The Armagh Observatory Business Plan 2009/2010

Business Plan for Period 2009 April 1 to 2010 March 31

Prepared by the Director

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2009 April 19

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 approximately 30 academic staff, which at the end of 2008 comprised 6 Research Astronomers and 20 other academic staff (including the director, several PDRAs and around a dozen PhD students) as well as several academic visitors, 3 core research and 4.5 core grounds and administrative support staff. The Observatory has an active visitors programme, hosting an average of around 15 temporary academic visitors from abroad each year who typically come for periods of 1–3 weeks at a time, 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 and the receipt of external grants from the UK Science and Technology Facilities Council (STFC) and other grant-awarding bodies. The total expenditure of the Observatory is in excess of £1M per year, of which approximately three-quarters is directed towards research. In 2007/2008, for example, £87.8k was spent on administration and corporate governance (cf. £106.4k in 2006/2007); £110.9k on buildings and grounds (cf. £148.8k in 2006/2007); and £945.5k on research and related education and public outreach projects (cf. £782.6k in 2006/2007).

Core DCAL resource funding has averaged approximately £660k per year over the last six years, with an uplift to £817k in 2008/2009. 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. The value of the Armagh Observatory's usage of UK facilities located abroad and in space has averaged a further £430k per year over the past ten years, representing an additional very significant rate of return on Northern Ireland investment on astronomy at Armagh.

Research Environment The Observatory carries out front-line astronomical research in three key areas of astrophysics, namely: Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics. These fields encompass the dynamical structure, evolution and origin of objects in the inner and 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 very 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, 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 research programmes (and others not mentioned) illustrate the Observatory's primary long-term research function; the projects typically have lead times of a year or more and require up to 3–5 years for completion.

Computer facilities are used primarily for numerical analysis, computer modelling and data reduction; the computers and peripherals are largely funded by the DCAL, but occasionally by external research grants, for example those funded by the STFC or PRTLI. Staff have access to a number of iMac workstations, approximately 40 Linux workstations and peripherals, a number of portable computers, and a computer cluster comprising 25 dual-processor work nodes and one master node with a total of 50 GB of memory. This is used for computationally intensive research projects in observational and theoretical astrophysics (including data reduction and modelling) in areas such as solar physics, stellar atmospheres, stellar winds, radiation hydrodynamics, numerical magneto-hydrodynamics, and solar-system dynamics.

The internal network is a 1 Gbps backbone ethernet linked with switched hubs. The external network is connected to the Joint Academic Network (JANET) through a dedicated 10 Mbps link provided through the Observatory's participation in the Northern Ireland Regional Area Network (NIRAN). It is planned to increase the Observatory's network capacity as part of a series of continuing upgrades to maintain the Observatory's capacity to participate in important new developments such as the Virtual Observatory and Grid-computing. Access to Grid technology is currently provided via CosmoGrid (http://www.cosmogrid.ie/). This provides access to a high-performance supercomputer cluster at the Irish Centre for High-End Computing (ICHEC) as well as advanced training programmes.

The Observatory's suite of 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, archives and museum collection together contain a unique and growing collection of historic books and manuscripts,

as well as images, photographic plates, scientific instruments, clocks and other artefacts concerning the development of astronomy in the UK and Ireland 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 agencies to use the Armagh series for reports and research into global warming. This is a subject of 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.

Outreach and Visitor Numbers In addition to its primary research function, the Armagh Observatory — in common with other cognate organizations (e.g. research institutes, universities and research councils) — undertakes an active programme of Science in the Community. 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 (2007) 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 around a 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.5).

Performance The Armagh Observatory has enjoyed considerable success during the past year, and indeed over a much longer time, with key performance indicators frequently exceeding prior-year targets and on generally ascending trajectories. The trends in the Observatory's performance are summarized in Table 1, Figure 1 (see p.3) and Figure 2 (see p.12), and Tables 3 and 4 (see p.13).

Over the past number of years, as described below (see Section 1, p.6), the Observatory has made very significant contributions to Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics, as well as to other areas such as the history of science and meteorology. It is developing new research programmes in each of these principal areas, as well as other projects, many of which are expected to be completed and to lead to new understanding over the next 3–6 years.

Key Objectives for 2009/2010 The Armagh Observatory is a vibrant international research institute that 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 2009/2010 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 3–5 PhD students and providing a high-quality research environment to facilitate the advanced training of 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.

The Observatory also plans to maintain its programmes of Science in the Community, and to play a leading role in public events associated with the United Nations International Year of Astronomy 2009 (IYA 2009), designated by the UN to mark the 400th anniversary of Galileo's first use of a telescope for astronomical observations. As part of IYA 2009, the Observatory is co-organizing the Second Cross-Border Schools Science Conference in Armagh (29–30 April 2009) and the Ninth European Symposium for the Protection of the Night Sky (to be held in Armagh from 17–20 September 2009); and a member of staff is playing a leading role in the promotion and administration of IYA 2009 throughout the island of Ireland.

