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CHANGING SOURCES FOR RESEARCH LITERATURE

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Abstract. Including material published previously, I considered all the references listed in the January issues of *Astronomy & Astrophysics* and the *Astrophysical Journal* in decade intervals from 1952 to 2006. The results are that journal papers, preprints, and reviews are growing in the frequency in which they are cited, while observatory publications, private communications, theses, conference papers, and monographs are decreasing in cited frequency. The last two are surprising in view of the rapidly increasing numbers of conferences and monographs published annually. It appears that sources of information that are readily available on-line are greatly preferred over sources that are not available on the internet.

1. Introduction

Part of our astronomical literature is used for tutorial and educational purposes, namely some monographs and review articles. However, most of it is used for research purposes, such as to justify statements made and to reference data and concepts used. By studying the references used in papers, we wish to determine which sources have been the most useful for research. These have changed with time. For instance, "private communications" are dead-ends in that readers cannot locate such sources easily, so journal editors discourage their use and they have nearly disappeared. Which sources have prevailed?

In 1995 Abt (1995) surveyed the frequencies of each of the sources at decade intervals from 1952 to 1992. He noted that preprints and conference papers were increasing in frequency, observatory publications were decreasing, and journal papers, theses, and monographs were constant. This study

brings those results up to date. We find differences from the previous results due to the fact that much of our research is now done with the internet.

2. Method and Results

As in the previous study, I scanned for 2006 all the references in the January issues of the *Astrophysical Journal* (ApJ) and *Astronomy and Astrophysics* (A&A), the main journals and Letters in both cases. There were 9816 and 5061 references in those two journals, respectively. Each reference was classified in one of the eight categories given below. The results are given in Table 1, and some explanations are as follows:

1. Journals papers.
2. Observatory publications. Although the conventional series of such publications have virtually stopped, observatories and other organizations are now distributing CD-ROMs, handbooks, and on-line datasets, which we assigned to this category.
3. Private communications. Only seven were found among the 14877 references scanned.
4. Preprints. These are often references to astro-ph when a final journal reference is not yet known,
5. Theses.
6. Reviews.
7. Conference papers.
8. Monographs. These are books written entirely by one, two, or three authors and do not include conferences, workshops, or compilations in which an editor(s) collects contributions from many different authors.

TABLE 1. References in January 2006 in ApJ and A&A.

Source	Total references	Fraction
Journal papers	13073	87.9±0.8
Observatory publications	222	1.5 0.1
Private communications	7	0.0 0.0
Preprints	232	1.6 0.1
Theses	81	0.5 0.1
Reviews	202	1.4 0.1
Conference papers	439	3.0 0.1
Monographs	621	4.2 0.2

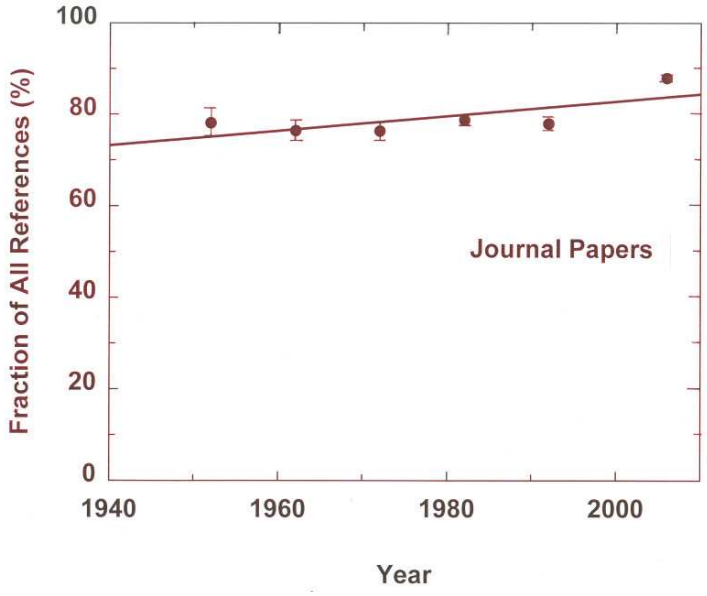

Figure 1. The frequencies of references to journal papers. The least-squares linear relation is fraction = -237.31 + 0.16005(year). The scatter is ±3.3% and the correlation coefficient is 0.727.

