the Observatory makes very significant contributions to the wider concept of Cultural Capital which lies at the heart of the DCAL Mission. This section demonstrates the very significant contributions to the Northern Ireland Programme for Government made by the Armagh Observatory.

4.1 DCAL PSAs

- PSA5 **"Tourism"**: to develop our tourism sector and promote Northern Ireland as a must-visit destination to facilitate growth in business and leisure visitors.

  The Armagh Observatory attracts in excess of 40,000 visitors per year to the Observatory Grounds and Astropark, highlights and promotes the City of Armagh on the national and international stage, and attracts visiting scientists and others to Northern Ireland from many parts of the world. The Observatory plays a leadership role in attracting visitors to Armagh, particularly through the Armagh Visitor Education Committee and associated conferences and publications. The allocation of additional Capital and Revenue funding to support the creation of a new Library, Archives and Historic Scientific Instruments building will provide Armagh with yet another important visitor facility, and so further strengthen the Observatory's indirect role in support of the Northern Ireland tourist industry.

- PSA6: **"Children and Family"**: to ensure that children are cared for, live in safety, are protected from abuse, receive the support they need to achieve their full potential, become more independent and grow into well-adjusted adults, taking their place in the community.

  As a result of the development of the Armagh Observatory's new and innovative programmes of Science in the Community, a great number of children have been exposed to the fascination of astronomy and related sciences. In addition, many children are supervised by Observatory staff on work-experience and related summer programmes, and other young people are trained at both undergraduate and postgraduate level. These activities contribute significantly to widening participation in science among young people, so improving their life chances and future opportunities for employment and leisure.

- PSA9: **"Promoting Access to Culture, Arts and Leisure"**: to contribute to Northern Ireland's economic, health and educational goals by increasing participation and access to Culture, Arts and Leisure activities.

  Man does not live by bread alone, and the Armagh Observatory makes a very large number of significant contributions to improving the quality of life for Northern Ireland's people (as well as that of visitors to the region) by widening access to the heritage of astronomy at Armagh, providing guided tours of the Observatory and its Grounds and Astropark, and arranging public lectures and one-day conferences to describe recent scientific results. There are many examples of such events, which are always well-attended and attract positive feedback; they demonstrate the strong appetite for such cultural events in the City.

  One of the Observatory's most important assets is that because it is a world-leading international research institute, there is a heritage of books, manuscripts, instruments and archives which together describe essentially the whole history of modern astronomy. In today's modern world it is often forgotten that the Observatory's founder was born less than a century after Galileo was threatened with torture for teaching that the Earth orbited the Sun, and in a world where the extent of the Solar System was thought by most people to be limited to the orbit of Saturn. As the oldest scientific institution in Northern Ireland and the longest continuously functioning astronomical research institute in the UK and Ireland, the Armagh Observatory is uniquely positioned to explain the significance of the cultural heritage of Northern Ireland science and to put the history of

astronomy and of mankind's attempts to understand the great age and size of the modern universe accessible to space telescopes in an appropriate historical context. Again, the new Library building will be a key element of this activity, as well as the expanded connection to the Internet that will enable external users to download images, videos and other outreach material designed to make the story of astronomy at Armagh directly accessible from people's homes anywhere in the world.

- PSA10: **"Helping our Children and Young People to Achieve through Education"**: to encourage all our children to realize their potential by improving access to formal and non-formal education and provision tailored to the needs of disadvantaged children and young people.

  As a 'spin-off' from the Observatory's primary research function, the Armagh Observatory provides guided tours of the Observatory and its Grounds and Astropark to visiting groups including young people, and also provides children with work-experience training and summer projects. These, as well as the Observatory's commitment to continue its therapeutic training of an individual with recognized learning difficulties, demonstrate how the Observatory contributes to this DCAL PSA.

- PSA12: **"Housing, Urban Regeneration and Community Development"**: to promote decent, energy efficient, affordable housing and regenerate disadvantaged areas and towns and city centres, and support community development to create environments which enhance quality of life and contribute to well-being.

  The Armagh Observatory contributes directly to this important goal by promoting the use of the Observatory Grounds and Astropark as one of the most interesting shared public spaces in the City of Armagh, with a growing and increasingly interesting range of outdoor educational exhibits, and by promoting the construction of the new Library and Archives building as a key 'legacy' project to celebrate the 300th anniversary of the Observatory's founder: Archbishop Richard Robinson. The new building must be of an architecturally high standard and fit both for its primary function in providing a secure and adequate storage facility for the Observatory's library and archives and an appropriate public space to display this material on a rotating basis, and for occasional public lectures and other events. In addition, it must be built to the highest possible standards of energy conservation, using innovative design features to ensure that it has a minimal or zero carbon footprint.

