A Demographic study of Australian Astronomy

A report to the National Committee for Astronomy for the Australian Astronomy Decadal Plan 2006-2015
By Working Group 1.1

September 2005

1 Summary

The key features of demographic data on the Australian astronomical community, compared to the decadal review in 1995, are summarised by the following points:

1. The total size of the Australian astronomical community has remained essentially unchanged over the past decade. The areas of research effort have remained similar, with an increase in effort in theoretical and computational astrophysics.
2. We are able to determine the sub-sample of the community who are in continuing appointments and spend some fraction of their time on research. This group is 25% of the entire community, with the researchers in tenured university appointments representing less than 15% of the community.
3. Of the tenured staff only 10% are women, though this fraction increases to 20% for the entire community and to 37% for the current postgraduate cohort.
4. The peak of the age profile of both the entire community and of the tenured staff has shifted to a slightly younger age vis the low 40's.
5. There has been a high turnover of staff, both going overseas and being hired from overseas, that is much higher than in the previous decadal review.
6. There has been a significant shift in research effort away from galactic astronomy to extragalactic astronomy. This reflects international trends.
7. The numbers of PhD students who have completed in the past 5 years appears has dropped, but this is partly due to wrong numbers being reported for Monash completions in the last decadal review. However there has been a shift in the institutions that are producing PhD graduates. The number of PhD students currently enrolled suggests that the number of graduates will increase over the next few years, if the completion rate continues to be reasonable.
8. About 50% of PhD graduates take positions in astronomy overseas, and about 20% go into industry or teaching as their first position after graduating.
9. Australia continues to be very active internationally in hosting conferences, in participation in international organisations, and in receiving awards and honours.
10. It also continues to be very active in public education at every level. Over half a million people attended the outreach activities in the 5-year period of the report.

The key features of bibliometric analysis data on the Australian astronomical community, compared to the decadal review in 1995, are as follows.

1. Australian astronomers publish 3-4% of the world's output, but their share of the citations is markedly higher. Excluding publications in geophysics, the relative citation rate is greater than 1.5 and has increased in the last decade.
2. Australian astronomers publish 60-70% of their papers in the highest impact journals. These are the 25% of journals with the highest citation rates. The expected value, taking account of the relative numbers of papers published in each journal, is 45%.
3. Australian astronomers have markedly changed their collaborative activity since the last decadal review: only 9% of papers are single author (previously 19%) and 77% of papers are now international collaborations (previously 55%).
4. Four institutions have a large fraction of the highly cited papers (ANU-RSAA, AAO, ATNF and UNSW). This is largely a result of the numbers of research astronomers at these institutions and is affected by the subject areas of their research staff.
5. The overall citation rates are significantly affected by a couple of very highly cited papers. These probably result from high profile international collaborations.

2 Background

The Australian astronomical community, under the guidance of the Australian Academy of Science's National Committee for Astronomy (NCA), undertakes a formal strategic planning process on a 10-year time scale. This process provides the opportunity for Australian astronomy to carry out a stock-take of its capabilities, assess its impact both nationally and internationally, present a vision for the future, and to set priorities and develop strategies on how that vision might be implemented.

The resultant Decadal Plan can then present the community's vision to key stakeholders outside the research sector. This includes Australian Astronomy's key stakeholder, the Commonwealth Government, as well as industrial/research partners, both nationally and internationally.

The period spanned by the previous Decadal Plan was 1995-2005, with a mid-term review in 2001. This decadal planning process is for the next ten-year period: 2006-2015.

The NCA's Demographics Working Group (WG1.1) designed an extensive survey (Appendix 1) to collect and collate the information necessary to quantise and assess the total astronomy effort within Australia. It was sent to identified department heads or their agreed representatives (Table 1), who took responsibility for their institution/department's data collection. These contacts consulted widely with their local constituents.

In order to retain consistency across these groups, we asked that all relevant statistics (e.g. student & staff breakdowns) be reported as of 31 March 2005. The material requested as part of the survey was typically tied to the most recent five-year "window" – i.e., 2000-2004 inclusive – although some questions employed a reduced time span to simplify reporting.

Of the 24 institutes contacted, the Working Group was successful in soliciting responses from 19. Since the completion of the 1995-2005 Decadal Plan ("Australian Astronomy: Beyond 2000"), four groups (Curtin University of Technology, CDSCC-Tidbinbilla, the Antarctic Division, University of Western Sydney-Macarthur) no longer considered themselves active and have not been included in the analysis that follows. However we note that Curtin anticipates being an

active participant in the next Decadal Plan. On the other hand, three new groups not included in the 1995-2005 Decadal Plan (Swinburne University of Technology, the Australian Centre for Astrobiology, and Queensland University of Technology) have been included in the present analysis.

Responses were not received from five institutions that are known to have small groups of active astronomers and astrophysicists. The Maths Department at ANU includes 2 continuing faculty members and their postgraduate students; James Cook University has a new astronomy group which includes 2 fixed term positions and a new online graduate program; LaTrobe University has one postgraduate student supervised by staff at ATNF; the University of Technology, Sydney has one continuing staff member and the University of Western Sydney has 2 continuing faculty members. None of these people have been included in the survey results.

Table 1 – Survey Contacts by Institute

Institute	**Contact**
AAO	Stuart Ryder
ATNF	Tasso Tzioumis
Australian Centre for Astrobiology	Malcolm Walter
ADFA	Robert Smith
ANU - RSAA	Frank Filardo
Macquarie University	Mark Wardle
Monash University	Allie Ford
Perth Observatory	Jamie Biggs
Queensland University of Technology	Stephen Hughes
Swinburne University of Technology	Brad Gibson
University of Adelaide	Roger Clay
University of Melbourne	Rachel Webster
University of New South Wales	Michael Burton
University of Queensland	Michael Drinkwater
University of Southern Queensland	Brad Carter
University of Sydney	Geraint Lewis
University of Tasmania	John Dickey
University of Western Australia	David Blair
University of Wollongong	Bill Zealey

3. Survey Results

3.1 Current Level of Funding

Unlike the survey in 1995, after consultation with various department heads, the Working Group did not seek full disclosure of absolute budget numbers. Instead, the percentage breakdown from a range of funding sources and agencies was requested, and the responses are listed in Table 2 (qualitative statements concerning apparent changes since 1995 are not possible, since without absolute numbers we cannot be sure that percentage changes actually correspond to absolute dollar changes). Broadly speaking, the distribution of funding sources remains similar to that reported in the 1995 Decadal Plan (Tbl 3.1). The significant changes since 1995 include the following:

- ANU-RSAA, UNSW, UQ, and Swinburne have substantially increased their respective fraction of ARC budget support
- Adelaide, ADFA, and UWA have all seen significant decreases in their respective fraction of ARC budget support
- In 1995, 10 institutions derived >20% of their total budget from the ARC; in 2005, only 6 institutions obtained >20% of their budget from the ARC
- No groups have significant industry funding
- At an institutional level, significant changes are noted at UWA (with ARC and industrial support down in terms of budget fraction, while funding from private endowments is up) and ADFA (where overseas support is down and CSIRO support is up).
- Two qualitative questions were asked: 9 of 17 institutions considered their research effort to be expanding, and 3 thought it was shrinking. Fourteen institutions considered their funding to be inadequate, and none thought they had more funding than they needed.

