Astrophysics Faces the Millennium VI

People, Places, Papers, and Power

by VIRGINIA TRIMBLE

When I was very young, I met an elderly member of the Sedgwick family, who had known someone, who had known someone, who had known Newton.

—Prof. Sir William H. McCrea (1904–2000)

SINCE SIR BILL was, in all other respects a gentleman of extreme probity (who will be quoted again), I have every reason to suppose this is true. It is, anyhow, perfectly possible, as you can figure out for yourself, if you get out your envelope back* and remember that Sir Isaac's dates were 1642–1727 (he managed, after all, to buy into the South Sea Bubble twice). That all of modern science is remarkably close to us, even in so ephemeral a unit as human generations, is a point to which we will return in this sixth, and probably last, episode of the continuing story of triumphs and tribulations of the Astrophysics Family over the past centuries. The thrust this time will be not the specific scientific advances (as in parts I to IV) or the synergistic technologies (as in part V), but some aspects of who has contributed to astronomy, where and how, and the ways in which the results of their endeavors have been promulgated. Some aspects you will have known before or recognize as just what you expected. Others may surprise. Inevitably, I

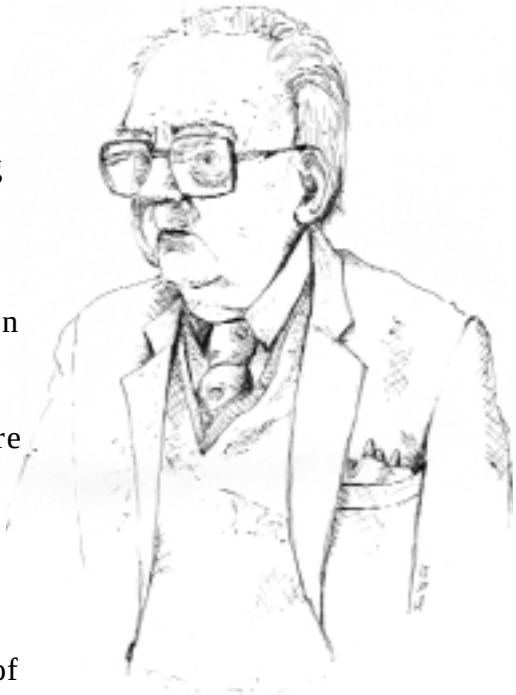
* *You may also need a pen or pencil, and I will buy dinner at the 2003 April APS meeting for anybody who remembers the Harry Lauder joke of which this is reminiscent.*

will succumb to the temptation of "why" and will try, at least, to be honest about where there are supporting data and where I'm just guessing.

PLACES AND PALABRAS

"'I'm learning Chinese,' said Wernher v. Braun," according to Tom Lehrer (or Wernher versus Braun, as a helpful copy editor once expanded the name). In other words, the world center of science in general and of particular sciences has shifted many times in the past and will surely shift again in the future. Thus, a thousand years ago, if you wanted to study astronomy, it would have been perfectly reasonable to go to China (if you had known about it), where they were compiling the Soochow Star Chart, recording the brightness of the supernova of 1054, and even forecasting some eclipses. And it may well be reasonable to go there for astronomical education again some day.

Before that, of course, came "the Greeks." Remember, however, first that they built on a Babylonian foundation of careful observations of positions of Venus, times of eclipses, and so forth, and, second, that "Greece" was, depending on your point of view, either bigger or more movable then than now, including southern Italy (the Pythagoreans), Asia Minor (Thales of Miletus, Anaximander), and Alexandria (Ptolemy, Aristarchus, Eratosthenes), though even then people went abroad for their graduate studies, as for instance Eudoxus of Cnidus, to interact with Plato in Athens. One suspects that the international language of science (natural



Sketch of Bill McCrea drawn by Jonathan Hare in 1996.

philosophy) in those days was broken Greek. At other distant times, there have been centers of excellence in astronomy in the Yucatan peninsula; Baghdad; Moslem Spain; Turkey, India, and Samarkand; and elsewhere.

Closer to the present, both the supporters of the Aquinian synthesis (Winter 1999 *Beam Line*, Volume 29, No. 3) and the framers of the ideas and instruments that eventually overthrew it were scattered across the face of western Europe, from Ireland (where, in the 700s, they had kept better track of the date of Easter than had Rome) eastward. Thus, you might, within a decade either side of 1600, have gone, with equal good sense, to study with Digges in England, with Kepler in Prague, or with Galileo in Padua, though it would have been a tactical error to go to Rome to study with Giordano Bruno after about the middle of 1600. They and their students often wrote in, and presumably spoke, Latin as well as their vernaculars (and no, I don't know whether Copernicus's first language was Polish or German). These were, as you know, also the places where many of the other foundations of modern learning were being established, and probably even then, they had significantly larger per capita incomes than most of the rest of the world. Co-development with other sciences and correlation with disposable income have always been characteristic of the astronomical centers, though I think these are not the whole story. Tycho's observatory at Hven is said to have cost about the same fraction of the income of the Denmark of Fredrick II as the European Southern Observatory did of the income of its member countries.

From the middle of the seventeenth century into the 1800s, most of the people to be found in indices of books on history of astronomy lived in places where the vernacular was English, French (including Huygens in Paris, despite his name), or German. The first modern, national observatories arose primarily to serve the needs of navigation, beginning with Paris in 1667 and Greenwich in 1675, followed by San Fernando (Spain) in 1757 and Coimbra (Portugal) 1772, all with almanacs in the vernacular and, often, coordinates centered at their own locations. What we now call Germany and Italy followed a different pattern, and by 1800 there were observatories in, at least, Heidelberg, Potsdam, Krakow, Munich, Hohenpeissenberg, and Göttingen; and Naples, Padua, Palermo, Torino, Trieste, and Pisa. None was a national observatory, and one is enormously tempted to say that the lag as well as the multiplicity were caused by the lack of political unity. It is also true that their locations put them in less urgent need of accurate astronomical information for navigational purposes than was the case for England, France, Spain, and Portugal.