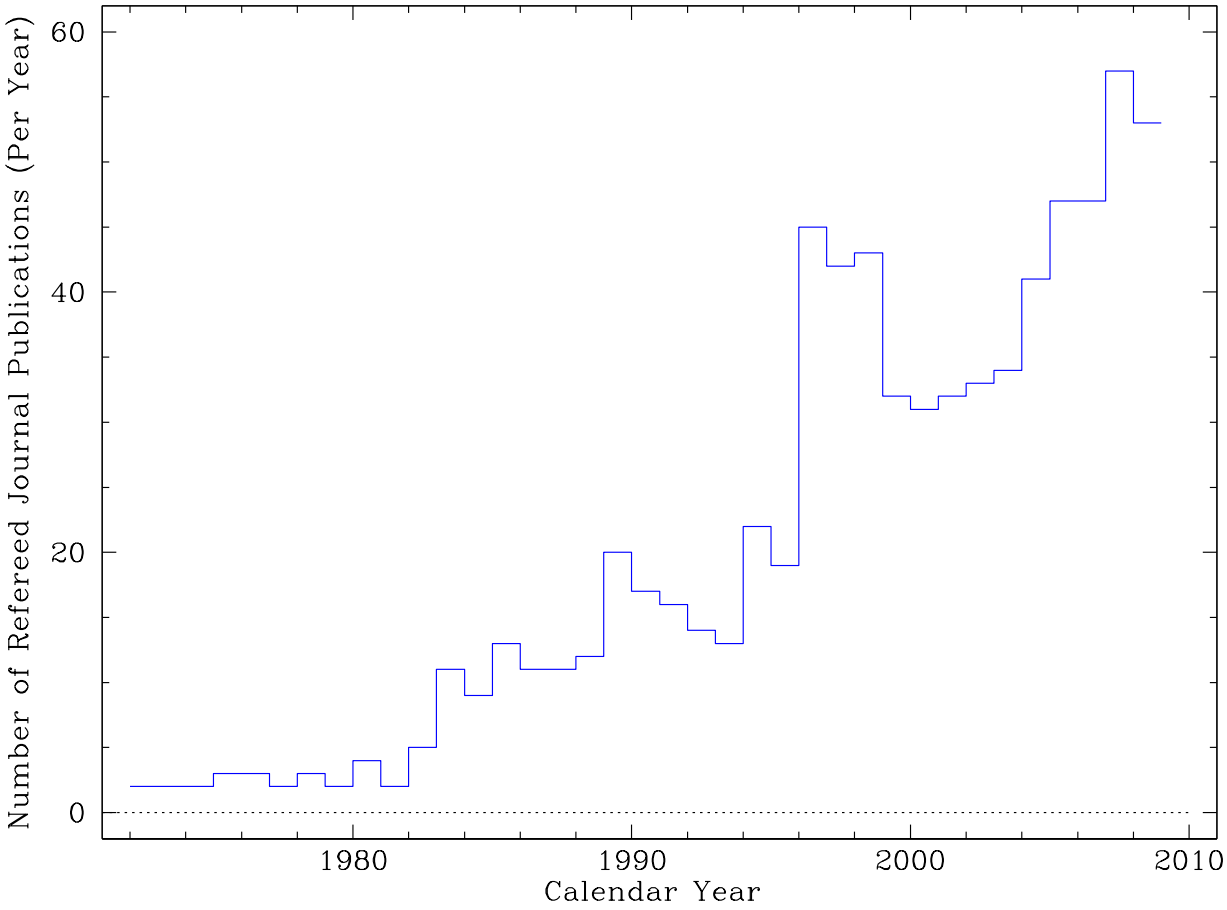

Figure 1: The number of refereed journal papers published by Armagh Observatory staff over the past thirty-five years for comparison with Key PI "Refereed Publications" illustrated in Figure 2 and Tables 1 and 3. Note how the Observatory's productivity has increased by a factor of approximately five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

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In addition to its programmes of frontline scientific research and public understanding of science, the Observatory has an important function to promote and preserve the historic library, archives and museum collection at Armagh, which together represent a very significant component of Northern Ireland's scientific heritage. Work that began during 2008/2009 to conserve and restore some elements of this collection will be continued during 2009/2010, and efforts will be made to digitize the most important archives, making the material accessible via the Internet to researchers, scholars and the general public from anywhere in the world.

Funding The chronic underfunding of the Armagh Observatory is an issue that has been drawn repeatedly to the attention of the Management Committee, the Board of Governors and the DCAL over the past decade. The position at the beginning of 2009/2010 is considerably better than that at the beginning of the previous year, but the Observatory still requires an uplift in core funding. The minimum required to allow the Observatory to maintain its present high level of frontline scientific research and other activities is an additional £105k, which has already been identified by the DCAL in principle to support the Observatory's core running costs. It has also been recognized that a further element of resource funding (c.£50k) will be necessary for the Observatory to progress its plans for a new Library, Archives and Historic Scientific Instruments building. These two items of additional funding, totalling £155k, have been included in Table 1, and a balanced budget (albeit excluding the uncertain additional £50k income and expenditure associated with the development of the new Library building project) is projected for 2009/2010 (see Tables 5 and 6; pp.15 and 16).

