On the Importance of PhD Institute in Establishing a Long-Term Research Career in Astronomy

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Abstract

We have examined the success rates of 19 American, Canadian, Australian, and Dutch graduate programs in producing long-term, career, research astronomers. A 20-year baseline was considered (1975-1994), incorporating 897 astronomy PhD graduates. The major conclusion from our study is that the fraction of PhD graduates still involved in astronomical research is surprisingly insensitive to the institutional source of one's PhD. With few exceptions, $\sim 55 \rightarrow 75\%$ of astronomy graduates, regardless of PhD source, remain active in the astronomical research community. While it remains true that graduates of so-called ''prestigious'' programs preferentially populate the same, it is also clear that an abundance of opportunities exist at smaller ''non-prestigious'' (and, sometimes, non-degree granting) institutions, liberal arts colleges, government, and industry. The latter, of course, generally carry enhanced administrative and/or teaching duties, but, on the other hand, do not entirely preclude a role in the research community. A Kepler-Meier survival analysis of two disparate institutes demonstrates that ''success'' is a dynamical entity, and that blind consideration of a 20-year baseline sample can mask important recent trends. Within ten years of PhD receipt, an equilibrium is reached in which $\sim 45\%$ of the graduates are in identifiably permanent positions, $\sim 20\%$ remain in soft-money positions, and $\sim 35\%$ have left research entirely. Graduates of American universities are $\gtrsim 2 \rightarrow 3\times$ more likely to find permanent employment in the USA than Canadian or Australian graduates are within their respective institute's country. While the number of American, Canadian, and Dutch PhDs have grown $\sim 20\%$ during the past decade, the growth in Australia has been closer to $\sim 70\%$.

1. INTRODUCTION

Attempting to assign any sort of quantitative ranking scheme, as a measure of an astronomy graduate program's ''quality,'' is a thankless task, and one almost certainly bound to be met with controversy, if not outright derision. Regardless, such rankings are, in fact, published on a semi-regular basis, most noticeably as part of the Gourman (1997) and U.S. News Graduate School Rankings (`http://www.usnews.com/usnews/edu/beyond/`). In both cases, though, the rankings are effectively a subjective measure of the astronomical community's perception of each school's graduate program.[1]

Very few attempts at objectively quantifying the quality of a given astronomy graduate program exist, the two most notable being Domen & Thronson (1988) and Trimble (1991). In the former, Domen & Thronson conclude that, in the mean, graduates of Berkeley, Harvard, Caltech, Princeton, and Chicago, were more than six times as successful as graduates of Arizona, UCLA, Colorado, Minnesota, and Virginia,[2] in obtaining junior[3] faculty positions at the 32 major institutes comprising their survey sample. In the latter, Trimble concludes that while $\sim 80\%$ of graduates from one ''prestigious'' university are typically still involved in astronomy research, the fraction from a comparison ''non-prestigious'' program is only $\sim 50\%$.[4]

Both the Domen & Thronson (1988) and Trimble (1991) studies provide crucial quantitative evidence in support of the hypothesis of a hierarchy of quality in astronomy graduate programs, although our contention is that there are some subtle effects within the numbers which suggest the situation is perhaps not as grim as it would appear on the surface. For example, Domen & Thronson only consider the PhD source for professorial employees of the 32 large degree-granting institutes in the USA - i.e., the sample is biased, to some degree. One is left wondering about those graduates employed at the numerous small colleges and non-degree-granting universities, along with those in industry and government laboratories, who still remain active members of the astronomy research community. Conversely, Trimble's comparison is based upon only two universities, and one might ask if these two are truly representative of the community at large. Addressing the (potential) shortcomings of these earlier studies is the focus of our current analysis.

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[1]Such subjective biases are, unfortunately, a reality students should be aware of, although we do not wish to dwell upon them here.

[2]The first versus bottom five entrants of their Table 2.

[3]By ''junior,'' we mean associate and assistant professorships.

[4]These percentages are based upon Trimble's (1991) Table 1, combining the entries for graduates employed at PhD-granting *and* government (or industrial) labs, along with the small fraction of graduates working in support duties (both hardware and software) who still maintain a modest publication record. The resulting sum should (roughly) parallel our selection criteria, as described in Section 2.