Astronomy, along with the rest of modern science, flowed gradually back from Western Europe to China, India, Japan, the Middle East, and other places where it had once flourished. "Why?" is irresistible here, but all I think I know about the topic has been said better by Jared Diamond (*Guns, Germs, and Steel*, 1999, but the book is really about geography, agriculture, technology, and demographics).

The eventual 500 pound gorilla appeared as a very small marmoset with the founding of the US Naval Observatory (again navigationally motivated and first urged by John Adams) in 1830 and the first college observatory at Harvard in 1839. Next were Cincinnati (1843), supported by the citizens of the city, and Dudley Observatory (Albany, NY, 1856), the creation of a private philanthropist. Notice also that these four illustrate the four main ways in which American astronomy supports its activities to this day. National and educational funding are part of the world pattern, but community and private funding are as American as maize (started here and slow to catch on elsewhere).

At present, US-based astronomers make up about one-third of the membership of the International Astronomical Union; publish a comparable fraction of the papers in astronomy, astrophysics, and cosmology; and educate a comparable fraction of the PhDs and postdocs entering the field. International mobility is probably rather higher than in most (other?) branches of physics. The international language is broken English

(I speak it myself after a couple of conference weeks). And the number of IAU members resident in a given country is a reasonable proxy for gross national product (see table on page 54). The table is neither alphabetical by country nor in order by population or GNP, but attempts to group the countries meaningfully. It is discussed a bit more under "People."

Somehow the properties of the places where these various centers appeared do not seem to have mattered as much as you might suppose. Alexandria, Athens, and Baghdad are indeed relatively cloudless, and the proximity of cities mattered little in pre-Edisonian times. But neither England, Germany, nor most of France are known primarily for their sunny skies. The same can be said for the Netherlands, which had a large, active astronomical community well before the advent of radio astronomy enabled its practitioners to peer through their clouds. In fact, the focussing of astronomers around clear, dry, high, dark mountains began only with the development of the California sites at Mt. Hamilton (Lick Observatory) and Mt. Wilson-Palomar. And, though the telescopes themselves are now more than ever concentrated to such sites (including the still clearer, dryer, higher, and darker reaches of space), the advent of remote observing means that the astronomers need not be.

It is therefore no surprise that people today do astronomy in more countries, cities, universities, observatories (some in name only), and all the rest than ever before. Good locations and large disposable income matter, of course, but (perhaps above some critical threshold level) do not dominate. McCrea (I said you would meet him again), when asked to provide an autobiography about 15 years ago, wrote instead on "clusterings of astronomers," mostly ones of which he had been part in his 65 year career. They were clusterings in four-dimensional space (Cambridge under Eddington, the Admiralty during World War II, UC Berkeley under Otto Struve, Warner and Swasey under McCuskey, this last quite focussed on certain aspects of stellar astronomy, and so forth). McCrea suggested a variety of causes (with interesting names like "the boat race effect" and "the Halley effect"), but feared his paper might well have been rejected by a refereed journal for lack of quantitative data.

THE JOURNAL OF THE SOCIETY OF SUCCESSFUL MAMMOTH HUNTERS

I have said before, and continue to think it true, that our modern professional societies with their meetings and publications are the remote descendents of a hunting party hunkering down around the fire to exchange stories about who did what during the current hunt, how it compares with previous hunts, and what they hoped to accomplish next time, and of painting a somewhat idealized version of the day's activities on cave walls. That is, they serve to validate a community and its shared store of knowledge, customs, and experiences.

The first purely secular (but largely amateur) scientific society was the Royal Society of London, founded in 1660, with its *Philosophical Transactions* appearing on the scene in 1665. Various other national, state, and city academies of science and their publications followed, beginning slowly in French-, German-, Italian-, and Scandinavian-speaking lands, and continuing down to the present, with flurries of activity whenever periods of international upheaval resulted in new, newly-Westernized, or newly re-established countries.

On the astronomical front, the national observatories published their almanacs, beginning with *La Connoissance* des Temps* from Paris in 1679 and the

* *No this isn't a typrographical error, just an old spelling, preserved, for instance, in the English cognate "reconnoiter," to be compared with "reconnaissance" related to the modern French spelling and "recognizance," more directly from the Latin recognoscere, to recall. While we're looking at words, the mythical society of course consisted of successful hunters of mammoths—the successful mammoths got away—but misplaced modifiers are almost as old a part of the scientific tradition as the ordeal or qualifying exam.*

Nautical Almanac and Astronomical Ephemeris from Greenwich and London in 1767, and eventually other kinds of papers as well. Observatory publications (of which more later) have no direct equivalent in most other sciences, except perhaps museum publications in taxonomy.

The first astronomical society, the Astronomical Society of London, and the first non-observatory regular publication, *Astronomische Nachrichten*, arose almost simultaneously in 1820 and 1821 respectively. Among the "causes for which I have no real evidence" you can include the thought that England, a long-unified country with a single focus of culture in London, "should" have begun with a society, holding regular meetings, and with members as close as Bristol and Cambridge designated as non-resident; while Germany, still divided and with many foci of learning, "should" have begun with a journal, whose editor received communications from colleagues all over Europe, and soon the world, had them typeset, and sent them back regularly to all the contributors.