Table 2 – Funding Source Distribution (by %)

Institute	ARC	Univ	DEST	CSIRO	State	Ind	O/sea	Priv	Oth
AAO	0	0	42	0	0	0	42	0	14
ATNF	3	1	16	67	1	0	9	0	3
ACA	0	100	0	0	0	0	0	0	0
ADFA	15	73	0	12	0	0	0	0	0
ANU-RSAA	12	48	21	0	1	1	10	0	7
Monash	10	90	0	0	0	0	0	0	0
Perth Obs	0	0	0	0	84	0	0	0	16
QUT	0	100	0	0	0	0	0	0	0
Swinburne	30	30	10	2	20	6	1	1	0
Adelaide	50	50	0	0	0	0	0	0	0
Melbourne	50	25	25	0	0	0	0	0	0
UNSW	65	33	1	0	0	0	0	0	1
UQ	37	60	1	0	0	0	2	0	0
USQ	0	100	0	0	0	0	0	0	0
Tasmania	20	70	0	0	0	5	0	5	0
UWA	11	6	50	0	1	2	0	30	0
Wollongong	0	100	0	0	0	0	0	0	0

3.2 Staff Demographics

The data collected on the staff and students in each institution was collected in a different manner from the previous survey: each person was listed, and a detailed breakdown provided of their demographic details, including age, research interests and research technique, and spread of functional activity. This means that the data presented in this report is more accurate than that collected a decade ago, and so additional analyses can be undertaken.

In addition to the analysis of the full population of astronomers reported from each institution, a second analysis was undertaken of those in continuing or tenured positions. Each institution filled out the details of their staffing workload in slightly different ways, so it was not possible to determine unequivocally the individual staff members in continuing positions who might be considered research active. This subset was defined therefore as anyone in a continuing position with some fraction of his or her time allocated to research.

The `full time equivalent' effort across Australian astronomy from 1995 to 2005 has remained constant (~420 staff), although there are a number of significant changes in the distribution at individual institutions:

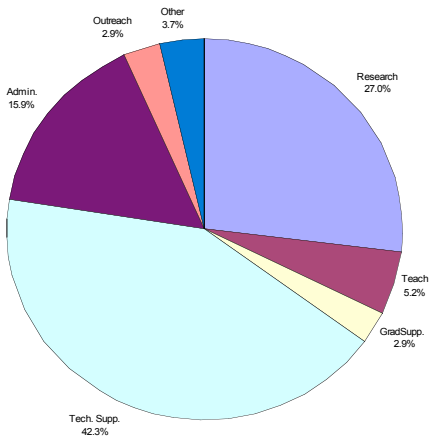
- The FTE research effort is estimated to be 111.4 (Table 3: it is difficult to make a direct comparison with the numbers in the previous decade since the 2005 workload model distributed 1.0 FTE over a greater number of `options').

Table 3 – Staff and Workload Distributions

Institute	**Staff**		**Workload Distribution (FTE)**							**Staff Movement (Last 5 Yrs)**	
	Cont.	**Fixed Term**	**Res.**	**Teach**	**Grad Supp.**	**Tech. Supp.**	**Adm.**	**Out.**	**Oth.**	**To O/sea**	**From O/sea**
AAO	54.7	12.0	4.40	0.45	0.10	42.64	17.79	1.27	0.00	7.0	6.0
ATNF	96.3	46.2	21.80	0.00	1.22	71.02	28.16	6.40	11.91	5.0	13.0
ACA	1.5	0.0	0.65	0.30	0.20	0.00	0.00	0.35	0.00	0.0	0.0
ADFA	4.0	1.0	2.35	1.85	0.10	0.00	0.70	0.00	0.00	0.0	0.0
ANU-RSAA	48.7	16.0	17.80	0.90	4.30	36.55	4.15	0.30	0.65	10.0	11.0
Macquarie	3.5	3.1	3.75	1.10	0.25	0.70	0.60	0.20	0.00	0.0	2.0
Monash	8.5	4.0	4.05	4.83	0.74	0.20	1.20	0.43	0.95	0.0	3.0
Perth Obs	10.0	1.0	1.50	0.30	0.05	3.85	2.60	1.85	0.85	0.0	0.0
QUT	1.0	0.0	0.20	0.80	0.00	0.00	0.00	0.00	0.00	0.0	0.0
Swinburne	5.0	23.7	12.47	2.17	1.45	8.20	4.17	0.64	0.55	4.0	19.0
Adelaide	3.5	2.5	3.40	0.90	0.60	0.50	0.60	0.00	0.00	0.0	1.0
Melbourne	3.0	4.0	1.90	0.70	0.95	2.60	0.85	0.00	0.00	1.0	2.0
UNSW	8.0	12.0	10.47	1.25	0.45	3.29	1.24	0.20	0.10	4.0	11.0
UQ	1.0	2.0	2.10	0.30	0.30	0.00	0.30	0.00	0.00	0.0	2.0
USQ	1.0	0.3	0.10	0.77	0.12	0.18	0.12	0.01	0.00	0.0	0.0
Sydney	7.8	21.1	17.21	3.25	0.79	4.45	2.29	0.10	0.45	6.0	9.0
Tasmania	3.0	1.0	0.95	1.10	0.25	0.10	0.80	0.30	0.00	1.0	4.0
UWA	1.0	5.0	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	1.0
Wollongong	1.0	0.0	0.30	0.40	0.10	0.00	0.15	0.05	0.00	1.0	0.0
TOTAL	**262.5**	**154.9**	**111.40**	**21.37**	**11.97**	**174.28**	**65.72**	**12.10**	**15.46**	**39.0**	**84.0**
TOTAL %			**26.7**	**5.1**	**2.9**	**41.7**	**15.8**	**2.9**	**3.7**		
TENURED %			**32**	**14**	**7**	**18**	**18**	**3**	**2**		

- In 1995, only 8% of the research effort was concentrated in Victoria; in 2005, this has grown to 17%, matching that in Canberra. This growth came at the expense of the other 6 states and territories, which each decreased by 1-2%.
- In terms of absolute numbers, the biggest changes (+/-10 in staff number) occurred at ANU-RSAA, Sydney, Tasmania, and UWA, each of which were down by >10 staff members since 1995; Swinburne and UNSW have both increased by >10 staff members since 1995. It has been the redistribution of numbers within these six institutes, which has dominated the staff demographic changes since 1995.

Figure 1: Distribution of Functional Effort



- The staff turnover since 1995 has been significant, despite the absolute numbers remaining fairly constant. This is partially measured by the movement of staff to and from overseas; Australian hires, or staff leaving for jobs in Australia, were not tracked. From 2000-2004, 39 (84) staff have gone (arrived from) overseas; in contrast, from 1990-1994, 28 (48) went (arrived from) overseas. These numbers mean that about 30% of the total staff either left for or arrived from overseas during the 5 year period.
- The latter point has contributed to the median age across all astronomy staff decreasing from 45 (in 1995) to 42 (in 2005). See Table 4.
- Across all astronomy, the male-to-female staff ratio is 80:20 (Table 4).
- In terms of research effort by astronomical area, the major development has been in the shift away from ‘stellar/pulsar/Galactic/Magellanic Clouds’ (41% of the research effort in 1995, down to 24% in 2005) to ‘extragalactic/cosmology/gravitational physics’ (26% of the research effort in 1995, up to 42% in 2005). See Table 5.

