The PhD and Careers in Astronomy in the UK

A report from

the Royal Astronomical Society

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Material in this paper was contributed by members of the RAS Council and its Membership Committee, with key input from Helen Walker, Paul Murdin and David Clements. The final version was prepared by Robert Smith, Chair of the Membership Committee.

Summary

This paper examines the career of an astronomer in the UK in the light of the fourth Demographic Survey of the astronomy community carried out by the Particle Physics and Astronomy Research Council (PPARC) and the Royal Astronomical Society (RAS) in 2003.

A career in astronomy has never been scientifically more rewarding, with astronomy as practised in the UK at the cutting edge of 21st century research. There are also clear positive benefits for students who study astronomy, whatever career they subsequently pursue. However, the paper highlights some of the challenges facing a student deciding to pursue a career in astronomy and suggests areas where the education, career structure and support process should be improved in the interests of the student. It addresses the proposal by PPARC to increase PhD student numbers and suggests limits to the increase.

It is easy for a qualified student to find a place to do a PhD in astronomy. It is also relatively easy for a student who has successfully completed a PhD to find a post doctoral position. It is less easy to continue a career as an astronomer, although the odds are certainly not impossibly against: the probability that an astronomy PhD student in the UK gets a job in astronomy in the medium term is currently a little over 20% (although a sizeable increase in the number of PPARC-funded PhDs would significantly reduce this figure – cf. Annex 3). There is however a certain amount of dissatisfaction amongst the nearly 80% of astronomy PhD students who will not achieve a career in astronomy, both about the structure of the PhD programme and about the career structure that means they cannot pursue their chosen career. The fact that a minority of students will achieve a career in astronomy in the medium term while the majority go on to careers in other fields should be fully recognised. The paper's conclusions include the following:

- A third to a half of the astronomy PhD students in the UK can expect a post-doctoral appointment at the end of their studies, but they may have to go overseas for it.
- It is unusual to achieve a permanent appointment in a university in astronomy before one's mid- to late-thirties.
- A minority of PhD students, perhaps a fifth, will achieve a career in astronomy in the medium term, again possibly overseas.
- Students undertaking a PhD in astronomy expect to learn how to do research in astronomy. They see it as a qualification for doing research in astronomy and not as a more general qualification with 'transferable skills'.
- Nevertheless, 'transferable skills' such as teaching experience and facility in Information Technology are learnt during a PhD and are potentially useful to students seeking employment within or outside astronomy. They are not recognised by all parties (including the students themselves) to the extent that they should be. Nor are they explicitly accredited. It is difficult therefore for PhD students to offer them as qualifications for a job and for

potential employers to assess them when the student seeks employment outside the field of astronomy. Such an accreditation process should be implemented.

- Over the last ten years there has been a progressive increase in the number of postdoctoral positions in astronomy and a small[1] but significant decrease in the number of astronomy PhD students, so there is little sign that the balance between PhD places and post-doc places will worsen if the number of PhD places is reasonably increased, say by 50 students per year, but not much more.
- However, a significant increase in astronomy PhD numbers will undoubtedly increase competition for the available post-doctoral and permanent career positions in astronomy and thus the proportion of astronomy PhD students who fail to achieve a career ambition. If such people are frustrated, possibly embittered, they are unlikely to serve science well. Thus, both the number of additional PhD places and the course structure for them need to be considered carefully.
- Over the past ten years, there appears to have been a small decline in the number of PhD students who are financed from non-PPARC sources, although the number financed by PPARC has increased. It appears that the PhD in astronomy has become less attractive to those who make individual choices to embark on one and some further study is required to confirm whether this is really the case and why.
- More location-independent post-doc positions are needed, for people to balance the ‘two-body’ problem (where both partners are professionals on short-term contracts, particularly where both partners are astronomers).
- The available help in universities and elsewhere for astronomers moving to other careers needs to be investigated, to ensure that best practice from individual supervisors or careers advisors is implemented more widely.

[1] The figures in Section 6 (Table 4) appear to show a dramatic drop in non-PPARC funded students, but most of this is an apparent decrease caused by a reduction in the time taken to submit a thesis.

1. Foreword

This paper has been prepared for the Council of the Royal Astronomical Society (RAS) at the initiative of Fellows concerned at the development of the careers of PhD students in astronomy. To generate this paper, the RAS has consulted within its membership and exposed the issues more widely to the community of PhD students at its National Astronomy Meetings in Milton Keynes in 2004 and in Birmingham in 2005, at each of which about 150 PhD students attended, with the majority attending special careers-oriented meetings. It has taken into account views expressed by its professional membership, which includes many teachers and researchers in astronomy, particularly at university level. It uses data from the Demographic Surveys of astronomers (and geophysicists) carried out in 2003 and on three earlier occasions under the auspices of the RAS, with full financial support from PPARC.

Scope and completeness

UK astronomy is defined as astronomy occurring in universities and institutes in the UK, or in institutes overseas (such as in La Palma or Hawaii) that are also supported principally from UK sources and subject to policies set within the UK political arena, principally by the Particle Physics and Astronomy Research Council (PPARC). Thus international organisations in which the UK is a minority member (like ESA and ESO) are excluded from the scope of this study. However, astronomy is an international subject and many of the astronomers operating in universities and institutes supported principally by the UK are not UK citizens. They are however fully integrated members of the community of astronomy in the UK and within the scope of this study. Conversely astronomers of British nationality operate in institutes outside the UK. Nationality is not an issue in this document, but the origin and channel of support is.

‘Astronomy’ includes the following studies: astronomy, astrophysics, particle astrophysics, planetary science, study of the Earth and its global atmosphere, solar-terrestrial physics, solar physics, and meteoritics, including instrumentation and software built for these studies whether from the ground or from space; but not the geophysics of the solid earth. Although we recognise that NERC supports some of these activities, we have restricted comments in this paper almost entirely to PPARC-supported studies. These studies may take place in universities or government or other institutes (‘establishments’) in the United Kingdom, or in overseas observatories funded by the UK government (in La Palma, Hawaii, etc). Estimates of the working population and numbers of career opportunities take account of these organisations, but not the international organisations (e.g. ESO or ESA).

Because teaching and research are co-mingled in university departments there are few people employed in such places purely to teach and who carry out no research. Thus, this study does not identify teaching astronomy to undergraduates as a separate career from research. The RAS is presently preparing a report on undergraduate teaching of astronomy.

Some of the conclusions drawn in this paper are based on data drawn from the Demographic Surveys and it is appropriate at this point to ask about the completeness of the sample. The data were compiled from returns to a questionnaire sent to heads of university departments and astronomical institutes, and completed in part by the department and in part by individual staff and students. There were 59 returns in the 2003 survey, and the authors of the survey recognise only two significant groups who did not respond. While the data are therefore necessarily incomplete, the level of incompleteness is estimated to be at the 5% level.

2. Training for a Career in Astronomy in the UK

The UK rates second only to the United States in its output of astronomy (as judged by the origin of research papers recorded by ISI). It belongs to a large number of international collaborations that allow access by the UK's astronomers to first ranked equipment. Its community thrives. The UK can thus be reckoned to be a world-leader in astronomy, and a vital element in its advance. That prestigious scientific and international position can be maintained only if we actively attract high-quality young people to astronomy and develop their future careers so that they are able to remain in the field.

The main route in the UK to a career in astronomy is through an undergraduate degree in physics or astrophysics (mathematics or computer science might also be appropriate, as might some branches of chemistry or engineering) followed by postgraduate training in astronomy and related fields. This postgraduate training is at a university department. 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 develops the knowledge, skills and determination necessary for sustained independent research in astronomy, and gathers the evidence that may gain the student a post in an astronomy research group in a university department, or a government institute, i.e. an 'establishment'.

Around 40 of the 120 or so universities in the UK offer modules/courses in astronomy at undergraduate level[2]. A large fraction of these – almost all – offer postgraduate opportunities and have active research groups whose members individually supervise the postgraduate students. This is possible because astronomy in the UK is set up with a number of centralised research facilities offered competitively for common use. Thus members of even a small group of astronomers at a university that offers minimal infrastructural support for research can have access to world-class equipment and pursue cutting-edge research. This enables the astronomers in even a small university group to supervise PhD students. The students in their turn learn by accompanying their supervisor in his or her endeavours. A few universities also run one-year MSc programmes, although numbers of full-time students have been small since PPARC stopped providing studentships for them.

The largest bloc of PhD students in the UK is supported by grants from PPARC, which pays fees to the university and provides a living allowance to the student. The number of such grants is controlled under a quota system. Additionally, students can be paid for by individual universities, by themselves or by other sources. Sometimes this is because the three-year grant to the student

[2] A brief discussion of undergraduate and school astronomy is given in Annex 1.

has run out but there remains work to do to finish a thesis up to its submission. Currently, the average time to submit a PhD thesis in astronomy is 3 years and 7 months, so that a student must reckon on gathering support from outside PPARC sources for an average of one sixth of the time it takes to get a PhD. However, a significant minority of the PhD students in astronomy in the UK are financed *entirely* by non-PPARC sources.

The PhD awarded through work in an astronomy research group is the 'entrance qualification' for a career in astronomy. Such a career has the objective to elucidate some of the properties and origins of the universe of planets, stars, galaxies and larger scale structure, including the discovery of new science operating on scales unachievable in a terrestrial laboratory. Additionally and at the same time, the government and its authorities have realised that astronomy is a subject that sparks young people to be interested in science, and keeps them interested, whilst they learn fundamental areas of mathematics, statistics, physics, chemistry, etc. This helps to provide the high-level, scientifically-literate work-force which is needed by the country for its future development.