The ASL (whose founding president was William Herschel) was chartered as the more familiar Royal Astronomical Society in 1831, at which point all its roughly 250 members became fellows (The founding population was about 100, that international and generation-transcending constant.) Publication of its *Memoirs* (the first astronomical society publication) began in 1821. Initially, the contents consisted largely of papers that had been presented in brief form at the monthly meetings. Soon it was necessary for the editors to point out that the fact that the President and Fellows had thanked a speaker for his presentation at the end did not necessarily reflect unqualified approval or guarantee space in the *Memoirs*. A small committee reviewed contributions from time to time and recommended to the Council of the Society which ones should be published. Thus *Memoirs* of the RAS can claim also to be the first refereed astronomical publication. Early issues had a very few items in French, but *Mem. RAS* soon became relentlessly monoglot, as did the other publication, *Monthly Notices of the Royal Astronomical Society* (debut 1827, now publishing 36 issues per year, and one of the leading three or four in the field worldwide).

Contrasting in many ways was *Astronomische Nachrichten*, for its first quarter century very much a one-man operation. The man was Heinrich Christian Schumacher, born in Bramstedt, duchy of Holstein (German-speaking but subject to the King of Denmark since about 1460). With functional literacy in five or six languages, Schumacher offered to publish astronomical contributions in "any European language." French and English were common from the beginning, and the fraction of English-language text has increased monotonically from a significant minority in the 1920s to nearly 100 percent at present (though the journal has become a marginal one after 40 years of near isolation in East Germany). The German society, Astronomische Gesellschaft, founded in 1863 in the context of the gradual unification of the country, assumed responsibility for *AN* late in the nineteenth century.

The first American astronomical journal (called the *Astronomical Journal*)* was a deliberate, though monoglot, imitation of *AN*, started by Benjamin Apthorpe Gould in 1849, after he had visited Schumacher and studied with Gauss (yes, that Gauss). Publication stopped at the onset of the War Between the States, but resumed, at Dudley Observatory, in 1896. The journal survives, now owned by the American Astronomical Society (founded in 1899 by about 100 people, under the name of the Astronomical and Astrophysical Society of America).

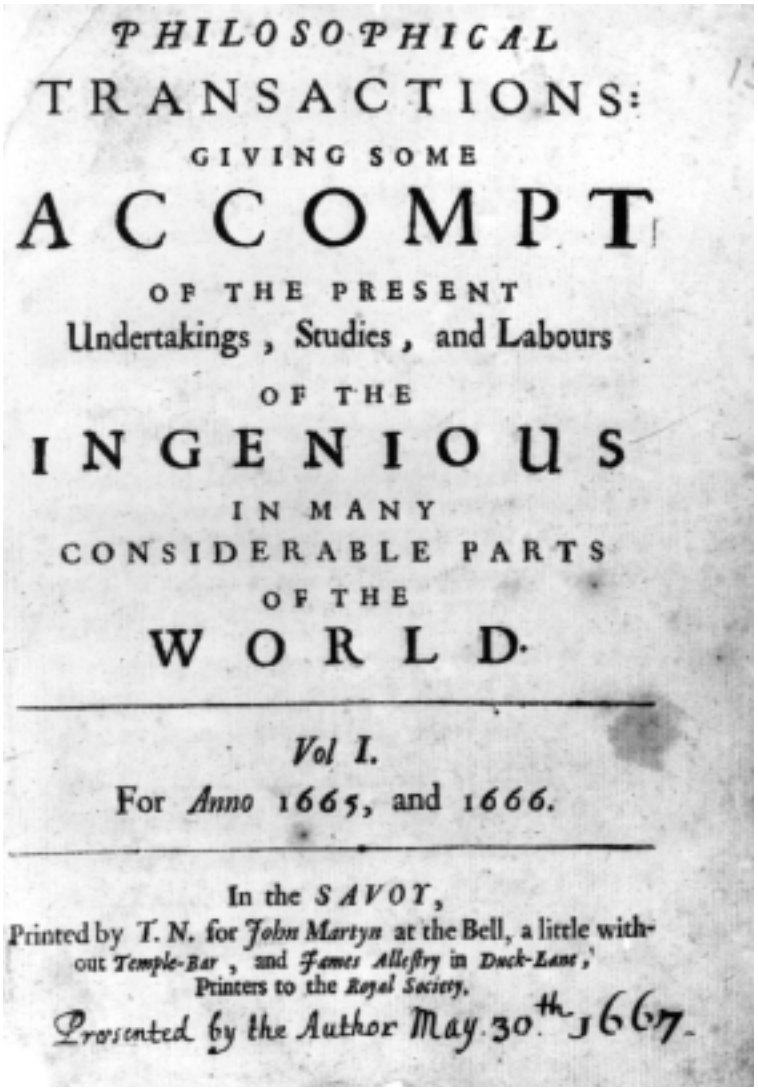
Somewhat later come national societies and/or publications in France (1887), Italy (1872), Belgium (1880), Canada (1868), Japan (1908), South Africa (1912), China (1922), New Zealand (1920), Poland (1925), Ireland (1937),

* *Yes, but remember that the answer to "who was born on Lincoln's Birthday?" is Charles Darwin, and to the others, "Mr. and Mrs. Grant," "1812-1815," and "future Americans, under George Washington, as well as the French and Indians."*

Netherlands (1921), Scandinavia (1916), Czechoslovakia (1947), and the Soviet Union (1924).