Table 4 – Gender and Age Distributions

Institute	Staff	Gender		Age						
		M	F	<20	20-29	30-39	40-49	50-59	60-69	>70
AAO	66.7	56.6	10.1	0.0	3.0	13.6	24.3	18.8	7.0	0.0
ATNF	142.5	104.0	38.5	2.0	23.2	32.3	49.2	27.5	8.3	0.0
ACA	1.5	1.5	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
ADFA	5.0	5.0	1.0	0.0	0.0	1.0	1.0	2.0	1.0	0.0
ANU-RSAA	64.7	60.7	4.0	0.0	6.0	26.7	15.0	11.0	6.0	0.0
Macquarie	6.6	4.6	2.0	0.0	2.5	0.0	3.0	1.0	0.1	0.0
Monash	12.5	8.5	4.0	0.0	1.0	3.0	3.0	2.0	2.5	0.0
Perth Obs	11.0	9.0	2.0	0.0	0.0	2.0	2.0	4.0	2.0	1.0
QUT	1.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Swinburne	28.7	23.0	5.7	0.0	13.0	8.0	7.7	0.0	0.0	0.0
Adelaide	6.0	5.0	1.0	0.0	2.0	0.0	1.5	2.5	0.0	0.0
Melbourne	7.0	5.0	2.0	0.0	3.0	3.0	0.0	1.0	0.0	0.0
UNSW	20.0	16.0	4.0	0.0	4.0	8.0	6.0	2.0	0.0	0.0
UQ	3.0	2.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
USQ	1.3	1.2	0.1	0.0	0.1	0.0	1.0	0.2	0.0	0.0
Sydney	28.9	23.0	5.9	0.0	1.0	9.0	5.5	2.8	3.0	1.0
Tasmania	4.0	3.0	1.0	0.0	0.0	2.0	1.0	1.0	0.0	0.0
UWA	6.0	5.0	1.0	0.0	0.0	3.0	2.0	1.0	0.0	0.0
Wollongong	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
TOTAL	**417.4**	**335.1**	**82.3**	**2.0**	**59.8**	**112.6**	**124.2**	**78.3**	**30.9**	**2.0**
TENURED	**107**	**96**	**11**	**0.0**	**2.0**	**17**	**42**	**31**	**14**	**0.0**

Figure 2: Age Distribution of Australian astronomical community

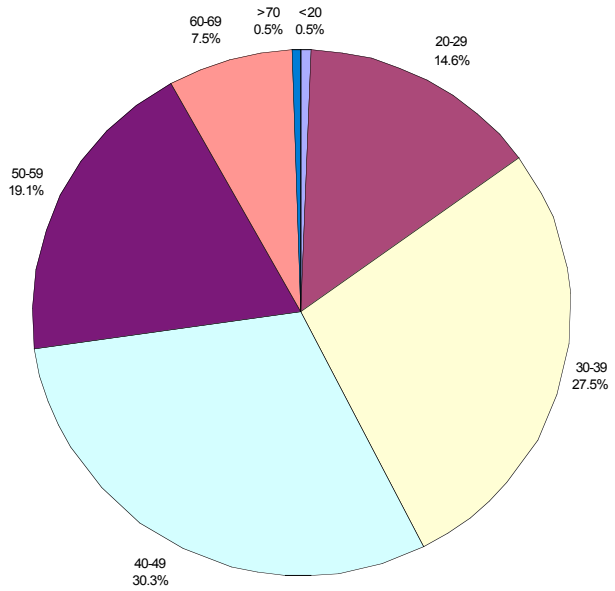
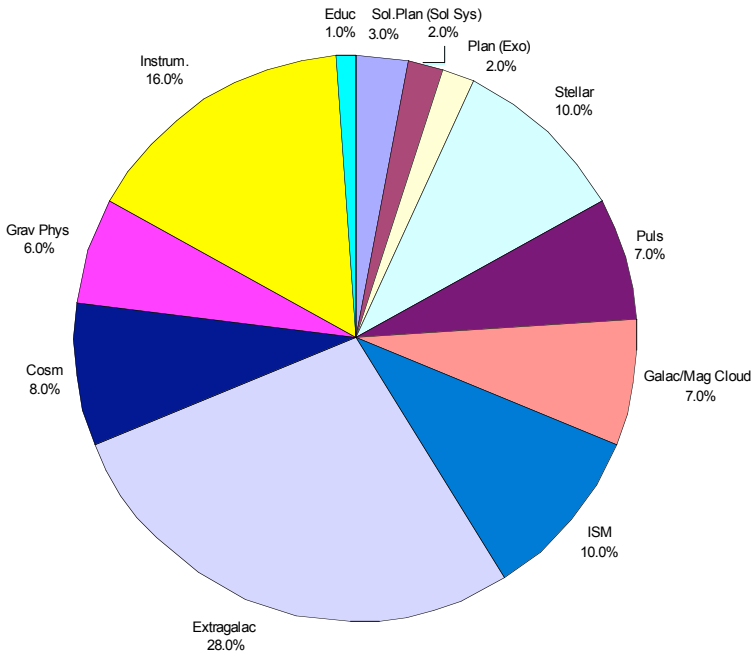


Table 5 – Distribution of Research Effort by Astronomical Area

Instituute	Res Staff	Sol.	Plan (Sol Sys)	Plan (Exo)	Stellar	Puls	Galac/ Mag Cloud	ISM	Extragal	Cosm	Grav Phys	Inst	Ed
AAO	4.40	0.00	0.02	0.20	0.40	0.00	0.16	0.23	1.46	0.76	0.00	0.78	(
ATNF	21.80	0.15	0.10	0.00	0.36	2.26	2.45	1.92	4.71	0.54	0.50	8.72	(
ACA	0.65	0.00	0.35	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	(
ADFA	2.35	0.00	0.00	0.00	1.05	0.00	0.00	1.18	0.00	0.00	0.00	0.12	(
ANU-RSAA	17.80	0.63	0.18	0.56	4.09	0.03	1.17	1.59	4.49	2.73	0.74	1.43	(
Macquarie	3.75												
Monash	4.05	0.64	0.52	0.18	0.80	0.01	0.00	1.00	0.06	0.02	0.20	0.00	(
Perth Obs	1.50	0.00	0.28	0.20	0.48	0.02	0.00	0.00	0.20	0.00	0.00	0.30	(
QUT	0.20	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	(
Swinburne	12.47	0.01	0.07	0.04	1.04	0.24	0.84	0.40	5.39	1.56	0.03	2.25	(
Adelaide	3.40	0.00	0.00	0.00	0.00	0.00	1.05	0.00	2.35	0.00	0.00	0.00	(
Melbourne	1.90	0.00	0.00	0.05	0.09	0.19	0.00	0.27	0.54	0.54	0.07	0.15	(
UNSW	10.47	0.00	0.00	0.11	0.00	0.10	1.72	1.94	2.58	1.79	0.00	1.14	(
UQ	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.30	0.00	0.03	(
USQ	0.10	0.00	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.03	(
Sydney	17.21	2.14	0.02	0.00	1.91	3.25	0.23	1.47	5.30	0.33	0.00	1.18	(
Tasmania	0.95	0.00	0.00	0.00	0.04	0.36	0.16	0.16	0.20	0.01	0.00	0.01	(
UWA	6.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	5.00	0.00	(
Wollongong	0.30	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	(
TOTAL	**111.40**	**3.57**	**1.54**	**1.46**	**10.52**	**7.46**	**7.78**	**10.31**	**29.05**	**8.68**	**6.54**	**16.24**	**(
TOTAL %	**100**	**3**	**2**	**2**	**10**	**7**	**7**	**10**	**28**	**8**	**6**	**16**	**1**
TENURED %	**100**	**3**	**6**	**3**	**13**	**6**	**9**	**7**	**19**	**6**	**2**	**25**	**2**

