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THE DEMOGRAPHY OF ASTRONOMY IN THE UNITED KINGDOM

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Abstract. This article is about the universities and the people involved in astronomy in the United Kingdom, including their numbers, their age, gender and ethnicity, where they study or work, and their career structures.

1. Introduction

In a previous article (Murdin 2006), I summarised the history, the scope and the organisation of British astronomy. In this article, I concentrate on demographic issues of the present day, 2011. I limit the geographical scope of my article to the United Kingdom (UK), which both has a centralised, overall organisational structure and comprises four nations with various degrees of self-government, namely England, Scotland, Wales and Northern Ireland. Research is regarded as a UK activity but education is national – the distinctions are somewhat reminiscent of those in Germany between the *Bundesrepublik* and the *Länder*, or in the USA between the Federal government and the individual states. I do not limit the scope of 'astronomy', which in this article includes planetary sciences, solar and solar-terrestrial physics, as well as cosmology and astrophysics. I rely for many figures on the *Demographic Surveys* by the Royal Astronomical Society (RAS) of the UK astronomical community, the most recent for 2010 available to me at the time of writing in draft form (McWhinnie 2011).

2. Universities

Astronomy research in the UK is carried out almost entirely at universities and the bulk of the astronomy population (90-95%, depending on definition) is at a university. Universities have research as one of their two core activities, the other being higher education, with 'enterprise' (business connections, outreach) being a third, being given greater emphasis now by the Government. UK universities and the Government are very positive about the interaction between the two core activities of teaching and research, on the one hand because of the mutual intellectual stimulation that exists between student and teacher, which benefits both endeavours, on the other because research in universities is both productive and cost effective, because many of the paid staff are young and therefore inexpensive, and the overheads of research are shared with teaching.

As a result of the concentration of astronomy in universities, the demography of astronomers in the UK is based mainly around academic criteria and is most readily described in terms of university status, progressing through academic career stages. Fig. 1 shows the stages of a typical academic career in England (with an individual in Scotland starting one year earlier), flanked by parallel career paths to which (and, more infrequently, from which) an individual might transfer at any stage.

The overall structure of higher education in the UK is evolving as a result of the Bologna process by which Europe is unifying its higher educational qualifications to make them comparable across Europe to enhance mobility between countries. The standard framework for training under the Bologna Accord is 3 + 2 + 3 years for a first degree at bachelor's level, a further degree at master's level and a research degree at doctoral level. The current norm for training in England is now best characterised as 4 + 4 years for a first degree at master's level and a research degree. But the state of affairs in the UK is evolving and some universities provide three year degrees, and additional one or two year courses so that students can readily make the transition from another system to theirs. The structure is currently overcomplicated, with almost everything differing from nation to nation within the UK, from university to university and from course to course (a fact in itself demonstrating the need for standardisation).

As at August 2010, there were 115 universities in the UK (Table 1),

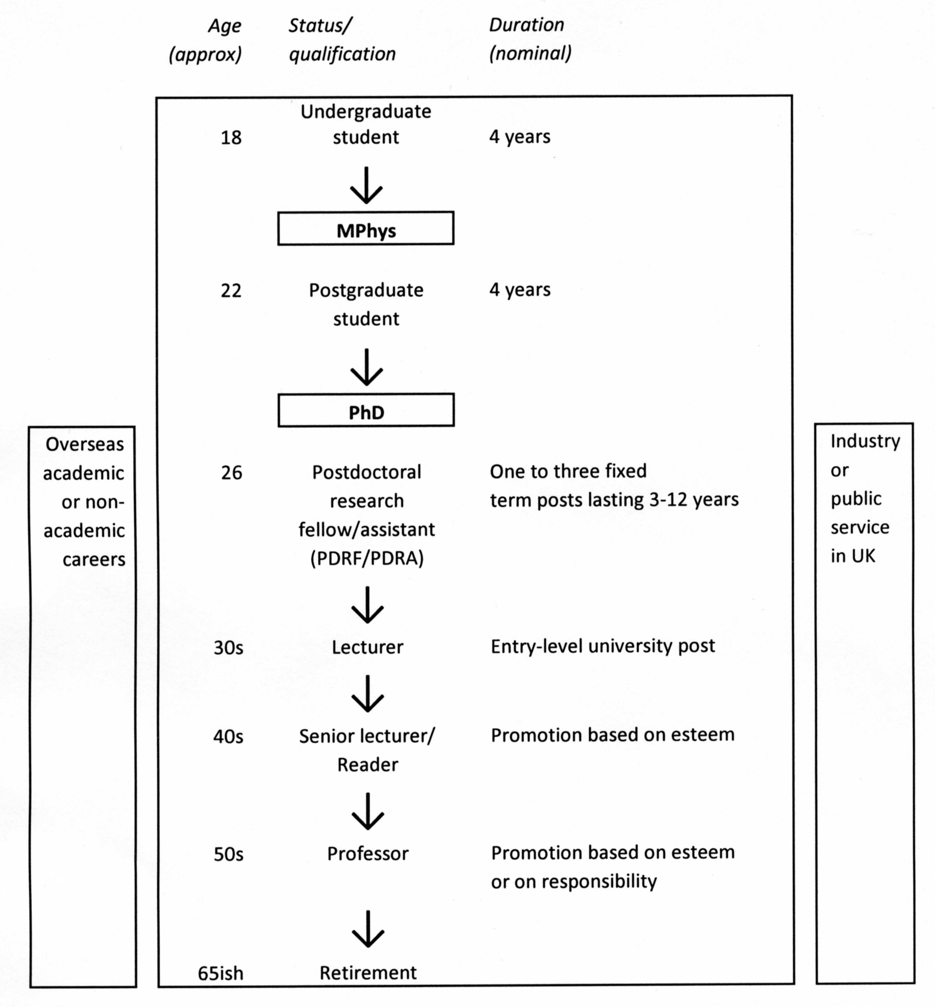

Figure 1. A nominal astronomical career path in England.