Astrophysics originally meant the application of spectroscopy to astronomical objects. It began with the recognition of sodium lines in the spectrum of the sun by Kirchhof and Bunsen (1858–1859) and spread rapidly through the scientific world, gaining converts from physics, chemistry, traditional astronomy (occasionally), and less likely disciplines, including medicine and brewing, in communities where amateur and professional astronomers still mingled. Stress and strain arose between the "new" (astrophysical) and "old" (positional) astronomers, with harsh words uttered on all sides. In England, the RAS and its publications managed to absorb the new topics, and issues of *MNRAS* from the 1920s and 1930s consist primarily of astrophysics, in the original sense, as well as the newer one of applying modern physics to problems of stellar, galactic, and cosmic structure and evolution. The American community partially fractured with the founding of the *Astrophysical Journal* in 1895 by George Ellery Hale and a few associates. It eventually spread over the entire country, and later the world, and the entire range of astronomical subfields, though there have been times when the editors thought it necessary to say explicitly that they would welcome papers in instrumentation, radio astronomy, and so forth (and were not always believed). The German and French communities also bifurcated as they grew, with *Zeitschrift für Astrophysik* in 1930 and *Annales d'Astrophysique* in 1938. Both were originally in the vernacular, but contained a good many papers in English by the time of their 1969 demise. *ApJ* was English-only from the beginning and remains so, though the second commonest phrase in its referees' reports is, "The English is perfectly awful." The commonest, of course, is some polite variant of, "the author hasn't cited enough of my papers."

No other national communities spawned separate astrophysics publications, and the practitioners either turned to academy proceedings and journals of physics in their home countries, or, increasingly to the *ApJ*.


PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

Vol I.
For Anno 1665, and 1666.

In the SAVOY,
Printed by T. N. for John Martyn at the Bell, a little without Temple-Bar, and James Allestry in Duck-Lane,
Printers to the Royal Society.
Presented by the Author May 30th 1667.

RUN-AWAY EVERYTHING?

"Is your journal still growing exponentially?" "No," said the editor of one of the higher-profile ones a while back.

"It's only about 5 percent per year." Apart from the misunderstanding of what is meant by "exponentially" incorporated in this response, it is interesting because (a) it is roughly true for numbers of astronomical words published during the 1990s, (b) it is rather steeper than the growth in numbers of astronomers during the same period, and (c) it must also be steeper than the 300 year average. Five percent per annum is a doubling time of 14.2 years or a factor of 2×10^6 in 300 years. Early volumes of the *Phil. Trans. Roy. Soc.* already carried more than one astronomical paper per year, and while the current literature is more than you would care to read, it comprises at very most 10^5 papers per year, not something $\times10^6$ (that is average growth rate 4 percent or a bit less per year). Point (d), you do not need to be told, is that this cannot keep up forever.

Returning to the present, it is true that there are "more" (1) astronomical societies, many of the recent ones belonging either to relatively new countries (the separate pieces of the former Czecholovakia, Yugoslavia, and Soviet Union) and developing countries, or to subspecialties, like divisions of solar physics, plasma astrophysics, and high energy astrophysics within larger organizations; (2) conferences (the growth rate for these was a good deal more than 5 percent a year, I think, but have not collected the supporting data); (3) papers; and (4) pages per paper (see figures on pages 50 and 51), though, looking back at the screeds of the 1700s, this must have gone through a relative minimum in the days of Schumacher and Gould (each of whom, incidentally, is worth very much more than the one-line mentions they get here).

Item (1) is (again without concrete evidence) part of the "validation" function of the campfire conversations and cave paintings for new platoons of mammoth hunters. Item (4) as the graphs show is not peculiar to astronomy or to the US from World War II up to 1981, though only the US astronomy curve has been extended to the present. Those are real data, collected by laboriously looking individually at, for instance, 31,161 papers published in the *Journal of the Chemical Society of London* between 1898 and 1965 and somewhat smaller numbers in each of 21 other journals and letters sections. The data almost went unpublished, because the first referee (the hero of the "5 percent a year" story, not entirely by chance) felt firmly that papers had got longer because they were reporting more science, that this was all to the good, and I should say so. I was not about to say so, and there the data might well have languished.

Enter again, however, Prof. W. H. McCrea, to whom I sent a copy of the manuscript (for reasons long forgotten). His response was that he could think of several explanations, not related to content, and a test to distinguish content-related from other hypotheses. These included increased numbers of authors for whom Eng lish was not the first language, less firm grounding in English grammar on the part of the native speakers (yes, his was exquisite), and enormous reduction in the amount of work involved in putting words and pictures on paper compared to the days of his first publications, when manuscripts were truly written by hand (and sometimes sent to the editor that way) and diagrams were drawn in India ink on Bristol board by the author. Word processors and computer-drawn diagrams became common about the time he stopped reading the literature (several years of blindness preceding his death), and I both shudder to think what he would say about the current mean paper and increasingly concur that ease of casting forth words is not an unalloyed good. At any rate, his comments inspired me to inflict the manuscript on a couple of historians of science and another editor. No two put forward quite the same set of whys, and the paper eventually appeared with a discussion section resembling the instructions for interpreting Rorschach ink blots (did you know Rorschach was only 37 or 38 when he died?).

Now comes the surprise. What there are not more of is journals in which to publish those more-and-longer astronomical papers. And there has been a gradual accompanying shift in publication patterns. Many of the prolific and well-known astronomers of the nineteenth

century placed half or more of their papers in academy proceedings and other venues in which astronomy rubbed pages with physics, biology, and so forth. Nearly all produced books recording their more extended efforts. And they made use of observatory publications, some restricted to authors at the particular observatory, many not.

