The Armagh Observatory Business Plan 2011/2012

Draft Business Plan for Period 2011 April 1 to 2012 March 31

Prepared by the Director

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1 Research

1.1 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 2010 (see Table 1) comprised 6 Research Astronomers and 21 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, each year hosting an average of around a dozen temporary academic visitors from abroad, people who come for periods of typically 1–3 weeks at a time, as well as several PhD students that 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 £1.3M per year, of which more than three-quarters is directed towards research. In 2010/2011, for example, £122.4k was spent on administration and corporate governance costs (cf. £107.5 in 2009/2010); £179.3k on buildings, buildings refurbishment and grounds costs (cf. £145.3k in 2009/2010); and £1266.7k on research and related education and public outreach projects (cf. £1093.8k in 2009/2010).

Year	Research Astronomers	Other Academic Research Staff	Core Research Support	Core Grounds and Admin.	External/Visitors and Others	Total
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
2009	6	21	3	5	6	41
2010	6	21	3	5	6	41

Table 1: The number of Armagh Observatory staff present in various categories at the end of each calendar year. **Table last updated 2011 March 7**.

Core DCAL resource funding is currently approximately £1.0M per year, with additional non-cash funding (attributed largely to depreciation and AME pension costs) totalling a further approximately £200k. In addition, the Observatory is able to participate in the Department's periodic monitoring rounds to provide additional in-year funding to support various research, education, public outreach, and technical equipment and infrastructure projects that cannot be progressed using core funding alone. In recent years such additional DCAL funding has averaged a very significant £150k per year. The final element of the Observatory's total income is largely made up of external grants from the UK Science and Technology Facilities Council (STFC) and other grant awarding organizations, obtained by senior research staff through a process of peer review in an increasingly competitive environment. In recent years this external grant income element has averaged around £245k per year (cf. Figure 1). A further element of external income also arises through the use by Armagh Observatory staff of UK facilities located abroad or in space. Over the last decade this has averaged around £0.5M per year, an 'in kind' contribution to the Observatory's research provided by collaboration with other research groups or accessed through central UK government subscriptions, for example facilities such as the European Southern Observatory or the European Space Agency. Thus, the Armagh Observatory provides a high rate of return on Northern Ireland government investment in astronomy at Armagh.

1.2 Research Environment

1.2.1 Principal Research Themes

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.

1.2.2 Computer Facilities

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 16 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 100 Mbps link provided through the Observatory's participation in the Northern Ireland Regional Area Network (NIRAN). The Armagh Observatory has also access to high-performance supercomputing at the Irish Centre for High-End Computing (ICHEC) as well as advanced training programmes.

1.2.3 Library and Archives

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 comprise 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. 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 must provide an addition to the Observatory complex that will complement and enhance the existing Grade A Listed building, and its later developments, and fit sensitively into the historic building complex in a way that reflects the Observatory's research function and its more than 200-year historical development. The new building must also provide additional space for academic staff, adequate space properly to house the collection and provide for its future needs in an appropriately controlled environment, and rooms to conserve and display on a rotating basis the Observatory's fascinating and unique historic material. During 2009 a grounds survey was completed and a draft outline specification for the new building was passed to CPD architects. Efforts will be made during 2011/2012 to build momentum for this key Observatory project.

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

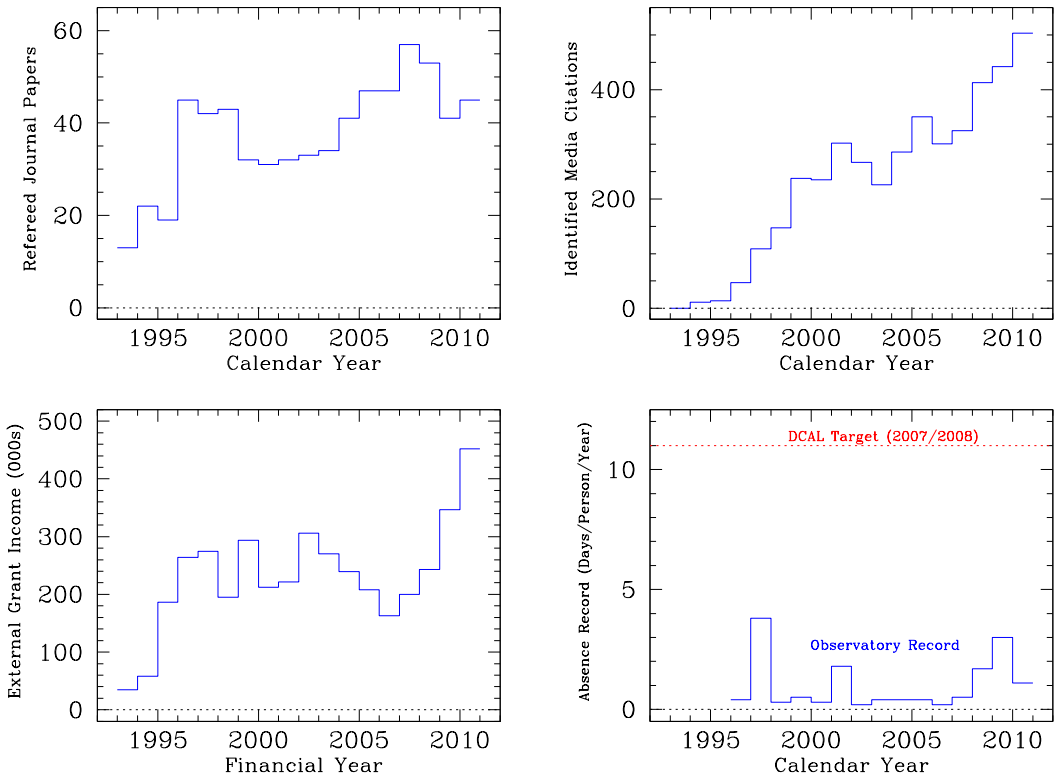

Figure 1: Histograms showing the trends of various performance indicators for the Armagh Observatory during the past fifteen years. The different panels show the number of refereed journal publications per calendar year; the amount of external (i.e. non-DCAL) grant income (£000s) received in cash terms per financial year; the number of identified mass-media citations to the Observatory, its staff and their work 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. Note that the result for external grant income received in cash terms during 2010/2011 is distorted by the receipt shortly before the end of the financial year of funds (£83.4k) for the new EUNAWE programme. **Figure last updated 2011 April 29**.