where 'university' means an organisation with the word in its title. Federal institutions such as the University of Wales and the University of London, and the Open University, are counted as one university for the purpose of Table 1, which needs to be interpreted with caution as a result of this rather mechanical selection procedure. The power of an organisation to award degrees, both as the result of a taught course or as the result of research, is regulated in the UK by law. Up to 1992 universities operated only under Royal Charters, i.e. individual constitutional documents defining an organisation's purpose, structure and powers, and authorised into law by

TABLE 1. Universities in the UK

Country	**Number of Universities**	**Fraction of the population of the UK living in that country**
England	89	84%
Scotland	14	9%
Wales	10	5%
Northern Ireland	2	3%
Total in the UK	115	100%

the monarch. Under the Further and Higher Education Act 1992, it is now the Privy Council, i.e. the body that (in the language of historic constitutional principles that underlie some aspects of state bureaucracy in the UK) 'advises the monarch in her duties as Head of State', which approves the use of the word 'university' (including 'university college') in the title of an institution of higher education. The Privy Council does so on the basis of an analysis by a Government agency, the Quality Assurance Agency for Higher Education, showing whether the institution is a well-founded, cohesive and self-critical academic community that can demonstrate firm guardianship of its standards.

A university can, as it pleases, offer courses at the levels and in the subjects that it wants to teach and research. It may structure itself how it wishes into colleges, faculties, schools, institutes and/or departments (all these are referred to hereafter as a 'department'). Astronomy is taught and/or researched at 48 universities (where here and subsequently I do differentiate between the colleges of the University of London, and similar cases where the organisation is to a large extent independent academically from others). Astronomy has its home typically in a department of physics, or of physics and astronomy, or of mathematics. A minority of universities have a standalone department of astronomy, or teach or research astronomy in association with some other physical science or engineering subject.

A few of the older universities have names without the word 'university' in them, like Imperial College, London, and a small number are named after people (founders or benefactors). Most typically, the name is of the form 'University of [Location]' or '[Location] University', and [Location] is usually a city. This is an indication of the fact that the 48 universities where astronomy is studied, and therefore astronomers, are distributed broadly in correlation with the population, with good geographical diversity.

A number of UK universities have formed groups with common interests, including so-called ‘mission groups’. The ‘Russell Group’ is an association of the 20 largest research-intensive universities, with its name reflecting the fact that it traditionally met at the Russell Hotel, London. The ‘1994 Group’, founded in that year, consists of 19 smaller research-intensive universities, formed in response to the formation of the Russell Group to balance its consolidated influence as the British ‘Ivy League’. These 39 universities include nearly all the universities where astronomy is studied (those universities in these two groups where astronomy is not studied limit themselves to a narrow, specialist group of subject areas, like the London School of Economics). Most of the remainder of the 48 astronomy universities belong to the University Alliance, formally launched in 2007, and comprising 23 universities which emphasise a balanced portfolio of research, teaching, enterprise and innovation as integral to their missions, i.e. they have a business-friendly stance, often with a high proportion of science and technical courses. Thus, astronomy is a subject taught and researched primarily within the 62 more active universities in the UK.

3. Taught degrees in astronomy

In the UK (see Fig. 1) a student typically enters university at age 18 (17 in Scotland) as an ‘undergraduate’, intending to progress and ‘graduate’ with a university qualification or ‘degree’. Up to recently, the degree would have been at bachelor’s level (a three or four year course in England and Scotland respectively), but it is now more typically at master’s level (in a further year’s study that is usually completely integrated into the previous bachelor’s level course). Except for the Open University (see below), which is ‘open’, each university controls the entrance of students through quality criteria, i.e. on the basis of the applicant’s academic record of examinations in school, and, especially in cases where the applicant has been disadvantaged and underachieved, on the basis of an estimate of the potential of the student to do well in the degree course in the intended subject. Because of the selection criteria, it is not usual for a student to drop out of a degree courses. Up to now, the total number of students in each university has been ultimately controlled by the UK Government through the total funding which it supplies, except for the University of Buckingham, which is the only independent university in the UK, accepting no Government funding; but it has no astronomy activity, indeed nothing at all in the physical sciences. But the number of students in each course has been controlled by the way the university divides this money to departments and courses (depending on demand and capacity). Students apply to the universities and courses that they select through a centralised system run by the Universities and Colleges Admissions Service (UCAS) – selection and agreement is directly between the student and the university, UCAS is purely administrative and coordinating. UCAS covers fulltime courses at nearly all universities in the UK, but notably has nothing to do with courses at the Open University (see below).

