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Authors

Trimble, V
Ceja, JA

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Productivity and impact of astronomical facilities: Three years of publications and citation rates

V. Trimble^{1,2,*} and J.A. Ceja¹

¹ Department of Physics and Astronomy, University of California, Irvine, CA 92697-4575, USA

² Las Cumbres Observatory, Goleta, California

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In calendar years 2001 to 2003, 20 journals of astronomy and astrophysics published 11 831 papers that reported or analyzed observations at wavelengths from meter radio to ultrahigh energy gamma rays. These were cited 161 556 times in the three calendar years following publication, according to the Science Citation Index/Web of Science, for an average of 13.66 citations per paper or 4.55 citations per paper per year. We examine these numbers as a function of subject matter, wavelength bands, journals, and individual telescopes used and explore a small subset of possible temporal trends, anomalies, and sources of uncertainty, including blockbuster journals, papers and facilities. Many of the results resemble qualitative expectations. There are hot topics (cosmology, exoplanets) and not so hot topics (binary stars, planetary nebulae). Papers reporting data from space are cited a bit more often, and ground-based radio papers a bit less often, than optical papers, while multi-wavelength ones do noticeably better than average. The total number of telescopes involved is surprisingly large, approximately 350 optical and infrared (mostly ground-based but including HST because of its long life), 144 radio facilities on about 100 sites (including WMAP and COBE and a few balloon-borne CMB experiments), and 105 space-based detectors (including satellites, interplanetary probes, things carried on rockets, balloons, the Shuttle, and so forth). The outstanding telescopes are generally both stable with time and predictable. HST and the VLA are responsible for the largest number of optical and radio papers respectively, but the most frequently cited optical papers come from SDSS (by a wide margin), Keck, and the AAT, while the JCMT, Parkes and (especially) CMB observatories lead the radio brigade. Among things that fly, leadership changes more quickly, as missions are launched, vigorously exploited, and turned off, sometimes achieving geostationary, suboceanic orbits. If you have a choice, large trumps small, but well-supported sites trump struggling ones by a comparable factor. And service to the community, in the form of catalogues and mission descriptions, is rewarded, at least in citation numbers, if not always in other ways.

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1 Introduction

History eventually decides what science, scientists, and experimental/observational facilities have been truly important, and sometimes changes its mind, as well as taking a long time. Feedback from reviewers of your grant proposals and papers comes immediately, but it is not always entirely unbiased. Counting of papers and citations to them picks out an intermediate time scale with an intermediate degree of bias. We present here a third, and for us last, set of numbers of papers and citations reflecting the productivity and impact of the full range of astronomical facilities over three years of publications and three years of citations after publication. It is our intent to be useful to our colleagues who have to make hard decisions. Not that we expect, or want, anyone to say, “Gee, we might as well close down our 94-inch; it doesn’t seem to be doing much.” But we would be glad if someone, looking at these numbers, decides “Hey, the MPT (Milford Poltroon Telescope) is more important than we realized and worth fighting to keep operating in good condition.”

The pioneer of astronomical studies of this type was Helmut A. (for Arthur) Abt (1981, 1985), and he remains active in the territory (Abt 2007). We began by looking at papers resulting from optical telescopes of more than 2-m diameter published in 1990–91 and cited in 1993 (Trimble 1995, 1996), finding that the largest numbers of papers and citations came from 4-meter class telescopes, the CFHT and AAT, with the CTIO 4-m close behind, while the largest impact factors (5 or more citations per paper per year) came from the University of Hawaii’s 2.2-meter and the Multi-Mirror Telescope in Arizona.

A decade later, 8-meter class telescopes existed in Hawaii and Chile, and others were rapidly being brought on line, and it seemed worth while to ask whether they and the Hubble Space Telescope might slowly be slaughtering the 4-meters. The short answer was yes (Trimble, Zaich & Bosler 2005; TZB05 below). We also expanded to the radio regime (Trimble & Zaich 2006, TZ06) and space-based astronomy (Trimble, Zaich & Bosler 2006; TZB06), examining papers published in 2001 and cited in 2002–04. We recognized that most things don’t stay in space very long, so that would be snapshot, and colleagues, both with and

* Corresponding author: vtrimble@astro.umd.edu

without referees' hats said firmly that a single year of data would be biased by temporary problems and passions.

A second year of data, publications in 2002, cited in calendar years 2003–05, was added in by Trimble & Ceja (2007, TC07), showing that anomalies were rather few, though one could see specific facilities (the VLT for instance) gradually coming on line, others recovering from a bad patch, and the continued fading of 4-meters, except for the infrared UKIRT and IRTF, which continued to hold their own in both papers and citations per paper. Things in space started off with the expected bang of highly-cited "mission description and first light" papers, then gradually tapered off, though archives remain useful for decades. These four papers mention a number of other investigations of telescope productivity and impact that address fewer facilities, fewer papers, or both.

The present study adds in publications from 2003 (a larger number than in either of the two previous years) and citations to them in 2004–06, again a larger number, both total and per paper. Section 2 recapitulates the methods used, very nearly identical to the first two years. Section 3 describes a variety of results pertaining to astronomical sub-disciplines, block-buster and invisible papers, and the contributing telescopes.

Section 4 ventures on a few conclusions and suggests things others might look at, since this will be our last compilation, for several reasons. First, notoriously in astrophysics, one is a discovery, two is a confirmation, and three is a well known class of objects, about which the fundamentals are known. Second, statistical errors for this sort of things shrink only as $1/N^{1/2}$. Third, author Ceja will shortly be completing his degree and moving on to greener, if less cited, pastures. And fourth, the literature continues to grow at a canonical 5% per year, and citations per paper almost as fast (White 2007), so that the task of identifying all the relevant publications, telescopes, and citation numbers gradually becomes more burdensome.

2 Methods

These were essentially the same as outlined in TZB05, TZB06, TZ06, and TC07. In outline, choose the journals to be considered (in our case the ones available in the UC Irvine science library); go through them page by page, recording bibliographic information for each paper presenting or analyzing observational data, the subject matter, and the telescopes used; choose a source for citation numbers, look them up, and do a bit of arithmetic. None of these is completely straightforward.

ADS includes in its list of "astronomy and astrophysics" journals some geoscience, a number of review publications, solar publications (which use an almost entirely disjoint set of facilities), Physical Review D (which has almost no observational astronomy, but quite a few highly cited papers), and a handful of publications that have become almost impossible to find (like the Armenian *Astrofizika*), but excludes

the highly-cited astronomy papers from *Nature* and *Science*. Our choice is shown in Sect. 2.1.

Next, we have heard from colleagues who identify facilities used just by words in the title or abstracts of papers. We have found that you must also look carefully at the observational methods sections, figure captions, footnotes, and sometimes the acknowledgements to find them all. And there is a bias. More papers are called "Hubble spectroscopy of faint blue variables" but make equal or greater use of photometry from several ground-based telescopes, than there are papers called "Variability of faint blue stars seen from New Zealand" which then mention the HST spectra only in a figure caption.

Third, assigning subject matter is not totally a thought-free process. QSO spectra can be used to try to understand the central engines (AGNs), to probe chemical evolution of the absorber gas (galaxies), or to trace large-scale structure (cosmology). We have tried to choose what the authors say they are most interested in (but lost a couple of papers per year at this stage).