Figure 3: Community Distribution by Research Area

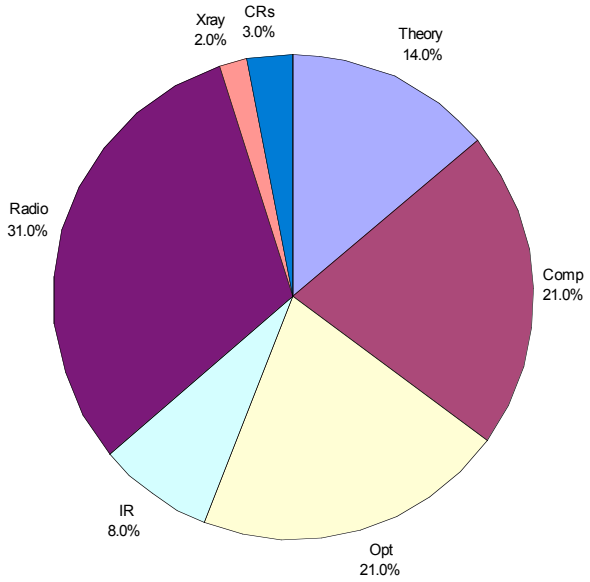


- The distribution of research by technique has changed little since 1995, although there has been a slight increase in computational and theoretical astrophysics (now at 35%, up from 30% in 1995). Computational astrophysics in particular has seen the greatest growth in the past decade, increasing from an 11% share in 1995, to 21% in 2005. See Table 6.

Table 6 – Distribution of Research Effort by Technique

Institute	Res Staff	Theory	Comp	Opt	IR	Radio	Xray	CRs
AAO	4.40	0.15	0.11	2.16	1.54	0.19	0.00	0.00
ATNF	21.80	0.24	0.65	0.38	0.56	19.50	0.35	0.08
ACA	0.65	0.15	0.00	0.10	0.40	0.00	0.00	0.00
ADFA	2.35	0.00	0.18	0.24	1.54	0.05	0.34	0.00
ANU-RSAA	17.80	3.02	3.22	6.61	2.34	1.72	0.19	0.00
Macquarie	3.75	1.88	0.92	1.38	0.00	0.08	0.00	0.00
Monash	4.05	1.53	1.72	0.16	0.03	0.28	0.03	0.00
Perth Obs	1.50	0.00	0.24	1.26	0.00	0.00	0.00	0.00
QUT	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00
Swinburne	12.47	0.73	5.52	2.76	0.44	2.98	0.03	0.00
Adelaide	3.40	0.00	0.00	0.00	0.20	0.26	0.20	2.74
Melbourne	1.90	0.71	0.22	0.38	0.06	0.53	0.00	0.00
UNSW	10.47	1.45	2.83	1.38	0.85	1.20	0.00	0.00
UQ	2.10	0.08	0.44	1.25	0.11	0.14	0.08	0.00
USQ	0.10	0.00	0.00	0.08	0.00	0.01	0.01	0.00
Sydney	17.21	4.62	1.83	2.68	0.90	5.57	0.22	0.00
Tasmania	0.95	0.00	0.00	0.07	0.03	0.48	0.37	0.00
UWA	6.00	0.00	5.00	1.00	0.00	0.00	0.00	0.00
Wollongong	0.30	0.00	0.00	0.15	0.00	0.15	0.00	0.00
TOTAL	**111.40**	**14.56**	**22.88**	**22.24**	**9.00**	**33.14**	**1.82**	**2.82**
TOTAL %	**100**	**14**	**21**	**21**	**8**	**31**	**2**	**3**
TENURED %	**100**	**14**	**13**	**22**	**8**	**38**	**2**	**3**

Figure 4: Community Distribution by Research Technique



The profile of the subsample of the staff who are in continuing research positions was also considered. These are key members of the community, since they set the research agenda, receive and spend a substantial fraction of the research income, and will remain members of the community for many decades. It is noted that some senior staff are not in continuing positions (for example Observatory Directors and ARC Fellows). The relevant data on the subsample of tenured staff is included in each of the tables above.

Some key features of the subsample of tenured staff are:

- There are 107 people in tenured positions who spend some of their time on research. In this cohort, 11 (10%) are female, 45 are at Observatories (ATNF, AAO and Perth Observatory). All others (ie 62 or 58%) are located in universities.
- At total of 35% of their time is spent on research, and 25% of that research is instrumental.
- 12 of the tenured staff do not have PhDs and 40 have PhDs from non-Australian institutions.
- About 18% of the tenured staff are younger than 40, and a further 39% are between 40 and 49. It is noted that there are no astronomers with expertise in extragalactic astronomy and cosmology in the youngest age bracket. This is an area where traditionally about 25% of the Australian effort has been concentrated.
- Both in subject areas and in technique, the research effort for the tenured staff is very similar to that for the whole research cohort. However it is noted that positions at the observatories weight instrumental/radio more heavily than extragalactic/computational. However the overall concordance is probably the result of the funding obtained by the tenured cohort.