In Section 2, we describe the methodology employed in determining the present-day (circa December 1998) status of 897 1975-1994 astronomy PhD graduates from 19 different schools in 4 different countries. While clearly not intended to be 100% complete,[5] the sample is fairly representative and unbiased, including examples of those schools traditionally considered as prestigious, as well as lesser-appreciated large and small programs, from several countries. Our putative ranking scheme is a simple objective one, based solely upon the fraction of a given school's PhD graduates who are still involved in astronomical research today, regardless of the perceived status of a given researcher's present-day institution. More complicated schemes could be envisioned whereby additional weight is ascribed to, say, publication frequency, citation history, grant application and/or observing proposal success rates, etc., but we are strongly of the opinion that *the simplest, and perhaps ultimate, measure of a given program, is the success rate of its graduates in finding long-term astronomical research careers*.

The main results and conclusions of our study are drawn in Section 3, and summarized in Section 4.

2. METHODOLOGY

Ideally, one would like to examine the success rates of *all* the astronomy and astrophysics degree-granting institutions.[6] Unfortunately, with 4695 theses listed in NASA's Astrophysics Data System (ADS) database (for the 1975-1994 baseline of our study), of which 3700 were classified as ''astronomy/astrophysics,''[7] 100% completeness was just not feasible. Instead, representative large versus small, and prestigious versus non-prestigious, institutions were randomly selected for study. For two of the universities in our study, the ADS list of PhD graduates was compared against the respective institutes' official records, and found to be 100% complete.

For the American universities, the top three from the 1998 U.S. News Astrophysics Graduate School Rankings (Caltech, Princeton and Harvard), three from just outside the top ten (Colorado, Maryland and Hawaii), and two unranked (New Mexico State (NMSU) and Wyoming) programs were selected. These eight schools accounted for $\sim$ 1/7 of the ADS-listed astronomy PhDs granted during 1975-1994. For the Canadian sample, we simply included all eight universities which granted more than ten PhDs during the same 20-year baseline. For these 16 North American institutes, their respective 1975-1994 graduate lists were culled from the ADS master list of 3700.

The non-North American institutions were more problematic, as the vast majority are either not included in ADS (the norm) or woefully incomplete - as such, only three universities fall into this category, two from Australia (Mount Stromlo & Siding Spring Observatories and Sydney University) and our sole European entrant (Leiden). For these three, we either had local access to a complete set of Annual Reports (within which year-by-year graduate information was available) or a contact at the institute in question had the relevant information in a readily available electronic form. While it would have been desirable to include, for example, several U.K. universities, year-by-year graduate information was not available to the authors.

In Table 1, the 19 institutions in our study are listed in descending order of total number of astronomy PhDs granted (n_g) during 1975-1994 (column 14); over an order of magnitude difference exists between the largest and smallest program. Five-year sub-samples (columns 2, 5, 8, 11) are provided, demonstrating the overall trend of increased astronomer production, a point to which we return in Section 3. Again, the 897 graduates tracked in this analysis represent $\sim$ 1/4 of the total number of astronomy PhDs (3700) in the ADS; our sample should be a fairly representative one of the population as a whole.

The next, and most arduous, step in ultimately determining a given program's success rate, was determining the whereabouts and/or astronomy ''status'' of the 897 PhD recipients listed in column 14 of Table 1. The methodology employed was typically as follows: (i) ADS, the Science Citation Index (SCI), or the Institute for Scientific Information Citation Database (ISI)[8] were searched for the most recent publication(s) - no preference was made as to an author's position in the author list; (ii) institutional affiliation and email address were noted; (iii) confirmation of institutional affiliation was ensured in all cases, either by relevant web page or email contact; (iv) institutional status (i.e., soft-money, fixed-term contract, tenured faculty, open-ended civil appointment, etc.) was confirmed in *all* cases, again, either by web page or email contact. In total, $\sim$ 1/3 of our total sample were contacted via email, the majority of whom provided clarification where necessary. No subjective classification based upon publication frequency was incorporated into the analysis; provided a present-day (late-1998) institutional affiliation could be confirmed, a graduate included in a given n_g entry in Table 1 would then also be counted in the corresponding n_{astr} entry.

Occasionally, an unequivocal conclusion regarding a given graduate's status in the community was impossible; those falling into this category[9] are included by their relevant entry of Table 1 in parantheses.