It should be noted, however, that in constructing this balanced budget the Observatory has had to make very substantial cuts in operating costs compared to prior-year plans, and there is a need to consolidate the £105k core-funding uplift together with a further £65k of additional core resource funding and for this to be protected against annual inflation in day-to-day running costs.

The Armagh Observatory does not lightly request additional funding. Rather, it would prefer to highlight its record of significant improvements in the quality and volume of its scientific output during the past decade and more, and the very significant rate of return that it provides, per pound, on Northern Ireland government investment in astronomy at Armagh. The average rate of return is typically approximately 20%, and more than twice this (i.e. greater than 40%) when the cost of the Observatory's use of external facilities at international observatories abroad and in space is included. In the recent Research Assessment Exercise, the Observatory's research was very highly rated, with 85% of its activity being of *international quality,* and its programmes of outreach and public understanding of science deemed *world-leading.*

The requested additional funding for this year, and its consolidation in the following year (Year 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. The provision of a sufficiency of funding for the Armagh Observatory to carry out this 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 which that entails.

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	113.9	955.9	242.8	300	53	50	997	1800	413	250	5 30 50 15	1.7	10
2009	**817.0**	**25.0**	**155.0**	**997.0**		**300**		**50**		**1800**		**250**			**10**
2010	**817.0**	**25.0**	**200.0**	**1042.0**		**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). 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 2008/2009 figure (£113.9k) is made up of £5k from the Planetarium and £64k from the DCAL, and £44.9k additional capital funding. For future years it is the required step-increase in core funding necessary for the remaining two years of the three-year planning period, including additional funds (£50k) to progress the new Library building.
3. Figures for External Grant Income refer to external grant income received in cash terms during each financial year, and at the time of writing are unaudited and still subject to change.
4. The 2008 RAE Result is a grade profile indicating the percentage of the Observatory's overall activity that is world-leading (5%), internationally excellent (30%), recognized internationally (50%), and recognized UK-nationally (15%), with none at less than UK-national quality. These figures indicate that 85% of the Observatory's overall activity is of international quality.
5. The number of days absence per person is defined as the ratio D/N, where D is the total number of days lost due to staff absence per calendar year and N is the number of staff in post at the end of the corresponding year. These figures too are extremely good, particularly compared to other areas of the public sector.
6. Note that targets and/or requirements for calendar year 2009 or financial year 2009/2010 and beyond are expressed in round figures.

Table 1: Trends of Armagh Observatory performance indicators (PIs) versus calendar year. Table last updated 2009 April 15.

1 Organization and Research Environment

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 approximately 30 academic staff, which at the end of 2008 comprised 6 Research Astronomers and 20 other academic staff (including the director, several PDRAs and around a dozen PhD students) as well as several academic visitors, 3 core research and 4.5 core grounds and administrative support staff. The Observatory has an active visitors programme, hosting an average of around 15 temporary academic visitors from abroad each year who typically come for periods of 1–3 weeks at a time, 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
2008	6	20	3	5	6	40

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, of which approximately three-quarters is directed towards research: in 2007/2008, for example, £87.8k was spent on administration and corporate governance (cf. £106.4k in 2006/2007); £110.9k on buildings and grounds (cf. £148.8k in 2006/2007); and £945.5k on research and related education and public outreach projects (cf. £782.6k in 2006/2007). Core DCAL resource funding has averaged approximately £660k per year over the last six years, with an uplift to £817k in 2008/2009, 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

The Observatory carries out front-line astronomical research in three key areas of astrophysics, namely: Solar-System Science, Solar Physics, and Stellar and Galactic Astrophysics. These fields encompass the dynamical structure, evolution and origin of objects in the inner and 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 very 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, 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 research programmes (and others not mentioned) illustrate the Observatory's primary long-term research function; the projects are often funded by external (i.e. non-DCAL) funding agencies with lead times of typically a year or two; they are normally led by an individual Research Astronomer; and can often require up to 3–5 years for completion.

Computer facilities are used primarily for numerical analysis, computer modelling and data reduction; the computers and peripherals are largely funded by the DCAL, but occasionally by external research grants, for example those funded by the STFC or PRTLI. Staff have access to a number of iMac workstations, approximately 40 Linux workstations and peripherals, a number of portable computers, and a computer cluster comprising 25 dual-processor work nodes and one master node with a total of 50 GB of memory. This is used for computationally intensive research projects in observational and theoretical astrophysics (including data reduction and modelling) in areas such as solar physics, stellar atmospheres, stellar winds, radiation hydrodynamics, numerical magneto-hydrodynamics, and solar-system dynamics.

The internal network is a 1 Gbps backbone ethernet linked with switched hubs. The external network is connected to the Joint Academic Network (JANET) through a dedicated 10 Mbps link provided through the Observatory's participation in the Northern Ireland Regional Area Network (NIRAN). It is planned to increase the Observatory's network capacity as part of a series of continuing upgrades to maintain the Observatory's capacity to participate in important new developments such as the Virtual Observatory and Grid-computing. Access to Grid technology is currently provided via CosmoGrid (http://www.cosmogrid.ie/). This provides access to a high-performance supercomputer cluster at the Irish Centre for High-End Computing (ICHEC) as well as advanced training programmes.