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.

1.2.4 International Standing

The Observatory's research environment extends to include access to world-class international facilities that are provided through STFC and UK Government subscriptions or through bilateral agreements and collaborations involving individual Armagh Observatory research staff. Thus, 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 some professional observing from Armagh, 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.

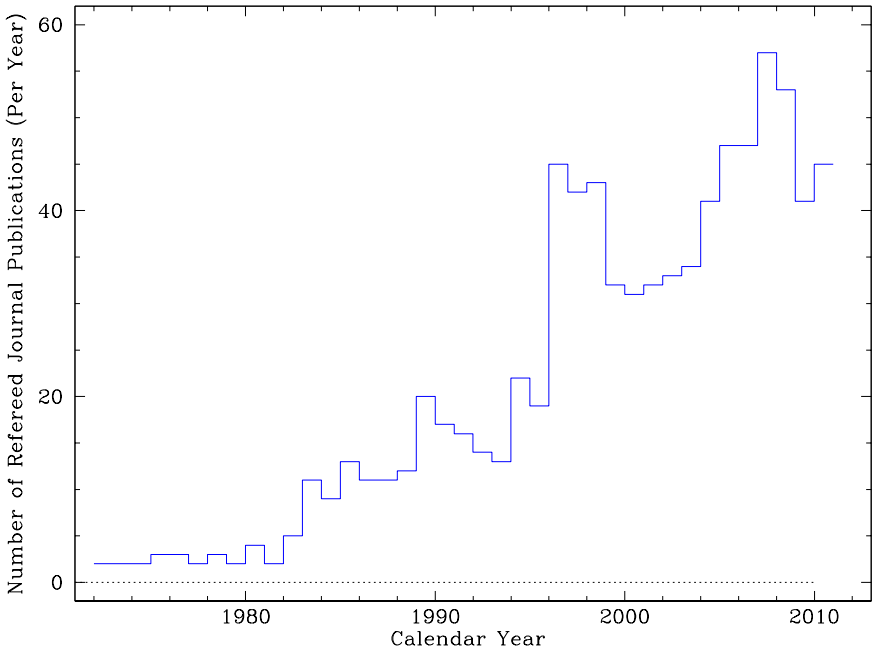

Figure 2: The number of refereed journal papers published per year by Armagh Observatory staff over the past thirty-five years for comparison with Key PI 'Refereed Publications' illustrated in Figure 1 and Tables 2 and 3. **Figure last updated 2011 February 24**.

1.3 Key Audiences and Outputs

The Observatory's principal research findings are published in the international scientific literature in the form of refereed journal publications, books, articles in conference proceedings (refereed and unrefereed), and in a variety of other media (e.g. web-sites, astronomical telegrams etc.). The number of refereed journal publications over the years is illustrated, for example, in Figures 1 and 2.

The initial beneficiaries or **audiences** of this work are members of the international astronomical community, for example our work developing new software for modelling stellar evolution and measuring stellar magnetic fields, and new theories and population codes for modelling stellar remnants and identifying new stellar tracers of Galactic structure. Similarly, in space astronomy our survey work will impact on space missions such as Kepler, LISA and PLATO; our work with the Atomic Data and Analysis Structure (ADAS) software on the Solar Dynamics Observatory (SDO) filter sets impacts on groups world-wide in their analyses of SDO data; and our work on the irregular satellites of the major planets will probe giant planet formation and the origin of the Solar System.

Other beneficiaries or audiences of our work will be teachers and researchers in astronomy and cognate disciplines, as well as those working in fields far removed from research astronomy, for example in art, literature, and areas such as film, TV documentaries and science writing. The Observatory's research frequently attracts media interest, and through this the Observatory's work facilitates an appreciation of astronomy by all.

Academic beneficiaries also include students of all ages, many of whom enter the world of work beyond academia. Those at postgraduate level benefit through seminars and advanced training courses, and by experiencing research at the forefront of world-leading projects. Others benefit through the Observatory's programme of **Science in the Community**, which includes public lectures, schools lectures, and work-experience projects. In this way, the Observatory's primary astronomical research programmes contribute directly to the Government's economic goals to improve scientific literacy throughout the community and to increase the number of people studying STEM (Science, Technology, Engineering and Mathematics) subjects at school and university, so benefiting all.

2 Science in the Community

In addition to its core function to carry out an international level programme of scientific research in astronomy and related sciences, and to expand the heritage of astronomy at Armagh, the Armagh Observatory also carries out a vibrant programme of Science in the Community. There are several strands to this programme, which includes education and learning for all as well as public lectures and guided tours of the Observatory and the Grounds, Astropark and Human Orrery. In addition, there are more formal education and training programmes, for example those associated with the Observatory's programmes of work experience, student training and engagement with the local community, all of which draw on the specific expertise of research astronomers at Armagh.

In the past, 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. The Observatory also presents a biennial public 'Robinson Lecture' in honour of Archbishop Richard Robinson, the Observatory's founder; and in alternate years has worked with the Centre for Cross Border Studies to provide a biennial Cross-Border Schools Science Conference, held using the facilities of the Observatory and those of the Royal School Armagh and the Armagh Planetarium.

The various strands of the Observatory's programme of Science in the Community highlight the contribution of the Observatory's astronomical heritage to Northern Ireland and to the City of Armagh. They help to explain to a wide audience the results of modern astronomy and the benefits of carrying out international-level astronomy, particularly for education, learning and training in the so-called 'STEM' subjects (Science, Technology, Engineering and Mathematics) of such importance for our knowledge-led economy. The Observatory also makes a major contribution to the international profile of Northern Ireland; helps to develop science and science-based skills in the community; and provides an active programme of public lectures, guided tours, and work-experience activities which together contribute to wider UK and Northern Ireland Government initiatives aimed at deepening scientific knowledge and improving scientific literacy across the whole community.