In fact, currently, a large majority of PhD students in astronomy make careers not in astronomy but in the scientific or technological parts of the economy. Many people with PhD training in astronomy have made successful careers outside astronomy altogether, such as being the president of Estonia, senior civil servants in the DTI, a successful rock musician and financial analysts. Others with undergraduate training in astronomy include plumbers, telephone engineers, the editor of *Good Housekeeping* and even a diocesan advisor.

Table 1. Occupation of first job of PPARC Research Students

	%
Clerical/administrative support	0
Computer occupations	8
Engineers, architects, surveyors and researchers	12
Management-related occupations	1
Mathematical scientists and researchers	3
Physical scientists and researchers	51
Social scientists and researchers	2
Teachers/Professors	21
Other occupations (not listed)	1

Source: An OST survey of postgraduates leaving study between 1987-1989.
http://www.ost.gov.uk/research/funding/postgrad_survey/summary.htm

According to the OST statistics in Table 1 (which, however, are over a decade old and unhelpfully treat teachers and professors as a single category) unemployment among people who have a PhD in astronomy is negligibly small, with most jobs at a suitable level. Half the appointments of those PPARC PhD students who completed their study in 1987-89 were as scientists or researchers. The Demographic Survey suggests that this number has changed little in the period to 2003 (see Table 7, Section 7), although the fraction who have appointments as teachers appears to have reduced by a factor of four.

3. Education and Training

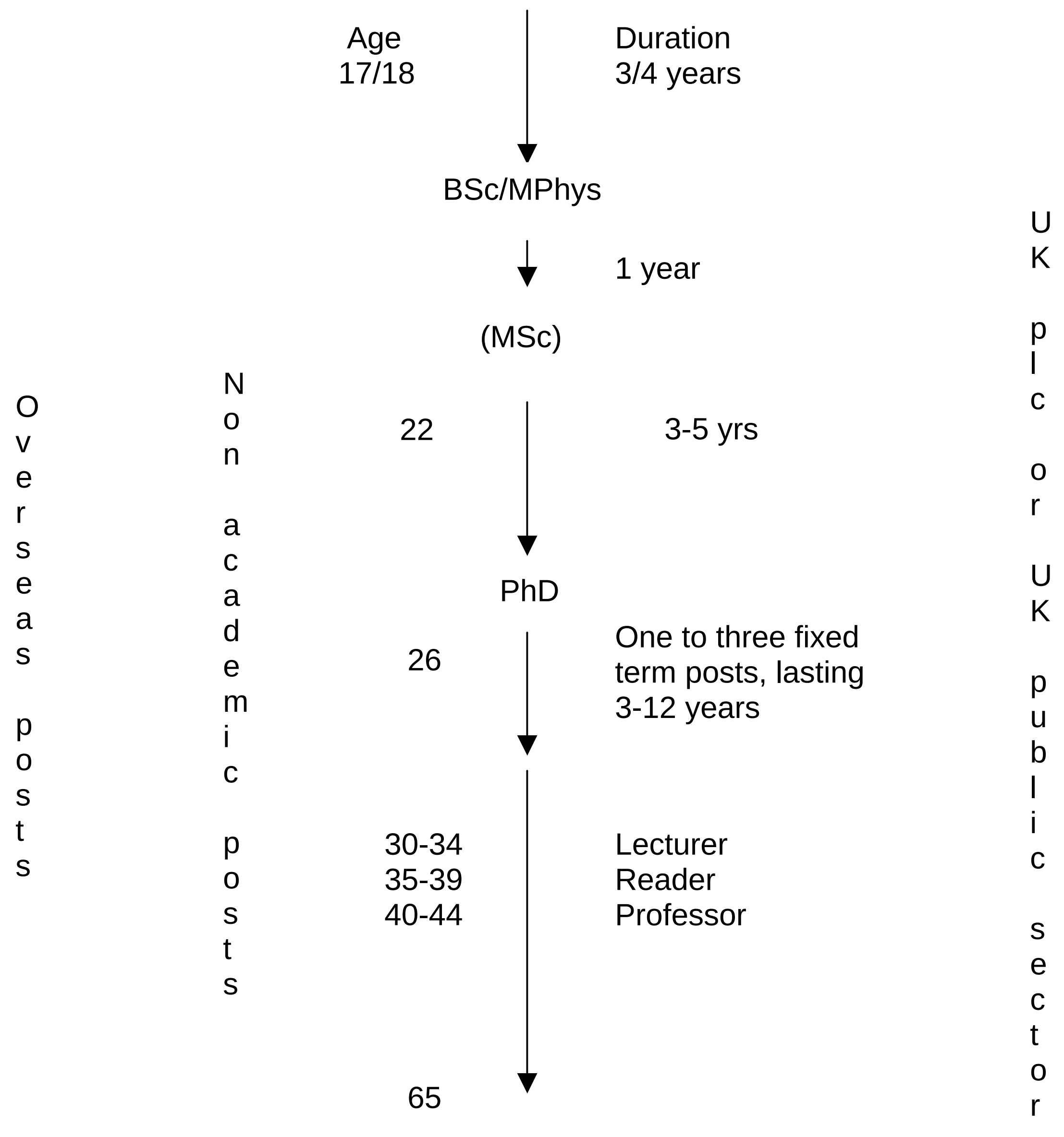
The normal career path for an astronomer in the UK is outlined in Figure 1. The main stream of astronomical careers is along the central track of posts at a university. The first three stages of Figure 1 constitute Higher Education in a university in England and Wales or in Scotland, leading to the award of a degree(s), up to the PhD level, as described in section 2.

The normal length of a degree course to Bachelor's level is three years (in England and Wales) or four years (in Scotland). It is increasingly the norm that students undergo a further one year's training to (undergraduate) Master's degree level (MPhys or MSci, depending on university) before entering a PhD course. Some students coming from a non-physics background may take an MSc (postgraduate degree) after their BSc, as a conversion course. The length of a PhD course in the UK is nominally three years. In practice it is quite common for a student to be writing up his or her thesis after this length of time, but the vast majority of students submit the thesis and receive their PhD degree well before the end of the fourth year.

Thus the UK operates nominally on a 4 year + 3 year system (MPhys or BSc/MSc + PhD) up to the award of a PhD. The Bologna Accord (see also Section 16) is a European initiative to harmonise higher education across Europe by 2010, agreed to by 40 countries. It is intended to facilitate the mobility of skilled staff and students from country to country, by making qualifications comparable. The Bologna accord implies a 3 + 2 + 3 year system.

The investment of time by a student to obtain a PhD in astronomy is thus set to increase if the UK moves towards fully following the Bologna pattern; this would require additional investment by government also. It is becoming even more important that the training should be relevant to both the development of research capability and future employment.

Figure 1 Astronomical career paths



An academic career path in the UK, starting from entering university in Scotland or England and Wales aged 17 or 18

4. The Questions

The PhD is the major tool in the educational system in the UK to provide scientifically literate workers at the highest level. It is a degree focussed on doing research and thus training people to undertake research in the future. However, an astronomy PhD is mostly used as a general qualification for employment in other ways.

This paper attempts to address that contradiction, with the following questions:

- What is the nature of an astronomical career in the UK?
- What is the range of career paths available?
- While preserving the essential characteristic of a PhD as a training for a research career, how should a PhD alter if the PhD is both to fulfil its newly developing emphasis as a training in the variety of high-level skills required by employers and to retain its attractiveness?
- Is there the right number of students studying astronomy at PhD level?
- Are post-graduate students and post-doctoral fellows adequately informed about and supported in their choices of career?

5. Career Structure

The typical astronomical career in a university after a PhD continues with one or more fixed term posts. These are research fellowships that last for a 'fixed term' of typically between one and three years. A fellowship may be awarded by a funding agency (such as a university, a research council – usually the Particle Physics and Astronomy Research Council (PPARC) for astronomers – or the Royal Society) to an individual on the basis of his or her outstanding qualities. In this case, the astronomer carries out a programme of work that he or she selects. Resources for a fellowship may also be given by a funding agency like PPARC to a university research group to award to someone to carry out a programme of work pre-selected by the university group. Such a person is called a PDRA, or Post-Doctoral Research Assistant (or Associate). There is significant competition for all these appointments, especially for individual fellowships that allow fellows to choose their own research programme.

Beyond this stage are more permanent appointments in universities, first as a Lecturer, then as Senior Lecturer (or Reader), and then as a Professor, usually as a personal promotion but sometimes as a result of taking on major organizational responsibilities. Needless to say, these posts are highly competitive too.

Some of these posts are permanent, with the post-holder given an open-ended contract. Some posts continue indefinitely but their continuation is subject to explicit conditions (such as continuing external funding).

Figure 1 shows not only the main stream of university careers in astronomy but, on the left, parallel streams of careers in astronomy available to astronomically trained people. One stream is of non-academic posts in research institutes or establishments, including the UK-financed observatories, and is within the scope of this study. These posts are divided between scientific staff and technical staff. The latter posts may or may not be available as part of an astronomical career, for example in software or in instrument science.

A second stream is of astronomical posts that are overseas, for example in a US university or a European or international institute. On the right of the figure is a third stream of posts outside astronomy in industry or the public sector, to which astronomically trained people may move.