Fourth and most difficult is how to apportion credit. Keeping the original three (rather approximate) wavelength bands separate was driven by initial studies having addressed only optical telescopes. Equal credit to every facility (within a wavelength band) used in a paper is also arbitrary, but attempting to give more credit to the telescope that produced the most data would be exceedingly time consuming, and the information is not always available in each paper (and probably shouldn't be). Madrid & Macchetto (2006) have done this unequal division, but for fewer than 200 papers. Our equal divisions range from half-and-half for two telescopes, down to one-twelfth or less for a few synoptic studies covering long periods and for radio observations made with an ad hoc assortment of dishes generally used separately. Citations are also equally divided, but only as integers. With four telescopes and seven citations, the telescope mentioned last by the authors gets only one.

What sorts of conclusions to put forward is also a sort of decision, and we have tended to steer away (or be steered away by referees) from any that offend anyone, leaving thereby somewhat spherical papers.

2.1 The journals employed

The 11 878 papers from 2001 to 2003 appeared in 20 journals. In order, from most papers to fewest, these are *Astronomy and Astrophysics* (5325), *Astrophysical Journal* (2756), *Monthly Notices of the Royal Astronomical Society* (1636), *Astronomical Journal* (1323), *Astrophysical Journal Letters* (1106), *Icarus* (332), *Publications of the Astronomical Society of the Pacific* (250), *Publications of the Astronomical Society of Japan* (242), *Astrophysical Journal Supplement Series* (218), *Astronomy Letters* (151), *Astronomy Reports* (128), *Nature* (110), *Science* (73), *Journal of Astrophysics and Astronomy* (37), *Astrophysics and Space Science* (50), *Acta Astronomica* (49), *Observatory* (35), *Astronomische*

Nachrichten (31), *Revista Mexicana de Astronomia y Astrofisica* (17, 2002 only), and *Journal of the Royal Astronomical Society of Canada* (9). Of these, the 45 journals listed by ADS in their “astronomy and astrophysics” class do not include *Nature* or *Science*, but do include six review journals, a couple of nontechnical publications, three journals of (mostly) theoretical and experimental physics, and journals of cosmic ray and other particle physics and astrophysics, as well as some small publications (like *Baltic Astronomy*) that we read when they are available but have not included here.

Clearly, the first five on our list include a large majority of all relevant papers, but *Icarus* (Solar System) and *Acta Astronomica* (microlensing projects and binary stars) occupy some specific niches. *Nature*, *Science*, and (sometimes) *Astrophysical Journal Supplements*, on the other hand, include very highly cited papers. We have generally refrained from reporting citation rates by journal, but note here that, for 2003, the 26 *Science* papers had $C/P = 30.0$ and the 44 *Nature* papers $C/P = 44.7$, compared to 15.7 for the complete 2003 set. And *ApJS* almost needs a logarithmic scale, because it included the WMAP first year data release and so a couple of papers with more than 1000 citations.

The 11 878 papers just mentioned is the largest number that will appear here, because there were a few for which the name of the journal and existence of observations was all that could be determined. A few gave no indication of the facilities used, and a few were unclear as to subject.

2.2 Definitions of wavelength bands

Optical astronomy means the data collected with about 350 ground-based optical and infrared telescopes, from the 11-meter Hobby-Eberly Telescope down to amateur-owned instruments of much less than one meter diameter, and also the Hubble Space Telescope, whose lifetime is now comparable with that of ground-based facilities. Radio includes a total of something like 144 collectors on 100 sites, ranging from meter wavelengths (GMRT for instance) down to the submillimeter (JCMT, which we accidentally included with optical observatories in TZB05), and also the COBE and WMAP CMB satellites, several balloon-borne CMB experiments, SWAS and Prognaus, and the Japanese satellite (VSOP or HALCA) used to provide baselines longer than the diameter of the earth for very long baseline interferometry. In the end, it contributed very few papers, but perhaps more than its share of the content of these.

Space is an even more heterogeneous collection of 105 facilities (though most had in common short lifespans, so that our analysis is inevitably unfair to the oldest and the newest). It includes X-ray, ultra-violet, γ -ray, and infrared satellites (plus a few rockets and balloons and aircraft), the Hipparcos astrometric satellite, solar system missions, the ODIN (submillimeter, short-lived) satellite, astrophysical data (mostly on gamma-ray bursters) from solar missions (RHESSI and SOHO, for instance), and a couple of rocket

Table 1 Numbers of 2001–2003 papers reporting data in various wavelength bands.

Optical (O)	5677	Radio (R)	1628	Space (S)	2619
O+R	433	R+O	433	S+O	919
O+S	919	R+S	286	S+R	286
O+R+S	285	R+O+S	285	S+O+R	285
All optical	7314	All radio	2632	All space	4109

and balloon data sets of uncertain wavelength. In addition, ground based-detectors for very high energy gamma rays (HEGRA for instance) and particles (MILAGRO for instance) live here.

These definitions are followed throughout, beginning with Table 1, whose purpose is to give some feel for the fraction of astronomical observation that is multi-wavelength. The numbers include papers that, for instance, made use of both radio and optical data but reported the telescope(s) only for one, and thus “all optical” is larger than the sum of optical telescopes in Table 4, as are the “all radio” and “all space” numbers compared with the totals in Tables 5 and 6. Notice that “optical” is still much the largest set, and that “pure” O, R, or S considerably outnumber the mixtures.

On the other hand, multi-wavelength papers are, on average, cited rather more often than the total: 4.49 vs. 4.19 per paper per year for 2001–2002 (TC07) and 7.10 vs. 5.24 citations per paper per year for 2003. The 2003 numbers are very sensitive to half a dozen WMAP papers that used optical as well as radio data and were very highly cited. Removing them from both samples leaves 5.03 and 4.84 citations per papers per year for the 2003 multiwavelength and total sets. They are also a bit less likely to go completely uncited. For 2003, there are 17 zeros out of 775 multiwavelength papers (2.2%) vs. 162 zeros out of 4107 papers (3.9%). A good deal more work would be needed to say firmly that these numbers imply higher quality for multiwavelength investigations (though more work is probably true). The alternative is merely having two sets of colleagues to cite you reliably.

2.3 Facilities tracked individually

Our original notes really do include names like Manastash Ridge Observatory, Baja Observatory in Hungary, and Piszkesteto; Wattzell, Svetloe, and Ny Alesund; and FAUST, WISP, and Apollo (remember Apollo!), in optical, radio, and space wavelengths respectively. But can anyone possibly want to know about a small, old, obscure facility that contributed, in our prorated method of bean counting fewer than a handful of lightly cited papers? Well, possibly yes, if it is yours, or if it is just coming on line and you want to be able to track early history at some time in the future. But exact complete tracking is not possible, because you cannot always say whether a particular set of small Greek telescopes used for one paper did or did not include a specific 0.3 meter on Crete used for another.

The decisions made were (1) all optical telescopes larger than 1.85 meter, (2) a class of “others” for each site with one or more of those larger ones, (3) two classes of small optical telescopes, with the cut at 1.5 m, for optical telescopes not on major sites, (4) an assortment of special-purpose optical facilities, (5) all radio telescopes (etc) responsible for more than five papers in any one year, and (6) all space facilities responsible for more than five papers in any one year. These last two required in a few cases going back to the 2001 and 2002 data to pick up telescopes that had just been getting started then.

We are aware of several obvious injustices. Lowell Observatory, for instance, just missed the size cut, as did Asiago, VATT, and perhaps a few others. WHAM (the Wisconsin H-alpha Mapper) should have had a “special purpose” designation, but got lumped with other small facilities. Notice that the Large Binocular Telescope, the South African Large Telescope, and the Gran Telescopio Canarias (LBT, SALT, GTC) did not, as far as we could tell, contribute to any 2001–2003 papers. Some beloved long-standing radio dishes did not make the five-paper cut for any one year, but added up to 5–10 over the triennium and are mentioned in Sect. 3, in association with Table 5. And a good many famous names from space – Ariel-5, Vela-5, Tenma, OSO-8, KAO, SAS-3, Giotto – didn’t even add up to five over the triennium, but left the senior author thinking “but I remember when they were launched!” Well, she remembers when Sputnik was launched and benefited a good deal when supposed American panic reached down into the educational system with PSSC physics and NSF fellowships.