The Observatory also plays a leadership role in the Armagh Visitor Education Committee (AVEC), particularly in assisting arrangements for the annual Armagh Heritage Day, usually held in May of each year, and in editing and publishing a book based on the proceedings of the first two such heritage days, namely 'Border Heritage: Tracing the Heritage of the City of Armagh and Monaghan County'. This was first published in 2008 by TSO (The Stationery Office; see http://www.tsoshop.co.uk/), and efforts to obtain funding for a reprint of the book with minor updates to facilities' information were successful during 2010/2011. The book helps to promote the shared cultural heritage of Northern Ireland and the City of Armagh, as well as the important role played by astronomy as part of Northern Ireland's international research strengths.

In short, the Observatory's vibrant programmes of science in the community highlight the strength of international astronomical expertise in Armagh and help to explain to a wider audience the very active research programmes in astronomy and related sciences that are and have been undertaken in Armagh. The Observatory is an international research institute that makes a major contribution to promoting the City of Armagh and Northern Ireland on the world stage. It attracts a high level of media interest (e.g. in recent years more than 400 mass-media citations to its work per year); its web-sites attract nearly a million distinct e-visitors (DEVs) annually from around the world; and in 2010 substantially more than 50,000 people were recorded visiting the landscaped Grounds and Astropark every year.

3 Trends of Historic Performance Indicators

The generally positive trends of the Observatory's key performance indicators over the past decade and more are shown in Table 2 and Figure 1. These results demonstrate a very high level of scientific and other outputs, an achievement that makes a significant contribution to the Observatory's high profile on the national and international stage.

Over the past number of years, as described in Appendix A (see p.15), the Observatory has made 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.

Calendar or Financial 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
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	163.1	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	922.0	25.0	78.3	1025.3	346.7	300	41	50	910	1800	442	250		3.0	10
2010	1027.0	25.0	207.4	1259.4	452.3	300	45	50	981	900	503	250		1.1	9
2011	**1030.0**	**0.0**	**0.0**	**1030.0**		**300**		**50**		**900**		**250**			**9**
2012	**1028.0**	**49.0**	**0.0**	**1077.0**		**300**		**50**		**900**		**250**			**9**
2013	**1028.0**	**25.0**	**0.0**	**1053.0**		**300**		**50**		**900**		**250**			**9**
2014	**1028.0**	**15.0**	**0.0**	**1043.0**		**300**		**50**		**900**		**250**			**9**

Notes to Table of Historic Key Performance Indicators:

1. Financial figures refer to the corresponding financial year, so that Core Revenue funding for 2010 refers to the core revenue funding received in cash terms during 2010/2011 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 (i.e. Announced Cash Funding), Core Capital (i.e. Announced Capital Funding) and Additional Funding received in-year (Resource and Capital). The latter represents funding provided by the DCAL in response to competitive bids from the Observatory to support specific in-year projects and other activities, whether Resource or Capital. The 2010/2011 figure includes an additional £81.0k for Astropark maintenance and various miscellaneous costs; £25.4k for part-settlement of the NICS Equal Pay claim; and £101.0k for grounds and other specialized technical equipment (e.g. computer systems and peripherals). The corresponding projected Revenue figures for 2011/2012 et seq. are based on the announced joint cash plus non-cash budget for the Armagh Observatory and Planetarium (£1828.0k for 2011/2012 plus £30k non-cash from the 2011 June monitoring round) less non-cash costs such as depreciation which are currently estimated as £119k for the Observatory and £231k for the Planetarium, i.e. a total of £350k, leaving a cash budget of £1508k to be split between the two institutions. In addition, under the Annually Managed Expenditure (AME) budget (not shown here), there is a further allowance of £125k (£81k for the Observatory and £44k for the Planetarium) for AME Pension Costs.
3. Figures for External Grant Income refer to external grant income received in cash terms during each financial year.
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 calendar year. The Observatory's absence results are very good.
6. Targets and/or requirements for calendar year 2011 and financial year 2011/2012 and beyond are expressed in round figures.

Table 2: Trends of Armagh Observatory performance indicators (PIs) versus calendar year. **Table last updated 2011 July 26**.

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	–	6.5	–	0.4	–	41	32
2005 or 2005/2006	18.1	–	7.2	–	0.4	–	47	35
2006 or 2006/2007	19.0	20.0	9.8	10.0	0.2	12.0	47	40
2007 or 2007/2008	20.7	20.0	7.4	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	24.2	21.5	8.0	8.2	3.0	10.0	41	50
2010 or 2010/2011	19.4	21.5	7.8	8.2	1.1	9.0	45	50
2011 or 2011/2012		**21.5**		**8.2**		**9.0**		**50**
2012 or 2012/2013		**21.5**		**8.2**		**9.0**		**50**
2013 or 2013/2014		**21.5**		**8.2**		**9.0**		**50**
2014 or 2014/2015		**21.5**		**8.2**		**9.0**		**50**

Table 3: The trend of annual results for 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 2011 April 29**.

4 Business Plan Outturn for 2010/2011

4.1 Key PIs and Performance Monitoring

Results for various performance indicators are summarized in Tables 2, 3 and 4 (see pp. 6, 7 and 8). Note that in this report all items with the exception of financial matters refer to calendar year. In order to avoid any confusion, we also note that total external grant income received in cash terms per financial year (Table 2) is not the same as the total external grant income per financial year shown in the accounts or total external income as defined implicitly in key PI 'A' Rate of Return (Table 3). The latter is calculated on an accruals basis following Resource Accounting rules.

4.2 2010/2011 Business Plan Objectives

The principal Business Plan objectives for 2010/2011 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 their advanced training as well as that of the postdoctoral staff at the Observatory at the beginning of their astronomical careers — **done**;
- progress plans for the design of a new Library, Archives and Historic Scientific Instruments building, a project that plays a central role in the Observatory's forward look — **not done**; and
- build on the success of IYA 2009 by developing recent and past initiatives in education and public outreach that have grown from the Observatory's world-class programme of Science in the Community — **done**.