Column 15 of Table 1 lists the number of 1975-1994 graduates still involved in astronomical research (n_{astr}), for each of the institutions, while column 16 provides the number which are currently (as of late-1998) in identifiably permanent astronomy research positions. The latter are over-

[5]Although, our sample does represent $\sim$ 1/4 of the astronomy PhDs granted during the 20-year 1975-1994 baseline.

[6]Doubly so, since it is safe to say that the first thing every reader of this paper will do is look for their own institution in Tables 1 and 2!

[7]Eliminating the $\sim$ 20% of ADS-listed PhDs which, for example, are classified as particle physics, atmospheric, solar, or lunar/planetary; we should stress though that our conclusions are *not* dependent upon the exclusion of these ''non-astronomy'' PhDs from the sample.

[8]The SCI and ISI are clearly superior for tracking down astronomy graduates whose publication habits, for one reason or another, avoid the traditional journals monitored by the ADS.

[9]Usually those who had either published a paper during 1997-1998, but for whom no confirmation of current institutional affiliation could be made, or those few who did not respond to the email request for institutional and/or job status clarification.

TABLE 1. Number of astronomy and astrophysics PhD graduates (n_g) per institution, along with the number still involved in astronomical research (n_{astr}), as of late-1998, and the number with identifiably permanent or tenure-track (n_{perm}) positions. The number of graduates of uncertain status are noted in parenthesis.

Institution	1975-1979			1980-1984			1985-1989			1990-1994			Total		
	n_g	n_{astr}	n_{perm}	n_g	n_{astr}	n_{perm}	n_g	n_{astr}	n_{perm}	n_g	n_{astr}	n_{perm}	n_g	n_{astr}	n_{perm}
Caltech	38	29	21(7)	31	21	17(2)	26	19	11(1)	37	21	8(1)	132	90	57(11)
Princeton	25	18	14(2)	20	13	7(3)	27	22	15(1)	29	21	10(2)	101	74	46(8)
Harvard	26	19	16(2)	20	17	13(2)	24	17	10(2)	21	17	5(2)	91	70	44(8)
Leiden	18	11	9(2)	22	14	13	26	14	10(3)	24	14	2(2)	90	53	34(7)
Maryland	26	14	9(4)	16	11	5(4)	22	17	5(6)	20	18	5(1)	84	60	24(15)
MSSSO	9	6	5	18	11	6	16	9	6	25	15	3	68	41	20
Colorado	12	5	5	10	8	6(1)	24	16(2)	8(3)	20	14(2)	3(1)	66	43(4)	22(5)
Toronto	15	7	6	18	8	6	17	9	8	11	6	1(1)	61	30	21(1)
Sydney	12	4	4	3	1	1	14	12	5	17	9(1)	2	46	26(1)	12
Hawaii	6	5	4(1)	3	2	1	3	3	2(1)	14	10	1	26	20	8(2)
NMSU	6	3(1)	2(2)	2	0(1)	0(1)	9	6	3(1)	5	3	0(1)	22	12(2)	5(5)
UBC	8	5	4(1)	3	1	1	3	3	1	7	4	1	21	13	7(1)
Western	7	2	2	2	0	0	4	3	1(1)	4	3	1	17	8	4(1)
Montreal	0	0	0	1	0	0	2	2	0(1)	11	9	1(2)	14	11	1(3)
Wyoming	1	0	0	5	3	2(1)	1	1	0	7	5	1(1)	14	9	3(2)
Victoria	1	1	1	4	4	4	2	2	0(1)	5	3	3	12	10	8(1)
Queen's	2	1	1	1	1	1	3	1	1	5	2	0	11	5	3
York	2	0(1)	0	3	0	0	1	0	0	5	2	0	11	2(1)	0
Calgary	2	1	1	2	1	1	1	1	0(1)	5	3	1	10	6	3(1)
Total	216	131(2)	104(21)	184	116(1)	84(14)	225	157(2)	86(22)	272	179(3)	48(14)	897	583(8)	322(71)

whelmingly based at university or national facilities, but occasionally may include industry positions if they are clearly related to astronomy research.[10] Again, five-year sub-totals are also provided under the relevant columns.

3. DISCUSSION

Before discussing any putative ranking based upon the production of long-term career astronomers, several general trends from Table 1 should be noted.

