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STATUS

A REPORT ON WOMEN IN ASTRONOMY

CONTENTS

A Publication of the American Astronomical Society Committee on the Status of Women in Astronomy

Photo by Moire Prescott

This article is based on the opening talk given at the conference Stellar Populations 2003, held in Garching, Germany on October 6–10, 2003. The conference was dedicated in memory of Beatrice M. Tinsley.

Beatrice Tinsley: A Tribute

By Robert C. Kennicutt, Jr.

It has become customary in our profession, when a distinguished scientist reaches the age of 60 or beyond, to organize a conference in his or her honor, a *Festschrift*. If Beatrice Tinsley were still with us today there is little doubt that we would be holding this conference on *Stellar Populations* in her honor. Unfortunately 22 years have passed since Tinsley's death at age 40, so she was deprived of her *Festschrift*. But this has not deterred the organizers of this conference from dedicating the meeting in her memory just the same. This is not the first such conference dedicated in her memory. The very first STScI Symposium in 1985, also entitled *Stellar Populations*, was dedicated to Beatrice, and that meeting opened with a similar dedicatory talk by Jim Gunn.

For the many of you who never met Beatrice Tinsley or worked on the subject when she was active, it may come as a surprise that her colleagues would still be honoring her memory so many years after her death. My task in this talk is to explain why. I approach the task with some reluctance, because unlike Jim Gunn and her other close collaborators, I only met Tinsley briefly at the end of her career (and at the beginning of my own), so I cannot speak from firsthand observation. This is important because much of the greatness in this complex person came from the way in which she interacted with other scientists, young astronomers in particular. So in order to remain on solid ground I will focus

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Pangratios Papacosta came to the US from Cyprus (via the University of London, England) and teaches science at Columbia College, Chicago. The following is a commentary on the life of Henrietta Leavitt.

The purpose of this short paper is to summarize the contents of a poster paper given by the author at the 2004 AAS annual meeting in Denver. The first objective of that poster paper was to disclose the content of letters by Professor Mittag, of the Swedish Academy of Sciences, and by Dr. Harlow Shapley, the director of the Harvard College Observatory. To the knowledge of the author none of these letters were published before. The second objective of the poster paper was to suggest that the importance of Henrietta Leavitt's discovery, the period-luminosity relation, has not been fully recognized by the public or fully appreciated by the astronomical community. Detailed description of the life and works of Henrietta Leavitt and the difficult conditions under which she, like most women of her time, had to work are topics of future publication.

Nobel Prize for a "Computer" named Henrietta Leavitt (1868–1921)

By Pangratios Papacosta

It is amazing that less than a hundred years ago people believed that our universe was just the Milky Way galaxy and that the spiral nebulae seen at its very edge were just disorganized leftover material. In 1924, only four years after the Great Debate between Heber D. Curtis and Harlow Shapley on the size of our galaxy and on the possibility of "island universes," Edwin Hubble showed that one of those spiral nebulae, Andromeda, was indeed a galaxy with billions of stars, not at the edge of our galaxy but almost a million light years away. Hubble was meticulous and thorough in his work, but even with such refined qualities, he would not have been able to make this discovery if not for two other significant factors. First, he was fortunate to be operating the 100-inch Hooker telescope at Mount Wilson, for many years the largest telescope in the world. With

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Figure 1: Beatrice Tinsley, gifted and dedicated teacher, mentor, and scientist.

most of my talk on her many fundamental contributions to the subjects of stellar populations and galaxy evolution, and the aspects of her science that were so special. Whenever appropriate I have added a few remarks about her life and the personal qualities behind her success, based on published accounts (some of which are listed at the end of this article) and from conversations with many of her colleagues and friends. Hers is a remarkable story of scientific genius, personal courage and perseverance, and generosity of spirit, and there are lessons in the story for all of us.

Early Life and Graduate School: 1941–1967

Beatrice Muriel Hill was born in 1941 in Chester, England. Her family moved to New Zealand five years later, and she remained there through college. Today she is embraced as a national hero in her adopted homeland (see **http://www.nzedge.com/index.html**). Her intellectual brilliance became apparent at an early age, and by age 14 she had decided to pursue a path in astrophysics. She graduated from high school at age 16 and entered Canterbury University, where she earned a First in Physics (BSc), followed by an MSc degree in 1963. While in school she married a fellow space physicist, Brian A. Tinsley, and 1963 the couple moved to Dallas, where Brian had been offered a long-term position at what is now the University of Texas at Dallas. For the next 13 years Beatrice filled the all-too-familiar role of the trailing partner, and in the absence of a permanent job supported herself with an assortment of part-time teaching positions, visiting appointments, and research fellowships.

Since UT Dallas did not offer a doctoral program in astronomy at the time, Tinsley enrolled in the newly created Ph.D. program at UT Austin, and commuted the 200 miles weekly to complete her degree. Her graduate career at Austin is a department legend. She completed her degree in record time (1964–1967), working largely on her own, and the thesis that emerged became a landmark work in its field. When *The Astrophysical Journal* published a collection of 53 seminal papers from the 20th century in its 1999 Centennial Issue, Tinsley's thesis paper *Evolution of the Stars and Gas in Galaxies* was one of them (Tinsley 1968, *ApJ*, 151, 547; also *ApJ*, 525C, 1146*). In her thesis Tinsley developed, virtually from scratch, the theoretical apparatus for constructing evolutionary synthesis models of the colors, gas contents, and chemical abundances of galaxies. She then applied her models to two fundamental problems, the evolutionary nature of the Hubble sequence, and the change in the observed magnitudes and colors of galaxies with cosmological look back time. In this one paper she helped to establish the modern evolutionary picture of the Hubble sequence, and demonstrate that the effects of

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galaxy evolution were readily observable to even modest redshifts, and thus needed to be accounted for in the prevailing cosmological tests of the time.

From today's perspective, when anyone can access web-based model programs and compute a full grid of evolutionary models in a few mouseclicks, it is difficult to overstate the groundbreaking and forward-looking character of this work. For the modeling she had to collect evolutionary tracks from dozens of papers, and use color-magnitude diagrams of star clusters to reverse engineer isochrones and tracks for for masses and evolutionary phases where theoretical models were not yet available (including for red giant stars, which dominate the light in many galaxies). Then the same for stellar atmosphere models, synthetic colors, and nucleosynthetic yields, and finally to make the whole population synthesis, star formation, and chemical evolution machinery run efficiently on 1960s generation computers. The thesis was no less impressive in its bold scientific vision, given the state of knowledge at the time. In 1964, when she embarked on her graduate work, the Crab pulsar had yet to be discovered, and the seminal work by Fowler and others on stellar nucleosynthesis was only a few years old. Photographic observations of "high-redshift" galaxies barely extended to redshifts of a few tenths, and the nature of quasars had only been established a year earlier. The discovery of the cosmic microwave background was still two years away, and the Big Bang paradigm itself was not yet firmly rooted. Despite this shaky ground Tinsley forged ahead with a daring set of calculations that paved the way for the modern subject of galactic evolution theory.

In order to test the efficacy of the models Tinsley first computed the expected broadband colors of present-day galaxies and compared them to the observed progression of colors along the Hubble sequence. She discovered that she could roughly account for the observed sequences of colors, gas fractions, and stellar mass/light ratios of galaxies with a set of models with a fixed maximum stellar age, composition, and IMF, with only one parameter — the age distribution of the stars—varying along the Hubble sequence. This remains the standard interpretation today, and despite the computational shortcuts those 1968 models still provide a reasonable fit to contemporary observations, even out to redshifts of 1 and beyond.

* For a more detailed commentary on this paper see Centennial Issue, Kennicutt 1999, *ApJ*, 525C, 1165.

In this one paper she helped to establish the modern evolutionary picture of the Hubble sequence, and demonstrate that the effects of galaxy evolution were readily observable to even modest redshifts, and thus needed to be accounted for in the prevailing cosmological tests of the time.

But the main objective was to compute the evolution in galaxies properties with cosmological lookback time. Tinsley used her models to calculate how the luminosities, colors, gas contents, and chemical abundances of galaxies evolved with cosmic time, and then applied these in turn to quantify how evolutionary brightening (what we today call "passive evolution") would affect the use of elliptical galaxies as standard candles for constraining the geometry and deceleration history of the universe. Today these tests are performed using supernovae, but at the time it was believed that red galaxies were stable enough in their photometric properties to be applied as cosmological standard candles—a program tracing back to Edwin Hubble himself. Tinley's results showed that the evolutionary effects were much larger than had been estimated earlier—by factors of several—and that uncertainties in the evolutionary inputs overwhelmed any effects expected from different cosmic expansion histories. Galaxy evolution would need to be understood much better before galaxies could be used to measure the geometry and expansion history of the universe.

Thus this boldly conceived thesis led to a bold conclusion, leaving open whether observations of distant galaxies really could reveal the history of cosmic expansion and determine whether we lived in an open or closed universe. The most enduring result of the thesis was its clear demonstration that galaxy evolution was an eminently observable phenomenon, even to the modest redshifts that were accessible 35 years ago, and worthy of detailed study in its own right. Within a decade this new subject would grow into one of the largest subfields in extragalactic astronomy.

Dallas: 1964–1974

The years in Dallas that followed her thesis brought yet more scientific accomplishment, but frequently were tempered by professional and personal isolation and frustration. Reaction in the extragalactic community to her thesis results were mixed, as might be expected for such a revolutionary work. Some colleagues recognized the brilliance in the work immediately, and soon initiated long-distance collaborations that would help to sustain her through the remaining years in Dallas. Others expressed skepticism or awaited confirmation of the results from other, more senior workers. As other groups caught up most of her main results were confirmed, and with it her international reputation grew.

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Over the next seven years Tinsley published approximately 20 papers, which taken as a whole laid down much of the foundation for the modern subject of galaxy evolution. These included papers that extended and solidified the results of her thesis, along with new investigations of the stellar populations in the solar neighborhood, the IMF, tests of stellar evolution models, nucleosynthetic constraints on galaxy evolution, supernova rates, the cosmic background radiation, the cosmic mass density, and even the cosmological constant! Some of these papers were written alone, but an increasing number were written with long-distance collaborators, including a few names you may recognize: Jean Audouze, Peter Biermann, Al Cameron, Richard Gott, Jim Gunn, Jerry Ostriker, William Rose, and David Schramm. I don't know whether this extraordinary cohort testifies to the insight of her collaborators in recognizing an exceptional young talent, or instead to Tinsley's impeccable judgement in selecting them as collaborators! Probably a combination of both. The breadth of subjects represented by these individuals testifies to Tinsley's own broad interests, and her remarkable ability to synthesize the requisite inputs from these diverse fields to the common problem of galaxy evolution was widely admired by her contemporaries.