In addition to these programmes of frontline scientific research and public understanding of science, the Observatory has an important function to promote, preserve and widen access to the Observatory Grounds and the historic library, archives and museum collection at Armagh, which together represent

Performance Indicator	Prior Year (2009 or 2009/2010)	Current In-Year Result (2010 or 2010/2011)	Current-Year Target (2010 or 2010/2011)
A: 'Rate of Return'	24.2%	19.4% (12 months)	21.5%
B: 'Admin. Efficiency'	8.0%	7.8% (12 months	8.2%
C: 'Staff Absence' (days/person/year)	3.0	1.1 (12 months)	9.0
D: 'Refereed Journal Publications'	41	45 (12 months)	50
External Grant Income Received In-Year (£000s)	346.7	452.3 (12 months)	300.0
Other External Income Received In-Year (£000s)	9.9	8.0 (12 months)	15.0
Distinct e-Visitors (millions)	0.91	0.98 (12 months)	0.90
Web-Site 'Hits' (millions)	15.5	17.09 (12 months)	15.0
Data Exported (TB)	7.82	9.51 (12 months)	8.00
Identified Media Citations	442	503 (12 months)	250
Astropark Visitor Numbers	55000	75000 (12 months)	45000

Table 4: In-year results for Armagh Observatory Performance Indicators. **Table last updated 2011 April 29**.

a very significant component of Northern Ireland's scientific heritage. During 2010/2011 it was intended to continue, as resources would allow, a programme to conserve some elements of this collection, improve the conditions in which the collection is held, and digitize some of the most important archives in order to make them accessible via the Internet to researchers, scholars and the general public from anywhere in the world — **done**.

The trends of the various key performance indicators which represent the sum of the Observatory's principal strategic objectives are summarized in Figure 1 (p.3), while further relevant material is presented in Tables 2, 3 and 4 (see pp.6, 7 and 8 respectively). Taken together, these Tables and Figures demonstrate that the Armagh Observatory has achieved considerable recent success and is well-placed to build on these activities and to make further very significant contributions to Northern Ireland's Cultural Capital.

5 Alignment with Government and DCAL Objectives

5.1 High-Level Goals

The Vision of the Armagh Observatory is:

> *"To build on its position as a thriving astronomical research institute, and to continue to expand our understanding of the Universe and of humanity's place in it."*

The Mission is:

> *"To advance the knowledge and understanding of astronomy and related sciences through the execution, promotion and dissemination of astronomical research nationally and internationally in order to enrich the intellectual, economic, social and cultural life of the community."*

These goals align closely with the corresponding aims and objectives of the Department, namely the Department's Vision "**To create a confident, informed and vibrant community**" and its Mission "**To protect, nurture and grow Northern Ireland's cultural capital by providing strategic leadership and resources for the promotion and sustainable development of the culture, arts and leisure sectors**".

The Armagh Observatory's primary function to carry out international-quality astronomical research is an imagination driver and a creator of Cultural Capital. The Observatory's research outputs as well as its secondary function to disseminate astronomical research nationally and internationally to widen knowledge of science and the heritage of astronomy at Armagh are highly ranked on the international stage. The Observatory also attracts significant quantities of external (i.e. non-DCAL) grant income from UK and other funding bodies every year, and substantially greater amounts of external support in kind, for example through the Observatory's use of ground and space-based telescope facilities abroad and through international collaboration. Thus, Northern Ireland gets an extremely high return on its investment in frontline astronomical research at the Armagh Observatory.

Astronomy stirs people's minds and has the capacity to stimulate a more scientific way of thinking. This leads directly to the development of a more scientifically trained and literate population, and to greater numbers of young people attracted towards science at school and university and into the important science, technology, engineering and mathematical (STEM) subjects that lie at the heart of a modern, technological high value-added economy. The low take-up of STEM subjects at schools and universities throughout Europe, and in Northern Ireland in particular, is of increasing government concern. Astronomical research helps to motivate young people towards science and provides an important stimulus for a more creative, vibrant and internationally competitive economy.

The Department's vision is to create a confident, informed and vibrant community. The Department recognizes the value of archives, public libraries, arts and sport as creating a *public value* in their own right and that they add value to the Northern Ireland economy particularly in regard to the creative industries, the knowledge economy and employment. Scientific research is a highly skilled and creative activity, and there are numerous examples where the fruits of scientific research have been used as the main basis for works of art, film, music and literature. Astronomy — the oldest science — addresses fundamental questions of existence and its impact extends across culture and throughout society.

The Department's mission is to protect, nurture and grow Northern Ireland's cultural capital by providing strategic leadership and resources for the promotion and sustainable development of the culture, arts and leisure sectors. It does this by (1) ensuring the effective delivery of high-quality culture, arts and leisure activities; (2) ensuring the effective provision of strategic leadership to the culture, arts and leisure sectors; and (3) ensuring effective governance, oversight, probity, and relationship management with its delivery partners. The Department recognizes that it cannot by itself 'do' culture, arts and leisure; rather, these activities are carried out and managed through the Department's sponsorship of and partnership with its principal Arms-Length Bodies.

5.2 Key Themes

The principal themes underpinning the Department's forward look are those aimed at creating (1) a Shared and Better Future; (2) Cultural Capital; and (3) Sustainable Development. These tie in closely with the Northern Ireland Executive's agreed Programme for Government by addressing four priorities, namely: (a) growing a dynamic, innovative economy; (b) promoting tolerance, inclusion, health and well-being; (c) investing to build our infrastructure; and (d) delivering modern, high-quality and efficient public services. A further important element of the Department's corporate plan is its recognition of the importance of Human Resources: it is *people* who do the work, and the Department's objectives can only be achieved through the contribution and commitment of the involved staff. This requires staff to be valued, to receive proper recognition and job satisfaction, and for lines of communication between the Department and the staff in its Arms-Length Bodies to be strengthened. This will smooth the way for the introduction of more streamlined governance and accountability procedures so as to provide better value-for-money outcomes for the citizen. In particular, the Observatory seeks to optimise its Management and Governance and Accountability structures so that they are closely tailored to the needs of the organization and that of the DCAL. The objective must be to provide the necessary financial and human resources, as well as a vibrant technical and research infrastructure, that will facilitate the Observatory's staff in delivering a world-leading programme of research and public understanding of science aligned with the Observatory's Vision and that of the Department, namely to contribute to (1) a Shared and Better Future; (2) Cultural Capital; and (3) state-of-the art Sustainable Development.