Table 2. Age distribution of astronomers in 2003

Age range	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65-**
Permanent posts										
Universities										
Professor				4	11	24	21	19	20	8
SL/Reader			3	24	29	18	10	11	7	1
Lecturer	1	1	14	30	18	4	2	3		1
Technical staff			2	10	6	2	5	7	3	
Research staff		1	1		1	3	1		1	
Sub-total	1	2	20	68	65	51	39	40	31	10
Establishments										
Scientific staff	3	7	17	32	20	19	20	20	3	
Technical staff	4	21	46.5	46	47	38	33	33	5	
Sub-total	7	28	63	78	67	57	53	53	8	
PDRAs/Fixed term/indefinite posts	5	128	146	87	38	19	23	12	2	2

Each segment of the university career path is labelled with the approximate age at which someone may normally start in that segment. The ages at which it is usual to start studies for the award of degrees are based on a normal progression of education from school leaving-age (usually, as indicated in Figure 1, 17 and 18 in the Scottish and English educational systems – but the career paths coalesce beyond the bachelor's degree). Beyond that, the ages are based on the actual population of astronomers in the UK, as revealed by the Demographic Survey for 2003. Table 2 and Figure 2 show the actual age distribution of staff working in astronomy in that year.

At any stage through the central academic route, an individual may leave and transfer to other career areas that flank the academic route. The reverse also happens, but much less so from 'UK plc or UK public sector' than from 'Overseas posts' or 'Non-academic posts'.

Table 2 shows that the age distribution of astronomers in permanent jobs in universities starts with a sharp rise at about age 32-35. The distribution is flat to age 47 and then declines slowly. There is of course a cut-off at retirement age, which in universities is around 65-67.

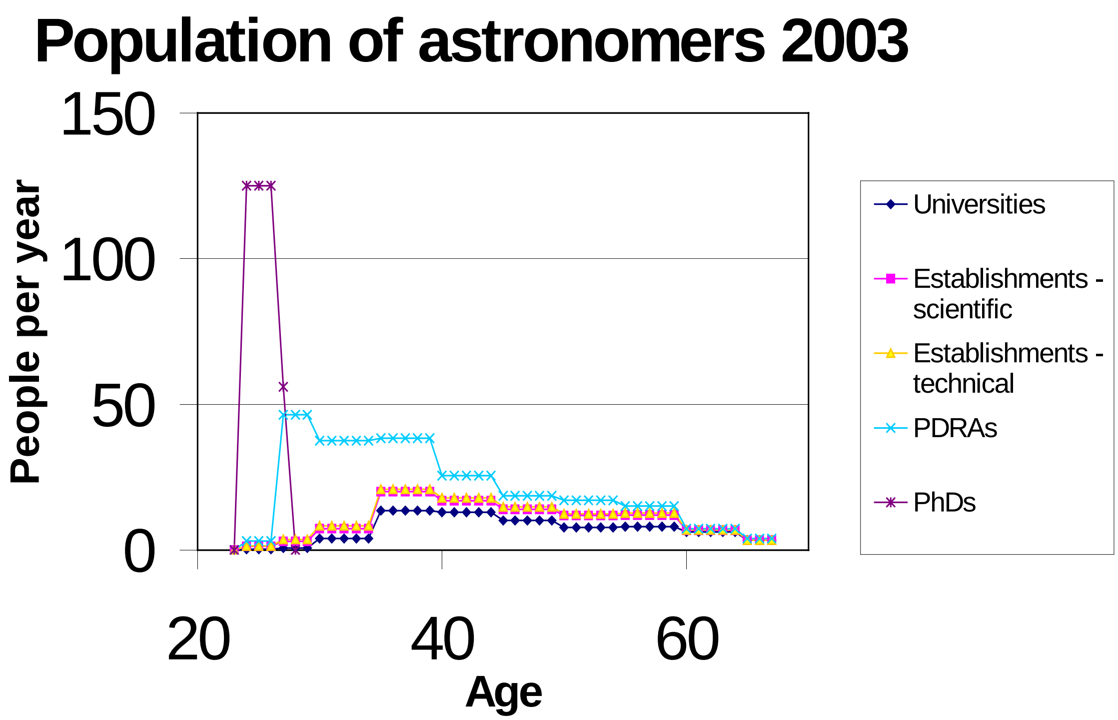


Figure 2. The age distribution of PhD students (left hand peak) and of astronomical career posts (right hand broad distribution). At the transition between PhD students and permanent career posts lie the posts of PDRAs and fellows. The astronomical career posts are subdivided into categories as shown, such that the overall envelope represents the total numbers of people in all the categories, i.e. the age distribution of astronomers in the UK. The assumptions are made that all the PhD students started their course aged 24 and remain as students at least three years, with a distribution such that the average duration of their course is 3.6 years and that 10% of the technical posts in establishments are suitable career posts for astronomers. The interpretation of this figure is made complex by transfer of members of the population into and from populations not shown (e.g. PDRAs who come from overseas).

If the population represented by the distribution is in a steady state, the flatness of the distribution suggests that there is an approximate balance between incoming and outgoing members of the population up to age 47 or so, but that leavers outnumber entrants after that. For example, experienced members of the university population might be head-hunted into senior positions outside research, or older members might retire early. The broadness of the population would suggest that the word ‘permanent’ to describe these positions would be justified, although it also seems that, if the population is in a steady state, half the population leaves astronomy before normal retirement age.

Alternatively, if the distribution is evolving then the peak at age 35-40 suggests that there has recently been an increased number of appointments, while the dearth above age 60 might reflect a slowness of recruitment into universities about 25-30 years ago. The appointments might be associated with the establishment and growth of astronomy groups in universities such as Liverpool John Moores, Nottingham, Exeter and Portsmouth (to name only a selected few), as well as the rejuvenation of long-established groups such as St Andrews.

Given the known financial cut-backs in universities in the 1980s, the significant number of people who took early retirement or voluntary redundancy as a result, and the significant time-lag before any replacements could be made, the evolving model seems much more plausible. The system has probably been relatively stable for the last five years, but has not yet reached a steady state.

The age distribution of permanent scientific (and technical) staff in establishments is similar to that in universities, but cuts on and off about 5 years before the population of university astronomers (some staff come straight from a first degree and retirement age is 60-65).

- In broad terms the age distribution of permanent posts in universities is well balanced and shows both youth (in that the peak in the age-distribution lies in the mid- to late-thirties) and experience (in that there is an extensive and significant tail to the broad distribution).

The age distribution of fixed term staff and those on continuing but indefinite appointments is quite different from the distribution of the ages of permanent staff. It is dominated by the population of PDRAs and fellows in universities. The population starts at age 26-27 and continues in a broad distribution to age 40-44. There is a long flattish small tail to age 60 and beyond.

These data suggest that it is normal in an astronomical career for an astronomer in the UK to be in a succession of fixed term posts between the ages of 25-7 and, say, 35-40. A number become permanent university staff around age 35, at which time a number have left their appointments and astronomy altogether. A number remain in fixed term appointments up to age 40 before achieving a university position or leaving the field or the country. According to a survey by PPARC of the PDRA astronomy staff that it financed, 14% of the PDRA staff employed in 2003 had been on Fixed Term contracts for more than 6 years. The proportion has been reducing since 1999. 8% have been in fixed term appointments for 12 years or more.

As well as including people on continuing but indefinite appointments, the long tail to this distribution may also include a number of people still in fixed-term positions at a late stage of their career. The question asked in the questionnaire circulated as part of the Demographic Survey also leaves open the possibility that the tail includes special cases such as Senior Fellowships – older permanent staff on a fellowship during some leave of absence from university duties, while replaced by a younger fixed-term lecturer. In the statistics, this situation substitutes two fixed-term posts for a permanent one.

PPARC-financed astronomy PhD students in 2003 took an average of 3.52 years to submit their thesis, according to PPARC's own figures. If this is typical of the whole population, the population number of 440 in Table 4 equates to a throughput of about 125 per year as plotted in Figure 2.

By age 30 the number of astronomers in universities is 37 per year, nearly all in fixed term posts. At age 40 it is 21 per year in permanent posts, and 18 per year in fixed term posts. At age 50 it is 12 per year and 5 per year respectively.

6. Evolution of Career Populations

Tables 3 and 4 show the numbers of staff in various stages and categories of careers in astronomy, at the dates of the three most recent Demographic Surveys, spanning the past ten years. (Data for the first survey of 1988 are omitted because the survey treated the categories differently.)