I have found citations or library listings for more than 200 of these. They appeared regularly or sporadically, over a few years for some and many decades for others, were typically exchanged for other observatory publications rather than being sold by subscription (a blessing for astronomers in countries whose currencies were not freely convertible), and they carried something like 1/6th of the abstracted literature during their heyday before 1940. Their names are a litany of the exotic—Aarhus and Abastumani, Delaware and Dunsink, Lembang and Lemberg, Perth and Poona, Zose and Zurich. Some, like the series from Harvard and Groningen, were famous and carried fundamental papers. All are gone (except, perhaps, in virtual form as numbered lists of papers published by the staff in ordinary journals). The last to provide important results in separate, observatory publication form was the Dominion Astrophysical Observatory in Vancouver. I still use one or two of its late products.

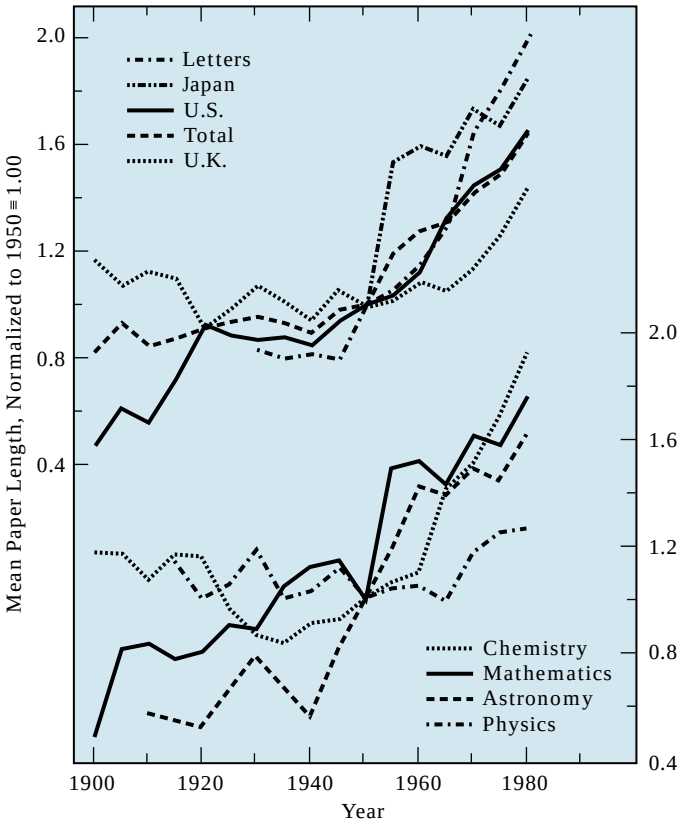
In contrast, the turn of the (new) century astronomer or astrophysicist publishes nearly all his papers in one or a few specialized journals (plus conference proceedings) and produces monographs only of the text and trade book variety, if at all. And the list of possible journals has shrunk. Five European ones (two French, two German, and one Dutch) merged in 1969 to form "the European journal" *Astronomy and Astrophysics*. *Bulletin of the Astronomical Institute of Czechoslovakia* and *Irish Astronomical Journal* (whose establishment was part of the post-war "validation" process) have since folded, aiming their former authors toward *A&A*.

The result is very considerable concentration of power in a few editorial hands. And, although two of those are mine, it is not a trend that I can regard as altogether benign. You will think immediately of the various sorts of web and Internet postings as a contrary trend, and you will be right to a certain extent. But the high-prestige ones are also under some control by small numbers of (I think) human beings, and the free-for-all ones are unlikely to be read. This was, of course, also true for the more obscure paper journals. The difference is that at least a few paper copies of these remain. I have read (not necessarily for very good reasons) publications from Dorpat (started in 1817) and Dushanbe (1934) and in the past few weeks papers from the 1728 and 1767 volumes of *Phil. Trans. Roy. Soc.* (special thanks to Brenda Corbin of US Naval Observatory for making these available), and rather doubt that the same will be possible for papers now posted when the year 2274, or even 2074, rolls around, though even the later of these is no more distant from us than Sir Isaac from Sir Bill.

Incidentally, detailed data exist to support the above remarks about publication patterns and have, so far, been rejected by two editors.

PEOPLE

The first astronomer could have flourished any time after 1366, the first physicist and the first scientist not until after about 1840, reflecting simply the first appearances of the words. The latter two are usually credited to William Whewell, though cases can be made for Mary Sommerville and an anonymous reviewer. "Scientist," at least, did not enter the lexicon without opposition, and Jacques Cattell, publishing his first directory about a century ago, chose to call it *American Men of Science*, rather than American Scientists, thereby setting the stage for decades of dispute and the even less euphonious present title, *American Men and Women of Science*. For once, "persons" would have been better, and "scientists" best of all. The three words are, in any case, now all normative, though if physicists and scientists are the equivalent of artists and pianists,



The Words In Mean Paper Index (WIMPI) for technical journals published in the U.S., U.K., and Japan in chemistry, math, astronomy, and physics. Letters journals were rare before the 1960s, and Japan ended paper rationing in the mid 1950s. Resonably careful account was taken of changes in page size, type font, and format in the journals over the years, virtually all of which increased the number of words per page, without arresting the inevitable upward creep in numbers of pages per paper.

we perhaps still need the equivalents of painters and piano players.

The first thing to be said about all three communities over the decades and centuries is, of course, "more." The cliche that more than half of all the scientists (astronomers, genome sequencers, dot.com-start-up entrepreneurs) who ever lived are still alive says just that the doubling time is less than the mean life time (so it could, in principle, be true even for all of humanity). All of the older professional societies to which I belong were started by 50–100 people, apparently, as noted above, a sort of critical mass. This includes American Physical Society (1898), American Astronomical Society (1899), the International Astronomical Union (1919), the American Association for the Advancement of Science (1850), and the Royal Astronomical Society (1820). All have grown considerably faster than their host populations to something $\times 10^3$ (RAS, AAS, IAU), something $\times 10^4$ (APS), or something $\times 10^5$ (AAAS) members.