5.3 Alignment between Observatory Business-Plan and DCAL Objectives

In order to show more clearly how the Observatory's Business-Plan objectives align with those of the Department (see http://www.dcalni.gov.uk/corporate_plan_2008-11.pdf) we refer the reader to pp. 24–28 of the corresponding DCAL Corporate Plan: Goals and Targets 2008/2009–2011/2012. The Observatory's primary focus is to build on its existing research strengths as a thriving astronomical research institute in order to carry out timely and internationally excellent research programmes in astronomy and related sciences so as to advance knowledge and understanding of the Universe and to enrich the intellectual, economic, social and cultural life of the community. This research mission aligns closely with the Department's vision to create a confident, creative, informed and vibrant community, and with its mission to protect, nurture and grow Northern Ireland's cultural capital.

The Observatory's additional, largely non-research objectives also align closely with core DCAL Public Service Agreements (PSAs) as well as with those of other Northern Ireland government departments and cross-cutting themes of the Executive's Programme for Government. These additional Business-

Plan objectives and their links to government PSAs are identified below, under three broad headings: Widening Access; Education and Learning; and Sustainable Development. Further information on the links between the Observatory's principal activities and both DCAL and Northern Ireland government PSAs is provided in Appendix C.

5.3.1 Widening Access

1. To widen access to the Armagh Observatory library, archives and astronomical museum collection reflecting the development of the specifically Northern Ireland (and the UK-and-Ireland) contribution to the development of modern astronomy over more than 220 years. The target is to construct a new museum, library and archives building having adequate office space, secure accommodation for books, archives and historically important scientific instruments, and space to display the material safely and securely for members of the public and visitors on self-guided tours of parts of the new building. **PSA 5, PSA 9, PSA 12, PSA 22**.

2. To increase the proportion of Armagh Observatory collections that are accessible via the Internet, including its unique archives and instruments, continually maintained datasets and records, such as the more than 200-year long meteorological series, and the more specific information resources maintained for astronomy and related sciences. The target is to increase the volume of data exported from the Observatory web-sites. **PSA 9**.

3. To attract at least 45,000 visitors per year to the Armagh Observatory Grounds and Astropark on self-guided tours, and to maintain a high-quality programme of education and public understanding of science, including work-experience placements, tours, public lectures, scientific conferences, and outreach at various levels into schools and with other collaborating partners. The target is to raise the public profile of the Armagh Observatory and the number of visitors using the Observatory Grounds and Astropark. **PSA 5, PSA9, PSA 10**.

4. To sustain use of the Observatory's Grounds and Astropark as a managed, environmentally friendly and biodiverse inner-city parkland. The facility provides a shared space for residents of the City of Armagh and visitors alike, freely available and open to all. It also provides an opportunity for people from all cultural backgrounds to improve their health and well-being by undertaking walks through the landscaped Grounds and Astropark, i.e. a 'stroll through the Universe'. In this way, the Armagh Observatory with DCAL support makes a significant contribution to the local economy and to the City of Armagh's expanding package of culture, arts and leisure facilities for visitors, directly promoting tourism and the Northern Ireland economy. The target is to maintain and promote wider use of this resource. **PSA 6, PSA 8, PSA 9, PSA 10**.

5.3.2 Education and Learning

1. To sustain the Observatory's existing provision of high-quality postgraduate student training and supervision, and of the Observatory's programmes of Science in the Community ranging from second-level to third-level and beyond, including programmes of lifelong learning aimed at family groups, members of the general public and older citizens. The target is to provide a high-quality education provision for people of all ages and backgrounds, contributing to the Observatory's Targeting Social Need and Science in the Community programmes, and to the Department's focus on a Shared and Better Future for all citizens. **PSA 5, PSA 6, PSA 9, PSA 10, the DCAL Education and Learning Strategy** and PSA 2, PSA 3 and PSA 16.

2. To use the facility of the Armagh Observatory Grounds, Human Orrery, and Astropark in innovative and creative ways to deliver new education and outreach programmes, for example building on International Year of Astronomy 2009 activities or on Departmental involvement in the Olympics 2012 activities. **PSA 6, PSA 9, PSA 10** and PSA 2.

3. To build on the Observatory's International Astronomy Year 2009 activities and develop a new UNAWE ('Universe Awareness') programme called EUNAWE (European Universe Awareness). This will increase the number of young people exposed to the inspiration of astronomy, thereby making a distinctive contribution to the Government's STEM Strategy. **PSA 6, PSA 9, PSA 10** and PSA 2.

5.3.3 Sustainable Development

1. To construct a new Museum, Library and Archives building drawing on best practice so far as design, built heritage, long-term sustainability and 'green' policies are concerned. The target is to progress this project in year. **PSA 9, PSA 12, PSA 22** and PSA 2.

2. To extend the Armagh Observatory's documentation and data management policies and procedures to include the Observatory's library, archives and museum collection in preparation for relocation of these materials into the new Library building and as a step towards the Observatory's goal to achieve accreditation as a registered Museum. Achieving this goal will open the door to new funding lines to help support these elements of the Observatory's heritage activities and provide long-term protection for the housing and security of the collection as a whole. The target is to implement at least part of a new cataloguing and documentation procedures policy during 2011/2012. **PSA 9, PSA 20**.

3. To maintain the Observatory's continuing very good results so far as staff absence is concerned. **PSA 21 and the DCAL target of 9.6 days absence per person per year**.

6 Objectives for 2011/2012

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 2011/2012 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 their advanced training as well as that of the postdoctoral staff at the Observatory at the beginning of their astronomical careers;
- build on the Observatory's involvement in the DCAL Learning Strategy by developing new initiatives in education and public outreach associated with the Observatory's programme of Science in the Community; and
- progress plans for the design of a new Library, Archives and Historic Scientific Instruments building, a project that plays a central role in the Observatory's forward look.

In addition to these programmes of frontline scientific research and public understanding of science, the Observatory has an important function to promote, preserve and widen access to the Observatory Grounds and the historic library, archives and museum collection at Armagh, which together represent a very significant component of Northern Ireland's scientific heritage. During 2011/2012 it is intended to continue, as resources allow, a programme to improve the documentation and storage conditions of the historic library, archive and astronomical museum collection.

