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Papers and Citations Resulting from Data Collected at Large, American Optical Telescopes

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ABSTRACT. Data compiled about a decade ago and pertaining to 1980–84 showed that the large, general-access American optical telescopes (the 4 meters at Kitt Peak and Cerro Tololo) were at least as productive in published papers, pages, and citations as the large, privately owned ones (3 m at Lick and 5 m at Palomar). A current very similar compilation shows that the relative contributions of these four telescopes have changed rather little, though several additional ones are now major contributors. For both papers and pages, the current ranking from most to least productive is CTIO, Palomar, KPNO, and Lick. (KPNO moves ahead of Palomar in numbers of citations.) If the numbers are normalized to the area of the primary mirror, the rankings change radically, and Lick becomes the most productive of the four in both 1980–81 and 1990–91. The average number of citations per paper per year is nearly unchanged at a bit more than four.

1. INTRODUCTION

Competitive soul searching is a long-standing American pastime. Is my family, my town, my country as bright, as cultured, as peace-loving as the neighboring family, town, country? And, if not, why isn't somebody doing something about it?

Astronomers and their institutions are at least occasional participants in such activities. Thus it was that, about a decade ago, Abt (1985) asked whether the major American publicly owned optical telescopes were as productive as the privately owned ones, especially in the realm of substantial papers that are highly influential in the community. He counted papers published in 1980 and 1981 that reported data collected at the KPNO and CTIO 4-m telescopes (open competitively to all astronomers) and at the Lick and Palomar 3- and 5-m telescopes (open primarily to astronomers associated with the institutions that own and operate them), and citations to them in 1982–84.

The papers considered were ones published in the *Astrophysical Journal*, plus its *Letters and Supplements*, and the *Astronomical Journal*. The citations considered were all the ones reported in the *Science Citation Index*, which samples all of the world's large English-language journals and a subset of smaller ones, review publications, and publications in other languages. Earlier work had shown that this would catch nearly all major research done by American astronomers using American telescopes.

Abt (1985) concluded that the two public-access telescopes were producing at least their fair share of (a) papers, (b) journals pages, (c) citations, and (d) highly cited papers (which are typically either reports of a single, hot discovery or extensive data compilations later used by many theorists and modelers).

The question of whether most large telescopes should be privately owned and operated, publicly owned and operated, or some combination of the two, tied to relative amount of financial support, is once again under dispute in the community. This paper is not intended to answer that question. It may not even be terribly relevant to it. The goal is the much more modest one of finding out whether the relative contributions of the various telescopes have changed much in the intervening decade. The answer to this much simpler question is, to first order, no.

A problem that will arise throughout the following sections is what to call the various telescopes. I have tried hard to use names that will be recognized easily. This is sometimes the site (Mt. Wilson 100″), sometimes the observatory (Lick 120″, which is on Mt. Hamilton), sometimes an acronym (CFHT), or its expansion (INT=Isaac Newton Telescope), and sometimes an explanation is required (for instance the ESO/Nordic telescope on La Palma). Very few are best known by their official names—Shane, Hooker, Mayall, and so forth.

2. THE DATA BASE

The initial intention was to duplicate Abt's (1985) investigation precisely, apart from a 10-yr time shift. This is not yet quite possible, since the 1994 *Science Citation Index* will not reach library shelves for several months. The reason for not waiting is that the data were of immediate interest to the administration of one of the telescopes concerned. In addition, it seemed worthwhile to consider some additional large telescopes and one additional American journal.

2.1 What Was Actually Done

The journals examined were all issues of the *Astrophysical Journal* (plus its *Letters and Supplements*), *Astronomical Journal*, and *Publications of the Astronomical Society of the Pacific* (not in Abt's sample) published between 1990 January and 1991 June. I read each article carefully enough to determine (a) whether any new observational data were reported in it, (b) whether any optical or near-infrared telescope with a diameter larger than two meters was used, (c) which telescope(s), and (d) the basic subject matter of the paper, crudely categorized as solar system, stars, interstellar medium, external galaxies, active galaxies, and cosmology. For a few papers (for instance, those reporting redshift sur-

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veys with implications for formation of large-scale structure), the subject assignment was somewhat arbitrary.

Items recorded for each paper were (a) name of senior author, (b) number of authors, (c) journal name, volume, and page number, (d) number of pages, rounded up to the nearest whole number, (e) subject, and, of course, (f) telescope(s) used. No fewer than 32 large optical and near-infrared telescopes appeared in the sample.