In the heyday of the welfare state in the UK (say 1950-1980), university education was provided to a rather small fraction of the population (of order 10%) at no charge to the student. It was financed through Government funding direct to universities, and students received grants to help with living expenses. As stated, entry to university was through merit, although performance in the examinations was helped by the school education received and was therefore strongly correlated with family circumstances. University education was thus not only for personal development and a training to enter intellectually-based professions, it was also an engine for social mobility, although a flawed one, and a way of driving development in the professions through the ability of their meritocracy.

In recent years, university education has been provided to a growing fraction of the population, with consequent strain on public finances, and consequent financial pressure by Government on universities. The Government has demanded ever greater efficiencies – larger classes, longer teaching hours, consolidated courses – and now spends half as much per student as twenty years ago. Taken together with the expansion of the numbers of students, some would say that this has led to reduced standards of education. The efficiency process has delivered the affordability that the Government has needed to help fund the delivery of higher education to a wider fraction of the population, but the money required to fund higher education has nevertheless increased dramatically. This has led to the governments of England and Northern Ireland gradually to withdraw funding from students and to require the student to pay fees[1].

Thus, in the years immediately before and up to 2011, the cost of attendance at a course was paid for partly through money supplied from centrally gathered tax funds, partly by funds gathered by the university from other sources, and partly (except in Scotland and Wales) by the student. The maximum that a student had to contribute in 2011 in England and Northern Ireland was GBP 3,375 p.a. Loans were available from the Government at reduced interest to cover the cost of tuition; loans were also available to cover living costs (currently reckoned at GBP 5,500 p.a., GBP 7,700 p.a. in London) with outright grants also available on a sliding scale depending on family income. Loans start to be paid back only when the new graduate is employed with a wage above a certain limit, which approximates to the median income in the UK.

[1]Scotland and Wales, however, maintained the principle of free university education, but required non-Scottish or non-Welsh students, respectively, to pay fees.

From 2012 the maximum tuition fee for an undergraduate course will greatly increase to GBP 9,000 p.a. – most universities that teach astronomy will charge the maximum, or near. In Scotland and Wales, the devolved Government intends to continue to pay student fees, although the universities in these countries are concerned about the further financial pressure that will result, and fear the effect of underfunding. For students resident outside the EU, fees are uncontrolled and can be up to about GBP 20,000 per year, depending on course (law, dentistry, medicine and laboratory subjects like physics being among the more expensive). For reasons of European mobility, fees of EU students are regulated by EU law, and such students receive the same treatment as English, Northern Irish, Welsh or Scottish students respectively – curiously, since the EU laws on mobility have no validity within a member state, students resident in England who wish to study in Scotland (and similarly) will be disadvantaged relative to, say French or German students, and have to pay fees, but of course they can always choose to study in France or Germany (say), on French or German terms.

About 36% of young people (40% of young women and 32% of young men) in the UK now go to a university. Fifty years ago a degree course may have been discussed in terms of social mobility, as well as personal development. Nowadays, a degree course is most commonly discussed as the gateway to a good career, as well as personal development.

The discussion of a good career in this context often centres on one that is well paid, presumably because this is more quantitative and objective than job satisfaction. The median differential in pay between a university graduate in Physics and Astronomy and someone who stopped studying science just before he or she would have gone to university is about GBP 5,000 per year. The additional lifetime earnings for physics and astronomy graduates over non-graduates are at least GBP 100,000 (the comparable figure for graduates in history, English and the like is considerably less). Of course, a significant fraction (about a third) of these extra earnings is remitted back to the Government in income tax, more than the cost of the education.

There is considerable concern about the effect on this analysis of the new system of student payment, in which it will be common to leave a university course with a debt for fees alone of GBP 35,000, accruing interest (albeit at a low rate). With the living costs, the debt might be so large that paying it back over 30 years with interest could cost as much as GBP 140,000. This will certainly take the shine off the additional lifetime earnings, possibly wipe them out, and therefore greatly reduce the financial attraction of a university education, especially for young people from less-affluent social classes. In spite of the post-war principles of universal education, the UK is a country with a relatively poor and worsening record of social mobility, compared with European countries in general and the USA. The UK Government intends that an augmented system for grants and bursaries will improve access to university education by those whose families cannot otherwise afford it and thus increase social mobility, but many fear that the new system of loans for fees for university education, which start a student into a career with a substantial debt, will do the reverse.

I have spelled out these financial and social considerations because they bear on the position of astronomy as a taught subject in UK universities. As well as personal inclination, considerations of cost and future employability greatly influence the student's choice of degree subject. As a result, astronomy is not sought after as a degree subject *on its own*, even if astronomy is a good training in interdisciplinary applied science. Students are more likely to opt for a subject that, it is believed, will lead more directly to a good job. At the same time, students are also more strongly attracted to astronomy as a subject to study for their personal satisfaction than many other sciences. Their ideal is to undertake a course that provides opportunities to study a bread-and-butter science with a future job in mind, with some flavoursome jam on top, like astronomy.