6.1 Required Resources: Income and Expenditure for 2011/2012

Tables 5 and 6, showing projected income and expenditure for 2011/2012, provide a detailed summary of the Observatory's balanced 2011/2012 Business-Plan Budget (Red) together with a comparison with the budget outturn for 2010/2011 (Green). Blue and Black columns represent opening values and are subject to in-year variations depending on possibly changing circumstances (e.g. additional funding provided by DCAL in-year and/or additional funding obtained in-year from external grant awarding organizations for new projects).

In comparing the 2011/2012 Business-Plan budget with that of the previous year (2010/2011) it is important to emphasize the significant additional income obtained from several monitoring rounds during 2010/2011 (cf. Table 2, p. 6). Nevertheless, along with other DCAL Arms-Length Bodies, the Observatory has had to make a number of difficult choices and decisions in order to achieve a balanced opening budget for the year.

These decisions have been made following a strategy to focus on the Observatory's core research function and to ensure that, wherever possible, any cuts do not irreversibly affect the Observatory's

ability to maintain a leading frontline role in research, education and advanced training. The savings that have been introduced in 2011/2012 have been made with the aim of minimising any adverse impact on the Observatory's primary research mission, and with the objective in the long term to ensure that its ability to sustain the breadth of its key research programmes and contributions to education and learning across the community is not permanently impaired.

Last Up-date 2011 July 26	2011/2012	2011/2012	2011/2012	2010/2011
INCOME: CASH	**Projection**	**TO DATE**	**Business Plan**	**Actual**
	(2011 July 25)	**(2011 July 25)**	**(2011 July 25)**	**£k**
DCAL recurrent grant paid				
DCAL recurrent grant paid - deferred + released	1030.0	284.5	1030.0	1027.0
Re-allocation of DCAL recurrent grant from Planetarium	0.0	0.0	0.0	0.0
Re-allocation of cash to non-cash to cover any non-cash projected shortfall	0.0	0.0	0.0	0.0
Additional in-year recurrent grant	0.0	0.0	0.0	106.4
Total DCAL recurrent grant paid	1030.0	284.5	1030.0	1133.4
DCAL capital grant				
Capital grant paid	0.0	0.0	0.0	25.0
Capital grant deferred/released	0.0	0.0	0.0	4.7
Additional in-year capital funds paid	0.0	0.0	0.0	101.0
Total DCAL capital grant paid	0.0	0.0	0.0	130.7
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/receivable	260.4	75.4	260.4	452.3
Grants and other restricted funds deferred	-45.7	0.0	-45.7	-156.8
Grants and other restricted funds released	77.0	0.0	77.0	0.8
Total	291.7	75.4	291.7	296.3
Miscellaneous income				
Interest	0.4	0.1	0.4	0.8
Rents	5.0	1.4	5.0	4.9
Miscellaneous	1.0	0.4	1.0	2.4
Total	6.4	1.9	6.4	8.0
Total Income (Cash)	1328.1	361.8	1328.1	1568.4

Last Up-date 2011 July 26	2011/2012	2011/2012	2011/2012	2010/2011
	Projection	**TO DATE**	**Business Plan**	**Actual**
SUMMARY OF DCAL OBSERVATORY INCOME AND EXPENDITURE: NON-CASH	**(2011 July 25)**	**(2011 July 25)**	**(2011 July 25)**	**£k**
Non-Cash Budget Income				
Opening non-cash DEL budget	119.0	119.0	119.0	
Allocation of cash to cover any non-cash projected shortfall	0.0	0.0	0.0	
Additional in-year non-cash DEL grant paid	15.0	15.0	15.0	
AME Pension Costs to cover any projected pension cost shortfall	81.0	81.0	81.0	
Total available non-cash	215.0	215.0	215.0	
Non-Cash Budget Expenditure (Depreciation)				
DEL Depreciation	119.0	119.0	119.0	
Re-allocation of half the Planetarium DEL depreciation deficit to Observatory	0.0	0.0	0.0	
Total Observatory expenditure on Depreciation	119.0	119.0	119.0	
Non-Cash Budget Expenditure (AME Pension Costs)				
Service Cost	136.0	136.0	136.0	
Interest on obligation	198.0	198.0	198.0	
Expected return on pension-fund assets (counts as negative expenditure)	222.0	222.0	222.0	
Employer's pension contributions (funded by DCAL Cash Resource; counts as negative expenditure)	113.0	113.0	113.0	
Total non-cash expenditure (AME Pension Costs)	-1.0	-1.0	-1.0	
Projected Net AME Pension Surplus (as at 2011 May)	82.0	82.0	82.0	

Last Up-date 2011 July 26				
SUMMARY OF TOTAL DCAL OBSERVATORY PLUS PLANETARIUM INCOME (CASH+NON-CASH)				
Observatory Total DCAL Income				
DEL Cash (Resource + Capital)	1030.0	284.5	1030.0	
DEL Depreciation	119.0	119.0	119.0	
AME Pension Costs	81.0	81.0	81.0	
Total Observatory DCAL Income	1230.0	484.5	1230.0	
Planetarium Total DCAL Income				
DEL Cash (Resource + Capital)	478.0	478.0	478.0	
DEL Depreciation	231.0	231.0	231.0	
AME Pension Costs	44.0	44.0	44.0	
Total Planetarium DCAL Income	753.0	753.0	753.0	
Total DCAL Income for Observatory and Planetarium (Cash + Non-Cash (DEL+AME) + Capital)	1983.0	1237.5	1983.0	

Table 5: Projected income following the Business Plan 2011/2012 and corresponding income received to date. Shaded rows indicate non-DCAL income. **Table last updated 2011 July 26.**