Table 3. Population numbers from the Demographic Surveys

	1993	**1998**	**2003**
University staff			
Permanent staff			
Professor	78	98	104
Senior Lecturer/Reader	100	97	105
Lecturer	101	117	74
Technical staff	129	78	35
Research staff		20	8
Sub-total	408	410	326
Non-permanent staff			
Lecturer	14	13	20
Post-doctoral fellow/RA	323	412	462
Post-graduate student	575	553	440
Technical staff (+ other)	126	153	190
Sub-total	1038	1131	1139
Establishment staff			
Permanent scientific	246	89	145
Permanent technical	109	201	282
Non-permanent scientific	28	55	35
Non-permanent technical	11	64	40
Sub-total	394	409	503
Grand total	1881	1950	1968

Table 4. Population numbers by category, including students

	1993	1998	2003
Scientific staff			
Permanent staff in universities	279	332	291
Non-permanent staff in universities	337	425	482
Sub-total: scientific staff in universities	616	757	773
Establishments	274	144	180
Sub-total	890	901	953
Post-graduate students	575	553	440
Technical staff (+ other)	375	496	548
Total	1840	1950	1941
Permanent scientific	525	421	436
Fixed term scientific	365	480	517
Post-graduate students supported or recently supported by PPARC (see text)	309	334	380
Post-graduate students supported other than by PPARC	266	219	60

The total pool of posts available in an astronomical career in astronomy in the UK has risen slightly (by about 5-10%, depending on the grouping chosen as typical) over the ten year baseline. Within the total however there has been a significant rebalancing of the community, the data in general confirming some trends in astronomy in the UK over the last ten years that are well known, but revealing some surprises:

- Astronomy relies on an increasing number of specialist technical staff, whose numbers have increased by 46%. This rise has, however, occurred entirely in the establishments, while the number in permanent posts in the universities has dramatically decreased.
- The number of university staff in both permanent and non-permanent jobs in astronomy has increased substantially, by about 25%, representing the establishment and growth of many new and re-invigorated astronomy groups.
- However, the number of permanent scientific staff in universities has remained constant or increased by a small amount. The number of such staff in establishments has decreased markedly by 37%, as a result of the reorganisation of the Royal Observatories and of the astronomy activities

in RAL by PPARC. Overall the number of permanent scientific staff in astronomy has decreased by 17%.

- Whilst the number of Lecturers and Senior Lecturers/Readers has remained more or less static, the number of Professors has increased by a third, possibly as a result of an increasing number of personal chairs being awarded.
- The number of fixed term scientific staff and those on indefinite contracts has seen the largest increase, by 42%.
- A survey of astronomy staff supported by PPARC as at 1 Nov 2003 identified 375 PDRAs (80% of the total). According to PPARC, the number of post-doctoral research associates financed by PPARC has reduced over ten years, so the increase is mainly due to the number of fellows financed other than by PPARC – by for example the Royal Society and the European Union, as well as the non-tenured staff supported by universities.
- There appear to be fewer PhD students, the population having apparently decreased by 23%.

The last conclusion is somewhat of a surprise, but is mostly attributable to the pressure put by PPARC and by universities on PhD students to complete their thesis within the nominal three year period. Since it was established, PPARC has been supplying PhD studentships in astronomy, according to a quota (data supplied by Education and Training Division, PPARC). In addition to quota allocations, PPARC supports a small number, about 6, of PhDs on schemes such as CASE studentships, and studentships associated with telescope collaborations like Gemini and La Palma. The time to submit a thesis has decreased from nearly 4 years to 3 years and 7 months. See Table 5. Multiplying by the appropriate lifetime as a PhD student gives the population of PPARC-supported or recently PPARC-supported students (second to last line of Table 4). The residue is of PhD students supported other than by PPARC (last line of Table 4).

Table 5. PhD studentships awarded by PPARC

Year	1988	94	‘95	‘96	‘97	‘98	‘99	2000	‘01	‘02	‘03	‘04	‘05
Quota student ships		75	75	85	86	95	94	107	102	102	102	105	110
Other		6	6	6	6	6	6	6	6	6	6	6	6
Average time to submit a thesis	3.94			3.67	3.74	3.63	3.65	3.59	3.58	3.58			

The decrease in total numbers of students recorded in Tables 3 and 4 is the result of a decline in the numbers of self-funded students, and students funded by a source other than PPARC (some of these will never have been funded by PPARC, but others will have been funded by PPARC in the past but now have come to the end of their grant). Such students might be supported by the universities, charities, overseas organisations, social security, parents and part-time employment, either throughout their course or in the time between the end of their 3 years of PPARC funding and the end of their registration as PhD students (while writing up a thesis).

The largest part of the apparent decline in student population comes from a reduction in the length of time to get a PhD. Some students complete on time in three years but most take longer and there are various sanctions against student and department that kick in when the PhD continues beyond 4 years. Indeed, some universities now insist that a PhD thesis is submitted within four years or not at all. However, some of the decline seems to result from a genuine decline in the population of self-funded students. This decrease is the more significant because it is a decline in the number of people who make an individual decision to embark on or to maintain themselves on the PhD course as a bridge to a career; one reason for deciding not to proceed to postgraduate work may be the increasing debt being accumulated during an undergraduate degree. This decline contrasts with an increase in the number centrally supplied, which can always be filled by relaxing the selection threshold. This may be what has happened. Comments made to the authors of this report suggest that some astronomers perceive that the quality of some of the PhD student population is more disappointing now than in the past. Of course, one must take care not to fall into unwarranted nostalgia for the ‘good old days’.

7. Population Dynamics

Table 6 draws together the population figures and the lengths of time that a person remains in each population to indicate the rate of flow of people through the system. The flow rate is strongly dependent on the assumed ‘lifetime’, and Table 6 should be read in conjunction with Figure 2, with which it is broadly but not quite in detail consistent. The ‘lifetime’ assumed for permanent staff is further dependent on whether the current distribution is steady or evolving. If it is evolving, the ‘lifetime’ for this group of people may be increasing, reducing the turnover rate, or ‘flow’, in Table 6.

The interpretation of these figures is made complex by interchange of population members with populations outside the UK astronomical community. Such populations are not part of Tables 3, 4 or 6, nor shown in Figure 2 but may have a significant effect on the population dynamics. A number of PhD students being educated in UK universities are from overseas and may return to their home country. A number of people trained overseas take up post-doctoral positions in the UK, and vice versa. (In 2003 the proportion of fixed term university staff who obtained their PhD in the UK was 62%, 15% in the EU and 22% elsewhere.) A number of PhD students, having completed their degree course, leave academic life for whatever reason. There are numerous other possibilities. In the absence of further information, this study assumes that as many astronomers in the UK population move to overseas posts as vice versa. This cross-fertilisation is most welcome. If it is true that there are equal numbers flowing in both directions, the population is in equilibrium under a detailed balance principle.

However, a survey that gives figures for the number of non-UK academics being recruited to UK universities has recently brought this issue to the public attention[3]. Across the whole of the university system, roughly 40% of recruits come from overseas[4]. According to the Demographic Survey, astronomy seems to be following this trend with roughly this fraction of lecturers and postdocs coming from outside the UK. This would seem to reduce significantly the chances of a UK PhD in astronomy getting a job in the field in their home country. We do, of course, export many UK astronomy PhDs to other countries, but does the export rate really match the import rate, as we assumed in the last paragraph, or are home-grown PhDs losing out? This is an area where some more research and statistics would help. In the meantime, The Times Higher[4] quotes concerns amongst academics that there is “a declining supply of home-grown staff”, perhaps because of poor pay and conditions compared to other sectors of employment.

Table 6. Population dynamics in UK astronomy

	Population	**Lifetime (yr)**	**Flow (per yr)**
Academic staff in universities			
PhD students	440	3-4	125
Post docs	462	6-8	65
Permanent scientific staff	311	15-20	15-20
Other			
Scientific staff in establishments	180	15-20	10
Technical staff in universities and establishments	548	15	36

Where the information was known to the person in the university department completing the questionnaire, the Demographic Surveys collected data on the first post-doctoral appointment of astronomy PhD students leaving

[3] see e.g. http://news.bbc.co.uk/1/hi/education/4138710.stm
[4] Recruitment and Retention of Academic Staff in Higher Education, National Institute of Economic and Social Research, 2005; see also The Times Higher Education Supplement, No.1702, 29 July 2005, p.1

between 1998 and 2002 (Table 7). Comparison of this data with the OST study of PPARC students who completed their PhD study in 1987-89 (Section 2) suggests that the fraction of students gaining appointments in astronomy has not much changed, but the fraction entering teaching has declined substantially.

Table 7. First post-doctoral appointment of astronomy PhD students

	1998	**1999**	**2000**	**2001**	**2002**	**Total**	
Astronomical	37	51	46	49	61	244	48%
UK industry	18	11	18	21	13	81	16%
UK public sector	10	4	5	2	5	26	5%
Teaching (school or college)	2	6	6	6	4	24	5%
Other (or unknown)	22	28	18	32	31	128	35%
Total	89	100	91	109	114		

The figures of Table 7 are consistent with the simple model expressed in Table 6. This situation may alter in the near future due to planned changes such as limits on the number of years permitted on a fixed-term contract and the possible changes in universities' funding as they move to 'full economic costing' of posts (see Section 16).

Reading the theoretical Table 6 in conjunction with the real data of Tables 2 and 7 etc., and Figure 2, leads to the following conclusions:

- There are 125 PhD students per year starting study in astronomy.
- When they finish their studies there are available career posts for 46-70 (35-55%) of them, as fellows or PDRAs in universities or posts in establishments. If the 2003 sample is typical, roughly 60% of the posts would be in the UK and therefore 40% overseas.
- The number of career posts in astronomy as a fraction of the number of PhD students has reduced to about a third by age 30.
- At age 40, there are about 26 posts available for the 125 PhD students (i.e. for about 20% of them). Up to 18 (13%) can have permanent posts in universities and establishments in the UK and another 8 (7%) can have fixed term posts.

To establish the turnover of staff the RAS Survey asked departments and establishments about new appointments in the five year period 1998-2003. There were 162 new appointments (over 30 per year) to replace 116 people who left. In the establishments there were 122 (25 per year) new appointments and 85 staff left.

The excess of new appointments over leavers suggests that in 2003 astronomy was growing. This continues a trend: in the four years up to 1999 the

Institute of Physics (IoP) found that there had been 70 new appointments in universities in astronomy and astrophysics to replace 44 people leaving (policy.iop.org/Policy/15.2.doc).