Because university education operates to a greater or lesser degree as a market, student choice is the driver of the courses that universities offer. It is expected that, as a result of the intensification of the arrangements by which students pay for their own education, there will be further changes in the courses that universities offer, but few people confidently forecast how this will affect astronomy. The effect of student choice up to now has been that astronomy is now typically offered at UK universities only in association with other subjects – 'Physics and astrophysics', for example.

Indeed, the experience of university physics departments is that a strong astronomy component to a physics degree course is attractive to students. The Institute of Physics has reported a survey of eight Russell Group universities that suggested that over 50% of first year and nearly 75% of final year physics undergraduates cited astronomy or astrophysics as being of significant interest in attracting them to their physics programme. This is the reason why some universities name their 'physics and astronomy' courses in such a way as to make them, it is hoped, even more attractive – 'physics with cosmology', for example.

Reasons like these underlie the recent steady expansion of astronomy in UK universities. Since the 1970s, one new astronomy group has been added to UK universities on average every year or two, a process still on-going. It is fortunate that these economic pressures are consistent with the view of many astronomers that astronomy has changed from a discipline with its own methodology and circumscribed subject matter to applied physics, mathematics and/or chemistry and is best studied as a multidisciplinary science, not as a standalone science.

Data on university applications are collected by UCAS. In 2010, after a period of some years of decline or stagnation, there were more applications and acceptances to study a course with physics in its name than for ten years, with 25,500 applications and 4,500 acceptances (each applicant can apply for up to 5 courses but of course will ultimately be accepted by at most one). It is not known why there has been an upsurge of applications to study physics; perhaps in response to the Government message ('science good', if not quite with the corollary 'arts bad') students are turning further from 'soft' subjects to 'hard' subjects with good employment prospects, leavened by more enjoyable components, like astronomy. Certainly, the physics community, led by the Institute of Physics, has put a lot of effort into making physics more attractive.

The definition used by UCAS includes any course with 'physics' in its name, including, say, 'engineering with physics'. If we restrict the definition of a physics course to one that is predominantly in physics, the number of physics undergraduates in English universities is about 9,700 (HEFCE 2010), i.e. about 2,600-3,000 entries per year. The undergraduate population in England is 1,020,000.

40 universities offered an undergraduate course with some sort of an astronomy component identified in its name, and there were 4,200 applications for entry to these courses with 700 acceptances (Massey 2011). Probably most of the students accepted to study what I am continuing for simplicity to call simply 'astronomy' overlap with those who will study physics, so more than 15% of undergraduate physics students study astronomy in significant quantity.

4. Postgraduate research

The main route in the UK to a career in astronomy is through an undergraduate degree in physics (or mathematics or similar) followed by postgraduate training, which for a doctorate in the UK lasts in principle 4 years, but in practice sometimes longer. The main output is a thesis describing a research project carried out under the supervision of an academic member of the university. If all is well, the student is awarded a doctorate of philosophy (PhD) or other further degree. It is during the period of postgraduate training that the student may develop the knowledge, skills, independence and determination necessary for sustained independent research in astronomy, and builds up the evidence that may gain the student a post in an astronomy research group, or, if not, another equivalent employment.

Over 40 universities offer postgraduate opportunities and have active research groups whose members individually supervise the research of postgraduate students. This is about the same, perhaps even a larger number than offer undergraduate courses. This is possible because astronomy in the UK is set up with a number of centralised research facilities (telescopes, etc.) offered competitively for common use. Thus members of even a small group of astronomers at a university, perhaps even a single individual, can have access to world-class equipment and pursue cutting-edge research even if the university affords minimal infrastructural support for scientific research or teaching, such as laboratories. This enables an astronomer in even a small group within a physics or mathematics department to supervise PhD students, even if there is no support there for teaching astronomy at an undergraduate level. The students in their turn learn by accompanying their supervisor in his or her endeavours.

These circumstances constitute another good reason why astronomy is attractive to newer universities: a small university can gain a high-profile share of a research activity at a high standard through the employment of a small number of the right people, without the requirement to provide expensive equipment on campus.

Postgraduate research in British universities is financed by a 'research council' which receives a block grant from central government and subdivides the money to finance various subjects and programmes, some money centrally directed by the research council but much given to universities for individual projects, in response to proposals received. The research council responsible for astronomy is the Science and Technology Research Council (STFC). The expansion of astronomy, for reasons directly connected with the market system for education that the Government has developed, placing the choice of course of study in the hands of the student and the incentive to respond to this in the hands of the universities, has placed a strain of severe competition on STFC as it seeks to satisfy the increasing demand by astronomers for support and facilities. This has placed upward pressure for resources on the Government. One paradoxical response by the Government is to propose to limit, through top-down direction, the range of universities carrying out research, in astronomy as in other subjects. One recent suggestion by the minister for universities is to limit the number of research intensive universities to about twenty, more than halving the number that exists at present.

The largest bloc of astronomy PhD students in the UK is supported by grants from STFC, which pays tuition fees to the university and provides a living allowance to the student. The allowance, tax free, was recently increased considerably and seems to support an adequate student lifestyle. The number of grants is controlled under a quota system; in general, grants are awarded only to students who have achieved first class honours in a relevant undergraduate degree, or the next lower grade, known as an 'upper second class', abbreviated 2(i). Additionally, students can be funded by individual universities, self-financed or financed by other sources, including sources overseas. Because the training scheme has recently moved from a 3-year PhD to, more typically now, a 4-year PhD, and everyone knows that money is in short supply, the grant given by STFC to the university to pass on to the student is sufficient to last 3.5 years, not 4. Universities typically provide 4-year training to as many students as they can afford and as the research project and the preparedness of the student demands. There are always significant numbers of students supported from outside the main Government-sponsored system.