3 Results

Here are several subsets of numbers extracted from the raw data and, in some cases, what we think they mean.

3.1 Division by subdiscipline

Table 2 divides the sample into 20 subfields giving numbers of papers and citations for 2001 + 2002 (separated in TC07), for 2003, and the sums, and citations per paper per year. Some lines are a bit fuzzy. Cosmology includes large scale structure and streaming and calibrations of the distance scale as well as parameter determinations. High resolution mapping of dense interstellar clouds (ISM) grades into the early stages of star formation (and the topic assignments together comprise about the same number of papers each year, but with the balance shifting in favor of star formation and young stellar objects). A detailed chemical analysis of one star is “stars”, but of, for instance, the whole disk population as a function of radius is “Milky Way.” And sometimes you have to read a paper right to the end to figure out whether a particular super-soft X-ray source has an accreting white dwarf or black hole. Over decades, there would, of course, be major shifts in proportions of papers in these various subfields, but from 2001 + 2002 to 2003 the

only obvious changes are that many of the increased total number of papers fall in the GRB, Milky Way, brown dwarf, and Service categories, this last meaning mission descriptions, calibrations, and catalogues that include several different kinds of sources, often from a single survey.

The main temporal trend is a larger number of citations per paper in 2003 than in the two previous years. This has affected most subjects, but particularly gamma ray bursts (arguably because the connection with Type Ic supernovae became clear during the next few years) and cosmology with a slight increase from 2001 to 2002 and a major one to 2003. Simply removing a few blockbuster WMAP papers from the sample does not bring the 2003 C/P/year number back to the previous average, but only from 13.88 down to 11.91. We would not suppress these numbers even if we could, but we remain concerned that increasing focus of effort, funding, and everything else on a few driver topics (more or less describable as “origins”) may not be good for the long term health of astronomy and for the increase of our knowledge of all aspects of the universe and its contents.

Clearly other possible slicings of astronomical subject space are possible. The neutron stars and black holes category could have been separated into single and binary, or the white dwarfs and CVs merged as single and binary WDs, or the CVs have been merged with other classes of binary stars. A class called stellar populations might well have been carved out of normal galaxies, Milky Way, and stars.

3.2 A rising tide swamps some boats

The analogy is not a perfect one, but nevertheless, if a rapidly rising tide of numbers of astronomers, papers, citations, and competition is anticipated, one may be wise not to moor one’s career to a specific subject matter or facility pier by too short a line. Comparison of the 2003 (ff) numbers with 2001 and 2002 reveals about 6% more papers and 33% more citations, with at least one-third of the citation growth coming from papers reporting results from WMAP. This has somewhat twisted results upward for telescopes used in parallel with it and twisted downward numbers for facilities that preceded WMAP. Colleague Thomas Dame tells us that the 2nd and 3rd most cited radio papers of 2001, coming from Maxima, faded rapidly in citation rate in the last couple of years.

The rest of the rapid upshift in citations per paper for 2003 has two or three contributors besides references to WMAP by all and sundry (including non-astronomers). First is the continued rise of numbers of papers per year on beyond 2003, which must cite something or other; second is a roughly monotonic rise in numbers of references per paper (White 2007), which we are inclined to attribute to antedephobia¹; and a possible third is somewhat more

¹ The fear that your paper may be refereed by someone who has previously worked on the subject and whom you forgot to cite.

Table 2 Papers and citations by subfield.

Topic	2001 + 2002		2003		Citations	Total	
	Papers	C/P/yr	Papers	C/P/yr		Papers	C/P/yr
Cosmology	312	8.91	166	20.49 ^a	18544	478	11.88 ^a
Clusters of Galaxies	416	5.42	207	4.79	9712	623	5.20
Gamma Ray Bursts	129	6.44	104	9.11	5333	231	7.20
Active Galaxies / Nuclei	874	4.25	459	4.57	17432	1333	4.36
Normal Galaxies	952	5.21	507	6.67	25046	1459	5.72
Milky Way	164	5.19	127	7.31	5337	291	6.11
NS/BH	683	3.95	317	3.77	11645	1000	3.88
Supernovae/Remnants	275	3.35	137	4.23	4511	412	3.65
Interstellar Medium	651	2.89	277	3.36	8448	928	3.01
Star Formation/YSOs	375	4.15	227	4.05	7428	602	4.11
Star Clusters	404	3.63	196	3.70	6580	600	3.66
Stars	864	2.85	408	3.08	12395	1272	2.92
Brown Dwarfs	72	7.96	56	7.61	3023	128	7.87
Planetary Nebulae	147	2.57	76	2.47	1701	223	2.54
White Dwarfs	67	3.16	29	3.33	926	96	3.21
Cataclysmic Variables	280	2.04	143	1.94	2546	423	2.01
Other Binaries	344	1.77	180	2.29	3071	524	2.12
Solar System	395	3.76	227	3.11	6565	622	3.52
Exoplanets	107	6.56	62	6.78	3366	169	6.64
Service	213	7.18	206	7.69	9404	419	7.48
Total	7724	4.19	4105	5.24 ^a	161556	11829	4.55 ^a

^a If the two most highly cited WMAP papers are left out, these four numbers become 12.46, 10.18, 4.91 and 4.44. In other words, these blockbusters have driven part but not all of the rise in C/P in general and C/P in particular for cosmology.

complete coverage of the literature by Science Citation Index, which adds to its list of journals scanned for citations from time to time.

Table 3 lists the 124 most-cited papers, by facility, journal, and subfield down to 100 citations per paper, the cut-off we picked before. The top 1% is 118 papers down to 103 citations each. This top 1% contributes 14.9% of all citations, while the fraction for 2001 + 2002 was 12.9% of the total, another upward twist largely driven by WMAP, implying a corresponding downward twist for other papers.

The simplest of bean-counting systems will tell you that the distribution of topics in Table 3 is very different from that in Table 2. Cosmology, Service (meaning catalogs of multiple types of sources, calibrations, and mission descriptions), ordinary galaxies, the Milky Way, exoplanets, and clusters of galaxies are over-represented by factors from 6.85 down to 1.06, and everything else under-represented by factors from 0.86 (active galaxies) down to zero for nine of the topics.

The opposite end of the distribution is represented by papers for which no citations at all have been recorded, 162 of the 4105 total in 2003, or 3.9%, which is slightly larger than the 3.3% of uncited papers from 2001 and 2002 in the three years after they were published. One could probably devise a metric by which this, plus the larger maximum C/P numbers, looked like increased variance. This 3.3–3.9% is probably an upper limit, because we spotted at least a few from major groups using large telescopes who surely cited

themselves in the next few years. You could also think of being cited as random, like being kicked in the head by your cavalry horse; note that an average of 13.65 citations in three years should have $(13.65)^{1/2} = 3.69$ scatter; and decide that zero is too far away from the average to bear interpretation of citations as a random process. You should be glad of this if you want to use citation rates as some measure of quality of a scientist, a journal, a university, or a facility.