The number of appointments made each year was 57 scientific and technical appointments per year, consistent with Table 6. There are thus numerous opportunities available, although competition and oversupply of applicants is large.

Relating these data to people's expectations we can conclude that

- A third to a half of the astronomy PhD students in the UK can expect a post-doctoral appointment at the end of their studies, but they may have to go overseas for it.
- It is unusual to achieve a permanent appointment in a UK university in astronomy before one's mid to late thirties.
- Someone in a post in astronomy aged 26-27 or so can expect that there are further posts in prospect for about 10 or 12 years. If such a person has no permanent position at an age of 40, it is progressively more difficult to get one.
- A minority of PhD students, perhaps a fifth, will achieve a career in astronomy in the medium term, again possibly overseas.

8. What is a PhD for?

Most students who wish to study for a PhD in astronomy, and are qualified to do so (i.e. have a first or upper second class degree), can find a grant and a place. Virtually all PhD students set out with the intention of following a career in astronomy if they can. When asked at the Careers Session of the National Astronomy Meeting in 2005, by far the majority of the almost one hundred astronomy PhD students present said that they were intending to try to do so. Only 2 students said that they did not intend to try to do this.

In the Demographic Survey students were asked why they embarked on the PhD course. Those who answered gave the following reasons (more than one reason was allowed):

To pursue a career in academia	48% of students
Identified need in another career	2%
Improve chances in the overall job market	8%
Persuasion by tutor or careers adviser	1%
Gain time to think about long-term career	9%
Other	30%

According to the statistics only a minority will succeed in realizing the most common ambition. However, most students had a more pessimistic view of their chances than is warranted by the actual situation. Considering that many students willingly give up the thought of a career in astronomy upon completion of their PhD and that the sample of students at the NAM were self-selected or selected by their supervisors to attend, and therefore perhaps more likely to be among the more enthusiastic astronomy PhD population, it seems likely that many or even most of that audience will continue in astronomical research and that we will continue to see their faces in the astronomy community for some time to come.

We should examine what in principle the PhD is for, and the discussion that took place in the preparation of this report showed that there were two views on this.

(1) One side sees the PhD as an opportunity for a young person to compete for a qualification to embark on a career in academia without any guarantee at all that this would be in prospect. It is assumed that the students are interested in astronomy at this level and want to participate in research in astronomy for three years. As with a training in drama or music, not all the participants will be able to develop a career in the subject that they had chosen to study at this level. Nevertheless the chances are not negligible and there is such an opportunity in view. If a student does not want to take up an academic career, or otherwise does not get the opportunity to develop one, the PhD is a qualification that does not normally[5] hinder employment opportunities outside astronomy and may even be an employment qualification in general.

(2) The other side of the argument says that the PhD is primarily an academic career qualification. The numbers that enter the PhD course and the number of post-doctoral positions available should be matched to the number of astronomers required in permanent university and establishment positions.

We may well ask whether the focus on research is the correct model for a PhD in the UK. Should effort be focussed on supporting the students who remain in astronomy-related disciplines or on the students who follow a different career path having achieved a PhD in astronomy? It has been suggested that the UK could encourage a 'gap' year or two between the first degree and the second degree, enabling students to experience the world of work before starting their

[5] Anecdotal evidence suggests that occasionally PhD graduates are seen as over-qualified for some jobs. However, no statistics are available on how often that occurs, and general statistics for the physical sciences show that the unemployment rate for PhDs is lower than for students with a first degree – see the report "What do PhDs do?", a report by the UK GRAD Programme, which can be found on the UK GRAD website, http://www.grad.ac.uk/.

PhD, and gain an appreciation of the transferable skills they will acquire in the following years. However, when asked, the PhD students did not want to postpone the opportunity to learn to do research, and were impatient at the thought of an ‘unnecessary’ delay. On the other hand, some universities are already introducing a new type of PhD, the New Route or Integrated PhD, in which there is more emphasis on training and less on original research (more information on this new PhD is given on p.7 of the report mentioned in the footnote on the previous page).

The RAS should take a position on which model of the PhD it feels is appropriate for astronomy.

9. Why do a PhD in Astronomy?

The overwhelming reasons for students to enter a PhD course in astronomy are interest in the subject, interest in scientific research and a desire to answer some of the questions posed in astronomy. The second set of reasons involves an intention to try for a career in astronomy. The overwhelming reasons for a university academic to want to supervise a PhD student are the reflection of these reasons that motivate the student. The reasons that motivate the supervisor are to get help in tackling astronomical problems and to identify people who will become future colleagues, as postdoctoral fellows and tenured academics, succeeding in careers in astronomy. Both groups of people wish to retain the essential characteristics of the PhD course – its intellectual challenge and endeavour.

In the majority of cases the first part of the intention is successful – the student carries out a quantum of research in astronomy. Moreover there remains a large number of science students wishing to enter the PhD course. However, because admissions decisions are made locally, with no national clearing house such as UCAS, there seem to be no reliable statistics on the ratio of applicants to places, so it is not clear whether there is a pool of well-qualified applicants who are not obtaining PhD places. Anecdotal evidence suggests that the majority of well-qualified students who really want to do a PhD in astronomy are already able to do so, raising questions about a possible dilution of quality by increasing the number of PhD places.

The students are the main customers for the PhD training, and the supervisors run a close second, so is this enough for the government and universities to encourage as many students as possible to study for a PhD in astronomy?

10. Can Astronomy use more PhD Students?

PPARC intends to increase the number of places that it offers to postgraduates in astronomy. It intends to do this to increase the supply of skilled high-level scientists into the UK economy in general, i.e. without increasing the number of career positions beyond the PhD.

This move may well counter the overall decline in postgraduate numbers over the last ten years. If so, one result will be that more astronomy is generated, because the research-focussed work-force will be larger. Will more post-docs and more academic staff members be needed to help teach and supervise PhD students?

Table 8 is drawn from Table 3 to show the potential supervisors of PhD students. A potential supervisor is defined here as 'Professors + Senior Lecturers/Readers + Lecturers + Research Staff'. (Usually a supervisor is someone with a permanent position in the university, else there is no stability in the supervisor/student relationship, but a certain proportion of the Fixed Term and Technical staff in universities could be added. These are not distinguishable in the statistics collected in the Demographic Survey.)

Table 8. Supervisors and PhD students

	1993	**1998**	**2003**
Potential supervisors	279	332	291
Post graduate students	575	553	440
Ratio	2.1	1.7	1.5

The progressive decrease in the number of students per potential supervisor represents an increase in the past ten years in the competition among supervisors for PhD students, which many in the astronomical community will recognise.

Some highly active supervisors have many PhD students and successfully use them to generate a high research output. If the number of PhD students were increased by a third, this would only restore the ratio of supervisors to students to its 1993 value. All this suggests that availability of supervisors will not be a problem if the number of students is increased by PPARC within limits, say by 50 per year, or even more.

Will the UK get a good return on its financial investment from an increased number of students? Students are not expensive and their output is high, so astronomy will benefit. However, any increase in the number of students will not feed through to an increased number of astronomers, since these are financed mainly by funding from PPARC (in the form of post doctoral research associates and fellows) and by the universities (in the form of academic staff appointments), and the funding is limited. The competition that results from the higher number of students and the small number of jobs will mean that people who succeed in becoming career astronomers are likely to be the best at it[6]. But as Table 9 shows, the number of students could substantially increase before the chances of gaining a Post Doctoral position reduced to their 1993 levels.

Table 9. PhD students and post doctoral fixed term posts

	1993	**1998**	**2003**
Fixed term university staff	337	425	482
PhD students	575	553	440
Ratio	0.59	0.77	1.1

The UK also benefits from those students who gain a PhD but do not go on to an astronomical career. According to the current government the UK needs more scientists in order to develop a ‘knowledge-based economy’, and students want to study astronomy. It makes economic sense to do so, anticipating that as they move out into the wider community they take their scientific knowledge with them[7].

- The conclusion is that it will be good for astronomy and good for the country if there were more PhD students, within limits – say, another 50 per year (150 altogether); more than that would reduce the long-term job prospects to less than 1 in 6 (Annex 3).

- However, because PPARC is not in complete control of PhD student numbers, the number of students that there are in the country being larger than the numbers that PPARC supports, it should keep a broader eye on PhD student numbers than it does now in order to monitor them.

[6] This seems reasonable at face value, but the problem is that we do not have foolproof methods of determining who the best people are. Anyone who has sat on a telescope time assignment or grants committee will know that for any given over-subscription rate there will be many more proposals around the cut-off line than well above it. This is just a natural consequence of Gaussian statistics. There is thus a lot of room for random factors, or factors outside the specific selection criteria, to make a small change to assessment criteria and shift a proposal above or below the cut. The same arguments are likely to apply to the selection of candidates for jobs whenever there is a substantial level of over-supply of candidates, so appointing committees should be aware of these issues.

[7] There are other models that could increase this contribution to the knowledge-based economy; one such model that involves MSc studentships is presented in Annex 3.

11. Where will an Increased Number of PhD Students go?

Since the large majority of PhD students already do not and an increased number cannot remain in astronomy in the UK, where will the increased number go? Some additional number may find astronomy jobs abroad. But the government's intention is likely to be realised: increasing the numbers of PhD students is likely to increase the flow of highly trained astronomy PhDs into the UK economy.

Some care has to be taken in making plain to everyone who is thinking about entering a PhD programme what the situation is: the student is going to be given every opportunity to carry out an important and satisfying quantum of original research in astronomy, and the chance to measure themselves against a job later in astronomy, if that is what they want.