First, the five-year sub-samples show that the number of 1985-1994 graduates (columns 8 and 11) is ~ 25% greater than the number of 1975-1984 (columns 2 and 5) graduates, growth which, in North America, is reflected primarily in what were once the smaller North American programs (e.g., Hawaii, NMSU, Montreal, and Quuen's), a trend already noted by Domen & Thronson (1988).

Second, and of particular interest (concern?) for Australian astronomy, is the fact that MSSSO and Sydney have increased their number of PhD graduates by ~ 50% and ~ 100%, respectively, from 1975-1984 to 1985-1994. These two institutions dominate astronomy PhD production in Australia, accounting for 50% of the total (Table 3.5.2 of ''Australian Astronomy: Beyond 2000''[11]). Of concern should be the fact that this ~ 70% increase in the number of PhDs granted has not been matched by a parallel increase in the number of postdoctoral and permanent faculty/research positions. For comparison, during the same time period, the number of American, Canadian, and Dutch PhDs increased by the more modest (but not insubstantial) ~ 20%.

Shear PhD production (column 14 of Table 1), while (perhaps) a useful measure at some level, should not be the only yardstick by which a given program's career astronomer-production ''efficiency'' is measured. More useful is normalizing the present-day number of active (both soft-money and permanent) research astronomers produced by each institution (n_{astr} and n_{perm} of Table 1), by the number of PhDs awarded (n_g).

In Table 2, this fraction of total astronomy PhD graduates still involved in astronomy research f_{astr}, along with the fraction possessing an identifiably permanent or tenured position f_{perm}, are listed for each of the 19 institutions in our study. Columns 10 and 11 give the numbers based upon the entire 1975-1994 baseline, while the five-year sub-sample fractions are likewise tabulated in the appropriate columns. The parenthesized uncertainties of Table 1 are reflected by hyphenated ranges in Table 2 (i.e., the underlined lower limits of columns 10 and 11 are certain), but some leeway (particularly as far as f_{perm} goes) remains, due to unresolved permanence-vs-non-permanence issues, for some graduates. Sorting of the institutions in Table 2 was done, in descending order, by present-day fraction of astronomers still active in the field (i.e., column 10).

Many caveats must be borne in mind when interpreting Table 2. First, and perhaps foremost, we must caution the reader against over-interpreting the rankings of the six small Canadian universities (the final six entrants of Table 1). With < 1 PhD granted per year, during this 20-year period, their rankings are subject to the whims of small number statistics. Second, no provision (of course) is made for those who willingly left the field to pursue non-astronomy career goals; indeed, considering the present-day astronomy job market,

[10] Such positions are generally astronomical software or instrumentation development-related, the research for which is published, and not restricted to ''in-house'' documents.

[11] After removal of the Monash University entry, which reflects the pure mathematics department as a whole, and not the small subset of astronomers therein.

TABLE 2. Fraction of PhD graduates still involved in astronomical research (f_{astr}), as of late-1998, along with the fraction of graduates categorized as permanent or tenure-track (f_{perm}).

Institution	1975-1979		1980-1984		1985-1989		1990-1994		Total	
	f_{astr}	f_{perm}	f_{astr}	f_{perm}	f_{astr}	f_{perm}	f_{astr}	f_{perm}	f_{astr}	f_{perm}
Victoria	1.00	1.00	1.00	1.00	1.00	.00-.50	.60	.60	.83	.67-.75
Montreal	.00	.00	.00	.00	1.00	.00-.50	.82	.09-.27	.79	.07-.29
Harvard	.73	.62-.69	.85	.65-.75	.71	.42-.50	.81	.24-.33	.77	.48-.57
Hawaii	.83	.67-.83	.67	.33	1.00	.67-1.0	.71	.07	.77	.31-.38
Princeton	.72	.56-.64	.65	.35-.50	.81	.56-.59	.72	.34-.41	.73	.46-.53
Maryland	.54	.35-.50	.69	.31-.56	.77	.23-.50	.90	.25-.30	.71	.29-.46
Caltech	.76	.55-.74	.67	.55-.61	.73	.42-.46	.57	.22-.24	.68	.43-.52
Colorado	.42	.42	.80	.60-.70	.67-.75	.33-.46	.70-.80	.15-.20	.65-.71	.33-.41
Wyoming	.00	.00	.60	.40-.60	1.00	.00	.71	.14-.29	.64	.21-.36
UBC	.63	.50-.63	.33	.33	1.00	.33	.57	.14	.62	.33-.38
MSSSO	.67	.56	.61	.33	.56	.38	.60	.12	.60	.29
Calgary	.50	.50	.50	.50	1.00	.00-1.0	.60	.20	.60	.30-.40
Leiden	.61	.50-.61	.64	.59	.54	.38-.50	.58	.08-.17	.59	.38-.46
Sydney	.33	.33	.33	.33	.86	.36	.53-.59	.12	.57-.59	.26
NMSU	.50-.67	.33-.67	.00-.50	.00-.50	.67	.33-.44	.60	.00-.20	.55-.64	.23-.45
Toronto	.47	.40	.44	.33	.53	.47	.55	.09-.18	.49	.34-.36
Western	.29	.29	.00	.00	.75	.25-.50	.75	.25	.47	.24-.29
Queen's	.50	.50	1.00	1.00	.33	.33	.40	.00	.45	.27
York	.00-.50	.00	.00	.00	.00	.00	.40	.00	.18-.27	.00
Total	.61-.62	.48-.58	.63-.64	.46-.53	.70-.71	.38-.48	.66-.67	.18-.23	.65-.66	.36-.44