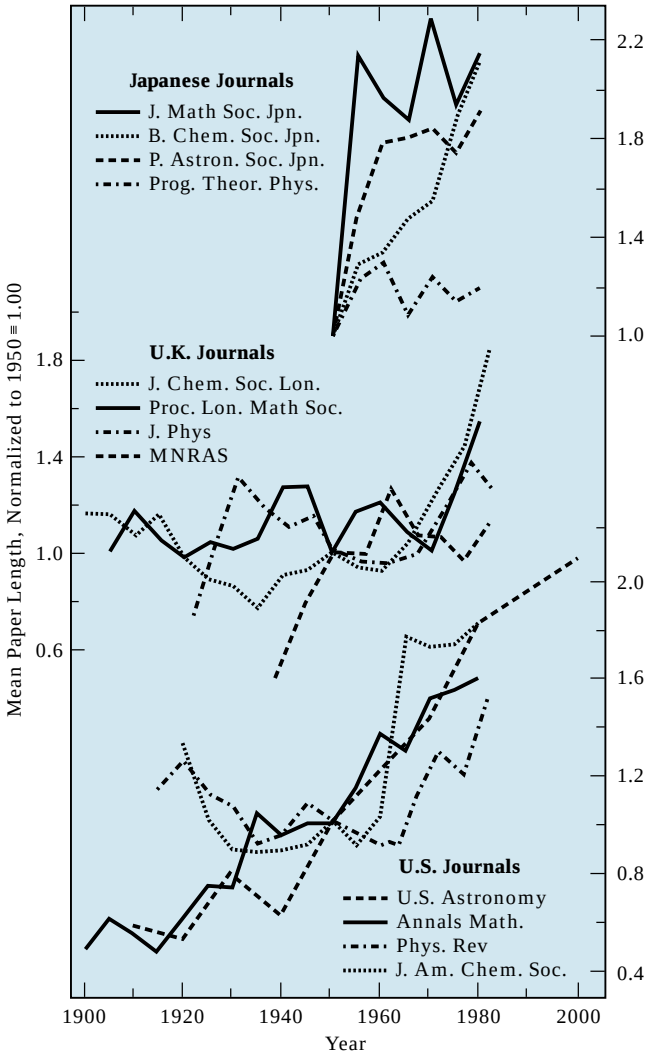
The "more" are by no means uniformly distributed across the face of the earth, as the table shows (see page 54). There are stray factors of two, depending on just who you count, a strong dependence on national income, and, perhaps, threshold effects. Notice that the countries of Eastern Europe and the former Soviet Union seem to be over-achieving in astronomers. You are fairly unlikely to guess which country is most off scale (and I have yet to have anyone in an audience get it right who did not have specialized knowledge), for it is Vatican City, with five IAU members in a total population of less than 1000. If you are tempted to protest that probably none of them was born there, the same is true for a quarter of the Americans, a percentage which has held steady for a century (yes, there are data), but seems poised to grow rapidly in the near future, as has perhaps already happened for the physics community (no, I don't have data).

Nor are the people who do astronomy random samples of the national populations from which they are drawn. The great amateur astronomers of the seventeenth, eighteenth, and nineteenth centuries were all persons (well, all right, men, but more of this later) of at least modest independent means, provided by inherited land or the church (Bradley and Michell held orders) or brewing (Hevelius and Carrington, the co-discoverer

of white-light solar flares) or medicine (Draper of the catalogue). Data collected by Lankford show directly that elite astronomers in the US before 1940 were very much more likely to have had white collar or professional fathers than the general run of the population, with (from less direct data) the general run of astronomers somewhere in between.

Has this become less true through time? Probably, though I have no American data and only one British anecdote.* But two recent papers (one published, one submitted, in the journal *Scientometrics*) show that the current Danish scientific community members have/had parents on average about one social class (in a set of five) higher than the national population, and that, among young scientists in Croatia (!) the women come from higher up the food chain than do the men, which brings us, of course, to "the emancipation of women," as it is called in that Croatian paper (the referee suggested an alternative).

If you are a physicist, you know that most of your colleagues are men, though how often you are really aware of this probably depends on which side of the fence you sit on. I once silenced a large committee with the remark, "Have you noticed that it is easier to ask what may be a stupid question of a member of your own gender?" Quite possibly none of the (15:2) men had ever had the opposite experience. You also know that the F:M ratio drops as you go up the hierarchy from graduate student to members of the National Academy and Nobel Prize winners. If you "do the numbers," you will discover that the leaky pipeline is leakier for women than for men all the way from junior high school (sorry, middle school) to Department Chair and beyond, and also that the F:M ratio is slightly larger in astronomy than in physics at all levels.