Indeed the uncited papers are not distributed randomly over journals, subfields, or facilities. And there are no real surprises. Only *Nature* and *Science* are completely exempt. *Ap&SS*, *Astron. Lett.*, and *Astron. Rep.* contribute considerably more than their fair share, and *ApJ*, *ApJ Lett.*, and *MNRAS* less. The largest number of 2003 zeros belongs to *A&A* (60 out of 1198 papers or 5%). These largely report results on unpopular topics, obtained with poorly supported facilities, often by astronomers located in difficult countries, and one might think either of generosity of the journal editors or of self-selection by authors in placing such papers there. Neither you nor we nor authors choosing a journal for publication are unaware of the existence of page charges for some but not others.

In the middle, we find the average paper with 4.17 citations per year for 2001 publications, 4.21 for 2002, and 5.24 for 2003 publications. A wide sweep of physics journals that publish some observational astronomy (*Physical Review D*, *Physical Review Letters*, for instance) would add a few highly-cited papers (perhaps ACBAR results just be-

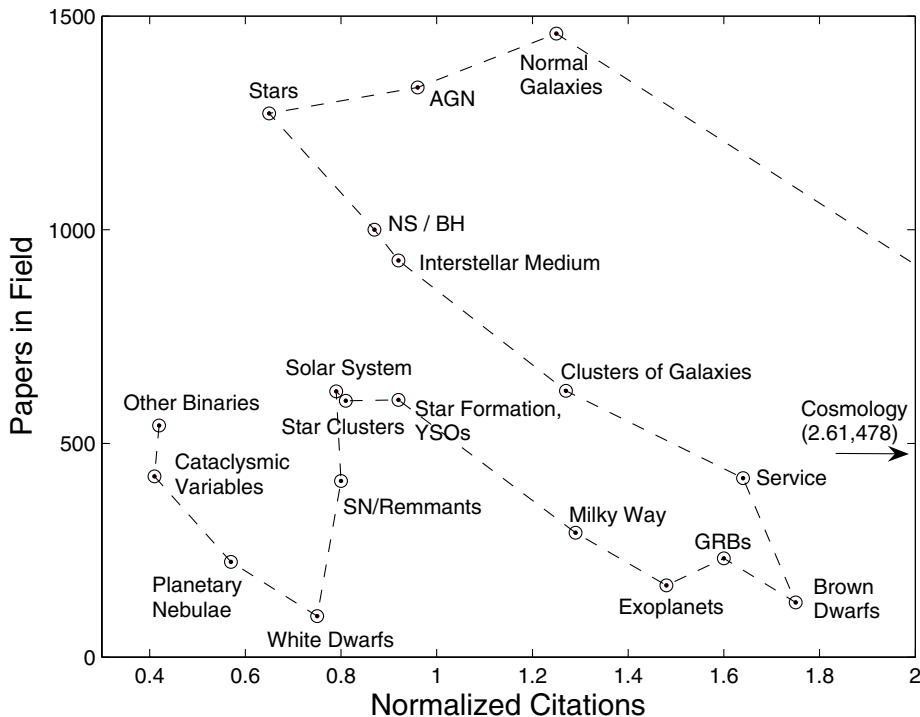


Fig. 1 The apparent absence of correlation between numbers of papers in a subfield (a proxy for size of the field) and the normalized citation rate (the right hand column of Table 2 divided by the rate for all papers). Notice that cosmology, with an intermediate number of papers, hangs far off the right side in citation rate. The only pattern we could see in these numbers came from a “connect the dots” experiment shown by the dashed line. The elder author, at least, is strongly reminded of the SCID-mouse.

fore WMAP entered the horizon). A more thorough culling of Solar System papers in *Earth, Moon, and Planets*; *Solar System Research*; and *Planetary and Space Science* would add a couple of dozen rarely-cited papers, since these journals have considerably smaller impact factors than *Icarus*. Someone would have to do quite a lot of work to see which way the average would shift if both these additions occurred.

Large vs. small numbers of citations per paper and superstar papers are not just (indeed not even primarily, we would say) a matter of community size, for which the number of papers published during the three years is a plausible proxy. Figure 1 displays papers per subject (from 96 for

white dwarfs up to 1439 for normal galaxies) vs. a normalized citation rate, from 2.61 for cosmology down to 0.42 for binary stars and CVs. The normalized rate is just C/P for the subject-divided by C/P for each year’s complete sample, averaged over the three years. Feel free to test any trends you think you see there.

We have left at least a few other do-it-yourself projects. Contemplate, for instance, the subject entries in Table 3. Cosmology and Service begin at the top and populate the entire list. On the other hand, there are three GRB papers in the top 16 and only one beyond; or one could look at citation numbers vs. sizes of the relevant IAU Commissions as a different proxy for community sizes.

Table 3: The papers most cited in three years after publication.

Number of Citations	Journal	Subject	Facilities
2770	ApJS	Cosmology	WMAP, ACBAR, CBI, AAT, HST, other optical
1301	ApJS	Cosmology	WMAP, optical & X-Ray unidentified
632	ApJ	Cosmology	HST
466	ApJS	Cosmology	WMAP
450	MNRAS	Galaxies	JKT, Siding Spring 2.3m, SDSS, IUE
397	ApJ	Cosmology	CFHT, CTIO-4, Keck II & I, CTIO-1.5, VLT, UKIRT, UHi 2.2, Vatican, WIYN, HST, SDSS
383	ApJS	Cosmology	WMAP, CBI, ACBAR, AAT, other optical
380	A&A	Service	XMM
375	AJ	Service	SDSS
370	A&A	Service	XMM
313	AJ	Service	SDSS
309	Nature	GRB	VLT 1 & 2
306	A&A	Service	XMM
298	ApJLett	GRBs	VLA, Keck, Palomar 5-m
281	ApJS	Cosmology	WMAP
281	ApJLett	GRBs	MMT, Magellan, Whipple-1.5
279	MNRAS	Galaxies	AAT
277	AJ	Service	Schmidt surveys (USNO catalogue)
275	ApJ	Cosmology	Boomerang
258	ApJ	Cosmology	HST, Keck, WIYN, ESO-3.6, CFHT, INT, ESO-NTT, CTIO-4
248	AJ	Service	USNO 1 m, SDSS
244	AJ	Cosmology	Keck
235	ApJ	Cosmology	DASI
232	MNRAS	Cosmology	AAT
224	ApJ	Cosmology	Maxima
223	ApJS	Service	WMAP, ACBAR, CBI, AAT, other optical
218	AJ	Galaxies	SDSS
218	ApJ	Cosmology	HST, Keck
210	ApJS	Milky Way	COBE, DAS1, CBI, WVA, IRAS, X-ray unidentified, Greenbank, Parkes, CTIO-small, KPNO-small, other optical (small), WMAP
208	AJ	Service	SDSS
205	ApJS	Cosmology	WMAP
186	ApJ	AGNs	VLT, ESO-NTT, 2.2, Chandra
185	ApJ	Galaxies	Keck
180	ApJ	Cosmology	Lick 3m
179	A&A	Service	XMM
177	AJ	AGN	SDSS, APO 2.5, Keck, HET, Calar Alto 3.5, HST
175	Nature	Cosmology	AAT
174	AJ	Service	SDSS
173	MNRAS	Galaxies	2MASS, AAT
170	ApJ	Cosmology	MDM 2.4m, Las Campanas 2.5m
170	AJ	AGNs	SDSS
169	ApJ	Galaxies	SDSS
168	AJ	Service	SDSS
162	A&A	Cls of Gals	XMM
159	AJ	Service	Chandra
157	AJ	Calibration	2MASS
154	AJ	AGNs	SDSS
156	ApJ	AGNs	HEAO-1, ASCA, Chandra

Continued on next page.

Table 3: Continued.