In recent years, up to 2009, the number of PhD students in astronomy being financed by STFC was about 150 students starting their studies per year. In 2010 the number was 132 and, according to STFC's financial plan, it will soon further decrease and plateau at 120-125. Since the training is typically for 4 years, the total number of mostly STFC-financed students in 2010 was about 490. According to the RAS Demographic Survey for 2010, there were 1060 PhD students in astronomy. The survey data were compiled in the winter of 2010/11, in the first months of the academic year, at the annual peak of PhD student numbers, with some students finishing off their theses after the time during which they are financed has run out. This might augment the number of STFC-supported and formerly-STFC-supported students by 10-20%, i.e. up to about 600. It follows that over 40% of PhD students in astronomy in the UK are financed by non-STFC sources.

By far most postgraduate students are full-time and 70% are domiciled in the UK, 30% outside the UK (half from the EU and the remainder in small numbers from many other countries).

5. Fixed-term post-doctoral researchers

The first position taken up by a newly-qualified astronomer with a doctorate, if he or she stays in astronomy, is typically as a fixed-term researcher. In making a grant to a university researcher to carry out specified projects, the STFC often provides funds for post-doctoral research assistants (PDRAs) to help with the research. Additionally STFC has funds available for research fellowships, competitively awarded to the most promising individual young scientists. In addition there are a number of fellowships (PDRFs) available from individual universities and colleges, the Royal Society, the Royal Astronomical Society, the EU, various charitable sources and foundations, etc. Such awards are made for a specified term of years – typically three. The Bologna process envisages that training will extend into the post-doctoral period, and it is often the case that post-graduates will receive training in transferable skills, i.e. skills that will equip the individual for employment both inside and outside astronomy research. This is seen in the UK as more and more essential, since the reality is that most PDRAs/PDRFs will not, in the long term, sustain an academic career in astronomy.

In 2010 there were about 450 PDRAs/PDRFs in astronomy in the UK. According to the RAS Demographic Surveys, this is about the same as in 2003; the number probably peaked between then and 2010, being brought back down from a high by the recent financial stringency. The number in 1998 and 1993 was about 410 and 320 respectively.

In the recent survey, 38% of PDRAs/PDRFs were foreign nationals, a larger proportion than were PhD students. 27% were from other EU countries, 2% from the USA and 9% from elsewhere. 30% of PDRAs/PDRFs obtained their PhD from outside the UK. The attraction of the UK to foreign nationals who want to research in astronomy is a mixture of the vigour of the science in the UK (second in output only to the USA), a desire (if they are not native English speakers) to exploit and develop the professional English-language skills that they will already have acquired and an attitude by UK astronomers to employ the best people as PDRAs/PDRFs without regard to nationality. Working against the latter principle is an increasingly difficult stance by UK immigration policy against economic migrants from outside the EU, although there are various exemptions for the well-qualified.

PDRAs/PDRFs are lucky enough to spend nearly all their time on research. They seem to reckon themselves adequately paid, almost exactly at the median wage in the UK, although this wage is less than they might have earned at the same career stage in some industrial positions.

6. Permanent posts

The entry level into the permanent academic staff of a university is Lecturer, with the name indicating the more important responsibility (certainly more time consuming, judging by the RAS Demographic Survey) of the appointee, namely, teaching, although of course research is of comparable weight. A few individuals are appointed to permanent research or technical staff positions, without teaching responsibilities. 'Permanent' is the customary adjective but is now too strong: there are increasing number of posts filled on the basis of there being continuing money available, and the concept in the UK of university 'tenure', the right to continued employment in the same job at a university until death or retirement, has weakened considerably. 'Indefinite', 'open-ended' or 'continuing' are more appropriate adjectives than 'permanent'.

As the individual gains age, responsibility and reputation, he or she may be promoted to Senior Lecturer or Reader (terminology differs from university to university; hereafter both referred to as 'Senior Lecturer'). An individual may then be selected through competition for an established 'chair' (as the post of professor may be called) or another position which has some structural or organisational responsibilities. Alternatively, an individual may be offered personal promotion to the rank of Professor. This promotion does not always come with an increase in pay, but it may be part of a package offered as an inducement by a university to an astronomer to transfer away from his current post.

This phenomenon, reminiscent of footballers' transfers from team to team (but on a reduced financial scale), is more frequent at regular intervals, at the times of the Government's periodic evaluation of universities, which influences the grants that it gives out to support university work other than teaching. Formerly known as the Research Assessment (RA) exercise, it is now called the Research Excellence Framework (REF), run jointly by the Higher Education Funding Councils for the four nations (like the one for England, HEFCE). The REF will take place in 2014, and will evaluate the output in the period 2008-13 of selected staff in post at the end of 2013. It is widely expected that there will be a migration of people with a good publications record in relevant years to other universities before the crucial census date, as universities respond to this market pressure on their funding. The next RAS Demographic Survey may well find that a number of professors of astronomy were created as a result of transfers taking place in the years 2011-2013.