The pressures of sustaining an active research program while supporting herself on soft money and raising two young adopted children were exacerbated by repeated failures to find a permanent job in Dallas. The disconnect between her growing international reputation—which by the mid-1970s included visiting appointments at Caltech, Maryland, and UT Austin, and permanent job offers elsewhere—and the lack of tangible recognition at home became an immense source of frustration, as documented in letters to her father at that time. The breaking point—and turning point—in her career came in 1974, when she filed for divorce and left Dallas to establish a career elsewhere, first at Lick on a visiting position and in 1975 to a tenure-track faculty position at Yale, where she worked for the remainder of her life.

The disconnect between her growing international reputation and the lack of tangible recognition at home became an immense source of frustration.

Yale: 1975–1981

At Yale Tinsley's intellectual productivity and creativity blossomed. She published some 60 papers over these seven years, initiating major long-term studies of galactic and chemical evolution, and turning her attention increasingly to cosmology. Soon the balance of her papers shifted away from long distance collaborations with fellow pundits, and increasingly toward papers written with students and a few long-term collaborations, most notably with Richard Larson, another young faculty member at Yale.

The range of problems that Tinsley addressed in these papers covered the full sweep of modern galactic evolution theory. They included a series of fundamental papers on chemical evolution theory, including a widely influential review paper with Jean Audouze. With Larson she refined her evolutionary synthesis models of galaxies, made some of the first quantitative estimates of star formation rates in galaxies, and applied them to the problems of interaction-triggered star formation, the effects of cluster environment on galaxy evolution, and the cosmic star formation rate and history. Her famous 1978 paper with Larson on star formation in interacting and peculiar galaxies (Larson & Tinsley 1978, *ApJ*, 219, 46) quantified the properties of what are known today as starburst galaxies, and demonstrated the importance of galaxy interactions and mergers as triggering agents for these bursts. She continued to explore the prospects for testing cosmological models with observations of distant galaxies, and she was among the few established scientists at the time to champion the possible existence and importance of a cosmological constant.

One of the highlights of her career at Yale, and one of her most lasting contributions to our subject, was her organization with Larson of the 1976 Yale conference *The Evolution of Galaxies and Stellar Populations*. She drew on her breadth of knowledge to design a conference that soon became regarded as a watershed in the subject. Galaxy evolution was on the verge of a paradigm shift as the first observational and theoretical evidences of hierarchical galaxy assembly and evolution were being manifested, and all of them were represented here: the early results by Searle and Zinn on the assembly of the Galactic halo; a review by Spinrad of observations of high-redshift galaxies and the newly discovered Butcher-Oemler effect; a classic paper by Alar Toomre on the galactic merger sequence; a review by Martin Rees laying down the cosmological foundation for the new hierarchical picture; papers by Strom, Ostriker, and van den Bergh on environmental effects on galaxy evolution and classification; a review by Faber on the interpretation of integrated spectra and abundances in elliptical galaxies; and of course the work by Larson and Tinsley themselves on star formation rates and interaction-triggered starbursts. Dog-eared copies of the blue-covered proceedings from this meeting soon populated the bookshelves of most graduate students and postdocs in the field, and the workshop itself became the standard by which all subsequent meetings in the field were judged.

When one reviews Tinsley's bibliography a few obvious things stand out, for example the amazing breadth of her published work and the intellectual creativity that is evidenced in her choice of research topics. Upon closer examination several deeper patterns emerge. One was her resilience and adaptability to new ideas. As the first glimmers of the hierarchical paradigm for galaxy formation and evolution emerged during this period, Tinsley and Larson were among the first to calculate photometric and chemical evolution models for merger-dominated systems. Instead of clinging to the old-school paradigm that had served as the foundation for most of her life work, she quickly embraced the radical new model, and her advocacy led others to pay serious attention to the emerging new paradigm.

Most impressive of all to me is the extraordinary scope and vision of her work. If you delve deeply into her published work you will find a handful of long-forgotten gems of ideas that were decades ahead of their time. Let me share three of my favorite examples. The most cited of the three, with a total of 22 ADS citations in 26 years, is a paper written with Rasheed Sunyaev and David Meier, with the provocative title *Observable properties of primeval giant elliptical galaxies or ten million Orions at high redshift* (Sunyaev, Tinsley, & Meier 1978, *Comments in Astrophysics*, 7, 183). In this paper the authors calculate the multi-wavelength spectral energy distribution of a young starburst galaxy, and consider how such objects might be detected at high redshift. They derive a synthetic restframe ultraviolet spectrum for the galaxy (using UV spectra of stars recently obtained with the Copernicus Observatory!), and correctly surmise that the best strategy for identifying very high-reshift galaxies ($z > 2$) would be by detection of the redshifted UV stellar spectra using large groundbased telescopes. They go on to point out that the most massive starbursts might be heavily obscurred by dust, in which case the detection of the redshifted far-infared continuum (which they also model) would provide another means of detecting these objects.

My second example, with a total of 20 ADS citations in 24 years, was written with a Yale undergraduate student (Laura Danly), and is *On the Density of Star Formation in the Universe* (Tinsley & Danly 1980, *ApJ*, 242, 435). This paper holds special interest for me because it contained one of the first prescriptions for measuring integrated star formation rates (SFRs) in galaxies. But the paper goes much farther; the authors apply this method to measure the local cosmic SFR density, and to constrain its evolution with cosmological lookback time. Although the paper does not contain a figure with the now-famous Madau-Lilly plot, all of the supporting elements are there, including a plot of the evolution with redshift of the gas mass in galaxies.

Finally my personal favorite, with a total of four ADS citations in 32 years, is one of those single-author paper written during the Dallas years, *Photoionization by Massive Stars in Protogalaxies* (Tinsley 1973, *Ap Letters*, 14, 15). In it she calculates the conditions under which the first generation of massive stars formed in the early universe might reionize the intergalactic medium. Although it was a simple calculation compared to those contained in the hundreds of papers on cosmological reionization written over the past five years, it demonstrates the reach of her vision 30 years ago. One can only wonder what future cutting-edge science topics may still lie hidden in those papers.

Final Years and Legacy

The year 1978 brought another one of those bittersweet turning points in Tinsley's life. In that year she was promoted to the rank of Full Professor at Yale, with the security of a tenured academic position —no small matter for a single mother in that era. At the same time she learned that she had contracted a virulent strain of melanoma, with little prospect of survival. After coming to terms with the initial shock of this revelation she threw herself into fighting the disease and making the most of whatever time remained. Over the next three years she published some of her very best papers, including her *magnum opus*, the review *Evolution of the Stars and Gas in Galaxies* (Tinsley 1980, *Fund Cos Phys*, 5, 287). This 100-page article is a veritable textbook on galactic and chemical evolution theory, and a bible for those of us who followed in her footsteps. It stands far-and-above as her most cited paper, and it continues to be read and cited heavily to this day. Other papers addressed the role that dark matter might play in explaining some of the evolutionary trends along the Hubble sequence, yet more evidence of that resilience and vision that was alluded to earlier. Her last paper, on analytical modeling of chemical evolution, was submitted for publication a few days before she succumbed to the cancer in March of 1981.

During her short career Beatrice Tinsley had a number of honors bestowed upon her, including the University of Canterbury's Hayden Prize for Physics when she graduated in 1962, and the AAUW/AAS Annie Jump Cannon Award in 1974. It was only after her death that our profession fully appreciated what it had lost, and many more honors have been bestowed upon her posthumously. In 1984 the University of Texas at Austin established an endowed visiting professorship in her name, and I am proud to be among those who have been honored with that appointment. In 1986 the AAS established its Beatrice M. Tinsley Prize for research of an especially creative or innovative character.

Since I began writing and speaking about Beatrice Tinsley five years ago I am frequently asked the same questions again and again. How could she (or any scientist) accomplish so much in such a short lifetime? What was her secret? And then the question that opened this talk: Why do scientists of my generation—even people like me who did not interact closely with her— hold such a strong emotional

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Dog-eared copies of the blue-covered proceedings from this meeting soon populated the bookshelves of most graduate students and postdocs in the field, and the workshop itself became the standard by which all subsequent meetings in the field were judged.

A Tribute to Tinsley *continued from page 5*

attachment to this long-departed scientist, now more than 23 years after her death?

At the risk of injecting too much of my own personal interpretation into another person's motivations, my own sense is that some of the same personal characteristics can provide insights into all of these questions, and they can provide useful lessons for all of us. Why was she so successful? There are some obvious factors: exceptional intellectual brilliance and creativity combined with immense drive and tenacity for sure, personal characteristics that were fired in that crucible in Dallas. But these obvious factors provide only part of the answer. The rest becomes clear whenever you speak about Tinsley with her colleagues and friends. They all cite two personal characteristics. One was her immense curiosity and broad scientific interests, which spanned any aspect of stellar, interstellar, extragalactic, or cosmological physics that might be relevant for understanding galactic evolution (in other words, just about everything!). As mentioned earlier, galaxy evolution really is not a free-standing subject on its own, but rather a synthesis of everything we know about subjects ranging from star formation and evolution to the physics of the ISM to the intricacies of stellar dynamics, hydrodynamics, nuclear astrophysics, and cosmology. Tinsley was remarkable both for her broad grounding in all of these subjects, as well as her ability to synthesize this immense swath of science in order to construct a new evolution model or to crack a specific problem in galaxy formation or evolution. And although she was trained as a theorist and devoted virtually all of her career to theory, she maintained an intense interest in and engagement with astronomical observations. Whether you were a theorist or an observer she was interested in your work, and scores of young observers of my generation gained inspiration from the attention that this eminent theorist bestowed upon their work. As pointed out in one of her obituaries in 1982, the number of her published papers were rivaled only by the number of papers by others that carried an acknowledgement to her for insightful comments or contributions. And I am convinced that this voracious appetite for new work in all of these fields was one of the secrets to her success. By keeping on top of the literature across such a broad expanse of research topics she was always among the first to identify new opportunities and research directions.

How could she (or any scientist) accomplish so much in such a short lifetime? What was her secret?

The other personal characteristic that is cited by her contemporaries, above all, was her deep interest for the welfare of the young scientists in her field, and her openness and generosity in her day-to-day interactions with them. That may have been yet another secret to her success; what better way to stay on top of a growing field than spend time with the young scientists who had the time to take on the really difficult problems, and who were unafraid to challenge the old ideas? But this engagement with young scientists was mainly borne of generosity of spirit, and in that respect it represented an interesting study in contrasts. Although most published accounts of her life (mainly published shortly after her death) describe her personality and character in wholly uplifting terms, as befitting the times, this tends to render a one-dimensional impression of a much more complex and three-dimensional person. In addition to her other qualities Tinsley was bold, ambitious, direct, critical, and exacting in her expectations of herself and others. She often could be brash and sharp-edged in her professional interactions, and she certainly did not suffer fools well, especially old fools who should have known better. But these tendencies were tempered (most of the time) when she interacted with her younger and more vulnerable junior colleagues.