If the expectation of all of the PhD students is that they are sitting at the feet of the master, learning astronomical research in order to follow in the master's footsteps, then too many will take other work after a frustrating and demoralising search for an astronomical post. Do such young people become disillusioned with science and academia as well as with the job opportunities available to them in the UK? Will they go out into the community with a positive attitude towards scientific research? Are those who go into teaching going to enthuse children about the possibilities of research when their own hopes for a career in that area have been dashed? They may present a bleak picture of science to the general public, with low pay and worsening career prospects, and that will do the opposite of encouraging people into science.

- A significant increase in astronomy PhD numbers will undoubtedly increase competition for the available post-doctoral and permanent career positions in astronomy and thus the proportion of astronomy PhD students who fail to achieve a career ambition. If such people are frustrated, possibly embittered, they are unlikely to serve science well. Thus, both the number of additional PhD places and the course structure for them need to be considered carefully.

It is interesting to note here that the figures for the USA are rather different. According to the Careers Brochure of the American Astronomical Society (AAS) there are about 6000 professional astronomers in the USA, compared to a little under 2000 in the UK (PPARC/RAS Demographic Survey, 2003). These are fed by PhD astronomy production rates of 125 – 250 PhDs a year for the USA (the AAS figures from the Careers Brochure and the American Institute of Physics (AIP) figures disagree here, with the AIP giving a greater number of astronomy PhDs), and about 125 per year in the UK. There are thus 0.04-0.02 PhDs per astronomy job in the US compared to 0.06 in the UK. We are thus already producing 1.5 to 3 times as many PhD astronomers per job in the field as the USA. Despite this, there seems at present (see Section 7) to be a dearth of UK students going into posts in British universities.

12. Transferable Skills?

What skills will the PhDs take with them into the UK economy? Studying for a PhD in astronomy may include training to develop skills in

- executing projects (often to tight deadlines),
- cooperating in international teams,
- working with junior members of the team (teaching),
- preparing operational plans (for example, for observing runs) and proposals (including budgets),
- optimising the use of resources (as in large computer calculations),
- numeracy and scientific literacy,
- computing and modelling,
- handling incomplete data sets,
- presenting an account of work to colleagues and to broader audiences.

All these activities are exercised in a less than completely defined environment, namely research into a problem where the answer is unknown. This is similar to life in the real world. The skills thus acquired are those that would be recognised as useful by business, government and the UK economy in general. This suggests that although the PhD training is oriented primarily towards research in astronomy it includes development of skills that are transferable.

- The PhD is not only a training for a career in astronomy. It is already, as it is taught, a general training for a scientifically-oriented career at a high level in any field of work.

The research councils are increasingly expecting students to attend training courses to develop transferable skills as part of their PhD. The PhD students consulted by the RAS were strongly of the opinion that they did not want to waste time in training for skills seen as irrelevant to their research. ‘They’re bullshit’ is a common dismissive judgement of such training courses by the students. To use time on such courses was seen as detracting from their chances of succeeding in their primary goal, namely showing through their PhD study their aptitude for an academic research career.

By contrast, the university teachers consulted by the RAS were much more supportive of such courses, describing some of them as well received, particularly by those seeking a non-academic future.

Thus, universities increasingly offer and perhaps require PhD students to attend such courses, not only on general topics such as ‘time management’ but also in immediately relevant topics such as ‘how to write a thesis’ or ‘how to prepare a paper’ and also ‘how to supervise undergraduate labs’ or ‘how to talk to the media’ which are perhaps more relevant to a particular range of careers. More specific requirements, for example to participate in ‘ambassador’ schemes, where students go into local schools, certainly fulfil corporate objectives (attracting school students to science and university education); they may also develop employment skills in some PhD students headed for a range of careers.

The PhD course in research training in itself develops useful transferable skills. Extra courses that are seen as onerous and distant from research training may be disliked and may de-motivate students. Care needs to be taken in constructing and implementing the requirement to take such courses, their number needs to be controlled thoughtfully and their objectives in helping employment prospects need to be considered in the light of the career aims of the individual student, including the aim to conduct research as a career. Thus there needs to be a degree of optionality as to whether a particular student takes such a course.

- Fundamental changes to the structure of a PhD training are both unnecessary and undesired. But optional add-on wider-skills courses add to student choice and future employability.

As an example, it might be appropriate for PPARC to run an ‘end-of-PhD’ course, similar to the induction course held in the September before students begin their PhD, but dealing with issues of careers, transferable skills and job hunting. If it were compulsory for PPARC students, it might be possible to attract company sponsorship and for the event to function partly as a recruitment fair. The difficulty here is that it would be difficult to find a time of year that did not clash for at least some students with the last phases of writing-up, leading to lack of interest (or resentment if it were made compulsory).

13. Demonstrating Transferable Skills

PhD students strongly voice the opinion that they registered for a PhD in astronomy because they wanted to undertake research in astronomy. This is recognised as being certified by the award of a PhD, which will, however, most often be used for evidence of suitability for something else.

What is needed is to develop an appreciation of the variety of skills that are acquired during PhD work as evidence of the ability to embark on a career outside academia. The RAS has started to raise awareness of what those skills are at NAM Careers sessions (including presentations from recent graduates with new careers in different areas, to broaden expectations).

Although students do other things such as teaching and IT for which they receive no formal qualification, the PhD may carry less conviction than it ought. What certification is needed for a career outside astronomy, and how should it be recorded?

For scientists beyond PhD level, their new and additional skills can be recorded via the Chartered Scientist route. The case for Chartered Scientist status is made by the Institute of Physics on its website under the title *Why become chartered?* and is summarised in Annex 2.

- A similar type of review of a PhD programme, leading to some form of accreditation as a preliminary to being chartered, should be available for all students, and will be particularly useful to someone who plans or needs to move to a career outside research.

14. Beyond the PhD

Is the relationship between the number of PhD places and the number of permanent positions the right one to give a sound career structure? What is the chance of an astronomy post-doc gaining a tenured post? How can astronomers be helped to find jobs outside astronomy? How easy is it for astronomers to change direction to other areas of work?

Some PhD students express the opinion that having been trained to do research they should be encouraged to continue, and that when major projects are approved they should be funded not only as a capital project and a continued operation but also for continued scientific exploitation. Other PhD students regard the opportunity to continue in research as a privilege, and think that only the fortunate few will be able to have a long career there. The research councils have hitherto taken the view that scientific exploitation is something best funded in competition and with the continuing supervision of peer review, and should not be centrally directed.

On the other side of the relationship, universities are fortunate in being able to select for newly available jobs from among the very best, most dedicated and successful astronomers who have been awarded a PhD.

From the Demographic Survey in 2003, only 22% of the (academic and technical) staff in an average university astronomy department have a permanent (tenured) post, and of 319 people on fixed-term contracts, 17% had been in their current department for more than three years and 13% for more than six years. Almost two-thirds of people on fixed-term contracts in 2003 thought their chances of getting tenure were either ‘poor’ or ‘impossible’. However, many astronomers prefer to remain in the field even with the insecurity caused by lack of tenure, and 95% would like a permanent job in astronomy.

The funding of astronomy outside the UK often works in a different way, for example post-docs in the USA are allowed to apply for funding to pay for their own salary. In the UK astronomy-related establishments employ around 80% of their staff on permanent jobs, whereas in NASA establishments in the USA, the figure is nearer 20% (closer to UK universities). UK astronomy has always benefited from the interchange of astronomers, both with UK astronomers working abroad and with overseas astronomers working in the UK. The RAS cannot easily track UK astronomers taking up posts abroad, but there must be concern that the most able astronomers in the UK are more likely to succeed in job applications abroad than the least able. Even if some of these astronomers return to the UK, UK science and the UK economy is impoverished by the absence of those who do not.

Whilst some university departments work hard at providing careers advice for post-graduates and post-docs, some struggle to provide any (especially high-quality) careers advice at this level. Too many post docs and PhD students have been profoundly disappointed by the level of advice that they have received. A working group set up by PPARC in May 2003 has recommended that there should be explicit statements in PPARC funding regulations about universities' responsibilities to provide training and personal skills development for postdoctoral researchers. It would be good if careers advice were included also.

Other research councils are also aware of the need to provide careers advice and assistance, and EPSRC recently (Summer 2004) devoted an issue of its magazine *spotlight* to the topic of supporting people.

Within astronomical societies there is help to access advice on careers in astronomy. The RAS has started a jobs e-mail list, jobs.ac.uk also exists, and the American Astronomical Society (AAS) has a well-known, long-established web-site/list, but these are mainly for academic and establishment posts in astronomy. Industry, IT and finance actively seek to employ scientists but they do not recruit at astronomy events in the UK. The AAS meetings (held twice a year) include a jobs fair which is well-supported, but this has not developed in the UK.

The annual UK National Astronomy Meeting is not sufficiently well-known outside astronomical circles for UK employers to utilise it. For post-docs changing fields during their careers, new opportunities have been established for their own career development to be recognised, through the Charter route (e.g. Chartered Scientist, Chartered Engineer, Chartered Science Teacher, etc).

- A post-doc on a fixed-term contract at a university is entitled to better careers support. Universities need help to provide it. There should be a pooling mechanism to make good ideas and good practice in one university available more widely.