and the PhD overproduction rate (Thronson 1991), programs which responsibly inform graduate students about the realities of the market, and offer parallel non-astronomy skills training, could end up suffering in the rankings in Table 2.[12] Third, it became readily apparent that certain schools have significant foreign student enrollment; due to the nature of *some* overseas fellowships, this occasionally allows young PhD recipients to return to their home country to an early faculty/permanent position. Again, some schools have their f_{perm} enhanced by this mechanism, but in general the effect is small. A (perhaps) more impartial measure of f_{perm} would be to compare each institute's graduate fraction who find permanent employment in that institute's country; we will return to this point at the end of this section.

Caveats of a more scientific nature are equally important to recall. First, averaging over any given institute's output can be potentially misleading; each school has their sphere of expertise, and at some level, one must worry about comparing an f_{astr} from an instrumentation-dominated program, with an f_{astr} from a theoretical cosmology program. Just as important, within any given school, there will exist a hierarchy in the success rates of particular PhD supervisors in training long-term career astronomers. This averaging over areas of expertise (and non-expertise) and individual faculty supervisors will not do justice to that lone supervisor who continually trains successful graduates, but who toils in relative obscurity in an otherwise mediocre department. Prospective students, for example, should bear these latter points in mind when investigating graduate school options, and should not blindly adhere to rankings of the like presented in Table 2, the annual U.S. News Gradute School or Gourman Rankings.

[12]On the other hand, so very few institutions, in our experience, present such options, that the cynic might say that such a putative effect is entirely non-existent!

Having presented the numerous caveats, though, there is still much to be learned from Table 2. Perhaps the most (pleasantly) surprising result of our analysis is that, with very few exceptions, $\sim 55 \rightarrow 75\%$ *of all the graduates, regardless of original institutional affiliation, are still involved in astronomical research.* In total, 583 of the 897 PhD graduates in our study, or $\sim 65\%$, were still involved in research, *at some level*, in late-1998.

Examining the five-year sub-samples, we see that there is little variation in f_{astr}, at the present-day, regardless of graduation date. The percentages for 1975-1979, 1980-1984, 1985-1989, and 1990-1994, are 61%, 63%, 70%, and 66%, respectively; we initially assumed the constancy in these f_{astr} values suggested that the decision to pursue non-astronomical interests was made within a few years of PhD receipt, with only marginal migration from the field thereafter. While this is perhaps true in some cases, we are now of the opinion that the similarity is more a conspiracy in the temporal evolution of the ''drop-out rate,'' in that research ''half-life'' for graduates from the 1970s was longer than those from the 1990s, the result of which is the $f_{astr} \approx 0.65$, for each of the five-year sub-samples of Table 2.

The first three of the five-year sub-samples of Table 2 also show similar fractions of astronomers now in permanent positions f_{perm}, typically $\sim 40 \rightarrow 50\%$; apparently, within ten years of graduation, an equilibrium has been reached in which the ratio of astronomy graduates with permanent positions to graduates on soft-money to graduates who have left research entirely[13] is approximately 45:20:35. The most recent sub-sample (1990-1994), as witnessed by the final entry to Table 2, has clearly not reached this equilibrium, which is not surprising, since many of the graduates in question

[13]Modulo our definition of ''leaving research'' described in Section 2.