The data from the RAS surveys for the numbers of permanent posts in universities are shown in Table 2. The erratic changes in totals since 1993 may be in part real and in part sampling differences between the surveys: in particular the 2003 survey was notably incomplete. Nevertheless there appears to have been a real increase since the 1990s, due to a mixture of reasons. I have already noted the continued establishment of new astronomy groups in universities (see above), although much of the increase appears to have been in universities where astronomy groups have been established for some time. Some of the growth is due to the closure after 1998 of the astronomical research functions of two research council institutes, the Royal Greenwich Observatory and the Royal Observatory, Edinburgh, and the reduction and merger of their technical operations. A number of astronomers were absorbed into universities in that process. There remain less than 100 staff in astronomy outside the universities compared to 400 or so before 1998.

Another feature of the 2010 figures is the rebalancing towards senior status positions: the doubling of the number of professors is particularly

TABLE 2. Permanent astronomy staff in UK universities

	1993	1998	2003	2010
Professors	78	98	104	227
Senior lecturers	100	97	105	160
Lecturers	101	117	74	111
Technical staff	129	78	35	70
Research staff		20	8	50
Totals	408	410	326	618

notable. This is probably due to the introduction of the schemes for personal promotion and appointment of professors on merit.

In 2010, 78% of permanent staff were British, 12% from other EU countries and 2% from the USA. 41% do not have children, comprising 27% of professors and 62% of lecturers. In general in the UK, 40% of UK university graduates aged 35 are childless and that at least 30% will stay that way, so the astronomy population seems to be typical in this respect.

All three grades of academic staff (Professor, Senior Lecturer and Lecturer) reported that they spend over a third of their time on research (between 35% and 39%). The teaching load (undergraduate and postgraduate) varied inversely with administrative load: Lecturers spend 41% of their time teaching and 13% in administration respectively, Senior lecturers 37% and 17%, Professors 28% and 21%. All grades spent 4-5% of their time on outreach.

7. Gender demography

The proportion of females among postgraduate students in astronomy is about 34% (2011). Given a goal of gender equality, this is a considerable improvement on the 1998 figure of just over 20% (Tadhunter 2000), but still well short of the goal. The proportion of female staff of different status is as shown in Table 3. As with other academic subjects in UK universities, the proportion of women decreases with both age and seniority of status, and is larger in fixed term positions than in permanent positions. However, astronomy is apparently more female-friendly than physics. Changes in the population of astronomers are driven by the young intake but take place in the population as a whole on a generational timescale. The male-preponderance presumably reflects the mid-time at which the population was formed, as well as a systematic tendency for females to drop out of the

TABLE 3. Proportion of females

Grade	Astronomy	Physics
Professor	7%	5%
Senior Lecturer/Reader	16%	11%
Lecturer	28%	20%
Permanent Research staff	10%	}17%
Fixed Term research staff	27%	
Permanent technical staff	30%	
Fixed term technical staff	20%	
Postgraduate students	34%	19%

career pipeline or to rise up against a glass ceiling.

8. Ethnic demography

The only data known on the ethnicity of astronomers in the UK is data collected in 2010 by the RAS Demographic Survey 2011. 95% of permanent staff and 97% of fixed term staff describe themselves as white. The figures for the UK population as a whole are rather contentious and often not free from the political bias of the source, but objective figures are available in the official census by the UK Office of National Statistics. 86% of the UK population described themselves as white in the 2001 census. The 2011 census figures are not yet available, but are likely to show a higher proportion of non-white people. It is clear that non-white people are considerably under-represented in the population of astronomers in the UK; from the scant data on this subject that is available, this is true of many countries.

9. Career development

Here is a very simple model of the astronomy population in the UK: The total number of permanent academic staff is roughly 600, the number of postgraduate students about 1000. There are 450 PDRAs/PDRFs. The time that an individual spends in each of these stages of a nominal career is, let us say, 4 years as a PhD student, 6 years as a PDRA and perhaps as long as 40 years, say 20 years on average, as an academic. If the system is closed to outside sources and sinks (it is not) and if the system is in steady state (astronomy has been expanding), it would follow that 25% of postgraduate students would become PDRAs/PDRFs, and half of them would then go on to enjoy a university career in astronomy. Overall about 10% of PhD students would go on to enjoy an academic career in astronomy.

Actual figures for 2009, established from a survey by the STFC of the PhD students of astronomy that the STFC financed, and who completed their studies 10-14 years earlier (STFC 2010), are as follows[2].

46% of the former students who responded were working in universities, 27% in the private sector and 23% in other government or public sector organisations. Of those employed in universities, 32% were lecturers or senior lecturers and a third were working outside the UK. In the private sector, about three quarters worked in business or financial services: in investment banks, money market traders, fund management companies and companies providing management consultancy services. Former students also worked for large business systems companies and a minority worked in manufacturing companies. Of those working in the public sector, half worked in UK or international research establishments. A common feature of all these roles was that they require high-level mathematical, computer modelling and information technology skills which are key components of most astronomy PhDs. Most of the remainder were working in organisations that did not undertake research directly, such as central or local government and schools or colleges. Unmentioned in the survey were careers in school teaching, journalism or astronomy outreach, e.g. at a planetarium; these positions have been of less interest to someone with a PhD in astronomy, although there are a number of such people, perhaps an increasing number, doing a good job in those careers in the UK.