3. Discussion

The fraction of all references from 1952 to 2006 to journal papers is shown in Figure 1. We see a linear increase from 76 % in 1952 to 88% in 2006. Journal papers are increasingly easy to find on-line and in databases such as the *Science Citation Index* and the NASA ADS (*Astronomical Data System*). Thus the bulk of our references is to journal papers, although the fraction is unlikely to reach 100%. In 2006 764 references (5.8±0.2 %) were in commercial journals (e.g. *Nature*, *Icarus*, *Solar Physics*) while the remaining 12309 references (94.2±0.2 %) were in journals (e.g. ApJ, AJ, A&A, MNRAS) from non-profit organizations.

Although observatory publications were a major location for research papers in the past, it was realized that the entire cost of publication and distribution fell on the observatories, rather than partly on the readers, so they have declined in numbers. However, currently some organizations have found it convenient to distribute material in the form of computer programs, CDs, instruction manuals, and other technical information directly from those organizations, rather than through journals. Therefore I am extending the definition of observatory publications to include such material, and that is the reason for the recent slight rise shown in Figure 2. Overall there has

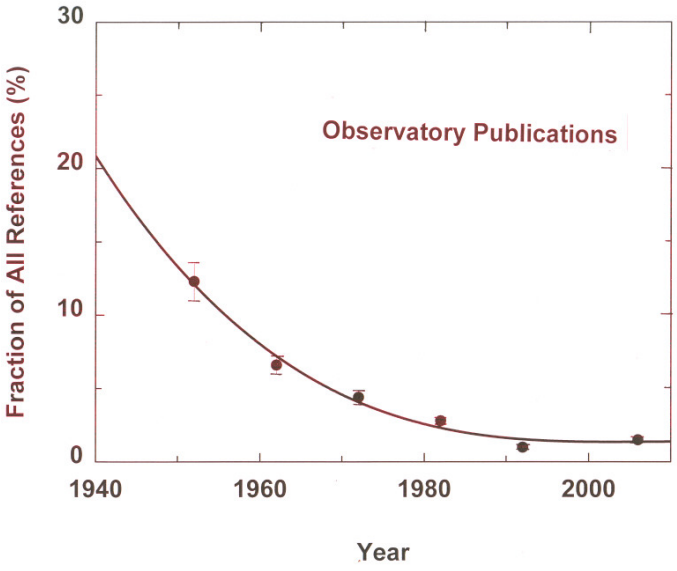

Figure 2. The frequencies of references to observatory publications. The least-squares relation is a fourth-order polynomial with a scatter of ±1.0% and correlation coefficient of 0.994.

been a decline from 12.3% in 1952 to 1.0% in 1992 and then a small increase.

Private communication references are shown in Figure 3, which shows that they have decreased from 2.1% in 1952 to the current zero as both editors and authors realize that such sources do not allow the readers to locate the referenced material.

References to preprints, shown in Figure 4, are rising from 0.8% to the current 2.3% for the following reason: as the rate of research becomes more rapid, researchers depend more on preprints, which are often provided by astro-ph. We can expect this source to increase in the future as the pace of research become quicker. The error bars indicate that there may be a higher-order variation, other than linear, and perhaps a leveling off.

Figure 5 shows that theses had increased from 0.4% in 1952 to 1.8% in 1972 and then declined, probably for the following reason: many universities have converted from the requirement of a 300± page detailed document showing all that the candidate knows about a topic to a concise paper(s) accepted by a standard journal. The former system started students toward writing verbose papers and then he/she had to learn how to write concise papers for the current literature. Also, university theses are not widely available, as are journal papers.

Review papers are very useful to recover the past literature on a topic.