Soon after arriving at Yale she took charge of the graduate program, and served as an advocate for the welfare of the students generally. Outside the department, stories abound of young scientists receiving a cheerful note or preprint card in the mail after the publication of one of their first papers, often with an invitation to visit New Haven. As a result the department became a magnet for bright young scientists in this emerging field of galaxy formation and evolution. These correspondences and interactions continued through the last months of her life, when she became bedridden and partially paralyzed. Even then the scientific projects, collaborations, and personal visits continued, and when she lost use of her writing hand she taught herself to write lefthanded, so the correspondence could continue up up to her last few days.

Therein lies the answer to why we memorialize this remarkable individual more than two decades after her death. In a profession that to this day confronts a young scientist with an endless gauntlet of opportunities for disappointment and negative feedback, Beatrice Tinsley was able to recognize and tap the enormous curative power that a little bit of positive feedback and encouragement could have on the motivation and self-confidence of a young astronomer, especially for a young scientist working in the 1970s, and, most of all, for a young woman scientist working in the 1970s. That influence has endured as she continues to serve as a role model for the succeeding generations of women in our profession. Although I would like to believe that the climate for today's young scientists has improved dramatically since her time, we all could profit by being a little bit like Beatrice and dispensing some of that curative medicine of encouragement ourselves from time to time. That would represent a truly meaningful tribute to her memory. ❖

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Tinsley, B.M. 1968, *APJ*, 151, 547

Tinsely, B.M. 1980, *Fund Comsic Phys*, 5, 287

Henrietta Leavitt *continued from page 1*

Figure 1: Photograph of Henrietta Leavitt. Photo Credit by American Association of Variable Star Observers.

such a powerful telescope Hubble could distinguish individual stars in the arms of those spiral nebulae, stars that could provide hints of their distance and hence distance of the spiral nebulae. Some of these stars were Cepheids, variable stars whose period or cycle of brightness he could measure. The second factor is that he had at his disposal a newly established method that used Cepheids as standard candles and therefore could measure distances that were much larger than those allowed by existing methods. Henrietta Swan Leavitt, the head of photographic photometry at the Harvard College Observatory, proposed in 1912 that a relationship exists between the period and luminosity of Cepheids. She made her discovery from photographs of the Small Magellanic Clouds that she was working on under the directorship of Edward Pickering, under whose name her paper was published.[1]

Her assignment at the time was to catalogue stars, not to investigate them. She made this famous and extremely valuable discovery on her own initiative. Although Ejnar Hertzsprung was the first to realize the value of such a discovery and made a crude calibration, it was Shapley who, after a revised calibration, used it to measure the distances of globular clusters. Hubble used Shapley's method to measure the distance of the Andromeda nebula, and also the distances of many other galaxies; this led to his 1929 discovery of the relationship between galactic speed and distance, as expressed in the famous Hubble law. In his 1936 book *The Realm of the Nebulae*, Hubble refers to the newly discovered property of Cepheids in the Small Magellanic Clouds as "a new feature of extraordinary significance."[2] Yet he remains lukewarm when he mentions Henrietta Leavitt in the next paragraph. He acknowledges the use and calibration of her period-luminosity relation first by Hertzsprung and later by Shapley and ends the "Period- Luminosity Relations to Cepheids" section in his book without ever mentioning that he, Hubble, had used Shapley's technique. Instead he writes,

> "Thus, whenever a Cepheid may be found, the period will indicate the absolute luminosity, and the apparent faintness then measures the distance. It was by this method that the first reliable distances of nebulae were determined." [2]

Hubble's underwhelming acknowledgment of Henrietta Leavitt is an example of the ongoing denial and lack of the professional and public recognition that Henrietta Leavitt suffers from, despite her landmark discovery. With the exception of naming a moon crater after her, the profession of astronomy has not done much to celebrate her work. No astronomy prize is named after her and the period-luminosity relation has not been renamed as the H. Leavitt law. The vision of the cosmos was dramatically enhanced thanks largely to her discovery, yet no space telescope bears the name Leavitt and no USA postage stamp has been issued to honor her. It is only through such bold changes that the public at large and the community of astronomy and cosmology will fully recognize the importance of her discovery and celebrate a true heroine of the profession. Sporadic efforts to recognize her work have been made in the past, and occasionally words were written to elevate the significance of her discovery. But such words remain private, at times confidential and often ignored. Here are some examples of such words and efforts.

> "Miss Leavitt's work on the variable stars in the Magellanic Clouds, which led to the discovery of the relation between period and apparent magnitude, has afforded us a very powerful tool in measuring great stellar distances. To me personally it has also been of highest service, for it was my privilege to interpret the observations of Miss Leavitt, place it on a basis of absolute brightness, and extending it to the variables of the globular clusters, use it in my measures of the Milky Way. Just recently in Hubble's measures of the distances of the spiral nebulae, he has been able to use the period-luminosity curve I founded on Miss Leavitt's work. Much of the time she was engaged at the Harvard Observatory, her efforts had to be devoted to the heavy routine of establishing standard magnitudes upon which later we can base our studies of the galactic system. If she had been free from those necessary chores, I feel sure that Miss Leavitt's scientific contributions would have been even more brilliant than they were." [3]

These were the words of Harlow Shapley, the director of the Harvard Observatory in a March 1925 letter to Professor Mittag-Leffler, a member of the Swedish Academy of Sciences. Dr. Shapley was responding to a letter that Professor Mittag wrote earlier to Henrietta Leavitt, who unfortunately died of cancer in 1921. Professor Mittag's letter, dated February 23, 1925, begins with the following sentence:

> "Honoured Miss Leavitt,
>
> What my friend and colleague Professor von Zeipel of Uppsala has told me about your admirable discovery of the empirical law touching the connection between magnitude and period-length for the S. Cephei-variables of the Little Magellan's cloud, has impressed me

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Photo Caption: A group of women computers a the Harvard College Observatory circa 1890, directed by Mrs. Williamina Fleming (standing).
Photo credit: The Harvard College Observatory

Photo Caption: Henrietta Leavitt at her desk.
Photo credit: The Harvard College Observatory.

> so deeply that I feel seriously inclined to nominate you to the Nobel prize in physics for 1926, although I must confess that my knowledge of the matter is as yet rather incomplete."[4]

Unfortunately, Nobel prizes are not awarded posthumously and we will never know whether Henrietta Leavitt would have received one had she lived longer. Regardless, the thought of nominating her, which interestingly came from people outside the USA, speaks highly of the importance of her discovery. Admittedly the importance of her work was felt only after Hubble made his dramatic discoveries, and had she lived longer, perhaps American astronomers would have recognized her in more appropriate ways, something that I sadly doubt. Astronomy, like any field, needs heroes and heroines that can inspire others and bring the subject to the public. We need to re-examine Henrietta Leavitt's contribution to astronomy and consequently to cosmology, using modern and current lenses of evaluation. Only then can we realize the full impact of her period-luminosity discovery. One such appraisal came in the work of historian of science Stephen Brush. In a 1979 article titled "The rise of astronomy in America,"[5] Brush lists the most important discoveries in astronomy from 1800 until 1950, as recognized in the works and references of other historians of science. For the period of 1900–1950 he lists ten major discoveries, of which the second is the period-luminosity relation with the names of Leavitt, Hertzsprung and Shapley attached to it.

We can explain but not justify the double standard treatment that women scientists like Henrietta Leavitt suffered under. Those were difficult times for women and it is no secret that women were not treated as equal to men in every field, including the arts and sciences. In the case of astronomy many women were employed and given the title of "computer", because their job was to examine thousands of photographic plates, identify and catalog stars according to their apparent brightness and spectral characteristics. They earned much less than men and did not receive the recognition that they deserved. In a recent article entitled "Gender and science: Women in American Astronomy, 1859–1940,"[6] authors J. Lankford and R.L. Slavings say, "Women measured plates and reduced data in the great factory observatories, helping raise American astronomy to world-class status while they themselves were relegated to second-class status." The authors suggest that such treatment merely mirrored the values in American culture and the rigid application of gender-specific roles. They quote Maria Mitchell, America's first woman astronomer, who on the subject of gender-specific roles pointed out some of the advantages that women astronomers had, over their male co-workers: "The eye that directs a needle in the delicate meshes of embroidery will equally well bisect a star with the spiderweb of a micrometer." "Routine observations…dull as they are, are less dull than the endless repetition of the same pattern in crochet-work." [6]

Henrietta's own personality compounded the situation of her relevant obscurity. In contrast to the prevailing antagonism and professional competition amongst male astronomers like Hubble and Shapley, Henrietta Leavitt was a humble, quiet and shy person, not because of her deafness but because of her personality and character. These were very much shaped by her upbringing, in a family that was proud of its Puritan ancestry and with a father who was a clergyman of national prominence. Such personal qualities were well described by Solon I. Bailey of the Harvard Observatory, in the obituary that he wrote for Henrietta Leavitt: [7]

> "Miss Leavitt inherited in a somewhat chastened form the stern virtues of her puritan ancestors. She took life seriously. Her sense of duty, justice and loyalty was strong. For light amusements she appeared to care little. She was a devoted member of her intimate family circle, unselfishly considerate in her friendships, steadfastly loyal to her principles, and deeply conscientious and sincere in her attachment to her religion and church. She had the happy faculty of appreciating all that was worthy and lovable in others, and was possessed of a nature so full of sunshine that to her all of life became beautiful and full of meaning." ❖

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AAVSO (American Association of Variable Star Observers).

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What Works for Women in Undergraduate Physics?

By Barbara L. Whitten, Suzanne R. Foster, and Margaret L. Duncombe

In 1998, women received about 40% of the bachelor's degrees in mathematics and chemistry, but only 19% of the bachelor's in physics. That underrepresentation worsens at higher levels: The same year, women constituted 13% of physics PhD recipients and 8% of physics faculty members.[1] According to NSF, the community of working PhD-level physicists in 2000 was 84% white and 93% male.[2] What accounts for such stark numbers?