Number of Citations	Journal	Subject	Facilities
153	AJ	Cosmology	Keck, SDSS
153	Nature	Galaxies	VLA, JCMT, Keck
152	AJ	Catalog	Chandra
150	A&A	Service	Integral
148	MNRAS	Galaxies	SDSS
148	ApJLett	Cosmology	Maxima
145	MNRAS	AGNs	SDSS
143	ApJ	Galaxies	Keck
143	MNRAS	Cosmology	AAT
142	AJ	Galaxies	2MASS & other optical
141	MNRAS	Cosmology	AAT
139	Nature	Milky Way	VLT
139	AJ	Service	SDSS
137	ApJ	Cosmology	DASI
136	ApJS	Catalog	Chandra
134	AJ	Galaxies	Keck, JCMT, VLA, Chandra, U Hi 2.2m, CFHT
134	ApJ	Galaxies	JCMT, VLA (optical X-ray unidentified)
134	A&A	Service	Integral
133	A&A	Cls of Gals	XMM
131	ApJ	AGNs	Chandra
131	ApJ	Galaxies	WHT, Palomar 5m, KPNO 4m, Keck
130	MNRAS	AGNs	XMM
129	MNRAS	Galaxies	SDSS
125	A&A	Service	Integral
125	MNRAS	Galaxies	AAT, SDSS, Schmidt Surveys
125	ApJ	Galaxies	2MASS, SDSS
124	AJ	AGNs	SDSS
124	ApJ	Cls of Gals	XMM
124	ApJ	Cls of Gals	Keck I & II, Pal 5m, KPNO 4m, WHT, WSO 3.6 m, ESO NTT, Las Campanas 2.5m
123	ApJ	Galaxies	HST, KPNO-4, (other optical)
123	ApJS	Galaxies	2MASS, SDSS
121	ApJ	Cls of Gals	Chandra
120	Science	Solar System	Mars Odyssey
120	ApJ	ISM	1.2m mm at CfA
120	ApJ	Exoplanets	HST
119	ApJ	Cosmology	SDSS
118	A&A	Milky Way	Hipparcos, DENIS
118	MNRAS	Galaxies	AAT
117	AJ	AGNs	SDSS
117	AJ	Brown dwarfs	1.55 m Strand, Hipparcos, WIYN, 2MASS, USNO 1m, SDSS, HST
116	ApJ	Galaxies	Keck
116	A&A	GRBs	BeppoSAX
115	Nature	Exoplanets	OGLE, Keck I
115	ApJLett	Galaxies	2MASS
115	ApJLett	Cosmology	Keck
115	Nature	Cosmology	DASI
115	PASP	Service	HST
114	A&A	Cls of Gals	ROSAT, ASCA
114	ApJ	Star formation	SDSS
114	MNRAS	Catalog	VLA, Greenbank, RXTE, optical unidentified

Continued on next page.

Table 3: Continued.

Number of Citations	Journal	Subject	Facilities
113	MNRAS	Service	HST
112	Nature	Cosmology	Cassini, Goldstone
112	Nature	Neutron stars	Parkes, ATCA
112	AJ	Galaxies	Subaru, Chandra, Keck I & II, WIYN
111	MNRAS	NS/BH	Ryle, RXTE
111	ApJ	Cosmology	CBI
111	ApJ	AGNs	VLA, ROSAT
109	MNRAS	AGNs	HST, VLA
109	Nature	Cosmology	VLT
108	Nature	Milky Way	Chandra
108	MNRAS	Stars	UKIRT
105	AJ	Galaxies	SDSS
105	ApJ	ISM	COBE, IRTS
105	APJLett	Galaxies	KPNO 4m
104	ApJ	Cosmology	Boomerang
104	ApJ	Cosmology	Keck I & II
104	AJ	Service	Subaru, U. Hi 2.2m, UKIRT, JCMT, VLA, Chandra
103	ApJ	Milky Way	VLT-4, VLA, Gemini
103	ApJ	Survey	Chandra
102	ApJ	Cosmology	CBI
101	ApJ	Galaxies	Chandra
101	ApJ	Cosmology	ROSAT
101	ApJ	Galaxies	2MASS
101	MNRAS	Cosmology	AAT
100	ApJ	Cls of Gals	Chandra
100	MNRAS	Cls of Gals	Chandra

3.3 Optical telescopes

The numbers are in Table 4, and most of what can be said about them fit nicely into short “NASA bullets,” if you will remind yourself from time to time that the papers and citations have been equally shared among all optical telescopes contributing to a given publication.

- HST contributed the largest share of papers (16% in 2001, 17% in 2002, and 13% in 2003), and they had somewhat higher than average citations, but not enormously so (compared, for instance, to SDSS or the AAT).
- The three new large telescopes (Gemini, Magellan, HET) are still ramping up, having yielded 7.7 papers total in 2001, 25.4 in 2002, and 45.4 in 2003, by which time Gemini was sometimes (not always) declared to be north or south and Magellan sometimes (not always) Baade or Clay, but none was yet approaching, for instance, the 49.9 2003 papers from Subaru.
- Somewhat similarly, Keck and the VLT have been expanding from about one full time mirror to more. In 2003 there were 41.1 “Keck” papers, 45.9 “Keck I” and 44.4 “Keck II.” The corresponding ESO numbers were 56.4 “VLT”, 48.4 “VLT-1” or Antu, 38.6 “VLT-2” or Kueyen, 12.2 “VLT-3” or Melipal, and 13.3 “VLT-4” or Yepun. We think that most of the generic Keck and VLT credits are for observations made when only one mirror was up and running. Increasingly, however, there will be cases of observations performed in various service modes where the authors will neither know nor care which specific telescope was used. The table merges all Keck and all VLT numbers.
- If you look back at TC07, you will see that the VLT crossed over Keck to producing the largest number of papers (though not yet the largest numbers of citations) in 2003.
- We think there is some minor mystery connected with observatories that have more than one research telescope and the larger number of papers or more cited papers come from the smaller mirror. Calar Alto and the Crimean Observatory seem to fall in this class.
- The “other” category for sites with large telescopes includes both moderate numbers of smaller mirrors and (especially for ESO/La Silla) observations made at the site and not credited to a specific telescope, which could have been a large one.
- The separate “other/unidentified” class consists primarily of highly cited papers that credited part of the optical data to a specific telescope but also used in an important fashion H-alpha maps, optical redshifts, or other data that were not credited. Cases where optical data were important but none credited to a specific facility appear in Table 1 as multi-wavelength papers but do not appear here.
- The microlensing class includes observations of both exoplanets (often highly cited) and binary stars (less so), as well as lingering information on dark matter candidates.
- Telescopes also die, and some are slaughtered. Bolton (2007) reports that the DDO 74” is down to four users, only two (of whom he is one) on a regular basis. The Lick 3-meter and Las Campanas 2.5-meter had brief, golden revivals in 2001 (see TZB05) connected with exoplanet searches at the former and redshift surveys at the latter. Both sorts of investigations have moved largely to other facilities, and paper numbers, and citations per paper have both dropped for both telescopes.
- Of the various 4-meter-class telescopes that have been around since 1990 or earlier, CFHT and the AAT have held up best, with comparable numbers of papers per year and citation rates well into the range of the 8-m mirrors.
- The infrared facilities, IRTF and UKIRT are also still holding their own, but our prediction that both will eventually yield to Gemini-north is still on the table to be refuted.
- A 2.2 meter (or thereabouts) at Mauna Kea, La Silla, or Mt. Stromlo contributes a good deal more (and is probably a better bet for your research) than 2.2-m most other places or even something larger but remote.
- Astrometry (the product of meridian circles, refractors, prototype interferometers, etc.), however fundamental, is not much loved (compare determination of fundamental stellar parameters from binary stars in Table 2).
- Only HST yielded more total papers than telescopes of less than 1.5 meters diameter, but the citation rates are very different.
- the “all optical” number in Table 1 is larger than the total shown in Table 4 because of papers that mention using or obtaining essential optical data for the project but give no indication of the telescope(s) used. This happens also for radio and space-facility papers, but to a lesser extent.