3.3 Student Demographics

Several significant developments have occurred in postgraduate (here, restricted to PhD students, as astronomy MSc numbers remain small) demographics since the 1995 Decadal Plan (Table 7):

- The number of PhD completions from 2000-2004 was 83, down significantly from the 108 PhD completions from reported 1990-1994. This drop is the result of significant decreases in the numbers of reported completions at ANU-RSAA and Monash, though this is partly compensated for by significant numbers of completions from Melbourne. Note however that the reported completions at Monash in the period 1990-1994 were too high by at least 10. A dip in the completion numbers at Tasmania is likely to be reversed with the renewal of the astrophysics group there.
- The current number of astronomy PhD students within Australia is 157. This number is the result of a real increase in capacity: there are 4 new institutions with increased enrolments, which do not have significant PhD completions over the period 2000-2004. These are Macquarie, the Australian Centre for Astrobiology, Swinburne University of Technology and the University of Queensland. No data was collected on completion rates during the period.
- Of the current 157 astronomy PhD students in Australia, 30% (70%) are international (Australian).
- A positive development since 1995 is the improved gender balance at the PhD level. In 1995, the ratio of male-to-female PhD students was 85:15, while the 2005 ratio is a much healthier 63:37. This may increase the numbers of female staff in future, however it is noted that many of the recent appointments into continuing positions were not Australian-trained. (Table 4).
- Institutions with postgraduate training course were asked to give a qualitative assessment of their expectations for the future of graduate training at their institution. Of the 18 institutions for which it was relevant, 7 believed that the quality of their postgraduate students would increase in future, 10 believed quality would remain the same, and 1 did not answer this question. For these same 18 institutions, 7 institutions (not usually the same ones) believed that the number of postgraduate students would increase, and 10 institutions believed the numbers would remain the same, and again 1 did not answer this question.

Table 7 – PhD Graduates

Institute	Graduates (2000-2004)			Current				
Institute	**Total**	**M**	**F**	**Total**	**M**	**F**	**Aus**	**Int**
AAO	n/a			n/a				
ATNF	n/a			n/a				
ACA	0	0	0	2	1	1	2	0
ADFA	4	3	1	1	1	0	1	0
ANU-RSAA	15	9	6	34	21	13	20	14
Macquarie	0	0	0	7	4	3	5	2
Monash	9	6	3	13	9	4	11	2
Perth Obs	1	0	1	0	0	0	0	0
QUT	0	0	0	0	0	0	0	0
Swinburne	3	3	0	15	10	5	11	4
Adelaide	6	4	2	8	5	3	6	2
Melbourne	9	5	4	11	8	3	7	4
UNSW	8	2	6	19	14	5	14	5
UQ	1	1	0	5	4	1	5	0
USQ	2	2	0	2	2	0	2	0
Sydney	17	9	8	24	18	6	19	5
Tasmania	4	4	0	6	5	1	6	0
UWA	3	3	0	8	8	0	0	8
Wollongong	1	1	0	1	1	0	1	0
TOTAL	**83**	**52**	**31**	**157**	**111**	**46**	**111**	**46**
TOTAL(%)		**67**	**37**		**71**	**29**	**71**	**29**

- Institutions with postgraduate training programs were also asked to estimate the number of applicants, both domestic and international, who applied to their institution during each of the years of the survey period. While is should be noted that some applicants apply to more than one institution, there does seem to be a significant increase in the number of applications over the period. This is consistent with the fact that there appears to be a significantly larger cohort of current postgraduate students than would be expected for the total number of graduates over the past 5 years.
- Universities graduated 143 honours students in astrophysics and astronomy over the 5 year period. Currently there are 111 local students and 46 international students. Although not all the current local postgraduate cohort will have graduated recently, nonetheless there is clearly a good retention rate from Honours into the postgraduate programs.
- 70% of the PhD graduates in astronomy and astrophysics took their first job in astronomy, and 70% of those took a position overseas. 20% move into either industry or teaching immediately.
- The survey of Honours students shows that most (81%) stay at the institution of their undergraduate degree for honours, and then the majority remain for at the same institution for their PhD (64%). However there is a little movement, principally to ANU for Honours, and more broadly after Honours.

Table 8 – PhD Graduates Initial Destinations*

Academic	**Industry**	**Teaching**	**None**	**Unknown**
64	15	3	2	7
Astronomy	**Other**			
63	19			
Australia (Astronomy)	**Australia (Teaching & Industry)**	**Overseas**		
17	16	49		

*Note that these numbers include 8 MSc graduates

Table 9 – Average number of scholarship applicants per institution

Category	**Year**				
	2000	2001	2002	2003	2004
Domestic (APA-eligible)	4.1	4.6	4.5	5.2	5.9
International	1.7	1.8	2.8	2.7	3.0

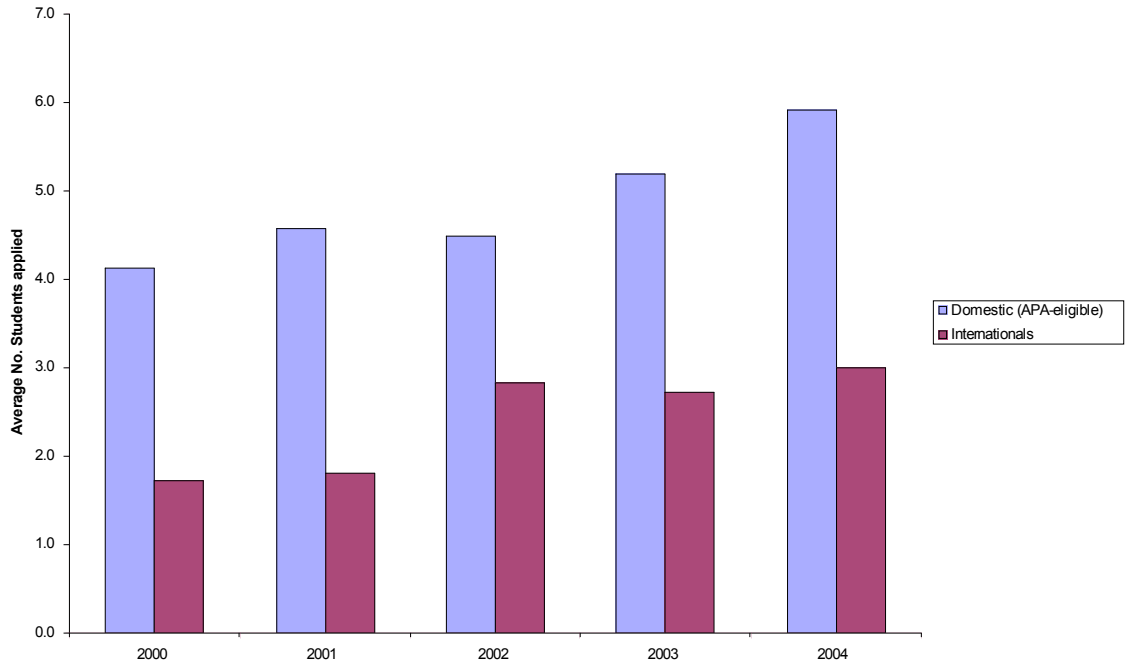


Table 10 – Honours Students (Completions)

Institute	Graduates (2000-2004)		
Institute	**Total**	**M**	**F**
AAO	-		
ATNF	-		
ACA	-		
ADFA	-		
ANU-RSAA	20	9	11
Macquarie	6	1	5
Monash	26	17	9
Perth Obs	2	2	0
QUT	-		
Swinburne	-		
Adelaide	10	7	3
Melbourne	13	6	7
UNSW	16	12	4
UQ	1	0	1
USQ	2	1	1
Sydney	28	18	10
Tasmania	12	10	2
UWA	7	7	0
Wollongong	-	-	-
TOTAL	**143**	**90**	**53**
TOTAL %		**63**	**37**

Table 11 - Honours Student Pre- and Post-Destinations

Pre:

Same Institution %	**Other Australian %**	**International %**		
81	14	5		
Post:				
P/Graduate	**Industry**	**Govt**	**Teaching**	**Unknown**
74	8	1	5	10
P/G Same %	**P/G Other Aust %**	**P/G International %**		
64	22	14		

3.4 Benefits to the Community

The astronomical community has traditionally been active in engaging with the public, both through public lectures, media interviews and popular articles and books. Comparison with the data from the previous survey suggests that, allowing for some expected inadequacy in the data, the level of these activities has remained fairly constant.