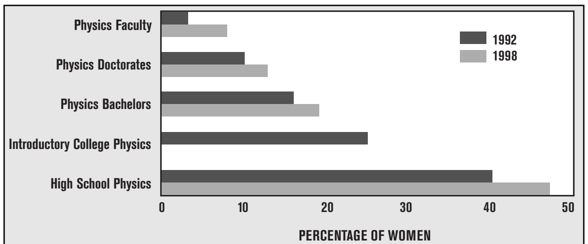

Figure 1: A "leaky pipeline" describes the declining percentages of women who participate at the various levels of physics education. College years account for the largest loss of women from the physics community. (Data for 1992 are adapted from the article in Physics Today by Mary Fehrs and Roman Czujko, August 1992, page 33. Data for 1998 are adapted from ref. 1.)

A "leaky pipeline" explains part of the problem. Judging from figure 1, women opt out of physics at every step up the academic ladder. Pacific University physicist Mary Fehrs and Roman Czujko, director of the Statistical Research Center of the American Institute of Physics, found that those women who chose not to remain in physics had performed on a par with their male colleagues who stayed in the field. (See Physics Today, August 1992, page 33.) Elaine Seymour and Nancy Hewitt, both sociologists at the University of Colorado at Boulder, confirmed that finding.[3] It implies a loss of talent, which the physics community can ill afford. To investigate the climate for women in graduate physics departments, the American Physical Society's Committee on the Status of Women in Physics (CSWP) began conducting a program of visits to physics departments in 1990. On the basis of those and continuing visits, the committee has recommended changes to make the departments more comfortable for women faculty and students.[4,5]

The biggest leak in the pipeline, though, appears in the college years following high school. If physics departments could learn how to persuade more of the girls who take high-school physics to major in physics in college, they would greatly increase the pool of women who might become professional physicists.

To complement the APS work on graduate programs, a team was formed to focus on undergraduate physics programs, taking as a starting point the fact that participation of women in different college physics departments varies widely. Some departments are successful at recruiting and retaining women as majors. We asked ourselves: What sets those successful departments apart? To answer the question, we've let the men and women speak for themselves, and have assembled a set of best practices or common features found in departments where women are thriving. But teasing out clear gender-related distinctions is difficult—what works for women will often work for men as well.

Our project

We conducted site visits to nine undergraduate physics departments. Five of those graduate a high percentage of female majors[1]—typically about 40%—and four graduate a percentage of female majors near the national average—typically 15–19%. We designated the first type as "successful," and the second as "typical." In other respects, we chose schools that were as diverse as possible: some public, some private, some religious, some secular, some liberal-arts based, some small universities, some predominantly white, some historically black. The schools also varied significantly in cost and selectivity.

Two or three female physicists from our eight person team spent two full days on each campus. We interviewed male and female faculty and students, the department chair, and the academic dean responsible for natural sciences. We observed classes and labs and toured the departments. The youngest of us (Foster, BA in physics, class of 2001) interviewed all of the students. We felt that students would be more candid talking to a contemporary.

While we were working on this project, friends and colleagues would frequently ask, "What have you found out?" They were expecting a quick answer and a couple of silver bullets that would transform a male-dominated department into one in which women thrive. What we found was very different, more akin to many small threads that interweave to form a friendly and inclusive department culture. We developed the weaving metaphor, pictured in figure 2, to portray the different

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Site Visit Participants

Patricia E. Allen of Appalachian State U., Boone, North Carolina
Suzanne R. Foster of Colorado C., Colorado Springs (all visits)
Paula R. L. Heron of the U. of Washington, Seattle
Laura McCullough of the U. of Wisconsin-Stout
Kimberly A. Shaw of Southern Illinois U., Edwardsville
Beverley A. P. Taylor of Miami U., Oxford, Ohio
Barbara L. Whitten of Colorado C. (all visits)
Heather M. Zorn of the U. of Washington, Seattle

(See reference 11 for a more complete description of the project and its results.)

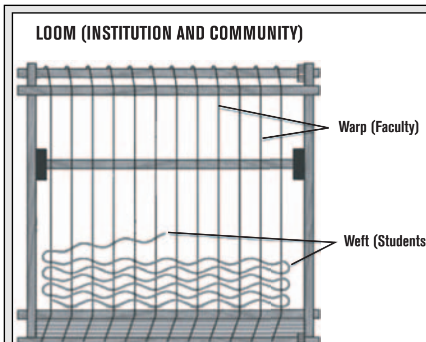

Figure 2: Departmental culture as woven fabric. Faculty, students, and the community combine to create a supportive environment.

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elements in a successful department: The loom itself represents institutional support for the faculty; the faculty form the warp, long taut threads that support the fabric and provide continuity; and the student culture weaves itself onto the structure like the weft of the fabric.

The loom: Recruiting diverse faculty

> We are different individuals and we do things differently but we know how to work together to get things done…We have different interests, we have different personalities, we have different teaching styles, so there is a bit of diversity in this very tiny department. (Male professor)

The most effective departmental cultures found at successful schools fit this professor's characterization. Working as a team does not mean that everyone must be the same and contribute equally to everything. Rather, faculty should recognize and respect each others' strengths, weaknesses, and approaches to teaching. Those differing styles and strengths can combine to create a rich and dynamic department.

> It would be nice to see some really good female professors who are supportive of females going through the science program, just to know that you can get somewhere. (Female student)

This student explains clearly why female role models are so important for other women. Elizabeth Tidball, a professor of physiology at George Washington University, has shown that the presence of female faculty is strongly correlated with the number of female students who become scientists.[6] Seeing how different women with different family situations arrange their lives helps newer female students see how they might balance a career in science with a satisfying personal life. And there are some issues that female students are reluctant to raise with even the most sympathetic male adviser.

However, despite their influence, female faculty are not absolutely essential for a female-friendly department. Three of our five successful schools had an all-male faculty. Clearly, men can be very effective mentors and supporters of female students; faculty need not wait to hire a woman to make their department female-friendly in other ways.

Family-friendly policies

To bolster their appeal, departments can take steps to attract talented women. Family issues typically are a critical part of the career decisions female faculty make. Sue Rosser, dean of Ivan Allen College at the Georgia Institute of Technology and former chief of women's programs at NSF, and E. O'Neil Lane, of the Georgia Tech Research Corp, interviewed female NSF-grant recipients about the most significant career challenges facing female scientists today.[7] By far the most common response, occurring more than twice as often as any other, was "balancing work with family responsibilities (children, elderly relatives, etc.)."

Yet at every school we visited, including the successful ones, deans and department chairs seemed unaware of any connection between family policies and the recruiting of female faculty. Although a department may want diversity in its faculty ranks, a person's dilemma of choosing a job where his or her partner also has good prospects is often viewed as simply a burden couples have to work out on their own. The issue does make it hard for colleges to hire new faculty, especially women. A full complement of family-friendly policies, will support different kinds of families at different life stages.

None of the schools we visited had all of the listed family-friendly policies in place. College administrations often resist such policies because they are too expensive. But failed searches are expensive, too, as is losing a new faculty member after spending money for startup equipment. Losses of a new hire are costly to faculty morale as well. We visited departments in which the faculty were exhausted and demoralized by search after failed search, and were making do with inexperienced temporary teachers. In one small, isolated department, the faculty seemed almost in shock because of the sudden and unexpected departure of a dynamic professor whose wife had found a job elsewhere. The costs of family-friendly policies need to be balanced by the benefits of recruiting and retaining a dynamic, diverse, and committed faculty. In that respect, educational institutions lag far behind the marketplace.

> [Professor----] is a person who is genuinely concerned and loving toward students, but he'll worry you to death--you know how your mom is always bugging you? That's [him]. He'll call you every day if he has something on his mind—drives me batty. (Female student)

Institutional support for personal lives is healthy for students as well as faculty. In an atmosphere of excessive devotion to students, faculty can become overly parental. That annoys students. More important,

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Essential Family-Friendly Policies

Solutions to the "two-body problem". Institutions can encourage both the hiring of faculty partners and networking with other institutions. Laurie McNeil and Marc Sher offer recommendations for couples and schools (see their article in PHYSICS TODAY July 1999, page 32).

Generous and inclusive family leave. Family leave policies should be designed for different kinds of families at different stages of life. Administrators should ensure that employees will not face repercussions for taking family leave.

Childcare. Childcare should be offered on-site and be partially subsidized. Coordination of school breaks with public school vacations may help working parents.

Family-friendly atmosphere. In such an environment, faculty children are welcome in the department: Administrators should be tolerant of family demands on the faculty.

it deprives them of responsibility. Faculty who prefer to spend time in their offices can be poor role models for students, particularly students who are wondering how they might combine their interest in physics with their desire for a family. A warm and active department culture is an important part of a female-friendly department, but it should not supersede commitments to family and friends outside the department. Margaret Eisenhart, professor in the school of education at the University of Colorado at Boulder, and Elizabeth Finkel, a science teacher at Noble High School, a public school in Maine, argue that fields like physics are "greedy," demanding too much time and energy, and driving away women who would like a rich and satisfying personal life in addition to their career.[8]

The warp: The introductory course

> How many times can you sit there and solve problems like "how fast is the block sliding down the incline?"…If you took physics in high school it was a lot of the same stuff. (Male student)

Each school we visited follows a traditional approach to the curriculum, even at the introductory level. That accords with the results of the SPIN-UP project (Strategic Programs for Innovations in Undergraduate Physics—see Bob Hilborn and Ruth Howe, Physics Today, Sept. 2003, page 38), which also found a remarkable uniformity in the physics-major curriculum. Our conversations with students suggest that faculty should consider more innovative subjects and interactive pedagogy in the introductory course. Both male and female students frequently described the traditional introductory course as boring and repetitive of high-school physics. Cookbook labs that emphasize error analysis rather than concept development received poor student reviews. Students spoke highly of open-ended, project -based labs, even if they were more time-consuming than traditional labs. Courses designed for nonmajors (astronomy and conceptual-physics classes, for instance) also received more positive reviews.

> [The physics course for elementary education majors included] a lot more examples and demos and real life situations—a lot less math. Things that anyone would be interested in knowing, like Bernoulli's principle is when the shower curtain comes in on you and sticks to you…General stuff that makes physics fun, especially for people who don't like math. (Female student)

The former elementary education student quoted here chose the physics major after taking the non-majors physics education course she describes. And she is not alone—we heard several cite a nonmajors introduction, approached from an innovative format, as a reason for the decision to major in physics. Faculty often feel freer to be exploratory and innovative in such courses than in the calculus-based course for majors—the pressure to cover content appears to inhibit experimentation.

Beyond the anecdotal level, validating the effect of innovation on teaching success has proved difficult. The uniformity in the traditional approach adopted in all of the departments we visited prevented us from making any strong correlations. Interestingly, however, in the few cases of nontraditional courses we found, women seemed more likely than men to experiment with innovative or interactive teaching formats.