TABLE 3. Fraction of PhD graduates with permanent, or tenure-track, astronomy research positions within the same country as their PhD institution (f_{perm}^{same}) - derived from number of graduates in this category (n_{perm}^{same}) and the total number of graduates (n_g).

Institution	n_g	n_{perm}^{same}	f_{perm}^{same}
Victoria	12	7	.58
Harvard	91	35	.38
Princeton	101	38	.38
Caltech	132	49	.37
Hawaii	26	8	.31
Colorado	66	20	.30
Maryland	84	22	.26
NMSU	22	5	.23
Wyoming	14	3	.21
Leiden	90	19	.21
Calgary	10	2	.20
Sydney	46	9	.20
UBC	21	4	.19
Queen's	11	2	.18
Western	17	3	.18
Toronto	61	7	.11
Montreal	14	1	.07
MSSSO	68	4	.06
York	11	0	.00
Total	897	238	.27

would still be in the midst of their second postdoctoral position.

In passing, we note that the Canadian numbers are slightly lower than the aforementioned $f_{astr} = 0.65$; ~ 54% of Canadian graduates are still involved in astronomical research (~ 30% in permanent positions). Canada's marginally poorer performance, in this regard, should not be overly surprising, when one takes into account the dismal funding situation faced by Canadian astronomers (van der Kruit 1994).

Regarding the implications for Australian astronomy - first, both the overall fraction still in astronomy (~ 59%) and the fraction with permanent positions (~ 28%), are only marginally lower than those for the entire sample (~65% and ~ 36%, respectively). What is perhaps of some concern is that the fraction of graduates who have eventually found permanent positions *within* Australia, as derived from Table 3, is only ~ 11%; ~ 20% of the 1975-1994 Sydney graduates currently fall into this category, while the fraction for MSSSO graduates is ~ 6%. While this 6% rate is one of the lowest of the 19 institutions in this study (Table 3), MSSSO compensates by training a very high fraction of graduates who eventually fill permanent overseas positions (~ 24%). In comparison, ~ 17% of Canadian university astronomy graduates have settled into permanent positions within Canada, ~ 21% of Leiden graduates now have permanent positions within the Netherlands, and ~ 34% of American institutional graduates now have permanent positions with the USA.

Another interesting aspect of the results of Tables 1-3, for Australian astronomy, relates back to one of the conclusions of the ''Australian Astronomy: Beyond 2000'' document (Section 2.2). A claim was made therein that ~ 21% of Australian PhD graduates obtain permanent astronomy positions within Australia.[14] Our analysis of the MSSSO and Sydney graduates, which, recall, account for half of *all* Australian astronomy PhDs, shows that this estimate was a factor of two too optimistic. In retrospect this should not be too surprising, since an underlying assumption of the ''Australian Astronomy: Beyond 2000'' claim was that all permanent astronomy positions in Australia are filled by Australian graduates; anecdotally, this is clearly a flawed assumption, and one which we have now confirmed quantitatively.

How do our results compare with the earlier Domen & Thronson (1988) and Trimble (1991) analyses? The former clearly demonstrated that the subset of PhD graduates from the top five programs in the U.S. News Graduate School Rankings (Caltech, Princeton, Harvard, Berkeley, and Chicago), in comparison with five more moderately-ranked programs (Arizona, Colorado, UCLA, Minnesota, and Virginia), were disproportionately more successful (by more than a factor of six) in obtaining permanent research positions at the 32 largest PhD degree-granting institutions. Our survey was not designed to substantiate or repudiate Domen & Thronson, but even a cursory analysis of our dataset would tend to lend credence to their claim, as would anecdotal wisdom - this is a negative aspect of such analyses. On the other hand, we choose to focus on the positive - our results clearly indicate that ~ 65%± 10% of graduates of *any* astronomy PhD program can expect to maintain a career in research astronomy - i.e., actual *source* of PhD is of little importance.[15] While it *is* true, as Domen & Thronson found, that the graduates of the so-called prestigious schools may preferentially fill positions at these same prestigious schools, this does *not* preclude the opportunity of pursuing a research career, quite often, for example, at one of the *many* non-degree granting colleges and universities. While such positions generally carry a heavier burden of teaching and administrative duties, reduced publishing frequency, and lead some researchers to feel somewhat isolated from the community, they do still allow the determined astronomer to pursue a research career, albeit (perhaps) at a reduced efficiency from those in the large, active, degree-granting programs. This result is perhaps not fully appreciated upon initial reading of Domen & Thronson, but is one in which the prospective graduating student should take heart!