Table 12 – Community Activity

	Pop. books published	Pop. articles published	Public lectures given
AAO	0	0	0
ATNF	1	4	60
ACA	0	0	0
ADFA	0	0	0
ANU- RSAA	0	1	12
Macquarie	0	0	2
Monash	0	0	7
Perth Obs	3	2	20
QUT	0	0	0
Swinburne	0	1	1
Adelaide	0	0	0
Melbourne	0	0	4
UNSW	0	3	10
UQ	0	0	4
USQ	0	0	3
Sydney	10	0	5
Tasmania	0	0	7
UWA	1	0	3
Wollongong	3	0	5
TOTAL	**18**	**11**	**136**

Each institution was asked to provide information about their public outreach activities. The results are impressive. Sixteen of the 17 institutions offer public lectures; 7 institutions operate visitor centres; 11 institutions provide open days; 10 institutions offer night viewing There is a range of other activities at 12 institutions. In all, around 510,000 people attended various public outreach activities over the 5 year period. In addition, 7 institutions offer teacher-training programs, 2 of which target primary teachers, and all of which target secondary teachers. Around 1293 teachers were involved in these programs. In addition, 12 institutions put on outreach activities with others, 5 with other astronomical institutes, 8 with amateur organisations, 5 with professional teachers associations, and 5 with other places. A total of about 103 outreach activities were put on with other groups. Finally, 7 institutions have funding specifically for outreach activities, and of these 7, the median amount is $10,000.

3.5 Quality of the Community

The Australian community plays an active role in hosting both major international conferences and smaller more focussed workshops. These all contribute to the high profile the Australian astronomical community enjoys internationally. A full list of these conferences is provided in Appendix 2. In addition, Australians are active in executive positions, both nationally and internationally. No attempt has been made to list all of these positions.

The quality of the research community has also been recognised by major awards: 9 astronomers are recognised as ISI laureates, many of the senior astronomers hold one or more positions in the IAU including the Presidency of the IAU, 3 astronomers have been awarded Federation Fellowships, one the Pawsey Medal of the AAS, one the Malcolm McIntosh Prize for the Physical Sciences, 2 have become Fellows of the Royal Society. Many of the senior astronomers have been recognised by medals and awards from other countries and prestigious visiting positions. In addition, Australian astronomers hold senior positions in major international collaborations such as SKA and Gemini, and serve on a range of visiting committees for many of the major observing facilities internationally.

Table 13 – Quality of Australian Astronomy

	Maj. Conf. Hosted	Workshops hosted	Executive Pos'ns held internationally	Executive Pos'ns held locally	Awards
AAO	3	15	8	13	7
ATNF	9	9	25	9	16
ACA	1	0	0	0	0
ADFA	0	0	0	0	0
ANU- RSAA	1	1	12	6	20
Macquarie	0	2	1	0	0
Monash	0	4	0	2	1
Perth Obs	0	1	0	0	0
QUT	0	0	0	0	0
Swinburne	3	1	0	0	0
Adelaide	0	1	1	0	0
Melbourne	0	7	2	0	0
UNSW	2	5	5	4	5
UQ	2	0	0	1	0
USQ	0	0	0	0	0
Sydney	2	5	13	18	2
Tasmania	1	3	0	0	0
UWA	1	1	1	0	5
Wollongong	0	0	0	0	0
TOTAL	**24**	**52**	**67**	**53**	**56**

3.6 Industrial Linkages

Of the 19 institutions who responded to the survey, 8 listed significant involvement with industry. In some cases, the technology was still being developed with industry, but useful contracts had been obtained to support the work. An example of this was the remote control of domes developed by USQ, and supported by NASA with a contract for $170k. In another example, the ATNF developed the methodology for antenna metrology, when their industrial partners were unable to accomplish this. Subsequently the technology has been licensed back to the relevant industries. A third and very different technology has been developed by Swinburne: this includes 8 Virtual reality theatres for scientific visualisation and astronomy public education, and the "Elysium 7" stereoscopic 3D movie and 3D theatre for use in the "to Mars and Beyond Exhibition" at the national Museum in Canberra and the Melbourne Museum.

3.7 Teaching and Education

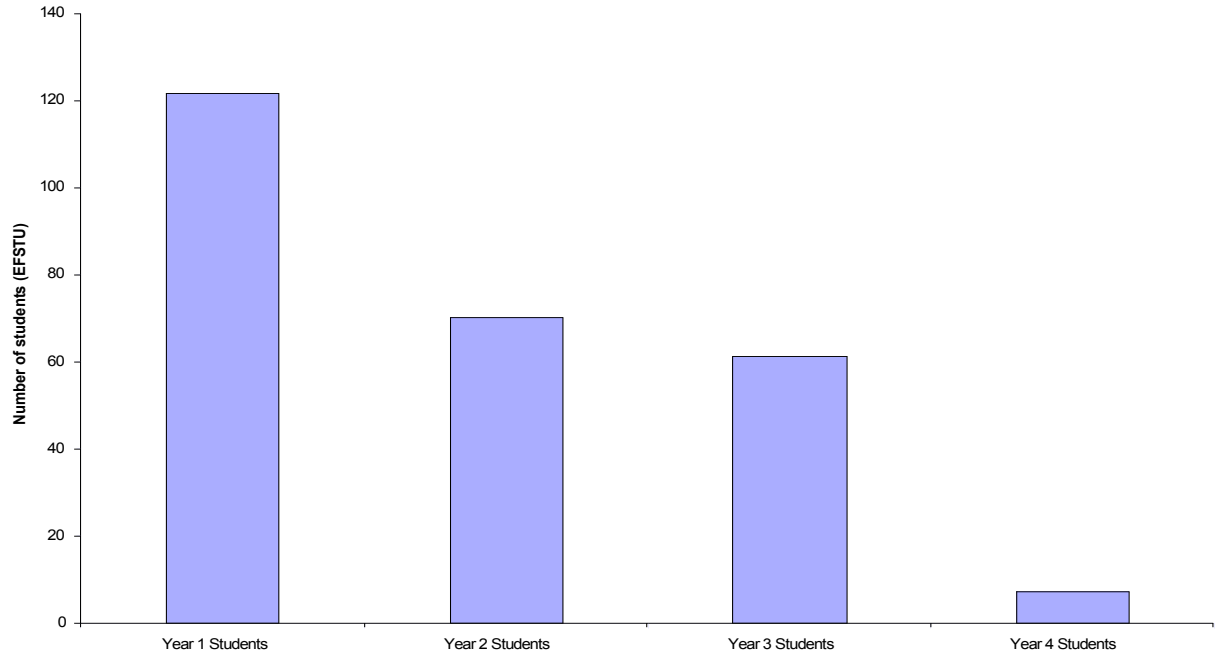
Anecdotal evidence has existed for years that astronomers contributed significantly to the education of not only future astronomers, but across arts and sciences as a whole. The recognition of astronomy as an `enabling science' is demonstrated in the responses provided to our survey (Table 12):

- Changes in the structure of university undergraduate degrees means that courses now carry well-defined weightings. Most universities teach astronomy and astrophysics as part of a physics and/or mathematics degree. Thus students take astronomy subjects as a fairly small part of their undergraduate degree. The teaching load represents about 270 EFSTU. These numbers do not include the weighting for Honours research projects, which would increase the effective fourth year load.