  The Grounds and Astropark are host to a growing diversity of flora and fauna; to the new Phenology Garden; and provide the necessary stable environment in which the Observatory's world-class climate site can continue to operate and make a contribution to our understanding of climate change.

4.2 PSAs of the NI Programme for Government

- PSA1: **"Productivity Growth"**: Facilitating enhanced Internet access through involvement in and promotion of NIRAN, the Northern Ireland Regional Area Network, which plans to increase the availability of next-generation network broadband speeds to the whole academic community and other organizations in the public and private sector (DETI/DEL); contributing to measurable improvements in research quality as assessed by the periodic Research Assessment Exercise (RAE), the key results being a graded profile of the Observatory's research quality (DEL).

- PSA2: **"Skills for Prosperity"**: To increase skills and career choices in science, technology, engineering and mathematics (STEM) subjects by expanding the Observatory's programme of high-level PhD training in astronomy and related sciences, and by continuing its programmes of school work-experience and lectures and related activities developed as part of its on-going Science in the Community programme (DE/DEL/DETI).

- PSA3: **"Increasing Employment"**: To deliver high-quality jobs in the science and technology employment sector and to maintain an on-going programme of therapeutic training to support an individual with specific learning difficulties (DEL).

- PSA5: **"Tourism"**: To manage and enhance Northern Ireland's cultural infrastructure by developing the Observatory's rolling programme of improvements to the Observatory's Grade A listed buildings and telescope domes and the facilities in the Observatory's Astropark, Historic Gardens and Demesne (DCAL/DETI), as well as maintaining a high research profile, all of which attracts visitors to Northern Ireland. In addition, through partnership with other bodies, for example the Armagh Visitor Education Committee (AVEC), we will continue to develop and implement new

programmes to grow tourism as part of the Observatory's programme of Science in the Community, including developing novel culture and heritage initiatives, encouraging the use of the Observatory grounds as attractive venues for special-interest groups (e.g. local history societies, walking clubs etc.), and so on (DETI).

- PSA: **"Children and Family"**: The Observatory's programme of school work experience, and its occasional public lectures (including schools lectures), provides additional opportunities to improve the outcomes and life-chances of children and young people throughout Northern Ireland (OFMDFM/DE/DCAL).

- PSA9: **"Promoting Access to Culture, Arts and Leisure"**: Whenever resources allow, the Observatory will maintain its ongoing programmes to widen digital access to its unique historic archives, maps, manuscripts etc. The aim is two-fold: first, to provide a high-resolution back-up electronic copy of this specialized material, which is not available anywhere else in the world, and secondly to enhance public access to the most imortant historic material in the Observatory's possession. In addition, the Observatory plans to maintain and expand the public outreach facilities in the Observatory Astropark, so as to enable the greatest possible number of people to improve their quality of life by experiencing, participating in and accessing this important part of Northern Ireland's scientific heritage. The plans to construct a new, high-quality Library, Archives and Historic Scientific Instruments building adjacent to the historic main Grade A listed building of the modern observatory are an important part of the Observatory's plans to contribute to PSA9 (DCAL).

- PSA10: **"Helping our Children and Young People to Achieve through Education"**: The Observatory will maintain its programmes of school work experience and also (e.g. with the support of the Sentinus programme) its summer programme involving the supervision by senior astronomers of a typically 4–6 week research project involving children and young people (DE/DEL/DCAL).

- PSA12: **"Housing, Urban Regeneration and Community Development"**: The Observatory will contribute to the main objective of this important PSA, namely to promote viable and vital towns and city centres, by progressing its plans to construct a new Library, Archives and Historic Scientific Instruments building, as well as promoting public access to and use of the Armagh Observatory Grounds, Astropark and Human Orrery. More than 40,000 people per year currently use this facility, making it one of the most attractive publicly accessible parks in the City of Armagh (DSD/DCAL).

- PSA16: **"Investing in the Health and Education Estates"**: The Observatory makes a major contribution to enhancing student learning and research excellence, so helping to provide a firm foundation for Northern Ireland's Further and Higher Education estates, and to enhancing the educational competiveness of the region and promoting Northern Ireland on the international stage (DEL/DE).