Further details of WIMPI-creep, broken down by journal. The curve for US astronomy (including Astrophysical Journal *and* Astronomical Journal*) has one additional point for 2000, showing that the increase in paper length continues. This is true even, for instance, for* Physical Review Letters*, where the four-page limit is now occasionally breached, and letters shorter than the maximum have gradually become scarcer than feathers on physicists.*

* *Once more Sir William, escorting me from London down to Sussex after an RAS meeting in about 1969, "Hmpmp. I seem to have a first class ticket, so I expect you better have one too." Experience never repeated with any younger astronomer.*

Rather than attempting to say anything about how or why, I would rather explore just a bit of the history of the process by which women have "broken into" astronomy. The first of whom we hear are assisting male relatives. Caroline Herschel is the best known, but there were also Sophia Brahe and Elizabeth Hevelius earlier and Margaret Huggins, whose husband (Sir William) is credited with the discovery that some nebulae are truly diffuse gas, not just unresolved star clusters. She was born the year (1848) Caroline Herschel died, and Cecilia Payne (1900–1974) could perfectly well have met her (but did not). Before I forget, Miss Herschel was the first woman to receive a Medal of the Royal Astronomical Society, in 1828. The second was Vera Rubin in 1996. Miss Herschel, Mrs. Sommerville, Lady Huggins, and Agnes Clerke (an astronomy popularizer of the late nineteenth century) were elected honorary fellows of the RAS.

Stage two are "the computers." Once upon a time, computers were people, hired to process data. The large American observatories all had them from the mid nineteenth century into the 1960s (I overlapped the last few at Mt. Wilson-Palomar). At Harvard, nearly all were women (of the upper classes as a rule, though Wilhelmina Fleming began as Pickering's housekeeper), elsewhere many but not all. The phenomenon was not unique to American observatories, though the ratio of computers to (male) astronomers was somewhat higher here than in the UK, Germany, and France from the 1880s to the 1930s. Nor, indeed, was the concept unknown outside astronomy. Three examples come to mind: (1) the women who scanned photographs from the bubble chambers of early nuclear and particle physics; (2) the women (possibly imaginary, but believable) who appear as co-authors with Cyril Burt on the papers reporting heritability of various traits in identical twins; and (3) the woman, described as "a computer" who carried out the tedious work of comparing many signatures to establish whether a particular one had been traced at the turn of the century (mentioned in an article on Hetty Green in the April 23–30, 2001, issue of the *New Yorker*). Even theorists sometimes had assistance with their computing, for instance Donna Elbert, who appeared on a good many of the papers of S. Chandrasekhar.

A woman named Ethel F. Bellamy, who originally assisted her uncle F. A. Bellamy in processing geodesy and earthquake data at Oxford, bridged the gap to a paid computer, working under Professor Turner, and indeed on to the third stage of independent scientist (seismologist) when World War II left her without supervision. She died in 1960 and must have been born about 1880. Her obituary appears in Volume 2 of the late, lamented *Quarterly Journal of the Royal Astronomical Society*. Also a bridger was Maria Mitchell (1818–1889) in the US, who began by assisting her father, worked as a computer for USNO, and ended on the faculty at Vassar.

Cecilia Payne (later Gaposchkin), who made a cameo appearance in the Spring 1994 *Beam Line*, Vol 24, No. 1, was by no means the first woman to earn a PhD in astronomy, but she does seem to have been the first to formulate her own problem (what are stars made of?), solve it (hydrogen and helium, mostly), and continue to work in the field the rest of her life. For more recent events in this aspect of demographics, circumspexi!

POWER, PAY, AND PRESTIGE

It has been nearly 20 years since I first wrote that if you want your papers to be cited a great deal, it pays to be a mature, prize-winning theorist, working on high energy astrophysics or cosmology at a prestigious institution. It also pays to be male. Large coefficients of correlation among desirable circumstances (academy memberships, directorships, large salaries, employment at a highly-ranked institution, winning prizes, being elected to society offices, having your papers accepted and widely cited . . .) were characteristic of the early American astronomical community as profiled by Lankford, and they remain so. If the correlation coeffi-

cients have gone down, it is perhaps only because there are now so many of us that few know all the others, introducing some randomness into the process. The people (OK men) who have chaired the decadal reviews of American astronomy make up a very small sample of six, who hale from Lick Observatory, Harvard, Princeton (one each the University and IAS), Caltech, and Berkeley. Astronomers at these places make up only 10 percent of AAS membership, so said chairs are not a random sample.

A curious counterexample is associated with various operations of the US government. Women could compete freely for NSF post-doctoral fellowships (though not quite for the predoctoral ones) long before they could apply with equal freedom for observatory and university positions. The hard working people who have run the various astronomy and astrophysics program at both NSF and NASA over the years have typically not come from the institutions correlated with NAS membership and large citation rates. And Dorrit Hoffleit (b. 1907 and still going strong at Yale) reports that she took a factor of two pay cut to return to Harvard just after World War II from a civil service (equal-pay) position at Aberdeen Proving Ground.

I won't absolutely swear that money talks, but it definitely murmurs from time to time. During the relatively stable period from 1900 up to the US entry into World War II, a miscellany of numbers (a few from Dr. Hoffleit, a few from Mrs. Fleming's diary, a few from my own family) indicate the following hierarchy: male astronomers at Harvard were paid more than male astronomers at Mt. Wilson, who were paid more than women astronomers anyplace (who were about on par with other women white collar workers), who were paid more than male laborers, who were paid more than female laborers. Unless corrected for inflation, the numbers all sound absurdly small (the Harvard male salary that Mrs. Fleming envied was $2500 per year), but the hierarchy remains true down to the present, except that some kinds of traditionally masculine blue collar work are now better remunerated than traditionally female white collar work.

Of the various, documented underrepresentations of women, the one that has changed most rapidly is service in professional organizations. No woman presided over the American Astronomical Society from its 1899 founding to 1975. There was one in the 1970s, two in the 1990s, and two (already, including a president-elect) in the 2000s.

Committee women are still outnumbered by committee men, but by a smaller factor than women by men among the general society membership. The International Astronomical Union has yet to elect its first female president, but has had half a dozen women among its vice presidents and secretaries general, all within my memory (which does not go back to the founding in 1919). If you have your APS directory handy, you can chart similar trends in its leadership.