The Observatory's suite of 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, archives and museum collection together contain a unique and growing collection of historic books and manuscripts, as well as images, photographic plates, scientific instruments, clocks and other artefacts concerning the development of astronomy in the UK and Ireland 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 agencies to use the Armagh series for reports and research into global warming. This is a subject of 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, Armagh Observatory staff regularly obtain telescope time on national and international facilities, such as the ESO Very Large Telescope (http://www.eso.org/outreach/ut1fl/) and various spacecraft missions (such as SoHO, TRACE, Hinode, XMM-Newton, and the Hubble Space Telescope). They attract research grants from a wide range of grant awarding bodies (e.g. the STFC, the Royal Society, the Leverhulme Trust, British Council etc.), and through the Observatory's membership of the UK SALT Consortium (UKSC) have access to the 11-metre diameter Southern African Large Telescope (SALT; see http://star.arm.ac.uk/SALT/), located at the Sutherland Observatory, South Africa. Complementing these international facilities, restoration of the Observatory's historic telescopes has brought opportunities to reintroduce professional observing from Armagh for research and student training, while new computer and camera technology has enabled a variety of new automatic observational programmes to be introduced from Armagh, recording data autonomously whenever the sky is clear.

Education and Public Outreach In addition to its primary research function, the Armagh Observatory also undertakes an active programme of Science in the Community. Recent innovative projects have included construction of the Human Orrery (the first such exhibit in the world to be laid out with precision) and the creation of the first International Phenology Garden in Northern Ireland, which is closely linked to European and Cross-Border phenology projects and to the Observatory's own unique climate record. In recent years, the Observatory's programme of Science in the Community has included

playing a major role in the Royal Society of London's "Living with a Star" exhibition and related UK and Ireland International Heliophysical Year (IHY 2007/2009) activities; organizing the first Cross-Border Schools Science Conference; and playing a leadership role in the Armagh Visitor Education Committee (AVEC), particularly in arrangements for the second Armagh Heritage Day "Robinson's Legacy to Armagh", and editing the proceedings of this and the previous year's heritage day into a book "Border Heritage: Tracing the Heritage of the City of Armagh and Monaghan County".

The Observatory's programme of Science in the Community highlights the heritage of international astronomical expertise in Armagh and helps to explain to a wider audience the very active research programmes in astronomy and related sciences that have been undertaken over the past more than two hundred years. The Observatory is an international research institute that makes a major contribution to promoting the City of Armagh, and indeed Northern Ireland, on the world stage. It attracts a high level of media interest (e.g. more than 300 mass-media citations to its work per year); its web-sites attract typically around a million distinct e-visitors annually from around the world; and more than 40,000 people visit the landscaped Grounds and Astropark every year. The trends of some of the Observatory's key performance indicators are shown in Table 1 (p.5) and Table 3 (p.13).

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.

In recent years, staff have regularly obtained 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 213-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 and the Observatory's contributions to the tercentenary celebrations, in 2008, of the birth of its founder, Archbishop Richard Robinson, in 1708). Recent key achievements have been the calibration of the meteorological archive and demonstrating the importance of clouds (suggesting an important indirect solar influence) on climate change. These examples illustrate the breadth of research interests in this small but vibrant international research group.

1.3 Research Plans for 2009/2010 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 2008/2009

The principal Business Plan objectives for 2008/2009 were to:

- obtain external grants and funding to support new research projects — **done**;
- 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) — **done in part**; 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 — **not done**.

In addition, the Observatory planned 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). **These additional Business Plan objectives were all progressed significantly or completed during 2008/2009**.

We note that (a) the detailed design for a new Library, Archives and Historic Scientific Instruments building was not advanced in 2008/2009 because of insufficient resources to procure the expertise to carry out the necessary development work; and (b) the necessary upgrade to the Observatory's connection to the Internet was not advanced as planned because the NIRAN upgrade itself was delayed by a year. Both these objectives are key strategic goals for the Observatory and are retained for completion during 2009/2010, subject to funding and other matters outside the Observatory's control.

The trends of the various key performance indicators which represent the sum of the Observatory's principal strategic objectives are summarized in Figure 2 (p.12), while other relevant material is presented in Table 1 (p.5). Table 3 illustrates the corresponding trends for the four new Key Performance Indicators introduced by the DCAL halfway through 2006, and Table 4 provides information on other recorded data. Taken together, these Tables and Figures demonstrate that the Armagh Observatory has achieved considerable success during the past number of years and is now well-placed, subject to the provision of sufficient core resource funding, to build on this success and make a very significant contribution to Northern Ireland's Cultural Capital.

2.1 Key Performance Indicators

Results for various key performance indicators are summarized in Table 1, and Tables 3 and 4 (see p.5 and p.13).