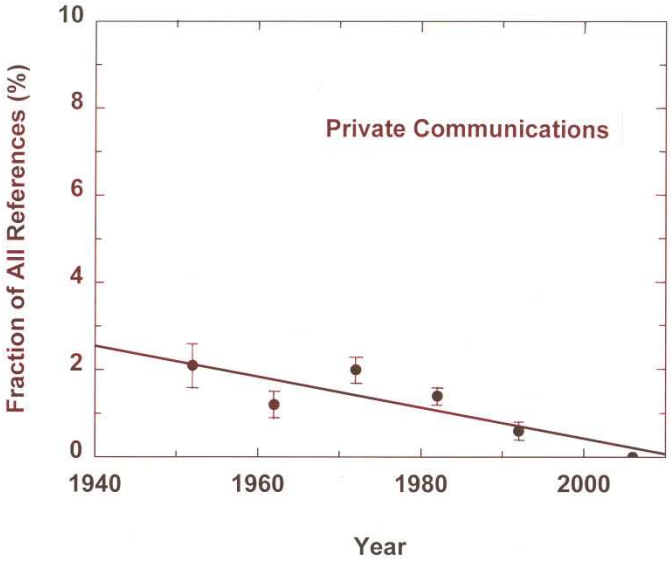

Figure 3. The frequencies of references to private communications. The least-squares linear relation is 71.09 - 0.03533(year) in percent. The scatter is ±0.5% with a correlation coefficient of 0.863.

However, authors are sometimes considered to be lazy if they simply reference a review paper, rather than the specific sources mentioned therein, to justify a statement. Nevertheless, as our literature becomes vastly larger to the point where few astronomers can read much of it, we are increasingly dependent on reviews to bring us up to date. Figure 6 shows a linear increase from 0.8% in 1952 to a current 1.7 %.

Figure 7 shows that references to conference papers reached a peak in 1982 of 8.2% and then decreased abruptly. Why? The numbers of astronomical conferences have increased steadily; the AAS Newsletter listed 20 in 1982 but 49 in 2006. Compared with 314 and 439 references to conference papers in 1982 and 2006, each conference is receiving fewer citations on the average, either in absolute numbers or in percentages of the total references. Conference papers are often extended abstracts that do not give the full data and details, as do journal papers. Therefore given a choice, authors will reference the journal papers rather than the conference papers. Also it is generally more difficult to have a paper accepted for publication in a journal than in conference proceedings, so the former is likely to be more substantial and reliable.

Figure 8 shows that monographs are decreasing in importance as sources of information for research papers, even though the annual number of mono-

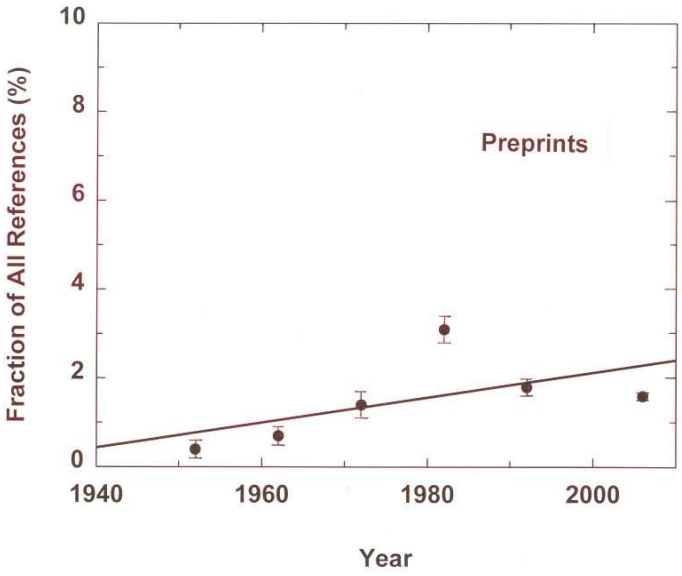

Figure 4. The frequencies of references to preprints. The least-squares linear relation is 54.30 + 0.02822(year) in percent. The scatter is ±0.9% and the correlation coefficient is 0.588. The small error bars and the low correlation coefficient suggest that the variation is of a higher order than linear.

graphs published is increasing. For instance, currently Springer has 346 astronomy-related books in print and the annual numbers have doubled since 2003 to a current number of 37. Of course some books are used but not cited, just as we often use dictionaries, encyclopedia, *Allen's Astrophysical Quantities*, or the *Bright Star Catalogue* without citing them. In 2006 there were 289 references to 199 different monographs, using a narrow definition of monographs that excluded all conference proceedings, workshops, and volumes written by many authors (e.g. the *Stars and Stellar Systems*, *Allen's Astrophysical Quantities*). Those had a mean publication date of 1984.1±1.2. However, eight books that received five or more citations in January 2006 accounted for 62 (21%) of all the references to monographs. They are listed in Table 2. Their mean date of publication is 1993.2±4.0, i.e. they tended to be more recent than the remainder.