Make of it all what you will. My relevant action items are (a) try to keep an eye out for the possibility that we may be encouraging women graduate students to do theses in less prestigious subfields than the guys (no data, just a recent suspicion), and (b) settle down and do the requisite paper work to apply for the next pay rank, so that I will no longer be the oldest Professor IV in the entire UCI school of physical sciences!

Finally, it must be said that there are a great many wonderful stories (a few of which I know) not told here, of the beginnings of the individual journals and societies, the "pro-am" connection in astronomy (another of its unique aspects), the tragic (and occasionally happy) effects of wars and (other forms of) politics, the transformation of our community from a family to a village and, soon, to a town, and much else.

Astronomers as an Economic Bellwether

Country	*N: No. of IAU Members in 2000*	*N÷GDP (dollars 1995)*	*Country*	*N: No. of IAU Members in 2000*	*N÷GDP (dollars 1995)*
USA	2235	2.7×10^{-10}	Russia	344	5.0×10^{-10}
Canada	199	3.0×10^{-10}	Armenia	31	3.3×10^{-9}
Australia	191	4.8×10^{-10}	Estonia	22	2.4×10^{-9}
New Zealand	26	4.0×10^{-10}	Latvia	8	7.9×10^{-10}
South Africa	46	1.7×10^{-10}	Lithuania	12	7.9×10^{-10}
UK (Britain)	535	4.3×10^{-10}	Georgia	19	2.4×10^{-10}
France	609	4.6×10^{-10}	Tajikistan	8	1.9×10^{-9}
Germany	488	2.9×10^{-10}	Ukraine	119	9.5×10^{-10}
Italy	409	3.4×10^{-10}	Uzbekistan	8	1.3×10^{-10}
Netherlands	167	8.7×10^{-10}	Poland	117	4.4×10^{-10}
Belgium	88	3.7×10^{-10}	Czech Rep.	71	6.4×10^{-10}
Denmark	52	4.2×10^{-10}	Slovak Rep.	27	5.8×10^{-10}
Norway	22	1.8×10^{-10}	Croatia	13	6.2×10^{-9}
Sweden	95	5.4×10^{-10}	Bulgaria	50	1.5×10^{-9}
Switzerland	70	4.0×10^{-10}	Hungary	41	5.4×10^{-10}
Vatican City	5	2.9×10^{-8}	Rumania	37	3.1×10^{-10}
Iceland	4	7.8×10^{-10}	Algeria	3	2.5×10^{-11}
Ireland	33	4.9×10^{-10}	Egypt AR	39	1.3×10^{-10}
Portugal	17	1.3×10^{-10}	Iran	15	3.9×10^{-11}
Spain	204	3.6×10^{-10}	Saudi Arabia	11	5.3×10^{-11}
Austria	31	1.8×10^{-10}	India	227	1.4×10^{-10}
Finland	37	3.6×10^{-10}	Indonesia	13	1.3×10^{-11}
Greece	89	6.4×10^{-10}	Malaysia	7	3.0×10^{-11}
Turkey	53	1.4×10^{-10}	Mexico	83	1.1×10^{-10}
Israel	45	9.6×10^{-10}	Argentina	90	2.5×10^{-10}
Japan	448	1.4×10^{-10}	Brazil	109	1.0×10^{-10}
Korea (South)	51	8.0×10^{-11}	Chile	368	2.2×10^{-10}
China, ROC	23	7.4×10^{-11}	Peru	1	8.7×10^{-11}
China, PR	368	8.6×10^{-11}	Uruguay	6	2.0×10^{-10}
			Venezuela	11	5.8×10^{-11}

Things to Read

John Lankford, **American Astronomy: Community, Careers, and Power 1859–1940**, Univ. of Chicago Press, 1997.

Jared Diamond, **Guns, Germs, and Steel**, the 1999 winner of the Phi Beta Kappa award for science writing.

William H. McCrea, "Clustering of Astronomers" in *Annual Reviews of Astronomy and Astrophysics* 25, 1 (1987).

Andre Heck. **Star Guides**. Now online through the NASA and Strassburg centers for astronomical data. Some of the numbers require thoughtful interpretation (for example, the American branch of Oxford University Press is not actually pre-Columbian, though the Oxford branch is).

Michael Hoskin, Ed., **A Concise History of Astronomy**, Cambridge Univ. Press, 1999.

Dennis Danielson, Ed., **The Book of the Cosmos**, Perseus Publishing, 2000.

Edward Harrison, **Cosmology, the Science of the Universe** (second edition), Cambridge University Press, 1999.

Virginia Trimble. Oh, absolutely anything she wrote! But data alluded to here appear in: PASP 96, 1007, 1984 (paper lengths), QJRAS 26, 40, 1985 (citation rates), PASP 100, 646, 1988 and *Scientometrics* 48, 403, 2000 (aspects of current American astronomical community), *Scientometrics* 20, 71, 1991 (effects of degree from prestigious institution), QJRAS 34, 235 & 301**,** 1993 (more citation rates), IOP Encyclopedia of Astronomy and Astrophysics, 2000 (societies and journals, abbreviated version, with M. A. Hoskin)

Oxford English Dictionary remains the source, but when you don't have time to lift it, **Funk and Wagnalls** isn't bad.

There is a whole book, each, on the origins of the American Astronomical Society (edited by David DeVorkin), the International Astronomical Union (written by Adriaan Blaauw), two on the Royal Astronomical Society, and undoubtedly many others. You may or may not want to know that much about the subject.