Table 4: Papers and citations from optical telescopes.

Location/Telescope	2001 + 2002		2003			Total	
	Citations	Papers	Citations	Papers	Citations	Papers	C/P
HST	10044	728.7	5346	334.4	15390	1063.1	14.48
New Large							
Gemini	277	17.4	351	19.0	628	36.4	17.25
Magellan	140	9.4	340	18.2	480	27.6	17.39
HET	45	6.3	158	8.2	203	14.5	14.00
Mauna Kea							
Keck	4566	234.2	3566	131.4	8122	365.6	23.33
Subaru	766	58.2	660	49.9	1426	109.1	13.07
CFHT	1179	80.3	687	43.5	1866	123.8	15.07
U. Hawaii 2.2 m	422	37.0	245	16.3	667	53.3	12.51
UKIRT	959	80.2	539	50.1	1498	130.3	11.50
IRTF	547	49.2	454	33.4	1001	82.6	12.12
ESO							
VLT	2566	176.4	3130	169.1	5696	345.5	16.49
3.6 m	673	71.5	603	45.5	1276	117.0	10.90
NTT	926	78.0	698	50.0	1624	128.0	12.69
2.2 m	342	43.5	329	17.4	671	60.9	11.02
other	954	193.7	864	81.9	1818	275.6	6.60
Mt. Hopkins							
MMT	261	23.5	367	13.4	628	36.9	17.02
other	500	30.7	361	16.8	861	47.5	18.13
SAO Russian 6m	254	67.6	101	32.0	355	99.6	3.56
Palomar Mountain							
5 m	371	34.3	341	23.5	712	57.8	12.53
other	178	10.7	108	7.3	286	18.0	15.89
Canarias							
Wm. Herschel Tel.	1375	105.9	612	52.7	1987	158.6	12.69
TN Galileo	282	25.2	212	14.5	494	39.7	12.44
NOT	488	61.4	288	25.0	776	86.4	8.98
INT	641	63.8	334	24.0	975	87.8	11.10
other	322	43.5	279	17.0	601	60.5	9.93
CTIO							
4 m	727	60.4	471	35.6	1198	96.0	12.48
other	720	79.4	458	44.7	1178	124.1	9.49
KPNO							
4 m	797	53.5	447	25.7	1244	79.2	15.71
WIYN	323	33.4	297	14.0	620	47.4	13.08
MDM	381	24.9	244	12.1	625	37.0	16.89
other	960	68.1	507	38.4	1467	106.5	13.77
Australia							
AAT	2720	114.1	1872	56.1	4592	170.2	26.98
MSSO 2.3 m	315	23.9	267	8.6	582	32.5	17.91
other	157	16.4	117	9.7	274	26.1	10.50
Apache Pt. 2.5	142	18.2	162	9.2	304	27.4	11.09
Lick/Mt. Hamilton							
3m	683	35.7	102	11.0	785	46.7	16.81
other	146	11.4	206	7.7	352	19.1	18.43
McDonald							
2.7 m	399	34.1	229	17.2	628	51.3	12.24
2.1 m	122	11.7	107	8.1	229	19.8	11.57
other	74	8.7	10	2.5	84	11.2	7.50

Continued on next page.

Table 4: Continued.

Location/Telescope	2001 + 2002		2003		Citations	Total Papers	C/P
	Citations	Papers	Citations	Papers			
Crimea							
2.6 m	35	13.0	19	6.0	54	19.0	2.84
other	71	35.0	27	11.9	98	46.9	2.09
Calar Alto							
3.5 m	317	32.6	215	16.5	532	49.1	10.84
2.2 m	319	29.9	238	19.2	557	49.1	11.34
other	114	15.3	36	3.2	150	18.5	8.11
Mt. Wilson	-	-	51	3.0	51	3.0	17.00
Las Campanas							
2.5 m	459	39.3	274	17.4	733	56.7	12.93
other	303	27.9	48	5.5	351	33.4	10.51
WIRO	50	1.5	3	1.9	53	3.4	15.59
Bappu	14	8.0	19	2.9	33	10.9	3.03
Xinglong	194	25.7	106	15.7	300	41.4	7.25
Steward							
2.3 m	181	18.7	98	6.3	279	25.0	11.16
other	20	4.0	30	1.7	50	5.7	8.77
Pic du Midi							
2.2 m	35	9.6	44	7.2	79	16.8	4.70
other	1	2.0	3	1.8	4	3.8	1.05
Catanea (Sanchez)	42	15.0	13	2.4	55	17.4	3.16
Casleo	116	32.8	51	16.6	167	49.4	3.38
San Pedro Martir							
2.1 m	105	21.8	75	10.4	180	32.2	5.59
other	19	7.2	16	5.2	35	12.4	2.82
E. Europe 2-m class ^a	154	47.6	100	22.6	254	70.2	3.62
Obs. Haute Provence							
1.93 m	306	27.5	181	14.7	487	42.2	11.54
other	116	20.7	133	18.9	249	39.6	6.29
South African Ast. Obs.							
1.9m	172	28.6	109	14.8	281	43.4	6.47
other	231	42.0	136	20.1	367	62.1	5.91
David Dunlap Obs 1.9m	64	9.2	19	2.8	83	12.0	6.92
Natl. Obs. Japan							
1.88 m	111	12.1	28	5.3	139	17.4	7.99
other	19	5.3	16	5.8	35	11.1	3.15
Dom. Ap. Obs. 1.85 m	33	10.2	38	4.4	71	14.6	4.86
SDSS	3271	80.3	3964	80.7	7235	161.0	44.94
2MASS	1344	91.7	1593	91.2	2937	182.9	16.06
DENIS	146	14.7	265	13.4	411	28.1	14.63
Schmidt surveys	1574	96.3	1856	151.5	3430	247.8	13.84
Microlens searches	1017	70.4	818	49.5	1835	119.9	15.30
APTs	269	44.5	148	15.1	417	59.6	7.00
Astrometric	253	24.8	117	17.8	370	42.6	8.69
1.5–1.85 m	386	102.2	292	42.0	678	144.2	4.70
<1.5 m	1907	344.9	1245	188.8	3152	533.7	5.91
Unidentified	426	43.6	2128	11.0	2554	54.6	46.78
OPTICAL TOTAL	51912	4381.5	41011	2520.2	92929	6901.7	13.46

^a Bulgaria, Azerbaijan, Ondrejov, Terskol, Tautenburg, and Maidanak.

3.4 Radio telescopes

The data are in Table 5. Clearly the radio publishing event of 2003 was the appearance of the first year of WMAP data. The first light papers were very highly cited over the next three years, producing large C/P ratios for WMAP itself and for the facilities whose results were used in combination with it. The WMAP three-year data were not published until spring 2007, so it will be some time before one can see whether it will produce as large a bump (our guess is no).

The radio facilities are divided into three classes, (1) centimeter to meter wave dishes and receivers, all ground based except HALCA, (2) devices used primarily for studies of the CMB and very large scale structure, of which COBE and WMAP are satellites, Boomerang traveled by balloon, CBI lives in the Atacama, DASI at the South Pole, and so forth, and (3) millimeter and submillimeter facilities, including the satellite SWAS, but otherwise ground-based. Some names conceal more than one device, especially Greenbank (the 140', the 300', the early results from the GreenBank Telescope, and a couple of things in between), but also the Robledo and Goldstone parts of the Deep Space Network, included with "Australia, other" because Tidbinbilla was responsible for the largest number of papers.