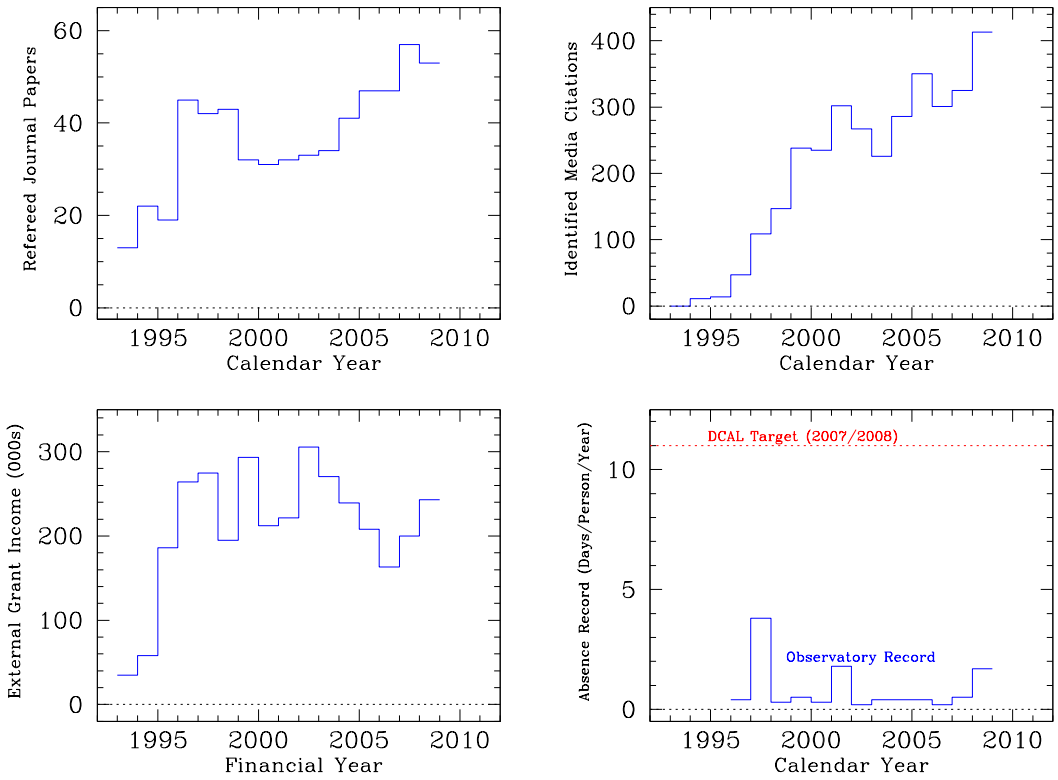

Figure 2: Histograms showing the trends of various performance indicators for the Armagh Observatory during the past fifteen years. The different panels show the number of refereed journal publications per calendar year; the amount of external (i.e. non-DCAL) grant income (£000s) received in cash terms per financial year; the number of identified mass-media citations to the Observatory, its staff and their work during 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.

In order to avoid any confusion, it should be emphasized that targets for external income in these Tables are *aspirational,* and are intended to provide a reminder and a pressure on staff to obtain external grant income to support their work wherever possible. More realistic current 'business plan' targets for 2008/2009, and 2009/2010 and 2010/2011 respectively, are of the order of £225k, £290k and £270k (e.g. see Table 5, p.15; cf. projected figures for these years provided in the prior-year Business Plan dated 2008 July 31, namely £219.1k, £239.1k, and £236.7k respectively).

Referring to Table 4, we note that the number of Distinct e-Visitors (1.0 million) and the number of web-site 'Hits' (13.6 million) are both less than the prior year 2007 and less than the target for the year. At the same time, however, the volume of data exported from the Observatory's web-sites to users elsewhere has increased by a very substantial factor (more than 50%), showing that the million or so users who currently use the web-site every year are now downloading a much greater volume of material, on average, than was previously the case. The trends for web-site activity are thus difficult to interpret, especially against a background of exponentially growing volume and use of the Internet world-wide. These indicators of the quality, volume and value of the Observatory's web-sites will continue to be monitored.

Government Key Performance Indicators Halfway through 2006, the DCAL required the Observatory to develop a new set of key PIs, three of which were non-negotiable and intended to be held in common both with the DCAL and other Arms-Length Bodies supported by the Department. The three new key PIs were (A) Rate of Return; (B) Administrative Efficiency; and (C) Staff Absence. It was agreed that the fourth key PI, reflecting the Observatory's research performance, would continue to be the number of refereed scientific journal publications per year, although it is recognized that the RAE 2008 result is more important, and that in general the *quality* of scientific pubilcations is more important than

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	20.2	21.5	8.2	8.2	1.7	10.0	53	50
2009 or 2009/2010		**21.5**		**8.2**		**10.0**		**50**
2010 or 2010/2011		**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. Table last updated 2009 April 15.