At this point, some arbitrary decisions had to be made. First was the problem of apportioning credit when more than one telescope contributed to the sample. In approximate parallel to the 1985 investigation, I chose to ignore small telescopes completely and to give equal weight to each of the large ones used in a particular project. The range was from one to nine telescopes per paper. Second, papers reporting results from Coudé or Echelle auxiliary feed telescopes were credited to the main telescope, including two papers from the CTIO 4-m Eschelle feed, six from the ESO 3.6-m CAT, and 9.3 from the KPNO 2.1-m Coudé feed. If you feel this was the wrong choice, the numbers are available in Table 1 to remove them. A preprint of this paper erroneously credited the 2.1-m Coudé feed papers to the 4 m at KPNO. Third, UKIRT and IRTF were kept in the sample, but WIRO was not, and in retrospect, probably should have been, because many people foresee the future of the Lick 120″ as primarily a near-infrared one, owing to the site conditions on Mt. Hamilton.

Next, the number of citations to each paper in the 1993 *Science Citation Index* was determined, making use of the name of the first author of each paper and the bibliographic data. Self-citations (ones where the first author of cited and citing paper are the same person) were included (another arbitrary decision). This operation cannot be perfectly performed. A large fraction of all literature citations have minor errors (Abt 1992), most often the year of publication, page or volume number, or author's initials. Authors themselves contribute to this by oscillating between forms like A. N. Other and A. Other or C. Have-Mate and C. H. Mate. Less often (at or below the 1% level according to Abt, 1992), an author's name is badly misspelled or a paper attributed to the wrong first author. The current record for the former is held by Djorgovski; and I caught at least two mistakes of the latter kind by chance, because other papers with more or less the same co-authors, but in different order, were in the sample. All obvious variations of initials and spelling were checked, as well as small variations in year and other numbers, but the numbers of citations recorded are necessarily lower limits. There is no reason to suppose that any one telescope is short changed more than another.

The sample collected in this way includes 663 papers appearing on 2790 pages and 2705 citations. The range in citations per paper is from 0 to 35, with a mean of 4.08.

2.2 Errors and Omissions

The omission of papers reporting data obtained with the Wyoming Infrared Observatory (WIRO) and the inherent uncertainty in numbers of citations have already been noted and are minor perturbations.

What more important items have been left out? Obviously, results published elsewhere than in *ApJ, ApJS, ApJL, AJ*, and *PASP*. Solar system work is, therefore, heavily discriminated against, being published largely in *Icarus* and elsewhere. It is not, however, a major consumer of time on most large optical telescopes. Conference proceedings and meeting abstracts often see the first appearance of new results, but the data are nearly always published later in archival journals. Thus their exclusion merely introduces a small time-shift, the same for all telescopes.

The largest journals not in the data sample are *Astronomy and Astrophysics* (plus *Supplements*) and *Monthly Notices of the Royal Astronomical Society*. And there are, of course, many other smaller ones. Abt (1985) did not scan these because he was primarily interested in the four large American telescopes, then used almost exclusively by astronomers resident in the U.S., who are quite faithful to their native journals.

The situation has probably changed in two ways. First, astronomers are even more mobile today than in the past, so that more people cross borders to use telescopes, and more collaborations involve people from several countries, with different loyalties. Second, even American astronomers are becoming less parochial and choosing venues for publication for reasons other than proximity.

If some American-operated observatories are more generous than others in assigning time to astronomers from other countries, then they are probably discriminated against in the numbers compiled here. More important, telescopes owned by institutions in other countries are greatly under-represented. Thus total numbers of papers and pages from them must not be compared to anything. The ratios of citations per paper or citations per page are, however, still of interest.

I believe that the samples are of reasonable, and comparable, completeness for the four telescopes in Abt's (1985) sample (KPNO, CTIO, Lick, Palomar) and probably also for those at McDonald, Steward, and Las Campanas, the MMT, and the University of Hawaii 2.2 m at Mauna Kea. Samples for telescopes at ESO, Calar Alto, La Palma, Australian sites, and other places in Europe, Latin America, and Atlantic islands are both very incomplete and varyingly so. I was surprised to find that about one-quarter of the papers examined are to be credited to non-American observatories.

3. RESULTS

The main points are the numbers of papers, citations, citations per paper, and numbers of highly cited papers resulting from data collected at each of the large telescopes considered. A number of minor points (many already well known) also appeared in the data.