Four-year mentoring

> As a freshman coming in and not having a lot of experience with the department, I wish they would do something to make the individual professors seem more approachable when you first start off. (Female student)

Sometimes, faculty don't really know how they strike students, even in departments like the ones we sampled—small, undergraduate-oriented, and focused on teaching. Faculty frequently say that they have an open-door policy, that students feel free to come in anytime to talk about classes, plans, or personal matters. But our interviews indicate that's not always the student perception at typical departments. Physics majors complained that, in their first year, they did not receive the open-door policy message the faculty thought they were sending. The problem vanishes in upper-level classes that are small and informal, when students get to know the faculty and their fellow students well. But in the introductory classes, special efforts on the part of faculty to approach students—potential majors, especially—are often lacking.

At one successful school, the professor teaching the introductory class identifies potential majors and regularly invites them to departmental activities. The day we visited he was handing out tickets for a trip to see Michael Frayn's play *Copenhagen*. Some departments designate a particularly good teacher who is also good at recruiting. One successful department teaches an introductory class specifically for physics majors, to avoid exposing less experienced, serious students to more experienced and possibly intimidating nonmajors who are less interested in the class. Yet another school designed a discussion-oriented section to appeal to women and minority students. Generally, students at schools without some form of personal attention more often spoke negatively about their first-year course.

The weft: Creating departmental culture

In a successful department, there exists an environment in which everyone is accustomed to working together: More experienced students guide less experienced ones, and faculty members act as

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role models, cooperating as a team and supporting each other in their professional and personal lives. The faculty can provide a comfortable, stable network of support for a healthy student body. Figure 3 illustrates the departmental connections.

Some of the threads of a warm, student-friendly department culture are given in the box on the next page. It is important to ensure that the student culture is not a boys club; some typical departments are so male-dominated that women may feel uncomfortable and out of place. The second part of the box suggests ways for faculty to help create an inclusive student culture.

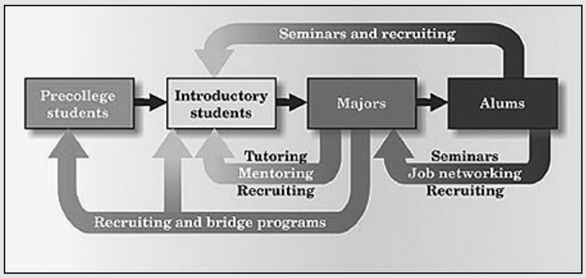

Figure 3: Students create the weft of an inclusive, female-friendly department culture. Successful schools create a network of support systems that extends beyond their current majors in both directions, to introductory students, precollege students, and alums.

Figure 4: This Louisiana university's physics department does an unusually good job of keeping in touch with alums and using them to recruit students to graduate schools and jobs. This photo wall of past graduates is prominent in the department office. (Photo courtesy of Matthew F. Ware, Grambling State University.)

Students do much of the work to create a warm, friendly, inclusive departmental culture. They staff tutorials and labs, run the physics club, and plan social activities. They work in recruiting and outreach programs and keep in touch with alumni and alumnae. These activities lighten faculty loads and give students a sense of belonging and responsibility.

Outreach

At successful schools, recruiting often begins before students even enroll in college. Faculty members judge science fairs, teach in summer bridge programs, and visit local high schools—all high-profile ways to advertise. Departmental Web sites designed to emphasize the participation of women also attract a wide pool of students. If available, the department's telescope or planetarium can be used for outreach at local schools. Current majors effectively assist with such efforts, and our findings suggest it is often female students who are most involved.

Successful departments extend their efforts in another direction as well. Faculty at most undergraduate schools maintain contact with a few alums who have gone on to prestigious graduate schools and academic careers. But at successful schools, the network is more extensive and connected with current students in the department. At two successful schools, the department chairs pointed out photographs of graduating classes and shared stories of alums who had taken various career paths (see figure 4). One chair described with equal enthusiasm a former student who is now a veterinarian and another who is in graduate school in physics at MIT. Posters of research done by present and former students decorated the walls and were pointed out to us with pride.

> In the physics department, we run a career panel where we bring back graduates from the last 10 or 20 years. And the networking system is displayed there. And some of the students from the '70s and '80s now are division chiefs, so they can offer jobs. They are good role models. We try to balance them in gender too. (Male professor)

At successful schools, faculty members invite alums to give seminars, recruit for graduate school, and provide students a sense of what life as a physics major can be. In a small department without graduate students or postdocs, that extra dimension adds perspective.

Historically black colleges and universities

Among the schools we visited, historically black colleges and universities (HBCUs) were especially effective at creating networks of support. These schools are well-known for producing great numbers of African American scientists.[9] Less well known is their female-friendliness. A recent study of African American female scientists showed that 75% received their bachelor's degrees at HBCUs.[10] Of the 20 schools that graduate the highest percentage of female physics majors in the US, 8 are HBCUs.[1] What accounts for that remarkable record?

The physics departments in the two historically black colleges in our study do many of the same things other successful departments do, and they do them exceptionally well. Faculty members at HBCUs are dedicated to the success of each student. They make strong efforts to recruit students by visiting local high schools and teaching summer bridge programs. They involve students in research and physics-department-related activities from the beginning and they maintain contact with alums, encouraging them to visit, advise inexperienced students, and recruit students to graduate schools and jobs. They also use their own students as tutors, recruiters, and mentors for less experienced students. And all of that is accomplished with minimal resources. The success of such efforts calls into question claims by wealthier schools that a program to improve the learning environment for female students is just too expensive.

> Really you don't start taking a physics class until you take calculus 1. I took elementary functions, which is basically precalc. Then I took calculus 1 and 2, now I'm in calc 3. It really depends on the person coming in. (Male student)

This student describes his starting point in physics and implicitly alludes to the alternative route, in which students with stronger backgrounds jump right away into the more traditional calculus-based introductory course. The matter-of-fact tone of his remarks is as important as the actual words—there is clearly no stigma attached to starting at a lower level.

That attitude is the one important and distinguishing feature common only to the historically black colleges we visited. Their faculty typically distinguish clearly between students who are interested and talented in physics and those who happen to have a good high-school physics background.

Figure 5: "Build it and they will come." A basic student lounge is often enough to draw students for conversation, brainstorming, tutoring sessions, or between-class snacking. A microwave oven, coffeemaker, and refrigerator are all on the other side of the room. (Photo courtesy of Michael S. Korth, University of Minnesota, Morris.)

Background courses in mathematics and physics are offered to prepare anyone with a background insufficient for the calculus-based majors course. The institution and faculty are dedicated to helping students overcome deficiencies in their background without lowering standards.

> Good faculty members will cover the content and go the extra mile and give the student the assistance, but they have to hold the student to the standard. They don't lower the standards because the student has a deficiency. Physics is physics wherever you are. (Female dean)

Our hope

A central result of our study is that several factors contribute to making a departmental culture inclusive to a variety of students. Typical departments have some of those threads, but successful departments have more of them. Not surprisingly, when departments make efforts to be more friendly and inclusive, both

Here are important threads in a student-oriented culture.

Provide a student lounge. This area gives students a place to study together, tutor other students, and interact socially. Departments with a comfortable lounge have markedly improved student relations. Faculty drop by to chat with students, which prompts casual interactions (see figure 5).

Offer a tutorial service. This service has many benefits: Newer students get another resource beyond sometimes intimidating professors; older students get a job that lets them practice explaining physics concepts. Students feel at home in the student lounge if sessions take place there. And perhaps most important, students in more advanced classes automatically become mentors to less experienced students.

Use student lab assistants. Students in more advanced classes may advise those in the introductory classes, thus providing the same benefits as a tutorial service. An added benefit: Physics majors gain valuable experience in setting up equipment and trouble-shooting problems.

Schedule departmental seminars. Use these sessions to focus on undergraduate interests—jobs or postgraduate opportunities, for example.

Create a Society of Physics Students chapter or other physics club. These clubs provide opportunities for social interactions, physics-related activities, and career counseling. Some successful departments have one club meeting specifically devoted to the concerns of introductory students.

Here are important elements that can foster a female-friendly culture.

Monitor the student culture. Make it clear that sexist and racist remarks and behavior are unprofessional and have no place in a laboratory or classroom.

Foster a cooperative spirit. Rather than create a competitive atmosphere in the department, encourage cooperation in class, from formal group activities to informal study groups.

Mention female and minority scientists. For example, emphasize Nobel laureates and leaders in the field to students in class or on departmental posters. Highlighting a variety of physicists may help women and minority students feel more strongly tied into the physics community.

Emphasize applications to environmental and social issues. Elaine Seymour and Nancy Hewitt found that women and minorities often choose careers in science for societal reasons.[3]

Encourage student-faculty research. Such research is an important part of an undergraduate education in science and can facilitate a less formal relationship with professors.

Ensure that students feel safe working in the department alone or at night. Of the female students we interviewed, none expressed concern over their safety. We include the caveat simply as a critical aspect of helping students feel comfortable in the department.

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genders notice the difference. But even though warming up a department benefits all students, it seems to help women in particular. Sociology partly explains the difference: Women tend to value interpersonal relationships more than men. And a sense of isolation may explain another part of the difference: Typical departments simply have many fewer women than men. Perhaps male students can more easily develop peer relationships that help them survive a "cold" department.

Many of our observations are in accord with the findings in the SPIN-UP—that is, many small factors combine to create thriving departments. The surprise is that SPIN-UP researchers did not observe a significant increase in women or minority students. We are continuing to study this complex issue, comparing SPIN-UP data to our own, to understand the differences between thriving departments and female-friendly ones. We also plan to widen our school sampling to include women's colleges and other minority-serving institutions.

Although we studied undergraduate-only physics departments, many of our results may be adapted to larger research-oriented departments that cater mainly to graduate students. To develop a warm, female-friendly culture in these schools, it is important to focus on the first year, before students are fully integrated into the department. Department chairs should choose the undergraduate adviser and the introductory (calculus-based) class instructors carefully; those faculty members should be friendly, accessible people to whom students easily relate. Other useful ways to integrate the department include encouraging graduate students to informally mentor undergraduates and inviting undergraduates to seminars and departmental parties. It may also be useful for the undergraduate adviser or the department chair to meet regularly with women students to discuss any concerns.

Physics departments around the country are making progress, and we hope that trend continues. Some research universities are beginning to see the relationship between family-friendly policies and the recruitment and retention of female faculty, for example. Both Georgia Tech (**http://www.advance.gatech.edu/overview.html**) and the University of California, Irvine (**http://advance.uci.edu/home.html**) have included family-friendly policies in their NSF ADVANCE institutional transformation grants. We encourage graduate-student-focused physics departments that are interested in improving their climate for women to contact the CSWP and request a site visit. The program is described on the CSWP Web page (**http://www.aps.org/educ/cswp/visits/**). Further results for graduate programs are found in references 4 and 5.