Performance Indicator	Result for Current Year	Target for Current Year	Result for Prior Year
External Grant Income Received In-Year (£000s)	242.8 (12 months)	300.0	200.0
Other External Income Received In-Year (£000s)	11.5 (12 months)	15.0	19.5
Distinct e-Visitors (millions)	1.00 (12 months)	1.80	1.59
Web-Site 'Hits' (millions)	13.6 (12 months)	15.0	14.0
Data Exported (TB)	7.01 (12 months)	5.00	4.47
Identified Media Citations	413 (12 months)	250	325
Astropark Visitor Numbers	45687 (12 months)	40000	45344

Table 4: In-year results for other Performance Indicators. Table last updated 2009 April 15.

their volume. The complete set of Government-defined key performance indicators is thus as follows:

A **"Rate of Return"**. This is 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, we emphasize, takes no account of the Observatory's significant use of external facilities) has averaged around 20%. In general, a high value is better, though it must be remembered that the Observatory is not a commercial organization.

B: **"Administrative Efficiency"**. This is 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, and in general any figure less than 10% is very good.

C: **"Staff Absence"**. This is the average number of days absence per person per calendar year (days per person per year). A low value is better, and in general any figure less than 3 days per person per year is very good.

D: **"Refereed Publications"**: the number of scientific papers published per calendar year in refereed scientific journals. In general, a high value is better, though (as already noted) high-quality, influential work is more important, and this can also appear in other media such as books, conference publications and so on.

The results for these Government-defined key PIs for prior years for which we have data, as well as targets for 2009/2010 and 2010/2011, are shown in Table 3 (note that we have also calculated the new PIs for prior years). Results for a variety of other PIs that are routinely collected to assess the Observatory's performance in different areas of activity are shown for information in Table 4. In addition to these specific performance indicators, various other data are routinely recorded for statistical or internal management purposes, many of which are presented in tabular or narrative form in each year's Annual Report. For past reports, see http://star.arm.ac.uk/annrep/.

It should be noted that in this report all items with the exception of financial matters refer to calendar year. We also remark, in order to avoid any confusion, that total external grant income received in cash terms per financial year (Table 1) is not the same as the total external grant income per financial year shown in the accounts, as in key PI 'A' Rate of Return (Table 3). The latter is calculated on an accruals basis following Resource Accounting rules.

Finally, we note that factors that should be considered when interpreting these results are the number of senior research staff available to obtain external grants and to direct research projects, other pressures on Observatory staff time, and the level of core funding provided by the sponsor government department.

3 Objectives for 2009/2010

The Armagh Observatory is a vibrant international research institute that 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 2009/2010 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 3–5 PhD students and providing a high-quality research environment to facilitate the advanced training of 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.

The Observatory also plans to maintain its programmes of Science in the Community, and to play a leading role in public events associated with the United Nations International Year of Astronomy 2009 (IYA 2009), designated by the UN to mark the 400th anniversary of Galileo's first use of a telescope for astronomical observations. As part of IYA 2009, the Observatory is co-organizing the Second Cross-Border Schools Science Conference in Armagh (29–30 April 2009) and the Ninth European Symposium for the Protection of the Night Sky (to be held in Armagh from 17–20 September 2009); and a member of staff is playing a leading role in the promotion and administration of IYA 2009 throughout the island of Ireland.

In addition to its programmes of frontline scientific research and public understanding of science, the Observatory has an important function to promote and preserve the historic library, archives and museum collection at Armagh, which together represent a very significant component of Northern Ireland's scientific heritage. Work that began during 2008/2009 to conserve and restore some elements of this collection will be continued during 2009/2010, and efforts will be made to digitize the most important archives, making the material accessible via the Internet to researchers, scholars and the general public from anywhere in the world.

4 Draft Budget: Income and Expenditure for 2009/2010

Tables 5 and 6 provide a detailed summary of the Observatory's projected income and expenditure for 2009/2010, together with a detailed comparison between the budget (2008 July 31) for 2008/2009 and the projected expenditure (as at 2009 April 17, Unaudited Figures) for 2008/2009, and with actual income and expenditure for 2007/2008.

Last Up-date 2009 April 19	2009/1010 Budget £k	2008/2009 2009-Apr-17 UNAUDITED	2008/2009 2008-Jul-31 BUDGET	2007/2008 Actual £k
Incoming				
DCAL recurrent grant paid				
DCAL recurrent grant paid	817.0	817.0	817.0	660.0
Re-allocation of DCAL recurrent grant from Planetarium	0.0	5.0	35.0	0.0
Additional in-year recurrent grant	105.0	64.0	60.0	0.0
Total DCAL recurrent grant paid	922.0	886.0	912.0	660.0
DCAL capital grant				
Capital grant paid	25.0	25.0	25.0	6.5
Capital grant deferred	0.0	0.0	0.0	0.0
Additional in-year capital funds paid	0.0	44.9	0.0	27.5
Total DCAL capital grant paid	25.0	69.9	25.0	34.0
DCAL Additional Restricted Funds				
Science and Skills funding received	0.0	0.0	0.0	175.0
Science and Skills funding deferred	0.0	0.0	0.0	-2.0
Science and Skills funding released	0.0	0.0	0.0	0.0
Pension deficit (Note: not shown as grant not yet announced)	0.0	0.0	0.0	0.0
Total DCAL additional restricted funds	0.0	0.0	0.0	173.0
External Grants and Other Restricted Funds				
New Library, Archives and Historic Scientific Instruments Building	0.0	0.0	0.0	0.0
Grants and other restricted funds received	273.4	242.8	182.9	200.0
Grants and other restricted funds deferred	-6.7	-40.6	-1.2	-17.3
Grants and other restricted funds released	25.1	27.8	37.4	24.5
Total	291.8	230.0	219.1	207.2
Miscellaneous income				
Interest	0.8	2.4	4.0	7.3
Rents	5.1	5.5	5.7	5.8
Miscellaneous	1.5	3.6	2.0	6.4
Total	7.4	11.5	11.7	19.5
Total Income	1246.2	1197.4	1167.8	1093.7