Our conclusions are in mild disagreement with those of Trimble (1991), although an *a posteriori* examination of her dataset shows that the disagreement is not as striking as first thought. Recall first though, that Trimble found that 18 years after PhD receipt, graduates of one ''prestigious, top four'' (called 'P') university were ~ 60 → 100% more likely to be active in astronomy research than the graduates of one ''non-

[14] An estimate was made that 112 out of 160 Australian astronomy positions are permanent; with an assumed lifetime per position of 35 years, a claim for 3.2 permanent positions per year is made. With (typically) 15 PhDs granted per year, this leads to their inferred claim that 21% of Australian graduates obtain permanent positions *within* Australia.

[15] It is interesting to note that of the seven American universities ranked below Caltech (the top-ranked program according to the U.S. News Graduate School Rankings), the graduates of four of these (including two from outside the top ten in the U.S. News rankings) programs actually ranked (marginally) higher when it came to maintaining a long-term astronomy research career.

prestigious, second ten'' school (called 'NP'). Our analysis though shows that for the eight US programs in our study, even the extrema (i.e., Harvard and NMSU) only differ 40%; for the five large US programs (i.e., > 2 PhD recipients per year), Harvard and Colorado differ by only 15% (recall Table 2).

In an attempt to uncover the source of the above discrepancy, we returned to Trimble's (1991) original Kepler-Meier survival curve (her Figure 2) showing the fraction of graduates from the two institutes in her study still publishing f_{pub}, as a function of time since PhD receipt t_{PhD}. While it is true that her dataset shows that graduates of 'P' are a factor of two more likely to be publishing at $t_{PhD} = 18$ yr, than are graduates of 'NP', we feel this is an overly pessimistic reading of the data. The optimistic interpretation is that at $t_{PhD} = 16$ yr the ''advantage'' enjoyed by graduates of 'P' over those of 'NP' is only $\sim 30\%$, consistent with our conclusions. At $t_{PhD} = 17$ yr, the 'NP' curve shows a precipitous drop in f_{pub}, the significance of which should be tempered with the realization that limited numbers in the yearly bins have now become important. While Trimble stressed this $t_{PhD} \geqslant 17$ yr discrepancy in her conclusions, we would counter by stressing the similarity of the samples for $t_{PhD} < 17$ yr.

We are in a position to perform a similar Kaplan-Meier survival analysis for our sample, but now covering the 1975-1994 baseline. To parallel Trimble's (1991) study, let us contrast the behavior of the traditionally top-ranked program (Caltech), with that of one chosen from outside the top ten (Maryland). The fraction still publishing f_{pub}, as a function of time since PhD receipt t_{PhD}, for both programs, is represented in Figure 1 by the filled circles.

The first thing to note from Figure 1 is that we see no precipitous drop in f_{pub} beyond $t_{PhD} = 16$ yr; over the full baseline, the difference in f_{pub} between the two programs is typically no more than 30%. More importantly, Kaplan-Meier curves can mask (not surprisingly) trends occurring on timescales less than the baseline. This is particularly evident when contrasting the behavior of f_{pub}, in the Maryland sample, since 1980; as the crosses in the upper panel demonstrate, this behavior is now indistinguishable from the Caltech sample, in the lower panel. In fact, since 1990, one might argue that Maryland graduates have been more successful in remaining in astronomy, although the numbers per bin are starting to get small, so we hesitate to overly interpret this result. A minor point to note is that $\sim 5 \rightarrow 10\%$ of graduates immediately leave the research field, never publishing anything beyond their PhD dissertation.[16]

While we have only shown two representative programs here (Caltech and Maryland), our ultimate conclusions do not depend on this choice, as was already evident by the institute-insensitive behavior of f_{astr} seen in Table 2.

[16]Unlike in Trimble (1991), we have counted the graduate's PhD dissertation as a publication, which is why $f_{pub} \equiv 1.0$ at $t_{PhD} \equiv 0$ yr.