This project was funded by the National Science Foundation Program for Gender Equity. The American Physical Society's Committee on the Status of Women in Physics was very supportive, especially Neal Abraham, Judy Franz, Suzanne Otwell, and Alice White. We are grateful to Rachel Ivie and Patrick Mulvey of the American Institute of Physics for providing statistical support. It is a pleasure to acknowledge our colleagues listed in the box above who lent their expertise and time. Finally, we are most grateful to the students and faculty of the departments we visited. ❖

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Applying to Graduate School

By Fran Bagenal

In my article on the 'pipeline problem' in the last issue of STATUS I commented that students applying for grad school lack good advice. Several people challenged me to provide examples. As I expected, I found plenty of good advice available once I asked around. Here is a compilation of responses to a request for suggestions posted on the AASWOMEN e-newsletter, beginning with my three thoughts on the subject.

- Visit the grad schools to which you are accepted and make a decision based on your gut reaction to the people, place and program (rather than perceived national ranking).
- If you take the physics GRE then study seriously for the exam. If you do not take the physics GRE recognize that unless you have good grades in physics courses at a well known college/ university, then the places you are applying to will not have this simple quantitative basis to judge your application compared with the 150 others.
- If you do a research project (e.g. REU) at a non-academic institution (e.g. govt. lab) make sure the person writing your recommendation letters can make a useful comparison of your performance with those of other students. General statements such as "I was amazed how quickly Amanda learned how to analyze the data" are nice but useless for admission committees. We are looking for "I was impressed that within a month Amanda taught herself IDL, learned how to extract and calibrate data from the BLAH database and re-plot them in the new co-ordinate system she developed with my assistance. I have worked with 10 students over the past 3 summers and the only student of her caliber is now finishing a PhD at Top Notch U."
- Good questions to ask when considering a graduate program:
    - Is the stipend enough to live on?
    - Do you have to scramble every year to get funding?
    - How is the qualifying exam(s) structured? How many pass?
    - How many grad students are accepted vs how many "slots" there are with advisors? (In other words are many accepted for the first two years to be TA's and then a large percentage expected to not pass the qualifying exam).
    - How is the thesis committee structured and is there a way that the committee can help you in the advent of bad advising by the thesis advisor? (I didn't ask about this when I was applying but have witnessed the experience of two friends who were screwed by extremely poor advising by their thesis advisor).
- Visit the department and talk to faculty, grad students and other people there. Be sure to have a chance to ask meaningful questions (what do you like/dislike about the department? etc.)—especially of the grad students away from faculty. A good list of questions is at: **http://spider.ipac.caltech.edu/staff/rebull/goodquestions.html** which I used for my own grad school search (not 5 years ago).
- At each school, look and talk to people you see as future advisors. Do you like talking to them? Talk to their students (do they like working for them? what don't they like?). Choose a school that has a few different people you might like to work with. Advisors can change schools, move to a different continent, or you might decide to switch fields of research, so it's good to have more than just one person in mind.
- When visiting the school, think about how you would like that department (and the town) five years later. For example, if you hate big cities, take that into account when thinking about a grad school. The environment you live in can have an effect on your mood and hence performance.
- Your graduate school application essay is NOT equivalent to your college application essay. Paens to the beauty of the night sky glimpsed through gauzy curtains as you drifted off to sleep in your cozy little suburb when you were 8 are not the ideal opening. Stating that your aspiration in life is to win a Nobel Prize is also discouraged. The readers of these essays want to know why they should want to invest >$200K in educating you to be a successful astronomer.

Continued on page 16

Applying to Grad School *continued from page 15*

- It is FINE (even, perhaps, preferable) to NOT KNOW what area or subfield you want to study when applying to graduate school. You should apply to places with at least a few options, but freely admit that you are open to different possibilities if it is true.
- Invest the time to read Department websites and talk to the best-connected astronomers at your institution before even deciding where to apply. There are many programs with very different characters, and the recipe for success is not finding the most famous one, but finding the place that best matches your background, interests, and temperament.
- Talk to the current grad students at each place you're accepted, and see whether they are happy. Do they like the program? Are they excited about what they're doing, and the opportunities they're given? Are they people you would like being with and learning from? That's a pretty good indication of whether you'd be happy there as well.
- There are a LOT of really good schools, with a lot of people doing excellent research. So don't feel it's pointless to start a career in astronomy unless you go to Harvard! Conversely, it doesn't hurt to apply: a good student from Podunk U. really can get into Caltech...but not if she doesn't apply there.
- Recommendations are useful, particularly those that are comparative and quantitative; one can overcome one bad showing (e.g., poor grades or GRE), if it's clear that one is addressing the problem (e.g., based on a well-written reference letter).
- Grad school is not the same as undergrad, in that one is not so much learning facts and ideas, as learning how to develop them; etc.
- For women the biggest points from everyone I've talked to are (1) check with other women in the department (especially students), and (2) worry if there aren't any! Though this isn't always a sign of deep problems.
- Do well on the verbal GRE. As far as I can tell, this is the best predictor of success in graduate school.
- In my many years of reading graduate applications I got a strong impression that recommendations from summer research supervisors tended to be much higher than those from the student's professors, and therefore needed to be given less weight. How could these letters be made stronger?
- Students should make sure they understand the grading system of the GRE! Specifically, that wrong answers lead to a subtraction of points (a substantial penalty). Guessing is only likely to work when you have narrowed down your choices to two possibilities. Only answer those questions that you absolutely know are correct. This is not like a typical exam you're used to taking in class. There is no partial credit for picking the answer that was almost correct, but not the correct one.
- I've been advising physics majors on the astro track for many years, and most students don't seem to understand the significance that grad school admissions committees put on the GRE and most do not prepare appropriately and sufficiently.
- A low GRE score the first time you take it can be compensated for if you take the exam again and do much better the second time.
- My advice is to collect as much information as possible about the schools, so that you can make an informed decision. My recommended list of questions is posted **http://www.astro.indiana.edu/grad_questions.shtml.**
- For three years now, I've maintained a webpage on this subject: **http://satchmo.as.arizona.edu/~jrigby/gschool/**. I started it in hopes of helping level the playing field for women & minority applicants and those from small schools (basically, everyone who doesn't get the advice from their professors.) It walks a prospective through the process, and includes several lists of questions-to-ask-while-visiting, with an emphasis on questions-to-ask-if-you're-female.
- It took me three tries to get into grad school with money. I had abysmal Physics GRE scores and some mediocre physics grades. In my favor, I had worked at an astronomy institute for almost five years before starting grad school and I knew IDL, IRAF, and all the nitty-gritty details of an instrument.
- I tried to play up my work experience and the fact that I was a more mature person who really wanted to go to grad school and was stubborn enough to finish a thesis.
- Looking back an alternative route that would have helped me immensely on the physics GRE's was to teach physics. A friend of mine did that route and aced the physics GRE. I now teach physics at a private high school and understand how that has really helped my understanding of the material.
- There is a resource about writing the essay that I found particularly helpful. Its a book by Donald Asher called Graduate Admissions Essays and it has good tips about how to start writing with lots of small exercises and specific

questions. It helps to first write down answers to specific questions and then figure out how to adapt them and string them together to make an effective essay. Also, **http://www.haverford.edu/cdo/New/gradschool/Asher-Questions.pdf** has some questions of his that might be useful.

The whole subject of the physics GREs and their role in admission to graduate astronomy programs is a large topic which we will explore further in future issues of STATUS. Moreover, the role of the applicant's personal statements needs attention—students probably spend many hours carefully crafting personal statements, but how critical are they in the admissions process? Please send me your words of advice to students on writing personal statements (at *bagenal@colorado.edu*). ❖

"Notes from a Life," first printed in the June 1999 issue of STATUS, are anonymous vignettes describing quotidian life of a woman in science.

Notes from a Life

An Anonymous Contribution from one of Our Readers

♀ While I can't say that I've had to deal with any overt discrimination in my career so far, despite having had two children while in grad school, the one thing I felt I have suffered from is a lack of role models. I know a few men who have had children in grad school, and several women who have had children after landing a professorship. But as a student, I didn't know any women who have had children as students, and only a handful who had children as post-docs.

Many people have told me that the best time to have children is during graduate school, since if you want to avoid having children during those critical post-doc years, it's either that or wait until you've got tenure and then have to deal with all the problems associated with having children late in life. However, I felt very alone as a new parent during grad school, both from a lack of peers and a lack of role models.

Few grad students are in a position either socially or financially to have children—either they don't have a life partner yet or their significant other is also an impoverished grad student. So I was the only female grad student to have children in my department. I don't mean to demean the experiences of the men who had children, but it is a fundamentally different experience. I felt like a pioneer in many ways. My department lacked (and still lacks) a formal policy regarding maternity or paternity leave for students. I often brought my babies in to work with me, and sometimes I'd even take them to talks, where they were usually the only attendees under the age of 18. I relied on the kindness of the administrative staff to watch my babies for a few minutes while I went to the bathroom.

I also found it difficult to find role models—women who had been through the experience of having children during grad school, and then gone on to have successful careers in astronomy. Occasionally someone would tell me, "oh, so-and-so had kids during grad school," but they were never anyone I personally knew, and I am uncomfortable contacting people out of the blue. When the times got tough, when I would wonder if I could really simultaneously be both a good mother and a good scientist or if I could even just get through writing up my thesis, it would have been helpful to have someone to turn to for encouragement or even to look at and say, "she did this, so can I."

I did manage to give birth to two children during grad school, and even defended my thesis just a few months after giving birth to my second child. I now have a post-doc at an institution where several of my colleagues also have children. I am getting bolder about crossing the post-doc/faculty boundary to talk about raising kids, because motherhood is a kind of sorority that creates bond across all sorts of social boundaries. As I was packing up my grad student office, a woman stopped by. She said she had noticed me bringing in my kids and seen the pictures of them on my office door, and that she, too, had had children during grad school and had still been able to pursue a successful career in science. It was gratifying to talk to her about her experiences, and I only wish she had stopped by sooner. For my part, I am trying to make some efforts to become a role model for present and future grad students, and maybe they won't feel quite so lost as I did. ❖

Send your "Notes" to ***bagenal@colorado.edu***

The Canadian Astronomical Society (CASCA) is blessed with a Graduate Student Committee (GSC) with representatives from departments across the country, whose activities enrich our annual meetings and foster effective communication on topics chosen by the students as being important to them, the next generation of Canadian astronomers. The initiative of two of their former chairs in undertaking this informative survey is typical of proactive, constructive efforts emerging from GSC discussions to improve the field in this country.