- PSA17: **"Rural Infrastructure"**: The Observatory's pilot programmes of Science in the Community, supported by an average of £150k per year during the past two years, reached many people, demonstrating the potential leverage, in terms of numbers of people reached, of an active and vibrant programme of Science in the Community (DARD). The Observatory is well placed, especially with 2009 being the United Nations International Year of Astronomy, to contribute to the improvement of educational opportunities for those living in rural parts of Northern Ireland (DARD).

- PSA21: **"Enabling Efficient Government"**: The Armagh Observatory is a small, highly efficient organization. With appropriate operational delegations, it can make significant contributions to delivering its programmes of frontline scientific research, education and public outreach, in the most efficient way possible (OFMDFM/DFP).

- PSA22: **"Protecting our Environment and Reducing our Carbon Footprint"**: The Observatory's high-profile campaign against light pollution is a very practical way to promote energy efficiency and the use of renewable energy, while its involvement in the Ninth European Symposium for the Protection of the Night Sky (2009 September 17–19) will place the issue of light pollution and energy conservation in the public eye (DOE/DETI/DSD). The Observatory is committed to maintaining and improving the conditions of the monuments and listed buildings in its care, and to conservation and preservation of both the natural and built environment and heritage (DOE). The Observatory's meteorological series, dating back to 1795, is the longest daily series from a single

site in the UK and Ireland, and provides an important baseline against which the effect of global warming and climate change in this part of the island of Ireland can be measured (DOE).

4.3 Cultural Capital

There are many ways in which the Armagh Observatory strengthens Cultural Capital and enriches the scientific inheritance of Northern Ireland, and — through its world-wide astronomical research mission — also that of the UK, Ireland and the rest of the world. Indeed, the broadly cultural and economic arguments for the support of fundamental research in astronomy and related sciences have been well rehearsed. Fifty years ago, Professor Bernard Lovell — arguably the 'father' of radio astronomy — responded thus:

> "The fundamental answer to this general question is written large in history. It is a matter of deep concern that succeeding generations have so often had to rediscover it for themselves — often by bitter experience. The technical devices which form the basis of the present economic and cultural strength of the Great Powers can be traced within a few generations to fundamental scientific investigations which were carried out in the abstract, without thought of direct practical benefit ... Fundamental research in astronomy or any other subject is an essential component of the welfare of modern civilization. Unless the West overcomes its parsimonious attitude to science and technology, then the relative quality of our civilization will decline, and our influence will pass to other peoples."

Sir Bernard Lovell's words, written half a century ago, have a rich resonance for Northern Ireland. They highlight the significance of science for the modern economy, and in particular for the future prosperity of the region. And they highlight especially the value of fundamental research in underpinning the vibrancy and confidence of our civilization and the vitality of the community.

In short, **fundamental research has a fundamental role to play in the health of the community. Fundamental research implies a commitment to investment in education and skills, and especially in the types of education and skills necessary to improve competitiveness**.

In addition, recent reviews of the value of physics and astronomy, and of the continued support of such subjects by central government, have highlighted especially the importance of astronomy in attracting young people towards science and to a scientific way of thinking, and particularly in countering what is increasingly a lack of adequate training in mathematics among young people. So much of modern society depends on science, and so a love for science and mathematics must be inculcated in children from an early age.

There are lessons here for Northern Ireland and the Republic of Ireland, particularly in their common objective to increase the number of young people studying mathematics and physics at school and therefore opting for technically demanding subjects and careers at university and beyond. A Department of Culture has the capacity to influence this trend as surely as a Department of Education, and the Armagh Observatory's objectives to pursue difficult and fundamental questions in astronomy and related sciences therefore align very closely with the underlying economic objectives of its core funding agency.

The concept of Cultural Capital plays a key role in the DCAL Strategic Plan; the DCAL Mission is "to protect, nurture and grow our Cultural Capital for today and tomorrow". The activity is not just a major theme of the Northern Ireland Programme for Government, it is central to the work of the Armagh Observatory — because **the Observatory's principal function as an astronomical research institute is to produce and sustain Cultural Capital**.

The Observatory's work is long-term and makes a primary contribution to mankind's accumulated knowledge about the world in which we live. In the same way, astronomical research contributes directly to the creation of a more confident, scientifically literate, informed and prosperous community, and helps to develop Northern Ireland's scientific heritage whilst generating a new cultural and educational resource for the future.

Science in the Community Another important element of the Armagh Observatory's activity is its responsibility to care for and maintain the Observatory Grounds and Astropark, the Historic Library, Archives, and Buildings, and to preserve and display to the best possible advantage the historic telescopes and scientific instruments.