No large temporal trends appear. Ooty was giving way to GMRT (and they have been combined in the table), the Ryle telescope in Cambridge was coming on line, and things were not getting any easier in difficult parts of the world.

Some famous names hide in the "other" categories, including the European VLBI Network, and we went back through the three years of raw data to see which ones might have approached or exceeded the five-paper minimum in the sum. What we found included Onsala (11.2 papers, prorated as usual), Dwingeloo (9.8), Nancay (9.7), Metsahova (6.3), Villa Elisa (6.2), University of Michigan (4.9), Har-tebeesthoek (4.4), Kosma (4.0), and Medicino (4.0). None of those specific papers or paper parts showed citation numbers very different from the classes in which they have been subsumed.

At first glance, it appears that the fraction of astronomy coming from radio wavelengths has had a growth spurt: 836 in 2001, 833 in 2002, and 963 in 2003. But notice that the Table 1 total (2632) is larger than the Table 5 total (2548), and more than half that difference arises from our having become more careful in recording as multi-wavelength papers ones that used radio data (sometimes redshifts, very often 21 cm maps, sometimes continuum maps at various frequencies) without indicating where those data had been recorded. The numbers of "pure" radio papers were about 550 each in 2001 and 2002 and 516 in 2003.

The VLA has remained the dominant organism throughout the period, contributing 22–23% of all radio papers each year. The nearest optical equivalent is, not surprisingly, HST, for which the average is 15% of optical papers. The single most productive "space" facility, the Chandra X-ray

telescope, comes in between at 18% over the three years and, again, no major year-to-year differences.

3.5 Space based astronomical facilities

The numbers are in Table 6, along with, when appropriate, launch and termination dates for the various missions. It is in the space-based realm that our snapshot approach is clearly least fair. Four missions launched in the present century were invisible in the papers of 2001 and 2002. Three of them (INTEGRAL in γ -rays, HETE in X- and γ -rays but tabulated with the γ 's and Mars Odyssey) clearly hit the air running, at least in terms of citation rates. ODIN (a Swedish submillimeter facility) was represented only by a first-lights package in *Astronomy and Astrophysics*. We had expected at least a couple of very-high-citation papers in the INTEGRAL first-lights issue of *Astronomy and Astrophysics*, but the mission team chose to publish 75 separate Letters (with almost as many first authors, presumably the motivation) rather than a few long papers with a single mission-description and single papers providing all the results about each class of interesting source. The largest number of citations in the next three years is, therefore, 150, compared to 380, 370 and 306 for the key XMM papers in 2001.

It is, on the other hand, of interest to note that at least five space observatories (ROSAT, IUE, ISO, IRAS, and CGRO), whose missions ended some time before 2003, have continued to contribute data to large numbers of papers with roughly average citation rates for their wavelength bands. Some of the papers are synoptic studies for which past fluxes and spectra are essential. In other cases (especially ROSAT and IRAS), nothing since has looked at the sky so thoroughly. In both contexts, the need for a fully stocked and well indexed virtual observatory is clear.

A few of the band designations are not perfectly describable by the single words in the table. Ground-based and space-based gamma categories include a few detectors and papers that actually are concerned with very high energy particles. Mir/Kvant includes just about everything flown, first, by the USSR and, later by Russia during the 14 years beginning in 1987. ODIN lives here (because of its short mission), while Prognaus (also a millimeter/ submillimeter project) is among the "others" of Table 5.

Our time frame happens to include the first light package for XMM-Newton, but just to have missed that for the Chandra X-ray Satellite (launched five months earlier). The comparison of their time histories so far is just interesting enough to justify a mini table (Table 7) which should probably be described as indicating a sort of gradual convergence in their scientometric footprints. You might be inclined to suspect (a) a certain amount of cream-skimming in the first year or two and (b) increased use of archival data by other than the original observers. Both count as things we think should happen in the astronomical community, and it would be interesting to know what the peak paper numbers and citation rates were for older missions in their first few years,

Table 5 Papers and citations from radio telescopes.

Facility	2001 + 2002		2003		Total		C/P
	Citations	Papers	Citations	Papers	Citations	Papers	
INTERFEROMETERS, PARTS USED SEPARATELY, AND SINGLE DISHES							
VLA	5634	380.9	2844	201.3	8478	582.2	14.6
VLBA + dishes	809	69.9	352	35.3	1161	105.2	11.0
Arecibo	636	56.4	333	28.3	969	84.7	11.4
Greenbank (all)	308	25.6	201	13.2	509	38.8	13.1
DRAO	88	14.1	143	17.0	231	31.1	7.4
Other W. Hemisphere	81	18.5	73	9.1	154	27.6	5.6
Aust. Tel. comp. Arr.	962	89.6	742	49.8	1704	139.4	12.2
Parkes	1164	68.1	505	30.5	1669	98.6	16.9
Aust. other + DSN	200	25.2	219	12.2	419	37.4	11.2
Merlin	326	38.0	177	18.2	503	56.2	8.9
Jodrell Bank (all)	153	14.5	64	5.1	217	19.6	11.1
Ryle	49	6.5	214	6.7	263	13.2	19.9
Euro. VLBI Network	150	19.3	54	7.7	204	27.0	7.6
Westerbork	447	37.2	194	24.1	641	61.3	10.5
Effelsberg	355	38.7	257	23.5	612	62.2	9.8
Puschina	36	12.3	31	12.7	67	25.0	2.7
RATAN600	26	12.2	25	5.2	51	17.4	2.9
Other Europe	369	75.5	190	22.0	559	97.5	5.7
GMRT + Ooty	98	24.0	108	12.1	206	36.1	5.7
Other Asian	81	19.5	32	4.3	113	23.8	4.8
VLBI other	69	12.6	46	8.4	115	21.0	5.5
HALCA	29	4.0	1	0.3	30	4.3	7.0
Class Total	12018	1060.0	6857	547.0	18875	1609.7	11.7
CMB AND COSMOLOGICAL STUDIES							
WMAP	–	–	2878	34.9	2878	34.9	82.5
COBE	423	25.2	305	20.1	728	45.3	16.1
Boomerang	610	12.4	111	5.0	721	17.4	41.4
Maxima	570	8.3	52	3.3	622	11.6	53.8
DASI	607	5.7	66	1.5	673	7.2	93.5
VSA	–	–	208	8.2	208	8.2	25.5
CBI	–	–	798	5.3	798	5.3	149.4
Other CMB	365	17.0	703	10.3	1068	27.3	39.1
3C, 6C, 7C, etc.	229	16.6	69	5.2	298	21.8	13.7
Class Total	2804	85.2	5190	93.7	7994	178.9	44.7
MILLIMETER AND SUBMILLIMETER							
NRAO 12 m	300	25.2	158	10.3	458	35.5	12.9
Caltech SO	273	19.3	187	12.2	460	31.5	14.6
5 Coll. RAO	308	21.3	77	13.9	385	35.2	10.9
OVRO	472	42.7	194	14.5	666	57.2	11.6
BIMA	566	39.2	265	19.0	831	58.2	14.3
SWAS (satellite)	170	14.6	19	2.0	189	16.6	11.4
JCMT	1951	102.2	1266	75.9	3217	178.1	18.1
IRAM 30 m	1108	73.0	477	40.2	1585	113.2	14.0
IRAM Interf.	361	24.7	319	17.7	680	42.4	16.0
SEST	305	35.9	125	18.9	430	54.8	7.9
H. Hertz	65	10.1	24	5.8	89	15.9	5.6
Nagoya 4 m	84	16.1	8	2.0	92	18.1	5.1
Nobeyama 45 m	199	34.0	70	9.8	269	43.8	6.2
Nobeyama Int.	72	12.9	59	11.2	131	24.1	5.4
Antarctic submm	40	5.3	–	–	40	5.3	7.6
Other mm /submm	342	25.4	49	3.9	391	29.3	13.3
Class Total	6726	501.9	3296	257.3	10023	759.2	13.2
RADIO TOTAL	21548	1647.0	15346	901.0	36894	2548	14.5

Table 6 Papers and citations from space-based facilities.