It is interesting to me to note that the period covered by this study includes a funding nadir while the federal government balanced its budget and began to curtail the growth of the federal deficit. Thanks to vigorous efforts by many to create new opportunities, a continuation of this study with statistics from the next five year period will be of great interest and value.

In 2000 the Canadian Long Range Plan for Astronomy and Astrophysics (LRP) was released. It included important recommendations regarding the development of human resources, which are reinforced in the report from a formal mid-term review process being formally released in December, 2004. Through a vigorous community campaign and coincidentally the creation of new funding opportunities for universities, important new resources have been allocated to Canadian astronomy in the past few years. The funded LRP activities play a key role in attracting and retaining highly qualified people in our universities and laboratories.

Having credible national statistics on demographics is a key tool for planning opportunities for all who aspire to participate in 21st century astronomy and astrophysics. As a society, CASCA needs to work with the authors to identify appropriate mechanisms to continue their pioneering effort, as well as to facilitate the full participation of the overworked heads of departments and laboratories in future surveys.

James E. Hesser, President
Canadian Astronomical Society

Women in Canadian Astronomy: A Ten Year Survey

By Michael A. Reid and Brenda C. Matthews

We have conducted the first comprehensive study of the relative representations of men and women in Canadian astronomy. We find that, during the period studied (1991-2000), women were significantly underrepresented at all levels of Canadian astronomy, but that the trend is toward greater equality. We find that the ratio of women to men is highest among graduate students, declines slightly among postdocs, and reaches its lowest level among professors. This is consistent with the representation of women in American astronomy. Because we did not receive responses from several larger departments in the country, our sample size is biased toward medium-sized and smaller departments and represents only about half of the population of Canadian astronomers.

Introduction

The under-representation of women in astronomy is a longstanding problem. Although women make up half or more of the general population, they constitute only a tiny fraction of professional astronomers. Moreover, studies in several countries have shown that their representation declines at each level of the academic hierarchy. For example, see studies from the U.S. (Urry 2000), the former Soviet Union (Izvekova & Suleymanova 1993) and the European Southern Observatory (Grebel 1993). Attempts are being made in scientific communities around the world—and here in Canada—to remedy this situation by both equalizing the opportunities for men and women and by creating programs which specifically facilitate the hiring of qualified women into faculty positions. In Canada, the Natural Sciences and Engineering Research Council (NSERC) offers grants called University Faculty Awards (UFA's), which provide salary supplementation and teaching relief to newly-hired female (and aboriginal) faculty in the natural sciences and engineering. Other programs, both formal and informal, attempt to encourage girls and women to pursue careers in math and science.

In several other countries, most notably the United States, detailed statistics are kept by government and professional bodies which allow the annual assessment of the status of women in astronomy. In the United States, both the American Astronomical Society (AAS) and National Science Foundation (NSF) gather such data nationally, and several institutions, including MIT, IPAC, STScI, and Caltech, have collected statistics and conducted surveys locally. Such statistics are essential tools to assess the success or failure of programs such as the UFA's and to locate the cracks in the educational system through which women may fall. Yet no Canadian body—governmental or professional—collects such statistics. (The relevant statistics gathered by NSERC do not distinguish between physicists and astronomers.)

Inspired by our colleagues in the AAS's Committee on the Status of Women in Astronomy and working under the aegis of the Graduate Student Committee of the Canadian Astronomical Society (CASCA), we decided to begin the collection of such statistics in Canada. This paper presents the results of our first attempt at such a survey. We begin with a description of our method , describe the response we received, present our analysis of the results, and conclude with our plans for continuing data-gathering.

Survey Method

We contacted the chairs or directors of 23 Canadian institutions where astronomy research takes place, including all universities known to employ researchers in astronomy or space sciences, as well as the two major independent astronomy

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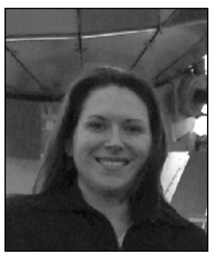
Michael Reid is a PhD candidate at McMaster University and a former Chair of the Graduate Student Committee of the Canadian Astronomical Society (CASCA). Brenda Matthews was chair of the GSC at the time of the survey and has just begun her second post-doctoral appointment. She is currently a Herzberg Fellow at the Herzberg Institute of Astrophysics, a division of the National Research Council of Canada, in Victoria, British Columbia.

research facilities (CITA and HIA; see Table 1.) We asked them to fill out a survey which inquired about the number of men and women in each institution whose study, work, or research involved astronomy in a significant way. These data were requested for each of the years in the interval 1991-2000. For each of the ten survey years, we asked respondents to report on the number of people of each gender in seven categories: full professors, associate professors, assistant professors, postdocs, Ph.D. recipients, M.Sc. recipients, and other astronomy researchers (due to ambiguities in our definition of the term and irregularities in the responses received, we have not used the data on 'other astronomy researchers' in this article). Survey recipients were asked to fill in the tables and return them in the self-addressed stamped envelopes provided.

Michael Reid



Brenda Matthews

A few caveats must precede our discussion of the results. First, we did not include undergraduates in our study because, at most Canadian universities, there is no clear distinction between undergraduate programs in physics and astronomy. Second, we can say nothing about the retention of women during graduate studies: our survey only inquired about the number of graduate degrees granted, not about the number of students entering graduate studies. Third, our study does not account for astronomers in private industry and those teaching at (three year) colleges: we believe the total number of people in such positions to be very small, in comparison to the total number of academic and government astronomers in Canada. Finally, due to the small size of the Canadian astronomy community, we are forced to work in the domain of small-number statistics. We are assessing possible methods of designing subsequent surveys to address the first two of these issues.

The Response

Of the 23 institutions polled, we received responses from 17 (see Table 1). Unfortunately, some of the larger departments declined to participate in our study, meaning that our sample is biased toward medium-sized and smaller universities. A few of the institutions which declined to participate cited as their reason the difficulty in reconstructing ten years' worth of records, particularly on a year-by-year basis (one institution sent us cumulative totals for the whole decade, which we deemed unsuitable to the present analysis and have hence excluded). We appreciate all of the feedback we received and have taken it all into account in planning continuing survey efforts.

In order to extract a meaningful trend from our sparse data, we have averaged over two five-year intervals. The first important result to emerge is that the representation of women improved at all levels of education and employment between the two periods, 1991-1995 and 1996-2000. Assessing the true significance of this improvement is complicated by the small-number nature of the statistics. We are especially interested in tracking the representation of women in and their progress through the educational system. Hence, we have separated the statistics into two sets: the first includes data from all of the participating institutions, and the second includes only data from degree-granting institutions (that is, it excludes CITA and HIA). As can be seen in Table 2, the trends do not differ much between the two groups.

Figure 1 shows a different representation of the data, wherein professors, postdocs, and students are treated as undivided groups. As can be seen in the top panel of Figure 1, for the period 1991-1995, the percentage representation of women fell with each step up the academic hierarchy, declining from 12% among graduate students to only 4% among professors. Greater balance was achieved in the following five years, however, as can be seen in the lower panel of Figure 1. During that period, the percentage representation of women rose to 17% among graduate students and remained at that level among postdocs. The representation of women among professors improved slightly from 4% to 6% (the difference is accounted for by the hiring of only two new female professors, while the number of mean number of male professors held constant). While it would be premature to extrapolate a trend from a time series consisting of two points, these data are consistent with trends seen in the United States, whereby the increasing representation of women at the lower levels of academia leads to a 'trickle up' effect (potentially complicated by a 'leaky pipeline'

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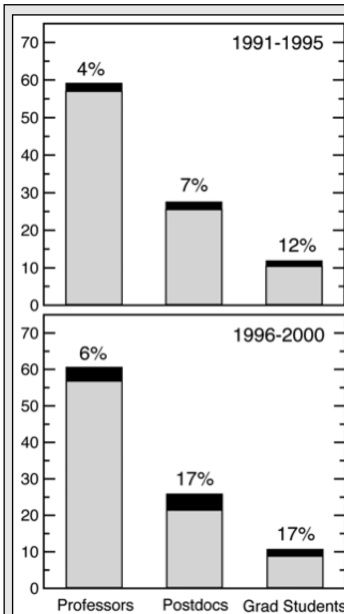

Figure 1: Relative representations of men and women at the three main levels of academia—graduate students, post-docs, and professors—averaged over the time periods 1991–1995 and 1996–2000 (for postdocs, the first period covers 1992-1995 only). The grey bars represent the average number of men in each category during each year in the interval; the black bars represent the same figure for women. The percentage representation of women in each category is indicated above each set of bars. Data from all of the participating institutions are included in this figure (this excludes six non-participating schools, some with large astronomy groups; see Table 2.

Women in Canadian Astronomy *continued from page 19*

Table 1: Results and Discussion

Our results reveal that women are significantly underrepresented at all levels of Canadian astronomy. Table 2 shows the percentage representation of women at each level, combining the data from all of the participating institutions. Readers who are surprised to find that there are no female full professors of astronomy listed, despite the fact that they may know several, are reminded that not all of the institutions polled chose to participate and that the survey does not account for hires and promotions more recent than the 1999–2000 academic year. (Though, as far as we know, there actually were no full professors of astronomy in Canada during the survey period).

Institutions Surveyed
Canadian Institute for Theoretical Astrophysics (CITA)
Herzberg Institute for Astrophysics (HIA)
Memorial University of Newfoundland
McGill University
McMaster University
Queen's University*
Saint Mary's University a
Trent University
University of Alberta*
University of British Columbia
University of Calgary
University of Guelph
Universite Laval
University of Manitoba
University of Montreal
University of Moncton*
University of Regina
University of Saskatchewan
University of Toronto*
University of Victoria*
University of Waterloo
University of Western Ontario
York University*

	All data[a]			Excluding CITA & HIA[b]		
	1991-1995	1996-2000	Increase	1991-1995	1996-2000	Increase
	(%)	(%)	(%)	(%)	(%)	(%)
Full Professors	0 (40)	0 (38)	0	0 (36)	0 (35)	0
Associate Professors	10 (13)	13 (15)	3	10 (13)	13 (14)	3
Assistant Professors	12 (7)	23 (8)	11	13 (6)	26 (7)	13
Postdocs	7 (28)[c]	17 (32)	10	22 (5)c	35 (12)	13
Ph.D.'s granted	9 [22]	14 [28]	5	9 [22]	14 [28]	5
M.Sc.'s granted	14 [37]	20 [25]	6	14 [37]	20 [25]	6

Table 2: Percentage of women at each level of work or study, averaged over five year periods. Numbers in parentheses are the mean number of people in that category during each year of the specified period. Numbers in square brackets are the total number of degrees of the specified kind granted during the specified period. Where necessary, numbers have been rounded to the nearest integer.