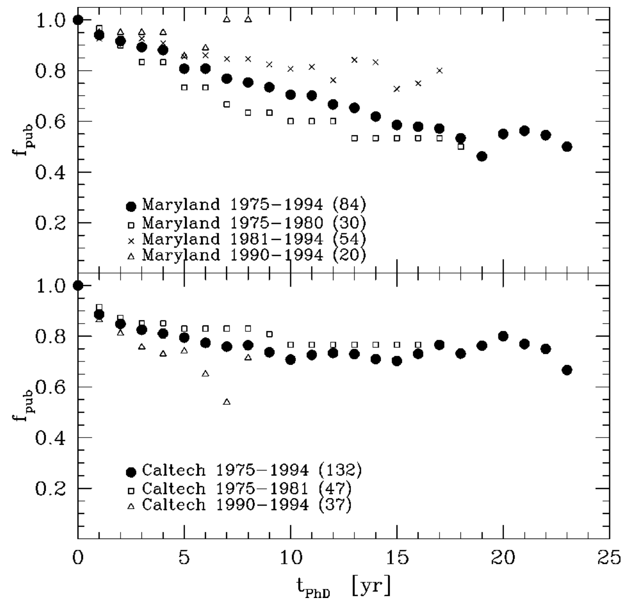

FIG. 1. Kaplan-Meier survival curves illustrating the fraction of PhD astronomers f_{pub} still publishing papers, as a function of time since PhD receipt t_{PhD}. After Trimble (1991), a ''top four'' (Caltech) and ''second ten'' (Maryland) program are highlighted. Even after 20 years, using the full samples of Table 1 (filled circles), there is only a 30% difference between the programs; more importantly, though, adopting the full sample has a tendency to mask recent trends. Since 1981, the fraction of Maryland graduates still involved in research is indistinguishable from the Caltech fraction; indeed, during the 1990s, one might argue that the roles have become reversed.

4. SUMMARY

Upon carefully analyzing the present-day status of 897 astronomy PhD recipients from 19 different institutions, our main conclusions can be summarized thusly:

1. Institutional source of one's PhD plays little part in whether or not (statistically) one will successfully pursue a long-term career in astronomy - $\sim 55 \rightarrow 75\%$ of all graduates, regardless of PhD source, do so.

2. Graduates of traditionally ''prestigious'' programs are almost certainly disproportionately successful in obtaining permanent positions at similarly ranked schools (echoing Domen & Thronson 1988), but this has obviously not precluded graduates of ''non-prestigious'' programs from pursuing their research careers from outside the elite, ranked, universities. Perhaps their efficiency has been hindered, but they have not had to completely forgo research either.

3. Our results complement those of Domen & Thronson (1988), although we have chosen to stress the positive aspects of the equal opportunity for long-term research careers, regardless of PhD source. Domen & Thronson's sample is biased in that it is restricted to researchers who settle at the largest, degree-granting institutes, while our unbiased sample includes researchers at institutes large and small, foreign and domestic, degree- and non-degree-granting.

4. ''Success'' is a dynamical entity - the survival analysis of Figure 1 demonstrates the danger of blindly adopting a 20-year baseline; in particular, recent trends will be masked.

5. Within a decade of graduation, 45% of graduates will have an identifiably permanent or tenured position, 20% re-

main in the soft-money/fixed-term contract category, and 35% have left the field.

6. American graduates are far more likely to obtain permanent astronomy positions in the USA (34%), than are Dutch (21%), Canadian (17%), or Australian (11%) graduates, in their respective countries.

7. During the decade 1985-1994, the number of astronomy PhDs granted by US, Canadian, and Dutch institutes increased by 20% over the previous decade; in Australia, though, the increase was ~70%.

Again, if nothing else, the one point we wish to leave with the reader, or prospective graduate student, is the optimistic primary conclusion above - i.e., regardless of the source of your PhD, one has just as good a chance to pursue a research career in astronomy (albeit perhaps only at the part-time level), as the graduate of any other program. It is true that you may not have (statistically) the same odds as graduates of the traditional ''prestigious'' schools in pursuing this career at a large, degree-granting, university, but the research opportunities within smaller universities and colleges (both degree and non-degree granting), overseas institutes, government labs, and industry, appear to compensate.

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