Table 5: Projected income for the Business Plan 2009/2010, last updated 2009 April 19, with assumed additional income of £105k core funding (cf. Table 6).

Last Up-date 2009 April 19	2009/1010	2008/2009	2008/2009	2007/2008
Expenditure	**Budget**	**2009-Apr-17**	**2008-Jul-31**	**Actual**
Research and Research Support Costs	**£k**	**UNAUDITED**	**BUDGET**	**£k**
Capital equipment from DCAL capital grant	25.0	25.0	25.0	6.5
Appropriation of DCAL recurrent grant for capital equipment	0.0	0.0	0.0	0.0
Additional capital equipment from in-year DCAL funds	0.0	44.9	0.0	27.5
Capital equipment funded by external grants and other income	0.0	7.0	9.6	0.0
New Library, Archives and Historic Scientific Instruments Building	0.0	0.0	0.0	0.0
Contribution to SALT operating costs	5.5	4.2	3.2	0.5
Other SALT/UKSC expenses	1.5	0.6	1.5	0.1
Salaries of permanent research and research support staff	552.5	542.5	544.8	506.5
Salaries of fixed-term research and research support staff	120.4	83.8	84.0	101.9
Student maintenance grants	97.4	90.9	90.3	111.9
Student maintenance funded by external grants	28.1	7.8	0.0	0.0
Research staff costs allocated to Skills & Science	0.0	0.0	0.0	-56.5
Student maintenance grants allocated to Skills & Science	0.0	0.0	0.0	-82.5
Student fees	9.3	8.4	10.0	9.3
Student fees funded by external grants	6.6	0.0	0.0	0.0
Former Director's pension supplement	2.3	2.0	2.2	2.0
Core travel and subsistence from DCAL funds	30.0	27.9	25.0	23.3
Travel and subsistence from external grants and other income	21.2	38.9	42.5	28.5
STFC Summer School	0.0	0.0	0.0	20.4
Visitors programme	12.0	3.2	3.0	1.5
Visitors programme funded by external grants and other income	0.0	1.2	0.0	0.0
Conferences	0.0	1.8	1.0	0.0
Hosting meetings and lectures	1.5	0.7	1.0	2.4
Royal Society Solar Exhibit	0.0	0.0	0.0	1.5
JANET access costs	36.0	25.6	36.0	25.9
Core computer consumables from DCAL funds	14.0	13.1	12.0	12.5
Computer consumables funded by external grants and other income	2.0	0.3	10.0	1.0
ADAS: The Atomic Data and Analysis Structure database (Solar Physics)	3.0	1.5	0.0	0.0
Library, archives and historic instruments	30.0	29.9	30.0	24.5
Publications	0.7	0.0	0.7	1.9
Archiving costs - Armagh Public Library and Conservation Costs (e.g. Birr, Met. etc.)	8.8	5.6	0.0	0.0
UK entertaining	0.1	0.0	0.1	0.1
Advertising and promotions	0.5	0.4	0.5	0.3
Public Understanding of Science	7.5	3.6	3.0	1.7
Historic books/instruments	0.0	0.0	0.0	0.0
STFC Projects Peer Review Panel meeting	0.0	1.7	0.0	0.0
IYA2009 Schools Science Conference (SSC2009)	2.2	0.0	0.0	0.0
Light Pollution Conference (2009 September 16-19)	5.3	0.0	0.0	0.0
Other IYA2009 Projects	0.0	2.9	0.0	0.0
North/South Schools Conference 2007 / Lindsay Meeting 2007 over-provision	0.0	0.0	0.0	-2.0
Agency staff costs (archives/meteorological records)	0.0	0.0	6.0	0.0
Pension deficit (Note: not shown as deficit not yet announced)	0.0	0.0	0.0	0.0
Losses and Special Payments	0.0	0.0	0.0	0.0
Total research and research support costs	1023.4	975.4	941.4	770.7
Skills & Science				
Direct costs				
Direct salaries	0.0	0.0	0.0	35.8
Re-allocation of core costs				
Student maintenance grants/fees	0.0	0.0	0.0	82.5
Research staff student supervision costs	0.0	0.0	0.0	56.5
Total Skills and Science costs	0.0	0.0	0.0	174.8
Buildings, Buildings Refurbishment and Grounds Costs				
Salaries of grounds and meteorological records support staff	38.4	38.1	39.0	37.0
Salaries of cleaning and security staff (shared with the Planetarium)	0.0	0.0	0.0	1.8
New Library, Archives and Historic Scientific Instruments Building Estates Costs	0.0	0.0	0.0	0.0
Agency Cleaning Costs	5.0	5.2	5.2	2.5
Cleaning consumables	1.6	0.8	1.5	0.9
Service contracts and professional fees	5.2	4.3	6.5	4.3
Central procurement costs	2.5	1.4	2.0	1.4
Property repairs, furnishings, minor equipment and grounds	27.0	32.4	33.0	24.1
Heat, light, power	31.6	31.4	30.0	29.1
Insurance	10.0	9.1	10.0	9.5
Rates	0.3	0.2	0.3	0.3
Total Buildings, Buildings Refurbishments and Grounds Costs	121.6	122.9	127.5	110.9
Administration and Corporate Governance Costs				
Salaries of administrative and administrative support staff	68.0	69.3	65.6	62.7
Management Committee/Board of Governors	3.5	1.7	1.5	0.7
Internal audit	3.5	3.0	1.8	1.8
External audit	4.1	3.5	3.8	4.2
Legal fees	0.0	0.0	0.0	0.0
Staff training	4.0	0.3	2.0	0.3
Recruitment	1.0	0.5	1.0	0.8
Stationery	2.5	1.5	2.5	2.1
Post and telephone	4.5	4.3	4.7	5.2
Printing	1.5	0.5	1.5	0.5
Office and miscellaneous equipment	0.5	0.0	6.0	2.9
General expenses	5.0	5.7	5.5	5.7
Other professional fees (Actuary, SELB, VLA, EEF)	3.1	8.4	3.0	0.9
Bank interest and other charges	0.0	0.0	0.0	0.0
Total Administration and Corporate Governance Costs	101.2	98.7	98.9	87.8
Total Expenditure	1246.2	1197.0	1167.8	1144.2
Surplus/-Deficit (Before Pension Costs)	**0.0**	**0.4**	**0.0**	**-50.5**
Net Pension Costs	0.0	0.0	0.0	18.0
Surplus/-Deficit (Including Net Pension Costs)	**0.0**	**0.4**	**0.0**	**-68.5**
Cash Reserves				
Opening Balance	**81.9**	**81.5**	**81.5**	132.0
Closing Balance Cash Reserves (Excluding Net Pension Costs)	**81.9**	**81.9**	**81.5**	**81.5**