[a] Includes all institutions surveyed.
[b] Includes only degree-granting institutions surveyed (that is, excludes CITA and HIA)
[c] Due to problems with the reporting of data for the year 1991, data for postdocs in the first interval span only the years 1992-1995.

effect whereby the retention rate of women at the higher levels of academia is chronically lower than that of men; see the article by Fran Bagenal in June 2004 issue of STATUS). To verify that trend, it will be necessary to continue collecting data for many more years.

Anecdotal evidence and informal polling indicates that, since the final year included in our survey (1999-2000), the percentage representation of women has continued to rise at all levels. Among professors, the continued improvement seems to derive largely from promotions and UFA-aided hires. We hope soon to be able to formally confirm this continuing positive trend in the representation of women.

Future Plans

We intend to maintain this project, collecting data at more frequent intervals and refining our survey questionnaire and information gathering techniques. We are consulting with the AAS in the United States, hoping to benefit from their long experience of conducting similar studies. In designing follow-up surveys, we will take into account the suggestions made by those institutions which declined to participate. We hope that the publication of these results, as well as the more frequent administration of our survey, will help secure the participation of all eligible Canadian institutions. ❖

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Jeno Sokoloski is an NSF Astronomy & Astrophysics Postdoctoral Fellow at the Harvard-Smithsonian CfA, where she works on observational studies of jets from accreting white dwarfs. She is also a volunteer teacher in the Cambridge Science Club for Girls and a co-coordinator of the CfA Women's Program Committee.

Progress on Gender Equity at Nine Top Research Universities

By J. L. Sokoloski

In 1999, the influential report on gender equity from MIT revealed a pervasive, if unintentional, bias against women faculty in the School of Science. Discrepancies between male and female faculty members were found in areas such as hiring, promotion, compensation, access to leadership roles, and the allocation of resources such as research space. In addition, women science faculty at MIT often felt less valued by their peers than did their male counterparts, and generally more marginalized. These inequities led to high levels of job dissatisfaction among female faculty.

The MIT study prompted the presidents or provosts of nine top research universities—U. C. Berkeley, Caltech, Harvard, MIT, U. Michigan, U. Penn, Princeton, Stanford, and Yale—to attend the President's Workshop on Gender Equity at MIT in 2001. At that meeting, representatives from each of the nine universities pledged to examine the status of women faculty at their own institutions, and to start taking the steps necessary to improve the hiring and retention of women on their campuses. They also agreed to hold a second president- and provost-level meeting to evaluate their progress. That follow-up meeting was held in April, 2004, in Washington, D.C.

Of the nine universities that attended the President's Workshop on Gender Equity in 2001, six have completed MIT-style studies of gender equity sponsored by top-level administration on their campuses. The reports from these studies, by Caltech, MIT (now including four additional schools besides the School of Science), U. Michigan, U. Penn, Princeton, and Stanford, can be found on either the website of the National Academies: **http://www7.nationalacademies.org/cwse/gender_faculty_links.html** or the website created by the Provost's Advisory Committee on the Status of Women Faculty at Stanford University: **http:/universitywomen.stanford.edu/reports.html**.

Three universities that participated in the President's Workshop—U. C. Berkeley, Harvard, and Yale—have not yet performed comprehensive studies. On the websites mentioned above, one can find the results of a more limited work-and-family survey from U.C. Berkeley, the 1991 Grosz report on women in the sciences at Harvard, and a survey by Yale's Women Faculty Forum of the numbers, distribution, and leadership roles of women faculty at Yale.

Based on the reports from the six institutions that have completed their analysis of gender equity on campus, women faculty at different universities experience some similar patterns of under-representation and bias. For example, several universities found that whether or not female junior faculty are hired in proportion to their availability in the applicant pool depends on the department. Furthermore, at least one report expressed concerns about a male bias in hiring at high seniority levels. After being hired, women are typically slower to be promoted. Although comparisons between faculty at the same rank often reveal no statistically significant salary discrepancies, the slower rate of promotion (as well as lower levels of non-salary compensation such as retention bonuses and the presence of what Stanford calls "a few male high-outliers") can produce salaries that are effectively lower for women (U. Michigan finds by about 3%). The Caltech report discusses another common problem: the number of women faculty in science and engineering is often so low that it is difficult to perform statistically meaningful comparisons between men and women. Despite the statistical challenges, however, the Stanford report notes that the "…overall pattern of difference is unidirectional". Women are making more of an appearance in upper-level administration (particularly noteworthy is Princeton, where currently the President, the Provost, the Dean of the College, and the Dean of Engineering and Applied Science are women). On the other hand, they are doing less well at attaining positions of power within their own departments. Women, especially senior-level women, typically report more job dissatisfaction than their male counterparts. With less support at home (the U. Michigan study finds that male faculty are much more likely than female faculty to share a home with an adult who works less than full time), female faculty report more stress associated with balancing work and family. Finally, junior women faculty generally receive less professional mentoring.

The six universities with published reports each made specific recommendations concerning actions

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Gender Equity *continued from page 21*

that need to be taken to improve the status of women faculty on their campuses. Common recommendations include: that funds be provided for recruitment and retention of female faculty; improved monitoring of hiring practices and record-keeping during faculty searches; more direct communication between department chairs and upper-level administration, including regular reporting on progress in hiring and retention of women; implementation of formal mentoring programs as well as making the path to career advancement more transparent; and that steps be taken to make universities more family-friendly (such as automatic extension of the tenure clock for new parents and establishing affordable child care). At several of the reporting institutions, these recommendations are already being implemented, in some cases with already documented positive results. ❖

Editors' notes:

Meg Urry (Yale University) attended the April 2004 Gender Equity Conference and reports that the meeting had a different tenor compared to the first 9-university meeting 3 years ago. There seemed to be cause for celebration, a sense of making progress. There is a change in paradigm from fixing the women to fixing the system. Yet, despite encouraging discussions about hiring processes and systematic data collection there remain substantial pipeline and retention issues. Universities are educating women who enter programs eager to pursue their scientific interests and determined to have careers in science , as well as families. After 4 or 5 years of graduate school they are worn down and discouraged because of what we teach them, including the impression that science has to be a religious calling, soaking up every last iota of energy. This is a retention problem not a pipeline problem. Many women claim they are leaving because of family issues but this may be hiding other concerns about not belonging, having few role models, feeling uncomfortable, being made to feel unwelcome. There is recognition that "off-scale" women will succeed but women in the middle still may not survive, whereas men in the middle can and do succeed.

The situation at Harvard has been attracting attention from the press. The September 17th 2004 issue of Science included a report on a June 18, 2004 letter sent by some two dozen women faculty to Harvard President Larry Summers calling attention to the fact that the percentage of women offered tenured slots at Harvard has dropped by half in the past 5 years. On October 7th the Boston Globe reported that little progress was made in a meeting of more than 50 senior professors with President Summers and William Kirby, Dean of Arts and Sciences. Anonymous faculty were quoted saying such things as "They acknowledged that there's a problem but they were basically saying 'Leave it to us.' Looking at the results of the last three years, I don't think people felt terribly comfortable with that answer." When pressed for a response, Summers said, "The university has a longstanding tradition, which as president I have a particular obligation to uphold…that appointments are made because of excellence in teaching and research and not to fill quotas." Watch this space for further developments on the gender gap at Harvard. But don't hold your breath.

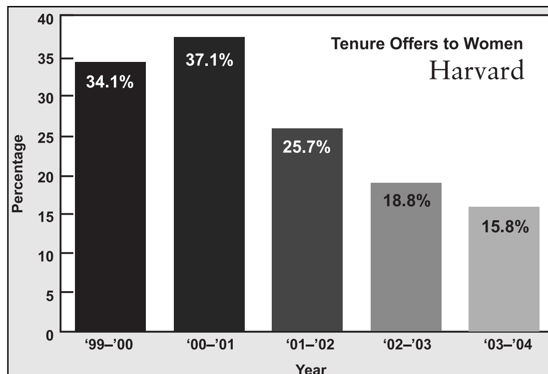

Figure 1: Percentage of tenure offers made to women professors at Harvard.

Childcare at University of Arizona: Investing in the Future

By Joannah Hinz and Jill Bechtold

In July 1989 the Arizona Board of Regents created the Commission on the Status of Women for the purpose of assessing the conditions of employment for women at the three universities in the U of AZ system. Members are drawn from the ranks of administrators, faculty, appointed personnel, and classified staff to serve 3-year terms as Commissioners. Graduate and undergraduate students serve renewable one-year terms. Several subcommittees serve within the larger Commission to address specific needs of the university community. The Childcare Workgroup has devoted itself to goals regarding the environment for family and children on campus.

In 2003, the Childcare Workgroup researched, wrote, submitted, and presented a series of recommendations to the University administration in the form of a 'white paper' entitled "Childcare: Investing in the Future". These recommendations proposed a series of family-friendly policies and practices that could be adopted by the administration in support of diverse needs of the community. The recommendations were received positively.

As a follow-up to this white paper plan, in March of 2004, the Childcare Workgroup submitted a proposal to the President to recommend the installation of diaper changing tables in men's and women's rest-rooms in ten buildings on campus of the 116 buildings that did not have those facilities. They suggested this action as a first sign from the administration of their interest and investment in child-friendly resources for a minimal cost. The funding for these tables was approved, and, in September and October of this year, the changing tables were installed.

In cooperation with the Commuter Student Affairs Office, the Childcare Workgroup also proposed this fall for funds to build a child-friendly play area in the University's new Student Union. This area, housed by the Commuter Student Affairs, is designed as an enclosed space equipped with child-sized tables, chairs, and bookshelves, and stocked with books and toys, where parents can take their children to relax and play while visiting campus. Though solely parent-supervised, the proximity to several computers, along with safe room dividers, will allow parents to monitor their children while doing simple tasks such as briefly checking email or printing assignments. To date, the Vice President of Campus Life, the Associate Vice President for Campus Life and Dean of Students, the Commuter Students Affairs Office, and the Director of the Student Union have all pledged funds for this area. Major items of furniture have been ordered, and donations of books and toys from local book-stores and members of the Commission on the Status of Women have been solicited. The goal is to have the area opened by the week of final exams.


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Future efforts by the Childcare Workgroup include establishing a "baby room" on-campus daycare center. This facility would be designed for ages six weeks to one year, when parents would most wish to have their child nearby for breastfeeding and other short visits during the work day. The age restriction would also bring demand for the facility to manageable levels for a first-time facility. The Workgroup is researching possible outside vendors, costs, liabilities, and state guidelines in opening this type of daycare, but have received much positive feedback from the University administration.

We hope the white paper and the steps outlined above might be of use to other institutions looking to improve the childcare resources available to them and would be glad to receive feedback from other committees addressing these issues. ❖

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