3.1 Major Results

Table 1 lists the telescopes (in somewhat arbitrary order) and the numbers of papers, pages, citations, pages per paper, citations per page,and citations per paper for each. Remem-

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TABLE 1
Papers and Pages Reporting Data from Large Optical Telescopes, and Citations Thereto

Telescope (Size)	Papers	Pages	Citations	Pages per Paper	Citations per Page	Citations per Paper
Lick (3)	45.4	506	197	11.1	0.389	4.34
KPNO (4)	52.0	564	238	10.8	0.422	4.58
KPNO (2.1)[a]	61.5	701	182	11.4	0.260	2.96
CTIO (4)[b]	72.8	843	338	11.6	0.401	4.64
Palomar (5)	62.6	650	222	10.4	0.342	3.55
CFHT (3.6)	58.6	559	213	9.5	0.381	3.64
du Pont (2.5)	35.0	443	120	12.7	0.271	3.43
McDonald (2.7)	20.0	205	104	10.2	0.507	5.20
McDonald (2.1)	9.6	142	40	14.8	0.282	4.17
MMT (4.5)	31.2	432	162	13.8	0.375	5.19
AAT (3.9)	37.1	502	184	13.5	0.367	4.96
Steward (2.3)	21.2	214	85	10.1	0.397	4.01
UHawaii (2.1)	17.2	193	94	11.2	0.485	5.46
ESO (3.6)[c]	25.1	242	73	9.6	0.302	2.91
IRTF	26.0	191	120	7.3	0.628	4.61
UKIRT	23.4	157	78	6.7	0.497	3.33
Other	64.9	746	255	11.5	0.342	3.93
Total	663	7290	2705	11.0	0.371	4.08

[a]Includes 9.3 papers, 113 pages, and 4 citations from Coudé feed.
[b]Includes 2 papers, 21 papers, and 1 citation from Echelle feed.
[c]Includes 6 papers, 58 pages, and 17 citations from Coudé Auxiliary Telescope.

ber that only the ratios are of any significance for the non-American telescopes, because only American journals were considered.

The second most productive telescope was "other." The category includes no fewer than 16 additional telescopes, larger than 2 m. Only one, the ESO-MPI 2.2-m, contributed more than ten papers. The others are Calar Alto (2.2 and 3.5 m), William Herschel Telescope, Isaac Newton Telescope, Mt. Wilson 100″, ESO New Technology Telescope, McGraw Hill, Michigan–Dartmouth–MIT, Mt. Stromlo and Siding Spring (2.3 and 3.9 m), Russian 6 m, El Leoncito 2.15-m, Bulgarian 2 m, San Pedro Martir, and the ESO-Nordic telescope at La Palma.

Many of the telescopes not represented in the 1985 data are still not major players. But the CFHT and AAT clearly are. This is the more surprising given that neither is primarily American, so that many papers must be published in journals not consulted in this study. The high productivity of the KPNO 2.1-m is striking (though papers relying on its data are somewhat less often cited than average).

Table 2 compares productivity (in our narrow sense of papers and citations!) of the four largest American telescopes that were fully operational throughout 1979–91. Both the raw data and approximate normalizations by area of glass are given. The fraction of papers, pages, and citations contributed by each has changed rather little in the decade. Abt (1985) decided against attempting any sort of correction factors for quality of site, area of glass, or anything else. Since none of the mirrors actually has a full πr^2 ($r=3$, 4, or 5 m) of collecting area, the normalized numbers in Table 2 are accurate at only the 10%–20% level. This is, however, sufficient to shift the rankings of the largest and the smallest mirror telescopes considerably.

Somewhere in the files of a multiplicity of night assistants and administrators there must exist numbers for "hours the dome was open" each year and "hours seeing was better than 2 arcseconds" for the four telescopes that would permit other normalizations. Any reader who has access to this information or can pry it loose is encouraged to experiment with the numbers. Meanwhile, I find it very tempting to suspect that the quality of the CTIO site is a factor in its very impressive productivity. Readers will undoubtedly have their own favorite hypotheses, including the policies of time assignment committees and so forth.