Table 14 – Astronomy Lecture Courses Taught (2000-2004) EFSTU

Institute	Year 1 Students	Year 2 Students	Year 3 Students	Year 4 Students	Online Students	Adult Ed
ADFA	0	22.8	23.5	0	0	0
ANU-RSAA	10.0	2.5	3.5	0	5	0
Macquarie	0	6.2	2.1	0.3	0	0
Monash	30.2	2.8	10.6	0	0	0
Perth Obs	0	0	0	0	0	0
QUT	0	0	0	0	0	0
Swinburne	0	0	0	0	485	0
Adelaide	15	4.1	2.1	0.4	0	0
Melbourne	21.9	7.5	2.5	2.2	0	0
UNSW	1.7	6.2	2.5	0.4	0	56.4
UQ	0	5.6	6.2	1.3	0	0
USQ	8.7	1.9	0.4	0	35	0
Sydney	22.0	0	1.4	0	0	0
Tasmania	3.3	1.1	0.2	0.3	0	0
UWA	8.8	5.0	5.0	1.9	0	0
Wollongong	0	4.4	1.2	0.5	50	0
TOTAL	**121.6**	**70.1**	**61.2**	**7.3**	**575**	**56.4**

Note: year 1-4 are average EFSTU per year, while Online and Adult Education students are in whole numbers.



Another significant part of training undergraduate students, and providing early experience in astronomical research is through summer vacation programs

Table 15: Summer Vacation Programs

	Summer vacation program offered?	Number of students enrolled 2000-2004	Ratio M:F	Number continued into a PhD	Formal educational links to 'engineering for astronomy'
AAO	Yes	30	1.5:1	24	Yes
ATNF	Yes	38	2:1	3	No
ACA	No				-
ADFA	No				No
ANU- RSAA	Yes	-	-	-	-
Macquarie	Yes	4	1:0	0	No
Monash	No				No
Perth Obs	Yes	2	1:0	1	No
QUT	No				No
Swinburne	Yes	12	0.5:1	2	No
Adelaide	Yes	4	1:1	0	No
Melbourne	Yes	10	1:1	7	No
UNSW	Yes	4	1:1	1	No
UQ	Yes	8	1:1	1	Yes
USQ	No				-
Sydney	Yes	-	-	-	No
Tasmania	Yes	3	0.5:1	0	Yes
UWA	Yes	20	2:1	7	Yes
Wollongong	Yes	1	-	0	-

Institutions were also asked whether funds were available to support teaching initiatives: 13 institutions responded that they have funding sources available for education and teaching grants. However 11 institutions believe that overall funding for education is inadequate, 4 institutions believe it is just adequate, and no institutions believe that funding for education is more than adequate. Six groups had been supported with specific teaching grants.

4. Bibliometric Analysis

As with the 1995 Decadal Review, an independent bibliometric analysis was commissioned, to provide an overview of the measurable performance of the astronomical sciences in Australia over the period 1994-2003. This report was prepared by Bev Biglia and Linda Butler of the RSSS-ANU and is included in Appendix 3. Since the information in the ISI datasets is indexed in a particular format, the questions which can be robustly answered are limited. The following points should be kept in mind while interpreting the statistics which are presented in the report:

- The paper and citation counts are institutional not departmental. Therefore, since geophysical journals were included in the primary analysis, institutions with significant research groups in geophysics may have biased results. A possible example might be the University of Melbourne. In the appendix of the Biglia and Butler report, the basic analysis is repeated with the geophysical journals removed. The Relative Citation Index increases.
- Unfortunately, some high impact journals, such as *Nature* and *Science* are not included in the analysis, as it is not possible to sort papers by discipline in these journals. While this probably does not impact on results for the discipline (unless astronomers published proportionally more in these journals), it will influence the results for individual institutions, where publication in these journals has been significant.
- Results are presented for institutions, not individuals. The movement of a small number of staff may significantly impact on bibliometric measures on short timescales.
- There is clearly a long tail on the distribution of citations. Thus participation in highly cited research programs has a major impact on the level of citations in the astronomical sciences. High profile programs substantially affect these programs.

The bibliometric analysis provides some robust conclusions on the performance of the Australian astronomical community relative to other disciplines. The following conclusions can be drawn:

- Australian astronomers publish 3-4% of the world's output, but their share of the citations is markedly higher. If publications in geophysics are not considered, the relative citation rate is greater than 1.5.
- Australian astronomers publish 60-70% of their papers in the highest impact journals. These are 25% of journals with the highest citation rates. The expected value, taking account of the relative numbers of papers published in each journal is 45%.

- Australian astronomers have markedly changed their collaborative activity since the last decadal review: only 9% of papers are single author (cf 19%) and 77% of papers are now international collaborations (cf 55%).
- Four institutions have a large fraction of the highly cited papers (ANU-RSAA, AAO, ATNF and UNSW). This is largely a result of the numbers of research astronomers at these institutions and is affected by the subject areas which their staff work in.
- The citation rates are significantly affected by a couple of very highly cited papers. These probably result from high profile international collaborations.

5 Contributors

Brad Gibson (WG chair) Sarah Maddison, Rachel Webster (WG co-chair), Melissa Wals, Tasso Tzioumis, Helen Sim, Sandra Ricketts and Bill Zealey.

Appendix 1: Survey Questions

The questions which were sent to each institute as listed in the following sections. The data was collected in a purpose designed spreadsheet.

A1.1 Research and Training Activity

In order to complete the survey, you will need to determine which personnel and activities at your institution are defined as 'astronomy and astrophysics' (A&A). As a guide, please include only those personnel and activities which would be primarily designated as A&A. This may include part of a person, but in those cases only use a weighting of 0.5.

In many sections, the period 2000-2004 is used. Assume that this covers the full 5 years.

Please list funding (for the year 2004; include percentages of total budget) (ARC, university (include all salaries) DEST/ITR, CSIRO, state, industry, overseas, private (eg endowments), other (specify)).

Does your institution feel its research efforts (funding, staffing) are currently expanding, steady, or shrinking?