Last Up-date 2011 July 26	2011/2012	2011/2012	2011/2012	2010/2011
EXPENDITURE	**Projection**	**TO DATE**	**Business Plan**	**Actual**
	(2011 July 25)	**(2011 July 25)**	**(2011 July 25)**	**£k**
Research and Research Support Costs				
Capital equipment from announced DCAL capital grant	0.0	0.0	0.0	25.0
Capital equipment from current year DCAL recurrent grant or prior year DCAL capital grant	0.0	0.0	0.0	4.7
Additional capital equipment from in-year DCAL capital grants	0.0	0.0	0.0	101.0
Capital equipment funded by external grants and other income	0.0	0.0	0.0	3.1
New Library, Archives and Historic Scientific Instruments Building Development Costs	0.0	0.0	0.0	0.0
Salary of Archivist/PRO/Outreach Officer	0.0	0.0	0.0	0.0
UKSC Subscription and SALT operating costs	16.0	0.7	16.0	15.5
Other UKSC/SALT expenses	1.0	0.0	1.0	1.5
ARTI project	0.0	0.0	0.0	0.0
Hosting Conferences, Workshops and Misc. Research Infrastructure	0.0	0.0	0.0	0.0
Salaries of permanent research and research support staff	587.2	144.6	587.2	603.0
Salaries of fixed-term research and research support staff	118.4	39.6	118.4	132.2
Former Director's pension supplement	2.4	2.3	2.4	2.3
Student maintenance grants	148.9	30.7	148.9	117.7
Student maintenance funded by external grants	35.0	3.4	35.0	23.8
Student fees	15.0	2.4	15.0	11.3
Student fees funded by external grants	8.3	0.8	8.3	2.9
Core travel and subsistence from DCAL funds	27.0	6.9	27.0	31.3
Travel and subsistence from external grants and other income	21.2	2.9	21.2	24.6
Visitors programme	3.0	0.0	3.0	2.2
Visitors programme funded by external grants and other income	0.0	0.0	0.0	0.0
Conferences (principally biennial Robinson Lecture)	0.0	1.7	0.0	6.0
Hosting meetings and lectures	1.0	0.9	1.0	2.4
JANET access costs	19.4	3.2	19.4	19.1
Core computer consumables from DCAL funds	16.0	3.7	16.0	35.4
Computer consumables funded by external grants and other income	0.0	0.4	0.0	0.7
ADAS: The Atomic Data and Analysis Structure database (Solar Physics)	0.0	0.0	0.0	-0.2
Library costs: book purchase, subscriptions and journals, binding etc.	39.0	4.3	39.0	45.0
Armagh Public Library: Observatory/NIMC/Pilgrim Trust funded joint documentation/storage project	16.3	0.0	16.3	33.1
Historic books/instruments: museum, library, archives collection purchases	0.0	0.0	0.0	0.0
Publications	0.5	0.0	0.5	1.0
Public Understanding of Science (including misc. externally funded outreach projects)	3.6	0.2	3.6	0.7
Cross-Border Schools Science Conferences (SSC2011, 2009, 2007); Lindsay Mtg 2007	1.5	0.0	1.5	0.0
15th ADAS Workshop (2010 Oct); IMC2010 (2010 Sep)	0.0	0.0	0.0	2.1
IMC2010 Conference	0.0	0.0	0.0	12.2
Advertising and promotions	0.5	0.4	0.5	0.2
UK entertaining	0.1	0.1	0.1	0.5
EuroPlaNet Technical Costs	10.0	0.0	10.0	0.0
Agency staff costs (telescope/archives/meteorological records)	0.0	0.0	0.0	5.3
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	0.9
Total research and research support costs	1091.3	249.2	1091.3	1266.7
Buildings, Buildings Refurbishment and Grounds Costs				
Buildings, domes and telescopes project funding (DCAL and EHS)	0.0	0.0	0.0	0.0
DDA and other capital costs	0.0	0.0	0.0	0.0
New Library, Archives and Historic Scientific Instruments Building Estates Costs	0.0	0.0	0.0	0.0
Salaries of grounds and meteorological records support staff	46.3	10.8	46.3	44.6
Agency Cleaning Costs	7.0	1.4	7.0	6.3
Cleaning consumables	1.5	0.1	1.5	2.3
Service contracts and professional fees	5.0	0.4	5.0	6.3
Central procurement costs	2.0	-1.7	2.0	7.0
Property repairs, grounds, furnishings, office and minor equipment	15.0	-0.3	15.0	64.1
Heat, light, power	31.0	2.6	31.0	36.6
Insurance	12.0	1.8	12.0	12.2
Rates	0.0	0.0	0.0	0.0
Total Buildings, Buildings Refurbishments and Grounds Costs	119.8	15.0	119.8	179.3
Administration and Corporate Governance Costs				
Salaries of administrative and administrative support staff	88.8	25.06	88.8	78.2
Management Committee/Board of Governors	2.0	1.41	2.0	0.9
Internal audit	4.0	0.69	4.0	5.8
External audit	5.0	0.83	5.0	6.0
Legal fees	0.0	0.00	0.0	0.0
Staff training	2.0	0.34	2.0	2.7
Recruitment	3.0	0.05	3.0	2.1
Stationery	2.0	0.09	2.0	4.0
Post and telephone	2.5	0.59	2.5	4.2
Printing	0.7	0.08	0.7	10.5
General expenses	4.0	0.34	4.0	7.4
Other professional fees (Actuary, SELB, VLA, EEF)	3.0	0.18	3.0	0.6
Currency fluctuations	0.0	0.00	0.0	0.0
Bank interest and other charges	0.0	0.05	0.0	0.1
Total Administration and Corporate Governance Costs	117.0	29.7	117.0	122.4
Total Expenditure	1328.1	293.9	1328.1	1568.4
Surplus/-Deficit (Before Pension Costs)	**0.0**	**67.9**	**0.0**	**0.0**

Table 6: Projected expenditure following the Business Plan 2011/2012 and corresponding expenditure to date. Shaded rows indicate cost centres that are funded 50% or more through external (i.e. non-DCAL) income. **Table last updated 2011 July 26.**

A Principal 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, Stereo and Solar Dynamics Observatory (SDO). 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 215-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.

A.1 Research Plans for 2011/2012 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.

B Remarks on Key Performance Indicators

The new performance indicators introduced by the DCAL during 2006/2007 are defined 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, the result (which takes no account of the value 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 or 'value for money' of the Armagh Observatory in delivering a high-quality astronomical service at the lowest reasonable cost. A low percentage administrative cost is better.

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.

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

Results for these key PIs for 2006/2007 et seq. as well as for prior years for which we have data and targets for 2009/2010 and 2010/2011, are shown in Table 3. Results for these and other PIs that are routinely collected to assess the Observatory's performance in different areas of activity are also shown 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/.