15. One Family, two Careers

The number of women studying for a PhD has risen dramatically in recent years, and the recent survey now puts the figure around 32%. However, the proportion of women PDRAs drops to 17% and the proportion of astronomers with a permanent job in astronomy who are female is about 8%, so there is a fairly steady fall in the proportion of women as they become more senior. This has been the case for more than a decade according to the earlier surveys undertaken by PPARC and the RAS. (This lack of improvement is in line with other equal opportunity statistics.) Young women themselves feel that the lower figures at more senior levels reflect the lack of women taking astronomy in previous decades. Since 1989, there has been an RAS Committee for Women in Astronomy and Geophysics (CWiAG) that meets to discuss these and other issues and has produced a careers brochure[8].

The normal length of time between PhD and permanent post takes an astronomer close to 40 years old. This remains a problem for women with ambitions for an academic career but who wish to bear and rear children, but the problem is beyond the scope of this paper to discuss. However, the Science Council is sufficiently concerned about the issues of equality of opportunity for women, and also for minority ethnic groups, that it has set up a project[9] to study the current situation and report by December 2005.

In this connection, it is worth noting that small unconscious biases have repeatedly been shown to operate against women. Many clear examples of such biases have been found, e.g. Nature, 1997, 387, 341-343, and it appears that these problems are cross disciplinary and international (see e.g. review by Serjeantso in WiseNet, 2000, issue 54; Handelsman et al. 2005, Science, 5738, 1190). There is no reason to think such processes do not apply to astronomy in the UK. There are also likely to be other unconscious biases, be they against women, people of different race or cultures, or different sexual orientation, whose effects are likely to be magnified if the job market is made still more competitive. This argues that ever greater care must be taken to monitor and control any biases, be they conscious or unconscious, in the hiring process.

One problem which used to be regarded solely as a ‘problem for women’, is the ‘two-body’ problem. In Newtonian dynamics the one-body problem is trivial, and the two-body problem is soluble but the three body problem is impossible. In academic life, the one-body problem of one person getting a job is hard but soluble, and the two-body problem is almost impossible. In practice this means

[8] For more details, see the Committee’s website at http://www.sstd.rl.ac.uk/rascwiag/ and the article by Helen Walker (Walker HJ, 2003, A&G, **44**, 1.04 http://www.blackwellpublishing.com/products/journals/aag/AAG_Feb03/aag_44104.htm).

[9] The project, which also involves the UK Resource Centre for Women in SET, is being carried out by Katalytik and The Diversity Practice and further information can be obtained by e-mail from info@katalytik.co.uk

that it is very difficult for two professional partners (say two astronomers) to get jobs with the same employer or even in the same city. One partner either has a very long commute to home (sometimes thousands of miles from one coast of America to the other) or one partner has to take a job outside the field. This problem is now more widespread among younger astronomers, partly because of the increasing proportion of female PhD students. For those people who are determined to follow an academic career as well as participate in a family life, this would be alleviated for a while if it were possible for a suitably qualified astronomer to follow a spouse to his/her job location. More flexible fellowships of the Dorothy Hodgkins type would be particularly helpful.

- More individual posts should be available to astronomers in such a way that the funds are not tied to one institute.

However, this is not necessarily a long-term solution and may simply delay the decision to leave astronomy to a point where it is harder to find a job in another field.

16. New Challenges

Much of this document has been written from the context of the astronomy community in the UK, and what can be done within this community with respect to the career aspirations of PhD students, postdocs and others. We do not, however, live in a vacuum, and there are, and will continue to be, challenges imposed on us from outside that may have significant effects on those who might seek careers in astronomy. While there may not be much that we can do about these, we need to at least be aware of them and consider their effects when planning changes to PhD numbers and career structures. Future challenges that we can foresee at this stage, though whose implications are unclear, are discussed here. From this list it is clear that discussion and policy setting with respect to astronomy careers will be an ongoing task for the RAS.

Tuition Fees

Tuition fees for undergraduate students at English universities will be introduced from the start of the 2006-7 academic year. These will significantly increase the burden of debt on potential English PhD students entering astronomy PhD courses starting from 2010-11, with debt increases of £12k-£15k being predicted. While there are already predictions that these extra costs will deter potential students from starting a degree[10], the effects of the increased debt on recruitment to graduate courses is unclear. PPARC and other research councils have made an effort to increase the student stipend to help with the current levels of student debt. This seems to have allowed PPARC-funded PhD student levels to remain healthy. However, it is the period since student loans for maintenance have been introduced (post-1998) that has seen the significant drop

[10] see e.g. http://news.bbc.co.uk/1/hi/education/4138410.stm

in non-PPARC PhD places discussed in section 6. This might suggest that demand for self- or university-funded PhD places is quite soft, and that increases in graduate debt levels will further reduce these non-PPARC places. Furthermore, it might suggest that still higher grants for PPARC PhD places will be needed to allow PhD students to cope with the higher levels of debt they will incur under the new regime. This will need to be considered as we approach the date at which fee-paying students begin PhDs in astrophysics.

The Bologna Declaration

This has already been discussed briefly in section 3. Its implications for UK universities and for PhD programmes in particular is still unclear. Largely, UK universities and Research Councils do not seem to be taking any action to meet the Bologna accord requirements, despite some worry about the effects of its introduction on recruitment of students from Europe. If the UK maintains its current 4+3 year degree-to-PhD structure this might be seen by European students as a benefit since they will get a PhD in 7 rather than 8 years, as specified by Bologna. On the other hand, it might be a disincentive since a 7 year PhD might be seen as a lower grade of qualification than an 8 year Bologna PhD. Until it is clear what is happening with Bologna in other European countries and what support and enthusiasm there might be in government, HEFCE and research councils for modifying UK degree programmes to match Bologna requirements, it is not obvious what the likely effects will be. If we are to move more towards a Bologna structure for higher education, then it seems clear that MSc programmes, separate from 1st degree, and prior to PhD, will have to be reintroduced. Research council funding would be needed to support students entering such programmes prior to a PhD. Annex 3 displays a model of postgraduate education that increases the number of MSc students relative to PhD students.

Fixed Term Contract Regulations

New regulations regarding the use of fixed-term contracts came into force in 2002. The implications of these regulations for postdocs and temporary lecturers are still unclear, but the basic elements of the new regulations are as follows:

- Staff employed on fixed-term contracts must not be treated differently to those on open-ended contracts
- A staff member employed on two or more fixed-term contracts for a period of 4 years or more (from the introduction of the new regulations) should be put onto an open-ended contract
- Redundancy waivers are no longer allowed for fixed-term contract staff
- Some of these regulations, especially that relating to transfer to an open-ended contract, can be escaped if there is ‘objective justification’ for the continued use of a fixed-term contract.

The reaction of various universities to these new regulations has been quite varied. Robert Gordon University has placed all research staff with contracts longer than 1 year onto continuing contracts. Glasgow University has the stated aim of making 75% of contract researchers permanent by 2006. Oxford

University has established a new framework for contract research staff, placing them on open-ended contracts and establishing bridging funds and internal redeployment processes to avoid redundancy[11]. Other universities seem to have done very little in response to the new regulations, perhaps hoping to rely on the ‘objective justification’ clause to keep them out of trouble. This also seems to be the attitude of PPARC, although we understand that NERC has been much more pro-active. It remains to be seen how this plays out since the meaning of ‘objective justification’ and its application to fixed-term contracts in universities will only be established once cases have come to court. Universities and Research Councils seem to have a very different perspective on the meaning and applicability of this clause from that of unions such as the AUT. If the AUT are right, then these new regulations could have a significant impact on the career prospects of postdocs and other fixed-term university staff. Universities may need to start functioning more like research companies and NASA institutes, with staff moving from one research field to another as funding for a particular initiative comes to an end and something else starts elsewhere. In the USA it is not unusual to find researchers who have experience over a wide range of scientific fields as a result of this practice – for example someone who has worked on the science exploitation of the Galileo probe to Jupiter is now working on the exploitation of CMB data from Planck. Research and development companies do the same thing, moving people from one project to another. In UK universities, distinct projects are not so often thought to overlap, with staff and expertise not generally being expected to transfer from one to the other, although this does occur in some instrumentation projects. The flexible practice in these groups may have to become more widespread with these new regulations.

Full Economic Costing

Funding of research in universities is just starting to be made on the basis of full economic costs (FEC). While this will potentially provide a better funded research environment, it is not yet at all clear what the implications will be for the number of postdoctoral positions that can be funded: will they really (as promised) be the same but better supported, or will they be fewer so that the money is available for them to be better supported? Time will tell.

Four Year PhDs

Another new feature, to be introduced by PPARC from October 2006, is the four-year PhD; departments have recently been asked to bid for these as part of the normal process of requesting quota studentships. It remains to be seen whether the proposal to increase the number of studentships will be transformed into an increase in the number of student-years without a large increase in the number of PhDs awarded.

[11] See http://www.aut.org.uk/media/html/sa_ftcs_whatshappening.html for more information.

Annex 1. School and Undergraduate Astronomy

Is astronomy a good way of training school-leaver or graduate-level scientists for future UK requirements? Now that astronomy is part of the National Curriculum, should the UK require teachers to be professionally qualified in the subject before they teach it, as is the case with most other subjects? Since astronomy is a subject in which there are continually new developments, should schools be encouraged to allow teachers of astronomy more opportunities for continuing professional development in the subject?