Further to develop the simple model above, of the progression of those scientists who set out on an academic career in astronomy, in conjunction with the standard ages of people who follow the nominal career of Fig. 1, it would follow that the age distribution would have a peak at young ages (PhD students, aged say 22-25), stepping down to a shoulder at a height of one-third peak for PDRAs/PDRFs (aged say 26-32), stepping down again to about 10% of peak (permanent staff, aged say 33-63).

The actual age distribution shows a triangular shape, declining almost monotonically and linearly from people who are in their early twenties to those about to retire aged 70. Thus individuals appear to leave an astronomy career in the UK at a constant rate per year. There is no known survey data of their destinations. Statistically, mortality and ill-health would be minor factors. Observation suggests that a number of those leaving UK astronomy migrate to academic posts overseas, for example to posts in overseas-based international organisations like the European Southern Observatory or to academic posts in other countries, like the USA, Germany, Australia, or South Africa. Some presumably shift to other, completely different parallel careers, whether in academia, public service or industry.

[2] The figures were, apparently, not corrected for any selection bias in the responses, e.g. university employees might be more readily located and more likely to respond.

It is rare for a person to be appointed to a permanent academic post before the age of 30, and staff in their late thirties are equally likely to be in permanent or fixed term posts; but some people in fixed term posts are in their forties and a few even in their fifties. It follows, since the age of a newly-qualified PhD is perhaps 27, that on average a person newly appointed to a permanent academic post would have had at least one, on average three, and perhaps more fixed-term PDRA/PDRF posts of three years duration. The people in these fixed-term positions are however at a time of their lives when family responsibilities, potential or de facto, are growing.

In general, PDRAs/PDRFs are realistic about the career that they could try to take further. Some never intended that they should take up an academic career in the UK in the long term. Some have seen what an academic career in astronomy entails, particularly the work-ethic of long hours, a salary that is perceived to be mediocre compared with the rumoured bonuses available in banking careers, the mobility and the flexibility of location that is necessary in the early years. They reject such a career, and move to something with a more conventional work-life balance.

For others, getting a permanent job in astronomy is a strong objective. They see as worthwhile rewards the constant intellectual challenge and the self-fulfilment that comes with understanding a problem in astronomy; they see the opportunity for travel, the sense of belonging to a global community and the respect that their peers give to an astronomer. They like what they see of the life lived by their more established colleagues.

In principle, there is no limit to the number of fixed-term posts that an individual may hold, although the older such a person becomes the more problematic is the next position. There have been some attempts to limit the number of positions or the maximum age at which a research council would permit a PDRA/PDRF to be employed, but these were illegal as well as paternalistic, and abandoned. However, EU employment legislation has reduced the distinction between fixed-term and permanent appointments in the rights of employment that accrue, and the distinction has become less crucial.

10. Part time study of astronomy

The Open University (OU) was established in 1969 to provide part-time or distance-learning for people wishing to achieve a university education in that way – typically adults who have for one reason or another have not taken the usual route at the usual time, perhaps for reasons of health or family circumstances. The OU's degree course is modular with units at different levels (correlating with the years of a conventional degree course) and weights. Successfully completed modules can be assembled, in a number of configurations, into a Certificate (mostly Level 1 study), a Diploma (mostly Level 1 + 2 study) or ultimately, after at least six years, into a Degree (Level 1 + 2 + 3 study). The degree is awarded either in a particular subject or in a broad range of subjects selected by the student within some given criteria of level and distribution. The OU has 250,000 students enrolled at any one time (about 50,000 outside the UK).

Astronomy modules are amongst the most, if not the most popular science courses at the OU, with 3,500 students enrolled in 2010 in at Level 1 (roughly equivalent to a conventional first year undergraduate course), 1,000 at Level 2, and 260 at Level 3, or 4,770 in total. The total enrolled in physics was 2,713. Taking account of the weighting of the courses, the total numbers were 595 and 970 full-time equivalent students respectively for astronomy and physics.

Following in the OU model, there are now university-level distance-learning courses in astronomy given from a collaboration of Liverpool John Moores University and the University of Central Lancashire. The units can be built up into a Degree or a Certificate of Higher Education, a qualification reckoned to be degree-level but not of the same scope as a degree.

Astronomy is also a subject which can be studied at school with an examination at the end of the course which is part of the General Certificate of Secondary Education (GCSE), taken typically at age 16. The examination can also be taken by adults on completion of a course at a college of further education, typically through evening courses. The number of people who take this examination has risen by a factor of ten over the last twenty five years to over 2,000 candidates in 2009, after a big increase in the numbers of educational institutions offering GCSE Astronomy, from its start when it was mainly taken by sixth formers in private residential schools. The National Curriculum taught in all schools requires school pupils to learn some astronomy, including basic things about the sun, earth, moon and the solar system.

Astronomy education in the OU and in schools is thus making some progress to widen the educational base in the UK and making a contribution to social mobility.