TABLE 2
Relative Productivity of Four Large Optical Telescopes in the 1980s and 1990s

	1980–81 Papers; 1982–84 Citations						1990–91 Papers; 1993 Citations								
	Papers		Pages		Citations		Papers			Pages			Citations		
Telescope	%	*N*	%	*N*	%	*N*	%	*N*	*NN*	%	*N*	*NN*	%	*N*	*NN*
CTIO	33.1	86	32.7	811.7	29.3	997	31.3	72.8	73	32.9	843	840	34.0	338	340
KPNO	24.4	63.5	24.5	607.2	27.3	927	22.3	52.0	52	22.0	564	560	23.9	238	240
Lick	22.1	57.5	19.1	473.3	23.3	791	19.5	45.4	81	19.7	506	900	19.8	197	350
Palomar	20.4	53	23.7	587.1	20.2	686	26.9	62.6	40	25.4	560	420	22.2	222	140

N=actual number of papers, pages, or citations in data base.
NN=number of papers, pages, or citations normalized on the assumption that each mirror has a collecting area=πr^2 ($r=3$, 4, 5 m) and rounded off.

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The papers that attract the most citations are, in some crude sense, more useful or more influential within astronomy than papers that are never cited at all. The top 5% (Abt's 1985 cut-off) comprises 33 papers with 13 or more citations (about three times the average rate). Sixteen telescopes contributed data to these papers. The major players and numbers of papers were CTIO (5.0), Lick (4.1), KPNO 4 m (3.5), CFHT (2.75), KPNO 2.1 m (2.6), AAT (2.5), and Palomar (2.3). Abt's conclusion was that the major telescopes had contributed about equally to the most highly cited papers (but he gave no numbers). This is probably still a fair statement, given the small sample sizes.

3.2 Minor Results

A number of previously known effects were rediscovered. Citation rates are, on average, higher for long papers than for short ones (except letters) and for papers with relatively large numbers of authors (Abt 1984). Papers pertaining to cosmology and high-energy astrophysics (including active galaxies) are more highly cited than those discussing stars and the interstellar medium (Trimble 1993). And papers published in the *Astrophysical Journal* are more often cited than papers published elsewhere (Trimble 1994), except for *Nature, Science*, and review journals, which are not in the present data base.

Astronomical papers are becoming ever longer and more numerous. The mean number of pages per paper for the four large American telescopes has stretched from the 9.5 found by Abt (1985) to 10.6 (after correcting for our different counting strategies). This is part of a trend that has pervaded most physical sciences for more than half a century (Trimble 1984). The 18-month sample from the 1990's has 202.5 papers from the large telescopes and journals that Abt surveyed, somewhat more than 3/4 of the 260 papers in his 2-yr 1980's sample. Papers reporting data from two or more telescopes have also become much more common.

At first glance, the number of citations per paper per year seems to have dropped, from 4.36 to 4.08. Most of this is an artefact caused by the inclusion of one additional journal. The current average is 4.33, unchanged from the 1980's level, if only those papers published in *ApJ, ApJL*, ApJS, and *AJ* are considered.

The two infrared telescopes (UKIRT, IRTF) have yielded the shortest papers (7.0 vs. 11.1 pages per paper on average), but a normal citation rate of 4.01 per paper per year.

Finally, we sympathize with, but do not entirely confirm the frequent complaint that "most papers aren't read by anybody," or, as Samuel Goudsmit used to put it, "[this journal] has more authors than readers." In fact, 112 of the 663 papers were not cited at all in 1993, 17% of the total.

4. CONCLUSIONS AND IMPLICATIONS

The relative productivity, in journal papers, pages, and citations, of the four large American optical telescopes has changed rather little over the last decade. For both papers and citations, the 1980's ranking was CTIO, KPNO, Lick, and Palomar. The 1990's one is CTIO, Palomar, KPNO, and Lick for papers; CTIO, KPNO, Palomar, and Lick for citations. With normalization by area of the primary mirror, both become Lick, CTIO, KPNO, and Palomar. The KPNO 2.1 m (including Coudé feed), CFHT, AAT, and Las Campanas 2.5 m are the next largest contributors to the literature (without normalization). They were not included in the 1980's data, so changes cannot be assessed; not all existed then.

Many of the numbers in Table 1 are fairly small, and the addition or subtraction of one or two highly cited papers would lead to superficially rather different impressions. If one is primarily interesting in large American optical telescopes and the issue of public versus private access, there is very little than can be done about this except to track the numbers year by year as papers published into the 1990's reach their times of peak citation rate and successive volumes of the *Science Citation Index* become available. In particular, I would recommend against assuming that the year-to-year variations will be well described by $N^{1/2}/N$. Publication of astronomical papers is surely a less Poissonian process than being kicked by French horses.

A compilation representing papers published in 2000–01 and cited in 2003–04 can be expected to feature many new names, including Keck, WIYN, and, we trust, Gemini and the VLT.

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