A1.2 Distribution of staff and faculty

Please provide an itemised list of all personnel which include the following: name, FTE appointment level (for people who are 0.5 A&A, please include 0.5 here), appointment type (fixed term or continuing), workload model FTE% (research, training, graduate supervision, technical/software support, administration, outreach, support, other), gender (male, female), age bracket (<20, 20-29, 30-39, 40-49, 50-59,60-69,70+), highest degree awarded, university of highest degree, year of highest degree, research effort: sub-disciplines (%) (solar, planets: solar system, planets: exo-planets, stellar, pulsars, galactic/Magellanic clouds, interstellar medium, extragalactic, cosmology, gravitational physics, instrumentation, education), research effort: technique (%) (theory, computational, optical, infrared, radio, X-ray, cosmic rays).

A1.3 Movement of professional staff in/out of Australia

Please list (name and year departed) all research staff who have departed to take up employment overseas in the years 2000-2004 (do not include recent PhD graduates who are going to their first substantive employment overseas). Also please list (name and year arrived) all research staff who have arrived from overseas to take up employment in the years 2000-2004.

A1.4 Postgraduate completions: 2000-2004

Please only include students who actually completed all the requirements of their degree in the specified time period. List name, degree, year awarded, gender (male, female), research effort: sub-disciplines (%) (solar, planets: solar system, planets: exo-planets, stellar, pulsars, galactic/Magellanic clouds, interstellar medium, extragalactic, cosmology, gravitational physics, instrumentation, education), research effort: technique (%) (theory, computational,

optical, infrared, radio, X-ray, cosmic rays), first substantive employment: type (academic, industry, teaching, none, unknown), first substantive employment: field (astronomy, other), first substantive employment: location (Australia, overseas).

A1.5 Currently enrolled postgraduate students

Please do not include students on leave-of-absence or lapsed. Please list name, degree, FTE, gender (male, female), country of origin (Australia, international), Honours research area (astronomy, physics, engineering, mathematics, computer science, other, no Honours research, no Honours degree), postgraduate research effort: sub-disciplines (%) (solar, planets: solar system, planets: exo-planets, stellar, pulsars, galactic/Magellanic clouds, interstellar medium, extragalactic, cosmology, gravitational physics, instrumentation, education), postgraduate research effort: technique (theory, computational, optical, infrared, radio, X-ray, cosmic rays).

In the future does your institute expect its postgraduate quality to increase, remain the same, or decrease. Does your institute expect its postgraduate numbers to increase, remain the same, or decrease.

Please list number of scholarship applicants (e.g. APA, University, IPRS), both domestic (APA-eligible) and international, for each of years 2000 to 2004.

A1.6 Honours completions: 2000-2004

Include those undertaking astronomy or astrophysics research projects for Honours. Please only include students who actually completed all the requirements of their degree in the specified time period. List name, degree, year awarded, gender (male, female), pre-Honours origin (same institute, other Australian institute, international institute), immediate post-Honours destination: postgraduate (same institute, other Australian institute, international institute), immediate post-Honours destination (industry, government, teaching, other international, none, unknown).

A1.7 Quality of Australian astronomy

Please list the following as they apply to the period 2000-2004: major conferences hosted; workshops hosted; executive positions held in international organizations; executive positions held in national interdisciplinary organizations, government committees, and industry boards; major awards, distinguished prizes, ISI citation laureats and federation fellows.

A1.8 Industry and technology

The Committee has been charged with producing a proposal for improving astronomy's interaction with industry and business. The motivation is not to try to sell astronomy as a self-financing enterprise, but to ensure that Australian astronomy is fully able to capture and promote the commercial benefits from its R&D activities, and that these benefits filter through to Australian industry.

The following question is to establish the number/scale/type of interactions that have taken place (go as far back in time as you like) and those which are now active. Please note we are not asking for information about everyday supplier/customer relationships, but are focusing on partnerships and the generation of new business and IP. Also, this question isn't limited to Australian experiences, so if you've had interactions abroad, we'd like to hear about them too.

Have you been involved with business in interactions where significant intellectual property was either actually generated for the partner by you, or was expected to be generated? If so, please give very brief outline, project details, company name and interaction type.

Again briefly, what were the reasons for success or failure in generation or transfer of IP?

Was the partner able to exploit commercially the IP that resulted from the project/interaction? Could you make a quantitative estimate of financial benefit?

A1.9 Benefits to the community

Please list, for the period 2000-2004, all popular books published, popular articles published and public lectures given.

A1.10 Outreach

What activities were undertaken at your institute in 2002-2004 relating to public outreach (public lectures, visitor centres, open days, night viewings, other)?. What ages/year levels was this targeting (primary students, secondary students, senior secondary students (HSC/VCE), general public)? How many people participated in these activities? Does your institute specifically provide astronomy training programs to teachers? If yes, did you target primary teachers? Secondary teachers? How many teachers attended these training sessions?

Do you conduct outreach activities in conjuction with other organizations? If yes, which other organizations were involved (other astronomy institutes, amateur socities, professional teachers' organization, other)? How many such joint events were run?

Does your institute provide specific funding for outreach activities? If yes, over 2002-2004, what level of funding was available for these activities?

A1.11 Undergraduate teaching

Complete for all undergraduate astronomy/astrophysics courses (defined as courses with astronomy/astrophysics in the title and/or >50% astronomy/astrophysics component in the syllabus) (course name, year level, number of students (final enrolment), male:female ratio, subject weighting (fraction of one year)).

Does your institute offer a summer vacation scholarship program? If yes, complete for 2000-2004, the total number of students in the program, the ratio of males to females, and how many of these students continued into your PhD program.

Does your department have formal educational links to 'engineering for astronomy' related subjects?

A1.12 Online and distance education

List any online or distance degree/diploma programs offered by your institute in 2002-2004. Please do not include on-campus courses that have an online component (name, delivery method (online, distance), number of students (final enrolment), male:female ratio, origin of students (%Australian, %international)).

A1.13 Educational Funding

Are funding sources available at your institute for education and teaching grants? Do you believe that overall funding for education is inadequate, just adequate, or more than adequate? List all education related grants that were awarded in 2000-2004, and whether they were internal to your institute or external.

Appendix 2: Conferences and Workshops 2000-2004

Name	Year	Hosts
ANU Physics Summer School "The New Cosmology", Canberra	Feb 2003	ANU/AAO
IAU Symposium 216 "Maps of the Cosmos", Sydney	Jul 2003	AAO/ATNF
IAU Symposium 220 "Dark Matter in Galaxies", Sydney	Jul 2003	AAO/ATNF/Sydney
IAU Symposium 217	July 2003	ATNF
IAU Symposium 218	July 2003	ATNF
IAU Symposium 219	July 2003	ATNF
International SKA Conference, Geraldton	2003	ATNF
IAU Symposium 213, Bioastronomy: Life Among the Stars	2002	ACA/ATNF
IAU Symposium 109; Planetary Nebulae: Their Evolution and Role in the Universe	2001	ANU-RSAA
Astronomical Society of Australia Annual Scientific Meeting & Harley Wood Winter School	2004	UQ
Astronomical Society of Australia AGM & Harley Wood Winter School	2001	Swinburne
IAU Symposium 221, Star Formation at High Angular Resolution	July 2003	UNSW/ATNF
IAU Special Session 2 on Astronomy in Antarctica; Sydney	July 2003	UNSW
IAU General Assembley	July 2003	NCA/ASA
4th Amaldi Conference	2001	UWA