These activities complement and provide a rich addition to the ecclesiastical and built heritage of the City of Armagh. There is synergy with the other specialist Libraries and Museums in the City (another DCAL responsibility), and in recent years the Observatory has helped Armagh to achieve a "critical mass" in this area through its leadership role in the Armagh Visitor Education Committee (AVEC).

The Observatory's active programme of Science in the Community attracts many visitors to Armagh, for example to the Armagh Observatory Grounds and Astropark, and to the Human Orrery and Phenology Garden. During 2004 approximately 20,000 visitors passed through the Observatory Grounds and Astropark; in 2007 the number was approximately 45,000. The presence of a flourishing astronomical research institute in the centre of the City of Armagh is a key component of the city's plans to develop its heritage and tourism product.

Armagh Observatory also maintains a vigorous programme of school work experience and training, as well as accommodating visits by young people including school parties. 2007, for example, saw the Observatory host (together with the Centre for Cross Border Studies) the first Cross-Border Schools Science Conference.

The Observatory sponsors a variety of public lectures and special events, all of which encourage visits to the Observatory and to the Observatory Grounds and Astropark by special interest groups and schools. The Observatory hosts a biennial Robinson Lecture and an associated biennial Robinson Schools lecture. Directly as a result of the Observatory's research, 2008 (and not 2009) will be celebrated as the tercentenary of the birth of the Observatory's founder, Archbishop Richard Robinson.

The new Human Orrery exhibit, funded largely by the DCAL with educational material supported by funding from the PPARC, also provides many innovative educational activities for school children and visitors at a variety of levels. This is the first such outdoor exhibit in the world, and so helps to put the Armagh Observatory — and Northern Ireland — firmly 'on the map' as a leading centre for research in astronomy education.

Staff at the Observatory make many contributions to lifelong learning and the promotion of a deeper understanding of astronomy and related sciences amongst the general public. In addition to attracting visitors to Armagh from across the UK and Ireland, and farther afield, they help to promote wider knowledge and understanding of the Observatory's unique meteorological record, the longest in the UK and Ireland from a single site, and of Ireland's and Northern Ireland's significant astronomical heritage.

Observatory staff also answer many technical questions on astronomy from members of the public, and engage actively with the mass media: radio, television and the press. The Observatory web-site attracts more than a million Distinct e-Visitors every year, who in 2007 together downloaded more than 4 Terabytes of data and other astronomical information, 30% more than the year before.

All these activities engage students and young people in science and help to generate the conditions necessary to create a scientifically more literate society.

The Observatory's achievements in astronomical research, as well as its efforts to promote greater public understanding of science, thus align closely with the DCAL's wider aims to improve access to Northern Ireland's cultural heritage, to create a confident, informed and vibrant community, and to protect, nurture and grow Northern Ireland's cultural capital for the enjoyment of both present and future generations.

The Armagh Observatory makes a unique contribution to projecting a positive image of Northern Ireland on the world stage. In this way it contributes to greater awareness and economic prosperity of the region whilst improving the self-awareness and confidence of the people who live there.

Economic and Cultural Benefits of Astronomy at Armagh Modern astronomy is an involving, inspirational activity with a unique ability to spark the imagination and to attract young people towards science and engineering. It has an impact that can last a lifetime and inspire future generations. During 2007/2008 the Observatory has been involved in International Heliophysical Year, and it is already planning to make a significant contribution to the United Nations International Year of Astronomy in 2009 (IYA 2009).

It is well known that scientists engaging in basic research contribute to the intellectual vibrancy of society, for example by attracting people into the region or simply by contributing to an active programme of education and public outreach in the community. They also help to create the conditions for a strong R&D base and those for society to participate in, and sometimes lead, scientific and technological projects of global significance.

Astronomy is a topic which leads naturally to increased public awareness of science and to the development of a more scientifically literate population. The fruits of astronomical research often rekindle our unique 'ability to wonder': a facility that in adults (as opposed to children) often lies dormant.

High-level scientific exchange and the involvement of the Armagh Observatory in international projects puts Armagh and Northern Ireland on the international map, for example through the Armagh Observatory's involvement in the Southern African Large Telescope or the involvement of staff in the European Southern Observatory in Chile. Such projects allow the Observatory to play an ambassadorial role on the world stage and encourage international co-operation and greater understanding of cultural diversity.

Finally, as has been noted before, staff at the Observatory obtain very significant amounts of external (i.e. non-DCAL) income to support their work. This helps to sustain fundamental research in the City of Armagh, provides additional reasons for visitors to come and stay in the City, for example through the support of scientific conferences, and makes a very significant contribution to the strength of the local and regional Northern Ireland economy.