I looked to see the publishers who published the most-frequently cited books in January 2006. Among the non-profit publishers they are the Cambridge Univ. Press with 73 references, the Princeton Univ. Press with 27 references, and the Oxford Univ. Press with 13 references. Among the commercial publishers they are Springer with 25 references, Wiley with 21 references, University Science Books with 15 references, and Freeman with

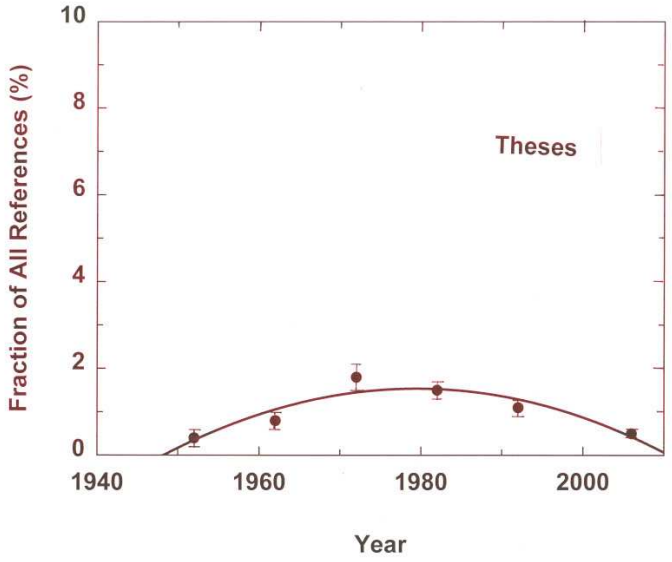

Figure 5. The frequencies of references to theses. The least-squares quadratic fit is -6168.41 + 6.23400(year) - 0.0015747 $(\text{year})^2$. The scatter is ±0.3% and the correlation coefficient is 0.922.

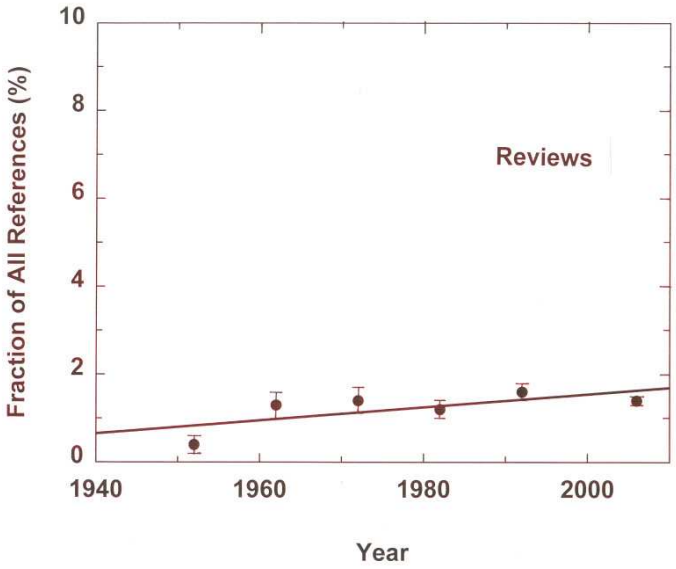

Figure 6. The frequencies of references to reviews. The least-squares linear relation is -28.23 + 0.01489(Year). The scatter is ±0.3% and the correlation coefficient is 0.700.