Table 6: Projected expenditure for the Business Plan 2009/2010, last updated 2009 April 19, with assumed development costs (c.£50k; cf. Table 1) for the new Library building zeroed (cf. Table 5).

A Alignment of Armagh Observatory and Government Objectives

This Appendix summarises how the Armagh Observatory makes major contributions to most, if not all, the DCAL's Public Service Agreements (PSAs) and provides an indication also how the Observatory makes major contributions to other NI Government objectives.

A.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 flows from its position as a world-leading international research institute. That is, 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 too will be the expanded connection to the Internet that will enable external users to download images, videos and other outreach material to make the story of astronomy at Armagh directly accessible from people's homes anywhere in the world. The programme to digitize the Observatory's archives provides a further illustration of how the Observatory's key Business Plan objectives are exactly aligned with corresponding DCAL goals and PSAs.

- 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. In the past year, it has exposed members of the Traveller Community to astronomy at Armagh, and is playing a major UK and Ireland role in the international 'Universe Awareness' (UNAWE) programme. These activities, as well as the Observatory's commitment to continue a programme of therapeutic training for 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, archives and astronomical museum collection, 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 host a growing diversity of flora and fauna; accommodate 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.

A.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). The Observatory's RAE result was indeed a very significant improvement over that in 2001, demonstrating that the quality and volume of the Observatory's research maintain their ascending trajectories.

- 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 the Skills and Science initiative, 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).

A.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 a recent speech at the University of Oxford, the Prime Minister has made the same point: "Some say that now is not the time to invest, but the bottom line is that the downturn is no time to slow down our investment in science." There is no doubt also as to the Northern Ireland Executive's commitment to the support of science as a fundamental driver of both the knowledge and 'real' economy.

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**.

Recent reviews of the value of physics and astronomy, and of continued support for 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 recognized as a lack of adequate training in mathematics and numeracy 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 adopting more 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 and 2008 the corresponding numbers were 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, and this ambitious but highly successful meeting will be repeated, with the support both of DCAL and the Republic of Ireland's 'Discover Science and Engineering' programme, in 2009.

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) was 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. It is anticipated that, as knowledge of the Human Orrery grows, this will become a feature copied for use in school grounds worldwide.

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 around a million Distinct e-Visitors every year, who in 2008 together downloaded more than 7 Terabytes of data and other astronomical information, more than 50% more than the year before.

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

The Observatory's achievements in astronomical research (very highly rated in the recent RAE), as well as its efforts to promote greater public understanding of science (described as *world-leading* in the RAE), 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 was involved in International Heliophysical Year; during 2009 it will 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 additional contribution to the strength of the local and regional Northern Ireland economy.