Interpretation of Key PIs The interpretation of some of these proxy performance indicators is straightforward and self-explanatory, but others are affected by factors outside the Observatory's control, and require greater care in analysis and/or interpretation. A number of such points are indicated below. Thus,

1. External grant income sometimes arrives in advance of expenditure and sometimes in arrears (and the funding agency nearly always retains a proportion of the grant until a satisfactory final report on the work done has been completed). The total amount of external grant income illustrates the high rate of financial return on DCAL investment in front-line astronomical research at Armagh (cf. bottom left-hand panel of Figure 1), despite taking no account of the value 'in kind' of the Observatory's use of UK and international facilities both abroad and in space.

2. The pressure on staff to publish a high number of refereed publications has changed in recent years, owing to a decision by the Research Councils to move towards a metric-based measure of the quality of a particular grant application, one that increasingly depends on the quality of the research infrastructure at the applicant's disposal and an increasing focus on producing 'popular' or 'influential' publications that are highly cited (and with the lead author's name first in a list of several). This can skew publication patterns in an unpredictable way.

3. The Observatory's staff-absence statistics are very good, but care must be used in comparing them with those of other institutions, particularly when the majority of Observatory staff (essentially all the research complement) can work perfectly well from home, even when unwell (and they often do), and are not required to work a conventional '9-to-5' working day.

4. Web-statistics are notoriously difficult to interpret; for example, neither the 'Distinct e-Visitor' (DEV) nor the 'Hits' metric, although easy to measure, actually measures the number of individual users accessing the web-site. Full details of the 'health warnings' attached to such measures are provided in the Armagh Observatory Annual Report for 2008 and 2008/2009 (see pp.6–8 of that report), but in general terms the DEV-statistic provides a firm lower limit to the number of individual users accessing the web-site (a lower limit that is decreasing with time), while the number of hits, although always larger than the number of DEVs, depends on the structure of each web-page as well as the same secular downward trend that affects the DEVs. Another measure of Internet traffic is the volume of data exported from the web-site (and we record this too), but this may be

increasing simply because astronomers are sharing ever larger data files between one another or because people are nowadays tending to put files (e.g. images, videos etc.) of ever larger size onto web-sites, or merely because they have the capacity to view such data.

5. Astropark visitor numbers correspond to the number of people recorded passing the counter at the entrance to the Astropark near the start of the Solar System scale model. Some people, for example those accessing and leaving the Astropark using the Observatory's main driveway, are never recorded, while others (those entering and leaving the Astropark beside the Solar System model) will be recorded twice; and repeat visitors are counted repeatedly. The numbers fluctuate significantly, depending (for example) on the time of year, the weather, public holidays, special outreach events and so on. Sometimes data are missing (e.g. when the counter fails or is vandalized), in which case numbers for the missing period are usually estimated simply by interpolation.

Finally, we note that other factors which 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. For all these reasons, it is important not to over-interpret Observatory performance measures, but to recognize that they are proxies for underlying trends, and possibly of value in comparison with other bodies.

In summary, Tables 3 and 4 together demonstrate the very high efficiency of the Observatory's corporate governance and administration systems (the latter costing typically rather less than 10% of total income per year), the exceptionally strong commitment of Armagh Observatory staff to their work, illustrated by remarkably low staff-absence figures, and their high research productivity. In particular, there is an increasing trend in the number of high-quality scientific papers published in refereed scientific journals every year (Figure 2, p.4), a growth in the public profile enjoyed by the Observatory (e.g. as evidenced by the growth in the number of mass-media citations to the Observatory or its work), and a very significant number of people visiting both the Observatory's web-sites and the Observatory's Grounds and Astropark every year (Table 4).

C Alignment of Armagh Observatory and Wider 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.

C.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 50,000 visitors per year to the Observatory Grounds and Astropark. It 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 local leadership role in attracting visitors to Armagh, particularly through its membership of the Armagh Visitor Education Committee and associated conferences and publications. The provision of additional Capital funding to support the construction of a new Library, Archives and Historic Scientific Instruments building will provide Armagh with an important new visitor facility, strengthening the Observatory's indirect role to support economic growth through tourism.

- 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.

  The Observatory's innovative programmes of Science in the Community have exposed a great number of children to the fascination of astronomy and related sciences. Many older children are supervised by Observatory staff on school work-experience and related summer programmes, and other young people are trained at 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.

  The Armagh Observatory makes a number of distinctive 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 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 lifelong learning and participation in cultural events in the City.

  In particular, there is a heritage of books, manuscripts, instruments and archives which together describe essentially the whole history of modern astronomy. It is often forgotten that the Observatory's founder was born just 75 years 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 believed 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. The new Library building is a key element of this activity, as too is a high bandwidth 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 to people's homes from anywhere in the world. The related programme to digitize the Observatory's archives provides a further illustration of how the Observatory's Business Plan objectives align closely 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 school children with work-experience training and advanced summer projects. In recent years 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, most recently developed as part of International Year of Astronomy 2009. These activities, as well as the Observatory's commitment to continue to provide a programme of therapeutic training for a person with recognized learning difficulties, all illustrate how the Observatory makes major contributions 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 which reflect the new programme of Public Art in the city, and by promoting the construction of the new Museum, Library and Archives building as a key 'legacy' project to celebrate the 300th anniversary of the early years of of the Observatory's founder: Archbishop Richard Robinson. The new building must be of an architecturally high standard and be 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 Climate Station and Phenology Garden; and provide a 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.

C.2 Additional 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 2008 RAE result was 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), the Observatory 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 and encouraging the use of the Observatory grounds as attractive venues for special-interest groups (e.g. local history societies, walking clubs), 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 many 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 important 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, Museum, Library and Archives 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 building, as well as by promoting public access to and use of the Armagh Observatory Grounds, Astropark and Human Orrery. More than 50,000 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 enhancing the educational competitiveness of the region and promoting Northern Ireland on the international stage (DEL/DE).

- PSA17: **"Rural Infrastructure"**: The Observatory's programmes of Science in the Community demonstrate considerable 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 following the success of the 2009 United Nations International Year of Astronomy, to contribute to the provision of improved 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 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) helped to 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 programmes of 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).