11. Amateur astronomy and public education

In Britain today there are over 10,000 amateur astronomers, probably more. This number is estimated from the membership of the 200 known amateur societies, which run meetings programmes and sometimes operate amateur observatories with star parties. The national amateur astronomical societies are the British Astronomical Association (BAA), with a membership of

3,000 amateur astronomers, and the Society for Popular Astronomy (SPA), with a similar sized membership of astronomy beginners, which has evolved out of a society directed specifically at young people. The principal amateur astronomy magazines in Britain are *Sky at Night* and *Astronomy Now*, with circulations reputed to be in the mid 20,000's. These amateur activities constitute an informal system of continuing professional development for large numbers of people who are likely to be in jobs with technical content.

There are large static planetaria at public education centres for astronomy in Armagh, Bristol, Chichester, Dundee, Glasgow, Greenwich, Isle of Wight, Jodrell Bank, Leicester, Liverpool, Sidmouth, Southend, Stockton, and Todmorton, some with active public observatories. Leicester is home to the National Space Centre (NSC), a major educational venture associated with Leicester University's Department of Physics and Astronomy. NSC has considerable success in attracting school students, especially the Challenger Learning Center, where it is possible to simulate space travel. There are important astronomy educational centres at the locations listed above, at the Spaceport on Merseyside, and elsewhere. Liverpool John Moores University is the home of the National Schools Observatory which, through the Liverpool Telescope, delivers inspirational astronomy to school children.

These facilities are greatly in demand by school teachers who understand the motivational power of astronomy for their students, and its ability to sugar-coat what the students may regard as the bitter pill of science-learning that they have to swallow, but who feel less than fully competent to teach space/astronomy studies. Indeed, the small number of school teachers teaching physics who have a degree-level qualification in physics is a matter of national concern, so these facilities provide a powerful complement to the study of physics in schools. The total throughput of people through these facilities is millions per year, the throughput of school children in the hundreds of thousands. For example, of the 2 million visitors to the Royal Observatory, Greenwich in 2008, 14,500 were school children in organised parties. 208,000 people per year visit the National Space Centre, of which 52,000 are school children; 100,000, 80,000 and 45,000 people each year visit the Merseyside Spaceport, the Jodrell Bank Visitor Centre, and the Armagh Planetarium, respectively, with similar proportions of school children.

Astronomy is recognised as an important educational activity by the BBC exercising its public service remit. Each episode of a recent BBC-TV series *Wonders of the Universe*, presented by Prof. Brian Cox, was watched by 6 million people (including on the Internet). The Open University also funds and provides material for significant astronomy programming on the BBC, including *The Cosmos: a Beginner's Guide*, presented by Adam Hart Davies. For 50 years, amateur astronomers have been catered for by a regular monthly programme *The Sky at Night*, presented by Patrick Moore, probably the world's longest running TV series with the exception of news programming, with about 2 million viewers. Astronomy stories are often (perhaps as often as daily) presented in one national newspaper or another and in radio and TV news programmes, typically as an upbeat item in an otherwise rather depressing assembly of general news about politics, the economy, crime and catastrophes. It is probable that a significant fraction of the population of the UK comes into contact with modern astronomy several times per year.

All this educational activity in astronomy is known from opinion surveys to be an important influence in attracting young people to science, and influencing the acceptance of the place of science in everyday activities by the population at large. This is recognised as such at Government level. This accounts for some of the support given to high-profile research astronomy by Government sources. Amateur astronomy is recognised as a component of continuing professional development for adults and its broad appeal has regularly figured in enquiries by the members of parliament who form the Parliamentary Committee on Science and Technology, who recognise astronomy's economic impact in raising competence in science and technology (House of Commons Science and Technology Committee 2011).

12. The future

Astronomy has established itself in the UK as a science in which the country excels. The science has its own scientific value, but its research output is sometimes described as taking place in 'blue skies', without results that are directly relevant to the economy. Of course, astronomy has direct economic value in the development in industry of cutting-edge technological capacity, spinning out from projects such as space instrumentation. Science and technology in the UK are acknowledged as having economic value to the 'knowledge economy', and have been favoured in Government spending accordingly, even after the economic downturn arising from the banking crisis of 2008; while most Government funding in the UK has been cut back starting in 2010, spending on science has remained broadly constant. It will be a continuing challenge to astronomers to demonstrate to Government that astronomy in particular has economic impact, because Government grants for research are increasingly being awarded on this basis, in addition to scientific merit. Both scientific merit and 'impact' figure in the REF, for example, and in the award of research grants by STFC.

Astronomers have, as a community, welcomed the role that their subject-matter gives them to be scientists who can inspire, motivate, attract and scientifically educate a wide range of people, particularly the young. In this nationally relevant goal, the astronomical community has been particularly successful, although from some of the demographics it seems that we could do better. It seems likely that the consequent economic impact that results from a broadly-based, scientifically well-educated, self-confident work-force is the largest economic impact that astronomy could possibly generate. The challenges are further to demonstrate this practical outcome, while at the same time maintaining scientific integrity, and structuring the participation in astronomy of the younger members of the UK academic community of astronomers, especially women and the ethnic minorities, in such a way that they embrace their probable future outside astronomy, while maintaining their enthusiasm and the standard of achievement in their early studies.

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