Facility	2001 + 2002		2003		Total		C/P
	Citations	Papers	Citations	Papers	Citations	Papers	
X-Ray:							
XMM (12/99–)	5346	170.4	2647	161.6	7993	332.0	24.08
Chandra (7/99–)	11929	434.6	5007	288.9	16936	723.5	23.41
ROSAT (6/90–2/99)	3269	236.2	1517	118.9	4786	355.1	13.48
BeppoSAX (6/96–4/03)	2181	143.3	716	49.4	2897	192.7	15.03
ASCA (2/93–7/00)	2303	171.2	543	38.2	2846	209.4	13.59
RXTE (12/95–)	3145	232.0	1473	104.7	4618	336.7	13.72
Einstein (11/78–4/81)	154	10.6	50	5.2	204	15.8	12.91
Ginga (2/87–10/91)	70	11.4	43	2.5	113	13.9	8.13
Exosat (5/83–4/86)	60	5.2	16	1.7	76	6.9	11.01
Other X-ray	270	30.5	225	8.3	495	38.8	12.76
X-Ray Total	28727	1445.4	12237	779.4	40964	2224.8	18.41
UV:							
FUSE (1/99–10/07)	1415	93.1	787	61.8	2202	154.9	14.20
EUVE (6/92–1/01)	316	33.5	99	12.2	415	45.7	9.08
IUE (1/78–9/96)	702	96.0	802	38.9	1504	134.9	11.15
UIT (2 weeks in 1995)	140	11.5	45	1.5	185	13.0	14.23
Other UV	298	41.4	113	10.4	411	51.8	7.93
UV Total	2871	275.5	1846	124.8	4717	400.3	11.78
Optical / IR:							
HIPPARCOS (8/89–8/93)	1778	148.0	662	73.4	2440	221.4	11.02
MSX(4/96–2/97)	137	12.8	162	22.5	299	35.3	8.47
ISO (11/95–5/98)	4503	295.0	1503	125.2	6006	420.2	14.29
IRAS (1/83–11/83)	1456	117.4	902	73.4	2358	190.8	12.36
Other opt/IR	345	20.1	375	14.5	720	34.6	20.81
Optical / IR Total	8219	593.3	3604	309.0	11823	902.3	13.10
Gamma Rays:							
CGRO (4/91–6/00)	1005	84.8	418	39.9	1423	124.7	11.41
Mir/Kvant (3/87–3/01)	127	21.5	41	4.8	168	26.3	6.39
INTEGRAL (10/02–)	–	–	1174	75.8	1174	75.8	15.49
HETE (10/00–)	–	–	345	14.3	345	14.3	24.13
Other (space)	124	7.4	21	0.9	145	8.3	17.47
HEGRA	219	10.8	325	8.3	544	19.1	28.48
Other (ground)	332	22.2	201	21.1	533	43.3	12.31
Gamma Ray Total	1807	146.7	2525	165.1	4332	311.8	13.89
Solar System;							
Cassini (10/97–)	153	8.3	206	5.0	359	13.3	26.99
Galileo (10/89–9/03)	495	34.2	37	5.8	532	40.0	13.30
MGS (11/96–2006)	488	27.7	405	23.6	893	51.3	17.41
Mars Odyssey (4/01–)	–	–	217	7.6	217	7.6	28.55
Voyager (1979–)	96	16.5	213	15.6	309	32.1	9.63
NEAR (2/96–2/01)	294	10.3	0	1.0	294	11.3	26.02
Other solar system	569	36.5	109	11.8	678	48.3	14.04
Solar System Total	2095	133.5	1187	70.4	3282	203.9	16.10
Other:							
ODIN	–	–	101	11.0	101	11.0	9.18
Solar for non-solar Ap.	–	–	162	10.9	162	10.9	14.86
Uncertain wavelength	–	–	57	13.5	57	13.5	4.22
SPACE TOTAL	43719	2597.0	21719	1484.7	65438	4081.7	16.03

Table 7 Time histories of papers and citations rates from XMM and Chandra.

Year	Chandra		XMM	
	Papers	C/P ^a	Papers	C/P ^a
2001	175.8	34.6	83.5	43.4
2002	258.8	22.6	86.9	19.6
2003	288.9	17.3	161.6	16.4

^a Citations per paper for the next three years.

while tracking SPITZER, Messenger (Mercury), and other new space-based observatories is left for future investigators!

4 Conclusions and implications

Over the past three years, we have attempted to provide quantitative information on the extent to which the full variety of astronomical facilities – radio wave to gamma rays; small private telescopes to the GigaDollar class – provide data that are then published in the main stream astronomical literature and the rates at which those publications are cited over the next few years. We conclude from the numbers shown here and those in the previous four papers that three years of publications, and three following years of citations, is sufficient to make the numbers robust for nearly all telescopes, observatories, and so forth. The most difficult case is that of orbiting telescopes and solar system missions, whose lifetimes are frequently not longer than the time needed to gather data for a paper, publish it, and wait for your colleagues to cheer, though the situation is not as grim as we had supposed before gathering the numbers. Yes, new things are launched, with luck have a superstar year or two, and then fade back to average before disappearing completely. But IUE, IRAS, and ROSAT will apparently be providing significant archival data for a long time. At the other extreme, Uhuru was cited as a pioneer in a number of papers, but only a couple made actual use of data gathered by it.

We have numbers in hand to study, but have not done so here, citation rates by journals, correlations of C/P with numbers of authors and lengths of papers, and some statistical traits of very high impact papers. And in response to a question we were asked privately, yes Gemini might have been wiser to produce a “first lights package” in 2002 or 2003 rather than let results appear from a very few observing programs as soon as they were ready.

Finally, we think the methods used here and pioneered for optical telescopes alone by Abt (1981) might well be applied to major shared facilities, data bases, tissue banks and germ cell lines, competing sources of SCID-mice², and other entities needed for research in fields very different from astronomy where things are expensive enough that researchers cannot have as many as they want. We would be happy to provide free advice, which is frequently worth just what you pay for it.

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References

- Abt, H.A.: 1981, PASP 93, 207
- Abt, H.A.: 1985, PASP 97, 1050
- Abt, H.A.: 2007, Scientometrics 72, 105
- Madrid, J.P., Macchetto, F.D.: 2006, BAAS 38, 1286
- Trimble, V.: 1995, PASP 107, 977
- Trimble, V.: 1996, Scientometrics 36, 237
- Trimble, V., Ceja, J.A.: 2007, AN 328, 483 (TC07)
- Trimble, V., Zaich, P.: 2006, PASP 118, 933 (TZ06)
- Trimble, V., Zaich, P., Bosler, T.A.: 2005, PASP 117, 111 (TZB05)
- Trimble, V., Zaich, P., Bosler, T.A.: 2006, PASP 118, 651 (TZB06)
- White, S.D.M.: 2007, RPPH 70, 883

² The senior author, many years ago, was a member of a committee that had to choose the outstanding paper from a group of several dozen touching on fields from string theory to clinical care, and, at the end, we admitted that, almost until we had selected that paper, we thought Skidmaus was the author.