University undergraduate study

In order to enter a science course at a university, the prospective student has to be inspired and attracted to do so in the first place. Many physics departments include astronomy options in their courses because this encourages students to enrol for a BSc. The experience of being at university, especially as an undergraduate, is now thought to be a good way of preparing young people for life and work generally, training them in analysis, in meeting deadlines, and in gaining social skills. It also provides a certain level of academic attainment, and if the student wishes to study astronomy, this is no barrier to a wide range of careers. Industry, IT and finance are not concerned about the specialism of the academic course, they are more interested in broader skills issues. They find that the numeracy skills, quantitative analytical skills, ability to draw objective and empirical conclusions from incomplete data, and team skills, all of which are more available in science than in many alternative university-level disciplines, are valuable in areas that are highly relevant to economic success. There are some jobs in astronomy-related fields, but unlike other sciences, these are very few (museums, planetaria, public observatories).

Schools

Astronomy has been recognised as a subject which sparks young people to an interest in science, and keeps them interested. Young people see the importance attached to astronomy and astronomical discoveries in the UK, and they are inspired by its dramatic successes (and even by its heart-breaking failures). They are often very knowledgeable about the astronomy that is available in the public media and they should be encouraged to study astronomy at school. Teachers should be supported with appropriate material and training so they are aware of current work and developments. The RAS helps by the production of leaflets, meetings, providing information, and running competitions, as do the research councils and government agencies. Frequent short training opportunities may be more essential in astronomy due to the rapidity of its development.

Annex 2: Chartered Scientist Status

The case for Chartered Scientist status for post-doctoral physicists (and astronomers) is made by the Institute of Physics on its website under the title *Why become chartered?* and is summarised in the following edited extracts. The RAS (through the IoP) has joined the Science Council scheme which offers the opportunity to gain Chartered Scientist accreditation.

> Physics is an integral part of our culture, providing the foundations for many scientific disciplines including chemistry, biology, the geo-sciences and engineering. The increase in wealth, economic globalisation, living standards and the quality of life in the 20th century was largely based on technological progress which in turn relied heavily on innovative research in physics. These trends are anticipated to continue and, indeed, strengthen in the 21st Century.
>
> As part of this the Institute has strengthened the standard for Chartered Physicist and made it a valuable tool for all employers (whether major multinationals on a recruitment cycle, SMEs or start-ups.). Chartered Physicists agree to be bound by a Code of Conduct that reflects best practice. The Code requires IoP members not only to show a high level of professionalism, but also to continually advance their competence through continuing professional development.
>
> The chartered title can be held by those eligible people in the Member and Fellowship categories of IoP membership. Chartered status stands for the highest standards of professionalism, up-to-date expertise, quality and safety, and for capacity to undertake independent practice and exercise leadership. As well as competence, the title denotes commitment to keep pace with advancing knowledge and with the increasing expectations and requirements for which any profession must take responsibility.
>
> Chartered status is the aspiration of members engaged at the leading edge of all fields of physics and its applications.
>
> In a profession as dynamic as physics the best never stand still. Similarly, the requirements for attaining and maintaining chartered status have advanced considerably since their introduction and are kept under continuous review. Physicists who are chartered are
>
> - promoting modern standards of accountability
> - professionals who are at the leading edge of their field.
>
> People employ Chartered Physicists for sound business reasons. Chartered Physicists provide sound advice and professional judgment, based on up-to-date skills. Chartered Physicists are cost-effective, outcome-orientated, take a holistic approach and are sensitive to all agenda.
>
> What does it mean to the employer?
>
> - Provides evidence of a commitment by the employer to society and high standards, by indicating that the employer appoints only staff of proven calibre
> - Indicates that the employee values and abides by the IOP code of conduct
> - Facilitates both staff benchmarking and competences
> - Assists with promotion and salary benchmarking
> - Supports the recruitment process.
>
> In general, to an employer, the charter qualification means an assurance of quality, accountability and superior value for money.

Which physicists graduate to Chartered Status? Those who:

- Believe in professionalism and the importance of belonging to a professional body
- Through continuing education, personal development and acceptance of ethical standards, seek to distinguish themselves from other scientific and engineering practitioners
- See that Chartered Status and the effective marketing of it by the Institute of Physics provides the professional standing and recognition that they seek.
- Wish to practise within physics and its applications and accept full responsibility for their work standards
- Wish to gain opportunities to practise in their field for the benefit of the wider community
- Wish to increase community confidence in physicists

Why are graduates and experienced staff graduating to chartered status? Academic qualifications are only the beginning of a career in physics and its applications. The need for continuing professional development is widely recognised to be the mechanism by which professionals maintain their knowledge after the formal education process has been completed. Chartered status signals a commitment to maintaining competence and moving ahead with the times.

The world is also becoming increasingly competitive. A job-for-life is a thing of the past and chartered status is rapidly becoming a vital pre-requisite for career advancement.

Annex 3. An alternative model of postgraduate education, using the MSc degree

This model, developed by David Clements, presents an alternative to the current structure that preserves both the money going into universities from astrophysics PhD students and postdoc overheads (without taking account of FEC) and retains the same level of research ‘effort’ while at the same time producing for the economy more people who have research experience. This is done by the use of one-year MSc students and as a by-product increases the job prospects within astronomy of qualified PhD students. Such a model may be necessary under the Bologna accord (Section 16).

Current status

	Population	Lifetime	Flow/yr	Effort Factor	Effort/yr	Income per unit	Income / yr
PhD Students	440	3.5	125.7	1	440	3010	1324400
Post Docs	462	7	66.0	2	924	12000	5544000
Permanent Staff	311	17	18.3	2	622	0	0
Est Staff	180	17	10.6	2	360	0	0
				Total effort/yr	2346	Total income	6868400
				Chance of job	0.23		
				Total to economy/yr	96.83		

Increase PhDs

	Population	Lifetime	Flow/yr	Effort Factor	Effort/yr	Income per unit	Income / yr
PhD Students	590	3.5	168.6	1	590	3010	1775900
Post Docs	462	7	66.0	2	924	12000	5544000
Permanent Staff	311	17	18.3	2	622	0	0
Est Staff	180	17	10.6	2	360	0	0
				Total Effort/yr	2496	Total income	7319900
				Chance of job	0.17		
				Total to economy/yr	139.69		

MSc Option 1: ~effort level same as current status

	Population	Lifetime	Flow/yr	Effort Factor	Effort/yr	Income per unit	Income / yr
MSc students	230	0.92	230.0	0.3	69	3010	692300
PhD Students	350	3.5	100.0	1	350	3010	1053500
Post Docs	470	7	67.1	2	940	12000	5640000
Permanent Staff	311	17	18.3	2	622	0	0
Est Staff	180	17	10.6	2	360	0	0
				Total effort/yr	2341	Total income	7385800
				Chance of job	0.29		
				Total to economy/yr	201.12		

MSc Option 2: more effort ~ same job chance as now

	Population	Lifetime	Flow/yr	Effort Factor	Effort/yr	Income per unit	Income / yr
MSc students	220	0.92	220.0	0.3	66	3010	662200
PhD Students	470	3.5	134.3	1	470	3010	1414700
Post Docs	440	7	62.9	2	880	12000	5280000
Permanent Staff	311	17	18.3	2	622	0	0
Est Staff	180	17	10.6	2	360	0	0
				Total effort/yr	2398	Total income	7356900
				Chance of job	0.22		
				Total to economy/yr	191.12		

The spreadsheet above gives the details of the model. It makes a number of assumptions:

- MSc and PhD fees are the same, at £3010 per year (2004/05 figure)
- Research 'effort' is normalised to 1 unit per year for a PhD student
- Postdocs are twice as productive as PhD students
- Permanent staff are as productive as a postdoc, being more experienced but with more demands on their time
- An MSc student is worth 30% of a PhD student, because of their limited experience when they come to produce a piece of research
- The numbers of permanent staff and staff at establishments remain unchanged under the different models
- PhD students take on average 3.5 years to obtain their thesis (cf. Table 5)
- MSc programmes last for 11 months
- A postdoc will remain on a fixed-term contract for 7 years before finding a permanent post, either in the system or outside it
- Staff remain in the system on average for 17 years

The chance of a job in a university or establishment for a PhD student entering the system is then given by the sum of the annual turnover of staff (18.3+10.6 in the Current Status table) divided by the annual flow of PhD students, and is currently a little under 1 in 4. The remaining students are assumed to enter the general economy, either directly or after several postdoc positions – the entry 'Total to economy/year' is the net annual flow of students and postdocs out of astrophysics research into the general economy. Currently, about half of PhD students leave without obtaining a postdoc position and more than half the postdocs do not obtain a permanent post in astrophysics.

An increase in the number of PhD places by 50 per year, with no other changes, would reduce the chance of a job in the system to about 1 in 6, although the system would gain both in total effort and in income. The lower two tables show what could happen if funded MSc students were re-introduced (it is tacitly assumed that all PhD students would then take an MSc before starting their PhD, but that doesn't actually affect the results).
In the first case, the numbers are chosen to keep the total effort level the same as at present. The chance of a job for a PhD graduate then increases to nearly 30%, although at the expense of nearly 57% of the MSc students leaving the system without going on to do a PhD; the filter is being applied earlier and fewer students do PhDs. However, the income to universities is increased considerably and twice as many people with experience of research in astronomy enter the economy each year as now.
In the second case, the numbers are chosen to keep the job chance for a PhD student about the same as now. This increases the number of PhD students, reduces the number of MSc students slightly, and increases the effort slightly (not as much as only increasing PhD numbers). It also increases the income and the numbers to the economy more than the non-MSc option.