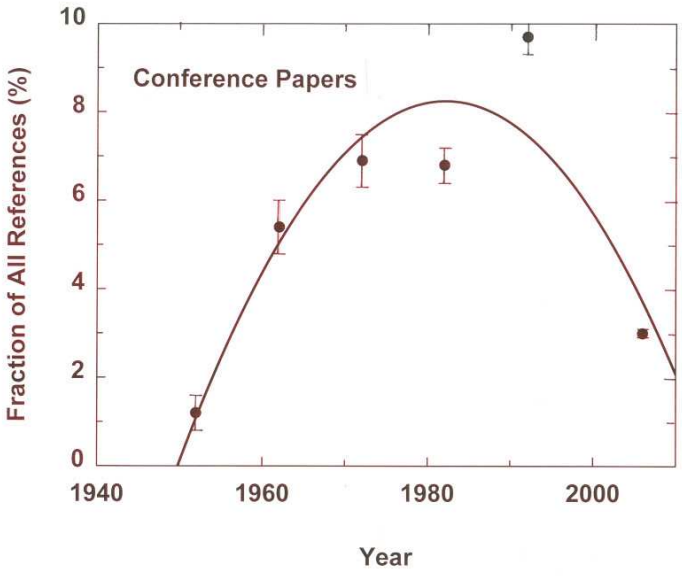

Figure 7. The frequencies of references to conference papers. The least-squares quadratic fit is -31067.44 + 31.35655(Year) - 0.007910(year)^2. The scatter is ±1.6% and the correlation coefficient is 0.909.

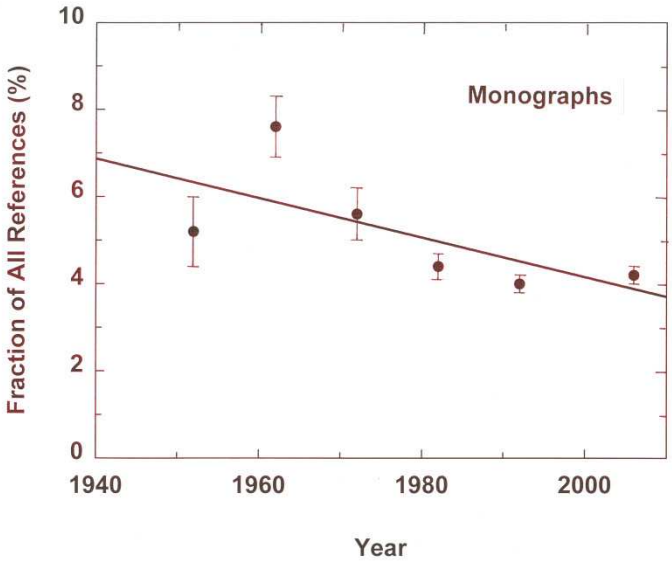

Figure 8. The frequencies of references to monographs. The least-squares linear relation is 94.68 - 0.04526(year). The scatter is ±1.1% and the correlation coefficient is 0.689.

TABLE 2. Monographs Cited ≥5 Times in January 2006.

Authors	Title	Publisher	References
Press et al.	Numerical Recipes in C: The Art of Scientific Computing	Cambridge	15
Osterbrock	Astrophysics of Gaseous Nebulae & Active Galactic Nuclei	Univ. Science. Books	12
Binney & Tremaine	Galactic Dynamics	Princeton	9
Hartmann & Burton	Atlas of Galactic Neutral Hydrogen	Cambridge	6
Binney & Merrifield	Galactic Astronomy	Princeton	5
de Vaucouleurs et al.	Third Reference Catalogue of Bright Galaxies	Springer	5
Pacholczyk	Radio Astronomy	Freeman	5
Warner	Cataclysmic Variable Stars	Cambridge	5

11 references. The monographs from the 36 non-profit publishers accounted for 59% of the references and those from the 24 commercial publishers 41%.

4. Conclusion

The sources quoted in reference lists in 2006 are dominated by journal papers (88%) and that source is growing slowly. Preprints and reviews are slowly increasing and account for 4% of the cited references, but observatory publications, private communications, theses, conference papers, and monographs are decreasing in importance. These results are probably due to the fact that the journal papers, preprints, and reviews are generally available on-line whereas many of the observatory publications, private communications, theses, and conference papers are not. The future seems to lie in the direction that if information is not readily available on the internet, it is ignored.

References

1. Abt, H. A. 1995, *Publ. Astron. Soc. Pacific* **107**, 401-403.